Annex 1: List of participants

Name	Institute	Country	e- mail
Alexey Russkikh	Knipovich Polar Research Institute of Marine Fisheries and Oceanography(PINRO)	Russia	russkikh@pinro.ru
Alf Harbitz	Institute of Marine Research	Norway	alf.harbitz@hi.no
Anatoly Chetyrkin	Knipovich Polar Research Institute of Marine Fisheries and Oceanography(PINRO)	Russia	chaa@pinro.ru
Anatoly Filin	Knipovich Polar Research Institute of Marine Fisheries and Oceanography(PINRO)	Russia	filin@pinro.ru
Anders Nielsen	DTU Aqua - National Institute of Aquatic Resources	Denmark	an@aqua.dtu.dk
Andrey Mikhailov	Russian Federal Research Institute of Fisheries and Oceanography	Russia	mikhailov1984@gmail.com
Arved Staby	Institute of Marine Research	Norway	arved.staby@hi.no
Asgeir Aglen	Institute of Marine Research	Norway	asgeir.aglen@hi.no
Bjarte Bogstad	Institute of Marine Research	Norway	bjarte.bogstad@hi.no
Caroline Aas Tranang	Institute of Marine Research	Norway	caroline.aas.tranang@hi.no
Daniel Howell (Chair)	Institute of Marine Research	Norway	daniel.howell@hi.no
David Miller	ICES Secretariat	Denmark	david.miller@ices.dk
Dmitry Vasiliyev	Russian Federal Research Institute of Fisheries and Oceanography	Russia	dvasilyev@vniro.ru
Edda Johannesen	Institute of Marine Research	Norway	Edda.johannesen@hi.no
Elvar Halldor Hallfredsson	Institute of Marine Research Tromsø	Norway	elvarh@hi.no
Hannes Höffle	Institute of Marine Research	Norway	hannes.hoffle@hi.no
Jose Miguel Casas	Instituto Español de Oceanografia (IEO)	Spain	mikel.casas@ieo.es
Kristin Windsland	Institute of Marine Research	Norway	kristin.windsland@hi.no
Matthias Bernreuther	Institute of Sea Fisheries - Thünen Institute	Germany	matthias.bernreuther@thuenen.de
Mikko Juhani Vihtakari	Institute of Marine Research	Norway	mikko.juhani.vihtakari@hi.no

Natalia Yaragina	Knipovich Polar Research Institute of Marine Fisheries and Oceanography(PINRO)	Russia	yaragina@pinro.ru
Olav Nikolai Breivik	Norwegian computing Center	Norway	olavbr@nr.no
Oleg Titov (by correspondence)	Knipovich Polar Research Institute of Marine Fisheries and Oceanography(PINRO)	Russia	titov@pinro.ru
Ricardo Alpoim	Portuguese Institute for the Ocean and Atmosphere, I.P. (IPMA)	Portugal	ralpoim@ipma.pt
Ross Tallman	Fisheries and Oceans Canada - Arctic Region	Canada	ross.tallman@dfo-mpo.gc.ca
Samuel Subbey	Institute of Marine Research	Norway	samuel.subbey@hi.no
Tone Vollen	Institute of Marine Research	Norway	tone.vollen@hi.no
Yury Kovalev	Knipovich Polar Research Institute of Marine Fisheries and Oceanography(PINRO)	Russia	kovalev@pinro.ru

Annex 2: Draft ToRs for next meeting

AFWG – Arctic Fisheries Working Group

2018/X/ACOMXX The **Arctic Fisheries Working Group** (AFWG), chaired by Daniel Howell, Norway, will meet at XX (tbc), on 17-23 April 2020 (tbc) to:

Address generic ToRs for Regional and Species Working Groups, for all stocks except the Barents Sea capelin, which will be addressed at a meeting in the autumn;

For Barents Sea capelin oversee the process of providing intersessional assessment;

Conduct reviews as required of time any series computed using the STOX and ECA open source software for use in assessment in the Barents Sea.

The assessments will be carried out on the basis of the Stock Annex. The assessments must be available for audit on the first day of the meeting.

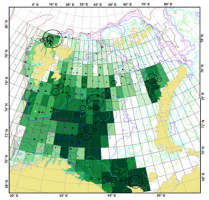
Material and data relevant for the meeting must be available to the group on the dates specified in the 2020 ICES data call.

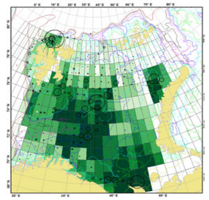
AFWG will report by XX May 2020 and XX October 2020 for Barents Sea capelin for the attention of ACOM

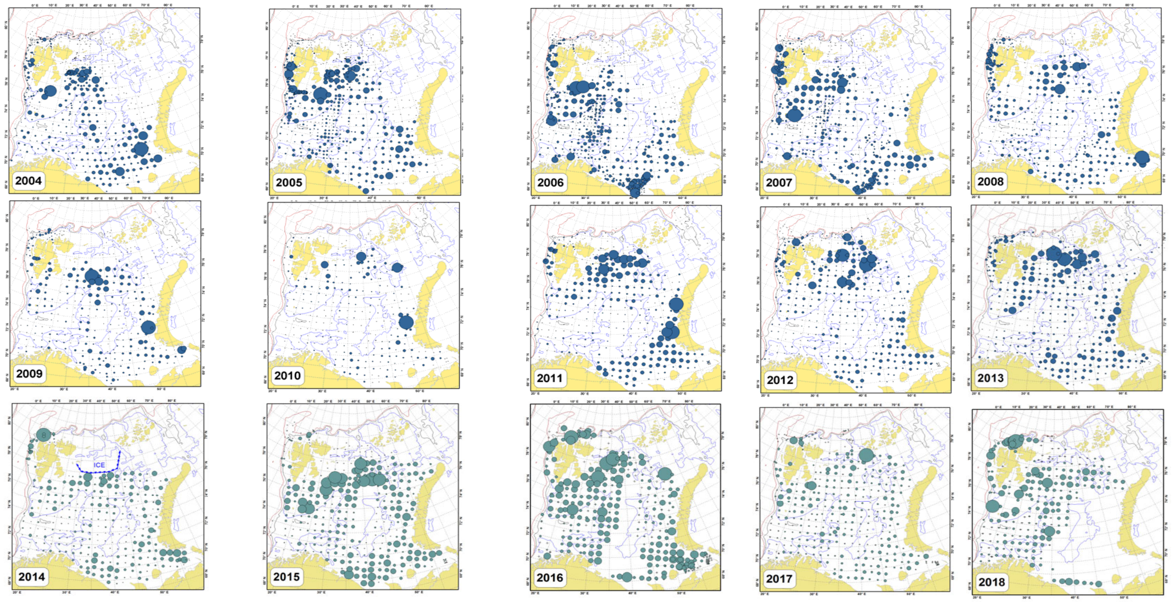
Annex 3: Working documents

Numbers of Northeast Arctic Cod Subareas 1 and II swept area estimation in August-September, ind.
*Additional estimation 0-group cod in pelagic layer in same time.

AGE\YEAR	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018 basic calcula	2018 (missing data in REEZ was interpolated manually)
*0+ (pelagic)	65,969,000,000	72,137,000,000	25,061,000,000	42,628,000,000	234,144,000,000	185,457,000,000	135,355,148,349	448,004,676,389	410,757,372,957	385,429,624,710	464,167,533,460	37,424,452,387	53,796,000,000	233,274,829,269	no data	
0+(bot)	543043827	180168866	276036279	101047588	483444472	903273844	652597518	2082961050	1412741073	2281839395	2445196115	350928401	1164833574	2316337064	1841190324	1841190324
1	330631130	440711170	479015340	333323541	130941903	569714897	310259067	509807608	1454272354	914192350	308152118	725315986	350788443	757497434	1620956461	2100290126
2	329740139	146597178	509664472	505358143	372611937	93519810	84155150	160004176	255852938	658991771	155120062	153988633	341343862	260628218	342220432	413806044
3	147720899	216599433	186104950	586191848	652619351	202337045	56811355	123647520	229092369	249105801	190015856	174410623	77182019	375003367	152180144	183609018
4	421528621	55799358	205590556	159152207	483428014	280639811	177043957	101526797	146406893	183591010	108592370	225163599	93716793	141494105	133597814	148870432
5	150214881	100855755	59854785	79074519	132268618	289625149	397182398	240166577	69962192	125688086	93909741	141294065	121593715	104917649	52046190	60034889
6	79761721	27998174	69754858	24568322	51067000	101693870	424932837	300389563	150768959	63154094	52808859	72569433	70088128	120876672	31228971	37643553
7	40210687	15645223	17640696	26919855	12815988	31883318	142729910	178433228	165155691	118220439	30410416	48559722	44438350	62575290	50975683	57078046
8	10088512	5652763	8089532	5967918	17453296	12662439	38534364	32276072	84513940	130196740	50180004	26240265	27216529	27955200	18510934	20191624
9	2210874	1172452	2557565	2164141	3283965	7276698	10549842	7693099	12698947	53847777	36338451	35256469	13801647	11207815	13123560	14441297
10	503390	464259	649658	932430	850157	2569231	6783647	1849795	4351948	9141091	12072868	26634386	13198391	6411862	4852779	5785155
11	128218	120001	248101	145584	228620	814921	1589247	1335895	1550456	3315461	3425765	7865353	5422231	4446171	2907406	3627643
12	65054	0	43801	205865	202136	283338	309677	593900	1429349	1521350	1024942	1696556	1650140	4486647	2909318	3477642
13	0	50079		0	108738	166792	204978	279561	428096	445255	837265	148578	491430	1779296	1955318	2041275
14	134857			34436	0	0	106583		142966	329399	266539	811245	447165	624015	598218	623661
15					0	0			75101	164247	204789	0	116769	279941	260291	239813
16					80306	54911					60807	95469	116769			
17													199830			
0+pel/bot (%)	1	0	1	0	0	0	0	0	0	0.59	0.53	1	2	1		


original


manual interpolation



Year/age	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
2004	6.9	30.1	121.4	505.0	831.4	1399.9	2381.5	3229.4	4511.5	6181.4	8381.2	19382.1	13480.0		14159.2		
2005	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0		0.0			
2006	11.3	39.7	159.5	482.8	1042.2	1646.7	2529.1	3612.4	4951.7	6508.2	10663.2	9866.5	8356.1				
2007	9.9	50.8	162.8	452.1	975.2	1800.8	2554.5	3740.1	5184.4	6464.4	8036.7	10508.9	11182.6		15529.0		
2008	6.9	45.1	205.7	502.1	1100.7	1849.8	3113.5	4174.4	5511.0	7557.9	8694.2	10737.6	10962.2	14691.2			19021.0
2009	6.9	28.6	167.4	455.5	954.4	1551.5	2350.4	3802.7	5179.7	6415.0	7429.9	8213.5	12370.3	10218.3			13875.0
2010	7.0	32.1	141.2	486.8	960.8	1649.1	2504.1	3664.4	5204.7	6374.4	7482.9	8479.7	9139.1	13188.6	16412.2		
2011	5.0	32.6	139.9	469.8	1068.4	1712.5	2456.2	3415.9	4593.0	6717.4	8688.2	11631.6	10615.7	12905.3			
2012	6.2	32.4	144.8	461.4	870.3	1631.1	2346.7	3227.1	4289.6	6417.5	8079.6	10069.5	11277.4	13551.7	10822.8	17840.0	

Weight at length

Length/yea	2004	2005	2006	2007	2008	2009	2010	2011	2012
3.5	0.1	1.0	0.1	0.1	0.1	0.1	0.1	0.1	0.1
8.5	6.0	5.7	6.1	5.3	5.8	5.6	5.6	4.7	5.7
13.5	19.0	18.9	19.2	20.5	18.9	19.6	18.8	21.6	20.9
18.5	48.3	46.9	44.0	47.5	46.6	40.3	42.2	40.9	47.8
23.5	97.4	99.2	102.6	101.3	110.0	103.1	100.7	102.3	100.5
28.5	180.5	184.3	184.4	176.6	192.9	179.5	175.8	176.9	183.2
33.5	308.3	309.7	292.9	297.0	315.1	306.3	307.8	298.7	307.4
38.5	459.6	477.7	476.6	447.7	475.0	461.0	466.8	456.6	467.5
43.5	684.5	689.6	696.1	666.2	669.2	667.0	680.9	671.6	680.2
48.5	944.3	985.6	951.7	901.3	991.6	930.5	979.6	957.5	951.0
53.5	1262.7	1365.7	1303.4	1229.9	1306.3	1246.4	1330.4	1320.6	1295.0
58.5	1661.7	1728.1	1680.1	1673.7	1700.4	1695.6	1738.1	1714.2	1687.5
63.5	2076.2	2181.7	2177.2	2170.9	2203.0	2155.3	2169.5	2147.9	2184.9
68.5	2585.1	2768.3	2708.8	2698.3	2743.5	2699.2	2740.0	2630.2	2638.1
73.5	3084.8	3326.9	3304.9	3332.5	3442.8	3313.3	3350.0	3269.9	3223.2
78.5	3829.3	4172.8	4086.1	4158.4	4232.4	4064.3	4078.0	3981.7	3908.5
83.5	4663.9	4941.0	4979.4	4894.0	5182.1	4926.2	5042.9	4719.7	4737.3
88.5	5659.2	5756.1	5972.8	5873.0	6080.8	5981.8	6018.6	5742.9	5753.2
93.5	6799.5	7140.3	7139.4	7100.7	7155.8	6937.8	6904.5	6835.9	6969.6
98.5	7502.3	8420.4	8356.1	7700.3	8502.4	8069.9	8166.8	8255.6	8388.8
103.5	9765.0	9987.5	9456.0	9158.2	9747.1	9785.6	9696.8	10143.5	9653.2
108.5	10880.0	10576.7	11029.4	11651.3	11506.2	10801.6	11540.0	11901.3	10822.8
113.5	13662.0		13703.3	11321.7	12705.0	13875.0	12643.3	12835.0	12791.3
118.5	13480.0	15762.2	14510.0	13076.3		15450.0		14519.0	14301.0
123.5	13940.0			15529.0	17475.0		20390.0	18093.3	17840.0
128.5	15970.0		26700.0						19270.0
133.5	23400.0				19021.0				

Converted to Norwegian length groups

Length/yea	2004	2005	2006	2007	2008	2009	2010	2011	2012
2.5	0.0	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0
7.5	4.1	3.9	4.2	3.7	4.0	3.8	3.9	3.2	3.9
12.5	15.1	15.0	15.3	16.2	15.0	15.6	14.9	17.1	16.6
17.5	40.9	39.7	37.3	40.2	39.4	34.1	35.7	34.6	40.5
22.5	85.5	87.0	90.0	88.9	96.5	90.5	88.4	89.8	88.2
27.5	162.1	165.6	165.7	158.6	173.3	161.3	157.9	158.9	164.5
32.5	281.5	282.8	267.4	271.2	287.7	279.7	281.1	272.8	280.7
37.5	424.7	441.4	440.4	413.7	439.0	426.0	431.3	421.9	432.0
42.5	638.4	643.1	649.2	621.3	624.1	622.1	635.0	626.3	634.4
47.5	887.1	925.8	894.0	846.7	931.5	874.1	920.2	899.5	893.3
52.5	1193.2	1290.5	1231.7	1162.2	1234.4	1177.8	1257.2	1247.9	1223.7
57.5	1577.9	1641.0	1595.4	1589.4	1614.6	1610.1	1650.5	1627.7	1602.5
62.5	1979.7	2080.2	2076.0	2070.0	2100.6	2055.0	2068.6	2048.0	2083.3
67.5	2473.5	2648.8	2591.9	2581.8	2625.1	2582.7	2621.8	2516.7	2524.2
72.5	2960.6	3193.0	3171.9	3198.3	3304.2	3179.9	3215.2	3138.2	3093.4
77.5	3684.8	4015.4	3931.9	4001.5	4072.8	3910.9	3924.1	3831.5	3761.0
82.5	4498.4	4765.6	4802.6	4720.3	4998.2	4751.3	4863.8	4552.1	4569.2
87.5	5469.5	5563.2	5772.7	5676.1	5877.0	5781.3	5816.9	5550.4	5560.4
92.5	6583.7	6913.7	6912.7	6875.3	6928.6	6717.6	6685.3	6618.9	6748.4
97.5	7276.1	8166.5	8104.1	7468.1	8246.1	7826.6	7920.6	8006.7	8135.9
102.5	9484.7	9700.8	9184.6	8895.3	9467.3	9504.6	9418.5	9852.3	9376.1
107.5	10581.9	10286.9	10727.2	11332.1	11191.0	10505.7	11223.9	11575.2	10526.3
112.5	13304.1		13344.3	11025.0	12372.1	13511.5	12312.1	12498.7	12456.2
117.5	13141.6	15366.5	14145.7	12748.0		15062.2		14154.5	13942.0
122.5	13604.1			15154.8	17053.9		19898.7	17657.4	17410.1
127.5	15600.1		26081.5						18823.6
132.5	22878.1				18596.8				
35	353.1	362.1	353.9	342.5	363.3	352.8	**356.2**	**347.4**	**356.3**
45	762.8	784.5	771.6	734.0	777.8	748.1	**777.6**	**762.9**	**763.9**
55	1385.5	1465.8	1413.6	1375.8	1424.5	1394.0	**1453.8**	**1437.8**	**1413.1**

Length		Numbers, ind	Tones	Mean weight, gr	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	5.9	607016	0.061	0.1	607016															
6	10.9	1584866291	9760.134	6.2	1584866291															
11	15.9	1296850576	24585.364	19	255717017	1041133559														
16	20.9	578922973	26472.569	45.7		540647075	38275898													
21	25.9	166140832	17241.635	103.8		36550983	126267033	3322817												
26	30.9	144366389	27659.288	191.6		2624844	129929750	11811795												
31	35.9	75805153	22976.036	303.1			39418680	33354267	2021471	1010735										
36	40.9	58813695	27365.287	465.3			5639669	48340024	4834002											
41	45.9	83167502	57119.063	686.8			1890170	41583751	38748495	945086										
46	50.9	66336318	62467.232	941.7			799233	11189258	46355499	7992328										
51	55.9	45320473	58353.408	1287.6				1320014	30800321	12320128	440005	440005								
56	60.9	29405121	49124.195	1670.6				753978	6785797	15833527	5654831	376989								
61	65.9	23834858	52690.834	2210.7				277150	2771495	8314485	9145934	3048645	277150							
66	70.9	26342475	72357.555	2746.8				227090	681271	3406354	9991973	11581605	454181							
71	75.9	25183610	84274.474	3346.4					412846	1857807	3096346	16720266	2477077	619269						
76	80.9	17912436	72148.604	4027.9						179124	1791244	11284835	4119860	358249	179124					
81	85.9	16235574	80187.687	4939					186616	186616	933079	5785090	6344937	2799237						
86	90.9	9480280	56554.962	5965.5							175561	1228925	3335654	3335654	1053364	351122				
91	95.9	6621222	47319.154	7146.6								509325	1018649	3395498	1188424	339550	169775			
96	100.9	4229985	35338.265	8354.2									483427	1933708	1329424	120857	362570			
101	105.9	4245271	41572.678	9792.7										471697	471697	1572322	943393	628929		157232
106	110.9	2733229	30645.179	11212.1										210248	630745	420497	840994	630745		
111	115.9	1382699	18933.101	13692.9													592585	592585	197528	
116	120.9	412234	6701.887	16257.5												103058		103058	103058	103058
126	130.9	297631	5044.844	16950															297631	
		4269513843	986893.498		1841190324	1620956461	342220432	152180144	133597814	52046190	31228971	50975683	18510934	13123560	4852779	2907406	2909318	1955318	598218	260291
		4269513843																		

Length		Numbers, ind	Tones	ean weight, g	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	5.9	4059006.51	0.405900651	0.1	4059006.51															
6	10.9	2310125967	13007.5847	5.630682	2281249392	28876574.59														
11	15.9	287423416.3	5687.667351	19.788462	31028665.56	256394750.7														
16	20.9	457427549.5	19810.86788	43.309302		443352856	14074693.48													
21	25.9	107000617.9	10923.75203	102.090551		27672573.62	77483205.92	1844838.31												
26	30.9	148884187.8	27855.33228	187.09396		1200679.51	105659746.3	42023762.02												
31	35.9	161981987.1	49513.42502	305.672414			47715623.55	113010688.9	1255674.65											
36	40.9	164938827.2	78665.21053	476.935673			11410862.27	130706240.4	21784373.12	1037351.41										
41	45.9	108733119	72505.94231	666.824818			3536036.91	63648654.65	38896400.61	2652026.87										
46	50.9	80041374.83	75981.94308	949.283333			748049.88	20945406.26	43386913.08	14961004.81										
51	55.9	69495527.56	90187.17743	1297.740741				1158259.02	23744305.48	35906022.8	8107811.78	579129.16								
56	60.9	62734509.27	105735.9026	1685.450382				1665517.78	6662071.76	27758632.66	26648287.06									
61	65.9	61482084.93	132808.8835	2160.123288					3310573.57	15606990.55	40199824.53	2364695.67								
66	70.9	53574470.69	142025.5472	2650.993007					2453792.73	3680688.82	30672406.67	16358616.93	408965.54							
71	75.9	39073102.71	129087.1288	3303.733766						1953655.14	10605556.39	22885674.61	3349123.26	279093.7						
76	80.9	28374824.62	110076.4255	3879.369369						540472.88	3513073.42	14322530.39	8107092.87	1351182.19	540472.88					
81	85.9	18060717.46	87377.75107	4838						622783.39	622783.39	3736700.13	9964533.81	2906322.35	207594.4					
86	90.9	13861346.32	82680.04302	5964.791667						198019.17	396038.49	1782173.12	4752461.56	3366326.92	2178211.6	990096.15	198019.17			
91	95.9	7913665.5	57103.26656	7215.779661								545770.06	818655.08	2455965.17	2455965.17	1364425.06	272885.03			
96	100.9	4435599.37	37797.11516	8521.309524							110889.98		443559.94	665339.91	554449.92	887119.87	1663349.76	110889.98		
101	105.9	3435032.49	33904.3074	9870.15625									110807.48	110807.48	110807.48	886460.01	1440497.5	443230.01	221615	110807.48
106	110.9	1626683.04	19704.69658	12113.42105											85614.9	256844.7	599304.27	342459.59	256844.7	85614.9
111	115.9	835181.31	11255.82203	13477.1											83518.13		167036.26	501108.79		83518.13
116	120.9	436666.42	6474.307454	14826.66667										72777.74	72777.74		145555.47		145555.47	
121	125.9	244900.23	4239.222981	17310											122450.12	61225.06		61225.06		
126	130.9	320382.91	6104.89635	19055														320382.91		
141	145.9	7673.37	243.7791282	31769.5																
		4196528421	1410758.404		2316337064	757497434.5	260628218.3	375003367.3	141494105	104917648.5	120876671.7	62575290.07	27955199.54	11207815.46	6411862.34	4446170.85	4486647.46	1779296.34	624015.17	279940.51
		4196520747																		

Length		Numbers, ind	Tones	Mean weight, gr	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
6	10.9	1138330550	7130	6.3	1125957386	12373164																
11	15.9	178620321	3542	19.8	38876188	139744133																
16	20.9	200548663	9263	46.2		174109771	26438892															
21	25.9	187320767	18622	99.4		23752489	163028448	539828														
26	30.9	130635209	23074	176.6		808887	123355229	6471093														
31	35.9	48048747	14422	300.2			24701117	22332516	1015114													
36	40.9	41227093	19618	475.8			3365477	30289293	7572323													
41	45.9	47743516	32518	681.1			454700	11822204	32738411	2728201												
46	50.9	50634676	47606	940.2				2893410	28934100	18807165												
51	55.9	63230026	80602	1274.8				1317292	17563896	39957863	4390974											
56	60.9	56485202	93852	1661.5				1516381	4928239	36772245	12889241	379095										
61	65.9	44836638	94765	2113.6					313543	15050060	25396977	4076058										
66	70.9	34855112	90910	2608.2					490917	4909171	17427556	10554717	1227293		245458							
71	75.9	28549226	90532	3171.1						2877054	7081979	15934452	2655742									
76	80.9	19870818	77630	3906.7					160249	320497	2243480	7852178	7691930	801243	160249	480746		160249				
81	85.9	18174552	87658	4823.1						171458	514374	3943535	10116024	2743329	514374	171458						
86	90.9	12201584	70469	5775.4							143548	1435481	3445153	4449990	2440317	287096						
91	95.9	9218113	65119	7064.3								141817	1418171	2269074	4538148	850903						
96	100.9	8376533	67429	8049.8									299162	2692457	3589943	1495809	299162					
101	105.9	4477663	42292	9445.1								121018	363054	605090	1089161	1573233	605090	121018				
106	110.9	1021980	11602	11352.3										240466	180349	300582	180349		120233			
111	115.9	438016	6007	13714.3											125147	62574	250295					
116	120.9	1050816	15658	14901.0											315245		315245	210163	210163			
121	125.9	350308	6715	19170.0															116769	116769	116769	
126	130.9	399661	8793	22000.0												199830						199830
146	150.9	129668	4669	36004.9																		
		2326775456	1090498		1164833574	350788443	341343862	77182019	93716793	121593715	70088128	44438350	27216529	13801647	13198391	5422231	1650140	491430	447165	116769	116769	199830
		2326645786																				

Length		Numbers, ind	Tones	ean weight, g	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1.0	5.9	5354310	0.535	0.1	5354310																
6.0	10.9	340910014	1921.493	5.6	328513285	12396729															
11.0	15.9	549100023	10621.075	19.3	15424159	530591031	3084833														
16.0	20.9	207853977	9582.381	46.1	1636646	171847776	34369555														
21.0	25.9	66687661	6915.028	103.7		9879654	53514790	3293218													
26.0	30.9	57676488	10197.203	176.8		600797	39652586	16822309	600797												
31.0	35.9	76724375	22943.170	299.0			17877524	55122366	3724484												
36.0	40.9	94495153	44069.138	466.4			3073014	61460262	29193625	768253											
41.0	45.9	117280554	78185.000	666.6			820144	25424456	87755379	3280575											
46.0	50.9	98963602	89282.448	902.2			1596187	7980936	63847485	25538994											
51.0	55.9	83987979	104126.196	1239.8				4307076	30867377	48095680	717846										
56.0	60.9	63914672	104059.897	1628.1					6982275	42967847	13427452	537098									
61.0	65.9	49616472	101240.442	2040.5					1587727	15083408	28976020	3969318									
66.0	70.9	35662514	92124.893	2583.2					604449	4533370	20551279	9671190	302225								
71.0	75.9	28722215	90929.516	3165.8						455908	5470898	18236327	3875219	455908		227954					
76.0	80.9	24845462	96122.849	3868.8						403991	2423948	11311755	6665855	3433926	403991	201996					
81.0	85.9	25071781	119610.159	4770.7						166038	830191	3984919	7803799	9796259	2158498	166038	166038				
86.0	90.9	23192847	132143.738	5697.6							171799	687195	5325765	10136133	6012960	858994					
91.0	95.9	20401910	137828.182	6755.7								161920	1619199	8257916	9067516	1295359					
96.0	100.9	11977913	96648.419	8068.9									544451	2722253	6397294	2313915					
101.0	105.9	4461319	41589.347	9322.2									103752	311255	1971280	1660026	415006				
106.0	110.9	1708643	18966.683	11100.4										74289	520022	668600	222867	148578	74289		
111.0	115.9	1131063	14135.199	12497.3											102824	308472	514119		205648		
116.0	120.9	342653	5212.783	15213.0										68531		68531	137061		68531		
121.0	125.9	362196	6131.078	16927.5													241464		120732		
126.0	130.9	381876	7009.334	18355.0												95469			190938		95469
136.0	140.9	151108	2638.340	17460.0															151108		
		1990978780	1444234.528		350928401	725315986	153988633	174410623	225163599	141294065	72569433	48559722	26240265	35256469	26634386	7865353	1696556	148578	811245	0	95469
		1990978783																			

Length		Numbers, ind	Tones	Mean weight, gr	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1.0	5.9	38171074	38.171	1.0	38171074																
6.0	10.9	2382957560	9035.382	3.8	2382957560																
11.0	15.9	256246049	4778.764	18.6	22477724	233768325															
16.0	20.9	92468683	4254.554	46.0	994287	69600084	21874312														
21.0	25.9	70860967	7012.874	99.0	595470	2977352	63715323	3572822													
26.0	30.9	77071221	14036.897	182.1		1806357	48771632	26493232													
31.0	35.9	83710121	24125.124	288.2			18602249	63114773	1993098												
36.0	40.9	70087735	31655.126	451.7			2156546	62000688	5930500												
41.0	45.9	61863962	40902.953	661.2				28032108	30931981	2899873											
46.0	50.9	51764216	47524.625	918.1				6089908	38569416	7104892											
51.0	55.9	53107626	66002.377	1242.8					23234586	29319835	553205										
56.0	60.9	47471133	76638.315	1614.4				382832	7273803	33306359	6508139										
61.0	65.9	36573727	76534.643	2092.6				329493	658986	14168201	20099075	988479	329493								
66.0	70.9	29130556	73574.966	2525.7						5612309	17638685	3474287	2138023	267253							
71.0	75.9	27422951	86278.779	3146.2						1246498	4736691	12464977	7229687	997198	498599	249300					
76.0	80.9	30716442	115762.290	3768.7						251774	3273064	8056772	13595802	4783708	503548			251774			
81.0	85.9	29899137	138399.291	4628.9								3686195	16178300	8601121	1228732					204789	
86.0	90.9	22803657	126122.881	5530.8								1341392	7473467	9772996	3257665	766510		191627			
91.0	95.9	14784030	96574.162	6532.3								152413	2743428	7773047	3200666	609651	152413	152413			
96.0	100.9	6393444	50360.920	7877.0								245902	491803	3196722	1598361	614754	245902				
101.0	105.9	2920890	26877.053	9201.7										865449	1081811	757268	108181	108181			
106.0	110.9	566696	6237.701	11007.1										80957	242870	161913	80957				
111.0	115.9	1066156	13083.737	12271.9											399809	133270	133270	133270	266539		
116.0	120.9	266201	3646.952	13700.0												133100	133100				
121.0	125.9	182421	2775.838	15216.7											60807		60807				60807
131.0	135.9	110313	2554.855	23160.0													110313				
		3488616968	1144789.226		2445196115	308152118	155120062	190015856	108592370	93909741	52808859	30410416	50180004	36338451	12072868	3425765	1024942	837265	266539	204789	60807
		3488616967																			

Length		Numbers, ind	Tones	Mean weight, gr	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1.0	5.9	84468097	42.234	0.5	84468097															
6.0	10.9	2127420914	8629.930	4.1	2104296763	23124151														
11.0	15.9	702105736	13412.041	19.1	93074535	607007838	2023356													
16.0	20.9	382825005	16554.626	43.2		269124937	113700068													
21.0	25.9	313136268	30466.247	97.3		14342120	296403797	2390354												
26.0	30.9	226642488	39201.497	173.0		593305	199350460	26698723												
31.0	35.9	121692779	35150.274	288.8			43706562	76700731	1285487											
36.0	40.9	119322845	54822.052	459.4			2687451	95673272	20424631		537490									
41.0	45.9	99126764	67038.317	676.3			1120077	39202675	57123898	1680114										
46.0	50.9	86876969	82972.019	955.1				6246056	63028390	17602523										
51.0	55.9	77911367	100857.182	1294.5				1833209	32539453	40788892	2749813									
56.0	60.9	65680470	109491.168	1667.0					5017258	44699209	14595660	1368343								
61.0	65.9	52453162	114718.586	2187.1					2112208	17601732	21122079	10913074	704069							
66.0	70.9	60611288	166720.368	2750.6				360781	721563	2525471	14070478	36078148	6494067	360781						
71.0	75.9	73073603	243647.383	3334.3					1034060		8961857	39294296	21025895	2412808	344687					
76.0	80.9	76623550	310546.126	4052.9					304061	608124	608124	23108690	43784886	7905604	304061					
81.0	85.9	57216915	279411.559	4883.4							508595	6357435	37127421	12969168	254297					
86.0	90.9	32945848	194899.989	5915.8						182021		546064	16563934	14379679	910106	364042				
91.0	95.9	16869726	118380.371	7017.3								351453	3397375	10074975	2343017	468604	234302			
96.0	100.9	8682833	73222.547	8433.0								109909	1099093	4396371	2418004	659456				
101.0	105.9	3069919	29586.581	9637.6								93028		930279	930279	744223	186056	186056		
106.0	110.9	2452799	27682.555	11286.1										262800	1051200	613200	350400		87600	87600
111.0	115.9	1475467	18858.723	12781.5										155312	388281	465937	388281	77656		
116.0	120.9	361538	5403.181	14945.0											120513		180769		60256	
121.0	125.9	383234	7151.910	18662.0											76647		76647	76647	76647	76647
126.0	130.9	314689	6055.139	19241.7													104896	104896	104896	
		4793744272	2154922.601		2281839395	914192350	658991771	249105801	183591010	125688086	63154094	118220439	130196740	53847777	9141091	3315461	1521350	445255	329399	164247
		4793744268																		

	Length	Numbers, ind	Tones	ean weight, g	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1.0	5.9	36420319	3.642	0.1	36420319															
6.0	10.9	1352767145	7710.773	5.7	1317168009	35599136														
11.0	15.9	946443932	19753.707	20.9	59152746	887291187														
16.0	20.9	508927025	24321.779	47.8		475297484	33629542													
21.0	25.9	179131877	18004.099	100.5		55182805	122251138	1697932												
26.0	30.9	92428564	16929.054	183.2		901742	71237625	20289197												
31.0	35.9	84705050	26039.950	307.4			23449421	60777069	478560											
36.0	40.9	114813199	53671.871	467.5			3299230	98976897	12537073											
41.0	45.9	99961137	67998.234	680.2			1985983	36409685	60903474	661995										
46.0	50.9	60941140	57952.374	951.0				8390447	47251464	4416025	883205									
51.0	55.9	50244789	65067.819	1295.0				1647370	19768441	23886867	4942111									
56.0	60.9	58297259	98378.931	1687.5				419404	5032857	25164285	26422499	1258214								
61.0	65.9	85264725	186297.768	2184.9					435024	13050723	55248061	13920772	2610144							
66.0	70.9	100263875	264502.367	2638.1				484367		2421833	43108622	48921021	5328032							
71.0	75.9	87232590	281169.382	3223.2						360465	17662797	54430252	14779075							
76.0	80.9	63267045	247277.815	3908.5							1830039	34770732	25620539	1045737						
81.0	85.9	31626296	149824.635	4737.3							395329	9092560	19766435	1976643	395329					
86.0	90.9	18511936	106502.760	5753.2							276297	2210381	12157092	3315571	414446	138149				
91.0	95.9	8755780	61024.710	6969.6								389146	3307739	3794171	1070151		194573			
96.0	100.9	4556510	38223.651	8388.8								91130	729042	1913734	1093562	364521	273391	91130		
101.0	105.9	1821875	17586.927	9653.2									72875	510125	801625	437250				
106.0	110.9	1286693	13925.598	10822.8								71483	142966	142966	428898	214449	142966		142966	
111.0	115.9	1109526	14192.316	12791.3											147937	295874	517779	147937		
116.0	120.9	501069	7165.782	14301.0												100214	300641	100214		
121.0	125.9	75101	1339.806	17840.0																75101
126.0	130.9	88816	1711.479	19270.0														88816		
		3989443273	1846577.232		1412741073	1454272354	255852938	229092369	146406893	69962192	150768959	165155691	84513940	12698947	4351948	1550456	1429349	428096	142966	75101
		3989443274		Weight at age	6.2	32.4	144.8	461.4	870.3	1631.1	2346.7	3227.1	4289.6	6417.5	8079.6	10069.5	11277.4	13551.7	10822.8	17840.0

Length		Numbers, ind	Tones	Mean weight, g	0	1	2	3	4	5	6	7	8	9	10	11	12	13
1.0	5.9	140226735	14.023	0.1	140226735													
6.0	10.9	1873632015	8833.976	4.7	1873632015													
11.0	15.9	351793531	7596.034	21.6	69102300	282691231												
16.0	20.9	223045823	9117.295	40.9		207208249	15837574											
21.0	25.9	98585591	10084.971	102.3		19448858	78466083	670650										
26.0	30.9	61082894	10806.528	176.9		459270	50060417	10563207										
31.0	35.9	55913827	16703.552	298.7			14511985	41401842										
36.0	40.9	40612218	18543.315	456.6			1128117	36851828	2256235	376039								
41.0	45.9	49409706	33181.582	671.6				23369455	25372552		667699							
46.0	50.9	58276105	55798.623	957.5				8218425	33620830	15689721	747129							
51.0	55.9	101169766	133606.679	1320.6				2572113	30865353	64302817	3429484							
56.0	60.9	134903617	231245.554	1714.2					6385970	88605334	38315820	798246	798246					
61.0	65.9	177517030	381284.391	2147.9					3025858	59508549	105905047	9077575						
66.0	70.9	154970176	407608.496	2630.2						10862396	99209880	43449582	1448319					
71.0	75.9	110303749	360677.428	3269.9						510666	42895902	63833188	3063993					
76.0	80.9	58167369	231605.045	3981.7						311055	8087442	39815098	9642719	311055				
81.0	85.9	29481423	139142.834	4719.7							1030819	16493104	9689699	2061638	206164			
86.0	90.9	10472275	60141.159	5742.9								4387034	4670069	1273655	141517			
91.0	95.9	5518761	37725.848	6835.9							100341	501706	2006822	2207504	401364	200682	100341	
96.0	100.9	2253187	18601.335	8255.6								77696	776961	776961	310784	233088	77696	
101.0	105.9	1396131	14161.606	10143.5									93075	558452	372302	186151	186151	
106.0	110.9	1034031	12306.267	11901.3									86169	258508	172339	172339	172339	172339
111.0	115.9	490651	6297.504	12835.0										245325	245325			
116.0	120.9	536110	7783.788	14519.0												428888		107222
121.0	125.9	172119	3114.213	18093.3												114746	57373	
		3740964842	2215982.047		2082961050	509807608	160004176	123647520	101526797	240166577	300389563	178433228	32276072	7693099	1849795	1335895	593900	279561
		3740964840		Weight at age	5.0	32.6	139.9	469.8	1068.4	1712.5	2456.2	3415.9	4593.0	6717.4	8688.2	11631.6	10615.7	12905.3

Length		Numbers, ind	Tones	Mean weight, g	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1.0	5.9	4867366	0.487	0.1	4867366														
6.0	10.9	575677028	3226.821	5.6	575677028														
11.0	15.9	247382389	4646.745	18.8	72053124	175329265													
16.0	20.9	126761988	5344.548	42.2		119112558	7649431												
21.0	25.9	55799753	5617.291	100.7		15081014	40216038	502701											
26.0	30.9	32394131	5694.410	175.8		736230	29081095	2576806											
31.0	35.9	19793477	6093.033	307.8			6090301	13195651	507525										
36.0	40.9	39512730	18443.424	466.8			1118285	26838835	11555610										
41.0	45.9	62669424	42668.788	680.9				11959813	48317648	2391963									
46.0	50.9	106277865	104107.978	979.6				1136662	72746346	32394857									
51.0	55.9	165503815	220188.923	1330.4					39720916	118500731	7282168								
56.0	60.9	222891648	387410.052	1738.1					3595026	168966250	49611368	719006							
61.0	65.9	221126378	479734.275	2169.5				600887	600887	61891349	153827045	4206208							
66.0	70.9	188451082	516358.863	2740.0						12563406	150277658	25610020							
71.0	75.9	111352645	373036.573	3350.0						473841	54017879	53544037	3316887						
76.0	80.9	57043250	232620.614	4078.0							8802971	38028834	8450852	1760594					
81.0	85.9	31394691	158318.874	5042.9							909991	17517327	11602386	909991	454995				
86.0	90.9	17523241	105465.661	6018.6							203759	2445103	10595448	3056379	1222552				
91.0	95.9	10306109	71158.606	6904.5								448092	4032825	2539186	2837914	448092			
96.0	100.9	3838199	31345.914	8166.8								112888	338665	1693323	790217	790217	112888		
101.0	105.9	2263076	21944.653	9696.8								98395	98395	590368	1082341	98395	196789	98395	
106.0	110.9	692349	7989.711	11540.0									98907		395628	197814			
111.0	115.9	164189	2075.895	12643.3												54730		54730	54730
121.0	125.9	103708	2114.599	20390.0														51854	51854
total		2303790531	2805606.739		652597518	310259067	84155150	56811355	177043957	397182398	424932837	142729910	38534364	10549842	6783647	1589247	309677	204978	106583
		2303790532		Weight at age	7.0	32.1	141.2	486.8	960.8	1649.1	2504.1	3664.4	5204.7	6374.4	7482.9	8479.7	9139.1	13188.6	16412.2

Length		Numbers, ind	Tones	Mean weight, gr	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1.0	5.9	965982	0.097	0.1	965982																
6.0	10.9	821963231	4597.192	5.6	821963231																
11.0	15.9	427795806	8383.546	19.6	79298733	348497073															
16.0	20.9	221730366	8940.754	40.3	1045898	214409080	6275388														
21.0	25.9	39348777	4057.758	103.1		5621254	33727523														
26.0	30.9	50666242	9095.065	179.5		1187490	38791342	10291580	395830												
31.0	35.9	76366894	23389.860	306.3			11785015	61282076	3299804												
36.0	40.9	117131580	54000.587	461.0			2940541	89196434	24014424	980180											
41.0	45.9	109764524	73216.235	667.0				33918652	65010748	10835125											
46.0	50.9	155728885	144898.800	930.5				6096149	103080330	44889821	1662586										
51.0	55.9	149600725	186461.354	1246.4				1104064	65691831	75628411	7176419										
56.0	60.9	127705836	216539.534	1695.6				448090	15235083	91858584	20164080										
61.0	65.9	87673011	188957.600	2155.3					3424727	51370905	29795125	2739782	342473								
66.0	70.9	45294053	122257.321	2699.2					487033	12419337	26786805	5600877									
71.0	75.9	22502781	74559.573	3313.3						1387158	11559648	7244046	1695415	462386	154129						
76.0	80.9	17126963	69608.323	4064.3						255626	3578768	9330360	2684076	1150318	127813						
81.0	85.9	8331435	41041.923	4926.2							784135	4018692	2744473	784135							
86.0	90.9	7824789	46806.024	5981.8							186304	2328806	2701415	1863045	465761	279457					
91.0	95.9	3879434	26914.890	6937.8								387943	1629362	1086241	698298	77589					
96.0	100.9	2483317	20040.143	8069.9								232811	698433	776037	543226	232811					
101.0	105.9	1723594	16866.326	9785.6									95755	957552	383021	95755	95755	95755			
106.0	110.9	568290	6138.460	10801.6									71036	142073	142073	71036	71036	71036			
111.0	115.9	164732	2285.656	13875.0										54911	54911						54911
116.0	120.9	174819	2700.957	15450.0												58273	116546				
total		2496516067	1351757.977		903273844	569714897	93519810	202337045	280639811	289625149	101693870	31883318	12662439	7276698	2569231	814921	283338	166792	0	0	54911
		2496516072		Weight at age	6.9	28.6	167.4	455.5	954.4	1551.5	2350.4	3802.7	5179.7	6415.0	7429.9	8213.5	12370.3	10218.3			13875.0

Length		Numbers, ind	Tones	Mean weight, gr	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1.0	5.9	6349225	0.635	0.1	6349225																
6.0	10.9	446864561	2591.814	5.8	438739750	8124811															
11.0	15.9	55005060	1040.411	18.9	35651428	19353632															
16.0	20.9	99149196	4619.451	46.6	2704069	92839702	3605426														
21.0	25.9	102968736	11324.354	110.0		10623758	91527765		817212												
26.0	30.9	215003944	41465.408	192.9			188915600	26088344													
31.0	35.9	249645076	78658.281	315.1			76899598	168287528	4457947												
36.0	40.9	306246125	145478.014	475.0			10560212	272218778	23467135												
41.0	45.9	239424301	160214.945	669.2			1103337	142330576	94887049	1103337											
46.0	50.9	194787276	193141.405	991.6				38792381	149391935	6602959											
51.0	55.9	182175014	237972.618	1306.3				4358253	141207428	36609333											
56.0	60.9	99458751	169115.011	1700.4				543490	59783949	37500840	1630471										
61.0	65.9	47820905	105350.720	2203.0					7600674	30719389	9184147	316695									
66.0	70.9	32664318	89614.047	2743.5					1814684	15035956	14258234	1296203	259241								
71.0	75.9	26971708	92858.340	3442.8						3801382	18644872	3077309	1267127	181018							
76.0	80.9	15094243	63885.615	4232.4						895421	6267948	4477106	3197933	255835							
81.0	85.9	9995417	51797.667	5182.1							619185	2919016	6103396	176910	176910						
86.0	90.9	4949072	30094.372	6080.8							334397	601914	3343968	601914		66879					
91.0	95.9	3512983	25138.073	7155.8							127745	127745	2299407	830341	127745						
96.0	100.9	1007049	8562.352	8502.4									530026	318015	106005	53003					
101.0	105.9	1125281	10968.235	9747.1									312578	437609	312578		62516				
106.0	110.9	698103	8032.512	11506.2									139621	418862			139621				
111.0	115.9	317298	4031.273	12705.0										63460	126919	63460		63460			
121.0	125.9	90557	1582.475	17475.0												45278		45278			
131.0	135.9	80306	1527.497	19021.0																	80306
total		2341404503	1539065.526		483444472	130941903	372611937	652619351	483428014	132268618	51067000	12815988	17453296	3283965	850157	228620	202136	108738	0	0	80306
		2341404501		Weight at age	6.9	45.1	205.7	502.1	1100.7	1849.8	3113.5	4174.4	5511.0	7557.9	8694.2	10737.6	10962.2	14691.2			19021.0

Length		Numbers, ind	Tones	Mean weight, gr	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1.0	5.9	4207032	0.421	0.1	4207032														
6.0	10.9	70361776	375.835	5.3	68645635	1716141													
11.0	15.9	62267183	1273.779	20.5	25944660	36322523													
16.0	20.9	281282552	13350.051	47.5	2250260	256529688	22502604												
21.0	25.9	218481656	22121.413	101.3		37870153	176241870	4369633											
26.0	30.9	300027428	52975.313	176.6		885036	236304789	61952568	885036										
31.0	35.9	212546238	63131.819	297.0			65398843	145103682	2043713										
36.0	40.9	239188924	107083.969	447.7			4910037	220250210	14028677										
41.0	45.9	161129797	107345.761	666.2				121755975	38162321	1211503									
46.0	50.9	81070856	73072.840	901.3				28834479	47639575	4596801									
51.0	55.9	53972882	66380.757	1229.9				3925300	35654813	14065660	327109								
56.0	60.9	51876788	86827.569	1673.7					18426182	28631451	4252196	283480		283480					
61.0	65.9	31566936	68529.872	2170.9					2162119	22269824	6270145	864848							
66.0	70.9	19919628	53748.249	2698.3					149772	6440181	8237440	5092236							
71.0	75.9	14617800	48713.591	3332.5						1484620	4225458	8222513	685209						
76.0	80.9	10579012	43992.079	4158.4						374478	1123435	7676805	1310674	93620					
81.0	85.9	5434131	26594.569	4894.0							132540	3247224	1656747	265080	132540				
86.0	90.9	3134735	18410.178	5873.0								1290773	1475170	307327	61465				
91.0	95.9	1045958	7426.996	7100.7								116218	522979	348653	58109				
96.0	100.9	1257585	9683.720	7700.3								125759	125759	503034	440155	62879			
101.0	105.9	574140	5258.106	9158.2									191380	255174	63793		63793		
106.0	110.9	100283	1168.425	11651.3										50142		25071	25071		
111.0	115.9	178101	2016.406	11321.7											118734		59367		
116.0	120.9	230534	3014.523	13076.3										57634	57634	57634	57634		
121.0	125.9	34436	534.756	15529.0															34436
total		1825086392	883030.995		101047588	333323541	505358143	586191848	159152207	79074519	24568322	26919855	5967918	2164141	932430	145584	205865	0	34436
		1825086394		Weight at age	9.9	50.8	162.8	452.1	975.2	1800.8	2554.5	3740.1	5184.4	6464.4	8036.7	10508.9	11182.6		15529.0

Length		Numbers, ind	Tones	Mean weight, gr	0	1	2	3	4	5	6	7	8	9	10	11	12
1.0	5.9	1224409	0.122	0.1	1224409												
6.0	10.9	178154320	1092.908	6.1	178154320												
11.0	15.9	227171648	4370.699	19.2	90037543	137134106											
16.0	20.9	378995436	16682.226	44.0	6620008	319415367	52960060										
21.0	25.9	204888709	21020.240	102.6		22465867	181524207	898634									
26.0	30.9	209828125	38697.552	184.4			196093920	13734206									
31.0	35.9	127775616	37422.778	292.9			74385804	52789926	599886								
36.0	40.9	84814328	40418.710	476.6			3996487	71048653	9769190								
41.0	45.9	71103440	49494.612	696.1			703994	33087739	36255714	703994	351998						
46.0	50.9	102983468	98008.539	951.7				11953438	85972806	5057224							
51.0	55.9	79728104	103921.001	1303.4				2291037	56817729	18328300	2291037						
56.0	60.9	42787180	71886.053	1680.1				301318	14463272	20489636	7231636	301318					
61.0	65.9	39288789	85540.779	2177.2					1598962	12563276	23527589	1370539	228423				
66.0	70.9	29187510	79064.400	2708.8						2445881	22175986	4076468	489176				
71.0	75.9	16846737	55677.609	3304.9						215984	11123166	4211684	1079919	215984			
76.0	80.9	8947226	36559.203	4086.1					69900		2656208	4473613	1537804	139800	69900		
81.0	85.9	5554031	27655.593	4979.4						50491	353438	2524560	2070139	504912	50491		
86.0	90.9	2499524	14929.271	5972.8					43095			430952	1379048	517143	43095	86191	
91.0	95.9	1786747	12756.250	7139.4								207761	914150	623284	41552		
96.0	100.9	832212	6954.004	8356.1							43801	43801	350405	262804	87601		43801
101.0	105.9	202338	1913.308	9456.0									40468	80935	40468	40468	
106.0	110.9	340326	3753.582	11029.4										212704	85081	42541	
111.0	115.9	236706	3243.656	13703.3											157804	78902	
116.0	120.9	28384	411.850	14510.0											28384		
126.0	130.9	45281	1209.003	26700.0											45281		
total		1815250595	812683.947		276036279	479015340	509664472	186104950	205590556	59854785	69754858	17640696	8089532	2557565	649658	248101	43801
		1815250593		Weight at age	11.3	39.7	159.5	482.8	1042.2	1646.7	2529.1	3612.4	4951.7	6508.2	10663.2	9866.5	8356.1

Length		Numbers, ind	Tones	Mean weight, gr	0	1	2	3	4	5	6	7	8	9	10	11	12	13
1.0	5.9	677969	0.678	1.0	677969													
6.0	10.9	148884199	853.361	5.7	148884199													
11.0	15.9	297385684	5608.596	18.9	29574266	267811419												
16.0	20.9	184805484	8670.165	46.9	1032432	164156827	19616224											
21.0	25.9	62120778	6160.955	99.2		8742924	52457546	920308										
26.0	30.9	77282961	14245.353	184.3			55761124	21521837										
31.0	35.9	99603687	30847.160	309.7			18294555	80292768	1016364									
36.0	40.9	87465502	41782.785	477.7			467730	79981823	6548219	467730								
41.0	45.9	41371438	28530.442	689.6				25252696	13163639	2955103								
46.0	50.9	42946042	42326.062	985.6				7782169	20175993	14699652	288229							
51.0	55.9	49456910	67542.595	1365.7				847833	12152270	35043753	1130444	282611						
56.0	60.9	42488061	73425.562	1728.1					2296652	32535903	7464119		191387					
61.0	65.9	23190302	50594.403	2181.7					366163	13181856	7933524	1464651	122054	122054				
66.0	70.9	12329000	34130.515	2768.3					80058	1521110	7365377	3042221	240175			80058		
71.0	75.9	9267455	30832.149	3326.9						298950	3213714	4708465	1046326					
76.0	80.9	6225582	25978.155	4172.8						119723	478891	4010711	1496534	119723				
81.0	85.9	3055623	15097.873	4941.0							123877	1569104	1114889	247753				
86.0	90.9	1342953	7730.196	5756.1						31975		479626	703451	127900				
91.0	95.9	981648	7009.305	7140.3								37756	377557	339801	226534			
96.0	100.9	651030	5481.904	8420.4								50079	300475	100158	150238			50079
101.0	105.9	159768	1595.688	9987.5									59913	19971	39942	39942		
106.0	110.9	142636	1508.617	10576.7										95091	47545			
116.0	120.9	23736	374.139	15762.2														
		1191858448	500326.658		180168866	440711170	146597178	216599433	55799358	100855755	27998174	15645223	5652763	1172452	464259	120001	0	50079
		1191834711																

Length		Numbers, ind	Tones	Mean weight, gr	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1.0	5.9	480712	0.048	0.1	480712														
6.0	10.9	504475731	3040.980	6.0	504475731														
11.0	15.9	266611684	5070.912	19.0	38087383	228524302													
16.0	20.9	149868848	7243.260	48.3		88608590	61260259												
21.0	25.9	188011181	18311.330	97.4		13498238	173548782	964161											
26.0	30.9	79848525	14411.686	180.5			73194482	6142195	511850										
31.0	35.9	57394479	17693.353	308.3			20068000	33312880	4013600										
36.0	40.9	115134644	52916.049	459.6			1668618	60070249	53395777										
41.0	45.9	203343674	139198.675	684.5				34994027	161729155	6620492									
46.0	50.9	188267508	177789.479	944.3				12237388	139317956	35770826	941338								
51.0	55.9	108715988	137270.272	1262.7					55249109	49308344	4158535								
56.0	60.9	54159536	89996.363	1661.7					6334448	35156190	11402008	1266890							
61.0	65.9	44441031	92269.299	2076.2					976726	18557793	20999608	3662722	244182						
66.0	70.9	38058737	98386.133	2585.1						4092337	24554024	8798526	613851						
71.0	75.9	27646997	85284.964	3084.8						708897	14000723	11519582	1417795						
76.0	80.9	17044216	65267.367	3829.3							3334738	11115793	2346667	247018					
81.0	85.9	6420290	29943.800	4663.9							323712	2751553	2697601	647424					
86.0	90.9	3036864	17186.170	5659.2								860445	1720890	303686	151843				
91.0	95.9	1646236	11193.652	6799.5							47035	235177	752565	517388	94071				
96.0	100.9	511895	3840.389	7502.3									204758	255947	51189				
101.0	105.9	298411	2913.983	9765.0									37301	186507	74603				
106.0	110.9	64779	704.791	10880.0											64779				
111.0	115.9	264516	3613.822	13662.0									52903	52903		52903			105807
116.0	120.9	130108	1753.853	13480.0											65054		65054		
121.0	125.9	1851	25.808	13940.0											1851				
126.0	130.9	29050	463.936	15970.0															29050
131.0	135.9	75314	1762.356	23400.0												75314			
total		2055982808	1077552.734		543043827	330631130	329740139	147720899	421528621	150214881	79761721	40210687	10088512	2210874	503390	128218	65054	0	134857
		2055982809		Weight at age	6.9	30.1	121.4	505.0	831.4	1399.9	2381.5	3229.4	4511.5	6181.4	8381.2	19382.1	13480.0		14159.2

Year/Age	0	1	2	3	4	5	6	7	8	9
2004	6	11	21	36	41	51	66	71	81	91
2005	6	11	21	36	46	51	56	61	71	81
2006	6	16	26	36	46	56	61	76	81	91
2007	6	16	26	36	46	56	66	71	81	96
2008	6	16	26	36	46	56	71	76	81	91
2009	6	11	26	36	46	56	61	76	81	86
2010	6	11	21	36	46	56	61	71	81	86

ICES AFWG 2019 WD 02

The effect of age-specific setting of variance parameters for the observations in North-East Arctic cod stock assessment by means of SAM

D.Vasilyev, Y. Kovalev and A.Chetyrkin
United VNIRO, Russia

In North-East Arctic cod stock assessment by means of SAM the fleet-specific variance parameters for the observations are used, but within the same fleet these parameters are age-independent (see table 1, representing the corresponding block in the model configuration file).

The first row in the table corresponds to catch-at-age, further rows correspond to “fleet 15”, “fleet 16”, “fleet 18” and “fleet 007”. The meaning of the same values in each of the rows is that the same values of variance are used for all age groups for a given fleet.

Table 1.

 # Coupling of the variance parameters for the observations.

```
  0  0  0  0  0  0  0  0  0  0  0  0  0
 -1  1  1  1  1  1  1  1  1  1 -1 -1 -1
 -1  2  2  2  2  2  2  2  2  2 -1 -1 -1
  3  3  3  3  3  3  3  3  3  3 -1 -1 -1
  4  4  4  4  4  4  4  4  4  4 -1 -1 -1
```

Probably, more detailed specification of variances could be more appropriate if to look at Table 2, where standard deviations (STD) for the model residuals are given:

Table 2. Standard deviations of residuals by fleets and age groups

Age / Fleet	3	4	5	6	7	8	9	10	11	12	13	14	15
Catch	1.01	0.73	0.67	0.62	0.69	0.55	0.50	0.83	0.77	1.16	1.31	1.71	2.30
Fleet 15		0.39	1.09	0.97	0.95	1.05	1.02	0.90	1.42	1.14			
Fleet 16		0.83	0.82	0.90	0.87	0.91	0.97	0.71	1.30	1.10			
Fleet 18	0.61	0.99	1.03	0.97	0.68	0.71	1.40	0.96	1.37	1.40			
Fleet007	0.92	0.79	0.93	0.96	1.04	1.07	0.55	0.63	1.01	1.60			

As it can be seen from Table 2, in catch-at-age residuals the STD values are much higher for age groups 14 and 15;
for fleet 15 the STD value for age 4 is much lower than the others for this fleet. and for age 11 – apparently higher;
for fleet 16 – age 11 gives higher STD with respect to other ages of this fleet;
for fleet 18 higher STD are observed for age group 9. 11 and 12;
for fleet 007 apparent relatively higher STD is seen for age group 12.

The attention to more detailed specification of variances came from an expectation that if to use “age-average” variance for an age group with much more variable residuals with respect to others for a given fleet data, the model may have not enough “flexibility” to be tuned at the data for this age group. Vice versa, for an age group with much lower STD the “age-average” variance could give too much space to the model-derived abundance estimate to deviate from the corresponding survey data.

In accordance to the above mentioned the corresponding block in the model configuration file was modified as follows (see Table 3):

Table 3.
 # Coupling of the variance parameters for the observations.

0	0	0	0	0	0	0	0	0	0	0	5	5
-1	6	1	1	1	1	1	1	7	1	-1	-1	-1
-1	2	2	2	2	2	2	2	8	2	-1	-1	-1
3	3	3	3	3	3	9	3	9	9	-1	-1	-1
4	4	4	4	4	4	4	4	4	10	-1	-1	-1

As it can be seen, different from others (but equal to each other) variances now are used for ages 14 and 15 for catch-at-age; specific variances for ages 4 and 11 for fleet 15; specific variance for age 11 for fleet 16; specific (but equal to each other) variances for ages 9, 11 and 12 for fleet 18; and specific variance for age 10 for fleet 007.

Naturally, more detailed specification can be imagined, but the idea was not to introduce too many new free parameters into the model.

The results of retrospective diagnostics of the model with new settings are presented in the Figure 1. For comparison the same for the model with traditional settings is presented in Figure 2.

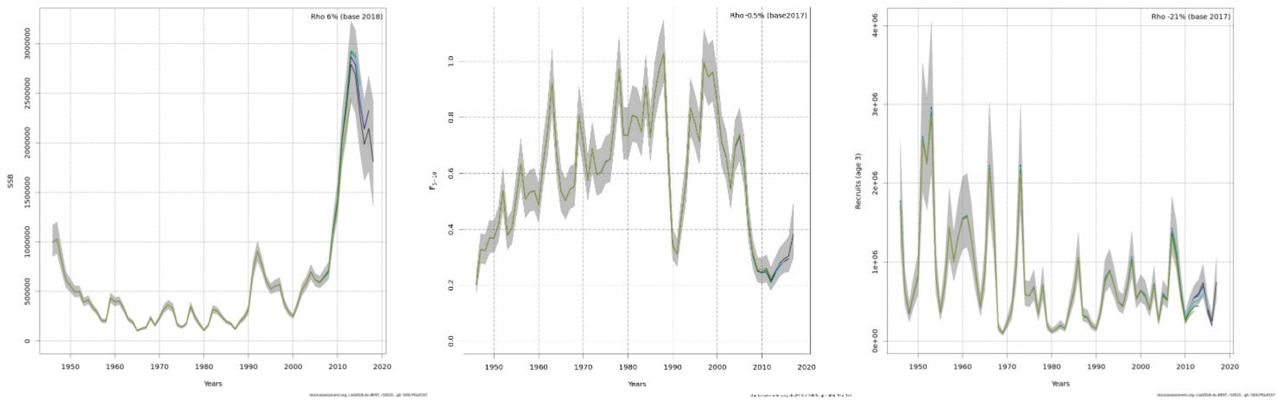


Figure 1.Retrospective diagnostics for the new settings of the model.

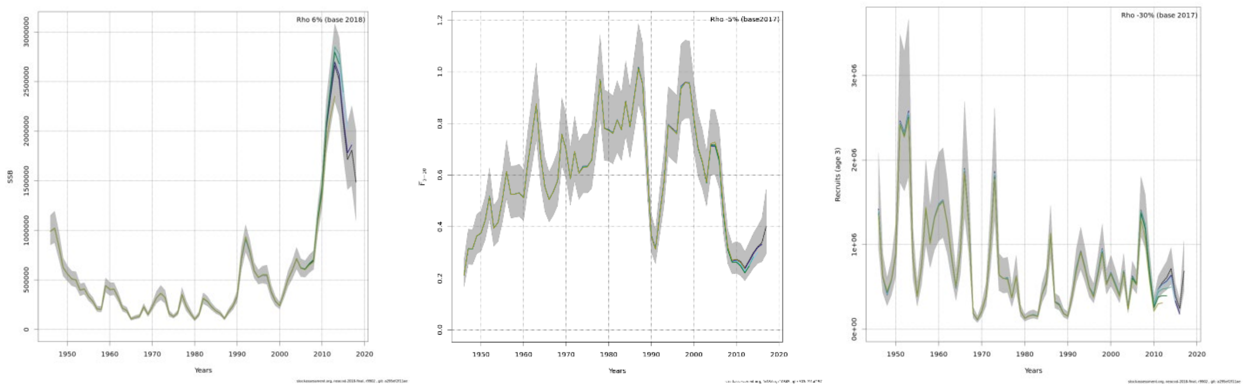


Figure 2.Retrospective diagnostics for traditional settings of the model.

Measures of retrospective bias for SSB, recruits and F are compared in Table 4. For recruits and F the new settings resulted in lower historical bias, while for SSB it was the same.

Table 4

	Rho(SSB)	Rho(R_3)	Rho($F_{5\text{-}10}$)
SAM (AFWG 2018)	6%	-30%	-5%
SAM-new settings	6%	-21%	-0.5%

Despite of higher number of parameters the value of Akaike's Information Criterion became better (see Table 5).

Table 5

	AIC
SAM (AFWG 2018)	2816.67
SAM-new settings	2544.75

Comparison of the results of SAM (AFWG-2018) and SAM with new settings (marked in the Figure 3 as SAM-2) shows that SSB for final years became somewhat higher, as well as recruitment; F became somewhat lower.

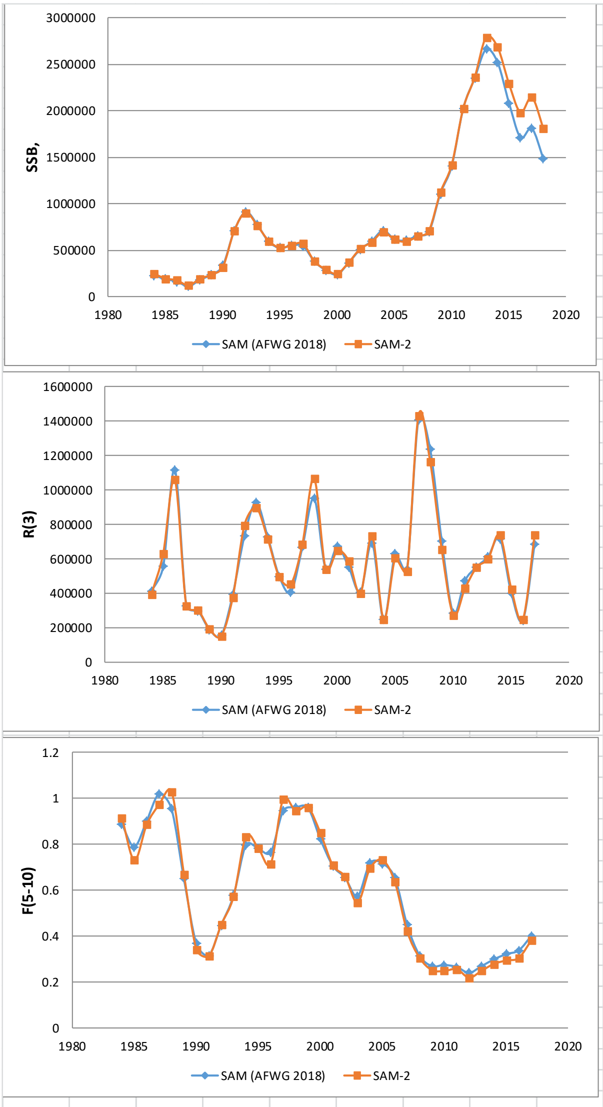


Figure 3. Comparison of the results of SAM(AFWG-2018) and SAM with new settings

Working Document to AFWG Lisbon 23rd to 30th of April 2019

Cod and haddock abundance indices by age from the ecosystem survey: comparing current indices from BIOFOX and new indices from StoX.

Edda Johannesen, Geir Odd Johansen and Dmitry Prozorkevich

Background

Bottom trawl indices from the Joint Norwegian Russian Barents Sea ecosystem survey (2004-) in the Barents Sea has been used in the assessment of Northeast Arctic cod (since 2015) and haddock (since 2011) in the Arctic fisheries working group (AFWG). The indices used in assessment are calculated at PINRO using the BIOFOX software and presented as a working document to AFWG each year. A working document from 2014 provides results for cod from various settings using BIOFOX (Prozorkevich and Gjøsæter 2014). Since 2015 a new open access survey software StoX (StoX 2015) has been developed at IMR. This software is used to calculate abundance indices from the joint IMR PINRO winter survey (Mehl et al 2016).

StoX gives uncertainty estimates based on bootstrap (not provided in this WD) and since it is open access it can be run by anybody who has access to data in the right format. However, it is not very well documented and therefore not necessarily easy to run. BIOFOX is easy to run and is flexible but not freely available. The BIOFOX software has many options for choosing trawl hauls and age-length keys. BIOFOX does not include uncertainty estimates.

Here we document the input data from the ecosystem survey and methods used by BIOFOX and StoX related to strata system, age length keys and swept area estimation. Then we compare the abundance indices from BIOFOX and StoX for cod and haddock run on the ecosystem survey data 2004-2018 for ages 1-10+

Methods

Survey design of the ecosystem survey

The Barents Sea ecosystem survey (BESS) covers the whole Barents Sea: an area of around 1.6 mill km^2 and is conducted in August-September when the Barents Sea shelf (in most years) is ice free. The survey was initiated by combining and extending several previous Barents Sea surveys. When initiated, there was no agreement on strata system. Since the ecosystem surveys are monitoring many aspects of the ecosystem, it was decided that the ecosystem trawl stations should be set out in a regular grid. This was taken from a 0-group survey that historically was the main predecessor of the BESS. In addition, in all years (except 2010, 2015-2016, Appendix figure) a denser and irregular station grid was applied along the shelf break west and north of Svalbard, due to the very steep depth gradient in this area.

The distance between the stations of about 35nm was a compromise to allow coverage of the whole shelf area within the allotted survey time. However, some notable deviations to the regular grid has occurred), mostly in the earliest years of the time series (Figure 1, Appendix Figure). On average 407 stations per year were taken (Table 1). In addition, some stations were set out at dense acoustic registrations close to the bottom or for other purposes, mostly on Russian vessels (Table 1 and Figure 1).

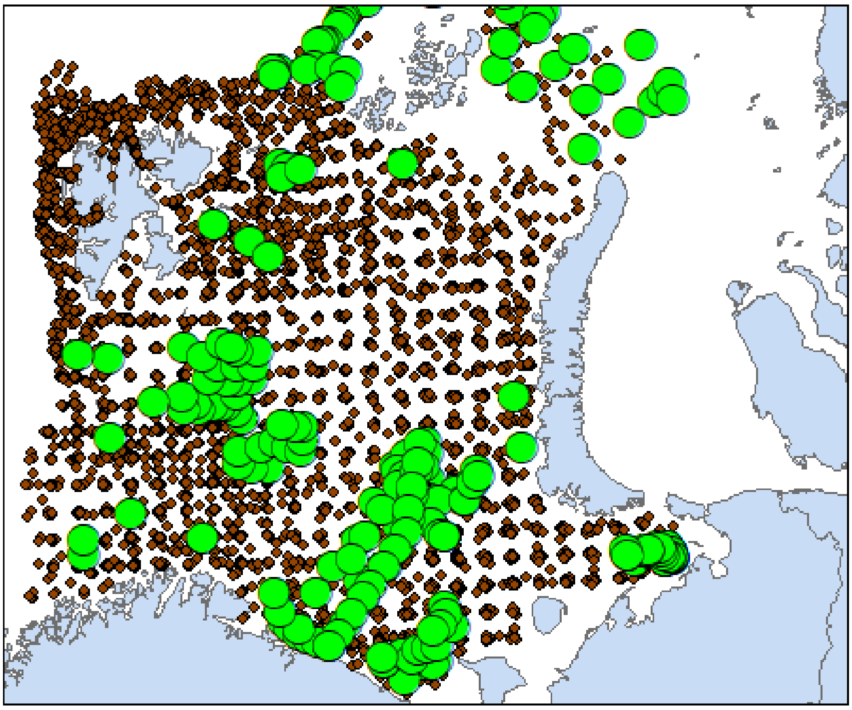


Figure 1. All bottom trawl stations 2004-2018. Brown dots are stations set of at predefined stations, green stations (extra stations) are bottom trawls set out at dense acoustic registrations close to the bottom or for other purposes. See also table 1 and text.

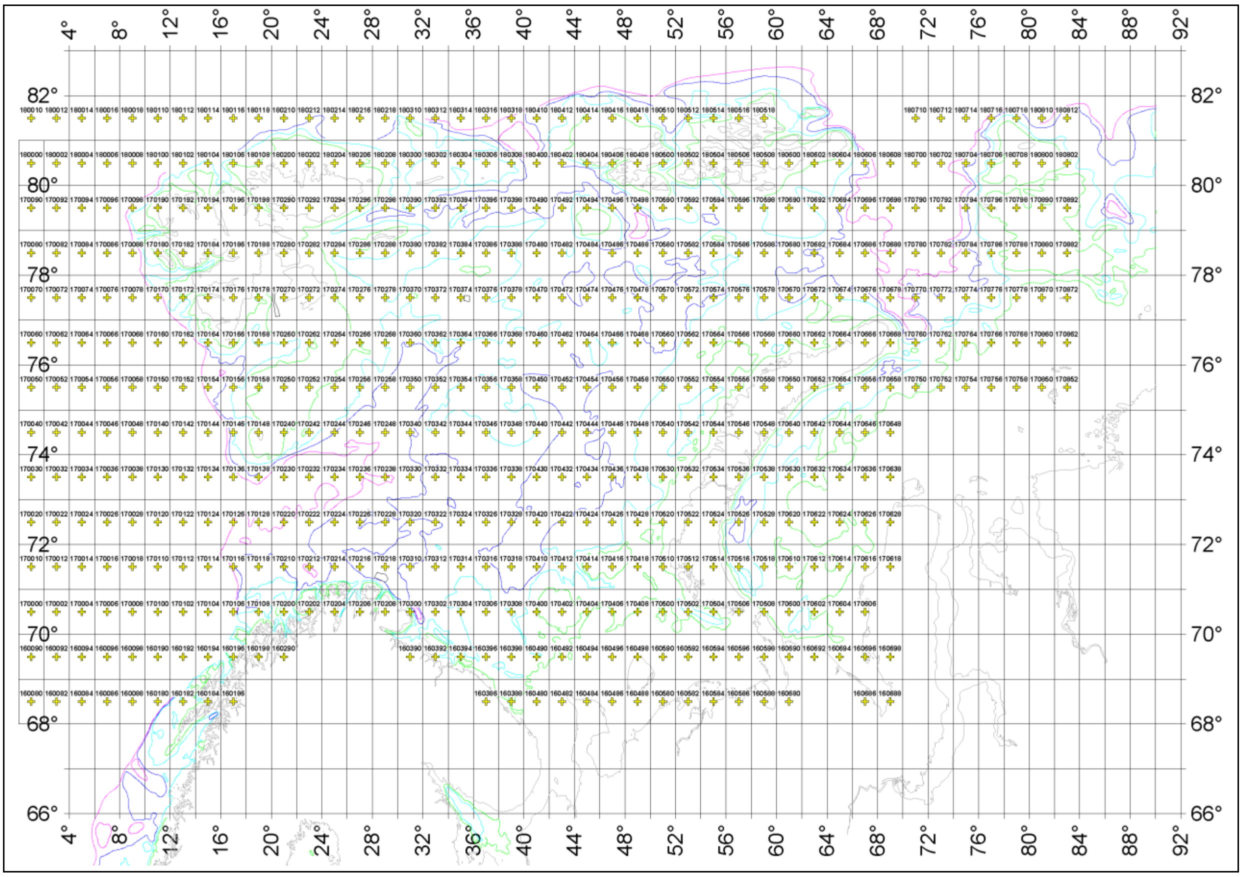
Table 1. Number of predefined and extra stations. Only 13 of the extra stations were set out by Norwegian vessels.

Year	**Predefined**	Extra
2004	600	2
2005	625	1
2006	638	0
2007	498	89
2008	387	21
2009	357	14
2010	321	6
2011	379	9
2012	428	13
2013	416	69
2014	294	8
2015	326	8
2016	294	10
2017	327	16
2018	224	1
Total	**6114**	267

The application of a strata system

BIOFOX

The BIOFOX method uses the same high resolution strata system (WMO squares; https://en.wikipedia.org/wiki/World_Meteorological_Organization_squares) that has been used for capelin abundance estimation.



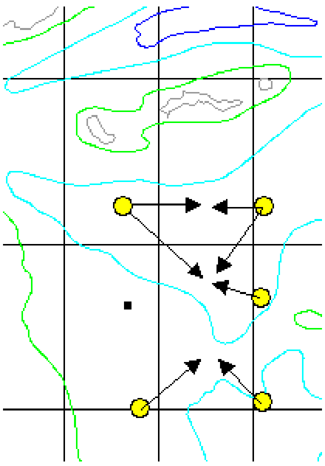


Figure 2

Top: The strata system used in the BIOFOX method. Each stratum is 1° latitude x 2° longitude. Each stratum is depth stratified using the following depth categories: <100, 100-200, 200-300, 300-400 and 400-800 m.

Bottom: Interpolation method used in BIOFOX. For strata-depth categories lacking stations, abundance is interpolated using the average abundance by length from the stations in the same depth interval in neighbouring strata.)

The BIOFOX strata system covers the whole Barents Sea and include the whole survey area, and was constructed based on standard 1° latitude x 2° longitude WMO squares. In addition, for the purpose of demersal fish abundance indices, it also included depth stratification by the ranges: <100, 100-

200, 200-300, 300-400 and 400-800 m, based on bathymetry data from GEBCO (https://www.gebco.net/). (Figure 2). This was done to enable possible future use of acoustic data in the calculations for stratum-depth categories lacking stations, abundance is interpolated using the average abundance by length from the station in the same depth interval from neighbouring strata (Figure 2). The interpolation radius is always within the range of one WMO square. At the edges, abundance is extrapolated to one neighbouring WMO square.

BIOFOX interpolates using neighbouring stations (Figure 2). In some years when the “holes” were small (2014, 2015), it is possible to use interpolation to fill the holes. In the case of “large holes” (as in 2018) it is impossible to fill the holes in a meaningful way (Figure 3).

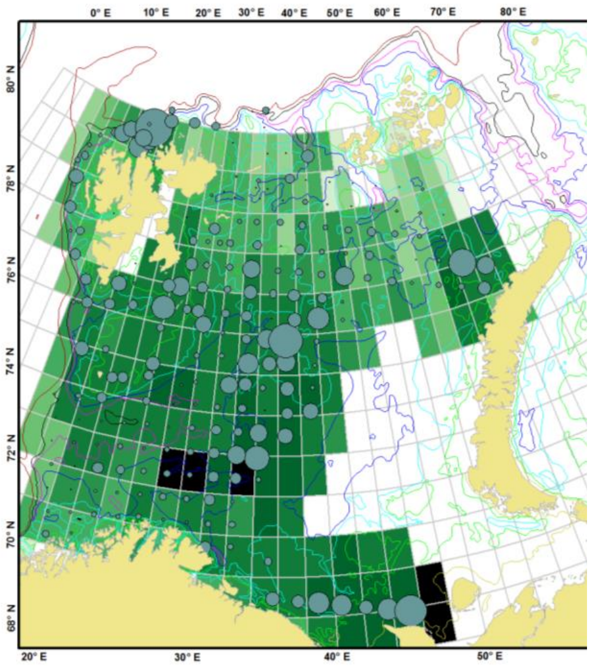


Figure 3. Biofox BESS 2018 cod index calculation. Actual cod catches (bubbles) and WMO strata filling.

StoX

StoX requires a strata system to calculate abundance indices. Within each stratum the average swept area abundance is calculated and then the total abundance in that stratum is calculated by multiplying the average with the area of that stratum. Total abundance is calculated by summing the abundances of all the strata.

Since there were no predefined strata system in BESS originally, but a regular grid with some notable deviations, we have developed a post-stratification of the survey. This is primarily based on the geographical distribution patterns of cod and haddock, observed at BESS and aggregated over the period 2009-2018. The 250 m depth contour were used as guideline for the borders between strata, as a preliminary analysis show that this depth seperate quite well between low density areas for demersal fish (deeper) and high density areas (shallower). Some practical considerations were also taken when defining the strata system. The size of the strata was defined so that each stratum ideally contained at least 20 trawl hauls (although this was difficult to satisfy some years). The strata system was in some areas separated geographically to homogenise the density and age structure of fish within strata. In addition, the southernmost strata were divided by the RUS-NOR border, since the survey effort varied between RUS and NOR vessels in this area some years. The 500 m depth contour was used as a limit for the strata system towards the Norwegian Sea in the west and the Polar Ocean in the north. The result is a basic strata system for demersal fish in the BESS, used as a starting point when generating the yearly strata systems used for estimation (Figure 4). We also modified the strata system some years to account for irregular sampling, ice coverage, and limited survey coverage due to other reasons (Appendix figures).

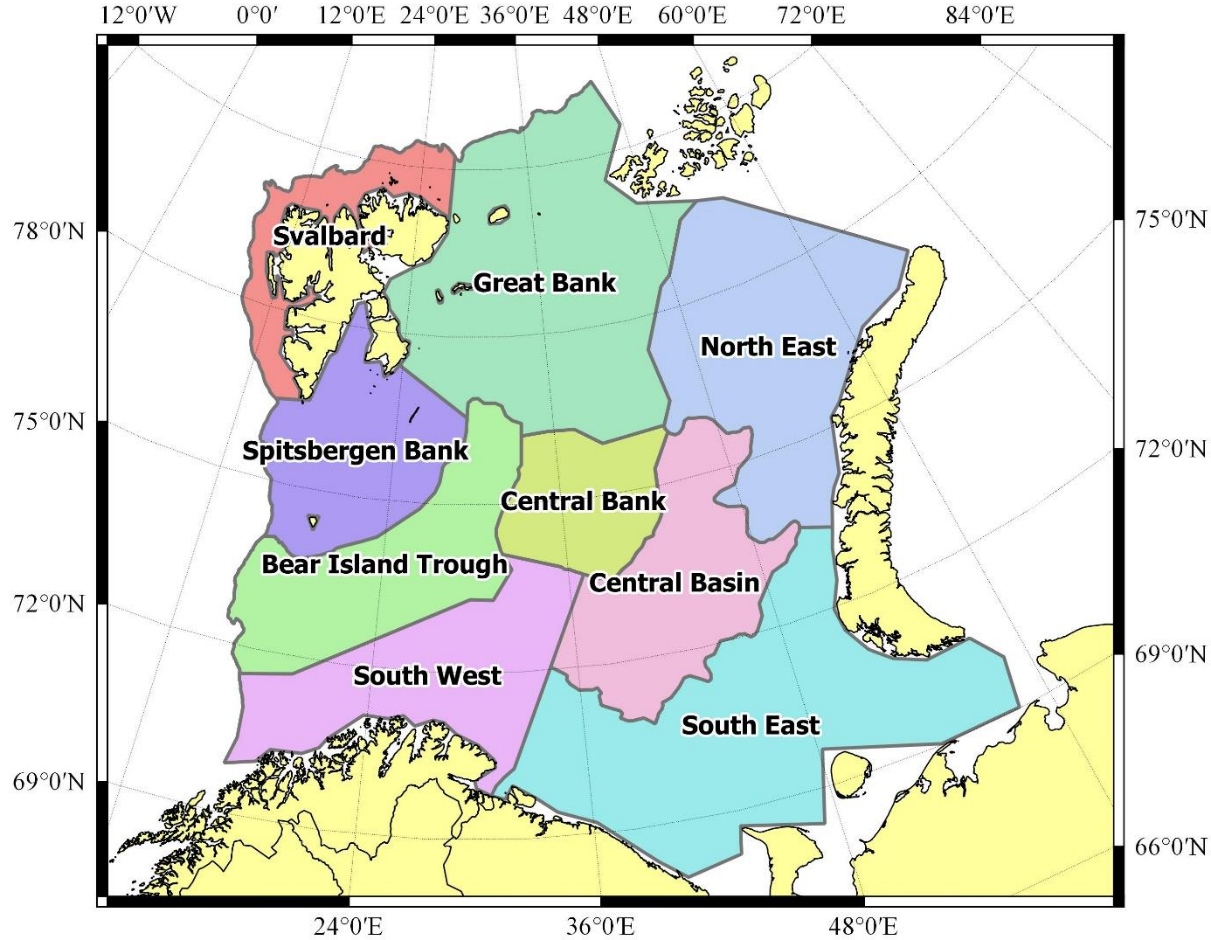


Figure 4. The basic strata system used in StoX. The names are given based on a combination of geographic area and well-known bathymetric features within each stratum. The strata system was modified each year to account for coverage issues and denser stations in some areas (Appendix Figure).

Age-length key and swept area estimation

Both Russian and Norwegian vessels used a standard research bottom trawl (Campelen 1800 shrimp trawl) with 80 mm (stretched) mesh size in the front and rockhopper ground gear. Details on rigging is given in Appendix Table. The small mesh size allows capture of small specimens. At least 100 cod and haddock from the trawl catches are measured to the nearest cm. Otoliths are sampled from one fish in each 5 cm length group from each station. Subsampling of catches occur particularly for large catches with smaller fish. Then the total number of fish by length group is calculated from the weight of the total catch relative to the weight of the subsample.

Stations included

The StoX method includes only the trawl hauls set out on predefined stations. The BIOFOX method includes the trawl hauls set out at predefined stations, as well as additional extra trawl hauls with the goal to fill in as many strata as possible by actual catch data. (Table 1, Figure 1).

Sweep width

Swept areas by length group and station is calculated using Dickson corrected length depended sweep width (see e.g. Mehl et al 2016), both in StoX and BIOFOX.

Age length keys

In StoX all cod in a 5 cm length group in a station is assigned to the same age as the individual in that station that was aged based on otoliths (see above). If age readings for some reason are lacking for that 5 cm length group in that station, age is selected at random from fish of the same length group within the same stratum. If data are missing at the stratum level, then an age is selected at random from fish from the whole survey area.

The BIOFOX method uses one age length key for the whole area per year.

Total abundance by age

Both BIOFOX and StoX use average swept area densities by strata. StoX first calculates density by age and stratum, then the age and stratum specific density is multiplied with the stratum area and then the stratum estimates are summed.

Total estimates for BIOFOX is obtained by multiplying the density with the stratum area and summing the strata. The BIOFOX software has many options for choosing trawl hauls and age-length keys, but for the final calculation options were chosen that gave the best internal consistency of the stock indexes ().

Age groups 1 – 10 + used for both cod and haddock as these are the ones reported by ICES AFWG.

Results

We compared the methods by comparing internal consistency and by comparing the percentage difference in the age and year specific estimates from StoX and BIOFOX (*StoX/BIOFOX).*

Northeast arctic cod

The estimates tended to be lower using the StoX method compared to the BIOFOX (Table 2, Figure 5, Figure 6). This varied by year, 2007 gave much lower StoX estimates than BIOFOX estimates, for all ages except 1-year olds. We do not know the reason for the discrepancy, but this year there was a high number of extra stations (Table 1): this might be relevant. The difference was also large in 2014, but this year there was ice hindrance in the northern Barents Sea during the survey and for that reason the indices from this survey was not used in the assessment of cod that year.

The largest difference by age across years was for 2-5 year olds (Figure 6).

Consistency was similar for the BIOFOX and StoX (Figure 7). Consistency was lowest from age 4 to 5 for both methods, but the problem was largest for BIOFOX (R^2<0.3) than for StoX (R^2<0.5). The problem was related to two years in particular: 2004 and 2009. In 2004 the estimates for 4-year olds was high, but the estimates for 5-year olds were comparably low. In 2009 the estimates for 4-year olds were low, but the estimates for 5-year olds in 2010 were comparably higher.

Table 2. Table of the swept area index estimates for Northeast arctic cod based on the BESS from StoX divided by those from BIOFOX (i.e. StoX/BIOFOX), by survey year and ages 1-10+. Green shading denotes proportions smaller than 0.80 (i.e. higher estimates from BIOFOX), and red shading denotes proportions larger than 1.20 (i.e. higher estimates from StoX).

Year	1	2	3	4	5	6	7	8	9	10+	Average	St_dev
2004	1.237	0.883	0.624	0.680	1.041	0.944	1.004	1.029	0.887	1.129	0.946	0.188
2005	0.806	0.834	0.823	0.625	0.965	1.115	1.165	1.235	1.512	1.666	1.075	0.331
2006	0.944	0.840	0.754	0.595	0.610	0.676	0.943	1.013	1.272	0.821	0.847	0.207
2007	0.909	0.592	0.509	0.475	0.583	0.392	0.598	0.538	0.597	0.485	0.568	0.138
2008	0.837	0.711	0.524	0.718	0.670	0.913	0.799	0.880	1.041	1.068	0.816	0.168
2009	0.944	0.769	1.057	0.845	1.219	1.272	0.838	0.867	1.106	0.999	0.992	0.170
2010	1.140	1.044	1.064	1.012	1.138	1.115	1.370	0.992	0.801	0.879	1.055	0.156
2011	0.734	0.942	0.914	0.962	0.917	1.060	1.199	0.938	1.014	1.020	0.970	0.119
2012	0.892	0.954	0.741	0.894	1.097	1.202	1.018	1.166	1.025	0.958	0.995	0.138
2013	0.741	1.006	1.015	0.808	0.863	0.802	1.026	1.004	1.052	0.904	0.922	0.113
2014	0.858	0.748	0.920	0.881	0.877	0.792	0.555	0.644	0.543	0.647	0.747	0.141
2015	0.821	1.137	1.058	0.976	1.050	0.855	1.259	1.273	1.017	0.951	1.040	0.152
2016	1.129	1.129	1.048	1.071	1.064	1.037	0.953	0.940	0.919	0.836	1.013	0.097
2017	0.964	0.766	0.937	0.667	0.648	1.161	1.165	0.964	1.063	0.933	0.927	0.184
Average	0.925	0.882	0.856	0.801	0.910	0.953	0.992	0.963	0.989	0.950		
St_dev	0.151	0.161	0.198	0.178	0.210	0.237	0.237	0.200	0.246	0.265		

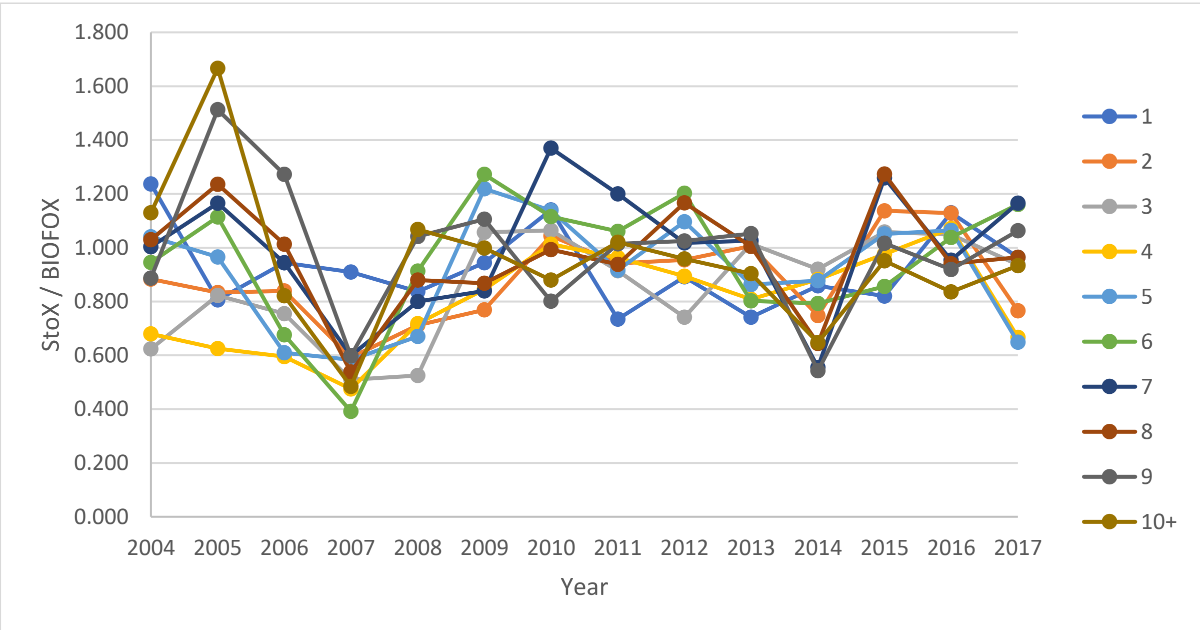
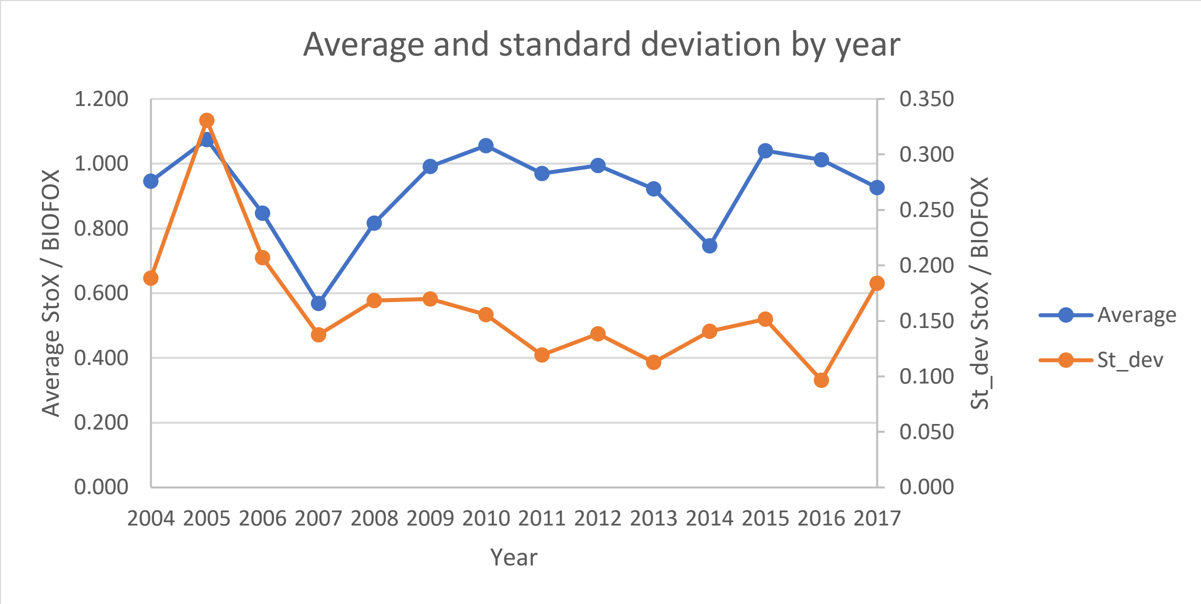


Fig 5 Swept area index estimates for Northeast arctic cod based on the BESS from StoX divided by those from BIOFOX (i.e. Stox/BIOFOX), by survey year and ages 1-10+.



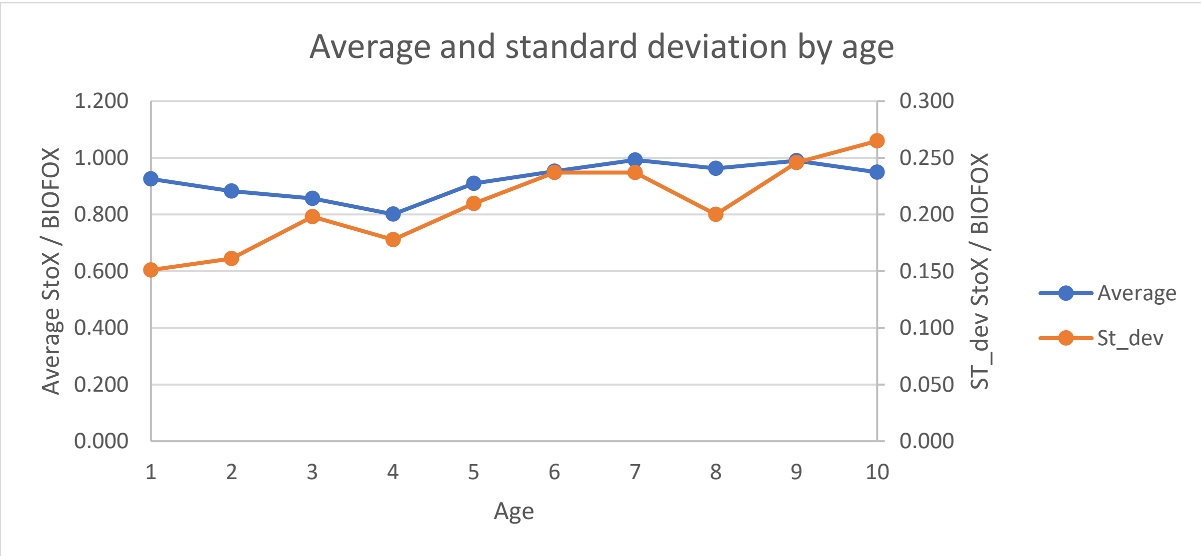


Fig 6. Average and standard deviation of proportions given in figure above by year (top) and age (bottom).

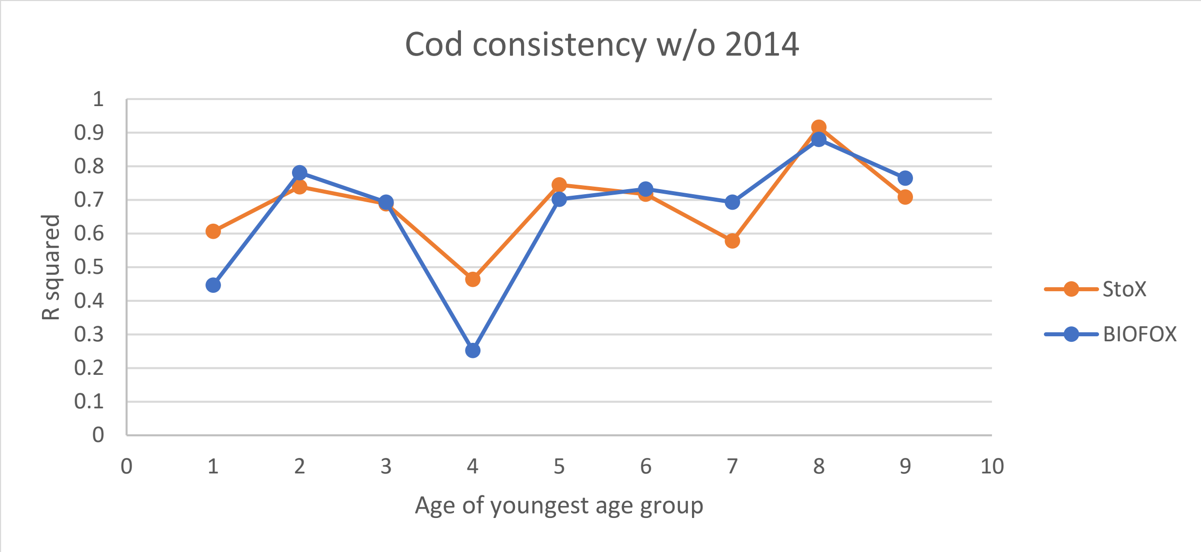


*Fig 7. Consistency between swept area indices for NEA cod from BESS of the year classes as age group a in survey year y and age group a+1 in survey year y+1. Consistency is given as R^2 (coefficient of determination) in linear regression of a+1 as a function of a for the year classes. Age of youngest age group denotes a. Indices for 2014 are not incl*uded and were excluded from the assessment due to po or survey coverage sue to ice coverage of large areas in the northern Barents Sea.

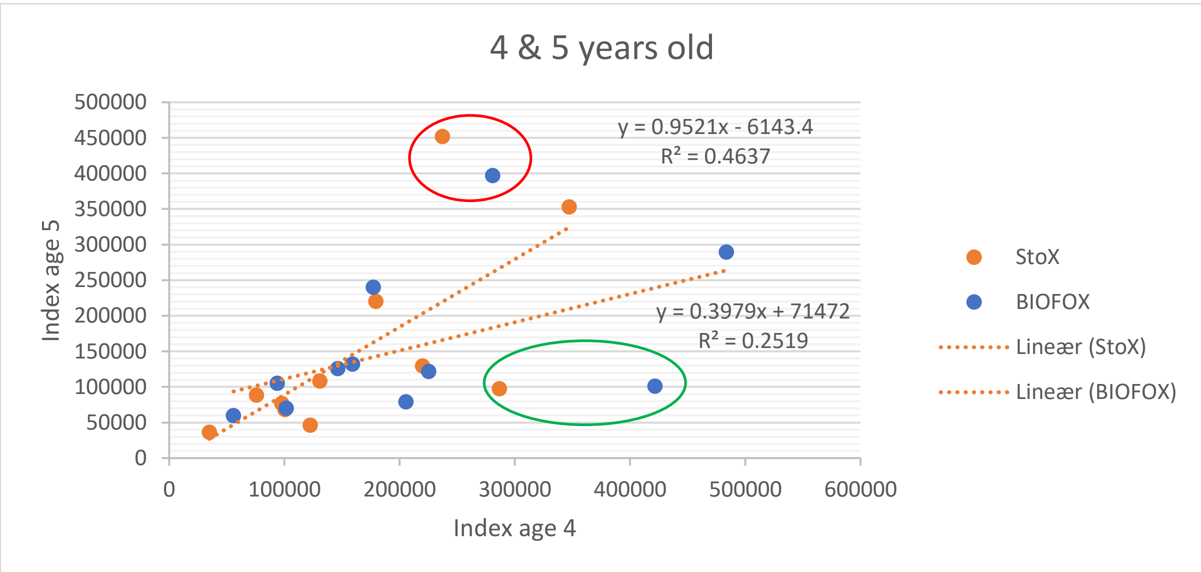


Fig 8. Consistency of 4-5 years old. The low consistency is due to extreme indices in 2009 (red circle) and 2004 (green circle).

Northeast arctic Haddock

Most years, StoX tended to give lower estimates than BIOFOX (Table 3). A notable exception was estimates from 2015 and 2017, were the numbers were much higher from StoX (Table 3, Figure 9, Figure 10). The reason for this is not known. Overall, StoX estimates were higher for the youngest (1-4) and oldest (9 to 10+) haddock, and BIOFOX estimates were higher for 5-8 year olds (Table 3, Figure 10).

Consistency was similar for the methods, except for a much lower consistency for StoX from 1 to 2 year olds and 7 to 8 and 8 to 9 year olds (Figure 11)

Table 3. Table of the swept area index estimates for Northeast arctic haddoc based on the BESS from StoX divided by those from BIOFOX (i.e. Stox/BIOFOX), by survey year and ages 1-10+. Green shading denotes proportions smaller than 0.80 (i.e. higher estimates from BIOFOX), and red shading denotes proportions larger than 1.20 (i.e. higher estimates from StoX).

Year	1	2	3	4	5	6	7	8	9	10+	Average	St_dev
2004	0.802	0.886	1.009	0.751	0.695	0.797	0.678	0.934	1.000	2.088	0.964	0.412
2005	0.337	0.275	0.305	0.525	0.168	0.330	0.266	0.246	0.221	0.328	0.300	0.095
2006	0.964	0.974	0.740	0.791	1.033	0.526	0.679	0.588	0.704	2.555	0.956	0.587
2007	0.886	0.539	0.400	0.519	0.400	0.412	0.240	0.404	3.814	0.550	0.816	1.067
2008	1.054	0.944	0.845	1.291	0.567	0.903	0.813	0.969	0.590	0.778	0.875	0.213
2009	1.253	0.716	0.885	0.948	0.486	0.258	0.284	0.207	1.180	2.940	0.916	0.806
2010	1.304	1.304	0.922	0.716	0.753	0.680	0.321	0.490	1.000	0.139	0.763	0.385
2011	0.770	1.186	0.568	1.691	0.552	0.747	0.582	0.414	0.434	0.667	0.761	0.394
2012	1.001	0.928	0.893	0.729	1.216	0.666	0.506	1.590	0.082	0.551	0.816	0.415
2013	1.113	1.048	0.775	0.916	1.270	0.731	0.838	0.759	0.725	1.471	0.965	0.255
2014	1.219	0.895	1.093	0.365	0.851	1.183	0.469	0.394	0.361	0.972	0.780	0.350
2015	2.494	2.635	1.775	2.047	1.804	2.860	2.253	2.254	2.343	2.543	2.301	0.352
2016	1.217	0.826	1.757	1.482	0.754	0.485	0.643	0.652	0.530	0.793	0.914	0.428
2017	2.536	3.320	2.411	2.814	2.684	2.728	4.223	1.610	2.445	2.338	2.711	0.684
Average	1.211	1.177	1.027	1.113	0.945	0.950	0.914	0.822	1.102	1.337		
St_dev	0.607	0.815	0.579	0.687	0.650	0.817	1.076	0.603	1.053	0.960		

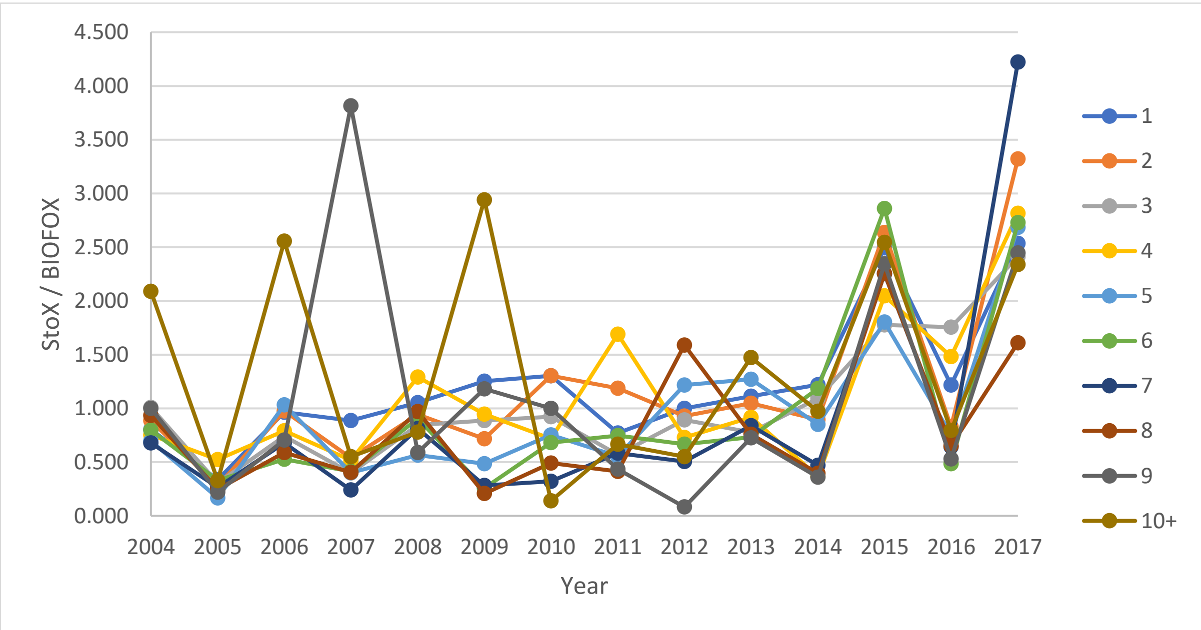
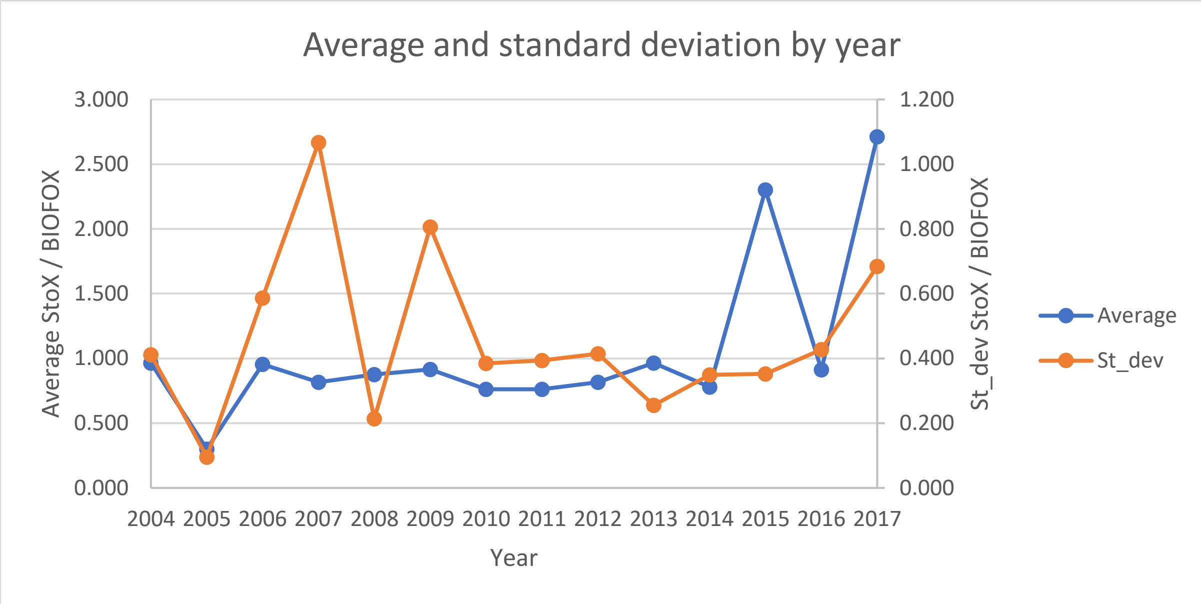


Fig 9. Swept area index estimates for Northeast arctic haddock based on the BESS from StoX divided by those from BIOFOX (i.e. Stox/BIOFOX), by survey year and ages 1-10+.



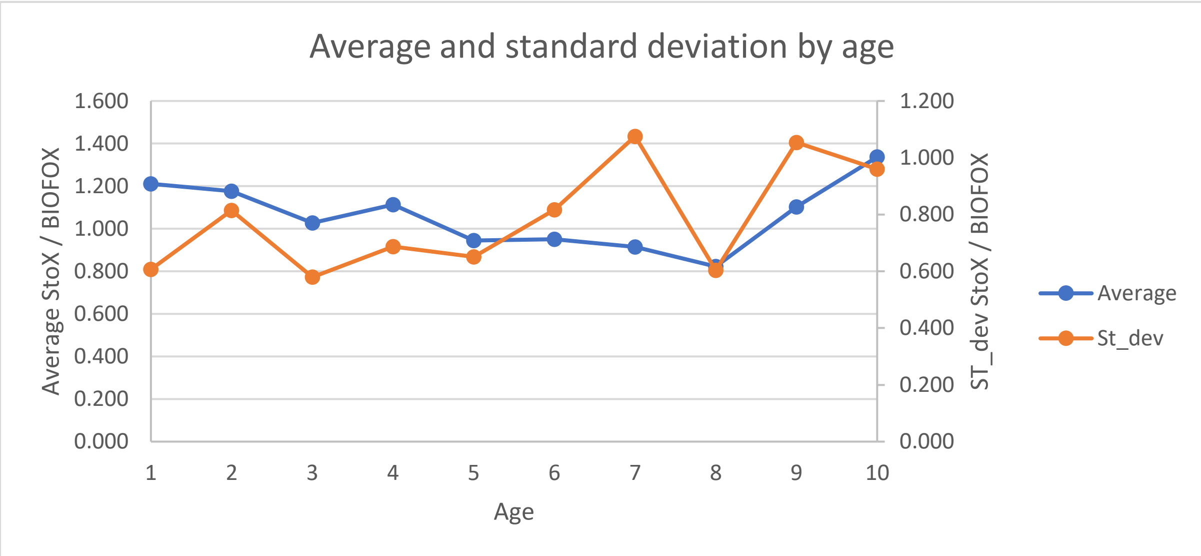


Fig 10. Average and standard deviation of proportions given in figure above by survey year(upper) and age (lower).

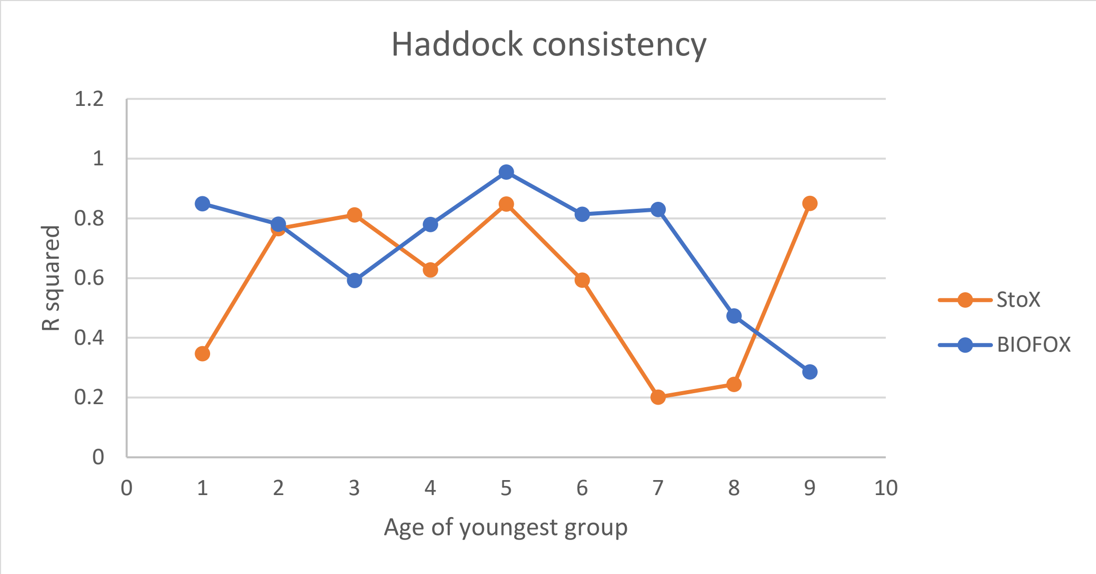


Fig 11. Consistency between swept area indices for NEA haddock from BESS of the year classes as age group a in survey year y and age group a+1 in survey year y+1. Consistency is given as R^2 (coefficient of determination) in linear regression of a+1 as a function of a for the year classes. Age of youngest age group denotes a.

Summary

1. There were greater differences between the StoX and BIOFOX abundance indices for haddock compared to cod.
2. Overall, consistency tended to be poorer for haddock than for cod, this was especially true using the StoX method.
3. The largest yearly differences between the methods when calculating indices for cod (2007 and 2014) could be explained by a high proportion of extra trawl stations included in BIOFOX (2007) and restricted survey coverage to the north (2014).
4. We cannot at the moment explain the largest largest differences for haddock (2015 and 2017 when StoX indices much higher than BIOFOX indices). The same applies to the low consistency for haddock using StoX for ages 7 to 8 and 8 to 9.

Given that the Russian winter survey is discontinued, there are now only two surveys available for assessment for haddock (three for cod which also has the Lofoton survey). Lately, a lot of haddock is found the Russian zone. It is vital that sufficient and consistent survey coverage is obtained every year, especially for haddock in the eastern Barents Sea, both at the winter survey and ecosystem survey.

References

Mehl, S, Aglen A, and Johnsen E. 2016. Re-estimation of swept area indices with CVs for main demersal fish species in the Barents Sea winter survey 1994 – 2016 applying the Sea2Data StoX software. Fisken og Havet 10 2016

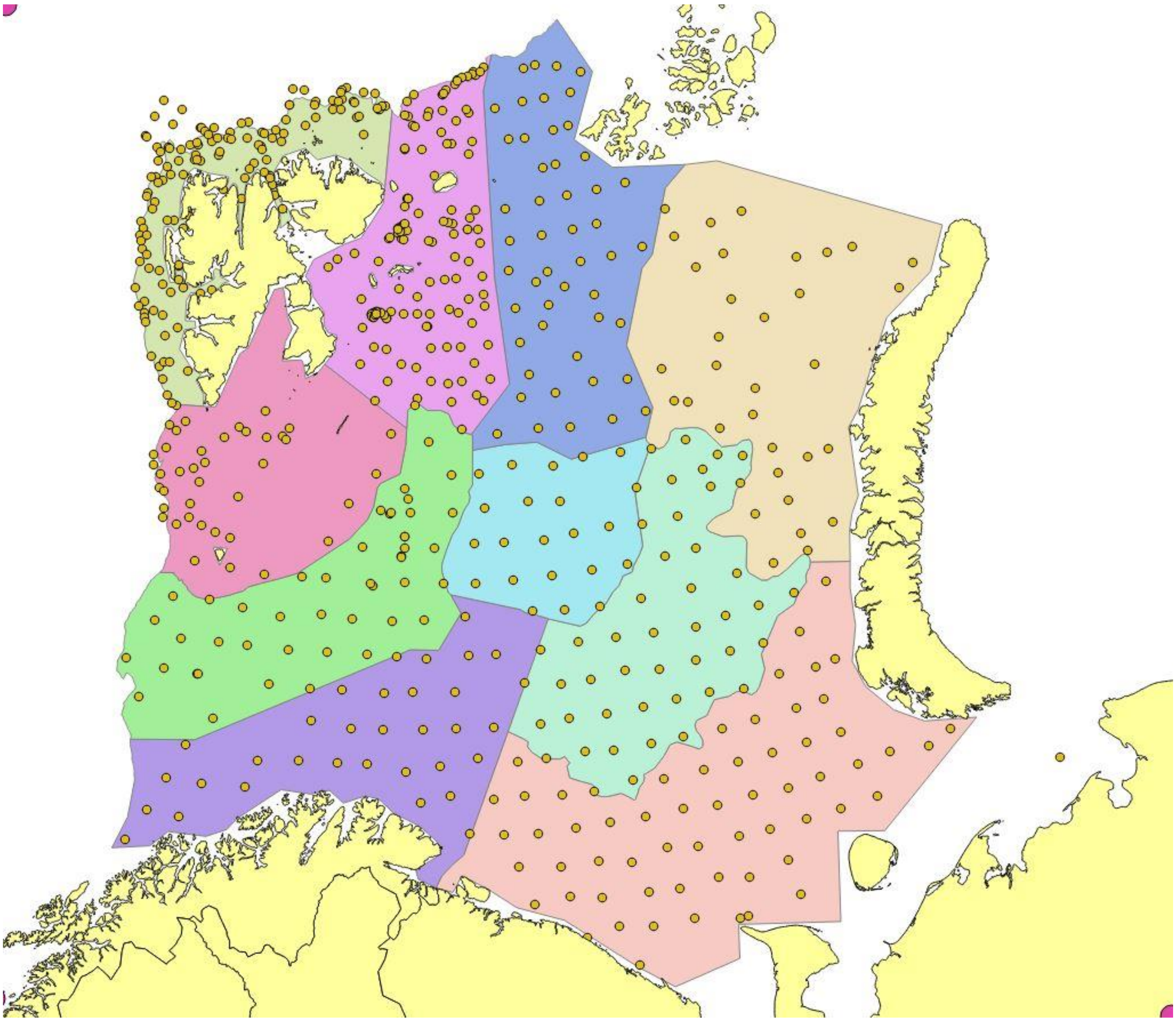
Prozorkevich D and Gjøsæter H. 2014. WD_02 cod_BESS_assessment.

StoX (2015) StoX: An open source approach to acoustic and swept area survey calculations. Institute of Marine Research, Bergen, Norway. URL: http://www.imr.no/stox

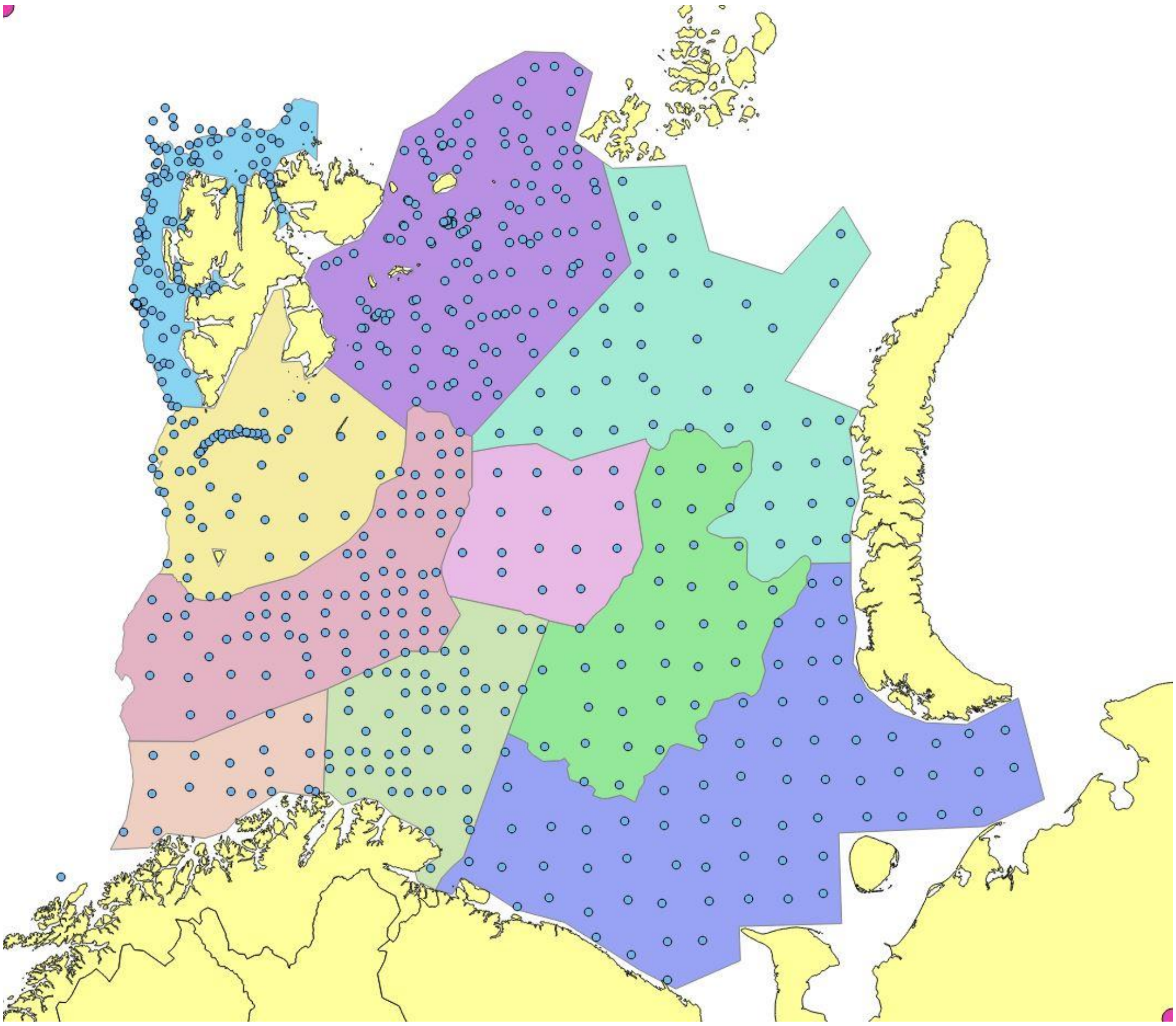
Appendix Table. Taken from appendix 6 to the Protocol from the March meeting 2019. Present overview of rigging and trawling procedure for the Campelen 1800 trawl used by IMR and PINRO

Parameters	Russian vessels	Norwegian vessels	Comments	Significant differences between PINRO and IMR	Significant differences from 2014
Trawl doors	Sparrow(1650 kg)	Thyborøn 7a(1800 kg)-all vessels		*	*IMR *PINRO
Distance between doors	47-55 m	50±2 m	PINRO and IMR use constraining rope		*PINRO
Warp/depth ratio	2.0- 4.5. Depends on depth.Depends on trawl master/cruise leader		2.5-4.5. Depends on depth. Norwegian vessels use information from roll sensors-trawl doors	*	
Bridle length	40m	40m			
Rigging of ground gear	Using 20 -25 cm rope between fishing line and groundgear	Rockhopper's -diameter 35 cm	PINRO rigging, reason to expect that center fishing line behind and close to seabed- resulting in higher catch rates of benthos etc. compared to Norwegian rigging	PINRO has not used tickler chain from 2015	*PINRO
Floats on headline	Total buoyancy 236 kg	Total buoyancy 261 kg±2 kg			
Floats on fishing line and extension			Norwegian vessels, Tromsø rigging(used on some few stations in the Svalbard area, soft bottom): Floats on fishing line(bouncy 130kg±2 kg) and on the extension(bouncy 52 kg±2 kg)	*	*IMR
Monitoring gear perfomance	Acoustic trawl sensors: door spread, roll and pitch of doors, speed, vertical opening	Acoustic trawl sensors: door spread, roll and pitch of doors, speed, vertical opening			*PINRO
Trawl design	Equal	Equal			
Trawl opening	Approx. 4 m	3.8-4.2 m			
Trawling procedure	Trawling duration 15 min after bottom contact	Trawling duration 15 min after bottom contact			
Speed	3 kn(speed over ground, GPS)	3 kn(through water)		*	

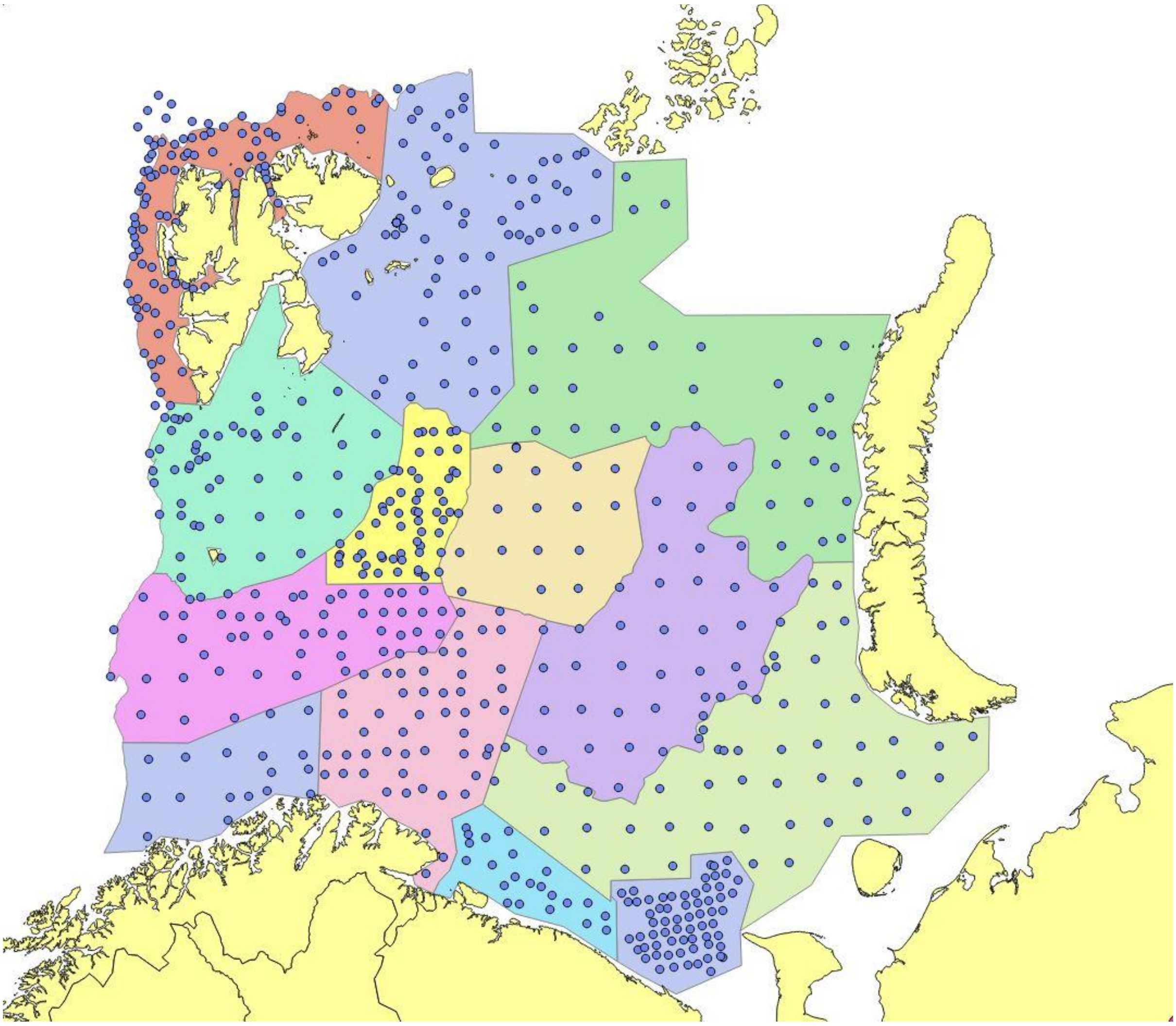
Appendix Figure. Strata systems (modified from figure 4) used in StoX and stations set out at predefined positions all years 2004-2018.



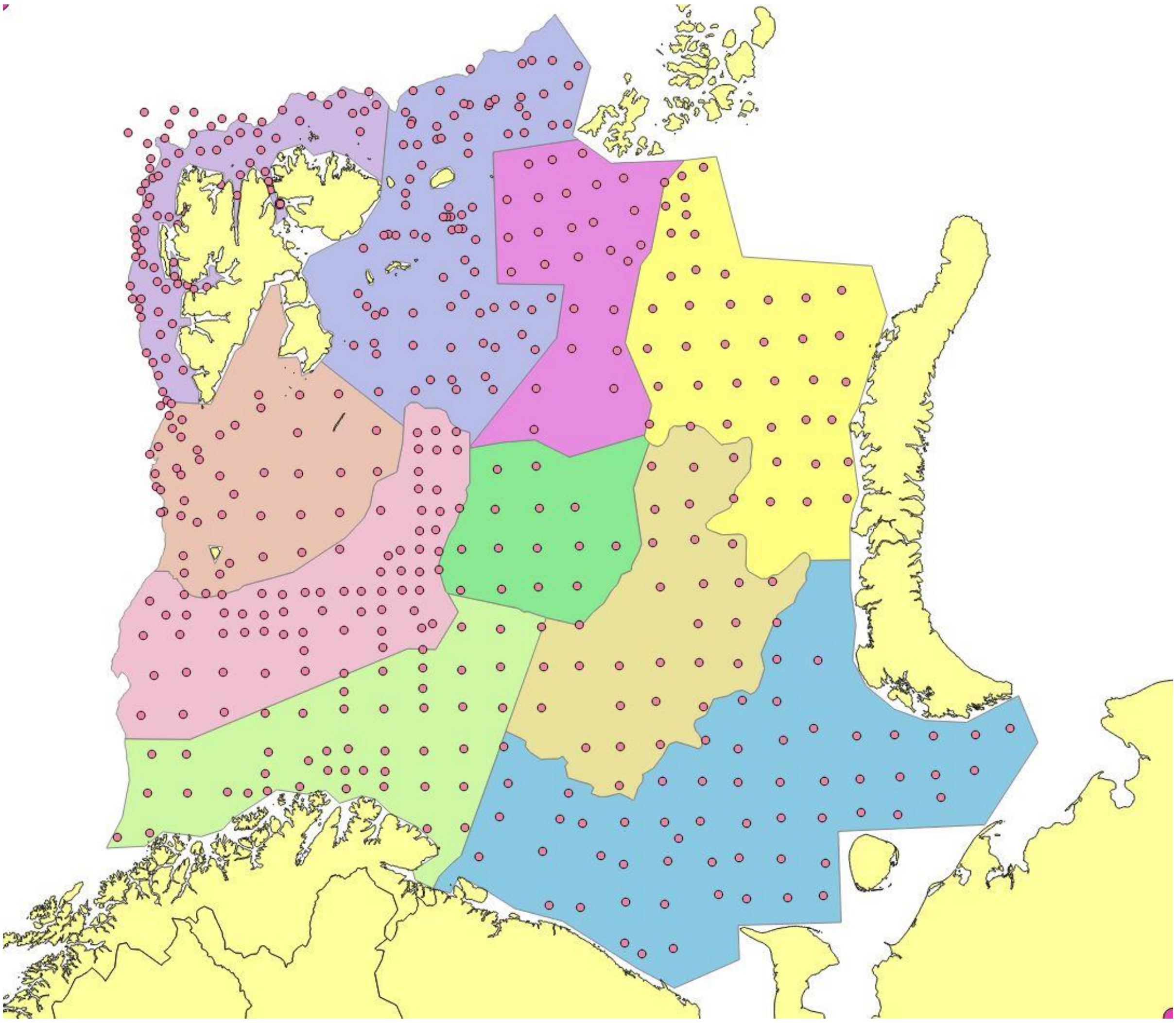
2004. Stations grid set out according to 0-group survey design with Mercator projection. Approximately 35 nautical mile grid station distance. Denser grid was due to Greenland halibut juvenile investigation in Storfjordrenna, and west and east of Svalbard, and due to this the “Great Bank” stratum is split to account for the denser sampling in the western part of this stratum. The “South East” stratum is reduced due to limited sampling coverage.



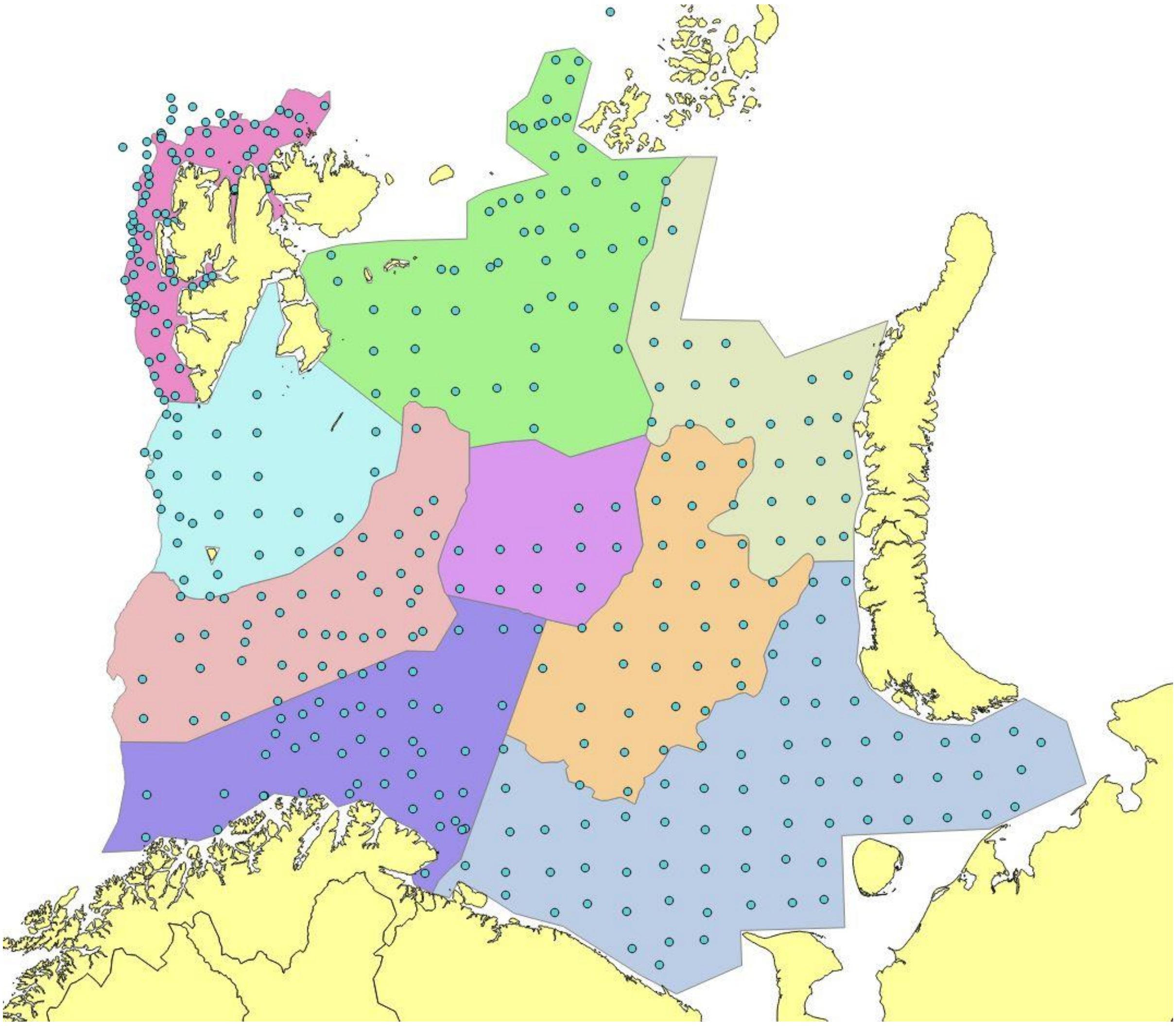
2005. Stations set out in a modified UTM with approximately 35 nautical mile grid station distance. Denser grid was due to Greenland halibut juvenile investigation in Storfjordrenna, and west and east of Svalbard, and shrimp investigations in the Bear Island trough. Due to this, the “Great Bank” stratum is split to account for the denser sampling in the western part of this stratum, and the eastern part of this stratum is added to the “North East” stratum to obtain sufficient sample size. The “South West” stratum was split in two for the same reasons. Northern and eastern edges was reduced due to limited sampling coverage.



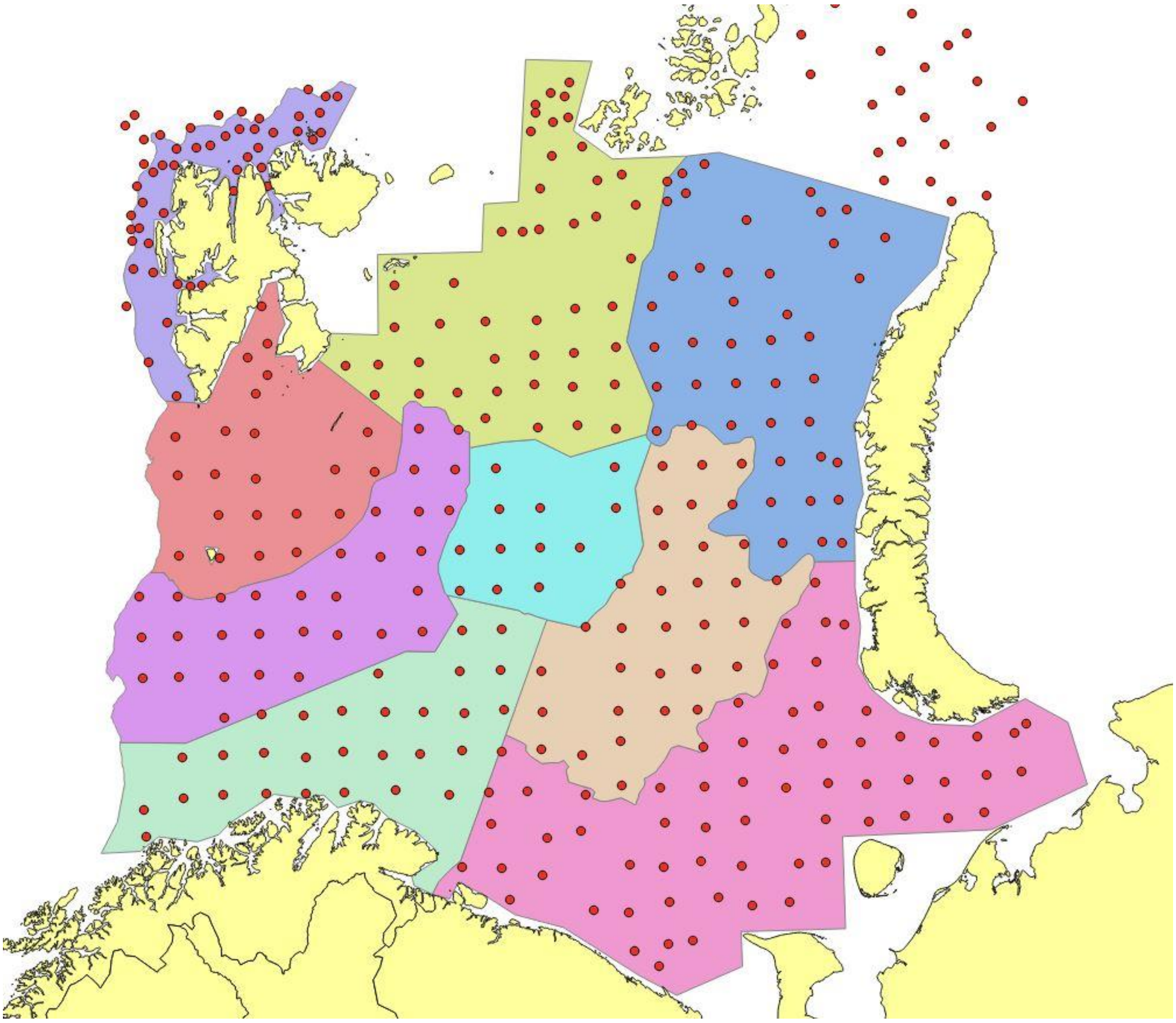
2006. Stations set out in a modified UTM with approximately 35 nautical mile grid station distance. Denser grid was due to Greenland halibut juvenile investigation in Storfjordrenna, and west and east of Svalbard and shrimp investigations in the Bear Island trough. The “Great Bank”, “Bear Island Through”, “South East” (flatfish investigations) and “South West strata were modified to account for denser sampling. Northern and eastern edges was reduced due to limited sampling coverage.



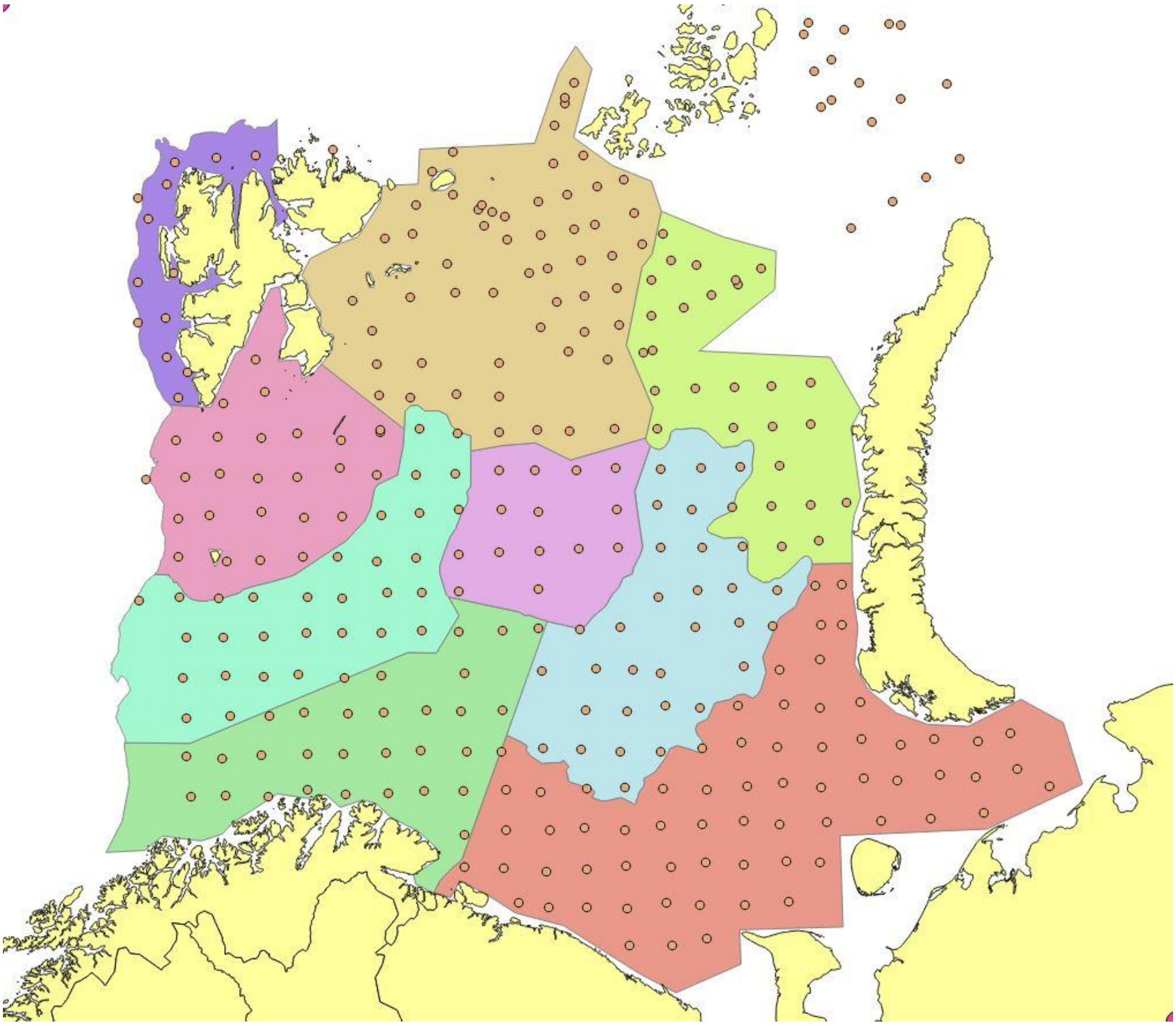
2007. Stations set out in a modified UTM with approximately 35 nautical mile grid station distance. Denser grid was due to Greenland halibut juvenile investigation in Storfjordrenna, and west and east of Svalbard, and shrimp investigations in the Bear Island trough. The “Great Bank” strata was spli to account for denser sampling. North-eastern and eastern edges was reduced due to limited sampling coverage.



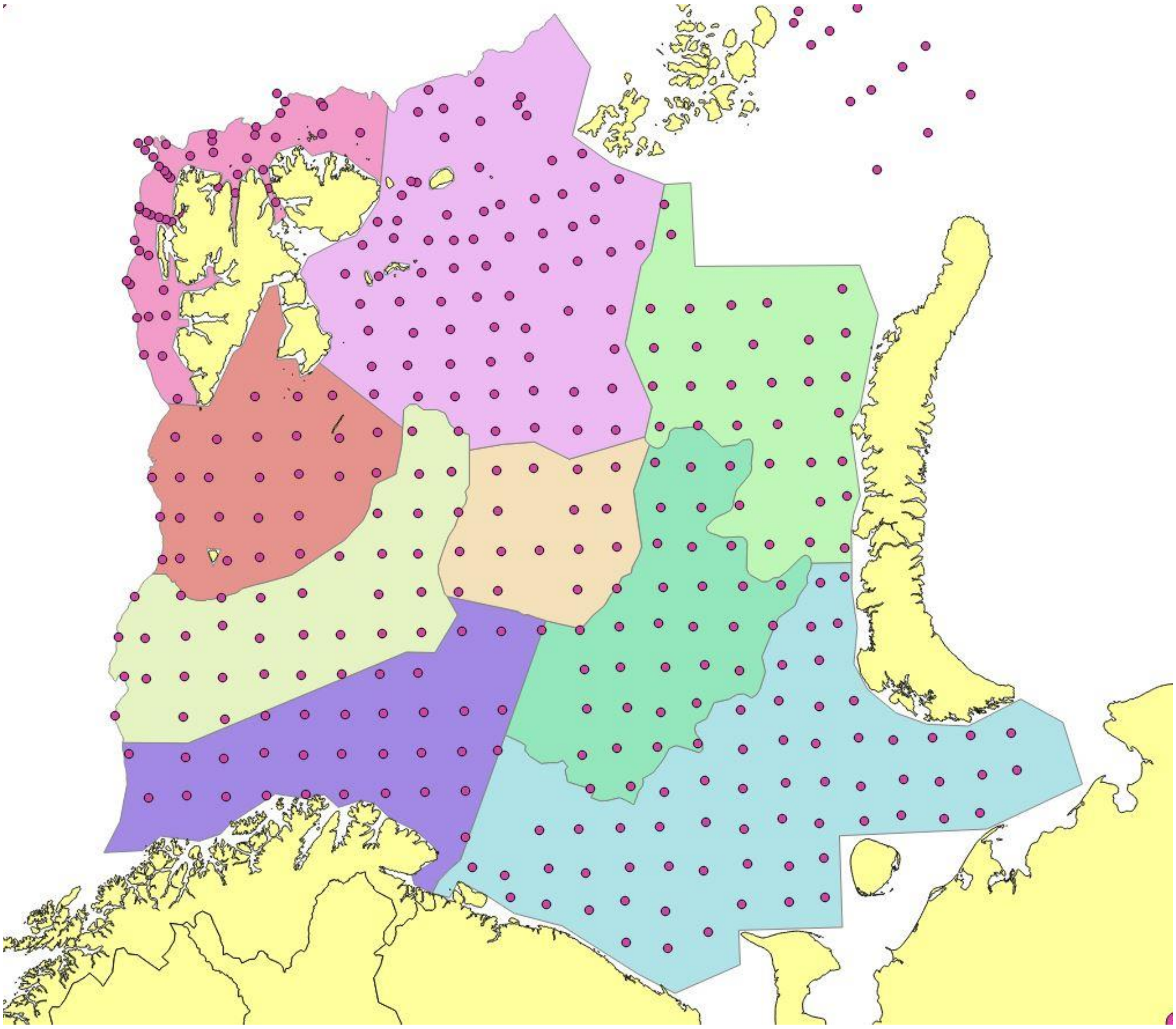
2008. Stations set out in a modified UTM with approximately 35 nautical mile grid station distance. Denser grid was due to Greenland halibut juvenile investigation in Storfjordrenna, and west and east of Svalbard and shrimp investigations in the Bear Island trough. The sampling effort was regarded as fairly regular compared to earlier years, so the only modification was reduction of the northern edges due to limited survey coverage. This year suffered a strong reduction in Norwegian survey time due to budget cuts.



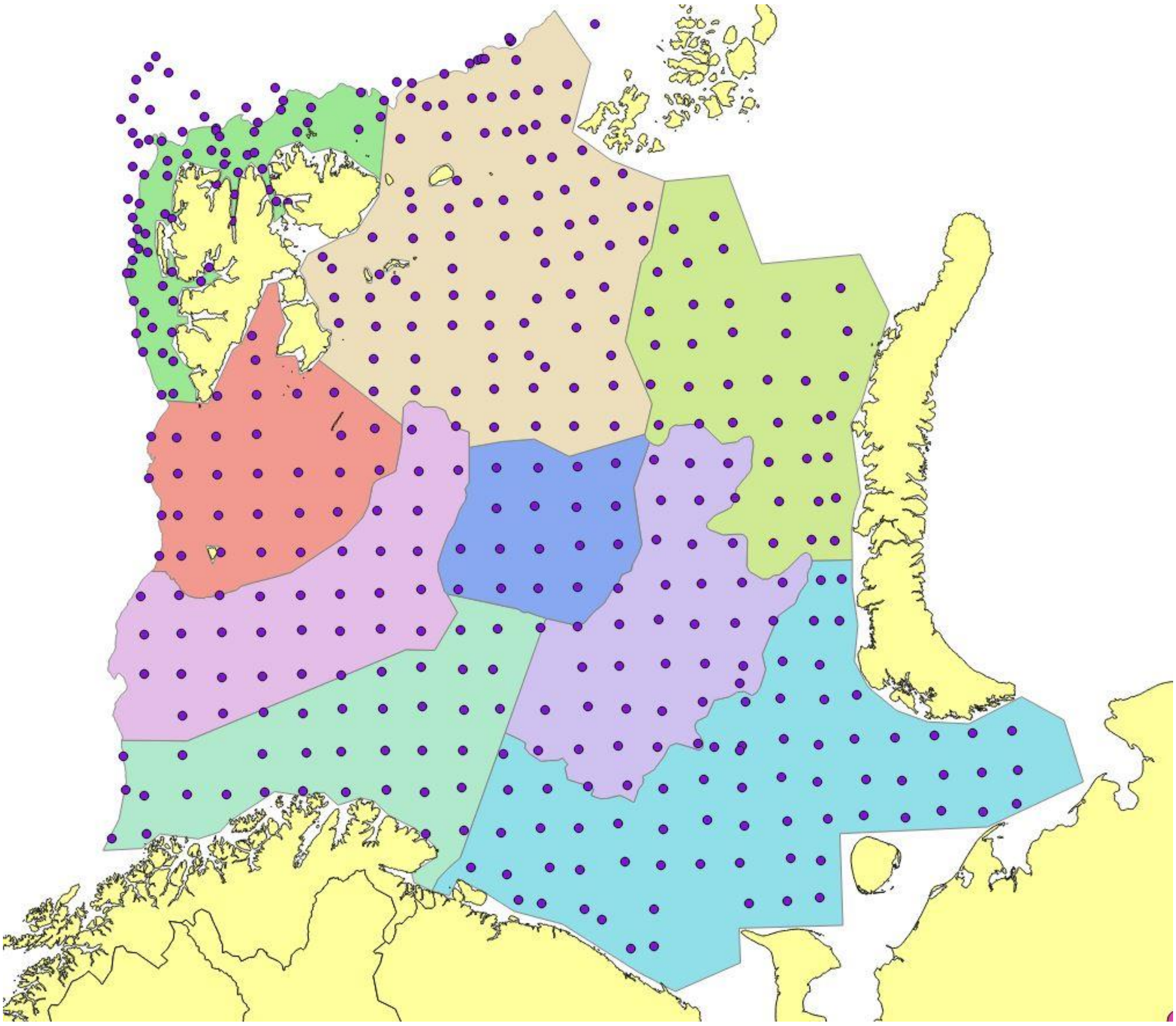
2009. Stations set out in a modified UTM with approximately 35 nautical mile grid station distance. Denser grid west of Svalbard due to steep depth gradients. Reduction of the northern edges due to limited survey coverage. Russian investigations in Kara Sea (North east) not included in StoX calculations.



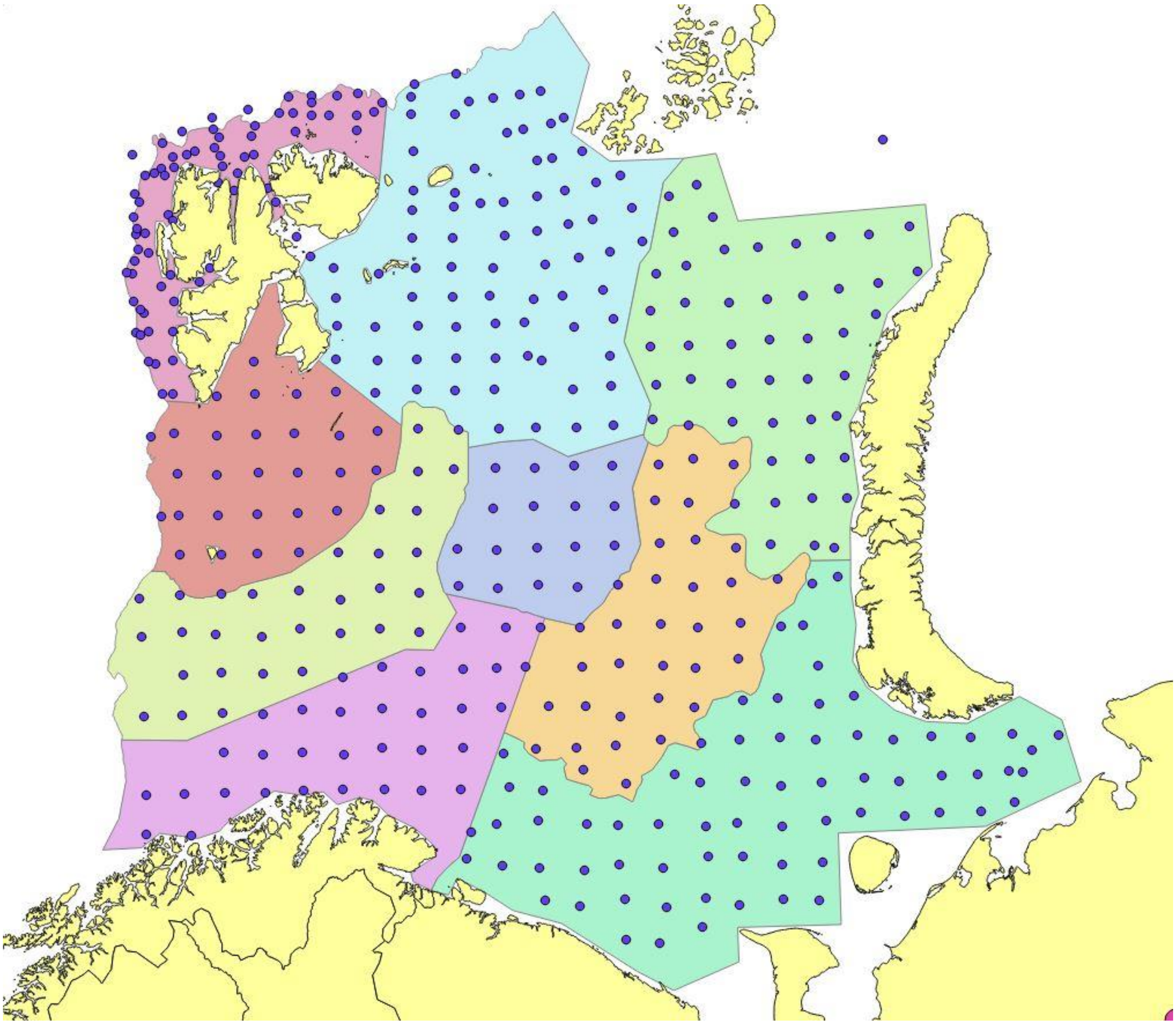
2010. Stations set out in a modified UTM with approximately 35 nautical mile grid station distance. Reduction of the northern edges due to limited survey coverage. Russian investigations in Kara Sea (North east) not included in StoX calculations.



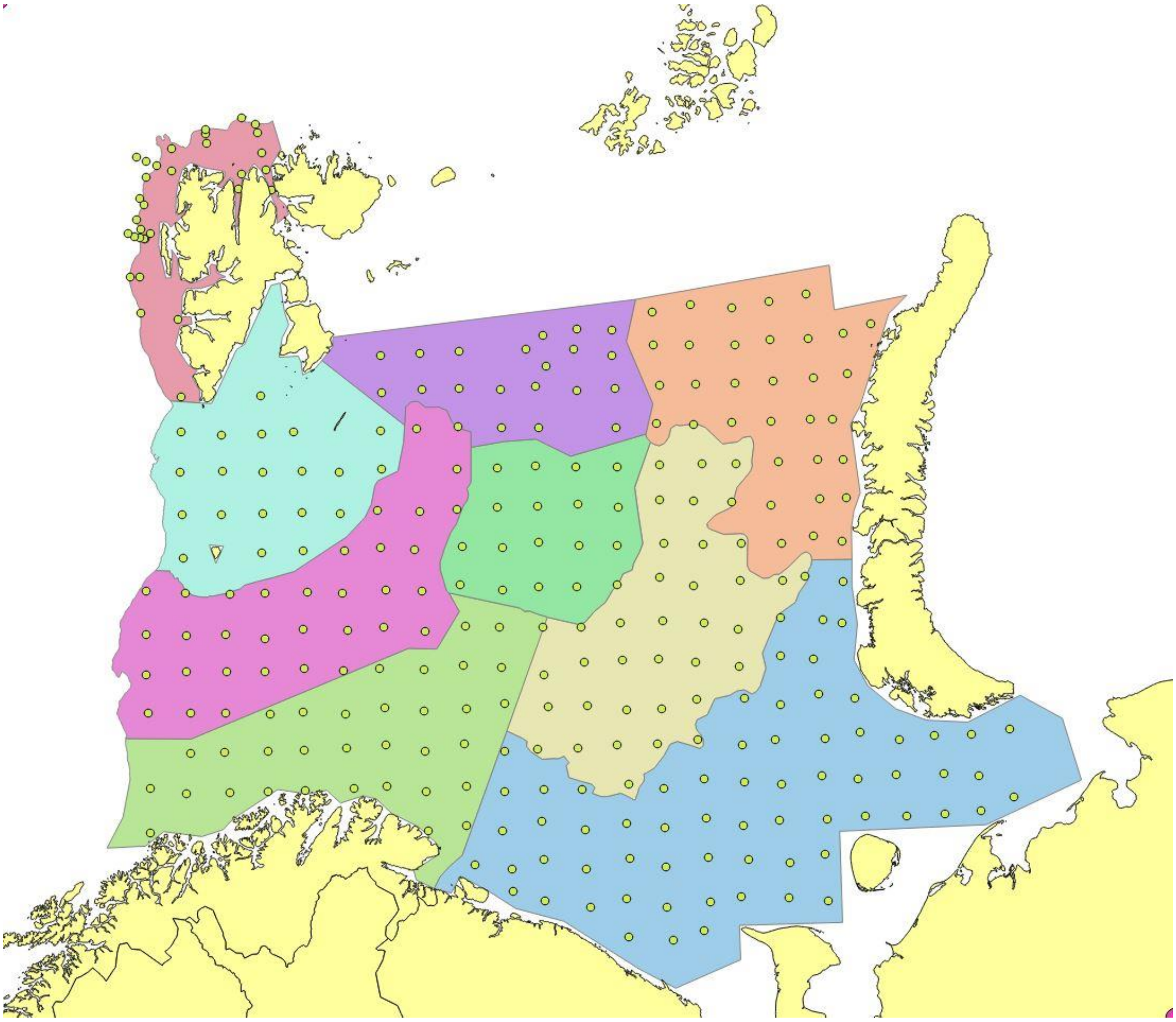
2011. Stations set out in a modified UTM with approximately 35 nautical mile grid station distance. Denser grid west of Svalbard due to steep depth gradients. Reduction of the northern edges due to limited survey coverage. Russian investigations in Kara Sea (North east) not included in StoX calculations.



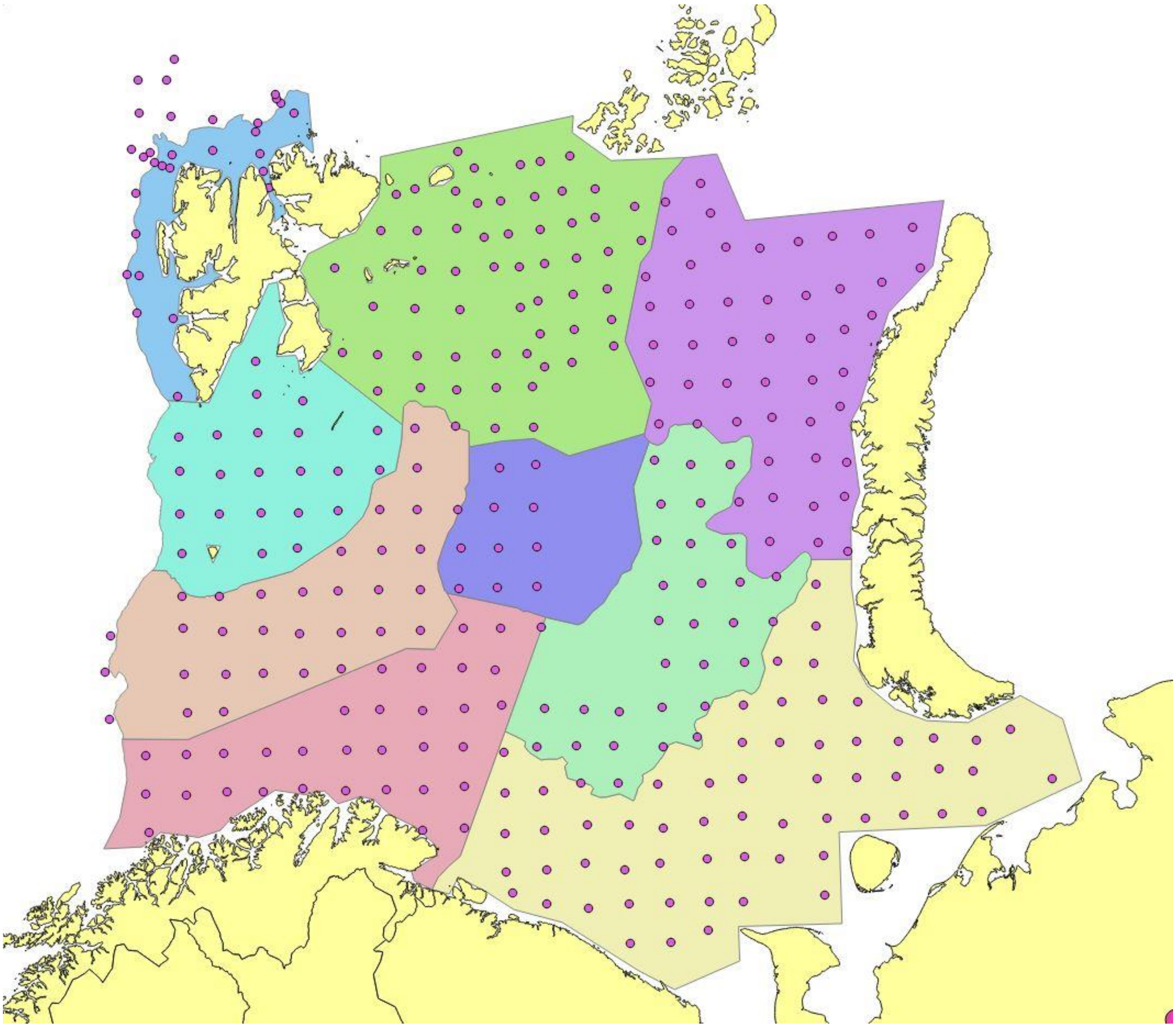
2012. Stations set out in a modified UTM with approximately 35 nautical mile grid station distance, except around Svalbard. Denser grid west of Svalbard due to steep depth gradients. Reduction of the north-eastern edges due to limited survey coverage. Russian investigations in Kara Sea (North east) not included in StoX calculations.



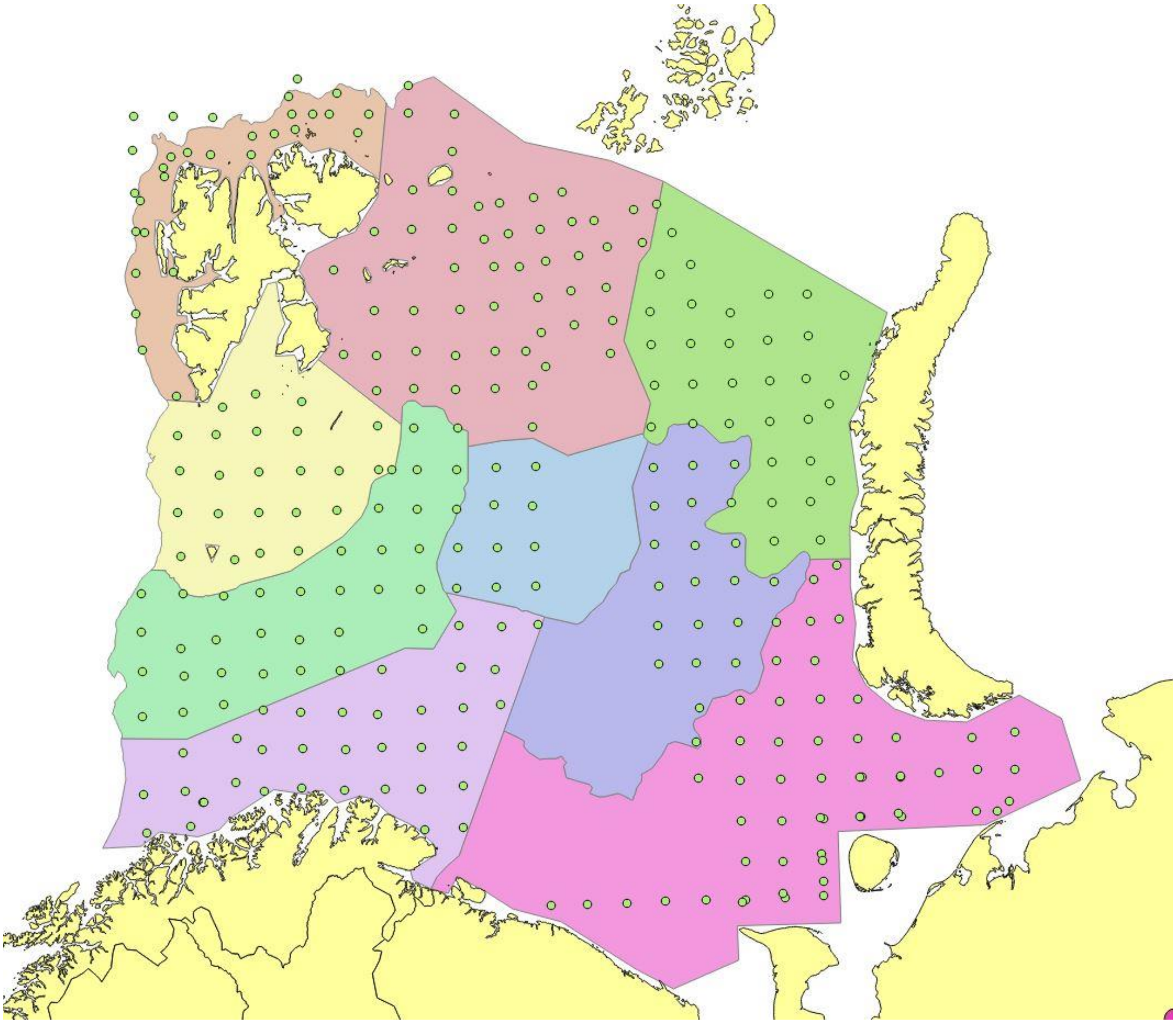
2013. Stations set out in a modified UTM with approximately 35 nautical mile grid station distance, except around Svalbard. Denser grid west of Svalbard due to steep depth gradients. Reduction of the north-eastern edges due to limited survey coverage.



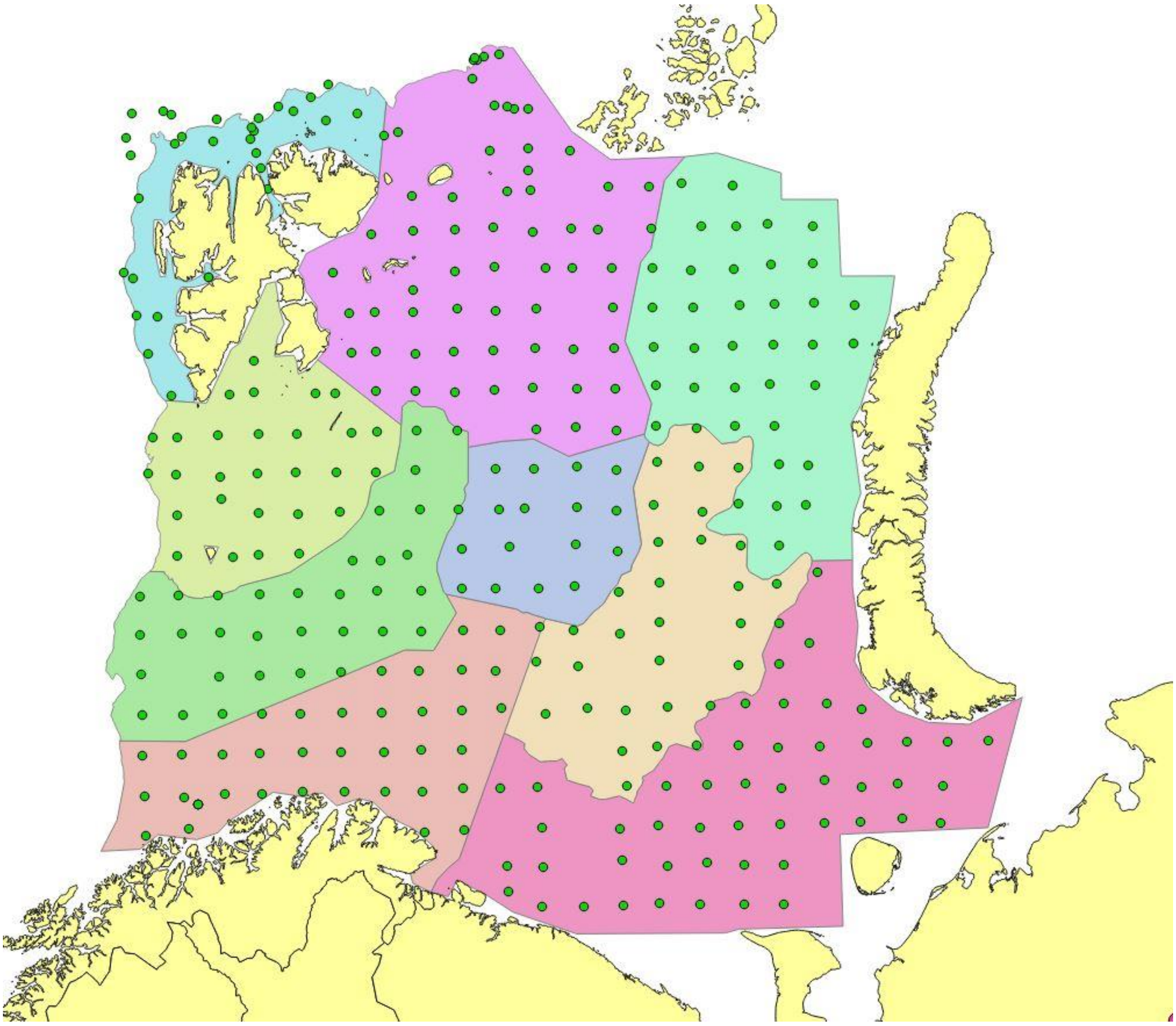
2014. Stations set out in a modified UTM with approximately 35 nautical mile grid station distance, except around Svalbard. Denser grid west of Svalbard due to steep depth gradients. Reduction of the northern edges due to limited survey coverage. NB! Ice restrictions in the north – this year the survey indices were not used in the cod assessment.



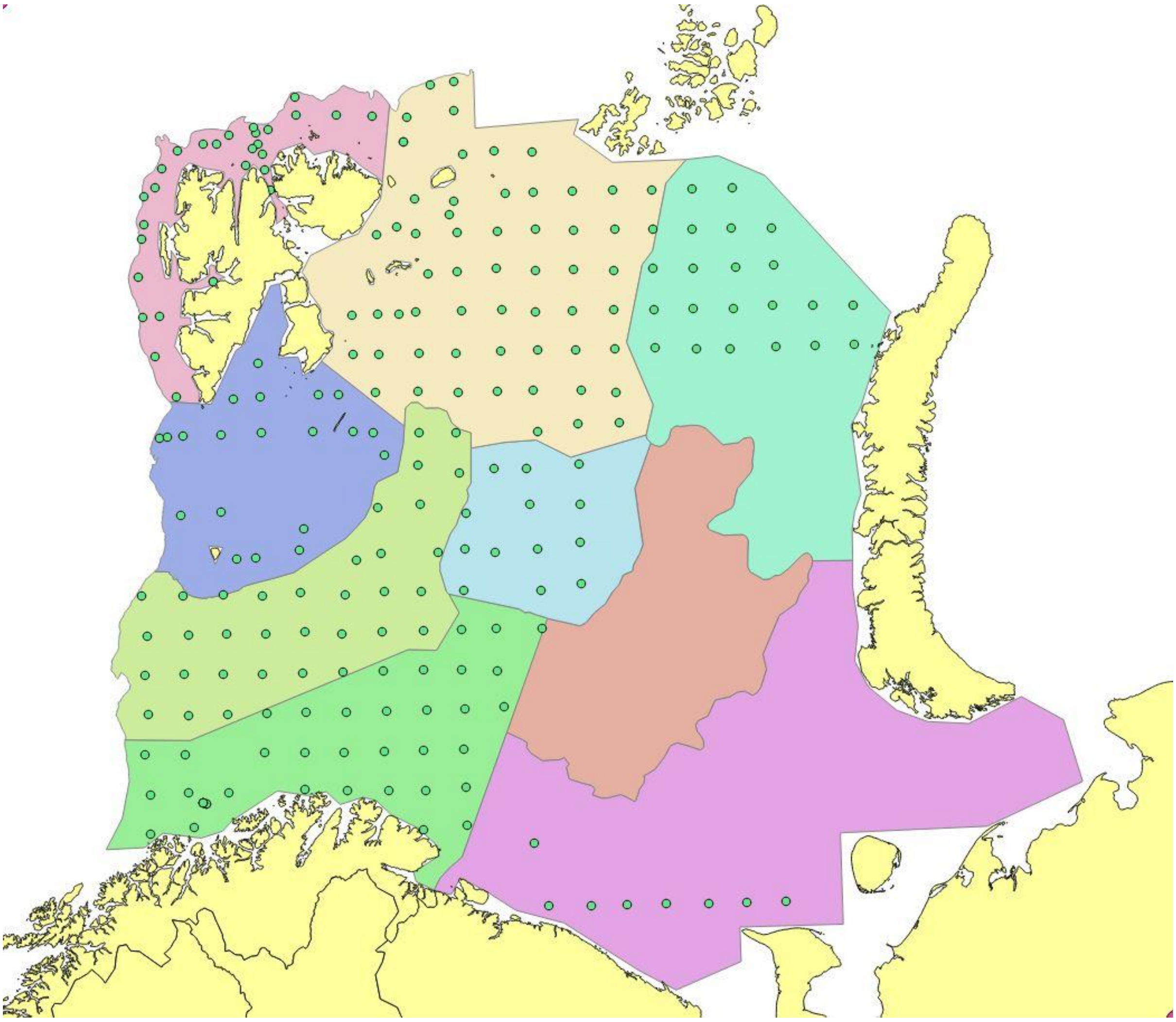
2015 Stations set out in a modified UTM with approximately 35 nautical mile grid station distance, except around Svalbard. Denser grid west of Svalbard due to steep depth gradients. No coverage in the loop hole due to unclear jurisdictions. Reduction of the northern edges due to limited survey coverage.



2016. Stations set out in a modified UTM with approximately 35 nautical mile grid station distance, except around Svalbard. Denser grid west of Svalbard due to steep depth gradients. No coverage in loop hole due to unclear jurisdictions. Russian military exercise limited survey access to the south eastern BS. Reduction of the north-eastern edges due to limited survey coverage.



2017. Stations set out with approximately 35 nautical mile grid station distance, according to Albers equal-area projection (also called: Albers Equal-Area Conic Projection) with the following parameter settings: Centre latitude: 75 N, Centre longitude: 30 E, 1st standard Latitude: 70 N, 2nd standard latitude: 80 N. Modified grid in the western part to avoid deeper stations than 500 m, and around Svalbard due to restrictions in natural reserves. Some additional stations in “Spitsbergen Bank”, “Svalbard” and “Great Bank” strata to cover Greenland halibut. Slight reduction of the north-eastern and south-eastern edges due to limited survey coverage.



2018. Stations set out with approximately 35 nautical mile grid station distance, according to Albers equal-area projection (also called: Albers Equal-Area Conic Projection) with the following parameter settings: Centre latitude: 75 N, Centre longitude: 30 E, 1st standard Latitude: 70 N, 2nd standard latitude: 80 N. Modified grid in the western part to avoid deeper stations than 500 m, and around Svalbard due to restrictions in natural reserves. Some additional stations in “Spitsbergen Bank”, “Svalbard” and “Great Bank” strata to cover Greenland halibut. Slight reduction of the north-eastern edges due to limited survey coverage. Lack of coverage in east was due technical problems with the Russian vessel. No attempt was done to calculate survey indices in 2018, due to this severe coverage problem.

Fish investigations in the Barents Sea winter 2019

Sigbjørn Mehl, Thomas de Lange Wenneck, Asgeir Aglen,
Edvin Fuglebakk, Harald Gjøsæter, Jane Aanestad Godiksen,
Silje Elisabeth Seim and Arved Staby
Institute of Marine Research
P.O. Box 1870 Nordnes, N-5817 Bergen, Norway

Alexey A. Russkikh and Konstantin Fomin
PINRO
6 Knipovich Street, 183038 Murmansk. Russia

CONTENTS

Preface

Annual catch quotas and other regulations of the Barents Sea fisheries are set through negotiations between Norway and Russia. Assessment of the state of the stocks and quota advices are given by the International Council for the Exploration of the Sea (ICES). Their work is based on survey results and international landings statistics. The results from the demersal fish winter surveys in the Barents Sea are an important source of information for the annual stock assessment.

The development of the survey started in the early 1970s and focused on acoustic measurements of cod and haddock. Since 1981 it has been designed to produce both acoustic and swept area estimates of fish abundance. Some development has taken place since then, both in area coverage and in methodology. The development is described in detail by Jakobsen *et al*. (1997), Johannesen *et al*. (2009) and Appendix 2. At present the survey provides the main data input for several projects at the Institute of Marine Research, Bergen:

- monitoring abundance of the Barents Sea demersal fish stocks
- mapping fish distribution in relation to climate and prey abundance
- monitoring food consumption and growth
- estimating predation mortality caused by cod

This report presents the main results from the surveys in January-March 2019. The surveys were performed with the Norwegian research vessels “Helmer Hanssen” and “Johan Hjort” and Russian research vessel “Vilnyus”. Annual survey reports since 1981 are listed in Appendix 1.

1 Introduction

The Institute of Marine Research (IMR), Bergen, has performed acoustic measurements of demersal fish in the Barents Sea since 1976. Since 1981 a bottom trawl survey has been combined with the acoustic survey. Typical effort of the combined survey has been 10-14 vessel-weeks, and about 350 bottom trawl hauls have been made each year. Most years three vessels have participated from about 1 February to 15 March.

The purpose of the investigations is presently:

- Obtain acoustic abundance indices by length and age for cod and haddock
- Obtain swept area abundance indices by length (and age) for cod, haddock, redfish, Greenland halibut and blue whiting
- Map the geographical distribution of those fish stocks
- Estimate length, weight and maturity at age for cod and haddock
- Collect stomach samples from cod, for estimating predation by cod. Results of such analyses for the period 1984-2017 are given in the 2017 survey report.
- Map the distribution of maturing/prespawning capelin

Data and results from the survey are used both for stock assessments in the ICES Arctic Fisheries Working Group AFWG and by several research projects at IMR and PINRO.

From 1981 to 1992 the survey area was fixed (strata 1-12, main areas ABCD in Fig. 2.1). Due to warmer climate and increasing stock size in the early 1990s, the cod distribution area increased. Consequently, in 1993 and further in 1994 the survey area was extended to the north and east (strata 13-23, main areas D'ES in Fig. 2.1) to obtain a more complete coverage of the younger age groups of cod, and since then the survey has aimed at covering the whole cod distribution area in open water. For the same reason, the survey area was extended further northwards in the western part in 2014 (strata 24-26 in Fig. 2.1). In many years since 1997 Norwegian research vessels have had limited access to the Russian EEZ, and in 1997, 1998, 2007 and 2016 the vessels were not allowed to work in the Russian EEZ. In 1999 a rather unusually wide ice-extension partly limited the coverage. Since 2000, except in 2006, 2007 and 2017, Russian research vessels have participated in the survey and the coverage has been better, but for various reasons not complete in most years. In 2008-2015 Norwegian vessels had access to major parts of the Russian EEZ. The coverage was more complete in these years, especially in 2008, 2011 and 2014. Table 3.6 summarizes degree of coverage and main reasons for incomplete coverage in the Barents Sea winter 1981-2019.

2 Methods

2.1 Acoustic measurements

The method is explained by Dalen and Smedstad (1979, 1983), Dalen and Nakken (1983), MacLennan and Simmonds (1991) and Jakobsen et al. (1997). The acoustic equipment has been continuously improved. Since the early 1990s Simrad EK500 echo sounder and Bergen Echo Integrator (BEI, Knudsen 1990) were used. The Simrad EK60 echo sounder replaced the EK500 on R/V "Johan Hjort" in 2005 and on R/V "Helmer Hanssen" since the 2008 survey. The latest R/V "G.O. Sars" has used EK60 since it replaced R/V "Sarsen" (former R/V "G.O. Sars") in 2004. The Large Scale Survey System (LSSS, Korneliussen *et al*. 2016) replaced BEI on R/V "G.O. Sars" and R/V "Johan Hjort" in 2007 and on R/V "Helmer Hanssen" since the 2008 survey. On the Russian vessels EK 500 was used from 2000 to 2004 and ER60 since 2005. The new Simrad EK80 echo sounder has been used on R/V "G.O. Sars" since 2017 and on R/V "Johan Hjort" since 2018.

In the mid-1990s the echo sounder transducers were moved from the hull to a retractable centreboard, on R/V "Johan Hjort" since the 1994 survey, on R/V "Sarsen" (former R/V "G.O. Sars") since 1997, on the latest R/V "G.O. Sars in 2004 and on R/V "Helmer Hanssen" since the 2008 survey. This latter change has largely reduced the signal loss due to air bubbles in the close to surface layer. None of the Russian vessels have retractable centreboards.

On the Norwegian vessels, acoustic backscattering values (s_A = nautical area scattering coefficient NASC) are stored at high resolution in LSSS. After scrutinizing and allocating the values to species or species groups, the values are stored with 10 m vertical resolution and 1 nautical mile (NM) horizontal resolution. The procedure for allocation by species is based on:

- composition in trawl catches (pelagic and demersal hauls)
- the appearance of the echo recordings
- inspection of target strength distributions
- inspection of target frequency responses

For each trawl catch the relative s_A-contribution from each species is calculated (Korsbrekke 1996) and used as a guideline for the allocation. In these calculations, the fish length dependent catching efficiency of cod and haddock in the bottom trawl (Aglen and Nakken 1997) is taken into account. There is no reason to believe that trawl catches give an accurate representation of species composition in the sea, so the calculated s_A-contribution from the trawl hauls are used as a guidance only.

The new Sea2Data software StoX has been applied to estimate acoustic indices with CVs for cod and haddock. Acoustic estimates for the period 1994-2017 were re-estimated using StoX (Mehl *et al*. 2018). The main difference between the SAS based BEAM Program (Totland and Godø 2001) used until 2017 and StoX acoustic abundance estimation is that in BEAM the survey area is divided into rectangles, and for each rectangle an average acoustic density (s_A) is calculated, while in StoX transects are defined within each stratum (Figure 2.1) as primary sampling units (PSUs) and used to calculate acoustic density (Jolly and Hampton 1990).

The survey area is divided into eight Main Areas (A, B, C, D, E, S and N, Fig 2.1) and 26 strata. In 2014, the investigated area was enlarged by three new strata in northwest, 24-26 (Main Area N, Fig. 2.1). Within each stratum, the acoustic course tracks are divided into transects, separated by the trawl stations in the stratum since the course tracks run through the net of fixed bottom trawl stations in the bottom trawl survey. An area of about 2 nautical miles around each station is not included in the transects. For the time series 2004-2017 this was done by first running a R-script tagging all the transects and then the transects were inspected and edited manually in StoX if necessary. Minimum length of a transect is 4 nautical miles. In this process miles with obvious errors in the s_A-values, e.g. bottom contribution, were removed from the transects.

For each transect and stratum, an arithmetic mean s_A is calculated for the demersal zone (less than 10 m above bottom) and the pelagic zone (more than 10 m above bottom).

The conversion of mean NASC (m^2 nmi^{-2}) to density of fish followed a standard procedure where all trawl stations within a stratum with a catch of more than 5 individuals were assigned to each PSU. If less than 3 trawl stations had been carried out in a stratum, stations in neighbouring strata were assigned to the PSUs such that at least 3 stations were assigned to each PSU.

The combined length distribution (d) was calculated for each transect (PSU (j)) as:

$$d_{l,j} = \sum_{s=1}^{S} d_{l,s,j}$$

where $d_{l,s,j}$ is density (number by 1 NM tow distance) by 1 cm length group (l) for the stations (s) assigned to PSU (j).

The trawl catches are normalised to 1 NM towing distance and adjusted for length dependent catch efficiency (Aglen and Nakken 1997, Dickson 1993a,) using the parameters given in the text table below:

Species	α	β	l_{min}	l_{max}
Cod	5.91	0.43	15 cm	62 cm
Haddock	2.08	0.75	15 cm	48 cm

The areal density of fish (ρ) (n per nmi^2) by length group l by transect j was calculated as

$$\rho_{j,l} = \frac{\mathrm{NASC}_{j,l}}{\sigma_l}$$

where $\mathrm{NASC}_{j,l}$ is the mean nautical area scattering coefficient by transect (j) and length group (l) and σ_l is the acoustic backscattering cross-section for a fish of length l.

$NASC_{j,l}$ is calculated as:

$$\mathrm{NASC}_{j,l} = \mathrm{NASC}_j \frac{\sigma_{l,p}}{\sum_l \sigma_{l,p}}$$

where $\sigma_{l,p}$ is the acoustic backscattering cross-section for a fish of length *l* multiplied with the proportion (*p*) of a fish of length *l* in the total length distribution and $NASC_j$ is the mean nautical area scattering coefficient in transect *j*.

The acoustic backscattering cross-section (m^2) for a fish of length *l* is calculated as

$$\sigma_l = 4\pi 10^{\left(\frac{TS_l}{10}\right)}$$

where the target strength, *TS*, for a fish of length *l* (cm) is calculated as

$$TS_l = m \log_{10}(l) + a$$

Where *m* and *a* are constants. For cod and haddock we applied

$TS = 20 \log(l) - 68$ (Foote, 1987),

The fish abundance (*N*) by length group (*l*) for stratum *k* is:

$$N_{k,l} = \rho_{k,l} A_k ,$$

where *A* is stratum area and the mean density of fish of length group *l* and stratum *k* is:

$$\rho_{k,l} = \frac{1}{n_k} \cdot \sum_{k=1}^{n_k} w_{kj} \rho_{kj,l}$$

where $w_{kj} = L_{kj} / \overline{L}_k$ (j= 1,2, n_k) are the lengths of the n_k sample transects.

Estimates by length are converted to estimates by age using available age-length data from all selected (filtered) stations in the stratum, weighted by station density. The total biomass is estimated by multiplying the numbers at age by weight at age. The abundance by stratum is then summed for defined main areas (Figure 2.1).

2.2 Swept area measurements

All vessels were equipped with the standard research bottom trawl Campelen 1800 shrimp trawl with 80 mm (stretched) mesh size in the front. Prior to 1994 a cod-end with 35-40 mm (stretched) mesh size and a cover net with 70 mm mesh size were mostly used. Since this mesh size may lead to considerable escapement of 1-year-old cod, the cod-ends were in 1994 replaced by cod-ends with 22 mm mesh size. At present a cover net with 116 mm meshes is mostly used.

The trawl is now equipped with a rockhopper ground gear (Engås and Godø 1989). Until and including 1988 a bobbins gear was used, and the cod and haddock indices from the period 1981-1988 have since been recalculated to ‘rockhopper indices’ and adjusted for length dependent catch efficiency and/or sweep width (Godø and Sunnanå 1992, Aglen and Nakken 1997). The sweep wire length is 40 m, plus 12 m wire for connection to the doors.

In the Norwegian Barents Sea shrimp survey (Aschan and Sunnanå 1997) the Campelen trawl has been rigged with some extra floats (45 along the ground rope and 18 along the under belly and trunk, all with 20mm diameter) to reduce problems on very soft bottom. This rigging has been referred to as “Tromsø rigging”. When the shrimp survey was terminated 2004 and later merged with the Barents Sea Ecosystem survey in 2005, improved shrimp data were also requested from the winter survey, and the “Tromsø rigging” was used in parts of the shrimp areas in 2004 (11 stations) and 2005 (9 stations). In 2006-2014 “Tromsø rigging” was used for nearly all bottom trawl stations taken by Norwegian vessels in the winter survey, while since 2015 “Tromsø rigging” has not been applied.

Vaco doors (6 m^2, 1500kg), were previously standard trawl doors on board the Norwegian research vessels. On the Russian vessels and hired vessels V-type doors (ca 7 m^2) have been used. In 2004, R/V “Johan Hjort” and R/V “G.O. Sars” started using a V-type door for bottom trawling (Steinshamn W-9, 7.1m^2, 2050 kg), the same type as used on the Russian research vessels. In 2010 the V-doors were replaced by 125” Thyborøn trawl doors. R/V “Helmer Hanssen” has used Thyborøn trawl doors since the 2008 survey. To achieve constant sampling width of a trawl haul independent of e.g. depth and wire length, a 10-15 m rope “locks” the distance between the trawl wires 80-150 m in front of the trawl doors on the Norwegian vessels. This is called “strapping”. The distance between the trawl doors is then in most hauls restricted to the range 48-52 m regardless of depth (Engås and Ona 1993, Engås 1995). Strapping was first attempted in the 1993 survey on board one vessel, in 1994 it was used on every third haul and in 1995-1997 on every second haul on all vessels. Since 1998 it has been used on all hauls when weather conditions permitted. Strapping is not applied on the Russians vessels, but the normal distance between the doors is about 50 m (D. Prozorkevich, pers. comm.).

Standard tow duration is now 15 minutes (until 1985 the tow duration was 60 min. and from 1986 to 2010 30 min.). Trawl performance is constantly monitored by Scanmar trawl sensors, i.e., distance between the doors, vertical opening of the trawl and bottom contact control. In 2005-2008 sensors monitoring the roll and pitch angle of the doors were used due to problems with the Steinshamn W-9 doors. The data is logged on files, but have so far not been used for further evaluation of the quality of the trawl hauls.

At the start of the survey at least two of the trawls on the Norwegian vessels should go through a “sea test”. The purpose of the test is to check that the geometry of the trawl is within the specified limits and that the trawl performance is satisfactory, especially that the bottom contact is stable. It is further checked that the trawl sensors operate as they should.

The positions of the trawl stations are pre-defined. When the swept area investigations started in 1981 the survey area was divided into four main areas (A, B, C and D, Fig 2.1) and 35 strata.

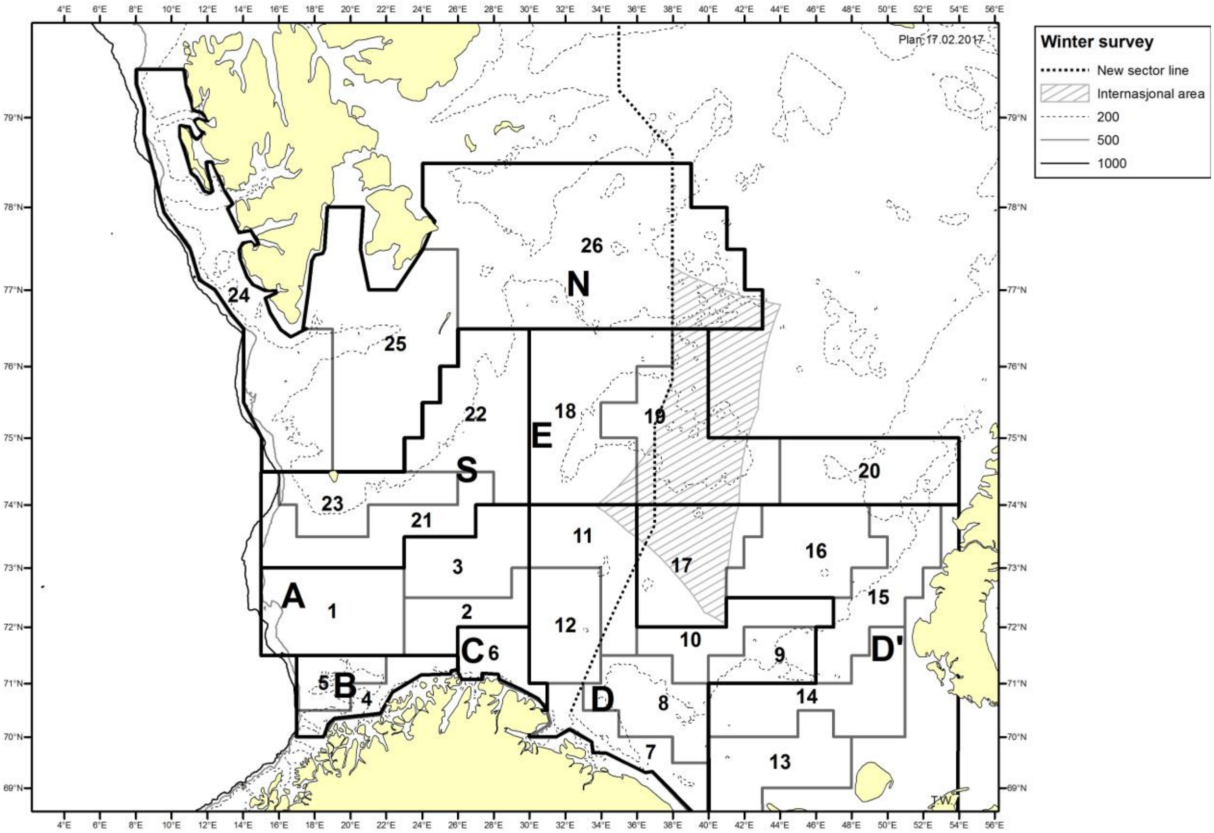


Figure 2.1. Strata (1-23) and main areas (A,B,C,D,D’,E and S) used for swept area estimations and acoustic estimations with StoX. Additional strata (24-26, main area N) are covered since 2014, but not included in the standard time series.

During the first years, the number of trawl stations in each stratum was set based on expected fish distribution to reduce the variance, i.e., more hauls in strata where high and variable fish densities were expected to occur. During the 1990s trawl stations were spread out more evenly, yet the distance between stations in the most important cod strata is shorter (16 or 20 NM) compared to the less important strata (24, 30 or 32 NM). Considerable amounts of young cod were now distributed outside the initial four main areas, and in 1993 the investigated area was therefore enlarged by areas D’, E, and the ice-free part of Svalbard (S) (Fig. 2.1 and

Table 3.5), 28 strata altogether. In the 1993-1995 survey reports, the Svalbard area was included in area A' and the western part of area E (west of 30°E). Since 1996 a revised strata system with 23 strata has been used (Figure 2.1). The main reason for reducing the number of strata was the need for enough trawl stations in each stratum to get reliable estimates of density and variance. In 2014 the investigated area was enlarged by three new strata in northwest, 24-26 (main area N, Fig. 2.1). However, the data are due to few years so far not included in the standard time series of standard abundance indices used in the assessments.

Swept area fish density estimation

Swept area fish density estimates ($\rho_{s,l}$) by species (s) and length (l) were estimated for each bottom trawl haul by the equation:

$$\rho_{s,l} = \frac{f_{s,l}}{a_{s,l}}$$

$\rho_{s,l}$ number of fish of length l per n.m.^{2} observed on trawl station s

$f_{s,l}$ estimated frequency of length l

$a_{s,l}$ swept area:

$$a_{s,l} = \frac{d_s \cdot EW_l}{1852}$$

d_s towed distance (nm)

EW_l length dependent effective fishing width:

$$EW_l = \alpha \cdot l^{\beta} \text{ for } l_{\min} < l < l_{\max}$$

$$EW_l = EW_{l_{\min}} = \alpha \cdot l_{\min}^{\beta} \text{ for } l \le l_{\min}$$

$$EW_l = EW_{l_{\max}} = \alpha \cdot l_{\max}^{\beta} \text{ for } l \ge l_{\max}$$

The parameters are given in the text table below:

Species	α	β	$l_{\min}$	$l_{\max}$
Cod	5.91	0.43	15 cm	62 cm
Haddock	2.08	0.75	15 cm	48 cm

The fishing width was previously fixed to 25 m = 0.0135 nm. Based on Dickson (1993a,b), length dependent effective fishing width for cod and haddock was included in the calculations in 1995 (Korsbrekke *et al*., 1995). Aglen and Nakken (1997) have adjusted both the acoustic and swept area time series back to 1981 for this length dependency based on mean-length-at-age information. In 1999, the swept area 1983-1995 time series was recalculated for cod and haddock using the new area and strata divisions (Bogstad *et al*. 1999).

For redfish, Greenland halibut and other species, a fishing width of 25 m was applied, independent of fish length.

The Sea2Data software StoX has been applied to estimate swept area indices with CVs for cod, haddock, golden redfish, beaked redfish, Norway redfish, Greenland halibut and blue whiting. Swept-area estimates for the period 1994-2016 was re-estimated using StoX (Mehl *et al*. 2016), and so was length and weight at age for cod and haddock. All estimates for 2017 and updated estimates for 2016 and strata 24-26 in 2014-2015 were estimated with StoX version 2.3, Rstox 1.5, while StoX version 2.5 and Rstox 1.8 were used in 2018. Input data downloaded from DataSet Explorer:
https://datasetexplorer.hi.no/apps/datasetexplorer/v2/navigation

The main difference between the SAS based Survey Program previously used (years 1981-1993 of the time-series, see earlier reports for results and method details) and StoX swept area estimation is in the use of the age-length data. StoX does not use age-length keys (ALK) in the traditional sense with ALKs estimated for large areas. Missing age information is imputed from known age-length data within station. If age information is still missing StoX searches within strata, or lastly within all strata. If no age is available for a length group, the abundance estimate is presented as unknown age. StoX does also allow for uncertainty estimation by bootstrapping primary sampling units (PSUs).

2.3 StoX input, filters and settings

StoX version 2.7 and Rstox 1.11 were used for acoustic, swept-area, length and weight at age and CV estimations for 2019 (http://www.imr.no/forskning/prosjekter/stox/). R for Windows version 3.5.2 was used in the R calls (https://www.r-project.org/).

In **FilterAcoustic, FreqExpr** was set to **frequency=38000 or frequency=37879**. In **NASCExpr, acocat** was **31** for cod and **30** for haddock.

In **NASC and LayerType** was set to **DepthLayer**.

Under **FilterBiotic** and **FishStationExpr**, in the acoustic estimations was applied: **fs.getLengthSampleCount('TORSK') > 5** for cod and **fs.getLengthSampleCount('HYSE') > 5 for haddock** and **fishstationtype !~ ['1', '2', '3']**, filtering out stations with less than six specimen and stations with experiments, (see Johnsen et al. 2016 and Mjanger et al. 2019 for more info about filters and codes).

In the swept area estimations was used: **FilterBiotic** and **FishStationExpr**, **gear** =~['3270','3271'] and **gearcondition** < 3 and **trawlquality** =~['1','3'] and **fishstationtype** != 2. In **DefineStrata**, **vintertokt_barentshavny.txt** was used as basis for strata definition. Nodes for strata towards north and east have been adjusted to reduce the strata according to coverage and ice border in each year.

In **StratumArea** and **AreaMethod**, **Accurate** was applied.

Under **StationLengthDist** and **LengthDistType**, **NormalLengthDist** was used, and under **RegroupLengthDis**t and **LengthInterval**, **1.0** is applied in the acoustic estimations and **5.0** in the swept area estimations.

Under **Catchability** and **Catchability Method**, **LengthDependentSweepWidth** was used for cod and haddock with the parameters given above.

In the swept area estimates, for **SweptAreaDensity, LengthDependent** was use, and for **SweepWidthMethod, Predetermined** was applied for cod and haddock and **Constant** with **SweepWidth 25 m** for the other species.

In the acoustic estimates, for **BioStationAssignment** and **AssignmentMethod**, **Stratum** was used. **EstLayers** was set to **1~PEL 2~BOT**.

Under **BioStationWeighting** and **WeightingMethod, SumWeightedCount** was used.

In **AcusticDensity**, **m** was set to **20** and a to **-68**.

Under **SuperIndAbundance** and **AbundWeightMethod**, **StationDensity** was used, with **LengthDist** set to **RegroupLengthDist**.

2.4 Estimation of variance.

The acoustic and swept area survey indices are presented together with an estimate of uncertainty (coefficient of variation; CV). These estimates were obtained by using StoX with a stratified bootstrap routine treating each transect as the primary sampling unit. In addition, a bootstrap routine for all trawl stations by strata was carried out within each run.

The estimated CV (Standard Deviation · 100/mean) is estimated from 500 iterations and is strongly dependent on the choice of estimator for the indices. A CV of 20% or less could be viewed as acceptable in a traditional stock assessment approach if the indices are unbiased (conditional on a catchability model). Values above this indicate a highly uncertain index with little information regarding year class strength.

2.5 Sampling of catch and age-length keys.

Sorting, weighing, measuring and sampling of the catch are done according to instructions given in Mjanger *et al*. (2019). Since 1999 all data except age are recorded electronically by Scantrol Fishmeter measuring board, connected to stabilized scales. The whole catch or a representative sub sample of most species was length measured on each station.

At each trawl station age (otoliths) and stomach were sampled from one cod per 5 cm length-group. In 2007-2009, all cod above 80 cm were sampled, and in 2010 all above 90 cm, limited to 10 per station. The stomach samples were frozen and analysed after the survey. Haddock and Greenland halibut otoliths were also sampled from one specimen per 5 cm length-group.

Regarding the redfish species *Sebastes norvegicus* and *S. mentella*, otoliths for age determination were sampled from two fish in every 5-cm length-group on every station. Table 3.3 gives an account of the sampled material.

2.6 Raising of indices

In 1997, 1998 and 2007 only the Norwegian EEZ (NEZ) and parts of the Svalbard area (S) was covered. The swept-area indices for cod, haddock, golden redfish, beaked redfish and Greenland halibut has therefore been raised to also represent the Russian EEZ (REZ) (Mehl *et al*. 2016).

In 2006, there was not a complete coverage in southeast due to restrictions. The observations in the partially covered strata 7 were extrapolated to the full strata, and the observations in the partially covered strata 13 were extrapolated to the same area as covered in 2005. In 2012 the coverage was incomplete in the eastern areas, and the cod and haddock swept area estimates within the covered area were raised by the “index ratio by age” observed for the same area in 2008-2011 (ICES 2012). The scaling factor (“index ratio”) for estimating adjusted total from <Total – area D’> was the average ratio by age for Total/(Total – area D’) in the years 2008-2011 (Aglen et al. 2012).

In 2017, the Norwegian vessel was not allowed to operate south of 70º 10’ N and west of 41º 00 º E, and no Russian vessel participated in the survey. Only a small part of strata 7 was covered, and strata 13, 15, 17 and 20 were not covered. The cod, haddock, Greenland halibut and beaked redfish swept area estimates and cod and haddock acoustic estimates within the covered area were raised following the same procedure as for 2012. The scaling factor for estimating adjusted total from <Total –strata 7 > was the average ratio by age for Total/(Total – (strata 7+13+15+17+20)) swept area indices in the years 2014-2016.

3 Survey operation and material

Table 3.1 presents the vessels participating in the survey in 2019 and IMR trawl station series numbers, and Figure 3.1 shows survey tracks, trawl stations and ice cover.

Table 3.1. Vessel participation by period and trawl station series numbers by vessel for the winter survey in 2019.

	Period	Series no.
Johan Hjort	31.01-18.03	70001-70259
Helmer Hanssen	23.01-25.02	70301-70189
Vilnyus	23.02-20.03	00001-00132

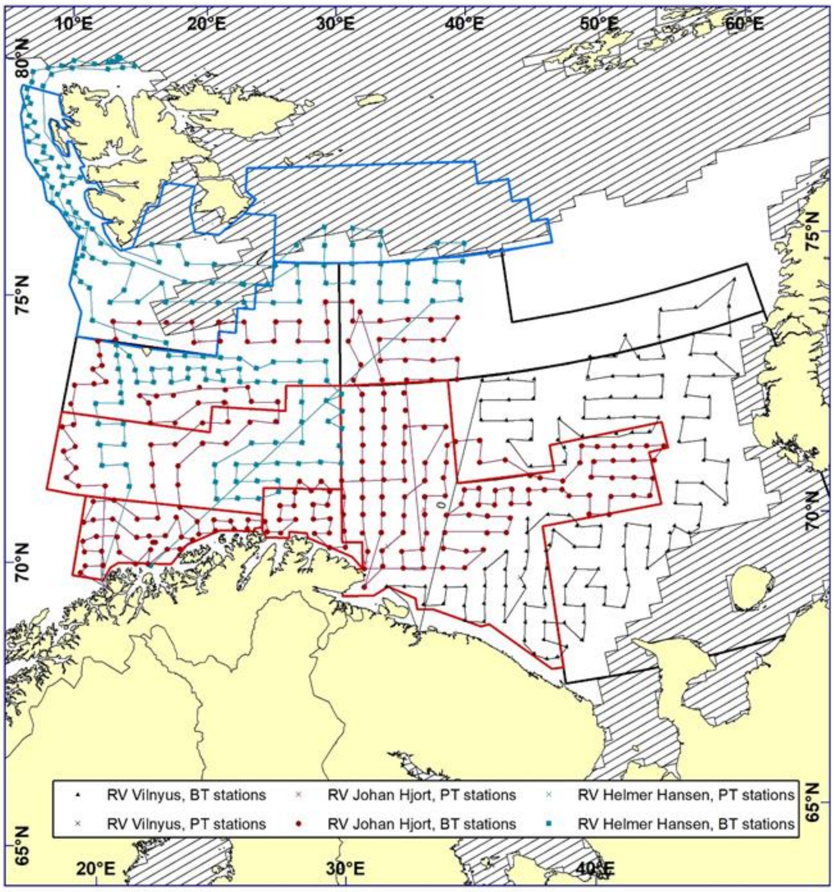


Figure 3.1. Survey tracks and all trawl stations in the winter survey 2019. Data source for the ice cover: ftp://sidads.colorado.edu/DATASETS/NOAA/G02135/north/monthly/shapefiles/shp_extent/02_Feb/

Table 3.2 presents the number of swept area trawl stations, other bottom trawl stations and pelagic trawl stations taken in the different main areas. For the calculation of swept area indices to be used in the assessments, only the successful pre-defined bottom trawl stations within the standard strata system (strata 1-23) were used. The number of stations in the new strata 24-26 are also given.

Table 3.2. Number of trawl stations by main area in the Barents Sea winter 2019. B_1= swept area bottom trawl (quality=1 and condition<3), B_2=other bottom trawl, P=pelagic trawl, N=trawl stations in new strata.

Main area	**Trawl type**	
A	B_1 B_2 P	48 6 1
B	B_1 B_2 P	33 13 -
C	B_1 B_2 P	17 - -
D	B_1 B_2 P	146 - 5
D'	B_1 B_2 P	91 1 -
E	B_1 B_2 P	35 3 2
S	B_1 B_2 P	72 3 1
Inside standard strata system	B_1 B_2 P	442 26 9
N	B_1 B_2 P	85 1 1
Outside strata system	B_1 B_2	11 3
Total	B_1+B_2 P	568 10

Table 3.3 gives an account of the sampled length- and age material from bottom hauls and pelagic hauls.

Table 3.3. Number of fish measured for length (L) and age (A) in the Barents Sea winter survey 1994-2019.

	Cod		**Haddock**		**Golden redfish**	**Beaked redfish**	**Greenland halibut**	**Blue whiting**
Year	**L**	**A**	**L**	**A**	**L**	**L**	**L**	**L**
1994	57290	3400	40608	1808	3157	12389	525	
1995	66264	3547	37775	1692	3785	9622	583	
1996	61559	3304	34497	1416	2510	10206	587	
1997	35381	2381	30054	1003	5429	10997	675	
1998	39044	2843	12512	859	1739	9664	649	
1999	22971	2321	12752	926	1266	6677	397	
2000	31543	2871	25881	1426	1161	8739	546	
2001	36789	2998	30921	1657	1173	7323	499	
2002	45399	3730	58464	2057	1143	6660	688	
2003	59573	2857	54838	1883	1102	4654	657	
2004	40851	3175	51705	1874	1438	5507	459	
2005	33582	3216	67921	2060	835	5166	832	
2006	19319	2683	23611	1899	728	3356	962	
2007	16556	2954	26610	2023	798	4544	973	4657
2008	26844	3809	50195	2490	897	8568	1020	1350
2009	22528	3486	40872	2433	455	9205	807	891
2010	30209	4085	35881	2367	429	8564	984	626
2011	26913	3959	29180	2260	286	6885	607	105
2012	17139	3020	33524	1854	574	5721	354	2441
2013	14525	2451	19142	1671	479	6087	263	1091
2014	22624	4501	35940	2586	563	9310	444	1846
2015	25401	3795	18483	2038	395	8933	541	1991
2016	16636	3368	25423	2067	614	8668	425	2396
2017	12402	2851	15689	1955	576	8898	448	4799
2018	42462	5178	43294	3307	1211	11500	548	1443
2019	16217		15967		761	8981	413	886

The coverage of the most northern and most eastern strata differs from year to year. The areas of these strata are therefore calculated according to the coverage each year. Table 3.4 gives the area covered by the survey every year since 1981. In that table “Extrapolated area” reflects the size of areas where some kind of extrapolations/adjustments have been made to take account of incomplete coverage (see also section 2.6). Table 3.5 summarizes the degree of coverage and main reasons for incomplete coverage in the whole period.

Table 3.4. Area (NM^2) covered in the bottom trawl surveys in the Barents Sea winter 1981-2019, 1994-2019 are StoX estimates.

	Main Area									Extra-
Year	**A**	**B**	**C**	**D**	**D'**	**E**	**S**	**N**	**Total excluding N**	**polated area**
1981-92	23299	8372	5348	51116	-	-	-		88135	
1993	23929	8372	5348	51186	23152	8965	16690		137642	
1994	27180	9854	5165	53394	36543	11417	17557		161110	
1995	26797	9854	5165	53394	58605	13304	24783		191904	
1996	26182	9854	5165	53394	54047	5738	11809		166190	
1997[1]	27785	9854	5165	23964	2670	0	18932		88371	56200
1998[1]	27785	9854	5165	23964	5911	3829	23931		100440	51100
1999	27785	9854	5165	43230	8031	5742	18737		118545	
2000	27173	9854	5165	52314	29438	14207	25053		163204	
2001	26609	9854	5165	53394	29694	15777	24157		164652	
2002	26594	9854	5165	53394	21914	15757	24689		157369	
2003	26621	9897	5165	52072	23947	6259	23400		147361	
2004	27785	9854	5165	53394	42731	4739	20760		164428	
2005	27785	9854	5165	53394	39104	19931	24648		179883	
2006[2]	27785	9854	5165	53394	35302	13872	24691		170064	18100
2007[1]	27785	9854	5165	23911	8498	20822	27858		123894	56700
2008	27785	9854	5165	53394	23792	18873	26313		165176	
2009	27785	9854	5165	53394	31978	15739	27858		171774	
2010	27785	9854	5165	53394	17882	18562	27858		160501	
2011	27785	9854	5165	53394	33432	16835	27858		174324	
2012[2]	27785	9854	5165	53394	9917	17289	27858		151263	16700
2013	27785	9854	5165	53394	58183	21118	27858		203358	
2014[3]	27785	9854	5165	53394	54800	29897	27858	58048	208754	
2015[3]	27785	9854	5165	53394	45449	26541	27858	47263	196047	
2016[3]	27785	9854	5165	53526	29266	20342	27630	54387	173568	
2017[2,3]	27785	9854	5165	45493	12223	18524	27858	38786	146903	37460
2018[3]	27785	9854	5165	53394	45193	23095	27630	44186	192117	
2019[3]	27785	9854	5165	53394	56452	26788	27630	34035	207121	

[1]REZ not covered

[2]REZ not completely covered (Strata 7 and 13 in 2006, Area D’ in 2012 and strata 7, 13, 15, 7 and 20 in 2017).

[3] Additional northern areas (N) covered, not included in total and standard survey index calculations.

Table 3.5. Barents Sea winter surveys 1981-2019. Main Areas covered, and comments on incomplete coverage.

Year	Coverage	Comments
1981-1992	ABCD	
1993-1996	ABCDD’ES	
1997	Norwegian EEZ (NEZ), S	Not allowed access to Russian EEZ (REZ)
1998	NEZ, S, minor part of REZ	Not allowed access to most of REZ
1999	ABCDD’ES	Partly limited coverage due to westerly ice extension
2000	ABCDD’ES	Russian participation starts
2001-2005	ABCDD’ES	Russian vessel covered where Norwegians had no access
2006	ABCDD’ES	No Russian vessel, not allowed access to Murman coast
2007	NEZ, S	No Russian vessel, not allowed access to REZ
2008	ABCDD’ES	Russian vessel covered where Norwegians had no access
2009	ABCDD’ES	Reduced Norwegian coverage of REZ due to catch handling
2010	ABCDD’ES	Reduced Norwegian coverage of REZ due to bad weather
2011	ABCDD’ES	Russian vessel covered where Norwegians had no access
2012	ABCDD’ES	No Norwegian coverage of REZ due to vessel problems
2013	ABCDD’ES	No Norwegian coverage of REZ due to vessel shortage
2014	ABCDD’ESN	Strata 24-26 (N) covered for the first time
2015	ABCDD’ESN	Slightly reduced/more open coverage due to bad weather
2016	ABCDD’ESN	No access to REZ, Russian vessel covered most of REZ
2017	ABCDD’ESN	No Russian vessel, not allowed access to southwestern REZ
2018	ABCDD’ESN	Russian vessel covered where Norwegians had no access
2019	ABCDD’ESN	Russian vessel covered where Norwegians had no access

4 Total echo abundance of cod and haddock

Table 4.1 presents the time series of total echo abundance (mean s_A multiplied by strata area and summed over all strata) of cod and haddock in the investigated areas.

Table 4.1. Cod and haddock. Total echo abundance in the Barents Sea winter 1994-2019 (m^2 reflecting surface · 10^{-3}) estimated by StoX. Observations outside main areas A-S are not included.

	StoX		
Year	**Cod**	**Haddock**	**Sum**
1994	5282	3898	9180
1995	3671	2948	6619
1996	2789	1248	4037
1997[1]	1355	832	2187
1998[1]	2254	543	2797
1999	1517	771	2288
2000	2833	1534	4367
2001	2158	1488	3646
2002	1976	2247	4223
2003	3717	3570	7287
2004	1174	2087	3261
2005	1370	2519	3889
2006	1116	2541	3657
2007[1]	675	2311	2986
2008	3510	6195	9705
2009	2452	5300	7752
2010	3526	5939	9465
2011	2967	3715	6682
2012	3478	4182	7660
2013	5026	3604	9656
2014	4847	2915	7762
2015	5245	2161	7406
2016	2879	1587	4466
2017[1]	2139	2588	4732
2018	3537	2851	6388
2019	3282	3039	6321

[1] not scaled for uncovered areas

Since 1993 the acoustic values have been split between the two species during the scrutinizing. The values for cod have showed an increasing trend since the late 2000s, with a peak in 2013-2015. Total echo abundance was 40% lower in 2016 compared to 2015 and decreased further from 2016 to 2017, while there was an increase of more than 50% from 2017 to 2018 and a small decrease in 2019. The values for haddock increased gradually from the end of the 1990s to 2008, decreased gradually to less than one third of the 2008 value in 2016 but increased considerably in 2017 and further in 2018 and 2019.

5 Distribution and abundance of cod

5.1 Acoustic estimation

Surveys in the Barents Sea at this time of the year mainly cover the immature part of the cod stock. Most of the mature cod (age 7 and older) have started on their spawning migration southwards out of the investigated area and are therefore to a lesser extent covered. There are indications that a higher proportion than normal spawned along Finnmark in some of the previous years, e.g. 2004-2006. Thereby a higher proportion of the spawners might have been covered by the survey these years.

Table 5.1 shows the acoustic indices for each age group by main areas in 2019. A rather high proportion of the 1-year olds was found in the extended area (N). The time series (1994-2019) is presented in Table 5.2. The estimates have been variable and increasing in later years, with a peak in biomass in 2013, and this may partly be explained by variable and not complete coverage of the distribution area towards north and east in several years. As cod grow older it gets a more south-westerly distribution during winter, it so to say “grows” into the incomplete survey. This is especially evident for the strong 2004 and 2005 year-classes, which as 6-11-year olds stand out as the strongest in the time series. Of more recent year-classes 2011 seems to be strong. 2014 seemed strong at age 1, while at age 2 it appears rather moderate. Table 5.4 shows indices for strata 24-26 in 2014-2019.

Table 5.4 presents estimated coefficients of variation (CV) for cod age groups 1-15 in 1994-2019. These estimates were obtained by using StoX with a stratified bootstrap routine treating each transect as the primary sampling unit. In addition, a bootstrap routine for all trawl stations by strata was carried out within each run. The estimated CV (Standard Deviation · 100/mean) is estimated from 500 iterations and is strongly dependent on the choice of estimator for the indices. A CV of 20% or less could be viewed as acceptable in a traditional stock assessment approach if the indices are unbiased (conditional on a catchability model). Values above this indicate a highly uncertain index with little information regarding year class strength. In all years, CVs for age groups older than 10 years are above what could be considered as acceptable.

Table 5.1. COD. Abundance indices (numbers in millions) for the main areas of the Barents Sea from acoustic survey winter 2019 estimated by StoX software.

	Age group															
Area	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15+**	**Total**	**Biomass ('000 t)**
A																	
B																	
C																	
D																	
D'																	
E																	
S																	
ABCD																	
AS																	
N																	
Total																	

Table 5.2. COD. Abundance indices (numbers in millions) from acoustic surveys in the Barents Sea standard area winter 1994-2019 estimated by StoX software.

	Age group																Biomass
Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15+	Total	('000 t)
1994	823.5	586.9	307.2	384.4	207.0	68.0	12.1	3.53	2.55	0.81	1.11	0.11	0.12	0	0	2397.4	1053.8
1995	2106.6	217.9	143.0	138.0	198.3	67.0	16.1	2.46	0.90	0.32	0.53	0.16	0	0	0	2891.2	669.3
1996	1748.9	261.1	110.0	89.5	115.0	83.3	23.0	2.20	0.27	0.08	0.05	0.05	0.06	0.01	0	2433.4	509.2
1997[1]	2832.9	842.9	209.2	49.2	51.5	43.1	24.9	5.73	1.00	0.23	0.22	0	0	0.03	0	4060.9	358.6
1998[1]	2633.1	555.8	444.5	210.8	46.6	44.4	28.6	16.90	1.85	0.46	0.16	0	0.02	0	0.07	3983.2	572.9
1999	351.1	227.0	151.6	133.3	51.8	12.0	7.02	3.98	1.54	0.32	0.02	0.01	0.01	0	0	939.6	265.4
2000	142.4	248.1	301.1	168.8	147.1	49.0	12.1	4.48	2.85	0.80	0.18	0.12	0.03	0	0	1077.0	546.7
2001	348.3	50.8	179.0	162.3	81.1	44.0	11.3	1.73	0.47	0.18	0.10	0	0	0	0.01	879.4	436.9
2002	18.4	208.8	62.4	105.5	98.0	53.4	20.2	2.96	0.30	0.53	0.12	0	0	0	0.02	570.6	430.7
2003	1399.7	52.0	307.0	120.6	121.8	118.7	39.1	9.32	1.84	0.33	0.07	0	0.07	0.05	0	2170.5	756.7
2004	147.1	111.2	33.3	85.2	33.5	28.5	18.0	5.35	1.15	0.36	0.06	0.01	+	0	0	463.8	245.5
2005	438.2	123.2	129.8	34.9	69.1	21.2	15.0	4.95	0.95	0.27	0.04	0.06	0.05	0.03	0	837.7	263.5
2006[2]	369.5	158.3	64.4	54.5	18.6	29.7	9.57	4.83	1.22	0.19	0.11	0.22	0	0	0	711.2	226.4
2007[1]	88.9	53.7	63.9	35.7	32.7	9.68	18.8	6.57	2.74	0.51	0.24	0.09	0.04	0	0	313.6	239.2
2008	48.5	91.9	196.1	292.0	116.0	73.7	21.1	14.1	2.62	0.72	0.05	0.02	0.01	0	0	856.8	819.8
2009	195.5	23.2	104.6	191.6	139.7	40.9	14.1	4.70	4.38	0.48	0.13	0.02	0.01	0	0	719.4	543.8
2010	696.1	41.8	21.8	86.9	161.8	153.8	46.2	14.4	3.87	2.86	0.91	0.11	0.14	0.09	0.01	1230.9	890.2
2011	248.5	88.7	39.1	28.7	65.4	106.6	102.4	19.4	6.71	1.49	1.07	0.28	0.13	0.10	0.02	708.5	790.0
2012[3]	508.1	45.3	87.8	47.6	35.1	70.9	135.8	60.3	8.19	5.19	1.26	0.66	0.45	0.01	0.10	1006.7	961.8
2013	293.3	82.4	59.1	85.4	70.6	50.2	100.0	129.9	57.0	5.37	3.98	1.63	0.70	0.21	0.05	939.8	1511.9
2014	582.2	154.2	234.0	115.9	96.0	68.4	37.7	84.7	55.3	24.1	2.46	1.51	0.17	0.04	0.16	1456.8	1336.6
2015	1183.0	107.6	110.2	188.0	119.5	130.2	84.9	33.8	51.7	23.0	6.27	0.57	0.14	0.04	0.01	2038.9	1374.6
2016	106.2	111.5	35.2	61.6	101.2	64.5	49.2	23.1	11.9	16.3	7.37	2.25	0.69	0.25	0.09	591.4	806.1
2017[3,4]	441.3	50.9	95.6	36.6	40.1	61.5	35.2	23.5	10.9	3.71	3.11	3.55	0.63	0.16	0.10	807.0	641.5
2018	1492.0	221.2	93.3	134.0	46.7	51.9	56.1	35.1	10.0	6.65	1.38	2.14	1.55	0.14	0.25	2152.4	817.7
2019	1000.3	287.4	182.1	97.7	124.3	53.4	33.7	31.6	8.7	2.83	0.38	0.33	0.20	0.23	0.16	1823.3	731.2

[1]Indices raised to also represent the Russian EEZ. [2] Not complete coverage in southeast due to restrictions, strata 7 area set to default and strata 13 as in 2005.
[3]Indices raised to also represent uncovered parts of the Russian EEZ. [4]Indices corrected due to typing error

Table 5.3. COD. Abundance indices (numbers in millions) for new strata 24-26 from acoustic surveys in the Barents Sea winter 2014-2019 estimated by StoX software.

	Age group															Biomass ('000 t)
Year	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15+**	**Total**	
2014	1112.5	54.0	54.5	11.7	14.6	7.31	2.26	4.73	2.98	0.27	0.02	0	0	0	0	1264.9	103.4
2015	589.7	88.3	25.2	49.0	12.7	11.2	5.34	1.08	3.40	1.16	0.77	0.05	0	0	0	787.9	122.4
2016	104.9	84.6	18.0	14.6	16.8	2.47	2.94	1.86	0.30	0.67	0.17	0.02	0.01	0	0	247.3	60.2
2017	31.1	28.7	26.5	5.44	5.68	4.13	1.54	0.65	0.24	0.05	0.28	0.04	0	0	0	104.4	40.1
2018	514.2	50.6	16.2	16.7	6.96	4.35	8.64	0.99	0.76	0.25	0.08	0.12	0.01	0	0	619.9	76.1
2019	371.4	75.3	20.9	27.8	20.5	7.98	3.63	5.27	0.42	0.44	0.14	0.04	0.01	0.03	0.05	533.9	112.1

Table 5.4. COD. Estimates of coefficients of variation (%) for acoustic abundance indices. Barents Sea standard area winter 1994-2019.

Year	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**
1994	33	40	29	12	7	10	12	18	20	29	27	73	97	-
1995	14	20	11	9	7	9	11	21	25	31	55	48	-	-
1996	10	15	14	11	11	10	13	15	29	43	61	60	111	117
1997[1]	33	22	13	12	11	9	9	13	25	55	74	-	-	118
1998[1]	24	17	10	8	10	9	8	10	21	44	57	-	97	-
1999	22	23	17	15	10	11	11	13	25	58	114	121	107	-
2000	31	26	17	10	7	10	17	21	22	42	72	68	110	-
2001	13	15	11	9	10	9	13	22	32	35	77	-	-	-
2002	18	16	10	6	7	10	15	17	32	78	72	-	-	-
2003	26	31	15	13	8	8	13	17	20	40	59	-	99	94
2004	17	16	13	10	10	10	9	13	16	45	58	95	125	-
2005	26	50	19	14	14	14	12	20	26	24	62	90	49	91
2006[2]	21	15	13	10	10	11	15	15	23	37	57	68	-	-
2007[1]	32	27	14	13	11	17	19	21	24	29	40	46	94	-
2008	18	24	15	16	13	10	16	14	20	44	75	65	100	-
2009	21	20	26	22	18	17	13	14	19	32	45	71	112	0
2010	36	17	19	25	16	12	11	12	17	22	28	86	74	70
2011	13	27	12	11	11	10	9	15	28	29	35	39	66	86
2012[2]	36	14	53	11	19	19	17	13	19	35	33	55	52	81
2013	12	24	15	9	21	25	21	18	22	41	49	59	75	111
2014	13	10	11	12	12	8	11	13	15	19	33	53	58	95
2015	17	24	16	16	12	20	18	20	24	25	50	64	71	82
2016	21	15	13	12	11	15	15	16	23	23	29	47	58	87
2017[2]	15	21	13	9	10	11	14	11	18	34	43	55	66	108
2018	10	11	8	8	10	11	10	14	16	23	26	36	50	56
2019	9	11	7	8	7	14	13	12	12	20	37	53	52	68

[1]REZ not covered

[2] REZ partly covered

5.2 Swept area estimation

Figures 5.1 - 5.4 show the geographic distribution of bottom trawl catch rates (number of fish per NM^2, for cod size groups < 20 cm, 20-34 cm, 35-49 cm and ≥ 50 cm. As in previous years, a high proportion of the smallest cod (less than 35 cm) were found in the eastern part of the survey area within the Russian EEZ and near the northern borders of the standard strata system (strata 1-23). In 2019 **% of the number of cod < 20 cm found in the standard survey area was found in the extended area. Mehl *et al*. (2013, 2014, 2015, 2016, 2017, 2018) found that since 2009 more of the largest cod had been found in the north-western part of the survey area (main areas S and N), and this trend is confirmed by the 2019 estimates.

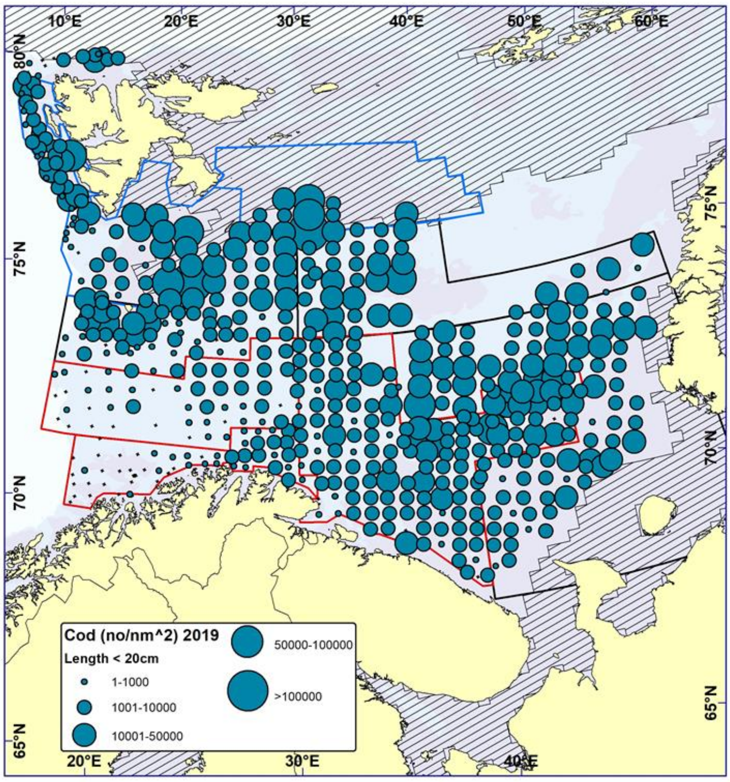


Figure 5.1. COD < 20 cm. Distribution in valid bottom trawl catches winter 2019 (number per nm^2). Black crosses indicate zero catches.

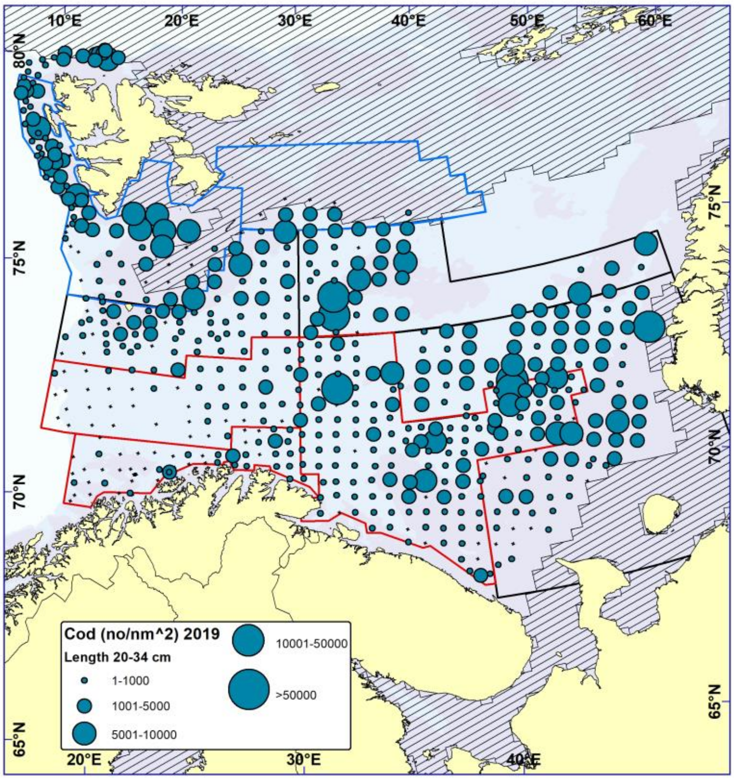


Figure 5.2. COD 20-34 cm. Distribution in valid bottom trawl catches winter 2019 (number per nm^2). Black crosses indicate zero catches.

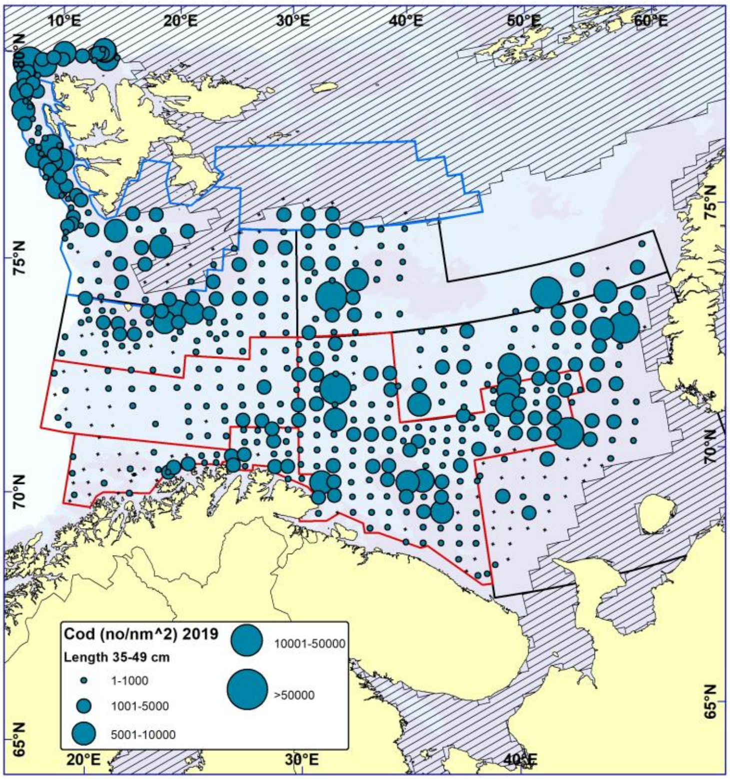


Figure 5.3. COD 35-49 cm. Distribution in valid bottom trawl catches winter 2019 (number per nm^2). Black crosses indicate zero catches.

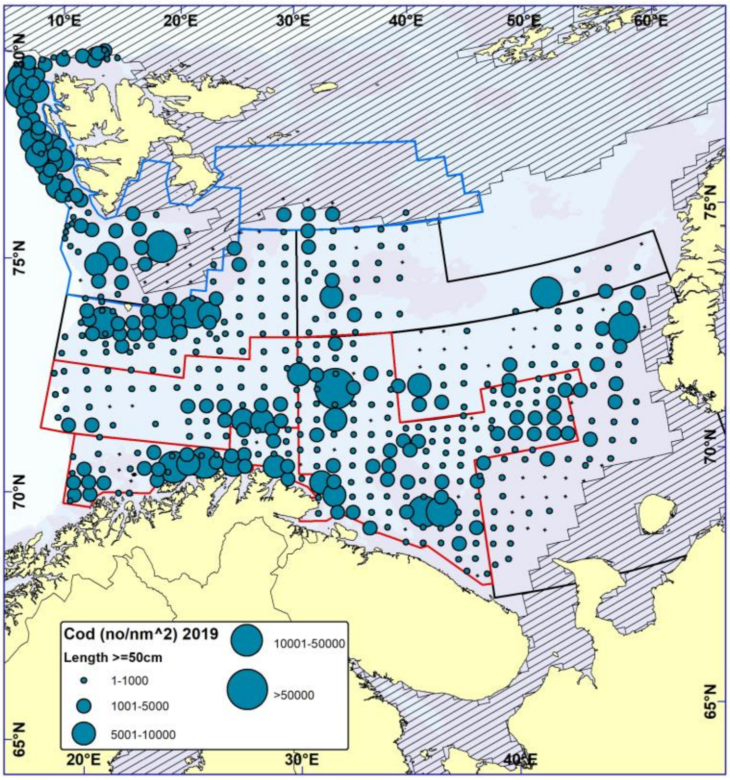


Figure 5.4. COD ≥ 50 cm. Distribution in valid bottom trawl catches winter 2019 (number per nm^2). Black crosses indicate zero catches.

Table 5.5 presents the distribution of the indices by main areas and age and the time series 1994-2019 is shown in Table 5.6. The bottom trawl indices have fluctuated somewhat due to the same reasons as for the acoustic indices, and the 2004 and 2005 year-classes stand out as the strongest in the time series. The 2009, 2011 and 2014 year-classes seemed to be strong as 1-year olds but have later been reduced to average level or below. A considerable amount of cod was found in the extended survey area (Table 5.3), on average over all age groups about **% of the amount found in the standard survey area by numbers and about **% by biomass. Tables 5.7 present swept area abundance indices by age for new strata 24-26 in 2014-2019.

Table 5.8 presents estimated coefficients of variation (CV) for cod age groups 1-15 in 1994-2019. Estimates are based on a stratified bootstrap approach with 500 replicates (with trawl stations being primary sampling unit). A CV of 20% or less could be viewed as acceptable in a traditional stock assessment approach if the indices are unbiased (conditional on a catchability model). Values above this indicate a highly uncertain index with little information regarding year class strength. In all years, CVs for age groups older than 10 years are above what could be considered as acceptable.

Table 5.5. COD. Abundance indices from bottom trawl hauls for main areas of the Barents Sea winter 2019 (numbers in millions).

	Age group															
Area	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15+**	**Total**	**Biomass ('000 t)**
A																	
B																	
C																	
D																	
D'																	
E																	
S																	
ABCD																	
AS																	
N																	
Total																	

Table 5.6. COD. Abundance indices (numbers in millions) from bottom trawl surveys in the Barents Sea standard area winter 1994-2019.

	Age group															Biomass
Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15+	Total	('000 t)
1994	1044.5	545.5	296.8	307.6	152.6	46.8	8.13	2.59	1.32	0.55	0.52	0.11	0.05	0	0	2407.0	760.2
1995	5343.8	540.2	280.4	242.1	252.3	77.1	17.9	2.33	1.13	0.55	0.59	0.19	0	0	0	6758.7	937.5
1996	5908.3	778.6	164.0	116.7	140.7	111.2	24.8	2.79	0.37	0.16	0.08	0.08	0.05	0.02	0	7247.9	725.4
1997[1]	5122.8	1413.7	315.4	69.2	75.0	60.7	26.8	4.95	0.63	0.68	0.46	0.00	0.00	0.00	0.00	7090.2	502.4
1998[1]	2512.1	492.5	355.2	167.4	31.7	26.4	17.5	8.26	0.79	0.52	0.65	0.00	0.35	0.00	0.04	3613.4	405.9
1999	479.7	353.6	189.6	181.9	61.3	12.8	6.83	5.19	0.98	0.27	0.02	0.03	0.02	0	0	1292.2	324.2
2000	128.2	242.8	247.5	130.0	112.0	27.0	4.73	1.82	1.23	0.36	0.10	0.03	0.02	0	0	895.8	364.7
2001	715.8	77.6	182.0	194.5	81.6	38.0	9.58	1.19	0.45	0.19	0.04	0	0	0	0.01	1300.9	433.8
2002	34.2	416.2	118.0	137.7	108.6	46.5	14.5	2.19	0.34	0.19	0.05	0	0	0	0.02	878.5	448.5
2003	3021.4	61.2	380.8	125.4	95.2	66.6	17.9	4.72	1.02	0.16	0.04	0	0.02	0.02	0	3774.3	546.9
2004	321.3	236.3	65.5	186.1	53.6	43.2	30.9	6.92	1.66	0.29	0.08	0.01	0.01	0	0	945.8	417.2
2005	846.8	216.4	244.8	54.8	102.7	22.4	16.4	3.80	0.88	0.30	0.04	0.02	0.03	0.04	0	1509.5	357.9
2006[2]	676.9	283.8	115.6	114.0	28.1	43.3	14.0	5.19	1.34	0.22	0.21	0.08	0	0	0	1282.6	332.2
2007[1]	584.2	369.9	365.8	127.3	68.9	13.7	23.6	6.85	2.20	0.40	0.31	0.08	0.00	0.00	0.00	1563.2	459.2
2008	69.0	103.3	192.5	300.0	115.6	40.8	18.0	8.29	1.86	0.35	0.02	0.02	0.01	0	0	850.0	694.5
2009	389.4	35.5	124.3	196.1	218.0	58.2	17.5	8.44	5.27	0.50	0.18	0.03	0.03	0	0	1053.4	740.3
2010	1031.5	96.5	37.0	114.9	155.5	144.5	39.8	11.2	3.70	1.64	0.57	0.05	0.02	0.03	0.02	1637.0	831.1
2011	615.3	225.6	85.4	50.7	129.9	138.0	103.1	16.7	4.34	1.17	0.79	0.20	0.17	0.04	0.02	1371.4	890.1
2012[3]	728.4	124.8	83.1	70.3	36.4	93.9	136.3	49.6	9.38	2.33	0.87	0.60	0.47	0.02	0.05	1336.6	901.6
2013	439.1	147.2	70.3	119.8	64.0	41.0	65.0	76.2	33.6	2.21	2.83	0.41	0.35	0.06	0.03	1062.0	958.1
2014	499.8	148.8	180.6	85.1	67.9	47.8	32.6	46.9	31.7	9.36	1.01	0.97	0.15	0.04	0.07	1153.0	789.0
2015	1295.0	196.8	125.4	170.2	135.7	99.8	71.2	27.4	52.8	17.0	2.86	0.72	0.10	0.07	0.04	2194.8	1220.0
2016	212.3	232.9	53.4	112.3	151.3	109.0	66.1	26.6	12.8	15.0	6.43	0.96	0.50	0.17	0.14	1000.0	979.3
2017[3]	471.5	71.0	116.1	39.7	48.7	56.6	27.8	18.9	7.63	3.01	2.22	3.49	0.53	0.17	0.06	867.5	540.9
2018	1686.2	394.8	107.6	148.7	46.1	55.7	53.4	23.9	7.48	5.41	1.13	2.24	1.19	0.13	0.39	2534.3	739.9
2019	1291.7	446.0	253.7	132.0	188.6	66.4	27.0	28.8	7.6	1.72	0.34	0.17	0.14	0.13	0.10	2444.3	789.5

[1]Indices raised to also represent the Russian EEZ. [2] Not complete coverage in southeast due to restrictions, strata 7 area set to default and strata 13 as in 2005
[3]Indices raised to also represent uncovered parts of the Russian EEZ.

Table 5.7. COD. Abundance indices (numbers in millions) for new strata 24-26 from bottom trawl surveys in the Barents Sea winter 2014-2019.

	Age group															Biomass ('000 t)
Year	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15+**	**Total**	
2014	748.1	43.0	48.6	10.1	20.4	9.27	1.32	5.43	4.64	0.30	0.03	0	0	0	0	891.1	116.8
2015	348.8	147.0	19.1	56.4	12.4	14.1	5.43	1.59	2.22	1.27	0.41	0.05	0	0	0	608.8	132.5
2016	102.7	77.4	37.6	23.6	37.2	4.30	6.17	2.73	0.50	1.24	0.30	0.02	0.02	0	0	293.7	108.9
2017	181.9	52.4	58.1	20.6	33.4	31.0	9.20	7.25	0.58	0.23	0.33	0.05	0	0	0	395.0	183.6
2018	1024.9	106.2	32.7	34.2	15.8	8.09	19.9	1.82	1.96	0.56	0.15	0.24	0.02	0	0	1246.6	166.7
2019	500.3	115.4	30.1	47.2	33.9	13.6	6.0	9.58	0.53	0.82	0.19	0.07	0.04	0.05	0	757.8	187.5

Table 5.8. COD. Estimates of coefficients of variation (%) for swept area abundance indices. Barents Sea standard area winter 1994-2019.

	Age group														
Year	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**
1994	11	17	13	8	7	8	13	21	23	25	22	67	66	-	-
1995	8	14	11	12	10	10	12	23	33	27	43	39	-	-	-
1996	7	12	19	10	12	10	13	13	25	44	51	42	59	106	-
1997[1]	27	28	16	14	13	10	9	14	21	55	70	-	-	-	-
1998[1]	8	12	15	11	11	10	8	10	17	48	61	-	95	-	68
1999	18	28	17	14	8	10	14	29	22	62	105	94	91	-	-
2000	12	18	13	8	8	9	13	10	14	32	59	61	84	-	-
2001	11	14	17	14	9	10	13	23	25	35	59	-	-	-	-
2002	14	24	25	8	9	12	9	15	25	40	70	93	-	-	-
2003	25	33	26	18	7	7	9	11	15	39	56	65	65	-	-
2004	13	15	17	14	11	12	15	14	16	35	39	100	95	-	-
2005	9	15	26	16	16	14	12	11	17	23	60	66	43	50	-
2006[2]	12	13	14	26	17	12	20	12	17	27	54	76	-	-	-
2007[1]	26	21	15	25	7	9	14	17	19	19	33	49	84	-	-
2008	9	16	17	23	33	10	35	14	26	23	74	83	97	-	-
2009	10	9	18	12	19	14	17	25	22	26	34	62	97	-	-
2010	33	9	11	18	13	11	22	13	24	21	27	64	57	57	97
2011	7	30	11	15	16	11	9	11	26	19	49	38	58	64	99
2012[2]	46	13	65	12	14	19	20	12	24	19	23	31	48	80	92
2013	10	18	16	19	12	10	11	10	18	22	55	35	59	102	99
2014	16	10	12	12	10	10	17	13	10	17	27	34	60	132	80
2015	7	24	9	9	14	13	30	21	42	20	20	34	95	82	87
2016	9	10	9	12	9	20	22	10	14	28	21	31	30	54	57
2017[2]	8	10	8	9	15	10	16	18	13	22	23	27	45	35	97
2018	8	18	9	11	12	14	9	13	16	33	21	40	46	43	44
2019	7	12	9	10	18	20	12	12	12	14	27	45	39	54	84

[1] REZ not covered

[2] REZ partly covered

5.3 Growth and survey mortalities

Tables 5.9 and 5.10 present the time series for mean length (1994-2019) and mean weight (1994-2019) at age for the standard area. There have only been moderate fluctuations, but with a decreasing trend for older fish (8+) in later year. The same pattern is reflected in the annual weight increments (Table 5.11). In 2017 weight and yearly weight increment increased, especially for fish older than six years, and decreased again in 2018. A higher proportion of mature cod in the southwestern area in 2017 may have caused this.

Table 5.12 gives the time series of survey based mortalities (log ratios between survey indices of the same year class in two successive years) since 1994. These mortalities are influenced by natural and fishing mortality, age reading errors, and the catchability and availability (coverage) at age for the survey. In the period 1994-1999 there was an increasing trend in the survey mortalities. The trend appears most consistent for the age groups 3-7 in the swept area estimates. Most later surveys show lower mortalities, but there are some fluctuations for the same reasons as mentioned for the acoustic and swept area indices. Presumably the mortality of the youngest age groups (ages 1-3) is mainly caused by predation, while for the older age groups the fishery mainly causes it. Before 2001 the survey mortalities for age 4 and older were well above the mortalities estimated in the ICES stock assessment. Decreasing survey catchability at increasing age could be one reason for this. Another possible reason could be that the assessment does not include all sources of mortality, like discards, unreported catches, or poorly quantified predation. The low survey mortalities in the most recent years, even with “impossible” negative values, could partly be caused by fish gradually “growing into” the covered area at increasing age. In 2017, the estimated mortalities increased to the same high levels as observed before 2001, while in 2018 estimated mortalities were negative for ages 2-7. The 2017 coverage in area D’ and E was not complete, and the indices were raised (extrapolated) by the “index ratio by age” observed for the same area in 2014-2016. However, in 2018 the coverage was even better than in 2014-2016, and the 2017 indices may have been underestimated compared to 2018.

The observed mortality rates in the acoustic investigations have been more variable, and the rates in 2017 were lower than in 2016 and mainly negative in 2018. This might be caused by changes in fish behaviour and how available the fish is for acoustic registration.

Table 5.9 COD. Length (cm) at age from bottom trawl surveys in the Barents Sea standard area winter 1994-2019. + indicates few samples.

Age/ Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1994	11.3	17.9	30.2	44.6	55.1	65.5	73.8	78.5	87.5	97.9	97.7	100.8	122.1	-
1995	12.2	18.0	28.8	42.1	54.0	63.7	75.7	80.2	83.9	99.1	+	109.0	-	-
1996	12.1	18.9	28.7	40.6	49.3	60.9	71.7	84.8	92.2	92.2	99.5	104.6	108.7	121.0
1997[1]	10.9	15.9	26.8	39.9	49.5	59.2	69.9	81.6	91.8	+	+	-	-	-
1998[1]	9.8	18.0	29.3	40.0	50.9	58.9	67.7	76.7	87.4	+	+	-	+	-
1999	12.0	18.3	29.0	39.9	50.4	59.4	70.4	78.5	88.7	88.4	+	+	+	-
2000	12.9	20.7	28.4	39.7	51.5	61.4	70.5	76.2	84.8	81.8	99.7	+	+	-
2001	11.6	22.6	33.0	41.1	52.2	63.3	70.2	77.7	86.0	96.2	103.8	-	-	-
2002	12.0	19.5	28.6	43.6	52.1	62.0	71.3	79.5	91.0	89.3	102.3	-	-	-
2003	11.4	18.0	28.9	39.4	53.4	61.7	70.6	80.8	89.1	90.6	104.5	-	105.8	111.6
2004	10.6	18.4	31.7	40.6	51.7	61.6	68.6	79.7	90.9	88.5	91.7	+	+	-
2005	11.2	18.3	29.5	43.5	51.1	60.3	71.0	79.6	88.9	96.2	109.4	+	+	+
2006	12.0	19.5	30.9	42.1	53.6	60.2	66.4	76.5	84.5	98.8	93.2	96.3	-	-
2007[1]	13.1	21.0	29.4	40.2	53.1	62.9	68.7	76.6	87.6	94.9	102.4	+	-	-
2008	12.1	22.4	33.1	43.2	51.7	64.1	69.0	81.3	88.4	94.6	108.9	+	+	-
2009	11.2	21.2	32.1	42.6	53.1	61.7	76.5	81.8	89.3	97.9	99.9	+	+	-
2010	11.2	18.2	31.5	42.7	52.4	60.7	70.6	80.4	88.5	96.2	102.7	+	+	+
2011	11.9	19.4	29.5	41.9	51.0	60.7	68.1	78.3	85.9	95.2	101.3	111.1	111.7	119.0
2012	10.6	18.4	29.7	41.0	52.4	58.0	66.5	75.7	86.0	91.4	106.2	113.4	119.7	+
2013	11.2	19.2	31.0	41.0	51.6	62.1	69.7	76.5	81.1	95.2	92.2	110.7	110.7	+
2014	9.8	17.3	29.1	40.1	51.8	59.5	70.3	77.0	81.9	87.1	96.7	98.1	110.5	+
2015	10.5	16.2	30.0	39.9	51.2	60.5	69.0	77.6	80.1	88.9	95.4	101.4	+	+
2016	12.2	18.5	29.9	40.6	50.0	60.6	68.3	76.7	85.6	86.0	90.0	92.6	111.8	122.2
2017	12.4	21.8	31.4	42.3	51.9	60.8	69.7	79.5	85.9	90.6	96.3	91.9	106.9	108.7
2018	11.2	18.6	31.9	42.2	51.1	61.5	68.9	77.6	83.7	87.9	97.0	98.8	100.1	105.8
2019	11.8	17.2	31.1	41.6	50.8	59.6	69.6	77.0	83.6	89.6	100.1	102.1	107.3	104.5

[1)] Adjusted lengths, REZ not covered

Table 5.10. COD. Weight (g) at age from bottom trawl surveys in the Barents Sea standard area winter 1994-2019. + indicates few samples.

Age/ Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1994	12	55	260	796	1463	2372	3477	4624	6782	8420	8530	13516	20786	-
1995	15	53	239	656	1341	2194	3628	4577	5315	8907	+	12176	-	-
1996	15	62	232	632	1079	1979	3327	5479	7655	8192	9760	13013	13614	14650
1997[1]	13	46	181	592	1097	1785	2917	4928	7290	+	+	-	-	-
1998[1]	8	50	256	608	1184	1749	2601	4040	6383	+	+	-	+	-
1999	14	58	231	588	1178	1827	2994	4123	6343	7326	+	+	+	-
2000	16	74	210	558	1210	1961	3042	3842	5384	5727	9960	+	+	-
2001	14	106	336	642	1288	2233	3090	4332	5727	8571	11022	-	-	-
2002	14	67	233	747	1225	2065	3189	4577	7472	6431	11645	-	-	-
2003	13	59	229	586	1313	2013	2982	4725	6511	7552	12467	-	12885	16112
2004	10	59	276	607	1142	1946	2618	4139	6684	6988	7957	+	+	-
2005	13	61	245	724	1145	1857	2953	4224	6418	8607	12488	+	+	+
2006	13	69	280	663	1413	1965	2599	4244	5783	10131	8620	10735	-	-
2007[1]	17	71	226	638	1370	2270	2918	4254	6556	8727	11130	+	-	-
2008	15	90	336	799	1410	2449	3144	5218	6793	9494	12918	+	+	-
2009	13	84	294	704	1293	2030	4061	5082	6884	9504	9614	+	+	-
2010	11	64	307	702	1297	2031	3165	4736	6501	9016	10417	+	+	+
2011	15	65	247	667	1129	1940	2725	4003	5914	8233	9888	13213	13814	+
2012	13	62	251	609	1278	1673	2480	3772	5923	7783	12298	14876	17868	+
2013	11	65	264	591	1201	2064	2804	3839	4814	8433	8759	15101	14729	+
2014	8	49	238	592	1234	1776	2849	3942	4946	6181	8368	9212	12578	+
2015	10	47	242	574	1250	1971	2760	4077	4621	6901	8096	11366	+	+
2016	13	54	239	602	1063	1952	2701	3855	5553	6034	6963	8061	15330	21950
2017	16	92	287	739	1253	2017	3092	4645	6088	7403	9186	8413	12416	14916
2018	12	66	305	687	1237	2074	2867	4180	5536	6793	9222	10497	11164	12268
2019	12	46	272	652	1157	1883	2916	3994	5303	6926	10034	11535	13243	11926

1) Adjusted weights, REZ not covered

Table 5.11. COD. Yearly weight increment (g) from bottom trawl surveys in the Barents Sea standard area winter 1994-2019.

Year\Age	1-2	2-3	3-4	4-5	5-6	6-7	7-8	8-9	9-10
1994-95	41	184	396	545	731	1256	1100	691	2125
1995-96	47	179	393	423	638	1133	1851	3078	2877
1996-97	31	119	360	465	706	938	1601	1811	-
1997-98	37	210	427	592	652	816	1123	1455	-
1998-99	50	181	332	570	643	1245	1522	2303	943
1999-00	60	152	327	622	783	1215	848	1261	-616
2000-01	90	262	432	730	1023	1129	1290	1885	3187
2001-02	53	127	411	583	777	956	1487	3140	704
2002-03	45	162	353	566	788	917	1536	1934	80
2003-04	46	217	378	556	633	605	1157	1959	477
2004-05	51	186	448	538	715	1007	1606	2279	1923
2005-06	56	219	418	689	820	742	1291	1559	3713
2006-07	58	157	358	707	857	953	1655	2312	2944
2007-08	73	265	573	772	1079	874	2300	2539	2938
2008-09	69	204	368	494	620	1612	1938	1666	2711
2009-10	51	223	408	593	738	1135	675	1419	2132
2010-11	54	183	360	427	643	694	838	1178	1732
2011-12	47	186	362	611	544	540	1047	1920	1869
2012-13	52	202	340	592	786	1131	1359	1042	2510
2013-14	38	173	328	643	575	785	1138	1107	1367
2014-15	39	193	336	658	737	984	1228	679	1955
2015-16	44	192	360	489	702	730	1095	1476	1413
2016-17	79	233	500	651	954	1140	1944	2233	1850
2017-18	50	213	400	498	821	850	1088	891	705
2018-19	34	206	347	470	646	842	1127	1123	1390

Table 5.12. COD. Survey mortality from surveys in the Barents Sea standard area winter 1994-2019.

	Age							
Year	**1-2**	**2-3**	**3-4**	**4-5**	**5-6**	**6-7**	**7-8**	**8-9**
	Acoustic investigations							
1994-95	1.33	1.41	0.80	0.66	1.13	1.44	1.59	1.37
1995-96	2.09	0.68	0.47	0.18	0.87	1.07	1.99	2.21
1996-97	0.73	0.22	0.80	0.55	0.98	1.21	1.39	0.79
1997-98	1.63	0.64	-0.01	0.05	0.15	0.41	0.39	1.13
1998-99	2.45	1.30	1.20	1.40	1.36	1.84	1.97	2.40
1999-00	0.35	-0.28	-0.11	-0.10	0.06	-0.01	0.45	0.33
2000-01	1.03	0.33	0.62	0.73	1.21	1.47	1.95	2.25
2001-02	0.51	-0.21	0.53	0.50	0.42	0.78	1.34	1.75
2002-03	-1.04	-0.39	-0.66	-0.14	-0.19	0.31	0.77	0.48
2003-04	2.53	0.45	1.28	1.28	1.45	1.89	1.99	2.09
2004-05	0.18	-0.15	-0.05	0.21	0.46	0.64	1.29	1.73
2005-06	1.02	0.65	0.87	0.63	0.84	0.80	1.13	1.40
2006-07	1.93	0.91	0.59	0.51	0.65	0.46	0.38	0.57
2007-08	-0.03	-1.30	-1.52	-1.18	-0.81	-0.78	0.29	0.92
2008-09	0.74	-0.13	0.02	0.74	1.04	1.65	1.50	1.17
2009-10	1.54	0.06	0.19	0.17	-0.10	-0.12	-0.02	0.19
2010-11	2.06	0.07	-0.27	0.28	0.42	0.41	0.87	0.76
2011-12	1.70	0.01	-0.20	-0.20	-0.08	-0.24	0.53	0.86
2012-13	1.82	-0.27	0.03	-0.39	-0.36	-0.34	0.04	0.06
2013-14	0.64	-1.04	-0.67	-0.12	0.03	0.29	0.17	0.85
2014-15	1.69	0.34	0.22	-0.03	-0.30	-0.22	0.11	0.49
2015-16	2.36	1.12	0.58	0.62	0.62	0.97	1.30	1.04
2016-17	0.74	0.15	-0.04	0.43	0.50	0.61	0.74	0.75
2017-18	0.69	-0.61	-0.34	-0.24	-0.26	0.09	0.00	0.85
2018-19	1.64	0.19	-0.05	0.08	-0.13	0.43	0.57	0.13
	Bottom trawl investigations							
1994-95	0.66	0.67	0.20	0.20	0.68	0.96	1.25	0.83
1995-96	1.93	1.19	0.88	0.54	0.82	1.13	1.86	1.84
1996-97	1.43	0.90	0.86	0.44	0.84	1.42	1.61	1.49
1997-98	2.34	1.38	0.63	0.78	1.04	1.24	1.18	1.84
1998-99	1.96	0.95	0.67	1.00	0.91	1.35	1.22	2.13
1999-00	0.68	0.36	0.38	0.48	0.82	1.00	1.32	1.44
2000-01	0.50	0.29	0.24	0.47	1.08	1.04	1.38	1.40
2001-02	0.54	-0.42	0.28	0.58	0.56	0.96	1.48	1.25
2002-03	-0.58	0.09	-0.06	0.37	0.49	0.95	1.12	0.76
2003-04	2.55	-0.07	0.72	0.85	0.79	0.77	0.95	1.04
2004-05	0.40	-0.04	0.18	0.59	0.87	0.97	2.10	2.06
2005-06	1.09	0.63	0.76	0.67	0.86	0.47	1.15	1.04
2006-07	0.60	-0.25	-0.10	0.50	0.72	0.61	0.71	0.86
2007-08	1.73	0.65	0.20	0.10	0.52	-0.27	1.05	1.30
2008-09	0.66	-0.19	-0.02	0.32	0.69	0.85	0.76	0.45
2009-10	1.40	-0.04	0.08	0.23	0.41	0.38	0.45	0.82
2010-11	1.52	0.12	-0.32	-0.12	0.12	0.34	0.87	0.95
2011-12	1.60	-0.14	0.19	0.33	0.32	0.01	0.73	0.58
2012-13	1.60	0.57	-0.37	0.09	-0.12	0.37	0.58	0.39
2013-14	1.08	-0.20	-0.19	0.57	0.29	0.23	0.33	0.88
2014-15	0.93	0.17	0.06	-0.47	-0.39	-0.40	0.17	-0.12
2015-16	1.72	1.30	0.11	0.12	0.22	0.41	0.98	0.76
2016-17	1.09	0.70	0.30	0.84	0.98	1.37	1.25	1.25
2017-18	0.18	-0.42	-0.25	-0.15	-0.13	0.06	0.15	0.93
2018-19	1.33	0.44	-0.20	-0.24	-0.36	0.72	0.62	1.15

6 Distribution and abundance of haddock

6.1 Acoustic estimation

Like for cod it is expected that the survey best covers the immature part of the stock. This time of the year a large proportion of the mature haddock (age 6 and older) are on its spawning migration south-westwards out of the investigated area. In some earlier years, e.g. 2004 and 2005, concentrations of mature haddock have been observed pelagically rather far above bottom along the shelf edge. The bottom trawl sampling poorly covers these concentrations. There are indications that the distribution of age groups 1 and 2 in some years are concentrated in coastal areas not well covered by the survey. This occurred in the late 1990s and will have strongest effect on poor year-classes. In the later surveys, small haddock have been widely distributed, and the strong year-classes have been found unusually far to the north. Favourably hydrographic conditions and/or density dependent mechanisms might cause this. However, it is difficult to separate the two factors. Table 6.1 shows the acoustic abundance indices by age within the main areas. As in most of the previous years the highest abundance was observed in main area D. The time series (1994-2019) are presented in Table 6.2. The strong 2004-2006 year-classes can be followed through the time series. In later years, the 2009, 2011, and 2013-2017 year-classes seem to be fairly strong.

Table 6.3 shows indices for strata 24-26 in 2014-2019. The contribution from main area N was rather low in all years, except from age 1 in 2018, when 41% of the number of haddock < 20 cm found in the standard survey area was found in the extended area.

Table 6.4 presents estimated coefficients of variation (CV) for haddock age groups 1-14 in 1994-2019. These estimates were obtained by using StoX with a stratified bootstrap routine treating each transect as the primary sampling unit. In addition, a bootstrap routine for all trawl stations by strata was carried out within each run. The estimated CV (Standard Deviation · 100/mean) is estimated from 500 iterations and is strongly dependent on the choice of estimator for the indices. A CV of 20% or less could be viewed as acceptable in a traditional stock assessment approach if the indices are unbiased (conditional on a catchability model). Values above this indicate a highly uncertain index with little information regarding year class strength. In most years, CVs for age groups older than 7 years are above what could be considered as acceptable.

Table 6.1. HADDOCK. Abundance indices (numbers in millions) for the main areas of the Barents Sea from acoustic survey winter 2019 estimated by StoX software.

	Age group																
Area	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15+**	**Total**	**Biomass ('000 t)**
A																	
B																	
C																	
D																	
D'																	
E																	
S																	
ABCD																	
AS																	
N																	
Total																	

Table 6.2. HADDOCK. Abundance indices (numbers in millions) from acoustic surveys in the Barents Sea standard area winter 1994-2019 estimated by StoX software.

	Age group															Biomass
Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15+	Total	('000 t)
1994	887.8	188.0	348.7	626.6	121.4	8.55	0.70	0.33	0.61	0.48	1.46	0.16	0	0	0	2184.8	643.5
1995	1198.2	88.6	41.5	121.5	395.4	47.6	2.80	0.05	0.12	0.03	0.00	0.54	0.14	0	0	1896.4	508.8
1996	132.6	94.5	30.0	22.1	68.7	143.7	5.67	0.94	0	0.01	0	0.02	0.04	0	0.0	498.2	248.3
1997[1]	508.9	26.5	57.3	22.2	15.5	56.1	62.8	4.68	0.07	0	0	0.01	0.05	0.06	0	754.1	217.2
1998[1]	211.0	151.0	33.8	58.8	24.2	7.70	14.1	20.7	1.44	0.02	0.04	0	0	0	0.12	522.8	152.1
1999	653.4	30.1	83.7	21.6	22.1	6.17	1.55	3.88	2.72	0.03	0	0.02	0	0	0	825.3	107.9
2000	1063.0	404.8	36.4	75.5	14.0	12.6	1.57	0.53	2.01	0.69	0.17	0.13	0.02	0	0	1611.5	189.8
2001	753.0	266.1	233.5	40.2	41.4	2.20	1.61	0.16	0.09	0.14	0.28	0.09	0.09	0	0.02	1338.8	206.5
2002	1315.2	267.9	255.2	201.8	18.5	11.7	1.59	0.29	0.03	0.13	0.26	0.09	0.05	0	0	2072.7	298.2
2003	2743.7	362.3	203.7	184.6	136.0	12.3	6.01	0.26	0.14	0.26	0.34	0.09	0.07	0	0	3649.8	444.5
2004	529.0	466.5	151.0	101.8	107.8	57.7	7.62	1.15	0.29	0.04	0.05	0.05	0.04	0.08	0	1423.2	323.0
2005	2276.5	144.0	221.3	115.7	57.4	56.7	12.7	0.38	0.32	0.01	0	0	0	0	0	2885.0	306.0
2006[2]	2091.1	624.8	56.3	123.8	47.4	19.3	13.6	3.23	0.08	0.15	0	0.03	0	0	0.09	2979.9	297.9
2007[1]	2015.7	953.5	209.3	46.1	80.6	28.9	10.00	5.05	2.26	0.30	0.18	0.00	0.00	0.00	0.05	3352.0	406.0
2008	778.4	1753.5	812.4	303.0	90.0	74.1	7.41	12.8	1.63	0.14	0.16	0.18	0	0	0	3833.8	920.4
2009	443.9	209.1	883.7	630.0	266.6	38.9	14.6	1.26	0.34	0.66	0.66	0	0.05	0	0	2489.0	865.4
2010	1559.4	86.0	128.1	631.0	604.0	167.0	12.1	2.94	0.96	0.99	0.10	0.06	0	0	0	3192.6	1035.9
2011	428.5	288.3	54.2	84.2	313.0	292.2	54.9	1.72	0.96	0.23	0	0.21	0.07	0	0	1518.4	712.1
2012[3]	1583.4	94.5	191.6	48.8	88.1	310.6	172.5	30.1	0.52	0.34	0.02	0.13	0	0	0	2520.8	814.6
2013	292.7	407.2	67.3	146.8	35.4	53.0	223.8	102.7	14.1	0.25	0	0	0	0	0	1343.2	759.6
2014	1703.7	109.0	324.5	38.2	107.9	22.4	33.8	84.5	35.3	1.46	0.50	0	0	0.01	0	2461.4	566.4
2015	1521.9	224.4	23.6	171.5	25.5	39.4	8.32	21.1	17.3	6.83	0.42	0.15	0	0	0	2060.5	339.5
2016	1260.3	105.4	68.5	11.8	56.0	11.8	16.6	6.86	15.5	11.9	2.43	0.48	0	0.03	0.02	1567.5	258.3
2017[3]	3263.8	323.2	79.9	62.8	4.4	32.2	5.84	7.01	1.50	6.43	5.48	2.01	0.44	0	0	3795.1	308.6
2018	2074.8	759.2	158.7	60.3	60.7	5.73	12.8	2.30	2.22	1.28	5.00	2.56	1.42	0.15	0	3147.1	355.8
2019	1472.7	663.5	490.6	142.0	29.7	21.2	4.45	3.38	0.97	1.49	0.42	0.46	0.33	0.20	0.08	2832.2	379.5

[1]Indices raised to also represent the Russian EEZ. [2] Not complete coverage in southeast due to restrictions, strata 7 area set to default and strata 13 as in 2005
[3]Indices raised to also represent uncovered parts of the Russian EEZ.

Table 6.3. HADDOCK. Abundance indices (numbers in millions) for new strata 24-26 from acoustic surveys in the Barents Sea winter 2014-2019 estimated by StoX software.

	Age group																Biomass ('000 t)
Year	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15+**	**Total**	
2014	135.0	0.88	10.3	0.92	0.81	0.80	0.96	1.84	1.31	0.20	0.02	0	0	0	0	153.0	17.9
2015	71.2	22.2	0.71	17.9	1.10	6.77	0.90	1.31	4.01	3.03	0.14	0	0.09	0	0	129.4	48.2
2016	15.7	1.77	3.32	0.26	3.67	0.70	0.71	0.62	1.75	0.83	0.33	0	0	0	0	29.7	16.1
2017	80.1	8.20	1.23	2.28	0.40	2.60	0.40	0.92	0.29	0.64	0.61	0.33	0	0	0	98.0	18.1
2018	855.7	46.4	11.7	2.57	3.48	1.15	2.97	0.45	0.33	0.25	0.54	0.39	0.38	0	0	926.4	54.6
2019	67.5	25.5	16.2	6.1	1.2	1.00	0.14	0.12	0.06	0.06	0.04	0.08	0.03	0.03	0.01	118.1	17.9

Table 6.4. HADDOCK. Estimates of coefficients of variation (%) for acoustic abundance indices. Barents Sea standard area winter 1994-2019.

	Age group													
Year	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**
1994	11	12	10	9	12	21	44	53	39	55	31	103	-	-
1995	16	22	24	15	10	15	34	128	85	114	-	55	90	-
1996	20	27	31	23	16	15	22	44	-	120	-	98	108	-
1997[1]	12	17	14	16	16	12	14	33	53	-	-	121	63	74
1998[1]	14	15	15	13	14	21	17	15	50	107	109	-	-	-
1999	19	24	21	28	22	23	32	34	26	118	-	123	-	-
2000	9	9	21	12	18	17	28	45	30	39	72	102	104	-
2001	17	16	16	25	16	30	35	65	66	96	62	94	86	-
2002	8	10	12	10	16	16	29	51	111	69	60	53	71	-
2003	11	11	11	9	15	25	38	80	106	90	76	102	107	-
2004	37	23	23	30	33	17	21	26	45	65	65	86	64	66
2005	10	16	11	15	12	16	19	59	76	104	-	-	-	-
2006[2]	12	10	27	20	12	15	20	33	66	67	-	78	-	-
2007[1]	9	7	9	12	12	15	21	29	40	52	88	-	-	-
2008	13	10	10	10	21	24	29	62	94	263	84	137	-	-
2009	14	13	9	11	14	19	19	43	79	48	-	107	-	-
2010	15	17	10	10	9	13	27	34	49	49	108	92	-	-
2011	15	13	16	12	11	10	15	40	58	94	-	84	115	-
2012[2]	16	28	16	35	24	20	20	27	86	50	105	68	-	-
2013	14	13	22	11	22	16	13	15	26	59	-	-	-	-
2014	13	19	12	20	18	17	16	15	15	44	79	-	-	109
2015	14	17	24	13	23	21	27	23	20	55	64	65	-	-
2016	11	15	15	19	12	14	15	19	17	15	30	43	-	70
2017[2]	6	9	15	13	22	16	22	23	34	29	24	36	67	-
2018	8	8	9	13	17	29	22	29	34	30	27	28	54	81
2019	9	8	9	11	16	15	29	31	44	30	63	56	77	114

[1] REZ not covered
[2] REZ partly covered

6.2 Swept area estimation

Figures 6.1 - 6.4 show the geographic distribution of bottom trawl catch rates (number of fish per NM^2) for haddock size groups < 20 cm, 20-34 cm, 35-49 cm and ≥ 50 cm. Like in previous years (Mehl *et al*. 2013, 2014, 2015, 2016, 2017, 2018), the distribution extends further to the north and to the east than what was usual in the 1990s. To a certain degree, one can follow the high densities through the size groups, especially the northern and eastern distributions.

Table 6.5 presents the indices for each age group by main areas. The time series (1994-2019) are shown in Table 6.6. As with the acoustic indices, the strong 2004-2006 year-classes dominates bottom trawl indices. Overall, this survey tracks both strong and poor year-classes fairly well. In later years, the 2009, 2011 and 2013-2017 year-classes are stronger than the 2007, 2008, 2010 and 2012 year-classes. Compared to cod a lower proportion of haddock was found in the extended survey area (Table 6.7). This difference is most pronounced for the young ages. The extended area represents about **% of the numbers in the standard area and about **% of the biomass.

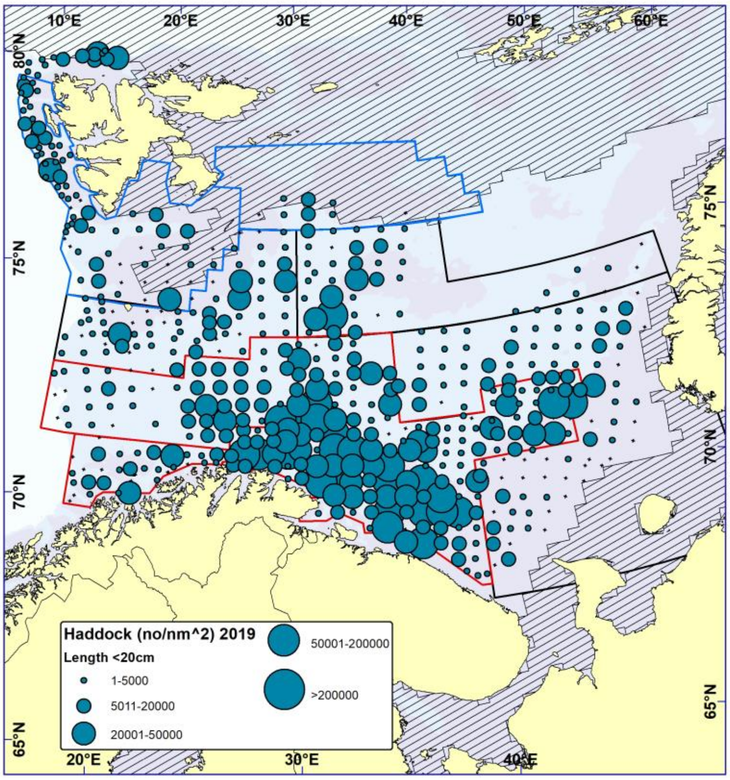


Figure 6.1. HADDOCK < 20 cm. Distribution in valid bottom trawl catches winter 2019 (number per nm^2). Black crosses indicate zero catches.

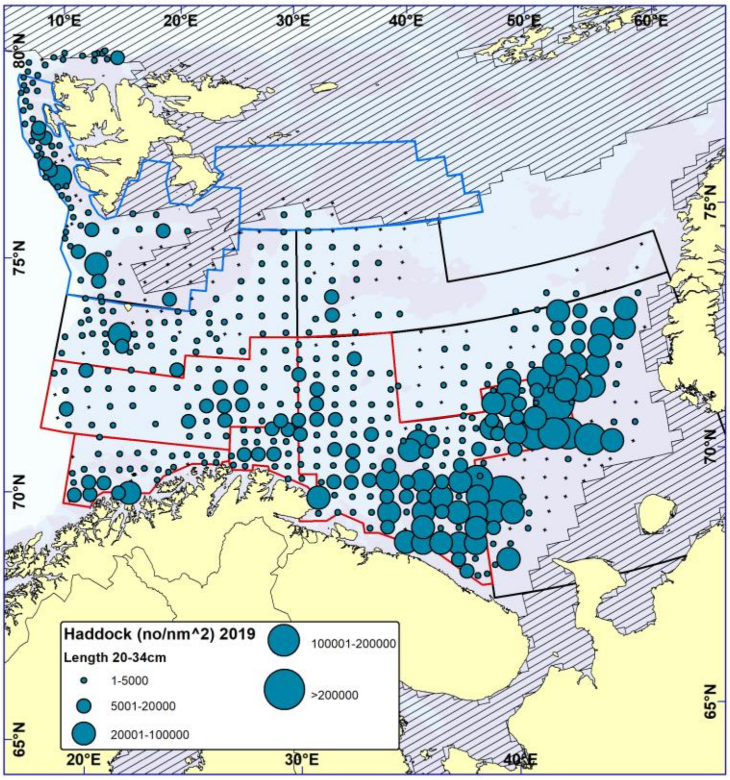


Figure 6.2. HADDOCK 20-34 cm. Distribution in valid bottom trawl catches winter 2019 (number per nm^2). Black crosses indicate zero catches.

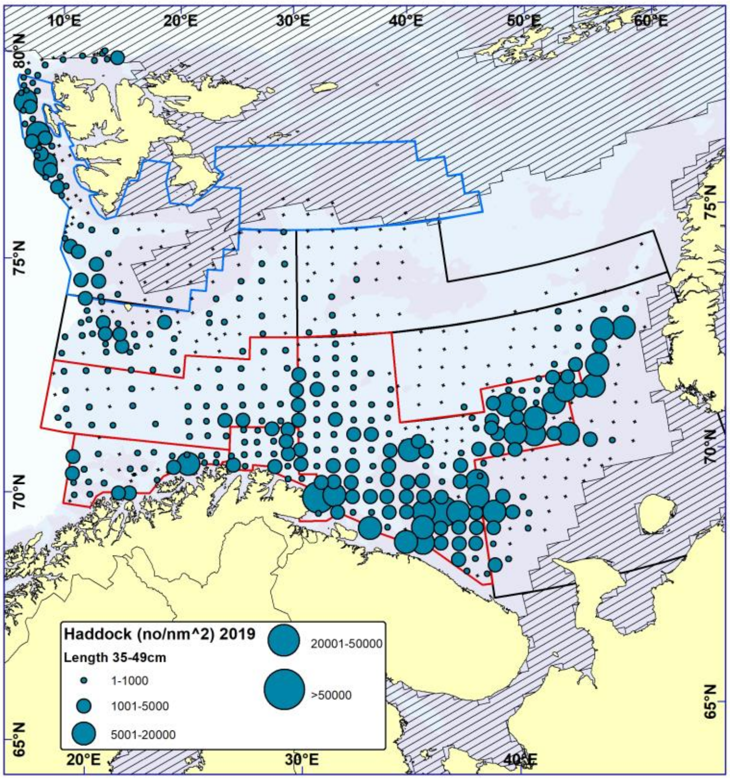


Figure 6.3. HADDOCK 35-49 cm. Distribution in valid bottom trawl catches winter 2019 (number per nm^2). Black crosses indicate zero catches.

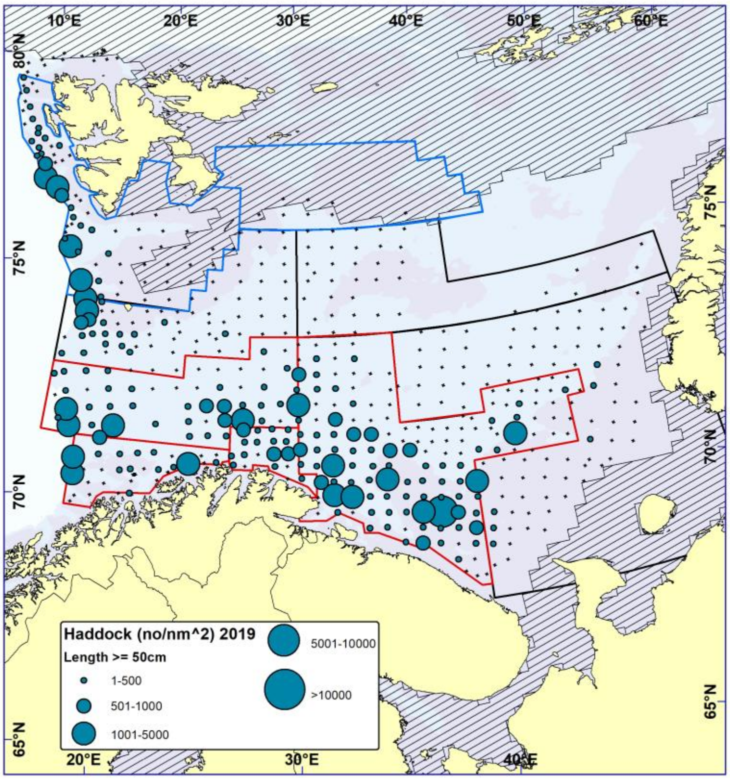


Figure 6.4. HADDOCK ≥ 50 cm. Distribution in valid bottom trawl catches winter 2019 (number per nm^2). Black crosses indicate zero catches.

Table 6.8 presents estimated coefficients of variation (CV) for haddock age groups 1-14 in 1994-2019. Estimates are based on a stratified bootstrap approach with 500 replicates (with trawl stations being primary sampling unit). A CV of 20% or less could be viewed as acceptable in a traditional stock assessment approach if the indices are unbiased (conditional on a catchability model). Values above this indicate a highly uncertain index with little information regarding year class strength. In most years, CVs for age groups older than 7 years are above what could be considered as acceptable.

Table 6.5. HADDOCK. Abundance indices from bottom trawl hauls for main areas of the Barents Sea winter 2019 (numbers in millions).

	Age group																
Area	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15+**	**Total**	**Biomass ('000 t)**
A																	
B																	
C																	
D																	
D'																	
E																	
S																	
ABCD																	
AS																	
N																	
Total																	

Table 6.6. HADDOCK. Abundance indices (numbers in millions) from bottom trawl surveys in the Barents Sea standard area winter 1994-2019.

	Age group																
Year	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15+**	**Total**	**Biomass ('000 t)**
1994	593.5	220.9	315.2	427.9	48.3	3.39	0.14	0.17	0.16	0.14	0.45	0.04	0	0	0	1610.4	402.5
1995	1392.8	182.1	57.6	163.0	338.4	28.8	1.87	0.03	0.04	0.04	0	0.25	0.11	0	0	2165.1	435.7
1996	295.5	245.0	55.5	32.5	161.0	250.9	18.3	1.11	0	0.01	0	0.03	0.03	0	0	1059.9	453.3
1997[1]	1068.7	93.5	80.9	39.6	18.2	61.4	87.3	3.22	0.08	0	0	0	0.03	0.02	0	1452.8	284.5
1998[1]	239.2	196.0	21.2	36.1	12.8	3.24	8.15	5.94	0.56	0.03	0.02	0	0	0	0.05	523.3	85.2
1999	1186.4	79.8	57.1	15.6	9.36	2.87	0.86	1.30	0.74	0.01	0	0.02	0	0	0	1354.2	85.5
2000	817.0	429.8	24.1	35.8	6.91	4.05	0.65	0.01	0.81	0.24	0.03	0.03	0.01	0	0	1319.5	123.3
2001	1215.5	450.0	291.8	26.1	22.7	1.73	0.78	0.06	0.06	0.05	0.16	0.10	0.02	0	0.01	2009.1	226.6
2002	1652.1	464.5	313.8	186.8	11.9	8.43	0.86	0.19	0	0.10	0.15	0.04	0.04	0	0	2638.9	307.0
2003	3254.4	481.3	337.8	175.1	72.3	5.04	1.73	0.12	0.09	0.09	0.09	0.01	0.01	0	0	4328.1	408.3
2004	705.1	707.3	174.9	99.3	77.7	50.9	7.37	0.89	0.13	0.04	0.05	0.04	0.04	0.07	0	1824.2	307.5
2005	4400.9	369.6	315.7	140.1	50.9	61.7	10.2	0.25	0.08	0.01	0	0	0	0	0	5349.5	427.1
2006[2]	4879.2	1296.8	78.8	129.8	45.5	22.6	15.9	3.20	0.09	0.14	0	0.04	0	0	0.07	6470.4	449.1
2007[1]	3654.3	1679.9	459.1	81.0	84.8	26.1	5.38	2.23	1.35	0.77	0.07	0	0	0	0.03	5995.0	677.3
2008	831.1	2072.2	1578.8	581.3	52.9	54.0	7.05	10.6	0.16	0.04	0.08	0.05	0	0	0	5189.1	1099.2
2009	550.0	329.1	1237.3	760.1	372.3	25.8	12.3	0.85	0.09	0.34	0	0.01	0	0	0	3288.1	986.5
2010	1586.4	81.4	96.1	492.8	454.6	149.4	7.80	0.99	0.35	0.42	0.03	0.02	0	0	0	2870.5	760.6
2011	670.9	354.4	52.6	125.7	472.5	293.6	66.3	1.45	1.11	0	0	0.14	0.03	0	0	2038.6	834.4
2012[3]	1844.8	137.3	321.6	29.1	76.1	270.9	156.4	24.5	2.64	0.31	0.04	0.07	0	0	0	2863.7	747.2
2013	335.7	480.2	55.5	146.0	20.9	34.2	193.8	68.6	6.00	0.08	0	0	0	0	0	1340.9	602.3
2014	1129.0	119.8	370.6	30.3	100.4	21.9	46.5	95.2	40.0	1.52	0.46	0	0	0.02	0	1955.7	631.3
2015	1071.7	315.2	30.2	176.7	44.1	35.6	13.6	18.3	27.7	7.76	0.28	0.13	0	0	0	1741.2	373.2
2016	2202.8	509.2	152.7	32.9	105.8	19.6	40.0	10.3	27.5	24.7	4.04	0.92	0	0.14	0.06	3130.8	518.8
2017[3]	4676.6	734.6	127.5	95.8	4.32	45.1	8.72	13.0	1.20	8.02	5.94	3.18	0.72	0	0	5742.8	485.2
2018	2690.3	1608.3	321.2	84.0	61.0	5.57	11.9	2.75	2.01	1.33	3.95	3.46	0.82	0.13	0.0	4796.8	497.6
2019	1791.0	1076.2	1038.3	179.7	45.9	15.8	3.78	2.79	0.69	0.97	0.14	0.29	0.17	0.01	0.03	4155.8	567.4

[1]Indices raised to also represent the Russian EEZ. [2] Not complete coverage in southeast due to restrictions, strata 7 area set to default and strata 13 as in 2005
[3]Indices raised to also represent uncovered parts of the Russian EEZ.

Table 6.7. HADDOCK. Abundance indices (numbers in millions) for new strata 24-26 from bottom trawl surveys in the Barents Sea winter 2014-2019.

	Age group																Biomass ('000 t)
Year	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15+**	**Total**	
2014	125.6	1.21	12.4	0.68	2.22	0.12	3.38	1.16	0.75	0.07	0.03	0	0	0	0	147.6	20.8
2015	48.0	17.4	0.32	13.1	0.46	4.30	0.88	0.56	3.51	2.16	0.05	0	0.02	0	0	90.8	34.4
2016	41.4	4.51	10.1	0.52	9.68	2.45	1.36	2.41	4.87	3.13	0.36	0	0	0	0	80.8	45.7
2017	191.3	15.6	3.79	5.80	2.18	7.56	0.80	2.03	1.06	1.85	2.41	0.72	0	0	0	235.0	51.2
2018	1141.1	66.1	17.9	3.20	5.03	2.27	3.66	0.90	0.54	0.36	0.72	0.48	0.56	0	0	1242.8	78.0
2019	115.3	45.6	30.1	7.74	3.03	1.13	0.15	0.15	0.03	0.07	0.05	0.06	0.04	0.04	0.02	203.4	29.9

Table 6.8. HADDOCK. Estimates of coefficients of variation (%) for swept area abundance indices. Barents Sea standard area winter 1994-2019.

	Age group													
Year	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**
1994	12	13	13	13	15	25	47	45	34	61	39	100	-	-
1995	12	19	28	29	16	21	38	181	75	97	-	58	97	-
1996	14	12	11	26	29	25	60	64	-	98	-	95	96	-
1997[1]	12	34	13	15	17	21	18	57	55	-	-	-	65	92
1998[1]	15	13	13	14	16	25	18	16	35	107	106	-	-	-
1999	15	37	14	24	21	23	25	31	22	88	-	97	-	-
2000	9	11	21	10	18	14	32	51	32	35	65	91	105	-
2001	11	15	11	18	11	40	34	46	59	51	47	86	62	-
2002	9	12	11	12	19	17	27	44	-	57	52	54	80	-
2003	18	26	25	12	11	20	35	62	60	69	56	91	93	-
2004	10	12	16	14	11	12	28	26	43	56	56	94	59	51
2005	9	16	11	19	13	22	15	71	48	93	-	-	-	-
2006[2]	14	14	18	12	13	16	20	30	44	70	-	63	-	-
2007[1]	11	7	10	20	12	12	24	25	46	51	58	-	-	-
2008	12	18	17	17	20	29	29	80	45	81	67	88	-	-
2009	13	21	16	17	19	19	33	25	91	68	-	94	-	-
2010	11	17	18	23	21	22	24	32	49	64	126	150	-	-
2011	10	10	16	25	17	13	18	33	73	-	-	83	84	-
2012[2]	20	29	16	17	14	12	15	34	73	47	83	62	-	-
2013	12	12	15	15	28	25	28	14	26	49	-	-	-	-
2014	9	24	14	19	17	22	21	17	24	41	62	-	-	99
2015	8	13	26	12	40	14	27	19	21	32	44	50	-	-
2016	22	26	15	46	11	17	20	16	17	21	29	46	-	62
2017[2]	5	13	16	13	21	15	21	31	31	22	27	45	77	-
2018	6	17	14	12	10	20	17	21	19	21	20	23	40	52
2019	10	11	16	14	29	11	38	21	31	28	40	39	45	92

[1] REZ not covered
[2] REZ partly covered

6.3 Growth and survey mortalities

Tables 6.9 and 6.10 present the time series (1994-2019) for mean length and mean weight at age for the standard area. Length estimates have been variable with no specific trends in the latest years. However, the variation is less than what it has been in earlier periods. Weight estimates also show less variation in later years. Annual weight increments are shown in Table 6.11, these are highly variable and show no trends.

Survey mortalities based on the acoustic indices (Table 6.12) have varied between years, and for most age groups there are no obvious trends. However, there are signs of co-variability within years. Survey mortalities based on the bottom trawl indices increased considerably from 2016 to 2017 to among the highest in the ten last years, but decreased somewhat from 2017 to 2018.

Table 6.9. HADDOCK. Length (cm) at age from bottom trawl surveys in the Barents Sea standard area winter 1994-2019. + indicates few samples.

Age/ Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1994	14.5	20.1	29.4	38.0	47.6	54.3	61.7	65.2	70.7	64.4	64.6	72.0	-	-
1995	15.1	18.4	28.7	34.0	42.8	51.0	59.6	60.0	67.2	68.0	-	64.7	78.6	-
1996	15.3	20.9	28.0	37.0	41.3	47.2	53.8	58.7	-	76.0	-	74.0	75.0	-
1997[1]	15.8	19.4	27.0	33.5	40.5	46.9	47.6	53.3	62.0	-	-	-	75.6	78.0
1998[1]	14.1	19.6	28.9	34.2	41.6	46.5	50.3	52.8	58.2	72.1	65.0	-	-	-
1999	14.3	18.0	32.3	38.6	46.5	51.9	56.1	55.1	58.8	62.0	-	72.0	-	-
2000	15.5	21.7	29.9	42.0	47.1	51.1	52.7	59.3	59.4	62.0	63.3	+	+	-
2001	14.6	22.1	32.1	37.6	48.0	50.1	59.2	55.0	64.9	66.3	67.7	+	+	-
2002	15.0	20.9	29.2	39.8	45.6	51.5	58.0	58.6	-	62.0	64.4	67.7	70.1	-
2003	15.8	24.0	26.4	36.5	45.8	49.8	54.5	61.2	62.6	60.3	66.0	70.0	+	-
2004	14.1	22.1	30.1	35.7	42.7	49.9	49.6	58.8	63.3	73.6	75.7	+	+	+
2005	14.8	20.6	29.9	36.1	40.4	48.4	51.5	56.2	60.8	67.0	-	-	-	-
2006	14.4	22.1	30.7	37.9	43.3	47.3	50.7	56.6	60.5	69.9	-	+	-	-
2007[1]	15.2	23.5	28.2	31.2	43.5	43.9	50.0	58.0	58.1	+	62.0	-	-	-
2008	15.7	23.7	29.6	37.9	42.7	46.0	52.9	52.5	58.5	+	63.3	63.0	-	-
2009	14.2	22.6	29.7	35.5	41.8	48.1	48.9	56.4	65.0	62.3	-	62.0	-	-
2010	14.4	19.8	30.6	36.8	40.8	45.1	49.9	59.9	58.9	62.3	+	66.5	-	-
2011	13.6	23.3	28.5	39.5	42.9	46.1	48.2	62.7	+	-	-	63.3	+	-
2012	14.6	19.2	31.6	35.1	43.7	47.1	50.2	50.8	47.6	65.0	67.0	72.0	-	-
2013	14.5	22.8	30.0	40.9	42.8	48.6	52.3	52.8	55.6	67.3	-	-	-	-
2014	15.5	18.6	31.9	39.0	46.5	52.7	53.5	55.3	54.9	60.3	59.2	-	-	75.0
2015	14.5	20.4	26.1	39.8	45.3	52.6	53.4	57.6	56.9	60.2	59.6	67.4	-	-
2016	14.8	18.5	30.7	35.8	47.8	53.0	56.0	58.4	61.0	60.4	59.8	64.5	-	72.0
2017	15.8	20.6	30.4	39.7	49.4	52.7	55.8	60.4	59.8	63.0	62.1	63.9	69.0	-
2018	14.3	22.1	30.4	39.5	47.6	54.1	57.7	61.1	64.3	66.0	64.4	63.4	67.1	68.6
2019	14.8	21.5	29.7	37.0	46.0	52.5	52.9	60.4	64.5	65.8	67.4	68.1	69.5	75.0

[1)] Adjusted lengths, REZ not covered

Table 6.10. HADDOCK. Weight (g) at age from bottom trawl surveys in the Barents Sea standard area winter 1994-2019. + indicates few samples.

Age/ Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1994	25	87	248	539	1056	1601	2201	2846	3439	2680	2712	3890	-	-
1995	30	71	221	380	775	1331	2005	2070	2685	2905	-	2502	3972	-
1996	32	93	218	472	668	1020	1537	1768	-	4630	-	4018	3626	-
1997[1]	35	85	188	329	619	1034	1064	1532	2474	-	-	-	3731	4130
1998[1]	24	89	232	416	815	1032	1298	1559	2006	3740	3040	-	-	-
1999	27	75	335	570	1022	1435	1791	1722	2011	2440	-	3525	-	-
2000	32	110	275	736	1061	1366	1521	2123	2239	2588	2741	+	+	-
2001	28	107	337	581	1145	1402	2147	1896	2903	3110	2965	+	+	-
2002	30	85	245	618	940	1375	1940	2048	-	2352	2670	3252	3497	-
2003	36	129	192	490	958	1209	1479	1933	2479	2533	3055	3470	+	-
2004	23	98	271	456	750	1162	1204	1958	2658	3926	4157	+	+	+
2005	29	98	261	474	666	1093	1372	1976	2120	2730	-	-	-	-
2006	25	109	302	561	810	1083	1358	1917	2102	3991	-	+	-	-
2007[1]	30	114	246	356	894	956	1388	2135	2508	+	2959	-	-	-
2008	32	113	245	553	832	1080	1573	1417	2120	+	2280	2840	-	-
2009	26	96	225	442	747	1147	1275	1726	2377	2563	-	2594	-	-
2010	27	87	270	466	658	949	1260	1897	2143	2512	+	3184	-	-
2011	21	117	220	520	727	939	1163	2285	+	-	-	+	2805	-
2012	28	73	305	432	816	1015	1285	1282	1219	2683	2980	3264	-	-
2013	24	113	272	644	783	1130	1350	1495	1836	3098	-	-	-	-
2014	32	68	357	611	1014	1424	1551	1677	1671	2141	2184	-	-	4800
2015	23	88	201	588	848	1423	1465	1921	1834	2078	2256	3133	-	-
2016	27	74	282	458	1057	1457	1752	2078	2280	2266	2404	2843	-	3555
2017	33	95	290	621	1220	1520	1785	2280	2309	2610	2594	2789	3369	-
2018	25	97	273	625	1040	1637	1941	2327	2697	2853	2667	2577	2997	3369
2019	25	90	242	507	965	1407	1558	2059	2712	2941	3001	3404	3412	3980

1) Adjusted weights, REZ not covered

Table 6.11. HADDOCK. Yearly weight increment (g) from bottom trawl surveys in the Barents Sea standard area winter 1994-2019.

Year\Age	**1-2**	**2-3**	**3-4**	**4-5**	**5-6**	**6-7**	**7-8**	**8-9**	**9-10**
1994-95	46	134	132	236	275	404	-131	-161	-534
1995-96	63	147	251	288	245	206	-237	-	1945
1996-97	53	95	111	147	366	44	-5	706	-
1997-98	54	147	228	486	413	264	495	474	1266
1998-99	51	246	338	606	620	759	424	452	434
1999-00	83	200	401	491	344	86	332	517	577
2000-01	75	227	306	409	341	781	375	780	871
2001-02	57	138	281	359	230	538	-99	-	-551
2002-03	99	107	245	340	269	104	-7	431	-
2003-04	62	142	264	260	204	-5	479	725	1447
2004-05	75	163	203	210	343	210	772	162	72
2005-06	80	204	300	336	417	265	545	126	1871
2006-07	89	137	54	333	146	305	777	591	-
2007-08	83	131	307	476	186	617	29	-15	-
2008-09	64	112	197	194	315	195	153	960	443
2009-10	61	174	241	216	202	113	622	417	135
2010-11	90	133	250	261	281	214	1025	-	-
2011-12	52	188	212	296	288	346	119	-1066	-
2012-13	85	199	339	351	314	335	210	554	1879
2013-14	44	244	339	370	641	421	327	176	305
2014-15	56	133	231	237	409	41	370	157	407
2015-16	51	194	257	469	609	329	613	359	432
2016-17	68	216	339	762	463	328	528	231	330
2017-18	64	178	335	419	417	421	542	417	544
2018-19	65	145	234	340	367	-79	118	385	244

Table 6.12. HADDOCK. Survey mortality from surveys in the Barents Sea standard area winter 1994-2019.

Year	1-2	2-3	3-4	4-5	5-6	6-7	7-8	8-9
	Acoustic investigations							
1994-95	2.30	1.51	1.05	0.46	0.94	1.12	2.64	1.01
1995-96	2.54	1.08	0.63	0.57	1.01	2.13	1.09	-
1996-97	1.61	0.50	0.30	0.35	0.20	0.83	0.19	2.60
1997-98	1.21	-0.24	-0.03	-0.09	0.70	1.38	1.11	1.18
1998-99	1.95	0.59	0.45	0.98	1.37	1.60	1.29	2.03
1999-00	0.48	-0.19	0.10	0.43	0.56	1.37	1.07	0.66
2000-01	1.38	0.55	-0.10	0.60	1.85	2.06	2.28	1.77
2001-02	1.03	0.04	0.15	0.78	1.26	0.32	1.71	1.67
2002-03	1.29	0.27	0.32	0.39	0.41	0.67	1.81	0.73
2003-04	1.77	0.88	0.69	0.54	0.86	0.48	1.65	-0.11
2004-05	1.30	0.75	0.27	0.57	0.64	1.51	3.00	1.28
2005-06	1.29	0.94	0.58	0.89	1.09	1.43	1.37	1.56
2006-07	0.79	1.09	0.20	0.43	0.49	0.66	0.99	0.36
2007-08	0.14	0.16	-0.37	-0.67	0.08	1.36	-0.25	1.13
2008-09	1.31	0.69	0.25	0.13	0.84	1.62	1.77	3.63
2009-10	1.64	0.49	0.34	0.04	0.47	1.17	1.60	0.27
2010-11	1.69	0.46	0.42	0.70	0.73	1.11	1.95	1.12
2011-12	1.51	0.41	0.10	-0.05	0.01	0.53	0.60	1.20
2012-13	1.36	0.34	0.27	0.32	0.51	0.33	0.52	0.76
2013-14	0.99	0.23	0.57	0.31	0.46	0.45	0.97	1.07
2014-15	2.03	1.53	0.64	0.40	1.01	0.99	0.47	1.59
2015-16	2.67	1.19	0.69	1.12	0.77	0.86	0.19	0.31
2016-17	1.36	0.28	0.09	0.99	0.55	0.70	0.86	1.52
2017-18	1.46	0.71	0.28	0.03	-0.26	0.92	0.93	1.15
2018-19	1.14	0.44	0.11	0.71	1.05	0.25	1.33	0.86
	Bottom trawl investigations							
1994-95	1.18	1.34	0.66	0.23	0.52	0.59	1.54	1.45
1995-96	1.74	1.19	0.57	0.01	0.30	0.45	0.52	-
1996-97	1.15	1.11	0.34	0.58	0.96	1.06	1.74	2.63
1997-98	1.70	1.48	0.81	1.13	1.73	2.02	2.69	1.75
1998-99	1.10	1.23	0.31	1.35	1.50	1.33	1.84	2.08
1999-00	1.02	1.20	0.47	0.81	0.84	1.49	4.45	0.47
2000-01	0.60	0.39	-0.08	0.46	1.38	1.65	2.38	-1.79
2001-02	0.96	0.36	0.45	0.79	0.99	0.70	1.41	-
2002-03	1.23	0.32	0.58	0.95	0.86	1.58	1.97	0.75
2003-04	1.53	1.01	1.22	0.81	0.35	-0.38	0.66	-0.08
2004-05	0.65	0.81	0.22	0.67	0.23	1.61	3.38	2.41
2005-06	1.22	1.55	0.89	1.12	0.81	1.36	1.16	1.02
2006-07	1.07	1.04	-0.03	0.43	0.56	1.44	1.96	0.86
2007-08	0.57	0.06	-0.24	0.43	0.45	1.31	-0.68	2.63
2008-09	0.93	0.52	0.73	0.45	0.72	1.48	2.12	4.77
2009-10	1.91	1.23	0.92	0.51	0.91	1.20	2.52	0.89
2010-11	1.50	0.44	-0.27	0.04	0.44	0.81	1.68	-0.11
2011-12	1.59	0.10	0.59	0.50	0.56	0.63	1.00	-0.60
2012-13	1.35	0.91	0.79	0.33	0.80	0.33	0.82	1.41
2013-14	1.03	0.26	0.61	0.37	-0.05	-0.31	0.71	0.54
2014-15	1.28	1.38	0.74	-0.38	1.04	0.48	0.93	1.23
2015-16	0.74	0.72	-0.09	0.51	0.81	-0.12	0.28	-0.41
2016-17	1.10	1.38	0.47	2.03	0.85	0.81	1.12	2.15
2017-18	1.07	0.83	0.42	0.45	-0.25	1.33	1.15	1.87
2018-19	0.92	0.44	0.58	0.60	1.35	0.39	1.45	1.38

7 Distribution and abundance of redfish

Earlier reports from this survey has presented distribution maps and abundance indices based on acoustic observations of redfish. In recent years, blue whiting has dominated the acoustic records in some of the main redfish areas. Due to incomplete pelagic trawl sampling the splitting of acoustic records between blue whiting and redfish has been very uncertain. The uncertainty relates mainly to the redfish, since it only makes up a minor proportion of the total value. This has been the case since the 2003 survey, and the acoustic results for redfish are therefore not included in the reports.

7.1 Golden redfish (*Sebastes norvegicus)*

Figure 7.1 shows the geographical distribution of golden redfish based on the catch rates in bottom trawl. In most years, the distribution is completely covered except towards northwest. Golden redfish was found in the extended survey area in 2014-2019, mainly west of Spitsbergen (strata 24). On average over all size groups about 16% of the amount found in the standard survey area by numbers was found in the extended area in 2019. Table 7.1 presents the time series (1994-2019) of swept area indices by 5 cm length groups for the standard area. The indices were low in many years since 1999 for all length groups. However, in 2016 and 2017 there was an increase in the indices of fish above 25 cm, and in 2018 the total index was at the same level as in 2017, while the total biomass was slightly lower. In 2019 the indices for fish between 35 and 50 cm increased further, and the total index and biomass were the highest since 1998. Table 7.2 present swept area abundance indices by length groups for new strata 24-26 in 2014-2019.

Table 7.3 presents estimates of coefficients of variation (%) by length groups. A CV of 20% or less could be viewed as acceptable in a traditional stock assessment approach if the indices are unbiased (conditional on a catchability model). Values above this indicate a highly uncertain index with little information regarding year class strength. In most years, except in 2018 and 2019, CVs for most length groups are above what could be considered as acceptable.

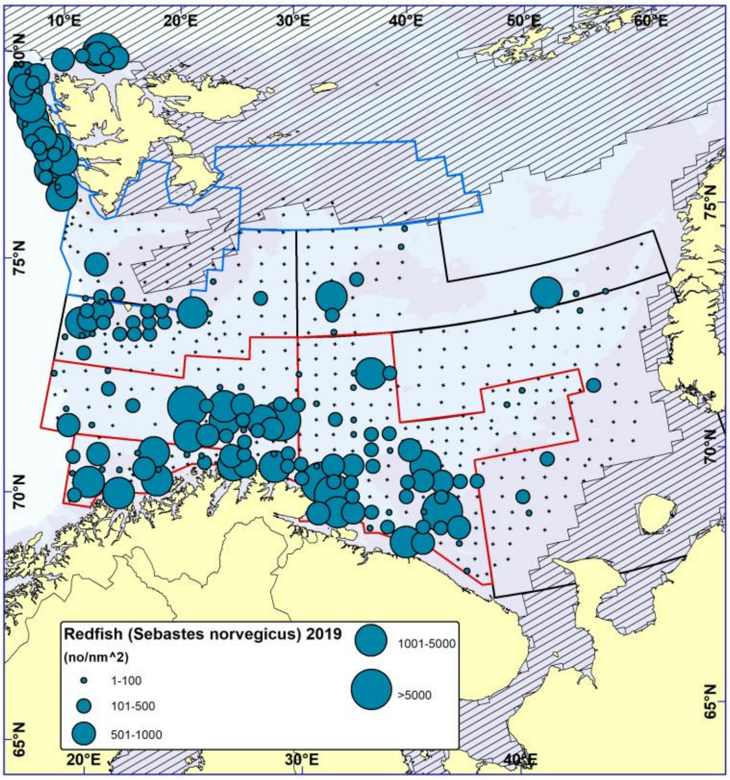


Figure 7.1. GOLDEN REDFISH (*Sebastes norvegicus)*. Distribution in the trawl catches winter 2019 (number per nm^2). Black crosses indicate zero catches.

Table 7.1. GOLDEN REDFISH (S*ebastes norvegicus*). Abundance indices (numbers in thousands) from bottom trawl surveys in the Barents Sea standard area winter 1994-2019.

Year	Length group (cm)												Total	Biomass
	5-9	10-14	15-19	20-24	25-29	30-34	35-39	40-44	45-49	50-54	55-59	≥60		(tons)
1994	675	7493	10100	12840	10914	17834	10065	4799	1645	937	202	121	77623	31841
1995	387	4658	13515	13118	10398	15429	16223	10587	3112	852	455	148	88883	42151
1996	40	715	3291	5983	8863	14089	15709	7502	2692	893	168	165	60010	35775
1997[1]	0	500	1197	2809	6522	22751	28797	8235	1747	1092	239	97	73985	44977
1998[1]	51	4525	2043	10795	73085	30862	14707	6984	1712	456	142	0	145363	49253
1999	181	928	2070	4002	4351	6275	6143	5474	2618	738	75	0	32854	20330
2000	533	1122	1506	4196	4895	5146	3611	1908	620	466	89	0	24092	10946
2001	55	411	398	2452	5802	5463	4509	3239	1154	343	96	37	23960	13896
2002	133	1053	2043	1854	3955	4204	3335	3654	1656	619	192	28	22726	13242
2003	0	478	1303	1538	4192	4081	2765	3204	1996	548	123	327	20554	13399
2004	700	195	420	973	2842	4365	5404	3858	2281	562	140	45	21786	15758
2005	0	119	203	362	1110	2090	3849	4664	2730	1276	299	128	16831	16389
2006[2]	0	0	0	178	2495	5534	6307	4155	3179	950	124	12	22934	18790
2007[1]	0	97	453	214	772	1526	2823	4275	2742	1194	197	58	14351	14553
2008	1736	2540	201	171	440	710	1969	2547	3049	1231	157	19	14768	12647
2009	0	0	86	0	39	436	1745	3779	4200	1959	267	101	12728	17237
2010	372	2017	1168	527	136	60	833	1062	2073	1596	205	128	10175	9787
2011	342	3187	2068	288	402	125	274	2329	3030	1912	131	243	14332	13302
2012[3]	805	4375	3995	1835	550	316	881	3645	4083	1775	320	85	22664	16011
2013	75	7418	4896	3952	1550	355	878	821	1284	1594	384	451	23658	11456
2014	128	1043	1440	3005	3363	1023	507	1427	2139	1176	633	193	16077	12087
2015	139	881	1467	3019	2603	2013	458	720	1237	1216	874	82	14710	10120
2016	748	1291	1484	2396	4290	3673	3391	1658	2147	2307	1114	250	24749	19847
2017[3]	341	1304	898	1065	4462	9060	6661	2980	2087	1776	604	498	31735	25050
2018	1129	2750	1799	1678	3282	4693	6335	4323	2012	1630	715	299	30645	22871
2019	671	3212	1700	2409	2515	3910	9024	9693	6709	1544	477	415	42279	36241

[1] Indices raised to also represent the Russian EEZ

[2] Not complete coverage in southeast due to restrictions, strata 7 area set to default and strata 13 as in 2005

[3] Indices not raised to also represent uncovered parts of the Russian EEZ.

Table 7.2. GOLDEN REDFISH (S*ebastes norvegicus*). Abundance indices (numbers in thousands) for new strata 24-26 from bottom trawl surveys in the Barents Sea winter 2014-2019.

Year	Length group (cm)								Total	Biomass
	5-9	10-14	15-19	20-24	25-29	30-34	35-39	40-44	>45		(tons)
2014	35	333	358	1440	2594	1315	211	501	379	7166	2913
2015	0	202	197	127	804	804	363	0	154	2651	1261
2016	0	0	103	300	597	1186	828	107	32	3151	1405
2017	0	66	93	587	519	679	547	96	66	2654	1053
2018	58	824	750	647	639	964	1855	546	50	6331	2598
2019	76	974	1445	567	666	1446	1043	519	112	6838	2525

Table 7.3. GOLDEN REDFISH (S*ebastes norvegicus*). Estimates of coefficients of variation (%) for swept area abundance indices. Barents Sea standard area winter 1994-2019.

	Length group (cm)										
Year	**5-9**	**10-14**	**15-19**	**20-24**	**25-29**	**30-34**	**35-39**	**40-44**	**45-49**	**50-54**	**55-59**
1994	51	42	22	27	18	34	13	29	20	23	40
1995	47	39	38	31	16	33	31	33	21	22	34
1996	68	51	47	25	16	27	25	20	16	24	46
1997[1]	-	40	30	28	20	64	71	37	14	19	34
1998[1]	67	28	25	56	82	64	48	42	27	28	44
1999	62	38	37	35	33	25	33	59	57	29	70
2000	46	27	21	24	22	28	28	26	22	21	56
2001	53	28	31	24	31	27	38	50	29	26	45
2002	54	61	51	25	29	23	28	39	49	26	41
2003	-	29	34	34	27	23	16	20	27	36	70
2004	72	38	26	32	35	54	52	26	30	22	54
2005	-	73	46	32	20	25	31	22	23	34	65
2006[2]	-	-	-	46	46	45	37	30	22	18	43
2007[1]	-	69	61	56	31	21	23	27	23	17	32
2008	33	30	41	60	42	27	22	23	17	24	64
2009	-	-	69	-	73	31	30	24	23	24	29
2010	54	31	45	51	41	70	31	34	17	19	31
2011	45	37	23	48	30	55	40	66	44	33	48
2012[2]	38	41	21	21	35	40	28	40	45	29	43
2013	55	40	27	17	22	45	38	39	38	27	44
2014	61	35	31	22	21	26	37	35	28	26	26
2015	64	44	33	29	26	24	30	36	27	18	37
2016	50	28	22	24	26	25	19	23	28	20	29
2017[2]	100	40	45	31	33	71	40	32	31	41	30
2018	37	24	19	25	20	17	22	19	23	21	24
2019	43	33	22	27	21	19	22	32	32	19	36

[1] REZ not covered

[2] REZ partly covered

7.2 Beaked redfish (*Sebastes mentella)*

The coverage of beaked redfish (Figure 7.2) was not complete west and north of Spitsbergen. About 3% of the amount found in the standard survey area by numbers was found in the extended survey area in 2019, which is less than what was found in previous years. Table 7.4 presents the time series (1994-2019) of swept area abundance indices by 5 cm length group in the standard area, while table 7.5 present indices for new strata 24-26 in 2014-2019. In 2015 and 2016, the estimated indices for 20-39 cm beaked redfish were among the highest in the time series, and in 2017 the indices for 30-39 cm beaked redfish were the highest in the time series, as were the total index and total biomass. The indices for most length groups decreased somewhat from 2017 to 2018 and remained at about the same level in 2019.

Table 7.6 presents estimates of coefficients of variation (%) by length groups. A CV of 20% or less could be viewed as acceptable in a traditional stock assessment approach if the indices are unbiased (conditional on a catchability model). Values above this indicate a highly uncertain index with little information regarding year class strength. In most years, CVs for length groups between 10 and 29 cm are at a level that could be considered as acceptable, and in most recent years up to 44 cm.

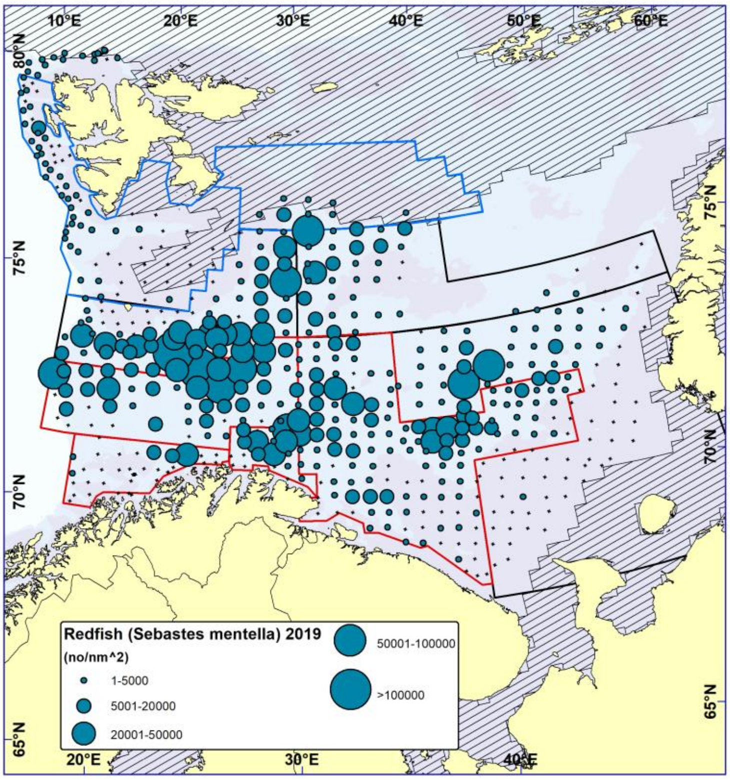


Figure 7.2. BEAKED REDFISH (*Sebastes mentella)*. Distribution in the trawl catches winter 2019 (number per nm^2). Black crosses indicate zero catches.

Table 7.4. BEAKED REDFISH *(Sebastes mentella)*[1]. Abundance indices (numbers in millions) from bottom trawl surveys in the Barents Sea standard area winter 1994-2019.

Year	Length group (cm)									Total	Biomass ('000 t)
	5-9	10-14	15-19	20-24	25-29	30-34	35-39	40-44	≥45		
1994	8.3	295.7	479.4	488.4	74.4	74.4	17.1	2.6	0.1	1440.4	161.2
1995	310.1	83.9	570.6	390.5	82.7	57.7	23.9	2.8	0.4	1522.5	153.0
1996	214.6	101.5	198.5	342.9	136.0	42.0	16.6	1.4	0.2	1053.8	127.9
1997[2]	64.6	118.45	22.0	242.4	258.2	70.2	39.1	4.4	0.1	819.4	165.3
1998[2]	1.0	88.0	62.4	101.4	203.2	40.0	12.9	1.7	0.2	510.7	96.1
1999	2.1	6.8	69.5	36.8	171.2	73.9	21.8	3.2	0.7	385.4	98.8
2000	9.2	12.9	40.2	78.0	142.2	94.8	24.5	7.0	1.5	410.3	111.5
2001	9.8	23.1	7.2	56.8	78.8	74.7	9.6	0.6	0.1	260.8	65.3
2002	16.5	7.5	19.3	36.5	96.2	116.7	23.9	1.4	0.03	318.1	90.2
2003	3.8	4.1	10.3	12.6	70.4	198.1	45.9	5.7	0.3	351.1	139.4
2004	2.2	3.0	6.9	18.5	32.8	86.3	31.6	1.9	0.8	183.4	68.4
2005	0	6.3	7.4	10.7	28.4	153.7	86.2	3.8	0.2	296.6	131.3
2006[3]	100.0	1.9	9.6	14.6	22.8	103.8	82.8	2.7	0.7	338.8	108.2
2007[2]	374.2	121.8	2.8	6.7	12.3	121.0	120.7	7.1	0	766.7	136.6
2008	858.2	359.1	26.8	4.6	11.5	103.6	165.4	4.7	0.1	1533.9	169.3
2009	95.3	324.7	135.5	5.4	8.8	67.1	162.6	5.8	0.4	805.7	155.1
2010	652.2	276.0	214.7	64.2	7.1	73.6	191.3	5.9	0.4	1485.4	198.1
2011	501.6	229.7	212.5	149.0	14.1	46.6	157.3	4.9	0.2	1315.8	177.8
2012[4]	129.4	280.1	86.4	125.3	47.3	14.4	153.9	17.7	0.2	854.7	170.7
2013	249.6	226.6	245.4	159.2	143.2	35.2	193.3	27.1	0.3	1279.8	242.2
2014	90.7	175.3	250.1	113.7	124.6	50.6	115.1	13.8	0.2	934.1	170.2
2015	175.2	110.7	216.2	302.2	289.8	214.8	170.9	18.1	0.2	1498.0	344.6
2016	615.1	105.3	148.6	331.5	213.1	162.7	123.6	14.1	0.6	1714.6	262.5
2017[5]	603.6	201.9	70.4	198.5	286.9	308.9	231.5	10.6	0.23	1914.9	403.9
2018	189.9	253.3	83.2	110.1	191.3	270.4	216.6	22.6	1.14	1338.5	348.6
2019	42.4	294.4	270.0	92.0	158.1	255.1	210.8	20.0	2.63	1343.2	340.3

[1] Includes unidentified Sebastes specimens, mostly less than 10cm
[2] Indices raised to also represent the Russian EEZ
[3] Not complete coverage in southeast due to restrictions, strata 7 area set to default and strata 13 as in 2005
[4] Indices not raised to represent uncovered parts of the Russian EEZ
[5] Indices raised to also represent uncovered parts of the Russian EEZ

Table 7.5. BEAKED REDFISH (*Sebastes mentella)*[1]. Abundance indices (numbers in millions) for new strata 24-26 from bottom trawl surveys in the Barents Sea winter 2014-2019.

Year	Length group (cm)									Total	Biomass ('000 t)
	5-9	10-14	15-19	20-24	25-29	30-34	35-39	40-44	>45		
2014	19.6	9.19	11.5	6.80	5.43	1.67	2.31	0.36	0	56.9	5.5
2015	13.5	5.51	8.27	11.3	11.4	5.23	3.43	0.12	0.03	58.9	9.4
2016	54.6	3.10	2.17	4.48	4.82	4.15	1.42	0.34	0	75.0	4.5
2017	81.9	13.1	1.32	4.45	6.01	6.44	3.59	0.60	0.03	117.4	7.8
2018	47.9	74.0	2.33	1.76	4.58	5.91	5.83	0.63	0	143.0	8.6
2019	10.9	10.1	7.02	0.71	1.38	1.32	2.07	0.18	0.03	33.7	3.0

[1] Includes unidentified Sebastes specimens, mostly less than 10cm

Table 7.6. BEAKED REDFISH (*Sebastes mentella*)[1]. Estimates of coefficients of variation (%) for swept area abundance indices. Barents Sea standard area winter 1994-2019.

Year	Length group (cm)								
	5-9	**10-14**	**15-19**	**20-24**	**25-29**	**30-34**	**35-39**	**40-44**	**45-49**
1994	40	14	25	28	20	23	26	49	53
1995	18	25	23	25	17	20	18	34	39
1996	18	23	27	22	19	36	23	37	58
1997[2]	18	15	13	11	14	17	26	53	53
1998[2]	28	16	21	14	17	16	21	31	77
1999	20	17	15	11	18	22	29	56	65
2000	16	12	17	12	16	21	31	64	76
2001	17	14	14	12	13	19	17	26	67
2002	57	13	15	18	16	21	19	31	65
2003	56	17	18	17	18	27	27	43	88
2004	19	15	15	19	16	14	18	21	59
2005	-	23	15	16	16	17	21	38	40
2006[3]	11	49	25	28	18	17	16	24	85
2007[2]	15	23	18	13	15	24	19	41	59
2008	14	15	29	23	20	23	22	24	45
2009	13	10	18	22	40	28	22	24	46
2010	14	12	12	18	22	31	31	22	80
2011	10	12	10	15	16	32	25	27	56
2012[3]	16	12	13	11	21	32	37	54	44
2013	15	15	35	23	32	29	39	41	49
2014	10	12	11	15	21	22	30	27	48
2015	14	11	14	18	26	22	19	29	52
2016	10	11	13	20	16	16	18	18	58
2017[3]	10	16	16	14	17	16	16	15	97
2018	8	9	11	14	11	14	17	21	33
2019	11	12	15	12	16	18	19	21	59

[1] Includes unidentified *Sebastes* specimens, mostly less than 10cm

[2] REZ not covered

[3] REZ partly covered

7.3 Norway redfish (*Sebastes viviparus)*

Figure 7.3 shows the geographical distribution of Norway redfish and Table 7.7 presents the time series (1994-2019) of swept area indices by 5 cm length groups in the standard area. Almost all Norway redfish are found in areas ABCD, mainly in main area B, and almost nothing in the extended survey area (Table 7.8). A few large catches often drive the indices. There was a large and unexplained increase in the indices of most length groups from 2013 to 2014 and 2015 to among the highest levels in the time series. In 2016 and 2017 the indices for most length groups were somewhat lower, while in 2018 there was a new increase for most length groups and the total index was the second highest in time series. In 2019 the indices of fish above 19 cm decreased somewhat compared to 2018, but the total index is still among the highest in the time series.

Table 7.11 presents estimates of coefficients of variation (%) by length groups. A CV of 20% or less could be viewed as acceptable in a traditional stock assessment approach if the indices are unbiased (conditional on a catchability model). Values above this indicate a highly uncertain index with little information regarding year class strength. In most years, CVs for most length groups are far above what could be considered as acceptable.

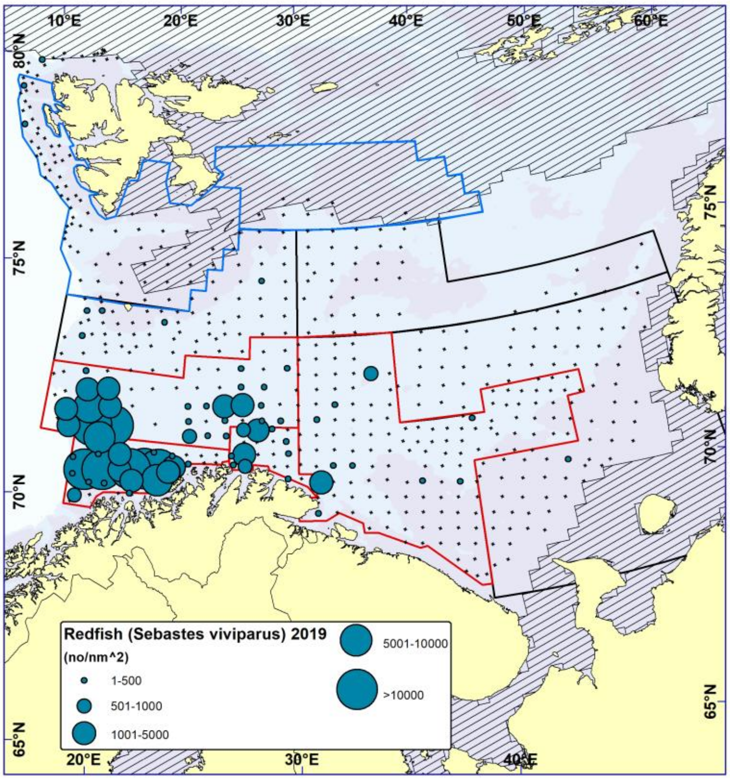


Figure 7.3. NORWAY REDFISH (*Sebastes viviparus)*. Distribution in the trawl catches winter 2019 (number per nm^2). Black crosses indicate zero catches.

Table 7.7. NORWAY REDFISH *(Sebastes viviparus)*. Abundance indices (numbers in thousands) from bottom trawl surveys in the Barents Sea standard area winter 1994-2019.

Year	Length group (cm) 5-9	10-14	15-19	20-24	25-29	≥30	Total
1994	75355	94809	17218	12818	1377	279	201857
1995	10716	68713	22737	9349	3306	503	115325
1996	439	45798	43673	35921	5498	87	131417
1997[1]	898	24202	28857	18768	4397	0	77122
1998[1]	703	9835	42183	20801	2939	91	76102
1999	1577	10134	11675	2921	707	35	27049
2000	1011	5127	37429	22122	2118	140	67947
2001	249	2243	30082	34405	3802	120	70901
2002	332	3345	17674	15168	1276	88	37884
2003	234	4306	22603	31019	4277	181	62619
2004	102	1794	24462	32769	3294	291	62712
2005	172	1582	16444	37360	6153	356	62068
2006[2]	819	4480	3653	10381	2244	205	21782
2007[1]	704	5238	15652	34395	2448	80	58517
2008	0	1882	5910	21022	4561	30	33344
2009	506	528	3096	11032	3405	419	18988
2010	1712	455	10134	53181	7572	22	73076
2011	533	1250	2169	7758	2197	106	14013
2012[1]	586	3950	4080	29157	6212	74	44059
2013	1211	9522	3302	23464	8545	100	46144
2014	11388	17755	21079	64094	15135	1990	131441
2015	7384	27351	30768	65870	9048	88	140509
2016	2795	26824	18396	29229	11286	933	89464
2017[1]	3848	58422	21556	22580	5685	426	112518
2018	700	24371	61515	37470	26283	1344	151763
2019	730	14679	58653	31991	6469	1250	113773

[1] Indices not raised to represent the Russian EEZ or uncovered parts, *Sebastes viviparus* is mainly found in NEZ
[2] Not complete coverage in southeast due to restrictions, strata 7 area set to default and strata 13 as in 2005

Table 7.8. NORWAY REDFISH (*Sebastes viviparus)*. Abundance indices (numbers in thousands) for new strata 24-26 from bottom trawl surveys in the Barents Sea winter 2014-2019.

Year	Length group (cm) 5-9	10-14	15-19	20-24	25-29	≥30	Total
2014	0	87	44	0	0	0	131
2015	0	0	35	0	0	0	35
2016	0	0	111	0	0	0	111
2017	0	0	0	0	0	0	0
2018	0	0	160	126	32	0	318
2019	0	0	51	0	0	0	51

Table 7.9. NORWAY REDFISH (*Sebastes viviparous*). Estimates of coefficients of variation (%) for swept area abundance indices. Barents Sea standard area winter 1994-2019.

Year	Length group (cm)					
	5-9	**10-14**	**15-19**	**20-24**	**25-29**	**30-34**
1994	34	52	25	39	41	70
1995	42	31	43	34	70	89
1996	62	24	31	36	51	57
1997[1]	84	31	27	48	56	-
1998[1]	39	20	43	68	71	79
1999	78	58	32	25	37	65
2000	52	29	47	48	41	51
2001	39	26	31	30	34	85
2002	61	34	20	23	46	83
2003	73	34	35	30	31	76
2004	57	36	38	35	24	66
2005	69	35	40	31	34	69
2006[2]	75	75	25	30	21	58
2007[1]	75	78	39	39	29	87
2008	-	58	32	28	42	73
2009	61	48	25	24	27	61
2010	47	42	47	52	57	97
2011	51	59	50	48	45	75
2012[2]	45	30	48	45	43	100
2013	58	32	25	41	51	98
2014	43	36	40	40	41	79
2015	38	32	34	43	53	100
2016	37	28	29	28	23	46
2017[2]	46	62	23	30	27	52
2018	46	46	47	54	40	60
2019	64	57	44	29	32	68

[1] REZ not covered

[2] REZ partly covered

8 Distribution and abundance of Greenland halibut

Figure 8.1 shows the distribution of bottom trawl catch rates of Greenland halibut. The most important distribution areas for the adult fish (depths between 500 and 1000 m along the western slope), are not covered by the survey. The observed distribution pattern in 2018 was similar to those observed in previous years' surveys. Greenland halibut was also found in the extended survey area in 2014-2019. In 2018, a higher number of fish less than 40 cm was found in the extended area than in the standard area (strata 1-23). On average over all size groups about 25% of the amount found in the standard survey area by numbers was found in the extended area in 2019.

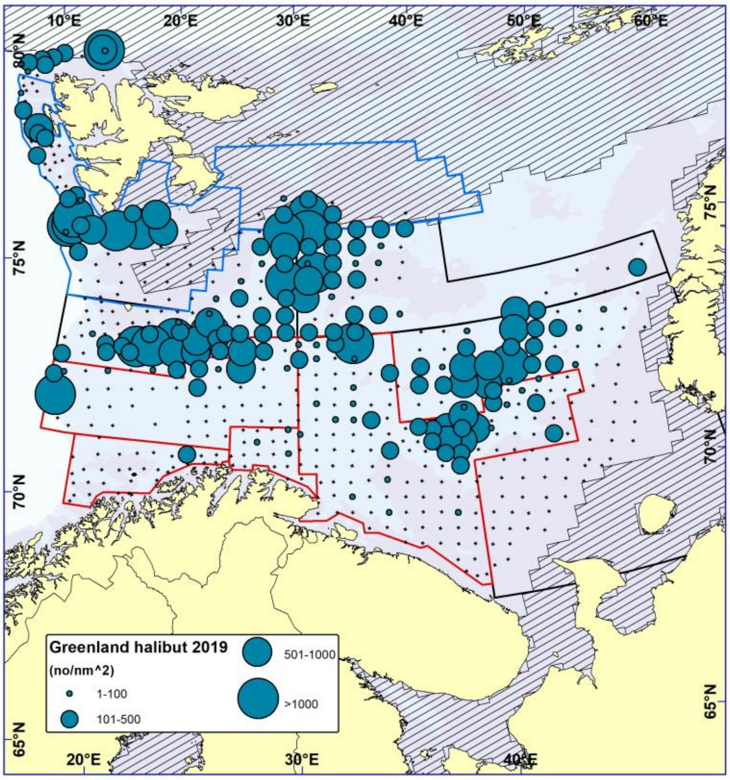


Figure 8.1 GREENLAND HALIBUT. Distribution in the trawl catches winter 2019 (number per nm^2). Black crosses indicate zero catches.

The time series (1994-2019) of swept area abundance indices by 5 cm length groups in the standard area is presented in Table 8.1. Abundance indices have been low in the whole period, with few signs of improved recruitment in the covered area. However, recruitment from more northern areas has led to an increase in abundance indices of length groups above 30 cm since about 2005. There was a large increase in the indices of most length groups between 30 and 79 cm from 2014 to 2015, and the total index was the highest in the time series back to 1994. In 2016, the indices of length groups between 25 and 44 cm showed an increase, while the indices of fish between 45 and 69 cm were lower than in 2015. The indices for most length groups decreased from 2016 to 2017 and the total index was the second lowest since 2004. In 2018 the indices were quite like those from 2017 but on average slightly lower, and the total index was the lowest since 2004. In 2019 the indices of all length groups above 34 cm increased, and the total index and biomass were at the same level as in 2015 and among the highest in the time series. Table 8.2 present swept area abundance indices by length groups for new strata 24-26 in 2014-2019.

Table 8.3 presents estimates of coefficients of variation (%) for length groups. Estimates are based on a stratified bootstrap approach with 500 replicates (with trawl stations being primary sampling unit). A CV of 20% or less could be viewed as acceptable in a traditional stock assessment approach if the indices are unbiased (conditional on a catchability model). Values above this indicate a highly uncertain index with little information regarding year class strength. In most years, only CVs for length groups between 40 and 59 cm are at a level that could be considered as acceptable.

Table 8.1. GREENLAND HALIBUT. Abundance indices (numbers in thousands) from bottom trawl surveys in the Barents Sea standard area winter 1994-2019.

Year	Length group (cm)															Biomass (tons)
	≤14	15-19	20-24	25-29	30-34	35-39	40-44	45-49	50-54	55-59	60-64	65-69	70-74	75-79	≥ 80	Total	
1994	0	0	21	76	148	1117	3139	4740	3615	1941	889	541	21	0	0	16248	19228
1995	298	0	0	0	90	129	2877	7182	5739	2027	1622	839	489	86	0	21378	27459
1996	4121	0	0	0	62	124	1214	4086	4634	1871	1112	638	337	74	12	18285	20256
1997[1]	0	68	0	0	55	163	949	4313	5629	2912	1609	643	300	65	21	16728	24214
1998[1]	68	220	945	578	481	487	1088	4016	6591	3076	1798	707	326	93	44	20518	27248
1999	43	84	241	436	566	269	784	1701	3097	1669	1094	491	89	75	0	10640	14681
2000	140	184	344	836	1722	3857	2253	1560	2144	1714	1191	615	249	76	0	16883	17246
2001	68	49	147	179	737	1525	3716	3271	2302	2010	1088	529	160	50	39	15871	18224
2002	271	0	70	34	382	1015	1916	3803	3250	2279	1138	976	242	159	114	15648	21198
2003	51	0	74	19	304	715	1842	3008	4765	2235	714	561	245	146	0	14678	19635
2004	106	104	15	0	319	1253	1229	1717	2277	1227	798	298	148	94	26	9615	11872
2005	263	70	159	1139	2235	2621	4206	3782	3847	2037	917	585	336	118	0	22314	22293
2006[2]	0	72	94	414	1968	5149	4613	5743	4283	2132	891	449	258	34	18	26118	25579
2007[1]	0	18	146	1869	1418	3114	5710	5947	4287	2205	963	658	391	80	89	26896	28006
2008	0	0	0	243	1708	5974	4654	6136	5198	3403	827	638	174	82	50	29088	30153
2009	55	0	0	26	1044	4327	8133	4551	4084	2266	996	627	442	253	154	26960	28919
2010	0	0	0	99	678	3648	5729	6560	4897	2467	1064	552	229	128	41	26092	25979
2011	51	0	0	0	216	4396	5864	5498	5237	3698	699	936	327	252	97	27271	31552
2012[3]	77	0	0	0	51	1145	4524	5366	4517	2774	1147	195	73	0	48	19917	22656
2013	0	0	0	0	0	511	5368	4868	5374	3687	1944	939	348	313	154	23504	31748
2014	0	0	46	92	156	368	2271	5587	5903	3555	2251	1369	154	260	79	22090	31112
2015	367	0	61	0	284	1612	3187	6452	7249	6752	3350	1936	587	334	0	32172	46828
2016	205	0	124	511	950	1953	3486	4539	5479	5613	1999	1973	646	98	80	27657	35831
2017[4]	52	0	0	78	592	1328	1885	3850	4852	4550	1721	1455	317	190	23	20827	29756
2018	0	0	62	0	383	1333	2049	3445	4258	3573	1904	1366	736	196	20	19325	28688
2019	0	0	0	375	272	1671	3285	4034	5177	4265	3570	2526	1328	535	137	27176	45912

[1] Indices raised to also represent the Russian EEZ

[2] Not complete coverage in southeast due to restrictions, strata 7 area set to default and strata 13 as in 2005

[3] Indices not raised to also represent uncovered parts of the Russian EEZ.

[4] Indices raised to also represent uncovered parts of the Russian EEZ

Table 8.2. GREENLAND HALIBUT. Abundance indices (numbers in thousands) for new strata 24-26 from bottom trawl surveys in the Barents Sea winter 2014-2019.

	Length group (cm)																Biomass
Year	**≤14**	**15-19**	**20-24**	**25-29**	**30-34**	**35-39**	**40-44**	**45-49**	**50-54**	**55-59**	**60-64**	**65-69**	**70-74**	**75-79**	**≥ 80**	**Total**	**(tons)**
2014	0	134	141	0	138	453	1350	1443	1351	293	803	39	117	0	0	6261	7366
2015	0	0	0	269	30	263	550	863	597	567	555	66	107	38	0	3903	5092
2016	678	933	607	436	336	431	331	728	340	254	68	34	140	0	34	5349	3059
2017	31	0	0	193	583	861	662	456	301	33	298	30	0	34	0	3485	2990
2018	136	28	0	434	775	1840	1099	1042	776	634	360	511	0	0	0	7636	7528
2019	296	92	81	78	137	1072	1144	1384	896	649	638	297	24	40	0	6826	8118

Table 8.3. GREENLAND HALIBUT. Estimates of coefficients of variation (%) for swept area abundance indices. Barents Sea standard area winter 1994-2019.

	Length group (cm)														
Year	**10-14**	**15-19**	**20-24**	**25-29**	**30-34**	**35-39**	**40-44**	**45-49**	**50-54**	**55-59**	**60-64**	**65-69**	**70-74**	**75-79**	**80-84**
1994	0	0	105	57	46	28	17	20	17	15	20	26	97	-	-
1995	91	-	-	-	71	40	18	22	25	24	27	41	63	94	-
1996	33	-	-	-	69	45	22	25	18	19	36	29	40	58	-
1997[1]	-	53	-	-	82	48	26	23	18	16	16	24	28	73	101
1998[1]	66	53	26	44	42	18	22	23	28	26	28	31	33	50	101
1999	91	54	53	26	32	31	24	21	18	16	18	25	52	51	-
2000	71	66	72	83	56	58	41	20	22	23	21	36	45	54	-
2001	92	99	85	47	40	48	44	46	37	14	17	34	43	56	-
2002	71	-	70	104	29	27	17	13	16	16	14	27	24	37	55
2003	66	-	63	95	30	27	20	44	34	32	44	28	38	37	-
2004	78	59	97	-	26	17	16	16	17	17	15	29	39	46	92
2005	66	70	37	46	33	15	19	17	16	20	25	24	28	64	-
2006[2]	-	81	81	67	32	18	18	11	11	16	22	22	30	67	-
2007[1]	-	99	52	23	20	13	12	12	14	14	24	37	26	44	99
2008	-	-	-	36	20	21	15	14	18	14	22	20	43	56	68
2009	98	-	-	103	23	14	16	16	19	18	17	21	26	46	53
2010	-	-	-	57	26	18	13	12	14	18	19	23	45	57	101
2011	66	-	-	-	43	18	15	14	17	14	25	26	33	46	70
2012[2]	93	-	-	-	100	23	13	14	14	11	24	70	72	-	-
2013	-	-	-	-	-	44	39	12	16	20	19	33	50	50	-
2014	-	-	99	68	68	37	20	14	20	18	18	24	53	51	72
2015	83	-	99	-	49	24	22	15	13	18	34	37	33	46	-
2016	-	-	101	50	43	31	21	34	26	31	16	20	36	70	98
2017[2]	102	-	-	72	42	25	23	13	14	17	21	26	45	65	95
2018	-	-	107	-	51	24	15	18	18	15	17	23	32	54	93
2019	-	-	-	54	37	20	20	24	21	17	16	17	23	31	68

[1] REZ not covered [2] REZ partly covered.

9 Distribution and abundance of capelin, polar cod and blue whiting

9.1 Capelin

Although capelin is primarily a pelagic species, small amounts of capelin are normally caught in the bottom trawl throughout most of the investigated area. In Figure 9.1 catch rates of capelin smaller and larger than 14 cm are shown for the winter survey in 2019. Capelin smaller than 14 cm during this period will mainly comprise the immature stock component, while the larger capelin constitutes the prespawning capelin stock. Some few trawl hauls show large capelin catches (numbers exceeding 100 000 individuals) and these can probably not be considered representative for the density in the area, because such hauls will either result from hitting a capelin school at the bottom or up in the water column. For this reason, we chose not to present swept-area based indices for capelin in this report.

At this time of the year, mature capelin has started their approach to the spawning areas along the coast of Troms, Finnmark and the Kola peninsula, while immature capelin will normally be found further north and east, in the wintering areas. This is reflected on the maps of capelin distribution, even though some large capelin is always found north of 75°N, and smaller capelin are found sporadically in near-coastal areas. The geographical coverage of the total capelin stock is incomplete, but the maturing component is probably best covered.

It has been noted during several surveys that when sampling capelin from demersal and pelagic trawls, the individuals from demersal trawls are normally larger (and older) than those sampled pelagically. This has led to formation of a hypothesis saying that larger individuals tend to stay deeper than smaller individuals and some even to take up a demersal life. This hypothesis has not been tested, and during the winter surveys there are probably too few pelagic hauls to study the vertical distribution of capelin in a systematic way.

9.2 Polar cod

Polar cod are not well represented in the trawl hauls conducted during the winter surveys (Figure 9.2). This reflects the more northern and eastern distribution area of this endemic arctic species. During this time of the year, the polar cod is known to be spawning under the ice-covered areas of the Pechora Sea and close to Novaya Zemlya. It is not clear whether the concentrations found in open water this time of the year are mature fish either on their way to spawning or from the spawning areas, or if this is immature fish.

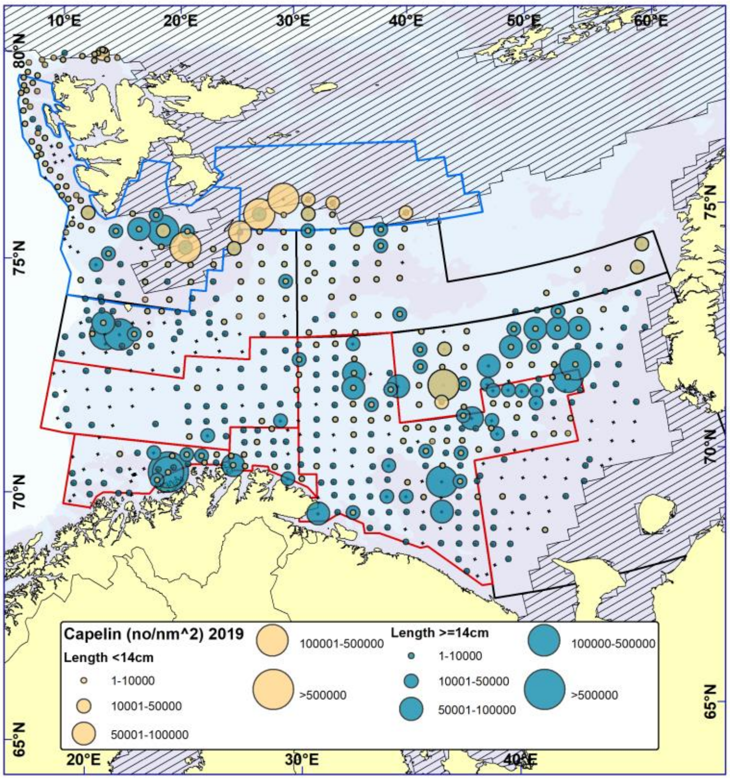


Figure 9.1. CAPELIN. Distribution in the trawl catches winter 2019 (number per nm^2). Black crosses indicate zero catches.

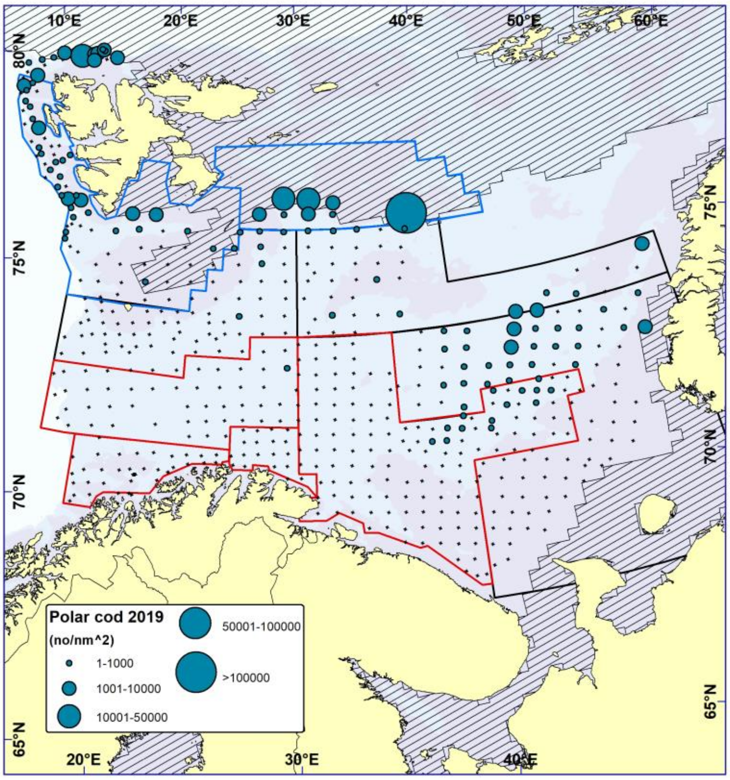


Figure 9.2 POLAR COD. Distribution in the trawl catches winter 2019 (number per nm^2). Black crosses indicate zero catches.

9.3 Blue whiting

Since the second part of the 1990s, blue whiting has shown a wider distribution than previously, and echo recordings indicated higher abundance in the Barents Sea. Figure 9.3 shows the geographical distribution of the bottom trawl catch rates of blue whiting in 2019. Since the fish is mainly found pelagically, the bottom trawl does not reflect the real density distribution but gives some indication of the distribution limits. Acoustic observations would better reflect the relative density distribution. The number of pelagic hauls has, however, been too low to properly separate the pelagic recordings. During the years with high abundance of blue whiting, dense concentrations of blue whiting might have masked recordings of pelagic redfish, haddock and small cod.

Table 9.1 shows the bottom trawl swept area estimates by 5 cm length groups for the years 1994-2019. High abundance of fish below 20 cm in 2001, 2002, 2004, 2005, 2012 and 2015 reflects abundant recruiting (age 1) year classes. These recruits are observed in the survey as larger fish in the following years. As for some of the other target species in the survey, there was a large increase in the indices for most length groups from 2014 to 2015. The recruitment signal was less in 2017, while the total index of fish above 20 cm and total biomass were the largest since 2006. In 2018 and 2019 the indices were the lowest since 2011. Only small amounts of blue whiting were found in the extended survey area (Tables 9.2). Table 9.3 presents estimates of coefficients of variation (%) by length groups. In most years, CVs for most length groups are far above what could be considered as acceptable for stock assessment.

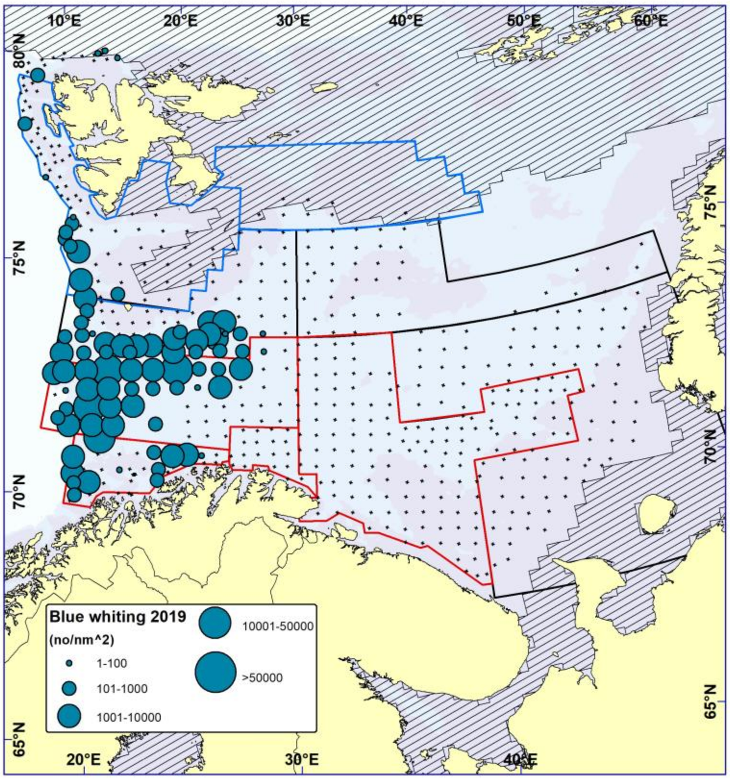


Figure 9.3 BLUE WHITING. Distribution in the trawl catches winter 2019 (number per nm^2). Black crosses indicate zero catches.

Table 9.1. BLUE WHITING. Abundance indices (numbers in millions) from bottom trawl surveys in the Barents Sea standard area winter 1994-2019.

Year	Length group (cm)								Total	Biomass
	5-9	10-14	15-19	20-24	25-29	30-34	35-39	≥40		('000 t)
1994	0	0	1.2	13.6	25.7	10.9	1.1	0.1	52.6	NA
1995	0	0.5	0.8	2.4	10.3	10.8	3.9	0.2	29.0	NA
1996	0	80.0	1371.8	8.4	18.6	7.1	3.8	0.1	1489.9	38.2
1997[1]	0	608.7	681.5	273.8	3.1	5.3	1.8	0.1	1574.3	NA
1998[1]	0	1.2	34.5	42.2	3.6	1.5	1.4	0.1	84.5	NA
1999	0	0.02	11.0	40.0	16.1	5.0	1.7	0.1	74.0	NA
2000	0	12.3	557.5	44.1	25.7	4.4	0.7	0.1	644.9	NA
2001	0.04	311.6	1420.8	631.5	46.0	5.4	1.6	0.1	2417.0	NA
2002	0	0.9	428.9	636.3	77.6	17.5	3.2	0.1	1164.4	56.6
2003	0	3.9	220.5	493.4	73.4	28.0	4.0	0.3	823.4	48.1
2004	0	7.1	712.0	821.6	276.2	37.8	1.1	0.2	1856.0	95.8
2005	0	125.1	717.2	984.7	223.3	31.8	0.1	0.1	2082.4	105.0
2006[2]	0	0	164.4	1500.5	598.0	69.0	2.0	0.1	2333.9	172.9
2007[1]	0	0	4.0	628.0	299.3	23.5	1.6	0.4	956.8	79.8
2008	0	0	0.3	12.1	126.1	19.8	1.3	0.1	159.7	20.6
2009	0	0	0.02	2.7	50.6	21.2	1.5	0.02	76.1	11.4
2010	0	0	0.5	1.6	9.4	16.9	1.0	0	29.4	5.2
2011	0	0	0.1	0.3	2.8	5.1	2.5	0	10.6	2.2
2012[1]	0	85.6	674.6	1.1	1.8	5.3	2.0	0.3	770.7	18.2
2013	0	0	75.3	395.9	12.6	11.5	6.8	0.1	502.2	28.6
2014	0	0	182.1	34.2	9.7	1.6	1.5	0.04	229.2	8.5
2015	0	115.6	907.4	141.2	40.8	8.8	7.4	0	1221.3	34.2
2016	0	0.1	260.0	367.6	38.0	6.3	3.0	0.1	674.9	39.1
2017[1]	0	0	29.1	939.6	279.2	26.1	11.5	0.05	1285.6	99.7
2018	0	0.02	0.8	45.4	50.2	8.3	1.7	0	106.5	10.5
2019	0.13	1.7	54.4	4.5	35.9	13.0	1.0	0.09	110.7	9.2

[1] Indices not raised to represent the Russian EEZ or uncovered parts, blue whiting is mainly found in areas A, B, C and S

[2] Not complete coverage in southeast due to restrictions, strata 7 area set to default and strata 13 as in 2005

Table 9.2. BLUE WHITING. Abundance indices (numbers in millions) for new strata 24-26 from bottom trawl surveys in the Barents Sea winter 2014-2019.

Year	Length group (cm)								Total	Biomass
	5-9	10-14	15-19	20-24	25-29	30-34	35-39	≥40		('000 t)
2014	0	0	0.29	0.28	0.10	0.19	0.13	0	1.0	0.12
2015	0	0	0.16	0.10	0.25	0.78	0.42	0	1.7	0.27
2016	0	0	2.12	5.35	1.54	0.46	0.35	0	9.8	0.84
2017	0	0	0.08	20.91	4.10	1.34	0.39	0	26.8	1.98
2018	0	0	0	0.16	0.37	0.23	0.16	0	0.9	0.13
2019	0	0	0.03	0.21	0.71	0.70	0.24	0	1.9	0.34

Table 9.3. BLUE WHITING. Estimates of coefficients of variation (%) for swept area abundance indices. Barents Sea standard area winter 1994-2019.

	Length group (cm)							
Year	5-9	10-14	15-19	20-24	25-29	30-34	35-39	40-44
1994	-	-	94	68	51	28	31	49
1995	-	59	55	51	66	32	28	48
1996	-	49	79	56	49	30	33	59
1997[1]	-	30	29	33	36	29	37	70
1998[1]	-	91	60	33	35	33	28	70
1999	-	98	26	27	28	31	43	71
2000	-	37	21	20	25	29	31	95
2001	69	21	18	25	26	35	39	90
2002	-	56	25	17	20	33	52	69
2003	-	87	47	23	17	27	58	83
2004	-	86	23	19	15	14	30	61
2005	-	28	25	16	24	24	71	90
2006[2]	-	-	17	12	13	26	46	61
2007[1]	-	-	50	16	12	17	42	84
2008	-	-	51	59	27	22	47	82
2009	-	-	97	60	21	20	61	95
2010	-	-	91	80	29	25	33	-
2011	-	-	100	88	45	48	62	-
2012[2]	-	32	30	39	45	38	29	98
2013	-	-	70	31	57	44	44	99
2014	-	-	23	23	24	27	18	137
2015	-	50	21	21	31	31	37	-
2016	-	96	33	24	17	27	29	97
2017[2]	-	-	24	16	16	16	42	101
2018	-	102	49	25	17	19	32	-
2019	68	37	38	29	35	31	50	101

[1] REZ not covered

[2] REZ partly covered

11 References

Aglen, A. and Nakken, O. 1997. Improving time series of abundance indices applying new knowledge. Fisheries Research, 30: 17-26.

Aglen, A., Dingsør, G., Mehl, S., Murashko, P. and Wenneck, T. de L. 2012. Results from the Joint IMR-PINRO Barents Sea demersal fish survey 21 January – 15 March 2012. WD #3 ICES Arctic Fisheries Working Group, Copenhagen, Denmark 20-26 April 2012.

Aschan, M. and Sunnanå, K. 1997. Evaluation of the Norwegian shrimp surveys conducted in the Barents Sea and Svalbard area 1980-1997. ICES C M 1997/Y:07. 24pp.

Bogstad, B., Fotland, Å. and Mehl, S. 1999. A revision of the abundance indices for cod and haddock from the Norwegian winter survey in the Barents Sea, 1983-1999. Working Document, ICES Arctic Fisheries Working Group, 23 August - 1 September 1999.

Dalen, J. and Nakken, O. 1983. On the application of the echo integration method. ICES CM 1983/B: 19, 30 pp.

Dalen, J. and Smedstad, O. 1979. Acoustic method for estimating absolute abundance of young cod and haddock in the Barents Sea. ICES CM 1979/G:51, 24pp.

Dalen, J. and Smedstad, O. 1983. Abundance estimation of demersal fish in the Barents Sea by an extended acoustic method. *In* Nakken, O. and S.C. Venema (eds.), Symposium on fisheries acoustics. Selected papers of the ICES/FAO Symposium on fisheries acoustics. Bergen, Norway, 21-24 June 1982. FAO Fish Rep., (300): 232-239.

Dickson, W. 1993a. Estimation of the capture efficiency of trawl gear. I: Development of a theoretical model. Fisheries Research 16: 239-253.

Dickson, W. 1993b. Estimation of the capture efficiency of trawl gear. II: Testing a theoretical model. Fisheries Research 16: 255-272.

Engås, A. 1995. Trålmanual Campelen 1800. Versjon 1, 17. januar 1995, Havforskningsinstituttet, Bergen. 16 s. (upubl.).

Engås, A. and Godø, O.R. 1989. Escape of fish under the fishing line of a Norwegian sampling trawl and its influence on survey results. Journal du Conseil International pour l'Exploration de la Mer, 45: 269-276

Engås, A. and Ona, E. 1993. Experiences using the constraint technique on bottom trawl doors. ICES CM 1993/B:18, 10pp.

Foote, K.G. 1987. Fish target strengths for use in echo integrator surveys. Journal of the Acoustical Society of America, 82: 981-987.

Godø, O.R. and Sunnanå, K. 1992. Size selection during trawl sampling of cod and haddock and its effect on abundance indices at age. Fisheries Research, 13: 293-310.

ICES 2012. ICES. (Aglen, A., Bogstad, B., Dingsør, G.E., Gjøsæter, H., Hallfredsson, E.H., Mehl, S., Planque, B. et al.) 2012. Report of the Arctic Fisheries Working Group, ICES Headquarters, Copenhagen 20-26 April 2012. ICES CM 2012/ACOM: 05. 633 pp.

Jakobsen, T., Korsbrekke, K., Mehl, S. and Nakken, O. 1997. Norwegian combined acoustic and bottom trawl surveys for demersal fish in the Barents Sea during winter. ICES CM 1997/Y: 17, 26 pp.

Johannesen, E., Wenneck, T. de L., Høines, Å., Aglen, A., Mehl, S., Mjanger, H., Fotland, Å., Halland, T. I. and Jakobsen, T. 2009. Egner vintertoktet seg til overvåking av endringer i fiskesamfunnet i Barentshavet? En gjennomgang av metodikk og data fra 1981-2007. Fisken og Havet nr. 7/2009. 29s.

Jolly, G. M., & Hampton, I. (1990). A stratified random transect design for acoustic surveys of fish stocks. Canadian Journal of Fisheries and Aquatic Sciences, 47(7), 1282-1291.

Knudsen, H.P. 1990. The Bergen Echo Integrator: an introduction. - Journal du Conseil International pour l'Exploration de la Mer, 47: 167-174.

Korneliussen, R. J., Heggelund, Y., Macaulay, G. J., Patel, D., Johnsen, E., & Eliassen, I. K. (2016). Acoustic identification of marine species using a feature library. Methods in Oceanography, 17, 187-205.

Korsbrekke, K. 1996. Brukerveiledning for TOKT312 versjon 6.3. Intern program dokumentasjon., Havforskningsinstituttet, september 1996. 20s. (upubl.).

Korsbrekke, K., Mehl, S., Nakken, O. og Sunnanå, K. 1995. Bunnfiskundersøkelser i Barentshavet vinteren 1995. Fisken og Havet nr. 13 - 1995, Havforskningsinstituttet, 86 s.

MacLennan, D.N. and Simmonds, E.J. 1991. Fisheries Acoustics. Chapman Hall, London, England. 336pp.

Mehl, S., Aglen, A., Alexandrov, D.I., Bogstad, B., Dingsør, G.E., Gjøsæter, H., Johannesen, E., Korsbrekke, K., Murashko, P.A., Prozorkevich, D.V., Smirnov, O.V., Staby, A., and Wenneck, T. de Lange, 2013. Fish investigations in the Barents Sea winter 2007-2012. IMR/PINRO Joint Report Series 1-2013, 97 pp.

Mehl, S., Aglen, A., Bogstad, B., Dingsør, G.E., Gjøsæter, H., Godiksen, J., Johannesen, E., Korsbrekke, K., Murashko, P.A., Russkikh, A.A, Staby, A., Wenneck, T. de Lange, Wienerroither, R. 2014. Fish investigations in the Barents Sea winter 2013-2014. IMR/PINRO Joint Report Series 2014(2), 73 pp. ISSN 1502-8828.

Mehl, S. Aglen, A., Amelkin, A., Dingsør, G.E., Gjøsæter, H., Godiksen, Staby, A., Wenneck, T. de Lange, Wienerroither. 2015. Fish investigations in the Barents Sea, winter 2015. IMR-PINRO report series 2-2015. 61 pp.

Mehl, S., Aglen, A., Amelkin, A.V., Bogstad, B., Dingsør, G., Korsbrekke, K., Olsen, E., Russkikh, A.A., Staby, A., Wenneck, T. de Lange and Wienerroither, R. 2016. Fish investigations in the Barents Sea winter 2016. IMR/PINRO Joint Report Series 2016-4, 76pp.

Mehl, S., Aglen, A., Bogstad, B., Russkikh, A.A., Staby, A., Wenneck, T. de Lange and Wienerroither, R. 2017. Fish investigations in the Barents Sea winter 2017. IMR/PINRO Joint Report Series 2017-3, 87pp.

Mehl, S., Aglen, A., Gjøsæter, H., Godiksen, J. A., Russkikh, A.A., Staby, A., Tretyakov, I., Wenneck, T. de Lange and Wienerroither, R. 2018. Fish investigations in the Barents Sea winter 2018. IMR/PINRO Joint Report Series 2018-1, 82pp.

Mehl, S., Aglen, A. and Johnsen, E. 2016. Re-estimation of swept area indices with CVs for main demersal fish species in the Barents Sea winter survey 1994-2016 applying the Sea2Data StoX software. Fisken og havet 10/2016. Institute of Marine Research, Bergen, Norway. 43 pp.

Mehl, S., Aglen, A., Johnsen, E. and Skålevik, Å. 2018. Estimation of acoustic indices with CVs for cod and haddock in the Barents Sea winter survey 1994 – 2017 applying the Sea2Data StoX software. Fisken og havet no. 5-2018. ISSN 0071-5638. Institute of Marine Research, Bergen, Norway. 29 pp.

Mjanger, H., Svendsen, B.V., Senneset, H., Fotland, Å., Mehl, S., Fuglebakk, E., Gulbrandsen, M.L., og Diaz, J. 2019. Håndbok for prøvetaking av fisk, krepsdyr og andre evertebrater. Versjon 5.0. Januar 2019. (In Norwegian).

Totland, A. and Godø, OR. 2001. BEAM – an interactive GIS application for acoustic abundance estimation. In T. Nishida, P.R. Kailola and C.E. Hollingworth (eds.): Proceedings of the First Symposium on Geographic Information System (GIS) in Fisheries Science. Fishery GIS Research Group. Saitama, Japan.

Appendix 1. Annual survey reports 1981-2016

Dalen, J., Hylen, A. og Smedstad, O. M. 1981. Intern toktrapport unummerert. Havforskningsinstituttet.

Dalen, J., Hylen, A., Jakobsen, T., Nakken, O., Randa, K. and Smedstad, O. 1982. Norwegian investigations on young cod and haddock in the Barents Sea during the winter 1982. ICES CM 1982/G: 41, 20 pp.

Dalen, J., Hylen, A., Jakobsen, T., Nakken, O., Randa, K., and Smedstad, O. 1983. Preliminary report of the Norwegian investigations on young cod and haddock in the Barents Sea during the winter 1983. ICES CM 1983/G:15, 23 pp

Dalen, J., Hylen, A., Jakobsen, T., Nakken, O. and Randa, K. 1984. Preliminary report of the Norwegian Investigations on young cod and haddock in the Barents Sea during the winter 1984. ICES CM 1984/G:44, 26 pp.

Hylen, A., Jakobsen, T., Nakken, O. and Sunnanå, K. 1985. Preliminary report of the Norwegian Investigations on young cod and haddock in the Barents Sea during the winter 1985. ICES CM 1985/G:68, 28 pp.

Hylen, A., Jakobsen, T., Nakken, O., Nedreaas, K. and Sunnanå, K. 1986. Preliminary report of the Norwegian Investigations on young cod and haddock in the Barents Sea. ICES CM 1986/G:76, 25 pp.

Godø, O. R., Hylen, A., Jacobsen, J. A., Jakobsen, T., Mehl, S., Nedreaas, K. and Sunnanå, K. 1987. Estimates of stock size of Northeast Arctic cod and haddock from survey data 1986/1987. ICES CM 1987/G: 37.

Hylen, A., Jacobsen, J.A., Jakobsen, T., Mehl, S., Nedreaas, K. and Sunnanå, K. 1988. Estimates of stock size of Northeast Arctic cod and haddock, *Sebastes mentella* and *Sebastes marinus* from survey data, winter 1988. ICES CM 1988/G: 43.

Jakobsen, T., Mehl, S., Nakken, O., Nedreaas, K. and Sunnanå, S. 1989. Estimates of stock size of Northeast Arctic cod and haddock, *Sebastes mentella* and *Sebastes marinus* from survey data, winter 1989. ICES CM 1989/G: 42.

Jakobsen, T., Mehl, S. og Nedreaas, K. 1990. Kartlegging av mengde og utbredelse av torsk, hyse og uer i Barentshavet januar mars 1990. Intern toktrapport, Senter for marine ressurser, Havforskningsinstituttet, Bergen. Engelsk abstrakt, tabell og figurtekster. 29 s. (upubl.).

Hylen, A., Jakobsen, T., Mehl, S., og Nedreaas, K. 1991. Undersøkelser av torsk, hyse og uer i Barentshavet vinteren 1991. Intern toktrapport nr. 1 -1992, Senter for marine ressurser, Havforskningsinstituttet, Bergen. Engelsk abstrakt, tabell og figurtekster. 30 s. (upubl.).

Godø, O.R., Jakobsen, T., Mehl, S., Nedreaas, K. og Raknes, A. 1992. Undersøkelser av torsk, hyse og uer i Barentshavet vinteren 1992. Intern toktrapport 39/92, Senter for marine ressurser, Havforskningsinstituttet, Bergen. Engelsk abstrakt, tabell og figurtekster. 33 s. (upubl.).

Korsbrekke, K., Mehl, S., Nakken, O. and Nedreaas, K. 1993. Bunnfiskundersøkelser i Barentshavet vinteren 1993. Rapp. Senter Marine Ressurser nr. 14-1993. Engelsk abstrakt, tabell- og figurtekster. 47s. Havforskningsinstituttet, Bergen.

Mehl, S. og Nakken, O. 1994. Bunnfiskundersøkelser i Barentshavet vinteren 1994. Fisken Hav (6) 1994. 72 s. Havforskningsinstituttet, Bergen.

Korsbrekke, K., Mehl, S., Nakken, O. og Sunnanå, K. 1995. Bunnfiskundersøkelser i Barentshavet vinteren 1995. Fisken Hav (13) 1995. 86 s. Havforskningsinstituttet, Bergen.

Mehl, S. og Nakken, O. 1996. Botnfiskundersøkingar i Barentshavet vinteren 1996. Fisken Hav (11) 1996. 68 s. Havforskingsinstituttet, Bergen.

Mehl, S. 1997. Botnfiskundersøkingar i Barentshavet (norsk sone) vinteren 1997. Fisken Hav (11) 1997. 72 s. Havforskingsinstituttet, Bergen.

Mehl, S. 1998. Botnfiskundersøkingar i Barentshavet (redusert område) vinteren 1998. Fisken Hav (7) 1998. 69 s. Havforskingsinstituttet, Bergen.

Mehl, S. 1999. Botnfiskundersøkingar i Barentshavet vinteren 1999. Fisken Hav (13) 1999. 70 s. Havforskingsinstituttet, Bergen.

Aglen, A., Drevetnyak, K., Jakobsen, T., Korsbrekke, K., Lepesevich, Y., Mehl, S., Nakken, O. and Nedreaas, K. 2001. Investigations on demersal fish in the Barents Sea winter 2000. Detailed report. IMR-PINRO Joint Report Series no. 5, 2001. 74 pp.

Aglen, A., Alvsvåg, J, Korsbrekke, K., Lepesevich, Y., Mehl, S., Nedreaas, K., Sokolov, K. and Ågotnes, P. 2002. Investigations on demersal fish in the Barents Sea winter 2001. Detailed report. IMR-PINRO Joint Report Series no. 2 2002, 66 pp.

Aglen, A., Alvsvåg, J., Drevetnyak, K, Høines, Å., Korsbrekke, K., Mehl, S., and Sokolov, K. 2002. Investigations on demersal fish in the Barents Sea winter 2002. Detailed report. IMR/PINRO Joint report series no 6, 2002. 63 pp.

Aglen, A., Alvsvåg, J., Halland, T.I., Høines, Å., Nakken, O., Russkikh, A., and., Smirnov, O. 2003. Investigations on demersal fish in the Barents Sea winter 2003. Detailed report. IMR/PINRO Joint report series no 1, 2003. 56pp.

Aglen, A., Alvsvåg, J., Høines, Å., Korsbrekke, K., Smirnov, O., and Zhukova, N., 2004. Investigations on demersal fish in the Barents Sea winter 2004. Detailed report. IMR/PINRO Joint report series no 5/2004, ISSN 1502-8828. 58pp.

Aglen, A., Alvsvåg, J., Grekov, A., Høines, Å., Mehl, S., and Zhukova, N. 2005. Investigations of demersal fish in the Barents Sea winter 2005. IMR/PINRO Joint Report Series, No 4/2005. ISSN 1502-8828, 58 pp.

Aglen, A., Alvsvåg, J., Høines, Å., Johannesen, E. and Mehl, S. 2008. Investigations on demersal fish in the Barents Sea winter 2006. Detailed report. Fisken Hav13 (2008). 49 pp.

Aglen, A. 2007. Report from demersal fish survey in the Barents Sea February-March 2007. WD #8 ICES Arctic Fisheries Working Group, Vigo, Spain 19-28 April 2007.

Aglen, A., Høines, Å., Mehl, S., Prozorkevich, D., Smirnov, O. and Wenneck, T. de L. 2008. Results from the Joint IMR-PINRO Barents Sea demersal fish survey 25 January – 14 March 2008. WD #16 ICES Arctic Fisheries Working Group, ICES Headquarters 21-29 April 2008.

Aglen, A., Alexandrov, D., Høines, Å., Mehl, S., Prozorkevich, D. and Wenneck, T. de L. 2009. Results from the Joint IMR-PINRO Barents Sea demersal fish survey 1 February – 15 March 2009. WD #11 ICES Arctic Fisheries Working Group, San-Sebastian, Spain 21-27 April 2007.

Aglen, A., Alexandrov, D., Gjøsæter, H., Johannesen, E., Mehl, S. and Wenneck, T. de L. 2010. Results from the Joint IMR-PINRO Barents Sea demersal fish survey 1 February – 17 March 2010. WD #15 ICES Arctic Fisheries Working Group, Lisbon, Portugal/Bergen, Norway 22-28 April 2010.

Aglen, A., Alexandrov, D., Gjøsæter, H., Johannesen, E. and Mehl, S. 2011. Results from the Joint IMR-PINRO Barents Sea demersal fish survey 1 February – 14 March 2011. WD #3 ICES Arctic Fisheries Working Group, Hamburg, Germany 28 April - 4 May 2011.

Aglen, A., Dingsør, G., Mehl, S., Murashko, P. and Wenneck, T. de L. 2012. Results from the Joint IMR-PINRO Barents Sea demersal fish survey 21 January – 15 March 2012. WD #3 ICES Arctic Fisheries Working Group, Copenhagen, Denmark 20-26 April 2012.

Aglen, A., Dingsør, G., Godiksen, J., Gjøsæter, H., Johannesen, E. and Murashko, P. 2013. Results from the Joint IMR-PINRO Barents Sea demersal fish survey 1 February – 13 March 2013. WD #3 ICES Arctic Fisheries Working Group, Copenhagen, Denmark 18-24 April 2013.

Aglen, A., Godiksen, J., Gjøsæter, H., Mehl, S., Russkikh, A. and Wenneck, T. de L. 2014. Results from the Joint IMR-PINRO Barents Sea demersal fish survey 22 January – 8 March 2014. WD #3 ICES Arctic Fisheries Working Group, Lisbon, Portugal 23-29 April 2014.

Mehl, S. Aglen, A., Amelkin, A., Dingsør, G.E., Gjøsæter, H., Godiksen, Staby, A., Wenneck, T. de Lange, Wienerroither. 2015. Fish investigations in the Barents Sea, winter 2015. WD #1 ICES Arctic Fisheries Working Group, Hamburg, Germany 23-29 April 2015.

Mehl, S., Aglen, A., Amelkin, A.V., Bogstad, B., Korsbrekke, K., Olsen, E., Russkikh, A.A., Staby, A., Wenneck, T. de Lange and Wienerroither, R. 2016. Fish investigations in the Barents Sea winter 2016. Preliminary report. Working Document # 4 Arctic Fisheries Working Group, ICES HQ, Copenhagen, Denmark, 19-25 April 2016.

Mehl, S., Aglen, A., Bogstad, B., Russkikh, A.A., Staby, A., Wenneck, T. de Lange and Wienerroither, R. 2017. Fish investigations in the Barents Sea winter 2017. Preliminary report. Working Document # 3 Arctic Fisheries Working Group, ICES HQ, Copenhagen, Denmark, 19-25 April 2017.

Mehl, S., Aglen, A., Gjøsæter, H., Godiksen, J. A., Russkikh, A.A., Staby, A., Tretyakov, I. and Wenneck, T. de Lange. 2018. Fish investigations in the Barents Sea winter 2018. Working Document # 1 Arctic Fisheries Working Group, 19-25 April 2018.

Appendix 2. Changes in survey design, methods, gear etc.

Year	Change from	To
1984	Representative age sample, 100 per station	Stratified age sample, 5 per 5-cm length group
1986	1 research vessel, 2 commercial trawlers	2 research vessels, 1 commercial trawler
1987	60 min. tow duration	30 min. tow duration
1989	Bobbins gear	Rock-hopper gear (time series adjusted for cod and haddock)
1990	Random stratified bottom trawl stations	Fixed station grid, 20 nm distance
	Simrad EK400 echo sounder	Simrad EK500 echo sounder and BEI post processing
1993	TS = 21.8 log L – 74.9 for cod and haddock	TS = 20 log L – 68 for all demersal species (time series corrected)
	Fixed survey area (ABCD), 1 strata system, 35 strata	Extended, variable survey area (ABCDD'ES) 2 strata systems, 53 + 10 strata
	Fixed station grid, 20 nm distance	Fixed station grid, 20/30/40 nm distance
	No constraint technique (strapping) on bottom trawl doors	Constraint technique on some bottom trawl hauls
	5 age samples per 5-cm group, 2 per stratum	2 age samples per 5-cm group, 4 per stratum (cod and haddock)
	Weighting of age-length keys by total catch	Weighting of ALK by swept area estimate
1994	35-40 mm mesh size in cod-end	22 mm mesh size in cod-end
	Strapping on some hauls	Strapping on every 3. haul
	Hull mounted transducers	Keel mounted transducers Johan Hjort
1995	Variable use of trawl sensors	Trawl manual specifying use of sensors
	Constant effective fishing width of the trawl	Fish size dependent effective fishing width (time series corrected)
	Strapping on every 3. haul	Strapping on every 2. haul
	2 research vessels, 1 commercial trawler	3 research vessels
1996	2 strata systems and 63 strata, 20/30/40 nm distance	1 strata system and 23 strata, 16/24/32 nm distance
	2 age samples per 5-cm group, 4 per stratum	1 age sample per 5-cm group, all stations with > 10 specimens (cod and haddock)
1997	16/24/32 nm distance	20 nm distance
	Hull mounted transducers	Keel mounted transducers G.O. Sars (Sarsen)
1998	Strapping on every 2. haul	Strapping on every haul
	20 nm distance	20/30 nm distance
2000	3 Norwegian research vessels	2 Norwegian and 1 Russian research vessel
2002	20/30 nm distance station grid	16/20/24/32 nm distance station grid
2003	Height trawl sensor for opening and bottom contact	Trawl eye for opening and bottom contact
2004	Vaco trawl doors	V- doors G.O. Sars and Johan Hjort
	EK 500 Sarsen	ER60 G.O. Sars
2005	EK 500	ER60 Johan Hjort and Russian vessels
2006	Standard Campelen rigging	"Tromsø rigging" on Norwegian vessels
2007	BEI	LSSS Norwegian vessels
2008	V trawl doors	Thyborøn doors Jan Mayen/Helmer Hanssen
2010	V trawl doors	Thyborøn doors G.O. Sars and Johan Hjort
2011	30 min. tow duration	15 min. tow duration
2015	"Tromsø rigging" on Norwegian vessels	Standard Campelen rigging
2017	Swept-area estimates by the Survey Program	Swept-area and CV estimates by StoX software
	EK 60 on G.O. Sars	EK80 in EK 60 modus on G.O. Sars
2018	Acoustic estimates by the BEAM Program	Acoustic and CV estimates by StoX software
	EK 60 on Johan Hjort	EK80 in EK 60 modus on Johan Hjort

WD:05
ICES AFWG 2019

The Spanish NE Arctic Cod Fishery in 2018

José Miguel Casas Sánchez
Ane Iriondo
Instituto Español de Oceanografía,
P.O. Box 1552, Vigo, Spain

In 2018 the Spanish fleet targeting for cod was composed by 5 single trawls. The activity of this fleet was carried out in ICES fishing areas I, IIa and IIb throughout year.

Scientific sampling in 2018 was carried out on board of one vessel. The observers recorded catch, effort and biological data from April to May in ICES Division Ib and from April to July in ICES Division IIb.

Table 1 shows catches of cod and by-catches by month and Division along with the effort distribution (number of otter trawls, number of days and estimated hours of activity), and the overall monthly yield of the otter trawls for the target species, V. gr. cod. Catch and effort data (by fishing days and hours), for the whole fleet have been estimated from the data provided by the Spanish General Secretary of Fisheries and the information gathered by the scientific observers on board. In Figure 1 the percentage of cod landings by each fishing grounds exploited is represented.

Tables 2 and 3 show the length and age distribution of cod catches by areas and quarters from on-board sampling. When the length distribution for a specific area/quarter was not available, a summarised length frequency from neighbouring areas or quarters was used. In the same way, the gaps in age-length distributions in determined areas and quarters were filled with data from neighbouring areas or quarters. The rest of gaps were filled in with information from the age-length key produced for the long-term period (2001-2017). In Figure 2, the cod length distribution as percentage by each fishing ground is shown.

Table 1.- Cod catches (kg) and estimated by-catch of the Spanish fleet in ICES Subarea I, Divisions IIa and IIb in 2018

BARENTS SEA SUBAREA (I)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
COD				519940	574104		105119	970641	444867		665	4021	2619356
HADDOCK				15124	8591		191	799	214				24920
REDFISH				2518	2150								4668
WOLFFISH				1863	1883			74	96		85	73	4074
LONG ROUGH DAB				65	65		122	1670	1042		14		2979
GREENLAND HALIBUT				916	537						42	126	1621
POLLOCK				573	343								916
Number of **otter trawls**				2	2		1	2	2		1	1	5
Fishing days (**otter trawls**)				19	20		4	32	25		1	1	102
Fishing hours (**otter trawls**)				366	352		58	544	435		3	4	1762
CPUE (kg/h) (**otter trawls**)				1422	1629		1823	1784	1022		222	1005	1486

NORWAY ZEE NORTH OF 62º (IIA)	Jan	Feb	Mar	Apr	May[1]	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
COD		62665	1139809	208031	50869								1461374
POLLOCK		4433	35245	19243									58920
REDFISH		32	760	846	41348								42986
HADDOCK		3075	2513	55	343								5985
ATLANTIC HALIBUT			1266	419									1685
LING		100	51										151
WOLFFISH					82								82
Number of **otter trawls**		1	1	1	2								2
Fishing days (**otter trawls**)		4	31	8	4								45
Fishing hours (**otter trawls**)		55	548	162	45								787
CPUE (kg/h) (**otter trawls**)		1138	2080	1282	1141								1857

[1] direct fisheries to redfish

Table 1 Cont.

SVALBARD (DIVISION IIB)	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Total**
COD				227627	1727441	2221804	1429722	791932	454224		909170	1300703	9062624
HADDOCK				217	20078	32799	27070	755			42266	15149	138334
GREENLAND HALIBUT				94	13300	18434	582	96			12503	13055	58065
WOLFFISH				1100	4851	6278	7890	513			14273	15995	50898
LONG ROUGH DAB				510	9250	7840	3034	1390	1050		1638	2590	27303
REDFISH				4076	945	4600					7938	3528	21087
GOLDEN REDFISH					573	178	38						789
POLLOCK				230									230
ATLANTIC HALIBUT					86						42	10	138
Number of **otter trawls**				2	4	4	3	2	2		1	1	5
Fishing days (**otter trawls**)				9	66	68	58	27	21		29	31	309
Fishing hours (**otter trawls**)				178	1262	1249	1045	432	359		494	544	5561
CPUE (kg/h) (**otter trawls**)				1282	1369	1780	1368	1834	1264		1842	2393	1630

Table 2: Length distribution of cod Spanish catches in ICES Subarea I, 2018

Length group (cm)	1st Q.	2nd Q.	3rd Q.	4th Q.	ALL
31-33					
34-36			0		0
37-39			289		289
40-42			1209		1209
43-45			2103		2103
46-48			3093		3093
49-51			4529		4529
52-54			5880		5880
55-57			8115		8115
58-60			12217		12217
61-63			14935		14935
64-66			15261		15261
67-69			14542		14542
70-72			15564		15564
73-75			11120		11120
76-78			8372		8372
79-81			5874		5874
82-84			3268		3268
85-87			1985		1985
88-90			1298		1298
91-93			710		710
94-96			529		529
97-99			224		224
100-102			128		128
103-105			109		109
106-108			13		13
109-111			25		25
112-114			0		0
115-117			6		6
118-120			11		11
121-123					
124-126					
127-129					
130-132					
133-135					
136-139					
Total			131404		131404
No. Samples			35		35
No. F. Measured			7412		7412
[1]Sampling Weight (kg)			294671		294671
Mean Length (cm)			66.1		66.1

[1]Weights corresponding to the length distributions

Table 2(cont.): Length distribution of cod Spanish catches in ICES Subarea IIb, 2018

Length group (cm)	1st Q.	2nd Q.	3rd Q.	4th Q.	ALL
22-24		0	76		76
25-27		362	377		739
28-30		861	718		1579
31-33		0	1321		1321
34-36		65	3336		3401
37-39		164	5051		5215
40-42		765	7704		8469
43-45		1535	9770		11306
46-48		2483	10164		12647
49-51		5900	13389		19290
52-54		10582	15184		25767
55-57		20442	14217		34660
58-60		27237	19032		46270
61-63		40121	19695		59816
64-66		44655	23175		67829
67-69		49966	19300		69267
70-72		46044	21199		67243
73-75		32706	14011		46718
76-78		21186	11274		32461
79-81		10666	5461		16127
82-84		5156	3051		8207
85-87		3765	2856		6622
88-90		2017	1534		3552
91-93		1009	1012		2021
94-96		696	343		1039
97-99		508	414		922
100-102		491	246		737
103-105		164	163		327
106-108		89	76		165
109-111		76	0		76
112-114		0	0		0
115-117		20	38		58
Total		329731	224187		553918
No. Samples		82	25		107
No. F. Measured		15982	2539		18521
[1]Sampling Weight (kg)		760824	446950		1207774
Mean Length (cm)		66.9	61.3		64.6

[1]Weights corresponding to the length distributions

Table 3: Age distribution of cod Spanish catches in ICES in ICES Subarea I, 2018

BARENTS SEA SUBAREA (I)	1st QUARTER			2nd QUARTER			3rd QUARTER[1]			4th QUARTER[1]			TOTAL[1]		
AGE	Number ´000	M. Length cm	M. Weight g	Number ´000	M. Length cm	M. Weight g	Number ´000	M. Length cm	M. Weight g	Number ´000	M. Length cm	M. Weight g	Number ´000	M. Length cm	M. Weight g
1															
2															
3				2.674	41.5	554	3.716	41.5	554	0.011	41.5	554	6.402	41.5	554
4				39.877	48.3	869	55.425	48.3	869	0.171	48.3	869	95.472	48.3	869
5				64.948	55.8	1304	90.273	55.8	1304	0.278	55.8	1304	155.499	55.8	1304
6				133.765	63.0	1851	185.921	63.0	1851	0.573	63.0	1851	320.259	63.0	1851
7				185.997	70.8	2592	258.519	70.8	2592	0.797	70.8	2592	445.313	70.8	2592
8				44.987	79.6	3622	62.528	79.6	3622	0.193	79.6	3622	107.707	79.6	3622
9				11.803	88.6	4930	16.405	88.6	4930	0.051	88.6	4930	28.259	88.6	4930
10				2.915	90.7	5329	4.051	90.7	5329	0.012	90.7	5329	6.979	90.7	5329
11				0.335	103.5	7763	0.466	103.5	7763	0.001	103.5	7763	0.802	103.5	7763
12				0.491	99.1	6873	0.682	99.1	6873	0.002	99.1	6873	1.176	99.1	6873
13				0.101	104.7	8026	0.141	104.7	8026	0.000	104.7	8026	0.242	104.7	8026
14															
15															
16															
17															
T. NUMBER (‘000)				487.892			678.127			2.090			1168.108		
No. of fish measured				7412			-			-			7412		
TOTAL CATCH (t)				1094.044			1520.626			4.686			2619.356		
SAMPLED CATCH (t)				294.671			-			-			294.671		
#OTOLITHS[2]				911			911			911			911		
MEAN WEIGHT (g)				2242			-			-			2242		

[1] length samples from I and 2nd quarter
[2] otolith samples from I and II, 2nd and 3rd quarter

Table 3 (cont): Age distribution of cod Spanish catches in ICES in ICES Division IIa, 2018

NORWAY ZEE NORTH OF 62º (IIA)	1st QUARTER[1]			2nd QUARTER[1]			3rd QUARTER			4th QUARTER			TOTAL		
AGE	Number ´000	M. Length cm	M. Weight g	Number ´000	M. Length cm	M. Weight g	Number ´000	M. Length cm	M. Weight g	Number ´000	M Length cm	M. Weight g	Number ´000	M. Length cm	M. Weight g
1															
2	1.933	28.0	180	0.416	28.0	180							2.349	28.0	180
3	0.863	41.0	540	0.186	41.0	540							1.049	41.0	540
4	19.435	50.1	962	4.184	50.1	962							23.620	50.1	962
5	59.520	56.4	1347	12.815	56.4	1347							72.335	56.4	1347
6	154.796	63.4	1883	33.328	63.4	1883							188.124	63.4	1883
7	232.548	70.5	2558	50.069	70.5	2558							282.616	70.5	2558
8	40.749	78.7	3503	8.774	78.7	3503							49.523	78.7	3503
9	8.007	88.3	4893	1.724	88.3	4893							9.731	88.3	4893
10	2.428	92.5	5653	0.523	92.5	5653							2.951	92.5	5653
11	0.415	103.6	7768	0.089	103.6	7768							0.504	103.6	7768
12	0.342	100.3	7119	0.074	100.3	7119							0.416	100.3	7119
13	0.105	100.6	7085	0.023	100.6	7085							0.127	100.6	7085
14															
15+															
T. NUMBER ('000)		521.140			112.205									633.345	
TOTAL CATCH (t)		1202.474			258.900									1461.374	
SAMPLED CATCH (t)		-			-									-	
#OTOLITHS[2]		-			-									-	
MEAN WEIGHT (g)		-			-									-	

[1] length samples from IIB 2nd quarter
[2] otolith samples from I and II, 2nd and 3rd quarter

Table 3 (cont): Age distribution of cod Spanish catches in ICES Division IIb, 2018

SVALBARD (IIB)	*1st QUARTER*			*2nd QUARTER*			*3rd QUARTER*			*4th QUARTER[1]*			*TOTAL*		
AGE	Number ´000	M. Length cm	M. Weight g	Number ´000	M. Length cm	M. Weight g	Number ´000	M. Length cm	M. Weight g	Number ´000	M Length cm	M. Weight g	Number ´000	M. Length cm	M. Weight g
1															
2				6.714	28.0	180	9.585	28.5	170	7.916	28.5	170	21.191	28.3	186
3				2.999	41.0	540	57.942	37.8	406	47.851	37.8	406	76.719	38.0	435
4				67.509	50.1	962	239.257	46.3	764	197.591	46.3	764	392.138	47.2	818
5				206.745	56.4	1347	209.143	54.9	1264	172.721	54.9	1264	544.700	55.7	1297
6				537.693	63.4	1883	312.321	62.8	1912	257.930	62.8	1912	1126.349	63.2	1865
7				807.769	70.5	2558	398.723	70.6	2745	329.285	70.6	2745	1603.774	70.5	2561
8				141.545	78.7	3503	84.203	79.2	3903	69.539	79.2	3903	298.994	78.9	3526
9				27.812	88.3	4893	22.882	88.8	5548	18.897	88.8	5548	66.691	88.5	4922
10				8.434	92.5	5653	5.656	91.2	6080	4.671	91.2	6080	18.616	92.0	5557
11				1.440	103.6	7768	1.001	104.7	9265	0.827	104.7	9265	3.223	104.1	7864
12				1.189	100.3	7119	1.288	100.4	8228	1.064	100.4	8228	3.239	100.4	7142
13				0.364	100.6	7085	0.236	100.7	8139	0.195	100.7	8139	0.794	100.7	7092
14															
15+															
T. NUMBER (‘000)				1810.213			1342.237			1108.486			4156.428		
No. of fish measured				15982			2539			-			18521		
TOTAL CATCH (t)				4176.872			2675.878			2209.874			9062.624		
SAMPLED CATCH (t)				96.749			230.600			-			327.349		
# OTOLITHS[2]				911			911			911			911		
MEAN WEIGHT (g)				2280			1885			1885			2120		

[1] length samples from IIB 3rd quarter
[2] otolith samples from I and II, 2nd and 3rd quarter

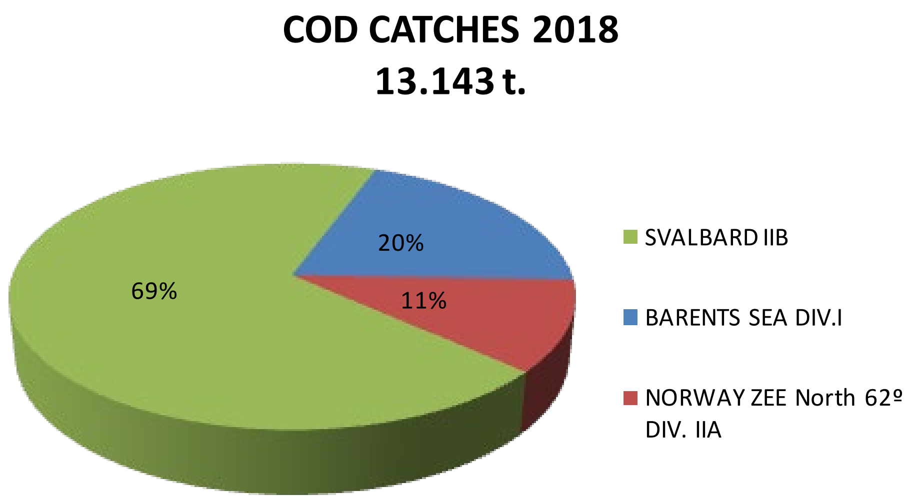


Figure 1: Catches of cod (%) by Spanish fleet in different fishing grounds during 2018.

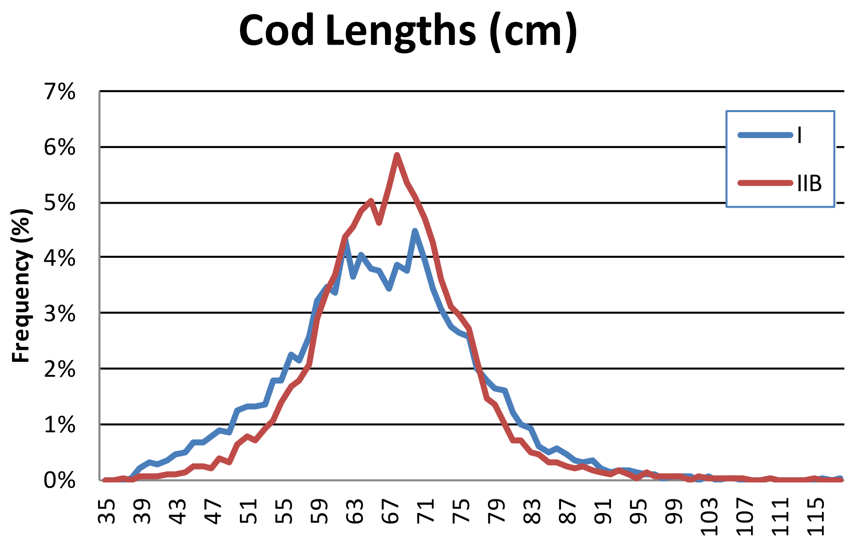


Figure 2: Length distributions of cod (%) in sampled fishing grounds during 2018.

WD:06
ICES AFWG 2019

The Spanish Pelagic Redfish Fishery in 2018

José Miguel Casas
Instituto Español de Oceanografía
P.O. Box 1552, Vigo, Spain

In 2018 the Spanish fleet targeting for pelagic redfish in ICES Division IIa was composed by 3 single trawls. The activity of this fleet was carried out in the Norwegian Sea outside EEZs from June to September.

Scientific sampling was carried out on board one of this vessel during 4 months from June to September. The observer recorded catch, effort and biological data (length distribution, sex ratio and length-weight relationship).

Table 1 shows catches of pelagic redfish and main by-catches of other species by month (estimated from the observer data), together with the distribution of effort (number of otter trawls, number of days and hours of activity) as well as the overall monthly yield of the otter trawls for the target species, V. gr. redfish. Catch and effort data for the whole fleet have been estimated from the data provided by the Spanish General Secretary of Fisheries.

Table 1.- Pelagic redfish catches and main bycatch species (kg) of the Spanish fleet in ICES Divisions IIa in 2018.

NORWAY ZEE NORTH OF 62º (IIA)	**Jun**	**Jul**	**Aug**	**Sep**	**Total**
PELAGIC REDFISH	158338	982326	920716	337723	2399103
POLLOCK		1258	580		1839
COD		422	356		778
HADDOCK			42		42
NORTHERN WOLFFISH			70	86	156
BLUE WHITING				882	882
Number of vessels	2	3	3	2	3
Fishing days	17	62	86	34	199
Fishing hours	277	1311	1860	689	4137
CPUE (kg/h)	572	749	495	490	580

Table 2.- Pelagic Redfish length distributions by sex and month of the Spanish catches carried out in ICES Division IIa in 2018.

	June		July		August		September		Total	
Total length (cm)	Males	Females	Males	Females	Males	Females	Males	Females	Males	Females
28	0	0	0	0	0	465	0	0	0	373
29	0	110	0	0	711	281	133	193	703	553
30	0	61	241	0	0	131	301	216	571	392
31	339	392	121	222	3013	281	879	875	3838	1825
32	665	171	4750	3259	4853	699	3062	1914	13184	6393
33	1794	1263	9695	6371	14596	5026	11594	2592	36414	15486
34	4325	2141	21749	13654	29344	11900	23502	5741	76902	33568
35	10122	3674	53670	27497	70680	21663	50992	12868	180888	66223
36	18563	7782	110301	47024	117372	44882	88623	16505	330846	116078
37	22975	17320	149696	97298	167323	90307	98993	21037	432015	226903
38	17225	32230	110299	161347	135270	142669	62251	34139	317936	374237
39	10639	29898	68464	219133	79431	161955	26214	23236	181572	442906
40	4309	21984	27298	147144	32352	110375	12617	16867	75128	302325
41	719	8049	8890	73809	8321	60358	3588	6930	21326	150449
42	525	3858	1335	37500	1443	20253	927	418	4256	64773
43	0	1297	136	7239	1224	4436	0	412	1143	13937
44	0	173	0	1274	0	470	0	0	0	2063
45	0	0	0	168	0	653	0	0	0	719
46	0	0	0	0	0	88	0	0	0	71
TOTAL	92200	130403	566645	842938	665931	676894	383676	143943	1676720	1819274
No. of fish measured	598	765	1571	2324	2001	2184	1561	634	5731	5907
No. Samples	11		26		28		15		80	
Total catch (kg)	158338		982326		920716		140057		2399103	

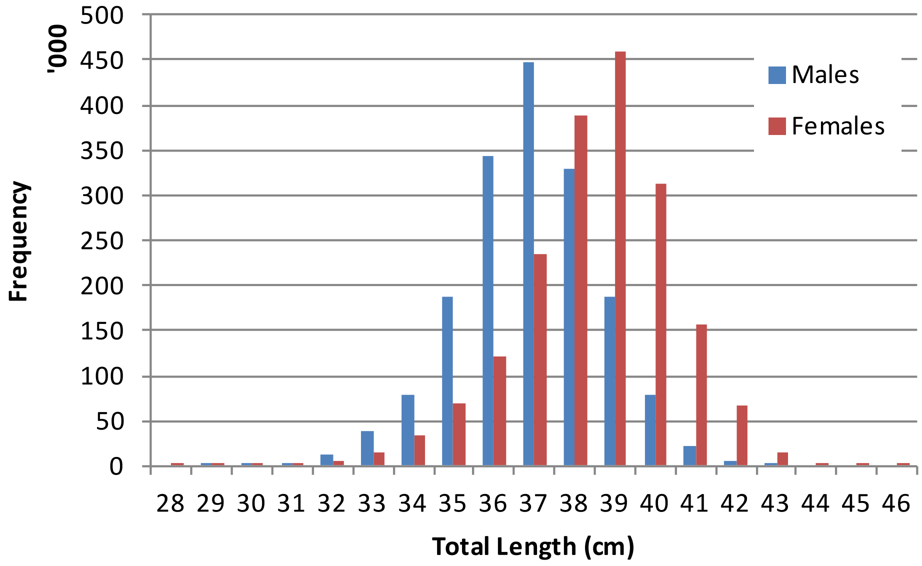


Figure 1.- Length composition of the Pelagic Redfish *S. mentella* on Division IIa in 2018.

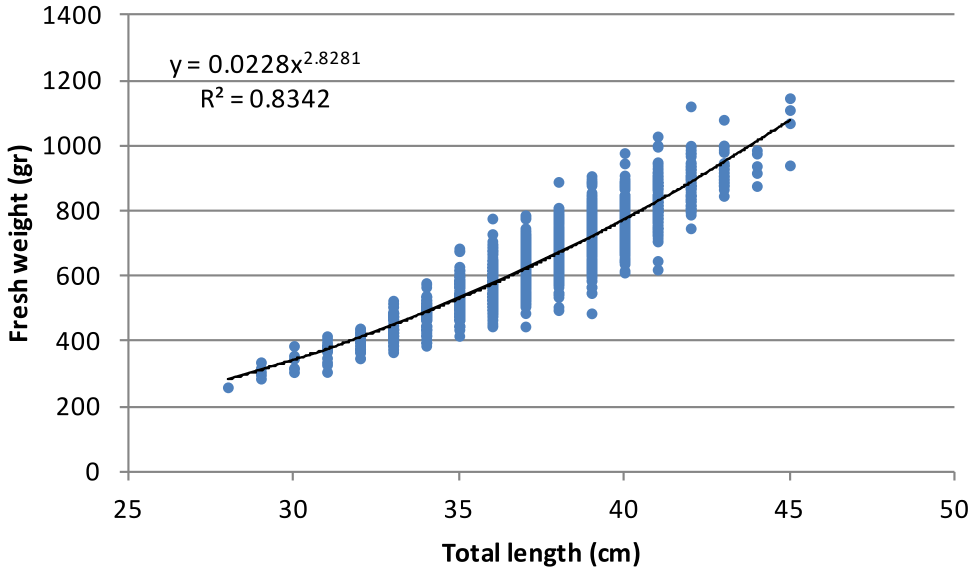


Figure 2.- Length weight relationship from pelagic redfish in ICES Division IIa 2018

Working document for AFWG2019: Using structures from XSAM in the NEA cod assessment

Olav Nikolai Breivik[1], Anders Nielsen[2] and Sondre Aanes[3]

[1]Norwegian Computing Center, Oslo, Norway, Email: olavbr@nr.no

[2]Technical University of Denmark, Copenhagen, Denmark

[3]Norwegian Computing Center, Oslo, Norway

April 30, 2019

1 Introduction

Input data in the NEA cod assessment are point estimates of the indices and commercial catches. There exists data on the uncertainty of these point estimates, and these are currently *not* utilised in the assessment. It is possible to include external uncertainty structures in the SAM framework (Berg et al., 2014), and it is the inclusion of these structures which is the main idea behind XSAM (Aanes, 2016a).

Anders Nielsen and Olav Nikolai Breivik has collaborated to include all options from XSAM into SAM before AFWG2019. During AFWG2019, Olav Nikolai Breivik will run SAM with some XSAM options to investigate how the assessment is affected.

2 Data

The data we have available are uncertainty estimates of is the FLT15 index and the commercial catches. These time series with uncertainty estimates are currently *not* utilized in the assessment. The resolution of the covariance data are year and age, meaning we have separate variance estimates for each age in each year. Within each year and fleet, we further have an estimate of the correlation structure. The variance time series are uploaded to SharePoint in files named "varCatch" and "varFLT15", and the correlation time series are uploaded in a file named "corFLT15". Note that only variance estimates of the commercial catch are included.

The time series representing the covariance structures uploaded at SharePoint are smoothed versions of the yearly estimated covariance structures. In section 4 we elaborate the smoothing procedure.

Note that all data used in this working document is based on data from the 2018 NEA cod assessment. During AFWG2019, the data will be updated.

3 Merging XSAM into SAM

In this subsection we elaborate the new features implemented in SAM, which enables us to run SAM with XSAM options. The source code is available at github (https://github.com/fishfollower/SAM). We start with the most important part, the inclusion of covariance structures as input to the assessment model.

3.1 Utilizing covariance structures

The observation equations in SAM are given by

$$\begin{aligned} \log C_{a,y} &= \log\left(\frac{F_{a,y}}{F_{a,y}+M_{a,y}}(1-e^{-F_{a,y}-M_{a,y}})N_{a,y}\right)+\epsilon^{c}_{a,y} \\ \log I^{(s)}_{y} &= \log(Q^{(s)}_{a}e^{-(F_{a,y}+M_{a,y})day^{(s)}/365}N_{a,y})+\epsilon^{s}_{a,y}. \end{aligned} \tag{1}$$

XSAM assumes that the covariance structures of the error terms in (1) can be expressed as

$$\boldsymbol{\epsilon}_y \sim N(0,c\boldsymbol{\Sigma}_y), \tag{2}$$

were $\{\boldsymbol{\Sigma}_y\}$ is a given time series of covariance matrices. Further is c a parameter estimated by the model. For brevity we do not included subscripts for surveys and catch in (2). Note further that the usage of external covariance matrices trough (2) is the same as the option given by equation (8) in Berg et al. (2014). In SAM, $\boldsymbol{\Sigma}_y$ is typically estimated inside the assessment model. Anders Nielsen and Olav Nikolai Breivik included the option for including external time series with covariance structures trough (2) in SAM during AFWG2018.

The option for including a time series with covariance matrices, $\boldsymbol{\Sigma}_y$, is included in SAM at the master branch at github.

3.2 Separate F-structure

The model for fishing mortality in XSAM builds on the formulation by Gudmundsson (1994) which assumes

$$\log \mathbf{F}_y = \log \mathbf{U}_y + \log \mathbf{V}_y + \boldsymbol{\epsilon}_y^{(F)} \tag{3}$$

Here both $\log \mathbf{U}$ and $\log \mathbf{V}$ follows standard Gaussian AR1 structures in time, and $\boldsymbol{\epsilon}^{(F)}$ is Gaussian noise. It is further imposed the restrictions that $\sum_a \log U_{a,y} = 0$ and $\log \mathbf{V}_{a_1,y} = \log \mathbf{V}_{a_2,y}$ for all a_1 and a_2. In (3), $\log \mathbf{U}$ can therefore be interpreted as the selectivity, and $\log \mathbf{V}$ as the effort.

The separable fishing mortality (3) is implemented as an option in SAM. We have however not yet found an example were the variance of $\boldsymbol{\epsilon}_y^{(F)}$ converge to any sensible value other than zero. XSAM is used for assessment of Norwegian Spring Spawning herring, and also for that stock does the variance of $\boldsymbol{\epsilon}_y^{(F)}$ converge to zero.

The separable fishing mortality (3) is currently included in SAM at a development branch at github.

3.3 Process error

The process equations in SAM are given by

$$\begin{aligned}
\log N_{1,y} &= \log R(\mathbf{N}_{y-1}) + \eta_{1,y} \\
\log N_{a,y} &= \log N_{a-1,y-1} - F_{a-1,y-1} - M_{a-1,y-1} + \eta_{a,y} \\
\log N_{A,y} &= \log \Big(\sum_{a=A-1}^{A} N_{a,y-1} \exp(-F_{a,y-1} - M_{a,y-1}) \Big) + \eta_{A,y}.
\end{aligned}$$

XSAM does not include η_a for $a > 1$. The removal of η_a for $a > 1$ is currently included in SAM at a development branch.

3.4 Recruitment function

XSAM includes an option for recruitment given by:

$$\log N_{1,y} \sim N(\mu_r, \sigma_r^2) \tag{4}$$

The recruitment function given by (4) is implemented in SAM, and can be used by setting the recruitment option equal 3 in the configurations. This structure is included in SAM at the master branch.

4 Smoothing covariance structures

It is reasonable that the yearly estimated covariance structures include noise and thereby should be smoothed before included in the assessment. In this section we describe how the covariance structures are smoothed. Let $v_{a,y,f}$ be the empirical variance of of the index at age a in year y by fleet f. We smooth the variance by assuming the log-variance can be expressed as a function of the log-index given by $\alpha_f + \beta_f \log(\mu)$. We further estimate β_f and α_f by means of least square. In SAM we need the standard deviation of the log-index. The variance on log scale, σ^2, is obtained by assuming the log-index is normally distributed and thereby is

$$\begin{aligned} \sigma^2 &= \log(CV_{obs}^2 + 1) \\ &= \log(e^{\alpha}\mu^{\beta-2} + 1). \end{aligned} \tag{5}$$

Here CV_{obs} is the CV at the original scale, and μ is the index at original scale.

The parameters α_f and β_f for the FLT15 survey index are estimated as -0.868 and 1.613 respectively. These estimates are based on 500 bootstrap samples from Rstox in the period 1994 to 2018 (except for year 2015 and 2016 because of issues related to extracting bootstrap samples from those years).

The parameters α_f and β_f for catch at age are estimated based on samples from R-ECA (Hirst et al., 2005), which is a program that currently estimates Norwegian catch at age. It is further assumed that the parameters in (5) for the international catch at age is the same as for the

Model	Log-likelihood
Current	-1342.6
Current+varC	-1162.6
Current+varC+varI	-1121.6
Current+varC+covI	-1135.4

Table 1: Log-likelihood obtained with different selections of covariance structures. The term "varC" and "varI" implies that the variance of the catches and indices are included. The term "covI" implies that the smoothed empirical correlation is included. An AR1 structure is assumed if the empirical covariance is not used.

Norwegian catch at age. We estimate α_f and β_f based on 500 samples from R-ECA for the years 2001 to 2011, and obtain $\alpha_f = 0.0814$ and $\beta = 1.475$. Note that these estimates differs from Aanes (2017), the difference is caused by that we use the same scale for catch at age as used in assessment when estimating α and β.

In this working document the correlation matrix is further smoothed by using a common average empirical correlation matrix for all years. We base the average empirical correlation matrix on log-index samples in years we have observations from all ages, and simply take the average of all those correlation matrices.

5 NEA cod assessment with variance time series

In this section we illustrate assessment results for NEA cod when utilizing variance time series in SAM, and compare these with the original assessment. The comparison is only based on including external variance estimates in the original assessment. We have not included correlation structures in this working document because the best likelihood is obtained with estimating the correlation structure inside SAM, see table 1. In Aanes (2017) the external covariance structures was also not used for NEA cod assessment. At AFWG2019, results with using more structures will be illustrated.

Figure 1 illustrates the estimated SSB based on the 2018-assessment with use of the variance time series for FLT15 survey and the commercial catches. Figure 2 further illustrates the one-step-ahead residuals, and figure 3 shows retrospective plots.

The scaling parameter c in (2) is estimated to be 2.0 (1.6, 2.5) for catch at age, and 6.8 (4,9, 9.9) for the FLT15 index. Numbers in parentheses are 95% confidence intervals. Table 2 gives a summary of the assessment.

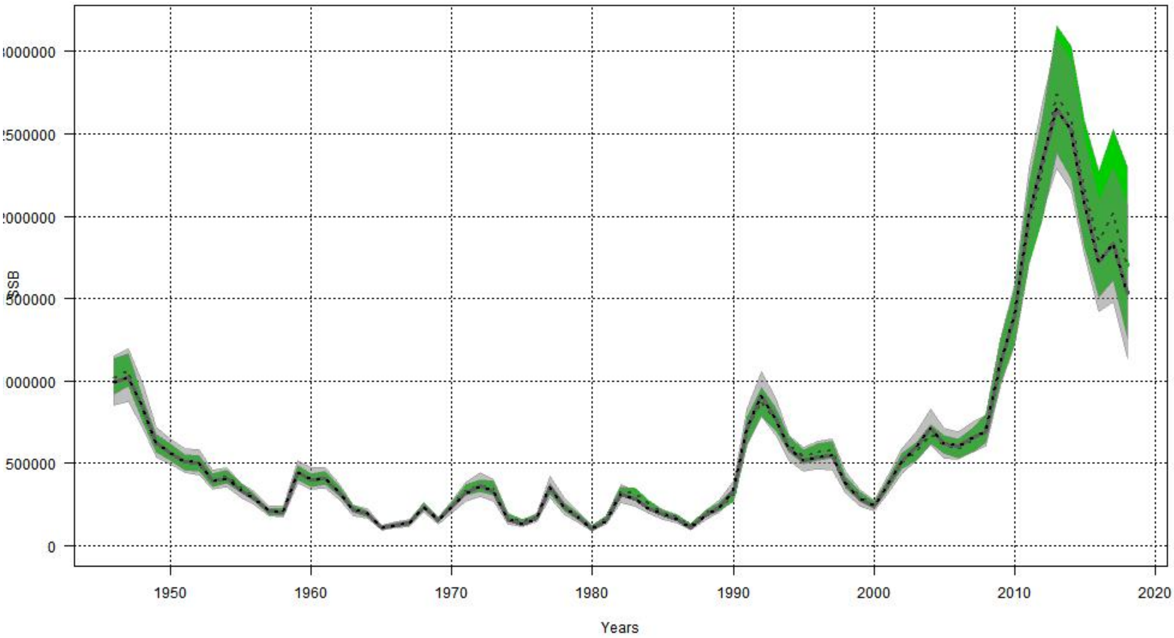
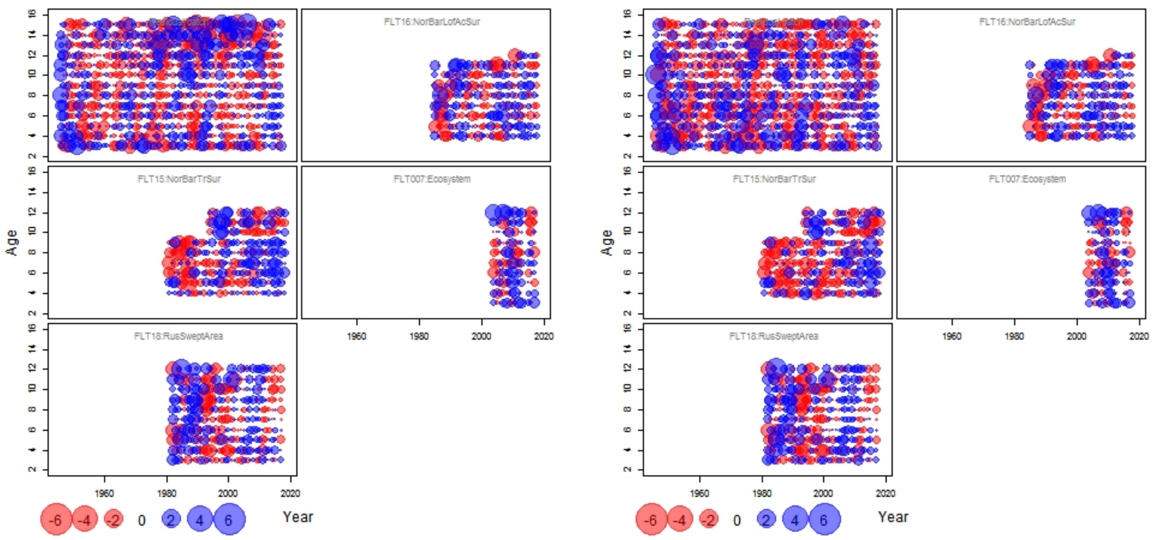
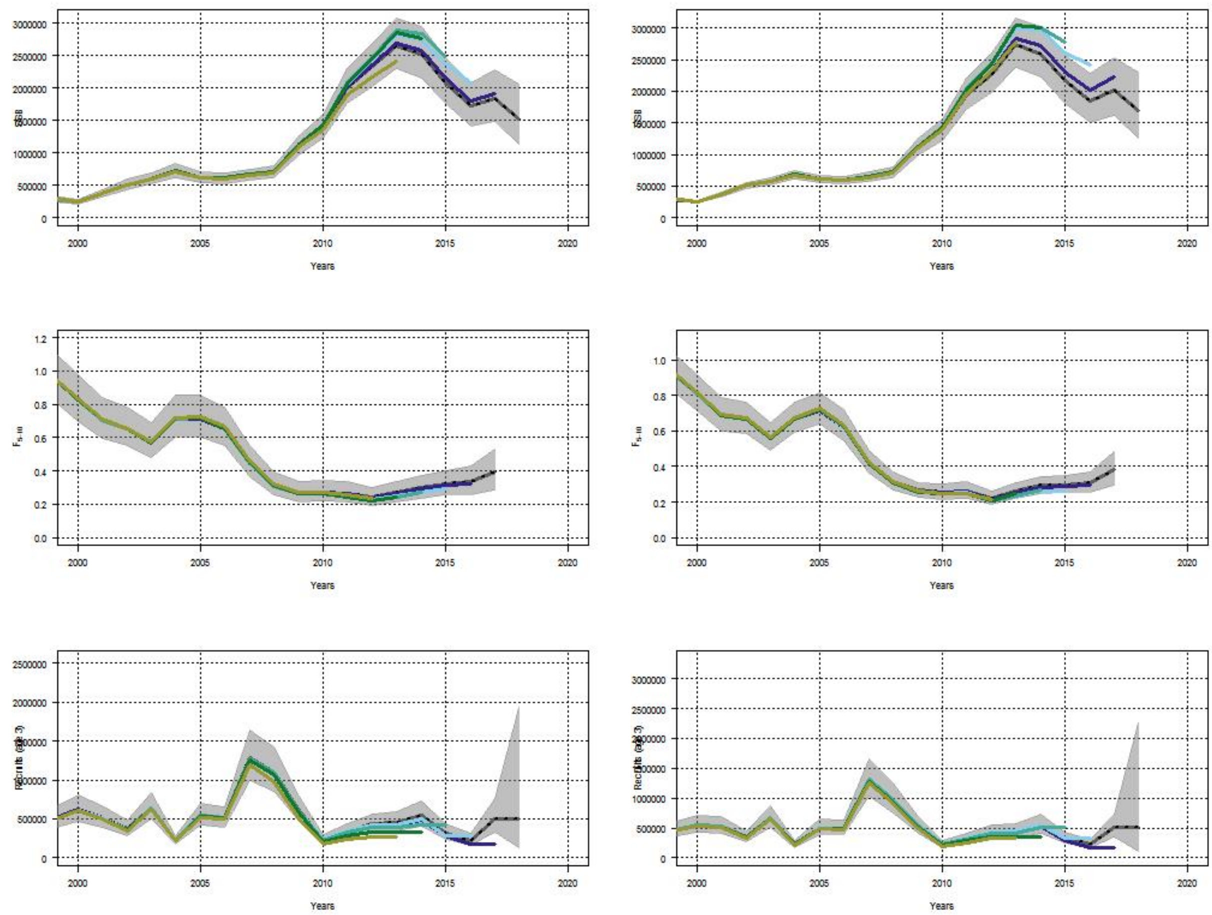


Figure 1: Estimated SSB with the current assessment compared with estimated SSB when including external variance structures. Black line and grey area represent point estimate and 95% C.I. with current assessment. Dotted line and green area represent point estimate and 95% C.I. when utlizing external variances.



(a) (b)

Figure 2: Leave-out-one residuals obtained with a) SAM with 2018 assessment configurations, and b) by also utilizing external variance structures.



(a) (b)

Figure 3: Retrospective plots obtained with a) SAM with 2018 assessment configurations, and b) by also utilizing external variance structures.

References

Aanes, S. (2016a). A statistical model for estimating fish stock parameters accounting for errors in data: Applications to data for norwegian spring-spawning herring. WD4 in ICES. Report of the Benchmark Workshop on Pelagick stocks (WKPELA), 29 February - 4 March 2016, ICES Headquarters, Copenhagen, Denmark.

Aanes, S. (2016b). Stock Annex: Herring (clupea harengus) in subareas 1, 2, and 5, and in division 4.a and 14.1 (Norwegian Spring Spawning).

Aanes, S. (2017). Working document for ibparctic cod 2017.

Berg, C. W., Nielsen, A., and Kristensen, K. (2014). Evaluation of alternative age-based methods for estimating relative abundance from survey data in relation to assessment models. *Fisheries Research*, 151:91–99.

Gudmundsson, G. (1994). Time series analysis of catch-at-age observations. *Journal of the Royal Statistical Society: Series C (Applied Statistics)*, 43(1):117–126.

Hirst, D., Storvik, G., Aldrin, M., Aanes, S., and Huseby, R. B. (2005). Estimating catch-at-age by combining data from different sources. *Canadian Journal of Fisheries and Aquatic Sciences*, 62(6):1377–1385.

	R(age 3)	Low	High	SSB	Low	High	Fbar(5-10)	Low	High
1980	116758	87577	155663	107544	95664	120899	0.734	0.647	0.832
1981	152521	115094	202120	165834	150058	183268	0.775	0.682	0.881
1982	206228	158908	267640	323451	293840	356047	0.772	0.680	0.876
1983	146841	112614	191470	316224	286896	348551	0.735	0.648	0.834
1984	350153	271995	450770	250293	228583	274066	0.876	0.772	0.993
1985	628778	493067	801843	196535	178513	216376	0.766	0.669	0.876
1986	882988	694944	1121916	173816	159134	189851	0.869	0.763	0.989
1987	300862	233990	386846	120243	110451	130904	0.990	0.876	1.120
1988	289644	223380	375565	192910	175323	212262	0.892	0.776	1.024
1989	188376	144422	245708	232137	207736	259405	0.637	0.544	0.746
1990	150952	113884	200084	305867	267435	349823	0.299	0.250	0.356
1991	362248	279769	469042	689946	611755	778131	0.329	0.283	0.382
1992	810617	632694	1038574	870310	785338	964476	0.462	0.406	0.526
1993	762897	593955	979891	762224	696666	833952	0.561	0.497	0.634
1994	544401	420481	704842	611264	566245	659862	0.825	0.737	0.923
1995	330386	256101	426218	534497	492092	580557	0.759	0.672	0.858
1996	332489	257741	428916	564234	516029	616943	0.701	0.620	0.793
1997	517362	406430	658573	577811	528496	631726	0.956	0.856	1.067
1998	878514	685284	1126228	385663	350491	424365	0.918	0.820	1.028
1999	457593	355242	589432	295869	268027	326603	0.930	0.829	1.042
2000	547618	422120	710426	247841	226539	271145	0.809	0.712	0.919
2001	528470	407986	684535	363799	330484	400473	0.686	0.598	0.787
2002	348056	267059	453619	510451	464663	560751	0.667	0.584	0.762
2003	670768	520525	864376	569125	517756	625591	0.563	0.493	0.644
2004	222647	174176	284607	675190	618237	737389	0.671	0.592	0.760
2005	507619	397456	648316	610825	559758	666551	0.721	0.637	0.815
2006	491890	386210	626488	588026	533944	647586	0.626	0.546	0.718
2007	1309499	1030522	1663999	638600	569539	716036	0.419	0.359	0.488
2008	974340	757839	1252692	707523	625520	800276	0.314	0.268	0.369
2009	535177	413649	692409	1107717	981496	1250170	0.265	0.225	0.312
2010	218195	166625	285726	1385294	1223703	1568223	0.256	0.217	0.303
2011	311907	237329	409920	1941269	1708831	2205323	0.264	0.222	0.313
2012	418131	323182	540976	2269966	1982290	2599390	0.222	0.187	0.262
2013	433982	334429	563169	2741904	2380726	3157876	0.262	0.223	0.308
2014	546555	413819	721866	2598013	2227584	3030042	0.293	0.250	0.344
2015	323954	245265	427888	2162719	1814180	2578219	0.298	0.252	0.352
2016	221005	160679	303980	1854525	1511214	2275827	0.306	0.253	0.371
2017	510352	358665	726191	2018434	1612206	2527020	0.381	0.298	0.486
2018	510352	115391	2257186	1699175	1257766	2295497	0.376	0.206	0.686

Table 2: Summary of 2018 NEA cod assessment with use of external variance structures.

Working document: New time series for bycatch of juvenile fish in the Barens Sea shrimp fishery

Olav Nikolai Breivik[1] and Kjell Nedreaas[2]

[1]Norwegian Computing Center, Oslo, Norway, Email: olavbr@nr.no

[2]Institute of Marine Research, Bergen, Norway

April 29, 2019

1 Introduction

During AFWG2019, new time series for bycatch in the Barents Sea shrimp fishery will be presented. This working document describes how the new time series for bycatch are calculated, and the new time series are shown in section 4.

Background

In around year 2009, IMR and the Norwegian Computing Center started collaborating to construct a spatio-temporal model for bycatch in the Barents Sea shrimp fishery (Aldrin et al., 2012). That model was further extended and improved in Breivik et al. (2016a). In Breivik et al. (2016b), the model was further used in combination with Norwegian commercial catch data to estimate historical bycatch in the Norwegian shrimp fishery. With thorough model validation, it was illustrated that the estimation procedure in Breivik et al. (2016b) gives reliable bycatch estimates, also with respect to uncertainty. During 2018, authors of Breivik et al. (2016a) and Breivik et al. (2016b) have worked on combining data from international fleets and Norwegian landing statistics to scale up the estimated Norwegian bycatch to the total bycatch taken by all countries. Results of this work are presented in this working document, and will be presented at AFWG2019.

Motivation

Previous estimates of bycatch in AFWG reports are based on the assumption that observed bycatch rates from research vessels and surveillance service are representative for commercial bycatch rates. It is reasonable that this assumption is violated since the commercial fishery target the shrimps better compared with the research vessels and surveillance service. In Breivik et al. (2016a) it was e.g. highlighted that the commercial fishery was 128 more times efficient catching shrimps compared with the surveillance service in an area north in the Barents Sea in 2004. The surveillance service had taken five observations in that area which resulted in a bycatch rate of 38.9 cod per kg of shrimp. Removing those five observations resulted in a reduction of the estimate from 30.6 million cod to 3.9 million cod taken as bycatch by Norwegian landings in 2004 with the ratio method used in previous AFWG reports. The new estimates presented in this working document is however not sensitive to observations with high bycatch rates for low shrimp catches.

Description of the model

In Aldrin et al. (2012); Breivik et al. (2016a,b) it was shown that there exists covariates which have predictive power for bycatch, e.g. season and depth. When all important covariates are included in the proposed model, there is still spatio-temporal unexplained structures in the bycatch data (Aldrin et al., 2012; Breivik et al., 2016a,b). We accommodate for these spatio-temporal dependence structures by including latent spatio-temporal Gaussian fields in the model. The modelling is done with usage of R-INLA (Rue et al., 2009).

We shall now go trough technical parts of the model. Let $B(\mathbf{s},t)$ be the number of juvenile fish of a specific species caught in a haul at location $\mathbf{s}$ and time t. We assume that:

$$\mathrm{P}(B(\mathbf{s},t)) = \begin{cases} \pi\big(\mu_\pi(\mathbf{s},t)\big), & B(\mathbf{s},t) = 0 \\ [1 - \pi\big(\mu_\pi(\mathbf{s},t)\big)]\mathrm{NB}^+(B(\mathbf{s},t); \mu_B(\mathbf{s},t), \varsigma), & B(\mathbf{s},t) > 0. \end{cases}$$

Here $\mathrm{NB}^+(\mu,\varsigma)$ represents the density of a conditional positive negative binomial distribution with mean μ and with overdispersion parameter ς and $\pi(\cdot)$ represents a binomial distribution. For brevity the we will refer to the expectation for a zero probability (μ_π) and for the positive part (μ_B) with a common $\mu(\mathbf{s},t)$. As in Breivik et al. (2016a,b), we assume that:

$$\mu(\mathbf{s},t) = \mathbf{X}(\mathbf{s},t)^T\boldsymbol{\beta} + \alpha(\mathbf{s}) + \upsilon(t) + \gamma(\mathbf{s},t), \tag{1}$$

where $\mathbf{X}(\mathbf{s},t)$ is a vector of covariates and $\boldsymbol{\beta}$ the vector of corresponding regression coefficients. The variables $\alpha(\mathbf{s})$, $\upsilon(t)$ and $\gamma(\mathbf{s},t)$ are Gaussian random fields in space, time and space-time. See Breivik et al. (2016b) for details regarding the covariates and the Gaussian random fields in (1), and for a description of the prediction procedure.

2 New data combined with Breivik et al. (2016b)

We have four data sources on shrimp catch and bycatch available.: 1) Observations from the Norwegian Surveillance Service, which consists of both shrimp catch and bycatch. 2) Norwegian catch log books, 3) Norwegian landing statistics, and 4) international catch data. Note that the three last data sources contain only information about shrimp catch, and *not* bycatch. It is the bycatch in the shrimp fishery elaborated in these three data sources we want to estimate. Compared with the bycatch estimation procedure in Breivik et al. (2016b), Norwegian landing statistics and international catch data are new data sources and will be elaborated in this section. Detailed explanation of the observations from the Norwegian Surveillance Service and Norwegian catch log books age given in Breivik et al. (2016b).

The landing statistics data contains shrimp catches aggregated over areas and quarters. See table 1 for a summary of the data given in the landing statistics. Note that the landing statistics include all catches in the log books, and in addition catches from boats smaller then 15 meters. However, the data in the landing statistics posses a much lower spatial and temporal resolution compared with the log books.

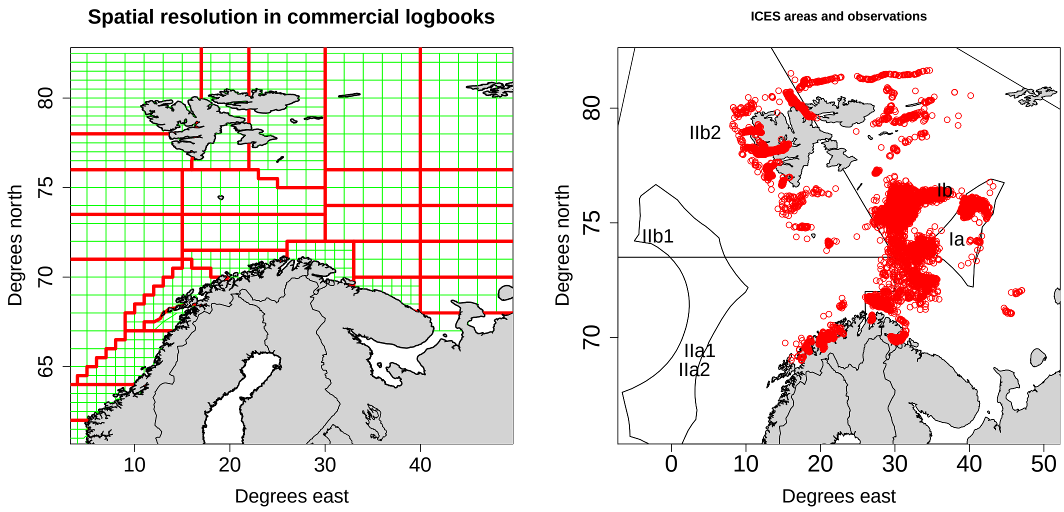
The international catch data contains international catches aggregated over ICES-areas and years. A summary of the international catch data is given in table 2.

Data	**Description**
Target catch	Aggregated shrimp catch in a given area, quarter and year by boats of a given type
Year	Year of aggregated catch
Quarter	Quarter of aggregated catch
Area	Area where the aggregated catch was taken (see large red areas in Figure 1a)
Boat type	Larger or smaller than 15 meters

Table 1: *Summary of landing statistics.*

Data	**Description**
Target catch	Aggregated shrimp catch in a given area and year by each nation
Year	Year of catch
Area	ICES region the catch was taken (see Figure 1b)

Table 2: *Summary of ICES-data.*



(a) (b)

Figure 1: *a) Map of the Barents Sea with small green rectangles describing the spatial resolution of the Fishery log books. The larger red Illustrates the spatial resolution of the landing statistics. b) Map of the Barents Sea with ICES areas, red dots illustrate the spatial distribution of the Norwegian Surveillance Service data.*

3 Estimation procedure

The estimation procedure elaborated in Breivik et al. (2016b) is used and combined with Norwegian catch log books and international catch data. The procedure can be divided into three parts: 1) bycatch by Norwegian boats larger than 15 meters, 2) bycatch by Norwegian boats smaller than 15 meters, and 3) bycatch from other nations than Norway.

3.1 Landing statistics

3.1.1 Boats larger than 15 meters

Data from boats larger than 15 meters are included in both the Norwegian log books and in the Norwegian landing statistics. It is assumed that the yearly aggregated catches from the landing statistics are more accurate compared with the log books. However, the opposite is the case for spatio-temporal resolution. To utilise both the spatio-temporal resolution in the catch log books and the aggregated catch in the landing statistics, the catches in the Norwegian log books are scaled such that the yearly aggregated catch in the log books equals the yearly aggregated catch the landing statistics. The procedure elaborated in Breivik et al. (2016b) is then followed with the scaled shrimp catch to estimate historical bycatch taken by Norwegian boats larger than 15 meters.

3.1.2 Boats smaller than 15 meters

Data from boats smaller than 15 meters are only given in the landing statistics. Unfortunately, the data in the landing statistics has a lower resolution compared to the log books. The effort, defined as hours trawled in a fine scaled spatio-temporal resolution, is not given in landing statistics. To follow the procedure in Breivik et al. (2016b), we must define the effort. We define the effort by assuming that the average shrimp catch per hour trawl by boats smaller than 15 meters is the same as the average catch per hour trawl by the surveillance service south of 72N. We further divide the aggregated quarterly catches into daily catches, and randomly sample the location of these daily catches along the coast in the corresponding reported area and quarter. The procedure elaborated in Breivik et al. (2016b) is then followed with the sampled daily catches to estimate historical bycatch taken by Norwegian boats smaller than 15 meters.

3.2 International catches

Bycatch taken by other nations than Norway is estimated by scaling the estimated bycatch by Norwegian boats larger than 15 meters. Define the ratio

$$C_{y,a} = \frac{I_{y,a}}{d_{y,a}}, \tag{2}$$

were $I_{y,a}$ is the aggregated international catch and $d_{y,a}$ is the aggregated catch from the scaled log books in year y and ICES-area a. Bycatch from other nations than Norway is estimated by scaling the estimated bycatch in the Norwegian fishery in year y and ICES area a with $C_{y,a}$.

4 Results

Figur 2 shows the estimated yearly bycatch with 90% confidence intervals for each species. Figure 3 shows the bycatch estimates divided by the yearly shrimp catch, and thereby illustrates the average bycatch rate in each year. All estimates are also available on a finer spatial and temporal resolution, but this is not illustrated in this working document.

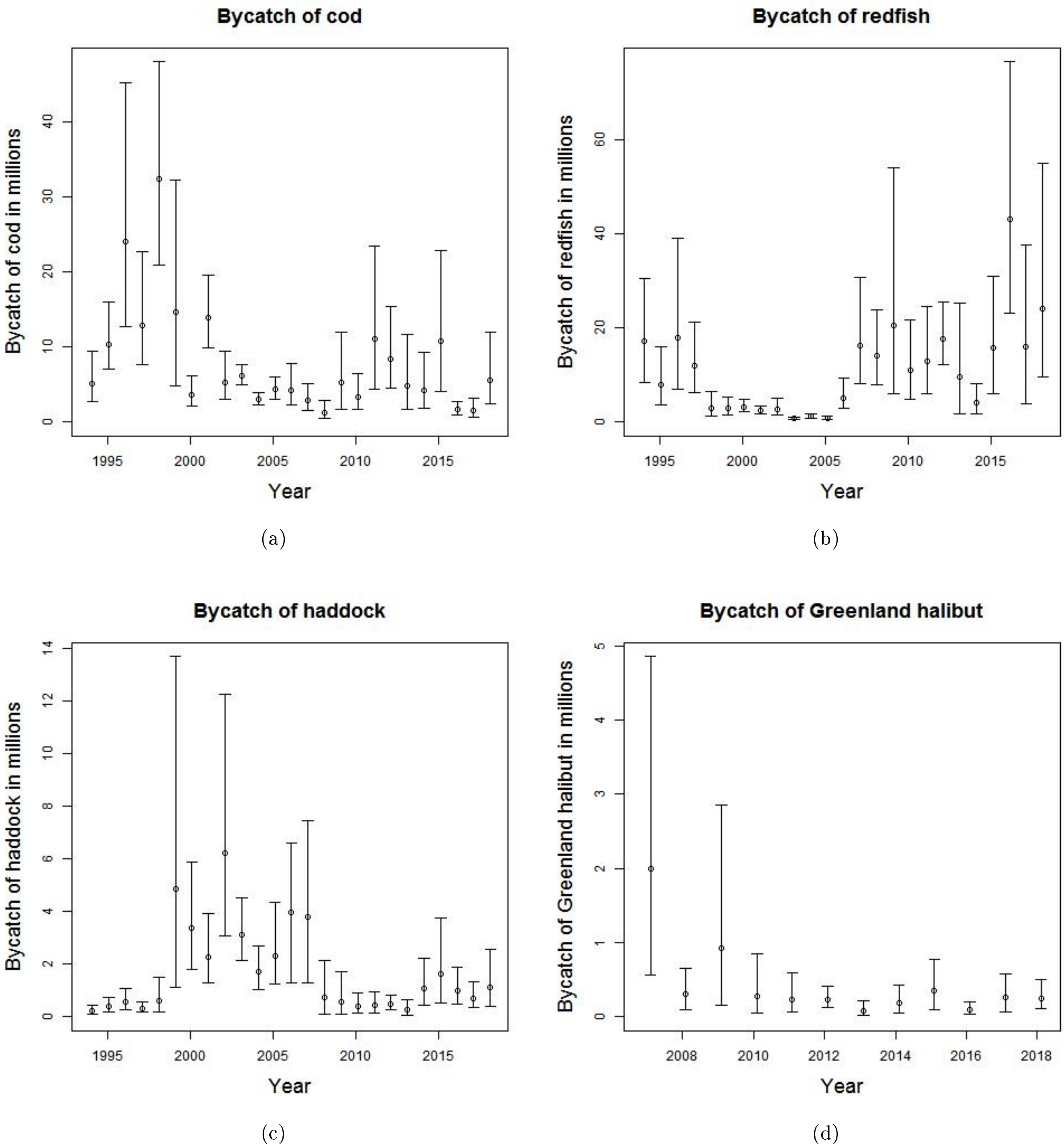


Figure 2: Estimated bycatch in millions, intervals are 90% confidence intervals. Note that the axis in the figures have different scale.

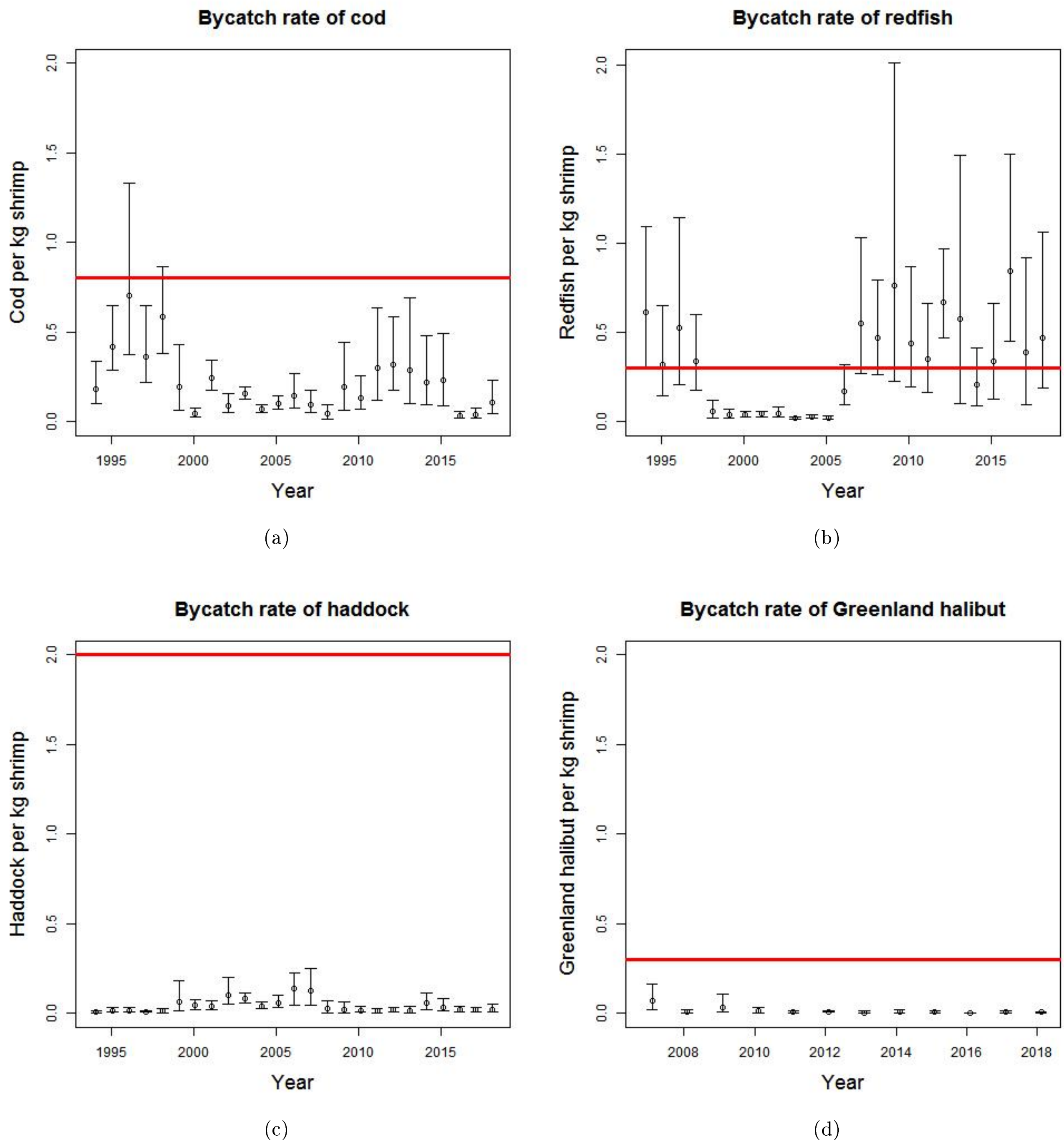


Figure 3: Estimated average yearly bycatch rate. Intervals are 90% confidence intervals. Red horisontal lines illustrate current upper limit of allowed bycatch rate of the specific species.

5 Discussion

5.1 Assumptions

A key assumption in the international scaling procedure in section 3.2 is that the Norwegian landings are representative for the international landings. This assumption was made because the international catches are given in a low spatio-temporal resolution. The spatial resolution of the international catches is illustrated by figure 1b. If the international vessels in a relative high degree trawl at locations not trawled by Norwegian vessels, the bycatch estimates illustrated in figure 2 may be biased in an unknown direction.

References

Aldrin, M., Mortensen, B., Storvik, G., Nedreaas, K., Aglen, A., and Aanes, S. (2012). Improving management decisions by predicting fish bycatch in the Barents Sea shrimp fishery. *ICES Journal of Marine Science: Journal du Conseil*, 69(1):64–74.

Breivik, O. N. (2016). Modeling excess zero count data using r-inla, applied to bycatch of cod and redfish in the barents sea shrimp fishery. *Olav's thesis*, pages 34–45.

Breivik, O. N., Storvik, G., and Nedreaas, K. (2016a). Latent Gaussian models to decide on spatial closures for bycatch management in the Barents Sea shrimp fishery. *Canadian Journal of Fisheries and Aquatic Sciences*, 73(8):1271–1280.

Breivik, O. N., Storvik, G., and Nedreaas, K. (2016b). Latent Gaussian models to estimate historical bycatch in commercial fishery.

Rue, H., Martino, S., and Chopin, N. (2009). Approximate Bayesian inference for latent Gaussian models by using integrated nested Laplace approximations. *Journal of the Royal Statistical Society: Series B (Statistical Methodology)*, 71(2):319–392.

AFWG 2019 WD_09

NEA cod stock assessment by means of TISVPA

D.Vasilyev

Russian Federal Research Institute of Fisheries and Oceanography (VNIRO),
17, V.Krasnoselskaya St., 107140, Moscow, Russia

The TISVPA (Triple Instantaneous Separable VPA) model (Vasilyev, 2005; 2006) represents fishing mortality coefficients (more precisely – exploitation rates) as a product of three parameters: f(year)*s(age)*g(cohort). The generation - dependent parameters, which are estimated within the model, are intended to adapt traditional separable representation of fishing mortality to situations when several year classes may have peculiarities in their interaction with fishing fleets caused by different spatial distribution, higher attractiveness of more abundant schools to fishermen, or by some other reasons.

The model was first presented and tested at the ICES Working Group on Methods of Fish Stock Assessments (WGMG 2006) and was used for data exploration and stock assessment for several ICES stocks, including North - East Atlantic mackerel, blue whiting, Norwegian spring spawning herring.

To NEA cod stock the TISVPA model was applied at AFWG in 1998; at benchmark group for arctic stocks (WKARST) in 2015 and at AFWG in 2015 and 2016.

The TISVPA model is applied to NEA cod using the same data as SAM. 4 sets of age - structured tuning data were included into analysis: ecosystem survey ("fleet 007"); joint bottom trawl surveys ("fleet 15"); joint acoustic surveys (Barents Sea and Lofoten) – "fleet 16", and Russian bottom trawl surveys ("fleet 18"). The All the input data, including catch-at-age, weight-at-age in stock and in catches, maturity-at-age were taken the same as for stock assessment by means of SAM.

Settings of the TISVPA model were used basically the same as in AFWG 2015 - 2018 assessments: so called "mixed" version, assuming errors both in catch-at-age and in separable approximation. Additional restriction on the solution was unbiased model approximation of logarithmic catch-at-age. The generation - dependent factors in triple - separable representation of fishing mortality coefficients were estimated for age groups from 3 to 12. For catch-at-age data the measure of closeness of fit was absolute median deviation (AMD) of distribution of residuals which is known as one of most robust measures of scale, free from the assumption about the distribution.

For the “fleets” the traditional sums of logarithmic squared residuals were used assuming lognormal errors. For the (terminal+1) year (year with surveys but without catch-at-age) the assumption of equal F in terminal terminal+1 years was used.

Profiles of the components of the TISVPA loss function with respect to SSB in 2019 are shown in Figure 1. As previously, fleet 18 indicates much lower stock biomass in comparison to other sources. In objective function it was down weighted by factor of 0.05.

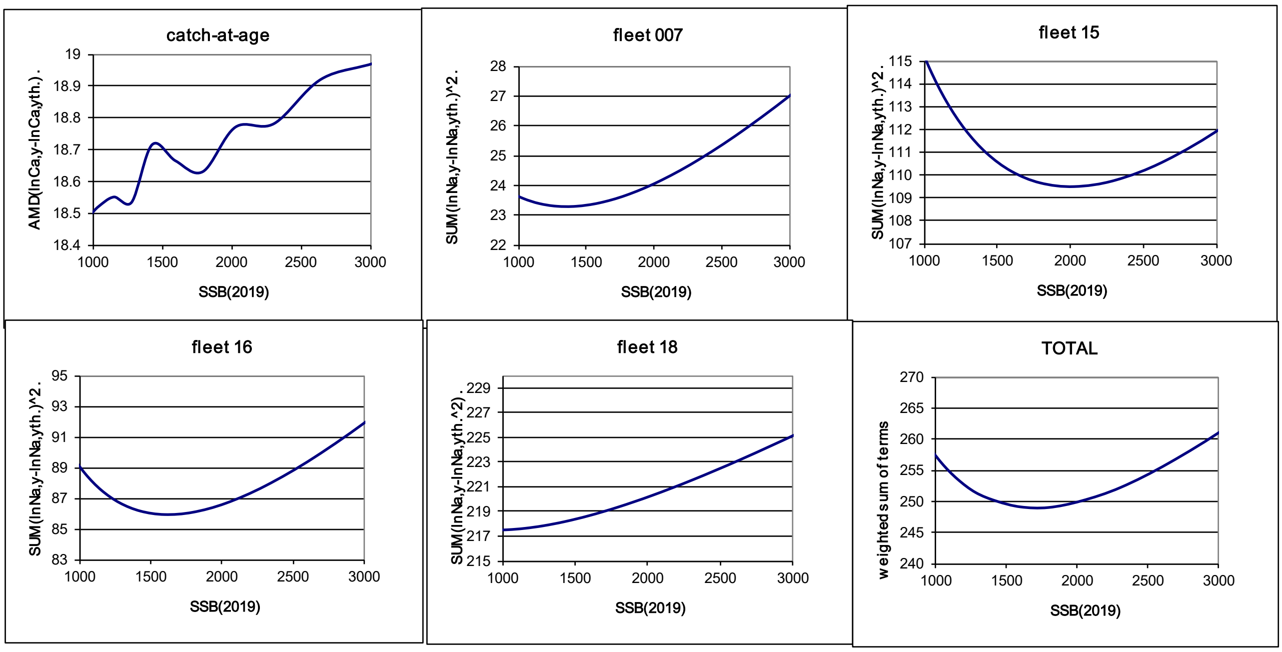


Figure 1. Profiles of the components of the TISVPA objective function

Figure 2 represents the results of retrospective runs.

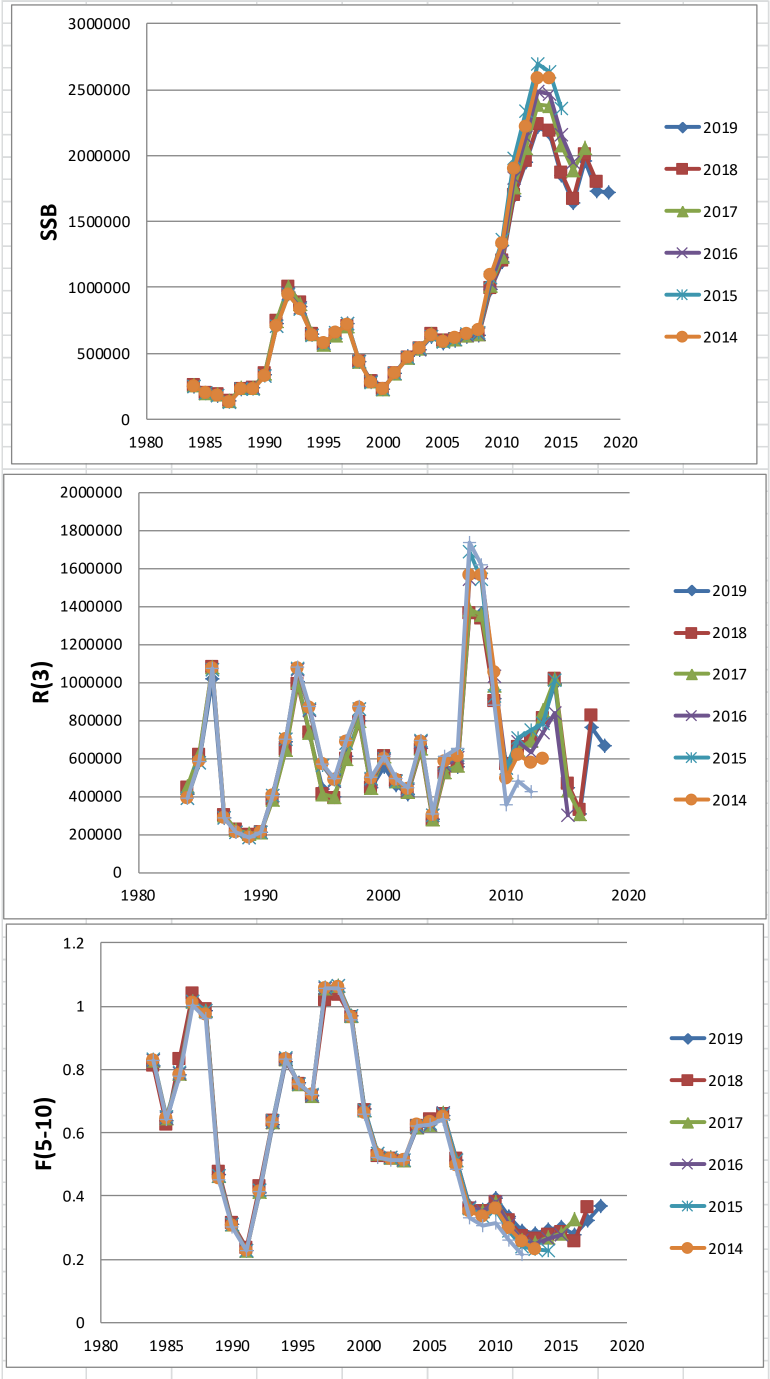


Figure 2. TISVPA retrospective runs

The residuals of the model approximation of catch-at-age and “fleets” data are presented in Figure 3.

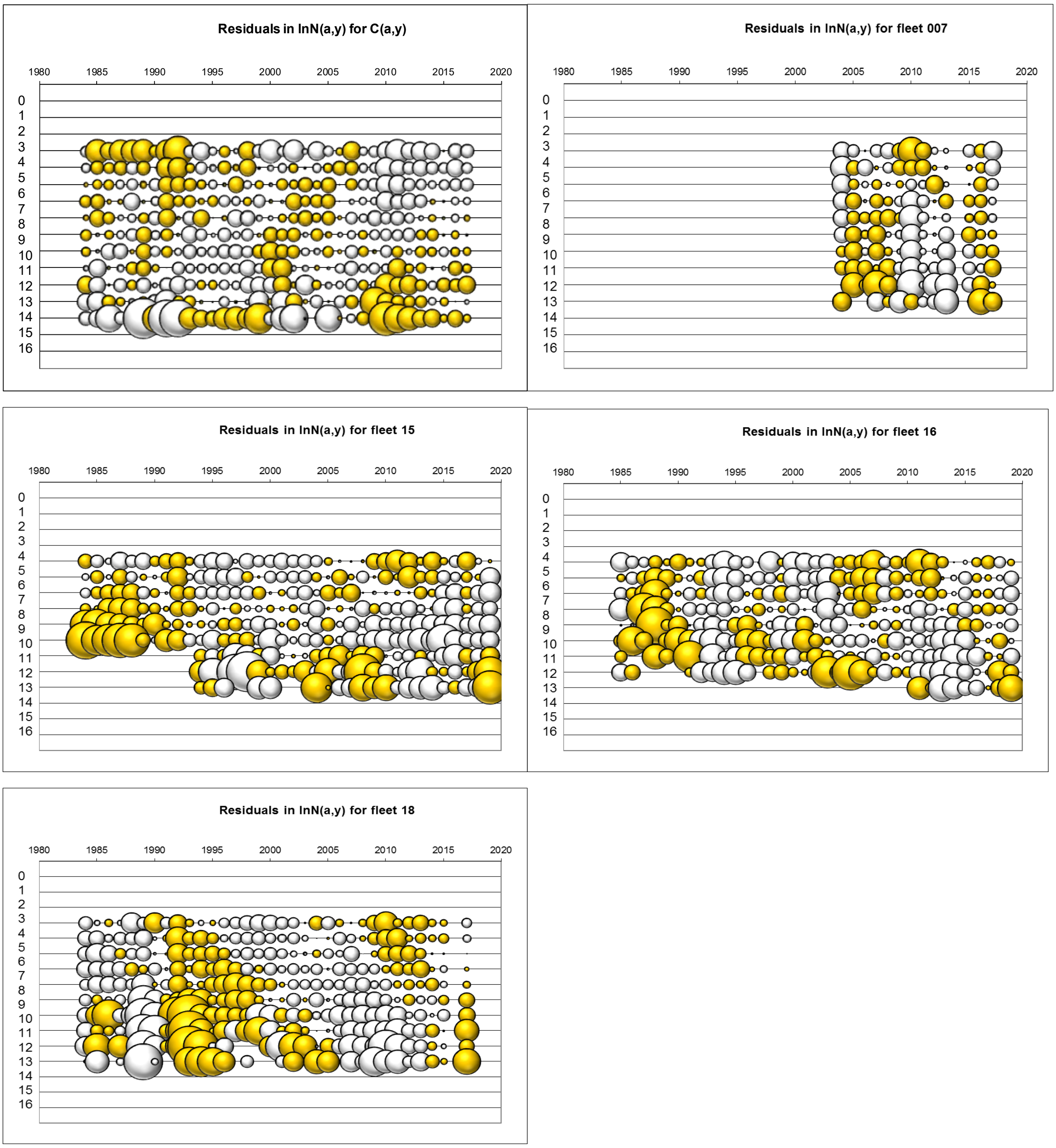


Figure 3. Residuals of the TISVPA data approximation.

The estimates of uncertainty in the results (parametric conditional bootstrap with respect to catch-at-age; "fleet" data were noised by lognormal noise with sigma=0.3) are presented on Figure 4.

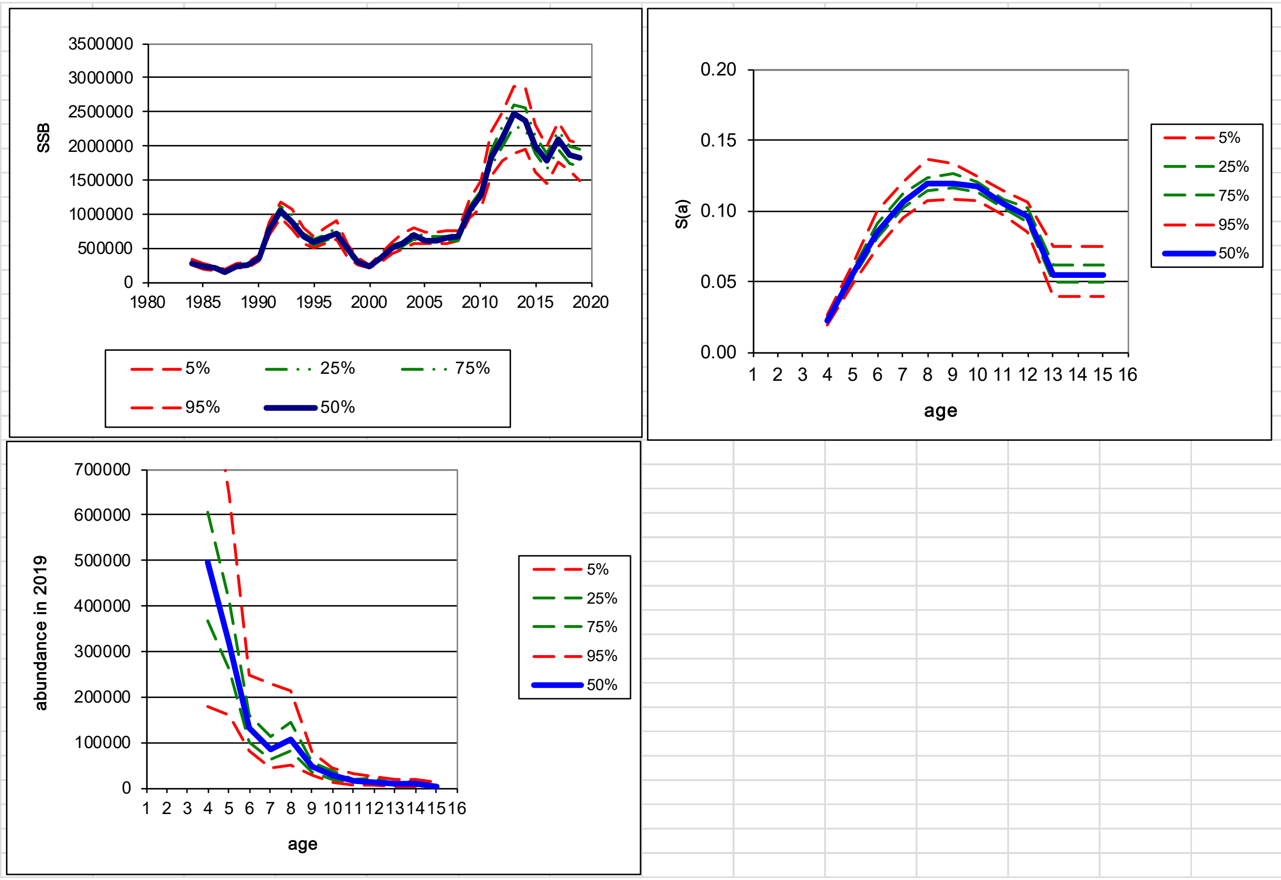


Figure 4. Bootstrap- estimates of uncertainty in the results.

Tables 1-3 represent the results of NEA cod stock assessment by means of TISVPA.

Year	B(3+)	SSB	R(3)	F(5-10)
1984	813201.9	251607.5	411969	0.812
1985	990155.5	199707.4	583047	0.639
1986	1363640	182246.7	1015891	0.785
1987	1223679	135358.6	284049	1.017
1988	1005886	225778.7	215992	0.987
1989	913902.6	237312.3	182324	0.467
1990	996936.9	334589.2	211590	0.311
1991	1569125	721824.8	408357	0.228
1992	1965822	964711	688971	0.411
1993	2455778	853206.1	1000433	0.624
1994	2232270	643640.6	728736	0.826
1995	1922693	579859.7	435074	0.756
1996	1856793	658311.5	394762	0.719
1997	1718566	721897.8	608997	1.048
1998	1287720	440631.1	793938	1.058
1999	1090944	286921.1	446610	0.970
2000	1062428	230196.1	557965	0.675
2001	1293487	351235.5	457530	0.536
2002	1425295	473949.2	409553	0.522
2003	1516577	532777.5	654027	0.515
2004	1481568	623001.2	276911	0.619
2005	1485127	580450.7	531612	0.625
2006	1523745	597825.6	552067	0.653
2007	1881561	625058.5	1368644	0.513
2008	2619874	633097.4	1360508	0.368
2009	3347953	987172.5	913069	0.355
2010	3695017	1196468	566554	0.393
2011	3802508	1690494	661291	0.334
2012	3879741	1949245	694998	0.288
2013	4132734	2220948	801536	0.283
2014	3843732	2171555	990962	0.294
2015	3671185	1850850	447642	0.301
2016	3325412	1638149	307976	0.278
2017	3420527	1958815	760154	0.321
2018	3060426	1731796	668649	0.368
2019	2796874	1717853		

Table 1. NEA cod stock assessments results by means of TISVPA

	3	4	5	6	7	8	9	10	11	12	13	14	15
1984	411969	139061	72716	41672	24693	12142	9031	1477	697	457	216	39	26
1985	583047	330380	99084	42263	18172	7060	3359	2485	476	404	185	123	31
1986	1015891	459773	230876	56920	20067	6805	2325	1317	1063	223	282	115	47
1987	284049	770659	311592	115323	23465	7158	2196	715	431	371	80	176	60
1988	215992	213745	519539	155444	36581	6232	2088	716	145	146	115	43	15
1989	182324	167846	150484	283707	59066	9080	1504	619	189	34	54	58	85
1990	211590	145761	121659	95349	156221	25788	3483	630	292	109	17	38	15
1991	408357	171671	112179	85629	60730	96049	14419	2020	361	184	72	10	20
1992	688971	330643	132991	79454	54531	35758	58492	8621	1267	243	133	55	6
1993	1000433	546892	245909	88345	44936	28326	17170	30413	4387	716	132	97	4
1994	728736	773315	408791	148380	45562	20319	11546	6693	12358	1781	289	68	14
1995	435074	510456	541471	243402	66668	14633	6112	3263	1805	3862	572	149	4
1996	394762	254975	336244	325503	118830	25532	5192	1897	944	506	1430	302	4
1997	608997	232904	164250	196273	159688	49521	9286	2006	585	307	179	659	3
1998	793938	390105	147310	81142	78757	47764	12972	2097	465	109	61	61	147
1999	446610	498114	237003	71986	31013	24240	10433	3675	496	140	25	24	88
2000	557965	337286	326568	111180	25495	10413	5833	2040	1146	159	55	4	55
2001	457530	429821	242950	172082	48475	9058	3672	1694	590	564	69	34	106
2002	409553	356582	312497	148332	80361	20298	3288	1653	632	246	337	47	31
2003	654027	305973	263507	191691	70741	31541	7725	1294	860	324	116	235	5
2004	276911	507948	231246	166165	97114	30891	12732	3537	596	515	179	76	38
2005	531612	212848	373710	146092	82715	37363	11203	4468	1362	243	287	112	33
2006	552067	388863	155248	218840	72806	33573	12813	4139	1507	580	109	195	673
2007	1368644	443401	272777	96627	108305	31457	12850	4080	1597	523	256	66	179
2008	1360508	1054614	328478	164233	54580	53275	14848	6134	1780	779	208	167	83
2009	913069	1045014	803297	228447	98346	31036	26307	7646	3286	868	432	137	131
2010	566554	684848	806110	567748	142615	57314	17060	13598	4282	1846	209	290	207
2011	661291	417158	516246	583683	365706	79198	29461	9041	6868	1685	877	77	0
2012	694998	426781	293097	379790	399285	219117	43412	14649	4033	3292	915	472	162
2013	801536	472156	297971	217208	265209	257380	128105	24020	7640	1989	1796	552	899
2014	990962	528033	354238	217297	156168	166721	148935	66554	12131	3883	1073	1144	855
2015	447642	658834	367932	247867	145615	102018	91610	82161	33714	6317	2058	654	1239
2016	307976	301749	469848	246795	155035	89009	63312	51657	44562	15285	3051	1285	1589
2017	760154	244223	217284	301657	154696	93021	52840	39519	27109	24123	8170	1852	1323
2018	668649	471549	180507	147182	183834	86526	50168	30203	23854	13510	13745	5031	1623
2019	0	472611	357359	123240	86972	101352	45214	26408	15931	13077	7677	9177	3359

Table 2. NEA cod. TISVPA. Estimates of abundance-at-age

F(a,y)	3	4	5	6	7	8	9	10	11	12	13	14
1984	0.0226	0.1381	0.3244	0.5624	1.0246	0.9882	1.0190	0.9539	0.2674	0.8280	0.4149	0.4149
1985	0.0202	0.1250	0.3151	0.4531	0.6211	0.9217	0.7453	0.7764	0.6621	0.2036	0.3397	0.3397
1986	0.0211	0.1526	0.4014	0.6484	0.7466	0.8757	1.1290	0.9064	0.8463	0.7143	0.3973	0.3973
1987	0.0257	0.1585	0.5043	0.8684	1.1553	1.0779	1.0555	1.4410	0.9857	0.9128	0.4640	0.4640
1988	0.0243	0.1662	0.4333	0.9068	1.2536	1.3342	0.9999	0.9959	1.1657	0.8288	0.4469	0.4469
1989	0.0135	0.0900	0.2461	0.3775	0.5728	0.6096	0.5435	0.4513	0.4122	0.4582	0.2330	0.2330
1990	0.0081	0.0593	0.1591	0.2664	0.3225	0.4063	0.3732	0.3408	0.2656	0.2437	0.1551	0.1551
1991	0.0063	0.0386	0.1135	0.1887	0.2532	0.2617	0.2857	0.2666	0.2260	0.1777	0.1147	0.1147
1992	0.0094	0.0669	0.1684	0.3225	0.4486	0.5286	0.4726	0.5282	0.4466	0.3717	0.1979	0.1979
1993	0.0145	0.0847	0.2535	0.4103	0.6726	0.8228	0.8384	0.7457	0.7632	0.6295	0.2897	0.2897
1994	0.0173	0.1157	0.2812	0.5516	0.7365	1.0854	1.1267	1.1730	0.9067	0.9253	0.3670	0.3670
1995	0.0163	0.1114	0.3113	0.4726	0.7609	0.8487	1.0430	1.1003	1.0093	0.7917	0.3629	0.3629
1996	0.0209	0.1065	0.3051	0.5427	0.6584	0.9062	0.8443	1.0544	0.9832	0.9021	0.3672	0.3672
1997	0.0277	0.1825	0.3922	0.7547	1.1720	1.1850	1.4455	1.3402	1.5442	1.3987	0.5098	0.5098
1998	0.0308	0.1851	0.5295	0.6965	1.1092	1.4377	1.1501	1.4251	1.1515	1.2958	0.5081	0.5081
1999	0.0251	0.1958	0.5015	0.9215	0.9186	1.2077	1.2408	1.0303	1.0976	0.9115	0.4720	0.4720
2000	0.0206	0.1230	0.4004	0.6145	0.8515	0.6925	0.7329	0.7586	0.5950	0.6221	0.3319	0.3319
2001	0.0147	0.1083	0.2638	0.5360	0.6389	0.7234	0.5108	0.5443	0.5117	0.4106	0.2602	0.2602
2002	0.0131	0.0881	0.2699	0.4085	0.6748	0.6689	0.6424	0.4647	0.4520	0.4245	0.2403	0.2403
2003	0.0133	0.0795	0.2198	0.4269	0.5156	0.7234	0.6088	0.5930	0.3960	0.3841	0.2261	0.2261
2004	0.0144	0.0992	0.2446	0.4329	0.7055	0.7187	0.8765	0.7379	0.6488	0.4274	0.2646	0.2646
2005	0.0152	0.0945	0.2707	0.4183	0.6029	0.8431	0.7217	0.8939	0.6783	0.5961	0.2695	0.2695
2006	0.0157	0.1061	0.2746	0.5042	0.6291	0.7770	0.9303	0.8022	0.8946	0.6757	0.2936	0.2936
2007	0.0125	0.0859	0.2375	0.3804	0.5566	0.5790	0.6035	0.7190	0.5718	0.6259	0.2436	0.2436
2008	0.0080	0.0635	0.1768	0.3029	0.3855	0.4731	0.4244	0.4461	0.4775	0.3878	0.1892	0.1892
2009	0.0075	0.0495	0.1615	0.2830	0.3931	0.4269	0.4538	0.4124	0.3972	0.4228	0.1852	0.1852
2010	0.0060	0.0525	0.1414	0.2954	0.4241	0.5077	0.4769	0.5141	0.4264	0.4090	0.2070	0.2070
2011	0.0064	0.0346	0.1241	0.2094	0.3562	0.4364	0.4510	0.4294	0.4230	0.3522	0.1896	0.1896
2012	0.0071	0.0381	0.0832	0.1883	0.2578	0.3781	0.4022	0.4202	0.3676	0.3609	0.1789	0.1789
2013	0.0077	0.0489	0.1061	0.1447	0.2704	0.3202	0.4129	0.4449	0.4260	0.3711	0.1964	0.1964
2014	0.0095	0.0555	0.1441	0.1955	0.2162	0.3548	0.3679	0.4838	0.4775	0.4550	0.2268	0.2268
2015	0.0117	0.0679	0.1614	0.2644	0.2895	0.2750	0.3990	0.4191	0.5070	0.4982	0.2569	0.2569
2016	0.0105	0.0704	0.1666	0.2465	0.3265	0.3055	0.2541	0.3710	0.3576	0.4279	0.2410	0.2410
2017	0.0141	0.0749	0.2068	0.3072	0.3682	0.4201	0.3409	0.2857	0.3858	0.3703	0.2720	0.2720
2018	0.0109	0.0696	0.1816	0.2978	0.3954	0.4491	0.4417	0.4397	0.4011	0.3652	0.2040	0.2040

Table 3. NEA cod. TISVPA. Estimates of fishing mortality coefficients

References

2. Vasilyev D. 2005 Key aspects of robust fish stock assessment. M: VNIRO Publishing, 2005. 105 p.

3. Vasilyev D. 2006. Change in catchability caused by year class peculiarities: how stock assessment based on separable cohort models is able to take it into account? (Some illustrations fo triple-separable case of the ISVPA model - TISVPA). ICES CM 2006/O:18. 35 pp

AFWG 2019 WD_ 10

NEA haddock stock assessment by means of TISVPA

D.Vasilyev
Russian Federal Research Institute of Fisheries and Oceanography (VNIRO),
17, V.Krasnoselskaya St., 107140, Moscow, Russia

The TISVPA model (Vasilyev, 2005; 2006) was applied to the same northeast arctic haddock data as XSA and SAM models, except the natural mortality values from cannibalism were taken from the SAM runs. The 4 sets of age - structured tuning data were included into analysis: Russian bottom trawl survey ("fleet 01"); Joint Barents Sea acoustic survey ("fleet 02), Joint Barents Sea bottom trawl survey ("fleet 04"), and Joined Russian-Norwegian ecosystem autumn bottom trawl survey in the Barents Sea ("fleet 007").

The TISVPA model was applied to northeast arctic haddock with the settings which gave in 2018 stock assessment more historically stable results – the case which was named TISVPA-2 in AFWG-2018 Report and in WD15 to AFWG-2018: so called "mixed" version, assuming errors both in catch-at-age and in separable approximation; additional restriction on the solution was the unbiased model approximation of separable representation of fishing mortality coefficients. The generation - dependent factors in triple - separable representation of fishing mortality coefficients were estimated and applied for age groups from 3 to 9. The tuning on surveys data was made not at abundance but at age proportions because of probable change in effective survey catchability the absolute median deviation (AMD) was used for catch-at-age and fleets 01 and 04. The profiles of the components of the TISVPA loss function for such model settings are shown in Figure 1.

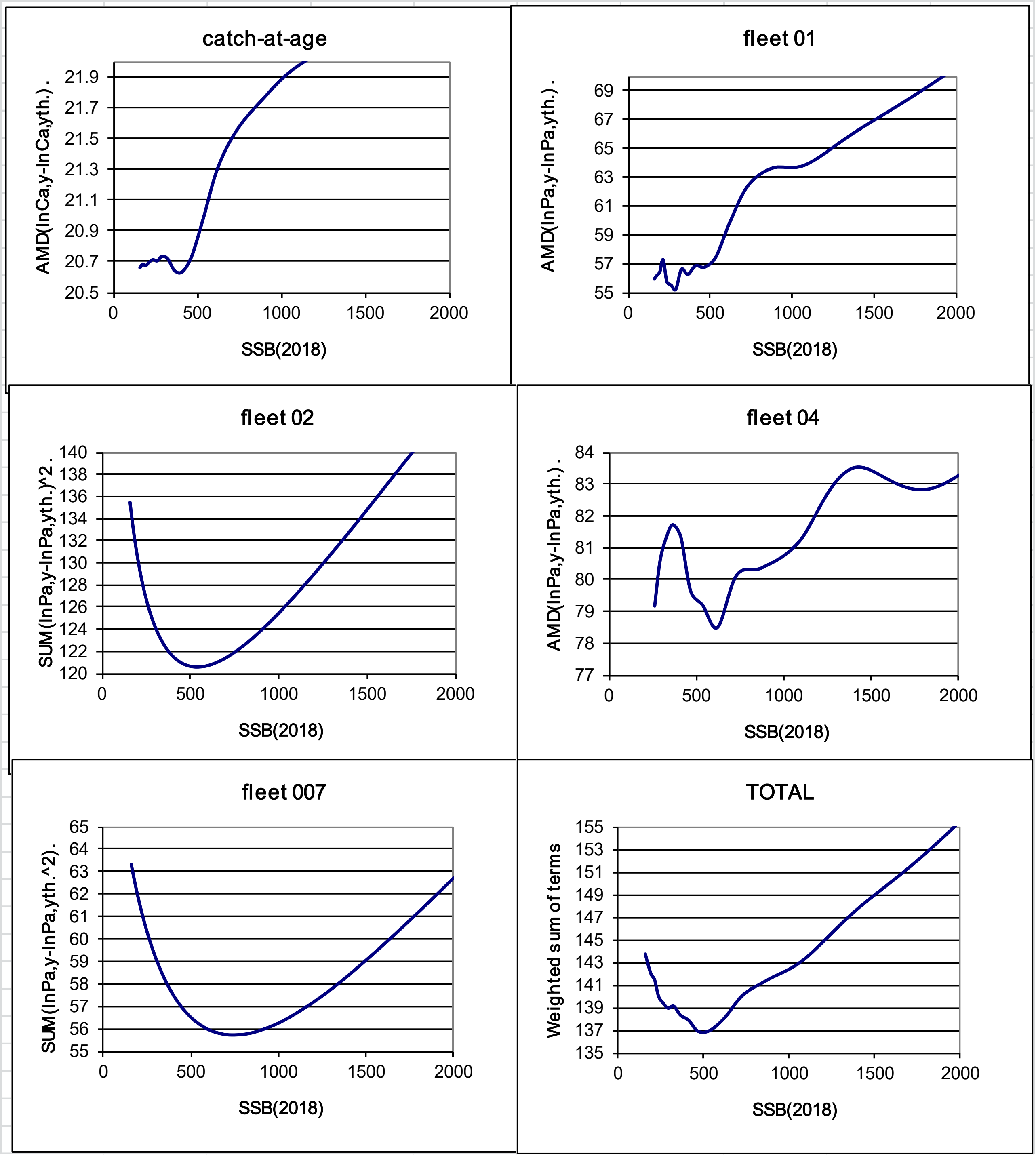


Figure 1. Profiles of the components of the TISVPA objective function for the preliminary model run.

As it can be seen, the catch-at-age data and surveys 02, 04 and 07 give rather similar indications about the stock.

Figure 2 represents the results of retrospective runs..

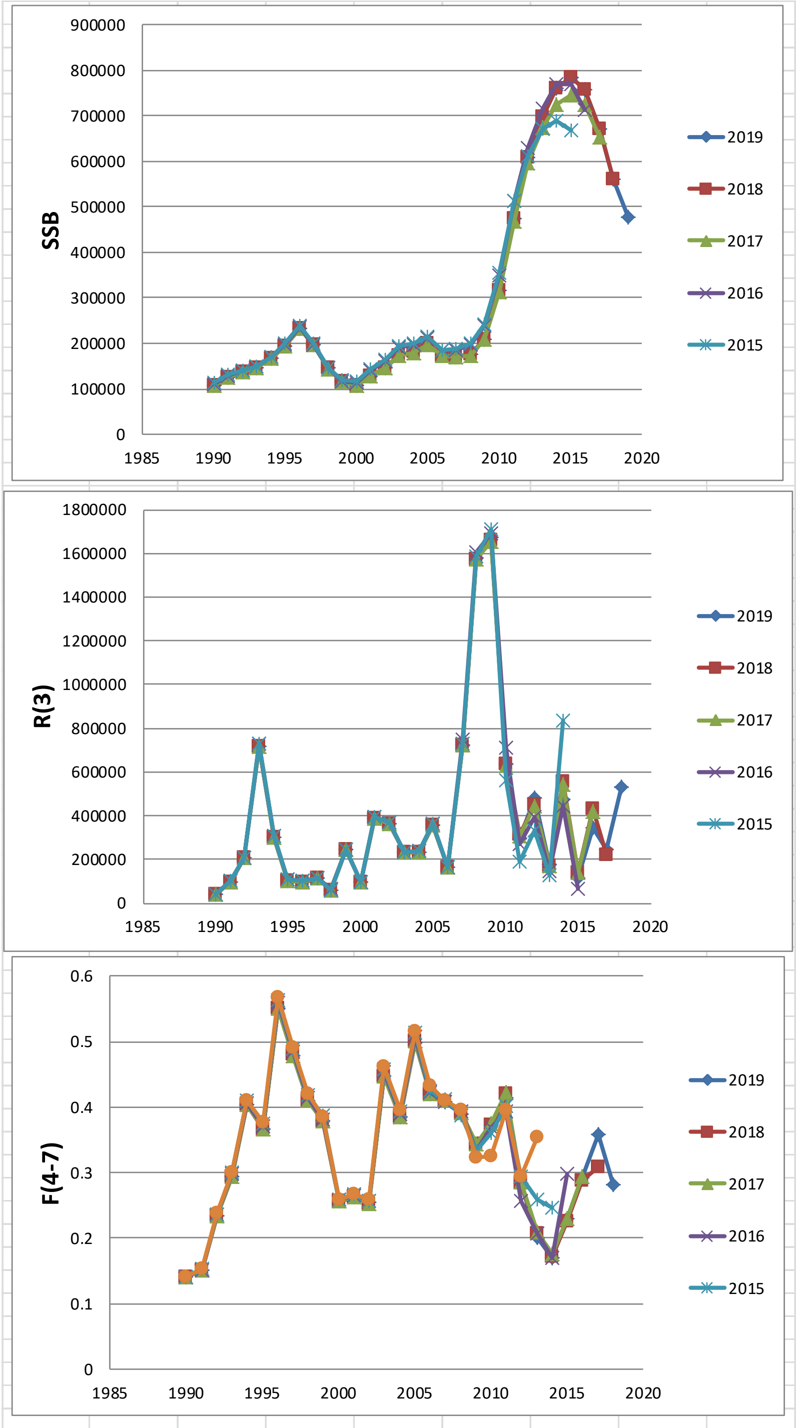


Figure 2. TISVPA retrospective runs

The residuals of the model approximation of catch-at-age and “fleets” data are presented in Figure 3. For “fleets” 01, 02, 04 and 007 the year-effect in abundance-derived residuals is apparent, that is why the age-proportions are highly likely more appropriate for tuning for the “fleets”.

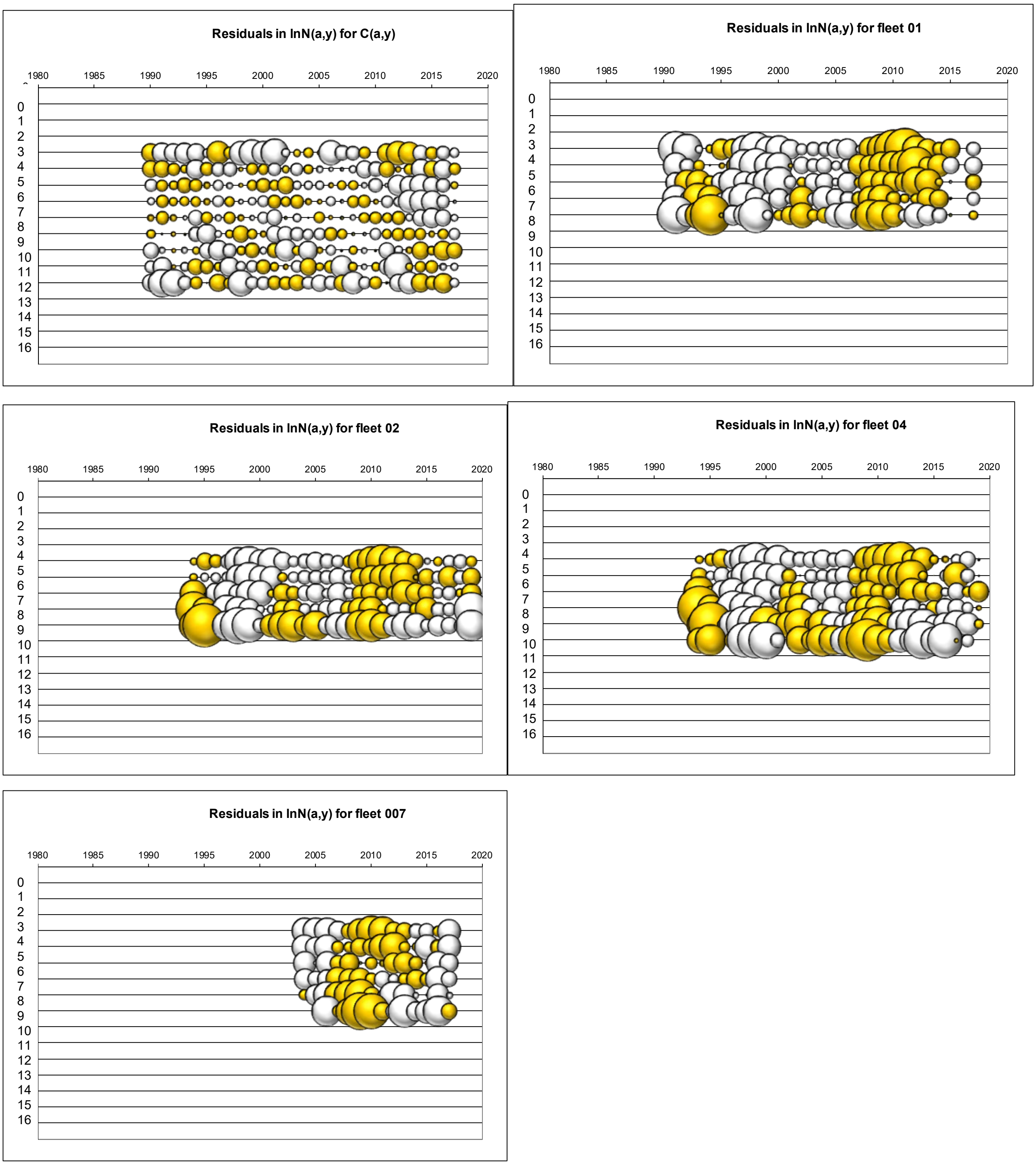


Figure 3. Residuals of the TISVPA data approximation.

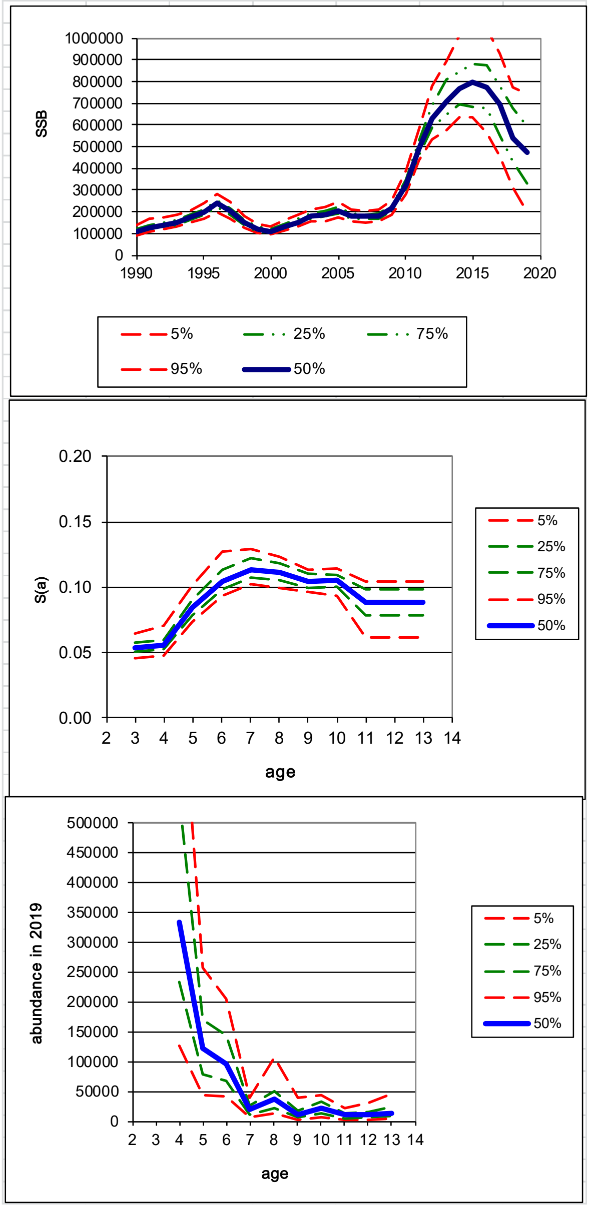


Figure 4. Bootstrap- estimates of uncertainty in the results.

The estimates of uncertainty in the results (parametric conditional bootstrap with respect to catch-at-age; “fleet” data were noised by lognormal noise with sigma=0.3) are presented on Figure 4.

The results of the assessment are presented in the Tables 1-3.

Year	B(3+)	SSB	R(3)	F(4-7)
1990	188070	108230	40142	0.142
1991	215798	126891	99216	0.152
1992	276807	137489	207046	0.234
1993	469862	145635	716991	0.295
1994	575643	166847	301700	0.404
1995	569952	193453	104291	0.367
1996	504478	232654	99178	0.551
1997	366738	196421	114112	0.479
1998	263418	145175	61542	0.411
1999	278358	116339	244415	0.379
2000	272560	108357	94737	0.257
2001	369207	128969	388783	0.263
2002	455951	146362	363343	0.254
2003	511771	172930	231364	0.447
2004	489815	180843	233723	0.386
2005	505404	199125	356330	0.500
2006	436697	174707	163008	0.420
2007	528412	171695	722207	0.408
2008	855545	175476	1577310	0.390
2009	1286152	210524	1672724	0.344
2010	1513396	315332	637295	0.373
2011	1509417	475206	296639	0.415
2012	1419155	609995	478493	0.284
2013	1274599	697956	174556	0.202
2014	1303659	759707	476817	0.170
2015	1231945	785417	112567	0.231
2016	1164762	758272	343297	0.293
2017	1034321	670447	243292	0.359
2018	973103	562375	531790	0.2816
2019		477428		

Table 1. Haddock. The results of the assessment by TISVPA

	3	4	5	6	7	8	9	10	11	12	13
1990	40142	19939	24424	34759	37219	5597	1606	459	267	156	528
1991	99216	29528	14415	17786	24625	25077	3873	1165	333	202	303
1992	207046	75555	21541	9842	11913	16483	16974	2737	850	254	143
1993	716991	153873	52592	14186	5826	7253	10546	10790	1809	630	164
1994	301700	520256	106468	30667	8191	3155	4246	6654	6912	1263	239
1995	104291	211647	354593	58045	14257	4328	1568	2231	3427	4224	609
1996	99178	72019	138721	203721	30721	6547	2522	869	1230	2215	2840
1997	114112	55263	45757	74011	86929	12314	2529	1279	407	632	1851
1998	61542	71169	37267	24774	33142	32192	5292	1213	718	232	1618
1999	244415	44629	45664	21857	12239	15189	12495	2568	664	478	966
2000	94737	168814	30019	24798	12054	5842	7198	5592	1434	420	1103
2001	388783	72144	112630	19460	14968	7425	3338	4399	3244	980	1671
2002	363343	281547	53537	65936	11808	8872	4728	1855	2614	2074	582
2003	231364	251742	188547	35442	35614	7337	5421	3176	1125	1685	1611
2004	233723	147225	159040	97950	19897	15036	4229	2630	1710	620	2074
2005	356330	149543	93808	87313	44491	11835	7300	2688	1264	1087	4378
2006	163008	231162	94760	52122	37966	16809	7215	3381	1361	798	1464
2007	722207	116916	152709	52340	27308	16887	7160	4650	1749	874	821
2008	1577310	475260	78177	84797	25609	12881	7377	3517	2783	993	771
2009	1672724	1015065	302951	45800	41998	12375	6510	3639	1890	1863	1695
2010	637295	1117465	672545	174710	25329	21798	6641	3760	2148	1253	3215
2011	296639	447211	771254	381365	87052	13399	12407	3682	2135	1336	3517
2012	478493	197513	295439	455715	182750	38723	7304	7432	2227	1357	3567
2013	174556	307233	142343	206178	275810	85849	20330	4698	5079	1558	3933
2014	476817	116925	218538	102746	143071	170397	46446	12342	3023	3683	4562
2015	112567	346834	87259	157176	73844	98324	107187	26334	8113	2040	2157
2016	343297	78313	225029	59224	104633	50103	62588	66203	16268	5423	1535
2017	243292	248531	56020	138121	36102	64504	31083	36278	41422	10073	1706
2018	531790	168916	167249	32948	68088	19540	37507	18359	21659	27371	8228
2019	0	372884	117197	105559	19301	38661	11362	22653	11298	14508	18334

Table 2. Haddock. Estimates of abundance-at-age

F	3	4	5	6	7	8	9	10	11	12	13
1990	0.0794	0.0980	0.1307	0.1507	0.1872	0.1575	0.1426	0.1345	0.0967	0.0967	0.0967
1991	0.0929	0.0907	0.1623	0.1774	0.1757	0.1893	0.1520	0.1444	0.1037	0.1037	0.1037
1992	0.1213	0.1427	0.2030	0.3046	0.2839	0.2420	0.2489	0.2104	0.1496	0.1496	0.1496
1993	0.1566	0.1592	0.2774	0.3239	0.4201	0.3333	0.2692	0.2615	0.1846	0.1846	0.1846
1994	0.1946	0.2323	0.3528	0.5186	0.5124	0.5731	0.4233	0.3705	0.2571	0.2571	0.2571
1995	0.1819	0.1916	0.3407	0.4193	0.5182	0.4334	0.4563	0.3386	0.2362	0.2362	0.2362
1996	0.2267	0.2886	0.4643	0.7108	0.7413	0.7819	0.6009	0.5234	0.3544	0.3544	0.3544
1997	0.2421	0.2228	0.4288	0.5573	0.7085	0.6133	0.6067	0.4739	0.3236	0.3236	0.3236
1998	0.1685	0.2394	0.3277	0.5166	0.5600	0.5927	0.4888	0.4334	0.2978	0.2978	0.2978
1999	0.2459	0.1757	0.3747	0.4143	0.5532	0.5047	0.5037	0.4213	0.2901	0.2901	0.2901
2000	0.0999	0.1858	0.1949	0.3342	0.3112	0.3482	0.3046	0.2899	0.2037	0.2037	0.2037
2001	0.1843	0.1103	0.3055	0.2579	0.3803	0.3029	0.3218	0.3013	0.2113	0.2113	0.2113
2002	0.1770	0.1919	0.1662	0.3844	0.2732	0.3453	0.2626	0.2930	0.2058	0.2058	0.2058
2003	0.2409	0.2893	0.4814	0.3243	0.6948	0.3994	0.4862	0.4620	0.3160	0.3160	0.3160
2004	0.2283	0.2332	0.4231	0.5690	0.3187	0.5675	0.3183	0.4131	0.2848	0.2848	0.2848
2005	0.2278	0.2666	0.4110	0.6203	0.7018	0.3262	0.5498	0.4542	0.3111	0.3111	0.3111
2006	0.1861	0.2185	0.3835	0.4771	0.6004	0.5660	0.2593	0.4019	0.2775	0.2775	0.2775
2007	0.2563	0.2051	0.3606	0.5215	0.5446	0.5771	0.5142	0.4155	0.2864	0.2864	0.2864
2008	0.2759	0.2611	0.3096	0.4455	0.5423	0.4774	0.4772	0.3932	0.2719	0.2719	0.2719
2009	0.1819	0.2552	0.3615	0.3435	0.4163	0.4277	0.3598	0.3367	0.2349	0.2349	0.2349
2010	0.1542	0.1988	0.4230	0.4848	0.3847	0.3979	0.3875	0.3446	0.2401	0.2401	0.2401
2011	0.1491	0.1723	0.3314	0.5913	0.5643	0.3778	0.3706	0.3621	0.2516	0.2516	0.2516
2012	0.1423	0.1238	0.2083	0.3245	0.4786	0.3894	0.2553	0.2748	0.1935	0.1935	0.1935
2013	0.1278	0.1283	0.1618	0.2225	0.2944	0.3671	0.2870	0.2298	0.1629	0.1629	0.1629
2014	0.1395	0.1188	0.1730	0.1778	0.2091	0.2379	0.2801	0.1988	0.1416	0.1416	0.1416
2015	0.1420	0.1833	0.2276	0.2728	0.2388	0.2433	0.2640	0.2462	0.1742	0.1742	0.1742
2016	0.1407	0.1710	0.3297	0.3318	0.3386	0.2541	0.2464	0.2794	0.1967	0.1967	0.1967
2017	0.1769	0.1750	0.3167	0.5129	0.4307	0.3746	0.2661	0.3292	0.2299	0.2299	0.2299
2018	0.1550	0.1656	0.2602	0.3348	0.3660	0.3422	0.3042	0.2855	0.2007	0.2007	0.2007

Table 3. Haddock. Estimates of fishing mortality coefficients

References

. Vasilyev D. 2005 Key aspects of robust fish stock assessment. M: VNIRO Publishing, 2005. 105 p.

. Vasilyev D. 2006. Change in catchability caused by year class peculiarities: how stock assessment based on separable cohort models is able to take it into account? (Some illustrations for triple-separable case of the ISVPA model - TISVPA). ICES CM 2006/O:18. 35 pp

What does NEA cod want for prediction - Fsq or TAC constrain?

WD 11 to ICES AFWG, 24-30 April 2019

Yury Kovalev, Anatolii Chetyrkin (Polar branch of VNIRO, Russia)

Introduction

Prediction of TSB and SSB in stock assessment and TAC estimation often producing using two approaches. ”F status quo” method (FSQ) which assumed F for “intermediate year” (a year after terminal year in assessment) equal to the F of previous year or average F for number of previous years. The second method – “TAC constrained” approach assumed F for intermediate year corresponding to actual/predicted catch at this year. Usually catch is taken as TAC for that year.

TAC for NEA cod for many years is predicted using FSQ method. It is stated in Quality Handbook for NEA cod. Historically it was observed that in some years predicted catch for intermediate year was significantly differ from TAC/actual catch. The reason for using FSQ method was that it gives more accurate prediction of TSB and SSB for beginning of the first year of prediction (TAC year).

At this WD we explore if the used reason is still valid.

Method

The main assessment model for NEA cod is SAM [1]. The work is done using the SAM model with same model configuration as used at AFWG-2018 [2]. The assessment and prediction are simulated in a way maximally corresponding to AFWG-2018 [2]. Terminal values of TSB and SSB as well as F pattern and Fsq were taken from SAM retro runs.

Retro runs were made for the period from 2012 to 2018 due to the fact that when we move backward there are not enough years with data on ecosystem surveys. Historical TAC values were taken from ACOM Advice table while biological data from AFWG-2018 [2]. Prediction of weight in stock, weight in catch, maturity ogives, fishing pattern and natural mortality were made like at AFWG-2018 (Table A.4-A.8). Recruitment was not modeled and taken from AFWG-2018 (Table A.1-A.3).

The forecast of catch and stock dynamics for intermediate year is made by 2 methods:

1 - F taken from the last year of the retro run (FSQ method),

2 - F matched accordingly the TAC of this year (TAC constrained).

Tables with the results of predictions are given below (Table A.1-A.3). The “true” SSB and TSB assumed equal the last group assessment values.

Comparison of the results of both prediction methods quality (Figures 1-4) is done visually and using Mohn`s rho and SSQ criteria (Table 1):

Mohn`s rho - the average deviation of the predicted values from the "true" run (AFWG 2018);

SSQ - the standard deviation of the predicted values from the “true” run (AFWG 2018).

Results:

The results of calculations of the TSB and SSB predicted values using two forecast methods are presented in figures 1-4.

Figures 3-4 shows the “true” terminal values of TSB and SSB in comparing with same data predicted by two methods for the beginning of “TAC year” started from terminal retro values. A systematic underestimation of TSB is noticeable compared with the “true” values. In contrast to TSB, for SSB in retro prediction there were deviations in both directions (over/underestimation).

According to the Mohn`s rho and SSQ criteria the FSQ method gives more adequate prediction of TSB and SSB at the beginning of TAC year.

Table 1. Mohn`s rho and SSQ criteria values for FSQ and TAC prediction methods in comparison with “true” assessment

		Rho	SSQ
TSB	Fsq	-0,148	0,18
	TAC constrained	-0,182	0,20
SSB	Fsq	-0,020	0,13
	TAC constrained	-0,068	0,14

It was also verified that with calculation F as average for 5 previous years the rho\ssq criteria values became slightly worse.

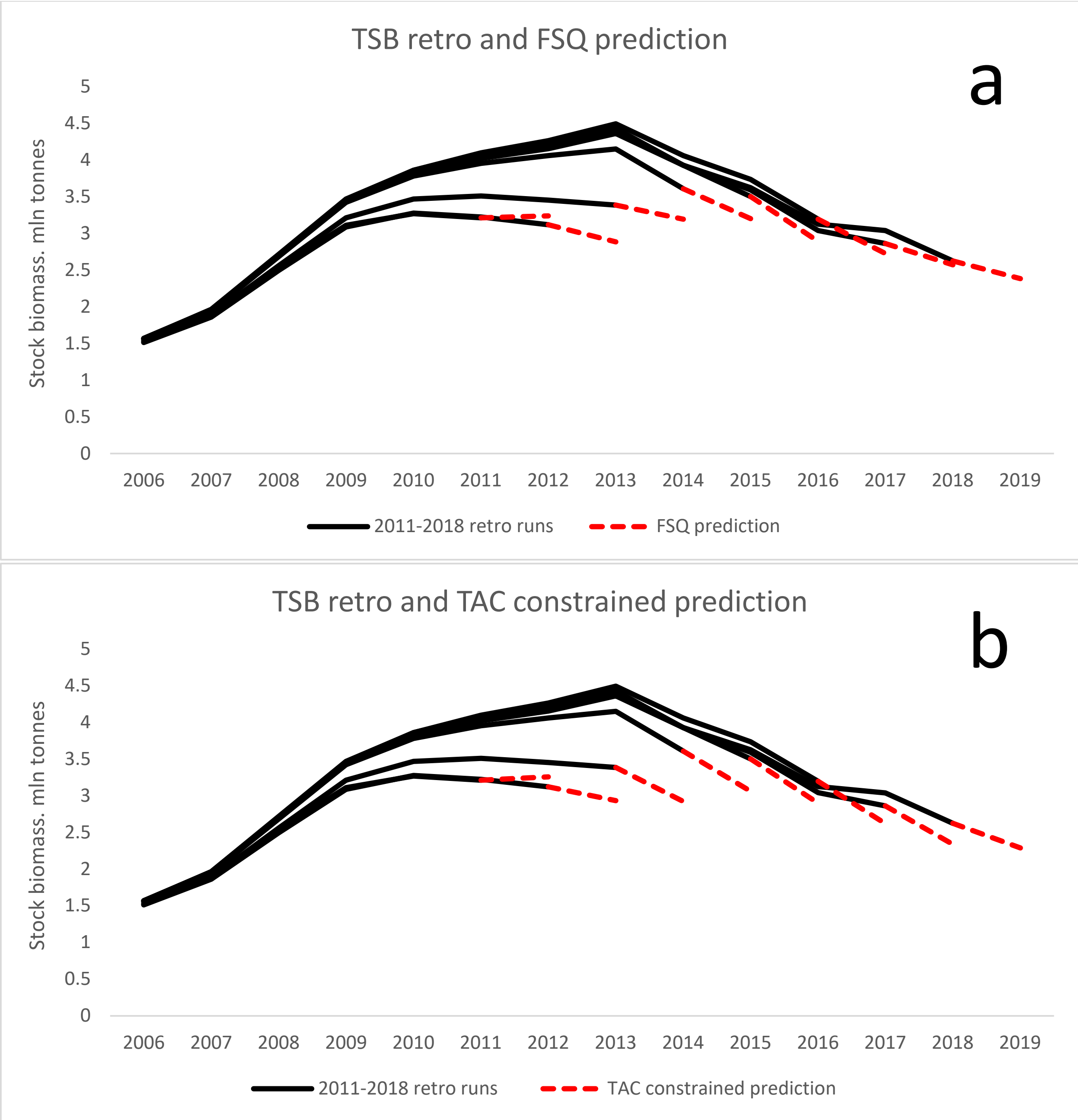


Figure 1. TSB values from retro run and FSQ (a), TAC constrained (b) methods of prediction

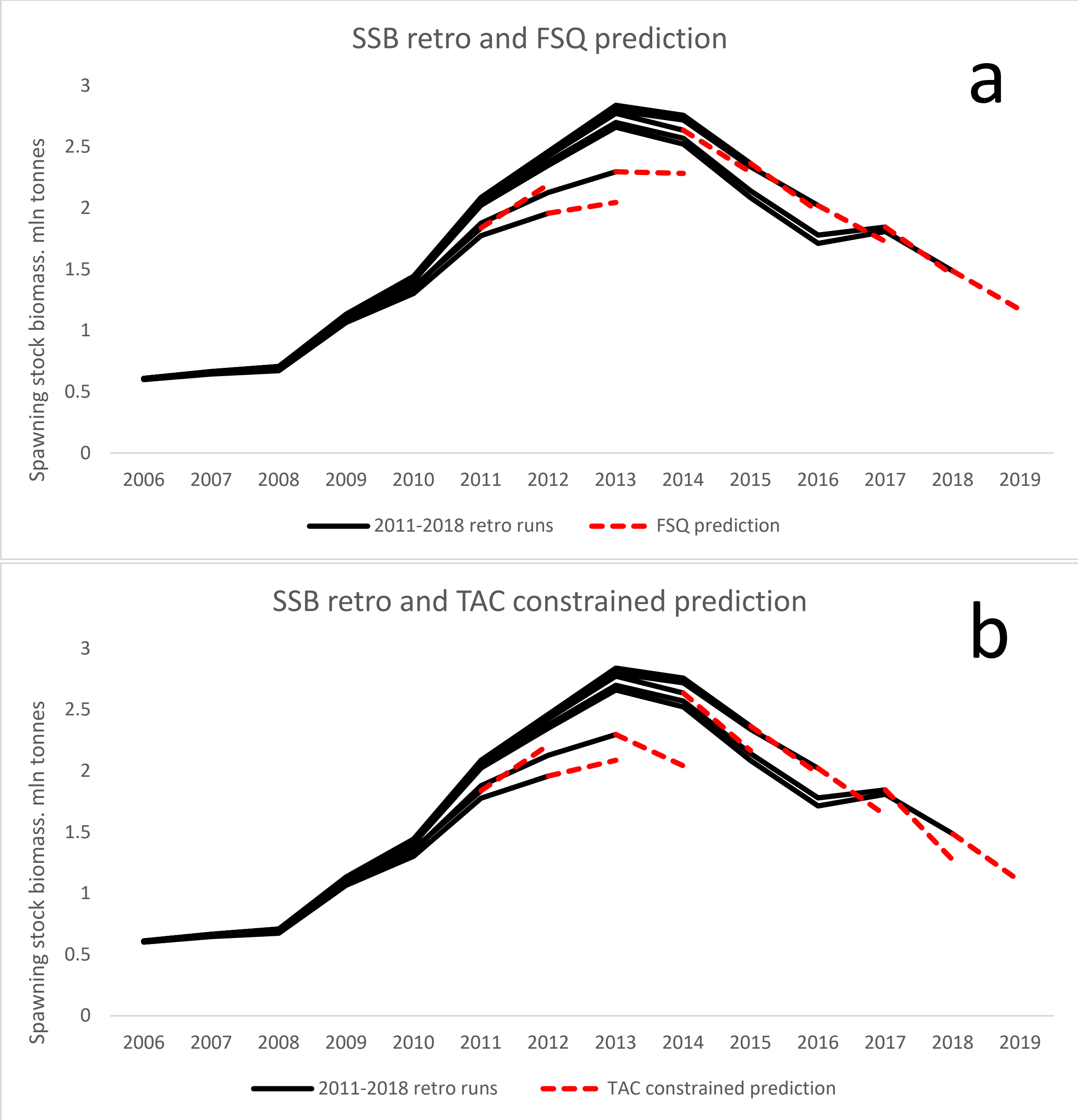


Figure 2. SSB values from retro run and FSQ (a), TAC constrained (b) methods of prediction

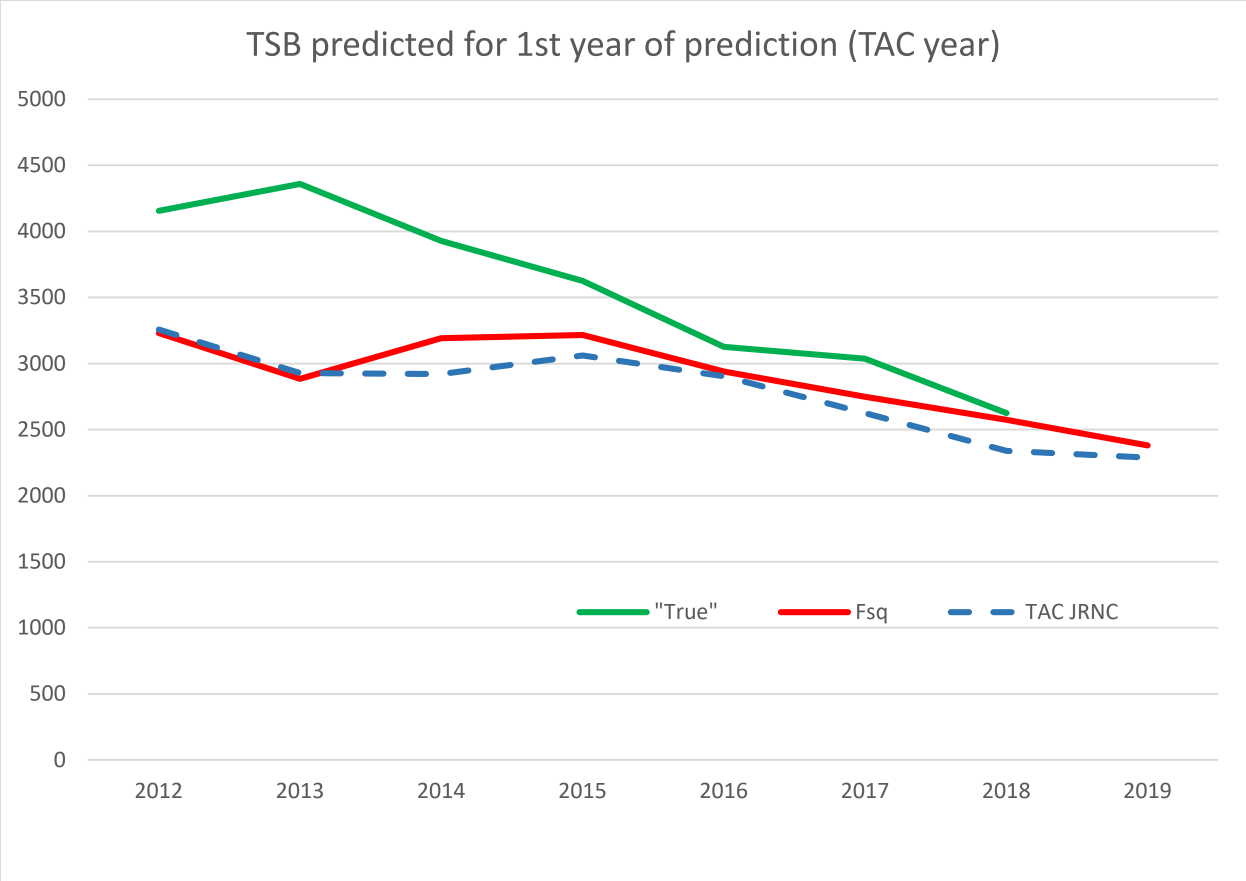


Figure 3. TSB predicted for 1st year of prediction

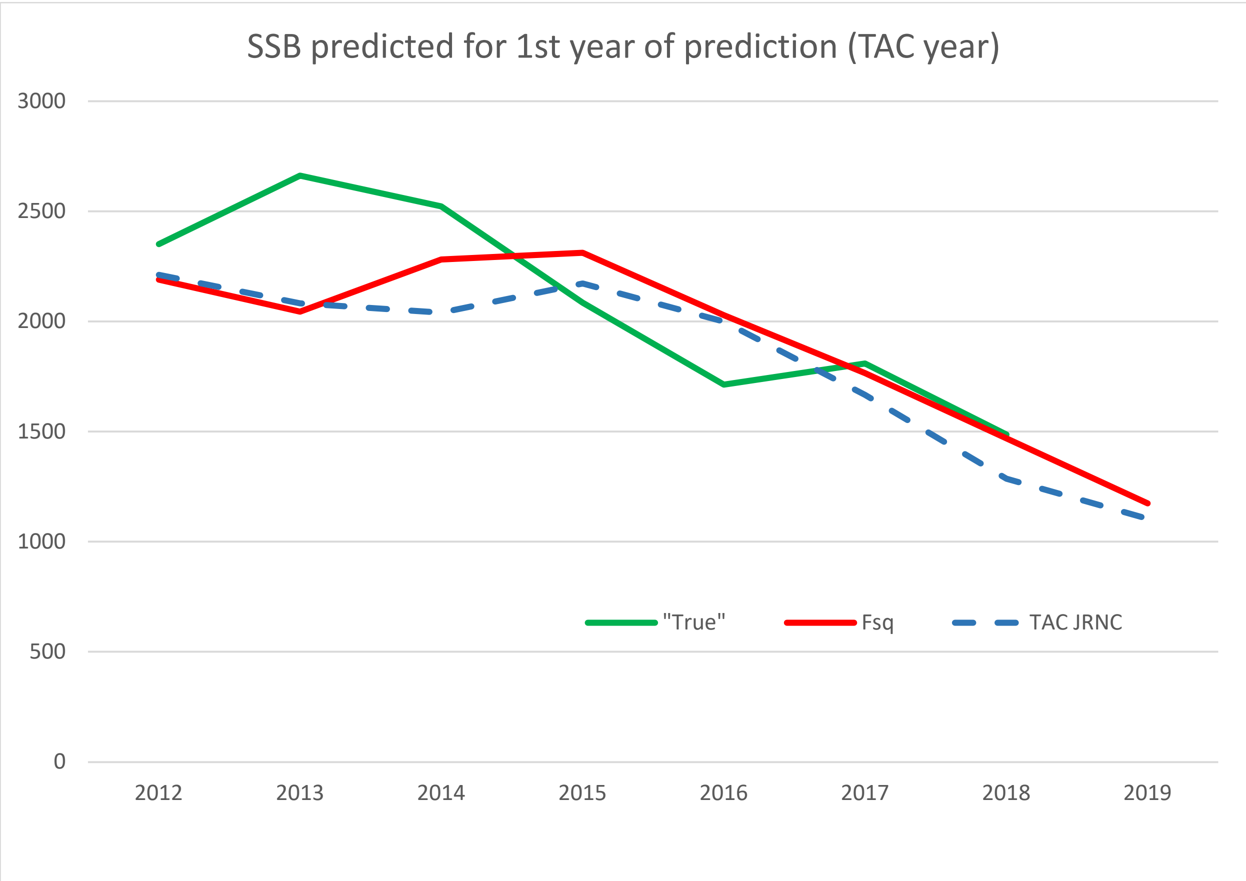


Figure 4. SSB predicted for 1st year of prediction

Appendix

Table A.1. Terminal values of abundance, TSB and SSB from SAM retro run

	Terminal stock assessment values							
	N							
	2011	2012	2013	2014	2015	2016	2017	2018
3*	473404	553893	613740	718586	399021	245294	688190	691000
4	97516	134484	193276	235228	298461	209331	134444	405639
5	250506	78787	118249	177960	203324	275231	151748	130203
6	363640	191019	77851	116186	151390	171182	191404	135076
7	372530	304819	153570	72811	104310	114604	102531	140551
8	119801	236480	233791	143583	54137	72187	77921	80112
9	37832	59287	160124	184310	113830	42647	45747	38865
10	13287	20675	34821	115504	117646	76294	27146	25304
11	12168	6449	13745	20529	57125	62392	31703	11296
12	2370	4479	3933	8446	11221	26193	25858	12574
13	611	984	2763	2763	5021	5908	10959	12097
14	271	344	661	2091	1835	2791	3339	6527
15	135	204	392	1146	2567	3160	3972	4783
TSB	3210	3119	3385	3607	3501	3194	2860	2624
SSB	1839	1959	2298	2637	2365	2022	1846	1486
"True"								
TSB 2018	**4021**	**4154**	**4360**	**3926**	**3624**	**3125**	**3037**	**2624**
SSB 2018	**2024**	**2350**	**2662**	**2523**	**2085**	**1713**	**1809**	**1486**

* recruitment is taken from AFWG-2018 report

Table A.2. Terminal values of abundance, TSB and SSB assessed by Fsq method

	N	Forecast on the end of intermediate year (TAC year)							
	2011	2012	2013	2014	2015	2016	2017	2018	2019
3*		553893	613740	718586	399021	245294	688190	691000	617000
4		323258	346667	385577	415865	236757	152860	472319	466535
5		71735	90923	125280	155934	197107	141564	91678	286328
6		176575	55391	82638	123405	138021	182080	96238	83548
7		246570	129944	53908	79640	100275	109405	116427	80076
8		239594	192369	100121	47141	64268	69491	61096	79385
9		72296	139673	144883	87879	31721	41650	44351	41391
10		22436	33327	95911	108897	64524	24414	25313	20002
11		7727	10919	19891	65993	65227	41470	13720	11243
12		6290	3039	7190	11569	32655	33732	15923	4885
13		1054	1923	2006	5010	6942	15826	14988	6694
14		358	486	1469	1751	3320	3984	7306	7724
15		151	208	421	1475	1312	2023	2421	4631
TSB		3230	2883	3190	3216	2939	2748	2573	2381
SSB		2189	2043	2281	2312	2029	1765	1469	1174
"True"									

TSB 2018		4154	4360	3926	3624	3125	3037	2624	
SSB 2018		2350	2662	2523	2085	1713	1809	1486	

* recruitment is taken from AFWG-2018 report

Table A.3. Terminal values of abundance, TSB and SSB assessed by TAC constrained method

	N	Forecast on the end of intermediate year (TAC year)							
	2011	2012	2013	2014	2015	2016	2017	2018	2019
3*		553893	613740	718586	399021	245294	688190	691000	617000
4		323391	346865	384442	415230	236661	152587	470196	465655
5		71900	91260	122851	154307	196566	139920	89228	282956
6		177476	55836	79024	120419	137112	177207	90061	81126
7		248296	131404	50630	76917	99350	105032	105260	76390
8		241830	195433	91752	44965	63465	66074	54266	74964
9		73150	142470	130216	82878	31255	39273	38725	38552
10		22716	34096	85085	101972	63483	22990	21870	18619
11		7829	11213	17328	61381	64112	38714	11460	10231
12		6402	3143	6055	10731	32140	31462	13269	4426
13		1079	1999	1673	4695	6857	15039	13175	6264
14		363	501	1245	1663	3289	3856	6767	7433
15		153	211	382	1432	1304	1982	2314	4530
TSB		3256	2929	2919	3060	2904	2625	2340	2288
SSB		2211	2083	2040	2172	1999	1666	1287	1104
"True"									
TSB 2018		4154	4360	3926	3624	3125	3037	2624	
SSB 2018		2350	2662	2523	2085	1713	1809	1486	

* recruitment is taken from AFWG-2018 report

Table A.4. Simulated predicted data of maturity ogive

	Mat								
	Avarage for last 3 years								
	2011	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	
3	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	
4	0,002	0,001	0,001	0,001	0,001	0,002	0,001	0,001	
5	0,061	0,053	0,043	0,030	0,024	0,013	0,012	0,007	
6	0,326	0,346	0,294	0,237	0,169	0,128	0,096	0,100	
7	0,622	0,656	0,590	0,561	0,519	0,427	0,350	0,343	
8	0,853	0,837	0,814	0,785	0,781	0,753	0,694	0,686	
9	0,944	0,948	0,925	0,919	0,915	0,907	0,872	0,876	
10	0,987	0,977	0,966	0,970	0,975	0,976	0,968	0,971	
11	0,985	0,982	0,985	0,990	0,992	0,992	0,991	0,991	
12	0,995	0,992	0,988	0,993	0,996	0,998	0,998	0,997	
13	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	
14	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	
15	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	

Table A.5 Simulated predicted data of weight in stock

	WEST								(	
	Increament = Avarage for last 3 years + last year data									
	2011	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**		
3	0,246	0,231	0,225	0,235	0,222	0,234	0,223	0,271		
4	0,642	0,563	0,543	0,605	0,569	0,577	0,548	0,609		
5	1,196	1,139	1,081	1,125	1,143	1,121	1,072	1,218		
6	2,091	1,898	1,812	1,923	1,899	1,958	1,740	1,955		
7	3,181	2,895	2,562	2,913	2,751	2,918	2,677	2,941		
8	4,685	4,108	3,927	4,088	4,010	3,972	3,776	4,309		
9	6,563	6,011	5,770	5,738	5,317	5,312	5,335	6,301		
10	8,707	8,357	7,870	7,625	7,000	6,935	7,142	7,711		
11	8,405	9,828	10,803	10,481	8,858	8,332	8,640	9,298		
12	12,591	13,190	14,478	12,432	10,946	11,222	11,819	13,048		
13	14,544	14,544	14,544	14,544	14,544	14,544	14,544	14,544		
14	16,466	16,466	16,466	16,466	16,466	16,466	16,466	16,466		
15	18,388	18,388	18,388	18,388	18,388	18,388	18,388	18,388		

Table A.6. Weight in catch data for prediction

	WECA									
				Forecast on internal year (for other years – constant)						
	2011	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	
2										
3	0,7781	0,832	0,635	0,679	0,882	0,914	0,777	0,787		
4	1,235	1,240	1,116	1,163	1,246	1,235	1,219	1,136		
5	1,762	1,863	1,685	1,696	1,735	1,617	1,672	1,665		
6	2,514	2,459	2,468	2,379	2,444	2,250	2,344	2,315		
7	3,532	3,416	3,367	3,341	3,336	3,172	3,249	3,271		
8	4,756	4,541	4,451	4,474	4,558	4,416	4,534	4,572		
9	6,464	6,002	5,804	5,582	5,532	5,764	5,856	5,988		
10	7,801	7,680	7,816	7,018	6,913	6,998	7,479	7,486		
11	8,548	8,681	9,577	8,422	8,133	7,633	8,557	8,269		
12	10,997	10,988	12,816	11,422	11,178	9,894	11,334	10,854		
13	12,800	12,800	12,800	12,800	12,800	12,800	12,800	12,800		
14	14,180	14,180	14,180	14,180	14,180	14,180	14,180	14,180		
15	15,550	15,550	15,550	15,550	15,550	15,550	15,550	15,550		

Table A.7. F pattern for prediction

	mean relative F for previous 3 years							
	2011	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**
3	0,042	0,033	0,032	0,030	0,032	0,035	0,036	0,031
4	0,235	0,213	0,210	0,208	0,215	0,229	0,217	0,192
5	0,521	0,461	0,480	0,485	0,517	0,532	0,532	0,476

6	0,713	0,643	0,673	0,688	0,724	0,800	0,809	0,762
7	0,950	0,910	0,937	0,935	0,983	0,989	0,952	0,927
8	1,201	1,141	1,145	1,159	1,157	1,152	1,089	1,149
9	1,269	1,314	1,285	1,300	1,271	1,178	1,173	1,159
10	1,346	1,532	1,480	1,433	1,348	1,349	1,445	1,526
11	1,810	1,930	1,842	1,488	1,242	1,366	1,463	1,594
12	2,402	2,256	1,946	1,284	0,969	1,000	1,034	1,075
13	1,312	1,766	1,776	1,020	0,739	0,639	0,615	0,621
14	1,522	1,067	1,033	0,593	0,469	0,402	0,364	0,357
15	1,522	1,067	1,033	0,593	0,469	0,402	0,364	0,357
Fbar	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000

Table A.8. Natural mortality data for prediction

	Natural mortality			**mean value for previous 3 years**				
	2011	2012	2013	2014	2015	2016	2017	2018
3	0,371	0,459	0,457	0,539	0,513	0,462	0,364	0,381
4	0,247	0,331	0,382	0,359	0,353	0,322	0,310	0,272
5	0,217	0,221	0,242	0,244	0,238	0,252	0,278	0,253
6	0,207	0,201	0,204	0,205	0,202	0,205	0,227	0,218
7	0,2	0,2	0,2	0,2	0,2	0,2	0,2	0,2
8	0,2	0,2	0,2	0,2	0,2	0,2	0,2	0,2
9	0,2	0,2	0,2	0,2	0,2	0,2	0,2	0,2
10	0,2	0,2	0,2	0,2	0,2	0,2	0,2	0,2
11	0,2	0,2	0,2	0,2	0,2	0,2	0,2	0,2
12	0,2	0,2	0,2	0,2	0,2	0,2	0,2	0,2
13	0,2	0,2	0,2	0,2	0,2	0,2	0,2	0,2
14	0,2	0,2	0,2	0,2	0,2	0,2	0,2	0,2
15	0,2	0,2	0,2	0,2	0,2	0,2	0,2	0,2

References

1. Nielsen, A., Berg, C.W., 2014. Estimation of time-varying selectivity in stock assessments using state-space models. Fish. Res. 158:96-101.

2. ICES 2018 Report of the Arctic Fisheries Working Group (AFWG), 18–24 April 2018, Ispra, Italy. ICES CM 2018/ACOM:06. 859 pp.

WD_12_AFWG2019_Coastal cod data from coastal areas between Senja and Stad

Coastal cod data from coastal areas between Senja and Stad

1. Survey data 2011-2018 collected by gillnet and fyke net surveys by small vessels in shallow areas, where large research vessels cannot operate

Gill net surveys in shallow areas between Senja (69 deg 30 min N) and Lofoten (68 deg N) in November 2011 and November 2012;

As a part of the KILO-project (Sundby et al 2013) five local vessels (35-45 ft) in the Lofoten-Senja region were hired in November 2011 for fishing with rather small meshed trammel nets at bottom depths between 5 and 30m. In addition, some fyke nets were tested out. The five vessels worked in separate regions (Figure 3). The skippers were asked to define some “priority areas” good for cod fishing. Half of the fishing stations were worked within these “priority areas”, and the other half was fished at similar depths in neighbor areas, at least 1 nautical mile outside the “priority areas”. In November 2012 most of these stations were repeated by the research vessel “Fangst” (50 ft).

Each gill net setting was rigged with 2 nets of 45 mm bar length meshes and 2 nets of 36 mm bar length meshes. A 10 m rope was used to separate the panels of different mesh size (Figure 1).

The experience in 2011 was that lots of brown crabs destroyed both the fish in the nets, and the net material. Therefore, in 2012 the nets were raised about ca 35 cm above bottom (Figure 2) to avoid catching too much brown crab. For the same reason soaking time was limited to 12 hours.

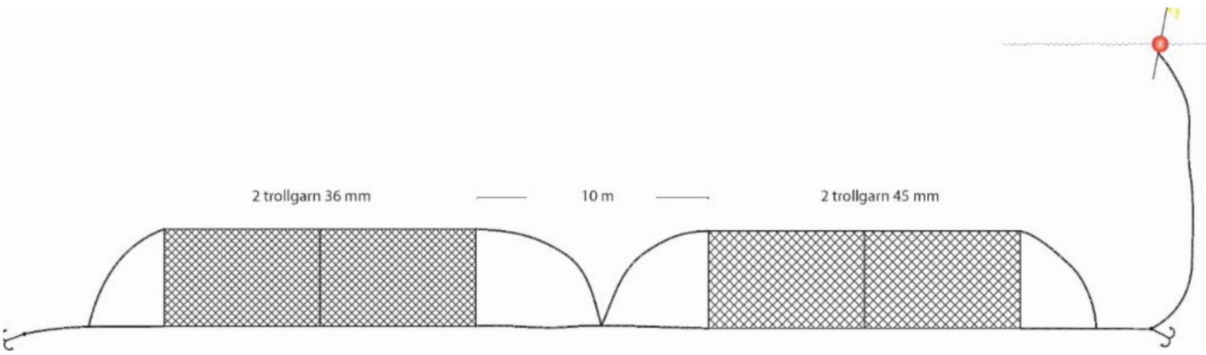


Figure 1. Gill net rigging: 2 nets of 36mm bar length meshes and 2 nets of 45mm bar length meshes.

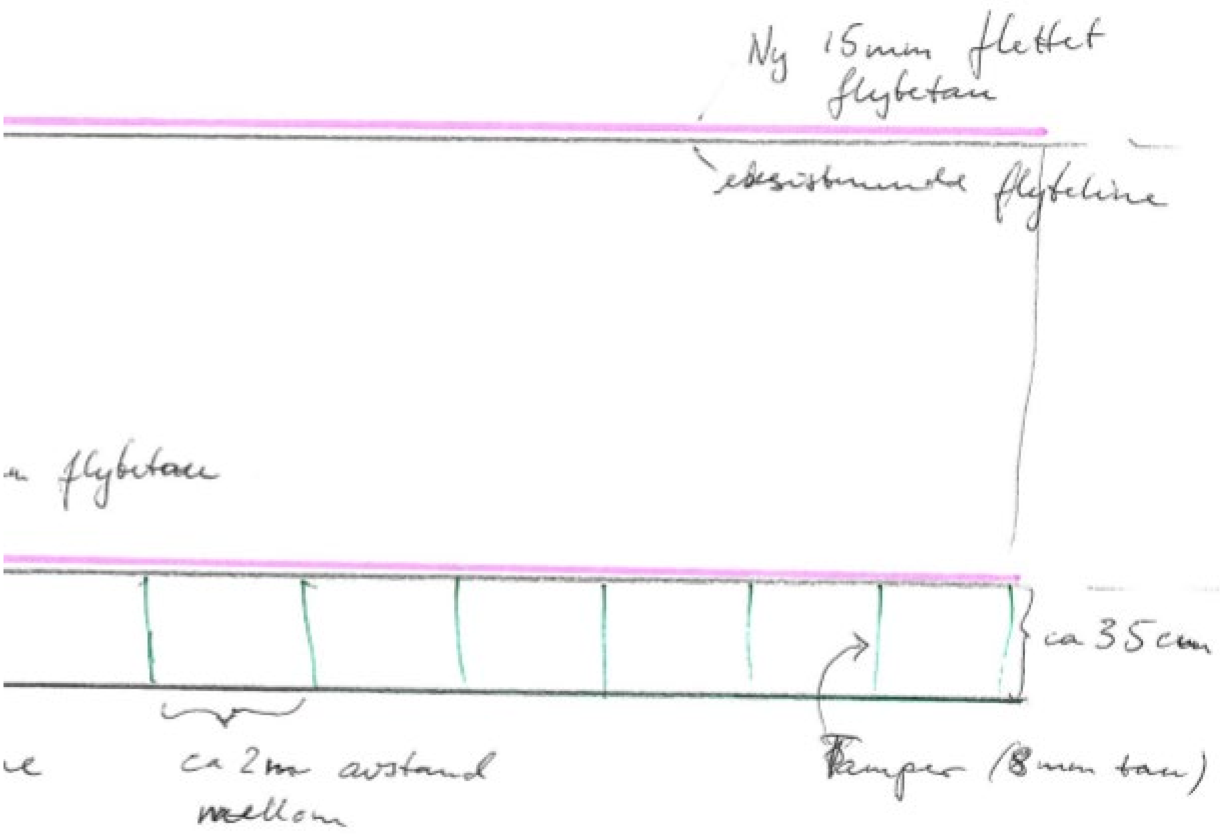


Figure 2. Modified rigging raising the gill net about 35 cm above bottom used in the 2012 surveys and later.

Results November 2011 and November 2012

Figure 3 and 4 show (by regions) the numbers of cod per gill net setting in November 2011 and 2012.

Table 1 and 2 show average catch rates (in numbers) and CV for the various regions in November 2011 and 2012. In regions with less than 8 stations the CV was rather high. The tables do not provide any proof that the preselected “priority areas” gave higher catch rates than the “other areas”.

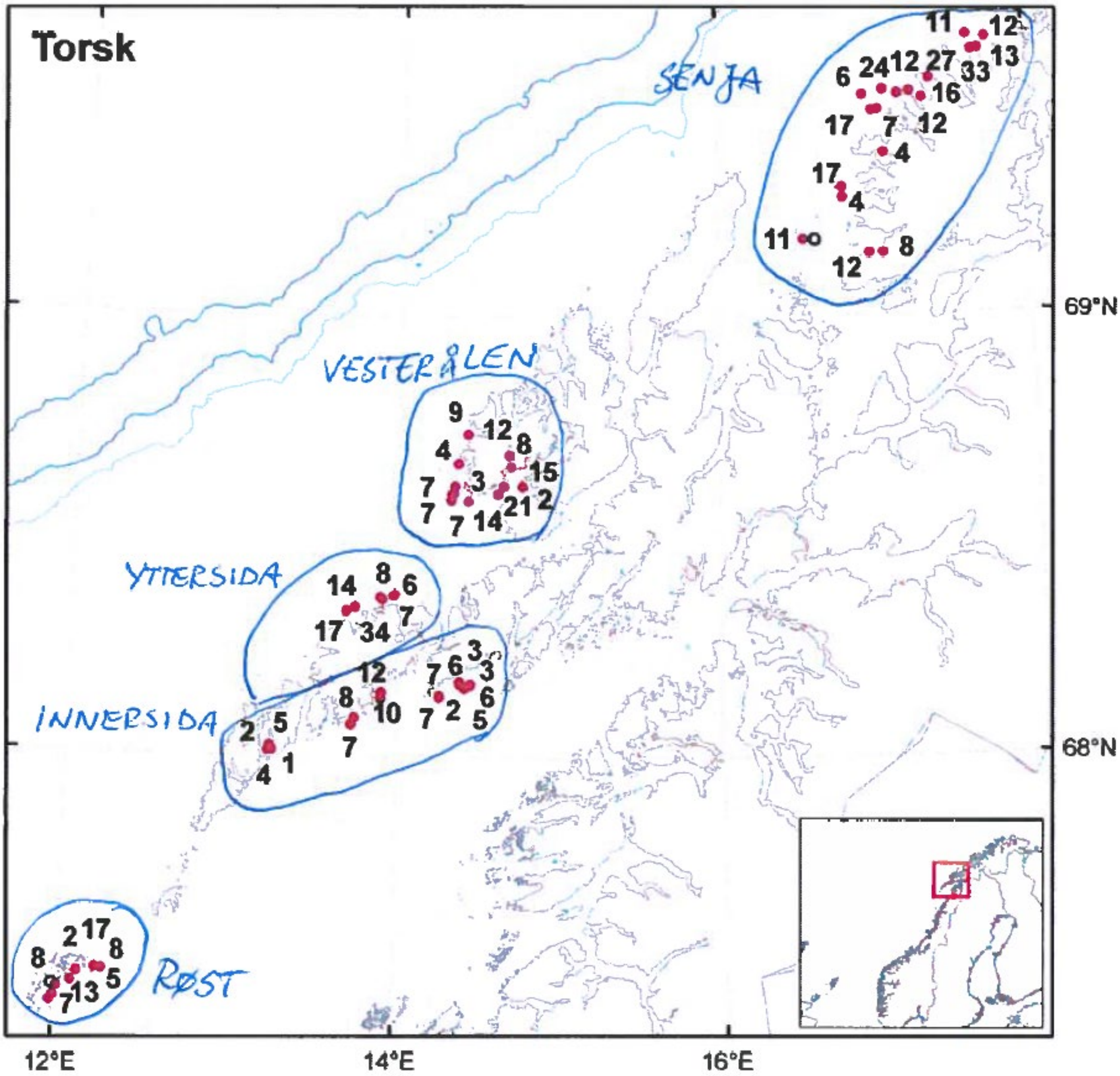


Figure 3. Number of cod per gill-net setting (2 nets of 45 mm bar length meshes and 2 nets of 36 mm bar length meshes), **November 2011**

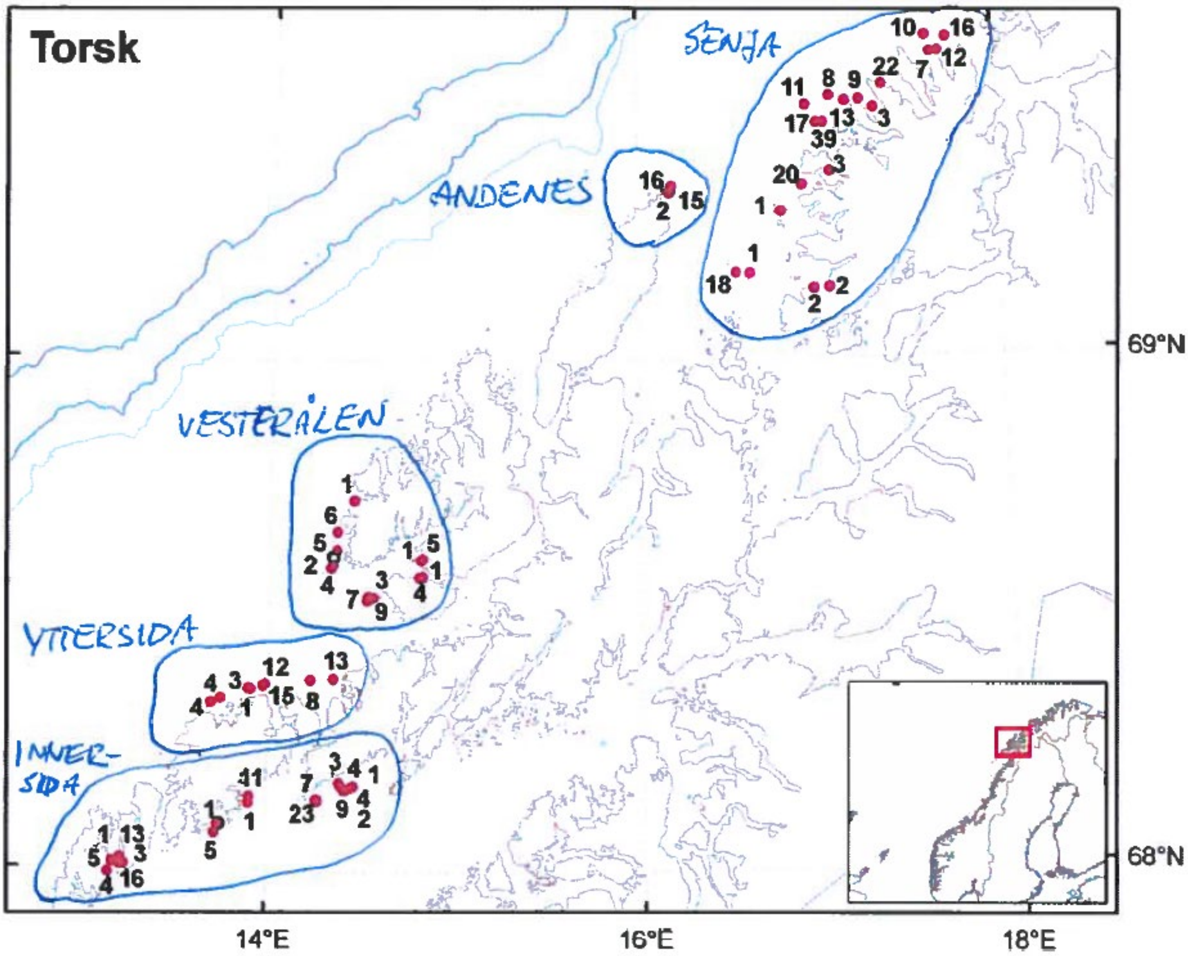


Figure 4. Number of cod per gill-net setting. (2 nets of 45 mm bar length meshes and 2 nets of 36 mm bar length meshes), **November 2012**.

Table 1. **Nov 2011**: Mean and CV for **Number of cod per gill-net station** (2 nets 36mm meshes, and 2 nets 45 mm meshes).

Region	Innersida preselected	Innersida others	Røst preselected	Røst others	Yttersida preselected	Yttersida others	Vesterål preselected	Vesterål others	Senja preselected	Senja others
Number of stations	8	8	4	4	3	3	10	9	10	9
av. Catch rate (#)	5.25	5.75	7.25	7.75	18.00	10.67	10.40	8.14	11.90	14.11
SD	2.92	3.28	7.14	4.50	14.42	5.51	3.85	6.62	7.03	9.64
SDmean	1.03	1.16	3.57	2.25	8.33	3.18	1.22	2.21	2.22	3.21
CV	**0.20**	**0.20**	0.49	**0.29**	0.46	0.30	**0.12**	**0.27**	**0.19**	**0.23**
av. Per single net	1.31	1.44	1.81	1.94	4.50	2.67	2.60	2.04	2.98	3.53

Table 2. **Nov 2012**: Mean and CV for **Number of cod per gill-net station** (2 nets 36mm meshes, and 2 nets 45 mm meshes).

Region	Innersida preselected	Innersida others	Andenes preselected	Andenes others	Yttersida preselected	Yttersida others	Vesterål preselected	Vesterål others	Senja preselected	Senja others
Number of stations	8	11	0	4	5	3	8	5	9	10
av. Catch rate (#)	7.00	5.70		11.00	10.40	2.67	3.88	4.25	13.22	9.50
SD	3.74	7.56		7.81	4.39	1.53	2.85	2.22	11.53	7.38
SDmean	1.32	2.28		3.91	1.96	0.88	1.01	0.99	3.84	2.33
CV	**0.19**	0.40		0.36	**0.19**	0.33	**0.26**	**0.23**	**0.29**	**0.25**
av. Per single net	1.75	1.43		2.75	2.60	0.67	0.97	1.06	3.31	2.38

Fishing with fyke nets in shallow areas between Senja (69 deg 30 min N) and Lofoten (68 deg N) in August 2012

In August 2012 R/V"Fangst" was used, -with an additional 17 ft boat used for fishing with fyke nets in some of the areas covered by the November surveys.

At the previously described survey in November 2011 also fyke nets were used, both the typical fyke nets designed for cod fishing and the smaller types designed for fishing eel. The experience was that catches of fish in fyke nets were quite low, mainly due to short day-light period in the high north in winter. In bad weather with heavy waves there was also problems caused by lot of sea-weed and kelps filling both the guiding net and the fish chambers of the fyke net. A separate survey was conducted with the "eel" fyke nets (Figure 5) during august2012. At that time of the year there are about 20 hours daylight per day and the weather is much more calm, compared to November.

10 double "eel" fyke nets (with a total of 40 "fish chambers") were operated each day. Figures 6 and 7 show the distribution of catches of cod per 5 double fyke nets (Fish lengths less than 20 cm and above 20 cm in different plots). Innersida was the region with highest catch rates both for the small (<20 cm) and larger (>20cm) cod.

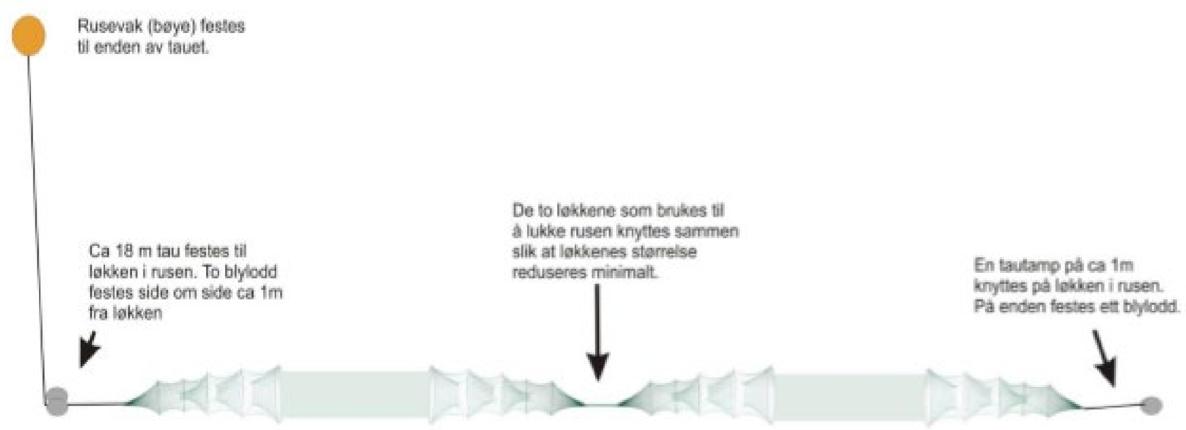


Figure 5. <u>Double «eel» fyke net</u>: From left; 1 fish chamber and 3 trunks, then guiding net, then 3 trunks and fish chamber. The second half mirrors the first. In total there are 4 fish chambers. (from van der Meeren, 2018).

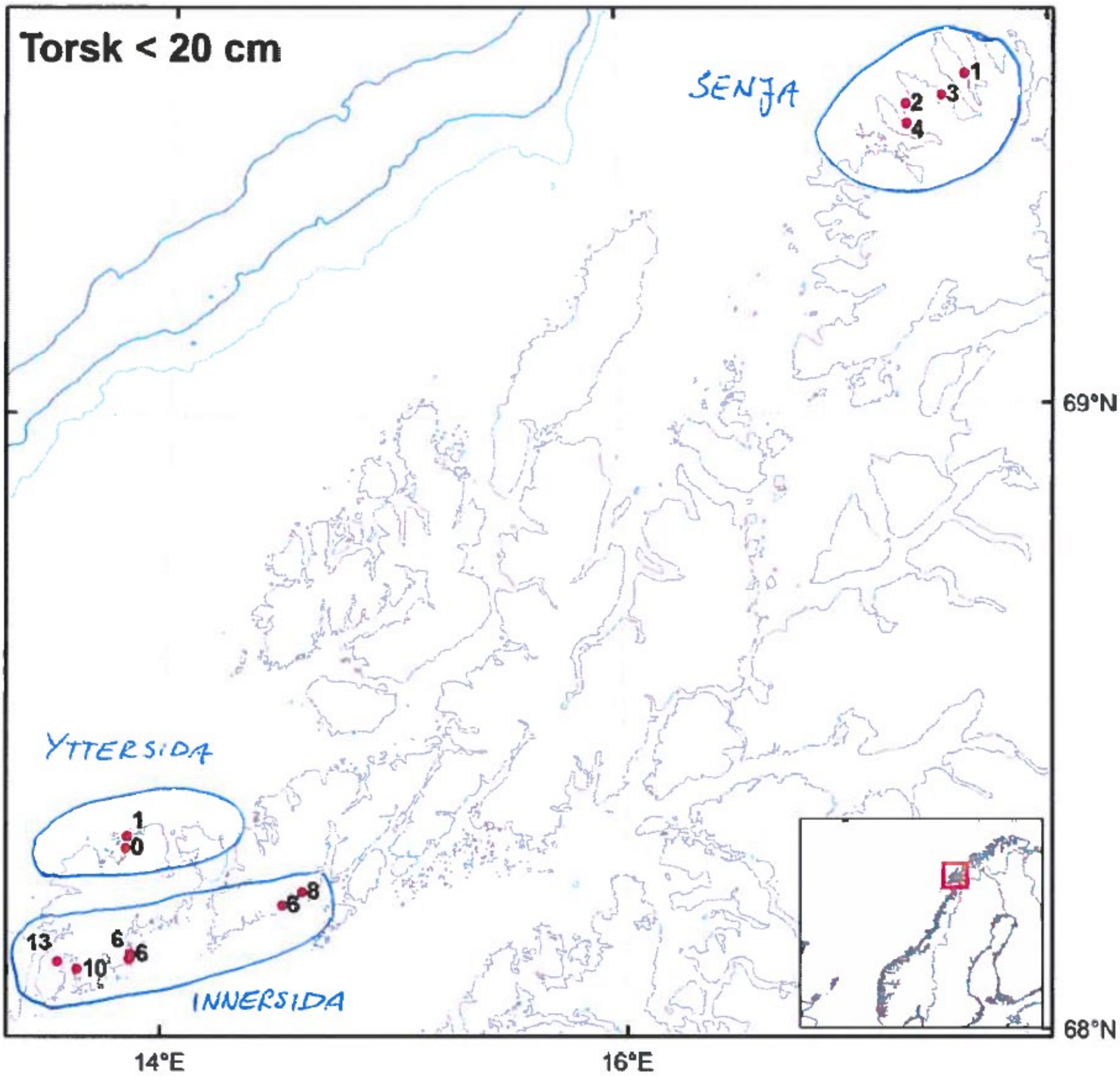


Figure 6. Number of cod<20cm in sets of 5 double “eel” fyke nets, August 2012.

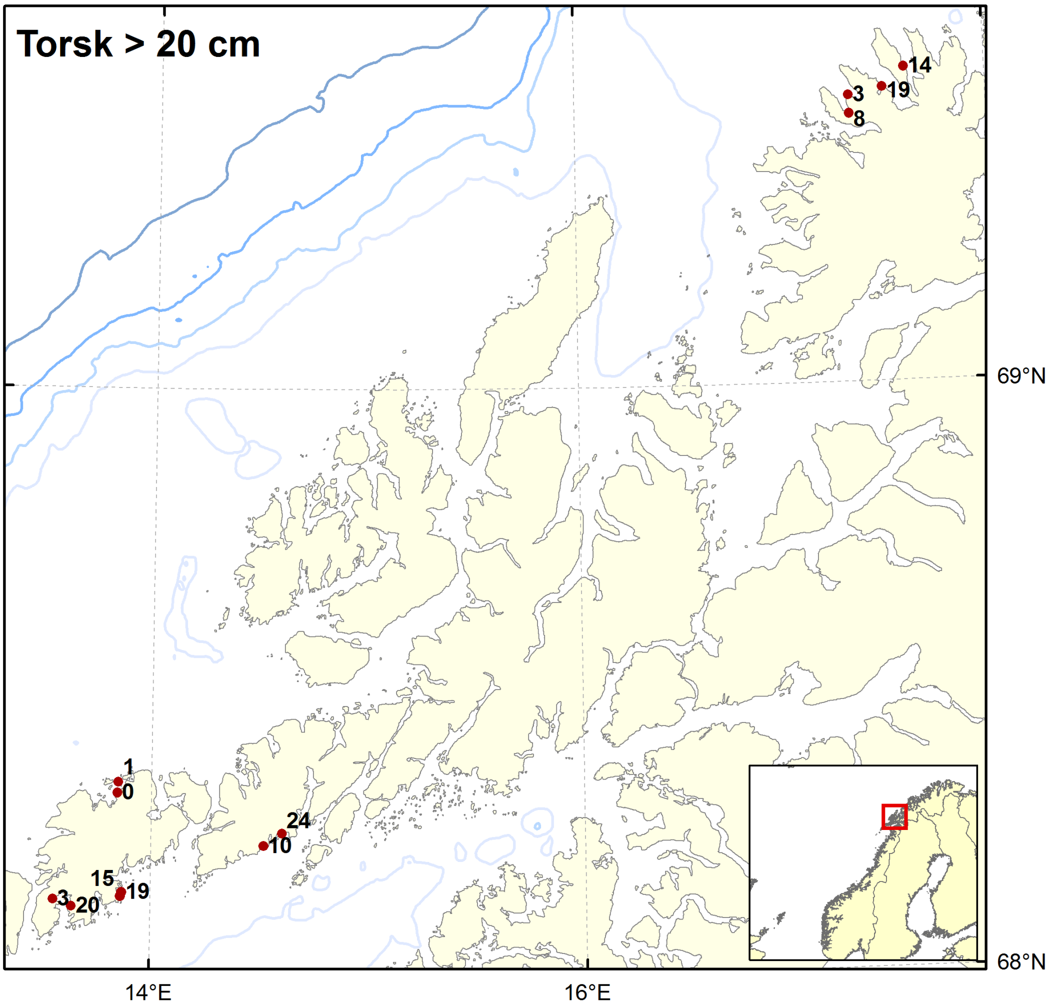


Figure 7. Number of cod>20cm in sets of 5 double “eel” fyke nets, August 2012.

Fishing with trammel nets and fyke nets in shallow areas between Steigen (68 deg N) and Vikna (65 deg N) in August 2013, 2016 and 2018

Based on the experience in Lofoten-Senja similar surveys have been conducted in the shallow areas between Steigen (68 deg N) and Vikna (65 degN) in 2013, 2016 and 2018, and in the shallow areas between Vikna and Stad (62 deg N) in 2015 and 2017.

It was decided to use 6 double fyke nets (Figure 5) and 2 gill net sets (as Figure 2) per fishing day. Within the Steigen-Vikna area 49 candidate fishing areas were defined, each suitable for one day fishing (Figure 8). Among those areas, 12 were fished in 2013, 21 in 2016 and 20 in 2018. Among those 20 fished in 2018; 11 have been fished in all 3 years, 8 in 2 years and 4 has been fished only one year. R/V “Fangst” was used in all surveys.

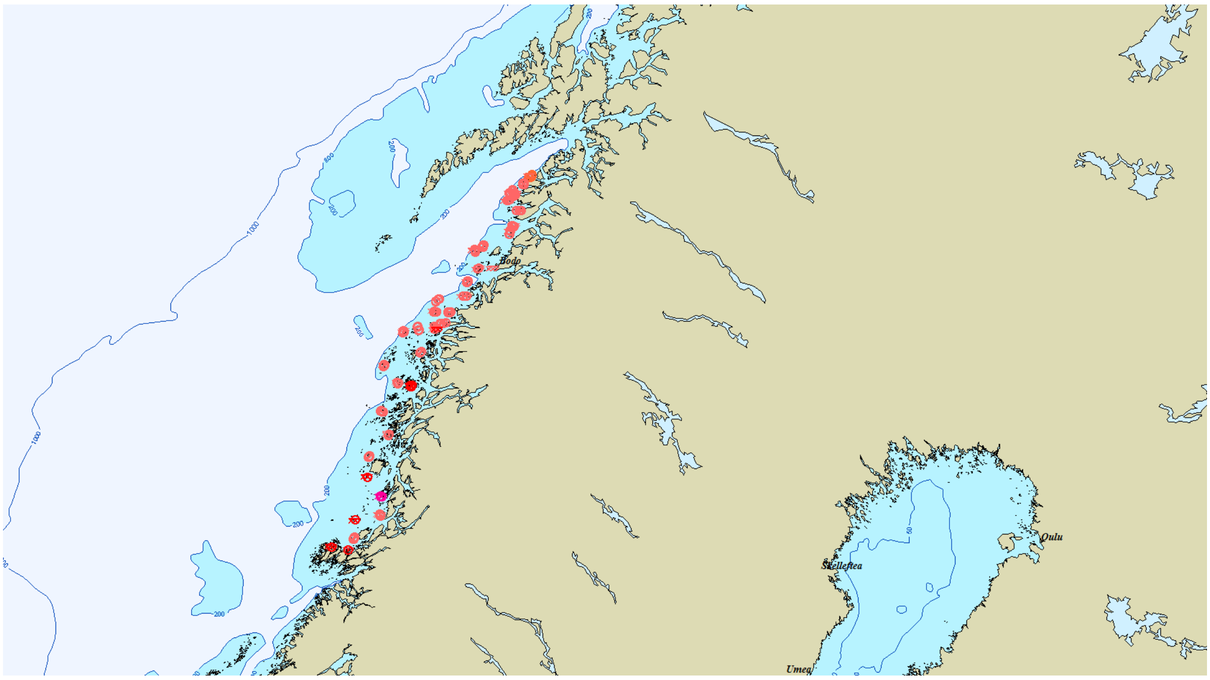


Figure 8. Predefined fishing areas Steigen-Vikna. (Scaling Max Sea; 1:1.5 mill).

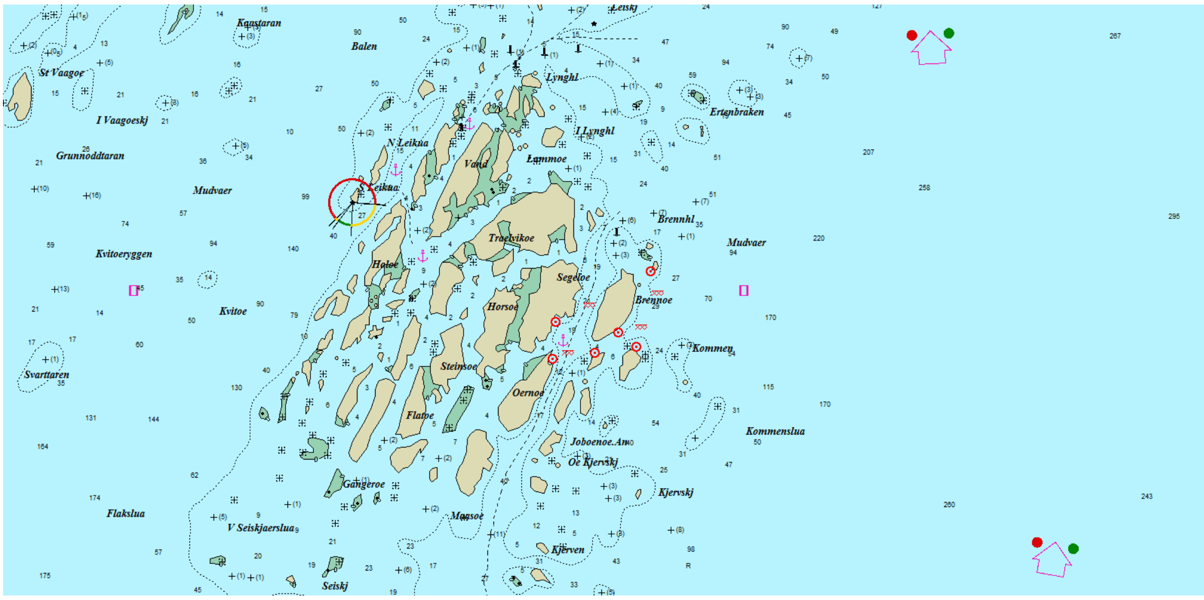


Figure 9. Mudvær, Vega; Example of fishing area. Red circles are fyke net positions, and xxx are start point and end point for trammel nets. (Scaling Max Sea; 1:25000).

Results cod

Table 3. Average catch of cod pr fishing day Steigen-Vikna

Year	# fishing days	av. Number of cod pr day	CV %
2013	12	**42.8**	**17**
2016	21	**41.6**	**14**
2018	20	**47.5**	**12**

Table 4. Average catch of cod at age (per fishing day) for each of the surveys

Age	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9+**	**Total**
2013	2.8	16.4	10.8	6.6	3.5	1.3	0.9	0.2	0.2	0.2	42.8
2016	2.9	11.3	12.0	7.0	5.6	1.0	1.2	0.4	0.3	0.1	41.6
2018	6.8	13.2	13.7	5.6	3.4	1.8	2.2	0.3	0.2	0.3	47.5

Summed over all ages the catch rates of cod appear rather stable over the 2013-2018 period. Compared to the two first surveys the 2018 results indicate some increase for age 0 and decrease for ages 3 and 4. The CVs for all ages merged (Table 3) indicate that large to moderate changes in abundance are likely to be significant, while small changes may not be significant.

Fishing with trammel nets and fyke nets in shallow areas between Vikna (65 deg N) and Stad (62 deg N) in August 2015 and 2017

Within the Vikna-Stad area 46 candidate fishing areas were defined, each suitable for one day fishing (Figure 8). Among those areas, 23 were fished in 2015, and 21 were fished in 2017. Among those 21 fished in 2017; 13 was also fished in 2015. The remaining 8 stations in 2017 have been fished only one year.

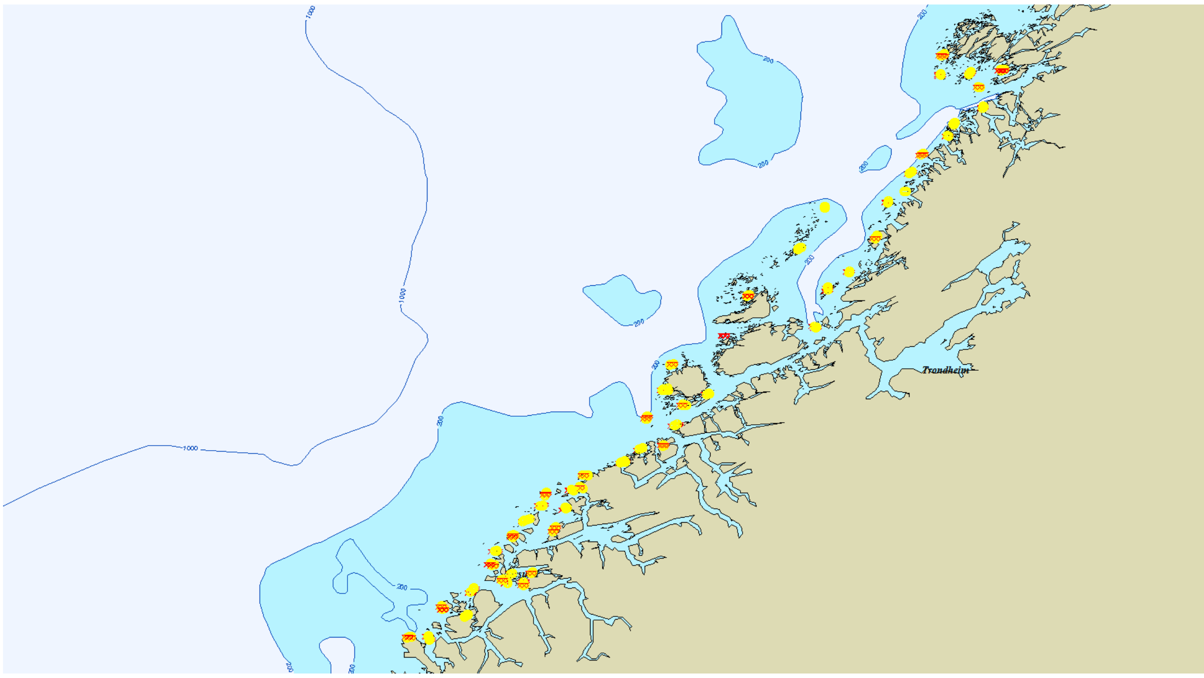


Figure 10. Predefined fishing areas Vikna-Stad. (Scaling Max Sea; 1:1.5 mill).

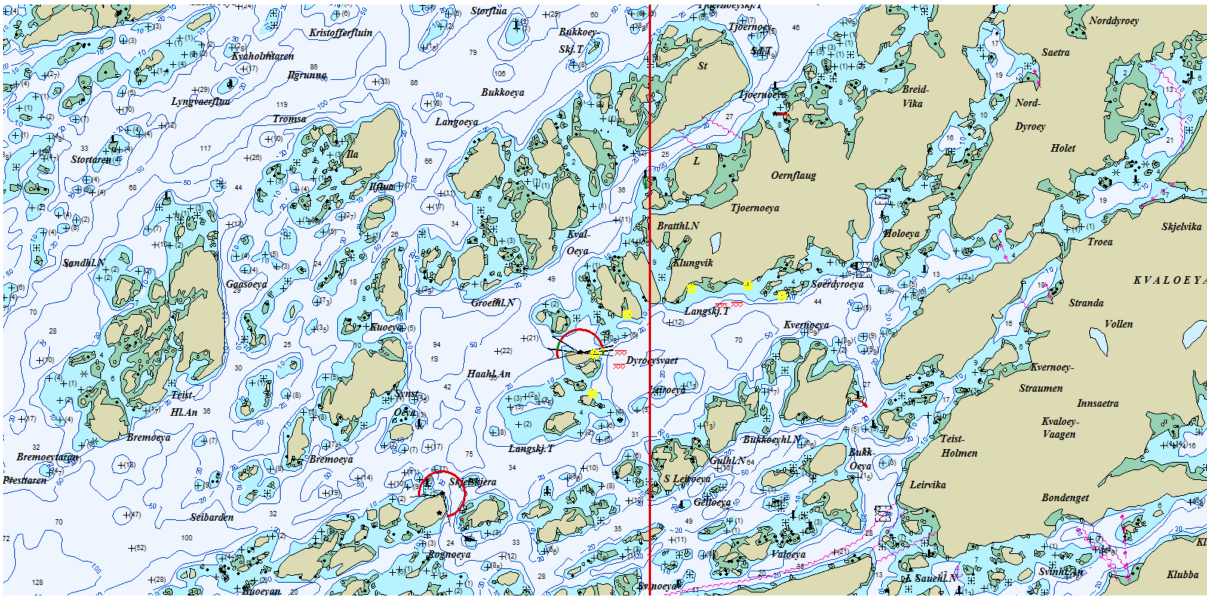


Figure 11. Dyrøysvaet, Frøya; Example of fishing area. Yellow circles are fyke net positions and xxx are start point and end point for trammel nets. (Scaling Max Sea; 1:25000).

Results cod

Table 5. Average catch of cod per fishing day Vikna-Stad

Year	# fishing days	av. Number of cod pr day	CV %
2015	23	**19.6**	**13**
2017	21	**22.1**	**11**

Table 6. Average catch of cod at age (per fishing day) for each of the surveys

Age	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9+**	**Total**
2015	0.10	6.57	5.76	3.34	1.31	1.31	0.71	0.20	0.20	0.00	19.6
2017	3.52	9.92	3.85	1.90	1.20	0.86	0.41	0.19	0.14	0.05	22.1

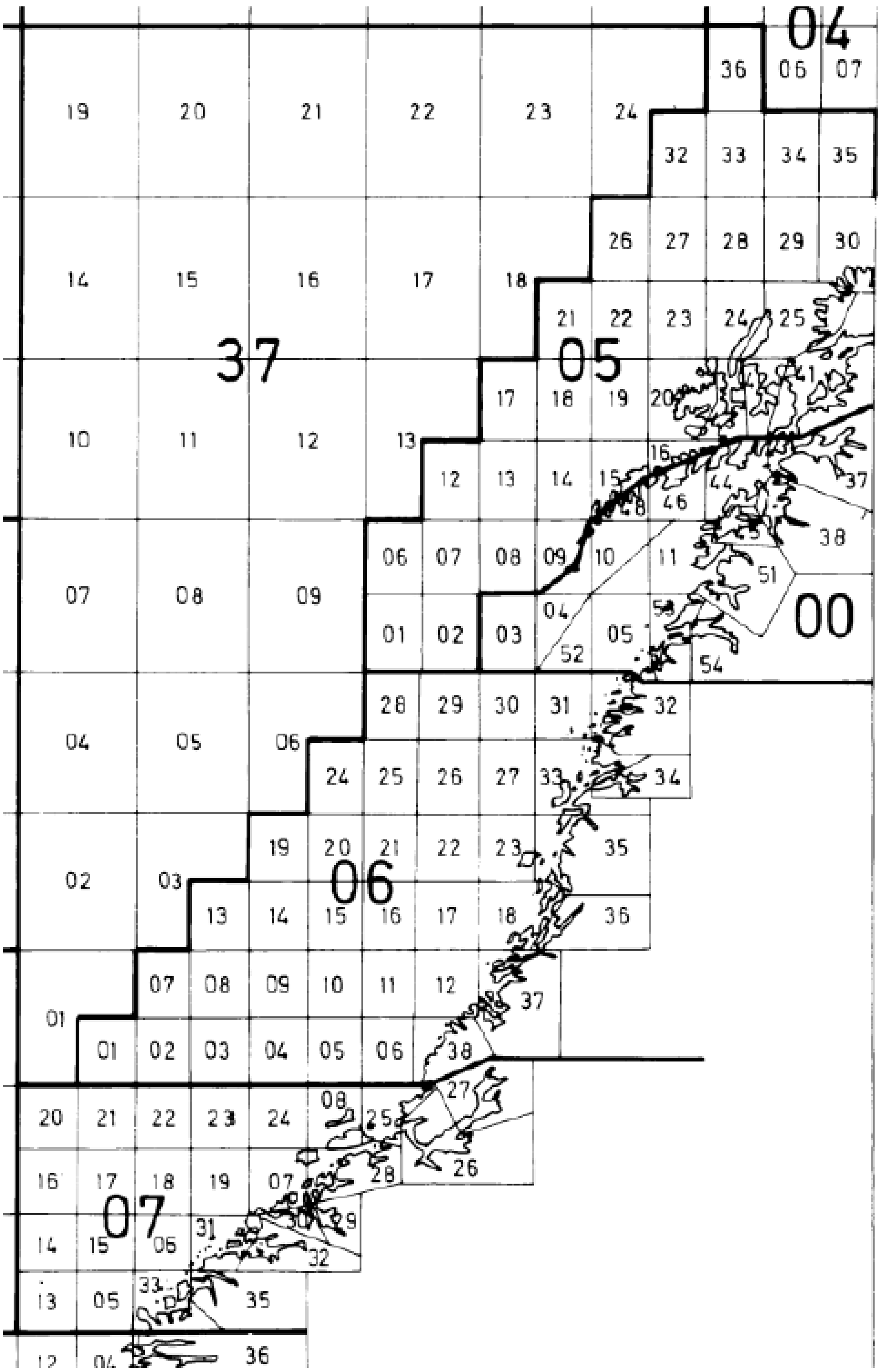
Summed over all ages the catch rates of cod appear rather similar for the two years. As for the Steigen-Vikna area, the between year relative difference is largest for age 0, which in this area is highest in 2017. Age 1 also indicate some increase, while the older ages show lower catch rates in 2017 compared to 2015.

The CVs for all ages merged (Table 5) indicate that large to moderate changes in abundance are likely to be significant, while small changes may not be significant.

2. cod results from the coastal “trawl-acoustic survey”

This survey covers the coastal area from the Norway-Russia border to Stad, in deeper waters (50-500 m) than the shallow water surveys (Mehl et al. 2018). Figure 14 shows the standard acoustic transects used in the survey. Some of these transects are adjacent to the areas covered by the shallow water surveys, but the bottom depths are considerably larger. The coastal cod results from the trawl-acoustic survey have traditionally been estimated within the “Norwegian Statistical Main Areas” (00,05,06,07 in Figure 12), but for the future, the plan is to use the regions A,B,C and D (Figure 13), that are implemented in the STOX-software. (Johnsen et al 2016). These areas are already in use for the saithe estimate from the same survey. A project has started for recalculating the coastal survey acoustic estimates using Stox. Another objective for that project is to obtain swept area estimates of cod based on the fixed trawl stations in the survey series.

Statistical Main Area 05 and 00 (Figure 12) cover areas adjacent to the shallow water areas Senja-Lofoten. Statistical Main Area 06 covers areas adjacent to the shallow water areas Steigen-Vikna. Statistical Main Area 07 covers areas adjacent to the shallow water areas Vikna-Stad.



Figur 12. Norwegian Statistical main areas 00,05, 06, 07. The small rectangles are used for reporting commercial catch.

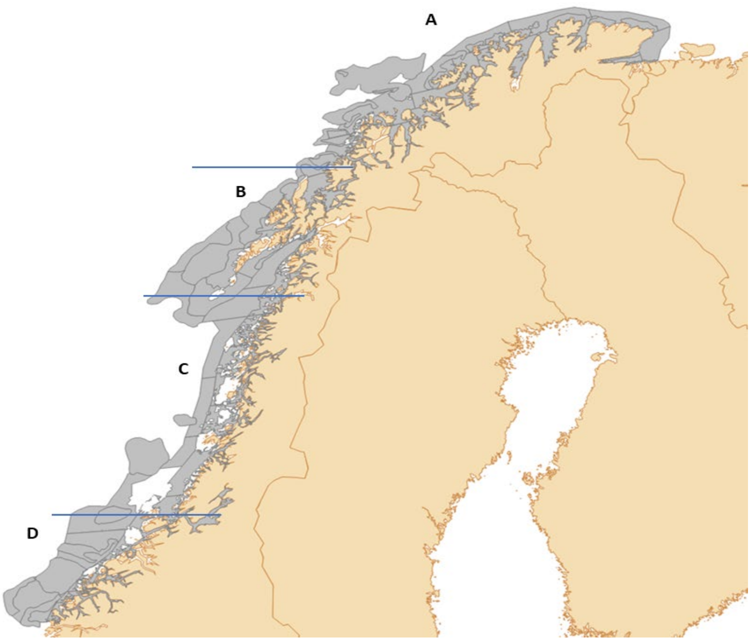


Figure 13. Sub-regions A-D used in the STOX-software.

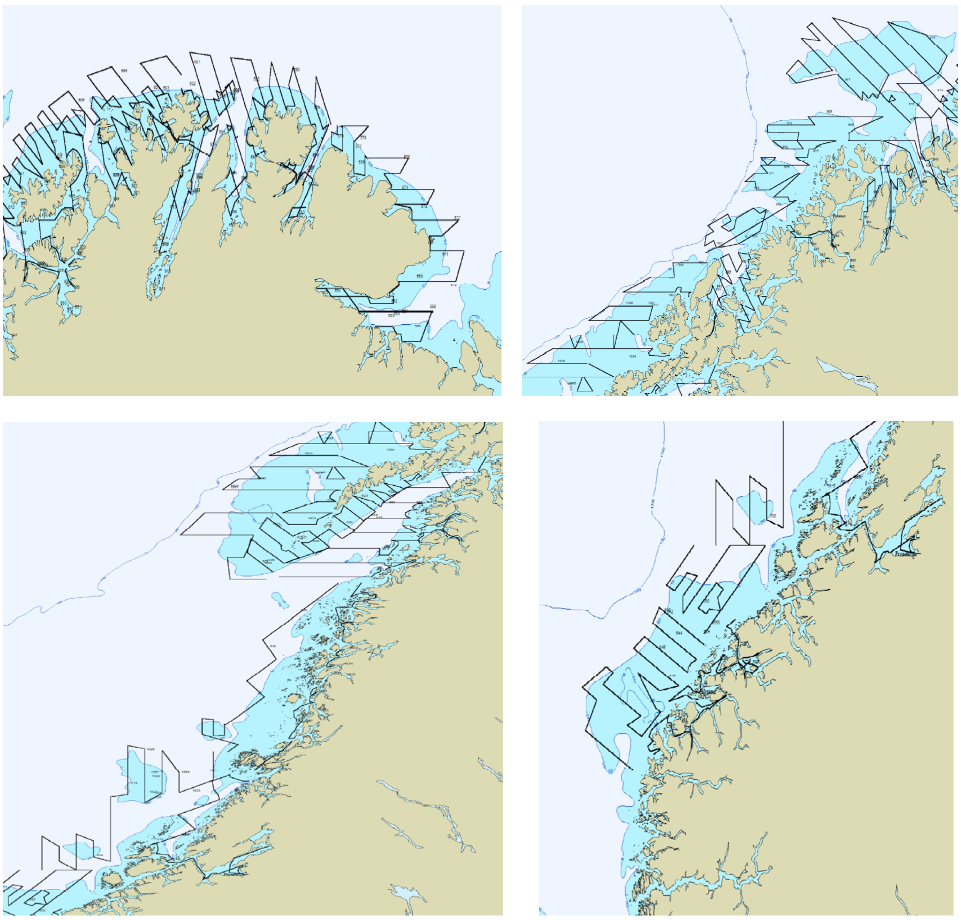


Figure 14. Standard transects in the coastal "trawl-acoustic" survey

Table 7. Trawl-acoustic survey. Coastal cod estimates (numbers in thousands) for Statistical Area 05 + 00, (adjacent to shallow waters in Senja-Lofoten)

Area 05+00	Age										
Year	1	2	3	4	5	6	7	8	9	10+	Total	3+
2011	1939	333	848	1115	701	633	60	187	0	43	5859	3587
2012	2129	354	513	1494	966	250	89	68	52	36	10048	3468
2013	2067	287	301	440	573	482	203	167	165	76	9465	2407
2014	792	557	603	769	1199	887	939	611	557	487	7401	6052
2015	1591	505	634	935	353	631	509	261	126	247	5793	3696
2016	508	136	561	1497	1482	753	415	504	21	124	6001	5357
2017	407	867	1111	590	964	598	301	177	86	41	5142	3868
2018	2004	433	582	669	488	638	276	232	84	164	5569	3133

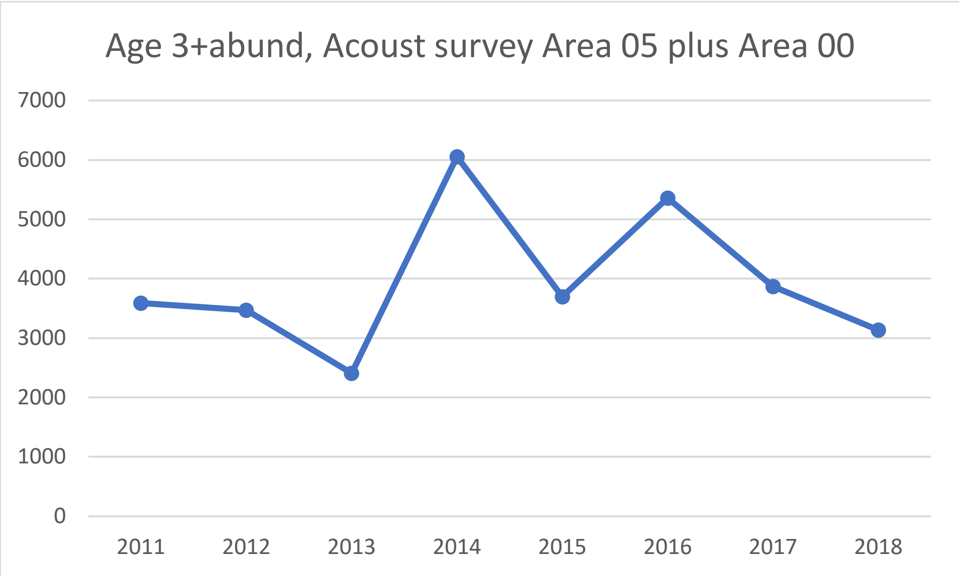


Figure 15. Trawl-acoustic survey estimates (thousands) 2011-2018 for areas 00 and 05 merged, sum of ages 3 and older.

Table 8. Trawl-acoustic survey. Coastal cod estimates (numbers in thousands) for Statistical Area 06 (adjacent to shallow waters in Steigen-Vikna).

Area 06	Age											
Year	1	2	3	4	5	6	7	8	9	10+	Total	3+
2011	2242	784	1544	1785	1033	231	18	69	10	28	7744	4718
2012	70	31	102	30	159	49	91	20	4	71	626	526
2013	3223	388	620	623	425	209	59	197	0	12	7711	2145
2014	162	505	243	86	387	14	46	35	0	0	1478	811
2015	1328	1298	785	865	613	415	52	20	28	0	5405	2778
2016	177	434	722	62	162	138	86	41	22	10	1855	1243
2017	15	41	60	31	27	22	12	15	10	0	234	177
2018	1859	248	248	124	124	0	0	0	0	0	2603	496

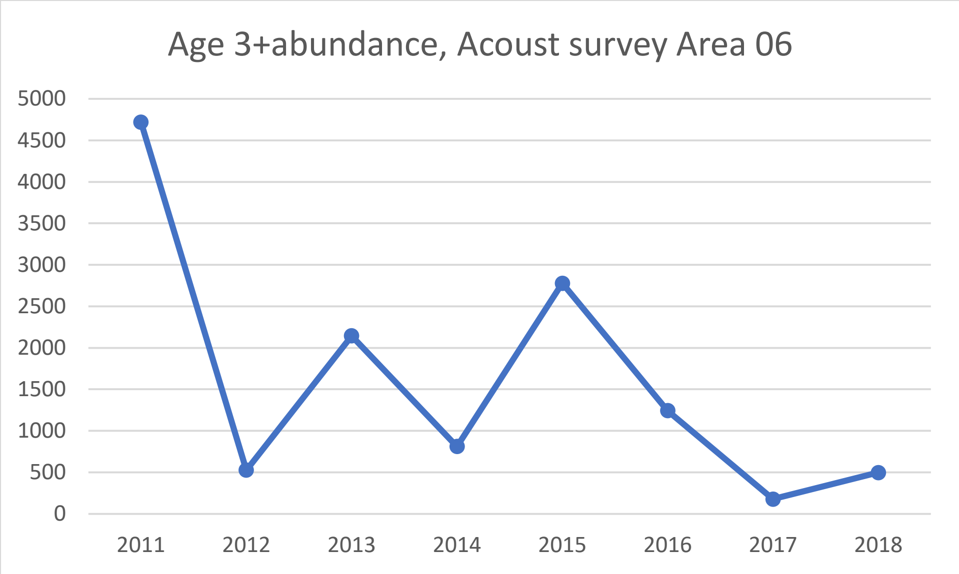


Figure 16. Trawl-acoustic survey estimates (thousands) 2011-2018, sum of ages 3 and older.

Table 9. Trawl-acoustic survey Statistical. Coastal cod estimates (numbers in thousands) for Area 07 (adjacent to shallow waters in Vikna-Stad).

Area 07	Age										
Year	1	2	3	4	5	6	7	8	9	10+	Total	3+
2011	0	17	70	82	28	46	14	7	4	7	275	258
2012	0	5	93	100	91	81	25	5	0	0	401	395
2013	0	0	0	0	0	4	23	4	0	0	30	31
2014	89	30	111	114	246	146	36	136	32	6	946	827
2015	0	5	48	174	42	55	17	61	60	3	465	460
2016	6	0	303	289	220	36	21	51	15	111	1050	1046
2017	0	41	28	142	61	75	65	15	1	1	430	388
2018	0	0	0	0	203	124	27	21	0	0	376	375

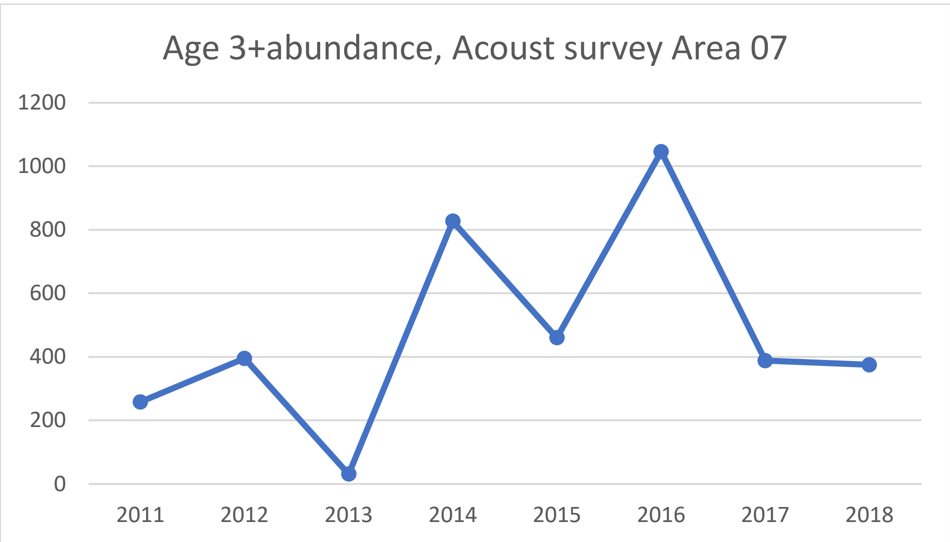


Figure 17. Trawl-acoustic survey estimates (thousands) 2011-2018, sum of ages 3 and older.

The acoustic results for Areas 00 and 05 (Table 7 and Figure 15) may contain some useful information for evaluation of stock status.

The patterns seen in Tables 8-9 and Figures 16-17 indicate that the acoustic survey results in areas 06 and 07 have rather high variability between years and between ages. Even when merging ages 3 and older, the between year variability in areas 06 and 07 seems to be dominated by "noise".

With several more years of shallow water surveys (fyke nets and gill nets) the basis for evaluating stock status in areas 06 and 07 would improve. Probably would more shallow water surveys in area 00 and 05 also improve the stock status evaluations for those areas.

3. Catch at age data from commercial fishery

Table 10. Estimated catch in tonnes of coastal cod by Area and quarter based on reported catches of NEAC+NCC, split by the fraction of NCC otolith-type (Rollefsen, 1933). Such estimates exist back to 1984 (Berg et al 1998).

Year		2010				
Qu./Area	03	04	00	05	06-07	Total
1	425	1141	1585	3442	3344	**9939**
2	1564	1341	1262	1385	1711	**7263**
3	853	603	225	480	362	**2523**
4	993	696	192	975	343	**3199**
Total	**3836**	**3781**	**3265**	**6282**	**5761**	**22925**

Year		2011				
Qu./Area	03	04	00	05	06-07	Total
1	1231	1888	2328	2762	4236	**12445**
2	2241	2289	1458	801	1785	**8573**
3	400	466	293	475	384	**2018**
4	1949	1330	430	1594	256	**5559**
Total	**5820**	**5973**	**4509**	**5632**	**6660**	**28594**

Year		2012				
Qu./Area	03	04	00	05	06-07	Total
1	1489	2031	2124	3268	4408	**13320**
2	1125	3282	3036	545	1330	**9318**
3	1166	810	255	626	347	**3204**
4	2351	1343	212	1810	350	**6066**
Total	**6131**	**7467**	**5627**	**6248**	**6434**	**31907**

Year		2013				
Qu./Area	03	04	00	05	06-07	Total
1	705	1003	568	3808	3204	**9288**
2	2035	738	1691	489	890	**5843**
3	1035	365	202	615	278	**2495**
4	1543	1609	182	1275	228	**4838**
Total	**5318**	**3714**	**2644**	**6188**	**4599**	**22464**

Year		2014				
Qu./Area	03	04	00	05	06-07	Total
1	826	1123	934	2613	3347	**8843**
2	2151	546	437	541	1118	**4793**
3	1164	854	251	831	209	**3309**
4	2621	1775	218	1363	247	**6225**
Total	**6762**	**4299**	**1839**	**5348**	**4922**	**23169**

Year		2015				
Qu./Area	03	04	00	05	06-07	Total
1	1516	3630	2146	8729	3201	**19222**
2	3363	2303	2294	612	926	**9499**
3	1698	1469	457	504	403	**4531**
4	2816	1679	124	1314	268	**6201**
Total	**9393**	**9082**	**5022**	**11159**	**4798**	**39455**

Year		2016				
Qu./Area	03	04	00	05	06-07	Total
1	3490	8601	7940	7697	3762	**31491**
2	1072	530	146	117	221	**2088**
3	1051	1638	270	501	327	**3790**
4	4419	1620	139	803	267	**7253**
Total	**10032**	**12388**	**8495**	**9118**	**4577**	**44610**

Year		2017				
Qu./Area	03	04	00	05	06-07	Total
1	4620	6806	11264	7053	2195	**31938**
2	1986	4732	255	1507	542	**9022**
3	1883	836	208	478	334	**3739**
4	4789	2513	184	466	236	**8188**
Total	**13278**	**14887**	**11911**	**9504**	**3307**	**52887**

Based on the catch reporting by area (Figure 12) and the age sampling program, catch numbers by age and otolith-type has been calculated, and a time series for catch numbers at age for NCC and for NEAC has been calculated for each of the main areas, both by a traditional method and by using ECA (Hirst et al. 2012). Those catch at age data for the entire coastal cod area have been used for "exploratory" stock assessments ICES Arctic Fisheries Working Group (ICES 2018). Figure 18 show $\log_e$ (catch numbers) by age and cohorts for all areas merged. The slope of the lines reflects total mortality.

These data may also provide some information on mortality rates within each of the statistical areas 05, 00, 06 and 07. However, the sampling data are for some years rather incomplete and the results prior to 1990 is considered rather uncertain, particularly in the statistical areas 06 and 07.

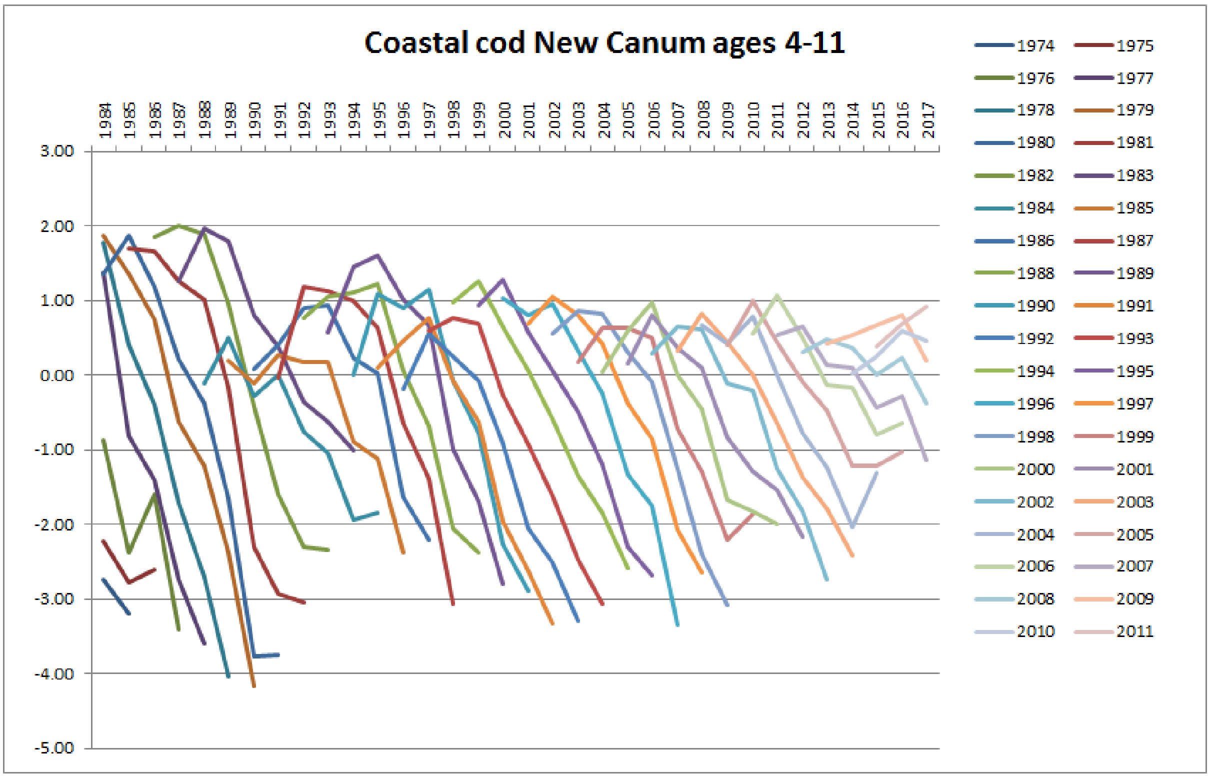


Figure 18. Log catch numbers-at-age by cohort (series names) and catch years (x-axis). ECA estimates.

4. Stock units / Genetics

Coastal cod north of 62 degrees N has so far been treated as one stock unit / management unit. Several genetic studies have, for several genetic markers, revealed large variations along the coast (Dahle et al 2018, Dahle 1991, Møller 1968). Some markers indicate trends when moving from north to south (Dahle et al 2018).

Many coastal cod spawning areas has been identified (Espeland et al 2013). Maps of coastal cod spawning areas are available at https://kart.fiskeridir.no/fiskeri. It is not feasible to manage all spawning sites separately, but some degree of regional management would reduce the risk of fishing down some of the potentially more vulnerable stock components.

Splitting the management area in several units would allow for adjusting the management to the more local needs, and for better utilizing smaller scale survey data. Defining one area north of 67 would correspond to the area where the trawl acoustic survey provides reasonable data. The area south of 67 could then make use of less expensive shallow water surveys. With the existing fyke net/gill net surveys alternating between years, it could be useful to define one stock unit from 67 N to 65 N (Bodø-Vikna) and one unit from 65 N to 62 N (Vikna-Stad).

References

Berg, E., Eriksen, I.A. and Eliassen, J-E. 1998. Catch-statistics for Norwegian Coastal cod 1984-1997, data and methods. Fiskeriforskning, Report 10/1998, 13pp.

Dahle, G. 1991: Cod, *Gadus morhua* L, populations identified by mitochondrial DNA. J Fish Biol 1991, 38:295–303.

Dahle, G., Quintela, M., Johansen, T., Westgaard, J-I., Besnier, F., Aglen, A., Jørstad, K.E., and Glover,K. 2018. Analysis of coastal cod (*Gadus morhua* L.) sampled on spawning sites reveals a genetic gradient throughout Norway`s coastline. BMC Genetics (2018) 19:42 https://doi.org/10.1186/s12863-018-0625-8

Espeland, S.H., Albretsen,J., Nedreaas, K.H., Sannæs, H., Bodvin, T. og Moy, F.2013. Kartlegging av gytefelt. Gytefelt for kysttorsk. Fisken og Havet. 1. 2013.

Hirst, D., Storvik, G., Rognebakke, H., Aldrin, M., Aanes, S., and Vølstad, J. H. 2012. A Bayesian modelling framework for the estimation of catch-at-age of commercially harvested fish species. Can. J. Fish. Aquat. Sci. 69: 2064–2076.

ICES 2018. Report of the Arctic Fisheries Working Group, Ispra, Italy, 18-24 April 2018. ICES C.M. 2018/ACOM:06, 863 pp.

Johnsen, E., Totland, A., Skålevik, Å., Holmin, A. J. and Dingsør, G. 2016. StoX Reference Guide. Version 20161003. Havforskningsinstituttet, Institute of Marine Research. 167 p. (http://www.imr.no/forskning/prosjekter/stox/documentation/en).

Mehl, S., Berg E., Korsbrekke, K., Olsen, E. and Staby, E. 2018. Akustisk mengdemåling av sei, kyst-torsk og hyse Finnmark – Møre hausten 2017. Acoustic abundance of saithe, coastal cod and haddock Finnmark – Møre Autumn 2017. *In Norwegian, legends in English*. Toktrapport/Havforskningsinstituttet/ISSN 1503-6294, Nr. 2 – 2018. 30pp.

Møller D. 1968. Genetic diversities in spawning cod along the Norwegian coast. Hereditas. 1968;60:1–21.

Rollefsen, G. 1933. The Otoliths of the cod. Report of the Norwegian Fishery and Marine Investigations Vol. IV, No. 3 p 1-14.

Sundby, S, P. Fossum, A. Sandvik, F.B. Vikebø, A. Aglen, L. Buhl-Mortensen, A. Folkvord, K. Bakkeplass, P. Buhl-Mortensen, M. Johannessen, M.S. Jørgensen, T. Kristiansen, C. Landa, M.S. Myksvoll and R. Nash. 2013. KunnskapsInnhenting Barentshavet-Lofoten-Vesterålen (KILO). Fisken og havet nr. 3-2013, 186 pp (in Norwegian).

van der Meeren, T. 2018. Undersøkelser av gyte- og oppvekstområder for torsk i Smøla og Aure kommuner våren og høsten 2017. Rapport fra Havforskningen, Nr 6-2018.

Asgeir Aglen, December 2018

Revision of acoustic Northeast Arctic saithe indices from the Norwegian coastal survey 2003–2009 applying the Sea2Data StoX software

Sigbjørn Mehl and Åsmund Skålevik

StoX input, settings and filters

Acoustic XML-files for the period 2003-2009 (mainly prior to the introduction of LSSS) were updated from BEI ListUserFile05 DB-reports on \\ces.imr.no\cruise_data due to errors or missing data in the XML-files based on LSSS DB-reports. Biotic and updated acoustic XML-files were then downloaded from https://datasetexplorer.hi.no/apps/datasetexplorer/v2/navigation.

StoX version 2.6 and Rstox 1.9 was used for estimation of revised acoustic indices with CVs, lengths and weights at age (http://www.imr.no/forskning/prosjekter/stox/). R for Windows version 3.4.3 was used in the R calls (https://www.r-project.org/).

In **FilterAcoustic, FreqExpr** was set to **frequency=38000**. In **NASCExpr, acocat** was 22 for saithe.

In **NASC, LayerType** was set to **WaterColumn**.

Under **FilterBiotic** and **FishStationExpr**, the following filter were applied: **fs.getLengthSampleCount('SEI') > 2** filtering out stations with less than three specimen (see Johnsen et al. 2016 for more info about filters).

Under **StationLengthDist** and **LengthDistType**, **NormLengthDist** was used, and under **RegroupLengthDis**t and **LengthInterval**, **1.0** was applied.

A process called **RelLengthDist** was then added, with function RelLengthDist and **LengthDist** = **RegroupLengthDis**t.

In **DefineStrata**, **kysttokt_strata.txt**. In **StratumArea** and **AreaMethod**, **Accurate** was applied.

Under **BioStationAssignment** and **AssignmentMethod**, **UseProcessData** was used, i.e. assignments from the KT-program with adjustments for 2003-2016. **EstLayers** was set to **1~PELBOT**.

Under **BioStationWeighting** and **WeightingMethod, SumWeightedCount** was used, with **LengthDist** = **RegroupLengthDis**t.

TotalLengthDist was set to **RelLengthDist.**

In Acustic**Density**, **m** was set to **20** and a to **-68**.

Under **SuperIndAbundance** and **AbundWeightMethod**, **StationDensity** was used, with **LengthDist** set to **RegroupLengthDist**.

Results

The revised estimates resulted in only minor changes in indices with CVs, lengths and weights at age for Northeast Arctic saithe. However, it is recommended that the new estimates are applied since they are now based on the official input files from the Norwegian coastal survey.

Table 1. SAITHE. Abundance indices (numbers in millions) from the Norwegian coastal acoustic surveys 2003-2017 estimated by StoX software. + indicates < 0.005.

	Age group																Biomass ('000 t)
Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15+	Total	
2003	**19.3**	**51.2**	**130.5**	**162.3**	**42.6**	**7.73**	**7.94**	**2.56**	**1.69**	**1.21**	**0.72**	**0.31**	**0.15**	**0.05**	**0.07**	**428.4**	**348.7**
2004	**0.01**	**153.3**	**191.2**	**107.6**	**44.3**	**15.2**	**4.25**	**2.06**	**3.56**	**0.77**	**1.36**	**0.61**	**0.27**	**0.21**	**0.11**	**524.8**	**425.7**
2005	**11.1**	**24.1**	**198.5**	**51.9**	**17.6**	**13.2**	**7.68**	**1.40**	**1.12**	**0.36**	**0.10**	**0.10**	**0**	**0**	**0**	**327.2**	**261.6**
2006	**2.89**	**83.9**	**40.9**	**129.9**	**14.4**	**4.62**	**9.49**	**6.13**	**2.39**	**1.05**	**0.83**	**0.17**	**0.31**	**0.01**	**0.02**	**297.0**	**258.7**
2007	**2.48**	**37.9**	**93.5**	**23.9**	**58.5**	**6.51**	**3.95**	**4.00**	**4.22**	**0.30**	**0.76**	**0.06**	**0**	**0**	**0**	**236.0**	**224.2**
2008	**0.01**	**50.7**	**55.9**	**15.9**	**7.84**	**9.99**	**3.06**	**0.97**	**1.41**	**0.98**	**0.13**	**0.15**	**0**	**0.06**	**0**	**147.1**	**124.1**
2009	**0**	**54.7**	**96.9**	**61.4**	**6.99**	**4.01**	**7.62**	**1.95**	**1.00**	**1.08**	**1.10**	**0.35**	**0.18**	**0**	**0**	**237.2**	**212.6**
2010	0.02	7.60	143.0	22.5	17.1	3.95	1.68	3.58	0.43	0.25	0.18	0.30	0.01	0.20	0	200.8	167.1
2011	0	15.2	42.7	59.6	4.61	4.23	1.07	0.81	0.78	0.19	0.03	0.06	0	0	0	129.4	117.7
2012	0.08	68.5	69.0	29.7	18.8	3.48	2.83	0.32	0.58	0.56	0.08	0.05	0	0	0	193.9	148.6
2013	5.02	12.3	77.1	16.5	13.3	11.6	2.19	1.21	0.61	0.39	0.02	+	0.10	0.14	0	140.5	139.1
2014	2.95	28.4	40.1	70.8	8.73	5.62	5.44	1.61	0.55	0.18	0.43	0.10	0	0	0.02	165.0	166.0
2015	0.06	93.5	72.4	22.7	30.1	6.08	4.22	1.85	0.20	0.14	0.07	0.05	0	0	0	231.4	177.6
2016	0.76	72.6	145.7	32.0	10.5	11.2	4.15	2.04	1.46	0.15	0.22	0.12	0.02	0.05	0	281.1	196.0
2017	35.4	23.6	91.1	63.9	13.3	2.76	5.35	2.21	0.62	0.46	0.01	0.02	0.04	0	0.05	238.8	177.2

Table 2. SAITHE. Ratio new/old acoustic abundance indices and total biomass from the Norwegian coastal acoustic surveys 2003-2016.

	Age group										Total	Biomass
Year	1	2	3	4	5	6	7	8	9	10+		
2003	**1.28**	**1.65**	**1.49**	**1.07**	**1.63**	**1.25**	**1.24**	**2.13**	**2.42**	**1.93**	**1.37**	**1.37**
2004	-	**1.01**	**0.90**	**0.91**	**0.90**	**0.79**	**0.90**	**0.69**	**1.16**	**1.07**	**0.93**	**0.96**
2005	**10.14**	**1.09**	**0.87**	**0.77**	**0.87**	**0.80**	**0.99**	**0.64**	**0.67**	**0.60**	**0.89**	**0.88**
2006	**0.66**	**0.85**	**0.96**	**0.91**	**0.75**	**1.01**	**1.12**	**1.09**	**1.16**	**0.68**	**0.91**	**0.96**
2007	**0.49**	**0.83**	**0.84**	**0.88**	**0.96**	**0.82**	**0.68**	**0.97**	**0.97**	**1.06**	**0.88**	**0.93**
2008	**0.54**	**0.91**	**0.58**	**0.55**	**0.57**	**0.84**	**0.76**	**0.90**	**1.35**	**0.82**	**0.68**	**0.74**
2009	**-**	**1.03**	**0.78**	**0.79**	**0.95**	**0.77**	**1.14**	**2.29**	**1.36**	**1.62**	**0.86**	**0.94**
2010	0.08	0.97	0.77	0.73	0.77	0.99	0.88	1.08	1.62	0.65	0.78	0.83
2011	-	1.19	0.91	0.77	0.89	0.74	1.11	0.25	0.39	2.39	0.84	0.80
2012	1.98	0.94	0.69	0.84	0.80	0.92	0.90	1.04	0.79	1.41	0.81	0.86
2013	1.81	0.96	0.68	0.83	1.22	1.04	0.77	0.89	0.80	0.93	0.81	0.86
2014	0.87	1.13	1.00	0.81	0.59	0.65	0.63	0.63	0.50	0.78	0.87	0.81
2015	0.54	1.18	1.00	0.78	0.88	0.81	0.73	0.58	0.59	0.65	1.00	0.92
2016	0.63	1.35	1.08	0.75	0.68	0.70	0.55	0.66	0.70	0.62	1.02	0.88

Table 3. SAITHE. Estimates of coefficients of variation (%) for acoustic abundance indices from Norwegian coastal acoustic surveys 2003-2017.

Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14
2003	**0.35**	**0.21**	**0.19**	**0.22**	**0.16**	**0.36**	**0.33**	**0.60**	**0.30**	**0.39**	**0.43**	**0.43**	**0.49**	**0.99**
2004	**1.98**	**0.26**	**0.16**	**0.28**	**0.25**	**0.22**	**0.39**	**0.59**	**0.43**	**0.40**	**0.35**	**0.39**	**0.39**	**0.70**
2005	**0.58**	**0.47**	**0.12**	**0.20**	**0.12**	**0.19**	**0.25**	**0.45**	**0.59**	**0.75**	**0.89**	**0.89**	-	-
2006	**0.53**	**0.13**	**0.40**	**0.30**	**0.23**	**0.35**	**0.34**	**0.46**	**0.42**	**0.46**	**0.36**	**1.02**	**0.65**	**0.88**
2007	**0.50**	**0.28**	**0.21**	**0.17**	**0.23**	**0.27**	**0.39**	**0.37**	**0.31**	**0.54**	**0.47**	**0.81**	-	-
2008	**1.31**	**0.19**	**0.21**	**0.27**	**0.27**	**0.14**	**0.19**	**0.37**	**0.36**	**0.37**	**0.60**	**0.50**	**-**	**1.16**
2009	**-**	**0.34**	**0.20**	**0.15**	**0.25**	**0.30**	**0.22**	**0.37**	**0.45**	**0.43**	**0.54**	**0.96**	**0.44**	**-**
2010	1.68	0.32	0.19	0.19	0.20	0.22	0.20	0.27	0.60	0.35	0.75	0.84	1.20	0.76
2011	-	0.23	0.18	0.16	0.24	0.38	0.40	0.48	0.33	1.11	1.04	1.00	-	-
2012	0.68	0.16	0.15	0.18	0.24	0.21	0.34	0.68	0.33	0.60	0.79	1.29	-	-
2013	0.56	0.17	0.12	0.13	0.31	0.19	0.34	0.41	0.42	0.62	1.09	3.11	0.93	0.82
2014	0.73	0.21	0.22	0.24	0.18	0.21	0.18	0.31	0.43	0.56	0.44	0.83	-	-
2015	1.60	0.17	0.16	0.20	0.22	0.26	0.25	0.31	0.30	0.72	0.49	0.58	-	-
2016	2.23	0.17	0.10	0.14	0.17	0.19	0.22	0.30	0.23	0.81	0.84	0.60	0.65	0.58
2017	0.34	0.61	0.13	0.17	0.20	0.34	0.48	0.45	0.39	0.26	0.73	0.94	0.92	-

Table 4. SAITHE. Length at age in the Norwegian coastal acoustic surveys 2003-2017 estimated by StoX software. + indicates few samples.

Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14
2003	**25.8**	**33.9**	**39.6**	**44.2**	**49.3**	**60.1**	**64.1**	**66.1**	**70.4**	**75.7**	**82.2**	+	+	+
2004	**28.0**	**32.3**	**39.7**	**46.3**	**53.6**	**58.9**	**69.7**	**74.4**	**74.6**	**78.1**	**77.8**	+	+	+
2005	**27.9**	**36.0**	**39.3**	**45.8**	**51.4**	**59.0**	**62.5**	**67.5**	**71.3**	**69.8**	**80.0**	+	-	-
2006	**26.3**	**35.2**	**40.9**	**43.5**	**51.2**	**57.8**	**64.4**	**66.8**	**70.0**	**73.1**	**76.5**	+	+	+
2007	**26.8**	**36.0**	**40.7**	**46.7**	**51.0**	**58.1**	**65.8**	**67.4**	**69.0**	**72.8**	**81.5**	+	-	-
2008	**26.0**	**36.8**	**41.7**	**47.9**	**51.9**	**58.4**	**61.2**	**68.6**	**73.3**	**77.2**	+	+	-	+
2009	-	**33.8**	**41.6**	**47.6**	**57.6**	**63.3**	**66.5**	**64.9**	**69.6**	**75.1**	**72.2**	**78.7**	+	-
2010	24.2	34.5	38.4	47.1	57.4	61.0	65.0	66.9	68.9	75.8	+	+	+	+
2011	-	36.8	41.7	44.7	56.7	62.8	69.5	65.7	76.0	+	+	+	-	-
2012	29.0	36.4	42.3	47.3	51.6	60.5	66.5	71.8	66.9	79.5	82.9	87.0	-	-
2013	26.0	36.7	41.1	48.7	55.2	60.0	68.8	74.5	75.3	75.4	78.8	+	+	+
2014	24.3	35.8	44.0	46.7	54.8	60.6	61.4	72.3	76.6	80.2	79.3	85.8	-	-
2015	29.3	34.7	41.1	48.8	53.6	60.0	65.8	71.5	+	+	+	+	-	-
2016	28.5	33.2	38.8	47.1	54.1	60.0	67.0	70.5	72.5	81.8	+	+	+	+
2017	25.1	32.6	39.9	45.7	53.5	63.7	69.6	69.6	69.8	73.1	+	+	+	-

Table 5. SAITHE. Weight at age in the Norwegian coastal acoustic surveys 2003-2017 estimated by StoX software. + indicates few samples.

Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14
2003	**161**	**388**	**568**	**832**	**1156**	**21662**	**2559**	**2895**	**3607**	**4300**	**6019**	+	+	+
2004	**230**	**339**	**616**	**929**	**1515**	**2055**	**3393**	**4119**	**4414**	**4822**	**4785**	+	+	+
2005	**229**	**482**	**612**	**912**	**1308**	**2029**	**2427**	**2941**	**3648**	**3130**	**3475**	+	-	-
2006	**181**	**434**	**699**	**793**	**1336**	**1877**	**2668**	**2808**	**3413**	**4072**	**4492**	+	+	+
2007	**183**	**468**	**644**	**924**	**1235**	**1815**	**2584**	**2854**	**2995**	**3661**	**4852**	+	-	-
2008	**193**	**461**	**644**	**982**	**1256**	**1870**	**2158**	**2977**	**3787**	**4349**	+	+	-	+
2009	-	**375**	**689**	**1012**	**1814**	**2525**	**2899**	**2652**	**3118**	**4046**	**3299**	**3960**	+	-
2010	146	409	556	1016	1814	2227	2624	2851	3116	4363	+	+	+	+
2011	-	503	735	853	1744	2267	3302	2598	4524	+	+	+	-	-
2012	240	456	682	954	1212	1907	2481	3088	2448	4573	4783	4870	-	-
2013	171	481	690	1097	1551	2050	3170	3799	4020	3840	5044	+	+	+
2014	135	445	826	1006	1538	2096	2201	3428	4269	4679	4762	5647	-	-
2015	237	380	624	1042	1361	1955	2674	3390	+	+	+	+	-	-
2016	227	338	518	944	1422	2009	2730	3411	3690	5757	+	+	+	+
2017	142	335	576	882	1477	2511	3165	3277	3246	3576	+	+	+	-

Working Document No. 14

ICES Arctic Fisheries Working Group (AFWG), April 2019

A. Aglen[1] E. Johannesen[1], K. Korsbrekke[1], A.A. Russkikh[2]
[1] Institute of Marine Research

[2] Polar Research Institute of Marine Fisheries and Oceanography **(PINRO)**

Adjustment method for estimation stock weight at age and maturity at age for Northeast Arctic haddock assessment in 2019.

The Russian autumn trawl-acoustic survey (TAS) was not conducted in the Barents Sea in 2016 and 2018 due to financial reasons. Russian haddock abundance indices, weight/length at age and maturity at age data that are supposed to be sources for stock assessments (for SAM and VPA model tuning as well as for calculation of combined data on weights in stock and maturity ogives) were not available for 2016/2017 and 2018/2019.

AFWG members have decided by correspondence to compute average historic difference in stock weight and maturity at age between Joint Barents Sea surveys – BS-NoRu-Q1 (further "Norwegian") in January-March and Russian TAS (RU-BTr-Q4 in November-December) (further "Russian") surveys, and to correct "Norwegian" 2017 and 2019 survey values by this difference.

The EXCEL program was used for calculations.

Weight at age

According the previous investigations it was decides to use some smoothing procedures for mean weight in stock and maturity data for NEA haddock in order to remove some of the sampling variability of the estimates. Raw data from surveys smoothed separately by Russia and Norway and smoothed data combined afterwards and used in assessment (further "final data"). Such procedure well described in Stock annex.

If we have not Russian or Norwegian data, we can estimate final data using ratios (relationships) between available set (Norwegian in 2019) and final data for previous years. In 2019 Norwegian data smoothed using new information for yearclasses 1993 upwards (marked in yellow) and values for years 2020 and 2021 estimated using regressions (Table 1). Thus, we need estimate mean ratios for period 1980-2018 and recalculate "final" set for yearclasses 1993 upwards until 2021 (Table 2). For ages 12-14 weight fixed as at age 11.

Maturity at age

As for weight at age, estimates were produced separately for the Russian and Norwegian survey and were later combined using an arithmetic average. These averages are assumed to give representative values for the beginning of the year.

The Norwegian maturity ogives for haddock tend to give a higher percent mature at age compared to the Russian ogives, which is consistent with the generally higher growth rates observed in haddock sampled by the Norwegian surveys. Also the methodology and timing for calculating the ogives is different which may lead to systematic differences.

The same approach was used for estimation of ratios for maturity at age as described above. Smoothed values from 1980 onwards (and ages 3- 10) were used. Values for yearclasses 1993 upwards (marked in yellow) and values for years 2020 and 2021 changed from 2018 (Table 3)

Ratios between final 2018 and Norwegian data were calculated. Than mean ratios for period 1980-2018 was used for restoring final values for yearclasses 1993 onwards for 2019 assessment (Table 4).

Table 1. Smoothed weight data from Norwegian surveys (kg) and final weight data used in 2018 (kg)

Year	2019 smoothed weight data from Norwegian surveys (kg)											2018 final weight data (kg)										
	1	2	3	4	5	6	7	8	9	10	11	1	2	3	4	5	6	7	8	9	10	11
1980	0.062	0.240	0.437	0.930	1.313	1.923	2.701	3.908	3.776	3.781		0.063	0.262	0.454	0.878	1.159	1.675	2.292	3.134	3.31	3.553	3.792
1981	0.045	0.273	0.547	0.764	1.357	1.738	2.352	3.096	4.177	4.034	4.015	0.051	0.274	0.603	0.805	1.315	1.582	2.118	2.728	3.51	3.679	3.904
1982	0.040	0.203	0.615	0.935	1.136	1.790	2.150	2.745	3.437	4.382	4.240	0.036	0.224	0.631	1.049	1.217	1.782	2.017	2.553	3.14	3.853	4.016
1983	0.039	0.183	0.471	1.038	1.362	1.526	2.207	2.535	3.095	3.724	4.537	0.035	0.164	0.524	1.098	1.558	1.663	2.255	2.448	2.97	3.524	4.165
1984	0.029	0.176	0.427	0.818	1.495	1.797	1.913	2.595	2.886	3.401	3.964	0.028	0.158	0.391	0.926	1.632	2.093	2.121	2.718	2.865	3.363	3.878
1985	0.032	0.135	0.414	0.748	1.208	1.951	2.215	2.284	2.945	3.198	3.665	0.03	0.127	0.379	0.7	1.394	2.195	2.626	2.572	3.158	3.261	3.728
1986	0.042	0.149	0.323	0.727	1.115	1.613	2.383	2.603	2.629	3.256	3.472	0.035	0.136	0.311	0.682	1.069	1.898	2.761	3.138	3.005	3.568	3.632
1987	0.049	0.189	0.356	0.579	1.086	1.500	2.011	2.776	2.953	2.943	3.527	0.042	0.161	0.331	0.569	1.047	1.473	2.411	3.307	3.616	3.412	3.946
1988	0.045	0.221	0.441	0.633	0.882	1.465	1.885	2.388	3.126	3.264	3.225	0.039	0.189	0.383	0.603	0.887	1.452	1.895	2.915	3.822	4.054	3.787
1989	0.040	0.202	0.508	0.770	0.957	1.213	1.844	2.253	2.736	3.431	3.535	0.037	0.175	0.445	0.689	0.936	1.248	1.878	2.317	3.395	4.297	4.449
1990	0.031	0.184	0.469	0.875	1.144	1.306	1.553	2.210	2.597	3.050	3.692	0.031	0.169	0.413	0.789	1.054	1.312	1.635	2.308	2.728	3.844	4.73
1991	0.027	0.143	0.430	0.814	1.284	1.536	1.662	1.890	2.552	2.911	3.330	0.025	0.141	0.402	0.737	1.193	1.458	1.714	2.035	2.732	3.122	4.256
1992	0.025	0.125	0.343	0.752	1.203	1.704	1.925	2.011	2.215	2.866	3.194	0.023	0.114	0.34	0.721	1.119	1.63	1.881	2.127	2.437	3.142	3.491
1993	0.025	0.120	0.302	0.612	1.120	1.607	2.113	2.297	2.343	2.522	3.149	0.025	0.107	0.279	0.616	1.1	1.537	2.08	2.308	2.54	2.831	3.531
1994	0.031	0.120	0.290	0.545	0.928	1.507	2.004	2.496	2.642	2.654	2.806	0.029	0.115	0.262	0.512	0.952	1.518	1.969	2.527	2.729	2.945	3.213
1995	0.037	0.135	0.290	0.525	0.834	1.269	1.892	2.381	2.846	2.956	2.939	0.033	0.126	0.282	0.484	0.8	1.327	1.952	2.401	2.959	3.135	3.335
1996	0.038	0.159	0.318	0.524	0.806	1.151	1.619	2.261	2.729	3.158	3.238	0.036	0.14	0.302	0.52	0.76	1.128	1.724	2.388	2.82	3.369	3.52
1997	0.037	0.162	0.369	0.568	0.804	1.115	1.481	1.964	2.605	3.043	3.434	0.036	0.157	0.332	0.551	0.816	1.076	1.481	2.127	2.814	3.22	3.751
1998	0.030	0.158	0.376	0.651	0.866	1.114	1.438	1.810	2.293	2.919	3.323	0.03	0.158	0.371	0.601	0.859	1.155	1.418	1.847	2.526	3.221	3.595
1999	0.029	0.131	0.367	0.663	0.983	1.196	1.436	1.762	2.129	2.602	3.202	0.029	0.131	0.371	0.664	0.929	1.21	1.523	1.775	2.215	2.911	3.604
2000	0.027	0.125	0.309	0.648	0.999	1.342	1.539	1.760	2.077	2.432	2.887	0.027	0.13	0.314	0.662	1.014	1.299	1.589	1.905	2.137	2.578	3.278
2001	0.032	0.116	0.296	0.554	0.978	1.363	1.711	1.884	2.075	2.378	2.715	0.03	0.12	0.31	0.567	1.009	1.399	1.695	1.983	2.292	2.495	2.929
2002	0.031	0.137	0.276	0.531	0.846	1.337	1.735	2.076	2.221	2.375	2.660	0.03	0.13	0.289	0.56	0.874	1.39	1.801	2.102	2.381	2.676	2.845
2003	0.029	0.134	0.323	0.497	0.815	1.170	1.705	2.103	2.427	2.542	2.657	0.03	0.134	0.31	0.524	0.864	1.218	1.785	2.205	2.51	2.775	3.049
2004	0.026	0.124	0.315	0.575	0.767	1.130	1.509	2.069	2.455	2.756	2.844	0.029	0.132	0.319	0.56	0.813	1.203	1.582	2.18	2.599	2.911	3.157
2005	0.022	0.112	0.293	0.563	0.877	1.068	1.461	1.850	2.419	2.785	3.061	0.025	0.128	0.315	0.575	0.864	1.138	1.562	1.952	2.564	2.975	3.297
2006	0.024	0.099	0.267	0.527	0.860	1.209	1.387	1.796	2.184	2.748	3.090	0.024	0.113	0.307	0.569	0.885	1.203	1.484	1.928	2.318	2.929	3.328
2007	0.026	0.104	0.237	0.483	0.809	1.187	1.556	1.712	2.125	2.504	3.053	0.025	0.107	0.272	0.556	0.877	1.232	1.561	1.838	2.289	2.672	3.27
2008	0.032	0.113	0.250	0.433	0.746	1.122	1.529	1.903	2.033	2.442	2.804	0.028	0.111	0.26	0.496	0.858	1.222	1.597	1.926	2.191	2.638	3.008
2009	0.030	0.136	0.268	0.454	0.674	1.042	1.452	1.873	2.241	2.344	2.741	0.028	0.125	0.269	0.474	0.772	1.197	1.587	1.968	2.286	2.535	2.97
2010	0.041	0.129	0.320	0.485	0.705	0.947	1.355	1.786	2.209	2.563	2.640	0.037	0.125	0.3	0.489	0.739	1.083	1.556	1.958	2.333	2.635	2.863
2011	0.036	0.172	0.304	0.571	0.749	0.988	1.241	1.676	2.114	2.530	2.865	0.034	0.158	0.3	0.542	0.761	1.04	1.416	1.922	2.325	2.686	2.966
2012	0.040	0.156	0.396	0.551	0.871	1.056	1.325	1.549	1.970	2.448	2.842	0.038	0.151	0.372	0.544	0.838	1.068	1.364	1.758	2.284	2.679	3.021
2013	0.033	0.171	0.363	0.694	0.848	1.207	1.371	1.644	1.854	2.281	2.743	0.032	0.163	0.357	0.661	0.842	1.169	1.397	1.697	2.101	2.635	3.016
2014	0.037	0.139	0.396	0.641	1.043	1.171	1.549	1.697	1.960	2.153	2.575	0.035	0.142	0.383	0.64	1.005	1.176	1.52	1.735	2.032	2.435	2.968
2015	0.033	0.161	0.328	0.699	0.973	1.426	1.516	1.901	2.019	2.270	2.448	0.031	0.151	0.339	0.682	0.979	1.382	1.531	1.879	2.073	2.36	2.755
2016	0.030	0.143	0.376	0.586	1.049	1.325	1.807	1.854	2.237	2.335	2.563	0.029	0.135	0.357	0.611	1.038	1.354	1.772	1.894	2.235	2.404	2.677
2017	0.031	0.131	0.338	0.664	0.894	1.426	1.697	2.184	2.195	2.563	2.634	0.032	0.127	0.32	0.64	0.941	1.427	1.747	2.161	2.255	2.58	2.721
2018	0.029	0.133	0.308	0.599	0.998	1.236	1.816	2.060	2.540	2.516	2.868	0.034	0.138	0.303	0.578	0.979	1.308	1.832	2.143	2.539	2.605	2.91
2019	0.038	0.128	0.313	0.555	0.912	1.363	1.583	2.195	2.414	2.880	2.817	0.033	0.147	0.327	0.550	0.891	1.354	1.696	2.238	2.533	2.900	2.942
2020*	0.035	0.164	0.303	0.559	0.847	1.256	1.742	1.937	2.551	2.747	3.188	0.033	0.143	0.345	0.587	0.850	1.239	1.746	2.089	2.631	2.904	3.235
2021*	0.035	0.149	0.382	0.544	0.856	1.173	1.613	2.112	2.280	2.887	3.055											

* - forecasted values using regressions

Table 2. Ratios between Norwegian and final data 2018 and restored data for 2019

Year	Ratio											2019 final weight data (kg)										
	1	2	3	4	5	6	7	8	9	10	11	1	2	3	4	5	6	7	8	9	10	11+
1980	1.01	1.09	1.04	0.94	0.88	0.87	0.85	0.80	0.88	0.94	1.00	0.063	0.262	0.454	0.878	1.159	1.675	2.292	3.134	3.31	3.553	3.792
1981	1.13	1.00	1.10	1.05	0.97	0.91	0.90	0.88	0.84	0.91	0.97	0.051	0.274	0.603	0.805	1.315	1.582	2.118	2.728	3.51	3.679	3.904
1982	0.90	1.10	1.03	1.12	1.07	1.00	0.94	0.93	0.91	0.88	0.95	0.036	0.224	0.631	1.049	1.217	1.782	2.017	2.553	3.14	3.853	4.016
1983	0.91	0.90	1.11	1.06	1.14	1.09	1.02	0.97	0.96	0.95	0.92	0.035	0.164	0.524	1.098	1.558	1.663	2.255	2.448	2.97	3.524	4.165
1984	0.98	0.90	0.91	1.13	1.09	1.16	1.11	1.05	0.99	0.99	0.98	0.028	0.158	0.391	0.926	1.632	2.093	2.121	2.718	2.865	3.363	3.878
1985	0.93	0.94	0.92	0.94	1.15	1.12	1.19	1.13	1.07	1.02	1.02	0.03	0.127	0.379	0.7	1.394	2.195	2.626	2.572	3.158	3.261	3.728
1986	0.84	0.91	0.96	0.94	0.96	1.18	1.16	1.21	1.14	1.10	1.05	0.035	0.136	0.311	0.682	1.069	1.898	2.761	3.138	3.005	3.568	3.632
1987	0.85	0.85	0.93	0.98	0.96	0.98	1.20	1.19	1.22	1.16	1.12	0.042	0.161	0.331	0.569	1.047	1.473	2.411	3.307	3.616	3.412	3.946
1988	0.87	0.86	0.87	0.95	1.01	0.99	1.01	1.22	1.22	1.24	1.17	0.039	0.189	0.383	0.603	0.887	1.452	1.895	2.915	3.822	4.054	3.787
1989	0.92	0.87	0.88	0.89	0.98	1.03	1.02	1.03	1.24	1.25	1.26	0.037	0.175	0.445	0.689	0.936	1.248	1.878	2.317	3.395	4.297	4.449
1990	1.01	0.92	0.88	0.90	0.92	1.00	1.05	1.04	1.05	1.26	1.28	0.031	0.169	0.413	0.789	1.054	1.312	1.635	2.308	2.728	3.844	4.73
1991	0.94	0.98	0.94	0.91	0.93	0.95	1.03	1.08	1.07	1.07	1.28	0.025	0.141	0.402	0.737	1.193	1.458	1.714	2.035	2.732	3.122	4.256
1992	0.91	0.91	0.99	0.96	0.93	0.96	0.98	1.06	1.10	1.10	1.09	0.023	0.114	0.34	0.721	1.119	1.63	1.881	2.127	2.437	3.142	3.491
1993	0.99	0.89	0.92	1.01	0.98	0.96	0.98	1.00	1.08	1.12	1.12	0.025	0.107	0.279	0.616	1.1	1.537	2.08	2.308	2.54	2.831	3.531
1994	0.93	0.96	0.90	0.94	1.03	1.01	0.98	1.01	1.03	1.11	1.15	0.030	0.115	0.262	0.512	0.952	1.518	1.969	2.527	2.729	2.945	3.213
1995	0.89	0.93	0.97	0.92	0.96	1.05	1.03	1.01	1.04	1.06	1.13	0.036	0.131	0.282	0.484	0.8	1.327	1.952	2.401	2.959	3.135	3.335
1996	0.94	0.88	0.95	0.99	0.94	0.98	1.06	1.06	1.03	1.07	1.09	0.037	0.154	0.313	0.52	0.76	1.128	1.724	2.388	2.82	3.369	3.52
1997	0.97	0.97	0.90	0.97	1.01	0.96	1.00	1.08	1.08	1.06	1.09	0.036	0.158	0.363	0.567	0.816	1.076	1.481	2.127	2.814	3.22	3.751
1998	0.99	1.00	0.99	0.92	0.99	1.04	0.99	1.02	1.10	1.10	1.08	0.029	0.153	0.371	0.650	0.879	1.155	1.418	1.847	2.526	3.221	3.595
1999	1.01	1.00	1.01	1.00	0.95	1.01	1.06	1.01	1.04	1.12	1.13	0.028	0.128	0.361	0.662	0.998	1.225	1.523	1.775	2.215	2.911	3.604
2000	1.02	1.04	1.01	1.02	1.01	0.97	1.03	1.08	1.03	1.06	1.14	0.026	0.122	0.305	0.647	1.014	1.375	1.592	1.905	2.137	2.578	3.278
2001	0.94	1.04	1.05	1.02	1.03	1.03	0.99	1.05	1.10	1.05	1.08	0.031	0.113	0.292	0.553	0.993	1.396	1.770	1.969	2.292	2.495	2.929
2002	0.97	0.95	1.05	1.05	1.03	1.04	1.04	1.01	1.07	1.13	1.07	0.030	0.133	0.272	0.531	0.859	1.369	1.795	2.170	2.349	2.676	2.845
2003	1.05	1.00	0.96	1.05	1.06	1.04	1.05	1.05	1.03	1.09	1.15	0.028	0.130	0.318	0.497	0.827	1.199	1.763	2.197	2.567	2.727	3.049
2004	1.13	1.07	1.01	0.97	1.06	1.06	1.05	1.05	1.06	1.06	1.11	0.025	0.120	0.310	0.575	0.778	1.157	1.561	2.162	2.597	2.956	3.095
2005	1.12	1.14	1.07	1.02	0.98	1.07	1.07	1.05	1.06	1.07	1.08	0.022	0.109	0.289	0.562	0.891	1.094	1.511	1.934	2.559	2.988	3.332
2006	1.01	1.14	1.15	1.08	1.03	0.99	1.07	1.07	1.06	1.07	1.08	0.023	0.096	0.263	0.526	0.873	1.239	1.434	1.877	2.310	2.948	3.363
2007	0.97	1.02	1.15	1.15	1.08	1.04	1.00	1.07	1.08	1.07	1.07	0.025	0.101	0.234	0.483	0.821	1.216	1.609	1.789	2.248	2.686	3.323
2008	0.89	0.99	1.04	1.15	1.15	1.09	1.04	1.01	1.08	1.08	1.07	0.031	0.109	0.246	0.432	0.758	1.150	1.582	1.988	2.151	2.619	3.052
2009	0.94	0.92	1.00	1.04	1.15	1.15	1.09	1.05	1.02	1.08	1.08	0.029	0.132	0.264	0.454	0.684	1.067	1.502	1.958	2.370	2.514	2.983
2010	0.91	0.97	0.94	1.01	1.05	1.14	1.15	1.10	1.06	1.03	1.08	0.039	0.125	0.315	0.484	0.715	0.970	1.402	1.866	2.336	2.749	2.873
2011	0.95	0.92	0.99	0.95	1.02	1.05	1.14	1.15	1.10	1.06	1.04	0.034	0.167	0.300	0.571	0.760	1.012	1.283	1.751	2.236	2.713	3.118
2012	0.94	0.97	0.94	0.99	0.96	1.01	1.03	1.13	1.16	1.09	1.06	0.039	0.151	0.391	0.550	0.884	1.082	1.370	1.619	2.084	2.625	3.094
2013	0.98	0.95	0.98	0.95	0.99	0.97	1.02	1.03	1.13	1.16	1.10	0.032	0.166	0.358	0.693	0.861	1.236	1.418	1.718	1.961	2.446	2.985
2014	0.93	1.02	0.97	1.00	0.96	1.00	0.98	1.02	1.04	1.13	1.15	0.036	0.136	0.391	0.640	1.059	1.200	1.602	1.773	2.073	2.309	2.802
2015	0.93	0.94	1.03	0.98	1.01	0.97	1.01	0.99	1.03	1.04	1.13	0.032	0.157	0.324	0.698	0.988	1.461	1.568	1.987	2.136	2.435	2.664
2016	0.97	0.94	0.95	1.04	0.99	1.02	0.98	1.02	1.00	1.03	1.04	0.029	0.139	0.371	0.585	1.065	1.357	1.869	1.937	2.367	2.505	2.790
2017	1.05	0.97	0.95	0.96	1.05	1.00	1.03	0.99	1.03	1.01	1.03	0.030	0.127	0.333	0.664	0.908	1.461	1.755	2.283	2.322	2.749	2.867
2018	1.16	1.04	0.99	0.97	0.98	1.06	1.01	1.04	1.00	1.04	1.01	0.028	0.129	0.303	0.598	1.013	1.266	1.878	2.153	2.686	2.699	3.121
2019												0.037	0.124	0.309	0.554	0.926	1.397	1.638	2.294	2.553	3.089	3.066
2020*												0.034	0.160	0.298	0.558	0.860	1.287	1.801	2.024	2.699	2.947	3.469
2021*												0.034	0.145	0.376	0.543	0.868	1.202	1.668	2.207	2.412	3.097	3.325
Mean	0.969	0.972	0.985	0.999	1.012	1.025	1.034	1.045	1.058	1.073	1.088											

* - forecasted restored values

Table 3. Smoothed maturity data from Norwegian surveys and final maturity data used in 2018

Year	2019 smoothed maturity data from Norwegian surveys									2018 final maturity data								
	3	4	5	6	7	8	9	10	11	3	4	5	6	7	8	9	10	11
1980	0.02	0.10	0.35	0.79	0.96	0.99	1.00	1.00	1.00	0.03	0.08	0.24	0.65	0.86	0.95	0.98	1.00	1
1981	0.02	0.11	0.45	0.77	0.96	0.99	1.00	1.00	1.00	0.06	0.10	0.30	0.55	0.86	0.95	0.98	1.00	1
1982	0.02	0.09	0.40	0.78	0.94	0.98	1.00	1.00	1.00	0.05	0.16	0.33	0.58	0.77	0.95	0.98	1.00	1
1983	0.02	0.14	0.45	0.80	0.95	0.99	1.00	1.00	1.00	0.06	0.18	0.47	0.67	0.80	0.91	0.98	1.00	1
1984	0.02	0.16	0.53	0.85	0.95	0.99	1.00	1.00	1.00	0.04	0.20	0.51	0.80	0.86	0.92	0.97	1.00	1
1985	0.02	0.11	0.55	0.84	0.95	0.99	1.00	1.00	1.00	0.03	0.15	0.52	0.80	0.93	0.95	0.97	0.99	1
1986	0.02	0.12	0.49	0.76	0.95	0.99	1.00	1.00	1.00	0.02	0.10	0.45	0.76	0.93	0.98	0.98	0.99	1
1987	0.02	0.08	0.36	0.74	0.93	0.99	1.00	1.00	1.00	0.02	0.08	0.29	0.71	0.92	0.98	0.99	0.99	1
1988	0.02	0.07	0.29	0.68	0.92	0.98	1.00	1.00	1.00	0.03	0.07	0.24	0.58	0.90	0.98	0.99	1.00	1
1989	0.02	0.08	0.29	0.65	0.90	0.98	1.00	1.00	1.00	0.03	0.09	0.25	0.53	0.82	0.97	0.99	1.00	1
1990	0.02	0.12	0.35	0.70	0.90	0.97	0.99	1.00	1.00	0.05	0.13	0.31	0.58	0.80	0.94	0.99	1.00	1
1991	0.03	0.13	0.40	0.73	0.92	0.97	0.99	1.00	1.00	0.04	0.16	0.36	0.62	0.82	0.93	0.98	1.00	1
1992	0.02	0.14	0.47	0.81	0.94	0.98	0.99	1.00	1.00	0.03	0.15	0.45	0.70	0.86	0.94	0.98	0.99	1
1993	0.02	0.12	0.42	0.78	0.93	0.99	0.99	1.00	1.00	0.02	0.11	0.40	0.74	0.88	0.95	0.98	0.99	1
1994	0.02	0.09	0.38	0.76	0.93	0.98	1.00	1.00	1.00	0.02	0.07	0.33	0.70	0.90	0.96	0.98	0.99	1
1995	0.02	0.07	0.31	0.72	0.92	0.98	1.00	1.00	1.00	0.02	0.06	0.23	0.63	0.89	0.97	0.99	1.00	1
1996	0.02	0.09	0.29	0.64	0.92	0.98	1.00	1.00	1.00	0.02	0.07	0.21	0.50	0.86	0.96	0.99	1.00	1
1997	0.03	0.09	0.27	0.66	0.89	0.97	0.99	1.00	1.00	0.03	0.08	0.20	0.50	0.76	0.95	0.99	1.00	1
1998	0.03	0.12	0.30	0.67	0.89	0.97	0.99	1.00	1.00	0.04	0.12	0.25	0.50	0.75	0.91	0.98	1.00	1
1999	0.03	0.12	0.36	0.61	0.91	0.97	0.99	1.00	1.00	0.05	0.13	0.32	0.52	0.76	0.90	0.97	1.00	1
2000	0.02	0.12	0.37	0.67	0.84	0.97	0.99	1.00	1.00	0.03	0.15	0.35	0.60	0.77	0.90	0.97	0.99	1
2001	0.02	0.09	0.36	0.68	0.87	0.94	1.00	1.00	1.00	0.03	0.11	0.39	0.64	0.82	0.91	0.97	0.99	1
2002	0.02	0.08	0.29	0.67	0.88	0.95	0.98	1.00	1.00	0.02	0.10	0.29	0.67	0.85	0.93	0.97	0.99	1
2003	0.02	0.07	0.27	0.59	0.87	0.96	0.98	0.99	1.00	0.03	0.08	0.28	0.58	0.87	0.94	0.98	0.99	1
2004	0.02	0.09	0.24	0.57	0.83	0.95	0.98	0.99	1.00	0.03	0.09	0.23	0.57	0.81	0.95	0.98	0.99	1
2005	0.02	0.09	0.30	0.54	0.82	0.94	0.98	0.99	1.00	0.03	0.10	0.26	0.50	0.80	0.93	0.98	0.99	1
2006	0.02	0.08	0.29	0.61	0.79	0.93	0.98	0.99	1.00	0.03	0.10	0.27	0.54	0.75	0.93	0.97	0.99	1
2007	0.01	0.07	0.27	0.60	0.84	0.92	0.97	0.99	1.00	0.02	0.09	0.27	0.55	0.78	0.90	0.97	0.99	1
2008	0.01	0.06	0.23	0.57	0.83	0.94	0.97	0.99	1.00	0.02	0.07	0.25	0.55	0.79	0.91	0.96	0.99	1
2009	0.02	0.06	0.20	0.52	0.81	0.94	0.98	0.99	1.00	0.02	0.06	0.21	0.52	0.80	0.92	0.97	0.99	1
2010	0.02	0.07	0.21	0.47	0.78	0.93	0.98	0.99	1.00	0.02	0.07	0.19	0.46	0.77	0.92	0.97	0.99	1
2011	0.02	0.09	0.24	0.49	0.74	0.92	0.97	0.99	1.00	0.02	0.08	0.20	0.44	0.73	0.91	0.97	0.99	1
2012	0.03	0.08	0.29	0.53	0.78	0.91	0.97	0.99	1.00	0.03	0.08	0.24	0.45	0.71	0.89	0.97	0.99	1
2013	0.02	0.12	0.28	0.61	0.80	0.92	0.97	0.99	1.00	0.03	0.12	0.24	0.50	0.71	0.88	0.96	0.99	1
2014	0.03	0.11	0.38	0.59	0.84	0.92	0.97	0.99	1.00	0.03	0.10	0.32	0.50	0.75	0.88	0.95	0.99	1
2015	0.02	0.13	0.34	0.70	0.83	0.94	0.97	0.99	1.00	0.03	0.12	0.29	0.61	0.75	0.89	0.95	0.98	1
2016	0.03	0.09	0.38	0.66	0.89	0.94	0.98	0.99	1.00	0.04	0.10	0.33	0.57	0.82	0.90	0.96	0.98	1
2017	0.02	0.12	0.30	0.70	0.87	0.96	0.98	0.99	1.00	0.04	0.12	0.27	0.61	0.80	0.93	0.96	0.99	1
2018	0.02	0.10	0.35	0.62	0.89	0.95	0.99	0.99	1.00	0.03	0.11	0.33	0.55	0.83	0.92	0.98	0.99	1
2019	0.02	0.09	0.31	0.67	0.85	0.96	0.98	0.99	1.00	0.03	0.10	0.30	0.61	0.79	0.93	0.97	0.99	1
2020*	0.02	0.09	0.28	0.63	0.88	0.95	0.99	0.99	1.00	0.03	0.10	0.29	0.59	0.83	0.92	0.98	0.99	1
2021*	0.03	0.08	0.28	0.59	0.85	0.96	0.98	0.99	1.00									

* - forecasted values using regressions

Table 4. Ratios between Norwegian and final data 2018 and restored data for 2019

	Ratio									2019 final maturity data								
Year	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11+**
1980	1.46	0.80	0.69	0.82	0.90	0.96	0.99	1.00	1.00	0.026	0.076	0.243	0.649	0.86	0.95	0.984	0.995	1
1981	2.51	0.98	0.68	0.71	0.90	0.96	0.99	1.00	1.00	0.056	0.104	0.303	0.549	0.857	0.948	0.984	0.995	1
1982	2.72	1.84	0.83	0.74	0.82	0.96	0.99	1.00	1.00	0.053	0.161	0.332	0.577	0.77	0.947	0.983	0.995	1
1983	2.36	1.35	1.04	0.83	0.85	0.92	0.99	1.00	1.00	0.057	0.183	0.472	0.665	0.8	0.906	0.983	0.995	1
1984	2.12	1.24	0.96	0.94	0.91	0.93	0.97	1.00	1.00	0.044	0.196	0.51	0.801	0.862	0.921	0.967	0.995	1
1985	1.08	1.30	0.94	0.94	0.98	0.96	0.98	0.99	1.00	0.027	0.149	0.522	0.796	0.928	0.953	0.973	0.989	1
1986	1.09	0.85	0.92	0.99	0.97	0.99	0.99	0.99	1.00	0.021	0.103	0.454	0.758	0.928	0.977	0.984	0.991	1
1987	1.29	0.91	0.81	0.97	0.99	0.99	1.00	1.00	1.00	0.021	0.076	0.294	0.713	0.918	0.976	0.993	0.994	1
1988	1.55	1.04	0.82	0.85	0.97	0.99	1.00	1.00	1.00	0.025	0.074	0.24	0.576	0.898	0.975	0.993	0.998	1
1989	1.73	1.10	0.86	0.83	0.91	0.99	1.00	1.00	1.00	0.032	0.09	0.25	0.534	0.822	0.966	0.993	0.998	1
1990	2.23	1.02	0.86	0.82	0.89	0.96	1.00	1.00	1.00	0.046	0.127	0.305	0.578	0.798	0.937	0.99	0.997	1
1991	1.57	1.22	0.90	0.86	0.89	0.95	0.99	1.00	1.00	0.041	0.164	0.358	0.623	0.82	0.925	0.98	0.997	1
1992	1.31	1.08	0.96	0.87	0.91	0.95	0.98	0.99	1.00	0.03	0.147	0.449	0.704	0.855	0.936	0.976	0.994	1
1993	0.92	0.97	0.94	0.95	0.94	0.96	0.98	0.99	1.00	0.018	0.113	0.396	0.741	0.878	0.95	0.979	0.992	1
1994	0.92	0.78	0.87	0.93	0.98	0.98	0.99	0.99	1.00	0.016	0.073	0.329	0.702	0.903	0.96	0.984	0.993	1
1995	1.00	0.83	0.74	0.88	0.96	0.99	0.99	1.00	1.00	0.016	0.059	0.227	0.633	0.885	0.969	0.987	0.995	1
1996	1.08	0.76	0.73	0.78	0.93	0.98	1.00	1.00	1.00	0.032	0.069	0.213	0.497	0.855	0.964	0.991	0.996	1
1997	1.27	0.89	0.75	0.75	0.86	0.97	0.99	1.00	1.00	0.040	0.098	0.204	0.495	0.76	0.948	0.989	0.997	1
1998	1.48	0.98	0.83	0.75	0.84	0.93	0.99	1.00	1.00	0.041	0.125	0.264	0.502	0.75	0.907	0.984	0.997	1
1999	1.88	1.09	0.88	0.86	0.83	0.93	0.98	1.00	1.00	0.039	0.129	0.320	0.535	0.76	0.898	0.969	0.995	1
2000	1.62	1.32	0.96	0.89	0.92	0.93	0.97	0.99	1.00	0.030	0.124	0.328	0.594	0.775	0.9	0.966	0.99	1
2001	1.68	1.19	1.08	0.94	0.94	0.97	0.97	0.99	1.00	0.028	0.094	0.318	0.601	0.808	0.909	0.967	0.989	1
2002	1.40	1.24	1.02	1.00	0.97	0.98	0.99	0.99	1.00	0.026	0.088	0.255	0.592	0.812	0.923	0.966	0.989	1
2003	1.24	1.08	1.05	0.97	1.00	0.99	0.99	1.00	1.00	0.032	0.078	0.240	0.524	0.807	0.925	0.972	0.988	1
2004	1.38	0.97	0.95	0.99	0.98	1.00	1.00	1.00	1.00	0.031	0.101	0.218	0.505	0.768	0.923	0.972	0.990	1
2005	1.59	1.05	0.87	0.92	0.98	0.99	1.00	1.00	1.00	0.028	0.097	0.269	0.476	0.756	0.906	0.971	0.990	1
2006	1.64	1.20	0.93	0.88	0.95	0.99	1.00	1.00	1.00	0.024	0.087	0.261	0.541	0.736	0.901	0.965	0.990	1
2007	1.58	1.26	1.03	0.92	0.93	0.98	1.00	1.00	1.00	0.021	0.075	0.237	0.531	0.778	0.892	0.963	0.987	1
2008	1.27	1.21	1.06	0.97	0.95	0.97	0.99	1.00	1.00	0.022	0.062	0.209	0.502	0.773	0.911	0.960	0.986	1
2009	1.15	1.01	1.04	0.99	0.98	0.98	0.99	1.00	1.00	0.025	0.067	0.177	0.463	0.754	0.908	0.967	0.985	1
2010	1.02	0.93	0.91	0.98	0.99	0.99	0.99	1.00	1.00	0.032	0.075	0.190	0.415	0.727	0.900	0.966	0.988	1
2011	1.16	0.85	0.85	0.89	0.98	0.99	1.00	1.00	1.00	0.029	0.099	0.210	0.436	0.690	0.888	0.963	0.987	1
2012	1.21	0.94	0.81	0.84	0.90	0.98	1.00	1.00	1.00	0.042	0.090	0.260	0.472	0.724	0.878	0.960	0.988	1
2013	1.22	0.95	0.84	0.82	0.89	0.95	0.99	1.00	1.00	0.037	0.132	0.250	0.537	0.737	0.889	0.955	0.986	1
2014	1.21	0.96	0.86	0.84	0.89	0.95	0.98	1.00	1.00	0.042	0.115	0.336	0.522	0.778	0.895	0.960	0.984	1
2015	1.32	0.96	0.86	0.87	0.90	0.95	0.98	0.99	1.00	0.032	0.133	0.305	0.616	0.771	0.913	0.962	0.986	1
2016	1.39	1.02	0.86	0.87	0.93	0.96	0.98	0.99	1.00	0.039	0.099	0.339	0.581	0.822	0.909	0.968	0.986	1
2017	1.58	1.04	0.90	0.88	0.92	0.97	0.98	0.99	1.00	0.033	0.122	0.270	0.616	0.805	0.930	0.967	0.989	1
2018	1.65	1.14	0.92	0.89	0.93	0.97	0.99	0.99	1.00	0.029	0.103	0.316	0.548	0.823	0.923	0.975	0.988	1
2019										0.029	0.091	0.278	0.595	0.785	0.930	0.972	0.991	1
2020*										0.028	0.092	0.250	0.556	0.812	0.915	0.975	0.990	1
2021*										0.039	0.088	0.253	0.523	0.791	0.926	0.969	0.991	1
Mean	1.48	1.06	0.89	0.88	0.93	0.97	0.99	1.00	1.00									

* - forecasted restored values

References

ICES. 2015. Report of the Benchmark Workshop on Arctic Stocks (WKARCT), Copenhagen 26-30 January 2015. ICES C. M. 2015/ACOM:31, xx pp.

ICES. 2016. Report of the Arctic Fisheries Working Group (AFWG), 19–25 April 2016, ICES HQ, Copenhagen, Denmark. ICES CM 2016/ACOM:06.

ICES. 2017. Report of the Arctic Fisheries Working Group (AFWG), 19–25 April 2017, Copenhagen, Denmark. ICES CM 2017/ACOM:06. 486 pp.

Working Document No. 15

ICES Arctic Fisheries Working Group (AFWG), April 2019

Updated mean ratios between the combined and Norwegian data on weight at age and maturity at age in Northeast Arctic cod

The Russian autumn trawl-acoustic survey (TAS) in the Barents Sea was not conducted in 2018. Russian cod abundance indices, weight at age and maturity at age data used for stock assessment were not available for 2018/2019.

Combined data on weight at age and maturity at age for 2018/2019 were adjusted using the same method as described in the WD 10 presented at the AFWG meeting in 2017. The mean 2019 ratios calculated between combined and Norwegian data differed slightly from the mean 2017 ratios (Table 1 -2).

There are the final NEA cod weight at age and maturity at age values for 2018/2019 in this WD (Table 3).

Table 1. NEA cod. Mean ratios between the combined and Norwegian data on weight at age with some statistical characteristics for years 1985-2016, 2018

Age, years	Number of years with data	Mean Ratio this year (2019)	Ratio 2017	95% confidence limits	St deviation	Coefficient of variation, %
1	33	0.93	0.91	0.87-0.99	0.17	18.24
2	33	0.93	0.93	0.89-0.98	0.12	12.46
3	33	0.88	0.88	0.85-0.91	0.09	10.34
4	33	0.88	0.88	0.85-0.90	0.07	8.23
5	33	0.93	0.93	0.91-0.95	0.06	6.22
6	33	0.95	0.95	0.93-0.97	0.06	6.34
7	33	0.96	0.96	0.94-0.98	0.06	6.04
8	33	0.98	0.98	0.96-1.00	0.06	5.82
9	33	1.01	1.01	0.99-1.04	0.08	7.53
10	31	1.01	1.01	0.98-1.04	0.08	7.99
11	30	1.10	1.11	1.04-1.16	0.17	15.02
12	29	1.01	1.01	1.00-1.02	0.03	2.92

Table 2. NEA cod. Mean ratios between the combined and Norwegian data on maturity at age with some statistical characteristics for years 1989-2016, 2018

Age, years	Number of years with data	Mean Ratio this year (2019)	Ratio 2017	95% confidence limits	St deviation	Coefficient of variation, %
3	14	0.88	0.88	0.11-1.65	1.33	151.71
4	25	0.94	0.90	0.71-1.17	0.56	59.09
5	29	0.82	0.82	0.74-0.91	0.21	25.74
6	29	0.83	0.82	0.79-0.88	0.12	14.40
7	29	0.91	0.90	0.87-0.94	0.09	9.42
8	29	0.96	0.96	0.94-0.99	0.07	7.26
9	29	0.98	0.98	0.97-0.99	0.03	2.87
10	29	0.99	0.99	0.99-1.00	0.01	0.96
11	29	1.00	1.00	0.99-1.00	0.01	1.17
12	29	1.00	1.00	1.00-1.00	0.00	0.39

Table 3. NEA cod. The combined data on weight at age in stock and maturity at age in 2019

Age, years	1	2	3	4	5	6	7	8	9	10	11	12
W,g	10	43	274	659	1188	1950	3101	4381	5928	7361	9632	11226
Maturity, portion			0.000	0.003	0.033	0.199	0.624	0.894	0.947	0.988	0.997	1.000

ICES Arctic Fisheries Working Group 2019

Working Document 16

Use of RStoX for estimating numbers@age of *Sebastes mentella* from the Barents Sea Ecosystem survey

Hannes Höffle, Caroline A. Tranang, Mikko Vihtakari, Tone Vollen, Alf Harbitz

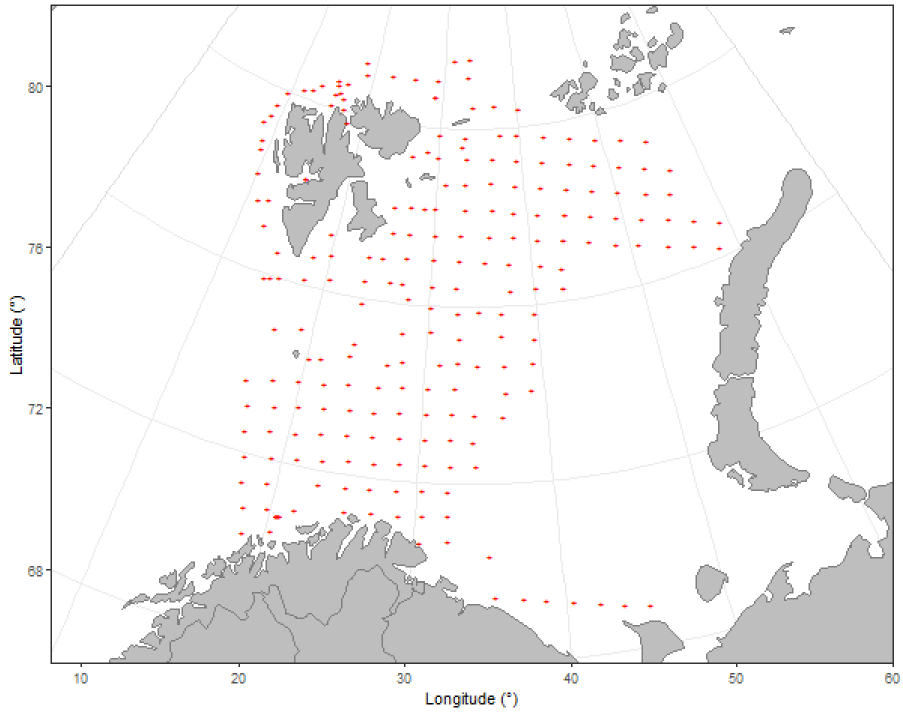
Institute of Marine Research, P.O. Box 6606 Langnes, 9296 Tromsø, Norway

1. Introduction

1.1. Barents Sea Ecosystem Survey: Eco-NoRu-Q3 (BTr)

The joint autumn ecosystem survey of the Barents Sea started in 2003 by combining five previous surveys into a single investigation. These five surveys comprised the joint Russian–Norwegian surveys for 0-group fish and capelin together with the Norwegian surveys for shrimp, Greenland halibut and redfish. Combining these surveys enabled the whole ice-free Barents Sea to be covered by oceanographic, acoustic, pelagic and demersal trawl investigations. Investigations on plankton, seabirds, marine mammals, marine pollution and benthos have also been carried out, but with various degrees of coverage. The survey is carried out in August and September each year, with the aim of covering the whole area before the cod and haddock 0-group starts to settle on the bottom. The survey data are also used as direct input to the capelin assessment, which is carried out in the first week of October. The survey is carried out during the period of minimum ice coverage, leading to a survey area on the order of 1.5 million square kilometres. The survey coverage and demersal trawl sampling for 2018 are illustrated in Figure 1. Data from the earlier Norwegian Svalbard (Division 2.b) bottom trawl survey (August-September) are available annually since 1986 (incl.) at fishing depths of 100–500 m, disaggregated by age only since 1992. The redfish and Greenland halibut survey covers the Norwegian Economic Zone (NEZ) and Svalbard including north and east of Spitsbergen during August down to 800 m depth.

The combined survey data provide swept area abundance estimates for *S. mentella* and *S. norvegicus* in the Barents Sea during summer. In addition, the 0-group component of the dataset is used to estimate the abundance of 0-group redfish for the two species combined.



=

Figure 1. Trawl stations at the Ecosystem survey, August-October 2018. Missing coverage in the south-eastern part was low due to delays in the Russian part of the survey.

1.2. Rational for this working document

Until 2018, numbers-at-length and age were derived from historical runs of the 'SAS-survey-program' (referred as 'SAS' from here on). However, this program is outdated and produced results that were not reproducible (Planque et al. 2018). Therefore, it is desirable to phase out SAS in favour of StoX. The StoX software is developed to produce reproducible results and offers an R-port version (RStoX) making it easier to run several years using similar parameters and offers integration with other elements of the software suite, such as ECA and SCAA.

The implementation of StoX for numbers-at-age should make the data preparation from the Barents Sea Ecosystem Survey survey more transparent and reproducible in the future. A downside of StoX is that, at the moment, it can only use strata systems defined by geographical coordinates alone, whilst SAS could use geographical **and** bathymetric coordinates. The strata systems used by SAS, Arctic (Arc15), Svalbard (Sva31) and Barents (Bar32), corresponding to different regions of the Barents Sea (Fig. 2), where not only defined by geography but also by depth intervals. Arc15 used intervals 100-300 m, 300-500 m and >500 m. The other two systems used 100 m intervals for the depth range of 0-500 m.

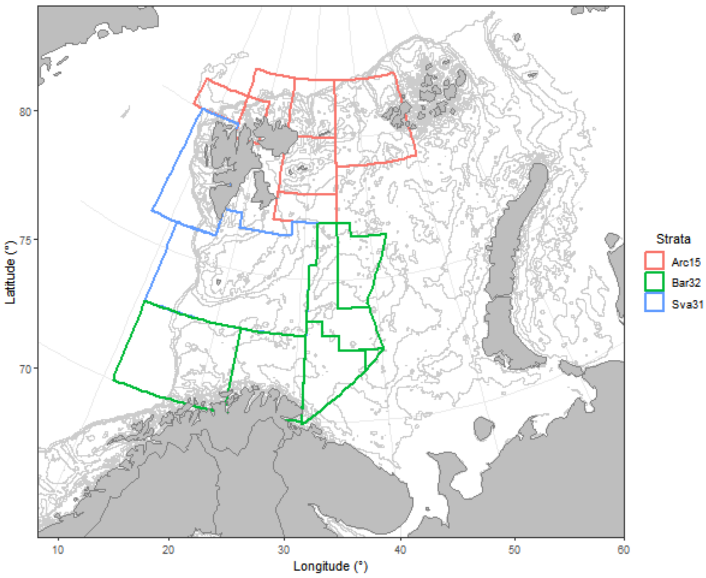


Figure 2. The SAS strata systems 15, 31 and 32 used for the Barents Sea ecosystem survey in summer. The strata are defined as a combination of geographical polygons (coloured lines) and depth ranges (grey lines).

Here we present two possible approaches to recalculate the numbers-at-length and age in RStoX. Firstly, using a strata system created for the 2017 survey, called Barents_Sea_Ecosystem_Survey_Areas_v2017 (‘BESA17’, *pers. comm.* Johansen). Secondly, we continue using the SAS strata as defined by geography but recalculate the numbers-at-length and age using the areas (n.mi.$^{-2}$) for 100 m depth intervals within these strata. This had to be done outside the RStoX system, because StoX only accepts strata in the form of wkt-formatted polygons.

1.3. Survey indices used in SCA

Data from the Ecosystem Survey as used in the Statistical Catch at Age mode (SCA) consists of numbers-at-age for *S. mentella* from 1996-to present and for ages between 2 and 15.

Numbers-at-length and age for the period before the introduction of the Ecosystem survey were not recalculated. Abundance indices for fish older than 15 years were calculated but not used in the assessment model, because older fish tend to migrate out of the Barents Sea and thus abundance estimates for them are not considered reliable.

Age reading of redfish otoliths has been inadequate due to lack of personnel, but the situation will be improved by the 2020 assessment. No otoliths were collected in 2010 and, consequently, age estimates are not provided for this year. The re-estimations done for this document cover the time from the beginning of the survey proper, 2003-2015.

2. RStoX configuration, input, settings and filters

Estimates of proportions-at-age are performed with RStoX, the R version of StoX (2015). This is done to allow a better integration of all the assessment steps, and to ease the work with several years of data. The code was run in R version 3.5.2 and RStoX version 1.11.

2.1. Parameters

RStoX uses horizontal strata-systems with separate regions treated as separate sampling strata. The BESA17 strata system (Fig. 3) was created to fulfil the requirements of the TIBIA project and is therefore based on both hydrographic and ecological criteria. The strata system was not developed for the calculation of trawl indices and a new system ('Basic') has recently been developed. The chosen parameters are presented in Table 1.

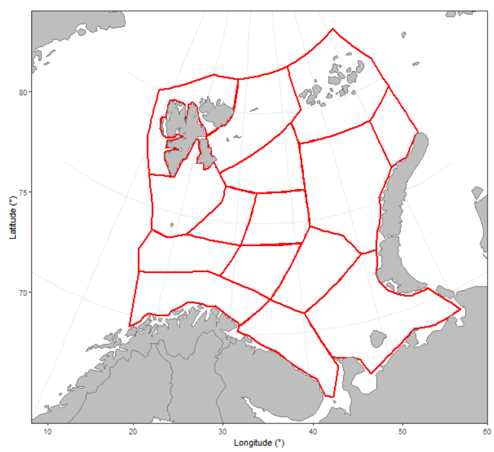


Figure 3. The strata system defined for the survey in 2017. Although it is only defined geographically, it does take some limited account of bathygraphy by being cut off at the shelf edge and having separate areas for features such as the Bear Island trench.

2.2. The RStoX process

After downloading the project-data and defining the parameters, RStoX produces numbers-at-length and age with just a few lines of R-code (Figure 4). Whilst this makes it easy to use, it also reduces transparency. However, results of all the calculation steps are stored in the R-object, a list that we usually name 'X'. Regardless of the name, the content of the list is always the same and the output of the calculation steps are stored under the list-object 'outputData'. With the output available every step of the calculation of numbers-at-age can be retraced with any spreadsheet software. Since numbers-at-age are derived by bootstrapping and imputation, retracing with a spreadsheet is not easily possible beyond the initial calculation of numbers-at-age. The calculated numbers-at-length are proportionally redistributed over the stations corresponding to the stratum and size class. These abundances are then bootstrapped and the age and other missing data imputed for each of the 50 bootstrap runs. The numbers-at-age are then the mean of these abundances over the number of bootstraps a given age has been imputed for.

2.3. Alternative estimation

The alternative calculation process begins with the creation of the depth strata, 100 m intervals between zero and 500 m across all strata, and the determination of the number of stations in each of them. The result is then stored in an R-object. After running the standard RStoX process with the Arc15, Sva31 and Bar32 strata systems, we extract the weighted count after it has been standardized to the abundance of desired length group per nautical mile (n.mi.) from the data frame 'RegroupLengthDist'. The standardization is done at this point because it is the last step in RStoX in which the serial numbers are attached, rather than a running number for the Primary Sampling Units (PSU = 1 Haul). The stored number of stations per stratum, the depth category and the stratum name and area are attached to the extracted table.

Table 1: Parameters for estimation of the Barents Sea ecosystem cruise indices. All calculation methods had the same settings except for the strata-systems.

Process	Parameter	Value
Retrieving data	RStoX configuration	*SweptAreaTemplate*
Baseline	Gear code	*<3500*
	Gear condition	*<3*[1]
	Trawl quality	*1*[2]
	Fish station type	*NOT 2 or C*
	Taxa	*166756 (Snabeluer) & 166705 (Uerslekten)*
	Strata system	*BESA17; Arc15 & Sva31 & Bar32, Basic, Basic + 500-750 m layer and depth-based polygons*
	Swept area function	*SweptAreaDensity*
	Fishing width	*Constant 25 m*
	Area calculation	*Accurate*
	Length Intervals	*5 cm*
Bootstrapping	n	*50*
	Seed	*1234*
	bioticMethod	*PSU~Stratum*
	bootstrapMethod	*SweptAreaLength*
	Length Intervals	*5 cm*

[1] Gear functioning properly

[2] Trawl at predetermined location

Using the weighted count *(f)* per station *(s)* and length group *(l)* the numbers per length group and n.mi.² ($P_{s,l}$) are calculated with a fixed trawl width (25 m):

$$P_{s,l} = \frac{f_{s,l} \times 25}{1852}$$

These numbers for each PSU are then averaged over all stations with stratum and raised to the abundance for the stratum by:

$$L_{p,l} = A_p \times \sum \bar{P}_{s,l} \times \frac{S_{p,l}}{S_p}$$

Where $L_{p,l}$ is the index for stratum *p* and length group *l*, A_p is the area of the stratum, $\bar{P}_{s,l}$ the mean number per length of group and n.mi.² for stratum. $S_{p,l}$ the number of stations for stratum and length group and S_p the number of stations for the stratum. The resulting index represents estimated number of fish at length/over the entire stratum *p*.

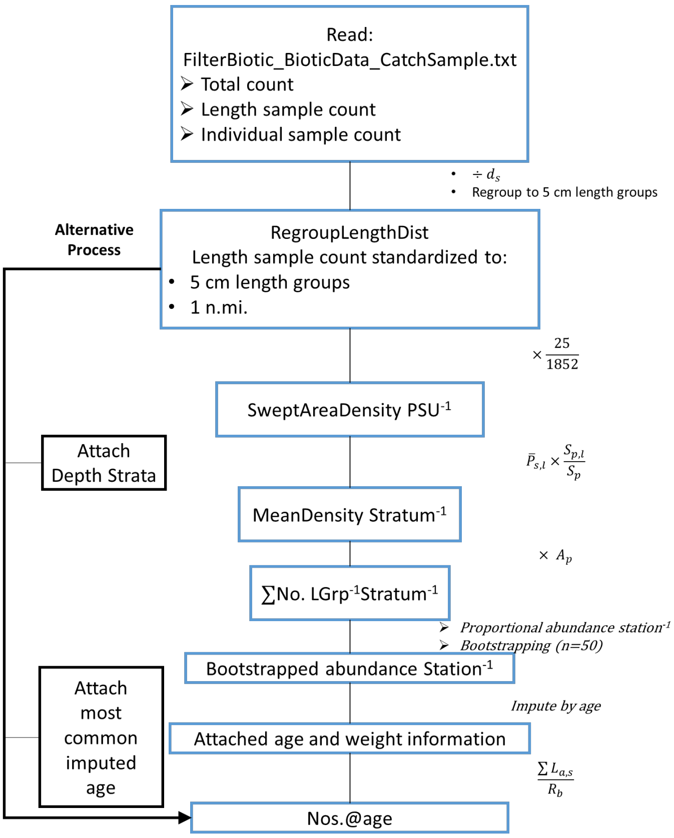


Figure 4. Flow chart of the RStoX and alternative calculation processes.

To estimate numbers-at-age, the age most commonly imputed to a length group at a certain station was extracted and attached to the table containing the numbers-at-length for each station. These numbers are then summed up to arrive at the numbers-at-age. This method provides the advantage that numbers-at-length and at age are the same, but at the cost of losing the uncertainty estimates.

3. Other strata systems considered

3.1. Depth-based strata

A further development of the alternative calculation is the creation of a new strata system, that is completely based on depth, due to the observation that the density distribution of *S. mentella* catches as related to depth is similar across the Barents Sea, here divided into four quadrants (Fig. 5), and across years (Fig. 6).

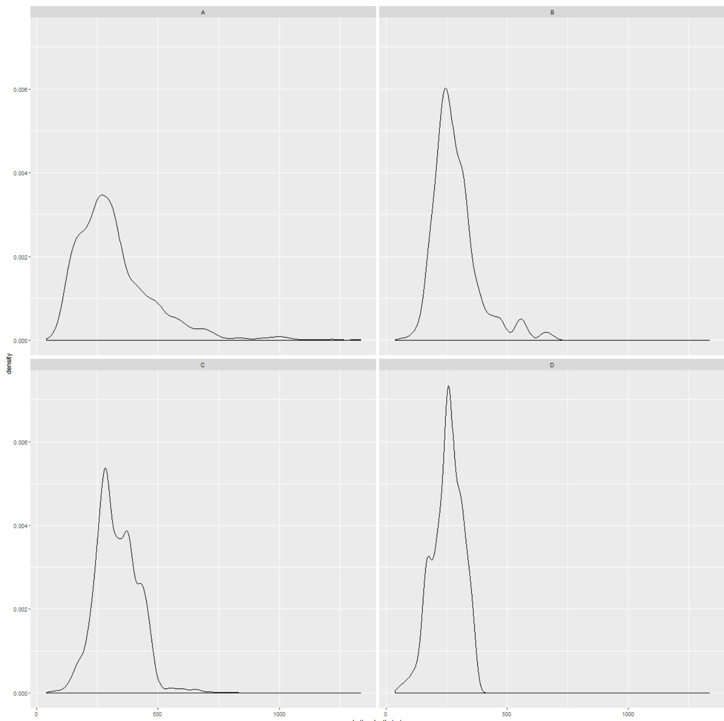


Figure 5. Density distribution of *S. mentella* catches plotted on the depth range across the Barents Sea, subdivided at 35° longitude and the 76th parallel.

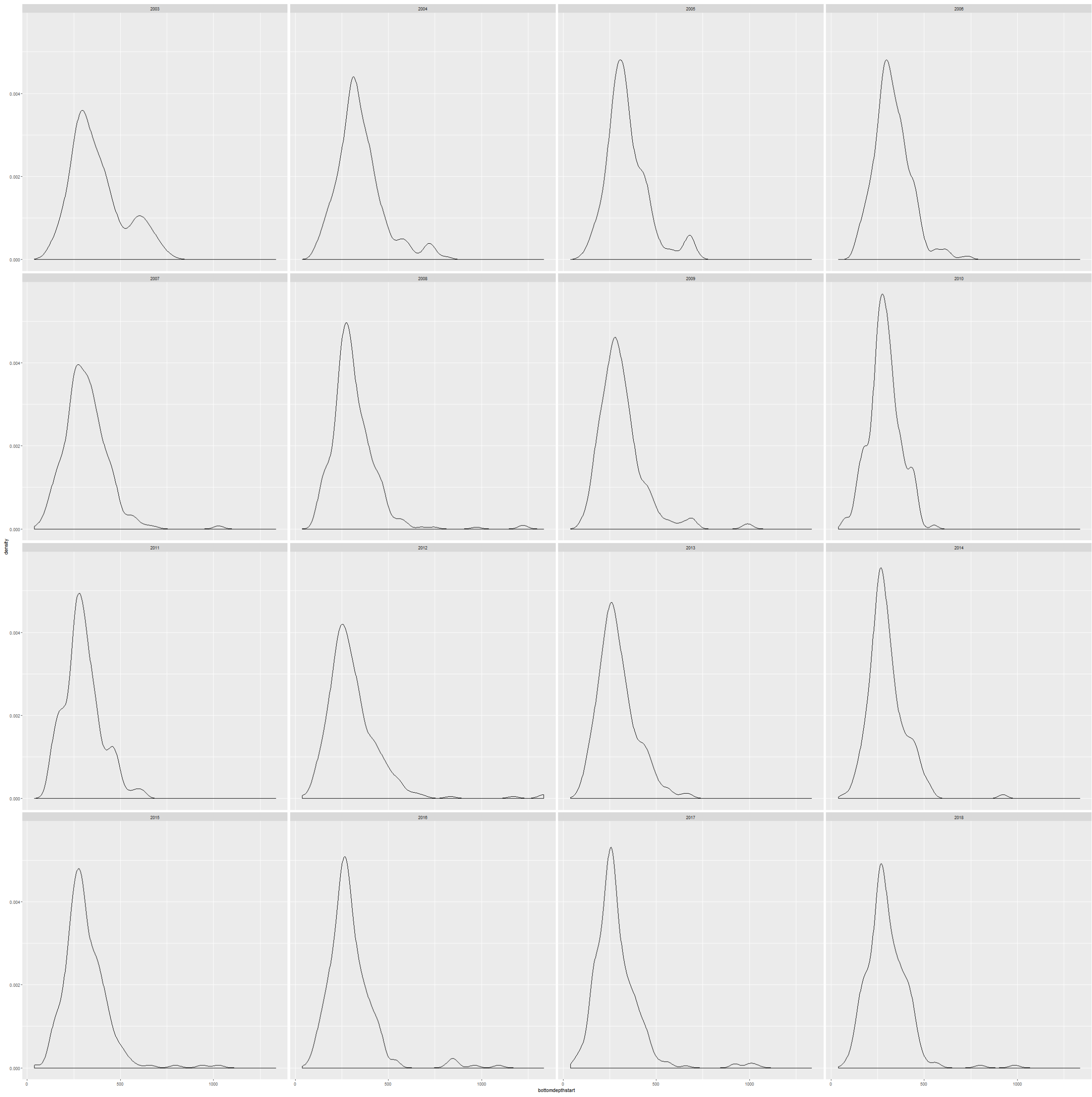


Figure 6. Density distribution of *S. mentella* catches plotted on the depth range across the Barents Sea for each year 2003 to 2018. The distribution is fairly homogenous.

The suggested strata system (Fig. 7), appears more ‘organic’ than the others, but combines very large with very small areas, giving an overweight to some.

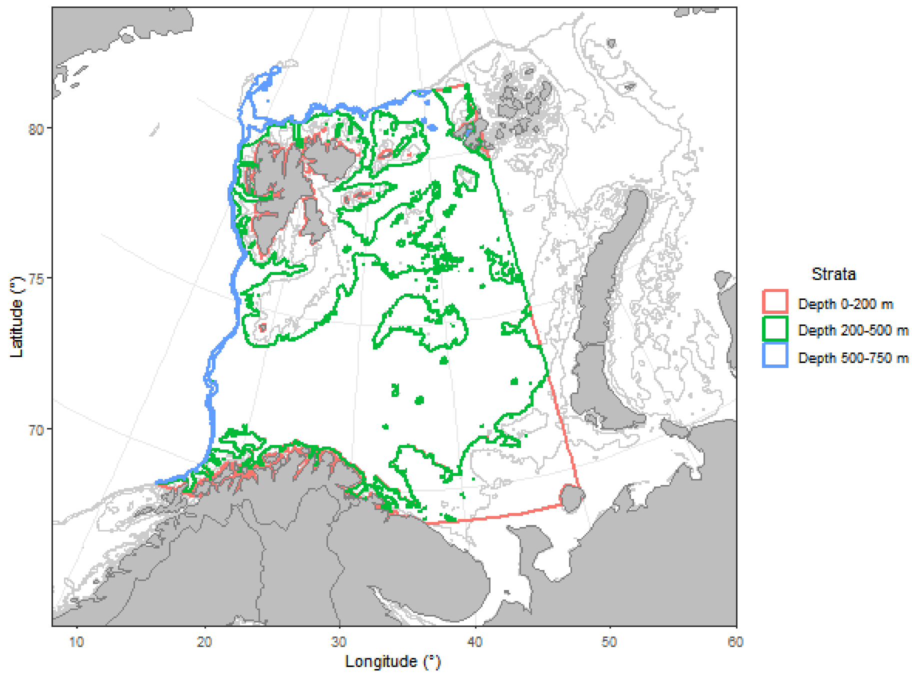


Figure 7. Suggested strata system based on depth as the sole criterion.

3.2. Basic ecosystem survey strata

Very recently, the basic strata system for the Ecosystem survey (WKT_Basic_ECO; *pers. comm.* Johansen) has been developed (Fig. 8). However, it is more targeted at correctly reflecting the distribution of cod (*Gadus morhua*) and haddock (*Melanogrammus aeglefinus*). It is similar to, but simpler than the 2017 strata-system, with 9 rather than 15 polygons and it cuts off at 500 m depth. Since this depth-limit does not fully cover the distribution of beaked redfish we attached the 500-750 m stratum from the depth-based system to it (Fig. 9).

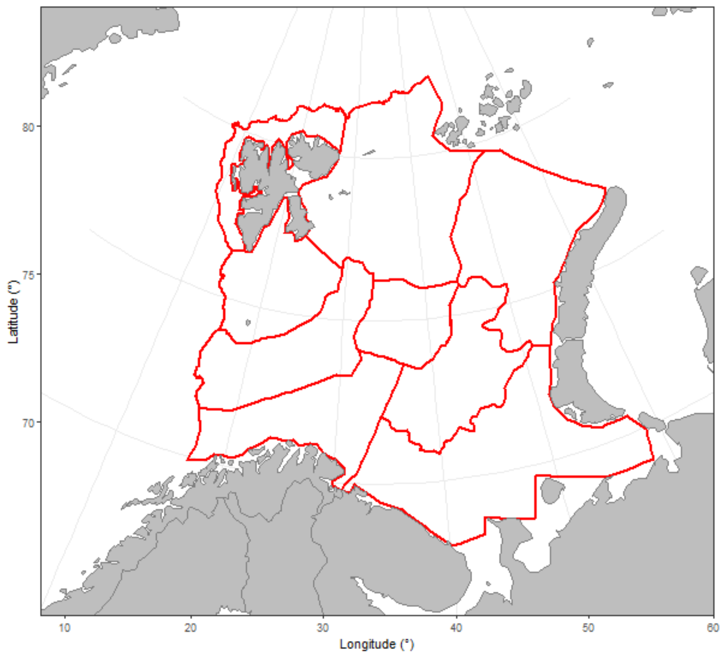


Figure 8. Basic strata system for the Barents Sea ecosystem survey, for the depth range 0-500 m.

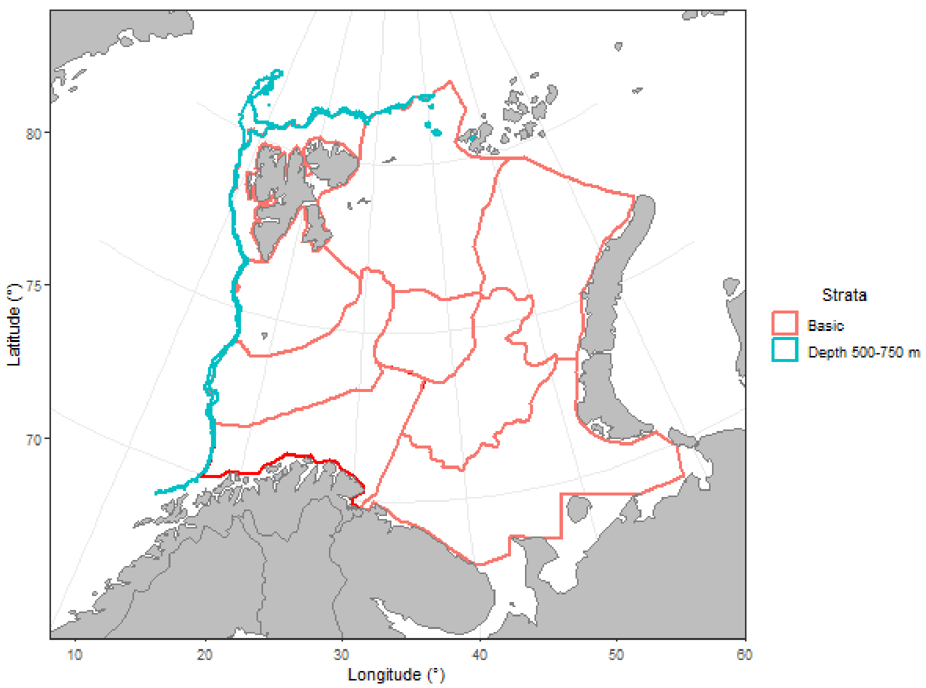


Figure 9. Basic strata system extended by the 500-750 m stratum to cover all *S. mentella* areas.

4. Results

Survey indices estimated with RStoX and the alternative approach are visually compared with the numbers-at-length, in 5 cm bins (0-45+ cm) and numbers-at-age given in the AFWG report 2018 (ages 2-16+, ICES 2018) in Figures 10 and 11. Numbers-at-age across the 2-16+ age range are likewise presented in the appendix (Table 1a). Comparing the new estimates to those from the SAS-system shows that the estimates using other strata systems tend to compare well to the SAS-estimates across most of the age range, but deviate for the ages 2 and 3 and in the alternative approach also for the ages 16+ (Fig. 10 & Fig. 11).

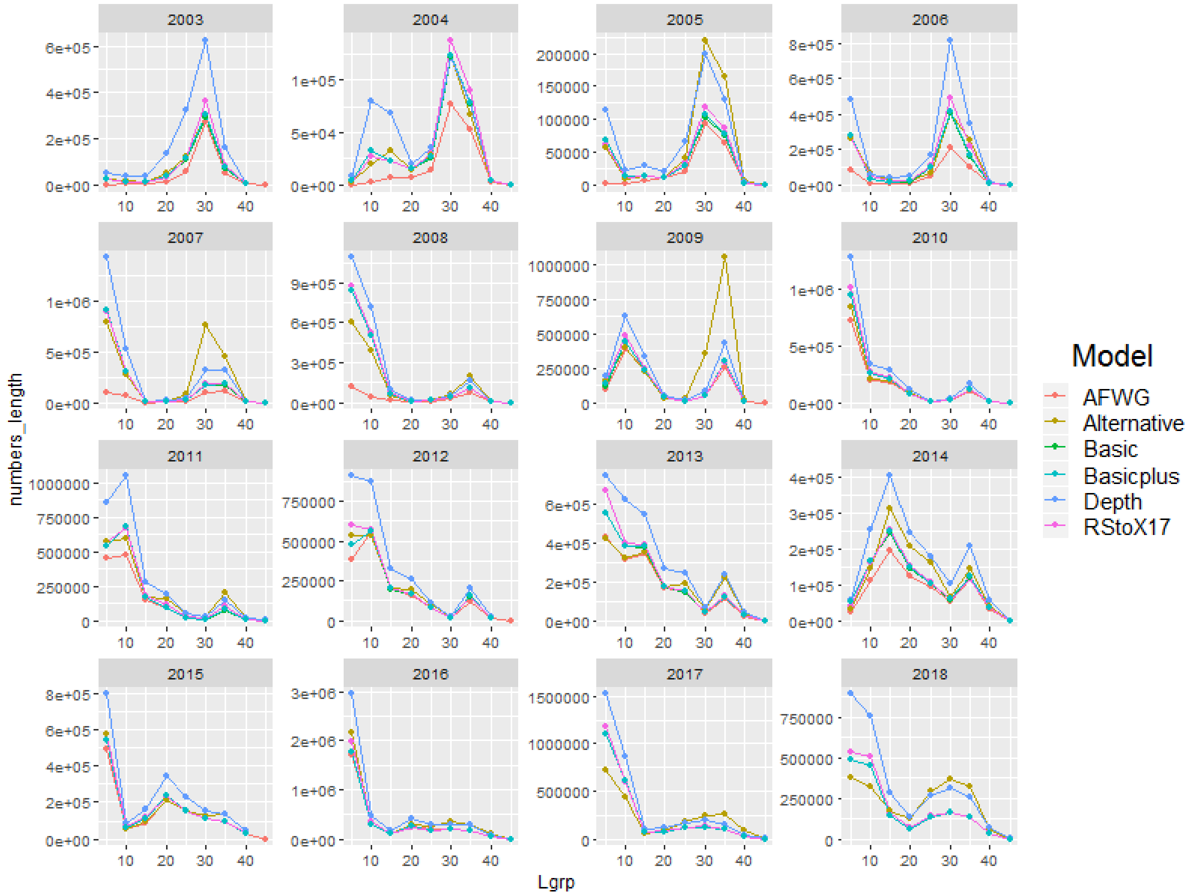


Figure 10. Comparison of estimates for numbers-at-length using different strata systems as well as the alternative estimation approach with the numbers presented in the 2018 AFWG-report. Whilst the RStoX estimates usually deviate from the earlier number at the low ages, the alternative approach tends to deviate more in the latter ages.

Abbr.: AFWG=Estimates from the SAS survey-system; Alternative = Estimates using depth strata without geographical coordinates; Basic = Strata system developed in 2019; Basic+ = Combination of the 'Basic' strata system with strata defined by depth, using polygons; and RStoX17 = Strata system developed for the Survey.

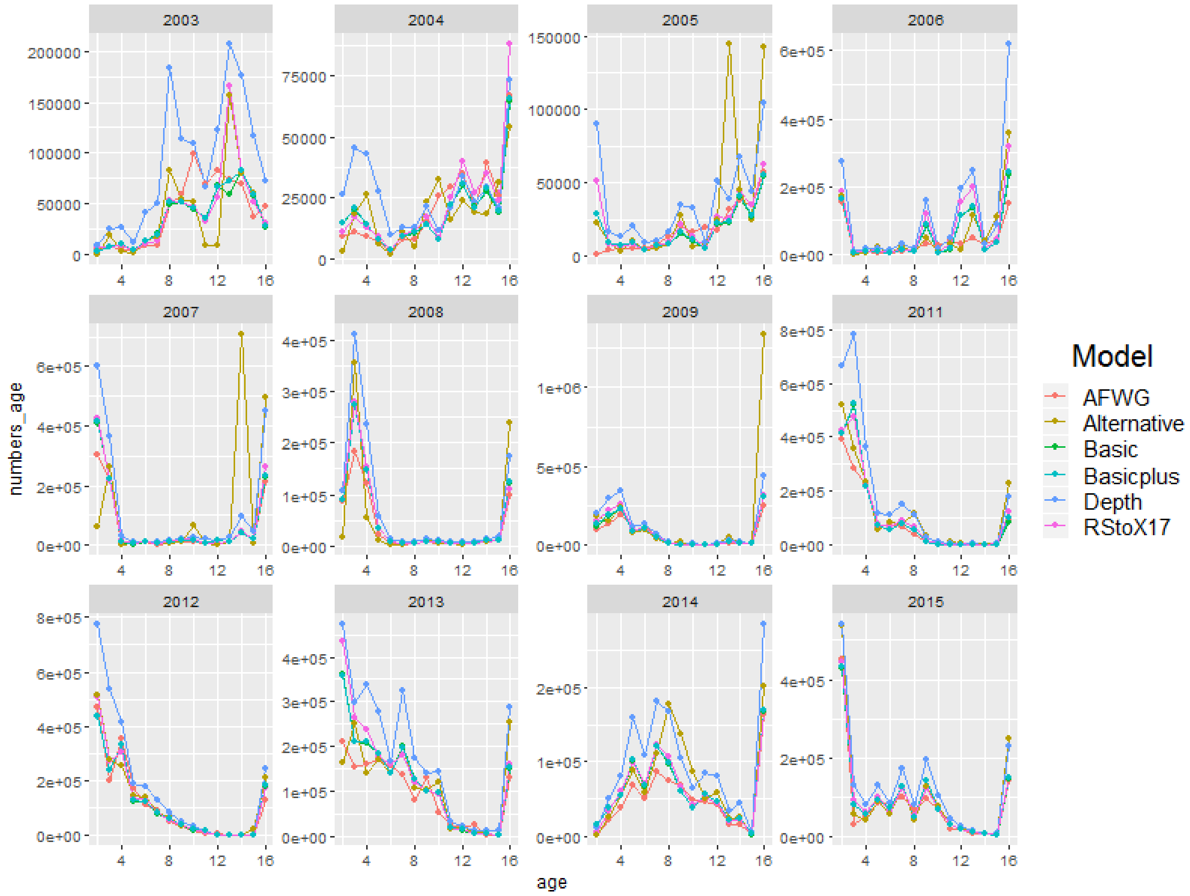


Figure 11. Comparison of estimates for numbers-at-age using different strata systems as well as the alternative estimation approach with the numbers presented in the 2018 AFWG-report. Whilst the RStoX estimates are more similar to the AFWG-numbers than for numbers-at-length, the alternative approach is still deviating much more.
Abbr.: AFWG=Estimates from the SAS survey-system; Alternative = Estimates using depth strata without geographical coordinates; Basic = Strata system developed in 2019; Basic+ = Combination of the 'Basic' strata system with strata defined by depth, using polygons and RStoX17 = Strata system developed for the Survey.

The strata system based on depth delivers higher numbers than any other method, even above the 95th-percentile of the 2017 strata system (Figs. 10 & 11). It also deviates from the pre-existing estimates at the youngest and oldest ages, similar to the 2017-strata and the alternative calculations, respectively. Both may be an effect of the 200-500 m stratum covering a large area of the Barents Sea. As this is also the depth stratum where the majority of redfish resides it provides a high integrated abundance estimate. Other strata systems use smaller regions, not affording any one region such a large influence. Therefore, reintroducing arbitrary boundaries into this strata system may be further investigated.

The basic strata system and the variant using the basic strata system extended by the 500 – 750 m provide nearly identical results (Fig. 12).

Figure 12. Estimates for numbers-at-age using the basic strata system and its variant extended by the 500 – 750 m depth interval. The results are nearly identical.

Comparing only the estimates produced by RStoX with confidence levels, represented by the 5th and 95th percentiles, shows that the AFWG-numbers are often within this interval, but also that the pattern in the numbers is more often reflected in the estimates for latter years, as well as being more in agreement for the different approaches (Fig. 13).

Pending further development of the depth-based strata system and considering that results hardly differ between the basic and the extended basic system we consider the basic and the

2017-strata systems as the best possible candidates to use for re-estimating the Barents Sea ecosystem survey indices (Fig. 14).

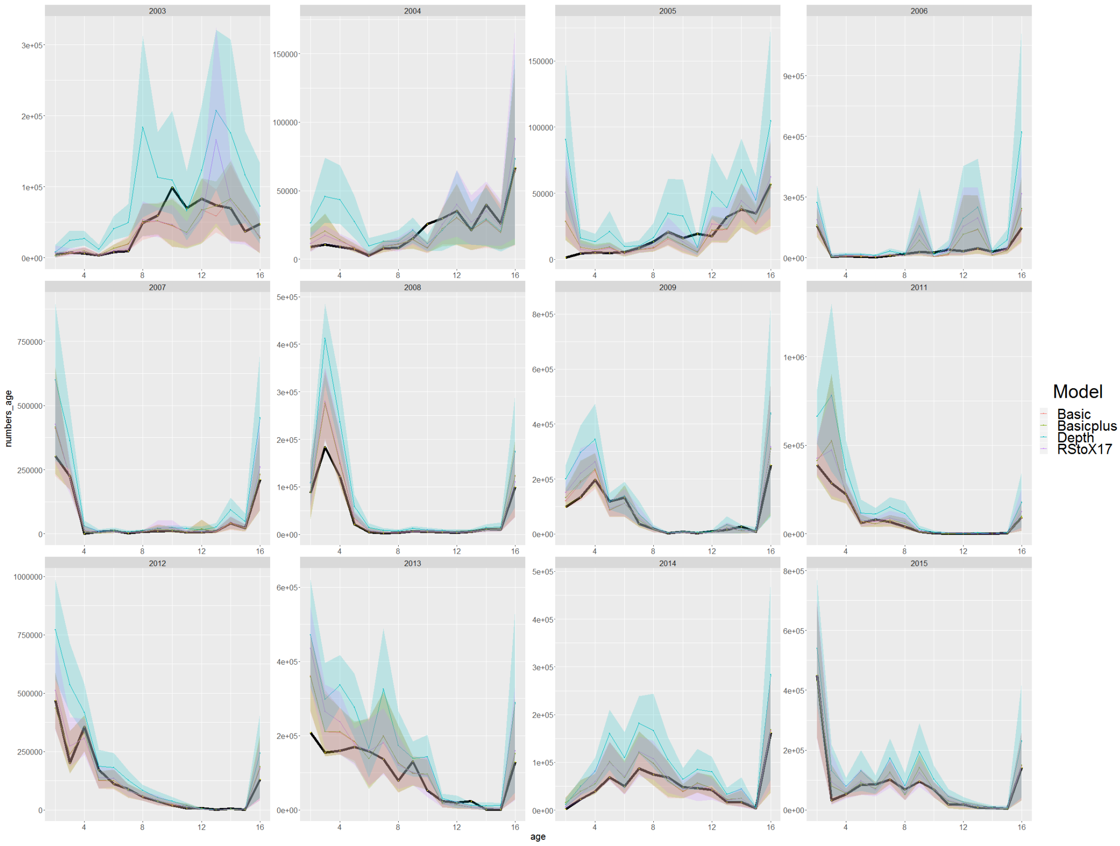


Figure 13. Comparison of numbers-at-age for different strata systems. The shaded areas are bounded by the 5th and 95th percentile. The black line shows the numbers-at-age as reported in earlier years.

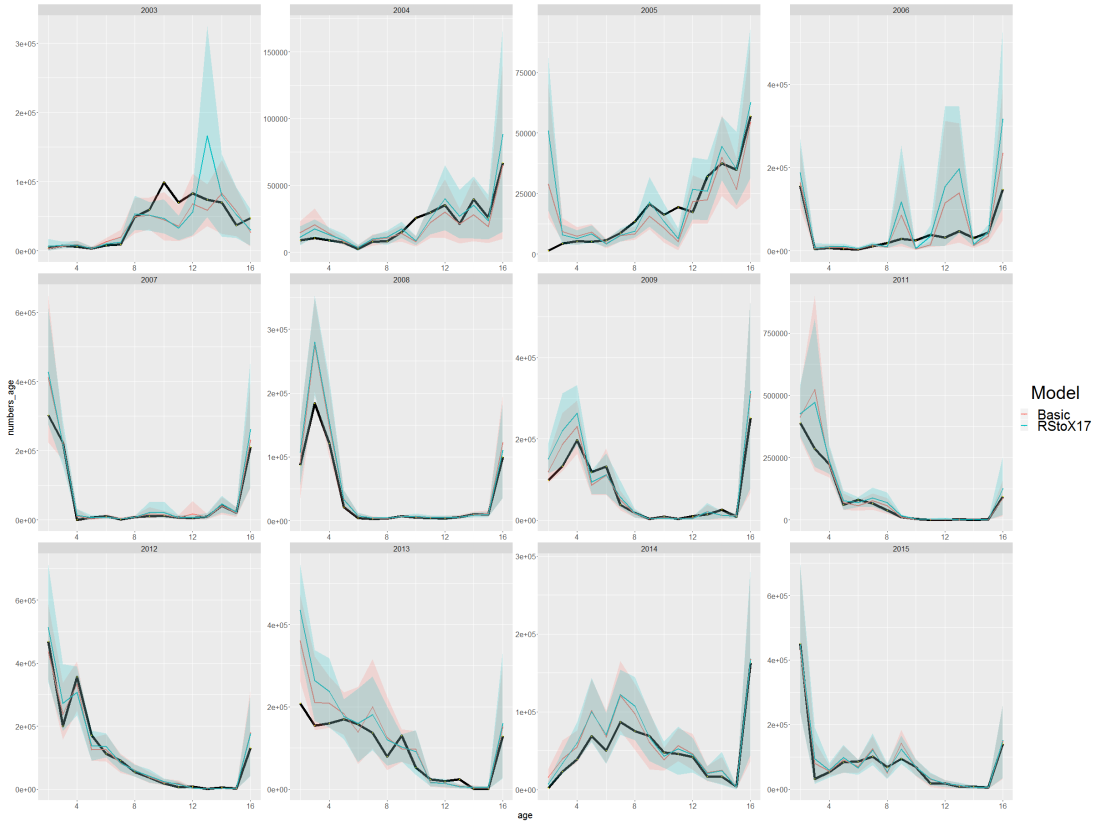


Figure 14. Comparison of numbers-at-age for strata systems 'basic' and for the 2017 strata system with the AFWG numbers-at-age as reference (black line). The shaded areas are bounded by the 5th and 95th percentile.

5. References

ICES. 2018. Report of the Arctic Fisheries Working Group (AFWG), 18–24 April 2018, JRC, Ispra, Italy. ICES CM 2018/ACOM:06, 857 pp.

Planque B., Nedreaas K., Vollen T., Filin A., Hallfredsson E., Berg E., Eriksen E. (2018). Description of scientific surveys used for the assessment of beaked and golden redfishes in ICES subareas 27.1 and 27.2. Working Document2, ICES WKREDFISH Copenhagen 29 January-2 February 2018. 12 pp.

StoX (2015) StoX: An open source approach to acoustic and swept area survey calculations. Institute of Marine Research, Bergen, Norway. URL: https://www.imr.no/forskning/prosjekter/stox/nb-no

6. Appendix 1: Summary table

Table 1a. Estimates of numbers-at-age (N) with RStoX for the different estimation approaches and strata systems as well as their standard deviation and %-difference to the numbers reported to ICES in earlier years. Highest and lowest differences for each approach are marked in red.

Abbr.: AFWG=Estimates from the SAS survey-system; Alternative = Estimates using depth strata without geographical coordinates; Basic = Strata system developed in 2019; Basic+ = Combination of the 'Basic' strata system with strata defined by depth, using polygons and RStoX17 = Strata system developed for the

Survey.

Year	Age	AFWG	Alternative		Basic			Basic+			Depth			RStoX17		
		N	N	%diff.	N	sd	%diff.	N	sd	%diff.	N	sd	%diff.	N	sd	%diff.
2003	2	3 954	111	-97.2	3 244	2.77	-17.9	2 892	2.64	-26.9	8 131	6.86	105.6	6 610	6.29	67.2
	3	7 394	18 841	154.8	6 851	1.71	-7.3	7 118	1.79	-3.7	24 314	8.52	228.8	7 760	3.12	5.0
	4	6 142	2 523	-58.9	9 481	2.92	54.4	9 599	2.85	56.3	26 956	6.13	338.9	8 984	3.12	46.3
	5	3 540	1 745	-50.7	3 705	1.28	4.7	3 727	1.21	5.3	12 123	3.59	242.5	3 572	1.29	0.9
	6	8 030	12 549	56.3	13 493	2.74	68.0	13 580	2.75	69.1	41 149	10.47	412.4	9 726	2.10	21.1
	7	9 388	17 018	81.3	19 918	6.13	112.2	19 505	5.64	107.8	49 758	14.52	430.0	12 655	3.75	34.8
	8	48 564	82 621	70.1	49 459	16.60	1.8	51 163	15.71	5.4	183 559	90.69	278.0	53 324	15.98	9.8
	9	59 051	54 491	-7.7	51 720	14.44	-12.4	52 321	14.04	-11.4	113 573	34.75	92.3	51 215	13.35	-13.3
	10	98 554	52 009	-47.2	44 890	20.48	-54.5	45 668	19.88	-53.7	109 421	43.40	11.0	47 071	16.59	-52.2
	11	69 901	9 331	-86.7	35 345	18.96	-49.4	35 332	17.57	-49.5	66 224	32.44	-5.3	32 927	12.73	-52.9
	12	83 192	8 822	-89.4	68 184	30.21	-18.0	67 057	29.36	-19.4	122 930	49.65	47.8	56 233	25.48	-32.4
	13	73 521	156 795	113.3	58 732	20.51	-20.1	73 058	25.13	-0.6	207 548	73.78	182.3	165 640	90.27	125.3
	14	69 970	80 333	14.8	82 700	36.25	18.2	83 220	36.58	18.9	175 705	84.25	151.1	79 856	38.73	14.1
	15	37 162	60 451	62.7	57 465	23.01	54.6	58 477	23.14	57.4	116 898	41.62	214.6	52 092	21.89	40.2
	16+	47 323	26 796	-43.4	26 964	1.50	-43.0	28 239	1.55	-40.3	72 550	3.38	53.3	30 269	1.55	-36.0
2004	2	9 068	3 139	-65.4	14 745	7.54	62.6	14 736	7.92	62.5	26 378	9.24	190.9	11 313	4.59	24.8
	3	10 837	18 602	71.6	20 518	6.00	89.3	20 721	6.30	91.2	45 669	15.44	321.4	17 375	3.85	60.3
	4	9 008	26 550	194.7	14 157	2.86	57.2	13 933	2.82	54.7	43 325	15.13	381.0	13 075	3.06	45.1
	5	7 292	5 786	-20.6	8 019	1.94	10.0	8 218	2.07	12.7	27 352	8.54	275.1	8 946	2.62	22.7
	6	2 510	1 887	-24.8	3 705	1.22	47.6	3 837	1.20	52.9	9 737	4.36	287.9	3 380	1.50	34.7
	7	7 896	10 974	39.0	9 156	2.54	16.0	9 227	2.57	16.9	13 142	3.30	66.4	9 992	1.86	26.5

	8	8 193	4 739	-42.2	10 618	2.74	29.6	10 881	2.79	32.8	12 907	4.38	57.5	11 445	3.19	39.7
	9	15 268	23 206	52.0	14 177	4.03	-7.1	14 365	4.09	-5.9	21 307	6.13	39.6	17 378	3.79	13.8
	10	25 544	32 858	28.6	7 893	2.53	-69.1	8 202	2.56	-67.9	11 399	3.52	-55.4	8 552	2.20	-66.5
	11	29 654	16 160	-45.5	22 137	8.36	-25.4	22 366	8.53	-24.6	20 798	9.81	-29.9	25 295	8.16	-14.7
	12	35 249	23 672	-32.8	30 069	15.25	-14.7	30 502	15.44	-13.5	33 875	16.69	-3.9	39 854	15.03	13.1
	13	21 142	19 205	-9.2	21 310	9.46	0.8	21 166	9.47	0.1	23 114	9.79	9.3	27 151	11.53	28.4
	14	39 581	18 664	-52.8	27 950	15.43	-29.4	28 643	15.27	-27.6	29 477	13.86	-25.5	35 324	14.61	-10.8
	15	25 976	31 630	21.8	19 149	9.24	-26.3	19 536	9.29	-24.8	20 657	9.82	-20.5	23 653	11.08	-8.9
	16+	66 792	54 124	-19.0	64 830	4.07	-2.9	65 523	4.09	-1.9	73 362	4.00	9.8	88 144	4.11	32.0
2005	2	1 310	23 015	1656.9	28 766	18.92	2095.9	28 474	18.39	2073.6	90 589	40.01	6815.2	50 811	19.75	3778.7
	3	4 406	9 044	105.3	9 209	3.17	109.0	9 296	3.14	111.0	16 228	4.42	268.3	7 868	2.49	78.6
	4	5 241	2 826	-46.1	7 314	2.35	39.5	7 231	2.32	38.0	13 194	3.80	151.8	6 380	1.86	21.7
	5	5 031	9 884	96.5	9 134	2.26	81.6	9 313	2.25	85.1	21 063	8.64	318.7	8 289	2.19	64.8
	6	5 722	4 614	-19.4	4 280	1.20	-25.2	4 235	1.18	-26.0	9 721	2.10	69.9	4 197	1.11	-26.7
	7	8 740	5 723	-34.5	7 536	1.59	-13.8	7 505	1.59	-14.1	10 345	2.55	18.4	7 727	1.90	-11.6
	8	13 452	7 856	-41.6	8 382	1.76	-37.7	8 657	1.78	-35.6	16 494	5.28	22.6	9 475	1.93	-29.6
	9	20 672	27 724	34.1	15 642	3.54	-24.3	16 806	3.45	-18.7	34 976	13.10	69.2	21 408	6.42	3.6
	10	16 207	6 518	-59.8	10 758	3.52	-33.6	11 293	3.39	-30.3	32 746	14.63	102.0	13 403	5.13	-17.3
	11	19 353	7 854	-59.4	5 195	2.32	-73.2	5 628	2.48	-70.9	9 272	4.14	-52.1	6 464	2.46	-66.6
	12	17 430	25 138	44.2	21 759	6.43	24.8	22 286	6.34	27.9	50 958	16.29	192.4	26 792	7.66	53.7
	13	32 028	144 675	351.7	22 440	5.57	-29.9	23 342	5.62	-27.1	39 247	11.59	22.5	25 971	7.43	-18.9
	14	37 564	45 328	20.7	39 928	10.04	6.3	40 581	10.01	8.0	67 667	19.02	80.1	44 512	9.63	18.5
	15	34 815	24 539	-29.5	26 707	6.45	-23.3	28 081	6.52	-19.3	44 628	12.30	28.2	35 025	9.52	0.6
	16+	57 103	142 616	149.8	54 376	1.06	-4.8	55 804	1.05	-2.3	104 616	2.02	83.2	62 415	0.97	9.3
2006	2	156 578	172 516	10.2	163 150	43.47	4.2	163 148	44.13	4.2	273 039	63.97	74.4	187 575	44.46	19.8
	3	5 162	509	-90.1	5 391	4.80	4.4	5 406	4.82	4.7	10 169	7.58	97.0	6 870	7.20	33.1
	4	6 695	4 540	-32.2	8 599	3.54	28.4	8 931	3.72	33.4	17 669	5.49	163.9	10 562	4.88	57.8
	5	5 217	19 952	282.4	7 914	2.23	51.7	8 725	2.23	67.2	16 441	3.86	215.1	11 034	3.26	111.5
	6	3 768	2 410	-36.0	4 527	1.14	20.1	5 041	1.19	33.8	11 021	2.84	192.5	5 935	1.67	57.5
	7	10 754	20 320	89.0	14 302	2.76	33.0	14 644	2.87	36.2	32 379	9.06	201.1	16 011	2.94	48.9
	8	18 771	7 867	-58.1	8 666	1.70	-53.8	8 868	1.67	-52.8	19 260	5.65	2.6	10 115	2.16	-46.1
	9	29 174	50 133	71.8	85 931	67.09	194.5	86 469	67.02	196.4	157 146	112.55	438.7	117 565	78.03	303.0
	10	25 278	9 469	-62.5	4 823	1.34	-80.9	4 923	1.22	-80.5	16 714	5.77	-33.9	5 817	1.71	-77.0

	11	38 958	31 575	-19.0	14 852	4.90	-61.9	19 452	6.79	-50.1	48 524	19.31	24.6	35 265	15.78	-9.5
	12	31 869	14 739	-53.7	115 398	97.23	262.1	115 308	96.94	261.8	194 748	149.64	511.1	154 290	107.22	384.1
	13	46 885	113 023	141.1	138 991	100.75	196.5	141 661	100.51	202.1	248 650	147.78	430.3	196 735	110.57	319.6
	14	30 895	39 339	27.3	13 001	3.18	-57.9	13 188	3.22	-57.3	31 350	9.99	1.5	16 003	4.07	-48.2
	15	44 299	109 710	147.7	35 255	9.06	-20.4	35 326	9.49	-20.3	88 819	30.05	100.5	44 641	11.24	0.8
	16+	147 951	357 280	141.5	234 311	5.27	58.4	242 457	5.02	63.9	620 189	14.60	319.2	316 105	6.51	113.7
2007	2	302 988	62 562	-79.4	410 775	133.38	35.6	414 737	131.75	36.9	599 518	201.83	97.9	426 522	100.97	40.8
	3	224 153	264 912	18.2	221 643	35.46	-1.1	222 827	35.93	-0.6	363 036	76.81	62.0	219 153	45.83	-2.2
	4	290	1 726	495.1	11 080	13.10	3720.7	10 713	12.03	3594.3	29 913	18.29	10214.9	14 006	11.72	4729.7
	5	7 686	7 840	2.0	3 097	1.93	-59.7	3 493	2.09	-54.6	9 293	4.21	20.9	6 697	3.93	-12.9
	6	11 346	8 311	-26.8	8 543	5.06	-24.7	8 609	4.84	-24.1	13 345	5.52	17.6	8 322	3.77	-26.7
	7	2 031	3 367	65.8	4 182	2.02	105.9	4 246	1.87	109.0	8 788	3.25	332.7	3 821	1.00	88.1
	8	7 903	5 261	-33.4	8 487	3.13	7.4	8 732	3.49	10.5	13 476	2.63	70.5	8 893	2.73	12.5
	9	10 770	9 151	-15.0	18 014	12.77	67.3	18 297	12.60	69.9	21 058	4.43	95.5	21 876	16.35	103.1
	10	12 182	65 396	436.8	15 184	7.00	24.6	15 264	6.90	25.3	24 075	7.35	97.6	22 222	14.44	82.4
	11	6 578	3 959	-39.8	6 794	3.49	3.3	7 042	3.49	7.1	20 015	6.86	204.3	7 308	3.10	11.1
	12	6 367	1 571	-75.3	17 779	18.91	179.2	18 135	19.17	184.8	16 096	8.11	152.8	7 666	4.33	20.4
	13	9 998	10 233	2.4	8 902	4.68	-11.0	9 136	4.74	-8.6	26 465	9.61	164.7	10 451	5.92	4.5
	14	41 425	707 918	1608.9	41 466	15.13	0.1	42 152	15.07	1.8	94 321	27.68	127.7	46 266	15.91	11.7
	15	22 090	7 769	-64.8	20 548	8.66	-7.0	20 693	8.50	-6.3	48 072	16.27	117.6	22 962	8.62	3.9
	16+	211 178	497 693	135.7	230 425	5.48	9.1	231 638	5.54	9.7	452 455	8.83	114.3	261 226	6.53	23.7
2008	2	86 880	16 150	-81.4	91 150	37.27	4.9	90 012	37.90	3.6	108 677	29.64	25.1	107 385	38.21	23.6
	3	183 796	357 215	94.4	275 160	43.84	49.7	275 710	42.27	50.0	412 498	56.97	124.4	279 178	54.88	51.9
	4	121 430	55 580	-54.2	147 561	33.10	21.5	149 132	32.58	22.8	236 766	44.22	95.0	155 311	35.90	27.9
	5	21 430	11 846	-44.7	33 817	9.09	57.8	33 182	8.69	54.8	58 880	15.28	174.8	33 110	7.89	54.5
	6	4 178	3 101	-25.8	7 875	2.96	88.5	8 069	3.38	93.1	14 360	5.12	243.7	8 266	2.99	97.8
	7	3 009	1 493	-50.4	4 564	1.94	51.7	4 243	1.85	41.0	8 231	3.06	173.5	4 110	1.68	36.6
	8	3 334	7 050	111.5	3 661	0.74	9.8	3 659	0.72	9.7	7 638	1.79	129.1	4 007	1.01	20.2
	9	6 991	13 755	96.7	6 940	1.18	-0.7	7 004	1.20	0.2	12 529	2.86	79.2	6 756	1.14	-3.4
	10	5 120	3 833	-25.1	6 357	1.79	24.2	6 476	1.82	26.5	9 908	2.55	93.5	6 908	2.29	34.9
	11	4 441	3 400	-23.4	5 159	1.73	16.2	5 139	1.69	15.7	8 090	2.52	82.2	5 077	1.84	14.3
	12	3 581	2 114	-41.0	5 027	2.36	40.4	4 954	2.19	38.3	6 176	2.39	72.5	4 775	2.04	33.3
	13	6 008	7 028	17.0	5 818	1.69	-3.2	5 827	1.72	-3.0	8 781	2.38	46.2	5 743	1.47	-4.4

	14	10 352	6 926	-33.1	9 445	2.82	-8.8	9 464	2.83	-8.6	14 255	5.00	37.7	8 747	2.59	-15.5
	15	10 172	11 777	15.8	11 137	2.94	9.5	11 141	2.96	9.5	15 818	5.60	55.5	10 263	3.15	0.9
	16+	99 808	240 856	141.3	122 106	2.27	22.3	123 695	2.19	23.9	174 755	3.19	75.1	110 214	2.06	10.4
	2	98 726	181 471	83.8	120 219	21.66	21.8	131 988	23.52	33.7	199 742	35.15	102.3	151 099	24.31	53.0
	3	133 218	157 250	18.0	186 393	47.84	39.9	191 620	46.42	43.8	296 208	75.27	122.3	220 097	59.80	65.2
	4	196 908	236 971	20.3	230 549	40.34	17.1	235 083	40.39	19.4	344 680	72.24	75.0	262 529	46.54	33.3
	5	118 322	77 548	-34.5	86 297	15.20	-27.1	87 602	16.53	-26.0	118 294	23.18	0.0	93 487	19.69	-21.0
	6	131 668	98 519	-25.2	111 276	36.04	-15.5	110 955	36.03	-15.7	139 562	37.70	6.0	111 619	35.00	-15.2
	7	37 586	42 377	12.7	50 799	16.58	35.2	50 874	16.65	35.4	73 059	25.24	94.4	57 109	22.48	51.9
	8	18 194	16 473	-9.5	15 950	5.50	-12.3	16 105	5.53	-11.5	24 007	6.03	32.0	17 490	6.78	-3.9
2009	9	3 679	24 936	577.8	2 788	1.02	-24.2	2 843	1.08	-22.7	4 077	1.63	10.8	3 034	0.93	-17.5
	10	8 633	1 519	-82.4	6 172	3.17	-28.5	6 242	3.16	-27.7	7 442	3.32	-13.8	5 852	3.33	-32.2
	11	3 494	6 948	98.8	3 445	1.39	-1.4	3 444	1.41	-1.4	5 785	1.89	65.6	3 314	1.25	-5.1
	12	9 736	12 341	26.8	5 499	2.46	-43.5	5 522	2.47	-43.3	8 216	4.35	-15.6	4 757	2.87	-51.1
	13	14 091	48 466	243.9	21 063	14.95	49.5	21 142	14.98	50.0	32 781	23.60	132.6	20 951	16.10	48.7
	14	25 949	12 165	-53.1	11 789	6.07	-54.6	11 733	6.05	-54.8	17 244	9.19	-33.5	12 708	5.29	-51.0
	15	8 384	15 915	89.8	11 040	3.83	31.7	10 996	3.76	31.2	15 016	7.74	79.1	10 074	4.13	20.2
	16+	251 370	1 336 152	431.5	309 719	9.69	23.2	309 950	9.71	23.3	439 526	15.36	74.9	316 427	9.29	25.9
	2	389 536	517 591	32.9	413 501	65.87	6.2	411 508	65.50	5.6	663 175	100.26	70.2	426 676	67.28	9.5
	3	285 787	358 520	25.5	522 270	201.05	82.7	524 842	203.19	83.6	781 817	294.14	173.6	472 151	183.58	65.2
	4	222 753	236 739	6.3	220 379	40.56	-1.1	218 641	39.92	-1.8	361 685	90.31	62.4	237 047	40.96	6.4
	5	60 809	54 662	-10.1	70 815	20.70	16.5	71 353	21.06	17.3	118 449	39.88	94.8	77 078	25.16	26.8
	6	80 266	85 451	6.5	56 975	12.07	-29.0	57 774	11.80	-28.0	112 537	22.56	40.2	69 737	13.18	-13.1
	7	67 419	79 460	17.9	76 782	19.73	13.9	77 411	19.62	14.8	151 438	40.00	124.6	89 154	22.98	32.2
	8	39 695	115 413	190.7	57 923	22.47	45.9	58 082	22.47	46.3	114 657	40.45	188.8	69 267	25.60	74.5
2011	9	12 409	35 829	188.7	12 551	3.46	1.1	12 606	3.43	1.6	28 532	10.46	129.9	16 539	5.16	33.3
	10	4 144	3 089	-25.5	3 295	1.49	-20.5	3 287	1.47	-20.7	10 285	5.74	148.2	3 567	2.13	-13.9
	11	1 175	9 684	724.2	2 277	1.27	93.8	2 245	1.17	91.1	3 675	2.15	212.8	3 327	1.84	183.2
	12	1 174	4 719	302.0	857	0.85	-27.0	1 782	1.16	51.8	2 209	1.41	88.2	3 685	3.16	213.9
	13	2 246	3 705	65.0	1 503	0.84	-33.1	1 520	0.83	-32.3	5 570	2.80	148.0	1 323	0.91	-41.1
	14	324	-	-	141	0.10	-56.5	135	0.09	-58.4	331	0.49	2.0	109	0.10	-66.3
	15	3 379	6 554	94.0	2 901	1.13	-14.2	2 901	1.12	-14.2	6 778	3.45	100.6	3 389	1.13	0.3
	16+	93 382	227 037	143.1	86 499	1.76	-7.4	99 237	2.08	6.3	178 726	3.60	91.4	125 294	2.80	34.2

2012	2	469 000	514 537	9.7	435 666	73.56	-7.1	436 014	73.68	-7.0	772 769	149.57	64.8	512 249	125.03	9.2
	3	201 000	276 000	37.3	237 979	51.35	18.4	239 139	52.00	19.0	535 727	110.96	166.5	272 601	69.00	35.6
	4	356 000	255 975	-28.1	332 668	50.86	-6.6	332 397	50.65	-6.6	416 649	72.69	17.0	307 260	48.08	-13.7
	5	172 000	147 225	-14.4	125 613	21.50	-27.0	126 972	22.20	-26.2	187 524	39.99	9.0	137 635	30.00	-20.0
	6	112 000	141 252	26.1	125 685	24.40	12.2	124 996	24.43	11.6	180 785	33.62	61.4	134 698	24.20	20.3
	7	90 000	85 520	-5.0	81 470	19.94	-9.5	82 669	19.74	-8.1	127 568	28.94	41.7	83 156	16.28	-7.6
	8	55 000	67 930	23.5	60 658	13.24	10.3	61 201	13.10	11.3	84 285	16.11	53.2	59 461	11.66	8.1
	9	37 000	36 390	-1.6	39 273	11.42	6.1	38 853	11.43	5.0	54 086	16.88	46.2	41 253	14.28	11.5
	10	19 000	32 828	72.8	21 916	7.28	15.3	23 182	7.51	22.0	38 193	8.32	101.0	24 739	6.28	30.2
	11	7 000	17 483	149.8	17 744	7.00	153.5	17 677	6.94	152.5	20 154	7.35	187.9	15 110	5.75	115.9
	12	8 000	3 286	-58.9	3 623	2.38	-54.7	3 650	2.42	-54.4	4 524	2.49	-43.5	3 304	2.31	-58.7
	13	838	1 116	33.2	1 293	0.67	54.3	1 280	0.64	52.7	1 670	0.84	99.3	1 028	0.68	22.7
	14	5 000	3 323	-33.5	1 881	0.99	-62.4	2 311	1.12	-53.8	2 965	1.22	-40.7	2 444	1.30	-51.1
	15	2 000	24 405	1120.2	3 339	2.31	66.9	3 339	2.32	66.9	3 956	2.79	97.8	3 413	2.15	70.7
	16+	131 000	214 200	63.5	179 090	3.34	36.7	184 709	3.36	41.0	244 531	4.44	86.7	176 144	3.14	34.5
2013	2	209 000	162 641	-22.2	360 736	62.92	72.6	357 967	63.64	71.3	471 595	83.25	125.6	434 385	74.47	107.8
	3	154 000	250 702	62.8	210 630	55.10	36.8	211 348	56.12	37.2	298 353	58.48	93.7	264 465	70.71	71.7
	4	160 000	138 918	-13.2	208 508	40.40	30.3	211 526	39.93	32.2	336 841	49.55	110.5	237 164	50.37	48.2
	5	170 000	171 357	0.8	183 655	35.17	8.0	184 012	37.63	8.2	276 901	56.48	62.9	176 864	34.26	4.0
	6	158 000	139 872	-11.5	138 589	58.37	-12.3	138 538	60.53	-12.3	166 248	52.38	5.2	159 784	66.22	1.1
	7	137 000	201 838	47.3	199 698	68.28	45.8	198 629	67.92	45.0	326 045	101.35	138.0	181 085	60.24	32.2
	8	79 000	105 341	33.3	125 398	60.09	58.7	126 248	59.91	59.8	173 405	52.27	119.5	120 120	46.82	52.1
	9	130 000	103 366	-20.5	98 018	25.03	-24.6	98 714	25.66	-24.1	139 250	28.87	7.1	102 114	21.02	-21.5
	10	53 000	120 999	128.3	96 952	29.94	82.9	96 364	29.18	81.8	143 160	38.22	170.1	91 458	32.58	72.6
	11	24 000	14 575	-39.3	17 419	5.63	-27.4	17 482	5.76	-27.2	31 004	10.50	29.2	16 233	6.39	-32.4
	12	20 000	23 594	18.0	13 807	5.26	-31.0	13 991	5.29	-30.0	20 902	10.03	4.5	14 454	6.25	-27.7
	13	24 000	6 069	-74.7	6 912	3.44	-71.2	6 706	3.18	-72.1	11 837	4.89	-50.7	6 744	3.62	-71.9
	14	1 000	10 802	980.2	4 440	2.65	344.0	4 397	2.56	339.7	11 431	7.09	1043.1	4 315	3.03	331.5
	15	1 000	11 550	1055.0	3 481	2.20	248.1	3 506	2.23	250.6	11 585	5.37	1058.5	3 690	2.29	269.0
	16+	129 000	252 814	96.0	151 284	3.65	17.3	151 816	3.63	17.7	289 215	6.36	124.2	159 370	3.96	23.5
2014	2	2 000	1 539	-23.0	16 270	6.32	713.5	16 352	6.19	717.6	12 300	5.51	515.0	7 212	2.65	260.6
	3	23 000	26 267	14.2	39 279	12.57	70.8	39 204	12.59	70.5	50 405	11.20	119.2	33 886	9.23	47.3
	4	39 000	54 541	39.8	54 859	13.20	40.7	54 830	13.51	40.6	81 448	20.00	108.8	60 327	14.96	54.7

	5	69 000	88 387	28.1	101 788	27.69	47.5	102 031	27.63	47.9	160 134	47.33	132.1	99 768	26.68	44.6
	6	50 000	58 511	17.0	67 583	20.87	35.2	67 857	21.13	35.7	109 505	36.28	119.0	70 337	21.34	40.7
	7	87 000	111 053	27.6	120 766	28.04	38.8	120 666	28.02	38.7	181 843	44.32	109.0	122 203	27.62	40.5
	8	75 000	176 964	136.0	97 360	31.79	29.8	98 416	31.74	31.2	166 355	55.30	121.8	107 686	28.52	43.6
	9	69 000	137 752	99.6	60 873	22.00	-11.8	61 432	21.87	-11.0	105 423	32.39	52.8	67 290	22.89	-2.5
	10	48 000	87 495	82.3	38 556	8.60	-19.7	38 921	8.56	-18.9	65 238	14.49	35.9	42 781	10.98	-10.9
	11	46 000	50 795	10.4	56 253	13.43	22.3	56 750	13.64	23.4	85 092	26.90	85.0	52 261	19.64	13.6
	12	42 000	57 916	37.9	45 939	15.52	9.4	46 289	15.53	10.2	79 990	18.90	90.5	44 607	14.59	6.2
	13	17 000	24 425	43.7	22 134	5.70	30.2	22 399	5.69	31.8	33 678	9.55	98.1	20 646	5.82	21.4
	14	17 000	25 488	49.9	24 683	10.95	45.2	24 935	10.86	46.7	44 514	15.76	161.8	24 362	12.85	43.3
	15	4 000	2 358	-41.1	3 082	1.28	-22.9	3 271	1.29	-18.2	6 360	2.98	59.0	2 871	1.47	-28.2
	16+	163 000	201 297	23.5	166 922	3.99	2.4	168 438	4.03	3.3	283 394	6.81	73.9	167 449	3.93	2.7
	2	451 000	535 122	18.7	430 323	148.49	-4.6	430 969	148.84	-4.4	539 129	149.43	19.5	446 203	142.60	-1.1
	3	32 000	58 055	81.4	80 525	47.94	151.6	79 170	45.05	147.4	130 474	55.69	307.7	93 626	52.80	192.6
	4	53 000	40 028	-24.5	55 926	10.07	5.5	55 563	9.98	4.8	78 875	17.14	48.8	59 442	13.70	12.2
	5	84 000	87 130	3.7	91 465	33.49	8.9	91 998	31.91	9.5	131 366	46.11	56.4	98 077	30.38	16.8
	6	85 000	56 755	-33.2	70 724	16.13	-16.8	70 819	16.31	-16.7	84 482	19.28	-0.6	66 026	15.91	-22.3
	7	101 000	125 452	24.2	125 505	22.96	24.3	125 601	23.00	24.4	173 185	37.40	71.5	121 474	32.06	20.3
	8	68 000	43 599	-35.9	50 990	14.68	-25.0	50 582	14.33	-25.6	80 518	22.94	18.4	55 116	16.69	-18.9
2015	9	94 000	125 068	33.1	142 260	27.52	51.3	142 147	28.19	51.2	194 648	55.16	107.1	123 751	31.99	31.7
	10	69 000	77 792	12.7	68 594	15.84	-0.6	68 942	15.51	-0.1	102 133	26.68	48.0	67 964	15.70	-1.5
	11	18 000	32 268	79.3	29 946	14.17	66.4	29 607	14.18	64.5	44 829	18.89	149.1	32 029	12.57	77.9
	12	18 000	20 546	14.1	18 281	8.65	a1.6	18 290	8.52	1.6	26 345	11.04	46.4	17 878	6.97	-0.7
	13	8 000	15 656	95.7	10 777	6.17	34.7	10 674	6.17	33.4	15 068	8.10	88.3	11 870	5.88	48.4
	14	8 000	7 812	-2.3	5 761	3.43	-28.0	5 805	3.51	-27.4	8 422	4.64	5.3	5 615	4.00	-29.8
	15	5 000	2 262	-54.8	4 994	2.68	-0.1	4 972	2.72	-0.6	6 820	3.63	36.4	5 816	3.48	16.3
	16+	141 000	250 418	77.6	147 247	3.88	4.4	149 016	3.93	5.7	230 442	5.87	63.4	150 006	3.79	6.4

7. Appendix 2: RstoX code for the estimates of numbers-at-length and age

The following code was run in R version 3.5.2 and RStoX version 1.11. The code is shown in blue and the console output in black and red. Note that the results presented in the working document are for the years 2003 to 2015. The range covered in this example (2003:2003) was chosen for demonstration purposes. Further note that the RStoX projects were downloaded previously and are called up from a list-object (‘allpr’) rather than being downloaded afresh. The relevant commands for the downloading are commented out (with #).

```
> library(Rstox)
> #library(rJava)
> require(plyr)
> require(tidyverse)
> require(ggplot2)
>
> #Set working directory
> setwd("R:/_Dyphavsarter/Arter/Uer/AFWG2019/Toktindex/Økotokt")
>
> ## Clean up and overall settings
> rm(list=ls())
>
> CS <- getNMDinfo("cs", recursive=FALSE) # Toktserieinfo ("cruise series")
> CS                                      # Nummerert liste over toktserier i database
n
 [1] "Atlantic Ocean West of British Isles INT blue whiting spawning survey in spring"
 [2] "Barents Sea NOR demersal fish cruise in August-September"
 [3] "Barents Sea NOR demersel fish cruise in October-November"
 [4] "Barents Sea NOR-RUS 0-group cruise in autumn"
 [5] "Barents Sea NOR-RUS ecosystem cruise in autumn"
 [6] "North Sea International ecosystem cruise in Q2_Q3"
 [7] "North Sea International IBTS cruise in Q1"
 [8] "North Sea International IBTS cruise in Q2_Q3"
 [9] "North Sea International IBTS cruise in Q4"
[10] "North Sea NOR mackerel cruise in summer"
[11] "North Sea NOR Sandeel cruise in Apr_May"
[12] "North Sea NOR seiskalle cruise in spring"
[13] "North Sea NOR shrimp NDSK cruise in Jan_Nov"
[14] "Norwegian Sea continental slope NOR deep-sea fish cruise in autumn"
[15] "Norwegian Sea International ecosystem cruise in May"
[16] "Norwegian Sea NOR mackerel cruise in summer"
[17] "Norwegian Sea NOR Norwegian spring-spawning herring spawning cruise in Feb_Mar"
[18] "Norwegian Sea NOR pelagic deep-sea fish cruise in summer"
[19] "Norwegian Sea NOR salmon cruise in summer"
[20] "Skagerrak NOR beach seine survey in autumn"
[21] "Varanger Stad NOR coastal cruise in autumn"
[22] "Barents Sea NOR-RUS demersal fish cruise in winter"
[23] "Lofoten NOR demersal fish cruise in Mar_Apr"
[24] "North Sea NOR Herring Acoustic Survey in summer"
[25] "Norwegian Sea continental slope NOR deep-sea fish cruise in spring"
>
> myCS<-CS[5]                            # Velger Ã¸kotoktet
> getNMDinfo(c("cs", myCS))
$`Barents Sea NOR-RUS ecosystem cruise in autumn`
   code              Cruise        ShipName Year
3     1 0087_2003_UFVZ_TSIVI       Tsivilsk 2003
6     2             2003110        G.O.Sars 2003
1     3             2003209     Johan Hjort 2003
4     4             2003703       Jan Mayen 2003
2     5             2003705       Jan Mayen 2003
5     6 0115_2003_UFFJ_SMOLE       Smolensk 2003
9     1             2004210     Johan Hjort 2004
7     2             2004702       Jan Mayen 2004
10    3             2004703       Jan Mayen 2004
```

```
8      4 0118_2004_UFFJ_SMOLE        Smolensk 2004
11     5 0088_2004_UANA_NANSE Fridtjof Nansen 2004
15     1             2005111        G.O.Sars 2005
12     2             2005209     Johan Hjort 2005
16     3             2005702       Jan Mayen 2005
13     4             2005703       Jan Mayen 2005
17     5 0093_2005_UANA_NANSE Fridtjof Nansen 2005
14     6 0092_2005_UFJJ_SMOLE        Smolensk 2005
18     1             2006702       Jan Mayen 2006
21     2             2006211     Johan Hjort 2006
19     3             2006704       Jan Mayen 2006
23     4             2006113        G.O.Sars 2006
20     5 0095_2006_UFJJ_SMOLE        Smolensk 2006
22     6 0094_2006_UANA_NANSE Fridtjof Nansen 2006
26     1             2007110        G.O.Sars 2007
24     2             2007210     Johan Hjort 2007
27     3             2007702       Jan Mayen 2007
25     4 0096_2007_UFJJ_SMOLE        Smolensk 2007
28     5 0097_2007_UFJN_VILNY         Vilnyus 2007
29     1             2008106        G.O.Sars 2008
32     2             2008703       Jan Mayen 2008
30     3             2008208     Johan Hjort 2008
33     4             2008822  Atlantic Star 2008
31     5 0100_2008_UFJN_VILNY         Vilnyus 2008
34     1             2009208     Johan Hjort 2009
36     2             2009702       Jan Mayen 2009
35     3 0105_2009_UFJN_VILNY         Vilnyus 2009
37     4             2009109        G.O.Sars 2009
40     1             2010111        G.O.Sars 2010
38     2             2010210     Johan Hjort 2010
41     3             2010703       Jan Mayen 2010
39     4 0106_2010_UFJN_VILNY         Vilnyus 2010
42     5 0107_2010_UANA_NANSE Fridtjof Nansen 2010
45     1             2011717  Helmer Hanssen 2011
43     2 0109_2011_UFJN_VILNY         Vilnyus 2011
44     3             2011830     Christina E 2011
46     4             2011213     Johan Hjort 2011
47     1             2012845  Helmer Hanssen 2012
48     2             2012209     Johan Hjort 2012
50     3             2012111        G.O.Sars 2012
49     4 0110_2012_UFJN_VILNY         Vilnyus 2012
51     1             2013843  Helmer Hanssen 2013
52     2             2013208     Johan Hjort 2013
54     3             2013111        G.O.Sars 2013
53     4 0112_2013_UFJN_VILNY         Vilnyus 2013
55     1             2014212     Johan Hjort 2014
57     2             2014806  Helmer Hanssen 2014
56     3             2014116        G.O.Sars 2014
58     4 0116_2014_UFJN_VILNY         Vilnyus 2014
61     1             2015210     Johan Hjort 2015
59     2             2015843  Helmer Hanssen 2015
62     3             2015114        G.O.Sars 2015
60     4 0117_2015_UFJN_VILNY         Vilnyus 2015
63     1             2016209     Johan Hjort 2016
65     2             2016847  Helmer Hanssen 2016
64     3             2016842            Eros 2016
66     4 0142_2016_UANA_NANSE Fridtjof Nansen 2016
69     1             2017209     Johan Hjort 2017
67     2             2017113        G.O.Sars 2017
70     3             2017856  Helmer Hanssen 2017
68     4  0143_2017_UFJN_VLNY         Vilnyus 2017
71     1             2018209     Johan Hjort 2018
72     2             2018110        G.O.Sars 2018
73     3             2018838  Helmer Hanssen 2018
74     4  0145_2018_UFJN_VLNY         Vilnyus 2018

>
> ## set years
> pre <- 2002
> years <- 2003:2003
> #years <- years[-8]
> years
[1] 2003
>
```

```
> #prepare lists for results
> allpr <- list()
> atlength <- list()
> atage <- list()
> age_uncertain <- list()
> age_uncertainv2 <- list()
> age_uncertainv3 <- list()
> basiclength <- list()
> basicage <- list()
> mikkolength <- list()
> mikkoage <- list()
> mikkolengthv2 <- list()
> mikkoagev2 <- list()
> basicpluslength <- list()
> basicplusage <- list()
> age_uncertainv4 <- list()
>
> load("Data/project_paths.rdata")
>
> for (i in years){
+
+   #lengthlist <- list()
+   #agelist <- list()
+
+   ######### Strata system 2017 - Barents_Sea_Ecosystem_Survey_Areas_v2017.txt ######
#################
+
+   ## Extract data
+   #system.time(projects<-getNMDdata(cruise=myCS, group="year", subset = i, model="Sw
eptAreaTemplate", subdir=TRUE, abbrev=T, ow=TRUE,run = TRUE))
+
+   #allpr[[i-pre]] <- projects
+   projects <- allpr[[i-pre]]
+
+   cruise.path=projects
+
+   ################## Setting of parameters - checked and confirmed with Tone #######
##############
+
+
+   ### Different Strata options - replace strata line in code below
+
+   # FileName="${STOX}/reference/stratum/Barents_Sea_Ecosystem_Survey_Areas_v2017.txt
"),
+   # FileName="${STOX}/reference/stratum/eco_strata.wkt"),
+   #FileName="${STOX}/reference/stratum/eco_afwg.txt"),
+
+   ## parameters
+   params <- list(FilterBiotic=list(functionName="FilterBiotic",
+                                     BioticData="Process(ReadBioticXML)",
+                                     #FishStationExpr="gear=~['3270','3271'] and gearc
ondition < 3 and trawlquality =~['1'] and fishstationtype != ['2','C']",
+                                     FishStationExpr="gear<'3500' and gearcondition <
3 and trawlquality =~['1'] and fishstationtype != ['2','C']",
+                                     CatchExpr="species =~['166756', '166705']"),
+                  DefineStrata=list(functionName="DefineStrata",
+                                     ProcessData="Process(ReadProcessData)",
+                                     UseProcessData=FALSE,
+                                     FileName="${STOX}/reference/stratum/Barents_Sea_E
cosystem_Survey_Areas_v2017.txt"),
+                  SweptAreaDensity=list(functionName="SweptAreaDensity",
+                                         FishingWidthMethod="Constant",
+                                         FishingWidth="25"),
+                  StratumArea=list(AreaMethod="Accurate"),
+                  RegroupLengthDist=list(LengthInterval="5"))
+
+   ## run Baseline
+   runBaseline(projects, parlist=params, save=TRUE) # Test
+
+   readBaselineParametersJava(projects) # this will show the updated baseline paramet
ers in Java
+
+   # get the output
+   X=getBaseline(projects)
```

```
+
+   # Show superindividuals:
+   head(X$outputData$SuperIndAbundance)
+
+   ### Numbers-at-length
+   Y=data.frame(stratum=X$outputData$Abundance$SampleUnit,area=X$outputData$Abundance
$Area, Lgrp=X$outputData$Abundance$LengthGroup,abundance=X$outputData$Abundance$Abunda
nce)
+   print(Y)
+
+   # group_by
+   Y <- subset(Y, abundance!="NA")
+   dim(Y)
+
+   Y_length <- Y %>%
+     ddply("Lgrp", summarise,
+           numbers_length=sum(abundance))
+
+   Y_length$year <- i
+
+   Y_length <- Y_length[,c(3,1,2)]
+
+   #Y_strata <- Y %>%
+   #  group_by(length, stratum) %>%
+   #  summarise(numbers_length=sum(abundance)) #and then by stratum - similar to sumi
f()
+
+   #Y_length <- Y %>%
+    # group_by(Lgrp) %>%
+     #summarise(numbers_length=sum(abundance)) #calculates numbers per lenght class -
similar to sumif()
+
+   #write.table(Y, file=paste("index_length_rstox", year, ".txt", sep=""), sep="\t")
+
+
+   ### Bootstrapping and numbers-at-age ################
+
+   # Run the bootstrapping to generate estimates of the variability in the data (cv):
+   rb1 <- runBootstrap(projects, nboot=50, cores=1, seed=1234, bioticMethod=PSU~Strat
um, bootstrapMethod="SweptAreaLength")
+   # Fill in missing data (missing length, weight and so on) based on the age informa
tion:
+   rb2 <- imputeByAge(projects,seed = 1234, cores =1, saveInd = TRUE)
+
+   # Save the bootstrap data:
+   saveProjectData(projects)
+
+   # Generate plots and reports:
+   plotfiles <- getPlots(projects)
+   reportfiles <- getReports(projects)
+
+   ### Extract rstox table for comparison
+   age_table=read.delim(paste0(cruise.path,"/output/r/report/bootstrapImpute_Abundanc
e_age.txt"),skip=9)
+
+   age_table$year <- i
+   age_table <- age_table[,c(8,1,2,3,4,5,6,7)]
+   age_uncertain[[i-pre]] <- age_table
+
+   #write.table(age_table, file=paste("index_age_rstox", year, ".txt", sep=""), sep="
\t")
+
+   Y_age <-  data.frame(age_table$age)
+   Y_age$numbers_age <- age_table$Ab.Sum.mean
+   Y_age$year <- i
+   names(Y_age) <- c("age", "numbers_age", "year")
+
+   Y_age <- Y_age[,c(3,1,2)]
+
+
+   atlength[[i-pre]] <-Y_length
+   atage[[i-pre]] <- Y_age
+
+   ############### End of standard RStox process ####################
```

```
+
+
+  ##################### End of Strata 17 ###############################
+
+
+ }
Running baseline process 1 to 15 (out of 15 processes)
Reading:
Baseline parameters
Process output ReadProcessData
Process output ReadBioticXML
Process output FilterBiotic
Process output StationLengthDist
Process output RegroupLengthDist
Process output DefineStrata
Process output StratumArea
Process output DefineSweptAreaPSU
Process output TotalLengthDist
Process output SweptAreaDensity
Process output MeanDensity_Stratum
Process output Abundance
Process output IndividualDataStations
Process output IndividualData
Process output SuperIndAbundance
Process output WriteProcessData
Process data bioticassignment
Process data suassignment
Process data assignmentresolution
Process data edsupsu
Process data psustratum
Process data stratumpolygon
Process data temporal
Process data gearfactor
Process data spatial
Process data platformfactor
Process data covparam
Process data ageerror
Process data stratumneighbour
                 stratum     area Lgrp    abundance
1      Bear_Island_Trench 24083.83    5   1243322.48
2      Bear_Island_Trench 24083.83   10   1734452.25
3      Bear_Island_Trench 24083.83   15   3171940.18
4      Bear_Island_Trench 24083.83   20   7862324.88
5      Bear_Island_Trench 24083.83   25  51714225.09
6      Bear_Island_Trench 24083.83   30 184248601.84
7      Bear_Island_Trench 24083.83   35  49264553.20
8      Bear_Island_Trench 24083.83   40    987815.89
9            Central_Bank 22680.97   15    116680.98
10 Franz_Victoria_Trough 37212.30    5   5742343.10
11 Franz_Victoria_Trough 37212.30   10    755878.83
12 Franz_Victoria_Trough 37212.30   20    146604.45
13 Franz_Victoria_Trough 37212.30   25     63812.20
14            Great_Bank 26970.90   NA           NA
15            Hopen_Deep 16654.82    5    137087.66
16            Hopen_Deep 16654.82   10    843750.80
17            Hopen_Deep 16654.82   15   2127700.98
18            Hopen_Deep 16654.82   20    389617.56
19            Hopen_Deep 16654.82   25   1316485.53
20            Hopen_Deep 16654.82   30    432908.40
21            Hopen_Deep 16654.82   35    144302.80
22            South_East 30709.67   30   1421857.76
23            South_East 30709.67   35   1421857.76
24            South_West 35050.37    5     92733.26
25            South_West 35050.37   10    439417.74
26            South_West 35050.37   15    464921.33
27            South_West 35050.37   20   2407434.82
28            South_West 35050.37   25   9260506.03
29            South_West 35050.37   30  26428233.06
30            South_West 35050.37   35   4553177.66
31            South_West 35050.37   40    456306.51
32     Southeastern_Basin 30050.12   NA           NA
33         Svalbard_North 22343.14    5   1183557.77
34         Svalbard_North 22343.14   10   4049730.49
35         Svalbard_North 22343.14   15   3602818.38
```

```
36         Svalbard_North 22343.14   20  18548427.09
37         Svalbard_North 22343.14   25  30935321.11
38         Svalbard_North 22343.14   30  19726578.48
39         Svalbard_North 22343.14   35   4633281.28
40         Svalbard_North 22343.14   40    302541.54
41         Svalbard_South 31940.90    5    144405.74
42         Svalbard_South 31940.90   10   2358302.02
43         Svalbard_South 31940.90   15   1096318.02
44         Svalbard_South 31940.90   20   2632328.85
45         Svalbard_South 31940.90   25  19466322.13
46         Svalbard_South 31940.90   30 129772272.95
47         Svalbard_South 31940.90   35  21727278.48
48         Svalbard_South 31940.90   40    711190.90
49      Thor_Iversen_Bank 19954.71   10    872256.47
50      Thor_Iversen_Bank 19954.71   15    527944.71
51      Thor_Iversen_Bank 19954.71   20    692449.22
52      Thor_Iversen_Bank 19954.71   25    242061.61
53      Thor_Iversen_Bank 19954.71   30     91816.47
54      Thor_Iversen_Bank 19954.71   35     91816.47
55     Bear_Island_Trench 24083.83    5   1081525.48
56     Bear_Island_Trench 24083.83   10     69692.57
57           Central_Bank 22680.97   NA           NA
58 Franz_Victoria_Trough 37212.30    5   2591757.17
59 Franz_Victoria_Trough 37212.30   10    812542.05
60             Great_Bank 26970.90   10     88800.19
61             Hopen_Deep 16654.82    5    189397.42
62             South_East 30709.67   NA           NA
63             South_West 35050.37    5   7248502.46
64             South_West 35050.37   10    752169.76
65    Southeastern_Basin 30050.12   NA           NA
66         Svalbard_North 22343.14    5   3039164.91
67         Svalbard_North 22343.14   10    934278.94
68         Svalbard_South 31940.90   15     50995.30
69         Svalbard_South 31940.90   30     50995.30
70      Thor_Iversen_Bank 19954.71    5     91816.47
Reading:
Process output SuperIndAbundance
Running 50 bootstrap replicates:
   |++++++++++++++++++++++++++++++++++++++++++++++++++| 100% elapsed = 09s
Imputing missing data (50 replicates):
   |++++++++++++++++++++++++++++++++++++++++++++++++++| 100% elapsed = 13s
Abundance by age for  bootstrap
 Abundance by age for  bootstrapImpute
    age    Ab.Sum.5%   Ab.Sum.50%   Ab.Sum.95%  Ab.Sum.mean    Ab.Sum.sd Ab.Sum.cv
1    NA 373.38465425 572.09862599 756.48668850 568.86748822 135.73319538 0.2386025
2     1   0.21263251   0.51245896   0.97099683   0.54756114   0.28031790 0.5119390
3     2   0.00000000   0.16223711   0.34418208   0.17725776   0.11145606 0.6287796
4     3   0.56057250   1.22548418   1.65362736   1.18764803   0.36921664 0.3108805
5     4   1.13053891   1.60209174   2.34287490   1.64057751   0.39745164 0.2422632
6     5   0.38523444   0.82715666   1.27412103   0.82443574   0.26629919 0.3230078
7     6   1.72613891   2.35065312   3.30421147   2.38240241   0.52311508 0.2195746
8     7   1.99192022   2.56807136   3.33523416   2.60165713   0.41373694 0.1590282
9     8   3.83977702   7.22316105   9.81100946   7.11997083   1.95154646 0.2740947
10    9   6.09051799  10.41927912  14.04866212  10.03488907   2.73994097 0.2730415
11   10   1.63194108   2.25549629   3.10391806   2.31342965   0.48901751 0.2113821
12   11   1.01120225   1.74505324   2.40047926   1.75044896   0.46397323 0.2650596
13   12   1.26111138   3.10576570   4.41204665   2.89699617   1.11423265 0.3846165
14   13   2.04062070   7.14244983  13.81959050   7.47196546   3.95720064 0.5296064
15   14   4.38611325   9.96787077  14.99220153   9.87494718   3.23515271 0.3276122
16   15   3.74001493   6.94184593  10.35101202   7.06366230   2.37881237 0.3367676
17   16   0.90558340   1.46810430   1.88888795   1.44790240   0.31849481 0.2199698
18   17   0.03788648   0.16342039   0.37311171   0.18748083   0.10122511 0.5399224
19   18   0.40975127   0.76785991   1.11159331   0.77902026   0.25353884 0.3254586
20   19   0.02590185   0.16977922   0.30684838   0.17071892   0.09368253 0.5487531
21   20   0.00000000   2.10884278   3.77000735   1.51529290   1.43158991 0.9447612
22   21   0.00000000   0.12181904   0.25556089   0.10549487   0.08914584 0.8450253
23   22   0.00000000   0.11840168   0.35219923   0.16593663   0.11773329 0.7095075
24   23   0.29018986   1.98988582   3.64414603   1.94052458   1.06028982 0.5463934
25   24   0.13978569   0.56459675   0.96741080   0.57797341   0.27333030 0.4729116
26   27   0.00000000   0.02528161   0.04721843   0.02023780   0.01929402 0.9533656
27   28   0.00000000   0.24126479   0.65205628   0.25108641   0.26835067 1.0687583
28   43   0.00000000   0.03854643   0.05798316   0.03254492   0.02350403 0.7222027
   age   Ab.Sum.5%  Ab.Sum.50%  Ab.Sum.95% Ab.Sum.mean  Ab.Sum.sd Ab.Sum.cv
1    1  6.97092938  14.0734806  26.0830836  16.0148920  6.9109991 0.4315358
```

```
2     2  0.00000000   5.6603225  17.4343623   6.6097735  6.2879671 0.9513136
3     3  3.72329992   7.0618118  13.5684635   7.7601223  3.1211713 0.4022065
4     4  5.07654203   8.3938365  14.3483081   8.9843860  3.1170971 0.3469460
5     5  1.81268989   3.5517214   6.0551429   3.5722882  1.2892771 0.3609107
6     6  6.80508083   9.6656405  12.8372907   9.7263261  2.1043576 0.2163569
7     7  8.72940592  11.6196204  20.2038621  12.6546383  3.7453833 0.2959692
8     8 30.24026161  52.3461346  79.6400169  53.3235146 15.9798026 0.2996765
9     9 29.22051043  53.3437307  70.4565370  51.2147995 13.3537258 0.2607396
10   10 25.40970654  42.1675230  74.3554910  47.0711385 16.5865727 0.3523725
11   11 15.32720086  33.6883757  51.0068272  32.9274381 12.7315461 0.3866546
12   12 22.54278632  52.9067935  90.2467477  56.2332105 25.4794193 0.4531027
13   13 48.49220419 149.0395282 324.2316027 165.6396333 90.2668120 0.5449590
14   14 20.46702690  76.2233478 139.3113983  79.8564225 38.7292816 0.4849864
15   15 18.60628571  49.8814947  91.4545498  52.0922553 21.8883252 0.4201839
16   16  5.41831504  11.3010937  18.4216096  11.6235206  3.9192359 0.3371815
17   17  0.04299694   0.3376919   1.0170244   0.4325655  0.3441703 0.7956488
18   18  0.47246122   1.4902428   3.3970433   1.6516732  0.9629827 0.5830346
19   19  0.12176092   1.1884477   3.0852044   1.4347505  1.1153516 0.7773836
20   20  0.00000000  11.1291633  19.2910367   7.9346474  7.7092876 0.9715980
21   21  0.00000000   0.2259387   0.7713422   0.2867386  0.2745526 0.9575013
22   22  0.00000000   0.1469758   0.6249804   0.2415486  0.2613426 1.0819461
23   23  0.71749096   2.9997262   4.6902317   2.8315914  1.2175546 0.4299895
24   24  0.85567204   2.4343285   6.1510952   2.9102178  1.8423595 0.6330659
25   27  0.00000000   0.1115587   0.4846137   0.1569713  0.1861909 1.1861461
26   28  0.00000000   0.2412648   1.4362456   0.5038530  0.5447486 1.0811656
27   43  0.00000000   0.3025415   0.5598579   0.2606349  0.2069867 0.7941635
>
> ## check content of lists
> summary(atlength)
     Length Class      Mode
[1,] 3      data.frame list
> summary(atage)
     Length Class      Mode
[1,] 3      data.frame list
>
>
> ## Create length table for all years - AFWG strata
> length_rstox <- atlength[[1]]
> head(length_rstox)
  year Lgrp numbers_length
1 2003    5       22785614
2 2003   10       13711272
3 2003   15       11159320
4 2003   20       32679187
5 2003   25      112998734
6 2003   30      362173264
>
> #ivec <- 2:(length(years)+1)
> #ivec <- ivec[-7]
> ivec <- 2:(length(years))
> ivec
[1] 2 1
>
> for (i in ivec){
+   length_rstox <- rbind(length_rstox, atlength[[i]])
+ }
>
>
> ## Create 45+ group
> dim(length_rstox)
[1] 8 3
> length_rstox <- subset(length_rstox, Lgrp!="NA")
> dim(length_rstox)
[1] 8 3
>
>
> length_low <- subset(length_rstox, Lgrp<45)
> length_high <- subset(length_rstox, Lgrp>=45)
> dim(length_low)
[1] 8 3
> dim(length_high)
[1] 0 3
>
> temp <- length_high %>%
```

```
+   ddply("year", summarise,
+         numbers_length=sum(numbers_length))
>
> temp$Lgrp <- 45
>
> temp <- temp[,c(1,3,2)]
>
> length_rstox <- rbind(length_low, temp)
> length_rstox$model <- "RStoX17"
> length_rstox$numbers_length <- (length_rstox$numbers_length)/1000
> length_rstox <- subset(length_rstox, Lgrp!=0)
>
> ## Create age table for all years - AFWG strata
> age_rstox <- atage[[1]]
>
> for (i in ivec){
+   age_rstox <- rbind(age_rstox, atage[[i]])
+ }
>
>
> ## Create 16+ group
> dim(age_rstox)
[1] 27  3
> age_rstox <- subset(age_rstox, age!="NA")
> dim(age_rstox)
[1] 27  3
>
> age_low <- subset(age_rstox, age<16)
> age_high <- subset(age_rstox, age>=16)
> dim(age_low)
[1] 15  3
> dim(age_high)
[1] 12  3
>
> temp <- age_high %>%
+   ddply("year", summarise,
+         numbers_age=sum(numbers_age))
>
> temp$age <- 16
>
> temp <- temp[,c(1,3,2)]
>
> age_rstox <- rbind(age_low, temp)
> age_rstox$model <- "RStoX17"
> age_rstox$numbers_age <- age_rstox$numbers_age*1000
> age_rstox <- subset(age_rstox, age!=1)
>
>
>   ## Create age table with uncertainties - Rstox17
>   uncertain_age <- age_uncertain[[1]]
>   head(uncertain_age)
  year age Ab.Sum.5. Ab.Sum.50. Ab.Sum.95. Ab.Sum.mean Ab.Sum.sd Ab.Sum.cv
1 2003   1  6.970929  14.073481  26.083084   16.014892  6.910999 0.4315358
2 2003   2  0.000000   5.660323  17.434362    6.609773  6.287967 0.9513136
3 2003   3  3.723300   7.061812  13.568464    7.760122  3.121171 0.4022065
4 2003   4  5.076542   8.393836  14.348308    8.984386  3.117097 0.3469460
5 2003   5  1.812690   3.551721   6.055143    3.572288  1.289277 0.3609107
6 2003   6  6.805081   9.665641  12.837291    9.726326  2.104358 0.2163569
>
>   #ivec <- 2:(length(years)+1)
>   #ivec <- ivec[-7]
>   ivec <- 2:(length(years))
>   ivec
[1] 2 1
>
>   for (i in ivec){
+     uncertain_age <- rbind(uncertain_age, age_uncertain[[i]])
+   }
>
>   names(uncertain_age) <- c("year", "age", "p05", "p50", "p95", "mean", "sd", "cv")
>
>
>   ## Create 16+ group
>   dim(uncertain_age)
```

```
[1] 27  8
>   uncertain_age <- subset(uncertain_age, age!="NA")
>   dim(uncertain_age)
[1] 27  8
>
>   age_low <- subset(uncertain_age, age<16)
>   age_high <- subset(uncertain_age, age>=16)
>   dim(age_low)
[1] 15  8
>   dim(age_high)
[1] 12  8
>
>   temp <- age_high %>%
+     ddply("year", summarise,
+           p05=sum(p05), p50=sum(p50), p95=sum(p95),
+           mean=sum(mean), sd=mean(sd), cv=mean(cv))
>
>   temp$age <- 16
>
>   temp <- temp[,c(1,8,2,3,4,5,6,7)]
>
>   uncertain_age <- rbind(age_low, temp)
>   uncertain_age$model <- "RStoX17"
>   uncertain_age$mean <- uncertain_age$mean*1000
>   uncertain_age$p05 <- uncertain_age$p05*1000
>   uncertain_age$p95 <- uncertain_age$p95*1000
>   uncertain_age <- subset(uncertain_age, age!=1)
>

>



> for (i in years){
+
+     #lengthlist <- list()
+     #agelist <- list()
+
+
+   ######### Old AFWG system - eco_afwg.txt ######################
+
+   ## Extract data
+   #system.time(projects<-getNMDdata(cruise=myCS, group="year", subset = i, model="Sw
eptAreaTemplate", subdir=TRUE, abbrev=T, ow=TRUE,run = TRUE))
+
+   projects <- allpr[[i-pre]]
+
+   cruise.path=projects
+
+   ################## Setting of parameters - checked and confirmed with Tone #######
##############
+
+
+   ### Different Strata options - replace strata line in code below
+
+   # FileName="${STOX}/reference/stratum/Barents_Sea_Ecosystem_Survey_Areas_v2017.txt
"),
+   # FileName="${STOX}/reference/stratum/eco_strata.wkt"),
+   #FileName="${STOX}/reference/stratum/eco_afwg.txt"),
+
+   ## parameters
+   params <- list(FilterBiotic=list(functionName="FilterBiotic",
+                                    BioticData="Process(ReadBioticXML)",
+                                    #FishStationExpr="gear=~['3270','3271'] and gearc
ondition < 3 and trawlquality =~['1'] and fishstationtype != ['2','C']",
+                                    FishStationExpr="gear<'3500' and gearcondition <
3 and trawlquality =~['1'] and fishstationtype != ['2','C']",
+                                    CatchExpr="species =~['166756', '166705']"),
+                  DefineStrata=list(functionName="DefineStrata",
+                                    ProcessData="Process(ReadProcessData)",
+                                    UseProcessData=FALSE,
+                                    FileName="${STOX}/reference/stratum/eco_afwg.txt"
),
+                  SweptAreaDensity=list(functionName="SweptAreaDensity",
```

```
+                                        FishingWidthMethod="Constant",
+                                        FishingWidth="25"),
+                    StratumArea=list(AreaMethod="Accurate"),
+                    RegroupLengthDist=list(LengthInterval="5"))
+
+   ## run Baseline
+   runBaseline(projects, parlist=params, save=TRUE) # Test
+
+   readBaselineParametersJava(projects) # this will show the updated baseline paramet
ers in Java
+
+   # get the output
+   X=getBaseline(projects)
+
+   # Show superindividuals:
+   head(X$outputData$SuperIndAbundance)
+
+   ### Numbers-at-length
+   Y=data.frame(stratum=X$outputData$Abundance$SampleUnit,area=X$outputData$Abundance
$Area, Lgrp=X$outputData$Abundance$LengthGroup,abundance=X$outputData$Abundance$Abunda
nce)
+   print(Y)
+
+   # group_by
+   Y <- subset(Y, abundance!="NA")
+   dim(Y)
+
+   Y_length <- Y %>%
+     ddply("Lgrp", summarise,
+           numbers_length=sum(abundance))
+
+   Y_length$year <- i
+
+   Y_length <- Y_length[,c(3,1,2)]
+
+   #Y_strata <- Y %>%
+   #  group_by(length, stratum) %>%
+   #  summarise(numbers_length=sum(abundance)) #and then by stratum - similar to sumi
f()
+
+   #Y_length <- Y %>%
+   # group_by(Lgrp) %>%
+   #summarise(numbers_length=sum(abundance)) #calculates numbers per lenght class - s
imilar to sumif()
+
+   #write.table(Y, file=paste("index_length_rstox", year, ".txt", sep=""), sep="\t")
+
+
+   ### Bootstrapping and numbers-at-age ###############
+
+   # Run the bootstrapping to generate estimates of the variability in the data (cv):
+   rb1 <- runBootstrap(projects, nboot=50, cores=1, seed=1234, bioticMethod=PSU~Strat
um, bootstrapMethod="SweptAreaLength")
+   # Fill in missing data (missing length, weight and so on) based on the age informa
tion:
+   rb2 <- imputeByAge(projects,seed = 1234, cores =1, saveInd = TRUE)
+
+   # Save the bootstrap data:
+   saveProjectData(projects)
+
+   # Generate plots and reports:
+   plotfiles <- getPlots(projects)
+   reportfiles <- getReports(projects)
+
+   ### Extract rstox table for comparison
+   age_table=read.delim(paste0(cruise.path,"/output/r/report/bootstrapImpute_Abundanc
e_age.txt"),skip=9)
+
+   #write.table(age_table, file=paste("index_age_rstox", year, ".txt", sep=""), sep="
\t")
+
+   Y_age <-  data.frame(age_table$age)
+   Y_age$numbers_age <- age_table$Ab.Sum.mean
+   Y_age$year <- i
```

```
+   names(Y_age) <- c("age", "numbers_age", "year")
+
+   Y_age <- Y_age[,c(3,1,2)]
+
+
+   #atlength[[i-pre]] <-Y_length
+   #atage[[i-pre]] <- Y_age
+
+   ############### End of standard RStoX process ###################
+
+   ############### Alternative calculation - using areas created by Mikko ###########
#####
+
+   ### Numbers-at-length ###
+   ### Extract numbers standardized to nautical mile
+   numbers <- X$outputData$RegroupLengthDist
+   dim(numbers)
+   names(numbers)
+
+   ### Create id
+   numbers <- numbers %>%
+     mutate(serialno=sub("^[^/]*", "", Station)) %>%
+     mutate(serialno=gsub("/","",serialno))
+
+
+   #numbers$serialno <- str_sub(numbers$Station,-4,-1)
+   numbers$year <- as.character(i)
+   numbers$id <- paste(numbers$year, numbers$serialno, sep = "_")
+
+   ## load station data to attach
+   #load("Data/ecostations_allgears.rda")
+   load("Data/ecostations_bunntral.rda")
+   x <- x_list[[i-2002]]
+
+   ### Create data frame for swept area ###
+   ### By merging with station data - based on id ###
+
+
+   swept <- merge(numbers, unique(x)[, c("id", "distance", "stratum", "depth_cat", "a
rea", "nstation_st")], by="id", all.x=TRUE)
+   swept$Lgrp <- swept$LengthGroup
+   swept$LengthGroup <- NULL
+
+   ### Calculate swept area densities ######
+
+   #Calculate swept area
+   #swept$area <- (swept$distance * 25)/1852 #general formula for swept area
+   swept$sweep_area <- (1 * 25)/1852 #as the count is already standardized to 1 n.mi.
towing distance
+
+   #Calculate swept area density and subset for non existent length groups and out of
area stations
+   swept$estimate <- swept$WeightedCount/swept$sweep_area
+   swept <- subset(swept, estimate!="NA")
+   swept <- subset(swept, nstation_st!="NA")
+
+   swept <- swept %>%
+     add_count(SpecCat, Lgrp, stratum, depth_cat, name="nstation_x")
+
+   #Calculate multiplier to get to area abundance
+   #nstations_x = number of stations with the species
+   #nstations_st = number of stations in the stratum
+   swept$multiplier <- swept$area*(swept$nstation_x/swept$nstation_st)
+
+   ##### calculate proportion of weighted count #####
+   swept <- swept %>%
+     group_by(SpecCat, stratum, depth_cat, multiplier, Lgrp) %>%
+     mutate(sum_count=sum(WeightedCount)) %>%
+     mutate(prop_count = WeightedCount/sum_count)
+
+
+   #Calculate mean swept area density for stratum, depth_category and length group an
d calculate abundance in the stratum
+   sweep_mean <- swept %>%
```

```
+     group_by(SpecCat, stratum, depth_cat, multiplier, Lgrp) %>%
+     summarise(mean_stratum = mean(estimate)) %>%
+     mutate(abundance = mean_stratum*multiplier)
+
+
+   ##### calculate abundance per stratum #####
+   abundance_stratum <- sweep_mean %>%
+     group_by(SpecCat, stratum, depth_cat, Lgrp) %>%
+     summarise(abundance_stratum=sum(abundance))
+
+
+
+
+   ### Merge swept and stratum abundance and calculate abundance per station
+   swept <- merge(swept, unique(abundance_stratum)[, c("SpecCat", "stratum", "depth_c
at", "Lgrp", "abundance_stratum")], by=c("SpecCat", "stratum", "depth_cat", "Lgrp"), a
ll.x=TRUE)
+
+   swept <- swept %>%
+     mutate(abundance_station=abundance_stratum*prop_count)
+
+   ##### calculate index #####
+   #index_length <- sweep_mean %>%
+   #  group_by(Lgrp) %>%
+   #  summarise(index_length=sum(abundance))
+
+
+   index_length <- sweep_mean %>%
+     ddply("Lgrp", summarise,
+           numbers_length=sum(abundance))
+
+   index_length$year <- i
+
+   index_length <- index_length[,c(3,1,2)]
+
+   mikkolength[[i-pre]] <- index_length
+
+   #write.table(index_length, file=paste("index_length_customs", year, ".txt", sep=""
), sep="\t")
+
+
+   ############### Numbers-at-age ##################################
+
+   #extract and create list of imputed ages
+   ageimpute_list <- getProjectData(projectName = projects,
+                                    var = "bootstrapImpute")
+
+
+   for (q in 1:50){
+     ageimpute_list$SuperIndAbundance[[q]]$run <- q
+   }
+
+   agerun <- ageimpute_list$SuperIndAbundance[[1]]
+
+   for (q in 2:50){
+     agerun <- rbind(agerun,ageimpute_list$SuperIndAbundance[[q]])
+   }
+
+   #Count and attach number of occurrences for species, serial number, length group a
nd imputed age
+   agerun$Lgrp <- agerun$LenGrp
+
+   agerun <- agerun %>%
+     add_count(SpecCat, serialno, Lgrp, age, name="agecount")
+
+
+   ### reduce to most common age
+   agemax <- agerun %>%
+     #select(-c(23:34,36:39)) %>%
+     group_by(serialno, SpecCat, Lgrp) %>%
+     slice(which.max(agecount))
+
+   ##Create id
+   agemax$year <- as.character(i)
```

```
+   agemax$id <- paste(agemax$year, agemax$serialno, sep = "_")
+
+   agemax <- agemax %>%
+     select(id, SpecCat, serialno, Lgrp, age)
+
+
+   ###attaching age to swept densities ###
+   swept$serialno <- as.integer(swept$serialno)
+
+   swept <- merge(swept, agemax, by=c("id","SpecCat", "serialno", "Lgrp"), all.x=TRUE
)
+
+   swept <- swept %>%
+     mutate(abundance_station=abundance_stratum*prop_count)
+
+   ##### calculate index #####
+   #index_age <- swept %>%
+   #  group_by(age) %>%
+   # summarise(numbers_age=sum(abundance_station))
+
+
+   index_age <- swept %>%
+     ddply("age", summarise,
+           numbers_age=sum(abundance_station))
+
+   index_age$year <- i
+
+   index_age <- index_age[,c(3,1,2)]
+
+   mikkoage[[i-pre]] <- index_age
+
+
+   #write.table(index_age, file=paste("index_age_customs", year, ".txt", sep=""), sep
="\t")
+
+   ##################### End of old AFWG ##############################
+
+
+ }
Running baseline process 6 to 15 (out of 15 processes)
Reading:
Baseline parameters
Process output ReadProcessData
Process output ReadBioticXML
Process output FilterBiotic
Process output StationLengthDist
Process output RegroupLengthDist
Process output DefineStrata
Process output StratumArea
Process output DefineSweptAreaPSU
Process output TotalLengthDist
Process output SweptAreaDensity
Process output MeanDensity_Stratum
Process output Abundance
Process output IndividualDataStations
Process output IndividualData
Process output SuperIndAbundance
Process output WriteProcessData
Process data bioticassignment
Process data suassignment
Process data assignmentresolution
Process data edsupsu
Process data psustratum
Process data stratumpolygon
Process data temporal
Process data gearfactor
Process data spatial
Process data platformfactor
Process data covparam
Process data ageerror
Process data stratumneighbour
       stratum      area Lgrp    abundance
1     15_Arc_1  5971.373    5    987409.19
2     15_Arc_1  5971.373   10    567473.62
```

3	15_Arc_1	5971.373	15	642111.61
4	15_Arc_1	5971.373	20	2545113.92
5	15_Arc_1	5971.373	25	634539.45
6	15_Arc_1	5971.373	30	96775.90
7	15_Arc_1	5971.373	35	50909.15
8	15_Arc_1	5971.373	40	110153.70
9	15_Arc_2	4612.001	5	367313.88
10	15_Arc_2	4612.001	10	2134640.04
11	15_Arc_2	4612.001	15	149386.56
12	15_Arc_2	4612.001	20	66433.31
13	15_Arc_2	4612.001	25	37961.89
14	15_Arc_2	4612.001	30	26211.78
15	15_Arc_3	8440.135	5	142101.18
16	15_Arc_3	8440.135	10	426303.54
17	15_Arc_3	8440.135	15	142101.18
18	15_Arc_3	8440.135	20	568404.72
19	15_Arc_3	8440.135	30	142101.18
20	15_Arc_6	13804.491	5	2396489.59
21	15_Arc_6	13804.491	10	315455.85
22	15_Arc_6	13804.491	20	61183.39
23	15_Arc_6	13804.491	25	26631.16
24	15_Arc_7	7829.537	NA	NA
25	31_Sva_1	28673.309	5	358933.27
26	31_Sva_1	28673.309	10	2451878.68
27	31_Sva_1	28673.309	15	5114869.80
28	31_Sva_1	28673.309	20	28084582.79
29	31_Sva_1	28673.309	25	52660060.59
30	31_Sva_1	28673.309	30	47924798.59
31	31_Sva_1	28673.309	35	12030276.02
32	31_Sva_1	28673.309	40	578159.45
33	31_Sva_2	64860.486	5	596613.69
34	31_Sva_2	64860.486	10	4145739.25
35	31_Sva_2	64860.486	15	4713715.86
36	31_Sva_2	64860.486	20	6295006.85
37	31_Sva_2	64860.486	25	43071578.85
38	31_Sva_2	64860.486	30	232762428.35
39	31_Sva_2	64860.486	35	42077341.32
40	31_Sva_2	64860.486	40	1424006.35
41	32_Bar_1	19828.811	10	667690.15
42	32_Bar_1	19828.811	15	560382.81
43	32_Bar_1	19828.811	20	302050.31
44	32_Bar_1	19828.811	25	190768.61
45	32_Bar_2	13027.506	NA	NA
46	32_Bar_32_5	27573.849	5	1402678.11
47	32_Bar_32_5	27573.849	10	1202844.04
48	32_Bar_32_5	27573.849	15	1637598.69
49	32_Bar_32_5	27573.849	20	8136999.07
50	32_Bar_32_5	27573.849	25	6708930.43
51	32_Bar_32_5	27573.849	30	18886216.96
52	32_Bar_32_5	27573.849	35	3410346.36
53	32_Bar_32_5	27573.849	40	232121.67
54	32_Bar_32_6	15994.080	10	225189.17
55	32_Bar_32_6	15994.080	15	155900.19
56	32_Bar_32_6	15994.080	20	847327.67
57	32_Bar_32_6	15994.080	25	134641.08
58	32_Bar_32_6	15994.080	30	1561476.53
59	32_Bar_32_6	15994.080	35	949011.49
60	32_Bar_32_6	15994.080	40	158374.80
61	32_Bar_4	41211.946	10	579232.29
62	32_Bar_4	41211.946	15	94227.81
63	32_Bar_4	41211.946	20	892774.96
64	32_Bar_4	41211.946	25	41938782.62
65	32_Bar_4	41211.946	30	106050310.47
66	32_Bar_4	41211.946	35	37982998.52
67	32_Bar_4	41211.946	40	1364182.72
68	15_Arc_1	5971.373	5	90740.37
69	15_Arc_1	5971.373	10	421294.59
70	15_Arc_2	4612.001	5	2214178.55
71	15_Arc_2	4612.001	10	470308.52
72	15_Arc_3	8440.135	5	10453318.06
73	15_Arc_3	8440.135	10	2459604.25
74	15_Arc_6	13804.491	5	1081634.96
75	15_Arc_6	13804.491	10	367510.06
76	15_Arc_7	7829.537	NA	NA

```
77     31_Sva_1 28673.309    5    100126.81
78     31_Sva_1 28673.309   10     64367.23
79     31_Sva_2 64860.486    5    126178.17
80     31_Sva_2 64860.486   10     58883.15
81     31_Sva_2 64860.486   15     58883.15
82     31_Sva_2 64860.486   30     58883.15
83     32_Bar_1 19828.811    5    194742.96
84     32_Bar_2 13027.506   NA           NA
85 32_Bar_32_5 27573.849    5    167029.35
86 32_Bar_32_6 15994.080   NA           NA
87     32_Bar_4 41211.946    5   9672484.37
88     32_Bar_4 41211.946   10    859828.74
Reading:
Process output SuperIndAbundance
Running 50 bootstrap replicates:
   |++++++++++++++++++++++++++++++++++++++++++++++++++| 100% elapsed = 09s
Imputing missing data (50 replicates):
   |++++++++++++++++++++++++++++++++++++++++++++++++++| 100% elapsed = 12s
Abundance by age for  bootstrap
 Abundance by age for  bootstrapImpute
    age   Ab.Sum.5%   Ab.Sum.50%   Ab.Sum.95%  Ab.Sum.mean    Ab.Sum.sd Ab.Sum.cv
1    NA 420.70830013 647.42418455 994.56797715 671.15053791 182.80751942 0.2723793
2     1   0.29778656   0.75810726   1.59818978   0.79877113   0.38380442 0.4804936
3     2   0.00000000   0.13807195   0.37631796   0.16692158   0.12206806 0.7312899
4     3   0.45654839   1.27956923   2.07956806   1.24567700   0.54352534 0.4363293
5     4   1.25410344   1.81431436   2.64361985   1.84820660   0.49758908 0.2692281
6     5   0.40775256   0.68818270   1.01614875   0.68714667   0.20161682 0.2934116
7     6   1.86159353   2.34695885   3.39351719   2.45728607   0.50542896 0.2056858
8     7   2.22529222   2.97171887   4.51157237   3.14540669   0.76548559 0.2433662
9     8   3.35769153   8.53869615  12.87795349   8.26667196   3.03887248 0.3676053
10    9   7.07964864  12.50759239  19.01256883  12.37103287   4.11878602 0.3329379
11   10   1.64632988   2.84660004   4.90020596   3.12094238   0.97835998 0.3134822
12   11   0.94118185   1.57687477   2.81024388   1.70842646   0.57619788 0.3372682
13   12   1.58615370   4.29665750   8.86561953   4.39299744   2.14807529 0.4889771
14   13   1.81107737   8.32216810  14.62308676   7.77899137   4.49360052 0.5776585
15   14   4.67015652  10.43614309  18.18947557  10.80906899   4.84079469 0.4478457
16   15   4.21576460   8.30608674  12.97947878   8.24278521   2.78047182 0.3373219
17   16   0.94321039   1.51421085   1.95098322   1.49208260   0.31453149 0.2108003
18   17   0.00000000   0.21041797   0.44785356   0.21362792   0.13619066 0.6375134
19   18   0.32524780   0.93413045   1.78844879   1.00541324   0.48748298 0.4848583
20   19   0.07213216   0.24194793   0.38220069   0.23675775   0.09346633 0.3947762
21   20   0.02649742   1.69247399   3.12136473   1.31875134   1.21885452 0.9242489
22   21   0.00000000   0.11606084   0.40885628   0.15436106   0.11604592 0.7517824
23   22   0.00000000   0.11224353   0.27747265   0.12998138   0.08553237 0.6580356
24   23   0.41068812   0.87008948   1.41653104   0.88598029   0.33369201 0.3766359
25   24   0.21213543   0.82806629   1.38286693   0.82904275   0.37399610 0.4511180
26   27   0.00000000   0.04950592   0.07874092   0.03597901   0.03133150 0.8708274
27   28   0.00000000   0.20338144   0.44816271   0.17643883   0.16743854 0.9489892
28   43   0.00000000   0.05090915   0.10393707   0.04542471   0.03946778 0.8688614
   age   Ab.Sum.5%   Ab.Sum.50%  Ab.Sum.95%  Ab.Sum.mean  Ab.Sum.sd Ab.Sum.cv
1    1 13.87428354  27.96651724  41.3620149  27.54334733  8.5831978 0.3116251
2    2  0.00000000   2.43557752   7.5469323   3.00964194  3.0433757 1.0112086
3    3  6.04030464  10.50081764  15.3878215  10.46708725  3.3926058 0.3241213
4    4  7.98039852  11.39240045  19.5085006  12.60316352  4.2380681 0.3362702
5    5  2.50410547   3.94272111   5.5530841   4.06373362  1.2038715 0.2962477
6    6  8.17896455  11.63740828  16.3254433  11.90041797  2.4853891 0.2088489
7    7  9.68193951  13.79122833  20.8448137  14.52375765  3.7287977 0.2567378
8    8 31.36681423  67.04003037 111.1485123  70.83332712 28.1588847 0.3975372
9    9 43.33765020  67.29587341 103.1538272  70.37030784 19.5476924 0.2777832
10  10 27.87011645  50.70706823  93.5477832  54.03249677 19.7924029 0.3663055
11  11 14.40574136  32.84376603  60.8439480  33.88123764 16.2862596 0.4806867
12  12 32.06761915  71.07261013 148.8429805  74.93374752 36.9871550 0.4935981
13  13 37.66019993 165.61955193 331.4244552 161.56700188 96.0793523 0.5946719
14  14 20.73776664  97.74432457 200.7798106 103.14438227 59.7185888 0.5789805
15  15 29.53875458  53.38613862  88.1895243  57.08859369 18.5600087 0.3251089
16  16  8.15702934  12.40334777  22.2427827  14.09415085  4.7600162 0.3377299
17  17  0.00000000   0.66980777   3.3149744   0.98148038  1.1129956 1.1339968
18  18  0.49656601   2.28087203   5.3573107   2.56116449  1.6123048 0.6295202
19  19  0.42779832   1.79185094   4.1515171   1.87671143  1.2753563 0.6795697
20  20  0.03595542   9.12706122  17.3060595   7.25582373  6.8474448 0.9437171
21  21  0.00000000   0.52863114   1.2881797   0.55042079  0.4196719 0.7624565
22  22  0.00000000   0.51262599   1.7520922   0.67305695  0.6508889 0.9670637
23  23  0.90207687   2.82508188   5.6031755   2.96938725  1.3748362 0.4630033
24  24  0.81860152   2.74091451   5.5266284   2.91700471  1.4560105 0.4991457
```

```
25  27  0.00000000   0.23025161   1.0419066   0.33012917  0.3881895 1.1758716
26  28  0.00000000   0.47847284   1.0770939   0.44793203  0.4288414 0.9573806
27  43  0.00000000   0.05090915   0.2293238   0.09520542  0.1055346 1.1084938
>
>
>
> ## check content of lists
> summary(mikkolength)
     Length Class      Mode
[1,] 3      data.frame list
> summary(mikkoage)
     Length Class      Mode
[1,] 3      data.frame list
>
> ## Create length table for all years - Mikko areas
> length_mikko <- mikkolength[[1]]
> head(length_mikko)
  year Lgrp numbers_length
1 2003    5       27453157
2 2003   10       19771775
3 2003   15       12014735
4 2003   20       48852291
5 2003   25      121960748
6 2003   30      304966096
>
> #ivec <- 2:(length(years)+1)
> #ivec <- ivec[-7]
> ivec <- 2:(length(years))
> ivec
[1] 2 1
>
> for (i in ivec){
+   length_mikko <- rbind(length_mikko, mikkolength[[i]])
+ }
>
>
> ## Create 45+ group
> dim(length_mikko)
[1] 8 3
> length_mikko <- subset(length_mikko, Lgrp!="NA")
> dim(length_mikko)
[1] 8 3
>
>
> length_low <- subset(length_mikko, Lgrp<45)
> length_high <- subset(length_mikko, Lgrp>=45)
> dim(length_low)
[1] 8 3
> dim(length_high)
[1] 0 3
>
> temp <- length_high %>%
+   ddply("year", summarise,
+         numbers_length=sum(numbers_length))
>
> temp$Lgrp <- 45
>
> temp <- temp[,c(1,3,2)]
>
> length_mikko <- rbind(length_low, temp)
> length_mikko$model <- "Alternative"
> length_mikko$numbers_length <- (length_mikko$numbers_length)/1000
> length_mikko <- subset(length_mikko, Lgrp!=0)
>
> ## Create age table for all years - Mikko areas
> age_mikko <- mikkoage[[1]]
>
> for (i in ivec){
+   age_mikko <- rbind(age_mikko, mikkoage[[i]])
+ }
>
>
> ## Create 16+ group
> dim(age_mikko)
```

```
[1] 27  3
> age_mikko <- subset(age_mikko, age!="NA")
> dim(age_mikko)
[1] 27  3
>
> age_low <- subset(age_mikko, age<16)
> age_high <- subset(age_mikko, age>=16)
> dim(age_low)
[1] 15  3
> dim(age_high)
[1] 12  3
>
> temp <- age_high %>%
+   ddply("year", summarise,
+         numbers_age=sum(numbers_age))
>
> temp$age <- 16
>
> temp <- temp[,c(1,3,2)]
>
> age_mikko <- rbind(age_low, temp)
> age_mikko$model <- "Alternative"
> age_mikko$numbers_age <- age_mikko$numbers_age/1000
> age_mikko <- subset(age_mikko, age!=1)
> for (i in years){
+
+   #lengthlist <- list()
+   #agelist <- list()
+
+   ######### New strata polygons - polygon_output_test.txt #######################
+
+   ## Extract data
+   #system.time(projects<-getNMDdata(cruise=myCS, group="year", subset = i, model="Sw
eptAreaTemplate", subdir=TRUE, abbrev=T, ow=TRUE,run = TRUE))
+
+   projects <- allpr[[i-pre]]
+
+   cruise.path=projects
+
+   ################## Setting of parameters - checked and confirmed with Tone #######
##############
+
+
+   ### Different Strata options - replace strata line in code below
+
+   # FileName="${STOX}/reference/stratum/Barents_Sea_Ecosystem_Survey_Areas_v2017.txt
"),
+   # FileName="${STOX}/reference/stratum/eco_strata.wkt"),
+   #FileName="${STOX}/reference/stratum/eco_afwg.txt"),
+
+   ## parameters
+   params <- list(FilterBiotic=list(functionName="FilterBiotic",
+                                    BioticData="Process(ReadBioticXML)",
+                                    #FishStationExpr="gear=~['3270','3271'] and gearc
ondition < 3 and trawlquality =~['1'] and fishstationtype != ['2','C']",
+                                    FishStationExpr="gear<'3500' and gearcondition <
3 and trawlquality =~['1'] and fishstationtype != ['2','C']",
+                                    CatchExpr="species =~['166756', '166705']"),
+                  DefineStrata=list(functionName="DefineStrata",
+                                    ProcessData="Process(ReadProcessData)",
+                                    UseProcessData=FALSE,
+                                    FileName="${STOX}/reference/stratum/polygon_outpu
t_test.txt"),
+                  SweptAreaDensity=list(functionName="SweptAreaDensity",
+                                        FishingWidthMethod="Constant",
+                                        FishingWidth="25"),
+                  StratumArea=list(AreaMethod="Accurate"),
+                  RegroupLengthDist=list(LengthInterval="5"))
+
+   ## run Baseline
+   runBaseline(projects, parlist=params, save=TRUE) # Test
+
+   readBaselineParametersJava(projects) # this will show the updated baseline paramet
ers in Java
```

```
+
+   # get the output
+   X=getBaseline(projects)
+
+   # Show superindividuals:
+   head(X$outputData$SuperIndAbundance)
+
+   ### Numbers-at-length
+   Y=data.frame(stratum=X$outputData$Abundance$SampleUnit,area=X$outputData$Abundance
$Area, Lgrp=X$outputData$Abundance$LengthGroup,abundance=X$outputData$Abundance$Abunda
nce)
+   print(Y)
+
+   # group_by
+   Y <- subset(Y, abundance!="NA")
+   dim(Y)
+
+   Y_length <- Y %>%
+     ddply("Lgrp", summarise,
+           numbers_length=sum(abundance))
+
+   Y_length$year <- i
+
+   Y_length <- Y_length[,c(3,1,2)]
+
+   #Y_strata <- Y %>%
+   #  group_by(length, stratum) %>%
+   #  summarise(numbers_length=sum(abundance)) #and then by stratum - similar to sumi
f()
+
+   #Y_length <- Y %>%
+   # group_by(Lgrp) %>%
+   #summarise(numbers_length=sum(abundance)) #calculates numbers per lenght class - s
imilar to sumif()
+
+   #write.table(Y, file=paste("index_length_rstox", year, ".txt", sep=""), sep="\t")
+
+
+   ### Bootstrapping and numbers-at-age ###############
+
+   # Run the bootstrapping to generate estimates of the variability in the data (cv):
+   rb1 <- runBootstrap(projects, nboot=50, cores=1, seed=1234, bioticMethod=PSU~Strat
um, bootstrapMethod="SweptAreaLength")
+   # Fill in missing data (missing length, weight and so on) based on the age informa
tion:
+   rb2 <- imputeByAge(projects,seed = 1234, cores =1, saveInd = TRUE)
+
+   # Save the bootstrap data:
+   saveProjectData(projects)
+
+   # Generate plots and reports:
+   plotfiles <- getPlots(projects)
+   reportfiles <- getReports(projects)
+
+   ### Extract rstox table for comparison
+   age_table=read.delim(paste0(cruise.path,"/output/r/report/bootstrapImpute_Abundanc
e_age.txt"),skip=9)
+
+   age_table$year <- i
+   age_table <- age_table[,c(8,1,2,3,4,5,6,7)]
+   age_uncertainv2[[i-pre]] <- age_table
+
+   #write.table(age_table, file=paste("index_age_rstox", year, ".txt", sep=""), sep="
\t")
+
+   Y_age <-  data.frame(age_table$age)
+   Y_age$numbers_age <- age_table$Ab.Sum.mean
+   Y_age$year <- i
+   names(Y_age) <- c("age", "numbers_age", "year")
+
+   Y_age <- Y_age[,c(3,1,2)]
+
+
+   mikkolengthv2[[i-pre]] <-Y_length
```

```
+   mikkoagev2[[i-pre]] <- Y_age
+
+   ############### End of standard RStoX process ###################
+
+ }
Running baseline process 6 to 15 (out of 15 processes)
Reading:
Baseline parameters
Process output ReadProcessData
Process output ReadBioticXML
Process output FilterBiotic
Process output StationLengthDist
Process output RegroupLengthDist
Process output DefineStrata
Process output StratumArea
Process output DefineSweptAreaPSU
Process output TotalLengthDist
Process output SweptAreaDensity
Process output MeanDensity_Stratum
Process output Abundance
Process output IndividualDataStations
Process output IndividualData
Process output SuperIndAbundance
Process output WriteProcessData
Process data bioticassignment
Process data suassignment
Process data assignmentresolution
Process data edsupsu
Process data psustratum
Process data stratumpolygon
Process data temporal
Process data gearfactor
Process data spatial
Process data platformfactor
Process data covparam
Process data ageerror
Process data stratumneighbour
        stratum       area Lgrp    abundance
1     D0-200_247  56290.186   NA           NA
2      D0-200_53   1359.868   NA           NA
3   D200-500_149 320225.719    5 6.576091e+06
4   D200-500_149 320225.719   10 3.053675e+07
5   D200-500_149 320225.719   15 3.201878e+07
6   D200-500_149 320225.719   20 1.322820e+08
7   D200-500_149 320225.719   25 3.193532e+08
8   D200-500_149 320225.719   30 6.118315e+08
9   D200-500_149 320225.719   35 1.590828e+08
10  D200-500_149 320225.719   40 6.190928e+06
11  D200-500_150   9431.042   NA           NA
12  D200-500_151  87075.956    5 1.017121e+07
13  D200-500_151  87075.956   10 1.235177e+06
14  D200-500_151  87075.956   15 3.401218e+06
15  D200-500_151  87075.956   20 8.209838e+05
16  D200-500_151  87075.956   25 4.300391e+05
17  D200-500_151  87075.956   30 1.303149e+05
18  D200-500_159     74.351   NA           NA
19   D500-750_20    264.069    5 8.891929e+03
20   D500-750_20    264.069   10 2.667579e+04
21   D500-750_20    264.069   15 8.891929e+03
22   D500-750_20    264.069   20 3.556771e+04
23   D500-750_20    264.069   30 8.891929e+03
24   D500-750_25   5200.698   10 3.255238e+05
25   D500-750_25   5200.698   15 2.140376e+03
26   D500-750_25   5200.698   20 8.530719e+04
27   D500-750_25   5200.698   25 1.759336e+06
28   D500-750_25   5200.698   30 1.553293e+07
29   D500-750_25   5200.698   35 2.183820e+06
30   D500-750_25   5200.698   40 1.105606e+05
31    D0-200_247  56290.186   NA           NA
32     D0-200_53   1359.868   NA           NA
33  D200-500_149 320225.719    5 1.859510e+07
34  D200-500_149 320225.719   10 5.656807e+06
35  D200-500_150   9431.042   NA           NA
36  D200-500_151  87075.956    5 1.594400e+07
```

```
37 D200-500_151  87075.956   10 2.017389e+06
38 D200-500_151  87075.956   15 1.466042e+05
39 D200-500_151  87075.956   30 1.466042e+05
40 D200-500_159     74.351   NA           NA
41   D500-750_20   264.069   NA           NA
42   D500-750_25  5200.698   NA           NA
Reading:
Process output SuperIndAbundance
Running 50 bootstrap replicates:
   |++++++++++++++++++++++++++++++++++++++++++++++++++| 100% elapsed = 09s
Imputing missing data (50 replicates):
   |++++++++++++++++++++++++++++++++++++++++++++++++++| 100% elapsed = 13s
Abundance by age for  bootstrap
 Abundance by age for  bootstrapImpute
    age   Ab.Sum.5%   Ab.Sum.50%   Ab.Sum.95%  Ab.Sum.mean    Ab.Sum.sd Ab.Sum.cv
1    NA 852.5598713 1.192205e+03 1852.9286571 1.259498e+03 3.024151e+02 0.2401077
2     1   0.4949455 9.905071e-01    1.7846258 1.068175e+00 4.123663e-01 0.3860477
3     2   0.0000000 3.023228e-01    0.6140623 3.206297e-01 1.910223e-01 0.5957722
4     3   1.2461782 2.267718e+00    3.6584590 2.308953e+00 7.785959e-01 0.3372074
5     4   2.1801774 3.058495e+00    4.0800217 3.102747e+00 7.187245e-01 0.2316413
6     5   0.8295220 1.474522e+00    2.0677159 1.443573e+00 4.176425e-01 0.2893117
7     6   3.0797492 4.523918e+00    6.2935628 4.499433e+00 1.011365e+00 0.2247761
8     7   3.9132220 5.413227e+00    7.9823251 5.600642e+00 1.278260e+00 0.2282345
9     8   6.4659741 1.678121e+01   27.9486923 1.595487e+01 6.622911e+00 0.4151027
10    9   8.2904826 1.558937e+01   26.8587724 1.663841e+01 6.206226e+00 0.3730059
11   10   2.3927647 4.996600e+00    7.4687025 4.881954e+00 1.537974e+00 0.3150324
12   11   1.4404720 3.405440e+00    5.1049598 3.290295e+00 1.212811e+00 0.3686024
13   12   2.6324636 5.924707e+00   10.5015517 6.093463e+00 2.520726e+00 0.4136772
14   13   4.3188211 1.203326e+01   19.7134556 1.181800e+01 4.444249e+00 0.3760577
15   14   7.4996584 1.461614e+01   26.7711053 1.528374e+01 6.048217e+00 0.3957290
16   15   5.9252979 1.305089e+01   18.3571142 1.273881e+01 4.413983e+00 0.3464987
17   16   2.1179686 2.762177e+00    3.8399927 2.903583e+00 5.525837e-01 0.1903110
18   17   0.0000000 2.886478e-01    0.4983460 2.962843e-01 1.587536e-01 0.5358153
19   18   0.3187162 1.256214e+00    1.9796634 1.208259e+00 5.055103e-01 0.4183790
20   19   0.0443591 2.781435e-01    0.4924706 2.833291e-01 1.412407e-01 0.4985039
21   20   0.0000000 4.795495e+00    6.5721233 3.516629e+00 2.750288e+00 0.7820808
22   21   0.0000000 1.909856e-01    0.2968137 1.404562e-01 1.221444e-01 0.8696263
23   22   0.0000000 2.771559e-01    0.5757714 3.053534e-01 1.733908e-01 0.5678364
24   23   1.0321308 2.766072e+00    3.9379232 2.638105e+00 9.844345e-01 0.3731597
25   24   0.5825101 2.177306e+00    2.9822346 1.984862e+00 7.660279e-01 0.3859351
26   27   0.0000000 9.728829e-03    0.0209812 1.025871e-02 6.553456e-03 0.6388185
27   28   0.0000000 9.801897e-01    1.4049677 7.494470e-01 5.489474e-01 0.7324700
28   43   0.0000000 2.495919e-01    0.3655553 1.929497e-01 1.464456e-01 0.7589834
   age  Ab.Sum.5%  Ab.Sum.50%  Ab.Sum.95% Ab.Sum.mean  Ab.Sum.sd Ab.Sum.cv
1    1 29.5625169  47.3756969  69.2779432  47.9332180 12.3255485 0.2571400
2    2  0.0000000   8.4289890  18.5257700   8.1305192  6.8637135 0.8441913
3    3 13.2998144  22.8810430  38.3469472  24.3141328  8.5200962 0.3504174
4    4 17.0584728  26.3948203  37.3559356  26.9555741  6.1335088 0.2275414
5    5  6.5028653  12.2764665  18.5046558  12.1230313  3.5860724 0.2958066
6    6 25.4212006  39.4728146  58.5083646  41.1493651 10.4713028 0.2544706
7    7 30.4462995  46.4712235  75.6792338  49.7579469 14.5220586 0.2918541
8    8 56.7062528 198.5552054 312.8588570 183.5585742 90.6929957 0.4940820
9    9 67.5484317 108.2350258 177.1392570 113.5727757 34.7456638 0.3059330
10  10 61.4572070 105.4324489 206.6988468 109.4211931 43.4015897 0.3966470
11  11 24.4979637  66.5511738 121.5305546  66.2235148 32.4367733 0.4898075
12  12 54.8686821 113.3368121 214.7652136 122.9304105 49.6463400 0.4038573
13  13 95.3590343 199.0956192 321.2356246 207.5484428 73.7792477 0.3554796
14  14 44.9535549 169.5211257 307.3238160 175.7047815 84.2461144 0.4794754
15  15 48.7878442 119.5653972 178.3041838 116.8980280 41.6191778 0.3560298
16  16 12.8169478  21.8626726  36.4043224  23.2216471  7.6595934 0.3298471
17  17  0.0000000   1.4115692   4.7212346   1.8156181  1.5642829 0.8615704
18  18  0.6015320   4.1301551   9.7895479   4.5343299  2.9150266 0.6428793
19  19  0.7016476   2.1695300   6.4668253   2.7921912  1.9277157 0.6903953
20  20  0.0000000  24.2590036  34.1308443  18.2452013 14.5537515 0.7976756
21  21  0.0000000   0.3963979   2.1613341   0.6418016  0.6601986 1.0286647
22  22  0.0000000   0.9490052   2.4534763   1.1059308  0.8818401 0.7973736
23  23  3.2635070   8.5224048  14.5157181   8.6799322  3.5703148 0.4113298
24  24  1.6378148   9.0640835  18.2466666   9.8768083  5.1754497 0.5240002
25  27  0.0000000   0.1732369   0.5018545   0.1826857  0.1584396 0.8672801
26  28  0.0000000   1.1364827   2.6101954   1.0041824  0.8483925 0.8448590
27  43  0.0000000   0.3105339   1.3223569   0.4492651  0.6078020 1.3528806
>
>
> ## check content of lists
```

```
> summary(mikkolengthv2)
     Length Class      Mode
[1,] 3      data.frame list
> summary(mikkoagev2)
     Length Class      Mode
[1,] 3      data.frame list
>
>
> ## Create length table for all years - AFWG strata
> length_mikkov2 <- mikkolengthv2[[1]]
> head(length_mikkov2)
  year Lgrp numbers_length
1 2003    5       51295291
2 2003   10       39798325
3 2003   15       35577632
4 2003   20      133223874
5 2003   25      321542606
6 2003   30      627650272
>
> #ivec <- 2:(length(years)+1)
> #ivec <- ivec[-7]
> ivec <- 2:(length(years))
> ivec
[1] 2 1
>
> for (i in ivec){
+   length_mikkov2 <- rbind(length_mikkov2, mikkolengthv2[[i]])
+ }
>
>
> ## Create 45+ group
> dim(length_mikkov2)
[1] 8 3
> length_mikkov2 <- subset(length_mikkov2, Lgrp!="NA")
> dim(length_mikkov2)
[1] 8 3
>
>
> length_low <- subset(length_mikkov2, Lgrp<45)
> length_high <- subset(length_mikkov2, Lgrp>=45)
> dim(length_low)
[1] 8 3
> dim(length_high)
[1] 0 3
>
> temp <- length_high %>%
+   ddply("year", summarise,
+         numbers_length=sum(numbers_length))
>
> temp$Lgrp <- 45
>
> temp <- temp[,c(1,3,2)]
>
> length_mikkov2 <- rbind(length_low, temp)
> length_mikkov2$model <- "Depth"
> length_mikkov2$numbers_length <- (length_mikkov2$numbers_length)/1000
> length_mikkov2 <- subset(length_mikkov2, Lgrp!=0)
>
> ## Create age table for all years - AFWG strata
> age_mikkov2 <- mikkoagev2[[1]]
>
> for (i in ivec){
+   age_mikkov2 <- rbind(age_mikkov2, mikkoagev2[[i]])
+ }
>
>
> ## Create 16+ group
> dim(age_mikkov2)
[1] 27  3
> age_mikkov2 <- subset(age_mikkov2, age!="NA")
> dim(age_mikkov2)
[1] 27  3
>
> age_low <- subset(age_mikkov2, age<16)
```

```
> age_high <- subset(age_mikkov2, age>=16)
> dim(age_low)
[1] 15  3
> dim(age_high)
[1] 12  3
>
> temp <- age_high %>%
+   ddply("year", summarise,
+         numbers_age=sum(numbers_age))
>
> temp$age <- 16
>
> temp <- temp[,c(1,3,2)]
>
> age_mikkov2 <- rbind(age_low, temp)
> age_mikkov2$numbers_age <- age_mikkov2$numbers_age*1000
> age_mikkov2$model <- "Depth"
> age_mikkov2 <- subset(age_mikkov2, age!=1)
>
> ## Create age table with uncertainties - Mikkov2
> uncertainv2_age <- age_uncertainv2[[1]]
> head(uncertainv2_age)
  year age Ab.Sum.5. Ab.Sum.50. Ab.Sum.95. Ab.Sum.mean Ab.Sum.sd Ab.Sum.cv
1 2003   1 29.562517  47.375697   69.27794   47.933218 12.325548 0.2571400
2 2003   2  0.000000   8.428989   18.52577    8.130519  6.863713 0.8441913
3 2003   3 13.299814  22.881043   38.34695   24.314133  8.520096 0.3504174
4 2003   4 17.058473  26.394820   37.35594   26.955574  6.133509 0.2275414
5 2003   5  6.502865  12.276467   18.50466   12.123031  3.586072 0.2958066
6 2003   6 25.421201  39.472815   58.50836   41.149365 10.471303 0.2544706
>
> #ivec <- 2:(length(years)+1)
> #ivec <- ivec[-7]
> ivec <- 2:(length(years))
> ivec
[1] 2 1
>
> for (i in ivec){
+   uncertainv2_age <- rbind(uncertainv2_age, age_uncertainv2[[i]])
+ }
>
> names(uncertainv2_age) <- c("year", "age", "p05", "p50", "p95", "mean", "sd", "cv")
>
>
> ## Create 16+ group
> dim(uncertainv2_age)
[1] 27  8
> uncertainv2_age <- subset(uncertainv2_age, age!="NA")
> dim(uncertainv2_age)
[1] 27  8
>
> age_low <- subset(uncertainv2_age, age<16)
> age_high <- subset(uncertainv2_age, age>=16)
> dim(age_low)
[1] 15  8
> dim(age_high)
[1] 12  8
>
> temp <- age_high %>%
+   ddply("year", summarise,
+         p05=sum(p05), p50=sum(p50), p95=sum(p95),
+         mean=sum(mean), sd=mean(sd), cv=mean(cv))
>
> temp$age <- 16
>
> temp <- temp[,c(1,8,2,3,4,5,6,7)]
>
> uncertainv2_age <- rbind(age_low, temp)
> uncertainv2_age$model <- "Depth"
> uncertainv2_age$mean <- uncertainv2_age$mean*1000
> uncertainv2_age$p05 <- uncertainv2_age$p05*1000
> uncertainv2_age$p95 <- uncertainv2_age$p95*1000
> uncertainv2_age <- subset(uncertainv2_age, age!=1)
>
```

```
> for (i in years){
+
+   #lengthlist <- list()
+   #agelist <- list()
+
+   ######### New standard strata - WKT_Basic_ECO.txt ######################
+
+   ## Extract data
+   #system.time(projects<-getNMDdata(cruise=myCS, group="year", subset = i, model="SweptAre
TRUE, abbrev=T, ow=TRUE,run = TRUE))
+
+   projects <- allpr[[i-pre]]
+
+   cruise.path=projects
+
+   ################## Setting of parameters - checked and confirmed with Tone #############
+
+
+   ### Different Strata options - replace strata line in code below
+
+   # FileName="${STOX}/reference/stratum/Barents_Sea_Ecosystem_Survey_Areas_v2017.txt"),
+   # FileName="${STOX}/reference/stratum/eco_strata.wkt"),
+   #FileName="${STOX}/reference/stratum/eco_afwg.txt"),
+
+   ## parameters
+   params <- list(FilterBiotic=list(functionName="FilterBiotic",
+                                    BioticData="Process(ReadBioticXML)",
+                                    #FishStationExpr="gear=~['3270','3271'] and gearconditi
lity =~['1'] and fishstationtype != ['2','C']",
+                                    FishStationExpr="gear<'3500' and gearcondition < 3 and
] and fishstationtype != ['2','C']",
+                                    CatchExpr="species =~['166756', '166705']"),
+                  DefineStrata=list(functionName="DefineStrata",
+                                    ProcessData="Process(ReadProcessData)",
+                                    UseProcessData=FALSE,
+                                    FileName="${STOX}/reference/stratum/WKT_Basic_ECO.txt")
+                  SweptAreaDensity=list(functionName="SweptAreaDensity",
+                                        FishingWidthMethod="Constant",
+                                        FishingWidth="25"),
+                  StratumArea=list(AreaMethod="Accurate"),
+                  RegroupLengthDist=list(LengthInterval="5"))
+
+   ## run Baseline
+   runBaseline(projects, parlist=params, save=TRUE) # Test
+
+   readBaselineParametersJava(projects) # this will show the updated baseline parameters in
+
+   # get the output
+   X=getBaseline(projects)
+
+   # Show superindividuals:
+   head(X$outputData$SuperIndAbundance)
+
+   ### Numbers-at-length
+   Y=data.frame(stratum=X$outputData$Abundance$SampleUnit,area=X$outputData$Abundance$Area,
Abundance$LengthGroup,abundance=X$outputData$Abundance$Abundance)
+   print(Y)
+
+   # group_by
+   Y <- subset(Y, abundance!="NA")
+   dim(Y)
+
+   Y_length <- Y %>%
+     ddply("Lgrp", summarise,
+           numbers_length=sum(abundance))
+
+   Y_length$year <- i
+
+   Y_length <- Y_length[,c(3,1,2)]
+
+   #Y_strata <- Y %>%
+   #  group_by(length, stratum) %>%
+   #  summarise(numbers_length=sum(abundance)) #and then by stratum - similar to sumif()
+
```

```
+   #Y_length <- Y %>%
+   # group_by(Lgrp) %>%
+   #summarise(numbers_length=sum(abundance)) #calculates numbers per lenght class - similar
+
+   #write.table(Y, file=paste("index_length_rstox", year, ".txt", sep=""), sep="\t")
+
+
+   ### Bootstrapping and numbers-at-age ###############
+
+   # Run the bootstrapping to generate estimates of the variability in the data (cv):
+   rb1 <- runBootstrap(projects, nboot=50, cores=1, seed=1234, bioticMethod=PSU~Stratum, bo
tAreaLength")
+   # Fill in missing data (missing length, weight and so on) based on the age information:
+   rb2 <- imputeByAge(projects,seed = 1234, cores =1, saveInd = TRUE)
+
+   # Save the bootstrap data:
+   saveProjectData(projects)
+
+   # Generate plots and reports:
+   plotfiles <- getPlots(projects)
+   reportfiles <- getReports(projects)
+
+   ### Extract rstox table for comparison
+   age_table=read.delim(paste0(cruise.path,"/output/r/report/bootstrapImpute_Abundance_age.
+
+   age_table$year <- i
+   age_table <- age_table[,c(8,1,2,3,4,5,6,7)]
+   age_uncertainv3[[i-pre]] <- age_table
+
+   #write.table(age_table, file=paste("index_age_rstox", year, ".txt", sep=""), sep="\t")
+
+   Y_age <-  data.frame(age_table$age)
+   Y_age$numbers_age <- age_table$Ab.Sum.mean
+   Y_age$year <- i
+   names(Y_age) <- c("age", "numbers_age", "year")
+
+   Y_age <- Y_age[,c(3,1,2)]
+
+
+   basiclength[[i-pre]] <-Y_length
+   basicage[[i-pre]] <- Y_age
+
+   ############### End of standard RStoX process ###################
+
+ }
Running baseline process 6 to 15 (out of 15 processes)
Reading:
Baseline parameters
Process output ReadProcessData
Process output ReadBioticXML
Process output FilterBiotic
Process output StationLengthDist
Process output RegroupLengthDist
Process output DefineStrata
Process output StratumArea
Process output DefineSweptAreaPSU
Process output TotalLengthDist
Process output SweptAreaDensity
Process output MeanDensity_Stratum
Process output Abundance
Process output IndividualDataStations
Process output IndividualData
Process output SuperIndAbundance
Process output WriteProcessData
Process data bioticassignment
Process data suassignment
Process data assignmentresolution
Process data edsupsu
Process data psustratum
Process data stratumpolygon
Process data temporal
Process data gearfactor
Process data spatial
Process data platformfactor
```

```
Process data covparam
Process data ageerror
Process data stratumneighbour
   stratum     area Lgrp    abundance
1        1 42347.07    5    983446.78
2        1 42347.07   10   1856966.49
3        1 42347.07   15   1706650.34
4        1 42347.07   20   6523853.91
5        1 42347.07   25   8616004.41
6        1 42347.07   30  23098541.67
7        1 42347.07   35   3798072.58
8        1 42347.07   40    351329.79
9        2 85314.83   20   5266768.95
10       2 85314.83   25   2633384.48
11       2 85314.83   30   2633384.48
12       3 16326.97    5   1027664.53
13       3 16326.97   10   3496868.41
14       3 16326.97   15   3144098.04
15       3 16326.97   20  15988292.43
16       3 16326.97   25  24972045.20
17       3 16326.97   30  14055269.27
18       3 16326.97   35   3298816.74
19       3 16326.97   40    243377.34
20       4 41556.31    5    671116.59
21       4 41556.31   10   2146792.07
22       4 41556.31   15   4626893.77
23       4 41556.31   20   5469308.58
24       4 41556.31   25  55271456.18
25       4 41556.31   30 193867316.67
26       4 41556.31   35  52008991.71
27       4 41556.31   40   1093648.19
28       5 42165.29   NA           NA
29       6 34890.13    5    254135.55
30       6 34890.13   10    526505.04
31       6 34890.13   15   1905446.82
32       6 34890.13   20   4552787.10
33       6 34890.13   25  19654021.67
34       6 34890.13   30  58745182.75
35       6 34890.13   35  12460823.01
36       6 34890.13   40    424595.04
37       7 22716.01   15    116861.23
38       8 79168.49    5   7853612.05
39       8 79168.49   10   1033790.38
40       8 79168.49   20    200506.03
41       8 79168.49   25     87273.83
42       1 42347.07    5   5098431.53
43       1 42347.07   10    706809.15
44       2 85314.83   NA           NA
45       3 16326.97    5   2658742.28
46       3 16326.97   10    817332.06
47       4 41556.31    5   2806353.76
48       4 41556.31   10     72605.93
49       5 42165.29   NA           NA
50       6 34890.13   15     89745.18
51       6 34890.13   30     89745.18
52       7 22716.01   NA           NA
53       8 79168.49    5   3544660.25
54       8 79168.49   10   1204378.88
Reading:
Process output SuperIndAbundance
Running 50 bootstrap replicates:
   |++++++++++++++++++++++++++++++++++++++++++++++++++| 100% elapsed = 08s
Imputing missing data (50 replicates):
   |++++++++++++++++++++++++++++++++++++++++++++++++++| 100% elapsed = 11s
Abundance by age for  bootstrap
 Abundance by age for  bootstrapImpute
    age    Ab.Sum.5%   Ab.Sum.50%   Ab.Sum.95%  Ab.Sum.mean    Ab.Sum.sd Ab.Sum.cv
1    NA 349.49012202 489.85756184 624.56114399 491.22290165 87.95226171 0.1790476
2     1   0.28913677   0.62534590   1.11160886   0.65337010  0.25559590 0.3911962
3     2   0.00000000   0.17441072   0.33930105   0.17031382  0.10941302 0.6424201
4     3   0.63274998   1.17078450   1.79281165   1.19722488  0.37193615 0.3106652
5     4   1.20154952   1.76184636   2.37321722   1.81120601  0.40179371 0.2218377
6     5   0.42696930   0.80738692   1.21711680   0.79445681  0.24951756 0.3140732
7     6   2.30743801   4.62917116   9.00414484   4.90642088  2.20115087 0.4486266
```

```
8    7    1.99259073   7.71963052  15.71720524   7.62988840  4.58687368 0.6011718
9    8    3.23658134   4.98521502   7.64443939   5.18050561  1.29046681 0.2491006
10   9    5.27322936   8.77132221  13.25706457   8.93681702  2.69733216 0.3018225
11  10    1.62862795   2.42884663   3.48102307   2.51587518  0.63235375 0.2513454
12  11    1.20782144   4.25575155   8.88140218   4.33832715  2.44551862 0.5637008
13  12    1.23464363   3.43029787   5.17539403   3.24553664  1.19680783 0.3687550
14  13    1.90919379   2.59820140   4.32033658   2.84955120  0.78877580 0.2768070
15  14    2.54823963   7.07183725  11.67812639   7.03707564  2.64200159 0.3754403
16  15    2.77153140   5.26496738   7.67133327   5.33093971  1.54799138 0.2903787
17  16    0.77117213   1.43645692   1.93178640   1.39346915  0.35660809 0.2559139
18  17    0.00000000   0.15507499   0.28626069   0.16627173  0.09451653 0.5684462
19  18    0.22123602   0.85482775   1.20003147   0.79742409  0.30956856 0.3882107
20  19    0.05178904   0.16833929   0.29514190   0.16746502  0.08015572 0.4786416
21  20    0.00000000   2.38936270   3.84541819   1.89197773  1.40115225 0.7405754
22  21    0.00000000   0.09991543   0.21926177   0.08610937  0.07903489 0.9178431
23  22    0.00000000   0.14476768   0.29039910   0.14567105  0.09781501 0.6714787
24  23    0.26877801   0.65847866   1.23328519   0.70822865  0.31002398 0.4377456
25  24    0.15985678   0.67376902   1.11093477   0.67934418  0.29213629 0.4300269
26  28    0.00000000   0.42459504   0.84919007   0.39062743  0.34140467 0.8739905
27  43    0.00000000   0.03047677   0.05381288   0.02375597  0.02150848 0.9053924
   age  Ab.Sum.5% Ab.Sum.50%  Ab.Sum.95% Ab.Sum.mean  Ab.Sum.sd Ab.Sum.cv
1    1 10.3971117 22.3104221  34.5969796  22.1198099  7.2517997 0.3278419
2    2  0.0000000  2.6845932   7.9916056   3.2444488  2.7684762 0.8532963
3    3  4.0295061  6.7797150   9.4383936   6.8506484  1.7085359 0.2493977
4    4  6.4824702  8.7840917  14.9757378   9.4810886  2.9199250 0.3079736
5    5  1.6799468  3.7071035   5.7213892   3.7046505  1.2815154 0.3459207
6    6  9.1159099 13.6980243  18.2221155  13.4931611  2.7431042 0.2032959
7    7 10.1935701 19.9129027  30.4686913  19.9178618  6.1264988 0.3075882
8    8 25.1451477 47.0169784  76.5522760  49.4589967 16.5960163 0.3355510
9    9 30.7681949 50.1450841  76.8891091  51.7197394 14.4353942 0.2791080
10  10 15.1538995 43.9756087  84.8549525  44.8898823 20.4793111 0.4562122
11  11 13.6327522 31.3410251  65.6332502  35.3453099 18.9585673 0.5363814
12  12 20.5865405 69.1067920 111.2467288  68.1835203 30.2069861 0.4430247
13  13 35.5273612 55.0204635  96.4947682  58.7323043 20.5138146 0.3492765
14  14 24.7352217 79.4134292 130.9206656  82.6998746 36.2543373 0.4383844
15  15 21.0042965 58.8339402  91.0123874  57.4649872 23.0053892 0.4003375
16  16  4.1980332  9.0180167  15.5493839   9.6306899  3.7396562 0.3883062
17  17  0.0000000  0.6072781   1.3841369   0.6175830  0.4701604 0.7612910
18  18  0.2212360  1.2505590   2.7822192   1.3416186  0.8168378 0.6088450
19  19  0.1104016  0.6780661   1.5279585   0.7757292  0.5101283 0.6576113
20  20  0.0000000 12.3360699  19.7465397   9.7669746  7.4464733 0.7624135
21  21  0.0000000  0.1148675   0.5145826   0.1446322  0.1682553 1.1633317
22  22  0.0000000  0.1510817   0.3253942   0.1641661  0.1225061 0.7462326
23  23  0.5231789  1.3919211   2.4500635   1.5065356  0.5949600 0.3949193
24  24  0.7200635  1.9226789   4.7068880   2.4786340  2.1349143 0.8613270
25  28  0.0000000  0.4245950   0.8888043   0.4008534  0.3480420 0.8682527
26  43  0.0000000  0.1191298   0.3941959   0.1370547  0.1454142 1.0609942
>
>
> ## check content of lists
> summary(basiclength)
     Length Class      Mode
[1,] 3      data.frame list
> summary(basicage)
     Length Class      Mode
[1,] 3      data.frame list
>
>
> ## Create length table for all years - AFWG strata
> length_basic <- basiclength[[1]]
> head(length_basic)
  year Lgrp numbers_length
1 2003    5       24898163
2 2003   10       11862048
3 2003   15       11589695
4 2003   20       38001517
5 2003   25      111234186
6 2003   30      292489440
>
> #ivec <- 2:(length(years)+1)
> #ivec <- ivec[-7]
> ivec <- 2:(length(years))
> ivec
[1] 2 1
```

```
>
> for (i in ivec){
+   length_basic <- rbind(length_basic, basiclength[[i]])
+ }
>
> write.csv(length_basic, "length_basic.csv")
>
> ## Create 45+ group
> dim(length_basic)
[1] 8 3
> length_basic <- subset(length_basic, Lgrp!="NA")
> dim(length_basic)
[1] 8 3
>
>
> length_low <- subset(length_basic, Lgrp<45)
> length_high <- subset(length_basic, Lgrp>=45)
> dim(length_low)
[1] 8 3
> dim(length_high)
[1] 0 3
>
> temp <- length_high %>%
+   ddply("year", summarise,
+         numbers_length=sum(numbers_length))
>
> temp$Lgrp <- 45
>
> temp <- temp[,c(1,3,2)]
>
> length_basic <- rbind(length_low, temp)
> length_basic$model <- "Basic"
> length_basic$numbers_length <- (length_basic$numbers_length)/1000
> length_basic <- subset(length_basic, Lgrp!=0)
>
> ## Create age table for all years - AFWG strata
> age_basic <- basicage[[1]]
>
> for (i in ivec){
+   age_basic <- rbind(age_basic, basicage[[i]])
+ }
Error in basicage[[i]] : subscript out of bounds
>
>
> ## Create 16+ group
> dim(age_basic)
[1] 26  3
> age_basic <- subset(age_basic, age!="NA")
> dim(age_basic)
[1] 26  3
>
> age_low <- subset(age_basic, age<16)
> age_high <- subset(age_basic, age>=16)
> dim(age_low)
[1] 15  3
> dim(age_high)
[1] 11  3
>
> temp <- age_high %>%
+   ddply("year", summarise,
+         numbers_age=sum(numbers_age))
>
> temp$age <- 16
>
> temp <- temp[,c(1,3,2)]
>
> age_basic <- rbind(age_low, temp)
> age_basic$numbers_age <- age_basic$numbers_age*1000
> age_basic$model <- "Basic"
> age_basic <- subset(age_basic, age!=1)
>
> ## Create age table with uncertainv3ties - basic
> uncertainv3_age <- age_uncertainv3[[1]]
> head(uncertainv3_age)
```

```
  year age Ab.Sum.5. Ab.Sum.50. Ab.Sum.95. Ab.Sum.mean Ab.Sum.sd Ab.Sum.cv
1 2003   1 10.397112  22.310422  34.596980   22.119810  7.251800 0.3278419
2 2003   2  0.000000   2.684593   7.991606    3.244449  2.768476 0.8532963
3 2003   3  4.029506   6.779715   9.438394    6.850648  1.708536 0.2493977
4 2003   4  6.482470   8.784092  14.975738    9.481089  2.919925 0.3079736
5 2003   5  1.679947   3.707104   5.721389    3.704650  1.281515 0.3459207
6 2003   6  9.115910  13.698024  18.222116   13.493161  2.743104 0.2032959
>
> #ivec <- 2:(length(years)+1)
> #ivec <- ivec[-7]
> ivec <- 2:(length(years))
> ivec
[1] 2 1
>
> for (i in ivec){
+   uncertainv3_age <- rbind(uncertainv3_age, age_uncertainv3[[i]])
+ }
>
> names(uncertainv3_age) <- c("year", "age", "p05", "p50", "p95", "mean", "sd", "cv")
>
> write.csv(uncertainv3_age, "uncertain_age_basic.csv")
>
> ## Create 16+ group
> dim(uncertainv3_age)
[1] 26  8
> uncertainv3_age <- subset(uncertainv3_age, age!="NA")
> dim(uncertainv3_age)
[1] 26  8
>
> age_low <- subset(uncertainv3_age, age<16)
> age_high <- subset(uncertainv3_age, age>=16)
> dim(age_low)
[1] 15  8
> dim(age_high)
[1] 11  8
>
> temp <- age_high %>%
+   ddply("year", summarise,
+         p05=sum(p05), p50=sum(p50), p95=sum(p95),
+         mean=sum(mean), sd=mean(sd), cv=mean(cv))
>
> temp$age <- 16
>
> temp <- temp[,c(1,8,2,3,4,5,6,7)]
>
> uncertainv3_age <- rbind(age_low, temp)
> uncertainv3_age$model <- "Basic"
> uncertainv3_age$mean <- uncertainv3_age$mean*1000
> uncertainv3_age$p05 <- uncertainv3_age$p05*1000
> uncertainv3_age$p95 <- uncertainv3_age$p95*1000
> uncertainv3_age <- subset(uncertainv3_age, age!=1)
>
>
> for (i in years){
+
+   #lengthlist <- list()
+   #agelist <- list()
+
+   ######### New standard strata - WKT_Basic_plus.txt ######################
+
+   ## Extract data
+   #system.time(projects<-getNMDdata(cruise=myCS, group="year", subset = i, model="SweptAre
TRUE, abbrev=T, ow=TRUE,run = TRUE))
+
+   projects <- allpr[[i-pre]]
+
+   cruise.path=projects
+
+   ################# Setting of parameters - checked and confirmed with Tone ############
+
+
+   ### Different Strata options - replace strata line in code below
+
+   # FileName="${STOX}/reference/stratum/Barents_Sea_Ecosystem_Survey_Areas_v2017.txt"),
```

```
+   # FileName="${STOX}/reference/stratum/eco_strata.wkt"),
+   #FileName="${STOX}/reference/stratum/eco_afwg.txt"),
+
+   ## parameters
+   params <- list(FilterBiotic=list(functionName="FilterBiotic",
+                                    BioticData="Process(ReadBioticXML)",
+                                    #FishStationExpr="gear=~['3270','3271'] and gearconditi
lity =~['1'] and fishstationtype != ['2','C']",
+                                    FishStationExpr="gear<'3500' and gearcondition < 3 and
] and fishstationtype != ['2','C']",
+                                    CatchExpr="species =~['166756', '166705']"),
+                  DefineStrata=list(functionName="DefineStrata",
+                                    ProcessData="Process(ReadProcessData)",
+                                    UseProcessData=FALSE,
+                                    FileName="${STOX}/reference/stratum/WKT_Basic_plus.txt"
+                  SweptAreaDensity=list(functionName="SweptAreaDensity",
+                                        FishingWidthMethod="Constant",
+                                        FishingWidth="25"),
+                  StratumArea=list(AreaMethod="Accurate"),
+                  RegroupLengthDist=list(LengthInterval="5"))
+
+   ## run Baseline
+   runBaseline(projects, parlist=params, save=TRUE) # Test
+
+   readBaselineParametersJava(projects) # this will show the updated baseline parameters in
+
+   # get the output
+   X=getBaseline(projects)
+
+   # Show superindividuals:
+   head(X$outputData$SuperIndAbundance)
+
+   ### Numbers-at-length
+   Y=data.frame(stratum=X$outputData$Abundance$SampleUnit,area=X$outputData$Abundance$Area,
Abundance$LengthGroup,abundance=X$outputData$Abundance$Abundance)
+   print(Y)
+
+   # group_by
+   Y <- subset(Y, abundance!="NA")
+   dim(Y)
+
+   Y_length <- Y %>%
+     ddply("Lgrp", summarise,
+           numbers_length=sum(abundance))
+
+   Y_length$year <- i
+
+   Y_length <- Y_length[,c(3,1,2)]
+
+   #Y_strata <- Y %>%
+   #  group_by(length, stratum) %>%
+   #  summarise(numbers_length=sum(abundance)) #and then by stratum - similar to sumif()
+
+   #Y_length <- Y %>%
+   # group_by(Lgrp) %>%
+   #summarise(numbers_length=sum(abundance)) #calculates numbers per lenght class - similar
+
+   #write.table(Y, file=paste("index_length_rstox", year, ".txt", sep=""), sep="\t")
+
+
+   ### Bootstrapping and numbers-at-age ###############
+
+   # Run the bootstrapping to generate estimates of the variability in the data (cv):
+   rb1 <- runBootstrap(projects, nboot=50, cores=1, seed=1234, bioticMethod=PSU~Stratum, bo
tAreaLength")
+   # Fill in missing data (missing length, weight and so on) based on the age information:
+   rb2 <- imputeByAge(projects,seed = 1234, cores =1, saveInd = TRUE)
+
+   # Save the bootstrap data:
+   saveProjectData(projects)
+
+   # Generate plots and reports:
+   plotfiles <- getPlots(projects)
+   reportfiles <- getReports(projects)
```

```
+
+   ### Extract rstox table for comparison
+   age_table=read.delim(paste0(cruise.path,"/output/r/report/bootstrapImpute_Abundance_age.
+
+   age_table$year <- i
+   age_table <- age_table[,c(8,1,2,3,4,5,6,7)]
+   age_uncertainv4[[i-pre]] <- age_table
+
+   #write.table(age_table, file=paste("index_age_rstox", year, ".txt", sep=""), sep="\t")
+
+   Y_age <-  data.frame(age_table$age)
+   Y_age$numbers_age <- age_table$Ab.Sum.mean
+   Y_age$year <- i
+   names(Y_age) <- c("age", "numbers_age", "year")
+
+   Y_age <- Y_age[,c(3,1,2)]
+
+
+   basicpluslength[[i-pre]] <-Y_length
+   basicplusage[[i-pre]] <- Y_age
+
+   ############### End of standard RStoX process ####################
+
+ }
Running baseline process 6 to 15 (out of 15 processes)
Reading:
Baseline parameters
Process output ReadProcessData
Process output ReadBioticXML
Process output FilterBiotic
Process output StationLengthDist
Process output RegroupLengthDist
Process output DefineStrata
Process output StratumArea
Process output DefineSweptAreaPSU
Process output TotalLengthDist
Process output SweptAreaDensity
Process output MeanDensity_Stratum
Process output Abundance
Process output IndividualDataStations
Process output IndividualData
Process output SuperIndAbundance
Process output WriteProcessData
Process data bioticassignment
Process data suassignment
Process data assignmentresolution
Process data edsupsu
Process data psustratum
Process data stratumpolygon
Process data temporal
Process data gearfactor
Process data spatial
Process data platformfactor
Process data covparam
Process data ageerror
Process data stratumneighbour
       stratum      area Lgrp    abundance
1            1 42347.067    5 9.834468e+05
2            1 42347.067   10 1.856966e+06
3            1 42347.067   15 1.706650e+06
4            1 42347.067   20 6.523854e+06
5            1 42347.067   25 8.616004e+06
6            1 42347.067   30 2.309854e+07
7            1 42347.067   35 3.798073e+06
8            1 42347.067   40 3.513298e+05
9            2 85314.832   20 5.266769e+06
10           2 85314.832   25 2.633384e+06
11           2 85314.832   30 2.633384e+06
12           3 16326.968    5 1.027665e+06
13           3 16326.968   10 3.496868e+06
14           3 16326.968   15 3.144098e+06
15           3 16326.968   20 1.598829e+07
16           3 16326.968   25 2.497205e+07
17           3 16326.968   30 1.405527e+07
```

```
18           3 16326.968   35 3.298817e+06
19           3 16326.968   40 2.433773e+05
20           4 41556.311    5 6.711166e+05
21           4 41556.311   10 2.146792e+06
22           4 41556.311   15 4.626894e+06
23           4 41556.311   20 5.469309e+06
24           4 41556.311   25 5.527146e+07
25           4 41556.311   30 1.938673e+08
26           4 41556.311   35 5.200899e+07
27           4 41556.311   40 1.093648e+06
28           5 42165.290   NA           NA
29           6 34890.134    5 2.541355e+05
30           6 34890.134   10 5.265050e+05
31           6 34890.134   15 1.905447e+06
32           6 34890.134   20 4.552787e+06
33           6 34890.134   25 1.965402e+07
34           6 34890.134   30 5.874518e+07
35           6 34890.134   35 1.246082e+07
36           6 34890.134   40 4.245950e+05
37           7 22716.006   15 1.168612e+05
38           8 79168.487    5 7.853612e+06
39           8 79168.487   10 1.033790e+06
40           8 79168.487   20 2.005060e+05
41           8 79168.487   25 8.727383e+04
42 D500-750_20   264.069    5 8.891929e+03
43 D500-750_20   264.069   10 2.667579e+04
44 D500-750_20   264.069   15 8.891929e+03
45 D500-750_20   264.069   20 3.556771e+04
46 D500-750_20   264.069   30 8.891929e+03
47 D500-750_25  5200.698   10 3.255238e+05
48 D500-750_25  5200.698   15 2.140376e+03
49 D500-750_25  5200.698   20 8.530719e+04
50 D500-750_25  5200.698   25 1.759336e+06
51 D500-750_25  5200.698   30 1.553293e+07
52 D500-750_25  5200.698   35 2.183820e+06
53 D500-750_25  5200.698   40 1.105606e+05
54           1 42347.067    5 5.098432e+06
55           1 42347.067   10 7.068091e+05
56           2 85314.832   NA           NA
57           3 16326.968    5 2.658742e+06
58           3 16326.968   10 8.173321e+05
59           4 41556.311    5 2.806354e+06
60           4 41556.311   10 7.260593e+04
61           5 42165.290   NA           NA
62           6 34890.134   15 8.974518e+04
63           6 34890.134   30 8.974518e+04
64           7 22716.006   NA           NA
65           8 79168.487    5 3.544660e+06
66           8 79168.487   10 1.204379e+06
67 D500-750_20   264.069   NA           NA
68 D500-750_25  5200.698   NA           NA
Reading:
Process output SuperIndAbundance
Running 50 bootstrap replicates:
   |++++++++++++++++++++++++++++++++++++++++++++++++++| 100% elapsed = 10s
Imputing missing data (50 replicates):
   |++++++++++++++++++++++++++++++++++++++++++++++++++| 100% elapsed = 12s
Abundance by age for  bootstrap
 Abundance by age for  bootstrapImpute
    age    Ab.Sum.5%    Ab.Sum.50%   Ab.Sum.95%  Ab.Sum.mean    Ab.Sum.sd Ab.Sum.cv
1    NA 3.683562e+02 5.033052e+02 653.01655403 508.43325294 92.023376811 0.1809940
2     1 2.891368e-01 6.253459e-01   1.11160886   0.65337010  0.255595896 0.3911962
3     2 0.000000e+00 1.744107e-01   0.33930105   0.17031382  0.109413020 0.6424201
4     3 6.327500e-01 1.170784e+00   1.79281165   1.19722488  0.371936154 0.3106652
5     4 1.201550e+00 1.761846e+00   2.37321722   1.81120601  0.401793710 0.2218377
6     5 4.269693e-01 8.073869e-01   1.21711680   0.79445681  0.249517560 0.3140732
7     6 2.307438e+00 4.629171e+00   9.00414484   4.90642088  2.201150866 0.4486266
8     7 1.992591e+00 7.719631e+00  15.71720524   7.62988840  4.586873676 0.6011718
9     8 3.485090e+00 5.430106e+00   8.21966819   5.49755317  1.419298514 0.2581691
10    9 5.295431e+00 9.079785e+00  13.92751044   9.23429203  2.808024500 0.3040866
11   10 1.628628e+00 2.428847e+00   3.48102307   2.51587518  0.632353751 0.2513454
12   11 1.207821e+00 4.255752e+00   8.88140218   4.33832715  2.445518619 0.5637008
13   12 1.234644e+00 3.430298e+00   5.17539403   3.24553664  1.196807826 0.3687550
14   13 2.041945e+00 3.153448e+00   5.57460267   3.44495209  1.118960219 0.3248115
```

```
15  14 2.562527e+00 7.403695e+00  12.15890515   7.34482121   2.770116362 0.3771523
16  15 2.777382e+00 5.780324e+00   7.83118823   5.63859155   1.632493714 0.2895215
17  16 7.711721e-01 1.436457e+00   1.93178640   1.39346915   0.356608090 0.2559139
18  17 0.000000e+00 1.550750e-01   0.28626069   0.16627173   0.094516529 0.5684462
19  18 2.212360e-01 8.548278e-01   1.20003147   0.79742409   0.309568559 0.3882107
20  19 5.733118e-02 1.893179e-01   0.30671384   0.17752854   0.079389990 0.4471956
21  20 0.000000e+00 2.389363e+00   3.84541819   1.89197773   1.401152248 0.7405754
22  21 8.230572e-03 1.080620e-01   0.22860462   0.09636809   0.078240196 0.8118891
23  22 0.000000e+00 1.447677e-01   0.29039910   0.14567105   0.097815006 0.6714787
24  23 2.687780e-01 6.584787e-01   1.23328519   0.70822865   0.310023978 0.4377456
25  24 1.598568e-01 6.737690e-01   1.11093477   0.67934418   0.292136286 0.4300269
26  27 0.000000e+00 9.728829e-03   0.02098120   0.01025871   0.006553456 0.6388185
27  28 0.000000e+00 4.245950e-01   0.84919007   0.39062743   0.341404671 0.8739905
28  43 0.000000e+00 3.047677e-02   0.05381288   0.02375597   0.021508479 0.9053924
   age   Ab.Sum.5% Ab.Sum.50%  Ab.Sum.95% Ab.Sum.mean  Ab.Sum.sd Ab.Sum.cv
1    1 10.68619467 22.7718417  36.4874442  22.3792370  7.4831372 0.3343786
2    2  0.00000000  2.6483644   7.8907283   2.8920426  2.6410543 0.9132142
3    3  4.69692810  7.1333361  10.3849823   7.1182187  1.7870212 0.2510489
4    4  6.19831468  9.0525743  14.1094641   9.5993841  2.8538250 0.2972925
5    5  1.85177615  3.6304996   5.5014639   3.7266759  1.2114086 0.3250641
6    6  9.19662591 13.5399057  18.7019620  13.5801423  2.7490464 0.2024313
7    7 10.22176034 19.6942106  27.7606108  19.5052781  5.6435375 0.2893339
8    8 30.68314189 48.3810686  76.4990508  51.1629409 15.7134130 0.3071249
9    9 32.92727707 52.7984627  75.8144374  52.3210518 14.0423603 0.2683883
10  10 15.67332457 44.1903620  82.2897785  45.6683769 19.8835031 0.4353889
11  11 12.85260464 30.5032515  65.0009078  35.3319167 17.5650379 0.4971436
12  12 19.78152970 68.5743787 111.7926419  67.0574396 29.3579927 0.4378037
13  13 43.75476267 69.6763888 107.1662634  73.0581830 25.1333783 0.3440187
14  14 22.48492990 80.5600645 136.6341201  83.2201449 36.5795719 0.4395519
15  15 22.16980117 59.1189125  93.0906852  58.4767549 23.1389558 0.3956949
16  16  4.08891103  7.8419936  19.9924560   9.6450901  5.1910173 0.5382031
17  17  0.00000000  0.5551485   1.9573681   0.6941323  0.6327231 0.9115310
18  18  0.23085689  1.1855405   2.1218379   1.2856642  0.7936381 0.6172981
19  19  0.54456955  1.1274368   2.8021421   1.3599772  0.7143934 0.5252980
20  20  0.00000000 12.7099214  19.5527573   9.8418297  7.5448266 0.7666081
21  21  0.06045694  0.3079030   0.6803270   0.3309258  0.1989716 0.6012573
22  22  0.00000000  0.1550794   0.3212508   0.1683708  0.1166878 0.6930406
23  23  0.63634748  1.3913753   2.3974242   1.5225701  0.5812744 0.3817719
24  24  0.59676673  2.1522549   5.2239585   2.6549320  2.1695141 0.8171637
25  27  0.00000000  0.1780568   0.4304465   0.1827380  0.1359340 0.7438736
26  28  0.00000000  0.4319753   0.8805516   0.4067109  0.3566316 0.8768676
27  43  0.00000000  0.1194189   0.4156014   0.1462795  0.1533068 1.0480403
>
>
> ## check content of lists
> summary(basicpluslength)
     Length Class      Mode
[1,] 3      data.frame list
> summary(basicplusage)
     Length Class      Mode
[1,] 3      data.frame list
>
>
> ## Create length table for all years - AFWG strata
> length_basicplus <- basicpluslength[[1]]
> head(length_basicplus)
  year Lgrp numbers_length
1 2003    5       24907055
2 2003   10       12214248
3 2003   15       11600728
4 2003   20       38122392
5 2003   25      112993522
6 2003   30      308031262
>
> #ivec <- 2:(length(years)+1)
> #ivec <- ivec[-7]
> ivec <- 2:(length(years))
> ivec
[1] 2 1
>
> for (i in ivec){
+   length_basicplus <- rbind(length_basicplus, basicpluslength[[i]])
+ }
>
```

```
> write.csv(length_basicplus, "length_basicplus.csv")
>
> ## Create 45+ group
> dim(length_basicplus)
[1] 8 3
> length_basicplus <- subset(length_basicplus, Lgrp!="NA")
> dim(length_basicplus)
[1] 8 3
>
>
> length_low <- subset(length_basicplus, Lgrp<45)
> length_high <- subset(length_basicplus, Lgrp>=45)
> dim(length_low)
[1] 8 3
> dim(length_high)
[1] 0 3
>
> temp <- length_high %>%
+   ddply("year", summarise,
+         numbers_length=sum(numbers_length))
>
> temp$Lgrp <- 45
>
> temp <- temp[,c(1,3,2)]
>
> length_basicplus <- rbind(length_low, temp)
> length_basicplus$model <- "Basicplus"
> length_basicplus$numbers_length <- (length_basicplus$numbers_length)/1000
> length_basicplus <- subset(length_basicplus, Lgrp!=0)
>
> ## Create age table for all years - AFWG strata
> age_basicplus <- basicplusage[[1]]
>
> for (i in ivec){
+   age_basicplus <- rbind(age_basicplus, basicplusage[[i]])
+ }
>
> ## Create 16+ group
> dim(age_basicplus)
[1] 27  3
> age_basicplus <- subset(age_basicplus, age!="NA")
> dim(age_basicplus)
[1] 27  3
>
> age_low <- subset(age_basicplus, age<16)
> age_high <- subset(age_basicplus, age>=16)
> dim(age_low)
[1] 15  3
> dim(age_high)
[1] 12  3
>
> temp <- age_high %>%
+   ddply("year", summarise,
+         numbers_age=sum(numbers_age))
>
> temp$age <- 16
>
> temp <- temp[,c(1,3,2)]
>
> age_basicplus <- rbind(age_low, temp)
> age_basicplus$numbers_age <- age_basicplus$numbers_age*1000
> age_basicplus$model <- "Basicplus"
> age_basicplus <- subset(age_basicplus, age!=1)
>
> ## Create age table with uncertainv4ties - basicplus
> uncertainv4_age <- age_uncertainv4[[1]]
> head(uncertainv4_age)
  year age Ab.Sum.5. Ab.Sum.50. Ab.Sum.95. Ab.Sum.mean Ab.Sum.sd Ab.Sum.cv
1 2003   1 10.686195  22.771842  36.487444   22.379237  7.483137 0.3343786
2 2003   2  0.000000   2.648364   7.890728    2.892043  2.641054 0.9132142
3 2003   3  4.696928   7.133336  10.384982    7.118219  1.787021 0.2510489
4 2003   4  6.198315   9.052574  14.109464    9.599384  2.853825 0.2972925
5 2003   5  1.851776   3.630500   5.501464    3.726676  1.211409 0.3250641
6 2003   6  9.196626  13.539906  18.701962   13.580142  2.749046 0.2024313
```

```
>
> #ivec <- 2:(length(years)+1)
> #ivec <- ivec[-7]
> ivec <- 2:(length(years))
> ivec
[1] 2 1
>
> for (i in ivec){
+   uncertainv4_age <- rbind(uncertainv4_age, age_uncertainv4[[i]])
+ }
>
> names(uncertainv4_age) <- c("year", "age", "p05", "p50", "p95", "mean", "sd", "cv")
>
> write.csv(uncertainv4_age, "uncertain_age_basicplus.csv")
>
> ## Create 16+ group
> dim(uncertainv4_age)
[1] 27  8
> uncertainv4_age <- subset(uncertainv4_age, age!="NA")
> dim(uncertainv4_age)
[1] 27  8
>
> age_low <- subset(uncertainv4_age, age<16)
> age_high <- subset(uncertainv4_age, age>=16)
> dim(age_low)
[1] 15  8
> dim(age_high)
[1] 12  8
>
> temp <- age_high %>%
+   ddply("year", summarise,
+         p05=sum(p05), p50=sum(p50), p95=sum(p95),
+         mean=sum(mean), sd=mean(sd), cv=mean(cv))
>
> temp$age <- 16
>
> temp <- temp[,c(1,8,2,3,4,5,6,7)]
>
> uncertainv4_age <- rbind(age_low, temp)
> uncertainv4_age$model <- "Basicplus"
> uncertainv4_age$mean <- uncertainv4_age$mean*1000
> uncertainv4_age$p05 <- uncertainv4_age$p05*1000
> uncertainv4_age$p95 <- uncertainv4_age$p95*1000
> uncertainv4_age <- subset(uncertainv4_age, age!=1)



>
```

```
## Save project list

#save(allpr, file="Data/project_paths.rdata")


save(years, length_rstox, length_mikko, length_mikkov2,  length_basic,
length_basicplus, age_rstox,

             age_mikko, age_mikkov2, age_basic, age_basicplus,
uncertain_age, uncertainv2_age,  uncertainv3_age, uncertainv4_age,
file="Data/ecotokt_output.rdata")

load("Data/ecotokt_output.rdata")

> ################ Plot results #############################
```

```
> ## load survey indices from report
> length_afwg <- read.table("Data/SurveyIndex_length.csv", header=TRUE, sep=";")
> dim(length_afwg)
[1] 279   3
> head(length_afwg)
  year Lgrp numbers_length
1 1986    5           6000
2 1986   10         101000
3 1986   15         192000
4 1986   20          17000
5 1986   25          10000
6 1986   30           5000
> length_afwg$model <- "AFWG"
>
> age_afwg <- read.table("Data/SurveyIndex_age.csv", header=TRUE, sep=";")
> dim(age_afwg)
[1] 285   3
> head(age_afwg)
  year age numbers_age
1 1996   2      146198
2 1996   3      112742
3 1996   4       22353
4 1996   5       53507
5 1996   6      165531
6 1996   7      181980
> age_afwg$model <- "AFWG"
>
> ## Combine tables
> length_models <- rbind(length_afwg, length_rstox, length_mikko, length_mikkov2, leng
th_basic, length_basicplus)
> age_models <- rbind(age_afwg, age_rstox, age_mikko, age_mikkov2, age_basic, age_basi
cplus)
>
> ## load results list - deliberately commented out to not run involuntarily
> #load("rstoxoutput.rdata")
>
> ################################# Plot comparisons for length and age #############
#######
> ## Reduce to ecotokt proper
> length_models <- subset(length_models, year>2002)
> age_models <- subset(age_models, year>2002)
>
> ## Length
> p1 <- ggplot()+
+         geom_line(data=length_models, aes(x=Lgrp, y=numbers_length, col=model))+
+         geom_point(data=length_models, aes(x=Lgrp, y=numbers_length, col=model))+
+   theme(legend.title.align = 0.5,legend.title=element_text(size=20), legend.text=ele
ment_text(size=15), text = element_text(size=12))+
+   facet_wrap(year~., scales="free")
>
> p1$labels$colour <- "Model"
>
> png(file="length_models.png", width=800, height=600)
>
> p1
>
> dev.off()
RStudioGD
        2
>
> ## Age
> p1 <- ggplot()+
+   geom_line(data=age_models, aes(x=age, y=numbers_age, col=model))+
+   geom_point(data=age_models, aes(x=age, y=numbers_age, col=model))+
+   theme(legend.title.align = 0.5,legend.title=element_text(size=20), legend.text=ele
ment_text(size=15), text = element_text(size=12))+
+   facet_wrap(year~., scales="free")
>
> p1$labels$colour <- "Model"
>
> png(file="age_models.png", width=800, height=600)
>
> p1
>
```

```
> dev.off()
RStudioGD
        2
>
>
>
> ## Age - no alternative
> age_modelsn <- subset(age_models, model!="Alternative")
>
> p1 <- ggplot()+
+   geom_line(data=age_modelsn, aes(x=age, y=numbers_age, col=model))+
+   geom_point(data=age_modelsn, aes(x=age, y=numbers_age, col=model))+
+   theme(legend.title.align = 0.5,legend.title=element_text(size=20), legend.text=ele
ment_text(size=15), text = element_text(size=12))+
+   facet_wrap(year~., scales="free")
>
> p1$labels$colour <- "Model"
>
> png(file="age_models_alternativlos.png", width=800, height=600)
>
> p1
>
> dev.off()
RStudioGD
        2
>
>
> ## Age - basics only
> age_modelsn <- subset(age_models, model=="Basic" | model=="Basicplus")
>
> p1 <- ggplot()+
+   geom_line(data=age_modelsn, aes(x=age, y=numbers_age, col=model))+
+   geom_point(data=age_modelsn, aes(x=age, y=numbers_age, col=model))+
+   theme(legend.title.align = 0.5,legend.title=element_text(size=20), legend.text=ele
ment_text(size=15), text = element_text(size=12))+
+   facet_wrap(year~.)
>
> p1$labels$colour <- "Model"
>
> png(file="age_models_basics.png", width=600, height=600)
>
> p1
>
> dev.off()
RStudioGD
        2
>
>
>
> ################ compare age with uncertainty intervals 5 and 95 percentile ####
> uncertain_model <- rbind(uncertain_age, uncertainv2_age, uncertainv3_age, uncertainv
4_age)
> uncertain15_model <- subset(uncertain_model, age!=16)
> age_afwg <- subset(age_afwg, year>=2003)
> age15_afwg <- subset(age_afwg, age!=16)
> age15_mikko <- subset(age_mikko, age!=16)
> uncertain15_age <- subset(uncertain_age, age<=15)
> uncertainv215_age <- subset(uncertain_age, age<=15)
> uncertainv315_age <- subset(uncertain_age, age<=15)
>
> ######################## all ages #####################################
> ## all Rstox systems - all ages
> p1 <- ggplot()+
+   geom_line(data=age_afwg, aes(x=age, y=numbers_age, colour="AFWG"), col="black", lw
d=2)+
+   geom_point(data=age_afwg, aes(x=age, y=numbers_age, colour="AFWG"), col="yellow",
cex=1)+
+   geom_line(data=uncertain_model, aes(x=age, y=mean, colour=model), lwd=0.5)+
+   geom_point(data=uncertain_model, aes(x=age, y=mean, colour=model), cex=0.5)+
+   geom_ribbon(data=uncertain_model, aes(x=age, ymin=p05, ymax=p95, fill=model), alph
a=0.2, show.legend=FALSE)+
+   theme(legend.title.align = 0.5,legend.title=element_text(size=40), legend.text=ele
ment_text(size=30), text = element_text(size=20))+
+   facet_wrap(year~., scales="free")
```

```
>
> p1$labels$colour <- "Model"
>
> png(file="age_models_rstox.png", width=2400, height=1800)
> p1
> dev.off()
RStudioGD
        2
>
> ## basic, strata17 - all ages
>
> uncertain_redux <- subset(uncertain_model, model=="Basic"|model=="RStoX17")
>
> p1 <- ggplot()+
+   geom_line(data=age_afwg, aes(x=age, y=numbers_age), col="black", lwd=2)+
+   geom_point(data=age_afwg, aes(x=age, y=numbers_age), col="yellow", cex=1)+
+   geom_line(data=uncertain_redux, aes(x=age, y=mean, colour=model), lwd=1)+
+   geom_point(data=uncertain_redux, aes(x=age, y=mean, colour=model), cex=1)+
+   geom_ribbon(data=uncertain_redux, aes(x=age, ymin=p05, ymax=p95, fill=model), alph
a=0.2, show.legend=FALSE)+
+   theme(legend.title.align = 0.5,legend.title=element_text(size=40), legend.text=ele
ment_text(size=30), text = element_text(size=20))+
+   facet_wrap(year~., scales="free")
>
> p1$labels$colour <- "Model"
>
> png(file="age_models_redux_rstox.png", width=2400, height=1800)
> p1
> dev.off()
RStudioGD
        2
>
> ####################### age 15 ####################################
> ## all Rstox systems - up to 15 yrs
> p1 <- ggplot()+
+   geom_line(data=age15_afwg, aes(x=age, y=numbers_age, colour="AFWG"), col="black",
lwd=2)+
+   geom_point(data=age15_afwg, aes(x=age, y=numbers_age, colour="AFWG"), col="yellow"
, cex=1)+
+     geom_line(data=uncertain15_model, aes(x=age, y=mean, colour=model), lwd=0.5)+
+   geom_point(data=uncertain15_model, aes(x=age, y=mean, colour=model), cex=0.5)+
+   geom_ribbon(data=uncertain15_model, aes(x=age, ymin=p05, ymax=p95, fill=model), al
pha=0.2, show.legend=FALSE)+
+   theme(legend.title.align = 0.5,legend.title=element_text(size=40), legend.text=ele
ment_text(size=30), text = element_text(size=20))+
+   facet_wrap(year~., scales="free")
>
> p1$labels$colour <- "Model"
>
> png(file="age_models_15_rstox.png", width=2400, height=1800)
> p1
> dev.off()
RStudioGD
        2
```

HAVFORSKNINGSINSTITUTTET

AKUSTISK MENGDEMÅLING AV SEI OG KYSTTORSK
FINNMARK – MØRE
HØSTEN 2018

Acoustic abundance of saithe and coastal cod Finnmark – Møre
Autumn 2018

Foreløpig rapport / Preliminary report 14.01.2019

Arved Staby, Sigbjørn Mehl, Erik Berg, Asgeir Aglen, Knut Korsbrekke
Havforskingsinstituttet / Institute of Marine Research
P.O. Box 1870 Nordnes
N-5817 Bergen
NORGE / NORWAY

INNHOLD

1. SAMMENDRAG

Et akustisk tokt med sikte på å framskaffe indekser for antall fisk og data over lengde og vekt for hver aldersgruppe av sei og kysttorsk nord for 62ºN er gjennomført årlig i oktober-november, siden 1985 for sei og siden 1995 for kysttorsk.

Resultater for 2018 viser:

- Ekkomengden av sei økte med 15% fra 2017 til 2018 til gjennomsnittet for 2003-2017. Det var en oppgang i nord og en liten oppgang på Møre og Nordland
- 4 år gammel sei (2014-årsklassen) var mest talrike, fulgt av 5-åringer (2013-årsklassen)
- Indeksene for 2 og 3-åringer var på henholdsvis 39% og 30% av gjennomsnittet for 2003-2017, og det tilsvarer en nedgang på 17% og 60% sammenlignet med 2017-indeksene
- Indeksen for 4 år gammel fisk var på nivå med gjennomsnittet og nokså lik 2017-indeksen, mens indeksene for 5-, 6- og 8-åringer var på henholdsvis 116%, 66% og 119% av gjennomsnittet for 2003-2017
- Lengde og vekt ved alder var litt over gjennomsnittet for 2003-2017 for 3-8 åringer

- For kysttorsk var det en nedgang i indekser for 2-åringer (24%) og 3-åringer (42%) sammenlignet med 2017-indeksene
- Indeksene for 4-5 åringer var det samme som i 2017, men økte for 6-åringer (42%) og 7-åringer (21%)
- Indeksen for totalantall kysttorsk gikk opp i alle områder bortsett fra i Vesterålen (område 05)
- Det var tegn på bedre rekruttering (alder 2) i 2014-2016
- Akustisk estimert biomasse gjekk opp med 11% fra 2017 til 2018
- Lengde og vekt ved alder var ganske lik estimater fra tidligere tokt
- **Det må understrekes at usikkerhet i beregninger for bestanden av kysttorsk er høy**

2. SUMMARY

An acoustic survey to obtain indices of abundance and estimates of length and weight at age of saithe and coastal cod north of 62ºN has been carried out annually in October-November, since 1985 for saithe and since 1995 for coastal cod.

The main results in 2018 were:

- Total echo abundance of saithe increased by about 15 % from 2017 to 2018, and was the same as the average for 2003-2017.
- 4 year old saithe (2014 year-class) was most abundant, followed by 5 year old fish (2013 year-class).
- Indices for 2 and 3 year olds were respectively 39% and 30% of the average for 2003-2017, corresponding to a decrease of 17% and 60% compared to 2017
- The index for 4 year old fish was the same as the 2003-2017 average, and indices for 5-, 6-, and 8 year old fish were respectively 116%, 66%, and 119% of the 2003-2017 average
- Length and weight at age of 3 to 8 year olds were above the 2003-2017 average

- Compared to 2017 the number of coastal cod decreased for age groups 2 (24%) and 3 (42%). Indices for 4 and 5 year old fish were the same as in 2017, while they increased for 6 (42%) and 7 (21%) year olds
- The total number of fish increased in all areas except for area 05 (Vesterålen).
- There were signs of improved recruitment (age 2) in the years 2014-2016.
- Acoustic estimated biomass increased by about 11% from 2017 to 2018.
- Average length and weight were similar to previous estimates
- **It must be emphasized that the uncertainty in acoustic abundance estimates of coastal cod is high**

3. INNLEDNING

Hovedformålet med toktet er å kartlegge geografisk fordeling og framskaffe mål for viktige bestandsvariabler som:

- Antall fisk, gjennomsnittlig lengde, vekt og modning i hver aldersgruppe i bestandene av sei, kysttorsk og hyse i kyst- og fjordområder fra Varanger til Stad

I tillegg ble det i 2018 gjennomført:

- Flere bunntrålhal til overvåking av dypvannsreker i Finnmarksfjordene, Lyngen, Malangen, Ullsfjord og Nordland
- Akustisk dekning av 0- og 1-gruppe sild i Varanger-, Lakse-, Tana- og Porsangerfjord
- Akustisk dekning av brisling i Trondheimsfjorden og Romsdalsfjordene
- Flere forhåndsbestemte bunntrålstasjoner for å forbedre datagrunnlaget for vanlig uer
- Flere CTD og planktonstasjoner i fjorder sør for Lofoten, langs Helgelandkysten og Møre og Romsdal
- Sedimentprøver og vannprøver i Laksefjorden, Vefsnfjorden, Namsenfjorden og Trondheimsfjorden for forurensingsanalyser
- Innsamling av frossen vanlig uer, snabeluer, breiflabb, og lyr
- Innsamling av gonadeprøver av sei og blålange

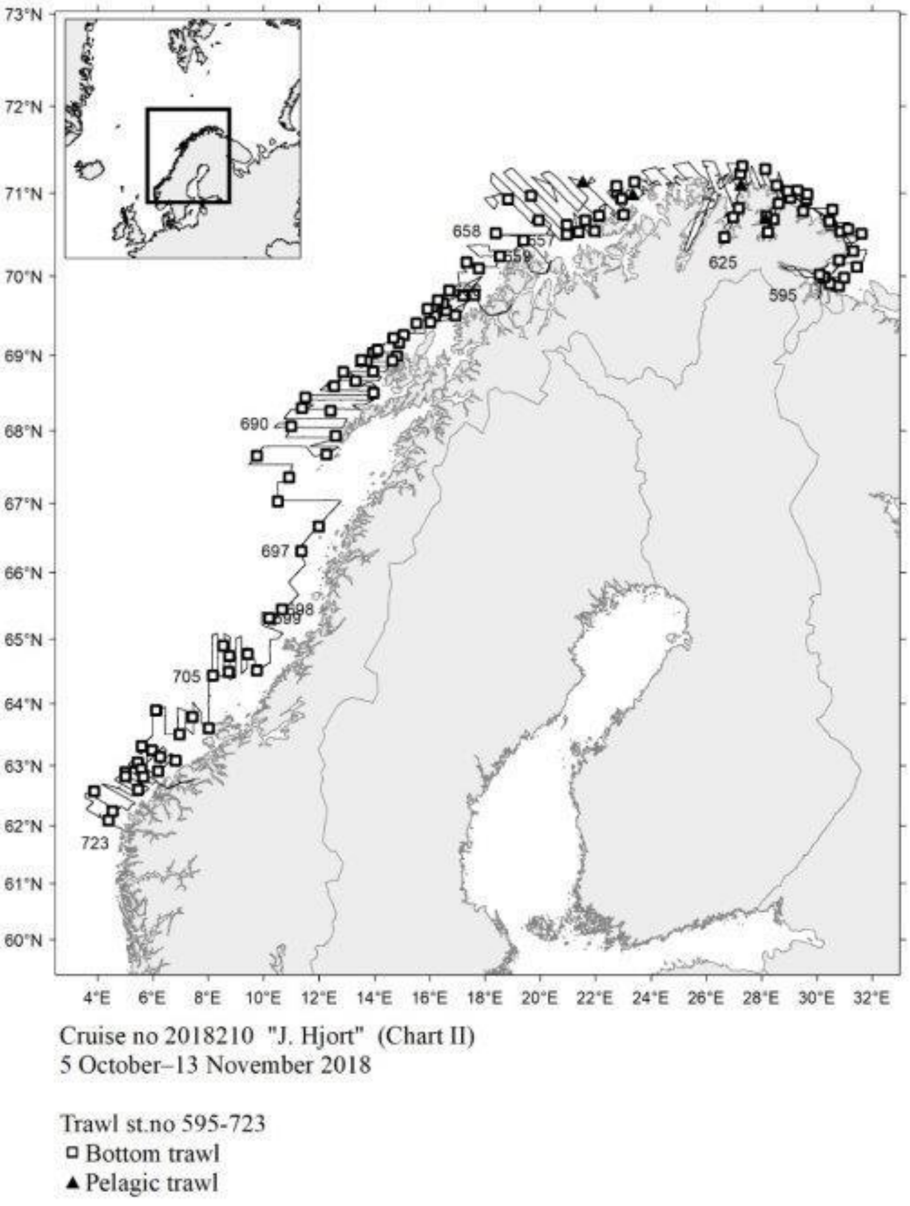
Innsamlete data og tilhørende resultater blir brukt i bestandsanalysene i ICES og i flere av Havforskingsinstituttet sine prosjekter.

4. GJENNOMFØRING OG METODIKK

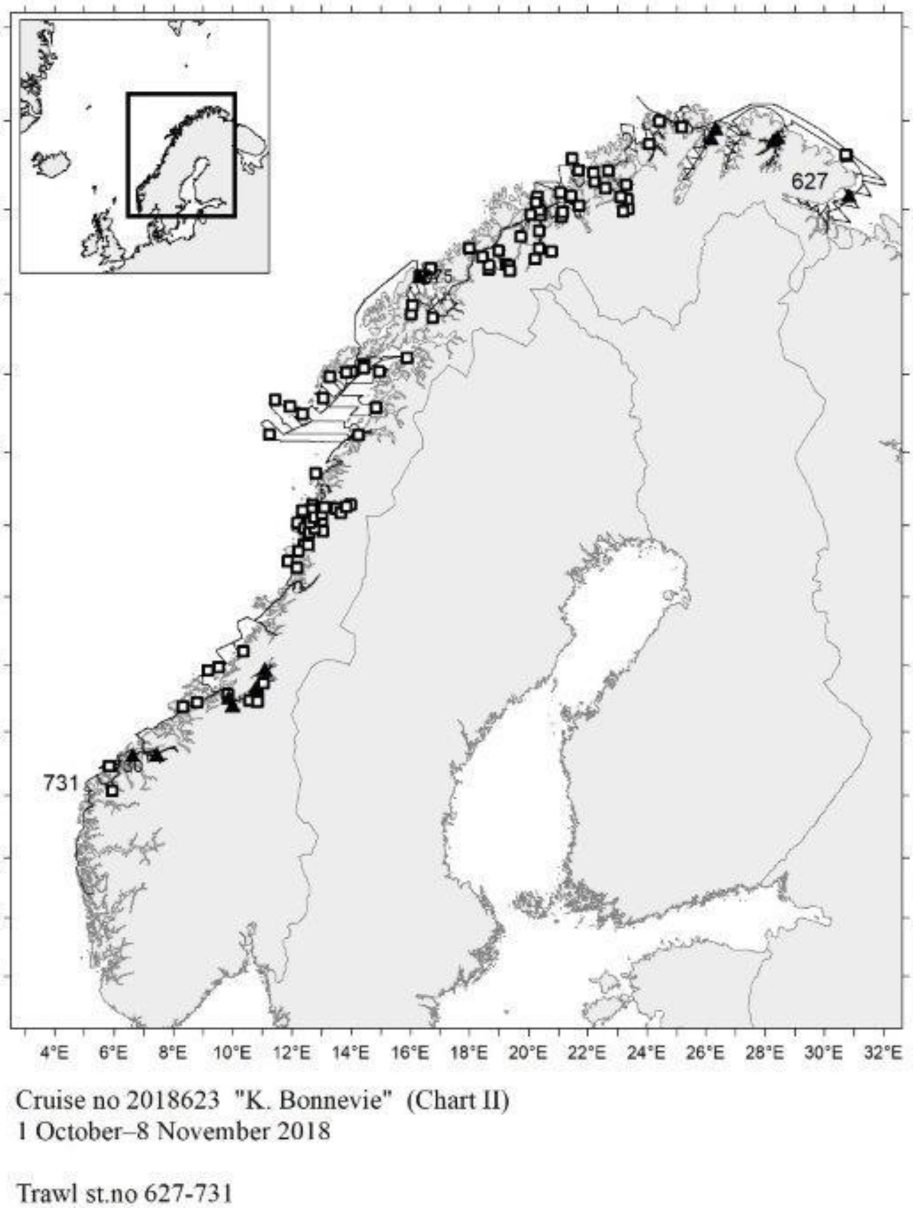
Toktet ble gjennomført med F/F "Johan Hjort" 05.10-13.11 (Toktnr. 2018210, serienr. 55001-55) og F/F ”Kristine Bonnevie” 01.10-07.11 (Toktnr. 2017620, serienr. 55201-55). Det ble i alt tatt 218 bunntrålhal og 16 pelagiske trålhal (Figur 4.1 og 4.2). Det ble dessuten tatt 129 hydrografiske stasjoner (CTD) for måling av temperatur og saltnivå. CTD-målinger ble gjort på en del faste bunntrålstasjoner, alle sedimentstasjoner og WP2 stasjoner og ellers med jevnt mellomrom (ca. 30 NM). Toktopplegget var stort sett det samme som er gjennomført siden 2003, men med tettere kurser i noen strata, ekstra transekter for dekking av ungsild og brisling, 32 ekstra trålstasjoner for å bedre datagrunnlaget for uer, og 22 ekstra trålstasjoner for overvåking av dypvannsreker.

4.1 Integreringskurser

Figur 4.4 presenterer standard integreringskurser for sei- og kysttorsk-undersøkelser etter sammenslåing av de to toktene i 2003. Som i 2017 ble det i 2018 lagt til flere kurser på Røstbanken, Buagrunnen, Kvalsnesdjupet, Eggagrunnen, Haltenbanken, Langgrunna, og Fugløybanken. For å bedre kunne sammenligne resultater med tidligere år, er bare deler av disse transektene (kursene) brukt i de presenterte utregningene for sei og kysttorsk. Kursene er satt ut med ulike avstander og i ulike retninger for best mulig å være representative for hvert enkelt område (stratum), der det også er tatt hensyn til dypet og tidligere fiskeforedling.



Figur 4.1 Kurser og trålstasjoner F/F "Johan Hjort" høsten 2018 (laget av Karen Gjertsen, HI).
Survey tracks and trawl stations R/V "Johan Hjort" autumn 2018 (Karen Gjertsen, IMR)



Figur 4.2. Kurser og trålstasjoner F/F ”Kristine Bonnevie” høsten 2018 (Karen Gjertsen, HI).
Survey tracks and trawl stations R/V “Kristine Bonnevie” autumn 2018 (Karen Gjertsen, IMR)

4.2 Prøvetakingsutstyr

Trål og fiskeutstyr

Som bunntrål blir det brukt standard prøvetakingstrål (Campelen 1800) med 80 mm (strekt) maskevidde i fremre del og 22 mm i posen. Sveipene er 40 m, og det blir brukt rockhopper gir. For pelagisk tråling er det ”Harstadtrål” og ”Åkratrål” som blir brukt. Det blir brukt ”Thyborøn” kombidører til all tråling. Dørspredning, trålåpning og bunnkontakt blir overvåket med Scanmar trålinstrumentering. På noen få stasjoner med dårlig/bløt bunn blir det brukt Tromsørigging for å unngå leire i fangstene og for å få bedre prøver fra fangsten.

4.3 Sortering av fangst, lengdemåling og alder-lengde nøkler

Sortering, veiing, måling og prøvetaking av fangst blir gjort etter gjeldende instrukser for dette (Mjanger *et al*. 2017). Et representativt utvalg av fangsten, eventuelt hele fangsten av viktige arter, blir lengdemålet på hver stasjon. På de fleste stasjonene blir det tatt individprøver med otolitter (øresteiner) av inntil 5 fisk i hver 5 cm-gruppe for sei, torsk, hyse og uerartene. Tilsammen blir det under toktet samlet inn og lest otolitter fra 1488 sei, 2464 torsk og 2903 hyse. Det blir dessuten tatt individprøver av 131 sjøkreps, 111 lysing, 91 kveiter, 25 breiflabb, 888 vanlig uer og 223 snabeluer, samt lengde og fryseprøver av ungsild, brisling, vanlig uer, snabel uer, sjøpølser og reker (7913 dypvannsreker, 1955 vanlig uer, og 783 snabeluer, 1610 sild, og 96 brisling blir lengde målt).

4.4 Innstillinger av det akustiske utstyret, tolking og beregning av mengdeindekser.

Målingene blir gjort med EK80 ekkolodd og ekkointegrering blir utført med ”Large Scale Survey System” (LSSS, Korneliussen *et al*. 2016). Tolkete verdier blir lagret for hver 1 NM med vertikaloppløsning på 10 m i det pelagiske lag og 1 m i bunnkanalen (10 m opp fra bunn). Når det gjelder ekkoloddinnstillingene vises det til instrumentrapportene fra toktet. S_V-terskelen var satt til -82dB, men under tolkning blir denne satt opp til –60dB (±3dB) for som en tilnærming å ta ut stimer med sterke fiskeregistreringer, og som en tommelfingerregel til 69dB (±3dB) for å ta ut planktonet. De akustiske registreringene i LSSS, dvs. gjennomsnittlig total ekkotetthet for hver 5 NM, blir tolket i samsvar med mønsteret på ekkogrammet og artsfordelinga på fiskestasjonene. Sei, torsk, hyse og sild blir skilt ut som egne artsgrupper. I tillegg blir 0-gruppe, 0-gr sild, plankton samt ”andre” brukt som egne tolkekategorier. Til hjelp i artsfordelingen av registrerte ekkotettheter blir alle trålfangster omregnet til relative s_A-verdier for hver art (Korsbrekke 1996). Dersom sammensetningen i trålfangstene gir et rett bilde av den arts- og størrelse sammensetningen som danner den totale ekkotettheten, kan total ekkotetthet deles direkte på art etter slike relative s_A-verdier. Men selv om det blir lagt stor vekt på å få trålfangstene mest mulig representative for ekkoregistreringene, vil variasjon i fordelingen over 5 NM samt trålseleksjon og unnviking med hensyn til art og størrelse alltid påvirke fangstresultatene. Arts- og størrelsesfordelingen av trålfangstene må derfor alltid ses i sammenheng med ekkogrammet og eventuelt målstyrkeobservasjoner fra ekkoloddet.

I estimeringene av akustiske indekser for sei blir programmet StoX brukt. Hele området er delt inn i 4 underområde (A 69°30’-71°30’N, B 67°00’-69°30’N, C 63°30’-67°00’N og D 62°00’-63°30’N, figur 4.4). For å estimere indekser til hver av disse underområdene, kjøres StoX fire ganger og der det for hver kjøring unnlates oppdrag som ikke ligger i de underområdene – dvs. til estimering av underområde A brukes det informasjon fra oppdrag 1,2,4, og 7, til underområde B fra oppdrag 9,10, og 11, til underområde C fra oppdrag 12 og 15, og til underområde D informasjon fra oppdrag 17.

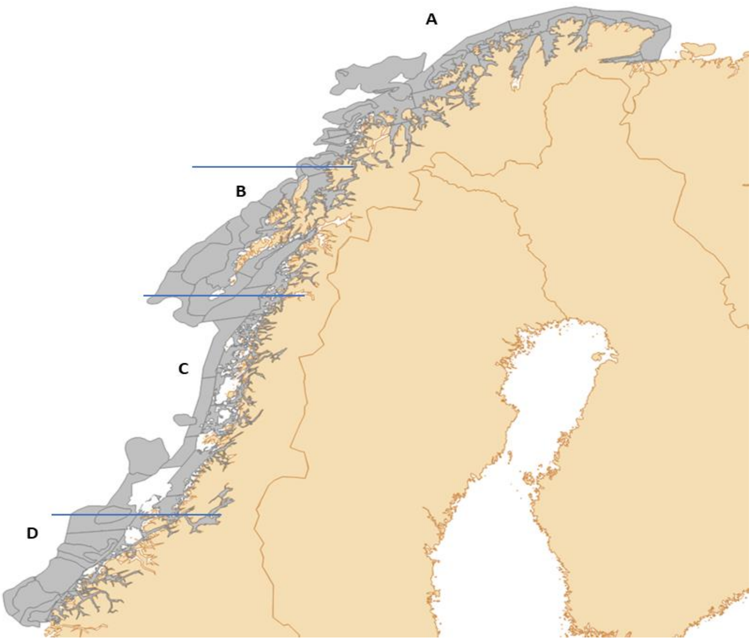
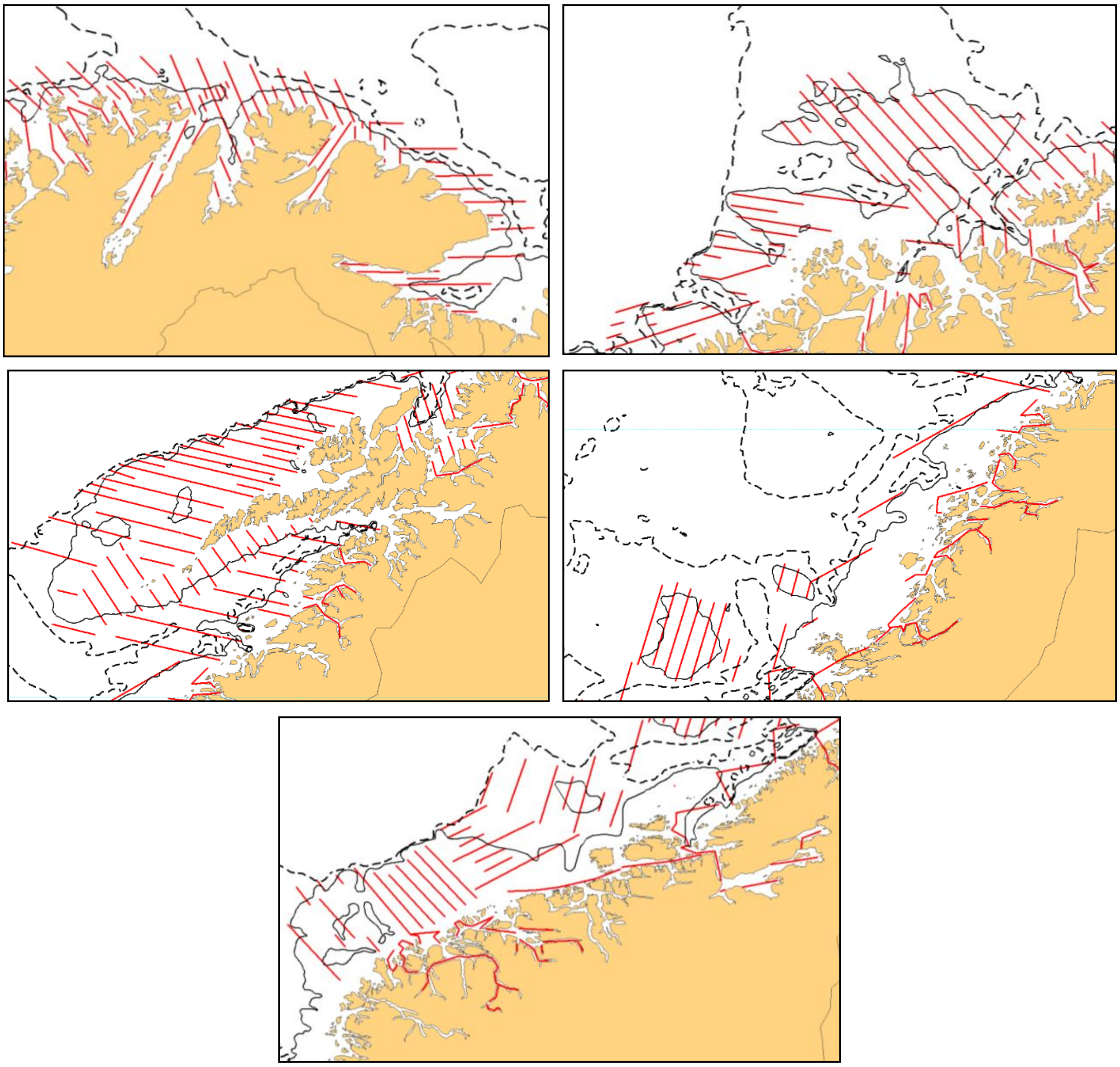


Figure 4.4. Strata og underområde (A,B,C og D) brukt i estimering av akustiske indekser med StoX.



Figur 4.5. Standard transekt i det kombinerte sei- og kysttorsktoktet.

Hvert underområde er delt inn i flere strata, som er definert ut ifra polygon der også ”smultringvarianten” finns. Det vil si at et stratum kan omslutte et annet stratum fullstendig. I hvert stratum blir de akustiske kursene delt opp i transekt (PSU = primary sampling unit) (figur 4.5). Grupper av strata er samlet i praktiske ”oppdrag” som blir gjennomført av enkeltfartøy. Stratanummereringen er unik bare innenfor et oppdrag.

Omregningen av gjennomsnittlig “nautical area scattering coefficient“ (NASC) (m^2 nmi^{-2}) til tetthet av fisk følger en standard prosedyre der minst 3 trålstasjoner (med en fangst på mer enn 2 individ av sei) blir allokert til hver PSU. Som en regel blir alle stasjoner innenfor et stratum allokert til hver PSU i det samme stratum, men dersom det er tatt færre enn 3 trålstasjoner i et stratum, blir også stasjoner i nabostrata allokert slik at minst 3 stasjoner er allokert til hver PSU.

En kombinert lengdefordeling (d) blir kalkulert for hvert transekt (PSU (j)) som:

$$d_{l,j} = \sum_{s=1}^{s} d_{l,s,j}$$

der $d_{l,s,j}$ er tetthet (tall per 1 NM tauet distanse) for 1 cm lengdegrupper (l) for stasjon (s) allokert to PSU (j).

Arealtetthet av fisk (ρ) (n per nmi^2) for lengdegruppe l for transekt j blir regnet ut som

$$\rho_{j,l} = \frac{\mathrm{NASC}_{j,l}}{\sigma_l}$$

der $\mathrm{NASC}_{j,l}$ er gjennomsnittlig "nautical area scattering coefficient" for transekt (j) og lengdegruppe (l) og σ_l er ekkoevne (backscattering cross-section) for en fisk med lengde l.

$\mathrm{NASC}_{j,l}$ er regnet ut som:

$$\mathrm{NASC}_{j,l} = \mathrm{NASC}_j \frac{\sigma_{l,p}}{\sum_l \sigma_{l,p}}$$

der $\sigma_{l,p}$ er ekkoevne for en fisk med lengde l multiplisert med delen (p) av fisk med lengde l i den totale lengdefordelinga og NASC_j er gjennomsnittlig "nautical area scattering coefficient" i transektet.

Ekkoevna (m^2) for en fisk med lengde l er regnet ut som

$$\sigma_l = 4\pi 10^{\left(\frac{TS_l}{10}\right)}$$

der målstyrken, TS, for en fisk med lengde l (cm) er regnet ut som

$$TS_l = m\log_{10}(l) + a$$

der m og a er konstanter. Det ble benyttet

$$TS = 20\log(l) - 68 \quad \text{(Foote, 1987)}$$

Mengde(N) sei av lengdegruppe (l) for stratum k er:

$$N_{k,l} = \rho_{k,l} A_k$$

der A er arealet av stratum k og gjennomsnittlig tetthet av sei i lengdegruppe l og stratum k er:

$$\rho_{k,l} = \frac{1}{n_k} \cdot \sum_{k=1}^{n_k} w_{kj}\rho_{kj,l}$$

der $w_{kj} = L_{kj} / \bar{L}_k$ (j= 1,2,n$_k$) er lengde av transekt n$_k$.

Estimat for lengde blir konvertert til estimat for alder ved å bruke alders-lengde data fra alle valgte stasjoner i hvert stratum, vektet med stasjonstetthet. StoX bruker ikke alder-lengde nøkler (ALKs) i tradisjonell forstand med ALKs estimert for større områder. Manglende aldersinformasjon blir tilregnet («imputed») fra kjente alder-lengde data innen hver stasjon. Dersom aldersinformasjon fremdeles mangler, søker StoX innen stratum, eller til slutt innen alle strata. Dersom ingen alder er tilgjengelig for en lengdegruppe, blir estimatet presentert med ukjent alder. Total biomasse blir estimert ved å multiplisere tallet på fisk i hver aldersgruppe med vekt ved alder. Trålindeksene i hvert stratum blir så summert for definerte underområder (figur 4.3).

StoX estimerer variasjonskoeffisienter ved "bootstrapping" av transekter og allokerte trålstasjoner. Den estimerte CV (standardavvik · 100/gjennomsnitt) er estimert fra 500 iterasjoner og er sterkt avhengig av valget av estimator for indeksene.

StoX er også brukt til å estimere nye akustiske indekser med CV samt lengde og vekt ved alder for sei for perioden 2003 til 2017 (Mehl et al. 2018). Hovedforskjellen mellom det SAS-baserte programmet BEAM (Totland og Godø 2001) brukt for sei fram til 2016 og StoX er at i BEAM er toktområdet delt inn i rektangler (Mehl et al. 2016), og for hvert rektangel blir gjennomsnittlig akustisk tetthet (s_A) regnet ut, mens i StoX blir det for hvert stratum definert transekt som primær prøvetakingsenhet («primary sampling units», PSUs), som så blir brukt til å regne ut akustisk tetthet (Jolly and Hampton 1990). BEAM bruker dessuten tradisjonelle alder-lengde nøkler.

I beregningene for kysttorsk er det undersøkte området delt i 25 underområder med tilhørende areal. Noen av underområdene er fjorder mens andre er åpne bankområder. Integreringskursene er parallelle kurser med 2-12 nautiske mils avstand, avhengig av om det er fjorder eller bankområder. Det blir regnet ut gjennomsnittlige s_A-verdier for hvert av disse underområdene og videre utregninger blir gjort med programpakken SAS. Etter at det totale antall torsk i hver lengdegruppe innenfor hvert område er regnet ut, blir dette fordelt på kysttorsk og nordøstarktisk torsk basert på alderslesing og typebestemmelse ut fra otolitter. Deretter blir de underområdene slått sammen til 6 hovedområder. Disse hovedområdene er de samme som Fiskeridirektoratet sine fangststatistiske områder (03, 04, 05, 00, 06 og 07). Lengdefordelingene er ikke korrigert for lengdeavhengig sveipebredde på bunntrålstasjoner.

5. RESULTAT OG DISKUSJON

5.1 Ekkomengde av sei

Tabell 5.1 viser ekkomengden av sei i hvert underområde for 2003-2018. Nedgangen fra 2007 til 2008 omfattet nesten alle område, så her kan det nok i tillegg være snakk om en årseffekt. Det at toktet i 2008 ble gjennomført en måned senere enn i de andre årene kan ha påvirket resultatet. Total ekkomengden av sei i 2018 var om lag 15% høyere enn i 2017, og er det samme som gjennomsnittet i tidsserien tilbake til 2003. I underområde A (nord for 69°30' N) var den registrerte ekkomengden nærmest det samme som i 2017, og 59% over gjennomsnittsnivå for 2003-2017. I underområde B (Lofoten – Vesterålen) var ekkomengden 43% over 2017-nivå og 17% over snittet. I underområde C (Sklinna-Halten-Frøyabanken) var ekkomengden nesten 21% høyere enn i 2017 (og 80% av snittet for 2003-2017), og var den høyeste ekkomengden siden 2010. Underområde D (Møre) hadde en økning på nesten 60% sammenlignet med 2017, men ekkomengden var den nest laveste i tidsserien, bare 40% av gjennomsnittet for 2003-2017.

Tabell 5.1 SEI**.** Ekkomengde (m^2 reflekterende overflate · 10^{-3}) 2003–2018 estimert med StoX**.**
SAITHE. Echo abundance (m^2 reflecting surface · 10^{-3}) 2003-2018 estimated by StoX.

	Underområde / *Subarea*				
År/*Year*	A	B	C	D	Sum
2003	345	443	178	658	1625
2004	440	605	332	496	1873
2005	366	329	100	384	1179
2006	201	278	337	344	1160
2007	116	379	89	417	1000
2008	93	167	45	299	604
2009	315	286	67	282	951
2010	188	204	89	284	765
2011	151	145	65	173	533
2012	218	210	50	324	801
2013	266	176	24	141	606
2014	172	242	60	245	719
2015	326	291	46	191	853
2016	440	249	51	236	975
2017	464	230	70	75	839
2018	430	330	85	120	965

5.2 Mengdeindeksar med CV og vekst for sei

Tabell 5.2.1 viser de akustiske mengdeindekser for lengde- og aldersgrupper sammenslått for alle de undersøkte områdene (oppdrag), og tabell 5.2.2 viser tall på fisk i hver aldersgruppe for hvert av de 4 underområdene. I det nordligste underområdet A (Finnmark – Troms) ble det funnet mest 2 og 5 år gammel sei (2013 og 2016-årsklassene). Totalt antall fisk estimert i det området var mye lavere enn i 2017. Det gjelder spesielt 1-3 åringer, det ble estimert mye 1-åringer i 2017 og nesten ingen i 2018 og bare 39% av 2017-estimatet for 3-åringer. Estimert antall 4-7+ år gammel fisk var nokså likt estimatet fra 2017. I underområde B (Lofoten – Vesterålen) var det mest 4 år gammel sei (2014 årsklassen, 48% av totalt antall fisk), med en tydelig økning i 4-7+ år gammel fisk sammenlignet med 2017 (160% høyere estimat), og et betydelig lavere estimat for 1-3 åringer (73% av 2017-estimatet). I underområde C (Sklinna-Halten-Frøyabanken) ble det registrert mest 4 og 5 år gammel sei (94% av totalt antall fisk) og 60% mer enn i 2017. Til tross for høyere estimater av eldre fisk i 2018 er total antall fisk litt lavere enn i 2017, siden antall 3-åringer registrert er mye lavere enn i 2017. Helt i sør (underområde D - Møre) blir det registrert mer sei enn i 2017, men fortsatt mye mindre enn i årene før. Det ble estimert mest 4- og 5-åringar (2013- og 2014-årsklassane), mens antall 3-åringer var likt estimatet fra 2017.

Tabell 5.2.1 SEI. Akustiske indekser (i millioner) på alder og lengde i 2018 estimert med StoX.
SAITHE. Acoustic indices (in millions) by length and age in 2018 estimated by StoX.

Lengde *Length* *(cm)*	Alder (Årsklasse) / *Age (Year class)* 1 (17)	2 (16)	3 (15)	4 (14)	5 (13)	6 (12)	7+ (11+)	Sum
20-24	0.002	-	-					0.00
25-30	0.187	0.2						0.35
30-35		12.5						12.50
35-40		6.1	4.8	0.2				11.13
40-45		0.8	19.5	18.0	0.2			38.47
45-50			6.4	31.5	8.0	0.1		45.85
50-55			-	8.9	19.6	0.5		28.98
55-60				1.6	11.1	3.2	0.1	16.02
60-65				0.9	4.8	4.5	1.3	11.60
65-70					1.3	3.1	2.5	6.96
70-75					0.4	0.6	3.2	4.20
75-80						0.2	3.1	3.34
80+							2.5	2.5
Sum:	0.19	19.6	30.6	61.1	45.4	12.3	12.8	181.9

Tabell 5.2.2 SEI. Akustiske indekser (i millioner) i hvert underområde i 2018 estimert med StoX.
SAITHE. Acoustic indices (in millions) by subarea in total in 2018 estimated by StoX.

Underområde *Subarea*	Alder (Årsklasse) / *Age (Year class)* 1 (17)	2 (16)	3 (15)	4 (14)	5 (13)	6 (12)	7+ (11+)	Sum
A	0.19	17.85	14.15	11.64	21.64	7.8	6.03	79.33
B	0	1.03	11.64	31.54	12.91	2.89	5.09	65.1
C	0	0.11	0.05	9.29	4.69	0.43	0.35	14.91
D	0	0.57	4.79	8.63	6.13	1.14	1.32	22.57
Total	0.19	19.55	30.63	61.09	45.36	12.29	12.78	181.9

Tidsserien av mengdeindekser er vist i tabell 5.2.3. Seien er vanligvis ikke ”rekruttert til toktet” før den er 3 år, av og til er den ikke fullt rekruttert før som 4-åring. Derfor øker antall på fisk i en og samme årsklasse med alderen, fra 2 til 3 eller 4 år. Dette skyldes hovedsakelig at de yngste aldersgruppene vokser opp helt inne på grunnere områder ved kysten, der de ikke er tilgjengelige for et stort forskningsfartøy. Etter hvert som fisken blir større og eldre trekker den ut og blir tilgjengelig i undersøkelser. Når fisken blir enda eldre og kjønnsmoden, blir den igjen mindre tilgjengelig for toktet på grunn av gyte- og næringsvandringer. Dette kan variere fra år til år.

Summen av indeksene for de yngste aldersgruppene (2-4 åringer) har siden 2007, med unntak av 2016, vært under gjennomsnittet for 2003-2017 og var i 2017 på 52% av dette nivået (sammenlignet med 82% i 2016). Indeksen for 2- og 3-åringar var mye lavere enn i 2017 og på henholdsvis 39% og 70% av snittet. Indeksen for 4 år gammel fisk (2014-årsklassen) var den samme som gjennomsnittet, mens indeksen for 5 åringer (2013 årsklasse) var mye høyere enn i 2017 og på 116% av gjennomsnittet. For 6-åringar var indeksen også mye høyere enn i 2017 og 66% over snittet. Eldre fisk (7+) var 30% høyere enn snittet og 45% større enn i 2017. Eldre sei som er på nærings- og gytevandring på denne tiden blir som før nevnt bare i liten grad dekket av toktet. Totalindeksen var på vel 73% av gjennomsnittet.

Tabell 5.2.4 viser estimat av variasjonskoeffisienter (CV) for aldersgrupper 1-14. En CV på 0.2 (20%) eller mindre kan anses som akseptabel i en tradisjonell bestandsvurdering dersom indeksene er uhildet (avhengig av en modell for fangbarhet). Verdier over dette indikerer indekser med høy usikkerhet med liten informasjon om årsklassestyrke. CV for aldersgruppe 2-5 er på et akseptabelt nivå i de fleste år, for aldersgruppe 6-7 i mindre enn halvparten av årens mens for aldersgruppe 1 og for 8 år gammel og eldre fisk er CV over det som kan anses som akseptabelt i alle år. I 2018 var CV for 4-6-åringer på eller under 0.2 (20%) , mellom 20-30% for 3 og 7 åringer, og høyre enn andre år for 2 åringer.

Gjennomsnittslengder og -vekter for de ulike aldersgruppene vises i tabell 5.2.5 og 5.2.6. I senere år er det stort sett bare registrert små endringer i vekstmønsteret. I 2018 var lengde ved alder for 3-9 år gammel sei over gjennomsnittet for tidsserien 2003-2017 og litt under snittet for 2 år gammel fisk. For vekt ved alder for 3-9 åringer var over gjennomsnittet, mens 2 år gammal sei var litt under gjennomsnittet.

Tabell 5.2.3 SEI. Akustiske indekser (i millioner) for hver aldersgruppe i 2003 – 2018 estimert med StoX. + indikerer < 0.005.
SAITHE. Acoustic abundance indices (in millions) by age in 2003 – 2018 estimated by StoX software. + indicates < 0.005.

	Age group																**Biomass**
Year	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15+**	**Total**	**(‘000 t)**
2003[1]	19.3	51.2	130.5	162.3	42.6	7.73	7.94	2.56	1.69	1.21	0.72	0.31	0.15	0.05	0.07	428.4	348.7
2004[1]	0.01	153.3	191.2	107.6	44.3	15.2	4.25	2.06	3.56	0.77	1.36	0.61	0.27	0.21	0.11	524.8	425.7
2005[1]	11.1	24.1	198.5	51.9	17.6	13.2	7.68	1.40	1.12	0.36	0.10	0.10	0	0	0	327.2	261.6
2006[1]	2.89	83.9	40.9	129.9	14.4	4.62	9.49	6.13	2.39	1.05	0.83	0.17	0.31	0.01	0.02	297.0	258.7
2007[1]	2.48	37.9	93.5	23.9	58.5	6.51	3.95	4.00	4.22	0.30	0.76	0.06	0	0	0	236.0	224.2
2008[1]	0.01	50.7	55.9	15.9	7.84	9.99	3.06	0.97	1.41	0.98	0.13	0.15	0	0.06	0	147.1	124.1
2009[1]	0	54.7	96.9	61.4	6.99	4.01	7.62	1.95	1.00	1.08	1.10	0.35	0.18	0	0	237.2	212.6
2010	0.02	7.60	143.0	22.5	17.1	3.95	1.68	3.58	0.43	0.25	0.18	0.30	0.01	0.20	0	200.8	167.1
2011	0	15.2	42.7	59.6	4.61	4.23	1.07	0.81	0.78	0.19	0.03	0.06	0	0	0	129.4	117.7
2012	0.08	68.5	69.0	29.7	18.8	3.48	2.83	0.32	0.58	0.56	0.08	0.05	0	0	0	193.9	148.6
2013	5.02	12.3	77.1	16.5	13.3	11.6	2.19	1.21	0.61	0.39	0.02	+	0.10	0.14	0	140.5	139.1
2014	2.95	28.4	40.1	70.8	8.73	5.62	5.44	1.61	0.55	0.18	0.43	0.10	0	0	0.02	165.0	166.0
2015	0.06	93.5	72.4	22.7	30.1	6.08	4.22	1.85	0.20	0.14	0.07	0.05	0	0	0	231.4	177.6
2016	0.76	72.6	145.7	32.0	10.5	11.2	4.15	2.04	1.46	0.15	0.22	0.12	0.02	0.05	0	281.1	196.0
2017	35.4	23.6	91.1	63.9	13.3	2.76	5.35	2.21	0.62	0.46	0.01	0.02	0.04	0	0.05	238.8	177.2
2018	0.19	19.6	30.6	61.1	45.4	12.3	4.24	4.62	2.60	0.32	0.44	+	0.19	0.08	0.3	181.9	231.4

[1]Justert høsten 2018 etter oppdatering av data og nye beregninger
[1]*Adjusted autumn 2018 after update of input data and new estimates*

Tabell 5.2.4. SEI. Estimat av variasjonskoeffisient for akustiske indekser for aldersgruppe 1-14 i 2003-2018 estimert med StoX.
SAITHE. Estimates of coefficients of variation for acoustic abundance indices for age groups 1-14 in 2003-2018 estimated by StoX software.

	Aldersgruppe / *Age group*													
År/*Year*	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**
2003[1]	0.35	0.21	0.19	0.22	0.16	0.36	0.33	0.60	0.30	0.39	0.43	0.43	0.49	0.99
2004[1]	1.98	0.26	0.16	0.28	0.25	0.22	0.39	0.59	0.43	0.40	0.35	0.39	0.39	0.70
2005[1]	0.58	0.47	0.12	0.20	0.12	0.19	0.25	0.45	0.59	0.75	0.89	0.89	-	-
2006[1]	0.53	0.13	0.40	0.30	0.23	0.35	0.34	0.46	0.42	0.46	0.36	1.02	0.65	0.88
2007[1]	0.50	0.28	0.21	0.17	0.23	0.27	0.39	0.37	0.31	0.54	0.47	0.81	-	-
2008[1]	1.31	0.19	0.21	0.27	0.27	0.14	0.19	0.37	0.36	0.37	0.60	0.50	-	1.16
2009[1]	-	0.34	0.20	0.15	0.25	0.30	0.22	0.37	0.45	0.43	0.54	0.96	0.44	-
2010	1.68	0.32	0.19	0.19	0.20	0.22	0.20	0.27	0.60	0.35	0.75	0.84	1.20	0.76
2011	-	0.23	0.18	0.16	0.24	0.38	0.40	0.48	0.33	1.11	1.04	1.00	-	-
2012	0.68	0.16	0.15	0.18	0.24	0.21	0.34	0.68	0.33	0.60	0.79	1.29	-	-
2013	0.56	0.17	0.12	0.13	0.31	0.19	0.34	0.41	0.42	0.62	1.09	3.11	0.93	0.82
2014	0.73	0.21	0.22	0.24	0.18	0.21	0.18	0.31	0.43	0.56	0.44	0.83	-	-
2015	1.60	0.17	0.16	0.20	0.22	0.26	0.25	0.31	0.30	0.72	0.49	0.58	-	-
2016	2.23	0.17	0.10	0.14	0.17	0.19	0.22	0.30	0.23	0.81	0.84	0.60	0.65	0.58
2017	0.34	0.61	0.13	0.17	0.20	0.34	0.48	0.45	0.39	0.26	0.73	0.94	0.92	-
2018	0.98	0.42	0.26	0.20	0.12	0.17	0.26	0.37	0.40	0.98	0.44	-	0.85	1.16

[1]Justert høsten 2018 etter oppdatering av data og nye beregninger
[1]*Adjusted autumn 2018 after update of input data and new estimates*

Tabell 5.2.5 SEI. Lengde (cm) ved alder i 2003-2018 estimert med StoX. + indikerer få prøver.
SAITHE. Length (cm) at age in 2003-2018 estimated by StoX. + indicates few samples.

	Aldersgruppe / *Age group*													
År/Year	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**
2003[1]	25.8	33.9	39.6	44.2	49.3	60.1	64.1	66.1	70.4	75.7	82.2	+	+	+
2004[1]	28.0	32.3	39.7	46.3	53.6	58.9	69.7	74.4	74.6	78.1	77.8	+	+	+
2005[1]	27.9	36.0	39.3	45.8	51.4	59.0	62.5	67.5	71.3	69.8	80.0	+	-	-
2006[1]	26.3	35.2	40.9	43.5	51.2	57.8	64.4	66.8	70.0	73.1	76.5	+	+	+
2007[1]	26.8	36.0	40.7	46.7	51.0	58.1	65.8	67.4	69.0	72.8	81.5	+	-	-
2008[1]	26.0	36.8	41.7	47.9	51.9	58.4	61.2	68.6	73.3	77.2	+	+	-	+
2009[1]	-	33.8	41.6	47.6	57.6	63.3	66.5	64.9	69.6	75.1	72.2	78.7	+	-
2010	24.2	34.5	38.4	47.1	57.4	61.0	65.0	66.9	68.9	75.8	+	+	+	+
2011	-	36.8	41.7	44.7	56.7	62.8	69.5	65.7	76.0	+	+	+	-	-
2012	29.0	36.4	42.3	47.3	51.6	60.5	66.5	71.8	66.9	79.5	82.9	87.0	-	-
2013	26.0	36.7	41.1	48.7	55.2	60.0	68.8	74.5	75.3	75.4	78.8	+	+	+
2014	24.3	35.8	44.0	46.7	54.8	60.6	61.4	72.3	76.6	80.2	79.3	85.8	-	-
2015	29.3	34.7	41.1	48.8	53.6	60.0	65.8	71.5	+	+	+	+	-	-
2016	28.5	33.2	38.8	47.1	54.1	60.0	67.0	70.5	72.5	81.8	+	+	+	+
2017	25.1	32.6	39.9	45.7	53.5	63.7	69.6	69.6	69.8	73.1	+	+	+	-
2018	26.5	34.1	42.4	46.9	54.2	62.5	71.4	70.1	75.8	74.6	75.5	-	+	+

[1]Justert høsten 2018 etter oppdatering av data og nye beregninger
[1]*Adjusted autumn 2018 after update of input data and new estimates*

Tabell 5.2.6 SEI. Vekt (gram) ved alder i 2003-2018 estimert med StoX. + indikerer få prøver.
SAITHE. Weight (gram) at age in 2003-2018 estimated by StoX. + indicates few samples

	Aldersgruppe / *Age group*													
År/Year	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**
2003[1]	161	388	568	832	1156	21662	2559	2895	3607	4300	6019	+	+	+
2004[1]	230	339	616	929	1515	2055	3393	4119	4414	4822	4785	+	+	+
2005[1]	229	482	612	912	1308	2029	2427	2941	3648	3130	3475	+	-	-
2006[1]	181	434	699	793	1336	1877	2668	2808	3413	4072	4492	+	+	+
2007[1]	183	468	644	924	1235	1815	2584	2854	2995	3661	4852	+	-	-
2008[1]	193	461	644	982	1256	1870	2158	2977	3787	4349	+	+	-	+
2009[1]	-	375	689	1012	1814	2525	2899	2652	3118	4046	3299	3960	+	-
2010	146	409	556	1016	1814	2227	2624	2851	3116	4363	+	+	+	+
2011	-	503	735	853	1744	2267	3302	2598	4524	+	+	+	-	-
2012	240	456	682	954	1212	1907	2481	3088	2448	4573	4783	4870	-	-
2013	171	481	690	1097	1551	2050	3170	3799	4020	3840	5044	+	+	+
2014	135	445	826	1006	1538	2096	2201	3428	4269	4679	4762	5647	-	-
2015	237	380	624	1042	1361	1955	2674	3390	+	+	+	+	-	-
2016	227	338	518	944	1422	2009	2730	3411	3690	5757	+	+	+	+
2017	142	335	576	882	1477	2511	3165	3277	3246	3576	+	+	+	-
2018	175	390	682	958	1504	2238	3342	3313	4060	3481	3576	-	+	+

[1]Justert høsten 2018 etter oppdatering av data og nye beregninger
[1]*Adjusted autumn 2018 after update of input data and new estimates*

5.3 Mengdeindekser og vekst for kysttorsk

Det må understrekes at det fremdeles er vanskelig å beregne mengden av kysttorsk akustisk, fordi registreringene er små på grunn av lav bestand.. Av samme årsak er også beregningene av middelvekt og modning ved alder usikre. I tillegg må det bemerkes at fjordene i Trøndelag/Møre ikke ble undersøkt i 2013 og på Sunnmøre i 2015 på grunn av tidsmangel. Dette gjør selvsagt at torskemengden i område 07 er underestimert i disse åra.

Tabell 5.3.1 viser akustisk estimert tall på kysttorsk fordelt på lengdegrupper og alder for hele det undersøkte området, og tabell 5.3.2 viser tallet på fisk i hver aldersgruppe for hvert av de 6 underområdene.

Tabell 5.3.1 Kysttorsk. Akustiske mengdeindekser (i tusen) på alder og lengde i 2018.
Coastal cod. Acoustic abundance indices (in thousands) by length and age in 2018.

Lengde *Length* *(cm)*	Alder (Årsklasse) / *Age (Year class)* 1 (17)	2 (16)	3 (15)	4 (14)	5 (13)	6 (12)	7 (11)	8 (10)	9 (09)	10+ (08+)	Sum
5-10	1213										1213
10-14	6297										6297
15-19	1746	2									1748
20-24	1608	132									1740
25-29	292	532	2								826
30-34	5	808	92								906
35-39		1067	361	19							1447
40-44		385	369	83	13	11					862
45-49		64	697	393	20	20					1194
50-54		5	437	424	76	49	2				994
55-59			338	613	198	87		36	2		1274
60-64			91	818	358	220	17	18			1523
65-69			149	360	604	310	136	8	36	90	1693
70-74				193	361	579	92	77	44	33	1378
75-79				26	209	302	124	58	47	49	815
80-84				5	282	179	145	95	21	52	781
85-89				6	36	179	132	43	13	19	429
90-94					52	70	100	55	46	50	374
95-99							6	33	11	12	61
100+							51	20	37	64	172
Sum:	11160	2995	2537	2940	2209	2006	805	444	257	371	25725

Tabell 5.3.2 Kysttorsk. Akustiske mengdeindekser (i tusen) i hvert underområde og totalt i 2018.
Coastal cod. Acoustic abundance indices (in thousands) by sub areas and in total in 2018.

Område *Area*	Alder (Årsklasse) / *Age (Year class)* 1 (17)	2 (16)	3 (15)	4 (14)	5 (13)	6 (12)	7 (11)	8 (10)	9 (09)	10+ (08+)	Sum
03	3313	914	883	874	614	401	145	103	65	93	7405
04	3577	1324	753	1147	688	812	329	85	69	115	8900
05	434	304	264	361	414	488	248	153	84	135	2884
00	1572	127	318	308	74	150	32	79	-	28	2688
06	2264	326	302	192	168	31	14	3	-	-	3300
07	-	-	17	58	252	124	37	21	39	-	548
Total	11160	2995	2537	2940	2209	2006	805	444	257	371	25725

Tidsserien av mengdeindekser vises i tabell 5.3.3. Kysttorsken er som seien ikke ”rekruttert til toktet” før den er 2-3 år, fordi den vokser opp på grunt vann og derfor ikke er mulig å fange representativt med trål. Etter hvert som fisken blir større og eldre trekker den ut på dypere vann og blir tilgjengelig i undersøkelser. Derfor øker ofte antall fisk i en og samme årsklasse med alderen fra 1 til 3 år. Rekrutteringen har blitt svakere og svakere i hele perioden fra 1995 og fram til og med 2002. Det var en liten økning i antall 1- og 2-åringar i 2003 og 2004, mens antall i 2005 igjen var nede på om lag samme nivå som i 2002, som er det laveste observerte i tidsserien. I 2006 - 2009 var det igjen en liten økning i antall 1-åringer, og antall fra 2010, 2011 og 2013-2015 er de høyeste siden 2001. Antall 1-åringer i årets tokt er et av de høyeste i hele tidsserien. Det er større usikkerhet i otolitt-type av 1-åringer enn av eldre fisk, men en kan håpe at den økning vi har sett for 1-åringer de forrige årene og i 2018 fortsetter, og at det om noen år vil blir synlig i den eldre delen av bestanden. For 2-åringer er otolitt-type mer sikker og toktmålet for 2-åringar er et bedre mål for rekruttering. Her ser vi en nedgang siden 2014.

Toktindeksen i 2018 for aldersgrupper med moden fisk (4+), er ganske likt gjennomsnittet for 2003-2017, mens indeksen for 7-9 åringer er litt under gjennomsnittet. Sammenlignet med 2017 var det i 2018 en økning i beregnet antall kysttorsk i alle områder utenom område 05 (Vesterålen), stort sett på grunn av en økning i antall 1 åringer. Tar man ikke disse med i betraktning så har antall kysttorsk i områder 04 og 05 gått ned.

Lengde og vekt ved alder for aldersgruppene 1-10+ år vises i tabell 5.3.4 og 5.3.5. Både lengde og vekt ved alder var i 2018 omtrent på same nivå som i 2017 for de flest aldersgruppene.

Totalt registrert akustisk biomasse av kysttorsk er vist i tabell 5.3.6. Det var en kraftig nedgang i 2015 (om lag 40%), mens toktet i 2016 viste en økning på over 20%. 2017-toktet viste en nedgang på om lag 30%, og er den laveste registrerte siden 2010. 2018-toktet viser en økning på 11%, som tilsvarer 93% av gjennomsnittet for perioden 2001-2017.

Andel av kjønnsmoden fisk ved alder er vist i tabell 5.3.7, og beregnet gytebiomasse er vist i tabell 5.3.8. Gytebiomassen beregnet fra toktet i 2018 er 18.4 tusen tonn. Det er 31% høyere enn resultatet fra toktet i 2017, men fortsatt langt under målet i gjenoppbyggingsplanen (60 tusen tonn).

Tabell 5.3.3 Kysttorsk. Akustiske mengdeindekser (i tusen) for hver aldersgruppe 1995 – 2018.
Coastal cod. Acoustic abundance indices (in thousands) by age 1995 – 2018.

År *Year*	Alder / *Age* 1	2	3	4	5	6	7	8	9	10+	Sum
1995	28707	20191	13633	15636	16219	9550	3174	1158	781	579	109628
1996	1756	17378	22815	12382	12514	6817	3180	754	242	5	77843
1997	30694	18827	28913	17334	12379	10612	3928	1515	26	663	124891
1998	14455	13659	15003	13239	7415	3137	1578	315	169	128	69099
1999	6850	11309	12171	10123	7197	3052	850	242	112	54	51960
2000	9587	11528	11612	8974	7984	5451	1365	488	85	97	57171
2001	8366	6729	7994	7578	4751	2567	1493	487	189	116	40270
2002	1329	2990	4103	4940	3617	2593	1470	408	29	128	21607
2003	2084	2145	3545	3880	2788	2389	1144	589	364	80	19008
2004	3217	3541	3696	4320	2758	1940	783	448	98	110	20914
2005	1443	1843	3525	3198	3217	1700	1120	552	330	78	17006
2006	1929	2525	4049	3783	3472	2509	1811	399	229	13	20719
2007	2202	3300	4080	5518	3259	2447	1444	760	197	34	23241
2008	2128	2181	2475	2863	2101	1219	815	403	319	177	14681
2009	3442	2059	2722	3959	2536	1603	1259	793	443	141	18955
2010	7768	2513	2729	2820	2417	1098	501	426	260	305	20837
2011	9015	3266	3950	4571	3012	2185	448	478	171	339	27435
2012	4887	2292	3003	2993	1990	1125	814	339	144	430	18015
2013[1]	10478	3222	2780	3545	2742	2072	1164	971	449	431	27854
2014	5104	5516	3425	2659	4514	2660	2053	1189	980	676	28776
2015[2]	6939	5084	3695	3441	2053	1984	1029	601	529	404	25759
2016	4857	4214	4850	3760	3108	1455	1022	955	187	474	24881
2017	1712	3950	4402	2910	2220	1412	664	436	248	234	18186
2018	11160	2995	2537	2940	2209	2006	805	444	257	371	25725

[1] Fjordene i område 07 ikke dekket i 2013
[2] Sørlige fjorder i område 07 ikke dekket i 2015

Tabell 5.3.4 Kysttorsk. Gjennomsnittslengde (cm) i hver aldersgruppe 1995 – 2018.
Coastal cod. Mean length (cm) at age 1995 – 2018.

År	Alder / *Age*									
Year	1	2	3	4	5	6	7	8	9	10+
1995	21.5	33.0	43.0	52.0	59.1	64.1	76.0	87.4	89.0	108.3
1996	19.0	30.2	41.7	52.5	59.2	65.2	79.1	84.8	87.0	114.2
1997	16.8	28.7	40.8	51.6	58.1	65.9	73.6	80.8	102.0	110.7
1998	20.3	33.3	43.8	51.4	59.1	66.3	74.1	81.0	93.2	116.9
1999	21.5	32.6	43.8	54.6	59.6	65.8	77.9	90.8	99.4	118.0
2000	21.6	33.3	43.4	53.5	61.0	66.1	75.5	90.8	99.1	105.5
2001	21.1	33.3	44.5	53.6	62.9	64.7	88.7	84.2	85.7	102.1
2002	22.5	34.4	44.6	56.0	61.6	67.7	72.4	66.6	89.0	108.3
2003	18.9	33.8	42.1	51.6	60.0	67.2	72.7	76.9	84.9	94.8
2004	20.7	32.9	43.5	54.5	59.9	68.0	71.9	75.0	74.6	91.8
2005	22.5	32.8	42.2	57.9	60.6	64.0	71.3	69.9	73.5	108.4
2006	22.2	36.1	47.0	55.5	61.4	68.0	69.5	77.8	87.0	100.5
2007	21.6	36.0	48.0	57.9	62.2	66.8	71.8	86.6	100.2	106.3
2008	21.9	36.9	49.2	59.0	66.1	70.9	71.7	74.1	77.6	98.8
2009	20.9	34.5	47.8	57.8	65.8	70.5	77.9	78.4	85.1	73.5
2010	20.3	34.9	46.4	57.5	64.6	71.2	76.9	75.2	78.9	82.7
2011	20.6	32.9	47.2	59.5	66.1	71.5	79.9	82.0	81.1	83.9
2012	21.3	32.4	46.9	58.8	66.1	72.0	77.0	77.5	82.2	87.3
2013	21.5	33.6	44.5	56.7	66.2	71.3	74.2	84.2	84.6	88.1
2014	21.7	35.1	47.7	57.3	66.4	73.5	76.6	80.5	81.7	93.0
2015	19.9	33.5	46.9	58.0	66.5	70.3	77.8	77.7	80.5	85.5
2016	20.5	32.9	47.8	58.7	67.8	72.2	75.1	83.0	89.7	86.9
2017	23.5	35.6	47.2	58.3	66.1	72.6	75.2	82.4	82.6	91.2
2018	19.4	35.4	47.7	58.8	68.1	71.3	79.8	80.3	85.5	84.4

Tabell 5.3.5 Kysttorsk. Gjennomsnittsvekt (gram) i hver aldersgruppe 1995 – 2018.
Coastal cod. Mean weight (grams) at age 1995-2018.

År	Alder / *Age*									
Year	1	2	3	4	5	6	7	8	9	10+
1995	81	390	791	1525	2222	2881	4665	6979	6759	9897
1996	59	252	724	1433	2053	2748	4722	6685	6932	9723
1997	43	240	683	1364	1893	2816	4426	6406	7805	1827
1998	52	372	883	1456	2107	2950	4319	5625	8323	12468
1999	70	323	841	1675	2192	2857	4540	6579	9454	12902
2000	72	365	809	1554	2539	3049	4352	6203	8527	12066
2001	51	396	966	1524	2314	3320	3695	6144	8768	12468
2002	103	428	895	1741	2433	3133	4273	4397	7759	12992
2003	62	385	738	1353	2145	3103	3981	4921	6923	9956
2004	83	352	834	1690	2255	3312	4150	4594	4383	9733
2005	112	359	786	2168	2265	2756	4174	3373	4502	15887
2006	105	474	1080	1746	2430	3336	3684	5125	7028	14650
2007	103	518	1185	2011	2500	3160	4241	6806	11051	14931
2008	96	508	1208	2095	2987	3671	3976	4387	5415	11588
2009	85	434	1116	2003	2894	3632	4875	5400	6125	4719
2010	75	419	1026	1996	2839	3665	4868	4895	5685	6504
2011	77	343	1062	2119	2882	3761	5505	6336	6309	6570
2012	89	336	1038	2006	2998	3727	4783	5071	5851	7446
2013	88	365	851	1815	2856	3561	4122	6435	5974	7670
2014	93	423	1071	1845	2886	3905	4495	5249	5871	8762
2015	75	370	1045	1940	2910	3518	4927	4753	5864	7277
2016	77	344	1121	2033	3081	3734	4286	5895	7556	6984
2017	78	421	1026	1868	2687	3746	4419	6050	6887	7637
2018	69	392	1158	1948	3192	3705	5304	5354	6428	6038

Tabell 5.3.6 Kysttorsk. Akustiske biomasseindekser (tonn) i 1995 – 2018.
Coastal cod. Acoustic biomass indices (tons) in 1995 – 2018.

År *Year*	Alder / *Age* 1	2	3	4	5	6	7	8	9	10+	Sum
1995	2337	7868	10786	23846	36039	27515	14445	8761	4933	7779	144309
1996	145	4386	16521	17739	25687	18731	15562	4376	3130	46	106323
1997	1319	4518	19748	23644	23435	29884	15060	8860	249	8643	135360
1998	752	5078	13247	19274	15627	9255	6675	1646	1329	2083	74966
1999	477	3650	10233	16960	15774	8720	4723	2097	1220	567	64421
2000	688	4321	9824	14464	20482	17067	5936	4359	926	1232	79299
2001	425	2662	7724	11548	10993	8521	5517	3010	1705	1917	54022
2002	137	1279	3672	8600	8801	8124	6282	1794	225	1663	40577
2003	125	876	2569	5328	5788	6995	4201	2754	2674	1136	32446
2004	329	1269	3087	7394	6089	6901	3009	1779	454	1058	31405
2005	109	675	2947	6521	7167	4807	3648	1942	1315	1205	30336
2006	202	1197	4374	6605	8435	8367	6672	2045	1602	190	39689
2007	227	1709	4835	11097	8148	7733	6124	5173	2177	508	47731
2008	206	1212	3120	6085	6593	4203	3437	2014	1492	2066	30506
2009	294	893	3037	7933	7335	5821	6137	4282	2707	665	39107
2010	583	1053	2800	5629	6862	4024	2439	2085	1478	1984	28936
2011	695	1120	4195	9686	8681	8218	2466	3029	1079	2227	41396
2012	295	767	2974	5914	5574	4143	3820	1673	775	3265	29199
2013[1]	519	1192	2767	6890	8067	7252	4756	5937	2797	3178	43355
2014	456	2218	3849	5026	13418	9994	9691	6367	7308	6608	64935
2015[2]	424	1972	3872	6423	5646	6546	4587	2747	3172	2794	38183
2016	250	1364	5792	7746	10236	5409	4156	6091	1322	3657	46023
2017	133	1664	4516	5436	5965	5289	2934	2638	1708	1787	32070
2018	770	1173	2939	5726	7051	7433	4270	2377	1652	2240	35631

[1] Fjordene i område 07 ikke dekket i 2013. [2] Sørlige fjorder i område 07 ikke dekket i 2015

Tabell 5.3.7 Kysttorsk. Andel kjønnsmodne ved alder i perioden 1995 – 2018.
Coastal cod. Maturity ogives by age in the period 1995 – 2018.

År *Year*	Alder / *Age* 1	2	3	4	5	6	7	8	9	10+
1995	0.00	0.00	0.01	0.21	0.48	0.71	0.87	0.87	1.00	1.00
1996	0.00	0.00	0.03	0.25	0.56	0.81	0.92	0.99	1.00	1.00
1997	0.00	0.00	0.06	0.29	0.45	0.76	0.97	1.00	1.00	1.00
1998	0.00	0.02	0.15	0.25	0.53	0.74	0.87	0.89	1.00	1.00
1999	0.00	0.02	0.03	0.21	0.43	0.66	0.74	1.00	1.00	1.00
2000	0.00	0.00	0.00	0.16	0.31	0.61	0.76	0.64	0.99	1.00
2001	0.00	0.00	0.00	0.04	0.37	0.78	0.98	0.99	0.97	1.00
2002	0.00	0.02	0.02	0.26	0.88	0.93	0.90	0.97	1.00	1.00
2003	0.00	0.00	0.00	0.05	0.29	0.49	0.90	0.98	0.96	1.00
2004	0.00	0.00	0.01	0.09	0.37	0.76	0.95	0.98	1.00	1.00
2005	0.00	0.00	0.00	0.07	0.40	0.56	0.89	0.98	1.00	1.00
2006	0.00	0.00	0.00	0.14	0.52	0.75	0.91	0.87	0.96	1.00
2007	0.00	0.00	0.00	0.14	0.54	0.76	0.96	0.83	1.00	1.00
2008	0.00	0.00	0.03	0.12	0.48	0.72	0.89	0.94	0.96	1.00
2009	0.00	0.00	0.02	0.06	0.26	0.35	0.59	0.74	0.60	0.92
2010	0.00	0.00	0.00	0.08	0.38	0.66	0.83	0.88	0.95	0.97
2011	0.00	0.01	0.00	0.06	0.42	0.73	0.81	0.53	0.92	0.85
2012	0.00	0.00	0.01	0.05	0.38	0.66	0.90	0.92	0.97	0.99
2013	0.00	0.00	0.00	0.01	0.32	0.65	0.86	0.94	0.99	0.96
2014	0.00	0.00	0.00	0.06	0.24	0.66	0.81	0.94	1.00	0.97
2015	0.00	0.00	0.00	0.07	0.23	0.57	0.75	0.88	0.89	0.94
2016	0.00	0.00	0.00	0.09	0.30	0.59	0.83	0.85	0.97	1.00
2017	0.00	0.00	0.00	0.07	0.30	0.65	0.88	0.94	0.97	0.97
2018	0.00	0.00	0.01	0.15	0.41	0.69	0.83	0.95	1.00	0.92

Endringer i fiskefordeling og fangster siden 2015

I toktet i 2015 utgjorde torsken en ganske liten andel av ekkomengden i blandete registreringer på ekkoloddet. Dette sammen med manglende dekning i grunne områder og stor blindsone i bratte skråninger gjør at det er stor usikkerhet i det akustiske mengdemålet for torsk. Resultata fra toktet i 2015 var likevel lavere enn en kunne vente etter de to foregående toktene. Det er særlig tre årsaker som trolig kan forklare nedgangen. Dårlig dekning i de indre områdene i det sørligste området (07) ga lavere indeks, siden det er i de indre områdene det tidligere har vært registrert mest torsk. Den største nedgangen ble registrert i område 04 og 05. I de indre delene av område 04 ble det under toktet i 2015 registrert svært høye akustiske verdier ($S_{A)}$ på dypt vann som ikke stammet fra fisk (dypere enn 150-200 meter). På det tetteste ble det registrert S_A-verdier på opp mot 30000 per nautisk mil. Det viste seg etter en del forsøk ved Universitetet i Tromsø at det trolig var ribbemaneter og siphonoforer som var årsaka, både levende og delvis dødende/halvt oppløste (Knutsen et al. 2017). I områder med slike tette forekomster var det generelt svært lave fangster av fisk. Det er derfor mulig at fisken i større grad har trukket inn på grunnere vann og dermed sto i bratte kanter og var mindre tilgjengelig for akustisk registrering enn tidligere. Noe av det samme ble registrert i 2017, men ikke i like stor grad. Den tredje årsaken til nedgangen kan være at det i desember 2014 og januar 2015 var et stort fiske av torsk i et område rundt grensa mellom 04 og 05 som trolig i all hovedsak var kysttorsk. Innsiget av skrei var uvanlig seint i 2015, samtidig med at det kom inn nokså mye kysttorsk under innsiget av sild høsten 2014. Hele desember 2014 og januar 2015 ble det fisket nokså store kvanta torsk på et relativt avgrenset område før skreien kom. Siden det ikke var torsk å få i andre områder grunnet sent skrei-innsig, steg prisene dramatisk og mange fartøy kom nord til dette området og fisket hele kvoten her. Det ble landet om lag 17000 tonn torsk i januar i område 04 og 05. Mye av dette var trolig kysttorsk. Det er også i den voksne delen av bestanden som er utsett for kommersiell fangst at vi ser nedgangen. Det var et relativt bra fiske av torsk i perioden november 2015 til februar 2016 nord i område 05 og sør i område 04 hvor silda kom inn til kysten. Selv om skreiinnsiget også i 2016 kom sent til dette området ble det nok landet mindre kysttorsk enn året før. Dette kan nok være noe av årsaken til at en ikke så en videre nedgang for kysttorsken i 2016.

Skreiinnsiget kom sent også i 2017, og det ble fisket «sildetorsk» i et større område enn de foregående årene fordi det i 2017 også kom en del sild inn i fjordene i Nord-Troms. Også i starten av 2018 ble det fisket betydelig mengder kysttorsk i sildeansamlinger i fjordene i Nord-Troms.

Tabell 5.3.8 Kysttorsk. Akustiske gytebiomasseindekser (tonn) i 1995 – 2018.
Coastal cod. Acoustic spawning biomass indices (tons) in 1995 – 2018.

År	Alder / *Age*										
Year	1	2	3	4	5	6	7	8	9	10+	Sum
1995	0	0	96	4925	17424	19614	12573	7648	4933	7779	74992
1996	0	0	468	4467	14320	15130	14365	4311	3130	46	56237
1997	0	0	1185	6857	10546	22712	14608	8860	249	8643	73660
1998	0	92	2026	4870	8252	6804	5774	1461	1329	2083	32691
1999	0	56	315	3544	6778	5716	3478	2097	1220	567	23771
2000	0	0	0	2366	6354	10426	4486	2798	916	1232	28579
2001	0	0	15	508	4102	6662	5398	2978	1650	1917	23230
2002	0	20	87	2240	7702	7551	5650	1747	225	1663	26885
2003	0	0	0	269	1670	3428	3778	2686	2554	1136	15521
2004	0	0	28	679	2252	5253	2853	1736	434	722	13959
2005	0	0	0	447	2844	2670	3247	1898	1315	288	12709
2006	0	0	0	925	4386	6275	6072	1779	1538	571	21546
2007	0	0	0	1554	4400	5877	5879	4294	2177	508	24689
2008	0	0	107	734	3189	3012	3049	1902	1434	2066	15493
2009	0	0	61	476	1907	2037	3621	3169	1624	612	13508
2010	0	0	0	450	2608	2656	2024	1835	1404	1924	12901
2011	0	11	0	581	3646	5999	1997	1605	993	1893	16725
2012	0	0	22	278	2126	2748	3457	1539	755	3219	14143
2013[1]	0	0	0	56	2580	4713	4112	5576	2773	3046	22856
2014	0	0	0	314	3222	6593	7831	5958	7307	6433	37659
2015[2]	0	0	0	457	1301	3719	3436	2414	2811	2627	16763
2016	0	0	0	725	3084	3196	3464	5190	1278	3657	20597
2017	0	0	0	374	1779	3464	2582	2489	1662	1729	14078
2018	0	0	29	859	2891	5129	3544	2258	1652	2061	18423

[1]Fjordene i område 07 ikke dekket i 2013.
[2] Sørlige fjorder i område 07 ikke dekket i 2015

5.4 REFERANSER

Foote, K.G. 1987. Fish target strengths for use in echo integrator surveys. Journal of the Acoustical Society of America, 82: 981-987.

Jolly, G. M., & Hampton, I. (1990). A stratified random transect design for acoustic surveys of fish stocks. *Canadian Journal of Fisheries and Aquatic Sciences*, *47*(7), 1282-129.

Knutsen, T., Hosia, A., Falkenhaug, T., Skern-Mauritzen, R.,. Wiebe, P.H., Larsen, R.B., Aglen, A., and Berg,E. 2018. Coincident Mass Occurrence of Gelatinous Zooplankton in Northern Norway. Frontiers in Marine Science. doi: 10.3389/fmars.2018.00158

Korneliussen, R. J., Heggelund, Y., Macaulay, G. J., Patel, D., Johnsen, E., & Eliassen, I. K. (2016). Acoustic identification of marine species using a feature library. *Methods in Oceanography*, *17*, 187-205.

Korsbrekke, K. 1996. Brukerveiledning for TOKT312 versjon 6.3. Intern program dokumentasjon., Havforskningsinstituttet, september 1996. 20s. (upubl.).

Mehl, S., Aglen, A., Berg, E. Dingsør, G. and Korsbrekke, K. 2016. Akustisk mengdemåling av sei, kyst-torsk og hyse Finnmark – Møre hausten 2016. Acoustic abundance of saithe, coastal cod and haddock Finnmark – Møre Autumn 2016. Toktrapport/Havforsknings-instituttet/ISSN 1503-6294, Nr. 15 – 2016. 38s.

Mehl, S., Skålevik, Å., Aglen, A. and Johnsen, E. 2018. Estimation of acoustic indices with CVs for saithe in the Norwegian coastal survey 2003-2017 applying the Sea2Data StoX software. Fisken og havet 01/2018. Institute of Marine Research, Bergen, Norway. 19 pp

Mjanger, H., Svendsen, B.V., Senneset, H., Fotland, Å., Mehl, S., Fuglebakk, E., Gulbrandsen, M.L., og Diaz, J. 2019. Håndbok for prøvetaking av fisk, krepsdyr og andre evertebrater. Versjon 5.0. Januar 2019. (In Norwegian).

2017 Acoustic Barents Sea winter survey and Lofoten Acoustic survey

		age1	age2	age3	age4	age5	age6	age7	age8	age9	age10	age11	age12	age13	age14+	sum (mill)	Biomass (thousand t)
BS_Win_Acoust	N(mill)	396.60	48.50	91.20	40.40	48.40	67.70	36.90	26.20	13.70	5.45	3.14	5.19	0.66	0.56	784.50	721.40
BS_Win_Acoust	meanW(kg)	0.016	0.092	0.297	0.737	1.253	2.016	3.091	4.645	6.088	7.403	9.186	8.412	12.416	16.803		
BS_Win_Acoust	frac.mat	0	0	0	0.0018	0.0020	0.0932	0.3899	0.7253	0.9150	1.0000	1.0000	0.9860	1.0000	1.0000		
Lof Acoust N(mill)						0.18	8.94	12.86	24.07	14.76	12.58	11.58	12.01	3.72	3.51	104.20	636.3
Lof Acoust meanW (kg)						1.958	2.478	2.942	4.804	5.739	7.122	8.160	9.117	10.430	12.308		
Lof Acoust mat	frac.mat					0.9500	0.8400	1.0000	0.9100	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000		
Combined BS_Lof N(mill)		396.60	48.50	91.20	40.40	48.58	76.64	49.76	50.27	28.46	18.03	14.72	17.20	4.38	4.07	888.70	1357.66
Combined BS_Lof meanW (kg)		0.016	0.092	0.297	0.737	1.256	2.070	3.052	4.721	5.907	7.207	8.379	8.904	10.729	12.926		
Combined BS_Lof mat	frac.mat	0.000	0.000	0.000	0.002	0.005	0.180	0.548	0.814	0.959	1.000	1.000	0.996	1.000	1.000		

2018 Acoustic Barents Sea winter survey and Lofoten Acoustic survey

		age1	age2	age3	age4	age5	age6	age7	age8	age9	age10	age11	age12	age13	age14+	sum (mill)	Biomass (thousand t)
BS_Win_Acoust	N(mill)	1492.4	221.3	90	135.9	46.7	51.1	56.3	35	10.1	6.56	1.47	2.16	1.54	0.4	2150.9	818.1
BS_Win_Acoust	meanW(kg	0.011	0.066	0.306	0.688	1.243	2.074	2.85	4.179	5.524	6.791	9.223	10.497	11.164	12.268		
BS_Win_Acoust	frac.mat	0.0000	0.0001	0.0000	0.0014	0.0168	0.1088	0.2633	0.4857	0.8933	0.9750	1.0000	0.9670	0.9811	1.0000		
Lof Acoust N(mill)					0.2	0.6	3.5	11.5	11.2	8.5	7.8	4.4	3.7	2.8	3.1	104.20	380.8
Lof Acoust meanW (kg)					2.237	3.247	2.721	3.408	4.528	6.512	7.943	9.694	12.059	12.053	13.146		
Lof Acoust mat	frac.mat				0.0000	1.0000	0.9500	0.9700	1.0000	0.9900	1.0000	1.0000	1.0000	1.0000	1.0000		
Combined BS_Lof N(mill)		1492.40	221.30	90.00	136.09	47.32	54.58	67.75	46.21	18.58	14.34	5.91	5.89	4.36	3.46	2255.10	1198.90
Combined BS_Lof meanW (kg)		0.011	0.066	0.306	0.690	1.269	2.115	2.944	4.264	5.975	7.416	9.576	11.485	11.739	13.044		
Combined BS_Lof mat	frac.mat	0.000	0.000	0.000	0.001	0.030	0.162	0.383	0.610	0.937	0.989	1.000	0.988	0.993	1.000		

2019 Acoustic Barents Sea winter survey and Lofoten Acoustic survey

		age1	age2	age3	age4	age5	age6	age7	age8	age9	age10	age11	age12	age13	age14+	sum (mill)	Biomass (thousand t)
BS_Win_Acoust	N(mill)	1000.3	287.4	182.1	97.7	124.3	53.4	33.7	31.6	8.7	2.83	0.38	0.33	0.2	0.39	1823.3	731.2
BS_Win_Acoust	meanW(g)	11	46	311	748	1275	2007	3022	4074	5464	6357	9921	11464	13618	12341		730.7
BS_Win_Acoust	frac.mat	0.0000	0.0000	0.0000	0.0035	0.0385	0.2089	0.5828	0.8532	0.8992	0.9876	0.9520	1.0000	1.0000	1.0000		
Lof Acoust N(mill)						0.5	2.9	14.3	36.1	17.7	18.4	6.1	2.5	2.4	5.0	106.02	662.9
Lof Acoust meanW (g)						1896	2888	3721	4817	6069	7432	8684	11069	13867	13420		
Lof Acoust mat	frac.mat					0.4593	0.8157	0.9292	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	0.9787		
Combined BS_Lof N(mill)		1000.30	287.40	182.10	97.70	124.84	56.28	48.03	67.69	26.37	21.24	6.48	2.87	2.64	5.42	1929.32	1394.10
Combined BS_Lof meanW (g)		11	46	311	748	1277	2052	3231	4470	5869	7288	8757	11115	13848	13343		
Combined BS_Lof mat	frac.mat	0.000	0.000	0.000	0.003	0.040	0.240	0.686	0.931	0.967	0.998	0.997	1.000	1.000	0.980		

Greenland halibut EcoJuv survey index

Tone Vollen, Kristin Windsland, Elvar Hallfredsson and Mikko Vihtakari

29 april 2019

1 Why recalculate the EcoJuv index?

Over the last few years, the institute has moved all raw data from a simple text-format (database name “årsmaterialet” with file format = “spd”) to a new database (database name “Sea2Data” with file format xml). The flexibility of the new database and the accompanying software/hardware (Fish2Data) allowed us to improve the somewhat complicated Greenland halibut sampling regime. Since 2016, the sampling regime was changed, and the previous index calculations could not be used on newer data (2016-2018).

Prior to 2016, catch size and length distributions were stored split on “Females”, “Males” or “Unsexed” in the database. With the new sampling regime, catch size and length distributions are no longer split by sex in the database, and the number of samples has decreased a lot. This means that splitting the indices on sex is not as straight-forward as it was earlier.

The EcoJuv-index is based on data from two cruise series, the old Greenland halibut juvenile cruise (1996-2002) and the Ecosystem cruise (2003-pt). ***ICES names***

2 New and old raw data

When comparing raw data from the new and old database, there were differences (Table 1).

- the cruise series definitions differed, and thereby also the extracted dataset (not applicable to EcoJuv data series)
- corrections had been made to the data in the new database (ex. 2004, 2005)
- new errors were introduced when transferring data to the new database (ex. 2005, 2006)
- some data are still missing in the new database (ex 2000, 1998, 1999)

The influence of these difference on the index and length distributions is investigated further in section 6.

Table 1. Number of stations and samples in the two datasets. 2014 survey is excluded due to poor survey coverage.

	Old dataset			New dataset		
year	**stations**	**length samples**	**length-sex samples**	**stations**	**length samples**	**length-sex samples**
1996	56	1072	933	56	1081	882
1997	81	1936	1800	81	1958	1786
1998	104	3626	1875	–	–	–
1999	92	2757	1511	–	–	–
2000	82	3264	1873	76	3205	538
2001	87	3034	1910	87	3035	414

	Old dataset			New dataset		
year	stations	length samples	length-sex samples	stations	length samples	length-sex samples
2002	84	3483	2077	75	3452	2048
2003	66	2703	1518	66	2703	1115
2004	203	11644	10238	203	11717	10258
2005	156	10649	4957	156	11400	4957
2006	108	7055	4574	108	7055	4574
2007	122	6492	4421	122	6739	4132
2008	61	1217	1078	61	1217	1078
2009	54	1250	1150	54	1250	1150
2010	77	1799	1527	77	1799	1527
2011	70	1231	811	70	1231	811
2012	91	1777	1136	91	1777	1136
2013	79	1362	750	78	1196	722
2015	48	598	504	48	598	364
2016	–	–	–	47	605	380
2017	–	–	–	61	1309	810
2018	–	–	–	54	489	290

3 Old survey index

The “old index” (1996-2015) is the index used in the last assessment (AFWG 2017). The calculations are based on spd-files extracted from the “årsmaterialet”. Before 2016, all levels of greenland halibut data is split by sex, and the index calculations are done separately for males, females and unsexed. In the biomass index, unsexed were split by sex using the ratio females : males the same year. In the length distributions, unsexed in the length interval 20-45 cm were split using the ratio females : males within the same year and length group. If this was not possible, they were split using the overall ratio females : males withing the interval 20-45 cm the same year. The same ratio was used to split unsexed <20 cm (where sex determination was not trusted), and unsexed >45 cm (very few). In 2015, the number of sexed individuals were few, and the overall ratio females : males in the length interval 20-45 cm (ratio = 0.52) was used to split unsexed in all length groups.

4 New survey index

The “new index” (1996-2018) is based on data from the S2D database. Data were downloaded in xml format using the R-package Rstox, which provides functions for downloading as well as reading xml files into R.

Splitting by sex proved difficult due to the low number of samples the last few years (Table 1). However, we expect the sex ratio to be close to 1:1 in the juvenile area. This was investigated by plotting the yearly sex ratio of each 1 cm length group (Figure 4.1). Sex determination of fish smaller than 20 cm is difficult, and therefore not included. The sex ratio is close to 1:1 for individuals smaller than 50 cm, which is 99.6 % of all individuals in the survey. To keep things simple, ratio females : males was fixed to 1:1 for all years and all length groups. In the future, the higher proportion of females in larger length groups should be accounted for.

Figure 4.2 and 4.3 shows the old and new index together. Both indices are split by sex. In the new index, females and males are identical (e.i. lines are exactly on top of each other). Data for 1998 and 1999 are currently missing in the new database. The new 1:1 ratio calculations are therefore performed on old data for these years.

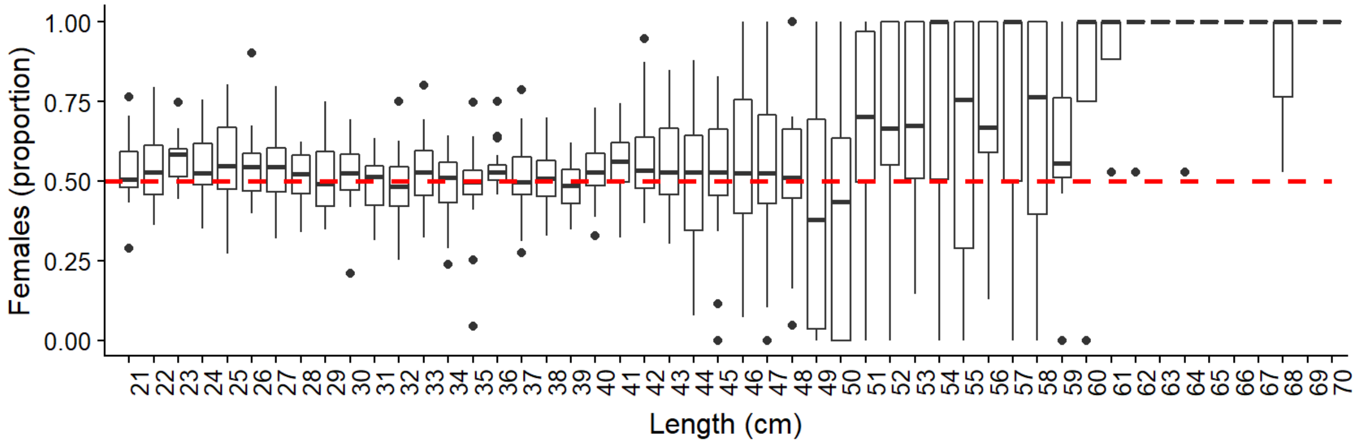


Figure 4.1: Yearly proportion of females by length. Dotted line (red) is ratio 1:1. Individuals < 20 cm are removed because sex determination is not trusted. 99.6 % of individuals are < 50 cm.

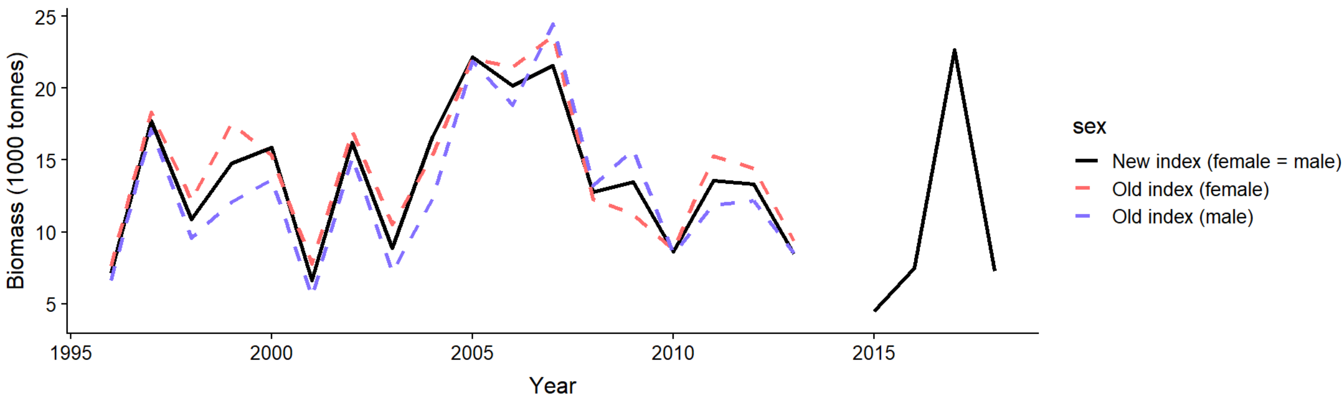


Figure 4.2: Old and new Greenland halibut EcoJuv index, split by sex. Old index in red (females) and blue (males), new index in black (females = males). Old data are used to split sex 1:1 for years 1998 and 1999. 2014 survey is excluded due to poor survey coverage.

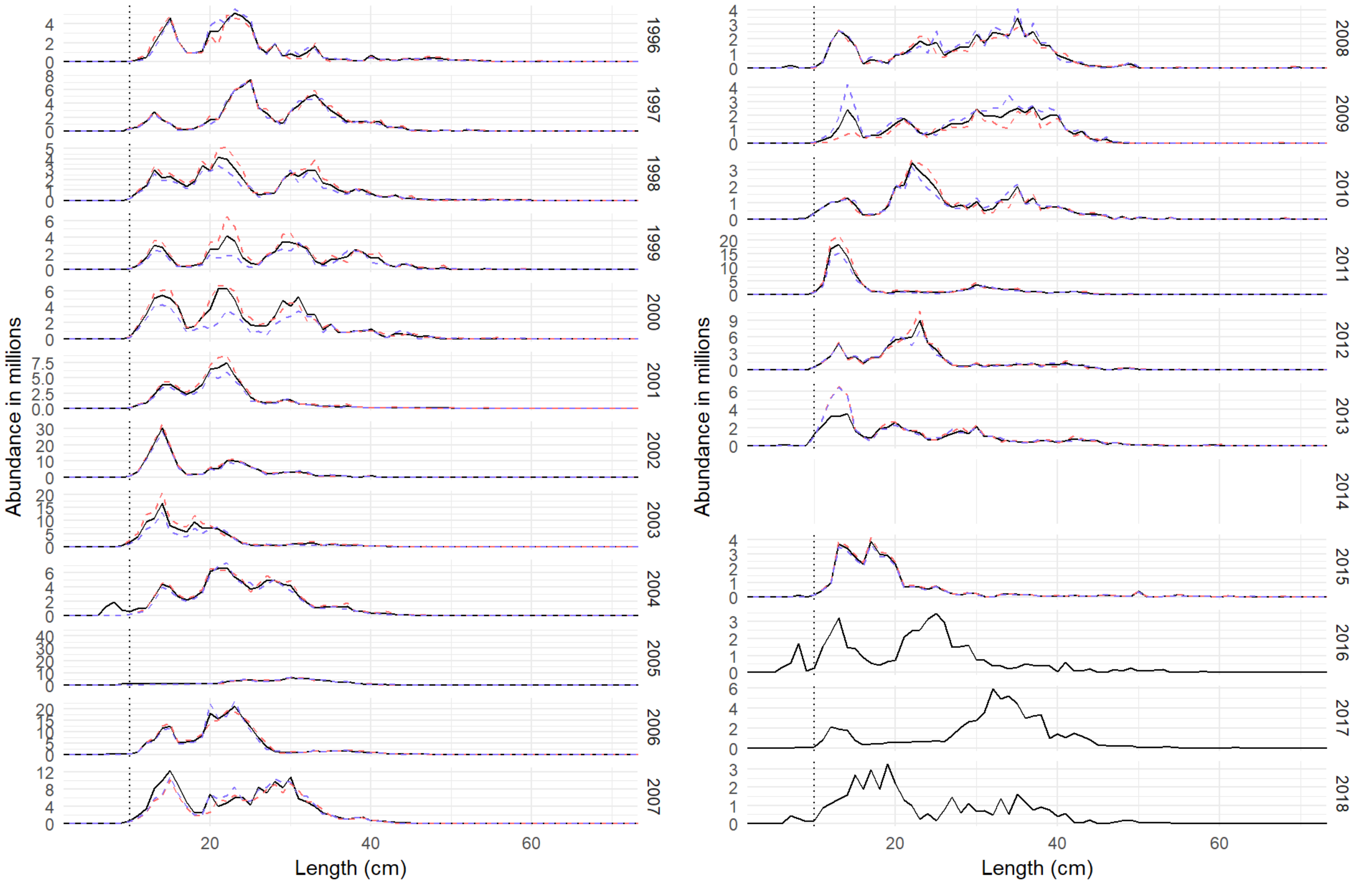


Figure 4.3: Old and new Greenland halibut EcoJuv index, split by sex. Old index in red (females) and blue (males), new index in black (females = males). Dotted line marks the smallest length included in gadget. Smaller lengths are set to 0. Old data are used to split sex 1:1 for years 1998 and 1999. 2014 survey is excluded due to poor survey coverage.

5 Sex ratio

The proportion of females in the new and old biomass index was compared (Figure 5.1 and 5.2). Within years, the indices differed by less than 10 %, so using a 1:1 ratio seems reasonable. The length frequency distributions is much more variable, particlularly for large fish where the sample size is small. The trends seen in fish < 20 cm in 1996 and 2009 are probably due to systematic errors in sex determination. In 2015, a ratio of 0.52 (females : males) was used to split all lengths by sex in the old index.

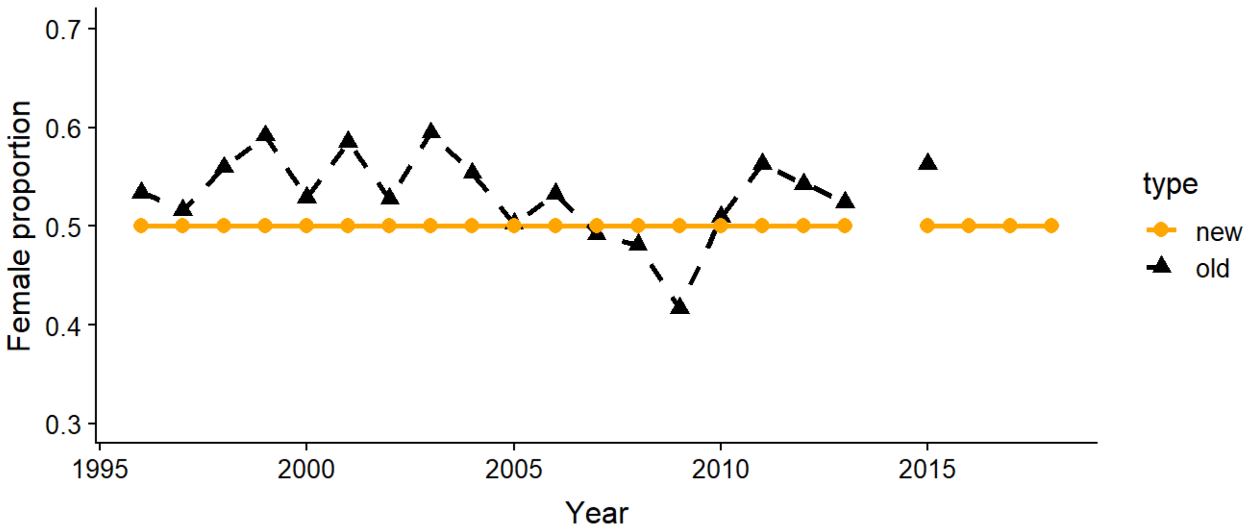


Figure 5.1: Proportion of females in the biomass index, comparison of old and new index.

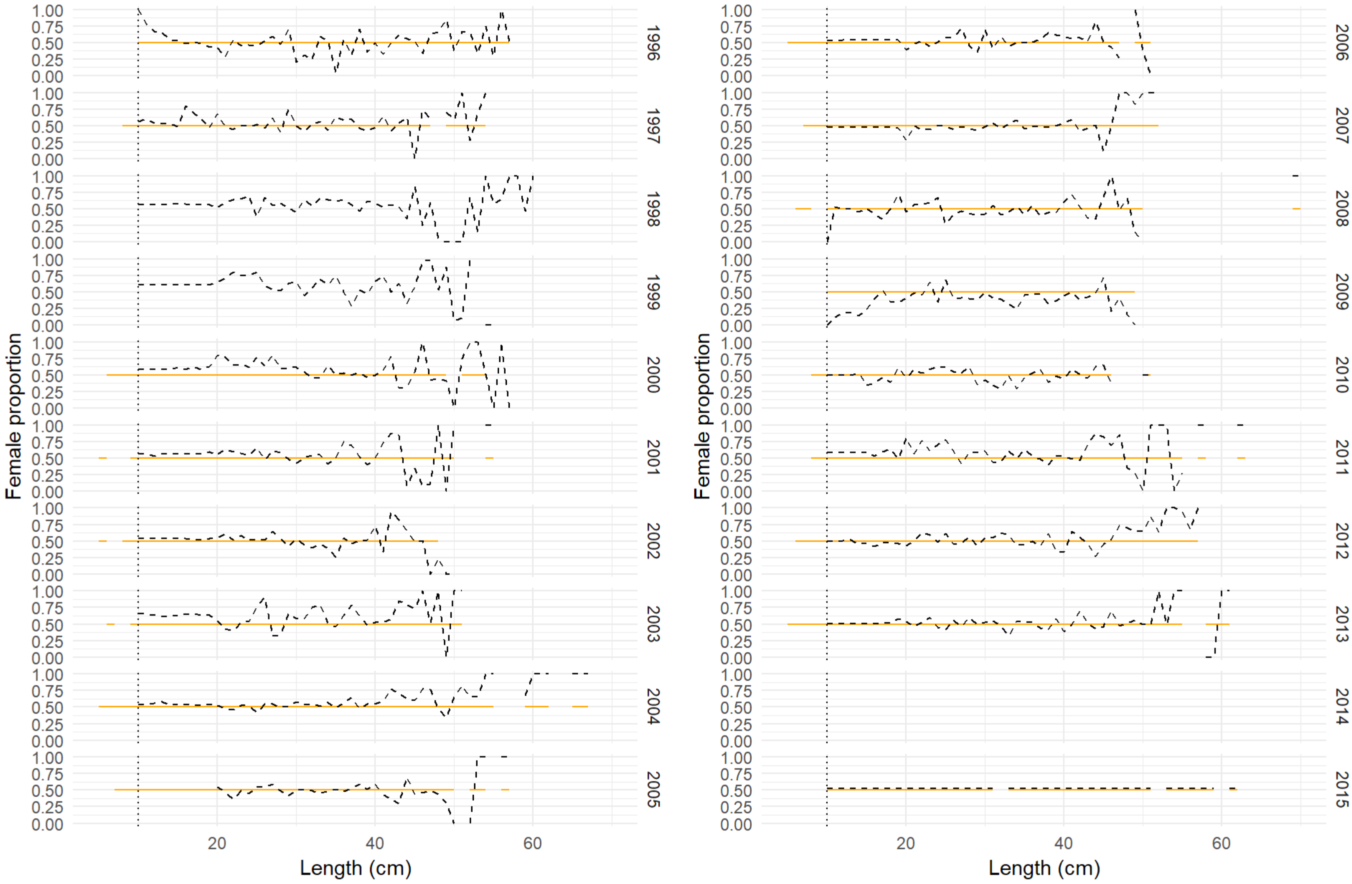


Figure 5.2: Proportion of females in the length distributions, comparison of old and new index. Data for 1998 and 1999 are currently missing in new database.

6 Difference in raw data

Figure 6.1 and 6.2 shows the old and new index and length distributions, sex combined. Differences between the indices are due to data that are partly or completely missing in the new database at this time (1998, 1999, 2000), or due to corrections and/or introduced errors (2004, 2007, 2013). Missing data and introduced errors will corrected before the next AFWG.

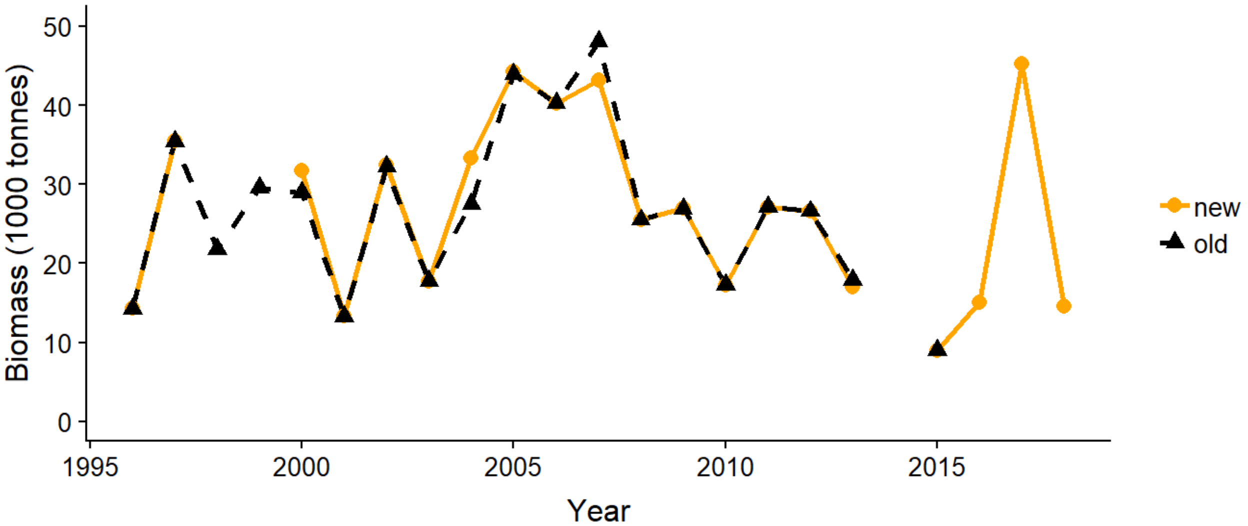


Figure 6.1: Biomass index, sex combined. Comparison of new and old dataset.Data for 1998 and 1999 are currently missing in new database.

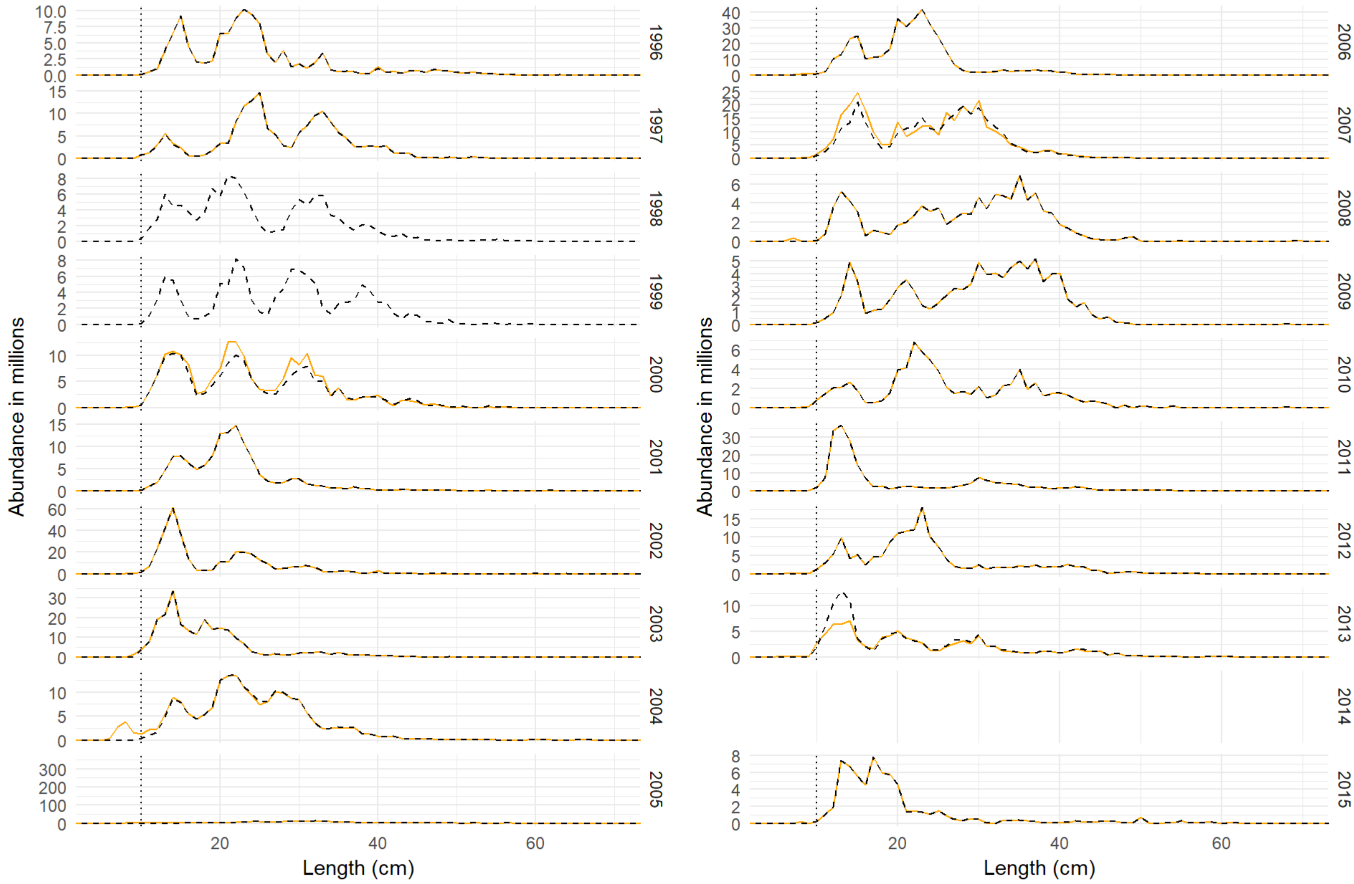


Figure 6.2: Length distributions, sex combined. Comparison of new and old dataset. Data for 1998 and 1999 are currently missing in new database.

7 Conclusion

Due to changes in the sampling regime, the old method used for index calculation could not be used for years 2016 onwards, and changes needed to be made. The new database currently have some flaws such as some missing data and introduced errors, but many of these have been compensated for. At the other hand, errors in the old data and index were also identified.

We recomment that the new index is used for the AFWG 2019 assessment.

Greenland halibut EcoSouth survey index

Tone Vollen, Kristin Windsland, Elvar Hallfredsson and Mikko Vihtakari

29 april 2019

1 Why recalculate the EcoSouth index?

Over the last few years, the institute has moved all raw data from a simple text-format (database name “årsmaterialet” with file format = “spd”) to a new database (database name “Sea2Data” with file format xml). The flexibility of the new database and the accompanying software/hardware (Fish2Data) allowed us to improve the somewhat complicated Greenland halibut sampling regime. Since 2016, the sampling regime was changed, and the previous index calculations could not be used on newer data (2016-2018).

Prior to 2016, catch size and length distributions were stored split on “Females”, “Males” or “Unsexed” in the database. With the new sampling regime, catch size and length distributions are no longer split by sex in the database, and the number of samples has decreased a lot. This means that splitting the indices on sex is not as straight-forward as it was earlier.

The EcoSouth-index is based on data from the Ecosystem cruise (2003-pt). ***ICES names***

2 New and old raw data

When comparing raw data from the new and old database, differences were found (Table 1).

- the cruise series definitions differed, and thereby also the extracted dataset (ex. 2004-2006)
- corrections had been made to the data in the new database (ex. 2005, 2006)
- new errors were introduced when transferring data to the new database (ex. 2005, 2006)
- some data are still missing in the new database

The influence of these difference on the index and length distributions is investigated further in section 6.

Table 1. Number of stations and samples in the two datasets.

	Old dataset			New dataset		
year	**stations**	**length samples**	**length-sex samples**	**stations**	**length samples**	**length-sex samples**
2003	–	–	–	249	670	434
2004	282	504	399	291	652	426
2005	354	1232	726	377	3797	1902
2006	424	1065	1004	472	1341	1278
2007	304	1015	785	304	1065	835
2008	270	494	458	270	494	458
2009	218	394	394	218	394	394
2010	213	413	237	213	440	237

	Old dataset			New dataset		
year	stations	length samples	length-sex samples	stations	length samples	length-sex samples
2011	234	335	306	234	335	306
2012	250	439	434	250	439	434
2013	259	382	374	258	383	372
2014	229	225	223	236	229	227
2015	210	202	185	212	212	195
2016	–	–	–	199	226	130
2017	–	–	–	202	240	213
2018	–	–	–	124	177	151

3 Old survey index

The “old index” (2004-2015) is the index used in the last assessment (AFWG 2017). The calculations are based on spd-files extracted from the “årsmaterialet”. Before 2016, all levels of greenland halibut data is split by sex, and the index calculations are done separately for males, females and unsexed. In the biomass index, unsexed were split by sex using the ratio females : males the same year. In the length distributions, unsexed individuals >20 cm were split using the ratio females : males within the same year and length group. The overall ratio for 20-45 cm (0.49) was used to split unsexed <20 cm, where sex determination was not trusted.

4 New survey index

The “new index” (2003-2018) is based on data from the S2D database. Data were downloaded in xml format using the R-package Rstox, which provides functions for downloading as well as reading xml files into R.

4.1 Sex split

To split the data on sex, a female-proportion-at-length key was needed to split each 1 cm length group of the yearly length frequency distributions. First, separate female-proportion-at-lengths for each year were tested. In the calculations, any proportion based on stations with less than four sexed individuals was discarded. The results are shown with a lowess smoother in Figure 4.1. However, the number of sexed samples in each length group is very low the last few years (Figure 4.2), as well as in the smallest and largest length groups. We therefore decided to make an overall female-proportion-at-length, joining data from all years. A gam (family=quasibinomial) was run on the length interval 30-70 cm, as sex determination may be difficult for smaller individuals. Sex ratio for lengths <20 cm was fixed to 1:1. Individuals > 70 cm were assumed to be females. The resulting overall female_proportions-by-length (Figure 4.3) was used to split all years by sex.

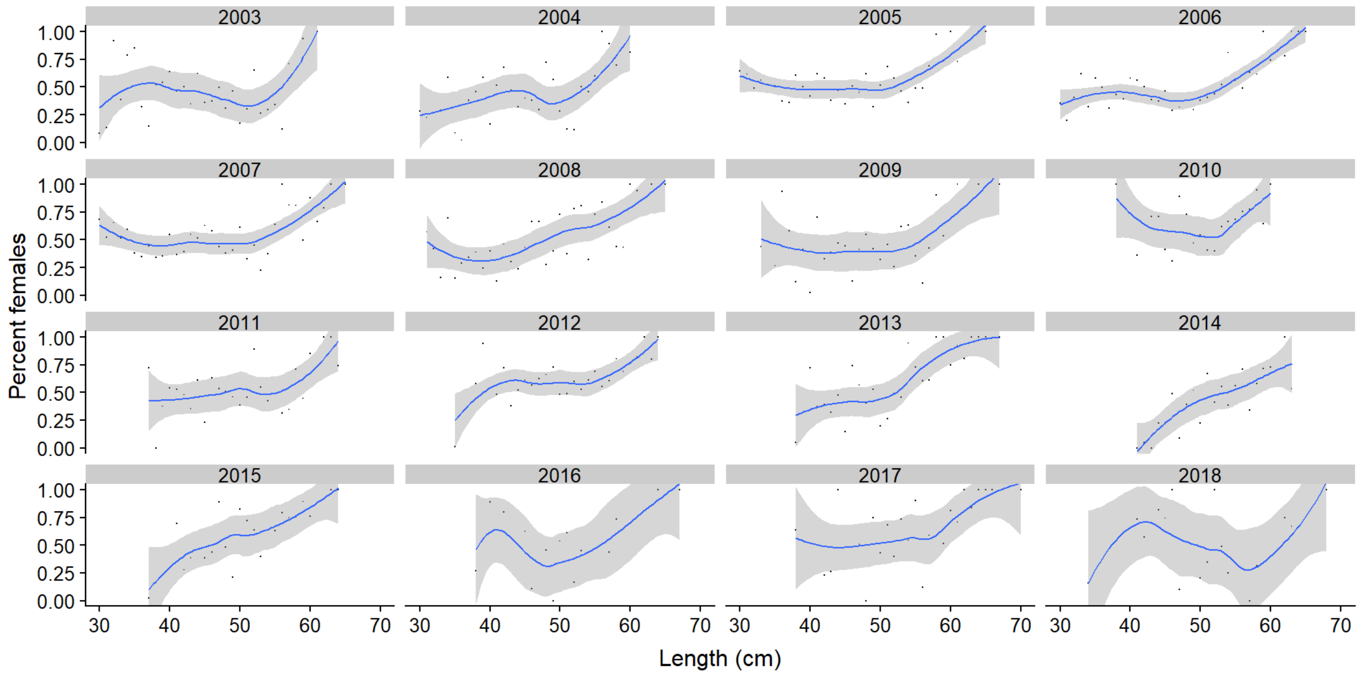


Figure 4.1: Lowess smoother female proportion by 1 cm length group and year.

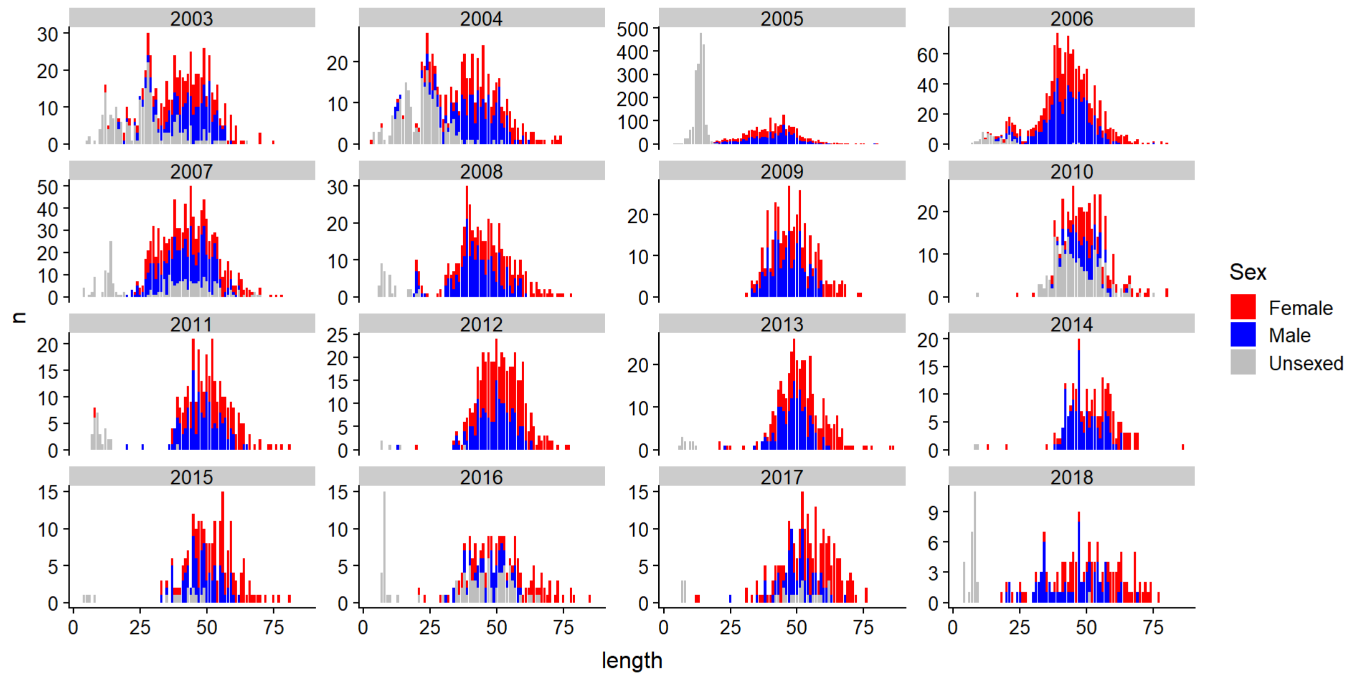


Figure 4.2: Total number of sexed length-samples by year, 1 cm length group, and sex (new dataset).

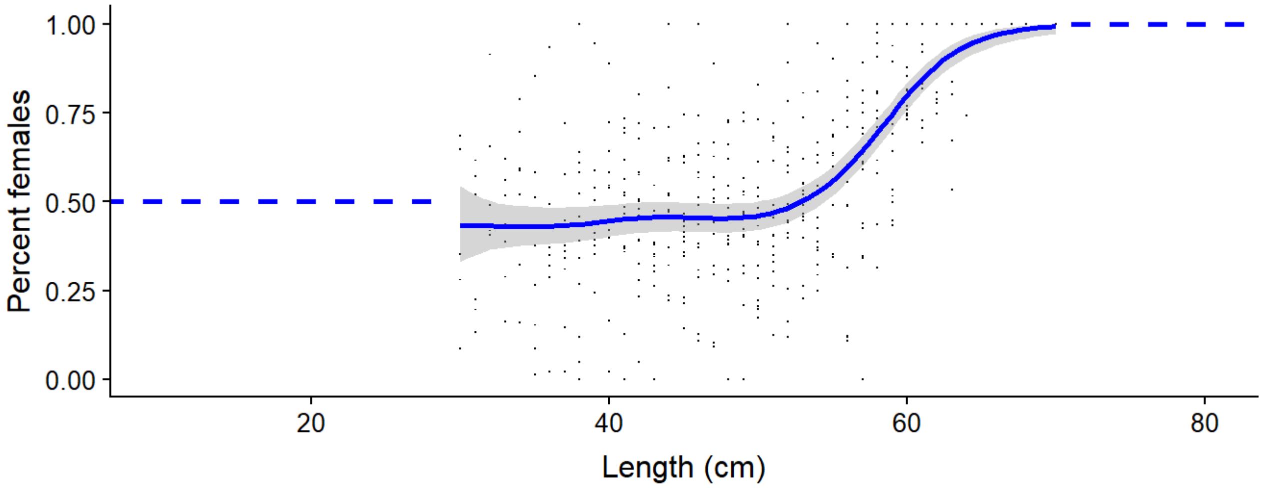


Figure 4.3: Final key for splitting on sex. For 0-30 cm the proportion of females is set to 50%, and for 70-100 cm it's set to 100%. For the interval 30-70 cm, a gam was fitted to all available data.

4.2 Length-weight relationship

In the data from 2016-2018, catch- and sampleweight was not available by sex. The weight ratio of females : males in the samples was therefore needed to calculate a biomass index split by sex. As only a fraction of the individs in the length samples were also weighed, individual weights were derived using a length-weight relationship (Figure 4.4). The LW-relationship was based on all available data from the Norwegian and Barents Sea in the IMR database. There was no difference between sex, so an general LW-relationship was used.

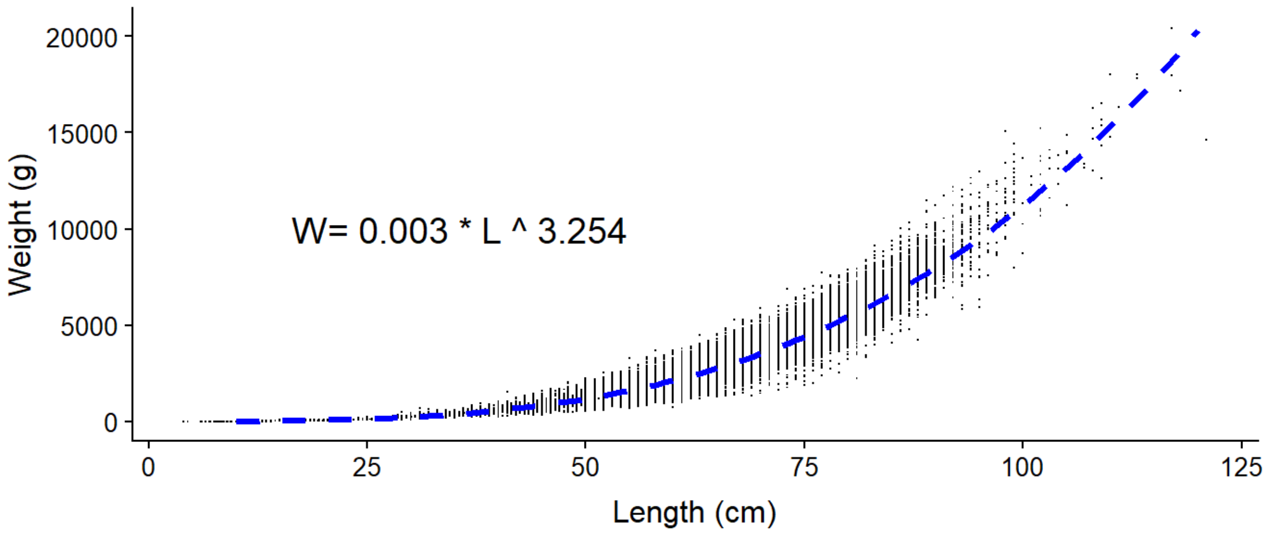


Figure 4.4: Length-weight relationship, linear model: log(W)= + b*log(L), R2=0.9814, p<0.001.

5 Comparing new and old index

Figure 5.1, 5.2 and 5.3 shows the resulting new index together with the old index. The year 2014 stands out in the original data, with a high proportion of males. This may be due to errors in sex determination this particular year, or due to poor survey coverage, which is known to have had an effect on the index of other species this year. This issue is camouflaged in the new survey index, but should be investigated further.

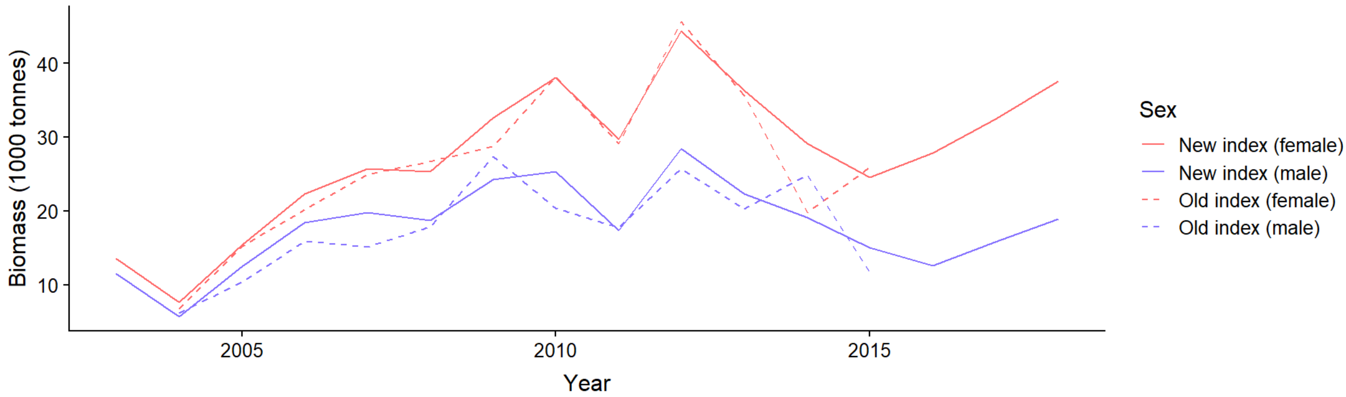


Figure 5.1: Old and new Greenland halibut EcoSouth index.

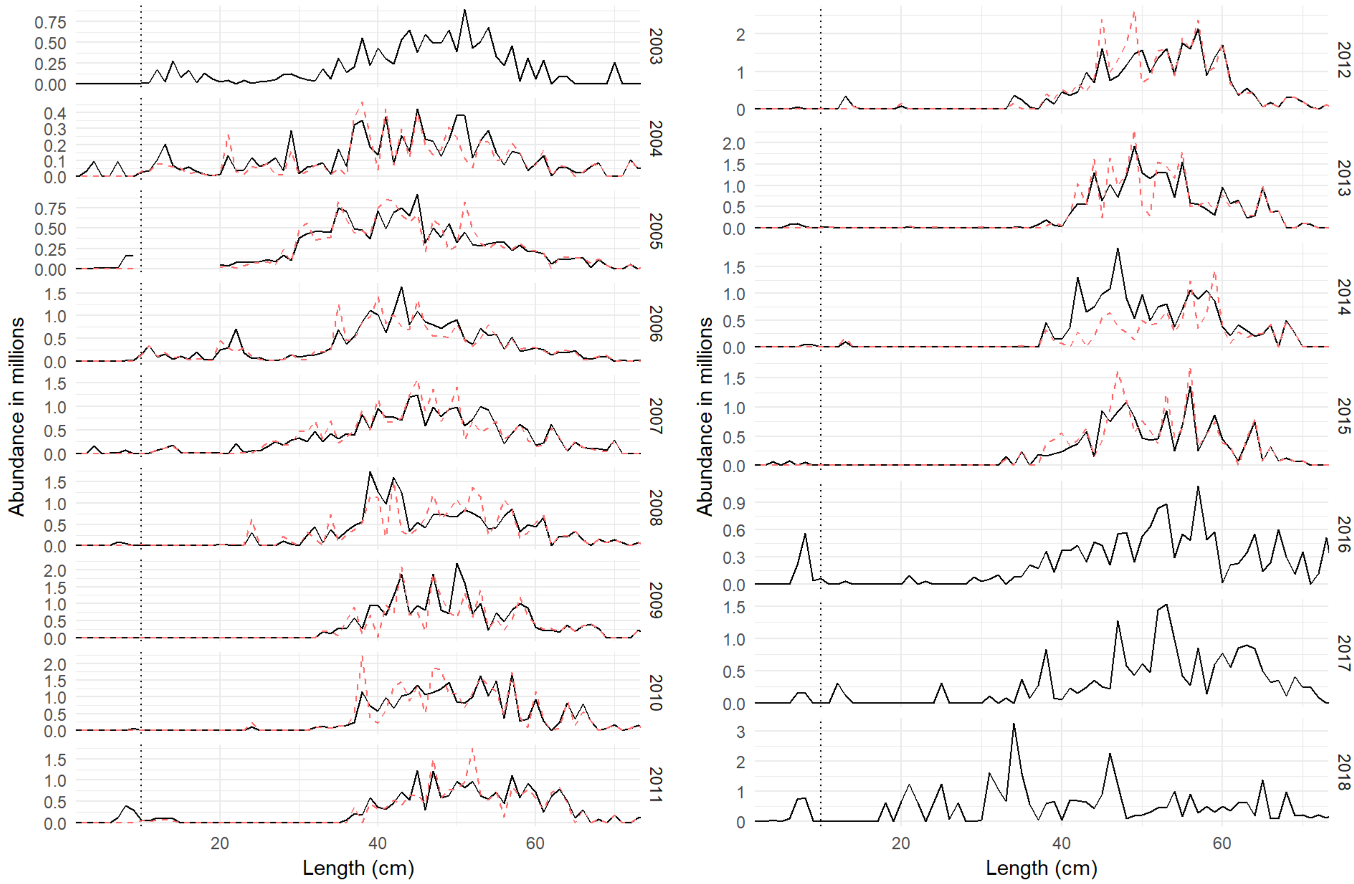


Figure 5.2: Female Greenland halibut, new (black, solid) and old (red, dotted) length distributions. Dotted vertical line marks the lower length limit included in gadget files.

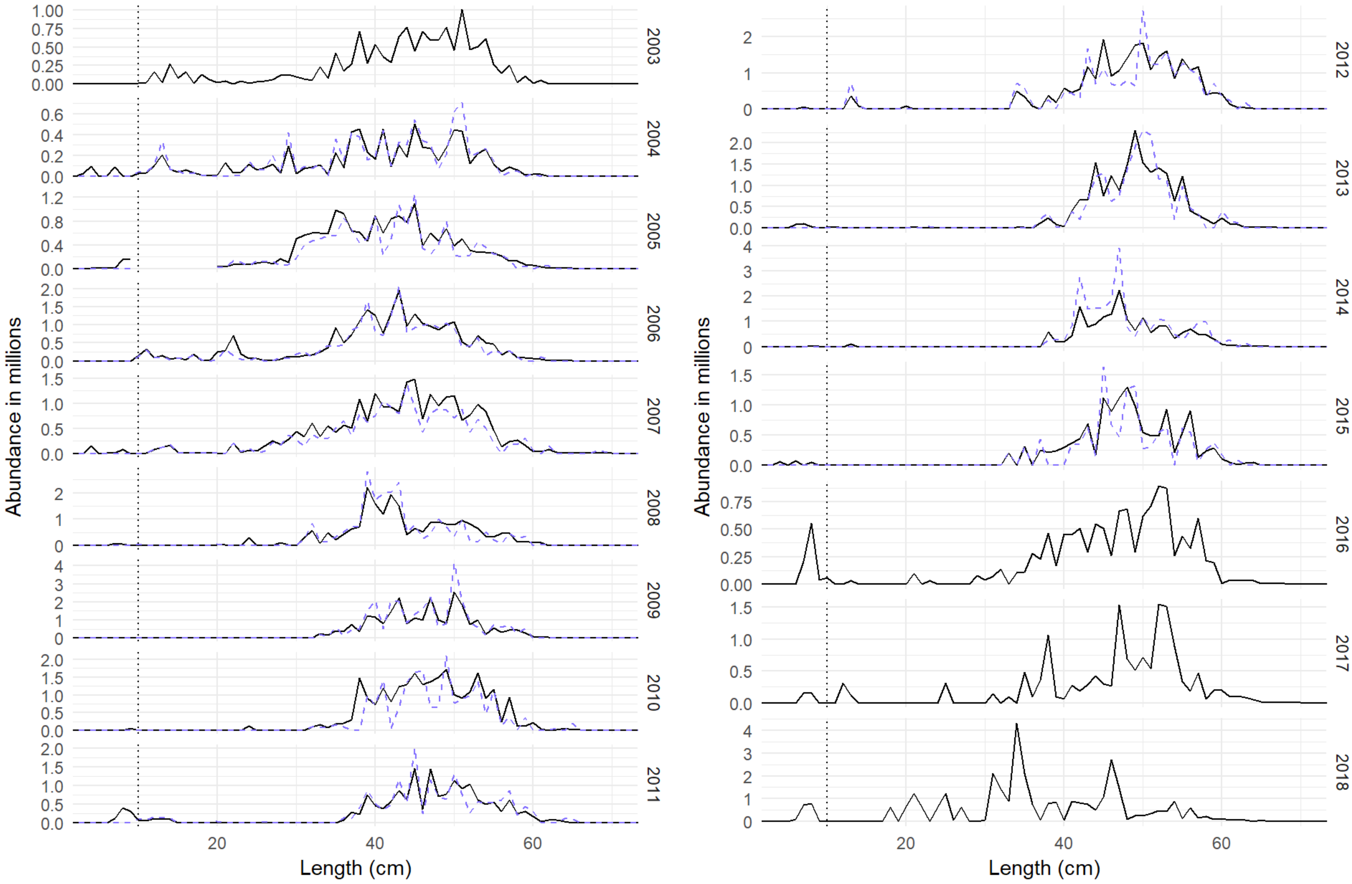


Figure 5.3: Male Greenland halitut, new (black, solid) and old (blue, dotted) length distributions. Dotted vertical line marks the lower length limit included in gadget files.

6 Sex ratio

The proportion of females in the new and old biomass index was compared (Figure 6.1 and 6.2). The new method of splitting by sex using a fixed proportion-of-females-by-length had a smoothing effect on the sex ratio compared to the old index. This is partiularly true when looking at the length distributions.

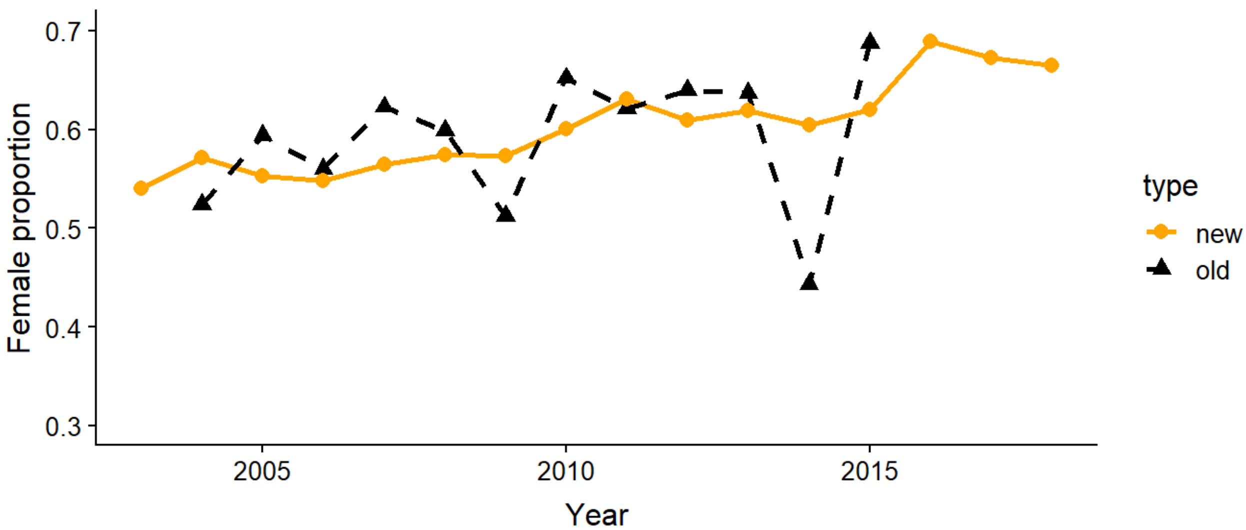


Figure 6.1: Proportion of females in biomass index, comparison of old and new index.

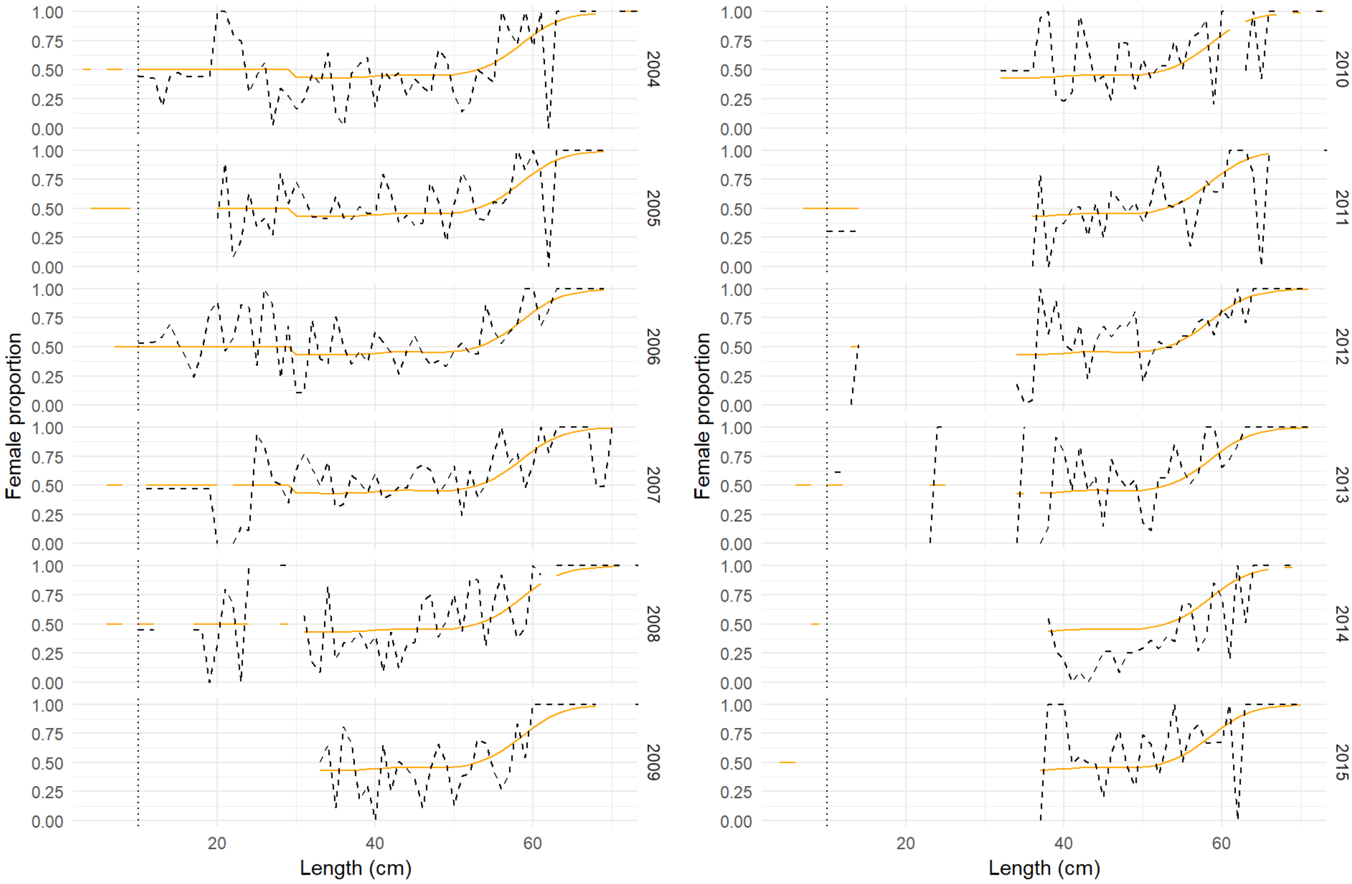


Figure 6.2: Proportion of females in the length distributions, comparison of old and new index.

7 Errors in data

To illustrate the effect of differences in raw data between the new and old database, the indices and length distributions were plotted for sex combined (Figure 7.1 and 7.2). The new index is slightly higher, particularly for 2006 and 2006, whereas the length distributions are almost identical.

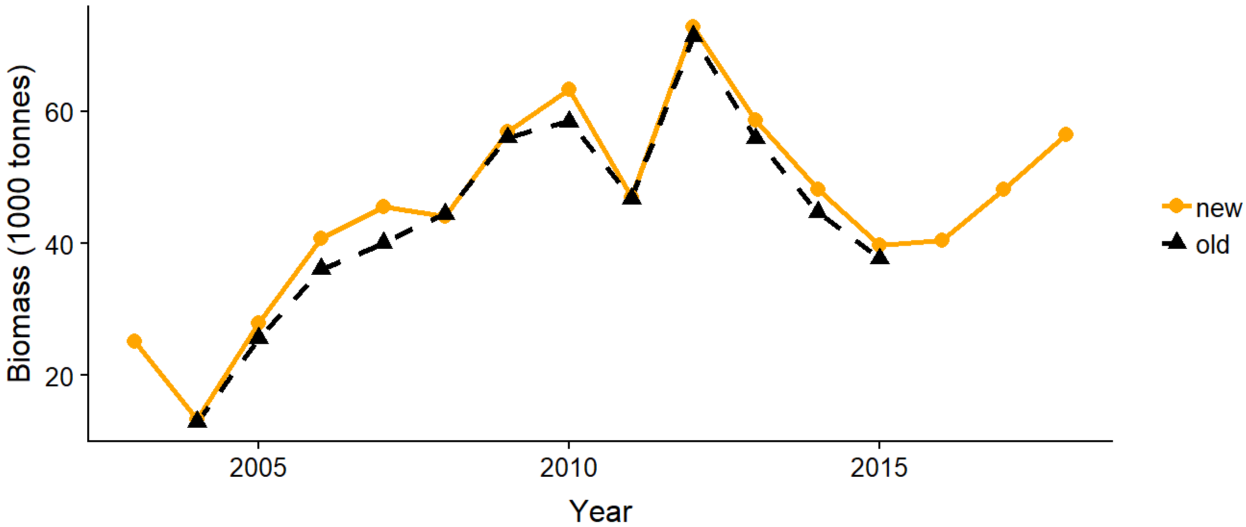


Figure 7.1: Biomass index, sex combined. Comparison of new and old dataset.

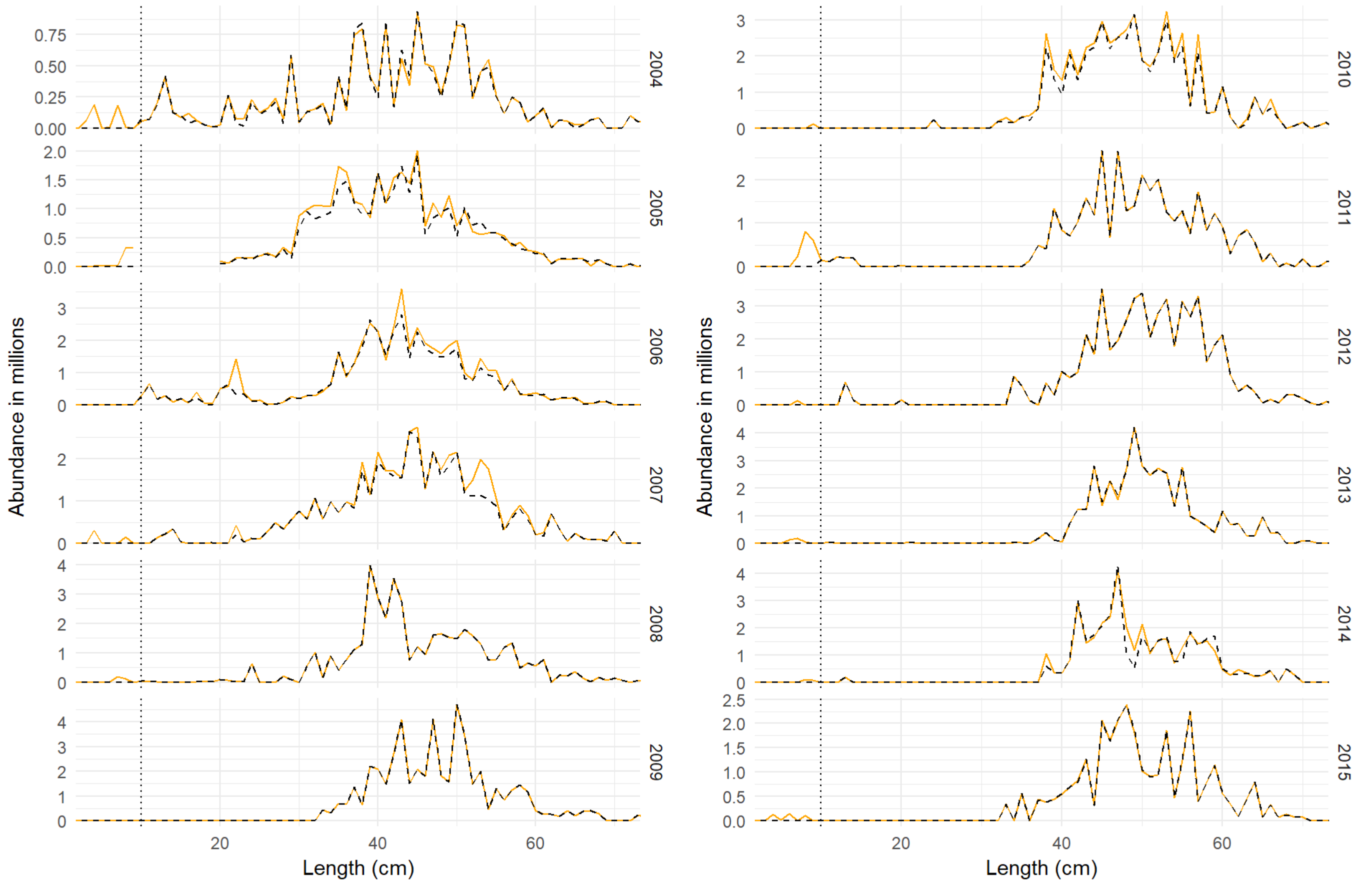


Figure 7.2: Length distributions, sex combined. Comparison of new and old dataset.

8 Conclusions

Due to changes in the sampling regime, the old method used for index calculation could not be used for years 2016 onwards, and changes needed to be made. For 2016-2018, there were not enough data to split the index on sex using same years' samples, so for these years a fixed proportion-of-females-by-length needed to be used. In addition, for all years, the proportion-of-females-by-length needed to be fixed for the smalles and largest length groups. Rather than swithcing methods in the middle of the time series, we chose to use the same method all years.

The new database currently have some flaws such as some missing data and introduced errors, but many of these have been compensated for. At the other hand, errors in the old data and index were also identified.

We recomment that the new index is used for the AFWG 2019 assessment.

AFWG2019 WD_21

Update referent point estimation for Greenland halibut based on production model

A. Mikhaylov
Russian Federal Research Institute of Fisheries and Oceanography (VNIRO),
17, V.Krasnoselskaya St., 107140, Moscow, Russia

This document presents the update of estimations of referent point for Greenland halibut based on production model. The input data for analysis were the catches for the period from 1935 till 2018 and several series of abundance indices (see Table 1).

Table 1 Catch (thousand tons) and indices (standard units) of the Greenland halibut abundance in the Barents Sea in 1935-2018

Year	Catch, tons	USSR catch/hour trawling (t)		Norwegian catch/hour trawling (t)		CPUE catch/hour trawling (t)
		RT[1]	PST[2]	A[3]	B[4]	
1935	1534	-	-	-	-	-
1936	830	-	-	-	-	-
1937	616	-	-	-	-	-
1938	329	-	-	-	-	-
1939	459	-	-	-	-	-
1940	846	-	-	-	-	-
1941	1663	-	-	-	-	-
1942	955	-	-	-	-	-
1943	824	-	-	-	-	-
1944	678	-	-	-	-	-
1945	1148	-	-	-	-	-
1946	1362	-	-	-	-	-
1947	1437	-	-	-	-	-
1948	1987	-	-	-	-	-
1949	375	-	-	-	-	-
1950	2074	-	-	-	-	-
1951	2861	-	-	-	-	-
1952	2953	-	-	-	-	-
1953	2601	-	-	-	-	-
1954	4090	-	-	-	-	-
1955	3300	-	-	-	-	-
1956	3939	-	-	-	-	-
1957	4635	-	-	-	-	-
1958	4192	-	-	-	-	-
1959	7939	-	-	-	-	-
1960	10961	-	-	-	-	-
1961	11813	-	-	-	-	-
1962	13360	-	-	-	-	-
1963	14540	-	-	-	-	-
1964	40391	-	-	-	-	-

1965	34751	0.80	-	-	-	-
1966	26321	0.77	-	-	-	-
1967	24267	0.70	-	-	-	-
1968	26168	0.65	-	-	-	-
1969	43789	0.53	-	-	-	-
1970	89484	0.53	-	-	-	-
1971	79034	0.46	-	-	-	-
1972	43055	0.37	-	-	-	-
1973	29938	0.37	-	0.34	-	-
1974	37763	0.40	-	0.36	-	-
1975	38172	0.39	0.51	0.38	-	-
1976	36074	0.40	0.56	0.33	-	-
1977	28827	0.27	0.41	0.33	-	-
1978	24617	0.21	0.32	0.21	-	-
1979	17312	0.23	0.35	0.28	-	-
1980	13284	0.24	0.33	0.32	-	-
1981	15018	0.30	0.36	0.36	-	-
1982	16789	0.26	0.45	0.41	-	-
1983	22147	0.26	0.40	0.35	-	-
1984	21883	0.27	0.41	0.32	-	-
1985	19945	0.28	0.52	0.37	-	-
1986	22875	0.23	0.42	0.37	-	-
1987	19112	0.25	0.50	0.35	-	-
1988	19587	0.20	0.30	0.31	-	-
1989	20138	0.20	0.30	0.26	-	-
1990	23183	-	0.20	0.27	-	-
1991	33320	-	-	0.24	-	-
1992	8602	-	-	0.46	0.72	-
1993	11933	-	-	0.79	1.22	-
1994	9226	-	-	0.77	1.27	-
1995	11734	-	-	1.03	1.48	-
1996	14347	-	-	1.45	1.82	-
1997	9410	0.71	-	1.23	1.60	-
1998	11893	0.71	-	0.98	1.35	-
1999	19517	0.84	-	0.82	1.77	-
2000	14297	0.94	-	1.38	1.92	-
2001	16365	0.82	-	1.18	1.57	-
2002	13293	0.85	-	1.07	1.82	-
2003	13447	0.97	-	0.86	2.45	-
2004	18899	0.63	-	1.16	1.79	-
2005	18834	0.61	-	1.30	2.29	-
2006	17904	0.57	-	0.96	2.09	-
2007	15453	0.64	-	-	-	-
2008	13792	0.48	-	-	-	-
2009	12990	0.77	-	-	-	-
2010	15229	-	1.57	-	-	28
2011	16606	-	2.32	-	-	34.94545
2012	20288	-	2.06	-	-	34.06752
2013	22167	-	2.25	-	-	33.9525
2014	23025	-	2.52	-	-	37.65207

2015	24748	-	-	-	-	40.60682
2016	24948	-	-	-	-	48.92763
2017	26380	-	-	-	-	42.32766
2018	28543	-	-	-	-	39.56652

1 Side trawlers, 800–1000 hp. From 1983 onwards, stern trawlers (SRTM), 1,000 hp. From 1997 based on research fishing.
2 Stern trawlers, up to 2,000 HP.
3 Norwegian trawlers, ISSCFV-code 07, 250–499.9 GRT.
4 Norwegian factory trawlers, ISSCFV-code 09, 1000-1999.9 GRT

The production model [AFWG WD18] is based on the following equations of dynamics (1) and observation (2):

$$\ln \frac{B_{t+1}}{B_t} = F_{MSY}\left(\frac{1}{\gamma}\left(\gamma + 1 - \left(\frac{B_t}{B_{MSY}}\right)^{\gamma}\right)\right) - \frac{C_t}{B_t} + \varepsilon \quad (1)$$

$$\ln CPUE_{t,f} = \ln B_t + \ln q_f + \eta \quad (2)$$

Where C is the catch, q – the catchability, and η- residuals, and γ - the Pella-Thomlinson models[1970] coefficient (for Schaefer model [1954,1957] γ=1)
The reference points were among parameters estimated in this formulation of the production model.
To estimate the parameters were used winsorizated least mean square objective function, which provided more robustness.
The results for Schaefer model are summarized in the following table:
Table 2. Results of estimations

MSY (ktons)	B_{MSY} (ktons)	F_{MSY} (year^{-1})
34.52	499.67	0.069

The comparison with previous results with the previous results of the production model application [Mikhailov, 2015] [Mikhailov, 2016] [Mikhailov, 2017] is shown in the following table 3

Table 3. The comparison of results

	MSY(ktons)	B_{MSY} (ktons)	F_{MSY} (year^{-1})
Schaefer model (winsorizated least mean square) 1965-2018	34.52	499.67	0.069
Schaefer model with sex structure 1984-2015	36.00	577.40	0.06
Schaefer model (winsorizated least mean abs. value) 1965-2015	37.47	500.00	0.075
Production model with GADGET data 1992-2014	38.70	418.12	0.0925

We can see that the estimates are similar to each other, and therefore to some extent reflect the long-term characteristics of the stock and can be used to control. We can be more precautionary if we will limit top of the TAC by the lowest estimate of MSY on the level of 34.5 ktons and will be aimed at maintaining the stock level above the highest BMSY value of 577 ktons. In general, we can conclude that the stock can withstand the current fishing load and the fishing regime is approaching optimum.

References

1. Pella J. S., Tomlinson P. K. A Generalized Stock-production Model. Bull. Inter-Amer. Trop. 1969. Tuna Comm. 13, P. 421-496.
2. Schaefer M. B. Some Aspects of the Dynamics of Populations Important to the Management of the Commercial Marine Fisheries // Bull. Inter-Am. Trop. 1954. Tuna Comm. V. 1. № 2. P. 27–56.
3. Report of the Arctic Fisheries Working Group ICES CM 2018/ACOM:06
4. Mikhaylov.A.2015 MSY estimation for Greenland Halibut. ICES Arctic Fisheries Working Group, Working Document 18 6 p
5. Mikhaylov.A.2016 Long-term HCR-parameters estimation for Greenland halibut based on production model. ICES Arctic Fisheries Working Group, Working Document 14 3 p
6. Mikhaylov.A.2017 Long-term HCR-parameters estimation for Greenland halibut based on production model with consideration the sex structure of the population. ICES Arctic Fisheries Working Group, Working Document 18 6 p

AFWG-2019 WD 22

Assessment of population recruitment abundance of Northeast Arctic cod considering the environment data

by

Oleg Titov

Abstract

Analysis of results of approbation of methods of abundance assessment of northeastern arctic (NEA) cod at the age of 3 with advance time of 1-4 years has been carried out (Titov, 1999, 2001, 2011, 2018).

Introduction

One of the most important practical and theoretical problems connected with studying of marine ecosystems is prediction of values of commercial fishes' population recruitment. At present, natural processes, influencing the dynamics of the marine ecosystem, are hardly taken into consideration when predicting values of the Barents Sea commercial fishes' population recruitment. This leads, in particular, to sufficient shortening of the advance time and to decrease of accuracy of predictions of recruitment abundances of NEA cod and, correspondingly, to errors at prognostication of TAC. One of experiments on application of the ecosystem approach to prediction of the Barents Sea capelin and NEA cod recruitment abundance was models with the use of data on physical and chemical status of environment as indices of long-term variations of the Barents Sea ecosystem as a single whole (Titov, 1999; Titov, 2001). The models, as well as several statistical models, which use multiple linear regressions, have been compared by the ICES AFWG (e.g. Bulgakova, 2005; Stiansen *et al*., 2005; Titov *et al*., 2005, Svendsen *et al*., 2007). In 2009 statistical models (Titov et al., 2005, Titov, 2008) were partially changed. Joint ecosystem autumn survey index for 0-group cod was replaced on 0-group cod abundance index, corrected for capture efficiency (Anon, 2009). The data till 1983 were excluded at calculation of statistical models in 2010. In order to improve prediction the water temperature data was added to one of the models in 2011. Because of the danger of over-fitting regression models, one should always strive for simplicity (Dingsør et al., 2010). Prediction capabilities of the models were improved by dropping one or more terms. This was done in 2011 in accordance with statistical criteria. All models are greatly simplified. In general, 7 independent variables were removed from the 5 models.

In 2016 - 2017 there was a significant break in the program for the implementation of the oceanographic section "Kola Meridian", the data of which are used in forecasting models. From June 2016 until the time of preparation of the forecasts on the AFWG (April 2017), the data from the oceanographic section was not received and there is no way to restore the break. It was decided to not publish the corresponding forecasts in 2017.

In accordance with the recommendations of AFWG 2016 (Anon., 2016), an alternative version of the forecast was presented in which the spawning biomass of NEA cod is used as a predictor.

In view of the significant correction of the historical series of biological data that occurred in 2017, the calculations of the retrospective forecast for 2016 was given. A comparative analysis of the forecasts made on the biological characteristics of the NEA cod for 2016 and 2017 was given (Anon, 2017).

In 2018 at the meeting of the AFWG, the correction of models was continued. Due to the fact that in 2017 there was a significant correction of the initial biological data, which caused significant changes in the results of the prognostic models, in 2018 a complete audit of both the prognostic models and the hybrid model combining the results of their work was carried out. The main

purpose of the model revision was to increase the stability of the models, that is, to reduce the possibility of potential correction of the models due to correction of the biological parameters included in the model. The solution of the problem was found by increasing the retrospective database by almost 2 times, that is, from the beginning of the 80s to the beginning of the 60s of the last century. Accordingly, sets of predictor sets have been revised. As a result, after comparing the results of constructing independent retrospective forecasts using the methodology previously used in ICES SGRF (Anon. 2013), it was decided to abandon the use of biological predictors and to use only environmental data in the NEA cod recruitment forecasting models. The number of models was reduced from 5 to 2 and the names of the models were changed from Titov (0, 1, 2, 3, 4) to TitovES (environment, short prediction) and TitovEL (environment, long prediction).
In 2019, the models are designed for two cod recruitment abundance options.

Materials and methods

The initial information (legend is in brackets):

- (Ta) mean monthly anomalies of air temperature at the Murmansk station since 1979 by data from the information site of Internet (http:/www.ncdc.noaa.gov) averaged by 12 values in the end of the period of averaging;
- (Tw) mean monthly anomalies of water temperature at stations 3-7 of the Kola section (0-200 m layer) since 1981 by data of PINRO data base averaged 12 values in the end of the period of averaging;
- (I) mean monthly anomalies of ice coverage of the Barents Sea (percentage ratio between the area covered by ice and total area) since 1979 by data of the Murmansk UGMS averaged 12 values in the end of the period of averaging;
- (OxSat) mean monthly anomalies of saturation by oxygen of near-bottom water layers at 3-7 stations of the Kola Section since 1979 by data from the information base of PINRO averaged by 12 values in the end of the period of averaging;
- (Cod3) annual (start of year) values of abundance of cod at the age of 3 considering cannibalism since 1983 (Anon, 2018);
- (CodC0) annual values of 0-group cod abundance index, corrected for capture efficiency since 1980 (Anon, 2018);
- (CodB1) bottom trawl swept area abundance of cod at the age of 1 estimates in Joint winter (Februar) Barents Sea survey since 1981 (Anon, 2018)
- (CodB2) bottom trawl swept area abundance of cod at the age of 2 estimates in Joint winter Barents Sea (February) survey and the Norwegian Lofoten acoustic survey since 1982 (Anon, 2018)
- (CodB3) bottom trawl swept area abundance of cod at the age of 3 estimates in Joint winter (February) Barents Sea survey and the Norwegian Lofoten acoustic survey since 1983 (Anon, 2018)
- (SSB) annual (start of year) values of spawning part biomass of cod population since 1980 (Anon, 2018).

Calculation of indices ITw. As a characteristics of intensity of interaction between the arctic and boreal oceanic systems on the shelf of the Barents Sea the indice ITa was used which was calculated by the numerical comparison between variations of the thermal status of ocean in the southern part of the Barents Sea and its ice coverage by the method of linear regression (Titov, 1999; Titov, 2001). Parameters of the linear regression model, describing the changes of ice coverage of the Barents Sea, were calculated by variations of water temperature. After that the differences (remainders) of mean monthly values of ice coverage and analogous values derived by the known parameters of the regression equation were calculated. Time lag, at which maximum cross-correlation relationship between variations of the mentioned parameters appeared, was taken into consideration.

Lag constituted 3 months for ice coverage relatively to water temperature. Equations used for calculations were as follows:

$$ITw_t = I_t – (-12,017*Tw_{t-3}-0,0688) \quad (1)$$

Names of indices in equations are mentioned above in the text, low indices characterize time lags in months.

Calculation of index DOxSat. Earlier (Titov, 1999; Titov, 2001) it was shown that formation of cod year classes abundance (Cod3) was influenced by the airing of near-bottom layers (OxSat) in a complex manner. From one side, there is a feedback between these parameters at larger time lag and a direct link at the less time lag; correspondingly, the densest link is between Cod3 and velocity of change of oxygen saturation of near-bottom layers. On the other side, a direct link has an exponential character. For a full account of these links the index DOxSat was calculated by the formula:

$$DOxSat_t = \exp(OxSat_t) – OxSat_{t-26} \quad (2)$$

Names of indices in equations are mentioned in the text, low indices characterize the time lags in months.

Searching for nonlinear links. Searching for nonlinear links between abundance of year classes of cod with indices mentioned above was carried out. It was stated that some links are approximated best of all by the quadratic equations or in an exponential form.

Regression equation of link of Cod3 with abiotic and biotic parameters.
The final set of predictors was determined by the method of step-by-step multiple regression. Parameters were chosen on the basis of recommendations on the use of package Statgraphics Plus for Windows 2.1. It is allowed to enter all the variables into the model at one time. But because of the danger of over-fitting regression models, one should always strive for simplicity (Dingsør et al., 2010). Prediction capabilities of the models were improved by dropping one or more terms. This was done in accordance with statistical criteria on the basis of recommendations of Statgraphics Plus. In determining whether the model can be simplified, the
highest P-value on the independent variables was noticed. In case of P-value was greater or equal to 0.10 (no statistical significance at the 90% or higher confidence level), such independent variables remove from the model.

The parameters in the equations vary automatically.

The equation for the forecast of Cod3 with advanced time of 0 years (a), 1 year (b), 2 years (c), 3 years (d), 4 years (e) with meanings of parameters for April 2018 are shown below.
Due to the lack of data on oxygen and water temperature from the oceanographic section “Kola Meridian” since June 2016 to May 2017, in 2018 this data were restored be linear interpolation of its anomalies. The predictions of recruitment abundances of NEA cod, by using the models TitovES (a) for 2018, TitovEL (b) for 2020, 2021 should be used with caution.

(a) $Cod3_t = a*DOxSat_{t-13}\hat{}2 + b*ITw_{t-43} - c*10^{-6}*\exp(Ice_{t-40}) - d*Ice_{t-15} + e$

$R^2 = 0.64 – 0.66; n =57$

(b) $Cod3_t = - a*OxSat_{t-39} + b*ITw_{t-43} + c$

$R^2 = 0.40 - 0.42$; n =57

For all statistical models values P<0.01, that corresponds to the level of significance 99 % (all individual P<0.1).

Tables 1 present initial parameters used in modeling.

Table 1. Parameters of models (low indices correspond to the time lag (months from the start of the year to which the value Cod3 is attributed).

Year	$Cod3_t*10^6$ (SPALY run)	$Cod3_t*10^6$ (Final run)	$OxSat_{t-39}$	$DOxSat_{t-13}$	ITw_{t-43}	Ice_{t-15}	$expIce_{t-40}*10^6$
1962	1250450	1292322	-0,2	-6,6	1,9	0,5	0,00
1963	842509	828474	-0,9	-2,4	1,6	1,5	0,00
1964	485216	428596	1,6	1,2	2,5	9,0	0,00
1965	907526	873400	0,9	-0,2	3,9	15,7	0,00
1966	1899526	2240060	-1,1	-4,0	8,0	5,3	0,00
1967	1262674	1511690	-0,2	-2,8	8,2	5,0	9,28
1968	186334	169339	1,5	-0,1	3,8	15,5	0,00
1969	111350	95436	0,9	0,6	1,8	15,9	0,00
1970	213861	221996	-0,2	-0,2	3,5	19,8	7,86
1971	389450	383445	0,1	-0,1	-0,1	18,8	2,66
1972	994529	941651	-3,3	-6,6	14,5	-0,6	428,92
1973	1862348	2231117	-2,1	-10,4	19,1	1,8	768,62
1974	641060	579419	1,1	-1,7	2,4	2,0	0,00
1975	598801	570561	1,9	0,8	-2,6	-1,2	0,00
1976	609951	686700	1,3	-1,3	-3,1	-1,9	0,00
1977	373618	336354	-0,1	-1,8	-2,4	2,5	0,00
1978	627373	717515	1,2	0,1	1,1	-1,0	0,00
1979	209981	188057	0,5	-1,5	-0,1	3,5	0,00
1980	129936	120993	-0,3	-2,7	2,0	12,9	0,00
1981	159985	152874	0,8	-0,2	1,9	14,7	0,00
1982	174971	200438	0,8	0,6	-3,2	8,0	0,07
1983	156432	153254	0,8	0,2	1,9	12,2	8,54
1984	413732	392799	-2,2	-2,4	-3,1	12,9	0,00
1985	558141	623486	-0,1	-1,2	3,6	-1,2	0,09
1986	1118909	1046035	-2,1	-4,4	1,4	-8,5	2,89
1987	327381	315985	-0,3	-1,7	2,1	0,6	0,00
1988	297828	293648	0,9	-1,4	-2,3	3,8	0,00
1989	188918	193461	0,3	-3,4	-5,2	10,5	0,00
1990	155641	159980	1,1	-1,3	-4,2	10,5	0,00
1991	396154	383103	0,9	0,7	2,4	6,5	0,03
1992	735643	798991	1,3	0,5	1,4	-0,9	0,02
1993	927910	888841	-2,0	-3,9	6,1	-0,6	0,00

1994	732611	699632	-0,5	-2,3	8,3	-4,9	0,00
1995	500001	488242	0,8	-2,4	4,4	1,8	0,00
1996	410747	445026	0,9	-0,1	0,5	0,7	0,00
1997	671971	677708	0,9	0,2	3,1	-7,3	0,00
1998	956873	1052482	0,3	-6,1	-2,3	-2,5	0,00
1999	544727	529765	-0,7	-2,4	-6,8	2,9	0,00
2000	672798	629642	1,9	1,5	-2,3	13,6	0,00
2001	551468	578837	0,6	0,1	-6,0	2,3	0,00
2002	409501	394623	-0,9	-1,0	3,6	-9,9	0,76
2003	694292	743330	-0,4	-0,6	8,5	-5,8	0,00
2004	247602	252623	-2,2	-2,5	-4,6	-1,4	0,00
2005	633125	606471	-1,6	-1,8	-1,5	4,9	0,00
2006	542436	545107	-1,2	-1,7	-4,0	-6,0	0,00
2007	1421853	1470329	-1,4	-4,4	7,4	-12,3	0,00
2008	1248669	1185542	-1,1	-1,6	3,4	-18,0	0,00
2009	710394	678599	0,8	-1,8	-1,6	-17,5	0,00
2010	289761	293867	-0,4	-2,6	-8,9	-9,0	0,00
2011	479622	448443	0,8	-0,1	-5,0	-4,3	0,00
2012	563238	572835	0,9	-0,1	-5,1	-4,3	0,00
2013	628109	625805	0,0	-0,1	1,4	-10,5	0,00
2014	745585	771499	-0,5	-1,0	1,4	-17,8	0,00
2015	426911	447415	-1,3	-1,6	-2,2	-10,5	0,00
2016	269656	268554	-1,3	-1,9	-7,5	-5,8	0,00
2017	724455	750022	-0,3	-0,6	-1,7	-14,7	0,00
2018	431988	498154	-1,2	-1,4	0,1	-21,0	0,00
2019			-0,6	-1,1	-1,7	-13,4	0,00
2020			-2,0	-2,2	-6,3	-13,8	0,00
2021			-0,8		-1,4		0,00
2022			-1,6		-2,5		0,00

Results

Prognoses from models (a) – (b) are shown in Table 2.

Table 2. Recruitment models prognoses (Final run)

Model	Species	Variable	Years	Prognosis available	**2019**	**2020**	**2021**	**2022**	Unit
TitovEL	NEA cod	Age 3	4	At assessment	**543**	**460**	**570**	**585**	$*10^6$
		weight			*0,25*	*0,23*	*0,53*	*1,00*	
TitovES	NEA cod	Age 3	2	At assessment	**598**	**504**			$*10^6$
		weight			*0,54*	*0,59*			
RCT3	NEA cod	Age 3	3	At assessment	**977**	**742**	**728**		$*10^6$
		weight			*0,22*	*0,18*	*0,47*		

Hybrid	NEA cod	Age 3	4	At asses sment	**667**	**537**	**644**	**585**	$*10^6$

Table 2. Recruitment models prognoses (SPALY run)

Model	Speci es	Variable	Ye ars	Prognosis available	**2019**	**2020**	**2021**	**2022**	Unit
TitovEL	NEA cod	Age 3	4	At asses sment	**544**	**434**	**573**	**582**	$*10^6$
		weight			*0,25*	*0,23*	*0,53*	*1,00*	
TitovES	NEA cod	Age 3	2	At asses sment	**593**	**494**			$*10^6$
		weight			*0,54*	*0,59*			
RCT3	NEA cod	Age 3	3	At asses sment	**955**	**736**	**725**		$*10^6$
		weight			*0,22*	*0,18*	*0,47*		
Hybrid	NEA cod	Age 3	4	At asses sment	**660**	**524**	**644**	**582**	$*10^6$

[1] Model that are proposed to Hybrid 2018 (Anon, 2018)

References

Anon. 1991. Recommendations on the rational exploitation of the Barents Sea capelin. Murmansk, PINRO. 193p. (in Russian).

Anon. 2002. Ecological conditions in the Barents Sea, 2001-2002. ICES AFWG 2002/WD:01

Anon. 2003a. A regression model for recruitment of 3-year-old NEA cod based on capelin biomass, survey index and climate. ICES AFWG 2003/WD:08

Anon. 2003b. Ecological conditions in the Barents Sea, 2002-2003. ICES AFWG 2003/WD:01

Anon. 2007 Report of the Arctic Fisheries Working Group. ICES CM 2007/ACFM:16

Anon. 2008. Survey report from the joint Norwegian/Russian ecosystem survey in the Barents Sea August-October 2008 (vol. 1).

Anon. 2013 ICES SGRF Report 2013 ICES Advisory Committee ICES CM 2013/ACOM:24

Anon. 2016 Report of the Arctic Fisheries Working Group (AFWG), Dates 19-25 April 2016, ICES HQ, Copenhagen, Denmark. ICES CM 2016/ACOM:06. 621 pp.

Borisov V., Bulgakova T. An attempt to incorporate environmental factors in stock-recruitment relationship for NEA cod//ICES AFWG 2002/WD:08

Borisov V., Bulgakova T. NEA cod dynamic simulation for the testing of various management scenarios//ICES AFWG 2003/WD:08

Dingsør G.E., Bogstad B., Stiansen J.E., and Subbey S. How can we assess recruitment models for (age-3) NEA cod? //ICES AFWG 2010/WD:19

Subbey, S., JE. Stiansen, B. Bogstad, T. Bulgakova and O. Titov 2008. Evaluating Recruitment Models for (Age 3) NEA Cod. //ICES AFWG 2008/WD:27

Titov, O. V. 2001. System approach to the analysis of natural long-term changes of the Barents Sea ecosystem. Murmansk. PINRO. P. 119 (in Russian).

Titov O. V. Long-term cyclic succession of the Barents Sea ecosystem and prognostication of recruitment of commercial fish population // ICES CM 1999/O:01.- 17 pp.

Titov, O., Pedchenko, A. and Karsakov, A., (2005). 'Assessment of Northeast Arctic cod and capelin recruitment from data on ecological situation in the Barents Sea I 2004-2005'. Working document #16 in: Report of the Arctic Fisheries Working Group', Murmansk, Russia, April 19-28, 2005. ICES C.M. 2005/ACFM:20, 564 pp.

Titov, O. Assessment of population recruitment abundance of Northeast Arctic cod considering the environment data //ICES AFWG 2011/WD:23

Working document 23
to the Arctic Fisheries Working Group
Lisbon, Portugal, 24-30 April 2019

Consumption of various prey species by cod in the Barents Sea in 1984-2018

by

A.V.Dolgov

Polar Branch of Russian Federal Research Institute of Fisheries and Oceanography
(PINRO after N.M. Knipovich), 6 Knipovich Str., Murmansk 183763 Russia
E-mail: dolgov@pinro.ru

Diet composition of cod in 1984-2018 is presented in Table 1.

Food consumption of various prey species by cod in 1984-2018 is presented in Table 2.

Consumption of cod and haddock by age group (biomass and abundance) is given in Tables 3-6.

The values of annual food rations by different age groups of cod are given in Table 7.

The main peculiarities of cod diet and consumption in 2018:

- Increasing of weight percent of herring (from 1.1-1.6 % in 2016-2017 to 6.2 % in 2018) and juvenile haddock (from 4.0-7.3 % in 2014-2017 to 13.1 % in 2018) in cod diet;
- Decsreasing of weight percent of capelin (from 31.3-32.9 % in 2016-2017 to 22.2 % in 2018) and juvenile cod (from 11.2 % in 2017 to 8.5 % in 2018) in cod diet;
- Decreased compared to the period 2008-2016, but still high total food consumption by cod (6.1 million tons) in 2018;
- Decreased consusmption of capelin – from 2 144-4 469 thousand tons in 2008-2017 to 1 614 thousand tons in 2018;
- Increased consusmption of herring – from 45-97 thousand tons in 2011-2017 to 217 thousand tons in 2018;
- High consumption of juvenile cod (from 175 thousand tons in 2015 to 353 thousand tons in 2018) and haddock (from 155-180 thousand tons in 2014-2016 to 484 thousand tons in 2018).

Table 1.

Food composition of the Barents Sea cod in 1984-2018, % by weight

Prey species	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Hyperiids	0,86	7,59	16,86	20,58	23,74	19,31	1,59	0,41	0,17	1,10	3,31	5,24	12,61	2,13	4,91	2,41	3,93
Euphausiids	0,49	0,06	0,74	1,28	8,18	5,80	0,38	0,15	0,27	0,20	2,44	2,73	6,57	4,39	3,07	2,35	1,33
Shrimp	23,31	6,26	11,32	10,73	5,76	6,53	6,25	2,12	9,24	3,51	7,82	6,00	5,08	6,12	11,23	8,86	10,49
Herring	3,00	1,94	2,60	0,30	0,96	0,16	0,94	1,16	7,44	7,48	5,25	8,12	4,39	2,79	2,63	2,05	1,11
Capelin	19,25	53,76	20,24	6,32	7,08	22,40	43,94	68,12	42,01	47,40	30,40	6,99	11,29	16,10	11,65	44,19	43,04
Polar cod	0,38	0,01	6,49	7,12	0,02	1,49	0,25	0,68	3,88	3,58	6,40	4,11	3,52	4,62	11,38	6,15	7,79
Cod	2,06	2,75	5,14	2,76	0,62	0,36	0,80	0,89	1,52	4,68	11,69	18,38	18,93	26,90	16,74	6,74	5,86
Haddock	1,90	1,44	3,54	1,41	2,95	0,30	0,56	0,72	2,29	3,55	4,22	5,92	4,48	2,78	2,20	0,73	1,31
Blue whiting	0,56	1,12	0,34	0,41	0,59	0,05	0,77	0,11	0,00	0,15	0,02	0,01	0,26	1,08	1,47	1,73	1,09
Norway pout	0,08	0,45	1,07	0,48	2,57	0,51	0,44	0,17	1,69	1,44	0,01	0,01	1,35	0,27	0,52	0,06	0,06
Redfish	15,08	3,49	8,57	18,61	5,28	7,68	4,62	2,33	4,72	1,36	2,35	4,94	2,77	3,00	1,57	0,95	0,31
Wolffish	0,01	0,02	0,03	0,01	0,03	0,37	0,16	0,01	1,16	0,08	0,11	0,02	0,89	0,21	0,06	0,03	0,00
Long rough dab	3,77	1,26	1,27	1,16	1,02	3,40	2,63	0,60	1,21	2,85	1,56	1,84	2,56	2,34	1,67	0,87	1,39
Greenland halibut	0,00	0,00	0,11	0,01	0,00	0,01	0,00	0,01	0,01	0,08	0,01	0,06	0,12	0,23	0,00	0,03	0,07
Other fish	20,54	15,40	17,01	16,23	24,61	18,45	28,87	21,00	11,99	6,12	9,14	10,11	10,91	13,51	11,96	10,56	12,49
Other food	8,71	4,45	4,67	12,59	16,12	13,18	7,66	1,51	12,40	16,29	15,19	25,39	14,17	13,53	18,94	12,29	9,73
Stomachs number	3729	4124	6042	5941	5688	8289	8443	6671	5217	7660	7554	10636	12207	12093	15102	14461	15692
Empty stomachs, %	20,1	29,8	19,6	23,9	17,5	16,8	14,3	16,9	36,7	32,2	29,2	23,0	24,0	29,7	27,4	26,8	22,2
Mean ball of fullness	2,7	2,6	2,3	1,8	2,5	2,6	2,7	3,2	2,4	2,8	2,3	2,8	2,6	2,4	1,4	2,6	2,8
Mean index of fullness	163,3	331,9	186,5	182,0	178,4	156,1	242,1	285,9	240,6	245,8	213,9	175,2	158,4	196,5	199,9	240,2	273,3

Table 1 (continued).

Food composition of the Barents Sea cod in 1984-2018, % by weight

Prey species	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Hyperiids	0,65	0,39	2,55	12,23	4,41	1,20	2,91	0,06	0,83	0,92	0,34	0,61	0,58	0,34	4,24	2,18	0,26	0,47
Euphausiids	1,49	1,15	0,71	1,44	3,63	4,00	4,08	1,89	1,19	3,25	1,49	0,65	0,97	0,74	1,80	1,96	1,83	3,49
Shrimp	8,02	6,77	5,36	4,63	5,44	6,05	6,36	4,14	2,93	2,83	2,77	3,20	3,13	3,13	2,85	3,97	3,88	2,59
Herring	5,70	1,60	7,21	3,76	11,51	11,68	8,95	4,60	7,92	3,59	1,75	1,30	0,71	3,90	2,52	1,13	1,61	6,29
Capelin	39,19	45,52	22,84	23,43	10,91	26,30	19,30	25,65	23,94	31,30	29,78	17,65	24,13	27,94	28,16	31,33	32,90	22,12
Polar cod	2,85	7,87	4,42	7,39	8,12	2,03	6,01	6,09	7,80	9,79	4,44	4,22	3,02	0,64	2,36	4,31	1,27	2,25
Cod	5,12	5,73	10,39	6,01	6,93	5,88	6,15	5,74	4,96	6,42	7,65	6,86	11,24	10,10	5,92	7,52	11,17	8,52
Haddock	4,14	4,62	10,03	6,67	10,76	11,37	13,30	14,36	9,88	8,94	11,67	12,89	11,94	4,73	4,23	4,03	7,37	13,07
Blue whiting	7,47	4,40	1,40	1,62	4,00	5,22	1,66	1,27	0,18	0,10	0,35	0,47	0,26	0,37	0,82	1,39	0,32	1,15
Norway pout	1,17	0,09	0,35	0,50	0,66	2,22	0,66	0,56	1,04	0,77	0,89	0,82	0,73	0,47	0,38	0,15	0,17	0,25
Redfish	0,21	0,40	0,14	0,26	0,29	0,59	0,50	0,56	0,45	0,57	1,09	0,47	0,74	0,29	1,73	0,70	0,26	1,14
Wolffish	0,36	0,28	0,14	0,18	0,17	0,13	0,13	0,20	0,12	0,11	0,03	0,01	0,10	0,04	0,01	0,23	0,01	0,02
Long rough dab	2,02	1,29	2,49	3,64	2,68	2,00	3,21	2,55	1,92	2,39	3,25	3,38	3,82	2.99	3,65	4,95	5,00	2,94
Greenland halibut	0,01	0,01	0,00	0,27	0,74	0,02	0,04	0,44	0,07	0,21	0,09	1,16	0,42	0,35	1,40	0,13	0,37	1,68
Other fish	8,08	10,59	20,46	16,09	18,85	11,89	13,30	16,21	13,74	9,98	13,01	14,43	11,16	13,47	10,41	12,38	11,90	16,51
Other food	13,52	9,28	11,42	11,88	10,90	9,42	13,44	15,68	23,03	18,83	21,4	31,88	27,05	30,50	29,52	23,64	21,61	17,51
Stomachs number	15122	15800	12874	23124	18593	17352	12942	14224	12037	13657	11632	11469	12102	13825	11377	11098	12839	9019
Empty stomachs, %	36,40	26,4	30,3	26,2	26,7	32,4	26,6	29,0	25,7	26,5	29,4	25,3	23,6	24,1	22,4	22,8	25,20	23,90
Mean ball of fullness	2,0	1,8	1,5	1.5	1.5	1,5	1,80	1,70	1,90	1,80	1,60	1,6	1,7	1,4	1,5	2,0	1,7	1,4
Mean index of fullness	241,2	268,2	232,4	212.7	216.5	196,3	213,40	202,57	208,55	206,62	208,71	183,39	190,73	191,43	195,13	222,33	194,32	196,12

Table 2. Consumption of various prey species by the Barents Sea cod in 1984-2018, thousand tons

Year	Euphausiids	Hyperiids	Shrimp	Herring	Capelin	Polar cod	Cod	Haddock	Blue whiting	Norway pout	Redfish	Long rough dab	Greenland halibut	Other fish	Other food	Total consumption
1984	94.1	31.2	353.0	33.7	593.3	17.6	13.5	50.3	4.8	1.2	196.4	51.6	0.0	271.1	287.7	1999.3
1985	30.6	440.3	210.3	25.6	1039.2	0.0	89.2	35.4	17.5	13.5	99.5	21.9	0.0	545.6	206.4	2775.0
1986	66.0	948.2	159.1	50.8	854.6	169.1	25.7	99.1	3.1	26.0	165.8	26.0	0.8	401.3	187.6	3183.1
1987	78.5	592.4	232.9	8.9	175.3	117.4	23.0	2.4	9.7	14.9	119.5	5.2	0.5	306.0	219.7	1906.3
1988	238.6	195.8	146.4	20.8	348.3	0.0	20.5	76.5	0.0	0.0	133.1	21.6	0.0	262.3	282.3	1746.3
1989	190.6	324.4	116.8	4.3	768.1	37.1	34.7	1.9	0.0	0.0	178.3	63.9	0.0	219.5	277.0	2216.4
1990	104.7	30.8	265.8	65.3	1264.4	7.6	24.1	14.8	38.8	14.2	237.1	78.9	0.0	103.8	160.1	2410.3
1991	54.6	81.2	276.7	25.5	3205.3	45.2	52.0	21.7	5.7	5.8	141.5	45.8	5.4	128.2	154.7	4249.3
1992	211.0	38.0	257.4	334.7	2017.6	195.5	82.0	36.5	0.0	71.5	116.6	41.6	0.8	295.8	419.5	4118.6
1993	183.8	173.2	219.7	169.5	2738.8	169.6	143.7	148.1	3.6	24.3	40.0	47.4	4.9	159.6	378.3	4604.5
1994	358.3	296.0	457.7	101.8	1275.2	485.3	382.8	71.6	1.2	1.4	55.3	40.3	0.1	98.3	347.0	3972.4
1995	396.3	455.1	533.2	192.5	670.1	190.7	541.1	129.6	0.3	0.5	109.9	51.5	2.7	157.2	344.3	3775.0
1996	957.2	346.4	194.5	73.7	469.7	73.9	450.6	57.2	8.5	35.7	66.7	44.5	0.1	467.9	169.6	3416.3
1997	508.9	134.1	257.1	51.4	510.5	111.6	382.9	35.1	16.4	0.1	29.4	16.5	1.5	96.9	365.5	2518.1
1998	644.4	219.3	284.6	72.9	913.3	134.1	130.5	23.3	23.7	18.5	14.6	19.6	0.0	55.2	237.0	2791.1
1999	457.7	80.6	266.7	79.5	1536.2	176.3	49.3	16.0	27.2	0.9	13.5	8.7	0.4	60.3	117.8	2891.2
2000	436.6	122.3	393.2	52.5	1797.5	167.3	59.3	31.5	28.2	9.0	4.0	21.3	0.1	38.1	195.1	3356.1
2001	410.4	74.9	321.8	92.5	1520.7	147.4	62.2	51.8	144.8	30.4	4.1	30.8	2.3	156.5	196.5	3246.9
2002	285.8	45.2	201.3	54.8	2398.8	301.4	99.7	80.1	110.2	3.8	3.5	17.1	0.0	44.6	176.3	3822.6
2003	546.8	170.8	226.8	152.7	1218.7	220.5	131.9	330.9	27.6	5.2	1.6	51.5	0.0	96.9	298.0	3479.8
2004	477.4	392.7	255.8	129.1	1096.5	368.9	86.0	143.9	48.0	20.3	7.3	62.4	15.7	186.4	289.0	3579.4
2005	686.7	162.7	243.5	167.5	1022.0	320.1	112.6	270.8	67.1	39.6	7.3	46.9	2.2	340.3	239.5	3728.7
2006	1543.5	85.5	273.5	268.1	1339.6	124.7	95.5	285.5	103.1	107.1	17.2	148.7	0.6	127.7	550.5	5070.8
2007	1333.8	191.6	419.0	275.1	1875.0	288.9	68.3	330.1	32.0	26.0	29.1	72.9	0.8	281.3	521.6	5745.3
2008	999.3	50.9	342.7	122.1	3264.1	662.0	156.6	333.1	16.6	20.4	59.8	121.7	13.4	413.9	583.1	7159.7
2009	936.6	188.7	282.9	229.1	3349.0	826.9	142.0	347.8	7.8	121.1	28.4	285.0	0.4	170.0	754.2	7670.0
2010	1839.0	329.0	255.0	142.6	4115.9	513.2	181.0	248.3	15.9	66.3	162.8	136.8	1.1	249.9	657.2	8913.9

Table 2 (continued).

Year	Euphausiids	Hyperiids	Shrimp	Herring	Capelin	Polar cod	Cod	Haddock	Blue whiting	Norway pout	Redfish	Long rough dab	Greenland halibut	Other fish	Other food	Total consumption
2011	829.8	202.0	225.6	84.8	4469.0	422.9	260.4	361.9	57.5	95.7	142.9	171.6	1.6	208.3	949.5	8483.6
2012	599.0	164.2	272.1	96.6	2983.5	439.7	290.9	419.3	32.8	98.4	41.4	134.1	7.1	291.2	1381.3	7251.7
2013	642.0	208.6	332.2	45.1	3651.8	145.5	450.1	276.7	39.4	65.1	178.3	217.5	2.4	215.0	1084.3	7553.9
2014	735.8	119.2	205.6	55.4	3296.5	96.1	390.4	170.9	26.6	37.3	19.9	156.1	7.2	197.5	1148.3	6662.9
2015	1134.5	294.2	425.7	67.6	2621.8	157.3	174.7	179.6	38.0	26.5	85.8	118.0	14.0	179.5	903.9	6421.2
2016	750.3	642.8	205.4	83.0	2144.3	235.1	238.7	154.8	48.6	11.6	46.4	332.1	3.0	285.5	1210.9	6392.5
2017	648.7	80.6	296.9	92.1	2587.1	69.7	264.0	304.8	24.2	19.9	186.1	249.2	3.3	162.9	817.3	5806.7
2018	1577.6	149.4	183.8	271.2	1614.3	114.2	352.6	483.6	38.0	44.8	42.6	120.7	42.9	170.3	937.7	6143.6
Mean	614.6	236.2	271.8	110.6	1886.8	221.6	177.9	164.0	31.2	31.6	76.2	89.1	4.0	211.0	493.0	4544.6

Table 3. Biomass of cod consumed by cod in 1984-2018 (thousand tons)

Year	Age groups of cod							Sum
	0+	1	2	3	4	5	6	
1984	0.00	6.81	5.36	0.00	0.00	0.00	0.00	12.17
1985	5.46	13.39	33.28	30.39	6.67	0.00	0.00	89.19
1986	0.22	6.21	4.95	14.19	0.09	0.00	0.00	25.66
1987	3.25	4.31	1.16	8.16	6.09	0.00	0.00	22.96
1988	0.04	13.22	0.34	6.06	0.75	0.00	0.00	20.41
1989	0.08	31.78	2.36	0.47	0.00	0.00	0.00	34.69
1990	0.29	18.95	4.76	0.13	0.00	0.00	0.00	24.14
1991	15.19	21.92	8.49	6.18	0.26	0.00	0.00	52.04
1992	7.88	58.92	12.16	3.08	0.00	0.00	0.00	82.04
1993	11.75	84.36	36.35	8.69	4.14	1.35	0.33	146.96
1994	79.48	149.60	45.95	37.85	48.61	16.33	0.76	378.58
1995	66.23	330.23	21.06	56.12	51.98	10.90	1.99	538.52
1996	49.05	272.65	65.25	23.07	28.87	14.80	1.13	454.81
1997	21.69	152.53	143.72	48.72	12.81	2.75	0.70	382.94
1998	2.73	49.82	24.69	38.14	14.39	0.69	0.02	130.49
1999	0.78	20.57	12.41	13.11	2.42	0.00	0.00	49.29
2000	13.65	17.63	6.32	10.82	9.57	1.27	0.00	59.26
2001	1.66	30.36	10.43	13.39	6.13	0.23	0.00	62.19
2002	36.27	10.14	20.62	22.52	6.54	0.54	0.00	96.63
2003	14.03	48.42	42.48	25.23	1.75	0.00	0.00	131.90
2004	7.54	24.72	34.44	10.23	8.96	0.11	0.00	86.00
2005	0.37	21.59	24.56	29.53	12.56	22.06	1.94	112.62
2006	10.52	35.69	32.96	8.31	4.00	3.41	0.62	95.50
2007	1.85	15.89	18.69	24.38	6.98	0.46	0.03	68.27
2008	64.48	4.17	14.15	43.23	29.59	1.02	0.00	156.63
2009	20.17	94.79	12.00	10.33	3.74	0.97	0.03	142.03
2010	14.83	107.62	28.23	20.12	7.24	2.77	0.20	181.00
2011	61.63	52.96	54.49	38.93	10.62	23.62	18.11	260.36
2012	44.92	148.26	73.57	17.47	5.56	0.87	0.29	290.94
2013	28.93	120.82	220.40	17.05	25.79	31.90	5.20	450.09
2014	54.57	51.81	116.92	132.66	28.97	5.50	0.00	390.43
2015	4.44	71.89	62.27	23.05	9.64	3.33	0.06	174.68
2016	4.64	112.05	43.23	4.91	16.76	48.63	8.45	238.69
2017	26.42	86.21	33.14	42.63	20.80	29.61	25.14	263.96
2018	5.65	163.01	90.01	53.23	39.24	1.46	0.00	352.61
Mean	19.45	70.09	38.89	24.07	12.33	6.42	1.86	173.11

Table 4. Abundance of cod consumed by cod in 1984-2018 (millions individuals)

Year	Age groups of cod							Sum
	0+	1	2	3	4	5	6	
1984	0.0	200.3	41.1	0.0	0.0	0.0	0.0	241.4
1985	208.5	408.7	282.9	64.5	7.0	0.0	0.0	971.7
1986	8.6	201.9	51.3	42.4	0.1	0.0	0.0	304.4
1987	108.2	151.1	14.1	34.7	11.4	0.0	0.0	319.5
1988	1.6	416.5	3.5	24.2	1.6	0.0	0.0	447.4
1989	2.8	753.2	15.8	1.4	0.0	0.0	0.0	773.1
1990	10.9	440.8	24.2	0.3	0.0	0.0	0.0	476.2
1991	453.5	626.2	46.0	10.8	0.2	0.0	0.0	1136.8
1992	315.1	1988.9	86.3	5.8	0.0	0.0	0.0	2396.0
1993	451.8	5191.1	379.2	22.0	3.4	0.7	0.1	6048.4
1994	4967.7	8141.6	642.6	142.2	60.7	10.8	0.3	13965.9
1995	3311.5	16615.5	265.0	237.0	95.3	8.7	0.9	20533.8
1996	2096.1	14541.1	829.9	97.8	51.5	13.6	0.5	17630.5
1997	964.1	9533.3	1825.0	152.4	20.7	2.4	0.4	12498.3
1998	191.0	3113.9	266.7	157.0	22.9	0.6	0.0	3752.0
1999	38.6	1293.6	197.3	73.5	4.4	0.0	0.0	1607.3
2000	523.1	623.0	71.6	33.3	13.7	1.0	0.0	1265.7
2001	102.3	1434.9	84.1	28.7	7.0	0.1	0.0	1657.0
2002	2238.9	496.8	199.4	52.0	9.0	0.4	0.0	2996.5
2003	2192.2	2274.9	442.9	56.2	2.2	0.0	0.0	4968.4
2004	355.5	726.1	340.0	27.5	10.8	0.1	0.0	1459.9
2005	16.1	578.1	222.1	82.6	19.4	16.1	1.0	935.4
2006	459.2	1044.3	192.8	17.4	4.9	2.7	0.3	1721.6
2007	61.0	444.8	166.7	45.6	7.6	0.3	0.0	726.0
2008	9482.2	95.8	95.2	93.4	27.0	0.6	0.0	9794.1
2009	1371.9	3001.7	121.6	23.9	3.3	0.5	0.0	4522.8
2010	828.6	3785.1	200.6	46.7	7.6	1.6	0.1	4870.2
2011	6924.4	1676.3	523.3	119.2	13.7	16.9	9.2	9282.9
2012	5478.4	5172.6	593.6	31.3	5.0	0.5	0.1	11281.5
2013	3856.9	5742.0	1778.9	38.1	36.2	25.9	2.9	11481.0
2014	8025.0	2093.0	1156.5	480.5	33.0	3.1	0.0	11791.2
2015	189.7	3649.8	421.3	55.7	10.3	2.0	0.0	4328.9
2016	198.4	3581.8	440.5	12.8	22.3	33.9	3.5	4293.2
2017	1212.1	2178.2	153.2	96.0	25.9	20.2	11.2	3696.7
2018	241.6	5695.6	644.7	112.4	47.4	1.0	0.0	6742.7
Mean	1625.4	3083.2	366.3	72.0	16.7	4.7	0.9	5169.1

Table 5. Biomass of haddock consumed by cod in 1984-2018 (thousand tons)

Year	Age groups of haddock							Sum
	0+	1	2	3	4	5	6	
1984	4.55	45.69	0.04	0.00	0.00	0.00	0.00	50.27
1985	7.00	27.75	0.63	0.00	0.00	0.00	0.00	35.38
1986	0.59	11.65	20.70	65.44	0.67	0.00	0.00	99.05
1987	0.00	1.59	0.74	0.10	0.00	0.00	0.00	2.42
1988	0.00	6.12	6.37	20.85	30.48	12.24	0.45	76.51
1989	0.00	1.56	0.26	0.02	0.00	0.03	0.03	1.90
1990	1.18	6.68	2.39	3.48	0.19	0.00	0.00	13.92
1991	0.06	19.78	1.77	0.09	0.00	0.00	0.00	21.69
1992	1.19	25.35	9.56	0.40	0.00	0.00	0.00	36.50
1993	26.62	43.58	23.57	52.94	1.43	0.00	0.00	148.14
1994	15.89	15.60	7.04	19.28	11.51	1.34	0.53	71.19
1995	6.44	64.52	16.97	4.74	20.04	16.77	0.08	129.57
1996	7.55	25.95	7.71	5.30	0.91	5.08	4.67	57.16
1997	1.60	17.74	10.08	3.48	0.67	0.76	0.73	35.07
1998	7.74	10.72	2.80	0.73	1.16	0.12	0.02	23.30
1999	4.09	10.60	1.17	0.13	0.00	0.00	0.00	15.99
2000	10.68	14.31	6.16	0.35	0.01	0.00	0.00	31.50
2001	6.32	26.67	16.70	2.06	0.01	0.00	0.00	51.76
2002	4.60	44.97	22.95	7.00	0.22	0.28	0.06	80.09
2003	15.28	224.79	64.45	15.64	10.49	0.00	0.00	330.66
2004	27.43	68.58	27.47	12.38	4.90	3.16	0.04	143.95
2005	75.56	126.84	37.47	17.77	10.77	1.71	0.65	270.76
2006	76.57	143.07	47.07	12.62	3.57	1.86	0.72	285.48
2007	14.02	244.91	57.02	9.66	2.65	1.70	0.14	330.09
2008	50.18	44.50	123.97	102.59	39.13	3.10	7.13	370.61
2009	80.04	133.56	35.13	83.26	39.81	11.44	0.19	383.44
2010	18.92	74.42	45.78	21.33	47.74	33.30	6.81	248.30
2011	43.07	56.35	107.83	30.99	42.52	45.42	35.77	361.94
2012	5.23	296.73	17.73	46.40	4.28	7.64	41.32	419.33
2013	70.92	28.24	138.55	20.24	22.24	4.46	32.24	316.88
2014	51.91	64.48	25.09	35.24	3.03	18.41	3.65	201.81
2015	45.45	106.24	28.89	4.88	7.94	1.10	4.67	199.17
2016	48.40	55.37	16.08	6.19	3.58	31.90	6.00	167.52
2017	11.74	192.93	51.56	18.89	24.32	2.35	3.86	305.65
2018	17.04	154.22	196.73	81.55	24.13	9.93	0.00	483.59
Mean	21.65	69.60	33.67	20.17	10.24	6.12	4.28	165.73

Table 6. Abundance of haddock consumed by cod in 1984-2018 (millions individuals)

Year	Age groups of haddock							Sum
	0+	1	2	3	4	5	6	
1984	94.80	456.86	0.09	0.00	0.00	0.00	0.00	551.76
1985	191.30	267.90	2.28	0.00	0.00	0.00	0.00	461.48
1986	15.57	264.77	162.32	120.07	0.70	0.00	0.00	563.43
1987	0.00	40.14	7.95	0.40	0.00	0.00	0.00	48.49
1988	0.00	102.03	57.78	92.71	71.55	15.86	0.37	340.31
1989	0.00	17.88	1.97	0.09	0.00	0.03	0.03	20.00
1990	17.48	115.57	13.74	14.24	0.30	0.00	0.00	161.34
1991	0.76	197.76	10.28	0.18	0.00	0.00	0.00	208.99
1992	21.56	546.32	54.15	0.70	0.00	0.00	0.00	622.73
1993	733.22	726.35	195.62	124.46	1.67	0.00	0.00	1781.32
1994	131.33	286.17	84.10	107.97	36.72	1.15	0.33	647.78
1995	154.16	1597.03	168.39	24.15	55.90	19.59	0.05	2019.27
1996	160.21	648.84	48.31	24.87	1.75	5.99	3.82	893.79
1997	41.33	1108.73	128.06	11.22	1.18	0.86	0.62	1292.01
1998	184.80	248.73	19.01	2.91	2.31	0.12	0.02	457.90
1999	88.21	230.36	10.55	0.44	0.00	0.00	0.00	329.55
2000	262.99	453.34	36.46	0.95	0.01	0.00	0.00	753.75
2001	139.55	526.65	83.62	4.71	0.01	0.00	0.00	754.55
2002	101.61	1278.90	145.24	15.95	0.30	0.17	0.03	1542.19
2003	768.03	3700.72	411.95	43.00	13.65	0.00	0.00	4937.35
2004	721.76	1817.84	192.55	33.13	7.85	3.20	0.02	2776.35
2005	1978.13	2655.17	302.95	56.04	18.91	2.01	0.52	5013.74
2006	1668.22	2653.65	340.69	36.47	4.47	1.78	0.54	4705.82
2007	356.73	6138.04	282.73	17.99	3.15	1.52	0.10	6800.25
2008	2039.90	723.20	862.24	275.09	47.49	2.48	4.75	3955.14
2009	2910.67	3936.86	241.17	299.47	73.57	11.62	0.12	7473.47
2010	687.83	1681.54	441.75	70.31	82.73	35.07	5.30	3004.51
2011	1643.86	1195.53	709.25	113.89	78.12	49.93	30.16	3820.73
2012	176.72	5837.93	91.27	107.47	6.19	7.70	33.53	6260.80
2013	2533.00	384.99	845.94	43.43	30.39	4.57	25.53	3867.86
2014	2237.62	1683.91	241.12	106.35	4.37	17.85	2.89	4294.12
2015	1360.69	2881.62	202.03	15.06	11.26	0.86	2.58	4474.09
2016	1216.08	877.15	143.34	14.82	4.43	26.34	3.44	2285.60
2017	354.64	3454.35	276.32	40.43	30.68	2.10	2.38	4160.89
2018	571.91	3209.04	1386.92	181.15	35.38	9.16	0.00	5393.55
Mean	673.28	1484.17	234.35	57.15	17.86	6.29	3.35	2476.43

Table 7.

Total annual food rations of the Barents Sea cod in 1984-2018, grams per 1 individual

Age	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
1	262	295	179	145	183	282	288	241	178	133	180	194	170	119	232	261	186
2	895	753	526	432	704	909	1006	936	969	476	512	497	498	341	528	431	545
3	1611	1658	1455	852	1075	1465	1694	2670	2475	1512	1212	962	1028	992	1081	1128	1288
4	2748	2681	3455	1558	1628	2207	2693	4472	2866	2865	2402	1801	1916	1908	2016	2490	2551
5	3848	4264	5001	3073	2391	3243	3278	6037	3995	3944	3517	3204	3059	2668	2823	3676	4387
6	5486	6599	5991	4380	4386	4798	3833	7844	5137	5108	5359	4847	4189	3503	4089	5222	6559
7	6992	8241	6458	7357	8207	6578	5583	9590	6723	7372	7560	7332	6987	4954	5469	6398	8833
8	8561	9745	8157	9667	9978	8725	6870	11543	7414	8945	10001	9688	10212	7980	7346	8220	10483
9	10572	10974	9766	12705	10868	11134	10715	14969	8755	10343	11818	13835	12185	12174	9586	9194	11522
10	13166	14448	11457	14481	16536	15798	11426	19292	12303	11600	12896	15247	13614	16762	13012	13364	15132
11	13200	17327	13188	15899	14639	16313	13555	18590	14288	14835	14499	16899	14529	16710	14404	15268	17090
12	15547	17391	14621	16616	16046	18436	15964	21720	15184	16536	17656	19273	16275	18410	15640	16990	19793
13	17153	19186	16134	18318	17000	18041	17595	23960	16745	18249	19469	21254	17945	20308	17243	18727	21822
14	18707	20923	17599	19965	17423	18386	19175	26128	18256	19906	21223	23170	19561	22144	18794	20408	23787
15+	18707	20923	17599	19965	17423	18386	19175	26128	18256	19906	21223	23170	19561	22144	18794	20408	23787

Table 7 (continued).

Total annual food rations of the Barents Sea cod in 1984-2018, grams per 1 specimen

Age	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
1	150	252	228	250	255	354	234	223	217	235	248	207	190	242	234	307	244	316
2	413	677	618	654	687	925	681	719	624	651	721	588	656	622	745	870	779	867
3	1163	1303	1296	1412	1514	1881	1874	1697	1495	1401	1497	1203	1641	1321	1390	1722	1582	1846
4	2110	2699	2028	2567	2504	2813	3128	2959	2526	2577	2513	2292	2552	2340	2406	2813	2531	2699
5	3430	3847	3547	3857	3896	4019	4459	4194	4304	4065	3859	3266	3809	3608	3915	3474	3748	3736
6	5571	5591	4716	5660	5264	5332	5893	6073	5623	5757	4963	4461	4952	4387	4922	4740	4943	5000
7	6835	7846	6684	7730	7192	7450	7563	7809	7855	8312	6848	5862	5791	5560	5960	6754	6601	6489
8	10233	10796	8905	11126	9395	10328	9178	10464	11490	11805	9213	7629	7757	7447	7505	9117	9180	9170
9	12457	13238	13418	15907	13163	13111	12032	13627	13341	16090	13799	11713	10881	9017	10265	10665	11302	11166
10	15130	18787	14492	20770	15981	17759	15919	17254	15988	16844	19074	16211	14989	12547	12116	14810	16016	14577
11	17341	17836	19480	21607	20628	19488	19961	21590	18770	20129	20784	19345	19785	16044	16245	19921	20086	18672
12	19307	20278	19309	24940	21448	22322	21644	23373	21866	23023	23791	21032	22386	18854	19978	24195	23464	21848
13	21345	22359	21292	27503	23639	24609	23863	25779	24111	25387	26241	23190	24691	20781	22023	26683	25870	24091
14	23337	24373	23212	29984	25760	26824	26011	28107	26285	27676	28611	25279	26923	22646	24002	29092	28198	26263
15+	23867	24373	23212	29984	25760	26824	26011	28107	26285	27676	28611	25279	26923	22646	24002	29092	28198	26263

Working Document Submitted to AFWG 2019 WD24

(Submitted to AFWG)

Report of the Portuguese fishery in 2018: ICES Div. I, IIa and IIb.

by

R. Alpoim, J. Vargas and E. Santos

ralpoim@ipma.pt, jvargas@ipma.pt
Instituto Português do Mar e da Atmosfera – IPMA
Rua Alfredo Magalhães Ramalho, 6, 1495-165 Algés, Portugal

A. Status of the fisheries

In 2018, the Portuguese nominal catches recorded 3,216 ton proceeding from the traditional grounds of both Divisions I and II (Norway and Svalbard) and 356 ton proceeding from the redfish pelagic fishery in the "Banana Hole" zone (international waters of Div. IIa) (Tab. I). In the traditional grounds, the nominal catches increased from 1993 (4,036 ton) to 1997 (8,661 ton) followed by a decline till 2003 (4,250 ton). In 2004 total catches increased and were maintained between 5,300 and 5,900 ton till 2010. From 2010 till 2018 catches decreased and have oscillated between 3,200 and 4,950 ton, exception for 2015 (1754 ton - the lowest value since 1993).

In the traditional grounds, fishing effort increased till 1998 (1118 fishing days) but decreased gradually afterwards, reaching 277 fishing days in 2003. Between 2004 and 2007, the trend of fishing effort in the traditional grounds shows an increase, from 486 to 558 fishing days but since then effort decreased gradually reaching a minimum in 2015 (100 fishing days). Despite the increase fishing effort in 2016 and 2017 (197 and 192 fishing days respectively) the effort fell again in 2018 to 135 days. This decreased was in the Svalbard area. (Tab. I)

For the period 1993-2018, cod (*Gadus morhua*) was the most important species in the catches in Divisons I and II, exception for 1993 in Division IIa. Cod catches more than doubled from 2015 to 2016 but since then catches decrease to 2,672 ton in 2018. In 2018, the fishing effort (not including the fishery in the "Banana Hole" zone) was almost all in the Norwegian zone.

Redfish (*Sebastes mentella*) catches and effort in the international waters of Div. IIa decreased from 1697 ton in 2006 to values around 600-700 ton in 2008-2009, and from 175 days to 88 days, respectively. In 2010 the fishing effort was only 16 days and the redfish catches were 244 ton. Both catch and effort increased in the two following years to 600 ton and 42 days in 2011 and 1038 ton and 139 days in 2012. In 2013-2015 effort was only 59 days but catches were 852 ton in 2013, 544 ton in 2014 and 678 ton in 2015. In 2016 although only 35 days were spent the catches increased to 822 ton, but in 2017 it was need 79 days to catch the same amount. In 2018 both catches and effort fell to half of the values in 2017 (356 ton and 31 days) (Tab. I).

The Portuguese fleet operating in the traditional grounds of both Divisions I and II, was composed by 2 trawler using a bottom trawl gear. The fishery in the international waters of Div. IIa was carried out by 1 trawler fishing with a pelagic trawl gear.

B. Portuguese Annual Sampling Program

On 2018, like in 2015 and 2017, Portuguese cod fishery was not sampled on ICES Divisions I and II. Our National Sampling Programme on board is based on nurse men from the vessels to be monitored on NAFO, since their presence on board is mandatory on North West Atlantic trips. But that is not the case for North East Atlantic (partly due to shorter trips closer to shore) and so most Portuguese vessels fishing on ICES divisions don´t take a nurse man aboard. In order to meet the objectives of our National Sampling Program, the solution has been in recent years to contract the services of a company that provide experienced observers to work on board on behalf of either scientific or control national programmes. But on 2018, and despite our continuous efforts, we were not able to put an outsider scientific observer on any of the vessels with cod quotas on either ICES Divisions.

1. Catch and effort sampling.

Effort and cpue data for 2018 Portuguese trawl fishery on ICES Div. IIa (international waters) were obtained from one trawler, through the revision of the skipper logbook kindly supplied by the owner. All the information (round weight of the catch by species, fishing effort, positions and depths) has been recorded on a tow-by-tow basis. The vessel conversion factors were used to convert its processed landings in catches.

In the "Banana Hole" zone (Div. IIa international waters – outside Norwegian EEZ), all pelagic fishing effort was directed to redfish. The daily catch and effort data from the logbook were used to estimate the target species, directed effort and CPUE, as well as the main by-catch species on a monthly basis (Tab. II).

1.1. Comments on redfish catch rate data.

Based on the observed vessel, the redfish catch rates decrease in July (0.23 ton/h) regards July 2017 (0.73 ton/h). In August, catch rates slightly increase (0.578 ton/h) regards the 2017 level but doubled the July 2018 value (Table II).

2. Biological Sampling

In 2018, biological sampling was obtained from one stern trawler fishing in ICES Div. IIa (July and August), with a pelagic trawl gear from 327 m to 442 m depths, outside Norwegian EEZ. Redfish was the only species sampled during this period (Tab III).

All commercial information is representative of the catch as a whole. The mean weights in the catch are derived from the calculated 2018 length-weight relationship (Tab. IV).

2.1. Comments on length composition of the 2018 trawl catches.

2.1.1 - Redfish (*S. mentella*)

In Div. IIa international waters (Tab. V, Fig. 1), lengths between 34 cm and 40 cm dominated catches, with a modal class at 36 cm (mean length and weight of 37 cm and 652 g).

Acknowledgements

This study was supported by the European Commission (Programme for the Collection of Data in Fisheries Sector) and IPMA.

TABLE I - A: Portuguese provisional nominal trawl catches (ton) in Norway (Div.I and IIa), Svalbard (Div.I and IIb) and International waters (Div. IIa) regions, 2018.

SPECIES \ AREA	I and IIa Norway	I and IIb Svalbard	IIa International waters (Banana hole)	SUBTOTAL Norway + Svalbard	TOTAL 2018
Cod	2549.9	122.0		2671.9	2671.9
Redfish	391.5	0.0	356.4	391.5	747.9
American plaice	0.1	0.1		0.1	0.1
Greenland halibut	5.3	0.1		5.5	5.5
Atlantic halibut	5.5	0.1		5.6	5.6
Anarhichas spp.	8.1	1.0		9.1	9.1
Hadocck	70.3	10.7		81.1	81.1
Skates					
Pollock	50.7			50.7	50.7
Shrimp					
Monkfish					
Unidentified	0.7			0.7	0.7
TOTAL	3082.2	134.1	356.4	3216.2	3572.6
Fishing Days	130	5	31	135	166

TABLE I - B: Portuguese nominal trawl catches (ton) in Norway ZEE (Div. I and IIa) not including International waters of Div. IIa.

SPECIES / YEAR	2017	2016	2015	2014	2013	2012	2011	2010	2009	2008	2007	2006	2005	2004	2003	2002	2001	2000	1999	1998	1997	1996	1995	1994	1993
Cod	2770.1	2522.0	1192.0	1819.9	2530.0	1515.0	1705.1	2559.7	3340.4	2567.2	2269.3	2558.2	2629.7	2670.5	2204	2205.1	2199.7	2184.4	2230.4	3494.6	4906.0	4380.9	3817.1	3253.5	27.3
Redfish	359.3	244.8	0.1	1.6	8.0	4.4	4.6	27.8	92.5	112.7	89.7	92.5	126.9	91.3	23	142.1	110.2	114.3	58.9	124.2	470.6	479.5	740.3	777.4	724.7
American plaice			0.2					0.7	10.6	2.5	0.4	3.6	8	12.5	21.8	14.4	23.9	36.5	28.4	192.0	29.4	70.2	27.2	16.0	
Greenland halibut	1.2	18.6	3.7		0.86	0.05	0.2	0.1	9.2	1.3	1.8	7.6	13.4	24.2	9.6	4.6	12.5	18.1	33.1	80.0	40.9	55.1	75.2	26.1	16.5
Atlantic halibut	2.3	2.0	1.0	1.1	0.4	0.7	0.6	2.4	6.3	8.9	11.5	11	3.8	1	1.1	0.3	0.6	0.8		0.3		0.3	0.2		
Anarhichas spp.	3.2	10.2	3.4		1.4		2.0	0.03	6.0	2.9	0.4	3.6	19.7	48.4	46.8	69.7	87.5	117.8	51.6	344.7	94.4	94.9	82.5	80.5	3.2
Hadocck	87.1	122.3	34.8	27.4	34.0	22.2	30.0	137.8	406.1	407.8	372.3	286.2	223.1	184.6	144.5	85.4	78.7	109.6	19.5	34.9	119.3	59.8	33.4	34.0	10.8
Skates										2.0				1.5	3.1		0.5	6.2	2.9	38.4	14.7	7.6	9.8	3.5	0.1
Pollock	85.5	53.0	9.7	11.7	17.0	7.3	41.0	93.3	209.0	346.9	397	333.9	343.4	98.2	143.5	110.9	72.3	45.7	17.4	47.3	12.0	23.8	4.2	0.6	0.6
Shrimp																									
Monkfish							0.02	1.5	6.4	2.0															
Unidentified											0.5		0.1								0.1	0.5	3.5	6.3	2.9
TOTAL	3308.8	2972.9	1244.9	1861.7	2591.7	1549.6	1783.5	2823.2	4086.4	3454.2	3142.9	3296.6	3368.1	3132.2	2597.4	2632.5	2585.9	2633.4	2442.2	4356.4	5687.4	5172.5	4793.3	4197.9	786.1
Fishing Days	99	121	81	56	74	60	76	132	274	271	278	333	298	284	179	169	267	399	327	748	494	350	306	-	-

TABLE I - C: Portuguese nominal trawl catches (ton) in Svalbard (Div. I and IIb).

SPECIES / YEAR	2017	2016	2015	2014	2013	2012	2011	2010	2009	2008	2007	2006	2005	2004	2003	2002	2001	2000	1999	1998	1997	1996	1995	1994	1993
Cod	1208.0	1948.6	505.5	1539.2	2117.0	1940.4	1871.1	2094.7	1366.7	1554.7	1490.3	1649	1686.2	1714.5	1424.1	1424.8	1424.3	1403.0	1654.9	1967.4	2622.3	2384.4	2378.1	2390.4	1761.1
Redfish	0.450	0.004		5.5	31.0	18.8	38.8	48.8	41.8	47.8	156.9	83.4	68.5	148.7	27.2	134.0	74.9	16.9	8.6	6.8	63.5	42.8	219.0	208.2	315.3
American plaice	2.5	4.3	0.0	6.2	12.5	3.8	1.3	10.7	8.7	22.7	34.1	38.7	37.1	32.9	27	79.6	44.9	74.4	42.3	66.3	27.6	14.8	21.9	10.5	29.0
Greenland halibut	4.6	2.8	0.8	0.0	3.0	1.6	21.4	10.8	19.5	45.4	27.6	16.4	12.3	26.3	9.9	10.8	21.9	18.9	15.7	18.9	8.6	24.4	24.1	10.1	25.6
Atlantic halibut	0.1					0.3	0.8	1.3	1.5	1.1	4.8	3.6	1.4	0.1									0.1		
Anarhichas spp.	19.4	3.8	2.2	9.6	8.5	9.3	7.2	32.4	74.9	66.7	97.8	49.1	47.8	47.3	30.9	37.2	63.7	43.6	39.7	123.6	122.4	69.5	424.8	511.0	523.2
Hadocck	21.3	18.1		24.4	53.0	120.9	952.7	349.7	250.5	204.9	550	193.8	219	170.7	120.1	75.6	22.0	21.4	18.0	10.2	48.4	148.2	573.7	720.7	571.6
Skates								0.9			13.2	7.9	1.3		5.1		1.9	0.4	6.6	7.8	12.8	2.3	5.9	6.9	22.1
Pollock	3.1			0.2	0.3		1.8		0.2	1.2	9.2	5.2	11.1	6.6	3	10.7	2.9	0.1					0.8	1.3	0.3
Shrimp											0.6			24.1			219.3	264.0	826.7	168.4	67.9				
Monkfish																									
Unidentified																					0.1	1.9	1.8	1.7	2.2
TOTAL	1259.5	1977.6	508.6	1585.1	2225.3	2095	2895.0	2549.4	1763.7	1944.5	2384.5	2047.1	2084.7	2171.2	1647.3	1772.7	1875.8	1842.7	2612.5	2369.4	2973.6	2688.3	3650.3	3861.0	3250.3
Fishing Days	93	76	15	65	40	85	133	130	106	150	280	213	145	202	98	125	188	235	484	370	325	137	252	-	-

TABLE I - D: Portuguese nominal trawl catches (ton) in Div. I and II, not including International waters of Div. IIa.

SPECIES / YEAR	2017	2016	2015	2014	2013	2012	2011	2010	2009	2008	2007	2006	2005	2004	2003	2002	2001	2000	1999	1998	1997	1996	1995	1994	1993
Cod	3978.1	4470.6	1697.5	3359.1	4647.0	3455.4	3576.2	4654.4	4707.1	4121.9	3759.6	4207.2	4315.9	4385	3628.1	3629.9	3624.0	3587.4	3885.3	5462.0	7528.3	6765.3	6195.2	5644.0	1788.4
Redfish	359.8	244.8	0.1	7.2	39.0	23.2	43.4	76.6	134.3	160.4	246.6	175.9	195.4	240	50.2	276.1	185.1	131.2	67.5	131.0	534.1	522.3	959.3	985.6	1040.0
American plaice	2.5	4.3	0.2	6.2	12.5	3.8	1.3	11.4	19.3	25.2	34.5	42.3	45.1	45.4	48.8	94.0	68.8	110.9	70.7	258.3	57.0	85.0	49.1	26.5	29.0
Greenland halibut	5.8	21.4	4.5	0.0	3.9	1.6	21.5	10.9	28.7	46.8	29.4	24	25.7	50.5	19.5	15.4	34.4	37.0	48.8	98.9	49.5	79.5	99.4	36.2	42.1
Atlantic halibut	2.5	2.0	1.0	1.1	0.4	1.0	1.5	3.6	7.7	10.0	16.3	14.6	5.2	1.1	1.1	0.3	0.6	0.8		0.3		0.3	0.3		
Anarhichas spp.	22.6	14.0	5.7	9.6	9.9	9.3	9.2	32.5	80.9	69.6	98.2	52.7	67.5	95.7	77.7	106.9	151.2	161.4	91.3	468.3	216.8	164.4	507.3	591.5	526.3
Hadocck	108.3	140.4	34.8	51.7	87.0	143.1	982.7	487.5	656.6	612.7	922.3	480	442.1	355.3	264.6	161.0	100.7	131.0	37.5	45.1	167.7	207.9	607.1	754.7	582.5
Skates								0.9		2.0	13.2	7.9	1.3	1.5	8.2		2.4	6.6	9.5	46.2	27.5	9.9	15.8	10.4	22.2
Pollock	88.6	53.0	9.7	11.9	17.3	7.3	42.8	93.3	209.2	348.1	406.2	339.1	354.5	104.8	146.5	121.6	75.2	45.8	17.4	47.3	12.0	23.8	4.9	2.0	0.9
Shrimp											0.6			24.1			219.3	264.0	826.7	168.4	67.9				
Monkfish							0.02	1.5	6.4	2.0															
Unidentified											0.5		0.1								0.2	2.3	5.3	8.1	5.1
TOTAL	4568.3	4950.5	1753.5	3446.9	4817.0	3644.6	4678.6	5372.6	5850.1	5398.8	5527.4	5343.7	5452.8	5303.4	4244.7	4405.2	4461.7	4476.1	5054.7	6725.8	8661.0	7860.8	8443.6	8058.9	4036.4
Fishing Days	192	197	96	121	114	145	209	262	380	421	558	546	443	486	277	294	455	634	811	1118	819	487	558	-	-

TABLE II: Portuguese trawl fishery cpue's and bycatch by month and division for 2018.

DIVISION	TARGET SPECIES	MONTH	DEPTH RANGE (m) MIN.	DEPTH RANGE (m) MAX.	CPUE (ton/hour)	MAIN BYCATCH SPECIES	MAIN BYCATCH %	TOTAL BYCATCH (%)
IIa (*)	RED	JUL	327	428	0.230	-	0.0	0.0
IIa (*)	RED	AUG	248	442	0.578	-	0.0	0.0

(*) - Banana Hole (International waters of division IIa)

TABLE III: Intensity of the trawl sampling during 2018, by species, division and month.

SPECIES	DIV.	MONTH	Nº OF SAMPLES	Nº FISH MEASURED	SAMPLING WEIGHT(Kg)	OTOLITHS Nº	OTOLITHS LENGTH RANGE (cm)
REDFISH (*S. mentella*)	IIa (*)	JUL	1	100	70	63	22-42
REDFISH (*S. mentella*)	IIa (*)	AUG	28	2804	1833	81	29-44

(*) - Banana Hole (International waters of division IIa)

TABLE IV: Length-weight relationship by species, stock and sex in 2018.

Species	Stock	Sex	a	b	n	r^2	Length interval (cm)
REB	IIa (*)	F	0.0132	2.9877	952	0.999	30-43
REB	IIa (*)	M	0.0177	2.9046	1951	0.993	29-44
REB	IIa (*)	T	0.0144	2.9621	2903	0.996	29-44

(*) - Banana Hole (International waters of division IIa)

TABLE V: REDFISH (*S. mentella*), International waters of DIV. IIa, 2018: length composition (0/000) of the trawl catches.

LENGTH GROUP	JUL	AUG	3rd Q. =YEAR	LENGTH GROUP
29		1.0	1.0	29
30		2.4	2.4	30
31		5.8	5.8	31
32	10.0	14.9	14.8	32
33	10.0	43.5	43.2	33
34	60.0	63.3	63.3	34
35	130.0	131.4	131.4	35
36	120.0	204.6	203.8	36
37	130.0	178.3	177.9	37
38	210.0	178.9	179.2	38
39	200.0	100.6	101.5	39
40	60.0	53.2	53.3	40
41	50.0	17.0	17.3	41
42	20.0	4.2	4.3	42
43		0.7	0.7	43
44		0.3	0.3	44
TOTAL	1000	1000	1000	
No. SAMPLES	1	28	29	
SAMPLING WEIGHT(kg)	70	1833	1903	
No. F.MEASURED	100	2804	2904	
MEAN LENGTH(cm)	37.9	37.2	37.2	
MEAN WEIGHT (g)	692	651	652	
DEPTH RANGE (m)	327/428	248/442	248/442	

Fig. 1- Annual length composition of redfish (*S. mentella*) International waters of Division IIa trawl fishery in 2018.

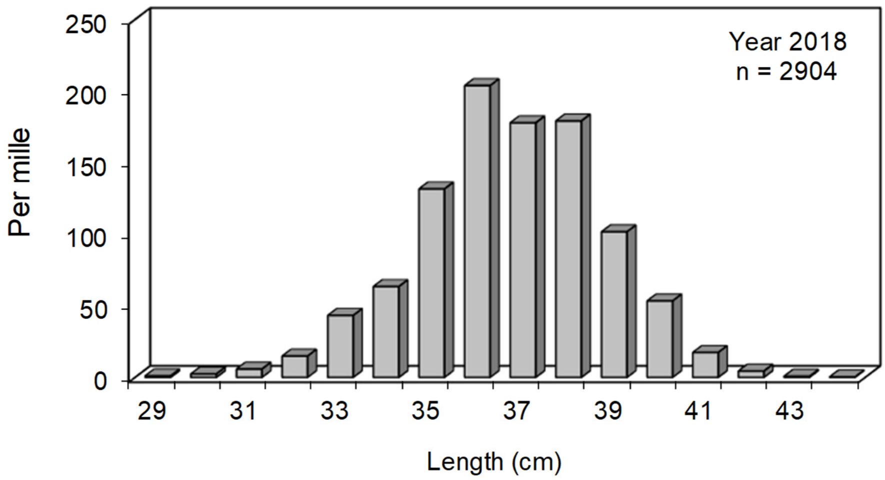


TABLE I - A: Portuguese provisional nominal trawl catches (ton) in Norway (Div.I and IIa), Svalbard (Div.I and IIb) and International waters (Div. IIa) regions, 2018.

SPECIES \ AREA	I and IIa Norway	I and IIb Svalbard	IIa International waters (Banana hole)	SUBTOTAL Norway + Svalbard	TOTAL 2018
Cod	2549.9	122.0		2671.9	2671.9
Redfish	391.5	0.0	356.4	391.5	747.9
American plaice	0.1	0.1		0.1	0.1
Greenland halibut	5.3	0.1		5.5	5.5
Atlantic halibut	5.5	0.1		5.6	5.6
Anarhichas spp.	8.1	1.0		9.1	9.1
Hadocck	70.3	10.7		81.1	81.1
Skates					
Pollock	50.7			50.7	50.7
Shrimp					
Monkfish					
Unidentified	0.7			0.7	0.7
TOTAL	3082.2	134.1	356.4	3216.2	3572.6
Fishing Days	130	5	31	135	166

TABLE I - B: Portuguese nominal trawl catches (ton) in Norway ZEE (Div. I and IIa) not including International waters of Div. IIa.

SPECIES / YEAR	2017	2016	2015	2014	2013	2012	2011	2010	2009	2008	2007	2006	2005	2004	2003	2002	2001	2000	1999	1998	1997	1996	1995	1994	1993
Cod	2770.1	2522.0	1192.0	1819.9	2530.0	1515.0	1705.1	2559.7	3340.4	2567.2	2269.3	2558.2	2629.7	2670.5	2204	2205.1	2199.7	2184.4	2230.4	3494.6	4906.0	4380.9	3817.1	3253.5	27.3
Redfish	359.3	244.8	0.1	1.6	8.0	4.4	4.6	27.8	92.5	112.7	89.7	92.5	126.9	91.3	23	142.1	110.2	114.3	58.9	124.2	470.6	479.5	740.3	777.4	724.7
American plaice			0.2					0.7	10.6	2.5	0.4	3.6	8	12.5	21.8	14.4	23.9	36.5	28.4	192.0	29.4	70.2	27.2	16.0	
Greenland halibut	1.2	18.6	3.7		0.86	0.05	0.2	0.1	9.2	1.3	1.8	7.6	13.4	24.2	9.6	4.6	12.5	18.1	33.1	80.0	40.9	55.1	75.2	26.1	16.5
Atlantic halibut	2.3	2.0	1.0	1.1	0.4	0.7	0.6	2.4	6.3	8.9	11.5	11	3.8	1	1.1	0.3	0.6	0.8		0.3		0.3	0.2		
Anarhichas spp.	3.2	10.2	3.4		1.4		2.0	0.03	6.0	2.9	0.4	3.6	19.7	48.4	46.8	69.7	87.5	117.8	51.6	344.7	94.4	94.9	82.5	80.5	3.2
Hadocck	87.1	122.3	34.8	27.4	34.0	22.2	30.0	137.8	406.1	407.8	372.3	286.2	223.1	184.6	144.5	85.4	78.7	109.6	19.5	34.9	119.3	59.8	33.4	34.0	10.8
Skates										2.0				1.5	3.1		0.5	6.2	2.9	38.4	14.7	7.6	9.8	3.5	0.1
Pollock	85.5	53.0	9.7	11.7	17.0	7.3	41.0	93.3	209.0	346.9	397	333.9	343.4	98.2	143.5	110.9	72.3	45.7	17.4	47.3	12.0	23.8	4.2	0.6	0.6
Shrimp																									
Monkfish							0.02	1.5	6.4	2.0															
Unidentified											0.5		0.1								0.1	0.5	3.5	6.3	2.9
TOTAL	3308.8	2972.9	1244.9	1861.7	2591.7	1549.6	1783.5	2823.2	4086.4	3454.2	3142.9	3296.6	3368.1	3132.2	2597.4	2632.5	2585.9	2633.4	2442.2	4356.4	5687.4	5172.5	4793.3	4197.9	786.1
Fishing Days	99	121	81	56	74	60	76	132	274	271	278	333	298	284	179	169	267	399	327	748	494	350	306	-	-

TABLE I - C: Portuguese nominal trawl catches (ton) in Svalbard (Div. I and IIb).

SPECIES / YEAR	2017	2016	2015	2014	2013	2012	2011	2010	2009	2008	2007	2006	2005	2004	2003	2002	2001	2000	1999	1998	1997	1996	1995	1994	1993
Cod	1208.0	1948.6	505.5	1539.2	2117.0	1940.4	1871.1	2094.7	1366.7	1554.7	1490.3	1649	1686.2	1714.5	1424.1	1424.8	1424.3	1403.0	1654.9	1967.4	2622.3	2384.4	2378.1	2390.4	1761.1
Redfish	0.450	0.004		5.5	31.0	18.8	38.8	48.8	41.8	47.8	156.9	83.4	68.5	148.7	27.2	134.0	74.9	16.9	8.6	6.8	63.5	42.8	219.0	208.2	315.3
American plaice	2.5	4.3	0.0	6.2	12.5	3.8	1.3	10.7	8.7	22.7	34.1	38.7	37.1	32.9	27	79.6	44.9	74.4	42.3	66.3	27.6	14.8	21.9	10.5	29.0
Greenland halibut	4.6	2.8	0.8	0.0	3.0	1.6	21.4	10.8	19.5	45.4	27.6	16.4	12.3	26.3	9.9	10.8	21.9	18.9	15.7	18.9	8.6	24.4	24.1	10.1	25.6
Atlantic halibut	0.1					0.3	0.8	1.3	1.5	1.1	4.8	3.6	1.4	0.1									0.1		
Anarhichas spp.	19.4	3.8	2.2	9.6	8.5	9.3	7.2	32.4	74.9	66.7	97.8	49.1	47.8	47.3	30.9	37.2	63.7	43.6	39.7	123.6	122.4	69.5	424.8	511.0	523.2
Hadocck	21.3	18.1		24.4	53.0	120.9	952.7	349.7	250.5	204.9	550	193.8	219	170.7	120.1	75.6	22.0	21.4	18.0	10.2	48.4	148.2	573.7	720.7	571.6
Skates								0.9			13.2	7.9	1.3		5.1		1.9	0.4	6.6	7.8	12.8	2.3	5.9	6.9	22.1
Pollock	3.1			0.2	0.3		1.8		0.2	1.2	9.2	5.2	11.1	6.6	3	10.7	2.9	0.1					0.8	1.3	0.3
Shrimp											0.6			24.1			219.3	264.0	826.7	168.4	67.9				
Monkfish																									
Unidentified																					0.1	1.9	1.8	1.7	2.2
TOTAL	1259.5	1977.6	508.6	1585.1	2225.3	2095	2895.0	2549.4	1763.7	1944.5	2384.5	2047.1	2084.7	2171.2	1647.3	1772.7	1875.8	1842.7	2612.5	2369.4	2973.6	2688.3	3650.3	3861.0	3250.3
Fishing Days	93	76	15	65	40	85	133	130	106	150	280	213	145	202	98	125	188	235	484	370	325	137	252	-	-

TABLE I - D: Portuguese nominal trawl catches (ton) in Div. I and II, not including International waters of Div. IIa.

SPECIES / YEAR	2017	2016	2015	2014	2013	2012	2011	2010	2009	2008	2007	2006	2005	2004	2003	2002	2001	2000	1999	1998	1997	1996	1995	1994	1993
Cod	3978.1	4470.6	1697.5	3359.1	4647.0	3455.4	3576.2	4654.4	4707.1	4121.9	3759.6	4207.2	4315.9	4385	3628.1	3629.9	3624.0	3587.4	3885.3	5462.0	7528.3	6765.3	6195.2	5644.0	1788.4
Redfish	359.8	244.8	0.1	7.2	39.0	23.2	43.4	76.6	134.3	160.4	246.6	175.9	195.4	240	50.2	276.1	185.1	131.2	67.5	131.0	534.1	522.3	959.3	985.6	1040.0
American plaice	2.5	4.3	0.2	6.2	12.5	3.8	1.3	11.4	19.3	25.2	34.5	42.3	45.1	45.4	48.8	94.0	68.8	110.9	70.7	258.3	57.0	85.0	49.1	26.5	29.0
Greenland halibut	5.8	21.4	4.5	0.0	3.9	1.6	21.5	10.9	28.7	46.8	29.4	24	25.7	50.5	19.5	15.4	34.4	37.0	48.8	98.9	49.5	79.5	99.4	36.2	42.1
Atlantic halibut	2.5	2.0	1.0	1.1	0.4	1.0	1.5	3.6	7.7	10.0	16.3	14.6	5.2	1.1	1.1	0.3	0.6	0.8		0.3		0.3	0.3		
Anarhichas spp.	22.6	14.0	5.7	9.6	9.9	9.3	9.2	32.5	80.9	69.6	98.2	52.7	67.5	95.7	77.7	106.9	151.2	161.4	91.3	468.3	216.8	164.4	507.3	591.5	526.3
Hadocck	108.3	140.4	34.8	51.7	87.0	143.1	982.7	487.5	656.6	612.7	922.3	480	442.1	355.3	264.6	161.0	100.7	131.0	37.5	45.1	167.7	207.9	607.1	754.7	582.5
Skates								0.9		2.0	13.2	7.9	1.3	1.5	8.2		2.4	6.6	9.5	46.2	27.5	9.9	15.8	10.4	22.2
Pollock	88.6	53.0	9.7	11.9	17.3	7.3	42.8	93.3	209.2	348.1	406.2	339.1	354.5	104.8	146.5	121.6	75.2	45.8	17.4	47.3	12.0	23.8	4.9	2.0	0.9
Shrimp											0.6			24.1			219.3	264.0	826.7	168.4	67.9				
Monkfish							0.02	1.5	6.4	2.0															
Unidentified											0.5		0.1								0.2	2.3	5.3	8.1	5.1
TOTAL	4568.3	4950.5	1753.5	3446.9	4817.0	3644.6	4678.6	5372.6	5850.1	5398.8	5527.4	5343.7	5452.8	5303.4	4244.7	4405.2	4461.7	4476.1	5054.7	6725.8	8661.0	7860.8	8443.6	8058.9	4036.4
Fishing Days	192	197	96	121	114	145	209	262	380	421	558	546	443	486	277	294	455	634	811	1118	819	487	558	-	-

TABLE II: Portuguese trawl fishery cpue's and bycatch by month and division for 2018.

DIVISION	TARGET SPECIES	MONTH	DEPTH RANGE (m) MIN.	DEPTH RANGE (m) MAX.	CPUE (ton/hour)	MAIN BYCATCH SPECIES	MAIN BYCATCH %	TOTAL BYCATCH (%)
IIa (*)	RED	JUL	327	428	0.230	-	0.0	0.0
IIa (*)	RED	AUG	248	442	0.578	-	0.0	0.0

(*) - Banana Hole (International waters of division IIa)

TABLE III: Intensity of the trawl sampling during 2018, by species, division and month.

SPECIES	DIV.	MONTH	Nº OF SAMPLES	Nº FISH MEASURED	SAMPLING WEIGHT(Kg)	OTOLITHS Nº	OTOLITHS LENGTH RANGE (cm)
REDFISH (*S. mentella*)	IIa (*)	JUL	1	100	70	63	22-42
REDFISH (*S. mentella*)	IIa (*)	AUG	28	2804	1833	81	29-44

(*) - Banana Hole (International waters of division IIa)

TABLE IV: Length-weight relationship by species, stock and sex in 2018.

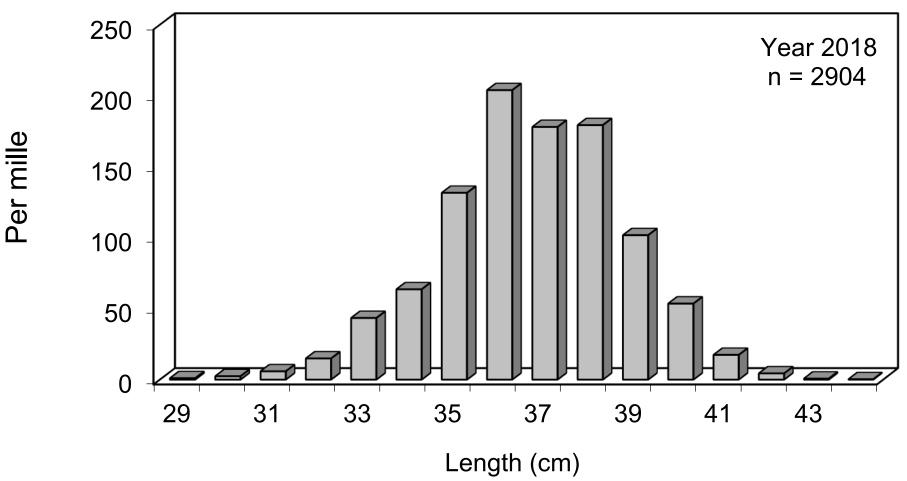
Species	Stock	Sex	a	b	n	r^2	Length interval (cm)
REB	IIa (*)	F	0.0132	2.9877	952	0.999	30-43
REB	IIa (*)	M	0.0177	2.9046	1951	0.993	29-44
REB	IIa (*)	T	0.0144	2.9621	2903	0.996	29-44

(*) - Banana Hole (International waters of division IIa)

TABLE V: REDFISH (*S. mentella*), International waters of DIV. IIa, 2018:
length composition (0/000) of the trawl catches.

LENGTH GROUP	JUL	AUG	3rd Q. =YEAR	LENGTH GROUP
29		1.0	1.0	29
30		2.4	2.4	30
31		5.8	5.8	31
32	10.0	14.9	14.8	32
33	10.0	43.5	43.2	33
34	60.0	63.3	63.3	34
35	130.0	131.4	131.4	35
36	120.0	204.6	203.8	36
37	130.0	178.3	177.9	37
38	210.0	178.9	179.2	38
39	200.0	100.6	101.5	39
40	60.0	53.2	53.3	40
41	50.0	17.0	17.3	41
42	20.0	4.2	4.3	42
43		0.7	0.7	43
44		0.3	0.3	44
TOTAL	1000	1000	1000	
No. SAMPLES	1	28	29	
SAMPLING WEIGHT(kg)	70	1833	1903	
No. F.MEASURED	100	2804	2904	
MEAN LENGTH(cm)	37.9	37.2	37.2	
MEAN WEIGHT (g)	692	651	652	
DEPTH RANGE (m)	327/428	248/442	248/442	

Fig. 1- Annual length composition of redfish (*S. mentella*)
International waters of Division IIa trawl fishery in 2018.



Annex 4: Audit reports

Audit of Northeast Arctic saithe (AFWG 2019)

Date: 03 May 2019
Auditor: Matthias Bernreuther

General

The Northeast Arctic saithe assessment and draft advice have been approved by the Working Group.

For single stock summary sheet advice:

1. **Assessment type**: update
2. **Assessment:** analytical
3. **Forecast**: presented
4. **Assessment model**: SAM – tuning by one acoustic survey (split in two time-series)
5. **Data issues:** The biological sampling from the fishery may have become critically low after the termination of the original Norwegian port-sampling program in 2009. In 2015 this was in particular the case for samples from trawl in quarter two and three in ICES subarea 1 and age samples from purse seine fishery south of Lofoten and in quarter two in ICES Subarea 1. As in 2016 and 2017, the biological sampling has improved in 2018, but the relatively low level of sampling may still affect the precision of the catch, weight and maturity at age data. Lack of reliable recruitment estimates is still a major problem.
6. **Consistency:** Last year´s assessment was accepted. The assessment, recruitment and forecast models have been applied as specified in the stock annex.
7. **Stock status**: The SSB has been above B_{pa} since 1996, declined considerably from 2007 to 2011, then increased again and is presently (2018/2019) estimated to be well above B_{pa}. The fishing mortality was below F_{pa} from 1997 to 2009, started to increase in 2005 and was above F_{pa} in 2010 and 2011, but is presently estimated to be most likely below F_{pa}. The recruitment has since 2005 been at about the long-term geometric mean level.
8. **Management Plan**: Agreed 2011 (first time in 2007): $F_{MP} = 0.32$ and SSB above $B_{pa} = 220\,000$ t. The TAC is based on an average TAC for the coming three years based on F_{MP}. There is a 15% constrain on TAC change between years. The plan was evaluated by ICES and was found in agreement with the precautionary approach.

General comments

This was a well-documented, well-ordered and considered section. It was easy to follow and interpret. All datasets described in the stock annex are available.

Technical comments

No technical comments.

Conclusions

The assessment has been performed correctly and gives a valid basis for advice. However, the low level of biological sampling is, despite an improvement in the last year, still a source of uncertainty in the assessment.

Audit of Greenland halibut (*Reinhardtius hippoglossoides*) in subareas 1 and 2 (Northeast Arctic)

Date: 03/05/2019
Auditor: Alfonso Pérez Rodríguez

General

The stock is assessed by a GADGET length-based model since 2015. There is no agreement on age-reading methodology between Norway and Russia and the model is tuned using only length data. This gives uncertainty on the absolute levels of modelled biomass and F. The peaks of recruitment identified by the model are corroborated by survey length distributions, but the weaker year classes may be poorly modelled. None of the surveys individually covers the complete stock distribution and there are discrepancies between the surveys, leading to high uncertainty and a marked retrospective pattern. The stock has biennial advice and the last advice was given in 2017 for 2018 and 2019. A new stock assessment is run in 2019 to provide advice for 2020 and 2021.

For single stock summary sheet advice:

1. **Assessment type**: update (benchmark in 2015)
2. **Assessment**: stock assessed by a GADGET length-based model since 2015
3. **Forecast**: not presented
4. **Assessment model**: In addition to GADGET, two production models (one of them SPICT) have been used to assessed the stock in the past, however production model was not updated for presentation at the current meeting.
5. **Data issues**: Data available and used as described in stock annex. There was a revision of the commercial fishing data, with minor discrepancies between the data sets after 2005. However, in relation to the survey data, there are problems with sex-split in the EcoJuv and EcoSouth indices, especially in 2016–2018. This has produced an increase in the estimated survey around the 10%.
6. **Consistency**: This year's assessment has been conducted in a manner consistent with last year (benchmark) and stock annex.
7. **Stock status**: This stock is assessed in relation to precautionary reference points. On this regard $B>B_{lim}$, however, it is warned that the lack of reliable age estimations involves that the current assessment has important uncertainties in relation to the actual absolute level of biomass and F level. It is concluded that all of the exploratory work indicates that the overall trends are robust, but that care should be taken in interpreting the absolute abundance estimates, and hence absolute estimates of harvest rate.
8. **Management Plan**: No

General comments

The assessment is well-documented and structured in the report. The update assessment gives a valid basis for advice. The current GADGET assessment model provides appropriate evaluation, however in order to make it more sounded from the quantitative side (absolute estimates of biomass and F levels), the current existing problem in relation to age reading needs to be solved.

Technical comments

The assessment is done according to decisions taken during benchmark in 2015 and according to the stock annex.

Conclusions

The assessment has been performed correctly

Audit of: had21.1-2 (Haddock in subareas 1 and 2)

Date: 9 May 2019
Auditor: Arved Staby

For single stock summary sheet advice:

1. **Assessment type**: update
2. **Assessment**: analytical
3. **Forecast**: presented
4. **Assessment model**: SAM; tuned by 3 research surveys (4 fleets). Data from the 2018 Joint Barent Sea Ecosystem survey and the Russian autumn survey not included in the tuning series. Haddock consumed by cod included in natural mortality, haddock consumption is estimated based on the final SAM assessment of cod.
5. **Data issues**: Missing the Russian trawl and acoustic survey in 2016 and 2018. Missing Barent Sea Ecosystem survey data from 2018 (due to insufficient coverage). It seems that the REC3 input table is missing the estimate from the NO_RU swept-area for age 3 in 2019.
6. **Consistency**: The SSB is estimated to have been halved compared to its peak in 2012. The retrospective runs show rather large discrepancies.
7. **Stock status**: SSB has been much larger then B_{lim} for more than 10 years.
8. **Management Plan**: Various MPs have been in use since 2004. The current HCR for haddock is as follows (see details in Protocol of the 46th Session of the Joint Russian–Norwegian Fisheries Commission, 14 October 2011): TAC for the next year will be set at level corresponding to F_{MSY}. The TAC should not be changed by more than ±25% compared with the previous year TAC. If the spawning stock falls below B_{pa}, the procedure for establishing TAC should be based on a fishing mortality that is linearly reduced from F_{MSY} at B_{pa} to F = 0 at SSB equal to zero. At SSB-levels below B_{pa} in any of the operational years (current year and a year ahead) there should be no limitations on the year-to-year variations in TAC. At the 46th Session of the Joint Russian–Norwegian Fisheries Commission in 2016 it was decided to keep the existing HCR for haddock in next five years. TAC in 2020 based on 25% constraint.

General comments
The survey data and catch data are correctly included and the analysis is correctly done.

Technical comments
Included in the report as comments.

Conclusions
The assessment is recommended as basis for the 2019 TAC advice.

Audit of Cod (*Gadus morhua*) in subareas 1 and 2 (Northeast Arctic)

Date: 20 May 2019

Auditor: Ross Tallman, Fisheries and Oceans Canada

General

The Northeast Arctic cod assessment and draft advice have been approved by the Working Group.

For single stock summary sheet advice:

1. **Assessment type:** update
2. **Assessment**: analytical
3. **Forecast**: presented
4. **Assessment model:** SAM
   Four surveys were used for the assessment: (Barents Sea Joint bottom trawl (Feb-Mar, years 1981-2019), Barents Sea+Lofoten Joint acoustic survey (Feb-Mar, years 1985-2019), Russian bottom trawl survey (Oct-Dec, years 1982-2015,2017), Ecosystem survey (Aug-Sep, years 2004-2017)

a) SAM Parameter settings:

i. # Min Age (should not be modified unless data are modified accordingly)

3

ii. # Max Age (should not be modified unless data are modified accordingly)

15

iii. # Max Age considered a plus group (0=No, 1=Yes)

1

iv. # Coupling of correlation in observations

(NA, NA, NA, NA, NA, NA, NA, NA, NA, NA, NA, NA),

(-1, 0, 1, 2, 3, 4, 4, 4, 4, -1, -1, -1),

(-1, 5, 6, 7, 8, 9, 10, 10, 10, -1, -1, -1),

(11, 12, 13, 14, 14, 14, 14, 14, 14, -1, -1, -1),

(15, 16, 17, 18, 19, 20, 20, 20, 20, -1, -1, -1)

v. # Coupling of OBSERVATION VARIANCES

(0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0),

(-1, 1, 1, 1, 1, 1, 1, 1, 1, 1, -1, -1, -1),

(-1, 2, 2, 2, 2, 2, 2, 2, 2, 2, -1, -1, -1),

(3, 3, 3, 3, 3, 3, 3, 3, 3, 3, -1, -1, -1),

(4, 4, 4, 4, 4, 4, 4, 4, 4, 4, -1, -1, -1)

vi. # Stock recruitment model code (0=RW, 1=Ricker, 2=BH, ... more in time)

0

vii. # Years in which catch data are to be scaled by an estimated parameter

0

viii. # Define Fbar range

5 10

A comparison with XSA was done.

Model options chosen for XSA
(used as an additional model for checking of results):
Tapered time weighting applied, power = 3 over 20 years
Catchability independent of stock size for ages > 12
Catchability independent of age for ages > 12
Survivor estimates shrunk towards the mean F of the final 5 years or the 3 oldest ages
S.E. of the mean to which the estimate are shrunk = 1.5
Shrinkage to the population mean (p-shrinkage) not applied
Minimum standard error for population estimates derived from each fleet = 0.3
Prior weighting not applied

5. **Data issues:** Historically the plus group was age 13+ but with the current presence of abundant year classes close to the age 13 it was decided change to the plus group to age 15+. For age 12 and older some smoothing of data is needed but the procedure for that has not been settled yet.

Biological sampling from the Norwegian fishery and from the Russian trawl fishery has been low. In 2016 the sampling was low for Norwegian trawl catches in coastal areas in ICES area 2.a, thus samples for trawl here were merged with other similar gears when calculating age compositions. Also the split between NEA cod and coastal cod may have been affected by the sampling coverage, and possibly the amount of coastal cod catch is overestimated.

There is a concern that catch records have some contradictions in reporting depending on the source. There are discrepancies in catch by area depending on agency reported to (e.g. amounts from same area different depending on whether reporting is to ICES or Russian authorities). There is likely a problem with ICES inter-catch.

The 2014 Ecosystem Survey coverage was affected by ice in an area where there had been significant biomass recorded in previous years. It was decided to discard the results from the 2014 Ecosystem survey.

Updated mean ratios between the combined and Norwegian data on weight-at-age and maturity-at-age in Northeast Arctic cod

The Russian autumn trawl-acoustic survey (TAS) in the Barents Sea was not conducted in 2018. Russian cod abundance indices, weight at age and maturity-at-age data used for stock assessment were not available for 2018/2019.

Combined data on weight-at-age and maturity-at-age for 2018/2019 were adjusted using the same method as described in the WD 10 presented at the AFWG meeting in 2017. The mean 2019 ratios calculated between combined and Norwegian data differed slightly from the mean 2017 ratios (Table 1 -2).

6. **Consistency**: Last year's assessment was accepted.

   The assessment, recruitment and forecast models have been applied as specified in the stock annex.

7. **Stock status**: The SSB (currently, 1 233 772 t) has been above B_{pa} (460 000 t) since 2003 and F below or around F_{pa} since 2003. Recruitment is uncertain but reasonably stable. Total stock biomass in 2019 is estimated to 2 440 330 t which is somewhat above the long-term mean and well below the highest level observed (4 360 000 t in 2013).
8. **Man. Plan.**: Biomass reference points: The values adopted by ACFM in 2003 are B_{lim} = 220 000 t, B_{pa} = 460 000 t. (ICES CM 2003/ACFM:11). Fishing mortality reference points: The values adopted by ACFM in 2003 are F_{lim} = 0.74 and F_{pa} = 0.40. (ICES CM 2003/ACFM:11). Harvest control rule: At the 31st session of The Joint Norwegian-Russian Fishery Commission (JRNFC) in autumn 2002, the Parties agreed on a new harvest control rule. This rule was applied for the first time when setting quotas for 2004. The rule was somewhat amended at the 33rd session of The Joint Norwegian-Russian Fishery Commission in autumn 2004. The amended rule was evaluated by ICES in 2005 and found to be precautionary.

General comments

This was a well-documented, well ordered and considered section. It was easy to follow and interpret.

Technical comments

No technical comments.

Conclusions

The assessment has been performed correctly and gives a valid basis for advice.