Stock Annex: Sandeel (*Ammodytes marinus*) in the North Sea area 6 (SA6)

Stock-specific documentation of standard assessment procedures used by ICES.

Stock: Sandeel (*Ammodytes* spp.) in subdivisions 20-22, Sandeel Area 6 (Kattegat)

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Last updated by: WKSand

A. General

A.1. Stock definition

Stock identity

The area boundaries developed for WKSAN 2010 were based on the Christensen *et al.* (2008) bio-physical model of larval transport. During the 2016 benchmark process an alternative hydrodynamic model; HBM-ERGOM (Christensen et al., 2008) was used in the bio-physical model to re-assess the divisions.. This new model was used to consider the 2010 divisions as well as alternative area-divisions decided upon during the WKSand data preparation workshop held in Copenhagen in June 2016 and a proposal made with the industry during the benchmark in November 2016. Model output in 2010 as well as 2016 did not include the Kattegat, and this approach is therefore not relevant for SA6.

Some limited sandeel fishing activity is noted near the border to SA2; however there was no evidence that suggested that a new area definition should be applied (Figure A.1.1). Further research into the validity the stock integrity would require information on drift and migration of sandeel between neighbouring areas. Otolith microchemistry can provide a useful natural tag for studying dispersal and connectivity in regions where significant spatial differences can be detected Gibb *et al.* (2017). Such studies can corroborate biophysical model evidence for connectivity between areas (Christensen *et al.*, 2008). With the lack of new information on stock structure for sandeel in the Kattegat the WKSAND decided to retain the boarders of SA6 (Figure A.1.3.1), however in the end any area division that does not support a robust stock assessment model is irrelevant.

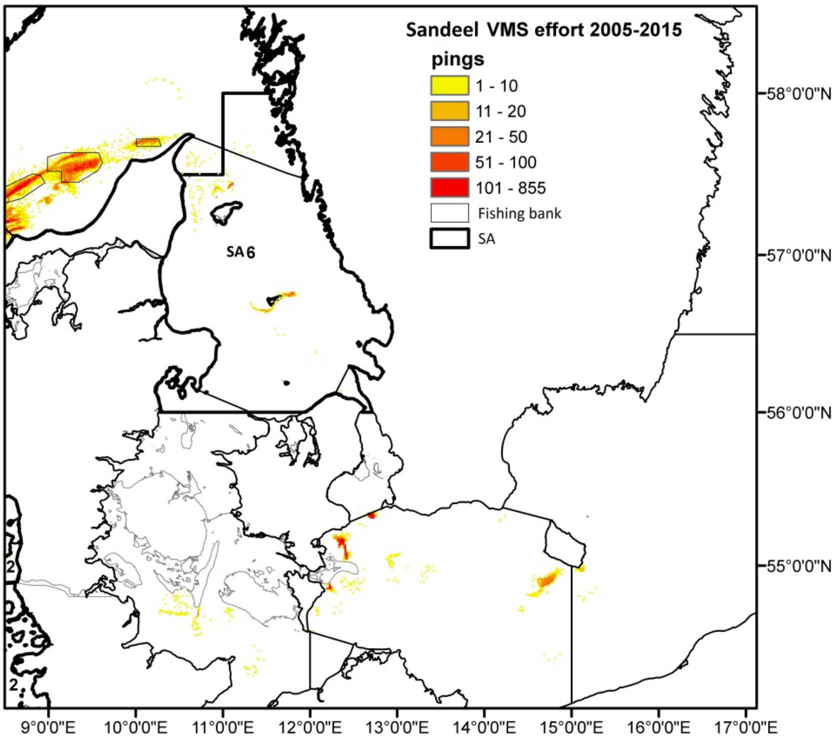


Figure A.1.1. SA6 area-boundaries following ICES rectangles closest to the Subdivision 21 boarders (the Kattegat) as decided upon during the WKSAND data preparation workshop held in Copenhagen in June 2016. A layer with VMS density distribution of sandeel catching vessels (2005-2016) is added to illustrate the main sources of catch data.

A.1.1 Comparison of stock trends

High consistency in stock trends in terms of numbers at age among the sandeel assessment regions would not support the need for separate assessment areas. However in contrast to neighbouring areas no indices of stock trends exist for SA6.

A.1.2 Demographic comparisons among stock assessment areas

As stocks are expected to reflect groups with different growth and mortality parameters we would expect that the proposed sandeel stocks should differ with respect to age and size composition. Since WKSAN 2010, further studies have examined the geographical variation in size and age composition. Rindorf *et al.* (2016) confirmed the regional variation in size at age suggested by earlier studies (Bergstad *et al.*, 2001; Boulcott *et al.*, 2007). They also found a 4 fold variation in weight at age across the North Sea with size at age being higher on the warmer, deeper central and north eastern fishing grounds and lowest in SA4.

A.1.3 Final stock definition based on WKSAND 2016

With off-set in the above research the WKSAND decided to re-draw the sandeel areas of the North Sea (Figure A.1.3.1). There were no changes to the SA6 borders.

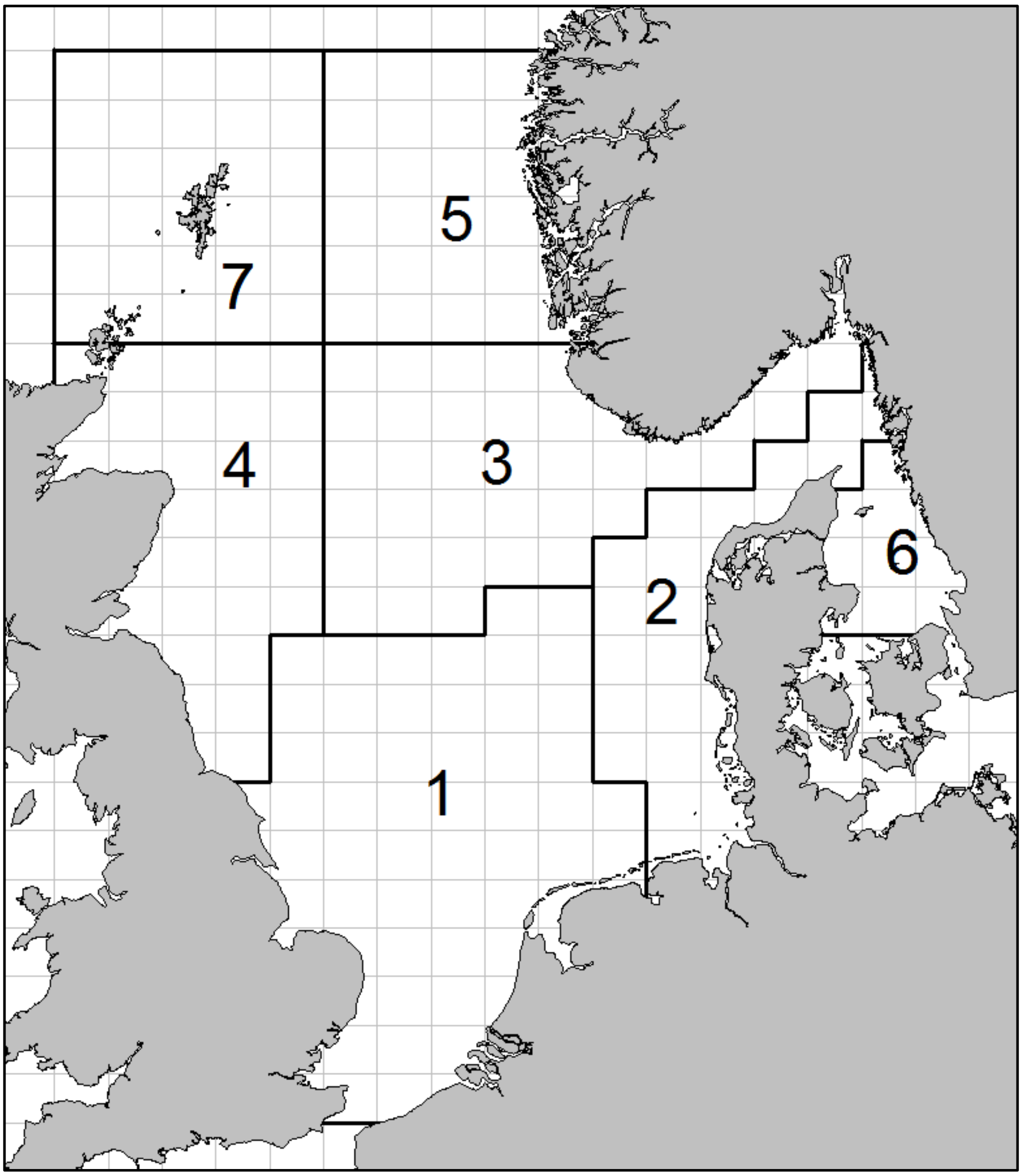


Figure A.1.3.1. Sandeel areas established at WKSand 2016.

A.2 Fishery

Most of the sandeel catch consists of the lesser sandeel *Ammodytes marinus*, although small quantities of other *Ammodytoidei* spp. are caught as well. There is little bycatch of protected species (ICES WGNSSK 2004).

General description

Denmark, Norway, Sweden, UK, and Germany participate in the sandeel fishery, where Denmark is the main contributor to the sandeel landings. Up to 2002 Denmark in average contributed 73% of the total landings and after 2002 73%.

The fishery is highly seasonal. The geographical distribution of the sandeel fishery varies seasonally and annually, taking place mostly in the spring and summer. In the third quarter of the year the distribution of catches generally changes from a dominance of the west Dogger Bank area back to the more easterly fishing grounds.

The sandeel fishery developed during the 1970s, and landings peaked in 1999 with 1.2 million tons. There was a significant shift in landings in 2003. The average landings of the period 1994 to 2002 was 880 000 tons whereas the average landings of the period 2003 to 2016 was 300 000 tons.

The size distribution of the Danish fleet has changed through time, with a clear tendency towards fewer and larger vessels (ICES, 2007). From 2000 there was a decline in the sandeel fishery and many Danish fishing vessels were scrapped and the quotas sold (Figure A.2.1). In 2004 an introduced ITQ led to a concentration of the fishery quotas and building of larger vessels. The investment and thereby the improvement of the vessels lead to building of large trawlers, at sizes which made it possible to use even bigger trawls and codends (Figure A.2.2). During the last ten years, the number of Danish vessels participating in the North Sea sandeel fishery has been stable with around 100 active vessels.

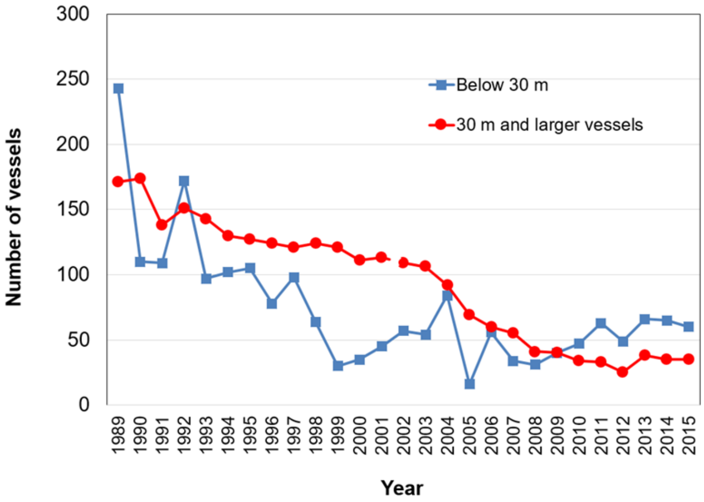


Figure A.2.1. Number of Danish vessels landing sandeel 1989-2015. (Data: Danish Agrifish Agency 2016.)

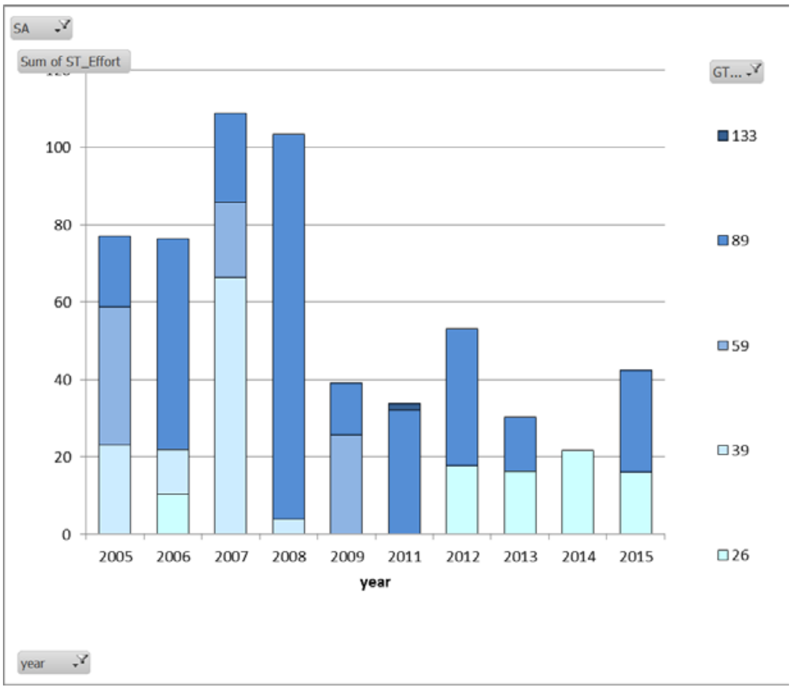


Figure A.2.2. Bar plot of annual sum of standardised VMS-effort (Sum of ST_Effort) in SA6 by tonnage group (GT).

The sandeel fleet in the Kattegat has not followed this trend and is instead composed of relatively small vessels fishing on a quota designated for the coastal fishery (Figure A.2.2).

Fishery management regulations

Technical measures for the sandeel fishery include a minimum percentage of the target species at 95% for meshes <16 mm, or a minimum of 90% target species and maximum 5% of the mixture of cod, haddock, and saithe for 16 to 31 mm meshes.

The fishery is regulated by a TAC by area (since 2011). Since 2005, Danish vessels have not been allowed to fish sandeel before 31 March.

A.3 Ecosystem aspects

Sandeel are small, short-lived, lipid-rich, shoaling fish. They represent high quality food for many predatory fish, seabirds and marine mammals (Greenstreet *et al.*, 1997, 1998; Brown *et al.*, 2001; Stafford *et al.*, 2006; Macleod *et al.*, 2007; Daunt *et al.*, 2008). The sensitivity of the best known species is reviewed by Engelhard *et al.* (2014), who lists fish, seabird and marine mammal predators of sandeel (see section 3.2.2). Sandeel overwinter buried in sandy bottom habitats. Commercial catches show a steep decrease in catches between August and April indicating that the overwintering period for adult sandeel on average lasts for 8 months (Winslade 1974; Wright *et al.*, 2000; Høines and Bergstad 2001) interrupted only by spawning in December/January (Macer 1966; Boulcott and Wright 2008). During the period when sandeel are buried in the sand, they are inaccessible to many predators such as surface-feeding seabirds, though they continue to be eaten by some predatory fish, seals, and diving seabirds which apparently can dig them out of the sand (Hammond *et al.*, 1994).

Bottom-up effects on sandeel

There is strong evidence that sandeel stocks are affected by bottom-up processes involving climate and changing plankton stocks. A study of early larval survival suggested that the match between hatching and the onset of zooplankton production may be an important contributory factor to year-class variability in this species (Wright and Bailey, 1996). Frederiksen *et al.* (2005) used Continuous Plankton Recorder (CPR) data to develop an index of sandeel larval abundance for the Firth of Forth area. The sandeel larval index was strongly positively related to the abundance of phyto- and zooplankton, suggesting strong bottom-up control of sandeel larval survival (Frederiksen *et al.*, 2005).

Top-down effects on sandeel

Sandeel are important prey to a long list of predators. The sensitivity of the best known species is reviewed by Engelhard *et al.* (2014), who lists fish, seabird and marine mammal predators of sandeel (Extracts presented in Table A.3.1.1). Combining this with information of spatial distribution of the different species and the quality (size and condition) of the sandeel available gives an indication of where the biomass of sandeel is most likely to be related to predator performance.

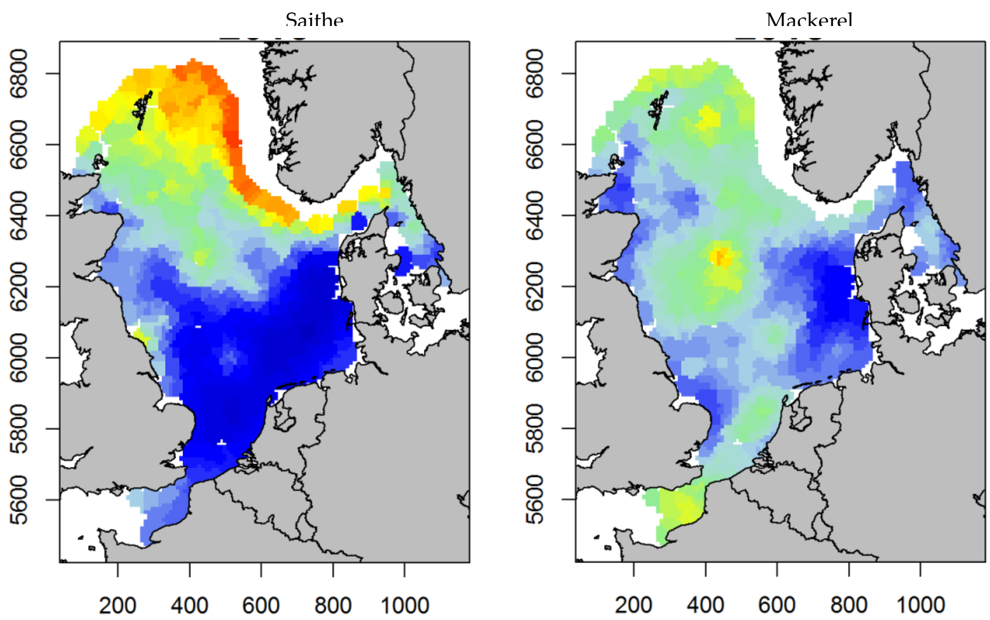
Table A.3.1.1. Documented evidence on dependencies of North Sea top predators on sandeel. Table shows, for each predator species, the levels of mobility; proportion of diet made up by sandeel; and documented cases of effects of low sandeel abundance on top predators. Mobility describes the potential of the predator to relocate to different feeding areas in response to localised prey shortages: I, immobile year-round; IB, immobile during the breeding season only; M, mobile year-round. Diet proportions refer to the percentage composition by mass of a particular prey type, averaged over one year and over North Sea: note that local and seasonal percentages can be substantially higher or lower. Shading of species cells indicates high likelihood of effects of low forage fish availability, resulting from both a low potential to relocate and a high (>20%) proportion of forage fish in the diet. Shading of diet indicates >20% (light grey) or >50% (dark grey), and shading of reported effects indicates those on condition or growth (light grey) and on reproductive success (dark grey). From Engelhard *et al.* (2014); Literature sources: [1] Windsland *et al.* (2007); [2] Sharples *et al.* (2009); [3] Cunningham *et al.* (2004); [4] Reijnders *et al.* (2010); [5] ICES (2011); [6] Engelhard *et al.* (2014); [7] Santos *et al.* (2008); [8] MacLeod *et al.* (2007); [9] BWPi (2004); [10] Mendel *et al.* (2008); [11] Harris and Wanless (1991); [12] Stienen (2006); [13] Rindorf *et al.* (2000); [14] Furness (2007); [15] Wanless *et al.* (2005); [16] Mitchell *et al.* (2004); [17] Frederiksen *et al.* (2004); [18] Engelhard *et al.* (2013); [19] Rindorf *et al.* (2008); [20] Pomeroy *et al.* (1999); [21] Reilly *et al.* (2014).

Predator	Mobility	% Sandeel in diet	Reported effects of low forage fish abundance
Marine mammals			
Minke whale *Baleonoptera acutorostrata*	M	56%	No evidence reported for the North Sea
Grey seal *Halichoerus grypus*	IB	41%	No evidence reported, in peer reviewed literature though there is a reference in Engelhard *et al.* 2014 to an unpublished study.
Harbour seal *Phoca vitulina*	IB	37%	Later pupping dates [4], which in turn are associated with higher likelihood of breeding failure and lower pup weights [20]
Striped dolphin *Stenella coeruleoalba*	M	3%	No evidence reported
Harbour porpoise *Phocoena phocoena*	M	2%	Poor nutritional status of stranded animals reported to concur with low sandeel intake in 2002 and 2003 [8], but this does not appear to be linked to low recruitment of sandeel in the dredge survey in Firth of Forth [HAWG 2016].
Seabirds			
Sandwich tern *Sterna sandvicensis*	I	high	Highly vulnerable to changes in local food supply (especially clupeids): reproductive performance, breeding numbers and breeding distribution [12]
Arctic tern			Cury et al 2011, also papers by Monaghan's group; massive decline in breeding numbers in Shetland following collapse of sandeel stock in area 7
Shag *Phalacrocorax aristotelis*	I	high	Reproductive output probably limited by local sandeel availability at Isle of May [13] see also Cury et al 2011; massive decline in breeding numbers in Shetland following collapse of sandeel stock in area 7
Great skua *Catharacta skua*	IB	10-95%	Reproductive success influenced by local sandeel availability [14] also several papers by Votier et al, Cury et al 2011, Meek et al 2011
Arctic skua			Cury et al 2011, Phillips & Furness, Meek et al 2011; massive decline in breeding numbers in Shetland following collapse of sandeel stock in area 7
Puffin *Fratercula arctica*	IB	55%	No evidence reported for the North Sea; massive decline in breeding numbers in Shetland following collapse of sandeel stock in area 7
Guillemot *Uria aalge*	IB	42%	Provisioning of chicks influenced by local abundance and quality of sandeel and sprat [15] see also Cury et al 2011
Razorbill *Alca torda*	IB	37%	Reproductive output probably limited by local sandeel availability at Isle of May [16]
Kittiwake *Rissa tridactyla*	IB	28%	Reproductive performance strongly dependent on local sandeel availability [17] see also Cury et al 2011, Cook et al 2014; massive decline in breeding numbers in Shetland following collapse of sandeel stock in area 7
Gannet *Morus bassanus*	IB	18%	No evidence reported
Lesser black-backed gull *Larus fuscus*	M	low	No evidence reported

Northern fulmar *Fulmarus glacialis*	M	11%	Decline in breeding success with reduction in sandeel in fulmar diet, particulary around Shetland (Cury et al 2011)
Fish			
Saithe *Pollachius virens*	M	5%	No evidence reported
Horse-mackerel *Trachurus trachurus*	M	17%	No evidence reported
Whiting *Merlangius merlangus*	M	7% 85% on sandbanks [21]	Positive correlations between local sandeel abundance and condition [18]. However, [21] finds that whiting are not prey-limited in the Firth of Forth even in years of low sandeel abundance.
Starry ray *Amblyraja radiata*	M	18%	No evidence reported
Grey gurnard *Eutrigla gurnardus*	M	12%	Positive correlations between local sandeel abundance and condition [18]
Cod *Gadus morhua*	M	4%	Positive correlation between overlap with sandeel and growth in the North Sea [19]
Haddock *Melanogrammus aeglefinus*	M	15% 45% on sandbanks [21]	Haddock were not found to be prey limited during years of low sandeel abundance in the Firth of Forth [21]
Mackerel *Scomber scombrus*	M	10%	No evidence reported

Distribution of sandeel predators

Saithe and haddock tend to have a northerly distribution, whereas Gurnards, whiting and mackerel tend to be more widespread (Figure 3.2.3.1). The abundance of fish predators is generally lower in the German bight area. Within the northern area, saithe is more abundant in the eastern areas. Seabirds and grey seals tend to be distributed close to the coast of northern Britain, with the exception of sandwich tern, which is concentrated close to the coast in the German bight (ICES 2016 WKSand report). The distribution of cetaceans seems highly variable between years (ICES 2016 WKSand report).



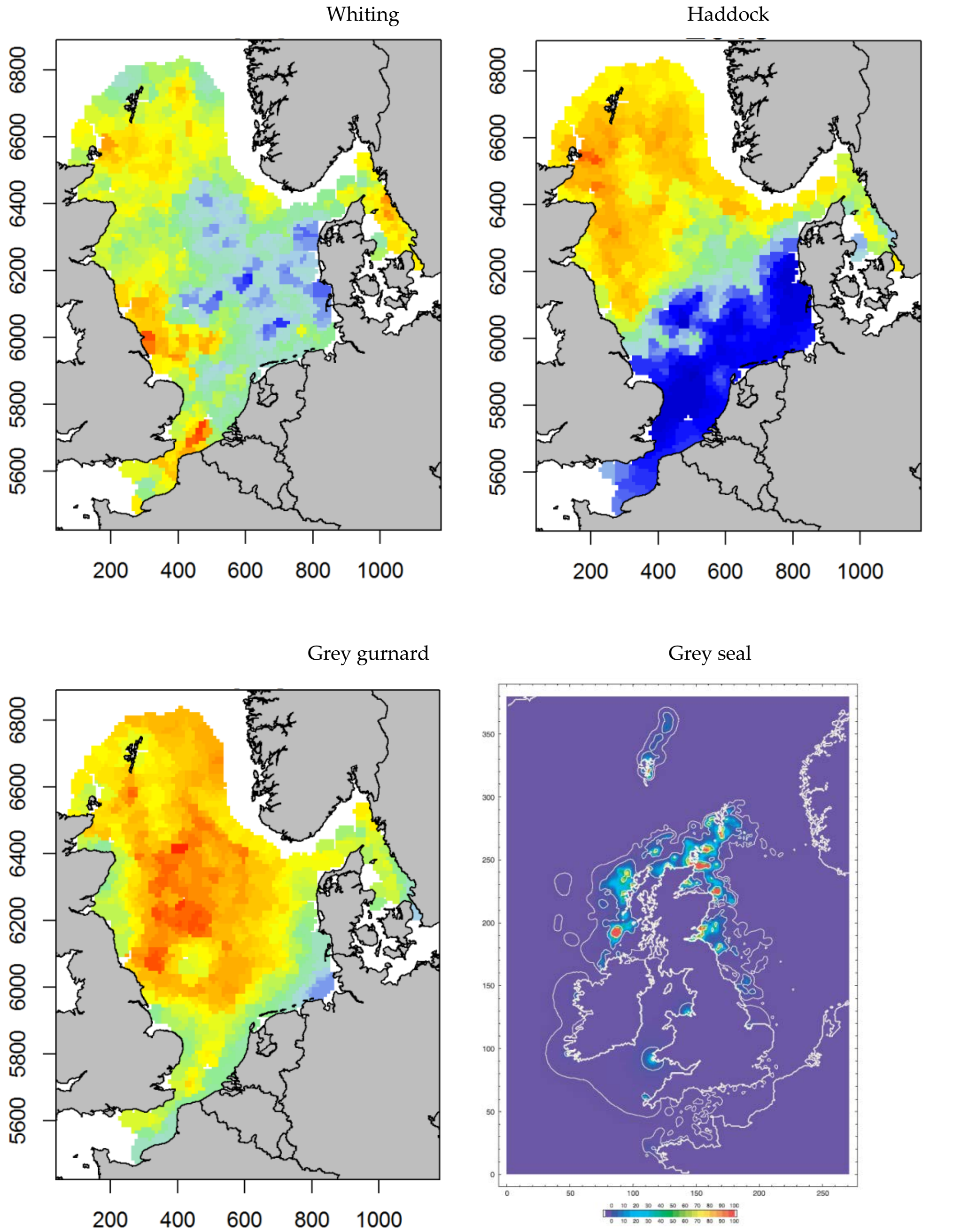


Figure 3.2.3.1. Distribution of saithe, mackerel, whiting, haddock, grey gurnards and grey seals. Fish distributions are 2015 distributions derived from www.FishViz.org. Grey seal distribution is derived from Matthiopoulos *et al.* (2004).

B. Data

B.1 Commercial catch

Denmark, Norway, Sweden, UK, and Germany participate in the sandeel fishery, where Denmark is the main contributor to the sandeel landings. Up to 2002 Denmark in average contributed 73% of the total landings and after 2002 73%.

The fishery is highly seasonal. The geographical distribution of the sandeel fishery varies seasonally and annually, taking place mostly in the spring and summer. In the third quarter of the year the distribution of catches generally changes from a dominance of the west Dogger Bank area back to the more easterly fishing grounds.

B.1.1 Landings data

Landings are reported from all countries, however, only Danish and Norwegian catches are sampled for biological parameters (see section B.2). All landings are used for reduction purposes.

B.1.2 Data coverage and quality

Sampling of commercial catches is low due to the limited total catch in SA6 (see table 3).

B.1.3 Discards estimates

No discards have been reported or observed in the sandeel fishery in SA6 and there is no historical time series of data available.

B.1.4 Recreational catches

Not relevant for this stock

B.2 Biological sampling

Self-sampling and scientific sampling from Danish landings is the basis for information from the SA6 fishery.

B.2.1Maturity

Maturity estimates from 2005 onwards are normally obtained from the Danish dredge survey in December; however no dredge survey is carried out in SA6.

B.2.2 Natural mortality

Predation rates are not estimated for SA6.

B.2.3 Length and age composition of landed and discarded fish in commercial fisheries

Before 1989, only logbook information stating the catch in directed Danish sandeel fishery is known. As the large majority of the catch in the sandeel fishery consists of sandeel, the distribution of catches in the directed sandeel fishery on rectangle and months were assumed to represent the distribution of sandeel catches. The total catch in tones was derived from the report of the working group on the assessment of Norway pout and sandeel (ICES 1995) and distributed on rectangles and month in the particular year according to the distribution of catches derived from Danish logbooks. From 1989 to 1993, the landings of sandeel per rectangle and month from the Danish fishery are available at DTU-AQUA. These were used to distribute total landings to rectangle and month. From 1994 to 1998, international sandeel catches in ton per rectangle per year are available. These catches were distributed to months according to the monthly distribution of Danish catches in the rectangle in the given year. If no Danish catches were recorded from the rectangle, the monthly distribution of the total catches in the ICES division was used. After 1999, international sandeel catches in ton per rectangle per month and year are available.

All catches were scaled in order to sum to official ICES landing statistics. Total catches per area are seen in Figure B.2.3.1.

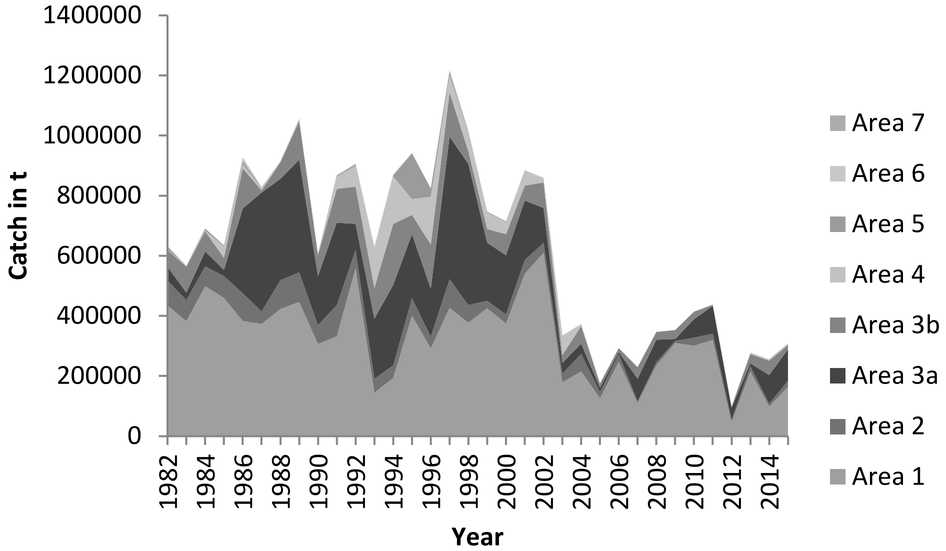


Figure B.2.3.1. Total catches pr. Sandeel area.

B.2.3.1 Estimating catch in numbers and mean weight

The catch in numbers per age (1000s), month and rectangle of sandeel was estimated as the product of sandeel catches in kg and the number-at-age of sandeel per kg in the particular rectangle. The total number in a larger area and longer time period is estimated as the sum over individual rectangles and months in this area. The mean weight is estimated as the weighted average mean weight (weighted by catch in numbers of the age group in the rectangle and month). Mean weight is given in kg.

B.2.3.2 Number of samples taken in each area

The number of biological samples taken was insufficient (<10 for two or more consecutive years) to conduct analytical assessments for areas 5, 6 and 7 and for area 4 prior to 1993 (Table B.2.3.2.1).

Table B.2.3.2.1. Number of samples taken in each area and suggested combined areas. Years with less than 10 samples are coloured orange

Yearly	Area 1	Area 2	Area 3	Area 4	Area 5	Area 6	Area 7	Area 3a	Area 3b	Area 2+3b
1983	79	15	34	0	0	0	0	0	34	49
1984	116	15	44	0	2	3	0	13	31	46
1985	101	20	13	19	2	3	0	1	12	32
1986	26	2	42	1	0	1	0	27	15	17
1987	62	6	66	1	0	1	0	60	6	12
1988	42	2	80	0	0	1	0	67	13	15
1989	40	5	47	0	0	1	0	43	4	9
1990	1	1	40	0	0	2	0	37	3	4
1991	25	8	54	1	0	0	0	30	24	32
1992	56	17	49	4	0	7	0	24	25	42
1993	23	16	111	15	0	7	0	64	47	63
1994	20	8	80	15	0	4	0	50	30	38
1995	41	15	75	7	7	2	0	58	17	32
1996	43	12	163	27	19	1	0	113	50	62
1997	41	23	177	25	8	3	0	116	61	84
1998	70	10	200	7	0	2	0	176	24	34
1999	263	24	68	44	0	1	0	42	26	50
2000	102	12	83	59	0	2	0	47	36	48
2001	213	9	66	90	1	1	0	33	33	42
2002	288	28	121	62	0	1	0	50	71	99
2003	281	45	64	160	0	2	0	30	34	79
2004	451	60	183	47	0	1	0	26	157	217
2005	320	20	56	30	0	1	0	34	22	42
2006	550	13	115	2	0	2	0	72	43	56
2007	295	13	261	0	0	1	0	108	153	166
2008	290	9	167	1	0	0	0	49	118	127
2009	302	7	127	0	0	1	0	12	115	122
2010	169	28	282	1	0	3	0	40	242	270
2011	167	42	29	4	0	4	0	17	12	54
2012	220	64	79	21	0	12	0	31	48	112
2013	292	21	240	5	0	3	0	41	199	220
2014	143	52	110	18	0	5	0	29	81	133
2015	309	62	103	38	0	4	0	48	55	117

B.3 Surveys

Not used for SA6.

B.4 Commerical CPUE

Not used for SA6.

B.5 Other relevant data

None

C. Assessment methods and settings

C.1 Choice of stock assess model

This stock is in the stock category 5.2.0. Only catch statistics are available for SA 6. Until 2004 catches were on average more than 1500 t annually, but since 2005 catches have remained low (< 500 t annually). Biological sampling has on average been at a low level (2.6 samples per year since year 2000). This information is inadequate to evaluate stock status or trends, and the state of the stock is therefore unknown.

C.2 Model used of basis for advice

Not relevant.

C.3. Assessment model configuration

Not relevant.

D. Short-term prediction

Not relevant.

E. Medium-term prediction

Not relevant.

F. Long-term prediction

Not relevant.

G. Biological reference points

Not relevant.

H. Other issues - Note: This section will be completed during HAWG 2017

H.1 Biology of species

H.2 Stock dynamics, regulations in 20th century - historic overview

Year (Y)	2007	2008	2009	2010	2011	2012
Assessment Model						

Software	
Catch data range	
CPUE Series 1 (years)	
CPUE Series 2 (years)	
Index of Biomass (years)	
Error Type	
Number of bootstrap	
Maximum F	
Statistical weight B1/K	
Statistical weight for fisheries	
B1-ratio (starting guess)	
MSY (starting guess)	
K (starting guess)	
q1 (starting guess)	
q2 (starting guess)	
q3 (starting guess)	
Estimated parameter	
Min and Max allowable MSY	
Min and Max K	
Random Number Seed	

Data	**2006**	**2007**	**2008**	**2009**

Catch data
Survey: A_Q1
Survey: B_Q4
Survey: C

H.3 Current fisheries

See section A.2.1

H.4 Management and advice

See section A.2.2

H.5 Others (e.g. age terminology)

None.

H.6 References

Christensen *et al.* (2008) Sandeel (Ammodytes marinus) larval transport patterns in the North Sea from an individual-based hydrodynamic egg and larval model. Canadian Journal of Fisheries and Aquatic Sciences, 65(7), 1498-1511.

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