THEME SESSION V: Unaccounted Mortality in Fisheries

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AN ESTIMATION OF THE COD (*Gadus morhua*) CATCH IN THE BOTTOM GILL NETS LOST ALONG THE SOUTHERN COAST OF SWEDEN

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Abstract

According to a survey of the Swedish cod gillnet fleet operating in the Baltic Sea, 3.6 – 3.8 gill nets are lost per vessel every year, corresponding to 156 – 165 km of netting. An experiment with deliberately "lost" nets showed some catching efficiency left still after 27 months. A considerable amount of nets are retrieved by trawlers, but still some nets continue fishing for a long time. In this paper an attempt is done to estimate the unaccounted cod mortality caused by gillnets lost by the Swedish fishing fleet. In the model used, cod catch was assumed to depend on 1) the length of lost nets in two categories (newly lost and accumulating), 2) the relative catching efficiency of the lost nets (from the experiment mentioned above) in the same two categories, 3) CPUE during the corresponding period for the gillnet fleet and 4) the retrieval (by trawlers) rate of lost nets. Of the total number of nets used during a 28-month period, 157 000 km, the model estimated 145 – 158 km to have been lost. Two retrieval rate scenarios were applied, giving 24 and 100 km nets left and continuing fishing (no lost nets assumed at the start). Total catch of cod by those nets during the 28-month period was estimated to 76 and 162 tonnes (with large confidence intervals), compared to 8445 tonnes landed by the fleet during the same period. Considering the total gillnet fishery in the Baltic, everything should be made to avoid this unaccounted cod mortality.

Keywords: lost gillnets, unaccounted mortality, Baltic Sea

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Introduction

According to a survey of the Swedish cod gillnet fleet operating in the Baltic Sea, 3.6 to 3.8 gill nets per operating gill net vessel are lost every year. For example in 1998 the amount of lost gears was estimated to a 156 to 165 km of netting (Tschernij and Koppetsch, 1999). The most common reason for gear loss at sea was conflicts with trawlers, which has been increasing substantially due to hardening competition on the last economically profitable fishing grounds.

Usually when a trawler runs over a gill net fleet some of the nets or pieces of the fleet are caught by the otter doors, sweeps or by the trawl. An attempt to make a rough approximation of the annual total net amount retrieved by the Swedish trawler fleet resulted in an estimate between 57 and 217 km of netting brought ashore by trawlers (Tschernij and Koppetsch, 1999). That amount of retrieved netting is presumably containing also nets coming from other than the Swedish gill net fleet.

An experiment with deliberately “lost” nets showed that such nets in the Baltic Sea most likely will retain their catching efficiency over a long time period. During the first month lost gill nets were estimated to catch between 100 and 30% of the catch in commercial nets. Toward the end of the first year the relative efficiency of lost nets was observed to stabilize on a level around 15 to 10%, after that decreasing only moderately. After 25-27 months soaking time the efficiency was estimated to be somewhere around 5 to 6% of that of commercial nets (Tschernij and Larsson, 2001).

This paper presents an estimation of the amount of bottom gill nets that was lost by the Swedish gill net fleet, the amount of netting that was retrieved by Swedish trawlers and length of netting that can be assumed to have been left in the sea during a 27-month period starting from Sep 1^{st} 1999 along the southern coast of Sweden. Moreover, an estimate of the total weight of cod caught in these nets is presented and discussed.

Material and methods

Principal of gear conflict

The described succession of events is based on the information that was collected by Tschernij and Koppetsch (1999) by interviewing both gill net and trawl skippers. In the coastal areas most trawl skippers are well aware of the areas where gill nets usually are deployed. In a case that they tow too close to these areas and collide with a net fleet we assumed that only the outer end of the net fleet would be damaged. If both surface markers are lost the remaining part of the damaged fleet is not retrieved either by the gill net fisherman or by the particular trawler. The reason why we assume that only the outer end of net is hit is because trawlers are seldom capable of entering so deep into a gill net ground that they would hit right in the centre of a fleet. Likewise it is not that often a gill net skipper is risking his fleets by setting them too far into the trawling grounds. Usually trawlers tend to avoid repeating exactly the same track within a certain time because operation with a towed gear has been observed to disperse fish schools. Furthermore, we assumed that an accident of this kind would be unlikely to happen twice exactly in the same area. This lead to an assumption in the model that the rate of *gear loss* and *gear retrieval* in the same area *r* and month *m* where rather related to the activity of consecutive months than to the activity of same month.

Model and assumptions

The study area in our calculation was chosen in coherence with the area investigated by Tschernij and Larsson (2001). Unit area in our model was set to one ICES statistical rectangular measuring roughly 60 by 60 km because that is the lowest feasible aggregation level of available logbook data (Figure 1). The time period was set from Sep 1st 1999 to Dec 30th 2001 (28 months; same as in the experiment reported by Tschernij and Larsson, (2001)) to exclude possible between-year variability in the determined catching efficiency of lost gill nets. The time unit was set to one month (30 days).

We assumed that all gear loss that occurred in the included areas was caused by gear conflicts i.e. a trawler running over a net fleet. In those unit areas or during months with no trawling activity no gear loss was expected. In case of reported gill net activity a trawler operating in that area was assumed to both cause gear loss and retrieve some of the lost nets in the area. The estimated monthly net losses were then assumed to results in a catch per unit area and time, which were summarised to give the total catch for the whole chosen study area and for the determined time period.

Because we assumed that the length of lost nets was dependent both on the existence of gill net effort but as well on the trawling activity, a *gear loss* variable χ was introduced to enable an activity dependent, chronological and geographical distribution of lost gears between unit areas and time. The variable was obtained by dividing the total estimated length of lost gill nets by the number of conducted tows during the determined time period and whole study area. The total length of lost nets was in turn calculated by multiplying the length of all used commercial nets with the weighed mean gear loss rate of 0.001 (Tschernij and Koppetsch, 1999). The overall gear loss rate was assumed binomial distributed and follow an exponential distribution (β =0.00154).

In each of the 308 calculations (=11 areas x 28 months) two types of lost nets were distinguished; 1) newly lost and 2) accumulating amount. Observe that no existing lost gears were assumed in the beginning of month 1 in the study area.

The length of newly lost nets per unit area *r* and month *m* was calculated by multiplying χ with the number of reported tows $N_{r(m)}$. Therefore in the model if $N_{r(m)}$ was zero no gear loss was expected. Similarly if $N_{r(m)}$ was larger than zero but no gill net activity was reported in the given area *r* and month *m* the result was zero newly lost nets.

The total length of all lost nets in a given area *r* and month *m* was calculated by adding the length of newly lost nets with the length of old nets from previous month $L_{r(m-1)}$ subtracted by the amount of retrieved nets, which was assumed to depend on the trawling activity. A *gear retrieval* variable γ was introduced following the same principal as when determining the gear loss variable χ. The average gear retrieval variable was determined by dividing the estimated length of all retrieved nets by the total number of reported tows. The total length of retrieved nets was obtained by multiplying the total length of lost nets with the determined overall retrieval rate (Tschernij and Koppetsch, 1999). Two normal distributed retrieval rate scenarios were assumed (μ_1=0.355; μ_2=0.854 with same variation (σ =0.04) but values less than zero and more than one were not accepted.

The catch of cod in the lost nets for a given area *r* and month *m* was assumed to depend on 1) the length of lost nets in two categories (newly lost and accumulating), 2) the relative catching efficiency of the lost nets in two categories (newly lost and accumulating), 3) CPUE for the commercial gill net fleet and 4) the recapturing rate of lost gill nets.

The relative catching efficiency of newly lost nets was calculated using the fitted mean curve ($\varepsilon_{t(1)}$=46.699 x t $^{e(-0.5932)}$) where the exposure time t given in months was randomly selected from a uniform distribution with a lowest excepted minimum value of 0.277 and highest excepted value 1.277. The relative catching efficiency of accumulating lost net category $\varepsilon_{t(m)}$ was calculated using the same mean curve but by letting the exposure time t vary randomly following a uniform distribution with a low value of 1.277 months and high value of *m* minus 1.277 months.

CPUE for the gill net fishery was determined by dividing the reported landed catch with the reported length of all used nets per unit area *r* and month *m*.
The set-up in the experiment reported by Tschernij and Larsson (2001) did not allow for monitoring the catch of same particular net more than ones. Therefore we lack information on how often the unit catch that was recorded in the experiment is caught by the same net. Fishermen engaged in a NAG (national advisory group) of the EU-project FANTARED considered that a realistic recapturing rate could vary between 7.5 (every forth day) and 15 (every second day) times per month. The recapturing rate in the model was set to follow a discrete distribution with an equal probability of 0.33 for each of the three chosen values (7.5, 10 and 15). The equation (1) that was used in the model can be written as follows:

$$(1) \qquad C_{total} = \Sigma_m \left\{[(\chi \text{ x } N_{r(m)} \text{ x } \varepsilon_{t(1)} \text{ x } c_{r(m)}) + ((L_{r(m-1)} + (\chi \text{ x } N_{r(m)}) - \gamma \text{ x } N_{r(m)})) \text{ x } \varepsilon_{t(m)} \text{ x } c_{r(m)})] \text{ x } i\right\}$$

where

C_{total} = amount of catch in the lost nets per whole study area and determined time
Σ_m = sum of lost net catches for *m* number of months (*m*=1 to 27)
χ = *gear loss* variable
$N_{r(m)}$ = number of tows per unit area *r* and month *m*
$\varepsilon_{t(1)}$ = lost net catching efficiency during the first month of exposure
$c_{r(m)}$ = CPUE of commercial gill net fleet per area *r* and month *m*
$L_{r(m-1)}$ = accumulating length of lost gill nets for area *r* in previous month (*m*-1)
γ = *gear retrieval* variable
$\varepsilon_{t(m)}$ = lost net catching efficiency during the month *m* of exposure
i = *recapturing rate* variable

Log book data
The needed effort and catch data were derived from the official log book data base hosted by the Swedish National Board of Fisheries. The obtained file included aggregated data (by month and ICES statistical rectangular) on the number of sets/tows, total length of used gill

nets/number of towing hours and amount of landed catch both for the gill net and trawler fleet for the period extending from beginning of September 1999 to end of December 2001.

According to the data the length of all used gill nets in the study area summed to almost 157000 km used in 22400 gill net sets giving a mean fleet length of 7 km. The total landed catch for the gill net fleet was 8445 tonnes resulting in a mean landed amount of 377 kg per set. The trawler fleet conducted during the same time ca 22300 tows resulting in a total landed catch of 19900 tonnes, which gives an average landed catch of 890 kg per tow. The gill net (km/area/month) and trawl effort (tows/area/month) are given in tables 1 and 2.

Simulation
Simulation based on the model (equation 1) was implemented on a spreadsheet using Microsoft Excel-2000 program. To take into account the variability and uncertainty involved in the data and defined random input variables, Monte Carlo simulation (Johnson 1987) was used with 1000 iterations. Randomising and recalculations were carried out using @RISK program (Palisade corporation 2000), which is an add on tool for Microsoft Excel-2000.

Results

All the obtained frequency distributions for output variables were skewed (Figure 2). The model sensitivity analysis (based on a rank order correlation value returned by the @RISK program) showed that of the four random input variables *gear loss rate* had the largest influence on the output variables (Figure 3) which explained the binomial shape of the output distributions. Consequently median-value was to be considered as the most representative estimate. The variability of the input variables and the results are given in table 3.

The model estimates that during the 28-month period in the study area the total length of all lost gill nets was somewhere between 145 and 158 km. According to obtained results a range with a lower limit of 6 and an upper limit of 854 km would cover 95% of all probable outcomes, which is between 0.004 and 0.54% respectively of the total length of used gill nets.

Naturally the higher the *retrieval rate* the longer was the length of the nets that the model estimated that would be retrieved by the operating trawlers. In this case there were two scenarios of which in *scenario 1* 56 km (95% of estimates between 3 and 304 km) and in *scenario 2* 121 km (95% of estimates between 5 and 713 km) was estimated that would be gradually retrieved during the 28 months by the trawler fleet. Therefore, depending on the scenario, it was estimated that the length of old netting that was not retrieved and thus could be expected to exist in the area in the end of December 2001 varied between 24 and 100 km (95% of estimates between 1 and 550 km). Converted to an accumulation rate of lost nets in the sea this corresponds to an annual increase of between 11 and 45 km (95% of estimates between 0 and 244 km).

The total catch of cod in the lost nets for the whole area during the 28-month period was estimated in scenario 2 to 76 tonnes and in scenario 1 to 162 tonnes (in both scenarios together 95% of estimates between 3 and 906 tonnes).

As expected the model showed a concentration of lost nets in the areas with the highest fishing activity. The majority of the estimated gear loss took place in five of the eleven rectangles; 3958, 3959, 4059, 4060 and 4061 (Figure 4).

Discussion

The total length of netting that was used by the gill net fleet between September 1999 and December 2001 in the study area was 157000 km. We estimate that of this net amount approximately 145-158 km were lost due to conflicts with trawlers. The obtained estimates were widely spread (95% of estimates between 6 and 854 km). Using the defined '95% confidence limit' this amount of netting is not more than between 0.004 and 0.54% of all used nets. However, it is important to keep in mind that this rate of gear loss can be assumed to apply only for the coastal waters i.e. where both the gill net and trawler fleet are Swedish. The estimated length of lost netting (6 to 854 km) is equivalent to a number of lost nets between 60 and 8130 for a period of 2.3 years. This amount can easily be put in context e.g. by relating it with the amount of netting sold by one of the most important net makers in Sweden (Blekinge Fiskeredskap AB). According to personal communication during recent years this company alone has delivered between 4000 and 5000 new nets a year. Apparently the lost gill nets are far from being the only reason for purchasing new nets. Our model was built on an overall principal where all gear conflicts, regardless of the fishing ground and the involved fragments of the fleets, were supposed to follow the same pattern and lead to same outcome. Our knowledge on the subject is yet incomplete and this assumption may turn out to be false because the gear loss rate used in the model was based on the knowledge obtained on 'voluntary' basis from the gill net fishermen self and may therefore be underestimated. However, none of the randomly chosen gill net fishermen refused to be interviewed but anyhow they might have felt some degree of uncertainty of the objectives of this project and chosen to underestimate the amount of lost netting.

Because the most common reason for gear loss was found to be gear conflicts this 6 to 854 km of netting is lost to great extent in areas with a continuously high trawling activity. Thus it is only logical to assume that sooner or later some part of it will be retrieved by trawlers. However, there are some facts that indicate a possibility that a part of this amount is not brought ashore but is instead ripped into smaller pieces and spread around by trawlers over a wide area. One of the biggest problems in the model is the lack of detailed understanding of this phenomenon and reliable data on the rate trawlers are retrieving lost netting. Therefore, the only realistic approach for us was to investigate how different hypothetical retrieval rates would affect the amount of lost nets left in the sea in the investigated area and a given time period. Based on the very rough calculation of the presumed retrieval rate of lost nets in the Swedish trawler fleet (Tschernij and Koppetsch, 1999) two different scenarios were set up.

In the case of the lowest assumed retrieval rate (35% of lost nets would be successively retrieved by trawlers), the amount of netting left in the sea would increase with an average rate of 45 km per year. After 28 months the total length of netting in the study area would be around 100 km of netting (95% of estimates between 4 and 550 km). In the second case 85% of lost nets were assumed to be brought ashore by trawlers corresponding to an accumulation rate of 11 km per year (95% of estimates between 0 and 68 km). After 28 months the total amount of lost netting in the sea would amount to ca 24 km (95% of estimates between 1 and 154 km). The presented scenarios do not take into account the amount of netting already existing in the area. So we assumed that in the beginning the bottoms would be perfectly clear of any nets. We did not consider any extrapolation over time appropriate because that would include an evident high risk of strongly biased results.

All the netting that was lost in the model, the part that was later on retrieved and, especially, the part that was assumed to be left in the sea for a longer time (=accumulating length of netting) were assumed to be in a similar condition and follow the same physical evolution as the nets that were monitored in the experiments reported by Tschernij and Larsson (2001). The net fleets used in the experiment were short as it was assumed that those parts of commercial fleets that would be hit by a trawler and not retrieved by the gill net fishermen would be shorter than a full fleet (5-7 km). Still the major difference is that the experimental nets were never exposed to a gear conflict, which the real lost nets always are. This might imply a risk that real lost nets, even if they would be of similar length, are severely damaged and twisted in a manner that substantially lower their catching efficiency compared to that of our experimental nets. We estimated, depending on the chosen *retrieval rate* scenario, that the total catch of cod by lost nets during the 28 months could be somewhere between 3 and 906 tonnes. Compared to the total weight of reported and landed cod catch from the same area and time period (28345 tonnes) the lost net catch is between 0.01 and 3.2%.

This catch quantity is, however, likely to be too high at least for two reasons. Firstly we believe that the catching efficiency of lost nets reported by Tschernij and Larsson (2001) is overestimated because the reported catch in commercial nets did not include cod smaller than the minimum landing size whereas the experimental catch included all captured cod. Secondly, we don't know for sure in what condition the amount of netting left in the sea is and, most of all, can we expect their catching efficiency to be as high as for our experimental nets. Apparently in many cases we cannot do that. Today both gillnetters and trawlers are targeting cod attracted to more or less the same last slopes that provides presuppositions for an economical operation. So the nets that are lost as a result of gear conflict can only be expected to exist in those areas where trawlers operate. Consequently if the trawling activity in the area continues the lost nets will be frequently run over or hit by trawlers leading presumably to a rapid removal or deterioration. There is, on the other hand, a small chance that some part of the nets will be occasionally lost in certain less frequently visited areas along the boarder zone between gill net and trawling grounds. These particular nets can be expected to resemble the nets that were used in the experiments. A low frequent periodical presence of trawlers in vicinity of gill net grounds can lead to a situation where lost gill nets are left for longer times without a chance that other trawlers would further run over them and promote the degradation of the nets.

The bi-mortality in a fish stock exposed to heavy over-fishing should not be neglected, especially if the problem causing the mortality is clearly identified and could be solved relatively easily. On the other hand the industrial objectives should not be to direct the political or the medial interest on problems that would in the end have relatively small biological consequences on the development of the stock. During recent years topics related to lost gill nets have had the tendency of easily gaining a large medial attraction. According to our results the amount of cod that are caught in the lost nets is very small compared to the catch that is landed. For instance in year 2000 the amount of cod that are caught and discarded at sea as under-sized in the Baltic cod fishery is estimated to 18% of the catch weight that was lifted aboard (Anon. 2001). Major part of discarded cod is dead before they reach the water again (Otterlind 1960, Thurow and Bohl 1976).

The mortality caused by lost gill nets along the Swedish south coast is to a great extent connected with gear conflicts. Even if it from biological point of view would be of minor importance, its roll as an indicator of the environmental responsibility within the industry cannot be denied. Because of the large medial interest all voluntary actions to prevent gear conflicts and ameliorate the impact of lost gears would be highly beneficial for the whole fishing industry.

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Tables

Table 1. The length (km) of all used nets given per unit area and month.

	ICES statistical rectangular										
Month	3957	3958	3959	3960	4059	4060	4061	4159	4160	4161	4162
Sep-99	35	902	147		1 662	1 629	835	165	521	922	1 128
Oct-99	58	381	209	8	936	1 350	560	114	511	426	1 428
Nov-99	13	169	160		1 430	2 121	564	51	420	920	1 510
Dec-99		114	26		425	580	85	130	274	360	548
Jan-00	82	438	141	3	1 631	1 839	291	111	455	921	675
Feb-00	10	597	77	103	1 822	2 406	296	207	352	972	552
Mar-00		569	122	12	1 833	1 799	424	153	339	826	140
Apr-00	208	829	394	7	1 600	1 308	450	30	506	1 156	248
May-00	138	990	688	9	1 354	1 149	502	11	468	1 471	419
Jun-00	20	232	607		999	863	68	16	379	992	88
Jul-00	8	34	20		143	28				309	4
Aug-00	19	238	217		645	961	279	116	141	641	397
Sep-00	21	630	328	5	1 253	1 935	455	229	306	853	1 990
Oct-00	3	510	404	4	1 306	2 396	676	58	380	857	486
Nov-00	63	239	197	12	858	2 043	353	112	324	1 173	870
Dec-00	123	457	147	12	807	1 458	129	92	265	600	1 270
Jan-01	47	731	136	2	1 342	2 368	493	55	277	846	788
Feb-01	9	626	142		1 235	1 699	161	4	274	754	399
Mar-01	10	1 317	153		1 572	1 701	303	2	294	1 083	384
Apr-01	120	1 438	606	9	1 296	1 112	106	22	457	1 216	101
May-01	262	1 405	855	6	1 138	1 179	24		434	1 527	121
Jun-01	131	734	1 085		784	781	76		192	1 352	93
Jul-01		67	5		47					70	10
Aug-01	24	262	191	10	512	551	128	7	223	454	375
Sep-01	4	752	124		1 265	1 363	221	18	636	806	1 632
Oct-01	58	502	246	12	1 229	915	219	38	442	1 161	1 428
Nov-01	80	472	155	44	536	1 304	284	53	311	621	1 011
Dec-01	128	326	38	6	653	1 167	588		394	1 018	507
Total	1 673	15 958	7 620	261	30 312	38 007	8 567	1 792	9 574	24 306	18 598

Table 2. The trawl effort (number of tows) given per unit area and month.

	ICES statistical rectangular										
Month	3957	3958	3959	3960	4059	4060	4061	4159	4160	4161	4162
Sep-99		230	169	1	203	121	98			1	10
Oct-99	1	85	176		187	115	137			4	10
Nov-99	6	26	137		236	132	268			13	85
Dec-99	14	20	46	1	105	105	112			8	20
Jan-00	13	90	71	4	170	158	110			8	32
Feb-00		28	77	16	314	305	206			49	16
Mar-00		49	91	27	297	318	232			14	6
Apr-00		34	79	59	212	121	138				1
May-00		18	90	415	181	106	39			1	1
Jun-00		53	128	436	136	44	6				1
Jul-00			36	42	13	8					
Aug-00		133	122	6	109	57	49			1	
Sep-00	1	300	198	10	128	182	110	2	1	3	5
Oct-00	8	311	309	8	243	182	107		2	8	32
Nov-00	22	59	185	1	254	280	241		2	16	89
Dec-00	3	11	78	2	159	143	100			13	34
Jan-01	1	103	102	6	290	172	160			10	17
Feb-01		75	84	1	310	112	140		1	38	27
Mar-01		72	79	26	278	187	301			30	22
Apr-01	2	36	94	179	395	129	200			2	1
May-01		39	282	838	235	66	94		2	1	2
Jun-01		105	231	499	111	36	4				
Jul-01		10	64	34	5	3					
Aug-01		88	152	5	113	48	32		1		
Sep-01	1	227	225	2	142	108	86			26	15
Oct-01	5	136	170	1	208	115	117		3	43	113
Nov-01	17	62	125	1	194	140	229	1	2	41	67
Dec-01	4	33	46		149	147	171			30	22
Total	98	2 433	3 646	2 620	5 377	3 640	3 487	3	14	360	628

Table 3. A summary of basic model statistics giving the variability of both input (fixed and random) and output variables for the three simulated scenarios. The two columns to the right gives the 2.5% and 97.5% percentiles for the obtained distributions.

Input variable	Unit	Fixed	Mean	Median	2.5% Per	97.5% Per
Total used net length	km	156 669				
Total number of tows	n	22 306				
Net length for area *r* month *m*	km	from table 1				
Number of tows area *r* month *m*	n	from table 2				
Gear loss rate	rate		0.00154	0.00106	0.00005	0.00572
Gear retrieval (scenario 1)	rate		0.35324	0.35319	0.27600	0.43344
Gear retrieval (scenario 2)	rate		0.85217	0.85205	0.77347	0.92858

SCENARIO 1

Output variable		Mean	S.D.	Median	2.5% Per	97.5% Per
Length of lost gill nets	km	229	238	158	7	854
Length of retrieved nets	km	82	86	56	3	304
Length of nets left in the sea	km	147	154	100	4	550
Accumulation rate of lost nets	km/year	65	68	45	2	244
Total catch of cod in lost nets	tonnes	239	250	162	7	906
Catch in accumulating nets	tonnes	158	167	106	5	607

SCENARIO 2

Output variable		Mean	S.D.	Median	2.5% Per	97.5% Per
Length of lost gill nets	km	222	229	145	6	844
Length of retrieved nets	km	184	191	121	5	713
Length of nets left in the sea	km	38	41	24	1	154
Accumulation rate of lost nets	km/year	17	18	11	0	68
Total catch of cod in lost nets	tonnes	116	121	76	3	453
Catch in accumulating nets	tonnes	38	42	23	1	151

Figures

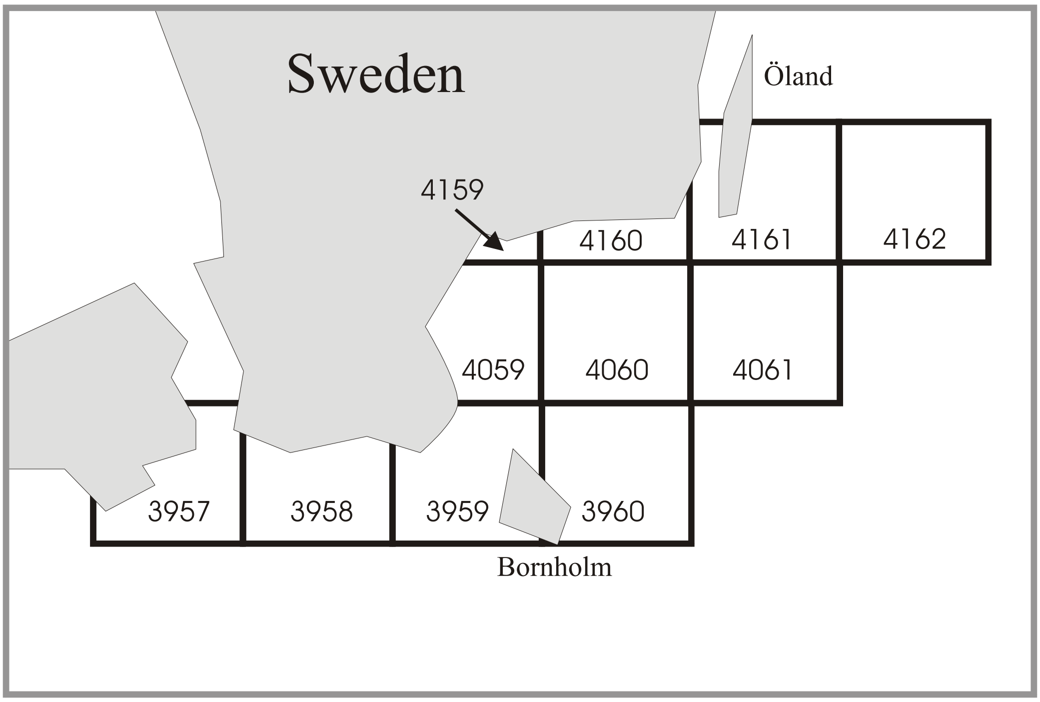

Figure 1. A map showing the 11 selected areas (squares marked with bold lines). The corresponding number of the ICES statistical rectangular is given for each of the squares. One full square has an area of ca 3600 km^2.

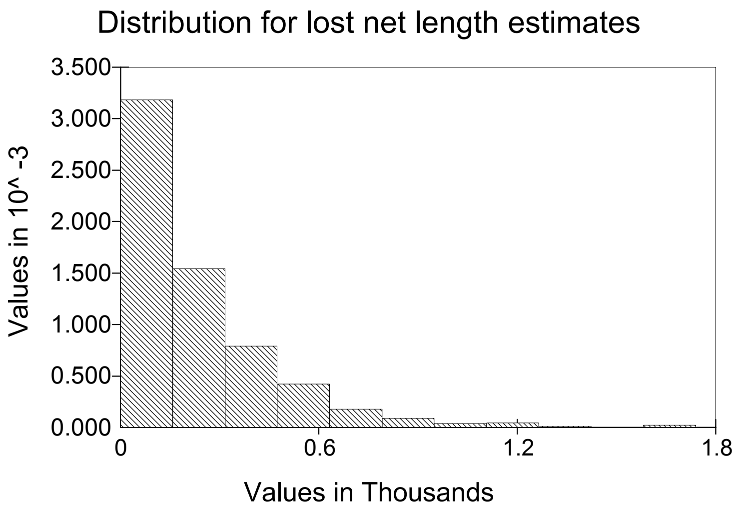

Figure 2. The obtained distributions from the simulations were all skewed. Here is the frequency distribution of the total length of lost gears in the study area.

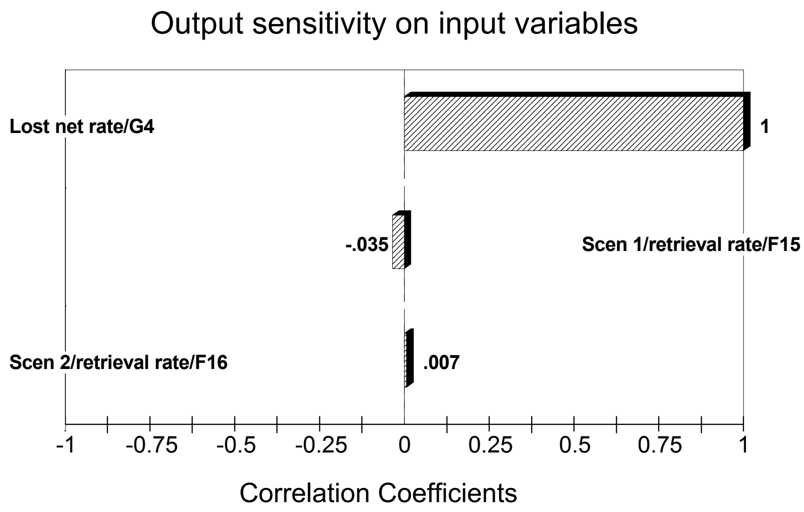

Figure 3. The sensitivity of output variable (in this case the length of lost nets) on three input variables; G4) lost net rate, F15) retrieval rate in scenario 1 and F16) retrieval rate in scenario 2.

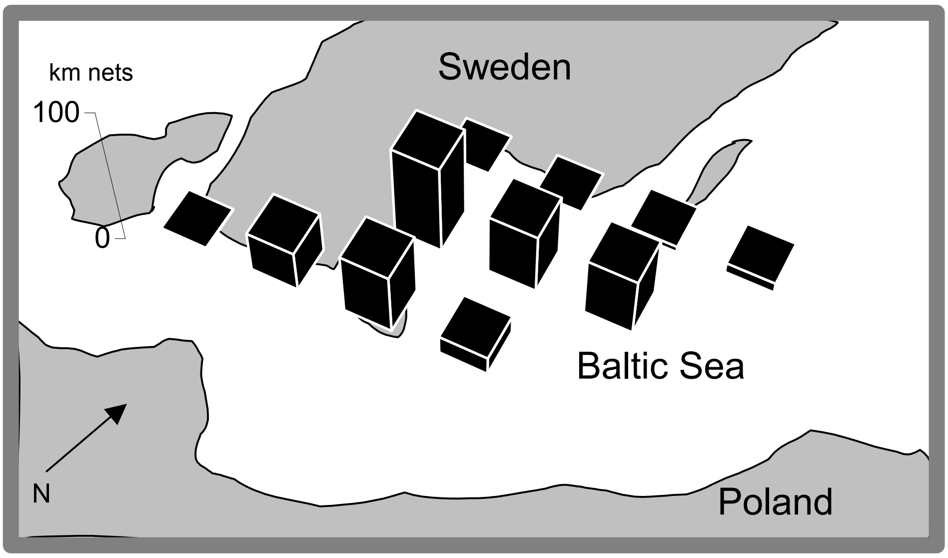

Figure 4. The estimated geographical distribution of lost nets given per the included 11 statistical rectangles.