Economic impacts of coastal habitat change on eel fisheries: A fishermen's knowledge based survey

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Abstract
While the link between the decrease in European eel stocks and different anthropogenic factors is still under study, this paper presents new information about eel fishery on the Swedish west coast and shows, through a statistical analysis of the results of a survey applied to eel fishermen, that habitat loss has a significantly negative effect on eel catches. The economic loss derived from the decrease in the availability of eelgrass meadows for the fishing activity is estimated to be equal to 6.4 million Swedish kronor per year and is shown to be comparable in importance to the effect of other disturbances affecting the fishery, such as the damage produced by seals and predation by cormorants, and greater than the problems produced by crabs or fouling of gears. The paper unveils the habitat contribution to the economic activity and suggests that the impact of environmental change on fisheries is significant and should be taken into consideration when designing policies to increase the long-run sustainability of the fishing activity.

1. Introduction

From the 1980s to the beginning of this century, around 60% of the total area of eelgrass (*Zostera marina)* meadows have disappeared from the Swedish Skagerrak coast (Baden et al., 2003). Baden et al. equally attribute this dramatic reduction to natural disturbances and anthropogenic perturbations that have affected the water quality[2]. Loss of a seagrass habitat is an international phenomenon; the global loss of seagrass habitats during the period of 1985 to 1995 has been estimated to correspond to a 7% overall reduction of seagrass meadows (Spalding et al., 2003). Seagrass meadows are an important biotope, where different animal species find

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[2] According to The Fisheries Secretariat, "discharges of pollutants and other substances from households, industry and traffic have all contributed to deteriorating water quality in what used to be excellent habitats for eels." Cf. http://www.fishsec.org/article.asp?CategoryID=1&ContextID=35 (4 March 2007). See also Dekker (2004).

food and protection (Pihl et al., 2006), and it is the preferred location for fishing eel (*Anguilla anguilla*), which is "common throughout the eelgrass meadows from the Skagerrak to the Baltic" (Baden et. al., 2003, p. 374).

The two questions approached in this paper are whether this habitat change has affected the eel fisheries on the Swedish west coast, and to which extent it has economic consequences for these fisheries. The lack of previously available information about the issue has led to the application of a survey to fishermen in the area, following the literature suggesting that fishermen's knowledge can be a useful source of information when scientific results are not available (for example, Neis et. al., 1999, and Daw, 2003).

This paper contributes to the literature by presenting original information − important for the understanding of the fisheries and not previously available − about eel fishery on the Swedish west coast. It is also, to my knowledge, one of few examples of how to use fishermen's knowledge to economically value the impact of habitat loss on commercial fisheries.

The rest of the paper is organized as follows: section 2 presents general information about eel fisheries on the Swedish west coast; section 3 introduces the methodology used, and questions and answers to the questionnaire are presented in section 4. Section 5 shows the results of a statistical analysis of the information given by the fishermen and compares their perception of economic effects of the decrease in seagrass with the impact of other disturbances affecting the fisheries. The final section (6) presents a discussion of the results of the analysis and their policy implications.

2. Eel fishing in the Swedish west coast[3]

The European eel (*Anguilla anguilla*) is an important fish species, mainly because of its role in small-scale coastal fisheries all over Europe, where more than 25,000 fishermen depend on it for their income (Dekker, 2004). In Sweden, 2/3 of the 150 fishermen on the Swedish west coast have eel as their main source of income (NBF, 2001, p. 56).

The fishing activities start between February and March and can go on until November, mainly in soft bottoms and areas with vegetation. During the summer, fishermen catch eel also in rocky bottoms. On the west coast, the main fishing area is around the South and North of the mouth of the Göta River.

A great problem for the eel fishery is that recruitment has been in decline since the beginning of the 1980's, reaching a historical minimum around 1 or 2% of the pre-

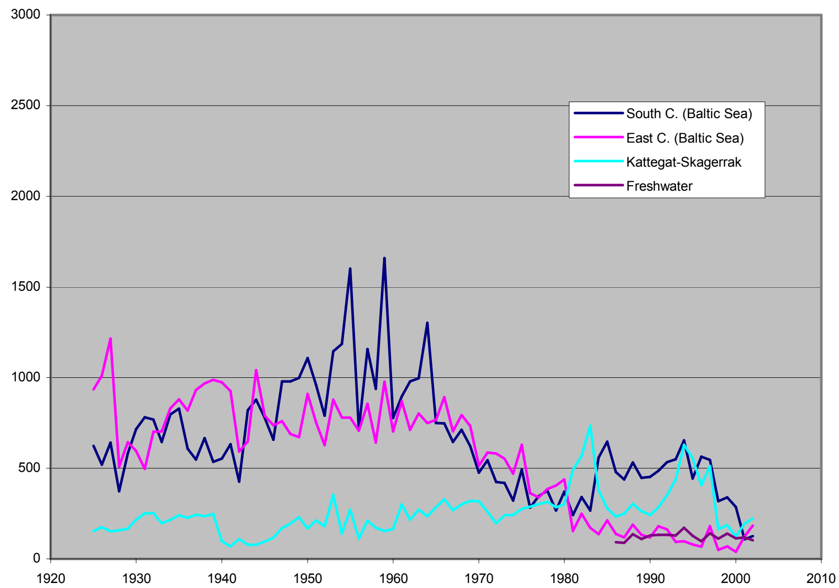
[3] The main sources of information for writing this section are Sandström (2000), Wickström (2005), and personal communication with Håkan Westerberg (from the Swedish National Board of Fisheries in Gothenburg), and Håkan Wickström (from the Institute of Freshwater Research, Swedish National Board of Fisheries, Drottningholm).

1980 level in 2001, and showing no improvement since then (ICES, 2005). This decrease in eel stocks affects the already mentioned important fraction (2/3) of professional fishermen who get their income from eel fishing. In Sweden, the decrease in catches was mostly observed in the Baltic Sea area up to 1997. Since then, catches have also decreased on the west coast, i.e. Kattegat-Skagerrak (Chart 1).

However, catches per effort on the west coast have not decreased as much as on the east coast, probably because the west coast is the first stop for the eel coming from the spawning area in the Sargasso Sea. The Gulf Stream brings the larvae northeast through the Atlantic and the North Sea and during the spring or early summer, the larvae arrive in Northern Europe. The eel's life-cycle is still not well known, but the fact that there is only one single stock of European eel that spawns only once in its lifetime makes this decline alarming. Exploitation and other anthropogenic factors (such as habitat loss, pollution and transfer of diseases) are suggested as the best explanations for the decreasing stock (ICES, 2005).

For eel fisheries, the problem of a generally decreasing stock is combined with the additional problem of a loss of habitats that constitute suitable locations for harvest. This paper focuses on the latter problem by studying the particular case of seagrass habitat loss on the Swedish west coast and its impact on eel fisheries.

Chart 1: Eel catches in tons



Source: NBF (2004)

The information about eel fishery in Sweden is mostly gathered by the Swedish National Board of Fisheries (NBF). Even though there are statistics on eel catches, there is very little information available about in what habitats catches take place. The scarcity of such information is the explanation for the methodology chosen for this study. Following other studies that have assessed and/or used fishermen's knowledge to provide useful information for science and management (for example Nies et. al., 1999, and Daw, 2003), a survey was conducted to find out how fishermen see the evolution of eel fisheries and its connection to habitat changes observed on the west coast of Sweden.

3. Methodology – A survey of fishermen

The purpose of the survey is to identify the habitat (i.e. eelgrass meadows) contribution to the eel fishing activity and investigate and value the impact of environmental change (i.e. the observed habitat loss) on the fisheries. The survey was designed as a mail questionnaire with an option for subjects to give responses by telephone, see details below. Consultations with a professional eel fisherman and NBF officials indicated a high risk of fatigue among fishermen towards mail questionnaires, and a contact by telephone with the fishermen was therefore judged to be crucial for obtaining a satisfactory response rate. The population for the survey was defined as professional eel fishermen based on the Swedish west coast, in this case defined as the counties of Bohuslän and Halland, as shown in Figure 1. Professional eel fishermen mean fishermen in these counties who have a license to fish eel. Names and addresses for these fishermen were obtained from an official representative of eel fishermen. They amounted to 106 in total, and they were all selected for the survey.

The development of the survey instrument tried to maximize the chances of a well-functioning questionnaire by following five phases: (i) contacts with NBF officials for ensuring that data of interest could not be obtained from NBF statistics; (ii) discussions with NBF officials and fish ecologists about the contents of the questionnaire; (iii) discussions with a representative of eel fishermen, an NBF official and fish ecologists about preliminary drafts of the questionnaire; (iv) test of a draft questionnaire on an eel fisherman; (v) pilot study in March 2005 of the final draft questionnaire by mailing it to 14 eel fishermen and approaching them by phone for collecting responses and interviewing them about the questions. The last phase only motivated some minor changes in the questionnaire.

Figure 1: The Swedish west coast, for the purpose of this study

The final version of the questionnaire was posted in April 2005 and is found in Appendix A.[4] All fishermen with telephone numbers who could be found in telephone directories were contacted by phone. These contacts by phone both served as reminders to answer the questionnaire and as an option to give responses by phone. In July, a new copy of the questionnaire was mailed to those who had not responded at that time together with a request to at least fill in and send back a separate half-page form where they were invited to state the reason for not answering the questionnaire. The response rate finally became 61.5 per cent, see Table 1 for details.

[4] The complete questionnaire and cover letter in Swedish are available from the author upon request

Table 1. Response rate	
Gross sample	106
Deceased	-1
Not fishing eel at the west coast	-9
Net sample	*96*
Respondents	59 (61.5 %)
Non-respondents	37 (38.5 %)

Non-responses are not of any concern if the group of non-respondents is not systematically different from the group of respondents. However, the usual problem is that not much is known about the non-respondents. Only two of the 37 non-respondents answered the separate form about reasons for not answering the questionnaire (their reasons were lack of interest and lack of time). A more important indication of potential systematic errors can be obtained by comparing results from the survey with official statistics. The possibility of making such comparisons is limited because the questionnaire was largely collecting data not available in official statistics. One important exception concerns landings of eel. According to official statistics, 227,000 kg of eel were landed on the west coast during 2004 (SCB, 2005). The total number of eel fishermen is 96, which indicates an average landing per fisherman of 2,365 kg. Corresponding figures from the survey are a total eel catch in 2004 of 130,567 kg for 54 eel fishermen (59 respondents minus 5 non-responses to the catch question), giving an average of 2,418 kg per fisherman. This suggests that, on average, the groups of respondents and non-respondents are very similar regarding catches. While this does not preclude other potential sources of systematic bias, this similarity regarding an important fisherman characteristic is interpreted as an indication that the group of respondents can be viewed as a random sample of the population. This will be assumed in the following.

4. Questions and answers from the fishermen

The questionnaire, whose English version is presented in Appendix A, consists of 22 questions distributed in five parts (A to E). The first contains 12 questions and aims at getting general information about the individual fishing activity like, for example, the years of experience as a fisherman, the geographical area where the activity was carried out, the size of the catch and the effort used. Part B inquires into the link between eelgrass meadows and the fishery and the questions focus on whether a decrease in seagrass meadows was observed and how it affected the activity. The third part attempts to make a comparison between the effects of habitat loss and those occurring due to other problems that might affect the fishery, like the presence of predators such as seals and cormorants. Part D contains 4 follow-up questions about the general evolution of eel fishery and the importance of different bottom types and the interest of the respondent in being subject to an interview later. The last part (E) was an open question asking for extra comments.

Table 2 summarizes most of the information from the survey by a statistical description of the main variables and allows the reader to have an overall view of the data used in this paper. In what follows, we use Table 2 to describe the main questions and answers to the questionnaire.

The responses to the survey show that the majority (70%) of the fishermen who answered the questionnaire are active in Bohuslän (24% in the northern part of the county, 46% in the southern area), while the others carry out their activity in Halland (19%) or in both counties (see Table 2 for the absolute number of observations in each region and Chart 2 for the percentages).

Chart 2

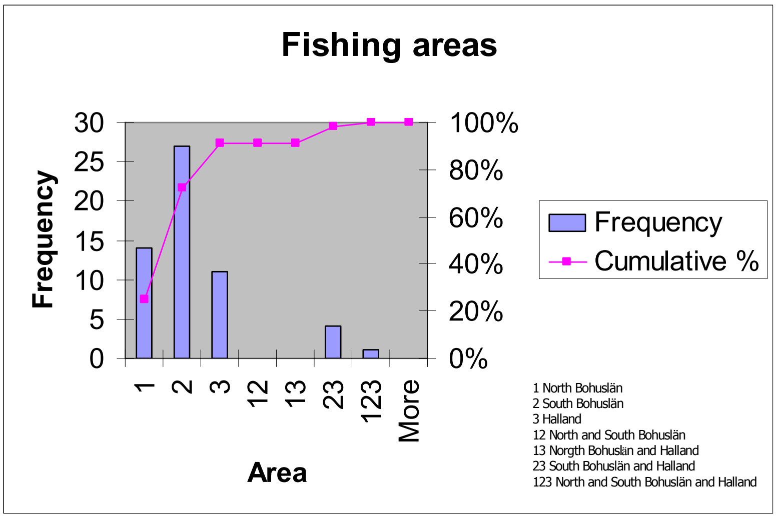


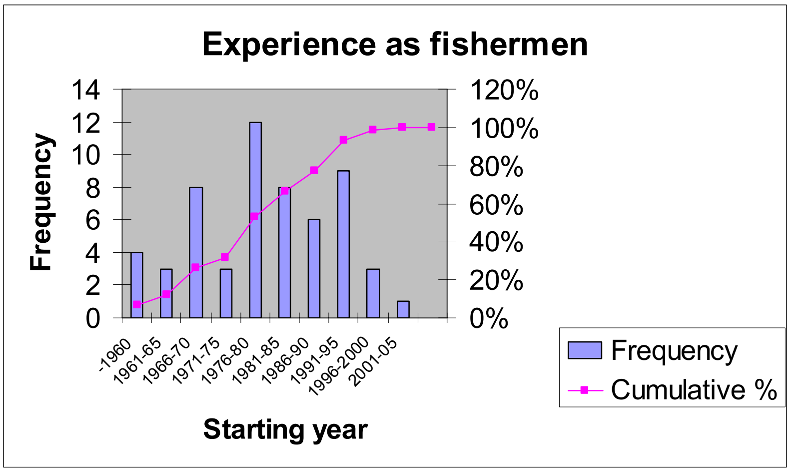
Table 2 - Statistical description of variables[5]

Variable name	Mean	Median	S. D.	Number of observations	Range
NORLYSE				15	
SOULYSE				32	
HALLAND				16	
EXPERT	1979.9	1980	11.6	57	1955/2001
Y	2417.9	1650	3171.1	54	70/21000
YNOSIZE	395.9	200	579.7	47	7.5/3000
CHECK	2.7	3	0.6	56	1/5
DAYS	144.6	132.5	85.1	54	15/361
HOURS	8.6	9	3.1	54	3/19
SIMPLE	96.4	90	76.2	55	0/300
DOUBLE	209.3	120	295.1	55	0/1650
EELPOT	7.8	0	24.4	55	0/110
DAYSEG	89.3	80	63.8	51	0/240
DAYSSBV	39.0	10	54.3	49	0/240
DAYSSBW	7.5	0	19.6	49	0/100
DAYSSAND	5.0	0	12.3	50	0/60
DAYSHB	73.1	60	56.9	50	0/240
DAYSOTHE	1.8	0	9.4	50	0/60
NETSEG	171.5	80	240.2	51	0/1200
NETSSBV	44.6	20	70.3	50	0/400
NETSSBW	14.5	0	38.0	50	0/150
NETSSAND	5.7	0	16.3	51	0/100
NETSHB	83.3	72.6	82.3	51	0/400
NETSOTHE	2	0	9.9	50	0/50
DECREEG	0.79	1	0.41	56	0/1
WHEN	1991.5	1992	8.0	41	1979/2001
WHAT					
EFFECTS				Yes=32 No=8	
MINCATCH	475.2	300	615.1	27	0/2500
MORHOURS	1.6	1.5	1.5	25	0/5
MORECOST	6455	1000	10957.6	22	0/40000
CRABCATC	182.7	12.5	367.4	48	0/1700
CRABHOUR	1.0	0.75	1.3	50	0/6
CRABCOST	3511.4	0	7977.1	44	0/35000
ALGCATCH	77.8	0	170.0	47	0/1000
ALGHOURS	1.0	0.5	1.2	51	0/5
ALGCOST	1761	0	4285.9	41	0/20000
SEALCAT	693.7	500	1075.7	49	0/5900
SEALHOUR	1.7	1.5	1.6	49	0/7.5
SEALCOST	19526	8750	36342.8	38	0/200000
BIRDCAT	491.8	300	937.9	47	0/5900
BIRDHOUR	1.2	1	1.4	48	0/7.5
BIRDCOST	9154	3000	13419	37	0/50000
SEKPHOUR	136.2	116	78.0	34	25/400

[5] For more detailed information about the description and treatment of the variables presented here, see Appendix B.

As it is shown in Chart 3, most of the respondents have been fishing for more than 20 years. Both the average and the median respondent to the questionnaire is a fisherman who fishes since 1980, which indicates that most of the respondents have a considerable experience of eel fishing conditions on the west coast.

Chart 3



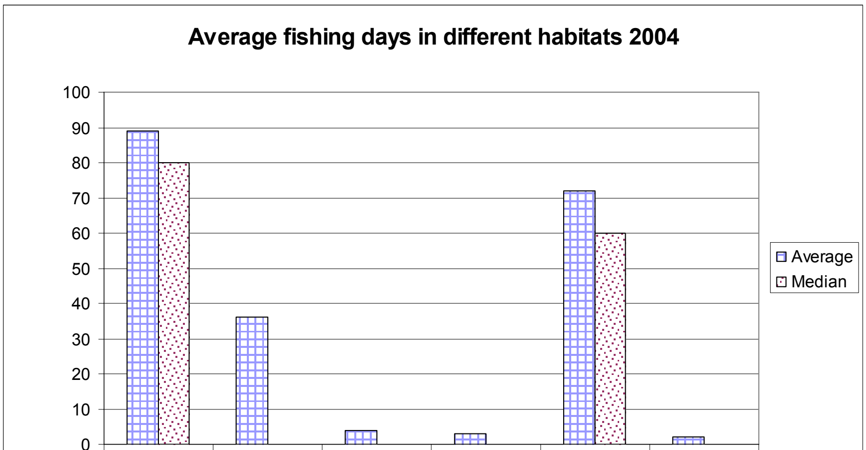
The questions about harvest focused on the situation in 2004 and during this year, the average fisherman caught 2.8 tons of eel, 0.4 of which were below the minimum size allowed; he[6] worked around 150 days in total, more than 8.5 hours a day, checking gears every two or three days.

The most used type of gears is fyke nets, in particular double ones. Eel pots are less commonly used.

Even if, when answering to the questionnaire, a number of fishermen made additional comments indicating that they fish in all kinds of bottoms, moving their gears from one place to another the year round, an analysis of the information given about their fishing effort shows that the main habitat for fishing eel on the Swedish west coast is eelgrass meadows (Chart 4). There, the fishermen put most of their effort both in terms of fishing days and in terms of number of gears. The second habitat is the rocky bottoms and the third most preferred alternative is other types of soft bottoms with other kinds of vegetation (not eelgrass). Soft bottoms without vegetation and pure sand bottoms are very seldom used for fishing, according to the answers to the questionnaire.

[6] The use of the masculine pronoun here is a natural choice, since the only woman in our sample fishes together with her husband. Fishing definitely seems to be a very segregated profession, at least is this the situation on the west coast of Sweden.

Chart 4



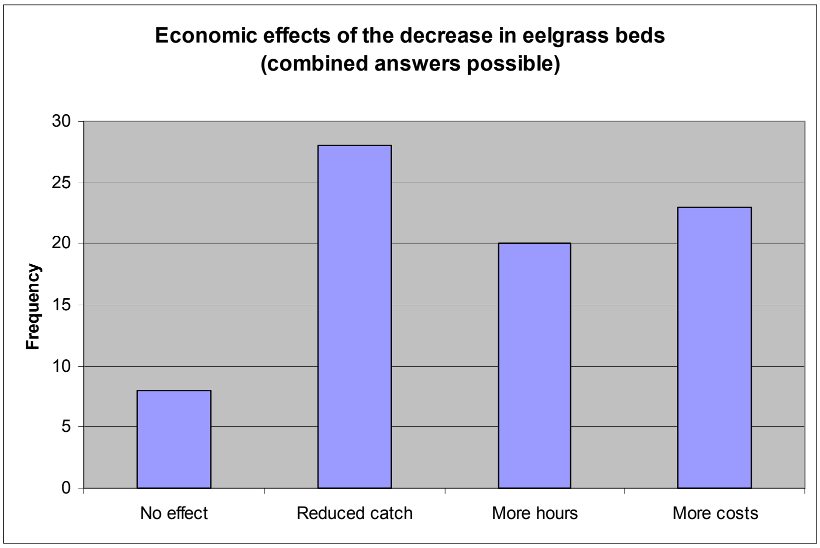
	Eelgrass	Soft bottom with other vegetation	Soft bottom without vegetation	Sand bottom	Hard bottom	Other
Average	89	36	4	3	72	2
Median	80	0	0	0	60	0

As for the habitat loss issue, more than 77% of the respondents report that eelgrass meadows have decreased in the areas where they fish eel. This decrease has occurred for most of them (around 80%) between the years 1985 and 2000. This is coherent with the already mentioned inventories carried out during the 1980s and in the year 2000, showing a 60% decrease of the eelgrass area in the bottoms of the Swedish Skagerrak coast during 10-15 years (Baden et al., 2003).

How did this observed decrease in eelgrass meadows affect the fisheries? For 39% of the fishermen surveyed, the decrease in this kind of vegetated habitat produced a change in the place chosen for setting the gears, i.e., fishermen search for other areas where they find eelgrass to conduct their activity. 35% of the fishermen fish in other types of bottoms, mainly rocky bottoms, while 32% marked the answer “fish other fish species to complement the eel catch”. Other alternatives marked were to use other kinds of gears (changing the type of fyke net used or changing from fyke net to eel pot) or increasing the number or gears used in the fishing.

When it comes to the effects of the decrease in seagrass meadows, as shown by Chart 5, half of the fishermen say that the catches decreased, 35% of the respondents have marked the alternative that the decrease in eelgrass implies more working time, while 40% of the respondents marked the alternative of increasing costs for the activity. It is interesting to analyze these numbers together with specific fishermen comments in question number 20.

Chart 5



In fact, question number 20 offered an open space for the fishermen to describe the importance of different kinds of habitats for the activity. Common answers were: "I fish only where there is eelgrass; no eelgrass, no eel" (fisherman #1); or "eelgrass is very important since I only fish where there is eelgrass (fisherman #49); or even "eelgrass is the most important habitat, but it is difficult to find it nowadays" (fisherman #79). In total, around 25 fishermen spontaneously mention eelgrass as "important", "most important" or "decisive" for the fishing activity, suggesting that the habitat loss has economic consequences. This is subject to further analysis in the next section.

5. Eel fishermen's knowledge in detail – A statistical analysis

Two approaches were followed for understanding and valuing the contribution of coastal habitats to the eel fishery, an indirect and a direct one. The first – the indirect approach – is to estimate a simple production function for eel, on the basis of survey data from part A of the questionnaire. The second approach is to ask the fishermen directly about the role of eelgrass in the fisheries, as is done through questions 13 to 16 of the questionnaire. These two different approaches are presented in the next two sections (5.1 and 5.2), while section 5.3 puts the negative impact of the reduction in eelgrass meadows into perspective by comparing it to the negative effects of some other environmental disturbances faced by eel fishermen on the west coast of Sweden.

5.1. The habitat as an input in the eel production function

Implicit in the questionnaire applied, there is a model where eel catches are supposed to be explained by the geographical area where the fisherman is active;

the effort he uses, in terms of days, hours, and number and type of gears; his experience in terms of the number of years working as a fisherman; and the specific kind of habitat where he sets the gears. This intuitive model of the determinants of eel catch was explored through a statistical analysis of the survey data. Estimation results are summarized in Table 3, which presents the models from the simplest to the most refined one, in the sense that more disaggregated explanatory variables are included in a sequential way.

The dependent variable, as we saw in Table 2, is the fish harvest over the minimum size, expressed in kilograms. We used a simple regression model where the explanatory variables can be divided into three groups:

a) EXPER as an indicator of the years of experience (measured as the number of years the fisherman had been fishing, i.e., the year of the survey, 2004, minus the starting date as a fisherman);
b) DAYS (number of fishing days at sea), HOURS (number of hours worked per day) and ANTALRED (number of gears in use), are general aggregated variables representing effort;
c) DAYS* and NETS* are the disaggregated variables for different habitats, where * indicates the different bottom types where the fishermen fished eel during the year 2004, i.e., EG for eelgrass, SBV for soft bottom with vegetation, SBW for soft bottom without vegetation, and HB for rocky bottom.

A first finding was that the variables associated with the geographical area where the fishermen catch eel did not have any significant impact and were therefore discarded from the analysis.

Model A in Table 3 is basically a decomposition of different elements of effort and the experience variable EXPER and the estimation of this model showed promising results: the coefficients of the effort variables had the expected signs and were significantly different from zero. The model also succeeded in explaining about 2/3 of the variation in catch (adjusted R^2=0.650). However, the experience variable was not significant.

In model B, the most complete of the five models presented, effort is disaggregated by using both the number of days and the number of gears for the different habitat types. However, as can be seen in Table 3, Model B did not work satisfactorily: no habitat variable was significant and the R^2 value was much lower than for model A. A probable explanation for the not encouraging results of Model B is that, except for the eelgrass meadows and the rocky bottoms habitats, all the other habitat variables had very few observations for both days and number of gears and, as could be seen in Table 2, presented zero as their most frequent value. Further, the way in which the number of days in different habitats was measured in the questionnaire was probably not sufficiently detailed, because a model (detailed results not reported here) including habitat variables for days but not for gears (only the aggregated number of gears (ANTALRED) was used) also resulted in a loss of explanatory power.

Table 3 - Estimation results for the statistical analysis of determinants of eel catch
Dependent variable: Y

Explanatory variable	Coefficient estimates (t-ratio)				
	Model A	Model B	Model C	Model D	Model E
CONSTANT	0.553	3.013	-0.385	0.050	0.665
	(0.672)	(2.659)**	(-0.342)	(0.052)	(0.890)
DAYS	0.689		1.004	0.988	0.954
	(3.408)***		(5.111)***	(6.245)***	(6.185)***
HOURS	0.740	1.583	0.910	0.909	0.945
	(2.066)**	(4.829)***	(2.836)***	(2.876)***	(3.013)***
ANTALRED	0.328				
	(1.698)*				
EXPER	0.019	0.096	0.255	0.174	
	(0.106)	(0.489)	(1.722)*	(0.977)	
DAYSEG		0.060			
		(0.362)			
NETSEG		-0.025	0.022	0.021	0.021
		(-0.150)	(2.936)***	(1.836)*	(1.905)*
DAYSSBV		-0.001			
		(-0.001)			
NETSSBV		0.014	0.009		
		(0.034)	(1.217)		
DAYSSBW		-1.117			
		(-1.472)			
NETSSBW		1.090	-0.010		
		(1.475)	(-1.216)		
DAYSHB		-0.095			
		(-0.447)			
NETSHB		0.086	-0.025	-0.028	-0.025
		(0.406)	(-2.746)***	(-2.509)**	(-2.359)**
Number of observations	54	50	50	51	51
Adjusted R^2	0.650	0.369	0.681	0.681	0.682

Notes: Variables explained in text and in Table 2. * denotes significant at 10%; ** significant at 5%; *** significant at 1%.
All regressions used OLS and log variables. When the Breusch-Pagan test indicated presence of heteroscedasticity, White's method was used for computing a robust covariance matrix of the OLS estimators (see, e.g., Greene, 1997).

Model C, which instead includes the aggregated number of days (DAYS) and habitat variables for gears, resulted in a greater explanatory power than model A, see table 3. Moreover, model C indicated a significant impact on catch of the habitat variables for eelgrass (NETSEG) and rocky bottoms (NETSHB). The coefficient of NETSEG had a positive sign, which confirms the important role of eelgrass meadows as a location for harvest. In contrast, rocky bottoms have a negative impact on catch, which might be due to each fisherman having a limited number of gears that he must allocate to the different habitats available for fishing. Since eelgrass is the favorite habitat and the place where most eels are found, allocating gears to rocky bottoms is only a second best option. An increase in the number of gears in rocky bottoms would imply that the number of gears to catch eel in the seagrass environment must be decreased, *ceteris paribus*. The negative sign for the variable NETSHB could be capturing this feature.

Model C also suggests that fishermen's experience as measured by EXPER indeed has a positive influence on catch. However, this impact is not stable for when NETSSBV and NETSSBW were excluded from the analysis because of their insignificance in model C, EXPER once more became insignificant, see Model D in Table 3. Excluding EXPER (Model E) also resulted in an increase in explanatory power to 0.682. While this increase was very slight, model E was used for further analysis of what impact on catch is predicted by changes in one or several explanatory variables.

Model E shows that, as expected, the effort variables 'days at sea' and 'number of working hours' are important explanatory variables for eel catch. Moreover, Model E makes explicit the link between the use of gears in eelgrass meadows and its positive effect on eel catch. It also clearly suggests that if it were possible to remove gears from rocky bottoms and set them in eelgrass meadows, this would increase eel catches, *ceteris paribus*.[7]

In fact, model E predicts that if it were possible to use all the gears in eelgrass areas, instead of rocky bottoms, the fishermen would catch, on average, 13% more eel. Making the change the other way around, i.e., setting all available gears in rocky bottoms instead of in eelgrass meadows would decrease production by 13%. Ignoring possible complementarities between eelgrass meadows and other habitats and forgetting the complex ecosystem relations between habitats and fish populations, it would be possible to apply this percentage to the average annual catch of 2418 kg of eel per fisherman and conclude that an impossibility of fishing on eelgrass would imply a loss of 314 kg of eel per year for every individual fisherman in the Bohuslän and Halland areas. According to Stål and Pihl (2007), there are around 180 km^2 of eelgrass meadows in these two areas. Roughly speaking, this means that if the 180 km^2 of eelgrass meadows that still exist in Bohuslän's and Halland's coastal area were to disappear, there would be a loss in catches of about 314 kg, which means an average of 1.75 kg of eel catch lost for every square kilometer of habitat lost. It is interesting to keep these numbers in mind when we now turn to the answers of the fishermen concerning the economic impact of the decrease in the availability of eelgrass meadows for fishing eel.

5.2. The economic effect of the habitat deterioration

When directly asked about the economic effect of the decrease in the availability of *Zostera marina* for fishing eel, the fishermen state that, on average, there is a catch loss of 475 kg per year; an increase in working hours of 1.6 hours per day; and additional costs (such as higher fuel consumption) of 6455 Swedish kronor per year.

Aggregating these results to the whole population of eel fishermen on the Swedish west coast implies a loss of catch of about 45.6 tons of eel per year and more than 22,300 additional working hours. The fishermen's answers to question 18 suggest

[7] The findings of the model are confirmed by some fishermen's comments, like for example: "since eelgrass meadows have decreased, I am obliged to fish more and more in rocky bottom areas, leading to extra wear of the gears" (fisherman #18).

that their average salary for one hour of work is 136.2 Swedish kronor. Given a price of eel of 60 SEK/kg[8], the total economic loss[9] derived from the habitat deterioration would be:

Total loss = cost of extra working hours + value of catch lost + extra costs

The economic loss derived from the habitat loss would, for the whole population of eel fishermen on the west coast, be equal to 6.4 million Swedish kronor per year. If we take the information of the respondents to the survey and extrapolate to the whole population of 96 fishermen, we find that this economic loss amounts to more than 40% of what would be the total revenues of the catches in the year 2004.[10]

It is important to here consider the risk of fishermen giving biased answers to the direct questions about the consequences of eelgrass loss. There could be an interest for the fishermen in overestimating their losses. However, the results of the indirect approach presented in 5.1 confirm the high importance of eelgrass meadows in the eel production function. In addition, the responses can be related to the fact that Baden et al. (2003) and Phil et al. (2006) found out that the eelgrass meadows in the county of Bohuslän have decreased from 320 to 130 km^2. Assuming that also eelgrass areas in Halland have experienced this 60% decrease, this implies a loss from about 450 km^2 to today's 180 km^2 in Bohuslän and Halland (Stål and Pihl, 2007). If we consider the loss in catch indicated as a yearly average by the fishermen for 2004 (475 kg) , this suggests that, on average, there has been a loss of 1.76 kg in catch for every square kilometer of habitat lost (475 kg/270 km^2). This number is close to the estimated loss per km^2 of habitat lost from section 5.1. These two findings suggest that the information given by the fishermen is anchored in reality and is not the result of strategic behavior. Other studies, for example, Poizat and Baran (1997), also show coherence between fishermen's answers and data obtained by other kinds of data gathering, concluding that fishermen's ecological knowledge should not be ignored in scientific investigations.

5.3. The decrease in eelgrass meadows and other disturbances to the fishing activity

Different environmental disturbances affect the eel fishing activity and have, over the years, shown to have serious economic effects. For example, the damages produced by seals to Swedish fisheries in general have been studied by Westerberg et al. (2000) and, for the year 1997, have been estimated to reach 500 tons of catch lost – around 22 million Swedish kronor.[11] The seals are considered to be the most

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[8] NFB and SCB (2006). From Tables 1.1 and 1.2 in “Fakta om svenskt fiske”, we get an average eel price of 60 Swedish kronor for the year 2005.

[9] Some fishermen have probably left eel fisheries because of the eelgrass decline and might have gotten an improved economic situation because of this, so this loss might apply to those fishermen who remained in the fisheries.

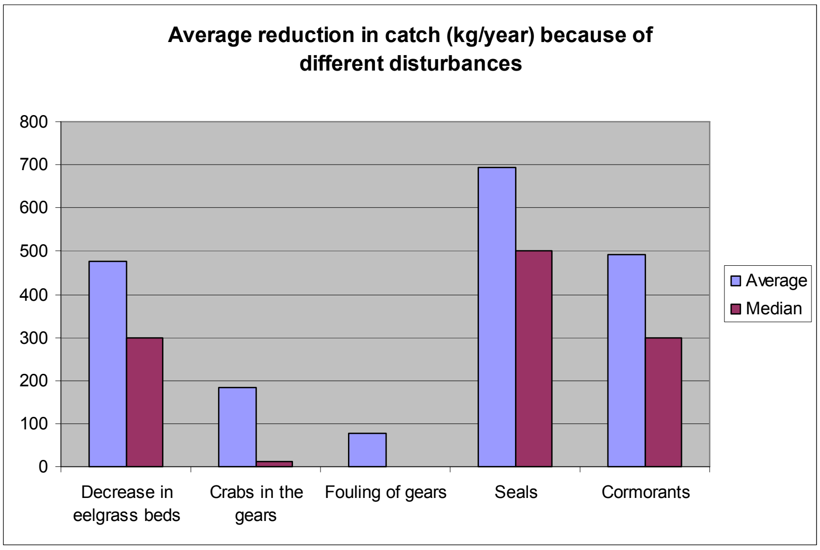
[10] If each fisherman catches 2418 kg of eel, and the price of eel is SEK 60, the total revenues of catches in 2004 would be around 14 million SEK.

[11] Cf. Westerberg et. al., 2000, p. 24. Recent news refer to between 50 and 60 million Swedish kronor of damage to Swedish fisheries in general from the action of seals every year (*Dagens Nyheter*, 14 November 2006).

important single factor damaging the eel fishery on the Swedish west coast and "the eel fishery is the Swedish West Coast fishery with the largest damages from seals or cormorants" (Königson et. al., 2003, p. 5). Other environmental factors that have a negative effect on eel fishery on the west coast of Sweden are the presence of crabs in the gears, the fouling of gears and the already mentioned predation by cormorants. In order to evaluate the negative impact of the decrease in seagrass meadows on the eel fishing activity on the west coast, we compare it to the impact of these other disturbances.

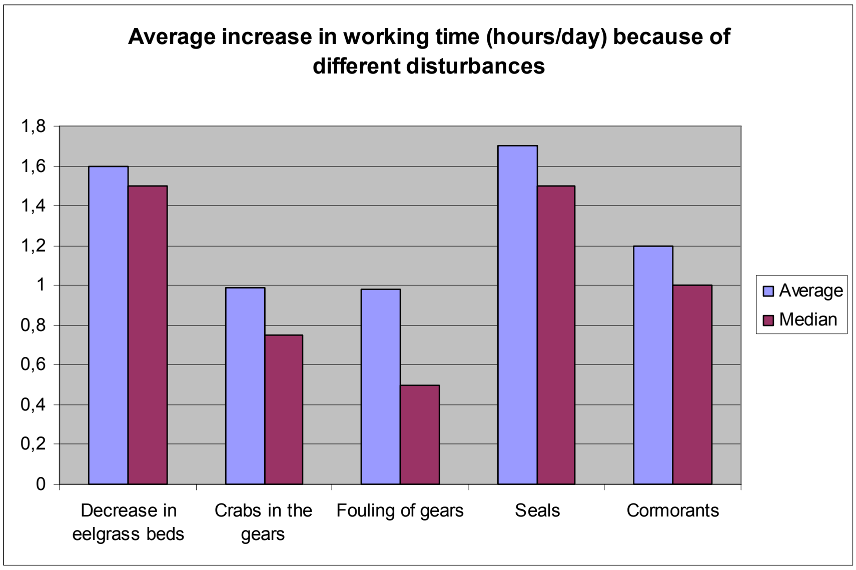
Chart 6 shows that, in terms of catch loss, the decrease in eelgrass meadows is, on average, the third most important factor affecting the fishery, very closely competing with the presence of cormorants.

Chart 6



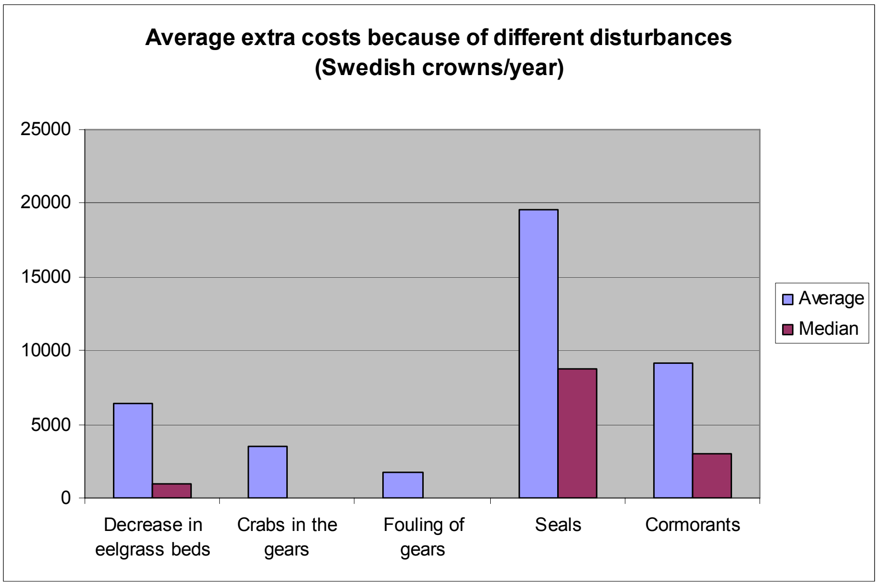
In terms of increase in working hours, the habitat loss is even more important than cormorants, becoming the second most important disturbance to eel fishery, as shown in Chart 7.

Chart 7



In terms of additional costs, the decrease in eelgrass meadows once more appears in third place, as shown in Chart 8.

Chart 8



In any case, what these three charts show is that the loss in eelgrass meadows on the Swedish west coast is an important factor negatively affecting the eel fisheries and should, therefore, rank among the problems requiring attention from public policy.

6. Discussion

In the last two decades, the Swedish west coast has been suffering a process of habitat loss, with a reduction in the area of eelgrass meadows amounting to 60% of the previously existing area. This environmental degradation, partly produced by anthropogenic causes, partly caused by natural factors, has different ecological and economic impacts (Pihl et. al., 2006).

To illustrate the problem of habitat loss and its economic effects, this paper focused on the impact of the decrease in the area of *Zostera marina* on eel fisheries. Due to the lack of information available to analyze the issue, a survey was conducted to gather information directly from the resource users, i.e. the eel fishermen in the Kattegat and Skagerrak regions.

The eel fishermen interviewed, almost 60% of the total population of eel fishermen in the area, stated that they have noticed the decrease in the availability of seagrass for their fishing activity, and their information coincides with the scientific inventories conducted in the area. They have also informed us about the economic impact of this habitat loss, in terms of catch loss, extra working hours and extra costs. The information gathered allowed us to compare the importance of the reduction in *Zostera marina* with other disturbances affecting the eel fishery.

The statistical analysis presented in this paper confirmed the fishermen's information and showed there to be a statistically significant direct correlation between eel catches and the kind of habitat where the fishermen set the gears, with eelgrass meadows showing a significant positive correlation to catches.

The comparison with other disturbances also contributes to unveil the importance of the habitat deterioration in terms of economic losses for the fishermen. One might speculate about whether the fishermen themselves are conscious of this result. For the whole population of eel fishermen on the west coast of Sweden, the loss in eelgrass meadows has implied a yearly loss of more than 6 million Swedish kronor. This loss is sufficiently important to require attention on the part of the public sector. As almost 90% of the Swedish population live close to the coastal areas, the impact of human activities would be expected to tend to increase the environmental degradation of coastal zones.

Eel fishery sustains 2/3 of the fishermen on the west coast or, at least, constitutes their most important source of income. This paper shows that it is not only seals and cormorants that should be taken into consideration. The environmental degradation of the coastal areas, less visible and less present in the demands of the fishermen for financial support, is shown by this valuation exercise to have clear and measurable impacts that might contribute to affect the sustainability of the eel fisheries on the west coast.

References

Baden, Susanne, et. al. (2003), "Vanishing Seagrass (*Zostera marina*, L.) in Swedish Coastal Waters", Ambio Vol. 32, No. 5, August, pp. 374-377.

Biemer, P. P., Lyberg, L. E. (2003), *Introduction to Survey Quality*. John Wiley & Sons, Inc., Hoboken, NJ.

Dagens Nyheter (2006), "Inga fler pengar för sälskador", November 15, http://www.dn.se/DNet/jsp/polopoly.jsp?d=1042&a=588691&previousRenderType=1

Daw, Tim (2003), "The One that Got Away – Strengths and Weaknesses of Fishers' Knowledge for Science and Management", unpublished manuscript, University of Newcastle.

Dekker, W. (2003), "Did lack of spawners cause the collapse of the European eel, *Anguilla anguilla*?, *Fisheries Management and Ecology*, 10, 365-376.

Dekker, W.illem (2003a), "Eel stocks dangerously close to collapse", (http://www.ices.dk/marineworld/eel.asp (2005/12/18)).

Dekker, W. (2004), *Slipping through our hands – Population dynamics of the European eel*, University of Amsterdam, the Netherlands, 11/10/2004, (http://www.diadfish.org/doc/these%202004/Dekker-Thesis-eel.pdf (2006/01/10)).

Frost, Hans, et. al. (2001), *A socioeconomic cost-benefit analysis of the use of glass eel*, Report nr. 118, The Danish Institute of Food and Resource Economics, April.

Greene, W. H., 1997. *Econometric Analysis, Third Edition*. Prentice-Hall, Inc., Upper Saddle River, NJ.

ICES, Cooperative Research Report, unknown number, (http://www.fiskeriverket.se/laboratorier/sotvatten/projekt/pdf/Aal_ICES_advice.pdf (2005/11/29))

Königson, Sara, Lunneryd, Sven-Gunnar and Lundström, Karl (2003), "Sälskador i ålfisket längs den svenska västkusten: En studie av konflikten och dess eventuella lösningar", Fiskeriverket, Finfo 2003:9.

NBF (2006), *Fakta om svenskt fiske,* Fiskeriverket (National Board of Fisheries), Göteborg.

NBF (2001), *Småskaligt kustfiske och insjöfiske – en analys*, Fiskeriverket (National Board of Fisheries).

NBF (2004), "Den Gåtfulla Ålen", f-Fakta 2004:18, Fakta om fisk, fiske och fiskevård. Fiskeriverket (National Board of Fisheries) http://www.fiskeriverket.se/laboratorier/sotvatten/projekt/pdf/aal_faktablad_fiv.pdf (downloaded December 13, 2006)

Neis, B., Schneider, D. C., Felt, L., Haedrich, R. L., Fischer, J., and Hutchings, J. A. (1999), "Fisheries assessment: what can be learned from interviewing resource users?", *Can. J. Fish. Aquat. Sci.*, 56: 1949-1963.

Pihl, Leif, et. al. (2006), "Shift in fish assemblage structure due to loss of seagrass *Zostera marina* habitats in Sweden", *Estuarine Coastal and Shelf Science XX*, pp. 1-10.

Poizat, Gilles and Baran, Eric (1997), "Fishermen's knowledge as background information in tropical fish ecology: a quantitative comparison with fish sampling results", *Environmental Biology of Fishes* 50: 435-449.

Sandström, Olof (2000), "Fisk och fiske i svenska kustvatten", *Fiskeriverket Rapport 2000:1*, Fiskeriverket, april.

SCB (Statistiska Centralbyrån) 2005. Saltsjöfiskets fångster under december 2004 och hela år 2004 [Swedish sea-fisheries during December 2004 and the year 2004]. Statistiska Meddelanden JO 50 SM 0501. Statistics Sweden, Stockholm.

Spalding, M., Taylor, M., Ravilious, C., Short, F., Green, E., 2003. Global overview: the distribution and status of seagrasses. In: Green, E.P., Short, F.T. (Eds.), World Atlas of Seagrasses: Present Status and Future Conservation. University of California Press,

Berkeley, USA, ISBN 0-520-24047-2, 298 pp. (prepared by UNEP World Conservation Monitoring Centre).
Stål, Johan, and Pihl, Leif, "Quantitative assessment of the area of shallow habitat for fish on the Swedish west coast", *ICES Journal of Marine Science*, Vol. 64, in press.
Svedäng, H. (1999), "Vital population statistics of the exploited eel stock on the Swedish west coast", *Fisheries Research* 40:251-265.
Söderqvist, Tore (2003), "Are farmers prosocial? Determinants of the willingness to participate in a Swedish catchment-based wetland creation programme", *Ecological Economics* 47, pp. 105-120.
Westerberg, Håkan, Fjälling, Arne and Martinsson, Anders (2000), "Sälskador Idet svenska fisket – Beskrivning och kostnadsberäkning baserad på loggboksstatistik och journalföring 1996-1997", Fiskeriverket Rapport 2000:3, pp. 3-38.
Wickström, Håkan, (2005), *Anguilla anguilla, Faktablad,* ArtDatabanken, 2005-05-11. (http://www.fiskeriverket.se/laboratorier/sotvatten/projekt/pdf/aal_faktablad.pdf (2005/12/18))

Appendix A – Questionnaire

The Beijer International Institute of Ecological Economics –
The Royal Swedish Academy of Sciences

HOW DO ENVIRONMENTAL CHANGES AFFECT YOUR EEL FISHING ACTIVITY ECONOMICALLY?

This is a questionnaire survey carried out by the Beijer Institute of Ecological Economics (one of the research institutes of the Royal Swedish Academy of Sciences), in cooperation with Kristineberg Marine Research Station in Fiskebäckskil. The survey is part of a research project that , among other issues, deals with the importance of different types of sea bottoms for fish and fisheries. Eel is one of the species that we study. With the help of your answers, we want to show how different environmental changes economically affect eel fisheries.

Answer all questions. **If a question is difficult, it is still better to give an approximate answer (or an interval) than giving no answer at all.** Send the booklet as soon as possible in the enclosed postage-free envelope. We will also call a sample of those who got the questionnaire and collect answers by telephone.

Thank you in advance for your answers!

A. GENERAL INFORMATION ABOUT YOUR EEL FISHING ACTIVITY

1. Where do you fish eel? Indicate the geographic area (for example Southern Gothenburg Archipelago, along Orusts North coast, and so on).
   Answer:
   ____
   ____
2. For how long have you been fishing eel?
   Answer: *Since year* _________.
3. Did you carrry out your eel fishing together with somebody else during 2004?
   ☐ *Yes* → **Go to question 4**
   ☐ *No* → **Go to question 7**

4. With how many other people did you carry out your fishing in 2004?
   Answer: ________
5. Did the/those person(s) with whom you carried out your fishing in 2004 also get this questionnaire?
   - ☐ *Yes* → **Go to question 6**
   - ☐ *No* → **Go to question 7**
6. We would ask you to coordinate your answers with the person(s) you carried out your fishing with. Either one of you answers for both/all, or you should divide the information among you, for example, catch, working time, costs, in an appropriate way, in order to avoid double counting. In which way do you coordinate for answering?
   - ☐ *I answer for both/all.* → The answers to the questionnaire should refer to your **total** eel fishing.
   - ☐ *I and he/she/they answer for each one of us.* → The answers to the questionnaire should refer to **your share** of your total fishing.
7. How big was your catch of eel above the minimum size and under the minimum size in 2004?
   Answer: ________________ *kg over the minimum size, and*
   ________________ *kg under the minimum size.*
8. How often do you go through the fishing nets and collect the catch? Indicate an average for the 2004 season.
   - ☐ *Every day*
   - ☐ *Every other day*
   - ☐ *Every third day*
   - ☐ *Other:* ________________________________
9. How many days did you work with fishing eel in total (including preparations, gear maintenance, etc.) in 2004?
   Answer: __________ *days.*
10. How many hours per fishing day do your normally work fishing eel (including preparations, gear maintenance, etc.)?
    Answer: __________ *hours per day.*
11. How many gears did you use for fishing eel in 2004?
    Fill in the table with the number of gears.

	Number of gears
Simple fike nets	
Double fike nets	
Eel pots	

12. In which type of bottom did you fish eel during 2004?
Fill in number of days, number of gears per day and type of gear in the table.

	Number of days in 2004 that I fished in each type of sea bottom	*Number of gears I normally used per day in each type of sea bottom*	*Type of gear (simple fike nets, double fike nets or eel pots)*
Eelgrass meadows			
Soft bottom with other vegetation then eelgrass			
Soft bottom without vegetation			
Sand bottom			
Rocky bottom			
Other bottom: __________			

B. SEAGRASS MEADOWS AND YOUR FISHERY

13. Different investigations indicate that the extent of seagrass meadows has decreased during the last decades. Have you observed this kind of decrease in the areas where you fish eel?
   - ☐ *Seagrass meadows have decreased in the area where I fish.* → **Go to question 14**.
   - ☐ *Seagrass meadows have not decreased in the area where I fish.* → **Go to question 17**.
14. Since when have you noticed this decrease in seagrass meadows?
   Answer: *Since (year)* ____________.
15. How has this decrease in seagrass meadows affected your eel fishing? Mark one or several alternatives.
   - ☐ *Not at all.*
   - ☐ *I use more gears instead.*
   - ☐ *I fish in other seagrass meadows instead.*
   - ☐ *I fish in other kinds of bottoms instead, like for example* (mention type of bottom)*:* ______________________________________
   - ☐ *I complement my eel fishing with other fishing instead.*
   - ☐ *I use other kinds of gears instead.*
   - ☐ *I use eel pots instead of fike nets.*
   - ☐ *Other changes:* ______________________________________

16. Have you noticed that the decrease in seagrass meadows has had any economic effects for you? Take the situation during 2004. Mark one or more alternatives. Try to answer to the subsequent questions, rather with an approximate answer (or an interval) than not at all.

- ☐ *Yes, eel catches have decreased.*
  → Indicate your estimate of the yearly decrease in catches of eel over the minimum size: _____________ *kg/year.*
- ☐ *Yes, it has implied more working time.*
  → Indicate your estimate of how many extra work hours per day ______________ *hours/day.*
- ☐ *Yes, it has resulted in more costs* (for example, higher fuel consumption, development of new tools, etc).
  → Indicate your estimate of increase in costs per year: ____________ *kr/year.*
- ☐ *No.*

C. OTHER DISTURBANCES TO YOUR EEL FISHING

17. Seen from a whole year's perspective and for the whole activity, in which ways do the following natural factors disturb your eel fishery? Take the situation in 2004 as the basis and indicate in the following table what are the consequences of every type of disturbance, in terms of:
– decreased catches of eel over the minimum size
– extra working time and
– extra costs (for example, more fuel consumption, development of gears, need for extra gears and so on)

18. (Try to answer to the subsequent questions, rather with an approximate answer (or an interval) than not at all). Answer zero if the natural factor does not lead to any disturbance in your eel fishery).

	Decrease in catch (kg/year)	Extra working hours (hours/day)	Extra costs (Swedish kronor/year)
Crabs in the gears			
Fouling of gears (for example, algae and other organisms)			
Seals			
Cormorants			
Others: ___________			
Others: ___________			

19. In order to know the economic effect of the extra working time, we would like to know how much you estimate that each working hour is worth for you (gross value, before taxes). Take the situation in 2004 into consideration. (You can consider this as the total income minus the total variable costs and divide that by the total working hours).
    Answer: ________________ *Swedish kronor.*

D. CONCLUDING QUESTIONS

20. How would you describe the evolution of eel fishery during the years you have been a fisherman?
    Answer:____

21. How would you describe the importance of different types of bottom for your fishing activity?
    Answer:____

22. Would you like us to send you a report describing the results of this survey?
    ☐ *Yes*
    ☐ *No*
23. Would you be available for an interview about this questionnaire?
    ☐ *Yes*
    ☐ *No*

E. COMMENTS

You are welcome to write extra comments here:
____
____
____
____
____

Thanks for your participation!

Please send your answers in the enclosed prepaid envelope. In case you don't have the envelope available, just send your answers in a normal envelope to the following address. You don´t have to pay for the postage.
Beijerinstitutet
Kungl. Vetenskapsakademien
SVARSPOST
Kundnummer 110 301 700
110 50 Stockholm
Questions? The contact person at The Beijer Institute is Tore Söderqvist, e-mail tore@beijer.kva.se, phone # 08-6739500, 070-4937473.

Appendix B – Variables and value imputation procedures

The following table presents the variables used in the paper and their description. The subsequent paragraphs explain the imputation procedures used.

Variable name	Variable description
NORLYSE	Geographical area North Bohuslän
SOULYSE	Geographical area South Bohuslän
HALLAND	Geographical area Halland
EXPERT	When started fishing activity (year)
Y	Fish harvest (over minimum size, kg)
YNOSIZE	Fish harvest (under minimum size, kg)
CHECK	Frequency of checking the nets (days)
DAYS	Number of working days
HOURS	Number of working hours
SIMPLE	Number of gears, simple fyke nets
DOUBLE	Number of gears, double fyke nets
EELPOT	Number of gears, eel pot
DAYSEG	Number of days eelgrass
DAYSSBV	Number of days soft bottom with other vegetation
DAYSSBW	Number of days soft bottom without vegetation
DAYSSAND	Number of days sand bottom
DAYSHB	Number of days rocky bottom
DAYSOTHE	Number of days other bottom types
NETSEG	Number of gears eelgrass
NETSSBV	Number of gears soft bottom with other vegetation
NETSSBW	Number of gears soft bottom without vegetation
NETSSAND	Number of gears sand bottom
NETSHB	Number of gears rocky bottom
NETSOTHE	Number of gears other bottom types
DECREEG	Decrease in eelgrass (yes=1, no=0)
WHEN	Since when decrease in eelgrass
WHAT	Changes in fishing activity (no=0, yes=1,2,3,4,5,6,7)
EFFECTS	Effects of decreasing eelgrass (no=0; yes=1,2,3)
MINCATCH	Decrease in catches
MORHOURS	Increase in working hours
MORECOST	More costs
CRABCATC	Decrease in catch because of crabs (kg/year)
CRABHOUR	Extra time because of crabs (hours/day)
CRABCOST	Extra cost because of crabs (crowns/year)
ALGCATCH	Decrease in catch because of algae (kg/year)
ALGHOURS	Extra time because of algae (hours/day)
ALGCOST	Extra cost because of algae (crowns/year)
SEALCAT	Decrease in catch because of seals (kg/year)
SEALHOUR	Extra time because of seals (hours/day)
SEALCOST	Extra cost because of seals (crowns/year)
BIRDCAT	Decrease in catch because of cormorants (kg/year)
BIRDHOUR	Extra time because of cormorants (hours/day)
BIRDCOST	Extra cost because of cormorants (crowns/year)
SEKPHOUR	Value of one working hour (crowns)

When analyzing the answers to the questionnaire, we realized that some questions were in a few cases [probably as long as we are talking about really few, I would say not more than 5 or so] not answered as they should be. For example, some fishermen gave a "yes" answer when they were asked to fill in a quantity. In such a case, we assumed that a "yes" answer indicated a willingness to answer with a positive number that was not known or that the respondent was uncertain about what to answer. In some cases, for example, the respondent gave a number of working days, without indicating the number of hours of work per day. Or worse, there were a few cases where the hours were given, without indicating the number of working days. The same problem was observed in question 16, where some respondents indicated the number of gears used in different habitats, without indicating the number of days. Or in question 17, when some answered "yes" to extra time, extra cost or decrease in catch, without giving a quantitative answer as expected.

In each of these few cases, in question 12, we imputed values following a direct modeling approach to imputation (Biemer and Lyberg, 2003): imputation was based on regression models that either linked days in different habitats to the total number of fishing days (for example, DAYSHB = 26.94 + 0.322 DAYS); or number of gears in different habitats to the total number of gears (NETSHB = 14.89 + 0.22 ANTALRED).

A simpler imputation approach was followed for "yes" answers to question 17: the value imputed was equal to the median value computed without including zero answers to the question. In that way, by computing a positive value to the "yes" answers related to the importance of different factors negatively affecting eel fishery, we avoid the risk of overestimating the importance of the loss in eelgrass as a disturbance factor affecting the activity.