Using Expert Knowledge to Identify Possible Groundfish 'Essential Fish Habitats'

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Abstract
Despite over a century of exploitation of fish in European waters, scientists know surprisingly little about the precise distribution of the major commercially exploited fish species, and their habitat requirements. This is the first European study that aims to identify essential fish habitats of commercially important fish species (cod, haddock, whiting, plaice, sole, plaice, lemon sole) in the Irish Sea and the English Channel (UK). Areas of the seabed that harbour the highest densities of these species were identified and mapped using an existing database spanning 12 years' data from national stock assessments.

Demersal fishers observe samples from the sea floor every time they haul their nets, which far exceed the sampling schemes that scientists can afford or mobilise. Experienced fishers may have decades of observations to bring to bear and keep detailed records of exactly where and when they fish and how much they catch. Although the ultimate goal of fishing is to provide income from the catch, rather than to test scientific hypotheses, many fishers seek to understand the very questions about the seabed that motivate our study. Therefore, we decided to liase with the fishing industry to refine our broad scale fish maps for future survey. Information was gathered in a pilot study through questionnaires filled in at a fishing exhibition. Through a process of informal presentations and meetings, fishermen have helped us to refine our studies by pinpointing fishing grounds of importance for the fish species in question. The co-operation with fishers has not only added to the credibility of the study and any management decisions that may depend on its findings, but has also highlighted once more the vast amount of knowledge that can be gained from this declining species.

Introduction
Habitats used by marine fish are generally 'hidden' underwater, and may, therefore, have received less attention from scientists than more obvious and accessible terrestrial faunas (Koehn 1993). As with terrestrial species, fish may be dependent upon the availability of certain habitat types, and alterations to such areas may be partially responsible for the recently witnessed decline in the world fisheries (FAO 1995), and should therefore be addressed in fisheries science and management (Benaka 1999). Despite centuries of intensive commercial exploitation of fish in European waters, scientists know relatively little about the variation in the small-scale distribution of the major commercially exploited marine fish species, and their habitat requirements. Freshwater biologists, by contrast, have an extensive tradition of research that has focused on the habitat requirements for fish (e.g. Keast *et al.* 1978; Ebert and Filipek 1988; Koehn 1993). In recent years, the wider ecological effects of fishing have become a global environmental concern (*e.g.* Dayton *et al.* 1995; Jennings and Kaiser 1998; Collie *et al.* 2000). Consideration (and mitigation) of the effects of fishing on marine habitats that are critical for certain life-stages of commercially important fish species became a legal requirement in the United States with the reauthorisation of the Magnuson-Stevens Fisheries Conservation and Management Act (1996). These habitats have been termed 'Essential Fish Habitats' (EFH) and would include areas that are spawning and nursery grounds, provide specific feeding resources and shelter from predators, or form part of a migration route (Benaka 1999). This new emphasis on EFH has resulted in a number of studies in North America (see Banaka 1999; Coleman *et al.* 2000). The present study is the first in Europe that specifically aims to identify the EFH for cod (*Gadus morhua* L.), haddock (*Melanogrammus aeglefinus* (L.)) and whiting (*Merlangius merlangus* (L.)) in the Irish Sea.

Haddock, cod, whiting and plaice (*Pleuronectes platessa* L.) accounted for 52% of the demersal species landed by UK vessels in 2000 (DEFRA 2000). National landings of haddock and cod have generally decreased from *ca* 90,000t and 75,000t to 53,000t and 42,000t, respectively, between 1996 and 2000 while landings of whiting and plaice decreased between 1996 and 1998, but have remained constant between 1998 and 2000. Fishing effort remains very high, while spawning stocks have fallen below the precautionary level, and the numbers of young

fish have generally declined since 1990, raising concerns about the risk of stock collapse.

In general, the spawning grounds and nursery areas of many species of fishes are well known. In contrast, we know relatively little about the specific habitat requirements of fish during different parts of their lives. One component of essential fish habitats, which to date has received relatively little attention, would constitute those areas in which fish are able to feed effectively and reduce their risk of predation.

It is well known that certain fish species are associated with specific habitat features (*e.g.* reefs, sandbanks), a fact used by fishers to target particular species. Demersal fishers observe samples from the seabed each time they haul their nets, which far exceed the sampling schemes that scientists can sustain (Maynou and Sardà 2001). Furthermore, experienced fishers may have knowledge based on decades of observations, and that has been passed down from one generation to the next (Freire and García-Allut 1999; Sardà and Maynou 1998). In addition, they often keep detailed records of exactly where and when they fish and how much they catch. Present day ship-based electronic instruments permit fishers to see first-hand the link between different seabed types and textures. Although the ultimate goal of fishing is to provide income from the catch, rather than to test scientific hypotheses, many fishermen seek to understand the very questions about the seabed that motivate our study. Despite this obvious wealth of experience, and the fact that the Magnuson-Stevens Act requires the National Marine Fisheries Service (USA) to consult with fishers before submitting its advice, few studies, to our knowledge, have sought to consider or integrate fishers' views and knowledge on EFHs (but see Pederson and Hall-Arber 1999). The need to improve the collaboration between scientists and the fishing industry is widely recognised by scientists and fishers alike (*e.g.* Mackinson and Nøttestad 1998; Taylor 1998; Freire and García-Allut 1999; Baelde 2001; Maynou and Sardà 2001; Marrs *et al.*, in press). The involvement of the fishing industry in fisheries science might not only improve the credibility of fisheries science but also enhance the support for any regulations that may be based upon it.

In the present paper, two complementary approaches were adopted to identify possible EFHs. We used existing data from annual national groundfish surveys of fish abundance and biomass and compared them with fishing grounds outlined by fishers. Fishers marked grounds they considered to be important on nautical charts for a finer scale resolution of fish distribution (Taylor 1998). Information on habitat characteristics of target fish was also sought in a questionnaire format.

MATERIALS AND METHODS

Identification of potential EFHs Using National GroundFish Surveys

Areas of seabed, which consistently harbour the highest densities of cod, haddock and whiting in the Irish Sea (ICES division VIIa), were identified using two databases spanning a decade of fishery-independent data from national groundfish surveys. The Centre for Environment, Fisheries and Aquaculture Science (CEFAS, Lowestoft) holds a complete data set from 1990 to 1998. Fish were sampled every autumn using a 4-m beam trawl at fixed stations (Ellis *et al.* 2000). The Department of Agriculture and Rural Development of Northern Ireland (DARDNI, Belfast) database spans a period from 1991-2000. Fish were caught by otter trawling at fixed stations every summer or autumn.

In our analysis, the abundance of each species for each station per year was ranked and a mean rank over time (per station) calculated to identify potential EFHs for further habitat survey (reported elsewhere). Plots of mean abundance or total abundance over a set time period were not considered useful to the identification of habitats that are used consistently from one year to the next. In addition, an exceedingly high abundance of fish in any one year could skew the results. We converted abundance to ranks within each year. Our rationale for using a rank score was that it is most relevant to know which habitat is consistently attractive to fish. These ranks were plotted using ArcVIEW GIS 3.2 software.

Using Expert Knowledge

We consulted with the fishing industry to refine our broad scale fish maps (from bottom trawl surveys) in terms of the seasonal and spatial distribution of fish. The project was first introduced to the fishing community through an article in 'Fishing News', the main national industry paper. It is often not practical to consult directly with individual fishers that spend most of their time at sea, often for more than a week at the time. Therefore, information was gathered in a pilot study through questionnaire-based interviews with maps (n=19) at an annual national fishing exhibition.

The interviews were designed to study fishers' perceptions of the relationship between fish and habitat features, perceived changes to habitats and to gain information about the location of potential EFH. Further information was gathered by sending out revised questionnaires with maps and more detailed information about the project to Sea Fisheries Committees and other relevant fisher's organizations with requests to circulate these among their members. Further interviews were conducted at a fish fayre in Lowestoft (English SE coast fishing port) (n=2) and a fishing exhibition in Newcastle (Northern Ireland) (n= 5). We collated a total of 39 questionnaires and 19 maps. These hand-drawn charts were digitized using ArcVIEW GIS and plotted in a chart format suitable for comparison with the charts generated from the scientific ground fish surveys.

The questionnaire (Figure 1) contained a total of 16 questions (following Pederson and Hall-Arber 1999), only six of which were analysed in this paper (see below). The responses were analysed by calculating the frequency of categories ticked and the frequency of statements made.

RESULTS

Fishing ground locations and distribution of mean ranks of fish abundance

Most fishers were very responsive and helpful during interviews. Following contacts with the Irish Sea Sea Fisheries Committees, the Fleetwood Fish Forum provided a high-resolution chart detailing the seasonal distribution of commercial fish species in the eastern Irish Sea (Fig. 2). Figure 2 represents the aggregated knowledge of 50 fishers that have outlined information gathered over a period of *ca* 50 years. More responses were obtained from contacts with Sea Fisheries Committees and Fisheries Producer Organizations but many of these 'mail shots' were answered by respondents that worked outside the Irish Sea or that targeted other species. Eighteen fishers out of 40 (excluding Fleetwood) plotted fishing ground locations on charts but only eight of these were located in the Irish Sea.

The geographical position of the fishing grounds outlined by fishers for cod, haddock and whiting were similar (Figs 3a-c). The main fishing grounds for these species appeared to be located between the north of the Isle of Man, southwest of Scotland and around the Solway Firth (NW England). It should be noted that several fishers highlighted areas in this region and north off the Welsh coast independently, which increases the confidence in these data. Some of these grounds are no longer visible in Figures 3a-c because they lie on top of each other. Further grounds are located off the Irish and Northern Irish coast and along the North Wales coast.

Similarly, fisheries survey data indicated that the highest mean ranks of cod from the two databases were situated off the Ribble Estuary (NW England), off Belfast Lough (Northern Ireland), off Colwyn Bay/Anglesey (N Wales), the Solway Firth (NW England) and in St George's Channel (Fig. 3a). The distribution of haddock mean ranks was similar to the distribution of fishing grounds (Fig. 3b). No

1. What do you regard as important ground features for your target species ? Please identify seabed structures (e.g. mud, gravel, boulders) or other characteristics of the grounds (e.g. sea weed, sponges) that you associate with your target species:
_____

2. What do you regard as the most important factors that affect the grounds that you fish?
_____

3. Do you think fishing gear has altered the grounds that you usually fish? ☐yes ☐no.
If 'yes' how has it affected the grounds? Please explain:
_____

4. Have you noticed any changes over the time that you have been fishing?
☐target species ☐bottom animals and plants ☐habitat structure ☐fish health ☐bycatch ☐other changes.
Specify:_____

5. Which of the following have you observed over time for the species that you target?
☐no change ☐increase ☐decrease ☐moved to other areas ☐replaced by another species ☐decrease in size
Please describe your observations:_____

6. If you noticed a change to the grounds or species that you fish, please indicate what you think may be the cause(s): ☐climate☐pollution ☐changes in fishing gear ☐changes in prey abundance
☐habitat loss ☐overfishing ☐other
Please explain:_____ _____

Figure 1: Questionnaire format used in interviews and mail shots.

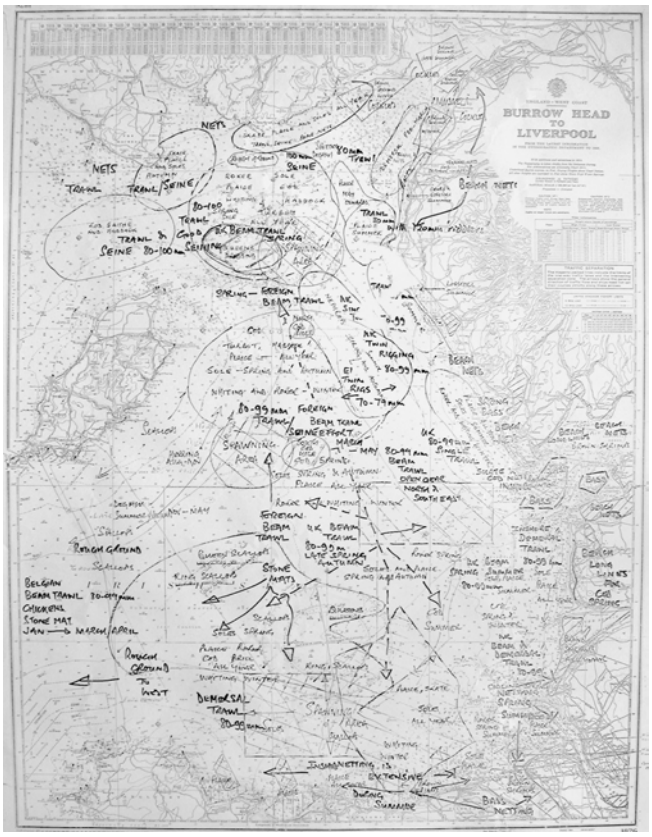
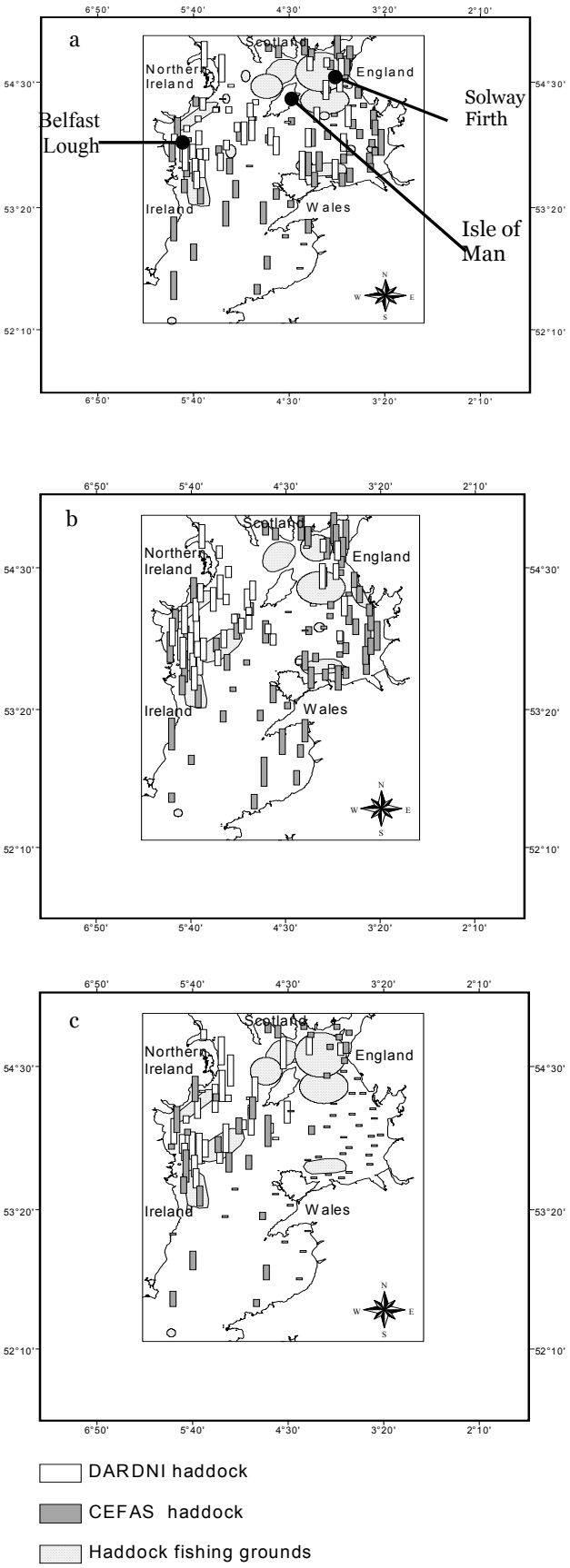


Figure 2. Chart with important fishing ground locations provided by the Fleetwood Fish Forum

haddock fishing grounds were outlined at the low abundance stations off the English coast. There was less consistency between the whiting fishing ground locations and the distribution of the higher mean ranks of whiting (Fig. 3c). For example, no whiting fishing grounds were outlined off the Ribble Estuary, an area with high mean ranks of whiting but this may be explained by a low mean size of fish.

Questionnaires

Question 1. Cod, haddock and whiting were targeted by 16 out of 39 total respondents. The most important ground types stated for cod included sand (56%), mud (56%), 'hard' ground (comprises the categories boulders, cobble, rocks, stones, 'rough') (44%) and gravel/shingle (31%) (Fig. 4). For haddock the most frequently stated ground types were hard grounds (69%), sand (56%), mud (50%) and gravel/shingle (38%) while important grounds for whiting comprised mud (56%), sand (50%), hard grounds (31%) and gravel/shingle (31%) (Fig. 4).



Figures 3a-c. Distribution of mean ranks of fish abundance (bars) in the Irish Sea from 1990 to 2001 and fishing ground locations as outlined by fishers.

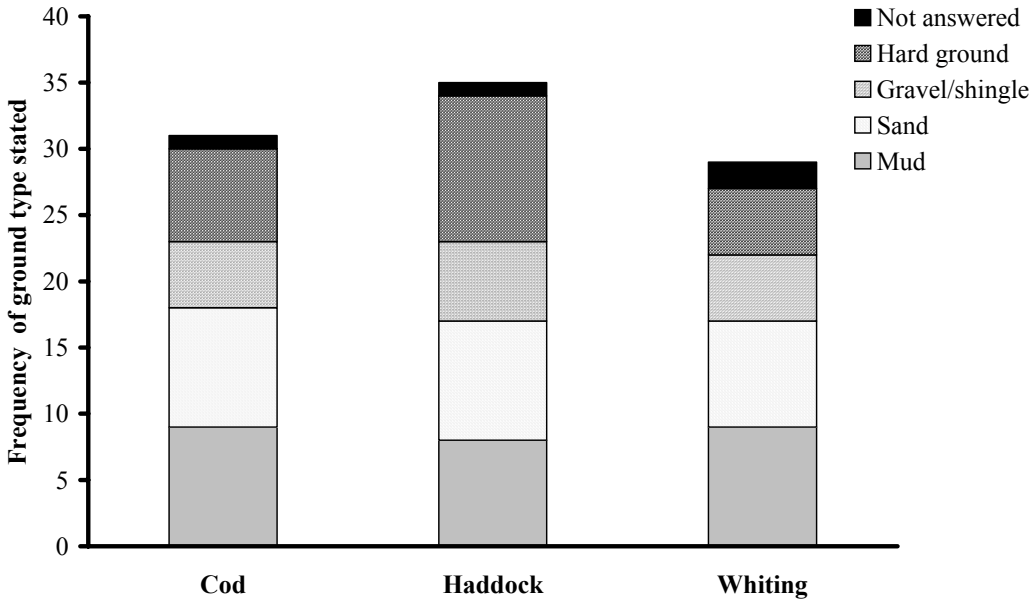


Figure 4: The most important ground types stated for cod included sand (56%), mud (56%), 'hard' ground (comprises the categories boulders, cobble, rocks, stones, 'rough') (44%) and gravel/shingle (31%)

The most frequent stated habitat features for cod were sand, feed (meaning the ground contained food for the fish), hard grounds (each 25%), wrecks, gravel (each 19%), mixed grounds and mussel beds (each 6%). Haddock habitat features included hard grounds (25%), brittlestar beds (19%), feed (19%), gravel, sand, mud (13%), seaweed (we interpret this to mean emergent growths of weed-like bryozoans such as *Flustra spp.*) and mixed grounds (6%). Sandeels (*Ammodytes spp.)* were perceived as important prey items of cod (67%) and haddock (80%), followed by 'small fish' (50% and 60%, respectively) shrimps (25% and 40%, respectively) and small crabs (38% and 20%, respectively). The most frequently stated habitat features for whiting were hard grounds (19%), mud, sand, gravel (13%), sea grass[1] and soft corals (*Alcyonium digitatum*) (6%). The response rate to this open-ended question was relatively low: 25% of the respondents did not comment on cod habitat features, haddock habitat (44%) or whiting habitat (69%).

Question 2. 21% of the respondents named heavy fishing gear such as beam trawls, scallop dredges and twin otter trawls as important factors that affect targeted habitats. Other factors stated included fishing (effort) (21%), feed (15%), weather (15%) and season (13%).

[1]Although the respondent used the term 'seagrass' we doubt that the angiosperm plant was meant. It seems more likely that he used this term for seaweed or weed-like bryozoans or hydroids.

Question 3. Fifty-six percent of the respondents thought that fishing gear had altered their grounds (96% response rate).

Questions 4.-6. A third of the respondents observed changes in their target species such as a decrease in numbers (74%) and size (35%), and only two percent stated that there was no change in their target species (Table 1). These changes were attributed to overfishing (56%), climate (38%) and pollution (36%), changes in fishing gear (28%) and prey abundance (23%).

Discussion

Fishing ground locations and distribution of mean ranks of fish abundance

Although many fishers volunteered to fill in questionnaires, fewer were willing to outline their fishing grounds on charts. This was largely for reasons of confidentiality and due to suspicion that such information might lead to negative management developments for fishers. For example, the information may inform the choice of potential areas for closure or the imposition of further limits on fishing practices (Pederson and Hall-Arber 1999). Furthermore, many respondents worked in areas other than the Irish Sea or targeted other species, which restricted the number of charts used in this paper to eight. The similarity of the fishing grounds outlined for the three different fish species reflects, to some extent, the fact that several fishers did not distinguish between which

Table 1: Results of three questions posed in questionnaires (*n*=39 unless stated otherwise; f= frequency of category checked; %= percentage of frequency)

Changes over time			Changes in your target species			Cause of change		
	f	%		f	%		f	%
Target species	12	31	No change	2	5	Climate	15	38
Bottom animals and plants	12	31	Increase	5	13	Pollution	14	36
Habitat structure	3	8	Decrease	29	74	Changes in fishing gear	11	28
Fish health	1	3	Moved to other areas	5	13	Changes in prey abundance	9	23
Bycatch	7	18	Replaced by another species	2	5	Habitat loss	3	8
No changes	5	13	Decrease in size (*n*=26)	9	35	Overfishing	22	56
Other changes	5	13	Other changes	1	3	Other causes	4	10
Not answered	9	23	Not answered	4	10	Not answered	7	18

species were targeted in the different areas outlined. In those cases, it was assumed that respondents fished for all of their target species in the area outlined although we recognize that it may have been a prime ground for one particular species.

At first sight, it would appear that areas of the highest fish densities obtained from databases do not always coincide with those given by fishers. For example, cod, haddock and whiting densities were generally high along the (Northern) Irish coastline according to the fisheries survey bases, whereas many fishers highlighted grounds off the Solway Firth (S Scottish and N English coast). This, however, may partly reflect a local bias in the port of origin of many of the respondents that attended the fishing exhibition in Scotland at which many of the interviews were undertaken. Owing to logistic problems, it was more difficult to reach (Northern) Irish fishers. It should be noted, however, that two Irish fishermen also outlined grounds off the Solway Firth. An attempt to interview more (Northern) Irish fishers at the Fisheries Co-operative meeting in Newcastle (Northern Ireland) yielded five questionnaires but no charts as many fishers targeted shellfish, or were unwilling to mark their fishing grounds. After closer inspection of Figures 3a-c, however, it is apparent that the highest mean ranks for haddock and cod coincided with fishing grounds off the Solway Firth (S Scotland and N England) and those off the N Welsh coast. A greater sample size, involving more fishers from (Northern) Ireland, would allow for a less biased comparison between the fishers' data and the groundfish survey data. It is possible that this spatial bias could be circumvented by restricting a spatial analysis of the ground fish survey data to subsets in the vicinity of respondents' ports.

The fishers' information has added to our confidence that high density sites indicated by the fisheries survey data are indicators of areas targeted by fishers, Several fishers highlighted the same grounds in the northern Irish Sea and off Ireland and off Wales. These areas presumably have features that consistently attract fish in sufficient numbers and quality to be of interest to fishers. Some of the discrepancies between the fishers' charts and the groundfish survey data may also lie in the fact that there were relatively few sampling stations located between the N Isle of Man, NW Scotland and NW England. This is probably due to differences in the gear historically used for the CEFAS ground fish survey, a beam trawl, the use of which would be restricted over the rough grounds around the Isle of Man. Recent studies from the NW Atlantic indicate that young cod and haddock prefer habitats of coarse sediment interspersed with rocks (Lough *et al.*,1989; Gotceitas *et al.* 1995; Gregory and Anderson 1997; Lindholm *et al.* 1999). On the other hand, the groundfish survey may include areas that fishers normally avoid because they would catch too much 'rubbish'[2] that may clog up their nets during the longer commercial tows.

Although it could be argued that no 'filter' was incorporated in our questionnaires to test if questions were answered truthfully (Johannes 1981; Maynou and Sardà 2001) we believe that most respondents answered the questions to the best of their knowledge. Maurstad (2000) highlighted that the publication of maps and other information given by fishers in a purely scientific context can put scientists into a dilemma in terms of intellectual property rights and confidentiality. Also the

[2] inert material and by-catch of non-target species

knowledge becomes separated from its sociological context. We decided to publish our results, however, as we feel that the quality of the charts presented here is not sufficiently accurate to pose a threat to any individual respondent's livelihood. Also, it is likely that the information volunteered is known by many fishers.

Questionnaires

Sand, mud and hard grounds were most frequently named as key ground types for all three fish species, although more respondents (69%) considered 'hard' grounds as important for haddock *vs* the other species. In a similar study in the US, fishers indicated that they preferably fished whiting on fine-grained sediments whereas other groundfish were targeted across all habitat categories (Pederson and Hall-Arber 1999). 'Feed' was named as one of the critical sea bed features for cod and haddock. Sandeels were reported to be important prey items of cod and haddock and many fishers were concerned about a decline in sandeels due to an increased effort in industrial fishing over recent years. Information on fish diet can be regarded as particularly valuable as fishers gut high numbers of fish and often observe their stomach contents. Pederson and Hall-Arber (1999) even suggested that trained fishers could sample and preserve stomach contents for scientific purposes.

Interestingly three fishers stated independently that 'wigs' (probably brittlestar beds) are an important habitat feature for haddock, especially after spawning. Although fishers suggested that haddock sought out brittlestar beds to 'clean themselves' after spawning it is known that haddock feed on brittlestars as a grinding substance in their stomachs (Mattson 1992). This emphasizes the potential value of apparently obscure observations made by fishers even though their conclusions may be partially inaccurate.

A few other fishers noted that weed (possibly hydroids or the wide-spread bryozoan, *Flustra spp.*) was often found in their haddock or plaice catches and one fisher also associated whiting with soft corals, *Alcyonium digitatum*. These habitat features may provide fish with shelter from predators or act as foci of prey species (*e.g.* pandalid shrimps). These features of fish habitats are currently the subject of further investigation (Freeman *et al.*, unpublished data). Similar to the findings of Pederson and Hall-Arber (1999), few fishers commented on habitat features other than ground types (see above), and such features were given in interviews rather than in mail shot questionnaires. Fishers often do not know scientific names, especially those of non-target invertebrates, and seem unwilling to offer their own interpretation that may be proven incorrect (Mackinson 2001). It was easier to steer and expand questions during interviews through explanations and by showing images of marine animals that fishers would recognize. In a more comprehensive survey, the provision of a standard photo card showing common marine animals could help to increase the response rate and train fishers that are often keen to expand their knowledge of the marine environment.

More than 50% of the fishers believed that fishing gear has, in some way, altered their grounds. Many recent studies have shown that towed bottom fishing gears have altered the seabed (Jennings and Kaiser 1998). Fishers were also concerned about heavy mobile fishing gear such as scallop dredges, beam trawls and twin otter trawls. Similarly, Collie *et al.* (2000) showed that scallop dredging together with intertidal dredging has the greatest initial impact on benthic biota.

It should be noted that most fishers attributed habitat changes to gear types that were not used by them. Less than a third of the respondents polled in a study in the US believed that fishing gear had changed the grounds (Pederson and Hall-Arber 1999). This difference may be attributed to the fact that in Pederson and Hall-Arber's study fishers were asked if their own gear had altered the grounds. In the same study, more than 50% of the fishers identified mobile gear as the most important factor that affected habitats.

A third of the respondents observed changes in their target species such as a decrease in number and size, which reflect recent trends in the state of the fishery. Overfishing, climate change and pollution were perceived as the most important causes for declines in fish abundance. Again, many fishers complained about the decline of sandeels (due to industrial fishing) as an important food source for their target species, and an increase in seal populations that feed on their target species. The majority of fishers attributed changes to overfishing.

It should be noted that only a few fishers commented on habitat loss over time although many fishers stated that fishing gear smoothes seabed topography and 'damages the ground'. It is possible, that once stated, fishers thought it unnecessary to repeat the statement in

subsequent questions of the questionnaire. Also, fishers may have been unfamiliar and therefore uncomfortable with the term 'habitat', although the meaning was explained either verbally or on enclosed information leaflets and the word 'ground' was used instead in most questions.

Although more time-consuming, questionnaire based interviews on a one to one basis yielded the best data as it enabled the essential establishment of trust between the scientist and the fisher and allowed for elaboration of specific questions when technical terms were unclear. Our consultation with fishers has not only added to the credibility of the study and any future management decisions that may rely on its findings (Maurstad and Sundet 1994), but has also highlighted how our current knowledge can be expanded. Further insights may be gained by an analysis of statements made in questionnaires which are then integrated with biological data using fuzzy logic (Mackinson 2000). The integration of fishers' knowledge into science and management is a potentially invaluable tool that should not be overlooked (Pederson and Hall-Arber 1999).

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