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# Combining Scientific and Fishers' Knowledge to Identify Possible Roundfish Essential Fish Habitats

Melanie Bergmann,[1,2] Hilmar Hinz, Rob E. Blyth, and Michael J. Kaiser
*School of Ocean Sciences, University of Wales-Bangor, Menai Bridge LL59 5AB, UK*

S. I. Rogers
*Centre for Environment, Fisheries and Aquaculture, Lowestoft, UK*

M. J. Armstrong
*Department of Agriculture and Rural Development, Belfast, UK*

***Abstract.*** Fishers have often complained that standard United Kingdom groundfish survey data do not adequately reflect the grounds targeted by commercial fishers, and hence, scientists tend to make over-cautious estimates of fish abundance. Such criticisms are of particular importance if we are to make a creditable attempt to classify potential essential fish habitat (EFH) using existing data from groundfish surveys. Nevertheless, these data sets provide a powerful tool to examine temporal abundance of fish on a large spatial scale. Here, we report a questionnaire-type survey of fishers (2001–2002) that invited them to plot the location of grounds of key importance in the Irish Sea and to comment on key habitat features that might constitute EFH for Atlantic cod *Gadus morhua*, haddock *Melanogrammus aeglefinus*, and European whiting *Merlangius merlangus*. Plotted grounds were cross-checked using records of vessel sightings by fishery protection aircraft (1985–1999). A comparison of the areas of seabed highlighted by fishers and the observations made on groundfish surveys were broadly compatible for all three species of gadoids examined. Both methods indicated important grounds for cod and European whiting off northern Wales, the Ribble estuary, Solway Firth, north of Dublin, and Belfast Lough. The majority of vessel sightings by aircraft did not match the areas plotted by fishers. However, fishing restrictions, adverse weather conditions, and seasonal variation of fish stocks may have forced fishers to operate outside their favored areas on the (few) occasions that they had been recorded by aircraft. Fishers provided biological observations that were consistent among several independent sources (e.g., the occurrence of haddock over brittle star [ophiuroid] beds). We conclude that fishers' knowledge is a useful supplement to existing data sets that can better focus more detailed EFH studies.

## Introduction

Subtidal marine habitats are less accessible and, therefore, have received less attention from scientists than have terrestrial habitats (Koehn 1993). As with terrestrial species, the populations of some species of fish may be dependent upon the availability of certain habitat types. Degradation of fish habitat quality may be partially responsible for recent declines in world fisheries (FAO 1995), and the importance of habitat quality needs to be addressed in fisheries science and management (Benaka 1999). Despite centuries of intensive exploitation of fish in European waters, relatively little is known about the small-scale distribution and habitat requirements of commercially exploited marine fish species. Freshwater ecologists, by contrast, have extensively researched the habitat requirements of fish (e.g., Keast et al. 1978; Ebert and Filipek 1988; Koehn 1993). Since the 1980s, the ecological effects of fishing have become a worldwide environmental concern (e.g., Dayton et al. 1995; Jennings and Kaiser 1998; Collie et al. 2000). For example, a consideration (and mitigation) of the effects of fishing on marine habitat that is critical for certain life stages of commercially important fish species became a legal requirement in the United States with the reauthorization of the Magnuson–Stevens Fisheries Conservation and Management Act in 1996. These habitats have been termed essential fish habitats (EFH) and include areas that are

[1] Corresponding author: mbergmann@awi-bremerhaven.de
[2] Present address: Alfred Wegener Institute for Polar and Marine Reesearch, Am handelshafen 12, 27570 Bremerhaven, Germany

spawning and nursery grounds, provide prey resources and protection from predators, and form part of a migration route (Benaka 1999). This recent emphasis on EFH has resulted in a number of studies based in North America (see Benaka 1999; Coleman et al. 2000). The present study is the first in Europe that specifically aims to identify key habitats (EFH) for Atlantic cod *Gadus morhua*, haddock *Melanogrammus aeglefinus*, and European whiting *Merlangius merlangus* in the Irish Sea (northeastern Atlantic).

Haddock, Atlantic cod, European whiting, and plaice *Pleuronectes platessa* accounted for 52% of the demersal species landed by UK vessels in 2000 (DEFRA 2000). National landings of haddock and Atlantic cod have decreased from approxiimately 90,000 metric tons (mt) and 75,000 mt to 53,000 mt and 42,000 mt, respectively, between 1996 and 2000. Landings of European whiting and plaice decreased between 1996 and 1998 but have remained constant between 1998 and 2000. Fishing effort for these species remains very high while spawning stocks have fallen below their precautionary level, and the numbers of young fish have generally declined since 1990, raising concerns about the risk of stock collapse (DEFRA 2000).

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 with every haul of their nets, which far exceeds the sampling schemes that scientists can sustain (Maynou and Sardà 2001). Furthermore, experienced fishers may have knowledge accumulated over decades through the knowledge of ancestors (Sardà and Maynou 1998; Freire and García-Allut 1999). In addition, they often maintain detailed records of the location and time when they fished and how much they caught. Nowadays, ship-based electronic instrumentation enables fishers to make links between different seabed types and textures and the fish they seek to catch. Although the ultimate goal of fishers is to provide income from the catch rather than to test scientific hypotheses, many fishers are motivated to understand the links between the marine habitat and the distribution of fish. Despite this obvious wealth of experience, few studies have sought to consider or integrate fishers' views and knowledge on EFH (but see Pederson and Hall-Arber 1999; Williams and Bax 2003). The need to improve the collaboration between scientists and the fishing industry is widely recognized by scientists and fishers alike (e.g., Taylor 1998; Freire and García-Allut 1999; Baelde 2001; Mackinson 2001; Maynou and Sardà 2001; Marrs et al. 2002; Moore 2003). 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 upon which it is based.

In the present paper, we assessed the use of two complementary approaches to identify possible locations of EFHs for Atlantic cod, haddock, and European whiting in the Irish Sea for future comprehensive habitat survey. We used existing data from annual national groundfish surveys of fish abundance and compared them with fishing grounds outlined by fishers in response to a questionnaire-type survey.

## Methods

### *Identification of Potential Essential Fish Habitat Using National Groundfish Surveys*

Annual groundfish surveys have been undertaken since 1988 to assess the state of marine resources in the Irish Sea across a wide grid of sampling stations (Ellis et al. 2002). Therefore, data from these surveys may provide a unique tool to study the distribution of fish over large areas and longer-term time scales. Areas of the seabed that consistently harbor the highest densities of Atlantic cod, haddock, and European whiting in the Irish Sea (International Council for the Exploration of the Sea [ICES] division VIIa) were identified using these two databases spanning a decade of fishery-independent data from national groundfish surveys. Such grounds may have features that attract fish and, thus, might be candidates to be considered as EFH. The Centre for Environment, Fisheries and Aquaculture Science (CEFAS, Lowestoft, UK) holds a complete data set from 1990 to 1998. Fish were sampled using a 4-m beam trawl at fixed stations every autumn (Symonds and Rogers 1995). The Department of Agriculture and Rural Development (Belfast, UK) database spans a period from 1991 to 2000. Fish were caught by otter trawling at fixed stations every summer or autumn (Ellis et al. 2002). The two sampling gears have a different selectivity for gadoids (Ellis et al. 2002), and therefore, the data could not be combined.

In our analysis, the abundance of each of the three species was separately ranked (based on the populations of stations sampled) for every station and year, and a mean rank over time (per station) was calculated to identify potential EFH for further habitat surveys (reported elsewhere). Plots of mean abundance or total abundance over time were not considered useful to identify habitats that were used consistently from one year to the next, as a strong year-class 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 a particular species of fish. The mean rank values for each station were plotted using ArcView geographic information system 3.2 software.

### *Fishers' Knowledge*

The project was first introduced to the fishing community by publishing an article that described the background and purpose of the study in the main national industry paper *Fishing News*. We then liaised with the fishing industry to compare our broad-scale fish distribution maps (from groundfish surveys) with fishers' locations of fishing grounds in terms of the seasonal and spatial distribution of fish. It is often not practical to consult directly with individual fishers who spend most of their time at sea, often for more than a week at the time. Information was gathered in a pilot study through questionnaire-based face-to-face interviews with maps at an annual national fishing exhibition in Glasgow, UK (respondents were selected at random). Sample size ($n$ = 19) was limited by the time available to undertake interviews and the willingness of potential participants. The questionnaire was designed to study fishers' perceptions of the relationship among commercially important fish, habitat features, and changes in abundance and to gain information about the location of potential EFH. It consisted of 16 questions in total (see Pederson and Hall-Arber 1999), which were variously dichotomous, multiple choice, and open ended. Only six questions are analyzed here due to constraints of space (Figure 1). Furthermore, fishers were asked to plot grounds that they perceived as important for their target species on standard maps. Such grounds may be characterized by particular features or the presence of prey organisms and, therefore, harbor high abundances of fish. Thus, they could be indicative of EFH. The hand-drawn plots on the standardized maps were digitized as a chart (ArcView 3.2, ESRI, UK) suitable for comparison with maps that showed mean ranks of fish abundance generated from groundfish surveys.

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., seaweed, 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
☐ 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 habitat loss
☐ changes in prey abundance ☐ overfishing ☐ other. Please explain. ____________

***Figure 1.*** Questionnaire format used in face-to-face interviews and mail questionnaires.

More information was then gathered by mailing out revised questionnaires with maps and more detailed information about the project to Sea Fisheries Committees and other relevant fishers' organizations and requesting them to circulate these among their members. Additional interviews were conducted at a fishing exhibition in Newcastle (Northern Ireland; $n = 5$). The responses to questionnaires were analyzed by calculating the frequency of categories ticked and the frequency of key statements made in response to open-ended questions. The fraction of respondents who did not answer a question was excluded when percentage frequencies were calculated.

To compare the fishers' verbal habitat descriptions (in terms of seabed types) with the occurrence of seabed types in the areas they plotted on charts, we overlaid these plots with data from the British Geological Survey (2002). For this purpose, the sediment classification used by the British Geological Survey had to be regrouped so as to match the terminology used by fishers (Table 1). We then calculated the percentage area covered by mud, sand, hard grounds, and gravel or shingle in areas that had been plotted as important fishing ground for each species of fish (MapInfo Professional 7.0, MapInfo Corporation, UK).

Fishers were invited to give either their name or the name of their vessel, which enabled us to cross-check the areas plotted by individual fishers using records of named vessel sightings collated from fishery protection overflights. These aircraft patrolled the fishing grounds around the United Kingdom from 1985 to 1999 and recorded a description and location of all vessels that were observed fishing. The aircraft overflew most ICES subrectangles *c.* 100 times per year (Jennings et al. 2001). It should be noted that the fisheries protection aircraft predominantly flew over UK waters, resulting in very few sightings off the Irish coast. Using these data, we calculated the number of sightings for each fishing vessel (whose identity had been disclosed) that corresponded with the areas plotted by the respective owner. For reasons of confidentiality, the identification of vessels and the corresponding respondents to questionnaires were anonymous.

***Table1.*** Sediment conversions used in calculations.

| British Geological Survey classification | Attributed "folk" classification |
|---|---|
| Diamicton | Mud |
| Gravel | Gravel/shingle |
| Gravelly mud | Mud |
| Gravelly muddy sand | Sand |
| Gravelly sand | Sand |
| Mud | Mud |
| Muddy sand | Mud |
| Muddy sandy gravel | Gravel/shingle |
| Rock and sediment | Hard ground |
| Rock or diamicton | Hard ground |
| Sand | Sand |
| Sandy gravel | Gravel/shingle |
| Sandy mud | Mud |
| Slightly gravelly mud | Mud |
| Slightly gravelly muddy sand | Sand |
| Slightly gravelly sand | Sand |
| Slightly gravelly sandy mud | Mud |
| Undifferentiated solids | Hard ground |

## Results

### *Fishing Ground Locations and Distribution of Mean Ranks of Fish Abundance*

Most fishers were responsive and helpful during face-to-face interviews. We collected a total of 39 questionnaires and 28 maps. 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 (Figure 2). This map represents the aggregated knowledge of 50 fishers gathered over a period of ca. 20 years. More responses were obtained from contacts with Sea Fisheries Committees and Fisheries Producer Organizations, but many of these questionnaires were answered by fishers who worked outside the study area or targeted other species. These questionnaires could not be included in this analysis, so only 18 of these maps are included in Figure 3 (includes the Fleetwood chart counted as $n = 1$).

A total area of 13,695 $km^2$ of fishing grounds were plotted for Atlantic cod, 5,173 $km^2$ for haddock, and 11,446 $km^2$ for European whiting. The locations of fishing grounds for Atlantic cod and European whiting were similar (Figure 3A, 3B). The main fishing grounds were located between the Isle of Man and Scotland, around the Solway Firth, north of England and Wales. Similarly, groundfish survey data indicated that the highest mean ranks for Atlantic cod were situated off the Ribble estuary, Belfast Lough, Anglesey/Colwyn Bay, Solway Firth, and the central Irish Sea (Figure 3A). Several fishers independently plotted areas in this region and off the northern coast of Wales, which increases our confidence in these data. There was broad consistency between the European whiting fishing grounds indicated by fishers and the distribution of high mean ranks of European whiting (Figure 3B), although no fishing grounds were plotted off the Ribble estuary, which had a consistent high mean rank abundance of European whiting. Fishing grounds for haddock were largely located along the Irish coast and the Solway Firth. The distribution of high haddock mean ranks was similar to the distribution of fishing grounds, although groundfish surveys indicated low abundances in the northeastern Irish Sea, where several fishers highlighted grounds of key importance (Figure 3C). No haddock fishing grounds were outlined at the low abundance stations off the English coast.


*Figure 2.* Chart with important fishing ground locations provided by the Fleetwood Fish Forum (approval for publication from fishers has been granted).

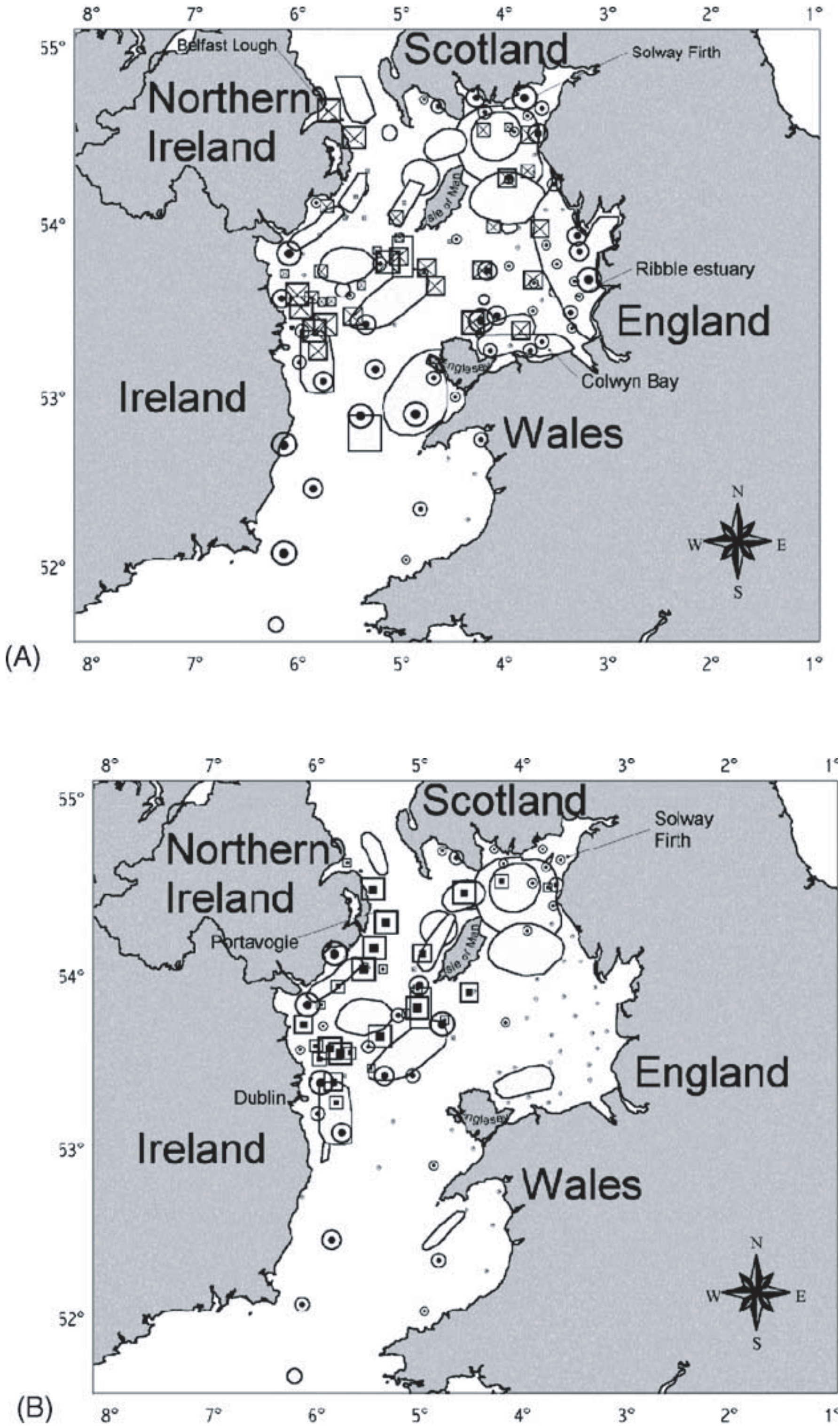


***Figure 3.*** Distribution of mean ranks of fish abundance in the Irish Sea from 1990 to 2001 and fishing ground plotted by fishers for (A) Atlantic cod, (B) European whiting, and (C) haddock.

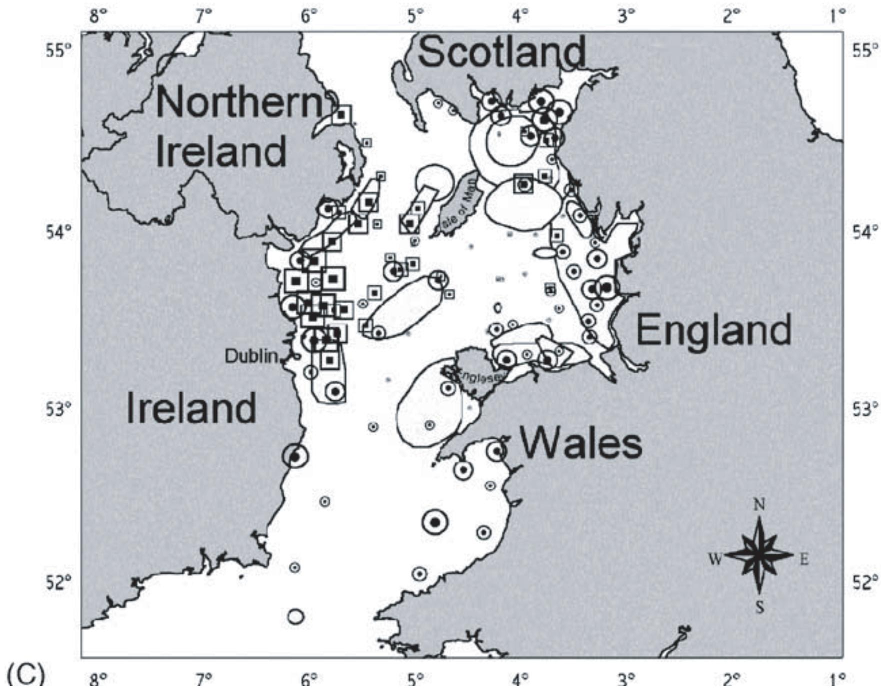


*Figure 3.* Continued.

Only seven of the fishers who plotted fishing grounds disclosed their identity sufficiently to facilitate a comparison between the location of their plots and records of vessel sightings by fishery protection aircraft (Table 2). Of these, only two vessels provided plots that coincided with sightings reported by aircrafts.

## Questionnaires

### Question 1

Atlantic cod, haddock, and European whiting were targeted by 16 of a total 39 respondents. The most important ground types stated for Atlantic cod included sand (29%) and mud (29%) (Figure 4). The most frequently stated habitat features for Atlantic cod included sand, feed (which we interpret to mean the ground that contained food for the fish), hard grounds (each 25%), wrecks and gravel (each 19%), mixed grounds, and mussel beds (each 6%). By comparison, the areas that were plotted by fishers as important grounds for Atlantic cod and overlaid with sediment maps of the British Geological Survey (BGS 2002) consisted predominantly of sand (55%) followed by mud (25%) and gravel or shingle (19%) (Figure 5). Haddock grounds contained similar proportions of sediment types. However, fishers most frequently stated hard grounds (31%) and sand (15%) as important ground types for this species. Furthermore, they named hard grounds (25%), brittle star beds (19%), feed (19%), gravel, sand, mud (13%), seaweed (we interpreted this to mean emergent growths of weed-like bryozoans), and mixed grounds (6%) as important habitat features for haddock.

Fishers responded that mud (31%) and sand (27%) were important grounds for European whiting (Figure 4). However, most of the European whiting grounds plotted

*Table 2.* Sightings of seven vessels associated with questionnaire respondents showing the total number of sightings of that vessel made during Department for Environment Food and Rural Affairs enforcement overflights, the number of those sightings that coincided with areas plotted on charts (number of matching sightings), the total number of grounds plotted by those fishers, and the number of those grounds in which that vessel was sighted (number of matching plots).

| Fishing vessel | Total sightings | Matching sightings | Total grounds plotted by fishers | Matching plots |
|---|---|---|---|---|
| 1 | 77 | 8 | 1 | 1 |
| 2 | 54 | 0 | 1 | 0 |
| 3 | 26 | 24 | 6 | 5 |
| 4 | 83 | 0 | 2 | 0 |
| 5 | 98 | 0 | 2 | 0 |
| 6 | 18 | 0 | 2 | 0 |
| 7 | 22 | 0 | 1 | 0 |

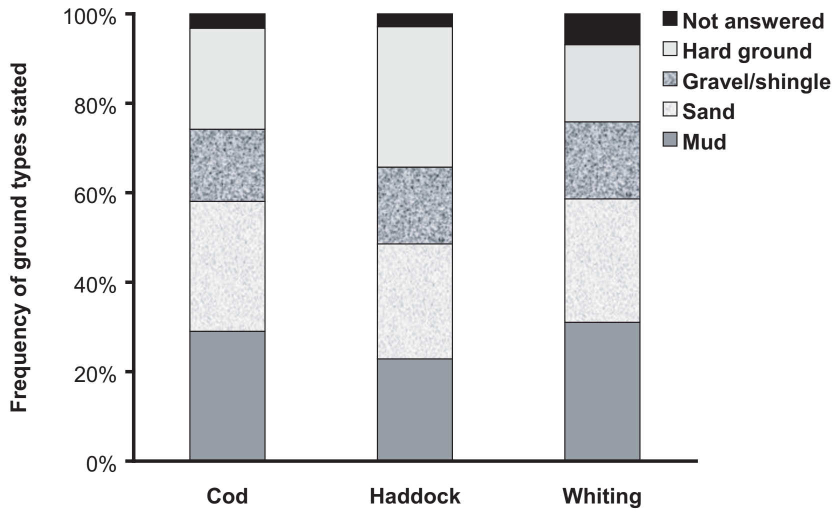


***Figure 4.*** Frequency of important ground types as stated by fishers ($n$ = 39) for Atlantic cod, haddock, and European whiting during interviews and mail questionnaires.

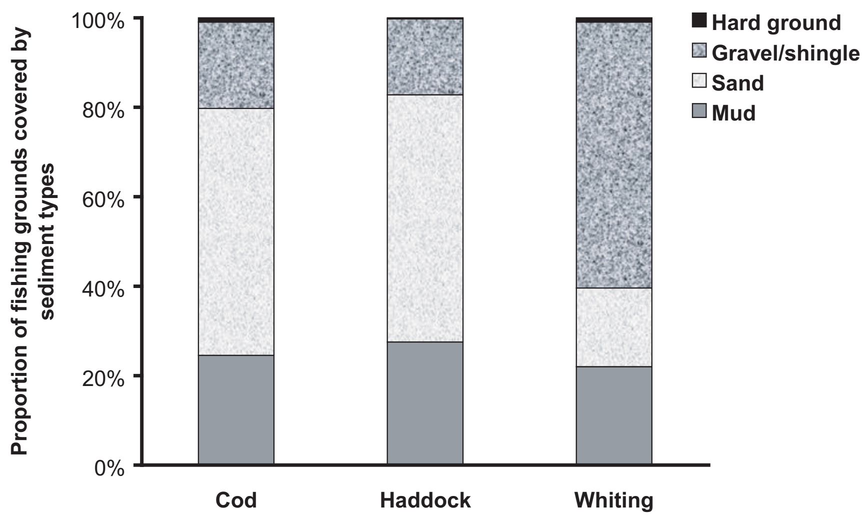


***Figure 5.*** Proportion of fishing grounds plotted by fishers that are covered by different sediment types based on British Geological Survey data.

by fishers were characterized by gravel or shingle (60%), followed by mud (22%) and sand (18%), according to British Geological Survey maps (British Geological Survey 2002; Figure 5). The most frequently stated habitat features included hard grounds (19%), mud, sand, gravel (13%), seagrass (the respondent used the term seagrass, but we doubt that the angiosperm plant was meant given its restricted distribution in the Irish Sea; it seems more likely that he used this term for seaweed or weed-like bryozoans or hydroids), and soft corals (*Alcyonium digitatum*, 6%).

### *Question 2*

Heavy fishing gear such as beam trawls, scallop dredges, and twin otter trawls were named as important factors that affect targeted habitats (21% of the 39 respondents). Other factors stated included fishing effort (21%), feed (15%), weather (15%), and season (13%).

*Question 3*

Fifty-six percent of the 39 respondents thought that fishing gear had altered their grounds. There was a high response rate to this question (96%).

*Questions 4–6*

A third of the respondents in the present study reported they had observed changes in catches of their target species such as a decrease in numbers (74%) and size (35%). Only 5% of the respondents stated that there was no change in catches of their target species (Table 3). Observed changes were attributed to overfishing (56%), climate change (38%), pollution (36%), changes in fishing gear (28%), and prey abundance (23%).

## Discussion

### *Fishing Ground Locations and Distribution of Mean Ranks of Fish Abundance*

While many fishers responded to questionnaires, only a proportion of these were willing to outline important fishing grounds on charts. This reluctance was related to reasons of confidentiality and due to a suspicion that this information might lead to negative management developments for fishers. For example, fishers might be concerned that the information may be used to identify areas for closure or the imposition of further restrictions to fishing (Pederson and Hall-Arber 1999).

When consulting with fishers, scientists need to modify their terminology to find common ground and to bridge social gaps. Therefore, during our survey, we used the term "ground" rather than "habitat." However, EFH does not necessarily constitute good fishing grounds (i.e., grounds that are amenable to fishing and provide economically viable catches). For example, an EFH characterized by topographically complex hard grounds also increases the risk of damage to fishing gear and could jeopardize the safety of the fishing vessel. Nevertheless, good fishing grounds should be indicative of potential EFH, as fishers are unlikely to prosecute areas that do not yield economically viable catches.

The areas of highest fish densities as identified from survey data did not always coincide with grounds plotted by fishers. This may partly reflect a local bias in the port of origin of many of the respondents that attended the fishing exhibition in Scotland. Although we targeted a fishing exhibition in Northern Ireland, the number of attendees was an order of magnitude lower (100 versus 1,000). Nevertheless, it is interesting that two Irish fishers also outlined grounds off the Solway Firth. A greater sample size, involving more fishers from Northern Ireland, would increase the balance when comparing among fishers' data and the groundfish survey data. It is possible that the spatial bias observed could be circumvented by restricting a spatial analysis of the groundfish survey data to subsets of data in the vicinity of respondents' ports.

The similarity of the fishing grounds outlined for the three different gadoids reflects, to some extent, the fact that several fishers did not distinguish among species when outlining fishing areas on the charts provided. In those cases, it was assumed that respondents fished for all their target species in the area outlined, although we recognize that it may have been a prime ground for one particular species.

The fishers' information has independently corroborated that high-density sites as plotted by the groundfish surveys are indicators of areas targeted by fishers and, therefore, are candidates for further research. The areas that were independently highlighted by several fishers in the northern Irish Sea and off Ireland and northern Wales presumably have features that consistently attract fish in sufficient numbers and quality to be of interest to fishers. Consequently, we have undertaken further surveys in these areas (Belfast Lough, Anglesey, Dublin, Ribble estuary) to investigate why they consistently attract fish.

***Table 3.*** Responses to questions 4 (Q4), 5 (Q5), and 6 (Q6) posed in questionnaires (*n* = 39 unless stated otherwise; f = frequency of category checked; %= percentage of frequency).

| Characteristic | Frequency of category checked | % |
|---|---|---|
| **Changes over time (Q4)** | | |
| Target species | 12 | 31 |
| Bottom animals and plants | 12 | 31 |
| Habitat structure | 3 | 8 |
| Fish health | 1 | 3 |
| Bycatch | 7 | 18 |
| No changes | 5 | 13 |
| Other changes | 5 | 13 |
| Not answered | 9 | 23 |
| **Changes in target species (Q5)** | | |
| No change | 2 | 5 |
| Increase | 5 | 13 |
| Decrease | 29 | 74 |
| Moved to other areas | 5 | 13 |
| Replaced by another species | 2 | 5 |
| Decrease in size (*n* = 26) | 9 | 35 |
| Other changes | 1 | 3 |
| Not answered | 4 | 10 |
| **Cause of change (Q6)** | | |
| Climate | 15 | 38 |
| Pollution | 14 | 36 |
| Changes in fishing gear | 11 | 28 |
| Changes in prey abundance | 9 | 23 |
| Habitat loss | 3 | 8 |
| Overfishing | 22 | 56 |
| Other causes | 4 | 10 |
| Not answered | 7 | 18 |

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 northern Isle of Man, northwestern Scotland, and northwestern England. This is probably due to differences in the gear historically used for the CEFAS groundfish survey, a beam trawl, which is not ideally suited for use over the rough grounds around the Isle of Man. However, recent studies from the northwestern Atlantic indicate a preference of young Atlantic cod and haddock for habitats of coarse sediment interspersed with rocks (Lough et al. 1989; Gotceitas et al. 1995; Gregory and Anderson 1997; Lindholm et al. 1999); hence, these areas may have been missed or avoided during the beam trawl survey. Conversely, the groundfish survey probably includes areas that fishers normally avoid because they would catch too much "rubbish" (inert material and bycatch of nontarget species) that might clog up and damage their nets and catch during the longer commercial tows.

Although 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. There were, however, some discrepancies between the ground types that fishers stated as important for each fish species and the sediment composition (determined from British Geological Survey data) of grounds that they plotted on charts. Large areas of the Atlantic cod and haddock fishing grounds were characterized by sand, although this sediment type was mentioned less frequently in questionnaires. Similarly, the European whiting fishing grounds were composed of a much higher proportion of gravel or shingle than was stated in questionnaires. Generally, hard grounds were named as an important habitat feature more often than would appear from the features of plotted fishing grounds, which might be explained with differences between the British Geological Survey-converted sediment classification and the categories used by fishers. For example, gravel or shingle may have been termed hard grounds by some respondents. Also, muddy sand (here termed as mud) may have been classed as sand by some fishers. Alternatively, the resolution of fishers' knowledge may exceed the sampling resolution of the British Geological Survey sediment data, which relied on interpolation between widely interspersed sample points.

Further discrepancies became evident when comparing the location of fishing grounds plotted by individual respondents with aircraft patrol sightings for the same fishing vessel. This could have several reasons. Fishers often target different species throughout the seasons, which also affects their fishing locations. When sighted by aircraft, a vessel may have been fishing for a species other than that for which fishing grounds were plotted. Also, weather conditions and fishing restrictions may have prevented respondents from fishing in their favored areas, leading to the observed discrepancies.

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 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*

Fishers named a wide range of ground types of similar importance for all three fish species. This may indicate that adult Atlantic cod, haddock, and European whiting are caught over a variety of seabed types and that they may be "habitat generalists." In a similar study in the United States, fishers indicated that they preferred to fish for whiting on fine-grained sediments, whereas other groundfish were targeted across all habitat categories (Pederson and Hall-Arber 1999).

Interestingly, three fishers stated independently that "wigs" (brittlestar beds) are an important habitat feature for haddock, especially after spawning. Although fishers suggested that haddock sought out brittle star 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.

A few fishers noted that weed (possibly hydroids or the widespread bryozoan *Flustra* spp.) was often found in their haddock catches, and one fisher also associated European whiting with dead men's fingers (*Alcyonium digitatum*, a soft coral). Such structures 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. 2002). 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 mailed questionnaires. Fishers are often ignorant of species names, especially those of nontarget invertebrates, and seem unwilling to offer their own interpretation that may be proven incorrect (Mackinson 2001). It was easier to 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, who are often keen to expand their knowledge of the marine environment.

More than 50% of the respondents 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 has one of the greatest initial impacts on benthic biota. Fishers tended to attribute habitat changes to gear types that were not used by themselves. Less than a third of the respondents polled in a study in the United States believed that fishing gear had changed their 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 the their own gear had altered the grounds; thus, more than 50% of the fishers identified mobile gear as the most important factor that affected habitats (different question). Also, fishing is more intense in Europe, and different countries tend to dominate different gear sectors (e.g., The Netherlands and Belgium operate the largest beam trawl fleets in northern Europe).

Only a few fishers commented on habitat loss through 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 face-to-face interviews yielded the best data, enabled the 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. Most importantly, it has helped us to pinpoint areas that may constitute EFH for further comprehensive habitat surveys. One drawback of using fishers' knowledge and data from groundfish surveys in order to locate possible EFH is that only trawlable areas are included. Although certain areas may be more suitable for gadoids than other trawlable areas, they may not necessarily constitute EFH. For example, a high abundance station may be located next to an EFH such as a rocky reef or wreck that was saturated with fish, such that some fish spill over into the second best habitat that is amenable to sampling with a trawl gear. Jagielo et al. (2003) found significant differences in the density of several flatfish and rockfish species in trawlable and untrawlable habitats. Additional interviews with scuba divers, sea anglers, and fishers that use fixed gears may yield information from a wider range of habitats in future research.

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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