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Ecosystem trends: evidence for agreement between fishers' perceptions and scientific information

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Abstract:

The results of a survey on fishers' perceptions of recent changes in the eastern English Channel ecosystem carried out in 2006 were compared with fishery and bottom-trawl survey data. A hypothesis-testing framework was used, testing the null hypothesis that fishers' statements were true, which permitted evaluation of both agreement and disagreement. Overall good agreement between fishers' statements and scientific data was found, and both sources suggested that the fish community in the Channel is undergoing large changes, among which are decreases in some commercially important species; in addition, a number of human pressures impact the ecosystem. Fishers had an accurate perception of changes and their time-frames, but not necessarily of their causes. They had a greater power than survey data to detect recent changes, showing that fishers' perceptions have great potential as early warning signals.

Keywords: eastern English Channel, ecosystem approach to fisheries management, fisher knowledge, hypothesis testing, stakeholder interview

1. Introduction

The ecosystem approach to fisheries management requires the involvement of ecosystem users and other stakeholders to be efficient (Garcia and Cochrane, 2005). Effective stakeholder involvement implies and includes a common knowledge base (Degnbol, 2003; Hoefnagel *et al.*, 2006). Distrust between scientists and fishers is pervasive, as has been found for example in Europe (Delaney *et al.*, 2007; Schwach *et al.*, 2007) and West Africa (Sall, 2007). In Canada, it was one of the causes for the weakening role of science in fisheries management (Shelton, 2007). Fishers contest the science and complain that their knowledge is not recognized as of due value (Delaney *et al.*, 2007), whereas scientists often do not trust information provided by fishers (Freire and García-Allut, 1999; Mackinson and van der Kooij, 2006). Indeed, classical modes of user–science interactions in environmental policy-making tend to view lay knowledge with scepticism, and truth to be in the realm of science (Bailey and Yearley, 1999; Corburn, 2007). However, Johannes (1981) showed that fishers' knowledge of fish species, catches, ecology, and habits can be very precise and helpful to fishery management. Therefore, it is not surprising that calls for combining local and scientific knowledge have multiplied (Mackinson and Nøttestad, 1998). Several methods for achieving this have been developed, from expert systems (Mackinson, 2001; Grant and Berkes, 2007) and cognitive mapping (Radomski and Goeman, 1996; Özesmi and Özesmi, 2004) to geographic information systems (Hall and Close, 2007).

However, not all local knowledge is necessarily reliable, and validation is required before it can be used (Freire and García-Allut, 1999; Maynou and Sardà, 2001; Hamilton *et al.*, 2005). While validation through experiments and observation, as well as statistical significance, and peer-review is a cornerstone of scientific knowledge, what makes local knowledge reliable is less well defined and pertains to tradition, experience, and community stories (Freire and García-Allut, 1999; Corburn, 2007). Social scientists use cross-checks and consensus methods for validation, assuming that beliefs shared by many people are more likely to be true (Neis *et al.*, 1999; Wilson *et al.*, 2006). Each kind of knowledge can be internally validated with its own criteria, but, if all are recognized as valid knowledge, none can be taken as a standard against which to evaluate others. Hence, when it comes to combining local and scientific knowledge, the crucial point is their mutual consistency and compatibility. For reconciling and combining knowledge, the first step is to elucidate the differences in understanding (Degnbol, 2003) and to highlight complementarities. There have been some attempts to contrast local and scientific knowledge, by qualitatively comparing the results of a fishers' survey with published ecological data on a fish species (Silvano and Begossi, 2005) or with the results of a visual assessment of stream ecological integrity (Silvano *et al.*, 2005). Perceptions of stock status or trends have been compared by simply juxtaposing them (Scholz *et al.*, 2004; ICES, 2007a). Published formal comparisons include the assessment of Catalan fishers' belief that shrimp catches are better on Friday than on other weekdays (Sardà and Maynou, 1998), and the investigation of environmental factors on *Nephrops* catchability based on fishers' beliefs (Maynou and Sardà, 2001). In both cases fishers knowledge was turned into hypotheses that were tested in a standard framework, i.e. estimating the probability of data under the null hypothesis of no difference between weekdays, or no effect of factors. This amounts to testing the hypothesis that fishers' beliefs were wrong. By contrast, for validating local knowledge of stock trends, Ainsworth and Pitcher (2005) examined the proportion of trend statements in stakeholder interviews that agreed with scientific assessments, considered as the truth. Here, we use a third approach by which fishers' knowledge is taken as the truth, and we test whether it is supported by available information.

Agreement between local knowledge and stock assessment results can be poor, especially for stocks with high interannual variability, but less so for long-term changes (Ainsworth and Pitcher, 2005). On the other hand, North Sea fishers when asked about their perceptions of stock changes relative to 1, 6, and 20 years before were in good agreement with the ICES assessments for the former and the latter period, although they did not perceive the medium-term halving of stock sizes which was estimated by the scientists (ICES, 2007a). Van Densen (2001) found that fishers have different perceptions than management authorities of long-term trends, because they have a less ability to detect trends in time-series, which in turn is related to catch variability and the size of the time-window. Therefore, two components are important when comparing perceptions of time-trends: whether a trend is perceived, and on which time horizon.

In 2006, local ecological knowledge of the Eastern English Channel ecosystem was investigated by a survey among fishers (Prigent *et al.*, submitted). The eastern English Channel (hereafter the Channel) was selected because it is a rather small ecosystem, with a wide diversity of fisheries resources and activities, and various environmental concerns. In the survey, fishers were asked about the way they perceived the marine ecosystem and the changes they had seen in it. They were not specifically interviewed about their perception of the time-frame of these changes, but in many cases they mentioned some time horizon. Here, the results of this survey are compared with fisheries and bottom-trawl survey data, to identify consistencies and discrepancies between both types of knowledge. To address the consistency in direction of change we used a non-standard hypothesis-testing framework, where null hypotheses were based on fishers' statements. This allowed us to distinguish both agreement and disagreement from inconclusive comparisons. The approach was applied to the last 5, 10, and 15 years to investigate the time-frame of changes and to compare them with the time horizons perceived by fishers.

2. Material and methods

2.1. The eastern English Channel ecosystem and fisheries

The English Channel (Figure 1) is a shallow shelf sea (depth <70 m) between southern England and northern France, with mainly sandy and gravel substrata. It is an open sea with strong currents in both east and west directions, the former dominating, creating highly dynamic water mixing, and providing migration routes and spawning grounds to many species. The numerous and large estuaries, especially on the French side (Seine and Somme), house nurseries for various species including some stocks that are important commercially. The spatial distribution of resources is structured by bottom type, depth, and temperature (Carpentier *et al.*, 2005; Vaz *et al.*, 2007), e.g. flatfish and gadoids are found on soft seabed, and chondrychthyans and gurnards are more abundant on hard substrata. The abundant benthic fauna provides food for a diverse and productive fish community, targeted by a range of fishing activities. Most commercial species of the Northeast Atlantic are present in the Channel, and up to 100 species are landed in the numerous French ports, of which Boulogne-sur-mer, Dieppe, and Port-en-Bessin are the most important (Ulrich, 2000). Pelagic and bottom trawls are the main gear deployed, and provide 90% of the landings by weight. They are used to target whiting (*Merlangius merlangus*), plaice (*Pleuronectes platessa*), sea bass (*Dicentrarchus labrax*) and herring (*Clupea harengus*), squid and cuttlefish, whereas beam trawls, dredges, and gillnets are the preferred gears to target more valuable species [sole (*Solea solea*), scallops, cod (*Gadus morhua*), and dab (*Limanda limanda*)]. Lines and pots are used by smaller-scale fleets to catch a diversity of local fish and shellfish. Many of the stocks in the area subject to assessment are reported as currently overexploited, with reduced reproductive capacity or unsustainable harvesting, or both (ICES, 2007b). There are also environmental concerns for the region given that it supports a heavy maritime traffic, receives effluents from several large cities, and is also subject to gravel extraction (Jones *et al.*, 2004).

2.2. Fishers' perceptions

In June 2006, a survey was conducted among French fishers in the Channel to capture their perception of the past and current state of the marine ecosystem and their expectations for the future. In total, 29 semi-direct interviews were carried out among fishers and shellfish farmers. Cognitive maps were used to formalize their experience and knowledge, as a bubble diagram with arrows indicating the main determining factors. Most interviewees mentioned a decrease of the resource in recent years and ascribed it to various human activities, such as pollution, degradation of the sea floor, and fishing; they were prone to put the blame for degradation on the activities of others (Prigent *et al.*, submitted). In all, the 13 statements presented in Table 1 articulate the major perceptions of time-trends by these fishers. Five deal with resources, which were generally perceived as decreasing, although some species were mentioned as increasing (statements 1–5), four (6–9) are related to changes in the fisheries, one (10) to the environment, and three (11–13) to human impacts. Some of the changes were perceived as occurring recently, or on longer time horizons, with some variations between interviewees and statements (Table 1).

2.3. Analyses

Most statements in Table 1 are about changes. Each statement was rephrased into one or several testable hypotheses that could be challenged by linear regression using available time-series of rigorously monitored data or published results (Table 1). The hypotheses tested were not standard null hypotheses. Rather, the hypotheses were consistent with fishers' statements and were about a change (e.g. index I increased: slope of time trend $\theta_I > 0$) rather than the classical no-change null hypothesis ($\theta_i = 0$). The reported *p*-values provide the probability of observing the data if the fishers' statement was true. That is, high *p*-values (>0.9) are to be interpreted as strong support of the statement by the available data, hereafter termed "agreement". By contrast, low *p*-values (<0.1) mean that there is little probability of observing the data if the statement was true, termed "disagreement" below. Intermediate *p*-values mean that there is little evidence either in favour or against the statement, a result referred to as "neutral".

To determine the time-scale over which changes were most likely to have occurred, trends were tested over three periods: last five (2001–2005), last ten (1996–2005), and last fifteen (1991–2005) years. Overall agreement on each time-scale was examined by combining *p*-values either for all statements tested, or only for the statements mentioned by fishers on that time scale (minus twice the sum of the log-transformed *p*-values distributed as χ^2; Sokal and Rohlf, 1995). If fishers have a poor or erroneous sense of time-frames of perceived trends, agreement is expected to be similar for both analyses, whereas agreement would be better in the latter analysis if the perception of time-horizons by fishers was accurate.

For specific populations, the population growth rate *r* was estimated as the slope of the log-transformed abundance index time-series from the scientific surveys (Trenkel and Rochet, 2003).

2.4. Data sources

Two types of data were considered. First, fisheries data (landings and effort) were used to compare with perceptions and to investigate the time-frame question. Unfortunately, we were not able to build catch per unit effort (cpue) time-series because only gross landings and rough measures of effort were available, so we could not challenge statements 8 and 9. Second, as many statements refer to resource status, we investigated whether the trends in landings were born out by similar trends in populations and the whole fish community, by analysing fisheries-independent data and stock assessment results.

National fisheries landings were obtained from fish market data registered by the French Fishery Ministry (DPMA) and extracted from Harmonie, the French Fisheries Information System database managed by Ifremer. For some species, a large proportion of the catch is sold outside the market, so market data do not reflect actual landings; this is the reason why we did not consider scallop landings. International landings were taken from international stock assessments or other working group reports produced by the International Council for the Exploration of the Sea (ICES, 2005a) available for 2000–2004 only. Mean weight in the catch was estimated by multiplying weight-at-age by numbers-at-age in the catch, then dividing by total numbers, as reported by the stock assessment working group (ICES, 2007b).

The French Channel Ground-Fish Survey (CGFS) provided abundance indices. Since 1988, this survey has been carried out annually in October in the eastern Channel. Each year 90–120 30-min tows are performed with a high-opening bottom-trawl (20 mm stretched mesh), using a stratified sampling scheme. All animals caught are identified, counted, and measured (Carpentier *et al.*, 1989). Scallops are monitored by a dedicated survey in Seine Bay, the major ground for this species in the Channel (Vigneau *et al.*, 2001). The latter survey has taken place annually since 1992 in July with a stratified random sampling scheme, each sampling unit consisting of a dredge tow of 0.5 nautical miles. Finally two Channel stocks are formally assessed by ICES (plaice and sole), whereas whiting and cod are assessed at a scale of the whole North Sea. We used estimates of spawning-stock biomass made by the 2007 working group as a more elaborate perception of stock state (ICES, 2008).

3. Results

Results are reported below for each of the fishers' statements, and summarized in Table 1.

Generally, resources decreased. Both total biomass and abundance of the trawlable community as estimated from the CGFS groundfish survey consistently declined from the early 1990s to 2005 (Table 2, Figure 2, top). From 2000 to 2003, national landings increased slightly, then dropped in 2004 (Figure 2, bottom), the data being overall neutral to the decrease statement (Table 2). Looking at individual species, on all three time-horizons the fishers' statement was supported by the survey time-trends for some species, but rejected for other species (Figure 3, Appendix).

1) *Especially flatfish (plaice and sole), whiting, and cod decreased, and more recently cuttlefish*. Landings recently decreased for these species, except for sole. On a longer term, cod landings

decreased since 1996, whereas cuttlefish, whiting, and sole increased over both the last 10 and last 15 years (Table 3, Figure 4); declines in stock estimates were consistent on all three time horizons, with sole again being an exception (Table 4, Figure 4). In contrast, the abundance indices did not show any significant decline over either time horizon (Table 4, Figure 4). Cuttlefish increased both in French (Table 3, Figure 4) and international (ICES, 2005b) landings, but dropped in 2005, in agreement with the statement; the abundance index from the survey increased too, but did not decline in 2005.

2) *There has been a change in species composition that may be due to water warming: red mullet appeared and increased whereas cod moved to more northern areas.* The many significant changes in abundance indices over the 1991–2005 and 1996–2005 periods strongly support the general statement of a change in species composition (Figure 3). More specifically, in agreement with the statement, red mullet (*Mullus surmuletus*) increased both in landings and the survey (Tables 3 and 4, Figure 4). Cod decreased in the Channel (Figure 4), but there was no evidence that it might have moved north. Indeed, the stock estimate for North Sea cod declined over all three time periods (Table 4).
3) *Spider crab, crab and sea bass increased, while scallops remained constant*. In agreement with the statement, at least for the longer time periods, spider crab, crab, and sea bass landings increased steadily during the 1990s, along with the corresponding abundance indices. The abundance index for scallops showed two exceptionally strong year classes, in 2004 and 2005, and therefore an increasing long-term trend, disagreeing with the statement (Tables 3 and 4, Figure 4).
4) *The average size of catch decreased, especially for sole*. The average weight of sole in international catches from area VIId decreased in the 1990s, i.e. before the 10-year period mentioned by the fishers (Figure 5). The increase in the most recent years might take place only for landings, and discarding of small fish might have recently increased owing to more rigorous enforcement of minimum landing sizes.
5) *The fishing season for sole shifted towards later dates and decreased in length*. In 2004 and 2005 sole landings peaked in April, compared with March in the four previous years (Figure 6) and in the 1990s (Guitton *et al.*, 2003). Therefore, fishers were sensitive to changes that were not necessarily examined in the traditional fisheries science approach. From the data available, it is difficult to detect a consistently reduced season.
6) *The number of foreign vessels fishing in the area increased*. There are no data on international fishing effort in area VIId. As a proxy, the share of foreign vessels in total landings from the area increased during the last five years (Table 2, Figure 2).
7) *Yields decreased.* No data available.
8) *The length of nets increased.* No data available.
9) *The sea warmed*. Water temperatures warmed in the 1990s compared with the 1970s on the English side of the Channel, and the increase has accelerated in recent years (Genner *et al.*, 2004). Also, water temperature rose by several degrees over the last two decades at the coastal station of Gravelines, on the boundary between the Channel and the North Sea (Woehrling *et al.*, 2005), and at Flamanville in the western Channel (Martin and Planque, 2006) (see location of these stations on Figure 1). Therefore, surrounded by warming waters, there is a good chance that waters in the eastern Channel used by French fishers warmed as well.
10) *Pollution, especially waste, was high, but decreased*. This statement is supported by various published studies. Water quality was assessed to be poor because of eutrophication in the most easternly part of the Channel, but improved in recent years (Le Goff and Riou, 2006). The concentrations of pollutants such as heavy metals, organochlorines, and aromatic hydrocarbon have decreased at many monitoring stations in the area over the past two decades (RNO, 2000). Cadmium and mercury concentrations in the Seine Estuary peaked in the early 1990s and have decreased consistently ever since (Nakhlé *et al.*, 2007). Waste density was low in the eastern Channel (0.18 debris ha^{-1}) compared with other European shelves in the late 1990s (Galgani *et al.*, 2000).
11) *Sea bottoms have been damaged by fishing gears and gravel extraction*. To our knowledge, there has been no study of the impact of fishing gears in the eastern Channel. In the adjacent southern North Sea, some local areas might be trawled up to 20 times a year, with an overall average of twice per year (Piet *et al.*, 2006), resulting in high mortality to the benthic fauna (Piet *et al.*, 2000), which in turn disturbs community structure (Frid *et al.*, 2000). Among the gears used in the Channel, scallop dredges are known to be the most damaging across a range of habitats, whereas otter-trawl impact is more variable across habitat types (Kaiser *et al.*, 2006). In adjacent areas, gravel extraction has been shown to damage epifaunal communities (Smith *et al.*, 2006),

but this activity is currently taking place only in a small number of coastal areas (16 km² in total). Overall, there is some agreement with the statement regarding fishing gears, but less so for gravel extraction.

12) *Gravel extraction damages spawning areas*. The current, small gravel extraction areas are located in regions identified by Riou *et al.* (2001) to have "very low" to "medium" potential as nurseries for plaice and sole. However, gravel extraction is potentially damaging (see statement 12), and there are a large number of projects that have requested exploration authorization or exploitation permits; the total authorized area might exceed 1200 km² in future (http://www.ifremer.fr/drogm/Realisation/Miner/Sable/tab-region/Manche.htm#GNz). These should be located in less coastal areas which are not nurseries for flatfish, but potentially for herring (Maucorps, 1969). Therefore, this statement cannot be ruled out, although only a dedicated impact study could provide adequate evidence.

When combining *p*-values from Tables 2–4, overall fishers' statements and scientific information weakly agreed for the 2001–2005 period ($p = 0.72$, Table 1) and disagreed on the longer time horizons. However, when comparisons were made only for the time-scales mentioned by the fishers (excluding shaded cells in Table 1), agreement increased with the length of the time-frame, with good support of the data for fishers' statements over the 15-year time horizon (Table 1). The results suggest that fishers had a pretty accurate perception of time horizon when they perceived a trend.

4. Discussion

Overall, fishers' statements on perceived temporal changes were supported by the available scientific information. Agreement was good for the general and more specific statements about resources, as well as for the fisheries, environment, and human impacts on the ecosystem. The joint assessment of the eastern English Channel ecosystem concludes that many resources have been decreasing on both short and long time horizons, that water is warming, and pollution is bad, although improving, and that the substrata might have been damaged by fishing gears.

Unlike previous studies (van Densen, 2001; Ainsworth and Pitcher, 2005; ICES, 2007a), we found few discrepancies between fishers' and scientific perceptions, nor that the latter would be more potent in detecting changes. On the contrary, *p*-values for the five-year trends were in many cases >0.5, providing some support for fishers' statements, but were seldom >0.9, so the short-term agreement column in Table 1 mainly contains "Neutral" conclusions, and overall agreement was weak for this time period. In other words, fishers had a greater power to detect short-term trends than scientific information, especially survey data. According to van Densen (2001), the difference in power, and therefore in the discrepancy, is caused by differences in time windows, in the variability around the trend, and in the risk of error. We now examine these differences.

We found that fishers had an accurate perception of the time-frames of changes, and that they were sensitive to trends in both the long and the short term – they even mentioned year-to-year variability (e.g. cuttlefish) when they reported changes. This finding challenges van Densen's (2001) view that fisheries authorities have a greater ability of detecting trends because they would examine longer time windows thanks to data having been recorded on longer time-scales than most fishers can remember personally. Our finding is more in accord with other reports that long-tem records are embedded within fishers' knowledge, for they accumulate it throughout their career (Hutchings and Ferguson, 2000; Dulvy and Polunin, 2004) or even across generations (Gendron *et al.*, 2000; Berkes and Turner, 2006; and several contributions in Haggan *et al.*, 2007).

Variability around the trend might obscure trend perception, and apparent variability is generally less for fisheries authorities owing to spatial and temporal aggregation of their data (van Densen, 2001). In our study the spatial effect is likely to be weak because the study area was small, and most of the fishers interviewed use trawl-like gears or a diversity of gears so that they can cover a large part of the area, and the difference between their catch and spatially aggregated catches will be weak. Variability in day-to-day catches is also relatively small in these technically advanced and mobile trawl fisheries (van Densen, 2001). Hence it is not surprising that landings statistics tend to agree with fishers' statements better than survey-based abundance indices. This is due to the great variability of the latter, which typically have CVs of ~30% (Trenkel and Rochet, 2003). The sampling intensity of a scientific survey is much lower than that of an individual fisher who is active all year round, and so is the power of a scientific survey to detect trends less (Nicholson and Jennings, 2004). Analyses of landings and formal stock estimates had a higher power and therefore provided greater support to fishers' perceptions than did survey indices.

The power to detect a trend is greater if a higher *α* risk is taken of making a type I error by concluding there is a trend when there is none, and van Densen (2001) hypothesized that authorities would be willing to take a greater *α* risk than individual fishers, especially when applying a precautionary approach. This might not necessarily be true, at least for trends detrimental to fishers, e.g. decreases in resource availability. As fishers make a living from their catch, they need to be aware of downward trends as soon as possible to plan their future activities and/or to raise authorities' attention to their potential difficulties. Therefore, the high power of fishers to detect short-term trends might also be attributable to a high *α* risk. There might be a dissymmetry in the *α* risk taken in perceiving increases vs. decreases. This might explain one of the two disagreements found between fishers and data, when the statement that resources decreased is challenged by testing the hypothesis that abundance of individual populations decreased. Although there was agreement for some stocks, we detected increases for many others. It is also worth noting that 76% of respondents mentioned declines in resources, and 41–52% made more specific decrease statements (1–3), whereas just 17% mentioned increases in some resources (statement 4). The fishers might be more sensitive to decreases than increases, i.e. more willing to take a high *α* risk for decreasing trends. Consistently, Ainsworth and Pitcher (2005) found that fishers were more likely to be more pessimistic than stock assessments. Obviously this holds in an individual interview but, when confronted with the management consequences of such a decrease, fishers as a group might put their case differently.

The second disagreement was related to statement 4, which was not only about change but also its purported cause. Whereas the data strongly supported the perceived changes, they disagreed with the cause suggested by the fishers, namely that "cod moved to more northern areas owing to warming waters". Channel fishers first had in mind environmental causes or others' activities rather than their own fishing activity to explain the changes they perceived (Prigent *et al.*, submitted), like many other fishers worldwide. For example, Melanesian fishers had accurate knowledge of recent changes in the abundance of local fish stocks, but their explanations for these changes were often magic (Hamilton *et al.*, 2005). Fishers from various tropical small-scale fisheries ascribed lost fish concentrations mainly to habitat changes (Wilson *et al.*, 2006). Similarly, although West African fishers recognized the loss of biodiversity, they did not relate this to stock depletion and fishing (Sall, 2007). Californian fishers agreed that natural cycles and pollution were more important for resource health than fishing pressure (Scholz *et al.*, 2004). Similarly, Brazilian farmers had some difficulty in seeing themselves as part of the environmental problems (Silvano *et al.*, 2005). This may be inherent to verbal knowledge which, because it relies on memory, will be less analytical and more subjective than written knowledge (Hoefnagel *et al.*, 2006). It might also be difficult for anybody to see him/herself as both the cause and the consequence of a change, i.e. to be both victim and guilty. A strength of cognitive mapping proved to be the help it provided to interviewees in articulating the causal relationships in their world's view (Prigent *et al.*, submitted).

The overall agreement we found between scientists and fishers is unexpected given the context of distrust highlighted in our introduction. This might be explained by the approach where fishers' and scientists' perceptions were compared outside a management arena. In a thorough analysis of disputes over Atlantic bluefish (*Pomatomus saltatrix*), fishers and scientists had a common understanding of facts, but they disagreed because of their roles in the institutional settings that constrained and distorted the debate (Wilson, 2002).

Although hypothesis-testing is not necessarily the best tool available for scientific inquiry (Stephens *et al.*, 2006), we suggest that it is relevant for comparing knowledge, provided appropriate hypotheses are tested. The strength of the approach used here lies in its ability to detect both agreement and disagreement, contrary to rejection vs. non-rejection in more standard frameworks. We tested trends by linear regression, which might not always accurately describe data variations, especially with highly fluctuating data such as survey-based abundance indices, or as the length of a time period increases and non-monotonous changes arise. More sophisticated methods such as smoothers or polynomial regression might provide a more accurate model of a time-series but would be more difficult to interpret in terms of simple directions of change.

To summarize, fishers' perceptions of time trends in the Channel were accurate in direction of change and time-frame, and more powerful on a short time-frame than scientific surveys, although there might be divergence on the causes of the change. An ecosystem approach to fisheries requires that resources be monitored, both target stocks and bycatch, and that the environment and fishing activity also be monitored, so as to be able to perceive changes in both short and longer term. Short time-frames might be more relevant than previously thought. Some boom-and-bust fisheries might deplete a resource within a few years (Boyer *et al.*, 2001), and catastrophic regime shifts can modify an ecosystem on very short time-frames (Harris and Steele, 2004). Therefore, the power to detect trends is important in the short and the longer term. In some cases it was easier to survey fishers' perception than to gather appropriate data such as yields or length of driftnets. Landings data and stock estimates take a long time to be gathered and processed, and in many cases they will not be available before a year or more has elapsed. They also provide a picture for commercial stocks only, and sometimes at an aggregated spatial scale (e.g. stock estimates for whiting and cod in this study are for the whole North Sea). Fishers perception have been used elsewhere to increase the power in detecting long-term trends for a scarce resource (Dulvy and Polunin, 2004) or in fishing activities (Hutchings and Ferguson, 2000), and it has been suggested that a wide use of fishers' knowledge might be the only way to develop the fisheries ecology understanding required to achieve ecosystem-based management (Johannes and Neis, 2007). Our work suggests that fishers' perceptions can be very useful as early warning signals for resource changes, keeping in mind that in cases such as reduction in abundance taking place together with stock contraction, they might be misled (Mackinson and van der Kooij, 2006). Indeed, North Sea fishers have been asked annually since 2002 about their perceptions of the current year's trends (compared with the previous year) for eight stocks (Marrs, 2005), and the results are presented to the North Sea stock assessment working group. No systematic analysis of the consistency with stock assessment and projection has been made yet, but generally the agreement is good, e.g. between fishers' perceptions and trawl survey indices, including at a fine spatial scale (ICES, 2007a). However, the results of that survey are not much used by the working group or by the Advisory Committee on Fishery Management, which merely reports selected results and comments on them and on the agreement with the formal assessment (ICES, 2007a).

We propose that in systems where scale issues do not generate too large a discrepancy between individual and aggregated perceptions, fishers' perceptions of short-term trends should be used as indicators for resource management. Fishers have a high power to detect detrimental changes, those which require timely action to be taken. On short time-frames, they are probably in an appropriate place to balance the risk of detecting a trend when there is none and making an unnecessary decision, against the risk of doing nothing when a change is actually happening. Of course, these short-term perceptions would have to be balanced with longer-term considerations that remain essential to an ecosystem approach to fisheries, and that could be monitored with other methods, including scientific surveys. Decisions based on fishers' perceptions might be more likely to be accepted, provided some progress is made in developing fishers' analytical capacity and building a common understanding of causal relationships (van Densen, 2001; van Densen and McCay, 2007).

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Figures

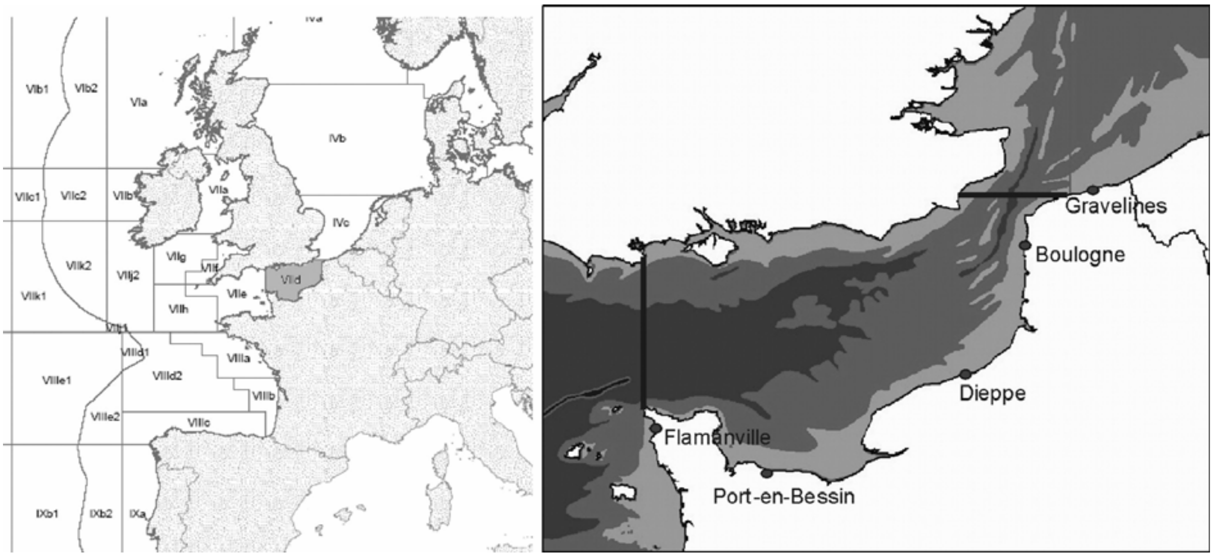

Figure 1. Location of the eastern English Channel (ICES VIId), and the bathymetry (showing the 20, 50, and 100 m isobaths).

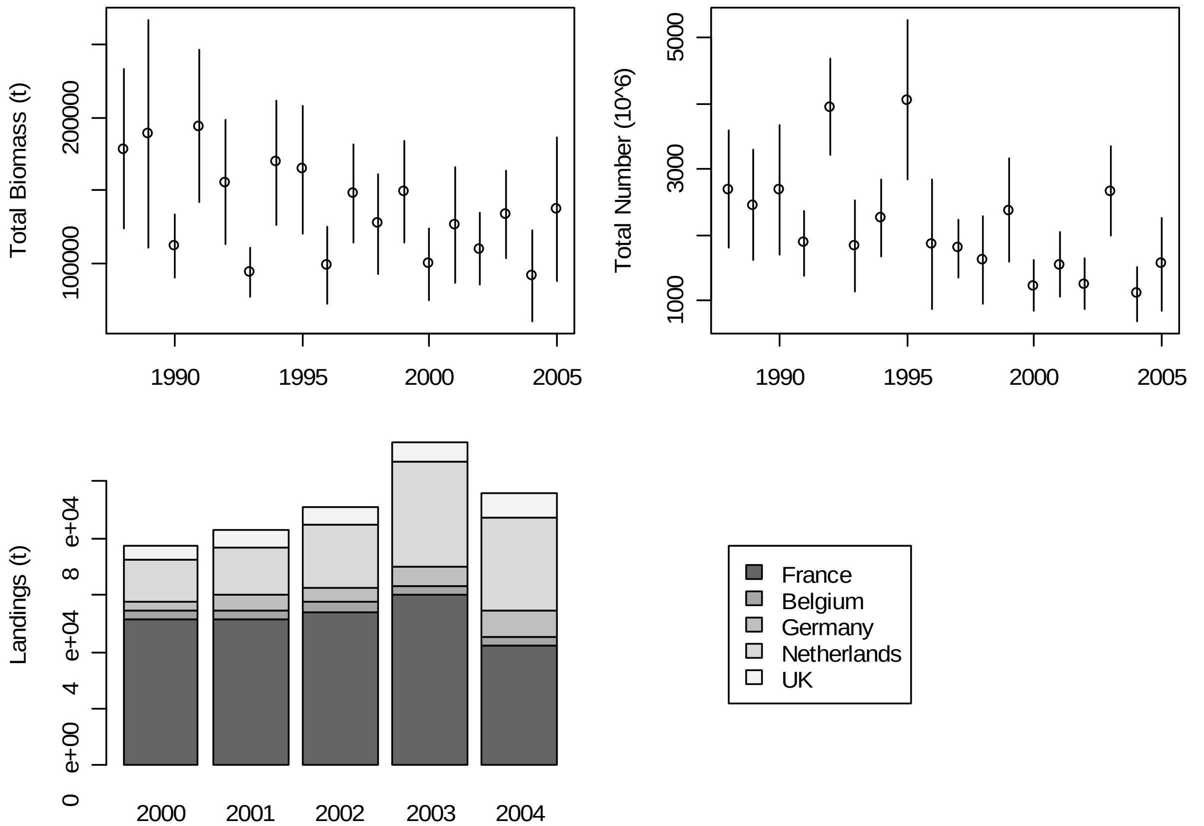

Figure 2. Eastern Channel total biomass and abundance of animals caught in the CGFS groundfish survey (top) and international landings (bottom; ICES, 2005a). Vertical bars are 95% confidence intervals.

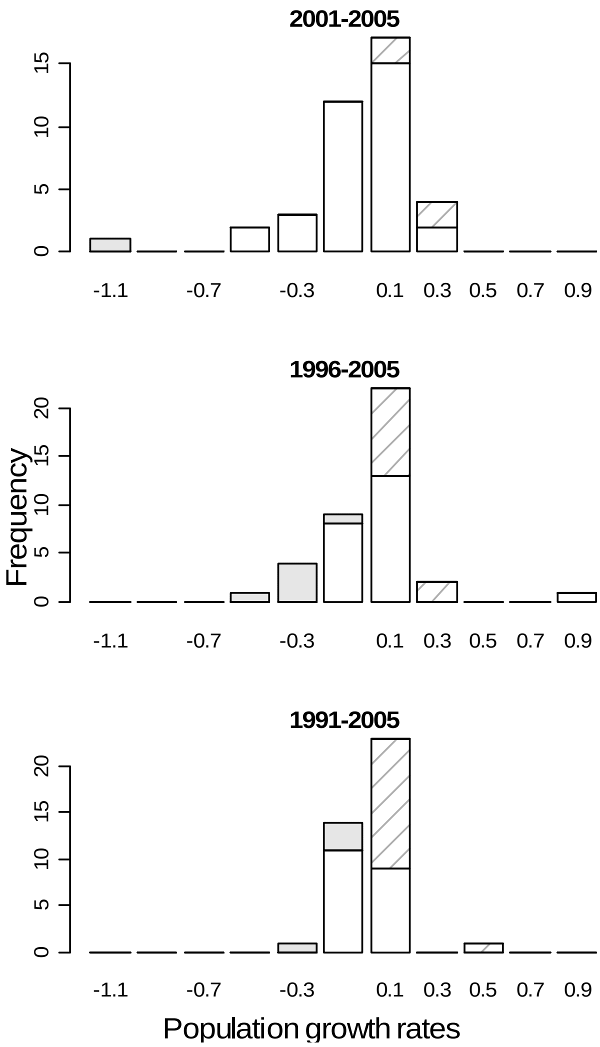

Figure 3. Frequency distribution of population growth rates (*r*, year^{-1}) for 39 fish and shellfish species estimated from the CGFS groundfish survey. Grey bars: slopes in agreement with the fishers' statement of a decrease (*p*-value >0.9); hatched bars: slopes in disagreement with the decrease statement (*p*-value <0.1); white bars: slopes neutral to the decrease statement (intermediate *p*-values). In case of a stationary community, 8 of these 39 species are expected to be non-neutral to the statement by chance. See list of species and *p*-values in the Appendix.

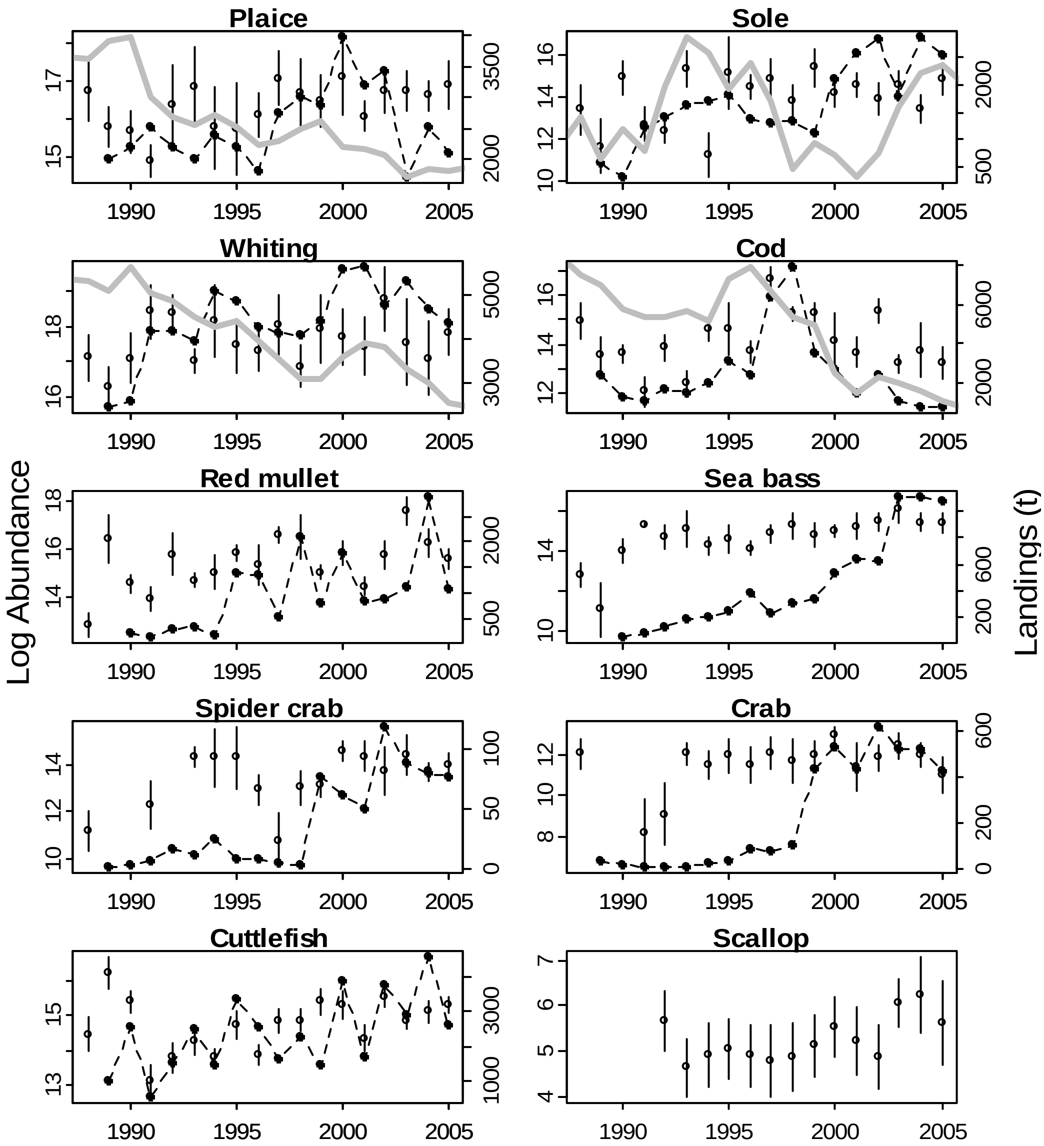

Figure 4. Survey-based log-transformed abundance indices (open circles with 95% confidence intervals, left axis), French landings (full circles and dashed lines, tonnes, right axis), and VPA-based stock estimates (grey lines; after ICES, 2008) for 10 target species in the eastern English Channel. Stock estimate ranges for plaice: 4470–14 700 t; sole: 7950–13 450 t; whiting: 97 000–317 000 t; cod: 28 500–96 500 t.

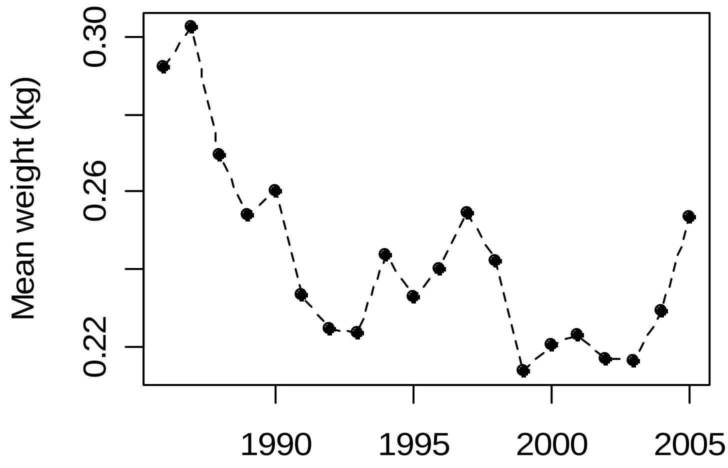

Figure 5. Average weight of sole in ICES area VIId, as estimated from the data in ICES (2007b). 2001–2005: $P(s < 0) = 0.07$; 1996–2005: $P(s < 0) = 0.715$; 1991–2005: $P(s < 0) = 0.639$.

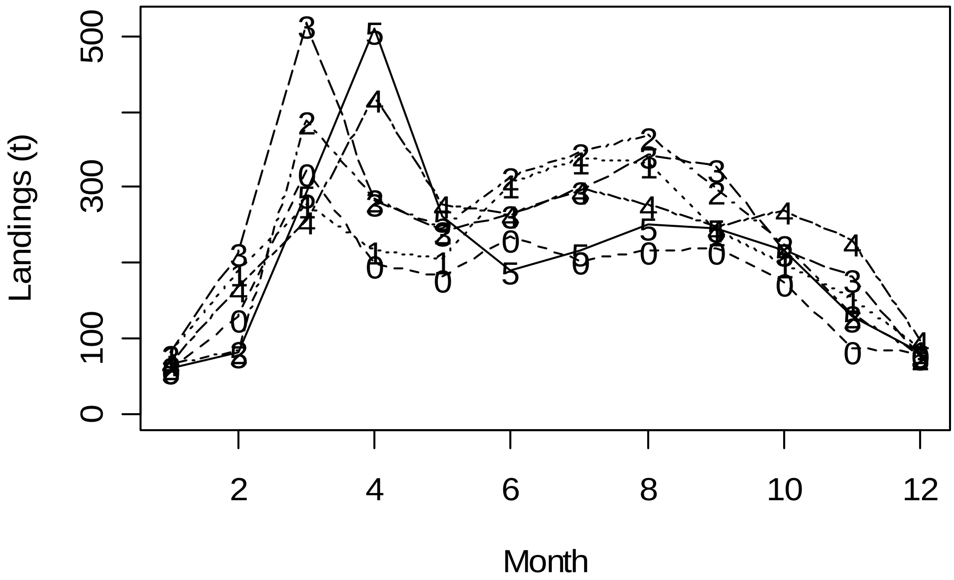

Figure 6. Monthly French landings of sole, 2000–2005. Each year is identified by its last figure (e.g. 0 for 2000).

Tables

Table 1. Fishers' statements, hypotheses tested, and results over three time horizons. Shaded cells do not contribute to the perception comparison and are reported for information only, because the corresponding time-frame was not mentioned by fishers. A agree, D disagree, N neutral.

Fishers' statement	Time-frame mentioned by fishers	H_0	Test result, 2001–2005	Test result, 1996–2005	Test result, 1991–2005	Full results
Generally, resources decreased	Both recent and longer term	Total abundance of trawlable resources decreased	Neutral	Neutral	Agree	Table 2
		Total biomass of trawlable resources decreased	Neutral	Neutral	Agree	Table 2
		Total French landings decreased	Neutral	No data	No data	No data
		Abundance of resource populations decreased	1A, 4D, 34N	6A, 11D, 22N	4A, 15D, 20N	Figure 3, Appendix
Especially flatfish (plaice and sole), whiting, and cod decreased, and more recently cuttlefish	Recent Cuttlefish: last year	Survey-indices decreased	Neutral	3N, 2D	3N, 2D	Table 4
		Stock estimates decreased	3A, 1D	3A, 1N	3A, 1D	Table 4
		Landings decreased	4A, 1N	1A, 2N, 2D	2N, 3D	Table 3
Red mullet appeared and increased, whereas cod moved to more northern areas.	Longer term	Red mullet population increased	Neutral	Agree	Agree	Table 4
		Cod population increased in the North Sea	Disagree	Disagree	Disagree	Figure 4
Spider crab, crab, and sea bass increased, whereas scallops remained constant.	Longer term	Populations increased	Neutral	Agree	Agree	Table 4
		Landings increased	3N, 1A	1N, 3A	Agree	Table 3
		No change for scallops	Neutral	Disagree	Disagree	Table 4
The average size of the catch decreased, especially of sole.	10 years ago	Average weight of sole in catch decreased	Disagree	Neutral	Neutral	Figure 5
The fishing season for sole shifted towards later dates and decreased in length	Undefined	Fishing season shifted	Agree	No data	No data	Figure 6
The number of foreign vessels fishing in the area increased	Recent	Share of foreign vessels in total landings increased	Agree	No data	No data	Table 2
	Longer term		No data	No data	No data	
The length of nets increased	Undefined		No data	No data	No data	
Water warmed	Variable	Temperature increased	Agree	Agree	Agree	See text
Pollution, especially waste, was high, but decreased	Variable	Pollution was high	Agree	Agree	Agree	See text
		Pollution decreased	Agree	Agree	Agree	See text

Seabed damaged by fishing gears and gravel extraction	Undefined	Bottom damaged	Weak agreement			See text
Gravel extraction can damage spawning areas	In future	Gravel extraction damages sea floor	Weak agreement			See text
Overall		All statements supported by data, irrespective of time-scale	Weak agreement (p = 0.724)	Weak disagreement (p = 0.155)	Disagree (p = 0.063)	
		Statements supported by data on the time-scales mentioned by fishers	Weak agreement (p = 0.770)	Agree (p = 0.959)	Agree (p = 0.998)	

Table 2. Direction of trend (sign of slope) and *p*-value of the relevant null hypothesis (H_0) for community indicators in the eastern Channel, for three time horizons, and for French landings and the foreign share in total landings from the area, 2000–2004.

Index	H_0	2001–2005		1996–2005		1991–2005	
		Direction	*p*-value	Direction	*p*-value	Direction	*p*-value
Total biomass (t year^{-1})	Decrease	+	0.485	–	0.599	–	0.966
Total abundance (millions year^{-1})	Decrease	–	0.525	–	0.711	–	0.968
French landings (t year^{-1}) (2000–2004)	Decrease	–	0.653	NA	NA	NA	NA
Foreign share (% year^{-1}) (2000–2004)	Increase	+	0.998	NA	NA	NA	NA

NA data not available.

Table 3. Direction of trend (sign of slope) and *p*-value of the relevant null hypothesis (H_0) for linear regression of French landings from the eastern Channel, for three time horizons.

Species	H_0	**2001–2005**		**1996–2005**		**1991–2005**	
		Direction	***p*-value**	**Direction**	***p*-value**	**Direction**	***p*-value**
Cod	Decrease	–	0.899	–	0.989	–	0.664
Whiting	Decrease	–	0.95	+	0.14	+	0.052
Plaice	Decrease	–	0.893	–	0.623	+	0.203
Cuttlefish	Decrease	+	0.262	+	0.067	+	0.009
Sole	Decrease	–	0.516	+	0.004	+	0.001
Crab	Increase	–	0.351	+	0.996	+	1
Sea bass	Increase	+	0.963	+	1	+	1
Spider crab	Increase	+	0.552	+	0.996	+	1
Red mullet	Increase	+	0.782	+	0.728	+	0.99

Table 4. Direction of trend (sign of slope) and *p*-value of the relevant null hypothesis (H_0) for survey-based abundance indices and/or VPA-based stock estimates (source ICES, 2008) of target species in the eastern Channel, for three time horizons.

Species name		**Latin name**	**2001–2005**		**1996–2005**		**1991–2005**	
			Direction	***p*-value**	**Direction**	***p*-value**	**Direction**	***p*-value**
Species expected to have decreased H_0: $r<0$								
Cod	survey	*Gadus morhua*	–	0.748	+	0.283	+	0.279
	stock assessment		–	0.953	–	1	–	1
Whiting	survey	*Merlangius merlangus*	–	0.645	+	0.173	+	0.168
	stock assessment		–	1	–	0.985	–	1
Plaice	survey	*Pleuronectes platessa*	+	0.07	+	0.018	+	0.013
	stock assessment		–	0.913	–	0.998	–	1
Cuttlefish		*Sepia officinalis*	+	0.196	+	0.11	+	0.103
Sole	survey	*Solea solea*	0	0.5	+	0.055	+	0.048
	stock assessment		+	0.008	+	0.196	–	0.655
Species expected to be stationary H_0: $r=0$								
Scallop		*Pecten maximus*	+	0.145	+	0.006	+	0.02
Species expected to have increased H_0: $r>0$								
Crab		*Cancer pagurus*	–	0.343	+	0.983	+	0.988
Sea bass		*Dicentrarchus labrax*	+	0.561	+	0.997	+	0.999
Spider crab		*Maja squinado*	–	0.237	+	0.989	+	0.993
Red mullet		*Mullus surmuletus*	+	0.738	+	0.971	+	0.977

Appendix

List of species analysed for trends in groundfish survey abundance indices and *p*-values of test for agreement with decrease statement on three time horizons

Species	**2001–2005**	**1996–2005**	**1991–2005**
Buglossidium luteum	0.298	0.763	0.004
Callionymus lyra	0.885	0.374	0.5
Cancer pagurus	0.657	0.626	0.018
Chelidonichthys cuculus	0.326	0.404	0.921
Chelidonichthys gurnardus	0.371	0.11	0.117
Chelidonichthys lucerna	0.392	0.283	0.168
Clupea harengus	0.507	0.412	0.883
Dicentrarchus labrax	0.439	0.006	0.018
Echiichthys vipera	0.444	0.283	0.005
Engraulis encrasicolus	0.768	0.11	0.557
Gadus morhua	0.748	0.947	0.289
Galeorhinus galeus	0.832	0.696	0.974
Hyperoplus	0.976	0.947	0.832
Limanda limanda	0.463	0.086	0.628
Liza aurata	0.57	0.895	0.687
Loligo sp.	0.304	0.016	0.103
Maja squinado	0.763	0.025	0.06
Merlangius merlangus	0.645	0.315	0.742
Microstomus kitt	0.635	0.283	0.079
Mullus surmuletus	0.262	0.396	0.033
Mustelus asterias	0.064	0.02	0.023
Mustelus mustelus	0.33	0.465	0.348
Necora puber	0.62	0.997	0.832
Platichthys flesus	0.777	0.982	0.055
Pleuronectes platessa	0.07	0.315	0.018
Raja clavata	0.142	0.013	0.001
Raja montagui	0.376	0.792	0.662
Sardina pilchardus	0.787	0.978	0.995
Scomber scombrus	0.239	0.827	0.883
Scyliorhinus canicula	0.295	0.095	0.018
Scyliorhinus stellaris	0.012	0.123	0.008
Sepia officinalis	0.196	0.055	0
Solea solea	0.5	0.708	0.11
Spondyliosoma cantharus	0.07	0.027	0.033
Sprattus sprattus	0.536	0.975	0.832
Trachurus trachurus	0.409	0.086	0.998
Trisopterus luscus	0.77	0.703	0.168
Trisopterus minutus	0.421	0.208	0.403
Zeus faber	0.578	0.033	0.233