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Practical issues affecting the utility of field survey data for biodiversity monitoring

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There is growing emphasis on monitoring biodiversity in European waters not least due to the EC's recent Marine Strategy Framework Directive (MSFD) listing biodiversity as one descriptor of 'Good Environmental Status' (GES). Member States already have various monitoring surveys in place, in particular groundfish and other fisheries surveys, which may provide a cost-effective way of assessing some elements of biodiversity. The MSFD recognises the "*need to ensure, as far as possible, compatibility with existing programmes*". Although existing field surveys are a potential source of quantitative data for examining spatial and temporal biodiversity patterns, it must be acknowledged that such surveys were often not originally designed to monitor 'biodiversity', and long-term surveys may have had changes in survey design at some point, and/or subtle changes in survey protocols over time. Field surveys for infauna and plankton typically collect and preserve samples at sea, and subsequent laboratory work includes the use of reference collections, quality assurance and longer-term sample storage. Surveys with towed gears can collect large amounts of complex biological material which is typically processed at sea, and so different forms of quality assurance are required. The taxonomic knowledge, experience and enthusiasm of sea-going staff can also influence the biodiversity information collected (e.g. time spent sorting complex catches, species identification). Hence, matrices of species-station data can contain 'artefacts' that need to be understood and addressed before deriving biodiversity metrics, and may even necessitate some degree of data filtering. This paper uses field data from selected surveys to illustrate how various factors can affect 'biodiversity information'.

Keywords: biodiversity, benthos, fish, survey design, temporal change

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Introduction

Offshore surveys have long been used to describe spatial and/or temporal patterns in the structure and distribution of marine faunal assemblages and faunal associations, including plankton (e.g. Rodriguez *et al.*, 2009), meiofauna (e.g. Schratzberger *et al.*, 2006), macrobenthic infauna (e.g. Rees *et al.*, 2007), larger epifauna (e.g. Callaway *et al.*, 2002) and fish (e.g. Farina *et al.*, 1997). There have also been several studies across ecological groups, for example combing the fish and epifauna, when multiple groups are sampled in a particular sampling gear (Ellis *et al.*, 2000). Such field studies may also allow the 'diversity' of these ecosystem components to be assessed over space and time.

There has been a growing interest in biodiversity and biodiversity indicators in recent years. Within European waters the recent Marine Strategy Framework Directive (MSFD) lists biodiversity as one descriptor of 'Good Environmental Status' (GES). This is defined as "*Biological diversity is maintained. The quality and occurrence of habitats and the distribution and abundance of species are in line with prevailing physiographic, geographic and climatic conditions*". Additionally, several other descriptors of GES also require biodiversity information, including descriptors 2 (Non-indigenous species), 3 (Commercial fish and shellfish), 4 (Marine food webs) and 6 (Seafloor integrity). The range of biological features and habitat types to be assessed under the MSFD (see CEC, 2008, Annex III, Table 1) addresses nearly all marine taxa (marine microbes and cephalopods do not seem to be addressed). In order to enable Member States to assess biodiversity status, the MSFD also emphasises the "*need to ensure, as far as possible, compatibility with existing programmes*".

European Member States already have various fisheries surveys that may provide a cost-effective way of assessing some components of marine biodiversity. Several ICES Expert Groups are well placed to try to standardise surveys, whether this is in terms of sampling gears and/or sampling protocols. There are well-established internationally-coordinated fish surveys, for example the various trawl surveys that are coordinated under the auspices of the International Bottom Trawl Survey Working Group (IBTSWG), the Beam Trawl Working Group (WGBEAM) and the Baltic International Fish Survey Working Group (WGBIFS), as well as other Expert Groups that coordinate ichthyoplankton and fishery acoustic surveys. Most existing long-term programmes are geared to gather data on commercially important fish and shellfish, and so non-commercial species may not have been considered in planning survey and sampling designs. ICES does not formally coordinate regular broad scale surveys of other marine taxa, however several dedicated Expert Groups have attempted to standardise sampling protocols. In some instances, some Expert Groups have succeeded to ensure that national surveys are sufficiently integrated to allow broad scale analyses, such as those undertaken by the Benthic Ecology Working Group (BEWG) for the North Sea (Rees *et al.*, 2007).

Although existing field surveys are an invaluable source of quantitative data for examining spatial and temporal patterns in the faunal group(s) sampled, it must be recognised that these surveys were typically **not** designed to monitor the broad array of biodiversity elements, including the many taxa that are not of commercial interest. As such, many elements of the survey, including the gear, sampling grid, degree of replication, temporal and spatial survey coverage, catch processing and taxonomic resolution used, may not be optimal for examining temporal patterns in ‘biodiversity’. Hence, all surveys will have associated caveats that must be acknowledged when such data are used to inform on ‘biodiversity’ status.

This paper highlights some of the issues that can be symptomatic for offshore surveys. For example, long-term surveys may have had changes in survey design at some point, and/or subtle changes in survey protocols over time, including.

- Change in gear (e.g. from a Granton trawl to GOV trawl; or change in type of grab)
- Change in tow duration (e.g. 60 to 30 minutes)
- Change in the timing of the survey
- Change in survey grid/spatial coverage and extent of survey area
- Change in species data collection over time (e.g. in taxonomic resolution and/or inclusion of minor taxa)
- Changes in sieve size for sample processing

Even within a single survey, there can be issues that may affect the samples and data collected, for example:

- Winch operations/fishing skipper effects
- Effect of sea conditions on sampling
- Processing of complex catches: what associated fauna is or isn’t recorded in trawl surveys (e.g. *Modiolarca* in sea squirts, fauna in the crevices of *Pentapora*)
- Processing large catches: sub-sampling procedures for trawl catches
- Individual differences in the way of sieving benthic samples (this can lead to, for example, fragile organisms (e.g. polychaete worms) being damaged and so hindering their identification to species level)
- Towed gears in which all the biological material that doesn’t always pass down to the cod-end (‘stickers’)
- Heavy catches reducing the mesh size in the cod end, and so potentially retaining more small material
- Taxonomic knowledge on board (e.g. when a ‘new’ species may be found in surveys)
- Misidentification of taxa
- Treatment of species that should not be collected by the gear (e.g. epifauna in corers, organisms smaller than mesh size)
- Use of various higher taxonomic levels within surveys

In addition to the above factors, quality assurance procedures can vary notably between surveys and over time. Field surveys for infauna and plankton typically collect and preserve samples at sea, and subsequent laboratory work includes the use of reference collections, quality assurance and longer-term sample storage. Hence, suspicious records can often be checked, and then either verified or corrected. However, surveys with towed gears can collect large amounts of biological material, thus restricting comparable quality assurance procedures. Catch processing in the field can also be of varying quality for practical reasons (e.g. when large or complex catches are made). Furthermore, the taxonomic knowledge, experience and enthusiasm of sea-going staff may influence the biodiversity information collected, for example in terms of the time that is spent sorting complex catches, or identifying or checking problematic species).

Hence, matrices of species-station data, often the starting point for biodiversity assessments, can contain ‘artefacts’ that need to be addressed before deriving biodiversity metrics, and that may even necessitate data filtering. Here we use field data from selected national and internationally-coordinated surveys (in the form of case studies) to illustrate how various factors can affect ‘biodiversity information’.

The overall aim of the paper is to highlight some of the problems and limitations that are often associated with time-series data. The paper does not suggest that assessments of 'biodiversity' are not practicable per se where any of the mentioned problems in time series occur (indeed, we would stress that many of the existing surveys contain invaluable information with which to examine temporal and spatial patterns in 'biodiversity'), but simply to reaffirm the view that survey coordinators and data collectors must be involved in the preparation, analysis and interpretation of such data. This is required to minimise the risks that data are misinterpreted, as has occurred on some occasions in the past.

Case study 1: Temporal changes in the catch processing of problematic taxa

Most surveys will encounter some problematic taxa. This may be because the taxa are little-known, appropriate identification or reference material is not available, and/or the staff collecting the data do not have the time or training to fully speciate that part of the catch.

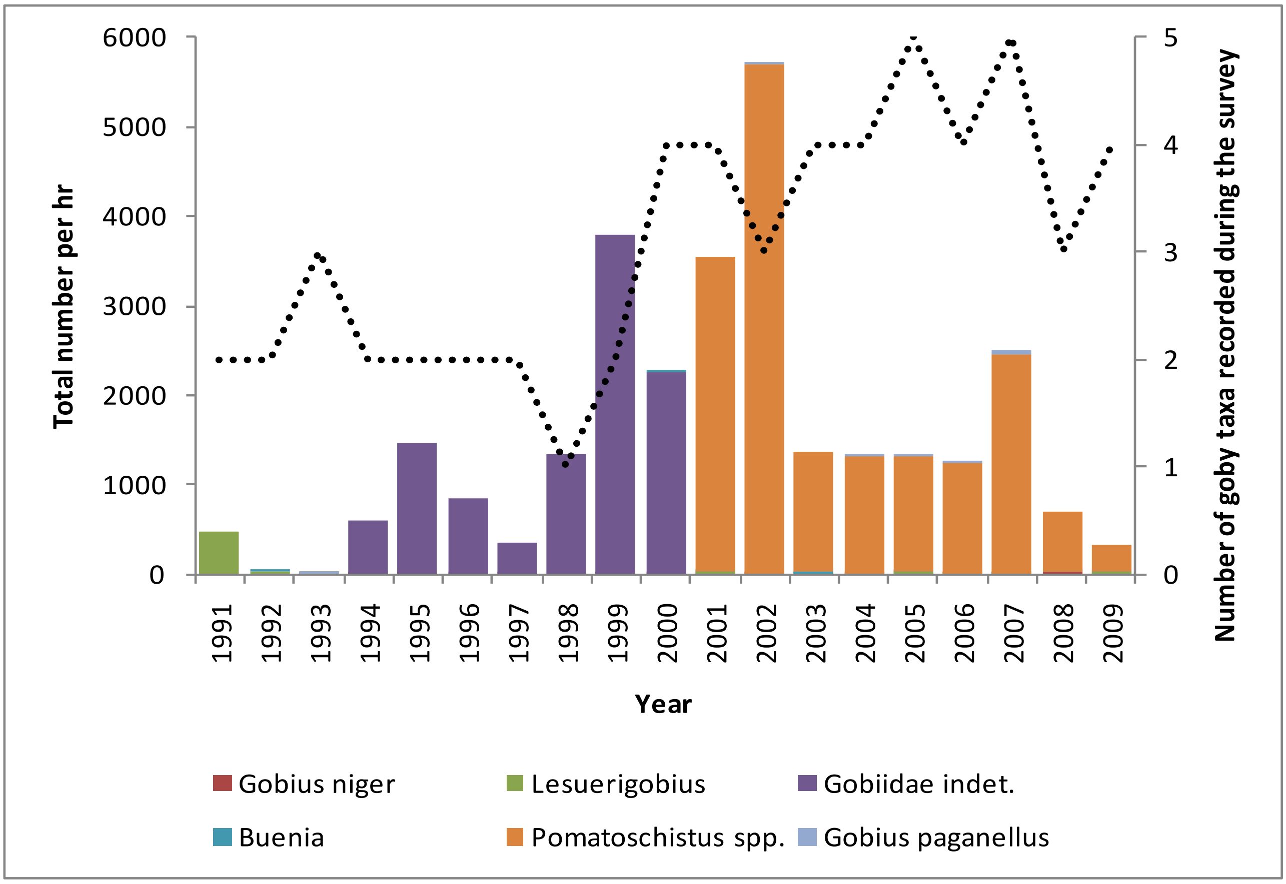
The recording of small-bodied, non-commercial fish captured in fishery surveys is a good example of this, as illustrated here by the quantification of gobies (Gobiidae) in the UK beam trawl survey of the Irish Sea and Bristol Channel (Parker-Humphreys, 2004a,b).

Only two species of goby were recorded in 1991: Fries's goby *Lesuerigobius friesii* and black goby *Gobius niger*. The former appears to be more abundant in this initial year, but most samples of this species were captured on exploratory tows in the North-western Irish Sea (on their preferred habitat, the muddy *Nephrops* ground), but there has been a lower density of stations on these grounds since then.

Although some of the larger and/or more conspicuous gobies were recorded in the early 1990s, this survey only started to record catches of sand goby *Pomatoschistus* spp. from 1993 (Figure 1), with all these recorded as 'Gobiidae (indet.)'. However, some other gobies will also have been recorded within this generic category as well. In 2001, it was decided that surveys should attempt to identify all gobies to species level, with the exception of sand gobies which were to be recorded to genus. Sand gobies can be difficult to identify, especially when large numbers of juveniles are captured, and there will possibly be five species in the study area (Miller, 1986). There also appears to be a peak in 'goby catches' in the middle period of the time series, although it should be noted that the epibenthic part of the catch was often sampled at every station during this time (e.g. Ellis *et al.*, 2000), and so more detailed processing of the catches could have resulted in more gobies being separated from the epibenthic bycatch and recorded.

It should also be noted that there is potential for some confusion between *Pomatoschistus* spp. and the similar sized Jeffrey's goby *Buenia jeffreysi*. This species was recorded in 1992 (when one member of sea-going staff was familiar with the species), but has only been recorded regularly since 2000, after more staff were trained in the identification of this species. The apparent absence of this species in the period 1993–1999 is possibly an artefact due to them not being misidentified as sand gobies.

Hence, in terms of the fish diversity, it must be recognised that gobies have not been sampled in a standard fashion in this survey, with the apparent increase from 1–3 goby taxa during the 1990s to 3–5 taxa since 2000 purely an artefact of improvements to the sampling protocol and the taxonomic expertise of the staff.



Species	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Buenia jeffreysi		■								■	■		■		■		■		■
Lesuerigobius friesii	■	■	■							■	■		■	■	■	■	■	■	■
Gobius niger	■		■	■	■	■	■		■	■	■	■	■	■	■	■	■	■	■
Gobius paganellus			■									■		■	■	■	■		
Gobiidae indet.				■	■	■	■	■	■	■									
Pomatoschistus spp.											■	■	■	■	■	■	■	■	■

Figure 1: Temporal changes in processing gobies in the UK beam trawl survey (1991–2009), giving (top) the total numbers of gobies caught (all catches raised to numbers per hour) and the total number of goby taxa (dotted line), and (bottom) the presence of different goby taxa in the data set.

Case study 2: The arrival (or re-appearance) of a 'new' species in a survey

Plankton and benthic surveys generally preserve samples collected in the field, with subsequent identification in the laboratory often using identification manuals, including dichotomous keys. Indeed, scientists in these disciplines are trained and encouraged to use dichotomous keys for correct identification. Furthermore, the samples are usually stored for several years and potential misidentifications can be checked and revised, or the taxonomic resolution of identifications improved, by re-investigation of archived samples. However, the field identification of larger organisms, such as fish and birds, is generally based on 'gestalt' recognition of the species.

A biologist on a groundfish survey will identify the collected specimens based on the visual inspection of the morphology and the presence of discriminating characters, and typically only use identification keys when a species is not recognised. Whereas this is appropriate for those distinctive fish taxa that are captured frequently, it does require an appropriate knowledge of all the fish species in the area and in adjacent waters. If the identifier is unfamiliar with a sympatric species with broadly similar morphological features, this species can be overlooked and erroneously identified as the more familiar species. In some surveys, unfamiliarity with sister taxa has confounded the identification of multiple species. With a greater encouragement for the correct identification of fish species in recent years, and concurrent improvements in staff training, some fish species have appeared (or re-appeared) in surveys.

The reporting of rockling (Gadidae; Lotinae) in groundfish surveys provides a good example of this. Of the six or seven rockling species that occur around the British Isles, many of the more common species are often separated by the number of barbels (i.e. whether they have three-, four- or five barbels). Some sea-going staff will incorrectly presume that any rockling with three barbels is a three-bearded rockling. However, although this may work for the identification of four-bearded rockling *Rhinonemus cimbrius*, it means that northern rockling *Ciliata septentrionalis* can be misidentified as five-bearded rockling *Ciliata mustela*, and that both big-eye rockling *Antonogadus macrophthalmus* and shore rockling *Gaidropsarus mediterraneus* can be incorrectly recorded as three-bearded rockling *Gaidropsarus vulgaris*.

For example, when the data for rockling held in the DATRAS database is examined (Figure 2), some nations have not recorded *C. septentrionalis*. Although English surveys recorded *C. septentrionalis* for several years in the 1980s, the prolonged absence of this species until 2007 suggests that they were confounded with *C. mustela* for much of the time-series. A similar issue also affects data from Dutch surveys, whereby *C. septentrionalis* were apparently absent from 1984 to 2003 inclusive. French surveys first recorded *C. septentrionalis* in 2005.

Given the widespread confusion between these sympatric taxa, any studies on fish diversity should ensure that data analysis is preceded by aggregation of these data to at least the level of genus, or possibly combined at the level of sub-family (Lotinae).

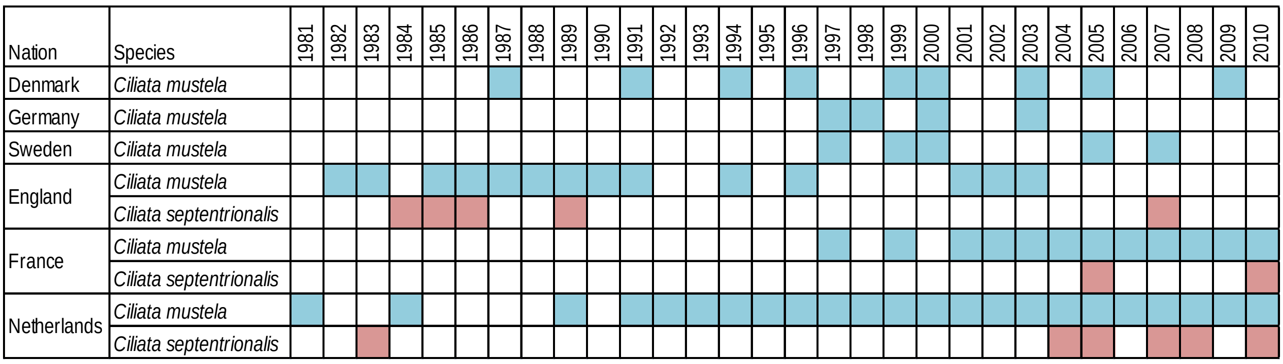


Figure 2: Presence of five-bearded rockling (*C. mustela*) and northern rockling (*C. septentrionalis*) in surveys in the North Sea (all quarters). Based on analyses undertaken by ICES, 2010b. (Data source: DATRAS)

Case study 3: Inconsistent use of various higher taxonomic levels within surveys, and how to deal with the improvements in identification

Another problem in many surveys is the use of higher taxonomic levels to group sister taxa, and then how to deal with any changes in identification skills during the time series. It is important to note that surveys should ensure and maintain appropriate training in identifications skills of the scientific staff that allow improved data to be collected over the course of the time series (e.g. through user-friendly keys, specific identification training courses for new staff). Furthermore, detailed and possibly long-term studies may be required to evaluate the possibilities to reconstruct the previous time series when species were grouped.

As explained above identification of fish species in ground-fish surveys is based on the visual inspection of the morphology and the presence of discriminating characters, and only use identification keys when a species is not recognised. Detailed sorting of time-consuming fish samples is usually carried out after sorting the "common" and abundant species. Nevertheless when identification of what may even be a very abundant species is difficult, and may be related to depth and/or area, or trends in abundance of each of the species, the utility of these data for biodiversity studies (e.g. number of species, ecological indices such as diversity or dominance.), and even length-based metrics may be compromised.

Argentines including the greater argentine (or greater silver smelt) *Argentina silus* and lesser argentine *A. sphyraena*, are sister and sympatric species that occur in a large area of the North Atlantic, with the lesser argentine considered to inhabit shallower waters than the greater silver smelt, although they overlap over a broad depth range (Whitehead *et al.*, 1986).

In the Spanish Porcupine Bank survey, argentines have been usually grouped together as *Argentine* spp., given the problems in speciating the smaller fish (which can be damaged) and the potentially large catches that can be made. Catches reached 1000 individuals per haul as a stratified mean in the first three years of the time series (Figure 3a), and more than 20% of the fishes were caught in the first years of the survey. Indeed, argentines were the second most abundant species in the survey after blue whiting. The problematic diagnosis to separate the species, which is based on the relative sizes of the eye and the number of scales on the lateral line (Queró *et al.*, 2003) makes it impracticable to separate large catches. Whereas the smaller catches made in shallower waters were sometimes clearly composed mainly of *A. sphyraena* (Figure 3b), the inconsistencies in identification over the whole survey has resulted in the generic use of *Argentina* spp. when providing overall results for the survey.

Nevertheless, there is a clearly a decreasing trend in the relative abundance of argentines (Figure 3a), and it has been deemed important to study if this trend affects both or only one of the species. Large changes in abundance may also affecting ecosystem function and community metrics (e.g. diversity and dominance), even if the number of species per se is not affected by these variations.

The decrease in argentine abundance has allowed a more careful identification of the material (as shown in Figures 3b and 4, from the 2009 survey), but this also poses the question of whether it is possible to estimate the relative abundances in previous years, since the bathymetric and geographic distributions of both species is not constant (Figure 3b, 4a), and they also have an overlap in the length distribution (Figure 4b). This could also have important consequences for other length-based metrics, such as the proportion of large fishes (Piet *et al.* 2007), since one of these species can attain a length of >40 cm. Improved identification work will have to continue for several years before better conclusions on the estimated proportions by depth and area can be made, so as to better understand the dynamics of these species and to inform on any potential for including the two species in biodiversity studies.

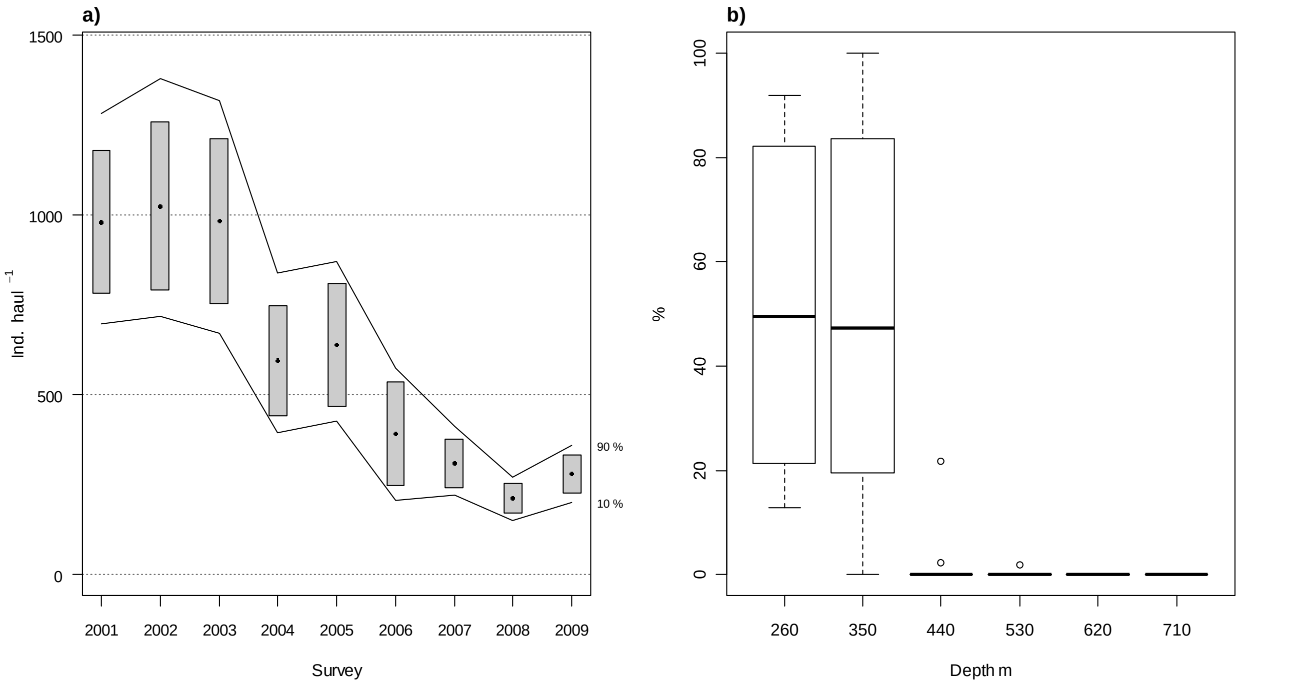


Figure 3. Argentines taken in the Spanish Porcupine Bank trawl survey indicating (a) the numerical abundance of *Argentina* spp. in the time series (2001–2009, boxes mark parametric standard error, lines a 1000 iterations bootstrap confidence interval), and (b) the percentage of *Argentina sphyraena* vs total *Argentina* spp. by depth, as recorded in the 2009 survey

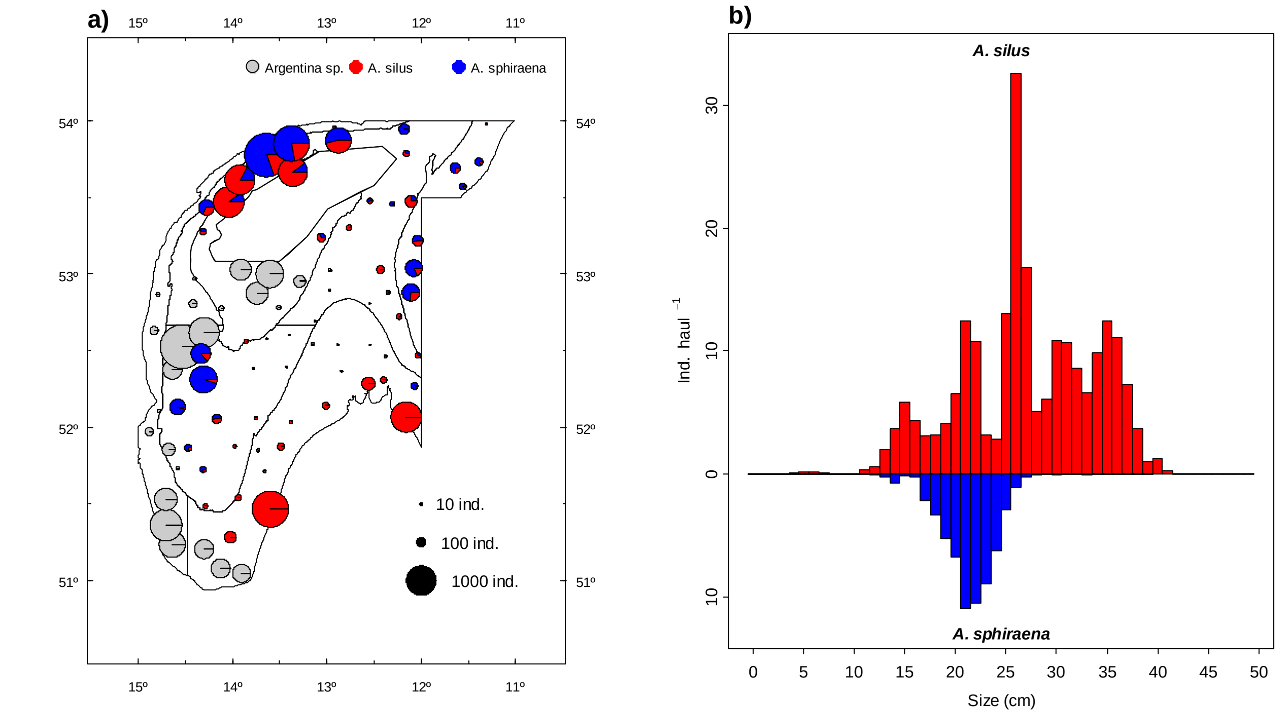


Figure 4. Argentines taken in the Spanish Porcupine Bank trawl survey indicating (a) the geographical distribution of catches of *Argentina* spp., *A. silus* and *A. sphyraena*, and (b) Length distributions of *A. silus* (red bars), and *A. sphyraena* (blue bars) during the 2009 survey

Case study 4: Change in gear type

Several surveys have had enforced changes in gear at some point in the time series. This may be due to problems sourcing materials or parts for 'older' gears, or reflect a change in gear so as to ensure better standardisation with parallel surveys. The English North Sea groundfish survey historically used a Granton trawl, but in 1992 switched to using the Grande Ouverture Verticale (GOV) trawl, so as to ensure standardisation within the North Sea IBTS. Surveys collecting time-series data should try to avoid step-wise changes and, if there are to be changes, attempt to implement them in as few years as possible. So, the change to GOV was also accompanied by a reduction in tow duration from 60 to 30 minutes.

Data from this survey were examined for the years 1990–1993 (i.e. two years of each gear) for the 57 stations that were fished in each of the 4 years. Five groups of taxa were aggregated at genus or family level, so as to reduce the impact of potential misidentifications over the period (Ammodytidae, Argentinidae, *Mustelus* spp., *Sebastes* spp. and Zoarcidae).

Data analysis (using the software package Primer version 6, Clarke and Gorley 2006) aimed to explore any differences in the fish catches (numbers per hour) between the two gears. Catch data were root transformed and the Bray-Curtis similarity calculated. Overall, there appeared to be only subtle differences between the catches of the Granton and GOV trawl (Figure 5), and these may be due to the higher headline height of the GOV trawl. Indeed, the GOV trawl was originally selected for use in the IBTS as this survey had evolved from a herring trawl survey (Heessen *et al.*, 2000).

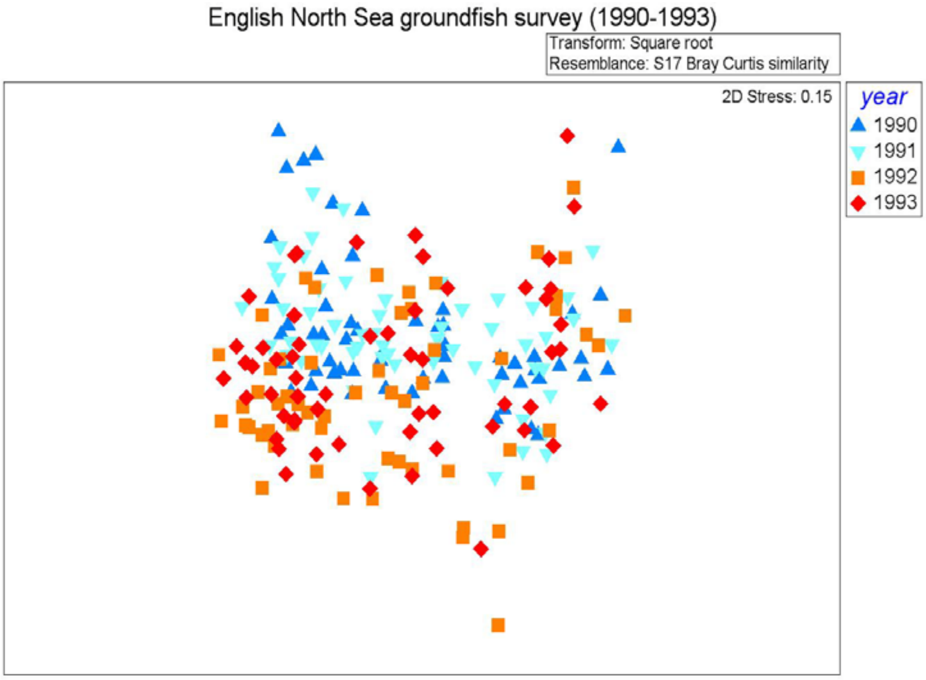
SIMPER analyses of the catch data highlighted that eight species (whiting *Merlangius merlangus,*Norway pout *Trisopterus esmarki,* haddock *Melanogrammus aeglefinus,* dab *Limanda limanda,* grey gurnard *Eutrigla gurnardus,* long-rough dab *Hippoglossoides platessoides,* herring *Clupea harengus* and cod *Gadus morhua*) were dominant in both gears. However, plaice *Pleuronectes platessa* and starry ray *Amblyraja radiata* were also important components of the Granton trawl catches and mackerel *Scomber scombrus* was an important component of the GOV catch. Overall, the average dissimilarity between catches from the gears was 64.7% (Table 1), although the mean similarity between the gears in three depth strata ranged from only 51% at intermediate depths to 57.8% in shallower waters.

Although the composition of the catches (transformed data) and the overall number of species captured (61–63 taxa) were broadly comparable in both gears, it is interesting to note that the Granton trawl appeared to catch more species over the course of low number of initial tows, although this was not evident when all stations had been completed, as shown by the similar asymptotes (Figure 6). This may be due to the confounding effect of tow duration, as tows with of 60 minutes duration may yield slightly more species than tows of 30 minutes (Ehrich and Stransky, 2001). The effects of tow duration are discussed further in the next case study.

One of the most important differences between these gears is the improved sampling of pelagic and bentho-pelagic species in the GOV trawl, and such taxa can be caught in large numbers. Hence, although the change of gear may not result in major differences in the total number of species recorded in the surveys, they are very different in terms of the numbers of individuals (Figure 7). This could lead to subtle, yet important, differences in various metrics of species richness, diversity and evenness.

Table 1: Results of SIMPER analyses of species responsible for dissimilarity between catches of Granton (1990–1991) and GOV (1992-1993) trawls. Species are listed in order of their contribution (Contrib%) to average dissimilarity between the two groups. It should be noted that pelagic species were usually caught in higher abundances with GOV trawl (species in bold)

Species		Av.Abund (Granton)	Av.Abund (GOV)	Av.Diss	Diss/SD	Contrib%	Cum.%
	Bentho-pelagic	**20.63**	**52.86**	12.69	1.12	19.62	19.62
	Pelagic	**7.3**	**30.94**	6.81	0.79	10.53	30.15
Melanogrammus aeglefinus	Demersal	14.01	29.85	6.63	1.22	10.24	40.39
Limanda limanda	Demersal	23.28	15.87	5.86	1.19	9.05	49.45
Merlangius merlangus	Demersal	21.73	29.74	5.61	1.3	8.67	58.12
	Pelagic	**4.16**	**10.56**	3.35	0.6	5.18	63.3
	Pelagic	**3.02**	**12.96**	3.07	0.46	4.75	68.05
Hippoglossoides platessoides	Demersal	11.35	9.84	2.76	1.26	4.27	72.33
Eutrigla gurnardus	Demersal	8.38	7.85	2.48	0.87	3.83	76.16
	Pelagic	**2.66**	**7.22**	2.12	0.64	3.27	79.43
Gadus morhua	Demersal	4.08	5.27	1.33	0.74	2.05	81.48
Argentinidae	**Bentho-pelagic**	**2.94**	**2.47**	1.19	0.69	1.84	83.32
Pleuronectes platessa	Demersal	4.46	2.17	1.14	0.9	1.76	85.08
Amblyraja radiata	Demersal	4.35	1.59	1.1	1.06	1.71	86.79
Microstomus kitt	Demersal	2.36	2.71	0.8	1.08	1.24	88.02
Echiichthys vipera	Demersal	1.59	1.12	0.78	0.37	1.21	89.23
Pollachius virens	Demersal	1.44	1.86	0.77	0.56	1.19	90.43



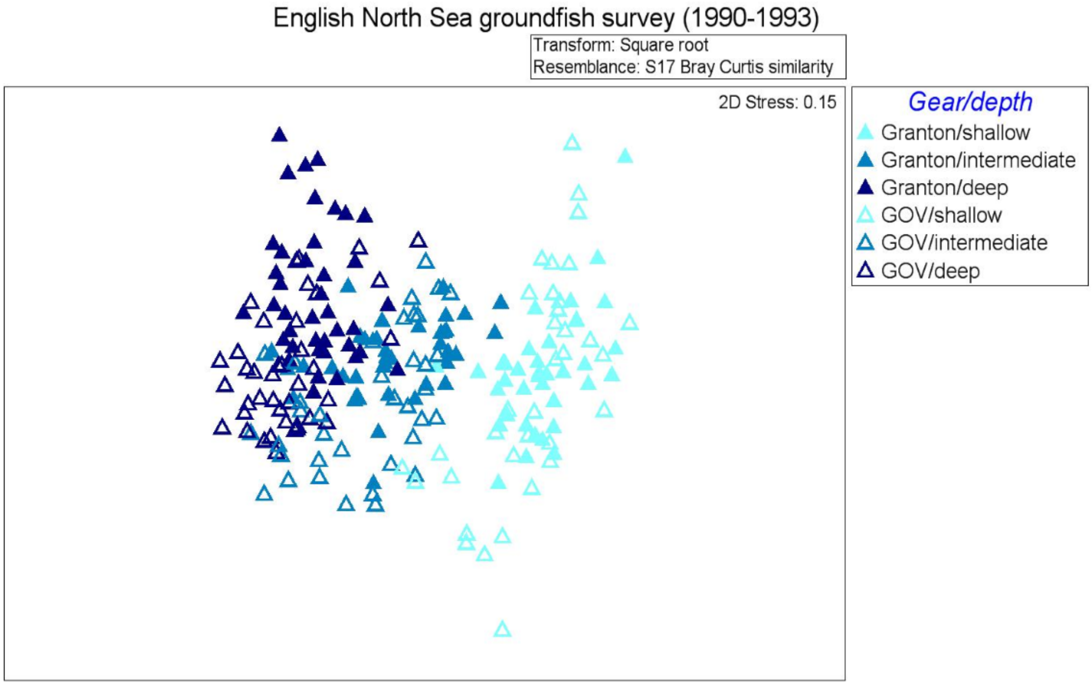


Figure 5: Fish catches in the English North Sea groundfish survey. MDS plot of fish catches from Granton trawl (1990–1991) and GOV trawl (1992–1993) by year (top) and depth strata (bottom). The following depth strata were used: shallow (mean depth of survey stations shallow = 23–50 m, 18 stations), intermediate (50–100 m, 19 stations), deep (100–180m, 20 stations).

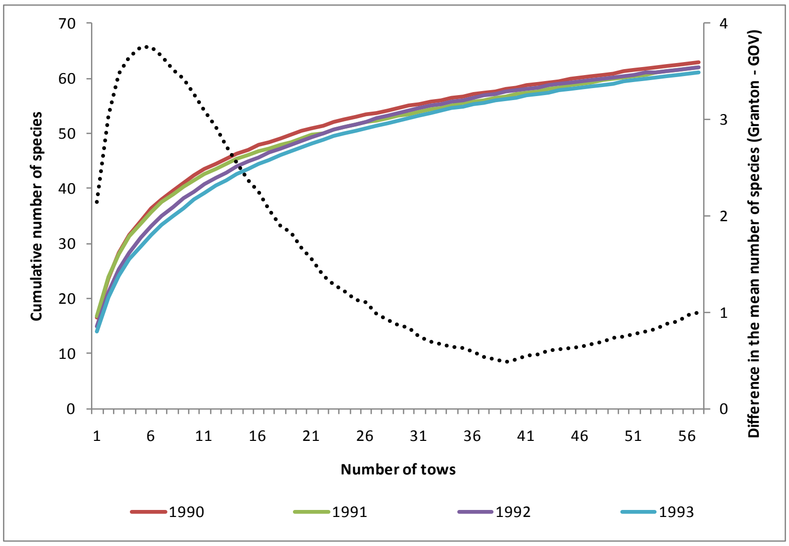


Figure 6: Fish catches in the English North Sea groundfish survey showing the species accumulation curves (based on 999 random sequences, error bars not shown) for the four years. The dashed line indicates the difference in the mean number of species caught between the Granton and GOV trawl.

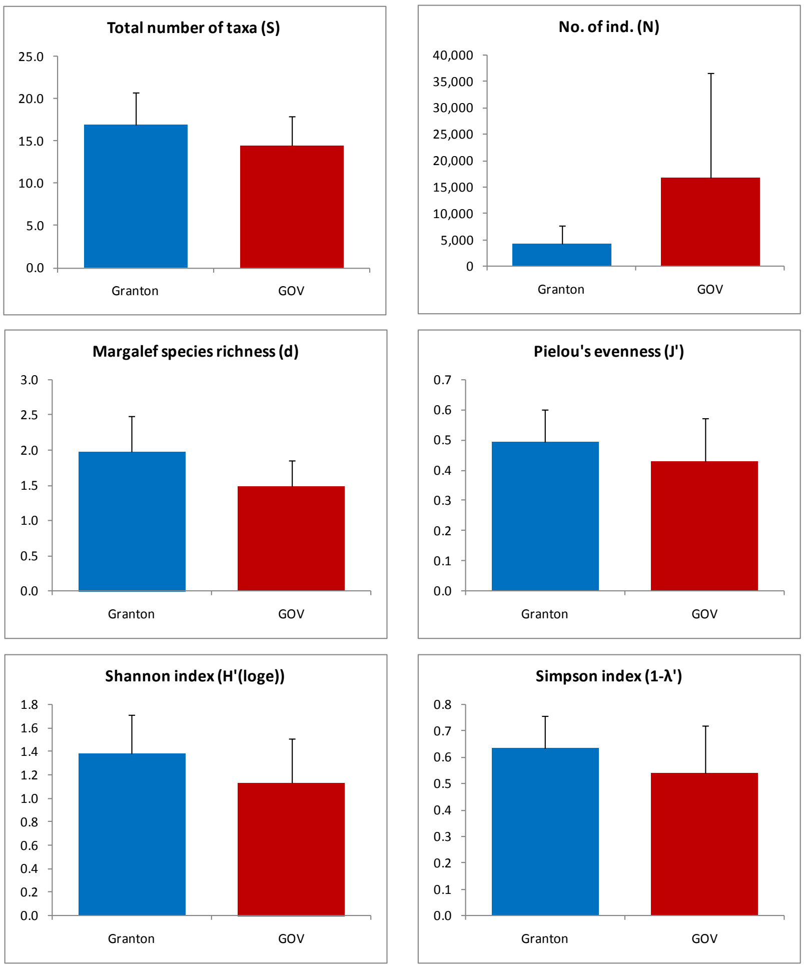


Figure 7: Diversity metrics for fish catches in the English North Sea groundfish survey showing the number of taxa, total number of individuals and selected diversity metrics for Granton trawl catches (1990-1991, blue bars) and GOV trawl catches (1992-1993, red bars).

Case study 5: Change in tow duration

There has been much discussion amongst statisticians and survey managers regarding the implications of sampling more stations with shorter tow durations for the representativeness of stations sampled. Often little is gained in terms of sampling accuracy and precision by increasing the tow duration (Godø *et al.*, 1990; Pennington and Vølstad, 1991, 1994; Gunderson, 1993; Goddard, 1997; Kingsley *et al.*, 2002; Johnson *et al.*, 2008). Hence, reductions in tow duration have been implemented in some surveys to be able to increase the number of stations sampled. For example, Pennington and Vølstad (1991) showed that 70 tows of 15 minutes (i.e. 17.5 hours of total tow duration) produced density estimates for ocean pout that were as precise as 60 tows of 30 minutes (i.e. 30 hours of total tow duration). Therefore, decreasing tow duration can not only save survey time, but also reduce operating costs since total towing time for a survey will be significantly reduced. Gear and equipment wear are a function of tow length, and less fuel will also be consumed whilst trawling.

Additional benefits of reducing tow duration are that smaller catches will require less sorting time, fewer large catches would need to be sub-sampled, and there would be more time for taking other biological measurements. Although the total catch will be less if tow duration is reduced, estimates of biological characteristics, such as length or age frequencies, will be more precise because the number of stations and hence the effective sample size will be larger (Pennington and Vølstad, 1994).

Nevertheless, in terms of biodiversity, reducing the tow duration could affect the catchability of faster swimming species, and also have an effect on the likelihood of catching rare or low abundant species, thus affecting the data for biodiversity studies in different ways. Indeed, most of the experimental studies on the effects of tow duration have examined catch rates and size frequencies of a small number of target species (e.g. Somerton *et al.*, 2002; Wieland and Storr-Paulsen, 2006), and in some instances the reduced tow duration has resulted in an increased catch per swept area, which could also affect time series information (Somerton *et al.* 2002). Few studies have examined the implications on the number of species caught, although Ehrich and Stransky (2001) reported an increase in the number of fish species caught with an increase in tow duration.

This case study illustrates the effects of tow duration in the Portuguese fish community in the autumn. The Portuguese groundfish surveys (see ICES, 2010b) have been conducted since 1979, continuously in autumn and partially in winter and summer, on the R.V. *Noruega* (or, in its absence, R.V. *Capricórnio*). Initially the main objectives of the surveys were to estimate the abundance and study the spatial distribution of the most important commercial species in the Portuguese trawl fishery. Later, recruitment indices of abundance and distribution for hake and horse mackerel were also evaluated in the autumn surveys. The data collected has been used in several biological studies and stock parameter estimations, including those related to the species distribution by area and depth, recruitment estimation, abundance indices, length-weight relationships, age determination, maturity, fecundity, food habits, and geostatistical analyses. Recent interest for biodiversity studies has emerged and, since 2004, greater efforts have been directed towards identifying species to the lowest taxonomic level practical.

The tow duration in the Portuguese surveys varied through the time series. It was 60 minutes from 1979-1980, reduced to 30 minutes from 1981-1989, increased back to 60 minutes in 1990-2001, and has been 30 minutes since 2002. Trawl speed has been constant (3.5 knots).

The first decrease from 60 to 30 minutes in 1981 was based on an analysis which indicated that tows of 30 minutes duration were sufficient to get abundance indices for the species targeted at that time (Cardador 1983a). However in the summer survey of 1989, results from new experiments were conducted. The two durations at the trawling speed of 3.5 knots indicated that 60 minute tows were more adequate to sample all developmental stages of the horse mackerel population. The large adults of horse mackerel were not caught in 30 minute tows at a trawling speed of 3.5 knots, which may be due to the faster swimming speed and/or endurance of these fish in front of the trawl net. The juveniles were considered to be sampled effectively with 30 minutes trawling at 3.5 knots (Cardador *et al.*, 1997). The experiments performed in the Portuguese summer survey of 2002 indicated that 30 minute tows were adequate to sample recruits of hake and horse mackerel, which were the main target species of the autumn surveys. So, it was decided in 2002 that the tow duration would be moved back to 30 minutes at this time of the year, as the objectives of the autumn surveys are to produce recruitment estimates. That decision allowed for a slight increase in the number of hauls per survey, thereby getting a better resolution on the estimate (Cardador, pers. comm.).

The data used to assess the impact of the change in tow duration of the Portuguese fish community included the surveys performed with R.V. *Noruega* with a Norwegian Campelen Trawl (NCT) with rollers in the groundrope. Data from the surveys in 1996, 1999, 2003 and 2004 were not used in the present study, as they were collected using a different vessel and gear. The Portuguese data used for this tow duration case study were the abundance and weight data by trawling location (station) for the following years:

1) **60 min**: 1997; 1998; 2000; 2001
2) **30 min**: 2002; 2005; 2006; 2007; 2008; 2009

Stations with less than 20 min duration were excluded from the 30 min surveys (3 in 2005; 2 in 2006; 3 in 2007; 6 in 2008; 2 in 2009) and stations with less than 50 min duration were excluded from the 60 min surveys (13 in 1997; 18 in 1998; 8 in 2001; 5 in 2001).

The effects of the change in tow duration on fish community indices (Table 2) were estimated using a three-way nested analysis of variance (ANOVA), where the response variable is the index tested (Table 2) and the effects are the tow duration (2 levels), the sampling year nested within the tow duration (4 levels per year), and the geographic strata in which the sampling was conducted (12 levels). All strata were sampled every year. The accumulation curves for the two tow durations were also computed.

The results from the nested ANOVA for the density and the species richness indicated a significant interaction between the 30 and 60-minute tow duration and the strata in which the sampling was conducted (Table 2). Shannon's diversity and Pielou's evenness indices showed a significant nested term (Year within Tow duration) and a significant single effect of tow duration. The graphical examination of the interaction (Figure 8) and the single effect (Figure 9) indicated that the 30-minute tow duration displayed higher values for almost all indices in all the strata. Comparison of the species accumulation curves (SAC, i.e. the cumulative number of species against the sampling effort in terms of the number of sites fished) indicated that the sampling effort for the two tow durations was sufficient to collect most of the species present, as both SAC easily reached an asymptote (Figure 10). However, the asymptotic value was higher for the 30 minute tows compared to 60 minute tows. Overall, results suggested that the efficiency of the Portuguese trawl surveys was increased by reducing tow duration from 60 to 30 minutes.

Table 2: Results from the three-way nested ANOVA estimating the effect of tow duration, the year nested in the tow duration, and the geographic strata in which the sampling was conducted. Df: Degree of freedom, SS: Sum of squares, MS: Mean square, p: Probability

	Df	SS	MS	F value	P
ln(Density)					
Tow duration	1	172.7	172.7	31.3147	<0.0001
Strata	11	155	14.1	2.5559	0.0032
Tow duration(Year)	6	107.7	17.9	3.2553	0.0034
Tow duration * strata	11	142.9	13	2.3569	0.0068
Residuals	3971	21893.8	5.5		
Species richness					
Tow duration	1	360.6	360.6	13.5026	0.0005
Strata	11	2398.71	218.06	8.1654	<0.0001
Tow duration(Year)	6	796.78	132.8	4.9726	0.0003
Tow duration * strata	11	737.76	67.07	2.5114	0.0109
Residuals	63	1682.47	26.71		
Shannon's index					
Tow duration	1	3.0462	3.0462	15.9974	0.0002
Strata	11	4.7703	0.4337	2.2774	0.0206
Tow duration(Year)	6	3.5356	0.5893	3.0946	0.0102
Tow duration * strata	11	3.5253	0.3205	1.6831	0.0980
Residuals	63	11.9963	0.1904		
Pielou's index					
Tow duration	1	0.22065	0.22065	12.15	0.0009
Strata	11	0.37643	0.03422	1.8844	0.0585
Tow duration(Year)	6	0.27333	0.04555	2.5085	0.0306
Tow duration * strata	11	0.34956	0.03178	1.7499	0.0827
Residuals	63	1.14408	0.01816		

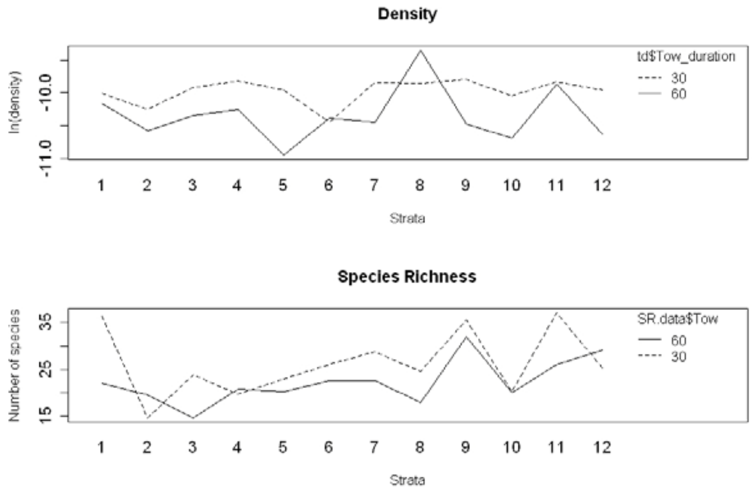


Figure 8: Interaction plot for the density and the species richness in trawls of 60 (solid line) and 30 minute duration (dotted line) in 12 strata.

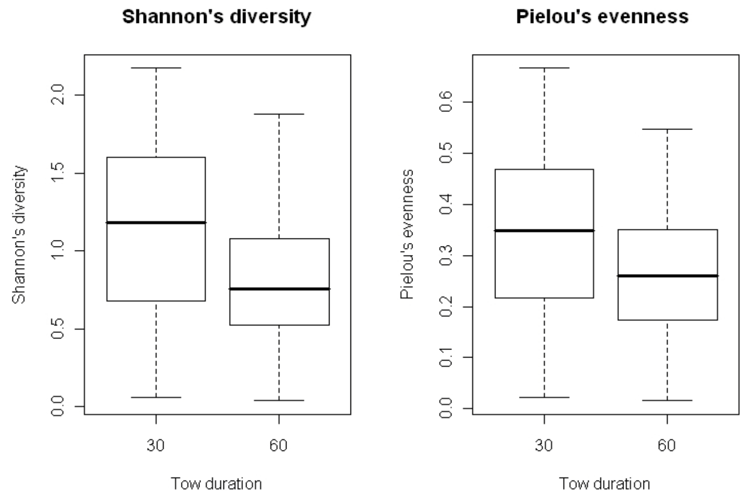
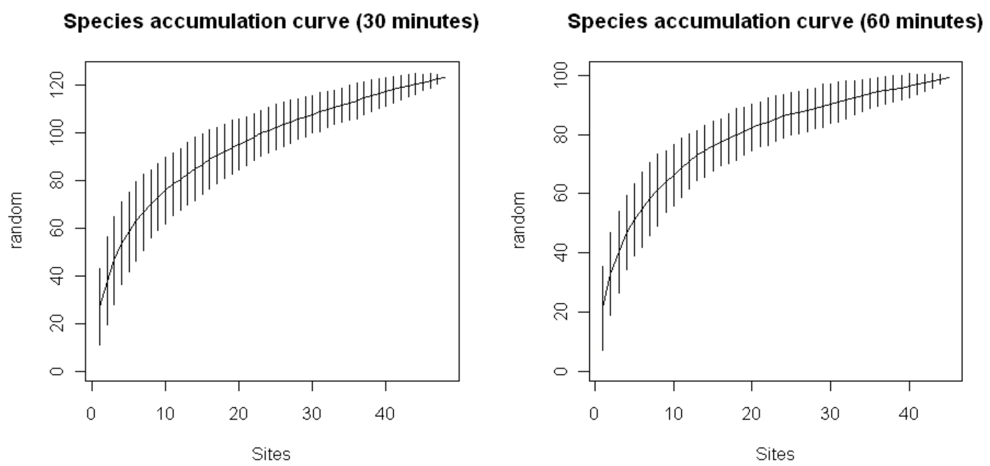


Figure 9: Mean Shannon's diversity (left) and Pielou's evenness (right) estimated by tow duration



Other factors that may affect ‘biodiversity’ information

The above case studies give some actual examples of how biodiversity information may be affected in time series information. However, there can be many other issues that occur during data collection that can also potentially influence species diversity information. Some of these factors relate to survey design and sampling protocols, and are elaborated on below, but some of these issues are related to the differences in behaviour and more difficult to quantify. For example, research vessels will have several fishing skippers and deck crew, and although protocols are constrained to ensure comparability in sampling, there can be differences in the behaviour of fishing skipper. For example, some fishing skippers may make minor adjustments to the length of warp deployed, or the towing speed/direction, and these could have implications for how much a trawl or dredge digs into the sediment.

(a) Changes in survey grid /spatial coverage

As noted above, changes in tow duration may affect diversity information in different ways. On the one hand, tows with an increased tow duration may have slightly more species (Ehrich and Stransky, 2001), but if reducing tow duration allows for more hauls to be made, then there is the potential for more sites to be fished, which may result in the overall survey recording more species. Indeed, the spatial coverage of a survey may have important implications for ‘biodiversity’ information.

Defining the bottom trawl sampling design relies on previous knowledge of the area to be sampled, as well as the types of species to be sampled and their seasonal behaviour and spatial distributions. Bottom trawl coverage is also constrained by untrawlable rocky grounds on the continental shelf and slopes, and water depth (with larger vessels not able to operate in shallow water, and some smaller vessels not equipped to sample deep water).

Many surveys may prioritize those stations to be sampled, but also have sampling sites of secondary importance which are sampled if there is time. In the event of poor weather, the principle scientist can then make informed decisions on which are the most important sites to sample. Stations of secondary importance, which may be sampled in only some years of the time series, may often be on the periphery of the main sampling grid (e.g. in deeper waters). Many surveys sample a variety of faunal assemblages (which may be related to biogeographical and/or bathymetric factors), and secondary sites may extend onto such assemblages that are not always sampled in the survey, which could lead to the sporadic appearance of species in a data set.

The Portuguese groundfish surveys started in June 1979 covering the continental shelf and upper slope, and followed a stratified random design (Pennington and Grosslein, 1978). In 1981 the stratification was defined by 12 sectors along the shelf subdivided into 4 depth bands (20–100, 101–200, 201–500 and 501–750 m) with a total of 48 strata (Borges, 1984, 1986; Cardador, 1983a,b). Nevertheless, randomly changing the sampling location every year in order to increase spatial accuracy estimates in that year, do not allow to measure consistently with low variance abundance/ biomass trends, because these variables are spatial correlated. Advantages of systematic designs over random stratified designs have been discussed by Kimura and Somerton (2006).

In order to reduce variance in the estimates of the Portuguese time series since 1990, the stations were fixed relative to 1989. Sampling design experiments were carried out during 2001, whereby a systematic design and a hybrid design were evaluated regarding hake abundance estimates (Jardim and Ribeiro, 2008). The systematic design included regular locations at smaller distances and the hybrid design overlapped the regular grid with the historical fixed stations. The results for hake abundance indicated a lower estimate with the hybrid design than with the systematic design (Jardim and Ribeiro, 2008).

Since 2005 a new sampling scheme, based on systematic and stratified random sampling, was implemented in the Portuguese groundfish surveys (ICES, 2010b). The reason was to facilitate the use of geostatistical models and to overcome the difficulties in the estimation of the variance but also allowing the calculations with the former 48 strata. The new sampling scheme includes depths from 20–500 m, since the main objective of the survey is to estimate recruitment indices for hake and horse mackerel. This mixed sampling scheme comprises 66 trawl positions distributed over a fixed grid and 30 random trawl positions, all sampled with tows of 30 minutes duration.

Multi-decadal time series of data can provide an essential historical perspective of the evolution of marine ecosystems under anthropogenic pressures and can be used to estimate ecosystem indicators (e.g. Methratta and Link, 2006; Cotter *et al.*, 2009). However, groundfish surveys have been driven principally by data requirements for conventional single species management, and so may not be ideal for deriving ecosystem indicators. Jouffre *et al.* (2010) identified a reference list of the main methodological challenges encountered when using scientific survey data as a source for estimating ecosystem indicators, and these are associated with four challenges: i) the delimitation of the target ecosystem, ii) gear associated catchability (important food web components may not be caught); iii) the change in sampling techniques and protocols through time; iv) the consistency and taxonomic level of species identification.

Quoting Link et al (2008): *Clearly there is a range of ways one can optimize surveying effort, including a re-examination of statistical survey designs*

(b) Processing biogenic fauna

Some beam trawl surveys and groundfish surveys collect information on the epibenthic bycatch, with such taxa either quantified (catch numbers and biomass), or the presence noted. There are some habitat-forming invertebrates, however, that have an associated fauna. Often the associated fauna is quite small (e.g. caprellids and other amphipods), or problematic to identify (e.g. small colonies of epizoite) and so are not recorded. Some associated fauna can however be more conspicuous and included within the overall catch.

For example, the bryozoan *Pentapora fascialis* has a complex structure with many crevices that can be occupied by a variety of other species, including squat lobsters *Galathea* spp., long-clawed porcelain crabs *Pisidia longicornis* and feather stars *Antedon bifida.* Although colonies of *Pentapora* may be recorded in catches (total biomass), the degree of more detailed examination to collect other fauna that may be hidden in the colony may depend on the member of staff and the time that is available (given that many fisheries surveys do not have the resource for preserving and subsequently examining large quantities of invertebrates).

Figure 11: Catch of *Pentapora fascialis*, showing some of the fauna that can be associated with this complex, habitat-forming species (inset shows the cowrie *Trivia* sp., squat lobster *Galathea* sp. and variegated scallop *Chlamys varia*).

(c) Recording of commensal organisms

Many organisms may have symbiotic relationships, and one commensal organism may simply be included in the enumeration of the main species, For example, the hermit crab *Pagurus prideaux* is invariably associated with the cloak anemone *Adamsia carciniopados.* Whereas the total biomass (including any undissolved shell and the anemone) and numbers of the hermit crab may be recorded in some surveys, it should be recognised that this species 'category' comprises two species.

Data for other less-frequent commensal organisms may also be potentially problematic. For example the anemone *Calliactis parasitica* will occasionally occur on the shells of hermit crab *Pagurus bernhardus*. Whereas some sea-going staff may record both species, other sea-going staff may ignore the anemone. Similarly, some small mytilids (e.g. *Modiolarca* spp.) may occur on (or in) the tests of ascidians (*Ascidia* spp., *Ascidiella* spp.), with some sea-going staff recording these species, and other staff may either over-look or not record the associated fauna.

It must be recognised that temporally or spatially comprehensive field data, including those collected during internationally coordinated surveys, will have been collected by staff with varying degrees of taxonomic skill and possibly different perceptions as to what data should be collected for some species. Hence, there does need to be due consideration of the dataset, and data collectors should assist in any data filtering that is deemed appropriate prior to data analysis.

Figure 12: Examples of commensal organisms, including (left) the hermit crab *Pagurus prideaux* and associated cloak anemone *Adamsia carciniopados,* and (right) hormathiid anemone on a common spider crab *Maja brachydactyla,*

(d) Inconsistent use of various higher taxonomic levels within surveys

Problematic taxa in field surveys may often be reported to higher taxonomic level, especially for taxa that are difficult to identify as juveniles, or that may be damaged during sampling. This then poses various problems with regards using the resulting data (although this issue is not addressed in this paper). However, it is also important to recognise that sea-going staff and data recorders may not always be fully aware of taxonomic hierarchies and nomenclature. An example of this would be for sandeels. There are five species of sandeel in northern European seas, which are distributed in three genera and a single family (Ammodytidae).

Raitts sandeel	*Ammodytes marinus*
Lesser sandeel	*Ammodytes tobianus*
Smooth sandeel	*Gymnammodytes semisquamatus*
Immaculate sandeel	*Hyperoplus immaculatus*
Greater sandeel	*Hyperoplus lanceolatus*

Trawl survey data may report information to species level (but these data may not necessarily be of high quality), and information may also be reported for 'Ammodytidae' and '*Ammodytes* spp.'. Whereas the latter term should only refer to the genus (i.e. one of two species), in reality some data collectors and providers who are not fully conversant with taxonomic hierarchies often presume that Ammodytidae and *Ammodytes* spp. are synonymous and inter-changeable, and such issues have to be recognised by data analysts.

(e) Processing of large catches and sub-sampling procedures

Towed gears can often generate large catches, and in such cases it is not realistic to process the whole catch. In general, the preferred method to sample such catches is to examine the whole catch and to note a small number of predominant species that can be sub-sampled in a 'mix'. Then the whole catch is processed and all other species removed (i.e. they are full samples from the total catch). The remaining sample, which should in theory only contain the defined range of *x* abundant species, is then weighed and this part of the catch is sub-sampled, with the composition of the sub-sample raised accordingly. Such procedures are the preferred methods for use in trawl surveys (e.g. ICES, 2010b).

However, in some field surveys (depending on vessel design and/or the volume of such large catches), some catches may be sub-sampled only. Although such a procedure is not ideal, it is sometimes the only pragmatic way of handling the catch with the time and staff available. Whereas the data collected from such sub-sampling are unlikely to have a major influence on studies on assemblage structure, given that such analyses are strongly influenced by the dominant fauna, the range of 'rarer' species within the sub-sample may influence studies on biodiversity, and the number of such species may depend on the total volume of the sub-sample examined. To date there have been few studies on the implications of sub-sampling (but see Heales *et al.*, 2000, 2003) and further studies are required.

Epibenthic catches in beam trawl surveys are often sub-sampled, although there has been little investigation into the possible affects of this. Table 3 shows data collected at a site in the Irish Sea where the catch was dominated by dead-man's fingers *Alcyoium digitatum,* and two sub-samples were processed. Although both sub-samples were of similar weights, and five species (*A. digitatum*, *Metridium senile*, *Asterias rubens*, *Flustra foliacea* and *Necora puber*) accounted for >98% of the biomass in both sub-samples, there were subtle differences in the number of species recorded in each sub-sample (the two sub-samples resulting in ca. 89% and 72% of the total number of taxa observed across both sub-samples). Obviously, this is an example of a single catch, and further field studies are required to better understand the implications of sub-sampling.

Table 3: Example of the differences in epibenthic sub-samples from a beam trawl catch in the Irish Sea

	Sub-sample A		Sub-sample B	
Species	**Kg**	**%**	**Kg**	**%**
Alcyonium digitatum	15.000	72.25	16.560	80.00
Metridium senile	2.735	13.17	2.705	13.07
Asterias rubens	1.710	8.24	0.935	4.52
Flustra foliacea	0.805	3.88	0.260	1.26
Necora puber	0.175	0.84	0.050	0.24
Hydrozoa (indet.)	0.160	0.77	0.025	0.12
Tritonia hombergi	0.070	0.34	0.030	0.14
Liocarcinus holstaus	0.030	0.14	0.010	0.05
Archidoris pseudoargus	0.025	0.12	0.035	0.17
Liocarcinus depurator	0.015	0.07	0.005	0.02
Inachus spp.	0.005	0.02	0.005	0.02
Alcyonidium diaphanum	0.010	0.05		
Macropodia spp.	0.005	0.02		
Ascidiacea (indet.)	0.005	0.02		
Ophiothrix fragilis	0.005	0.02		
Pandalus spp.	0.005	0.02		
Psammechinus miliaris			0.075	0.36
Ophiura albida			0.005	0.02
Total biomass sorted	20.76		20.70	
Number of taxa observed	16		13	

(f) Material that can stick in the net

Towed gears can collect a great deal of biological material and, when hauling the net and emptying the cod end, most of the contents are passed down to the cod end. In terms of fishing surveys, deck crew will check the net (as much as they can) to check that all fish and commercial shellfish are removed. However, many invertebrates and even some fish can 'stick' in the net (e.g. Figure 13). This can result in several issues for 'biodiversity' studies. As some of this biological material may pass down to the cod end in subsequent tows, catch processors need to try and ensure that material from previous hauls are not included within the catch. Whereas 'old' material can be obvious in groups of animal (e.g. the gills of dead fish are paler than those of recently caught fish), it may be difficult to fully

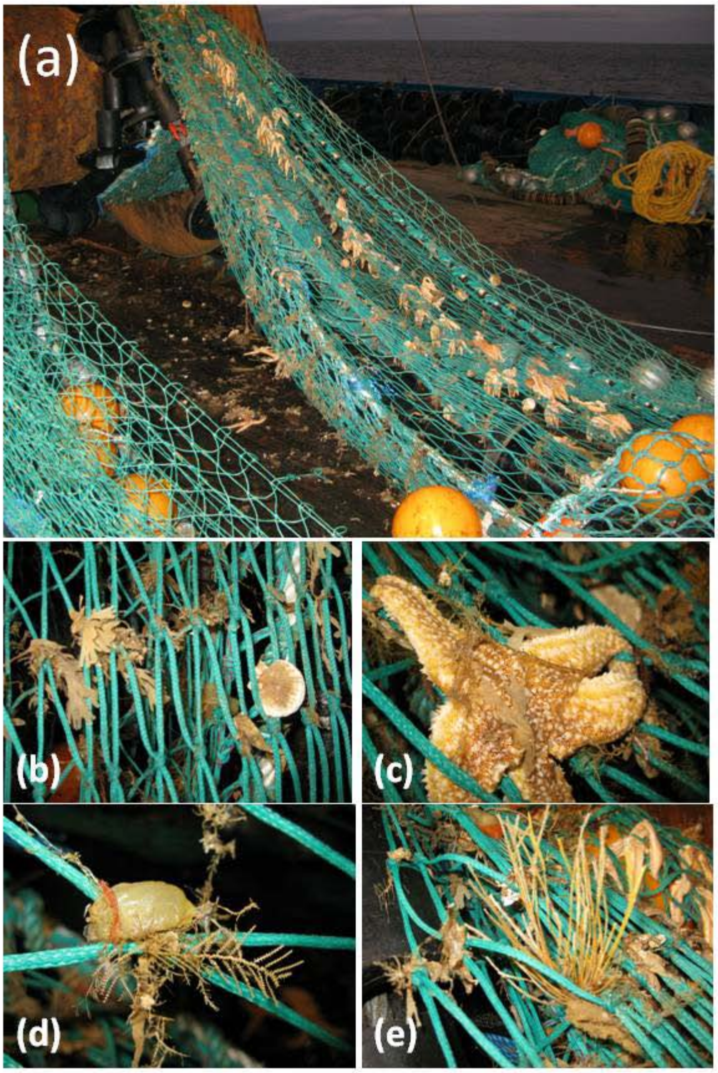


Figure 13: Trawl net with (a) biological material in wings of the net, including (b) the bryozoan *Flustra foliacea* , (c) common starfish *Asterias rubens*, (d) ascidian and hydroids, and (e) the hydroid *Nemertesia*.

(g) Treatment of sieved samples

Although many of the above examples have referred to towed gears, there are several practical issues that may affect the quality of field data for infaunal sampling. There have been numerous studies examining the effects of mesh size on benthic diversity (e.g. James *et al.*, 1995; Schlacher and Wooldridge, 1996; Crewe *et al.*, 2001; Gage *et al.*, 2002; Thompson *et al.*, 2003; Rodrigues *et al.*, 2007), and studies on the differences on sieving fresh and preserved material (e.g. Degraer *et al.*, 2007). However, there can be individual differences in sieving protocol which, although little discussed and hard to evaluate, may influence sample quality.

There can be individual differences in the way benthic samples are sieved, and this can lead to, for example, fragile organisms (e.g. polychaete worms) being badly damaged and so hindering their identification to species level. At sea, a deck hose is generally used to help sieve samples, and this is usually used with a gentle water flow to prevent damage to the infauna. Some inexperienced sea-going staff may increase the water flow when sediments are cohesive (e.g. muddy sediments) whilst other staff may spend more time 'puddling' muddy samples in water to then decanting the samples over the sieve.

Discussion

The MSFD establishes a framework within which "*Member States shall take the necessary measures to achieve or maintain good environmental status in the marine environment by the year 2020 at the latest*" (CEC, 2008). To date, there are few papers in the scientific literature regarding the MSFD (but see Fletcher, 2007; Mee *et al.*, 2008).

Field data from groundfish surveys and other temporally and/or spatially comprehensive surveys will provide invaluable information to allow marine scientists to monitor patterns and possible change in 'biodiversity' (at least in relation to species diversity). These data should allow Member States to make informed decisions about what elements of species diversity can be used to determine and monitor 'Good Environmental Status', as well as what elements of marine biodiversity are not being included within descriptors for GES.

However, it must be recognised that these surveys (e.g. gear, survey grid, sampling frequency, data collection) may not have been designed explicitly to evaluate and monitor temporal patterns in species diversity. In the case of surveys with a long time series, there may have been enforced changes in survey grid, gear or sampling protocol, as well as more subtle 'improvements' in recent years in terms of information relevant to diversity studies. Hence, more rigorous studies to better understand these data are required, with such studies involving data collectors, before indicators of GES for the various elements of the marine ecosystem can be defined.

There are several trawl surveys covering wide areas of the continental shelf within EC and adjacent waters, including those participating in surveys for which there is coordination by ICES Expert Group. These groups can ensure best practice in sampling methodologies and, for some surveys, the use of standardised gears. These trawl surveys can help inform on the "*structure of fish populations, including the abundance, distribution and age/size structure of the populations*" (as stated in the MSFD), although it must be acknowledged that not all fish species are sampled effectively. Towed gears may pass over multiple discrete habitats, and the various constituent species within any community may have very different catchabilities. Hence the catch composition of trawl samples is not necessarily reflective of the fish community (this being defined as a group of interdependent organisms living and interacting with each other and the environment in the same habitat). Although a variety of fish species will be sampled, trawl data represent the fish catch, which may be better assumed to equate with the 'fish assemblage', given that an 'assemblage' may be defined as "*the result of adequate sampling of all organisms of a specific category in a defined place*" (Magurran, 1988).

The sampling of other marine taxa across broad regions of the ICES area is not as well established as for fish (see ICES, 2010a), although there is a clear role in ICES Expert Groups promoting standardisation in sampling protocols, quality assurance and data reporting, and ensuring appropriate data analysis. Groundfish surveys have acted as platforms of opportunity to allow broad scale sampling of, for example, epibenthic fauna (Jennings et al., 1999; Zühlke et al., 2001; Callaway et al., 2002; Ellis et al., 2002). There is ongoing discussion on how to better integrate existing surveys to help better inform on the Ecosystem Approach (ICES, 2009).

It should also be recognised that Member States have obligations under the Convention on Biological Diversity (CBD) to achieve "*a significant reduction of the current rate of biodiversity loss*…", and the MSFD is meant to "*support the strong position taken by the Community, in the context of the Convention on Biological Diversity, on halting biodiversity loss*". Offshore sampling can provide survey-specific information on diversity metrics, but monitoring nominal 'trends' in such metrics can be very different to preventing a loss of biodiversity, particularly if the surveys in question do not sample those species that are at risk of being extirpated from a region.

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