# TMAP *ad hoc* Working Group Fish
# Progress report 2007

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# Summary

Building on previous work done by the TMAP ad hoc Working Group Fish, a meeting and a workshop were held in Hamburg in June and October 2007. The most important aim of both was to come to an agreement on how to proceed with the data preparations and analyses, and to facilitate the exchange of data and analyses procedures.

Data from the Demersal Fish Survey (Wageningen IMARES, The Netherlands), the Demersal Young Fish Survey (Bundesforschunganstalt für Fischerei, Germany) and the Schleswig-Holstein Survey (Marine Science Service / National Park Agency, Germany) have been taken into account. A number of fish metrics were identified which together are considered to give a good reflection of the fish community in the Wadden Sea. These selected metrics consist of abundance and size metrics for 'priority species', and species composition metrics. The priority species were identified previously based on various selection criteria and the occurrence in ongoing monitoring programs. The list was slightly modified this year.

The fish metrics were calculated and the (mostly descriptive) analyses were carried out before, during and after the workshop. Mayor progress has been achieved especially for the DYFS data, for which the abundance data are now available for the full time span (although not yet fully quality controlled). Furthermore, the spatial resolution is now at the level of the Wadden Sea sub-areas, which gives much more detail than in the last Quality Status Report (2004).

The mayor focus of the work in 2007 was getting the fish monitoring data ready for analyses and doing the first (mostly descriptive) analyses. Other work carried out was the development of a (preliminary) reference species list, a literature review on indicator studies in marine ecosystems and compiling an overview (on a meta-data level) of the available environmental data.

Managers would like to get a conclusion on the status of the Wadden Sea in terms of 'good', 'moderate' or 'poor', but scientists are against giving such qualifications due to the lack of knowledge on the causal factors underlying the observed changes. The most advanced result that we can provide now is to monitor the changes in fish fauna in an effective way by making the best use of the ongoing Wadden Sea surveys and to develop a system by which we can adequately describe trends in a consistent way for future quality status reports. The work of the TMAP ad hoc Working Group Fish is building step by step toward such a system, and will eventually lead to a more complete picture of the status of fish in the Trilateral Wadden Sea area.

# 1. Introduction

***Trilateral Cooperation***

Since 1978, The Netherlands, Denmark and Germany have been working together on the protection and conservation of the Wadden Sea covering management, monitoring and research, and political matters. An important element of the Trilateral Cooperation with regards to monitoring and research is the Quality Status Report (QSR). This report is published every 5 years and it presents the results of various ongoing monitoring programs in the Wadden Sea. Another important element of the Trilateral Cooperation is the Trilateral Monitoring and Assessment Program (TMAP) which aims at providing a scientific assessment of the status and changes in the ecosystem, and the effectiveness of implementing targets set by the Trilateral Wadden Sea Plan. The results of these monitoring and assessment programs are presented in the QSR. Finally, the Trilateral Cooperation with regards to monitoring and research is facilitated and enhanced by means of the International Scientific Wadden Sea Symposia.

Fish play (both as predator as well as prey) an important role in the ecology of the Wadden Sea, and the Wadden Sea is an important habitat for (certain life stages of) various fish species. The importance of fish for the Wadden Sea and visa versa has not been recognized sufficiently within the Trilateral Cooperation. Although a chapter on fish was included in the Quality Status Reports of 1999 (De Jong et. al., 1999) and 2004 (Vorberg et. al., 2004), fish are not included in the TMAP, nor is fish mentioned (explicitly) in the Wadden Sea Plan. A closer international cooperation and more focus on fish monitoring and research was recommended by the QSR 2004 and the 11$^{th}$ International Scientific Wadden Sea Symposium (2005).

***TMAP ad hoc Working Group Fish***

The recommendations in the QSR 2004 have led to the instigation of the TMAP ad hoc Working Group Fish. The group reports to the Trilateral Monitoring and Assessment Group (TMAG), through the Common Wadden Sea Secretariat (CWSS).

The group met for the first time in Hamburg on 29-30 March 2006. A large group of fish experts was invited, including scientists working in other areas than the Wadden Sea. The nature of the meeting was mainly informative; presentations were given about ongoing monitoring programs and the development of assessment methods and tools (TMAP, 2006a).

A sub-group of the March meeting reconvened in Wilhelmshaven on July 3$^{rd}$, 2006 to draft a report to TMAG. This sub-group identified 2 topics which required further attention before submitting the report to TMAG:
1) The preparation of a list of typical/important Wadden Sea fish species and the development of criteria for the selection of 'priority' species for TMAP/QSR .
2) The evaluation of the applicability of the fish-assessment-tool approach that was developed for the Water Framework Directive (WFD) in transitional waters.

The follow-up work and the report were completed by correspondence. The report was submitted to TMAG in August (TMAP, 2006b), and the evaluation of the WFD was submitted as a separate document (Bioconsult, 2006a).

The sub-group re-convened in Haren on November 20$^{th}$, 2006 with the specific goal to jointly discuss the progress and directions taken with regards to the species list, the selection of priority species and the evaluation of the applicability of the WFD approach. Furthermore, a strategy of approach for follow-up work to be carried out in 2007 was developed (Bolle, 2006).

***Follow-up in 2007***

The TMAP ad hoc Working Group Fish agreed on 4 of the follow-up activities listed below. An additional step, i.e. a literature study, was proposed and carried out by IMARES.

1. Reference list for Wadden Sea fish fauna
2. Selection of priority species
3. Literature study on indicators in marine ecosystems
4. Data analysis
5. Recommendation on TMAP assessment tool

A meeting and a workshop were held in Hamburg in 2007 (26-27 June & 22-25 October). The most important aim of both was to come to an agreement on how to proceed with the data preparations and analyses, and to facilitate the exchange of data and analyses procedures. Part of the analyses were carried out during the workshop in October.

The work that was carried out by IMARES for the TMAP ad hoc Working Group Fish was commissioned and financed by the National Institute for Coastal and Marine Management (RWS RIKZ).

The present report is considered to be a 'living document', a preliminary document which can serve as contribution or starting point for a more comprehensive Quality Status Report in 2009.

# 2. Methods

## 2.1 Species lists and selection of priority species

***Wadden Sea Fish Fauna***

The Wadden Sea Fish Fauna table is presented in Appendix 1 and lists the typical Wadden Sea fish primarily based on the occurrence in the ongoing monitoring programs in recent years. The table also contains several criteria that can be used to select ‘priority species’. The TMAP ad hoc Working Group Fish had already prepared a this table in 2006 (Bolle, 2006), but minor update of the settings for the selection criteria was carried out this year. The table may will probably be revised again in the following years. Firstly, because the monitoring data can be elaborated if the fyke data collected by the Royal Netherlands Institute for Sea Research are made available. Secondly, the information presented in the selection criteria columns will probably be updated based on new insights due to ongoing research.

***Selection of priority species***

In principle, the Wadden Sea Fish Fauna table in Appendix 1 supplies all information required to be able to select priority species. Although a scoring system has been developed, which attempts to provide an objective quantitative tool to select the priority species, it is still necessary that the outcome is reviewed based on expert judgment. The resulting priority species to be included in the analyses are listed in Table 1. The catchability of these species differs between the gear-types, therefore the different species were allocated to different gear-types.

Table 1. Priority species to be included in the spatial and temporal trend analyses (CA=diadromous, ER=estuarine resident, MJ=marine juvenile, MS=marine seasonal)

| Species | | Ecological guild | Stratification | Beamtrawl | Stownet |
|---|---|---|---|---|---|
| Alosa fallax | Twaite shad | CA | Pelagic | (x) | x |
| Osmerus eperlanus | Smelt | CA | Pelagic | (x) | x |
| Lampetra fluviatilis | River lamprey | CA | Pelagic | - | x |
| Platichthys flesus | Flounder | ER | Demersal | x | (x) |
| Zoarces viviparus | Eelpout | ER | Demersal | x | - |
| Ammodytes sp. | Sand eel | ER | Pelagic & Burried | x | - |
| Pleuronectes platessa | Plaice | MJ | Demersal | x | - |
| Solea vulgaris | Sole | MJ | Demersal | x | - |
| Limanda limanda | Dab | MJ | Demersal | x | - |
| Gadus morhua | Cod | MJ | Demersal | x | - |
| Merlangius merlangus | Whiting | MJ | Demersal | x | - |
| Clupea harengus | Herring | MJ | Pelagic | (x) | x |
| Sprattus sprattus | Sprat | MS | Pelagic | (x) | x |
| Engraulis encrasicolus | Anchovy | MS | Pelagic | - | x |

***Reference species list***

Although quantitative historic data is lacking, anecdotal historic data exists on species composition in the Wadden Sea. It was decided to compile a reference list of all species ever encountered in the Wadden Sea. For this list information presented in Fishes and fisheries of the Wadden Sea (Witte and Zijlstra, 1978; Zijlstra, 1978), the Schleswig-Holstein Fish Atlas (Vorberg & Breckling 1999) will be used. Furthermore data from various ongoing monitoring programs will be included. A preliminary version of the reference species list is presented in Appendix 2.

## 2.2 Overview fish monitoring data available to TMAP

**Important note**: The available data form the various fish monitoring programs will exclusively be used within the framework of this project.

The data included in the present analyses and report are from the:
- Demersal Fish Survey (DFS, Wageningen IMARES, The Netherlands),
- Demersal Young Fish Survey (DYFS, Bundesforschunganstalt für Fischerei, Germany)
- Schleswig-Holstein Survey (SHS, Marine Science Service / National Park Agency, Germany)

The spatial and temporal coverage of the 3 surveys is summarised by the overview of the number of hauls per year and area presented in Table 2. The area-codes (QSR areas and D(Y)FS areas) referred to in Table 2 are mapped in Figure 1. A detailed description of the survey designs is given in the following sections.

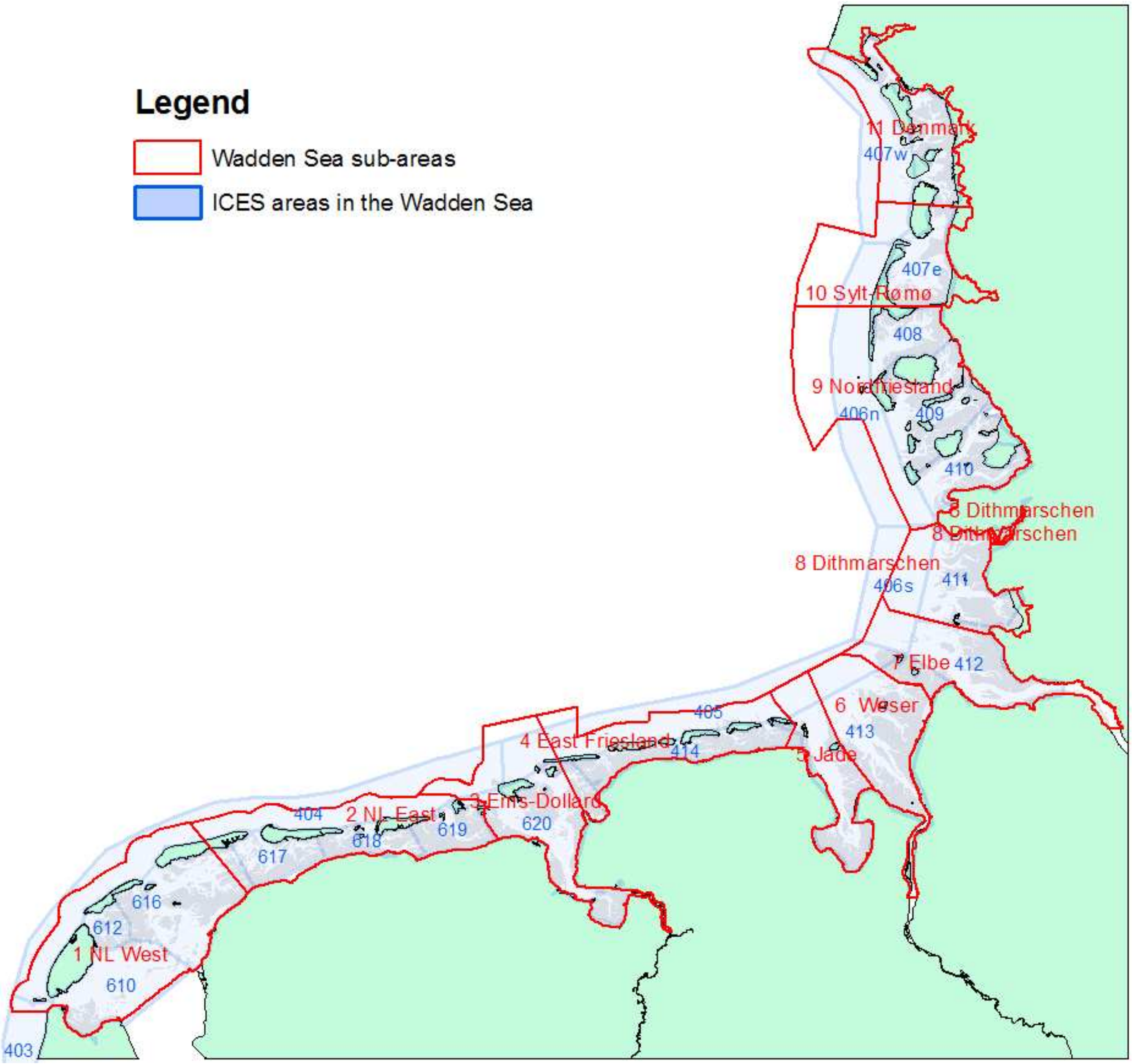


*Figure 1. Map of the Wadden Sea sub-areas or QSR areas (as defined within the context of Quality Status Report), and the ICES areas or D(Y)FS areas (as defined in the original DFS/DYFS survey design).*

Table 2. Overview fish monitoring data: number of hauls by year, region and survey.

| data owner (1) | IMARES | IMARES | IMARES | BFA | BFA | BFA | BFA | BFA | BFA | NPA | NPA |
|---|---|---|---|---|---|---|---|---|---|---|---|
| data collection (1) | IMARES | IMARES | IMARES | BFA | BFA | BFA | BFA | BFA | BFA | MSS | MSS |
| survey (2) | DFS | DFS | DFS | DYFS | DYFS | DYFS | DYFS | DYFS | DYFS | SHS | SHS |
| gear | beamtrawl | beamtrawl | beamtrawl | beamtrawl | beamtrawl | beamtrawl | beamtrawl | beamtrawl | beamtrawl | stownet | stownet |
| QSR area | 1 western NL Wadden Sea | 2 eastern NL Wadden Sea | 3 Ems Dollard | 4 East Frisia | 5 Jade | 6 Weser | 7 Elbe | 8 Dith-marschen | 9 North Frisia | 8 Dith-marschen | 9 North Frisia |
| D(Y)FS area | 610, 612, 616 | 617, 618, 619 | 620 | 414, 405 | 413, 405 | 413, 405 | 412, 406s | 411, 406s | 408, 409, 410, 406n | 411 | 408 |
| 1970 | 47 | 38 | 20 | | | | | | | | |
| 1971 | 49 | 29 | 21 | 21 | | | | | | | |
| 1972 | 42 | 30 | 20 | 22 | 5 | 8 | 12 | | | | |
| 1973 | 44 | 29 | 22 | 15 | 7 | 6 | 12 | | | | |
| 1974 | 49 | 33 | 21 | 18 | | | 4 | 22 | 24 | | |
| 1975 | 53 | 33 | 21 | | | | 4 | 22 | 24 | | |
| 1976 | 53 | 33 | 21 | 32 | | | 4 | 22 | 24 | | |
| 1977 | 54 | 34 | 21 | 17 | 7 | 3 | 21 | 22 | 24 | | |
| 1978 | 54 | 33 | 21 | | | | 3 | 22 | 24 | | |
| 1979 | 47 | 30 | 19 | 34 | | | 18 | 22 | 24 | | |
| 1980 | 54 | 33 | 21 | 25 | | | 21 | 21 | 21 | | |
| 1981 | 53 | 33 | 21 | | | | 33 | 21 | 24 | | |
| 1982 | 54 | 32 | 21 | 37 | | | 34 | 22 | 24 | | |
| 1983 | 53 | 32 | 21 | 45 | | | 25 | 9 | | | |
| 1984 | 54 | 31 | 21 | 41 | | | 28 | 19 | 18 | | |
| 1985 | 54 | 30 | 20 | 46 | | | 26 | | 44 | | |
| 1986 | 54 | 32 | 21 | 45 | | | 27 | 29 | 25 | | |
| 1987 | 54 | 31 | 23 | 49 | | | 25 | 15 | 40 | | |
| 1988 | 47 | 30 | 22 | 44 | | | 26 | 23 | 32 | | |
| 1989 | 47 | 31 | 23 | 53 | | | 25 | 21 | 24 | | |
| 1990 | 46 | 31 | 23 | 55 | | | 28 | 28 | 41 | | |
| 1991 | 53 | 33 | 24 | 45 | | | 27 | 17 | 39 | 8 | |
| 1992 | 55 | 18 | 28 | 46 | | | 26 | 27 | 31 | 8 | |
| 1993 | 50 | 33 | 28 | 34 | | | 25 | 21 | 37 | 12 | |
| 1994 | 50 | 28 | 25 | 33 | | | 25 | 25 | 37 | 9 | |
| 1995 | 54 | 34 | 26 | 43 | | | | 27 | 48 | 12 | |
| 1996 | 62 | 34 | 27 | 34 | | | 25 | 33 | 34 | 12 | |
| 1997 | 55 | 35 | 27 | 34 | | | 25 | 51 | 39 | 12 | |
| 1998 | 62 | 35 | 26 | 30 | | | 23 | 33 | 60 | 11 | |
| 1999 | 57 | 36 | 22 | 36 | | | 25 | 38 | 42 | 12 | |
| 2000 | 68 | 36 | 26 | 40 | | | 24 | 32 | 42 | 10 | |
| 2001 | 53 | 35 | 26 | 35 | | | 22 | 31 | 37 | 10 | 6 |
| 2002 | 53 | 33 | 26 | 27 | | | 24 | 32 | 36 | 10 | 12 |
| 2003 | 55 | 31 | 26 | 26 | | | 19 | 36 | 39 | 9 | 12 |
| 2004 | 61 | 32 | 25 | 19 | | | 25 | 30 | 27 | 12 | 11 |
| 2005 | 60 | 33 | 33 | 33 | 7 | 25 | 21 | 31 | 50 | 11 | 11 |
| 2006 | 62 | 32 | 29 | 35 | 6 | 33 | 34 | 28 | 52 | 11 | 11 |
| **total** | **1972** | **1186** | **868** | **1149** | **32** | **75** | **746** | **832** | **1087** | **169** | **63** |

(1) NPA = National Park Agency (Germany)
MSS = Marine Science Service (Germany)
IMARES = Wageningen IMARES (Netherlands)
BFA = Bundesforschunganstalt für Fischerei (Germany)

(2) DFS = Demersal Fish Survey
DYFS = Demersal Young Fish Survey
SHS = Schleswig-Holstein Survey

### *Beam-trawl*

The Netherlands has started “a census of juvenile fish” in 1969 in the Dutch Wadden Sea and from the Dutch to the Danish coast in offshore areas (Boddeke, 1970). German scientists joined in from 1970 onwards for various parts of the German Wadden Sea (Boddeke et al., 1972). However, comparable survey data for the entire German region are considered to be available only since 1972/1975 depending on region. Furthermore, the German scientists are still in the process of digitising and quality control, especially for the data collected prior to

1996. The survey was initially called the Demersal Young Fish Survey (DYFS) in both countries, but the name was changed to the Demersal Fish Survey (DFS) in the Netherlands at a later stage.

The survey gear in both countries is almost identical (WGbeam, 2006). The gear used is a 3-m beam trawl with roller chain ('bobbin rope' ) and 20 mm mesh (stretched). The Dutch DFS uses one tickler chain which was omitted in the German DYFS because of the excessive catch of dead shells in many of the German stations (Rauck, pers.com.). Campaigns were carried out in both spring (April-May) and autumn (September-October), but the spring surveys were terminated in 1986 in the Netherlands and in 2004 in Germany. The main parameters and handling procedures were kept the same over the entire period, e.g. haul duration (15 min.), sorting, counting and measuring all fish by species or genus. The areas investigated mostly remained the same as well. Only minor changes occurred in the setup: the chartering of different vessels with increasing draught, slight shifts of survey weeks due to weather conditions and the intensity of sampling as a result of funding problems. Precision of some data improved over time according to the advances in technology, such as trawled distances (GPS based track recording compared to estimated mean tow distances in the early days of the DYFS), the use of electronic sea-going scales for weight measurements instead of the estimation of catch volumes and recently the recording of data for temperature and depths by applying data loggers attached to the gear instead of surface and ship data.

The borders of the DYFS-code-areas were originally not precisely fixed but confined by the gully systems and rough lines drawn in an overview map. Only recently (WGbeam, 2007) distinct borderlines were defined for the purpose of recalculating surface areas of the geographically and depth orientated strata.

The DFS / DYFS was initially established entirely for fishery science and stock assessment purposes concerning commercial fish species, in particular plaice and sole. Brown shrimp was soon added to the list of published indices. The young fish indices are used since the eighties by the ICES working group on stock assessments and give a first indication on the year class strengths of the relevant species.

As all other fish and many other benthic invertebrate species were recorded within that monitoring programme, it contains one of the most valuable data series for the Wadden Sea and Southern North Sea as well. Therefore the DFS / DYFS data also became relevant for a number of other programmes and conventions besides ICES, either concerning fishes themselves or their habitats. Among these are the European Common Fisheries Policy (CFP) with stock management measures, Oslo-Paris-Convention (OSPAR) with fish monitoring requirements and EcoQos, TMAP (Trilateral Monitoring and Assessment Programme) preparing to include fish monitoring in coastal and transitional waters into the wide range of other monitoring programmes, Red List of fishes in the North and Wadden Sea (RL), Water Framework Directive (WFD) using fishes as a quality measure for transitional waters, Flora-Fauna-Habitat Directive (FFHD) monitoring and protecting habitats and their species including fish habitats, European Marine Strategy Directive (EMS) co-ordinating the marine environmental monitoring programmes. Many of these programmes are much more recent than the DFS/DYFS programmes and intend to use the data held by the involved governmental agencies.

### *DYFS (Germany)*

- North Frisia and Dithmarschen, i.e. Schleswig-Holstein region (DYFS-codes 406, 408, 409, 410, 411):

The earliest data were gathered in 1970 and are available only in aggregated form (Boddeke et al. 1972). From 1975 onwards a fixed net of 50 stations was established covering all tidal basins from the northern Elbe estuary towards the "Hörnum Tief" which is south of the island of Sylt. For ecological reasons the border line of DYFS-region 411 and 412 was shifted to the north transferring some of the southern most stations to the Elbe estuary code. The tidal basin north of Sylt and the Danish part of the Wadden Sea have never been sampled so far by the DYFS programme. Cutter, captain, scientific team and conditions were the same for that region until 1984 and the area was covered twice (spring and autumn) in ten fishing-days. Then - except for the nets, gear and working procedure - everything changed. Other cutters had to be chartered separately for region 411 and the northern most parts of the area 410 and after some years again new and bigger vessels came into the programmes which due to more draught, may possibly have caused the loss of hauls in the shallowest parts fished before.

The fixed positions could no longer be kept and the days available were restricted by the available funds to 7 or 6, sometimes 2 days instead of 10. This inevitably led to a variable haul distribution; however, the same tidal basins were fished. Haul frequency was increased and depth range widened towards some more deeper stations outside the island chain whenever possible according to weather conditions (Neudecker, 2001). The entire region was always fished during daylight, sometimes starting in the dusk. Fishing occurred only with the tidal current leading to a pattern of leaving port in the morning with ebb tide, reaching outer stations normally at low water and returning to port with flood tide or at high water. Exceptions were rare and caused by combinations of daylight, tidal and weather conditions.

When the old wooden rollers were worn out, new rubber rollers came into use at the end of the eighties. Mesh size of these standard 3-m- beam-trawls was always kept the same, but net material changed to thinner threads when new nets had to be put into use.

The scientific team always held one DYFS-experienced biologist to keep up the quality in fish determination. Nevertheless, problems in distinguishing difficult species remained like e.g. with gobies, sand eels and sea-snails. In theses cases the data were stored on genus level. In the early part of the DYFS only numbers and lengths were recorded besides a volume, which was mostly guessed from measuring pitchers as it was generally not possible to make exact measurements by f.e. water replacement. Since 2001 the first of seagoing, marine scales became available with slightly increasing accuracy from 5 to 1 g, and weights were taken for fish and invertebrate groups. It is intended to recalculate weights from recent length-weight relationships by species for the older parts of the time series.

- Elbe estuary (DYFS-code 412)

The Elbe estuary was always fished from Cuxhaven by the cutter “Ramona” belonging to the same family starting in 1972. Until 1986 another scientific team than that from the North Frisian part did the investigations with the same type of equipment and procedures as applied in the other regions. To keep continuity only part of the team was changed when necessary in later years. Normally two days were spent to cover the region, one day below Cuxhaven towards the outer estuary and another day for the inner part of the estuary. Due to sediment shifts some stations had to be abandoned and were replaced by others in the same area. To give a more stable vessel condition in the stronger currents of the Elbe, always two beam trawls were used; however, only one net was sampled. As a land-based laboratory was available in that region, sometimes - when adverse weather conditions prevailed - samples were collected and analysed later in the lab ashore.

The main difference of the investigations in Cuxhaven compared to the northern regions is, however, that about half of the fishing was done at night over dusk to daylight. The day-night-effect has not been analysed so far for the DYFS data but is known to be significant from the fisheries. It might lead to an increased abundance index for that region and the “Cuxhaven”-data, as higher catches of shrimp (and possibly also fish) are taken by commercial fisheries when fishing at night.

As mentioned above, the southern-most stations of the “Büsum”-series fished south of the island “Trischen” were also attributed to the Elbe estuary and DYFS-region 412. These were entirely day-light hauls.

- Jade-Weser estuaries (DYFS-code 413)

Except for some hauls in the early seventies, DYFS-region 413 was not covered by the DYFS programme until 2005. The extremely tide-dependent small harbour of Wremen is the base for the cutter chartered, meaning that fishing is only possible between absolute high water situations. Three days are spent in that region, one for the Jade, one for the fishing ground “Nordergründe” between Weser and Elbe and the third one for the Weser itself. The positions of the hauls were kept the same in these few years. Equipment and procedures are identical to those applied in other regions.

- East Frisian Wadden Sea (DYFS-codes 414 and 405)

This part of the Wadden Sea was investigated before the real start of the German DYFS programme by a campaign in 1972, including the entire west-east extending tidal systems. Then the “Accumer Ee”, the system between the mainland and the islands Baltrum and Langeoog, was continually visited by the team also investigating the Cuxhaven area until 1993. Therefore in the earlier part of that series part of the hauls was taken at night or dusk, later mainly at daylight which could lead to a day-night effect. Cutters have changed over time and became larger in recent years which also could affect the depth distribution of the hauls. One of the problems in this area is the accessibility of the offshore part outside the island chain (DYFS-region 405). Quite often it was not possible to pass the sand barrier and surf between the islands. This fact combined with the small size of area has lead to a relatively high sampling intensity in the tidal channels compared to the other regions of the DYFS campaigns.

***DFS (The Netherlands)***

An important source of information on the fish fauna in the Wadden Sea is the Demersal Fish Survey (DFS). This survey was initiated in 1969 (Boddeke et al., 1969) and covers the Dutch Wadden Sea, the Ems-Dollard estuary, the Scheldt estuary, and the shallow coastal waters from the Dutch-Belgian border to Esbjerg, Denmark.

Initially the survey was carried out in spring (April-May) and autumn (September-October), but since 1987 only the autumn survey has been continued. Slight shifts in the sampling period (depending on the region and vessel) have occurred. In principle a fixed sampling period for an annual survey is optimal because this should minimize variation caused by seasonal patterns, but as inter-annual variability in seasonal patterns also occurs, it is impossible to exclude this source of variation alltogether.

Sampling is stratified by geographical area (DFS areas) and depth (5m depth classes). Sampling is restricted to water deeper than 2-3 m, because of the draught of the research vessels. Three different research vessels cover the survey area, one for the Scheldt estuary, one for the coastal waters and one for the Wadden Sea + Ems Dollard. The gear used is either a 6m beam-trawl (coastal waters) or a 3m beam-trawl (Scheldt estuary, Wadden Sea and Ems Dollard). The beam-trawls are rigged with a shrimp net, a bobbin rope and a fine-meshed cod-end (20 mm stretched).

Although the DFS was originally designed to provide recruitment indices of commercial flatfish species, all fish and epibenthos species have always been processed, providing valuable information on bottom-dwelling species in coastal and estuarine waters.

Trawling details such as the position, date, time and depth are recorded for each haul. Since 2002 in the estuarine waters and since 2004 in the coastal waters, sophisticated hydrographic data (temperature, salinity and visibility profiles) are collected with a data-logging CTD. Before this only basic hydrographic measurements (surface water temperature and visibility estimates using a secchi disc) were collected by haul on all DFS cruises

Only the DFS data collected within the Dutch Wadden Sea and the Ems Dollard (areas 610, 612, 616-620 in Figure 1) are included in the spatial and temporal analyses. The data collected in the coastal waters adjacent to the Wadden Sea (areas 404-407) were not included in theses analyses, but they have been included in the Wadden Sea fish fauna table in Appendix 1 (as a separate survey). The DFS areas in the Wadden Sea correspond to the tidal basins. In the QSR area definitions, the 6 tidal basins in the Dutch Wadden Sea have been combined into 2 larger regions (Figure 1).

***Stow-net***

In 1991, a fish monitoring program started in the Meldorf Bight (Dithmarschen) using a stow net as standard sampling gear (Vorberg, 2001). Since 2001, a second sampling location has been installed in the Hörnum Deep, a tidal basin between the North Frisian island of Sylt, Amrum and Föhr. Sampling takes place once a year in August.

The stow net, operated from an anchored vessel, reached from the water surface down to the bottom and was suitable to obtain quantitative data for pelagic fish (Breckling and Neudecker, 1994). At each site three stations has been installed, and at each sampling station four hauls were made, resulting in a total number of 24 hauls per year.

## 2.3 Overview environmental data available to TMAP

The TMAP ad hoc Working Group Fish compiled a first basic overview of the environmental data available. This overview is probably far from complete. Only the data sources known to working group participants were included, no further search or literature review was carried out.

Most of the information presented here is on a meta-data level, i.e. description of what's available in terms of variables measured, resolution, time span. The information presented for NAO index (this section) and the fishing pressure by the German shrimp fishery (Appendix 3) is more elaborate.

Further elaboration of the overview is required, both in terms of sources as well as information collated per source. A future step will be to correlate the fish parameters with relevant environmental parameters, in which the relevance of an environmental factor is based on hypotheses that have been formulated using general ecological knowledge and specific knowledge built up in ongoing research projects.

***Temperature and salinity***

Source: BSH (13,500 data sets)
Region: German Bight
Temporal resolution: monthly mean, min, max, standard deviation
Spatial resolution: ?
Time span: 1975-2006
Accessibility: ?

Source: Royal Netherlands Institute for Sea Research (Royal NIOZ)
Region: western Dutch Wadden Sea
Temporal resolution: monthly mean
Spatial resolution: 1 station in Marsdiep
Time span: 1861-2006
Accessibility: freely accessible

***Oxygen***

Source: BSH (13,500 data sets)
Region: German Bight
Temporal resolution: monthly mean, min, max, standard deviation
Spatial resolution: ?
Time span: 1975-2006
Accessibility: ?

***Nutrients & Chlorophyll***

Source: QSR/ TMAP data units
Region: Wadden Sea (Netherlands, Lower Saxony, Schleswig-Holstein, Denmark)
Temporal resolution: ?
Spatial resolution: ?
Time span: Nutrients in water: NL 1971-2003; LS 1999-2006; SH 1990-2006; DK 1986-2006
Phytoplankton: NL 1971-2006; LS 1999-2005; SH 1999-2002; DK 1990-2006
Accessibility: limited to QSR/TMAP

***NAO***
The North Atlantic Oscillation (NAO) is a well known and key parameter for the climate in our northern hemisphere. Data on the air pressure difference between Iceland and the Azores are gathered daily since 1864 at different stations and are readily available via internet e.g. as monthly means. The Winter (December through March) index of the NAO is based on the difference of normalized sea level pressure (SLP) between Lisbon, Portugal and Stykkisholmur/Reykjavik, Iceland. The SLP anomalies at each station were normalized by division of each seasonal mean pressure by the long-term mean (1864-1983) standard deviation. Normalization is used to avoid the series being dominated by the greater variability of the northern station. Positive values of the index indicate stronger-than-average westerlies over the middle latitudes. A link to various sources is also available, e.g. http://www.cgd.ucar.edu/cas/jhurrell/indices.info.html#naopcdjfm.

The NAO has a strong influence on many other parameters like sea surface temperatures, winds and currents and by that influences strongly weather and environmental conditions for flora and fauna. Correlations between these environmental parameters and marine species have been investigated and documented but need to be reviewed. Purps et al. (1999) found a significant effect of the extended NAO winter index (DJFM) on the VPA assessments of plaice 0-group year class strengths and the June-NAO index and 0-group sole. Concerning brown shrimp Neudecker et al. (unpublished) could demonstrate a strong correlation of the NAO winter index (DJF) as well as winter SST with the landings of the German shrimping fleet, while Siegel et al. (2005) found significant correlations of the extended NAO winter index (DJFM), winter SST and autumn river runoff on the autumn abundance of brown shrimp investigated by the DYFS. A check whether the extended winter (DJFM), May or June NAO values from 1971 to 2006 would correlate to the DYFS plaice indices for the same period gave no result, however (Neudecker and Damm, pers. comm. 2007).

***Musselbeds***
Variable: GIS data on location, size, shape of blue mussel beds
Source: QSR / TMAP data units
Region: Wadden Sea (Netherlands, Lower Saxony, Schleswig-Holstein, Denmark)
Temporal resolution: n.a.
Spatial resolution: n.a.
Time span: subtidal: NL 1999-2003; LS 1999-2006; SH 1999-2006; DK 1999
intertidal: NL 2003
Accessibility: limited to QSR/TMAP

Variable: Biomass estimates in survey
Source: IMARES
Region: Dutch Wadden Sea
Temporal resolution: annual survey
Spatial resolution: ? hauls
Time span: subtidal: 1992-2007
intertidal: 1990-2007
Accessibility: limited to QSR/TMAP

***Dumping sites***
Source: QSR2004
Region: Wadden Sea
Temporal resolution: n.a.
Spatial resolution: n.a.
Time span: 1989-2003
Accessibility: freely accessible (http://www.waddensea-secretariat.org/QSR/chapters/QSR-02.6-2.11-human-activities.pdf)

Source: OSPAR Commission, 2006: Dumping of wastes at sea in 2004
Region: ?
Temporal resolution: n.a.
Spatial resolution: n.a.
Time span: 2004
Accessibility: ?

### *Fishing pressure*

Variable: Fishing mortality (Fbar) on adult plaice and sole in North Sea
Source: ICES-WGNSSK
Region: North Sea
Temporal resolution: annual estimate
Spatial resolution: n.a..
Time span: 1957-2006
Accessibility: freely accessible (http://www.ices.dk/iceswork/wgdetailacfm.asp?wg=WGNSSK)

Variable: Fishing effort (e.g. fishing days, nr of vessels) by German shrimp trawlers
Source: Bundesforschungsanstalt für Fischerei (BFA)
Region: German-Danish Wadden Sea
Temporal resolution: annual estimate
Spatial resolution: >2000: ICES rectangles (logbook obligation)
<2000: ?
Time span: 1952-1958, 1966, 1976, 1986, 1996, 2000-2006
Accessibility: ?

Variable: Landings by international shrimp fisheries
Source: ICES
Region: ?
Temporal resolution: annual estimate
Spatial resolution: ?
Time span: ?
Accessibility: ?

## 2.4 Fish metrics

The approach chosen by the group is mainly driven by work carried out in the estuaries in relation to requirements for the Water Framework Directive for transitional waters (WFD). For the implementation of this Directive an assessment tool was developed, which combines a number of fish metrics. The fish metrics actually are selected variables of the fish community which together are considered to give a good reflection of the fish community in general. In the case of the WFD, the fish metrics consisted of abundance indices of key species and species composition indices based on the number of species in certain ecological guilds (Jager & Kranenbarg, 2004; Bioconsult, 2006b; 2007)

The same approach with respect to selecting fish metrics was chosen for the Wadden Sea fish fauna. However for the Wadden Sea it was decided to add mean length of the key species to the fish metrics. Reason for this is that a shift in mean length indicates a change in the (sub-)population structure. This can be expected for species like plaice in which trends in abundance in the Wadden Sea are more apparent for one age group than the other. Length (mean, median, maximum) is commonly used as an indicator in marine ecosystems (see literature review in Appendix 4).

***Fish metrics***

The group decided to include the following fish metrics in the analyses. Possibly a smaller selection of metrics and/or priority species will be taken on into the next steps, this depends on the results of the analyses.
- Mean abundance of priority species by year and region
- Mean length of priority species by year and region
- Species richness and composition (~ecological guilds) by year and region

***Priority species***

The priority species are listed in Table 1 and the choice of these species is discussed in Chapter 2 and Appendix 1.

***Spatial resolution***

The spatial resolution for the calculations was set at the level of the so-called QSR areas, i.e. the Wadden Sea sub-areas which were distinguished in the previous QSR (Figure 1). These QSR areas largely correspond to single or aggregated DFS/DYFS areas (Figure 1 and Table 2). In the DFS/DYFS surveys a distinction is made between the area within the islands and the area outside of the islands. This distinction is not made for the QSR areas. For the present analyses, only the data for the areas within the islands was included.

***Mean abundance***

The catch rates per haul were standardized. In the case of the beam-trawl catches they were converted to numbers per $1000m^2$, in the case of the stow-net catches to numbers per $1000000m^3$. These abundance estimates were then averaged by year and region. In case of the beam-trawl surveys, it was discussed whether or not to weight the averages inversely by the number of hauls per depth-class. Argument in favor was that the weighting procedure will eliminate the potential effects of unbalanced sampling over the depth-classes (a change in the depth distribution of the sampling may suggest a trend in abundance which does not really exist). Arguments against were that weighting may cause a few hauls to have an extremely high weight and that the depth during one haul can vary strongly in an environment like the Wadden Sea. The group decided against weighting by sample size. The group recommended that in the future weighting by the surface area of the strata should be carried out.

***Mean length***

The mean length was calculated as the $\Sigma(N^*\text{length}) / \Sigma N$, in which N is number of fish. This formula was used for the mean length by haul calculation and for the mean length by region calculation. In effect, the mean length by region is the average of the mean lengths by haul weighted by the number of fish in the haul.

***Species richness***

In this study, species richness is defined as the total number of species observed in a region in a year. Mayor drawback of this parameter is that it is dependent on the number of hauls (in a non-linear way). Therefore species richness can not be compared between regions if the number of hauls differ. Furthermore, one should be careful when examining trends in species richness if the number of hauls vary between years.

In principle all fish were scored at the species level but due to identification problems a higher taxonomic level was chosen for some groups of species. These were:
- Pomatoschistus microps & Pomatoschistus minutus (& Pomatoschistus lozanoi) → Pomatoschistus sp.
- Liparis liparis & Liparis montagui → Liparis sp.
- Ammodytes tobianus & Ammodytes marinus & Hyperoplus lanceolatus → Ammodytes sp.

***Species composition***

In this study, species composition is defined as the total number of species per ecological guild (calculated for each year and region). The ecological guilds considered to be most relevant for the Wadden Sea are CA (diadromous), MJ (marine juvenile) and ER (estuarine resident). The other categories (excluding freshwater species) were grouped into 1 rest group. The name estuarine resident (ER) may be confusing in relation to the Wadden Sea, because some scientists do not consider the Wadden Sea to be a true estuary. In this study we define ER as species that are resident in the Wadden Sea, i.e. they spend the majority of their life span in the Wadden Sea. Whether or not the species also occurs (abundantly) outside of the Wadden Sea is irrelevant for the status of ER.

The aggregation of species because of identification problems sometimes causes problems for the calculation of the number of species per ecological guild. Greater sandeel (Hyperoplus lanceolatus) is considered to be a MJ, but the sandeel group (Ammodytes sp.), to which the greater sandeel has been added because of identification problems, is classified as ER.

***Status of the progress***

**Important note**: The calculation of the fish metrics must be considered preliminary. No doubt further corrections of the basic data will follow as a result of systematic quality controls and the ‘running-into-errors’ when working with the data (please note that the data for non-commercial species have not been used much yet). Furthermore, amendments and improvements of the calculation procedures will probably follow after more thought is given to the procedures and results. An example is the surface-area-weighting of the strata in the beam-trawl surveys (DFS/DYFS), which is considered to be better than the current procedure.

The taxonomic aggregation levels was only briefly discussed during the workshop in October, and in the process of working up the metrics after the workshop it became clear that further discussions are needed. This is also the case for the classification into ecological guilds of species groups.

# 3. Results & Discussion

## 3.1 Descriptive analyses of spatial and temporal trends

The spatial and temporal trends in fish fauna are illustrated by plotting all fish metrics (defined in section 2.4) by year and QSR-area.

***Species richness and species composition***

As mentioned before, species richness is sensitive to the number of samples. In principle, the number of species will increase curvilinearly with the number of samples until a certain maximum. Figure 2 clearly shows that the number of species encountered in the Dutch DFS increases if the number of hauls increases (per year and region). This relationship, at least partly, explains the differences in species richness between the 3 Dutch QSR-areas.

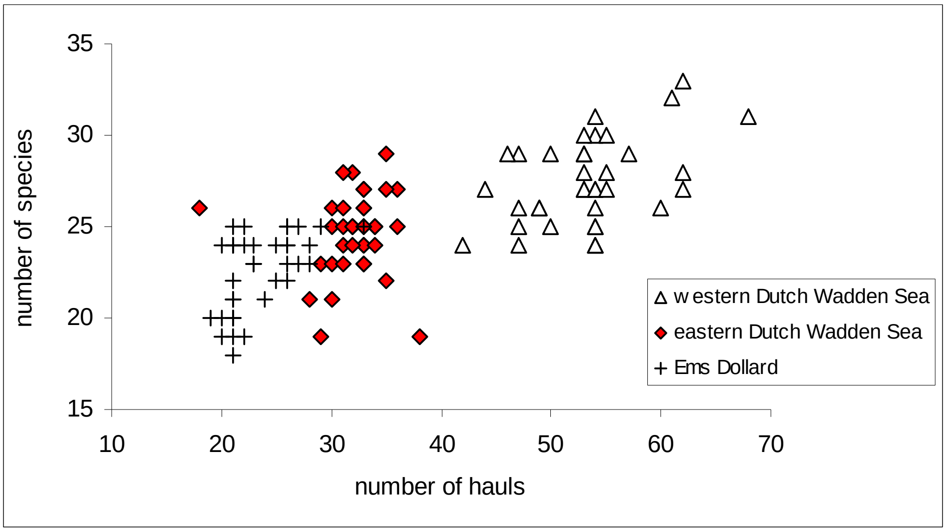


*Figure 2. Number of species per year and region in relation to the number of hauls per year and region.*

Overall there appears to be no clear temporal trend in species richness nor in species composition (Figure 3). The number of estuarine residents is remarkably stable, especially in the western and eastern Dutch Wadden Sea. Not much variation is observed in the number of marine juveniles either. Most of the variation in species richness is caused by the number of diadromous species or other (MA & MS) species.

A strange dip in species richness is observed in 1995 in the North Frisian area for the DYFS. Although this result can not be explained by an exceptionally low number of hauls in 1995 (Table 1), it seems suspect. Note that the German DYFS data prior to 1996 have not been (sufficiently) quality controlled yet.

***Abundance of priority species***

The mean abundance per year for each QSR-area and survey is plotted for all priority species in Figures 4.1 – 4.14. Note that the Y-axis of the plots are on a log-scale (and therefore the zero values have been converted into a small value). The long-term average is plotted as a horizontal line in all figures. The trends have been visually classified into 3 groups:

- no trend (blue) – flat line or large fluctuations without clear trend on full time scale
- up (green) – overall trend is an increase
- down (red) – overall trend is a decrease

The classification is indicated in the graphs by the colour of the symbols. The trend descriptions are summarised in Table 3. A fourth description - up & down - has been used in Table 3 and is further explained in the next paragraph. In these cases the overall trend is still classified as either up, down or no trend depending on the overall pattern.

The observed trends differ between species and regions, in which the differences between (adjacent) regions for 1 species are smaller than the differences between species. Overall more downward trends than upward trends are observed. A pattern observed in several species and regions is an increase in abundance in the seventies and a decrease in abundance in the eighties and/or nineties. This effect cannot (only) be ascribed to a survey effect because it is observed in both the DFS and DYFS which are 2 completely independent surveys. The occurrence of this pattern is indicated in Table 3 by the description "up & down".

The time span of the SHS survey is relatively short compared to the DFS and DYFS surveys, especially for the North Frisia area (only 6 years). Therefore caution should be taken when comparing the trends between the SHS and DYFS survey. What appears to be an upward trend in the SHS may be part of an overall downward trend if a longer time span is examined and visa versa. Furthermore note that the area coverage of the stownet sampling (within the QSR-area) is limited.

***Mean length of priority species***

The mean length has been calculated (according to the procedure described in section 2.4) for all priority species, QSR-areas and surveys. A selection of the results (1 area per survey for all priority species) is presented in Figure 5 and all results are summarized in Table 4.

Mean length estimates are obviously not available for years and areas with zero catches, and it was decided to only include mean length estimates that were based on at least 5 fish in total. This reduces the number observations for mean length per year and area. Furthermore, the German DYFS data collected prior to 1996 are not included in Figure 5 and Table 4. The data prior to 1996 have not been quality controlled yet and apparently many length records are either missing or not yet available digitally.

The classification as defined for the abundance plots (no trend, up, down) was also used for mean length. A classification was only given if estimates for at least 5 years were available. For most species and areas no clear trend in mean length was observed.

For plaice a decrease in mean length was observed in the Dutch QSR-areas as was expected based on the fact that we know that particularly the abundance of 1+ plaice has decreased (QSR2004). No trend was observed in the east Frisian area and Elbe area, and a slight increase was observed in the north Frisian and Dithmarschen areas. This can possibly be explained by the fact that 1+ group plaice have always been scarce in these areas (pers com. Uli Damm).

Based on the trends in abundance by age group for sole (QSR2004) a slight decrease in the mean length was also expected for sole in the Dutch Wadden Sea, but this does not appear to be the case.

The mean length of flounder decreases in the Dutch QSR-areas, especially the western Dutch Wadden Sea. We were not aware of differential trends for different age groups in the case of flounder, but the mean length results provide a cue to look into this.

Based on the present results it seems that the parameter mean length gives sub-optimal and indirect indications for the detection of changes in the population structure within the Wadden Sea. A better approach would be to make a distinction between juvenile and adult fish, or (in the case of marine juveniles) between 0 group and 1+ group fish.

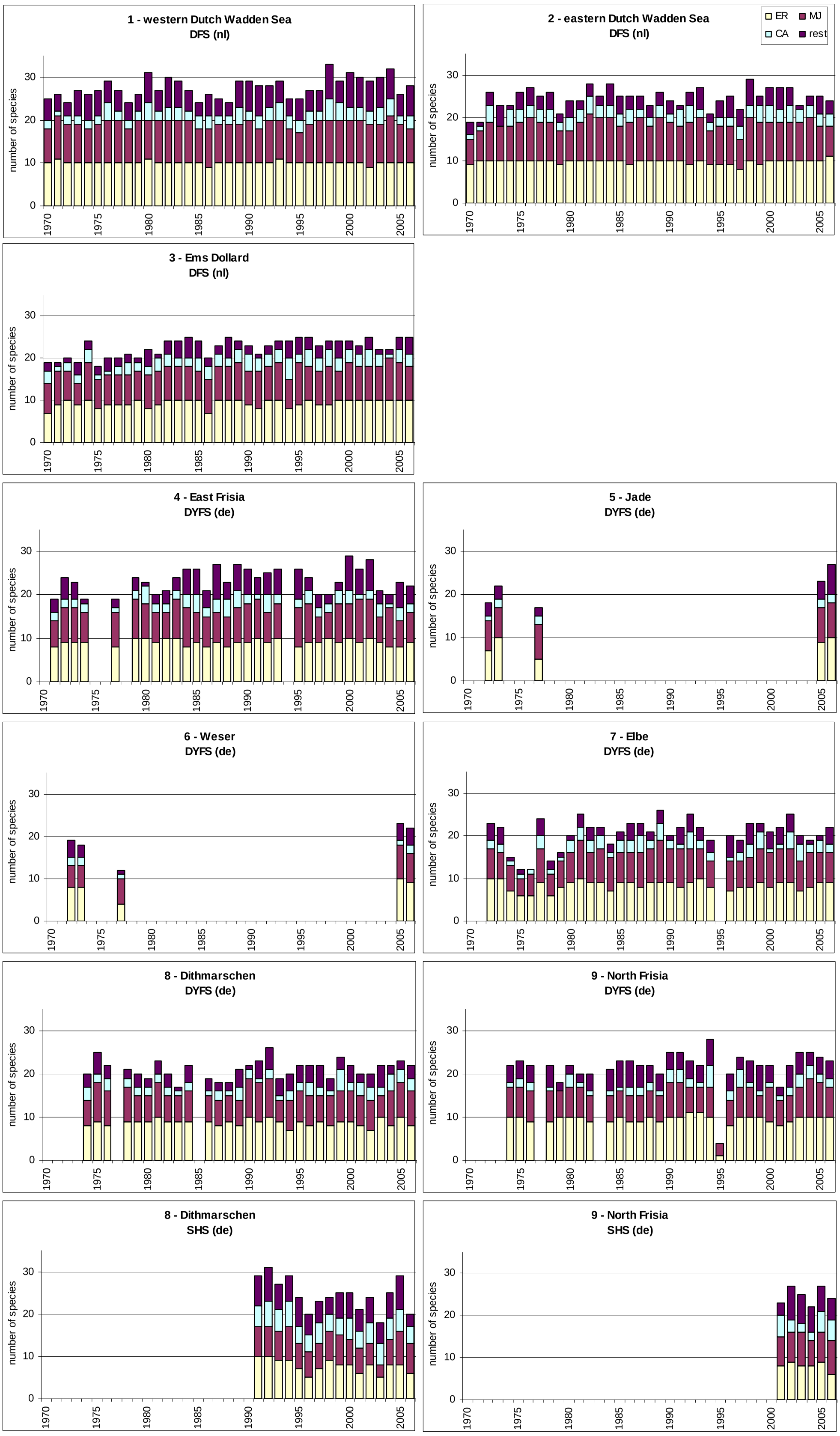


*Figure 3. Number of species per year and ecological guild for each region and survey*

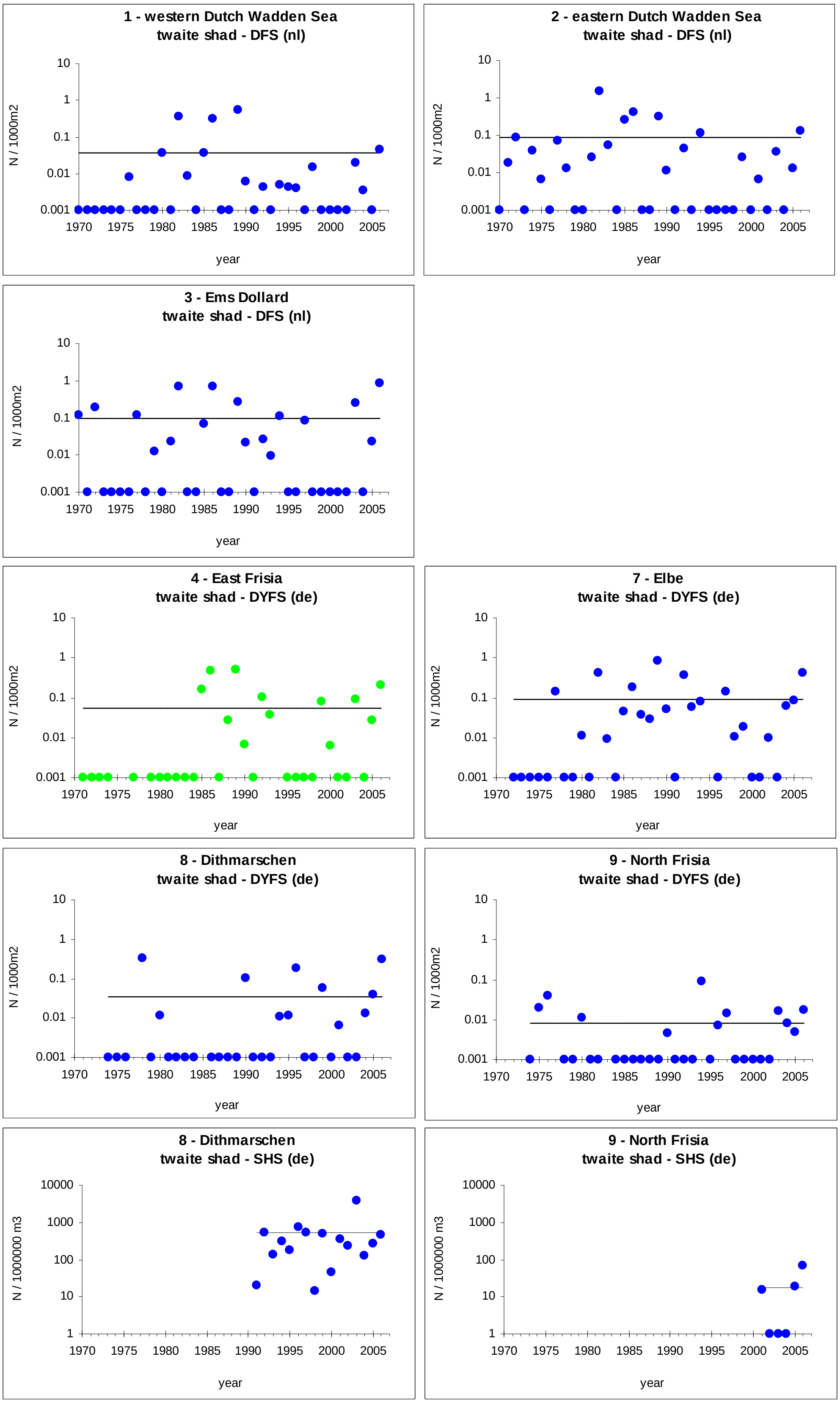


*Figure 4.1. Mean abundance of twaite shad per year (symbols) and the long-term average (line) for each region and survey.*

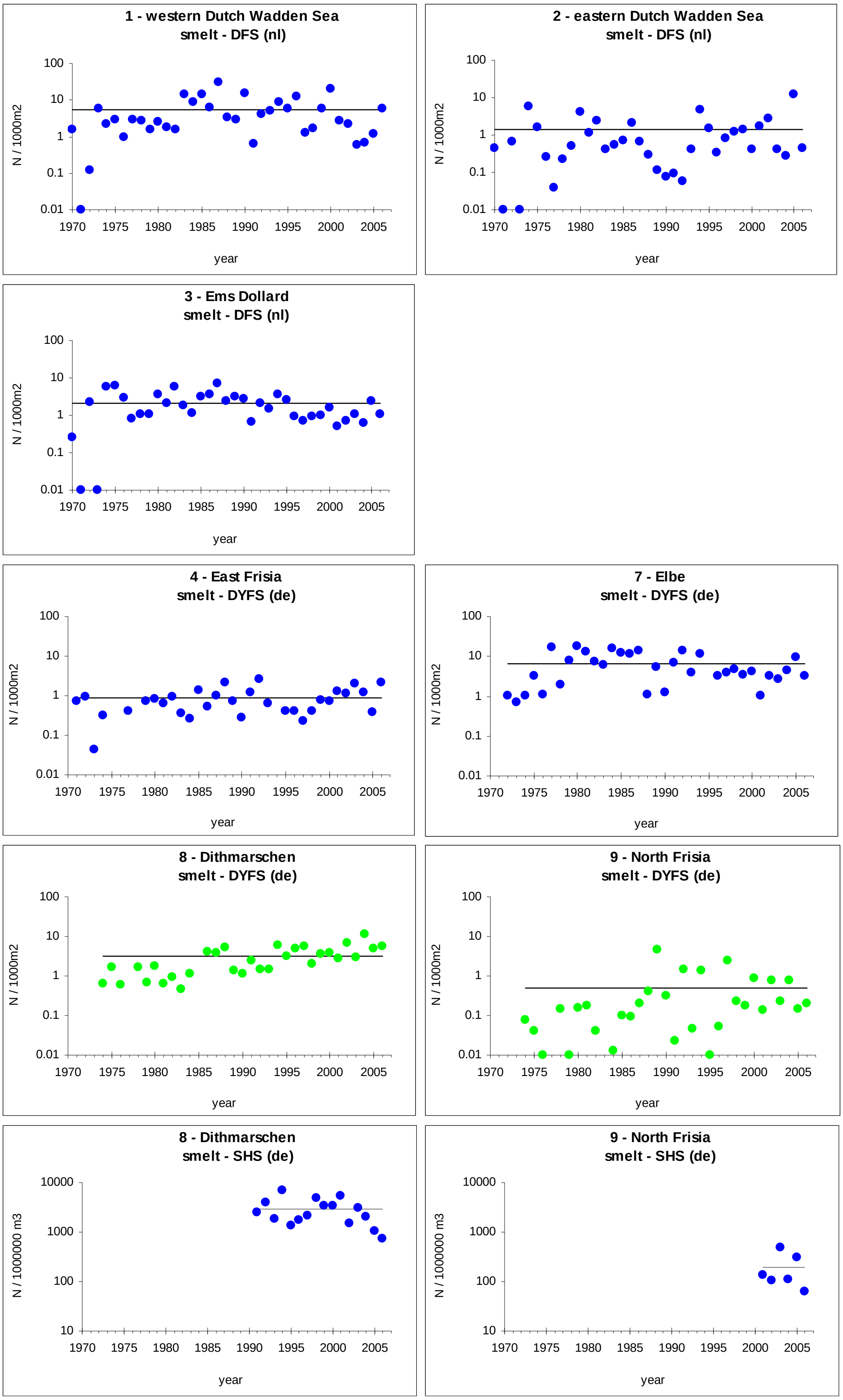


*Figure 4.2. Mean abundance of smelt per year (symbols) and the long-term average (line) for each region and survey.*

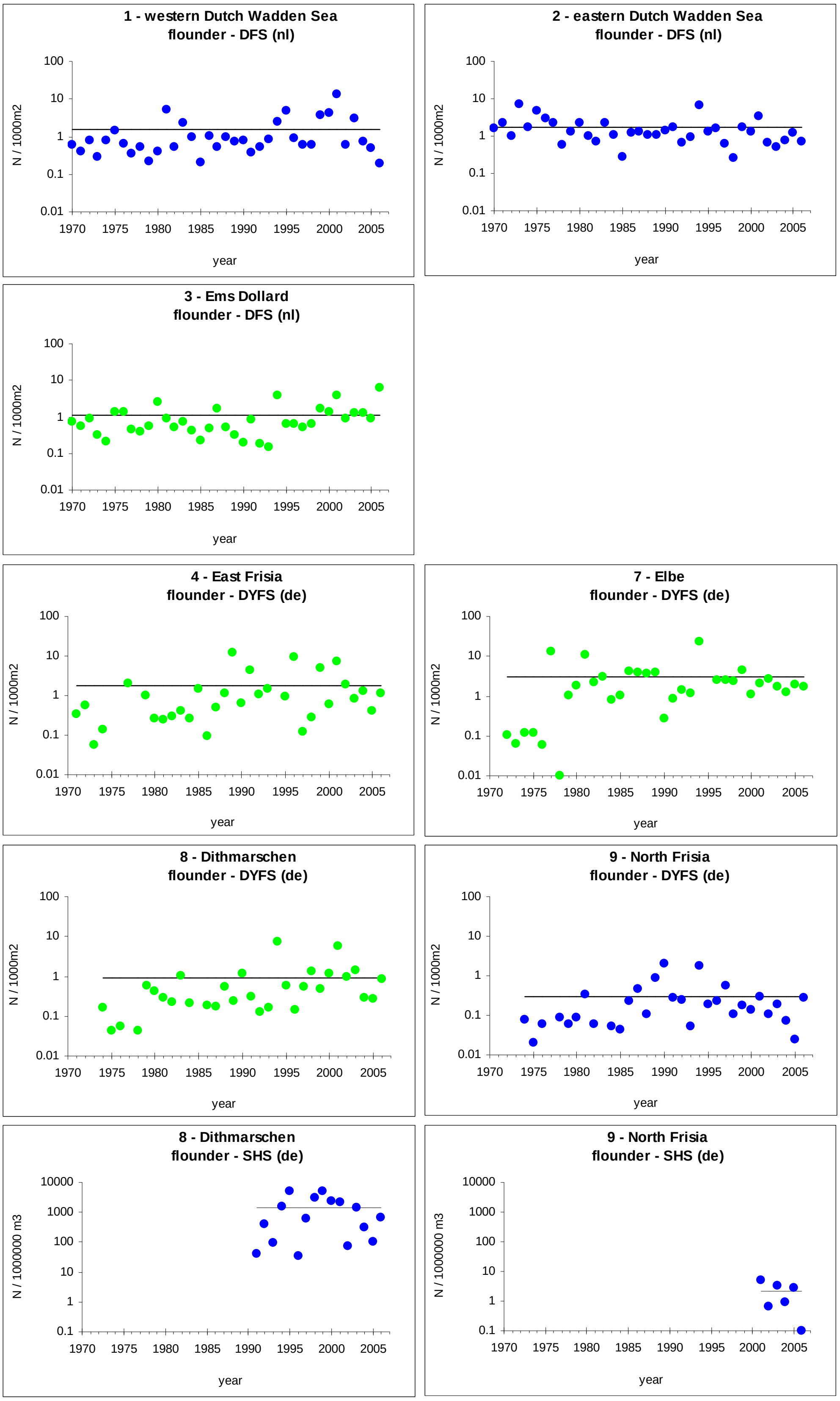


*Figure 4.3. Mean abundance of flounder per year (symbols) and the long-term average (line) for each region and survey.*

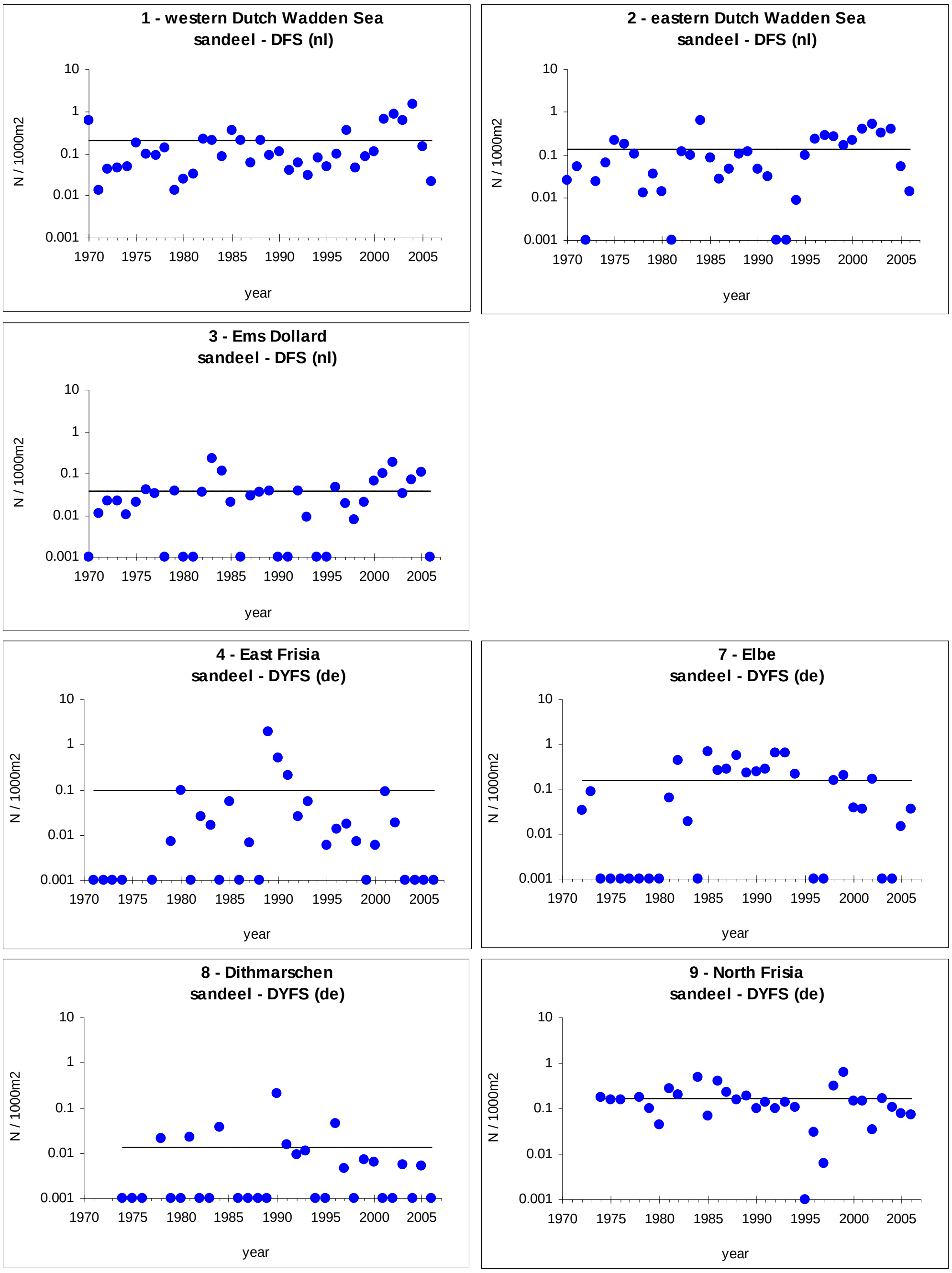


*Figure 4.4. Mean abundance of sandeel per year (symbols) and the long-term average (line) for each region and survey.*

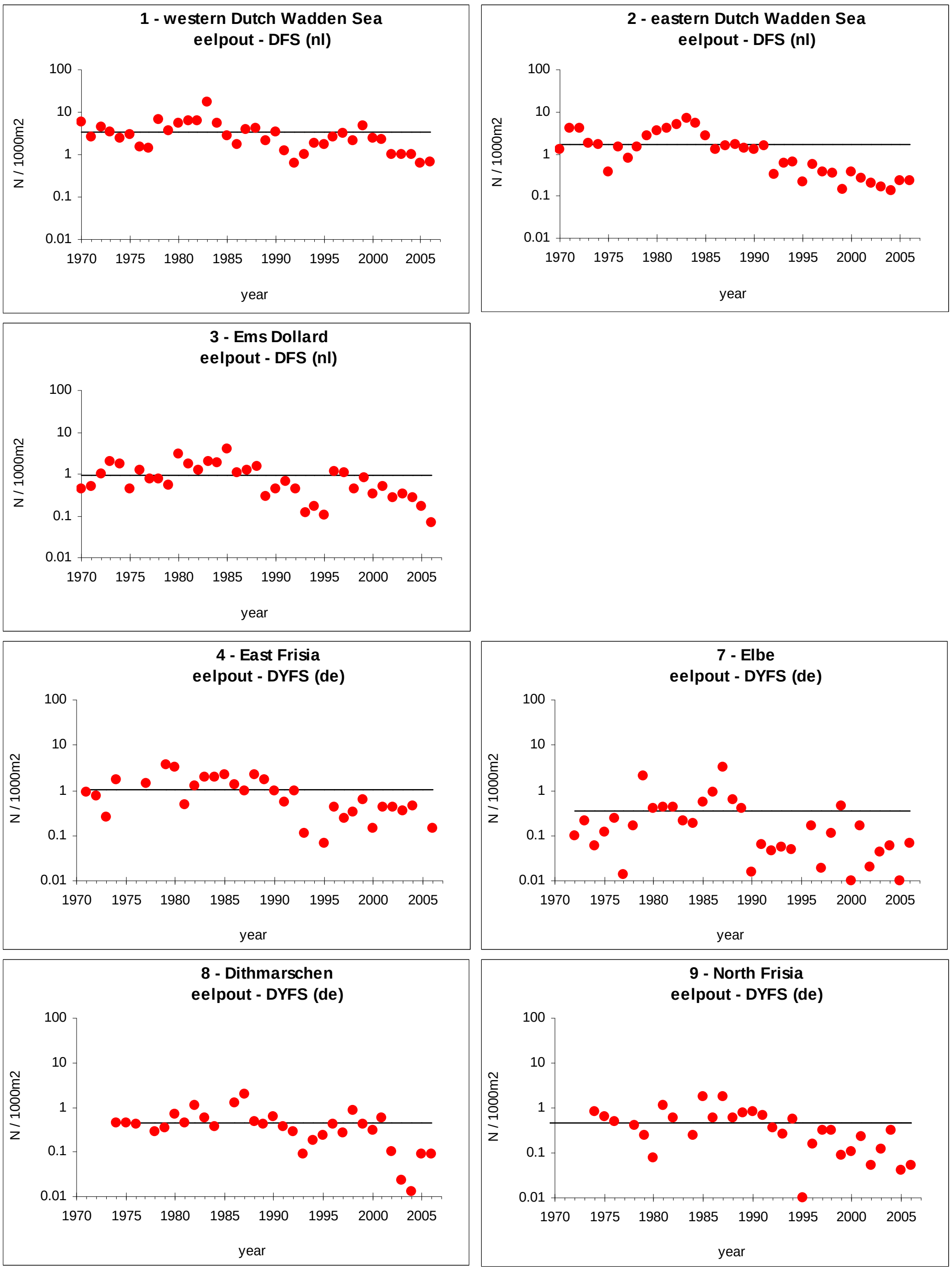


*Figure 4.5. Mean abundance of eelpout per year (symbols) and the long-term average (line) for each region and survey.*

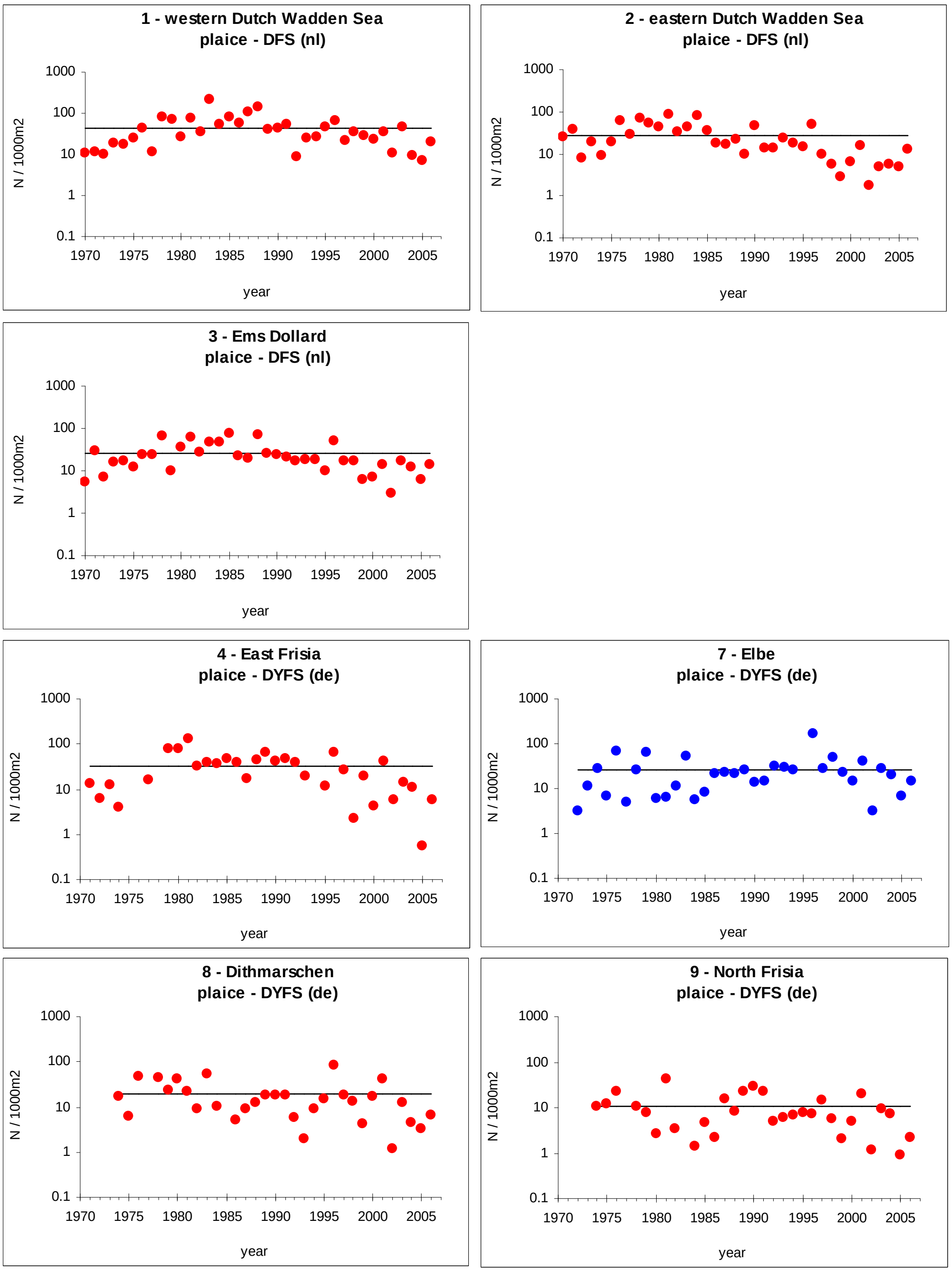


*Figure 4.6. Mean abundance of plaice per year (symbols) and the long-term average (line) for each region and survey.*

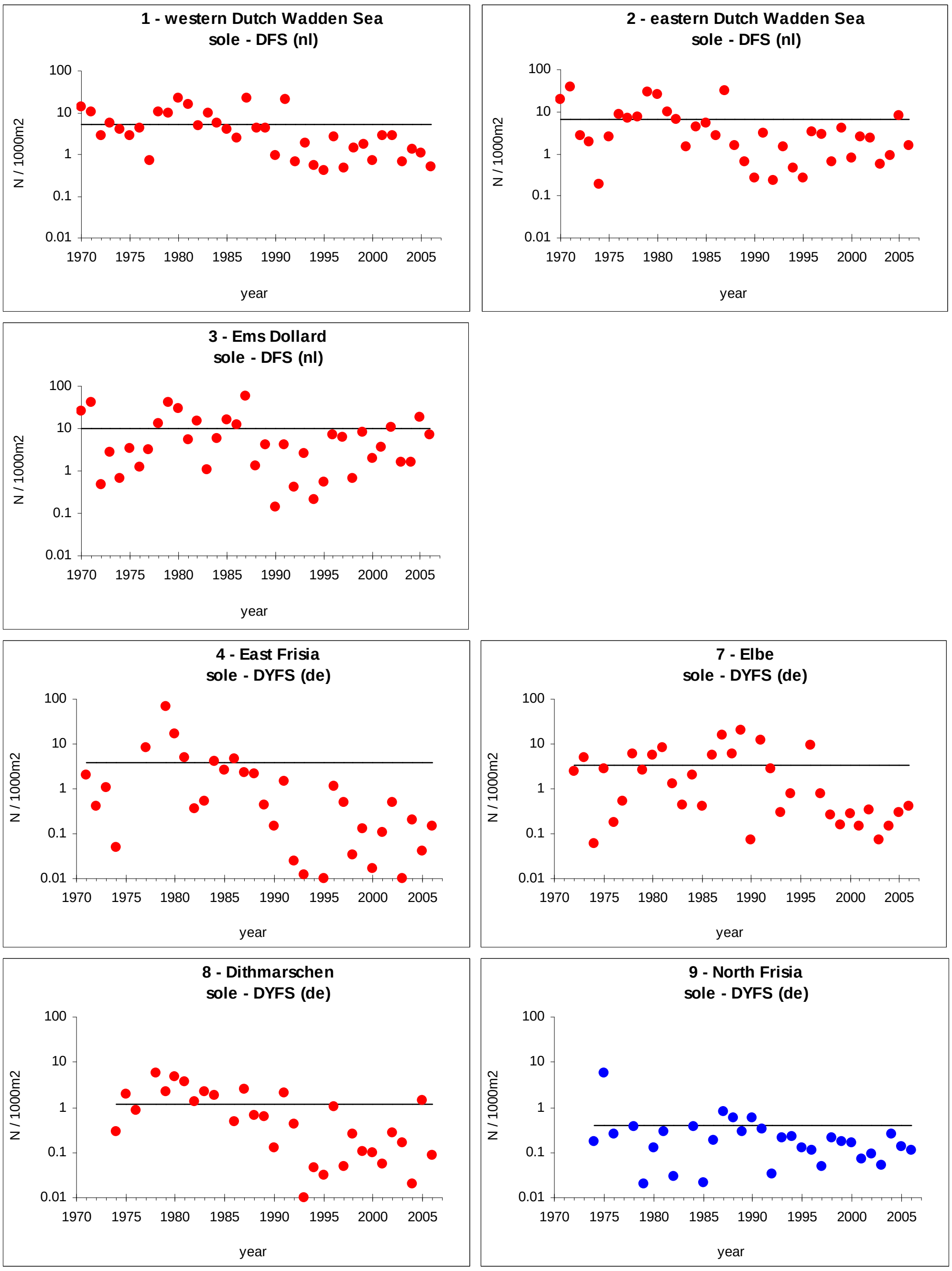


*Figure 4.7. Mean abundance of sole per year (symbols) and the long-term average (line) for each region and survey.*

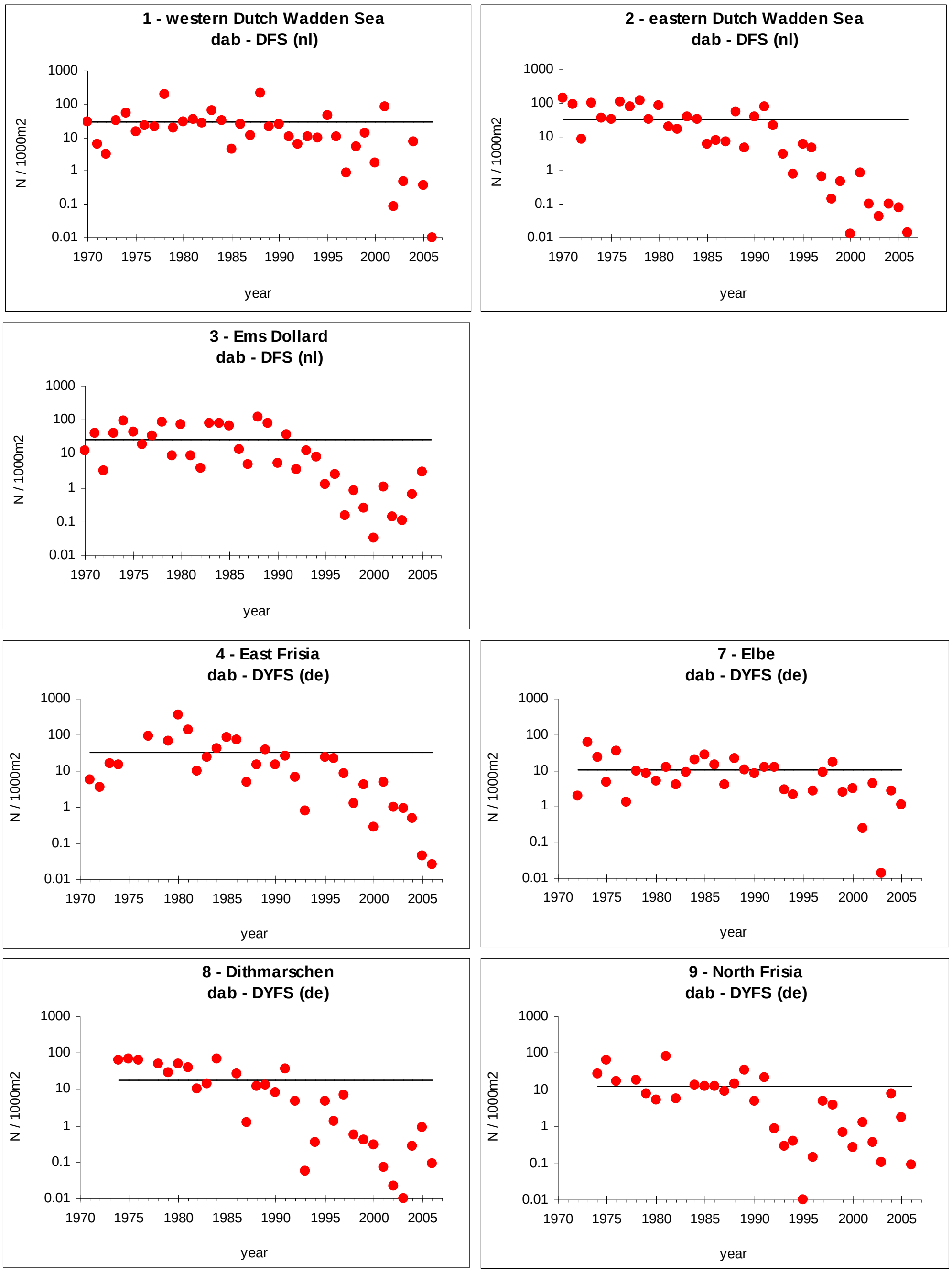


*Figure 4.8. Mean abundance of dab per year (symbols) and the long-term average (line) for each region and survey.*

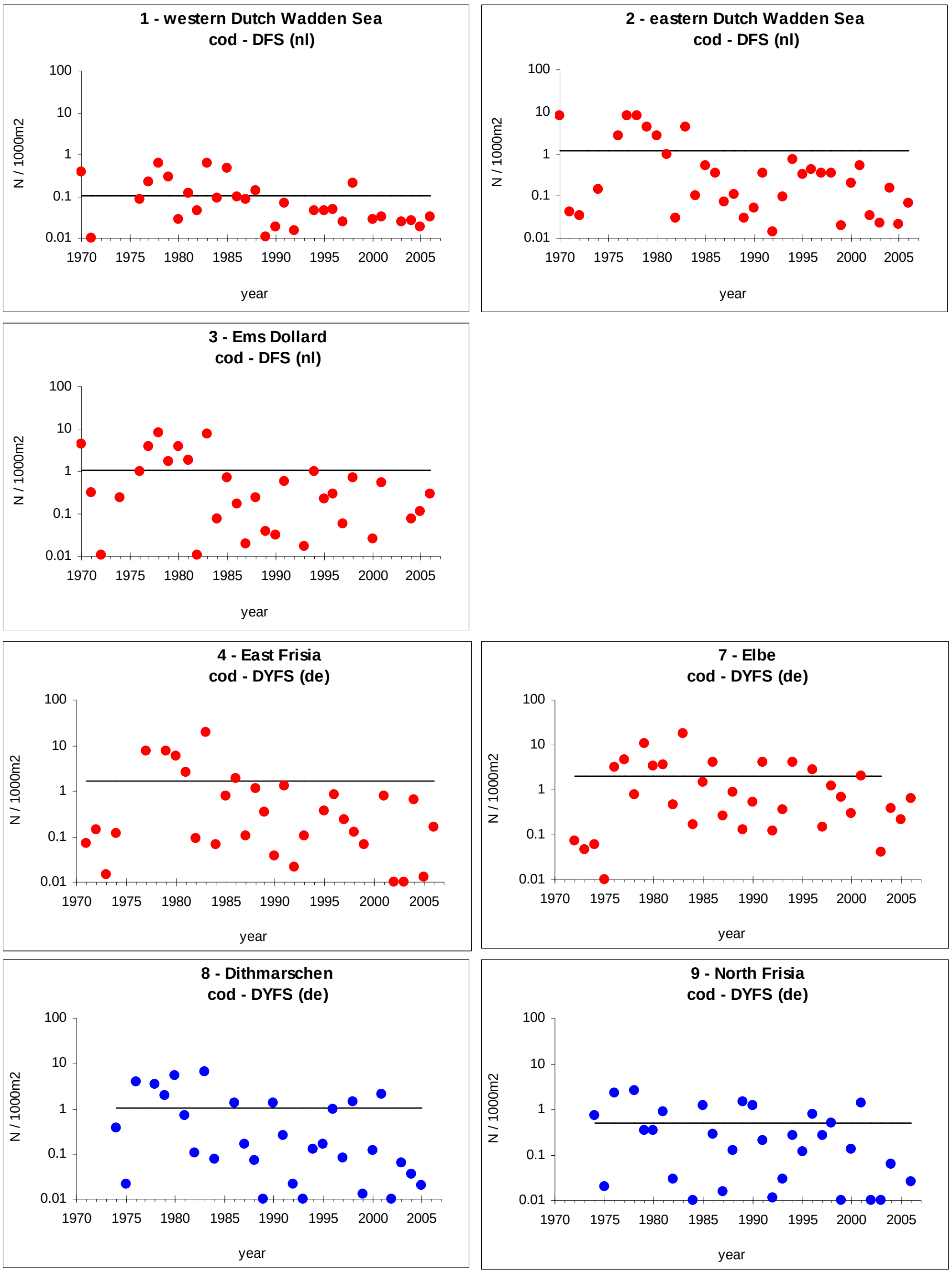


*Figure 4.9. Mean abundance of cod per year (symbols) and the long-term average (line) for each region and survey.*

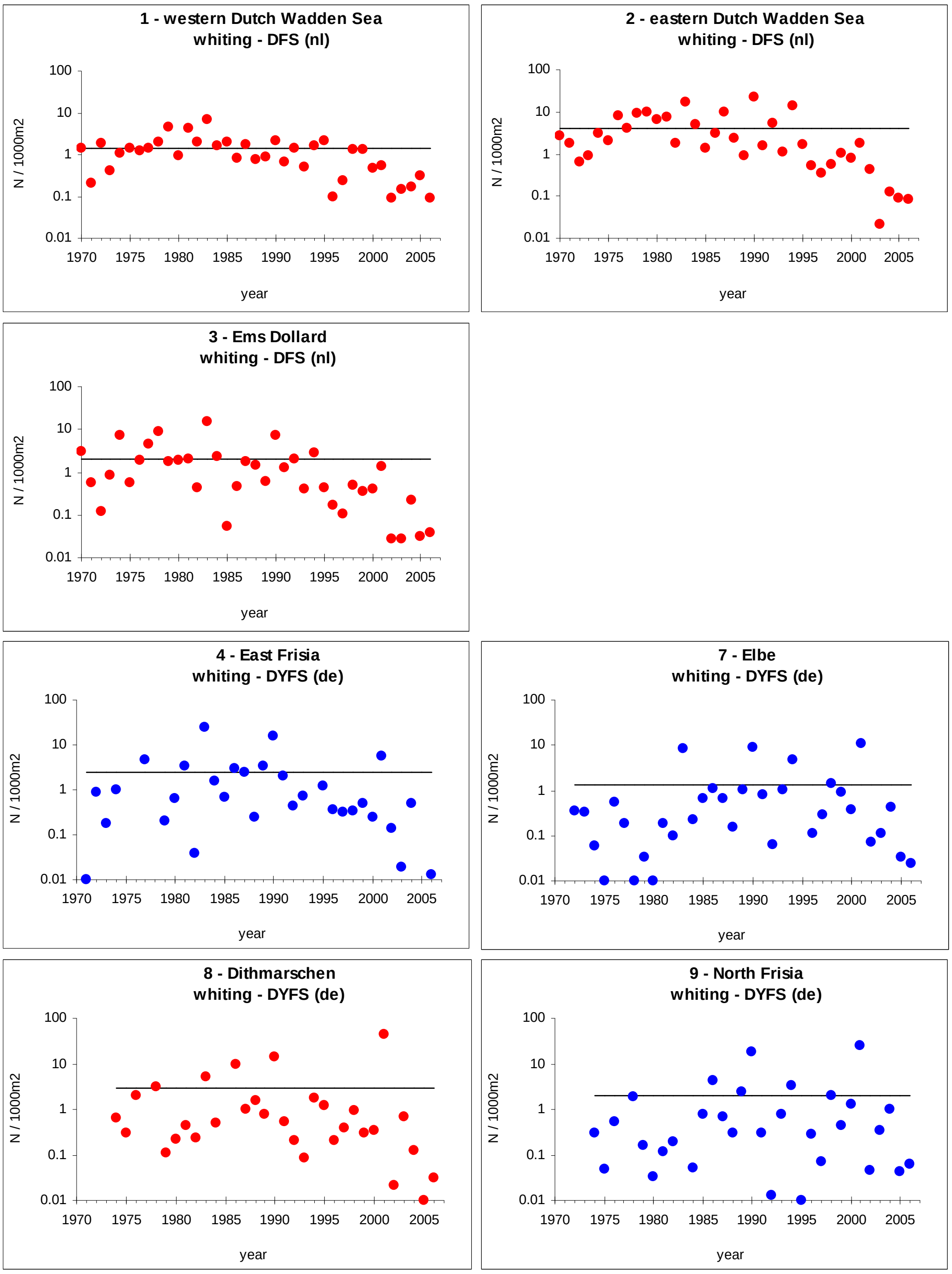


*Figure 4.10. Mean abundance of whiting per per year (symbols) and the long-term average (line) for each region and survey.*

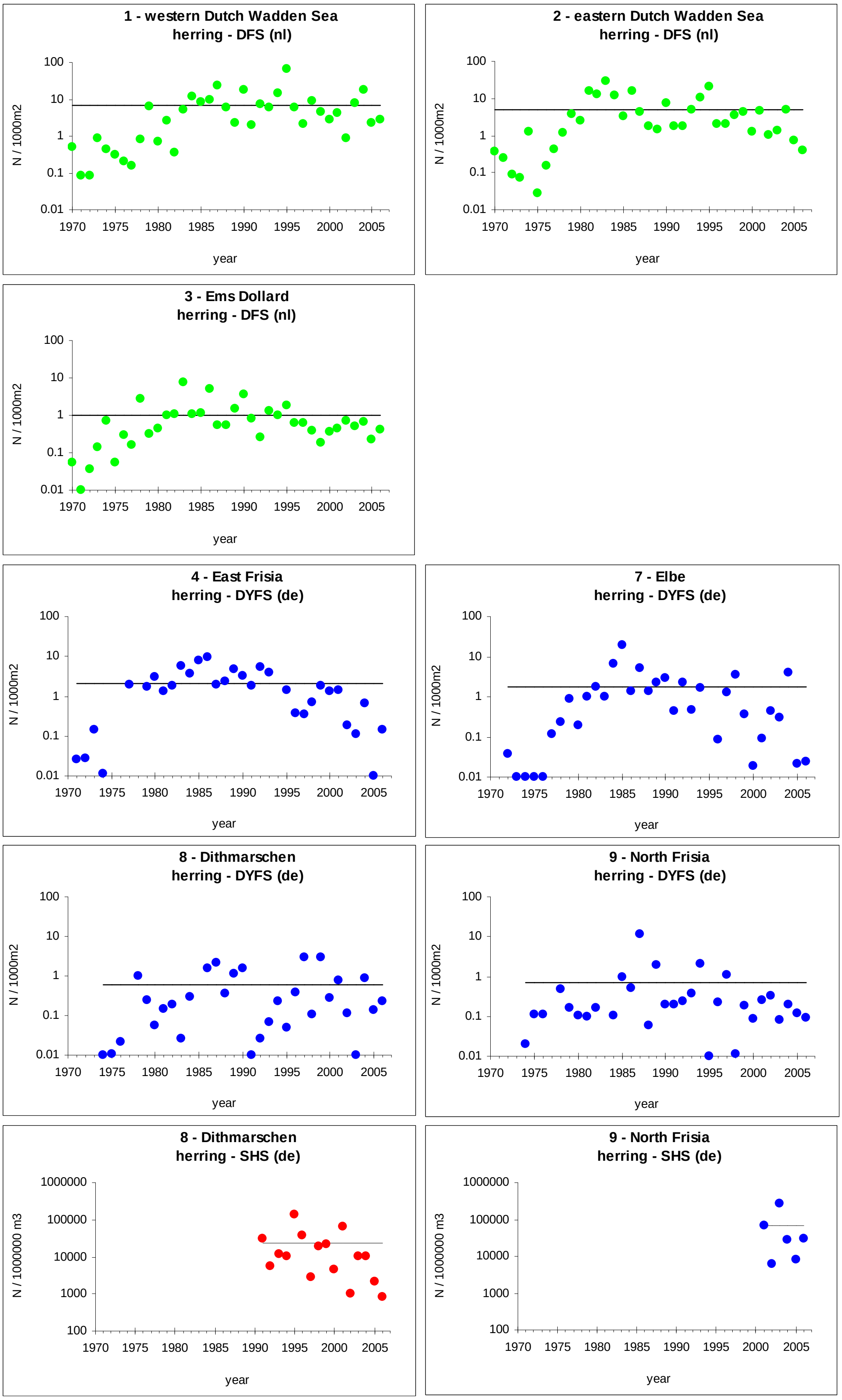


*Figure 4.11. Mean abundance of herring per year (symbols) and the long-term average (line) for each region and survey.*

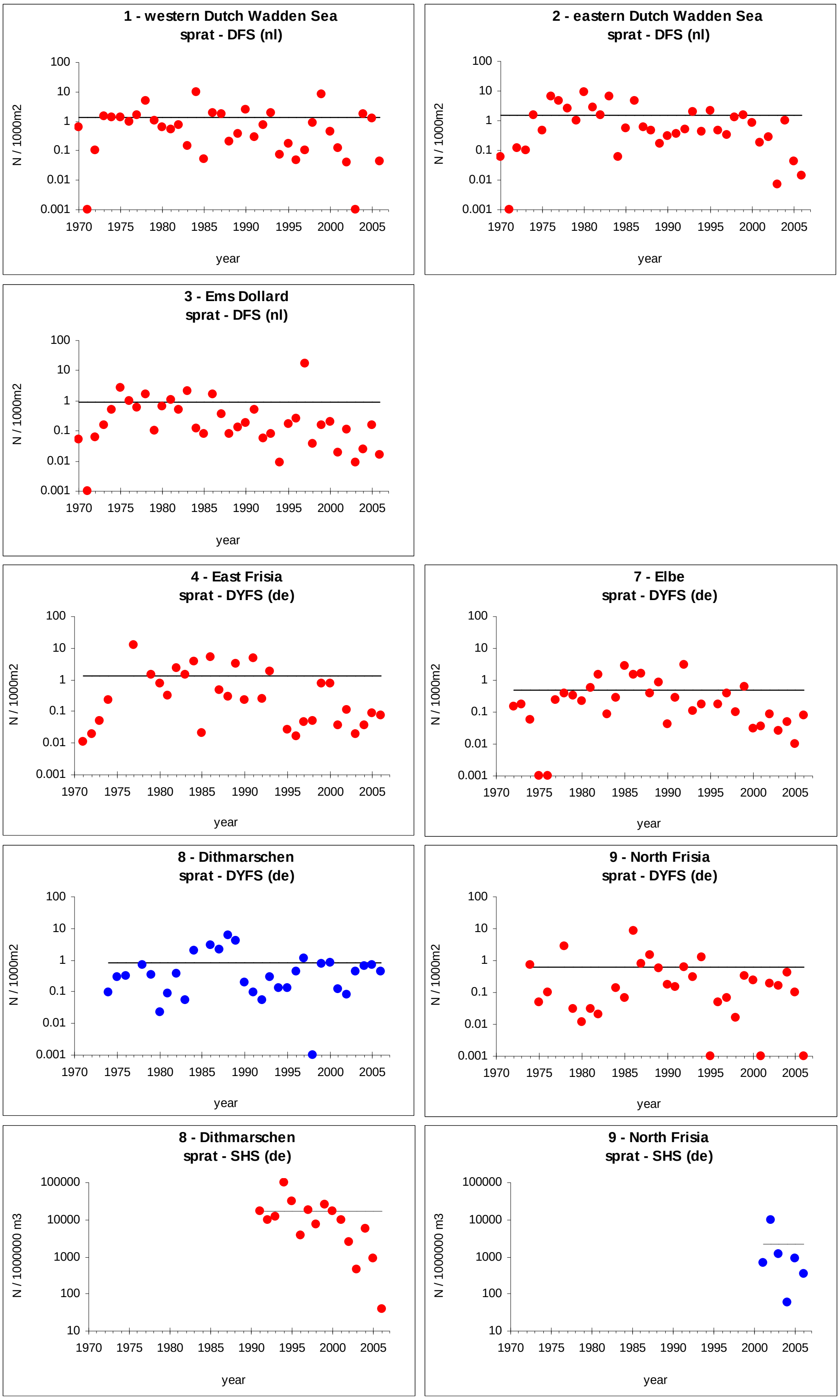


*Figure 4.12. Mean abundance of sprat per year (symbols) and the long-term average (line) for each region and survey.*

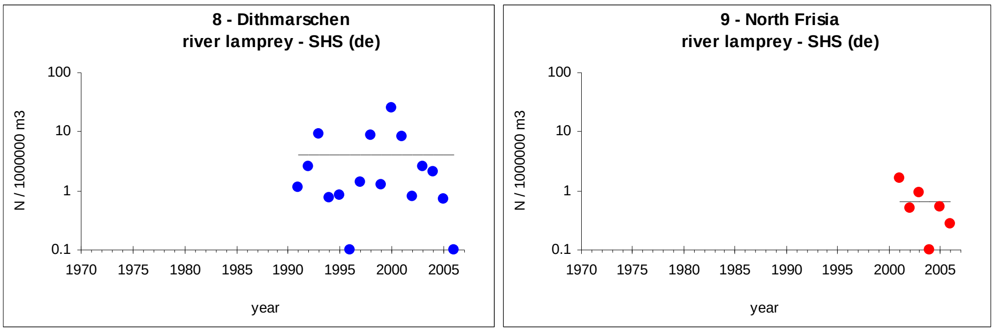


*Figure 4.13. Mean abundance of rivier lamprey per year (symbols) and the long-term average (line) for each region and survey.*

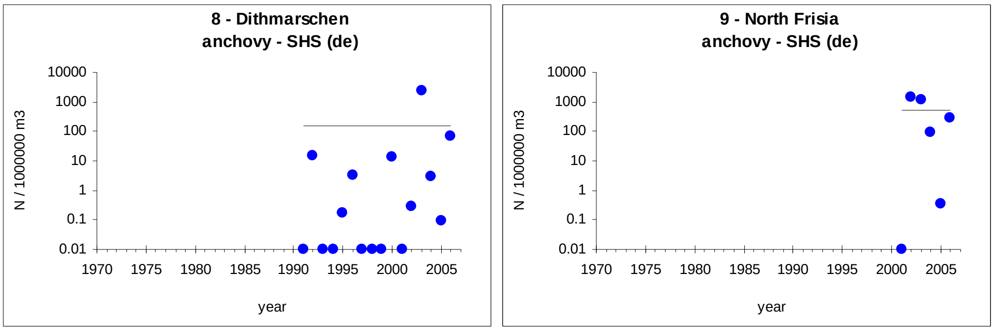


*Figure 4.14. Mean abundance of anchovy per year (symbols) and the long-term average (line) for each region and survey.*

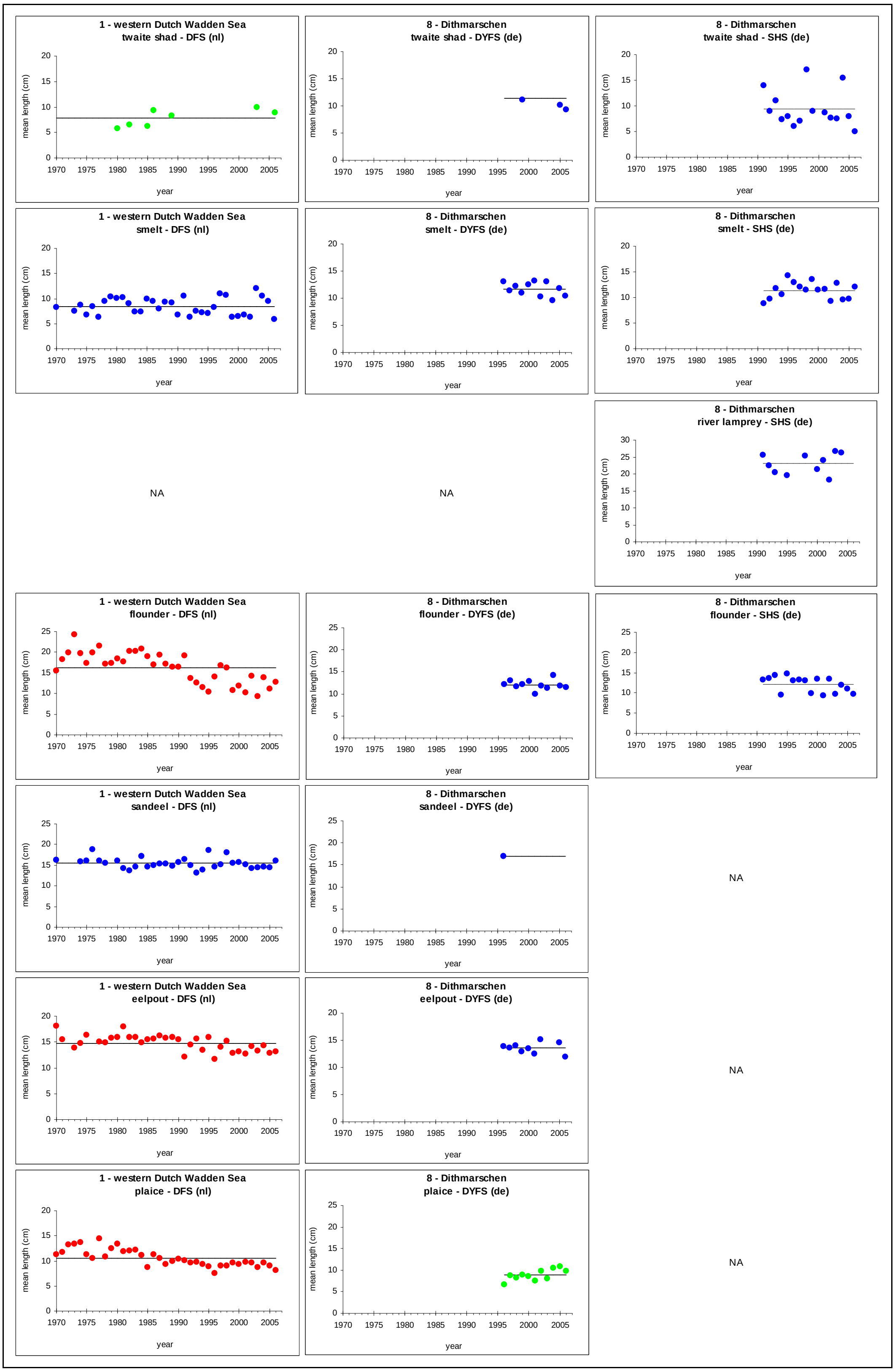


*Figure 5. Mean length per year for all priority species, for only 1 region per survey.*

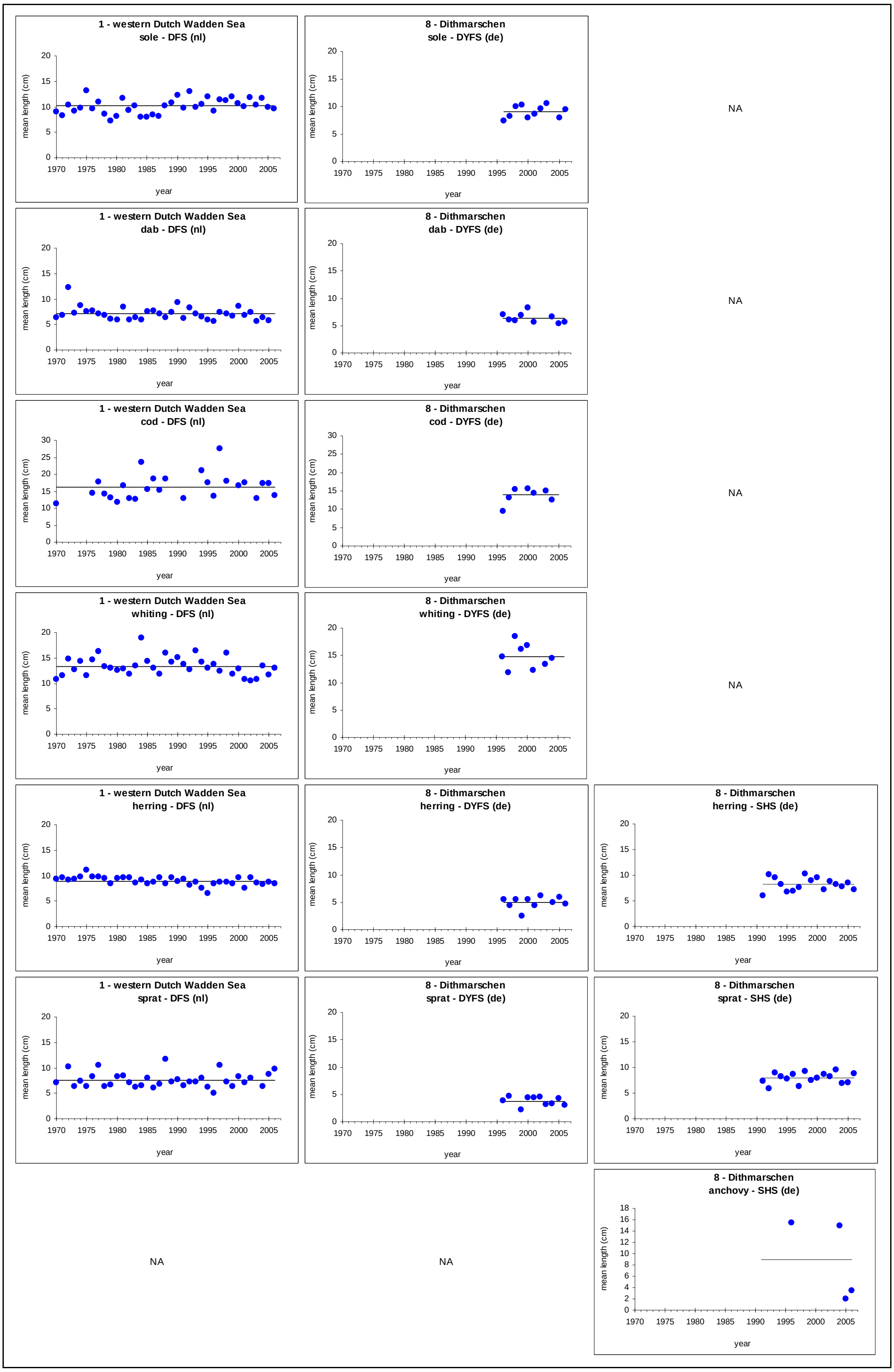


*Figure 5. continued.*

Table 3. Summary of spatial and temporal trends in abundance.

| survey | DFS | DFS | DFS | DYFS | DYFS | DYFS | DYFS | SHS | SHS |
|---|---|---|---|---|---|---|---|---|---|
| gear | beamtrawl | beamtrawl | beamtrawl | beamtrawl | beamtrawl | beamtrawl | beamtrawl | stownet | stownet |
| QSR area | 1 western Dutch Wadden Sea | 2 eastern Dutch Wadden Sea | 3 Ems Dollard | 4 East Frisia | 7 Elbe | 8 Dithmarschen | 9 North Frisia | 8 Dithmarschen | 9 North Frisia |
| Nyears | 37 | 37 | 37 | 33 | 34 | 32 | 32 | 16 | 6 |
| Nhauls | 1972 | 1186 | 868 | 1149 | 746 | 832 | 1087 | 169 | 63 |
| Twaite shad (CA) | no trend | no trend | no trend | up | no trend | no trend | no trend | no trend | no trend |
| Smelt (CA) | no trend | no trend | no trend | no trend | up & down | up | up | no trend | no trend |
| River lamprey (CA) | - | - | - | - | - | - | - | no trend | down |
| Flounder (ER) | no trend | no trend | up | up | up | up | up & down | no trend | no trend |
| Sand eel (ER) | no trend | no trend | no trend | up & down | up & down | no trend | no trend | - | - |
| Eelpout (ER) | (up &) down | (up &) down | (up &) down | (up &) down | (up &) down | (up &) down | (up &) down | - | - |
| Plaice (MJ) | (up &) down | (up &) down | (up &) down | (up &) down | no trend | down | down | - | - |
| Sole (MJ) | down | down | down | (up &) down | down | down | no trend | - | - |
| Dab (MJ) | down | down | down | (up &) down | down | down | down | - | - |
| Cod (MJ) | (up &) down | (up &) down | (up &) down | (up &) down | (up &) down | no trend | no trend | - | - |
| Whiting (MJ) | (up &) down | (up &) down | (up &) down | up & down | up & down | (up &) down | no trend | - | - |
| Herring (MJ) | up (& down) | up (& down) | up (& down) | up & down | up & down | no trend | no trend | down | no trend |
| Sprat (MS) | (up &) down | (up &) down | (up &) down | (up &) down | (up &) down | no trend | down | down | no trend |
| Anchovy (MS) | - | - | - | - | - | - | - | no trend | no trend |

Table 4. Summary of spatial and temporal trends in mean length

| survey | DFS | DFS | DFS | DYFS >1995 | DYFS >1995 | DYFS >1995 | DYFS >1995 | SHS | SHS |
|---|---|---|---|---|---|---|---|---|---|
| gear | beamtrawl | beamtrawl | beamtrawl | beamtrawl | beamtrawl | beamtrawl | beamtrawl | stownet | stownet |
| QSR area | 1 western Dutch Wadden Sea | 2 eastern Dutch Wadden Sea | 3 Ems Dollard | 4 East Frisia | 7 Elbe | 8 Dithmarschen | 9 North Frisia | 8 Dithmarschen | 9 North Frisia |
| Nyears | 37 | 37 | 37 | 11 | 11 | 11 | 11 | 16 | 6 |
| Nhauls | 1972 | 1186 | 868 | 349 | 267 | 375 | 458 | 169 | 63 |
| Twaite shad (CA) | up | no trend | no trend | - | - | - | - | no trend | - |
| Smelt (CA) | no trend | no trend | no trend | no trend | no trend | no trend | no trend | no trend | no trend |
| River lamprey (CA) | - | - | - | - | - | - | - | no trend | - |
| Flounder (ER) | down | down | down | no trend | no trend | no trend | no trend | no trend | - |
| Sand eel (ER) | no trend | no trend | no trend | - | - | - | no trend | - | - |
| Eelpout (ER) | down | no trend | no trend | no trend | no trend | no trend | no trend | - | - |
| Plaice (MJ) | down | down | down | no trend | no trend | up | up | - | - |
| Sole (MJ) | no trend | no trend | up | no trend | no trend | no trend | no trend | - | - |
| Dab (MJ) | no trend | no trend | no trend | no trend | no trend | no trend | no trend | - | - |
| Cod (MJ) | no trend | up | no trend | no trend | no trend | no trend | no trend | - | - |
| Whiting (MJ) | no trend | up | up | no trend | no trend | no trend | no trend | - | - |
| Herring (MJ) | no trend | no trend | no trend | no trend | no trend | no trend | no trend | no trend | no trend |
| Sprat (MS) | no trend | no trend | no trend | no trend | no trend | no trend | no trend | no trend | no trend |
| Anchovy (MS) | - | - | - | - | - | - | - | - | no trend |

## 3.2 Multivariate analysis: Principal Component Analysis (PCA)

### *General remarks*

Evaluation methods that can structure information determined in the field and thus make results more transparent may be of significance for ecological questions. For this reason an exemplary evaluation by means of PCA – in addition to the central trend analyses (see section 3.1) – was conducted within the framework of the present study with the aim of obtaining indications of possible interrelationships between species abundances and study years and/or of existing time gradients. The exemplary analysis carried out here is based on the catch data (standardized to ind. 1000 m-2) of the Demersal Fish Survey (DFS) from the Ems-Dollard area (DFS_Area 620, see Figure 1). Solely the fish species defined here as 'priority' for the Wadden Sea region were taken into account in this context (see Table 1). The abundance data were log-transformed prior to the analyses.

For representation in the form of an ordination the following PCA theoretical variables are depicted on the x and y axis in a linear model. The resulting aligned species values are shown as arrows. The arrow of a species concerned points towards increasing abundance. The longer an arrow belonging to a species is in the ordination, the greater the extent to which this species explains local and/or temporal differences.

### *Results*

The result of the PCA illustrates a generally large spatial and temporal variability of the priority species in the area examined (Area_620 Eems-Dollard). The variability is shown, among other things, by the fact that the hauls scatter relatively far beyond the ordination even within a catch period (here 5-year period, as seen by the haul designations of the same colour) (Figure 6).

However, the key result is that a relatively clear time pattern can be identified within the data record in spite of this pronounced variability. For instance, the hauls from the period '1970+' and '1980+' are grouped above or below the 1st main axis while particularly the hauls from the years '2000+' are located to the left of the 2nd axis, clearly separate from the former periods (Figure 6).

The interannual differences are based primarily on the fact that maximum catch values in the 1970s and especially in the 1980s as well as a predominantly significant decline in catch figures in the 1990s and/or in the 2000+ period were recorded for nearly all priority species. These findings are indicated by the direction and length of the 'species arrows'. With the exception of a few species such as flounder and twaite shad, which display a rather indifferent result (multiple R-square $<0.1$), the other species arrows clearly point to '1970+' and '1980+' and thus illustrate the species-specific maximum abundance values in these periods.

Special weight for structuring the data record and forming a time gradient is primarily given to dab, plaice and sole as well as whiting. The abundance differences between the decades for these species are the most pronounced: all showed a more or less distinct minimum abundance value in the 2000+ period. Figure 7 and Figure 8 depict this result using the example of the temporal and spatial abundance distribution of dab (multiple R-square = 0.52) and sole (multiple R-square = 0.54).

### *Conclusion*

The perceptible spatial and temporal variability within the decades (or 5-year periods) examined is predominantly overlapped by interannual differences between the decades with respect to the abundance of the priority fish species. These findings make it appear plausible that relatively significant changes in the fish fauna occurred in the Eems-Dollard area in the period from 1970-2006 which very probably cannot be explained by a method-related catch variability. The variance is explained quite well, to a degree of approx. 60%, by the first two main axes of the PCA. Indications of species-specific development trends can therefore be derived from the analysis.

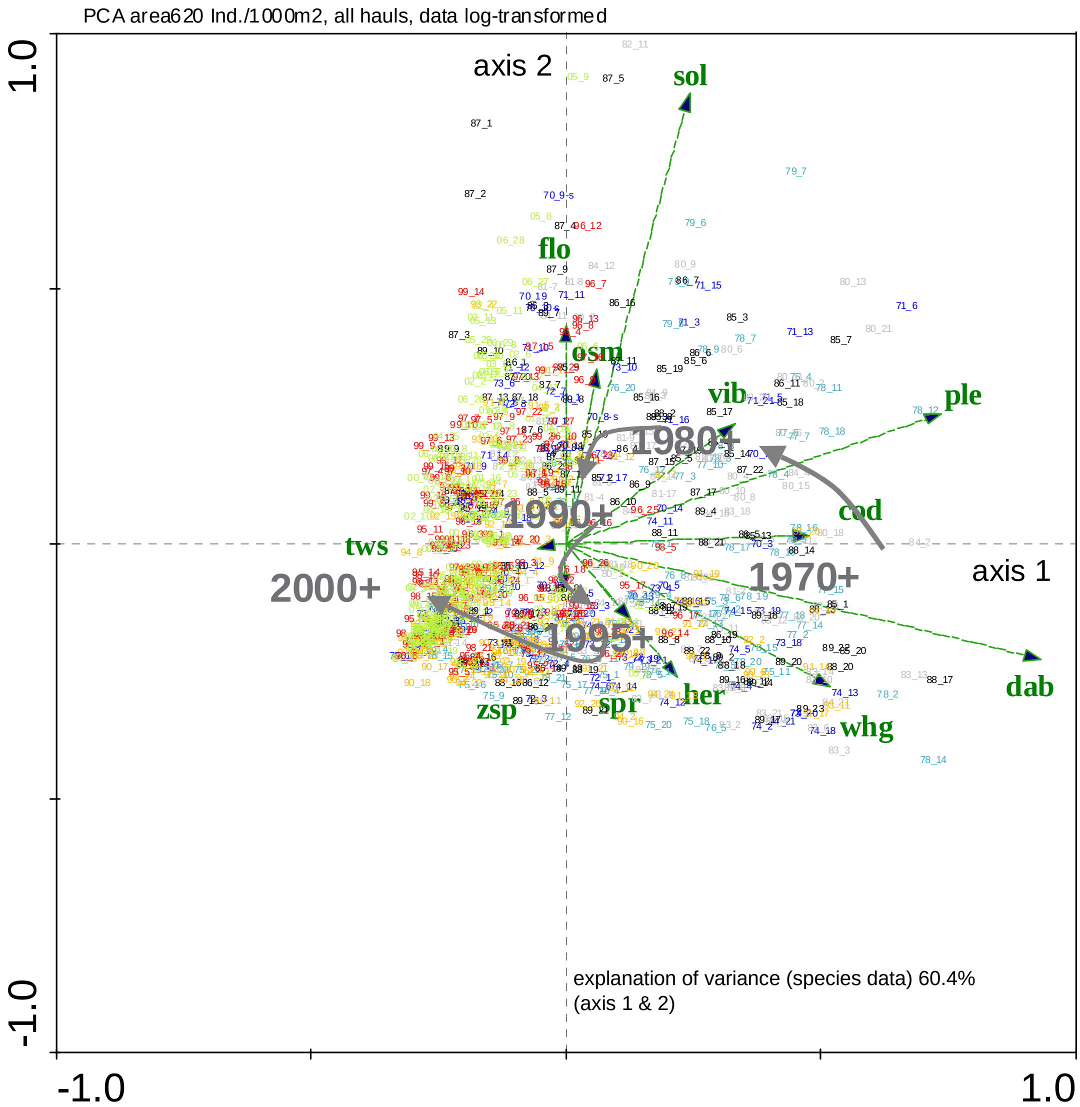


*Figure 6: Ordination diagram of the PCA on the basis of the DFS fishing data (1970-2006, N = 868) from the Ems-Dollart area (Area_620). Data log-transformed [(ln(Ay+B) transformation of species data. A = 1,000, B = 1,000)]. Hauls in the 1970-1974 period: dark blue, 1975-1979: light blue, 1980-1984: grey, 1985-1989: black, 1990-1994: orange, 1995-1999: red, 2000-2006: light green. Fish: cod = cod, dab = dab, flo = flounder, her = herring, osm = smelt, ple = plaice, sol = sole, spr = sprat, tws = twaite shad, vib = eelpout, zsp = sand eel*

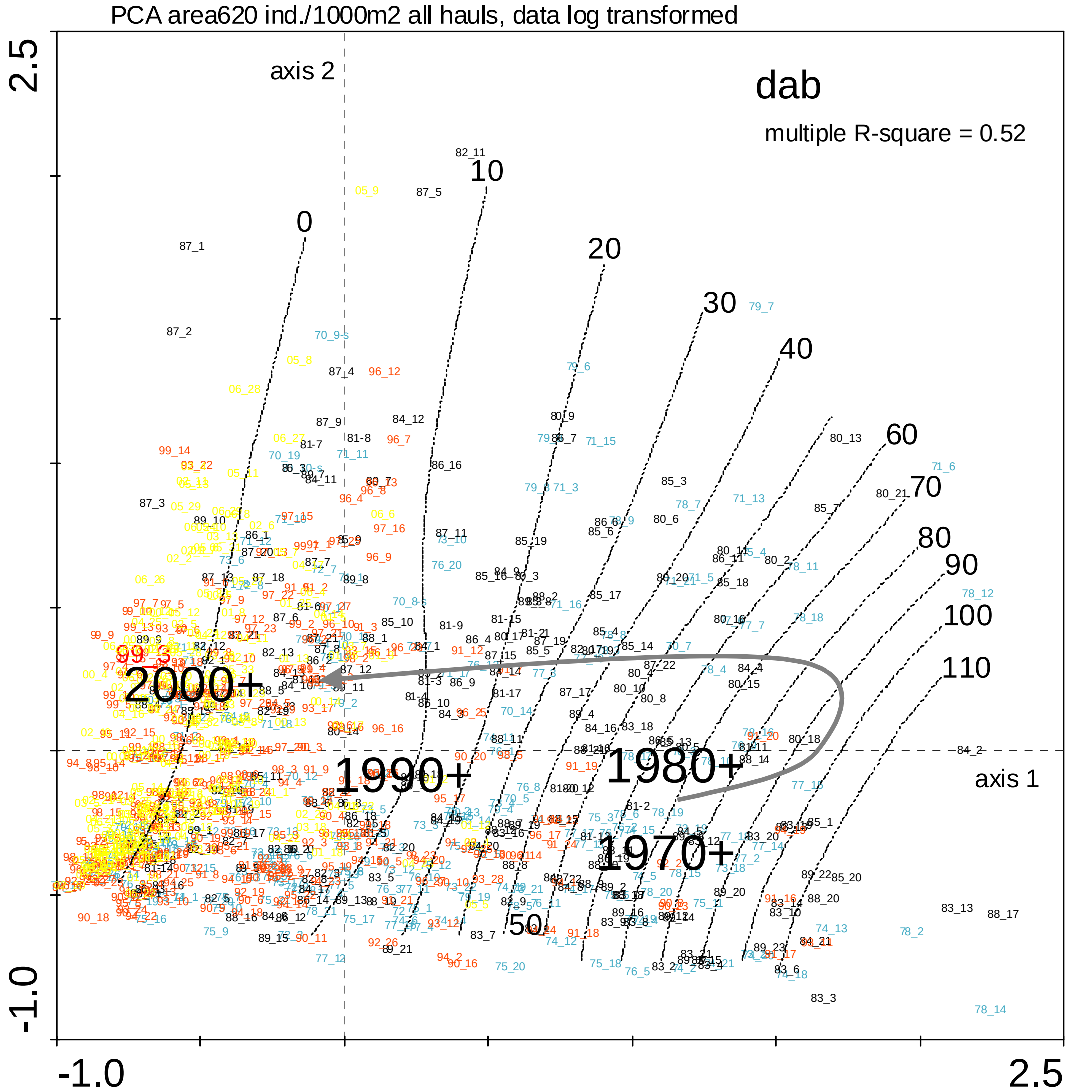


*Figure 7: Temporal-spatial abundance distribution of dab in Area_620 (for database see PCA). Hauls in the 1970+ period: blue, 1980+: black, 1990+: red, 2000+: yellow. Visualization: locally weighted scatterplot smoothing.*

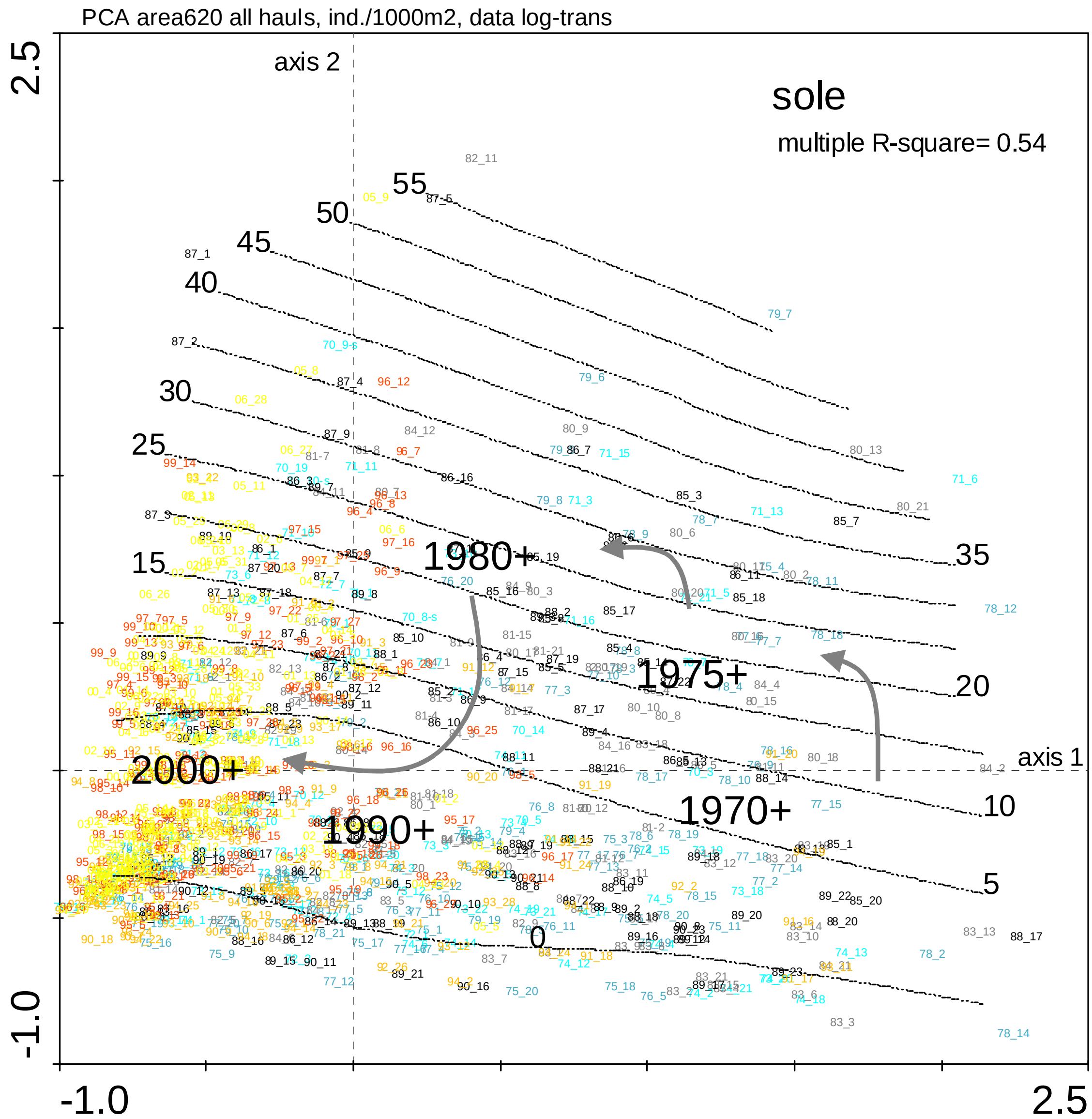


*Figure 8: Temporal-spatial abundance distribution of sole in Area_620 (for database see PCA). Hauls in the 1970+ period: blue, 1980+: black, 1990+: red, 2000+: yellow. Visualization: locally weighted scatterplot smoothing.*

## 3.3 Trend analysis

During the workshop simple linear regressions were carried out with the intention to examine if the overall trends were significantly increasing or decreasing. However, linear regression is not the appropriate method to analyse temporal trends due to autocorrelation (i.e. violation of the assumption of independence of the observed values for the response variable). Using linear regression when autocorrelation exists will inflate the P-values, i.e. insignificant trends may seem significant (Zuur et al, 2007). Therefore, other statistical tools are required to analyse the temporal trends correctly.

Two recently developed statistical methods which are currently frequently used in time-series analyses are 'TrendSpotter' and ' Dynamic Factor Analysis'. TrendSpotter is a (univariate) method for trend analyses, in which the autocorrelation problem has been solved (Visser, 2004). To illustrate the possibilities of this method, the data for one of the TMAP priority species (eelpout) in one QSR region (Ems Dollard) has been analysed using TrendSpotter. The results are presented in Figure 9. Dynamic Factor Analysis is a multivariate method for trend analyses is. A feature of this method is that it enables the detection and estimation of common trends in a multivariate time series dataset (Zuur et al., 2007). It is recommended to test and use one or both of these methods in the analyses to be carried out next year.

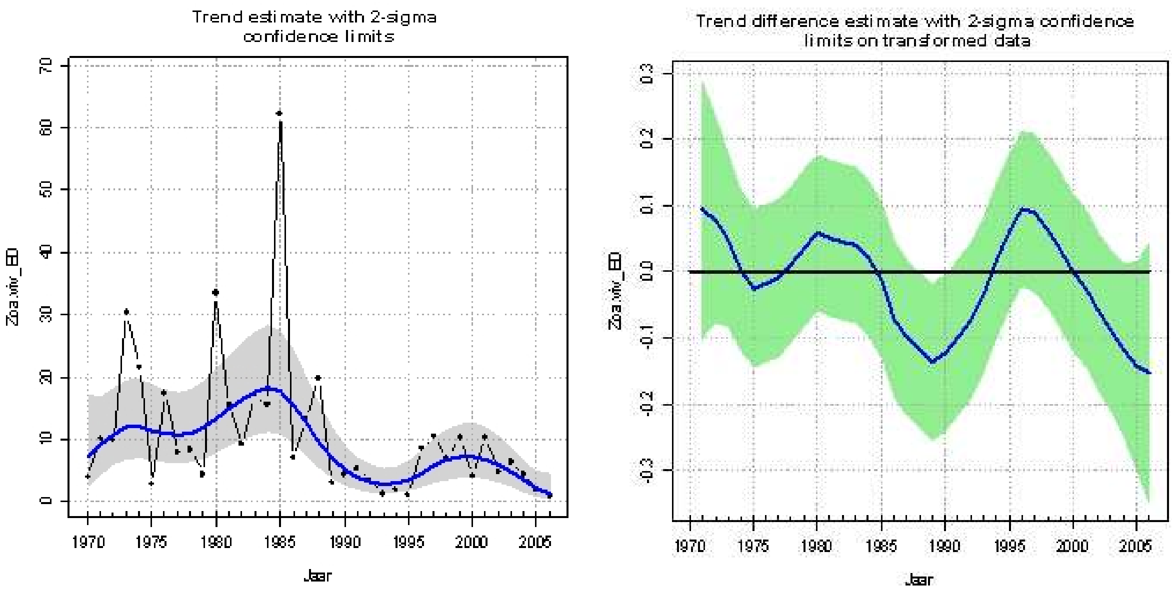


*Figure 9. Results of TrendSpotter analyses for eelpout abundance in Ems Dollard (DFS data). The left panel shows the observed values (annual mean abundance in N per 10000m$^2$) and the fitted trend with confidence limits. The right panel shows trend difference with confidence limits (transformed data), which indicates the degree of increase or decrease in abundance and the significance of the trend. A significant change (decrease) is only observed in 1989 (i.e. value 0 not in confidence interval).*

# 4. Recommendations

## 4.1 TMAP assessment tool

The request was put forward to the TMAP ad hoc Working Group Fish to evaluate if the fish metrics can be combined into a 'tool' that can be used to describe or maybe even evaluate the Wadden Sea fish fauna, similar to the 'assessment tool' developed for the WFD. However, a fundamental discussion is underlying this exercise.

Managers would like to get a conclusion on the status of the Wadden Sea in terms of 'good', 'moderate' or 'poor', but scientists are against giving such qualifications due to the lack of knowledge on the causal factors underlying the observed changes. The present level of knowledge is simply not advanced enough to allow this kind of judgement. Scientists can describe temporal and spatial trends in fish abundance and species composition, they can indicate if trends are significant or not, they can analyse if trends are comparable between sub-areas and species or not. A choice for scientifically sound metrics can be made and the long term average of these metrics can be calculated. But at present the factors and processes causing changes are still badly understood. Correlative studies between fish metrics and environmental factors have given and will give clues in which direction further (fundamental/process) research is required in order to understand what causes the observed changes.

Another aspect which complicates the evaluation in terms 'good', 'moderate' or 'poor', specifically with respect to setting management targets, is the fact that many of the selected fish species are probably strongly influenced by natural variations and/or by processes outside of the Wadden Sea. Furthermore, reference (i.e. historic) conditions are generally not known, but even if they were, you might argue why it would be desirable to go back to the status of hundred (or thousand) years before. The more so, because at present we are experiencing a period of climatic changes, which probably reflects in the fish fauna and may cause 'regime shifts' (non-linear changes).

The most advanced result that we can provide now is to monitor the changes in fish fauna in an effective way by making the best use of the available Wadden Sea surveys and to develop a system by which we can adequately describe trends in a consistent way for future quality status reports. The work of the TMAP ad hoc Working Group Fish is building step by step toward such a system, and will eventually lead to a more complete picture of the status of fish in the Trilateral Wadden Sea area.

### Future work

This report presents the results of the analyses carried out in 2007. These results are preliminary and the discussions on data handling, selection of metrics, and trend analyses are still ongoing. Based on the present results, the following is recommended for future work.

1) In the case of the beam-trawl surveys, re-calculate the means by year and region using the area-based weighting factors estimated by the ICES-WGbeam (see section 2.4).
2) Continue quality controls and corrections of basic data, specifically in the case of the German DYFS data (see section 2.4).
3) Analyse trends in abundance by using one or more appropriate (state of the art) statistical tools (see sections 3.2-3.3).
4) Analyse trends in abundance by size class, rather than trends in mean length, to examine changes in population structure (see section 3.1 and Figure 5).
5) Maintain current spatial resolution as differences in time-series between QSR-areas are observed (see Figures 4.1-4.14)
6) Evaluate choice of priority species based on results of trend analyses (e.g. sufficient data available to examine trends?, sampling gear suitable?) (see Figures 4.1-4.14).

7) Evaluate the species richness and species composition metrics in relation to sampling intensity (see section 3.1 and Figures 2-3)
8) Further evaluate applicability of indicators used in marine ecosystems (see Appendix 4).
9) Elaboration of overview of environmental data, both in terms of number of variables (data sources) as well as amount of information per variable.
10) Compile an overview of the hypotheses which have been postulated (in the literature and ongoing projects) on the causal factors underlying the changes in Wadden Sea fish fauna.
11) Analyse the correlations between fish metrics and relevant environmental parameters, in which the relevance of an environmental factor is based on the above mentioned hypotheses.

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# Referees

Report C133/07
Project Number: 4392501701

This report has been professionally prepared by Wageningen IMARES. The scientific validity of this report has been internally tested and verified by another researcher and evaluated by the Scientific Team at Wageningen IMARES.

| | |
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| Date: | 14 December 2007 |

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| Date: | 14 December 2007 |

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# Appendix 1 – Wadden Sea fish fauna

Table A1.1 presents a list of the fish fauna of the Wadden Sea. The decision on which species to include in this list was primarily based on the occurrence in the ongoing monitoring programs in recent years.

Three species were not caught during the ongoing monitoring programs in recent years, but were nevertheless considered relevant for the Wadden Sea. These species were houting (which is a Habitat Directive species) and the thick-lipped and thin-lipped grey mullets (both of which are expected to be abundant in fyke catches).

The ongoing monitoring programs included in the table are:

- The Demersal Fish Survey (DFS) carried out by Wageningen-IMARES (formerly known as RIVO, Netherlands) from 1970 onwards
- The Demersal Young Fish Survey (DYFS) carried out by the Bundesforschunganstalt für Fischerei (Germany) from 1974 onwards
- The Schleswig-Holstein Survey (SHS) carried out by the Marine Science Service (Germany) from 1991 onwards

A survey which was included in the table despite the fact that it is not an ongoing monitoring program (i.e. it will probably not be continued after 2007)

- The Seabird-Fish-Interactions Survey (SFIS) carried out by the Insitute of Avian Research (Germany) in the years 2005-2007

An ongoing monitoring program for which the data have not been made available to TMAP (yet) is:

- The Fyke sampling 't Horntje (NIOZ) carried out by the Royal Netherlands Institute for Sea Research from 1960 onwards

The DFS and DYFS are beam trawl surveys, the SHS and SFIS are stownet surveys, and the NIOZ series is a fyke net survey. Both beam trawl surveys have a large spatial coverage, together these 2 surveys cover the entire Dutch and German Wadden Sea and the adjacent coastal waters. The spatial coverage of the stownet and fyke net surveys is limited. Further information on the surveys is given in Report of the TMAP ad hoc working group fish, August 2006.

The objective of Table A1.1 was not only to list the Wadden Sea fish species, but also to serve as a basis for the selection of a limited number of species as candidates for monitoring within TMAP.

The first part of the table (in shades of yellow to red, named selection criteria) provides information on the ecology of the species, it's relevance to management and it's sensitivity to important driving forces. These parameters are important criteria for the selection of species for TMAP monitoring. The second part of the table (in shades of blue, named monitoring) presents the occurrence and abundance of each species in recent years (2001-2005 for the ongoing surveys and 2005-2006 for the SFIS) and the catchability of each species with different gears. These parameters indicate the feasibility of currently monitoring the species within the ongoing monitoring programs.

For each fish species a total score was calculated for the selection criteria and for the monitoring parameters separately. For this, each column received a weighting factor indicating the relative importance of each '+' within the column. These weighting factors were based on expert judgement and elaborate discussions within the TMAP ad hoc working group fish. Both scores (i.e. one for the selection criteria and one for the monitoring parameters) are a simple addition of each '+' multiplied by the weighting factor which is listed at the top of the table.

Table A1.1 has been sorted by scores, primarily the selection criteria scores and secondarily the monitoring result scores. Fourteen species have a high score (>2) for both selection criteria as well as monitoring results, these are the top 14 species in Table A1.1 and they are listed separately in Table A1.2. Four species have a high score (>2) for the selection criteria but a low score for the monitoring results, they are listed separately in Table A1.3.

Table A1.1: Wadden Sea fish fauna: All fish species caught in recent years in the Wadden Sea or in coastal waters bordering the Wadden Sea, and additional species not caught in recent years but considered relevant for the Wadden Sea.

| | | Selection criteria | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Ecology | | | Relevance for management | | | | Sensitivity to driving forces | | | | | |
| | | Ecological guilds [1] | Stratification [2] | Benthic habitat [3] | HD species [4] | WFD species for Eems [5] | Endangered or vulnerable [6] | Food for birds or mammals [7] | Climate change [8] | Nutrient enrichment [9] | Habitat degradation [10] | Fishing mortality (commercial species) [11] | Local pressures [12] | Score (maximum=11) [13] |
| | weight of each "+" | *n.a.* | *n.a.* | *n.a.* | *2* | *2* | *1* | *0.5* | *1* | *1* | *1* | *1* | *1* | |
| **Species caught in monitoring programmes in 2001-2005** | | | | | | | | | | | | | | |
| Pleuronectes platessa | Plaice | MJ | D | m-s | | + | | + | + | + | + | + | | **6.5** |
| Alosa fallax | Twaite shad | CA | P | | + | + | + | + | | | + | | | **6.5** |
| Clupea harengus | Herring | MJ | P | | | + | | ++ | + | | + | + | | **6** |
| Osmerus eperlanus | Smelt | CA | P | | | + | | ++ | | | + | + | | **5** |
| Solea vulgaris | Sole | MJ | D | m-s | | | | + | + | + | + | + | | **4.5** |
| Zoarces viviparus | Eelpout | ER | D | m-p | | + | | | | | + | | + | **4** |
| Platichthys flesus | Flounder | ER/CA | D | m-s | | + | | + | | | + | | | **3.5** |
| Limanda limanda | Dab | MJ | D | s | | | | + | | + | + | + | | **3.5** |
| Gadus morhua | Cod | MJ | D | | | | | + | + | | + | + | | **3.5** |
| Lampetra fluviatilis | River lamprey | CA | P | | + | | + | | | | | | | **3** |
| Ammodytes sp. | Sand eel | ER | DP | s | | | | ++ | | | + | + | | **3** |
| Sprattus sprattus | Sprat | MS | P | | | | | + | | | + | + | | **2.5** |
| Merlangius merlangus | Whiting | MJ | D | | | | | + | | | + | + | | **2.5** |
| Engraulis encrasicolus | Anchovy | MS | P | | | | + | + | + | | | | | **2.5** |
| Alosa alosa | Allis shad | CA | P | | + | | + | | | | + | | | **4** |
| Gymnocephalus cernuus | Ruffe | FW | D | | | + | | | | | + | | | **3** |
| Petromyzon marinus | Sea lamprey | CA | P | | + | | + | | | | | | | **3** |
| Myoxocephalus scorpius | Bull-rout | ER | D | m-p | | | | | | | + | | + | **2** |
| Liparis liparis | Sea-snail | ER | D | m-h | | | + | | | | + | | | **2** |
| Anguilla anguilla | Eel | CA | D | m-s | | | + | | | | | + | | **2** |
| Pholis gunnellus | Butterfish | ER | D | m-p | | | + | | | | + | | | **2** |
| Cyclopterus lumpus | Lumpsucker | MS | D | h-p | | | + | | | | + | | | **2** |
| Liparis montagui | Montaguis sea snail | ER | D | h | | | + | | | | + | | | **2** |
| Syngnathus acus | Greater pipefish | ER | D | s-p | | | + | | | | + | | | **2** |
| Echiichthys vipera | Lesser weever | MA | D | m-s | | | + | | | | + | | | **2** |
| Syngnathus rostellatus | Nilsson's pipefish | ER | D | s-p | | | | + | | | + | | | **1.5** |
| Pomatoschistus minutus | Sand goby | ER | D | s | | | | + | | | + | | | **1.5** |
| Pomatoschistus microps | Common goby | ER | D | s | | | | + | | | + | | | **1.5** |
| Trachurus trachurus | Horse mackerel | MA | P | | | | | + | | | | + | | **1.5** |
| Psetta maxima | Turbot | MJ | D | s-g | | | | + | | | | + | | **1.5** |
| Scophthalmus rhombus | Brill | MJ | D | s-g | | | | + | | | | + | | **1.5** |
| Belone belone | Garfish | MS | P | | | | | + | | | + | | | **1.5** |
| Hyperoplus lanceolatus | Greater sand-eel | MJ | DP | s | | | | + | | | + | | | **1.5** |
| Agonus cataphractus | Hooknose | ER/MS | D | m-s | | | | | | | + | | | **1** |
| Ciliata mustela | Five-bearded rockling | ER/MS | D | m-s | | | | | | | + | | | **1** |
| Eutrigla gurnardus | Grey gurnard | MS | D | m-s | | | + | | | | | | | **1** |
| Callionymus lyra | Dragonet | MA | D | m-s | | | | | | | + | | | **1** |
| Scomber scombrus | Mackerel | MA | P | | | | | | | | | + | | **1** |
| Gasterosteus aculeatus | Stickleback | CA | P | | | | | + | | | | | | **0.5** |
| Trigla lucerna | Tub gurnard | MJ | D | m-s | | | | | | | | | | **0** |
| Arnoglossus laterna | Scaldfish | MA | D | m-s | | | | | | | | | | **0** |
| Buglossidium luteum | Solenette | MA | D | m-s | | | | | | | | | | **0** |
| Trisopterus luscus | Bib | MJ | D | | | | | | | | | | | **0** |
| Salmo salar | Salmon | CA | P | | (+) | | + | | | | | + | | **2** |
| Mullus surmuletus | Striped red mullet | MA | D | s-h | | | | | + | | + | | | **2** |
| Atherina presbyter | Sand-smelt | MJ | P | | | | + | | | | + | | | **2** |
| Callionymus reticulatus | Reticulated dragonet | MA | D | m-s | | | + | | | | + | | | **2** |
| Stizostedion lucioperca | Pikeperch | FW | D | | | | | | | | + | + | | **2** |
| Dicentrarchus labrax | Bass | MJ | D | | | | + | | | | | + | | **2** |
| Perca fluviatilis | Perch | FW | D | | | | | | | | + | + | | **2** |
| Entelurus aequoraeus | Snake pipefish | ER | D | s-p | | | + | | | | | | | **1** |
| Microstomus kitt | Lemon sole | MA | D | s-g | | | | | | | | + | | **1** |
| Gaidropsarus vulgaris | Three-bearded rockling | MA | D | m-s | | | + | | | | | | | **1** |
| Callionymus maculatus | Spotted dragonet | MA | D | m-s | | | | | | | + | | | **1** |
| Galeorhinus galeus | Tope | MA | D | | | | + | | | | | | | **1** |
| Pollachius pollachius | Pollack | MA | D | | | | | | | | | + | | **1** |
| Nerophis ophidion | Straight-nosed pipefish | ER | D | | | | | | | | | | | **0** |
| Enchelyopus cimbrius | Four-bearded rockling | MA | D | m-s | | | | | | | | | | **0** |
| Trisopterus minutus | Poor cod | MA | D | | | | | | | | | | | **0** |
| **Other species relevant for the Wadden Sea** | | | | | | | | | | | | | | |
| Coregonus oxyrinchus | Houting | ER | P | | + | | + | | | | + | | | **4** |
| Chelon labrosus | Thick-lipped grey mullet | MA | P | | | | | | | | | | | **0** |
| Liza ramada | Thin-lipped grey mullet | MA | P | | | | | | | | | | | **0** |

Table A1.1: Continued

| | | Monitoring (14) | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Abundance (15) | | | | | | Occurrence (16) | | | | | | Catchability(17) | | | Score (maximum=12) (13) |
| | | NL: DFS outer area (beamtrawl, 2001-2005) | NL: DFS inner area (beamtrawl, 2001-2005) | DE: DYFS (beamtrawl, 2001-2005) | DE: SHS (stownet, 2001-2005) | DE: SFIS (stownet, 2005-2006) | NL: NIOZ (fyke, -) | NL: DFS outer area (beamtrawl, 2001-2005) | NL: DFS inner area (beamtrawl, 2001-2005) | DE: DYFS (beamtrawl, 2001-2005) | DE: SHS (stownet, 2001-2005) | DE: SFIS (stownet, 2005-2006) | NL: NIOZ (fyke, -) | Beamtrawl | Stownet | Fyke | |
| | *weight of each "+"* | *0.5* | *0.5* | *1* | *1* | *0* | *0* | *0.5* | *0.5* | *1* | *1* | *0* | *0* | *n.a.* | *n.a.* | *n.a.* | |
| **Species caught in monitoring programmes in 2001-2005** | | | | | | | | | | | | | | | | | |
| Pleuronectes platessa | Plaice | ++ | ++ | ++ | ++ | ++ | | ++ | ++ | + | ++ | + | | + | - | | **11** |
| Alosa fallax | Twaite shad | + | + | + | ++ | ++ | | - | - | - | ++ | + | | - | + | | **6** |
| Clupea harengus | Herring | ++ | ++ | ++ | ++ | ++ | | + | + | + | ++ | ++ | | - | + | | **10** |
| Osmerus eperlanus | Smelt | + | ++ | ++ | ++ | ++ | | + | + | + | ++ | ++ | | - | + | | **9.5** |
| Solea vulgaris | Sole | + | ++ | + | ++ | ++ | | + | + | + | + | ++ | | + | - | | **7.5** |
| Zoarces viviparus | Eelpout | + | + | + | + | + | | - | + | + | + | - | | + | - | | **5.5** |
| Platichthys flesus | Flounder | + | ++ | ++ | ++ | + | | + | + | + | ++ | + | | + | - | | **9.5** |
| Limanda limanda | Dab | ++ | ++ | ++ | + | + | | ++ | + | + | - | - | | + | - | | **7.5** |
| Gadus morhua | Cod | + | + | + | + | + | | + | + | + | + | + | | + | + | | **6** |
| Lampetra fluviatilis | River lamprey | + | + | + | + | + | | - | - | - | + | + | | - | + | | **4** |
| Ammodytes sp. | Sand eel | + | + | + | + | + | | + | + | - | - | + | | - | - | | **4** |
| Sprattus sprattus | Sprat | + | + | + | ++ | ++ | | + | + | + | ++ | ++ | | - | + | | **8** |
| Merlangius merlangus | Whiting | ++ | + | ++ | + | + | | + | + | + | + | + | | + | + | | **7.5** |
| Engraulis encrasicolus | Anchovy | - | - | + | + | + | | - | - | - | + | + | | - | + | | **3** |
| Alosa alosa | Allis shad | - | - | + | - | - | | - | - | - | - | - | | - | + | | **1** |
| Gymnocephalus cernuus | Ruffe | - | + | + | - | - | | - | - | - | - | - | | + | + | | **1.5** |
| Petromyzon marinus | Sea lamprey | + | - | - | - | + | | - | - | - | - | - | | - | + | | **0.5** |
| Myoxocephalus scorpius | Bull-rout | + | ++ | ++ | + | + | | + | + | + | + | - | | + | - | | **7.5** |
| Liparis liparis | Sea-snail | + | + | + | + | + | | + | + | + | - | + | | + | - | | **5** |
| Anguilla anguilla | Eel | + | + | + | + | + | | - | - | - | + | - | | - | - | | **4** |
| Pholis gunnellus | Butterfish | + | + | + | + | + | | - | + | - | - | + | | + | - | | **3.5** |
| Cyclopterus lumpus | Lumpsucker | + | - | + | + | + | | - | - | - | + | - | | + | - | | **3.5** |
| Liparis montagui | Montaguis sea snail | - | - | + | + | + | | - | - | - | + | + | | + | - | | **3** |
| Syngnathus acus | Greater pipefish | + | + | + | - | - | | + | - | - | - | - | | + | - | | **2.5** |
| Echiichthys vipera | Lesser weever | + | + | + | - | - | | + | - | - | - | - | | + | - | | **2.5** |
| Syngnathus rostellatus | Nilsson's pipefish | ++ | ++ | ++ | ++ | ++ | | + | + | + | ++ | ++ | | + | - | | **10** |
| Pomatoschistus minutus | Sand goby | ++ | ++ | ++ | ++ | ++ | | + | + | + | + | ++ | | + | - | | **9** |
| Pomatoschistus microps | Common goby | (18) | (18) | + | + | ++ | | (18) | (18) | - | - | ++ | | + | - | | **(18)** |
| Trachurus trachurus | Horse mackerel | + | + | + | ++ | ++ | | + | - | - | + | + | | - | + | | **5.5** |
| Psetta maxima | Turbot | + | + | + | + | + | | + | - | - | + | - | | + | - | | **4.5** |
| Scophthalmus rhombus | Brill | + | + | + | + | - | | - | - | - | + | - | | + | - | | **4** |
| Belone belone | Garfish | + | + | - | + | + | | - | - | - | + | + | | - | + | | **3** |
| Hyperoplus lanceolatus | Greater sand-eel | + | + | + | - | + | | + | - | - | - | + | | - | - | | **2.5** |
| Agonus cataphractus | Hooknose | ++ | + | ++ | + | + | | + | + | + | + | + | | + | - | | **7.5** |
| Ciliata mustela | Five-bearded rockling | + | ++ | + | + | + | | + | + | + | + | + | | + | - | | **6.5** |
| Eutrigla gurnardus | Grey gurnard | + | + | + | + | - | | - | - | - | + | - | | + | - | | **4** |
| Callionymus lyra | Dragonet | ++ | + | + | - | + | | + | - | + | - | - | | + | - | | **4** |
| Scomber scombrus | Mackerel | + | + | - | + | + | | - | - | - | + | - | | - | + | | **3** |
| Gasterosteus aculeatus | Stickleback | + | + | + | + | + | | - | - | - | + | - | | - | + | | **4** |
| Trigla lucerna | Tub gurnard | + | + | + | + | + | | + | - | - | + | - | | + | - | | **4.5** |
| Arnoglossus laterna | Scaldfish | ++ | + | + | - | - | | + | - | - | - | - | | + | - | | **3** |
| Buglossidium luteum | Solenette | ++ | + | + | - | + | | + | - | - | - | - | | + | - | | **3** |
| Trisopterus luscus | Bib | + | + | + | - | - | | - | + | - | - | - | | + | + | | **2.5** |
| Salmo salar | Salmon | - | - | - | + | - | | - | - | - | + | - | | - | + | | **2** |
| Mullus surmuletus | Striped red mullet | + | + | + | - | - | | - | - | - | - | - | | + | - | | **2** |
| Atherina presbyter | Sand-smelt | + | - | + | - | + | | - | - | - | - | - | | - | + | | **1.5** |
| Callionymus reticulatus | Reticulated dragonet | + | - | + | - | - | | - | - | - | - | - | | + | - | | **1.5** |
| Stizostedion lucioperca | Pikeperch | - | + | + | - | - | | - | - | - | - | - | | + | + | | **1.5** |
| Dicentrarchus labrax | Bass | + | + | - | - | - | | - | - | - | - | - | | - | + | | **1** |
| Perca fluviatilis | Perch | - | + | - | - | - | | - | - | - | - | - | | + | + | | **0.5** |
| Entelurus aequoraeus | Snake pipefish | + | + | + | - | + | | - | - | - | - | + | | + | - | | **2** |
| Microstomus kitt | Lemon sole | + | + | + | - | + | | - | - | - | - | - | | + | - | | **2** |
| Gaidropsarus vulgaris | Three-bearded rockling | + | - | + | - | - | | - | - | - | - | - | | + | - | | **1.5** |
| Callionymus maculatus | Spotted dragonet | - | - | + | - | - | | - | - | - | - | - | | + | - | | **1** |
| Galeorhinus galeus | Tope | + | - | - | - | - | | - | - | - | - | - | | + | + | | **0.5** |
| Pollachius pollachius | Pollack | - | + | - | - | - | | - | - | - | - | - | | + | + | | **0.5** |
| Nerophis ophidion | Straight-nosed pipefish | - | - | + | - | - | | - | - | - | - | - | | + | - | | **1** |
| Enchelyopus cimbrius | Four-bearded rockling | + | - | - | - | - | | + | - | - | - | - | | + | - | | **1** |
| Trisopterus minutus | Poor cod | + | + | - | - | - | | - | - | - | - | - | | + | + | | **1** |
| | | | | | | | | | | | | | | | | | |
| **Number of species** | | 48 | 45 | 49 | 34 | 38 | | 48 | 45 | 49 | 34 | 38 | | | | | |
| **Number of hauls** | | 295 | 582 | 1185 | 53 | 19 | | 295 | 582 | 1185 | 53 | 19 | | | | | |
| | | | | | | | | | | | | | | | | | |
| **Other species relevant for the Wadden Sea** | | | | | | | | | | | | | | | | | |
| Coregonus oxyrinchus | Houting | - | - | - | - | - | | - | - | - | - | - | | - | + | | **0** |
| Chelon labrosus | Thick-lipped grey mullet | - | - | - | - | - | + | - | - | - | - | - | | - | + | | **0** |
| Liza ramada | Thin-lipped grey mullet | - | - | - | - | - | + | - | - | - | - | - | | - | + | | **0** |

Table A1.1: Continued (footnotes)

**Footnotes**

| (1) Ecological guildes | (2) Stratification | (3) Benthic habitat |
|---|---|---|
| ER = estuarine resident | D = demersal | m = mud |
| MJ = marine juvenile | P = pelagic | s = sand |
| MS = marine seasonal migrant | DP = sand eels: pelagic or | g = gravel |
| MA = marine adventitious | buried in bottom | h = hard (rocks, musselbeds etc.) |
| CA = diadromous | | p = plants |
| FW = fresh water | | |

(4) Species included in the Habitats Directive - Annex 1 & 2. Fish species relevant for the Wadden Sea (species relevant for freshwater between brackets)

(5) Species abundance monitoring proposed in relation to the Water Framework Directive in transitional waters (all transistional waters except Eider)

(6) On any red list (Netherlands, Germany or Denmark)

(7) Critical food source as indentified by expert judgement of current group and by Heinis et al., 2005

(8) Publication(s) exist(s) indicating link between abundance/distribution of species and any climate change related factors

(9) Publication(s) exist(s) indicating link between abundance/distribution of species and nutrient enrichment or turbidity

(10) Publication(s) exist(s) indicating link between abundance/distribution of species and other sources of habitat degradation

(11) Species prone to direct fishing mortality (i.e. commercial species). Indirect mortality due to discarding or bottom-disturbance not included

(12) Species with a limited dispersal in all life stages, hence suitable indicators of small-scale changes and contaminations

(13) Score based on every "+" multiplied by weighting factor

(14) Ongoing monitorings programmes and an example of a shorter running survey (SFIS)

| **code = name** | **gear** | **institute** | **country** | **years** | **in table** |
|---|---|---|---|---|---|
| DFS = Demersal Fish Survey | beam trawl | Wageningen-IMARES (formerly known as RIVO) | The Netherlands | 1970- | 2001-2005 |
| DYFS = Demersal Young Fish Survey | beam trawl | Bundesforschunganstalt für Fischerei | Germany | 1974- | 2001-2005 |
| SHS = Schleswig-Holstein Survey | stownet | Marine Science Service | Germany | 1991- | 2001-2005 |
| SFIS = Seabird-Fish-Interactions Survey | stownet | Insitute of Avian Research | Germany | 2005-2007 | 2005-2006 |
| NIOZ = Fyke sampling 't Horntje | fyke | Royal Netherlands Institute for Sea Research | The Netherlands | 1960- | - |

(15) Abundance:
- ++ = top 10 in abundance
- \+ = present
- \- = absent

(16) Occurrence:
- ++ = present in 90-100% of the hauls
- \+ = present in 10-90% of the hauls
- \- = present in <10% of the hauls

(17) Suitability gear for quantitative abundance estimate

(18) Identifications unreliable, *P. microps* and *P. minutes* pooled

Table A1.2: Species with a high score (>2) on both selection criteria as well as monitoring results.

| **Species** | | **Ecological guild** | **Stratification** | **Benthic habitat** |
|---|---|---|---|---|
| Alosa fallax | Twaite shad | CA | P | - |
| Osmerus eperlanus | Smelt | CA | P | - |
| Lampetra fluviatilis | River lamprey | CA | P | - |
| Platichthys flesus | Flounder | ER | D | m-s |
| Zoarces viviparus | Eelpout | ER | D | m-p |
| Ammodytes sp. | Sand eel | ER | DP | s |
| Pleuronectes platessa | Plaice | MJ | D | m-s |
| Solea vulgaris | Sole | MJ | D | m-s |
| Limanda limanda | Dab | MJ | D | s |
| Gadus morhua | Cod | MJ | D | - |
| Merlangius merlangus | Whiting | MJ | D | - |
| Clupea harengus | Herring | MJ | P | - |
| Sprattus sprattus | Sprat | MS | P | - |
| Engraulis encrasicolus | Anchovy | MS | P | - |

Table A1.3: Species with a high score (>2) on selection criteria but a low score (<2) on monitoring results.

| **Species** | | **Ecological guild** | **Stratification** | **Benthic habitat** |
|---|---|---|---|---|
| Alosa alosa | Allis shad | CA | P | - |
| Petromyzon marinus | Sea lamprey | CA | P | - |
| Coregonus oxyrinchus | Houting | ER | P | - |
| Gymnocephalus cernuus | Ruffe | FW | D | - |

# Appendix 2 – Preliminary reference list Wadden Sea fish fauna

Author: Ralf Vorberg

Main tasks of the TMAP ad-hoc working group fish are the development of targets and assessment tools for trilateral Wadden Sea fish. A possible target could be "presence of a typical Wadden Sea fish fauna". As a provisional assessment tool a priority list of Wadden Sea fish species was defined, using data from the existing demersal and pelagic fish surveys. Another tool could be the defintion of a range for species composition and/or species abundances. For this purposes a comprehensive compilation of fish species occurring in the Wadden Sea turned out to be useful.

Information derived from running monitoring programmes as the 30-year data sets of the demersal (young) fish survey in the Netherlands and Germany and of the stow net fishery in Schleswig-Holstein and Lower Saxony. In addition species lists from the literature were used (Zijlstra et al., 1979; Fricke et al., 1994; Vorberg & Breckling, 1999).

The total number of North Sea fish species at the moment is 189 (Fröse & Pauly 2007). The compilation of Wadden Sea fish species yielded a total of 141 proofs, what means that about 75% of all North Sea fish species (can) occur in the Wadden Sea. With regard to a trilateral monitoring and assessment program only one half of all species is of practical importance: 53 species (37,6%) are common, 22 species (15,6%) are fairly common and 66 species (46,8%) have to be regarded as rare or even extremely rare in the Wadden Sea. The priority list created by the TMAP ad-hoc working group fish contains 55 species and similarity between these and common species is 93% (after Jaccard's similarity index). Thus, the priority list can be regarded as appropriate for further evaluating trilateral Wadden Sea fish species.

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| # | scientific name | english name | german name | dutch name | Witte & Zijlstra | DYFS | DFS | QSR 2004 | stow net S-H | stow net L-S | TMAP WG Fish | Atlas S-H | Red List Ger. | counts | occurrrence |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Abramis brama | Carp Bream | Brasse | Brasem | | x | | | | | | | | 1 | (e)r |
| 2 | Acipenser sturio | Sturgeon | Stör | Steur | x | | | | | | | | x | 2 | (e)r |
| 3 | Agonus cataphractus | Hook-nose | Steinpicker | Harnasmannetje | x | x | | x | x | x | x | x | x | 8 | c |
| 4 | Alopias vulpinus | Tresher | Fuchshai | Voshaai | x | | | | | | | | | 1 | (e)r |
| 5 | Alosa alosa | Allis Shad | Maifisch | Elft | x | | | x | x | x | x | | x | 6 | c |
| 6 | Alosa fallax | Twaite Shad | Finte | Fint | x | x | | x | x | x | x | x | x | 8 | c |
| 7 | Ammodytes tobianus | Sand Eel | Kleiner Sandaal | Zandspiering | x | x | | x | x | x | x | x | x | 8 | c |
| 8 | Anarhichas denticulatus | Northern Wolffish | Steinbeißer | | | | | | | | | | x | 1 | (e)r |
| 9 | Anguilla anguilla | Eel | Aal | Aal | x | x | | x | x | x | x | x | x | 8 | c |
| 10 | Aphia minuta | Transparent Goby | Glasgrundel | Glasgrondel | x | | | x | x | x | | x | x | 6 | c |
| 11 | Argyrosomus regius | Meagre | Umberfisch | Ombervis | | | | | | | | | x | 1 | (e)r |
| 12 | Arnoglossus laterna | Scaldfish | Lammzunge | Schurftvis | x | x | | x | | x | x | | x | 6 | c |
| 13 | Aspitrigla cuculus | Red Gurnard | Seekuckuck | Engelse Poon | x | | | | | | | | x | 2 | (e)r |
| 14 | Atherina presbyter | Sand-smelt | Ährenfisch | Koornaarvis | x | x | | x | x | x | x | x | x | 8 | c |
| 15 | Atherina boyeri | Big-scale Sand Smelt | Kleiner Ährenfisch | Kleine Koornaarvis | | | | | | | | | x | 1 | (e)r |
| 16 | Balistes carolinensis | Trigger-Fish | Grauer Drückerfisch | Trekkervis | x | | | | | | | | | 1 | (e)r |
| 17 | Belone belone | Garfish | Hornhecht | Geep | x | x | | x | x | x | x | x | x | 8 | c |
| 18 | Blicca bjoerkna | White Bream | Güster | Kolblei | | x | | | | | | | | 1 | (e)r |
| 19 | Boops boops | Bogue | Gelbstrieme | Bokvis | x | | | | | | | | x | 2 | (e)r |
| 20 | Brama brama | Ray's Bream | Brachsenmakrele | Braam | x | | | | | | | | x | 2 | (e)r |
| 21 | Buglossidium luteum | Solenette | Zwergzunge | Dwergtong | x | x | | x | | x | x | x | x | 7 | c |
| 22 | Galeus melastomus | Blackmouth Catshark | Fleckhai | Hondshaai | | | | | | | | | x | 1 | (e)r |
| 23 | Callionymus lyra | Dragonet | gestreifter Leierfisch | Pitvis | x | x | | x | x | x | x | x | x | 8 | c |
| 24 | Callionymus maculatus | Spotted Dragonet | gefleckter Leierfisch | | | x | | x | | | x | x | | 4 | fc |
| 25 | Callionymus reticulatus | Reticulated Dragonet | Ornament-Leierfisch | Rasterpitvis | x | x | | x | | | x | | | 4 | fc |
| 26 | Cetorhinus maximus | Basking Shark | Riesenhai | Reuzehaai | x | | | | | | | | | 1 | (e)r |
| 27 | Cheilopogon heterurus | Atlantic Flying-Fish | Fliegender Fisch | | | | | | | | | | x | 1 | (e)r |
| 28 | Chelon labrosus | Thick-lipped Mullet | Dicklippige Meeräsche | Diklippige Harder | x | x | | x | x | | x | x | x | 7 | c |
| 29 | Ciliata mustela | Five-bearded Rockling | Fünfbärtelige Seequappe | Vijfdradige Meun | x | x | | x | x | x | x | x | x | 8 | c |
| 30 | Clupea harengus | Herring | Hering | Haring | x | x | | x | x | x | x | x | x | 8 | c |
| 31 | Conger conger | Conger Eel | Meeraal | Zeepaling | x | | | | | | | | x | 2 | (e)r |
| 32 | Coregonus oxyrinchus | Houting | Nordseeschnäpel | Houting | x | | | x | | | x | x | x | 5 | fc |
| 33 | Crystallogobius linearis | Crystal Goby | Kristallgrundel | | | | | | | | | | x | 1 | (e)r |
| 34 | Ctenolabrus rupestris | Goldsinny | Klippenbarsch | Kliplipvis | x | | | | | | | | | 1 | (e)r |
| 35 | Cyclopterus lumpus | Lumpsucker | Seehase | Snotolf | x | x | | x | x | x | x | x | x | 8 | c |
| 36 | Cynoglossus browni | Nigerian tonguesole | Hundszunge | | | | | | | | | | x | 1 | (e)r |
| 37 | Dasyatis pastinaca | Common Stingray | Stechrochen | Pijlstaartrog | x | | | x | | | | | x | 3 | fc |
| 38 | Dentex maroccanus | Morocco Dentex | Marokkanische Zahnbrasse | | | | | | | | | | x | 1 | (e)r |
| 39 | Dicentrarchus labrax | Sea Bass | Wolfsbarsch | Zeebaars | x | x | | x | | x | x | | x | 6 | c |
| 40 | Echiichthys vipera | Lesser Weever | Kleines Petermännchen | Kleine Pieterman | x | x | | x | | x | x | | x | 6 | c |
| 41 | Enchelyopus cimbrius | Four-bearded Rockling | Vierbärtelige Seequappe | Vierdradige Meun | x | | | x | | | x | x | x | 5 | fc |
| 42 | Engraulis encrasicolus | Anchovy | Sardelle | Ansjovis | x | x | | x | x | x | x | x | x | 8 | c |
| 43 | Entelurus aequoreus | Snake Pipefish | Große Schlangennadel | Adderzeenaald | x | x | | | | x | x | x | x | 6 | c |
| 44 | Eutrigla gurnadus | Grey Gurnard | Grauer Knurrhahn | Grauwe Poon | x | x | | x | x | x | x | x | x | 8 | c |
| 45 | Gadus morhua | Cod | Kabeljau | Kabeljauw | x | x | | x | x | x | x | x | x | 8 | c |
| 46 | Gaidropsarus mediterranaeus | Shore Rockling | Mittelmeer-Seequappe | | | | | | | | | x | | 1 | (e)r |
| 47 | Gaidropsarus vulgaris | Three-bearded Rockling | Dreibärtelige Seequappe | Driedradige Meun | x | x | | x | x | | x | | x | 6 | c |
| 48 | Galeorhinus galeus | Tope Shark | Hundshai | Ruwehaai | x | | | | x | | x | x | x | 5 | fc |
| 49 | Gasterosteus aculeatus | Stickleback | Dreistacheliger Stichling | Driedoornige Stekelbaars | x | x | | x | x | x | x | x | x | 8 | c |
| 50 | Glyptocephalus cynoglossus | Witch | Hundszunge | Hondstong | | x | | | | | | x | x | 3 | fc |
| 51 | Gobiusculus flavescens | Two-spotted Goby | Schnappgrundel | | | | | | | | | | x | 1 | (e)r |
| 52 | Gymnocephalus cernuus | Ruffe | Kaulbarsch | Pos | | x | | | | | x | | | 2 | (e)r |
| 53 | Hexanchus griseus | Bluntnose Sixgill Shark | Grauhai | Stompsnuitzeskieuwshaai | | | | | | | | | x | 1 | (e)r |
| 54 | Hippocampus hippocampus | Sea-Horse | Seepferdchen | Zeepaardje | x | | | | | | | | | 1 | (e)r |
| 55 | Hippoglossoides platessoides | American Plaice | Doggerscharbe | Lange Schar | | x | | | | x | | | x | 3 | fc |
| 56 | Hyperoplus lanceolatus | Greater Sand Eel | Großer Sandaal | Groote Zandaal | x | x | | x | x | x | x | x | x | 8 | c |
| 57 | Labrus bergylta | Balan Wrasse | Gefleckter Lippfisch | Gevlekte Lipvis | x | | | | | | | | | 1 | (e)r |
| 58 | Lamna nasus | Porbeagle | Heringshai | Neushaai | x | | | | | | | | | 1 | (e)r |
| 59 | Lampetra fluviatilis | River Lamprey | Flußneunauge | Rivierprik | x | x | | x | x | x | x | x | x | 8 | c |
| 60 | Limanda limanda | Dab | Kliesche | Schar | x | x | | x | x | x | x | x | x | 8 | c |
| 61 | Liparis liparis | Sea Snail | Großer Scheibenbauch | Slakdolf | x | x | | x | x | x | x | x | x | 8 | c |
| 62 | Liparis montagui | Montagu's Sea Snail | Kleiner Scheibenbauch | Montagu's Ringbug | | x | | x | x | x | x | x | x | 7 | c |
| 63 | Lipophrys pholis | Shanny | Schan | Slijmvis | x | | | | | | | | x | 2 | (e)r |
| 64 | Liza aurata | Golden Grey Mullet | Goldmeeräsche | Goudharder | x | | | | | | | | x | 2 | (e)r |
| 65 | Liza ramada | Thin-lipped Grey Mullet | Dünnlippige Meeräsche | Dunlippige Harder | x | | | x | | | x | | x | 4 | fc |
| 66 | Lophius piscatorius | Angler | Seeteufel | Zeeduivel | x | | | | | | | | | 1 | (e)r |
| 67 | Maurolicus muelleri | Pearlsides | Lachshering | Lichtend Sprotje | x | | | | | | | x | x | 3 | fc |
| 68 | Melanogrammus aeglefinus | Haddock | Schellfisch | Schelvis | x | | | | | | | | x | 2 | (e)r |
| 69 | Merlangius merlangus | Whiting | Wittling | Wijting | x | x | | x | x | x | x | x | x | 8 | c |
| 70 | Merluccius merluccius | European Hake | Seehecht | Stokvis | x | x | | | | | | | x | 3 | fc |
| 71 | Micrenophrys lilljeborgi | Norway Bullhead | Zwergseeskorpion | | | | | x | | | | | | 1 | (e)r |
| 72 | Micromesistius poutassou | Blue Whiting | Blauer Wittling | Blauwe Wijting | x | | | x | x | | | | x | 4 | fc |
| 73 | Microstomus kitt | Lemon Sole | Limande, Rotzunge | Tongschar | x | x | | x | x | x | x | x | x | 8 | c |
| 74 | Mola mola | Sunfish | Mondfisch | Maanvis | x | | | | | | | | x | 2 | (e)r |
| 75 | Molva molva | Ling | Leng | Leng | | | | | | | | x | | 1 | (e)r |
| 76 | Mullus barbatus | Red Mullet | Rote Meerbarbe | | | | | | | | | | x | 1 | (e)r |
| 77 | Mullus surmelutus | Surmullet | Streifenbarbe | Mul | x | x | | x | x | x | x | x | x | 8 | c |
| 78 | Mustelus mustelus | Smooth Hound | Glatthai | Gladde Haai | x | | | | | | | | | 1 | (e)r |
| 79 | Myoxocephalus scorpius | Bull Rout | Seeskorpion | Zeeonderpad | x | x | | x | x | x | x | x | x | 8 | c |
| 80 | Nerophis lumbriciformis | Worm Pipefish | Krummschnauzige Schlangennadel | | | | | | | | | | x | 1 | (e)r |
| 81 | Nerophis ophidion | Straightnose Pipefish | Kleine Schlangennadel | | | | | | | | x | | | 1 | (e)r |
| 82 | Osmerus eperlanus | Smelt | Stint | Spiering | x | x | | x | x | x | x | x | x | 8 | c |
| 83 | Pagellus acarne | Axillary Seabream | Achselfleckbrasse | Spaanse Zeebrasem | | | | | | | | | x | 1 | (e)r |
| 84 | Pagellus bogaraveo | Blackspotted Seabream | Graubarsch | Zeebrasem | | | | | | | | | x | 1 | (e)r |
| 85 | Pagellus erythrinus | Common Pandora | Rotbrasse | Zeebrasem | | | | | | | | | x | 1 | (e)r |
| 86 | Parablennius gattorugine | Tompot Blenny | Gestreifter Schleimfisch | Gehoornde Slijmvis | x | | | | | | | | x | 2 | (e)r |
| 87 | Perca fluviatilis | European Perch | Flussbarsch | Baars | | | | | | | x | | | 1 | (e)r |
| 88 | Petromyzon marinus | Sea Lamprey | Meerneunauge | Zeeprik | x | | | x | | x | x | x | x | 6 | c |
| 89 | Pholis gunellus | Butterfish | Butterfisch | Botervis | x | x | | x | | x | x | x | x | 7 | c |
| 90 | Phrynorhombus norvegicus | Norwegian topknot | Norwegischer Zwergbutt | Dwergtarbot | | | | | | | | | x | 1 | (e)r |
| 91 | Platichthys flesus | Flounder | Flunder | Bot | x | x | | x | x | x | x | x | x | 8 | c |
| 92 | Pleuronectes platessa | Plaice | Scholle | Schol | x | x | | x | x | x | x | x | x | 8 | c |
| 93 | Pollachius pollachius | Pollack | Pollack | Pollak | x | | | x | | | x | | x | 4 | fc |
| 94 | Pollachius virens | Saithe | Seelachs | Koolvis | x | x | | x | | | | x | x | 5 | fc |
| 95 | Pomatoschistus lozanoi | Lozano's Goby | Lozanos Grundel | Lozanos Grondel | x | | | | | | | | x | 2 | (e)r |
| 96 | Pomatoschistus microps | Common Goby | Strandgrundel | Brakwatergrondel | x | x | | x | x | x | x | x | x | 8 | c |
| 97 | Pomatoschistus minutus | Sand Goby | Sandgrundel | Dikkopje | x | x | | x | x | | x | x | x | 7 | c |
| 98 | Pomatoschistus pictus | Painted Goby | Fleckengrundel | Kleurige Grondel | x | | | | | | | x | | 2 | (e)r |
| 99 | Psetta maxima | Turbot | Steinbutt | Tarbot | x | x | | x | x | x | x | x | x | 8 | c |
| 100 | Pterycombus brama | Atlantic Fanfish | Silberbrassen | | | | | | | | | | x | 1 | (e)r |
| 101 | Pungitius pungitius | Ninespine Stickleback | Zwergstichling | Tiendoornige stekelbaars | | x | | | | x | | x | x | 4 | fc |
| 102 | Raja clavata | Thornback | Nagelrochen | Stekelrog | x | | | | | | | | x | 2 | (e)r |
| 103 | Raniceps raninus | Tadpole-Fish | Froschdorsch | Vorskwab | x | | | | | x | | | | 2 | (e)r |
| 104 | Remora remora | Common Remora | Ansauger | | | | | | | | | | x | 1 | (e)r |
| 105 | Salmo salar | Salmon | Lachs | Zalm | x | x | | x | x | | | x | x | 6 | c |
| 106 | Salmo trutta | Sea Trout | Meerforelle | Zeeforel | x | x | | x | x | | | x | x | 6 | c |
| 107 | Sardina pilchardus | Sardine | Sardine | Sardien | x | x | | x | | x | | x | x | 6 | c |
| 108 | Scomber japonicus | Chub Mackerel | Mittelmeermakrele | Spaanse Makreel | | | | | | | | | x | 1 | (e)r |
| 109 | Scomber scombrus | Mackerel | Atlantische E3Makrele | Makreel | x | x | | x | x | x | x | x | x | 8 | c |
| 110 | Scomberesox saurus | Skipper | Makrelenhecht | Makreelgeep | x | | | | | | | | | 1 | (e)r |
| 111 | Scophthalmus rhombus | Brill | Glattbutt | Griet | x | x | | x | x | x | x | x | x | 8 | c |
| 112 | Scyliorhinus caniculus | Lesser spotted Dogfish | Kleingefleckter Katzenhai | Hondshaai | x | | | | | | | | x | 2 | (e)r |
| 113 | Scyliorhinus stellaris | Greater spotted Dogfish | Großgefleckter Katzenhai | Kathaai | | | | | | | | | x | 1 | (e)r |
| 114 | Scymnodon obscurus | Smallmouth Velvet Dogfish | Kleinmaulsamthai | Fluweelijshaai | | | | | | | x | | | 1 | (e)r |
| 115 | Sebastes marinus | Redfish | Rotbarsch | Noorse Schelvis | x | | | | | | | | | 1 | (e)r |
| 116 | Serranus cabrilla | Comber | Sägebarsch | | | | | | | | | | x | 1 | (e)r |
| 117 | Solea solea | Sole | Seezunge | Tong | x | x | | x | x | x | x | x | x | 8 | c |
| 118 | Spinachia spinachia | Sea Stickleback | Seestichling | Zeestekelbaars | x | x | | x | | | | x | x | 5 | fc |
| 119 | Spodyliosoma cantharus | Black Sea Bream | Streifenbrasse | Zeekarper | x | | | | | | | | | 1 | (e)r |
| 120 | Sprattus sprattus | Sprat | Sprotte | Sprot | x | x | | x | x | x | x | x | x | 8 | c |
| 121 | Squalus acanthias | Spur-Dog | Dornhai | Doornhaai | x | | | | | | | | | 1 | (e)r |
| 122 | Squatina squatina | Monkfish | Meerengel | Zeeengel | x | | | | | | | | x | 2 | (e)r |
| 123 | Stizostedion lucioperca | Pike Perch | Zander | Snoekbaars | | x | | | | | x | | x | 3 | fc |
| 124 | Symphodus melops | Corkwing | Goldmaid | Zwaartooglipvis | x | | | | | | | | | 1 | (e)r |
| 125 | Syngnathus acus | Great Pipefish | Große Seenadel | Grote Zeenaald | x | | | x | x | x | x | x | x | 7 | c |
| 126 | Syngnathus rostellatus | Nilsson's Pipefish | Kleine Seenadel | Kleine Zeenaald | x | x | | x | x | x | x | x | x | 8 | c |
| 127 | Syngnathus typhle | Deep-snouted Pipefish | Grasnadel | Trompetterzeenaald | x | | | | | x | | | x | 3 | fc |
| 128 | Taractes asper | Rough pomfret | Kleine Brachsenmakrele | | | | | | | | | | x | 1 | (e)r |
| 129 | Taractichthys longipinnis | Bigscale Pomfret | Langflossen-Brachsenmakrele | | | | | | | | | | x | 1 | (e)r |
| 130 | Taurulus bubalis | Long-spined Sea Scorpion | Seebull | Groene Zeeonderpad | x | | | | | x | | x | x | 4 | fc |
| 131 | Trachinotus ovatus | Derbio | Gabelmakrele | | | | | | | | | | x | 1 | (e)r |
| 132 | Trachinus draco | Greater Weaver | Petermännchen | Grote Pieterman | x | x | | | | | | | x | 3 | fc |
| 133 | Trachurus trachurus | Horse Mackerel | Stöcker | Horsmakreel | x | x | | x | x | x | x | x | x | 8 | c |
| 134 | Trigla lucerna | Tub Gurnard | Roter Knurrhahn | Rode Poon | x | x | | x | x | x | x | x | x | 8 | c |
| 135 | Trisopterus esmarki | Norway Pout | Stintdorsch | Kever | | x | | | | | | x | x | 3 | fc |
| 136 | Trisopterus luscus | Bib | Franzosendorsch | Steenbolk | x | x | | x | x | | x | x | x | 7 | c |
| 137 | Trisopterus minutus | Poor Cod | Zwergdorsch | Dwergbolk | x | x | | | | | x | x | x | 5 | fc |
| 138 | Xiphias gladius | Sword-Fish | Schwertfisch | Zwaardvis | x | | | | | | | | | 1 | (e)r |
| 139 | Zeugopterus punctatus | Topknot | Haarbutt | Gevlekte Griet | x | | | | | | | | x | 2 | (e)r |
| 140 | Zeus faber | Dory | Heringskönig | Zonnevis | x | | | | | | | | | 1 | (e)r |
| 141 | Zoarces viviparus | Eelpout | Aalmutter | Puitaal | x | x | | x | x | x | x | x | x | 8 | c |
| | | | | | 101 | 64 | 0 | 63 | 47 | 52 | 62 | 63 | 112 | | |

# Appendix 3 – Fishing pressure by the German shrimp fishery

Author: Thomas Neudecker

The fishing pressure in the Wadden Sea has changed over the last fifty years. While in Germany a great number of smaller boats were active just after the Second World War (approx. 850) the number decreased rapidly during the following years (Table A3.1). Since the nineties the number of shrimpers has not much changed due to the restricted number of licenses. While fishing effort per boat in fishing hours and also fishing power has drastically increased, the area fished remained more or less in the same order of magnitude (Neudecker, 1999) (Table A3.2).

Detailed information on the number of fishing days or even more precise effort data is not available until 1999. Only fishing trips were recorded but mostly “shrimp trips” were mixed with “fish trips” until 1994. Since in 2000 the EU log book system became compulsory much better data are available giving fishing hours by boat and ICES area (Figure A2.1).

Table A3.1: Some metrics on the German shrimping fleet

| Years | 1952-58 | 1966 | 1976 | 1986 | 1996 |
|---|---|---|---|---|---|
| Shrimp cutters | ca. 630 | 407 | 305 | 270 | 247 |
| Engine power Per cutter (hp) | 53 | 82 | 147 | 183 | 227 |
| Boat length (m) | 11,5 | 13,5 | 15,5 | 15,9 | 16,4 |
| Beam length (2x)(m) | 12 | - no | data | available - | 17,1 |

Table A3.2: Figures used for estimating fishing effort in German shrimp fisheries in 1954 and 1996.

| Years of comparison (1954 estimated according to different sources) | 1954 | 1996 |
|---|---|---|
| Number of vessels | 630 | 247 |
| Fishing days (1954 as 1996) | 137 | 137 |
| Mean duration of tows [ p.d. in h ] | 7 | 12,15 |
| Aggregated beam length [ m ] | 12 | 17,1 |
| Mean towing speed [ kn ] | 2,5 | 2,7 |
| Total towed area [ $km^2$ ] | 33 500 | 35 000 |
| Towed area by boat [ $km^2$ ] | 52,3 | 141,7 |

ICES rectangles are wide compared to the Wadden Sea and do not reflect the spatial fishing situation in an appropriate manner (Figure A2.2). From fishermen’s reports, however, it is known, that in earlier days of the shrimp fishing the boats have hardly left the Wadden Sea proper. Fishing took place in the shallower parts behind the chain of islands and sands, especially in the so called gullies. With the development of larger and technically more sophisticated shrimp boats more distant fishing grounds also in front of the islands were visited and longer trips became possible. That development occurred in the late sixties and seventies and has continued until present days as the remaining smaller boats are sold and are sometimes replaced by new and larger vessels with the latest technical equipment.

The ownership also shows changes. In former days the boats were entirely property of local fishermen. Now also companies own sometimes several vessels with hired staff on board. These developments in combination with economic pressures have also changed the traditional seasonal fishing pattern. While there used to be a three months lasting winter period without any fishing which is still valid for many of the vessels, many of the shrimpers have extended their activity into the winter period as they can meanwhile fish also under fairly windy conditions off shore.

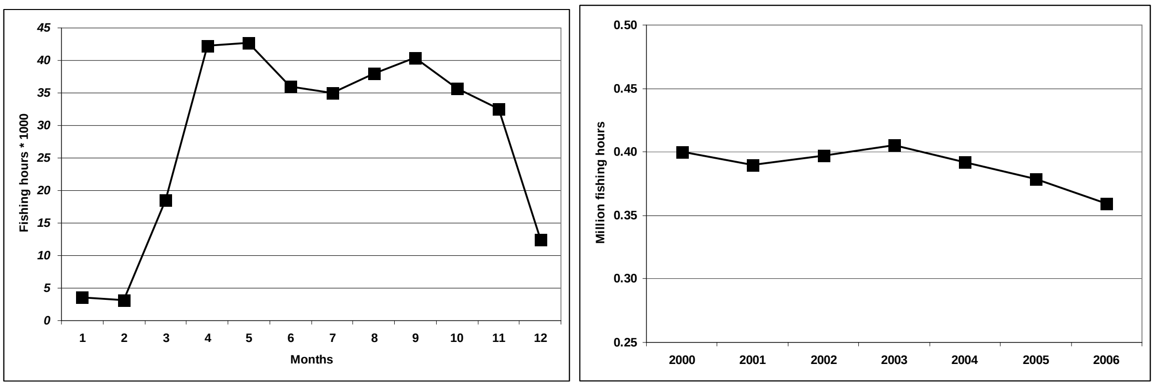
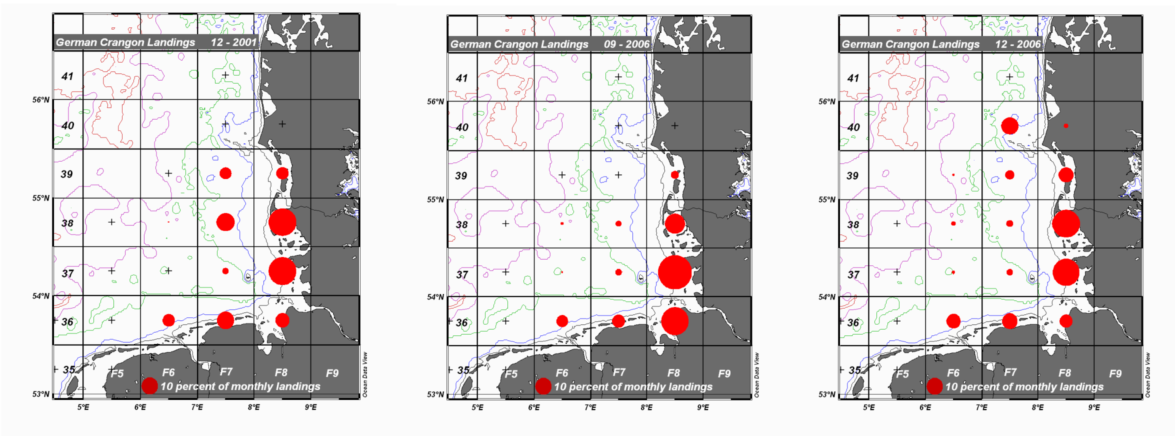



Figure A2.1: Left: Mean monthly fishing hours of German shrimp fleet (2000 - 2006). Right: Annual fishing hours of German shrimp fleet (2000 - 2006)

One of the most recent observations is that grounds further off shore at depths of about 30 metres and further north, off the Danish coasts are fished during winter and spring time, while the grounds nearer to the coast remain the preferred areas during summer and autumn, still the main fishing season. That development is illustrated by log book data presented in Figure A2.2:




| | | |
|---|---|---|
| A: Percent landings in December 2001 | B: Percent landings in September 2006 | C: Percent landings in December 2006 |

Figure A2.2: Comparison of log book data of fishing areas of the German fleet by ICES rectangle: Winter situation 2001 and 2006 showing the northern directed shift of fishing activity (A and C) and the seasonal shift from summer to winter activity in 2006 (B and C).

### ***References***


Neudecker, Th. (1999). Die Entwicklung des Aufwandes in der deutschen Garnelenfischerei Inf.Fischwirtsch. Fischereiforschung 46 (4) 9 – 13.

# Appendix 4 – Review on indicator studies in marine ecosystems

Author: Harriët van Overzee

Fish communities are continually exposed to anthropogenic influences and variations in natural conditions. The characteristics of fish communities are described by indicators. Different indicators are used when analysing the structure of a fish community, as information is collected at different levels. Variations in these indicators over time imply that changes have taken place in the fish community. These changes are relative as there is no absolute reference point.

This literature study reviews indicator studies carried out for marine ecosystems and identifies and discusses indicators that may be used to describe the fish community in the Wadden Sea. As the Wadden Sea is an extension of the North Sea, it is conceivable that the indicators used to describe the fish community in the North Sea may also be applied to the fish community in the Wadden Sea. On the other hand, the geographical connection / vicinity does not automatically mean that the conditions are the same in both regions. It is therefore also useful to look at the specific characteristics of the Wadden Sea.

## 1. Indicators for species composition of fish communities

Various studies have described the species composition of fish communities. The indicators are: (i) the number of rare species (Dulvy *et al.*, 2006); (ii) life history characteristics; (iii) biodiversity (Perry *et al.*, 2006; Greenstreet & Rogers, 2006; Piet & Jennings, 2005; Greenstreet & Hall, 1996; Rice & Gislason, 1996); (iv) trophic structure (Greenstreet & Rogers, 2006; Piet & Jennings, 2005; Nicholson & Jennings, 2004; Jennings *et al.*, 2002); (v) ecological guilds (Breine *et al.*, 2007; Elliot & Hemmingway, 2002). The species composition may be influenced by both anthropogenic influences and variations in natural conditions.

***Index of rare species***

Dulvy *et al.* (2006) developed a threat indicator based on the population status of 23 different North Sea fish from 1982 to 2001. This indicator responds to changes in the proportion of threatened species in a fish community. The percentage in decline of a species through time was linked to the vulnerability of the species using the World Conservation Union Red List A1 criteria (IUCN, 2004). The species could be classified as no threat = 0, vulnerable = 1 (≥50% decline), endangered = 2 (≥70% decline) and critically endangered = 3 (≥90% decline). From the late 1990s and onwards all the species met the vulnerable criterion and hence were all threatened.

Daan (2000) used the number of rare species to detect changes in the fish community in the North Sea. and found that the number of rare species – mostly, warm water species – was increasing. This may be attributable to a rise in the water temperature (van Densen & de Boois, 2000). The ratio between Boreal species (typical North Sea species) and Lusitanian species (southerly species, starting from the English Channel) may therefore serve as an indicator of the species composition of the fish community on the basis of one factor.
Variations in indicators describing rare species may illustrate changes that are occurring in a fish community which perhaps cannot be derived from analyses of the dominant part of the community (ICES WGECO, 2007). These indicators may therefore be useful in determining whether changes have occurred in the species composition.

***Life history characteristics***

Life history characteristics refer to the life cycle of an organism and can therefore vary between species. Depending on their life history characteristics, the species are sensitive to changes in the environment to different extents. Life history characteristics are therefore used as indicators to describe changes that may have occurred in the species composition.

A trade-off between different characteristics enables an organism to survive optimally in a specific environment; for example, K-strategists are slow-growing, late-maturing, long-living organisms that live in stable environments, while r-strategists are fast-growing, early-maturing, short-living organisms that live in variable environments. K-strategists and r-strategists stand at opposite ends of the spectrum. All species within the community lie somewhere between the two. Increased fishing mortality is expected to give r-strategists an advantage. Life-history characteristics are therefore often used as indicators of fish communities that have been exposed to fishing.

Age and length at maturity are life-history characteristics that have been used as indicators (Perry *et al.*, 2006; Greenstreet & Rogers, 2006) in studies to detect changes in the fish community of the North Sea. Values of age and length at maturity can be determined by observation either from survey data or from the literature (Jennings *et al.*, 1999). The number of individuals with the characteristic values can be determined and the mean value for each characteristic can be calculated. Fluctuations in these indicators through time suggest that changes are occurring in the species composition of the community. The life-history theory predicts that increased mortality at a certain age and size at maturation selects for earlier maturation. These indicators are therefore used to determine whether fishing has inflicted changes in the life-history characteristics of the fish community.

The mean maximum length of a fish community has been used as a life-history indicator in several studies (Perry *et al.*, 2006; Greenstreet & Rogers, 2006; Piet & Jennings, 2005; Nicholson & Jennings, 2004) to detect whether changes have occurred within the species composition of the North Sea. This is calculated as follows:

$$\overline{L_{max}} = \frac{\sum_{j} \left( L_{max\,j} N_j \right)}{N}$$

in which $L_{maxj}$ is the maximum length that can be reached by species j, $N_j$ is the total number of individuals of species j and N is the total number of individuals. The $L_{max}$ determined from the von Bertalanffy growth equation calculated for each species can be derived from the literature (e.g. Jennings *et al.*, 2002; Jennings *et al.*, 1999) whereas the other parameters can be derived from survey measurements. Because fishing inflicts additional mortality, this will bring about changes in the mean maximum length of a fish community. It is therefore not surprising that this indicator is often used to describe changes that fishing inflicts on a fish community. However, Perry *et al.* (2006) also used this indicator to demonstrate that an increase in water temperature coincided with a northwards shift of species with low maximum length in the North Sea.

The life-history characteristic, growth rate, has also been used (Greenstreet & Rogers, 2006) as an indicator of the species composition of the North Sea fish community. By using the growth rate of each species derived from the von Bertalanffy growth equation, Greenstreet & Rogers (2006) determined the mean growth rate for the entire fish community. Changes in this indicator through time showed that changes had occurred in the fish community. Both environmental and anthropogenic changes may give species with faster growth rates a selective advantage.

***Biodiversity***

Diversity indicators are also used frequently in studies of the North Sea (Greenstreet & Rogers, 2006; Piet & Jennings, 2005; Rice & Gislason, 1996). They provide information on the composition of the community. Biodiversity is a joint construct of species richness and species evenness: the actual number of species in a given area and the distribution of the individuals among the species. A higher number of species as well as a more even distribution among the species points towards higher biodiversity. As species richness or species evenness on its own cannot fully describe the diversity of a community, a combination of the two is used when describing diversity.

Several indicators are therefore used when describing the diversity of a fish community. The most common indicators used to describe diversity in the North Sea fish community over the entire range from species richness to species evenness are Hills $N_0$, $N_1$ and $N_2$ (Greenstreet & Rogers, 2006; Piet & Jennings 2005).
Hills $N_0$ is an indicator of species richness: it is a simple count of the number of species in the community. Hills $N_1$ is an indicator of species diversity: effectively the number of abundant species. Hills $N_2$ is also an indicator of species diversity: effectively the number of very abundant species (Indeco, 2006). These indices describe

biodiversity with numbers of species which are derived from samplings of the community. However, it should be noted that these indicators are sensitive to sampling size. Rogers *et al.* (1998) showed that the number of species that are recorded within an area depends on the intensity of the sampling within the area. A greater effort is required to catch the infrequent species.

Variations in natural conditions and anthropogenic activities may both affect the biodiversity of a fish community, but as the mechanism is not understood it is impossible as yet to link these changes to either of these causes. As diversity is a complex indicator that cannot be easily measured (Greenstreet & Piet, manuscript) it is questionable whether it can be used as an indicator of the species composition of any fish community, let alone the Wadden Sea

***Trophic structure***

Larger individuals generally, though not always, eat at higher trophic levels. This means that changes in the species composition of a fish community can be linked to changes in the trophic structure of that community. The mean trophic level of a community has been used in different studies (Greenstreet & Rogers, 2006; Piet & Jennings, 2005; Nicholson & Jennings, 2004; Jennings *et al.*, 2002) as an indicator of the composition of the fish community in the North Sea. This can be calculated as:

$$\overline{TL} = \sum (TL_{ij} W_{ij}) \Big/ \sum W_{ij}$$

in which $TL_{ij}$ and $W_{ij}$ are the trophic level and body mass respectively of species i with length class j. The trophic levels of individuals of different length classes determined by nitrogen-stable isotope analysis can be derived from the literature (Jennings *et al.*, 2002), but large area to area and year to year variations occur. Weight can be derived from survey measurements. This indicator is a measure of the complexity of the food web. A decrease in complexity might cause the system to be less resilient to environmental and/or man-induced changes. So far, the results of the different studies have been contradictory. However, more knowledge about the food web is needed to fully understand possible changes in the mean trophic level of the fish community. Different studies on the North Sea fish community (Greenstreet & Rogers, 2006; Piet & Jennings, 2005; Jennings *et al.*, 2002) have shown that this indicator for species composition did not show interpretable patterns. The mean trophic level is therefore probably not a useful indicator of species composition.

***Ecological guilds***

Guilds refer to species that are grouped according to similarities in their characteristics. Guilds are also used as indicators (Breine *et al.*, 2007). Fish use the Wadden Sea for different purposes. They may therefore be divided into groups that are classified according to the usefulness of the Wadden Sea for the fish. Zijlstra (1978) split the fish species in the Wadden Sea into different groups. The (near-)residents who are tolerant of the dynamic environment live their whole life in the Wadden Sea. The diadromous species, which include seasonal visitors who only come into the area when its conditions are suitable and species that only use the Wadden Sea as passageway. The third group consists of the marine juveniles of various North Sea fish species that use the Wadden Sea as a nursery area. Elliot & Hemmingway (2002) use the numbers of species in such groups as ecological guilds of fishes in estuaries. The number of species in an ecological guild may therefore be used as an indicator for describing the fish community of the Wadden Sea.

# 2. Indicators for size composition of fish communities

Various indicators can be used to describe the size composition of a fish community. These are: (i) slope of the size spectra, (ii) mean length, (iii) mean weight, (iv) the proportion of large fish (Rice & Gislason, 1996; Nicholson & Jennings, 2004; Piet & Jennings, 2005; Daan *et al.*, 2005; Greenstreet & Rogers, 2006). As fishing inflicts size-selective mortality, this may be come to light in a decline in size-based indicators. However, changing environmental conditions may also affect the growth and recruitment of fish species and hence lead to changes in the size composition. As these two factors are inseparable it is more or less impossible to determine how much each contributes to the changes in the indicators (Shin *et al.*, 2005).

### *Slope of the size spectra*

Size spectra analyses are used to demonstrate that the community shows a log-linear decrease in biomass or in the number of individuals with increasing size. The general formula is:

$\ln(y) = a*\ln(x) + b$

in which y is the biomass or number of individuals, x the size, a the slope and b the intercept. Both the slope and the intercept of this relationship are used as indicators in studies on changes in the size composition of the fish community in the North Sea (Rice & Gislason, 1996; Piet & Jennings, 2005; Daan *et al.*, 2005). The slope is a measure of the decline in numbers in relation to increasing length. The intercept is a measure of the numbers of small fish that have entered the community (recruits). This relationship can be derived from survey data. Depending on the fishing gear and the tow speed of the vessel, certain size classes may be underrepresented in the survey. In these analyses it is therefore necessary to decide on the lower and upper limits of the spectrum. Changes in the slope and intercept through time indicate a change in the size composition of the fish community.

### *Mean length*

The mean length and mean weight of the North Sea fish community are also used as indicators of the size composition (Greenstreet & Rogers, 2006; Piet & Jennings, 2005; Nicholson & Jennings, 2004). These are calculated as follows:

$$\overline{L} = \sum L/N$$

$$\overline{W} = \sum W/N$$

in which L and W represent the length and weight respectively of each individual and N is the total number of individuals. A change in these indicators in the course of time suggests that a change has occurred in the size composition. Obviously, a community comprising mostly small individuals will have a lower mean length and weight than a community comprising mostly large individuals. These indicators are therefore sensitive to recruitment events.

### *The proportion of large fish*

The proportion of large fish is also used as an indicator of the size composition of the North Sea fish community (Greenstreet & Rogers, 2006). Greenstreet & Rogers (2006) chose the percentage of fish larger than 30 centimetres as indicator. They used this arbitrary standard because 95 percent of the recorded fish community were shorter than 30 centimetres. A shift in this percentage would imply a change in size composition. ICES WGECO (2007) have redefined this indicator to the percentage of fish larger than 40 centimetres as this seems to reduce the variation (ICES, WGECO, 2007). This size-based indicator is used as an Ecological Quality objective (EcoQo) for fish communities in the North Sea. If this indicator is used for the Wadden Sea, analytical procedures are needed to identify the appropriate length threshold (ICES WGECO, 2007).

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