Assessing the status of Wadden Sea fish

Jager, Z. info@ziltwater.eu, L.J. Bolle, A. Dänhardt, B. Diederichs, G. Lüerßen, H. Marencic, T. Neudecker, J. Scholle, R. Vorberg

Abstract

Although the Wadden Sea is considered as a coastal water under the Water Framework Directive (WFD), which does not consider fish as a biological quality element, the TMAP ad hoc fish group was inspired by the approach that was chosen for the development of a fish index for the implementation of the (WFD) in transitional waters. The WFD fish index combines and assesses a number of metrics: selected variables of the fish community that together are considered to give a good reflection of the status of the fish (species composition and abundance) in the specific water body. The present state is compared to 'undisturbed' conditions, while the underlying assumption is that the metrics are in some way related to anthropogenic pressures on the water system.

The feasibility of this approach for the Wadden Sea fish fauna was evaluated. The lack of (quantitative) historic data makes it impossible to describe, or compare to, a pristine situation which can be used to define targets. The complexity of the Wadden Sea ecosystem and the lack of fundamental scientific knowledge make it extremely difficult to identify driving forces behind the observed changes in the fish fauna. Changes in the Wadden Sea fish fauna (where "more" is not necessarily "better") can be caused by human pressures, but also by natural variability. They can be a result of local processes (occurring within the Wadden Sea) or of large scale processes (occurring in the connected marine or freshwater systems). Furthermore, it is difficult to disentangle direct effects and indirect effects caused by inter-specific interactions.

Nevertheless, the TMAP fish group tried to develop targets and an assessment tool for trilateral Wadden Sea fish. First, a basic reference list was compiled describing the fish species that (can) occur in the Wadden Sea. To help select priority fish species, different selection criteria were considered. These were grouped into criteria on ecology, relevance for management, and sensitivity to driving forces. In addition, monitoring aspects counted as well. A selection of 14 priority species, scoring high on both types of selection criteria as well as monitoring results, was further considered in a joint data analysis of the Demersal Fish Survey (DFS; Wageningen IMARES, The Netherlands), the Demersal Young Fish Survey (DYFS; von Thünen Institut, Germany) and the Schleswig-Holstein Survey (SHS; National Park Agency and Marine Science Service, Germany).

The analyses were carried out on the level of QSR subregions, inside the Wadden Sea proper, thus providing a high spatial resolution. Trends in species richness, species composition and mean abundance of priority species since 1970 were determined, thus providing a good temporal coverage. The observed values are compared to the long term average, to identify relevant changes in indicator species and metrics and relate those, if possible, to causal factors. The (im)possibility of defining targets for Wadden Sea fish is illustrated by the results of this joint analysis.

1. Introduction

The shallow coastal waters of the Wadden Sea and its tributary estuaries support reproduction, maturing and feeding of fish and they serve as an acclimation area and transit route for long-distance migrants from sea to their spawning grounds located in fresh water (*e.g.* Haedrich, 1982; Kerstan, 1991; Elliott and Dewailly, 1995; Elliott and Hemingway, 2002; Elliott *et al.*, 2007). The estuaries, with their pronounced salinity gradient due to the mixing of riverine and marine waters, constitute a habitat of a very particular nature within the Wadden Sea. The Wadden Sea ecosystem is also connected with and influenced by the North Sea: marine juvenile and marine seasonal species form an important constituent of the Wadden Sea fish fauna.

Intermingled with the anthropogenic pressures (Lozán *et al.*, 1994; Schuchardt *et al.*, 1999; 2007; Essink *et al.*, 2005), natural variability plays a very important role. These pressures are reflected in the aquatic biotic communities and in the fish fauna in particular. Recently, an increasing number of publications point to the relationship between the North Atlantic Oscillation (NAO) and fish populations (Attrill and Power 2002, Henderson and Seaby 2005) or the effects of increasing water temperatures on fish (Henderson and Seaby 1994, Genner *et al.*, 2003, Pörtner and Knust 2007, Van Keeken *et al.*, 2007).

Despite the recognised importance of fish as an element of the Wadden Sea ecosystem (Vorberg *et al.*, 2005), fish was not considered in the Trilateral

Wadden Sea Plan (1997). In the mean time, the need to include fish in the Wadden Sea Plan and the TMAP has grown because the Water Framework Directive (WFD, 2000/60/EC) recognizes fish as a biological quality element for transitional waters (estuaries) and selected fish species are listed in the Habitats Directive (HD, 92/43/EEC). In addition, characteristic fish species should be used to assess the status of the relevant habitat types described in the HD (e.g. H1110 submerged sandbanks[1], H1130 estuaries, H1140 sand- and mudflats). Furthermore, some fish species serve as main food item for birds or seals that are listed under the Bird and Habitats Directive for the Wadden Sea. Recently, the Marine Strategy Framework Directive (2008/56/EC) has been adopted and is now being implemented. In this Directive, fish again are one of the qualitative descriptors of good environmental status.

Because the TMAP common package (TMAG, 1997) does not include fish monitoring, one is dependent on information that is provided by fish monitoring for other purposes (fish stock assessment for ICES) or (European) obligations. Following the requirements of the EU Water Framework Directive, new fish monitoring was initiated in 2006 in all Wadden Sea estuaries (the 'transitional waters' of the Ems, Weser, Elbe and Eider). In contrast to transitional waters, fish is not considered as a WFD biological quality element for coastal waters such as the Wadden Sea.

Proposed Fish targets for the Wadden Sea

As one of its tasks in supporting the TMAP revision process, the TMAP ad hoc fish expert group (established March 2006) formulated (preliminary) trilateral targets for fish as follows:

- Presence of a typical Wadden Sea fish fauna
- Occurrence and abundance of fish species according to the natural dynamics in (a)biotic conditions

In addition to these general targets of a typical Wadden Sea fish fauna, conditional sub-targets can be formulated for the different ecological guilds:

- Unhindered migration between the sea and upstream and/or inland waters [for diadromous fish].
- Viable stocks [populations] and a natural reproduction of typical fish species
- Diversity of habitats (subtidal areas and tidal flats, including areas with seagrass and mussel beds), to provide shelter and food for juvenile fish [nursery function] and substratum for spawning [for estuarine resident species and marine seasonal species]
- Suitable physical, chemical and morphological conditions with the underlying dynamic processes typical for tidal areas [for resident species and marine seasonal species].

Beside the fish targets and sub-targets, the topic of trophic integrity should be addressed in the Wadden Sea Plan Targets. Fish is an important food resource for birds and marine mammals. To sustain populations of the latter the following target is proposed:

- A natural fish fauna, providing food for sustainable populations of fish-eating birds and marine mammals.

To Denmark, the houting (*Coregonus oxyrinchus*) is a very important target species.

2. Methods

2.1 Overview of fish monitoring data available to TMAP

An overview of ongoing long-term fish monitoring programs of the different countries in the trilateral Wadden Sea area was reported (TMAP 2006). The most extensive and long-running are the Demersal Fish Survey (DFS, Wageningen IMARES) and the Demersal Young Fish and Brown Shrimp Survey (DYFS, von Thünen Institut). The survey methods are described in Boddeke *et al.,* (1970), Boddeke *et al.* (19729, Neudecker (2001) and ICES (2006a). Pelagic monitoring with a stow net has been carried out in the Schleswig-Holstein Wadden Sea (Schleswig-Holstein Stow net survey (SHS), National Park Agency and Marine Science Service) since 1991 (Meldorf Bight) or 2001 (Hörnum Deep) (Vorberg, 2001). The Seabird-Fish interaction survey is not a regular monitoring program but was undertaken for specific research goals (Dänhardt and Becker, 2008). The results of the NIOZ fyke net monitoring (since 1960 in the western Wadden Sea) were not available for analysis; results have been published in Van der Meer *et al.* (1995) and Philippart *et al.* (1996). The WFD monitoring data were not suitable for trend analyses, because this monitoring was only initiated in 2006.

2.1 Towards a Fish assessment tool

To assess the status of fish in the Wadden Sea, a joint data analysis was carried out, based on the

1 For H1110A in the Netherlands, recently the following fish species have been listed as qualitative indicators (LNV Profieldocument H1110, version of September 2008): *Clupea harengus*, *Liparis liparis*, *Myoxocephalus scorpius*, *Pholis gunnellus*, *Platichthys flesus*, *Pleuronectes platessa*, *Pomatoschistus minutus*, *Syngnathus acus*, *Zoarces viviparus*.

Species	Name	Ecological guild	Stratification
Alosa fallax	Twaite shad	CA	Pelagic
Osmerus eperlanus	Smelt	CA	Pelagic
Lampetra fluviatilis	River lamprey	CA	Pelagic
Platichthys flesus	Flounder	ER	Demersal
Zoarces viviparus	Eelpout	ER	Demersal
Ammodytes sp.	Sand eel	ER	Pelagic and Buried
Pleuronectes platessa	Plaice	MJ	Demersal
Solea solea	Sole	MJ	Demersal
Limanda limanda	Dab	MJ	Demersal
Gadus morhua	Cod	MJ	Demersal
Merlangius merlangus	Whiting	MJ	Demersal
Clupea harengus	Herring	MJ	Pelagic
Sprattus sprattus	Sprat	MS	Pelagic
Engraulis encrasicolus	Anchovy	MS	Pelagic

Table 1: Priority species to be included in the spatial and temporal trend analyses, ordered by ecological guild (CA=diadromous, ER=estuarine resident, MJ=marine juvenile, MS=marine seasonal). After Bolle *et al.*, 2007.

WFD-approach. For a better understanding, the WFD assessment procedure is described briefly. The developed WFD estuarine fish index combines a number of fish metrics which together give a good reflection of the status of the fish in the specific water body; the underlying assumption is that the metrics are in some way related to anthropogenic pressures acting on the water system (details in Jager and Kranenbarg 2004, Bioconsult 2006a, 2007a, Scholle *et al., in prep.*, Scholle and Schuchardt *in prep.*, Kranenbarg and Jager 2008). The WFD fish metrics for transitional water bodies (estuaries) consist of species composition indices, based on the number of species in certain ecological guilds, and abundance indices of key species. These are compared with a reference situation. The assessment tool aggregates the metrics scores of the index to calculate the status of the water body, based on the available monitoring data.

2.2 Reference list of Wadden Sea fish species

As a starting point for the development and evaluation of trilateral targets for Wadden Sea fish, a basic reference list was compiled describing the fish species that (can) occur in the Wadden Sea (Annex I). Information was derived from the running monitoring programs, such as the >35-year data sets of the demersal (young) fish survey in The Netherlands and Germany and of the stow net surveys in Schleswig-Holstein, Lower Saxony and from the River Elbe. In addition, species lists from the literature were used (Witte and Zijlstra, 1979; Fricke *et al.*,, 1994; Vorberg and Breckling, 1999). Altogether the list spans several decades.

2.3 Selection of Priority Species

The objectives of (TMAP) fish monitoring are to assess the status and the development of relevant or characteristic fish species in the Wadden Sea. In practice it is impossible to do this for all the fish species potentially occurring in this area. To help select the priority fish species, various selection criteria were applied (TMAP, 2006). They were grouped into criteria on ecology (ecological guild, habitat preference), relevance for management (HD-species or species belonging to the characteristic fish fauna of HD habitat types, WFD-species, endangered or vulnerable species, food for birds or marine mammals) and sensitivity to driving forces (climate change, nutrient enrichment, habitat degradation, fishing mortality and local pressures). In addition, monitoring criteria were considered (abundance, occurrence and catchability in the ongoing monitoring programs). Applying these criteria resulted in an exhaustive table, indicating the scores of different fish species according to the criteria mentioned above. A selection of 14 'priority species', scoring high on these selection criteria (Table 1), was further considered in a joint data analysis (Bolle *et al.*, 2007, 2009).

The allis shad (*Alosa alosa*), sea lamprey (*Petromyzon marinus*), houting (*Coregonus oxyrinchus*) and ruffe (*Gymnocephalus cernuus*) scored high on ecological and management relevance but are not covered by the current monitoring methods and programs. Despite their relevance, they could not be taken further into the analyses.

2.4 Joint analysis of survey data

A joint analysis of the German DYFS and the Dutch DFS was made possible because the methods had previously been harmonized in the ICES working group on beam trawl surveys (see for example ICES, 2006a). The demersal survey data have been analysed by QSR sub-area (Figure 1), which allows comparison of trends in abundance of species between different parts of the trilateral

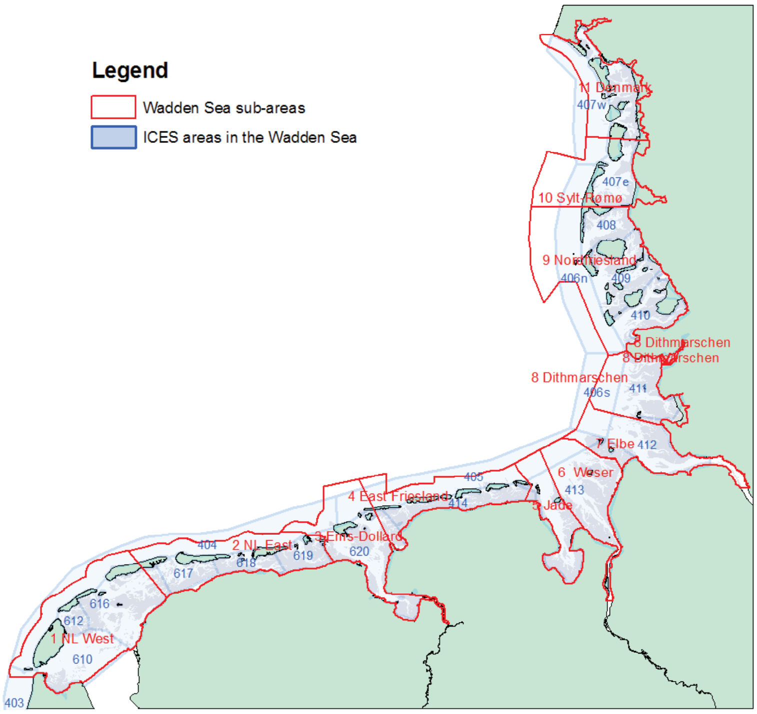


Figure 1: Map of the Wadden Sea sub-areas or QSR areas (as defined within the context of Quality Status Report), and the ICES areas or D(Y)FS areas (as defined in the original DFS/DYFS survey design). 1. Western Dutch Wadden Sea, 2. Eastern Dutch Wadden Sea, 3. Ems-Dollard, 4. East Frisia, 5. Jade, 6. Weser, 7. Elbe, 8. Dithmarschen, 9. North Frisia, 10. Sylt-Rømø, 11. Denmark. Areas 5, 6, 10 and 11 were excluded from (part of) the joint analyses due to insufficient data.

Wadden Sea. In addition, the SHS was involved in the joint analysis as far as the data allowed it. Full descriptions of the methodology and the outcome of the joint analysis are presented in Bolle *et al.* (2009), whereas selected results are presented in the Wadden Sea Quality Status Report 2009.

2.5 Selection of fish metrics in the joint analysis

The TMAP ad hoc fish expert group evaluated whether the WFD fish index could also be implemented for the entire Wadden Sea, taking into account differences in fish populations and environmental pressures as well as the difficulty in defining reference conditions for the entire Wadden Sea area.

The following fish metrics were included in the Wadden Sea analyses (Bolle *et al.*, 2009):

Species richness

Species richness was defined as the total number of species observed in a region in a year. 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 (Bolle *et al.*, 2009).

Species composition

Species composition was defined as the total number of species per ecological guild, calculated for each year and region. The ecological guilds considered most relevant for the Wadden Sea are: CA (diadromous), MJ (marine juvenile) and ER (estuarine resident) (Elliott and Hemingway 2002). The term ER indicates the species that spend the majority of their lifespan in the Wadden Sea; whether or not the species also occurs (abundantly) outside the Wadden Sea is irrelevant. The other categories (excluding freshwater species) were combined in one group.

Mean abundance

The catch rates per haul were standardized to numbers per 1000 m^2 (D(Y)FS beam trawl) or to numbers per 1,000,000 m^3 (SHS stow net). These abundance estimates were then averaged by year and region. For the beam trawl surveys, a weighted mean was calculated in which the abundance estimates were weighed by the surface area of the depth strata (for further details see Bolle *et al.*, 2009).

Trends in abundance

For the DFS and DYFS, trends in mean abundance were analysed using TrendSpotter, which is an analytical method based on structural time-series models in combination with a Kalman filter (Visser, 2004). Full details of this analysis are described in Bolle *et al.* (2009). TrendSpotter was used to model the trend between 1970/1974 - 2006 and to assess the significance of a positive or negative trend.

Mean length

Length (mean, median, maximum) is commonly used as an indicator in marine ecosystems (see literature review in Appendix 4 of Bolle *et al.*, 2007). A shift in mean length indicates a change in the (sub-)population structure. The mean length was calculated as the Σ(N*length)/ΣN, in which N is number of fish; for further details see Bolle *et al.* (2009).

3. Results

3.1 Fish species in the Wadden Sea

The Wadden Sea fish fauna consists of 150 species, including 13 freshwater species (Annex 1). Of the 150 Wadden Sea species, 50 (33,6%) are common, 26 (17,3%) are fairly common, but 74 (49,7%) have to be considered as rare or even extremely rare in the Wadden Sea. Of the 76 (fairly) common Wadden Sea fish species, 9 were diadromous, 15 estuarine resident, 12 marine juvenile, 9 marine seasonal and 28 marine adventitious, plus 3 fresh water species (*cf.* Elliott and Hemingway, 2002). New species in the Wadden Sea are the black goby *Gobius niger* (H. Asmus, pers. comm.) and the exotic Atlantic croaker *Micropogonias undulatus* which turned up in the Weser in 2004 (Bioconsult, unpubl.).

3.2 Species richness and species composition

A major drawback of the parameter 'species richness' is its dependence on the number of hauls. Figure 2 clearly illustrates that the number of species encountered in the Dutch DFS increases with the number of hauls (per year and region). In principle, the number of species will increase asymptotically with the number of samples. This relationship (partly) explains the differences in species richness between western and eastern Dutch Wadden Sea and Ems-Dollard.

The species richness as determined by the analysis of the DFS and DYFS ranged between 11 and 33 species per year over the period (October) 1970-2007 (Figure 3). Overall there appears to be no clear temporal trend, neither in species richness, nor in species composition in terms of ecological guilds. The number of estuarine resident species is remarkably stable, especially in the western and eastern Dutch Wadden Sea. Not much variation is observed in the number of marine juvenile species either. Most of the variation in species richness is caused by the number of diadromous species or marine seasonal/ marine adventitious species. The number of species in the SHS survey ranged between 18-29 (Meldorf Bight 1991-2008, sub-area 8 - Dithmarschen) or 22-27 (Hörnum Deep 2001-2008, sub-area 9 - North Frisia) (Figure 4.).

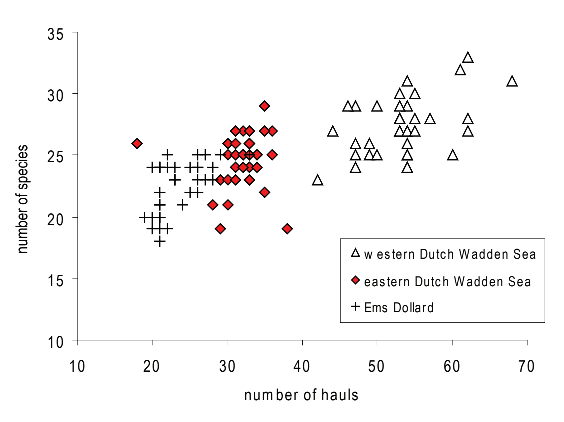


Figure 2: Number of species per year and region in relation to the no. of hauls per year and region (Bolle *et al.*, 2009).

3.3 Trends in abundance of selected Wadden Sea fish species ("priority species")

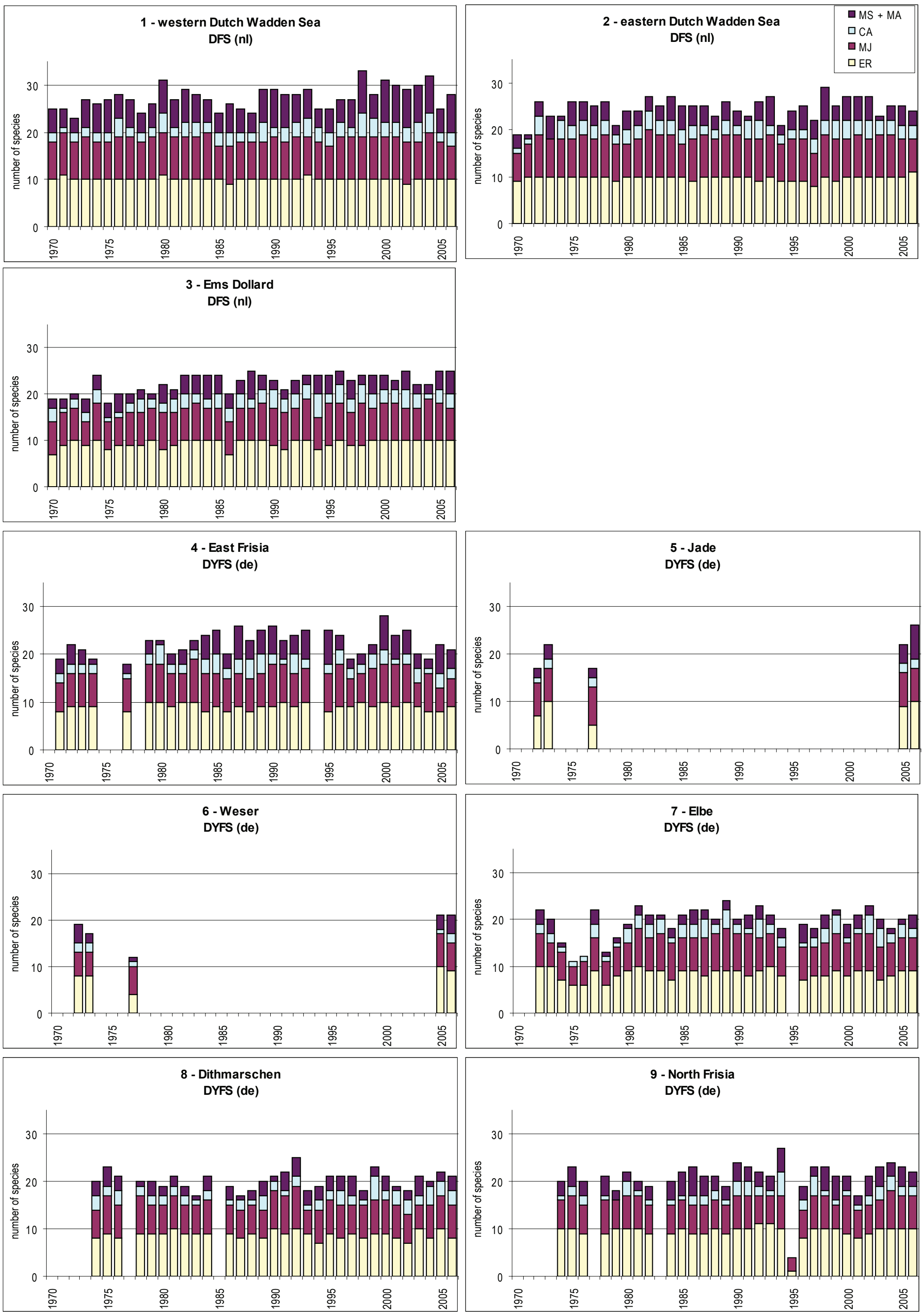
The selected results of the beam trawl surveys (DFS, DYFS) presented here are based on the joint analysis that is described and reported in full detail in Bolle *et al.* (2009).

The trends in abundance of 'priority species' are summarised in Table 2 (like Table 1 ordered by ecological guild). The observed trends differ between species and regions. Overall, more downward than upward trends are observed. A pattern that emerges in several species and regions is an increase in abundance in the 1970s, followed by a decrease during the 1980s or 1990s. During the period covered, an overall increase was shown in the smelt, flounder, herring and sprat. An overall decrease was found in eelpout, plaice, sole, dab, cod and whiting. No significant trends were observed in twaite shad and sandeel. Sometimes the trends were only significant during a few years, or more pronounced in one sub-area or period than in another (Table 2).

3.4 Mean length of fish in the Wadden Sea

The mean length of the plaice population in the western Wadden Sea decreased from approximately 13 cm during the 1970s to about 9 cm in the last decade. The mean length of sole, in contrast, did not show a significant trend, but fluctuated around a long-term average of 10 cm (Figure 5; Bolle *et al.*, 2009). Nevertheless, the abundance of sole in the Wadden Sea decreased significantly, but this apparently involved all length-classes.

Figure 3: Number of species per year and ecological guild for each region and survey (based on DFSandDYFS; Bolle *et al.*, 2009). DYFS data prior to 1996 are still subject to (ongoing) quality control. ER=estuarine resident, MJ=marine juvenile, CA=catadromous/anadromous, MS/MA=marine seasonal and marine adventitious guild.



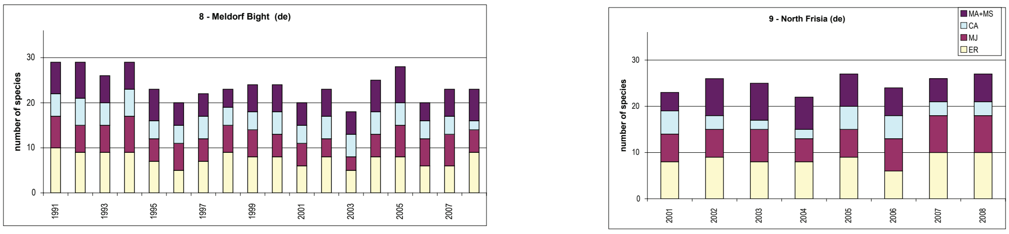


Figure 4: Number of fish species in all catches in August per year and ecological guilds, derived from the Schleswig-Holstein stow net monitoring in the Meldorf Bight (left panel) and Hörnum Deep (right panel). Source: SHS.

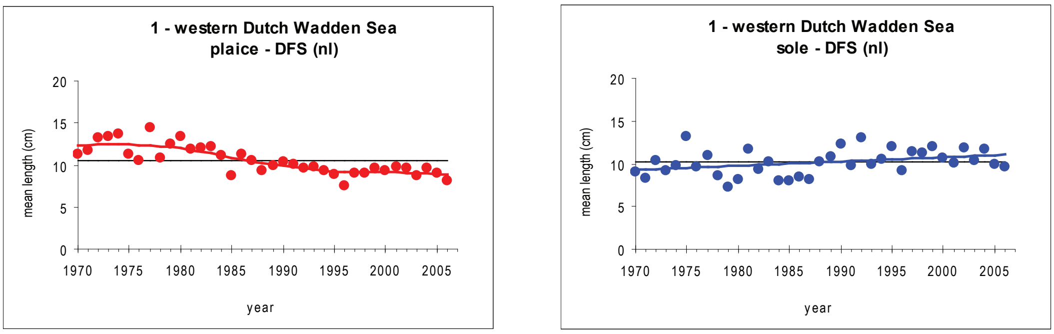


Figure 5: Mean length of plaice (left panel) and sole (right panel) in the western Dutch Wadden Sea. Source: DFS (Bolle *et al.*, 2009).

4. Discussion

4.1 Presence of a typical Wadden Sea fish fauna

To decide if a typical Wadden Sea fish fauna is present (assessing the first target, mentioned in the introduction), the species caught in the fish surveys are compared with the reference species list (Annex I). In the demersal surveys, 11-33 species were observed, which number could be increased with max. 6 to account for the taxonomic grouping. This is at least 14-43% of the amount of (fairly) common species on the reference species list within one year and sub-area. The number of species in the SHS (18-29 in the Meldorf Bight, 22-27 in Hörnum Deep) was max. 38% of the (fairly) common species. These numbers should not be taken too literally since an increased monitoring intensity would result in higher species numbers, because of the positive correlation between the number of hauls and the number of species. Likewise, the aggregation of regions and years would result in higher species numbers. Species richness and composition (number of species per ecological guild) was fairly constant over the observed time-span, at a more or less constant monitoring effort.

4.2 The status of Wadden Sea fish

The broad decrease in fish abundance and biomass in the Wadden Sea since the 1980s, as evidenced by the present results and also described by Tulp *et al.* (2008), seems to be confirmed by data from the western Wadden Sea long-term fyke monitoring by the NIOZ (Van der Veer, unpublished data).

Twaite shad showed a remarkable decline in the Schleswig-Holstein area since 2007, after previous years of higher abundance. Although the Weser and Elbe still sustain twaite shad populations (Bioconsult, 2005; Gerkens and Thiel, 2001), it is questionable whether the species can reproduce successfully in the Ems estuary: the numbers of adults are low, and twaite shad recruitment is very variable (Bioconsult, 2006b). Bottlenecks are found in the upstream parts of the Ems estuary, where unfavourable conditions during summer (oxygen deficits and fluid mud) hamper successful reproduction. This situation also affects the smelt (Scholle *et al.*, 2007b), but the abundance of smelt in the demersal fish surveys does not (yet) indicate significantly declining trends.

Sandeel is not adequately covered in the D(Y)FS, SHS surveys or the WFD monitoring because it lives in a pelagic manner during daytime and then buries itself in the bottom during night. Despite its importance as a food item for sea mammals and birds, which are protected under the Bird and Habitats Directive, no reliable information on the abundance of sandeel in the Wadden Sea area is available.

Herring and sprat are pelagic species, and like the species mentioned above they are not sampled well by the demersal surveys. The initial increase in herring abundance during the 1970s reflects a period of recovery of the collapsed North Sea herring populations after the closure of the fishery

Table 2: Summary of trends in abundance of priority fish species by Wadden Sea sub-area, determined by TrendSpotter analysis of the DFSandDYFS (Bolle *et al.*, 2009). The period in which the trend was significant is indicated. Grey colour means that there was no sampling. Green indicates a significant increasing trend, red a significant decreasing trend in fish abundance of a species. Explanation of the area codes: 1. Western Dutch Wadden Sea, 2. Eastern Dutch Wadden Sea, 3. Ems-Dollard, 4. East Frisia, 7. Elbe, 8. Dithmarschen, 9. North Frisia. * potential data errors, see text.

Twaite shad	1970	1975	1980	1985	1990	1995	2000	2005	overall description
area 1									no significant trend
area 2									no trend
area 3									no trend
area 4									no significant trend
area 7									no significant trend
area 8									no significant trend
area 9									no significant trend

Smelt	1970	1975	1980	1985	1990	1995	2000	2005	overall description
area 1									increase>decrease *
area 2									no significant trend
area 3									increase>decrease *
area 4									no significant trend
area 7									increase>decrease
area 8									increase
area 9									increase

Flounder	1970	1975	1980	1985	1990	1995	2000	2005	overall description
area 1									no trend
area 2									no trend
area 3									increase
area 4									no significant trend
area 7									increase
area 8									increase
area 9									no significant trend

Eelpout	1970	1975	1980	1985	1990	1995	2000	2005	overall description
area 1									decrease
area 2									increase<decrease
area 3									increase<decrease
area 4									increase<decrease
area 7									no significant trend
area 8									increase<decrease
area 9									decrease

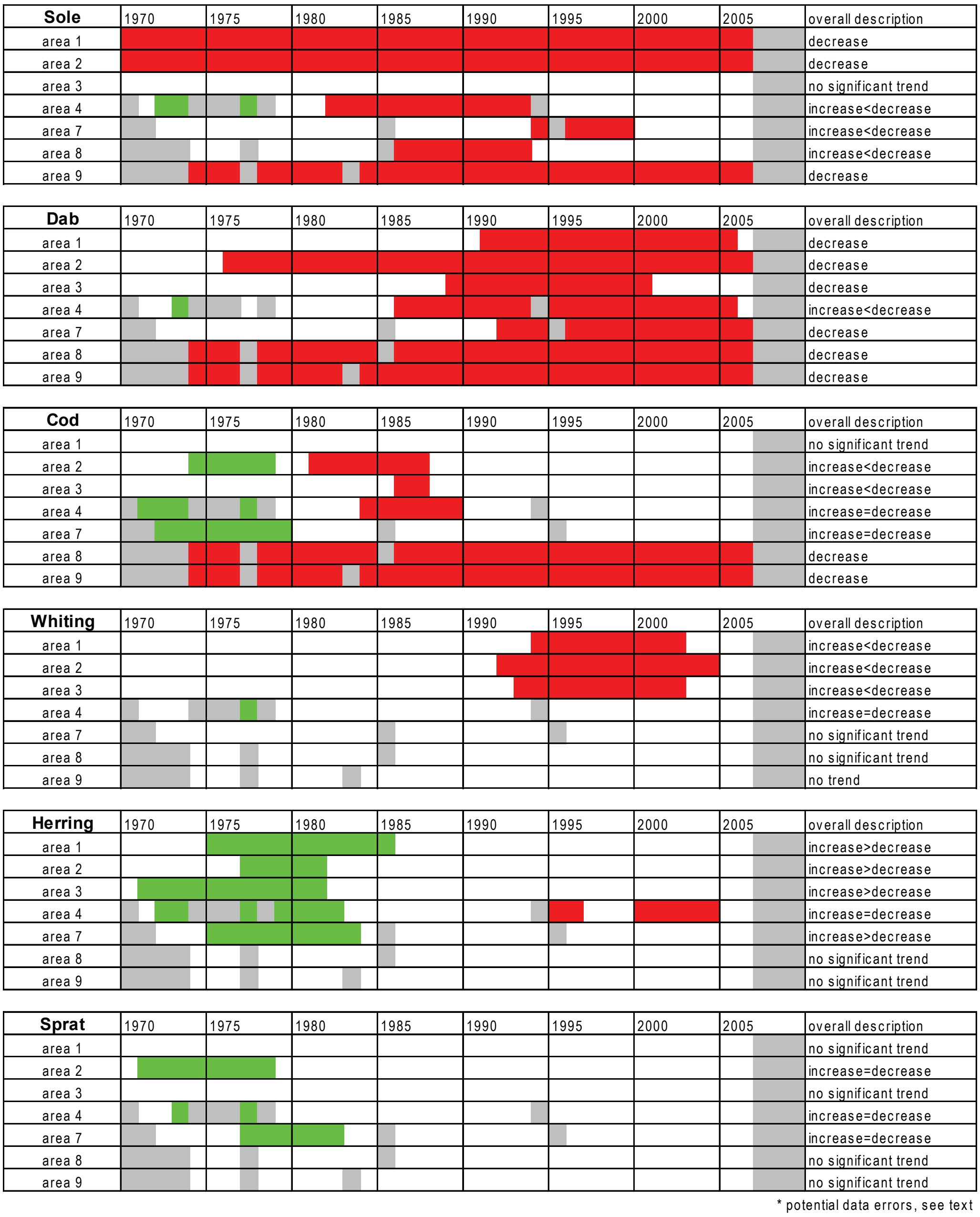
Sandeel	1970	1975	1980	1985	1990	1995	2000	2005	overall description
area 1									no trend
area 2									no trend
area 3									no trend
area 4									no significant trend
area 7									increase>decrease *
area 8									no trend
area 9									no trend

Plaice	1970	1975	1980	1985	1990	1995	2000	2005	overall description
area 1									increase=decrease
area 2									increase<decrease
area 3									increase=decrease
area 4									increase=decrease
area 7									no significant trend
area 8									no significant trend
area 9									no significant trend

between 1977 and 1983. Since 2001, poor herring reproduction has been observed for 6 years in a row. Among probable causes are the changes in the hydrography, and a shift in the dominant food items (from *Calanus finmarchicus* to *C. helgolandicus*) (ICES 2007).

The eelpout showed up and down trends, with a significant net decline over the last 35 years. A study on eelpout in the German Wadden Sea showed that thermally limited oxygen delivery in the fish tissues closely matches environmental temperatures (22.5 °C for eelpout) beyond which growth performance and abundance decrease (Pörtner and Knust, 2006). Water temperatures repeatedly exceeded 22.5 °C during summer periods of the 1990s and early 2000s. In the Ems estuary, high exposure to mercury (until 1976) affected the reproduction of eelpout by reduced survival of the fry (Essink, 1989).

The declining abundance of I-group plaice (Vorberg *et al.*, 2005), reflected in the decreasing mean length of plaice in the western Wadden Sea, was masked in the current trend analysis by the still abundant presence of 0-group individuals that dominate the catches. An offshore shift in the spatial distribution of young plaice apparently occurred in the 1990s, which is attributed primarily to a response to increased summer temperatures;



at the same time, decreased predation risk and competition in the offshore areas allowed the juvenile plaice to become more widely distributed (Van Keeken *et al.*, 2007). The shift in distribution of juvenile plaice was also manifest in the German Wadden Sea (Schmidt, 2008).

Dab and sole showed very pronounced decreases in abundance in most of the Wadden Sea sub-areas. Juvenile dab are, unlike plaice, sole or flounder, not confined to coastal nurseries, but can occur over a wide depth-range (Bolle *et al.*, 1994). In autumn, the 0-group migrate inshore and enter the Wadden Sea and estuaries. The catchability of dab fluctuates due to wind stress, temperature and turbidity, although these factors only explain a small proportion of variability in catch numbers (Bolle *et al.*, 2001). Dab catches in the DFS showed an inverse relation with temperature and secchi-depth (>1 m), although dab density seemed to decrease again at secchi-depths of <1 m (Bolle *et al.*, 2001). Increasing catches in the BTS (beam trawl survey, North Sea) indicate that the decrease in juvenile dab abundance in the Wadden Sea must be the consequence of a distribution shift toward offshore waters (Bolle *et al.*, 2001). The decreasing abundance of sole concerned all age groups, since the mean length in the demersal surveys remained more or less constant. A dynamic factor analysis

(DFA) indicated for the Wadden Sea a best-fit-model with the number of seals and beam trawl intensity as the two dominant environmental variables. In this model, sole showed a significant negative relation with beam trawl effort (Tulp *et al.*, 2008).

The period of increasing trend in cod abundance in the Wadden Sea until the early 1980s reflects the 'gadoid outburst' of the 1960s and 1970s that occurred in the North Sea (Hislop, 1996; Beaugrand *et al.,* 2003). Cod recruitment is affected by overfishing and fluctuations in plankton; the survival of larval cod depends on mean size of its prey, seasonal timing and prey abundance. Beaugrand *et al.* (2003) conclude that rising temperature since the mid-1980s has modified the plankton ecosystem in a way that reduces survival of young cod. It seems therefore likely that the present low abundance of cod in the Wadden Sea is mainly connected with processes acting in the North Sea. Whiting recruitment since 2002 has been below the long-term average, probably due to low stock size and environmental factors (ICES, 2008). The abundance of whiting in the Wadden Sea reflects the North Sea recruitment.

The recently experienced climatic changes have led to consequent changes in fish abundance, sometimes outranging the long-term average. The marine juvenile fish species in the Wadden Sea seem to reflect the heavy fishing pressure in the North Sea in combination with the climatic and hydrographic changes. The abundance of several other (estuarine resident) fish species also decreased to levels below the long-term average, but factors (natural or anthropogenic) causing these changes are still largely unknown.

4.3 Assessing the status of Wadden Sea fish

The assessment of fish in estuaries has been advanced by the requirements of the WFD, which urged the development of an assessment tool and according (fish) monitoring. For Wadden Sea fish, a first step toward a common assessment and the selection of suitable underlying metrics has been made, but further development is needed to end up with an applicable tool. The selected metrics each have their limitations and need to be evaluated and adapted if necessary. Species richness can only be compared between years and areas if monitoring effort is the same and constant between years. The species composition (number of species by ecological guild) is less dependent on the presence of individual species, but focuses on the functional aspects of the fish fauna. On the other hand, this metric appears not very sensitive in detecting changes that occur in the Wadden Sea. By looking at the mean length, the distribution shift occurring in some species or specific age-groups remains concealed. Abundance by age group/length class may be more revealing in this respect.

The joint analysis resulted in a more detailed and robust description of long-term trends in fish species. By applying the TrendSpotter methodology, a more objective way of determining the trends in abundance became available. The spatial resolution is now to the level of QSR sub-areas, which gives much more detail than the previous QSR 2004 which considered only the Dutch or German Wadden Sea. A next step might be to correlate the relevant explanatory parameters (as formulated in hypotheses, based on expert knowledge of the ecology of the species concerned) to fish metrics. For this purpose, an overview of available abiotic data has already been made on a meta-data level (Bolle *et al.*, 2007).

Focusing on priority species brings the risk of overlooking developments in other fish species, but the existing Wadden Sea fish monitoring has its limitations for analysing trends in the fish fauna. Fortunately, the newly installed WFD monitoring provides additional information for the status of fish in the estuaries. The status of fish in nearly all WFD transitional waters bordering the Wadden Sea shows moderate to large deviations from the 'undisturbed' situation for natural estuaries. Although species composition is still considered to resemble reference conditions, with the exception of the number of diadromous species, the abundance of typical indicator species is currently at a very low level compared to the situation of the early 20th century (Bioconsult, 2008).

Although we might like to draw conclusions on the status of the Wadden Sea fish in terms of 'good', 'moderate' or 'poor', from a scientific point of view it is not possible to give such qualifications to the outcome of the analyses due to the present lack of knowledge on the causal factors underlying the changes observed in the Wadden Sea. Many of the selected fish species are influenced to a large extent by natural variations, the causes of variation are hardly understood and our knowledge is not sufficiently advanced to allow this kind of judgement. Furthermore, (historic) reference conditions are not known; but even if they were, one might ask why it would be desirable to go back to the status of a hundred (why not a thousand?) years before.

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