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Herring (Photo: R. Vorberg)

8.6.1 Introduction

Fish play an important role in the ecology of the Wadden Sea and the connected estuaries. They represent a taxonomic group of exceptionally high biomass, act as predators over different trophic levels and serve as prey for birds and marine mammals. Fish can drive ecological processes on a wide scale. For example, mass invasions of juvenile cod and whiting into the Wadden Sea, as repeatedly observed, can cause a short-term breakdown of the brown shrimp population with far-reaching effects for the ecological processes in the Wadden Sea area (Neudecker, 1990; Berghahn, 1996).

Fish can indicate changes in environmental conditions long time before these changes are physically measurable. The occurrence of Mediterranean species in the North Sea and Wadden Sea, as is illustrated by mullets (*Chelon labrosus*) and anchovies (*Engraulis encrasicolus*), is regarded as an effect of temperature change and discussed in the context of climate change (Cushing and Dickson, 1976; Beare *et al.*, 2004).

However, the importance of fish as a biotic factor in the ecology of the Wadden Sea is not accordingly recognized. Fish were neither considered in the Trilateral Wadden Sea Plan (1997) nor appear in the Trilateral Monitoring and Assessment Program (TMAG, 1997) to a sufficient extent. Trilateral targets regarding fish do not exist. In the Water Framework Directive (WFD) fish is a biological quality element in transitional waters, such as estuaries, but not in coastal water types, to which most parts of the Wadden Sea have been assigned.

The occurrence of fish in the Wadden Sea is

determined by the various characteristics of this water system, being open to the North Sea, controlled by strong tidal currents and influenced by inflowing rivers. Zijlstra (1978) provided a widely used classification system of the fish species occurring in the Wadden Sea. His approach already incorporated the ecological guild concept that is nowadays used in estuarine fish science (Elliott and Dewailly, 1995; Elliott and Hemingway, 2002). Accordingly, the fish can be classified as resident or near-resident species when they are tolerant to the dynamic abiotic environment and live in the area during their whole life. Other species are seasonal visitors to the area when they consider conditions suitable. Other species again use the Wadden Sea only as a passage during their migration from the sea to the rivers or the other way around. Together, these are known as diadromous species. And last but not least, juveniles of a number of marine species use the Wadden Sea as nursery area.

Two groups of fish can be distinguished: pelagic fish, occurring in the water column, and demersal fish, dwelling near the bottom. Abundance data for selected species (Table 8.6.1) will be presented, and possible trends discussed.

8.6.2 Surveys

Research and monitoring of fishes in the Wadden Sea is limited to few programs. Information used for this report is derived from routine monitoring programs in Germany and the Netherlands, which focus on bottom dwelling species (Boddeke *et al.*, 1969; Neudecker, 2001). Data for pelagic fish species was obtained from national monitoring

Table 8.6.1:
List of fish species
presented in this chapter.

Fish species	Scientific name	Functional group	Vertical distribution	Habitats Directive ¹⁾	Red list Status ²⁾	Data source ³⁾
Herring	<i>Clupea harengus</i>	marine juvenile	pelagic		-	MB
Sprat	<i>Sprattus sprattus</i>	marine juvenile	pelagic		-	MB
Anchovy	<i>Engraulis encrasicolus</i>	marine seasonal	pelagic		-	MB
Smelt	<i>Osmerus eperlanus</i>	diadromous	pelagic		-	MB & MFS
Twaite shad	<i>Alosa fallax</i>	diadromous	pelagic	Annex II, V	vulnerable	MB & MFS
Houting	<i>Coregonus oxyrinchus</i>	diadromous	pelagic	Annex II, IV	critical	MPS
Salmon	<i>Salmo salar</i>	diadromous	pelagic	Annex II, V, ⁴⁾	critical	MPS
Sea trout	<i>Salmo trutta</i>	diadromous	pelagic		endangered	MPS
Eelpout	<i>Zoarces viviparus</i>	resident	demersal		-	DFS, DYFS
Bull rout	<i>Myoxocephalus scorpius</i>	resident	demersal		-	DFS, DYFS
Five-bearded rockling	<i>Ciliata mustela</i>	resident	demersal		-	DFS, DYFS
Hooknose	<i>Agonus cataphractus</i>	resident	demersal		-	DFS, DYFS
Butterfish	<i>Pholis gunellus</i>	resident	demersal		-	DYFS
Sand goby	<i>Pomatoschistus minutus</i>	near-resident	demersal		-	DYFS
Plaice	<i>Pleuronectes platessa</i>	marine juvenile	demersal		-	DFS, DYFS
Sole	<i>Solea solea/vulgaris</i>	marine juvenile	demersal		-	DFS, DYFS
Dab	<i>Limanda limanda</i>	marine juvenile	demersal		-	DFS, DYFS
Flounder	<i>Platichthys flesus</i>	diadrom/resident	demersal		-	DFS, DYFS, MFS
Cod	<i>Gadus morhua</i>	marine juvenile	demersal		-	DYFS
Whiting	<i>Merlangius merlangus</i>	marine juvenile	demersal		-	DYFS
Eel	<i>Anguilla anguilla</i>	diadromous	demersal		-	DFS, DYFS, MFS
River Lamprey	<i>Lampetra fluviatilis</i>	diadromous	demersal	Annex II, V	endangered	MB & MFS
Three-spined stickleback	<i>Gasterosteus aculeatus</i>	diadromous	demersal		-	MFS

¹⁾ Council Directive 92/43/EEC on the conservation of natural habitats and of wild fauna and flora.

²⁾ after Nordheim *et al.* (1996),

³⁾ Data source:

MB = Monitoring program in the Meldorf Bight (Germany) – 1991–2003,

DFS = Demersal Fish Survey in the Dutch Wadden Sea and Ems-Dollard (Netherlands-RIVO) – 1970–2003,

DYFS = Demersal Young Fish Survey in the German Wadden Sea (Germany) – 1974–2003,

MFS = Migratory Fish Survey in the Ems-Dollard estuary (Netherlands-RIKZ) – 1999–2001,

MPS = Management Plan for Salmonids in Danish rivers,

⁴⁾ only for freshwater.

projects in The Netherlands and Germany. Appropriate data from Denmark was not available, because no regular monitoring of fish has taken place in the Danish Wadden Sea since the 1960s.

8.6.2.1 Fish monitoring in Meldorf Bight and Hörnum Tief (Schleswig-Holstein)

In 1991, a fish monitoring program started in the Meldorf Bight using a stow net as standard sampling gear (Vorberg, 2001). 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). Three sites in the Meldorf Bight were sampled once a year in August. In 1997–2001 additional samples were taken in June in order to get more insight in seasonal variations of the fish fauna. Since 2001, a second sampling location has been installed in the Hörnum Deep, south of the island of Sylt.

8.6.2.2 Demersal Fish Survey (The Netherlands-RIVO)

An important source of information about 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 and the Ems-Dollard estuary. Initially the survey was carried out in spring (April–May) and autumn (September–October), but since 1987 only the autumn survey has been continued. Sampling is carried out with a 3-m-beam trawl rigged with one tickler chain, a shrimp net and a fine-meshed cod-end (20 mm). Sampling is restricted to the tidal channels and gullies deeper than 2 m, because of the draught of the research vessel. All fish and brown shrimp in the catches were analyzed.

8.6.2.3 Demersal Young Fish Survey (Germany)

After The Netherlands had started their 'census of juvenile fish' in 1969 in the Dutch Wadden Sea as well as in offshore areas up to the Danish coast (Boddeke *et al.*, 1969), German scientists joined in from 1970 onwards (Boddeke *et al.*, 1970). However, comparable survey data for the entire German region is considered to be available only since 1974 and this has not yet been fully digitized.

The survey design was equivalent to the Dutch DFS except for the tickler chain that was omitted

in the DYFS because of the excessive catch of dead shells in many of the German stations (Rauck, pers.com.). Spring (April–May) and autumn campaigns (September–October) were kept for the entire period as were towing time (15-min.-hauls) and the areas investigated. Since 1985, the area coverage of the Schleswig-Holstein part of the DYFS changed somewhat, and some deeper stations further off-shore were included (Neudecker, 2001).

For this report, DYFS abundance index data ($n/1,000\text{ m}^2$) was generally calculated on the basis of a mean towing distance of 1,400 m per haul with the 3-m-beam trawl. Length frequencies were used to discriminate age groups of commercially important species.

As data digitizing and error control has not been completed for all sub-regions, years and species in the DYFS, complete time series can only be presented for plaice, sole, cod and whiting for the autumn campaigns of the Schleswig-Holstein sub-region. All other data is given for all four sub-regions, viz. Husum (HUS), Büsum (BUS), Cuxhaven (CUX) and East Frisia (OF), and for the period 1999 to 2003.

8.6.2.4 Migratory Fish Survey (The Netherlands–RIKZ)

From 1999–2001 a survey was carried out in the Ems-Dollard estuary (Kleef and Jager, 2002) aimed at documenting the presence and abundance of diadromous fish species. This survey was undertaken as part of a project on the restoration of estuarine gradients and fish migration ('Gradiënten'). Sampling was carried out at two locations: Oterdum (near Delfzijl) in the middle part of the estuary, and Groote Gat, further upstream in the main channel of the Dollard (Groote Gat).

Monthly samples were obtained between February and December by applying stow nets with 16 mm mesh size in the cod-end during the flood and ebb period separately. The net opening covered the water column from surface to bottom, and both demersal and pelagic species were caught. The fish were sorted by species and the number of diadromous fish was counted directly or by taking sub-samples of the abundant species.

8.6.2.6 Management plan for salmonids (Denmark)

Since the 1980s, several studies have been conducted in Denmark to investigate the status of the last breeding population of the houting (*Coregonus oxyrinchus*). Danish authorities took responsibility to preserve this endangered diadromous species in the Wadden Sea and to design a man-

agement plan for achieving this goal (Jensen *et al.*, 2003).

Recently, genetic methods helped to identify a remnant stock of 'true' Wadden Sea salmon (*Salmo salar*) in the Varde Å and Ribe Å. This population is very small, and a program of supportive breeding is now carried out to strengthen this stock. During the last decades, the water quality of the Danish rivers has greatly improved as has the knowledge of habitat demands and migratory obstacles for the salmon and sea trout (*Salmo trutta*). Nowadays, several attempts are being made to reintroduce Atlantic salmon to their previous habitats in several Wadden Sea rivers, the most important and most ambitious being the Rhine-salmon project. In Denmark, the government launched an action plan for salmon in 1997. The plan covers nine rivers, where attempts are being made to re-establish lost populations of Atlantic salmon. Of these nine rivers, five drain into the Wadden Sea.

8.6.3 Pelagic species

The compilation of pelagic fish data for this report is based on the results of the Dutch and German stow net fishery in the Ems-Dollard and Meldorf Bight respectively. Catch data for pelagic species from bottom-trawl monitoring was omitted, because this sampling gear is not suitable to provide quantitative data for pelagic fish species.

8.6.3.1 Marine juveniles

Herring and sprat

Herring (*Clupea harengus*) and sprat (*Sprattus sprattus*) are the most abundant fish species in the pelagic of the Wadden Sea. Often both species occur side by side, building big shoals. As the Wadden Sea functions as a nursery for both species, the catches are dominated by juveniles of 5–10 cm length. Adults have to be regarded as visitors to the Wadden Sea. Herring abundance in the Meldorf Bight fluctuates heavily from year to year and no clear trend is detectable (Figure 8.6.1). In contrast, catch results for sprat in the Meldorf Bight indicate a continued decrease since 1995; an even more drastic decline is visible between 1999 and 2003 (Figure 8.6.2).

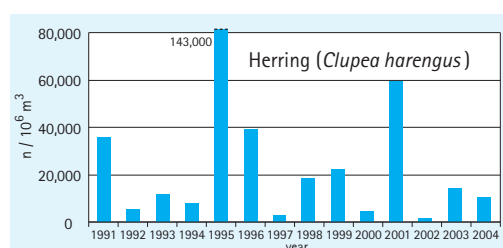
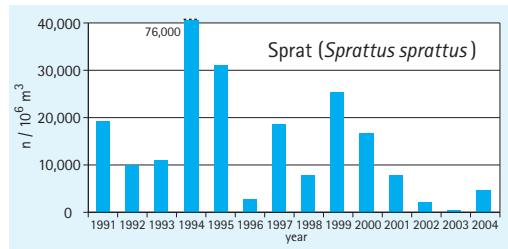


Figure 8.6.1: Abundance of herring (*Clupea harengus*) derived from the fish monitoring program in the Meldorf Bight (Schleswig-Holstein Wadden Sea). The bars show the mean of all catches in August per year.

Figure 8.6.2: Abundance of sprat (*Sprattus sprattus*) derived from the fish monitoring program in the Meldorf Bight (Schleswig-Holstein Wadden Sea). The bars show the mean of all catches in August per year.



8.6.3.2 Marine seasonal Anchovy

In the first half of the 1990s, while sampling in August, anchovies (*Engraulis encrasicolus*) were caught in the Meldorf Bight program only occasionally. With the expansion of the program to include sampling in early June (1997–2002) an increasing abundance could be assessed (Figure 8.6.3). The anchovies caught were adults of 15–17 cm length and the females were ready to spawn. For the first time 0-group (= 'first year') anchovies of 4–5 cm were caught in 2003 explaining the unusually high abundance value of this year. Adult anchovies, about 20, were also caught in the Ems–Dollard near Oterdum in May 2001.

Figure 8.6.3: Increasing abundance of anchovies (*Engraulis encrasicolus*) during fish monitoring in the Meldorf Bight (Schleswig-Holstein Wadden Sea). The bars show the mean of all catches per year.

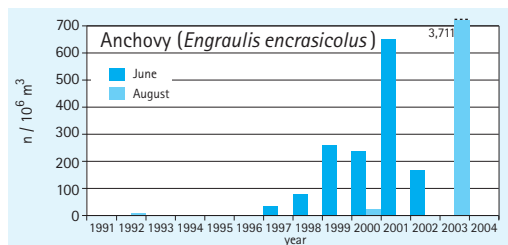


Figure 8.6.4: Abundance of smelt (*Osmerus eperlanus*) derived from the fish monitoring program in the Meldorf Bight (Schleswig-Holstein Wadden Sea). The bars show the mean of all catches in August per year.

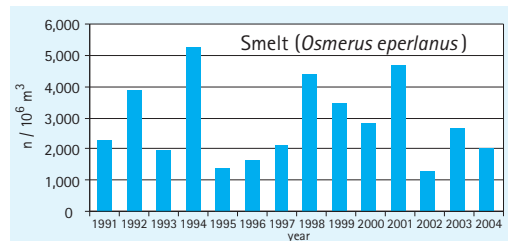
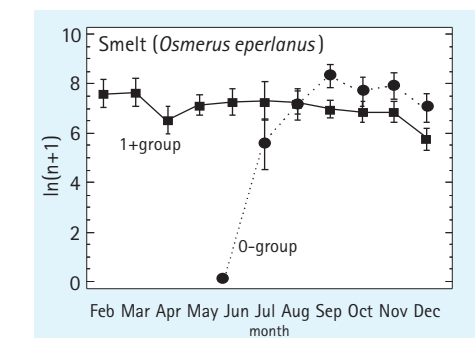


Figure 8.6.5: Catch of smelt (*Osmerus eperlanus*) (ln of the number standardized per 100 m² of net opening per tide) at two stations in the Ems–Dollard during 1999–2001; bars indicate 95% confidence interval.



8.6.3.3 Diadromous species

The Dutch migratory fish survey in the Ems–Dollard estuary (1999–2001) revealed nine diadromous species. Monitoring in the Meldorf Bight revealed only seven diadromous species during 1991–2003. The presence of thinlipped mullet (*Liza ramada*) and sea lamprey (*Lampetra fluviatilis*) could not be proven in the Meldorf Bight.

Smelt

Smelt (*Osmerus eperlanus*) is an anadromous species which lives in the Wadden Sea and migrates into larger rivers for spawning in winter/spring. The data obtained from the Meldorf Bight shows that the abundance is more or less stable over the years (Figure 8.6.4). In the Ems–Dollard region, smelt historically spawned upstream in the Ems near Oldersum and apparently use the lower estuary and Dollard as a nursery. Individuals older than one year (1+group) were present during the whole year in fairly constant numbers. The 0-group appeared in the catches in June–July and reached maximum numbers in September (Figure 8.6.5). The large population of anadromous smelt that once occurred in the Zuiderzee converted to a land-locked form living in the IJsselmeer after the construction of the Afsluitdijk in 1932.

Twaite shad

The twaite shad (*Alosa fallax*) is a common Wadden Sea species entering the larger rivers in spring for spawning but is not limited to the Wadden Sea (Maitland and Hatton-Ellis, 2003). At the beginning of the 20th century, twaite shad occurred in high densities e.g. in the Elbe and Rhine rivers (Ehrenbaum, 1936; de Groot, 1989, 2002) and was of great commercial importance. In the following decades the species suffered from overfishing, stowing of rivers and loss of spawning habitat. In the Rhine system, twaite shad disappeared around 1966 following the closure of the Haringvliet. Twaite shad is listed in Annex II of the Habitats Directive (Kloppmann *et al.*, 2003) and classified as vulnerable in the red list of marine fishes of the Wadden Sea (Nordheim *et al.*, 1996).

The results obtained in the Meldorf Bight clearly indicate that twaite shad regularly occurs in the Wadden Sea (Figure 8.6.6). Juveniles especially are caught in high densities. Exceptionally high numbers of individuals of 6–9 cm length were caught in 2003. Adults of 30–40 cm frequently appear in the catches of the commercial stow net fishery in the Elbe (Rübcke, pers. comm.).

In the Ems–Dollard, twaite shad showed differing patterns of density and age composition over the years. In 1999, twaite shad suddenly became abundant in the catches in August and a

relatively high density continued up to November (Figure 8.6.7). The individuals caught in August were about 8 cm long, and increased to 11 cm in November. De Groot (1992) gives mean lengths of 6 cm after 6 months and 10–13 cm after one year. Twaite shad in the Elbe reached a mean length of over 10 cm at the end of their year of birth (Thiel *et al.*, 1996). On the basis of the length observed in the Ems-Dollard, it is assumed that the twaite shad caught in autumn of 1999 belonged to the 0-group. They returned in May 2000 at about the same density level and length as was observed at the end of 1999. In 2000, the numbers steadily decreased to a low level that was maintained during 2001. In autumn 2000 and 2001, no 0-group twaite shad were observed in the stow nets. Adult twaite shad are sporadically caught by professional fishermen in the Mouth of the Dollard (Westerhuis, pers. comm.).



Twaite shad
(Photo: Z. Jager)

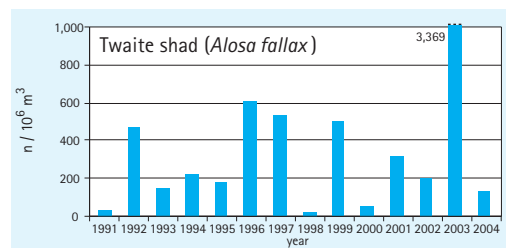


Figure 8.6.6: Abundance of twaite shad (*Alosa fallax*) derived from the fish monitoring program in the Meldorf Bight (Schleswig-Holstein Wadden Sea). The bars show the mean of all catches in August per year.

Houting

A hundred years ago, houting (*Coregonus oxyrinchus*) was common and widespread throughout the Wadden Sea. This anadromous species leaves the Wadden Sea in autumn to spawn in larger fresh-water courses. Today, houting is regarded almost extinct in the Netherlands. No houting were caught in the migratory fish survey in the Ems-Dollard, and only very few specimens were encountered in a fyke monitoring near the Afsluitdijk in the western Dutch Wadden Sea (Tulp *et al.*, 2002). In Germany there is only a tiny population maintained by a release program in the little river Treene, a tributary of the Eider. Houting is listed as priority species in Annex II of the Habitats Directive (Kloppmann *et al.*, 2003) and is classified as critical in the red list of the trilateral Wadden Sea area (Nordheim *et al.*, 1996).

From 1987 until 1992 large numbers of fry were released in order to re-establish the houting in the Danish watercourses discharging into the Wadden Sea. After the releases of fry were discontinued only the population in the Vidå remained fairly stable, indicating a self-reproducing population. This made the Danish authorities to launch a comprehensive management plan to improve the overall conditions for the houting (Jensen *et al.*, 2003). Apart from releases of fry additional measures are planned, e. g. setting up fish passages and creating new spawning and nursery areas.

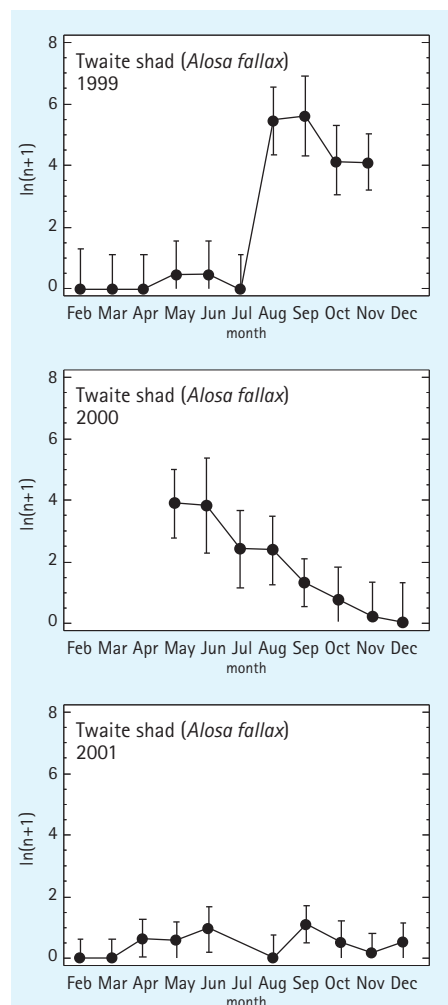


Figure 8.6.7: Catch density of twaite shad (*Alosa fallax*) (ln of the number standardized per 100 m² of net opening per tide) in the Ems-Dollard during 1999–2001; bars indicate 95% confidence interval.

Salmon and sea trout

The rivers flowing into the Wadden Sea used to be inhabited by large populations of Atlantic salmon (*Salmo salar*) and sea trout (*Salmo trutta*). Salmon is listed in Annex II of the Habitats Directive (only for fresh water) and is classified as critical in the red list of the trilateral Wadden Sea area (Nordheim *et al.*, 1996).

Salmon mainly used the Wadden Sea as a migratory pathway to the feeding grounds in the North Atlantic and on the way back to spawn in their natal rivers. Sea trout use the Wadden Sea also as a feeding area, spending a significant proportion of their life here. Salmon and sea trout used to be important species for the coastal commercial fishing in Denmark, Germany and The Netherlands, but man-made changes to the rivers have greatly impaired the conditions for these migratory fish and commercial catches are now negligible. Due to pollution, weirs, hydropower development and habitat destruction, the Atlantic salmon disappeared from all the rivers draining into the Wadden Sea during the last century. The only exception was the salmon in the Danish Skjern Å, located on the very Northern boundary of the Wadden Sea. In the Ems-Dollard, a few salmonid specimens were caught in spring 2001 near Oterdum, being mostly juveniles of 20–30 cm length; one adult of 51 cm was caught in August 2000. Stocking of salmonid fry in the Leda, tributary of the Ems, has been carried out since 1992 (Brumund-Rüther, pers. comm.).

State of the art methods in supportive breeding, stocking and habitat improvement, along with increasing public awareness about the importance of migratory salmonids, gives hope for the future of salmon in the Wadden Sea, especially because co-operation between Danish, German and Dutch researchers and managers resulted in the possi-

bility to use offspring from Skjern Å salmon for a future stocking program in Germany. The salmon from Skjern Å are much more closely related to the now extinct Rhine salmon than the foreign stocking material used so far in the Rhine and Elbe, and thus will hopefully be better able to survive and adapt to the conditions in the Rhine and the other rivers where they are being re-stocked.

Sea trout are still present in numerous rivers and streams in the Wadden Sea area, but in general these populations have also declined during the last century due to human activities. Sea trout is classified as endangered in the red list of the trilateral Wadden Sea area (Nordheim *et al.*, 1996).

As sea trout spend most of their time feeding in the coastal areas, a major problem has been the by-catch of juveniles (smolt and post-smolts) in commercial fishing gear, especially pound nets, targeting eel and herring in spring. Legal and illegal gillnet fishing in the near shore areas have also been reported to cause high mortality among adult sea trout and salmon. Recent regulation of these types of fisheries have led to higher survival of both trout and salmon juveniles.

8.6.4 Demersal species

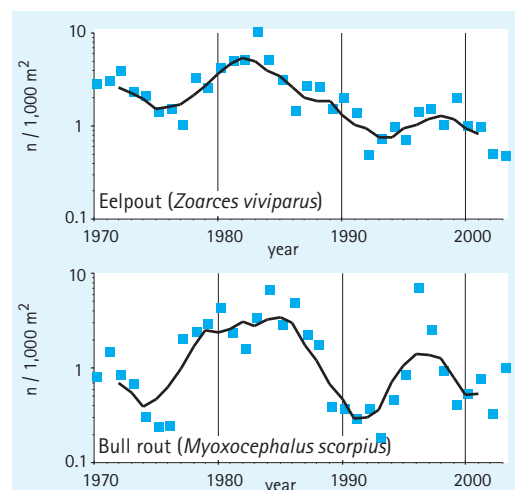
8.6.4.1 Residents

Eelpout and bull rout

Eelpout (*Zoarces viviparus*) and the bull rout (*Myoxocephalus scorpius*) are both typical resident species, *i.e.* they stay in the Wadden Sea during their whole life cycle. Both species are common inhabitants of the Wadden Sea, found particularly in the tidal channels in the vicinity of structures providing shelter such as mussel beds (de Jonge *et al.*, 1993). Most of the estuarine residents have demersal eggs and some form of parental care. Bull rout males guard their eggs and eelpout gives birth to fully developed juveniles (ovoviviparous), which is considered an extreme form of parental care (Zijlstra, 1978; Fonds *et al.*, 1989). The limited dispersal during the egg, larval and adult life phases make these species suitable indicators of small-scale changes in the environment.

Eelpout and bull rout show similar trends in abundance in the Dutch Wadden Sea (Figure 8.6.8). The abundance of both species increased in the late 1970s and the highest catch rates were observed in the early 1980s. Thereafter, the abundance decreased until 1992–93, increased until approximately 1997–98 and then decreased again. Present catch rates are significantly lower than in the early 1980s. Similarly low catch rates (mostly <1 specimen/1,000 m²) were found in the differ-

Figure 8.6.8:
Catch rates of eelpout (*Zoarces viviparus*) (a) and bull rout (*Myoxocephalus scorpius*) (b) in the Dutch Wadden Sea (DFS-data): the annual mean (symbols) and the 5-year running mean (solid line).



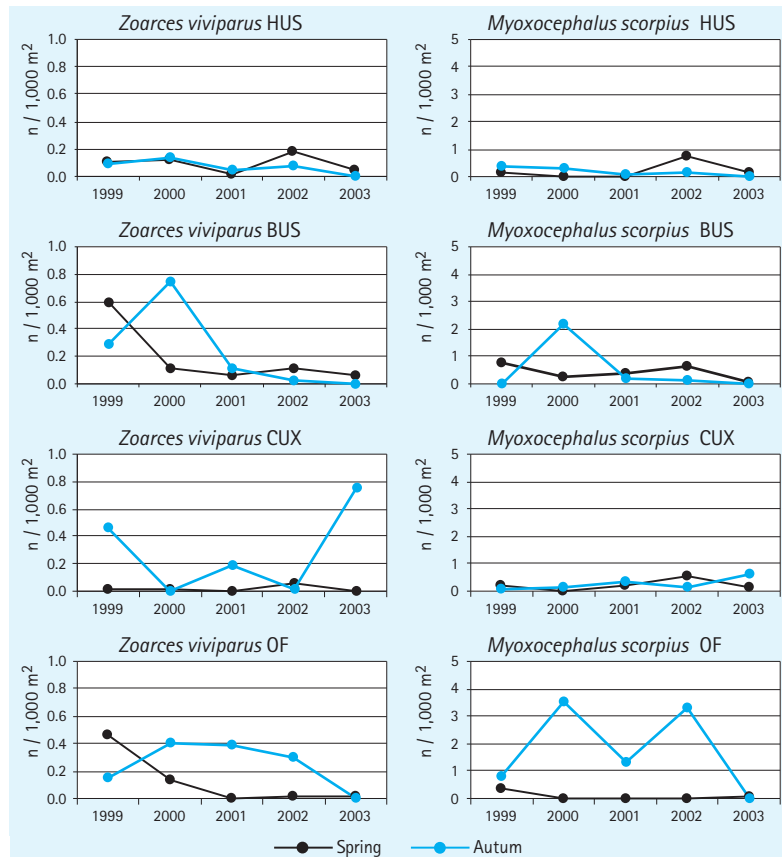


Figure 8.6.9: Catch rates of eelpout (*Zoarces viviparus*) (left) and bull rout (*Myoxocephalus scorpius*) (right) in the DYFS for the years 1999 to 2003 for the four German Wadden Sea regions: HUS = west and north of Husum, BUS = west of Büsum, CUX = near Cuxhaven, Elbe estuary, OF = East Frisia north and south of the islands of Langeoog and Baltrum

ent parts of the German Wadden Sea (Figure 8.6.9).

The similarity in the trends and the fact that both species are associated with hard substrates suggests that the fluctuations may be related to variations in the availability of suitable habitat. In the 1999 QSR this relationship was crudely examined and it was argued that the occurrence of blue mussel beds may influence the spatial distribution of eelpout and bull rout, but cannot explain the observed trends in time. De Boer *et al.* (2001) examined for various species the correlation between catch rates and the distance to mussel beds, but neither eelpout nor bull rout showed a significant correlation. A similar up-and-down pattern for eelpout and bull rout catch rates as found in the Dutch Wadden Sea was found by Tiews (1990) and Tiews and Wienbeck (1990) in their analysis of by-catch data from the German brown shrimp fishery in the Wadden Sea for the period 1954–1988.

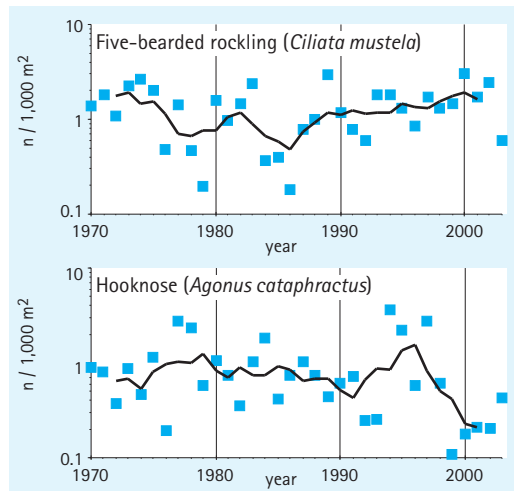
Also for bull rout, Dutch DFS and German by-catch data shows high values in the early 1980s and a decrease around 1990, in Germany at least for the Elbe estuary and an East Frisian region, while near Büsum there was a continuous fluctuation up and down over 50 years of sampling with a clear seasonality visible from the by-catch sam-

ples. So, the low level of bull rout in recent years seems to be within the natural range as well. A sign of a possible increase of the population was observed during the 2004 DYFS spring campaign in Germany (Neudecker, unpublished data).

Five-bearded rockling and hooknose

Five-bearded rockling (*Ciliata mustela*) and hooknose (*Agonus cataphractus*) are classified as (near) residents because they spend most of their life in the Wadden Sea. However, this classification is to some extent arbitrary. Although several authors (Zijlstra, 1978; de Boer *et al.*, 2001; Elliott and Hemingway, 2002) characterized hooknose as a true resident species, Fonds (1978) described a seasonal movement out of the Wadden Sea in winter. Five-bearded rockling leaves the Wadden Sea to spawn in deeper water (Zijlstra, 1978) and is therefore classified by some authors as a marine seasonal migrant (de Boer *et al.*, 2001; Elliott and Hemingway, 2002). Both species are common in inshore waters. Five-bearded rockling is a littoral species probably only moving to the sub-littoral during spawning, whereas hooknose is widely distributed throughout the southern North Sea (Witte *et al.*, 1991; Knijn *et al.*, 1993). Both species are important predators of brown shrimp (Tiews, 1978), but they also prey on other invertebrates and gobies

Figure 8.6.10: Catch rates of five-bearded rockling (*Ciliata mustela*) (a) and hooknose (*Agonus cataphractus*) (b) in the Dutch Wadden Sea (DFS-data): the annual mean (symbols) and the 5-year running mean (solid line).



(Kühl, 1961; Badsha and Sainsbury, 1978; de Boer *et al.*, 2001).

The catch rates of five-bearded rockling and hooknose in the Dutch Wadden Sea are plotted in Figure 8.6.10. Large annual variations in abundance estimates are observed, but there are no clear trends over longer time periods. Nor was any trend observed for five-bearded rockling in the time series from German by-catch data (Tiews, 1990). Catch rates in the recent DYFS are of similar magnitude as in the Dutch DFS, though with

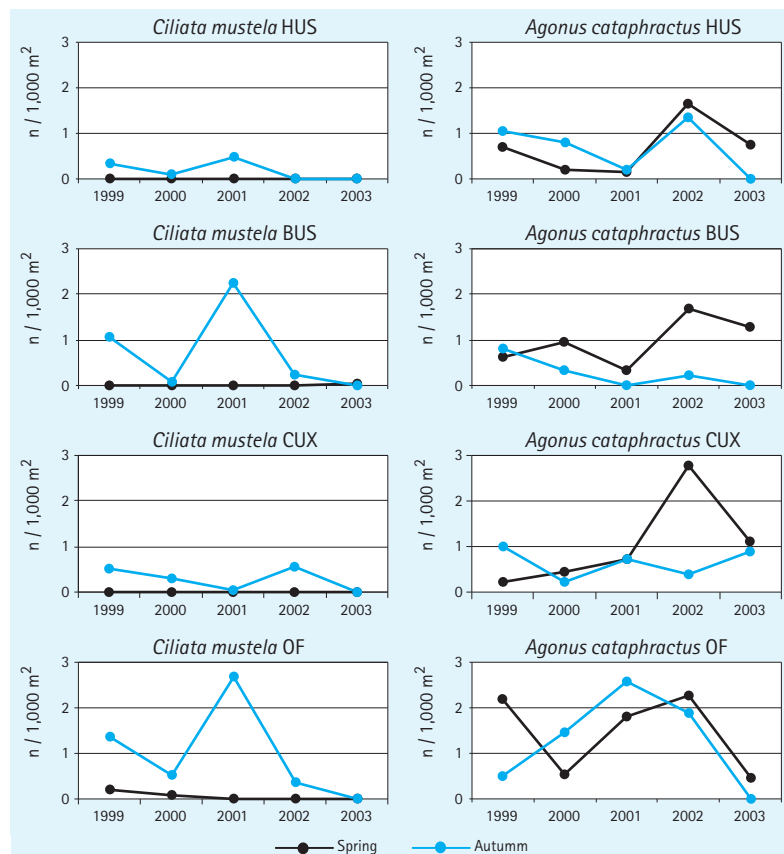
catch rates being considerably higher in autumn than in spring (Figure 8.6.11).

For hooknose the first two decades of the by-catch program show higher values for the Büsum area, however, in the Elbe estuary (CUX) the opposite seems to occur. The same is valid for the seasonal pattern derived from the by-catch samples, where a maximum can be seen in summer in the Elbe region and lowest values for the same period little further north near Büsum (Neudecker *et al.*, 1999). In East Frisia (OF), unusually high numbers were found in the 1970s in the by-catch time series (Tiews and Wienbeck, 1990), but a general trend up to the present cannot be seen. The recent DYFS catch rates for hooknose are similar as those in the Dutch Wadden Sea for the last five years and in the same range as 25 years before. The data in Figure 8.6.11 suggests a regional trend of decreasing abundance from East Frisia (OF) towards the northern part of the German Wadden Sea.

Butterfish and sand goby

Two further species common two shallow coastal waters may be mentioned, butterfish (*Pholis gunellus*) and sand goby (*Pomatoschistus minutus*). Butterfish was present in 30–90% of all DYFS campaigns in low numbers, while the short lived

Figure 8.6.11: Catch rates of five-bearded rockling (*Ciliata mustela*) (left) and hooknose (*Agonus cataphractus*) (right) in the DYFS for the years 1999 to 2003 for the four German Wadden Sea regions: HUS = west and north of Husum, BUS = west of Büsum, CUX = near Cuxhaven, Elbe estuary, OF = East Frisia north and south of the islands of Langeoog and Baltrum.



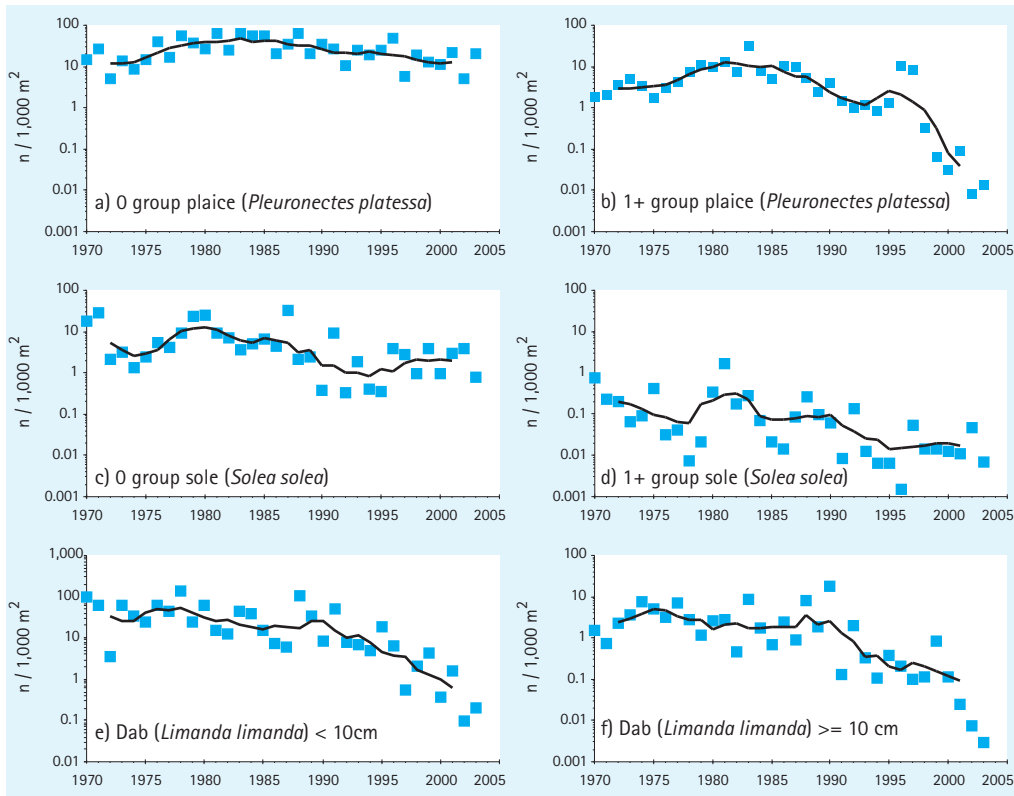


Figure 8.6.12: Catch rates by age group or size class of plaice (*Pleuronectes platessa*) (a–b), sole (*Solea solea*) (c–d) and dab (*Limanda limanda*) (e–f) in the Dutch Wadden Sea (DFS-data); the annual mean (symbols) and the 5-year running mean (solid line).

sand goby occurred in all catches with catch rates up to 30 per 1,000 m². There is no trend visible in the DYFS data (1999–2003). The fish by-catch time series shows no trend for butterfish either, but does show a decline of gobies over the 40 year period from 1955 to 1994 for the Büsum area as well as in the Elbe estuary (Neudecker *et al.*, 1999). This decline seems to be a result of the observed shift of fishing grounds of the German shrimping fleet towards deeper waters rather than a real population decline (Neudecker, 1999). An analysis of data for butterfish and sand goby from the Dutch Wadden Sea was not made.

8.6.4.2 Marine juveniles

Flatfish

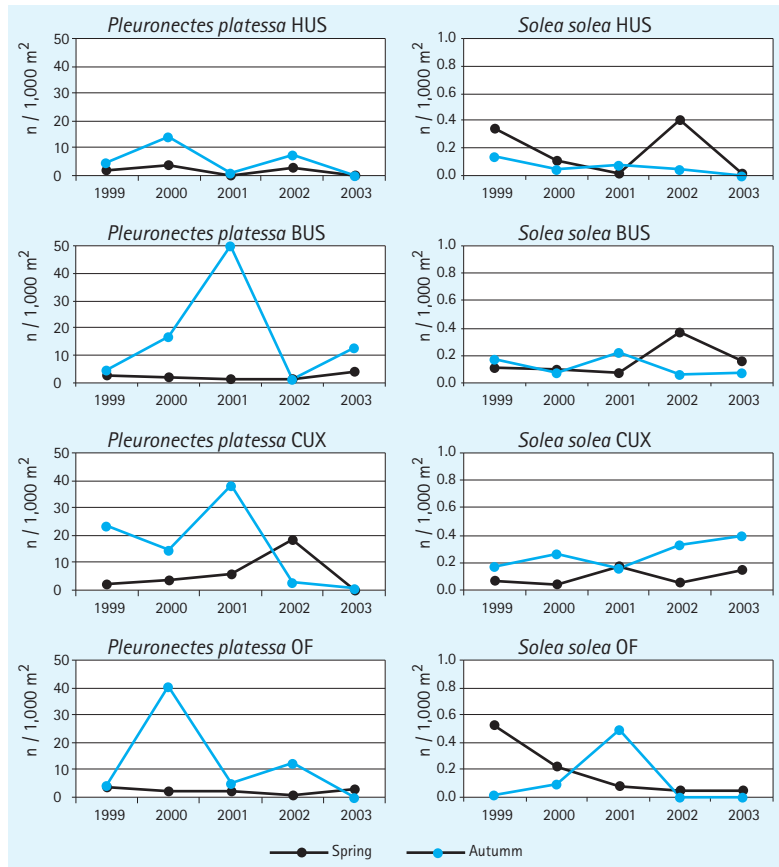
The Wadden Sea is an important nursery area for sole (*Solea solea*) and especially for plaice (*Pleuronectes platessa*) (Zijlstra, 1972, Beek *et al.*, 1989). Both fish species spawn in the North Sea and their pelagic eggs and larvae are transported to the coastal and estuarine nurseries by tidal currents (Talbot, 1976; Rijnsdorp *et al.*, 1985). After entering the Wadden Sea the pelagic larvae undergo metamorphosis and settle on the tidal flats. Dab (*Limanda limanda*) also spawns in the North Sea and also has pelagic eggs and larvae. After metamorphosis, post-larvae settle outside the Wadden Sea in sub-tidal coastal waters. Later, in its first

year of life, the dab moves into the tidal channels of the Wadden Sea (Bolle *et al.*, 1994). All three flatfish species leave the Wadden Sea before their first winter as juveniles. A part of the population re-enters the Wadden Sea in their second year of life, and most of them permanently leave the Wadden Sea before their second winter as juveniles.

For these three species, trends in abundance from the Dutch DFS have been examined separately for two age groups: the 0-group and the 1+ group. As for dab age determinations are only available for a limited number of years, 2 size classes were distinguished which roughly correspond to the 0-group and the 1+ group. The abundance of 0-group plaice, 0-group sole and 1+ group sole has declined since 1980 (Figure 8.6.12 a, c, d). Although significant, these trends are far less striking than the severe decline in abundance of 1+ group plaice, small dab and larger dab (Figure 8.6.12 b, e, f).

Similar low levels of abundance are apparent in the German Wadden Sea regions in the period 1999–2003, especially for plaice and sole, regardless of possible regional differences (see Figure 8.6.13). Plaice is least abundant in the northernmost region near Husum and shows decreasing abundances towards the more southern parts of

Figure 8.6.13
Catch rates of plaice (*Pleuronectes platessa*) (left) and sole (*Solea solea*) (right) in the DYFS for the years 1999 to 2003 for the four German Wadden Sea regions: HUS = west and north of Husum, BUS = west of Büsum, CUX = near Cuxhaven, Elbe estuary, OF = East Frisia north and south of the islands of Langeoog and Baltrum.



the Wadden Sea. Plaice abundance is highly variable; exceptionally strong year classes occurred in 1983, 1996 and 2001 (Figure 8.6.14, autumn data). These strong year classes, however, are not always reflected in the abundances in the spring survey of the following year, which may be due to time shifts – even small ones – in sampling and/or annual climatic variations. The by-catch time series data of Tiewes (Neudecker *et al.*, 1999) clearly shows the seasonal pattern with a summer peak

and a continuous decrease towards winter, but a variable though slight increase of plaice by-catch for the period from 1955 to 1994. The latter increase, however, is in contradiction to the more recent and shorter DYFS data set, which may have been caused by changes in the commercial fishing pattern (change to more offshore fishing grounds) and survey design due to different charter vessels (larger ones since 1984).

Sole may also show outstanding year classes as in 1982 or 1987 (Figure 8.6.15). This species is less common, with a preference for the deeper parts of the German Wadden Sea. Since the good year class of 1996, densities have remained rather low.

Dab exhibited rather low densities (<5 per 1,000 m²) in all German regions except for the East Frisian part, where densities of 10-20 per 1,000 m² prevail in 1999-2001 equaling the densities in the Dutch Wadden Sea.

The decreasing trends observed in sole and 0-group plaice in the Dutch Wadden Sea may partly be related to changes in stock size. The spawning stock size of North Sea plaice and sole is currently considered to be below safe biological limits (ICES, 2004a), which poses the risk of impaired recruitment. However, the magnitude of decline in the

Figure 8.6.14:
Catch rates of plaice (*Pleuronectes platessa*) in the DYFS for the years 1974 to 2003 for the Schleswig-Holstein region from spring and autumn campaigns (AG = Age Group).

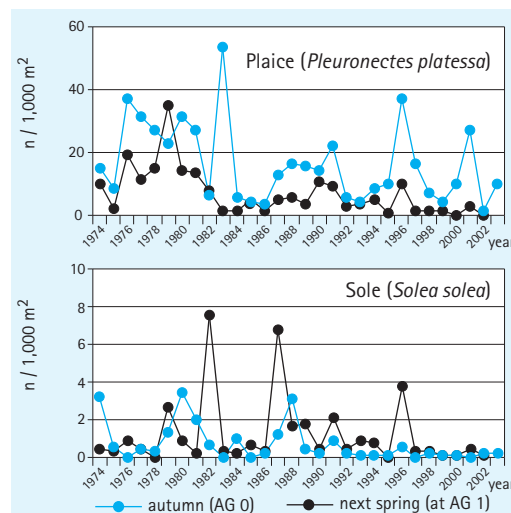


Figure 8.6.15:
Catch rates of sole (*Solea solea*) in the DYFS for the years 1974 to 2003 for the Schleswig-Holstein region from spring and autumn campaigns (AG = Age Group).

1+ group (Fig. 8.6.12) cannot be explained by changes in stock size. Examination of all demersal survey data (Beam Trawl Survey, Sole Net Survey and coastal Demersal Fish Survey) shows an off-shore shift in the distribution of juvenile plaice in recent years (Grift *et al.*, 2005.; Pastoors *et al.*, 2000). This indicates that the change in distribution is not caused by local changes within the Wadden Sea. Various causal factors have been suggested, such as rise in temperature, lower levels of eutrophication and decline in turbidity. However, no conclusive evidence is available yet. The present data on shift in distribution suggests that plaice is less sensitive than dab and more sensitive than sole to whatever the causal factors may be. Taking into account the temperature tolerance of these species (Fonds *et al.*, 1992; Fonds, pers. com.), there is ground for the hypothesis that a temperature rise is contributing to the shift in distribution of juvenile flatfish, resulting in a decreased abundance in the Wadden Sea.

Cod and whiting

Cod (*Gadus morhua*) and whiting (*Merlangius merlangus*) are fish of the North Sea rather than of the Wadden Sea. As 0- or 1-group predators they may, however, have an enormous impact on the fauna of the Wadden Sea. It happens that in certain years uncountable numbers aggregate near or in the tidal channels decimating every other species available in eatable size (Berghahn, 1996; Neudecker, 1990; Neudecker *et al.* 1999; Tiaws, 1978). In Figure 8.6.16, these mass aggregations of whiting are illustrated.

Cod showed similar invasions in 1970, to lesser extent in 1977, 1978 and for the last time in 1983 (Neudecker *et al.*, 1999). Since then stocks of cod have decreased dramatically and young cod are now rare also in the catches of the DYFS monitoring program (Figure 8.6.17).

8.6.4.3 Diadromous species

Flounder

Flounder (*Platichthys flesus*) spawns in the North Sea and the larvae enter the estuary in April-May using selective tidal transport (Jager, 1999), settle on the tidal flats and use the estuary as a nursery. Small flounders are found in the Wadden Sea but they also inhabit fresh water such as the lower reaches of rivers. Therefore, flounder has been classified as a resident species by some authors (Zijlstra, 1978; Elliott and Hemingway, 2002) and as a diadromous species by others (Duncker and Ladiges, 1960; Vorberg and Breckling, 1999).

In the Ems-Dollard estuary flounder reached catchable sizes for the stow net employed from

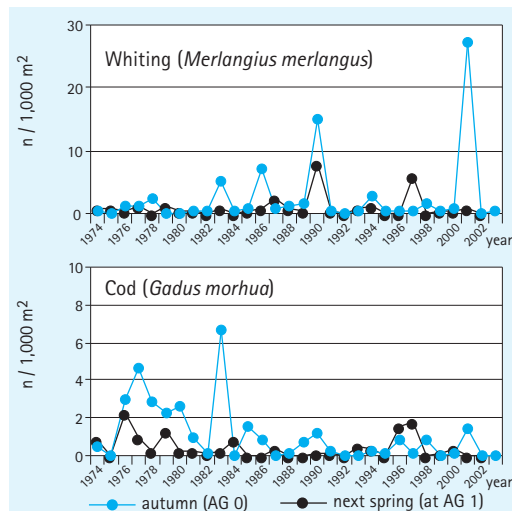


Figure 8.6.16: Catch rates of whiting (*Merlangius merlangus*) in the DYFS for the years 1974 to 2003 for the Schleswig-Holstein region from spring and autumn campaigns (AG = Age Group).

Figure 8.6.17: Catch rates of cod (*Gadus morhua*) in the DYFS for the years 1974 to 2003 for the Schleswig-Holstein region from spring and autumn campaigns (AG = Age Group).

May onwards and the 0-group reached maximum numbers in September-October and then decreased again. 1+-flounders were most abundant during May-July and then decreased (Figure 8.6.18). Long-term data as derived from the DFS do not show a clear trend over recent decades. Mean abundance fluctuates heavily from year to year whereas the 5-year running mean is more or less stable (Figure 8.6.19).

Yearly fluctuations are also found in the German DYFS and by-catch data. Flounder is present in the German Wadden Sea with an overall average density of ca. 1 per 1000 m² (Figure 8.6.20), lower numbers are present in the northern part, and higher numbers in the wider vicinity of the Elbe to Ems region.

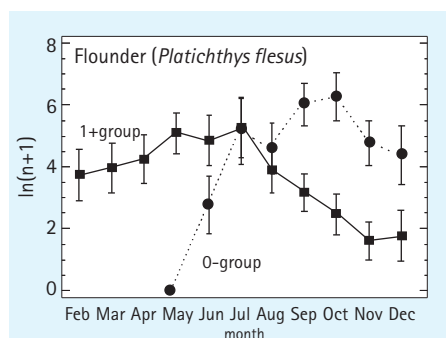


Figure 8.6.18: Catch of flounder (*Platichthys flesus*) (ln of the number standardized per 100 m² of net opening per tide) at two stations in the Ems-Dollard during 1999-2001; bars indicate 95% confidence interval, (Kleef and Jager, 2002).

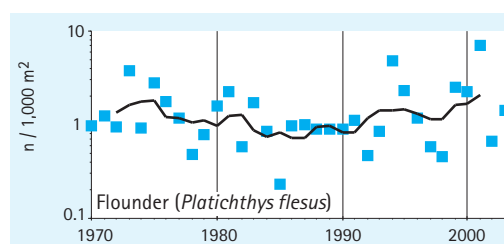


Figure 8.6.19: Catch rates of flounder (*Platichthys flesus*) in the Dutch Wadden Sea (DFS-data): the annual mean (symbols) and the 5-year running mean (solid line).

Figure 8.6.20
 Catch rates of flounder (*Platichthys flesus*) in the DYFS for the years 1999 to 2003 for the four German Wadden Sea regions: HUS = west and north of Husum, BUS = west of B usum, CUX = near Cuxhaven, Elbe estuary, OF = East Frisia north and south of the islands of Langeoog and Baltrum.

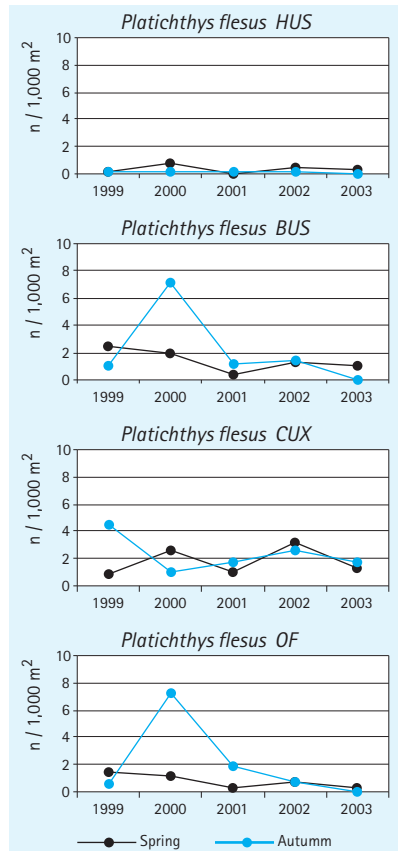


Figure 8.6.21:
 Catch of eel (*Anguilla anguilla*) (ln of the number standardized per 100 m² of net opening per tide) at two stations in the Ems-Dollard during 1999–2001; bars indicate 95% confidence interval, (Kleef and Jager, 2002).

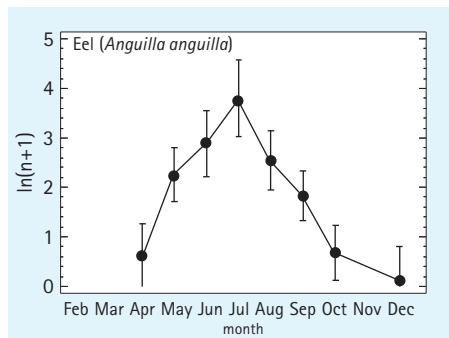
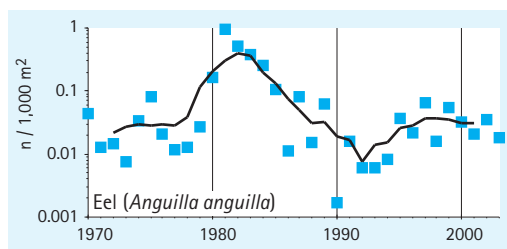


Figure 8.6.22:
 Catch rates of eel (*Anguilla anguilla*) in the Dutch Wadden Sea (DFS-data): the annual mean (symbols) and the 5-year running mean (solid line).



Eel

Eel (*Anguilla anguilla*) spawns in oceanic waters and the pelagic larvae are transported to coastal waters by currents. The larvae metamorphose into transparent 'glass eels' and migrate into fresh water where they spend 6–20 years before the onset of maturation at which they return to the sea ('silver eel' stage). Some juveniles do not migrate into fresh water; their growth phase takes place in brackish or salt water.

Strong seasonal variation in abundance of eel was found in the Ems-Dollard. Eel appeared in the samples in April, reached its maximum catch density in July and then decreased again (Figure 8.6.21). The silver eel migration usually takes place during autumn. Most of the eels that were caught in the Dollard during the summer months resembled the silver eel stage and are most likely a pre-stage of silver eel (called 'blinker').

The catch rates of eel in the Dutch DFS were low, 97–458 specimens caught in the whole survey area in the years 1980–1984, and only 1–49 specimens in later years. Despite the low catch rates, the abundance estimates (Figure 8.6.22) reflect the general trends in the eel population and correspond with the decline observed during the glass eel monitoring in Den Oever (Figure 8.6.23). Since the peak in 1981, eel abundance has decreased significantly, a slight recovery appeared to occur in the 1990s but since then the decline has continued. This decline is observed all along the western European coast and is not related to changes in the Wadden Sea (Loz an *et al.*, 1994; Dekker, 2004).

The catches of eel in the German DYFS time series were very low ($n < 0.01/1,000 \text{ m}^2$) and occasional but occurred in all sub-regions. This is a continuation of the decline from the 1950s to the late 1980s shown by Tiewes (1990).

Three-spined stickleback and river lamprey

Strong seasonal trends in abundance were found in the Ems-Dollard for three-spined stickleback (*Gasterosteus aculeatus*) and river lamprey (*Lampetra fluviatilis*). The three-spined stickleback spends the winter in the sea and starts its spawning migration to fresh water in early spring. If this spawning migration is blocked, for example by sluices or pumping-stations, accumulation outside these fresh-water discharge locations is commonly observed (Wintermans and Jager, 2001, 2002, 2003). Highest numbers of stickleback were caught in February–March, followed by a strong decrease over the summer months, increasing again from October onwards when they return to sea (Figure 8.6.24).

The river lampreys that were caught in the Ems-Dollard were mature adults with a length of >30 cm. The spawning migration starts in autumn. Thus, catches increased from July to reach maximum numbers in October–November (Figure 8.6.25). More river lampreys were caught at the Oterdum location than in the Dollard (Kleef and Jager, 2002). Reproduction of river lampreys was observed far inland in the small river Drentse Aa during spring 2000 (de Vroome, 2001, pers. comm.). It is presumed that river lampreys from the Ems-Dollard enter Dutch inland waters through the shiplock at Delfzijl (Wanningen, pers. comm.) and swim all the way to the Drentse Aa.

River lamprey regularly occurs in the Meldorf Bight but show strongly fluctuating numbers from year to year (Figure 8.6.26). No river lampreys were caught in 1996.

8.6.4.4 Brown shrimps

Although the brown shrimp (*Crangon crangon*) is a crustacean it is included in this chapter for a number of reasons. Firstly, because brown shrimp is an important prey species for fish and birds. Secondly, a large proportion of the fishery in the Wadden Sea targets brown shrimp. Finally, the Dutch DFS and the German DYFS provide long-term series on the abundance of brown shrimp.

In the Dutch Wadden Sea, the abundance of brown shrimp fluctuates strongly from year to year. There seems to be a slight decrease from 1980 onwards in the DFS time-series, but this decrease is not statistically significant (Figure 8.6.27).

The German DYFS time series for Schleswig-Holstein over the period 1974–2002, also shows high fluctuations in shrimp abundance. Here, however, a significant negative trend exists (Figure 8.6.28). It is not clear, though, whether this trend really reflects a decline of stocks. It may rather be an effect of slight changes in the survey, due to larger vessels being used since 1984, operating in slightly deeper water and more outside the island chain (Neudecker, 2001). Alternatively, a shift of the shrimp stocks to deeper waters such as observed for plaice may be a natural cause. The latter possibility, also reported by fishermen, needs still to be proven with scientific data. On the other hand, no trend is visible in the landings by the German shrimping fleet (Figure 8.5.30) which indicate a highly variable though stable stock of brown shrimp in the Schleswig-Holstein area.

8.6.5 Discussion and conclusions

The catchability of a species is related to the sampling gear used. The beam trawl is the most efficient sampling gear for flatfish and other demer-

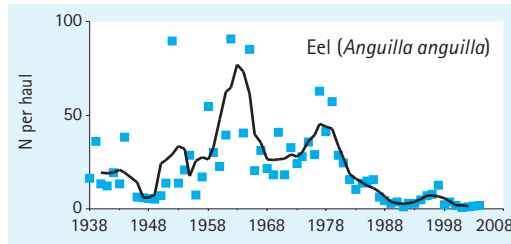


Figure 8.6.23: Catch rates of glass eel (*Anguilla anguilla*) migrating into fresh water at Den Oever (western Dutch Wadden Sea) in April (unpublished data W. Dekker; ICES, 2004b).

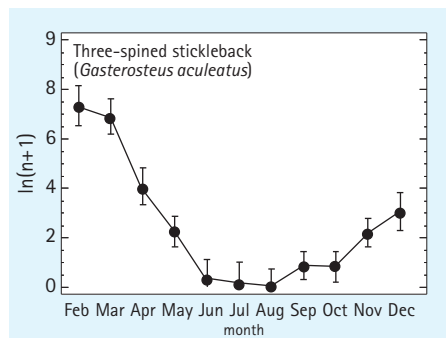


Figure 8.6.24: Catch of three-spined stickleback (*Gasterosteus aculeatus*) (ln of the number standardized per 100 m² of net opening per tide) at two stations in the Ems-Dollard during 1999–2001; bars indicate 95% confidence interval, (Kleef and Jager, 2002).

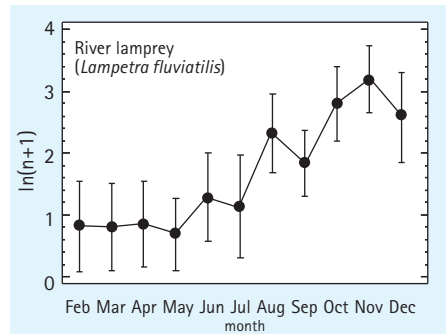


Figure 8.6.25: Catch of river lamprey (*Lampetra fluviatilis*) (ln of the numbers standardized per 100 m² of net opening per tide) at two stations in the Ems-Dollard during 1999–2001; bars indicate 95% confidence interval, (Kleef and Jager, 2002).

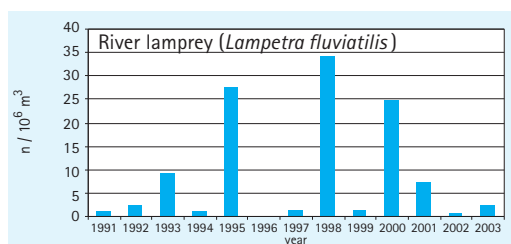


Figure 8.6.26: Abundance of river lamprey (*Lampetra fluviatilis*) derived from the fish monitoring program in the Meldorf Bight (Schleswig-Holstein Wadden Sea). The bars show the mean of all catches in August per year.

Figure 8.6.27:
Catch rates of brown shrimp (*Crangon crangon*) in the Dutch Wadden Sea (DFS-data): the annual mean (symbols) and the 5-year running mean (solid line).

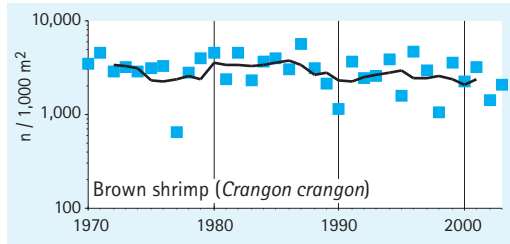


Figure 8.6.28:
Catch rates of brown shrimp (*Crangon crangon*) (autumns) in the Schleswig-Holstein region for 1974 to 2002 (DYFS data).

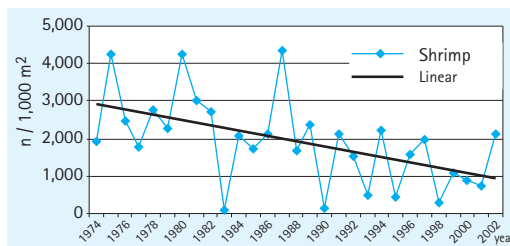
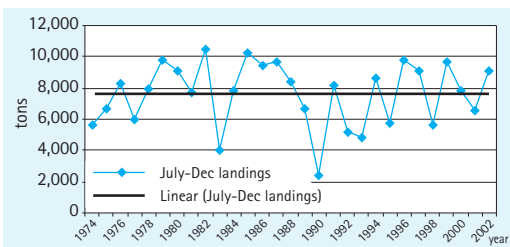


Figure 8.6.29:
Semi-annual landings of brown shrimp (*Crangon crangon*) (July to December) in Germany for 1974 to 2002.



sal species, but does not provide reliable quantitative data on pelagic species as that obtained with a stow net. Mesh size will largely determine whether or not small species and specimens are represented in the catches.

Besides gear, other factors can influence catch rates. Seasonal fluctuations must be known in order to properly interpret data from annual surveys. For example, catch rates of anchovy are generally higher in June than in August, stickleback sampling in the estuary should be carried out in first few months of the year, whereas 0-group flatfish should be monitored from summer to autumn. In addition, the area covered by a survey is important information when interpreting the data. Although the Demersal Fish Survey (Netherlands) and the Demersal Young Fish Survey (Germany) combined cover a large part of the Wadden Sea, these surveys of demersal fish are largely restricted to the tidal channels and gullies and are therefore mostly limited to habitats with medium to fine sandy sediments. The migratory fish surveys in the Ems-Dollard and in the Meldorf Bight both cover relatively small parts of the Wadden Sea. Moreover, the Dutch migratory fish survey is not a routine monitoring and was only carried out dur-

ing three years. Thus, survey results are of local validity and can differ between areas, e.g. twaite shad showing a stable population with an increasing trend in the Meldorf Bight and Elbe estuary, but an unstable situation in the Ems-Dollard.

When assessing the status of fish populations, and the changes in them, different geographic scales need to be considered. For example, in the Meldorf Bight small-scale differences (*i.e.* between stations) were found in the composition of functional groups (Vorberg, 2001). On a larger scale, when comparing fish fauna in Meldorf Bight and Hörnum Tief, differences in species diversity were found related to local habitat structure (e.g. hard substrate, sublittoral mussel beds) (Vorberg, unpubl. data).

The small changes in survey design during the execution of the DYFS are believed not to have severely influenced the abundance indices of fish. A more detailed analysis still needs to be made, especially for species with a seasonal pattern. This may be important for shrimp, where the timing of the survey is considered not optimal in view of the spring migration towards the shallower parts of the Wadden Sea (Siegel, 2003, pers. comm.). The effect of variability of environmental conditions on catch data is partly known but not well enough documented, e.g. the effect of weather, light intensity, turbidity, depths, sediment composition, tidal currents (Bolle *et al.*, 2001; Neudecker *et al.*, 1998) and might change results to some extent. However, strong year classes in fish or shrimp as well as clear trends will remain evident. Weak trends, however, could be the result of some bias due to underestimating the effects of environmental or seasonal factors. Conclusions have therefore to be drawn with great care and more research in this respect is necessary.

For this report we have collated all data available, but given the limitations within as well as between the surveys, this data cannot provide a comprehensive assessment of the status of fish in the Wadden Sea. Nevertheless, some important trends can be shown:

Herring, Sprat and Anchovy

Catch results for herring in the Meldorf Bight are in agreement with the development of the North Sea herring. After the population breakdown at the end of the 1970s and again in the mid 1990s, a successful fishery management and good reproduction has led to a stable and high standing stock. Sprat, on the other hand, shows a decreasing trend in the Meldorf Bight. This corresponds to North Sea data indicating low population size and recruitment success in the late 1990s (Zimmermann,

1998). A positive trend could be assessed for anchovy (Vorberg, 2003). The development of this species in the Wadden Sea area of Schleswig-Holstein is regarded a result of increased temperatures.

Twaiite shad

Twaiite shad is listed in Annex II of the Habitats Directive and classified as vulnerable in the red list of marine fishes of the Wadden Sea (Nordheim *et al.*, 1996). High numbers and an increasing trend of twaiite shad observed in the Meldorf Bight indicate a stable population, which uses the Elbe estuary for spawning. This would be in line with the improved stock in the German Bight (Stelzenmüller *et al.*, 2004). In the Ems-Dollard estuary the presence of adult and juvenile twaiite shad might indicate a local spawning population. Low numbers of 0-group twaiite shad in 1999 only, suggests that the population is not stable. Another possibility might be that the 0-group twaiite shad in the Ems estuary originate from, for example, the Elbe, where a fairly substantial spawning population exists (Thiel *et al.*, 1996).

Smelt

High densities of smelt occur in the Elbe River, especially in the lower reaches. An increasing consumer demand has led to an intensive fishery for the migrating fish. Since the end of the 1990s about 20-30 tons have been caught per year and the landings in 2003 even reached a new record of 45 tons.

Smelt is sensitive to low oxygen levels and may therefore be used as an indicator of water quality. In the Thames estuary, the smelt completely disappeared when water quality was poor due to the discharge of raw sewage. Smelt stocks managed to recover as water quality improved. Because the smelt is a good indicator of estuarine water systems, the recording of trend data of smelt population abundance is necessary. At present, such data is lacking.

River lamprey

The river lamprey is listed in Annex II of the Habitats Directive (Kloppmann *et al.*, 2003) and is classified as vulnerable in the red list of Wadden Sea fishes (Nordheim *et al.*, 1996). Hubold and Ehrich (2001) reported that river lampreys occur regularly in the German Bight since 1990 as well as in rivers flowing to the North Sea. Since 1998, fishermen in the Ems and Weser rivers found increasing numbers of river lampreys in their catches. Several hundreds of kilograms were thrown overboard due to the by-law on coastal fishery for Niedersachsen (Hagena, 2000).

Flatfish

The numbers of juvenile flatfish using the Wadden Sea as a nursery are clearly declining. The abundance of dab and 1-group plaice in particular has strongly decreased. The decline in flatfish in DFS catches is very prominent and has resulted in a decrease of the total catch weight. The lower catch rates in the Wadden Sea are mainly caused by an offshore shift in the distribution of juvenile flatfish, which, however, is unlikely to be related to local environmental changes within the Wadden Sea. The causal factors underlying this shift in distribution are not yet fully understood and certainly need further investigation.

Resident species

Five-bearded rockling and hooknose, classified as (near) resident species, do not show any clear trends in abundance over longer time periods, whereas the abundance estimates of the true resident species bull rout and eelpout seem to fluctuate on a decadal scale. Current catch rates are significantly lower than in the early 1980s, but not as a result of a continuous decline. It is plausible that the trends in abundance of bull rout and eelpout are related to the availability of suitable habitats, such as mussel beds, but no conclusive evidence has yet been presented to confirm this hypothesis. The possible effect of habitat change due to the development of Pacific oysters in the Wadden Sea has not been investigated at all.

Other species

In this QSR data for only twenty fish species of major importance is presented. It should be noted that the remaining species known from the area (*cf.* Witte and Zijlstra 1978; Vorberg and Breckling, 1999) may undergo changes of which we are not aware. The recently found increasing occurrence of reticulated dragonet (*Callionymus reticulatus*) in the German part of the Wadden Sea may serve as an example (Neudecker and Damm, 2004).

Brown shrimp

In certain years, brown shrimp suffered extreme predation by whiting. In more recent times, however brown shrimp have benefited from the extremely low stocks of cod and whiting and resulting low predation levels. Brown shrimp stocks seem to be in no way biologically endangered. According to present knowledge they may only suffer from short term natural changes or be subject to high exploitation rates which are generally compensated by new year-classes coming in following especially cold winters (Neudecker *et al.*, in prep.).

Regional shifts of the brown shrimp stocks are commonly known from fisheries and are partly reflected in the fluctuations of Dutch and German annual landings. A continuous decrease in the abundance and landings of brown shrimp on the French and Belgian coast (ICES, 2003; Tetard, pers. comm.) and a synchronous increase in the German–Danish region might indicate a biological response to climatic changes. This is a hypothesis which is not yet being investigated.

8.5.6 Recommendations

At present there is trend monitoring for demersal fish in the Dutch and German Wadden Sea (DFS and DYFS, respectively). Pelagic fish are being monitored only on a regional scale in the Schleswig–Holstein part of the German Wadden Sea. The Danish Wadden Sea is not covered by any such program. Therefore, the development of a trilateral monitoring program, based on trilateral targets to be developed, is recommended, which should take into account the following:

- The formulation of trilateral targets concerning fish is indispensable for structuring and focusing monitoring, and relevant concomitant research, of this important group of inhabitants of the Wadden Sea.
- A comprehensive monitoring of the Wadden Sea requires expansion of the spatial coverage of the demersal fish surveys in, for example, the Danish Wadden Sea and Weser – Jade region).
- The value of the current national monitoring programs can be increased by trilateral 'tuning' and harmonization of methods, gear and sampling sites and sampling times.
- More information should be collected on pelagic species (herring, smelt) and diadromous species. For the estuaries good data on smelt is required to be able to judge the state of these water systems.
- For pelagic fish monitoring a network of sampling sites has to be installed considering the spatial differences in the distribution of fish species in the trilateral Wadden Sea.
- For species showing a very strong seasonal pattern of abundance the present monitoring periods must be adapted.
- The functional relationship between fish species and habitats, e.g. the (sub)tidal mussel beds, eelgrass and reed beds should be investigated.
- For a better understanding of changes in the fish community, more knowledge of the (Wadden Sea specific) autecology of non-commercial species is required.

References

- Badsha, K.S. and Sainsbury, M., 1978. Aspects of the biology and heavy metal accumulation of *Ciliata mustela*. J. Fish. Biol. 12: 213-220.
- Beare, D., Burns, F., Jones, E., Peach, K., Portilla, E., Greig, T., McKenzie, E. and Reid, D., 2004. An increase in the abundance of anchovies and sardines in the northwestern North Sea since 1995. Global Change Biology, 10(7): 1209-1213.
- Beek, F.A. van, Rijnsdorp, A.D. and Clerck, R. de, 1989. Monitoring juvenile stocks of flatfish in the Wadden Sea and coastal areas of the southeastern North Sea. Helgoländer Meeresunters. 43: 461-477.
- Berghahn, R., 1996. Episodic mass invasions of juvenile gadoids into the Wadden Sea and their consequences for the population dynamics of brown shrimp (*Crangon crangon*). Mar. Ecol. 17 (1-3): 251-260.
- Boddeke, R., Daan, N., Posthuma, K.H., Veen, J.F. de and Zijlstra, J.J., 1969. A census of juvenile demersal fish in the Dutch Wadden Sea, the Zeeland nursery ground, the Dutch coastal area and the open sea areas off the coasts of The Netherlands, Germany and the southern part of Denmark. Ann. biol. Copenhagen 26: 269-275.
- Boddeke, R., Clerck, R. de, Daan, N., Müller, A., Postuma, K.H., Veen, J.F. de and Zijlstra, J.J., 1970. Young fish and Brown Shrimp survey in the North Sea. Ann. Biol. 27: 183-187.
- Boer, W.F. de, Welleman, H.C. and Dekker, W., 2001. De relatie tussen het voorkomen van vissoorten en garnaal in de Demersal Fish Survey in relatie tot het zoutgehalte en andere habitatvariabelen in de Waddenzee Oosterschelde en Westerschelde. Netherlands Institute for Fisheries Research, pp. 54.
- Bolle, L.J., Dapper, R., Witte, J.Y. and van der Veer, H.W., 1994. Nursery grounds of dab (*Limanda limanda* L.) in the southern North Sea. Neth. J. Sea Res. 32: 299-307.
- Bolle, L.J., Rijnsdorp, A.D., and van der Veer, H.W. 2001. Recruitment variability in dab (*Limanda limanda*) in the southeastern North Sea. J. Sea Res. 45: 255-270.
- Breckling, P. and Neudecker, T., 1994. Monitoring the fish fauna in the Wadden Sea with stow nets (Part 1): A comparison of demersal and pelagic fish fauna in a deep tidal channel. Arch. Fish. Mar. Res. 42 (1): 3-15.
- Cushing, D.H. and Dickson, R.R., 1976. The biological response in the sea to climate changes. Adv. Mar. Biol. 14: 1-122.
- Dekker, W., 2004. Slipping through our hands. Population dynamics of the European eel. Dissertation, ISBN 90-74549-10-1.
- Duncker, G. and Ladiges, W., 1960. Die Fische der Nordmark. Kommissionsverlag Cram, de Gruyter u. Co., Hamburg, pp. 432.
- Ehrenbaum, E., 1936. Naturgeschichte und wirtschaftliche Bedeutung der Seefische Nordeuropas. Schweitzerbart, Stuttgart.
- Elliott, M.F. and Dewailly, F., 1995. The structure and components of European estuarine fish assemblages. Neth. J. Aquat. Ecol. 29: 397-417.
- Elliott, M. and Hemingway, K.L., 2002. Fishes in estuaries, London, Blackwell science, pp. 636.
- Fonds, M., 1978. The seasonal distribution of some fish species in the western Dutch Wadden Sea. In: Dankers, N., Wolff, W. J. and Zijlstra, J.J. (Eds.), 1978. Fishes and fisheries in the Wadden Sea. Report 5 of the final report of the section 'Fishes and fisheries' of the Wadden Sea Working Group. Stichting Veth tot Steun aan Waddenonderzoek, Leiden, 42-77.
- Fonds, M., Jaworski, A., Iedema, A. and Puyl, P.v.d., 1989. Metabolism, food consumption, growth and food conversion of the shorthorn sculpin (*Myoxocephalus scorpius*) and eelpout (*Zoarces viviparus*). ICES CM 1989/G:31, pp. 10.
- Fonds, M., Cronie, R., Vethaak, A.D. and Puyl, P.v.d., 1992. Metabolism, food consumption and growth of plaice (*Pleuronectes platessa*) and flounder (*Platichthys flesus*) in relation to fish size and temperature. Neth. J. of Sea Res. 29: 127-143.
- Grift, R.E., Tulp, I., Clarke, L., Damm, U., McLay, A., Reeves, S., Vigneau, J. and Weber, W., 2004. Assessment of the ecological effects of the Plaice Box. Report of the European Commission Expert Working Group to evaluate the Shetland and Plaice boxes. Brussels, pp. 121.
- Groot, S.J. de, 1989. Decline of the catches of coregonids and migratory smelt in the lower Rhine, the Netherlands. ICES C.M. 1989/M:18. Anadromous and catadromous fish committee.
- Groot, S.J. de, 1992. Herstel van riviertrekvisen een realiteit? 8. De fint. De Levende Natuur 93(6): 182-186.
- Groot, S.J. de, 2002. A review of the past and present status of anadromous fish species in the Netherlands: is restocking the Rhine feasible? Hydrobiologia 478: 205-218.
- Hagena, W., 2000. Die Kleine Hochsee- und Küstenfischerei Niedersachsens und Bremens im Jahr 1999. Das Fischerblatt, 2000/Nr. 3, 89-109.
- Hubold, G. and Ehrich, S., 2001. Bedrohte Meeresfischarten wieder häufiger. Presseinformation Nr. 359 vom 12.12.2001, Inst. f. Seefischerei der Bundesforschungsanstalt für Fischerei, Hamburg.
- ICES, 2003. Report of the working group on *Crangon* fisheries and life history. ICES CM 2003/G:01, 56 pp.
- ICES, 2004a. Report of the Working Group on the Assessment of Demersal Stocks in the North Sea and Skagerrak (Boulogne-sur-Mer, 9-18 September 2003). ICES CM 2004/ACFM.
- ICES, 2004b. Report of the ICES/EIFAC Working Group on Eels. ICES C.M. 2004/ACFM:09.
- Jager, Z., 1999. Processes of tidal transport and accumulation of larval flounder (*Platichthys flesus* L.) in the Ems-Dollard nursery. Ph.D. thesis, Amsterdam University, ISBN 90-9012525-6.
- Jensen, A.R., Nielsen, H.T. and Ejbye-Ernst, M., 2003. National Management Plan for the Houting. Publ. by the Ministry of the Environment and Energy, the Forest and Nature Agency, the County of Sønderjylland and the County of Ribe, pp. 34.
- Jonge, V.N. de, Essink, K. and Boddeke, R., 1993. The Dutch Wadden Sea: a changed ecosystem. Hydrobiologia 265: 45-71.
- Kleef, H.L. and Jager, Z., 2002. Het diadrome visbestand in het Eems-Dollard estuarium in de periode 1999 tot 2001. Rapport RIKZ/2002.060. Rijksinstituut voor Kust en Zee, Haren.
- Kloppmann, M.H.F., Böttcher, U., Damm, U., Ehrich, S., Mieske, B., Schultz, N. and Zumholz, K., 2003. Erfassung von FFH-Anhang II-Fischarten in der deutschen AWZ der Nord- und Ostsee. Bericht i. A. des Bundesamtes für Naturschutz, F+E-Vorhaben FKZ: 802 85 200, Bundesforschungsanstalt für Fischerei, Hamburg und Rostock, pp. 82.
- Knijn, R. J., Boon, T.W., Heessen, H.J.L. and Hislop, J.R.G., 1993. Atlas of North Sea Fishes. ICES cooperative research report, No. 194.
- Kühl, H., 1961. Nahrungsuntersuchungen an einigen Fischen im Elbe-Mündungsgebiet. Berichte der Deutschen Wissenschaftlichen Kommission für Meeresforschung 16(2), 90-104.

- Lozán, J.L., Breckling, P., Fonds, M., Krog, C., Veer, H.W. van der and Witte, J.J., 1994. Über die Bedeutung des Wattenmeeres für die Fischfauna und deren regionale Veränderung. In: Lozán, J.L., Rachor, E., Reise, K., Westernhagen, H. von and Lenz, W. (Eds.), 1994. Warnsignale aus dem Wattenmeer, Blackwell, Berlin, 226-234.
- Maitland, P.S. and Hatton-Ellis, T.W., 2003. Ecology of the Alis and Twaite Shad. *Conserving Natura 2000 Rivers Ecology Series No.3*, English Nature, Peterborough.
- Neudecker, T., 1990. Ursachen für die geringen Fänge in der 'Krabbenfischerei'. *Inf. Fischwirtsch.* 37 (4): 136.
- Neudecker, T., 1999. Die Entwicklung des Aufwandes in der deutschen Garnelenfischerei. *Inf. Fischwirtsch. Fischereiforschung* 46 (4): 9-13.
- Neudecker, T., 2001. Der Demersal Young Fish Survey (DYFS) in Schleswig-Holstein – Entwicklung und derzeitiger Stand. In: Landesamt für den Nationalpark Schleswig-Holsteinisches Wattenmeer (Hrsg.), 2001. *Wattenmeermonitoring 2000*. Schriftenreihe des Nationalparks Schleswig-Holsteinisches Wattenmeer, Sonderheft, 24-30.
- Neudecker T. and Damm, U., 2004. Recognition of a third callionymid species, *Callionymus reticulatus* Valenciennes 1837 (reticulated dragonet), in the south-eastern North Sea. *J. Appl. Ichthyol.*, 20(3): 204-210.
- Neudecker T., Fischer, J. and Damm, U., 1998. Influence of tidal currents on fishing performance in the Wadden Sea. ICES C.M. 1998/BB:6 (Theme Session (BB) on Fisheries Assessment Methods), pp. 11.
- Neudecker, T., Damm, U. and Purps, M., 1999. Langzeitreihen – Fischbeifang aus der Garnelenfischerei. Abschlussbericht, Umweltbundesamt, UFOPLAN-Nr. 294 25 271 (226 Seiten, 22 Tabellen, 246 Abbildungen und 28 Literaturangaben). Unpublished report.
- Neudecker, T., Stein, M., Damm, U. and Kellermann, H.-J. (in prep.) (submitted to Fisheries Oceanography).
- Nordheim, H. von, Norden Anderson, O. and Thiessen, J. (Eds.), 1996. Red List of Biotores, Flora and Fauna of the Trilateral Wadden Sea Area, 1995. *Helgoländer Meeresunters.* 50, (Suppl.).
- Pastors, M., Bolle, L., Groeneveld, K., Groot, P., Leeuwen, P. van, Piet, G., Rijnsdorp, A., and Rink, G., 2000. Evaluatie van de scholbox. RIVO rapport C002/00. Rijksinstituut voor Visserij Onderzoek, IJmuiden.
- Rijnsdorp, A.D., Stralen, M. van and Veer, H.W. van der, 1985. Selective tidal transport of North Sea plaice larvae *Pleuronectes platessa* in coastal nursery areas. *Trans. Am. Fish. Soc.* 114, 461-470.
- Stelzenmüller V., Maynou, F., Ehrich, S. and Zauke, G.-P., 2004. Spatial analysis of twaite shad, *Alosa fallax* (Lacépède, 1803), in the Southern North Sea: Application of non-linear geostatistics as a tool to search for Special Areas of Conservation. *International Review of Hydrobiology*, 89: 337-351
- Talbot, J.W., 1976. The dispersal of plaice eggs and larvae in the Southern Bight of the North Sea. *J. Cons. int. Explor. Mer* 37: 221-248.
- Thiel, R., Sepulveda, A. and Oesmann, S., 1996. Occurrence and distribution of twaite shad (*Alosa fallax* Lacépède) in the lower Elbe estuary. *J. Fish Biol.* 46: 47-69.
- Tiewes, K., 1978. The predator-prey relationship between fish populations and the stock of brown shrimp (*Crangon crangon* L.) in German coastal waters. *Rapp. P.-v. Réun. Cons. Int. explor. Mer* 172; 250-258.
- Tiewes K., 1990. 35-Jahrestrend (1954-1988) der Häufigkeit von 25 Fisch- und Krebstierbeständen an der deutschen Nordseeküste. *Arch. Fisch Wiss.* 40: 39-48.
- Tiewes K. and Wienbeck, H., 1990. Grundlagenmaterial zu '35-Jahrestrend (1954-1988) der Häufigkeit von 25 Fisch- und Krebstierbeständen an der deutschen Nordseeküste'. Veröff. Inst. f. Küsten- und Binnenfisch. 103, pp. 64.
- TMAG, 1997. TMAP Manual. The Trilateral Monitoring and Assessment Program (TMAP). Trilateral Monitoring and Assessment Group, Common Wadden Sea Secretariat, Wilhelmshaven.
- Trilateral Wadden Sea Plan, 1997. In: Ministerial Declaration of the Eighth Trilateral Governmental Conference on the Protection of the Wadden Sea, Stade 1997, Annex 1. Common Wadden Sea Secretariat, Wilhelmshaven, pp. 13-83.
- Tulp, I., Willigen, J.A. van and Leeuw, J.J. de, 2002. Diadrome vis in de Waddenzee: resultaten van monitoring 2000-2002. RIVO rapport nr. C065/02.
- Vorberg, R., 2001. Zehn Jahre Fischmonitoring. In: Landesamt für den Nationalpark Schleswig-Holsteinisches Wattenmeer (Hrsg.). *Wattenmeermonitoring 2000*. Schriftenreihe des Nationalparks Schleswig-Holsteinisches Wattenmeer, Sonderheft, 21-23.
- Vorberg, R., 2003. Sardelle wieder im deutschen Wattenmeer heimisch. *Das Fischerblatt* 2003/Nr. 1, 4-6.
- Vorberg, R. and Breckling, P., 1999. Atlas der Fische im schleswig-holsteinischen Wattenmeer. Schriftenreihe des Nationalparks Schleswig-Holsteinisches Wattenmeer, Heft 10, pp. 178.
- Wintermans, G.J.M. and Jager, Z., 2001. Verslag visintrek Waddenzee kust voorjaar 2001. WEB-rapport 01-04.
- Wintermans, G.J.M. and Jager, Z., 2002. Verslag visintrek Waddenzee kust voorjaar 2002. WEB-rapport 02-04; Werkdocument RIKZ/OS/2002.610x.
- Wintermans, G.J.M. and Jager, Z., 2003. Verslag visintrek Waddenzee kust voorjaar 2003. WEB-rapport 03-03; Werkdocument RIKZ/OS/2003.602x.
- Witte, J.Y., Dapper, R., Noort, G.J. van and Veer, H.W. van der, 1991. De verspreiding van vissen op het Nederlands continentaal plat van de Noordzee, Netherlands Institute for Sea Research, pp. 110.
- Witte, J.Y. and Zijlstra, J.J., 1978. The species of fish occurring in the Wadden Sea. In: Dankers, N.; Wolff, W. J. and Zijlstra, J.J. (Eds.), 1978. *Fishes and fisheries in the Wadden Sea*. Report 5 of the final report of the section 'Fishes and fisheries' of the Wadden Sea Working Group. Stichting Veth tot Steun aan Waddenonderzoek, Leiden, 5-19.
- Zijlstra, J.J., 1972. On the importance of the Wadden Sea as a nursery area in relation to the conservation of the southern North Sea fishery resources. *Symp. zool. Soc. Lond.* 29: 233-258.
- Zijlstra, J.J., 1978. The function of the Wadden Sea for the members of its fish-fauna. In: Dankers, N.; Wolff, W.J. and Zijlstra, J.J. (Editors). *Fishes and fisheries in the Wadden Sea*. Report 5 of the final report of the section 'Fishes and fisheries' of the Wadden Sea Working Group. Stichting Veth tot Steun aan Waddenonderzoek, Leiden, 20-25.
- Zimmermann, C., 1998. Aktuelle Entwicklung der Herings- und Sprottenbestände südlich des 62. Breitengrades. *Inf. Fischwirtschaft* 45 (2): 68-72.