Review of the spatial and temporal distribution by life stage for 19 North Sea fish species

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Contents

Summary

Considering the increase in human activity in the North Sea, particularly cargo shipping and the rapidly expanding construction and operation of oil platforms and wind farms, as well as the continued use of the area for military purposes, fisheries and sand extraction, there is a growing concern about the potentially harmful impacts of such anthropogenic activities on marine life. Particular concerns have been raised about the effect of loud impulse sounds and high noise levels, which may affect marine animal life in different ways: habitat use, such as feeding and migration, and reproduction patterns may be disturbed. In the extreme case animals may suffer from sub-lethal or lethal physical damage such as hearing loss and disrupted swim bladders.

Knowledge of the spatial distribution and seasonal patterns in the presence of different life stages of marine species is therefore critical for assessing to what extent the dispersion of marine life overlaps with the distribution of human activities and for estimating how potentially harmful impacts can be mitigated both spatially and temporally. The aim of this desk study is consequently to provide a concise overview of existing information on seasonal patterns in the dispersion of fish species in the North Sea, in particular by highlighting the knowledge gaps.

A selection of 37 fish species was made for this study based on their significance (abundance, key-species within environmental protection policies, relevance as a prey-species for birds and mammals) in the Dutch Exclusive Economic Zone (EEZ). 19 out of the 37 selected fish species were then chosen for review of the existing knowledge about their spatial distribution and seasonal patterns for different life stages, based on the ecological value of the species within the marine ecosystem. The review is based on published literature, scientific papers and reports, and focused on species and life-stage specific temporal and spatial distributions in the North Sea and in particular within the Dutch EEZ. Each species was reviewed individually according to a format which is clear and concise with easy access to information on a certain species. This was aided by presenting a table for each species with an overview of our best estimates of the importance of the Dutch EEZ for the individual life stages thoughout the year.

It was found that for all of the selected species in this report, some biological information on the different life stages and the spatial distribution and seasonal patterns is available, however, the amount and detail of available data differs considerably between the selected species. Commercially important species are generally better studied than rare or less commercially interesting species. Also more knowledge is available on the distribution and seasonal migrations of adults, while often only sparse information exists on the early life history stages (eggs and larvae). On top of this, much of the information appears to be outdated. These knowledge gaps and uncertainties imply that for many of the species it is difficult to estimate the relative importance of the Dutch EEZ for the population. Yet, this desk study may be considered to give a complete overview of the currently available knowledge.

1 Introduction

Human activity in the North Sea is increasing, involving more motorized cargo shipping, and rapidly expanding construction and operation of oil platforms and wind farms. Furthermore, the North Sea is used on a large scale for military purposes, fisheries, and the extraction of sand (Paramor et al. 2009). These anthropogenic activities are sources of disturbance for the abiotic and biotic environment. Activities, specifically uncontrolled activities, may have unexpected, unwanted and possibly even irreversible effects on the marine ecosystem.

There is growing concern about the potential harmful impact of sound caused by human activities on marine life. Loud impulse sounds, such as from pile driving, involves brief extremely high noise levels, and common activities such as shipping and operational wind farms cause moderate to low but long-term noise levels. These unnatural anthropogenic sounds may affect marine animal life in different ways: habitat use, such as feeding and migration, and reproduction patterns may be disturbed. In the extreme case animals may suffer from sub-lethal or lethal physical damage, such as hearing loss and disrupted swim bladders. Hence, anthropogenic underwater noise may potentially have negative consequences for individual fitness and population health of marine life.

Knowledge of the spatial distribution and seasonal patterns in the presence of different life stages of marine species is critical for assessing to which extent the dispersion of the marine life overlaps with the distribution of human disturbances, including sound effects, and how harmful activities can be mitigated both spatially and temporally. Such knowledge of fish species in the North Sea is available, though at a low resolution. Information on seasonal patterns in the dispersion of fish species in the North Sea is either non-existing (coastal areas) or outdated (early '90-s). If a fish species is less commercially attractive or rare, knowledge of the species decreases, especially when it concerns early life stages. By presenting an overview of the existing information in this report, a clear outline of the knowledge gaps becomes apparent.

2 Assignment

Prior to the assignment, a selection of 37 fish species has been made based on their significance in the Dutch Exclusive Economic Zone (EEZ). Significance was defined by

- i) abundance,
- ii) key-species within environmental protection policies (e.g. Flora en Fauna wet (Ff), Natuurbeschermingswet (Nb)), and
- iii) relevance as a prey-species for birds and mammals (according to Leopold and Jansen, unpubl.).

The selected species cover a diverse range of habitats (i.e. pelagics and demersals, offshore and nearshore), and include both resident species, which spend their full life cycle in one specific area, and migrating fish which utilize different areas throughout their life, such as spawning, nursery and feeding grounds. Five of the selected species can be potentially used in experimental studies on the effects of underwater sounds on fish and fish larvae (sole, sea bass, cod, herring, and sprat), based on the fact that they can be reared (laboratory experiments) or tagged (field experiments) relatively easily.

In the framework of this assignment, 19 out of the 37 selected fish species were chosen for review of the existing knowledge of their spatial distribution and seasonal patterns for different life stages, with a focus on the Dutch EEZ. The second selection was based on the ecological value of the species within the marine ecosystem - i.e. species that fulfil both the criteria of being abundant as well as being prey for higher trophic levels - and the potential for being used in studies on the effects of underwater noise on fish. An overview of the selected species is given in Table 2.1.

Table 2.1: Selected fish species and criteria for selection (A=Abundant, P=Prey, K=Key species within environmental policies (Ff+Nb), U=species potentially used in studies on the effects of Underwater noise). Species in bold are incorporated in this review.

Scientific name	English name	Dutch name	Criteria
Lampetra fluviatilis	River lamprey	Rivierprik	*K*
Petromyzon marinus	Sea lamprey	Zeeprik	*K*
Acipenser sturio	Sturgeon	Steur	*K*
Anguilla anguilla	Eel	Aal	*K*
Alosa alosa	Allis shad	Elft	*K*
Alosa fallax	Twaid shad	Fint	*K*
Clupea harengus	**Atlantic herring**	**Haring**	**P,A,U**
Sprattus sprattus	**Sprat**	**Sprot**	**P,A,U**
Coregonus lavaretus oxyrinchus	Houting	Houting	*K*
Salmo salar	Salmon	Zalm	*K*
Gadus morhua	**Cod**	**Kabeljauw**	**P,U**
Trisopterus minutus	Poor cod	Dwergbolk	*P*
Trisopterus luscus	Bib	Steenbolk	*P*
Merlangius merlangus	**Whiting**	**Wijting**	**P,A**
Zoarces viviparus	Eelpout	Puitaal	*P*
Syngnathus rostellatus	Nilsson's pipefish	Kleine zeenaald	*A*
Trigla lucerna	Tub gurnard	Rode poon	*P*
Eutrigla gurnardus	**Grey gurnard**	**Grauwe poon**	**P,A**
Myoxocephalus scorpius	Bull-rout	Zeedonderpad	*P*
Trachurus trachurus	**Horse mackerel**	**Horsmakreel**	**P,A**
Dicentrarchus labrax	**Sea bass**	**Zeebaars**	**U**
Echiichthys vipera	Lesser weever	Kleine pieterman	*A*
Pholis gunellus	Butterfish	Botervis	*P*
Ammodytes tobianus	**Small sandeel**	**Kleine zandspiering**	**P,A**
Ammodytes marinus	**Lesser sandeel**	**Noorse zandspiering**	**P,A**
Hyperoplus lanceolatus	Greater sandeel	Smelt	*A*
Callionymus lyra	**Common dragonet**	**Gewone pitvis**	**P,A**
Pomatoschistus minutus	**Sand goby**	**Dikkopje**	**P,A**
Pomatoschistus microps	**Common goby**	**Brakwater grondel**	**P,A**
Pomatoschistus lozanoi	**Lozano's goby**	**Lozanoi grondel,**	**P,A**
Scomber scombrus	**Mackerel**	**Makreel**	**P,A**
Arnoglossus laterna	Scaldfish	Schurftvis	*A*
Limanda limanda	**Dab**	**Schar**	**P,A**
Platichthys flesus	**Flounder**	**Bot**	**P,A**
Pleuronectes platessa	**Plaice**	**Schol**	**P,A**
Solea solea	**Sole**	**Tong**	**P,A,U**
Buglossidium luteum	**Solenette**	**Dwergtong**	**P,A**

3 Methods

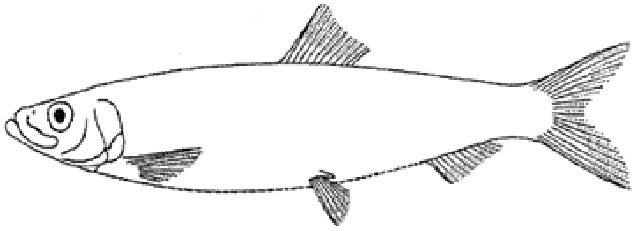
A review was performed based on published literature, scientific papers and reports. The review focused on species and life-stage specific temporal and spatial distributions in the North Sea and in particular within the Dutch EEZ. However, in many cases, literature was not specific to the North Sea or the Dutch EEZ, or available at species level for all life stage. In these cases, broader data is presented and an interpretation of how the data relates to the population in the North Sea and in particular the Dutch EEZ, is presented in the conclusion section for each species.

Each species was reviewed individually, with a concluding section on what the importance is of the Dutch EEZ for each life-stage of the species in question. The conclusions were followed by relevant references pertaining to that particular species. This format facilitates finding and accessing information on a certain species.

In each species specific conclusion section on the importance of the Dutch EEZ, a table is presented to provide an overview of our best estimates of the importance of this area for the individual life stages during different times of the year. Here, we based ourselves on the relative importance of the proportion of the population in the Dutch EEZ compared to the whole North Sea population. If less then 5% (based on visual inspection of the distribution maps) of the whole North Sea population occurred in the Dutch EEZ, we interpreted it as low importance (yellow), if 5% to 50% of the whole North Sea population occurred on the Dutch EEZ we interpreted it as medium (orange), and where over 50% of the population occurred in the Dutch EEZ, we interpreted it is as high (red) importance. However, in some cases, it is only known that the life stage or species occurs on the Dutch EEZ, but there is no information on the proportion of the North Sea population that occurs on the Dutch EEZ, or there is a general lack of information on the North Sea population itself. In these cases, we chose not to report the importance, but shade the cell of the table (grey), i.e. present but importance unknown.

4 Results

4.1 Atlantic herring – *Clupea harengus* (Linnaeus, 1758)



4.1.1 Introduction

Herring is a boreal benthopelagic species (Yang 1982, Ellis et al. 2002, Ellis et al. 2008) and is widely distributed in the north-west and north-east Atlantic, where they are distributed from the northern Bay of Biscay to Greenland, and east into the Barents Sea. They are mostly found in continental shelf seas to depths of 200m (Whitehead 1986), however, the Atlanto-Scandian herring disperses widely over the abyssal plains during its feeding migrations between Norway, Iceland and Greenland.

Herring can reach a maximum length of 40cm (North Sea adults range from 20-30cm) and a maximum reported age of 22 years (most North Sea herring are younger then 7 years). On average, more than 60% of the 2-year-olds and 95% of the 3-year olds are mature. Herring are iteroparous determinate spawners and have sticky demersal eggs that attach to coarse sand, gravel, shells and small stones during spawning. After hatching, the pelagic larvae drift to shallow nursery areas to metamorphose to juveniles, and after around 2 years, they move into deeper water as adults, and migrate (Corten 1996).

The Atlantic herring (*Clupea harengus*) is one of five clupeid species that occur in the North Sea. The North Sea herring stock is made up of a number of components (sub-populations) of fish that show different physical characteristics, spawning strategies and migration behaviour (Zijlstra 1958). These were originally called races of herring (Heincke 1898, Redeke and van Breemen 1907, Bjerkan 1917) but are now considered to be parts of the same stock as they are genetically indistinguishable (EU HERGEN project) and all mix at certain points of their life cycle (ICES 1965, Cushing and Bridger 1966, Cushing 1992). Variability in their environment (particularly temperature) during spawning, hatching and the first year of life is thought to create the differences between component parts of the stock by influencing growth and physical development (Jennings and Beverton 1991; Hulme 1995, McQuinn 1997). These physical differences are referred to as meristic characteristics (Zijlstra 1958, Hulme 1995, Heath et al. 1997).

Herring form large shoals, with diurnal vertical migration patterns through the water column. During the day, herring shoals tend to remain close to the sea bottom or in deep water to a depth of 200 m. At dusk they move towards the surface and disperse over a wider area during the night. Due to the shoaling behaviour, herring are an easy target for directed fisheries (purse seine and trawls) for human consumption, which use echo-sounding equipment to locate the shoals. Herring is also caught by industrial fisheries and reduced to extract fish meal and oil.

4.1.2 Eggs

Temporal occurrence of eggs:

The main herring sub-population in the North Sea is the autumn/winter spawner. These herring start spawning around August in Shetland/Orkney, in August-September on the Aberdeen Bank, in August-October in the Central North Sea and in November-January (Corten 1996; Schmidt et al. 2009) in the southern North Sea and the English Channel. The different times for the start of spawning is directly related to water temperature, with spawning commencing when temperatures

fall below 12°C. This occurs in the northern areas first, and in the southern areas this happens later in the season (Corten 1996).
Besides these autumn spawners, there are some 'races' of spring spawners. In the North Sea, mainly in the southern North Sea, some smaller populations of spring spawners occur.

Spatial distribution of eggs:
Spawning is restricted to areas with coarse sand, gravel, shells and small stones, because the demersal eggs stick well to these substrates. Since these areas are relatively small, there are often many layers of eggs deposited. This is detrimental for the eggs in the bottom layers as they do not get enough oxygen. Even when the eggs are not in thick layers, they need a continuous supply of oxygen-rich water. Furthermore, the eggs are vulnerable to becoming become covered by silt or sand and spawning areas are therefore located where there are strong tidal currents and hard substrates. The spawning areas are shown in figure 4.1.1.

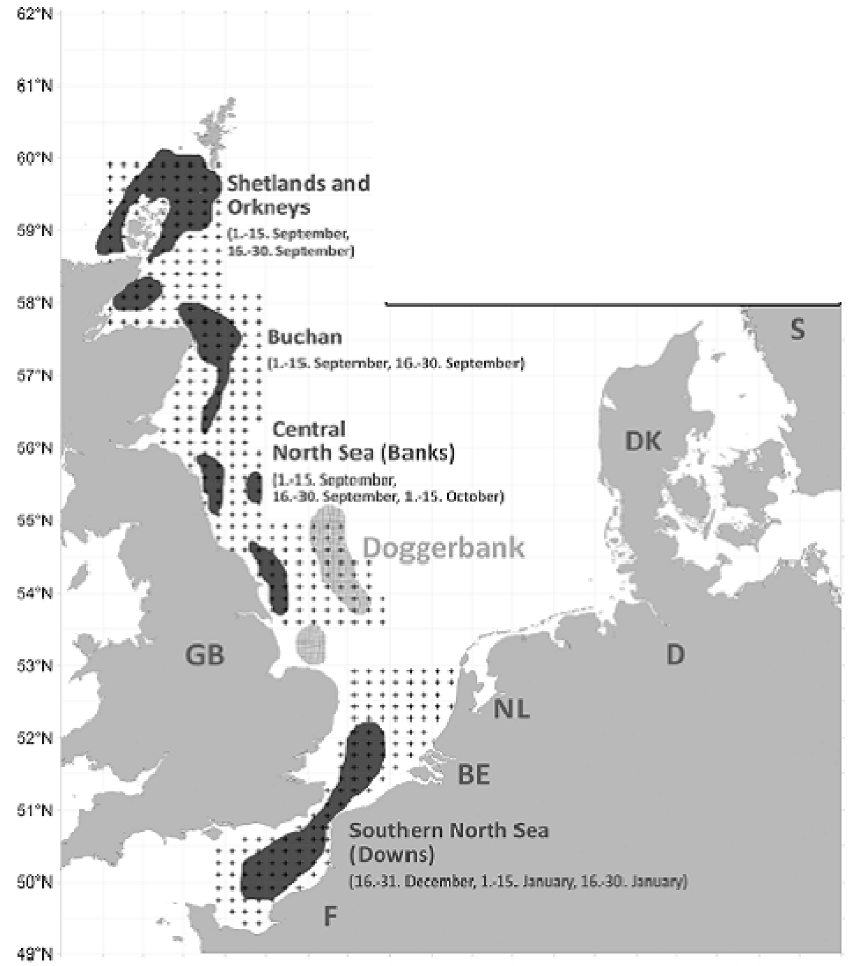


Fig. 4.1.1: Spawning areas of the autumn and winter spawning herring (dark grey) and historic spawning grounds (light grey). The small crosses indicate the station grid of the International Herring Larval Survey (from Schmidt et al. 2009).

4.1.3 Larvae

Temporal occurrence of larvae:
After one to two weeks the eggs hatch and the larvae are passively transported by the residual current. In the period November to March, most of the larvae drift from the western and southern part of the North Sea to the shallower coastal areas in the eastern North Sea and Skagerrak/Kattegat. In the Wadden Sea the larvae from the western North Sea appear from February, while those from the southern North Sea appear from March and are smaller then those from the western areas (Corten and van de Kamp 1979).
In the samples of the Helgoland roads station (54°11.18 N and 07°54.00 E), only a very small number of herring larvae were collected, these were all collected in March (Malzahn and Boersma 2007).

Spatial occurrence of larvae:
Herring larvae are sampled each year from September to January to cover the known timing of herring spawning. The sampling grid covers the areas of known herring spawning sites (Fig. 4.1.1). Based on the survey data an index of herring abundance is calculated, which is used by the ICES herring assessment working group. The spatial distribution of larvae in September, December and January is shown in figure 4.1.3. The distribution of larvae sampled in February is shown in figure 4.1.2. Larvae are shown to drift to the eastern coastal areas, into the Wadden Sea and the Skagerrak/Kattegat. These larvae are called 0-ringers or 0-group herring. The concepts of age and year class are a bit problematic in herring, because of the extended spawning season of autumn spawners from September to January. Herring scientists generally refer to the number of rings seen in otoliths, which means that all autumn spawners and spring spawners from one spawning season are combined in one cohort of 0-ringers, 1-ringers, etc. Using the convention of January 1st as the birthday, 0-ringers or 0-group refer to fish born between between 3 and 18 months ago.

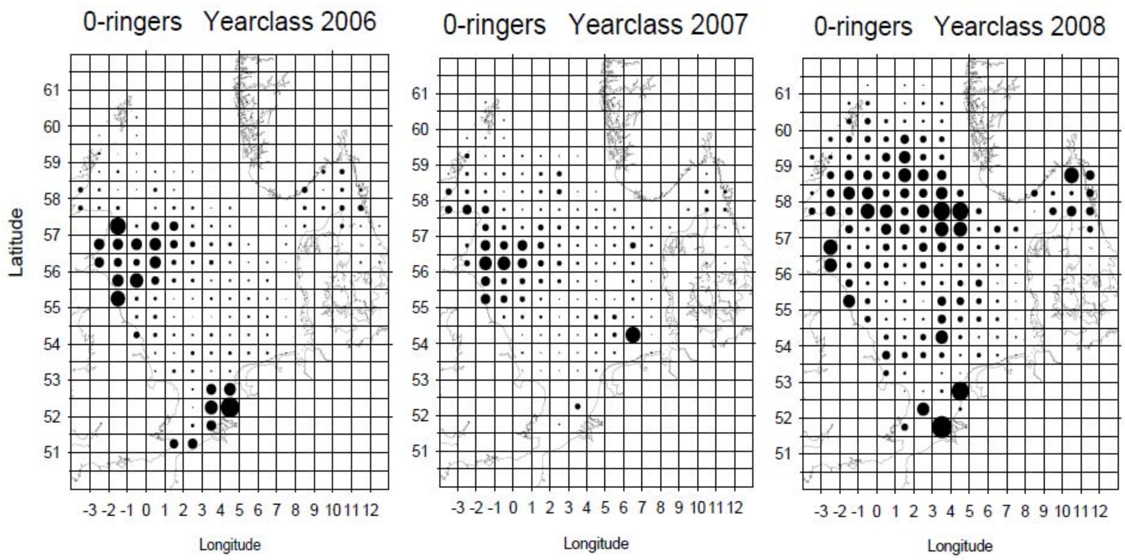


Fig. 4.1.2. Distribution of 0-ringer herring (born during the last spawning season), year classes 2006-2008. Density estimates of 0-ringers within each statistical rectangle are based on MIK catches during IBTS in February 2007-2009. Areas of filled circles illustrate densities in no m^{-2}, the area of a circle extending to the border of a rectangle represents 1 m^{-2} (ICES 2009a).

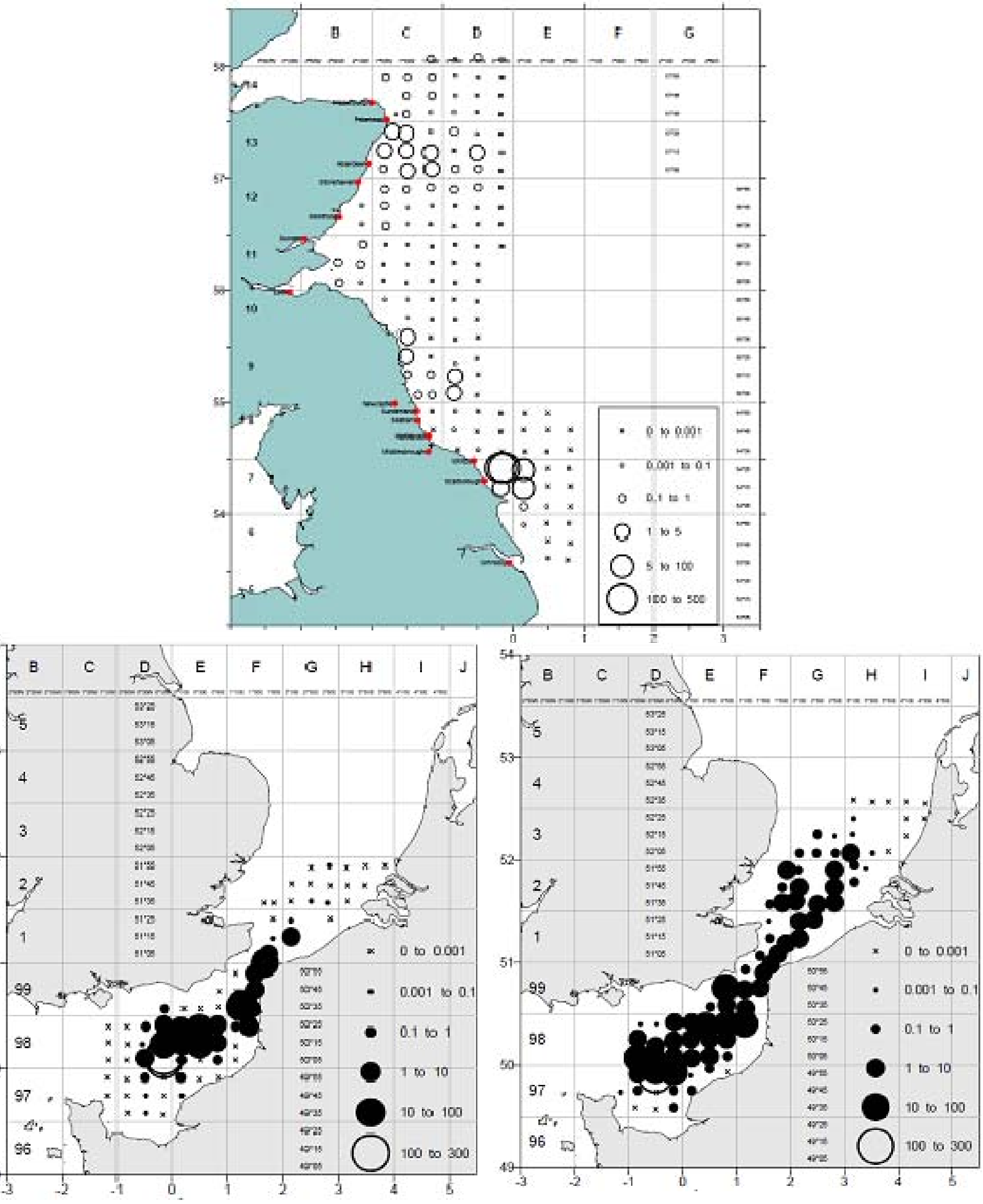


Fig. 4.1.3. Number of herring larvae per m^3 of filtered water, collected in September (upper) December (lower left) and January (lower right; from van Damme and Bakker 2009).

4.1.4 Juveniles

Spatial occurrence and seasonal migrations:

When herring larvae reach the coastal waters they metamorphose at a length of about 5cm. However, some of the larvae metamorphose in the western North Sea far from the coast (Corten 1996) and remain as juveniles within these offshore waters. Whilst most juveniles are distributed in the coastal waters of Denmark, Germany and the Netherlands some may spend their first summer in the Skagerrak/Kattegat. In Dutch waters, the Wadden Sea is an important area for the juveniles, but they are also found in the estuaries of Zeeland.

At the end of the summer, juveniles migrate to deeper waters, and during the following spring the 1-group herring are found in the south-eastern North Sea (Fig. 4.1.4, 4.1.5). During this year the juveniles grow to a length of 20cm and move slowly to deeper more northern areas. In their third year they spread even further and after their third summer they join the adults.

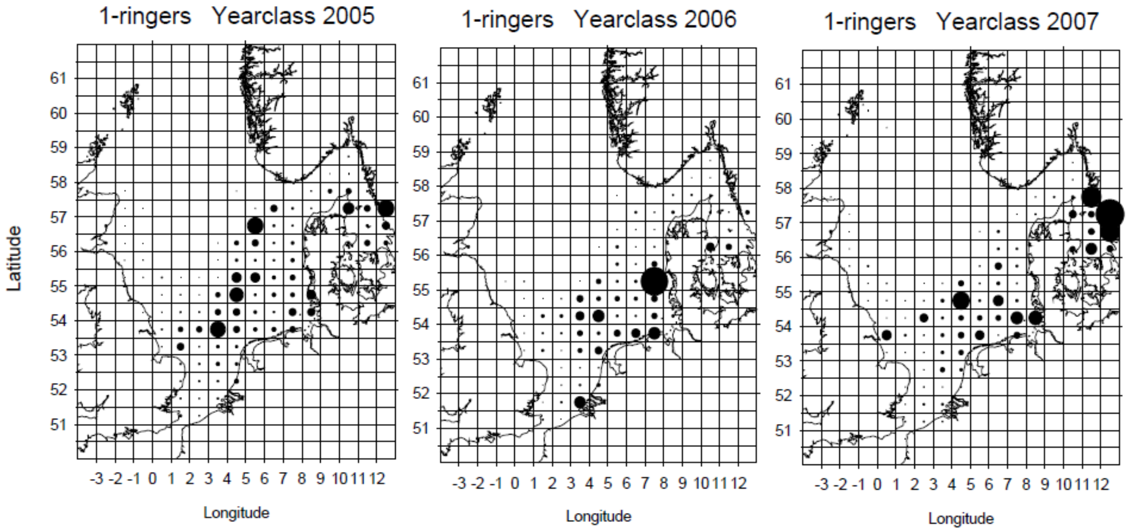


Fig. 4.1.4. Distribution of 1-group herring, year classes 2005-2007. Density estimates of 1-ringers within each statistical rectangle are based on GOV catches during IBTS in February 2007-2009. Areas of filled circles illustrate numbers per hour, the area of a circle extending to the border of a rectangle represents 45000 h-1 (ICES 2009a).

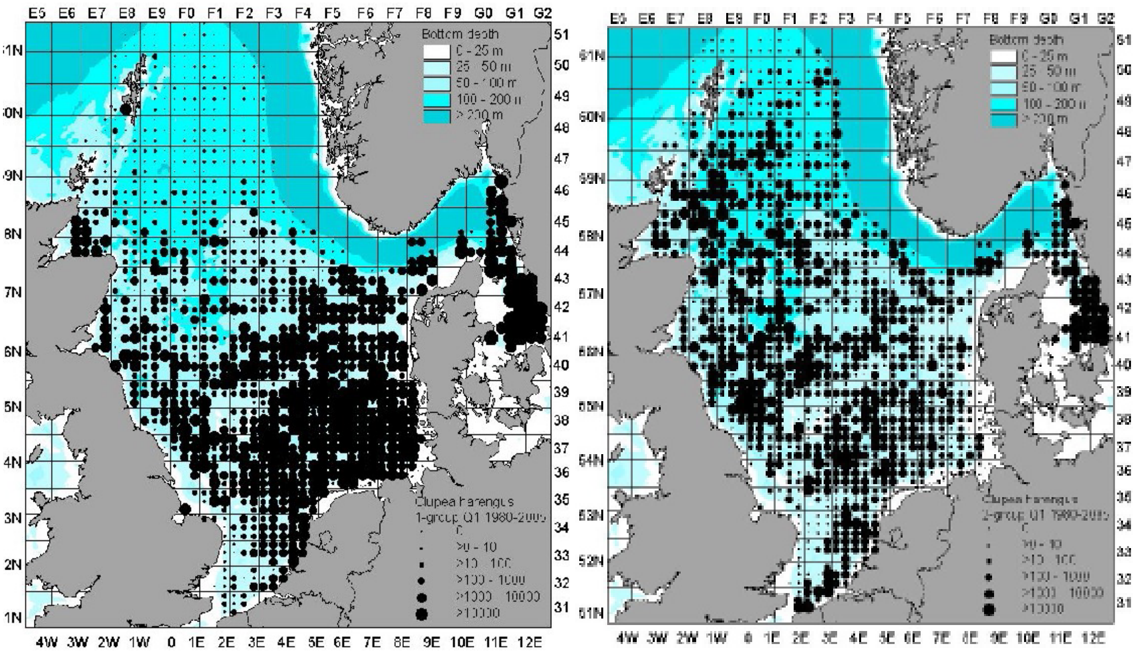


Fig. 4.1.5. Average annual catch rate (number per hour fishing) for 1-group herring (left) and 2-group (right) in quarter 1, based on the International Bottom Trawl Survey (IBTS) in 1977-2005 (from ICES fish atlas).

4.1.5 Adults

Spatial occurrence and seasonal migrations:
Most of the information above focuses on the autumn/winter spawners, because there is less information on the spring spawners. The adult spring spawners occur in the estuary of the Thames and Elbe, but they also occur in the Dutch Wadden Sea. In contrast to the autumn/winter spawners which have large migration routes, these spring spawners spend their whole life cycle in the southern North Sea. The feeding adult herring appear in the Norwegian area and the Skagerrak in April/May. Following this period the herring migrate in a north-western direction to the Shetland

Islands and to the central North Sea. In July (Fig. 4.1.6), most of the herring have enough fat reserves to start spawning (Corten, 1996) and they stop feeding. From August they start spawning, as described first in the most Northern areas and later in the southern areas. The herring spawning in winter in the Channel group in July around the Fladen grounds, around September/October they move along the Dutch coast to the Channel. After spawning these herring move slowly north and can found in the Dutch water from December to March. In April/May these herring can be found in the western central North Sea and in June they join the other herring in the north western North Sea.

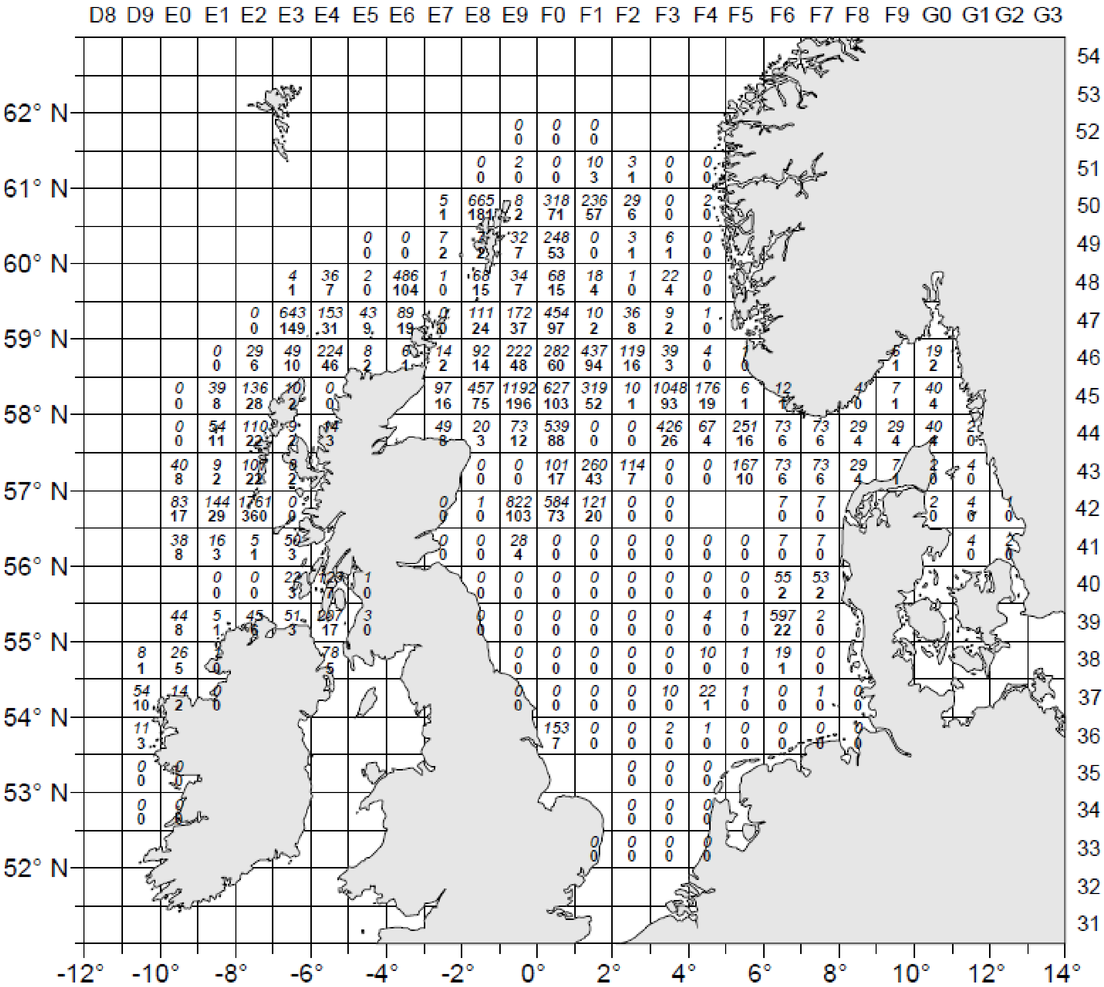


Fig. 4.1.6. Abundance of autumn spawning herring (winter ring 1–9+) from the combined acoustic survey in June–July 2008. Numbers (millions, upper figure) and biomass (thousands of tonnes, lower figure). Blank rectangles are not surveyed (ICES 2009b).

4.1.6 Conclusion

The importance of the Dutch EEZ for the different life stages of herring is summarised in Table 4.1.1. No spawning of autumn/winter spawners occurs in the Dutch EEZ and there are thus no eggs found. Larvae drift by the residual current into the Dutch EEZ, this happens in the beginning of the year. The larvae metamorphose in the coastal nursery areas, of which an important part is in the Dutch EEZ and Wadden Sea. The juveniles migrate to deeper water and spread over most of the Dutch EEZ. The adults have the migration behaviour and and only occur in the EEZ for a part of the year. Only a part of the adults pass through the Dutch EEZ, specifically the winter spawners occurs here.

Table 4.1.1: Summary of the importance of the Dutch EEZ for different life stages of herring at different times of the year. Eggs and larvae information is provided on a monthly basis, juvenile and adults on a quarterly basis. Importance levels (none or close to none = white; low = yellow; medium = orange; high = red; grey = unknown) relate to the extent of the distribution of each life stage within the Dutch EEZ and are based on best estimates from current knowledge.

Month	1	2	3	4	5	6	7	8	9	10	11	12
Eggs												
Larvae	*Med*	*High*	*High*									
Juveniles		*Med*			*Med*			*Med*			*Med*	
Adults		*Low*									*Low*	

4.1.7 References:

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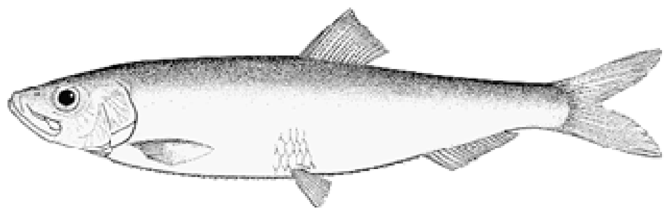
4.2 Sprat – *Sprattus sprattus* (Linnaeus, 1758)



4.2.1 Introduction

Sprat (*Sprattus sprattus*) is a Lusitanian pelagic species (Yang 1982, Ellis et al. 2002, Ellis et al. 2008) and is widely distributed in the coastal waters and inshore areas, of Europe and North Africa, ranging from Morocco to Norway, including the Mediterranean, Black, Baltic and North Sea.
Sprat is another of the five clupeid species in the North Sea. It can reach a maximum length of 19cm (but is usually smaller then 16cm) and an age of 6 years (Muus and Nielsen 1999), maturing at an age of 1-2 year (Muus and Nielsen 1999, ICES 2009b). It is an indeterminate batch spawner that spawns pelagic eggs.
Sprat are caught by trawl, midwater trawl, pair trawl and seine net, and are often preserved by smoking. Juvenile sprat are marketed as whitebait. However, the larger part of the international catch is used in the fishmeal industry.

4.2.2 Eggs

Temporal occurrence of eggs:
Spawning takes place in the North Sea from January to July, although sprat are also thought to spawn until September (Torstensen, IMR, Norway, pers. comm. in Taylor et al. 2007), mainly in the southeastern sector and in the Skagerrak (Munk and Nielsen 2005). The main period of spawning is May and July (Munk 1993). The highest abundance of eggs in the egg survey of 1989 were found in May (Fig. 4.2.1; van der Land 1990, 1991).

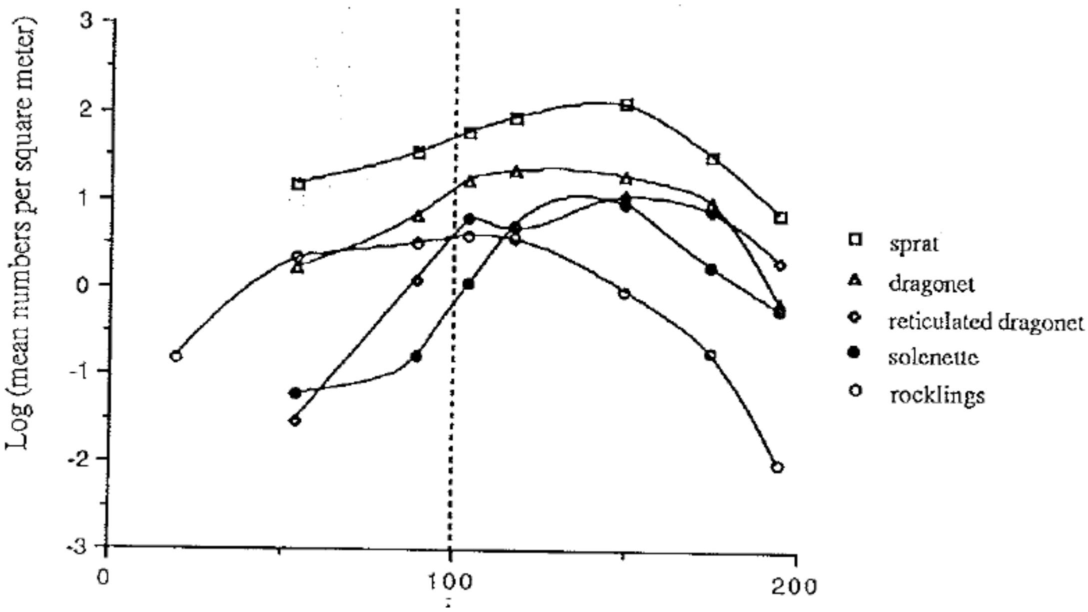


Fig. 4.2.1. Seasonal variation in abundance in fish eggs in 1989, upper line is sprat (van der Land 1990).

Spatial distribution of eggs:
Sprat spawn in a wide area of the North Sea and spawning seems to occur mainly offshore close to the transition between stratified and mixed waters (frontal zones; Munk 1991, 1993). Sprat eggs have been found throughout the Dutch EEZ (Fig. 4.2.2; van der Land 1990).
Distribution of sprat eggs based on the international ichthyoplankton surveys in 2004 is shown in figure 4.2.3. Highest numbers of eggs were collected in March and April (Taylor et al. 2007).

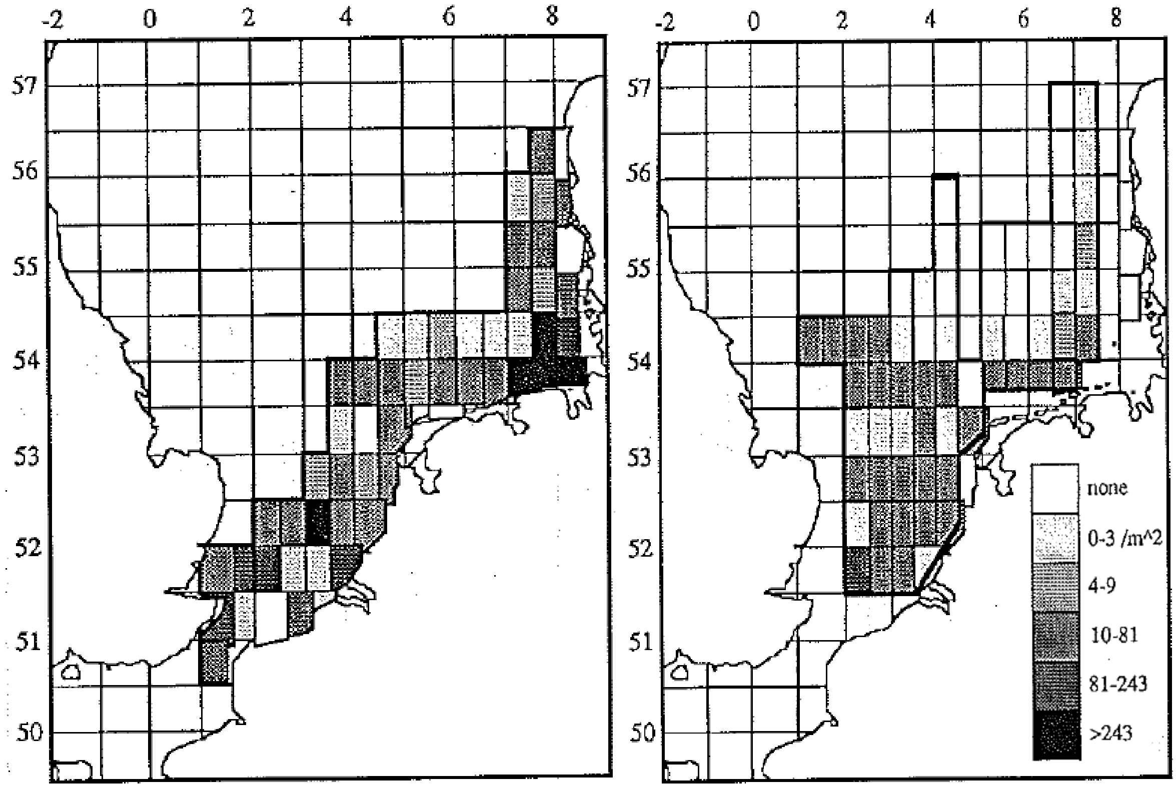


Fig. 4.2.2. Sprat eggs, stage I, late March (left); sprat eggs, stage I, May (right) (van der Land 1990).

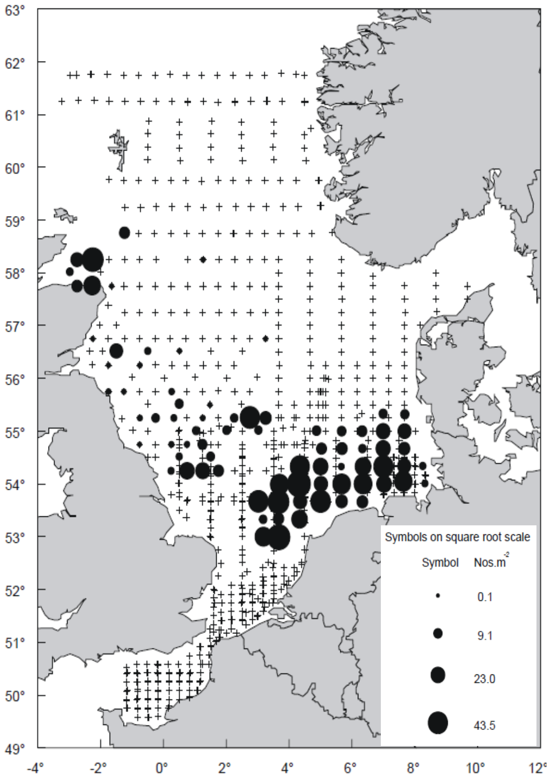


Fig. 4.2.3. Distribution of sprat eggs in the 2004 ichthyoplankton surveys (Taylor et al. 2007).

4.2.3 Larvae

Temporal occurrence of larvae:
Sprat larvae occurred from April to August in daily samples of the Helgoland roads station (54°11.18 N and 07°54.00 E), in the years 2003-2005 (Malzahn and Boersma 2007).

Spatial occurrence of larvae:
The spatial distribution and growth of sprat larvae is closely related to hydrographic features (ICES 2007). Sprat larvae were found in low densities in areas similar to their egg distrubition during the 2004 ichthyoplankton survey (Taylor et al. 2007). Most of the larvae were found in coastal areas (Munk 1993). In figure 4.2.4 the distribution of sprat larvae in the 2004 ichthyoplankton surveys is shown, however not all participants distinguished sprat larvae from pilchard (*Sardina pilchardus*) larvae (i.e. the German cruises in February and March; Taylor et al. 2007). Therefore a much larger area is blank in figure 4.2.4 compared to other larvae maps from the same surveys.

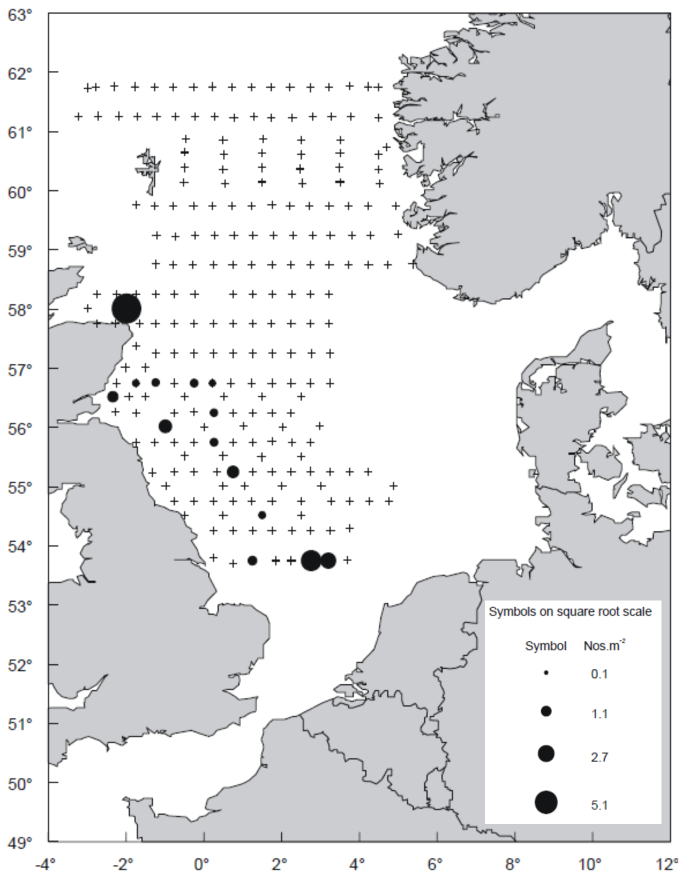


Fig. 4.2.4. Distribution of sprat larvae in the 2004 ichthyoplankton surveys (Taylor et al. 2007).

4.2.4 Juveniles

Spatial occurrence and seasonal migrations:

Juvenile sprat appear at least to occur throughout the southern part of the North Sea (Fig. 4.2.6). It is not likely that their distribution extends much further north, given the overall distribution of sprat in 1991-2004 (Fig. 4.2.7). Juvenile sprat occur widely around the coast of Britain, particularly in estuaries, which serve as nursery areas (Wheeler 1969). Here they are the main species causing intake-screen blockages of power stations (Turnpenny 1983); catches from one power station show that juvenile sprat are found in the Thames estuary the whole year round, but are highest in winter (Fig. 4.2.5; Power et al. 2000).

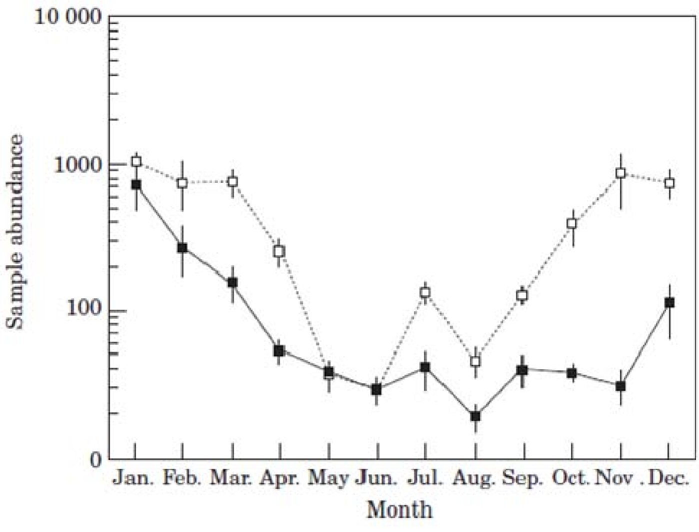


Fig. 4.2.5. Seasonal catches of sprat (solid) and herring (dashed) in the West Thurrock power station in the estuary of the Thames (Power et al., 2000).

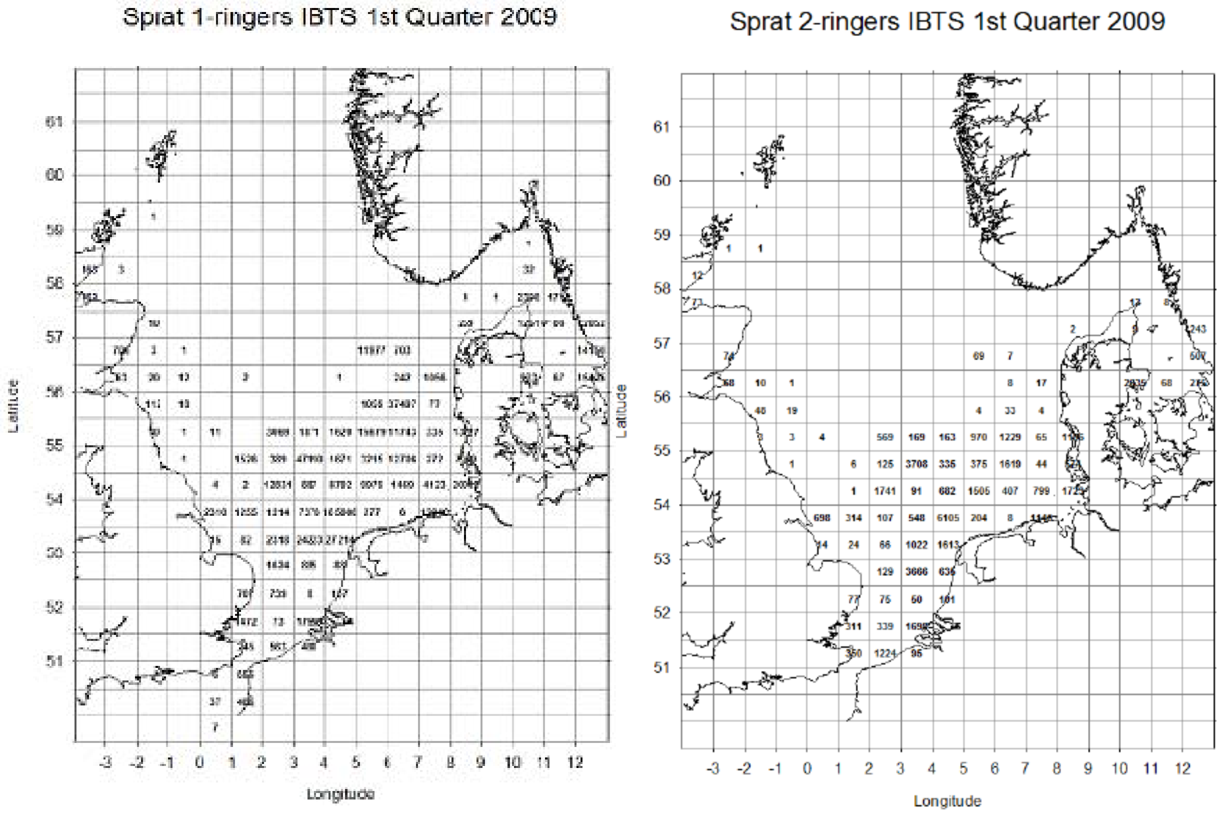


Fig. 4.2.6. Distribution of 1-ringers (left) and 2-ringers (right) sprat in the IBTS (February) 2009 in the North Sea and Division IIIa (Mean number per hour per rectangle) (ICES, 2009a).

4.2.5 Adults

Spatial occurrence and seasonal migrations:

Adult sprat is almost exclusively found in the eastern and southern parts of the North Sea, with highest abundances mainly in the central southern part (Fig. 4.2.6). A similar distribution is shown in commercial catches of sprat (ICES 2009a). Besides the North Sea, sprat also inhabits the estuarine areas bordering the North Sea (Power et al. 2000).

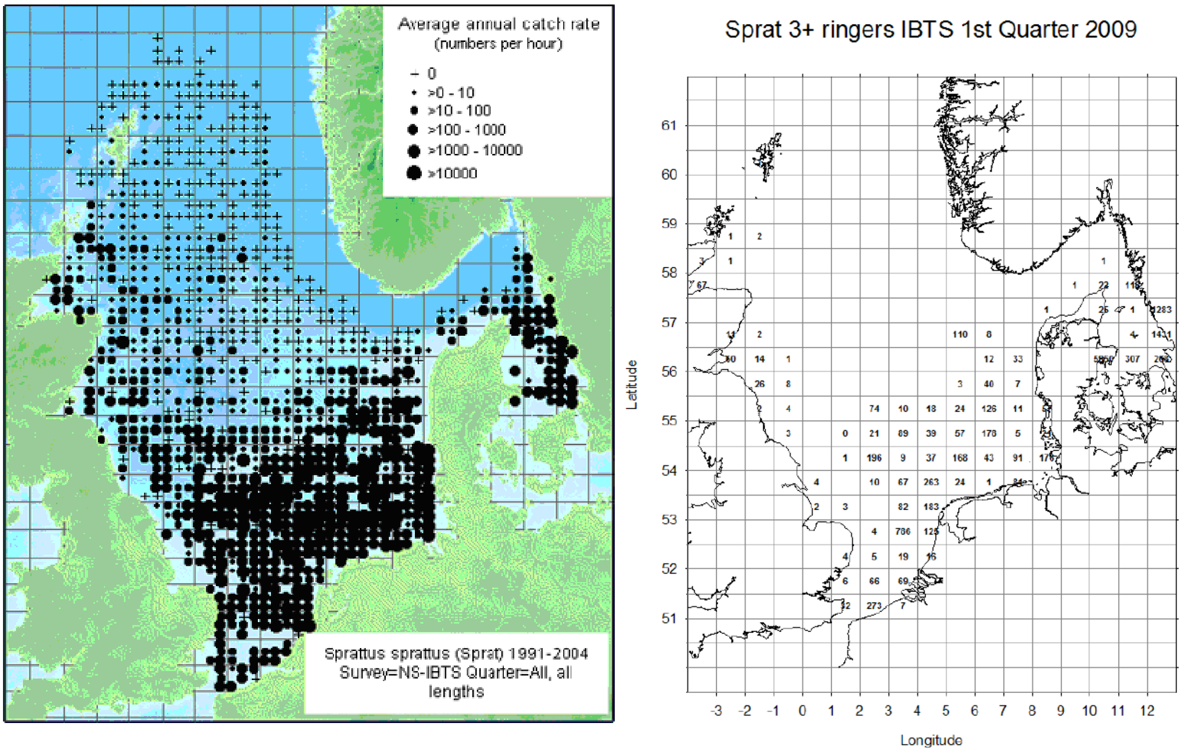


Fig. 4.2.7. Distribution of sprat in the IBTS averaged over 1991-2004 in the North Sea and Division IIIa (from ICES fish atlas) and the distribution of 3-ringers in February 2009 (ICES, 2009a).

4.2.6 Conclusion

The importance of the Dutch EEZ for the different life stages of sprat is summarised in Table 4.2.1. All life-stages of sprat are found in the Dutch EEZ. The highest egg and larvae concentrations are found in the Dutch EEZ and German Bight. Based on figure 4.2.2 and 4.2.3 it is estimated that the importance of the Dutch EEZ for the eggs of sprat is medium. For the larvae of sprat is known that large concentrations of larvae are found on the EEZ, but the extent of the full larval population is unclear. Therefore, no estimation of the importance of the EEZ can be made. The spread of juveniles and adults seems wider than the Dutch EEZ, but a large part of the population occurs here.

Table 4.2.1: Summary of the importance of the Dutch EEZ for different life stages of sprat at different times of the year. Eggs and larvae information is provided on a monthly basis, juvenile and adults on a quarterly basis. Importance levels (none or close to none = white; low = yellow; medium = orange; high = red; grey = unknown) relate to the extent of the distribution of each life stage within the Dutch EEZ and are based on best estimates from current knowledge.

Month	1	2	3	4	5	6	7	8	9	10	11	12
Eggs	*Med*	*Med*	*Med*	*Med*	*Med*	*Med*						
Larvae												
Juveniles		*High*			*High*			*High*			*High*	
Adults		*High*			*High*			*High*			*High*	

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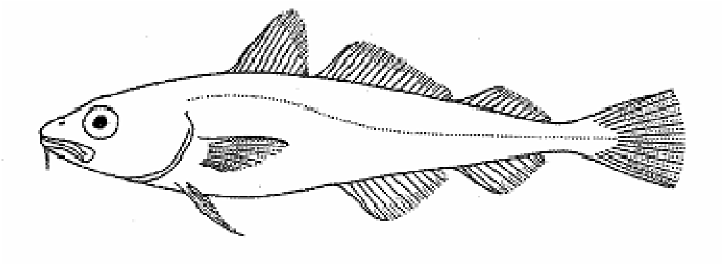
4.3 Cod – *Gadus morhua* (Linnaeus, 1758)



4.3.1 Introduction

Cod is a demersal species that occurs throughout the boreal region of the North Atlantic: in the west from North-Carolina to Labrador, around Iceland and Greenland, and in the Northeast Atlantic from the Bay of Biscay up to Svalbard (Spitsbergen) and Novaya Zemlya. In the North Sea, cod may be found from shallow coastal waters to the shelf edge (200 m depth), although catches have even also been reported from the deepest parts of the Norwegian Deeps at 500 m (Bergstad 1991). Cod is recognised as one of the most important commercial species of the North Atlantic of all times and has played a crucial role in both economy and politics of Iceland, Norway, Spain and Newfoundland (Kurlansky 1997). In recent years however, due to significant declines in abundance and biomass, Atlantic cod is now classified as 'vulnerable' by the IUCN (www.iucn.redlist.org).

Cod is not only an important commercial species, but due to its size (max. length ~ 1.5m) cod is also almost at the top of the food chain and thus plays a major role within the ecosystem, feeding on other commercial species as well as predating its own kind. In turn, cod is predated on by other fish eating species and marine mammals such as grey seals.

Because of its importance as a high trophic level predator in marine ecosystems, as well as its value to fisheries, rebuilding these stocks remains a key policy aim in Europe, the USA and Canada (Christensen et al. 2003).

4.3.2 Eggs

Temporal occurrence of eggs: Cod is a determinate batch spawner and the timing of spawning is related to latitude (Raitt 1967, Heessen and Rijnsdorp 1989, Brander 1994), with egg abundances peaking first in the English Channel (day 29, Fig. 4.3.1), followed by a peak around day 40 in the southern Bight (Fig. 4.3.1 and Fig. 4.3.2) and later spawning in the German Bight (day 63) and the west-central North Sea (day 68, Fig. 4.3.1, Brander 1994).

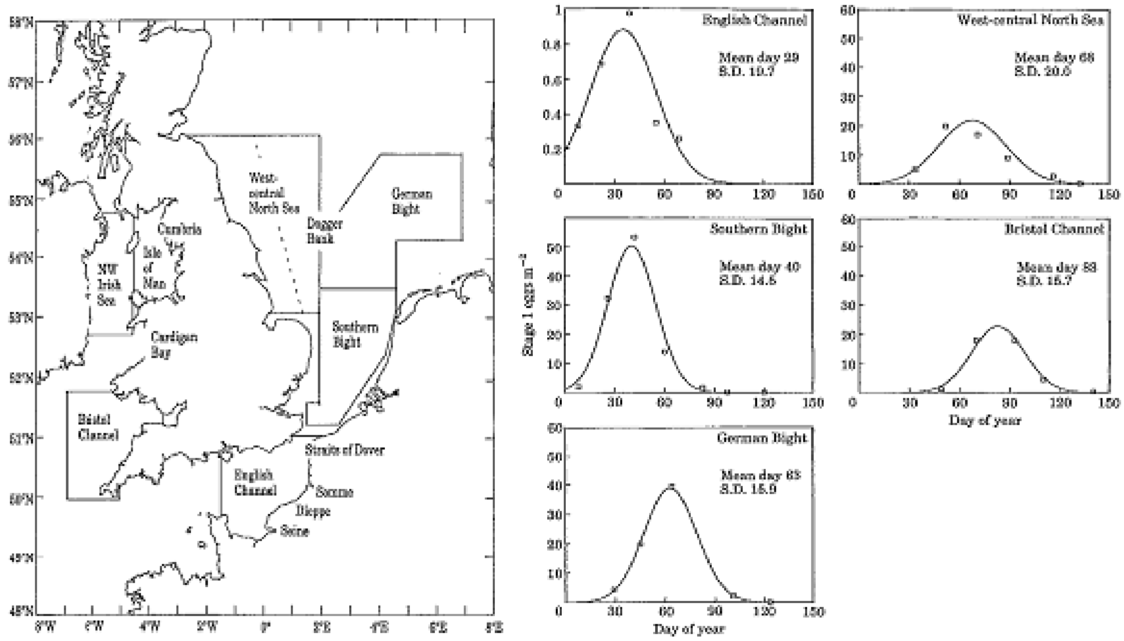


Fig. 4.3.1. (a) Areas in the North Sea for which spawning times (b) have been have been estimated by abundance of stage I cod eggs (from Brander 1994).

Spatial distribution of eggs: Data on which cod spawning areas are currently active in the North Sea are extremely limited (Fox et al. 2008). However, spawning does not appear to be limited to restricted areas and spawning aggregations can be found wide-spread across the North Sea. Nevertheless, main spawning areas have been identified previously around the southern flank of the Dogger Bank and in the Southern Bight (Fig. 4.3.3, Daan 1978), around Flamborough (England, Harding and Nichols 1987), around the southern to eastern flank of the Dogger Bank (Fig. 4.3.2, Heessen and Rijnsdorp 1989) and in the northern North Sea late-stage cod eggs have been collected to the east of the Shetland and in the Moray Firth (Raitt 1967, Heath et al. 1994). These findings are largely confirmed by the recent ichthyoplankton survey of 2004 (Fig. 4.3.3, Taylor et al. 2007).

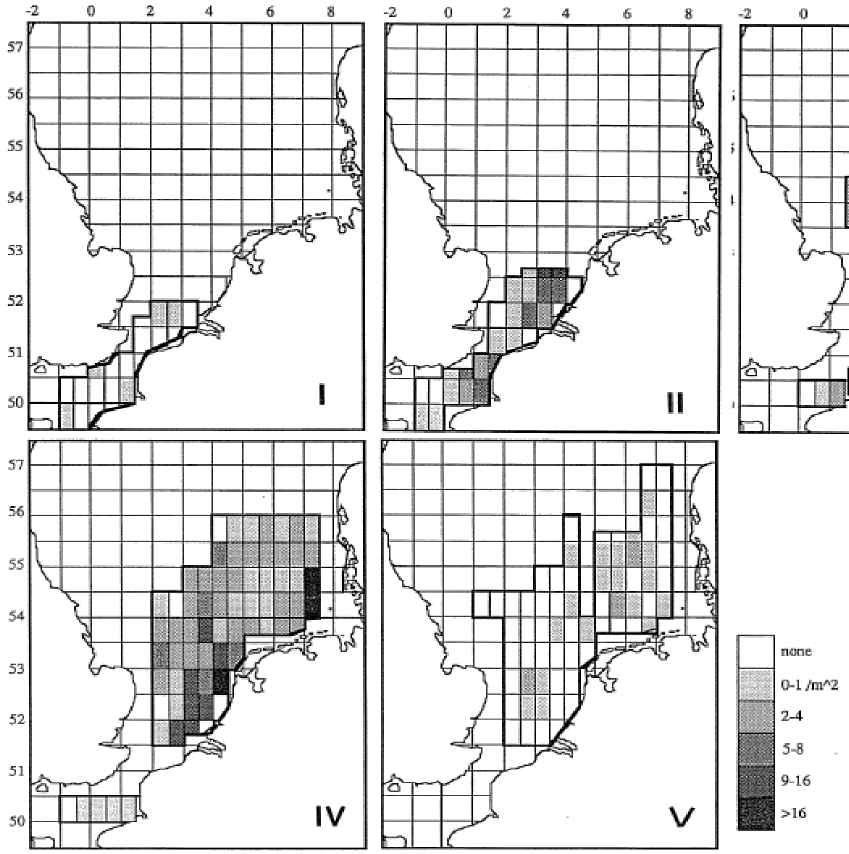


Fig. 4.3.2. Distribution of cod stage 1 eggs in: I) 12-23 December 1988; II) 6-12 January 1989; III) 10-20 January; 13 February-3 March; 28 March – 6 April 1989 (van der Land, 1990).

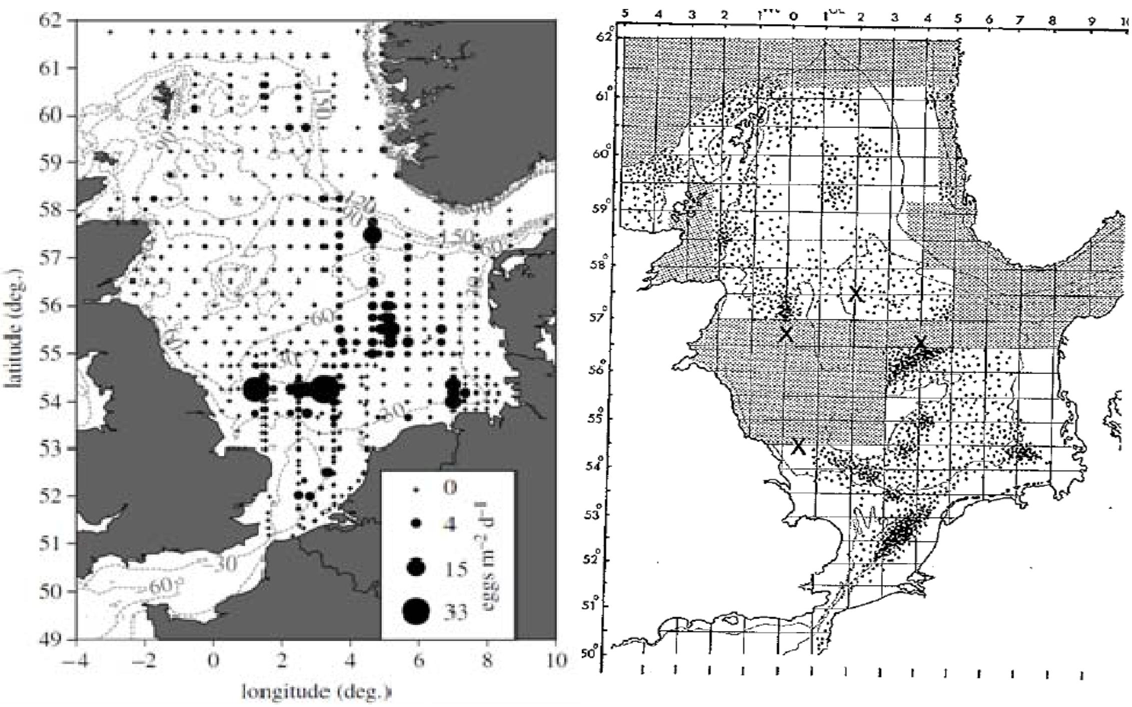


Fig. 4.3.3. Left: The distribution of stage I cod eggs from the 2004 ichthyoplankton survey. The area of the solid circles is proportional to the daily production of cod eggs at each station. Dashed contour lines show the bathymetry in metres (from Fox et al. 2008). Right: the distribution of stage I cod eggs according to information after 1945, shaded areas not surveyed (Daan, 1978). Crosses indicate where a plankton sample was collected but no stage I cod eggs were found.

4.3.3 Larvae

Temporal occurrence of larvae: The occurrence of cod larvae will largely depend on the timing of spawning in particular areas due to the latitudinal differences in timing of peak egg abundance. The eggs take ten to thirty days to hatch depending on temperature (Thompson and Riley 1981). Highest abundances (up to 56.9 larvae m^{-2}) of cod larvae haven been recorded in February and March in waters off the German Bight and coast of Denmark and in March in the northern North Sea (ICES 2007).

Spatial occurrence of larvae: Highest abundances (up to 56.9 larvae m^{-2}) of cod larvae are found in the German Bight and coast of Denmark, with an additional aggregation found in the northern North Sea to the east of the Shetlands (Fig. 4.3.4, ICES 2007, Munk et al. 2009)

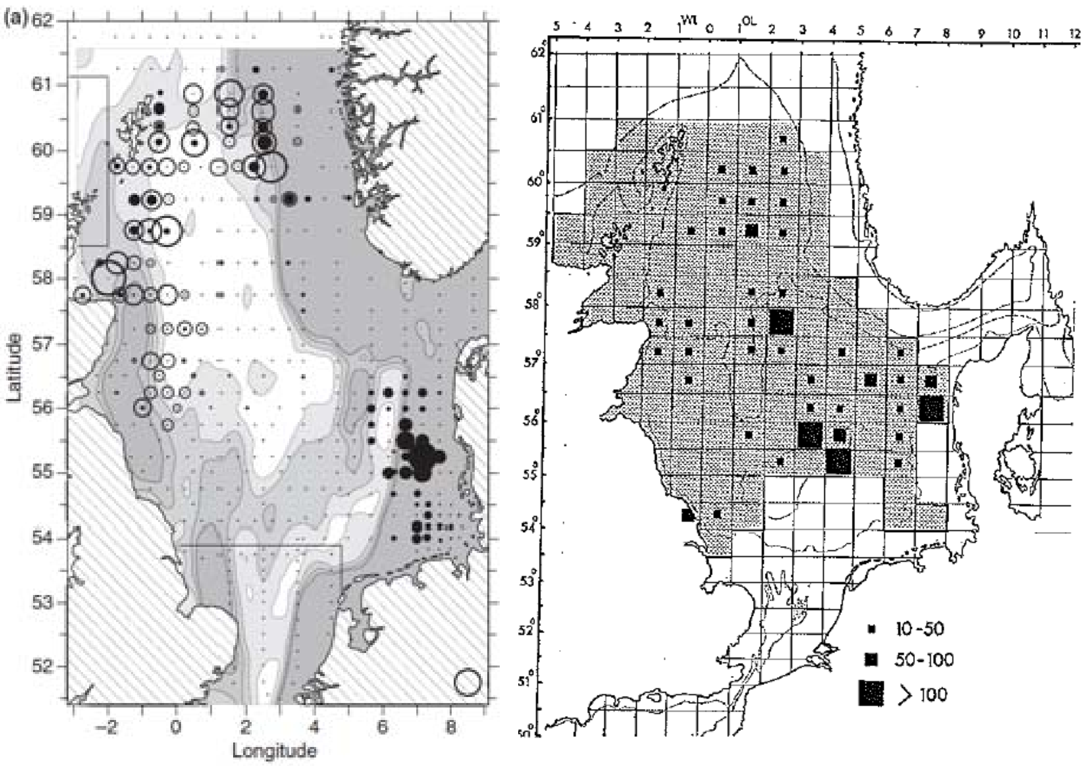


Fig. 4.3.4. Left: Concentrations of cod larvae (filled circles) in the North Sea during 2004. Abundance is illustrated by area of symbol; circle in bottom right corner illustrates area for an abundance of 50 larvae m^{-2} No estimates available for the south-west area indicated (from Munk et al. 2009). Right: Long-term (1969-1974) average densities of pelagic cod larvae in June/July (from Daan, 1978).

4.3.4 Juveniles

Spatial occurrence and seasonal migrations: After metamorphosis, juvenile cod spend some months as pelagic 0-group before adopting their demersal habitat in July/August at a size of 7cm. These pelagic 0-group are distributed over a large part of the central and northern North Sea (Fig. 4.3.5) with high concentrations during June/July off the coast of Jutland and the central part of the North Sea (ICES 1984). The full distribution of pelagic 0-group cod may be underestimated in coastal areas where is not possible to operate the pelagic gear, but where demersal gears have reported the presence of large numbers of 0-group (Daan 1978).
Demersal juveniles inhabit a wide variety of habitat but are often found in more shallow waters than the adults and therefore more exposed to variations in temperature. They are found at the highest water temperatures in summer and autumn and at the lowest temperatures in winter (Heessen and Daan 1994). Off-shore migrations to deeper waters have been described for 1- and 2- group cod when cod were still abundant in the North Sea (Heessen 1983). A North Sea wide-distribution during the whole year is evident (Fig. 4.3.6).

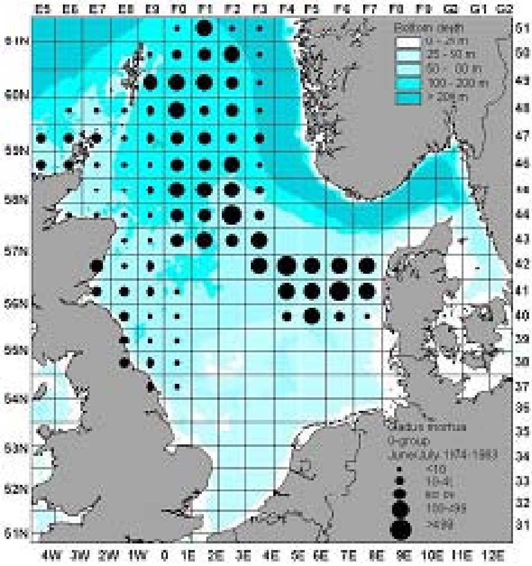


Fig. 4.3.5. Pelagic O-group distribution in June-July, average number per hour, 1974-1983 (from ICES FishMap, based on ICES 1984).

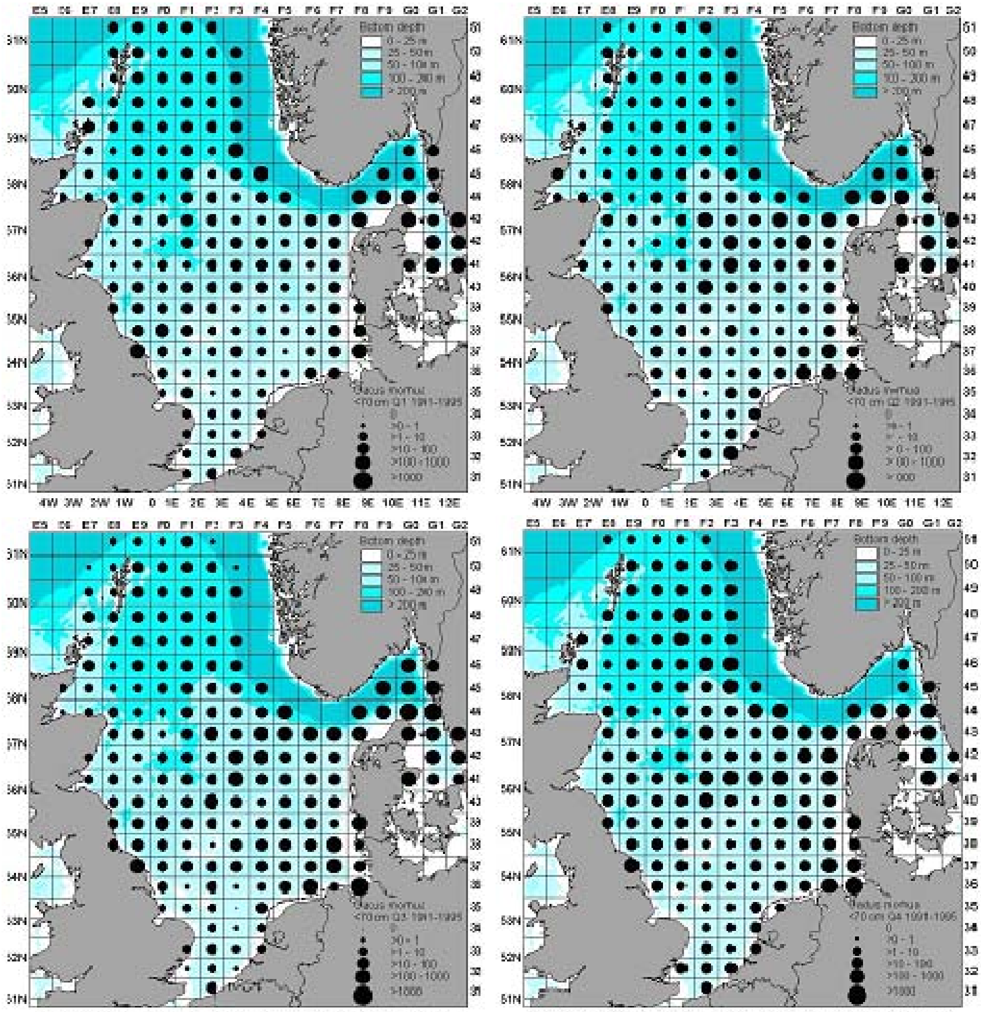


Fig. 4.3.6. Distribution of juvenile cod (< 70cm) reported from the quarterly IBTS 1991-1995 (from ICES FishMap), (a) Q1, (b) Q2, (c) Q3 and (d) Q4.

4.3.5 Adults

Spatial occurrence and seasonal migrations: Adult cod are caught over large parts of the North Sea (Fig. 4.3.7). Average densities are highest in the north, between Shetland and Norway, along the edge of the Norwegian Deep, in the Kattegat, as well as around the Dogger Bank and in the Southern Bight. Quarterly surveys reveal that cod are widely distributed during the colder times of the year (Q1, Fig. 4.3.7a) but retreat northwards in spring (Q2, Fig. 4.3.7b), and further north during the summer (Q3, Fig. 4.3.7c), before beginning their southward migration again as the water cools down in autumn (Q4, Fig. 4.3.7d).

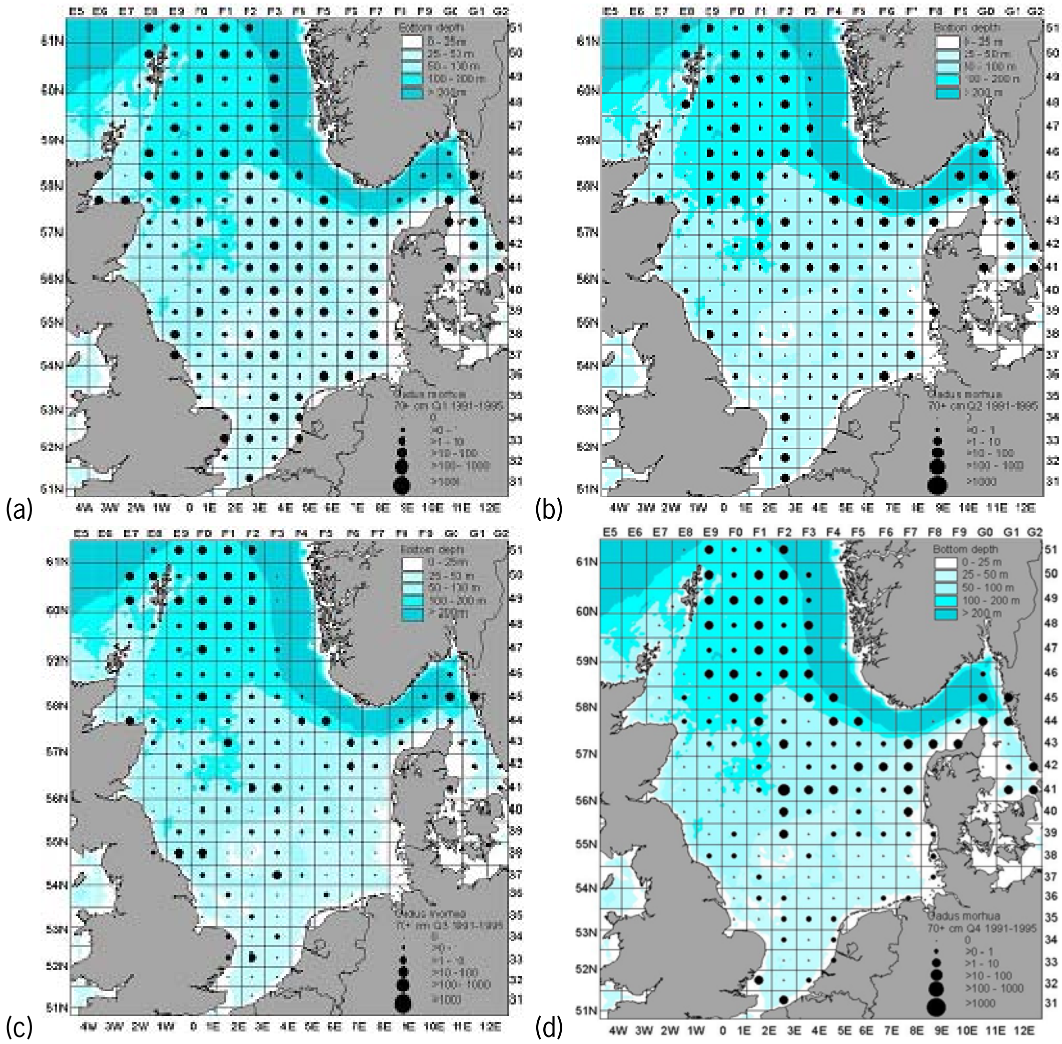


Fig. 4.3.7. Distribution of adult cod (> 70cm) reported from the quarterly IBTS 1991-1995 (from ICES FishMap), (a) Q1, (b) Q2, (c) Q3 and (d) Q4.

4.3.6 Conclusion

Overall, both juvenile and adult cod are found throughout most of the North Sea and apart from the adult shift northwards during the warmer months, cod show neither a particularly strong migration patterns nor a strong segregation between spawning grounds and feeding grounds. The most restricted distribution is found during the egg and larval stages, when some hotspots in abundance do occur in the German Bight and north-east of the Shetlands. There is also a hotspot of eggs in the Southern Bight during February, which partly lies within Dutch waters. For the 0-group pelagic stage of cod, no information is available for the southern North Sea, but juveniles (< 70cm) are again widely distributed throughout the entire North Sea, including the entire area of Dutch waters. The importance of the Dutch EEZ for the different life stages is summarised in Table 4.3.1.

Table 4.3.1: Summary of the importance of the Dutch EEZ for different life stages of cod at different times of the year. Eggs and larvae information is provided on a monthly basis, juvenile and adults on a quarterly basis. Importance levels (none or close to none = white; low = yellow; medium = orange; high = red; grey = unknown) relate to the extent of the distribution of each life stage within the Dutch EEZ and are based on best estimates from current knowledge.

Month	1	2	3	4	5	6	7	8	9	10	11	12
Eggs	*Low*	*Med*	*Low*									
Larvae												
Juveniles	*M*			*M*			*M*			*M*		
Adults	*M*			*L*			*L*			*L*		

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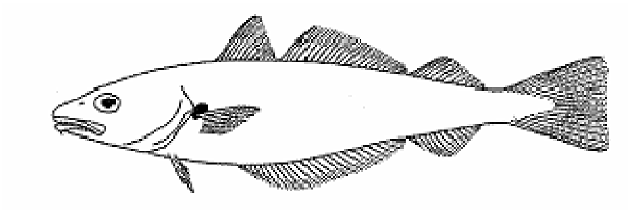
4.4 Whiting – *Merlangius merlangus* (Linnaeus, 1758)



4.4.1 Introduction

Whiting is distributed from the Bay of Biscay up to its northerly range around Iceland and the south-western Barents Sea, and is also found in the western Mediterranean (subspecies *M. merlangus merlangus*) and the Black, Aegean, and Adriatic Seas (subspecies *M. merlangus euxinus*, Svetnovidov 1986). *M. merlangus* is widely distributed in the North Sea, Skagerrak and Kattegat. It is commonly found near the bottom in waters less than 200m deep where it feeds on benthos and small fish. High numbers of whiting are found throughout the North Sea except on the Dogger Bank (Ices FishMap), which may reflect a north-south divide between two sub-populations (Hislop and MacKenzie 1976).

4.4.2 Eggs

Temporal occurrence of eggs: Whiting (batch spawner) may spawn between January to July (Fig. 4.4.1; Ehrenbaum 1905-09, van der Land 1990), although spawning usually occurs between February and June (Messtorff 1959) with peak spawning in March-April (Russell 1976). Whiting in the northern North Sea tend to spawn later than those in the south and yearly variation in timing may vary by up to a month depending on temperatures (Messtorff 1959). Eggs are shed in numerous batches over a period that may last for up to fourteen weeks.

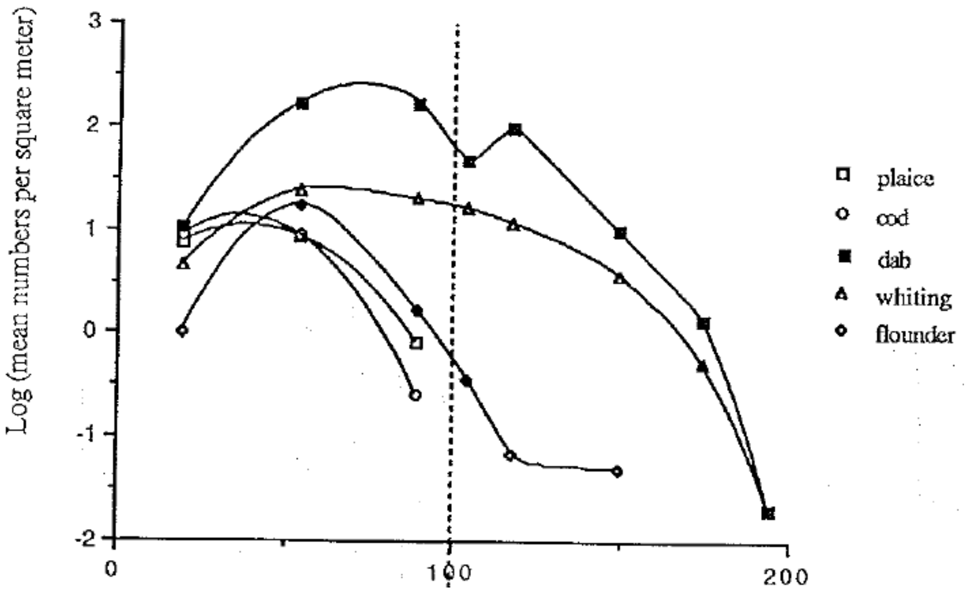


Fig. 4.4.1. Seasonal variation in abundance in fish eggs in 1989, triangle is whiting (van der Land 1990).

Spatial distribution of eggs: The distribution of whiting eggs, as observed in the 2004 ichthyoplankton survey, is consistent with the view that there are two whiting sub-stocks in the North Sea, north and south of the Dogger Bank. High egg concentrations were found south-west of the Dogger Bank, smaller numbers east of Shetland Isles and no eggs were found in the central North Sea (Fig. 4.4.2; Fox et al. 2005). However, it must be emphasised that the ichthyoplankton survey was not designed for surveying whiting eggs (target species were cod and plaice, which spawn earlier in the year) and thus only coincided with the start of whiting spawning. Consequently the relative abundances of eggs between the areas seen in figure 4.4.2 cannot be taken as evidence of the relative importance of these spawning grounds, since the peak of whiting egg production does not occur until later in the year (Fox et al. 2005). In the 1989 egg survey, whiting eggs where found over the whole Dutch EEZ and in the German Bight (Fig. 4.4.3; van der Land 1990)

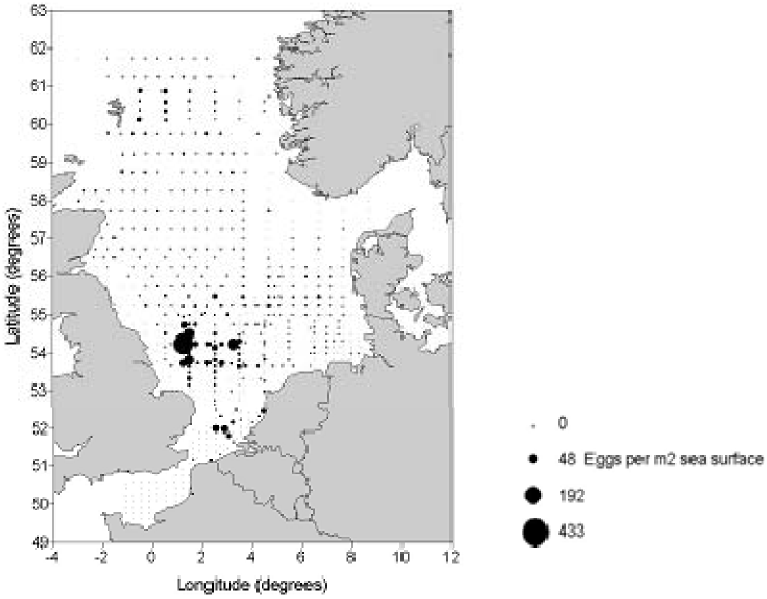


Fig. 4.4.2. Composite map of stage 1 whiting egg distribution for 2004. Symbol size (on square root scale) is relative to egg abundance as shown in the legend. (from Fox et al. 2005).

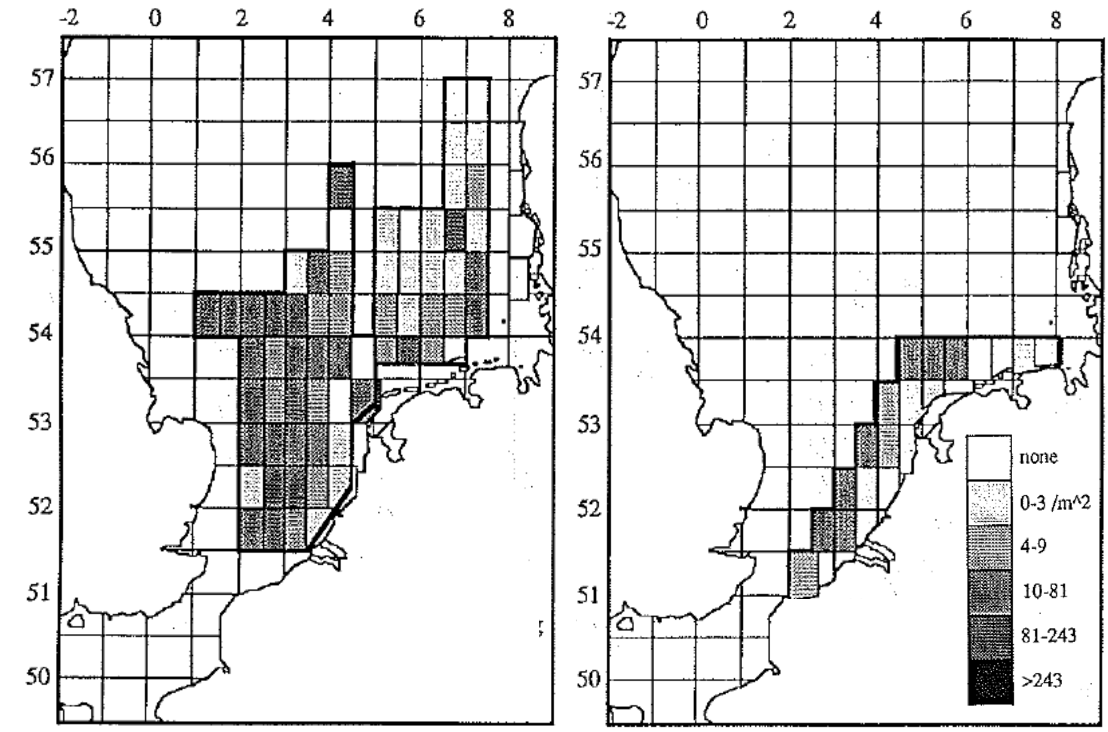


Fig. 4.4.3. Whiting eggs, stage I, late March (left); whiting eggs, stage I, April (right) (van der Land 1990).

4.4.3 Larvae

Temporal occurrence of larvae: Whiting eggs take about ten days to hatch (Russell 1976) and thus larvae can be expected in the plankton from March – June/July.

Spatial occurrence of larvae: Information on the spatial distribution of whiting larvae is limited and the available data has the same interpretation problems as the egg data, in that it stems from an ichthyoplankton survey not designed for whiting. No survey was conducted during the expected peak abundance of larvae therefore the distribution presented in figure 4.4.4 will not be representative of the larval distribution at peak abundance (Taylor et al. 2007).

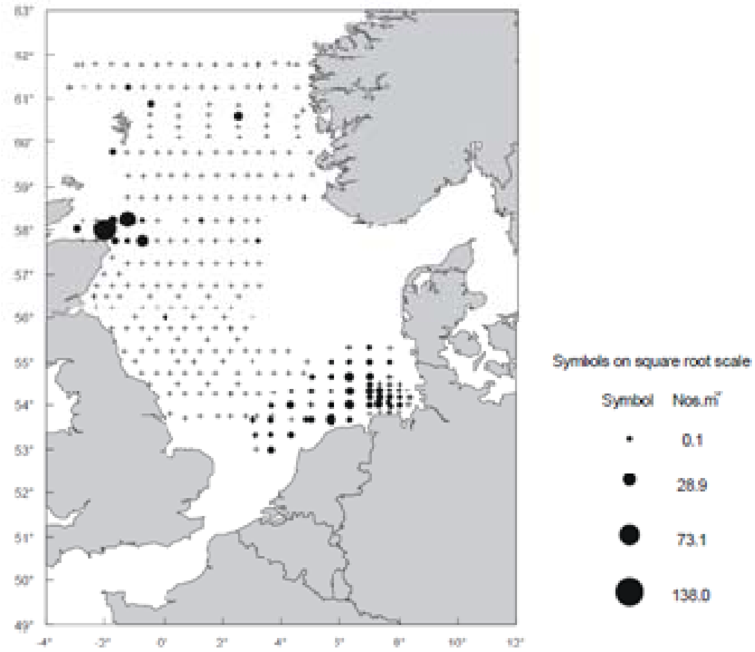


Fig. 4.4.4. Map of whiting (*Merlangius merlangus*) larval abundance (nos. m^{-2}) in 2004 (from Taylor et al. 2007).

4.4.4 Juveniles

Spatial occurrence and seasonal migrations: Juvenile whiting (< 20cm) are widely distributed in the North Sea all year round (Fig. 4.6.5 a-e, ICES FishMap).

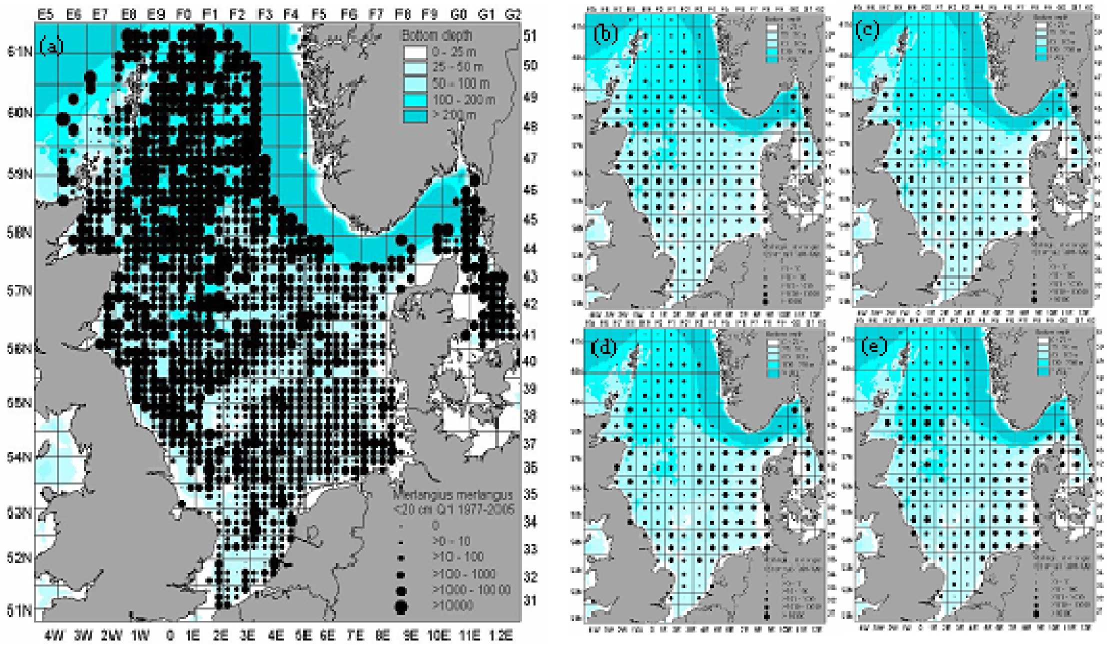


Fig. 4.4.5. Average annual catch rate (number per hour fishing) for juvenile (<20cm) whiting in (a) the quarter 1 IBTS survey, 1977-2005 and the average quarterly catch rates for quarters 1 (b), 2 (c), 3 (d), and 4 (e) for the IBTS survey 1991 – 1995.

4.4.5 Adults

Spatial occurrence and seasonal migrations: Whiting are widely distributed throughout the North Sea, Skagerarak and Kattegat and high densities of adult whiting can be found almost everywhere, with the exception of low densities on the Dogger Bank and the sentral-eatsern part of the North Sea (Fig. 4.4.6 a-e, ICES FishMap). Some seasonal movements of whiting occur (Fig. 4.4.6 b-e). In the northern North Sea, these are directed mainly along the Scottish coast (Hislop and MacKenzie 1976), whereas in south-eastern area an inshore-offshore migration is evident. Part of the Skagerrak population is thought to migrate into the north-eastern North Sea to spawn (Knudsen 1964) and further movements occur between the southern North Sea and the eastern Channel (ICES 2005).

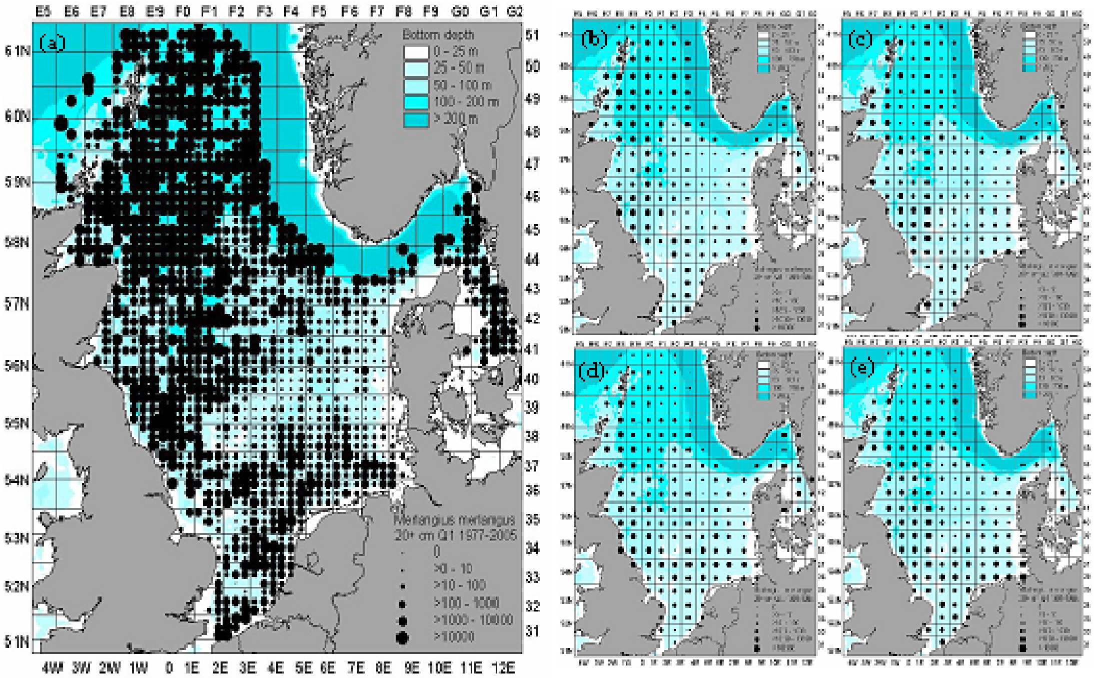


Fig. 4.4.6. Average annual catch rate (number per hour fishing) for adult (>20cm) whiting in (a) the quarter 1 IBTS survey, 1977-2005 and the average quarterly catch rates for quarters 1 (b), 2 (c), 3 (d), and 4 (e) for the IBTS survey 1991 – 1995.

4.4.6 Conclusion

Both adult and juvenile whiting are widely distributed in the North Sea throughout the year. Although some seasonal movements are evident, no strong migratory pattern is detected. A fairly restricted distribution is observed during the early life stages as eggs and larvae, however, estimates of the distribution of these two phases are biased by the timing of the surveys and a complete overview is lacking. Despite this lack of knowledge, the Dutch waters appear to be very important for these early life stages (eggs and larvae) where the distribution is restricted to the southern North Sea. The importance of the Dutch EEZ for the different life stages is summarised in Table 4.4.1.

Table 4.4.1: Summary of the importance of the Dutch EEZ for different life stages of whiting at different times of the year. Eggs and larvae information is provided on a monthly basis, juvenile and adults on a quarterly basis. Importance levels (none or close to none = white; low = yellow; medium = orange; high = red; grey = unknown) relate to the extent of the distribution of each life stage within the Dutch EEZ and are based on best estimates from current knowledge.

Month	1	2	3	4	5	6	7	8	9	10	11	12
Eggs	*Med*	*Med*	*Med*	*Med*	*Med*							
Larvae												
Juveniles	*Med*			*Med*			*Med*			*Med*		
Adults	*Low*			*Low*			*Low*			*Low*		

4.4.7 References:

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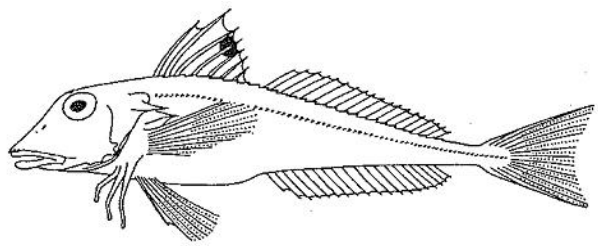
van der Land, M.A., 1990. Distribution and mortality of pelagic eggs of by-catch species in the 1989 surveys in the southern North Sea. ICES Doc. C.M. 1990/H:19.

4.5 Grey Gurnard – *Eutrigla gurnardus* (Linnaeus, 1758)



4.5.1 Introduction

Grey gurnard may be considered a Lusitanian-boreal species that is widespread in the Eastern Atlantic, occurring from Iceland, Norway, the southern Baltic, via the North Sea to southern Morocco and Madeira (ICES FishMap). The species is also found in the Mediterranean and Black Seas. In the North Sea, grey gurnard is by far the most common gurnard (of four species; Heessen and Daan 1996). Although grey gurnard is of limited commercial value, it is caught as by-catch in demersal fisheries and some will be landed for human consumption and more recently also by industrial fleets (Heessen and Daan 1996).
Since the late 1980's grey gurnards have shown a pronounced increase in the international bottom trawl surveys, and are considered an important predator in the North Sea ecosystem. Modelling results have predicted grey gurnard to be responsible for almost 60% of total predation mortality on Atlantic cod (*Gadhus morhua*) as well as having a significant top-down effect on whiting (*Merlangius merlangus*) and cod recruitment (Floeter et al. 2005).

4.5.2 Eggs

Temporal occurrence of eggs: Grey gurnards have a long spawning period (Russell 1976) with eggs being recorded from January to August in the English Channel (Clark 1920) and up to the end of summer (October) in the North Sea (Mielk 1925), but the main spawning period has been considered to be April to August (Wheeler 1978). During the 2004 ichthyoplankton survey however, highest abundances of gurnard eggs were reported during January in the southern North Sea (Taylor et al. 2007), but these were not identified to species level.

Spatial distribution of eggs: Some of the seasonal shift in gurnard distribution is expected to result from spawning migrations, where fish entering the German Bight in spring apparently spawn there (ICES FishMap). During 2003/2004 ichthyoplankton survey (i.e. outside the peak spawning period of grey gurnard), high abundances of gurnard eggs (not identified to the species level) were observed along the Belgian and south-western Dutch Coast and eggs occurred across a wider area within the western North Sea and to the east of the Shetlands at lower densities (Fig. 4.5.1, Taylor et al. 2007).

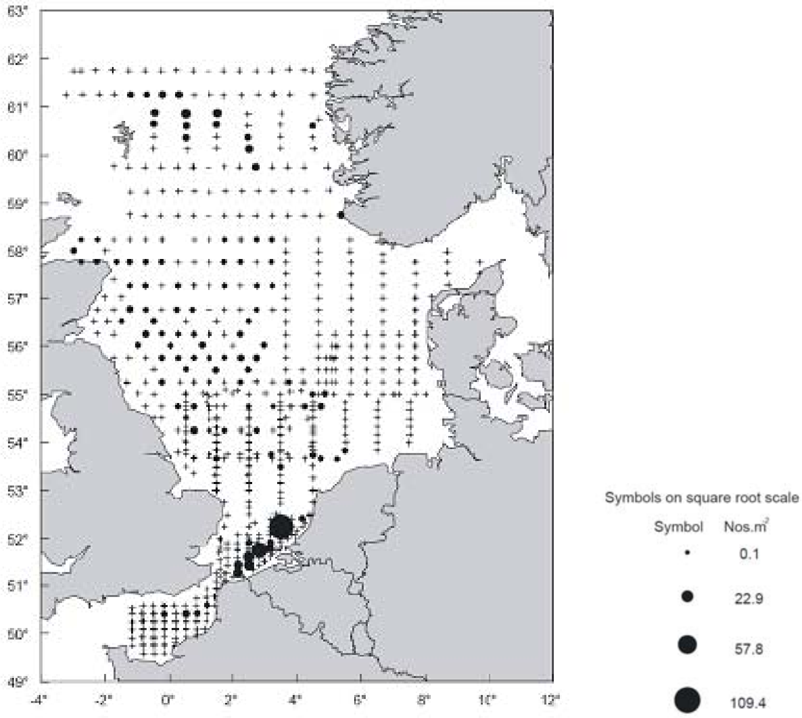


Fig. 4.5.1. Composite map of gurnard (Triglidae) egg abundance (nos. m^{-2}) in 2004 (from Taylor et al. 2007).

4.5.3 Larvae

Temporal occurrence of larvae: The incubation period of grey gurnard eggs can be as short as 5 days at 15°C (Ehrenbaum 1905), increasing with decreasing temperature, thus larvae can be expected to appear at similar periods to the eggs, from February to October.

Spatial occurrence of larvae: Larvae can be expected to occur in the southern North Sea based on the likely spawning positions of grey gurnard. However, as larvae quickly adopt the demersal life-stage, gurnard larvae are not caught in plankton surveys and knowledge on larval distribution is sparse (Taylor et al. 2007)

4.5.4 Juveniles

Spatial occurrence and seasonal migrations: The distribution of juvenile grey gurnards in the summer is throughout the southern North Sea and along the UK west coast (Fig. 4.5.2a). During winter the southern North Sea is vacated and a dense aggregation occurs in the western central North Sea (Fig. 4.5.2b, Knijn et al. 1993).

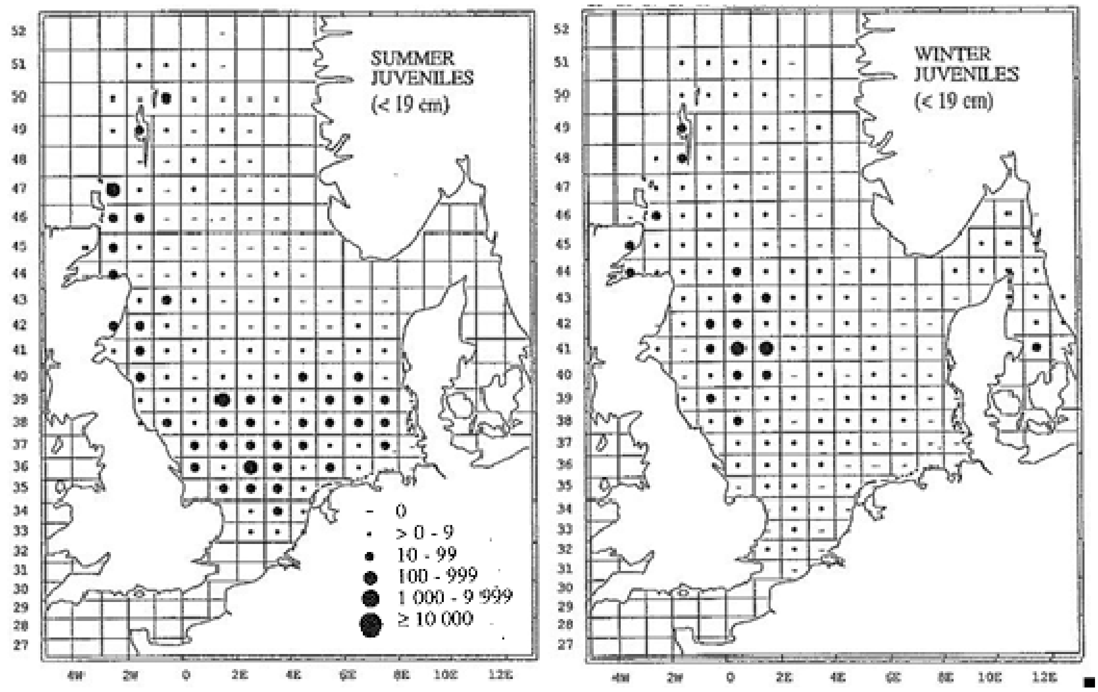


Fig. 4.5.2. Average annual catch rates (numbers per hour fishing) of juvenile grey gurnard (< 19cm) in the years 1985 – 1987 during (a, left) summer and (b, right) winter (from Knijn et al. 1993).

4.5.5 Adults

Spatial occurrence and seasonal migrations: The distribution of adult and juvenile grey gurnards is similar both in time and space (Knijn et al. 1993). Adult grey gurnard occur throughout the North Sea, but undergo some seasonal migrations (Fig. 4.5.3). During spring, the arae south of 56°N becomes densely populated, with lower abundances in the central North Sea, particularly in the East. Abundances are also higher along the west coast of the UK and extend North to the Shetlands (Fig. 4.5.3a, Knijn et al. 1993, ICES Fishmap). In the winter the distribution shifts and grey gurnards become concentrated to the northwest of the Dogger Bank at depths of 50-100m, whilst in other areas of the North Sea (Southern Bight, German Bight, Danish Coast) abundances decrease (Fig. 4.5.3b, Knijn et al. 1993, ICES Fishmap). Grey gurnards thus show a rather unusual northwest-southeast migration pattern. The withdrawal from colder coastal areas may reflect the southern nature of the species (ICES Fishmap).

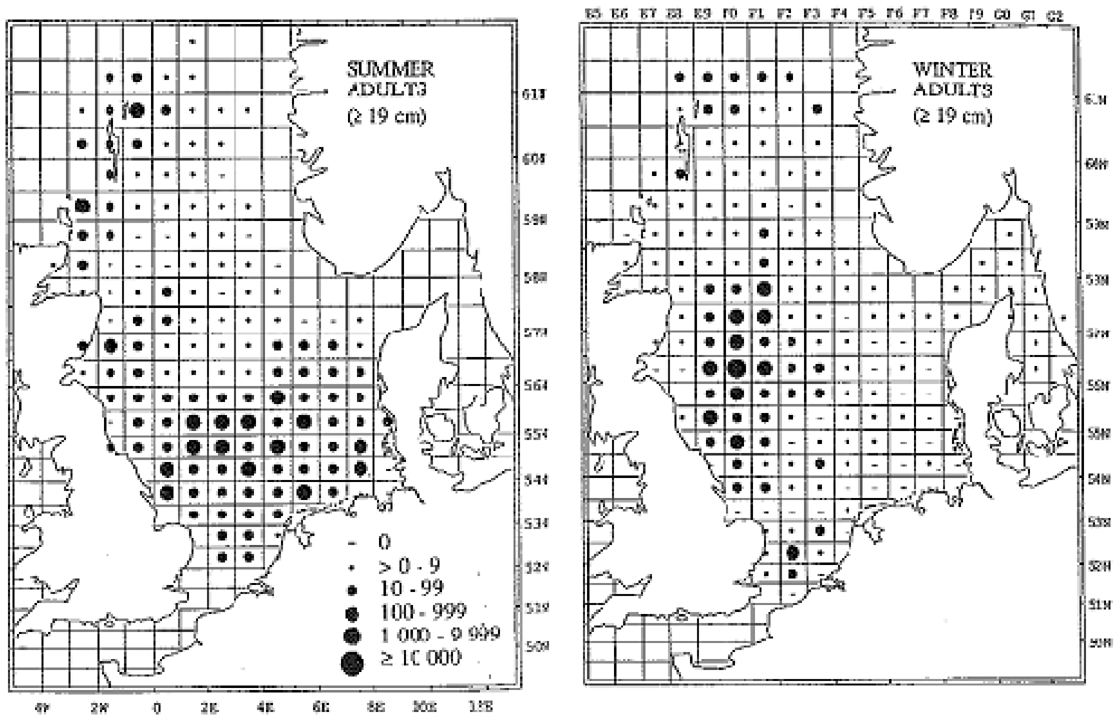


Fig. 4.5.3. Average annual catch rates (numbers per hour fishing) of adult grey gurnard (> 19cm) in the years 1985 – 1987 during (a) summer and (b) winter (from Knijn et al. 1993).

4.5.6 Conclusion

Grey gurnards are considered an important species within the North Sea ecosystem due to their piscivorous feeding habits. Detailed knowledge of spatial-temporal distribution of the earlier life stages is lacking. It is evident that during warmer months gurnards reside in the southern North Sea, shifting north during the winter. Juveniles and adults show similar spatial distribution and migration patterns, although juveniles may be slightly more restricted in their distribution.
Spawning areas of grey gurnard most likely overlap with Dutch waters, which also provide summer feeding grounds. The importance of the Dutch EEZ for the different life stages is summarised in Table 4.5.1.

Table 4.5.1: Summary of the importance of the Dutch EEZ for different life stages of grey gurnard at different times of the year. Eggs and larvae information is provided on a monthly basis, juvenile and adults on a quarterly basis. Importance levels (none or close to none = white; low = yellow; medium = orange; high = red; grey = unknown) relate to the extent of the distribution of each life stage within the Dutch EEZ and are based on best estimates from current knowledge.

Month	1	2	3	4	5	6	7	8	9	10	11	12
Eggs												
Larvae												
Juveniles	*Low*			*Med*			*Med*			*Low*		
Adults	*Low*			*Med*			*Med*			*Low*		

4.5.7 References:

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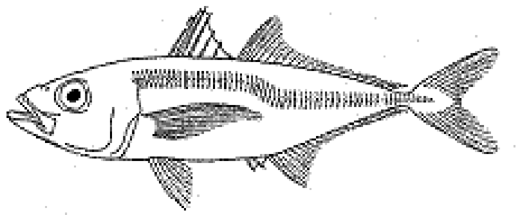
4.6 Horse Mackerel – *Trachurus trachurus* (Linnaeus, 1758)



4.6.1 Introduction

Horse mackerel is a lusitanian pelagic species (Yang 1982, Ellis et al. 2002, Ellis et al. 2008) that can reach a maximum length of around 60cm and is abundant and widespread in the tropical and temperate East Atlantic and Mediterranean, ranging from Norway to South Africa (where it is considered a distinct subspecies *T. trachurus capensis*, Smith-Vaniz 1986). It is assumed that there are three distinct spawning populations of *T. trachurus* in the northeast Atlantic (section 4.3 of ICES 1998): the *Southern horse mackerel* around the Iberian peninsula; the *Western horse mackerel* in the Norwegian Sea, northern North Sea, western part of Skagerrak, west and south off the British Isles, western Channel and west off France; and the *North Sea horse mackerel*, mainly restricted to the central and southern North Sea, eastern part of Skagerrak, Kattegat and eastern English Channel. Horse mackerel are a widely distributed pelagic species and although habitat preferences are poorly understood, a variety of hydrographical features may be expected to affect their distribution, temperature being an important one (Corten and Van de Kamp 1996).
North Sea horse mackerel is caught in a directed fishery for human consumption and as by-catch in the industrial fisheries.

4.6.2 Eggs

Temporal occurrence of eggs: Horse mackerel are indeterminate batch spawners and females will lay between 5–16 batches within a couple of months. Peak spawning of North Sea horse mackerel occurs between May–July (Fig. 4.6.1; Eltink 1991, Heessen et al. 2005), but varies with sea temperature (colder temperatures can delay spawning; Eltink 1991).

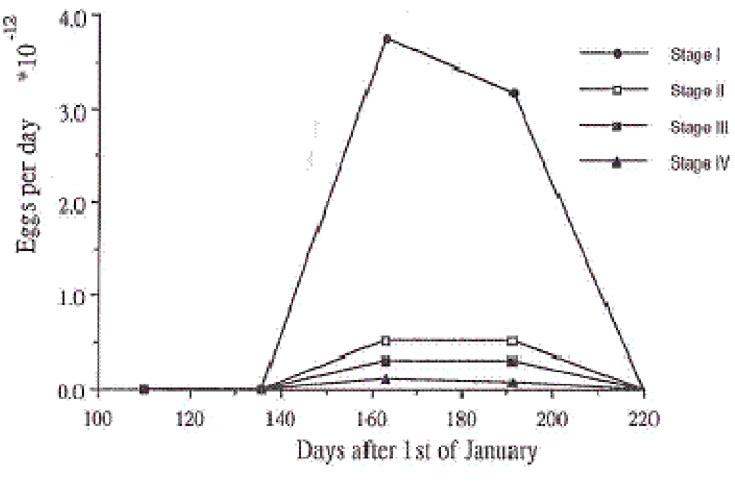


Fig. 4.6.1. Production curves for stage I, II, III, IV horse mackerel eggs from North Sea egg surveys in 1991. Total egg productions are 194.8×10^{12} for stage I eggs, 29.2×10^{12} for stage II eggs. 17.3×10^{12} for stage III eggs, 5.8×10^{12} for stage IV eggs (from Eltink 1991).

Spatial distribution of eggs: Horse mackerel show distinct areas for spawning (as well as for feeding and over-wintering, Fig. 4.6.2) and main spawning areas have been identified for the North Sea by a series of egg surveys from 1988-1991 (Fig. 4.6.3; Eltink 1990, 1991 and 1992). These show spawning to occur in the southern North Sea along the coast of Belgium, the Netherlands, Germany and Denmark (Fig. 4.6.2, Fig. 4.6.3; Eltink 1990, 1991 and 1992, Heessen et al. 2005). Transition zones with low egg abundances are recognised between the main spawning areas of the western and the southern as well as the western and North Sea area (ICES 1996), indicating no clear separation of stocks.

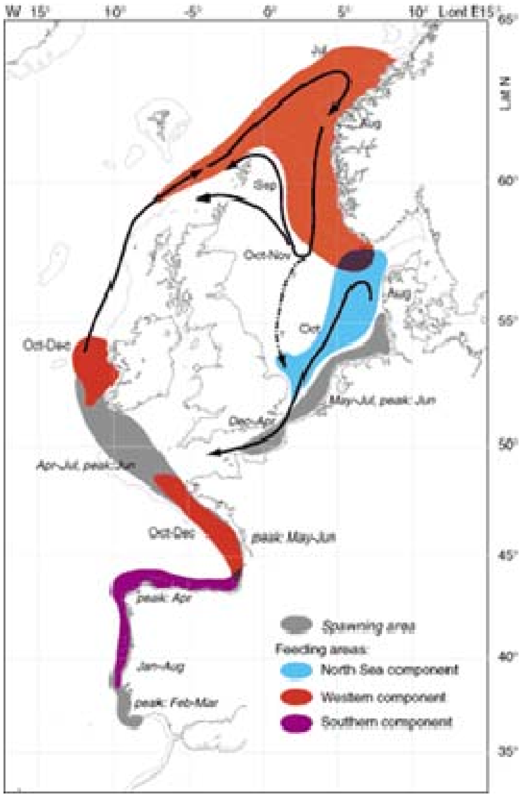


Fig. 4.6.2. Schematic outline of assumed migration routes, spawning and feeding areas for the three Horse Mackerel stocks. Depth line drawn is the 200 m contour (from *www.HOMSIR.org*).

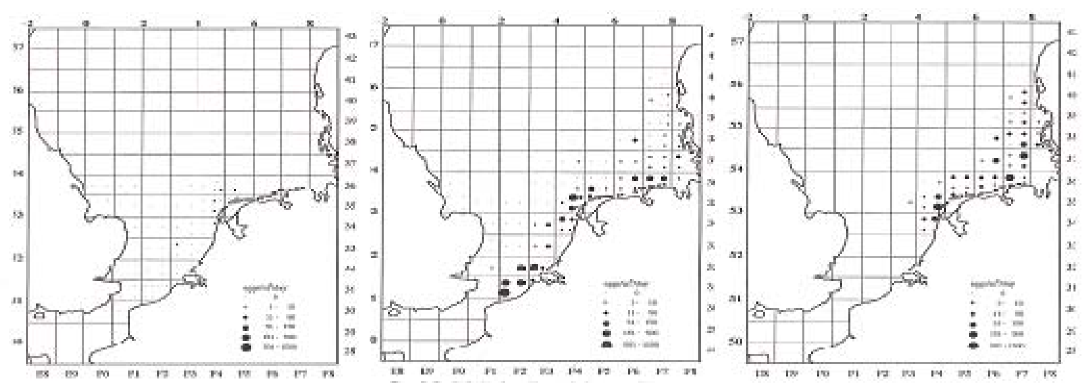


Fig. 4.6.3. The distribution of stage I horse mackerel eggs as numbers per m^2 per day (a) between 13.5.1991 – 22.3.1991, (b) between 28.5.1991 – 20.6.1991, and (c) between 8.7.1991 – 11.7.1991 (from Eltink 1991).

4.6.3 Larvae

Temporal occurrence of larvae: Maximum abundance of post larva is recorded in August in the English Channel (Russell 1976) and can be expected to be similar in other areas, varying depending on the timing of spawning.

Spatial occurrence of larvae: Based on the distribution of eggs and the consequent nursery grounds horse mackerel, larvae can be expected to be distributed around coastal areas of the southern North Sea.

4.6.4 Juveniles

Spatial occurrence and seasonal migrations: Juvenile horse mackerel (< 15cm) are abundant along the coasts of the southern North Sea, where they are distributed in the shallower waters, and absent from the northern part of the North Sea (Fig. 4.6.4).

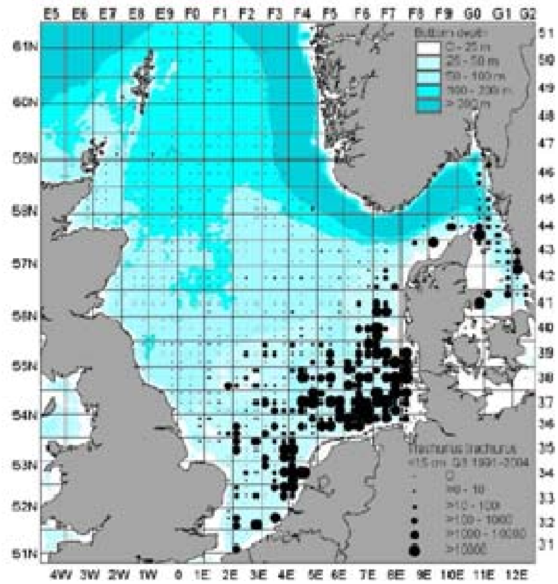


Fig. 4.6.4. Average annual catch rate (number per hour fishing) for juvenile (<15 cm) horse mackerel in the quarter 3 IBTS survey, 1991-2004 (from ICES FishMap).

4.6.5 Adults

Spatial occurrence and seasonal migrations: North Sea horse mackerel show a distribution close to the southern and eastern coasts. However, horse mackerel also undergo extensive seasonal migrations and show distinct separate areas for spawning, feeding and over-wintering (Fig. 4.6.2). The North Sea component appears in April on the feeding grounds in the southern North Sea and reaches the western Jutland coast and southern Norway by August. Parts of the Western stock may reach Trondheim Fjord in July-August (ICES 1998). Other parts of this component feed in areas west of Ireland or at the Bay of Biscay continental slopes. The southern stock does not enter the North Sea (Fig. 4.6.2, Fig. 4.6.5a).

In autumn, at a water temperature falling below ca. 10°C, *T. trachurus* retreat from the feeding areas in the southern Norwegian and the North Sea and migrate to the over-wintering areas further south, in the English Channel (Lockwood and Johnson 1977, Macer 1974 and 1977) and along the continental slope (Macer 1977) in the Bay of Biscay and Celtic Sea (Fig. 4.6.5b; Eaton 1983).

In winter dense schools are formed in deeper waters and in spring horse mackerel disperse again (Polonsky 1965) and migrate northward with increasing water temperature (e.g. Chuksin and Nazarov 1989).

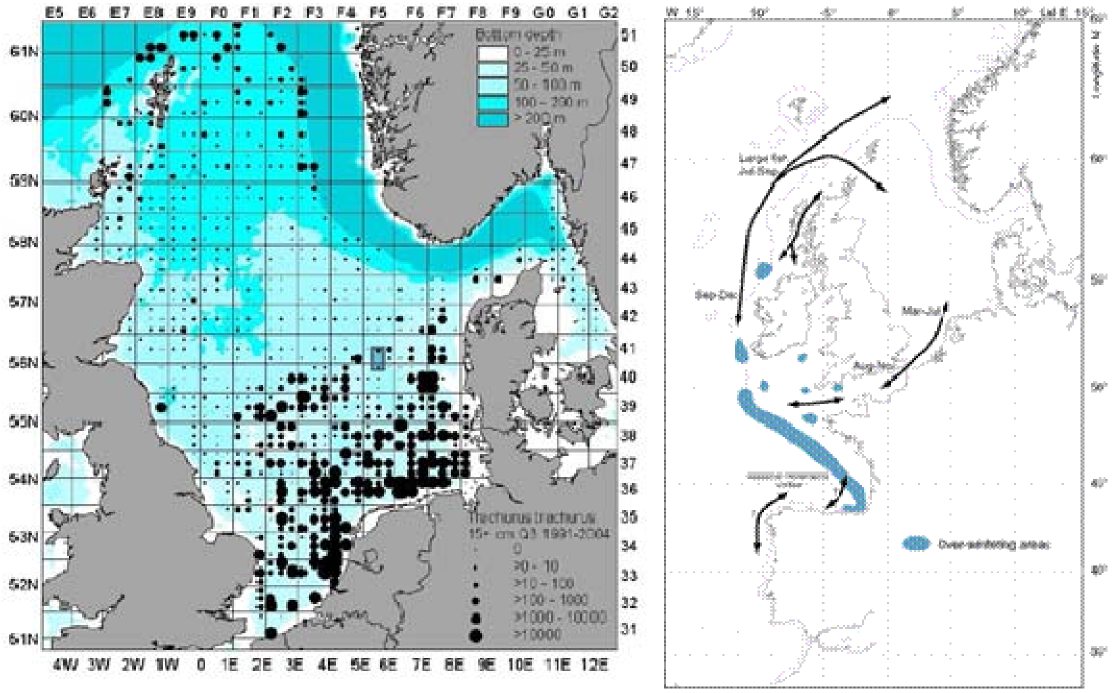


Fig. 4.6.5. (a) Average annual catch rate (number per hour fishing) for adult (>15 cm) horse mackerel in the quarter 3 IBTS survey, 1991 2004 (from ICES FishMap) (b) schematic outline of over-wintering areas and assumed migration routes, Depth line drawn is the 200 m contour (from *www.HOMSIR.com*).

4.6.6 Conclusion

Due to the extensive migrations that horse mackerel undergo, the spatial distribution of the different life stages has a strong seasonal component, with spawning grounds (late spring-summer) separated from feeding grounds (autumn) and overwintering grounds. Due to the influence of hydrographic variables on migration, some long-term trends and shifts in distribution in relation to these may occur. The spawning area runs directly through the Dutch waters, which also form an important component of the nursery grounds. Although information on the distribution of larvae is lacking, it can be assumed that these will occur in the Dutch EEZ (as indicated by grey boxes in Table 4.6.1) based on the importance of this area for eggs and juveniles (Table 4.6.1). The southern North Sea is used as a summer feeding ground for adult horse mackerel, which again includes the Dutch area of the North Sea. The importance of the Dutch EEZ for the different life stages is summarised in Table 4.6.1.

Table 4.6.1: Summary of the importance of the Dutch EEZ for different life stages of horse mackerel at different times of the year. Eggs and larvae information is provided on a monthly basis, juvenile and adults on a quarterly basis. Importance levels (none or close to none = white; low = yellow; medium = orange; high = red; grey = unknown) relate to the extent of the distribution of each life stage within the Dutch EEZ and are based on best estimates from current knowledge.

Month	1	2	3	4	5	6	7	8	9	10	11	12
Eggs					*Med*	*Med*	*Med*					
Larvae												
Juveniles				*High*			*High*					
Adults				*High*			*High*					

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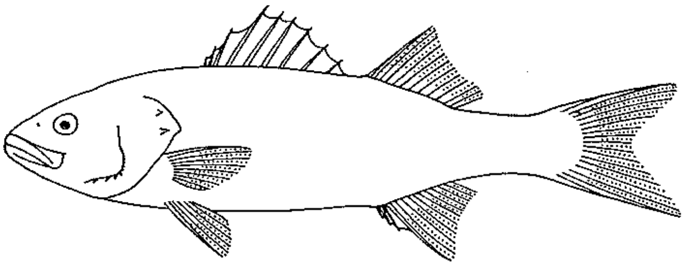
Yang, J., 1982. The dominant fish fauna in the North Sea and its determination. Journal of Fish Biology 20, 635-643.

4.7 Sea bass – *Dicentrarchus labrax* (Linnaeus, 1758)



4.7.1 Introduction

Sea bass, a benthopelagic Lusitanian species, is mainly distributed from approximately 30°N to 55°N in the Northeast Atlantic and occur only rarely in the coastal areas of the central and northern North Sea (Wheeler 1978), which is the cool extreme of their environmental range (Knijn et al. 1993). Overall their distribution stretches southward to Morocco and the Canaries and includes the Mediterranean and Black Sea (Lloris 2002).
Catches of sea bass during North Sea surveys are generally low, but are most likely influenced by the fact that sea bass are semi-pelagic fast swimmers and predominately coastally distributed (Knijn et al. 1993). Sea bass are commercially exploited in inshore and estuarine waters of the southern North Sea with gillnets, lines and trawls, but are also highly regarded by sport fishermen (Knijn et al. 1993).

4.7.2 Eggs

Temporal occurrence of eggs: The spawning period of sea bass takes place at temperatures between 8.5°C and 11°C and will therefore vary with latitude (Reynolds 2003). It is said that sea bass spawn from March to mid-June around Britain and south-west of Ireland (Kennedy and Fitzmaurice 1968). The development time of eggs is temperature dependant, taking between 4 days at 15°C up to 9 days at 9°C (Pickett 1994)

Spatial distribution of eggs: Reproduction of sea bass occurs offshore, where the eggs passively drift in currents towards the coast (Barnabé 1980). North Sea bass spawn off the south-coast of England, in the English Channel and along the southern North Sea, with spawning taking place closer to the shore later during the spawning period (Pawson 1987). Due to the presence of juvenile sea bass and the increased presence of adult sea bass along the Dutch coast (ICES 2006) it is assumed that sea bass may also spawn in Dutch waters (NVVS 2000).

4.7.3 Larvae

Temporal occurrence of larvae: Although only low numbers of larvae (single numbers) are recorded, these tend to have occurred between March and June (Russell 1976). Based on the development time of eggs (as described above) the occurrence of larvae can be predicted to overlap with the temporal occurrence of eggs.

Spatial occurrence of larvae: Postlarvae have been recorded of Plymouth in the English Channel (Russell 1976) but are known to drift to the coast by currents (Barnabé 1980). Following their arrival at the coast, larvae undergo a 2 month development period before metamorphosing into the juvenile stage and actively swimming into nursery grounds in estuaries, lagoons and harbour areas (Pickett 1994).

4.7.4 Juveniles

Spatial occurrence and seasonal migrations: Juvenile bass remain in their coastal nursery grounds for up to 4 – 5 years. During the winter the juveniles migrate to slightly deeper waters where cold weather conditions have less of an influence. The juveniles return to shallower waters again in spring when the sea temperatures rise. There is no migration of juveniles between nursery grounds and the juvenile stage may last between 4 – 7 years (ICES 2006)

4.7.5 Adults

Spatial occurrence and seasonal migrations: Adult sea bass occur broadly across the southern North Sea and in the English Channel (Fig. 4.7.1). At and age of 4 – 5 years, the movements of sea bass increase in distance until joining the full migration patterns of adult bass. Adults migrate south in the winter, thus occurring mostly in the English Channel and off the south coast of England. In warmer seasons adults will move northwards again (Nijssen 1987, Pickett 1994). Although it is evident that a small proportion is capable of long distance migrations, the majority of adults do not migrate over large distances (Pawson 1987, Fritsch 2005). Due to this and based on the assumption that gene flow between areas is small (ICES 2006), ICES consider a number of separate populations in their assessments (Fig. 4.7.1).

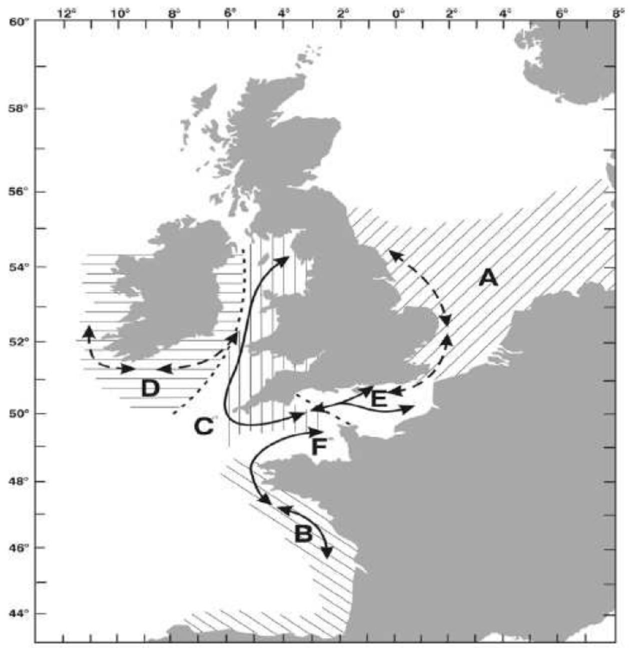


Fig. 4.7.1. Six populations (A – F) as separated by ICES (2006).

4.7.6 Conclusion

Although knowledge on sea bass is available, making valid statements on the importance of different areas for the sea bass population is hampered by a lack of a spatial understanding of the distribution of the different life stages. Based on the presence of recreational sea bass fishery in the Netherlands, it can be assumed that sea bass do occur in these waters, however, the importance of the Dutch EEZ in elation to the rest of the North Sea is undetermined (indicated by grey boxes in Table 4.7.1)

Table 4.7.1: Summary of the importance of the Dutch EEZ for different life stages of sea bass at different times of the year. Eggs and larvae information is provided on a monthly basis, juvenile and adults on a quarterly basis. Importance levels (none or close to none = white; low = yellow; medium = orange; high = red; grey = unknown) relate to the extent of the distribution of each life stage within the Dutch EEZ and are based on best estimates from current knowledge.

Month	1	2	3	4	5	6	7	8	9	10	11	12
Eggs												
Larvae												
Juveniles												
Adults												

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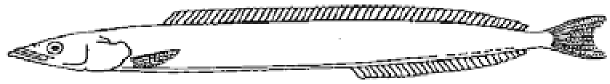
Wheeler, A., 1978. Key to the fishes of northern Europe. Frederik Warne, London. 380 pp.

4.8 Small sandeel – *Ammodytes tobianus* (Linnaeus, 1758)



4.8.1 Introduction

The small sandeel is a benthopelagic boreal species (Yang 1982, Ellis et al. 2002, Ellis et al. 2008) and its geographical distribution ranges from the Murman Sea to the west coast of Iceland, the Baltic sea and the south of Portugal (O'Connell and Fives 1995, Munk and Nielsen 2005). It has also been indentified in the Mediterranean and is one of the five Ammodytidae species present in the North Sea. In contrast to the lesser sandeel, the small sandeel is found in inshore waters, especially sandy bays and beaches. It occurs in the inter-tidal zone and estuaries. It is only rarely found offshore. During winter small sandeels hibernate buried in sand at depths of 20-50 cm (Muus and Nielsen 1999).
Although it is has a lower maximum length of 20cm compared to the lesser sandeel, the small snadeel also reaches maturity at age 1-2 and subsequently spawns up to 25,000 eggs in multiple batches (Munk and Nielsen 2005). The demersal eggs stick to the substrate until they hatch (Wright and Bailey 1996), after which, larvae are found in most of the water column. After metamorphosis the juveniles settle into the aggregations of adults.

4.8.2 Eggs

Temporal occurrence of eggs: Two distinct spawning periods of small sandeel have been reported (Reay 1970 in Daan et al. 1990), one from March to May and the other in November and December.

Spatial distribution of eggs: The small sandeel spawns demersal eggs, that need specific substrates and hydrographic conditions (Daan et al. 1990).

4.8.3 Larvae

Temporal occurrence of larvae: According to Russell (1976), larvae of the small sandeel appear in April and September. This is not entirely in accordance with the reported spawning period above, however, Russell (1976) reports different timing of appearance depending on the geographical location where the survey took place. For the western Channel for example, larvae were recorded from February to April (Russell 1976).

Spatial occurrence of larvae: The ichthyoplankton survey in 2004 (Taylor et al. 2007) reports on the occurrence of *Ammodytidae* larvae, which may contain small sandell larvae. However, the timing of the survey in February/March makes it unlikely that these are dominant in the samples (Fig. 4.9.2 right, section lesser sandeel). No further information on the distribution of the larvae of small sandeel was found.

4.8.4 Juveniles

Spatial occurrence and seasonal migrations: Detailed information on the distribution of juvenile small snadeels was not available. However, it is likely that the juveniles of small sandeel are contained within the aggregations of adults, similar to the lesser sandeel, and that the main migration occurs during the larval phase.

4.8.5 Adults

Spatial occurrence and seasonal migrations: The adult small sandeel are found in inshore waters, especially sandy bays and beaches. They occur in the inter-tidal zone and estuaries but are only rarely found offshore.
During a spring survey in 2007, which was carried out as part of a study on possible effects of Windmill parks, small sandeel were found off the Dutch coast (Fig. 4.8.1 left; Ter Hofstede et al. 2007). Catches of small sandeel were lower then those of lesser sandeel (see section 4.9).
During surveys in 2005 and 2006, done as part of a study on possible effects of the construction of Maasvlakte 2, small sandeel were found in spring and autumn in the Voordelta (Fig. 4.8.1 right, Couperus et al. 2009).

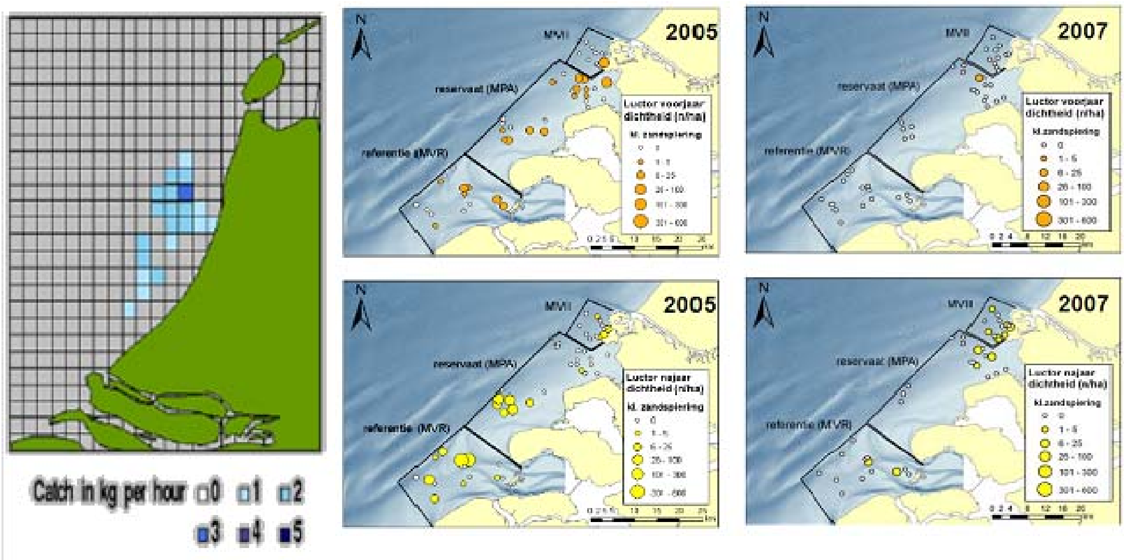


Fig. 4.8.1. Left: Distribution of small sandeel during a survey in spring 2007 (0=0, 1=10, 2=100, 3=1000 kg/hour fishing etc., Ter Hofstede et al. 2007). Right: Distribution of small sandeel during surveys in 2005 and 2007 (upper spring, lower autumn, Couperus et al. 2009).

4.8.6 Conclusion

The importance of the Dutch EEZ for the different life stages is summarised in Table 4.8.1. Based on some local surveys done in single years, it is clear that small sandeel is living on the Dutch EEZ most likely the whole year round including the spawning period. However, the importance of the Dutch EEZ in relation to the whole North Sea population is unclear. Also, little is know about the appearance or timing of eggs and larvae of this species on the Dutch EEZ.

Table 4.8.1: Summary of the importance of the Dutch EEZ for different life stages of small sandell at different times of the year. Eggs and larvae information is provided on a monthly basis, juvenile and adults on a quarterly basis. Importance levels (none or close to none = white; low = yellow; medium = orange; high = red; grey = unknown) relate to the extent of the distribution of each life stage within the Dutch EEZ and are based on best estimates from current knowledge.

Month	1	2	3	4	5	6	7	8	9	10	11	12
Eggs												
Larvae												
Juveniles												
Adults												

4.8.7 References:

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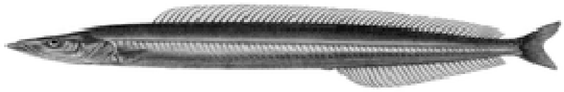
4.9 Lesser sandeel – *Ammodytes marinus* (Raitt, 1934)



4.9.1 Introduction

Lesser sandeel are a benthopelagic boreal species (Yang 1982, Ellis et al. 2002, Ellis et al. 2008) and are distributed across the North Atlantic Ocean from 74°N to 49°N south (the Channel Islands and western English Channel). Their range includes eastern Greenland, Iceland, the Barents Sea (not the White Sea), the Baltic (but not the Gulf of Bothnia and Finland) and the North Sea. Lesser sandeel occur in marine waters, usually between 10 and 150m depth, but can also occur in brackish water. The distribution is closely related to well-oxygenated bottom substrates consisting of gravel or coarse sand, in which the sandeel can bury. Burying occurs in the sand, when water temperature or prey abundance is low (Winslade 1974a, b), and at night, when low light intensity limits prey visibility (Winslade 1974c).

Five species of Ammodytidae occur in the North Sea, where the lesser sandeel (*Ammodytes marinus*) is the abundance dominant of the five Ammodytidae species. It reaches a maximum length of 25cm and a maximum age of 10 years (Muus and Nielsen 1999). Sexual maturity occurs at around age 2 (Macer 1966; Bergstad et al. 2001) and lesser sandeels may spawn up to 25,000 eggs in multiple batches (Munk and Nielsen 2005). The demersal eggs stick to the substrate until they hatch (Wright and Bailey 1996), whereupon larvae are found in most of the water column. After metamorphosis they settle into the aggregations of adults.

Lesser sandeel are key prey fish in the ecosystem and are preyed upon by many marine birds and mammals. They are also caught by industrial fisheries and reduced to extract meal and oil that are principally used to feed animals in agriculture and aquaculture. Some snadeel fish oil is added to human food such as biscuits and margarine. The sandeel fishery is predominantly a Danish and Norwegian fishery. In tonnes, it is the largest segment of the Danish fisheries (STECF 2008) and is also the largest single species fishery in the North Sea.

4.9.2 Eggs

Temporal occurrence of eggs: The lesser sandeel spawns from November to February over their whole distribution range (Muus and Nielsen 1999). A shorter period, from December to January, is reported by Bergstad et al. (2001) for the east central North Sea and the coast of southwest Norway. This period is similar to what was reported earlier for the southern North Sea (Macer 1966, Reay 1970).

Spatial distribution of eggs: The eggs are attached to the substrate and therefore their distribution is restricted to areas with well-oxygenated bottom substrate consisting of gravel or coarse sand. These suitable areas are defined based on their substrate and sandeel fishing activity (Jensen and Rolev 2004, Christensen et al. 2008; Fig. 4.9.1).

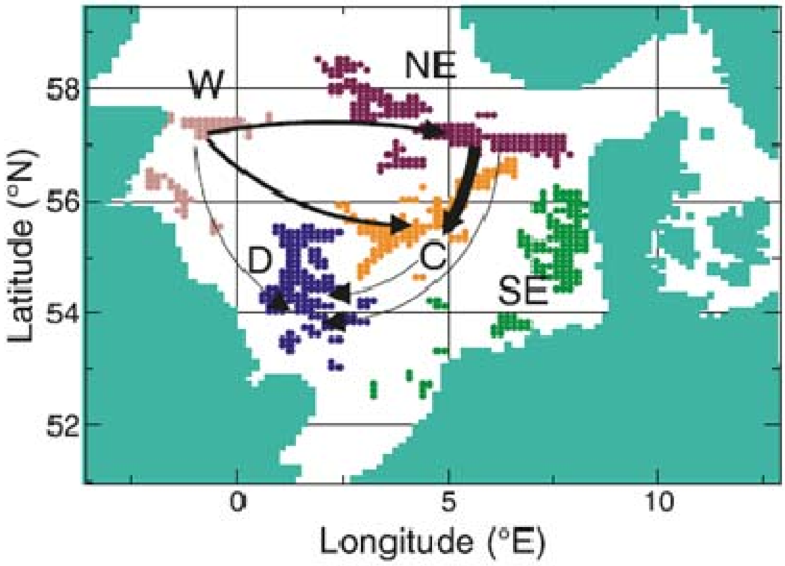
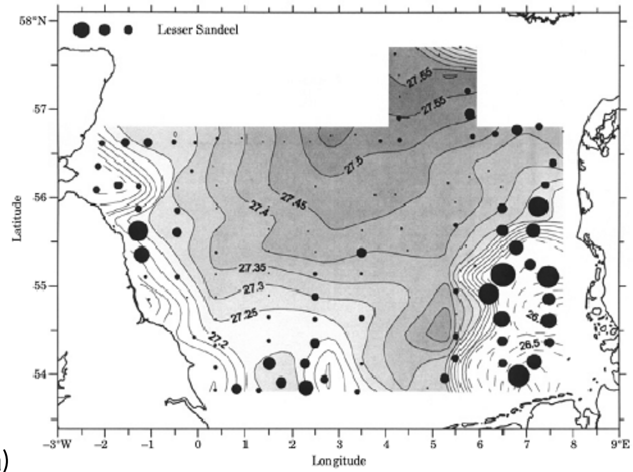


Fig 4.9.1. Suitable sandeel banks in the central and southern North Sea (W, D, C, NE, SE), and them most important interbank exchanges in the North Sea of sandeel larvae (Christensen et al. 2008).

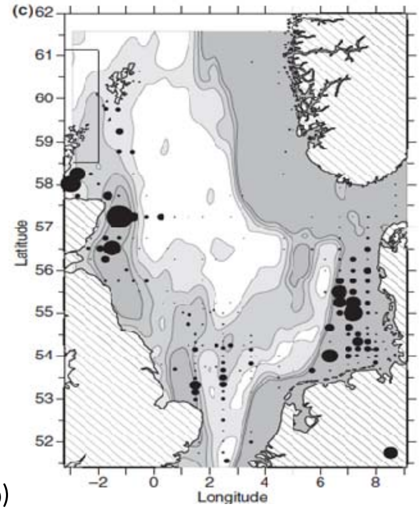
4.9.3 Larvae

Temporal occurrence of larvae: At an average temperature of 7 to 8°C the incubation period of lesser sandeel eggs was around 20 to 30 days (Russell 1976). Thus the larvae occur from January to April (Russell 1976) or to May (Wright and Bailey 1996). Also in the Helgoland roads station (54°11.18 N and 07°54.00 E), in the years 2003-2005, lesser sandeel larvae were caught from January to May. They were the most abundant species in all years, but showed considerable fluctuations in abundance between years (Malzahn and Boersma 2007).
The larvae have a relatively short drift phase of 1–3 months (Wright and Bailey 1996, Jensen 2001) which is believed to render the sandeel recruitment rather sensitive to optimal hydrographic conditions (Wright and Bailey 1996). They settle at a length of about 40mm into the aggregation of adults (Christensen et al. 2008).

Spatial occurrence of larvae: As the eggs are demersal and fixed to the bottom, hatching occurs in areas where the eggs were spawned. The spreading of lesser sandeel occurs mainly during the pelagic larval phase, post-settlement lesser sandeels do not move far from their habitat (Macer 1966, Jensen 2001), but distribution between the different suitable sandeel banks occurs (Jensen 2001, Christensen et al. 2008; Fig 4.9.1).
Southerly concentrations of larvae are found in the Southern Bight (Simpson 1949, Macer 1965 in Munk et al. 2002), off the southwestern flank of Dogger Bank (Macer 1965 in Munk et al. 2002) and in the German Bight (Kändler 1941 in Munk et al. 2002), while in the northern areas the important grounds are found off the Firth of Forth, in the Moray Firth and in the Orkney area (Langham 1971 in Munk et al. 2002). Distribution of lesser sandeel larvae based on a survey in March 1997 is presented in figure 4.9.2a. Also in figure 4.9.2b the distribution of Ammodytidae larvae (possibly all five species as the larvae were not determined to species level) in February/March 2004.



(a)



(b)

Fig 4.9.2. (a) Lesser sandeel larval abundance estimates in no. m^{-2} from a Danish survey in March 1997. Relative abundances of larvae are illustrated by area of filled circles, the three circles in uppermost left corner of figures illustrate circle areas when larval densities are either 20, 10 and 5 m^{-2} (from Munk et al. 2002), (b) Ammodytidae larvae abundance is illustrated by area of symbol; circles in bottom corners illustrate area for an abundance of 500 larvae m^{-2} during the International Ichthyoplankton surveys from 18 February and 23 March 2004 (Taylor et al. 2007; from Munk et al. 2009).

4.9.4 Juveniles

Spatial occurrence and seasonal migrations: The juveniles settle, 1 to 3 months after hatching of the eggs, at a length of 40mm into the aggregation of adults (Christensen et al. 2008), and thus use the same are areas as the adults..
Lesser sandeel recruitment is traditionally defined as the amount of post-settlement individuals in June. This recruitment has failed in latest years, most likely owing to climate related changes in the environment combined with fishing effects (Arnott and Ruxton 2002, Van Deurs et al. 2009).
A small part of the juveniles already became mature at age 1 (around 5%), 80.5% of the fish of 2 years old and 98.9% of the older fish were mature, based on samples from the Dogger Bank in January (Macer 1966). The stock assessment working group considers all sandeel to be mature at age 2 (ICES 2008). This indicates that the whole year round juveniles are part of the aggregations of adult sandeels.

4.9.5 Adults

Spatial occurrence and seasonal migrations: As said before the lesser sandeel is restricted to areas with well-oxygenated bottom substrate consisting of gravel or coarse sand, because it is buried in the bottom for most of the time. To be more specific, lesser sandeel was not found in areas where the silt/clay content was larger then 20% and densities declined in areas where the fractions ranged from 2 to 10% (Wright et al. 2000).
Sandeel generally show no migrational behaviour, the only exchange takes place during the larval phase (Macer 1966; Jensen 2001). However some minor migrations were shown by tagged sandeel in the northwestern North Sea (Gauld 1990).
During surveys in spring 2007, done as part of a study on possible effects of Windmill parks, lesser sandeel were collected in front of the Dutch coast (Fig. 4.9.3; Ter Hofstede et al. 2007). This indicates that they have a wider distribution then suggested in figure 4.9.1, based on sediment preference.

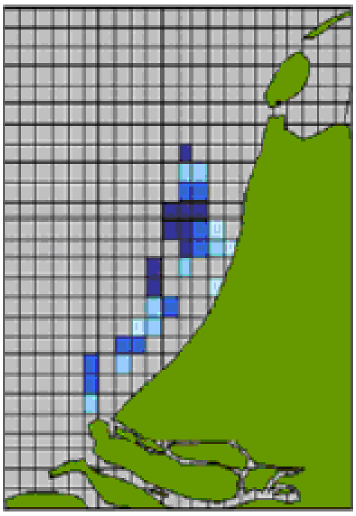


Fig. 4.9.3. Distribution of lesser sandeel during a survey in spring 2007 (0=0, 1=10, 2=100, 3=1000 kg/hour fishing etc., from Ter Hofstede et al. 2007).

4.9.6 Conclusion

The importance of the Dutch EEZ for the different life stages is summarised in Table 4.9.1. Lesser sandeel occur on the Dutch part of the Dogger bank and along the coastal area. Their eggs are found during winter in the same areas, and the larvae drift in the water column during winter and spring. The importance of the Dutch EEZ for the North Sea population of lesser sandeel is complicated. Only a small part occurs on the Dutch EEZ, however the perception is that in latest years the southern part is increasing in importance compared to the northern part. There is limited connectivity between sub-populations, owing to limited migrational behaviour and patch distribution, which increases the risk of local depletion. An example are the populations in the Norwegian waters, these are considered commercially extinct (ICES 2008).

Table 4.9.1: Summary of the importance of the Dutch EEZ for different life stages of lesser sandeel at different times of the year. Eggs and larvae information is provided on a monthly basis, juvenile and adults on a quarterly basis. Importance levels (none or close to none = white; low = yellow; medium = orange; high = red; grey = unknown) relate to the extent of the distribution of each life stage within the Dutch EEZ and are based on best estimates from current knowledge.

Month	1	2	3	4	5	6	7	8	9	10	11	12
Eggs	*Low*	*Low*									*Low*	*Low*
Larvae	*Low*	*Low*	*Low*	*Low*	*Low*							
Juveniles		*Low*			*Low*			*Low*			*Low*	
Adults		*Low*			*Low*			*Low*			*Low*	

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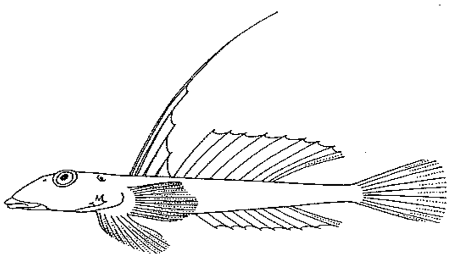
4.10 Common Dragonet – *Callionymus lyra* (Linnaeus, 1758)



4.10.1 Introduction

The common dragonet is a demersal Lusitanian species occurring on the shelf, with a maximum length of 32 cm (Yang 1982; Ellis et al. 2002; Ellis et al. 2008) and a maximum age of 5 years for males and 7 years for females (Wheeler 1969). Its distribution extends from as far south as Mauritania to as north as southern Iceland including the Mediterranean, western Black Sea, Azores the Canary Islands, North Sea, Skaggerrak/Kattegat and the southern Baltic.
In the North Sea, *Callionymus lyra*, is the most common of the three Callionymus species, the other two are *C. reticulates* and *C. maculates*. The Dragonets are normally found in water less than 50m deep (Wheeler 1969). Common Dragonet spawns between February and April. They spawn in shallow water where they perform an elaborate courtship display. The couple hold each other by the fins and circle up. The common dragonet is a batch spawner, most likely a determinate batch spawner. Both eggs and larvae are Pelagic. After their larval development, they settle on the seabed (van der Veer et al. 1990).
The dragonet has no commercial value and it thus not landed by fisheries.

4.10.2 Eggs

Temporal occurrence of eggs: The eggs occurred from March to at least July in samples taken in 1989. The peak occurred in May (Fig. 4.10.1, van der Land 1990; 1991). Russel (1976) described the spawning period to last from January to August.

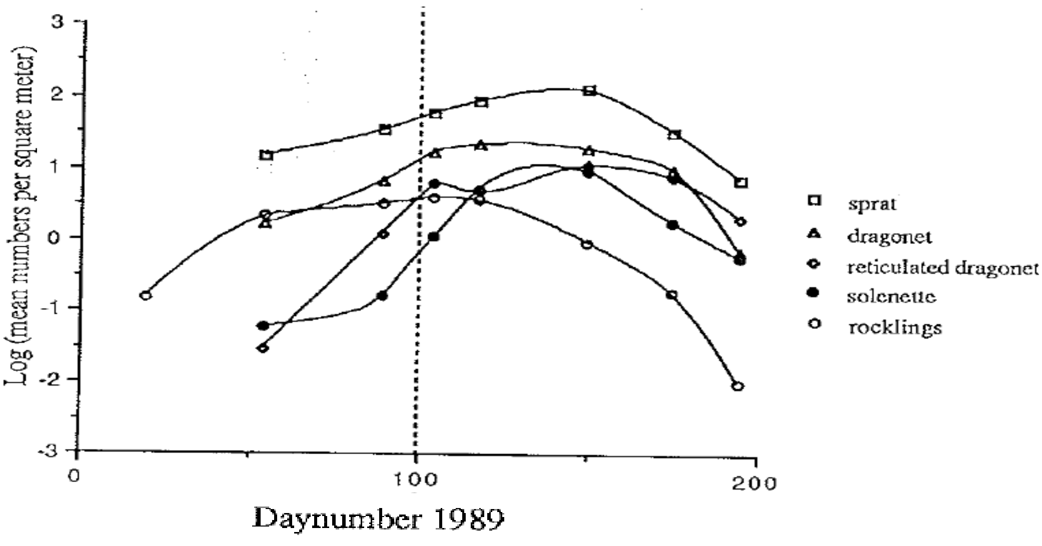


Fig. 4.10.1. Seasonal pattern in eggs of various species, triangles are common dragonet (van der Land 1990).

From December 2003 to early April 2004, an international ichthyoplankton survey took place intended to catch eggs and larvae of winter spawners (Taylor et al. 2007). During sampling in late February and March eggs of Callionymidae (not identified to the species level) were found, with the highest abundance in March. However, these are most likely *Callionymus maculatus* as their eggs occur in deeper water than the eggs of common dragonet.

Spatial distribution of eggs: During the international egg surveys in 2003/2004, highest catch rates of Callionymidae eggs (up to 27 m^{-2}) occurred off the northeast coast of Scotland and near the northern limits of the North Sea. (Fig. 4.10.2, Taylor et al. 2007). Figure 4.10.2 depicts all samples which identified Callionymidae eggs for the whole period. However, only part of the area was covered in March/April. For example: the German Bight area and the intensive grid in the Dutch coastal area were sampled in January, i.e. too early for common dragonet eggs. Therefore Figure 4.10.2 only depicts a part of the egg distribution.

In June 2008, during the mackerel egg survey, common dragonet eggs were caught throughout the whole survey area in higher numbers than in the 2003/2004 ichthyoplankton surveys (Fig. 4.10.3), the mackerel survey seems to have sampled just after the peak in May shown in the 1989 egg survey (4.10.1). The distribution of common dragonet eggs in the 1989 eggs survey is shown in figure 4.10.4.

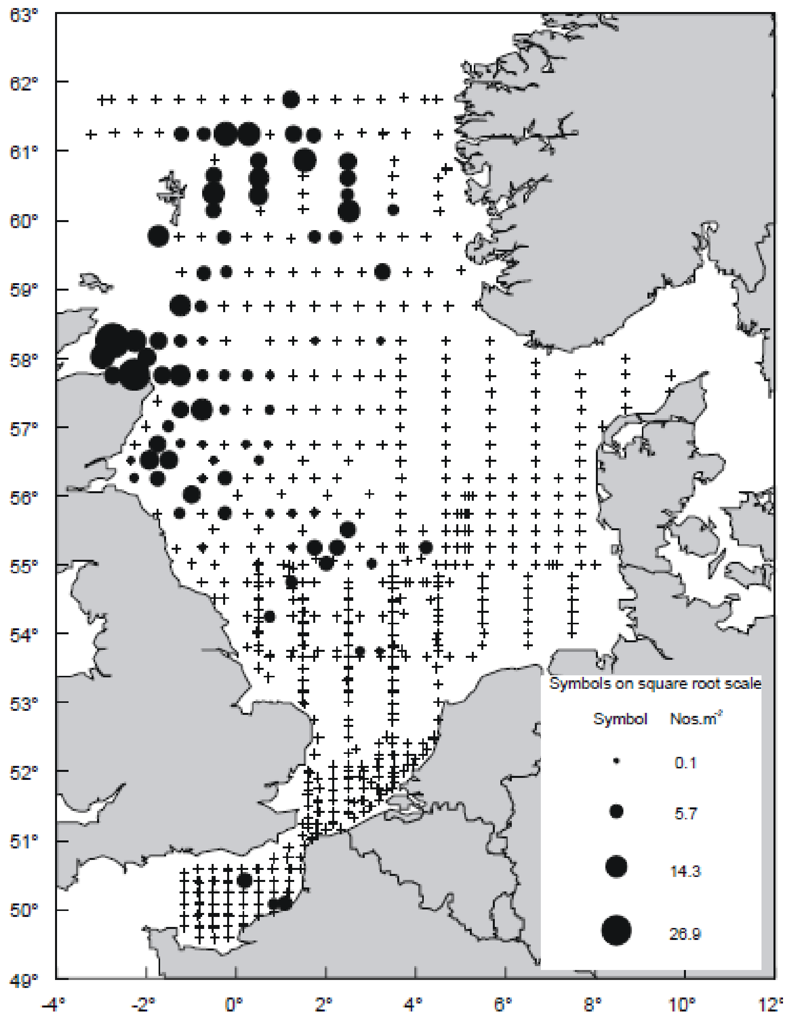


Fig. 4.10.2. The distribution of Callionymidae (all three species) egg abundance (nos. m^{-2}) from late December 2003 to early April 2004 from International Ichthyoplankton surveys (Taylor et al. 2007).

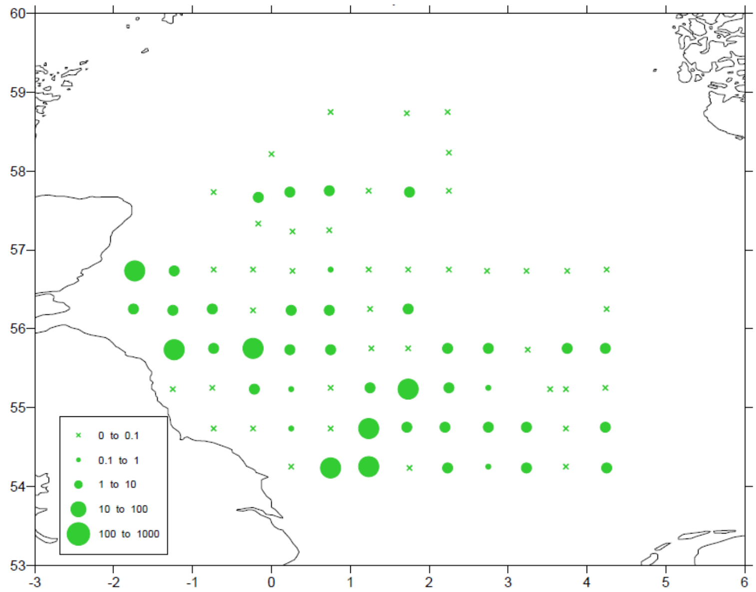


Fig. 4.10.3. Number of dragonet eggs per m^{-2} during a egg survey in June 2008 (van Damme 2008).

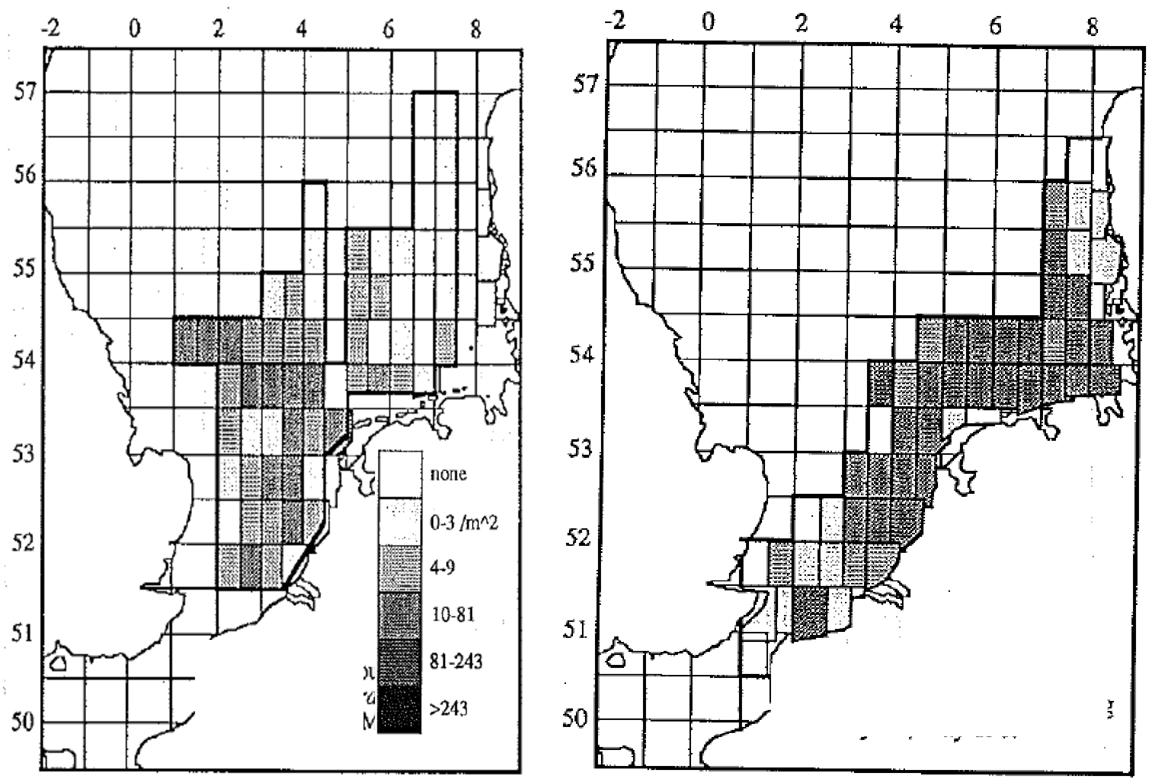


Fig. 4.10.4 Distribution of Common dragonet eggs during a survey in March (left) and May (right) 1989 (van der Land 1990), the sampled area differs between the two months.

4.10.3 Larvae

Temporal occurrence of larvae: Postlarvae of common dragonet occurred from February to November in the plankton off Plymouth, but were most abundant in May and June (Russell 1976). In the daily samples of the Helgoland roads station (54°11.18 N and 07°54.00 E), the larvae appeared from April to September (Malzahn and Boersma 2007). In numbers, the larvae were the 5th most abundant species in the Helgoland roads station, while in the Plymouth data they form

nearly 50% of the total larvae catch (excluding clupeid larvae) in the months when they were most abundant.
The larvae were rare in the 2003/2004 ichthyoplankton survey, probably because sampling occurred too early in most areas (latest in April), as described for the distribution of eggs. However it shows that in the northern North Sea larvae of Callionymidae already appear in March (Taylor et al. 2007).

Spatial occurrence of larvae: As the larvae occurred mainly from April to September, only a very low number was caught during the 2003/2004 ichthyoplankton surveys (Fig. 4.10.5, Taylor et al. 2007). These surveys occurred before the occurrence of larvae shown in the samples of the Helgoland roads station (Malzahn and Boersma 2007).

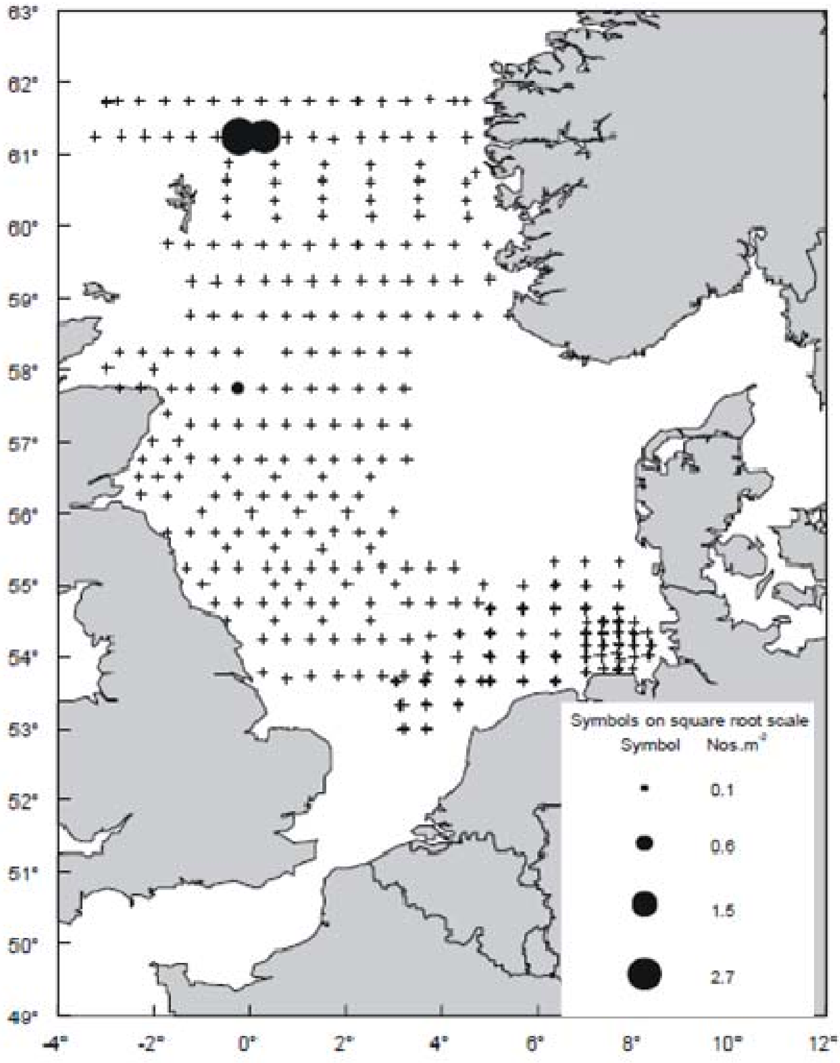


Fig. 4.10.5. The distribution of Callionynidae (all three species) larvae abundance (nos. m^{-2}) from late December 2003 to early April 2004 from International Ichthyoplankton surveys (Taylor et al. 2007).

4.10.4 Juveniles

Spatial occurrence and seasonal migrations: Dragonet < 24cm were reported in the "Atlas of North Sea Fishes" as juveniles, however males are already mature at a length of 13 cm. (Chang 1951 in Knijn et al. 1993). Based on a summer and winter survey, averaged for 1985-1987 (International Bottom Trawl Survey, IBTS), dragonet appear from the Moray Firth along the UK coast, the shallower southern North Sea, German Bight and into the Skagerrak/Kattegat (Fig.

4.10.6). The summer concentration seems to be in the Dutch EEZ and German Bight, while in winter they show a more widespread distribution.

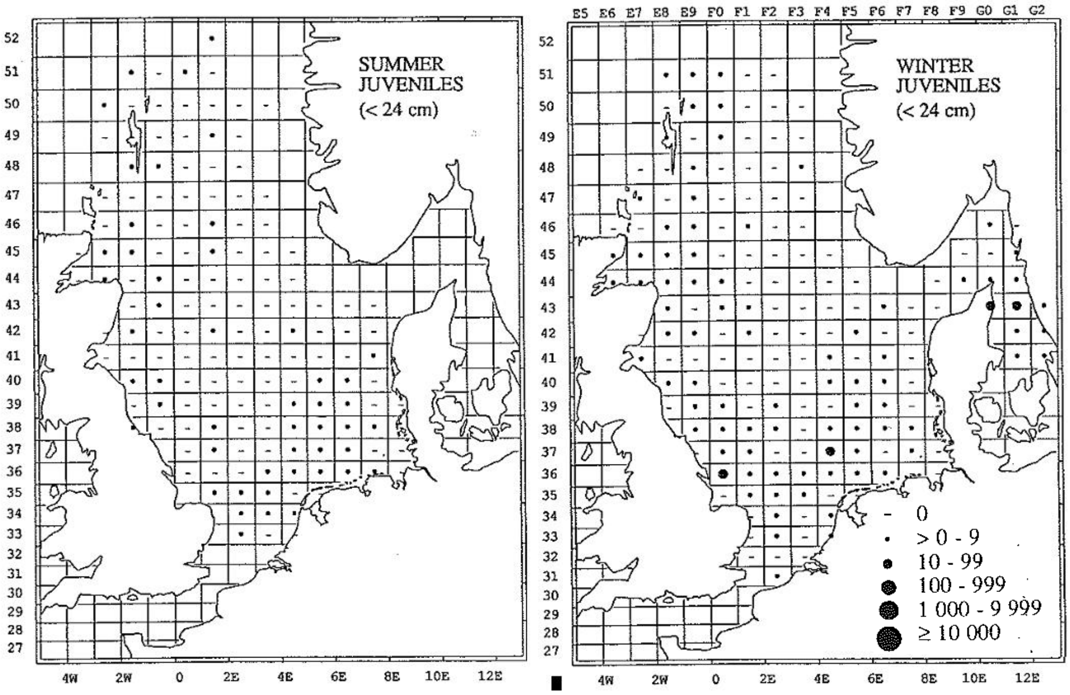


Fig. 4.10.6. Spatial distribution of "juveniles" of dragonet, average catch rates (number per hour fishing) in summer (left) and winter (right) in the years 1985-1987 (Knijn et al. 1993).

4.10.5 Adults

Spatial occurrence and seasonal migrations: Despite fluctuations in density, a general trend could be observed with highest numbers of dragonets in the coastal zone and decreasing numbers towards deeper water offshore, based on surveys from the period 1972 to 1984 irrespective of time of the year (van der Veer et al. 1990; Fig. 4.10.7). Specifically in summer in southern waters this coastal distribution appears, while in winter there is a more even spread in their distribution (Knijn et al. 1993, Fig. 4.10.8).

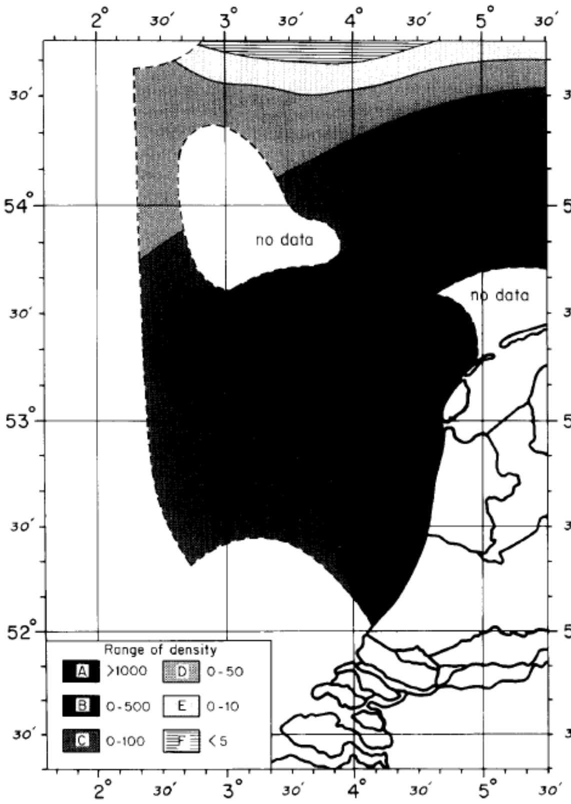


Fig. 4.10.7 Distribution of *Callionymus lyra* (n.10 000 m^{-2}) in the southern North Sea, divided into a number of subareas based on maximal occurrence per area (van der Veer et al. 1990).

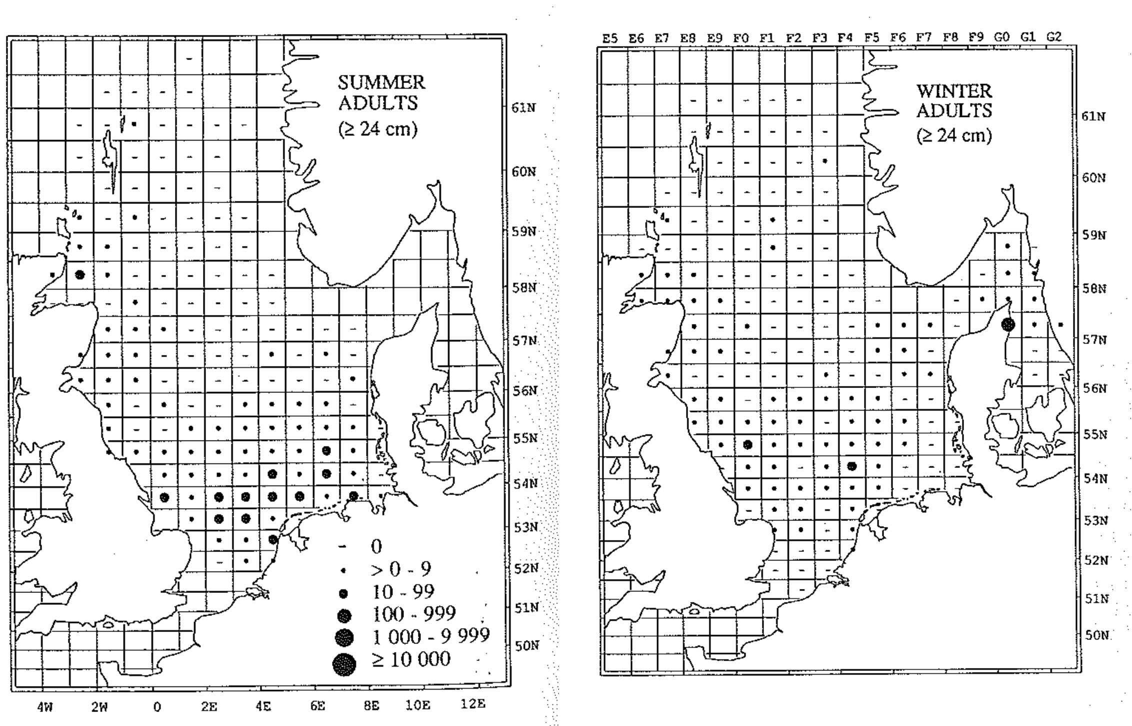


Fig. 4.10.8. Spatial distribution of "adults" of dragonet, average catch rates (number per hour fishing) in summer (right) and winter (left) in the years 1985-1987 (Knijn et al. 1993).

4.10.6 Conclusion

The importance of the Dutch EEZ for the different life stages is summarised in Table 4.10.1. Eggs occur from March to at least June, where specifically May and June are the peak months. Larvae are found approximately a month after the eggs with the peak also a month later. The Dutch EEZ is only a part of the distribution area of eggs and larvae as is shown by the Mackerel egg survey data and the egg survey in 1989.

The juvenile and adults occur on the Dutch EEZ the whole year, but the Dutch EEZ is only a part of their distribution area in the North Sea. For the adults it seems, based on the data from the summer IBTS, that they are aggregated in the southern North Sea, specifically on the Dutch EEZ, in summer.

Table 4.10.1: Summary of the importance of the Dutch EEZ for different life stages of common dragonet at different times of the year. Eggs and larvae information is provided on a monthly basis, juvenile and adults on a quarterly basis. Importance levels (none or close to none = white; low = yellow; medium = orange; high = red; grey = unknown) relate to the extent of the distribution of each life stage within the Dutch EEZ and are based on best estimates from current knowledge.

Month	1	2	3	4	5	6	7	8	9	10	11	12
Eggs			*Med*	*Med*	*Med*	*Med*						
Larvae				*Low*	*Low*	*Med*	*Med*	*Low*	*Low*			
Juveniles	*Med*			*Med*			*Med*			*Med*		
Adults	*Med*			*Med*			*High*			*Med*		

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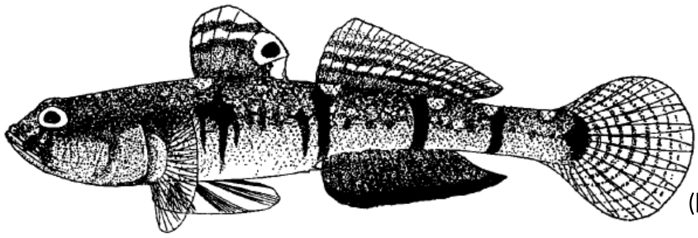
4.11 Sand Goby – *Pomatoschistus minutus* (Pallas, 1770)


(Fonds 1973)

4.11.1 Introduction

The Gobiidae are a large group of fish and up to 13 species are found in the North Sea. The sand goby (*Pomatoschistus minutus*), one of these 13 species, can reach a size of 5 to 7cm in the first year and 7 to 9 cm in the second year. This is their maximum size as they only reach an age of 2 years (Fonds 1973). However, an age of 3 years has been reported for the Tagus estuary, Portugal (Moreira et al. 1991) and a maximum length of 11cm (Muus and Dahlström 1978). Both sexes have a black spot in the first dorsal fin. In spring the males exhibit a green anal fin with black border and 5 to 6 rather broad dark transverse stripes on the body.
The species is classified as Lusitanian (Yang 1982; Ellis et al. 2008) and live especially in estuaries and on shallow sandy shores. In the Atlantic, its distribution extends from near Tromso, Norway, at ca. 69° N (Johnsen I936 in Webb 1980) and the Faeroes (Taning I940 in Webb 1980) to Brittany and northwest Spain (Duncker I928 in Webb 1980). Sand goby also occur in the Baltic, the southern Gulf of Bothnia and the Gulf of Finland (Lawacz I965 in Webb 1980). They have also been indentified on the south east coast of Spain, the Adriatic Sea and the Black Sea (Webb 1980). The sand goby is common in the Dutch estuaries and the North Sea coastal area from about 1 to 40m depth (Fonds 1973).
The sand goby are semelparous batch spawners (Hamerlynck and Cattrijsse 1994) that lay demersal eggs in empty shells (Russell 1976). The territorial males fan and guard these eggs, which can be spawned by multiple females. Based on the fact that eggs are consumed by male sand gobies, there seems to be competition among males for specific nest sites (Hamerlynck and Cattrijsse 1994). After the spawning season only few adults survive (Fonds 1973). The eggs hatch within 7 to 14 days depending on the temperature (Swedmark 1985 in Russel 1976), followed by a pelagic larval phase. This phase ends when the juveniles reach a length of 17-18mm and start their demersal life (Fonds 1973; Hamerlynck and Cattrijsse 1994).
The species has no commercial value.

4.11.2 Eggs

Temporal occurrence of eggs: Different spawning periods are reported for the sand goby, depending on area and temperature. Spawning starts when water temperature rises above 5 to 6 °C (Hesthagen 1977, personal observation in Lindström 1992), and the season can last up to 3 months (Lindström 1992). In the Southern Bight, eggs were found from late April to early June (Fonds 1973), while other periods reported are April to August (Danois 1913 in Russel 1976) and from March to July in Sweden and Brittany (Swedmark 1958 in Russel 1976).

Spatial distribution of eggs: The distribution of shells with sand goby eggs in the North Sea and the Wadden Sea (Fig. 4.11.1) shows that the species spawns in the North Sea at a depth of 10 to 25 m and water temperatures from 8 to 14° C. Sand gobies may spawn in estuarine lagoons, and eggs were also found occasionally in the Wadden Sea, but there is no evidence that sand gobies preferably reproduce in shallow parts of estuaries (Fonds 1973). They generally disappear from the inshore areas at the onset of the reproductive season. Spawning may be restricted to areas covered with numerous lamellibranch shells located outside the estuary (Fonds 1973).

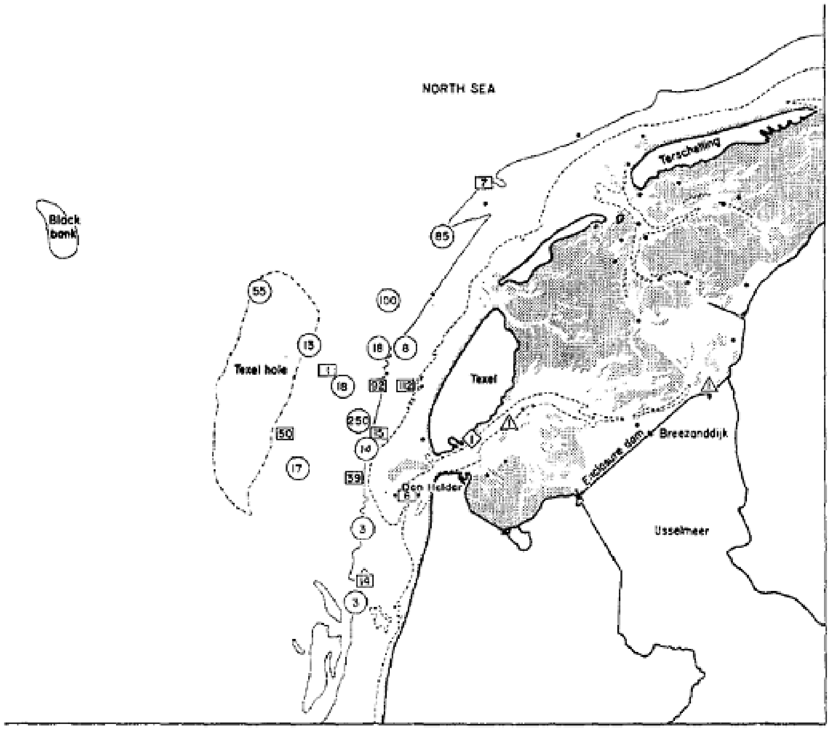


Fig. 4.11.1. The distribution of lamellibranch shells with sand goby eggs. Numbers collected in the North Sea in 1967 (in circles) and 1968 (in rectangles). Stations from dredging surveys are indicated by black dots (these had no goby eggs). Numbers of shells with sand goby eggs collected in the Wadden Sea in 1966 (in triangles) and in 1969 (in rhomb, from Fonds 1973).

4.11.3 Larvae

Temporal occurrence of larvae: The eggs hatch within 7 to 14 days depending on the temperature (Swedmark 1985 in Russel 1976), followed by a pelagic larval phase. The larvae were found from April to September (Shann 1910 in Russel 1976) with maximum abundance in June. The pelagic larvae were found in the Wadden Sea and the North Sea coastal area during spring and early summer (Fonds 1973). At Plymouth station, postlarvae were found from February to August (Lebour 1919, in Russel 1976, Lebour 1920).
In other studies which report occurrence and distribution of larvae, the goby larvae are not split up to species level, thus only reported as Gobiidae. This means that they can be of all 13 species in the North Sea. The North Sea ichthyoplankton survey in 2003-2004 reports Gobiidae larvae from February (Taylor et al. 2007). While the Helgoland roads station (54°11.18 N and 07°54.00 E) reports Gobiidae larvae from April to August (Malzahn and Boersma 2007). In these samples the Gobiidae larvae are the 3rd most abundant in 2003 and 2004 and the 5th in 2005. In a study in the surf zone of the Belgium coast, larvae were collected each month from May 1996 to July 1997. Eggs from *Pomatoschistus* species (not all of the 13 Gobiidae species belong to the genus Pomatoschistus) were collected in almost all months expect January and April (Beyst et al. 2001).

Spatial occurrence of larvae: The larvae appear in areas where the demersal eggs are spawned, from these areas they are transported by the tidal currents and will probably be carried in a north-eastern direction along the Dutch coast by the residual tidal current. Thus larvae from the spawning area off the coast of Texel will probably settle to demersal life further east in the Wadden Sea and in the North Sea coastal area off the isles of Terschelling and Ameland. The pelagic larvae caught in the western part of the Dutch Wadden Sea and in the North Sea at the lightvessel "Texel" probably originate from a spawning area situated more to the south (Fig. 4.11.2; Fonds 1973).

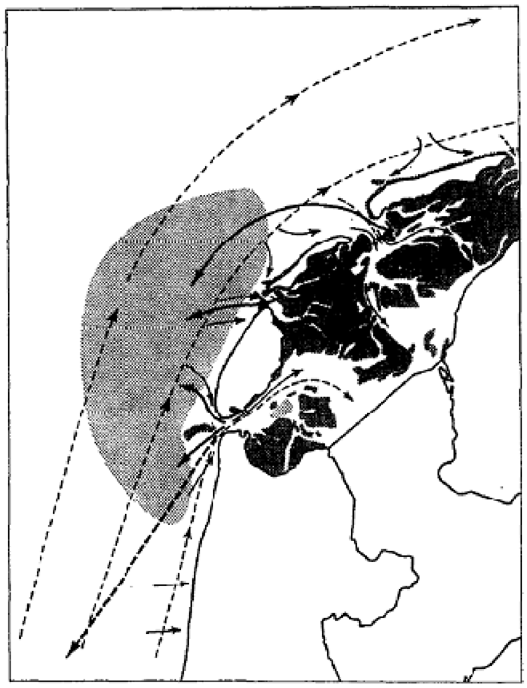


Fig. 4.11.2. Schematic outline of the presumed distributional pattern of sand gobies along the Dutch coast; indicated are main spawning area off Texel (hatched), residual tidal transport of pelagic larvae (broken arrows), migration of demersal young gobies towards the shore (thin arrows), and migration of adults to offshore spawning areas (heavy arrows; from Fonds 1973).

The distribution of Gobiidea larvae in the ichthyoplankton survey is shown in figure 4.11.3.

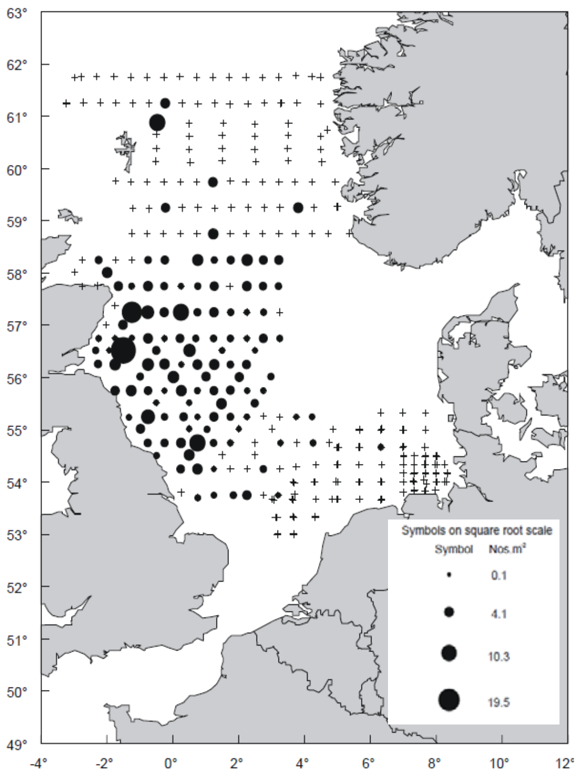


Fig. 4.11.3. The distribution of Gobiidae (all 13 species) larvae abundance (nos. m^{-2}) from late December 2003 to early April 2004 from International Ichthyoplankton surveys (Taylor et al. 2007).

4.11.4 Juveniles

Spatial occurrence and seasonal migrations: The pelagic phase ends when sand gobies reach a length of 17-18mm and start their demersal life (Fonds 1973; Hamerlynck and Cattrijsse 1994). At this stage they can be called juveniles. The first juveniles appear during summer and these grow rapidly to mature size in autumn (Fonds 1973). In the Wadden Sea these young sand gobies were generally more concentrated in the shallow areas, the deeper tidal channels are probably less favourable (Fonds 1973). The young sand gobies were generally more abundant in the coastal North Sea as compared to the Wadden Sea (Fonds 1973). Their distribution during summer and early autumn indicates that they migrate from the North Sea coastal area into the Wadden Sea (Fig. 4.11.2 and Fig 4.12.2 section *P. microps*). A similar inshore migration of young sand gobies has been observed in the Ythan estuary (Healey 1971 in Fonds 1973).

4.11.5 Adults

Spatial occurrence and seasonal migrations: Sand gobies are most abundant in the Wadden Sea in autumn. They disappear in winter to avoid temperatures below 2.5 °C. They retreat to greater depth and distance offshore, but appear again in the Wadden Sea in early spring as soon as the temperature reaches 3° to 4°C. The gobies stay on in the Wadden Sea during mild winters, when the temperature remains above 2.5° C (Fonds 1973). This seasonal migration to deeper water in winter is only shown in the northern area of their distribution (Fonds 1973).
The migration pattern of the larvae (Fig. 4.11.2) implies that adult gobies from the Wadden Sea migrate in spring in a southwesterly direction to reach appropriate spawning areas (Fonds 1973). The development of sand gobies is fast and at the end of the year in which they are spawned, they already mature. They spawn in their first year and most of the adults disappear after spawning. Only a small number of fish spawn a second time the year after.
Comparing sand gobies with Lozano's gobies (*Pomatoschistus lozanoi*), it seems that sand gobies are more adapted to estuarine conditions and a benthic food supply and they are more abundant in the North Sea along the Dutch coast and in the Wadden Sea (Fig. 4.11.4; Fonds 1973).

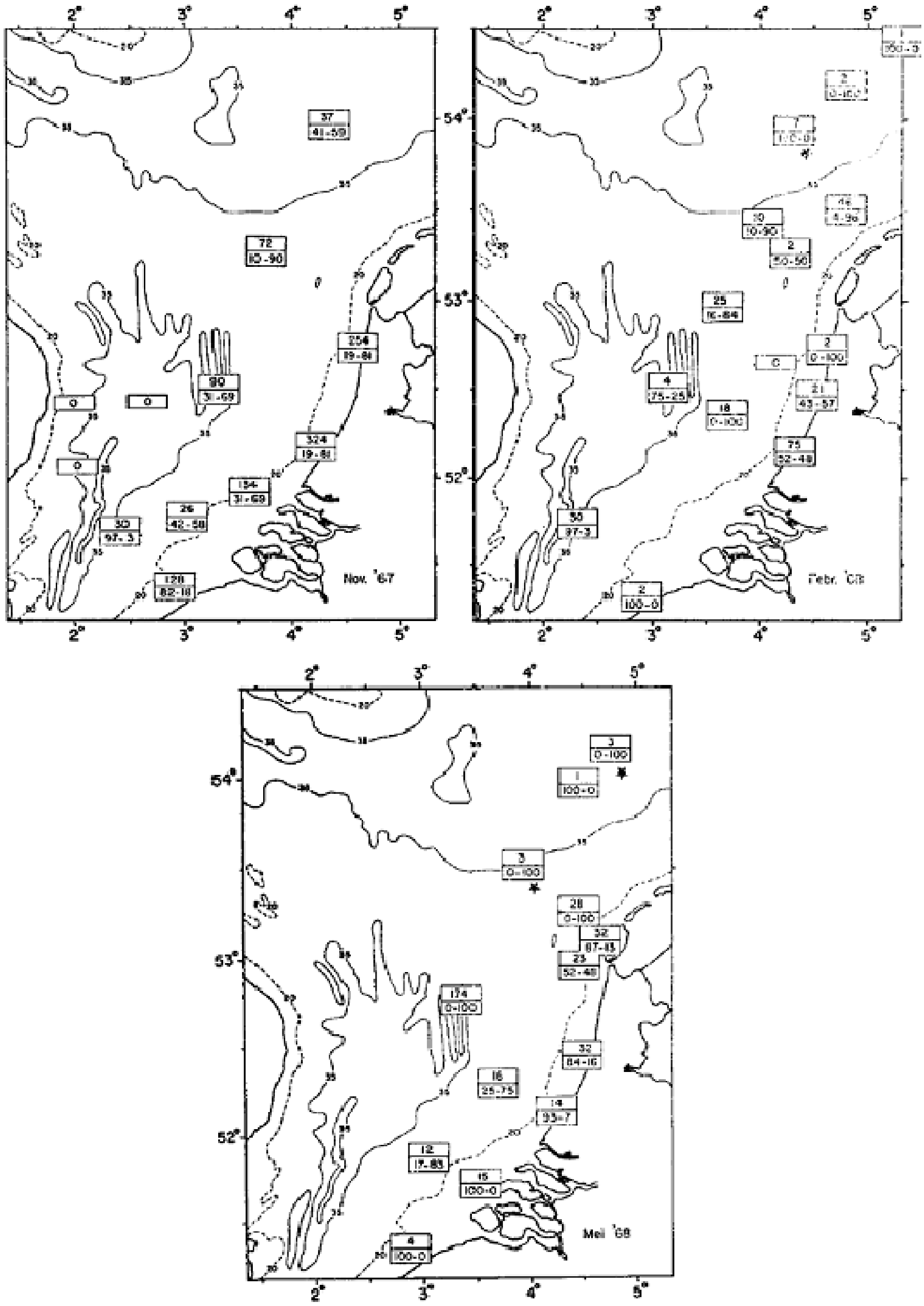


Fig. 4.11.4. Distribution of *Pomatoschistus minutus* and *P. lozanoi* in the southern North Sea in autumn, winter and spring. In each rectangle total number of sand gobies in the sample (above), *% P. lozanoi* (left), and *% P. minutus* (right).

4.11.6 Conclusion

An evaluation of the importance of the Dutch EEZ for sand goby is hampered by the lack of (species-specific) data. The periods which may be of importance for the different life stages is summarised in Table 4.11.1. Coastal waters and inshore waters (Wadden Sea and Schelde estuary) are important for sand gobies. The spawning sites appeared to be mainly located in coastal waters outside the Wadden Sea and Schelde estuary.

Table 4.11.1: Summary of the importance of the Dutch EEZ for different life stages of sand goby at different times of the year. Eggs and larvae information is provided on a monthly basis, juvenile and adults on a quarterly basis. Importance levels (none or close to none = white; low = yellow; medium = orange; high = red; grey = unknown) relate to the extent of the distribution of each life stage within the Dutch EEZ and are based on best estimates from current knowledge.

Month	1	2	3	4	5	6	7	8	9	10	11	12
Eggs												
Larvae												
Juveniles												
Adults												

4.11.7 References:

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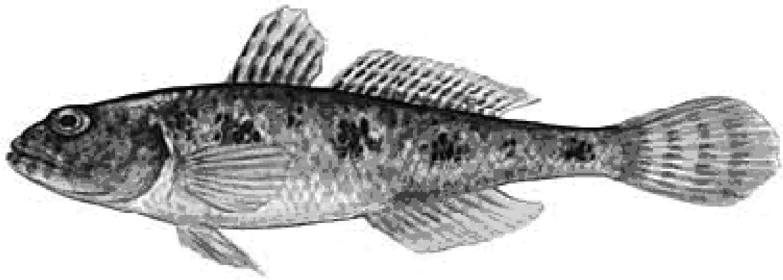
4.12 Common Goby – *Pomatoschistus microps* (Krøyer, 1838)



4.12.1 Introduction

Common goby, *Pomatoschistus microps*, is another of the 13 Gobiidae species in the North Sea. It is very similar to the other two species described above. They can reach a maximum length of 7 to 9 cm in the second year. An age of 26 months has been reported (Miller 1975; Moreira et al. 1991), but most adult fishes die in the second autumn a few months after their first spawning (Miller 1975, Jones and Miller 1966).
The common goby is classified as Lusitanian (Yang 1982; Ellis et al. 2008) and occurs inshore and extends further up estuaries into brackish water than *P. minutus* and *P. lozanoi*. In the eastern Atlantic, it extends from Morocco to Norway including the Baltic Sea and western Mediterranean. It is also found in the Mauritanian waters and around the Canary Islands.
The common goby is a semelparous batch spawners (Hamerlynck and Cattrijsse 1994) which lays demersal eggs in empty shells such as Mya or under stones (Russell 1976). The territorial males fan and guard these eggs, which can be spawned by multiple females. The demersal eggs are followed by a pelagic larval phase. This phase ends when the juveniles start their demersal life.
The species has no commercial value.

4.12.2 Eggs

Temporal occurrence of eggs: The demersal eggs of the common goby are found in April and May (Lebour 1920). In the Morecmbe area (West of the UK) nest sites were found from April to August (Fig. 4.12.1, Jones and Miller 1966). In the August, nesting sites of common goby where located in the Wadden Sea during diving (Fonds 1973). The nesting sites are limited to areas with enough empty shells or stones to lay eggs under.

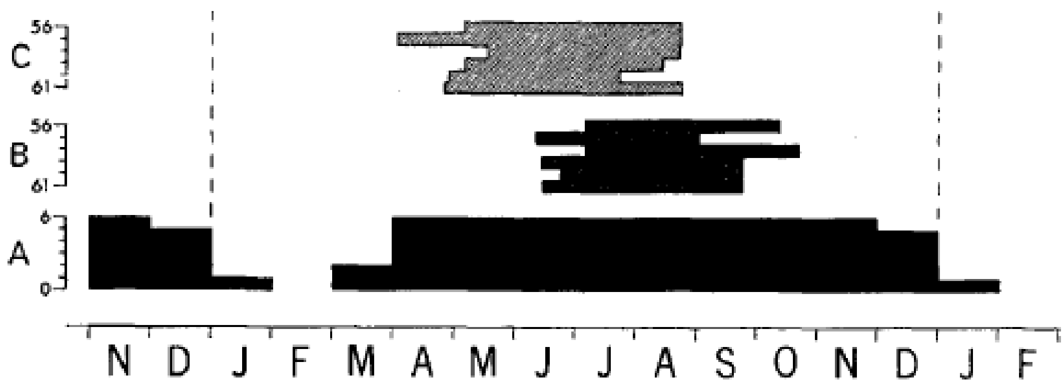


Fig. 4.12.1. Life-history of common goby at Morecambe (West of the UK) during 1956-1961, and annual temperature cycle. A, months in which common goby was common or abundant for each year; B and C, limits of occurrence in pools of newly metamorphosed young and nests respectively for each year (Jones and Miller 1966).

Spatial distribution of eggs: No clear reference for the distribution of eggs of common goby is found. Nesting gobies observed in shallow water (0.5m depth) in the North Sea and Wadden Sea were always the common goby (Fonds 1973). Lebour (1920) reports common goby eggs in the Sound in similar locations as *P. minutus* eggs. In figure 4.11.1 (section *Pomatoschistus minutus*), one rhomb is located in the Wadden Sea near Texel, this is a batch of *P. minutus* eggs found on a crowded spawning place of the common goby at 0.5m depth (Fonds 1973).

4.12.3 Larvae

Temporal occurrence of larvae: Larvae of common goby were observed from March to September with highest numbers in May on the west coast of Ireland (Five 1970 in Russel 1976). Postlarvae were collected at Plymouth station in July (Lebour 1920). The duration of the pelagic phase is estimate at 6 to 9 weeks (Jones and Miller 1966).
Probably, common goby larvae were part of the Helgoland road and ichthyoplankton data described for sand goby (section 4.11.3).

Spatial occurrence of larvae: Common goby larvae usually appear higher up the estuary then sand and Lozano's goby larvae. However, Lebour (1920) found larvae in the Sound at the same locations as sand goby larvae.

4.12.4 Juveniles

Spatial occurrence and seasonal migrations: Newly metamorphosed young were observed from June to October (Fig. 4.12.1 B, Jones and Miller 1966), which mature in spring the following year (Jones and Miller 1966). The distribution during winter is at greater depth to avoid low water temperatures (Jones and Miller 1966). This migration to the deeper waters by juvenile common gobies is shown in areas were winter temperatures normally fall below 5°C (Fig. 4.12.2). In the Wadden Sea, they migrate to deeper water as well, however there is little stratification in the deeper tidal channels. Therefore, they can not hide from extreme temperatures below a thermocline, and were incapable of surviving the extreme cold temperatures in 1963 (Fonds 1973). Other species that migrated further offshore were able to survive the extreme colds, however common goby apparently does not migrate far offshore and dies at temperatures below –1° C (Fonds 1973). During spring, the juveniles return to the shallower coastal water (Fig. 4.12.1).

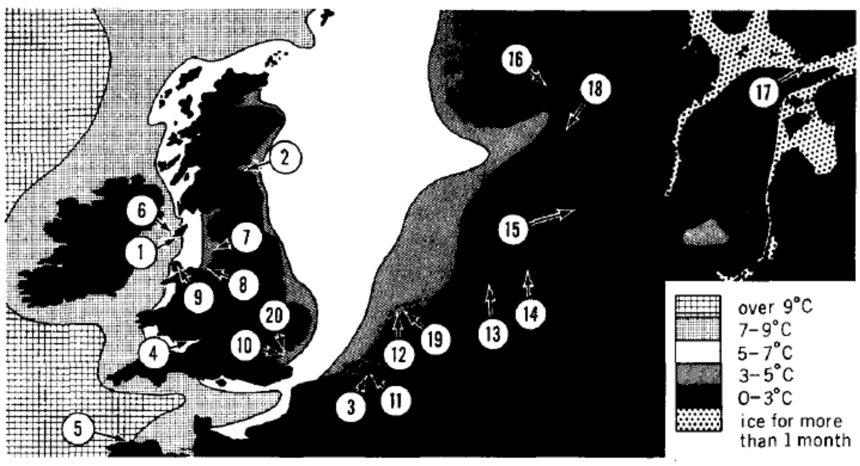


Fig. 4.12.2. Occurrence of winter migrations in common goby (*P. microps*) and sand goby (*P. minutus*) in relation to minimum winter sea surface temperatures (February) for southern boreal and Baltic Sea areas. Migration occurs at localities 7-17 (*P. microps*) and 18-20 (*P. minutus*); non-migration at 1-4 (*P. microps*) and 5 and 6 (*P. minutus*) (Jones and Miller 1966).

4.12.5 Adults

Spatial occurrence and seasonal migrations: The adults surviving to a second spawning period, show the same migration behaviour during winter as the juveniles. Together with the juveniles they return to the shallower areas in spring. The juveniles become mature and spawn in these areas together with the surviving adults of the year before (Jones and Miller 1966). Common goby is common and numerous in the shallow parts of the Dutch estuaries and in the Wadden Sea at 0.2 to 2 m depth. Of the three described gobies, the common goby is the most euryhaline species. It can survive at salinities of 0.9‰ S and is therefore more often found in the shallower parts, in estuaries and up rivers. Newly demersal young have a specific preference for less saline part of estuaries (Miller 1975).

4.12.6 Conclusion

An evaluation of the importance of the Dutch EEZ for common goby is hampered by the lack of (species-specific) data. The periods which may be of importance for the different life stages is summarised in Table 4.12.1. The whole life cycle of the common goby can be completed in coastal waters. However, they occur more often in the Wadden Sea, estuaries and up rivers than the other two goby species. Spawning takes place during summer in shallow water were they need shells or stone. Pelagic larvae are distributed by tidal currents and juveniles and adults use the shallow coastal and estuarine waters.
Because there is no data available on the population size of common goby for any of the separate life-stages, it is impossible to assess the importance of the Dutch EEZ for the whole common goby population. Therefore the whole table is left grey.

Table 4.12.1: Summary of the importance of the Dutch EEZ for different life stages of common goby at different times of the year. Eggs and larvae information is provided on a monthly basis, juvenile and adults on a quarterly basis. Importance levels (none or close to none = white; low = yellow; medium = orange; high = red; grey = unknown) relate to the extent of the distribution of each life stage within the Dutch EEZ and are based on best estimates from current knowledge.

Month	1	2	3	4	5	6	7	8	9	10	11	12
Eggs												
Larvae												
Juveniles												
Adults												

4.12.7 References:

Ellis, J.R., Engelhard, G.H., Pinnegar, J.K., 2008. RECLAIM; Report of WP1 Chapter 3 – Ecotypes; http://www.climateandfish.eu/default.asp?ZNT=S0T1O-1P177.

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Russell, F.S., 1976. The eggs and planktonic stages of British marine fishes. Academic Press, London, 524 pp.

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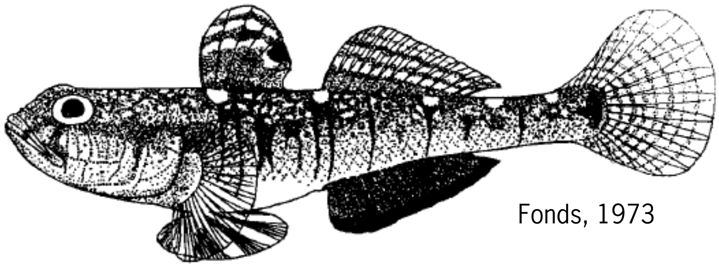
4.13 Lozano's Goby – *Pomatoschistus lozanoi* (de Buen, 1923)



Fonds, 1973

4.13.1 Introduction

Lozano's goby (*Pomatoschistus lozanoi*), has been identified as a separate species in 1973 by Fonds (1973), before it was considered a sub-species of the sand goby, *Pomatoschistus minutus Lozanoi*. This indicates the similarity to *P. minutus*, and thus the difficulty to distinguish the 2 species. They show small differences in appearance, and they differ in maximum size, in pattern of haemoglobins and vertebral number. They also differ in temperature requirements, spawning season and food preference (Fonds 1973). However, in many studies no difference between the two was made.
Lozano's goby reach a size of 4 to 6 cm in the first year, and are fully grown at 6 to 8 cm in the second year of life (Froese and Binohlan 2003). It has irregular dispersed speckles on the body and no spot in the first dorsal fin, except for the males in spring when they develop a black spot in the first dorsal fin in addition to a blue anal fin with black border and 7 to 9 rather narrow dark transverse stripes on the body.
Lozano's goby is classified as Lusitanian (Yang 1982; Ellis et al. 2008) and occurs from the Portuguese coast (Arruda and Azevedo 1987) to the Irish Sea and the North Sea. The most northern record is from Kames Bay, near Millport, Scotland, at ca. 56 °N (Webb 1980). There are no records so far from the Mediterranean or Baltic. In the North Sea it has a similar distribution as sand goby (*P. minutus*), although sand gobies may be more adapted to estuarine conditions (see section 4.14).
The Lozano's goby are repeat spawners (Hamerlynck and Cattrijsse 1994) that lay demersal eggs in empty shells (Russell 1976). The territorial males fan and guard these eggs, which can be spawned by multiple females. Contrary to sandy goby, males of Lozano's goby seem not to consume the *P. Lozanoi* eggs. This suggests that intraspecific competition for shells, or at least hostile takeovers are less important in Lozano's goby (Hamerlynck and Cattrijsse 1994). Interspecific competition with *P. minutus* is probably avoided by spawning later in the season. The smaller Lozano's goby are ready to spawn in April, just as *P. minutus*, but only start in June (Hamerlynck and Cattrijsse 1994). It has been suggested that this is because the smaller Lozano's goby loses the competition for nesting areas with the larger sand goby.
After the spawning season only few adults survive (Fonds 1973). The eggs hatch within 7 to 14 days depending on the temperature (Swedmark 1985 in Russel 1976), followed by a pelagic larval phase. This phase ends when the juveniles reach a length of 17-18mm and start their demersal life (Fonds 1973; Hamerlynck and Cattrijsse 1994).
The species has no commercial value, and is thus not landed at all.

4.13.2 Eggs

Temporal occurrence of eggs: According to Hamerlynck and Cattrijsse (1994), Lozano's goby start to spawn in June to avoid interspecific competition for shells with *P. minutus.* Eggs were reported from late May to mid August in the Southern Bight by Fonds (1973), which is later then *P. minutus*. Aquarium experiments show that Lozano's goby only starts spawning at temperatures from 10° to 15° C, while *P. minutus* started spawning at lower temperatures.

Spatial distribution of eggs: The spatial distribution of Lozano's goby eggs seems similar to the sand goby eggs (Fig. 4.11.1 of section *P. minutus*). The eggs of Lozano's goby occurred more often on smaller shells, *Mactra coraUina, Laevicardium crassum* and *Cardium echinatum*, than the eggs of P. minutes (Fonds 1973).

4.13.3 Larvae

Temporal occurrence of larvae: As spawning occurs later, the larvae also occur later in the season then those of *P. minutus*. The appearance of larvae as described by a.o. Russel (1976), does not distinguish *P. minutus* and *P. lozanoi* (see section 4.11.3).

Spatial occurrence of larvae: No species-specific information available, probably similar to *P. minutus*.

4.13.4 Juveniles

Spatial occurrence and seasonal migrations: No species-specific information available, probably similar to *P. minutus*.

4.13.5 Adults

Spatial occurrence and seasonal migrations: This species is less common in estuarine waters compared to sand goby and cannot survive salinities below 3 to 5‰ (Fonds 1973). However, Lozano's goby have been reported from a tidal reservoir in the Severn Estuary (Williams I977), but *P. lozanoi* seems to occur at the mouth of estuaries, where it can be found in mixed populations with *P. minutus* (Le Danois 1913; De Buen 1923 in Webb 1980). Lozano's goby was more abundant in the southern part of the North Sea, while *P. minutus* was more abundant in the North Sea along the Dutch coast and in the Wadden sea (Fonds 1973)(Fig. 4.13.1). During winter Lozano's goby was not found below 3.5°C.

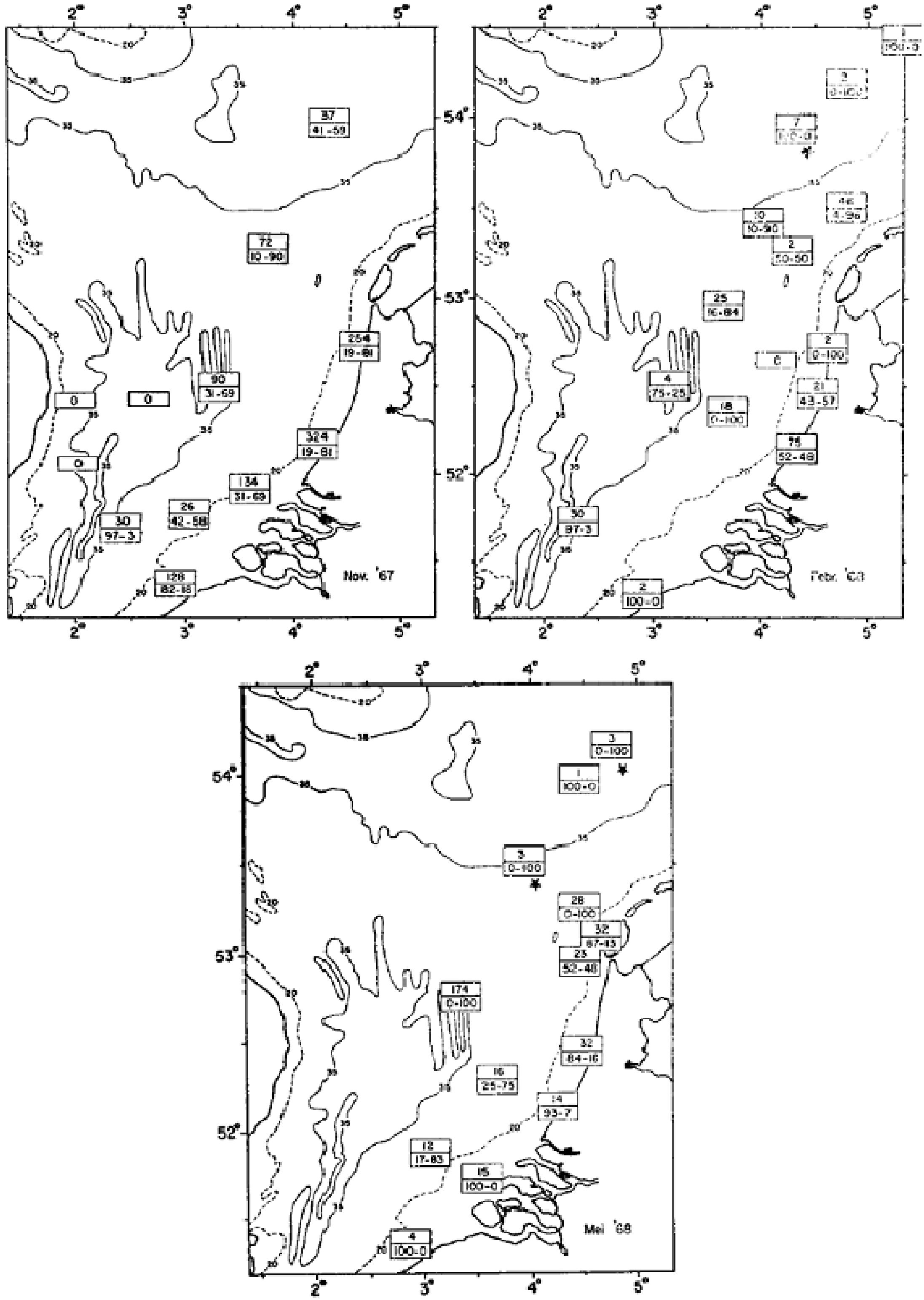


Fig. 4.13.1. Distribution of *Pomatoschistus minutus* and *P. lozanoi* in the southern North Sea in autumn, winter and spring. In each rectangle total number of sand gobies in the sample (above), *% P. lozanoi* (left), and *% P. minutus* (right) (Fonds, 1973).

4.13.6 Conclusion

An evaluation of the importance of the Dutch EEZ for Lozano's goby is hampered by the lack of (species-specific) data. The periods which may be of importance for the different life stages is summarised in Table 4.13.1. Coastal waters and, probably to a lesser extent, inshore waters (Wadden Sea and Schelde estuary) are important for Lozano's gobies. The spawning sites appeared to be mainly located in coastal waters. The development of Lozano's gobies is fast and at the end of the year in which they are spawned, they already mature. They spawn in their first year and most of the adults disappear after spawning. Only a small number of fish spawn a second time the year after.

Table 4.13.1: Summary of the importance of the Dutch EEZ for different life stages of lozano's goby at different times of the year. Eggs and larvae information is provided on a monthly basis, juvenile and adults on a quarterly basis. Importance levels (none or close to none = white; low = yellow; medium = orange; high = red; grey = unknown) relate to the extent of the distribution of each life stage within the Dutch EEZ and are based on best estimates from current knowledge.

Month	1	2	3	4	5	6	7	8	9	10	11	12
Eggs					▒	▒	▒	▒	▒			
Larvae						▒	▒	▒	▒	▒		
Juveniles							▒			▒		
Adults	▒			▒						▒		

4.13.7 References:

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Hamerlynck, O., Cattrijsse, A., 1994. The food of Pomatoschistus minutus (Pisces, Gobiidae) in Belgian coastal waters, and a comparison with the food of its potential competitor P. lozanoi. Journal of Fish Biology 44, 753-771.

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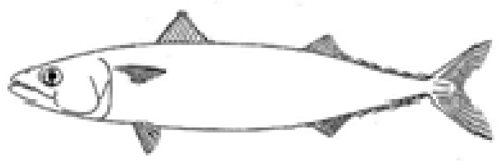
Yang, J., 1982. The dominant fish fauna in the North Sea and its determination. Journal of Fish Biology 20, 635-643.

4.14 Mackerel - *Scomber scombrus* (Linnaeus, 1758)



4.14.1 Introduction

Mackerel is a wide-ranging pelagic species, distributed from north-west Africa to Iceland and northern Norway in the eastern North Atlantic, including the Black Sea, Mediterranean and western Baltic Sea, and from North Carolina to Labrador in the western North Atlantic (Collette 1986). Its biogeographical guild is Atlantic (Yang 1982, Ellis et al. 2002, Ellis et al. 2008). It can reach a maximum length of 55 to 60cm and a maximum age of 17 years. Mackerel mature at the age of 3.

Two separate spawning stocks of mackerel are recognized in European waters, a North Sea stock, which spawns in the central North Sea (May - July; Lockwood 1988), and a Western stock, which spawns along the continental shelf break off the north of Spain and west of France, Ireland and Britain (January -July; Hamre 1980, Lockwood and Shephard 1984). Although the spawning areas are separated, some mixing of the two stocks occurs on the overwintering and feeding grounds (Bakken and Westgård 1986). Extensive migrations occur annually and the spatial distribution of the different mackerel life stages is likely to be affected by a variety of hydrographical features as well as the abundance and composition of zooplankton and other prey species (Iverson and Ljøen 1985, Reid et al. 1996).

4.14.2 Eggs

Temporal occurrence of eggs: Mackerel are determinate batch spawners and the North Sea stock is known to spawn between May and July (Lockwood 1988) in the central North Sea (Russell 1976), with the Western stock spawning earlier (January – July) but outside the North Sea region (Hamre 1980, Lockwood and Shephard 1984). North Sea egg surveys, which are coordinated by ICES and carried out on a triennial basis, show a peak in daily egg production occurring between Julian day 160 and 180 (June; Fig. 4.14.1)

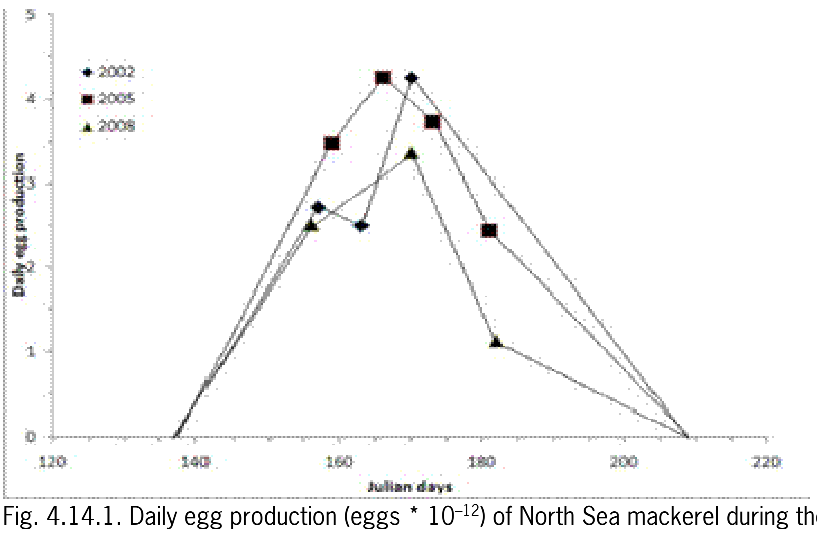


Fig. 4.14.1. Daily egg production (eggs * 10^{-12}) of North Sea mackerel during the 2002, 2005 and 2008 surveys (from ICES 2009).

Spatial distribution of eggs: In the North Sea over 91% of mackerel eggs occur above a thermocline at 26 m (Coombs et al. 1981). Recent North Sea egg surveys show a wide North Sea distribution between 53 °N and 60.5 °N and between 2 °W and 6 °W. The highest egg production (> 40 eggs per m^2) is found in the western part of the North Sea off the north English coast with a band of high production stretching north-eastwards (Fig. 4.14.2). Relatively lower egg production (< 40 eggs per m^2) is found in the northern part of the Dutch waters (Dutch EEZ in grey in Fig. 4.14.2). The spatial distribution of spawning areas however, has shifted over time from a central-eastern area during the 1980s to the western areas seen in the 2005 and 2008 egg survey data (Fig 4.14.3; ICES WGMEGS report 2009), possibly related to changing sea conditions (temperatures and salinities) which influence migrations and spawning onset (Reid et al. 1996).

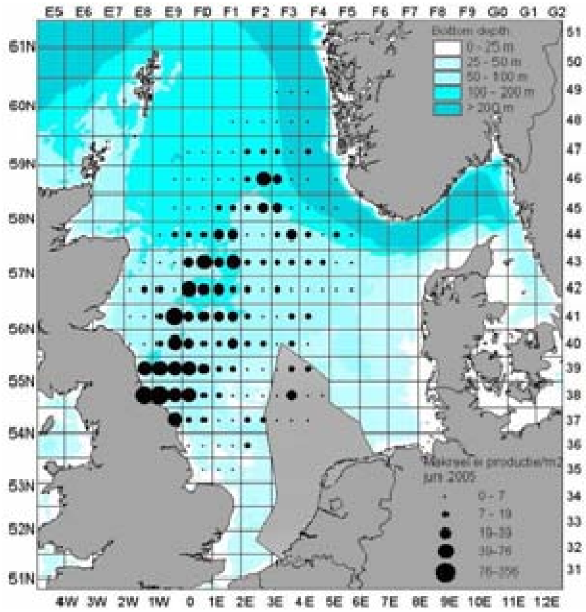


Fig. 4.14.2. Distribution of stage I mackerel eggs (as number per m^2) during spring 2005 (from ICES 2006). Dutch EEZ is marked by the grey triangle.

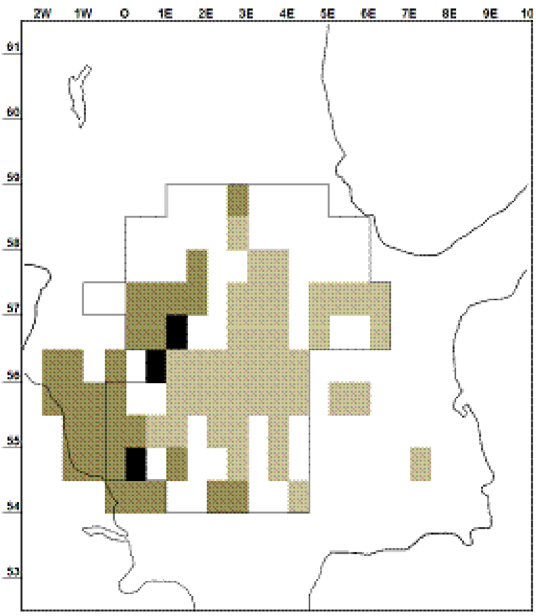


Fig. 4.14.3. Main spawning area in 1980, 1983, 2005 and 2008 defined as rectangles with at least 50 mackerel eggs/m^2/day. Light grey: 1980 and 1983, dark grey: 2005 and 2008. Black: overlapping area. The common sampling area for all four years is delineated (from ICES 2009).

4.14.3 Larvae

Temporal occurrence of larvae: Egg development time from fertilization to hatching is temperature dependant (177 days at 11°C to 49.5 hrs at 21°C; Russell 1976) and the temporal occurrence of post-larvae within the plankton of the North Sea and English Channel peaks between July and August, extending into September (Russell 1935)

Spatial occurrence of larvae: Small numbers of post-larvae are widely distributed across the North Sea, although observations from the continuous plankton recorder (CPR) showed mackerel post-larvae to be abundant mainly north of 56°N (Henderson 1954, Russell 1976).

4.14.4 Juveniles

Spatial occurrence and seasonal migrations: Juveniles (1-group) are found in the northern North Sea during the winter period, mainly along the continental shelf and the Norwegian Deeps, as well as some central parts of the North Sea (Fig. 4.14.4a; Knijn et al. 1993). The overwintering grounds thus overlap with those of mature and adult mackerel (see section 4.14.5).
During the summer feeding months juveniles are found in the southern North Sea, off the coast of Denmark, and along the western and southern coasts of Norway (Fig. 4.14.4b), although it is uncertain whether these individuals belong to the North Sea or the Western stocks. It has been suggested that these southern areas are used as nursery grounds, where mixing of the North Sea and Western stocks is likely to occur (Bakken and Westgård 1986).

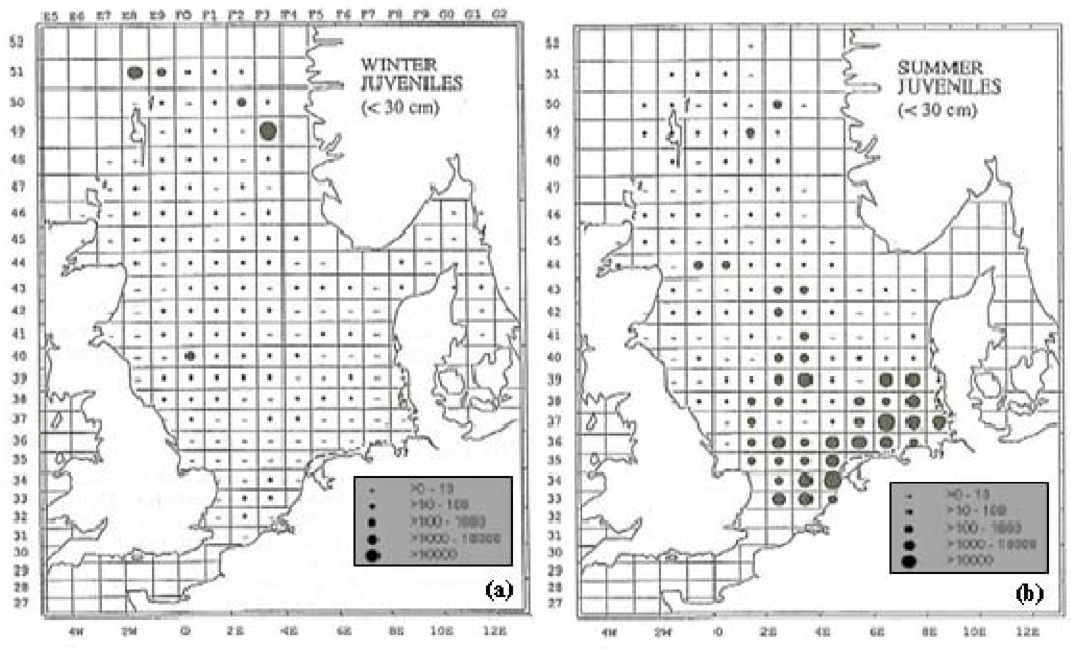


Fig. 4.14.4. Average annual catch rate (numbers per hour fishing) of juvenile mackerel in the years 1985 – 1987 during winter (a) and summer (b) months (from Knijn et al. 1993).

4.14.5 Adults

Spatial occurrence and seasonal migrations: The spatial distribution of adult mackerel varies temporally due to the extensive migrations that mackerel undergo (Fig. 4.14.5). During the winter, mackerel are found in the northern North Sea, in deep waters along the edge of the continental shelf (i.e. to the north and east of Shetland, and along the edge of the Norwegian Deeps; Fig. 4.14.5a). Some mixing occurs with the Western stock north of Scotland. Southerly migration of the North Sea stock towards spawning grounds in the central North Sea occurs during spring (Fig.

4.14.5b). Following spawning, further spreading of the population occurs towards feeding grounds in the southern and the northern North Sea (Fig. 4.14.5c) before the mackerel return to their overwintering grounds (Fig. 4.14.5d).

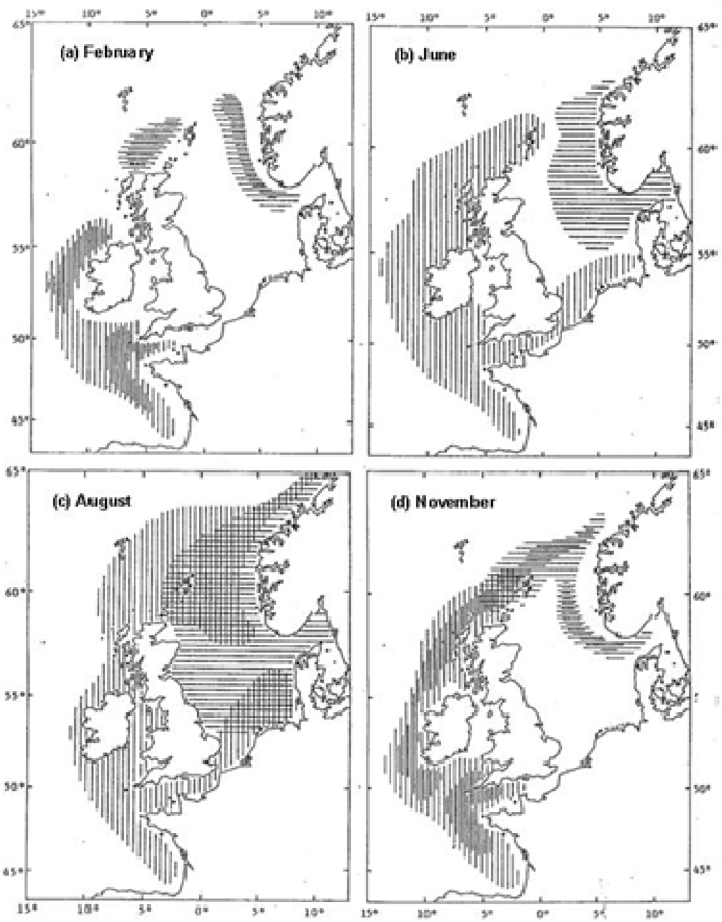


Fig. 4.14.5. Seasonal distribution of mackerel of the North Sea stock (horizontally hatched) and the Western stock (vertically hatched; from Bakken and Westgård 1986).

The western stock begins a southwest migration from the overwintering grounds to the western North Atlantic between January and February (dependant on temperature conditions; Reid et al. 1996), but returns to the North Sea both through the Channel and from the North of Scotland during the summer and autumn feeding periods, where distribution overlaps with that of the North Sea stock (Fig 4.14.5c). In the south, including the Dutch waters, mostly juveniles immigrate through the English Channel during spring to leave the area almost completely again in winter. It is uncertain whether individuals found in the southern North Sea, off the coast of Denmark, and along the western and southern coasts of Norway, belong to the North Sea stock and it has been suggested that these nurseries are used by part of the western mackerel stock (Bakken and Westgård 1986).

4.14.6 Conclusion

Due to the extensive migrations that mackerel undergo, the spatial distribution of the species and the different life stages has a strong seasonal component, with spawning grounds (late spring-summer) separated from feeding grounds (autumn) and overwintering grounds. Due to the influence of hydrographic variables and food availability on migration, some long-term trends and shifts in distribution in relation to these may occur. Mixing of the North Sea stock with the western stock occurs on the feeding grounds to the east and possibly through the influx of juveniles in the South.

Dutch waters form only a small part of the spawning area (in the North of the Dutch EEZ), which appears to have declined further in recent years. Larvae may be encountered in Dutch waters but are more prevalent North of 56 °N. Due to the lack of literature on the overall distribution, the contribution of the Dutch EEZ to the larval habitat can not be estimated, but some presence of larvae based on the egg distribution can be expected (indicated by grey boxes in Table 4.14.1). Juveniles, however, are widely distributed along the southern coast and it is likely that the Dutch waters form an important nursery area for Western mackerel during the summer months, as they migrate in through the English Channel. Adults of the North Sea stock may also use the coastal areas of the southern North Sea as feeding grounds following spawning. The importance of the Dutch EEZ for the different life stages is summarised in Table 4.14.1.

Table 4.14.1: Summary of the importance of the Dutch EEZ for different life stages of mackerel at different times of the year. Eggs and larvae information is provided on a monthly basis, juvenile and adults on a quarterly basis. Importance levels (none or close to none = white; low = yellow; medium = orange; high = red; grey = unknown) relate to the extent of the distribution of each life stage within the Dutch EEZ and are based on best estimates from current knowledge.

Month	1	2	3	4	5	6	7	8	9	10	11	12
Eggs					*Low*	*Low*	*Low*					
Larvae												
Juveniles					*High*			*High*				
Adults					*Low*			*Med*				

4.14.7 References:

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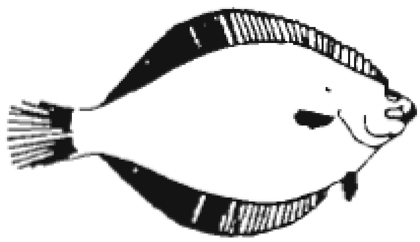
4.15 Dab – *Limanda limanda* (Linnaeus, 1758)



4.15.1 Introduction

Dab (*Limanda limanda*) is classified as a boreal species (Yang 1982, Ellis et al. 2002, Ellis et al. 2008) and its geographical distribution extends from the Bay of Biscay to Iceland and Norway. It also occurs in the Barents, White, Baltic and North Seam where it is the most abundant flatfish species (Rijnsdorp et al. 1992).
Dab can reach a maximum length of about 40cm (Nielsen et al. 1986) and an age of 12 years (Frimod 1995). It is a determinate batch spawner that matures at an age of 1 to 5 years (Munk and Nielsen 2005); females mature later then males. Dab spawns pelagic eggs and the egg phase is followed by a pelagic larval phase. Following metamorphosis the 0-group dab become demersal.
There is no directed fishery on dab, but it is commonly caught as by-catch in demersal fisheries for landed for human consumption.

4.15.2 Eggs

Temporal occurrence of eggs: Over the whole distribution of dab, spawning occurs from January to September. In British waters the main spawning season is March to June (Russell 1976). Also in the southern North Sea and the Kattegat spawning takes mainly place in March to June (Munk and Nielsen 2005). However, during an egg survey in 1989, egg production had already started in January, remained on a high level from February until April and dropped back to the January level in May (van der Land 1991; Fig. 4.15.1).

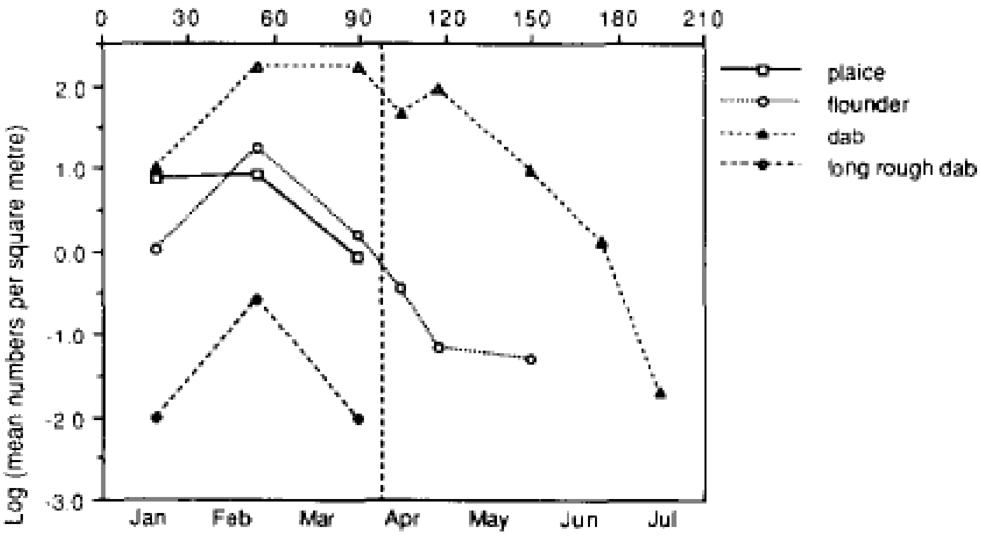


Fig. 4.15.1. Seasonal variation in abundance of flatfish eggs in 1989 (van der Land 1991).

Spatial distribution of eggs: Spawning of dab can occur throughout the North Sea. Highest densities of eggs have been reported in the German Bight northwest of Helgoland, around the Dogger Bank and off the northern part of the Dutch coast around 53°30'N (van der Land 1991; Fig. 4.15.2).

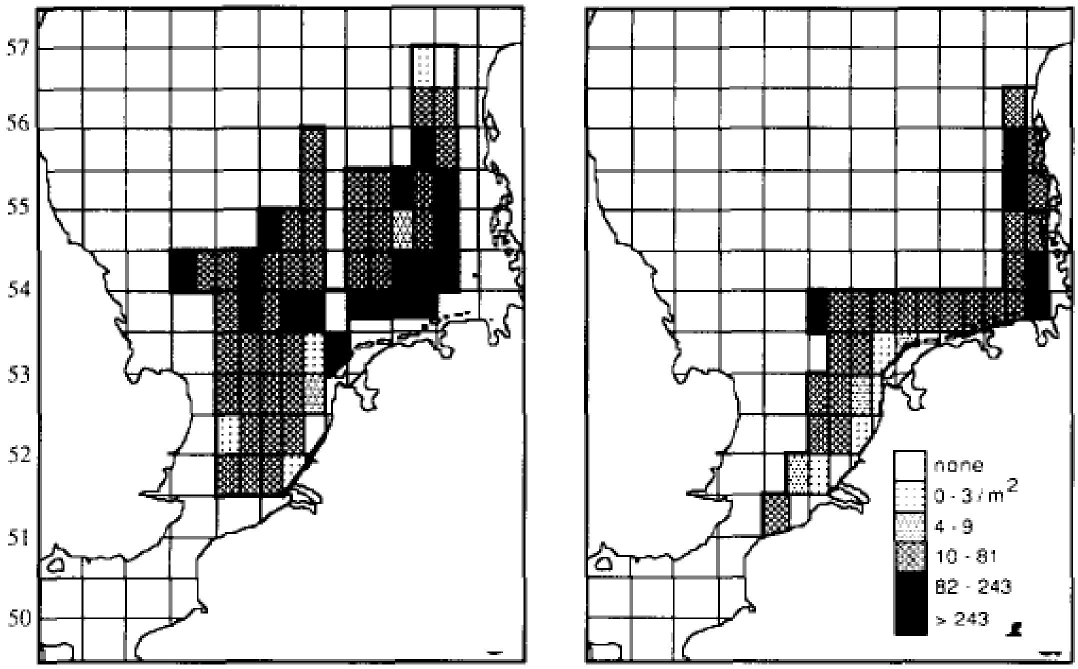


Fig. 4.15.2. Dab eggs, stage I, March (left); Dab eggs, stage I, late April (right) (van der Land 1991).

4.15.3 Larvae

Temporal occurrence of larvae: The development time of dab eggs can range from 3 to 12 days depending on temperature (Russell 1976). Larvae of dab are pelagic. In the Helgoland roads station plankton series (54°11.18 N and 07°54.00 E, Malzahn and Boersma 2007), first appearance of dab larvae have been reported in January and are found up to July. After the larvae of lesser sandeel, dab larvae were the most abundant in the series. In the 2004 ichthyoplankton survey, dab larvae were caught in February, March and April, with the highest catch rates observed in April (Taylor et al. 2007).

Spatial occurrence of larvae: Dab larvae were recorded in the southeastern North Sea during the 2004 ichthyoplankton survey. Here, maximum concentrations were 288.2 larvae m^{-2}. Patches of dab larvae were also found in the northern North Sea and off the British coast (Taylor et al. 2007, Fig. 4.15.3).

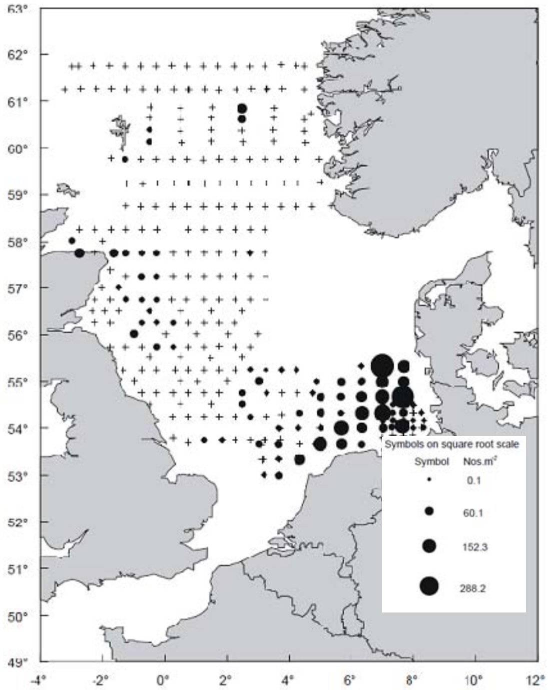


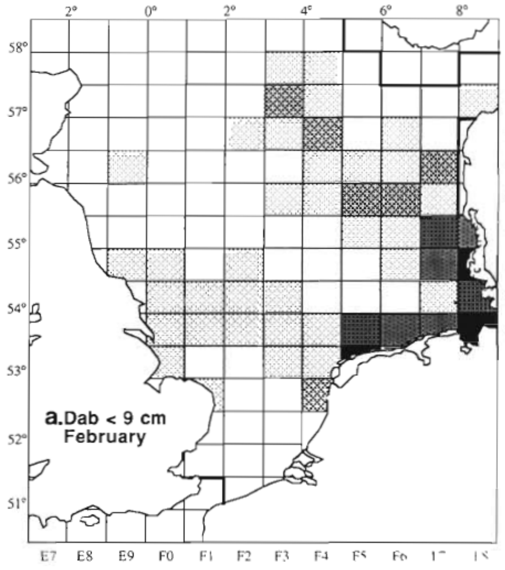
Fig. 4.15.3. Larval distribution of dab in the 2004 Ichthyoplankton survey (Taylor et al. 2007).

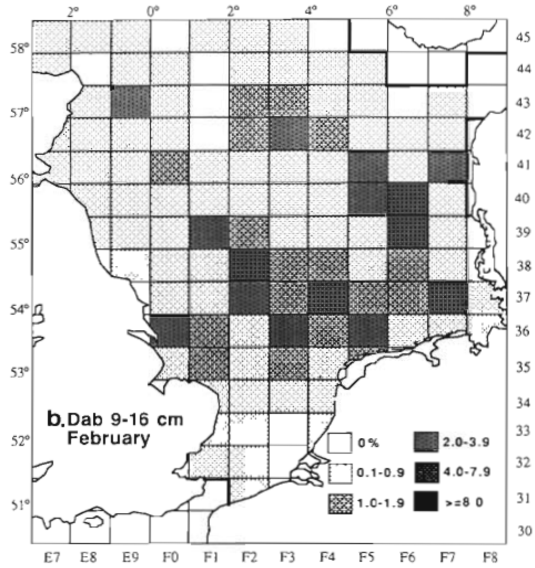
4.15.4 Juveniles

Spatial occurrence and seasonal migrations: In summer, 0-group dab arrive in coastal waters. They are most abundant in waters of 3 to 10m (Rijnsdorp et al. 1992), but also occur in significant numbers in offshore waters to a depth of 50m (Bolle et al. 1994). The Demersal Young Fish Surveys (DFS) carried out in September-October along the continental coast between Belgium and Denmark show that 0-group dab are mainly concentrated in waters of <10 m, whereas the 1- and 2-group show peak densities in waters of 10 to 15m depth (Rijnsdorp et al. 1992). Distribution of juvenile dab in February is shown in figure 4.15.4a and b. These maps indicate that dab move further offshore as they grow.

Migration of juvenile dab is observed in winter. It has been observed that dab leave the Wadden Sea and shallow coastal waters as the temperature drops and that they avoid temperatures below 2.5 °C (Creutzberg and Fonds 1971).

Long term changes in the distribution of juvenile dab have also been observed; the abundance in the Wadden Sea has strongly decreased since the mid 1980s, and dab has almost entirely disappeared from the Dutch and German Wadden Sea in the last decade (Bolle et al. 2009). This change in distribution may be related either to an increase in sea water temperature or a decrease in turbidity (Bolle et al. 2001).





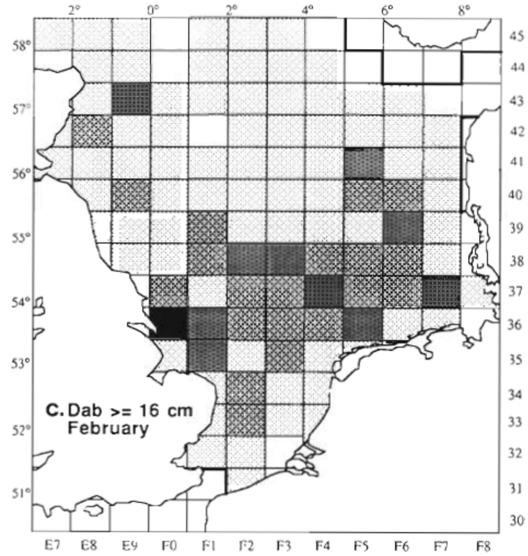


Fig. 4.15.4. Distribution of 3 size-groups of dab in February during the ICES International Young Fish Survey, expressed as proportion (%) of the total numbers present in each statistical rectangle, (a) <9cm; (b) 9-16cm; (c)>16cm.

4.15.5 Adults

Spatial occurrence and seasonal migrations: Adult dab occur throughout the North Sea (Fig. 4.15.4c) all year round. Some migrational behaviour is observed; tagging experiments indicate that when tagged in December, dab migrate away from the place of tagging in the German Bight without a clear preferred direction (Rijnsdorp et al. 1992). Dab tagged in July in the area north of the Frisian Islands were recaptured the following summer and autumn in a small area around the tagging position, but had migrated a long distance southwest into the Southern Bight prior to spawning. Comparison of the recaptures during the spawning period indicated that the spawning population of dab in a particular area may originate from individuals that are widely dispersed over a large area of the southern North Sea during the summer feeding period (Rijnsdorp et al. 1992).

4.15.6 Conclusion

The importance of the Dutch EEZ for the different life stages is summarised in Table 4.15.1. All life stages of dab occur in the Dutch EEZ. The high abundances of eggs, larvae and juveniles in the Dutch EEZ indicate that the area is of importance to the species, although for none of the life stages more then 50% of the North Sea population occurs on the EEZ. Therefore on the population scale the Dutch EEZ is of medium importance for the species.

Table 4.15.1: Summary of the importance of the Dutch EEZ for different life stages of dab at different times of the year. Eggs and larvae information is provided on a monthly basis, juvenile and adults on a quarterly basis. Importance levels (none or close to none = white; low = yellow; medium = orange; high = red; grey = unknown) relate to the extent of the distribution of each life stage within the Dutch EEZ and are based on best estimates from current knowledge.

Month	1	2	3	4	5	6	7	8	9	10	11	12
Eggs	*Med*	*Med*	*Med*	*Med*	*Med*	*Med*						
Larvae	*Med*	*Med*	*Med*	*Med*	*Med*	*Med*	*Med*					
Juveniles	*Med*			*Med*			*Med*			*Med*		
Adults	*Med*			*Med*			*Med*			*Med*		

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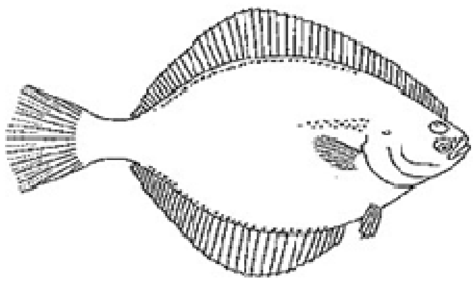
4.16 Flounder – *Platichthys flesus* (Linnaeus, 1758)



4.16.1 Introduction

Flounder is a euryhaline species and is distributed around the coasts of Europe from the Black to the Barents Sea, including the Baltic (Ehrenbaum 1905). Its ability to live in low saline water and its preference for such environments are features that do not occur in other European flatfish species to the same degree. The European flounder preferentially inhabits the muddy sea floor, mostly in coastal and estuarine areas, where it is well camouflaged to its surroundings. Due to its estuarine distribution flounder can be affected by pollution from river run off and is thus often used as a model species in ecotoxicology to examine the ecosystem impacts of anthropogenic pollution (Tysklind et al. 2009)
In the Middle Ages flounder was caught in the upper course of the river Rhine (Redeke 1908), At the turn of the 19th century, flounder was fished in the Netherlands in the lower course of the major rivers, the Zuiderzee (July-September), Lauwerszee, Dollard, and the coastal North Sea in winter (Redeke 1908). After the Zuiderzee was closed off by the Afsluitdijk to become the Ijsselmeer, catches decreased drastically (Havinga 1954).

4.16.2 Eggs

Temporal occurrence of eggs: Flounder eggs have a well defined spawning period between January and March, but peak abundances occur in February (van der Land 1991).

Spatial distribution of eggs: Flounder spawns in the open North Sea, where spawning areas may overlap with those of plaice (Harding et al. 1978). The majority of eggs occur in the area west and northwest of the Dutch coast, the eastern English Channel and the area northwest of Helgoland (Fig. 4.16.1, van der Land 1991). Spawning is said to occur within the 40m depth boundary and at distances < 60 miles from the coast (Ehrenbaum 1905).

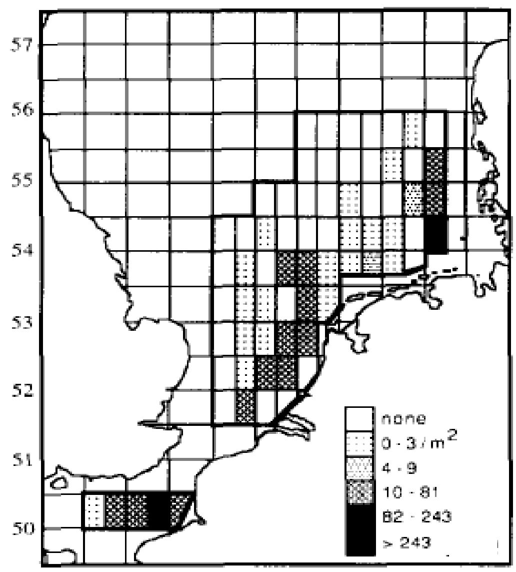


Fig. 4.16.1. Abundance of stage I flounder eggs during February (van der Land 1991).

4.16.3 Larvae

Temporal occurrence of larvae: During the 2004 ichtyhoplankton survey, larvae appeared in February with densities up to 16.6 larvae m^{-2}, but peak numbers were reached in April (38.9 larvae m^{-2}, Taylor et al. 2007)

Spatial occurrence of larvae: Larvae are found exclusively off the coasts of Germany and the Netherlands (Fig. 4.16.2, Taylor et al. 2007). Again, as in plaice, large quantities of small larvae from eggs hatching in the North Sea are transported to the coast and migrate into the Wadden Sea (van der Veer et al. 1991). Settling mainly occurs in the siltier parts of the Wadden Sea (de Vlas 1979), especially near freshwater inlets, due to strong rheotaxis behaviour (Berghahn 1984).

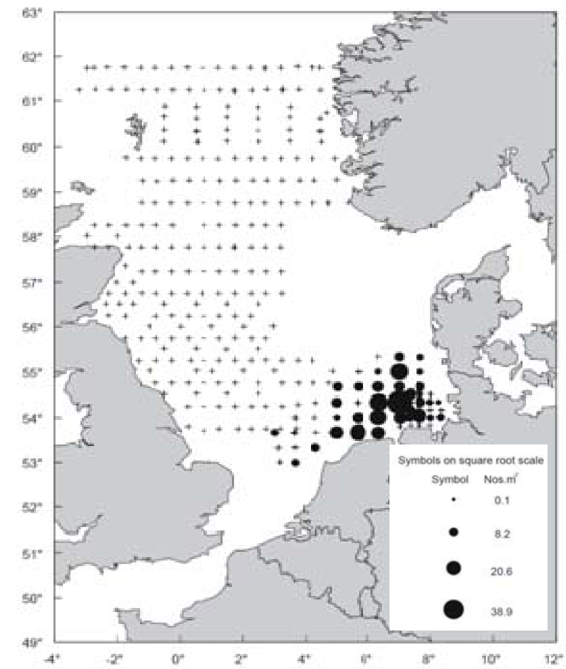


Fig. 4.16.2. Composite map of flounder (*Platichthys flesus*) larval abundance (nos. m^{-2}) in 2004 (from Taylor et al. 2007).

4.16.4 Juveniles

Spatial occurrence and seasonal migrations: Large parts of the settling flounder population are thought to migrate to fresh water (Berghahn 1984), with only part of the population remaining in the estuaries. Peak abundances of 0-group flounder on the Balgzand area are found between May and July (Fig. 4.16.3). Flounder may remain in the Wadden Sea for longer than 3 years (de Vlas 1979) before migrating to deeper waters.
Juveniles (< 20cm) are not found within the wider North Sea during summer (Fig. 4.16.4a) due to their coastal/estuarine preferences. During winter some juveniles are found in the German Bight and up the coast of Denmark (Fig. 4.16.4b).

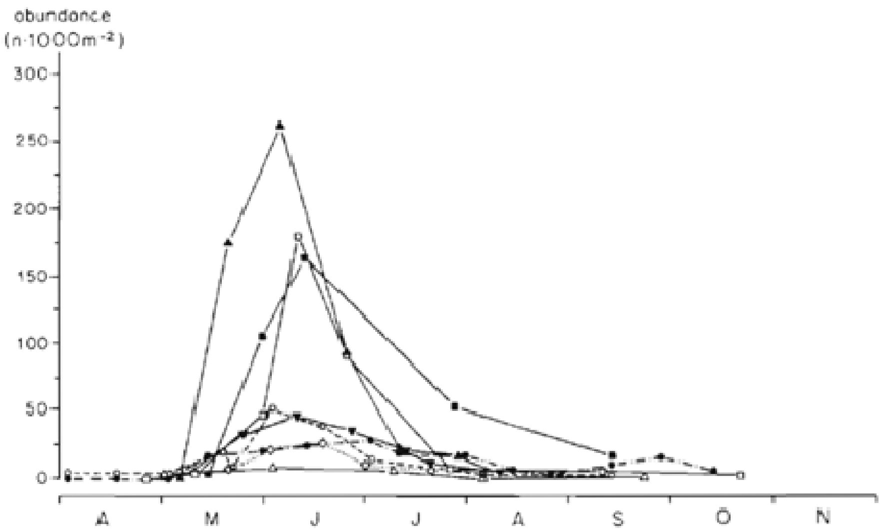


Fig. 4.16.3. Abundance of 0-group flounder (n 1000 m^{-2}) on the Balgzand in 1974 – 1982, mean values of 5 different transects sampled in van der Veer et al. 1991.

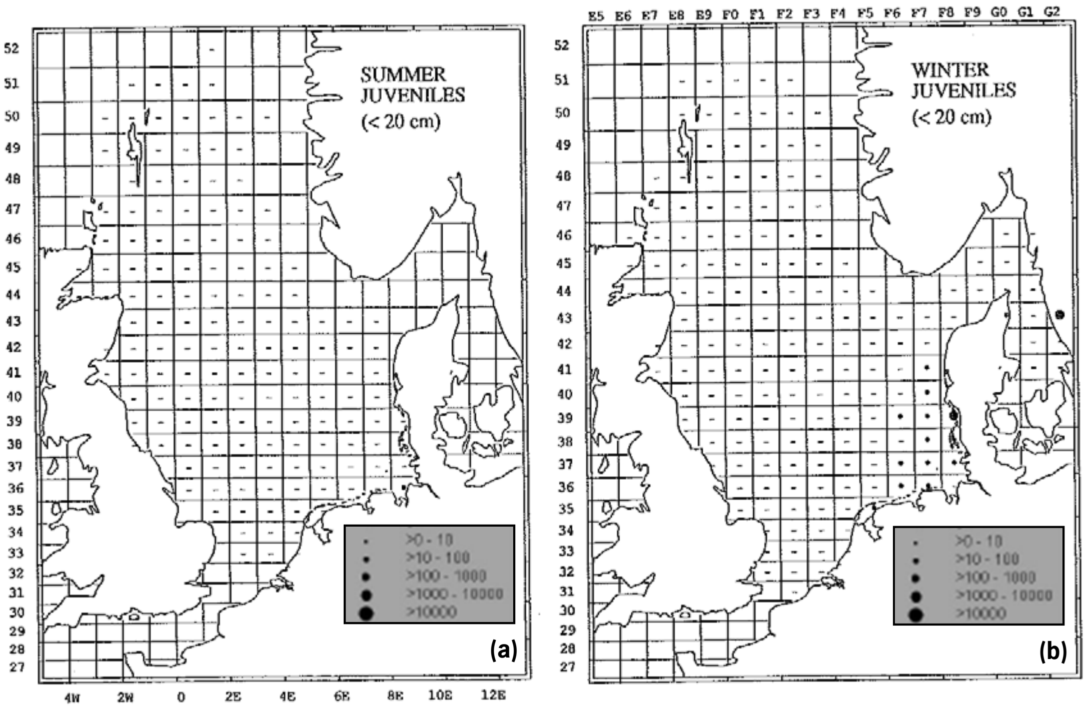


Fig. 4.16.4. Average annual catch rates (numbers per hour fishing) of juvenile founder (< 20cm) in the years 1985 – 1987 during (a) summer and (b) winter (from Knijn et al. 1993).

4.16.5 Adults

Spatial occurrence and seasonal migrations: Adult flounder are uncommon throughout the North Sea during the summer months (Fig. 4.16.5a) but undergo some seasonal migration to spawning grounds in the open North Sea from January-February (van der Land 1991) and can thus be found in patches in the southern North Sea during the winter (Fig. 4.16.5b).

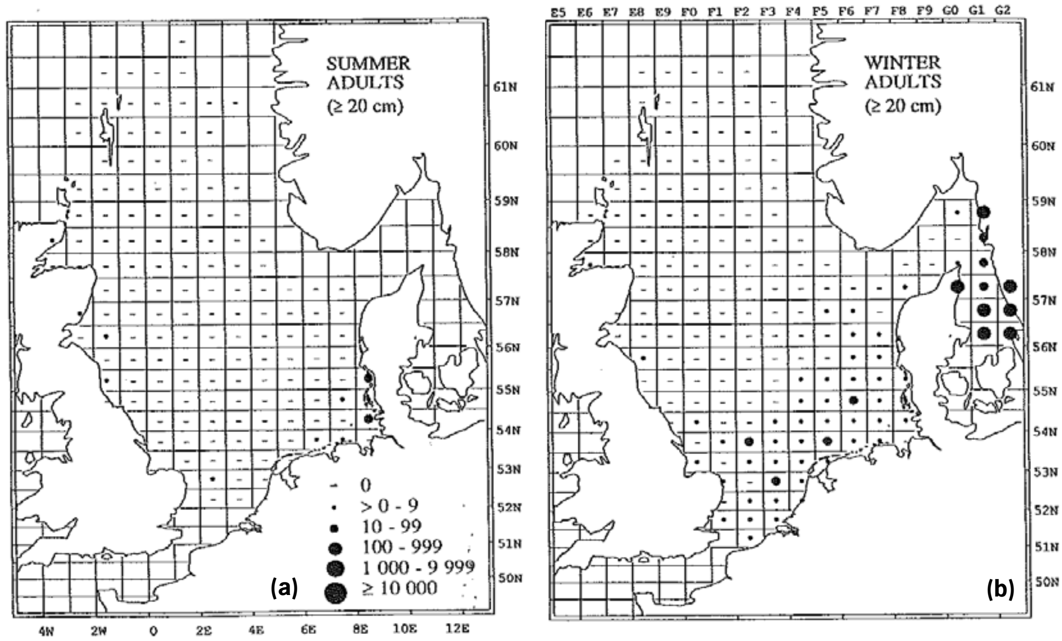


Fig. 4.16.5. Average annual catch rates (numbers per hour fishing) of adult founder (> 20cm) in the years 1985 – 1987 during (a) summer and (b) winter (from Knijn et al. 1993).

4.16.6 Conclusion

Flounder is not widely distributed throughout the North Sea, but the coastal and estuarine areas are an important habitat for both juvenile and adult flounder. Dutch waters are an important area for all life stages of flounder containing up to 50% of the North Sea egg and larvae distribution. The Wadden Sea is also important, particularly as a nursery ground, but also as adult habitat. The importance of the Dutch EEZ for the different life stages is summarised in Table 4.16.1.

Table 4.16.1: Summary of the importance of the Dutch EEZ for different life stages of dab at different times of the year. Eggs and larvae information is provided on a monthly basis, juvenile and adults on a quarterly basis. Importance levels (none or close to none = white; low = yellow; medium = orange; high = red; grey = unknown) relate to the extent of the distribution of each life stage within the Dutch EEZ and are based on best estimates from current knowledge.

Month	1	2	3	4	5	6	7	8	9	10	11	12
Eggs	*Med*	*Med*	*Med*									
Larvae		*Med*	*Med*	*Med*								
Juveniles	*Med*			*Med*			*Med*			*Med*		
Adults	*Med*			*Med*			*Med*			*Med*		

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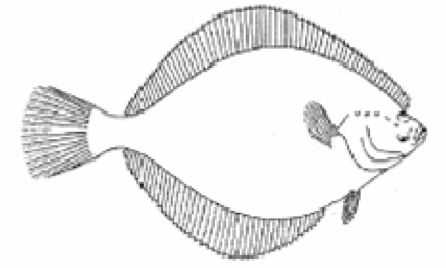
4.17 Plaice – *Pleuronectes platessa* (Linnaeus, 1758)



4.17.1 Introduction

The distribution of plaice ranges from the western Mediterranean Sea, along the coast of Europe as far north as the White Sea and Iceland, with occasional occurrences off Greenland (Nielsen 1986). Plaice is a demersal boreal species that can reach a maximum length of a meter (Yang 1982; Ellis et al. 2002; Ellis et al. 2008), however the common length is around 40cm. Plaice can reach an age of 50 years and matures at an age of 2 to 5 years, males mature earlier then females (Rijnsdorp 1989). Plaice is a determinate batch spawner, which spawns pelagic eggs and shows seasonal migration from feeding areas to spawning areas.
Plaice is an important commercial species in European waters, especially for the Dutch Beam trawl fleet and has been exploited for centuries. It is therefore also one of the best studied species in the North Sea. Although, plaice is managed as a single stock in the North Sea, in reality there is evidence for geographically separated sub-stocks with high gene flow (Horeau et al. 2002).

4.17.2 Eggs

Temporal occurrence of eggs: Plaice are winter spawners (determinate batch spawners) and eggs can occur in the plankton from December through to March/April (Ehrenbaum 1905, Russel 1976, van Damme et al. 2009). The peak spawning period however is usually late January to early February (Fig. 4.17.1, Russel 1976, van Damme et al. 2009) with potential recent shifts to an earlier end of spawning being observed in relation to sea temperature rise (Teal et al. 2008). Time to hatching of eggs is temperature-dependant and can take between 7-14 days (at 10°C) up to 20-21 days (at 6°C, Fox et al. 2003. Bolle et al 2009).

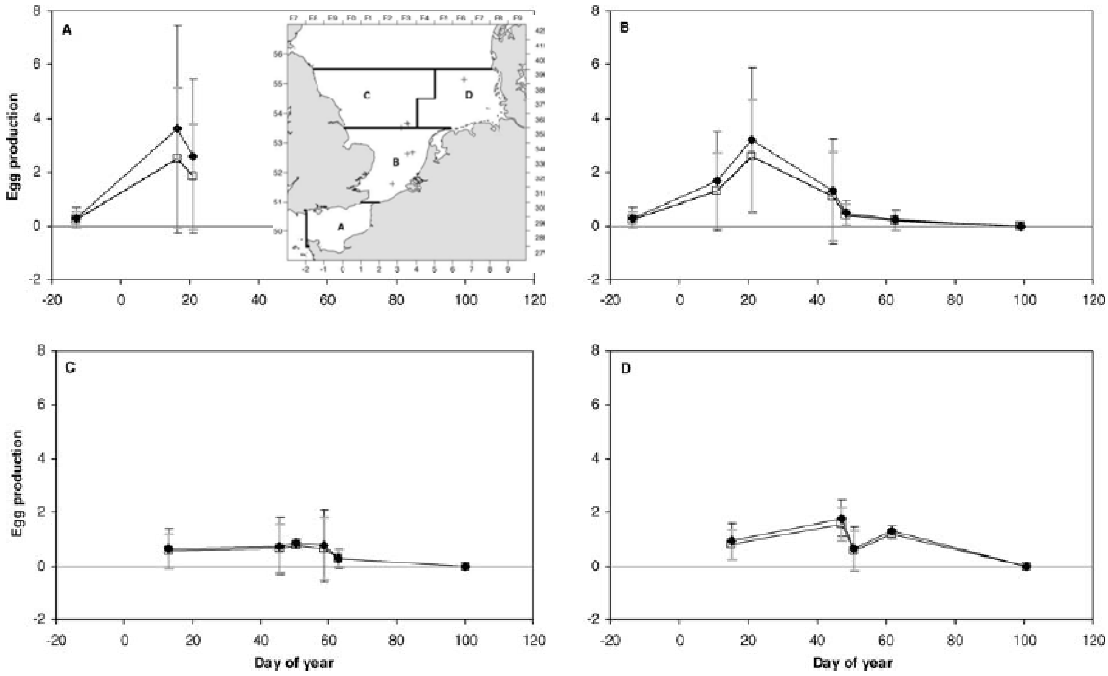


Fig. 4.17.1. Comparison of the seasonality in daily egg production in numbers m^{-2} d^{-1} of North Sea plaice in 2004. A-D correspond to survey areas depicted (A, Eastern Channel; B, Southern Bight; C, Dogger Bank; D, German Bight). Day of year = 0 is 1 January 2004. Daily production is estimated from daily mortality (filled diamonds) and (open squares) at the time of capture (for full methods see van Damme et al. 2009). Error bars denote 1 s.d., grey for Z = 0, and black for Z being temperature-dependent (van Damme et al. 2009).

Spatial distribution of eggs: The main spawning area of plaice is distributed around a number of hotspots in the southern North Sea (Fig. 4.17.2a, Harding et al. 1978), including the Southern Bight and the central part of the southern North Sea, which overlap with Dutch waters. Large concentrations of eggs are found on the southwestern flanks of the Dogger bank (Heessen and Rijnsdorp 1989) and in the area around and south of Fisher Banks (in the German bight, Munk et al. 2009), but eggs are also found although more sporadically off the coastal currents in other areas, as well as being abundant in the English Channel (Fig. 4.17.2b, Taylor et al. 2007). Observations indicate that spawning is related to hydrographic features in the North Sea, with peak abundances of eggs being found in areas of stronger frontal gradients (Munk et al. 2009).

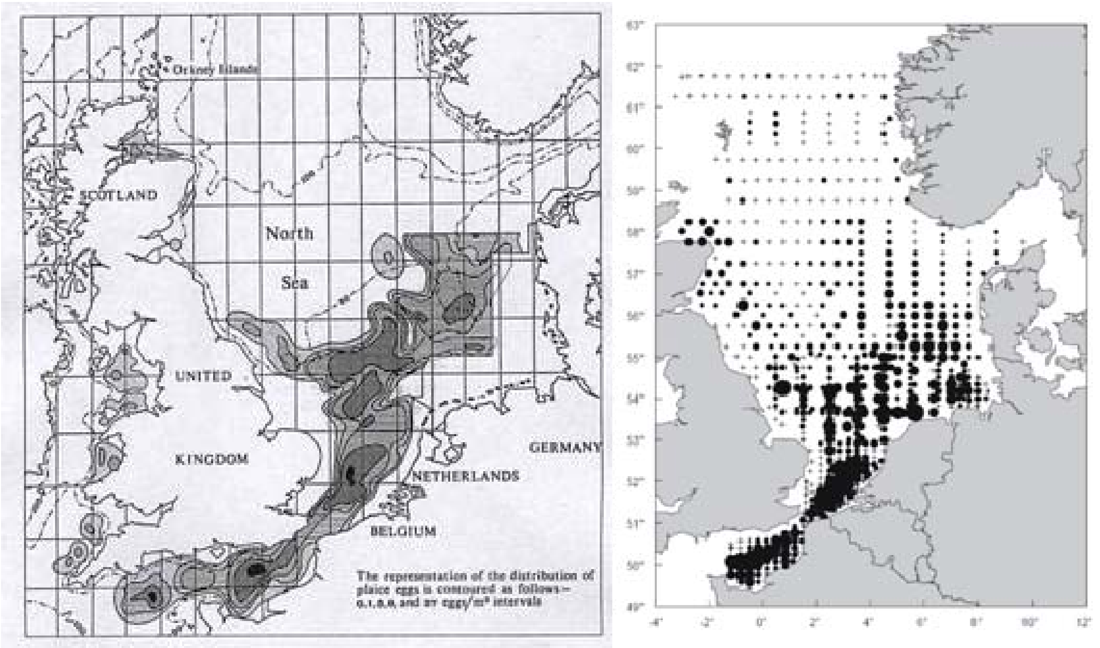


Fig 4.17.2. The North Sea area showing (a) main spawning grounds of plaice (shaded areas, from Harding et al. 1978 and (b) plaice egg abundance (nos. m^{-2}) in 2004 (from Taylor et al. 2007).

4.17.3 Larvae

Temporal occurrence of larvae: Development time of eggs is determined by parental effects (size of female and batch number) as well as temperature (Fox et al. 2003). Larval development is temperature dependent ranging from ±30 days at 10°C to ±60 days at 6°C (Bolle et al 2009). Larvae can be expected to occur in the plankton between February and April. Metamorphosing larvae (stages 4 and 5) enter the nursery areas in March and April (Rijnsdorp et al. 1985).

Spatial occurrence of larvae: Developing eggs and larvae from the Southern Bight drift on residual currents parallel to the continental coastline (Talbot 1976, 1978). The metamorphosing larvae move to the sea bed when they are still offshore (Harding and Talbot 1973). Larvae must cross 30-60 km of open sea prior to reaching the nursery areas along beaches and in estuaries of the continental coast of the North Sea (Creutzberg and Fonds 1971; Zijlstra 1972; Kuipers 1973; van Beek et al. 1983). Inshore migration of the larvae is achieved by both active and passive transport (Rijnsdorp et al. 1985, Bolle et al 2009). During ichthyoplankton surveys 1997 and 2004, high abundances of larvae were observed in the southern North Sea, particularly the German Bight (Fig. 4.17.3). However, due to limitations in the temporal and spatial coverage of these surveys with regard to plaice larvae, the spatial distribution presented in Fig 4.17.3 is evidently incomplete.

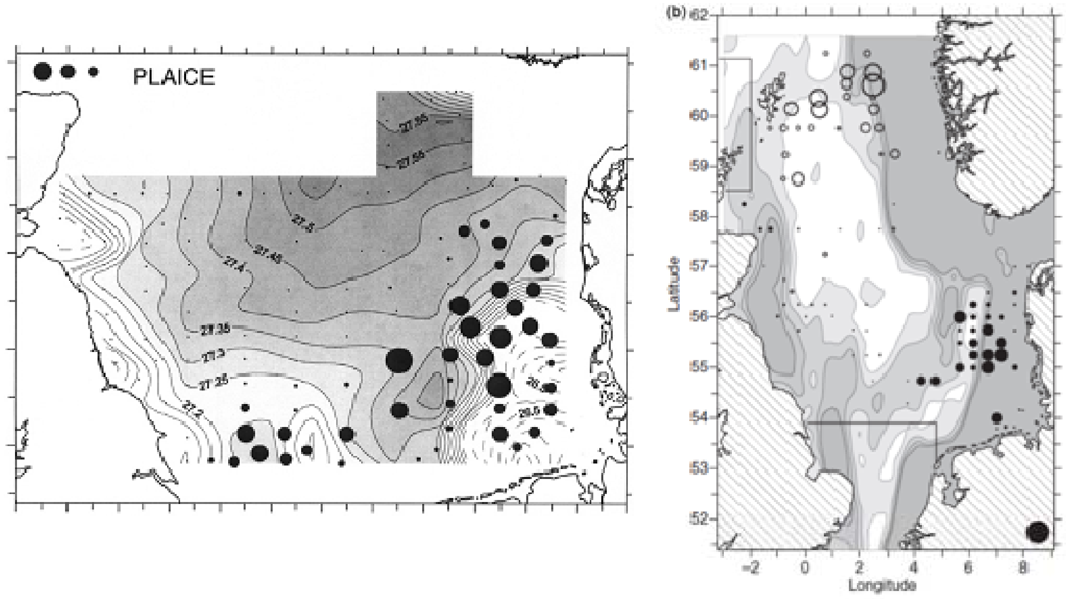


Fig. 4.17.3. (a) Larval abundance estimates in no. m^{-2} imposed onto the contouring of surface (5 m) water density (pycnolines at 0.05 kg m^{-3} intervals above 1026.95 kg m^{-3} and 0.2 kg m^{-3} intervals below) measured in March 1997. Relative abundances of larvae are illustrated by area of filled circles, the three circles in uppermost left corner of figures illustrate circle areas when larval densities are either 20, 10 and 5 m^{-2} (from Munk et al. 2002), and (b) concentrations of larvae (filled circles, no estimates available for the south-west area indicated) measured in spring 2004, illustrated by area of symbol; circle in bottom corner illustrates area for an abundance of 50 larvae m^{-2} (from Munk et al. 2009).

4.17.4 Juveniles

Spatial occurrence and seasonal migrations: Following metamorphosis and settlement, O-group plaice spend their first growing season in the shallow waters of estuaries and sandy beaches (Fig. 4.17.4a, Gibson et al. 1973, van der Veer 1986). Sediment characteristics are thought to be of importance during larval settlement and positive relationships have been found between grain size and plaice densities (Zijlstra et al. 1982), e.g. within the Wadden Sea, sandy flats are preferred over muddy areas (Berghahn 1986). Coastal and inshore waters of the North Sea represent essential nursery areas, with the most important areas in the German Bight and the Wadden Sea. These nurseries contribute the majority (50-90%) of the recruits to the North Sea plaice stock (Kuipers 1977, Zijlstra 1972, van Beek et al. 1989). 1-group plaice also show a mainly coastal distribution (Fig. 4.17.4b), while older plaice gradually leave the shallow coastal waters and move into deeper waters further offshore (Wimpenny 1953, Rijnsdorp and van Beek 1991). 2- and 3- group plaice are thus found progressively further offshore as well as further north (Fig. 4.17.4c & d).

Long term changes in the distribution of juvenile plaice have been observed, potentially related to an increase in sea temperature, reduction of oxygen concentrations, changes in predation or fishing effort (van Keeken et al. 2007). Since the mid 1980s, a gradual offshore movement has taken place, and consistent with this offshore movement, the population of 1-group plaice has left the Dutch Wadden Sea almost completely since the late 1990s (van Keeken et al. 2007). The change in distribution was particularly pronounced in the 20–29 cm and the 30–39 cm length classes and off the Danish coast, but less clear off the Dutch coast.

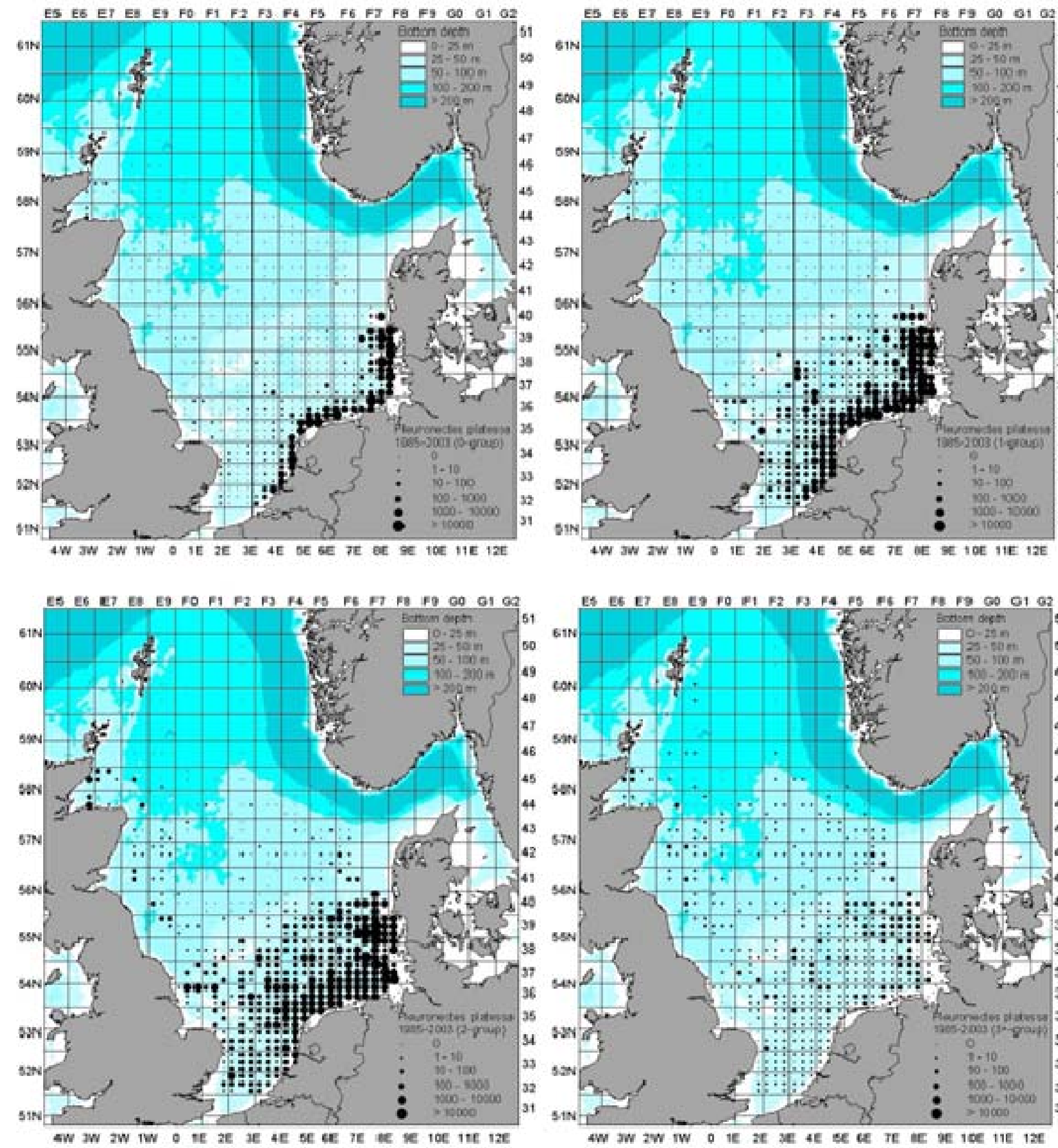


Fig. 4.17.4. Average annual catch (number per fishing hour) for 0-, 1-, 2- and 3+group plaice in the quarter 3 BTS survey,1985 2003 (from ICES FishMap).

4.17.5 Adults

Spatial occurrence and seasonal migrations: Adult plaice undergo seasonal migrations between feeding and spawning grounds. They are known to make use of tidal stream transport, moving downstream with the tide in mid-water and remaining on the bottom showing little or no movement during the opposing tide (Greer Walker et al. 1979, Metcalfe and Arnold 1997). Part of the North Sea plaice population spawns in the Channel and returns to its feeding grounds in the North Sea afterwards. Within the North Sea, spawning-feeding migrations occur along a north-south axis and the distance over which the plaice migrate increases with size (Hunter et al. 2003). Tagging experiments have shown strong site fidelity behaviour for large plaice, with individual fish returning to the same spawning and feeding areas, where they had been before (Hunter et al. 2003). Adult plaice are thus widely distributed around the North Sea throughout most of the year (Fig. 4.17.5), with some spawning aggregations as described above found in Q1 and Q2, although these are not that evident in the southern North Sea based on figure 4.17.5.

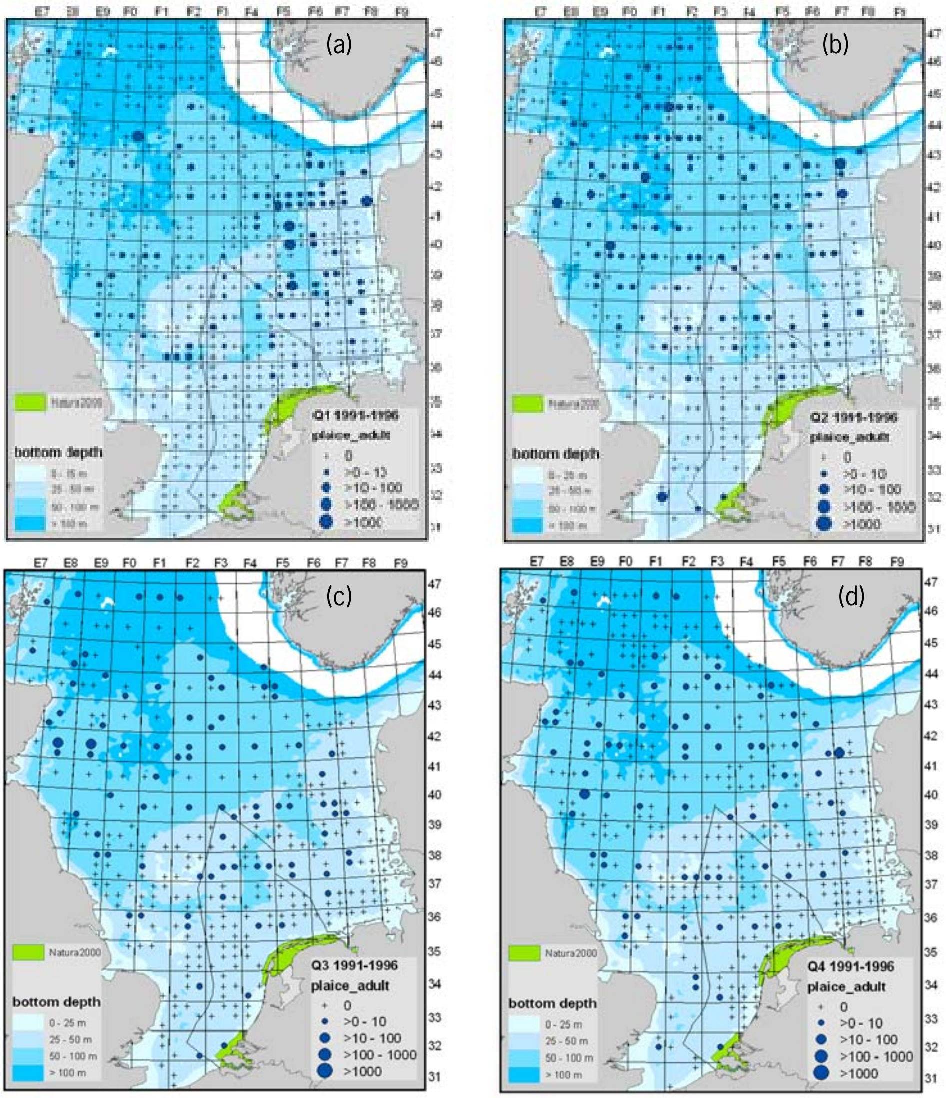


Fig. 4.17.5. Distribution of adult plaice in the North Sea during (a) 1st, (b) 2nd , (c) 3rd and (d) 4th quarter in the period 1991-1996. Data are derived from the IBTS (from ter Hofstede et al. 2008).

4.17.6 Conclusion

Plaice are a particularly important commercial species within the North Sea. Coastal and inshore waters of the North Sea form extremely important nursery grounds for the North Sea plaice stock. The most important nursery areas are the German Bight and the Wadden Sea as these nurseries contribute the majority (50-90 %) of the recruits to the North Sea plaice stock (Zijlstra 1972, Van Beek et al. 1989). The Dutch waters are thus of great importance to 0-group and juvenile plaice. As plaice grow and move offshore, their distribution becomes very wide-spread in the North Sea and although plaice are still found within Dutch waters, these form only a small area of the adult habitat. The importance of the Dutch EEZ for the different life stages is summarised in Table 4.17.1.

Table 4.17.1: Summary of the importance of the Dutch EEZ for different life stages of plaice at different times of the year. Eggs and larvae information is provided on a monthly basis, juvenile and adults on a quarterly basis. Importance levels (none or close to none = white; low = yellow; medium = orange; high = red; grey = unknown) relate to the extent of the distribution of each life stage within the Dutch EEZ and are based on best estimates from current knowledge.

Month	1	2	3	4	5	6	7	8	9	10	11	12
Eggs	*Med*	*Med*	*Med*									
Larvae		*Med*	*Med*	*Med*								
Juveniles	*Med*			*High*			*High*			*Med*		
Adults	*Med*			*Med*			*Med*			*Med*		

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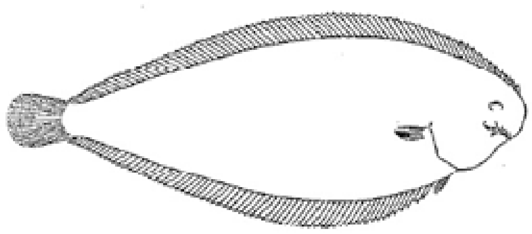
4.18 Common Sole – *Solea solea* (Linnaeus, 1758)



4.18.1 Introduction

The biogeographical range of sole extends from the northwest African coast and Mediterranean in the south to the Irish Sea, southern North Sea, Skagerrak and Kattegat in the north. They are sometimes caught in low numbers around Scotland and occasionally even along the southern coast of Norway (Wheeler et al. 1969), but as a southern species, the North Sea is the northern limit. Sole is mainly found in the southern and eastern North Sea, south of the line from Flamborough to North Jutland. This line corresponds to the position of a steep temperature gradient that, in summer and autumn, divides the North Sea into a cold stratified northern section with bottom temperatures of about 7ºC and a warm mixed southern section with bottom temperatures of up to 17ºC.
Sole tend to occupy shallow, sandy and sandy/muddy habitats which are widespread in the North Sea. As for plaice, older and bigger individuals tend to occur in deeper waters than the juveniles, but they remain largely restricted to waters < 50m deep (ICES FishMap).
Sole is a popular consumption fish and of great commercial importance. Due to its preference for burying into sandy or muddy bottoms, heavy bottom trawling gear is required to catch sole. Due to their diurnal feeding behaviour, sole are easier to catch at night. As North Sea surveys are exclusively carried out during the daytime, catch rates may therefore underestimate absolute abundances. Within the North Sea several different sub-populations have been distinguished based on egg distribution and tagging experiments. However, these are to a large extent mixed during the feeding season. Assessments examine the North Sea sole as one stock unit, with the stocks in the eastern Channel and the Skagerrak/Kattegat being assessed separately (ICES FishMap).

4.18.2 Eggs

Temporal occurrence of eggs: Sole are indeterminate spawners and females produce between 700 and 800 eggs per gram body weight, which corresponds to about 350,000 eggs for a 35 cm fish (Rijnsdorp et al. 1992). Spawning may take place from spring to early summer. Egg distribution studies have reported first spawning in March in the Southern Bight, developing northwards along coastal areas as the season progressed (van Beek 1989). In the 2004 ichthyoplankton survey (Taylor et al. 2007), sole eggs were identified in their highest abundance (up to 9.1 eggs m^{-2}) from the samples collected in January, however, as peak spawning has been shown to occur in April or May (van Beek 1989, van der Land 1991), these surveys would have missed the real maximum of egg production.

Spatial distribution of eggs: Spawning of sole in the North Sea occurs mainly in southern areas, in the English Channel and along the coast of Belgium, the Netherlands, Germany and Denmark (Fig. 4.18.1a, Russell 1976, van der Land 1991, Bolle et al. in prep). Within the spawning area, which is usually within the 30 m depth contour, highest egg densities occur in the Helgoland Bight and off the Danish coast (between 55° and 56° N), as well as off the Belgian Coast (Fig. 4.18.1a, van der Land 1991, Bolle et al. in prep).

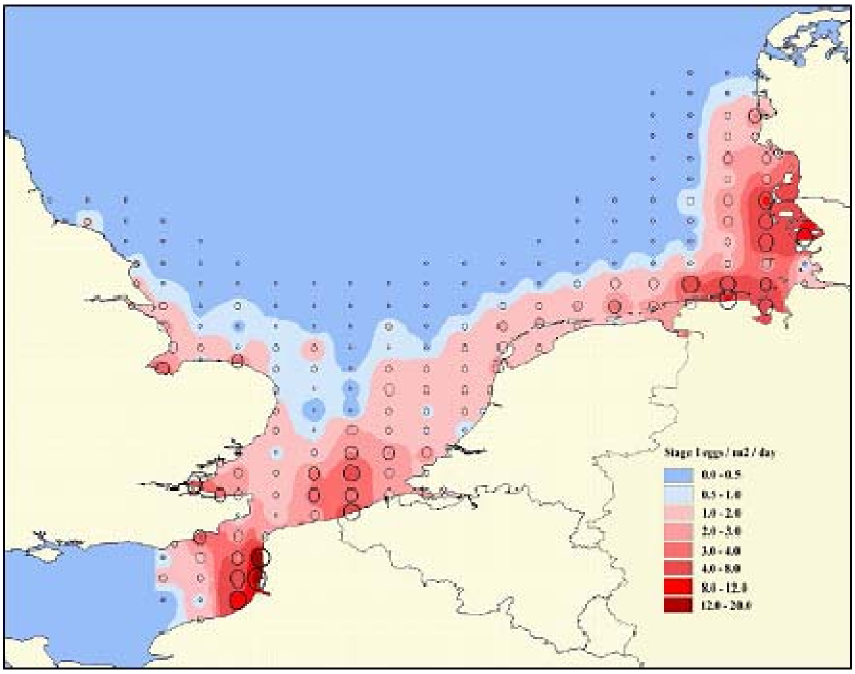


Fig. 4.18.1. Spawning areas of *Solea solea* in the southern North Sea based on the occurrence of stage-I eggs (from Bolle et al. in prep).

4.18.3 Larvae

Temporal occurrence of larvae: Hatching of eggs is temperature dependant and may take from 2-4 days at 19°C to 9-13 days at 8°C (Flüchter 1970, Bolle et al. 2005). As spawning in the North sea is concentrated at water temperatures of around 8-12°C, egg development can take up to 2 weeks, after which the pelagic larvae develop into demersal sole within about one month (Knijn et al. 1993, Bolle et al. 2005). With peak spawning times around April and May, larvae can thus be expected to reach peak abundances in May and June.

Spatial occurrence of larvae: Due to the near-shore location of the spawning grounds and their rapid development, passive transport of larvae only occurs over short distances (van Beek et al. 1989, Bolle et al. 2005) and their spatial distribution will thus overlap with that of eggs and 0-group sole in the shallow coastal areas, including estuaries, of the southern North Sea. Although classed as pelagic, sole larvae live near the bottom (below a depth of 10-15m, Russell 1976) and are thus never abundant in ichthyoplankton surveys.

4.18.4 Juveniles

Spatial occurrence and seasonal migrations: Larvae reach metamorphosis at around 10-12mm and settle in the shallow coastal areas and estuaries of the southern North Sea. Unlike plaice and flounder, the intertidal areas along the southern coasts do not function as settlement areas and do not provide an important nursery area for 0-group sole (e.g. Balgzand, van der Veer et al. 2001, Dollard, Jager et al. 1993, North Frisian German part, Berghahn 1984). Instead 0-group sole migrate into the subtidal and relatively deeper parts of the coastal areas where their distribution within the continental nursery areas can be quite variable between years (Fig. 4.18.2, van Beek et al. 1989). The Dutch coast, Schelde estuary and the Wadden Sea remain important nursery grounds for sole (van Beek et al. 1989). As juveniles grow they begin an offshore movement and start to spread out into the North Sea (Fig. 4.18.3 a-d) with 1- and 2- group sole occurring in slightly deeper waters than the 0-group (Fig. 4.18.3 a-c) and 3-group sole becoming quite evenly dispersed in the southern North Sea (Fig. 4.18.3d)

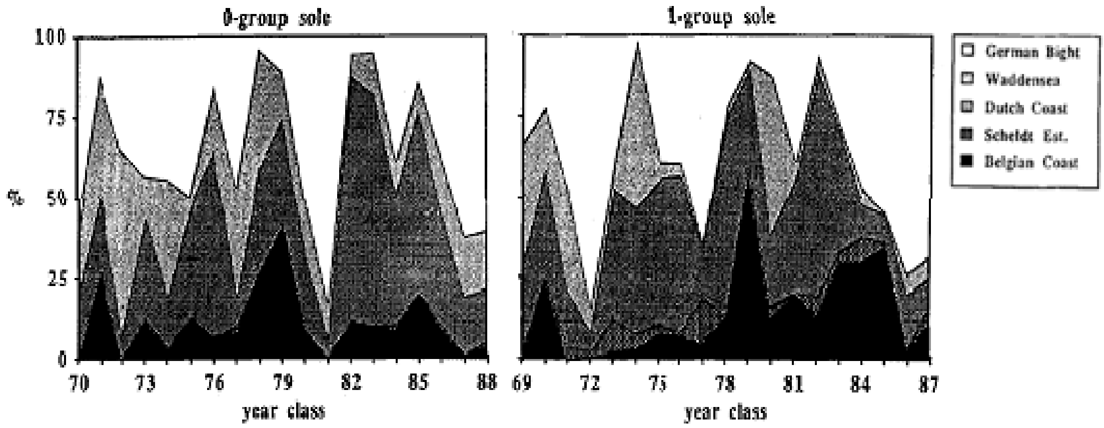


Fig. 4.18.2. North Sea sole, annual variation in the contribution of different parts of the continental nurseries to the DYFS (Demersal Young Fish survey) index (from van Beek et al. 1989).

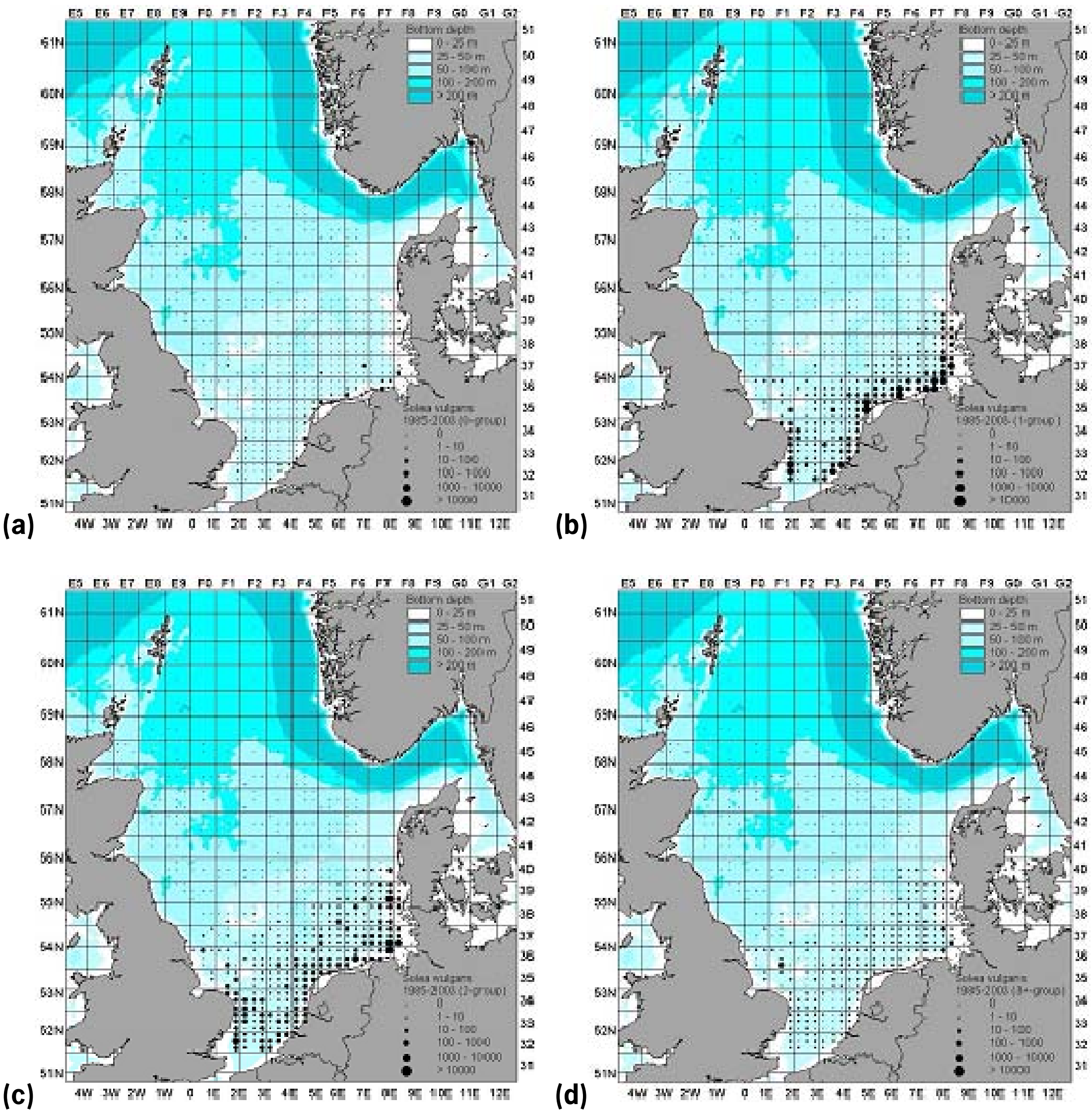


Fig. 4.18.3. Average annual catch (number per fishing hour) for (a) 0-group, (b) 1-group, (c) 2-group and (d) 3-group *S. solea* in the quarter 3 BTS survey, 1985 2003 (from ICES FishMap).

4.18.5 Adults

Spatial occurrence and seasonal migrations: In the North sea, adult sole can be found mainly in the southern and eastern areas, south of around 56°N (Fig. 4.18.4, ICES FishMap). As sole is a southern species, its distribution is confined to areas with relatively high bottom temperatures (Knijn et al. 1993). Seasonal movements of sole are most likely to be temperature-induced, involving an offshore movement to deeper (warmer) waters during the winter, and inshore movements between March–May. During extremely cold winters, sole have been observed to form dense aggregations in deeper, warmer waters like the Silver Pit, where valuable catches of sole have been made during cold winters (Fig. 4.18.4, Woodhead 1964, Knijn et al. 1993).

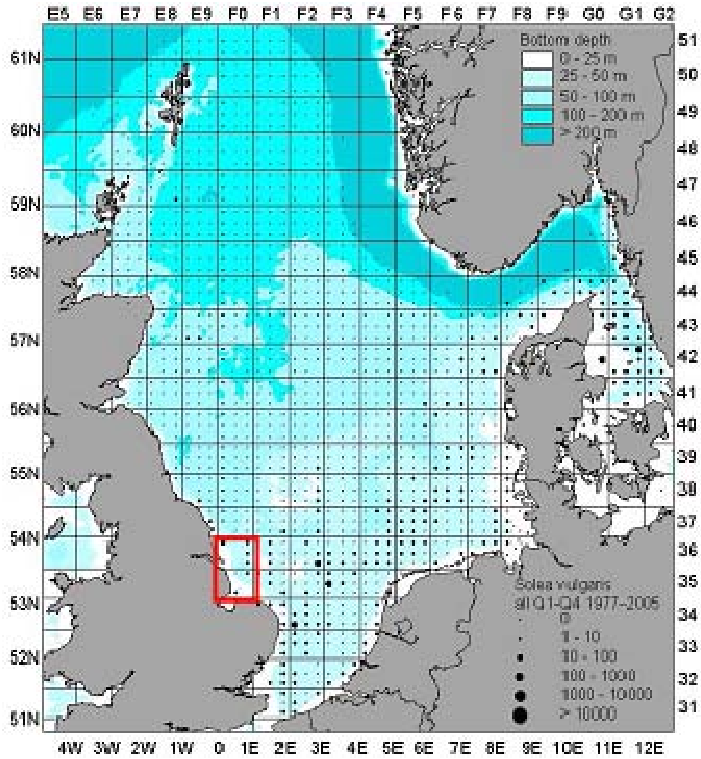


Fig. 4.18.4. Distribution of adult sole during the quarter 1 IBTS survey, 1977 2005 (from ICES Fishmap). The red rectangle marks the location of the Silver Pit.

4.18.6 Conclusion

Sole is a southern species and due to the preference for relatively warmer waters inhabits only the southern parts of the North Sea. The shallow coastal areas from the English Channel up to Denmark, of which the Dutch areas form a large part, are particularly important spawning and nursery grounds. Dutch waters are thus important particularly during the early life stages (eggs, larvae, juveniles) before sole move further offshore and become more evenly distributed throughout the southern North Sea. Seasonal migrations do occur in relation to temperature, but are not as extensive as in other species and the southern North Sea remains inhabited throughout the year. The importance of the Dutch EEZ for the different life stages is summarised in Table 4.18.1.

Table 4.18.1: Summary of the importance of the Dutch EEZ for different life stages of sole at different times of the year. Eggs and larvae information is provided on a monthly basis, juvenile and adults on a quarterly basis. Importance levels (none or close to none = white; low = yellow; medium = orange; high = red; grey = unknown) relate to the extent of the distribution of each life stage within the Dutch EEZ and are based on best estimates from current knowledge.

Month	1	2	3	4	5	6	7	8	9	10	11	12
Eggs			*Med*	*Med*	*Med*							
Larvae				*Med*	*Med*	*Med*						
Juveniles	*Med*			*Med*			*Med*			*Med*		
Adults	*Med*			*Med*			*Med*			*Med*		

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4.19 Solenette – *Buglossidium luteum* (Risso, 1810)

4.19.1 Introduction

Solenette is the smallest species of the Solidae in Europe. It is distributed from the Mediterranean along the west coast of Europe to Norway and around the British Isles. It is classified as a Lusitanian species, which lives as a demersal species on the inner shelf (Yang 1982, Ellis et al. 2002, Ellis et al. 2008). The highest abundance occurs offshore at depth range of 5 to 37m (Wheeler 1969), however it has been reported at depths down to 450m (Muus and Nielsen 1999).
Solenette rarely occurs in shallow waters and avoids low salinity estuaries (Amara et al. 2004). The preferred habitats are muddy or sandy sediments, but it is not restricted by these sediment types (Amara et al. 2004). It grows fastest in the first year and reaches a mean length of 7 cm at the start of the second winter (Baltus and Van der Veer 1995), and grows to a maximum length of 13-15cm (Wheeler 1969). It reaches a maximum age of 15 (Amara et al. 2004).
It matures at a length of 6-8cm depending on the water temperature. Spawning starts in January/February in the warmer southern area of its distribution (Nichols 1976, Ferreiro and Labarta 1988). In the North Sea, spawning starts in March/April, peaks in May/June and ends in August (Nottage and Perkins 1983). The eggs and larvae are pelagic. Solenette feed on a wide range of benthic invertebrates mainly on crustaceans, polychaetes and molluscs and in small amounts of echinoderms (Piet et al. 1998, Labberton 2009). The species has no commercial value.

4.19.2 Eggs

Temporal occurrence of eggs: During an egg surveys in 1989, first solenette eggs were caught in March, while the highest egg numbers were caught in May (Fig. 4.19.1). By June, densities had decreased considerably, and in July egg production had almost ceased (van der Land 1991).

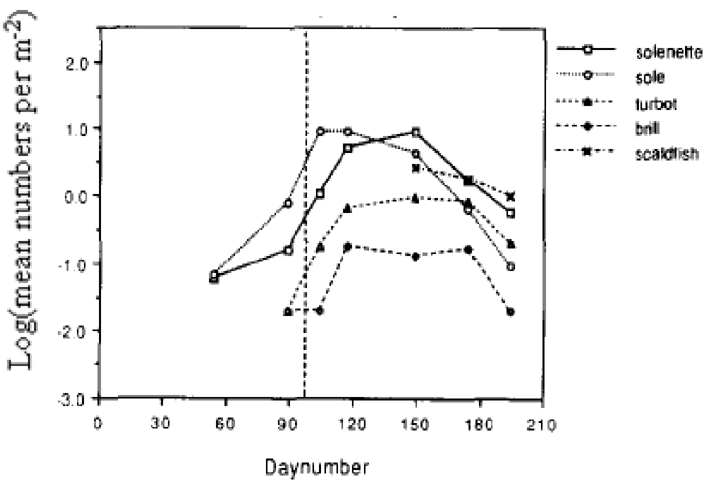

Fig. 4.19.1. Seasonal variation in abundance of flatfish eggs in 1989. The vertical dashed line indicates the change in survey area (van der Land 1991).

Spatial distribution of eggs: During the same egg survey in 1989 only few solenette eggs were found in the eastern English Channel and north of Helgoland. Highest densities were found between 52°N and 54°N (Fig. 4.19.2; van der Land 1991). During an egg survey directed at mackerel eggs, a more northwestern area is surveyed in June. In the southeastern part of this survey area, solenette eggs were caught (Fig. 4.19.3)

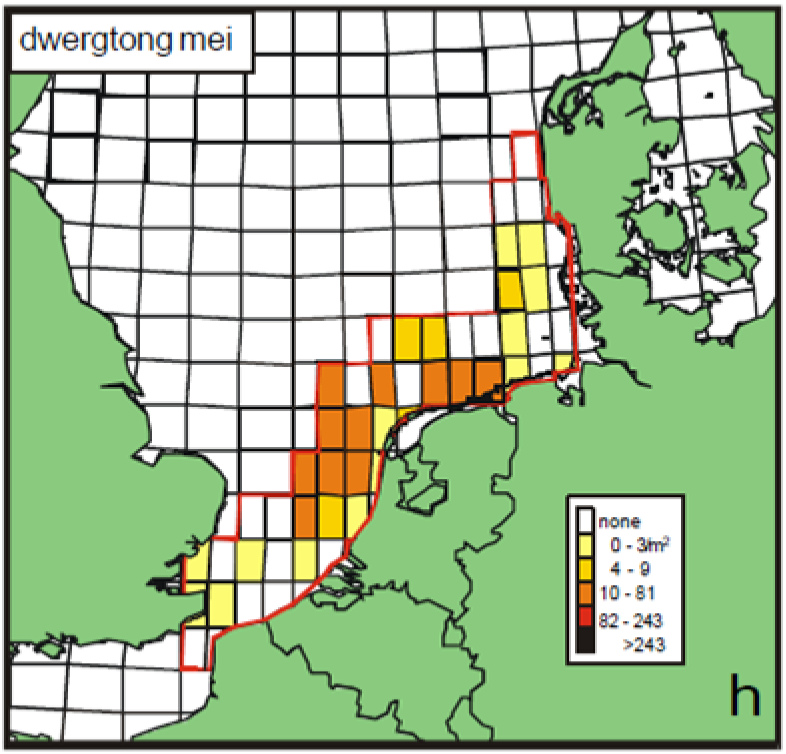

Fig 4.19.2: Distribution of all stages of egg development of Solenette in May in 1989 (Rozemeijer 1999, adjusted from van der Land 1991), red line is the area surveyed.

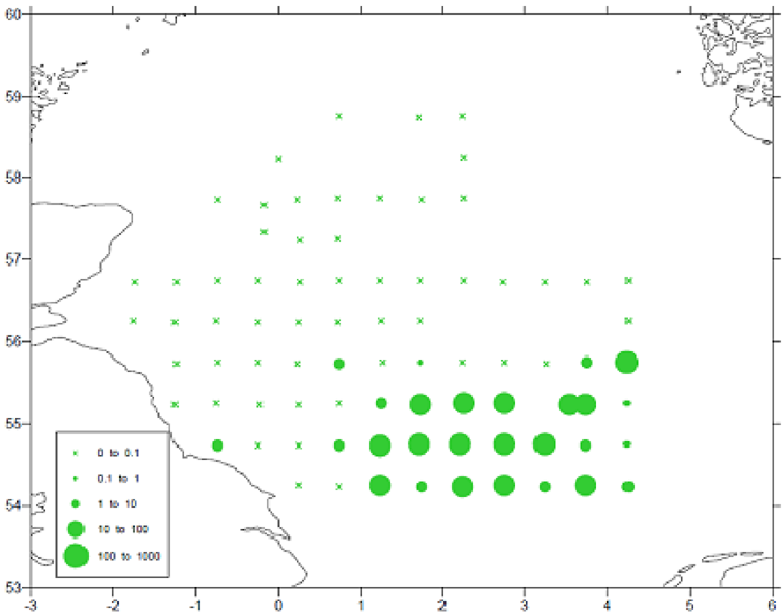

Fig. 4.19.3: Number of solenette eggs per m^{-2} during a egg survey in June 2008 (van Damme 2008).

4.19.3 Larvae

Temporal occurrence of larvae: Solenette larvae occurred from May to August in daily samples of the Helgoland Roads station (54°11.18 N and 07°54.00 E), in the years 2003-2005 (Malzahn and Boersma 2007). In abundance solenette larvae were the 5th most abundant species in 2004, the 6th in 2003 and the 8th 2005 (Malzahn and Boersma 2007). It is unclear from the data if this is due to variation in the abundance of solenette larvae or due to variation in the abundance of other species.

Spatial occurrence of larvae: The spatial distribution of solenette larvae is similar to the eggs and other life-stages. Thus the larvae are not found in shallow coastal waters or the Wadden Sea. It is unclear whether larvae do not reach these areas, or whether these areas are unsuitable for settlement (Baltus and van der Veer 1995). Settlement takes place in offshore waters or deeper inshore waters.

4.19.4 Juveniles

Spatial occurrence and seasonal migrations: 0-group solenette were widely distributed in the North Sea in the period October-November (Fig. 4.19.4), while none were found in the Wadden Sea surveys (Baltus and van der Veer 1995). There was no difference in distribution compared to the adults (Baltus and van der Veer 1995).
Monthly average population densities of 0-group solenette varied irregularly. The first 0-group specimens of both specimens were found in October, maximum numbers occurred in November (Baltus and van der Veer 1995).

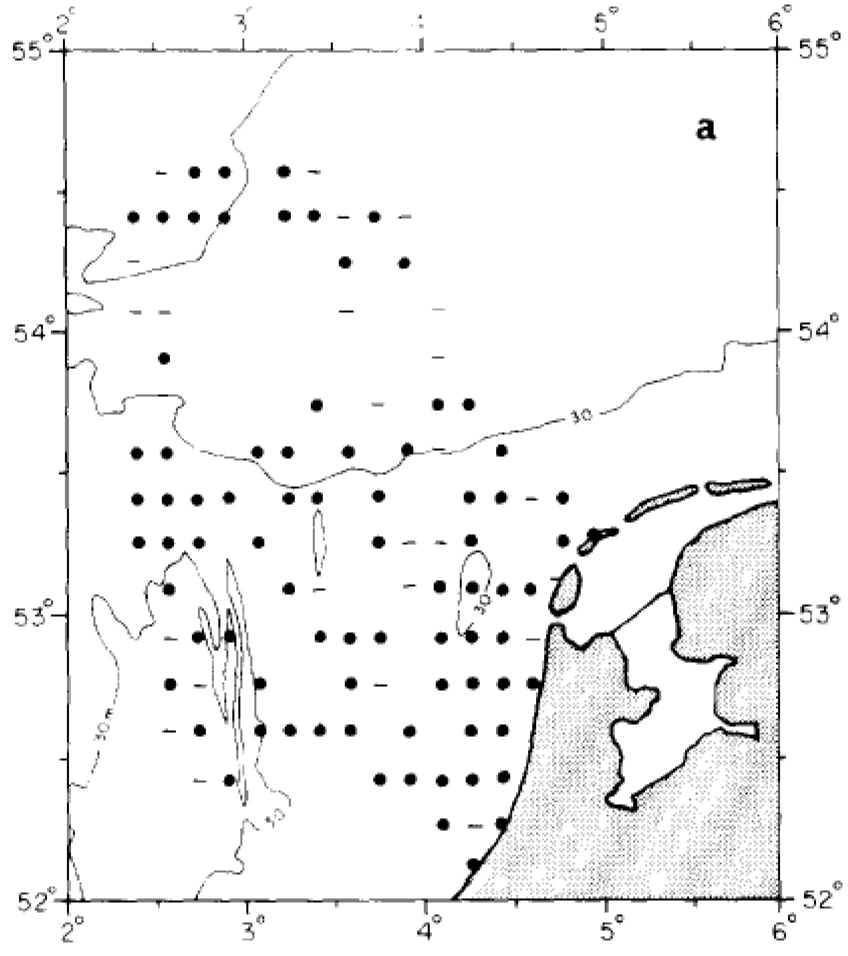

Fig. 4.19.4. Distribution of 0-group solenette (a) in the southern North Sea in the period October-November; (black dots) presence, (dash) absence (Baltus and van der Veer 1995).

4.19.5 Adults

Spatial occurrence and seasonal migrations: Solenette is a lusitanian species, preferring warmer conditions and their main distribution is south of the North Sea. Until the end of the 1980s, they occurred in the southern North Sea just past the Dutch Islands. Following the warmer winters in the beginning of the 1990s, they moved northward extending their range at least to 57° N and in the Moray firth. Following the cold winter of 1996 they disappeared from the northern areas occupying the same areas as before 1990 (Fig. 4.19.5; van Hal et al. 2009 in press). They again had a more northern distribution in 2008.
Solenette do not show an obvious seasonal migration, They however have been observed to display an offshore movement in winter, probably to avoid the colder shallower waters (Nottage and Perkins 1983).

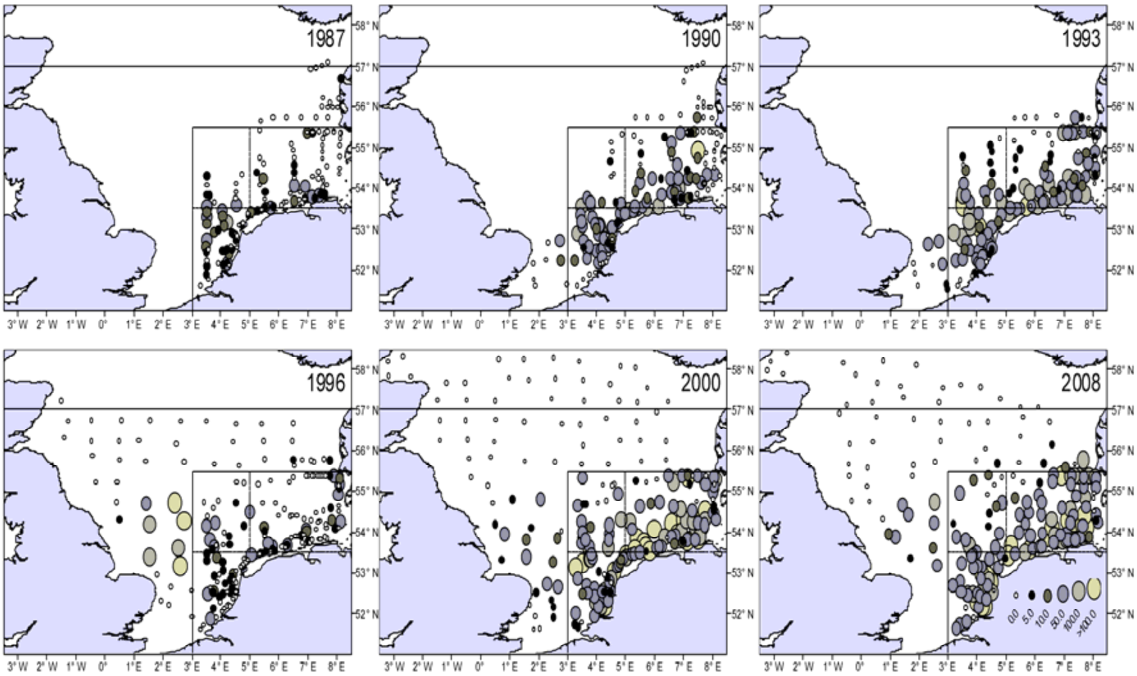

Fig. 4.19.5. Spatial distribution of Solenette in August/September based on Dutch Beam trawl surveys (van Hal et al. 2009 in press).

4.19.6 Conclusion

The importance of the Dutch EEZ for the different life stages is summarised in table 4.19.1. All life-stages of solenette occur in the same area, and in almost the whole Dutch EEZ. Due to their southern distribution the Dutch EEZ, together with the southern English coast are the main areas for solenette in the North Sea. However, due to their northward expansion since the 1990s also areas north of the Dutch Islands and the German Bight have increased in importance.Therefore the importance of the Dutch EEZ for the total population decreased to less then 50%.
The second quarter is most import for the pelagic eggs while the end of the second quarter and beginning of the third quarter are most important for the larvae. Juveniles and adults inhabit the Dutch EEZ during the whole year.

Table 4.19.1: Summary of the importance of the Dutch EEZ for different life stages of solenette at different times of the year. Eggs and larvae information is provided on a monthly basis, juvenile and adults on a quarterly basis. Importance levels (none or close to none = white; low = yellow; medium = orange; high = red; grey = unknown) relate to the extent of the distribution of each life stage within the Dutch EEZ and are based on best estimates from current knowledge.

Month	1	2	3	4	5	6	7	8	9	10	11	12
Quartile		1			2			3			4	
Eggs			*High*	*High*	*High*	*High*	*High*					
Larvae					*Med*	*Med*	*Med*	*Med*				
Juveniles		*Med*			*Med*			*Med*			*Med*	
Adults		*Med*			*Med*			*Med*			*Med*	

4.19.7 References:

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5 Conclusions

For all of the selected species in this report, some biological information on the different life stages and the spatial distribution and seasonal patterns is available. However, the amount and detail of available data differs considerably between the selected species. Although in general more detailed data is available for the commercial species, information on the early life stages (eggs, larvae) remains limited. Most of the available data dates back to the 1970s or 1980s, and is from single surveys or single locations, thereby temporal information is scarce. The 2004 ichtyoplankton survey, which is widely used as a reference for information on early life stages, is targeted at specific species. Although existing data for the non-targeted species is presented in this report, these are often limited as it does not include the peaks of occurrence (temporal) or since the surveys were not performed in the relevant areas (spatial). These flaws have been highlighted in the text.
Because of the uncertainties it is often difficult to estimate the full North Sea population for the specific life-stages of a species. Thus estimating the relative importance of the Dutch EEZ for the population is difficult. In some cases it was only possible to note whether or not a particular lif-stage of a species occurs within the Dutch EEZ, but the relative importance of the area for the whole North Sea population remains unknown (grey shaded areas in the conclusion tables). A summary of all the tables presented in the conclusion section for each species, is presented in table 5.1. It should be noted that these are estimates of the importance of the area and do not include seasonal or yearly variation. Explaination of the terms used in the table is given in the glossary (section 6).
Although the available data is limited, this report shows that for certain species the Dutch EEZ is an important area during one or more life-stages.

Table 5.1: Overview of selected species and their biogeographical guild, habitat, location in the water column of the eggs and spawning type, and summarizing the importance of the Dutch EEZ for the different life-stages. The '(?)' marks indicate unknown information. Presented is the highest level of importance as reported in section 4 for each species, e.g. if in one month the importance was indicated as high, while the importance during other months were blank or low, the table below shows high importance. White=not on the NCP; striped=importance for Dutch EEZ unknown; yellow= less then 5% of the population occurs on the Dutch EEZ, orange= 5 to 50% of the population occurs on the Dutch EEZ; red= more then 50% of the population occurs on the Dutch EEZ.

			Overview of selected species				Importance for the Dutch EEZ			
English name	**Scientific name**	**Dutch name**	**Biogeographical**	**Habitat**	**Eggs habitat**	**Spawning type**	**Eggs**	**Larvae**	**Juveniles**	**Adults**
Atlantic herring	*Clupea harengus*	Haring	Boreal	Benthopelagic	Demersal	Iteroparous group-synchronous determinate total	white	red	orange	yellow
Sprat	*Sprattus sprattus*	Sprot	Lusitanian	Pelagic	Pelagic	Iteroparous asynchronous indeterminate batch	orange	striped	red	red
Cod	*Gadus morhua*	Kabeljauw	Boreal	Demersal	Pelagic	Iteroparous group-synchonous determinate batch	orange	striped	orange	orange
Whiting	*Merlangius merlangus*	Wijting	Lusitanian	Demersal	Pelagic	Iteroparous group-synchonous determinate batch	orange	striped	yellow	yellow
Grey gurnard	*Eutrigla gurnardus*	Grauwe poon	Lusitanian	Demersal	Pelagic	Iteroparous (?)	striped	striped	orange	orange
Horse mackerel	*Trachurus trachurus*	Horsmakreel	Lusitanian	Pelagic	Pelagic	Iteroparous asynchronous indeterminate batch	yellow	striped	red	red
Sea bass	*Dicentrarchus labrax*	Zeebaars	Lusitanian	Benthopelagic	Pelagic	Iteroparous group-synchonous determinate batch	striped	striped	striped	striped
Small sandeel	*Ammodytes tobianus*	Kleine zandspiering	Boreal	Benthopelagic	Demersal	Iteroparous (?) batch	striped	striped	striped	striped
Lesser sandeel	*Ammodytes marinus*	Noorse zandspiering	Boreal	Benthopelagic	Demersal	Iteroparous (?) batch	yellow	yellow	yellow	yellow
Common dragonet	*Callionymus lyra*	Gewone pitvis	Lusitanian	Demersal	Pelagic	Iteroparous (?) "determinate" batch	orange	orange	orange	red
Sand goby	*Pomatoschistus minutus*	Dikkopje	Lusitanian	Demersal	Demersal	Semelparous synchronous determinate total	striped	striped	striped	striped
Common goby	*Pomatoschistus microps*	Brakwater grondel	Lusitanian	Demersal	Demersal	Semelparous synchronous determinate total	striped	striped	striped	striped
Lozano's goby	*Pomatoschistus lozanoi*	Lozanoi grondel	Lusitanian	Demersal	Demersal	Semelparous synchronous determinate total	striped	striped	striped	striped
Mackerel	*Scomber scombrus*	Makreel	Atlantic	Pelagic	Pelagic	Iteroparous asynchronous determinate batch	yellow	striped	red	orange
Dab	*Limanda limanda*	Schar	Boreal	Demersal	Pelagic	Iteroparous group-synchonous determinate batch	orange	orange	orange	orange
Flounder	*Platichthys flesus*	Bot	Lusitanian	Demersal	Pelagic	Iteroparous (?)	orange	orange	orange	orange
Plaice	*Pleuronectes platessa*	Schol	Boreal	Demersal	Pelagic	Iteroparous group-synchonous determinate batch	orange	orange	red	orange
Sole	*Solea solea*	Tong	Lusitanian	Demersal	Pelagic	Iteroparous asynchronous determinate batch	orange	orange	orange	orange
Solenette	*Buglossidium luteum*	Dwergtong	Lusitanian	Demersal	Pelagic	Iteroparous indeterminate batch	red	orange	orange	orange

6 Glossary

Life-stage:

Egg: The eggs stage is considered from the moment of spawning up to the moment of hatching. In literature different eggs stages are considered depending on the development of the eggs, but these are neglected in the report.

Larvae: Similar to the eggs, all the different development stages of the larvae are neglected. The larval stage is considered from the moment of hatching up to the moment of metamorphoses.

Juvenile: The juvenile stage is considered from the moment of metamorphoses up to the moment of maturation. However, in most case not all juveniles mature at the same age. Then the age at which a significant number has matured is considered as adults.

Adult: the adult stage is considered as all fish that are mature.

Habitat:

Demersal: Species that live close by or on the bottom but are not attached or buried.

Pelagic: Species that pertain to the part of the open sea or ocean comprising the water column, i.e., all of the sea other than that near or on the sea floor.

Benthopelagic: Species that live in the water column but are associated with the sea floor.

Biogeographical guilds:

Boreal: Boreal fishes are considered to be northerly taxa, and include both boreal species (which extend northwards to the Norwegian Sea and Icelandic waters) and boreal-Arctic species (which extend into Arctic waters and may even extend into the cold waters of the North-West Atlantic). These fish species generally have the southern limits of their distribution around the British Isles or west of Brittany.

Lusitanian: Lusitanian fishes are those southerly species that tend to be abundant from the Iberian Peninsula (including the Mediterranean Sea) to as far north as the British Isles, and may have northerly limits in the southern or central North Sea (although many of these species extend to more northerly latitudes on the western seaboards of the British Isles, and so can also occur in the north-western North Sea). Many of these species have distributions extending into the Mediterranean Sea and off North-west Africa.

Atlantic: Atlantic fishes are those (often pelagic or deep-water) species that are widespread in the North Atlantic, and includes many of the deeper-water species that may be widely distributed along the continental slope. Some Atlantic fishes occur on both sides of the Atlantic, but are limited to the more tropical parts of the north-east Atlantic.

Spawning types (Murua and Saborido-Rey 2003, Kjesbu 2009):
A summary for the selected species is given in table 6.1

Breeding opportunity

Semelparous spawner: Fish that have only one breeding period in their life time, can spawn the eggs in a single or multiple batches, well known examples are eel and salmon.

Iteroparous spawner: Fish that have multiple breeding periods in their life. Most fish species are iteroparous.

Fecundity type

Determinete spawner: All oocytes of this breeding period are in vittelogenisis before spawning. The eggs can than be spawned in one single batch (example herring) or multiple batches (example plaice).

Indeterminate spawner: Oocytes are being recruited to the vitellogenic stock during the breeding season, example horse mackerel. As a consequence all indeterminate spawners are batch spawners.

Spawning pattern

Total spawner: All ripened eggs are spawned in a unique event or over a shorter period of time but as part of a single event

Batch spawner: Within on breeding period eggs are released in multiple batch at several days intervals.

Ovarian organization

Synchronous: At least two populations of oocytes can be distinguished at the same time during ripening and spawning - a fairly synchronous population of larger oocytes (defined as a clutch) and a more heterogeneous population of smaller oocytes from which the clutch is recruited.
Group synchronous: At least two populations of oocytes can be distinguished at the same time during ripening and spawning

Asynchronous development: Successive cohorts of oocytes in different stages of development can be distinguished in ovaries of ripening and spawning females

Feeding behaviour

Capital spawner: Fish that stop feeding during the breeding season and have to build up energy reserves (capital) for spawning prior to the breeding season, examples herring and plaice.

7 Quality Assurance

IMARES beschikt over een ISO 9001:2000 gecertificeerd kwaliteitsmanagementsysteem (certificaatnummer: 08602-2004-AQ-ROT-RvA). Dit certificaat is geldig tot 15 maart 2010. De organisatie is gecertificeerd sinds 27 februari 2001. De certificering is uitgevoerd door DNV Certification B.V. Het laatste controlebezoek vond plaats op 22-24 april 2009. Daarnaast beschikt het chemisch laboratorium van de afdeling Milieu over een NEN-EN-ISO/IEC 17025:2005 accreditatie voor testlaboratoria met nummer L097. Deze accreditatie is geldig tot 27 maart 2013 en is voor het eerst verleend op 27 maart 1997; deze accreditatie is verleend door de Raad voor Accreditatie.

References in the common sections.

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Justification

Rapport C126/09
Project Number: 430250801

The scientific quality of this report has been peer reviewed by the a colleague scientist and the head of the department of IMARES.

Approved: Dr. Henk J.L. Heessen
Senior Scientist

Signature:

Date: 1 December 2009

Approved: Drs. J. Asjes
Head of Dept. Ecology

Signature:

Date: 1 December 2009

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