Shortlist Master plan Wind Monitoring fish eggs and larvae in the Southern North Sea: Final report *Part A*

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Contents

Contents 3

Summary 4

Samenvatting 5

1 Introduction 6
1.1 Problem definition 6
1.2 Background 6
1.3 Reading guide 7

2 Objective 8

3 Materials and Methods 9
3.1 Gear 9
3.2 Fishing method 9
3.3 Sampling grid 10
3.4 Workup of the samples on board 12
3.5 Workup of the samples in the lab 14
3.6 Calculations 15

4 Results 16
4.1 Stations sampled 16
4.2 Temperature and salinity 18
4.3 Eggs and larvae 22
4.4 Species 33

5 Discussion and conclusions 50

6 Acknowlegdements 52

7 Quality Assurance 53
7.1 Check on the sorting and identification of the samples 53
7.2 ISO 53

References 54

Justification 56

Summary

This report presents the results of twelve monthly ichthyoplankton surveys carried out from April 2010 until March 2011 in the southern North Sea. The aim of this study was to collect data on the temporal and spatial distribution of fish eggs and larvae on the Dutch Continental Shelf (NCP). However, since fish eggs and larvae are transported with the currents onto the NCP a larger area covering the majority of the southern North Sea was sampled during the surveys. Despite technical problems or bad weather conditions preventing the sampling of all planned stations during each survey, the coverage was good and the general trends in ichthyoplankton abundance became apparent.

Fish eggs were found in all months but species and numbers varied per month across the southern North Sea. The highest abundance of fish eggs was found from January until May with fish eggs being found at all stations from April until July. Very few eggs were found between August and November. From December onwards abundance of eggs increased again. The pattern was the same on the NCP. In total 35 different species of fish eggs were found.

Fish larvae were found in all months but species and numbers varied in a similar pattern to the fish eggs, except the highest abundance of larvae was found in December and January in the English Channel (mostly herring). Numbers of larvae in the southern North Sea increased from April until June and afterwards then gradually declined until November. After this the abundances increased again. Larvae were found at almost all stations from May until September. In October and November larvae were found at half of all the stations both in the whole sampling area and on the NCP. The patterns was the same on the NCP. In total 74 different species of fish larvae were found.

Based on the results of a modelling study, a mitigating measure was issued by the Dutch authorities forbidding pile driving of offshore wind farm foundations from January to June, in order to ensure that negative effects on prey availability for birds and marine mammals within Natura 2000 areas are minimised. The results of the year-round monthly surveys show that from April until September fish larvae were found throughout the survey area, including the NCP, in varying numbers and varying species. Still in October and November larvae were found at half of the stations although at lower abundances. Even in December larvae were still found at a quarter of the stations on the NCP. Whilst the abundance of larvae was low in October and November, there are a few species with larvae present that are absent at other times of the year. These results on ichthyoplankton abundance and results of the experimental study on the effect of pile driving on fish larvae need to be combined. Ideally they should also be assessed with subsequent studies of ichthyoplankton transport and impact on the Natura 2000 sites.

This unique study is the first to comprehensively sample and analyse the ichthyoplankton with monthly resolution in the southern North Sea. These data on spatial and temporal distribution of fish eggs and larvae can be used in modelling studies to assess the effects of human activities in the southern North Sea, on different fish stocks.

Samenvatting

In dit rapport worden de resultaten gepresenteerd van twaalf maandelijkse ichthyoplankton surveys, uitgevoerd van april 2010 tot maart 2011, in de zuidelijke Noordzee. Doel van dit onderzoek is het monitoren van de ruimtelijke en temporele verspreiding van viseieren en vislarven op het Nederlandse Continentale Plat (NCP). Maar, omdat viseieren en larven via reststromen naar het NCP getransporteerd worden is een groter gebied in de zuidelijke Noordzee bemonsterd. Vanwege technische problemen of slecht weer tijdens de surveys was het niet altijd mogelijk om alle geplande stations te bemonsteren.

Vis eieren zijn in alle maanden van het jaar gevonden. Aantallen en soorten wisselden per maand. Hoogste aantallen viseieren zijn gevonden van januari tot mei. Van april tot juli zijn op bijna alle stations in het bemonsterde gebied viseieren gevonden. Van augustus tot november namen de aantallen viseieren snel af. Vanaf december namen de aantallen weer toe. Op de stations op het NCP zijn van januari tot juli viseieren gevonden. De aantallen namen af van augustus tot november. De aantallen viseieren namen weer toe vanaf december. In totaal zijn er van 35 verschillenden vissoorten eieren gevonden in de monsters.

Vislarven zijn in alle maanden van het jaar gevonden. Maar net als bij viseieren is er variatie in de aantallen en soorten per maand. De hoogste aantallen vislarven zijn gevonden van in december en januari in het Engels Kanaal. In de zuidelijke Noordzee namen de aantallen vislarven toe van april tot juni, maar daarna namen de aantallen per maand geleidelijk af tot november. Na november namen de aantallen vislarven weer toe.
Van mei tot september zijn op bijna alle bemonsterde stations vislarven gevonden. In oktober en november zijn, zowel in de zuidelijke Noordzee als op het NCP, op de helft van de stations vislarven aangetroffen. In december zijn nog steeds vislarven aanwezig op de helft van alle stations in de zuidelijke Noordzee, maar slecht op een kwart van de stations op het NCP. In februari en maart zijn weer op alle stations in de zuidelijke Noordzee en het NCP vislarven gevonden.
In totaal zijn er van 74 verschillende soorten vislarven gevonden.

Op de basis van een modelstudie, die het mogelijke effect van heien op de voedselbeschikbaarheid van vogels en zeezoogdieren in Natura 2000 gebieden heeft bestudeerd, is er een mitigerende maatregel ingesteld die het heien van palen voor de fundaties van wind turbines op zee verbied van januari tot juni. De resultaten van deze jaarronde survey tonen aan dat van april tot september vislarven aanwezig zijn in de gehele zuidelijke Noordzee, inclusief het NCP, in variabele aantallen en verschillenden soorten. Ook in oktober en november worden nog steeds op de helft van de stations vislarven aangetroffen in wisselende aantallen en soorten. Zelfs in december worden op een kwart van de stations op het NCP nog vislarven aangetroffen. De aantallen vislarven in oktober en november zijn laag in vergelijking met andere maanden, maar juist in oktober en november worden er soorten gevonden die in andere maanden niet aanwezig zijn. De resultaten van deze studie en de resultaten van de experimentele studie van het effect van heien op vislarven zouden moeten gecombineerd worden.

Deze studie is een eerste maandelijkse studie van ichtyoplankton in de zuidelijke Noordzee. De data verzameld in deze surveys over de ruimtelijke en temporele verspreiding van viseieren en –larven zijn uniek en kunnen gebruikt worden in modelstudies om de mogelijke effecten van bepaalde vormen van menselijk ingrijpen op visbestanden in de zuidelijke Noordzee te bepalen.

1 Introduction

1.1 Problem definition

Human activity in the North Sea is widespread. Fishing is fairly ubiquitous, shipping is increasing, the network of platforms for offshore oil and gas exploration and exploitation is extensive but stable and the number of offshore wind farms are increasing. Such activities result in a noticeable increase in anthropogenic impact on the marine environment.

Knowledge about the spatial abundance and seasonal patterns of the eggs and larvae of marine fish species can be used to investigate potential overlaps with anthropogenic impacts. Our current understanding of the seasonal dynamics and spatial abundance of ichthyoplankton in the southern North Sea is currently very limited. There is some information about a number of commercial species, or for more species during the spring but rare for non-commercial species and the rest of the year (Taylor, et al., 2007; Teal et al. 2009).

Thus year-round monitoring of fish eggs and larvae on the Dutch Continental Shelf (NCP) provides valuable and unique information on the spatial and temporal distribution of the early life stages of fish.

1.2 Background

Within the framework of the "Appropriate Assessment Dutch offshore wind farms", the effect of pile driving noise on the southern North Sea population of herring, sole, and plaice larvae was simulated (Prins et al. 2009). For this, an existing larval transport model (Bolle et al. 2005, 2009) was expanded with crude assumptions about larval mortality caused by pile driving. The model results combined with expert judgement were then extrapolated to other fish species and older life stages in an attempt to assess the effect of offshore piling on the prey availability for birds and marine mammals in (near-shore) Natura 2000 areas (Bos et al. 2009). This assessment, unfortunately, highlighted a large number of knowledge gaps. Two of the major knowledge gaps were addressed in the research programme "Shortlist Masterplan Wind".

Firstly, little is known about impacts and potential mortality caused by the under-water sound pressure of pile driving on fish larvae. This knowledge gap was addressed in the project "Effect of piling noise on the survival of fish larvae (pilot study)" (Bolle et al. 2011).

Secondly, extrapolating the results of the modelling study to other species is hampered by the limited knowledge of the spatial and temporal abundance of fish eggs and larvae. Based on the results of the modelling study, a mitigating measure was installed: limitating pile driving to summer and autumn (i.e. the period in which herring, sole, and plaice larvae are absent). However, in this period eggs and larvae of other fish species may be present on the NCP (e.g. whiting and sprat). It is therefore important to map the spatial and temporal distribution of eggs and larvae for all fish species on the NCP. The existing knowledge, collated in Teal et al. (2009), is limited. Therefore, a study was started to gather new information by means of a year-round ichthyoplankton survey, which, unlike all previous ichthyoplankton surveys, will not focus on the spawning period of specific commercially important species. This report contains the results of this study.

1.3 Reading guide

For easier reading this report consists of two parts. Part A with the main text, background and problem definition, methods, general results, including the description of the temporal and spatial abundance per species or species group, and conclusions. Part B contains the spatial and temporal distribution maps per development stage for each species or species group.

2 Objective

The purpose of this study is to provide an information base on the spatial distribution and seasonal patterns in the appearance of fish eggs and larvae on the NCP. To this end, a year-round survey was carried out during which ichthyoplankton samples were taken on the entire NCP and surrounding areas.

3 Materials and Methods

3.1 Gear

The sampling of the fish eggs and larvae was carried out with a "High Speed Plankton Sampler Gulf VII" (Figure 3.1) with a plankton net with mesh size 280 µm (Nash et al. 1998). If clogging of the net occurred due to large amounts of phyto- and microzooplankton in the water, the complete net was changed for one with a 500 µm mesh size. Due to clogging we used the 500 µm net in April and May. Almost all fish eggs are bigger than 500 µm, thus the bigger mesh size only results in a loss of other non-target plankton, while the net does not clog. A small Scripps depressor (25 kg) was attached to the plankton sampler. The amount of water filtered during each haul was measured using a Valeport (Model 001; http://www.valeport.co.uk/Portals/0/Docs/Datasheets/Valeport_Model001&002_v2a.pdf) electronic flowmeter mounted inside the nosecone. A similar 'external' flowmeter was mounted on the frame of the sampler. The ratio of 'internal' to 'external' flowmeter revolutions provided an index of the extent of net clogging.

A Seabird 911plus CTD with a Benthos PSI 916 altimeter were mounted on the sampler frame to provide a 'real-time' graphical display (Figure 3.2) of the depth of the sampler in the water column and its height off the seabed and the temperature and salinity continually throughout each deployment.

Figure 3.1. Gulf VII plankton sampler.

3.2 Fishing method

The survey was carried out on board the 'Ms Arca', 'Ms Zirfaea' and the 'Rv Tridens'. The speed during fishing with the plankton sampler was 5 knots through the water. At each station a 'double oblique' haul was performed (V-shaped haul through the water column; Figure 3.2). This way each 10 meters of the water column are sampled 1 minute going down and going up.
The plankton sampler was lowered to 5 meter above the sea floor. To ensure that enough water was filtered, the haul duration needed to be at least 10 minutes. At shallower stations a double or triple

‘double oblique’ was performed without the plankton sampler breaking the surface of the water to ensure sufficient water was filtered.

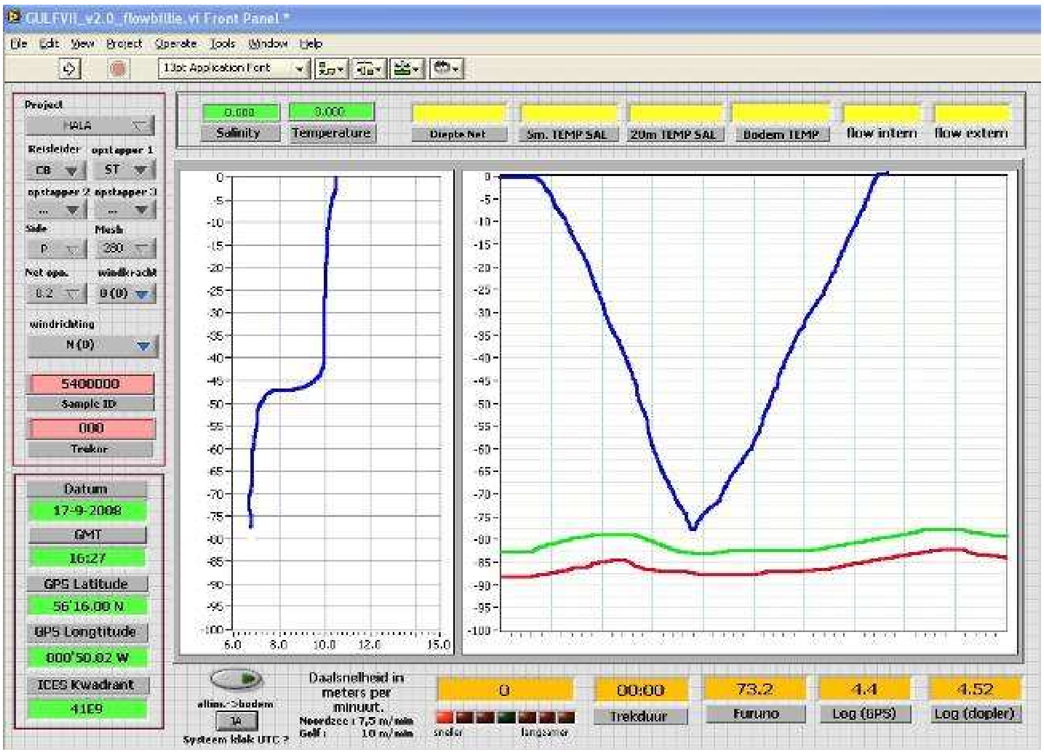

Figure 3.2. Illustration of an oblique haul in the Labview program. In the right frame: The blue line shows the depth profile of the plankton sampler, the red line is the sea bottom depth, the green line is the 5 meter above the bottom safety line. In the left frame: The blue line shows the temperature through the water column.

3.3 Sampling grid

The English Channel and the south-western North Sea are important spawning areas for many fish species. The prevailing currents transport eggs and larvae from these areas towards the NCP. Therefore the sampling area was extended to the south and west of the NCP. Figure3.3 indicates the planned sampling area. This area covers all areas that may contribute to the ichthyoplankton on the NCP (based on general maps of residual currents, e.g. Laevastu 1983 in ICONA 1992).

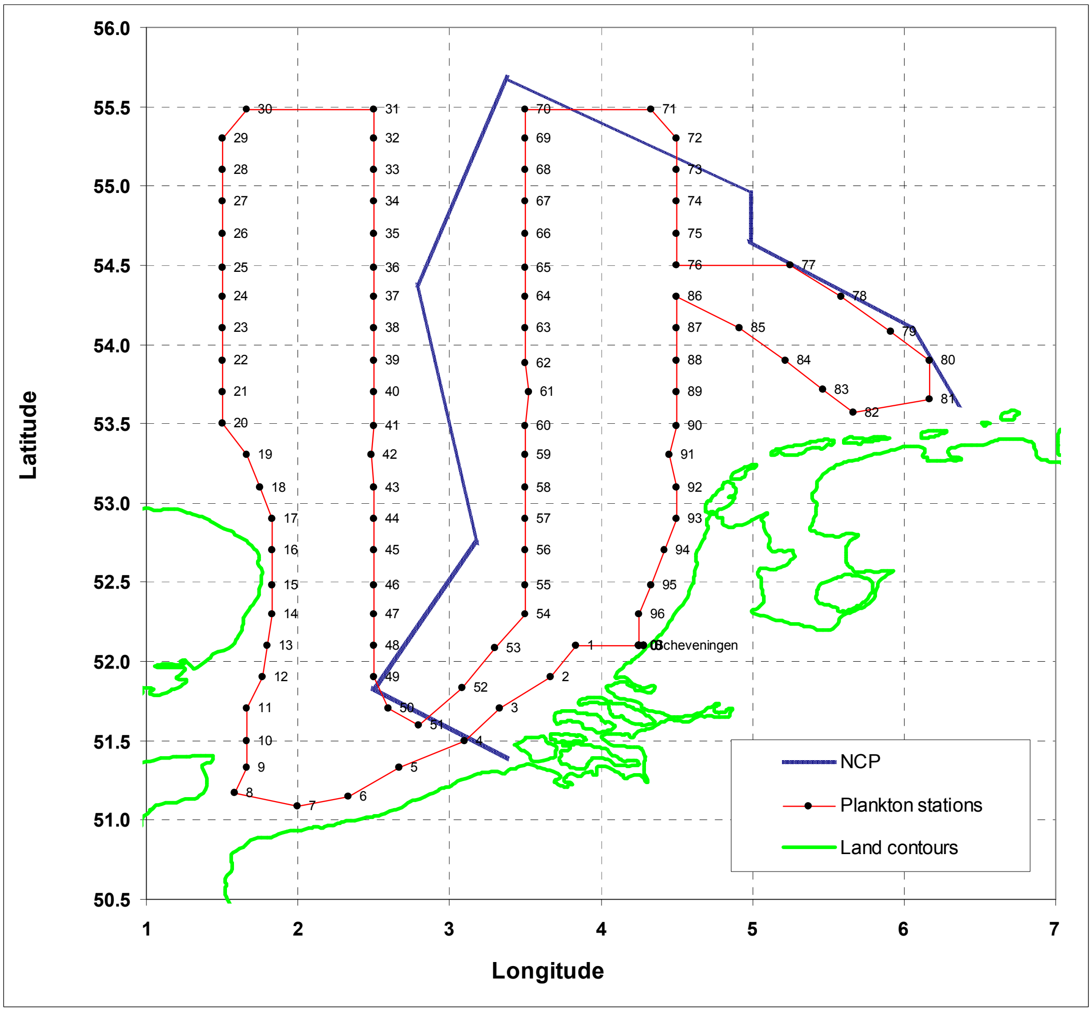

Figure 3.3. Survey grid for the surveys in April and May 2010.

The station grid presented in Figure 3.3 was sampled successfully on the first two cruises (in April and May 2010). A logistic aspect which had to be taken into account is a time restraint on the shipping time due to labour conditions. The request was put forward to change the sampling grid so it could be completed within 5 days (i.e. estimated arrival time Friday evening) with 'Ms Arca'. It was impossible to maintain the spatial coverage of the first grid (Figure 3.3) given the imposed time restraint.
Results of a small modelling exercise carried out to evaluate the sampling grid (Bolle & Van Beek 2011) show that the westernmost stations will only contribute substantially to the larval population on the NCP in case of 'above-average-currents'. The chance of 'above-average-currents' is difficult to quantify given the large variability in hydrodynamics on both small (tidal cycle) and large (annual) temporal scales. A very tentative guestimate of the chance that eggs from the westernmost stations reach the NCP is 1-10%. The specific aim of this project is to estimate the spatial and temporal abundance of fish larvae on the NCP. Focussing on this specific aim and taking into account the modelling results, led to the conclusion that the sampling grid could be compressed in easterly direction (Figure 3.4). An advantage of this modified sampling grid compared to the initial sampling grid is a higher resolution, especially in the eastern part of the NCP. Disadvantage of moving the sampling grid to the east is that spawning concentrations in the western part of the southern North Sea may be missed. Examination of published spawning distributions (collated in Teal et al. 2009) shows that by shifting the station grid as proposed in Figure 3.4, spawning concentrations off Flamborough Head (± 54°N and 1.5°E) will be missed. Spawning

concentrations off Flamborough Head have been observed in several species (e.g. sprat, cod, whiting, plaice).

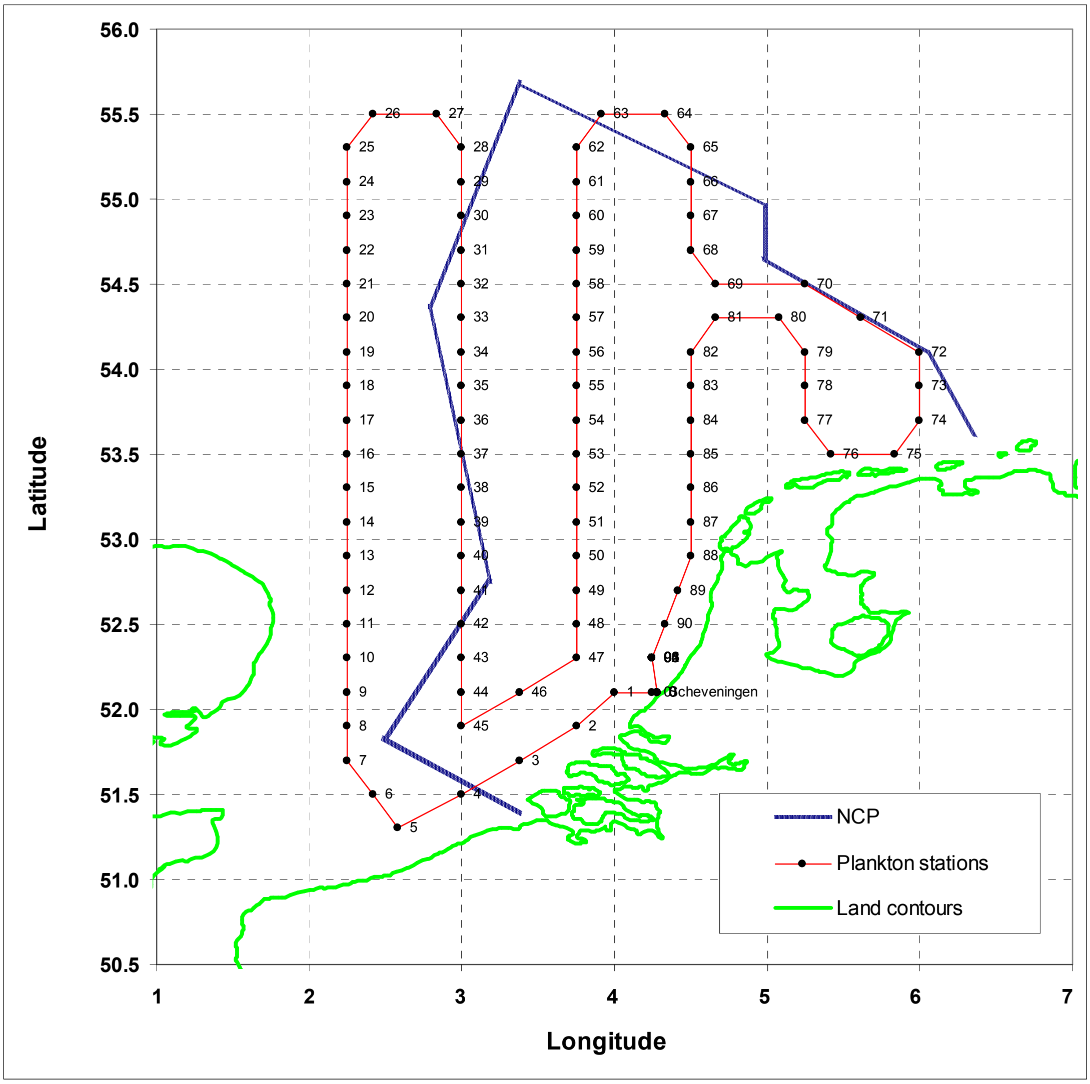

Figure 3.4. Survey grid for the last nine surveys (June until March).

3.4 Workup of the samples on board

After each deployment, as soon as the plankton sampler was on board the vessel, the sample (Figure 3.5) was taken to the laboratory on board of the vessel. All fish larvae were sorted out from the fresh sample (Figure 3.6) and put into 4% buffered formaldehyde (formaldehyde solutions were buffered with sodium acetate trihydrate). The sample was kept cool in the laboratory and sorting of the larvae was kept to a maximum of 15 minutes. The remainder of the plankton was also fixated in 4% formaldehyde, but in a separate container.

Figure 3.5. The codend with the plankton sample.

Figure 3.6. Larvae from a plankton sample

After at least 24 hours of fixation, the fish eggs were separated from the other plankton using the 'spray method' (Eltink 2007). When few eggs were left in the sample, the whole sampled was checked by hand to pick out remaining eggs and larvae, which were missed in the fresh sample. If the non-ichthyoplankton volume was very small and/or the sample contained eggs with high buoyancy, it was quicker to pick the eggs out by hand.

3.5 Workup of the samples in the lab

Due to time constraints and weather conditions it was impossible to sort out and analyse the eggs of all samples on board. This was continued in the lab. The analysis of the egg samples (species identification, stage identification, size measurements) was done using image analysis (Figure 3.7). Eggs were staged according to the 6-stage scale (Table 3.1; Lockwood et al. 1977).

Table 3.1 Egg development stages.

Stage	Description
1A	From fertilisation until cleavage produces a cell bundle in which the individual cells are not visible
1B	Formation of the blastodisc, visible as a 'signet ring' and subsequent thickening a one pole.
2	From the first sign of the primitive streak until closure of the blastopore. By the end of this stage the embryo is half way round the circumference of the egg. However, the tail still tapers to end flattened against the yolk, in this stage.
3	Growth of the embryo from half way to three-quarters of the way around the circumference of the egg. The end of the tail has thickened, becoming bulbous in appearance.
4	Growth of the embryo from three-quarters to the full circumference of the egg.
5	Growth of the embryo until the tail is touching the nose or beyond.

If the sample contained hundreds of eggs, all eggs were separated from the remaining plankton. Then the eggs were sub-sampled using a 'Folsom' splitter (Griffiths et al. 1984). At least 100 eggs were identified and measured in each sample.

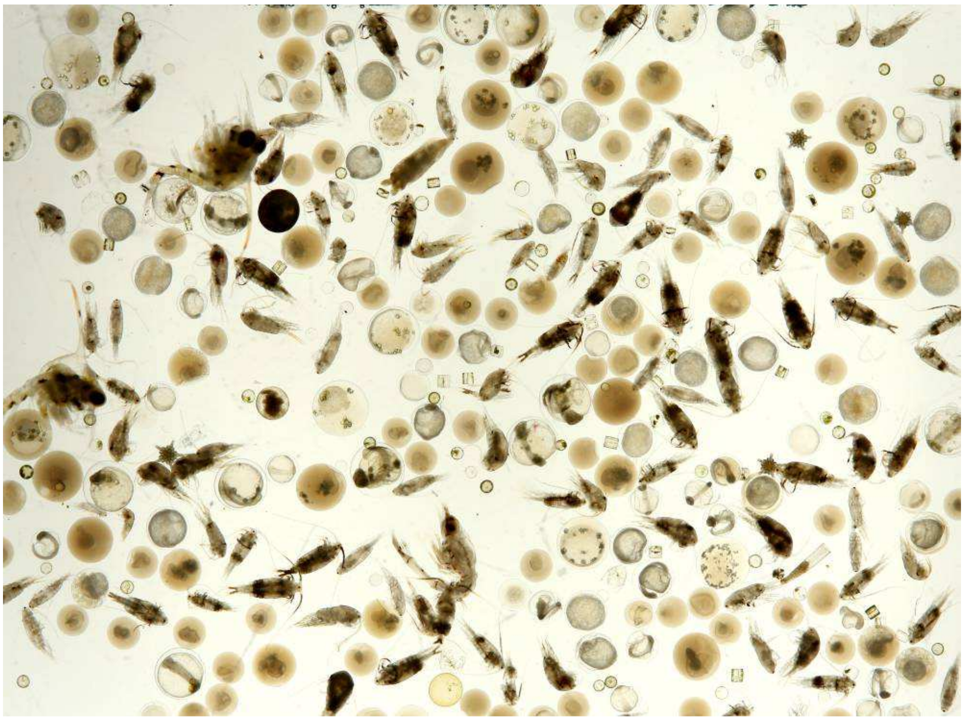

Figure 3.7. Eggs and other plankton in a sample.

As soon as possible upon return to the lab, the larvae samples were sent to the Polish Fisheries institute (Sea Fisheries Institute, ul. Kazimierza Królewicza 4-E, 71-550 Szczecin, Poland) for species identification and measurements.
Larvae development was classified following 4 development classes (Table 3.2; see also Ryland 1966, Doyle 1977, Al-Maghazachi & Gibson 1984).

Table 3.2 Larvae development stages.

Stage	Description
Yolk sac	Yolk sac still present
Non-yolk sac	Yolk sac absorbed but notochord still straight
Bent notochord	Postlarva with bent notochord, till the notochord is turned straight upward.
Metamorphosis	From the upturned notochord till metamorphosis is complete

For quality assurance purposes the sorting of the samples was checked. After each survey, 5 samples of each plankton-team (with different total amounts of plankton) were checked to see if larvae and eggs were properly sorted. If >5% of the total number of larvae or eggs was found during this check, then all samples of this team were checked and catch numbers were adjusted.

3.6 Calculations

The total number of larvae and eggs in the sample were counted and abundances were calculated using the below formulae (Smith & Richardson 1977). The numbers below a square metre of sea surface at each station were calculated as:

$$n / m^2 = \frac{larvae\ per\ sample\ (n) * bottom\ depth\ (m)}{volume\ filtered\ (m^3)}$$

The volume filtered is obtained from the formula:

$$Volume\ \ filtered = \frac{area\ of\ \ mouth\ opening\ (m^2)*efficiency\ \ factor*flowmeter\ revolutions}{flowmeter\ calibration\ constant}$$

For each development stage, the number of eggs and larvae per m^2 were plotted per station per month (Part B).

Temperature and salinity were plotted per month using the natural neighbour gridding method in Golden Software Surfer v8.01.

4 Results

4.1 Stations sampled

The first survey was carried out in April 2010, the last survey was conducted in March 2011. Figure 4.1 and Table 4.1 show the number of stations planned and sampled during all surveys. In April and May the original grid (Figure 3.3) was sampled. The remaining nine months the reduced grid (Figure 3.4) was sampled. In December and January the survey overlapped with the yearly international herring larvae survey (HELA) carried out by IMARES. During the HELA surveys sampling is conducted with the same gear and following the same sampling protocol, thus samples are comparable between the HELA and ichthyoplankton surveys. Overlapping stations were not sampled during the ichthyoplankton survey, but during the HELA survey, ensuring that no double sampling was carried out. All samples from the HELA survey were also sorted for eggs to gain extra information.

In April, October, February and March all planned stations were sampled (Figure 4.1 and Table 4.1). In May, June, July and January some technical problems occurred and a few stations had to be dropped (Bolle et al. 2010, Hoek et al. 2010a, Van Damme 2010, Hoek 2011). In August and September 'Ms Arca' was called to an oil spill and the survey was carried out on board the 'Ms Zirfaea'. The maximum speed of 'Ms Zirfaea' is lower compared to 'Ms Arca'. Because of this and problems with the A-frame 6 stations had to be dropped in August (Hoek et al. 2010b). In September extreme weather conditions were experienced with high wind force and wave heights (Hoek 2010a). Only 27 stations could be sampled in September. In October all planned stations were sampled. In November and December again bad weather conditions occurred and it was not possible to sample all the stations (Hoek 2010b, 2010c). However, in December the southern area was covered during the HELA survey.
At all stations a CTD profile was recorded (Table 4.1).

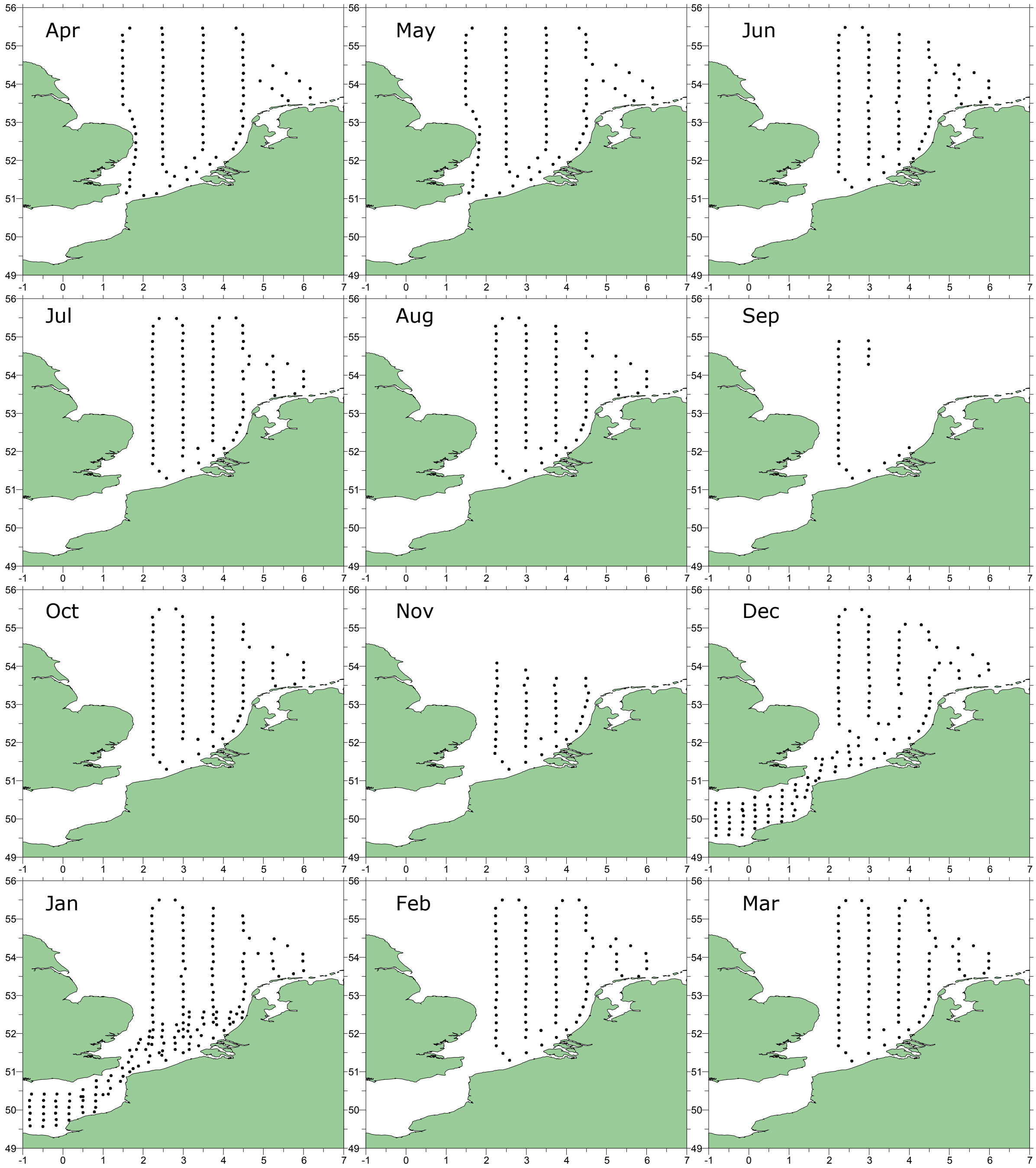

Figure 4.1. Stations sampled from April 2010 to March 2011, including the herring larvae surveys in December and January.

Table 4.1. Number of stations sampled during each survey.

Month	Stations planned	Stations sampled	CTD profiles	Plankton samples	Invalid hauls
April	96	96	96	95	1
May	96	95	95	95	0
June	91	88	88	88	0
July	91	90	90	90	0
August	91	85	85	85	0
September	91	27	27	27	0
October	91	91	91	91	0
November	91	47	47	47	0
December	91	73	73	72	1
Hela December	66	66	66	66	0
January	91	87	87	87	0
Hela January	89	89	89	89	0
February	91	91	91	91	0
March	91	91	91	90	1

4.2 Temperature and salinity

Highest numbers of eggs are usually found in the surface layers of the water column (Sundby 1983) although the highly mixed water column typical of the southern North Sea means that the eggs can be found at most depths in the column. Water temperature at the surface and 20m depth (Figure 4.2 & 4.3) increased from April to August and afterwards decreased again. The lowest water temperature was in February. In summer highest temperatures are found in the coastal waters, while in winter coldest temperatures were found along the coast. There is also an influx of slightly warmer water from the English Channel. During the summer months temperature at the surface are slightly higher compared to 20m depth. In winter temperatures are the same at the surface and at 20m depth.

Salinity does not change much over time and is comparable at the surface and at 20m depth (Figure 4.4 & 4.5). Along the coast salinity is slightly lower due to fresh water influence of the rivers Rhine and Meuse.

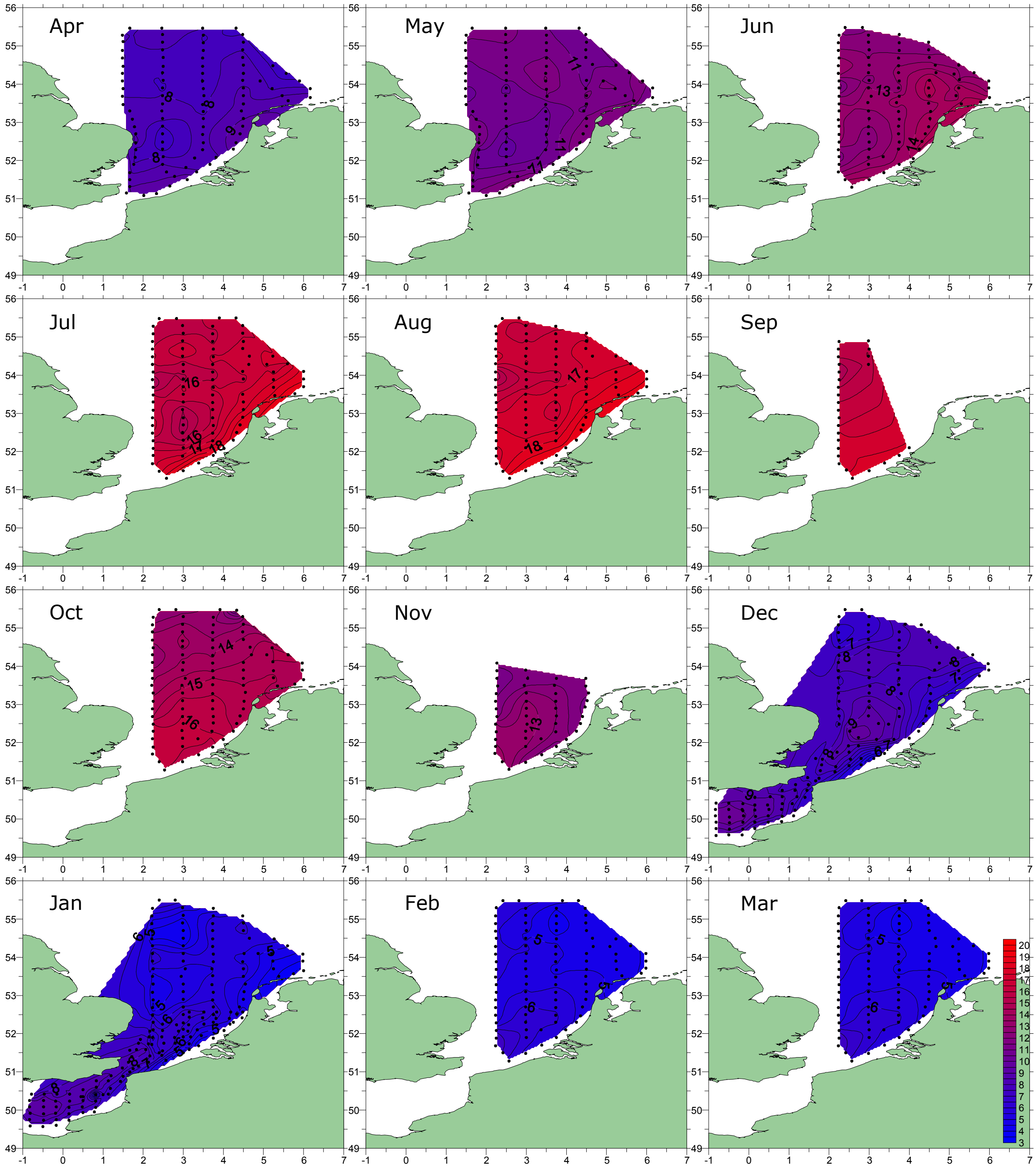

Figure 4.2. Sea surface temperature from April 2010 to March 2011.

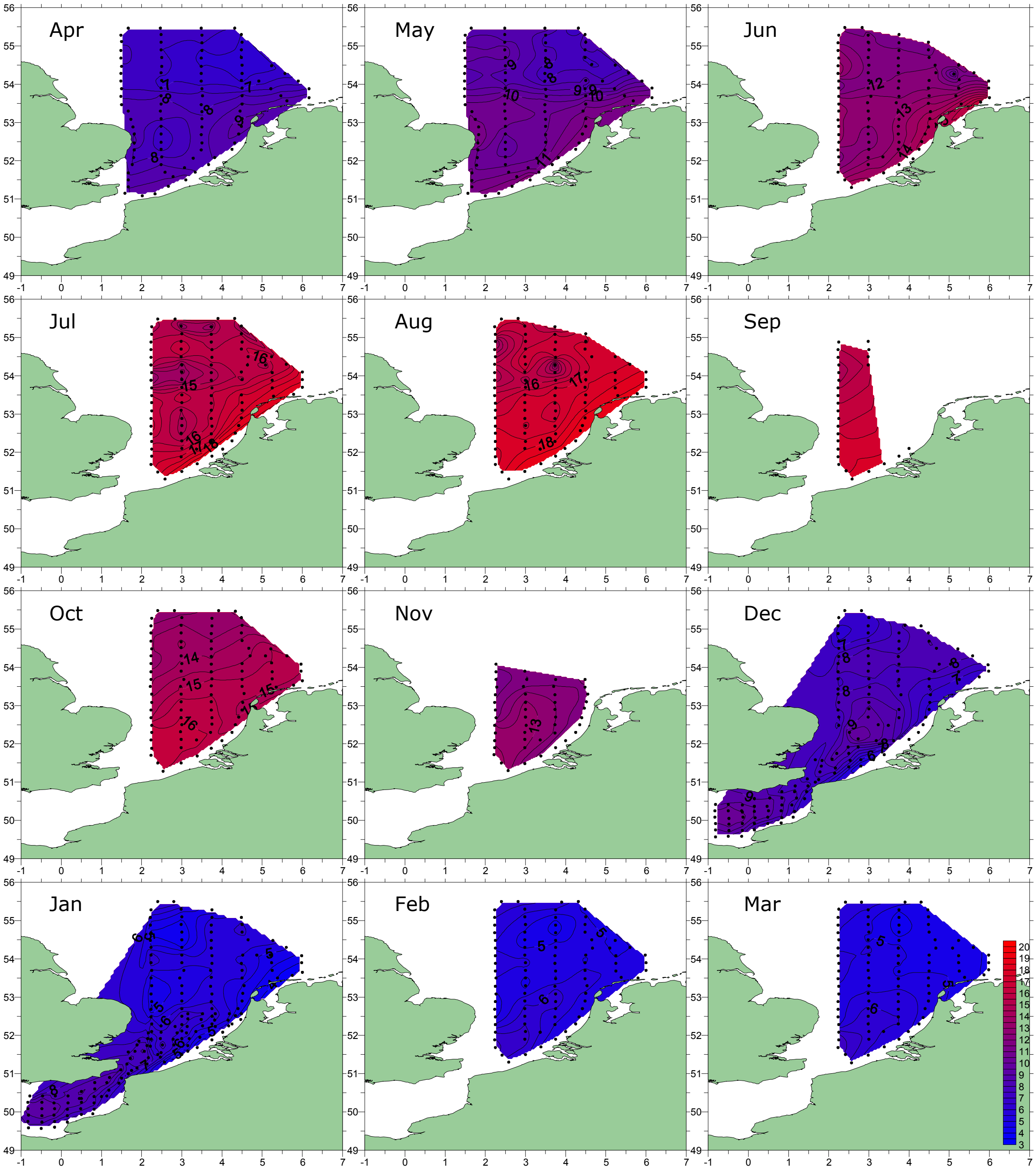

Figure 4.3. Sea temperature at 20m depth from April 2010 to March 2011.

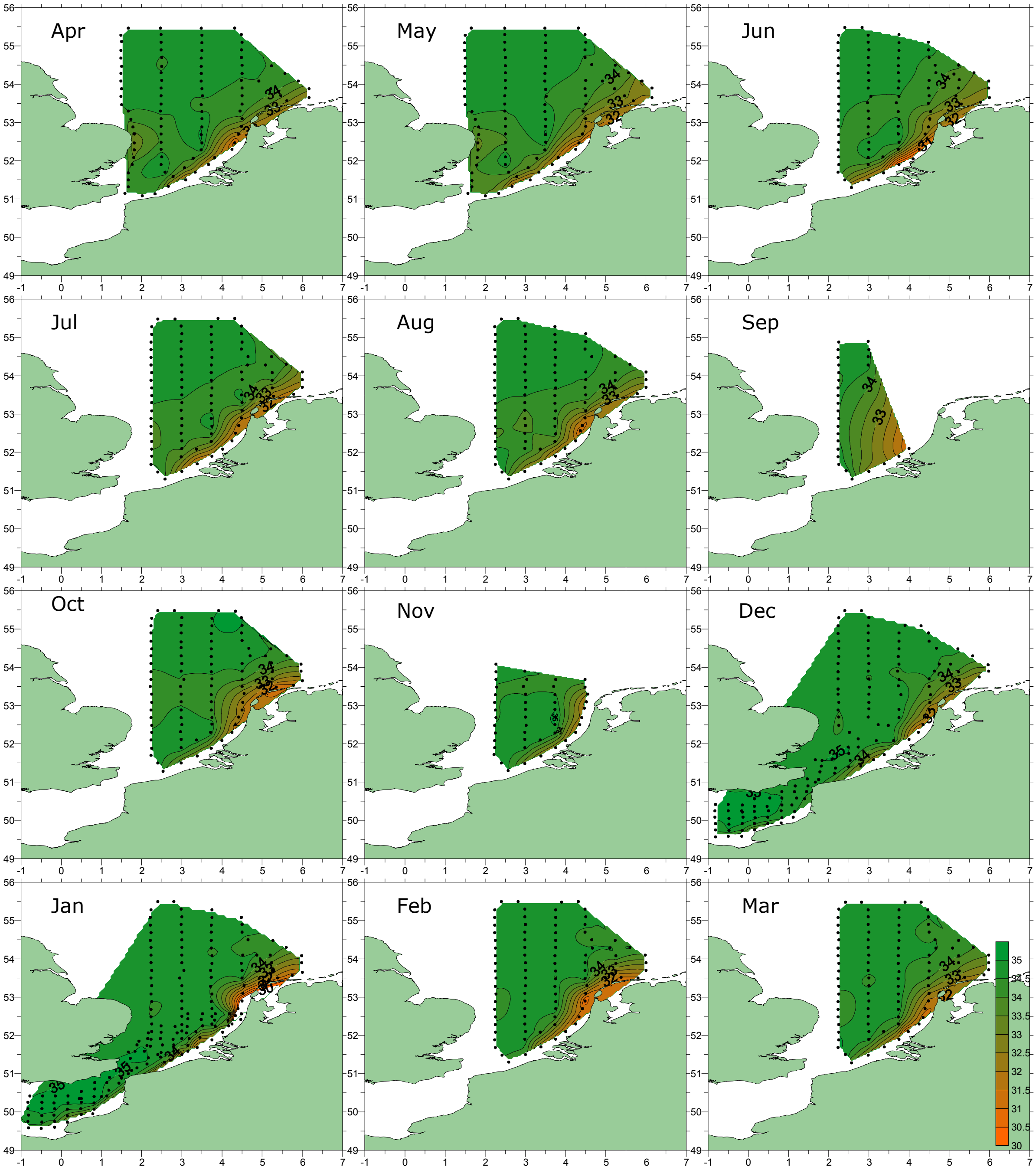

Figure 4.4. Sea surface salinity from April 2010 to March 2011.

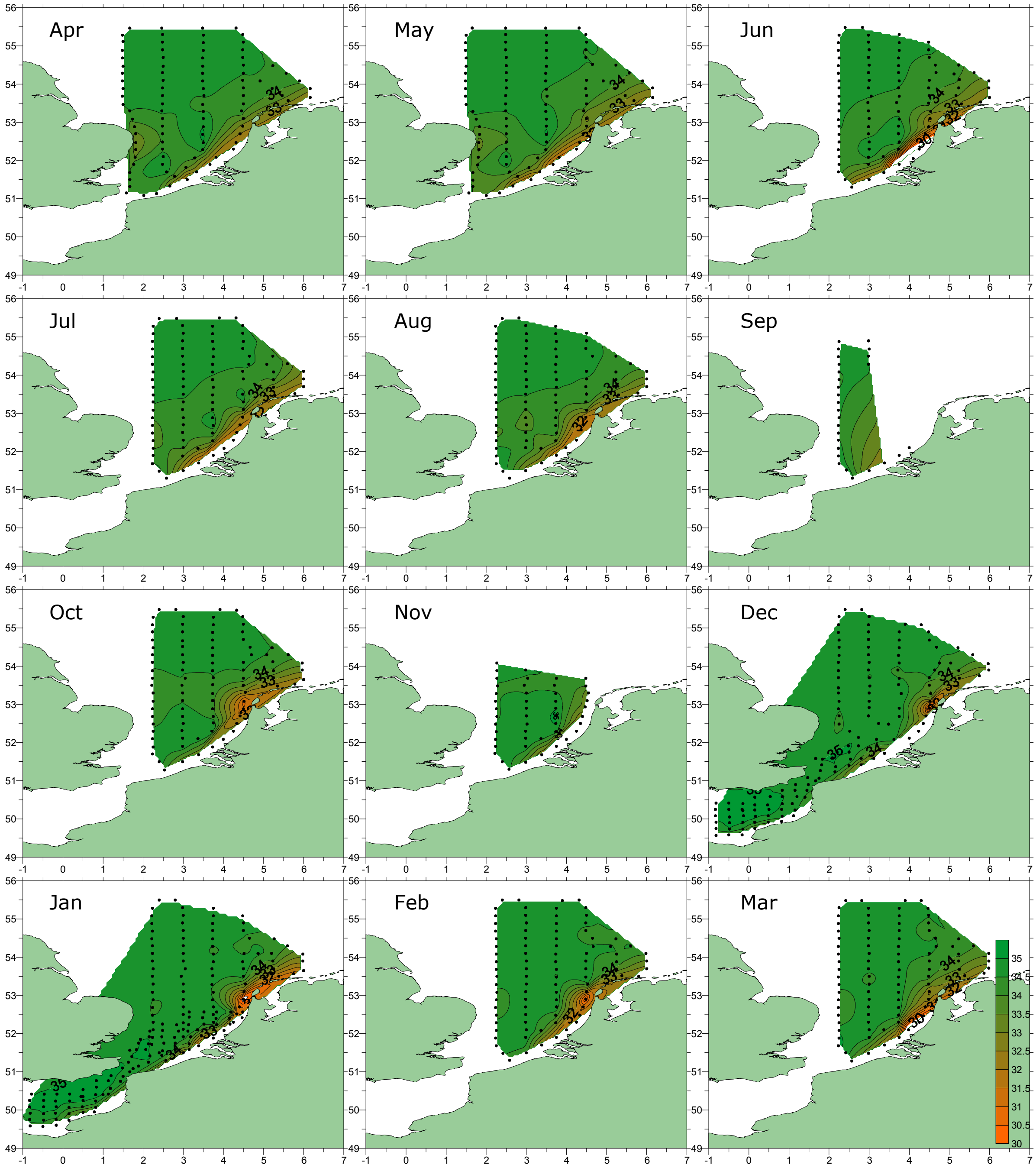

Figure 4.5. Salinity at 20m depth from April 2010 to March 2011.

4.3 Eggs and larvae

In total 219,235 eggs were sampled. Eggs were found in all months but the numbers and species differed between months (Figures 4.6 - 4.10 & Table 4.2). In April and May eggs were found at all stations at high numbers. In June and July eggs were found at all but one station, however the abundance of eggs was lower compared to April and May. By August although eggs were found at more than half of the stations, the abundances were lower. In August, stations close to the northern and northwest Dutch coast did not contain eggs. But eggs were found at the stations in the southwest, northwest and northeast of the NCP. In September only limited number of stations were sampled but a few eggs were found in the northwest of the sampling area. In October and November eggs were found at few stations in very low numbers. In December the number of stations with eggs and the numbers of eggs increased again. In January, February and March eggs were found in high numbers at almost all stations.

Table 4.2. Number of stations with fish eggs in the total sampling area and the NCP.

Month	**Stations with eggs**	**% of total stations sampled**	**% of stations sampled on NCP**
April	95	99	100
May	95	100	100
June	88	100	100
July	88	98	97
August	59	69	67
September	6*	22	50
October	9	10	6
November	4	9	6
December	83	54	58
January	160	89	98
February	82	90	100
March	90	99	100

In Figures 4.6 to 4.10 distributions of eggs are presented by development stage (see Table 3.1 for the description of the different stages). Stage 1 eggs are present in high numbers (Figure 4.6). Stage 1B is a development stage with a short duration, hence only few eggs in this stage were found in the samples. Due to natural mortality the number of eggs declines in the later development stages (Figures 4.8 - 4.10).

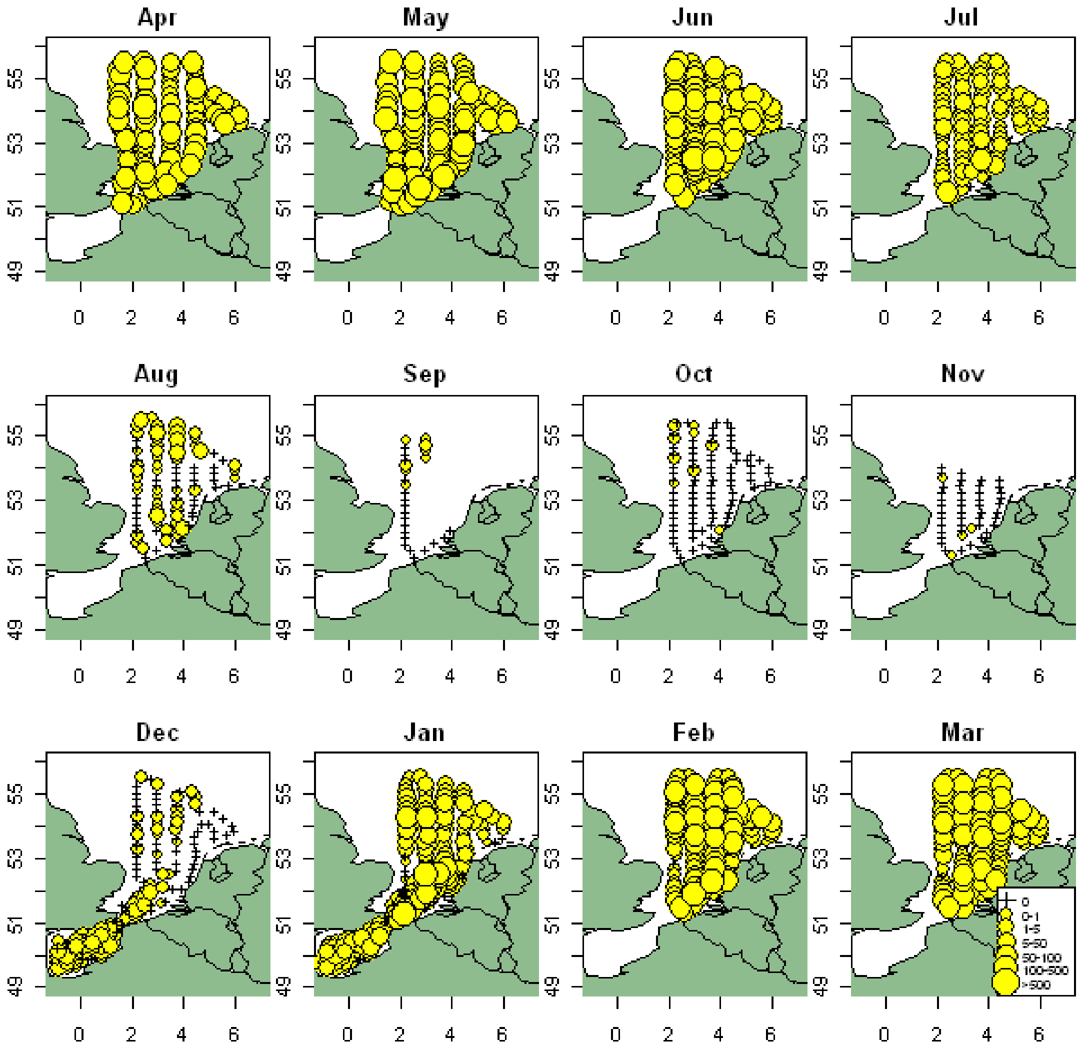

Figure 4.6. Distribution of all stage 1 eggs (combined 1A and 1B) for all species (numbers per m²).

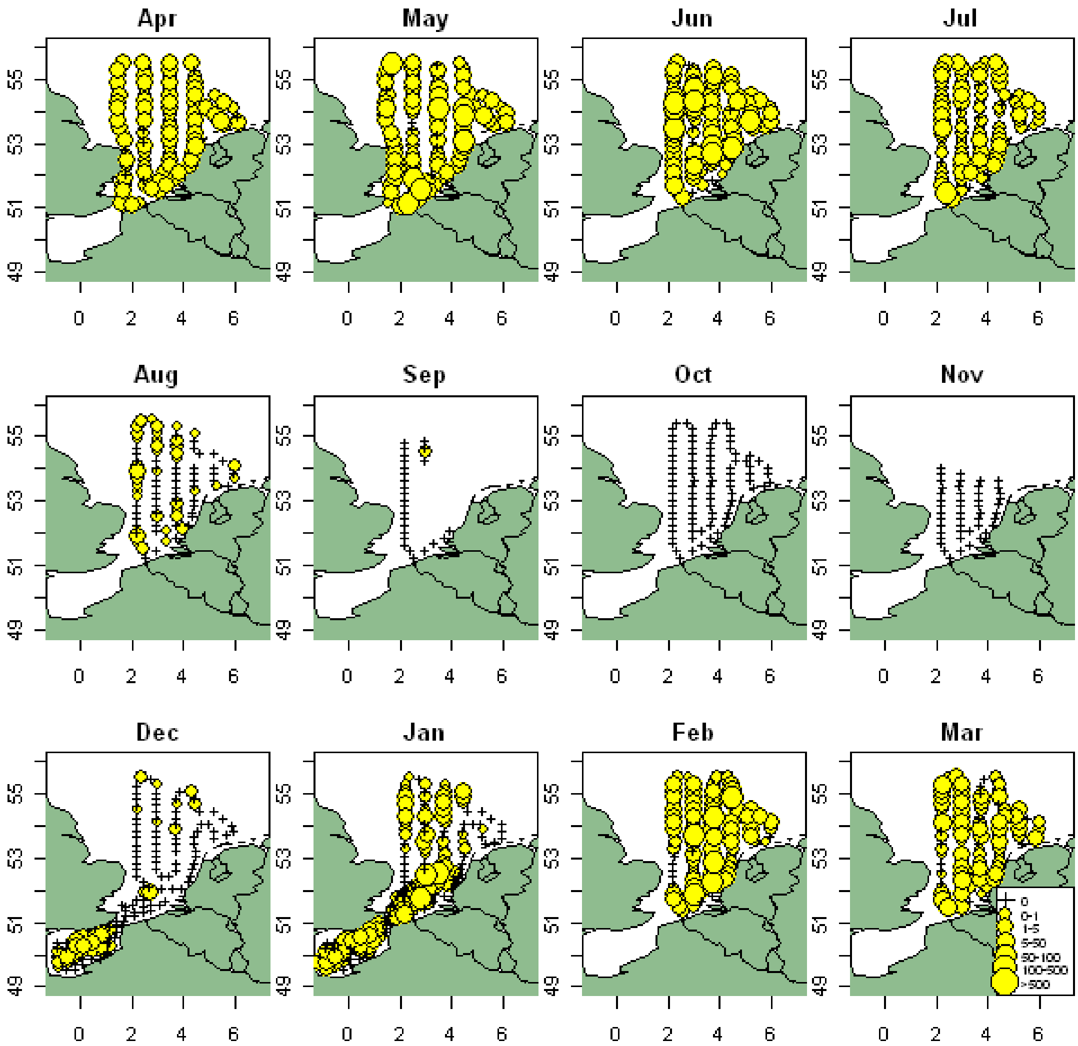

Figure 4.7. Distribution of all stage 2 eggs combined for all species (numbers per m^2).

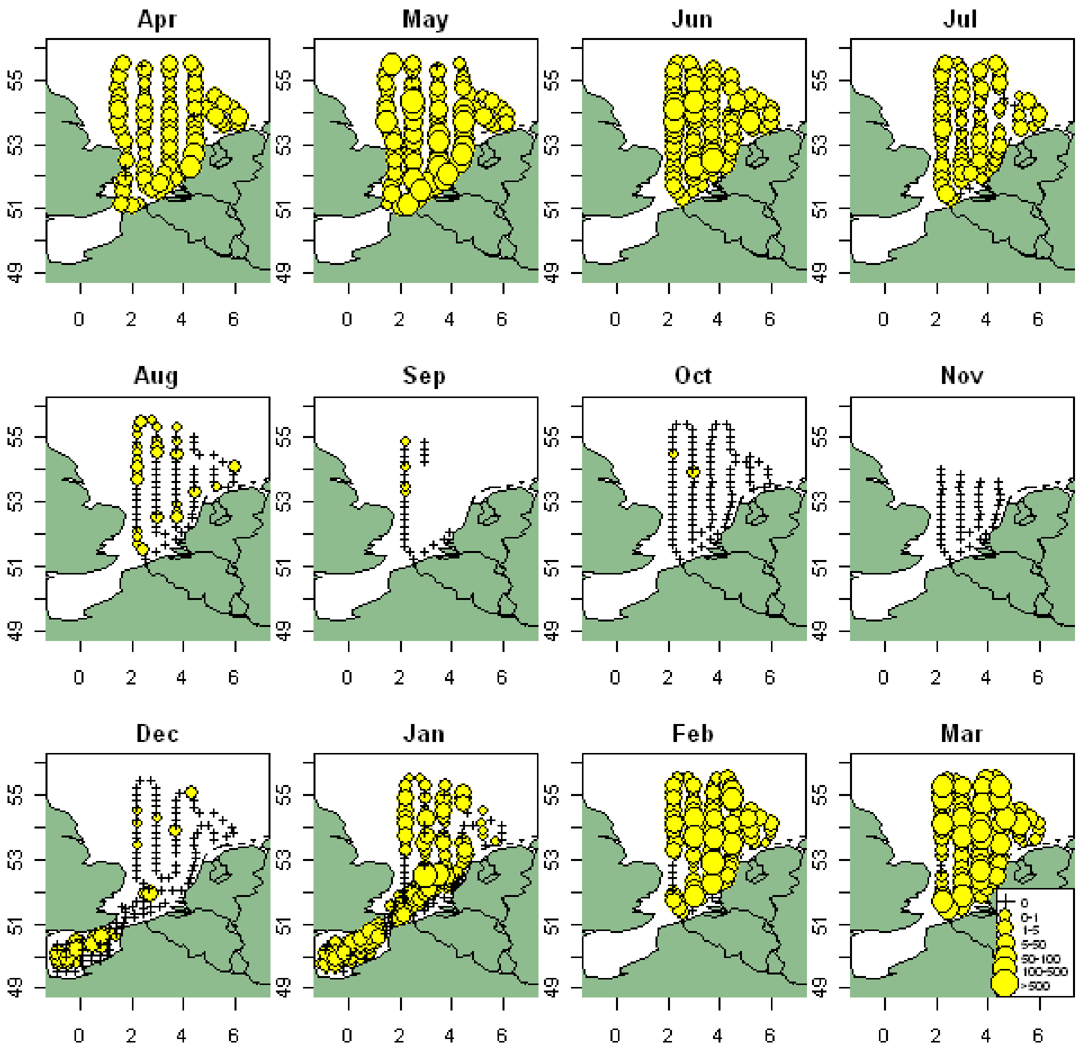

Figure 4.8. Distribution of all stage 3 eggs combined for all species (numbers per m^2).

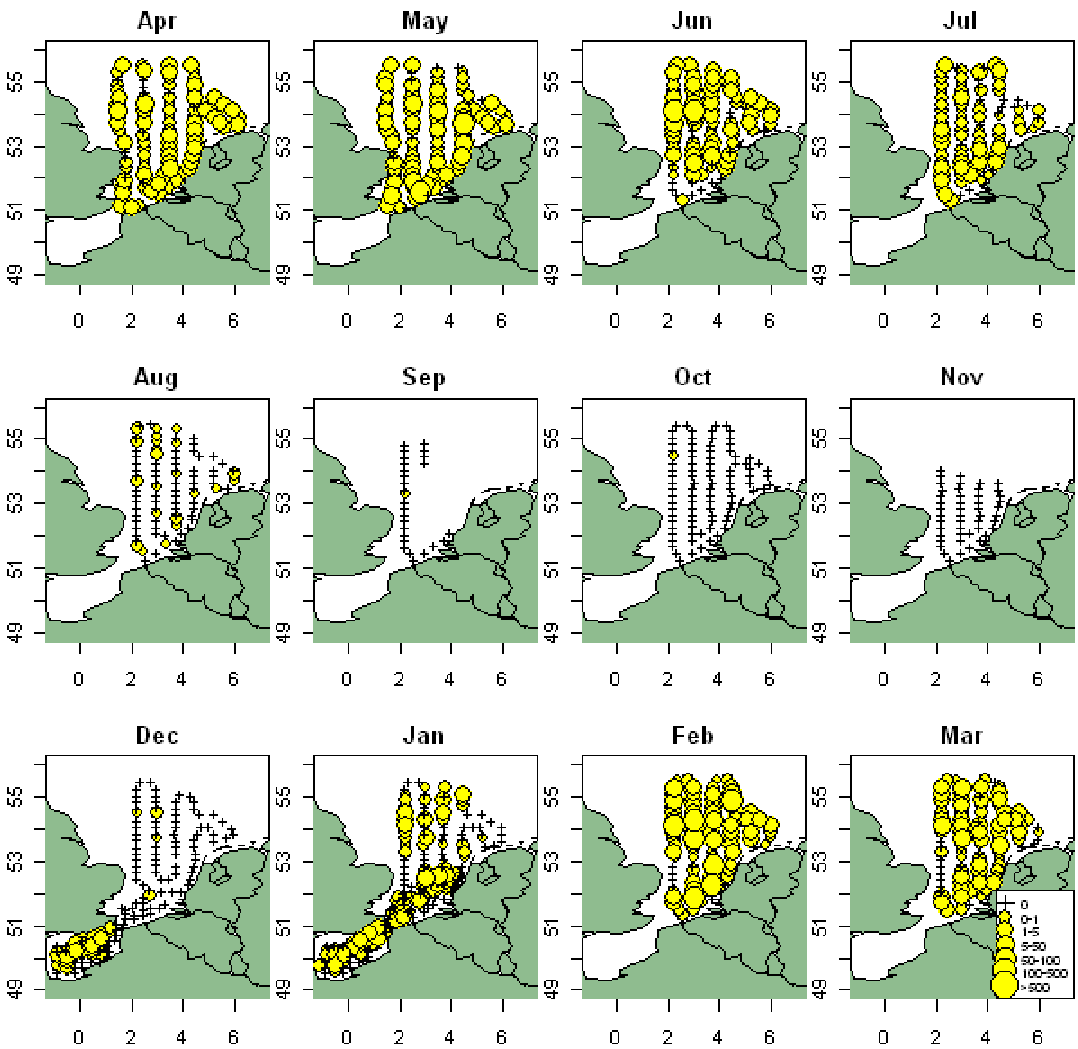

Figure 4.9. Distribution of all stage 4 eggs combined for all species (numbers per m^2).

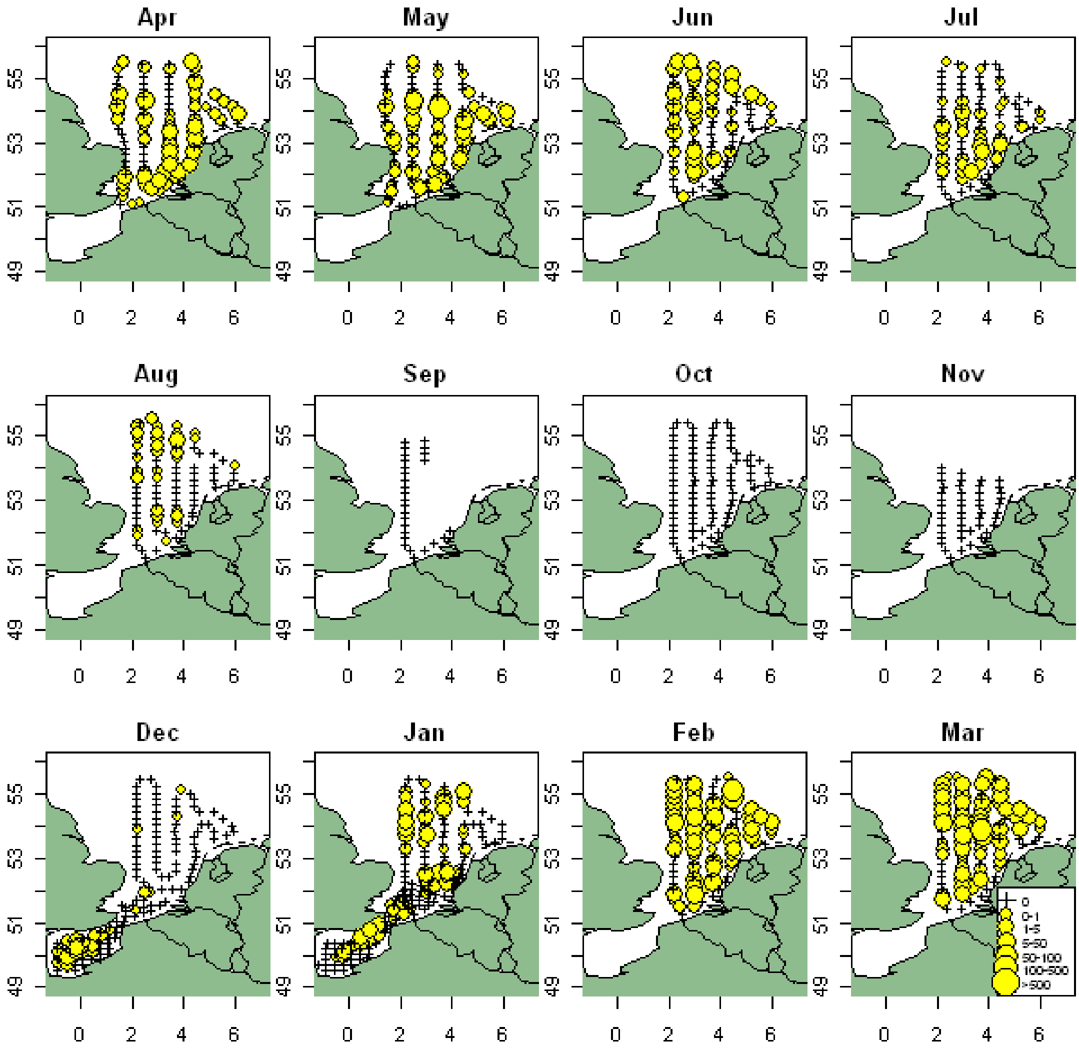

Figure 4.10. Distribution of all stage 5 eggs combined for all species (numbers per m^2).

In total 108,530 larvae were sampled. Only 8 larvae were so highly damaged that they could not be identified to species or groups. Larvae were found in all months, but numbers and species varied by month. Highest numbers of fish larvae were found in December and January in the English Channel (Figures 4.11 – 4.14). This is when herring dominated the samples. The abundance of larvae increased from April until June and thereafter gradually declined until November (Figures 4.11 – 4.14 and Table 4.3). Despite this pattern (which is similar to the eggs if you discount the herring) larvae were still found at almost all stations from May until September. In October and November larvae were found at half of all the stations both in the whole area and on the NCP. In December larvae were found at half of the stations in the whole sampling area and still on a quarter of all stations on the NCP. In February and March larvae were again ubiquitous in both the whole area and the NCP.

Table 4.3. Number of stations with fish larvae in the total sampling area and the NCP.

Month	**Stations with larvae**	**% of total stations sampled**	**% of stations sampled on NCP**
April	84	88	90
May	86	91	84
June	88	100	100
July	89	99	98
August	85	100	100
September	27	100	88
October	54	59	53
November	25	53	47
December	88	58	25
January	126	70	61
February	75	82	83
March	84	92	94

The number of larvae found varied per development stage. Most larvae caught were in the non-yolk sac and bent notochord stage. It should be noted that in some species like the clupeids the yolk sac is easily damaged during sampling and it might be that stage yolk sac larvae are thus misclassified.

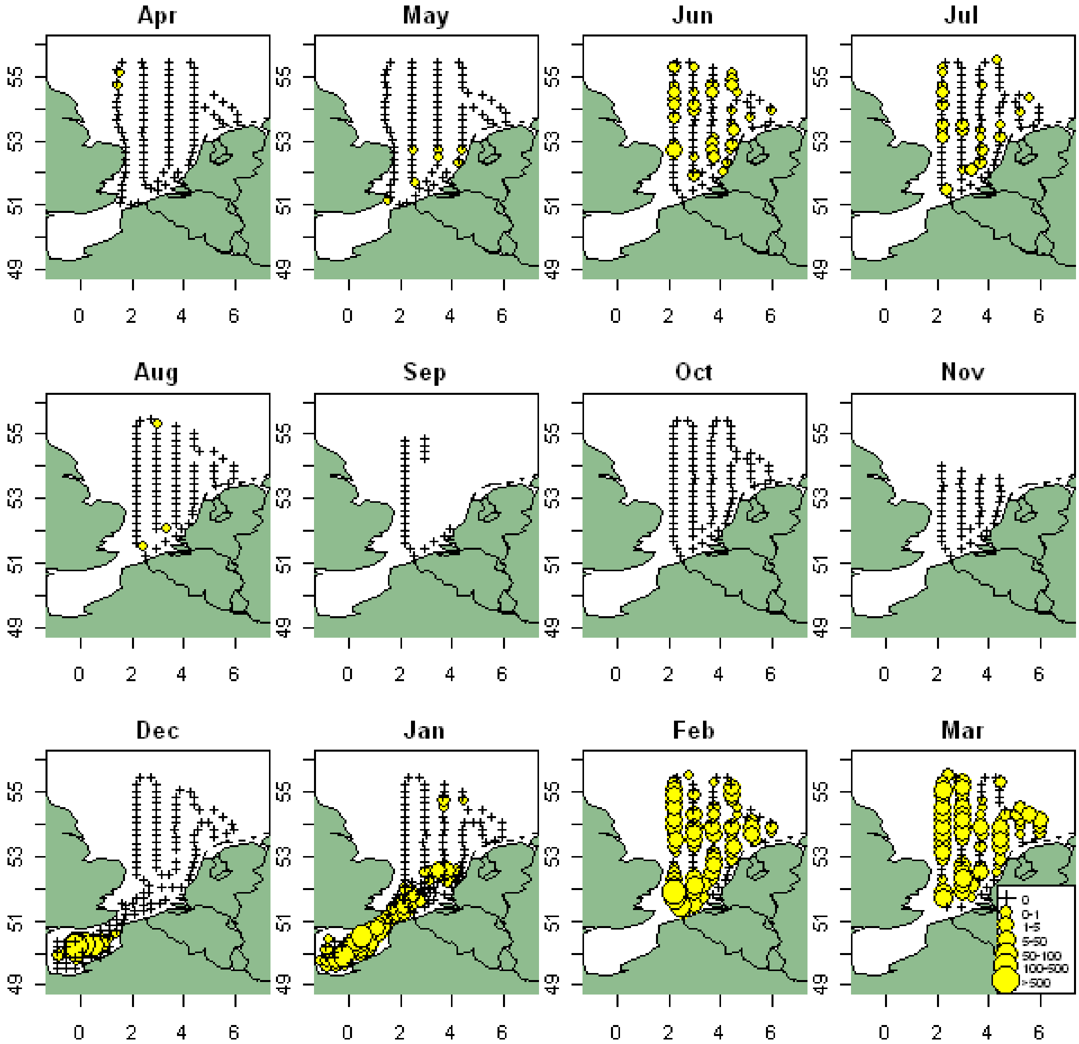

Figure 4.11. Distribution of all yolk sac larvae combined for all species (numbers per m^2).

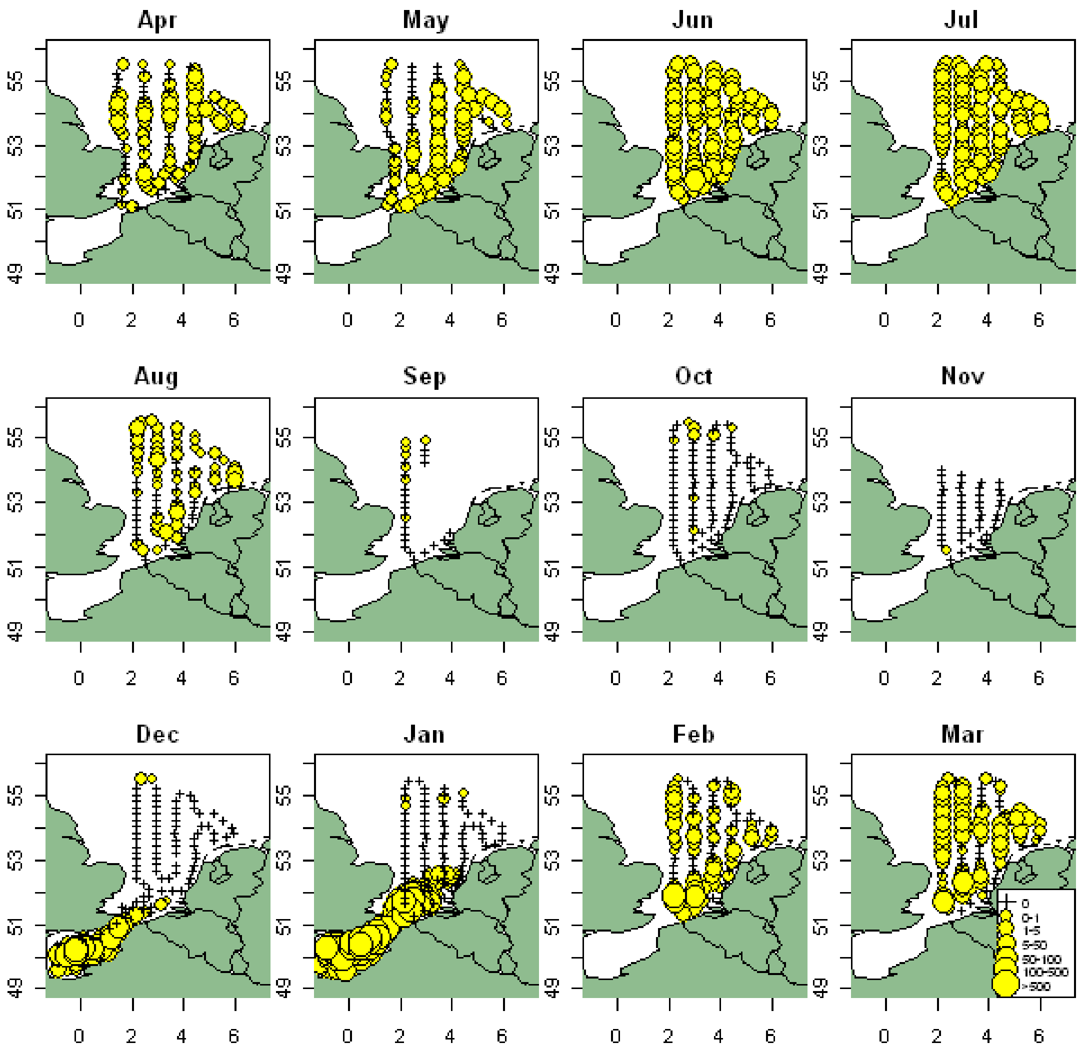

Figure 4.12. Distribution of all non-yolk sac larvae combined for all species (numbers per m^2).

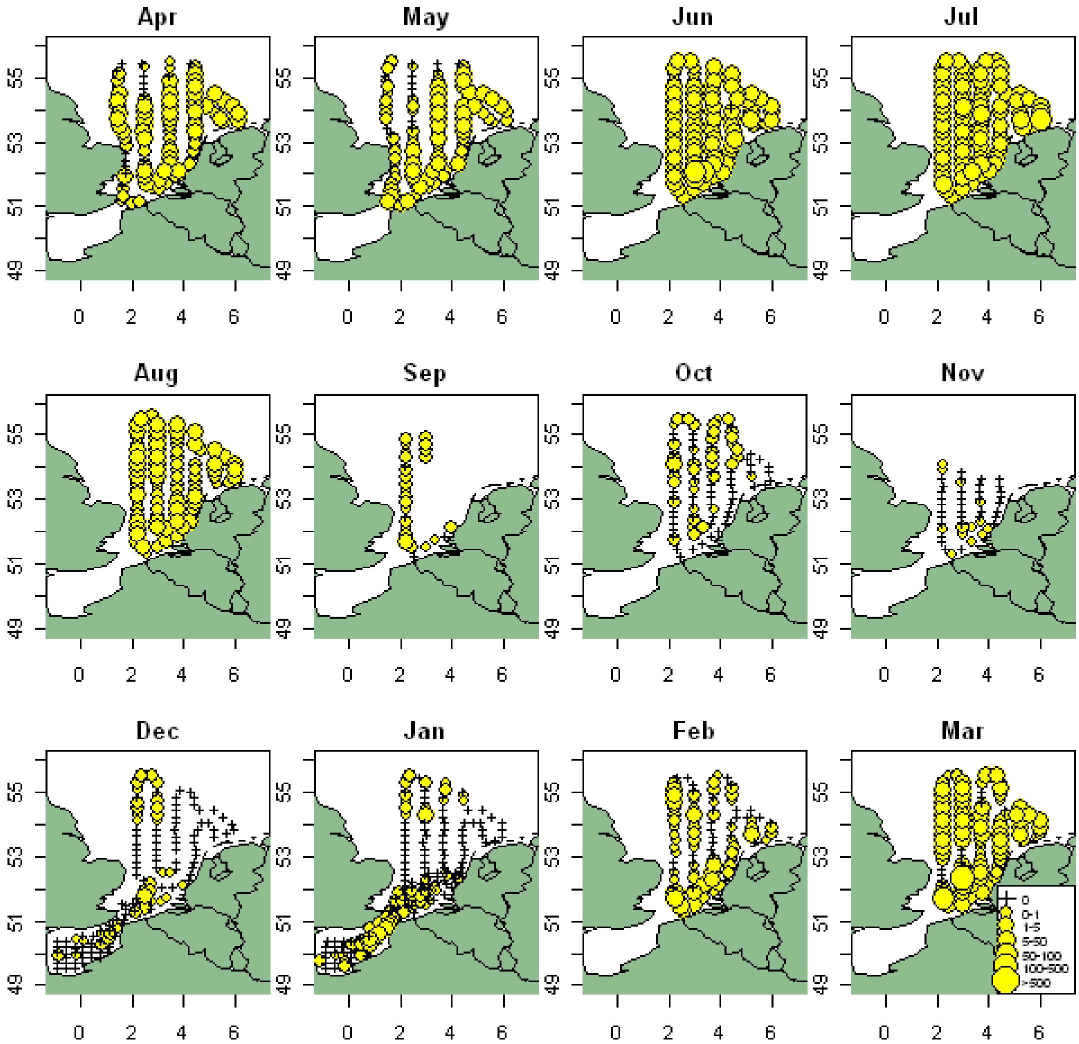

Figure 4.13. Distribution of all bent notochord stage larvae combined for all species (numbers per m^2).

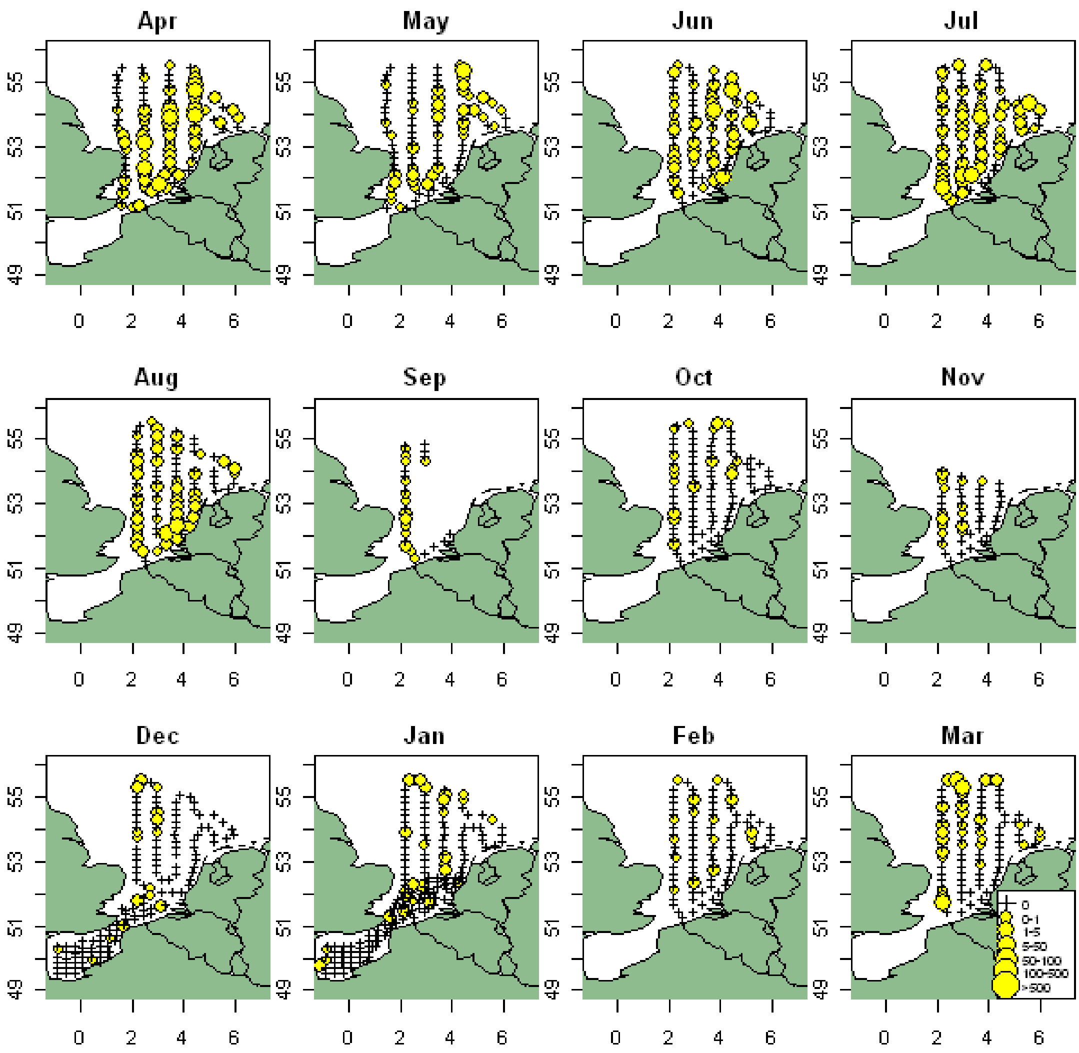

Figure 4.14. Distribution of all metamorphosing larvae combined for all species (numbers per m²).

4.4 Species

Eggs were visually identified to species (Ehrenbaum 1909, Russel 1976, Munk & Nielsen 2005). Eggs were photographed using a Canon 40D SLR camera with an EF-s 60 mm lens. Eggs were measured, identified and staged from the pictures using the fish eggs ObjctJ macro (http://simon.bio.uva.nl/objectj/examples/CindysFisheggs/Manual-Cindy-5.htm) in the image analysis program ImageJ (http://rsbweb.nih.gov/ij/index.html). There is an overlap in sizes and characteristics between some species. Hence, not all eggs could be identified to species level but were assigned to a group. Table 4.4 shows the species and species groups that were identified. In total 35 different egg taxon were found over the year. The number and spatial and temporal distribution varied by species.

Table 4.4. Egg species found in all samples. (Actual species is the name assigned to the species or group; species 1 is the most likely species; possible other species are the species which overlap with species 1.)

Actual species	Species 1	Possible other species
Sprattus sprattus	Sprattus sprattus	
Sardina pilchardus	Sardina pilchardus	
Engraulis encrasicolus	Engraulis encrasicolus	
Merluccius merluccius	Merluccius merluccius	
Cod like	Cod like	Microstomus kitt, Glyptocephalus cynoglossus, Platichthys flesus, Trisopterus minutus
Trisopterus like	Merlangius merlangus	Trisopterus luscus, Platichthys flesus, Trisopterus esmarkii, Microstomus kitt, Glyptocephalus cynoglossus
Trisopterus luscus	Trisopterus luscus	
Merlangius merlangus	Merlangius merlangus	
Raniceps raninus	Raniceps raninus	
Rocklings	Rocklings	
Capros aper	Capros aper	
Dicentrarchus labrax	Dicentrarchus labrax	
Trachurus trachurus	Trachurus trachurus	
Ctenolabrus rupestris	Ctenolabrus rupestris	
Echiichthys vipera	Echiichthys vipera	
Trachinus draco	Trachinus draco	
Callionymus spp.	Callionymus spp.	
Callionymus lyra	Callionymus lyra	
Triglidaelike	Lepidorhombus whiffiagonis	Scophthalmus maximus, Trachinus draco, Zeugopterus punctatus, Dicentrarchus labrax, Scophthalmus rhombus
Triglidae	Triglidae	
Scophthalmus maximus	Scophthalmus maximus	
Scophthalmus rhombus	Scophthalmus rhombus	
Zeugopterus punctatus	Zeugopterus punctatus	
Phrynorhombus norvegicus	Phrynorhombus norvegicus	
Lepidorhombus whiffiagonis	Lepidorhombus whiffiagonis	
Arnoglossus-like	Arnoglossus laterna	Phrynorhombus norvegicus, Arnoglossus thori, Rocklings, Raniceps raninus
Arnoglossus laterna	Arnoglossus laterna	
Hippoglossoides platessoides	Hippoglossoides platessoides	
Dab like	Limanda limanda	Platichthys flesus, Ctenolabrus

Actual species	Species 1	Possible other species
		rupestris, Trisopterus luscus, Trisopterus minutus
Limanda limanda	Limanda limanda	
Pleuronectes platessa	Pleuronectes platessa	
Microstomus kitt	Microstomus kitt	
Platichthys flesus	Platichthys flesus	
Solea solea	Solea solea	
Buglossidium luteum	Buglossidium luteum	

Larvae were also visually identified to species with a dissecting microscope (Ehrenbaum 1909, Russel 1976, Munk & Nielsen 2005). More characteristics are available for visual identification compared to eggs. Where eggs had to be assigned to groups, e.g. cod like, these larvae could be identified to species. Also some of these larvae hatch from non-pelagic eggs, e.g. herring *Clupea harengus*, and larvae were caught, but the eggs were therefore not caught in the plankton hauls. Some larvae were damaged and could only be identified to family. In total 74 different taxon were identified in all the plankton samples. The spatial and temporal abundance of larvae varied by species.

Table 4.5. Larvae species found in all samples.

Species
Clupeidae
Clupea harengus
Sprattus sprattus
Sardina pilchardus
Engraulis encrasicolus
Belone belone
Syngnathus rostellatus
Nerophis ophidion
Merluccius merluccius
Gadidae
Gadus morhua
Trisopterus luscus
Merlangius merlangus
Enchelyopus cimbrius
Ciliata mustela
Ciliata septentrionalis
Dicentrachus labrax
Trachurus trachurus
Mullus surmuletus
Ctenolabrus rupestris
Crenilabrus melops
Ammodytidae
Gymnammodytes semisquamatus
Hyperoplus lanceolatus
Ammodytes tobianus
Ammodytes marinus
Echiichthys vipera
Trachinus draco
Scomber scombrus
Gobiidae

Species
Gobius niger
Gobiusculus flavescens
Pomatoschistus spp
Pomatoschistus minutus
Pomatoschistus microps
Pomatoschistus pictus
Aphia minuta
Crystallogobius linearis
Callionymidae
Callionymus spp
Callionymus lyra
Callionymus maculatus
Callionymus reticulatus
Blennius ocellaris
Lipophrys pholis
Pholis gunnellus
Mugil spp
Triglidae
Eutrigla gurnardus
Trigla lucerna
Myoxocephalus scorpius
Taurulus bubalis
Micrenophrys lilljeborgi
Agonus cataphractus
Liparidae
Liparis liparis
Liparis montagui
Bothidae
Scophthalmidae
Scophthalmus maximus
Scophthalmus rhombus
Phrynorhombus norvegicus
Arnoglossus laterna
Pleuronectidae
Hippoglossoides platessoides
Limanda limanda
Pleuronectes platessa
Microstomus kitt
Glyptocephalus cynoglossus
Platichthys flesus
Soleidae
Solea solea
Buglossidium luteum

Below is the description of spatial and temporal distributions of each species, the figure numbers after the species name refer to the distribution maps that can be found in Part B of this report. Spawning time and development differs among species and eggs and larvae temporal distribution changes (Table 4.6 & 4.7). Most abundant species found in the southern North Sea are also found as eggs and/or larvae on the NCP (Table 4.6 & 4.7).

Table 4.6. Temporal occurrence of eggs and larvae by species in the sampled area. (Red: eggs; Black diagonal lines: larvae)

Species	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar
Clupea harengus	L	L					L	L	L	L	L	L
Sprattus sprattus	E+L	E+L	E+L	E+L	L	L	L	L	L	E+L	E+L	E+L
Sardina plichardus	E+L	E+L	E+L	E+L	E+L	L	L	L	L	L		
Engraulis encrasicolus			E	E+L	L							
Merluccius merluccius	E	E	E	E	L		L					
Cod like	E	E	E	E	E				E	E+L	E+L	E
Gadus morhua	L	L										L
Trisopterus like	E	E	E					E	E	E		
Trisopterus luscus		L	E+L	L					L	L	L	L
Merlangius merlangus	L	L	E+L	E+L	L		E+L		L	L	L	L
Raniceps raninus			E									
Rocklings	E	E	E	E						E	E	
Enchelyopus cimbrius		L	L	L	L		L					L
Ciliata mustela		L	L									
Dicentrachus labrax	E	E	L									
Trachurus trachurus	E	E	E+L	E+L	E+L	L						
Syngnathus rostellatus			L	L	L	L	L	L	L	L	L	
Gymnammodytes semisquamatus			L	L	L	L						
Hyperoplus lanceolatus	L	L	L	L	L	L	L				L	L
Ammodytes tobianus				L			L		L	L		
Ammodytes marinus	L	L	L				L	L	L	L	L	L
Echiichthys vipera	E	E	E+L	E+L	E+L	E+L			E	E	E	
Trachinus draco		E	E	E	L							
Scomber scombrus			L	L	L							
Gobiusculus flavescens			L	L								
Gobiidae	L	L	L	L	L		L	L				
Gobius niger				L	L	L						
Pomatoschistus spp.		L	L	L	L	L			L	L		
Pomatoschistus		L	L	L	L	L		L	L	L	L	

Species	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar
minutus												
Pomatoschistus microps												
Pomatoschistus pictus												
Aphia minuta												
Crystallogobius linearis												
Callionymidae												
Callionymus lyra												
Callionymus maculatus												
Pholis gunnellus												
Triglidae like												
Triglidae												
Eutrigla gurnardus												
Trigla lucerna												
Myoxocephalus scorpius												
Taurulus bubalis												
Liparis liparis												
Liparis montagui												
Scophthalmus maximus												
Scophthalmus rhombus												
Zeugopterus punctatus												
Phrynorhombus norvegicus												
Lepidorhombus whiffiagonis												
Arnoglossus like												
Arnoglossus laterna												
Pleuronectidae												
Hippoglossoides platessoides												
Dab like												
Limanda limanda												
Pleuronectes platessa												
Microstomus kitt												
Glyptocephalus cynoglossus												
Platichthys flesus												
Soleidae												

Species	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar
Solea solea												
Buglossidum luteum												

Table 4.7. Temporal occurrence of eggs and larvae by species on the NCP. (Red: eggs; Black diagonal lines: larvae)

Species	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar
Clupea harengus	larvae	larvae							larvae	larvae	larvae	larvae
Sprattus sprattus	eggs, larvae	eggs, larvae	eggs, larvae	eggs, larvae	larvae				larvae	eggs, larvae	eggs, larvae	eggs, larvae
Sardina plichardus	eggs, larvae	eggs	eggs, larvae	eggs, larvae	eggs, larvae	larvae	larvae	larvae	larvae	larvae		
Engraulis encrasicolus			eggs	eggs, larvae	larvae							
Merluccius merluccius	eggs	eggs	eggs	eggs			larvae					
Cod like	eggs	eggs	eggs	eggs	eggs				eggs	eggs	eggs	eggs
Gadus morhua	larvae	larvae								larvae	larvae	larvae
Trisopterus like	eggs	eggs	eggs					eggs	eggs			
Trisopterus luscus			eggs, larvae	larvae						larvae		
Merlangius merlangus	larvae	larvae	eggs, larvae	eggs, larvae			eggs			larvae	larvae	larvae
Raniceps raninus												
Rocklings	eggs	eggs	eggs	eggs						eggs	eggs	
Enchelyopus cimbrius		larvae	larvae	larvae								
Ciliata mustela		larvae	larvae									
Dicentrachus labrax	eggs	eggs	larvae									
Trachurus trachurus	eggs	eggs	eggs, larvae	eggs, larvae	eggs, larvae	larvae						
Syngnathus rostellatus			larvae	larvae	larvae	larvae	larvae	larvae	larvae	larvae	larvae	
Gymnammodytes semisquamatus			larvae	larvae	larvae							
Hyperoplus lanceolatus	larvae	larvae	larvae	larvae	larvae		larvae				larvae	larvae
Ammodytes tobianus				larvae						larvae		
Ammodytes marinus	larvae	larvae	larvae				larvae	larvae	larvae	larvae	larvae	larvae
Echiichthys vipera	eggs	eggs	eggs	eggs, larvae	eggs, larvae	eggs, larvae						
Trachinus draco		eggs	eggs									
Scomber scombrus			larvae	larvae	larvae							
Gobiusculus flavescens			larvae	larvae								
Gobiidae			larvae	larvae	larvae		larvae	larvae				
Gobius niger												
Pomatoschistus spp.		larvae	larvae	larvae	larvae				larvae	larvae		
Pomatoschistus		larvae	larvae	larvae	larvae	larvae		larvae	larvae	larvae	larvae	

Species	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar
minutus												
Pomatoschistus microps												
Pomatoschistus pictus												
Aphia minuta												
Crystallogobius linearis												
Callionymidae												
Callionymus lyra												
Callionymus maculatus												
Pholis gunnellus												
Triglidae like												
Triglidae												
Eutrigla gurnardus												
Trigla lucerna												
Myoxocephalus scorpius												
Taurulus bubalis												
Liparis liparis												
Liparis montagui												
Scophthalmus maximus												
Scophthalmus rhombus												
Zeugopterus punctatus												
Phrynorhombus norvegicus												
Lepidorhombus whiffiagonis												
Arnoglossus like												
Arnoglossus laterna												
Pleuronectidae												
Hippoglossoides platessoides												
Dab like												
Limanda limanda												
Pleuronectes platessa												
Microstomus kitt												
Glyptocephalus cynoglossus												
Platichthys flesus												
Soleidae												

Species	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar
Solea solea												
Buglossidum luteum												

Clupeidae
23 clupeidae larvae were damaged and could not be identified to species level.

Herring *Clupea harengus* (Fig. 1)
Herring eggs are spawned on gravel on the sea bottom and are therefore not found in plankton samples. Herring larvae were found in high quantities from December to April. Main spawning areas are in the eastern English Channel. Hatching of larvae commences in December. In December and January yolk sac larvae are found close to the spawning grounds. Non-yolk sac larvae are found in the English Channel in December and January and move with the water stream to the coastal areas in the eastern southern North Sea. Non-yolk sac and bent notochord stage herring larvae are found in the coastal areas from January to April. Metamorphosing larvae have probably already moved to the nursery areas on the coast and Wadden Sea which were not sampled.
In December, January and February bent notochord larvae were found on and below the Dogger Bank. These larvae originate from the autumn spawning grounds along the English coast.

Sprat *Sprattus sprattus* (Fig. 2)
Sprat eggs were found from January until July. Spawning starts in January in the English Channel. In February spawning starts in the south of the southern North Sea and moves north. In April, May and June spawning occurs throughout the southern North Sea, with highest numbers of stage 1A eggs found in April and May. Later egg development stages are found throughout the southern North Sea from March until July. Larvae are found in the southern part of the Southern North Sea in March and April. In May, June and July larvae are found throughout the southern North Sea. In August larvae are still found in the northwest part on the Doggerbank.

Pilchard *Sardina pilchardus* (Fig. 3)
Pilchard eggs in all stages are found along the Dutch and Belgium coast from May until July. From June to August non-yolk sac and bent notochord larvae are also found in the coastal areas. From August to December bent notochord larvae are also found in the north west, on the Doggerbank, and on one station in front of the Voordelta and Belgium.

Anchovy *Engraulis encrasicolus* (Fig. 4)
Anchovy eggs were found along the Dutch and Belgium coast in June and July. Anchovy larvae in different development stages were also found along the coast in July and August.

Garfish *Belone belone*
Only one garfish larva was found off the English coast at Lowestoft.

Nillson's pipefish *Syngnathus rostellatus* (Fig. 5)
Nillson's pipefish larvae were found in low numbers from June to February along the Wadden Sea islands and in the Voordelta.

Straightnose pipefish *Nerophis ophidion*
One straightnose pipefish larva was found in the middle of the southern North Sea in April.

Hake *Merluccius merluccius* (Fig. 6)
Hake eggs were found along the Dutch and Belgium coast in different development stages in May and June. In June eggs were also found south of the Doggerbank. From August to October hake larvae were found in low numbers on the Doggerbank.

Cod like (Fig. 7)
Cod like eggs were found in high numbers in the English Channel in December and February. In January cod like eggs are also found in the western part of the southern North Sea. From February to May eggs are found in high numbers throughout the southern North Sea. In June eggs are still found throughout the area, but numbers are declining. In July and August eggs are found in the south and on the Doggerbank.

Cod *Gadus morhua* (Fig. 8)
In February and March cod larvae in different development stages were found in moderate numbers scattered over the whole southern North Sea.

Trisopterus like (Fig. 9)
Trisopterus like eggs were found distributed over de western and central southern North Sea in moderate numbers in April and June. In July Trisopterus like eggs were found in low numbers on the Doggerbank.

Bib *Trisopterus luscus* (Fig. 10)
Stage 1A bib eggs were found north of the Wadden Sea islands. Larvae in different development stages were found in low numbers in the English Channel and southernmost part of the southern North Sea from January until July.

Whiting *Merlangius merlangus* (Fig. 11)
In June a few stage 1A eggs were found in the south of the sampling area. Yolk sac larvae were found in February along the coast from the Wadden Sea islands to Belgium. From March to June larvae were found along the coast and in the central southern North Sea and Doggerbank. Highest numbers of larvae are found in April.

Tadpole fish *Raniceps raninus* (Fig. 12)
Stage 1A and 3 eggs were found in low numbers on the southern-most station of the southern North Sea in June.

Rocklings (Fig. 13)
Rockling eggs of different development stages were found in low numbers scattered over the southern North Sea from January to July.

Four-bearded rockling *Enchelyopus cimbrius* (Fig. 14)
Larvae of four-bearded rockling were found from May to July on the Doggerbank and North of the Wadden Sea islands.

Five-bearded rockling *Ciliata mustela* (Fig. 15)
A few five-bearded rockling larvae in bent notochord development stage were caught in May north of Texel.

Northern rockling *Ciliata septentrionalis*
A few northern rockling larvae were found in April and May north of the Wadden Sea islands.

European seabass *Dicentrachus labrax* (Fig. 16)
In May eggs of European seabass in different development stages were found in the central southern North Sea and Doggerbank. In June 5 seabass larvae were found in the central southern North Sea.

Horse mackerel *Trachurus trachurus* (Fig. 17)
Horse mackerel eggs in different development stages were found along the Dutch, Belgium and English coast from May until July. Larvae are found along the coasts from June until August.

Red mullet *Mullus surmuletus*
Few red mullet larvae were found in July and August at 7 different stations scattered over the southern North Sea.

Goldsinny *Ctenolabrus rupestris*
Six eggs of goldsinny were found in April around the Doggerbank and seven larvae were found in the same area in July and August.

Corkwing wrasse *Crenilabrus melops*
One larva of corkwing wrasse was found in the south of the Southern North Sea in August.

Ammodytidae
Ammodytidae lay benthic eggs in the sand thus these are not found in the plankton samples. In June and July low numbers of damaged ammodytidae larvae were found in the south of the southern North Sea.

Smooth sandeel *Gymnammodytes semisquamatus* (Fig. 18)
In June, July and August smooth sandeel larvae were found in the south and the west of the Southern North Sea in different development stages. Highest numbers were found in July.

Greater sandeel *Hyperoplus lanceolatus* (Fig. 19)
In March high numbers of greater sandeel larvae are found in the west of the southern North Sea. From April until August lower numbers are found in the eastern and central southern North Sea and north of the Wadden Sea islands. In all months larvae are found in different development stages.

Small sandeel *Ammodytes tobianus* (Fig. 20)
Small sandeel larvae are found in the English Channel in December.

Lesser sandeel *Ammodytes marinus* (Fig. 21)
Lesser sandeel larvae are found in high numbers in February until April throughout the southern North Sea. In May numbers of larvae are declining. In February and March larvae are mostly in yolk sac and yolk-sac stage. In April they have reached bent notochord stage.

Lesser weever *Echiichthys vipera* (Fig. 22)
Eggs of lesser weever were found in different development stages throughout the southern North Sea from April until August. Highest numbers were found in July over the whole North Sea. Larvae in different development stages were found from July until September. Highest numbers of larvae were also found in July throughout the southern North Sea.

Greater weever *Trachinus draco* (Fig. 23)
Greater weever eggs were found in May and June in low numbers in the south of the Southern North Sea. Eggs were in different development stages. Only two greater weever larvae were found in the south in August.

Mackerel *Scomber scombrus* (Fig. 24)
Mackerel larvae were found in the northern, central and western southern North Sea in June and July in high numbers. Larvae were in all development stages In August a few bent notochord stage mackerel larvae were found on the Doggerbank.

Gobiidae (Fig. 25)
Gobiidae lay benthic eggs and are thus not found in the plankton samples. Some damaged gobiidae larvae, which could not be identified to species, were found in the Voordelta and the Belgium coast in August.

Black goby *Gobius niger* (Fig. 26)
Ten bent notochord black goby larvae were found in the south of the southern North Sea in September.

Two-spotted goby *Gobiusculus flavescens* (Fig. 27)
Some two-spotted goby larvae, non-yolk sac stage, were found in July in the Voordelta.

Pomatoschistus spp (Fig. 28)
Pomatoschistus larvae were found in low numbers in the southeast from June until August in different development stages. In June larvae were also found north of the Wadden Sea islands.

Sand goby *Pomatoschistus minutus* (Fig. 29)
Larvae of sand goby were found throughout the southern North Sea in high numbers from June to July. From September until December low numbers were found in the south.

Common goby *Pomatoschistus microps* (Fig. 30)
Common goby larvae in different development stages were found throughout, but highest number along the Dutch and Belgium coast, the southern North Sea from June until August. Metamorphosed larvae were found at single stations from September until January in the south of the southern North Sea.

Painted goby *Pomatoschistus pictus* (Fig. 31)
Low numbers of painted goby larvae were found in the north in June, along the Dutch and Belgium coast and in the south of the southern North Sea in July and in the western part of the southern North Sea in August. In June and July mostly yolk sac and non-yolk sac larvae were found. In august larvae were mostly in bent notochord stage.

Transparent goby *Aphia minuta* (Fig. 32)
Transparent goby larvae were found in highest numbers in August, in the southwest and north of the Wadden Sea islands. In August most larvae were in bent notochord stage. In September larvae were found in low numbers in the south. In October and November low numbers of bent notochord and metamorphosing larvae were found in the south and on the Frisian Front.

Cristal goby *Crystallogobius linearis* (Fig. 33)
From October until February low numbers of cristal goby larvae, in bent notochord and metamorphosing development stage, were found in the northern part of the southern North Sea.

Callionymidae (Fig. 35)
Callionymidae eggs in early development were found in the north from April until July. Highest numbers were found in May above the Wadden Sea islands. Larvae were found in high numbers along the Dutch and Belgium coast in June and July. Mostly non-yolk sac and bent notochord stage larvae were found. In August lower numbers of larvae were found along the coast but also in the north west. In August larvae were in bent notochord and metamorphosing development stage.

Common dragonet *Callionymus lyra* (Fig. 36)
Eggs of common dragonet were found in May and June along the Dutch coast and on the northwest most station. Common dragonet larvae in all development stages were found throughout the southern North Sea from June until September. Highest larvae numbers were found in July. Early development stages were found in June and July, while the later were mostly found in August and September.

Spotted dragonet *Callionymus maculatus* (Fig. 37)
Low numbers of bent notochord spotted dragonet larvae were found in the north of the southern North Sea.

Reticulated dragonet *Callionymus reticulatus*
Only four reticulated dragonet larvae were found in August in the southeast of the southern North Sea.

Butterfly blenny *Blennius ocellaris*
One butterfly blenny larvae was one in the south of the southern North Sea in August.

Shanny *Lipophrys pholis*
In the south of the southern North Sea four shanny larvae were found in July.

Butterfish *Pholis gunnellus* (Fig. 38)
Few butterfish larvae were found in the south of the southern North Sea from February until April. Development stages progressed from February until April.

Mugil spp
Single mugil spp. larvae were found in August, September and October in the south of the southern North Sea.

Triglidae (Fig 39 & 40)
Triglidae and triglidaelike eggs were found from April until August throughout the southern North Sea. Highest numbers of eggs were found from May until July.

Grey gurnard *Eutrigla gurnardus* (Fig. 41)
Grey gurnard larvae in different development stages were found from June until August in the northern part of the southern North Sea.

Tub gurnard *Trigla lucerna* (Fig. 42)
Some larvae of tub gurnard were found in August in the south of the southern North Sea and Voordelta.

Bull-rout *Myoxocephalus scorpius* (Fig. 43)
Larvae of bull-rout were found in low numbers in the northwest of the southern North Sea in March.

Sea scorpion *Taurulus bubalis* (Fig. 44)
Sea scorpion larvae were found along the English coast, off Lowestoft, in April.

Norway bullhead *Micrenophrys lilljeborgi*
One Norway bullhead larvae was found in May in the south of the southern North Sea.

Hooknose *Agonus cataphractus*
In January three hooknose larvae were found in the eastern English Channel.

Sea snail *Liparis liparis* (Fig. 45)
In March some sea snail eggs in yolk sac stage were found in the Voordelta and north of Texel.

Montagu's sea snail *Liparis montagui* (Fig. 46)
Some montagu's sea snail larvae were found in the south of the southern North Sea in March.

Bothidae and Scophthalmidae
One damaged bothidae larvae, which could not be identified to species, was found in June. One damaged scophthalmidae larvae was found in May.

Turbot *Scophthalmus maximus* (Fig. 47)
Turbot eggs were found from May until July. In May and June only early stage development eggs were found. In May turbot eggs were found in the Voordelta, in June along the coast and the central and northwest part of the southern North Sea. In July eggs were only found in the northwest part. Non-yolk sac larvae were found in the Voordelta in May. From June until August non-yolk sac larvae were found in the central and northwest part of the southern North Sea.

Brill *Scophthalmus rhombus* (Fig. 48)
In September brill stage 1A eggs were found in the northwest of the southern North Sea. Few brill larvae were found along the Dutch coast in May and June.

Topknot *Zeugopterus punctatus* (Fig. 49)
Stage 1 to 3 topknot eggs were found north of the Voordelta along the Dutch coast in June.

Norwegian topknot *Phrynorhombus norvegicus* (Fig. 50)
Norwegian topknot eggs, in different development stages, were found in the southern part of the southern North Sea along the coast from April until June. In June highest numbers of eggs were found, also distributed in the central and northern part of the southern North Sea. Larvae were only found in the northwest of the southern North Sea in June and July.

Megrim *Lepidorhombus whiffiagonis* (Fig. 51)
Megrim eggs were found in different stages in the Voordelta and Belgium coast in May and June.

Arnoglossuslike (Fig. 52)
Stage 1A Arnoglossuslike eggs were found throughout the southern North Sea in high numbers from February until August. Highest numbers were found from May until July. Later egg development stages were only found from May until August.

Scaldfish *Arnoglossus laterna* (Fig. 53)
Scaldfish eggs were found in high numbers from April until July throughout the southern North Sea. Stage 1A eggs were found in all months, later development stages were only found in June and July. Highest numbers of eggs occurred in June and July. Non-yolk sac larvae were found from June until July throughout the southern North Sea. Bent notochord stage larvae were found from July until September. Metamorphosing larvae were found in July and August. Highest numbers of larvae were found in July and August.

Pleuronectidae (Fig. 54)
Pleuronectidae larvae which could not be identified to species were found in the eastern English Channel in January.

Long rough dab *Hippoglossoides platessoides* (Fig. 55)
Stage 1A long rough dab eggs were found east of the Doggerbank in February. Non-yolk sac long rough dab larvae were found northwest in the southern North Sea in March.

Dab like (Fig. 56)
Dab like eggs were found in high numbers throughout the southern North Sea from January until July. Highest numbers were found in February and March. All development stages were found in this period.

Dab *Limanda limanda* (Fig. 57)
All stages of dab eggs were found in high numbers from April until July throughout the southern North Sea. Highest numbers of eggs were found in April and May. Yolk sac larvae were found throughout the southern North Sea in February and March. Non-yolk sac larvae were found in high numbers from February until July, but highest numbers were found from April until June. In June larvae were only found in the northwestern part. Bent notochord larvae were found from March until August, from March until Jun throughout the area, but in July and August only in the northwest. Metamorphosing larvae were found from May until July.

Plaice *Pleuronectes platessa* (Fig. 58)
Plaice eggs were found in all development stages from December until March throughout the eastern English Channel and southern North Sea in high numbers. Highest numbers were found in January and February. Larvae in yolk sac, non-yolk sac and bent notochord development stages were found throughout the area from January until March. Metamorphosing larvae were not found in the southern North Sea.

Lemon sole *Microstomus kitt* (Fig. 59)
Some lemon sole eggs were found on the Doggerbank in September. Non-yolk sac and bent notochord stage larvae were found in moderate numbers from July until December in the northwest part of the southern North Sea. Metamorphosing larvae were found in the northwest from December until March.

Witch flounder *Glyptocephalus cynoglossus* (Fig. 60)
Some bent notochord stage larvae were found in the northwest part of the southern North Sea in October.

Flounder *Platichthys flesus* (Fig. 61)
Stage 1A flounder eggs were found in April in low numbers in along the English coast in the east of the southern North Sea. From May to July stage 1A flounder eggs were found in the central part of the survey area and northwest of Texel. Flounder larvae were found along the northwest Dutch coast in February and north of the Wadden Sea islands in March.

Soleidae (Fig. 62)
Three damaged soleidae larvae that could not be identified to species were found in June in the northwest if the southern North Sea.

Sole *Solea solea* (Fig. 63)
Sole eggs in all development stages were found along the Dutch coast, including north of the Wadden Sea islands, the Belgium and English coasts in high numbers from April until June. In July eggs were found along the English coast and in August eggs were found in the Voordelta. Sole larvae were found in May and June along the Belgium and southern Dutch coast.

Solenette *Buglossidium luteum* (Fig. 64)
Solenette eggs, in development stages 1a to 3, were found in high numbers throughout the southern North Sea from April until August. Highest numbers were found in May and June. Stage 4 and 5 eggs were only found along the northeast Dutch coast and north of the Wadden Sea islands. Larvae of solenette were found throughout the southern North Sea in all development stages from June until August. Highest numbers of solenette larvae were found in June and July.

5 Discussion and conclusions

Twelve monthly surveys have been carried out in the southern North Sea from April 2010 until March 2011. Despite technical problems or bad weather conditions preventing the sampling of all planned stations during each survey, the coverage was good and the general trends in ichthyoplankton abundance became apparent. Also in August and September 'Ms Arca' was called to assist with an oil spill and we used the 'Ms Zirfaea' which had a much lower maximum speed. Because of this and the extreme weather conditions in September only 27 stations could be sampled.

Plankton was sampled with a Gulf VII plankton torpedo at a fishing speed of 5 knots. The plankton sampler samples through the water column till 5 meter above the sea floor. Some fish species, e.g. herring, ammodytidae, gobiidae, lay benthic eggs. Eggs of these species will not be caught in the water column. The yolk sac of some larvae species, e.g. clupeidae, are easily damaged. Numbers of yolk sac larvae in the samples were low, but could be underestimated because of damage to the yolk sac. The larvae in the metamorphosing stage swim actively and it could be possible for them to avoid the plankton sampler. Sampling was carried out day and night. Visibility of the plankton sampler changes with daylight this might have influenced the avoidance of the larger larvae. However the survey shows expected pattern during the spring when compared to Taylor et al. (2007) and other studies, so it could be assumed that sampling was effective.

Fish eggs were found in all months but species and numbers varied per month across the southern North Sea. The highest abundance of fish eggs was found from January until May. Fish eggs were found at all stations from April until July. From August onwards abundance of eggs declined. Very few eggs were found between August and November. From December onwards abundance of eggs increased again. The pattern was the same on the NCP. In total 35 different species of fish eggs were found.

Fish larvae were found in all months but species and numbers varied in a similar pattern to the fish eggs, except the highest abundance of larvae was found in December and January in the English Channel (mostly herring). Numbers of larvae in the southern North Sea increased from April until June and afterwards then gradually declined until November. After this the abundances increased again. Larvae were found at almost all stations from May until September. In October and November larvae were found at half of all the stations both in the whole sampling area and on the NCP. In December larvae were found at half of the stations in the whole sampling area and still on a quarter of all stations on the NCP. In February and March larvae were again found at almost all stations on both the whole sampling area and the NCP. In total 74 different species of fish larvae were found.

This unique study is the first to comprehensively sample and analyse the ichthyoplankton with monthly resolution in the southern North Sea. However our findings are in accordance with the previous studies that focused on certain species, specific times of the year or used spawning adults as indication of spawning areas. Most of the fish egg and larvae species have been reported in these previous studies as being present in the southern North Sea (e.g. Russell 1976, Taylor et al. 2007, Teal et al. 2009). No unexpected species were found.

Based on the results of a modelling study, a mitigating measure was issued by the Dutch authorities forbidding pile driving of offshore wind farm foundations from January to June, in order to ensure that negative effects on prey availability for birds and marine mammals within Natura 2000 areas are minimised. The results of the year-round monthly surveys show that from April until September fish larvae were found throughout the survey area, including the NCP, in varying numbers and species. Still in October and November larvae were found at half of the stations although at lower abundances. Even in December larvae were still found at a quarter of the stations on the NCP. Whilst the abundance of larvae was low in October and November, there are a few species with larvae present that are absent at other times of the year. These results on ichthyoplankton abundance and results of the experimental study on the effect of pile driving on fish larvae need to be combined. Ideally they should also be assessed with subsequent studies of ichthyoplankton transport and impact on the Natura 2000 sites.

These data on spatial and temporal distribution of fish eggs and larvae can be used in modelling studies to assess possible effects of human activity in the southern North Sea, on different fish populations. This would provide important information for implementing mitigation rules as well as possibly indicating at which locations impact of human activity will be lowest.

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7 Quality Assurance

7.1 Check on the sorting and identification of the samples

Following the protocols for the IMARES standard plankton surveys sorting of the samples and identification was checked (Damme et al. 2010). All participants in the survey are required to use the 'spray technique' on two samples with known numbers of eggs before going to sea.

For quality assurance purposes, the effectiveness of the 'spray technique' was assessed by manually sorting a proportion of the samples. After each survey, 5 samples of each plankton-team (with different total amounts of plankton) were checked to see if larvae and eggs had been properly sorted. If >5% of the total number of larvae or eggs were found in the check, then all samples of this team were checked and catch numbers adjusted.

The progress reports gave an overview of the numbers of samples that were checked for sorting of eggs and larvae. Larvae were collected before eggs were sorted out, thus all samples were checked for larvae sorting while eggs were sorted out. In all samples <5% of the larvae remained. Since all participants were well trained in the 'spray' technique before going to sea, all checked samples contained <5% of the total amount of eggs.

Some of the eggs and larvae in the samples, divided over the year, were checked for species identification. The eggs and larvae were identified a second time by a different identifier from IMARES to check the species identification. If the checked eggs or larvae were found incorrectly assigned to species the data files were adjusted.

7.2 ISO

IMARES utilises an ISO 9001:2008 certified quality management system (certificate number: 57846-2009-AQ-NLD-RvA). This certificate is valid until 15 December 2012. The organisation has been certified since 27 February 2001. The certification was issued by DNV Certification B.V. Furthermore, the chemical laboratory of the Environmental Division has NEN-AND-ISO/IEC 17025:2005 accreditation for test laboratories with number L097. This accreditation is valid until 27 March 2013 and was first issued on 27 March 1997. Accreditation was granted by the Council for Accreditation.

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Justification

Rapport C098/11
Project Number: 4302501501

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

Approved: Mark Dickey-Collas
Senior researcher

Signature:

Date: the 22th of August 2011

Approved: Jakob Asjes
Head of department Fish

Signature:

Date: the 12th of August 2011