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REPORT OF THE STUDY GROUP ON REGIONAL SCALE ECOLOGY OF SMALL PELAGIC FISH (SGRESP)

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PLYMOUTH, UK

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Contents

1 Executive summary

A component of the ecosystem approach to fisheries management is the understanding of the environment induced variability in fish stocks. To start making that component operational, SGRESP was concerned about building the means by which ecological knowledge can serve stock health diagnostic, recruitment projection and management strategy.

A major result from SGRESP in 2004 was the recognition that the environment-population relationship was to be seen as an interaction between the population status (demography and habitat spatial occupation) and the environmental regime. This led to considering the spatialisation of the life cycle: spawning habitats, adult migrations, larval survival and incorporation of juveniles to the life cycle of adults. Life cycles have now been documented and survey data inventoried for an extensive list of pelagic populations in ICES waters: anchovy (Biscay), sprat (Baltic and North Sea), herring (Norwegian spring spawning, North Sea, Baltic, Celtic sea and North West Ireland), North East Atlantic sardine, mackerel and blue whiting. Differences in the spatial structure of the life cycles were documented for the different species and a biological framework was build to support spatial population modelling. In particular, being long-lived and still able to reproduce at a small size, sardine showed a complex spatial structure in its life cycle: it showed local independent populations of small fish (a characteristic of anchovy), as well as a large migratory spawning component of bigger fish (a characteristic of mackerel).

When spatialising the life cycle essential habitats were identified as well as linkage between generations for the maintenance of their occupation. Habitats were often associated with particular meso-scale oceanographic features which made life cycle closure dependent on these features. Characterising meso-scale oceanographic features was thus recognised essential for the understanding of the variability in spatial patterns and population dynamics. But in general, environmental parameters available to the fisheries biologist are long-term indices of ocean climate (e.g. NAO). The group recognised the importance to construct long-term series of meso-scale oceanographic features. Tools were presented that allowed to extract from circulation model outputs fronts, eddies, vortices, water column stratification. A workshop was proposed to deal with this issue as tools need to be transferred to users for building the long-term time series of the meso-scale features in each area.

SGRESP is an international group which has the capacity and the objective to assemble multi source international data on fish stocks. Long-term variation in anchovy distribution at large scale in ICES waters were studied for the first time. Data were compiled from all available bottom trawl surveys from 1990 to 2004. Anchovy distribution expanded north of 50°N since 1994 and in particular in the North Sea with no particular change in the Southern limits. There was a presumption based on the analysis of fish length that the expansion was due to good recruitments in local northern small relict populations.

Adult spawning behaviour (i.e., spawning windows in space and time) was essential for understanding the influence of the environment on the recruitment dynamics as well as on the long-term variation in population distribution. Following GLOBEC/SPACC conceptual framework which differentiated potentiality, realisation and usefulness in spawning habitats, the group estimated potential habitats for sardine, reported on variation in useful habitats for anchovy and documented changes in realised spawning windows in winter for herring and sprat. The group agreed that realised spawning windows needed to be monitored for adequately predicting recruitment.

To transfer and incorporate the previous ecological knowledge in stock projection and management, two products from SGRESP were considered: short-term recruitment prediction and medium-term interaction between population status and environmental regime. Guide lines

were proposed to operationalize the use of environment-based recruitment indices in population projection scenarios and to deal with the possibility of inaccuracy in the projection. Propositions were based on applications to Baltic sprat and Biscay anchovy. For the medium-term advice, schemes of life cycle structure with their dependence on oceanographic features represented a biological framework allowing consideration of spatial management strategies. In order to go further, spatial population models and simulation platforms were recognised as necessary tools to be developed.

2 Introduction

The Study Group on Regional Scale Ecology of Small Pelagic Fish (SGRESP) was established for 3 years (2004-2006) at the ICES Statutory Meeting in 2003 and recognised as a joint GLOBEC SPACC / ICES activity in 2004. The SG was established with the purpose of i) integrating various survey data together as well as with meteo, satellite, fishery and/or ecosystem model outputs and ii) feed the assessment WG with synthetic understanding of how the spatial dynamics of the biological cycle and the stock dynamics are related to the ecosystem. The objective being to increase ICES ability to use ecological information in assessment, prediction and management of small pelagics and provide means to make operational the ecosystem approach to fisheries management.

A major result from the 2004 SGRESP meeting was that environment forcing was to be reconsidered as an interaction between a population status and an environmental regime. Adult behaviour and population history generate an interaction between population dynamics and environment via spatial occupation. Underlying biological mechanisms would relate to links across generations. Changes in correlative relationships between population recruitment series and that of environment indices were interpretated by possible changes in the adult spawning behaviour and migration pattern.

The 2004 report was well received by the Living Resources Committee which supported the three major items of SGRESP workplan: (i) adult spatial dynamics, (ii) updates of recruitment indices and (iii) liaison with the assessment and advisory process. Discussions at the Committee suggested increasing the number of stocks.

In 2005, we had ToRs to continue data assembly and analysis: a) and b). We also had ToRs relating to long-term series that allow investigating the importance of adult behaviour and population history: c) and d). Because what we do has an interest for the diagnosis and management of fish stocks, we had ToRs dealing on these matters: e) and f). It is noteworthy that ACE (advisory committee on ecosystems) added ToR f), strengthening the implementation of the Ecosystem Approach in the work of SGRESP.

The Study Group on Regional Scale Ecology of Small Pelagic Fish [SGRESP] (Chair P. Petitgas, France) met from 28 February to 2 March 2005 in Plymouth, UK to:

a. Identify gaps in the data inventory and continue to assemble data on life history stages (adult, egg, larva, juvenile) of pelagic fish (mackerel, sardine, anchovy, sprat, herring, and horse mackerel) in ICES waters at regional scale and in a long-term perspective;
b. Continue to characterise habitats of life cycle stages (spawning, nursery, feeding and wintering grounds) with particular attention to physical meso-scale processes and multi-species context, evidence inter-annual changes and reconstruct long-term history of the spatial pattern of populations;
c. Assemble long-term series of environmental indices using survey data, meteorological data and model outputs at basin-scale and meso-scale in order to reconstruct long-term history of environmental changes at different scale ;

d. Review and update adult fish behaviour in relation with oceanographic and ecosystem features and characterise how adult fish migration, feeding and spawning impact the environment-population interaction;
e. Identify situations which have potential impact on the assessment, projection or management processes: update the relevant assessment working groups and survey planning groups with the information through working documents and provide these groups with quantitative information on fishery-ecosystem interactions;
f. Liaise with WGMHSA to identify the means by which Management Strategies could be developed based on WGRESP findings

The meeting was hosted by GLOBEC IPO who is thanked for very nice local arrangements.

Stocks available to the group were: North East Atlantic mackerel, blue-whiting, and sardine, herring in the North Sea, Baltic and around Ireland, sprat in the Baltic and North Sea, and anchovy in Biscay. The work of the group consisted of presentations, discussions and simple data analyses performed on survey data compiled internationally prior to the meeting.

3 Progress on the Terms of Reference

3.1 ToR a)

Identify gaps in the data inventory and continue to assemble data on life history stages (adult, egg, larva, juvenile) of pelagic fish (mackerel, sardine, anchovy, sprat, herring, and horse mackerel) in ICES waters at regional scale and in a long-term perspective

SGRESP is an international group which has the capacity to assemble multi source international data on fish stocks. Building from SGRESP 2004 recommendations, international data has been assembled for different species in order to address population variation at relevant spatial and temporal scales which are the large geographical scale and in the long term. North East Atlantic mackerel life cycle can be followed at European scale because data from different sources and types were gathered and data bases built for mackerel (ichthyoplankton, acoustics, trawl, and fishery). This effort is similar to that of PGHERS on North Sea herring. Blue-whiting assessment would probably benefit from a similar effort in assembling survey data. North East Atlantic sardine spawning habitats can now be analysed because relevant egg data were put together. Long-term variation in anchovy distribution at large scale in ICES waters can now be studied because anchovy catches from all bottom trawl surveys around Europe were extracted from existing data bases and assembled. To analyse Baltic sprat spawning, fragmented files on the ichthyoplankton and acoustic files on the adult spawners were assembled.

In assembling data, access to primary level data (e.g., original survey data) was essential. Though data collection is internationally coordinated, efforts for its easy access still remain to be made. Group members struggled with different formats, updates and sometimes national user rights. Large scale, long-term international and multi source data assemblage is not a straightforward exercise and is in itself a product of SGRESP.

3.1.1 North East Atlantic mackerel data types and sources

It is clearly essential that pan-European databases are assembled to allow the migration patterns, age structures, long-term changes for NEA mackerel to be ascertained. European commercial and scientific databases were compiled at FRS to provide any information on mackerel. The databases found so far are described below.

- FRS trawl survey (Scottish sea areas; 1925-present; patchy seasonally)
- IBTS trawl survey (North Sea; 1965–2000; patchy seasonally)

- DATRAS trawl survey (North Sea; 2001-present; patchy seasonally)
- FRS market sampling (Scottish sea areas; 1960-present; good coverage seasonally)
- Scottish commercial landings (Scottish sea areas; 1960-present; good coverage seasonally)
- International recruit trawl sampling (Western continental shelf; 1980–2003; patchy seasonally)
- International egg survey (Triennial; 1977–2004; good coverage seasonally)
- Assessment working group inputs (Aggregated numbers at age matrices)

Fisheries Research Services Trawl database (1925-present). The long temporal coverage by FRS means that time-series can be constructed for the period 1925 –present. We nevertheless realise that the interpretation of such data may be severely hampered by time-varying catchability effects. Notwithstanding this considerable problem we believe there may be some useful 'qualitative' information in the series; e.g. the groups of years when peaks in abundance occur may be 'real'.

The IBTS and DATRAS Trawl Survey Databases. The IBTS (International Trawl Survey Database) were also made available to SGRESP for the time between 1965 and 2000, mostly for quarter 1, although other seasons were surveyed for a period in the early 1990s. [Note: some but not all FRS data are sent to IBTS so there is a degree of overlap]. These data permit the extension of the FRS data into the southern North Sea. A new database (DATRAS) is currently under development at ICES. The goal of this database is to incorporate the North Sea data together with data from other areas (e.g. West of Scotland, Western Approaches, Bay of Biscay). DATRAS will also incorporate beam trawl data. For SGRESP a subset of DATRAS data for the North Sea were made available allowing an extension of the North Sea time series up to quarter 1 2004.

The International Mackerel Recruit Trawl Survey Database. The International Mackerel Recruit Database was prepared for WGHMSA and made available to SGRESP by Dr D. Reid. It consists of trawl CPUE data for mackerel for age groups 0, 1, 2, and 3. The data were compiled from trawl surveys carried out by Portugal, Spain, England, Ireland, France and Scotland. Again, there is some overlap with these data and the FRS trawl data for the west coast. The data cover the years 1981–2003, and are patchy in spatial and seasonal dimensions

International Egg Survey Database (1978–2004). Internationally coordinated egg surveys are carried out along Europe's western continental shelf every 3 years. Mackerel has a long spawning season, all of which must be surveyed. This means that the egg survey has unusually extensive seasonal coverage (February – July) which is maintained in order to encompass as much spawning activity as possible. By calculating the amount of egg production by mackerel over a spawning season it is possible to derive an estimate of the spawning stock biomass.

Scottish commercial landings database (1960-present). Commercial landings data for Scotland are provided by the Scottish Executive in the form of kilograms of fish landed per statistical rectangle per month. For the times when fishing is active, both seasonal and spatial coverage are extremely good. There are well known problems with these data because the fishermen are known to misreport what they catch, where and when. Nevertheless the landings data form a rich database and many of the known aspects of the biology of mackerel over the last few decades are believed to be well reflected by these data. It would be interesting to assemble similar data bases for mackerel from other countries.

3.1.2 North East Atlantic sardine egg data base for characterising spawning habitats

During the recent SPACC Workshop (van der Lingen and Castro, 2004) a common framework and methodology (quotient plots) were agreed for describing the spawning habitat of small pelagics using data routinely collected in ichthyoplankton surveys. First attempts to describe potential spawning habitat (PSH) during the SPACC Workshop (van der Lingen and Castro 2004) and after (Planque *et al.*, 2004) were confronted with the spatio-temporal limitations in the available data sets. To define PSH from monitoring data requires combined analysis of surveys covering the widest possible geographical range of the species distribution area and over a long period of years. A first attempt to use large scale combined European surveys in the spawning habitat characterisation of various fish species was made using ichthyoplankton data from the triennial mackerel and horse mackerel egg production surveys (Ibaibarriaga *et al.* in prep.). Nevertheless, these data come from a single year (1998). Although results indicate that combining international surveys improves the spatial coverage of spawning habitats, and thus its characterisation, full characterisation of the potential spawning habitat had not be achieved prior to this meeting.

Within SGRESP, a joint effort was initiated to describe the potential spawning habitat of sardine and anchovy in ICES waters and to identify the main reasons of inter-annual variation in realised spawning habitat. Analysis is exclusively based on ichthyoplankton observations from CUFES (eggs per unit volume of water filtered) during acoustic and DEPM surveys over the period 2000–2004. The advantage of these data is that collection has been performed with the same sampler across surveys (more than 5000 observations over the study period), although analysis is limited by the fact that egg density measures do not integrate the entire water column. All data have been collected and partially compiled under various EU projects (PELASSES, SARDYN, National Sampling Plan of France, Spain and Portugal), while international coordination on sampling protocols were achieved under PELASSES (acoustic surveys) and ICES SGSBSA (DEPM surveys). However, the data available during the meeting only permitted the combined use of Portuguese, Spanish and French spring surveys from 2000 and 2001 (only for sardine). Compilation of remaining surveys and analysis for both sardine and anchovy will be performed in the course of 2005 and final results will be presented in the SGRESP meeting of 2006.

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3.1.3 Anchovy distribution in ICES waters from bottom trawl surveys

Anchovy numbers at length were extracted from IBTS, DATRAS bottom trawl surveys as well as from national surveys. The assemblage allowed analysing at European scale the evolution of anchovy distribution in the past 15 years. Although bottom trawls are not the adequate sampling gear for catching anchovy, it is believed that anchovy catch in the bottom trawl survey reflects the pan-European large scale and long-term variation of the species distribution as this signal is greater than the noise coming from data representatively.

3.1.4 Baltic sprat ichthyoplankton and acoustic data bases

The data inventory on sprat eggs and larvae in the deep basins of the Central Baltic include various surveys from 1987 to 2004. To overcome the fragmented nature of the data in various data files and file formats, an effort to collect the data in a database together with environmental background data has been initialized. This will be followed during the next year so that the data are available for spatio-temporal analyses of early-life stage distribution in relation to environmental forcing and to characterize habitats (and changes in these).

Adult sprat distribution data from hydroacoustic surveys has been collected during the 2002/2003 field phase of the GLOBEC-GERMANY project and is presently under analysis. Further, historical data from surveys in May (during peak spawning time) have been and will be further digitized with funding through the project. The Baltic international hydroacoustic survey data base (BAD 1) from autumn surveys is only available at the scale of ICES statistical rectangles, a resolution which appears too coarse for analysing adult behaviour and their interannual variation in relation to the prevailing environment. The status and future development of an additional database (BAD 2) containing more original (national) data is presently still unclear as well as the user-rights. In the light of the usefulness of the data to SGRESP and to a suite of ongoing and planned EU 6th framework research projects (e.g. BECAUSE, PROTECT), the group recommends the clarification of these problems.

3.2 ToR b)

Continue to characterise habitats of life cycle stages (spawning, nursery, feeding and wintering grounds) with particular attention to physical meso-scale processes and multi-species context, evidence inter-annual changes and reconstruct long-term history of the spatial pattern of populations

In SGRESP 2004 report, life cycle ID cards were produced for Norwegian spring spawning herring, North East Atlantic mackerel, sardine around Iberia and in Biscay, anchovy in Biscay, and Baltic sprat. This year, new stocks were considered for which similar ID cards were produced.

Characterising meso-scale physical features was recognised essential for the understanding of the variability in spatial patterns and population dynamics. Tools were presented that allow extraction from circulation model outputs: fronts, eddies, vortices, water column stratification. A workshop was proposed to deal with this issue as tools need to be transferred to users for building the meso-scale features time series in each area.

Results from the German-GLOBEC program on Baltic sprat were an example of how physics impacted the plankton food web making resource availability varies across years, in a multi-species competition context. (The ID card for Baltic sprat is in the 2004 SGRESP report).

Long-term variations in population distributions was analysed on anchovy. In Biscay, the anchovy population is seen to have lost spawning grounds. Data were assembled that questioned whether encountering adults was necessary for juveniles to effectively colonise lost habitats. (The ID card for anchovy in Biscay is in the 2004 SGRESP report). At large scale in ICES waters in the context of climate change; data were compiled from all available bottom trawl surveys from 1990 to 2004. Anchovy distribution expanded in northern waters since 1995 with no particular change in the southern limit. There was presumption that expansion came from good recruitments from micro local residual populations.

Long-term variations in NEA mackerel were evidenced using the extensive compilation of both fishery and scientific surveys on eggs, recruits, adults, landings and log-books. Bottom trawl surveys suggest that three main peaks of abundance have occurred: in the late 1930s; the late 1950s and the late 1990s. Egg surveys suggest that spawning activity by mackerel may have declined from 1998 onwards. Landings show that the mackerel fishery changed from being a summer one in the 1960s to a winter one in the 1980s, 1990s and 2000s.

3.2.1 ID card for North East Atlantic blue whiting

Life history traits. Individuals of age 10 years or older are presently rare although ages in excess of 20 years have been reported earlier. Most blue whiting are believed to mature at ages 2–4 years, although the maturity ogive used by WGNPBW assumes that maturation of a cohort is not complete before age 7 years. Blue whiting is a batch spawner. Growth is very fast during the first year (up to 18–20 cm) but decelerates rapidly thereafter; most fish are less than 32 cm with the reported maximum length at about 50 cm.

Wintering. Over-wintering juveniles can probably be found throughout the species' range. Adults are migrating towards the spawning grounds during the winter months.

Spawning. Time**:** Spawning occurs mostly during February-April, with seasonal northward progression. Habitat: Blue whiting spawn in open water over great depths (>1000m) or close to and on the shelf edge. Schooling behaviour: Dense spawning aggregations are formed during the spawning season, typically occurring in 300–500 metres depth. Diurnal movements are small. Co-occurring species: mesopelagic fish such as hatchet fishes and lantern fishes.

Feeding. Time: Late spring and summer is the main feeding period. Very little feeding occurs during the spawning season (February-April). Habitat: traditionally, the Norwegian Sea is considered as the main feeding area; also south of Iceland and along the continental shelf edge from Bay of Biscay to and into the Barents Sea. Predation mode: snapping. Prey species: crustaceans (large copepods, amphipods, krill), small cephalopods, small fish and fish larvae (Bailey 1982; Monstad, 2004). Schooling behaviour: loose layers or schools that show diurnal migrations; juveniles can occur in the surface waters during night. Re-occurring species: saithe, redfish and various mesopelagic fish below 200m; herring and mackerel above 200m; also demersal fish on the shelf areas.

Migrations. Mature blue whiting migrate to the spawning grounds west of the British Isles during the winter months. In spring-early summer, the post-spawning migration brings the adults back to the feedings areas. Exact migration patterns are not well known

Larval drift and nursery areas. The hatched larvae drift northwards, towards the Norwegian Sea and Iceland, or southwards, towards the Bay of Biscay. The direction of drift depends on the spawning area; hydrographic modelling suggests that the separation line between northern and southern drift varies from year to year but is usually at the northern parts of the Porcupine Bank (Skogen *et al*., 1999). By February the year after spawning, blue whiting probably originating from the main spawning area are found in surveys in the Barents Sea (Heino *et al*., 2003). A part of the northward-drifting larvae enter the North Sea and fishery there by the fourth quarter of the year. The main nursery areas are in the Atlantic water in the Norwegian Sea, south of Iceland, southwest Barents Sea, and Bay of Biscay. Also the deeper parts of shelf areas around the Faroes and the British Isles function as nursery area.

Long-term trends. Little is known about the stock size prior to 1981, the first year in the current ICES assessment. The stock appeared to be declining in the early 1980s, was relatively stable until late 1990s after which it has increased due to strong recruitment. The latest years in the assessment are highly uncertain, but suggest that the stock is on decline from its historic high. Since 1995 the recruitment has been considerably higher than what has been observed before; what were considered “strong” year classes before 1995 would be now considered “weak”.

Nowadays characteristics. The increased recruitment has been accompanied by increased abundance of blue whiting in some areas, notably in the Barents Sea. The stock is dominated by young individuals (ages 1–5 years). At the level of the stock, there are no striking changes in condition, size-at-age or maturation, although this is also a reflection of poor knowledge and problems in age readings. Some survey time series suggest density dependence in growth.

Potential environmental influence. (1) Hydrographic conditions during the spawning season affect the relative amounts of eggs and larvae drifting to northern and southern nursery areas; a certain spawning area may seed northern areas in one year, southern areas in another (Skogen *et al*., 1999). (2) There is a positive effect of the large inflow of warm Atlantic water to the Barents Sea (as indicated by a positive salinity anomaly on the Fugløya-Bear Island section) on abundance of blue whiting in the Barents Sea one year later (Heino *et al*., 2003). (3) The strength of year classes as 0-group in the North Sea is only weakly coupled to the strength of year classes in the main Atlantic stock. This suggests either local recruitment or variation in transportation of larvae into the North Sea. (4) Increased inflow of Atlantic water into the Norwegian Sea through Faroe-Shetland Channel (as indicated by a positive temperature anomaly, e.g. Hátún *et al*., 2005) coincides with increased recruitment, although earlier warm periods have not witnessed a similar increase in recruitment.

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Supporting figures 1–4.

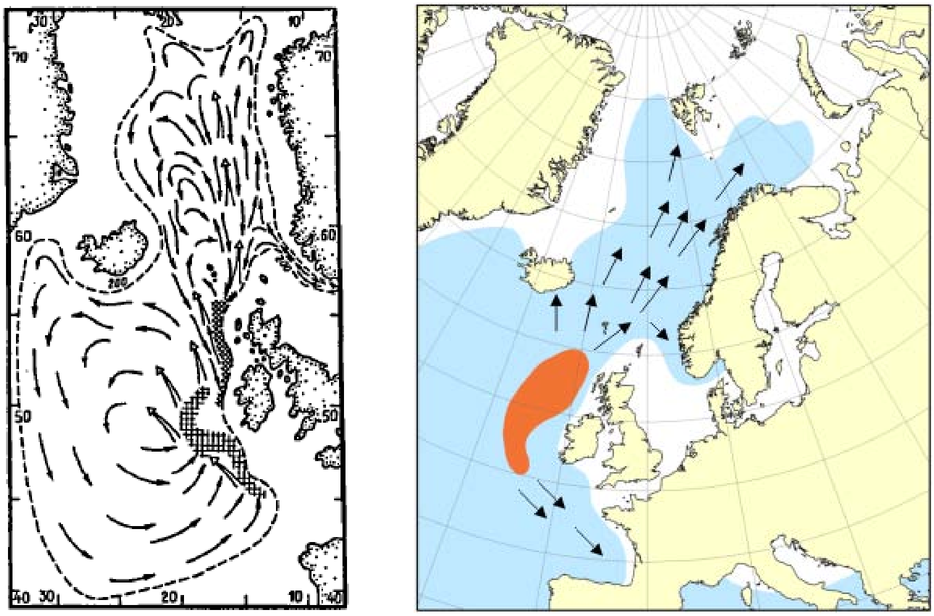

Figure 1: Migration of blue whiting. The left panel shows the migration pattern of adult blue whiting as suggested by Isaev *et al.* (1992). Hatched area shows the main spawning grounds. The current understanding does not fully support the pattern suggested for the component spawning around the Porcupine Bank by not accounting for the Bay of Biscay component. The migrations in the west are also virtually unknown. The right panel shows the current understanding on the drift patterns of blue whiting larvae.

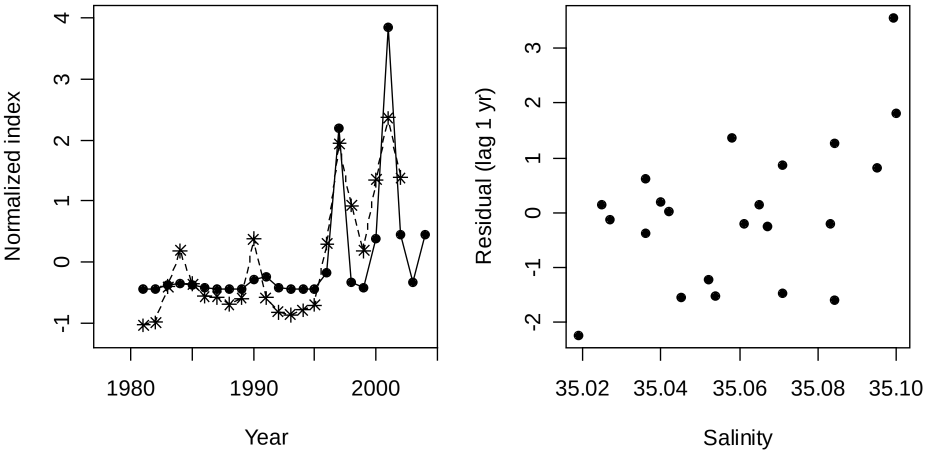

Figure 2: Abundance index of 1-group blue whiting based on the Barents Sea winter survey conducted by IMR (Norway) (continuous line), and recruitment in the main Atlantic blue whiting stock (dashed line; WGNPBW 2004). Residuals from the log(abundance index)~log(recruitment) regression are positively correlated with salinity in the Fugløya-Bear Island section (r=0.49). High salinity on this section is presumed to indicate large inflow of Atlantic water into the Barents Sea which should facilitate the entry of young blue whiting into the survey area.

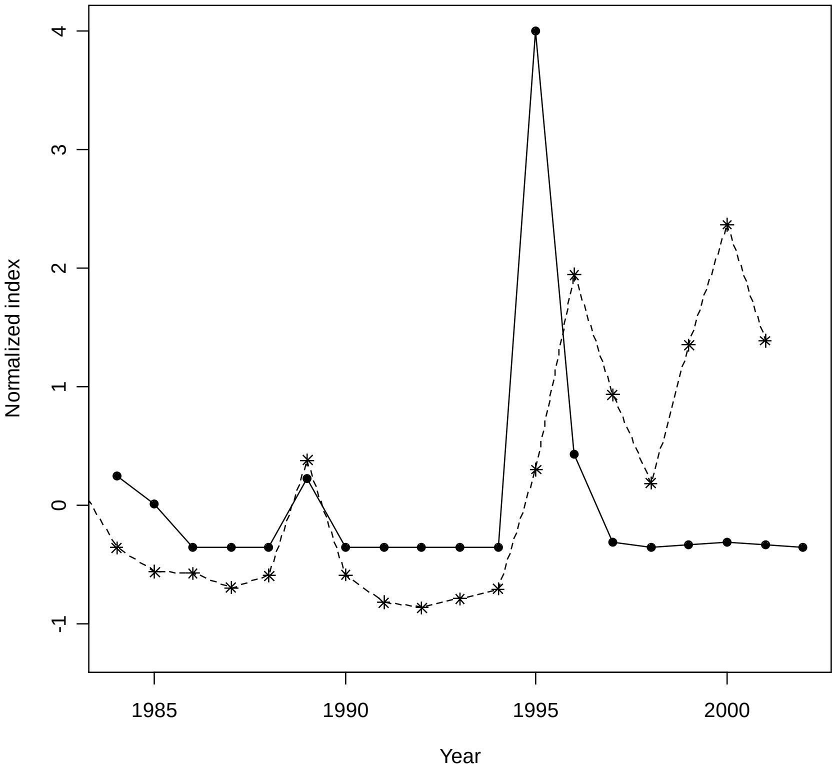

Figure 3: Abundance index of 0-group blue whiting based on the North Sea shrimp survey conducted by IMR (Norway) (continuous line), and recruitment in the main Atlantic blue whiting stock (dashed line; WGNPBW 2004). In many years, hardly any 0-group blue whiting are caught, and in particular, only the two first of the strong year classes after 1995 have appeared in the North Sea in significant numbers.

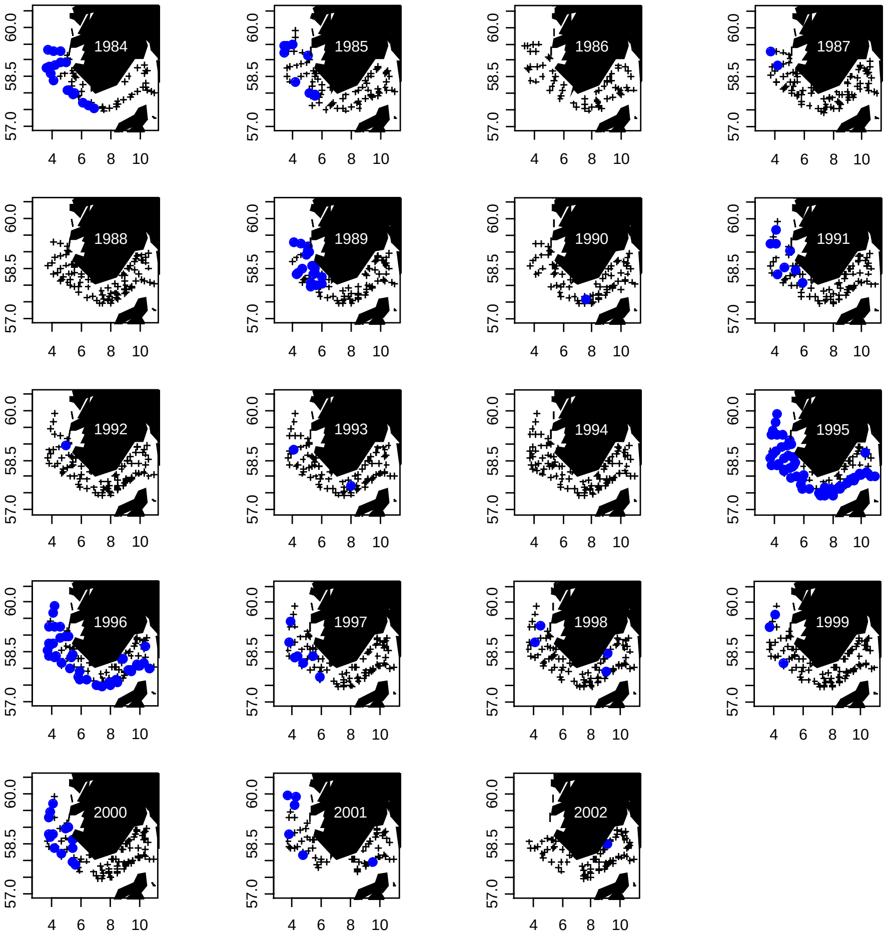

Figure 4: Distribution of trawl stations (crosses) and stations with 0-group blue whiting (blue dots) in the North Sea shrimp survey conducted by IMR (Norway). 0-group blue whiting tend to occur (1) in the western parts of the survey area, and (2) in some years also in the southern slopes of deep waters in Skagerrak.

3.2.2 ID card for North Sea sprat

Life history traits: Life span=5+yrs, predominated by 0/1–2 yrs; mat=1–2y; indeterminate multiple batch spawner, larvae metamorphose at 2.5–3.0cm.

Spawning: Time: March-August. Sprat eggs can be found almost all year round at least in some parts of the North Sea. This is explained by shifts in timing of the spawning periods from the Channel to the North Sea and the protracted spawning seasons. There is some evidence (e.g., larvae in winter MIK hauls; 0-group in acoustic summer surveys) for occasional autumn-winter spawning outside traditional spawning window. Habitat: Spawning occurs along the coasts with no clear defined spawning grounds. Spawning occurs close to the surface.

Adult growth: time: summer/autumn; habitat: coastal areas, co-occurring species: juvenile herring

Nursery: coastal areas

Feeding: predation mode: filter/snapping, prey species: predominantly small copepods *Temora longicornis*, *Pseudo-Paracalanus* spp, *Acartia* spp.

Migrations: adult migration: seems that they migrate out from the more coastal over-wintering areas but any spawning migration like in herring, not documented

Larval drift and nursery areas: not documented but might depend on wind driven current situation transporting larvae out in the central North Sea and along the Danish west coast.

Long term trends: A high stock size in the mid 1970s. A significant decline in the spawning stock and recruitment occurred in the northwestern North Sea in the period 1978–1980. A more southeasterly distribution was observed in the following years and has been rather stable since. Corten (1986) concluded that the decline of the stock in the late 1970s was most likely related to environmental changes.

Nowadays characteristics: The stock status is rather imprecisely known but seems to be in good condition: the biomass appears to increase and the 2003-year class is strong and recruited to the fishery in 2004. In the 1970s, three spawning areas were distinguished, but the present situation is unknown.

Potential environmental influence: Spawning seems to start when minimum temperature is between 5.5º and ends at 6.0ºC. Sprat is an important prey species for other species, i.e. whiting, saithe, cod, mackerel.

Knowledge gaps: The most yawning gaps in knowledge are (1) better sampling of age and length composition, (2) validation of the criteria used in aging (sprat over-wintering as larvae do not show a winter ring, and, using the present criteria, would thereby be allocated to a wrong year class), and (3) existence of an autumn-spawning stock component, and its contribution to recruitment.

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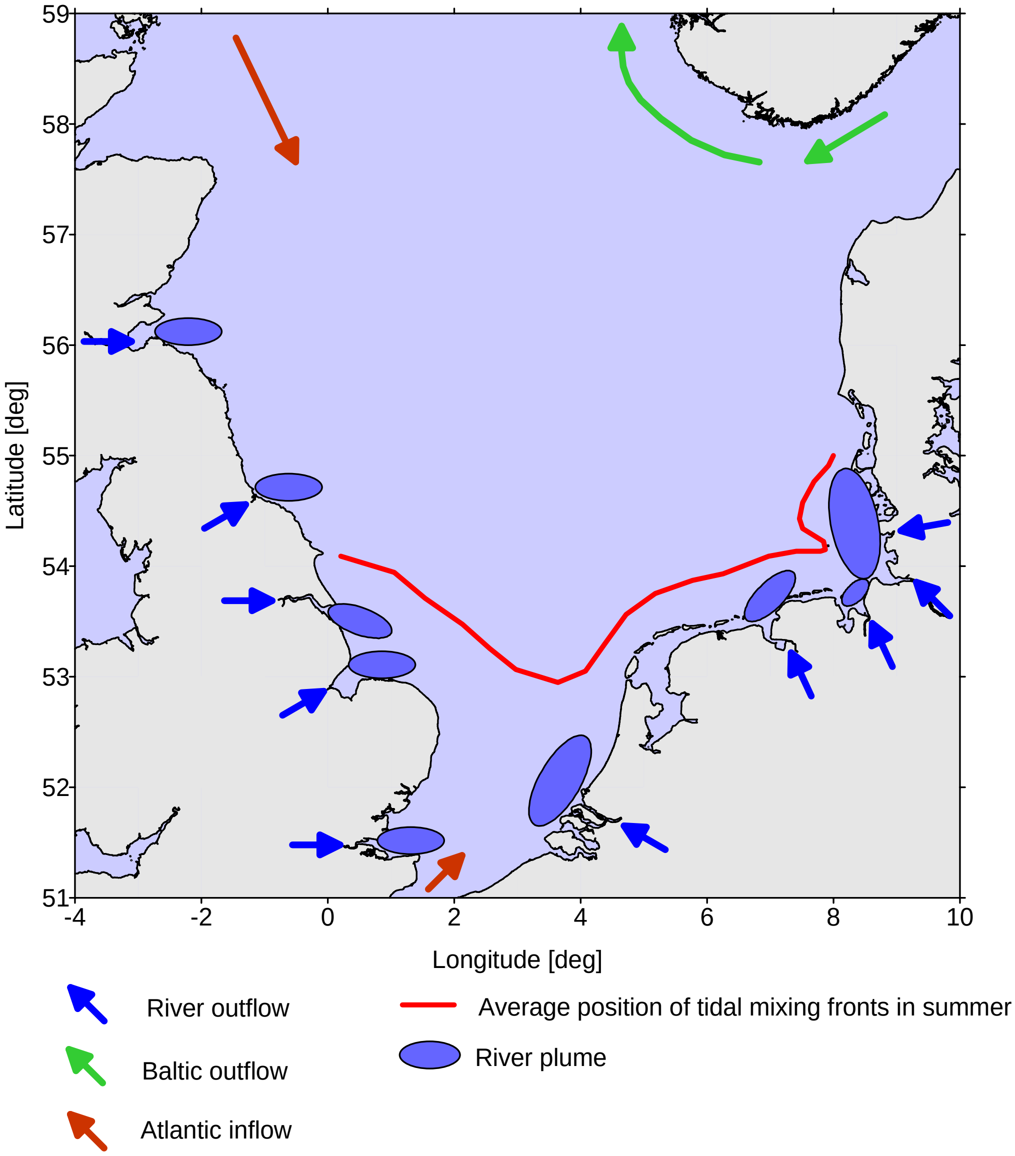
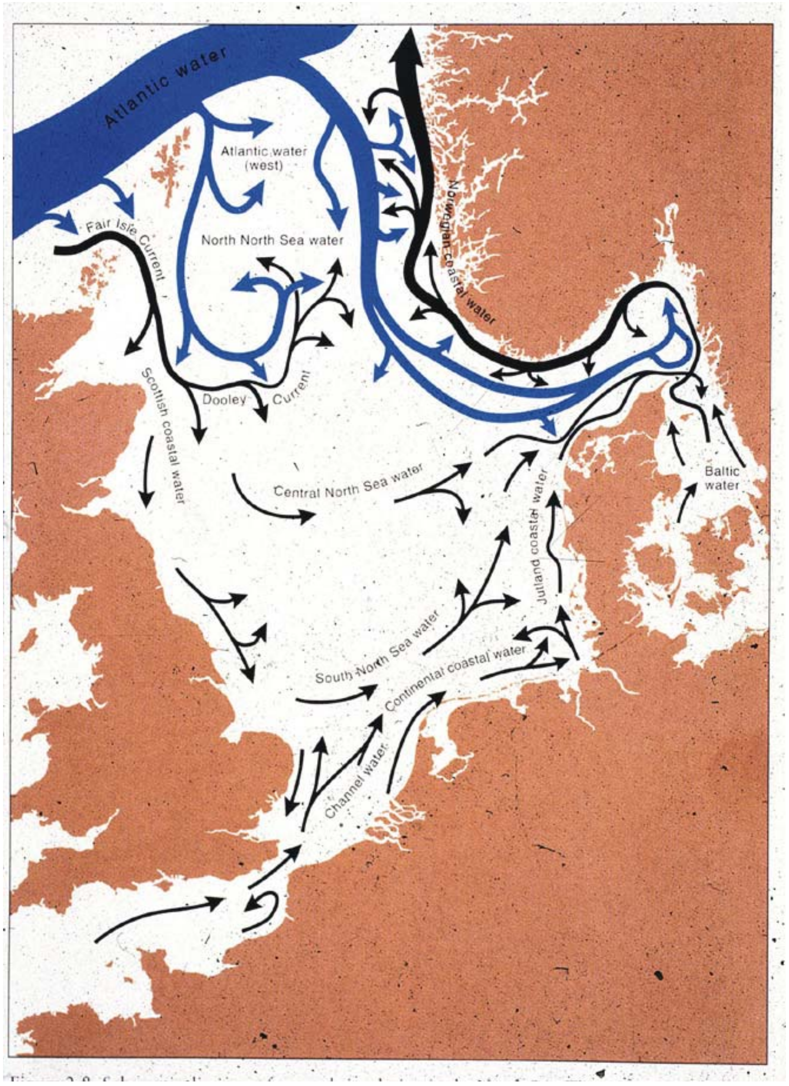
3.2.3 Schematic diagrams of North Sea physical features

General circulation is that of a gyre, with Atlantic inflow from the North West and Baltic outflow to the North East. Tidal mixing fronts are important in the southern part while in central and northern parts summer thermal stratification develops. The southern part also shows many river discharges.





Schematic outline of the general circulation in the North Sea showing the Atlantic inflow in the North West, the English channel inflow in the South West and the Baltic outflow in North East with their associated currents along the coast and across the North Sea.

3.2.4 ID card for North Sea herring

The high phenotypic plasticity in Atlantic herring (Jennings and Beverton, 1991; McQuinn 1997) makes the influence of the environment fairly strong on most characteristics of the population (Cushing, 1967). It also results in many substock components (Heinke, 1898; Redeke and van Breemen, 1907; Cushing, 1955; Zijlstra, 1958; Blaxter and Hall, 1960; Bridger, 1961) that interact with each other and are influenced in different ways by the environment (Wallace, 1924; Antony and Forgarty, 1985; Hulme, 1995). There are also strong density dependent effects in the population characteristics (Cushing and Bridger, 1966; Hubold, 1978; Winter and Wheeler, 1997) that are currently very pertinent as the population has increased substantially in the late 1990s (Nichols, 2001; ICES, 2004). Whilst most studies on North Sea herring refer to winter rings rather than ages, for simplification the term age and year will be used in this work. (However remember that for most North Sea herring spawning occurs at age –1).

Life History Traits. Life span to between 17–20 years (38–39 cm length; RIVO data). North Sea herring currently mature at between 2 and 3 years although this changes over time (3–5 years in 1950–1960s, Cushing, 1967) with population size and individual year class strength (ICES, 1965; 2004; Burd, 1978; 1984). Mean length at maturity also expresses a trend of rising from the 1930 to the 1970s and then declining (mean length mature 25–27cm at age 2, 26–28 cm at age 3, Saville, 1978). Atlantic herring is a synchronous determinate batch spawner (Bowers and Holliday, 1961; Blaxter and Hunter, 1982).

Spawning. Spawning of the main North herring population begins in the north of the North Sea in September and then progresses southwards with time, ceasing in January in the eastern English Channel (Boeke, 1906; Cushing and Burd, 1957, Zijlstra, 1969; Burd and Howlett, 1974; see Figure 1). Smaller coastal populations tend to spawn in the spring (Redeke and van Breemen, 1907; de Groot, 1980; Fox, 2001, Roel, *et al*., 2004). The number of spawning sites varies with stock size (Burd, 1985; Corten 1999a; 2001a) with a decline in spawning sites at lower biomass of North Sea herring. Due to the phenotypic differences exhibited by herring associated with each spawning site or spawning season (Baxter 1959; 1963; Cushing, 1958; Almatar and Bailey, 1989; Hulme 1995), the fecundity and egg size and obviously the associated sea temperatures result in larvae with different characteristics and energetic requirements (Sinclair and Tremblay, 1984; Heath *et al*., 1997). From here on these different groups will be refereed to as sub-components of the stock. Atlantic herring spawn benthic eggs that stick to the substratum or each other (Blaxter and Hunter, 1982; McPherson *et al*., 2003). In the North Sea, herring use gravel beds that are generally between 20–40m depth (see Cushing and Burd, 1957; Parrish *et al*., 1959). In thicker egg mats mortality due to oxygen deficiency can be high (Parrish *et al*., 1959; Aneer, 1985) and the mats attract predators (spurdog, haddock, mackerel, lemon sole and other herring; Hempel and Schubert, 1969; de Groot, 1980; Skaret *et al*, 2002, and personal observations). Atlantic herring are spatial repeat spawners (McQuinn, 1997) and this behaviour is either caused by natal returns to the “home” spawning bed or adopted behaviour (Harden Jones, 1968; Wheeler and Winters, 1984; McQuinn, 1997 and references cited therein). Like Pacific herring, Atlantic herring are assumed to spawn in waves (temporally discrete cohorts, see Ware and Tanasichuck, 1989; McPherson *et al*., 2003), but the evidence to support or reject this idea is weak. Recruits from one spawning will not necessarily mature in synchrony (McQuinn, 1997; Brophy and Danilowicz, 2003). Data on reproductive traits has been compiled by NAFO Working Group on Reproductive Potential and ICES Study Group on Growth, Maturity and Condition in Stock Projections.

Feeding. The main feeding time of North Sea herring is from April to June (Hardy, 1924; Savage 1937). Feeding intensity reduces in the build up to spawning and little feeding occurs over winter (Hardy, 1924). As the majority of North Sea herring are autumn and winter spawners, they exhibit a different energy-strategy than Norwegian spring spawning herring

(Isles, 1984; Winters and Wheeler, 1996; Slotte, 1999). Herring mostly feed by foraging and targeting prey items, with perhaps very limited filtering at low light intensities (Hardy, 1924; Batty *et al.*, 1986; 1990). The prey of North Sea herring varies by location (Savage, 1937), season (Hardy, 1924) and year (Last, 1989). Larvae feed on nauplii and micro-zooplankton (Checkley 1982), moving onto *Pseudocalanus*, *Paracalanus* and *Temora* copepodites and small meroplankton and then the adults feed on *Calanus*, *Temora*, *Oikopleura*, Schizopoda, Amphipoda and juvenile *Ammodytes* spp (Hardy, 1924; Savage, 1937; Last, 1989). In the north of the area the gastropod *Limacina* is also prominent in the diet. The seasonality in stomach contents is clear; fish eggs are present in the very early spring (when the feeding rate is low; Daan *et al.*, 1985; RIVO unpublished data) and in June (Savage, 1937). *Calanus* is eaten in large numbers in the spring, and then the smaller copepods begin to dominate the diet by summer. In years when post-larval and juvenile sandeels are present in the stomachs (about 50% in the southern and western North Sea), they are present in substantial biomass in February through to April (Hardy, 1924; Savage, 1937; Last, 1989). It is generally agreed that adult North Sea herring feeds in similar areas, whatever the subcomponent; to the north of the North Sea. Harden Jones (1968) suggested that there were subtle differences between the subcomponents but limited empirical proof has been found to support this hypothesis. It is clear that the distribution of feeding shoals is correlated with plankton abundance; herring shoals are rarely found near diatom blooms (Savage and Wimpenny, 1936), and their distribution whilst feeding is invariably associated with zooplankton abundance (Maravelias and Reid, 1997; Maravelias, 2001). Variability in spatial structure of these shoals tends to be at a scale of 6.5 and 20 nautical miles (Maravelias *et al*., 1996), ignoring the unresolved small scale variability. The distribution of the feeding herring shows very strong affinity with the southerly incursion of *Calanus* and *Limacina* into the North Sea every year (Bainbridge and Forsyth, 1972), both of which are influence by the Atlantic inflow. In years when the *Calanus* peak is further north, herring catches are also further north (Corten 2001b). The ratio between zooplankton production in the Buchan area, compared to the NE North Sea is also thought to influence where the herring feed (Bainbridge and Forsyth, 1972), as years with poor zooplankton production in the Buchan areas were also years when the herring moved further north (as determined by catches). Herring feeding shoals are often associated with feeding mackerel.

Wintering. The location of over-wintering is based on knowledge from historic herring catches, however, detailed information, in the form of maps, is lacking. Harden Jones (1968), Burd (1978) and Corten (2000) assumed that over-wintering occurs to the south west of Norway in most years. This is only applicable to those fish that have already spawned (the Shetland, Buchan and Banks components) as the Downs component is still spawning at this late stage in the year (Figure 3). Corten (2000) suggested that an early onset of C*alanus* production to the SW of Norway, results in a delay in the fish leaving this area to migrate to the normal feeding grounds. There is very little in the way of survey data to support the positions or the dynamics of the populations during the over-wintering period and in recent years there is no fishery data on the over-wintering fish to the east of the North Sea at winter time. The location of over-wintering may change over longer time scales (Alheit and Hagen, 1996; 1997; Corten, 1999b and references therein) when Open Skagerrak Periods or Bohslän herring periods take place. These are when some of the over-wintering herring enter the Skagerrak in wintertime.

Larval Drift and Nursery Areas. Due to the herring laying demersal eggs, the yolk sac larvae are highly associated with the spawning grounds (Postuma and Zijlstra, 1974). The abundance of young larvae is clearly linked to spawning potential (e.g. SSB) with a slight influence of temperature at time of spawning (Postuma and Zijlstra, 1974; Saville, 1978). Larval drift is thought to be driven by wind induced flows (Heath and Rankine, 1988; Heath *et al*., 1997). The larvae drift up to 9km a day (Heath and Rankine, 1988). MIK (Methot Isaacs-Kidd) net surveys of post larvae show a general movement of the larvae in an easterly direction (Figure 4, ICES 2004). The abundance of herring post-larvae in the MIK net survey shows a strong relationship to the following associated recruiting year class at age 2 (ICES 2004; Nash and

Dickey-Collas *in press*) suggesting that the year class strength is mostly determined between the larvae and post-larvae stages (see Anthony and Fogarty, 1985). Most post larvae metamorphose between April and July (Heath and Richardson, 1989). Variability in larval growth is thought to be largely temperature dependent with added variability from prey availability (Heath *et al.*, 1997; Fiksen and Folkvord, 1999; Johannessen *et al.*, 2000). In terms of larval abundance, the North Sea is not isolated, as larvae originating from the west of Scotland are also introduced by the Scottish coastal current into the northern North Sea (Heath and Rankine, 1988; Heath 1989). The metamorphosed juvenile 0 group fish begin to appear in the eastern North Sea (German Bight and Skagerrak) in the third quarter of the year (International Bottom Trawl Survey (IBTS) results shown in Heath *et al.*, 1997) and appear to stay there (and to a much lesser degree in other coastal areas) until they are 2 year old when they join the feeding adult population through active migration (Wallace, 1924). Recruiting to the adult population is probably size and maturity dependent (Brophy and Danilowicz, 2003). Burd (1984) suggested that at age 1 the population is most likely to exhibit density dependent effects on growth, but Heath *et al.* (1997) suggest that these differences in length come from variability in growth during the larval stages. The length of fish at age 1 has a great influence on their length at later ages (Hubold, 1978). Recent year classes of North Sea herring (e.g. 2000) are apparently exhibiting density induced decreases in growth and maturation rate (ICES 2004). The main co-occurring species on the nursery grounds are whiting, sprat, juvenile cod, sand eel and more recently anchovy.

Migrations. The migrations of North Sea herring have been broadly mentioned in the sections above and can be summarised by Figures 3 and 5. As stated above, the characteristics of and mechanisms for, over-wintering are vaguer than the spawning and feeding information. The occurrence of different migration patterns based on phenotypic differences of the subcomponents is currently thought to adhere to the Adopt-Migrant hypothesis (McQuinn, 1997), where generally stocks mix in the nursery areas and the summer feeding grounds, but migrate with others of their size as they approach the need to spawn. Isolated migrants (fast growers or slow growers) can join other subcomponents, and dispersal is more prevalent when established populations become unstable (after collapse or a recruitment boom, McQuinn, 1997; Corten, 2001a). Repeated imprinting of migration intensifies the spatial patterns making straying less likely with spawning experience. However evidence from the west of the British Isles (Brophy and Danilowicz, 2002; 2003) suggest that whether fast or slow growing, and from different nursery grounds, Celtic Sea maturing herring all return to their broader spawning area, suggesting natal homing (see Harden Jones, 1968).

Long-Term Trends. The North Sea herring fishery has a long history, with countries going to war of the rights to fish and land their catches (England and Holland in 1652–1654). The fishery was known to be variable and the variability in year-class strength lead to the 18th century idea that North Sea herring were part of a ‘mega’ stock that migrate to the Arctic in the winter and a variable proportion of the mega-stock return every year to the North Sea. This was discredited in the late 19th century. However it was often noted that variability in recruitment strength in the North Sea was considered less than in the Baltic (Cushing, 1996) and this is the case (Myers, 2001). It was also noted early on that the recruitment patterns from subcomponents of the stock were different (Bjerkan, 1917; Cushing 1992). In the 20th century, mechanisation of the fishery lead to severe impact by humans on the stock for the first time (Hodgson, 1936; Cushing and Burd, 1957; ICES 1965; Burd, 1978; 1985; Cushing, 1992; Nichols, 2001), as the stock went from a spawning stock biomass of over 2 million tonnes to below 50,000 tonnes. This was a real collapse as recruitment became highly impaired. The fishery was closed from February 1977 to Oct 1981 (Burd, 1985). The collapse affected different components of the stock in different ways, with the southern components declining before the northern components (Burd, 1985; Cushing, 1992). As the stock declined, spawning became restricted and many spawning grounds became abandoned. Recovery was slower than predicted but the stock was considered healthy again by the early 1990s, however as decline in biomass occurred again in the mid-1990s and a swift response by management ensured that the stock did not collapse (Nichols, 2001). Currently the stock is now perceived to be above 2 million tonnes and density dependent effects are being detected again. It is widely accepted that the recruit to stock relationship is domed for herring and that productivity per spawner is impaired at high spawning biomasses (Anthony and Fogarty, 1985; Zheng, 1996; Fox 2001) but overall stock size or area size may influence this density dependent effect (Winters and Wheeler, 1987). In the last 25 years, only 20% of year classes of North Sea herring have failed to correspond to a virtually linear relationship between spawning potential and recruitment strength at age 1 (Nash and Dickey-Collas *in press*).

Recent Characteristics. The production of larvae is increasing, but the ichthyoplankton surveys may no longer be covering the whole stock, as stock recovery leads to spawning on grounds away from the main centres (e.g. on Dogger Bank). The higher temperatures in the southern North Sea at present are apparently not restricting the spawning of herring in the area (ICES 2004). Recent work has concentrated on the interaction between the North Sea herring stock and the western Baltic spring spawners. The juveniles of these stocks mix in the Kattegat during their nursery phase. The mean weights at age are still declining from the high in the 1970s. Apart from the variability between the relative proportions of the subcomponents of the stock, there is no reason to suggest that the current migrations are different from those described throughout the 20th century.

Potential Environmental Influence. Corten (2001a) suggests that many recent fluctuations in the distribution of North Sea herring are driven by stock increase, changes in the zooplankton production and variability in the Atlantic inflow by the Fair Isle Current. The interaction of year class strength and environmental signals (combined imprinting effects on individual, hence lag effects on the population) may make the interpretation of the influence of environment difficult (Corten, 2001a). There appears to be a relationship between the changes in the distribution of over-wintering herring and the North Atlantic Oscillation (NAO), as seen in the Open Skagerrak Periods (Alheit and Hagen, 1996; 1997; Corten, 1999b) and the location of the feeding grounds in relation to areas of high zooplankton abundance (see above). The spatial nature of the life cycle has never been accounted for in an MSVPA (Multi-Species Virtual Population Analysis) type of approach (ICES 2003), hence realistic multispecies interactions are difficult to assess. An attempt to consider the spatial nature of North Sea herring dynamics was begun relatively successfully by Heath *et al*. (1997). Overall, the evidence suggests that changes in horse mackerel and sand eel abundances, as well as *Calanus*, *Temora* and *Pseudo/Paracalanus* production (Beaugrand, 2003; Reid *et al*., 2003) will impact on herring production and distribution (Bainbridge and Forsyth, 1972), and *visa versa*. The increased abundance of herring, combined with a reduction in zooplankton, will increase the impact of herring on the egg survival of plaice and cod (Ellis and Nash, 1997; Segers *et al*., in prep). Sprat and herring appear to have a complex relationship with some sympatric signals (Tortensen and Gjøsæter 1995) and divergent signals in other areas (Corten 2001a).

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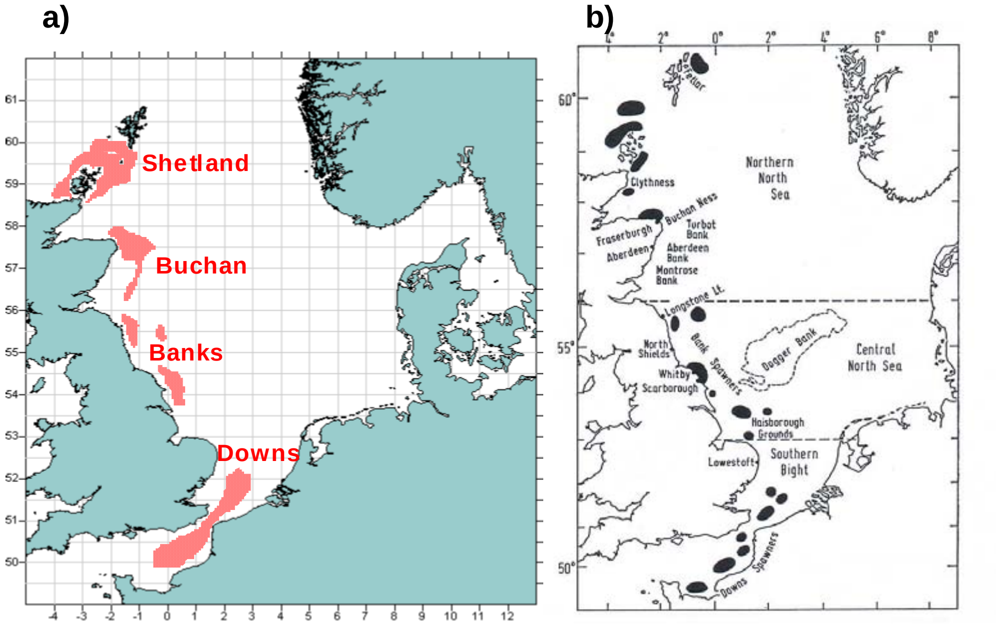

Figure 1: Major herring spawning grounds. Left: inferred from the presence of newly hatched larvae in the ICES herring larval survey (1996 to 2003) and labelled by stock sub components; right: from Burd and Howlett (1974). Spring spawning coastal populations are not shown. Recent ICES surveys do not cover the Dogger Bank area (see Figure 2).

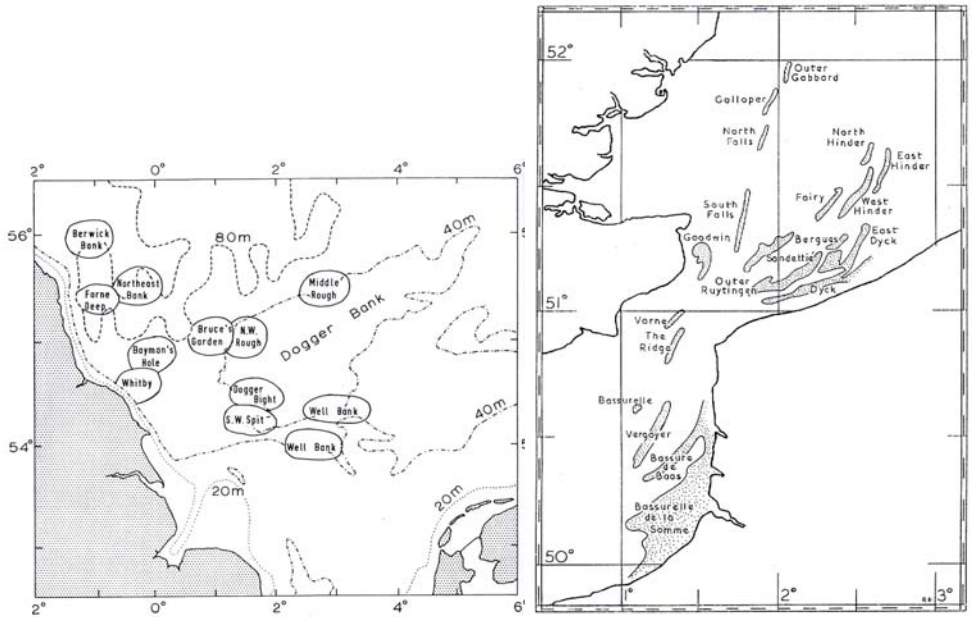

Figure 2: Specific spawning grounds of Banks and Downs sub-components of the North Sea herring stock. Left: the Banks sub-component (from Cushing and Bridger, 1966), spawning does not occur at all of the grounds. Rigth: the Downs sub-component (from Cushing and Burd 1957).

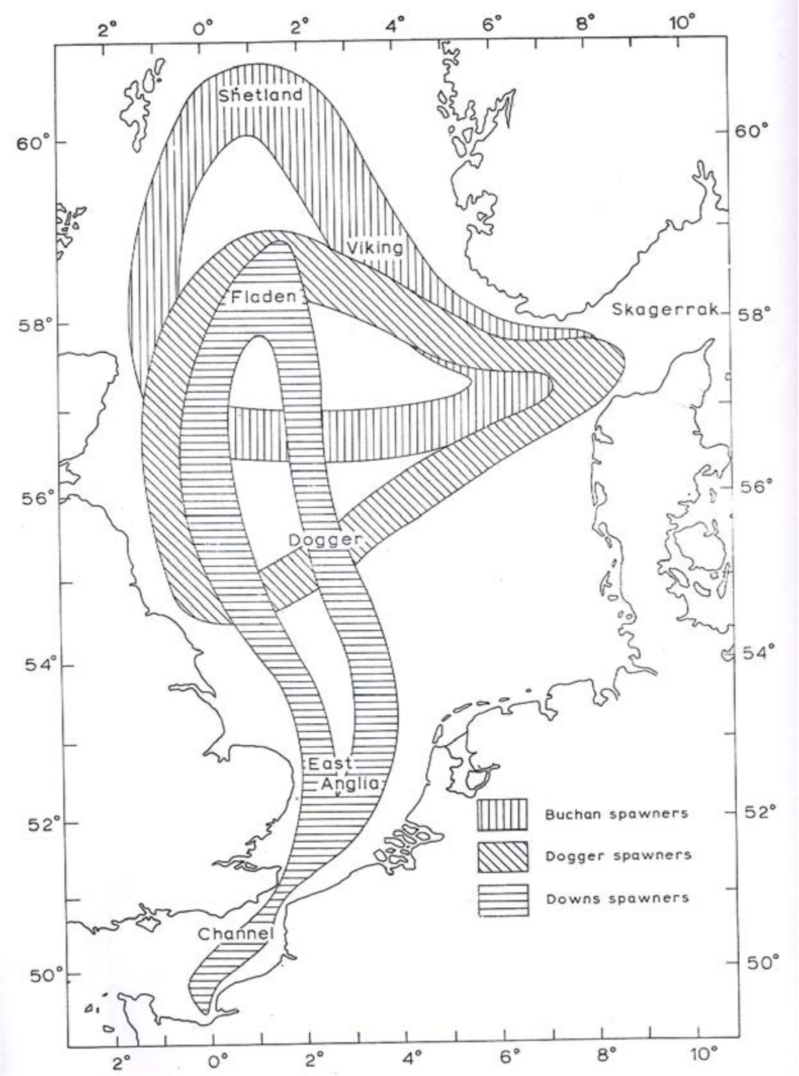

Figure 3: Suggested migrations routes of three subcomponents of the North Sea herring stock. From Cushing and Bridger (1966).

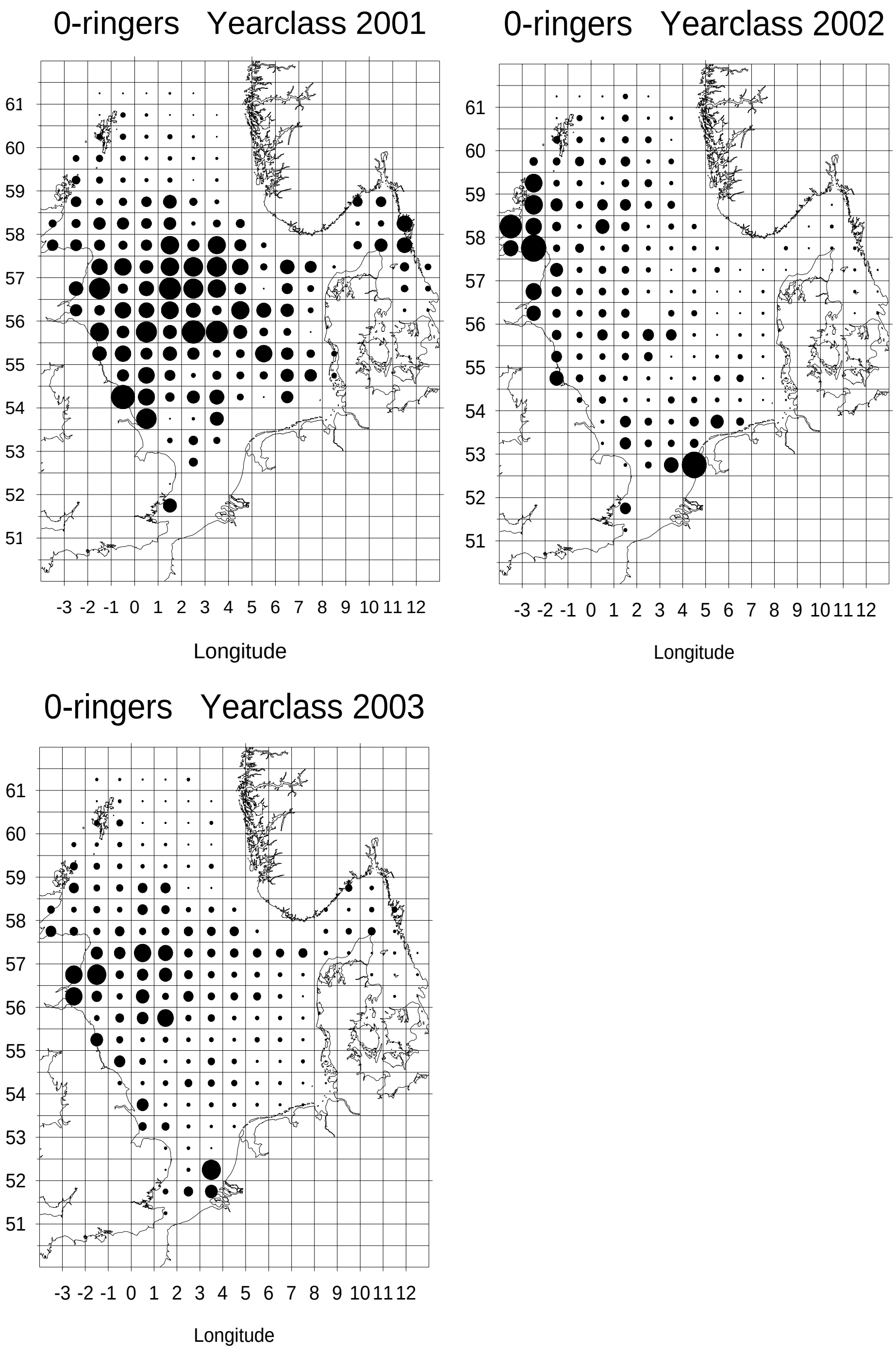

Figure 4: Distribution of 0-ringer herring, year classes 2001–2003. Abundance estimates of 0-ringers within each statistical rectangle are based on MIK catches during IBTS in February 2002–2004. Areas of filled circles illustrate densities in no m², the area of a circle extending to the border of a rectangle represents 1 m². Taken from ICES (2004).

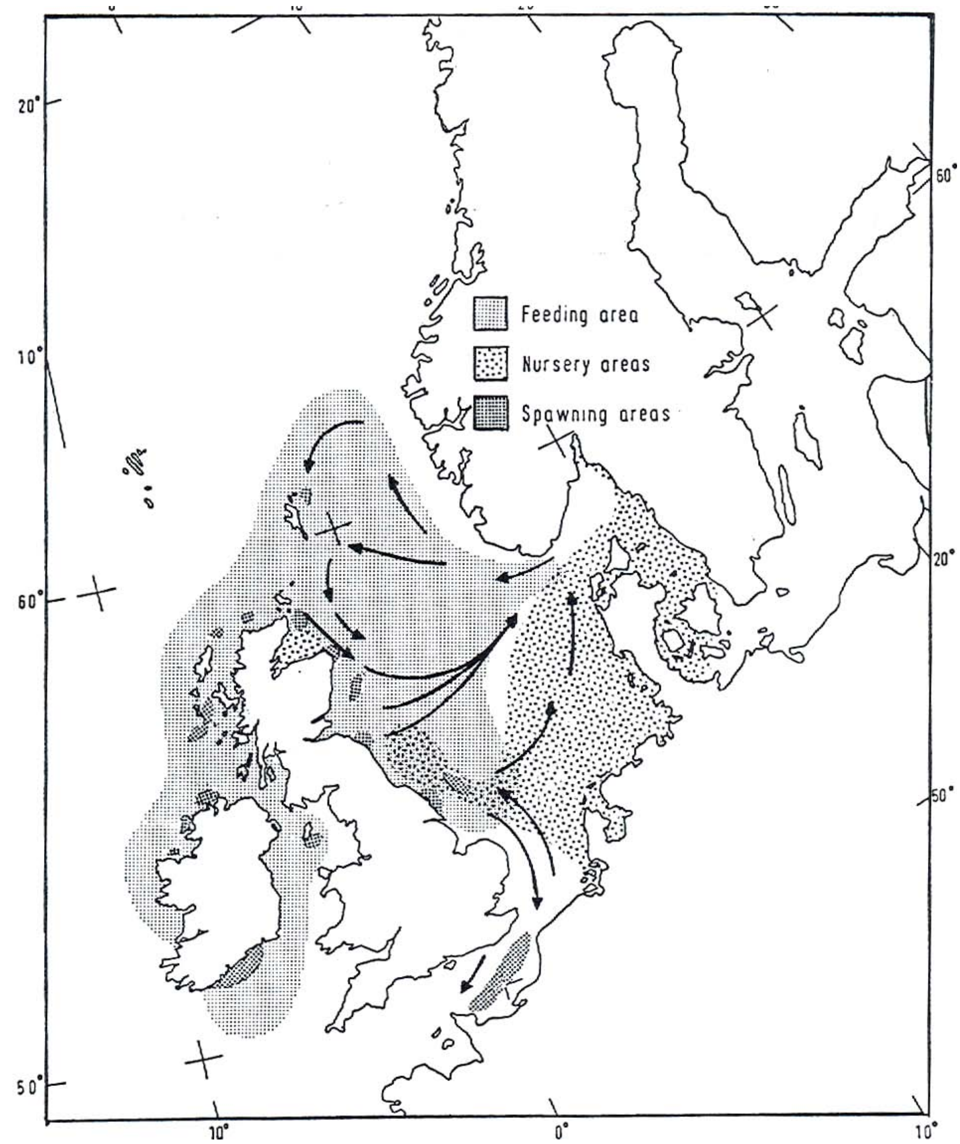

Figure 5: Schematic summary of generalised migration patterns of North Sea herring, taken from Burd (1978).

3.2.5 ID card for Celtic Sea herring

Life History traits: Life span = up to 11+ years, 50% mature at age one and 100% mature at age two. Changes in maturity over time have been documented and are linked to growth changes (Molloy, 1979); *Clupea harengus* is a determinate one-batch spawner (Blaxter and Hunter, 1982).

Wintering: Shoals congregate for spawning in inshore waters along the coastline and then move to deeper waters after spawning. Some shoals of spent fish have been found close to the coast.

Spawning

Location: Spawning grounds are well defined along the south and southwest of the Irish coast (Molloy, 1980). Location of spawning grounds, derived from the distribution of small sized herring larvae, ready to spawn adult fish and anecdotal information of fishermen overlap and are consistent over years (Breslin, 1998). Individual spawning beds within the spawning grounds have been mapped and consisted of either gravel or flat stone (Breslin, 1998).

Timing: Celtic Sea herring consist of a mixture of autumn and winter spawners with spawning occurring between late September and February. The timing of peak spawning is undergoing change as autumn spawning was not evident prior to 1974 (Molloy and Cullen, 1981). Spawning off the southeast coast occurs in autumn from October to November and in winter with peak spawning in January (Molloy, 1989; Breslin, 1998). Southwest Herring are autumn spawners that spawn between September and October but an extension of spawning is evident in recent years with an increase in winter spawning occurring around the Dingle peninsula.

Feeding: Feeding occurs in spring and summer with fat reserves peaking in June to August (Molloy and Cullen, 1981). Feeding is interrupted during spawning and autumn spawners, spawning in September, resume feeding briefly in October before stopping again during the winter. No feeding occurs throughout the winter period. Feeding grounds are located in offshore waters in the central Celtic Sea (ICES, 1994). The summer offshore feeding grounds have shown an absence of immature stage one fish indicating that pre-recruits do not migrate with the adults to the summer grounds (Burd and Bracken, 1965). Shoals are dispersed during feeding (Molloy, 1980) and are located in the upper part of the water column (Breslin, 1999).

Migrations: Juveniles migrate from nursery areas to spawning areas at first time of spawning. Age distribution of the stock suggests that recruitment in the Celtic Sea occurs first in the eastern part of the Celtic Sea and follows a westward movement (ICES, 1994). Tagging experiments and analysis of otolith microstructure have shown that juveniles migrate from the Irish Sea to the Celtic Sea (Molloy *et al.*, 1993; Brophy and Danilowicz, 2002, 2003). The juveniles are believed to originate from the Celtic Sea stock and reside in Irish Sea nursery areas. In autumn and winter they migrate back into the Celtic Sea for first time spawning (Molloy *et al.*, 1993). Adult Celtic Sea herring migrate from spawning grounds to feeding grounds and vice versa in spring and autumn (Burd and Bracken, 1965). Shoals congregate and move into the shallow coastal waters for spawning after which the shoals disperse into deeper offshore waters for feeding in the central Celtic Sea (Molloy, 1980). Off the southwest coast herring congregate for spawning in autumn but little is known about where they reside in winter (ICES, 1994).

Larval drift and nursery areas: Herring larvae are found between October and January in close proximity to above described spawning grounds. Larvae are transported by currents either into the Irish Sea or westwards along the southcoast (Molloy and Corten, 1975; ICES, 1994). Nursery areas are located in the bays and estuaries of the south and southwest coast (Hay, 2000) and in the western and eastern Irish Sea. Microstructure analysis of otholiths from juveniles in Irish Sea nursery grounds indicated that a high proportion of individuals caught were winter spawners, originating from the eastern Celtic Sea. Juveniles originally from the Celtic Sea stock were found to have different growth rates depending on whether they resided in nursery areas in the Celtic Sea, the western and eastern Irish Sea. The variability in growth rate patterns occurred mainly in the larval phase and could be attributed to the different temperature regimes of the Celtic and the Irish Seas, suggesting that larval drift into the Irish Sea could be a factor in Celtic Sea recruitment variability (Brophy and Danilowicz, 2002). Larval dispersal can further influence maturity at age. In the Celtic Sea faster growing individuals mature in their second year (1 w. ring) while slower growing ones spawn for the first time in their third year (2 w. winter ring). Pre-recruitment dispersal such as into the Irish Sea and subsequent decrease in growth rates could thus determine whether juveniles are recruited to the adult population in the second or third year (Brophy and Danilowicz, 2003).

Long term trends: In the early part of the last century until the 1950s the fisheries were relatively small and catches remained below 15 000t (Burd and Bracken, 1965). Sharp increases in the catches in the 1950–1960s period coupled with low recruitment caused the fisheries to collapse and a closure was implemented in 1977 (Molloy, 1980). The fishery was reopened in 1982 and ICES Divisions VIIa S and VIIg were joined with Division VIIj to form a new management and assessment area. A number of good year classes recruiting to the stock in the 1980s helped to rebuild the stock. In addition, management measures in the form of rotational spawning ground closures were implemented (Molloy, 1989). There have been temporal trends in mean weights at age with an increase of mean weights at age towards the late 1970s followed by a continual decline since then (ICES, 2004). Mean lengths at age have also been declining since the late 1970s (ICES, 1994).

Present characteristics: There has been a strong decline in biomass since 1995. Poor recruitment in the mid/late 1990s followed by stronger year classes in ’99 and ’00 have resulted in a high proportion of young fish in the population (ICES, 2004).

Potential environmental influence: In the Celtic Sea, herring is at its most southerly distribution in the northeast Atlantic and is therefore expected to be vulnerable to environmental fluctuations. Warm water temperatures cause a fast growing and fast maturing stock but high temperatures are expected to have a negative effect on recruitment as has been shown in other species at the southern limits of their distribution (Brander, 1998). Physical factors controlling the dispersal of larvae from the Celtic Sea into the Irish Sea such as wind driven circulation and the formation of the Celtic Sea front influences transport to nursery grounds and can therefore affect growth rates and subsequent maturation age (Brophy and Danilowicz, 2002, 2003).

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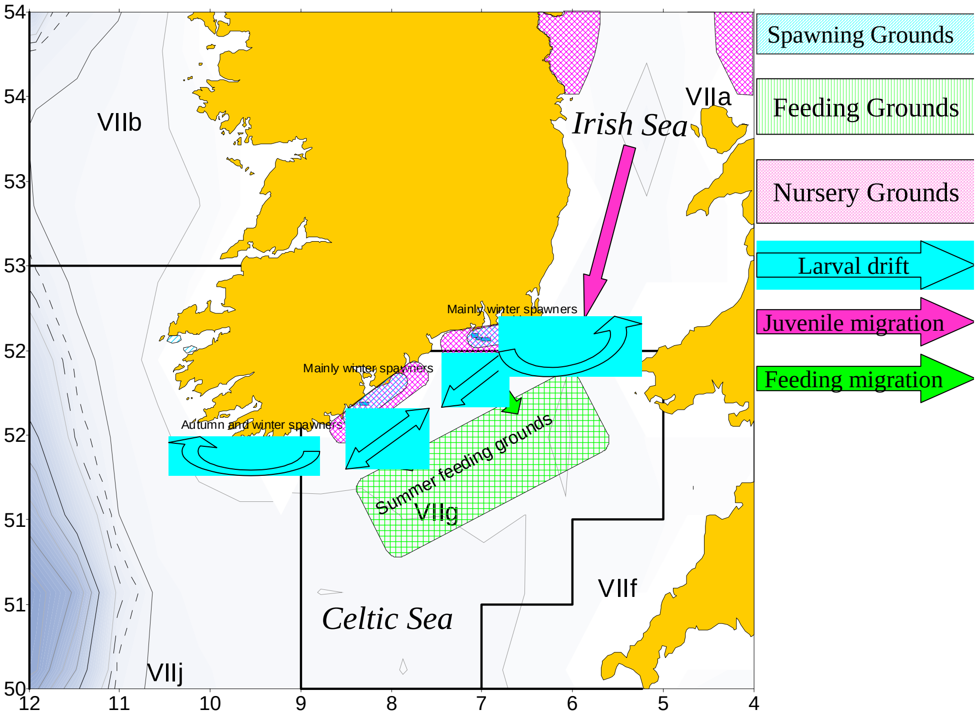

Figure 1: Schematic presentation of the life cycle of Celtic Sea and VIIj Herring.

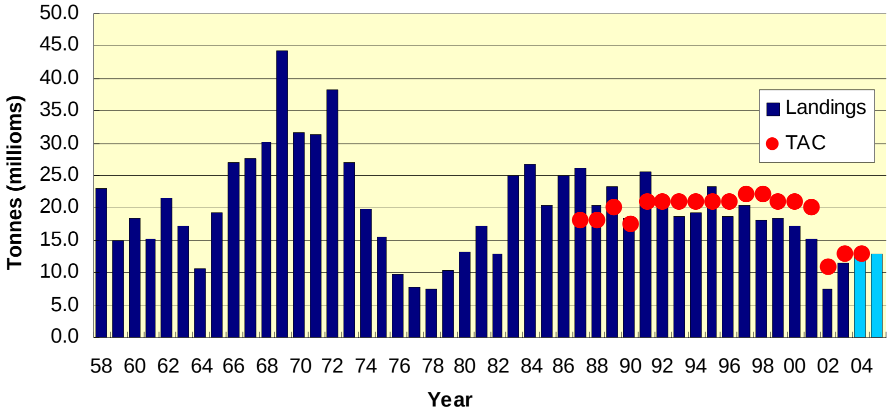

Figure 2: Long-term changes in landings for Herring in the Celtic Sea and VIIj.

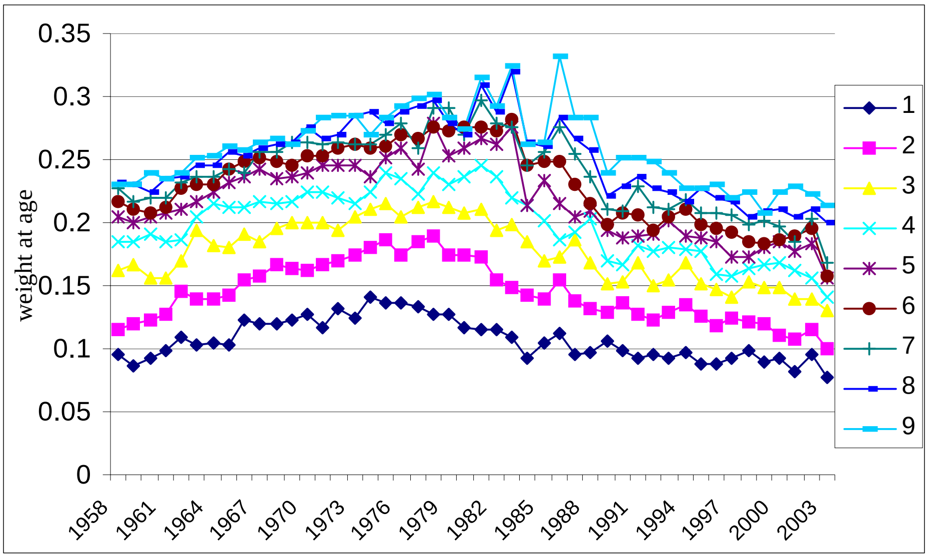

Figure 3: Long-term changes in mean weight at age for Celtic Sea Herring.

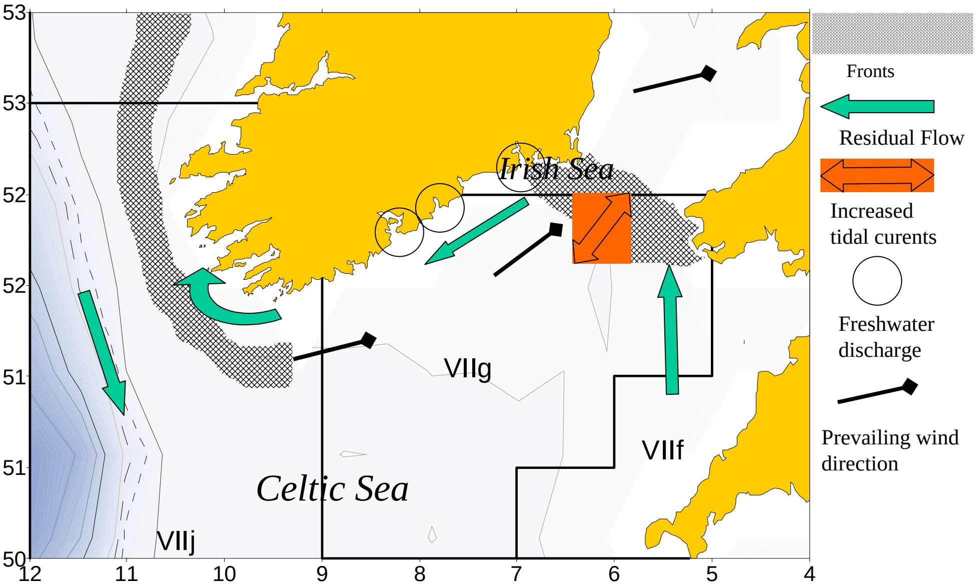

Figure 4: Schematic presentation of prevailing oceanographic conditions. Fronts are 1) the Celtic Sea front in the eastern Celtic Sea, a tidal-mixing front which limits exchange between tidally mixed water from the Irish Sea and stratified water from the Celtic Sea and 2) the Irish shelf front to the west of the Celtic Sea, a thermohaline front separating coastal shelf water from Atlantic water. Residual currents are the Irish coastal current, a clockwise density current and the Atlantic shelf edge current. Circulation is mainly wind driven with prevailing south-easterly winds from October to May and density driven from May to October when the Celtic Sea is stratified.

3.2.6 ID card for Northwest Irish herring

Life History Traits: While NW herring can reach up to 14 years the oldest age group in the assessment is 9+ group. 100% mature at year 3, (2 w. rings). No changes in maturity over time have been documented (ICES, 2004). *Clupea Harengus* is a determinate 1-batch spawner (Blaxter and Hunter, 1982).

Wintering: Spawning occurs during the autumn and winter months and shoals congregate and move to inshore spawning grounds. After spawning shoals disperse and move to offshore waters. The distribution of shoals after spawning has changed. Aggregations of over-wintering fish have traditionally been fished along the west coast but recently no high concentrations of over-wintering fish have been found in these areas (ICES, 1994; Anon., 2000). Some occurrences of over-wintering fish have still been found northwest of Ireland for several weeks in January (Anon., 2000).

Spawning: Spawning occurs in shallow water close to the west and northwest coast of Ireland (Molloy, 1983; Molloy and Barnwall, 1988; Breslin, 1998) although recently spawning also occurs in deeper waters (Anon., 2000). West coast Herring are autumn spawners with spawning grounds off the mouth of the river Shannon, around the entry of Galway Bay to east of Aran Islands and along the coast of Sligo and Mayo (ICES, 1994; Breslin, 1998). Spawning has been traditionally between September and October with a southwards progression of spawning (Molloy, 1983; Grainger and McArdle, 1985; Molloy and Barnwall, 1988). Recently spawning has extended into November (Breslin, 1998; Anon., 2000). In the Northwest herring fishery there are three separate spawning units: autumn spawners during September and October in Donegal Bay and winter and spring spawners off the north coast (Molloy, 1983; Breslin, 1998). Anecdotal evidence from fishermen suggests that the spring spawning component of the northcoast is recently increasing (Breslin, 1998). Peak spawning times from the autumn spring component have been inferred by larval surveys and occur late September and October in water temperatures ranging between 10–12ºC (Molloy and Barnwall, 1988).

Feeding: Feeding times have been analysed in terms of fish fat content. No feeding occurs throughout the winter with a minimum fat content in March and April. Feeding is resumed in late spring and fat reserves peak during July and August. Feeding is also interrupted during spawning and autumn spawners briefly resume feeding in October/November before overwintering (Molloy and Cullen, 1981).

Migrations: Tagging experiments conducted in 1990 off the west coast of Ireland (Co. Mayo) have shown that the majority of fish migrated northwards between July and February and were recaptured not far from the release area. Some fish also migrated southwards and were captured between October and November in Galway Bay, the mouth of the river Shannon and Dingle Peninsula. Maturity stages of recaptured fish suggested migration to spawning grounds (Molloy *et al*., 1993).

Larval Drift and nursery areas: Distribution of different larval size categories have shown that larvae spawned on the west and northwest coast follow a northwards drift with Donegal larvae drifting towards the Scottish West Coast (Grainger and McArdle, 1985; Molloy and Barnwall, 1988). In depth studies in Galway Bay indicated that larvae are circulated in a cyclonic gyre in the bay with some larvae being advected (Grainger). Maximum larval depth is below the surface between 5-15m and there has been no evidence of diel migration, or variation in the distribution of different larval size categories (Grainger). Important nursery areas are Galway Bay and Donegal Bay, several inshore lochs and also Stanton Bank, an offshore area northwest of the Irish north coast (ICES, 1994; Anon., 2000).

Long term trends: Spawning stock size peaked in 1988 and has followed a steady decline since then. Landings have drastically fallen since 1999 (ICES, 2004). Long-term changes in the spawning component have occurred in the area and time of spawning. In 1920–1930s there was a north coast fishery that spawned in the North in spring and an autumn fishery that spawned in the west of Donegal. Sligo and Galway had no important fishery. In the ‘40–50 herring all over Ireland declined and the recovery in the 1960s occurred mainly in Mayo, Sligo and Galway as autumn spawners. Recently there has been a shift to the northern fishery, while little fishing occurs on the west coast of Ireland. The northwest herring fishery was based on hard (stage V) herring but towards the late 1980s the focus shifted to spawning herring.

Present characteristics: The stock seems to have stabilised at a low level. Anecdotal evidence from fishermen and catch data indicate that in recent years spawning occurs in deeper water, herring are distributed more northerly and spawning occurs later (Anon., 2000).

Potential environmental influence: Herring abundance in the form of catch data was analysed in relation to oceanographic variation by Grainger (Grainger). Long-term trends in herring catches showed herring abundance decreasing with a warming of the sea surface temperature in the 1930s–1940s. Short-term fluctuations of catches are believed to reflect real fluctuations in herring abundance on a circle of ca 10 years and were correlated with: (i) Salinity in western approaches especially in the two winter quarters at a lag period of 3 years; (ii) SST on the shelf and west off the shelf especially November, December, and January with a lag period of 3–4 years. Although herring correlated negatively to temperature in the long term, short-term variations were positively correlated.

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Supporting igures 1–3.

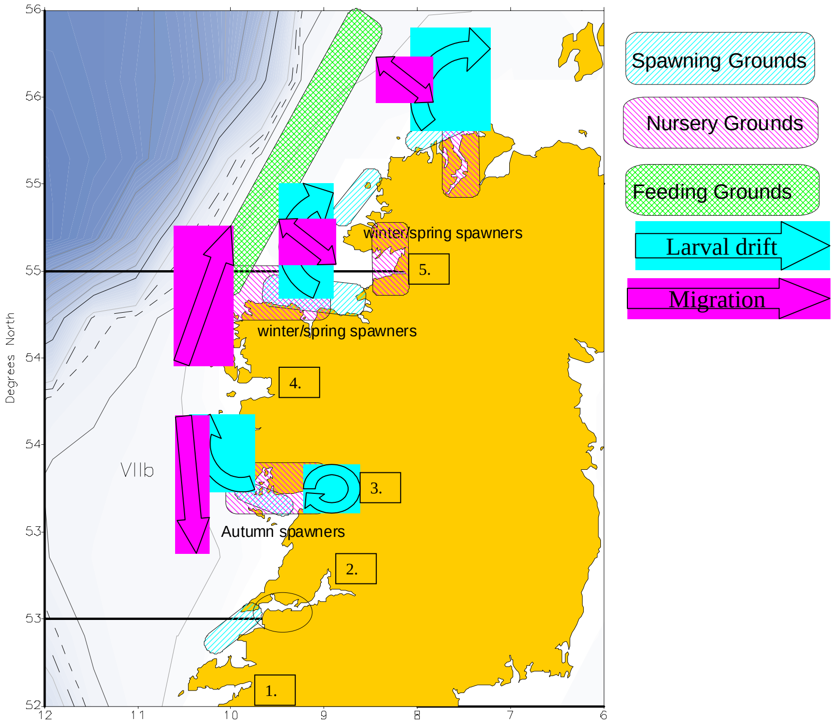

Figure 1: Schematic presentation of the life cycle of Herring west and northwest of Ireland. Numbers represent locations mentioned in the text: 1: Dingle Peninsula, 2: Shannon River, 3: Galway Bay, 4: Mayo, 5: Donegal Bay.

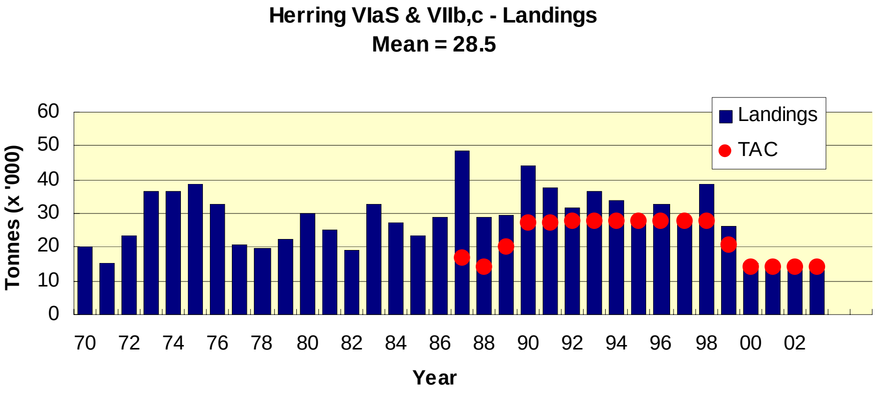

Figure 2: Long-term changes in landings for Herring in the northwest of Ireland (VIaS and VIIIb,c).

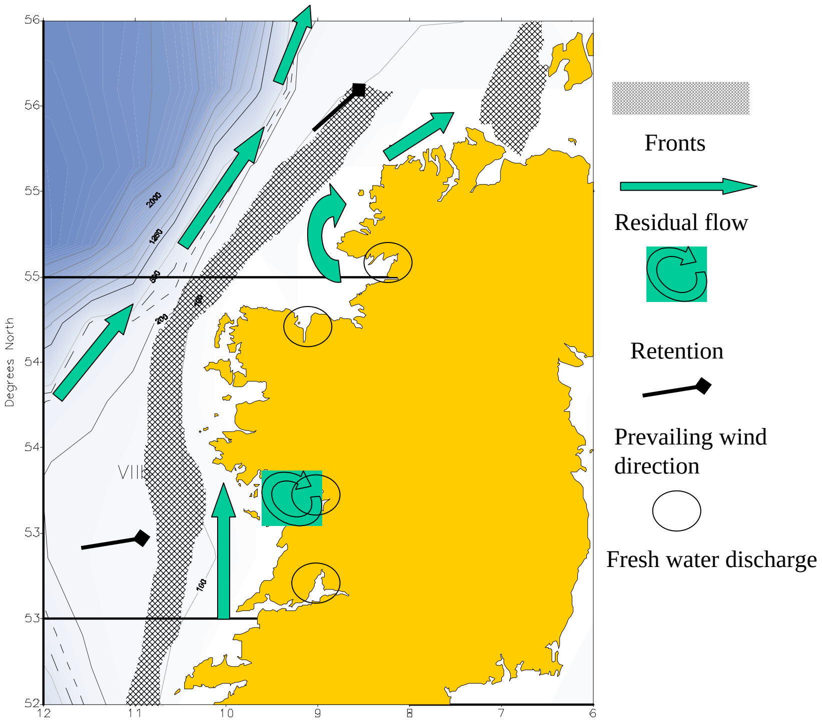

Figure 3. Schematic presentation of prevailing oceanographic conditions in the west and northwest of Ireland. Fronts are 1.) the Islay front northeast of Ireland and 2.) the Irish shelf front to the west of the Celtic Sea, both fronts are a thermohaline fronts persisting throughout the year with an additional tidal mixing front developing near Islay during summer stratification. Residual currents are the Irish coastal current, a clockwise density current and the Atlantic shelf edge current. Circulation is mainly wind driven with prevailing south-easterly winds from October to May and density driven from May to October.

3.2.7 ID card for Baltic herring

Life history traits: life span = 9–10y (but up to 20y); maturity = 2–3y; maximum length: 25–32 (depending on the area, decrease from south-west to north-east); 1-batch determinate spawner.

Spawning: time: March-May, it may continue during summer in the northern areas; habitat: spawning occurs on filamentous green and brown algae or on hard seabed; behaviour: investigated only in some areas, mostly in the Archipelago Sea. Succeeding schools seem to enter the inshore area throughout the spawning season. Egg deposition proceeds from very shallow (2–3 meters) to deeper areas during the spawning season.

Growth: time: late summer-autumn-early winter; schooling behaviour: feeding schools forming at sunrise and migrating downwards during the day, dispersed in surface waters at night; older and larger herring deeper in the water column; co-occurring species: sprat and cod; factors acting on growth: variations in prey abundance and intra- as well inter-specific competition with sprat.

Feeding regime: mode: particulate or filtering depending on prey density and size; period: daylight hours; prey species: mostly large copepods (e.g. *Pseudocalanus elongatus* and *Temora longicornis*) but also cladocerans in late summer and autumn; larger individuals feed also on nektobenthos (mysids, amphipods and polichaetes); in winter larger share of nektobenthos; main feeding period: summer and autumn.

Migrations: adult spawning migrations to inshore areas during spring and feeding migration to offshore areas in summer-autumn. Juveniles are associated to coastal areas. Several subpopulations are discerned depending on the different spawning sites.

Nursery areas: inshore areas all around the Baltic basin.

Trends: constant decrease in SSB from 1970s to 2001, thereafter an increase occurred. The abundance of the spawning stock did not follow the same pattern as SSB, being quite constant between the mid 1980s and mid 1990s. The discrepancy between SSB and spawning stock abundance during this period seems to be due to a strong decrease in weight-at-age. Recruitment shows a general decrease from the 1970s, however some peaks occurred in the early 1980s and 1990s. The 2003 had also a relatively high recruitment.

Environmental influence: even though recruitment seems to be linked to SSB (a stock-recruitment relationship do exists), environmental factors can affect both directly and indirectly herring recruitment by acting on different phases of its life-cycle. Oxygen, temperature and the life cycle of the algae the eggs are deposited on may, for example, directly affect egg survival. Temperature influences also the timing of zooplankton production in the Baltic and, in turn, herring larvae feeding and growth. On the other hand, salinity drives the dynamics of the main food species for adult herring and, therefore, adult herring growth and condition. Herring condition prior to spawning is important for the hatching success and survival of its eggs. However, biotic interactions, as intra-specific competition and competition with sprat, act also on herring condition and, thus, need to be carefully addressed when studying the environment effects on herring recruitment.

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Supporting figures 1–4.

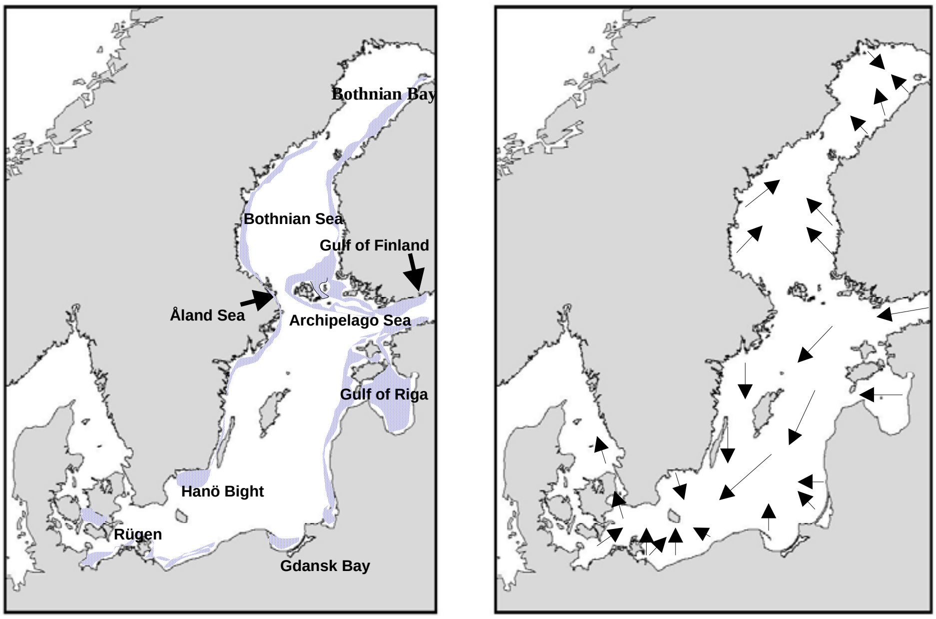

Figure 1: Spawning locations and feeding migration of Baltic herring.

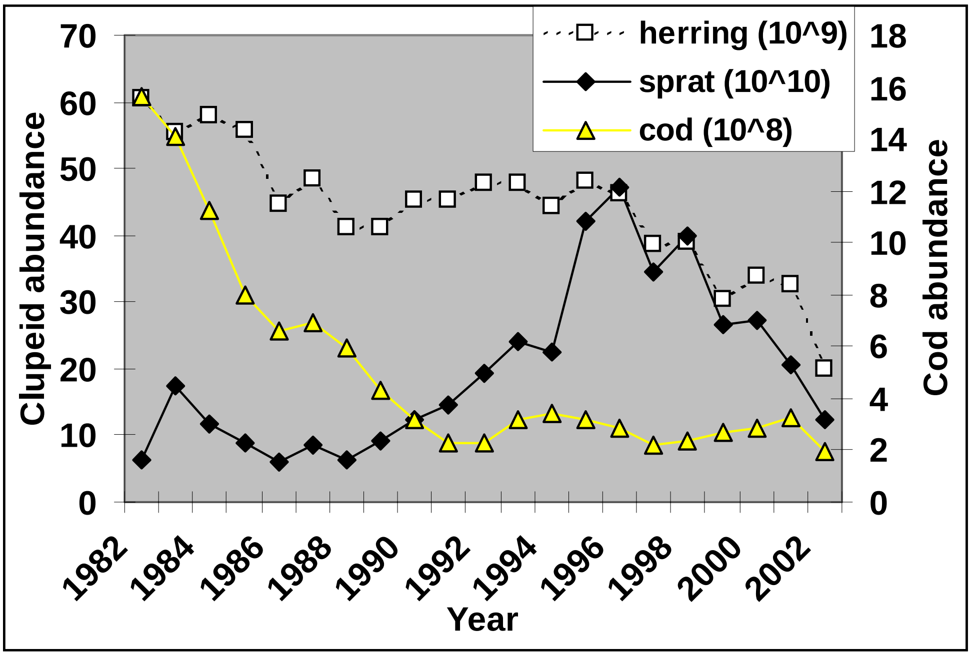

Figure 2: Long-term trend in catches.

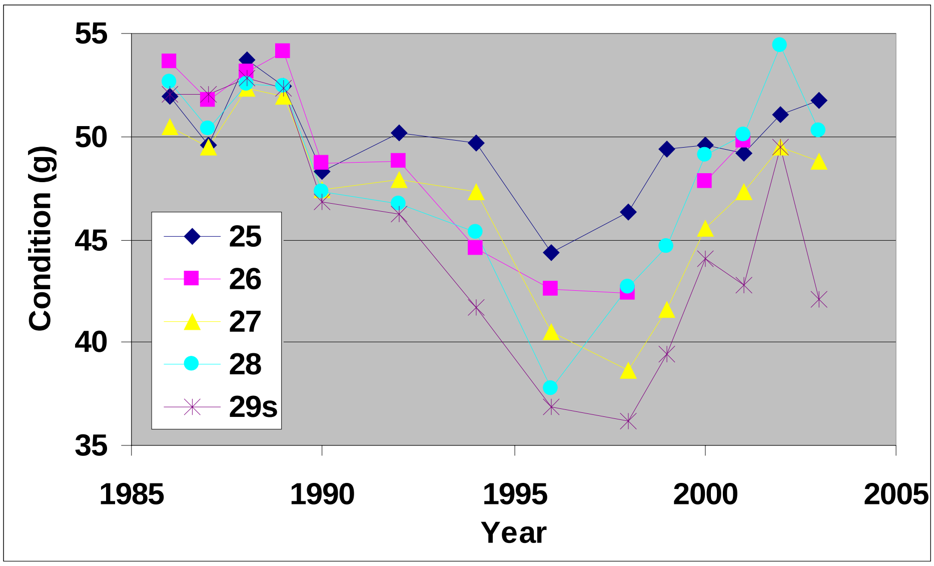

Figure 3: Condition factor of fish caught in acoustic surveys.

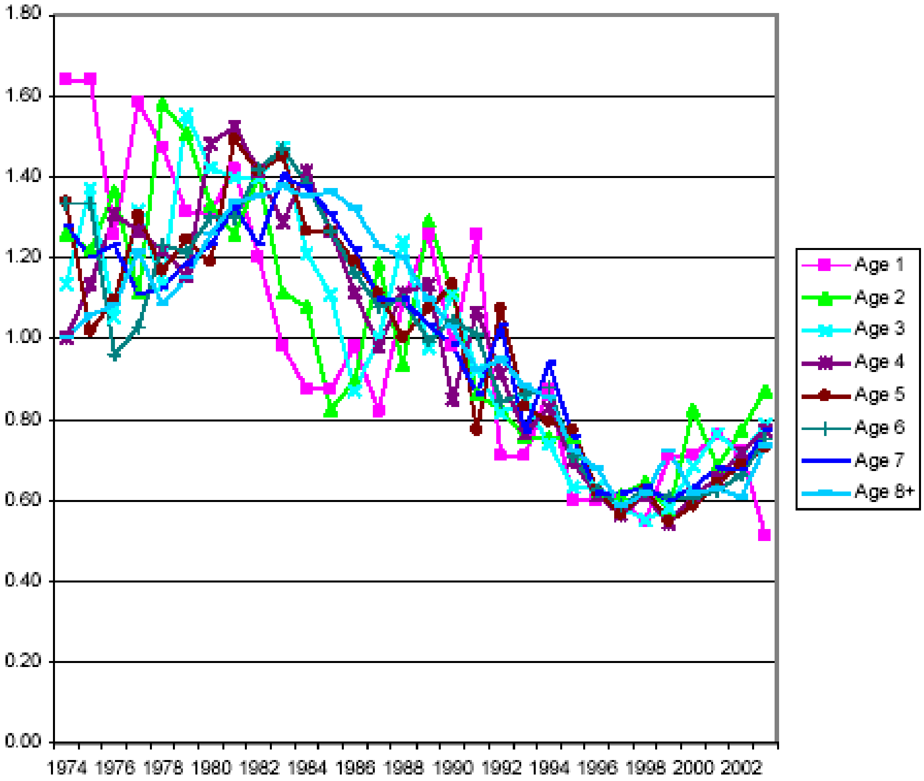

Figure 4: weight at age of fish caught in acoustic surveys.

3.2.8 Synthetic schemes of life cycles for the different species

The life cycles of the different species and populations have different spatial scale and structure. Structural differences between life cycles have potential consequence on population dynamics, linkage with environmental features and management strategies. Differences between life cycles were synthesised into schematic structural diagrams.

A population was defined as a life cycle that manages to get closed. Similar basic processes occur in all life cycles : adults perform spawning, feeding (possibly wintering) ; juveniles perform growth by feeding ; larvae perform growth and survival by feeding. In all life cycles, encounter between juvenile and adult fish is critical for the life cycle closure.

Structural differences between life cycles concern the spatial implementation of these basic processes. Different causes may explain differences in life cycle structures:

- geographical area which determines discreteness of grounds for feeding, nursery, spawning (e.g., herring around Ireland has more fragmented populations than herring in the North Sea) ;
- fish life span and size which affect the scale at which the population can develop in space (e.g., small fish like anchovy or sprat do not form large scale continuous populations like mackerel) ;
- species specificity related to reproductive traits (e.g., adaptation to high or temperate latitudes, capability to reproduce at a small size relative to its largest size).
- reproductive population components which may mix or separate in space and time (e.g., spring/autumn spawners, homing) and thus increase the number of life cycles in a stock

Amongst the life cycles studied, the differences were thought to be the following:

- spatial scale of population extension ;
- discreteness / continuity of habitats at different moments of the life cycle ;
- mixing / separation of population components at different moments of the life cycle.

Anchovy and sprat form local populations that are potentially connected by the means of vagrancy only. In contrast, the population of mackerel and that of blue whiting extend at the scale of ICES waters, with adults making large scale migrations. Mackerel has discrete local nursery grounds and large continuous spawning grounds where adults are mixed. Herring has discrete spawning grounds where population components are separate and large continuous nursery and feeding grounds where population components are mixed. The life cyle of sardine has some characteristics of anchovy and sprat and some of mackerel. Sardine reproduces at a small size (10–15cm). Small sardines (<18cm) show discrete local populations. Large sardines (>20cm) recruit to a mixed component and undergo large migrations covering the extent of all the local populations. Change in behaviour between small and large sardines is related to a change in diet (small sardine feed on zooplankton while larger sardine also feed on phytoplankton).

Because life cycle types differ in their structure, it can be expected that each life cycle shows a specific variability with hydro-climate variation.

Changes in spawning windows in space and time are expected to change the environment-recruitment relation, meaning that adult behaviour should be checked for predicting recruitment. Also, encounter between the young and the old in a population may result to be a critical period for keeping young individuals in a population.

Supporting tables 1–2.

Table 1: structural differences between pelagic species life cycles in ICES waters

	SPATIAL SCALE	MIXED COMPONENTS	DISCRETE GROUNDS
anchovy and sprat	small	juvenile, feeding	spawning
Herring	large	juvenile, feeding	spawning
Mackerel	large	spawning, feeding	juvenile
Sardine	large small	spawning, feeding	 spawning, juvenile

Table 2: Means by which changes in life cycles can occur due to environmental change.

	VARIATION IN YEAR CLASS STRENGTH	VARIATION IN LARGE ADULT MIGRATION	VARIATION IN SPAWNING COMPONENT
Anchovy	burst/loss of local population		
Sprat	burst/loss of local population		loss of winter spawners
Herring	loss of spawning grounds	failure of encounter between young/old fish	loss of winter spawners
Mackerel	burst/loss of nursery grounds	variation in spawning sites failure of encounter between young/old fish	
Sardine	burst/loss of local population [small fish]	variation in spawning sites failure of encounter between young/old fish	

Supporting figures 1–2.

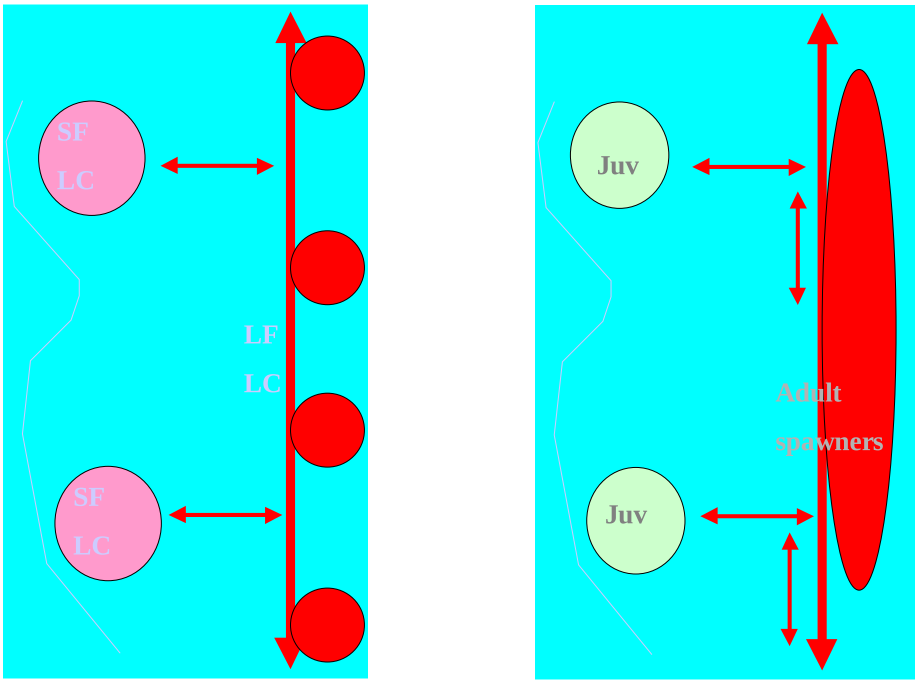

Figure 1: Life cycle schematic diagrams for sardine (left) and mackerel (right). LC = life cycle, SF = small fish, LF = large fish, Juv = juvenile. Small sized sardines form local discrete populations, large sized sardines form a large scale continuous population with continuous spawning grounds. Juvenile mackerel is located on discrete habitats. Spawners undergo migrations (the bigger the fish the larger the migration) over a large continuous area and form one large reproductive component.

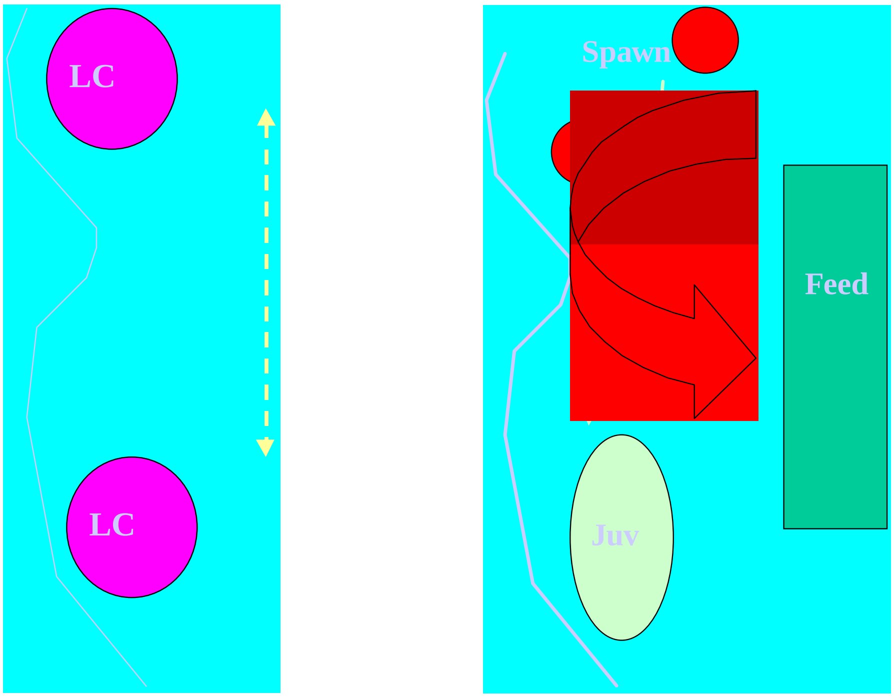

Figure 2: Life cycle schematic diagrams for anchovy and sprat (left) and herring (right). LC = life cycle, Juv = juvenile. Dashed line (left) represents vagrancy at larval and adult stages.

3.2.9 Inter-annual changes in Baltic sprat

Changes in growth. Condition is an index of the physiological state of a fish considered to be a proxy of its energy reserves. Herring and sprat in the Baltic Sea have shown large inter-annual oscillations in condition during the last few decades. For example, herring condition decreased from the end of the 1980s until 1996–1998 and then increased again reaching in 2003 the original levels, while sprat decreased during the 1990s (Möllmann *et al*., 2004a). In the Baltic Sea, clupeid condition is believed to be mainly linked to the feeding conditions. For example, the variability in clupeid condition has been related to changes in the zooplankton community that are largely driven by oceanographic features, especially the decrease in the copepod *Pseudocalanus* sp. (Möllmann *et al*., 2003; 2004a; Rönkkönen *et al*., 2004). However, inter- as well intra-specific competition could also affect food availability and, in turn, condition (Cardinale and Arrhenius, 2000; Cardinale *et al*., 2002; Rönkkönen *et al*., 2004; Möllmann *et al*., 2004a). Baltic herring and sprat have different and separate life cycles, with herring spawning demersally in coastal areas and sprat pelagically in offshore regions of the Baltic main basins. However, during the common feeding season (late spring – early summer) the two species meet in the offshore areas of the deep Baltic basins and there food spectrum largely overlaps (Möllmann *et al*., 2004b). During this period herring and sprat suffer for high levels of feeding competition being reflected in their condition. Later in the season, sprat migrate more inshore, whereas herring stay in the offshore areas. At this time, therefore, inter-specific competition for food could be supposed to be lower.

Changes in spawning habitat. Habitats of different Baltic sprat life cycles have been characterized in more detail for the area of the Bornholm Basin, acting as a case study in the GLOBEC Germany project. Horizontal distribution of the adult stock showed a strong seasonality. At the beginning of the spawning season in March sprat left their more shallow feeding areas and started to aggregate in the eastern part of the basin. Over the course of the spawning season adult sprat invaded the complete area of the deep basin (>60m depth), reaching high densities. At the end of the spawning season, remaining concentrations were only found in the north-eastern part. These distribution pattern were mirrored by the egg distribution. Abundance of adult sprat in the area >60m depth decreased from >55 billion fish at peak spawning time in April 2002 to <5 billion in July 2002. Abundance stayed on this low level until the beginning of 2003, when abundance started to increase again for next years spawning . Evaluation of combined hydroacoustic and hydrographical data allowed a seasonal habitat definition for the adult stock. During winter time adult sprat were restricted to the water body having temperatures of >4°C and >1.5ml/l oxygen. Sprat was therefore captured between cold waters from above and the oxygen-depletion-zone from below and did not perform diurnal vertical migrations. After warming of the surface waters in spring, sprat started to perform diurnal migrations. During night-time they stayed above or in the thermocline, while they were found within and below the halocline down to low oxygen concentrations during day-time. In summer sprat were more dispersed during day-time, staying within or above the halocline. Potential winter habitat varied over years between the main spawning grounds (ICES SD 25, 26 and 28). Size of the winter habitat seemed to be linked to adult distribution for next years spawning time. The vertical distribution pattern and diel migration behaviour of Baltic sprat larvae changed between 1989–1990 and 1998–2002. In 1989 and 1990 they migrated to the surface at night, while they stayed at 30–50m depth during day-time. In 1998–2002 sprat larvae showed no signs of diel vertical migration. They stayed the whole day in the warmer, near surface waters. This behavioural change happened concurrently to changes in the Baltic ecosystem. The major prey organism (*Acartia* spp.) of Baltic sprat larvae increased in abundance. In the Bornholm Basin near surface temperature increased since the 1990s and *Acartia* spp. aggregated in this water layers. Therefore the vertical profile of suitable food for sprat larvae changed, resulting in high food levels in the surface layers. The observed change in vertical distribution patterns of sprat larvae might have influenced the generally higher but also more variable recruitment in Baltic sprat in the last decade. Transport of sprat larvae to their juvenile spawning grounds was investigated by detailed drift model simulations for the years 1979–2002. Different modelling approaches with and without diurnal vertical migration (see above) were utilised. Data on spawning location and timing of spawning were used as input to a particle tracking model. Most important potential nursery grounds for sprat were identified along the south-eastern Baltic coast. Inter-annual variations were mainly due to variable wind conditions over the Baltic Sea. The horizontal distribution of simulated larval or 0-group sprat is mostly consistent with the observed distribution of 0-group sprat obtained from the hydroacoustic field surveys. This analysis will also allow to determine the potential for advective mixing between juveniles originating from different spawning sites or from different stock components throughout the spawning season.

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3.2.10 Changes in anchovy distribution in Biscay

Long-term variation in anchovy distribution in Biscay was revisited. The stock is seen to have nearly disappeared from the Spanish coast and lost spawning grounds. A larval drift and survival model identified potential successful spawning on the Spanish coast. A circulation model evidenced a circulation pattern which seeds the Spanish coast with larvae from the present French spawning grounds. But no re-colonisation of the Spanish coast is occurring. During a survey targeting juveniles, these were observed alone, independent of adults offshore and on the Spanish coast when they were mixed with adults on the French coast (recruited to the adult stock). The question was raised whether encountering adults is necessary for juveniles to effectively colonise particular habitats.

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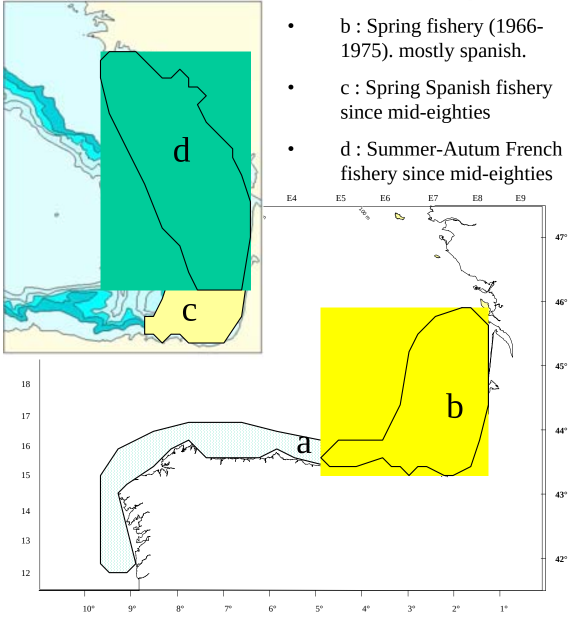
Supporting figures 1-3.



Spatial evolution of the fishery:

- a : Spring fishery first half of XXth century (up to 1960). mostly spanish.
- b : Spring fishery (1966-1975). mostly spanish.
- c : Spring Spanish fishery since mid-eighties
- d : Summer-Autum French fishery since mid-eighties

Figure 1: Long–term evolution of anchovy fishery in space and seasons [ICES CM 2004/G:06]

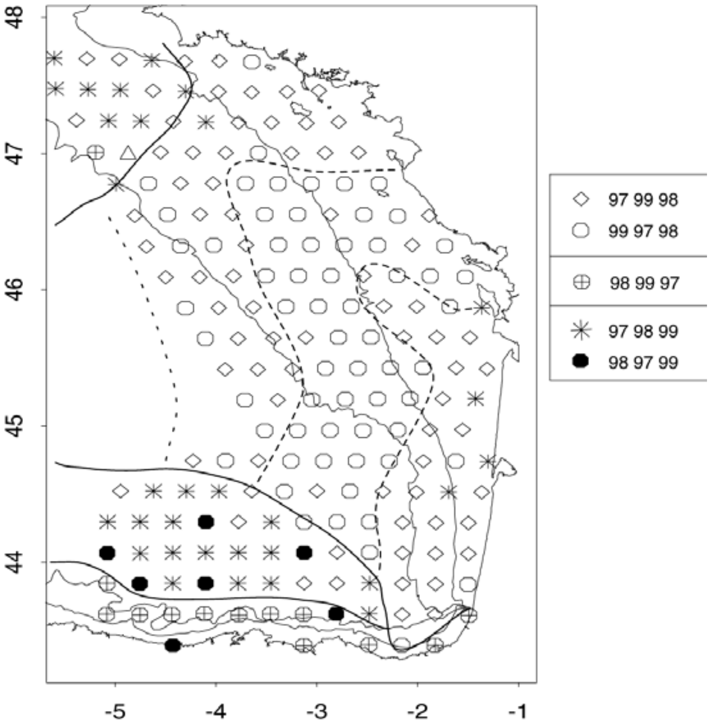


Figure 2: Potential larval survival ranked between years and mapped [ICES CM 2004/J:14]

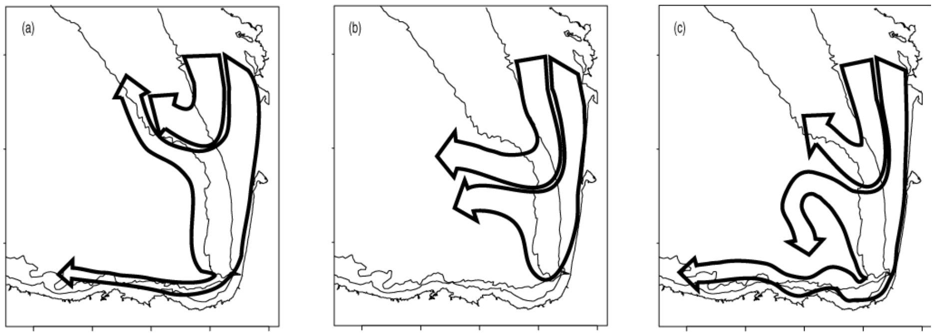


Figure 3: Major larval drift patterns from Gironde spawning ground during spring and summer as estimated with IFREMER MARS3D hydrodynamic model [ICES CM 2004/J:14]

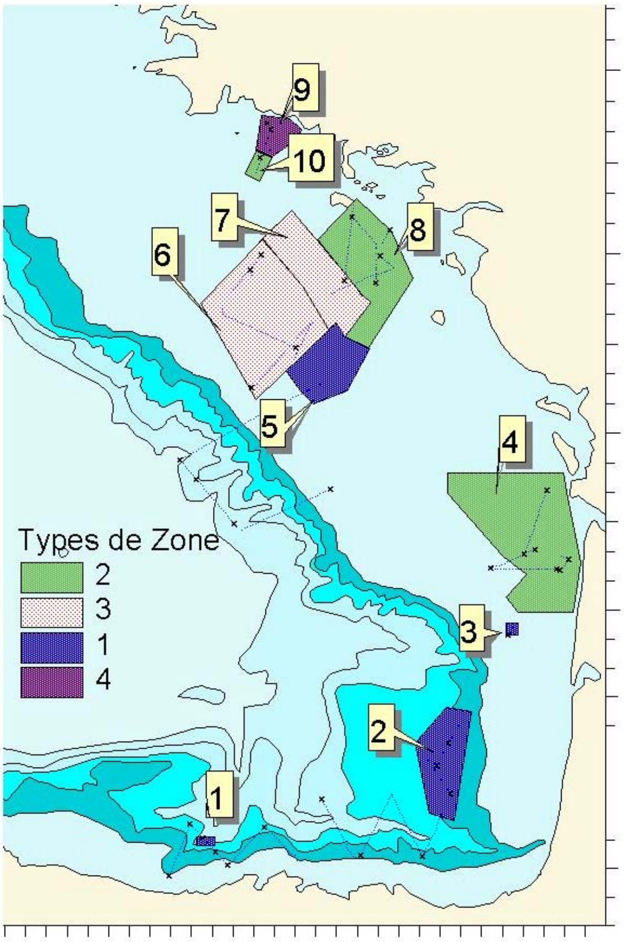


Figure 4: Zonation of anchovy appearance based on echo traces and pelagic trawl hauls. Data of IFREMER juvenile acoustic survey JUVAGA03 in October 2003. Blue zones 1,2,3,5: Age-0 anchovy alone forming typical subsurface schools by day and night. Green zones 4,8,10: Age-0 anchovy mixed with adult anchovy forming typical adult-like schools with day-night behaviour. [ICES CM 2004/J:13]

3.2.11 Changes in anchovy distribution at large scale in ICES waters

Data were compiled from all available bottom trawl surveys in a given year, from 1990 to 2004 (see ToR a) to give a broad picture of the evolution of the species distribution at large scale in ICES waters. Anchovy distribution expanded in northern waters since 1994 with no particular change in the southern limit. The means by which anchovy is expanding in the North Sea was questioned. There is presumption that expansion comes from good recruitment from micro local populations.

The distribution plots in Figures 1–3 show the evolution of the anchovy distribution in selected years from 1990 to 2004. The missing years were omitted due to missing data. No data for the Cantabrian Sea area were available for this meeting. The data have been presented as bubble plots of catch rate per hour on a log scale (<10, 10 to 100 etc up to 100,000). It should be noted that the surveys were carried out in different areas at different times of year. Notwithstanding the plots give a broad picture of recent changes. In 1990, and probably before, anchovy were concentrated in the Biscay area, with smaller catches in the Gulf of Cadiz. Small numbers were also picked up in the channel as far as the Dover Straits, and very rare vagrants elsewhere. From 1992 to 1997, there were many more anchovy found on the southern coast of the North Sea, and extending into the Skagerrak and Kattegat. The scale of this then seemed to reduce in 1999 and 2002. However, in 2003, and again in 2004, catch rates across the whole North Sea increased substantially in size and in spatial coverage.

Two hypotheses could explain the expansion of anchovy in the North Sea: good recruitment in micro local northern populations or vagrancy of adults from southern populations attempting to establish new life cycles in the North. In order to start building presumptions for or against these hypotheses, the spatial pattern of presence of small (<10cm) and large (>15cm) anchovy was looked for in the trawl catches in Quarter 1 (It is the period when anchovy is most present in the North Sea). Small anchovy was mostly distributed in the southern North Sea while large anchovy was in the east northern part (Figures 4–5). A significant spatial pattern in anchovy distribution was first seen in 1998: anchovy was small (<10cm) and distributed in the southern North Sea, thus favouring the hypothesis of local recruitment from micro local populations present in the Southern North Sea.

Supporting figures 1–5.

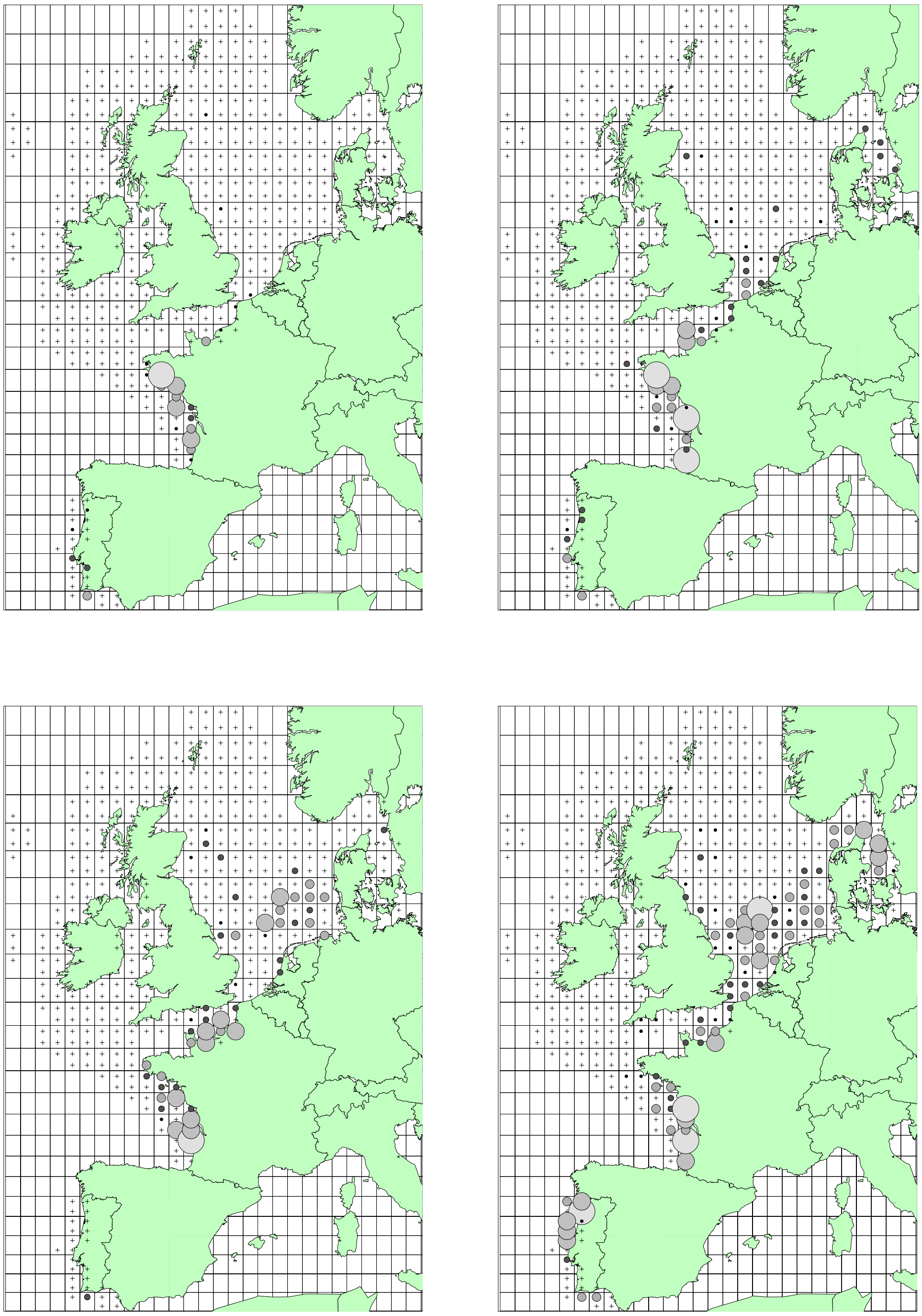


Figure 1: Catch rates (ind. per hour) for anchovy in bottom trawl surveys 1990 (top left), 1992, (top right), 1994 (bottom left) and 1995 (bottom right). Bubbles are log scaled to a maximum of 10,000.

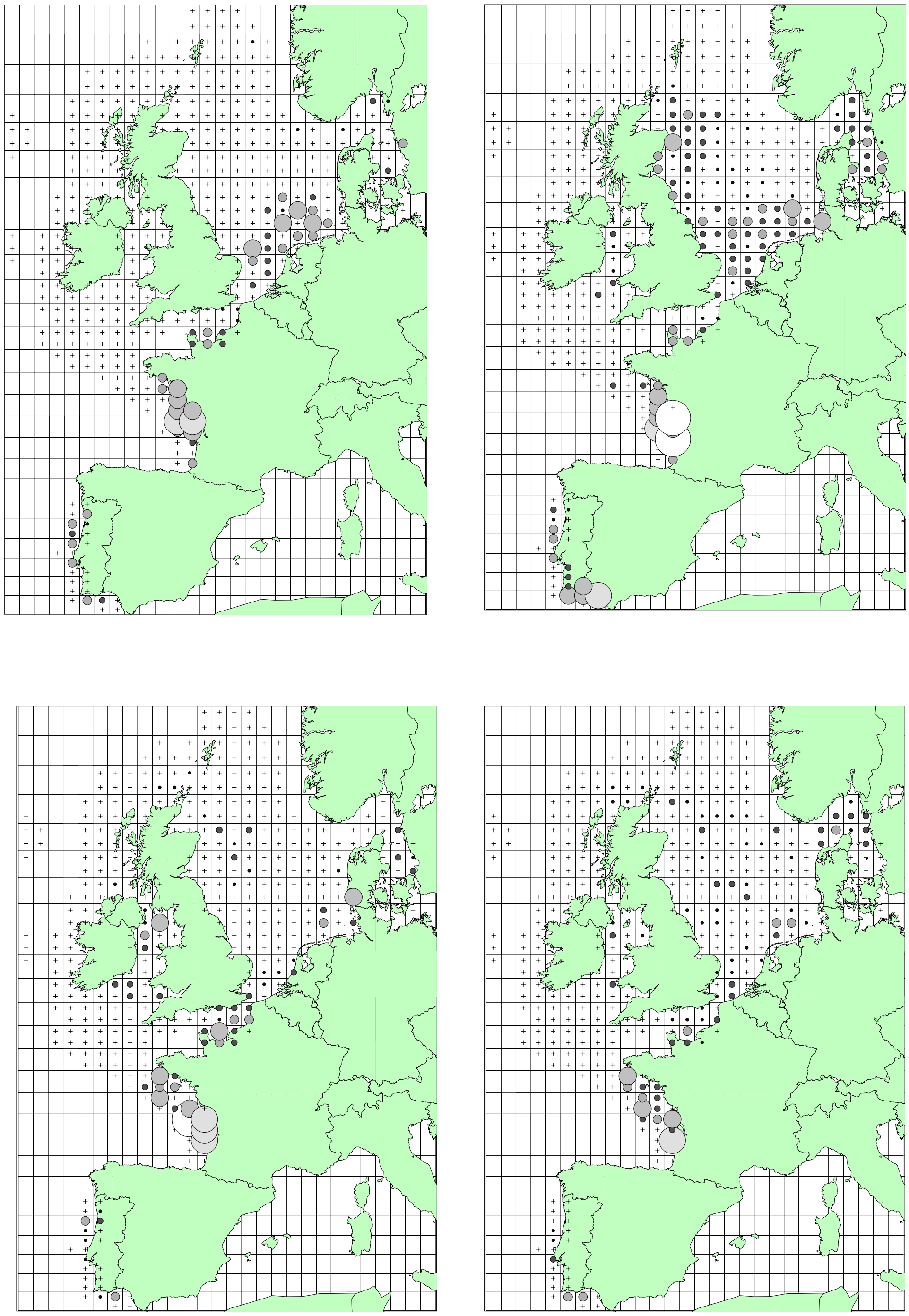


Figure 2: Catch rates (ind. per hour) for anchovy in bottom trawl surveys 1997 (top left), 1998, (top right), 1999 (bottom left) and 2000 (bottom right). Bubbles are log scaled to a maximum of 10,000.

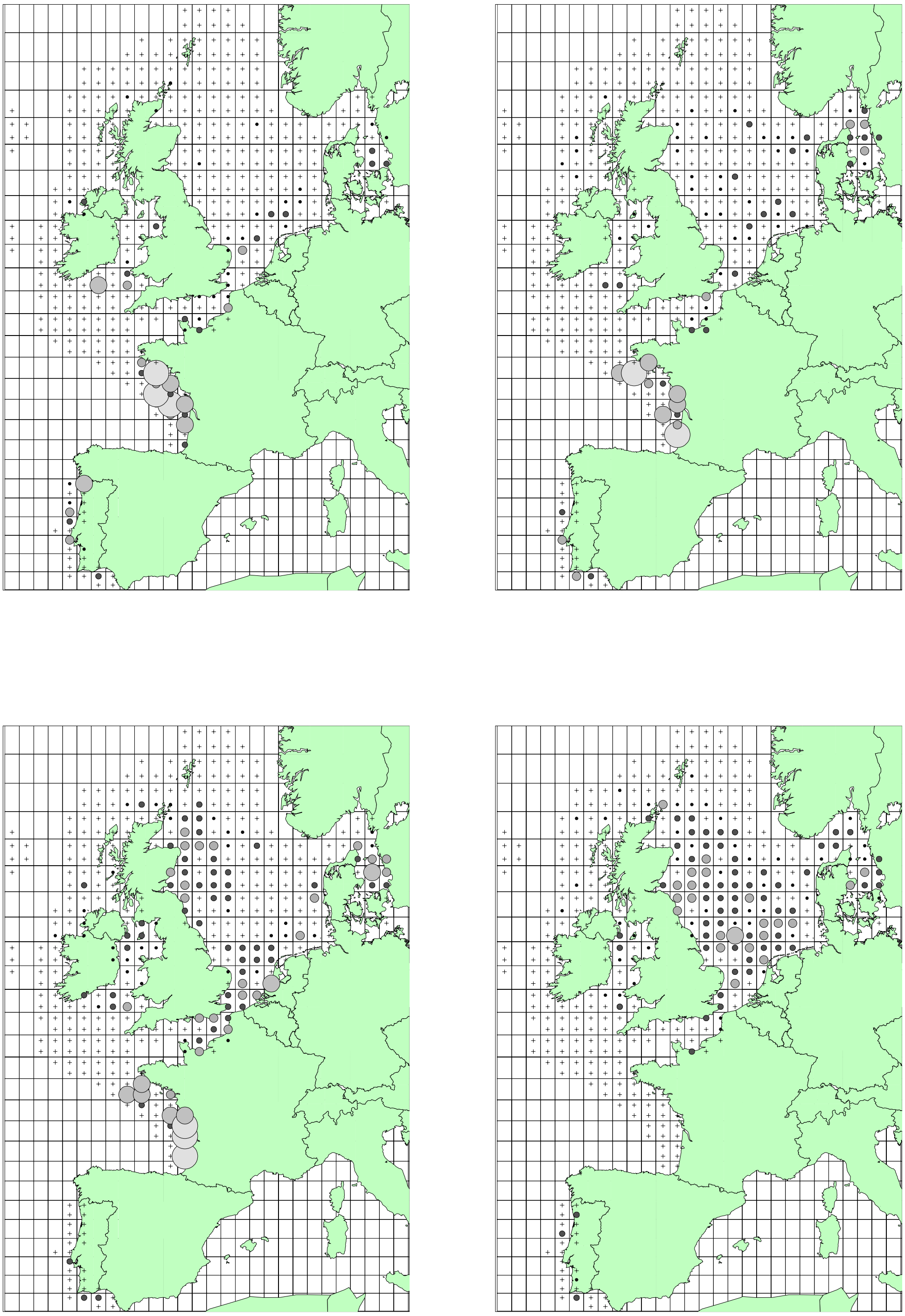


Figure 3: Catch rates (ind. per hour) for anchovy in bottom trawl surveys 2001 (top left), 2002, (top right), 2003 (bottom left) and 2004 (bottom right). Bubbles are log scaled to a maximum of 10,000. Data for Biscay and Celtic Sea were not available at the time of this report.

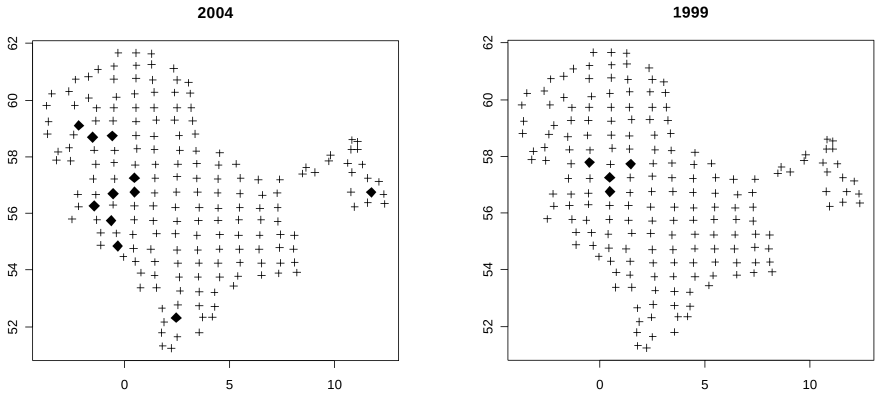


Figure 4: Presence (diamonds) of large anchovy (L>15cm) in North Sea Quarter 1 trawl catches, 1995–2004. Missing years are those in which there was less than 4 positive hauls.

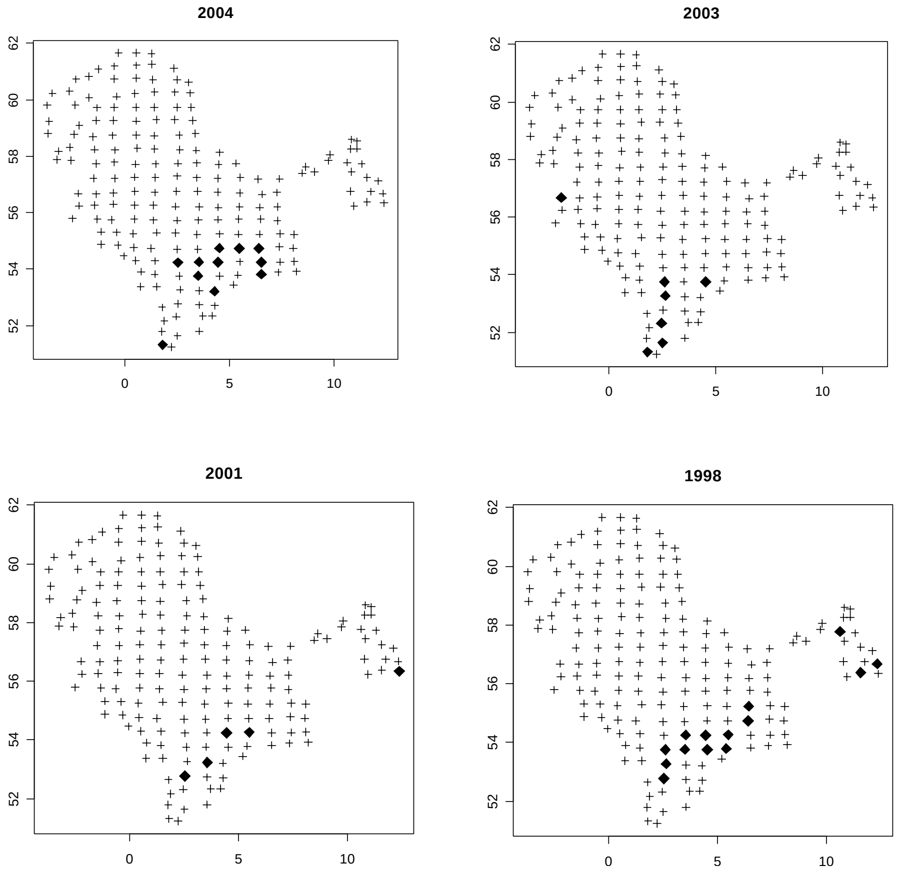


Figure 5: Presence (diamonds) of small anchovy (L<10cm) in North Sea Quarter 1 trawl catches, 1995–2004. Missing years are those in which there was less than 4 positive hauls.

3.2.12 Changes in NEA mackerel as revealed by assembling data bases

A range of tools were developed to plot the mackerel abundance from the various data sources.

Fisheries Research Services Trawl database (1925-present). The total numbers (catch per hour trawled) are plotted in Figure 1 from FRS (Fisheries Research Services) data exclusively. The maps show large numbers of mackerel to the west of Scotland and a smaller component in the North Sea. In quarter 3 the mackerel have spread into and around the North Sea (Figure 2). A time-series for ICES area IVa, for example, summarising mackerel abundance is plotted in Figure 3. The data suggest that three main peaks of abundance have occurred: in the late 1930s; the late 1950s and the late 1990s.

The IBTS and DATRAS Trawl Survey Databases. Instead of plotting the total numbers caught per hour (see Figures 1–3), mackerel numbers by age have been plotted here for the IBTS data. All age groups (quarter 3) appear to be distributed fairly evenly around the North Sea.

The International Mackerel Recruit Trawl Survey Database. Age 1 mackerel along the western continental shelf are depicted in Figure 4. The data suggest that a good recruitment may have occurred in 2002, viz. the high densities of age 1 mackerel noted north west of Ireland. The data were investigated to examine whether there was a detectable signal from recruitment. To do this CPUE per statistical rectangle by age (0,1,2,3), quarter and year were calculated. Then the numbers of age 0 in quarter 4 were plotted against the number of age 1s the following year (Figure 5). There is some evidence of correlation, i.e. large numbers of age 0 mackerel in quarter 4 (high recruitment) tend to lead to large numbers of age 1 mackerel in quarter 1 of the following year. The regression (Figure 5) is significant and $R^2 = 37\%$. The key point to note from this correlation is that it indicates that the surveys in the two quarters can be considered as sampling the same populations in the same way.

International Egg Survey Database (1978–2004). The density of stage 1 mackerel eggs per m^{-2} per day for five surveys (1992, 1995, 1998, 2001 and 2004) is summarised in Figure 6. The plot (Figure 6) suggests that spawning activity by mackerel may have declined from 1998 onwards. A similar slight decline was reported in 2004 by the ICES WGMHSA.

Scottish commercial landings database (1960-present). The change in the seasonality of mackerel landings between 1960 and 2003 is summarised in Figures 7 and 8. The plots show how the mackerel fishery changed from being a summer one in the 1960s to a winter one in the 1980s, 1990s and 2000s.

Supporting figures 1–8.

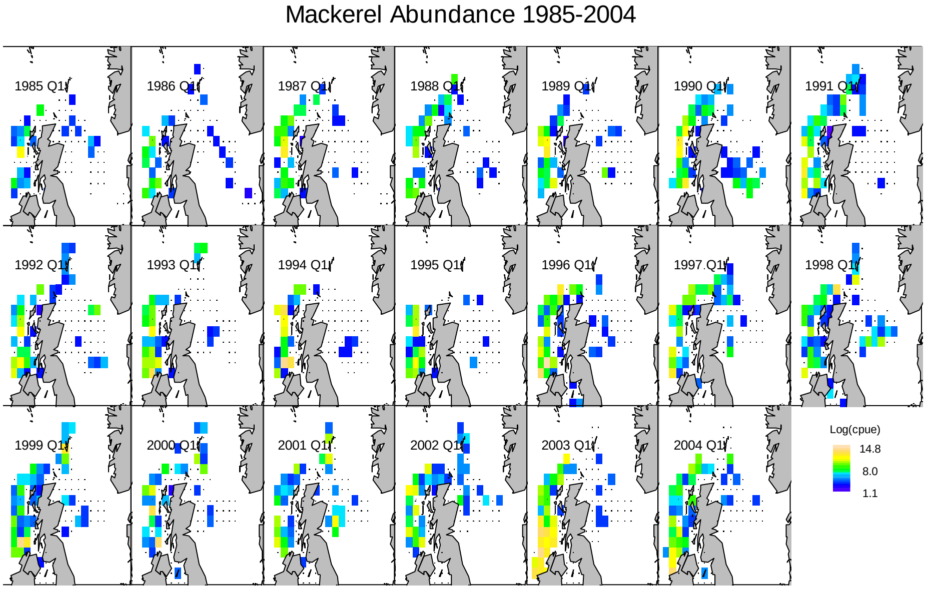


Figure 1: FRS trawl survey data for mackerel (1985–2004): total number caught by hour in quarter 4.

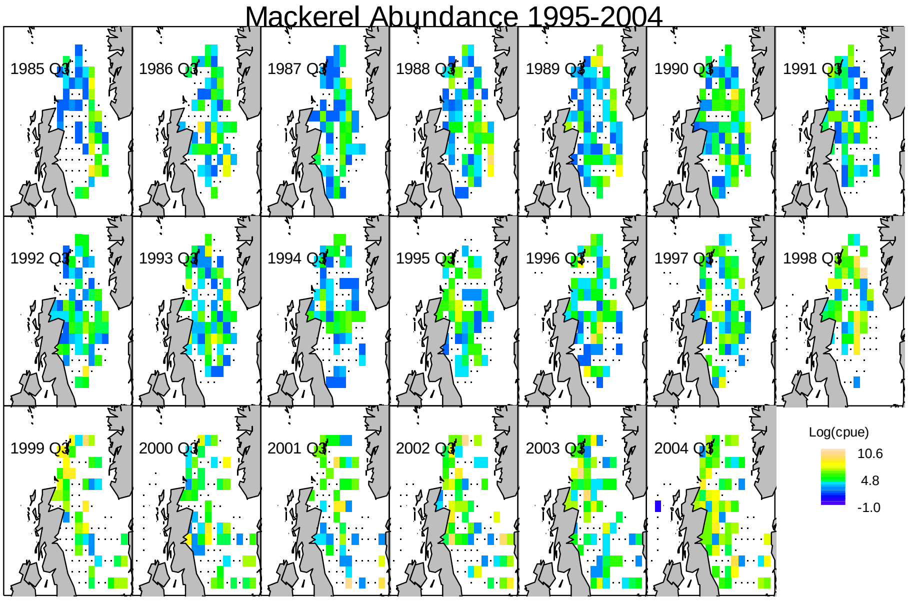


Figure 2: FRS trawl survey data for mackerel (1985–2004): total number caught per hour in quarter 3.

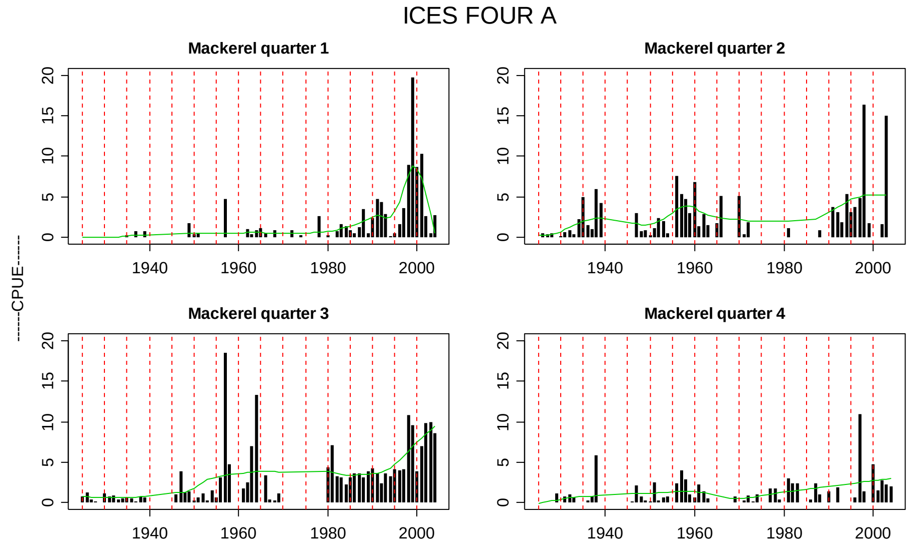


Figure 3: FRS trawl survey data (1925–2004): CPUE by quarter for mackerel

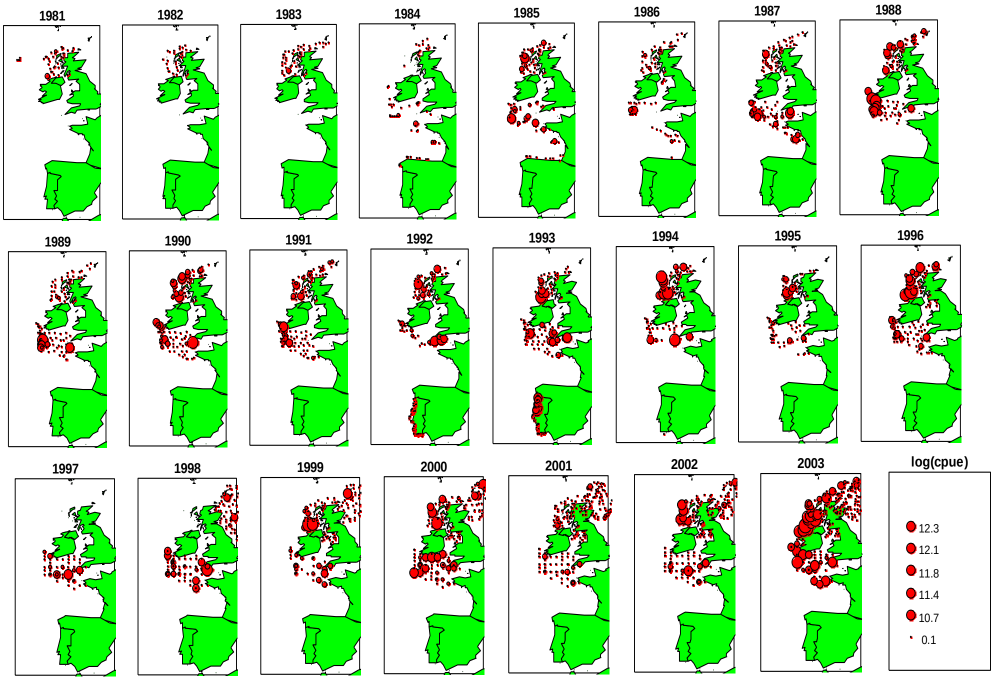


Figure 4: International mackerel recruit survey: distribution of age 1s in quarter 1.

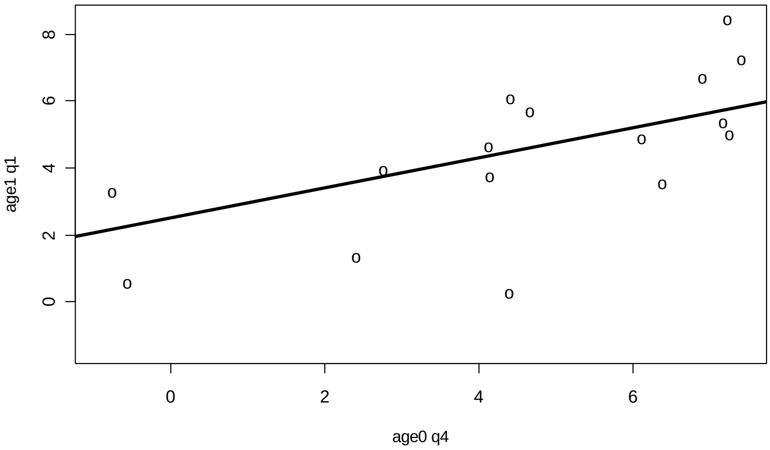


Figure 5: International recruit survey database (1981–2003): relationship between Age 0s and Age1s the following year.

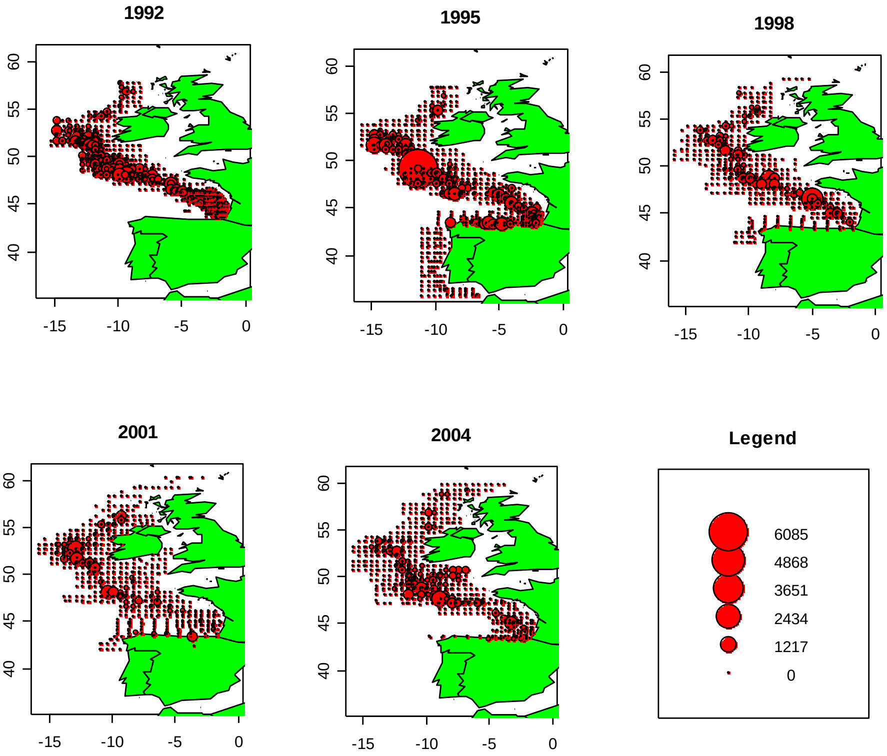


Figure 6: International egg survey data (1992–2004): stage 1 egg density per m^2 per day.

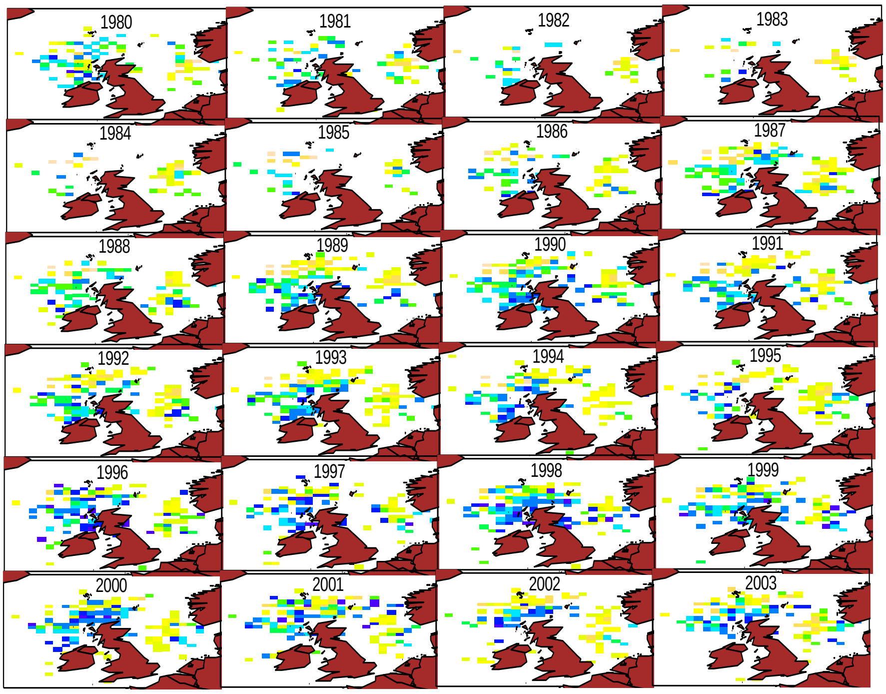


Figure 7: Scottish mackerel landings (kgs) between 1980 and 2003.

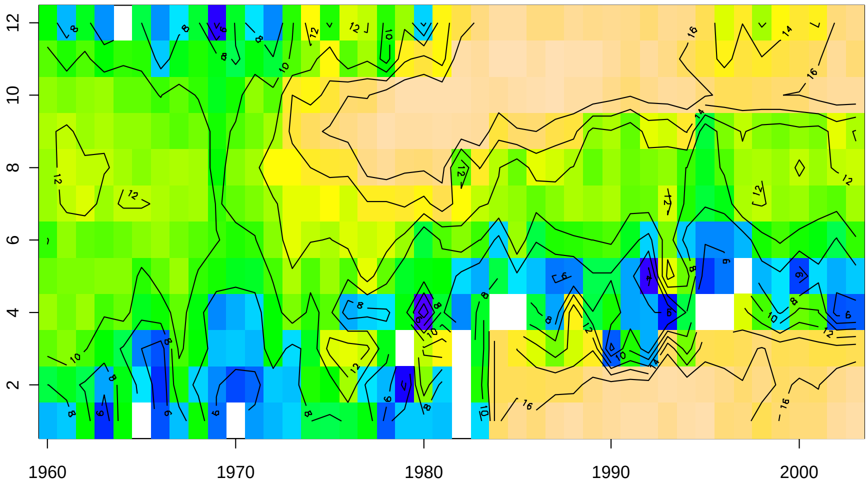


Figure 8: Total Scottish mackerel landings by year (x-axis) and month (y-axis) between 1960 and 2003.

3.3 ToR c)

Assemble long-term series of environmental indices using survey data, meteorological data and model outputs at basin-scale and meso-scale in order to reconstruct long-term history of environmental changes at different scale

Long-term indices of ocean climate are generally based on large scale features such as atmospheric circulation (e.g. NAO) oceanic circulation (e.g. Gulf Stream index), changes in SST, and so on. Long-term time series of these features are available. In the North Sea and Baltic Sea a large scale regime shift has been described which happened around 1987 and which re-organized the marine communities and trophodynamic relationships. In certain areas (e.g., the Baltic) NAO, temperature, circulation pattern has been shown to be correlated to fish stock variability. In the Baltic Sea the German GLOBEC program evidenced how the NAO regime translated into regional modification of larval retention into the basins and of the plankton community. In other areas (e.g., Biscay) the downscaling between large features and regional meso-scale features is not direct. The group recognised the importance of the variability in meso-scale features to explain biological variation and therefore the importance to construct long-term series of meso-scale features. These are not yet available. Tools are proposed for doing so and a workshop is recommended on this subject.

3.3.1 Regime shift in the North Sea and Baltic

Shifts in climate regimes can re-organize marine communities and trophodynamic relationships and induce changes in the mix of dominating species over decadal time scales. Ecological regime shifts in the marine realm were defined in a pragmatic way as “changes in marine system functioning that are relatively abrupt, persistent, occurring at a large spatial scale, observed at different trophic levels and related to climate forcing” (deYoung *et al*., 2004). Apparently, when trying to unravel causal relationships between external climate forcing and the reaction of fish populations long-term time series on physical and biological variables are required. Climate indices such as those of the NAO (North Atlantic Oscillation), PDO (Pacific Decadal Oscillation) or ENSO (El Nino Southern Oscillation) are useful proxies integrating information on several physical variables such as temperature, wind stress and direction, precipitation, etc. Bottom up-control of fish populations through climate involves the lower trophic levels such as phyto- and zooplankton. For example, the 1987/88 regime shift in the Central Baltic Sea, which initiated the dramatic increase of sprat recruitment, biomass and catches, was related to changes in the composition of the phyto- and the zoooplankton (Alheit *et al*., 2005). Diatom production decreased whereas dinoflagellate production increased. The change in diatom production was demonstrated by comparing long-term time series of silicate concentration and silicate consumption (Wasmund and Uhlig 2003). The increase in sprat biomass was probably caused by the synchronous increase of their most important dietary items, the copepods *Acartia* spp. and *Temora longicornis* as indicated by long-term information on these species (Möllmann and Köster 2002). The increase of copepod biomass was related to increased hatching from hibernating resting eggs induced by higher midwater temperatures in the Central Baltic since the late 1980s (Dutz *et al*., 2004). All these lower trophic level processes contributed potentially to the conspicuous biomass increase of sprat after the regime shift 1987/88 (Alheit *et al*., 2005).

Supporting references

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DeYoung, B., Harris, R., Alheit, J., Beaugrand, G., Mantua, N., and Shannon, L. 2004. Detecting regime shifts in the ocean: data considerations. Progress in Oceanography, 60: 143–164.

Dutz, J., Mohrholz, V., Peters, J., Renz, J., and Alheit, J. 2004. A strong impact of winter temperature on spring recruitment of a key copepod species in the Bornholm Basin: potential linkages to climate variability. GLOBEC International Newsletter 10, 1: 13–14.

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Wasmund, N., and Uhlig, S. 2003. Phytoplankton trends in the Baltic Sea. ICES Journal of Marince Sciences, 60: 177–186.

3.3.2 Environmental change in the Baltic and sprat recruitment

A recent study has demonstrated the relationship between hydroclimatic variables (NAO, ice cover, temperature) and sprat recruitment in the Central Baltic Sea (MacKenzie and Köster 2004). Temperature has been shown to have increased during the 1990s as a response to the positive NAO period (Fonselius and Valderramq 2003). Investigations on long-term dynamics of copepods have demonstrated a drastic increase in abundance of *Acartia* spp. during spring-spawning time of sprat (Möllmann *et al.*, 2003). This increase was observed to be step-wise with drastically higher abundances during the 1990s visible also in other biotic and abiotic variables (especially temperature) and frequently termed a "regime-shift" (Alheit *et al.*, 2005). This points out the need to identify productivity regimes in the ecosystem to reliably predict the recruitment potential of Baltic sprat. The group recognised the importance of characterising the environment to evidence change/persistence in the conditions of recruitment and updated environment-recruitment relationships (see ToR e).

A presently conducted study within GLOBEC-GERMANY uses long-term hydrodynamic modelling (with a 3-d circulation model) to study and predict recruitment variability in Central Baltic sprat. Retention or dispersion was defined based on the relative number of simulated particles within or outside the sprat spawning area (Baumann *et al.*, 2004). Similarly warmer/colder than average temperatures experienced by the particles indicate retention in colder deeper waters or dispersal to warmer coastal waters. High retention situations are generally related to higher recruitment, while advection out of the deep basins seems to be in synchrony with low survival. The process behind this relationship (e.g. higher predation pressure in coastal areas) is unknown and needs further investigations.

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Köster, F.W., Hinrichsen, H.-H., Schnack, D., St. John, M.A., MacKenzie, B.R., Tomkiewicz, J., Möllmann, C., Kraus, G., Plikshs, M., Makarchouk, A. and Eero, A. 2003. Recruitment of Baltic cod and sprat stocks: identification of critical life stages and incorporation of environmental variability into stock-recruitment relationships. Scientia Marina, 67 (suppl. 1). 129–154.

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3.3.3 Identification of meso-scale hydrographic features

Long-term indices of ocean climate are generally based on large scale features such as atmospheric circulation (e.g. NAO) oceanic circulation (e.g. Gulf Stream index), changes in SST, and so on. Although such indices provide some indication of large scale changes in the ocean, they often provide limited insight on the possible response of pelagic fish because the scale of the physical processes described is far greater than the scale at which fish behaviour (at individual, school or population levels) is generally understood. Process understanding of fish response to the environment is generally more obvious at the meso-scale (10–100km, days-weeks) where oceanographic features such as fronts, plumes, upwelling or eddies occur. An understanding of fish response to climate compatible with process understanding requires that meso-scale oceanic features be detected and tracked over long periods of time.

In order to enhance the assemblage of long-term series of meso-scale structures, the group felt that the methods should be made available more widely through workshops and training sessions. A workshop is envisaged (see section on recommendations) that should provide a good opportunity to realise such transfer. Realistic simulations of meso-scale features over long periods of time are mostly limited by the accuracy of boundary conditions and external forcing on existing hydrodynamical models. The coupling of regional models (such as MARS3D, Lazure and Jegou, 1998) with realistic general circulations model simulations, together with the newly available re-analyses from the ECMWF should greatly improve the quality of regional hydrodynamical models (e.g. ERA40 reanalysis provides sea surface climate: u,v,slp, cloud cover, relative humidity, temperature, back to 1958 on a 6 hr basis).

This section provides a description of some tools in a development phase or currently available to provide indicators of meso-scale features over long period of times.

Fronts. Frontal structures in the ocean (mainly thermal) have been well described from satellite imagery and also from model simulations. These structures are often associated with particular biological processes such as increased primary production or animals aggregations. Automatic algorithms to detect such structures have been developed at least since the early 1990s. The method of Cayula and Cornillon (1992) consist of a sliding local image filter which determine a) the existence of 2 distinct temperature populations within a restricted window and b) test for cohesion of pixels on both sides of the front. By scanning an entire image the algorithm reveals the thermal frontal structures. The algorithm is generic and can be applied to satellite images or model outputs, and to the detection of non-thermal fronts (e.g. turbidity, salinity). Figure 1 provides an example of fronts detected on the output of a model simulation of the model MARS3D for the Bay of Biscay region.

Recirculation features. Recirculation features can play a critical role in the retention/dispersion processes of pelagic fish eggs and larvae. The definition of such structures (also termed vortices) is yet not well expressed in coastal areas because they can a) be rapidly evolving, b) have non ellipsoidal shapes, c) be independent of sea surface elevation. Several methods are available to identify vortices. Analytical methods based of the calculation of vorticity fields are efficient in the open ocean but they tend to detect false vortices when vorticity is high (e.g. meanders). Streamlines techniques generally do not suffer from over detection when meanders are present but they tend to have a lower sensitivity to true vortices. A novel approach developed by the computing laboratory at the University of Calais (France) and based on « ant algorithms » appears promising of providing accurate detection of vortices from 3D hydrodynamic model outputs (Segond *et al*., in press). Figure 2 illustrates the detection of vortices in the output of the Mercator model at 10m depth.

Seasonal hydrological typologies. The temporal changes in the vertical hydrology in coastal areas is known as a major driver of biological processes (e.g. the spring and autumn phytoplankton blooms as a response to onset and rupture of the seasonal stratification). It appears therefore useful to described hydrological structures in a dynamic way which would include the temporal evolution, rather than in a static manner. An example of such description as been done for the Bay of Biscay in spring (Planque *et al*., 2004), with the objective of classifying the different types of changes in hydrology during the season? The method is based on the comparison of time-series of hydrological profiles taken from the MARS3D model outputs. The evolution of hydrology in each pixel of the model is compared with that of all others and pixels are grouped according to their similarities. The results provide a synoptic view of the main hydrological landscapes over the region (Figure 3). These hydrological landscapes may then be compared to species distribution and serve as indicators of pelagic fish habitats.

Current limitations and foreseen improvements. The methods presented above suffer from 2 main types of limitations. First, they are not yet readily available to the fisheries ecology community at large, and second they heavily depend upon the ability of 3D hydrodynamical models to faithfully mimic oceanographic meso-scale processes over long periods of time (>10 years).

Supporting references

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Lazure, P., and Jégou, A.-M., 1998. 3D modelling of seasonal evolution of Loire and Gironde plumes on Biscay bay continental shelf, Oceanol. Acta 21, 165–177.

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Supporting figures 1–3.

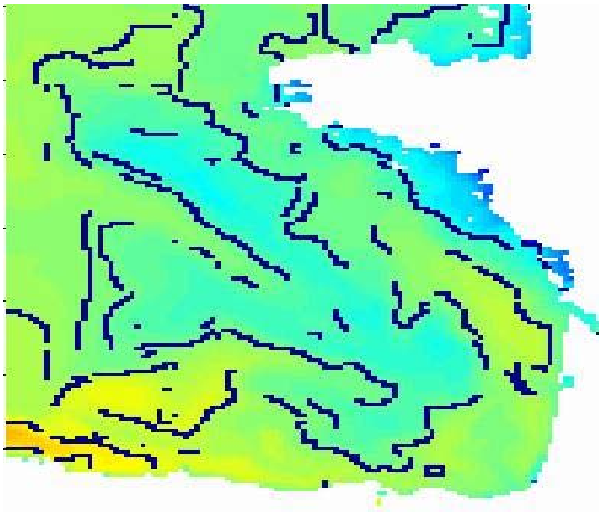

Figure 1: Detection of thermal fronts. Colour indicates temperature in each pixel. The dark blue lines are automatically detected fronts. Thermal field is from the MARS3D simulation.

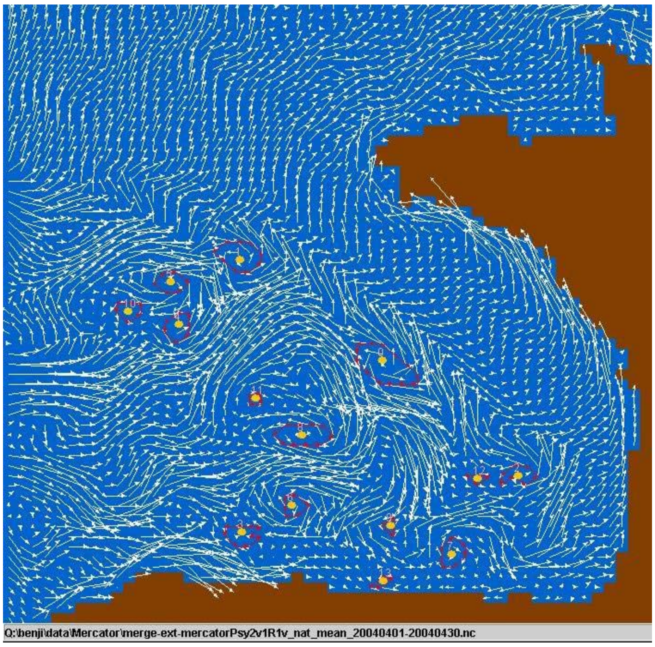

Figure 2: Recirculation features detected using the ant algorithm. Each structure is identified by its central location and its contour. The vortices can be followed through time when model simulations are available for successive dates. The velocity field is from the Mercator model.

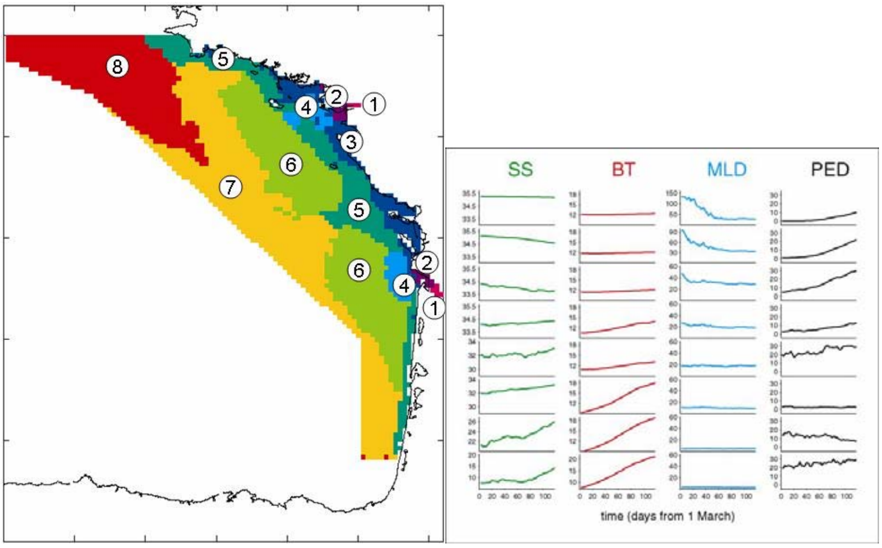

Figure 3. Hydrographic landscapes in the Bay of Biscay in spring. Left: the spatial distribution of the main hydrological landscapes over the period 1987–2001. 1. high estuary, 2. low estuary, 3. coastal, 4. river plume, 5. near coastal, 6. central shelf, 7. open shelf, 8. north-western shelf. Right the seasonal evolution of sea surface temperature (ST), sea surface salinity (SS), mixed-layer depth (MLD) and stratification (PED) for each hydrological landscape (from landscape 1 at the bottom to landscape 8 at the top)

3.4 ToR d)

Review and update adult fish behaviour in relation with oceanographic and ecosystem features and characterise how adult fish migration, feeding and spawning impact the environment-population interaction

The spawning windows in space and time are essential for understanding the influence of the environment on the recruitment dynamics. Spawning windows are the result of adult behaviour. Changes in the spawning and migration patterns during the winter period have been evidenced for herring and sprat in the context of increasing winter sea surface temperature. For sprat, there is some evidence that the fish can be triggered to spawn in winter and also spawn again in summer depending on nutrition condition. Tendency for the wintering phase to disappear in herring has been documented around Ireland.

During the recent SPACC Workshop “Characterising and comparing the spawning habitats of small pelagic fish” (Concepción, Chile – 12–13/1/2004), spawning habitats characteristics were defined as follows:

- Potential habitat: habitat where the hydrological conditions are suitable for spawning (i.e. fraction of the habitat delimiting species distribution);
- Realised habitat: habitat where spawning actually occurs in a given spawning season (i.e. fraction of the potential spawning habitat);
- Successful habitat: spawning habitat resulting in successful recruitment (i.e. fraction of the realised spawning habitat).

Different data/methods are required to describe each of the above three components of spawning habitat. Potential spawning habitats can be estimated by compiling large data sets of egg surveys with environmental condition to estimate the range of environmental parameters in which spawning occurs. For sardine, results suggest potential spawning outside the traditional Iberian and Biscay spawning areas of Iberia and Biscay. Successful habitats can be estimated using coupled biophysical models of larval drift and survival. For anchovy in Biscay, results suggest variation between years of successful spawning sites. The implication is then that spawning needs to be mapped and this information taken into account for adequately predicting recruitment.

3.4.1 Potential spawning habitats of sardine in North East Atlantic

The egg data assembled was used to define sardine potential spawning habitat (PSH) by applying the method of quotient plots (van der Lingen and Castro, 2004). These are computed in relation to environmental variables measured in situ (mainly temperature and salinity at 3 m depth, but also chlorophyl density and bottom depth). For that, the R library Shachar (developed by Miguel Bernal at IEO and described in ICES, 2004) was adapted to include a randomisation test, which estimates the 95% confidence limits for rejecting the null hypothesis, i.e. that the observed quotient within a particular bin of an environmental variable is obtained by pure chance alone. Figures 1 and 2 provide examples of quotient plots for sardine egg abundance in relation to sea surface temperature (Figure 1) and salinity (Figure 2) using a subset of the data described in Table 1 (2000 and 2001).

Table 1: Mean and range of observed sea surface temperature (at 3 m) during spring acoustic surveys (CUFES data) in the Bay of Biscay and the Iberian Peninsula (NA indicate surveys for which the data were not available during the meeting).

YEAR	FRANCE	SPAIN	PORTUGAL
2000	13.2 (11.8 – 18.1)	12.9 (12.0 – 14.3)	15.5 (13.9 – 16.7)
2001	15.1 (10.4 – 19.9)	14.3 (13.0 – 16.3)	15.5 (14.1 – 18.7)
2002	14.7 (13.0 – 17.3)	NA	15.8 (13.2 – 20.7)
2003	18.5 (12.6 – 21.4)	NA	14.4 (11.8 – 20.8)
2004	13.8 (12.3 – 18.1)	NA	NA

The combined data set (all years pooled) will also be used to fit a GAM on species egg presence as a function of the environmental variables considered and their interactions (only considering interactions that are physiologically plausible or that depict distributional variations across areas). The resulting model will then allow to predict the extent and spatial location of PSH in each survey and to estimate the fraction of PSH actually occupied in any given year, to identify areas of persistent presence or absence and to compare with the fish distribution from concurrent acoustic observations.

Supporting references:

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Supporting figures 1–2.

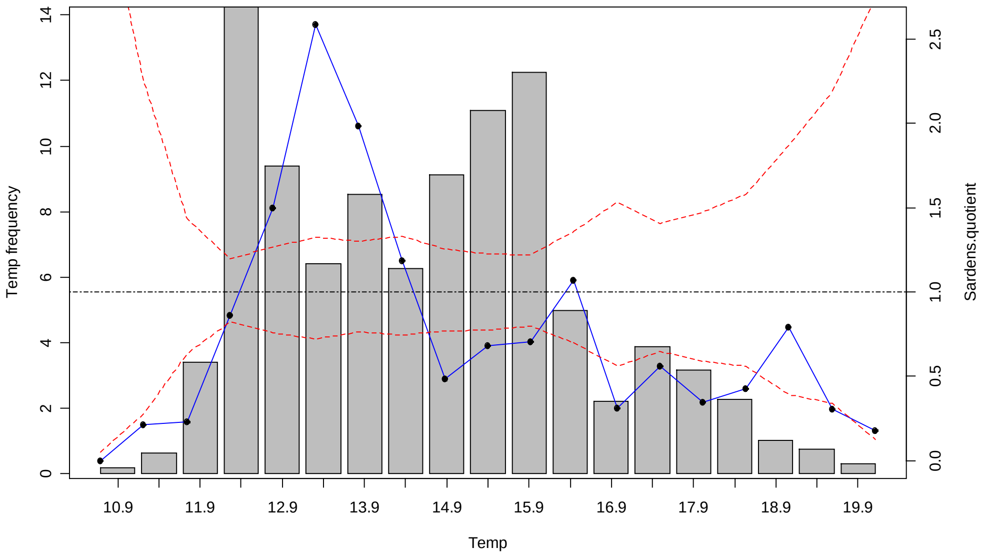

Figure 1: Quotient plot for sardine egg abundance in relation to sea surface temperature from the Bay of Biscay and the Iberian Peninsula (CUFES data from spring acoustic surveys in 2000 and 2001). Red broken lines indicate 95% limits for rejecting the null hypothesis.

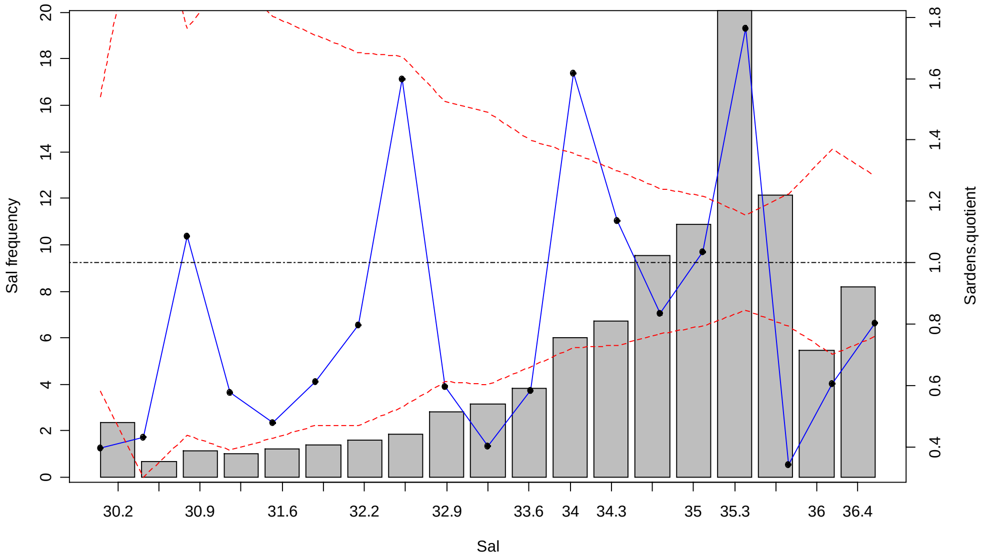

Figure 2: Quotient plot for sardine egg abundance in relation to sea surface salinity from the Bay of Biscay and the Iberian Peninsula (CUFES data from spring acoustic surveys in 2000 and 2001). Red broken lines indicate 95% limits for rejecting the null hypothesis.

3.4.2 Potential successful spawning habitats of anchovy in Biscay

Successful spawning habitats can be estimated using a larval drift and survival model (e.g., coupled biophysical model). Such model was developed in Biscay for anchovy (Allain *et al*., 2003; Allain *et al*., 2004). By seeding the model with spawning in all locations during all the spawning season, it is possible to estimate those space and time windows that potentially provide successful survival. At each point in space, the survival probability of that site was estimated in each year. This was done for 3 years (1997–1999) for which the model is well calibrated on field data. At each point in space, the years were ranked by increasing order of the probability values. The ranks were mapped, providing a picture of successful spawning across the years (Figure 1). A spatial pattern is clear meaning that different areas contribute differently to recruitment. Successful spawning occurs on the South French coast for years when spawning on the Spanish coast does not recruit and vice versa. The interaction between population and environment is clearly dependent on where spawning occurs. Spawning time and location should be monitored if recruitment is to be predicted accurately.

Supporting references

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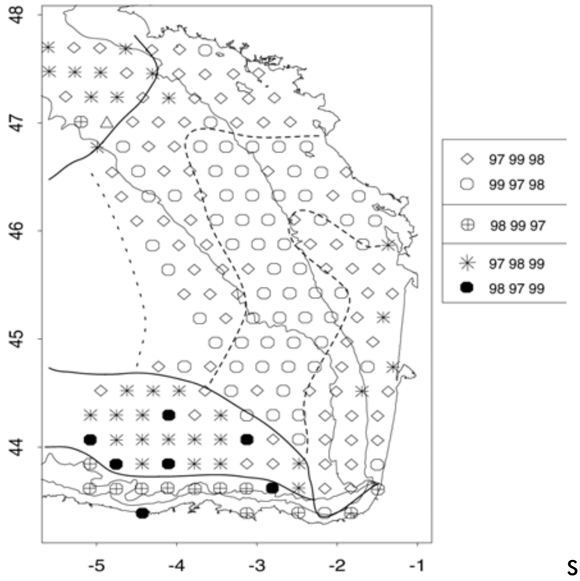
Allain, G., Petitgas, P., Grellier, P., and Lazure, P. 2003b. The selection process from larval to juvenile stages of anchovy in the Bay of Biscay investigated by Langrangian simulations and comparative otolith growth. Fish. Oceanogr., 12(4/5): 407–418.



Supporting Figure 1

Figure 1: Potential larval survival ranked between years and mapped [ICES CM 2004/J:14]

3.4.3 Spatial structure in spawning and its interaction with recruitment: Biscay anchovy

Anchovy spawns in a variety of spawning grounds from inshore to offshore, including beyond the continental shelf. This variety of spawning places partly respond to a differential spatial spawning strategy by ages, by which the smaller and young fishes (mainly of age 1, but also the smaller of ages 2 and 3) spawn predominantly close to coastal areas under the influence of water outflows (close to Gironde and Adour rivers over the French shelf), while bigger, and generally older fishes, tend to spread over more offshore grounds or even outside the continental shelf (Cort *et al*., 1976; Motos *et al*., 1996; Petitgas *et al*., 2003). In Figure 1 the spawning areas of a tipical spawning year (1998) is shown over a range of sea surface salinities, showing clear association between spawning and low salinity coastal waters.

The spatial structure in the adult population was modelled (Ibaibarriaga and Uriarte). The ultimate goal of the analysis is the modelling of the spatial strategies of spawning by sizes and ages of the Bay of Biscay anchovy. Data analyzed corresponded to the adult samples used for the application of the Daily Egg Production Method in years 1990–1992, 1994–1995, 1997–1998 and 2001–2004. First, average weight was modelled in terms of spatial covariates using linear and generalized additive models. In general, smaller fish are found generally close to the coast. However, inter-annual variation is found to be high due to changes in recruitment. Secondly, a logistic model of proportion at age 1 depending on average weight was fitted. Intercepts varying between years could be interpreted in terms of the recruitment strength in each year. The proportion at age 1 predicted from these two models were compared with a GAM model in which proportion at age 1 was fitted directly in terms of the spatiotemporal covariates. In all cases the interannual variability was large. These two models achieved an explanation of about 50–62% of the original total deviance of the data. The 1998 predicted surfaces for the mean weight and the proportion at age 1 represent typical spatial distributions and are presented in Figure 2.

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Motos, L., Uriarte, A, and Valencia, V. 1996. The spawning environment of the Bay of Biscay anchovy (*Engraulis encrasicolus* L.). Sci. Mar., 60 (Supl.2): 117–140.

Petitgas, P., J. Massé, P. Grellier and P. Beillois, 2003. Variation in the spatial distribution of fish length: a multi-annual geostatistics approach on anchovy in Biscay. 1985–2002. ICES CM 2003/Q:15

Uriarte, A., L. Motos, P. Alvarez, M. Santos, P. Prouzet and J. Massé, 1999. Population estimates of the Bay of Biscay anchovy by the Daily Egg Production Method. Final Report to European Commission of Project 96/034.

Supporting figures 1–2.

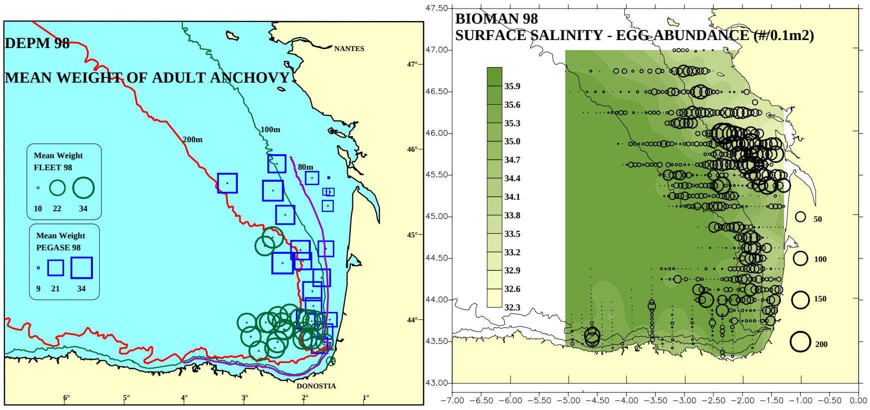

Figure 1: Anchovy egg distribution and abundance per 0.1 m^2 superimposed on sea surface salinity during the egg survey Bioman 98 (left) and adult mean size spatial distribution (right) in samples from fishing vessels (green) and acoustic survey Pegase 98 [Uriarte *et al.*, 1999].

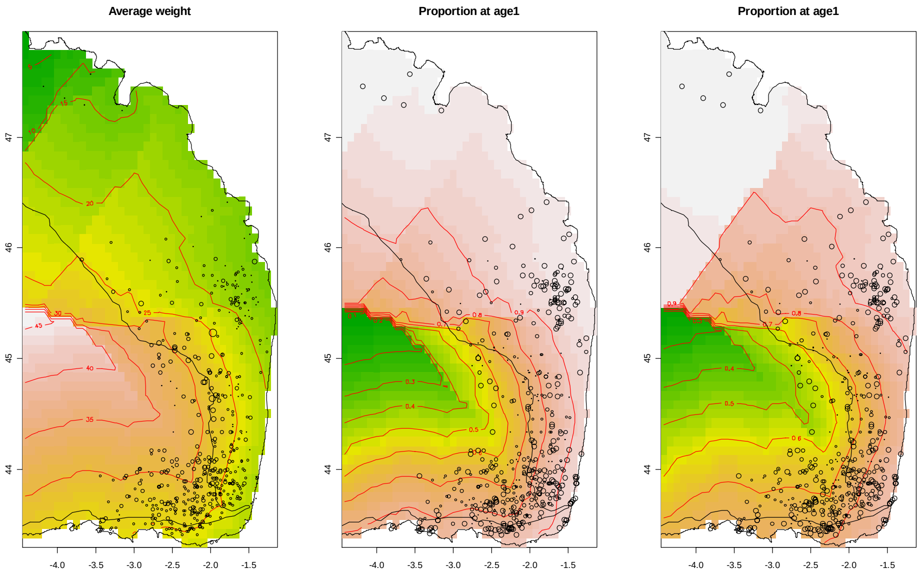

Figure 2: Left: 1998 map of fish average weight estimated with the two step model; center: 1998 map of proportion at age 1 estimated with the two step model; right: 1998 map of proportion at age 1 estimated with a GAM. Points represent all observed values for all years and are proportional to the observed values.

3.4.4 Change in migration and spawning - herring around Ireland

Changes in migration and spawning time have been occurring but so far the link with variation in oceanographic conditions is unknown.

Change in the migration. A change in the post spawning migration pattern has been evident in Northwest and Celtic Sea Herring. After spawning herring have traditionally remained aggregated inshore and over wintered. In recent years this has changed and the majority of spent fish disperse into offshore waters straight after spawning (ICES, 1994; Anon., 2000).

Change in spawning. A latening of the spawning season has occurred in the Celtic Sea and the Northwest Herring stocks within the spawning components, resulting in extended spawning periods for autumn spawners until November and winter spawners until February (Breslin, 1998; Anon., 2000). In addition the winter spawning component has recently increased in proportion in both the Celtic Sea and the Northwest herring stocks (Breslin, 1998; Anon., 2000).

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Anon. 2000. Herring in VIaS and VIIbc, a review of fisheries and biological information. Marine Institute, Killybegs Fishermen's Organisation17 pp.

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3.4.5 Loss of autumn spawners in Baltic herring

Herring in the Baltic Sea are currently divided in spring-spawning and autumn-spawning stocks based principally on spawning time but also on meristic and morphometric features as well as otolith characters. However, beginning from the early 1970s, the autumn spawners virtually disappeared in correspondence to a rapid increase in fishing effort and an increase in oxygen-depleted areas in the Baltic Sea. At present, herring in the Baltic Sea is almost exclusively constituted by the spring spawning component. Spawning can occur, however, also in winter and summer likely due to year-to-year changes in fish growth and maturation conditions. Spring-spawning herring stock is divided in several sub-populations discriminated by their linkage to different spawning sites. Therefore, the sub-populations are separable only during spawning, even though other features, as growth and otolith characters, have been used. The major spawning sites are considered to be the Rügen area, the Gdansk Bay, the Hanö Bight, the Gulf of Riga, the Gulf of Finland, the Archipelago Sea, the Åland Sea and both the west and east coast of the Gulf of Bothnia. Several important spawning grounds also exist along the entire Swedish east coast. However, no studies have investigated the possible changes in spawning locations of spring-spawning herring in relation, for example, to different degrees of eutrophication, changes in oceanography and changes in adult behaviour. Moreover, the contribution of each spawning site on herring recruitment is unknown. This is also confirmed by the fact that the stock-recruitment relationship holds only for some of the stocks assessed in the Baltic, this further emphasising that different processes might act in different areas.

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3.4.6 Occasional winter spawning of North Sea sprat

North Sea sprat (divisions IVa, IVb, IVc) is traditionally considered to be a spring-summer spawner, but existence of an autumn-spawning component is possible. There are indications that larvae from autumn spawning will over-winter as larvae and metamorphose the year after. This is based on MIK-hauls taken during the IBTS February surveys that have in some years caught over-wintering larvae of sprat in the central-southern area. The contribution of this putative stock component to recruitment is unknown.

3.4.7 Extra winter spawning of Baltic sprat

The winter of 2001/2002 was the fifth mild winter in succession in the Baltic area resulting in positive water temperature anomalies in the southern Baltic Sea of up to 4.8ºC in February (ICES, 2003). Positive deviations from the long-term mean air temperature continued, with very warm air masses from southern Europe causing unusually stable “subtropical” conditions in August and September. Meteorological conditions in late summer caused an inflow of extremely warm waters from the western Baltic into the eastern basins. The advection of water masses resulted in exceptionally high water temperatures in October 2002 of up to 14°C in the surface layer, and 10°C in the near bottom layer of the Bornholm Basin, which is 3°C higher than the long-term mean.

Spawning in clupeids is induced by sufficient temperature and energy levels (e.g., Johnson 1970, Hunter and Leong 1981). Sprat in the Central Baltic deep basins normally spawn between March and July with a peak in early June. Within the GLOBEC-GERMANY programme sprat were sampled for maturation and fecundity studies from April 2002 to April 2003. This allowed detecting the effect of the warm water intrusion on the sprat maturation cycle. The proportion of mature individuals in spawning condition firstly peaked as expected between April and June 2002. But, during winter 2002/2003 the unusual high temperatures induced a secondary maturation cycle and spawning individuals were observed from November onwards with a second spawning peak in January 2003. However, the unusual winter spawning was characterised by extremely high spawning frequencies indicating that no regular spawning patterns could be established (Kraus *et al*., 2003). Furthermore, spawning was restricted to a small part of the basin, corresponding to the unusually warm water body, which gradually decreased due to mixing processes. Overall egg abundance was low compared to spring spawning. While some eggs could successfully develop, hatched larvae encountered in the field obviously starved. All larvae caught had consistently empty stomachs, to be explained by very low zooplankton abundance at this time of the year. Larval length frequencies were accordingly restricted to the yolk-sac stages.

A negative effect on spawning activity during the following regular spawning time was not observed. It seems that sprat were able to completely regain their energy level between February and April. In early 2003 the loss of energy by winter-spawning was probably counterbalanced by a unusually good food supply for adult sprat, i.e. high abundances of adult *Pseudocalanus* sp. copepods.

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3.5 ToR e)

Identify situations which have potential impact on the assessment, projection or management processes: update the relevant assessment working groups and survey planning groups with the information through working documents and provide these groups with quantitative information on fishery-ecosystem interactions

The group focused on environment-based recruitment indices with Baltic sprat and Biscay anchovy as case studies. In both cases strong correlations between environmental parameters and year class strength had been evidenced and underlying mechanisms supported the correlations. In both cases, hydrodynamic circulation models had been used to construct oceanographic parameters. Guide lines were defined to operationalise the use of an environment-based recruitment index in stock projection and to deal with the possibility of inaccuracy in the projection. A list of criteria's was:

- Base the index on an understanding of the mechanisms. The correlation evidenced between a recruitment series and a series of environmental parameters should be based on underlying mechanisms.
- Improve and update the index. Change / persistence in the oceanographic regime should be documented each year as well as in the adult stock spawning behaviour to evidence change / persistence in the underlying mechanisms. The use of a correlation model in projection mode (extrapolation) is a risky game because a new forcing parameter may be prevailing when this was not observed before. It is thus of prior importance to develop the ability to detect changes.
- Characterise the statistical conditions for the index to be useful. Precision of model predictions depends on the level of noise in the index as well as the number of points in the series. It is suggested that model predictions be compared to a base line geometric mean recruitment for different levels of noise in the index. This should allow for the estimation of the minimum noise level for the index to be useful.
- Characterise the predictive capability of the index. A retrospective analysis of the model prediction is suggested to allow for the estimation of the probability for the model prediction to be correct.
- Use the index to build projection scenarios. The model prediction could be used to decide on a recruitment scenario. The scenario would have the probability of the model prediction to be correct. For instance, when the model suggests poor recruitment, stock projection could be made using an average of the lowest historical recruitments.

For Baltic sprat, the German GLOBEC program examined in detail the explicative mechanisms of larval survival. Two regimes were evidenced. In each regime different environmental parameters explained stock recruitment variability. A retrospective analysis demonstrated that the environmental-based predictions were both closer to the observed values and less variable than the ICES-derived predictions based on the 10-year geometric mean. For Biscay anchovy, a similar oceanographic process (e.g., upwelling) was estimated using different parameters (satellite derived wind fields or a 3D circulation model). Different recruitment models were built using a different number of environmental parameters. The noise in the index was at the edge of being useful in stock projection. A retrospective analysis of the prediction concluded that conditions for low recruitment could be detected with acceptable precision.

3.5.1 Baltic sprat recruitment

A recent study has demonstrated the relationship between hydroclimatic variables (NAO, ice cover, temperature) and sprat recruitment in the Central Baltic Sea (MacKenzie and Köster 2004). The study showed further that recruitment can be predicted before adults spawn (i.e., 15 months earlier than using present technology) by using linkages between recruitment and the hydro-climatic variables. A retrospective analysis demonstrated that the quality of the environmental-based predictions were both closer to the observed values and less variable than the ICES-derived predictions based on the 10-year geometric mean (MacKenzie and Köster 2004).

Temperature has been shown to have increased during the 1990s as a response to the positive NAO period (Fonselius and Valderramq 2003), and caused the high recruitment success of sprat during the 1990s (Köster *et al*., 2003). A candidate mechanism behind the temperature-recruitment relationship is a direct thermal effect on egg survival as demonstrated by experiments (Nissling 2004). However, correlation analysis between SSB and the various consecutive early life-stage abundance and production revealed significant relationships between SBB, egg production and larval abundance. No significant correlation among larval and 0-group abundance was found, suggesting the larval stage to be critical in the life-cycle of Baltic sprat (Köster *et al*., 2003). Beside a direct positive effect of higher temperatures on the survival of larvae (Nissling 2004) an indirect effect via food supply may be important. Investigations on the feeding ecology of larval sprat indicated the importance of the copepod *Acartia* spp. for the nutrition of the larvae (Voss *et al*., 2003). Investigations on long-term dynamics of copepods have demonstrated a drastic increase in abundance of *Acartia* spp. during spring-spawning time of sprat (Möllmann *et al*., 2003). This increase was observed to be step-wise with drastically higher abundances during the 1990s visible also in other biotic and abiotic variables and frequently termed a “regime-shift” (Alheit *et al*., 2005). Preliminary explorative analyses showed a close relationship between the abundance of copepodites C1-3 of *Acartia* spp. and sprat recruitment at age 1 from MSVPA (Figure 1). Further, recent investigations on sprat recruitment processes within GLOBEC-GERMANY combining field survey results, hydrodynamic modelling and biochemical techniques revealed the importance of later copepodite stages of *Acartia* spp. for the survival of late-stage sprat larvae in summer (Voss *et al*., submitted).

Based on the two periods (“regimes”) observed in the ecosystem separate stock-recruitment relationships can be constructed clearly showing the two different productivity states (Figure 2). This points out the need to identify productivity regimes in the ecosystem to reliably predict the recruitment potential of Baltic sprat.

A presently conducted study within GLOBEC-GERMANY uses long-term hydrodynamic modelling (with a 3D circulation model) to study and predict recruitment variability in Central Baltic sprat. A first approach defined retention and dispersion based on the relative number of simulated particles staying within and going outside the sprat spawning area (Baumann *et al*., 2004). A new approach used depth and temperature information to define retention/dispersal Bauman *et al*. (in prep.). Positive depth anomalies calculated over the trajectories of all seeded particles indicated retention in the deep basins, whereas negative anomalies indicated transport to shallow areas. Similarly warmer/colder than average temperatures experienced by the particles indicated retention in colder deeper waters or dispersal to warmer coastal waters. The depth anomalies (WDA) of particles seeded on julian day 181 were found to explain a high amount of variability in the 0-group recruitment time-series (from MSVPA). The relationship was good in the 1990s, as was observed with the “old” retention index (Baumann *et al*., 2004). High retention situations are generally related to higher recruitment, while advection out of the deep basins seems to be in synchrony with low survival. The process behind this relationship (e.g. higher predation pressure in coastal areas) is unknown and needs further investigations. Using the WDA in combination with the abundance of *Acartia* spp. (the main food item for larval sprat – see above) and SSB results in multilinear regression models explaining >70% of the variance on the recruitment.

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Supporting figures 1–2.

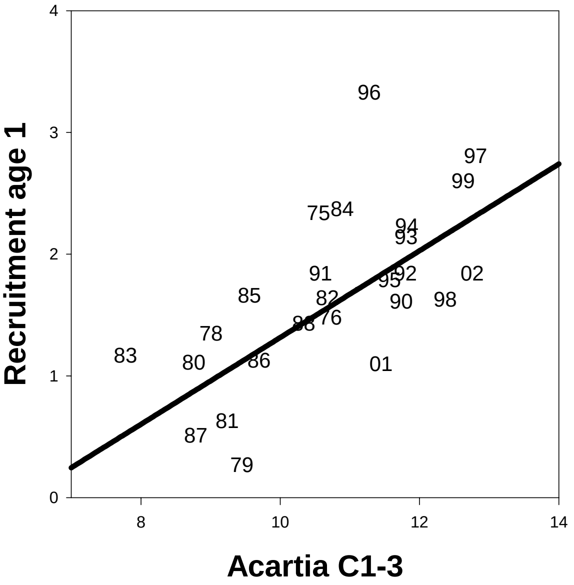

Figure 1: Relationship between recruitment at age 1 (millions, ln-transformed) and *Acartia* spp. C1-3 abundance (nb m^{-2}, ln-transformed).

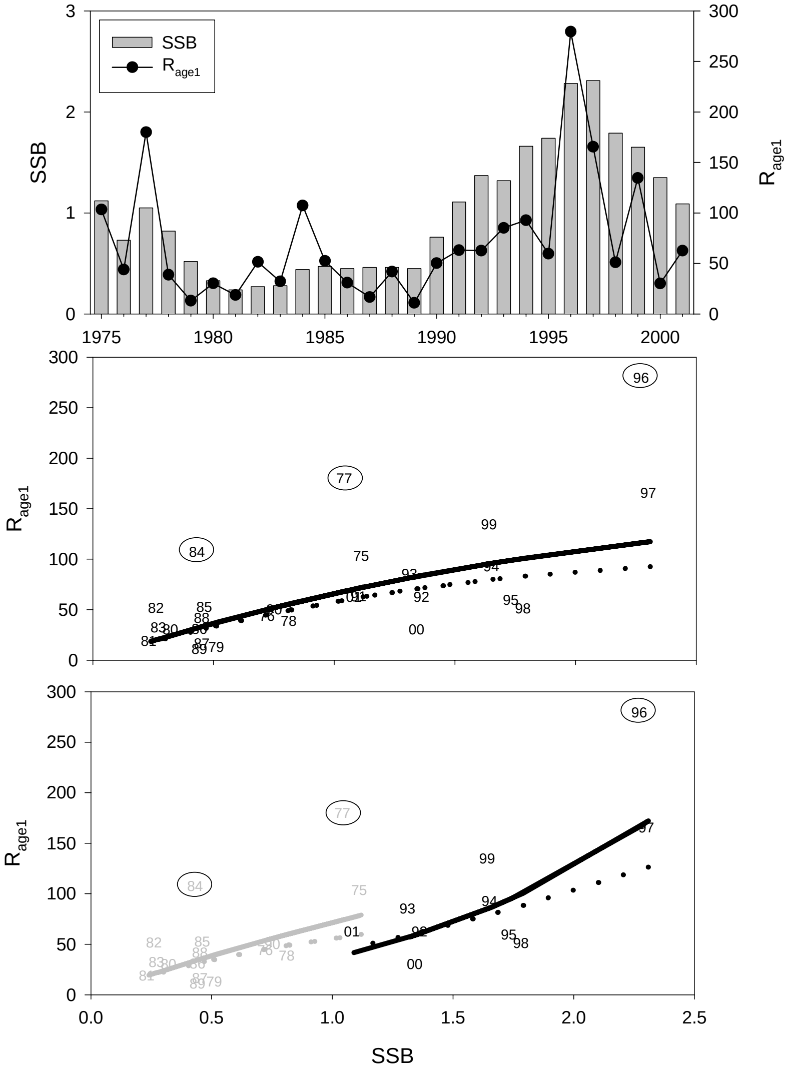

Figure 2: Stock and recruitment of Central Baltic sprat: SSB (1000t) and recruitment at age 1 (millions, from MSVPA) [upper panel], stock-recruitment relationship for the whole period (dotted line without outliers in circles) [middle panel], and stock-recruitment relationships for 1974–1989 and 1990–2001 (dotted line without outliers in circles) [lower panel].

3.5.2 Bay of Biscay anchovy recruitment

Several environmental indices in the Bay of Biscay during anchovy spawning time in the current year have been shown to be in good correlation with year class strength in the subsequent year. This led to develop by regression modelling environment-based recruitment indices and propose their use for predicting the population one year in advance. Borja *et al.* (1996, 1998) showed that for the period 1967–1996, north-easterly winds of medium intensity in spring/summer were related to good levels of anchovy recruitment. The major oceanographic event linked to that wind regime is weak upwelling. The derived index had some utility for predictions, but was not sufficiently accurate (ICES 2001) and this relationship has worsen in recent years partly because of changes made by NOAA in its estimates of satellite derived wind fields (Uriarte *et al.*, 2003). Allain *et al.* (2001) improved the previous relationship for the period 1986–1997 by simulating the oceanographic processes using a 3D hydrodynamic model (MARS 3D model of IFREMER: Lazure and Jégou, 1998). In addition to an upwelling index a stratification breakdown index was also retained as having a significant negative effect on recruitment. The stratification breakdown index is associated to summer gales. These two variables explained about 75 % of the recruitment inter-annual variability in the period 1986–1997.

Since 1999, Borja’s upwelling index and Allain *et al.*’s indices of upwelling and stratification breakdown are delivered annually to WGMHSA as well as the corresponding recruitment indices providing WGMHSA with a basis for anchovy stock projection in the next year. So far WGMHSA has delayed the incorporation of these indices in the building of scenarios of stock projection until better understanding of the performance of the indices was achieved. In its 2005 report, WGRED (ICES 2005) suggested the incorporation of environmental indices in anchovy stock projection in the context of the ecosystem approach to fisheries management (EAFM). In its 2005 report WGMHSA (ICES 2005) concluded that Allain *et al.*’s recruitment index was robust at predicting poor recruitment, although performed less well for medium recruitment levels.

The group revisited the performance of the environmental indices. Simple log-linear models predicting recruitment (age-1 in the subsequent year) were fitted to the environment series of indices of upwelling and stratification breakdown (in the current year). Figure 1 (1986–2003) shows the fitted log lineal models of environmental indices (in year n) on anchovy recruitment estimates (age-1 in year n+1) along with their coefficient of determination. Borja’s upwelling index is not significant at alpha 5%, whereas the Allain’s *et al*. bivariate model is significant. The group also revisited the predictive performance of the recruitment indices (i.e., the log-linear models) by means of a retrospective analysis for the period 1996–2003. The prediction as available to the WGMHSA in the past year [n-1] was compared to the abundance of age-1 fish as estimated by WGMHSA in the current year [n]. Values used were those in the 2005 report of WGMHSA. Figure 2 (1996–2003) shows a poor performance of Borja’s index in predicting recruitment since 1998. Allain’s *et al*. bivariate model was successful in predicting the failure of the 2001 recruitment (age-1 fish in 2002). This was not observed for the 2003 recruitment (although the 2003 recruitment estimate is still preliminary), which rendered non significant the overall predictions since 1996.

The prediction performance of a correlation model used in projection mode (extrapolation) was thought to depend on (i) the residual variance of the fit and (ii) the persistence of the underlying mechanisms. The second point suggests that a list of potential parameters be analysed each year for their explanatory power in order to test for changes in the mechanisms.

Considering that in a given period where underlying mechanisms are consistent and that a given correlation model applies, the residual variance in this model will determine its usefulness for stock projection. De Oliveira *et al*. (2003) analysed the conditions for useful projection. They compared recruitment forecasts based on environmental indices directly (expected R used in TAC formulation) or indirectly (expected R used as a trigger to increase or decrease the TAC) for a range of coefficient of determination (r^2) of the environmental indices on recruitment. Results show that improvements over the current Working Group approaches (in term of *risk* and average catch) are only attainable for $r^2 = 0.5$ and when a significant number of observations, 30 in that study, are available to fit the environmental index-recruitment relationship. This puts the current environmental models for anchovy recruitment at the edge for helping the formulation of management advice (because they may have r^2 values of about 0.3–0.5 based on 17 years of observations).

Increasing the predictability of an environment-recruitment model is also an ecological problem. Explanatory environmental indices are potential and as such they describe a general condition over an area and a season. Predictive power in the model forecast could be achieved by using biological indices relative to the adult behaviour. The transformation of potentiality into predictability was thought to require information on the adult spawning windows in space and time, both the realised windows as estimated e.g., by a spatio-temporal spawning model and the useful windows as estimated e.g., by a biophysical larvae drift and survival model (Allain *et al*., 2004).

A more qualitative way of using environment-recruitment correlations for stock projection was discussed. Based on the forecast probability of the recruitment index, scenarios of recruitment can be built from the historic recruitment series, thus making indirect use of the environment-recruitment correlation. For instance, when Allain's *et al*. model suggests poor recruitment, projections could be made using an average of the lowest historical recruitments e.g. the bottom 25 percentile or probabilistic density of past recruitments estimates below historical median, etc. In the alternative case, the projection could be run with a historic mean recruitment. SGRESP recommended to continue along that line of research. For anchovy in South Africa, scenarios of most likely recruitments have been defined by applying regression trees to an ensemble of environmental and biological indices and the approach has been made operational (Korrûbel *et al*., 1999; Miller and Field, 2002).

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Supporting figures 1–2.

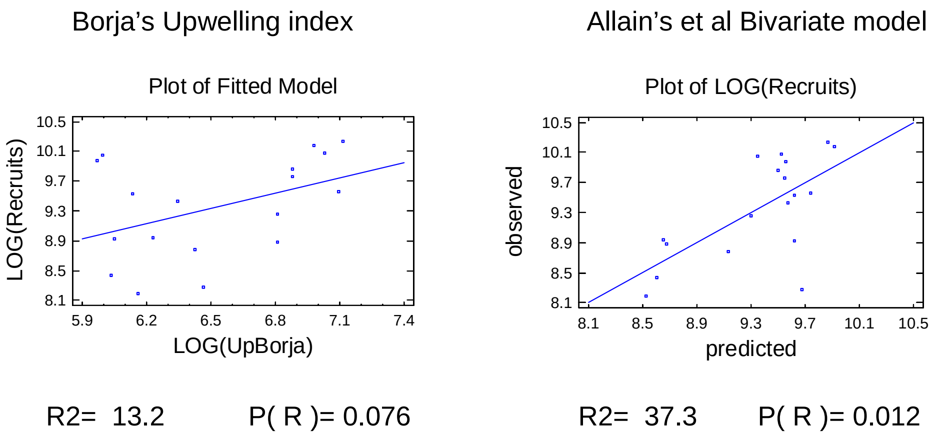

Figure 1: Fitted Log lineal models of environmental indices on anchovy recruitment.

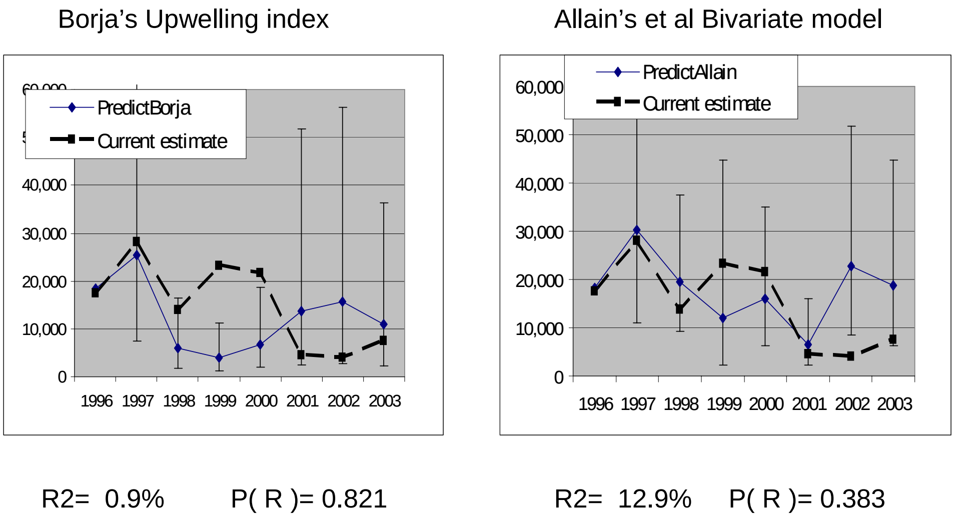

Figure 2: Retrospective analysis of the predictions of the Log lineal models of environmental indices on anchovy recruitment since 1996 compared with the ICES series of recruitment estimates.

3.6 ToR f)

Liaise with WGMHSA to identify the means by which Management Strategies could be developed based on SGRESP findings

Some participants to the group were also members of WGMHSA allowing direct linkage between SGRESP and WGMHSA. Two products from SGRESP were considered: short-term recruitment prediction and medium-term interaction status between population and environment regime. A methodology to incorporate environment-based recruitment prediction in population projection has been considered in answering ToR e). Work along that line is expected to provide WGMHSA with working documents in 2005. The medium-term status of the population-environment interaction relates to suggesting alternative management options. This was considered here.

Because life cycle types differ in their structure (see ToR b), it can be expected that a given life cycle will show specificities for implementing a management strategy. Such specificities would be based on the discreteness / continuity of habitats as well as on the mixing / separation of population components at different moments of the life cycle. Tools need be developed for modelling life cycles as well as for assessing the impact of conservation measures. Modelling of life cycles will require the development of spatial population models. Testing the effect of conservation measures such as prohibiting fishing effort on particular parts of the life cycle (e.g., protection of old spawners or juveniles) or particular habitats (e.g., area closures) will require the development of simulation platforms (e.g., Begley *et al.*, 2003; Mahévas *et al.*, 2004) which can integrate spatial population dynamics and fishing tactics. An area closure has been suggested to WGHMSA for anchovy conservation, which was based on the results of a spatial population model (Vaz *et al.*, 2002; Petitgas *et al.*, 2003). Results showed the dependence of the population dynamics to a particular spawning habitat. Assessing the effective impact of such area closure still remains to be performed. Plans are being made along these lines for future work.

The data and knowledge required for supporting life cycle modelling is scarce for many stocks, which often jeopardizes the development of spatial population models. Data and knowledge required are listed in Table 1 where it is clear that the major gap in knowledge relates to fish movements.

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Supporting table 1

Table 1: Data required to support the modelling of life cycles.

LIFE CYCLE DISTRIBUTION /EVENT	CHARACTERISTICS	DATA REQUIRED
Spawning Grounds	Continuous	Surveys: eggs, acoustics on adults
	Discrete	
	Separate components	Batch fecundity / Maturity; Adult length distribution; Age structure; Other: Otolith chemistry, genetics, morphometrics, etc
Nursery Grounds	Continuous	Surveys: IBTS, juveniles, larvae
	Discrete	
	Separate components	Otholith chemistry
Feeding Grounds	Continuous	Surveys: IBTS, acoustics
	Discrete	
	Separate components	Genetic, Otolith chemistry, etc.
Spawning migration	Common	Length distribution, tagging
	By components	
Feeding migration	Common	Length distribution, tagging
	By components	
Recruitment	Local	Length distribution
	To the population	

4 Recommendations

4.1 Assembling and combining data

The group recognised the importance of building large scale pictures of species and stock distributions by combining survey data at regional scale in ICES waters. The group recommends to extract from all bottom trawl surveys performed in ICES waters the following information for pelagic species: survey code, country, gear, year, month, quarter, haul code, ICES rectangle, haul longitude (decimal degree), haul latitude (decimal degree), haul duration (hour), species, fish length class (cm), numbers of fish caught. Species of interest are: anchovy, sprat, sardine, mackerel, blue-whiting, horse-mackerel and herring.

4.2 ICES 2006 workshop proposal on meso-scale oceanographic indicators

The group recognised the importance and the lack of time series of indices for meso-scale oceanographic features that potentially relate to the fish life cycle regionally. Tools are now available as well as hydrodynamic model outputs to construct such indices. The group felt timely to enhance work on this subject. The group recommends that a workshop be held in 2006 on indices of meso-scale structures in ICES waters. For the setting of this workshop as well as for co-chairing, SGRESP will liaise with WGPBI and GLOBEC-Focus 3 WG.

The **Workshop on Indices of Meso-scale Structures in ICES waters** [WKIMS] (Co-Chair B. Planque, France; *** to be contacted) will meet at *** in *** to:

a. review numerical methodologies for the constructions of indices of meso-scale structures such as fronts, eddies, transport, upwelling, and vertical hydrological changes;
b. disseminate available tools and software for the automatic detection of meso-scale structures;
c. construct long-term (>10 years) time series of indices of meso-scale structures in a number of systems in ICES waters.

Long-term indices of ocean climate are generally based on large scale features such as atmospheric circulation (e.g. NAO) oceanic circulation (e.g. Gulf Stream index), changes in SST, and so on. Although such indices provide some indication of large scale changes in the ocean, they often provide limited insight on the possible response of pelagic fish because the scale of the physical processes described is far greater than the scale at which fish behaviour (at individual, school or population levels) is generally understood. Process understanding of fish response to the environment is generally more obvious at the meso-scale (10–100km, days-weeks) where oceanographic features such as fronts, plumes, upwelling or eddies occur. An understanding of fish response to climate compatible with process understanding requires that meso-scale oceanic features be detected and tracked over long period of times. The aim of the workshop is to apply automated detection of meso-scale hydrological structures in a number of systems in ICES waters in order to provide long-term time series of these indices. These new time-series would complement those of existing indices (such as regional SST, NAO, Baltic inflow, etc.). The ultimate goal will be to relate time-series meso-scale indices to times series of fish populations on the basis of process understanding gained at the meso-scale by field/process studies.

It is intended that participants to the workshop will bring simulation outputs from 3D hydrodynamical models in their regional waters. These would include temperature, salinity, density and velocity fields as well as any other relevant parameter. The preferred format for model output will be NetCDF. The main output from the workshop will be the time series of meso-scale indices.

4.3 GLOBEC-SPACC/ICES 2006 workshop proposal

The group proposed last year a workshop dedicated to long-term variability in SW Europe. The proposition is repeated this year for SPACC executive committee to comment on it at its 2006 meeting.

Title: Long-term variability in SW European and adjacent waters. Co-Chairs: J. Alheit (De) for SPACC. Co-Chairs from convening countries will be approached. Suggested venue is for the end of 2006. The objective of the workshop is to enhance assembly, combination and analysis of different types of data (physics, plankton, landings, surveys, model outputs) at regional scale and in a long-term perspective (20–50 years).

4.4 ICES ASC 2007 Theme Session proposal

The group proposed last year a Theme Session which is standing for the 2007 ASC.

Title: Large scale changes in the migration of small pelagic fish and the factors modulating such changes. Co-Chairs: J. Alheit (De), D. Reid (UK).

This session aims to bring together studies on observed changes in migration patterns. These could include; track, timing, distance or speed. Papers are invited on any documented changes in such migrations, but particularly where potential explanatory phenomena have been identified. These could include:

- Environmental change e.g. upwelling and other oceanic events (e.g. ENSO), or climate change e.g. NAO, current changes etc. These may include both physical (e.g. temperature) and biological (e.g. food availability) factors;
- Population structure: For example stock abundance and demography (age structure) as well as population parameters such as condition factor, maturity ogives etc. The role of experienced adult fish in modulating migrations would be of particular interest.

Anthropogenic factors: This is principally aimed at the impact of fishing activity, particularly before and after stock collapses, but can include the direct result of fishing activity on migration paths and timings.

4.5 SGRESP 2006 meeting

The **Study Group of Regional Scale Ecology of Small Pelagic Fish** [SGRESP] (Chair P. Petitgas, France) will meet from 27 February to 02 March 2006 in Galway (Ireland) to:

a. Continue the assemblage of primary level data (e.g., sample based) on life history stages (adult, egg, larva, juvenile) of pelagic fish (mackerel, sardine, anchovy, sprat, herring, blue whiting) in ICES waters at regional scale and in a long-term perspective;

b. Combine second level data (e.g., rectangle based) on fish life cycle stages with that on their environment (measurements or model outputs), with particular attention to physical meso-scale processes, lower trophic levels and multi-species contexts, to evidence inter-annual changes in long-term history and spatial population patterns;

c. Update the understanding of particular phases in the life cycle (e.g., recruitment, spawning habitats, migration) that are critical for life cycle closure in the contexts of population collapse or expansion;

d. Increase knowledge on the expansion of anchovy and sardine in ICES waters north of 50°N;

e. Identify situations with potential impact on the assessment, projection and management processes and explore the means by which projections and management strategies can be developed and report findings to relevant ICES groups (e.g., WGMHSA, WGRED);

f. Review state of the art in modelling of population life cycles (e.g., spatial population models), report on their adequacy and identify the knowledge necessary to support modelling;

g. Summarize the knowledge produced by SGRESP and suggest a scientific plan for further progress on environment - population interaction.

Supporting Information

Priority:	The work of the Group is essential if ICES is to progress the understanding of environmental forcing on life history, spatial and population dynamics of pelagic fish to provide alternative basis to management on stocks recognised to fluctuate under environmental forcing.
Scientific Justification:	Present Study Groups and Planning Groups of LRC consider survey methods and tools for a variety of surveys on small pelagics in ICES areas (eggs, larvae, acoustics, aerial). On the other hand, assessment WGs of ACFM cannot deal with data integration although they consider that small pelagic stocks fluctuate under environmental forcing. The purpose of the SG is i) to integrate various survey data together as well as with meteo, satellite, fishery and/or ecosystem model outputs and ii) feed in the assessment WG with synthetic understanding of how the spatial dynamics of the biological cycle and the stock dynamics are related to the ecosystem thus increasing ICES ability to use ecological information in assessment and prediction of small pelagics. The SG will work on different case studies in the ICES waters.
Relation to Action Plan:	This group responds to Goal 1 Understand the physical, chemical, and biological functioning of marine ecosystems, in particular action numbers 1.2.2 Changes in spatio-temporal distributions in relation with environmental change, 1.6 assess and predict impact of climate variability and 1.7 play an active role in collaborations between ICES and other international research such as GLOBEC. This group is also related to Goal 4 Advise on the sustainable use of living marine resources, in particular action number 4.11 Develop the scientific basis for an ecosystem approach to management.
Resource Requirements:	No specific resource requirements beyond the need for members to prepare for and participate in the meeting.
Participants:	These would include scientists working in WG MHSA, scientists performing egg and acoustic surveys as well as scientists in population modelling, environmental change and scientists participating to GLOBEC/SPACC.
Secretariat Facilities:	None specific
Financial:	None specific
Linkages To Advisory	link with ACFM through WG MHSA

Committees:	
Linkages To other Committees or Groups:	The Group will deliver products to the WG MHSA and liaise with WG RED. It will take data from PG on egg, aerial and acoustic surveys
Linkages to other Organisations:	widened participation for this group will be seeked including GLOBEC/SPACC and relevant academic science
Cost:	National expenses

Annex 1: List of participants

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Annex 2: Inventory of survey data

North Sea herring surveys

- Annual herring larvae survey
- Annual herring acoustic survey
- Annual MIK net survey
- North Sea IBTS

North Sea herring larvae survey (coordinated by ICES, contracted by EC)

Data are available in the following database: ICES North Sea herring larvae database- held by Norbert Rohlf at IFM at the University of Kiel, for ICES PGHERS. (http://www.ifm.uni-kiel.de/fb/fb3/fi/research/projects/ihls.html)

They are accessible by SG members in the following way: Email request

Contact person for data request: Dr. Norbert Rohlf <nrohlf@ifm.uni-kiel.de>

Country	International	
acronym	PGHERS (HERLAV)	
Type of Survey	Double oblique ichthyoplankton samples	
months	Sept to January following year	
Areas	North Sea and eastern English Channel	ICES areas IV and VIId
target species	Herring *Clupea harengus*	

	1	2	3	4	5	6
secondary species	usually none	some labs sprat				

environmental parameter	X	T°	Sal	Fluo	Zoo	OPC
1972	x					
1973	x					
1974	x					
1975	x					
1976	x					
1977	x					
1978	x					
1979	x					
1980	x					
1981	x					
1982	x					
1983	x					
1984	x					
1985	x					
1986	x					
1987	x					
1988	x					
1989	x					
1990	x					
1991	x					
1992	x					
1993	x					
1994	x					
1995	x					
1996	x					
1997	x					
1998	x					
1999	x					
2000	x					
2001	x					
2002	x					
2003	x					
2004	x					

Comments

Surveys were carried out back to 1948 and the data are held in the archives on CEFAS, FRS, RIVO and a few other laboratories.
The survey now covers very specific areas and times of larval spawning, and hence is restricted to the centres of larval production.

North Sea herring acoustic survey (coordinated by ICES, contracted by EC)

Data are available in the following database: ICES acoustic survey database- held by John Simmonds, FRS Aberdeen for ICES PGHERS.

They are accessible by SG members in the following way: Email request

Contact person for data request: John Simmonds <j.simmonds@marlab.ac.uk>

Country	International
acronym	PGHERS (Acou)
Type of Survey	Acoustic survey
months	June/July
Areas	North Sea ICES IV
target species	Herring *Clupea harengus*

	1	2	3	4	5	6
secondary species	sprat					

environmental parameter	X	T°	Sal	Fluo	Zoo	OPC
1984	x	VEs	VEs			
1985	x	VEs	VEs			
1986	x	VEs	VEs			
1987	x	VEs	VEs			
1988	x	VEs	VEs			
1989	x	VEs	VEs			
1990	x	VEs	VEs			
1991	x	VEs	VEs			
1992	x	VEs	VEs			
1993	x	VEs	VEs			
1994	x	VEs	VEs			
1995	x	VEs	VEs			
1996	x	VEs	VEs			
1997	x	VEs	VEs			
1998	x	VEs	VEs			
1999	x	VEs	VEs			
2000	x	VEs	VEs			
2001	x	VEs	VEs			
2002	x	VEs	VEs			
2003	x	VEs	VEs			
2004	x	VEs	VEs			

Comments

Other species: some Institutes use the survey to investigate sandeel and Norway pout distributions without quantifying abundance.
The hydrographic data is not centrally held, but maintained by each Institute.

North Sea IBTS (coordinated by ICES, contracted by EC)

Formally ICES IYHS (see Heessen *et al.*, 1997; CM 1997/Y:31).

Data are available in the following database: Held at ICES. See DATRAS project. Data prior to 1971 is yet not on central database.

They are accessible by SG members in the following way: Email request within ICES data policy.

Contact person for data request: J.C. Mahé, IFREMER-Lorient jean.claude.mahe@ifremer.fr

Country	International	
acronym	IBTS	
Type of Survey	GOV trawl of fixed stations	taken during IBTS
months	annually Jan to Feb Q1	
Areas	North Sea, Skagerrak and Kattegat	
target species	Herring *Clupea harengus*	

	1	2	3	4	5	6
secondary speci	cod	sprat	haddock	whiting	Norway pout	saithe

environmental parameter	X	T°	Sal	Fluo	Zoo	OPC
1965						
1966	x					
1967	x					
1968	x					
1969	x					
1970	x					
1971	x					
1972	x					
1973	x					
1974	x					
1975	x					
1976	x					
1977	x					
1978	x					
1979	x					
1980	x					
1981	x					
1982	x					
1983	x					
1984	x					
1985	x					
1986	x					
1987	x					
1988	x					
1989	x					
1990	x					
1991	x					
1992	x					
1993	x					
1994	x					
1995	x					
1996	x					
1997	x					
1998	x					
1999	x					
2000	x					
2001	x					
2002	x					
2003	x					
2004	x					

^ = Comments

The original IBTS (the IYHS) targeted herring. The timing, location and storage of hydrographic data is unclear. Data prior to 1971 are not fully available as yet. A long series of surveys from Q3 still exists and in certain years (1991 to 1995) the survey took place each quarter.

North Sea MIK net (coordinated by ICES, contracted by EC)

Data are available in the following database: Held at Danish Institute for Fisheries Research, Charlottenlund, Denmark

They are accessible by SG members in the following way: Email request within ICES data policy.

Contact person for data request: Peter Munk, DIFRES <pm@dfu.min.dk>

Country	International	
acronym		
Type of Survey	Double oblique MIK net samples	taken during IBTS
months	annually Jan to Feb Q1	
Areas	North Sea	
target species	Herring *Clupea harengus*	

	1	2	3	4	5	6
secondary species	sprat					

environmental parameter	X	T°	Sal	Fluo	Zoo	OPC
1976						
1977	x					
1978	x					
1979	x					
1980	x					
1981	x					
1982	x					
1983	x					
1984	x					
1985	x					
1986	x					
1987	x					
1988	x					
1989	x					
1990	x					
1991	x					
1992	x					
1993	x					
1994	x					
1995	x					
1996	x					
1997	x					
1998	x					
1999	x					
2000	x					
2001	x					
2002	x					
2003	x					
2004	x					

Comments

The MIK net survey targets 0 group herring and is executed as part of the ICES North Sea IBTS. Originally the Isaacs-Kidd Midwater Trawl was used and this was replaced by the Method Isaacs Kidd net in 1990. The information on the hydrographic data is patchy (see IBTS previously).

Celtic Sea herring

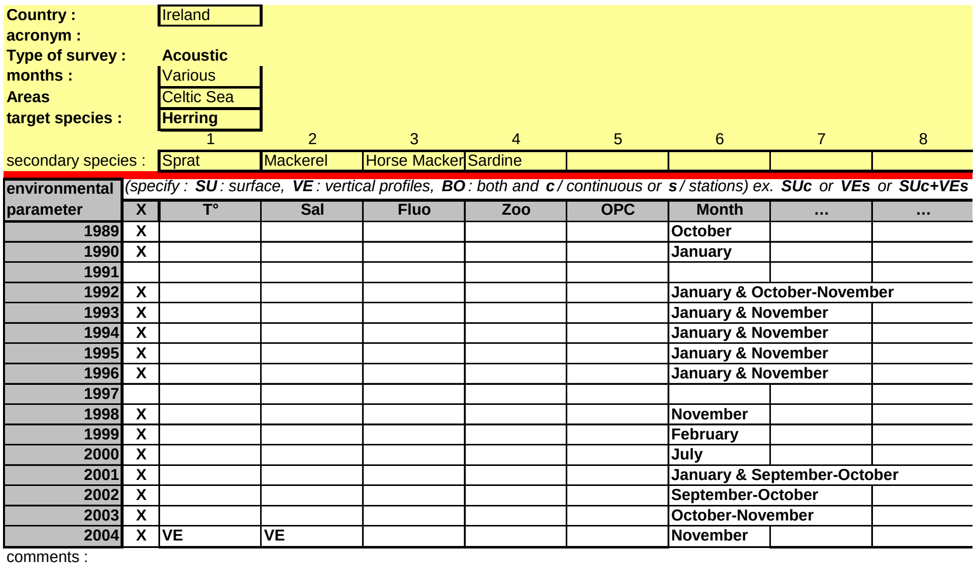
- Acoustic surveys
- Larvae surveys

Acoustic surveys

Data are available in the following data base: Files at Marine Institute in Excel formats

They are accessible by SG members by the following way: On request for joint analysis only

Contact person for data request: Ciaran O'Donnell, Marine Institute, Galway (Ireland), email: ciaran.odonnell@marine.ie, phone: 00 353 91730400



Country : Ireland
acronym :
Type of survey : **Acoustic**
months : Various
Areas Celtic Sea
target species : **Herring**

	1	2	3	4	5	6	7	8
secondary species :	Sprat	Mackerel	Horse Macker	Sardine				

*(specify : **SU** : surface, **VE** : vertical profiles, **BO** : both and **c** / continuous or **s** / stations) ex. **SUc** or **VEs** or **SUc+VEs***

environmental parameter	**X**	**T°**	**Sal**	**Fluo**	**Zoo**	**OPC**	**Month**	**…**	**…**
1989	X						October		
1990	X						January		
1991									
1992	X						January & October-November		
1993	X						January & November		
1994	X						January & November		
1995	X						January & November		
1996	X						January & November		
1997									
1998	X						November		
1999	X						February		
2000	X						July		
2001	X						January & September-October		
2002	X						September-October		
2003	X						October-November		
2004	X	VE	VE				November		

comments :

Larval surveys

Data are available in the following data base: Files at Marine Institute in different formats

They are accessible by SG members by the following way: On request for joint analysis only

Contact person for data request: Leonie Dransfeld, Marine Institute, Galway (Ireland), email: leonie.dransfeld@marine.ie, phone: 00 353 91730400

Country :	Ireland
acronym :	
Type of survey :	**vertical plankton stations**
months :	October-February
Areas	Celtic Sea
target species :	**Herring**

	1	2	3	4	5	6	7	8
secondary species :								

environmental parameter	*(specify : **SU** : surface, **VE** : vertical profiles, **BO** : both and **c** / continuous or **s** / stations) ex. **SUc** or **VEs** or **SUc+VEs***								
	X	**T°**	**Sal**	**Fluo**	**Zoo**	**OPC**	**...**	**...**	**...**
1978	**x**	**SU**							
1979	**x**	**SU**							
1980	**x**	**SU**							
1981	**x**	**SU**							
1982	**x**	**SU**							
1983	**x**	**SU**							
1984	**x**	**SU**							
1985	**x**	**SU**							
1986									
1987									
1988									
1989	**x**	**SU**							
1990	**x**	**SU**							
2004									

comments :

Herring in North West Ireland

- Acoustic surveys
- Larvae surveys

Acoustic surveys

Data are available in the following data base: Files at Marine Institute in Excel formats

They are accessible by SG members by the following way: On request for joint analysis only

Contact person for data request: Ciaran O'Donnell, Marine Institute, Galway (Ireland), email: ciaran.odonnell@marine.ie, phone: 00 353 91730400

Country : Ireland
acronym :
Type of survey : **Acoustic**
months : Various
Areas Northwest
target species : **Herring**

	1	2	3	4	5	6	7	8
secondary species :	Sprat	Mackerel	Horse Mackerel					

environmental parameter *(specify : **SU** : surface, **VE** : vertical profiles, **BO** : both and **c** / continuous or **s** / stations) ex. **SUc** or **VEs** or **SUc+VEs***

	X	T°	Sal	Fluo	Zoo	OPC	Month	…	…
1994	**X**						**July**		
1995	**X**						**July & August**		
1996	**X**						**July & August**		
1997									
1998									
1999	**X**						**October**		
2000	**X**						**November**		
2001	**X**						**November**		
2002	**X**						**March & November**		
2003	**X**						**February**		
2004	**X**	**VE**	**VE**				**January**		

comments :

Larvae surveys

Data are available in the following data base: Files at Marine Institute in different formats

They are accessible by SG members by the following way: On request for joint analysis only

Contact person for data request: Leonie Dransfeld, Marine Institute, Galway (Ireland), email: leonie.dransfeld@marine.ie, phone: 00 353 91730400

Country :		Ireland							
acronym :									
Type of survey :		**vertical plankton stations**							
months :		September-November							
Areas		Northwest of Ireland							
target species :		**Herring Larvae**							
		1	2	3	4	5	6	7	8
secondary species :									
environmental parameter	*(specify : **SU** : surface, **VE** : vertical profiles, **BO** : both and **c** / continuous or **s** / stations) ex. **SUc** or **VEs** or **SUc+VEs***								
	X	**T°**	**Sal**	**Fluo**	**Zoo**	**OPC**	**...**	**...**	**...**
1981	**x**	**SU**							
1982	**x**	**SU**							
1983	**x**	**SU**							
1984	**x**	**SU**							
1985	**x**	**SU**							
1986	**x**	**SU**							
1987	**x**	**SU**							
1988	**x**	**SU**							

comments :

Baltic herring

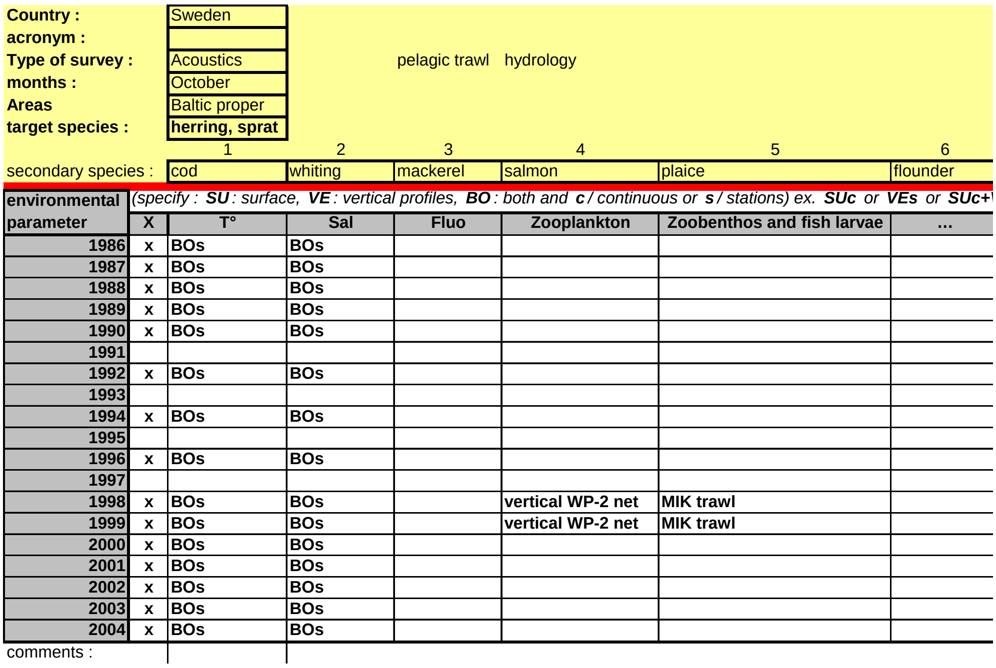
- Acoustic surveys
- Bottom trawl surveys

Acoustic surveys

Data are available in the following data base: Files at IMR, Lysekil (Sweden).

They are accessible by SG members by the following way: On request with ICES data policy

Contact person for data request: Niklas Larson, IMR Lysekil, email : Niklas.Larson@fiskeriverket.se, phone : 0046–0523–18773



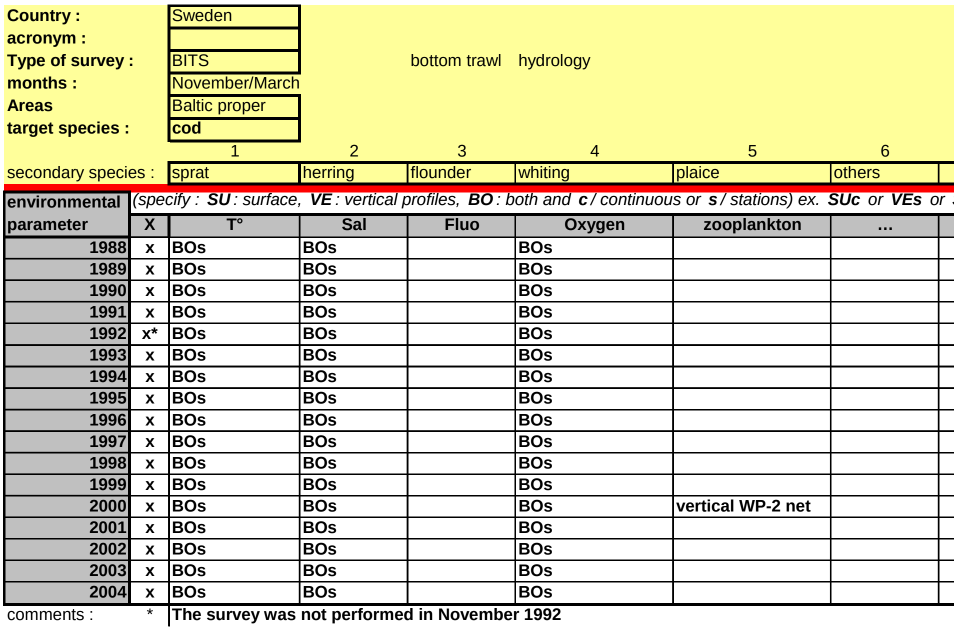
Country :		Sweden					
acronym :							
Type of survey :		Acoustics		pelagic trawl	hydrology		
months :		October					
Areas		Baltic proper					
target species :		**herring, sprat**					
		1	2	3	4	5	6
secondary species :		cod	whiting	mackerel	salmon	plaice	flounder
environmental parameter	*(specify : **SU** : surface, **VE** : vertical profiles, **BO** : both and **c** / continuous or **s** / stations) ex. **SUc** or **VEs** or **SUc+***						
	X	**T°**	**Sal**	**Fluo**	**Zooplankton**	**Zoobenthos and fish larvae**	**...**
1986	**x**	**BOs**	**BOs**				
1987	**x**	**BOs**	**BOs**				
1988	**x**	**BOs**	**BOs**				
1989	**x**	**BOs**	**BOs**				
1990	**x**	**BOs**	**BOs**				
1991							
1992	**x**	**BOs**	**BOs**				
1993							
1994	**x**	**BOs**	**BOs**				
1995							
1996	**x**	**BOs**	**BOs**				
1997							
1998	**x**	**BOs**	**BOs**		**vertical WP-2 net**	**MIK trawl**	
1999	**x**	**BOs**	**BOs**		**vertical WP-2 net**	**MIK trawl**	
2000	**x**	**BOs**	**BOs**				
2001	**x**	**BOs**	**BOs**				
2002	**x**	**BOs**	**BOs**				
2003	**x**	**BOs**	**BOs**				
2004	**x**	**BOs**	**BOs**				
comments :							

Bottom trawl surveys (coordinated by ICES): BITS

Data are available in the following data base: Files at IMR, Lysekil (Sweden).

They are accessible by SG members by the following way: On request with ICES data policy

Contact person for data request: Joakim Hjelm, IMR Lysekil, email: Joakim.Hjelm@fiskeriverket.se, phone: 0046–0523–18751



Country :		Sweden					
acronym :							
Type of survey :		BITS		bottom trawl	hydrology		
months :		November/March					
Areas		Baltic proper					
target species :		**cod**					
		1	2	3	4	5	6
secondary species :		sprat	herring	flounder	whiting	plaice	others
environmental	*(specify : **SU** : surface, **VE** : vertical profiles, **BO** : both and **c** / continuous or **s** / stations) ex. **SUc** or **VEs** or*						
parameter	**X**	**T°**	**Sal**	**Fluo**	**Oxygen**	**zooplankton**	**…**
1988	**x**	**BOs**	**BOs**		**BOs**		
1989	**x**	**BOs**	**BOs**		**BOs**		
1990	**x**	**BOs**	**BOs**		**BOs**		
1991	**x**	**BOs**	**BOs**		**BOs**		
1992	**x***	**BOs**	**BOs**		**BOs**		
1993	**x**	**BOs**	**BOs**		**BOs**		
1994	**x**	**BOs**	**BOs**		**BOs**		
1995	**x**	**BOs**	**BOs**		**BOs**		
1996	**x**	**BOs**	**BOs**		**BOs**		
1997	**x**	**BOs**	**BOs**		**BOs**		
1998	**x**	**BOs**	**BOs**		**BOs**		
1999	**x**	**BOs**	**BOs**		**BOs**		
2000	**x**	**BOs**	**BOs**		**BOs**	**vertical WP-2 net**	
2001	**x**	**BOs**	**BOs**		**BOs**		
2002	**x**	**BOs**	**BOs**		**BOs**		
2003	**x**	**BOs**	**BOs**		**BOs**		
2004	**x**	**BOs**	**BOs**		**BOs**		
comments :	*	**The survey was not performed in November 1992**					

North East Atlantic blue whiting

- Acoustic surveys
- Bottom trawl surveys

Due to the very large distribution area of this species, blue whiting is encountered in a large number of surveys. Surveys where blue whiting is known to be a by-catch species occurring in significant numbers are listed in the following table.

Table: suveys in which blue whiting is known to occur

Survey	Coverage	Quarter	Time series
Faroese demersal	Faroe plateau	2Q	1996-present
Faroese demersal	Faroe plateau	4Q	1994-present
Spanish demersal	NW(-N) Spain	4Q	1980-present
Portuguese demersal	Portuguese coast	3Q	1979–2001
Portuguese demersal	Portuguese coast	3Q	1979-present
IFREMER demersal	Biscay + Celtic Sea	4Q	1987-present
IFREMER acoustic	Bay of Biscay	2Q	1983-present
FRS demersal survey	W-NE Scotland	1Q	1986-present
FRS demersal survey	Rockall, N North Sea	3Q	1985-present
IBTS North Sea	North Sea (blw in N)	1Q	1960s-present
IBTS North Sea	North Sea (blw in N)	3Q	1970s-present

The following are listed surveys that target blue whiting or in which blue whiting data have been analyzed are listed.

Norwegian surveys

Data are available in the following data base: files in a database at IMR, Bergen (Norway).

They are accessible by SG members by the following way: On request with ICES data policy

Contact person for data request: Mikko Heino, IMR Bergen,

Acoustic surveys west of the UK

Country :	Norway		
acronym :			
Type of survey :	Acoustics	pelagic trawl	hydrology
months :	3, 4		
Areas	West of the British Isles		
target species :	**Blue whiting**		

	1	2	3	4	5	6	7
secondary species :							

environmental parameter	*(specify : **SU** : surface, **VE** : vertical profiles, **BO** : both and **c** / continuous or **s** / stations) ex. **SUc** or **VEs***							
	X	**T°**	**Sal**	**Fluo**	**Zoo**	**OPC**	**Eggs & larvae**	**…**
1981	x	VEs	VEs					
1982								
1983	x	VEs	VEs					
1984	x	VEs	VEs					
1985								
1986	x	VEs	VEs					
1987	x	VEs	VEs					
1988	x	VEs	VEs					
1989	x	VEs	VEs					
1990	x	VEs	VEs					
1991	x	VEs	VEs					
1992	x	VEs	VEs					
1993	x	VEs	VEs					
1994	x	VEs	VEs					
1995	x	VEs	VEs					
1996	x	VEs	VEs					
1997								
1998	x	VEs	VEs					
1999	x	VEs+SUc	VEs+SUc	SUc				
2000	x	VEs+SUc	VEs+SUc	SUc				
2001	x	VEs+SUc	VEs+SUc	SUc			x	
2002	x	VEs+SUc	VEs+SUc	SUc			x	
2003	x	VEs+SUc	VEs+SUc	SUc			x	
2004	x	VEs+SUc	VEs+SUc	SUc			x	

Comments: Russia has run a similar surveys in most years between 1982–1996 and again from 2002 onwards with 1–2 vessels. Since 2004 this survey is run as a coordinated international survey with also EU joining.

Norwegian Sea acoustic surveys

Country :		Norway						
acronym :								
Type of survey :		Acoustic	pelagic trawl					
months :		7, 8						
Areas		Norwegian Sea						
target species :		**herring**						
		1	2	3	4	5	6	7
secondary species :		blue whiting						
environmental parameter	*(specify : **SU** : surface, **VE** : vertical profiles, **BO** : both and **c** / continuous or **s** / stations) ex. **SUc** or **VEs***							
	X	**T°**	**Sal**	**Fluo**	**Zoo**	**OPC**	**…**	**…**
1981	**x**	**VEs**	**VEs**					
1982	**x**	**VEs**	**VEs**					
1983	**x**	**VEs**	**VEs**					
1984	**x**	**VEs**	**VEs**					
1985	**x**	**VEs**	**VEs**					
1986	**x**	**VEs**	**VEs**					
1987	**x**	**VEs**	**VEs**					
1988	**x**	**VEs**	**VEs**					
1989	**x**	**VEs**	**VEs**					
1990								
1991								
1992	**x**	**VEs**	**VEs**					
1993	**x**	**VEs**	**VEs**					
1994								
1995	**x**	**VEs**	**VEs**					
1996	**x**	**VEs**	**VEs**					
1997	**x**	**VEs**	**VEs**					
1998	**x**	**VEs**	**VEs**					
1999	**x**	**VEs**	**VEs**					
2000	**x**	**VEs**	**VEs**					
2001	**x**	**VEs**	**VEs**					

comments :

North Sea shrimp bottom trawl surveys

Country :		Norway						
acronym :								
Type of survey :		bottom trawl						
months :		10, 11						
Areas		North Sea (Norwegian Deeps, Skagerrak)						
target species :		**shrimp *Pandalus borealis***						
		1	2	3	4	5	6	7
secondary species :		blue whiting						
environmental parameter	*(specify : **SU** : surface, **VE** : vertical profiles, **BO** : both and **c** / continuous or **s** / stations) ex. **SUc** or **VEs***							
	X	**T°**	**Sal**	**Fluo**	**Zoo**	**OPC**	**…**	**…**
1984	**x**							
1985	**x**							
1986	**x**							
1987	**x**							
1988	**x**							
1989	**x**							
1990	**x**							
1991	**x**							
1992	**x**							
1993	**x**							
1994	**x**							
1995	**x**							
1996	**x**							
1997	**x**							
1998	**x**							
1999	**x**							
2000	**x**							
2001	**x**							
2002	**x**							
2003								
2004								

comments :

Barents Sea surveys

Country :	Norway						
acronym :							
Type of survey :	Acoustics	bottom trawl	pelagic trawl	hydrology			
months :	2, 3						
Areas	Barents Sea						
target species :	**Cod**						
	1	2	3	4	5	6	7
secondary species :	Haddock	Redfish	Greenland hal	blue whiting			

environmental parameter	*(specify : **SU** : surface, **VE** : vertical profiles, **BO** : both and **c** / continuous or **s** / stations) ex.* **SUc** *or* **VEs**							
	X	**T°**	**Sal**	**Fluo**	**Zoo**	**OPC**	**…**	**…**
1981	**x**	**VEs**	**VEs**					
1982	**x**	**VEs**	**VEs**					
1983	**x**	**VEs**	**VEs**					
1984	**x**	**VEs**	**VEs**					
1985	**x**	**VEs**	**VEs**					
1986	**x**	**VEs**	**VEs**					
1987	**x**	**VEs**	**VEs**					
1988	**x**	**VEs**	**VEs**					
1989	**x**	**VEs**	**VEs**					
1990	**x**	**VEs**	**VEs**					
1991	**x**	**VEs**	**VEs**					
1992	**x**	**VEs**	**VEs**					
1993	**x**	**VEs**	**VEs**					
1994	**x**	**VEs**	**VEs**					
1995	**x**	**VEs**	**VEs**					
1996	**x**	**VEs**	**VEs**					
1997	**x**	**VEs**	**VEs**					
1998	**x**	**VEs**	**VEs**					
1999	**x**	**VEs**	**VEs**					
2000	**x**	**VEs**	**VEs**					
2001	**x**	**VEs**	**VEs**					
2002	**x**	**VEs**	**VEs**					
2003	**x**	**VEs**	**VEs**					
2004	**x**	**VEs**	**VEs**					

comments :

North Sea sprat

- Norwegian acoustic survey targeting sprat
- North Sea International Bottom Trawl Surveys (IBTS-series)
- Summer Acoustic Surveys for herring (Planned and coordinated by ICES PGHERS)

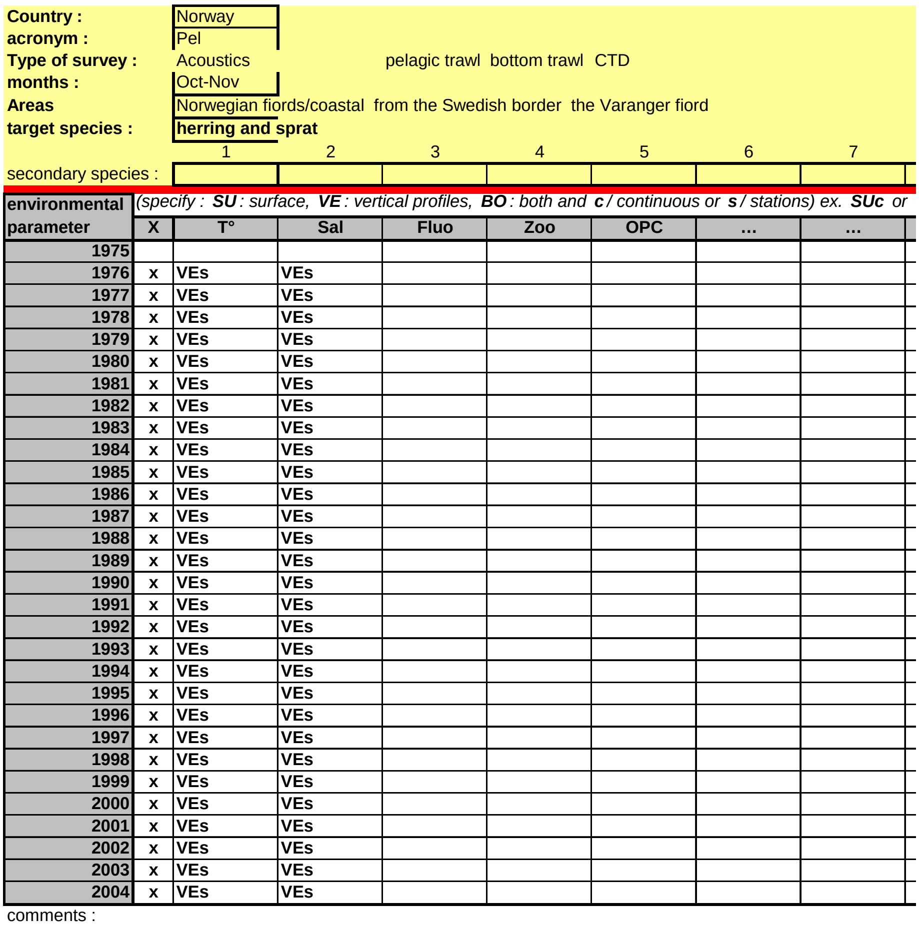
In the Norwegian acoustic survey sprat is a target species while it is a by-catch in IBTS and herring surveys.

Norwegian acoustic surveys

Data are available in the following data base: files in a database at IMR, Bergen (Norway).

They are accessible by SG members by the following way: On request with ICES data policy

Contact person for data request: Else Torstensen, IMR Bergen, Else.Torstensen@imr.no



Country : Norway
acronym : Pel
Type of survey : Acoustics pelagic trawl bottom trawl CTD
months : Oct-Nov
Areas Norwegian fiords/coastal from the Swedish border the Varanger fiord
target species : **herring and sprat**

	1	2	3	4	5	6	7
secondary species :							

*(specify : **SU** : surface, **VE** : vertical profiles, **BO** : both and **c** / continuous or **s** / stations) ex. **SUc** or*

environmental parameter	**X**	**T°**	**Sal**	**Fluo**	**Zoo**	**OPC**	**...**	**...**
1975								
1976	x	VEs	VEs					
1977	x	VEs	VEs					
1978	x	VEs	VEs					
1979	x	VEs	VEs					
1980	x	VEs	VEs					
1981	x	VEs	VEs					
1982	x	VEs	VEs					
1983	x	VEs	VEs					
1984	x	VEs	VEs					
1985	x	VEs	VEs					
1986	x	VEs	VEs					
1987	x	VEs	VEs					
1988	x	VEs	VEs					
1989	x	VEs	VEs					
1990	x	VEs	VEs					
1991	x	VEs	VEs					
1992	x	VEs	VEs					
1993	x	VEs	VEs					
1994	x	VEs	VEs					
1995	x	VEs	VEs					
1996	x	VEs	VEs					
1997	x	VEs	VEs					
1998	x	VEs	VEs					
1999	x	VEs	VEs					
2000	x	VEs	VEs					
2001	x	VEs	VEs					
2002	x	VEs	VEs					
2003	x	VEs	VEs					
2004	x	VEs	VEs					

comments :

Annex 3: Presentations

ID card for herring in the North Sea. M. Dickey-Collas, RIVO (NL)

ID card for herring around Ireland. L. Dransfeld, MI (IRL)

ID card for herring in the Baltic. M. Casini, IMR (SE)

ID card for sprat in the North Sea. E. Torstensen, IMR (NO)

ID card for North East Atlantic blue whiting. M. Heino, IMR (NO)

Possible connections between WGRED and SGRESP. D. Reid, FRS (UK).

Meso-scale environmental indicators. B. Planque, IFREMER (FR).

Analysing spawning habitat variation with a comprehensive data base on sardine eggs. M. Bernal, IEO (SP) and Y. Stradoudakis, IPIMAR (PT).

Comprehensive data base on mackerel and suggested analysis. D. Beare, FRS (UK).

Distribution patterns of life history stages of Baltic sprat: Impact of environmental forcing. C. Möllman, DIFRES (DK) and R. Voss, IFM-Kiel (DE).

Habitats of different Baltic sprat life cycles have been characterized in more detail for the area of the Bornholm Basin, acting as a case study in the GLOBEC Germany project. Horizontal distribution of the adult stock showed a strong seasonality. At the beginning of the spawning season in March sprat left their more shallow feeding areas and started to aggregate in the eastern part of the basin. Over the course of the spawning season adult sprat invaded the complete area of the deep basin (>60m depth), reaching high densities. At the end of the spawning season, remaining concentrations were only found in the north-eastern part. These distribution patterns were mirrored by the egg distribution. Abundance of adult sprat in the area >60m depth decreased from >55 billion fish at peak spawning time in April 2002 to <5 billion in July 2002. Abundance stayed on this low level until the beginning of 2003, when abundance started to increase again for next years spawning. Evaluation of combined hydroacoustic and hydrographical data allowed a seasonal habitat definition for the adult stock. During winter time adult sprat were restricted to the water body having temperatures of >4°C and >1.5ml/l oxygen. Sprat was therefore captured between cold waters from above and the oxygen-depletion-zone from below and did not perform diurnal vertical migrations. After warming of the surface waters in spring, sprat started to perform diurnal migrations. During night-time they stayed above or in the thermocline, while they were found within and below the halocline down to low oxygen concentrations during day-time. In summer sprat were more dispersed during day-time, staying within or above the halocline. Potential winter habitat varied over years between the main spawning grounds (ICES SD 25, 26 and 28). Size of the winter habitat seemed to be linked to adult distribution for next years spawning time. The vertical distribution pattern and diel migration behaviour of Baltic sprat larvae changed between 1989–1990 and 1998–2002. In 1989 and 1990 they migrated to the surface at night, while they stayed at 30–50m depth during day-time. In 1998–2002 sprat larvae showed no signs of diel vertical migration. They stayed the whole day in the warmer, near surface waters. This behavioural change happened concurrently to changes in the Baltic ecosystem. The major prey organism (*Acartia* spp.) of Baltic sprat larvae increased in abundance. In the Bornholm Basin near surface temperature increased since the 1990s and *Acartia* spp. aggregated in this water layers. Therefore the vertical profile of suitable food for sprat larvae changed, resulting in high food levels in the surface layers. The observed change in vertical distribution patterns of sprat larvae might have influenced the generally higher but also more variable recruitment in Baltic sprat in the last decade. Transport of sprat larvae to their juvenile spawning grounds was investigated by detailed drift model simulations for the years 1979–2002. Different modelling approaches with and without diurnal vertical migration (see above) were utilised. Data on spawning location and timing of spawning were used as input to a particle tracking model. Most important potential nursery grounds for sprat were identified along the south-eastern Baltic coast. Inter-annual variations were mainly due to variable wind conditions over the Baltic Sea. The horizontal distribution of simulated larval or 0-group sprat is mostly consistent with the observed distribution of 0-group sprat obtained from the hydroacoustic field surveys. This analysis will also allow determination of the potential for advective mixing between juveniles originating from different spawning sites or from different stock components throughout the spawning season.

On the functional role of adult dispersion: a hypothesis. P. Petitgas, IFREMER (FR).

A life cycle was understood to be associated with particular oceanographic features that have a certain degree of predictability across years. A population was defined as a life cycle that managed to get closed by making use of the oceanographic features. The distribution area of a species was made by various populations that were connected to each other in two different ways. The connection could be a systematic important flux of individuals by larval drift or adult migration, or a small flux of vagrants. In the former case, the populations formed a metapopulation where as in the latter they could be considered seperate populations. Vagrancy is often seen as random with more evolutionary than ecological significance. The hypothesis was made that vagrancy of adults played a major role in maintaining population occupation of habitats in a changing environment in the context of depleted populations. The hypothesis was presented that (1) vagrancy has a functional ecological role in searching for establishing the life cycle in new areas or recolonising lost habitats as a response to medium/long-term variation in the ocean and (2) that old adults are most efficient for doing so. First, consequences of the hypothesis were listed and work suggested. In particular it was suggested to combine survey data at large scale at other periods than spawning and identify what large and small fish do. Secondly, long-term variation in anchovy distribution in Biscay was revisited with the hypothesis. The stock is seen to have nearly disappeared from the Spanish coast and lost spawning grounds. A larval drift and survival model identified potential successful spawning on the Spanish coast. A circulation model evidenced a circulation pattern which seeds the Spanish coast with larvae from the present French spawning grounds. But no re-colonisation of the Spanish coast is seen occurring. During one survey targeting juveniles, these were observed alone, independent of adults on the Spanish coast when they were observed mixed with adults and recruited to the adult stock on the French coast. The question was raised whether encountering adults is necessary for juveniles to effectively colonise particular habitats and install a life cycle. Some consequences of the possible role of adults where listed and work suggested. In particular it was suggested to combine survey data at large scale at other periods than spawning and identify what the large and the small fish do.

Spatial-temporal distribution of Bay of Biscay anchovy by size and age at spawning time. L. Ibaibarriaga and A. Uriarte, AZTI (SP).

This work describes the spatial distribution by size and age of anchovy (*Engraulis encrasicolus L.*) in the Bay of Biscay during its spawning time (May-June). Data analyzed correspond to the adult samples used for the application of the Daily Egg Production Method in years 1990–1992, 1994–1995, 1997–1998 and 2001–2004. First, average weight was modeled in terms of spatial geographic covariates using linear and generalized additive models. In general, smaller fish are found generally close to the coast. However, inter-annual variation is found to be high due to changes in recruitment. Secondly, a logistic model of proportion at age 1 depending on average weight was fitted. Intercepts varying between years could be interpreted in terms of the recruitment strength each year. The proportion at age 1 predicted from these two models were compared with a GAM model in which proportion at age 1 was fitted directly in terms of the spatiotemporal covariates. At the end further work aiming at understanding the spatial temporal dynamics of the spawning of this species is briefly outlined.

Egg and larvae distribution of seven fish species in North East Atlantic waters. L. Ibaibarriaga (AZTI, SP), X. Irigoien, M. Santos, L. Motos, J. Fives, C. Franco, A. Lago de Lanzos, S. Acevedo, M. Bernal, N. Bez, G. Eltink, A. Farihna, C. Hammer, S. Iversen, S. Milligan and D. Reid.

The distribution of egg and larvae of mackerel, horse mackerel, sardine, hake, megrim, blue whiting and anchovy along the European Atlantic waters (south Portugal to Scotland) during 1998 is described. Time of the year, sea surface temperature and bottom depth are used to define the spawning habitat of the different species. Mackerel, horse mackerel and sardine eggs and larvae presented the widest distribution, whereas megrim and anchovy showed a limited distribution, restricted to the Celtic Sea and the Bay of Biscay respectively. Correspondingly mackerel, horse mackerel and sardine showed the highest aggregation indices. Blue whiting spawned at the lowest temperatures, whereas anchovy were found in the warmest waters. The analysis is a basis for judgment of evaluation of upcoming or ongoing changes in the oceanographic regime of the north east Atlantic.