

Spawning and nursery grounds of selected fish species in UK waters

J. R. Ellis, S.P. Milligan, L. Readdy, N. Taylor and M.J. Brown

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This report should be cited as: Ellis, J.R., Milligan, S.P., Readdy, L., Taylor, N. and Brown, M.J. 2012. Spawning and nursery grounds of selected fish species in UK waters. Sci. Ser. Tech. Rep., Cefas Lowestoft, 147: 56pp.

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1. Introduction

1.1 Background

An evidence-based understanding of the distribution of fish spawning and nursery grounds, and other ecologically important fish habitats is required to allow scientific advisors and regulators to better manage human activities in our seas. For example, many offshore wind farm developments are currently subject to seasonal restrictions in order to minimise disruption from anthropogenic noise, particularly the sounds associated with pile driving, on spawning fish and to protect egg and larval stages. Similarly, there is more conservative management and regulation of some human activities that operate in areas of seabed considered important or potentially important to key life-history stages, for example in relation to the spawning grounds of herring *Clupea harengus*.

Such management actions have implications for developers in terms of both cost and delivery of projects. Consequently, it is essential that the provenance of data on spawning and nursery grounds is understood to ensure that its interpretation within Environmental Impact Assessments and regulatory decision-making is appropriately applied. This report describes the sources, spatial and temporal coverage and limitations of the data, including where there are data gaps. Using the maps in isolation may result in misrepresentations of the data, so in all cases the supporting rationale should also be considered.

Lee & Ramster (1981) compiled an atlas of the seas around the British Isles, in which the spawning grounds of several commercial fish were illustrated. Subsequently, a collaborative project between the national fisheries laboratories (Cefas and the then Fisheries Research Services, Scotland), with the UK Offshore Operator's Association (UKOOA), the Scottish Fishermen's Association (SFF) and the National Federation of Fishermen's Organisations (NFFO) aimed to provide broad scale maps of the sensitive habitats of marine fish in UK waters (Coull *et al.*, 1998). This report aimed to assist in the environmental impact assessment process, and included maps indicating the main spawning and nursery grounds for 14 commercially important species: herring, cod *Gadus morhua*, haddock *Melanogrammus aeglefinus*, whiting *Merlangius merlangus*, saithe *Pollachius virens*, Norway pout *Trisopterus esmarki*, blue whiting *Micromesistius poutassou*, mackerel *Scomber scombrus*, sprat *Sprattus sprattus*, sandeels (Ammodytidae), plaice *Pleuronectes platessa*, lemon sole *Microstomus kitt*, sole *Solea solea* and Norway lobster *Nephrops norvegicus*.

Coull *et al.* (1998) correctly acknowledged that "spawning distributions are under continual revision. It

follows that these maps should not be seen as rigid, unchanging descriptions of presence or absence". Since these maps were produced there have been further ichthyoplankton surveys in some areas, and there are now other fish species for which there is an interest in the location of 'critical habitats'.

This report aims to update some of these maps with more recent data, and so highlighting some of the evidence for their selection, and to provide a first attempt at identifying some of the ecologically important habitats for some other fish species, including some species of conservation importance (e.g. OSPAR, 2008) that have been considered in marine planning. It is important to note that such data are not available for all fish species, and many coastal, continental shelf, and shelf edge waters are still to be surveyed for ichthyoplankton and juveniles.

In addition to eight of the highly mobile species included within Coull *et al.* (1998), it was considered that existing groundfish surveys could assist in the preliminary spatial description of the nursery grounds for some other species of commercial and/or conservation importance, including spurdog *Squalus acanthias*, tope *Galeorhinus galeus*, common skate *Dipturus batis*-complex, thornback ray *Raja clavata*, spotted ray *Raja montagui*, undulate ray *Raja undulata*, ling *Molva molva*, hake *Merluccius merluccius*, anglerfish *Lophius piscatorius* and horse mackerel *Trachurus trachurus*.

The summary report is based on a report provided to Defra¹, and comprises two main sections. Section 2 provides an overview of the data collation for the species, including a summary of available fishery-independent trawl surveys and ichthyoplankton surveys. This section also includes a discussion on the limitations and caveats of these data (e.g. issues on gear selectivity, the timings and locations of surveys, and taxonomic identification in surveys) and the users of the GIS data are encouraged to use this information to assist in the interpretation of distribution data. Section 3 provides more detailed information on the derived data layers for the various species.

¹ Ellis *et al.* (2010). MB5301 Mapping spawning and nursery areas of species to be considered in Marine Protected Areas (Marine Conservation Zones). Report No 1: Final Report on development of derived data layers for 40 mobile species considered to be of conservation importance.

1.2 Ecologically important fish habitats

Ecologically-important habitats for highly-mobile marine fish can include sites of importance to breeding (e.g. mating sites, spawning beds and grounds, and parturition grounds), recruitment and growth of early life-history stages (i.e. nursery grounds), as well as feeding grounds and migratory pathways (ICES, 2003).

1.3 Spawning grounds

Many fish species aggregate to spawn. Whereas some species may aggregate behaviourally and so may have extensive spawning grounds that may change location slightly from year to year, other species may aggregate over a more restricted spatial extent. There are numerous modes of reproduction in fishes, and broadcast spawning, which involves shedding the eggs and sperm into the water column, is one of the more frequent strategies (Balon, 1984). Such species may have more extensive spawning grounds than those species which deposit eggs on the sea floor or on biogenic structures.

The presence of eggs and larvae of broadcast spawners can be indicative of spawning grounds, although it should be noted that later larval stages may have been advected away from the spawning site. Mature fish with running eggs or sperm can also be indicative of spawning grounds, although these data were not used in the current project, as not all areas have surveys at the right time of year in order to assess the spawning state.

For the purposes of the present report we use the term 'spawning ground' in its generic sense, and so use it to include oviposition sites (for egg-laying elasmobranchs) and parturition sites (for live-bearing species).

Skates (Rajidae) are oviparous and these species deposit egg-cases (the 'mermaids purse') on the sea floor and although there are some data for the occurrences of these egg-cases on the strandline, field data to delineate spawning grounds (presence of viable egg-cases) are lacking or limited. However, juveniles, including recently hatched fish, are taken in trawl surveys, with beam trawl surveys particularly effective for sampling the smallest size classes of skate. Although biological sampling of skates is undertaken in groundfish surveys, the timing and location of these surveys means that very few 'active' fish (i.e. with egg-cases in the oviducts) are sampled.

Viviparous sharks carry the developing young in the uteri, and gravid females will then give birth (e.g. at parturition sites). Data on the locations of mature females with term or near-term pups are rare for some of these species, although the locations of juveniles are known for some of the species from groundfish surveys on the continental shelf. Larger pelagic sharks are only captured very occasionally in groundfish surveys and there are no data to accurately identify sites of importance in UK waters.

1.4 Nursery grounds

The grounds where juveniles are found are termed nursery grounds. It has been suggested that nursery grounds are those sites where juveniles occur at higher densities, have reduced rates of predation and have faster growth rates than in other habitats, which should result in nursery grounds providing a greater relative contribution to adult recruitment in comparison to non-nursery ground habitats (see Beck *et al.*, 2003; Heupel *et al.*, 2007). Whilst field data are available to highlight areas where juveniles occur at higher densities, comparable data to confirm that they avoid predation more successfully, have enhanced growth rates and provide greater relative contributions to recruitment are generally lacking.

Heupel *et al.* (2007) went on to suggest that nursery grounds could be identified based on three criteria, (1) the density of juveniles was greater than in other areas, (2) there would be greater site fidelity, and (3) the nursery area was used repeatedly over the years. When field data from annual surveys are the main data source for the identification of nursery grounds, then a more robust identification of nursery grounds may be inferred from high catch rates of juveniles and also the proportion of years in which juveniles have been observed at the site. Where appropriate broad scale data were available, data layers generated include the presence of 'juveniles' (derived from an analysis of the length distribution), the maximum catch rates of juveniles and, for fixed station surveys, and the sites where juveniles have been caught regularly (e.g. in 50 or 70% of the tows).

It should also be noted that, depending on the life-history of the fishes (including the reproductive mode and location and extent of spawning grounds), there can be subtle changes in what may be considered as a nursery ground. For example, it has been suggested for elasmobranch fishes that those locations where pups are born (in the case of viviparous species) or hatch (in the case of oviparous species) and spend the initial periods of their life can be termed 'primary nursery grounds'. As the recently hatched fish grow they may extend and/or shift their home range and habitat, and so larger juveniles may occupy what is termed a 'secondary nursery ground' (e.g. Bass *et al.*, 1973). This concept may be usefully extended to teleost fishes, and here we use the term primary nursery grounds to equate with sites of importance to recently-settled and 0-group (<1 year old) fish, and secondary nursery grounds equating to the broader extent of habitat that may be utilised by a wider range of juveniles.

2. Data collation

2.1 Distribution of fish eggs and larvae

Data on the distribution of the planktonic stages of fish eggs and larvae (ichthyoplankton) were collated from numerous surveys (Figure 1) conducted by Cefas and associated UK fisheries laboratories, and from internationally-coordinated ichthyoplankton surveys, as discussed below.

- Bristol Channel plankton surveys: A series of five cruises (524 valid stations) conducted in the Bristol Channel in 1990 which were conducted primarily to provide data on sole and bass, but collected data for other fish species and edible crab larvae. For further information see Horwood (1993).
- Sole surveys: A series of four cruises in 1991 (304 valid stations) conducted in the English Channel and Southern Bight, primarily to sample sole and bass, with data collected for other fish species and edible crab larvae.
- Irish Sea plankton surveys: This extensive series of cruises was conducted in the Irish Sea (although data were limited from the southern parts of St George's Channel) in 1995 (13 cruises, 1024 valid stations), 2000 (8 cruises, 804 valid stations), 2006 (5 cruises, 397 valid stations) and 2008 (5 cruises, 486 valid stations). For further information see Fox *et al.* (1997) and Bunn and Fox (2004), with earlier cruises also described by Nichols *et al.* (1993).
- Eastern Irish Sea plaice surveys: A series of cruises that were undertaken in the eastern Irish Sea, primarily to target plaice, that were conducted in 2001 (5 cruises, 227 stations), 2002 (4 cruises, 158 stations) and 2003 (5 cruises, 345 stations). For further information see Bunn *et al.*, (2004).
- North Sea cruises: A series of cruises by several international institutes covering a large area of the North Sea (927 stations) over a four month period from late December 2003 to early April 2004. For further information see Fox *et al.* (2005) and Taylor *et al.* (2007).
- International Herring Larval Survey (IHLS): An internationally coordinated survey that samples over the main herring spawning grounds in the North Sea. Only data for 2008 (481 stations) were used, as 2009 data were unavailable. For further information see ICES (2009a).
- Triennial mackerel egg survey: An internationally coordinated survey that includes extensive sampling along the western seaboard of the British Isles. Mackerel and horse mackerel are the main target species. For this survey, only data from the most recent

survey (2007) and for stage 1 eggs were included. For further information see ICES (2009b).

Hence, most of the available ichthyoplankton data were from the Irish Sea, English Channel and Bristol Channel, from an internationally coordinated survey in the North Sea, and from international species-specific surveys for herring and mackerel. Although there have been studies on the wider ichthyoplankton of the Celtic Sea (e.g. Horstman and Fives, 1994; Acevedo *et al.*, 2002; Alvarez *et al.*, 2004; Ibaibarriaga *et al.* 2007), multi-species data are not available for recent surveys. Similarly, the waters of north-western Scotland have been subject to few ichthyoplankton surveys (except for herring and mackerel).

2.2 Distribution of juvenile fish

Data from national groundfish surveys were used to support the identification of nursery grounds, the summary details of these surveys are provided in Table 1, and the distribution of survey stations is illustrated in Figure 2.

For the purposes of the present study, an internationally agreed length for identifying juveniles was used (e.g. following ICES, 2009c). It should be noted that survey data were collected at different times of the year and as a single length range was used (Table 2), as opposed to different length ranges by season, the data used may encompass fish of just over one year of age for surveys undertaken in the first part of the year.

For other species, the length-frequencies of Cefas-held groundfish survey data were initially examined, and a length range corresponding to the first cohort(s) identified. In those instances where data were limited for the first cohort, then a broader length range of juveniles was included, as detailed in the species-specific information below.

It should be noted that some data from the Young Fish Survey (YFS) are available, with these data collected by 2m beam trawl (Rogers *et al.*, 1998). However, as these data are more regional, only cover a part of the UK coastline, and are currently subject to on-going analyses, they have not been included in the present report.

2.3 Quality assurance

There are several issues with regards to data quality that need to be considered, particularly taxonomic identification and the design of the survey (gear type, location of stations, timing of the survey etc.), when interpreting the data layers.

2.4 Taxonomic standards

Accurate taxonomic identification is fundamental to providing robust evidence-based information for species of interest, and such issues can compromise the quality of some of the data available for a selected number of the species considered in this report, and these are detailed below.

There are several problems with the taxonomy and identification of skates (Rajidae). For example, some nations fishing in the North Sea may confuse thornback ray and starry ray (thorny skate), and spotted ray and blonde ray may be easily confused, particularly in commercial data. There is also confusion between various long-snouted species, which compromises the data for common skate.

A recent study by Iglésias *et al.* (2010) has revealed that common skate is actually a complex comprising two species, and so the data layers provided are for the species complex. A subsequent study has confirmed these genetic differences (Griffiths *et al.*, 2010). The nomenclature of the 'common skate complex' is currently being updated, and so the scientific name *Dipturus batis* will soon be an invalid synonym. Taxonomists working on the problem have proposed that former scientific names should be resurrected for these two species: *Dipturus cf. flossada* and *D. cf. intermedia*, but this proposed change needs to be validated by the International Commission on Zoological Nomenclature (Iglésias *et al.*, 2010). Although the overall geographical distributions of the two species are unclear, Griffiths *et al.* (2010) observed that samples from North-west Scotland (Vla) were generally genetically distinct from samples collected in the Celtic Sea, with flapper skate *D. cf. intermedia* and occasional blue skate *D. cf. flossada* taken in Vla, and *D. cf. flossada* taken on the Rockall Bank and in the Celtic Sea.

The taxonomy of some species of *Molva* is problematic, especially in terms of blue ling (*Molva dypterygia*) and Spanish ling (*M. macrophthalma*). Some authors consider these two species separate, whilst other authors have considered them to be sub-species (*Molva dypterygia dypterygia*, and *M. dypterygia macrophthalma*). Blue ling has a more northerly distribution, and is common off NW Scotland, whereas Spanish ling is more southerly and is found in the Celtic Sea and further south.

Data on anglerfish from scientific trawl surveys are available for two species, namely anglerfish *L. piscatorius* and black-bellied anglerfish *L. budegassa*, although the latter species is not considered in this report. Although research vessel surveys do not cover the entire species range, commercial data do not separate the two species.

There are five species of sandeel in UK seas, and even data collected from scientific trawl surveys should be flagged as of uncertain data quality with regards the correct species identification. For broad scale mapping data were aggregated at the family level.

2.5 Gear selectivity

All fishing gears have different gear selection patterns and efficiencies for the various species, and the interpretation of trawl survey data must be viewed in the context of the suitability of the gears.

Beam trawls have a low net height, with the main beam only 45-50cm above the sea floor, hence there is an extremely low chance of catching pelagic fishes (e.g. herring and mackerel). The presence of the chain mat ensures close ground contact and prevents large boulders entering the net, but the dimensions of the chain mat are such that large-bodied fish, such as larger skates, may be under-represented in catches.

Beam trawls are best suited for sampling small to medium sized demersal fishes, and these gears can be fished on a variety of ground types. For the purposes of the present study, beam trawls are considered appropriate for informing on the relative abundance of plaice, sole and the juveniles of cod, whiting, skates, anglerfish and ling. For other species/size classes, these data are presented as either presence/absence or presence only.

The main types of otter trawl for which most data are available are the Grande ouverture vertical (GOV) trawl and the Portuguese high headline trawl (PHHT). These gears have high headline heights, so as to sample pelagic fish as well as demersal species. The gear efficiency will be less for small-bodied demersal species, as these can escape through the meshes on the bottom panels.

Although these surveys are used to inform on the distribution of pelagic and benthopelagic species (e.g. horse mackerel, herring, mackerel, blue whiting and sand eels), it should be recognised that catch rates of such shoaling species are highly variable and can be dependent on their position in the water column. The more common larger-bodied demersal species are also sampled by this gear and may be used for either relative abundance (e.g. whiting, hake, cod and larger plaice) or for presence/absence (e.g. ling, anglerfish). Some of the benthopelagic sharks (tope and spurdog) can be captured in large numbers, but trawl surveys may under-represent faster-swimming species. Juvenile skates are not sampled as effectively as in beam trawl surveys, although otter trawls are more suitable than beam trawls for sampling larger skates.

2.6 Timing of surveys

Most recent surveys are conducted on an annual basis, and so do not encompass seasonality in fish distributions. Although some surveys (including for the North, Celtic and Irish Seas) have benefited from biannual surveys (e.g. spring and autumn) in the early parts of the time series, contemporary spatial data showing seasonal changes on wide geographical scales are not available for most species. It is recognised that some fish species may exhibit pronounced seasonal patterns in either distribution or abundance. Other species may have more restricted seasonal changes in distribution (e.g. moving into deeper water during the winter).

2.7 Locations of surveys

Most of the surveys examined sample at fixed stations, although some surveys use a stratified random survey design, and these stations are selected to ensure that the area is effectively sampled for the species of interest, with stations selected by ICES rectangle, depth or strata. These tows are also selected to minimise the chances of gear damage.

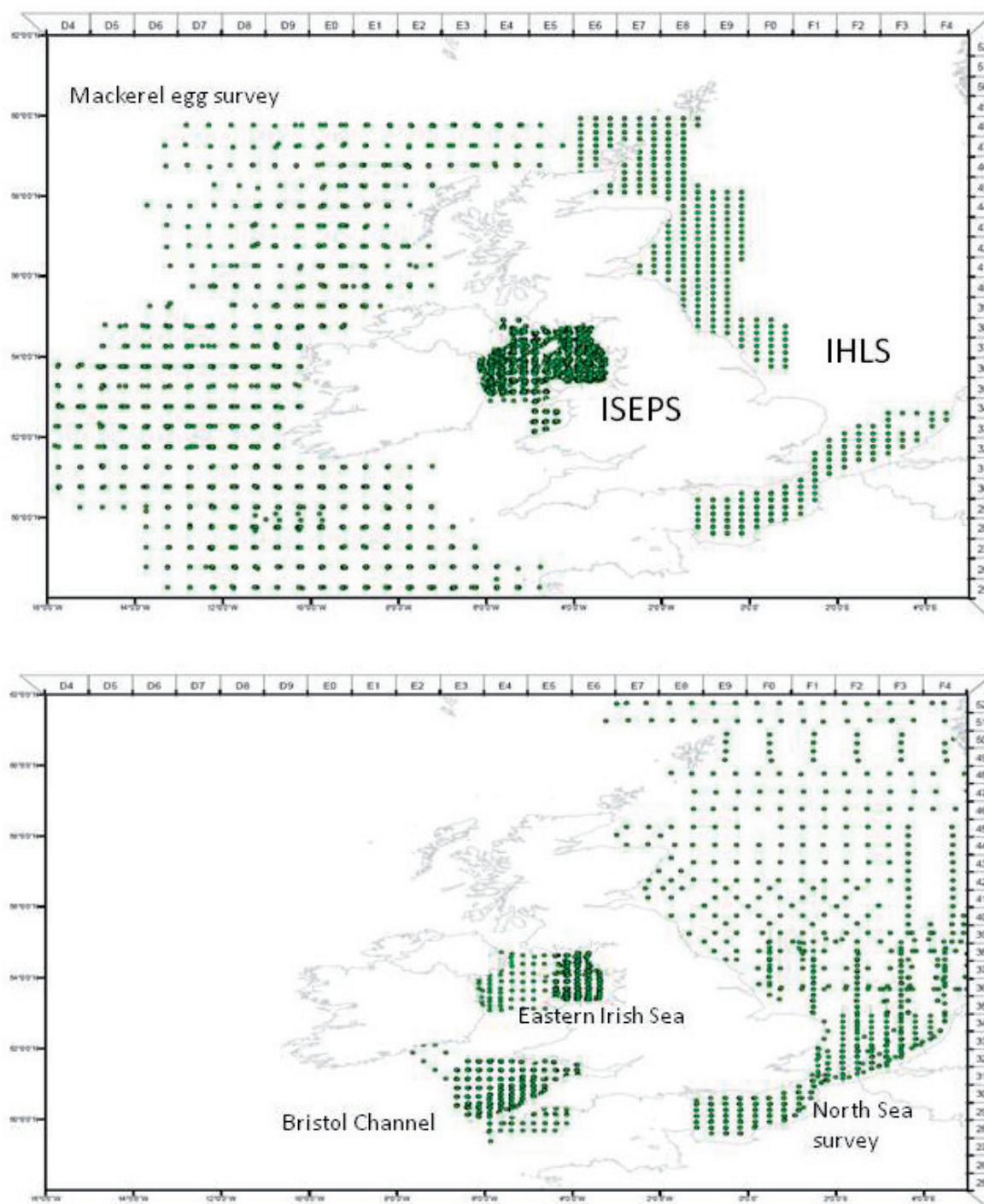
The English North Sea IBTS survey has one station per selected rectangle, as these rectangles are fished twice when considering all the participating nations in this

internationally-coordinated survey. Although otter trawl surveys on the west coast also attempt to fish in each rectangle, some rectangles are fished at more than one location, as there can be large differences in depth.

The beam trawl surveys in the eastern English Channel, Bristol Channel and Irish Sea were originally designed to sample juvenile plaice and sole, and so there is a greater density of stations in coastal waters and a lower density of stations in offshore regions.

Most groundfish surveys are undertaken on research vessels, and these vessels rarely fish in waters less than 15m deep. Hence, these surveys have less ability to

Figure 1: Distribution of selected ichthyoplankton surveys for which egg and larvae data were collated.



inform on the estuarine and coastal habitats, which can be particularly important for the earliest life history stages of several species. Although the Young Fish Survey is conducted by inshore vessels in some areas, these data do not cover the entire UK coastline, and so could only be used in more site-specific studies. These data are currently being analysed and will be reported on in the future.

Most groundfish surveys are undertaken in continental shelf waters, and so most have very limited ability to inform on deep-water species. Although deep-water surveys are conducted by Marine Scotland, there will hopefully be more spatially comprehensive data on deep-water species in the future, as there are plans for internationally-coordinated surveys (e.g. with Ireland and France), and these data will better inform on the distributions of deep-water fish occurring to the west of the British Isles.

It is also important to interpret data from groundfish surveys with the distributions of the species/stocks in question. In some instances, existing surveys cover all or most of the species/stock distributions, although for more wide-ranging species, existing surveys may only cover a proportion of their range. For example, blue whiting is wide ranging in the deeper waters of the NE Atlantic, and so groundfish surveys on the UK continental shelf only sample the fringes of their distribution.

2.8 Coastal and estuarine habitats

Much of the survey data used in the production of this report and associated data layers have been collected during research vessel surveys. These surveys generally operate in waters >20m deep, and comparable broad scale data for estuarine and transitional waters are often lacking. The generated layers for spawning and nursery grounds included here are based on sub-rectangles of ICES statistical rectangles, and so may extend into coastal waters. The extent to which the coastal fringes may be used by the case study species is given in the supporting text (Potts and Swaby, 1993a,b).

Marine fish occurring in estuarine habitats may be attributed to the following groupings (adapted from Potts and Swaby, 1993a):

- Fully estuarine fish living almost their entire life-cycle in estuarine habitats;
- Diadromous fish migrating through estuaries;
- Marine fish visiting estuarine habitats to feed;
- Marine fish utilising estuarine habitats as nursery grounds;
- Fully marine species which are recorded occasionally in estuaries.

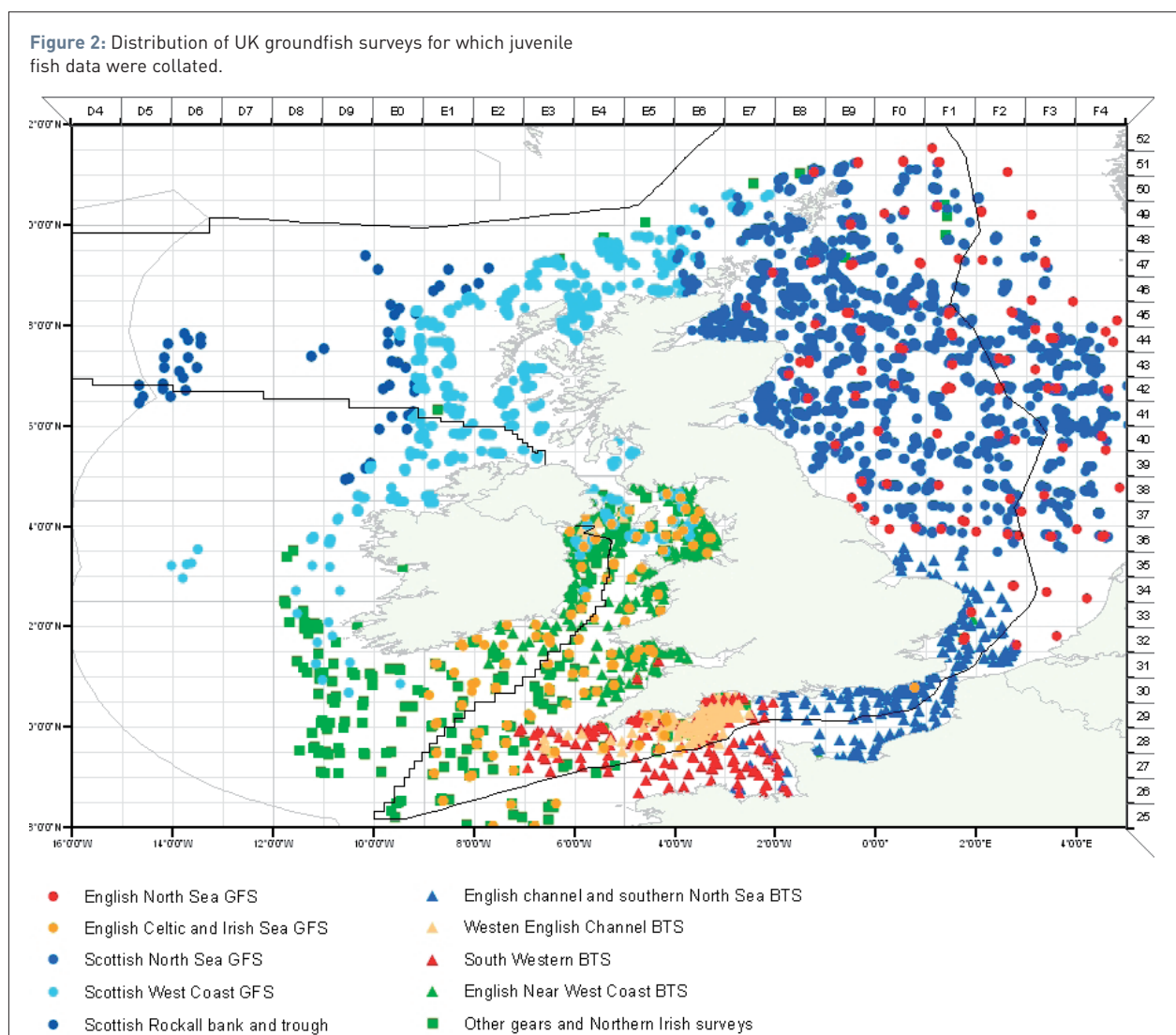


Table 1: List of groundfish surveys (GFS) and beam trawl surveys (BTS) included within the present analyses, summarising their temporal and spatial extent, gear type, total number of samples (stations) fished and sources of more detailed information. It should be noted that there are some differences between GOV trawls (type of ground gear, kite or extra floatation, nylon or polyethylene trawl net etc.)

Survey	Time period (years)	Quarter	Survey area (ICES Divisions)	Gear	Total number of stations fished	References
English North Sea GFS	1992–2008	3	IVa-c	Grande ouverture vertical (GOV) trawl	1275	ICES (2006, 2009c)
English West Coast GFS	1982–2004	1	VIIe-j	Portuguese high headline trawl (PHHT)	1566	Warnes and Jones (1995); Tidd and Warnes (2006)
English Celtic and Irish Sea GFS	2003–2008	4	VIIa, e-h	GOV with either rockhopper or standard ground gear	422	Harley and Ellis (2007); ICES (2009c)
English channel and southern North Sea BTS	1988–2008	3	VIIId, IVc	4 m beam trawl	2039	Parker-Humphreys (2005); ICES (2009d,e)
English Near West Coast BTS	1988–2008	3	VIIa,f,g	4 m beam trawl	3284	Parker-Humphreys (2004a,b); ICES (2009d,e)
Western English Channel BTS	1989–2008	4	VIIe	4 m beam trawl deployed off a commercial fishing vessel	1239	ICES (2009d,e)
South Western BTS	2006–2008	1	VIIe	Twin 4 m beam trawl	228	-
Scottish North Sea GFS	1983–2008	1, 2, 3	IVa,b	GOV trawl	3939	ICES (2006, 2009c)
Scottish surveys of Rockall Bank	2006–2008	4	VIa, b	GOV trawl (rock hopper)	77	ICES (2009c)
Rockall Trough	1998–2008				213	
Scottish West Coast GFS	1986–2008	1, 4	VIa, VIIb,c,j	GOV trawl (rock hopper)	2946	ICES (2009c)
Northern Irish GFS	1992–2008	1, 3	VIIa	Rockhopper trawl	2260	ICES (2009c)

Table 2: Summary of length range used to map juvenile habitats and the observed depth distributions of fish within this size range

Species	Length range of juvenile cohort(s) examined (cm)	Depth range (m) where juveniles were caught (all surveys, all juveniles)	Depth ranges (m) of sites where juveniles were caught regularly (>50% of tows)
Spurdog	24 – 47	10 – 500	10 – 405
Tope	24 – 69	11 – 171	90 – 117
Common skate	19 – 42	10 – 500	15 – 460
Thornback ray	3.5 – 17	6 – 405	18 – 180
Spotted ray	5 – 17	7 – 220	13 – 189
Undulate ray	9 – 28	9 – 140	30 – 39
Herring	1 – 17	8 – 460	10 – 450
Cod	2 – 22	7 – 450	9 – 405
Whiting	2 – 19	7 – 460	7 – 450
Blue whiting	2 – 18	10 – 592	10 – 592
Ling	7 – 48	8 – 500	15 – 450
Hake	3 – 19	10 – 500	10 – 500
Anglerfish	3 – 27	7 – 500	10 – 500
Horse mackerel	1 – 8 / 1 – 14	8 – 500	21 – 500
Sandeels	2.5 – 12	7 – 405	15 – 270
Mackerel	2.5 – 23	10 – 500	10 – 500
Plaice	1.5 – 11	6 – 405	6 – 385
Sole	1 – 12	6 – 350	11 – 119

3. Spawning and nursery grounds of selected fish species

3.1 Interpretation of data layers

The following issues are highlighted to avoid misinterpretation of the data layers provided.

It must be recognised that all bubble plots with an index of relative abundance/catch rates are on a species-specific scale, and so cannot be compared across taxa.

Sampling points (shooting positions for trawl and ichthyoplankton surveys) are provided as single points, although it should be noted that stations fished during trawl surveys can cover 2 nm (if trawled at 4 knots for 30 minutes).

Single layers of bubble plots of relative abundance/catch rates have been provided for each species, rather than by survey, to limit the number of layers. However, different surveys will have different catchabilities for the various species (due to a combination of gear type, survey protocol, timing of survey etc.). Hence, these data should be viewed in conjunction with the distribution of the surveys themselves. Spatial differences in the catch rates over the survey grid of one particular survey can be used to infer spatial differences in the relative abundance of the species. On a broader scale (i.e. across surveys), any apparent regional differences in catch rates should not be inferred to represent true spatial differences in the relative abundance of the stock.

It should be recognised that some surveys have a low density of sampling stations. Other surveys have a high density of stations and/or high survey effort (e.g. in the Irish Sea for both ichthyoplankton and trawl surveys), and these data may allow finer scale studies.

The distribution of ichthyoplankton includes a range of egg and larval stages, and later stages will have advected away from the original spawning ground. Although only the distributions of the earliest egg stages were plotted for the triennial mackerel egg survey, aggregated egg data were used for other taxa and surveys, in order to maximise the data available.

In terms of the spawning ground information, the egg numbers are on a single scale across the various surveys, and the user should recognise that there can be differences in the catch rates between surveys due to other factors (e.g. timing of survey) as well as regional differences. Larval data are also on a single scale across all surveys, but on a different scale to the data layer for eggs. Some surveys (e.g. the triennial mackerel egg survey) do not provide comparable data for larvae, and so the apparent absence of larvae in these areas is an artefact of sample processing.

The data layers below were used in conjunction with data layers for UK territorial waters, ICES Division, ICES

Rectangle (i.e. rectangles of 1° longitude and 0.5° latitude) and bathymetry.

The following GIS data layers for spawning grounds were produced:

- (a) Haul locations (i.e. sites sampled during ichthyoplankton surveys). It should be noted that these are not evenly distributed in UK waters, so while some areas have been subject to intensive sampling over time (e.g. Irish Sea), other areas have been surveyed occasionally (e.g. North Sea and English Channel) and other areas or have only been surveyed for mackerel and horse mackerel eggs (e.g. Celtic Sea).
- (b) Original location(s) of nominal spawning grounds as provided by Coull *et al.* (1998).
- (c) Occurrence and relative abundance of eggs of the species of interest. Where surveys only identified egg stage for selected species, then the data were aggregated across all egg stages. The exception to this is for horse mackerel and mackerel where broad scale data on the distribution and abundance of early stage eggs were available, with early stages of eggs more likely to correspond to a close proximity to the spawning ground.
- (d) Occurrence and relative abundance of larvae of the species of interest.
- (e) Updated spawning ground layer based on half ICES statistical rectangles, with sites of higher importance noted for selected species. This layer was based on the evidence provided by the ichthyoplankton survey data and the layers provided by Coull *et al.* (1998).

The following GIS data layers for nursery grounds were produced:

- (a) Haul locations (i.e. sites fished during groundfish surveys).
- (b) Original location(s) of nursery grounds as provided by Coull *et al.* (1998).
- (c) Presence of juveniles in field surveys (within the length range given in Table 2) and whether they were found in at least one haul, 50% of hauls at the station (for fixed station surveys) or 70% of the hauls at the station.
- (d) The maximum catch per unit effort (CPUE) by survey station location, also indicating how regularly juveniles were captured at that haul station.
- (e) Updated nursery ground layer based on half ICES statistical rectangles, with sites of higher perceived importance noted for selected species. This layer was based on the evidence provided by the trawl survey data and the layers provided by Coull *et al.* (1998).

3.2 Spurdog *Squalus acanthias*

General information

Spurdog occur on the continental shelf throughout the North-eastern Atlantic and this stock is widespread within the UK EEZ. As a viviparous species, ecologically important habitats would include sites where mature (especially gravid) females occur, as well as juveniles. Limited data are available on the presence of gravid females taken in scientific surveys, but given that they have complex and widespread seasonal migrations (Vince, 1991) and that they carry the pups for 22–24 months, such habitats may be difficult to accurately delineate. Scientific trawl surveys sample juvenile spurdog, and trawl survey data could be used for the preliminary identification of parturition grounds and nursery grounds.

Spurdog are born at a length of 19–30 cm (Gauld, 1979) and, as data for specimens <30 cm were limited, a length of <48 cm was used to better inform on the distribution of primary and secondary nursery grounds.

Spawning grounds

Locations and temporal stability of specific parturition grounds are not well established.

Nursery grounds

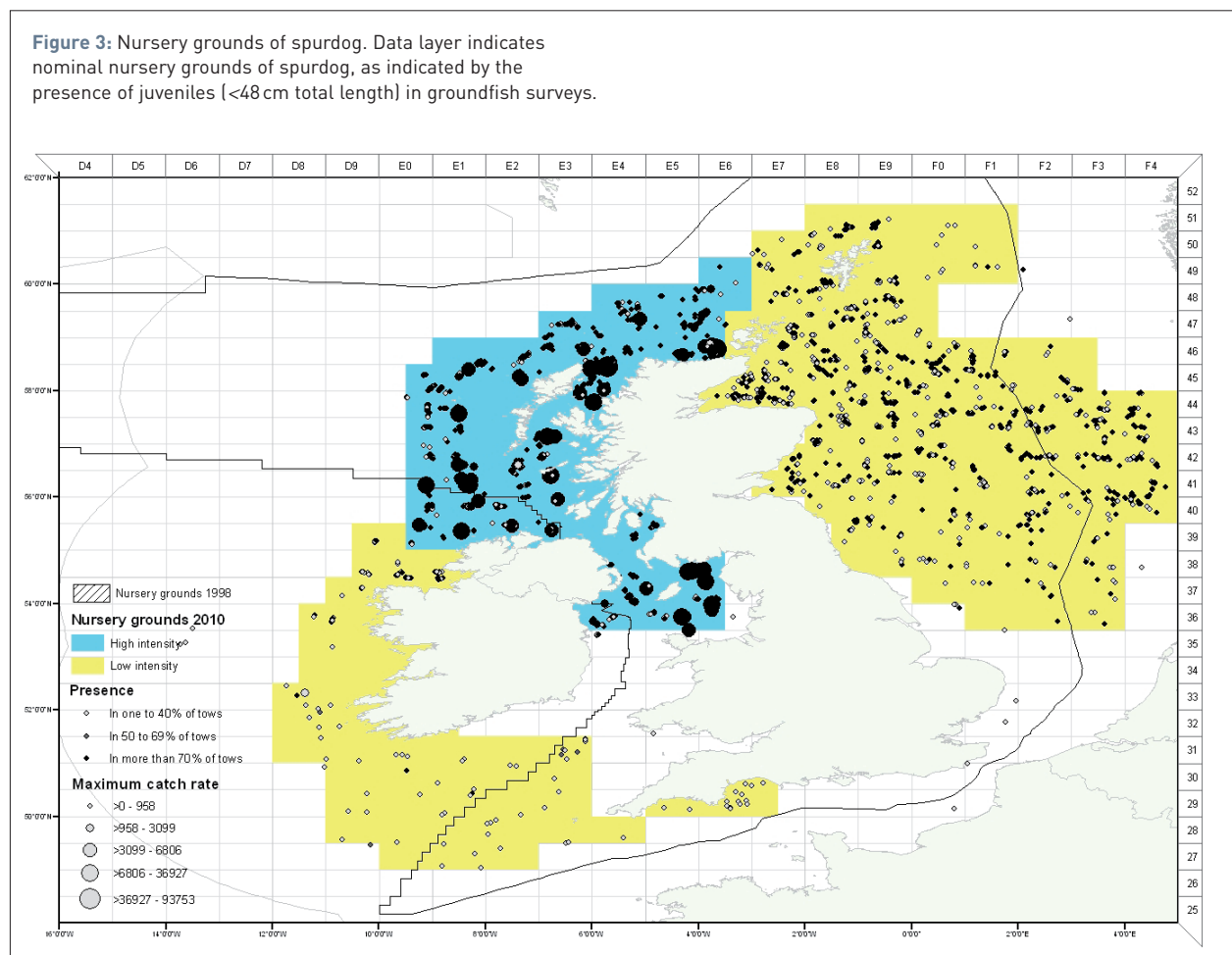
Juvenile spurdog were widely distributed in the Central and Northern North Sea, North-west Scotland, northern Irish Sea and Celtic Sea (Figure 3). The apparent absence of juveniles from the eastern English Channel and southern North Sea may be in part an artefact of the sampling, as there were fewer otter trawl surveys in this area. The highest catches of juveniles were made off North-west Scotland and in the northern Irish Sea.

Estuarine and coastal zone

Spurdog is a fully marine species that is recorded occasionally in estuaries. It does not typically occur in waters <10 m deep (Wheeler, 1978).

Data gaps

More data on this species (e.g. maturity stages) could usefully be collected during internationally coordinated groundfish surveys, and this will be undertaken in the future. Tagging studies using electronic tags could usefully be undertaken to better understand the movements of mature female spurdog. Dedicated field studies may be able to confirm the utility of some of the potential nursery grounds.



3.3 Tope shark *Galeorhinus galeus*

General information

The North-eastern Atlantic stock of tope is wide-ranging from boreal to sub-tropical waters. Seasonal patterns in the movements and distribution around the British Isles are poorly known, although there is the suggestion of some north-south migrations (Holden and Horrod, 1979). There are few data on the reproductive biology of this species around the British Isles, although small numbers of juveniles can be taken in groundfish surveys. Hence, these data may provide the basis for the preliminary identification of nursery grounds.

Tope are born at a length of 30–40 cm (Compagno, 1984) and, as data for specimens <40 cm were limited, a length of <70 cm was used to better inform on the distribution of primary and secondary nursery grounds.

Spawning grounds

Locations and temporal stability of specific parturition grounds are not well established.

Nursery grounds

Juvenile tope have been caught sporadically in the North Sea (e.g. Greater Thames Estuary and Firth of Forth), Irish Sea, Bristol Channel and areas off North-western Scotland (Figure 4), suggesting that juvenile tope occur in inshore areas with slightly reduced salinity. The apparent absence of juveniles from the eastern English Channel and southern North Sea may be in part an artefact of the sampling, as there have been fewer otter trawl surveys in this area. Sites such as The Solent may also act as nursery grounds for tope, as they are caught in recreational fisheries in this area.

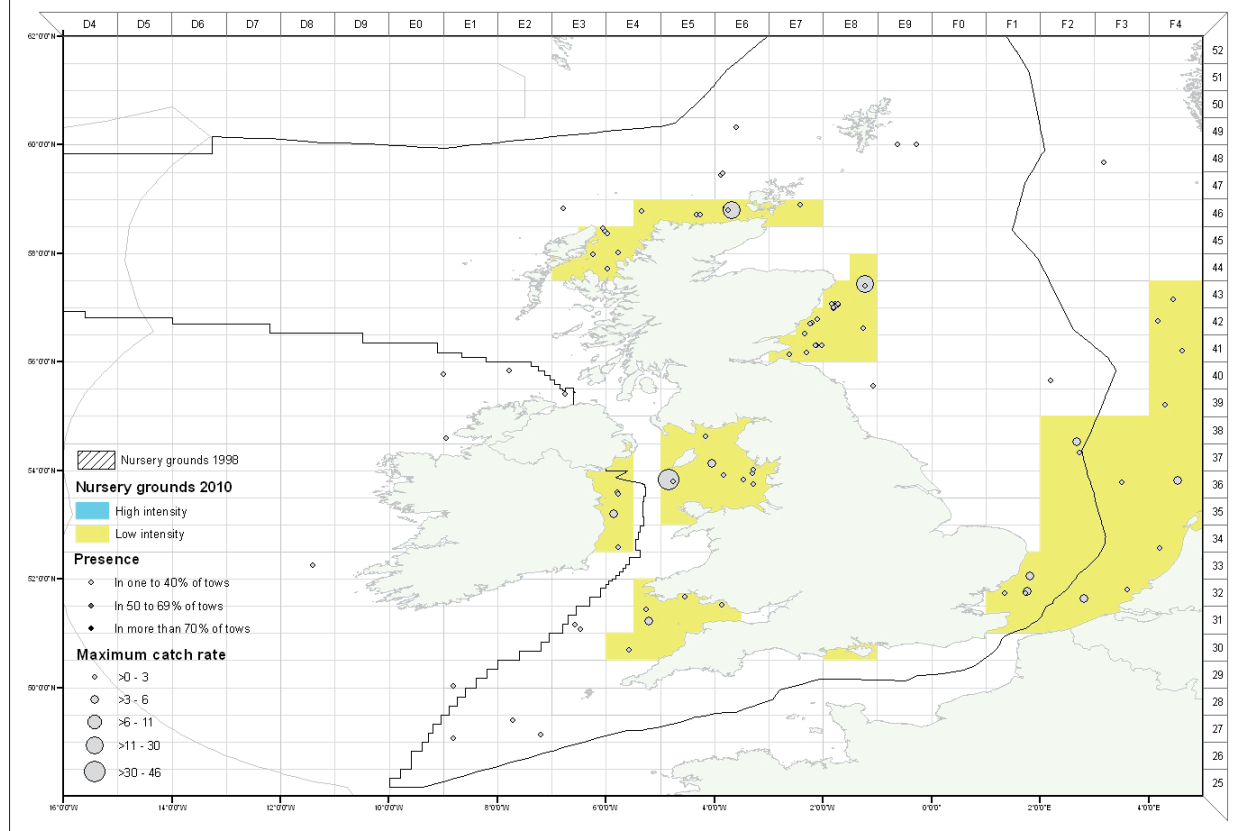
Estuarine and coastal zone

Tope is a marine species that may utilise the outer reaches of some estuaries and coastal waters as a parturition ground and nursery ground.

Data gaps

More data on this species could usefully be collected during internationally coordinated surveys. Tagging studies using electronic tags could usefully be undertaken to better understand the movements of tope in UK waters. Dedicated field studies using a gear appropriate for sampling tope could confirm the utility of potential nursery grounds.

Figure 4: Nursery grounds of tope. Data layer indicates nominal nursery grounds of tope, as indicated by the presence of juveniles (<70 cm total length) in groundfish surveys. Data limited for English Channel, although the Solent is often regarded as an important habitat for tope.



3.4 Common skate *Dipturus batis*-complex

General information

A recent study by Iglésias *et al.* (2010) has revealed that 'common skate' actually comprises two species and the data layers provided are for the species complex. The nomenclature of the 'common skate complex' is currently being updated, and so the scientific name *D. batis* will soon be an invalid synonym. Taxonomists working on the problem have proposed that former scientific names should be resurrected: flapper skate *D. cf. flossada* and blue skate *D. cf. intermedia*, but this proposed change needs to be validated by the ICZN (Iglésias *et al.*, 2010). The current geographical distributions of the two species are unclear. Griffiths *et al.* (2010) observed that samples from ICES Division VIa were generally genetically distinct from samples from the Celtic Sea, with *D. cf. intermedia* and occasional *D. cf. flossada* taken in VIa, and *D. cf. flossada* taken on the Rockall Bank and in the Celtic Sea.

The common skate complex has a reduced distribution in UK waters in comparison to its historical distribution. It occurs in the deeper waters of the northern North Sea, west coast of Scotland and Celtic Sea. There are few data on the distribution of egg-cases with which to define spawning areas. As an oviparous species, nursery grounds should overlap the spawning grounds.

Groundfish survey data may allow for the preliminary identification of nursery areas, although data are limited

for some of their range (e.g. in deeper waters). For the present study, a length range of <43cm was used, which broadly equates with the first cohort apparent in survey data. Common skate hatch at a length of ca. 21 cm (Clark, 1926), and so the data refer primarily to 0- and 1-groups.

Spawning grounds

There are insufficient data on the occurrence of the egg-cases or egg-bearing females with which to delineate spawning grounds, although these should broadly overlap with nursery grounds.

Nursery grounds

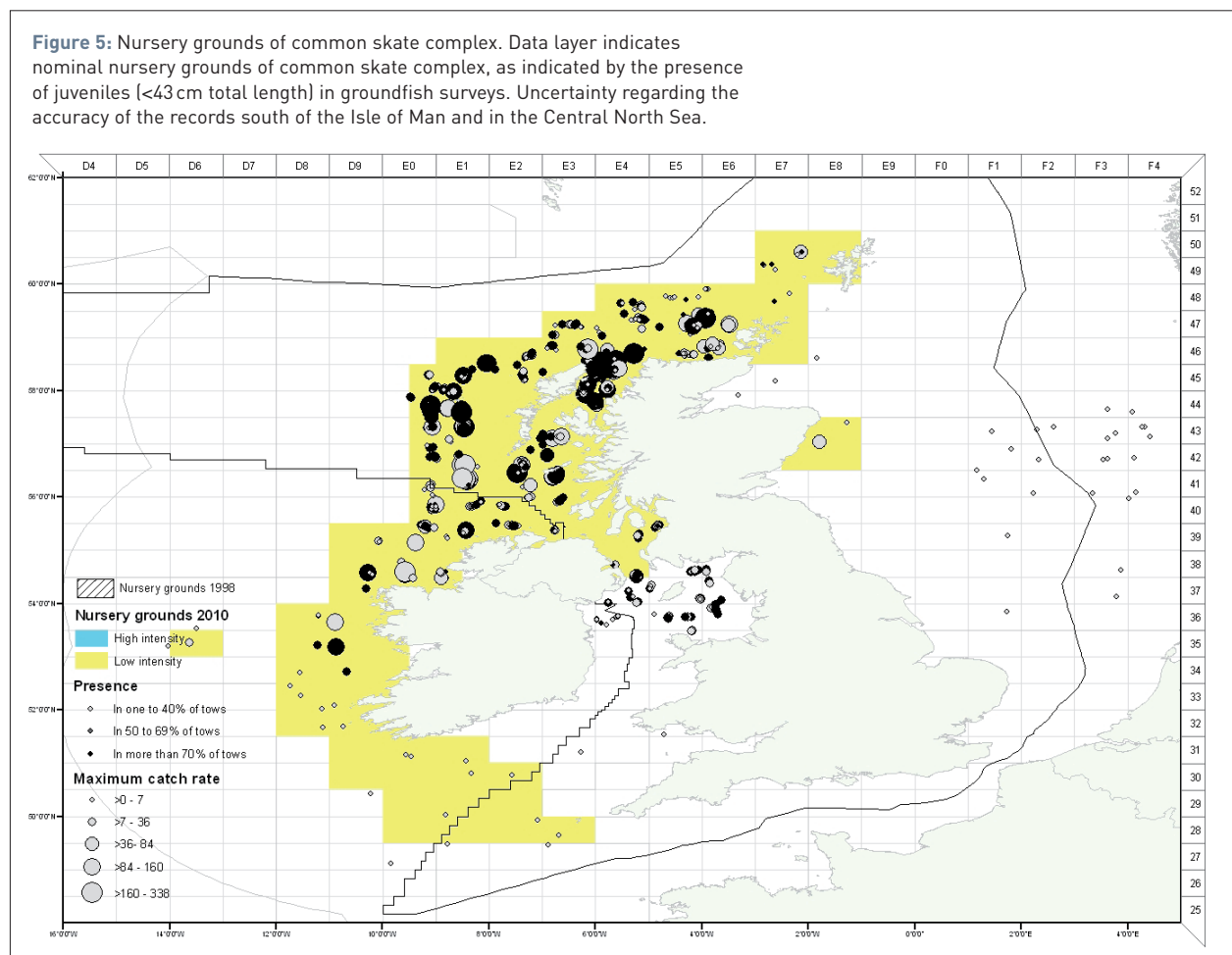
Juvenile common skate were captured primarily off North-western Scotland and Celtic Sea (Figure 5), with Scottish surveys having the highest catch rates. Some data for common skate were considered questionable, and have been excluded from the delineation of nursery grounds.

Estuarine and coastal zone

Common skate is a fully marine species that is recorded occasionally in estuaries. It does not typically occur in waters <30m deep (Wheeler, 1978).

Data gaps

Improved delineation of nursery grounds is required. Groundfish surveys could usefully report on the capture of egg-cases with developing embryos.



3.5 Thornback ray *Raja clavata*

General information

Thornback ray is a widespread and relatively abundant skate. There are few field data on the distribution of females with egg-cases, and there are also few data on the distribution of *in situ* egg-cases (although data are available for specimens from the strandline), and so it is not currently practical to accurately define spawning areas.

Groundfish survey data may allow for the preliminary identification of nursery areas. For the present study, a length range of <18cm was used, which broadly equates with the first cohort apparent in survey data. Thornback ray hatch at a length of ca. 10–12 cm (Clark, 1926; Ellis and Shackley, 1995), and so the data refer primarily to 0-groups (Brander and Palmer, 1985).

Spawning grounds

There are insufficient data on the occurrence of the egg-cases or egg-bearing females in the spawning season with which to delineate spawning grounds, although these should broadly overlap with nursery grounds.

Nursery grounds

Juvenile thornback rays were frequently taken in beam trawl surveys, with otter trawl catches having a lower catch efficiency for these size fish. Areas of importance to juvenile thornback ray included the Greater Thames Estuary, Bristol Channel, Cardigan Bay, and eastern and western Irish Sea (Figure 6), as suggested in earlier studies (Ellis *et al.*, 2005).

Although juvenile thornback rays were also reported from the deeper waters off North-western Scotland, there could be some confusion with similar looking skates in this area (e.g. *Rajella fyllae*), and so these records have not been attributed to thornback ray nursery grounds.

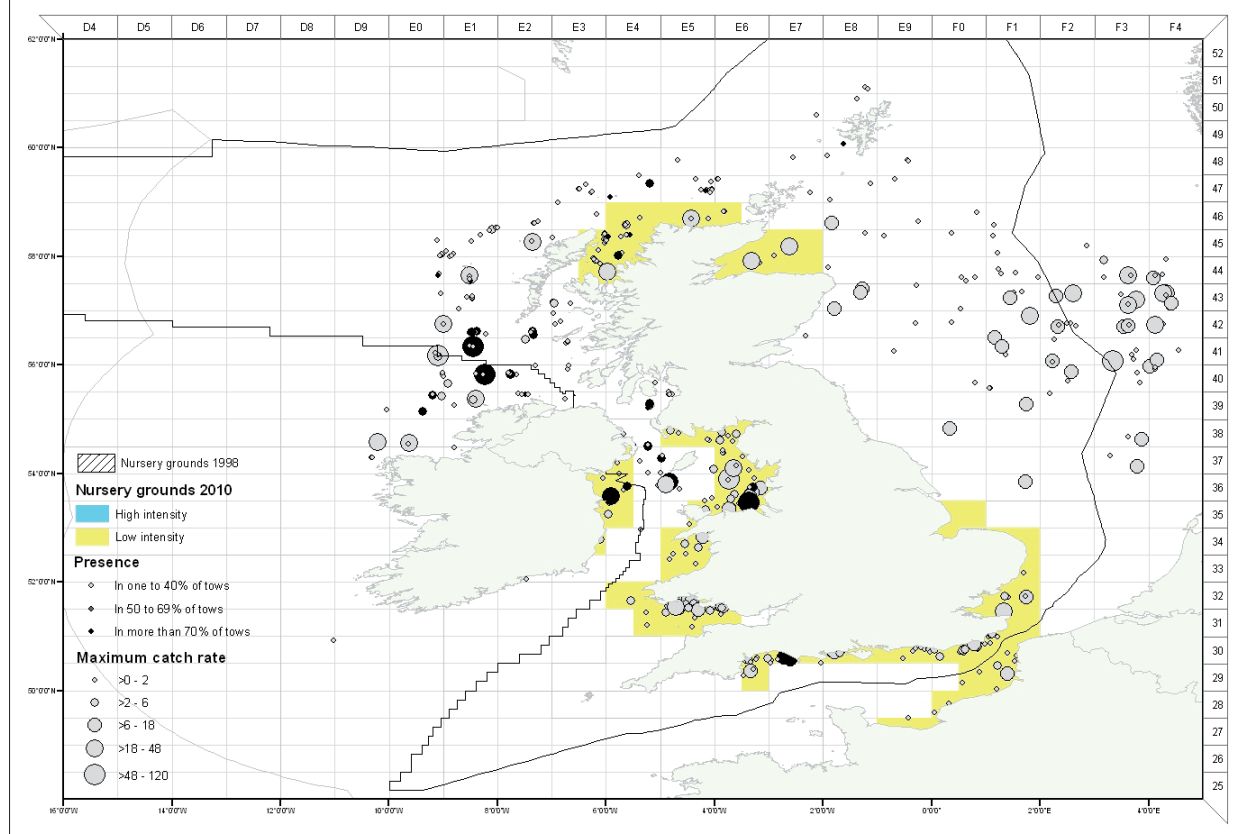
Estuarine and coastal zone

Thornback ray is a fully marine species that is recorded occasionally in estuaries. Juveniles may occur in coastal waters, but are mostly found in waters >10m deep (Wheeler, 1978).

Data gaps

Improved delineation of spawning and nursery grounds is required. Groundfish surveys could usefully report on the capture of egg-cases with developing embryos.

Figure 6: Nursery grounds of thornback ray. Data layer indicates nominal nursery grounds of thornback ray, as indicated by the presence of juveniles (<18 cm total length) in groundfish surveys. There is uncertainty regarding the accuracy of the records off the edge of the Hebridean shelf and in the Central North Sea, which may represent misidentified skates.



3.6 Spotted ray *Raja montagui*

General information

Spotted ray is a widespread and relatively abundant skate. There are few field data on the distribution of females with egg-cases, and there are few data on the distribution of egg-cases (excluding specimens from the strandline) with which to accurately define spawning areas.

Groundfish survey data may allow for the preliminary identification of nursery areas. For the present study, a length range of <18cm was used, which broadly equates with the first cohort apparent in survey data. Spotted ray hatch at a length of ca. 10–12cm (Clark, 1922), and so the data refer primarily to 0-groups (Ryland and Ajayi, 1984).

Spawning grounds

There are insufficient data on the occurrence of the egg-cases or egg-bearing females with which to delineate spawning grounds, although these should broadly overlap with nursery grounds.

Nursery grounds

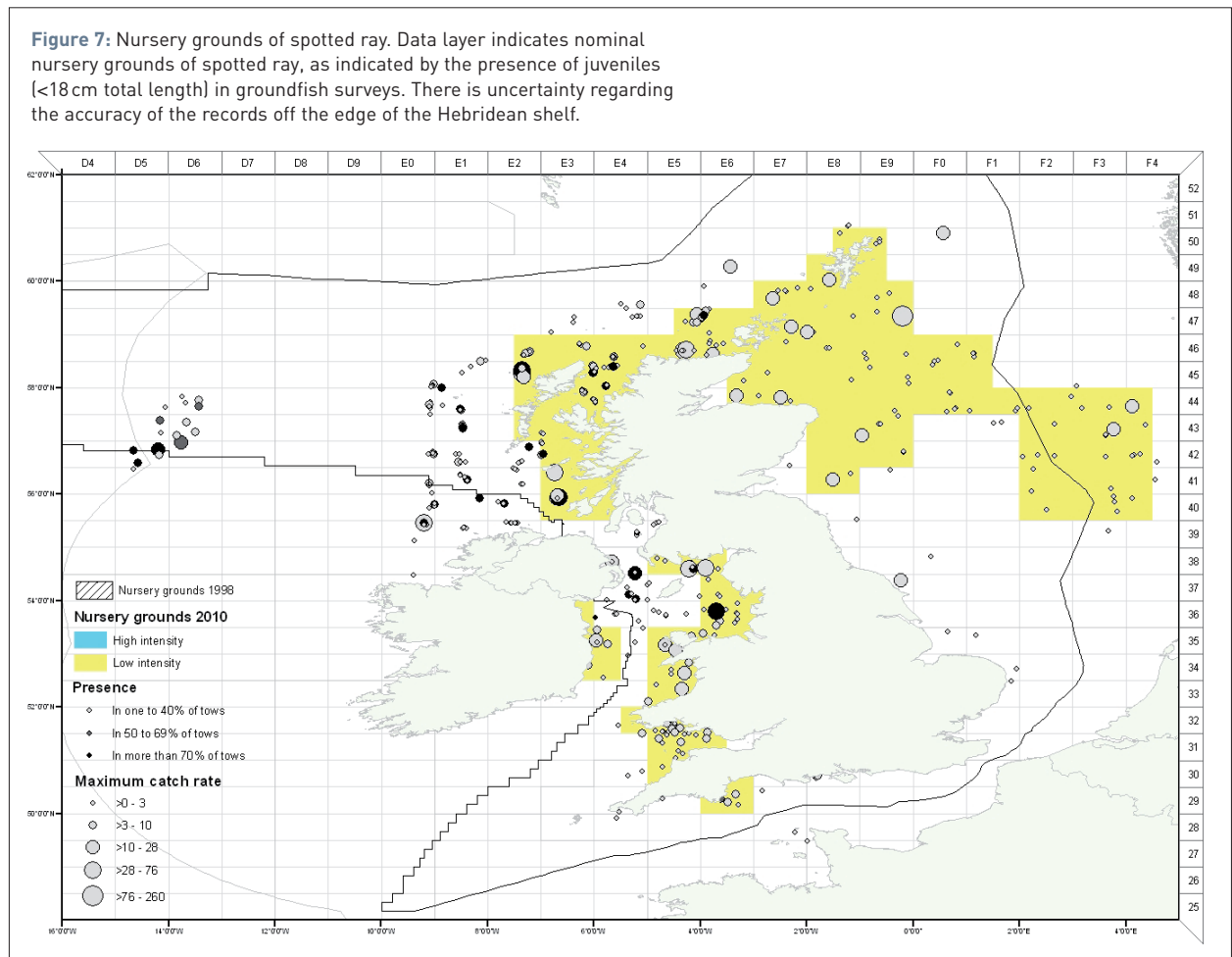
Spotted rays were taken in a variety of surveys, with juveniles sampled most effectively by beam trawl. Data layers were provided for the presence of juveniles, fixed stations where they were caught regularly (50% of tows) and maximum catch rates. The potential nursery grounds (Figure 7) were broadly similar to those of thornback ray, as suggested in earlier studies (Ellis *et al.*, 2005), although juvenile spotted rays were less abundant in the Greater Thames Estuary.

Estuarine and coastal zone

Spotted ray is a fully marine species that is recorded occasionally in estuaries. Juveniles occur in coastal waters, although adults are usually found further offshore (Wheeler, 1978).

Data gaps

Improved delineation of spawning and nursery grounds is required. Groundfish surveys could usefully report on the capture of egg-cases with developing embryos.



3.7 Undulate ray *Raja undulata*

General information

Undulate ray has a restricted distribution within the UK EEZ, being most commonly encountered in the English Channel, especially from the Channel Islands to the Solent and coast of Sussex. There are limited field data on the distribution of females with egg-cases, and there are few data on the distribution of egg-cases (excluding specimens from the strandline) with which to accurately define spawning areas.

Groundfish survey data may allow for the preliminary identification of nursery areas. This species is locally common in parts of the English Channel, but current data are limited. For the present study, a length range of <29 cm was used, as there were very few records of newly hatched fish in these survey data. Indeed, neither the age and growth of juveniles nor the size at hatching is well documented, although Coelho and Erzini (2006) caught juveniles as small as 19 cm. Moura *et al.* (2007) suggested that the nursery grounds of undulate ray occurred in estuarine waters.

Spawning grounds

There are insufficient data on the occurrence of the egg-cases or egg-bearing females with which to delineate spawning grounds, although these should broadly overlap with nursery grounds.

Nursery grounds

Undulate rays were generally taken in beam trawl surveys in the English Channel (Figure 8). Data layers were provided for the presence of juveniles, fixed stations where they were caught regularly (50% of tows) and maximum catch rates. Juvenile undulate ray tended to occur in the coastal fringe of the English Channel, with the Channel Islands the site of the most regular occurrence of juveniles. Data off North-eastern Scotland were considered erroneous records (e.g. incorrect species code). Elsewhere in Europe, juvenile undulate rays are typically found in coastal waters, particularly in shallow, inshore zones such as coastal lagoons, rías and estuaries (e.g. Coelho and Erzini, 2006; Moura *et al.*, 2007).

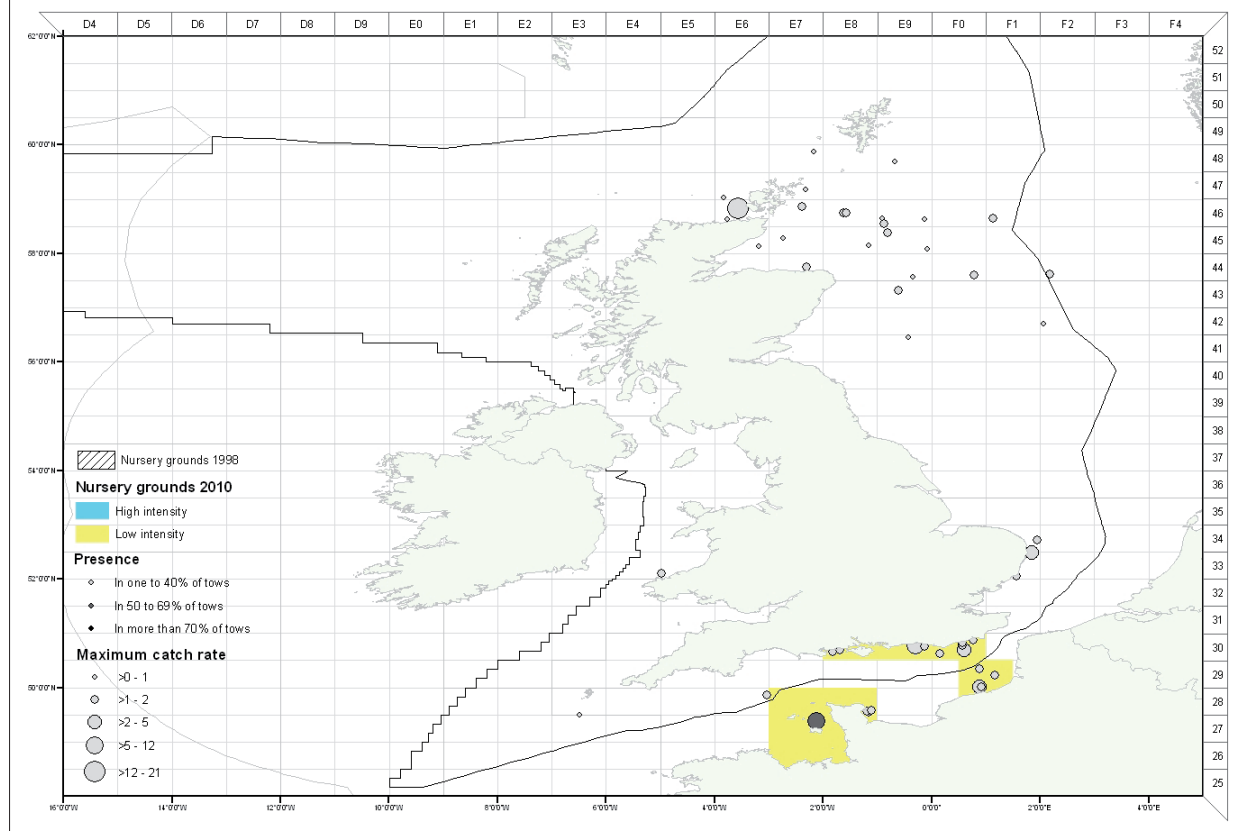
Estuarine and coastal zone

Undulate ray is a coastal, marine species that utilises the outer reaches of some estuaries as a nursery ground.

Data gaps

Improved delineation of spawning and nursery grounds. Inshore surveys in the English Channel could usefully identify important inshore habitats. Groundfish surveys could usefully report on the capture of egg-cases with developing embryos.

Figure 8: Nursery grounds of undulate ray. Data layer indicates nominal nursery grounds of undulate ray, as indicated by the presence of juveniles (<29 cm total length) in groundfish surveys. Records in northern North Sea considered a database error.



3.8 Herring *Clupea harengus*

General information

Herring is a widespread and abundant pelagic fish species and there are several nominal stocks in the UK EEZ.

The eggs are demersal (0.9–1.5 mm in diameter), and the larval and post-larval stages pelagic (Russell, 1976). There are several historical accounts identifying the spawning beds (often areas of coarse sand and gravel). The use of such beds can change over time and so the inclusion of all such information would inform on potential spawning beds, not just active spawning areas. Herring eggs and larvae can also be an important food source for some predators (e.g. Rankine and Morrison, 1989).

This information was augmented by international data on herring larvae distributions from internationally coordinated surveys in the North Sea and eastern Channel, and surveys in the Irish Sea, although recent comparable data were lacking for other western waters.

Juvenile herring are taken in otter trawl surveys although it must be acknowledged that these surveys have few stations in shallow inshore waters, where 0-group herring can be abundant (e.g. Wood, 1959). For the purposes of the present study, a length range of <17.5 cm was used to identify 0-groups, as used by ICES (2009c), although this will include some older fish for surveys conducted at the start of the year.

Spawning grounds

Herring spawn on gravel and similar habitats (e.g. coarse sand, maerl, shell) where there is a low proportion of fine sediment and well-oxygenated water (e.g. Bowers, 1980; de Groot, 1980; Rankine, 1986; Aneer, 1989; Stratoudakis *et al.*, 1998; Maravelias *et al.*, 2000). There are few surveys of herring spawning grounds, although surveys for herring larvae can indicate which of the nominal spawning grounds are in active use.

Herring larval surveys in the eastern English Channel and North Sea confirm the importance of the main Shetland, Orkney and Buchan (off Scotland), Banks (off North-eastern England) and Downs (Eastern Channel and Southern Bight) stocks (Figure 9), and there are still discrete spring-spawning stocks in certain areas, such as parts of the Greater Thames estuary (see Dempsey and Bamber, 1983; Fox and Aldridge, 2000). These surveys do not always inform on the utilisation of the smaller spawning grounds.

It has been suggested that the importance of spawning grounds is related to the overall health of the stock of autumn-spawning herring (see Schmidt *et al.*, 2009), and

some historic spawning grounds (e.g. parts of the Dogger Bank) currently have no, or very little, spawning activity. Nevertheless, it should be recognised that spawning grounds can be 'recolonised' over time (e.g. Corten, 1999) and so ensuring that the physical nature of these grounds does not restrict re-colonisation is an appropriate management measure.

Herring larvae have also been taken in the Irish Sea ichthyoplankton surveys, where there are thought to have been subtle shifts in the spawning grounds (Dickey-Collas *et al.*, 2001), although few data are available to inform on egg or larval distributions of other western stocks of herring.

Nursery grounds

Juvenile herring were recorded in a variety of surveys, and data layers were provided for the presence of juveniles and maximum catch rates. Although the current survey data (Figure 10) broadly supported the original nursery grounds proposed by Coull *et al.* (1998), there were some very slight differences, with the nursery grounds reported here extending slightly further offshore. The grounds indicated by Coull *et al.* (1998) may equate with the more inshore primary nursery grounds used by the smallest length classes, whereas the length range used in the present study (<17.5 cm) would be indicative of the more extensive secondary nursery grounds.

Estuarine and coastal zone

Herring is a marine species that utilises estuarine habitats as nursery grounds (e.g. Power *et al.*, 2000b). Certain stocks also spawn in estuarine areas (e.g. Milford Haven).

Data gaps

The apparent distribution of herring larvae may be strongly influenced by the distribution of survey stations. Given the lack of recent, detailed spawning information for the constituent stocks, it may be more pragmatic to recognise broader spawning areas (e.g. in parts of the eastern Irish Sea, off North-eastern Scotland and in the southern North sea/eastern Channel), as evidenced by the distribution of larvae, as well as more site-specific spawning grounds, as illustrated by Coull *et al.* (1998). The latter being those grounds where there are sites of suitable spawning substrate and known herring spawning (whether active or historic). Dedicated field surveys are needed to better inform on the contemporary use of some of the potential spawning grounds. Inshore surveys with an appropriate gear would be required to better inform on inshore nursery grounds.

Figure 9: Spawning grounds of herring. Data layers indicate spawning and potential spawning grounds of herring, giving the original polygons provided in Coull *et al.* (1998) and recent larval data from international surveys (recent, comparable data lacking for western areas).

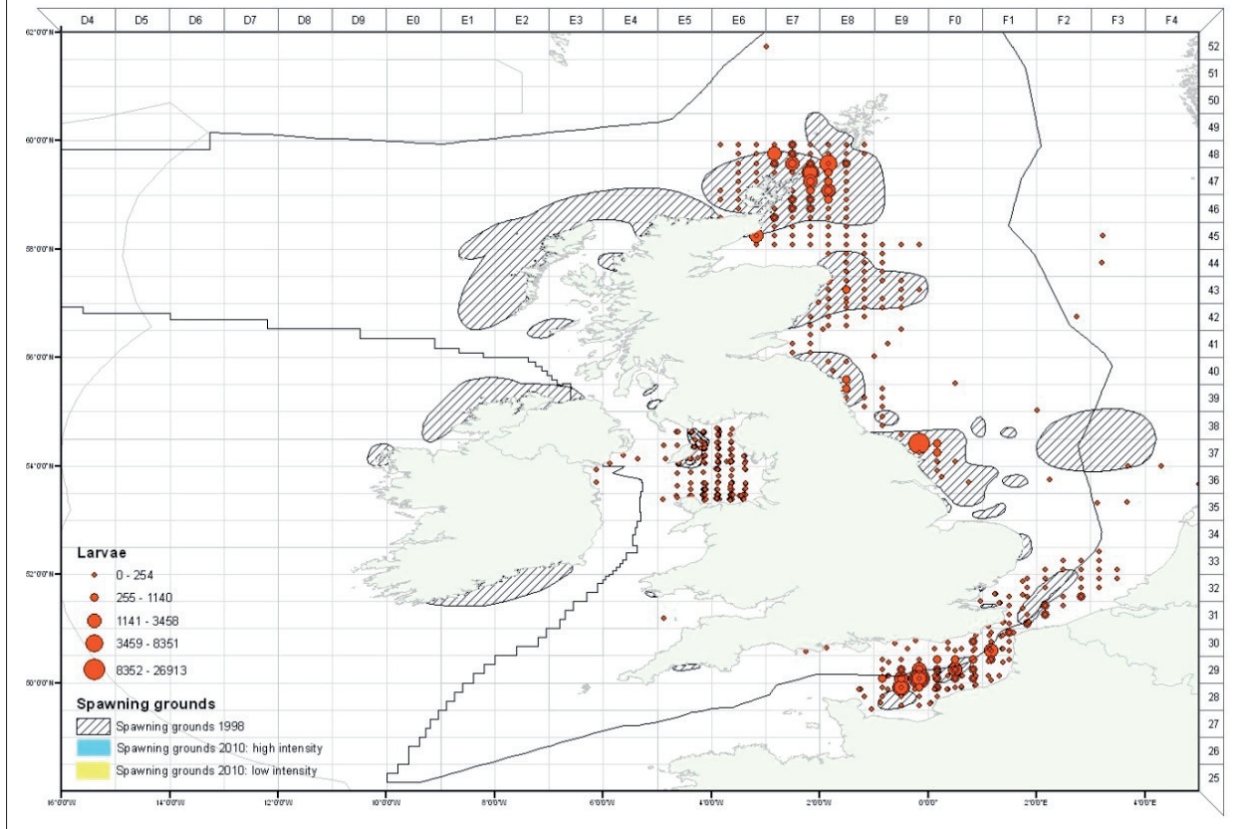
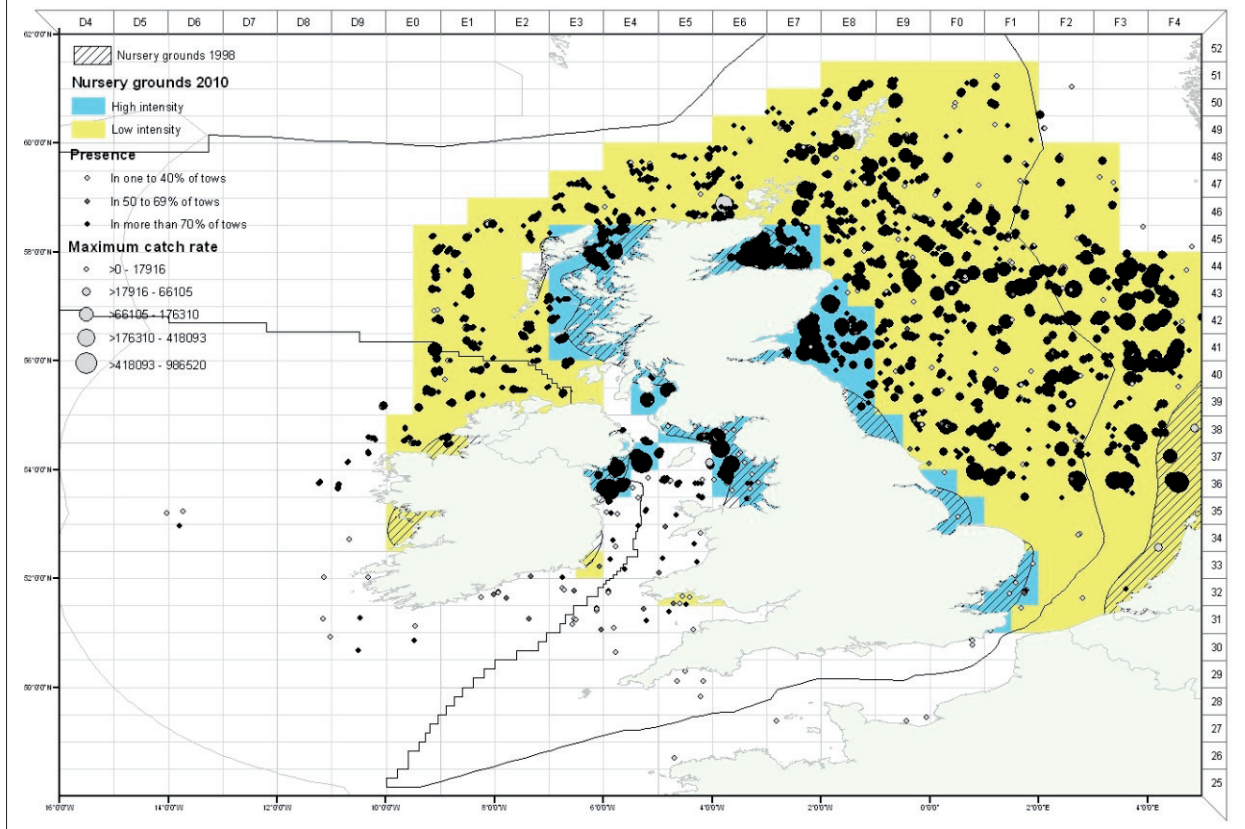


Figure 10: Nursery grounds of herring. Data layer indicates nominal nursery grounds of herring, as indicated by the presence of juveniles (<17.5 cm total length) in groundfish surveys. Inshore areas originally included by Coull *et al.* (1998) retained, although recent field data to support these areas are lacking.



3.9 Cod *Gadus morhua*

General information

There are several nominal cod stocks in the UK EEZ, including west of Scotland (ICES Division VIa), Rockall (VIb), Irish Sea (VIIa), south-west (VIIe-k) and the North sea and adjacent waters (ICES Subarea IV, Divisions VIId and IIIa).

Although ichthyoplankton survey data do not cover the entire study area, limited information on the distribution of the eggs and larvae of cod are available for many areas. The eggs are pelagic (1.16–1.89mm in diameter), and the post-larval stage (following yolk-sac absorption) begins at a length of approximately 4.5mm (Russell, 1976).

It should be noted that the identification of cod eggs is problematic as the eggs have no distinguishing features in the early stages, other than size. Smaller cod eggs can easily be confused with those of other gadoids, particularly those of whiting, and the size range of cod and haddock eggs almost completely overlap. Recent studies have used genetics to better identify and quantify cod eggs in samples (see Taylor *et al.*, 2002; Goodsir *et al.*, 2008), although the accuracy of the identification of more historic data may not be as assured. Nevertheless, such data can inform on the broad locations of some of the spawning grounds.

Beam trawl and otter trawl surveys operate around many parts of the UK EEZ and these surveys are designed to examine the distribution of juvenile fish. Some of these surveys may have limited coverage of the inshore waters of the UK, where juvenile cod are often abundant, although they can be used to inform on the broader extent of other nursery grounds. For the purposes of the present study, a length range of <23cm was used to identify 0-groups, as used by ICES (2009c), although this will include some older fish in surveys conducted at the start of the year.

Spawning grounds

Cod eggs and larvae were taken in a variety of ichthyoplankton surveys (Figure 11; Fox *et al.*, 2008). They were widespread in the North Sea, and although data were limited, there was evidence that spawning may be more widespread than indicated by Coull *et al.* (1998). Similarly, the important spawning grounds off Trevoise Head (north Cornwall) and in the eastern and western Irish Sea may be slightly more widespread than suggested. There were no recent data available to examine the distribution of cod spawning grounds off North-western Scotland, Rockall and southern Ireland, although Wright *et al.* (2006) found evidence of a high fidelity to the spawning grounds identified off the west coast of Scotland. A high site fidelity in cod spawning grounds was also reported for Irish Sea cod (Fox *et al.*, 2000).

Nursery grounds

Juvenile cod were taken in a variety of surveys, and data layers were provided for the presence of juvenile cod and their maximum catch rates (Figure 12). Although the current survey data broadly supported the original nursery grounds proposed by Coull *et al.* (1998) and other sources (e.g. Gibb *et al.*, 2007), there were some slight differences, with potentially important nursery grounds more widely distributed in the North Sea (including the Moray Firth) and along the western seaboard of the UK (e.g. eastern Irish Sea and Fifth of Clyde).

It should also be noted that Munk *et al.* (2002) reported cod larvae as occurring in shallow areas in the North Sea (e.g. Dogger Bank and German Bight), especially in the frontal zones between those water masses with a freshwater influence and shelf water masses, with the abundance of larvae peaking near these haline fronts.

Estuarine and coastal zone

Cod is a marine species that utilises estuarine habitats and other coastal waters as nursery grounds (Wheeler, 1978; Rogers *et al.*, 1998).

Data gaps

There was no recent evidence of major spawning activity within the patchy distribution of cod spawning grounds given in Coull *et al.* (1998). Spawning in the North Sea may be more widespread, although the supporting data are limited. Further field data are still required to determine the importance on some of the nominal spawning grounds described in that report (e.g. eastern English Channel, southern Ireland and St George's Channel, North-western Scotland, Rockall). Additionally, other areas (e.g. Bristol Channel and neighbouring parts of the western English Channel, and North Sea) could usefully be subject to further investigations. Indeed, the most recent data for the Bristol Channel were from 1990.

In terms of nursery grounds, current groundfish surveys do not always sample near-shore sites, although some of these sites may serve as important cod nursery grounds.

Figure 11: Spawning grounds of cod. Data layers indicate spawning grounds of cod, giving the original polygons provided in Coull *et al.* (1998) and recent larval data from ichthyoplankton surveys (recent, comparable data lacking for some southern and western areas).

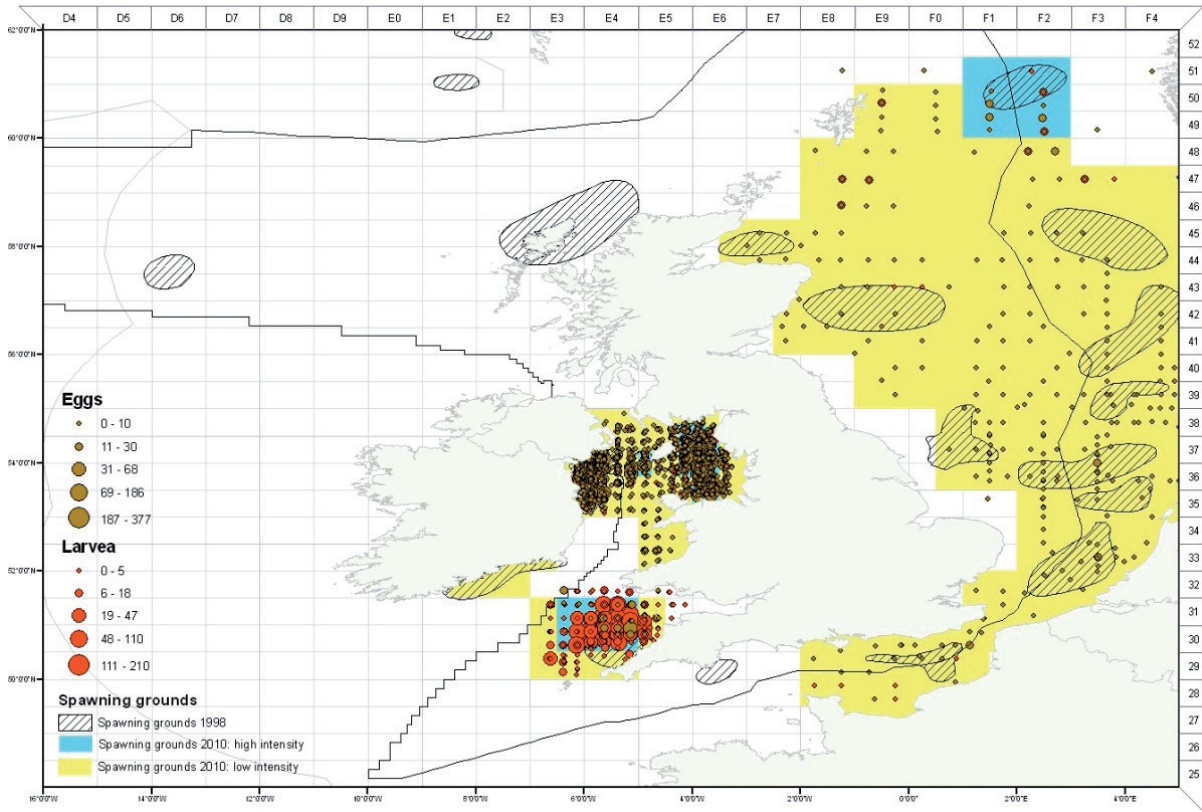
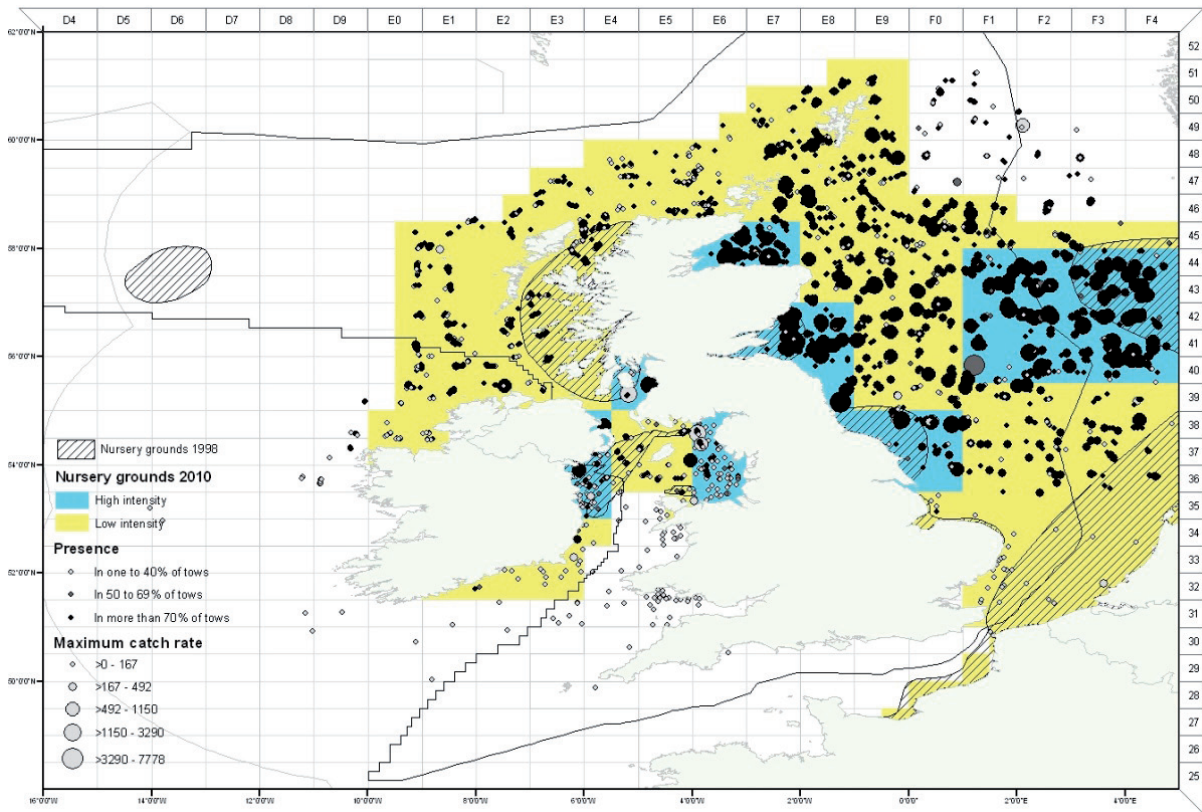


Figure 12: Nursery grounds of cod. Data layers indicate nominal nursery grounds of cod, as indicated by the presence of juveniles (<23 cm total length) in groundfish surveys. The inshore areas originally included by Coull *et al.* (1998) are retained, although recent field data to support some of these areas are lacking.



3.10 Whiting *Merlangius merlangus*

General information

There are several nominal whiting stocks in the UK EEZ, including west of Scotland (ICES Division VIa), Rockall (VIb), Irish Sea (VIIa), south-west (VIIe-k) and the North sea and adjacent waters (ICES Subarea IV, Division VIId).

Although ichthyoplankton survey data do not cover the entire study area, information on the distribution of the eggs and larvae of whiting are available for many areas, although it must be noted that the identification of the eggs of some gadoids is problematic (see above). Nevertheless, available data can inform on the broad locations of some of the spawning grounds. The eggs are pelagic (0.97–1.32mm in diameter) and possess no distinguishing features in early development. The post-larval phase begins at a length of about 4.3mm (Russell, 1976), when they are often associated with jellyfish before switching to a more demersal existence.

Beam trawl and otter trawl surveys operate around many parts of the UK EEZ and these surveys are designed to examine the distribution of juvenile fish, including whiting. For the purposes of the present study, a length range of <20cm was used to identify 0-groups, as used by ICES (2009c), although this will include some older fish for surveys conducted at the start of the year.

Spawning grounds

Whiting eggs and larvae were taken in a variety of ichthyoplankton surveys (Figure 13). They were widespread in the North Sea, and although data were limited, there was evidence that spawning may be more widespread than indicated by Coull *et al.* (1998). Similarly, the important spawning grounds off Trevoise Head and in the eastern and western Irish Sea may be slightly more widespread than suggested. There were no recent data to examine the distribution of whiting spawning grounds in the English Channel and off North-western Scotland and southern Ireland.

Nursery grounds

Juvenile whiting are taken in a variety of surveys (Figure 14). Data layers were provided for the presence of juvenile whiting, fixed stations where they were caught regularly (50 and 70% of tows) and their maximum catch rates. Although the current survey data broadly supported the original nursery grounds proposed by Coull *et al.* (1998), there were some very slight differences, with the nursery grounds possibly extending slightly further offshore than reported previously.

Estuarine and coastal zone

Whiting is a marine species that utilises estuarine habitats and other coastal waters as nursery grounds (Wheeler, 1978; Potter *et al.*, 1988; Henderson & Holmes, 1989)

Data gaps

The lack of data on the distribution of whiting eggs is an artefact of sample analysis, as the eggs are impossible to identify to species morphologically, using light microscopy. New genetic techniques have allowed some of the more recent surveys to better identify whiting eggs. It is also noted that whiting is a widespread, serial spawner (i.e. spawning may be both spatially and temporally extensive), and so the limited (temporal) extent of some surveys may under-represent wider spawning activity.

Figure 13: Spawning grounds of whiting. Data layers indicate spawning grounds of whiting, giving the original polygons provided in Coull *et al.* (1998) and recent larval data from ichthyoplankton surveys (recent, comparable data for some southern and western areas are lacking).

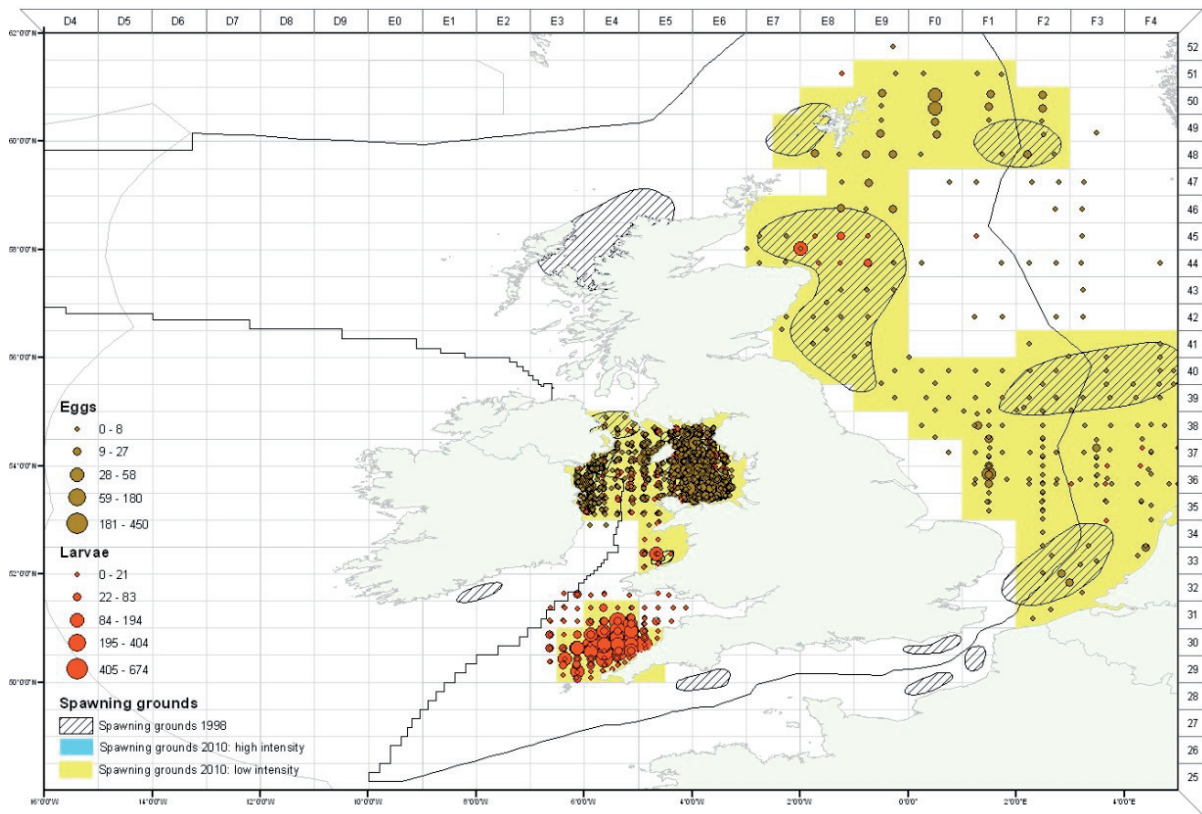
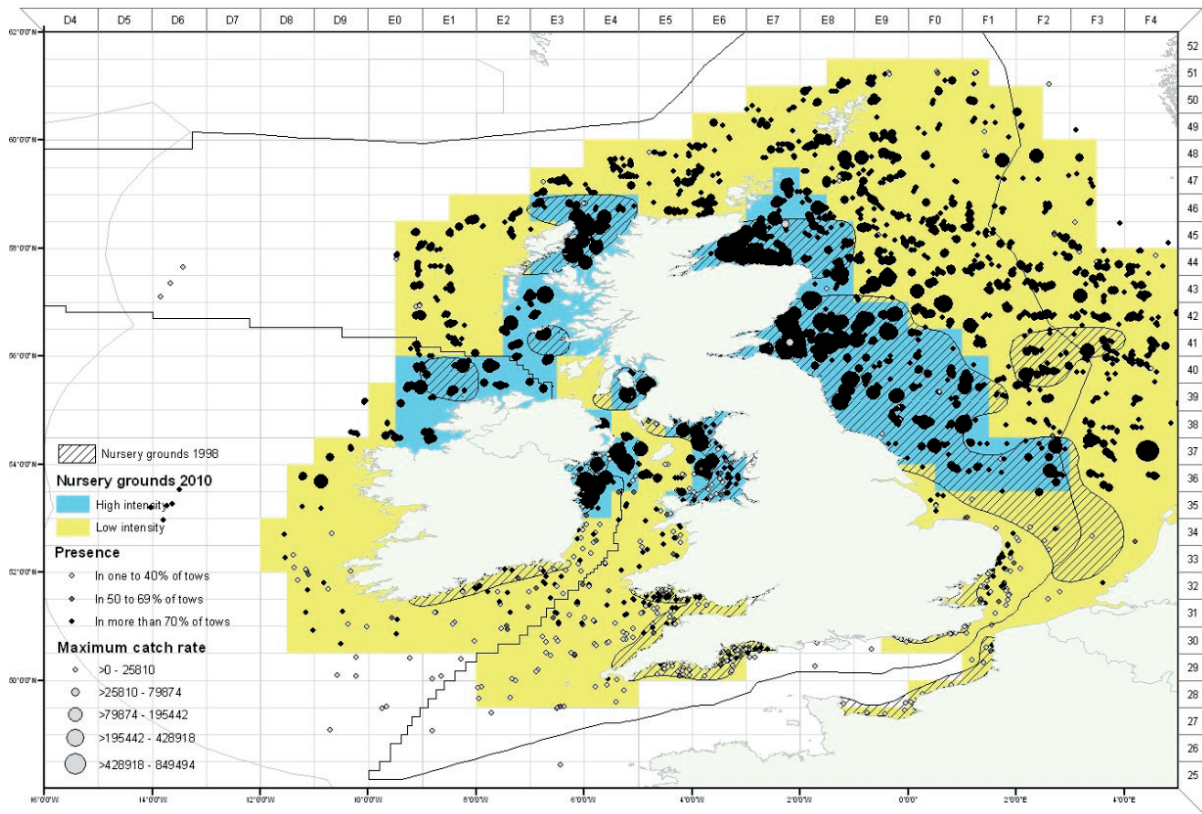


Figure 14: Nursery grounds of whiting. Data layers indicate nominal nursery grounds of whiting, as indicated by the presence of juveniles (<20 cm total length) in groundfish surveys. The inshore areas originally included by Coull *et al.* (1998) also shown, although field data are lacking for some of these areas.



3.11 Blue whiting *Micromesistius poutassou*

General information

Blue whiting is a widespread and abundant benthopelagic species, most abundant in deeper waters of the outer continental shelf and slope.

The eggs are pelagic (1.04–1.28 mm in diameter) and possess no distinguishing features to aid positive identification, and the post-larval phase begins at a length of approximately 6.7 mm (Russell, 1976). For the purposes of the present study, a length range of <19 cm was used to identify 0-groups, as used by ICES (2009c). Otter trawl surveys will catch juveniles, although it should be noted that only the fish in the shallower parts of the stock range are caught in these surveys. It should also be noted that blue whiting may have extensive vertical migrations. The extent of such migrations and degree of occupancy of sea floor habitats (where they may be taken in demersal trawls) can be variable.

Spawning grounds

The eggs are difficult to positively identify, and the larvae of blue whiting have been observed in few samples from the surveys utilised in this report (Figure 15). Consequently, no new information to update the spawning grounds for this species was available. The spawning grounds have been described by various authors (e.g. Gerber and Demenin, 1992; Bartsch and Coombs, 1997; Hatun *et al.*, 2009). However, given the size of the blue whiting stock, based on commercial catches from the 'industrial' fishery, it is likely that most of the spawning activity takes place in areas to the west of the UK that are not regularly sampled.

Nursery grounds

Juvenile blue whiting were recorded in a variety of surveys, and data layers were provided for the presence of juveniles, fixed stations where they were caught regularly (50 and 70% of tows) and maximum catch rates (Figure 16). Most of the surveys used in the current study were more southerly and inshore than the nursery grounds proposed by Coull *et al.* (1998). Juvenile blue whiting were more widespread in the northern North Sea and high catches were also made off North-western Scotland, suggesting that their nursery ground may extend further south along the edge of the continental shelf than previously supposed.

Estuarine and coastal zone

Blue whiting is a fully marine species that is recorded only very occasionally in estuaries. Typically occurs further offshore, in waters >50 m deep.

Data gaps

Existing surveys only occasionally sample the eggs and larvae of blue whiting, as the spawning grounds are off the edge of the Scottish and Irish continental shelves. Similarly, existing groundfish surveys only inform on a part of the potential nursery grounds, and the importance of deeper, offshore waters for juvenile blue whiting still needs to be elucidated.

Figure 15: Spawning grounds of blue whiting. Data layers indicate spawning grounds of blue whiting, giving the original polygons provided in Coull *et al.* (1998) and recent larval data from ichthyoplankton surveys. No recent data were available for the main spawning grounds, and the data layers in Coull *et al.* (1998) are not updated for his species.

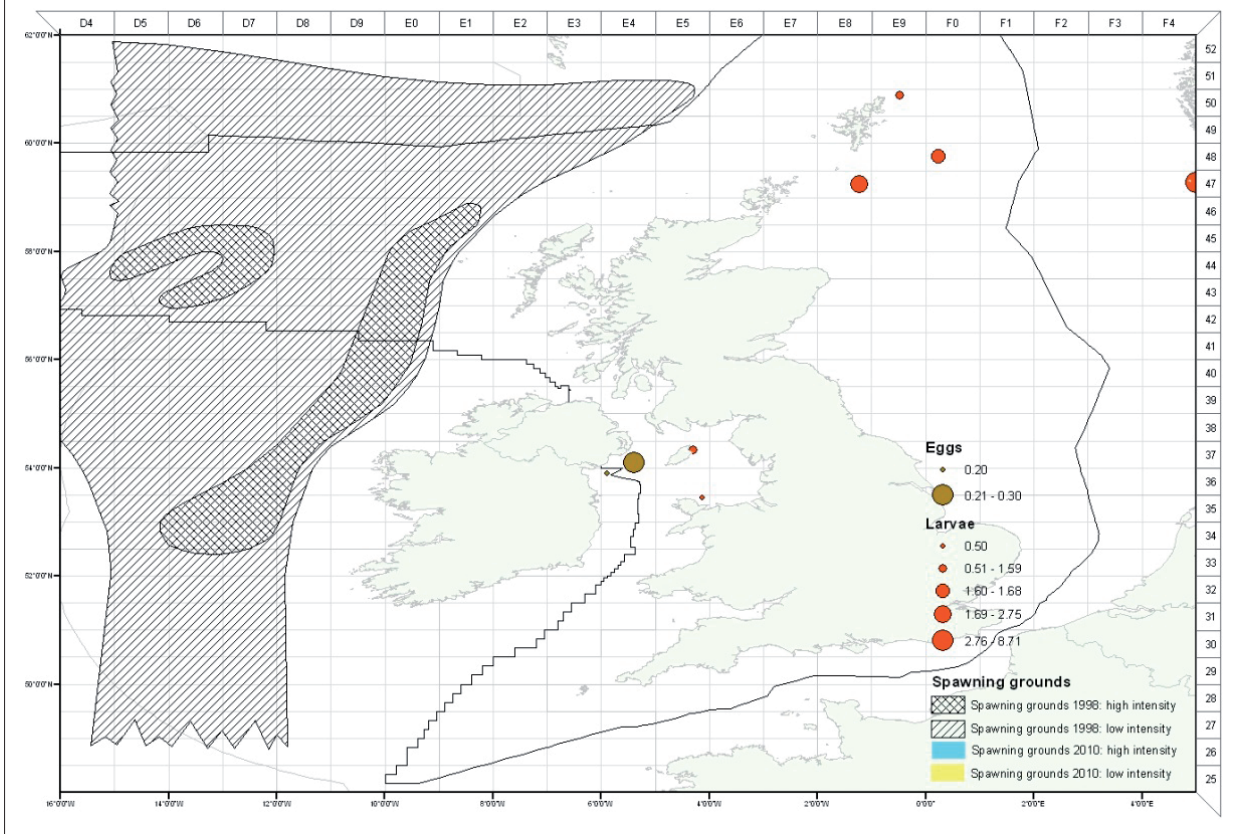
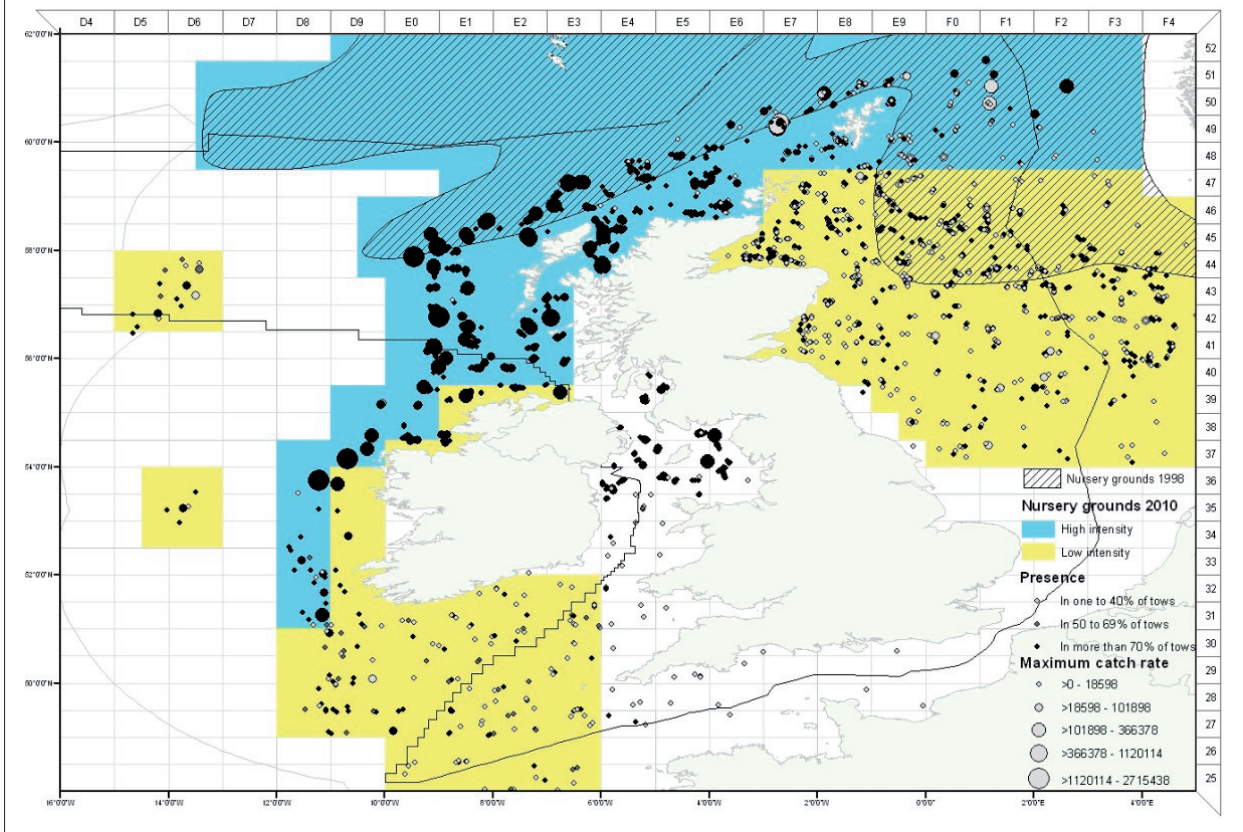


Figure 16: Nursery grounds of blue whiting. Data layer indicate nominal nursery grounds of blue whiting, as indicated by the presence of juveniles (<19 cm total length) in groundfish surveys. Offshore areas originally included by Coull *et al.* (1998) also included, although no supporting data were available.



3.12 Blue ling *Molva dypterygia*

General information

Blue ling is a deep-water species that is most abundant on the continental slope and as such is only taken very occasionally in groundfish surveys. They have planktonic eggs and larvae that are rarely found.

Spawning grounds

The spawning grounds of blue ling occur in the deeper waters off North-western Scotland, off the Faroe Islands, and in parts of the northern North Sea (Wheeler, 1969), including Rockall and Lousy Bank (Ehrich, 1982). Existing ichthyoplankton surveys are generally in more inshore waters, and so do not sample the eggs of this species.

Earlier fisheries targeted spawning aggregations. Known sites of high spawning activity have been identified (Large *et al.*, 2010), and blue ling spawning grounds are now subject to management measures to protect spawning aggregations (CEC, 2009). Spawning grounds are known off the continental slope of Scotland, and off the Rosemary, Hatton and Lousy Banks in waters of 730–1100m depth (Figure 17), although the exact range of these and other potential grounds (e.g. Rockall Bank, Faroe Bank and Bill Bailey Bank) is not fully understood.

Nursery grounds

There was insufficient information to map the distribution of juvenile blue ling in UK waters. Additionally, some of the available data may be confused with Spanish ling.

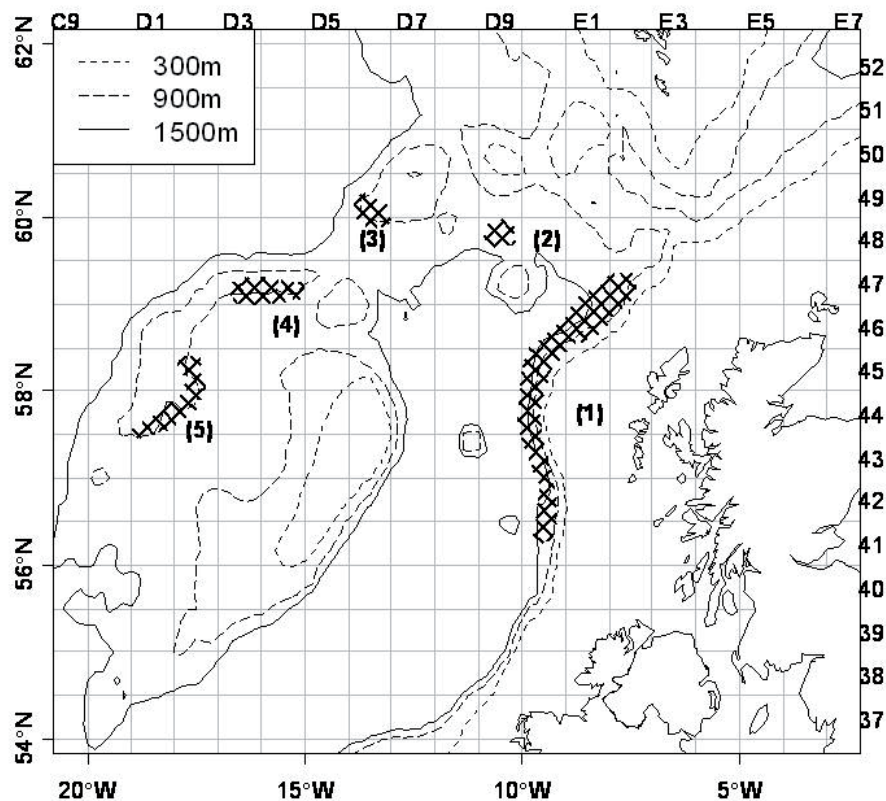
Estuarine and coastal zone

Blue ling occurs offshore, usually in waters >150m deep.

Data gaps

More biological data on this species could usefully be collected during internationally coordinated deep-water surveys.

Figure 17: Spawning grounds of blue ling. Some of the sites of blue ling spawning activity have been identified from (1) along the continental slope of Scotland; (2) north-west of Rosemary Bank; (3) south-west of the Lousy Bank; (4) north-east margin of the Hatton Bank; and (5) southern and eastern margin of the Hatton Bank (Large *et al.*, 2010). The overall distribution of these and other possible spawning grounds is not fully known, and no data layers were provided. Figure adapted from Large *et al.* (2010).



3.13 Ling *Molva molva*

General information

Ling is widespread, but not abundant, in the deeper waters of the continental shelf. The eggs are difficult to positively identify. They are pelagic, 0.97–1.13mm in diameter and contain a single oil globule (Russell, 1976). Egg stages are only recorded sporadically from ichthyoplankton surveys, presumably due to the main spawning grounds occurring in deeper waters to the north and west of the British Isles. The post-larval stage begins at a length of approximately 5mm (Russell, 1976).

Trawl surveys are inefficient at sampling the smallest juvenile stages (i.e. primary nursery grounds), although larger juveniles are taken which may indicate the distribution of secondary nursery grounds. For the purposes of the present study the occurrence of ling <49cm was examined. Although the length at maturity is not reliably known for ling, recent field surveys have indicated that fish <49cm are immature.

Spawning grounds

The eggs and larvae of ling were only recorded occasionally in existing ichthyoplankton surveys (Figure 18), and although there were some data to suggest some spawning activity in the Bristol Channel and Irish Sea, more data from the outer continental shelf are required to better define the main spawning grounds for this species. Hence, the data layer generated for ling is missing the main spawning grounds.

Nursery grounds

Ling has not traditionally been considered an important commercial species and consequently has not been subject to routine biological sampling. For the purposes of the present study, the length cut-off broadly equated with all juveniles and so the nominal nursery ground information refers to secondary nursery grounds (Figure 19). Catches of the smallest length-classes of ling were generally small. Juvenile ling were recorded in a variety of surveys, and data layers were provided for the presence of juvenile ling and maximum catch rates. It was not possible to highlight fixed stations where they were caught regularly, due to the sporadic nature of captures. Current data suggest that juvenile ling are taken in the northern North Sea and off North-western Scotland, with the largest catches in deeper waters. The apparent records of juvenile ling in the eastern English Channel may represent misidentified rockling.

Estuarine and coastal zone

Ling is a fully marine species that is only recorded very occasionally in estuaries. It typically occurs further offshore, in waters >50m deep.

Data gaps

Ling eggs and larvae were taken in a variety of ichthyoplankton surveys in western waters, although only in small numbers. Data were too limited to draw firm conclusions on spawning in the northern North Sea, in the deeper waters of the western Channel and Celtic Sea and western seabords of Ireland and Scotland. Eggs were found in samples collected from the Irish Sea and off Trevose Head, with larvae also taken in the latter area. Although these grounds are identified here as ling spawning grounds, it should be recognised that ling is more widespread in the deeper waters of the continental shelf and along the continental slope, and there may be more extensive and important spawning grounds in these areas.

Figure 18: Spawning grounds of ling. Data layers indicate some potential inshore spawning grounds of ling, Data were only available for some inshore surveys, and it should be noted that the main spawning grounds are thought to occur offshore, where field data are lacking.

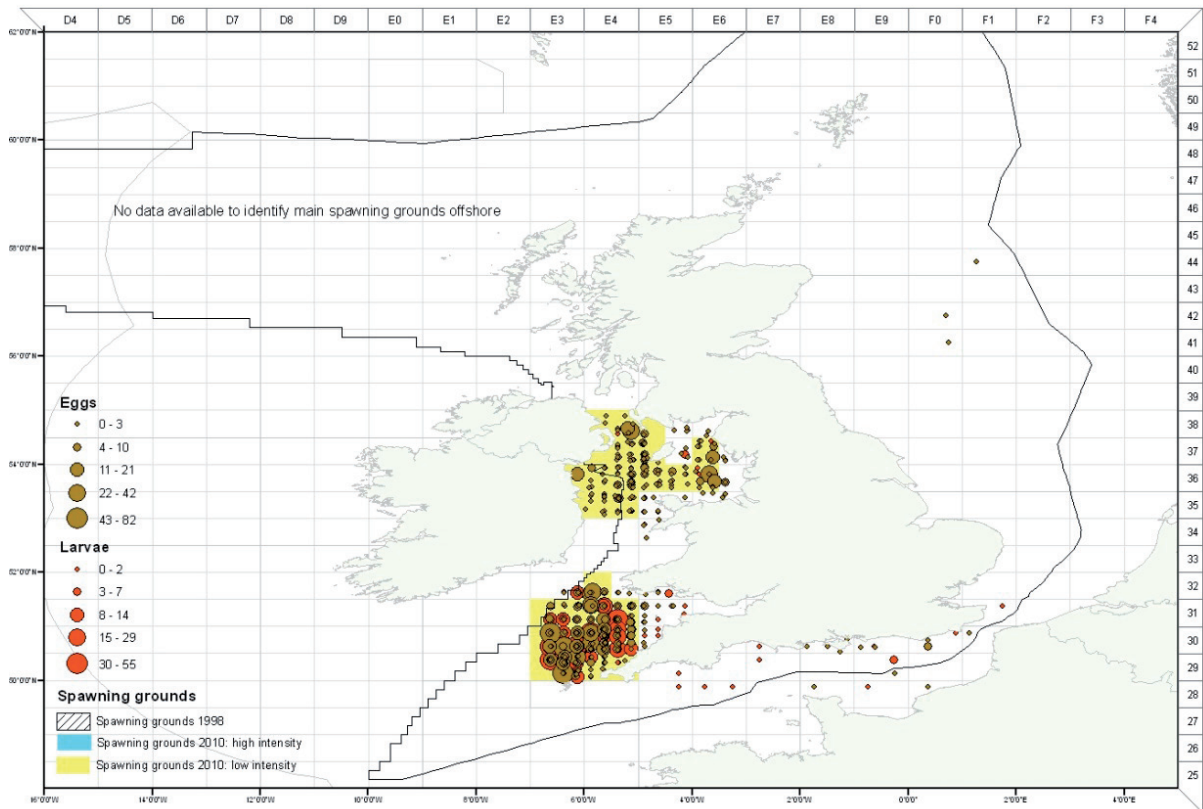
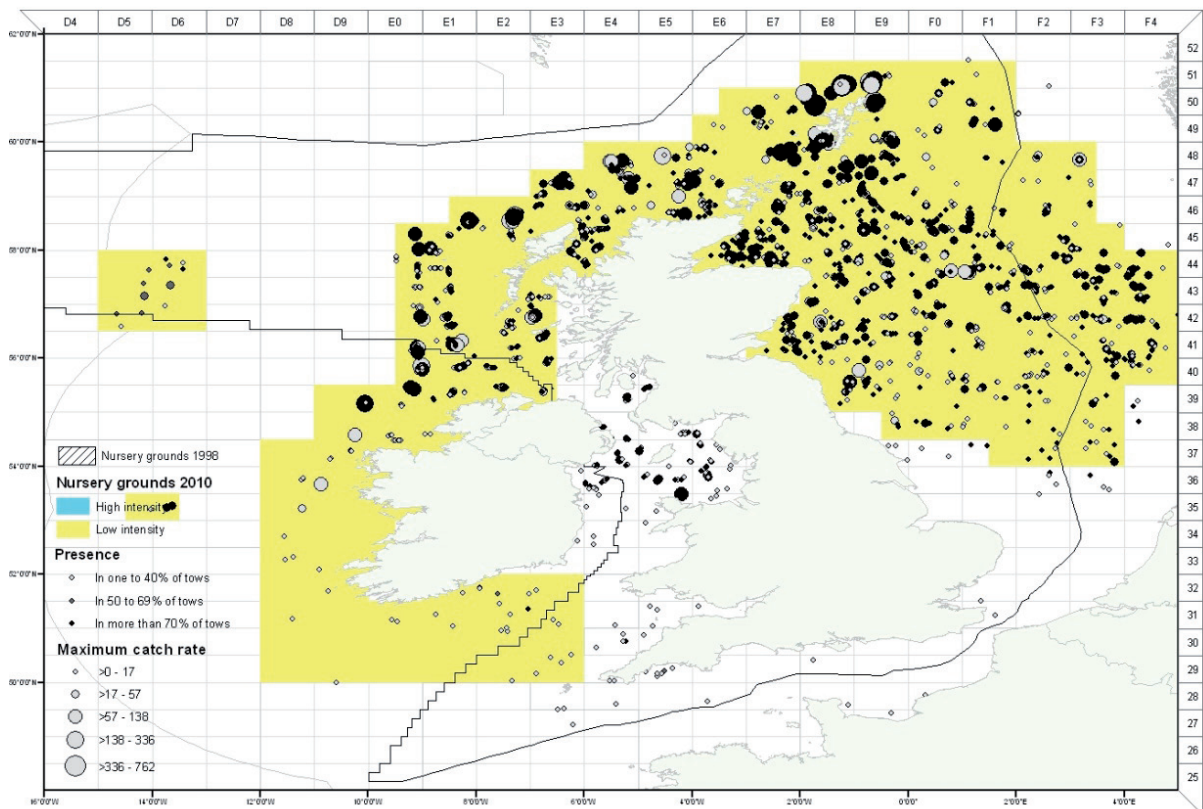


Figure 19: Nursery grounds of ling. Data layers indicate nominal nursery grounds of ling, as indicated by the presence of juveniles (<49 cm total length) in groundfish surveys.



3.14 European hake *Merluccius merluccius*

General information

Hake is widespread in the deeper waters of the continental shelf. The eggs are pelagic, 0.94–1.03 mm in diameter and contain a single oil globule. The post-larval stage begins at a length of approximately 5 mm (Russell, 1976).

Trawl surveys sample juvenile stages, which may indicate the distribution of nursery grounds, although the density of trawl stations in these areas is often low. For the purposes of the present study, a length range of <20 cm was used to identify 0-groups, as used by ICES (2009c), although this will include some older fish for surveys conducted at the start of the year.

Spawning grounds

Hake eggs were captured occasionally in the deeper waters of the Irish Sea (near the Isle of Man) and off Trevose Head, where larvae were also taken (Figure 20). Although these grounds are identified as hake spawning grounds, hake are more widespread and abundant in the deeper waters of the continental shelf and along the continental slope and there will be more extensive and important spawning grounds in these areas.

Alvarez *et al.* (2004) reported that the North-eastern Atlantic stocks of hake generally spawned over depths of 200–1000 m, although there could be some latitudinal variation in the depth of spawning. Olivar *et al.* (2003) reported hake spawning in the Mediterranean was most pronounced between the 100 m isobath and the shelf edge.

For the purposes of the present study, those sites between 200–1000 m have been identified (Figure 20), as well as some of the outer continental shelf of the Celtic Sea, where eggs and larvae were reported by other authors (e.g. Fives *et al.*, 2001; Alvarez *et al.*, 2004). The extent of any spawning north of Scotland is unclear, although Howell (1921) reported eggs and newly hatched larvae just north of 58°N.

Nursery grounds

Juvenile hake are taken in a variety of surveys, and data layers were provided for the presence of juvenile hake, fixed stations where they were caught regularly (50 and 70% of tows) and their maximum catch rates. Current data suggest that juvenile hake are taken in the northern North Sea and along the western seaboard of the British Isles (Figure 21).

Estuarine and coastal zone

Hake is a fully marine species that is recorded only very occasionally in estuaries. It typically occurs further offshore, in waters >50 m deep.

Data gaps

Although only limited data were available for hake, the proposed grounds west of Ireland and in the Celtic Sea are widely acknowledged as important spawning grounds. Field surveys off North-western Scotland are required to better determine the extent of potential hake spawning in this region.

Figure 20: Spawning grounds of hake. Data layers indicate some of the inshore spawning grounds of hake, as inferred from ichthyoplankton survey data. The main spawning grounds occur offshore, in depths of 200-1000 m, but supporting data were not available.

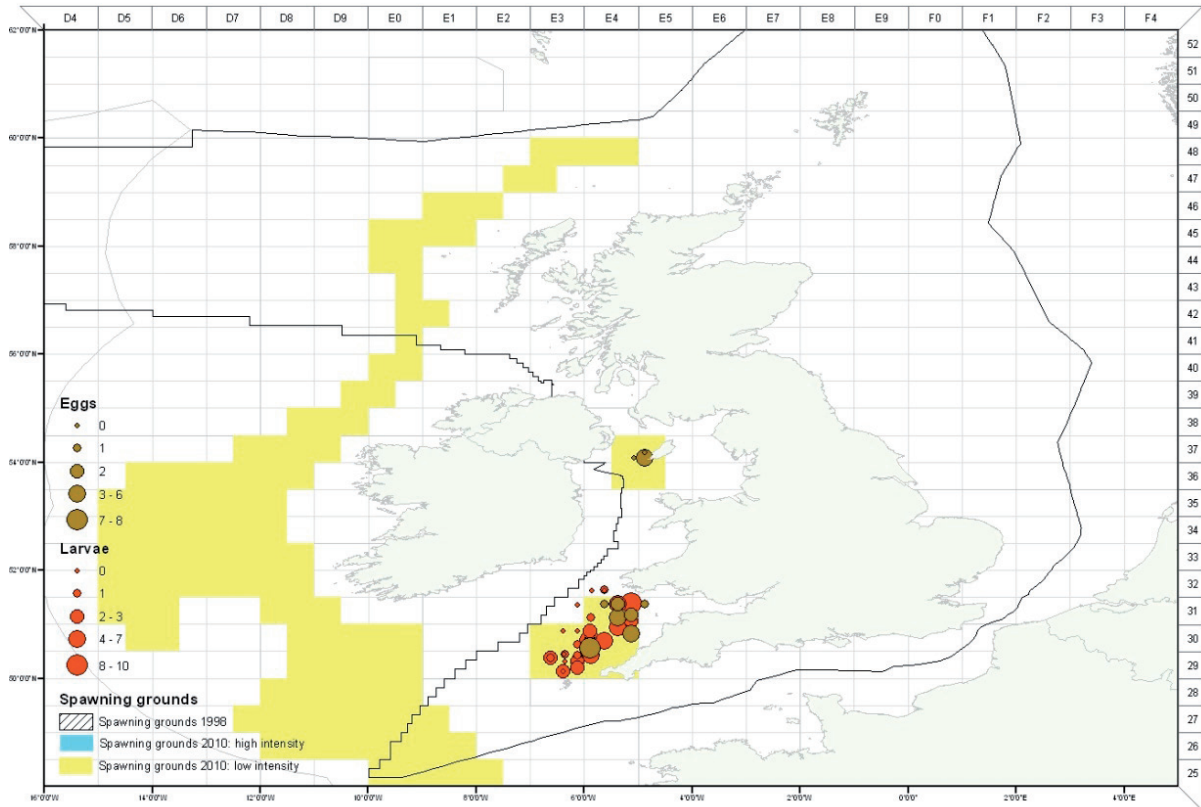
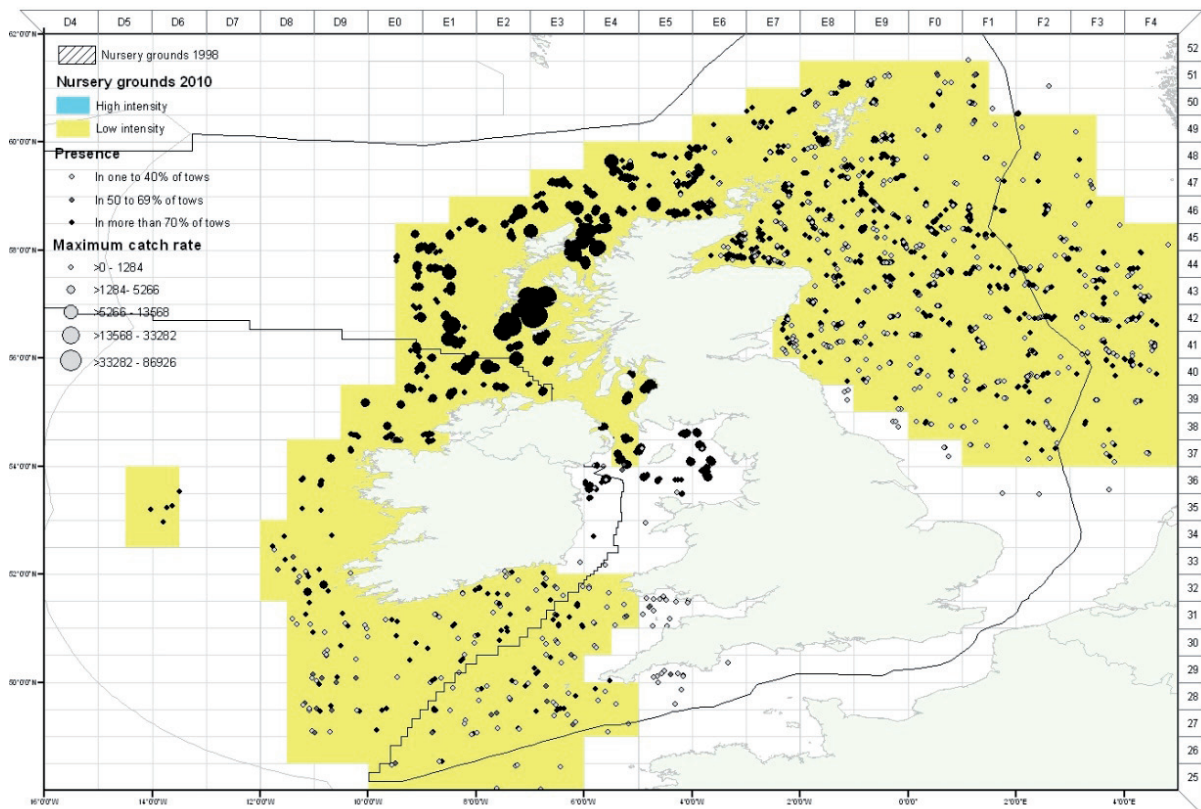


Figure 21: Nursery grounds of hake. Data layer indicates nominal nursery grounds of hake, as indicated by the presence of juveniles (<20 cm total length) in groundfish surveys.



3.15 Anglerfish *Lophius piscatorius*

General information

Anglerfish is widespread in the deeper waters of the continental shelf and slope, but small numbers are also taken in shallow waters. Both beam trawl and otter trawl surveys catch low numbers of this species, although the smallest size categories are taken very infrequently. Hence, trawl surveys may be indicative of the broader secondary nursery grounds on the continental shelf, although the relative importance of these sites within large un-surveyed areas is unclear. For the purposes of the present study, a length range of <28cm was examined, which included the first main peak and broadly equates with 0-group and some 1-group fish. However, it should be noted that anglerfish <10cm are recorded infrequently in surveys.

Anglerfish spawn in deep water, with most records of spawning in UK waters from northern and western areas. The eggs are included within a gelatinous ribbon, and even the post-larval stage may have a prolonged pelagic existence.

Spawning grounds

There is very limited information (Figure 22), but they are presumed to spawn in deep water along the edge of the continental slope (Hislop *et al.*, 2000, 2001; Arkhipov and Mylnikov, 2002; Laurenson, 2006). Very few ribbons of eggs have been caught in plankton samplers or other gears, and too few larvae have been captured in ichthyoplankton surveys to identify specific sites of spawning.

Nursery grounds

Juvenile anglerfish are taken in a variety of surveys, albeit in low numbers (Figure 23) and data layers were provided for the presence of juveniles, fixed stations where they were caught regularly (50 and 70% of tows) and their maximum catch rates. Current data suggest that juvenile anglerfish are taken in the northern North Sea and along the western seaboard of the British Isles (including North-western Scotland, parts of the Irish Sea and the Cornish peninsula).

Estuarine and coastal zone

Anglerfish is a fully marine species that is recorded only very occasionally in estuaries. Juveniles may occur in coastal waters, although adults tend to occur further offshore.

Data gaps

Very little is known about the egg and larval distribution, and of mature females in spawning condition, as catches of these stages are very sporadic. Data are unlikely to become available in the absence of a high degree of survey effort.

Figure 22: Spawning grounds of anglerfish. Location of anglerfish larvae taken in current ichthyoplankton surveys. Insufficient data are available to identify spawning grounds, which are considered to occur in deep-water.

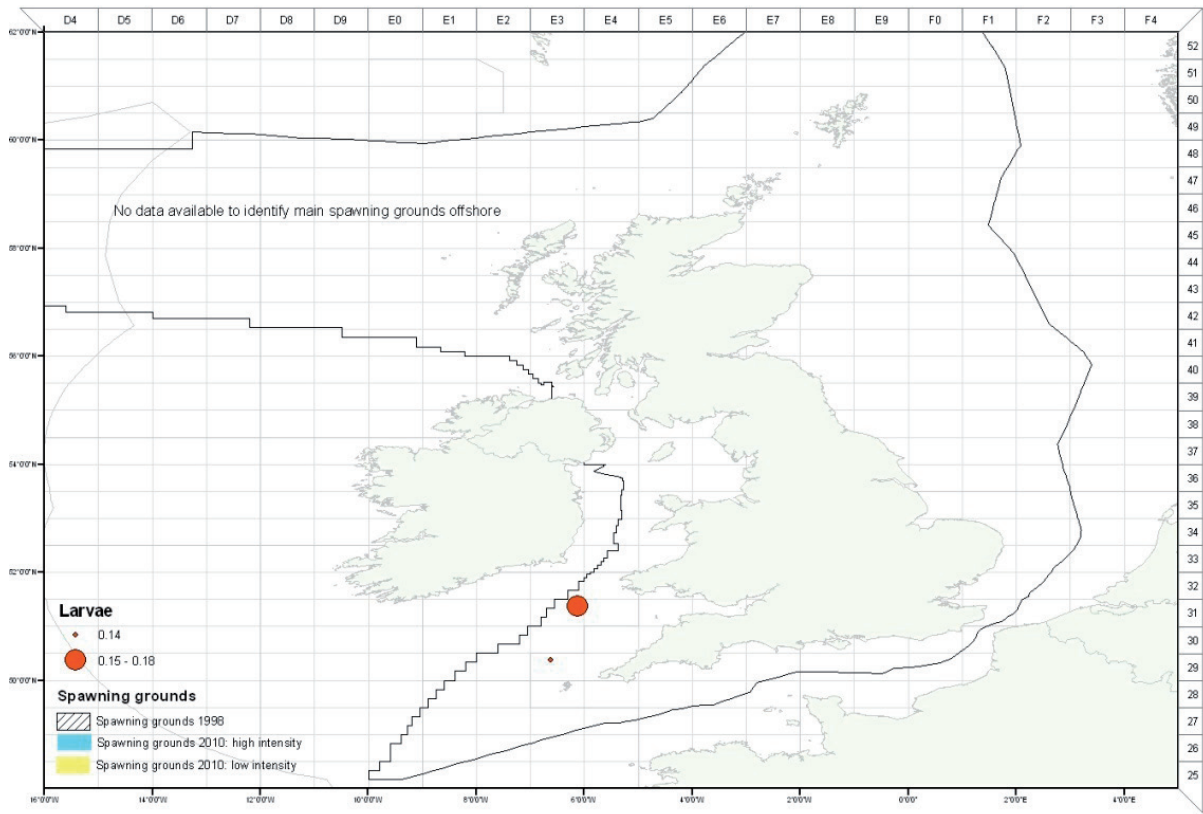
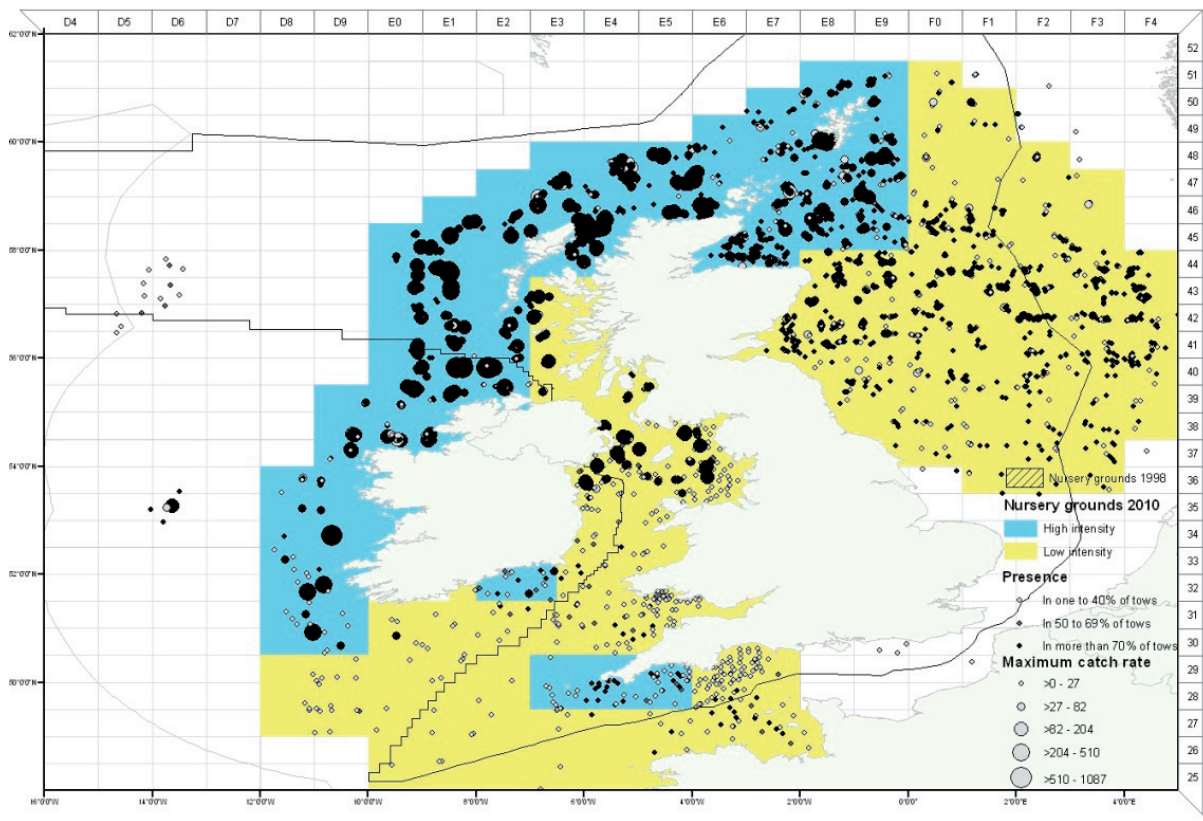


Figure 23: Nursery grounds of anglerfish. Data layers indicate nominal nursery grounds of anglerfish, as indicated by the presence of juveniles (<28 cm total length) in groundfish surveys.



3.16 Horse mackerel *Trachurus trachurus*

General information

Horse mackerel is a widespread and abundant pelagic fish species. ICES currently assess three stocks, including a North Sea stock (in ICES Divisions IIIa, IVb,c and VIId) and a western stock (in ICES Divisions IIa, IVa, Vb, VIa, VIIa-c, e-k, VIIIa,b,d,e).

Surveys with PHHT and GOV trawls, which have high headline heights, are considered appropriate for providing data on the juveniles of this species. Initially, a length range of <15cm was used to identify the sites of 0-groups, as used by ICES (2009). However, given the widespread distribution of horse mackerel within this length range, a reduced length range of <8cm was also used.

The eggs are pelagic (0.8–1.04mm in diameter, and contain a single oil globule), and the post-larval stage begins at a length of approximately 3.5mm (Russell, 1976).

Spawning grounds

Horse mackerel eggs are taken extensively in the international triennial mackerel egg survey (Figure 24), emphasising the importance of the outer continental shelf for the spawning of this species (Coombs *et al.*, 2001; Fives *et al.*, 2001; Abaunza *et al.*, 2003). Nevertheless, there was also evidence of spawning activity off Trevose Head and in the south-eastern English Channel and Southern Bight (see Macer, 1974), and some spawning in the Irish Sea.

Nursery grounds

Juvenile horse mackerel were recorded in a variety of surveys, and data layers were provided for the presence of juveniles, fixed stations where they were caught regularly (50 and 70% of tows) and maximum catch rates. Juvenile horse mackerel were distributed widely around the UK, although the lack of records from the eastern English Channel is considered an artefact of the sampling, as beam trawl surveys are the main gear used in this area. Given the extensive occurrence of juvenile horse mackerel (Figure 25), there was no evidence for spatially-defined nursery grounds, and so no data layers were provided.

Estuarine and coastal zone

Horse mackerel is a fully marine species that is common in coastal waters, but only recorded occasionally in estuaries.

Data gaps

Data for the North Sea were not available during the project, although surveys do operate in this area (coordinated by WGMEGS). The apparent absence of larvae in western waters is an artefact of sampling protocols, as this survey focuses on egg stages, and larvae are rarely identified to species. Some participating laboratories retain the samples, and so analyses of the larvae of horse mackerel (and other species) could be undertaken for archived samples, resource permitting.

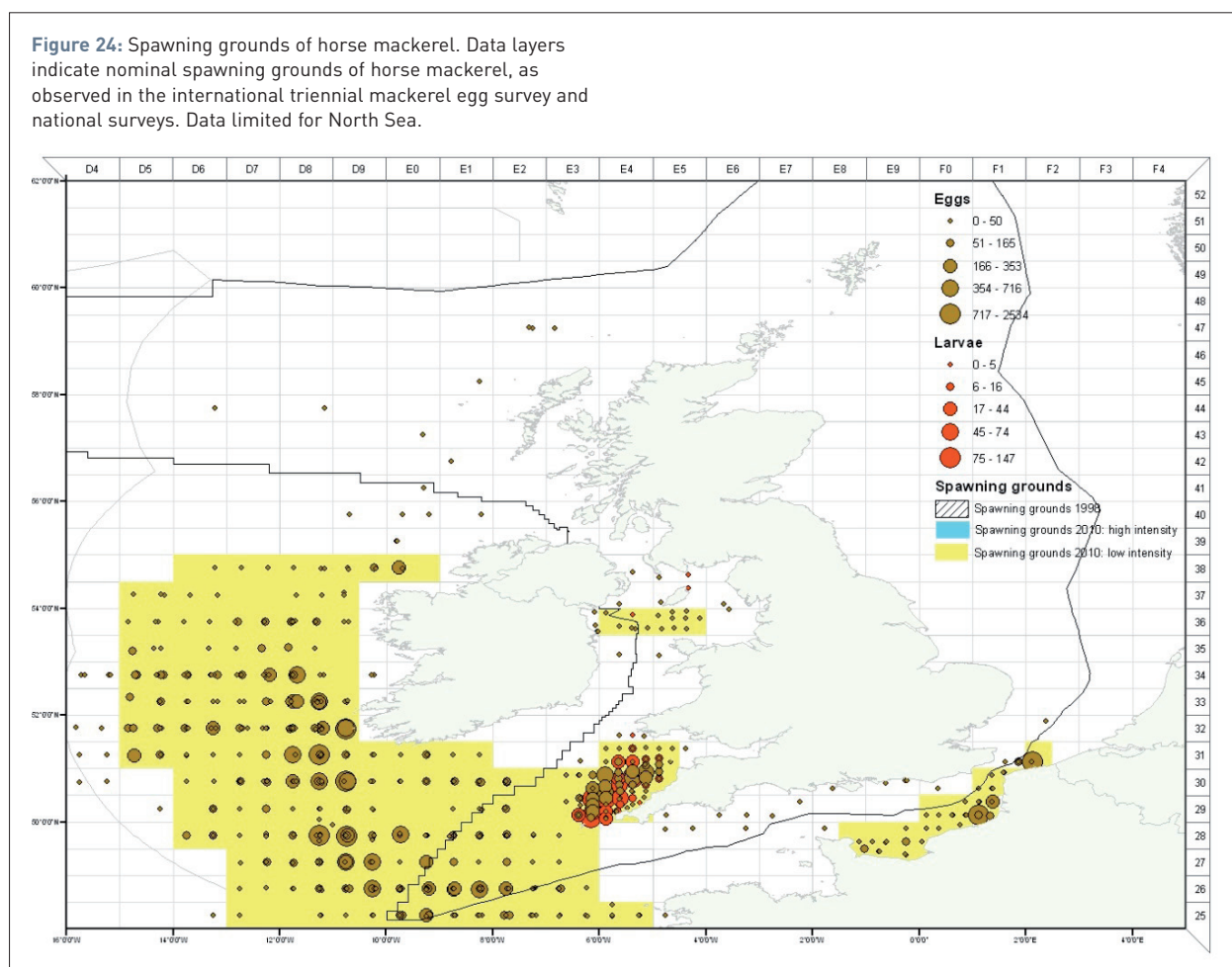


Figure 25(a): Nursery grounds of horse mackerel. Data layer indicates catches of horse mackerel (<15 cm total length) in groundfish surveys. Horse mackerel appear to be widespread and with no spatially discrete nursery grounds.

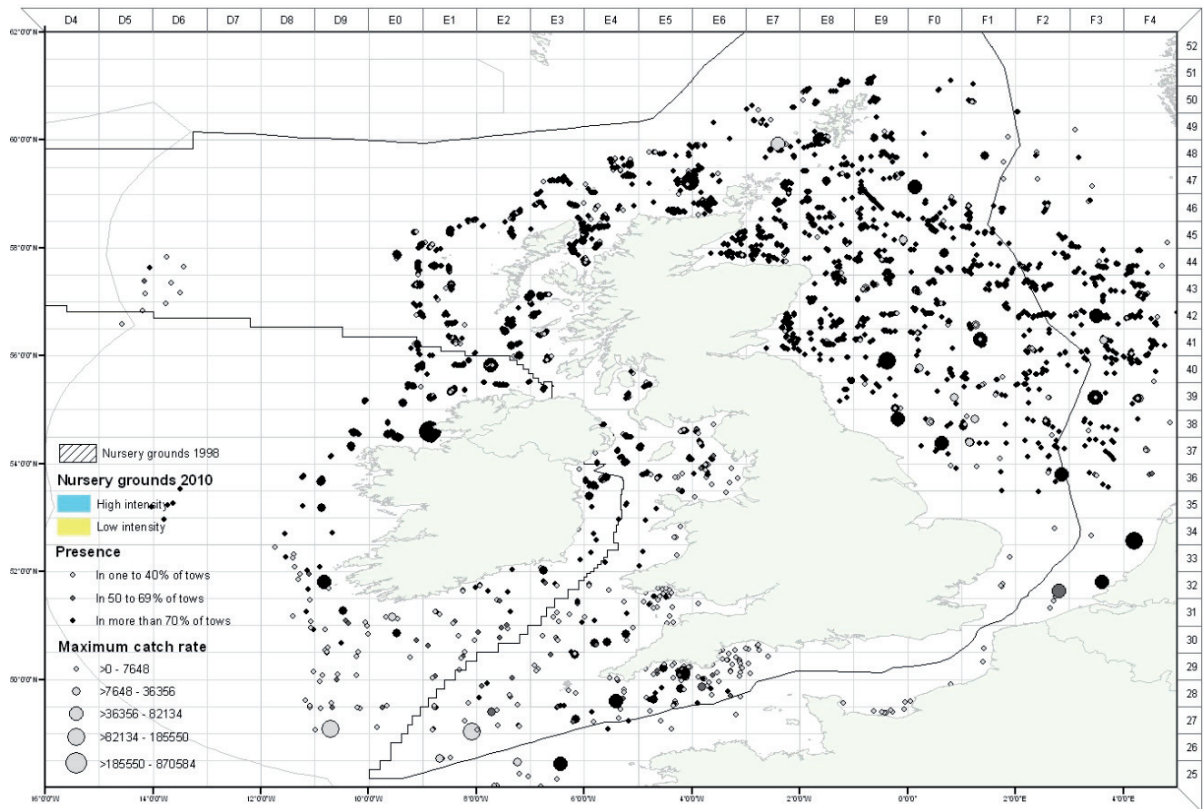
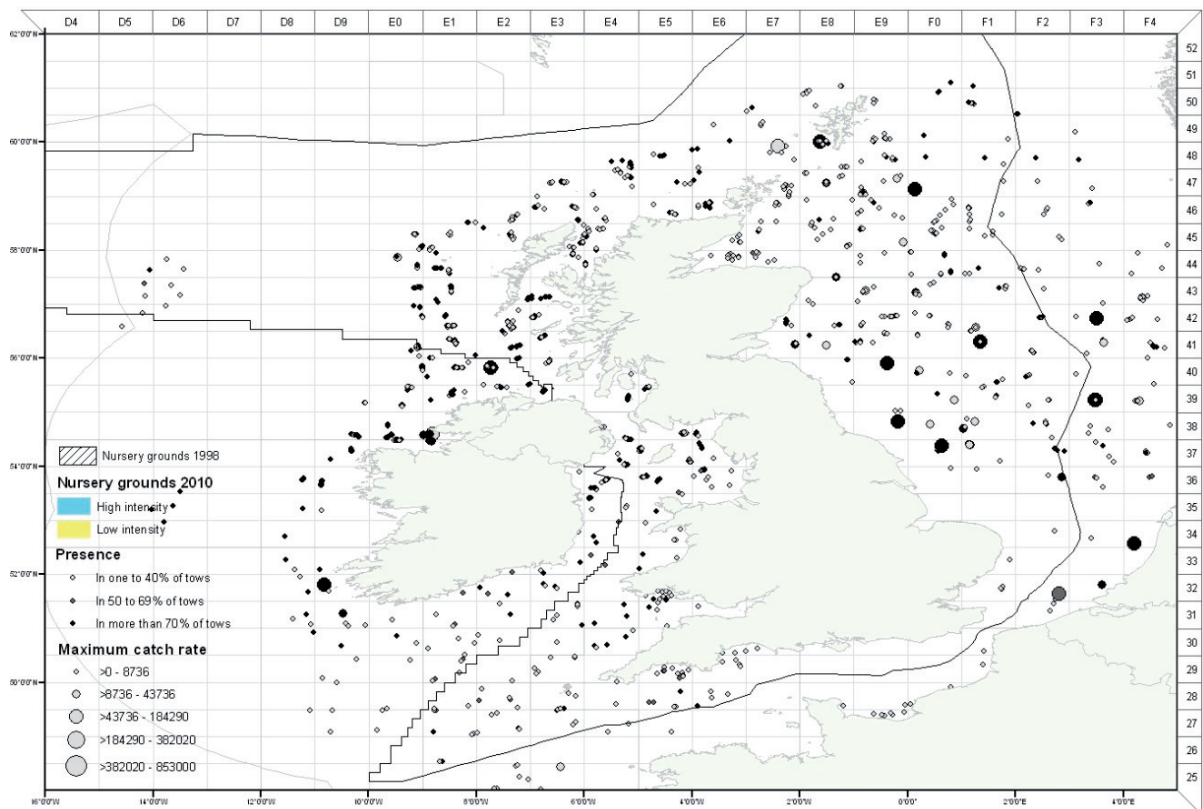


Figure 25(b): Nursery grounds of horse mackerel. Data layer indicates catches of horse mackerel (<8 cm total length) in groundfish surveys. This size class is also very widespread.



3.17 Sandeels *Ammodytidae*

General information

There are five species of sandeel in UK waters and these are widely distributed and abundant on suitable habitats. Neither beam nor otter trawls are very effective for examining their relative abundance, especially for the smallest life-history stages. Sandbanks and other sandy substrates may be important habitats for these species, and some of these areas are not effectively sampled in existing groundfish surveys.

The eggs are demersal, which makes the identification of precise spawning grounds difficult, although plankton samplers will occasionally capture eggs that have presumably been disturbed from the sediment. The larval stages are pelagic and are taken in ichthyoplankton surveys.

Preliminary investigations on the occurrence of the smaller size classes may indicate general areas of importance as nursery grounds. For the purposes of the present study, a length range of <13cm was used, which includes the first main cohort, but will likely include fishes of ages 0-3 (Bergstad *et al.*, 2002). Given the demersal egg stage of sandeels and their sedimentary requirements, for the purposes of the present study it was assumed that the distribution of the nursery grounds may also represent the extent of the spawning grounds.

Spawning grounds

Although there are no comprehensive data on the demersal spawning grounds of sandeels per se, given the demersal egg stage and sediment preferences of the species, the presence of larvae and juveniles will likely overlap the spawning grounds. Sandeel larvae (and some eggs) were taken in a variety of ichthyoplankton surveys, (Figure 26) which broadly corroborated the spawning grounds suggested by Coull *et al.* (1998), although there are also important spawning grounds for sandeels in the Irish Sea (e.g. Liverpool Bay area) and in the Bristol Channel, including off Trevose Head.

Nursery grounds

Juvenile sandeels were taken in a variety of surveys (Figure 27), and data layers were provided for the presence of juveniles, stations where they were caught regularly (50% of tows) and their maximum catch rates. Current data suggest that juvenile sandeels are more extensively distributed than previously reported, although the apparent absence from the western English Channel and Irish Sea in Coull *et al.* (1998) reflected the increased management interest in the North Sea sandeel stocks at that time.

Estuarine and coastal zone

One species, *Ammodytes tobianus*, is often found in estuaries, with this and other species occurring in coastal waters.

Data gaps

More comprehensive ichthyofaunal surveys of sandbank habitats and the utilisation of such habitats by sandeels could be undertaken, as areas of sandbank are not often comprehensively surveyed in existing field investigations. Although more data are available for the North Sea (e.g. ICES, 2010), high resolution data with which to accurately delineate spawning grounds in other areas are unlikely to become available in the absence of a high degree of survey effort, although it could be assumed that the overall distribution of adult sandeels would broadly include both spawning and nursery grounds.

Figure 26: Spawning grounds of sandeels. Data layers indicate nominal spawning grounds of sandeels, giving the original polygons provided in Coull *et al.* (1998) and recent larval data from ichthyoplankton surveys. Recent, comparable data are lacking for north-western and south-western areas).

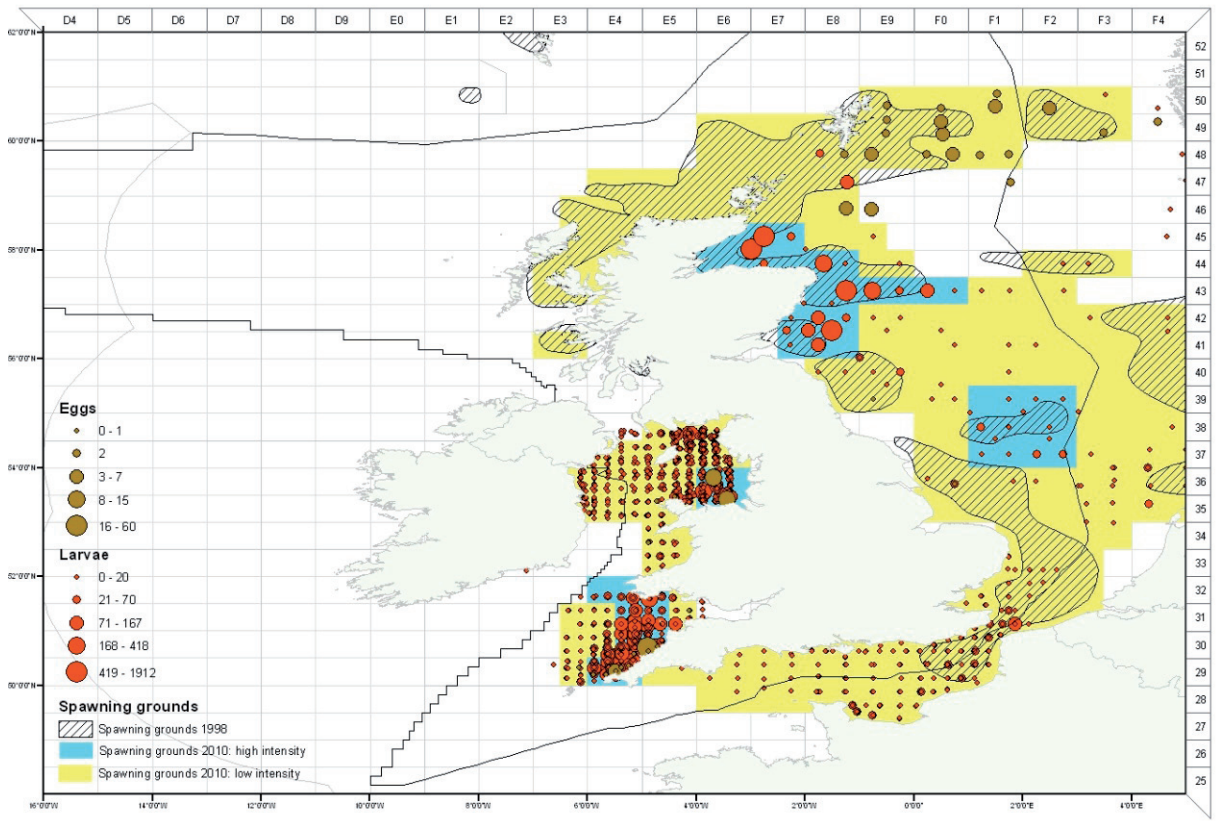
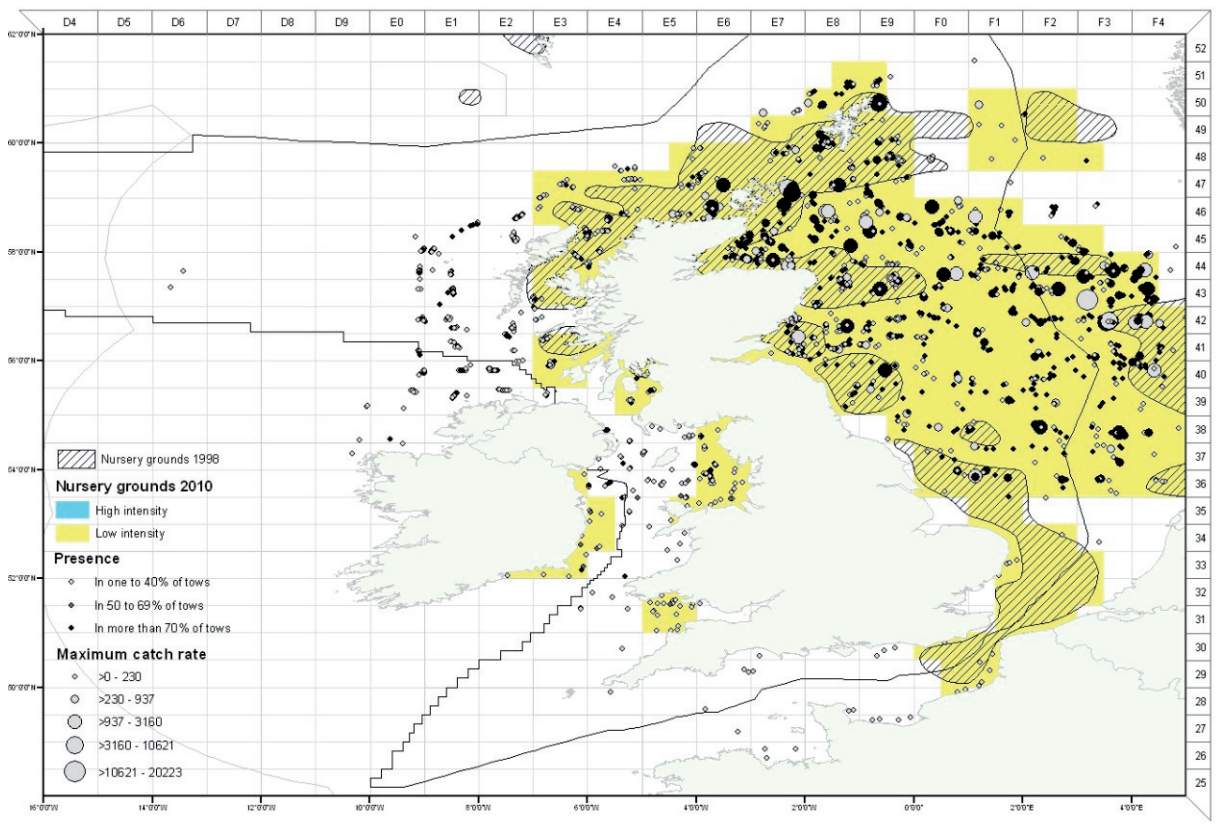


Figure 27: Nursery grounds of sandeels. Data layers indicate nominal nursery grounds of sandeels, as indicated by the presence of juveniles (<13cm total length) in groundfish surveys. North Sea sites originally included by Coull *et al.* (1998) also shown.



3.18 Mackerel *Scomber scombrus*

General information

Mackerel is a widespread and abundant pelagic fish species. Surveys with PHHT and GOV trawls, which both have a high headline height, are considered appropriate for providing data on the larger juveniles of this species. For the purposes of the present study, a length of <24 cm was used to identify 0-groups, as used by ICES (2009c), although this will include some older fish for surveys conducted at the start of the year.

The eggs are pelagic (1.0–1.38 mm in diameter, and contain a single oil globule), and an adult-like appearance is apparent at a length of approximately 21 mm (Russell, 1976). There are dedicated, internationally coordinated (by WGMEGS) surveys to examine the distribution and abundance of mackerel eggs west of the British Isles for stock assessment purposes.

Spawning grounds

Mackerel eggs were taken extensively in the triennial mackerel egg survey (Figure 28), emphasising the importance of the outer continental shelf to the west of the British Isles for mackerel spawning (Coombs and Mitchell, 1981; Priede *et al.*, 1995; Coombs *et al.*, 2001; Fives *et al.*, 2001). Nevertheless, there was also evidence of some spawning activity off Trevoise Head and in the south-eastern English Channel, as well as in the Irish Sea. Data for examining mackerel spawning in the North Sea were unavailable.

Nursery grounds

Juvenile mackerel were recorded in a variety of otter trawl surveys (Figure 29), and data layers were provided for the presence of juveniles, fixed stations where they were caught regularly (50% of tows) and maximum catch rates. The locations of juvenile mackerel were fairly consistent with that proposed by Coull *et al.* (1998), although they were taken over greater areas of the North and Irish Seas. The largest catches were taken in Scottish surveys off North-western Scotland. As a highly migratory species, there may be some annual and seasonal variation in the relative importance of nursery areas. The apparent absence of juveniles from the eastern English Channel and southern North Sea is considered an artefact of the sampling, as there have been fewer otter trawl surveys in this area.

Estuarine and coastal zone

Mackerel is a fully marine species that is common in coastal waters, and is only recorded occasionally in estuaries.

Data gaps

Data for the North Sea were not available during the project, although surveys do operate in this area (coordinated by WGMEGS). The apparent absence of larvae in western waters is an artefact of sampling protocols, as this survey focuses on egg stages, and larvae are rarely identified to species. Some participating laboratories retain the samples, and so analyses of the larvae of mackerel (and other species) could be undertaken for archived samples, resource permitting.

Figure 28: Spawning grounds of mackerel. Data layers indicate nominal spawning grounds of mackerel, as observed in the international triennial mackerel egg survey and national surveys. Comparable data for North Sea were not available during the course of the project, and so the original data layer from Coull *et al.* (1998) has not been updated for this area.

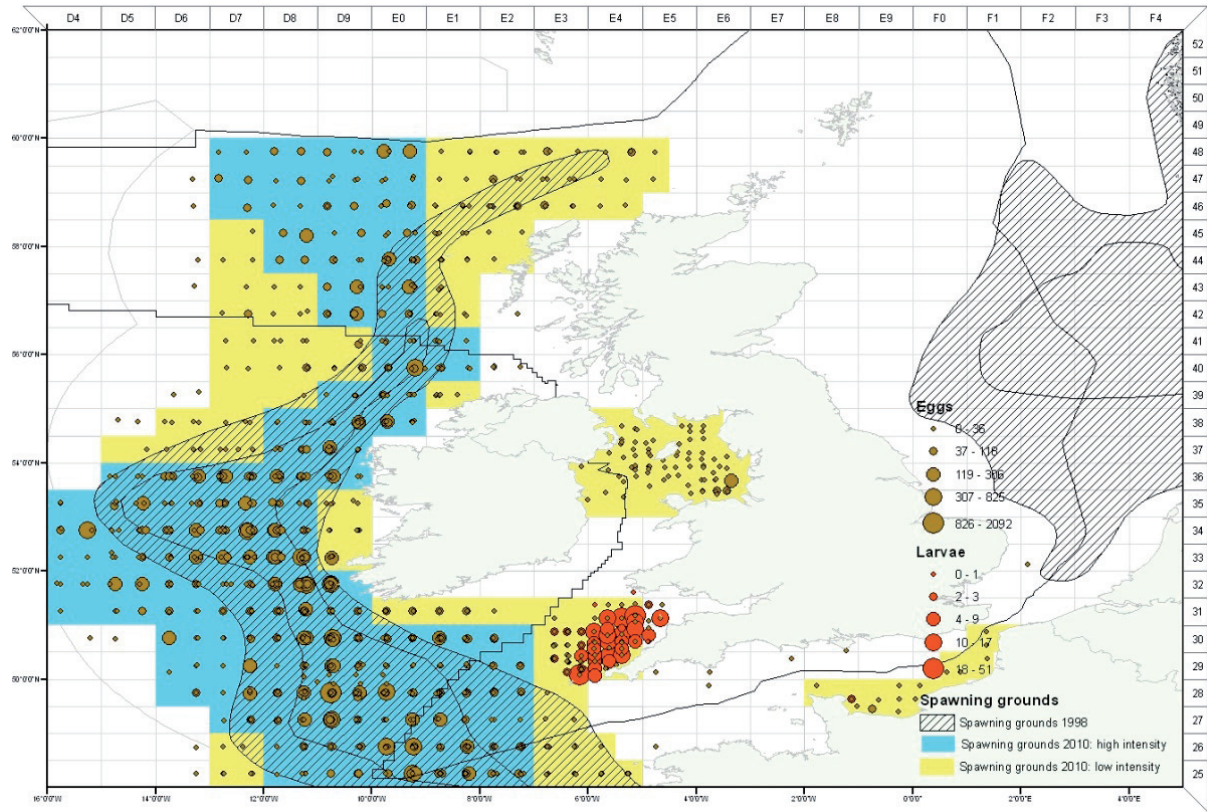
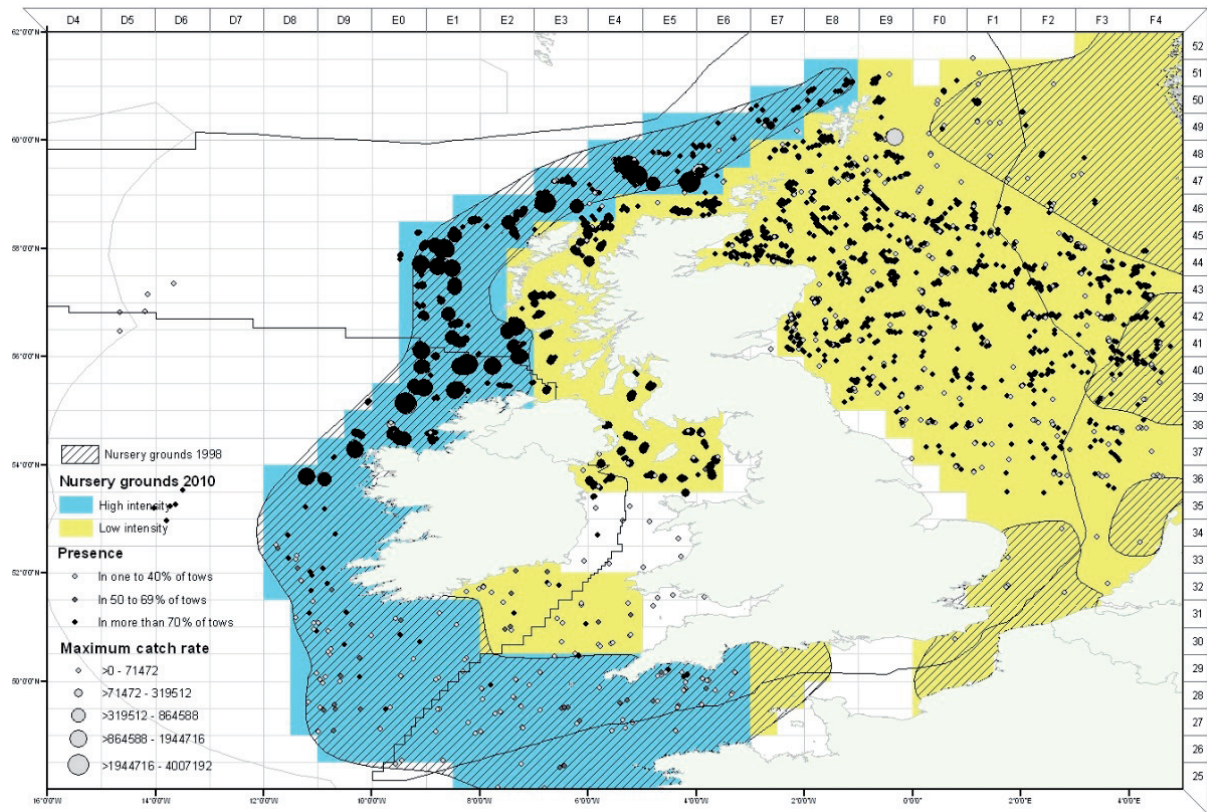


Figure 29: Nursery grounds of mackerel. Data layers indicate nominal nursery grounds of mackerel, as indicated by the presence of juveniles (<24 cm total length) in groundfish surveys. Appropriate field data limited for southern coasts of UK.



3.19 Plaice *Pleuronectes platessa*

General information

There are several nominal stocks of plaice in the UK EEZ, including Celtic Sea (ICES Divisions VII f and g), Irish Sea (VII a), eastern English Channel (VII d), western English Channel (VII e) and North Sea (Subarea IV) stocks.

Plaice eggs are pelagic (1.66–2.17 mm in diameter), and the demersal post-larval stage begins at a length of approximately 13 mm (Russell, 1976). Although ichthyoplankton survey data do not cover the entire study area, information on the distribution of the eggs and larvae of plaice are available for many areas, and these data can inform on the broad locations of some of the spawning grounds.

For the purposes of the present study, a length of <12 cm was used to identify 0-groups, as used by ICES (2009c), although this will include some older fish for surveys conducted at the start of the year. Inshore beam trawl surveys operate around many parts of the coast of England and Wales, and these surveys are designed to examine the distribution of juvenile plaice and sole.

In general, the youngest plaice occur in inshore areas in defined nursery grounds (e.g. Poxton and Nasir, 1985; Wennhage *et al.*, 2007), although the distribution of juvenile habitats increases as they attain larger sizes and start to recruit to the parent stock (Lockwood and Lucassen, 1984). Data from the Young Fish Survey will allow for improved regional data for parts of the UK coastline to be mapped at a finer resolution in the future.

Spawning grounds

Existing data from ichthyoplankton surveys confirms the importance of parts of the North Sea (including the Southern Bight; Coombs *et al.* (1990)), eastern English Channel, Trevose Head and eastern and western Irish Sea (e.g. Ellis and Nash, 1997; Fox *et al.*, 2000), with eggs and larvae also more widely distributed in these areas (Figure 30). A current Defra-funded programme (MA003) will help identify, with some certainty, the location of spawning grounds in the Irish Sea. No recent data were available to inform on the potential spawning grounds in the western English Channel, and off North-western Scotland and southern Ireland.

Nursery grounds

Juvenile plaice were taken in a variety of surveys (Figure 31), and data layers were provided for the presence of juveniles, fixed stations where they were caught regularly (50% of tows) and their maximum catch rates. Although the current survey data broadly supported the original nursery grounds proposed by Coull *et al.* (1998), there were some very slight differences, with the nursery grounds presented here extending slightly further offshore. The grounds indicated by Coull *et al.* (1998) would broadly equate with the perception of primary nursery grounds, whereas the length range used in the present study (<12 cm) would be indicative of the more extensive secondary nursery grounds.

Estuarine and coastal zone

Plaice is a marine species that utilises estuarine habitats and coastal zones as nursery grounds (e.g. Power *et al.*, 2000a).

Data gaps

Although there are extensive ichthyoplankton data for the Irish Sea, more recent data for the Bristol Channel could usefully be collected. Furthermore, further sampling of ichthyoplankton in the southern and central North Sea could usefully be collected, including the more inshore waters (e.g. Greater Thames Estuary, The Wash *etc.*). Although the data used in the present study for juveniles indicated data gaps in the southern North Sea, on-going studies of Young Fish Survey data will address some of these gaps.

Figure 30(a): Spawning grounds of plaice. Data layers indicate spawning grounds of plaice, giving the original polygons provided in Coull *et al.* (1998) and recent egg and larval data from ichthyoplankton surveys (recent, comparable data lacking for some north- western spawning grounds).

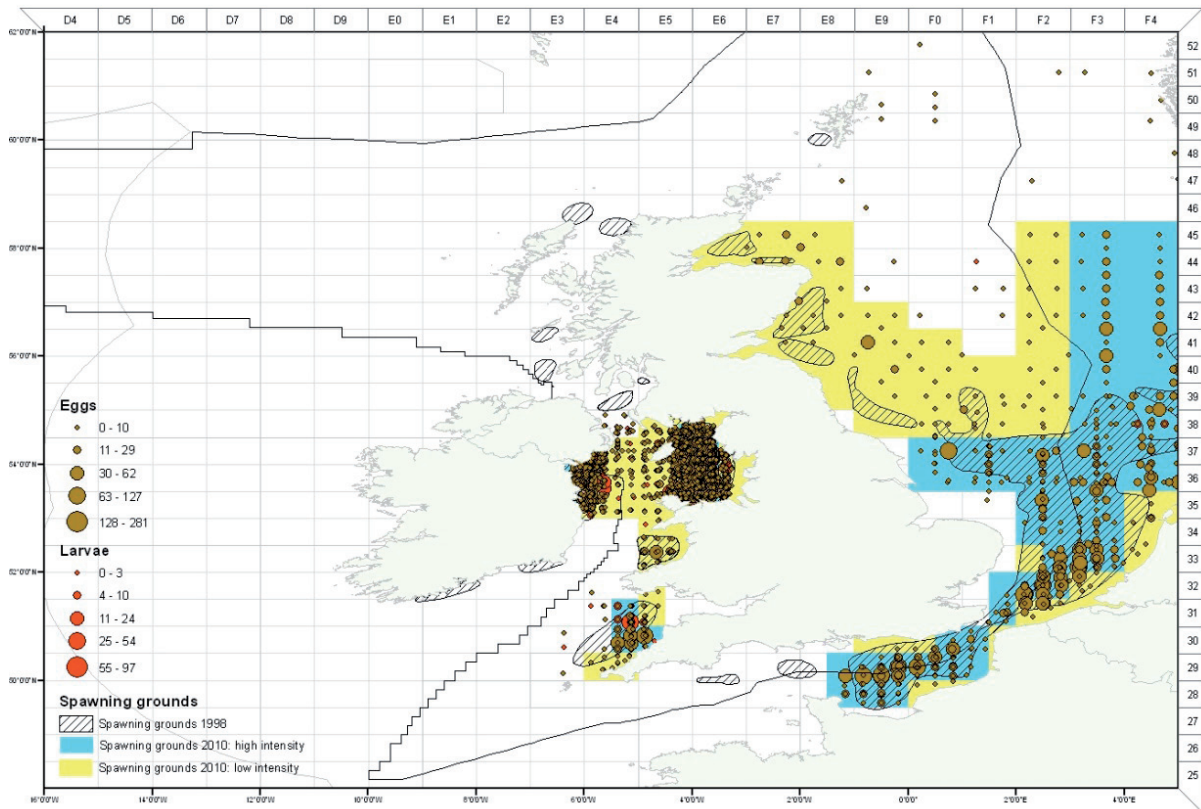


Figure 30(b): Spawning grounds of plaice. Data layers indicate spawning grounds of plaice. Figure as above, but point source information omitted to better illustrate areas of higher spawning activity in the Irish Sea.

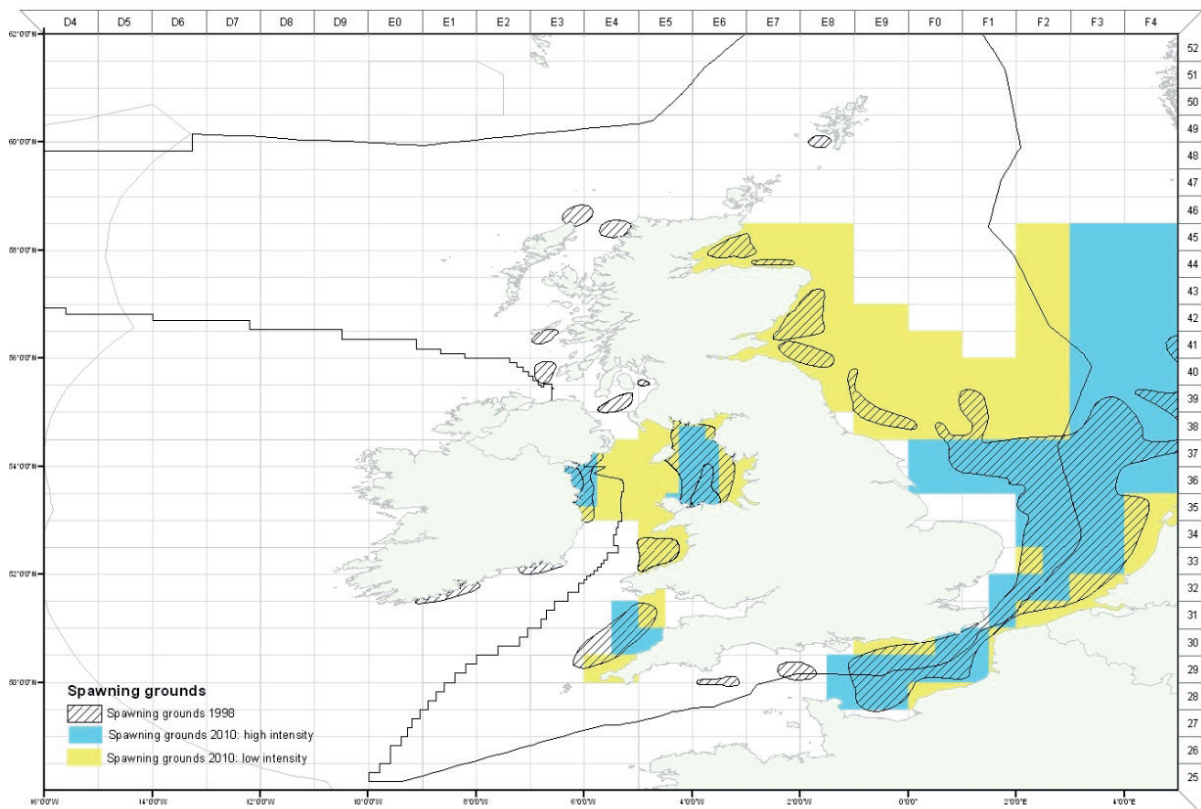
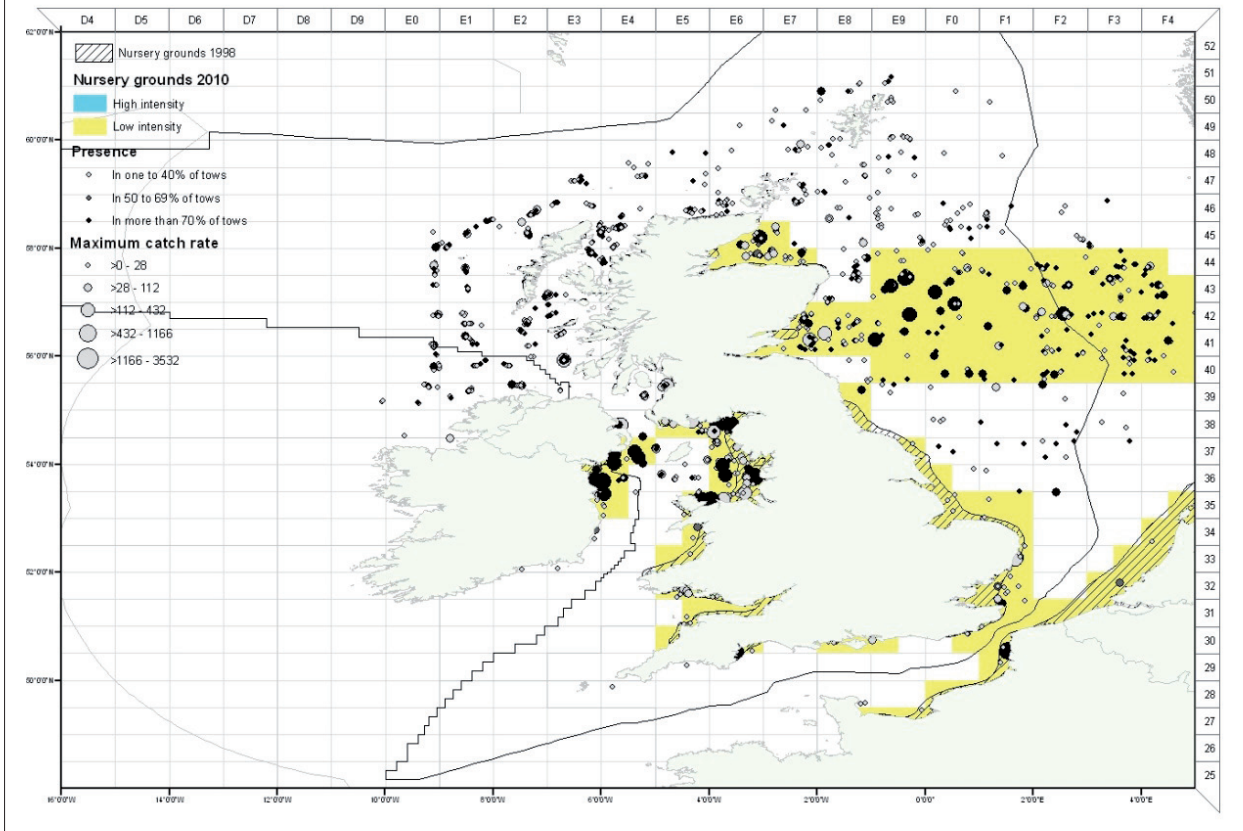


Figure 31: Nursery grounds of plaice. Data layer indicates nominal nursery grounds of plaice, as indicated by the presence of juveniles (<12 cm total length) in groundfish surveys. Appropriate field data limited for much of the shallower inshore waters of the UK.



3.20 Sole *Solea solea*

General information

There are several nominal sole stocks in the UK EEZ, including the Celtic Sea (ICES Divisions VIIf and g), Irish Sea (VIa), eastern English Channel (VIId), western English Channel (VIle) and North Sea (Subarea IV) stocks.

Although ichthyoplankton surveys do not cover the entire study area, data on the distribution of sole eggs and larvae are available for many areas, and these data can inform on the broad locations of some of the spawning grounds. The pelagic eggs (1.0–1.6mm diameter) contain many distinctive small oil globules. The post-larval (demersal) stage begins at a length of about 7 mm (Russell, 1976).

Inshore beam trawl surveys operate around many parts of the coast of England and Wales, and are designed to examine the distribution of juvenile sole. In the present study a length of <13cm was used to identify juveniles.

Spawning grounds

Sole spawning grounds are mainly in the shallow waters of the eastern Irish Sea, Cardigan Bay, Trevoise Head, eastern English Channel and Greater Thames Estuary (Figure 32; Child *et al.*, 1991). Few data were available to inform on the potential spawning grounds in other parts of the North Sea, and data were limited for the western English Channel.

Nursery grounds

Juvenile sole were taken in a variety of surveys (Figure 33),

and data layers were provided for the presence of juveniles, fixed stations where they were caught regularly (50 and 70% of tows) and maximum catch rates. Although the current survey data broadly supported the original nursery grounds proposed by Coull *et al.* (1998), there were some minor differences, with the nursery grounds reported here extending further offshore. The grounds indicated by Coull *et al.* (1998) correspond with primary nursery grounds, whereas the length range used in the present study would indicate the more extensive secondary nursery grounds. The present study confirms important nursery grounds in areas identified in earlier studies, including North Wales (Rogers, 1992), Bristol Channel (Claridge and Potter, 1987; Symonds and Rogers, 1995; Henderson and Seaby, 2005), parts of the English Channel (Eastwood *et al.*, 2003; Gilliers *et al.*, 2006) and Greater Thames Estuary (Riley, 1974)

Estuarine and coastal zone

Sole is a marine species that utilises estuarine habitats and coastal zones as nursery grounds (Claridge & Potter, 1987).

Data gaps

More recent spawning information could usefully be collected for the Bristol Channel (not surveyed since 1990) and western English Channel. Sole may also spawn in shallow water, and so surveys to better sample shallow water (e.g. in the Bristol Channel, Liverpool Bay and the Thames) could usefully be undertaken to complement data collected by larger research vessels.

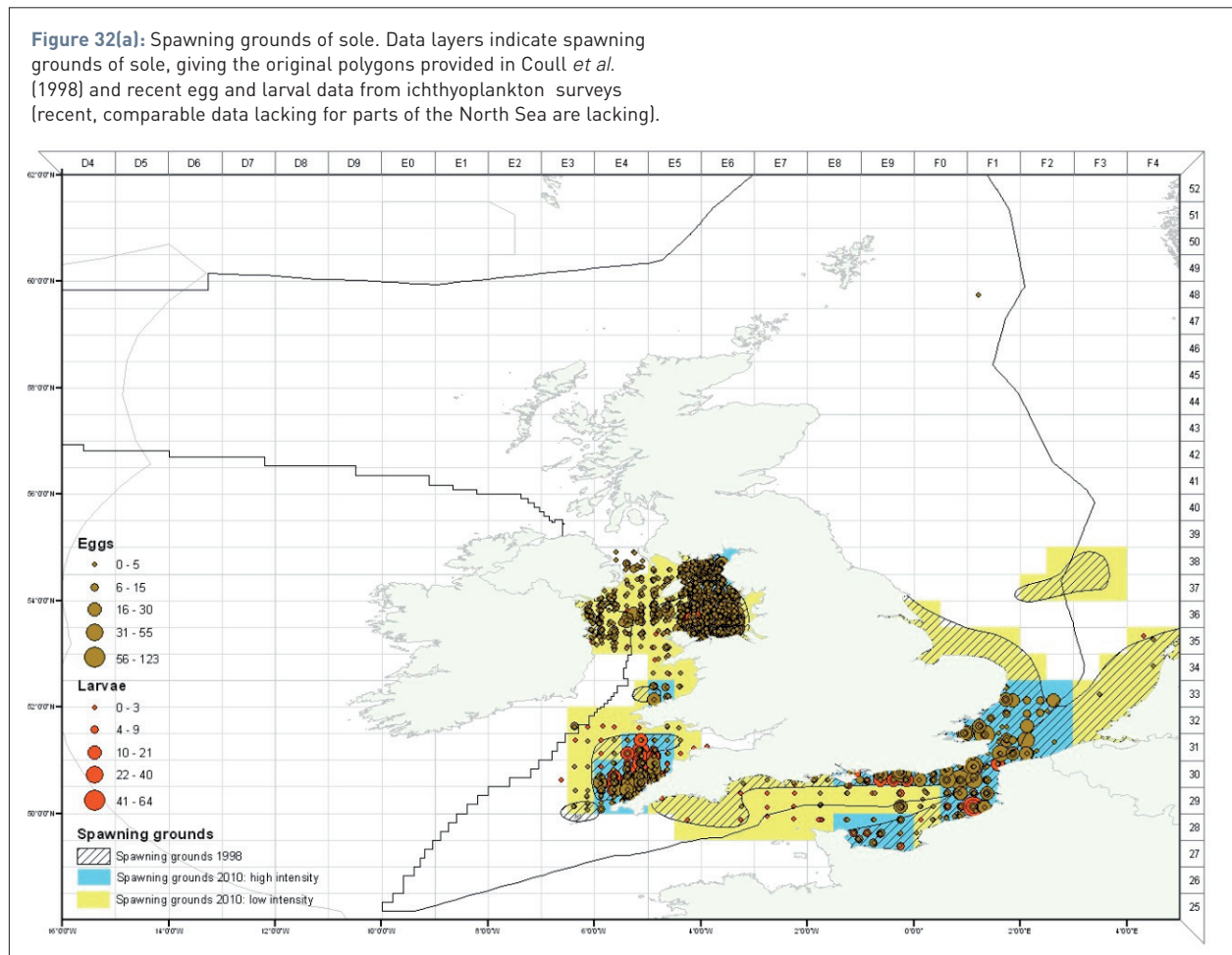


Figure 32(b): Spawning grounds of sole. Data layers indicate spawning grounds of sole. Figure as above, but point source information omitted to better illustrate areas of higher spawning activity in the Irish Sea.

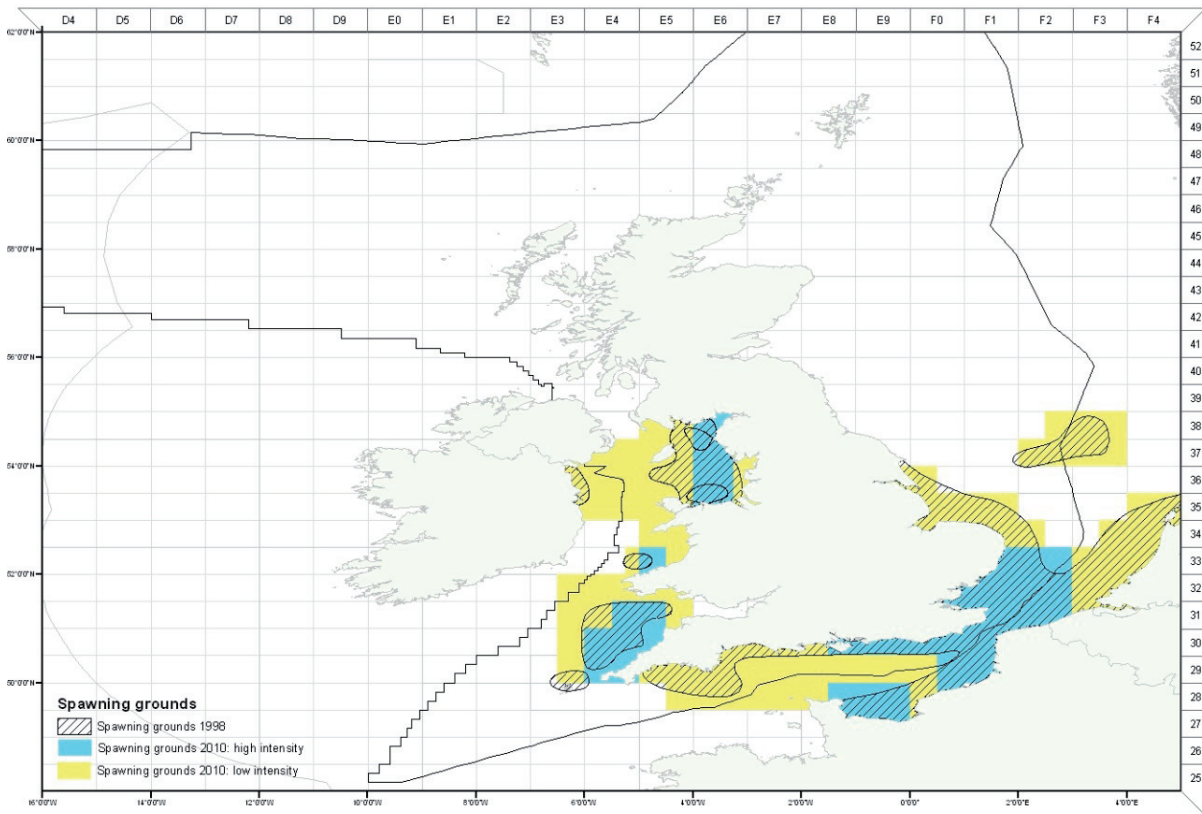
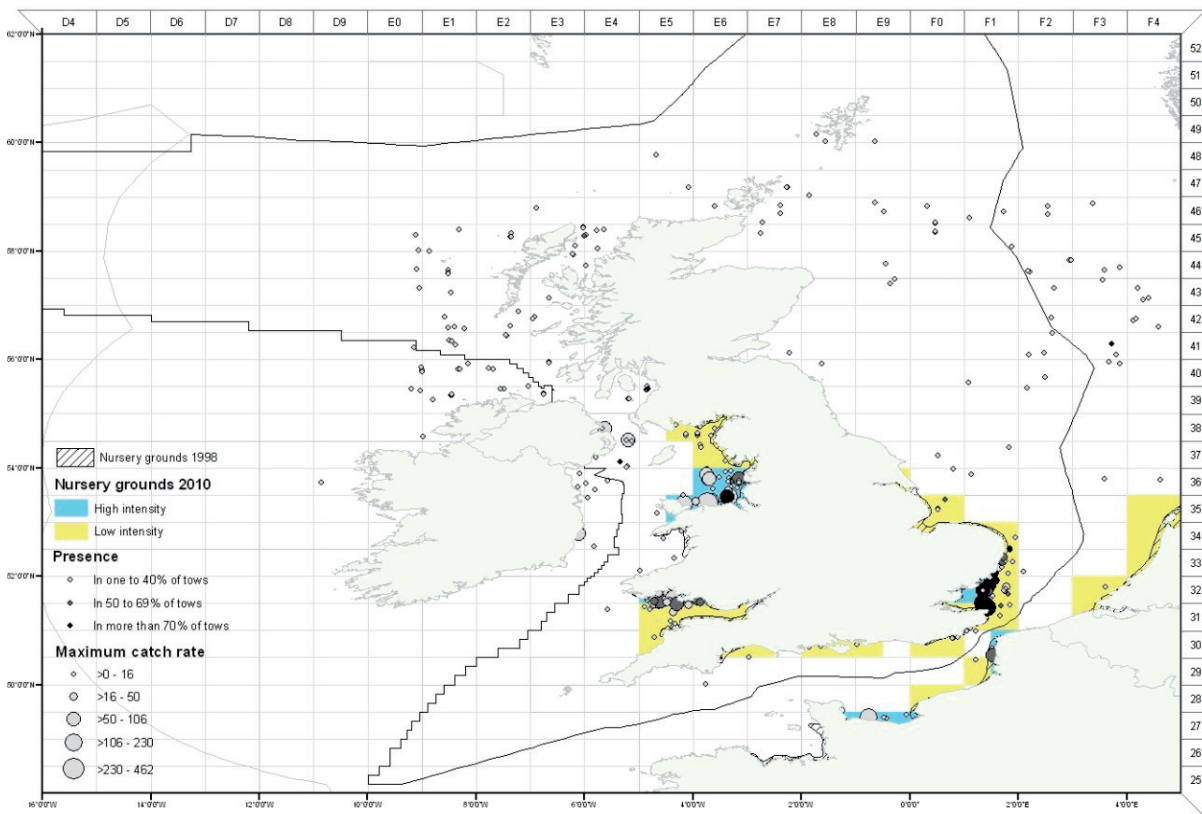


Figure 33: Nursery grounds of sole. Data layers indicate nominal nursery grounds of sole, as indicated by the presence of juveniles (<13 cm total length) in groundfish surveys. Appropriate field data are limited for much of the shallower inshore waters of the UK.



4. Other considerations

In order to provide comprehensive maps over the entire UK shelf, the layers provided by Coull *et al.* (1998) were based on a range of evidence, including local observations, individual local surveys, reports from published material and interpretation of broad scale field data. The absence of the supporting data in this report has largely been rectified in the present project.

The spawning and nursery grounds proposed by Coull *et al.* (1998) were polygons and, the authors highlighted that “*these maps should be seen as representing the widest known distribution given current knowledge and should not be seen as rigid, unchanging descriptions of presence or absence*”. In practice, however, the end users (including consultants and regulators) have often wrongly inferred the borders of these polygons to be exact and well-defined boundaries. For the present project we have identified the broad scale distributions of spawning and nursery grounds by rectangle, so that the user is more likely to infer that the boundaries are not fixed, and that the limits of spawning grounds can be variable from year to year (and season to season).

With the exception of spawning mackerel, Norway pout and blue whiting, the grounds described by Coull *et al.* (1998) did not attempt to highlight parts of nursery or spawning areas that were considered of ‘greater’ importance. Where data have permitted, we have attempted to highlight some of the more important grounds. For some areas, notably the Irish Sea, there has been a high density of survey effort, and so these data may also be viewed on a finer scale in relation to site-specific issues in this area. Such high-resolution data (particularly for ichthyoplankton) are not available for other parts of the UK continental shelf.

The project also identified a number of issues related to the collection, quality assurance, collation, access and onward dissemination of data. The issues with the collation of data from fisheries surveys highlighted a number of issues, as discussed in Section 2.

The fish species used in the current project were a subset of species that had been identified *a priori* based on nature conservation listings. Hence, several commercially-important fish species, for example bass and haddock, were not included. A more targeted approach to identify which fish species and/or stocks would benefit from spatial management is required.

Additionally, many aspects of fish ecology and demography, including spatial distributions, the states of constituent stocks, migration routes etc., can change over time. If biological data layers are to be used for spatial management in the future, then there needs to be a process whereby data layers are updated periodically.

Spawning grounds

Cefas has undertaken or participated in many of the surveys for ichthyoplankton sampling, and so most data were available. Some data (e.g. for North Sea mackerel) were not available. Because some surveys only identify the target species, there are preserved samples that have been archived that could inform on other species.

Data from the Continuous Plankton Recorder (CPR) may be able to provide useful information on the distribution and abundance of some species of fish larvae. Although there are some data limitations (e.g. The CPR is towed at a fixed 10 m depth and data mostly collected from important shipping lanes), these data may be a cost-effective way of examining the distribution of larvae in the waters of the outer continental shelf and oceanic waters, where there is an absence of dedicated ichthyoplankton surveys.

Nursery grounds

The majority of fisheries-dependent data held in the national fisheries laboratories are held on databases and are available. Much of these data are also submitted to the DATRAS system stored by ICES. However, other datasets collected by the fisheries laboratories (e.g. for research projects) and stored electronically or on paper may not be easily identified or accessed.

Whereas fishery-independent groundfish survey data are available for broad regions of the inner and outer continental shelf surrounding the British Isles, data for coastal areas and deep-water are more limited.

Many of the juvenile fish surveys included in this report are conducted from July onwards, and so sample larger 0-groups. There are few published studies on the distribution patterns of recently settled (post-larval) fish, especially over the wider UK continental shelf, and this constitutes a major gap in our knowledge of the ecology of UK marine fish.

Young Fish Survey data, as described in Rogers *et al.* (1998), were not used in this report as they are subject of ongoing analyses. These data could usefully inform on the distribution of selected 0-group fish in some inshore areas along the southern and eastern coasts of England. Comparable information for other parts of the UK coastal zone are lacking for recent years. A field programme could usefully be undertaken to better identify and delineate important inshore grounds along the western coasts of England and Wales.

With respect to the comparative importance of nursery grounds, there is an important need to identify which of the nominal nursery grounds provide the greatest contribution to the stocks of adult fish.

Given the issues of catchability and the distribution of survey stations in relation to the distribution of any given fish species, groundfish survey data are most suitable for the main demersal stocks. However, many of the species for which there is an interest in spatial planning are not sampled effectively in existing fishery-independent surveys. Although there are some sources of *ad hoc* data from some of these species, the absence of coordinated and appropriate sampling limits the utility of such data sources.

Dedicated field surveys to more accurately delineate the current distributions of the rarest fish species and their ecologically important habitats in UK waters are needed, especially if spatial management is deemed appropriate for their conservation and management.

Although there are some data available for some of the more migratory and wide-ranging species included in this report, the use of electronic data storage tags for some of these species could usefully be undertaken. This would provide more specific details of their offshore distributions, movements and habitat utilization.

Seasonal information is limited and, in recent years, many national surveys have only been conducted once per year. Hence, data are limited for those species that have important seasonal differences in spatial distribution.

Acknowledgments

This work was supported by Defra project MB5301 and is an edited version of the final report of this project, *Mapping spawning and nursery areas of species to be considered in Marine Protected Areas (Marine Conservation Zones)*.

5. References

- ABAUNZA, P., GORDO, L., KARLOU-RIGA, C., MURTA, A., ELTINK, A.T.G.W., SANTAMARIA, M.T.G., ZIMMERMANN, C., HAMMER, C., LUCIO, P., IVERSEN, S.A., MOLLOY, J. AND GALLO, E. 2003. Growth and reproduction of horse mackerel, *Trachurus trachurus* (Carangidae). *Reviews in Fish Biology and Fisheries*, 13: 27–61.
- ACEVEDO, S., DWANE, O. AND FIVES, J.M. 2002. The community structure of larval fish populations in an area of the Celtic Sea in 1998. *Journal of the Marine Biological Association of the United Kingdom*, 82: 641–648.
- ALVAREZ, P. FIVES, J., MOTOS, L. AND SANTOS, M. 2004. Distribution and abundance of European hake *Merluccius merluccius* (L.), eggs and larvae in the North East Atlantic waters in 1995 and 1998 in relation to hydrographic conditions. *Journal of Plankton Research*, 26: 811–826.
- ANEER, G. 1989. Herring (*Clupea harengus* L.) spawning and spawning ground characteristics in the Baltic Sea. *Fisheries Research*, 8: 169–195.
- ARKHIPOV, A.G. AND MYLNIKOV, N.I. 2002. On the pelagic phase of the life cycle of the common angler (*Lophius piscatorius* Linne) around seamounts of the Rockall-Hatton area. *ICES CM 2002/M:33*
- BALON, E. 1984. Patterns in the evolution of reproductive styles in fishes. In "Fish reproduction: Strategies and tactics" (G.W. Potts and R.J. Wootton, eds.). Academic Press, London, 35–53.
- BARTSCH, J. AND COOMBS S. 1997. A numerical model of the dispersion of blue whiting larvae, *Micromesistius poutassou* (Risso), in the eastern North Atlantic. *Fisheries Oceanography*, 6: 141–154.
- BASS, A.J., D'AUBREY, J.D. AND KISTNASAMY, N. 1973. Sharks of the east coast of southern Africa I. The genus *Carcharhinus* (Carcharhinidae). *Investigational Report, Oceanographic Research Institute (Durban)*, 33: 1–168.
- BECK, M.W., HECK, K.L. JR, ABLE, K.W., CHILDERS, D.L., EGGLESTON, D.B., GILLANDERS, B.M., HALPERN, B.S., HAYS, C.G., HOSHINO, K., MINELLO, T.J., ORTH, R.J., SHERIDAN, P.F. AND WEINSTEIN, M.P. 2003. The role of nearshore ecosystems as fish and shellfish nurseries. *Issues in Ecology*, 11: 1–12.
- BERGSTAD, O.A., HØINES, Å.S. AND JØRGENSEN, T. 2002. Growth of sandeel, *Ammodytes marinus*, in the northern North Sea and Norwegian coastal waters. *Fisheries Research*, 56: 9–23
- BOWERS, A.B. 1980. Characteristics of herring (*Clupea harengus*) spawning grounds. *ICES CM 1980/H:13*
- BRANDER, K. AND PALMER, D. 1985. Growth rate of *Raja clavata* in the Northeast Irish Sea. *Journal du Conseil international pour l'Exploration de la Mer*, 42: 124–128.
- BUNN, N. AND FOX, C.J. 2004. Spring plankton surveys of the Irish Sea in 2000: hydrography and the distribution of fish eggs and larvae. *Science Series Technical Report, CEFAS, Lowestoft*, 124; 131 pp.
- BUNN, N., FOX, C.J. AND NASH, R.D.M. 2004. Spring plankton surveys of the Irish Sea in 2001, 2002 and 2003: Hydrography and the distribution of fish eggs and larvae. *Science Series Data Report, Cefas, Lowestoft*, 42; 213 pp.
- CEC (2009) Council regulation (EC) No 43/2009 of 16 January 2009 fixing for 2009 the fishing opportunities and associated conditions for certain fish stocks and groups of fish stocks, applicable in Community waters and, for Community vessels, in waters where catch limitations are required. *Official Journal of the European Union L22*, 1-205.
- CHILD, A.R., HOWELL, B.R. AND HOUGHTON, R.G. 1991. Daily periodicity and timing of the spawning of sole, *Solea solea* (L.), in the Thames estuary. *ICES Journal of Marine Science*, 48: 317–323.
- CLARIDGE, P.N. AND POTTER, I.C. 1987. Size composition and seasonal changes in abundance of juvenile sole, *Solea solea*, in the Severn Estuary and Inner Bristol Channel. *Journal of the Marine Biological Association of the United Kingdom*, 67: 561–569.
- CLARK, R.S. 1922. Rays and Skates (Raiae) No. I: Egg capsules and young. *Journal of the Marine Biological Association of the United Kingdom*, 12: 577–643.
- CLARK, R.S. 1926. Rays and skates. A revision of the European species. *Scientific Investigations, Fishery Board of Scotland*, 1: 1–66.

- COELHO, R. AND ERZINI, K. 2006. Reproductive aspects of the undulate ray, *Raja undulata*, from the south coast of Portugal. *Fisheries Research*, 81: 80–85.
- COMPAGNO, L.J.V. 1984. FAO Species Catalogue. Sharks of the World: an annotated and illustrated catalogue of shark species known to date. Part 2: Carcharhiniformes. FAO Fisheries Synopsis No. 125, Vol.4(2): 251–655.
- COOMBS, S.H., MORGANS, D. AND HALLIDAY, N.C. 2001. Seasonal and ontogenetic changes in the vertical distribution of eggs and larvae of mackerel (*Scomber scombrus* L.) and horse mackerel (*Trachurus trachurus* L.). *Fisheries Research*, 50: 27–40.
- COOMBS, S.H., NICHOLS, J.H. AND FOSH, C.A. 1990. Plaice eggs (*Pleuronectes platessa* L.) in the southern North Sea: Abundance, spawning area, vertical distribution, and buoyancy. *ICES Journal of Marine Science*, 47: 133–139.
- COOMBS, S.H. AND MITCHELL, C.E. 1981. Long-term trends in the distribution, abundance and seasonal occurrence of larvae of mackerel (*Scomber scombrus* L.) around the British Isles, 1948–1978. *Journal of the Marine Biological Association of the United Kingdom*, 61: 343–358.
- CORTEN, A. 1999. The reappearance of spawning Atlantic herring (*Clupea harengus*) on Aberdeen Bank (North Sea) in 1983 and its relationship to environmental conditions. *Canadian Journal of Fisheries and Aquatic Sciences*, 56: 2051–2061.
- COULL, K.A., JOHNSTONE, R., AND ROGERS, S.I. 1998. Fisheries Sensitivity Maps in British Waters. Published and distributed by UKOOA Ltd., v + 58 pp.
- DEMPSEY, C.H. AND BAMBER, R.N. 1983. Spawning of herring (*Clupea harengus* L.) in the Blackwater Estuary, spring 1979. *Journal du Conseil international pour l'Exploration de la Mer*, 41: 85–92.
- DICKEY-COLLAS, M., NASH, R.D.M. AND BROWN, J. 2001. The location of spawning Irish Sea herring (*Clupea harengus*). *Journal of the Marine Biological Association of the United Kingdom*, 81: 713–714.
- DOMÍNGUEZ-PETIT, R., SABORIDO-REY, F. AND MEDINA, I. 2010. Changes of proximate composition, energy storage and condition of European hake (*Merluccius merluccius*, L. 1758) through the spawning season. *Fisheries Research*, 104: 73–82.
- DUARTE, R., AZEVEDO, M., LANDA, J. AND PEREDA, P. 2001. Reproduction of anglerfish (*Lophius budegassa* Spinola and *Lophius piscatorius* Linnaeus) from the Atlantic Iberian coast. *Fisheries Research*, 51: 349–361.
- EASTWOOD, P.D., MEADEN, G.J., CARPENTIER, A. AND ROGERS, S.I. 2003. Estimating limits to the spatial extent and suitability of sole (*Solea solea*) nursery grounds in the Dover Strait. *Journal of Sea Research*, 50: 151–165.
- EHRICH, S. 1982. Fishery biological investigations on blue ling stocks in the area north of Rockall Deep. *Inf. Fischwirtsch.*, 29: 53–55.
- ELLIS, J. R. AND SHACKLEY, S.E. 1995. Observations on egg-laying in the thornback ray. *Journal of Fish Biology*, 46: 903–904.
- ELLIS, J.R., CRUZ-MARTINEZ, A., RACKHAM, B.D. AND ROGERS, S.I. 2005. The distribution of chondrichthyan fishes around the British Isles and implications for conservation. *Journal of Northwest Atlantic Fishery Science*, 35: 195–213.
- ELLIS, T. AND NASH, R.D.M. 1997. Spawning of plaice *Pleuronectes platessa* L. around the Isle of Man, Irish Sea. *ICES Journal of Marine Science*, 54: 84–92.
- FIVES, J. M., ACEVEDO, S., LLOVES, M., WHITAKER, A., ROBINSON, M. AND KING, P.A. 2001. The distribution and abundance of larval mackerel, *Scomber scombrus* L., horse mackerel, *Trachurus trachurus* (L.), hake, *Merluccius merluccius* (L.), and blue whiting, *Micromesistius poutassou* (Risso, 1826) in the Celtic Sea and west of Ireland during the years 1986, 1989 and 1992. *Fisheries Research*, 50: 17–26.
- FOX, C.J. AND ALDRIDGE, J.N. 2000. Hydrographic circulation and the dispersal of yolk-sac herring (*Clupea harengus*) larvae in the Blackwater Estuary. *Journal of the Marine Biological Association of the United Kingdom*, 80: 921–928.
- FOX, C.J., DICKEY-COLLAS, M. AND WINPENNY, A.J. 1997. Spring plankton surveys of the Irish Sea in 1995: The distribution of fish eggs and larvae. Science Series Technical Report, Cefas, Lowestoft, 104: 106pp.
- FOX, C., O'BRIEN, C., DICKEY-COLLAS, M. AND NASH, R. 2000. Patterns in the spawning of cod (*Gadus morhua* L.), sole (*Solea solea* L.) and plaice (*Pleuronectes platessa* L.) in the Irish Sea as determined by generalized additive modelling. *Fisheries Oceanography*, 9: 33–49.
- FOX, C.J., TAYLOR, M., DICKEY-COLLAS, M., FOSSUM, P., KRAUS, G., ROHLF, N., MUNK, P., VAN DAMME, C.J.G., BOLLE, L.J., MAXWELL, D.L. AND WRIGHT, P.J. 2008. Mapping the spawning grounds of North Sea cod (*Gadus morhua*) by direct and indirect means. *Proceedings of the Royal Society of London, Series B: Biological Sciences*, 275: 1543–1548.
- FOX, C.J., TAYLOR, M., DICKEY-COLLAS, M., VAN DAMME, C.J.G., BOLLE, L., DANN, N., ROHLF, N., KRAUS, G., MUNK, P., FOSSUM, P. AND BAILEY, N. 2005. Initial results from the 2004 ichthyoplankton survey of the North Sea. ICES CM 2005/AA:04 (mimeo).

- GAULD, J.A. 1979. Reproduction and fecundity of the Scottish Norwegian stock of Spurdogs, *Squalus acanthias* (L.). ICES CM 1979/H:54; 15 pp.
- GENNER, M.J., HALLIDAY, N.C., SIMPSON, S.D., SOUTHWARD, A.J., HAWKINS, S.J. AND SIMS, D.W. 2010. Temperature-driven phenological changes within a marine larval fish assemblage. *Journal of Plankton Research*, 32: 699–708.
- GERBER, E.M. AND DEMENIN, A.A. 1992. On the spawning of blue whiting in the West European basin. *Journal of Ichthyology*, 32: 96–104.
- GIBB, F.M., GIBB, I.M. AND WRIGHT, P.J. 2007. Isolation of Atlantic cod (*Gadus morhua*) nursery areas. *Marine Biology*, 151: 1185–1194.
- GILLIERS, C., LE PAPE, O., DESAUNAY, Y., MORIN, J., GUEREAULT, D. AND AMARA, R. 2006. Are growth and density quantitative indicators of essential fish habitat quality? An application to the common sole *Solea solea* nursery grounds. *Estuarine, Coastal and Shelf Science*, 69: 96–106.
- GOODSIR, F., ARMSTRONG, M.J., WITTHAMES, P.R., MAXWELL, D.L. AND FOX, C.J. 2008. The use of species-specific TaqMan probes for identifying early stage gadoid eggs following formaldehyde fixation. *ICES Journal of Marine Science*, 65: 1573–1577.
- GRIFFITHS, A.M., SIMS, D.W., COTTERELL, S.P., EL NAGAR, A., ELLIS, J.R., LYNHAMMAR, A., MCHUGH, M., NEAT, F.C., PADE, N.G., QUEIROZ, N., SERRA-PEREIRA, B., RAPP, T., WEARMOUTH, V.J. AND GENNER, M.J. 2010. Molecular markers reveal spatially segregated cryptic species in a critically endangered fish, the common skate (*Dipturus batis*). *Proceedings of the Royal Society B*, 277: 1497–1503.
- GROOT, S.J. DE 1980. The consequences of marine gravel extraction on the spawning of herring, *Clupea harengus* Linne. *Journal of Fish Biology*, 16: 605–611.
- HARLEY, B. AND ELLIS, J. 2007. The modified GOV and ground gear 'D'. ICES CM/Q:02, 32pp.
- HATUN, H., PAYNE, M.R. AND JACOBSEN, J.A. 2009. The North Atlantic subpolar gyre regulates the spawning distribution of blue whiting (*Micromesistius poutassou*). *Canadian Journal of Fisheries and Aquatic Sciences*, 66: 759–770.
- HENDERSON, P.A. AND HOLMES, R.H.A. 1989. Whiting migration in the Bristol Channel: A predator-prey relationship. *Journal of Fish Biology*, 34: 409–416.
- HENDERSON, P.A. AND SEABY, R.M. 2005. The role of climate in determining the temporal variation in abundance, recruitment and growth of sole *Solea solea* in the Bristol Channel. *Journal of the Marine Biological Association of the United Kingdom*, 85: 197–204.
- HEUPEL, M.R., CARLSON, J.K. AND SIMPFENDORFER, C.A. 2007. Shark nursery areas: concepts, definition, characterization and assumptions. *Marine Ecology Progress Series*, 337: 287–297.
- HISLOP, J.R., GALLEGO, A., HEATH, M.R., KENNEDY, F.M., REEVES, S.A. AND WRIGHT, P.J. 2001. A synthesis of the early life history of the anglerfish, *Lophius piscatorius* (Linnaeus, 1758) in northern British waters. *ICES Journal of Marine Science*, 58: 70–86.
- HISLOP, J.R., HOLST, J.C. AND SKAGEN, D. 2000. Near-surface captures of post-juvenile anglerfish in the North-east Atlantic - an unsolved mystery. *Journal of Fish Biology*, 57: 1083–1087.
- HOLDEN, M.J. 1975. The fecundity of *Raja clavata* in British waters. *Journal du Conseil*, 36: 110–118.
- HOLDEN, M.J., ROUT, D.W. AND HUMPHREYS, C.N. 1971. The rate of egg laying by three species of ray. *Journal du Conseil*, 33: 335–339.
- HOLDEN, M.J. AND HORROD, R.G. 1979. The migrations of tope, *Galeorhinus galeus* (L.), in the eastern North Atlantic as determined by tagging. *Journal du Conseil international pour l'Exploration de la Mer*, 38: 314–317.
- HORSTMAN, K.R. AND FIVES, J.M. 1994. Ichthyoplankton distribution and abundance in the Celtic Sea. *ICES Journal of Marine Science*, 51: 447–460.
- HORWOOD, J. 1993. The Bristol Channel sole (*Solea solea* (L.)): A fisheries case study. *Advances in Marine Biology*, 29: 215–368.
- HOWELL, G.C.L. 1921. *Ocean research and the great fisheries*. Clarendon Press, Oxford.
- IBAIBARRIAGA, L., IRIGOIEN, X., SANTOS, M., MOTOS, L., FIVES, J.M., FRANCO, C., LAGO DE LANZOS, A., ACEVEDO, S., BERNAL, M., BEZ, N., ELTINK, G., FARINHA, A., HAMMER, C., IVERSEN, S.A., MILLIGAN, S.P. AND REID, D.G. 2007. Egg and larval distributions of seven fish species in north-east Atlantic waters. *Fisheries Oceanography*, 16: 284–293.
- ICES 2003. Report of the Working Group on Fish Ecology (WGFE). ICES CM 2003/G:04; 113 pp.
- ICES 2006. Report of the International Bottom Trawl Survey Working Group (IBTSWG), 27–31 March 2006, Lysekil, Sweden. ICES CM 2006/RMC:03, Ref. ACFM; 298 pp.
- ICES 2009a. Report of the Herring Assessment Working Group for the Area South of 62 N, 17–25 March 2009, ICES Headquarters, Copenhagen; 648 pp.
- ICES 2009b. Report of the Working Group on Mackerel and Horse Mackerel Egg Surveys (WGMEGS), 20–24 April 2009, Hamburg, Germany. ICES CM 2009/LRC:09; 107 pp.

- ICES 2009c. Report of the International Bottom Trawl Survey Working Group (IBTSWG), 30 March–3 April 2009, Bergen, Norway. ICES CM 2009/RMC:04; 241 pp.
- ICES 2009d. Report of the Working Group on Beam Trawl Surveys (WGBEAM), 9–12 June 2009, La Rochelle, France. ICES CM 2009/LRC:04; 196 pp.
- ICES 2009e. Manual for the Offshore Beam Trawl Surveys, Revision 1.2, June 2009. Working Group on Beam Trawl Surveys, 30 pp.
- ICES 2010. Report of the Working Group on the Assessment of Demersal Stocks in the North Sea and Skagerrak (WGNSSK), 5–11 May 2010, ICES Headquarters, Copenhagen. ICES CM 2010/ACOM:13; 1048 pp.
- IGLÉSIAS, S.P., TOULHOAT, L. AND SELLOS, D.Y. 2010. Taxonomic confusion and market mislabelling of threatened skates: important consequences for their conservation status. *Aquatic Conservation: Marine and Freshwater Ecosystems*, 20: 319–333.
- KORTA, M., DOMÍNGUEZ-PETIT, R., MURUA, H. AND SABORIDO-REY, F. 2010. Regional variability in reproductive traits of European hake *Merluccius merluccius* L. populations. *Fisheries Research*, 104: 64–72.
- LARGE, P.A., DIEZ, G., DREWERY, J., LAURANS, M., PILLING, G.M., REID, D.G., REINERT, J., SOUTH, A.B. AND VINNICHENKO, V.I. 2010. Spatial and temporal distribution of spawning aggregations of blue ling (*Molva dypterygia*) west and northwest of the British Isles. *ICES Journal of Marine Science*, 67: 494–501.
- LAURENSEN, C.H. 2006. A note on the development of the embryos of anglerfish *Lophius piscatorius*. *Journal of Fish Biology*, 68: 1287–1290.
- LEE, A.J. AND RAMSTER, J.W. (Eds.) 1981. *Atlas of the Seas Around the British Isles*, Ministry of Agriculture, Fisheries and Food, London..
- LOCKWOOD, S.J. AND LUCASSEN, W. 1984. The recruitment of juvenile plaice (*Pleuronectes platessa* L.) to their parent spawning stock. *Journal du Conseil international pour l'Exploration de la Mer*, 41: 268–275.
- MACER, C.T. 1974. The reproductive biology of the horse mackerel *Trachurus trachurus* (L.) in the North Sea and English Channel. *Journal of Fish Biology*, 6: 415–438.
- MARAVELIAS, C.D., REID, D.G. AND SWARTZMAN, G. 2000. Seabed substrate, water depth and zooplankton as determinants of the prespawning spatial aggregation of North Atlantic herring. *Marine Ecology Progress Series*, 195: 249–259.
- MOURA, T., FIGUEIREDO, I., FARIAS, I., SERRA-PEREIRA, B., COELHO, R., ERZINI, K., NEVES, A. AND GORDO, L.S. 2007. The use of caudal thorns for ageing *Raja undulata* from the Portuguese continental shelf, with comments on its reproductive cycle. *Marine and Freshwater Research*, 58: 983–992.
- MUNK, P., WRIGHT, P.J. AND PIHL, N.J. 2002. Distribution of the early larval stages of cod, plaice and lesser sandeel across haline fronts in the North Sea. *Estuarine, Coastal and Shelf Science*, 55: 139–149.
- NICHOLS, J.H., HAYNES, G.M., FOX, C.J., MILLIGAN, S.P., BRANDER, K.M. AND CHAPMAN, R.J. 1993. Spring plankton surveys of the Irish Sea in 1982, 1985, 1987, 1988 and 1989: hydrography and the distribution of fish eggs and larvae. *Fisheries Research Technical Report*, Ministry of Agriculture, Fisheries and Food, 95: 111 pp.
- OLIVAR, M. P., QUÍLEZ, G. AND EMELIANOV, M. 2003. Spatial and temporal distribution and abundance of European hake, *Merluccius merluccius*, eggs and larvae in the Catalan coast (NW Mediterranean). *Fisheries Research*, 60: 321–331,
- OSPAR COMMISSION 2008. *Case Reports for the OSPAR List of Threatened and/or Declining Species and Habitats*. OSPAR Commission Biodiversity Series, 261 pp.
- PARKER-HUMPHREYS, M. 2004a. Distribution and relative abundance of demersal fishes from beam trawl surveys in the Irish Sea (ICES Division VIIa) 1993–2001. *Science Series Technical Report*, CEFAS, Lowestoft, 120, 68 pp.
- PARKER-HUMPHREYS, M. 2004b. Distribution and relative abundance of demersal fishes from beam trawl surveys in the Bristol Channel (ICES Division VIIf) 1993–2001. *Science Series Technical Report*, CEFAS, Lowestoft, 123, 69 pp.
- PARKER-HUMPHREYS, M. 2005. Distribution and relative abundance of demersal fishes from beam trawl surveys in the eastern English Channel (ICES division VIId) and the southern North Sea (ICES Division IVc) 1993–2001. *Science Series Technical Report*, CEFAS, Lowestoft, 124, 92 pp.
- POTTER, I.C., GARDNER, D.C. AND CLARIDGE, P.N. 1988. Age composition, growth, movements, meristics and parasites of the whiting, *Merlangius merlangus*, in the Severn Estuary and Bristol Channel. *Journal of the Marine Biological Association of the United Kingdom*, 68: 295–313.
- POTTS, G.W. AND SWABY, S.E. 1993a. Review of the status of estuarine fishes. *English Nature Research Report No. 34*, 278 pp.

- POTTS, G.W. AND SWABY, S.E. 1993b. Marine and estuarine fishes of Wales. The development of the British Marine Fishes database and monitoring programme for Wales. Countryside Council for Wales, Bangor.
- POWER, M., ATTRILL, M.J. AND THOMAS, R.M. 2000a. Environmental factors and interactions affecting the temporal abundance of juvenile flatfish in the Thames Estuary. *Journal of Sea Research*, 43: 135–149.
- POWER, M., ATTRILL, M.J. AND THOMAS, R.M. 2000b. Temporal abundance patterns and growth of juvenile herring and sprat from the Thames estuary 1977–1992. *Journal of Fish Biology*, 56: 1408–1426.
- POXTON, M.G. AND NASIR, N.A. 1985. The distribution and population dynamics of 0-group plaice (*Pleuronectes platessa* L.) on nursery grounds in the Firth of Forth. *Estuarine, Coastal and Shelf Science*, 21: 845–857.
- PRIEDE, I.G., RAID, T. AND WATSON, J.J. 1995. Deep-water spawning of Atlantic mackerel *Scomber scombrus*, west of Ireland. *Journal of the Marine Biological Association of the United Kingdom*, 75: 849–855.
- RANKINE, P.W. 1986. Herring spawning grounds around the Scottish coast. ICES CM 1986/H:15
- RANKINE, P.W. AND MORRISON, J.A. 1989. Predation on herring larvae and eggs by sand-eels *Ammodytes marinus* (Rait) and *Hyperoplus lanceolatus* (Lesauvage). *Journal of the Marine Biological Association of the United Kingdom*, 69: 493–498.
- RILEY, J.D. 1974. The distribution and mortality of sole eggs (*Solea solea* (L.)) in inshore areas. In "The early life history of fish". Proceedings of an International Symposium held at the Dunstaffnage Marine Research Laboratory of the Scottish Marine Biological Association at Oban, Scotland, 17–23, 1973. pp. 39–52.
- ROGERS, S.I. 1992. Environmental factors affecting the distribution of sole (*Solea solea* (L.)) within a nursery area. *Netherlands Journal of Sea Research*, 29: 153–161.
- ROGERS, S.I., MILLNER, R.S. AND MEAD, T.A. 1998. The distribution and abundance of young fish on the east and south coast of England (1981 to 1997). Science Series, Technical Report, CEFAS, Lowestoft, 108, 130 pp.
- RUSSELL, F.S. 1976. The eggs and planktonic stages of British marine fishes. Academic Press, London, 524 pp.
- RYLAND, J.S. AND AJAYI, T.O. 1984. Growth and population dynamics of three *Raja* species in Carmarthen Bay, British Isles. *Journal du Conseil international pour l'Exploration de la Mer*, 41:111–120.
- SCHMIDT, J.O., VAN DAMME, C.Y.G., RÖCKMANN, C. AND DICKEY-COLLAS, M. 2009. Recolonisation of spawning grounds in a recovering fish stock: recent changes in North Sea herring. *Scientia Marina*, 73S1: 153–157.
- STRATOUDAKIS, Y., GALLEG0, A. AND MORRISON, J.A. 1998. Spatial distribution of developmental egg ages within a herring *Clupea harengus* spawning ground. *Marine Ecology Progress Series*, 174: 27–32.
- SYMONDS, D.J. AND ROGERS, S.I. 1995. The influence of spawning and nursery grounds on the distribution of sole *Solea solea* (L.) in the Irish Sea, Bristol Channel adjacent areas. *Journal of Experimental Marine Biology and Ecology*, 190: 243–261.
- TAYLOR, M.I., FOX, C.J., RICO, I. AND RICO, C. 2002. Species-specific probes for simultaneous identification of the eggs of cod (*Gadus morhua*), haddock (*Melanogrammus aeglefinus*) and whiting (*Merlangius merlangus*). *Molecular Ecology Notes*, 2: 599–601
- TAYLOR, N., FOX, C.J., BOLLE, L., DICKEY-COLLAS, M., FOSSUM, P., KRAUS, G., MUNK, P., ROLF, N., VAN DAMME, C. AND VORBACH, M. 2007. Results of the spring 2004 North Sea ichthyoplankton surveys: The distribution of fish eggs and larvae from the international ichthyoplankton survey. ICES Cooperative Research Report 285: 59 pp.
- TIDD, A. AND WARNES, S. 2006. Species distributions from English Celtic Sea groundfish surveys 1992–2003. Science Series Technical Report, CEFAS, Lowestoft, 137, 54 pp.
- VINCE, M.R. 1991. Stock identity in spurdog (*Squalus acanthias* L.) around the British Isles. *Fisheries Research*, 12: 341–354.
- WARNES, S. AND JONES, B.W. 1995. Species distributions from English Celtic Sea groundfish surveys, 1984 to 1991. Fisheries Research *Technical Report*, MAFF Directorate of Fisheries Research, Lowestoft, 98: 42 pp.
- WENNHAGE, H., PIHL, L. AND STAL, J. 2007. Distribution and quality of plaice (*Pleuronectes platessa*) nursery grounds on the Swedish west coast. *Journal of Sea Research*, 57: 218–229.
- WHEELER, A. 1969. The fishes of the British Isles and North-west Europe. Michigan State University Press, 613 pp.
- WHEELER, A. 1978. Key To the fishes of northern Europe. Frederick Warne, 380 pp.
- WOOD, R.J. 1959. Investigations on 0-group herring. *Journal du Conseil pour L'exploration de la Mer*, 24: 264–276.
- WRIGHT, P.J., GALLEY, E., GIBB, I.M. AND NEAT, F.C. 2006. Fidelity of adult cod to spawning grounds in Scottish waters. *Fisheries Research*, 75: 148–158.

Appendix A: List of acronyms

BTS	Beam trawl survey
Cefas	Centre for Environment, Fisheries and Aquaculture Science
CPR	Continuous Plankton Recorder
DATRAS	DATAbase of TRAWl Surveys (managed by ICES)
Defra	Department for Environment Food and Rural Affairs
EEZ	Exclusive Economic Zone
FRS	Fisheries Research Services (now Marine Scotland)
GIS	Geographic Information System
GFS	Groundfish survey
GOV	Grande ouverture vertical (a high headline trawl)
IBTS	International Bottom Trawl Survey
IBTSWG	International Bottom Trawl Survey Working Group
ICES	International Council for the Exploration of the Seas
ICZN	International Commission on Zoological Nomenclature
IHLS	International Herring Larval Survey
ISEPS	Irish Sea Egg Production Surveys
NFFO	National Federation of Fishermen's Organisations
nm	Nautical mile (equivalent to 1.853 km)
OSPAR	OSPAR Convention (formerly Oslo and Paris Conventions) for the Protection of the Marine Environment of the North-East Atlantic
PHHT	Portuguese high headline trawl
SFF	Scottish Fishermen's Association
UKOOA	UK Offshore Operator's Association
VMS	Vessel Monitoring System
WGBEAM	Working Group on Beam Trawl Surveys
WGMEGS	Working Group on Mackerel and Horse Mackerel Egg Surveys
YFS	Young Fish Survey

Appendix B: ESRI shape file metadata

(a) Metadata associated with the data for supporting the identification of nominal nursery grounds.

Abstract:

A points layer of presence and abundance of selected juvenile species conducted by fishery-independent research surveys in UK waters.

Purpose:

To provide the evidence-base behind the identification of nursery grounds for selected highly mobile species.

Supplemental_Information:

Point layer identification fields:

FID, OBJECTID, Shape, MedianLat, MedianLon

Field descriptions:

Gear – gear type used: PHHT = Portuguese high headline trawl, GOV = Grande Ouverture Verticale trawl, BT = Beam trawl
fldCountry – Value – ENG = England and Wales, SCO = Scotland, NI = Northern Ireland

It should be noted that various forms of GOV are used in the various surveys, and so relative abundance should only be interpreted within a survey region and not across the entire study area. Northern Ireland use a non GOV rockhopper trawl.

XXX_Mx – Maximum abundance recorded at each station

XXX_P – Presence – Value

-9999 = no data,

1 = presence in 1 or more tows at each station

50 = present in over 50% of tows at each station

70 = present in over 70% of tows at each station

The study undertook 2 analyses with different length splits for horse mackerel, because fish ≤ 14 cm were so ubiquitous. For the other species the length splits are shown below.

HOM_M_8

Maximum abundance of Horse Mackerel which are less than or equal to 8cm

HOM_P_8

Presence of Horse Mackerel which are less than or equal to 8cm long

HOM_Mx_14

Maximum abundance of Horse mackerel which are less than or equal to 14cm

HOM_P_14

Presence of Horse Mackerel which are less than or equal to 14cm

Where;

XXX is the three letter species identifier outlined in the species coding list below.

to get presence for 50% of tows for each station both 50 and 70 must be used.

Species coding list:

Whiting, *Merlangius merlangus*, WHG, < 20 cm

Common skate, *Dipturus batis*, SKT, < 43 cm

Sandeels, Ammodytidae, SAN, < 13 cm

Herring, *Clupea harengus*, HER, <17.5cm

Cod, *Gadus morhua*, COD, < 23 cm

European hake, *Merluccius merluccius*, HKE, < 20 cm

Plaice, *Pleuronectes platessa*, PLE, <12 cm

Mackerel, *Scomber scombrus*, MAC, <24 cm

Sole, *Solea solea*, SOL, < 13 cm

Horse mackerel, *Trachurus trachurus*, HOM, < 8 cm and < 14 cm

Thornback ray, *Raja clavata*, THR, < 18 cm

Spotted ray, *Raja montagui*, SDR, < 18 cm

Undulate ray, *Raja undulata*, UNR, <29 cm

Spurdog, *Squalus acanthias*, DGS, < 48 cm

Ling, *Molva molva*, LIN, < 49 cm

Anglerfish, *Lophius piscatorius*, MON, < 28 cm

Blue whiting, *Micromesistius poutassou*, WHB, < 19 cm

Tope shark, *Galeorhinus galeus*, GAG, < 70 cm

(b) Metadata associated with the data for supporting the identification of nominal spawning grounds.

Abstract:

A points layer of egg-surveys conducted in UK waters between 1990 & 2008 used to identify the spawning grounds of selected UK fish.

Purpose:

To provide the evidence-base behind the revised spawning grounds of selected UK fish.

Supplemental_Information:

Species coding list:

Whiting, *Merlangius merlangus*, WHG
 Sandeels, Ammodytidae, SAX
 Herring, *Clupea harengus*, HER
 Cod, *Gadus morhua*, COD
 European hake, *Merluccius merluccius*, HKE
 Plaice, *Pleuronectes platessa*, PLE
 Mackerel, *Scomber scombrus*, MAC
 Sole, *Solea solea*, SOL
 Horse mackerel, *Trachurus trachurus*, HOM
 Ling, *Molva molva*, LIN
 Anglerfish, *Lophius piscatorius*, MON
 Blue whiting, *Micromesistius poutassou*, WHB

More intensive surveys have been undertaken in the Irish Sea for COD, SOL and PLE.

Series:

Ichthyoplankton data were collated from the following surveys:

Bristol Channel plankton surveys: A series of five cruises (524 valid stations) conducted in the Bristol Channel in 1990 which was conducted primarily to inform on sole and bass, but collected data for other fish species and edible crab larvae. For further information see Horwood (1993).

1991 Sole survey: A series of four cruises in 1991 (304 valid stations) conducted in the English Channel and Southern Bight, primarily to sample sole and bass, with data collected for other fish species and edible crab larvae.

ISEPS: Irish Sea Egg Production Surveys. This extensive series of cruises were conducted in the Irish Sea (although data were limited from the southern parts of St George's Channel) and were conducted in 1995 (13 cruises, 1024

valid stations), 2000 (8 cruises, 804 valid stations), 2006 (5 cruises, 397 valid stations) and 2008 (5 cruises, 486 valid stations). For further information see Bunn & Fox (2004). For further information see Fox *et al.* (1997) and Bunn *et al.* (2004), with earlier cruises also described by Nichols *et al.* (1993).

Eastern Irish Sea: Eastern Irish Sea plaice surveys: A series of cruises that were undertaken in the eastern Irish Sea, primarily to target plaice, that were conducted in 2001 (5 cruises, 227 stations), 2002 (4 cruises, 158 stations) and 2003 (5 cruises, 345 stations). For further information see Bunn *et al.*, (2004).

North Sea_Larvae: A series of cruises by several international institutes covering a large area of the North Sea (927 stations) over a four month period from late December 2003 to early April 2004. For further information see Fox *et al.* (2005) and Taylor *et al.* (2007).

North Sea_Eggs: A series of cruises by several international institutes covering a large area of the North Sea (927 stations) over a four month period from late December 2003 to early April 2004. For further information see Fox *et al.* (2005) and Taylor *et al.* (2007).

IHLS: International Herring Larval Survey: An internationally coordinated survey that samples over the main herring spawning grounds in the North Sea. Only data for 2008 (481 stations) were used, as 2009 data were unavailable. For further information see ICES (2009a).

MAC_HOM (stage 1 only): Triennial mackerel egg survey: An internationally coordinated survey that includes extensive sampling along the western seaboard of the British Isles. Mackerel and horse mackerel are the main target species. For this survey, only data from the most recent survey (2007) and for stage 1 eggs were included. For further information see ICES (2009b).



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