

CRUISE REPORT CEND 2-09

A survey of Irish Sea cod spawning grounds for Defra project MEMFISH

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3.1. Outline of the survey

Staff

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- 1.2. David A. Righton (2IC, Cefas Lowestoft)
- 1.3. Mark Etherton (Cefas Lowestoft)
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- 1.6. Benjamin Hatton (Cefas Lowestoft)
- 1.7. Louise Cox (Cefas Lowestoft)
- 1.8. Julian Martin (Cefas Newlyn)
- 1.9. Kirsten Abernethy (University of East Anglia, Norwich)
- 1.10. Caoimhe Ni Dhuill (Marine Institute, Dublin)

Duration

7–18 February 2009

Location

Northern Irish Sea

Ojectives

1. Assess the distribution of cod at known spawning areas in the Irish Sea
2. Assess the size and age composition of the spawning cod population through data on trawl catch compositions (including collection of otoliths)
3. Assess the biological characteristics of individual cod on the spawning grounds, through information on the size, weight and body condition (including hepatosomatic index), and reproductive status (sex, age, maturity, gonad weight)
4. Collect biopsy samples from the ovaries of female cod to determine the reproductive status, egg size etc.
5. Collect tissue samples for genetic analysis on population structure, through fin-clipping

Additional objectives

6. Assess the presence/absence or abundance of potential predators of cod eggs (such as sprat and herring)
7. Assess the physical characteristics of cod spawning areas
8. Tag plaice in support of Defra's PREDATE project, allowing studies on plaice movements in the Irish Sea (using Petersen tags)
9. Remove full stomachs from a variety of fish predators (~30–40 samples) to be frozen and returned to Cefas, to trial a new method of fish identification (based on mass-spec derived collagen peptide fingerprints)

3.2. Narrative

RV Endeavour left Lowestoft harbour at 07:00 on Saturday February 7th and immediately set a course for the Irish Sea. One 'shake down' trawl was performed in the Western Channel off Plymouth (50°1.17'N 4°24.11'W) on Sunday 8th February. RV Endeavour arrived on station at the eastern study site near Morecambe Bay (53°48.9'N 3°29.25'W) at 08:00 on Monday 9th February and immediately began a trawl and acoustic survey of the area. Trawls were fished continuously throughout each day based on the positions of commercial cod catches the previous year, ending at approximately midnight. Overnight, a multibeam survey was conducted of the area to be fished the following day to detect possible trawl hangs. After three days working the eastern study site, RV Endeavour steamed west to begin the survey of the western study site, located between the Isle of Man and the Northern Irish coast. Surveying continued at the western study area for three days, the Endeavour moved north late on Saturday 14th February to survey areas within the North Channel. Surveying was aborted after one tow resulted in serious damage to the trawl, and Endeavour returned to the western study area for the remainder of workable time. Surveying was completed at 15:40 on Tuesday 17th February, when Endeavour set a course for Belfast harbour, arriving alongside at 7:00 AM on Wednesday 18th February.

3.3. Preliminary results of the survey

3.1. Distribution and abundance of cod

Hour-long trawls using the Portuguese high headline trawl (PHHT) were used to assess the abundance of cod, focussed on two areas that yielded high commercial catch rates in February 2008 (Figure 1). In total, 70 valid trawls were completed; five trawls were invalidated because the trawl came fast or because the trawl was observed to be damaged on hauling.

Overall, catch rates of cod were not high – only 164 cod were caught in the valid hauls (average of 2.34 per haul) over the course of the survey. Catch rates were particularly low in the shallow (average station depth 26.11 m), eastern study area,

where 16 cod were caught in 25 trawls of 1 hr duration, with a maximum of two cod caught within one hour. In contrast, catch rates were much higher at the deeper (105.52 m) western study area: 148 cod were caught in 45 trawls (Figure 2), with a maximum of 32 cod caught within one trawl.

Aside from differences in depth, the habitat type within each study area differed in terms of ground-type, temperature and the type and abundance of prey species available. In the eastern area, the ground type was typically sandy, with relatively little complexity in the terrain. Depth gradients were shallow. In contrast, the western study area was muddy with rocks, offering more complexity. In addition, the western study area was characterised by steeper depth gradients. The western area was also warmer: the mean seabed temperature at each station was 8.16°C, compared against a mean seabed temperature of 5.93°C in the eastern area.

The distribution and abundance of cod prey is discussed in a later section.

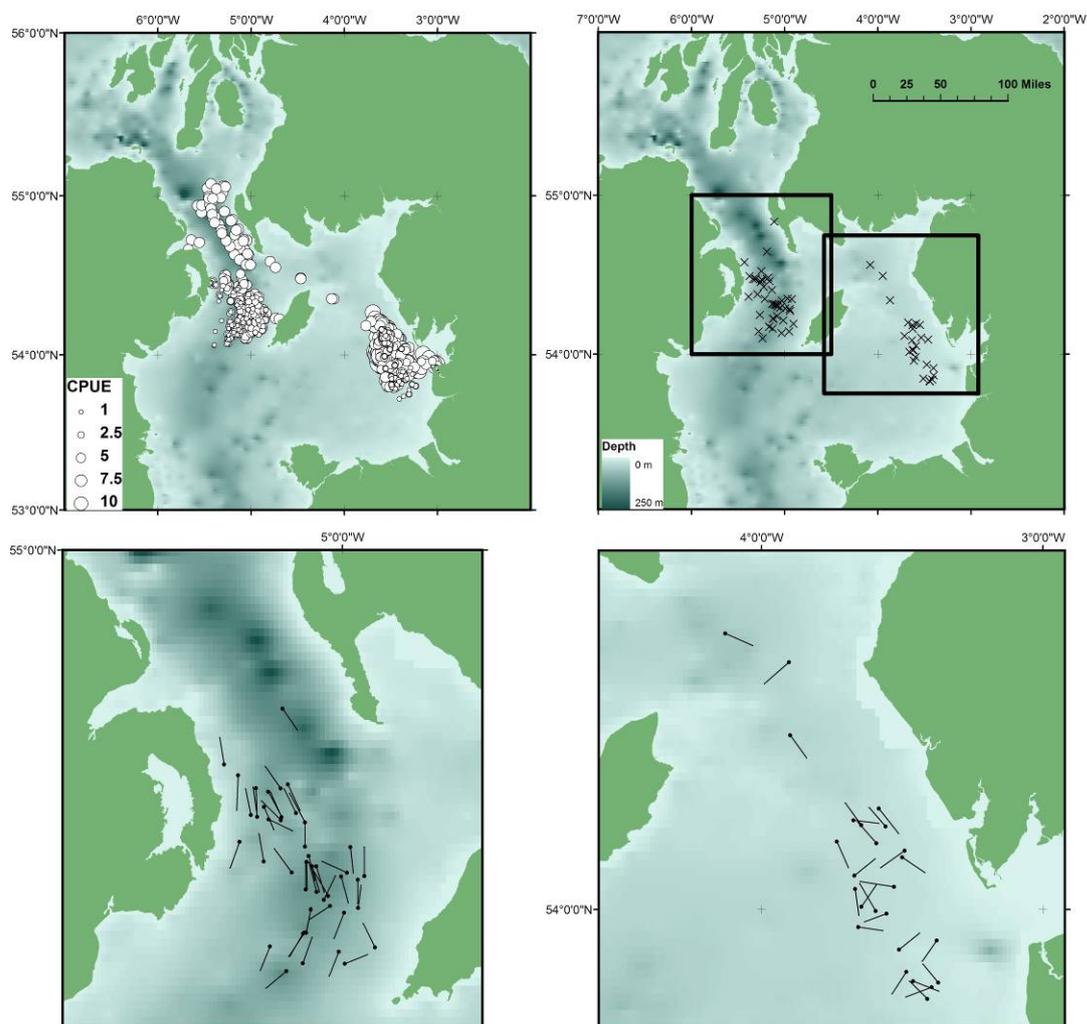


Figure 1. Map of study sites showing (a) CPUE of cod caught by English commercial otter trawlers in February 2008; (b) survey trawl positions and locations of the two study areas; (c) trawl paths in the western area (the large filled circles at the end of the lines indicate the haul position) and (d) the trawl paths in the eastern study area.

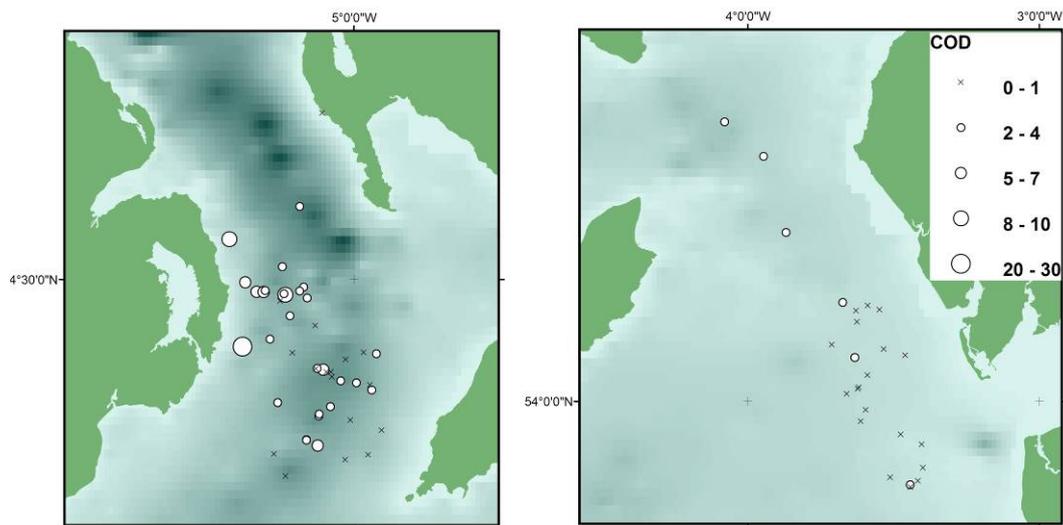


Figure 2. Locations of cod catches. Symbols size is proportional to the number of cod caught in the trawl.

3.2. Size composition of cod at spawning areas

In the western Irish Sea, far more cod were caught per unit of time fishing than in the eastern Irish Sea, and there were notable differences in the size composition and the sex ratio in both areas (Figure 2).

Size distribution. The stations west of the Isle of Man yielded a broad size distribution of cod, with peaks at several length modes: at 10–25 cm (juveniles mainly in the shallower sites close to the Northern Ireland coast; probably 1 year old); 35–45 cm (possibly 2 year olds); and the majority of cod caught here, being >50 cm. These larger cod were mainly found in the deeper waters (where most of our western stations were located). — In the eastern, much shallower study area, no juveniles were caught, and it was here that the largest of all cod was caught: an 89.3 cm female.

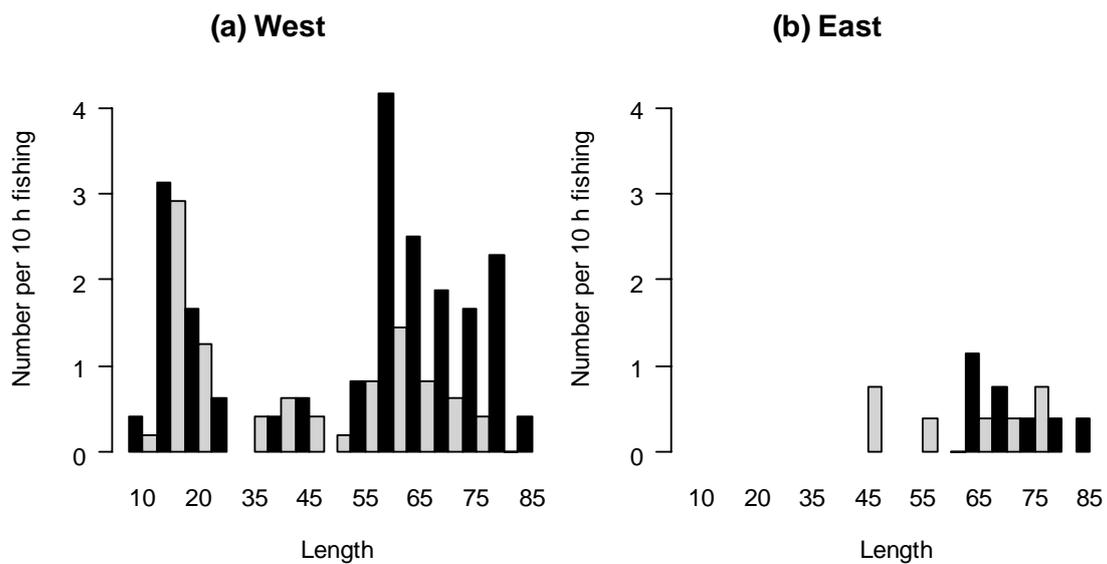


Figure 2. Length distributions of female (*black bars*) and male cod (*grey bars*) observed in the western (a) and eastern (b) Irish Sea.

Sex ratio. The smaller cod (<50 cm) observed in the western Irish Sea (mainly in the shallower parts) showed about equal numbers of males and females (Table 1). However, amongst the adults caught in the west (mainly the deeper parts) we found far more females than males: so much that adult females outnumbered adult males by a factor 3 (Table 1). As adult females are generally larger than adult males, the difference between male and female biomass was even more pronounced.

No such biased sex ratio was found in the much smaller number of (all adult) cod found in the eastern Irish Sea: here, the sex ratio was at unity (8 females, 8 males).

Table 1. Numbers of female and male cod smaller and larger than 50 cm caught in the western and eastern study areas, and sex ratios expressed as % females and % males.

<i>Size</i>	<i>Area</i>	<i>Females</i>	<i>Males</i>	<i>% Females</i>	<i>% Males</i>
<50 cm	West	30	26	54%	46%
	East	0	0	—	—
>50 cm	West	70	25	74%	26%
	East	8	8	50%	50%

3.3. Maturity and reproductive characteristics of individual cod

Maturity stages were determined for a total of 165 cod (one of these from an invalidated haul). Females and males at all stages of gonad maturity were observed (excepting spent males) (Figure 3). All males <30 cm and females <42 cm were immature. Above these lengths, the majority of fish had maturing gonads. Hyaline, running and spent gonads were observed relatively infrequently, and these more advanced maturity stages tended to occur only in the largest of fish, in line with a somewhat more rapid timing of gonad development in the biggest fish.

In the shallow eastern Irish Sea, the relatively few cod caught tended to be at somewhat more advanced maturity stages.

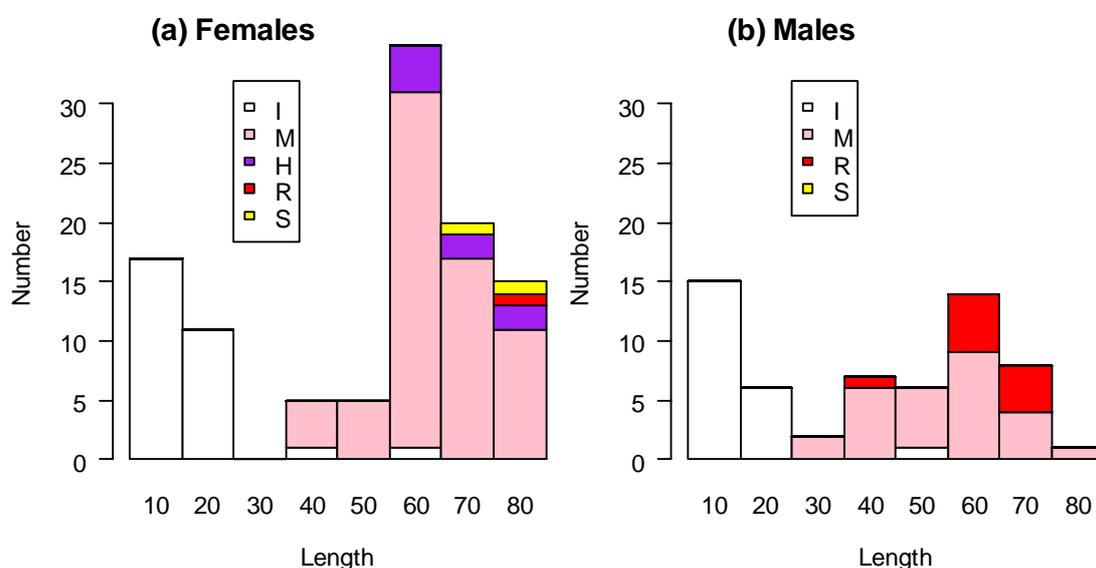


Figure 3. Maturity stages of (a) female and (b) male cod by 10-cm length groups. I immature; M maturing; H hyaline (females only); R running; S spent.

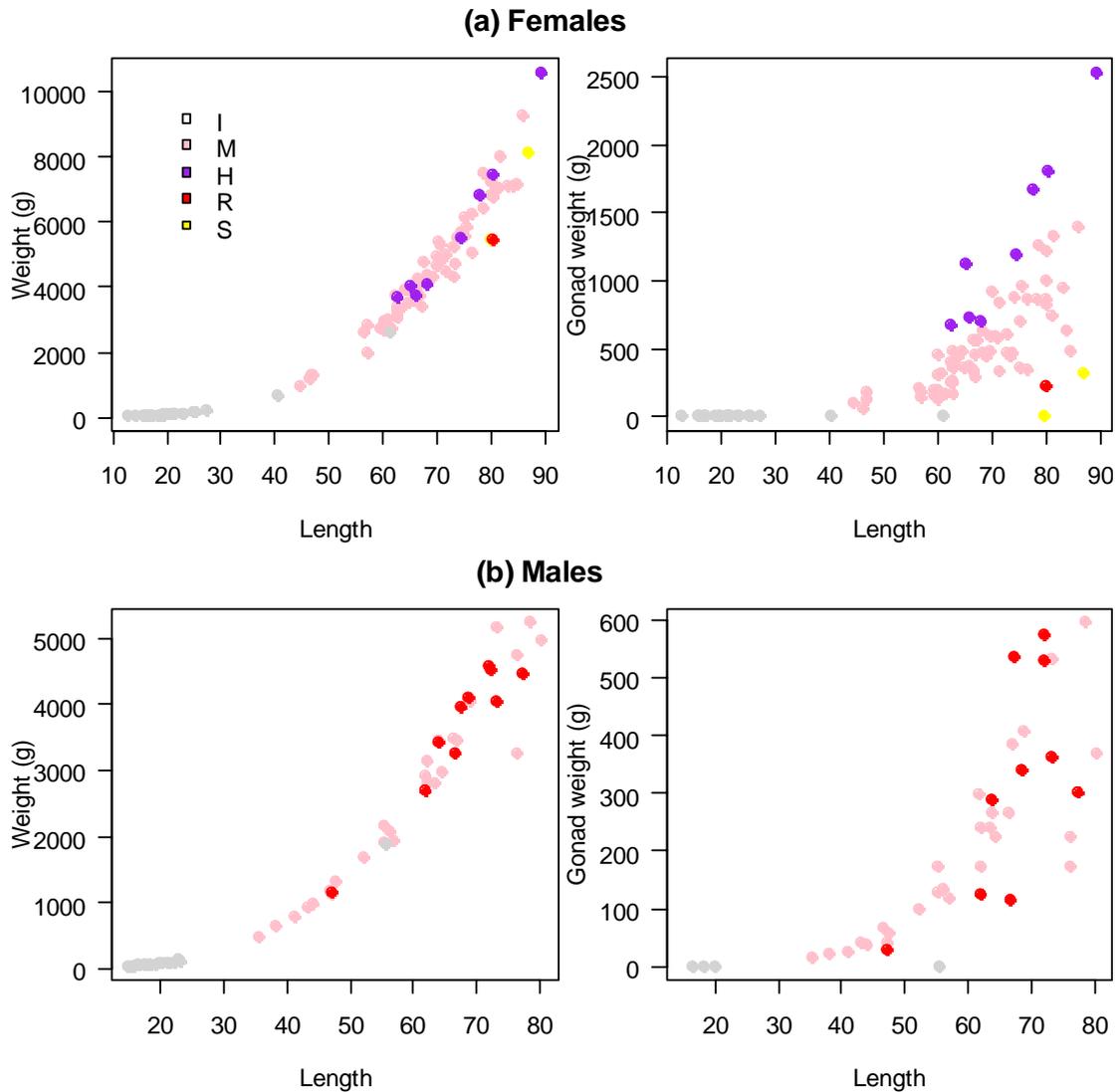


Figure 4. Length–weight relationships (*left panels*) and length–gonad weight relationships (*right panels*) of (a) female and (b) male cod caught in the survey. For each individual fish, the colour of the symbol indicates its maturity stage (see legend: I immature; M maturing; H hyaline [females only]; R running; S spent).

Length–weight relationships and length–gonad weight relationships are shown in Figure 4, for female and male cod separately. These relationships underline that the largest of fish invest disproportionately more in reproduction. For example, in the largest female, body weight was 10.58 kg and ovary weight 2.53 kg, i.e. 24% of body weight; this was on average 10% in females between 3 and 4 kg body weight. The highest ovary weights were observed in females with hyaline gonads. In fish with running or spent gonads, gonad weight had obviously rapidly declined.

3.4. Diet of cod on spawning grounds

A total of 167 Irish Sea cod were examined for stomach contents. Most of the fish had been feeding extensively, and in only 21 cod the stomach was found to be empty (12.7% of all cod), plus one additional cod with everted stomach. However it was mainly in the western study area where extensive feeding by cod was observed: males and females in the west, regardless of length group, showed considerably greater stomach fullness than in the east (Table 2).

The cod had a very broad diet, and no less than 28 prey species were recorded, mostly from the west (not all of these could be identified to species level). These belonged to the following phyla or classes: polychaetes (1 species), molluscs (4 species), crustaceans (10 species), echinoderms (2 species) and fish (11 species; see Table 3 for an overview of all prey species eaten by cod).

Table 2. Mean weight of total stomach contents (in g) of female and male cod by length group, compared between the western and eastern study areas. Note far greater stomach fullness in west.

<i>Length group</i>	<i>Females</i>		<i>Males</i>	
	West	East	West	East
10-19	0.5		0.4	
20-29	0.6		1.9	
30-39			4.6	
40-49	17.9		13.6	8.8
50-59	40.6		19.0	0
60-69	53.5	0.8	44.8	0
70-79	59.4	3.8	26.5	8.6
80-89	86.7	16.9		
All	58.5	5.9	29.5	6.2

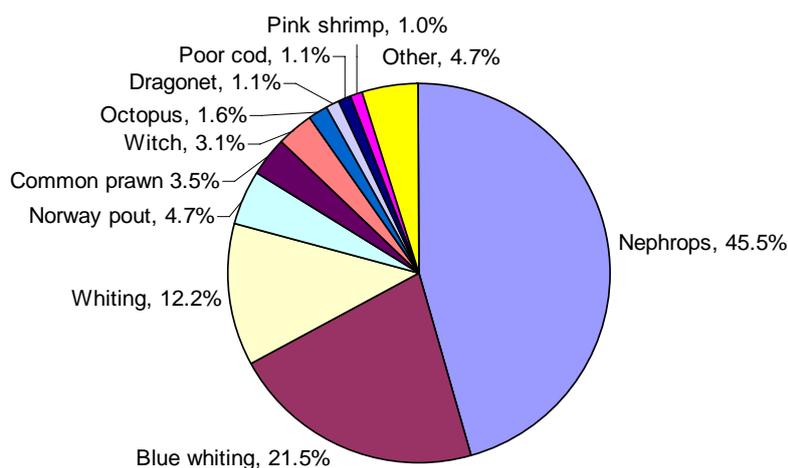


Figure 5. Irish Sea cod diet composition by prey weight. Diagram shows the % of total prey weight, comprised by each of the 10 principal prey species, and by all other prey species combined

Table 3. Overview of all prey items found in the stomachs of 167 Irish Sea cod, identified to species or lowest taxonomic level. *N* is the total number of prey individuals recorded.

<i>Phylum/class</i>	<i>Abbreviation</i>	<i>English name</i>	<i>Scientific name</i>	<i>N</i>
<i>Polychaetes</i>	AAC	Seamouse	<i>Aphrodita aculeata</i>	5
<i>Molluscs</i>	TNT	Thin tellin	<i>Tellina tenuis</i>	1
	DEE	Tusk shell	<i>Dentalium entalis</i>	1
	ATS	Squid	<i>Alloteuthis subulata</i>	1
	OCV	Octopus	<i>Octopus vulgaris</i>	2
<i>Crustaceans</i> ¹	PSO	Ghost shrimp	<i>Pasiphaea sivado</i>	1
	CPR	Common prawn	<i>Palaemon serratus</i>	49
	PRM	Pink shrimp	<i>Pandalus montagui</i>	36
	CRN	Brown shrimp	Crangonidae	2
	NEP	Nephrops	<i>Nephrops norvegicus</i>	205
	PEB	Hermit	<i>Pagurus bernhardus</i>	3
	GLX	Squat lobster	<i>Galathea</i> sp.	9
	MJX	Spider crab	<i>Macropodia</i> sp.	5
	CRS	Swimming crab	<i>Liocarcinus</i> sp.	1
	XAP	Risso's crab	<i>Xantho pilipes</i>	1
	<i>Echinoderms</i>	OPF	Common brittlestar	<i>Ophiothrix fragilis</i>
URX		Sea urchin	? <i>Echinocardium cordatum</i>	1
<i>Fish</i> ²	SPR	Sprat	<i>Sprattus sprattus</i>	7
	WHG	Whiting	<i>Merlangius merlangus</i>	6
	WHB	Blue whiting	<i>Micromesistius poutassou</i>	28
	NOP	Norway pout	<i>Trisopterus esmarki</i>	16
	POD	Poor cod	<i>Trisopterus minutus</i>	4
	Rockling	Rockling	<i>Ciliata/Enchelyopus/Gaidropsarus</i>	2
	Pipefish	Pipefish	<i>Syngnathus</i> sp.	1
	CDT	Common dragonet	<i>Callionymus lyra</i>	1
	POM	Sand goby	<i>Pomatoschistus</i> sp.	2
	WIT	Witch	<i>Glyptocephalus cynoglossus</i>	3
	SOT	Solenette	<i>Buglossidium luteum</i>	1

¹ Also, 9 unidentified shrimps, 9 unidentified crabs and 2 crab claws

² Also, 92 unidentified fish

Although Irish Sea cod were truly omnivorous, a few prey species constituted the majority of all food consumed in terms of weight (Figure 5). Most importantly, *Nephrops* comprised over 45% of cod diet: this may be unsurprising given that the western study area coincides with an important *Nephrops* fishing ground. Five gadoid fishes (especially blue whiting and whiting, also Norway pout, poor cod and occasionally rockling) together constituted over 40% of cod diet; other fish species comprised 5%. Small crustaceans were relatively frequently eaten by the cod; although in terms of weight not so important in cod diet (6.2% of total prey weight), they nevertheless comprised about 26% of the total number of prey items eaten. Most of these were common prawn, pink shrimp and small crabs (Table 3).

3.5. Distribution of prey of cod

Of the 10 ‘main’ prey species of cod (see Section 3.4), Norway pout were most abundant; during the survey ~18,000 fish were caught, almost all of which were concentrated in the deeper waters of the western study area (Figure 6). Poor cod and blue whiting were also abundant in the western study area; the total numbers caught of these species were ~6000 and ~5400, respectively (Figure 7, 8). Of the cod’s most important prey species *Nephrops*, nearly 9700 individuals were caught in the eastern and western study area, but particularly to the southern end of the western study site (Figure 9). Cod catches corresponded well to all these species, but particularly to *Nephrops*.

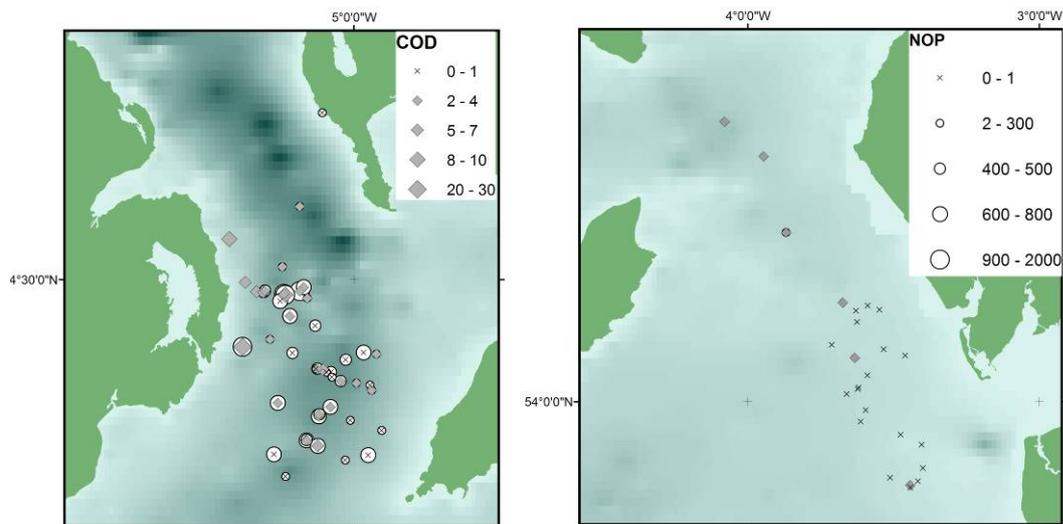


Figure 6. Locations of Norway pout (NOP) and cod catches. Symbol sizes proportional to the number of fish caught in the trawl (at different scales for the two species).

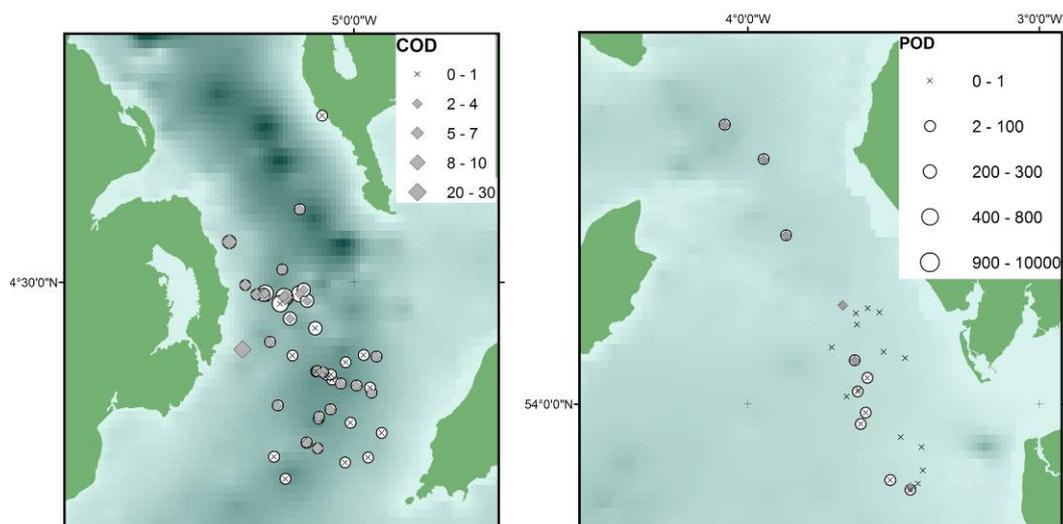


Figure 7. Locations of poor cod (POD) and cod catches. Symbol sizes proportional to the number of fish caught in the trawl (at different scales for the two species).

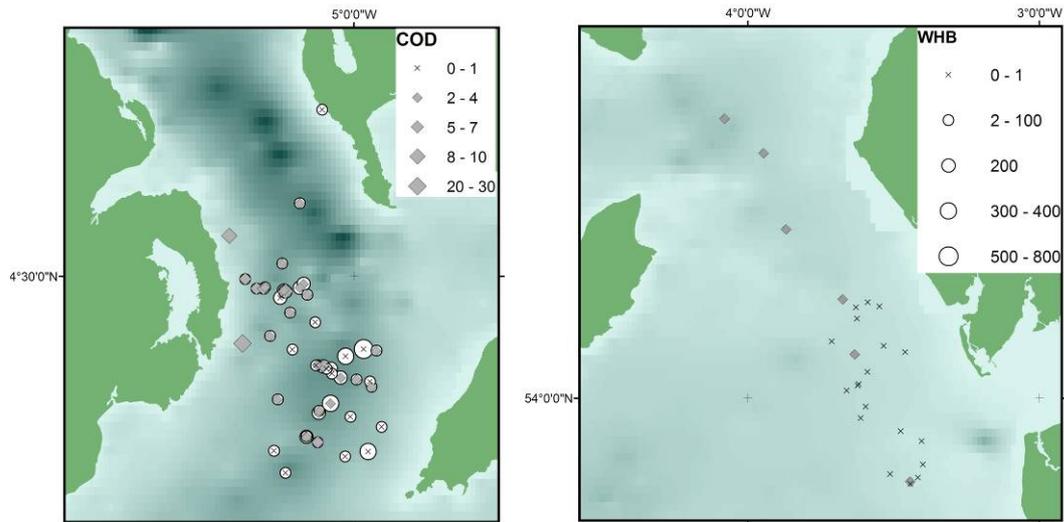


Figure 8. Locations of blue whiting (WHB) and cod catches. Symbol sizes proportional to the number of fish caught in the trawl (at different scales for the two species).

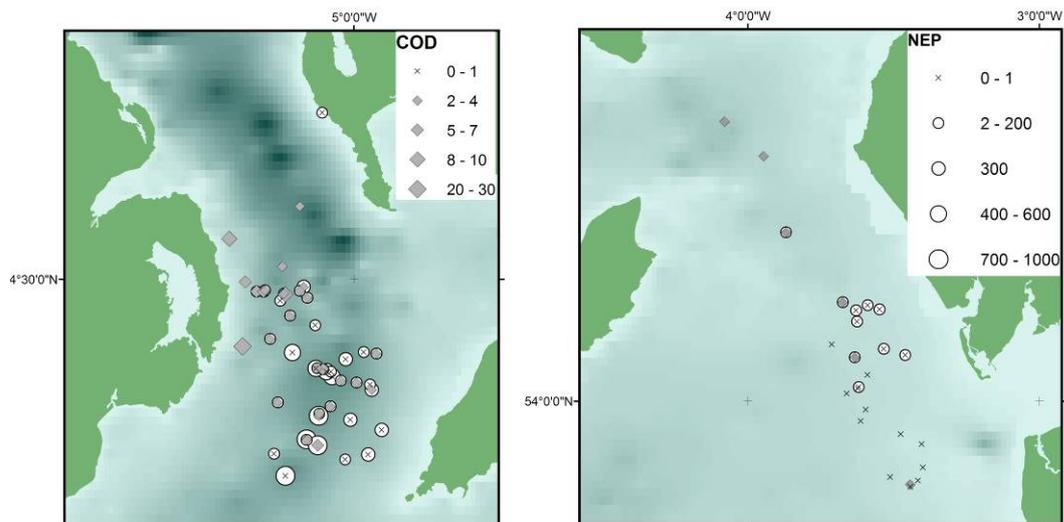


Figure 9. Locations of *Nephrops* (NEP) and cod catches. Symbol sizes proportional to the number of animals caught in the trawl (at different scales for the two species).

3.6. Distribution of potential cod egg predators

Sporadic evidence was found that the pelagic, planktivorous species herring and sprat, and possibly squid, may act as potential cod egg predators in the Irish Sea. Herring and sprat were caught at almost every trawl station, and of all fish species, were caught in highest numbers overall (>60,000 herring and >40,000 sprat). However, they were found in particular abundance in the eastern study area (notably herring), where cod were least abundant (Figures 10, 11). The pelagic squid *Alloteuthis subulata* was found mainly in the western study area (Figure 12).

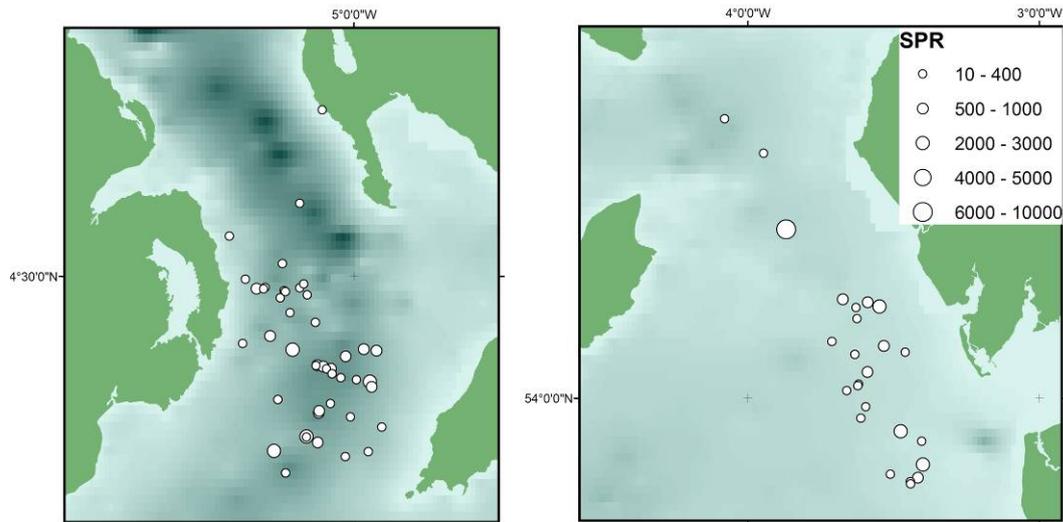


Figure 10. Locations of sprat (SPR) catches. Symbol sizes proportional to the number of fish caught in the trawl.

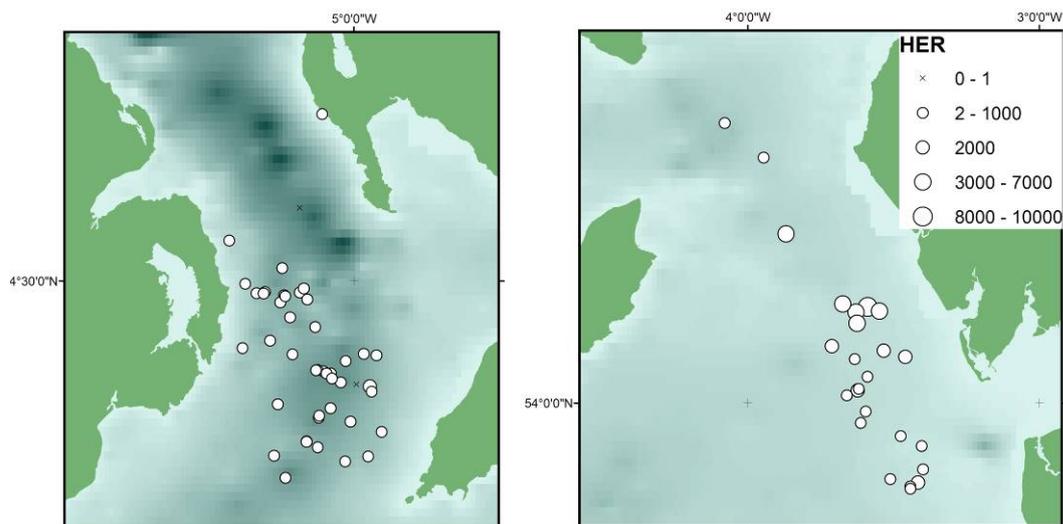


Figure 11. Locations of herring (HER) catches. Symbol sizes proportional to the number of fish caught in the trawl.

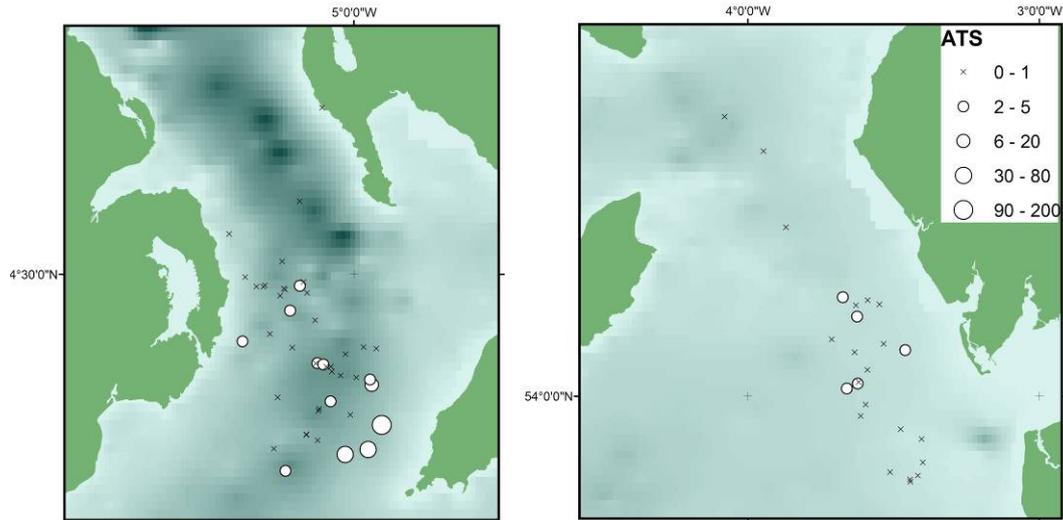


Figure 12. Locations of *Alloteuthis* squid (ATS) catches. Symbol sizes proportional to the number of squid caught in the trawl.

We examined the stomach contents of 140 herring, 70 sprat and 22 squid (16 *Alloteuthis subulata*, and 6 *Loligo vulgaris*), collected from 17 different stations (Table 4). The vast majority of stomachs of these pelagic species were empty, including all sprat and *Alloteuthis* (many of the sprat were found to have ripe or ripening gonads), all but one *Loligo*, and 132 out of 140 herring. Table 4 provides an overview, and shows the very few prey found in stomachs that contained food remains. Fish eggs were only found in 2 out of the many herring examined: the stomach of a 15.1 cm long herring (20.2 g body weight) contained 2 “cod-size” eggs; and that of a 21.2 cm herring (25.5 g) contained one “cod-size” egg, and one “plaice-size” egg.

Hence evidence that herring and sprat may act as potential cod egg predators remained anecdotal, but it should be noted that both species were abundant, and that most of the cod observed during the survey were in maturing (or hyaline) condition, and that the survey therefore probably slightly pre-dated the main spawning season.

Table 4. Overview of results from stomach contents analysis of herring, sprat and squid (*Alloteuthis subulata* and *Loligo vulgaris*) caught during the survey.

<i>Species</i>	<i>Herring</i>	<i>Sprat</i>	<i>Alloteuthis</i>	<i>Loligo</i>
<i>Stomachs examined</i>	140	70	16	6
<i>Empty stomachs</i>	132	70	16	5
<i>Stomachs with:</i>				
Fish eggs ¹	2 (4)	0	0	0
Unidentified fish ¹	2 (3)	0	0	0
Crab claw	0	0	0	1
Pink shrimp	1	0	0	0
Unidentified remains	3	0	0	0

¹ Number between brackets refers to the total number of prey items of a given type observed

3.7. Ovary and fin tissue samples collected

During the survey a total of 72 biopsy samples of ovary tissue were taken from adult female cod, to be analysed in near future for egg number and mean egg size. Each sample consisted of 104 mg (or 0.1 ml) ovary tissue, taken in triplet and stored in microtubes pre-filled with 0.1 M sodium phosphate buffered, 3.6% formaldehyde. The microtubes were labelled 121–129 (eastern Irish Sea, $N = 7$) and 130–196 (western Irish Sea, $N = 65$).

Further, a total of ... fin tissue samples were collected from male and female, adult and juvenile cod, to be analysed using molecular techniques to further insight into cod population structure. The samples were taken in support of a NERC-Defra Sustainable Marine Bioresources project. Each sample consisted of a 'fin clip' of very approximately 0.5 by 1.5 cm, and was stored in Eppendorf tubes pre-filled with a 30% ethanol solution. The tubes were labelled 178–194 (eastern Irish Sea, $N = 17$); and 113–155, 195–238 and 306–369 (western Irish Sea, $N = 147$).

3.8. Plaice tagged and released

Ninety-nine plaice that had been caught during the survey with the Portuguese high-headline trawl and observed to be reasonably lively after capture, were tagged using conventional Pedersen tags and kept in fish holding tanks for up to 4 days. They were then released at 3 locations.

The majority of plaice were tagged in the eastern Irish Sea, and released at 53°56.772'N, 3°31.033'W ($N = 83$; tags E628109–E628191). A smaller number of plaice were caught in the western Irish Sea, and the tagged individuals were released at 54°25.287'N, 5°12.640'W ($N = 14$; tags E628193–E628200 and E699520–E699525) and at 54°31.935'N, 5°17.109'W ($N = 2$; tags E699526–E699527).

Appendix 1: In search of the elusive Irish Sea cod (a diary of an SIC)

Appendix 1

In Search of the Elusive Irish Sea Cod

Narrative of survey CEND 2-07, Irish Sea, 7–18 February 2009

Georg H. Engelhard (SIC)

Prologue

We are onboard RV *Cefas Endeavour* (or: *Endeavour*, as she is usually referred to) for a 12-day survey to the Irish Sea for Defra project ‘Memfish’. The main cruise objectives are to study Irish Sea cod at known spawning grounds in February, coinciding with the spawning season. An additional aim is to study potential predators of cod eggs—there are currently very few cod around in the Irish Sea, and there is concern that cod eggs are heavily preyed upon by small pelagic species, hampering the cod stock to recover from its depleted state. A further, additional aim is to carry out tagging studies of plaice, in support of Defra project ‘Predate’. Still, we consider it as most important to get to know more about the cod’s own distribution and abundance, their condition, reproductive status, size and age composition, and simply how healthy they are. But we realise it will be a great challenge to obtain decent sample sizes of cod to allow this; and we are half excited, half worried, whether we will manage to locate the elusive, and enigmatic, species.

7 February 2009, Saturday. — *Lowestoft to Eastern Channel*

With the morning high tide of 7:17, RV *Cefas Endeavour* passed Lowestoft’s Bascule Bridge and before long steered south towards the English Channel. Onboard there are 10 scientific staff and 17 staff comprising the ship’s crew. At 9:00, a ‘toolbox talk’ was held in the ship’s lounge attended by both parties, to communicate the general outline of the cruise, what gear to be used and along what shifts to be worked, etc.

The rest of the morning was spent by the scientists to prepare the wetlab, and get all fish sorting, weighing and measuring gear sorted. Our deckmasters Ian and Mark were particularly good in getting the EDC system running allowing us the rapid entry of the vast quantities of catch data, and by the afternoon had managed to set up the wetlab’s ‘deckmaster’ pc so as to communicate with the pc up on the bridge, where the station data are being logged. Christie and Louise were very good in preparing all dissection equipment, allowing us to collect all the necessary data on the individual cod in an efficient way. Also, blank datasheets were printed, and data entry files prepared; and I had a meeting with Dave to discuss the various types of data to be collected from the cod.

Meanwhile, the ship’s crew had their hands full with the preparation of the Portuguese high-headline trawl that we will be using in our survey, but also still with storing the extensive equipment that is currently onboard *Endeavour*: because after

our survey there are 3 more surveys to be done in the west and south-west, and all equipment for each of these surveys has to be stowed, too.

The white cliffs of Dover were passed around 14:00—to the delight of our Australian team member, Kirsten. We saw much ship's traffic in this area, and I learned that ships steaming westward stay to the north, those going eastward to the south. Along the South England coast, almost every cliff, outcrop or lighthouse was pointed out to us by Jules; he has been at sea since he was 9, and this part of the Channel is like home for him. Towards darkness we were probably somewhere near the Isle of Wight.

8 February 2009, Sunday. — *Western Channel and Celtic Sea*

This morning in the Western Channel, some 20 miles south-west of Plymouth, we had our first haul—a trial haul, of course, as we are still far from the Irish Sea. It has been very useful to get the whole team going, and to move towards a routine. It took us about 3 hours to go through the entire catch, and to get everything really properly set up. We had one cod (a male), which was excellent because it allowed us, in a practical way, also to go through the dissection part of the survey.

In the afternoon I spent time with Dave to finalise the datasheets for entering, etc., based on the experience of the morning. On this survey, we're not just collecting the standard data on cod (length, weight, liver and gonad weight, sex and maturity, age), but also as suggested by Dave, a whole bunch of qualitative data, e.g. parasites, appearance, colour, thickness of lateral line, eyes intact/damaged, fins intact/damaged, etc. (the type of data he tends to refer to as 'gut feeling data'). Which is quite fun; the fact that we are unlikely to catch many cod and therefore have to collect as many data as possible on few individuals, reminds me a bit of my PhD study on elephant seals, some 10 years ago.

Around noon I talked with the captain, Bob, about where to start our survey on Monday morning when we will have arrived in the Irish Sea, but he was more than happy to refer me about this quite exclusively to Alex, our 1st officer, with whom I have indeed communicated regularly over the past weeks about our station positions. In the weeks before Christmas I've been spending some time, studying where we might be most likely to catch cod in the Irish Sea. In particular, I have looked at VMS data on the movements by UK trawlermen targeting cod—they are the ones with the best knowledge on this. In this analysis three fairly distinct areas of higher fishing activity showed up; which quite optimistically, I have labelled "cod hotspots": Area A off Morecambe Bay; Area B to the west of the Isle of Man (in what is mainly a *Nephrops* fishing area); and Area C in the North Channel.

This meeting was in late afternoon (when Alex was back on watch) and, with taking account of the weather predictions, the plan was set up to work the south of Area A (off Morecambe Bay) on Monday; spend Tuesday doing the north (which we *think* might be slightly better); and do the middle part on Wednesday. Then on Thursday, pending on our success, we'll either go back to the richest of these three, or (if we feel cod catches are very low) move over to "hotspots" B and C. "It sounds like a plan", as Bob confirmed.

9 February 2009, Monday. — *Eastern Irish Sea: South of ‘Hotspot A’*

First day in the Irish Sea; the search has begun! And I’m more than happy with the success booked so far. Although our first haul was slightly delayed (in the water around 7:30, and hauled by 8:30), we have so far (it is now 20:30) managed to do 6 hauls today, and the 7th is being shot right now. The prize: 4 amazing, big cod.

We are, as planned, in an area comprising about the southern third of the earlier mentioned “hotspot A” (off Morecambe Bay). Our tows of today provide a quite decent spatial coverage of this area, and we have focused to some extent on the sites where the trawlermen would also tend to go. Although there are several limitations to us in doing so. The Morecambe gasfields are here (with the gas stations marking off against the horizon), with many pipelines running over the seafloor in various directions. It is rather shallow here (16–26 m) so our ship can’t go everywhere we’d like to. And there is also the tide to be accounted for: ideally, our skippers Alex, Rolie and Colin trawl either with or against the tide, and not with the tide going sideways which can cause the trawl to be positioned awkwardly and not catching properly. But the vessel has excellent navigation systems, and our skippers are of course highly skilled, making these problems less of a worry for the scientists.

Our first haul (station 2) yielded no cod; it did contain very many dab in spawning condition—almost all females (the same was observed in later stations). This same phenomenon has also puzzled me before; how can these dab reproduce if there are, say, 99 ripe females to 1 (often tiny) male? And elsewhere, there may be completely male-dominated sites (as was observed last year). But while dab reproduction could still puzzle our minds during station 2, all excitement at station 3 was drawn towards a truly amazingly large, female cod.

Her weight was 10.58 kg! She was 89 cm long, and her belly round and swollen from the huge ovaries inside—which were no less than 2.5 kg heavy. Clearly, this was an individual with very large reproductive potential, and probably several millions of eggs inside. There is a certain sadness when catching a cod this size for a survey, considering their importance to keep a spawning stock in check; but it is hopeful to realise that such very large, very fertile, and apparently healthy females (no parasites or abnormalities observed at all) are around.

At station 4 (nearby 3), two cod were found also of good size: a male of 77 cm, a female of 68 cm. When comparing the 2 females, it is interesting to note how a comparatively small length increase (only by factor 1.3) translates into a much bigger weight increase (by factor 2.6), but an even bigger increase in gonad weight (by factor 3.6), again underlining the importance of the (very) large females. Concerning the males, it may be noted that our 48 cm, maturing male of yesterday had a testis weight of just under 2 g, whereas today’s, 77cm male’s testes were 302 g. — The cod caught during the second-last haul of the day weighed 4.6 kg.

So indeed, we appear to be at a spawning ground of Irish Sea cod, and although our total sample size so far is moderate, this is certainly not below what we would have expected, and those individuals that we did catch are clearly animals in spawning condition.

However, at each of these stations, rather high numbers of sprat and juvenile herring have been caught — potential predators of cod eggs...

10 February 2009, Tuesday. — *Eastern Irish Sea: North of 'Hotspot A'*

We have surveyed the northern 'box' within 'Hotspot A' in the eastern Irish Sea.

A beautiful day — weatherwise and scenic-wise. Especially in the afternoon: to the north, the sea was deep-blue; to the west, you'd see the snowy hills of the Isle of Man; to the east, and closerby, the coastal peaks of the Lake District; to the south, the sun reflected in a thousand little waves of the Irish Sea.

A poor day — cod-wise. Though not totally void of cod; in 9 hauls, we caught 2 (a 6 kg female full of hyaline eggs, and a <1 kg male). Intriguingly, throughout the area we caught lots of herring and sprat. These pelagic species forage in the water column close to the surface, where cod eggs would float; although they are known to obtain the bulk of their growth each year from eating zooplankton during spring and summer, fish eggs would be more or less the only prey available to them in February. We made a start collecting data, to allow testing the hypothesis that there may be a link between egg predation by pelagics and lack of cod recovery. In the morning I began opening up tens of sprat and herring stomachs to see what they had eaten, and also several squid (*Alloteuthis*) stomachs; and many more were checked from noon onwards by Ben and Christie.

All stomachs empty! So far, sprat, herring and squid are cleared of 'guilt', but we'll continue collecting data. Because as Dave stated it, "If there are no cod eggs floating around, sprat won't eat them." It's also a little early (the cod observed so far were not yet 'running', i.e. actually spawning). Over the next days we'll continue collecting these data, to see if anything changes either when we're entering an area with more cod, or by the time more cod will be in 'running' maturity stage.

With so few cod in the catch, dab managed to puzzle us again. Today we had several stations with, by far, more males than females: the opposite situation as yesterday when we were about 20 nautical miles south of here. Concerning plaice, I heard we also tended to have many more males than females. It may be worth checking, back home, to what extent the reproductive tactics of these two flatfish species have been studied.

[Will write something about the tagging later on, at the stage we'll release them]

11 February 2009, Wednesday. — *Finishing off 'Hotspot A' and piggy-back north*

When I entered the wetlab in the morning, I found a message placed on the whiteboard by the late-night shift team: "Station 16: herring recorded with 2 cod (?) eggs in stomach! (At the same station two cod had been caught; bringing the Irish Sea cod count at 8). Later on, a second herring was recorded with 2 cod-like eggs in the stomach. We used the stereomicroscope to have a good look at the eggs. One of the eggs in the herring of station 16 was too small for a cod egg (possibly a plaice or dab egg), but the other 3 were of the right size and shape. However, cod eggs are, even through a microscope, almost impossible to distinguish from haddock eggs; but then again, we've up to now, in this whole survey, only seen one smallish haddock (haddock are quite abundant in the western Irish Sea). In short: herring are back in the picture as potential cod egg predators, although I admit that the evidence is quite anecdotal: 3 cod-like eggs found in about 100 herring stomachs.

One wonders, though, what all these herring with empty stomachs *could* do once our cod will start to spawn. But really, we can't draw any conclusions based on this flimsy evidence. We need more data.

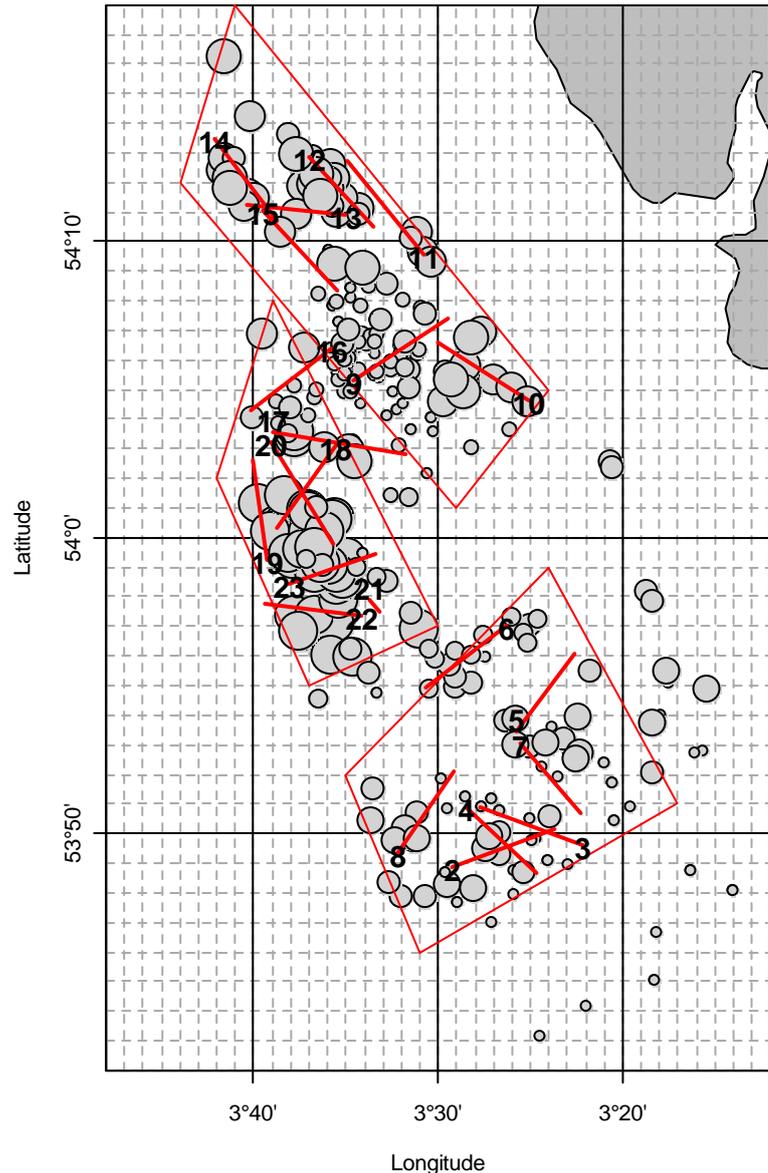
Our cod count is ticking on, little by little; today we reached the double numbers and by the 8th haul of the day, had gone up to 12. Almost all of them large or fairly large, spawn-ready cod, and often a (large or very large) female in the same haul as a (more moderate-sized) male.

"I think", suggested David, "that they're courting, which will make them more vulnerable to the trawl."

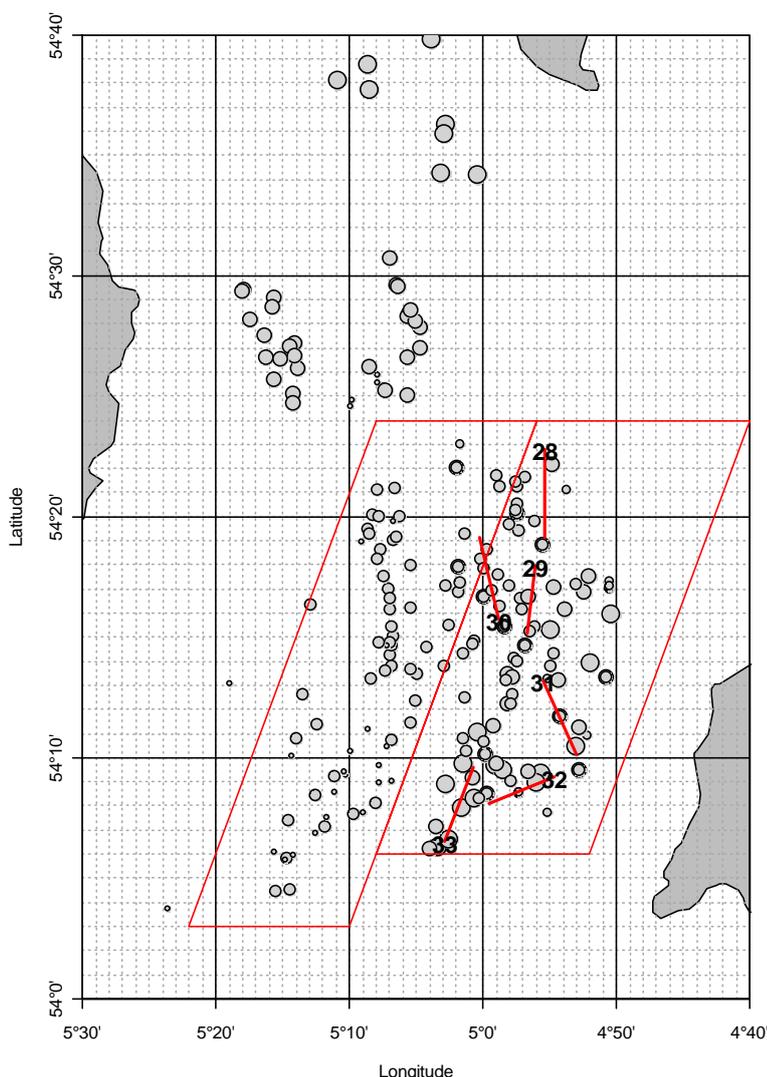
We finished the work in our 'Cod Hotspot B' (see figure) by around 17:00, after we had spent the day working in the central box. This is again an area of gasfields and some pipelines in it. Our last station in this box (nr. 23) indeed followed a pipeline and it may not be coincidental that we got two cod here. Overall this is an area with little variation in a shallow and flattish seafloor; and the pipelines may give a bit of change in this that the cod might like, and/or might give the cod some protection from the trawlers.

When station 23 was done, we started to 'piggy-back' northwards. This is what Alex calls a series of trawls and short steams all in about the same direction, working yourself in the direction you want to without wasting your time in long steams. So by the time I write this (23:25) we're well outside and north-north-west of our first study area (and have caught 2 more cod since we left the hotspot) and right now, shooting the trawl at a site where Alex remembers that Jim Ellis, about 4 months ago, had a good catch of cod. But I'll hear about that tomorrow*.

*Heard later that the station yielded 2 smallish cod.



12 February 2009, Thursday. — *First day in ‘Hotspot B’ west of Isle of Man*



Around midnight we did, after the piggy-back exercise of the evening before, the little that remained of the steam along the north of the Isle of Man that was needed to move into our second study area, ‘Hotspot B’. This is an area to the west of the Isle of Man, largely with muddy grounds, where a variety of fishing vessels target *Nephrops* but also catch cod. An eastern ‘box’ within the area (see map) was chosen as the site to be worked on the 12th.

The remainder of the night was spent by the vessel crisscrossing the area to be worked later during the day, with the multibeam running. With this acoustic device, information can be obtained about the seafloor, not only useful for the scientists but also for the skipper to see if there are any wrecks, rocks etc. that are to be avoided with the trawl. As we are often trawling at sites where the *Endeavour* has never been

before, this is a good policy to minimise the chances of having the trawl damaged as a result of running into some large obstacle on the seafloor. This exercise of running the multibeam to observe the seafloor before trawling, is repeated each night of our survey.

The 12th was, up to now, our best day in terms of cod catches! I should admit that I have lost count now, but we are somewhere in the 20s. This is a much deeper area (>70 m) than where we were previously (~20–30 m), and the cod aren’t in as beautiful a condition when the catch is being landed on deck, owing to more time spent in the trawl and the greater pressure difference. We now appear to be catching more females than males, and mainly animals with maturing gonads; we now also find some young cod of ~20–30 cm. The ‘gut-feeling’ data tell us that up to now, all cod are apparently in healthy condition; and I find that there is a good proportion of large, older fish. We have the impression that they may be a bit more common (less rare) in this area than in ‘Hotspot A’.

Whilst in the eastern Irish Sea we had observed large numbers of sprat, herring and squid in almost all catches, we now encountered far smaller numbers (though still present in all catches) of these potential cod egg predators (whether guilty or not? is

still unclear). This was a bit of a relief also to the fish sorters, as herring and sprat really are quite hard to tell apart. But to keep us challenged, we now had huge mixes of Norway pout, poor cod, bib, whiting and blue whiting. These are species that, if you have one in your hand, you can easily recognise, but if mixed together in a catch of thousands of fish, can keep you busy at the sorting table for a long time; with your fingers getting chillier and chillier.

Late in the afternoon we had a fantastic surprise. We were all sorting fish when the telephone in the wetlab rang. It was Alex from the bridge: “Just to let you know there are dolphins at port side!” I said, “Port side? That’s left isn’t it?” and ran to my team to tell them, and there we saw them, jumping in and out of the water, a pod of 10 or so! They swam with the ship for a few minutes, then they were gone, as quick as they came; but how really, really wonderful!

13 February 2009, Friday. — *Second day in ‘Hotspot B’ west of Isle of Man*

We surveyed an area west of where we were on the 12th, comprising a ‘box’ about halfway between Northern Ireland and the Isle of Man. This is also a deeper area (generally >100 m) and the seafloor seems to be mainly muddy, with a lot of *Nephrops* around. It proved our best day in terms of cod catches up to now.

Apart from that, a few rarer species were recorded. One that none of us recognised was a little ‘dog’ (small shark) of about 25 cm somewhat similar to a lesser spotted dogfish, however not with many tiny dots but with larger dark blotches on its back, also with a noticeably longer caudal fin (serrated on top), and as we later noticed, a diagnostic black mouth — a juvenile of blackmouth dogfish. We’ve saved it in the freezer to bring back to Lowestoft, and hand it over to our colleague Jim Ellis who is very interested in elasmobranchs. Further, interesting species in these deeper waters included a tiny fish called pearlsides, a <10 cm myctophid fish which can be abundant in such deeper waters; it usually reaches the surface in a somewhat smashed condition which is unfortunate, as it has a lovely pattern of light organs on each side.

In the afternoon, Louise mentioned that Dave had come up with a theory. “Remember,” he said, “how in the eastern Irish Sea we would often be catching one male and one female in the same catch, with really ripe or even running gonads. Here in this region it’s totally different. We seem to be catching virtually only females, often with maturing, but not yet running gonads. And look at all those stomachs, full of *Nephrops*, blue whiting, and prawns!” So the idea he had based on these observations, was that “clearly, this is an area with a lot of food for them – plenty of *Nephrops*, for example – and where the ladies go feeding as much as possible, ripening their gonads; but for the actual spawning, they may move over to the east, or perhaps just to shallower waters. And there they will be courted by the males.” I found it a fascinating thought, and perfectly in line with the potential of movements of these highly vagile fish (for example, cod previously tagged in the southern Irish Sea off Dublin moved all the way to the North Channel and back within a few months); and an idea that maybe worth further investigating in the future.

14 February 2009, Saturday. — *Third day in ‘Hotspot B’ and a brief visit to ‘C’*

Now we surveyed a more northerly ‘box’ within ‘Hotspot B’, to the north and north-west of where we had been the previous 2 days. Within this box, the initial

trawls of the day focused on sites of known cod fishing activity in previous years in the same season; with very much success: the first 3 hauls, for example, yielded 6, 3 and 9 cod — more than 2 full days in our eastern ‘Hotspot’. As within this ‘box’ fishing activity was only known to us for a very limited area, we soon found ourselves also trawling to the west and east of it, also with very decent success. It became our record day in terms of cod numbers.

By teatime, we were happy with our coverage of ‘Hotspot B’; but were unfortunate in that our last haul had led to a small cut in the net. This was repaired in due time by Ted, leading hand on deck; about 1½ hour was needed to do the job. We made optimal use of this ‘dead’ time by steaming over to the Northern Ireland coast to do an inshore tow close to the [] lighthouse. This is station 86 of the Northern Ireland groundfish survey: through e-mail correspondence with Pieter-Jan Schön of DARDNI, Belfast, I had learned that RV *Corystes*, a few weeks ago, had a good catch of cod here, although mainly juveniles. Now, RV *Endeavour* caught 10 cod here, too, mainly juveniles.

Now it was time to move on to our third study area, “Hotspot C”. This third area of higher cod fishing activity in the Irish Sea, as identified by my VMS analysis, is in the North Channel. The tow near the lighthouse had already brought us halfway; once that one was done we steamed over, and our first haul in the North Channel was shot at a quarter to midnight. But our visit to “Hotspot C” was to be of short duration.

15 February 2009, Sunday. — *Back in “Hotspot B” and catching lots of cod*

The first haul in “Hotspot C” was carried out over midnight, and thereafter some of the North Channel was acoustically surveyed using the multibeam (we had made a start with this also the night before). Both the haul and the multibeaming led us to believe that “Hotspot C” would not be a recommendable study area for us. Multibeaming, because Roly observed many irregularities and pinnacles on the seafloor. The haul, because the trawl caught on one of those pinnacles or on some other obstacle on the seafloor, causing 2 big cuts in the belly of the trawl; it cost Ted and his team many hours to repair it — by the time I got up at 6:00, they were still mending. Up on the bridge, I heard it from Alex: “Go back to bed, get some more sleep — they’ll need at least another hour, and I can give you a phonecall to wake you up once they’re done. For now we’re back to where we were yesterday; better catching some more cod, than spending the rest of the survey mending nets!”

Obviously, plans had to be revised, and we will now continue surveying “Hotspot B” and the surrounding region, including deeper as well as shallower sites; more or less in the vicinity of those sites where we had been most happy with our cod catches. Indeed it paid off, and the total cod count at the end of this day had climbed up to 96.

It proved an area with a fair number of conger eels around. This survey is for me the first time I’ve seen these, and my first thoughts were, “I thought such creatures got extinct by the end of the Cretaceous!” The massive serpentlike creatures reminded me of the neck and head in some popular illustrations of the ancient marine reptile, *Plesiosaurus*. But these ones were truly alive, and incredibly difficult to get hold of so slippery and wiggly as they are: and also enormously powerful. It’s a real wrestling match to catch them and lift them into the basket to weigh them, especially when you don’t yet know the way to do it, which is by holding them by their gills; if you don’t do that, they are most likely to slither out of your hands, and don’t forget that they can

give you a powerful bite. We had about ten, and all but one of these were well over 1 m in length, at least 3 over 1.5 m. The biggest one was 177 cm long, and weighed >14 kg; the second-biggest 159 cm, 12.5 kg. This means that the largest of all animals caught in the survey is no longer a cod (the very first one caught in the Irish Sea, 10.6 kg); now we have two conger eels superseding it.

16 February 2009, Monday. — *In “Hotspot B”*

An unlucky day, and especially difficult for the crew: we did several hauls in the somewhat shallower grounds near the Northern Ireland coast, but in almost each of these the net got either stuck on some obstacle on the seafloor, or dugged itself in in the mud. We had repeatedly extensive net damage, and the crew spent many hours mending the net. It is great, though, that we have the skills on board allowing us to fix such major cuts reasonably quickly, because otherwise a survey like this could have quickly come to an end. So although a considerable amount of time was lost, we still managed to get about 6 or 7 hauls done on this ‘worst’ of our days so far.

The reason for all these problems may have laid in the fact that, after my exciting discussions with David about possible differences in cod behaviour between shallower and deeper grounds, we had both become very keen in getting at least some hauls done in the shallower parts of the western Irish Sea, nearby the deeper parts where we have been so successful in catching large, maturing, and mainly female cod. Would, as in the east,