Not to be cited without prior
reference to the author

Theme Session K
Small scale and recreational fisheries surveys, assessment, and management
ICES CM 2008/K:13, 45 pp.

The status and management of thornback ray *Raja clavata* in the south-western North Sea

Jim R. Ellis*, Gary J. Burt*, Louise P. N. Cox*, David W. Kulka† and Andrew I. L. Payne*

Thornback ray *Raja clavata* is the dominant skate species in the southern North Sea (with the stock extending into the eastern English Channel) and is an important target and bycatch species for inshore fisheries in the Greater Thames Estuary. Preliminary assessments, using survey data collected during the International Bottom Trawl Survey (IBTS), indicated that the distribution and abundance of thornback ray had declined markedly in the North Sea as a whole. Although it became apparent that some of the IBTS data were compromised by confusion between thornback ray and thorny skate *Amblyraja radiata*, more recent studies still indicate a decline in the distribution of thornback ray. Despite this longer-term decline in geographical extent, survey catches in the south-western North Sea have increased in recent years. Given the general concern over the status of the stock, and subsequent management measures brought in during 2007, a one-year Fishery Science Partnership (FSP) project was initiated to collect further data on this stock, using commercial inshore vessels. The objectives were: to examine discard survival of skates caught in gillnet, longline and trawl fisheries, to determine size and species compositions of skates, and to collect other biological information. These data, including tag returns collected to date, are presented and contrasted with data from annual stock monitoring surveys (using beam trawl and GOV trawl), and from young fish surveys (undertaken on inshore vessels in the same area as our study). The benefits of dedicated inshore surveys in this area are discussed.

Keywords: discard survival, North Sea, Rajidae, skates

Contact author: Jim Ellis [Tel: +44 1502 524300; e-mail: jim.ellis@cefas.co.uk]

* Cefas, Pakefield Road, Lowestoft, Suffolk, NR33 0HT, UK

† Scientist Emeritus, Fisheries and Oceans, Newfoundland and Labrador Region, St Johns, A1C 5X1, Canada

1. Introduction

In all, 13 skate[1] species (Rajidae) have been recorded from UK shelf seas (Wheeler *et al.,* 2004), with another dozen species occurring in deepwater west of the British Isles. The most abundant species in the shallower waters of the southern North Sea are thornback ray, or roker (*Raja clavata*) and to a lesser extent, blonde ray (*Raja brachyura*) and spotted ray (*Raja montagui*). Smalleyed ray (*Raja microocellata*) and undulate ray (*Raja undulata*) are most frequently found in the Bristol Channel and English Channel, respectively, although vagrants have been reported from the southern North Sea. Other skate species occur farther north, in the central and northern North Sea, and include starry ray (*Amblyraja radiata*), cuckoo ray (*Leucoraja naevus*), shagreen ray (*L. fullonica*), sandy ray (*L. circularis*) and common skate (*Dipturus batis*) (Ellis *et al.*, 2005a).

Because commercial landings data have most often[2] been reported as "skates and rays" (some nations do report some species individually and/or have market sampling to provide species composition data), the only consistent species-specific data that have been available to the ICES Working Group on Elasmobranch Fishes (WGEF) have been survey data. To date, the exploratory assessments and advice for thornback ray have been based on data collected during groundfish surveys, particularly the IBTS surveys (ICES, 2007). Nevertheless, this is not an ideal situation, as the gear used, the Grand Ouverture Vertical (GOV) trawl, and the sampling grid of the survey were not designed to survey skates. There have also been problems with species identification, with regard to confusion between thornback ray and starry ray, also known as thorny skate (see ICES, 2007).

There have been concerns over the longer-term decline in distribution and abundance of thornback ray in the wider North Sea (Walker and Heessen, 1996; Walker and Hislop, 1998), although it is unclear to what extent this is affected by inaccurate species identification. Catch rates in fishery-independent surveys in the Greater Thames Estuary and eastern English Channel have been stable or increasing in recent years, with this evident in both the International Bottom Trawl Survey (IBTS) and the Cefas 4-m beam trawl survey (Ellis *et al.,* 2005b; ICES, 2007), and the stock is concentrated in the Greater Thames Estuary.

Given the historical decline in the geographical extent of thornback ray, with it contracting to the south-western North Sea, and that the larger bodied common skate has disappeared from the southern North Sea (ICES, 2007), ICES (2006b) advised that "*The stocks of common skates and*

[1] Within the UK, the term 'skate' is generally used for those species with an elongated snout, and the term 'ray' for species with shorter snouts. For the purposes of this paper, we use the 'skate' as the general term for all rajids, and retain the term 'ray' for the common names of the various species.
[2] From 2008, EC member states should report species-specific landings for the main skate species taken in the North Sea (CES, 2008).

thornback rays are depleted. Target fisheries should not be permitted and bycatch in mixed fisheries should be reduced to the lowest possible level. If the fisheries for rays continue to be managed with a common TAC for all ray species, this TAC should be set at zero for 2007". Subsequently, the 2007 TAC for "skates and rays" (Rajidae) was reduced and a bycatch quota was established, where *"These species shall not comprise more than 25% by live weight of the catch retained on board*" (CEC, 2006).

The south-western North Sea has a low diversity of fish species (Rogers *et al*., 1998b, 1999), with thornback ray, cod (*Gadus morhua*), sole (*Solea solea*) and bass (*Dicentrarchus labrax*) the main commercial species taken in seasonal, inshore fisheries. Hence, the 25% skate bycatch quota was particularly problematic for inshore vessels operating in the Greater Thames Estuary, because of the low diversity of other commercial species, all three main commercial species being under quota management, the high relative abundance of thornback ray in the local area, and because trips for inshore vessels in this area are usually only one day. This bycatch quota was subsequently withdrawn for smaller boats in 2008 (CEC, 2008).

Other management options that have been considered include size restrictions and closed areas (Hunter *et al.*, 2006). The Kent and Essex Sea Fisheries Committee (SFC) has a local byelaw to prevent the landing of juvenile skates, although the Eastern SFC has no comparable byelaw. Additionally, such measures only affect vessels operating within territorial waters (6 nm from shore). There has been recent interest in the potential benefits of affording protection to the larger animals within elasmobranch populations, especially as the largest individuals are typically female and that fecundity and egg size (and potentially quality) may also increase with size (see Ellis *et al.,* 2008). The creation of closed areas specifically for thornback ray could be contentious, as this would further reduce the extent of fishing grounds, given that there are already several areas that restrict fishing opportunities for other reasons (e.g. sand banks, navigation channels, and offshore wind farms).

In terms of management scenarios, some other major issues that need to be addressed are stock boundaries for thornback ray and discard survival from commercial fisheries. The latter is particularly important if measures such as bycatch ratios, size restrictions and TAC and/or trip limits are to be used.

Although there have been several earlier tagging studies on thornback ray in this area (see Walker *et al.,* 1997; Hunter *et al*., 2005a,b, 2006) and the biology of this skate species is relatively well known (see ICES Fish Map), the absence of data on discard survivorship has restricted the evaluation of potential benefits of possible management strategies. Hence there is a need for studies to examine the health and survival of thornback rays taken in UK inshore fisheries operating in the Greater Thames Estuary, and so such a project was undertaken under the Fishery Science Partnership (FSP), a Defra-funded programme that aims to build relationships between UK fishers and scientists, and to involve fishers in the co-commissioning of science.

Given that the Greater Thames Estuary is an area of regional importance to thornback ray, which is one of the most commercially important skate species in UK waters, a FSP project was undertaken in 2007/08 to:

1) examine the species, sex and size composition of skates (Rajidae) taken in inshore fisheries in the southern North Sea.
2) assess the health state/survivorship of commercially caught fish.
3) undertake a tag-and-release programme for thornback ray to inform on longer-term survival

This paper highlights up to date results from this FSP project, and also summarizes other relevant survey work being undertaken in the area (including IBTS surveys, and national beam trawl and young fish surveys). These data are contrasted, and the merits and limitations of the various surveys for informing on the status of thornback ray in the Greater Thames Estuary are discussed.

2. Material and Methods

Data presented here originate from a Fisheries Science Partnership project examining thornback ray in the Greater Thames Estuary, and also in summary from a Young Fish Survey operating in a similar area, and an annual groundfish survey (using a 4-m beam trawl) in the eastern English Channel and southern North Sea.

2.1 Fisheries Science Partnership

During the course of the FSP study, seven one-day trips were undertaken on five inshore fishing vessels (detailed below and summarized in Table 1), in order to (a) gauge the differences between the gears used by the various components of the inshore fleet, and (b) to cover wider parts of the Greater Thames Estuary (Figure 1). Gear deployments (tow length, soak time) were of commercial duration wherever practicable during these trips, with the exception of some fixed gillnet studies, for which the soak times were mostly 24 h. Commercial fishing with these gears would normally leave nets to fish for 30–48 h, depending on tidal state and location of fishing grounds[3].

For each gear deployment, the positions (latitude, longitude, depth and times) were recorded. Once the catch was made, the total length (L, to the cm below), sex and health state of the skates (1: lively, 2: sluggish; or dead) were recorded. The maturity of male skates was assessed by visual inspection of the claspers (Table 2). If a skate had a large part of the end of the tail missing, then disc width (D) was recorded, and the total length estimated using the length-width relationship, as given by the relationship: $D = 0.693.L – 0.248$.

Skates were tagged using numbered Petersen discs (Figure 2). The tags were placed in the centre of the wing, because if placed too near the margin, they can be snagged on fishing nets and pulled out. Smaller skates (<30–35 cm) were not generally tagged, because allowing sufficient space for the growth of the fish would likely result in the tag snagging. Release and recapture data were stored on the Tagged Fish database (Burt *et al*., 2006). Owing to the size of the vessels involved in the fishery and the fishing locations, the utility of examining short-term survival using holding tanks was limited, although such studies were undertaken during complementary studies in the Bristol Channel (Catchpole *et al.*, 2007).

Gillnet studies: Trips on the *T-Rex*, an inshore gillnetter operating out of Ramsgate[4], were undertaken in June and July 2007, and used five nets. Two were gillnets, one made from single

[3] Kent and Essex Sea Fisheries Committee byelaws state that "*No fixed net shall be left uncleared for a period of more than 30 hours, although an exemption will be granted in the case of bad weather, illness of the crew or engine failure*".
[4] Place names mentioned in the text are shown on either Figure 1 or Figure 19.

monofilament and one from multi-strand monofilament. The remaining three nets were all trammelnets. Lengths of the nets ranged from 800 to 1 000 m. All the mesh sizes were 26.3 cm. In all, 34 sets were fished successfully. The *Jolene* undertook studies with gillnets during February and March 2008, operating off the Suffolk coast. Stations were generally fished with drift trammelnets (100 mm inner mesh, 600 mm outer mesh, 40 meshes deep (inner) and 366 m long), with some stations sampled with static 'roker' nets (180 mm mesh size, 30 meshes deep, 366 m long). Stations were fished with 1–3 nets. In all, 27 stations were fished (23 with drift trammelnet and four with static nets). Drift trammelnets generally had a soak time of 1–3 h, with static 'roker' nets left overnight.

Trawl studies: Three small inshore trawlers were used, the *Harvester* and *Jessica M* operating out of West Mersea, and the *Janeen* operating out of Leigh-on-Sea (Southend). Studies on the *Harvester* and *Jessica M* used twin-rig trawls in June 2007 and, in all, 33 and 36 stations were fished successfully, respectively. Studies on board the *Janeen* were conducted between August and December 2007, using a triple rig trawl and 53 stations were fished successfully.

Longline studies: The *Jessica M* undertook a series of trips using longline, with some days in summer 2007, and the remaining days in January and February 2008. The gear used was a longline 3,700' (ca 1,128 m) long, with about 750 hooks per line (traces about 18" (46 cm) long, and 6/0 hooks baited with squid). In all, 11 gear deployments were fished successfully. Soak times were generally 1.5–2 h. The *Jolene* operated out of Orford, and work on this vessel was undertaken during February 2008, with 12 stations (strings of line) fished each day, and each station fished with 1–9 baths[5]. In all, 11 stations were fished successfully. The gear used was a demersal longline. Each bath of longline contained up to about 720 yards (660 m) of line with about 225–270 hooks per bath. Traces were 27" (68 cm) long and baited with squid (*Loligo* or *Illex*).

2.2 Young Fish Survey

The primary objective of the Young Fish Survey (YFS) is to provide abundance indices for juvenile demersal fish in the North Sea for, in particular 0-group and I-group plaice and sole, prior to their recruitment to the fishery (Rogers *et. al.*, 1998a). The survey has been conducted annually since 1981. Currently, the survey samples the inshore, coastal waters of the central North Sea (ICES Division IVb) from the River Humber to the north Norfolk coast, and the Greater Thames Estuary in the southern North Sea (ICES Division IVc). These areas are fished annually between late August and early September, coinciding with the period when the 0-groups have recruited to the shallow nursery grounds in high numbers. Data from the survey also provide valuable information on the

[5] Inshore longliners in the area store individual baited lines (each ca. 560–660 m long, depending on the diameter of the line) in metal 'baths', and these lines are then connected to each other during shooting.

relative abundance and spatial distributions of other commercial and non-commercial species. The geographic coverage of the YFS has changed over time, although the Greater Thames Estuary has been surveyed continually over this period.

The YFS is divided into sectors (mini-areas), which are based on geographic features, and there are three mini-areas in the Greater Thames Estuary (the inner estuary, as well as the northern and southern sectors of the outer Thames). There are 80 fixed stations sampled annually in the Greater Thames Estuary, and each fixed station is assigned to a depth stratum.

Small inshore vessels are chartered for the survey. Fishing is conducted during dayight. A 2-m wooden beam trawl, rigged with three tickler chains and a 4 mm mesh liner, is towed with the tide for 10 minutes, covering a distance of ca. 450 m. The gear normally catches only small fish <150 mm, and most sampling is undertaken in waters of 3–20 m. Environmental observations are also made at each station and, in recent years, a more accurate distance towed has been estimated using a hand-held GPS.

On completion of the tow, the finfish catch is sorted to species level (although sand gobies, *Pomatoschistus* spp. are only recorded to genus). For excessive quantities of fish caught of a particular species, the catch for that species is sub-sampled and the raising factor noted. All finfish are measured to the half centimetre below.

The catches of fish were converted to a standardised catch per unit effort (CPUE) based on the number per swept area (1 000 m^2), and the mean calculated for all valid tows.

2.3 Beam Trawl Survey

The eastern English Channel beam trawl survey uses a standard 4-m beam trawl with a chain mat, flip-up rope, and a 40 mm codend liner to retain small fish. The gear is towed at 4 knots (over the ground) for 30 minutes, averaging 2 nautical miles per tow. Fishing is only carried out in daylight. Further details of the gear are given in Kaiser & Spencer (1994) and the survey described by Kaiser *et al.* (1999) and Parker-Humphreys (2005). Surveys in the eastern English Channel and southern North Sea started in 1989, although the fixed station survey grid has only been standardised since 1993. This annual survey is conducted during July/August. All fish species are measured to the cm below. Only those fixed stations fished for more than 11 of the 15 years were included for the calculation of the mean annual CPUE, with these calculated for both the eastern English Channel (VIId) and southern North Sea (IVc).

3. Results

3.1 Fisheries Science Partnership

3.1.1 Species composition

Overall, three species of skate were recorded during the surveys: blonde ray, spotted ray and thornback ray, with the last species dominant, accounting for almost all of the skates caught (by number) in the study area within periods, by gear and vessel (Table 3). Spotted and blonde ray were of minor importance on these fishing grounds[6].

3.1.2 Sex ratio

Uneven sex ratios were observed during most surveys, especially in terms of females dominating the largest length category (Table 4). The smallest size category (<50 cm) generally exhibited an equal sex ratio, although the trawl survey on the *Janeen* caught significantly more females. The intermediate size category (50–74 cm) usually had similar proportions of males and females, although line catches on the *Jolene* and trawl catches on the *Janeen* comprised significantly greater proportions of males and females, respectively. The largest size category (≥ 75 cm) always contained significantly more females.

3.1.3 Length composition

The length distributions of thornback rays caught in the seven surveys are illustrated in Figures 3–5. Gillnet surveys (Figure 3) on the *T-Rex* caught few small fish. The overall length range observed was 42–97 cm, and nearly 90% of the specimens were 60–90 cm inclusive. Given the large size of fish in this survey, there were no discernible peaks in the length distribution. Gillnet surveys on the *Jolene* used a combination of drift trammelnets (typically used for sole) and roker nets, so a greater proportion of small fish was taken. The overall length range recorded in this survey was 23–87 cm, with a peak at 33–47 cm, and no obvious peaks in larger size classes.

Trawl surveys (Figure 4) on the *Harvester* and *Jessica M* were undertaken at the start of summer, and at that time of year there were few fish at a length that would correspond to 0-group[7], and only three fish at 14 cm. The first main peaks in the size distributions were at approximately 17–33 cm

---

[6] Commercial fisheries operating to the north of the study area land both these species in higher proportions than observed on these grounds.

[7] No associated age data were collected. Thornback rays can be aged by examination of the vertebrae or caudal thorns, and published accounts of the age and growth are available (Holden, 1972; Holden and Vince, 1974; Ryland and Ajayi, 1984; Brander and Palmer, 1985; Walker, 1998; Gallagher *et al.*, 2005; Whittamore and McCarthy, 2005).

and 35–50 cm in both surveys. Trawl surveys on the *Janeen* were conducted towards the end of summer, and accordingly there was a greater number of 0-groups observed, with peaks at 11–23 cm, 25–43 cm and 44–54 cm. The largest thornback rays sampled in these three trawl surveys ranged from 89 to 91 cm.

Longline surveys (Figure 5) on the *Jessica M* sampled fish of 41–99 cm, with 90% of fish 50–85 cm. Given the relatively small sample size (n = 110) and large size of fish, there were no discernible peaks in the length distribution. Longline samples from the *Jolene* also comprised mostly larger fish. Once again >90% of thornback rays were between 50–85 cm inclusive, and the overall size range (39–95 cm) was similar to that observed from line catches on the *Jessica M.*

Overall, trawl surveys sampled the widest length range of fish, with an overall length range of 11–91 cm, with gillnets and longlines selecting more larger fish (Figure 6).

3.1.4 Distribution and relative abundance

Thornback ray was common throughout the area surveyed by the *Harvester* (Figure 7) and *Jessica M* (Figure 8). Smaller fish were more abundant in the shallower northwestern part of the survey area, and larger fish were more common at the more offshore sites of the survey area. Comparable patterns were seen on the area surveyed by the *Janeen*, with smaller fish abundant at the inshore stations and larger fish taken further offshore (Figure 9).

Catch rates on longlines were generally low off West Mersea, with 2–16 thornback ray per line, and catches were comparable throughout the area surveyed (Figure 10). Thornback rays were taken on longlines throughout the area surveyed by the *Jolene* (Figure 11), although none were recorded at the site where only one line was shot. Elsewhere, catch rates of small thornback rays (<50 cm) ranged from 0.2 to 6.3 per bath, and juveniles were more frequent on the inshore stations. Catch rates of thornback rays in the 50–74 cm size group were the most commonly encountered (5.4–38.5 per bath), with smaller quantities of the ≥75 cm size group (0.6–7.4 per bath). Overall catch rates ranged from 6.4 to 50.5 thornback rays per bath of line.

Thornback rays were also taken on these fishing grounds while gillnetting on the *Jolene* (Figure 12), with good numbers of fish in the <50 cm and 50–74 cm length groups. Fewer large fish (≥ 75 cm) were taken. Thornback rays were common throughout the area surveyed by the *T-Rex* (Figure 13), although catches of smaller fish were too low (due to a low gear selectivity) to identify areas of importance for juveniles.

3.1.5 Health state

Although no data on short-term survival could be collected during these surveys, the health of each fish on capture was recorded on a qualitative scale (lively, sluggish, dead). For most surveys, the fish were caught using traditional fishing practices (i.e. in terms of tow duration or soak time), although it is acknowledged that the soak times during some of the studies using roker nets were generally 24 h (instead of the commercial 30–48 h).

All studies (Table 5) indicated that most fish appeared in a good state of health (in terms of little bruising; and the spiracles, gills, mouth, wings and tails all showing regular movements). Comparisons between surveys are restricted to qualitative descriptions, because different observers may have slightly different perceptions regarding lively/sluggish categories.

Of the 937 thornback rays caught by the *Harvester*, 591 (63.1%) were considered lively at the point of tagging, 323 fish (34.5%) were considered sluggish and 22 individuals (2.3%) were dead. Health was unrecorded for one fish. Visual assessment of health suggested that the two larger size categories (50–74 cm and ≥75 cm) were in better condition (74.1% lively; 25.5% sluggish; 0.2% dead) than fish <50 cm (51.8% lively; 43.6% sluggish; 4.5% dead). Of the 1 125 thornback rays caught on the *Jessica M*, 1 122 (>99%) were considered lively at the point of tagging, with three fish considered sluggish and no dead individuals reported. This visual assessment of health was consistent across all length classes. Similar results were also recorded on the *Janeen,* where 1 608 (91.3%) of the 1 761 thornback rays caught were considered lively at the point of tagging, 152 (8.6%) were considered sluggish, and only one individual was dead. Visual assessment of health also suggested that the two larger size categories (50–74 cm and ≥75 cm) appeared to be in better condition (96.9% lively; 3.1% sluggish) than fish <50 cm (85.7% lively; 14.2% sluggish).

Longline studies indicated that thornback rays were generally lively. Of the 110 thornback rays caught on the *Jessica M*, 104 (94.5%) were considered lively at the point of tagging and six (5.5%) were rated as sluggish. Owing to the large numbers of thornback rays caught while lining on the *Jolene*, the health could only be recorded for those fish being tagged and released (or released untagged shortly after capture). In total, the health was recorded for 707 thornback rays, of which 690 (>97%) were considered lively at the point of release and 17 (2.4%) as sluggish. A few individual thornback rays had mouths that were obviously damaged during capture. Some of those with minor damage to the mouth were tagged (n = 10) and released, although fish exhibiting greater damage were not tagged. Given that attempts were made to land thornback rays in as good a condition as possible, accurate figures indicating the proportion of fish that would suffer severe damage to the mouth (or in very rare instances, the body cavity) are not available, so the health should be viewed as a best-case scenario. It should also be noted that skates and dogfish with evidence of prior capture by hook and line (e.g. broken jaws) were observed, but with these earlier wounds healed.

Of the 445 thornback rays caught by gillnet on the *T-Rex*, 436 (98%) were considered lively at the point of tagging, and nine (2%) were dead. Eight of the dead fish were in the 50–74 cm length category, with only one fish in the largest length group (≥ 75 cm) dead. Studies on the *Jolene* generally used drift trammelnets with 2–3 h soak times, because only small numbers of thornback ray were captured in roker nets set overnight. The health records suggested that most (*n* = 388, 73%) were lively, and the remaining fish (*n* = 142, 27%) sluggish. No dead fish were recorded. These values were on a similar scale for the various size categories (<50 cm length class: 78% lively, 22% sluggish; 50–74 cm length class: 69% lively, 31% sluggish; and ≥75 cm length class 89% lively, 11% sluggish).

3.1.6 Tag and release information

In all, 4 152 thornback rays were tagged and released across the seven surveys, most were tagged following capture by trawl (*n* = 2 481, 60%), with 912 (22%) and 759 (18%) tagged following capture by gillnet and longline, respectively. Slightly more female thornback rays (57%) were tagged than males (43%). Most thornback rays tagged and released were 50–74 cm (ca. 60%), with the <50 cm and ≥ 75 length groups accounting for 23% and 17% of the releases, respectively (Table 6).

Reported recaptures[8] of thornback rays tagged in 2007 ranged from 6.5–15.5%. Return rates from gillnet studies on the *T-Rex* were 6.5%, with returns from the three surveys on trawlers ranging from 6.6–15.5%, although it should be noted that fish tagged on the *Janeen* have been at liberty for less time, which will influence the return rate. Although only few fish caught by longline on the *Jessica M* were tagged and released in summer, 12.8% have been recaptured (Table 7). Fish tagged in winter 2008 have not been at liberty for a sufficient time to allow a meaningful analysis of recaptures, although small numbers have already been returned. Once again, longlines have yielded slightly greater proportions of returns; 5.2% and 9.5% on the *Jolene* and *Jessica M,* respectively. Gillnet studies on the *Jolene* used mostly drift trammelnets with short deployment times, and the return rate is currently 5.2%.

Most fish recaptured were caught in the Greater Thames Estuary, with small numbers of fish taken elsewhere in the southern North Sea (ICES Division IVc) and in the eastern English Channel (VIId). The recaptures from the various surveys are illustrated in Figure 14.

[8] All recapture information extracted from the Tagged Fish Database on 30 July 2008

3.2. Results from the Young Fish Survey

3.2.1 Species composition and length distribution

Thornback ray was the only skate species caught during the YFS in the Greater Thames Estuary from 2000 to 2007. During this time, 166 thornback rays were captured. Most were relatively small with a modal total length of 12 cm (Figure 15). The length distribution showed two peaks, one between 10 and 15 cm, which corresponds to the 0-group, and another between 24 and 38 cm. Very few fish >38 cm were caught, reflecting the selectivity of the gear, although one of 80 cm was recorded.

3.2.2 Spatial distribution and relative abundance

The spatial distribution and relative abundance, expressed as a mean catch (No. / 1000 m^2) over the period is given in Figure 16. Thornback ray were distributed throughout the survey area at both inshore and offshore locations. The larger catches were encountered at the more inshore locations, highlighting the importance of these shallow areas as nursery grounds for this species. The three sites where thornback rays occurred in high abundance were off the coasts of West Mersea, Isle of Sheppey and Margate, with the greatest mean catch rate (1.47 fish 1000 m^{-2}) off West Mersea. Thornback rays were not recorded at stations nearer the mouth of the River Thames, west of Southend-on-Sea.

3.2.3 Trends in relative abundance

The number of valid stations completed each year, the mean annual relative abundance (CPUE) and the percentage occurrence of thornback ray in the YFS are summarized in Table 8. Over the eight-year period an average of 79 valid stations was completed annually. The mean annual CPUE was relatively low, and varied between 0.15 and 0.51 fish / 1000 m^2, with a mean of 0.28. Catch rates have remained relatively constant over the period, although there was a marked increase in both the CPUE and percentage occurrence in 2007 (Figure 17).

3.3. Results from the Beam Trawl Survey

3.3.1 Species composition and length distribution

4-m beam trawl surveys highlight the regional importance of the south-western North Sea for thornback ray, with this species accounting for nearly 93% (by number) of the skates recorded in Division IVc, with spotted and blonde rays accounting for 5.9 and 1.3% respectively (Table 9). Within the eastern English Channel, thornback ray is still the major skate species (accounting for 79% of the skates observed), with spotted and blonde rays both accounting for greater proportions of the skate fauna (in contrast to the southern North Sea) and other skate species, such as smalleyed ray and undulate ray, appearing more frequently.

The length distribution of thornback ray taken in the beam trawl survey (10–93 cm) indicates that juveniles are mostly caught in this survey (Figure 18), with >95% of records for fish <70 cm total length. This will be partly related to the importance of these inshore areas as nursery grounds for thornback ray, but will also be due to the size-selectivity of this gear.

3.3.2 Spatial distribution and relative abundance

The spatial distribution and relative abundance, expressed as the mean catch ($n.h^{-1}$) over the period, from this survey (Figure 19) indicates that thornback rays are widely distributed throughout the area, with the largest catches encountered at inshore locations, including the Greater Thames Estuary, south coast of England (off Dungeness, Brighton and Isle of Wight) and parts of the French coast (Baie de Somme). Catches were lower in the deeper parts of the Channel and in the Baie de Seine. Although the 4-m beam trawl can achieve high catch rates (up to 100 fish per h in this survey), this gear typically samples smaller sized fish (see above).

3.3.3 Trends in relative abundance

Catch rates ($n.h^{-1}$) for this survey (omitting data collected prior to 1993, and only including those fixed stations fished at least 11 times during the 15 year time series, 1993–2007) are summarised in Table 10 and illustrated in Figure 20. Catch rates of thornback ray in VIId have remained broadly stable in recent years. Catch rates in the southern North Sea have increased in recent years, although it must be remembered that there have been a limited number of stations fished routinely there. An increased number of sampling stations have been fished in recent years, and these data will be examined in future studies.

4. Discussion

Thornback ray is the most abundant skate (Rajidae) in the south-western North Sea, and within the Greater Thames Estuary can account for some 93–100% of the skate catch, depending on the gear and location. Spotted and blonde rays are of lesser importance, although may be proportionally more common in localised areas within this ICES Division. Other skate species, such as undulate and smalleyed ray, are occasional vagrants to this area from the English Channel. Cuckoo ray and starry ray occasionally occur in the southern North Sea, but the main North Sea stocks of these species are further north. In terms of biomass, thornback ray is one of the major species in the Greater Thames Estuary, so could be an important within the trophic structure of this ecosystem. They prey primarily on decapod crustaceans (shrimps and brachyuran crabs), with larger individuals also consuming fish (Ellis *et al.*, 1996), although recent studies on their feeding habits in the Thames are lacking.

Thornback rays aggregate by sex and size, and more study to better delineate (in space and time) sites of importance to the mature female component of the stock could usefully be undertaken. It is evident that juvenile thornback ray are widespread in the shallower waters of the Greater Thames Estuary and along the Channel coast of Southern England (see also Ellis *et al*., 2005a), although the location of any sites where the egg-cases are deposited on a regular basis are still to be identified. Thornback ray is an oviparous species, laying 38–66 eggs per year (Ellis & Shackley, 1995; Chevolot *et al.*, 2007), and whereas some oviparous elasmobranchs are thought to have specific spawning beds (see Ellis *et al*., 2005a for an overview), it is not known whether there are specific spawning grounds for thornback ray.

To date, the assessments undertaken by the ICES WGEF have mostly used survey data from the IBTS surveys (ICES, 2007, Figures 21–22). The gear used in these surveys is the GOV trawl (Grand Ouverture Vertical). Although the catch efficiency for skates is not known, catchability in the IBTS series is consistent over time and thus provides a broad picture of the population trends and distribution of thornback ray. Figure 21 shows not only that thornback rays are concentrated mainly in the south-western North Sea but that its range has diminished in recent years. Present total area occupied by thornback ray is only 44% of the extent of the species in the 1980s (Figure 21). However, the area of high concentration around the Greater Thames Estuary has increased slightly (ICES 2007). Since 1980, the IBTS abundance trend did not decline but rather fluctuated and during more recent years has increased (Figure 22). Trends in survey catch rates in the Greater Thames Estuary (where thornback ray concentrates) closely resembles the overall IBTS trend in abundance, Thus, loss of areas previously occupied having had very low concentrations or fish, had little affect on overall population abundance. Nonetheless, disappearance of thornback ray from a part of its range in the North Sea, particularly post-1996 (see Figure 21), is of concern. This reduction is not likely related to bottom water temperature since the North Sea has been warming in recent years (ICES, 2008).

The IBTS survey is designed to cover the entire North Sea, and thornback ray are distributed over only a small portion of that area. As a result, the density of stations in this area is comparatively low (Figure 23). This is particularly evident in the Q3 IBTS survey, where only Denmark and England sample the southern Bight, and the main area for the stock (south of 52.5ºN and west of 3ºE) is only sampled by five hauls. This area is sampled more in the Q1 IBTS survey, during which 12 hauls can be made. In neither survey are the inshore waters of the Greater Thames Estuary (ICES Rectangles 31F0 and 32F0) sampled. There is a similar lack of sampling in the inner parts of the Wash (ICES Rectangle 34F0) and low density of sampling stations around the coast of Norfolk, another important ground for thornback ray.

The 4-m beam trawl survey undertaken by Cefas has reasonable coverage of the south-western North Sea, with stations along the Suffolk coast and in the outer reaches of the Greater Thames Estuary sampled. However, the shallower waters of the Greater Thames Estuary are not sampled, and sampling has only occasionally been undertaken north of Lowestoft (see Figure 1). The beam trawl used seems to be reasonably effective for sampling juvenile skates, at least in contrast to the GOV trawl, although the catching efficiency for larger fish may be low with this gear. Hence, this survey may not be optimal for any longer-term monitoring and biological sampling of mature fish.

To some extent, the paucity of stations in the inner parts of the Greater Thames Estuary is unavoidable, as the shallower water, presence of sand banks and shipping lanes restricts sampling opportunities for larger research vessels. Hence, there could be benefits of using inshore, commercial vessels for sampling this stock, if managers wish to better ascertain the status of thornback ray in the south-western North Sea.

Fisheries in the southern North Sea are reliant on comparatively few finfish species. Although some inshore vessels may also engage in shellfish fisheries (e.g. potting for edible crab *Cancer pagurus,* lobster *Homarus gammarus*), the three main commercial finfish species for the UK fleet (sole, cod and thornback ray) together constitute >70% of demersal fish landings in ICES Division IVC (Table 11). Other fish species, such as spurdog *Squalus acanthias* and bass can be seasonally important, and in recent years species such as red mullet *Mullus surmuletus* and smoothhounds *Mustelus* spp. have been more frequently caught. The seasonality of the fisheries and the reliance on comparatively few species means that fisheries managers should consider all three main species when addressing management plans, and not consider each species in isolation.

In terms of management actions for thornback ray, bycatch ratios can be problematic. During 2007, when the 25% bycatch limit affected inshore vessels, some vessels are thought to have mis-reported the landing area (the bycatch limit affected sub-area IV, but did not affect the adjacent eastern English Channel (VIId), into where the stock distribution extends). Additionally, as the bycatch quota was based on the fish retained on board, there were instances when vessels retained non-commercial species (e.g. lesser-spotted dogfish *Scyliorhinus canicula*, smoothhounds, etc.) in order to be able to land catches of skate, but would later dump the non-target fish. Furthermore, although bycatch limits may encourage larger vessels to seek alternative fishing grounds following capture of large quantities of skate (at least in theory), inshore vessels undertaking one-day trips do not necessarily have the ability to switch grounds.

The inshore fleet certainly has the capacity to release unwanted skates alive, especially in terms of longliners, inshore trawlers and driftnetters, although the mortality in roker nets left for 30-48 h is potentially high. Fish observed on capture were generally in good condition, and the overall recapture rate[9] of 7.9% (ranging from 5.2–15.5% for the various gears and vessels) would indicate that the longer-term survival is good. Smaller fish were not usually tagged in this study (as leaving sufficient room between tags to allow for growth could have made the tags more prone to snagging), although smaller fish were mostly considered as healthy. Longlines and roker nets were more size selective, with the youngest fish not captured in either of these gears. Although small thornback rays were taken in otter trawls and drift trammelnets, the short soak times used for these gears by the inshore fleet would improve discard survival. Studies on the discard survival of skates captured by other fleets such as beam trawlers, which have longer tow durations, are still required.

Tagged fish have been at liberty for <14 months, and so analyses of longer term movements are not currently possible. Reported recaptures indicate that most thornback rays are taken in the Greater Thames Estuary, although smaller numbers of fish have been taken in the wider southern North Sea and eastern English Channel. This would seem to support the view that the southern North Sea stock of thornback ray extends into VIId, as indicated by earlier tagging studies (Walker *et* al., 2007) and genetic studies (Chevolot *et al.*, 2006). Although thornback ray are widely distributed along the coast of East Anglia, from the Thames to the Wash, there have been no reported recaptures from the north Norfolk coast, supporting earlier studies. Further tagging studies could usefully be undertaken in this area to better ascertain the stock structure and degree of mixing.

The local thornback ray stock is now clearly concentrated in the Greater Thames Estuary, although fish tagged there do seem to move more widely around the southern North Sea (Hunter *et al.*,

[9] It should also be recognised that the reported recaptures are considered under-estimates, as it has been reported that some commercial fishermen are not returning tags, as they are wary that the data will be used to estimate fishing mortality.

2005a). Initial studies conducted by WGEF (ICES, 2002) were compromised by poor species identification in survey data, although more recent studies still indicate that thornback rays are caught less frequently in the western parts of the Central North Sea (ICES, 2007, Figure 21). Hyper-aggregation has been observed in overexploited stocks; for example, northern cod were caught in enhanced densities while the biomass was in decline (Rose and Kulka, 1999). However, given that the decreased spatial extent of thornback ray has affected areas where only low densities were observed in the past, the two situations seem to be rather different, and thornback rays may not be hyper-aggregating. Nevertheless, that the thornback ray fishery is based on a stock with a restricted distribution means that an appropriate management strategy needs to be in place to preclude localized depletion from taking place.

In terms of the implications of any management actions, it is also important that managers consider the implications of fisheries interactions, especially with regards the triumvirate target species of sole, cod and thornback ray. For example, measures that restrict the use of roker nets could lead to inshore netters diverting to smaller-mesh gillnets aimed at sole, though this may still have a bycatch of juvenile thornback rays.

Existing management measures include TAC and quota regulations (CEC, 2008) and, in some inshore areas, a minimum landing size (MLS). Quotas restrict landings rather than catch, but the whole issue is more important for fisheries in which discard mortality is high. Given the short tow duration used by inshore trawlers, discarded thornback rays should have reasonably good survival (depending on fisher behaviour, in terms of the time taken for unwanted fish to be discarded). Similarly, the short soak time associated with longline and drift trammelnet fisheries should facilitate juvenile and other unwanted skates to be discarded alive (although hook damage in line fisheries does occur). Other gillnet fisheries may have a higher discard mortality, especially when soak times are 30-48 h. At this point in time, discard survival in offshore trawl fisheries (e.g. the beam trawl fleets), where tow duration can be longer, is unclear and will depend on factors such as catch weight and composition, and tow duration.

The bycatch ratio for trips used in 2007 was an unpopular measure with commercial fishermen, not only because it limited catch, but also in terms of the practicalities for inshore vessels operating on one-day trips. Bycatch ratios result in fishermen needing to balance the denominator and a numerator, so can have wider ecosystem implications (e.g. increased retention of non-target fish). Additionally, the practicalities of deciding which fish to retain during the course of the day and guessing what might be caught in subsequent hauls can lead to a fisherman either landing fish illegally, or discarding dead fish at the end of the day.

Size restrictions could potentially be applied to thornback rays, with strong biological rationales for protecting the smaller juveniles (e.g. with a MLS) and the larger females (e.g. through a maximum landing length (MLL)). Although commercial fishermen often view the former measure positively, a MLL could (depending on the selected size) be unpopular because of the perceived loss of income. Therefore, further demographic modelling needs to be undertaken to ascertain better the potential benefits of size restrictions.

Marine protected areas (MPAs) have been suggested as potentially effective measures to protect elasmobranchs (e.g. Bonfil, 1999), especially when there are important life-history stages in a defined area. Some skate species are thought to have specific spawning grounds that are occupied regularly, as indicated by the presence of high densities of egg cases (e.g. Hitz, 1964; Hoff, 2008), and such sites may benefit from spatial and/or temporal restrictions on damaging human activities. There are extensive nursery grounds for thornback ray in the Greater Thames Estuary, and adults do make repeated migrations to the area (Hunter *et al*., 2005b), but the existence and/or location(s) of oviposition sites have not been determined, so more research on this issue is required. It should also be noted that the Greater Thames Estuary is an important site for other human activities (e.g. navigation, offshore wind farms) and has a network of sandbanks, so there are several areas where fishing activities are already restricted. Hence, the potential benefits to thornback rays from such 'closed areas' should be evaluated before designing alternative MPAs.

Given the above, effective management of this commercially valuable stock will be challenging, but from ecosystem and biodiversity perspectives, is crucial.

Acknowledgements

We thank the skippers and fishermen who assisted with the FSP Thames skate tagging project, who participate in the Young Fish Survey, and who have returned tags. Additional thanks to the scientists who have participated on the various surveys, Mary Brown for assistance with the illustrations, and Beatriz Roel for commenting on this manuscript.

References

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.

Bonfil, R. (1999). Marine protected areas as a shark fisheries management tool. Proceedings of the 5th Indo-Pacific Fish Conference, Nouméa, 1997 (B. Séret and J.-Y. Sire, eds), 217–230.

Burt, G., Goldsmith, D. and Armstrong, M. (2006). A summary of demersal fish tagging data maintained and published by Cefas. *Science Series Technical Report, Cefas Lowestoft*, **135**: 40pp.

Catchpole, T.L., Enever, R. and Doran, S. (2007). Bristol Channel ray survival. Cefas, Lowestoft, *Fisheries Science Partnership Report* **21**, 15 pp.

CEC (2006). Council Regulation (EC) No 41/2006 of 21 December 2006 fixing for 2007 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.

CEC (2008). Council Regulation (EC) No 40/2008 of 16 January 2008 fixing for 2008 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.

Chevolot, M., Ellis J.R., Hoarau, G., Rijnsdorp, A.D., Stam W.T. and Olsen J.L. (2006). Population structure of the thornback ray (*Raja clavata*) in British waters. *Journal of Sea Research,* **56**: 305–316.

Chevolot, M., Ellis J.R., Rijnsdorp, A.D., Stam W.T. and Olsen J.L. (2007). Multiple paternity analysis in the thornback ray *Raja clavata* L. *Journal of Heredity*, **98**: 712–715.

Ellis, J.R., Clarke, M.W., Cortés, E., Heessen, H.J.L., Apostolaki, P., Carlson, J.K. and Kulka, D.W. (2008). Management of elasmobranch fisheries in the North Atlantic. In *Advances in Fisheries Science. 50 years on from Beverton and Holt* (A.I.L. Payne, A.J. Cotter and E.C.E. Potter, eds.), pp. 184–228. Blackwell Publishing, Oxford. xxi + 547 pp.

Ellis, J.R., Cruz-Martinez, A., Rackham, B.D. and Rogers, S.I. (2005a). The distribution of chondrichthyan fishes around the British Isles and implications for conservation. *Journal of Northwest Atlantic Fishery Science*, **35**: 195–213.

Ellis, J.R., Dulvy, N.K., Jennings, S., Parker-Humphreys, M. and Rogers, S.I. (2005b). Assessing the status of demersal elasmobranchs in UK waters: A review. *Journal of the Marine Biological Association of the United Kingdom*, **85**: 1025–1047.

Ellis, J. R., Pawson, M.G. and Shackley, S.E. (1996). The comparative feeding ecology of six species of shark and four species of ray (Elasmobranchii) in the North-East Atlantic. *Journal of the Marine Biological Association of the United Kingdom*, **76**:89–106.

Ellis, J. R. and Shackley, S.E. (1995). Observations on egg-laying in the thornback ray. *Journal of Fish Biology*, **46**:903–904.

Gallagher, M.J., Nolan, C.P. and Jeal, F. (2005). Age, growth and maturity of the commercial ray species from the Irish Sea. *Journal of Northwest Atlantic Fishery Science*, **35**: 47–66.

Hitz, C.R. (1964). Observations on egg cases of the big skate (*Raja binoculata* Girard) found in Oregon coastal waters. *Journal of the Fisheries Research Board of Canada*, **21**: 851−854.

Hoff, G.R. (2008). A nursery site of the Alaska skate (*Bathyraja parmifera*) in the eastern Bering Sea. *Fishery Bulletin*, **106**: 233–244.

Holden, M.J. (1972). The growth rates of *Raja brachyura, R. clavata* and *R. montagui* as determined from tagging data. *Journal du Conseil International pour l'Exploration de la Mer*, **34**: 161–168.

Holden, M.J. and Vince, M.R. (1973). Age validation on the centra of *Raja clavata* using tetracycline. *Journal du Conseil International pour l' Exploration de la Mer*, **35**: 13–17.

Hunter, E., Berry, F., Buckley, A.A, Stewart, C. and Metcalfe, J.D. (2006) Seasonal migration of thornback rays and implications for closure management. *Journal of Applied Ecology,* **43**: 710–720.

Hunter, E., Buckley, A.A., Stewart, C. and Metcalfe, J.D. (2005a) Migratory behaviour of the thornback ray, Raja clavata, in the southern North Sea. *Journal of the Marine Biological Association of the United Kingdom,* **85**: 1095–1105.

Hunter, E., Buckley, A.A., Stewart, C. and Metcalfe, J.D. (2005b) Repeated seasonal migration by a thornback ray in the southern North Sea. *Journal of the Marine Biological Association of the United Kingdom,* **85**: 1999–1200.

ICES (2002). Report of the Study Group Elasmobranch Fishes (SGEF), 6–10 May 2002, ICES, Copenhagen, Denmark. ICES CM 2002/G:08, 119 pp.

ICES (2005). Report of the Working Group on Fish Ecology (WGFE), 21-26 February 2005, Santander, Spain. ICES CM 2005/G:05, 220 pp.

ICES (2006a). 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 (2006b). Report of the ICES Advisory Committee on Fishery Management, Advisory Committee on the Marine Environment and Advisory Committee on Ecosystems, 2006. ICES Advice. Books 1-10, **6**, 310 pp.

ICES (2007). Report of the Working Group on Elasmobranch Fishes (WGEF), 22–28 June 2007, Galway, Ireland. ICES CM 2007/ACFM:27, 318 pp.

ICES (2008). Report of the Working Group on Fish Ecology (WGFE), 3–7 March 2008, ICES, Copenhagen, Denmark. ICES CM 2008/LRC:04, 119 pp.

Kaiser, M.J., Rogers, S.I. & Ellis, J.R. (1999). Importance of benthic habitat complexity for demersal fish assemblages. *American Fisheries Society Symposium*, **22**, 212–223.

Kaiser, M.J. & Spencer, B.E. (1994). Fish scavenging behaviour in recently trawled areas. *Marine Ecology Progress Series*, **11**2, 41–49.

Parker-Humphreys, M. (2005). Distribution and relative abundance of demersal fishes from beam trawl surveys in 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.

Rogers, S.I., Millner R.S. and Mead T.A. (1998a). 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.

Rogers, S.I., Rijnsdorp, A.D., Damm, U. and Vanhee, W. (1998b). Demersal fish populations in the coastal waters of the UK and continental NW Europe from beam trawl survey data collected from 1990 to 1995. *Journal of Sea Research,* **39**:79–102.

Rogers, S.I., Clark, K.R. and Reynolds, J.D. (1999). The taxonomic distinctness of coastal bottom-dwelling fish communities of the Northeast Atlantic. *Journal of Animal Ecology*, **68**: 769–782.

Rose, G.A. and Kulka, D.W. (1999). Hyperaggregation of fish and fisheries: How catch-per-unit-effort increased as the northern cod (Gadus morhua) declined. *Canadian Journal of Fisheries and Aquatic Sciences*, 56: 118-127.

Ryland, J.S. and Ajayi, T.O. (1984). Growth and population dynamics of three *Raja* species (Batoidei) in Carmarthen Bay, British Isles. *Journal du Conseil International pour l'Exploration de la Mer*, **41**: 111–120.

Walker, P.A. (1998). Fleeting images: Dynamics of North Sea Ray populations. PhD Thesis, University of Amsterdam, the Netherlands, 145 pp.

Walker, P.A. and Heessen, H.J.L. (1996) Long-term changes in ray populations in the North Sea. *ICES Journal of Marine Science,* **53**: 1085–1093.

Walker, P.A. and Hislop, J.R.G. (1998) Sensitive skates or resilient rays? Spatial and temporal shifts in the ray species composition in the central and North-western North Sea between 1930 and the present day. *ICES Journal of Marine Science,* **55**: 392–402.

Walker, P., Howlett, G. and Millner, R. (1997) Distribution, movement and stock structure of three ray species in the North Sea and eastern English Channel. *ICES Journal of Marine Science* **54**: 797–808.

Wheeler, A.C. Merrett, N.R. and Quigley, D.T.G. (2004). Additional records and notes for Wheeler's (1992) List of the Common and Scientific Names of Fishes of the British Isles. *Journal of Fish Biology*, **65** (Supplement B), 1–40.

Whittamore, J.M. and McCarthy, I.D. (2005). The population biology of the thornback ray, *Raja clavata* in Caernarfon Bay, north Wales. *Journal of the Marine Biological Association of the United Kingdom*, **85**: 1089–1094.

Electronic Reference

ICES Fish Map: http://www.ices.dk/marineworld/fishmap/ices/pdf/thornback.pdf (accessed 20 May 2008).

Table 1: Summary of vessels and gears used in the FSP project

Vessel	Port	Gear	Dates of fieldwork
Jessica M	West Mersea	Trawl	20–28 June 2007
		Longline	30 July–01 August 2007; 04, 28–29 January 2008; 08 February 2008
Harvester	West Mersea	Trawl	20–28 June 2007
T-Rex	Ramsgate	Gillnets	21–24 June 2007; 20–24 July 2007
Janeen	Southend	Trawl	29 August – 06 September 2007; 23 October 2007; 12 December 2007
Jolene	Orford	Longline	02, 07–08, 17–21 February 2008
		Gillnets	9–13 February 2008; 13–14 March 2008

Table 2: Maturity stages for male skates

Stage	State	Description
A	Immature	Claspers undeveloped, shorter than extreme tips of posterior margin of pelvic fin.
B	Maturing	Claspers just longer than posterior margin of pelvic fin, their tips more structured, but the claspers are soft and flexible and the cartilaginous elements are not hardened.
C	Fully mature	Claspers longer than posterior margin of pelvic fin, cartilaginous elements hardened and claspers stiff (can be soft at some times of the year).
D	Active	Clasper reddish and swollen, sperm present in clasper groove, or flows if pressure exerted on cloaca.

Table 3: Species composition (numbers and percentage) of skates observed in the seven FSP surveys, and the length range of thornback rays sampled

Vessel name	Gear	Period	Blonde Ray		Spotted ray		Thornback ray		Length range of thornback ray (cm)	
			No.	%	No.	%	No.	%	Male	Female
Jessica M	Trawl	Summer	–	–	1	0.1	1125	99.9	17–91	17–90
	Longline	Summer/ winter	–	–	–	–	110	100	41–76	41–99
Harvester	Trawl	Summer	–	–	–	–	937	100	14–78	14–89
T-Rex	Gillnet	Summer	–	–	–	–	445	100	47–88	42–97
Janeen	Trawl	Autumn	2	0.1	4	0.2	1761	99.7	12–88	11–90
Jolene	Lines	Winter	–	–	3	0.3	1142	99.7	39–88	41–95
	Gillnet	Winter	–	–	–	–	530	100	23–84	33–87
Total	All gears		2	< 0.1	8	0.1	6050	99.8	12–91	11–99

Table 4: Sex ratio of thornback rays (by length category) observed in the FSP surveys. Statistical significance in the sex ratio was determined by Chi-squared test.

Vessel name	Gear	< 50 cm				50–74 cm			
		M	F	Ratio	*P*	M	F	Ratio	*p*
Jessica M	Trawl	255	279	1:1.1	–	258	264	1:1.0	–
	Longline	3	5	1:1.7	–	40	34	1:0.9	–
Harvester	Trawl	230	233	1:1.0	–	214	180	1:0.8	–
T-Rex	Gillnet	1	2	1:2	–	100	121	1:1.2	–
Janeen	Trawl	400	480	1:1.2	<0.01	262	465	1:1.8	<0.001
Jolene	Lines	29	22	1:0.8	–	502	358	1:0.7	<0.001
	Gillnet	95	83	1:0.9	–	154	170	1:1.1	–

Vessel name	Gear	≥ 75 cm				All sizes			
		M	F	Ratio	*P*	M	F	Ratio	*p*
Jessica M	Trawl	13	55	1:4.2	<0.001	526	598	1:1.1	–
	Longline	2	26	1:13	<0.001	45	65	1: 1.4	–
Harvester	Trawl	12	68	1:5.7	<0.001	456	481	1:1.1	–
T-Rex	Gillnet	79	142	1:1.8	<0.001	180	265	1:1.5	<0.001
Janeen	Trawl	15	139	1:9	<0.001	677	1084	1:1.6	<0.001
Jolene	Lines	64	167	1:2.6	<0.001	595	547	1:0.9	–
	Gillnet	9	19	1:2.1	–	258	272	1:1.1	–

Table 5: Visual inspection of health state of thornback rays observed in the FSP surveys.

Vessel/gear	Length category	Lively		Sluggish		Dead		Total
		No.	%	No.	%	No.	%	No.
Harvester (Trawl)	< 50 cm	240	51.8	202	43.6	21	4.5	463
	50–74 cm	292	74.1	101	25.6	1	0.3	394
	≥ 75 cm	59	74.7	20	25.3			79
	Total	591	63.1	323	34.5	22	2.4	936
Janeen (Trawl)	< 50 cm	754	85.7	125	14.2	1	0.1	880
	50–74 cm	703	96.7	24	3.3			727
	≥ 75 cm	151	98.1	3	1.9			154
	Total	1 608	91.3	152	8.6	1	0.1	1 761
Jessica M (Trawl)	< 50 cm	534	99.8	1	0.2			535
	50–74 cm	520	99.6	2	0.4			522
	≥ 75 cm	68	100.0					68
	Total	1 122	99.7	3	0.3			1 125
Jessica M (Longline)	< 50 cm	8	100.0					8
	50–74 cm	68	91.9	6	8.1			74
	≥ 75 cm	28	100.0					28
	Total	104	94.5	6	5.5			110
Jolene (Longline)	< 50 cm	48	100.0					48
	50–74 cm	514	97.0	16	3.0			530
	≥ 75 cm	128	99.2	1	0.8			129
	Total	690	97.6	17	2.4			707
Jolene (Gillnet)	< 50 cm	138	77.5	40	22.5			178
	50–74 cm	225	69.4	99	30.6			324
	≥ 75 cm	25	89.3	3	10.7			28
	Total	388	73.2	142	26.8			530
T-Rex (Gillnet)	< 50 cm	3	100.0					3
	50–74 cm	213	96.4			8	3.6	221
	≥ 75 cm	220	99.5			1	0.5	221
	Total	436	98.0			9	2.0	445

Table 6: Numbers of thornback rays tagged and released by sex and length during the seven FSP surveys.

Vessel name and gear	Female				Males				Total
	<50	50–74	≥ 75	Total	<50	50–74	≥ 75	Total	
Harvester (twinrig otter trawl)	47	158	68	273	46	188	10	244	517
Jessica M (twinrig otter trawl)	117	185	50	352	108	188	12	308	660
Janeen (triplerig otter trawl)	244	461	139	844	183	262	15	460	1 304
Jessica M (longline)	5	34	26	65	3	40	2	45	110
Jolene (longline)	15	205	97	317	19	282	31	332	649
Jolene (gillnets)	69	154	18	241	84	145	9	238	479
T-Rex (gillnets)	2	116	141	259	1	94	79	174	433
Total	499	1 313	539	2 351	444	1 199	158	1 801	4 152

Table 7: Numbers of elasmobranchs released and the number and percentage recaptured and reported by the various surveys conducted in summer/autumn 2007 (top) and winter/spring 2008 (bottom). Data extracted on 30 July 2008.

Year	Vessel	Gear	No. caught	No. tagged	No. recaptured	Return rate
2007	*Harvester*	Twin rig otter trawl	937	517	80	15.5%
	Jessica M	Twin rig otter trawl	1 125	660	60	9.1%
	T-Rex	Gillnets	445	433	28	6.5%
	Janeen	Triple rig otter trawl	1 761	1 304	86	6.6%
	Jessica M	Longlines	47	47	6	12.8%
2008	*Jessica M*	Longlines	63	63	6	9.5%
	Jolene	Gillnets	530	479	25	5.2%
	Jolene	Longlines	1 142	649	35	5.4%
		Total	6 050	4 152	326	7.9%

Table 8: Occurrence, relative abundance and size range of thornback rays taken in the Young Fish Survey in the Greater Thames Estuary (2000–2007)

Year	No. of valid hauls	Positive hauls (% occurrence)	Mean CPUE (ind.1000m^{-2}) ± SD	Total length Range (cm)
2000	80	16 (20.0%)	0.25 ± 0.57	11–37
2001	79	8 (10.1%)	0.15 ± 0.46	10–34
2002	81	14 (17.3%)	0.33 ± 0.86	11–71
2003	80	18 (22.5%)	0.33 ± 0.80	11–64
2004	76	21 (27.6%)	0.24 ± 0.48	11–55
2005	80	14 (17.5%)	0.19 ± 0.44	10–57
2006	79	13 (16.5%)	0.21 ± 0.60	11–62
2007	79	31 (39.2%)	0.51 ± 0.92	10–80

Table 9: Species composition (by numbers) of skates (Rajidae) taken in 4-m beam trawl surveys in the eastern English Channel (VIId) and southern North Sea (IVc). Data for 1993–2007, and only those stations fished at least 11 times in the survey series included.

Species	VIID	IVC
Leucoraja naevus	0.1	-
Raja brachyura	3.1	1.3
Raja clavata	79.5	92.7
Raja microocellata	2.5	-
Raja montagui	10.6	5.9
Raja undulata	4.3	0.1

Table 10: Percentage occurrence in hauls and relative abundance (n.h^{-1}) of thornback rays taken in the 4-m beam trawl survey in the southern North Sea and eastern English Channel (1993–2007) (note: only stations fished at least 11 times in the survey series included)

	IV c			VII d			Total		
Year	Stations fished	% Occur.	Mean CPUE	Stations fished	% Occur.	Mean CPUE	Stations fished	% Occur.	Mean CPUE
1993	4	75.0	6.50	71	36.6	2.63	75	38.7	2.84
1994	5	60.0	3.60	73	41.1	2.41	78	42.3	2.49
1995	13	61.5	2.77	73	30.1	1.32	86	34.9	1.53
1996	13	69.2	5.08	74	36.5	2.46	87	41.4	2.85
1997	7	85.7	9.14	70	41.4	2.19	77	45.5	2.82
1998	13	76.9	4.92	75	33.3	2.14	88	39.8	2.55
1999	13	69.2	8.62	69	39.1	2.99	82	43.9	3.88
2000	13	69.2	9.08	70	40.0	2.69	83	44.6	3.69
2001	13	76.9	11.54	74	33.8	3.24	87	40.2	4.48
2002	12	58.3	8.33	71	33.8	1.95	83	37.3	2.87
2003	13	100.0	12.15	72	38.9	2.45	85	48.2	3.93
2004	12	83.3	11.74	69	37.7	2.33	81	44.4	3.72
2005	7	85.7	24.00	58	25.9	1.43	65	32.3	3.86
2006	13	76.9	8.31	70	37.1	4.36	83	43.4	4.97
2007	12	75.0	16.83	68	42.6	2.51	80	47.5	4.66

Table 11: Reported landings of demersal fishes by UK (English & Welsh) vessels from the southern North Sea (ICES Division IVc) from 2002–2007.

								Mean annual landings (2002-2007)	
Species	2002	2003	2004	2005	2006	2007	Total	Tonnes	%
Skates and rays	407.1	413.4	466.2	323.7	261.3	258.4	2130.1	355.0	28.5
Cod	387.1	521.3	266.0	125.0	173.9	234.6	1707.9	284.6	22.9
Sole	256.5	290.0	265.6	264.6	295.8	329.6	1702.0	283.7	22.8
Plaice	104.9	119.6	85.4	41.0	45.8	30.4	427.1	71.2	5.7
Bass	74.3	80.2	79.0	69.5	63.0	58.5	424.5	70.7	5.7
Spurdog	75.0	23.0	50.6	27.9	13.6	15.9	206.0	34.3	2.8
Whiting	25.7	26.5	29.8	18.1	53.2	24.2	177.5	29.6	2.4
Smoothhounds	1.7	17.7	19.3	49.5	26.9	14.8	130.0	21.7	1.7
Lesser-spotted dogfish	22.9	12.6	7.7	5.7	7.8	23.6	80.2	13.4	1.1
Flounder	17.8	12.2	5.1	11.7	15.6	10.4	72.9	12.1	1.0
Tope	12.0	10.5	6.8	8.8	12.4	4.4	54.9	9.2	0.7

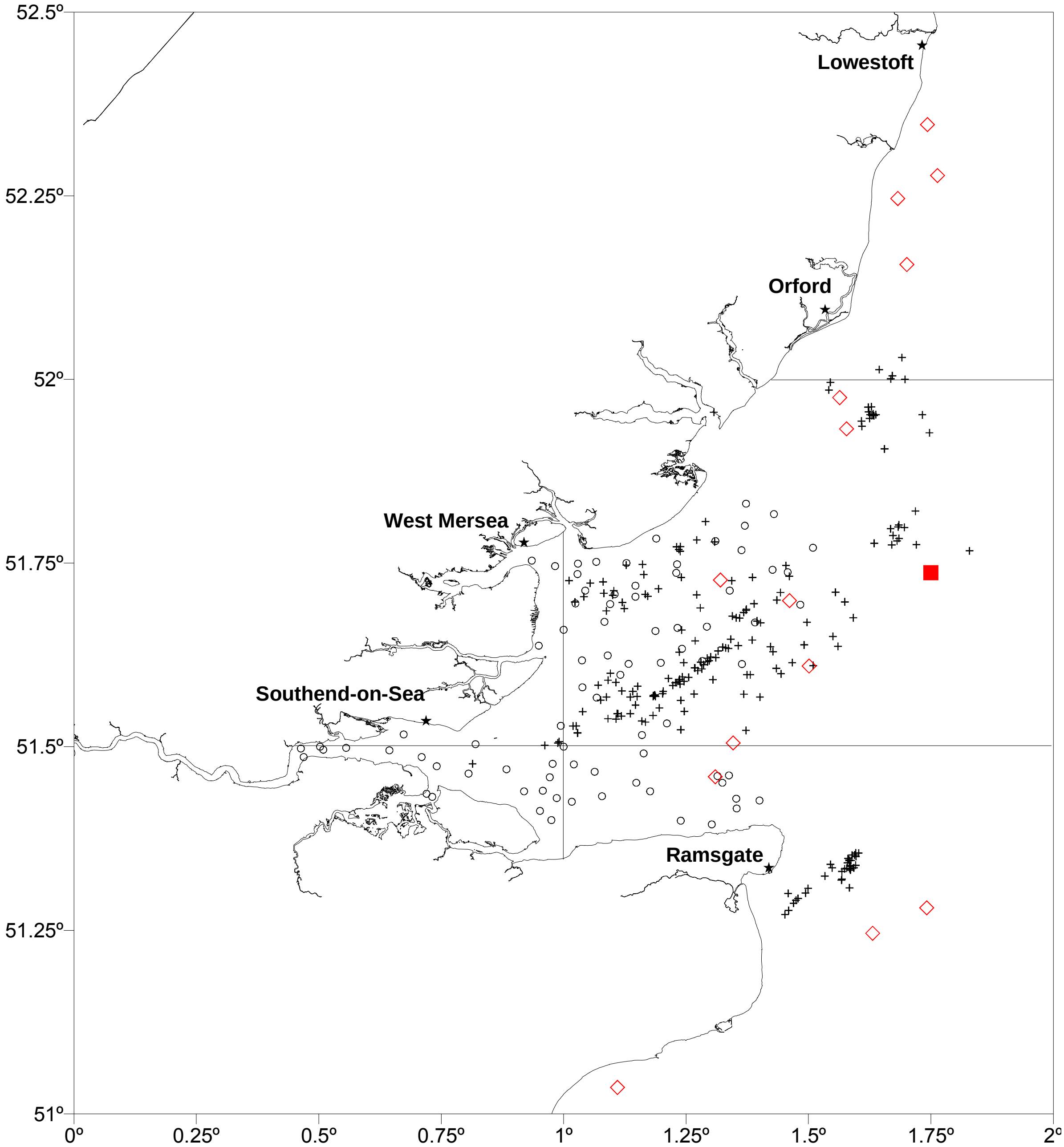
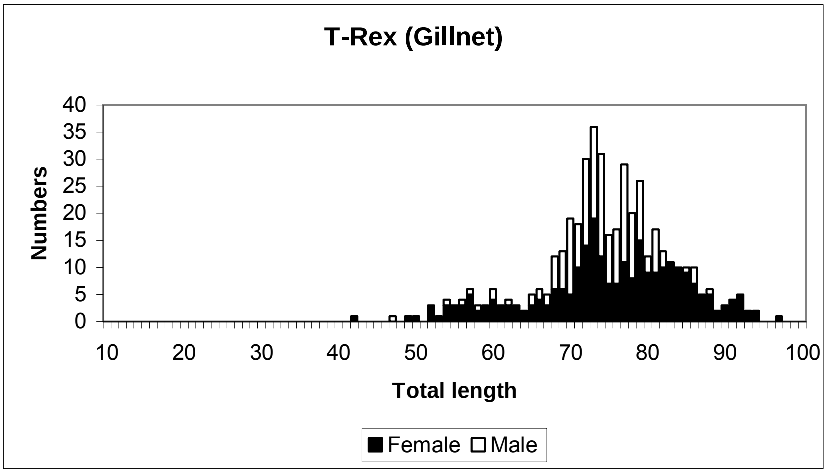


Figure 1: Map of the Greater Thames Estuary showing sites sampled during the FSP thornback ray tagging project (+, 2007/08), and annual Cefas surveys using 2-m beam trawl (○, Young Fish Survey), 4-m beam trawl (◇) and GOV trawl (IBTS survey, ■)

Figure 2: Tagged thornback ray *Raja clavata*



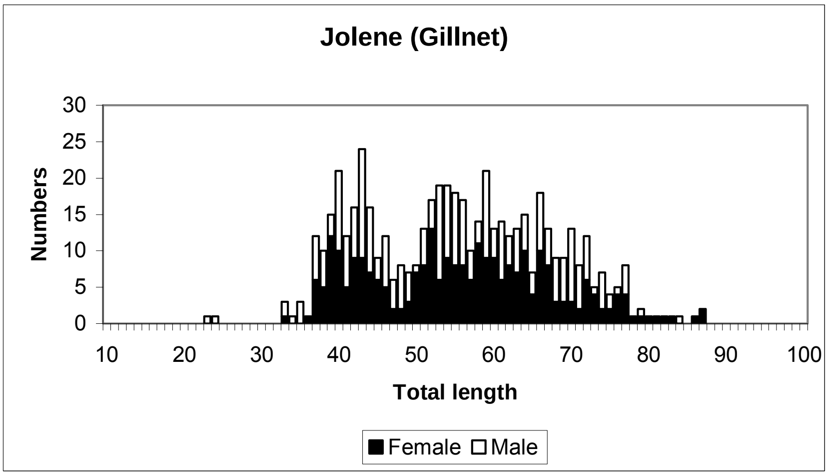


Figure 3: Length distributions of thornback rays taken in gillnet surveys (roker nets on the *T-Rex*, and drift trammelnets and roker nets on the *Jolene*)

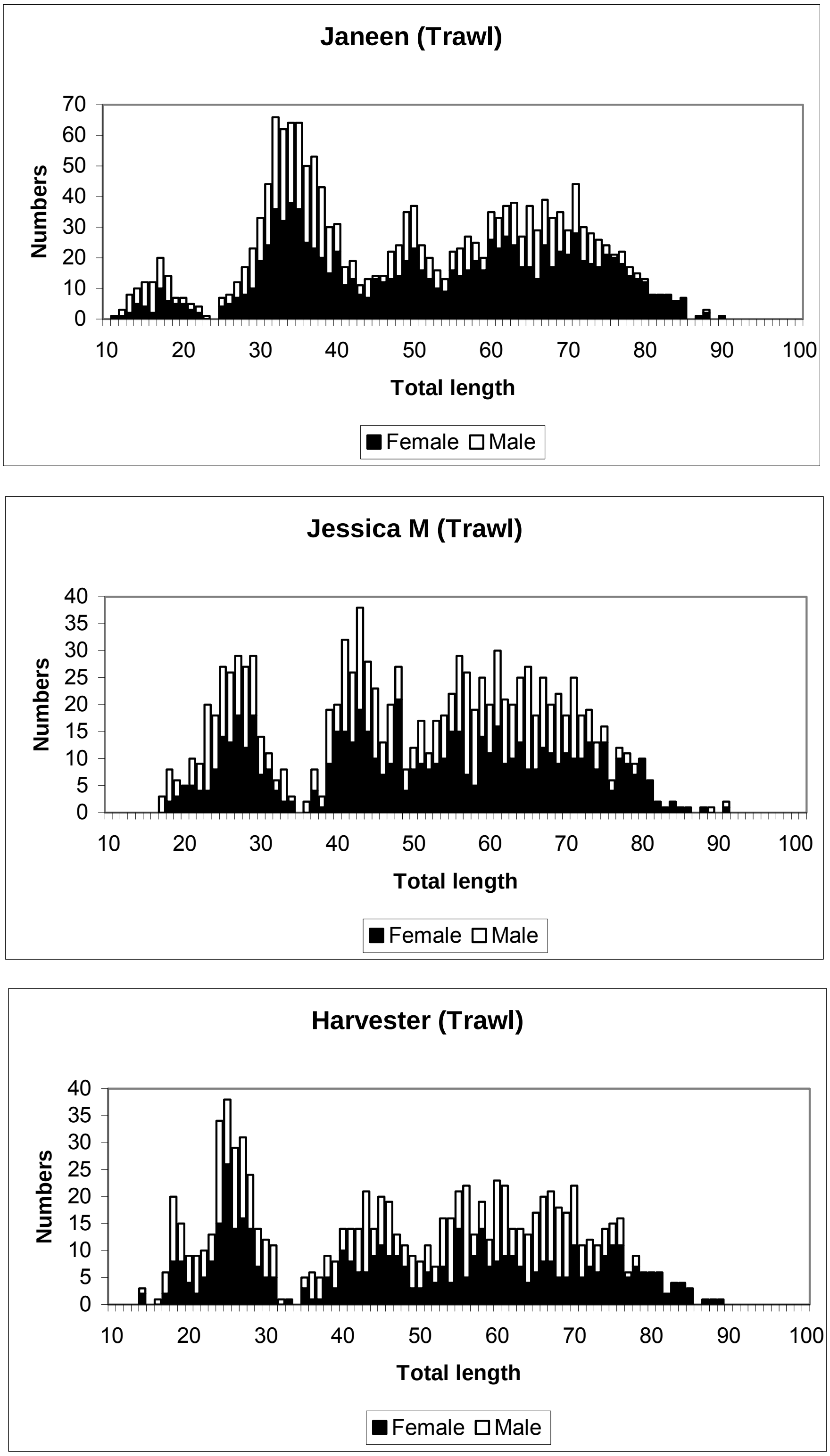


Figure 4: Length distributions of thornback rays taken in the three FSP inshore trawl surveys

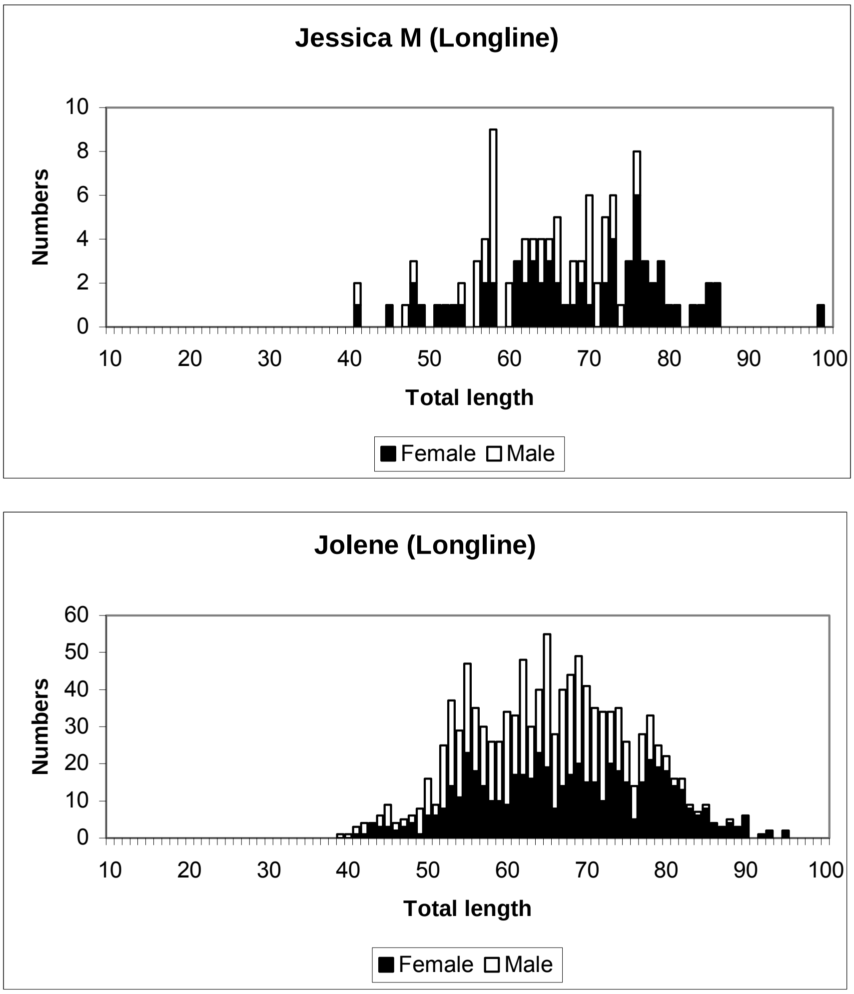


Figure 5: Length distributions of thornback rays taken in longline surveys

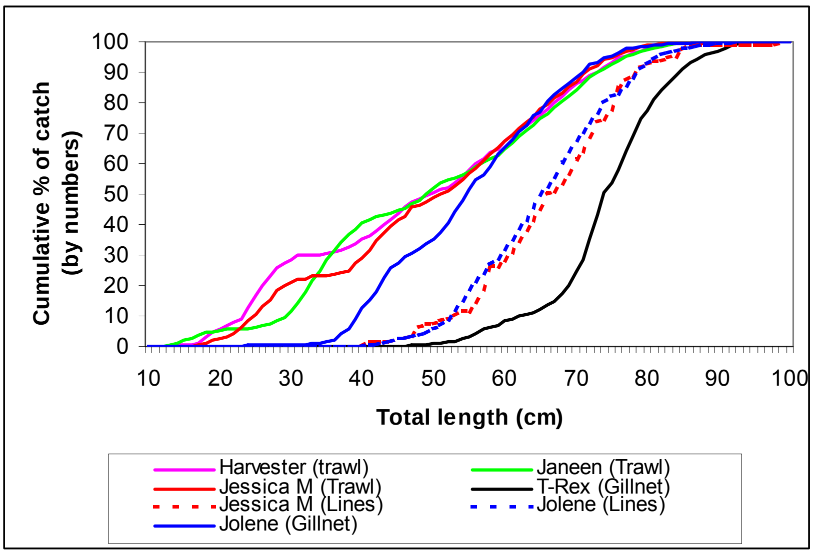


Figure 6: Cumulative proportion (by numbers) of thornback rays taken by length in trawl, gillnet and longline surveys

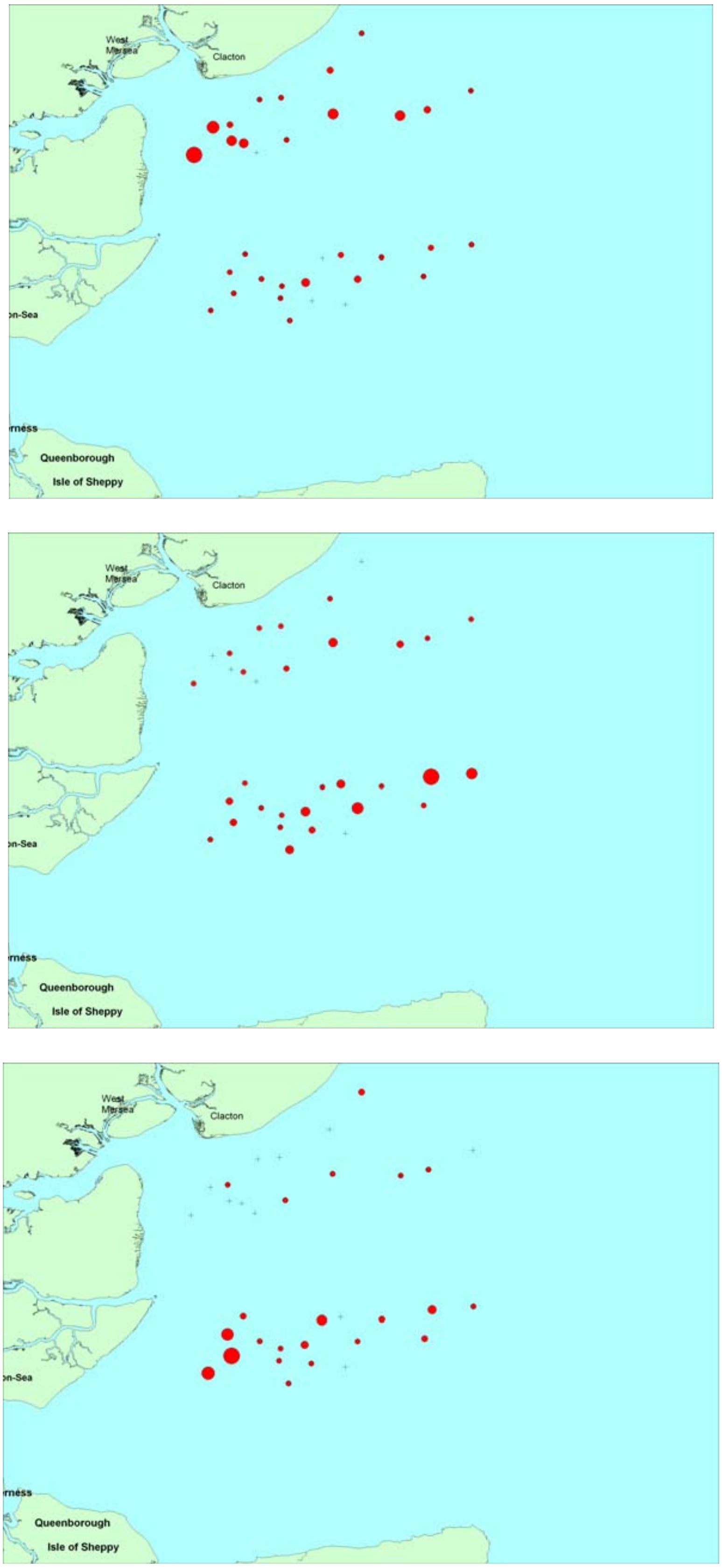


Figure 7: Numbers of thornback ray caught during the *Harvester* trawl survey by length group, <50 cm (top), 50–74 cm (middle) and ≥ 75 cm (bottom). Maximum bubble sizes are 77, 72 and 15 fish, respectively.

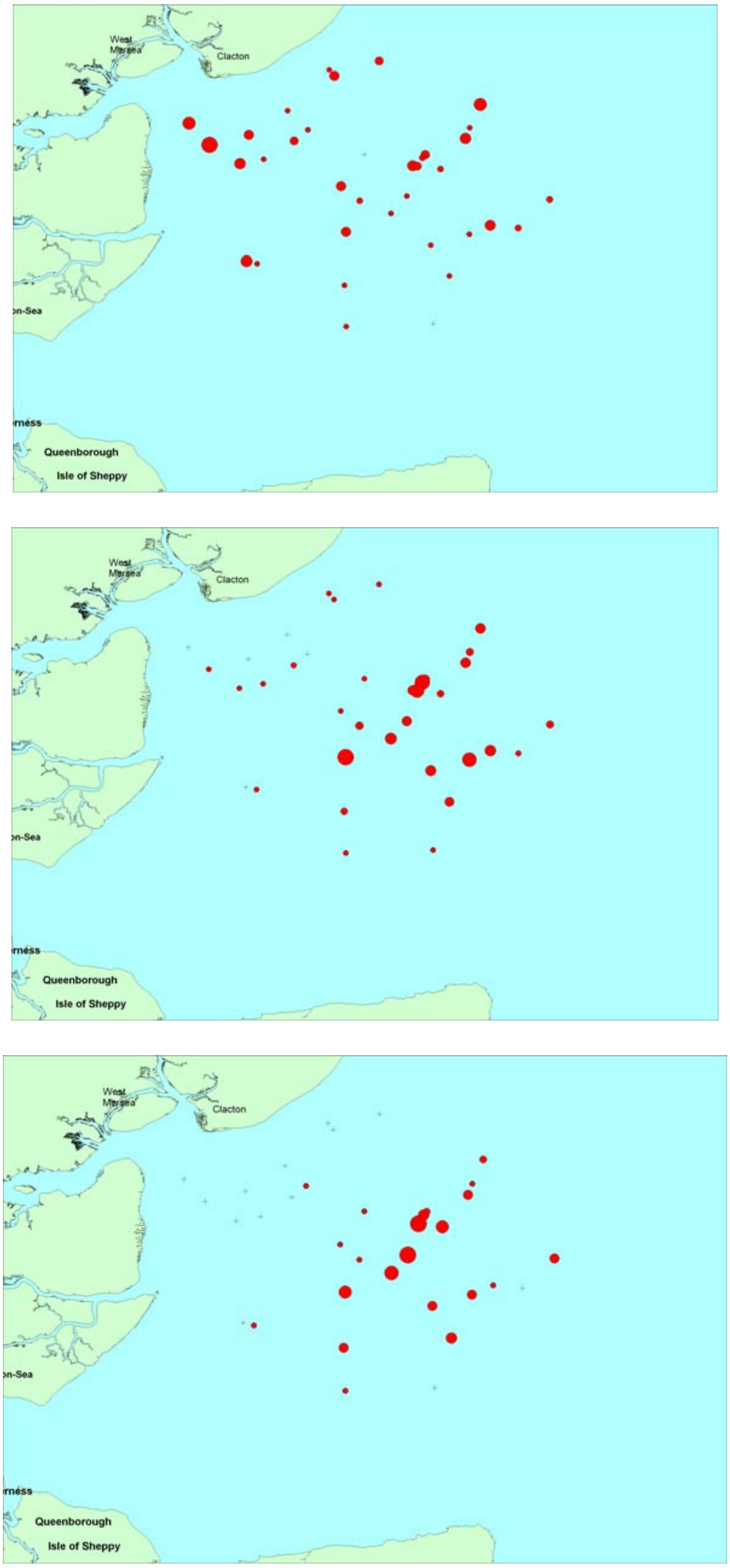


Figure 8: Numbers of thornback ray caught during the *Jessica M* trawl survey by length group, <50 cm (top), 50–74 cm (middle) and ≥ 75 cm (bottom). Maximum bubble sizes are 53, 52 and 8 fish, respectively.

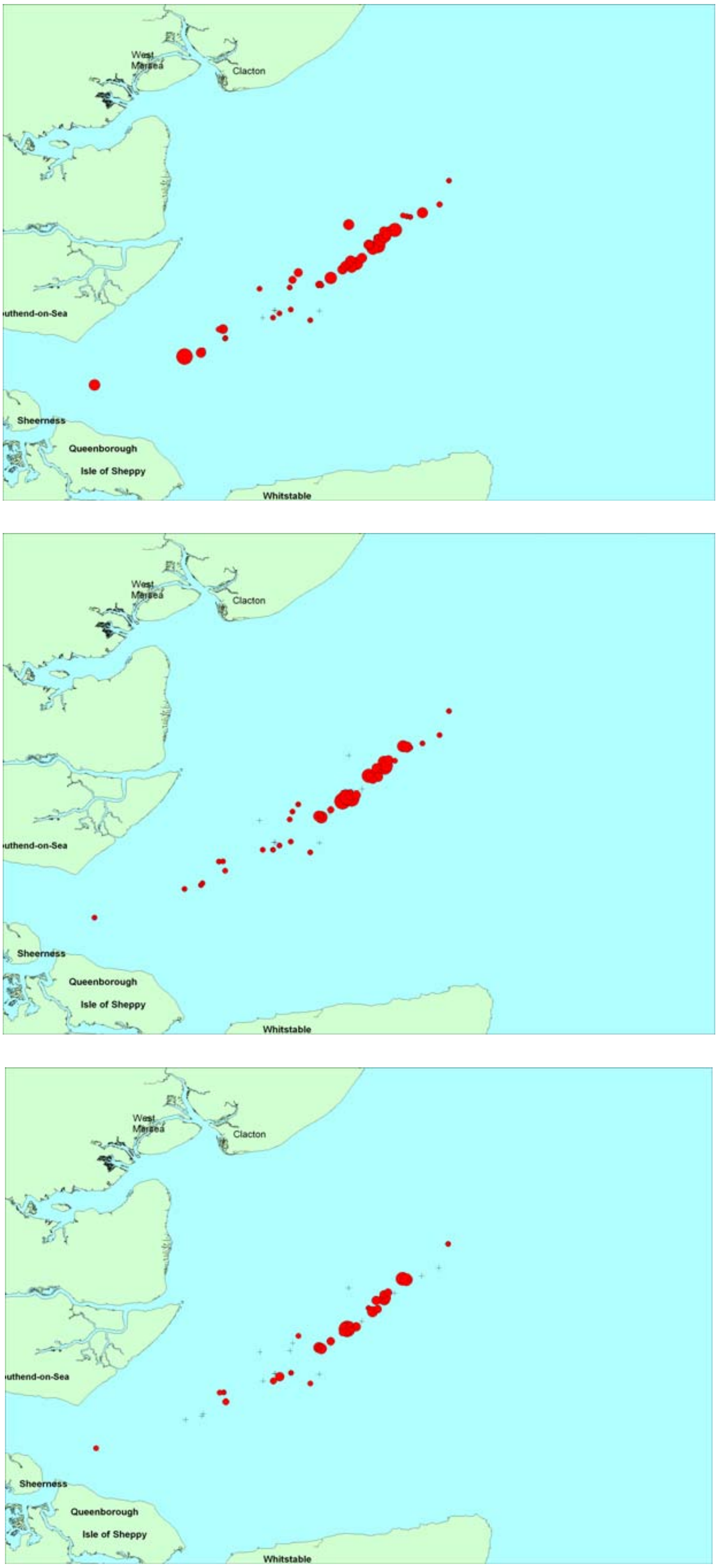


Figure 9: Numbers of thornback ray caught during the *Janeen* trawl survey by length group, <50 cm (top), 50–74 cm (middle) and ≥ 75 cm (bottom). Maximum bubble sizes are 58, 53 and 14 fish, respectively.

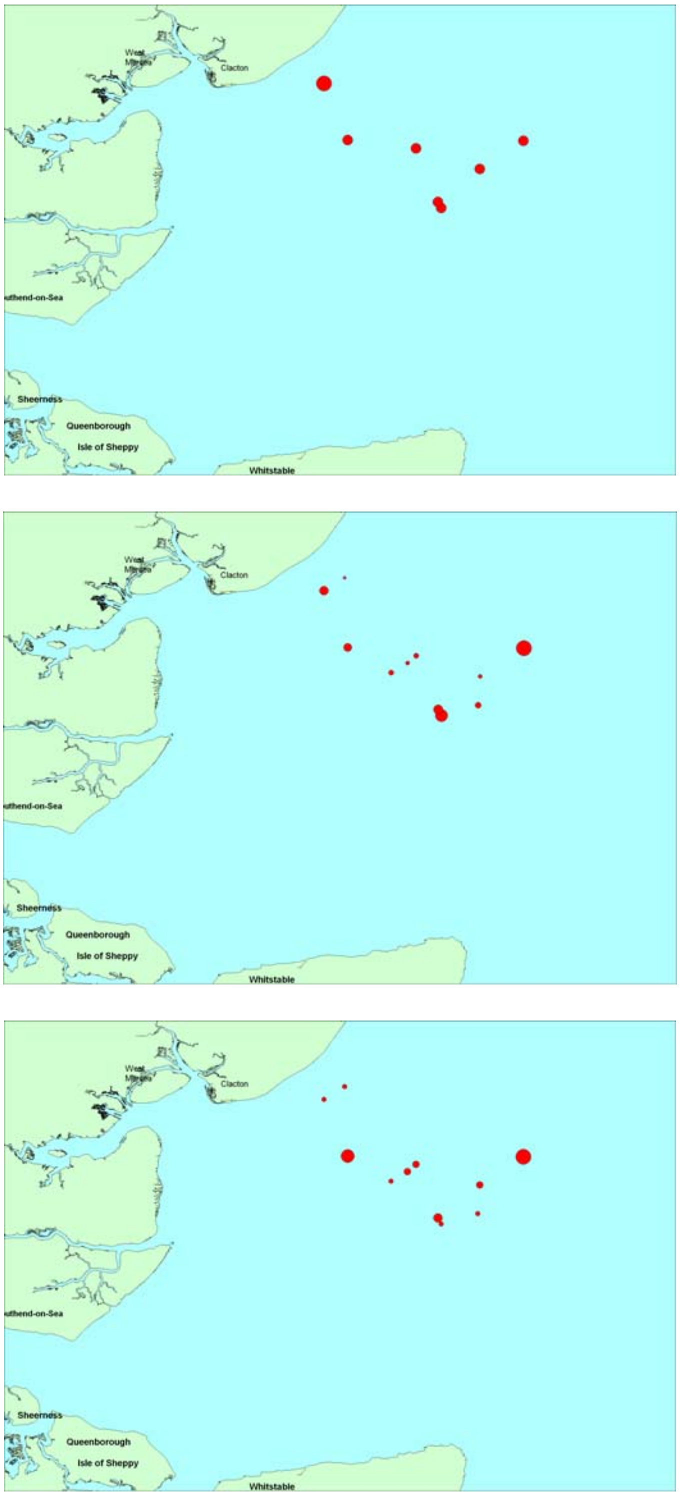


Figure 10: Number of thornback ray caught per line during the *Jessica M* longline survey by length group, <50 cm (top), 50–74 cm (middle) and ≥ 75 cm (bottom). Maximum bubble sizes are 2, 21 and 8 fish, respectively.

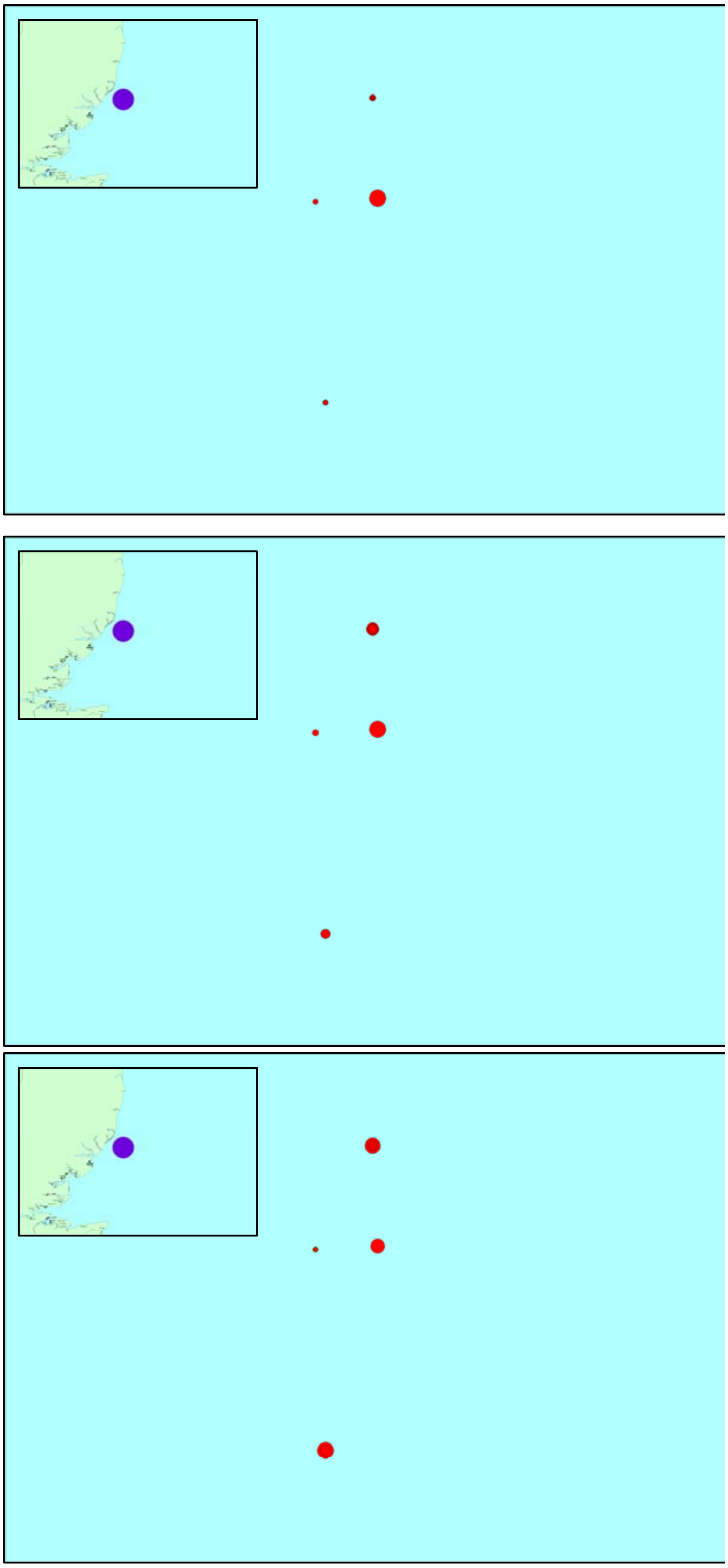


Figure 11: Survey area (inset) and relative numbers of thornback ray caught by length group, <50 cm (top), 50–74 cm (middle) and ≥ 75 cm (bottom) during the *Jolene* longline survey. Maximum bubble sizes are 6.3, 38.5 and 7.4 fish per bath of line, respectively (note: several stations were fished more than once).

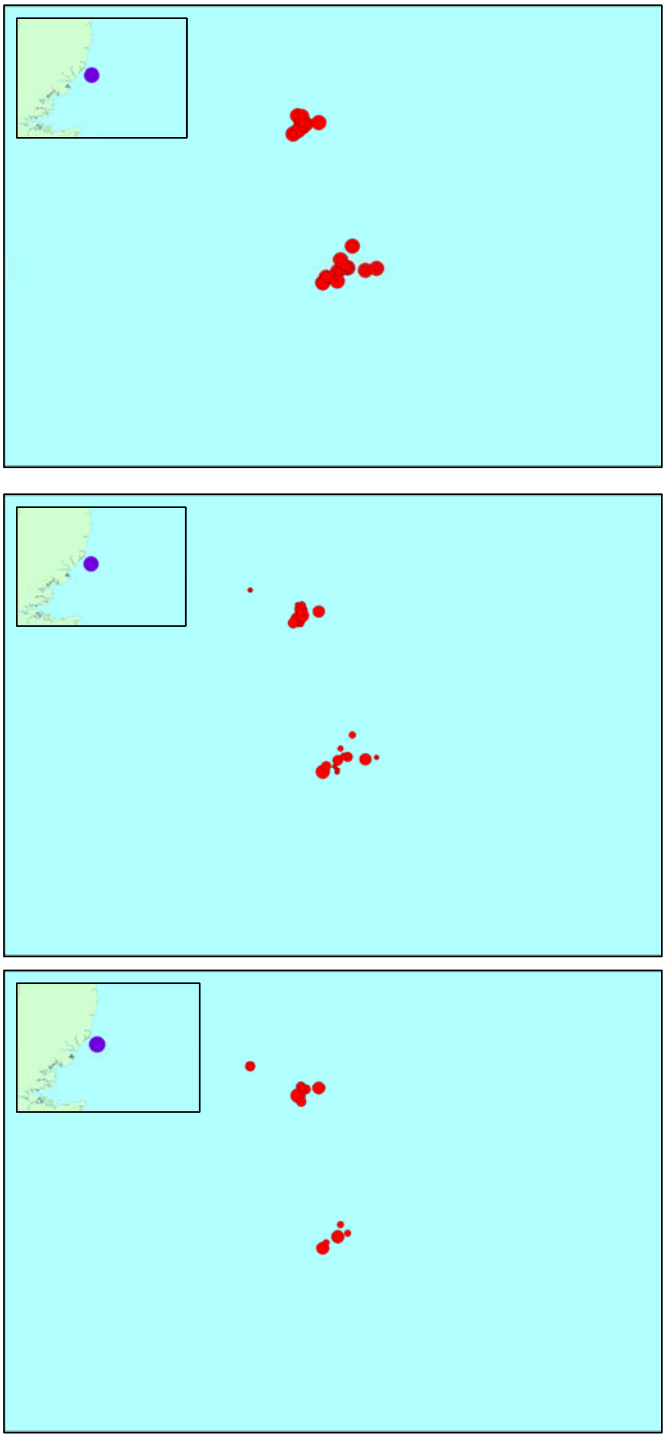


Figure 12: Survey area (inset) and numbers of thornback ray caught by length group, <50 cm (top), 50–74 cm (middle) and ≥ 75 cm (bottom) during gillnet surveys by the *Jolene.* Maximum bubble sizes are 21, 33 and 4 fish, respectively.

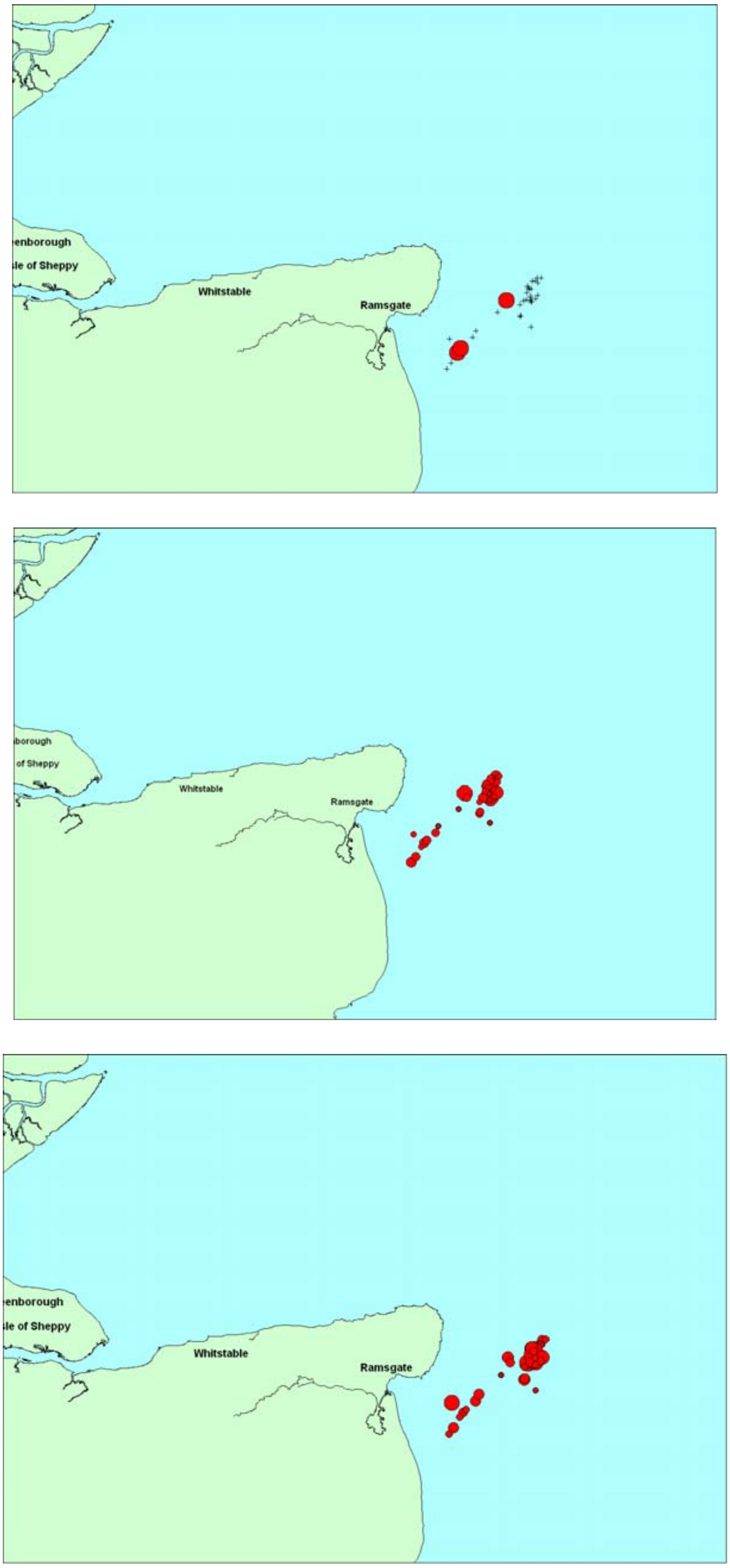


Figure 13: Numbers of thornback ray caught during the *T-Rex* gillnet survey by length group, <50 cm (top), 50–74 cm (middle) and ≥ 75 cm (bottom). Maximum bubble sizes are 1, 18 and 15 fish respectively.

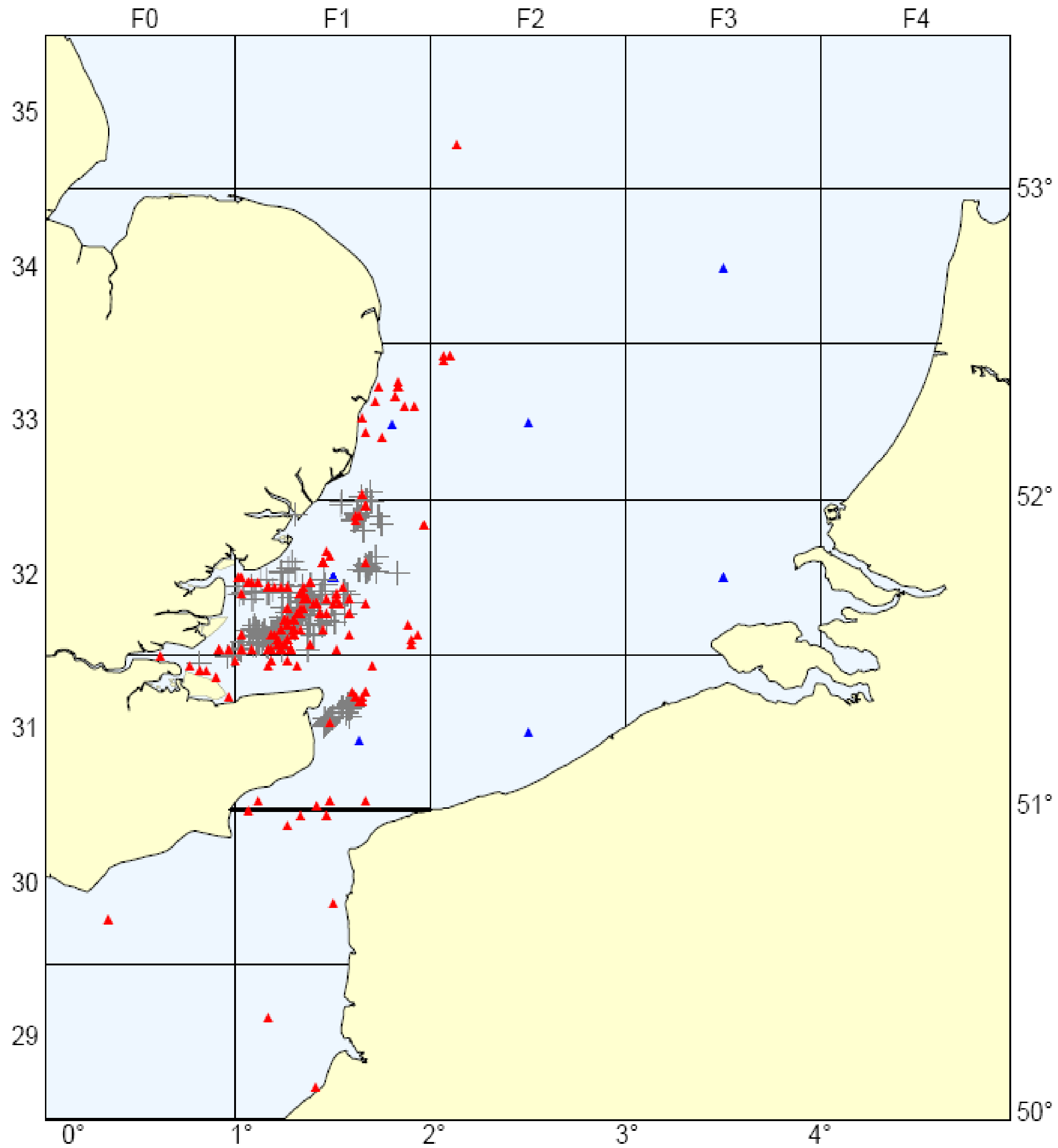


Figure 14: Release and recapture positions of thornback ray *Raja clavata* tagged during 2007/8 in the Greater Thames Estuary (+ release positions, ▲ recapture positions, ▲ recapture positions as centre rectangle).

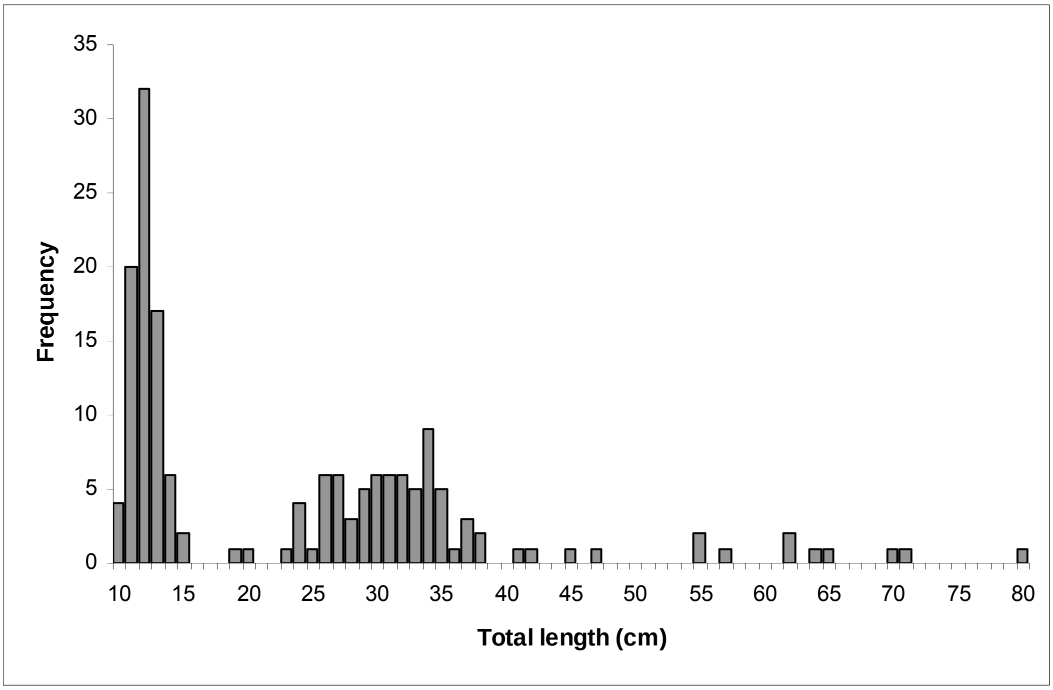


Figure 15: Length distribution of thornback ray (n = 166) caught by 2-m beam trawl during the YFS (2000–2007) in the Greater Thames Estuary.

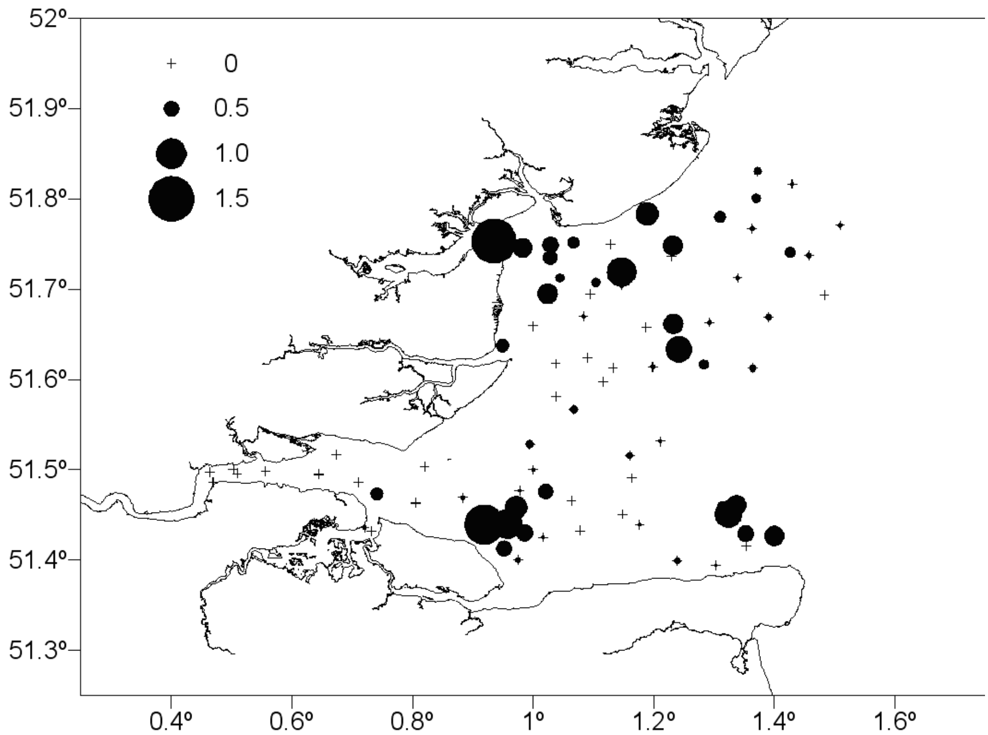


Figure 16: Spatial distribution and relative abundance of thornback ray in the Greater Thames Estuary (mean ind.1000 m^{-2} at fixed stations fished during the YFS, 2000–2007).

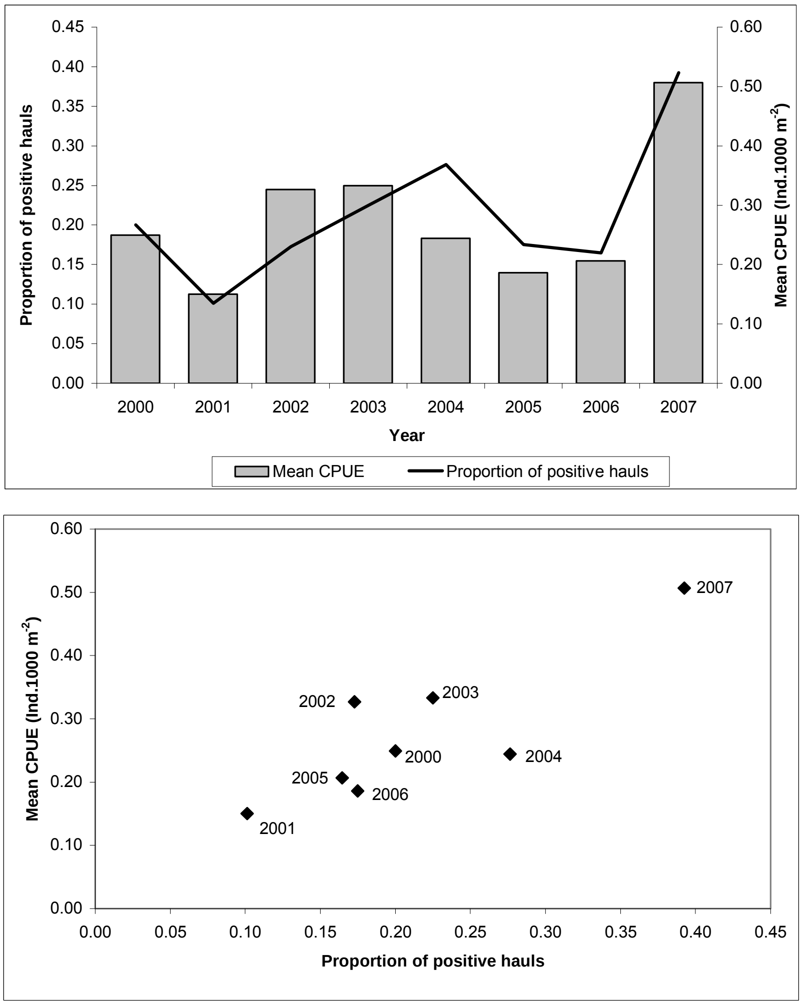


Figure 17: Relative abundance of thornback ray caught during the YFS (2000–2007) in the Greater Thames Estuary showing the mean CPUE (ind.1000 m^{-2}) and percentage occurrence in survey hauls (top); the abundance-occupancy relationship (bottom).

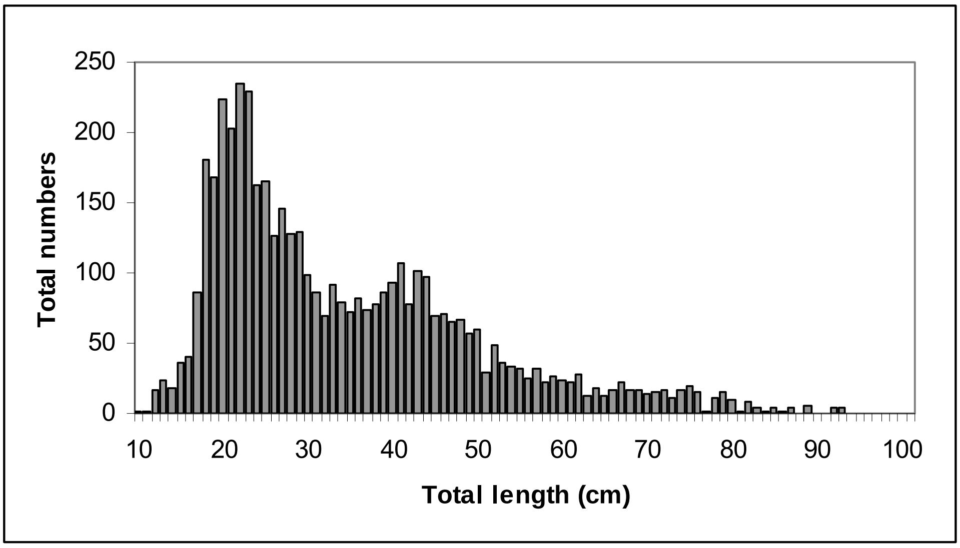


Figure 18: Length distribution of thornback ray (raised numbers per hour, all stations, 1993–2007, n=4661) caught by 4-m beam trawl during surveys in the eastern English Channel and southern North Sea.

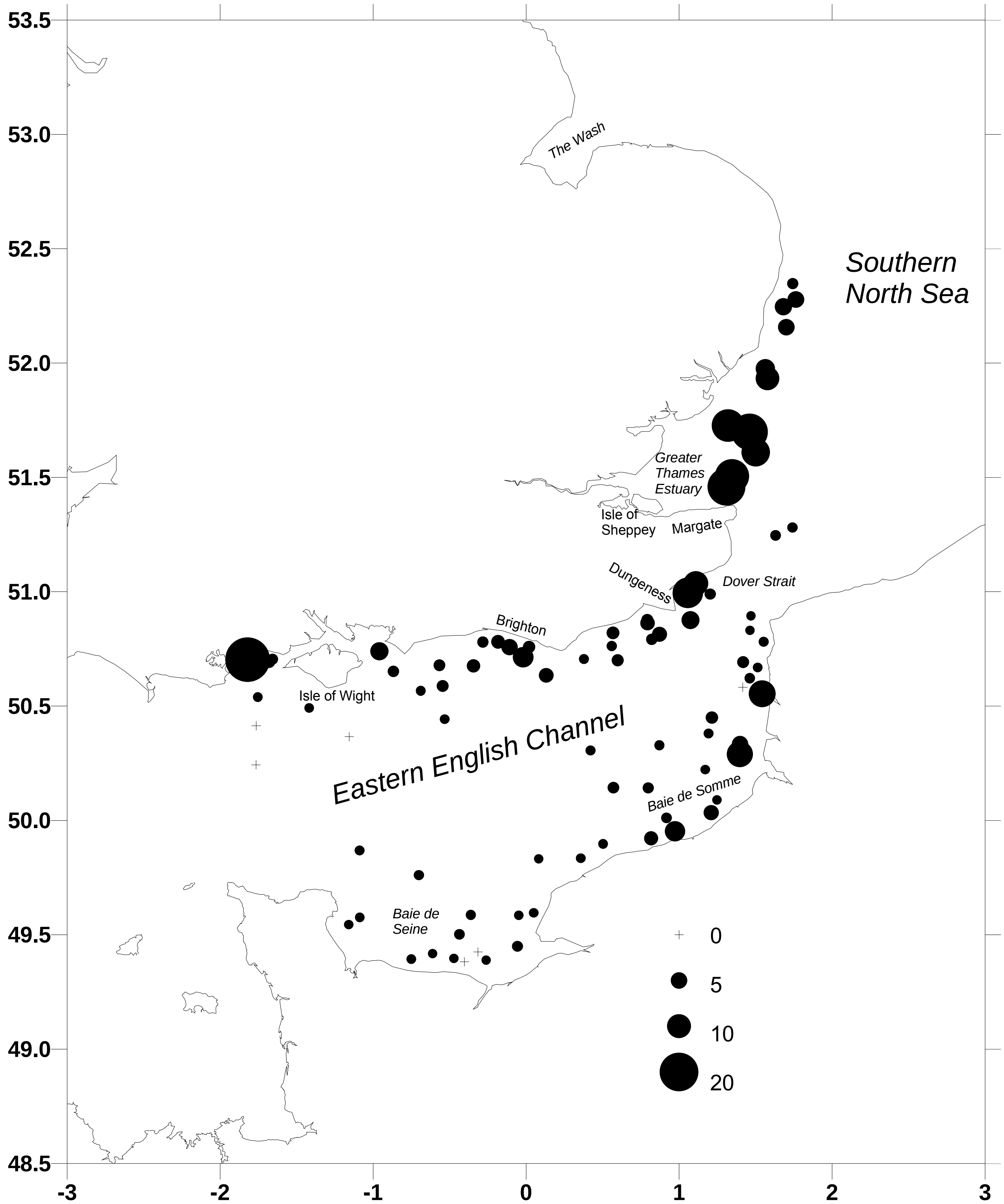


Figure 19: Spatial distribution and relative abundance of thornback ray in the eastern English Channel and southern North Sea (1993–2007). Only stations fished at least 11 times in the survey series included.

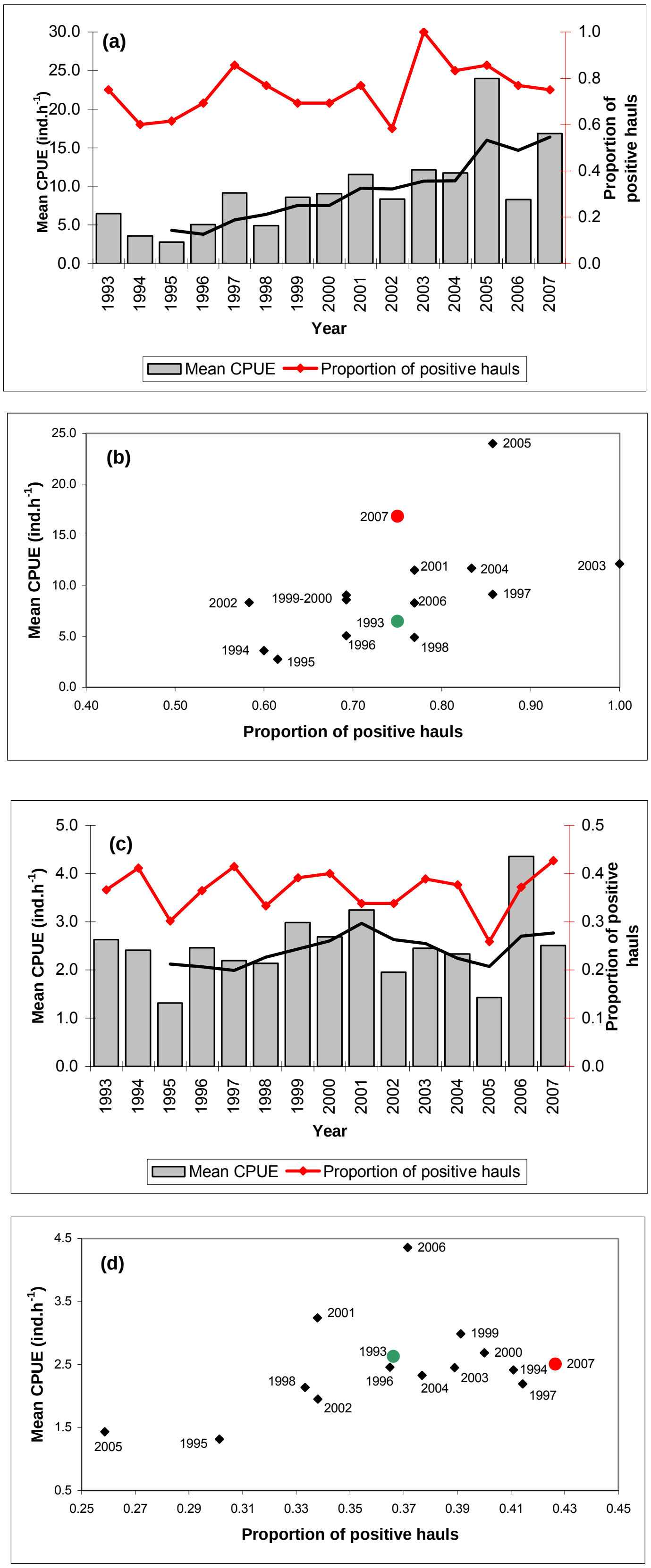


Figure 20: Results from the 4-m beam trawl survey (1993–2007) showing (a) relative abundance and (b) abundance-occupancy relationship of thornback ray in the southern North Sea; and (c) relative abundance and (d) abundance-occupancy relationship of thornback ray in the eastern English Channel. Figures (a) and (c) show the mean CPUE ($n.h^{-1}$), three year moving average (black line) and percentage occurrence in survey hauls (red line). Only stations fished at least 11 times in the survey series included.

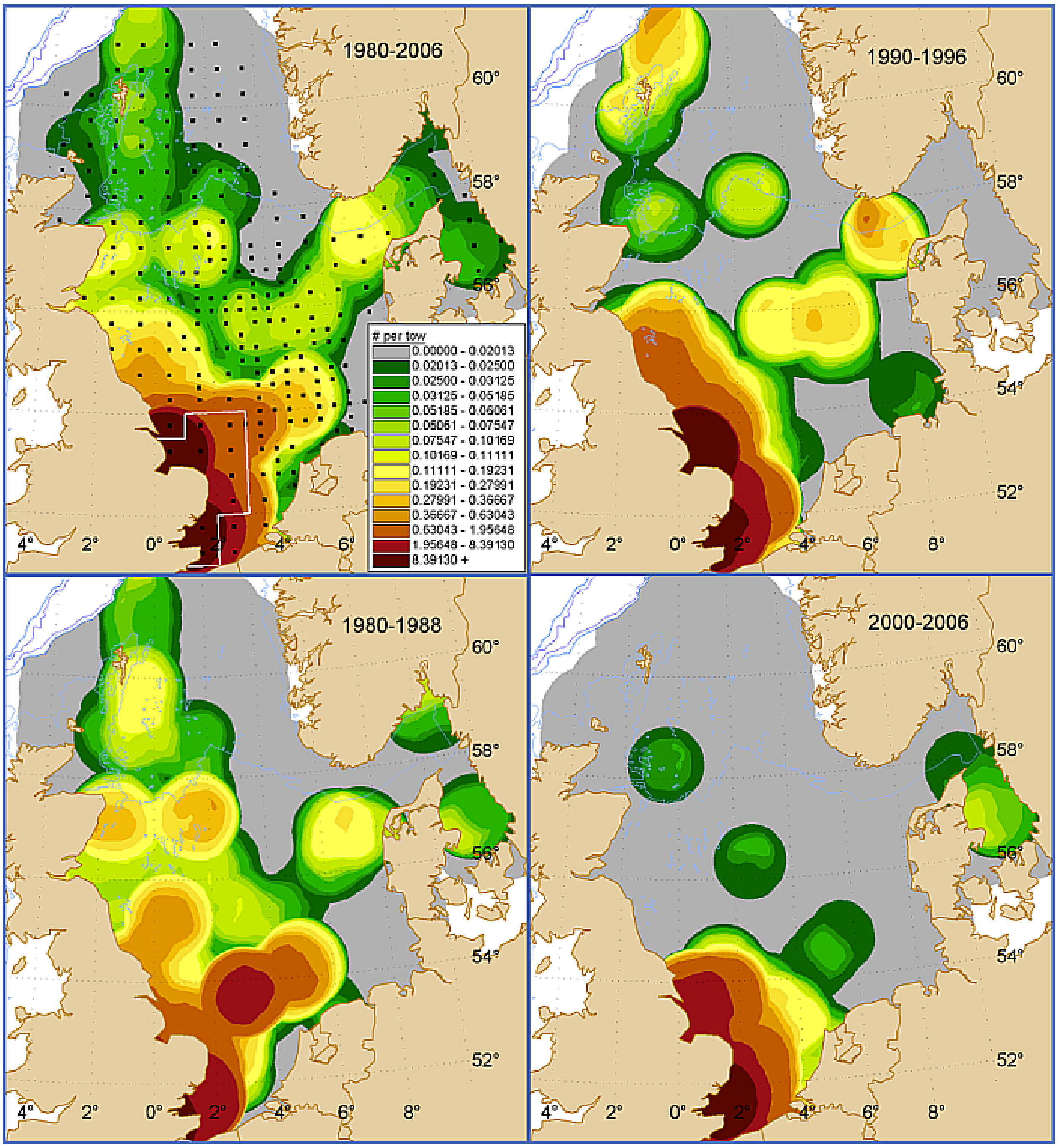


Figure 21: Distribution of *Raja clavata* in the North Sea during four periods and averaged over the entire survey period (1980–2006), as reported during the Q1 IBTS survey. Density strata are expressed as mean number per tow. Red and brown denotes high density (where ~90% of the abundance occurs), yellow and green very low and grey surveyed areas where no *R. clavata* were caught. Squares on “All Years” map are grid averaged survey locations. The white lines in the upper left panel delineates RFA 5. After ICES (2007).

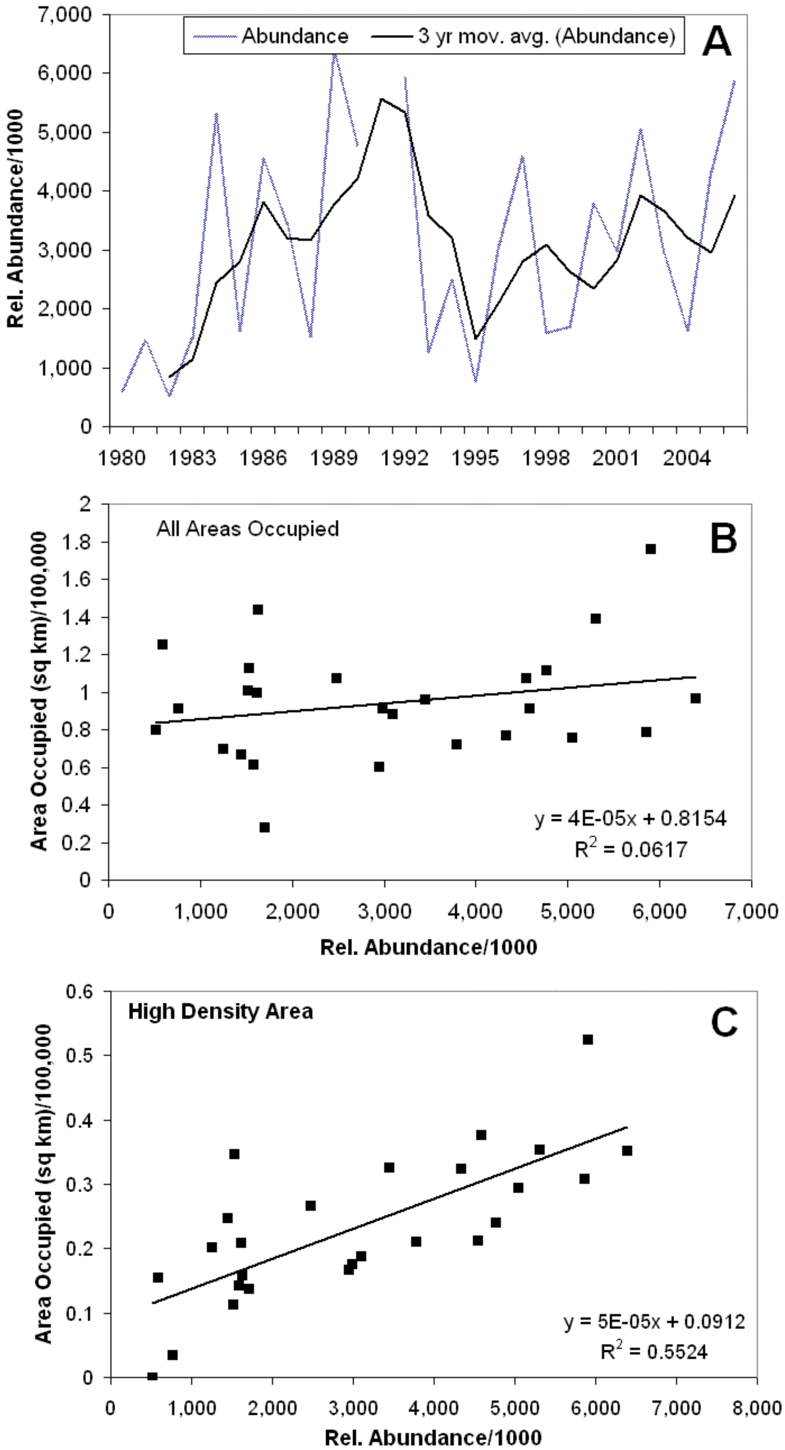


Figure 22: Spatial patterns observed for *Raja clavata* in the Q1 North Sea IBTS survey showing (a) annual estimates of relative abundance using SPANdex (with a 3-year running average shown to smooth the high inter-annual variation of the estimates); (b) relationship between total area occupied and relative abundance and (c) relationship between high density area occupied and relative abundance.

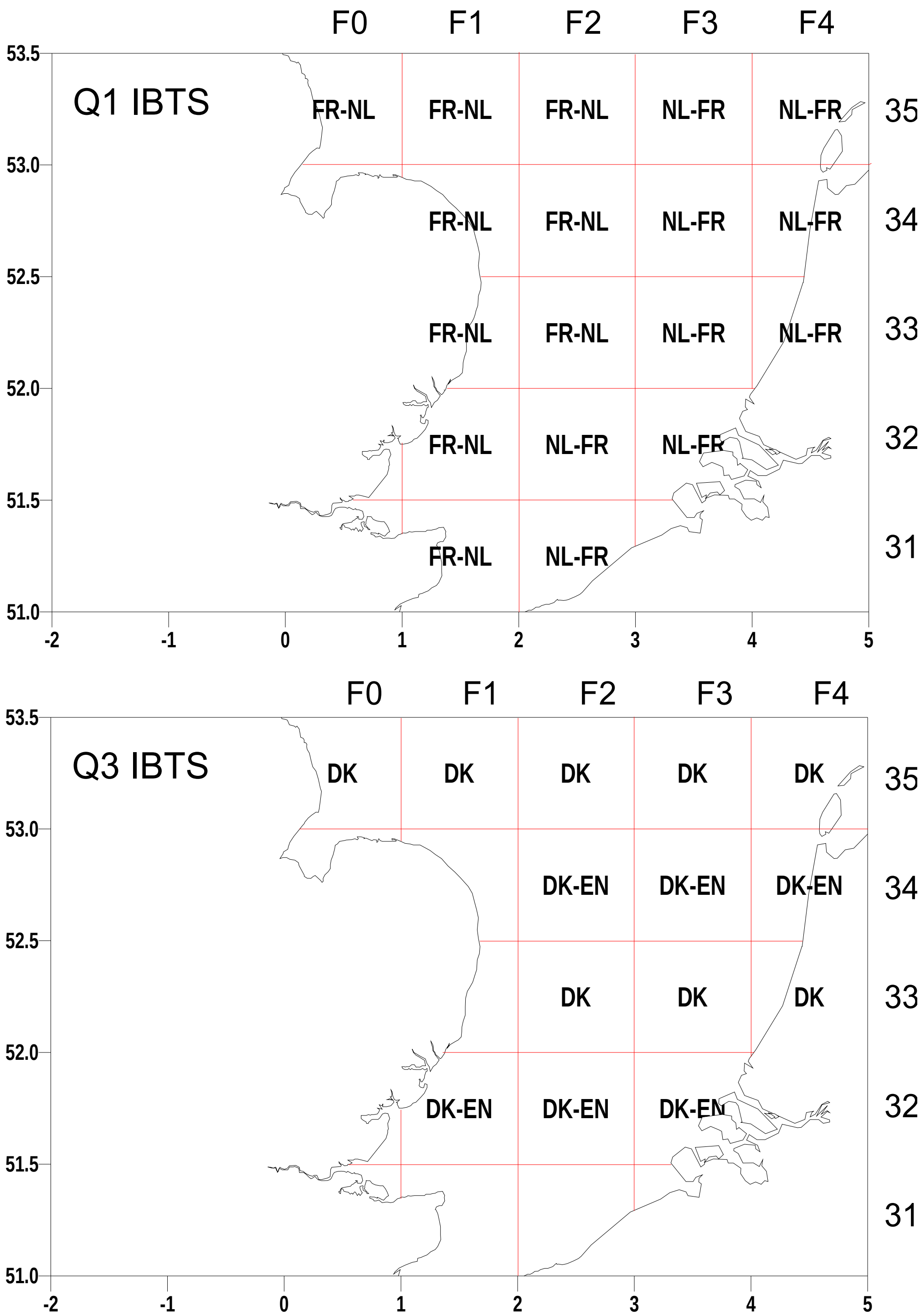


Figure 23: Distribution of survey hauls in the southern North Sea by nations participating in the Q1 and Q3 IBTS surveys (DK: Denmark; EN: England; FR: France; NL: Netherlands). Adapted from ICES (2006a).