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Movements of sole in the southern North Sea and eastern English Channel from tagging studies (1955–2004)

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Cefas

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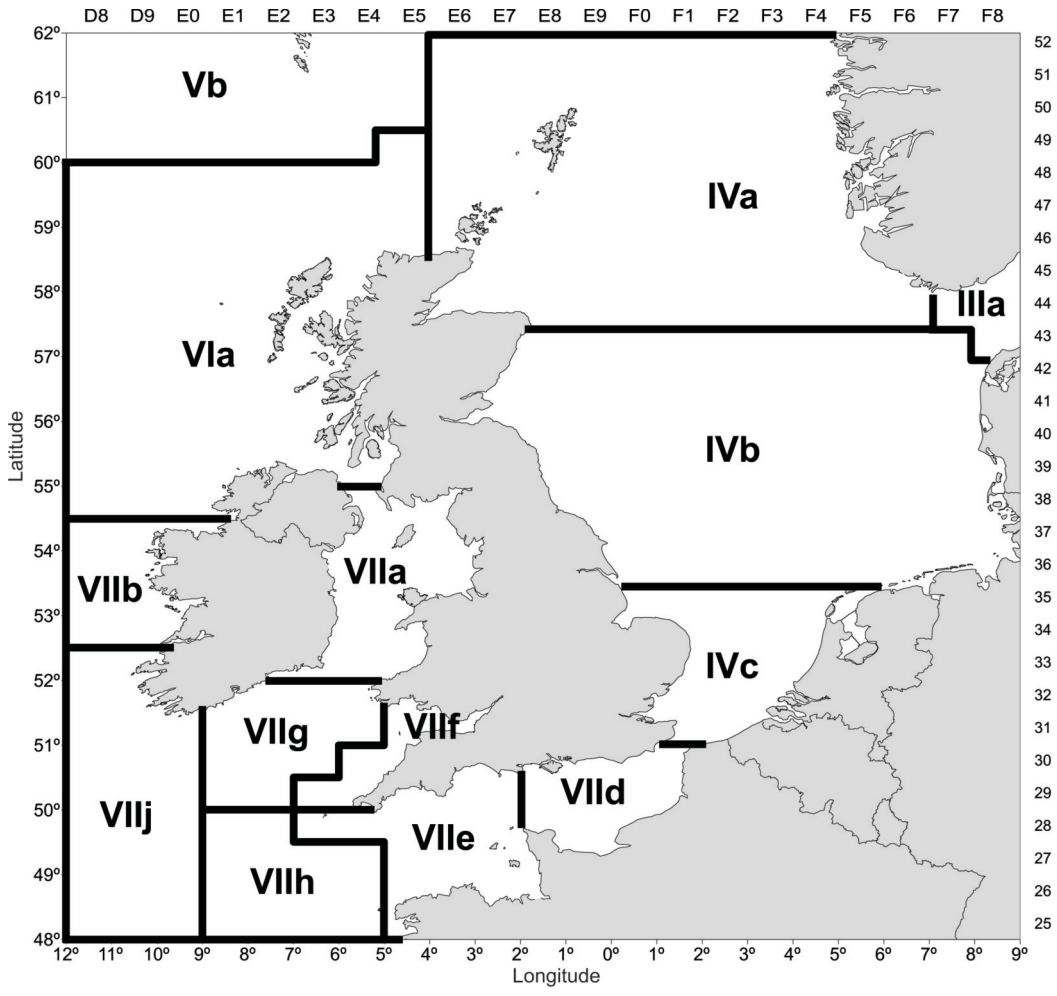
1. Introduction

Tagging has been widely used to study the behaviour, distribution and movement of many commercial fish species on fishing grounds around the UK. Much of the early work in the North Sea focused on plaice (*Pleuronectes platessa*) and cod (*Gadus morhua*), and relatively little addressed the movements of sole (*Solea solea*). However, the results of an international tagging exercise in the North Sea from 1959 to 1963 showed that sole spawned inshore in spring and generally moved offshore to feed in summer and autumn (ICES, 1965). Along the coasts of The Netherlands and Denmark, the inshore migration was thought to be a swift one in spring, associated with water temperatures inshore of 6–7°C. Along the coast of Belgium and England, however, the extent of the movement was thought to be much less than farther north.

Wallace and Watson (1980) described two small experiments on adult sole in the Thames, which showed a generally offshore movement in winter and a return to the same release area to spawn in spring. Data from a number of studies based on tagging of juveniles were collated by ICES (1989). The results indicated a seasonal pattern of movement, with inshore recaptures in the second and third quarters and a more offshore distribution at other times of the year. Also, for the first time, the results indicated

Figure 1. ICES Divisions and Rectangles.



movement of juvenile sole between ICES management areas, and in particular between VIId and the North Sea, and between VIId and VIIe (see Figure 1 for the ICES Divisions).

For management purposes, the sole stocks in ICES Divisions IV and VIId are considered to be separate units. This assumes that there is relatively little interchange of sole between them and that their responses to exploitation by fishing fleets in the two areas can be assessed within the management areas. Tagging studies have provided a means of observing the interchange between management boundaries. This report extends the analysis started by ICES, and reviews the movements of juvenile and mature sole tagged between 1955 and 2004 in the North Sea and the eastern English Channel.

2. Fisheries

In the North Sea, sole are caught mainly by Dutch beam trawlers in a mixed fishery for sole and plaice. In 2005, the landings of sole were 15 579 t, of which 70% was taken by the Netherlands and 9% by Belgium, also mostly by beam trawlers; Denmark, France, Germany and the UK contributed the balance of the landings. In the English fishery in the North Sea (IVb and IVc), sole are targeted mainly by small inshore vessels fishing with trawls and fixed nets between March and October. Ramsgate, Lowestoft, Whitstable and Folkestone were traditionally the main ports of sole landings into England.

Landings of sole in the eastern English Channel (VIId) were 4 140 t in 2005, mainly taken by French vessels (57%), with Belgium taking a further 29% and England 14%. Along the French and English coasts, there is a directed fishery for sole by small inshore vessels using fixed nets and trawls. These vessels catch sole throughout the year, with peak catches being made in spring and autumn. There is also a directed fishery by Belgian and English beam trawlers that are able to catch sole offshore in winter before the fish move inshore to spawn. Sole are taken as bycatch by French trawlers fishing offshore for mixed demersal species in the Channel and southern North Sea. Hastings, Shoreham and Rye were the main English ports for landings of sole in the eastern English Channel.

3. Distribution and biology

In the northeast Atlantic, the distribution of sole extends from the Mediterranean and the coast of North Africa up to as far north as southern Norway and the Shetlands. The main populations of sole around the UK are in the shallow southern North Sea, mainly south of 56°N, English Channel and Irish Sea. The northern limit is determined by the winter sea temperature, which needs to be above the lower lethal limit of about 3–4°C for sole (Woodhead, 1964; Horwood and Millner, 1998). Sole prefer sandy and muddy grounds, feeding mainly at night on small invertebrates such as polychaete worms and small bivalves (de Groot, 1971; Lagardere, 1987; Braber and de Groot 1973; Le Mao, 1986; Rogers, 1992).

Spawning in the southern North Sea and eastern English Channel begins in March when the water temperature reaches about 7°C, peaks in April, and lasts sporadically until late June. Spawning in the North Sea and Channel also takes place inshore, particularly near the mouths of estuaries and in protected bays, including The Wash and the River Thames estuaries in the North Sea, and Rye Bay, Baie de Somme and Baie de Seine in the eastern English Channel. The larvae drift into shallow sandy nursery grounds close to the areas of spawning. These are always areas of high productivity, providing suitable feeding conditions for the juvenile demersal sole. It is thought that the size of suitable nursery areas is one of the factors controlling the population size of sole (Rijnsdorp *et al.*, 1992). Sole are resident in these nursery areas for up to two years before moving farther offshore and becoming more widely distributed.

4. Methods

Sole tagging experiments undertaken in ICES Divisions IVb, IVc and VIId were extracted from the Cefas Tagged Fish Database (Burt *et al.*, 2006) covering the period 1955–2004. The largest numbers of tags were from experiments in the 1980s aimed at investigating the movement of sole from inshore nursery grounds. Other experiments were initiated to investigate the general distribution and behaviour of sole in the North Sea and eastern English Channel. Most of the tags were on juvenile sole, classified as fish <26 cm total length.

Sole were caught, tagged and released from research vessels and chartered commercial vessels. Fish for tagging were held in tanks with running seawater, measured to the nearest cm below, and their external condition noted. Any fish unsuitable for tagging were rejected. Standard or mini "Petersen" discs were the dominant tag type used. These are discs uniquely numbered and placed on the dorsal side and secured by a piece of stainless steel wire through a hole, and anchored to a disc on the under body (Figure 2). Fish were released close to the capture position as soon as possible after tagging. In order to encourage the return of tags, a reward was offered for both the tag and the fish. For all recaptures, a "Cefas Tagged Fish Return Form" was completed, from which the details were entered onto the Cefas Tagged Fish Database.

Figure 2. The attachment of a "Petersen" disc tag to a sole.

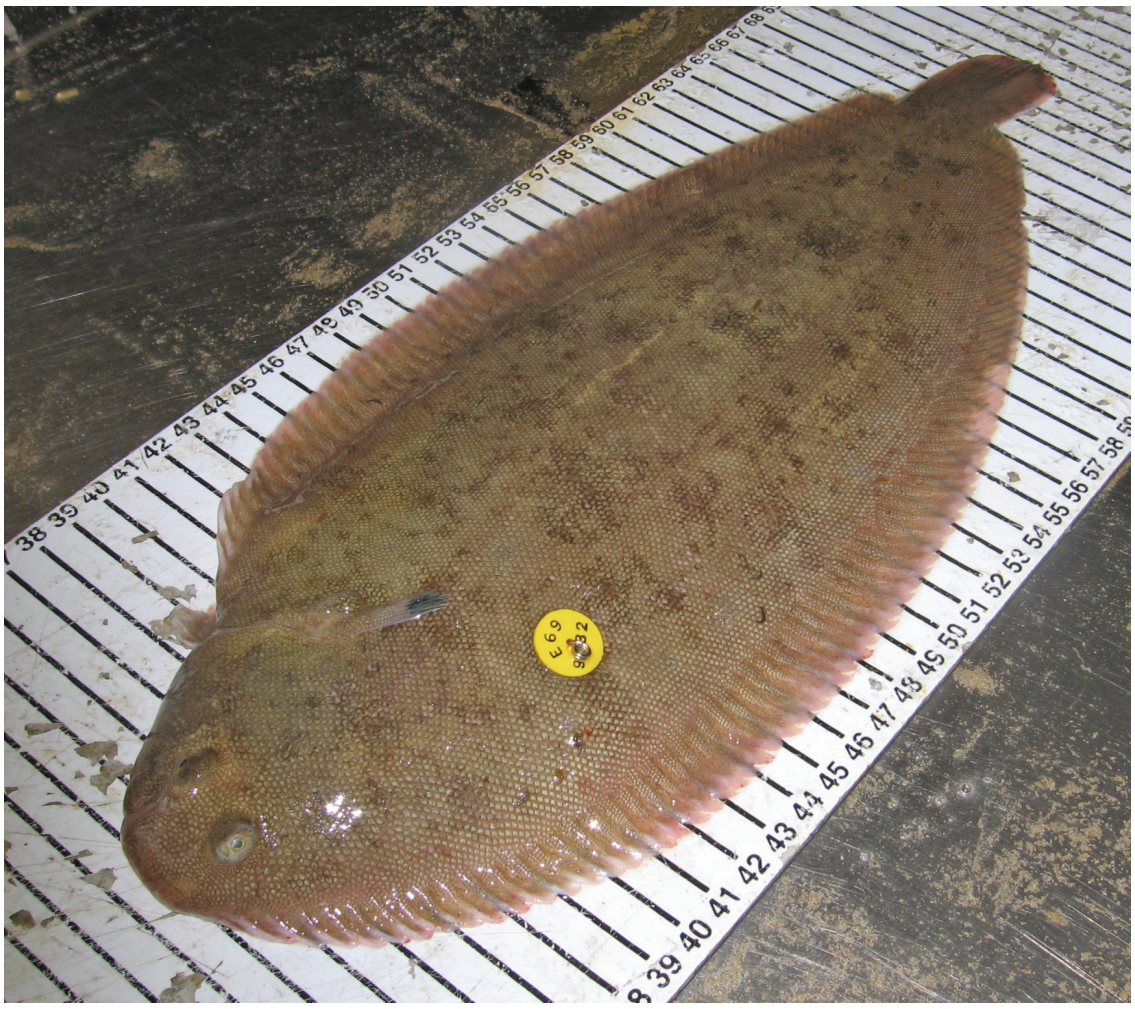
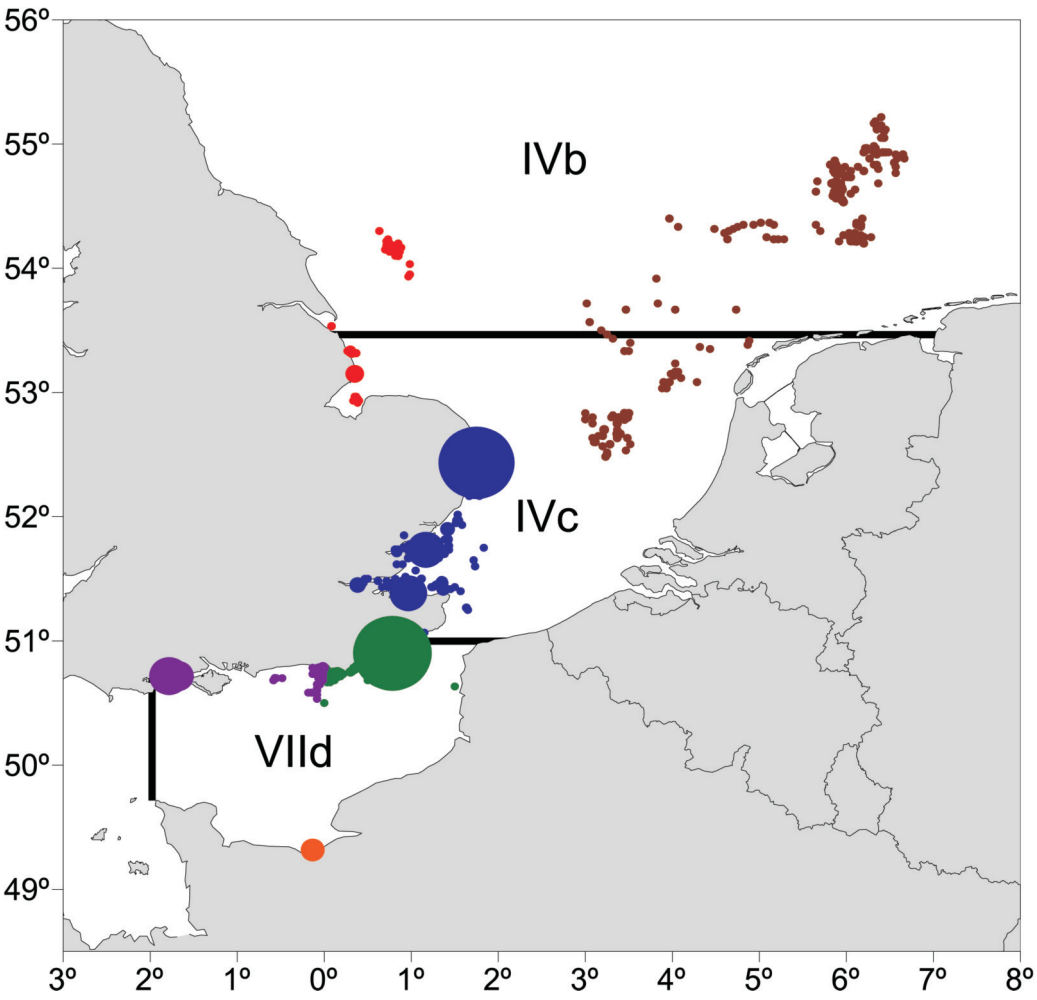


Figure 3. Geographic release areas. (1) Greater Thames Estuary (blue); (2) Flamborough – Wash (red); (3) Dutch offshore (brown); (4) Rye Bay – Newhaven (green); (5) Brighton – Poole Harbour (purple); (6) French coast (orange).



Six separate geographic release areas were identified (Figure 3). Five of these were inshore sites related to known sole nursery areas, where both immature and mature sole were released. At the only offshore release area, off the Dutch coast, only mature sole were tagged. In addition to splitting the data by geographic release area, the dataset was subdivided by time at liberty, release quarter, recapture length and recapture quarter. Where only the ICES rectangle was given as the recapture position, the centre point of the rectangle was output as the recapture point. Release and recapture lengths were classified as being either <26 cm (immature) or ≥26 cm (mature). All recaptures were included in the analysis, with the exception of five sole caught in the Irish Sea in ICES Division VIIa (Rectangles 36E6 and 38E4), which were sufficiently remote from the other recaptures that they were excluded as outliers so as to not to bias the population analysis.

Some 11% of the recaptures did not have a recapture length recorded, so as a means to maximize the dataset for analysis, simple growth regressions were applied to predict the lengths for these recaptures. All fish were measured at release, and appropriate growth rates were grouped by the three release ICES Divisions and two release length categories, to calculate separate growth regressions.

A large number of recaptures was made soon after release, so it was decided to group the recaptures only for fish at liberty for more than 90 d. This would have given the fish time to disperse from their initial release site, eliminating the immediate effects of the tagging procedure.

For each recapture, a range of movement variables was calculated (Jones, 1976), to allow comparison of the distance and direction moved by sole from different release areas. The calculations shown in Table 1 were applied to individual recaptures and averaged for each of the recapture populations.

Table 1. Population movement calculation methods and units.

Variable	Symbol	Unit	Calculation
Total number of fish	n		
Time at liberty	t	d	$\sum_{1}^{n} t$
Total distance travelled	r	km	$\sum_{1}^{n} r$
Overall bearing	ψ	°N	$\sum_{1}^{n} \theta \Big/ n$
Total northward movement	r (N)	km	$\sum_{1}^{n} r(\mathrm{N})$
Total eastward movement	r (E)	km	$\sum_{1}^{n} r(\mathrm{E})$
Velocity	v	km d^{-1}	$\sum_{1}^{n} v \Big/ n$
Mean square dispersion coefficient	a^2	km^2 d^{-1}	$\frac{1}{n}\left\{\sum\left(\frac{r^2}{t}\right) - v^2 t\right\}$

A more detailed analysis of the recaptures was carried out for each geographic release area, and the movements of sole were quantatively summarized for those fish released in quarters 2 and 3 and at liberty for >90 d. The individual release and recapture positions were plotted by recapture quarter, and the areas where there was a 95%, 75% or 50% probability of recapture being located shown using Kernel Probability Density Functions (KPDF) (Silverman, 1986; Worton, 1987, 1989). The seasonal movements are also depicted graphically by averaging the individual distances travelled by the week of the year the recaptures were made and the number of recaptures; measures of dispersion have been tabulated by quarter for juvenile and mature fish at the time of recapture. The results for each geographical release area are presented in the same format.

The recapture rate is partly determined by the extent of fishing effort in each area. Over the 50-year period of this dataset, it has not been possible to standardize the results for fishing effort, which may lead to some biases in the comparison of recaptures between areas.

5. Results

Between 1955 and 2004, 91 separate tagging experiments were undertaken and 29 609 sole were released (Table 2), of which 8 129 were recaptured. Of these, 7 488 had a recapture date and position recorded and were therefore suitable for analysis (Table 3). The main release period was during the 1980s, with the exception of the releases in the Dutch offshore area, which were during the 1950s and 1960s (Table 2a). Appendices 9.1 and 9.2 provide a breakdown of the number of releases and recaptures by year of release and by individual experiment. For the 7 488 recaptures, 90% of the positions were true, and the remaining 10% were derived from the ICES rectangle midpoint. Table 3 shows the data subsets by time at liberty, release quarter, recapture length group and geographic release area. The main release periods were spring and summer in quarters 2 and 3.

Some 23% of sole recaptures were made up to 90 d after release (Table 3). Indeed, several sole were caught the same day as they were released. For sole at liberty for more than 90 d, the average time spent between release and recapture was 636 d. The maximum time spent at liberty by an individual was 6 469 d (>17 years). This individual was

Table 2. Sole release dataset sample sizes.

a) Numbers released by area.

Release quarter	Release length group	Greater Thames Estuary	Flam-borough – Wash	Dutch offshore	Rye Bay – Newhaven	Brighton – Poole Harbour	French coast	Total
1	Juvenile	9		688	16	25		738
	Mature			1 875	190	273		2 338
	Total	9		2 563	206	298		3 076
2	Juvenile	8 432	1 886	374	2 143	2 716	804	16 355
	Mature	1 525	59	1 491	313	273	58	3 719
	Total	9 957	1 945	1865	2 456	2 989	862	20 074
3	Juvenile	1 186	499	5	605	64		2 359
	Mature	758	701	18	98	349		1 924
	Total	1 944	1 200	23	703	413		4 283
4	Juvenile	282	1	96	101	181		661
	Mature	60	52	406	512	485		1 515
	Total	342	53	502	613	666		2 176
Total	Juvenile	9 909	2 386	1 163	2 865	2 986	804	20 113
	Mature	2 343	812	3 790	1 113	1 380	58	9 496
	Total	12 252	3 198	4 953	3 978	4 366	862	29 609

b) Percentages released by decade.

Decade of release	Greater Thames Estuary	Flam-borough – Wash	Dutch offshore	Rye Bay – Newhaven	Brighton – Poole Harbour	French coast	Total
1950s	14.3%	2.1%	52.1%	6.1%			15.7%
1960s	1.0%	23.8%	47.9%				11.0%
1970s	19.8%	17.7%		24.9%	22.9%		16.8%
1980s	63.8%	56.4%		69.0%	77.1%	100.0%	56.1%
1990s							
2000s	1.0%						0.4%

Table 3. Sole recapture dataset sample sizes for fish with a notified recapture date and position.

Number of days at liberty	Release quarter	Release length group	Greater Thames Estuary	Flam-borough – Wash	Dutch offshore	Rye Bay – Newhaven	Brighton – Poole Harbour	French coast	Total
>90	2 & 3	Juvenile	685	74	10	476	389	26	1 660
		Mature	1 582	153	219	655	681	78	3 368
		Total	2 267	227	229	1 131	1 070	104	5 028
	1 & 4	Juvenile	13		30	12	13		68
		Mature	16	3	208	262	190		679
		Total	29	3	238	274	203		747
<=90	2 & 3	Juvenile	539	15	8	196	93	28	879
		Mature	235	20	71	57	49	3	435
		Total	774	35	79	253	142	31	1 314
	1 & 4	Juvenile			60	3	2		65
		Mature		2	295	22	15		334
		Total		2	355	25	17		399
Total			**3 070**	**267**	**901**	**1 683**	**1 432**	**135**	**7 488**
% return rate			**25.1%**	**8.3%**	**18.2%**	**42.3%**	**32.8%**	**15.7%**	**25.3%**

captured in August 1993, 34 km from its original release position just off the coast of Brighton in May 1975. The maximum distance recorded from a release position was 763 km, by a sole tagged close to the Isle of Wight and recaptured 1 128 d later on the Helgoland Grund fishing grounds just off the German coast.

Recapture rates (Table 3) varied considerably, reflecting differing levels of fishing intensity, but also some variation in the return rate from fishers. The rate was highest in the English Channel, where some 32–43% of the releases were recaptured. The return rate was poorer for releases on the French coast and in the Dutch offshore area (16–18%), probably because of the greater difficulties in sourcing tags retaken by non-UK fishers. The Flamborough–Wash release had the lowest return rate of just 8%, a reflection probably of the limited fishing effort for sole in the area. Recaptures peaked (Figure 4) after 12 and 24 months, indicating seasonal aggregations of sole and/or increased fishing activity, and coinciding with the main release periods in quarters 2 and 3.

Sole were recaptured by a variety of fishing methods (Table 4), of which demersal otter trawl, beam trawl and fixed/drift nets were the most common. In the Dutch offshore area, gear type was rarely recorded, but it is expected to be beam trawl because of the dominance of beam trawling effort there.

Figure 4. Recapture months/years at liberty.

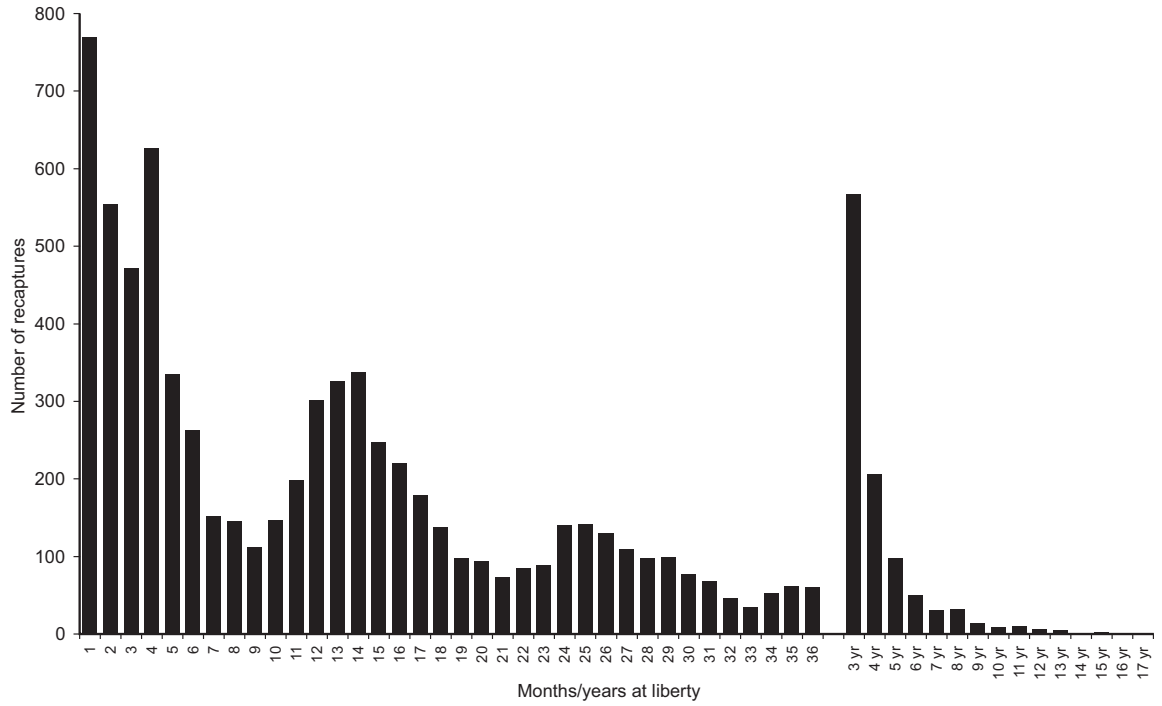


Table 4. Tagged sole recapture method by geographic release area.

Recapture method	Greater Thames Estuary	Flamborough – Wash	Dutch offshore	Rye Bay – Newhaven	Brighton – Poole Harbour	French coast	All
Demersal otter trawl	43.4%	61.8%	13.7%	29.4%	37.0%	63.9%	36.4%
Beam trawl	28.5%	18.9%	0.1%	14.7%	29.3%	16.0%	21.4%
Fixed / drift net	7.5%	4.3%	7.8%	46.8%	22.9%	7.6%	18.6%
Other gears	0.4%	0.3%	1.9%	1.1%	4.4%	2.8%	1.5%
Not recorded	20.1%	14.6%	76.5%	8.0%	6.4%	9.7%	22.1%

5.1 The North Sea (IVb, c)

5.1.1. The Greater Thames Estuary

The seasonal recapture pattern is summarized in Table 5 and Figures 5–7. For the Greater Thames Estuary there were sufficient returns for it to be possible to split the recaptures into mature and immature fish.

The results indicate a movement of fish away from the coast during the first and fourth quarters, whereas sole remained generally closer to the coast for the rest of the year. Most of the dispersion during late autumn and winter is in an eastward and northward direction, i.e. away from the coast, and mainly northwards along the coast of Essex, extending as far north as the River Humber during quarter 1. Although the dominant movement was east and north, there was some southwest movement, with 8.2% of the recaptures coming from VIId and 2.1% from VIIe (see Table 11a later). In quarters 2 and 3, 95% of the recaptures were in a relatively confined area between Rye Bay in the English Channel and The Wash (Figures 5 and 6), whereas <50% of the fish remained within this boundary during late autumn and winter (quarters 1 and 4).

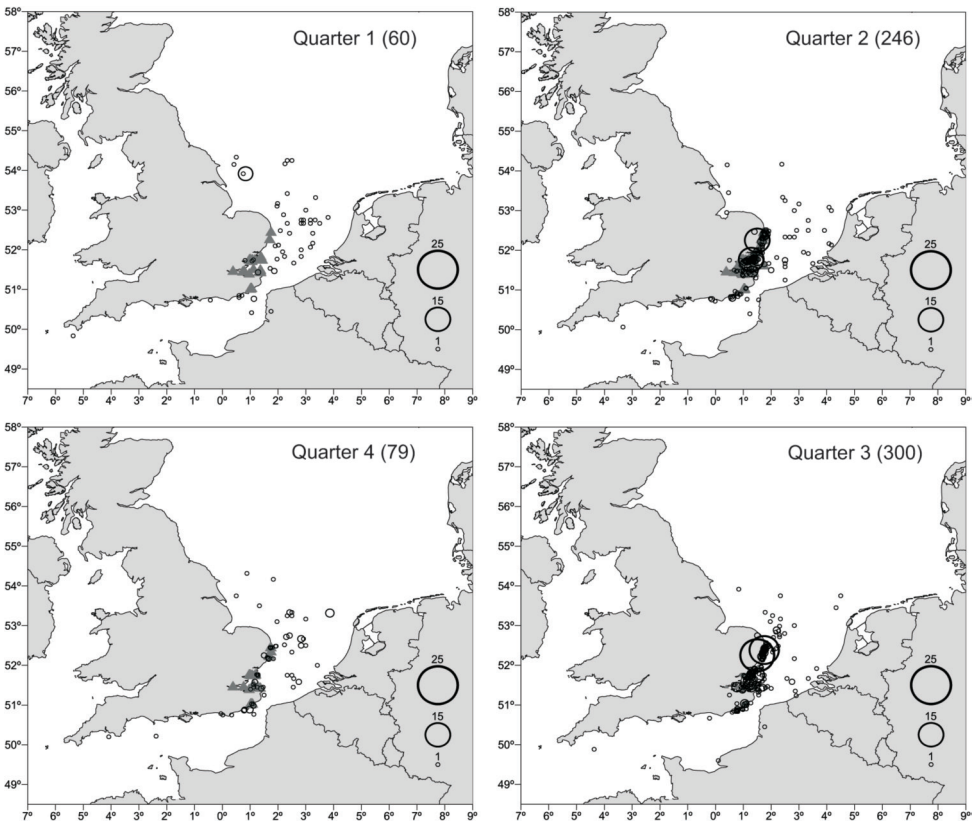
A comparison between the two length groups reveals little difference between them. In general, juveniles showed the same marked dispersion in winter and inshore movement during spring and summer as mature fish, though the movements were less pronounced (Figure 7a). Fish recaptured in the first quarter had travelled furthest from the release site, on average by 176 km for mature sole compared with 76 km for the recaptures in quarter 2 (Table 5). Similar differences were exhibited by juvenile sole, but the average distances travelled were shorter, 149 km for quarter 1 and 46 km for quarter 2. The lowest dispersion coefficients for each of the quarters were in quarter 2, reflecting probable aggregation associated with spawning of mature fish in spring. The similar pattern for juveniles suggests that they behave in like manner once they have left the shallow inshore nursery grounds. On average, fish remained within 75 km (mature fish) and 43 km (juveniles) from their release positions during summer, dispersing north and east through autumn.

Table 5. Overall movement parameters of recaptured juvenile and mature sole, released in the Greater Thames Estuary during quarters 2 and 3.

Recapture length group	Juvenile					
Recapture quarter	**Q1**	**Q2**	**Q3**	**Q4**	**Q1 & 4**	**Q2 & 3**
Total number of fish	60	246	300	79	139	546
Average time at liberty	341.33	463.26	318.57	287.10	310.51	383.76
Average distance (km)	149.99	46.89	43.73	87.03	114.21	45.16
Average northward movement (km)	94.64	7.78	11.99	37.78	62.32	10.09
Average eastward movement (km)	41.17	14.77	17.04	33.77	36.97	16.02
Overall direction of movement (°)	23.51	62.22	54.88	41.79	30.67	57.79
Mean square dispersion coefficient	40.74	10.02	14.39	28.33	35.13	12.55
Recapture length group	**Mature**					
Recapture quarter	**Q1**	**Q2**	**Q3**	**Q4**	**Q1 & 4**	**Q2 & 3**
Total number of fish	227	471	542	342	569	1013
Average time at liberty	864.74	776.76	695.87	598.72	704.85	733.48
Average distance (km)	176.40	76.18	74.96	126.97	146.69	75.53
Average northward movement (km)	113.96	11.97	24.59	61.05	82.16	18.72
Average eastward movement (km)	16.14	23.90	24.27	27.68	23.08	24.10
Overall direction of movement (°)	8.06	63.40	44.62	24.39	15.69	52.15
Mean square dispersion coefficient	27.11	14.17	18.29	37.13	33.14	16.39

Figure 5. Quarterly recaptures of juvenile sole, tagged in the Greater Thames Estuary and released in quarters 2 and 3. a) The release positions are shown as solid triangles and the numbers recaptured as open circles. The total number of recaptures by quarter is given in parenthesis against the quarter. b) Recapture 95% (red), 75% (orange) and 50% (yellow) KPDFs.

a)



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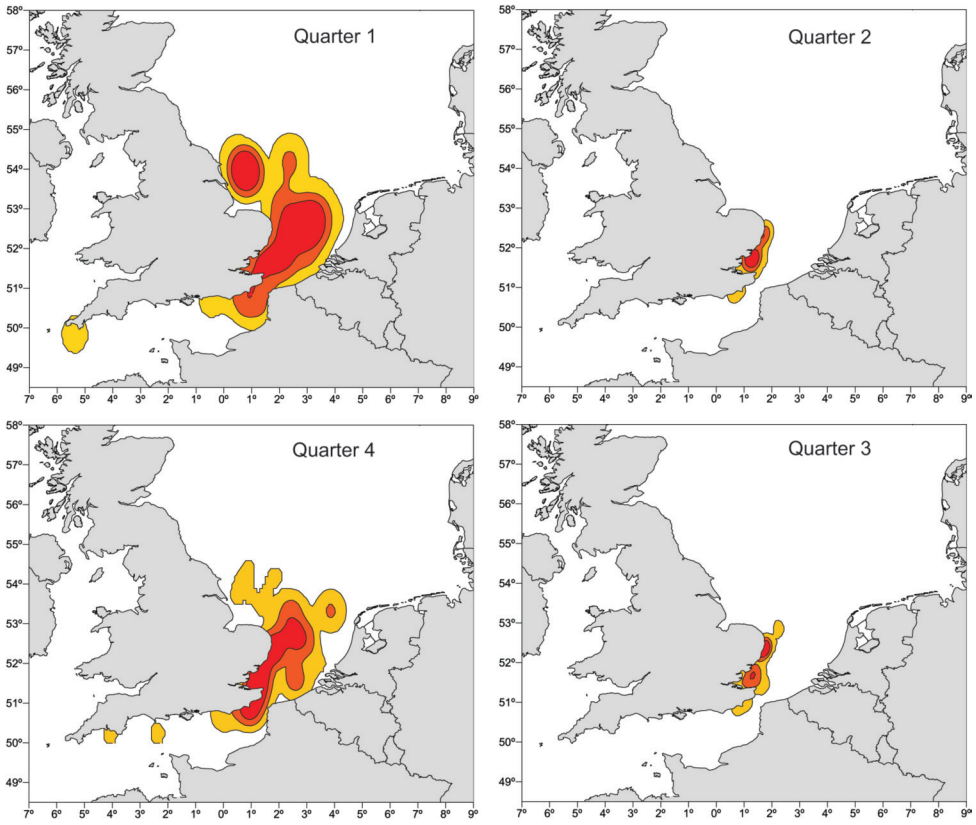
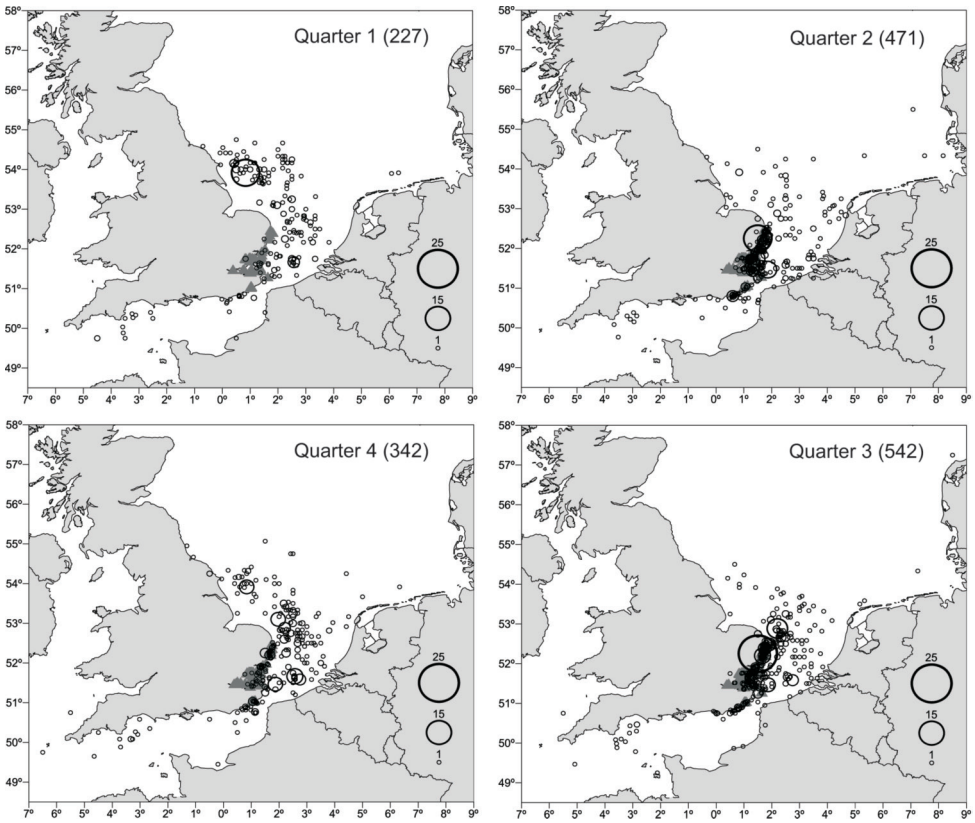


Figure 6. Quarterly recaptures of mature sole, tagged in the Greater Thames Estuary and released in quarters 2 and 3. a) The release positions are shown as solid triangles and the numbers recaptured as open circles. The total number of recaptures by quarter is given in parenthesis against the quarter. b) Recapture 95% (red), 75% (orange) and 50% (yellow) KPDFs.

a)



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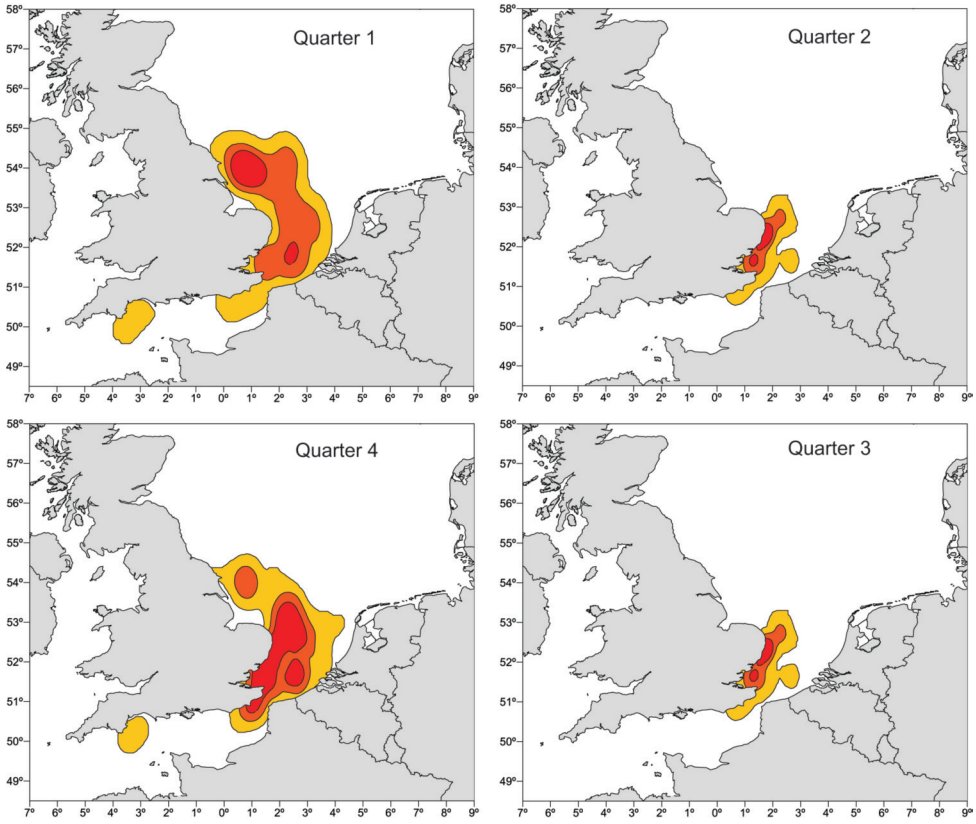
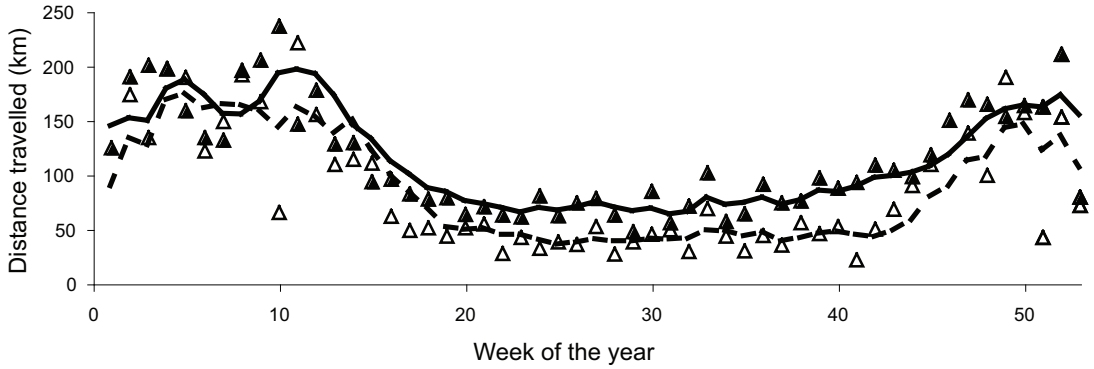


Figure 7. Mean distances travelled by recaptured juvenile (open triangles) and mature (solid triangles) sole by the week of the year, released in quarters 2 and 3 in the Greater Thames Estuary. The dashed and solid lines show the four-week moving averages for juvenile and mature sole, respectively. a.) Overall distance travelled, b.) Distance travelled in an east/west direction, and c.) Distance travelled in a north/south direction.

a.)



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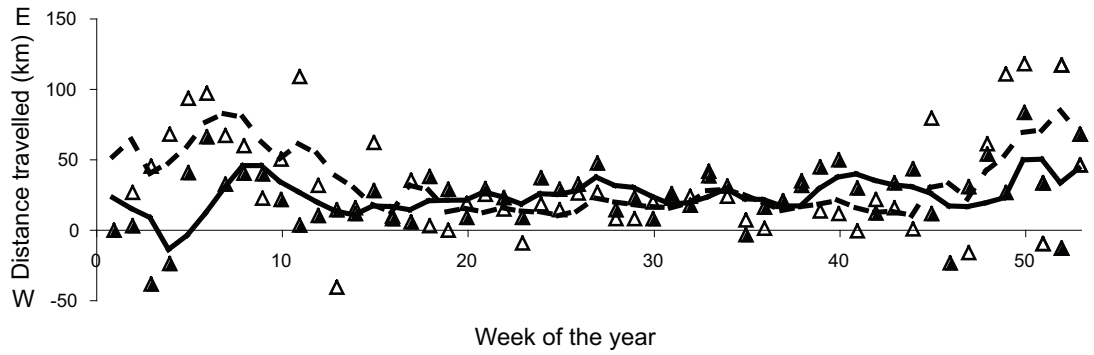

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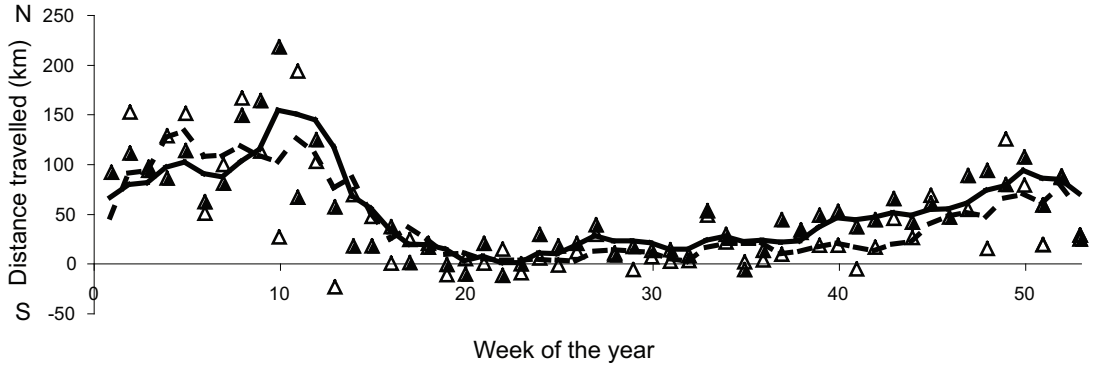


5.1.2. UK coast between Flamborough and The Wash

This analysis combined recaptures of juvenile and mature sole because of the relatively small sample sizes involved. Table 6 and Figures 8 and 9 show the seasonal pattern of movement of sole released off the UK coast between Flamborough and The Wash.

Sole released in quarters 2 and 3 dispersed into an area along the coast during autumn and winter (quarters 4 and 1), 95% of the recaptures being made between the Northumberland and north Norfolk coasts (Figure 8). The pattern was mainly northwards along the northeast coast, with limited net movement east and offshore (Figure 9). Some of the recaptures were made off the Dutch coast, but there was very little movement in a southeasterly direction and no recaptures were made in the eastern English Channel. In quarter 2, 95% of the sole remained within the localized area between The Wash and the River Humber, then began to disperse north along the coast during quarter 3.

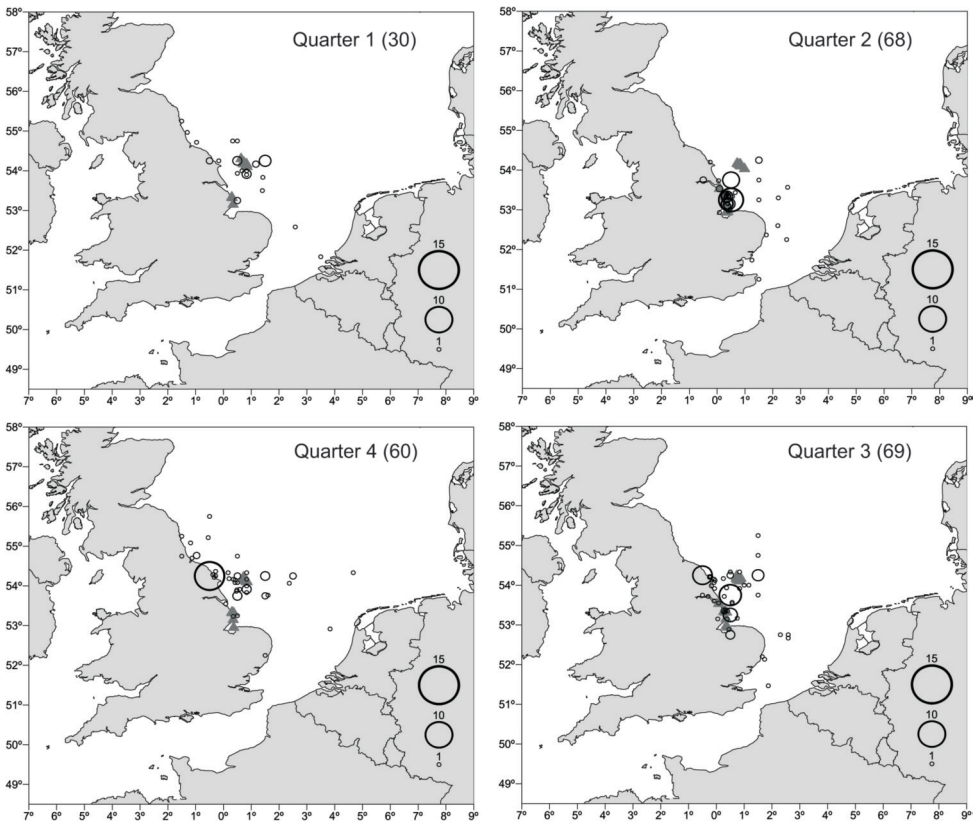
The results in Table 6 show that sole recaptured in the first and fourth quarters had moved an average of 107 km from their spring/summer release site. By comparison, during early spring and summer they had dispersed little and had travelled on average <57 km from their release position. Table 6 also emphasizes the difference in the northward component between quarters. During quarters 2 and 3, the average movement was 12 km, compared with 72 km during winter.

Table 6. Overall movement parameters of recaptured sole, released off the coast between Flamborough and The Wash during quarters 2 and 3.

Recapture length group	All					
Recapture quarter	**Q1**	**Q2**	**Q3**	**Q4**	**Q1 & 4**	**Q2 & 3**
Total number of fish	30	68	69	60	90	137
Average time at liberty	786.53	1 036.28	940.93	1 095.60	992.58	988.26
Average distance (km)	95.04	38.39	75.10	113.33	107.23	56.88
Average northward movement (km)	58.19	-4.89	28.77	80.38	72.98	12.07
Average eastward movement (km)	14.56	12.09	6.44	-1.83	3.63	9.25
Overall direction of movement (°)	14.05	-67.99	12.62	-1.30	2.85	37.46
Mean square dispersion coefficient	12.06	6.56	6.75	13.35	12.98	7.11

Figure 8. Quarterly recaptures of sole, tagged between Flamborough and The Wash and released in quarters 2 and 3. a) The release positions are shown as solid triangles and the numbers recaptured as open circles. The total number of recaptures by quarter is given in parenthesis against the quarter. b) Recapture 95% (red), 75% (orange) and 50% (yellow) KPDFs.

a)



b)

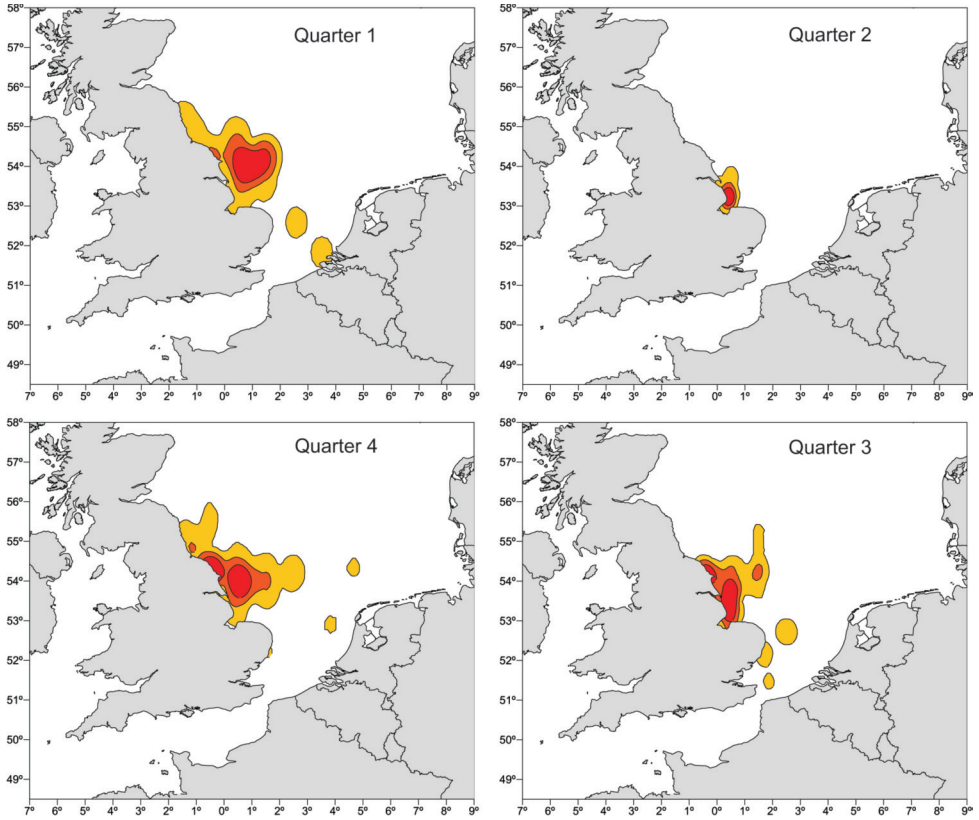
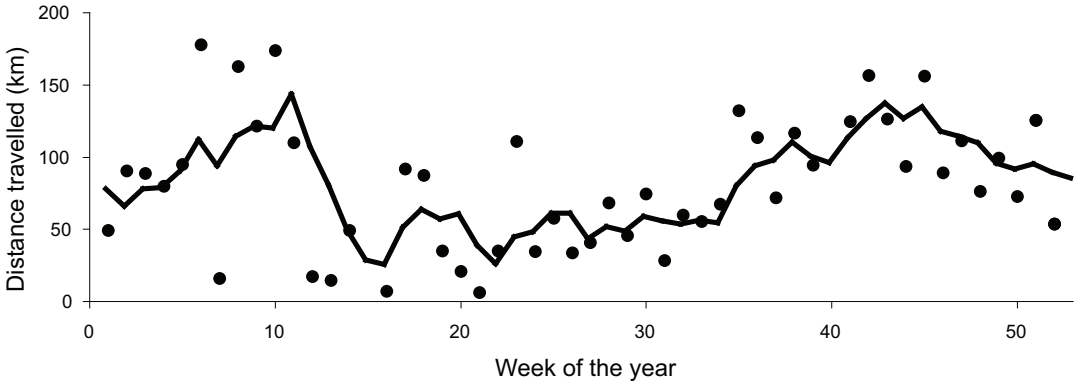
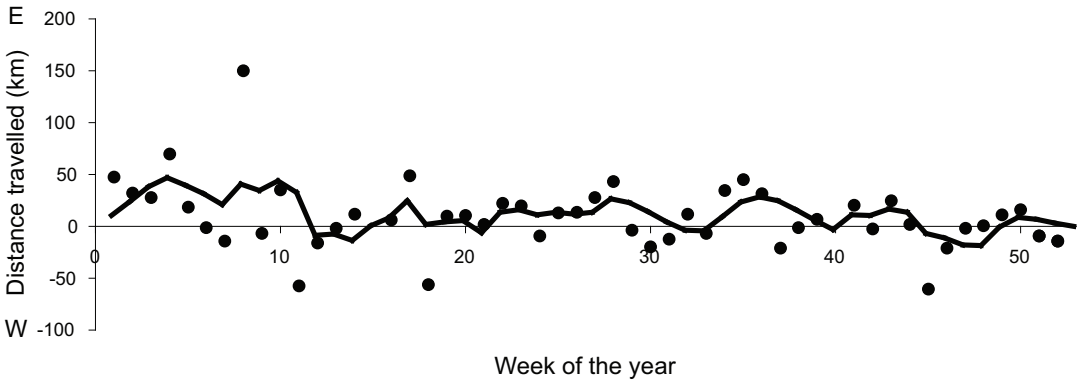


Figure 9. Mean distances travelled by recaptured sole by the week of the year, released in quarters 2 and 3 between Flamborough and The Wash. The solid line shows the four-week moving averages. a.) Overall distance travelled, b.) Distance travelled in an east/west direction, and c.) Distance travelled in a north/south direction.

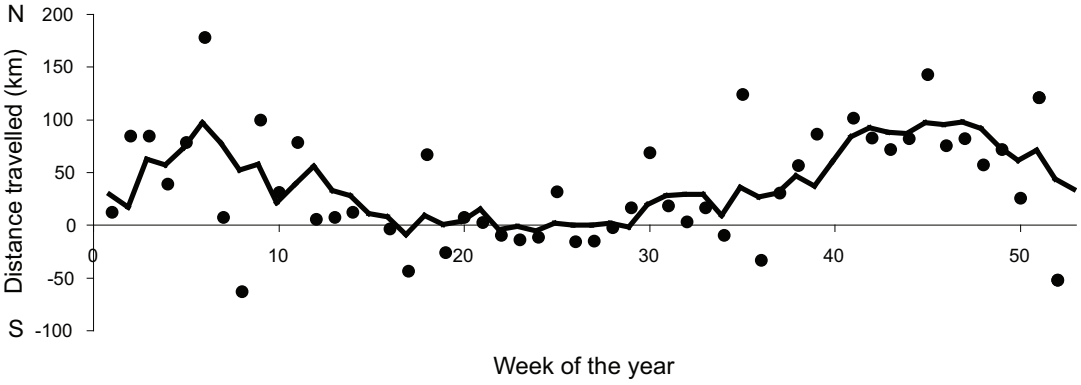
a.)



b.)



c.)



5.1.3. Dutch offshore

These release sites differed from the other sites because the releases were situated farther offshore and consisted mainly of mature sole >26 cm on recapture. The results are shown in Table 7 and Figures 10 and 11.

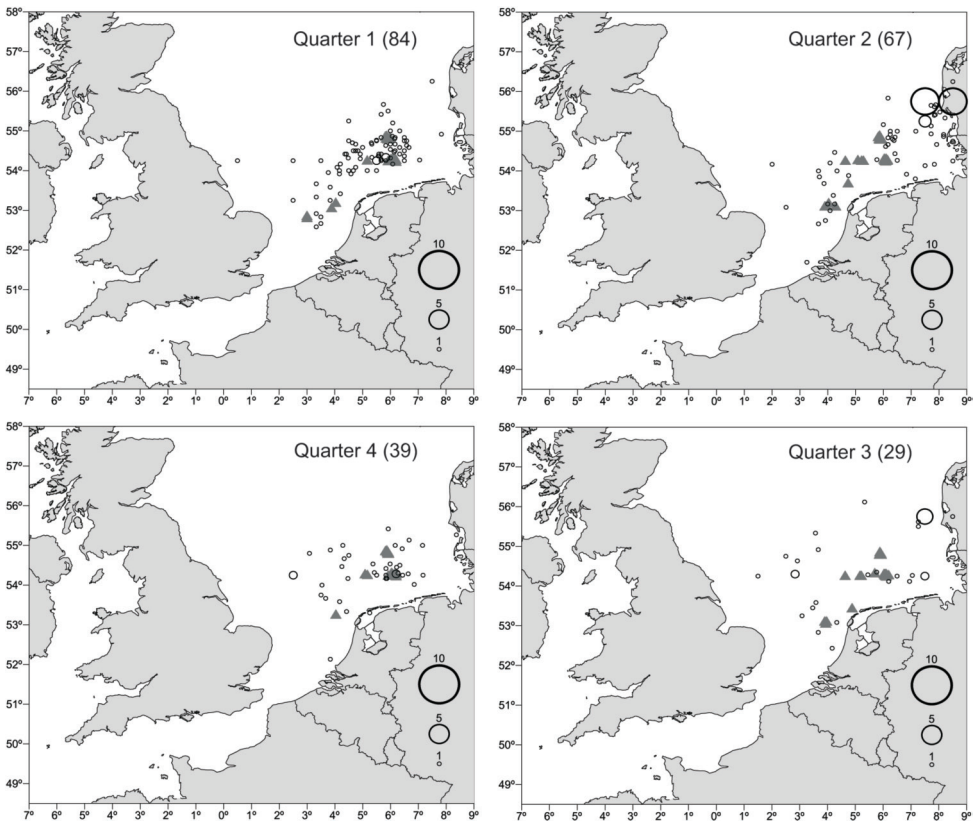
The seasonal pattern of movement shown in Figure 10 shows that in quarter 2, although some fish remained offshore, sole had generally travelled northeastwards from the release area and had congregated inshore, off the coast of Denmark. Sole were still recaptured along the Danish coast during quarter 3, but were more dispersed and had moved west. During autumn and winter (quarters 4 and 1), sole were encountered mainly offshore, with few recaptures inshore along the continental coast. Figure 11 also shows the northeastward movement associated with spring and summer migration. Throughout the year there was an indication of movement south, but no recaptures were made as far south as the English Channel. The movement to the west was restricted to the central North Sea, and only one recapture was made off the Yorkshire coast. In the first quarter, mature fish had moved on average <86 km, and remained at their closest to their offshore release positions, which was also the case for the quarter 4 recaptures, for which similar values were calculated (Table 7). Sole dispersed farther and travelled more over the next two quarters, by around 130 km on average.

Table 7. Overall movement parameters of recaptured mature sole, released in the Dutch offshore area during quarters 2 and 3.

Recapture length group	Mature					
Recapture quarter	**Q1**	**Q2**	**Q3**	**Q4**	**Q1 & 4**	**Q2 & 3**
Total number of fish	84	67	29	39	123	96
Average time at liberty	705.57	721.94	586.86	571.77	663.15	681.14
Average distance (km)	85.98	132.52	130.32	95.91	89.13	131.85
Average northward movement (km)	1.69	35.68	41.32	-2.71	0.30	37.39
Average eastward movement (km)	-40.49	53.26	-12.71	-42.20	-41.03	33.33
Overall direction of movement (°)	-87.60	56.18	-17.10	86.33	-89.58	41.72
Mean square dispersion coefficient	9.20	21.09	43.42	16.97	11.94	28.03

Figure 10. Quarterly recaptures of mature sole, tagged in the Dutch offshore area and released in quarters 2 and 3. a) The release positions are shown as solid triangles and the numbers recaptured as open circles. The total number of recaptures by quarter is given in parenthesis against the quarter. b) Recapture 95% (red), 75% (orange) and 50% (yellow) KPDFs.

a)



b)

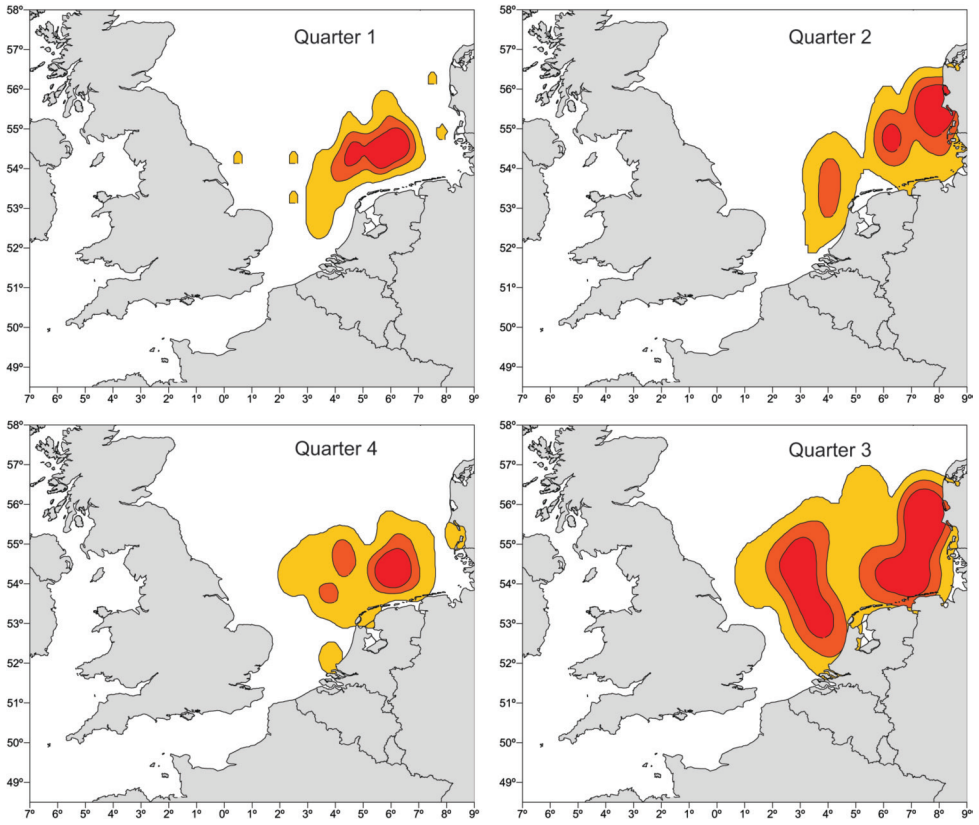
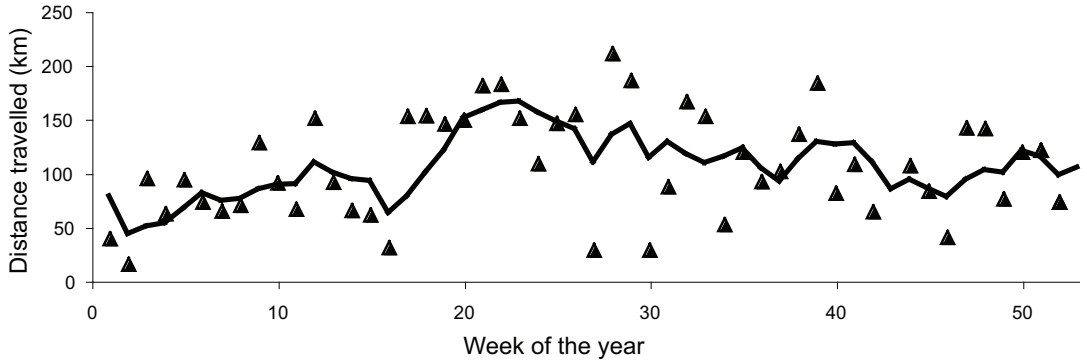
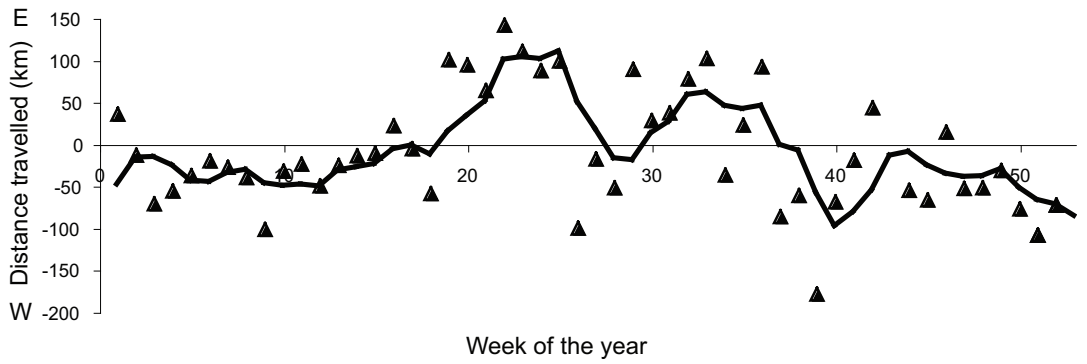


Figure 11. Mean distances travelled by recaptured mature sole by the week of the year, released in quarters 2 and 3 in the Dutch offshore area. The solid line shows the four-week moving averages. a.) Overall distance travelled, b.) Distance travelled in an east/west direction, and c.) Distance travelled in a north/south direction.

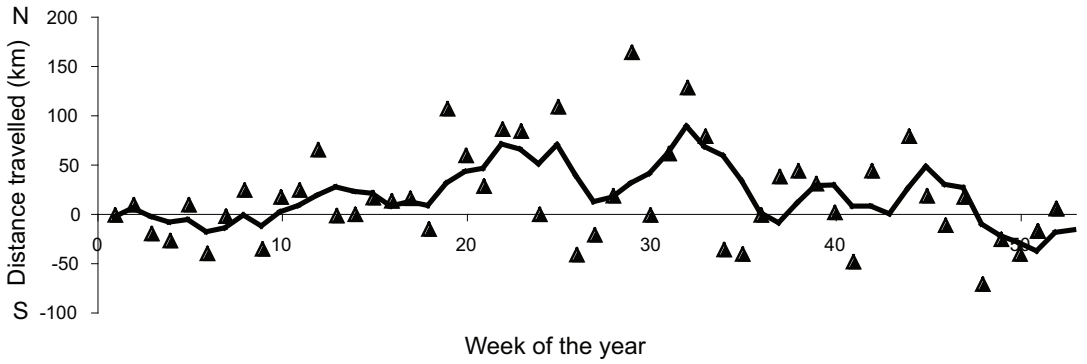
a.)



b.)



c.)



5.2. Eastern English Channel (VIId)

5.2.1. UK coast between Rye Bay and Newhaven

The seasonal pattern of movement for juvenile and mature recaptured sole released off the southeast English coast between Rye Bay and Newhaven is presented in Table 8 and Figures 12–14.

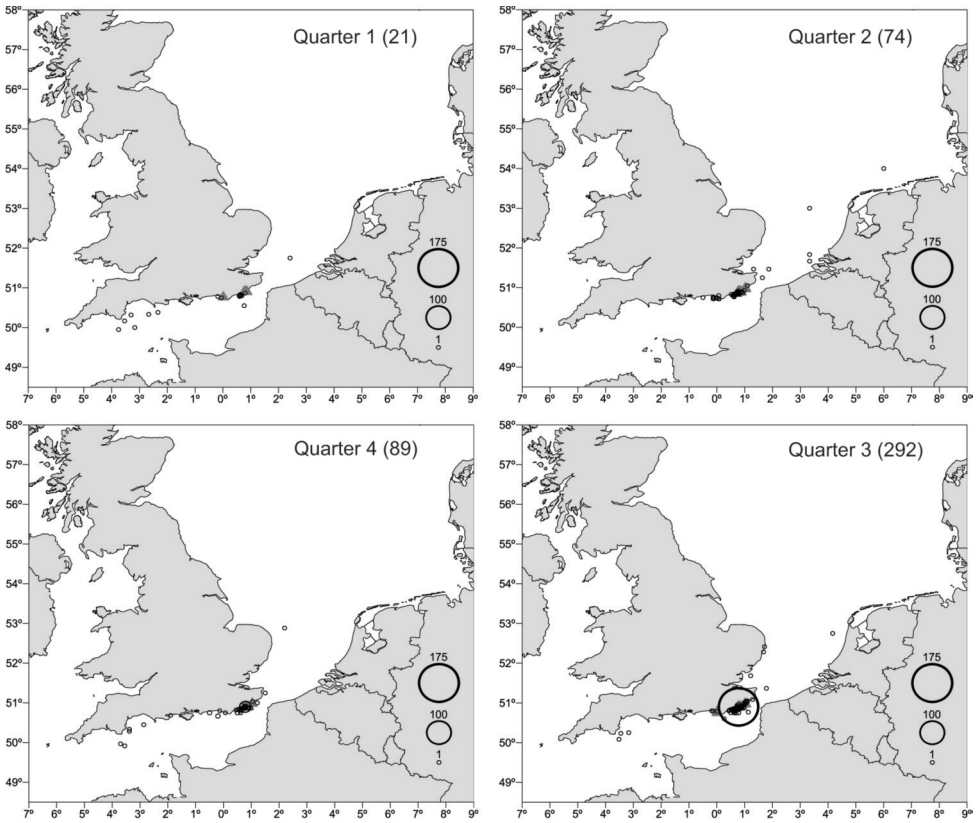
Juvenile sole moved away from the release site relatively little during quarters 2, 3 and 4, and 95% remained within about 50 km of their release position. The main period of dispersion appears to take place during quarter 1, with a significant number of recaptures then coming from the western Channel (Figure 12). The mature recaptures show more pronounced movement than juveniles. In the second and third quarters, 75% of the fish were recaptured near the release positions, whereas in quarters 1 and 4 sole had dispersed farther (Figure 13). The movement was mainly westward along the English coast towards Brixham, where fish were recaptured in all four quarters. Over the year, fewer than 20% of the mature fish were recaptured in the North Sea and there was virtually no movement south towards the French coast, as was the case for the juvenile sole recaptured . Mature sole generally moved greater distances from their release site in all quarters than juveniles (Table 8 and Figure 14a). The increased east–west movement in quarter 1 is also evident in Figure 14b. The seasonality described in Figures 12–14 is also shown by the average distances and dispersion coefficients calculated for the different quarters in Table 8. For both length groups, the data show that sole recaptured in the first and fourth quarters had travelled farther and dispersed more from their release sites than those recaptured in quarters 2 and 3, and the average distances travelled were greater for mature fish than for juveniles, in all quarters.

Table 8. Overall movement parameters of recaptured juvenile and mature sole, released between Rye Bay and Newhaven during quarters 2 and 3.

Recapture length group	Juvenile					
Recapture quarter	**Q1**	**Q2**	**Q3**	**Q4**	**Q1 & 4**	**Q2 & 3**
Total number of fish	21	74	292	89	110	366
Average time at liberty	301.05	425.00	171.92	202.74	221.51	223.09
Average distance (km)	103.49	37.27	10.67	34.45	47.63	16.05
Average northward movement (km)	-25.68	5.67	1.29	-4.97	-8.93	2.18
Average eastward movement (km)	-84.27	-0.15	-2.57	-26.29	-37.36	-2.08
Overall direction of movement (°)	73.05	-1.52	-63.27	79.29	76.56	-43.65
Mean square dispersion coefficient	75.66	13.23	5.92	16.87	29.38	7.43
Recapture length group	**Mature**					
Recapture quarter	**Q1**	**Q2**	**Q3**	**Q4**	**Q1 & 4**	**Q2 & 3**
Total number of fish	79	188	245	143	222	433
Average time at liberty	729.80	708.17	518.80	466.33	560.09	601.02
Average distance (km)	127.65	93.31	81.25	80.73	97.43	86.49
Average northward movement (km)	-3.72	15.66	2.47	7.47	3.49	8.20
Average eastward movement (km)	-66.29	-14.38	-38.30	-29.48	-42.58	-27.91
Overall direction of movement (°)	86.79	-42.56	-86.31	-75.79	-85.32	-73.63
Mean square dispersion coefficient	39.63	22.35	20.71	22.53	28.61	21.51

Figure 12. Quarterly recaptures of juvenile sole, tagged between Rye Bay and Newhaven and released in quarters 2 and 3. a) The release positions are shown as solid triangles and the numbers recaptured as open circles. The total number of recaptures by quarter is given in parenthesis against the quarter. b) Recapture 95% (red), 75% (orange) and 50% (yellow) KPDFs.

a)



b)

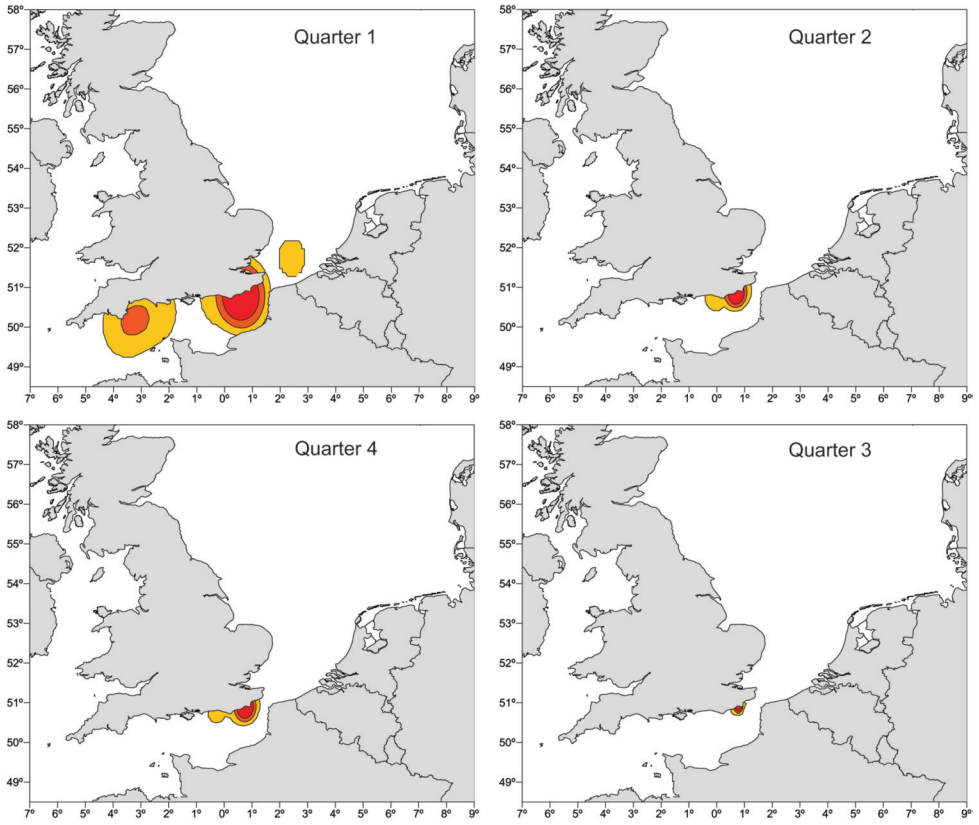
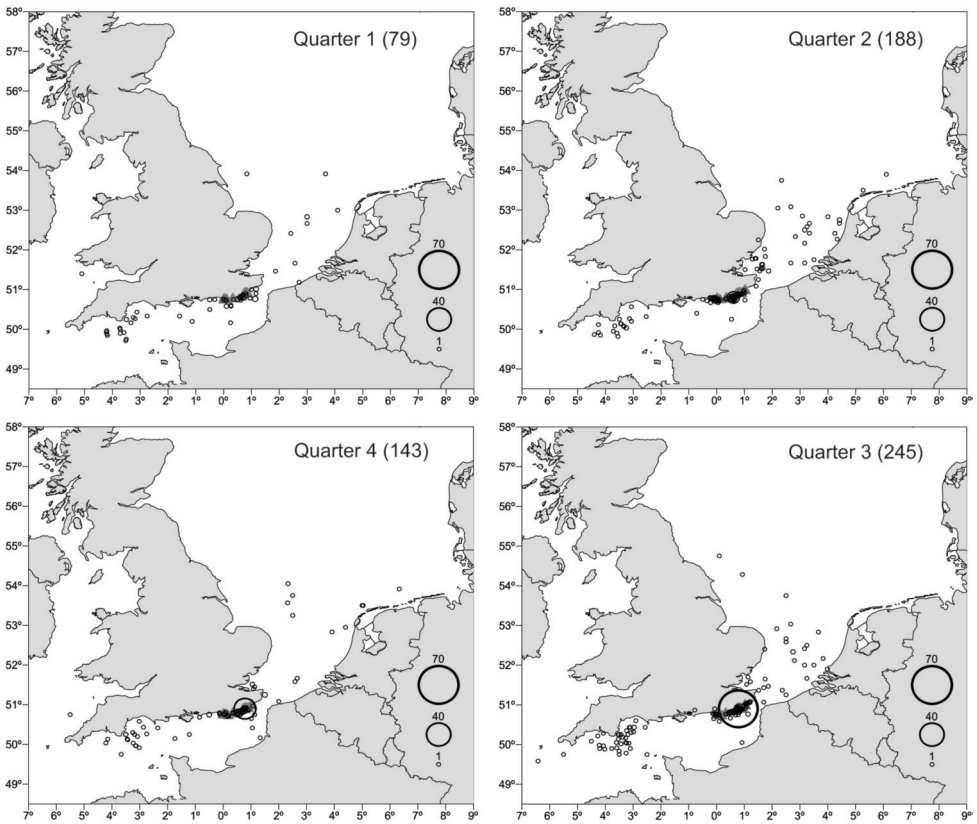


Figure 13. Quarterly recaptures of mature sole, tagged between Rye Bay and Newhaven and released in quarters 2 and 3. a) The release positions are shown as solid triangles and the numbers recaptured as open circles. The total number of recaptures by quarter is given in parenthesis against the quarter. b) Recapture 95% (red), 75% (orange) and 50% (yellow) KPDFs.

a)



b)

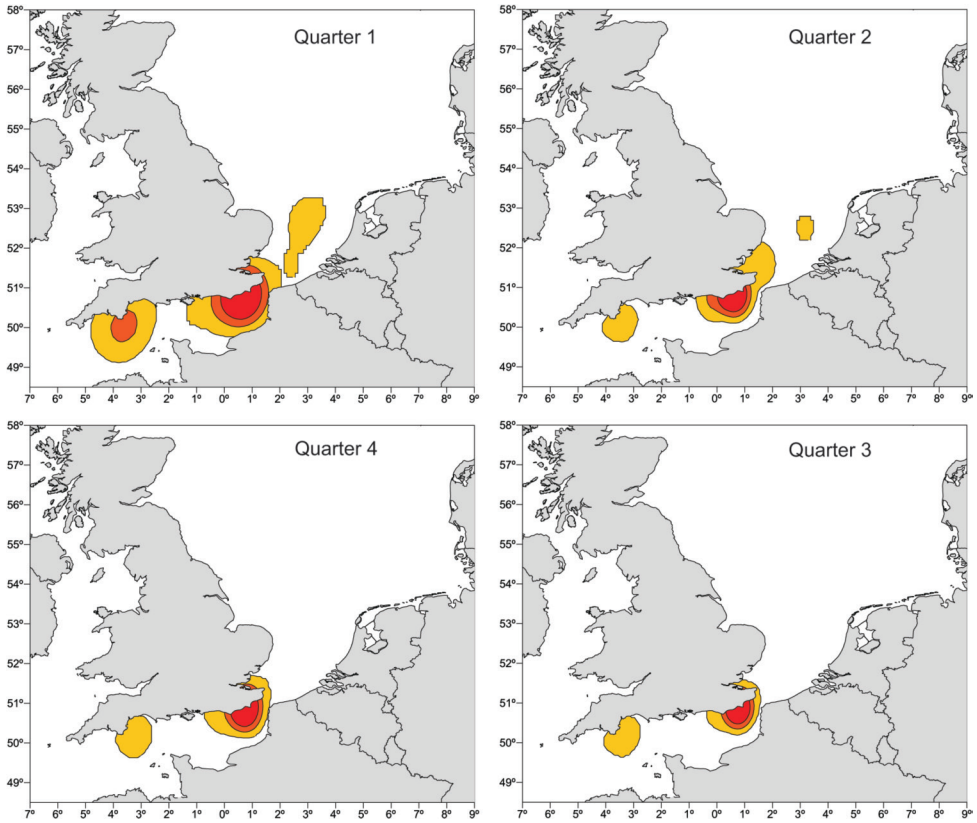
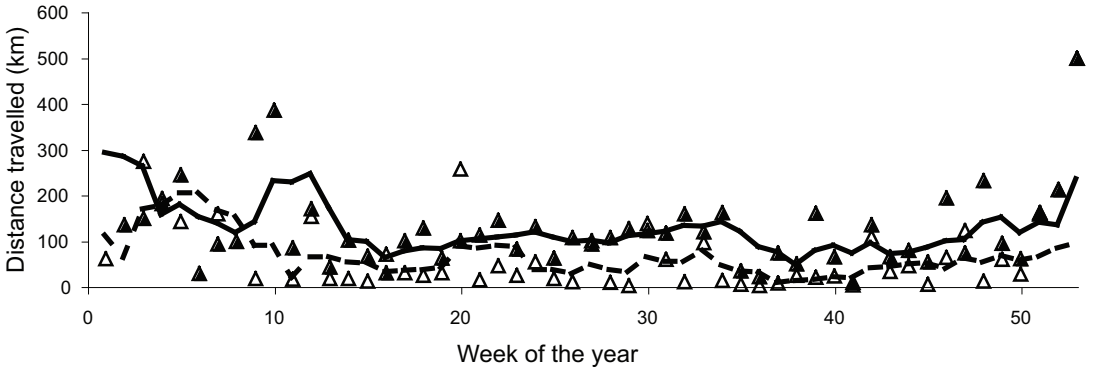
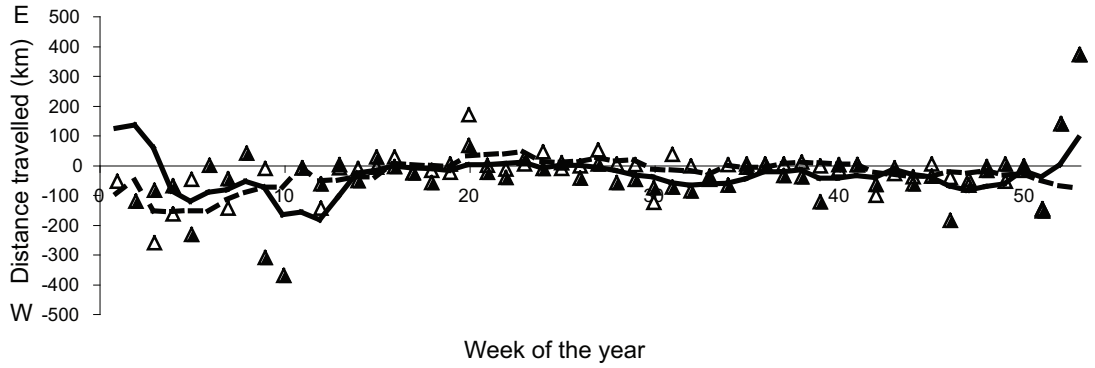


Figure 14. Mean distances travelled by recaptured juvenile (open triangles) and mature (solid triangles) sole by the week of the year, released in quarters 2 and 3 between Rye Bay and Newhaven. The dashed and solid lines show the four-week moving averages for juvenile and mature sole, respectively. a.) Overall distance travelled, b.) Distance travelled in an east/west direction, and c.) Distance travelled in a north/south direction.

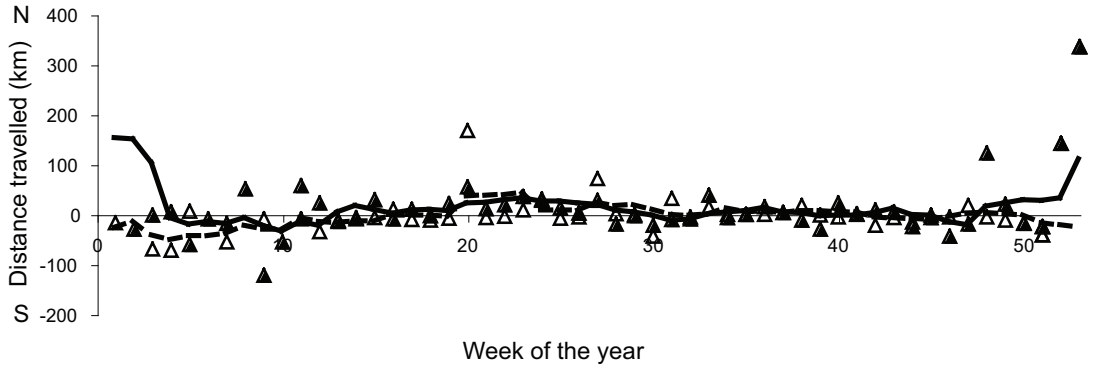
a.)



b.)



c.)



5.2.2. UK coast between Brighton and Poole Harbour

Table 9 and Figures 15–17 summarize the recapture pattern for sole released between Brighton and Poole Harbour. For this release area, there were sufficient recaptures to permit analysis of juvenile and mature fish separately.

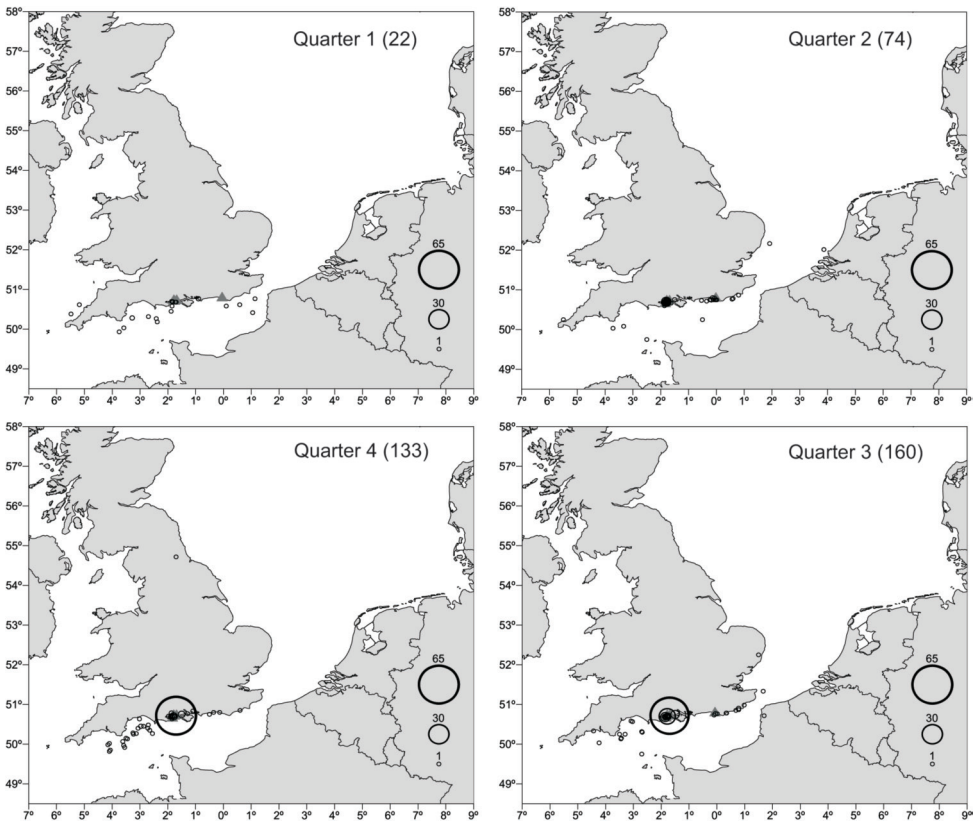
The results from the recaptures of juvenile sole show that the fish remain relatively close to their release positions for most of the year and that any dispersal away from the release area was in both an eastward and a westward direction (Figure 15). The pattern of movement exhibited by mature sole is more marked than for juveniles, and Figure 17a shows that the distances travelled were generally greater for most of the year than for juvenile recaptures. There was a 95% probability of sole being recaptured within the English Channel in the area between Cornwall and Kent (Figure 16). The 50% boundaries show that mature sole remained closer to their release position in quarters 2 and 3, but dispersed in a mainly westward direction in autumn and winter (quarters 4 and 1). Mature sole were also recaptured west of the release area during the second and third quarters. For both length groups, few fish were recaptured along the French coast, and movement north into the North Sea was minimal. Figure 17a shows the generally seasonal nature of the dispersion for both juveniles and mature sole. As in the adjacent area off Rye Bay, it appears that the first quarter of the year may be used as a dispersal period by juvenile fish.

Table 9. Overall movement parameters of recaptured juvenile and mature sole, released between Brighton and Poole Harbour during quarters 2 and 3.

Recapture length group	Juvenile					
Recapture quarter	**Q1**	**Q2**	**Q3**	**Q4**	**Q1 & 4**	**Q2 & 3**
Total number of fish	22	74	160	133	155	234
Average time at liberty	440.00	561.35	240.10	230.95	260.62	341.69
Average distance (km)	98.79	47.07	28.28	29.60	39.42	34.22
Average northward movement (km)	-25.14	1.30	1.91	-3.58	-6.64	1.72
Average eastward movement (km)	-26.23	22.93	6.89	-12.56	-14.50	11.96
Overall direction of movement (°)	46.22	86.76	74.47	74.10	65.40	81.82
Mean square dispersion coefficient	35.88	18.38	14.14	19.24	22.04	15.58
Recapture length group	**Mature**					
Recapture quarter	**Q1**	**Q2**	**Q3**	**Q4**	**Q1 & 4**	**Q2 & 3**
Total number of fish	118	177	205	181	299	382
Average time at liberty	1 097.35	1 094.05	821.88	771.08	899.84	947.99
Average distance (km)	100.56	79.22	96.11	91.73	95.21	88.29
Average northward movement (km)	-29.45	-4.00	-21.39	-24.43	-26.41	-13.33
Average eastward movement (km)	-48.49	2.06	-31.74	-48.58	-48.54	-16.08
Overall direction of movement (°)	58.73	-27.27	56.02	63.30	61.45	50.33
Mean square dispersion coefficient	19.50	17.81	11.87	18.72	19.19	15.09

Figure 15. Quarterly recaptures of juvenile sole, tagged between Brighton and Poole Harbour and released in quarters 2 and 3. a) The release positions are shown as solid triangles and the numbers recaptured as open circles. The total number of recaptures by quarter is given in parenthesis against the quarter. b) Recapture 95% (red), 75% (orange) and 50% (yellow) KPDFs.

a)



b)

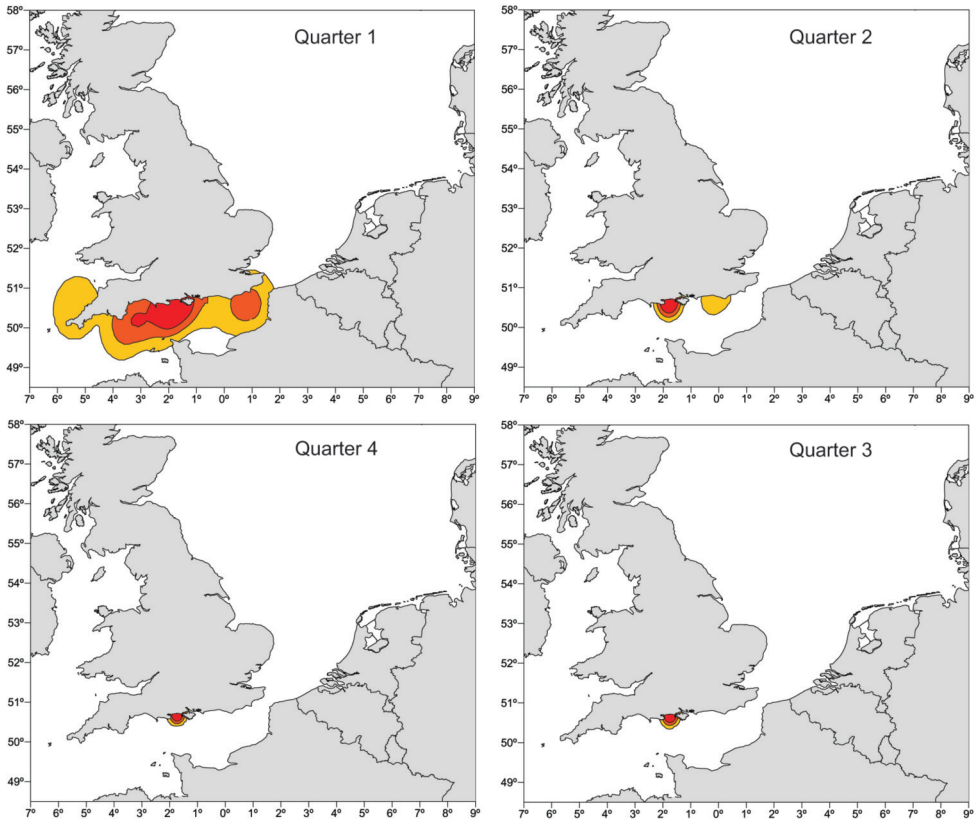


Figure 16. Quarterly recaptures of mature sole, tagged between Brighton and Poole Harbour and released in quarters 2 and 3. a) The release positions are shown as solid triangles and the numbers recaptured as open circles. The total number of recaptures by quarter is given in parenthesis against the quarter. b) Recapture 95% (red), 75% (orange) and 50% (yellow) KPDFs.

a)

b)

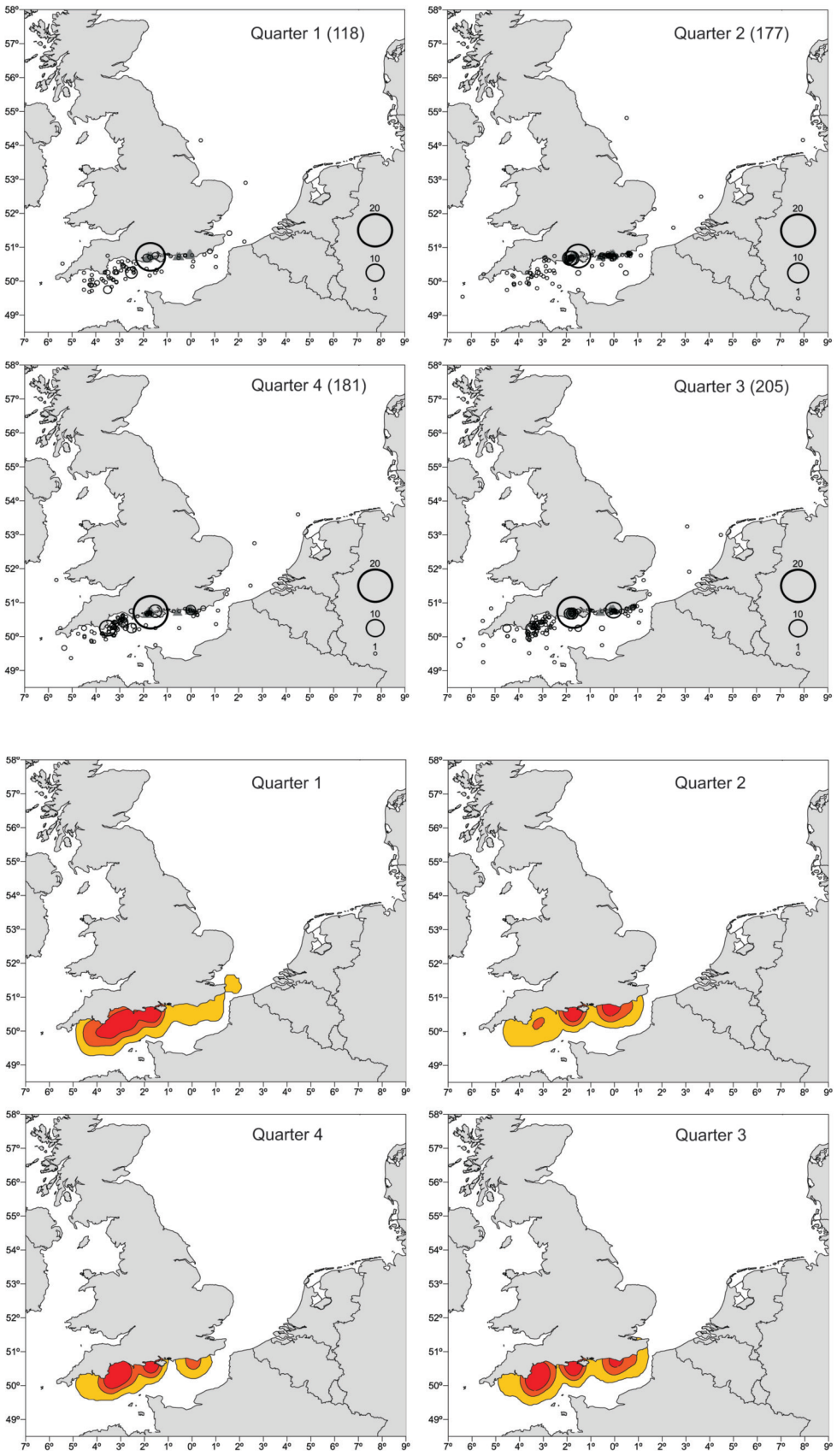
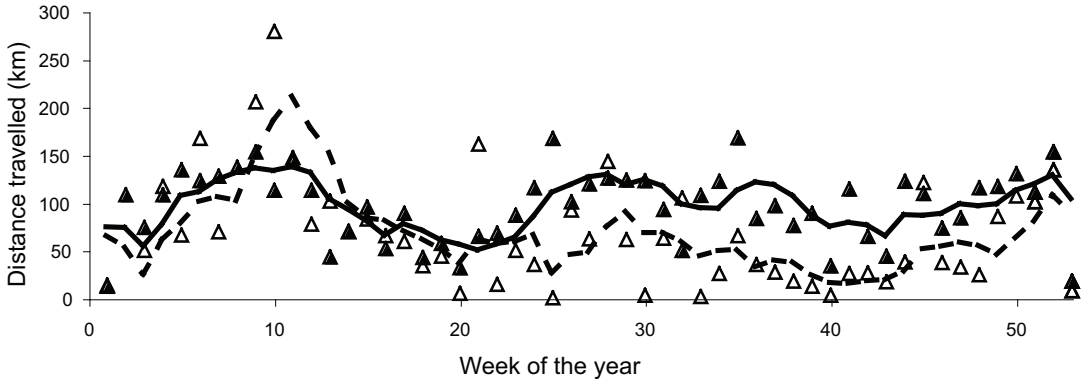
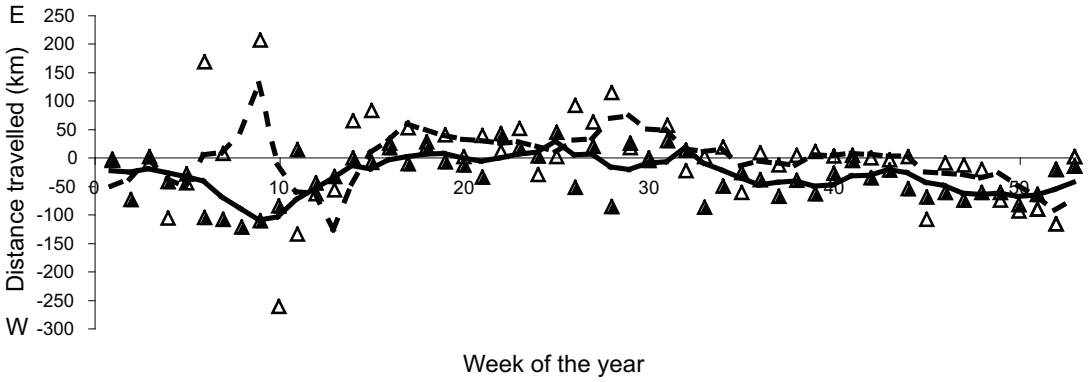


Figure 17. Mean distances travelled by recaptured juvenile (open triangles) and mature (solid triangles) sole by the week of the year, released in quarters 2 and 3 between Brighton and Poole Harbour. The dashed and solid lines show the four-week moving averages for juvenile and mature sole, respectively. a.) Overall distance travelled, b.) Distance travelled in an east/west direction, and c.) Distance travelled in a north/south direction.

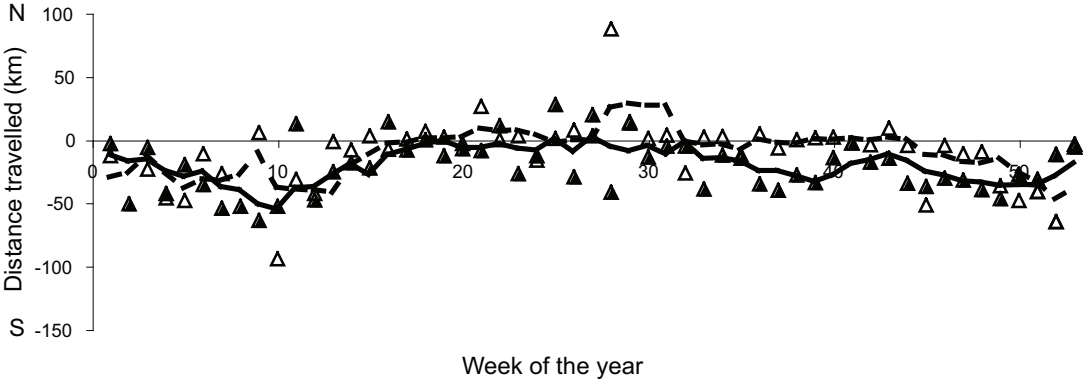
a.)



b.)



c.)



5.3. French coast

Table 10 and Figures 18 and 19 show the results for sole released off the French coast. Owing to the small sample sizes, it has not been possible to break the recaptures down into juvenile and mature fish, and mapping of the recapture positions in Figure 18 is combined for quarters 1 and 4 and for 2 and 3.

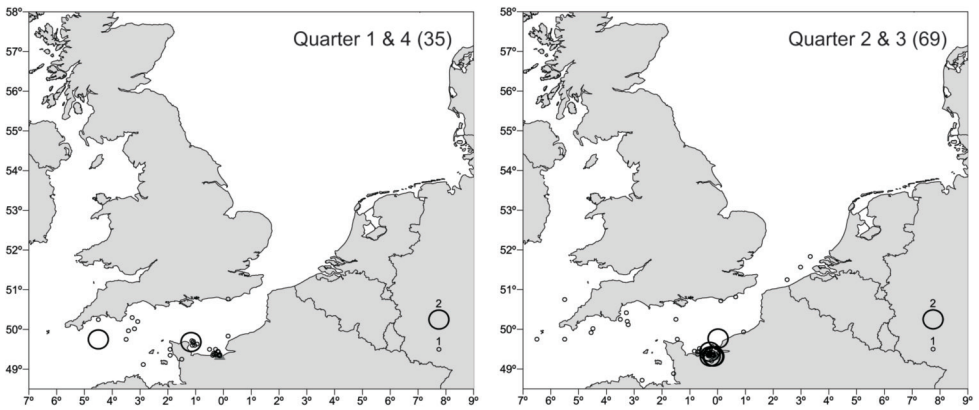
Sole caught and released in the Baie de Seine remained closest to the release site in quarters 2 and 3 (Figure 18). During winter and autumn (quarters 1 and 4), though most recaptures were near their release site, sole dispersed and exhibited a general westward movement (Figure 19), and a number of fish reached the English coast between Brixham and Falmouth. As sole were recaptured there during spring and summer, this suggests that this movement may be permanent. Sole recaptured in the first and fourth quarters had travelled farther, on average 108 km compared with 85 km for the second and third quarters, which provides further evidence of seasonality in their movement (Table 10).

Table 10. Overall movement parameters of recaptured sole, released off the French coast during quarters 2 and 3.

Recapture length group	All					
Recapture quarter	**Q1**	**Q2**	**Q3**	**Q4**	**Q1 & 4**	**Q2 & 3**
Total number of fish	12	24	45	23	35	69
Average time at liberty	705.83	594.17	470.93	501.87	571.80	513.80
Average distance (km)	180.69	102.80	75.90	70.12	108.03	85.26
Average northward movement (km)	57.30	56.22	25.78	24.18	35.53	36.37
Average eastward movement (km)	-156.55	-14.10	-59.48	-60.46	-93.41	-43.69
Overall direction of movement (°)	-69.90	-14.08	-66.56	-68.20	-69.17	-50.23
Mean square dispersion coefficient	8.35	19.04	12.03	6.06	8.73	14.49

Figure 18. Quarterly recaptures of sole, tagged off the French coast and released in quarters 2 and 3. a) The release positions are shown as solid triangles and the numbers recaptured as open circles. The total number of recaptures by combined quarter is given in parenthesis against the quarter. b) Recapture 95% (red), 75% (orange) and 50% (yellow) KPDFs.

a)



b)

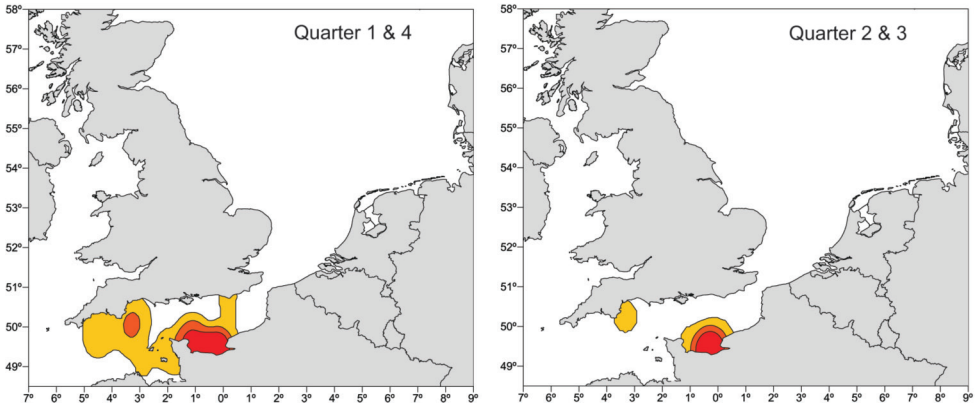
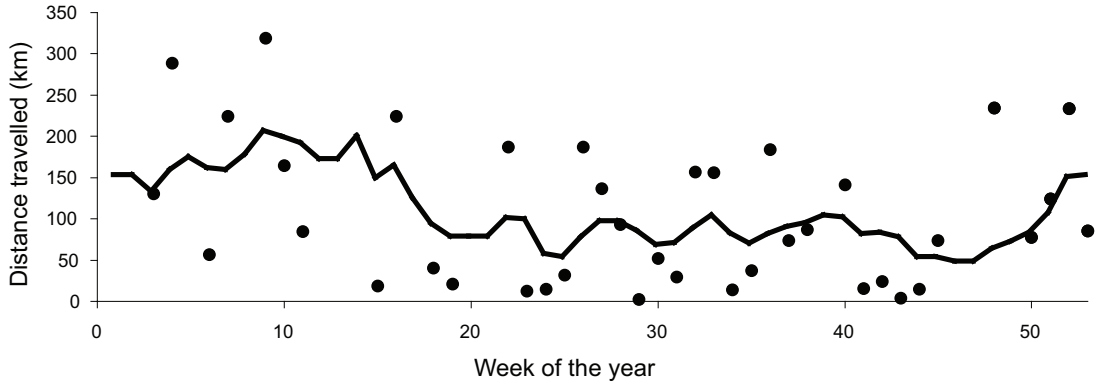
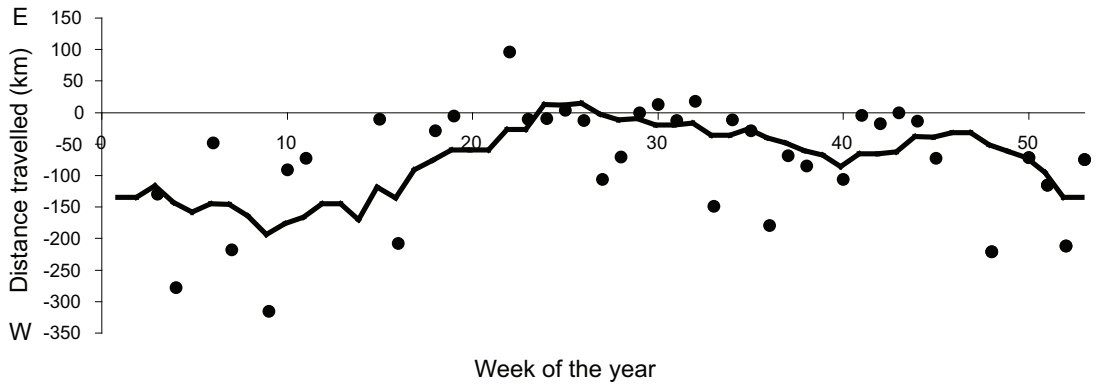


Figure 19. Mean distances travelled by recaptured sole by the week of the year, released in quarters 2 and 3 off the French coast. The solid line shows the eight-week moving averages. a.) Overall distance travelled, b.) Distance travelled in an east/west direction, and c.) Distance travelled in a north/south direction.

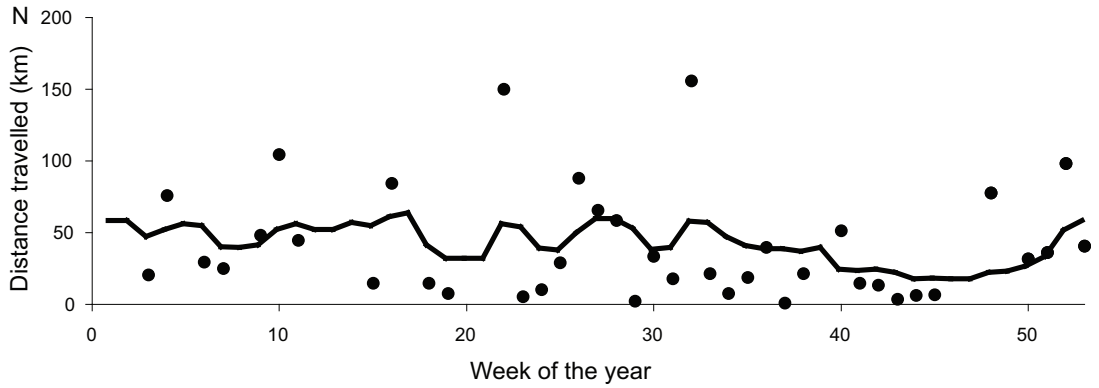
a.)



b.)



c.)



6. Exchange between release sites and ICES management areas

Figure 20 illustrates the extent of interaction for all returns combined, irrespective of recapture length group, for each of the release groups or substocks. In the North Sea during spring, sole were found inshore, then began to disperse offshore in summer. They then stayed mainly offshore during winter, returning to the same inshore grounds in spring.

For each quarter the three substocks remained largely segregated, apart from the Thames and The Wash, where there is limited overlap on the grounds that the sub-stocks occupy.

The extent of segregation of fish released in the English Channel is less apparent. The three separate releases all show that sole travelled west during autumn and winter, some of which was during quarters 2 and 3, whereas the majority returned to the same grounds in spring. Few fish in the English Channel migrate towards the French coast, but some sole released off the French coast migrate across the Channel to the English coast.

The exchange of fish between ICES management Divisions for sole released in quarters 2 and 3 is presented in Table 11. For the two most northerly releases in the North Sea, in the Dutch offshore area and off the UK coast between Flamborough and The Wash, all the recaptures were made in the North Sea. Some 90% of the sole released in the Greater Thames Estuary were recaptured in Division IV, and the remainder were returned mainly from VIId. Most sole tagged between Rye Bay and Newhaven were recaptured in VIId throughout the year, whereas ~20% had moved into the neighbouring Divisions IV and VIIe, in equal proportions. The seasonal westward movements exhibited by sole released between Brighton and Poole

Figure 20. Seasonal interaction of recaptures between each of the release sites. The different coloured lines show the recapture 75% KPDF area limits and the coloured dots the general release areas; Dutch offshore (brown); Flamborough – Wash (red); Greater Thames Estuary (blue); Rye Bay – Newhaven (green); Brighton – Poole Harbour (purple); French coast (orange). For the French recaptured sole, quarters 1 and 4, and 2 and 3, are combined.

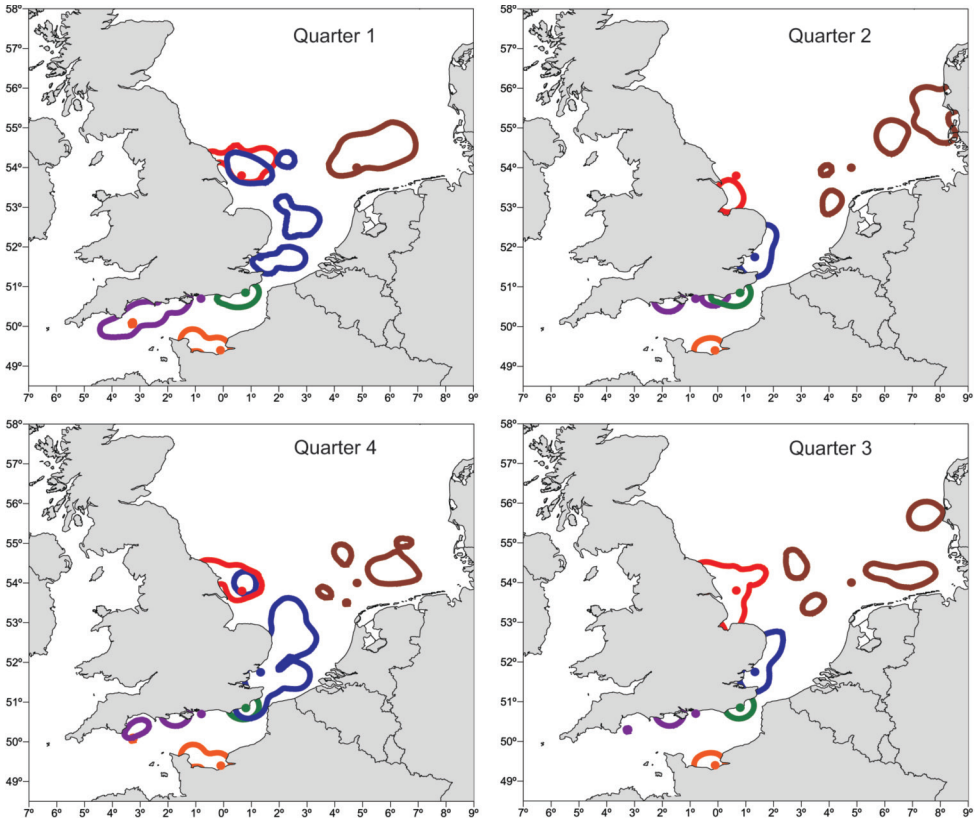


Table 11. Exchange between ICES management areas for releases made in quarters 2 and 3 and at liberty >90 d, shown as the percentage of recaptures recaptured in each ICES management area for a) each of the six geographic release areas, and b) each of the ICES management release areas (+ indicates < 0.1%).

a.)

The Greater Thames Estuary (ICES management area II, IV)

	Recapture quarter		
% returned in ICES management area	Q1 & 4	Q2 & 3	All
II, IV	88.0%	90.3%	89.6%
IIIa, IIIbcd		0.1%	+
VIId	8.2%	8.1%	8.2%
VIIe	3.7%	1.3%	2.1%
VIIfg	0.1%	0.1%	0.1%
VIIhjk		0.1%	+
Number of recaptures	708	1 559	2 267

Rye Bay - Newhaven (ICES management area VIId))

	Recapture quarter		
% returned in ICES management area	Q1 & 4	Q2 & 3	All
II, IV	11.4%	12.8%	12.4%
IIIa, IIIbcd			
VIId	74.1%	79.7%	78.1%
VIIe	13.9%	7.5%	9.4%
VIIfg	0.6%		0.2%
VIIhjk			
Number of recaptures	332	799	1 131

Flamborough - Wash (ICES management area II, IV)

	Recapture quarter		
% returned in ICES management area	Q1 & 4	Q2 & 3	All
II, IV	100.0%	100.0%	100.0%
IIIa, IIIbcd			
VIId			
VIIe			
VIIfg			
VIIhjk			
Number of recaptures	90	137	227

Brighton - Poole Harbour (ICES management area VIId)

	Recapture quarter		
% returned in ICES management area	Q1 & 4	Q2 & 3	All
II, IV	2.4%	2.4%	2.4%
IIIa, IIIbcd			
VIId	53.7%	72.9%	64.8%
VIIe	42.5%	23.9%	31.8%
VIIfg	1.1%	0.6%	0.8%
VIIhjk	0.2%	0.2%	0.2%
Number of recaptures	454	616	1 070

Dutch offshore (ICES management area II, IV)

	Recapture quarter		
% returned in ICES management area	Q1 & 4	Q2 & 3	All
II, IV	100.0%	100.0%	100.0%
IIIa, IIIbcd			
VIId			
VIIe			
VIIfg			
VIIhjk			
Number of recaptures	126	103	229

French coast (ICES management area VIId)

	Recapture quarter		
% returned in ICES management area	Q1 & 4	Q2 & 3	All
II, IV		4.3%	2.9%
IIIa, IIIbcd			
VIId	68.6%	79.7%	76.0%
VIIe	31.4%	14.5%	20.2%
VIIfg		1.4%	1.0%
VIIhjk			
Number of recaptures	35	69	104

b.)

All IV release sites (ICES management area II, IV)

	Recapture quarter		
% returned in ICES management area	Q1 & 4	Q2 & 3	All
II, IV	90.8%	91.6%	91.3%
IIIa, IIIbcd		0.1%	+
VIId	6.3%	7.1%	6.8%
VIIe	2.8%	1.2%	1.7%
VIIfg	0.1%	0.1%	0.1%
VIIhjk		0.1%	+
Number of recaptures	924	1 799	2 723

All VIId release sites (ICES management area VIId)

	Recapture quarter		
% returned in ICES management area	Q1 & 4	Q2 & 3	All
II, IV	6.0%	8.1%	7.3%
IIIa, IIIbcd			
VIId	62.6%	76.9%	71.8%
VIIe	30.5%	14.6%	20.3%
VIIfg	0.9%	0.3%	0.5%
VIIhjk	0.1%	0.1%	0.1%
Number of recaptures	821	1 484	2 305

Harbour and from the French coast is confirmed in Table 11a, where throughout the year, some 20–31% of the fish move into VIIe. The exchange varied according to the time of the year. During winter, the proportion recaptured in VIIe was slightly greater (14%) than in spring and summer (8%). The extent of movement between VIId and VIIe increases closer to the boundary between the two areas. Consequently, of the fish tagged in the Brighton – Poole Bay area, some 32% were recaptured in VIIe, and this proportion increased to 43% during winter. Similarly on the French coast, the percentages were 20% overall and 31% during winter. However, the abundance of sole in the western part of VIId is much lower than in the eastern area, based on landings and effort from local fisheries and surveys (Parker-Humphreys, 2005), so this movement across the management boundary, although significant, probably represents a relatively small number of fish.

Overall for the year, 91% of sole in the North Sea and 71% in VIId remained resident (Table 11b). Most of the sole in VIId that moved to another management area had moved west into neighbouring VIIe, but more noticeably so in autumn and winter.

7. Discussion

These results have not taken into account differences in fishing effort either in the separate areas analysed or over the period of the tagging programme. Although effort and landings are available from English vessels, no detailed data were available from international fleets fishing in the southern North Sea or English Channel. Although fishing effort will have influenced the absolute return rate from the different areas, the overall pattern of returns is considered to be a true reflection of the seasonal movement undertaken by sole in each area.

Sole undertake relatively short movements away from their coastal nursery and spawning grounds. Average distances for fish in the Thames was 75 km for mature fish in the period around spawning (quarters 2 and 3) and close to twice this distance during the rest of the year. By comparison, cod from closely similar releases averaged 114 km during their spawning period and around 220 km when dispersing to feed (Righton *et al.*, 2007). This is a relatively small movement compared with that of many other species, some of which undergo medium to long-distance migrations (Cushing, 1975). In both the North Sea and eastern English Channel, sole showed similar behaviour throughout the year. In spring and early summer (quarters 2 and 3), mature sole moved inshore to spawn and were found in relatively shallow water often associated with reduced salinity, as in the Thames, The Wash and Rye Bay. At that time of year they are most densely aggregated. During the next two quarters, there was progressive movement offshore, and sole remained offshore during winter. This is consistent with the results of earlier studies (Wallace and Watson, 1980; ICES, 1965, 1989) and with sole elsewhere (Horwood, 1993). As sole are close to the northern limit of their distribution in the North Sea, the winter distribution is probably associated with the need to avoid the coldest temperatures, which are found in shallow water inshore. The seasonal movement of tagged juvenile sole was similar to that of mature fish, although the extent of the movement was less marked.

In both the North Sea and VIId, the offshore movement is associated with a shift in distribution along the coast. In the North Sea, movement is mainly northwards, suggesting that it is associated with the northward residual current movement (Lee and Ramster, 1981). In the eastern English Channel where the current systems are east–west orientated (Lee and Ramster, 1981), the main movement again mirrors current flow. However, there is a stronger westerly component, particularly in the second and third quarters, and this was most noticeable for sole tagged in the west of the area off Poole.

Sole in the North Sea and eastern English Channel are managed as two separate stocks. The basis for management is that the populations in the two areas are exploited separately and that juveniles from one area mainly recruit to the adult population in the same area (Pawson, 1995). In the North Sea, >90% of the fish tagged in the Greater Thames Estuary stayed in Subarea IV. Although there was some movement east towards the continental coast, most of the recaptures were west of 3°E, effectively recruiting back to the Thames spawning population. The population is not, however, completely isolated, because there is some movement from the sole nursery grounds on the Belgian and Dutch coasts into the Thames area (ICES, 1989). In the two other release areas in the North Sea, no movement into other management areas was recorded.

In the main nursery area in the eastern Channel (Rye Bay–Newhaven), there is also strong site fidelity, nearly 80% of the fish being recaptured in VIId. However, there is some exchange with neighbouring management areas, and ~12% move to the North Sea and a further 9% into VIIe. There is also movement of sole from the nursery areas along the Belgian and Dutch coasts into VIId. These nurseries areas are estimated to contribute roughly 9% to VIId as juveniles (ICES, 1989). In terms of management and assessment of the different stocks, Kell *et al.* (2004) suggested that even small movements between stocks can lead to bias in the estimate of the stock abundance. However, as most of the movement of sole occurs as juveniles before recruitment to the fishery, it is probable that these results will not substantially impact on the management of the different stocks.

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9. Appendices

Appendix 9.1. Numbers of sole released by geographic release area and year, and the corresponding number of recaptures (Rel = released; Recap = recaptured).

Year of release	Greater Thames Estuary		Flamborough - Wash		Dutch offshore		Rye Bay - Newhaven		Brighton - Poole Harbour		French coast		Total	
	Rel	Recap	Rel	Recap	Rel	Recap	Rel	Recap	Rel	Recap	Rel	Recap	Rel	Recap
1955	238	20			20	5	42	2					300	27
1956	186	13			3	1							189	14
1957	843	161	67	9	198	33							1 108	203
1958	489	166			12	2	201	67	1	1			703	236
1959					2 349	494							2 349	494
1960	55	11			1 209	398							1 264	409
1961														
1962					639	132							639	132
1963			453	68									453	68
1964					259	0							259	0
1965														
1966														
1967			53	5	264	14							317	19
1968	69	25											69	25
1969			256	25									256	25
1970														
1971														
1972														
1973							131	28	221	32			352	60
1974							600	267	61	11			661	278
1975	35	7	1	0			192	49	427	142			655	198
1976	1 104	244					68	17	289	65			1 461	326
1977	956	211											956	211
1978	131	23	564	45									695	68
1979	201	15											201	15
1980	1 297	186					140	15	2	1			1 439	202
1981	2 472	777	556	38			715	222	165	43			3 908	1 080
1982	3 904	1 472	1 248	132			1 452	870	1 529	685			8 133	3 159
1983	147	21											147	21
1984							437	187	957	296	862	144	2 256	627
1985									714	217			714	217
No fish were released between 1986 and 2001.														
2002	85	14											85	14
2003														
2004	40	1											40	1
Total	**12 252**	**3 367**	**3 198**	**322**	**4 953**	**1 079**	**3 978**	**1 724**	**4 366**	**1 493**	**862**	**144**	**29 609**	**8 129**

Appendix 9.2. Individual sole tagging experiments undertaken between 1955 and 2004 by geographic release area.

Geographic release area	Year	Vessel / location	Cruise	Number of releases	Number of recaptures
Greater Thames Estuary	1955	Platessa	014	238	20
	1956	Onaway	006	119	12
	1956	Platessa	019	67	1
	1957	Onaway	006	843	161
	1958	Onaway	005	120	116
	1958	Onaway	007	369	50
	1960	Tellina	001	55	11
	1968	Tellina	009	69	25
	1975	Tellina	008	35	7
	1976	Nucella	011	10	1
	1976	Nucella	014	1	0
	1976	Providence	001	1 072	240
	1976	Tellina	11a	21	3
	1977	Louandric	001	500	129
	1977	Nucella	003	7	2
	1977	Nucella	009	151	21
	1977	Pakefield Beach	001	56	10
	1977	Tellina	004	218	43
	1977	Tellina	05a	24	6
	1978	Tellina	003	131	23
	1979	Thames Water Board	001	201	15
	1980	Corella	006	233	33
	1980	Tellina	002	939	135
	1980	Tellina	006	13	4
	1980	Thames Water Board	001	112	14
	1981	Tellina	001	8	1
	1981	Tellina	002	1 681	510
	1981	Tellina	003	597	242
	1981	Thames Water Board	001	186	24
	1982	Breadwinner	001	1 222	462
	1982	Julia Braiden	001	1 230	546
	1982	Louandric	001	1 219	421
	1982	Thames Water Board	001	233	43
	1983	Thames Water Board	001	147	21
	2002	Fisher Lassie	001	85	14
	2004	Columbine	001	40	1
			Total	12 252	3 367

Continued

Appendix 9.2. Individual sole tagging experiments undertaken between 1955 and 2004 by geographic release area. *Continued*

Geographic release area	Year	Vessel / location	Cruise	Number of releases	Number of recaptures
Flamborough – The Wash	1957	Onaway	006	67	9
	1963	Platessa	013	453	68
	1967	Clione	012	53	5
	1969	Corella	013	256	25
	1975	Tellina	008	1	0
	1978	Tellina	006	564	45
	1981	Tellina	001	254	8
	1981	Tellina	003	302	30
	1982	Challenge	001	1 248	132
			Total	3 198	322
Dutch Offshore	1955	Platessa	014	20	5
	1956	Platessa	011	3	1
	1957	Sir Lancelot	008	198	33
	1958	Ella Alexia	001	12	2
	1959	Platessa	005	2 111	420
	1959	Platessa	020	238	74
	1960	Platessa	003	1 209	398
	1962	Platessa	002	639	132
	1964	Clione	006	259	0
	1967	Clione	012	264	14
			Total	4 953	1 079
Rye Bay – Newhaven	1955	Platessa	014	42	2
	1958	Onaway	005	43	43
	1958	Onaway	007	158	24
	1973	Rosehearty	001	47	14
	1973	Tellina	004	84	14
	1974	Rosehearty	001	34	8
	1974	Rosehearty	002	566	259
	1975	Mascot	001	47	2
	1975	Rosehearty	001	109	35
	1975	Rosehearty	002	36	12
	1976	Clione	003	41	9
	1976	Clione	009	11	7
	1976	Clione	012	16	1
	1980	Tellina	002	140	15
	1981	Akela	001	451	126
	1981	Tellina	002	264	96
	1982	Akela	001	1 452	870
	1984	Akela	001	437	187
			Total	3 978	1 724

Continued

Appendix 9.2. Individual sole tagging experiments undertaken between 1955 and 2004 by geographic release area. *Continued*

Geographic release area	Year	Vessel / location	Cruise	Number of releases	Number of recaptures
Brighton – Poole Harbour	1958	Onaway	005	1	1
	1973	Rosehearty	001	16	3
	1973	Tellina	004	205	29
	1974	Rosehearty	001	61	11
	1975	Rosehearty	001	31	7
	1975	Rosehearty	002	396	135
	1976	Clione	003	32	4
	1976	Clione	009	14	5
	1976	Clione	012	17	4
	1976	Clione	017	226	52
	1980	Tellina	002	2	1
	1981	Clione	006	150	36
	1981	Tellina	002	15	7
	1982	Avon Valley	001	1 529	685
	1984	Avon Valley	001	533	157
	1984	Bogey	001	424	139
	1985	Avon Valley	001	714	217
			Total	4 366	1 493
French Coast	1984	Avon Valley	001	862	144
			Total	862	144
			Grand Total	**29 609**	**8 129**

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