ISSN 1175-1584

MINISTRY OF FISHERIES
Te Tautiaki i nga tini a Tangaroa

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T. H. Kendrick
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New Zealand Fisheries Assessment Report 2003/55
December 2003

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T. H. Kendrick
N. Bentley

Trophia
P O Box 63
Kaikoura

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Published by Ministry of Fisheries
Wellington
2003

ISSN 1175-1584

Citation:
Kendrick, T.H.; Bentley, N. (2003).
Movements of rock lobsters (*Jasus edwardsii*) tagged by commercial fishers around the coast of New Zealand from 1993.
New Zealand Fisheries Assessment Report 2003/55. 48 p.

This series continues the informal
New Zealand Fisheries Assessment Research Document series
which ceased at the end of 1999.

EXECUTIVE SUMMARY

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Since 1993–94, rock lobster fishers around New Zealand have released over 80 000 tagged lobsters (*Jasus edwardsii*). The primary purpose of these tagging programmes was to provide information on growth rates for stock assessments. However, many release and recapture records include accurate release and recapture position coordinates. The movements of these lobsters are summarised and described.

Movements around most of New Zealand were generally small with most individuals recaptured within 5 km of their release site: 89% of recoveries from CRA 2, 94% from CRA 3, 98% from CRA 4, 92% from CRA 5 and 59% from CRA 8 represented movements of less than 5 km. The nature of these short-distance movements is not investigated or described in any detail and is assumed to mainly relate to foraging behaviour. Longer-distance movements (over 5 km) are described for all the main tagging areas. The proportion that had moved more than 5 km varied markedly among areas but may in large part be accounted for by differences in size at onset of maturity around the country, which determines the degree to which commercial pots retain immature lobsters.

Tag recoveries from a southern fishstock, CRA 8, are described in greater detail, in the context of previous movement studies, with much higher proportions of lobsters demonstrated to have moved than previously reported. These analyses confirm patterns previously described and give evidence of a further aspect of the large-scale movement; a seasonal inshore-offshore movement of mature females on the Fiordland coast, out to the reef edge at the end of the egg-bearing period, presumably to release newly hatched larvae into the stronger currents of deep water. Similar behaviour has been observed by divers in other parts of the country and is suspected to be widespread, but has been difficult to demonstrate as it is best studied by constant tracking. The horizontal distances moved may be small, and the pattern is detected only by a seasonal movement through depth. This pattern of movement probably explains the seasonal 'homing' behaviour previously observed in large females, and helps to confirm the purpose of the large-scale, long-distance migrations of immature females and small males, described in several studies of the south coast of New Zealand since 1969.

The two patterns of movement described in detail for the southern fishstock CRA 8 are migrations of different kinds. The first is a long-distance, one-way migration of immature rock lobsters, the second is an annual inshore-offshore cycle that occurs at the destination and involves mature egg-bearing females.

1. INTRODUCTION

Movements of lobsters were categorised by Herrnkind (1980) into "homing", "nomadism", and "migration". Homing is characterised by short-distance, often "random" movements. Migration is larger scale movement of an individual or a population over a considerable distance, often periodically. Migration includes long-distance movements associated with moulting and reproduction, females moving to strategic sites for egg-hatching, and mass movements in response to environmental change. Nomadism, or "wandering", is distinguished from migration in that it typically lacks group directedness, periodicity, and temporal confinement.

Large scale movements of *Jasus edwardsii* in New Zealand are limited to specific areas. Booth (1997) summarised recoveries from 31 000 lobsters tagged at 32 localities at widespread sites around New Zealand, many of which had not been previously reported. Only south of Mahia and in Fiordland did the percentage of tag recaptures that had moved more than 5 km usually exceed 5%, and only south of Kaikoura did the long-distance movements have group-directedness; elsewhere, the movement pattern better fitted nomadism.

The large-scale migration of immature females and similar-sized male rock lobsters around the southern coast of New Zealand has been described since 1969 (Street 1969, 1971, 1973, Annala et al. 1980, McKoy 1983, Annala & Bycroft 1993). Several research-tagging studies have investigated aspects of this migration, but each has necessarily been limited in its coverage, spatially, temporally, or in terms of the sex/size component of the population.

Street (1969, 1971, 1973) described tagging studies conducted in Otago, Southland, and Fiordland in 1957–70 that supported observations of a large-scale migration south down the east coast of the South Island to Stewart Island in Foveaux Strait, including three individuals that moved from Foveaux Strait, north up the west coast of the South Island to Fiordland.

Possible evidence for large-scale movement of rock lobsters into the Fiordland area between September and February was discussed by Annala et al. (1980). They suggested that an increase in the mean size of the onset of maturity (SOM) of females between September and February could have resulted from an influx of immature females from an area where the mean SOM was greater than in Fiordland. Such females are likely to have originated in Stewart Island, Foveaux Strait, or Otago.

McKoy (1983) described a study of 4393 female and small male rock lobsters tagged and released near Stewart Island and in eastern Foveaux Strait between 1974 and 1978. Eighty-seven percent of recaptures were within 5 km of release sites. He described the movement of immature females and small males clockwise around the island, and the strongly directional movement along the southeast coast of Stewart Island, including 16 movements to Fiordland. He concluded that there was no single area of origin, but that rock lobsters from many localities made such movements between September and December. He also suggested that they did not have any single area of destination, as they appeared to contribute to and become established in populations along the east, south, and southwest coasts of Stewart Island, and on the coast of the South Island between Te Waewae Bay and at least as far north as Milford Sound. Street (1969) had observed that sexually mature females did not move over long distances and that their movements were primarily random local movements. McKoy (1983) could not confirm this because of the small number of mature females that were recovered from his tagging studies.

Annala & Bycroft (1993) reported a study of 3417 rock lobsters tagged and released between 1979 and 1982 along the Fiordland coast between Thompson and Caswell Sounds. They showed that the largest proportions of rock lobsters that moved and those that moved the longest distances were immature females and small males. The movements of these two sex/maturity stages showed definite directionality, with most recaptures having moved north. They confirmed that few mature females

moved, and those showed no directionality. The small proportion of recaptured rock lobsters that had moved (10%), as well as the large number of multiple recaptures that were repeatedly caught in the same location (90%), suggested to them that most rock lobsters along the Fiordland coast are 'resident' animals that do not make long-distance movements.

Annala & Bycroft (1993) further noted that the multiple recaptures of some mature females during and immediately after the egg-bearing season along the Fiordland coast suggested that 'homing' of some animals might have occurred. Of 211 mature females recaptured more than once, 51 were recaptured only once each year from the same location while they were bearing eggs, or just after egg-bearing had finished in September–November during two or more years. These females were not recaptured outside this period, or at different locations, despite relatively heavy fishing occurring along most parts of the coast at other times of the year. These recaptures suggested to them that individuals may move to areas that are not fished for most of the year and then return to specific locations during and immediately following egg-bearing.

Since 1993 there has been ongoing tagging of lobsters in the major rock lobster fishing areas. The primary objective of this tagging programme is to obtain information on growth for improved stock assessment. However, in addition to recording the size of lobsters at release and recapture, the new programme also records ancillary information on the depth and latitude and longitude of release and recapture. Although the tracking of movements is not the primary focus of this tagging programme, the widespread use of Geographic Positioning Systems (GPS) on commercial lobster fishing vessels in New Zealand means that the new programme contains the most extensive data on the rock lobster movement currently available. In this study we summarise patterns in these movement data.

2. METHODS

2.1 Tag release and recapture

The recent programme tags lobsters that are caught in commercial fishing pots. Initial tag and release of rock lobsters is carried out on commercial vessels by trained technicians. Data are recorded and downloaded electronically to reduce data entry and transcription errors. Lobsters are tagged with the HallPrint™ Floy type tags inserted into the abdominal muscle block between carapace and tail on the dorsal side, released soon after capture to minimise losses caused by handling, as close as possible to the capture site to minimise any displacement effects. Very small lobsters are difficult to tag by this method, and there is also effectively a minimum size imposed, i.e., that size of lobster retained by commercial pots (which employ regulation escape gaps). A variety of other tagging methods has been employed in research programmes.

No attempt is made to select lobsters of a particular size, although usually the lobsters that are tagged and released are below the minimum legal size limit or berried females that must be returned to the water anyway. Near the end of the season, fishers will often allow all or most of the catch to be tagged and released. Similarly, no attempt is made to target initial tag releases in particular locations. Commercial fishers voluntarily record recaptures and some recoveries are also reported by recreational fishers and through fish packing sheds.

2.2 Data

The Ministry of Fisheries *tag* database (administered by NIWA) is used to store tag release and recapture data. All data collected in the recent tagging programme are included in the database, which contains data from a number of previous tagging projects, some of which have been previously described and some that have not (see Booth 1997 for review). The primary purpose of including these previous tagging data in the database was for obtaining growth information. Thus most of the records from previously described movement studies do not include all release or recapture information and could not be re-analysed here. This study mainly summarises the recoveries from

rock lobsters tagged and released since 1993–94, along with a small number of recaptures from previous taggings. These data have not been previously described and augment previous studies.

2.3 Error checking

Error and range checking eliminated any lobsters that had changed sex, decreased in size by more than 10 mm tail-width (TW), moved at a rate greater than 7 km per day, or which were placed by either their release or recapture coordinates in water greater than 200 m deep, or on land. Additionally, large and unusual movements that were considered possible outliers were eliminated if the reported statistical area suggested that the coordinates were in error. Lobsters recorded as having moved from area 925 to 926 (from research tagging in 1986) were eliminated because their release coordinates did not correspond with the Snares Islands or any other known feature. Two individuals from recent tagging that appeared to have moved across Foveaux Strait between areas 924 and 926 were deleted because anomalies suggested incorrect identification. One, a 67 mm TW mature female, moved from the South Island to Stewart Island over a year and apparently grew 20 mm. The other, which moved from Stewart Island to Fiordland, had changed from mature to immature over the year that it was at liberty. One individual that apparently moved a great distance from Marlborough through Cook Strait to the upper west coast of the south island, was eliminated because the recorded statistical area of recapture did not agree with the coordinates. Other data were not subjected to such rigorous examination and other errors may remain. Multiple (not for the first time) release-recapture events are recorded in area 906 for lobsters for which initial release-recapture records do not exist. This is a recording error and has resulted in more apparent recaptures than releases in 1998.

2.4 Numbers tagged, spatial and seasonal distribution

The recent tagging programme released 81 223 individual lobsters from spring of the fishing year 1993–94 to 31 March 2001 (Table 1). There were 228 tag recoveries from earlier research projects included (Table 2), and 7366 recoveries from the recent programme (not necessarily first time recaptures) with valid position information at 31 March 2001 (Table 3). These are referred to as valid recaptures in this document. A total of 2918 recoveries from lobsters tagged in CRA 8 had release and recapture positions adequate for tracking movement. Most of these (2733) were from the recent tagging programme: 3258 tags from CRA 8 had depth information for both release and recapture.

2.5 Definitions

In this study, females are defined as mature or immature at release based on presence or absence of setae, where that information is available. Females without maturity information were included as mature if they were greater or equal to 60 mm TW. Males were defined as large (greater or equal to 54 mm TW) or small (less than 54 mm TW) because maturity cannot be determined externally. These four categories are referred to as "classes" of lobster in this document.

Movements greater than 5 km in a straight line between release and recapture sites are considered here to indicate nomadic or migratory behaviour. Although an arbitrary threshold, 5 km was considered by McKoy (1983) and Annala (1993) to be the minimum to reliably indicate a net movement from the release area, and by Booth (1997) to define a "long-distance" movement.

Results are presented for those rock lobster (CRA) management areas that have supported major tag release and recapture programmes, and within these where possible, by statistical area (Figure 1).

3. INTERPRETATION OF MOVEMENT DATA

Because of the manner in which lobsters are tagged and recaptured, caution must be taken when interpreting the movements inferred from these data. In particular, biases may exist due to spatial differences in rates of exploitation and the reporting of tag recaptures. A higher exploitation rate means that a tagged lobster will have a higher chance of being recaptured and higher reporting rates among fishers mean that the recapture will have a high probability of being represented in the final data set. For example, if the area to the north of a release site has a higher exploitation rate and reporting rate than an area to the south, then even if lobsters are moving randomly it would be expected that there would be more lobsters in the final data set that had moved northward. Information on the exploitation rate and reporting rates in different areas is not available so we can not correct for these effects.

Distances are minimum straight-line distances and likely to be underestimates in most cases, but especially in area 926 where the straight-line route does not represent the route taken around the coast. Thus all movement rates and distances are indicative only and should be treated with caution.

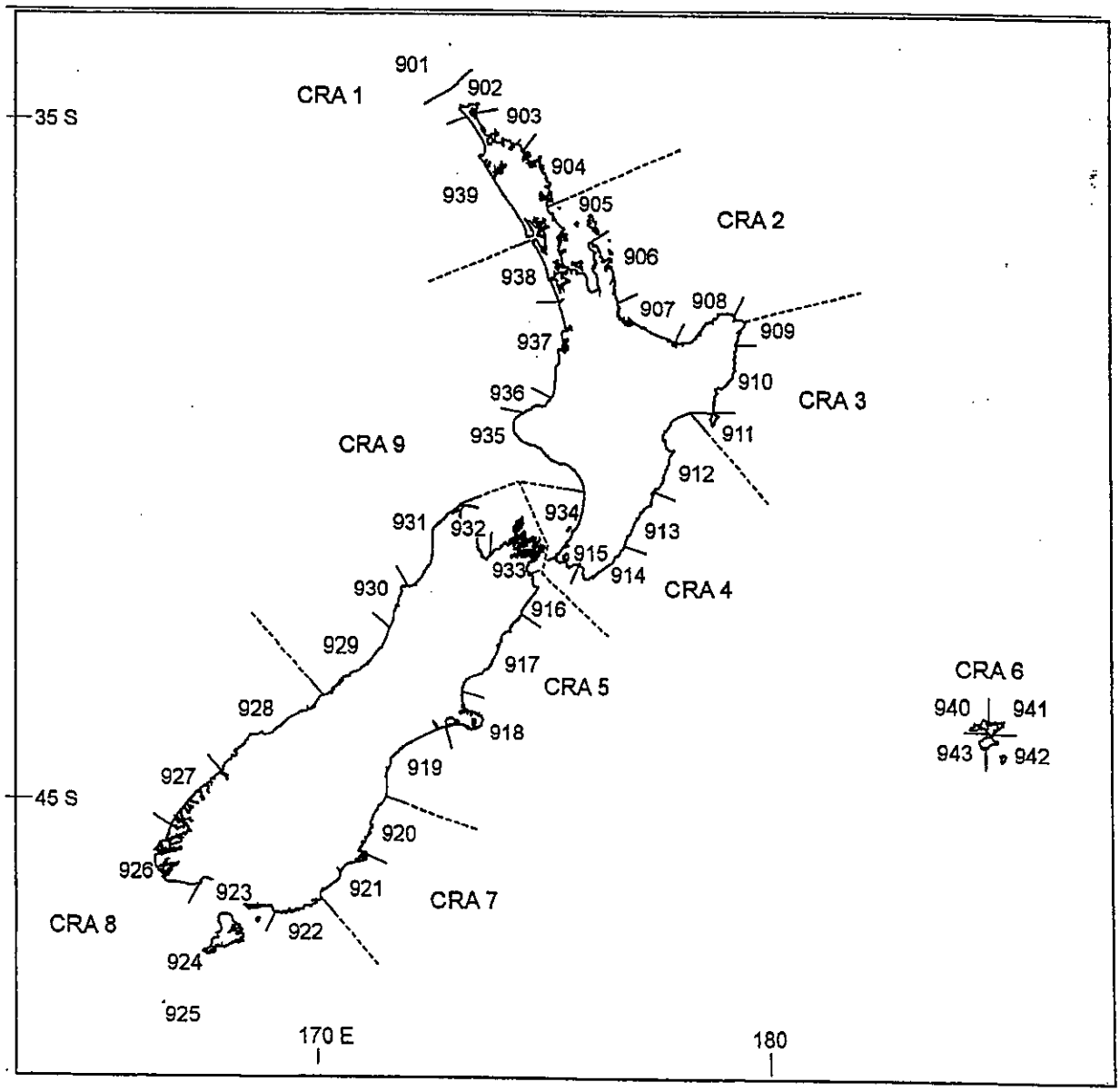


Figure 1: Boundaries of rock lobster statistical areas.

Table 1: Number of lobsters tagged and released in the recent tagging programme at 31 March 2001, by statistical area, fishing year and season. AW, autumn–winter (1 April–30 September); SS, spring–summer (period of release).

Fishing year	1994	1995	1996	1996	1997	1997	1998	1998	1999	1999	2000	2000	
Season	SS	SS	AW	SS	AW	SS	AW	SS	AW	SS	AW	SS	Total
Statistical area													
901	0	0	0	0	0	0	0	0	0	0	2080	0	2080
902	0	0	0	0	0	0	0	0	0	0	152	0	152
903	0	0	0	0	0	0	0	0	0	0	69	0	69
904	0	0	0	0	0	0	0	0	0	0	81	0	81
905	0	0	0	392	140	0	16	0	0	0	0	0	548
906	0	0	2422	1036	238	0	7	0	2	0	0	0	3705
907	0	0	2561	0	1530	0	2	0	2	3	0	0	4098
908	0	0	1442	0	557	0	1	0	1	0	0	0	2001
909	0	0	0	0	315	0	0	0	0	0	0	0	315
910	0	1923	157	3631	0	579	2	0	0	0	0	0	6292
912	0	0	0	0	0	0	0	3189	6	1451	0	0	4646
913	0	0	0	0	0	0	0	3188	2	1512	111	0	4813
914	0	0	0	0	0	0	0	2896	246	1493	122	0	4757
915	0	0	0	0	0	0	0	0	0	1886	2100	640	4626
916	0	0	1	5705	11	1226	6	0	2	0	1968	1954	10873
917	0	0	0	0	1779	0	0	0	1	1876	863	1	4520
923	0	0	0	0	336	459	0	33	0	399	0	0	1227
924	0	0	0	0	1409	1194	5	449	291	349	0	0	3697
925	0	0	0	0	0	0	0	339	0	0	0	0	339
926	0	0	0	0	784	208	1036	2237	306	251	0	0	4822
927	1	492	0	0	1398	250	928	254	150	2	1	0	3476
928	0	210	0	63	325	52	616	294	451	0	0	0	2011
931	0	0	0	0	0	0	0	0	0	596	0	219	815
933	0	0	0	0	1868	0	1	0	0	1876	1	0	3746
935	0	0	0	0	0	0	0	0	0	365	0	0	365
939	0	0	0	0	0	0	0	0	0	0	1079	1323	2402
940	0	6	100	150	417	0	1	0	0	0	0	0	674
941	0	58	2154	108	187	0	0	0	0	0	0	0	2507
942	0	0	924	23	207	0	0	0	0	0	0	0	1154
943	0	0	94	65	35	0	0	0	0	0	0	0	194
													218
													81223

Table 2: Number of tag recoveries including multiple recaptures, with position information, included in this study from lobsters released in previous research projects. AW, autumn–winter (1 April–30 September); SS, spring–summer (period of release).

Fishing	1978	1978	1979	1979	1980	1980	1984	1985	1993	1994	1994	1995	1995	1996	1997	
Season	AW	SS	AW	SS	AW	SS	AW	SS	SS	AW	SS	AW	SS	AW	AW	Total
Statistical																
916	0	0	0	0	0	0	22	0	0	0	0	0	0	0	0	22
910	0	0	0	0	16	5		0	0	0	0	0	0	0	0	21
922	0	0	0	0	0	0	10	0	10	0	0	0	0	0	0	20
923	2	9	11	2	0	5	0	0	0	0	0	0	0	0	0	29
924	0	0	0	0	0	0	0	0	8	1	1	1	0	0	0	11
926	0	0	0	0	0	0	91	1	23	1	1	3	2	1	0	123
927	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	2
																228

Table 3: Number of tag recoveries including multiple recaptures, with position information, included in this study from lobsters released in the recent tagging programme. AW,autumn–winter; SS,spring–summer (period of release).

Fishing year	1994	1995	1996	1996	1997	1997	1998	1998	1999	1999	2000	2000	
Season	SS	SS	AW	SS	AW	SS	AW	SS	AW	SS	AW	SS	Total
Statistical area													
905	0	0	0	6	0	0	4	0	0	0	0	0	10
906	0	0	402	239	339	0	214	0	22	7	0	0	1223
907	0	0	222	0	65	0	17	0	8	3	0	0	315
908	0	0	184	0	82	1	8	1	2	0	0	0	278
909	0	0	0	0	28	0	0	2	1	0	0	0	31
910	0	78	8	109	6	22	0	0	1	0	0	0	224
912	0	0	0	0	0	0	0	175	31	84	31	0	321
913	0	0	0	0	0	0	0	118	7	108	50	0	283
914	0	0	0	0	0	0	0	341	70	23	8	0	442
915	0	0	0	0	0	0	0	0	0	27	46	4	77
916	0	0	1	696	115	93	15	1	2	0	0	0	923
917	0	0	0	0	195	8	49	4	5	190	55	0	506
923	0	0	0	0	47	7	0	0	0	1	0	0	55
924	0	0	0	0	263	152	44	52	43	16	2	0	572
926	0	0	0	0	128	38	92	123	29	12	0	0	422
927	1	22	0	0	543	158	353	179	138	56	23	3	1476
928	0	23	0	11	96	19	31	12	15	0	1	0	208
933	0	0	0	0	181	0	34	0	16	53	16	0	300
													7666

4. RESULTS

Results are presented for the major tag release and recapture areas. At the time these data were extracted (31 March 2001) there were few or no recoveries from very recent tagging in CRA 1 (Northland) and CRA 5 (Wellington–Hawkes Bay). There were also very few recoveries from intensive tagging carried out earlier in CRA 3 (Gisborne), CRA 7 (Otago), and CRA 6 (the Chatham Islands).

4.1 CRA 2 (Bay of Plenty), statistical areas 905–909

4.1.1 Proportion that moved (CRA 2)

From 10 119 lobsters tagged in CRA 2, 1847 were recaptured, and 89% of these had moved less than 5 km even though 50% had been at liberty for more than 314 days. Between 10 and 18% of recaptured lobsters that were tagged in each of the statistical areas of CRA 2 had moved more than 5 km (Table 4). Higher proportions (around 50%) are recorded for small males and immature females in each area, but these are based on less than 10 individuals.

Table 4: Number of lobsters tagged and released, number of tags recovered with valid position information, not neccesarily for the first time, number in each class that had moved more than 5 km for rock lobsters tagged in CRA 2. LM =large males >= 54 mm TW, MF = mature females (with setae, or >= 60 mm TW), SM=small males (< 54 mmTW), IF= immature females (no setae or < 60 mm TW).

	No. tagged				No. recovered				No that moved > 5 km			
Stat	Males		Females		Males		Females		Males		Females	
Area	LM	SM	MF	IF	LM	SM	MF	IF	LM	SM	MF	IF
905	256	52	199	41	0	0	0	0	0	0	0	0
906	999	582	1956	168	633	198	375	17	49	26	33	9
907	1627	231	1999	241	180	19	110	6	29	9	17	3
908	495	390	998	118	148	47	76	7	18	6	5	0
909	1	191	121	2	2	17	12	0	0	2	0	0

4.1.2 Distance and direction moved (CRA 2)

The long-distance movements of small male and immature female lobsters are shown in Figure 2. There is no overall trend to the direction moved, with distances of 12 km on average, being moved in either direction along the coast, or inshore-offshore between suitable habitats. One individual, a 50 mm TW male, moved a straight-line distance of 213 km from East Cape west to the east coast of the Coromandel Peninsula in 335 days at liberty. Excluding this individual, the average distance covered (by those that moved more than 5 km) was 12.1 km, with 50% moving less than 11 km and 95% moving less than 27 km.

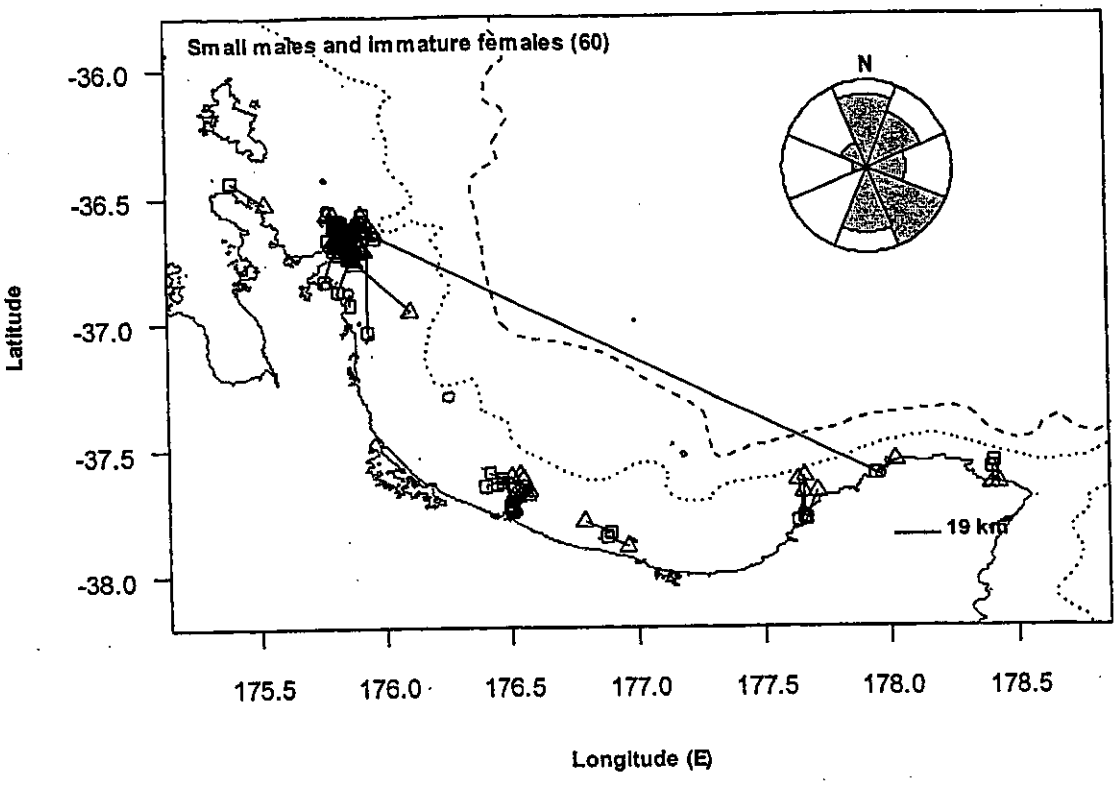


Figure 2: Movements (> 5km) of small male and immature female lobsters tagged in CRA 2. Inset plot shows the relative frequency of direction of movement, in a 45 degree quadrant. Squares: initial release, circles: recapture/re-release event, triangles: last recorded recapture. To maintain fisher privacy, all positions have a random error of 1n.mile added to them. Water depths: inside dotted line: < 200 m, inside broken line, < 1000 m.

There were more records of large males and mature females moving long distances, but, as for the small and immature lobsters, there was no trend in direction travelled. Four mature females and three large males moved more than 100 km, crossing from the east coast of the Bay of Plenty to the north-eastern side of the Coromandel Peninsula, the maximum distance being 211 km (Figure 3). The average distance moved (by those that had moved more than 5 km) was 19.6 km, but 50% of individuals had moved less than 9 km, and 95% had moved less than 63 km.

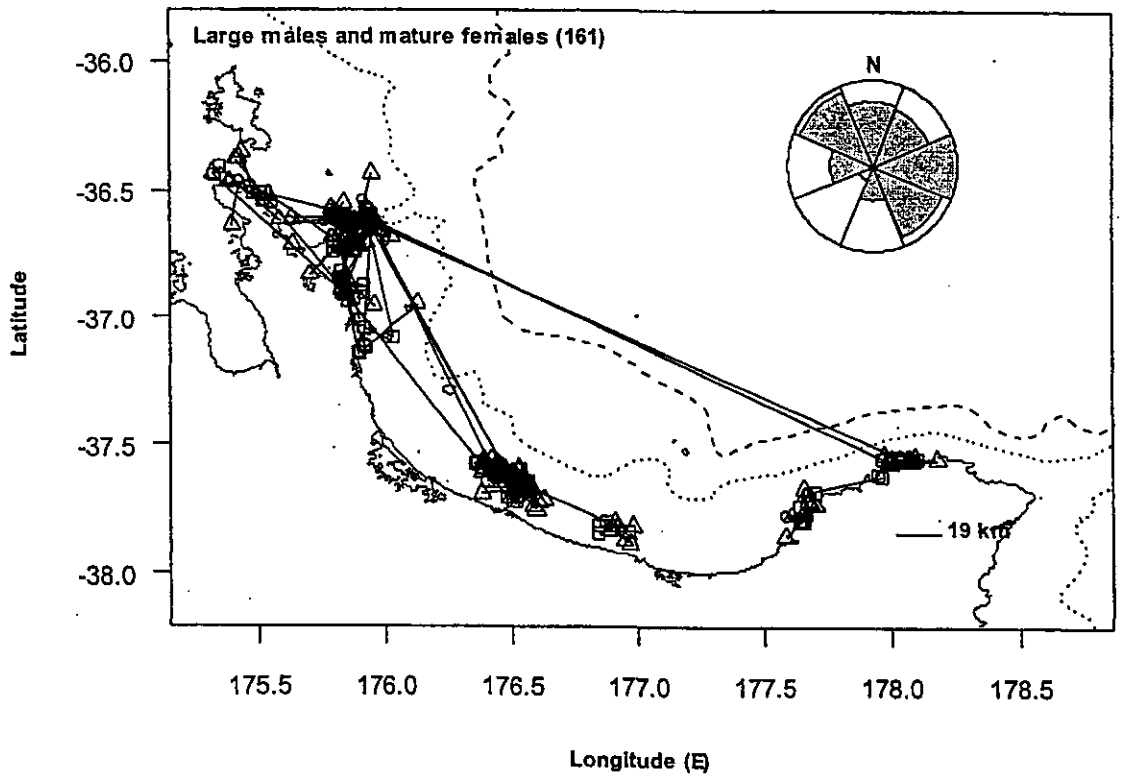


Figure 3: Movements (> 5km) of large male and mature female lobsters tagged in CRA 2. Inset plot shows the relative frequency of direction of movement, in a 45 degree quadrant. Squares: initial release, circles: recapture/re-release event, triangles: last recorded recapture. To maintain fisher privacy, all positions have a random error of 1n.mile added to them. Water depths: inside dotted line, < 200 m; inside broken line, < 1000 m.

4.2 CRA 3 (Gisborne), statistical areas 909–911

4.2.1 Proportion that moved (CRA 3)

Of 6 313 lobsters tagged in CRA 3, there were 252 valid recaptures, and just 6% of those (16 individuals; 6 large males and 10 small males) had moved more than 5 km (Table 5), even though 50 % had been at liberty for more than 229 days,

Table 5: Number of lobsters tagged, number of tags recovered with valid position information, not neccesarily for the first time, number in each class that had moved more than 5 km, from lobsters tagged in CRA 3. LM =large males >= 54mm TW; MF, mature females (with setae, or >=60 mm TW); SM, small males (<54mmTW); IF= immature females (no setae or <60 mm TW).

	No. tagged				No. recovered				No that moved > 5 km			
Stat	Males		Females		Males		Females		Males		Females	
area	LM	SM	MF	IF	LM	SM	MF	IF	LM	SM	MF	IF
910	1235	2948	2067	42	61	159	31	1	6	8	0	0

4.2.2 Distance and direction moved (CRA 3)

Movements of those lobsters that were tagged in CRA 3, and had moved more than 5 km are shown in Figure 4. Movements were up or down the coast, with either direction as likely as the other. The average distance moved was 6.1 km and the maximum was 9.3 km.

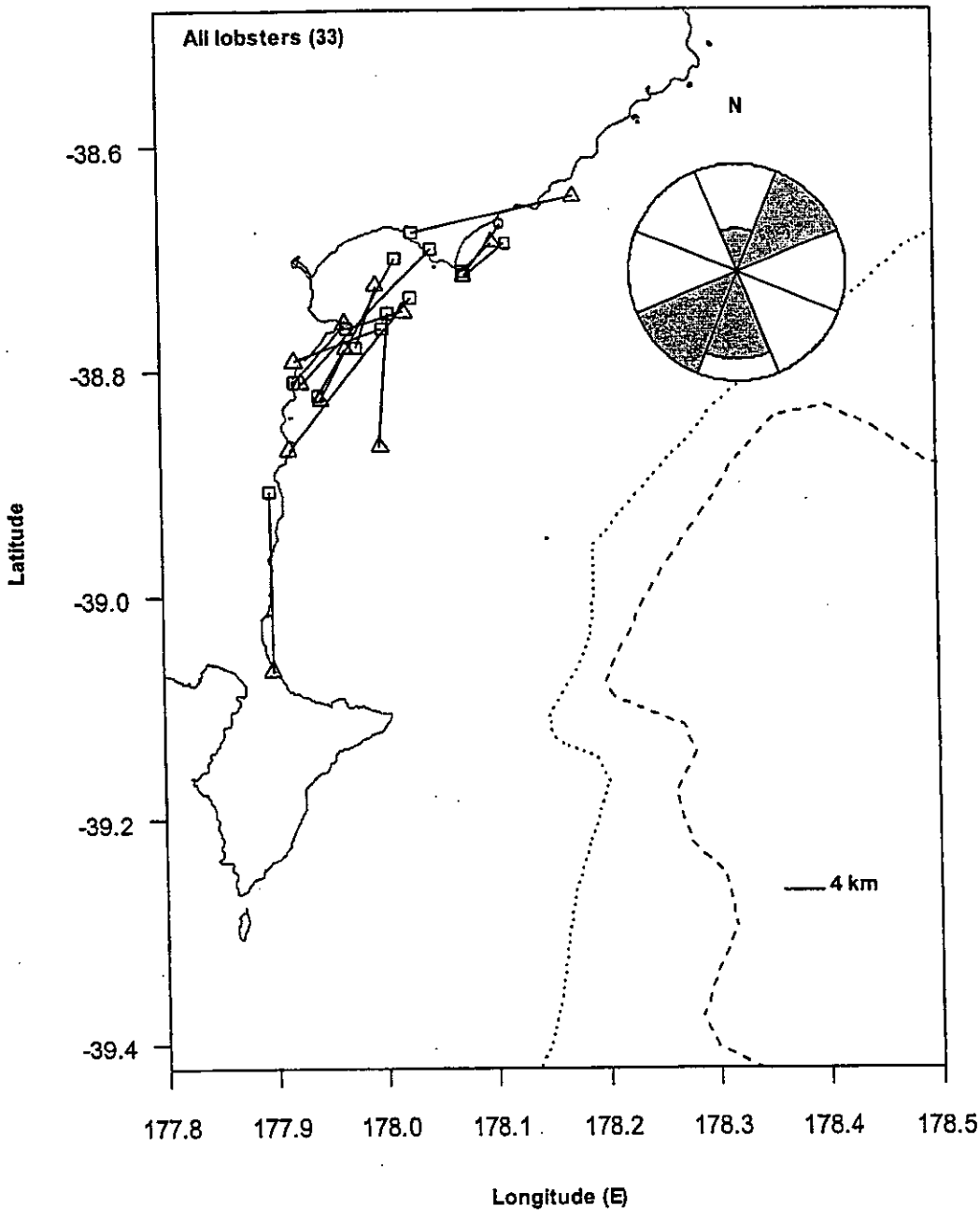


Figure 4: Movements (> 5km) of lobsters (all males) tagged in CRA 3. Inset plot shows the relative frequency of direction of movement, in a 45degree quadrant. Squares: initial release, circles: recapture/re-release event, triangles: last recorded recapture. To maintain fisher privacy, all positions have a random error of 1nm added to them. Water depths: inside dotted line, < 200 m; inside broken line, < 1000 m.

4.3 CRA 4 (Wellington–Hawkes Bay), statistical areas 912–915 and 934

4.3.1 Proportion that moved (CRA 4)

Of 14 196 lobsters tagged in CRA 4, there were 1122 valid recaptures. Small and large males are well represented, as are mature females, but there were only two recaptures of females that had been immature when tagged. 98% of all lobsters recaptured had moved less than 5 km even though 50% had been at liberty for more than 183 days. Only 22 individuals had moved further than 5 km from where they were released (Table 6).

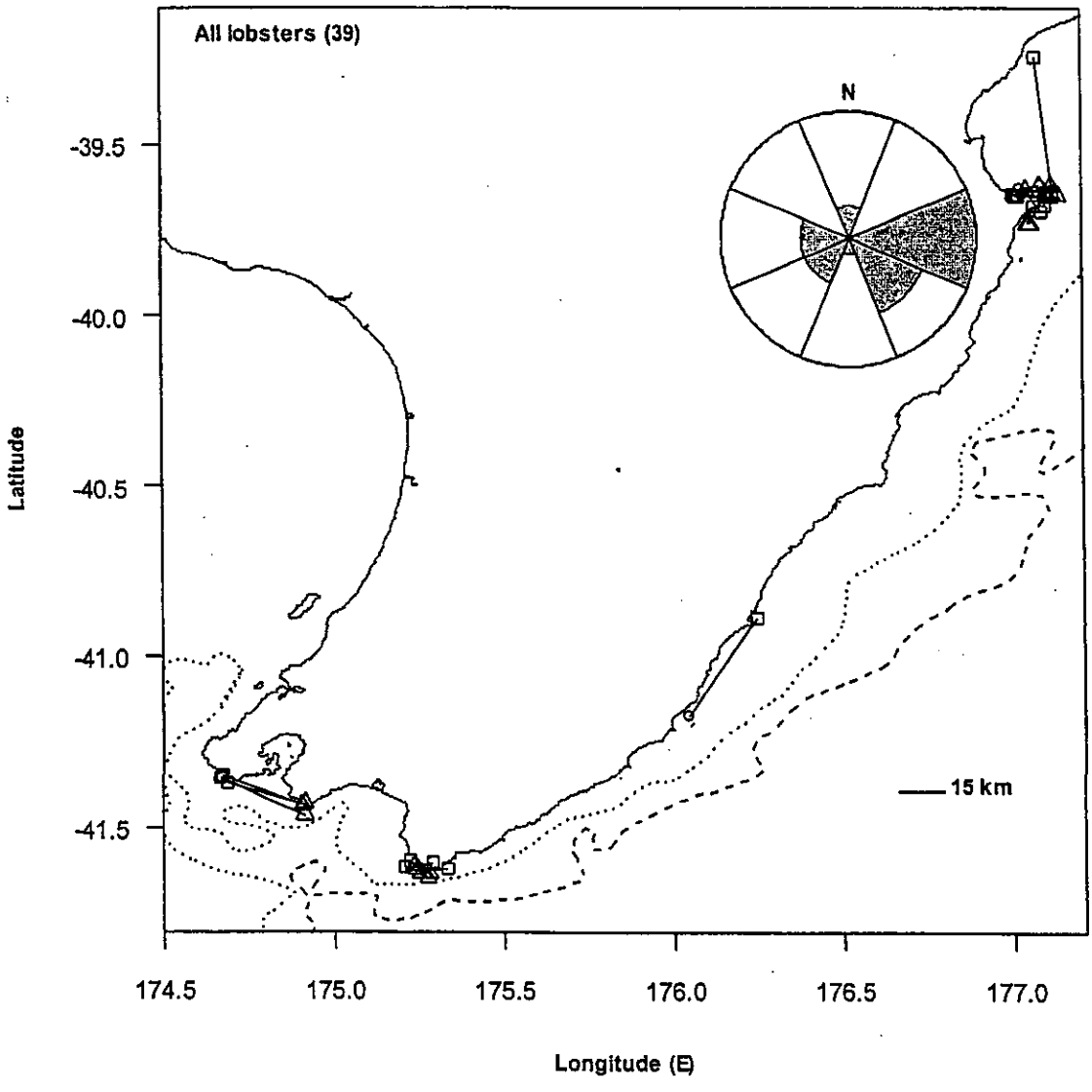


Figure 5: Movements (> 5km) of lobsters tagged in CRA 4. Inset plot shows the relative frequency of direction of movement, in a 45 degree quadrant. Squares: initial release, circles: recapture/re-release event, triangles: last recorded recapture. To maintain fisher privacy, all positions have a random error of 1n.mile added to them. Water depths: inside dotted line, < 200 m; inside broken line, < 1000 m.

4.3.2 Distance and direction moved (CRA 4)

Release and recapture positions of those lobsters tagged in CRA 4 that had moved more than 5 km are shown in Figure 5. There are too few individuals to identify trends in direction, though most had moved east (along Young Nicks Head or along the south coast). The average distance moved was

12.4 km and the maximum was 43.9 km, though 50% had moved less than 9 km, and 95% had moved 35 km or less.

Three large berried females tagged on the same day in August 2000 were recaptured together 6 days later having moved 22 km east across the bottom of the North Island.

Table 6: Number of lobsters tagged, number of tags recovered with valid position information, not necessarily for the first time, number in each class that had moved more than 5 km, from lobsters tagged in CRA 4. LM =large males >= 54mm TW, MF = mature females (with setae, or >= 60 mm TW), SM=small males (< 54mmTW), IF= immature females (no setae or < 60 mm TW).

	No. tagged				No. recovered				No that moved > 5 km			
Stat.	Males		Females		Males		Females		Males		Females	
Area	LM	SM	MF	IF	LM	SM	MF	IF	LM	SM	MF	IF
912	586	1897	2046	117	86	199	36	0	6	5	2	0
913	1064	639	3056	54	166	76	40	1	1	0	0	0
914	1008	612	3129	8	201	80	160	0	2	1	2	0
915	394	645	3412	175	8	1	67	1	0	0	3	0

4.4 CRA 5 (Marlborough–Canterbury), statistical areas 933, and 916–919

4.4.1 Proportion that moved (CRA 5)

From 19 161 lobsters tagged in CRA 5, there are 1751 valid recaptures. Small and large males are well represented, as are mature females, but there is a paucity of recoveries of immature females. Ninety two percent of all lobsters recaptured had moved less than 5 km (Table 7), even though 50% had been at liberty for more than 211 days: 136 individuals had moved more than 5 km.

Table 7: Number of lobsters tagged, number of tags recovered with valid position information, not necessarily for the first time, number in each class that had moved more than 5 km, from lobsters tagged in CRA 5. LM =large males >= 54mm TW, MF = mature females (with setae, or >=60 mm TW), SM=small males (<54mmTW), IF= immature females (no setae or <60 mm TW).

	No. tagged				No. recovered				No that moved > 5 km			
Stat.	Males		Females		Males		Females		Males		Females	
Area	LM	SM	MF	IF	LM	SM	MF	IF	LM	SM	MF	IF
933	732	273	2701	40	173	30	95	2	8	2	2	2
916	3493	3146	4096	138	275	408	246	16	15	20	16	1
917	917	430	3657	250	85	90	312	19	1	23	39	7

4.4.2 Distance and direction moved (CRA 5)

Release and recapture positions for those large male and mature female lobsters tagged in CRA 5, that had moved (more than 5 km) are shown in Figure 5. Movements of small males and immature females are given in Figure 6. Movements up or down the coast occurred with almost equal frequency.

The average distance travelled was 12.2 km and the maximum was 230 km, though 50% had moved less than 7 km, and 95% had moved 19 km or less.

Two large lobsters, a male and a female, and one small male moved more than 100 km from Marlborough south as far as, or further than, Kaikoura.

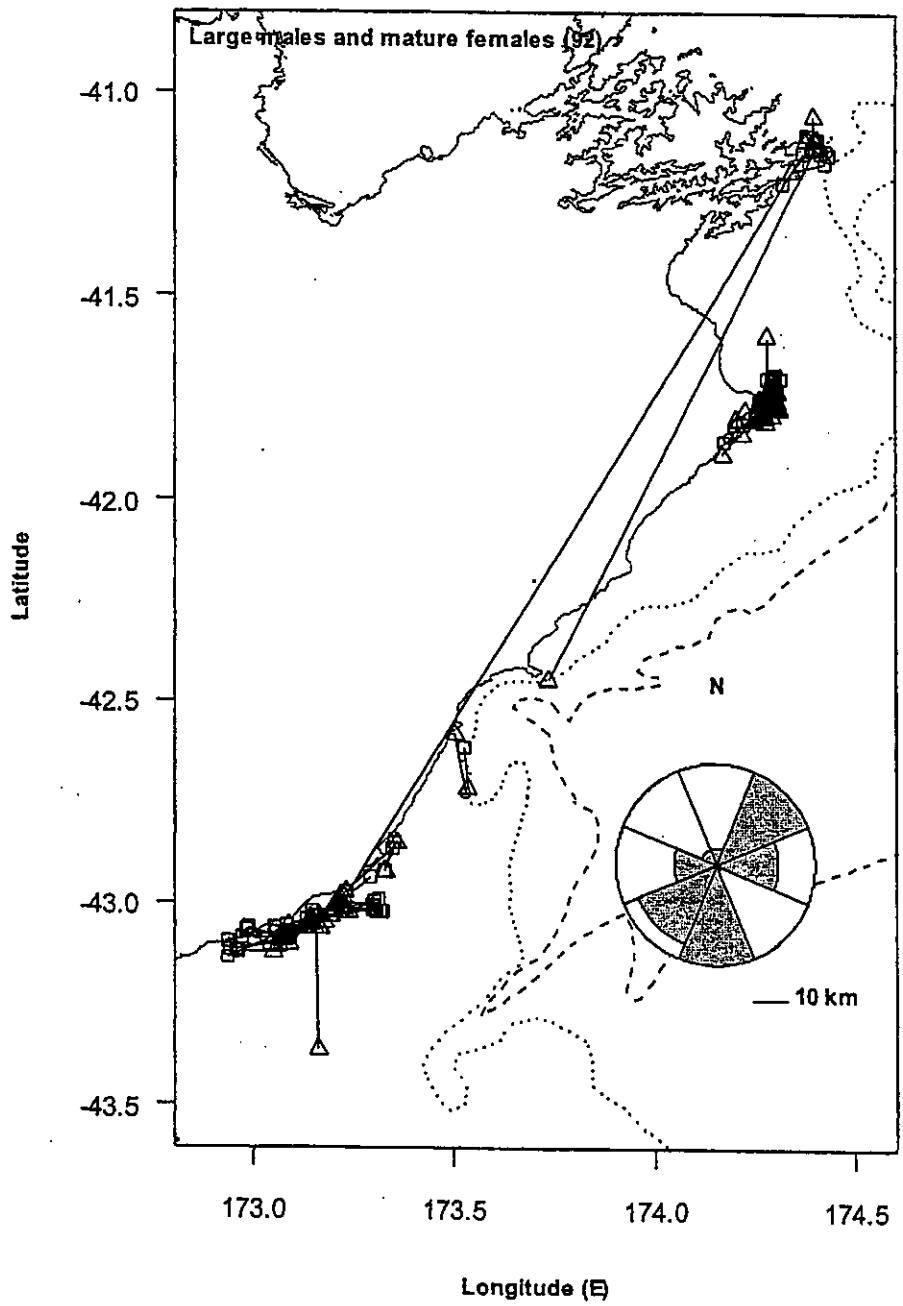


Figure 6: Movements (> 5km) of large male and mature female lobsters tagged in CRA 5. Inset plot shows the relative frequency of direction of movement, in a 45 degree quadrant. Squares: initial release, circles: recapture/re-release event, triangles: last recorded recapture. To maintain fisher privacy, all positions have a random error of 1n.mile added to them. Water depths: inside dotted line, < 200 m; inside broken line, < 1000 m.

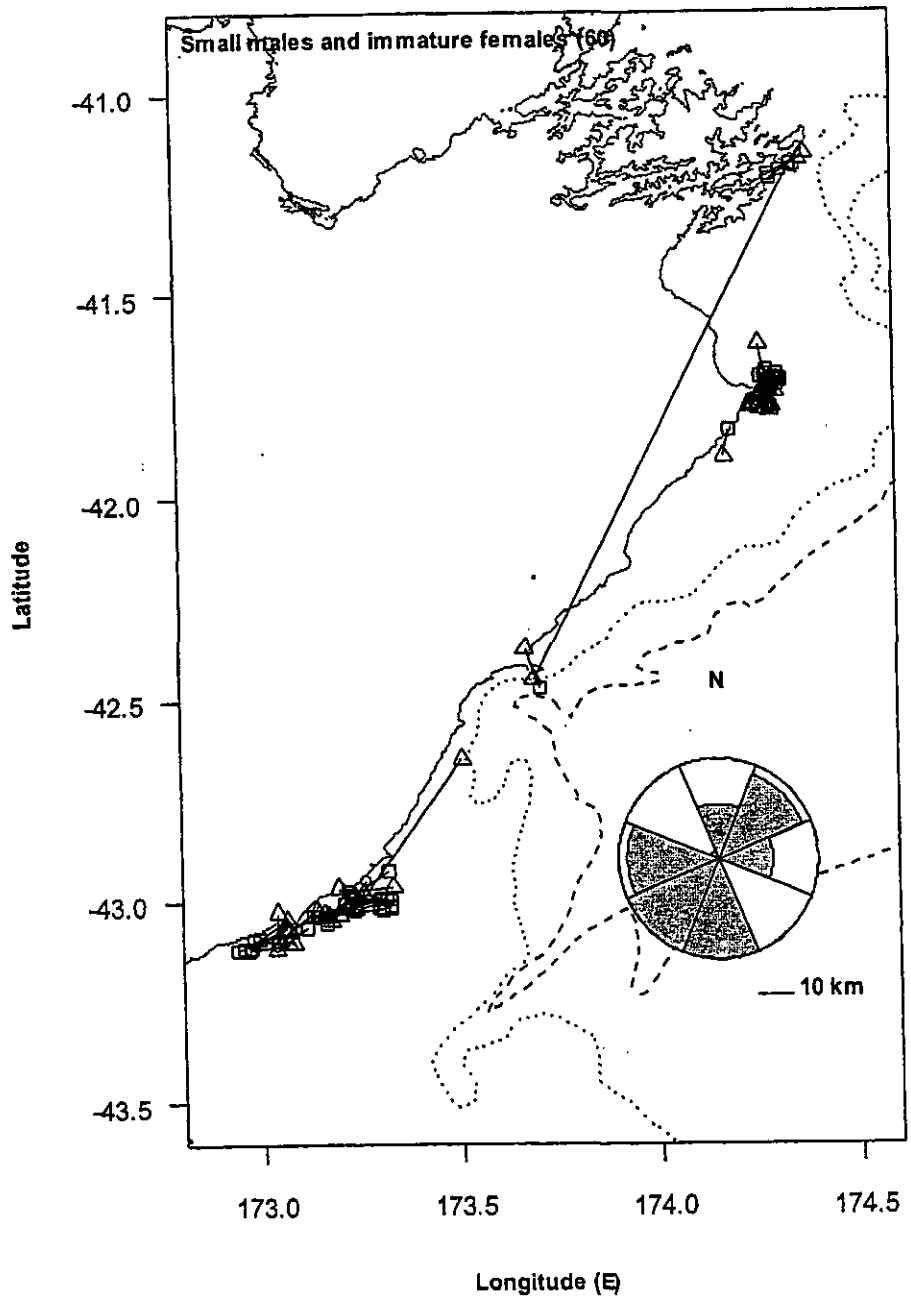


Figure 7: Movements (> 5km) of small male and immature female lobsters tagged in CRA 5. Inset plot shows the relative frequency of direction of movement, in a 45 degree quadrant. Squares: initial release, circles: recapture/re-release event, triangles: last recorded recapture. To maintain fisher privacy, all positions have a random error of 1n.mile added to them. Water depths: inside dotted line, < 200 m; inside broken line, < 1000 m.

4.5 CRA 8 (Southland–Stewart Island–Fiordland), statistical areas 922–928

4.5.1 Proportion that moved (CRA 8)

Of 15 572 lobsters tagged in CRA 8, 2918 were recaptured. Most (55–100%) recaptured small males and immature females tagged in areas 922, 923, 924, and 926 had moved more than 5 km (Table 8); a smaller proportion (20–46%) of those tagged in areas 927 and 928 had moved. For areas 922 to 927 (excluding 925) there were consistent differences in the proportion that moved in the following order: immature females greater than small males, greater than mature females, greater than large males (Figure 7). For all sex-size classes of lobster combined, the proportion that moved was consecutively smaller, east to west along the route of the southern migration (Figure 8). The median number of days at liberty for recaptured lobsters was 321.

Table 8: Number of lobsters tagged, number of tags recovered, not necessarily for the first time, with valid position information, number in each class that had moved more than 5 km from lobsters tagged in CRA 8. LM =large males >= 54mm TW, MF = mature females (with setae, or >=60 mm TW), SM=small males (<54mmTW), IF= immature females (no setae or <60 mm TW).

	No. tagged				No. recovered				No that moved > 5 km			
Stat.	Males		Females		Males		Females		Males		Females	
Area	LM	SM	MF	IF	LM	SM	MF	IF	LM	SM	MF	IF
922	0	3	5	1	0	6	4	9	0	5	3	9
923	7	321	153	746	3	25	4	52	0	19	2	42
924	34	1471	257	1953	38	223	27	294	13	152	12	213
926	41	2583	314	1884	42	251	25	225	7	139	8	141
927	30	1513	910	1023	100	496	593	288	9	158	108	132
928	25	889	530	567	8	47	128	25	2	14	24	5

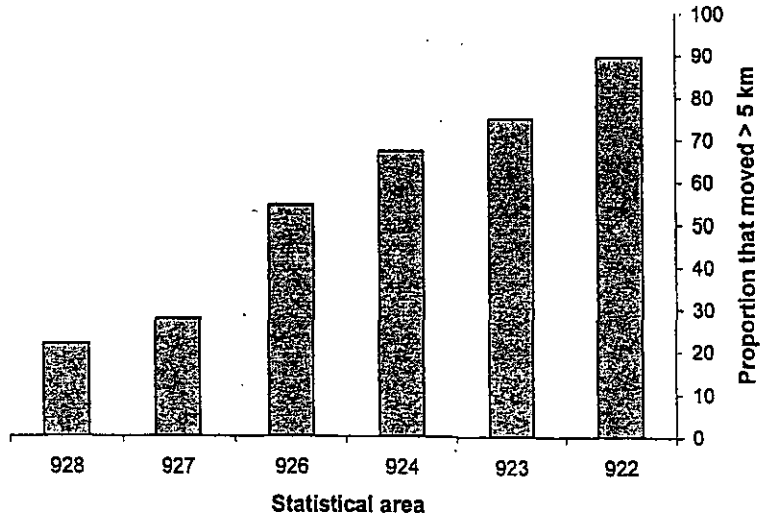


Figure 8: Proportion of tags recovered that had moved > 5 km, for statistical areas in CRA 8 (west to east, left to right), all size-sex classes combined.

4.5.2 Direction moved (CRA 8)

Around Southland, Stewart Island and Fiordland, there were adequate numbers of recoveries from lobsters that had moved long distances to confirm the migration patterns previously described. Movements over 5 km are plotted for the CRA 8 region separately for each sex-size class of lobster, and by the area in which they were released (Figures 10–17). Each figure includes distribution plots of directions (straight-line bearings) moved, to clarify the trends in direction and to indicate the extent of the group-directedness that distinguishes the migration from nomadic movements. For small males and immature females, additional plots show just those movements over 50 km for the whole of CRA 8 (see Figures 18 19).

Large males and mature females very rarely moved great distances. Mature females showed little directionality along the Stewart Island and area 927 coasts, moving equally as often in both directions. In areas 926 and 928 there were notable proportions of inshore movements (see Figures 15 & 17). No mature females crossed Foveaux Strait or moved from area 926 up into Fiordland. Two long-distance movements from the Southland coast to the north-east of Stewart Island were by females over 60 mm TW for which maturity information was not available; they were possibly immature (Annala et al. 1980). There were very few large males recaptured, and some may have also been immature. They tended to move north in most areas of Fiordland (see Figures 14–17).

Among smaller and immature lobsters, the most dramatic mass movements include those from area 926 on the southwest coast of the South Island up into Fiordland (Figure 14). Only 12 individuals crossed Foveaux Strait, 3 males and 5 females crossed from Stewart Island to the South Island, and 2 females and 2 males crossed in the opposite direction. Immature females moved strongly southwest along the southeast Stewart Island coast (Figure 11) and north from area 926 (Figure 14). Within area 927 there were movements in both directions along the coast but mostly north, and within area 928 the predominant direction was south along the coast back towards area 927 (Figures 15–17). Patterns for small males are similar.

4.5.3 Distance and rate of long–distance movements (CRA 8)

The average distances travelled by those lobsters that moved more than 5 km are given in Table 9. For most classes of lobster the greatest distances were moved from area 922, though these are based on very few individuals (Table 4). Otherwise, the distances travelled by all classes combined were in the order 926 > 924 > 927 > 928, and 12% and 17% respectively of small males and immature females tagged in area 926 had moved more than 50 km. These distances are likely to be underestimates in most cases, but especially in area 926, where the straight-line route does not represent the route taken around the coast (Figure 14).

Table 9: Average (minimum straightline) distance (km) with median and 95 percentile in brackets, for lobsters that moved more than 5 km in CRA 8. Numbers of lobsters as in Table 4. LM =Males >= 54mm TW, MF = mature females (with setae, or >= 60 mm TW), SM=small males (< 54mmTW), IF = immature females (no setae or <60 mm).

Stat.	LM		SM		MF		IF	
Area	mean	(50, 95%)	mean	(50, 95%)	mean	(50, 95%)	mean	(50, 95%)
922	-		53	*(57, 68)*	123	*(115, 139)*	95	*(98, 142)*
923	-		25	*(16, 49)*	16	*(16, 16)*	44	*(36, 165)*
924	18	*(12, 34)*	24	*(14, 58)*	32	*(13, 112)*	23	*(17, 48)*
926	54	*(32, 126)*	39	*(17, 147)*	32	*(10, 116)*	48	*(18, 160)*
927	17	*(15, 30)*	15	*(10,29)*	12	*(8, 27)*	16	*(10, 44)*
928	9	*(9,9)*	11	*(8, 28)*	11	*(8, 27)*	15	*(6, 32)*

Average rates of movement (km/day) were calculated for those lobsters that moved more than 5 km, as the minimum straight-line distance between release and recapture, divided by the number of days at liberty, and are given in Table 10. Average (min) rate of movement for all sex/size classes of lobster except large males, was greatest for those tagged in 924, at about twice the rate of the same class of lobster tagged in 926 (but see the note above).

Table 10: Average (minimum straight-line) rates of movement (km / day) for lobsters that moved more than 5 km in CRA 8. Numbers of lobsters as in Table 4. LM, large males >= 54mm TW; MF, mature females (with setae, or >= 60 mm TW); SM, small males (< 54mmTW); IF, immature females (no setae or < 60 mm TW).

Stat. area	LM	SM	MF	IF
922	–	0.22	–	0.14
923	–	0.11	0.15	0.29
924	0.51	0.28	0.34	0.36
926	0.62	0.16	0.03	0.16
927	0.08	0.19	0.12	0.18
928	0.05	0.12	0.30	0.05

4.5.4 Days at liberty (CRA 8)

Average number of days spent at liberty by those lobsters that moved more than 5 km are given in Table 11. The few lobsters tracked from area 922 were at liberty for more than 14 months on average. Among the other areas of CRA 8, lobsters tagged in 926 were at liberty the longest. Mature females tagged in area 926 were particularly elusive, being free on average for about 16 months.

Table 11: Average number of day at liberty for lobsters that moved more than 5 km in CRA 8. Numbers of lobsters as in Table 4. LM, large males >= 54mm TW; MF, mature females (with setae, or >= 60 mm TW); SM, small males (< 54mmTW); IF = immature females (no setae or < 60 mm TW).

Stat. area	LM	SM	MF	IF
922	–	506	715	568
923	–	346	120	356
924	157	317	180	290
926	80	385	486	444
927	297	318	365	399
928	195	261	279	229

Fishers report a tendency for lobsters to be recaptured at or very near the anniversary of the day they were released and distinct 'bands' are evident in plots of days at liberty (not shown) at or near multiples of 365 days. When day of the year tagged was plotted against day of the year recaptured however (excluding those recaptured within 100 days of release), it became clear that lobsters are recaptured over the entire fishing season in numbers proportional to fishing effort, regardless of the day they were tagged. The highly seasonal nature of the fishery has seen lobsters tagged and recaptured in greatest numbers over a narrow band of time, and this largely accounts for the anniversary effect. A seasonal movement of large females described later in this study accounts for some of these observations, but in these data, lobsters caught on or very near to their anniversary date were commonly also caught at other times over the fishing season.

4.5.5 Distance moved – standardised for days at liberty (CRA 8)

To explore variability in *distance* moved among *area* and *class* of lobster, taking into account the effect of *days at liberty*, a two factor analysis of variance model was used with *days at liberty* as a co-factor. *Distance* moved was the dependent variable and was predicted from *days at liberty* taking into account any systematic effect of statistical *area* and sex-maturity *class* The variables were offered to a lognormal linear model in a forward stepwise procedure to establish their relative importance. *Area*, *days at liberty,* and *class*, in that order, were significant in explaining variance in *distance* moved (α = 0.005). Partial coefficients from this model are shown for levels of the significant variables in Figure 9. Longer time spent at liberty was not the sole reason for the greater distances moved by lobsters tagged in 926. Immature females moved greater distances than small males, mature females moved less, and variance among the small number of large males prevents comparison.

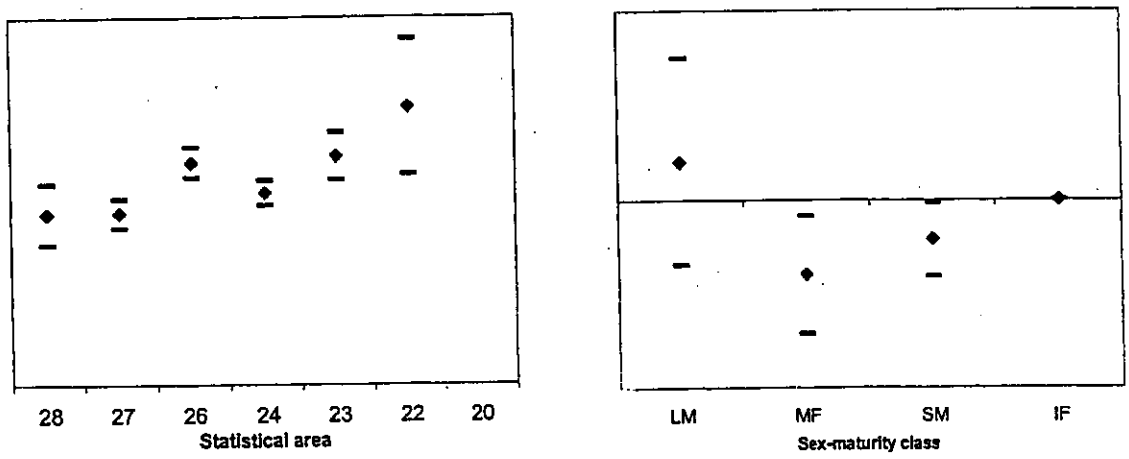


Figure 9: The relative effect of statistical area (left) and of sex–maturity class relative to immature females (right) on distance moved ±3 standard errors. LM, large males >= 54mm TW; MF, mature females (with setae, or >= 60 mm TW); SM, small males (< 54mmTW); IF = immature females (no setae or < 60 mm TW).

4.5.6 Season and duration of southern migration (CRA 8)

There is little evidence, in these very seasonal data, of the months over which movements occurred, or, if seasonal, whether the migration is resumed in subsequent seasons. From area 924, the distances involved are just as likely to have been covered in one month at liberty as in one year. From area 926, distances over 100 km were moved only by individuals at liberty for more than 365 days (Figure 20). Only in the multiple release-recapture data is there direct evidence of individuals that have sustained long distance movements over more than one year. Figures 21 and 22 show the release and recapture positions of two immature females that were recaptured three times over two years, and had travelled long distances between each event. These females were still immature when last recaptured.

A.

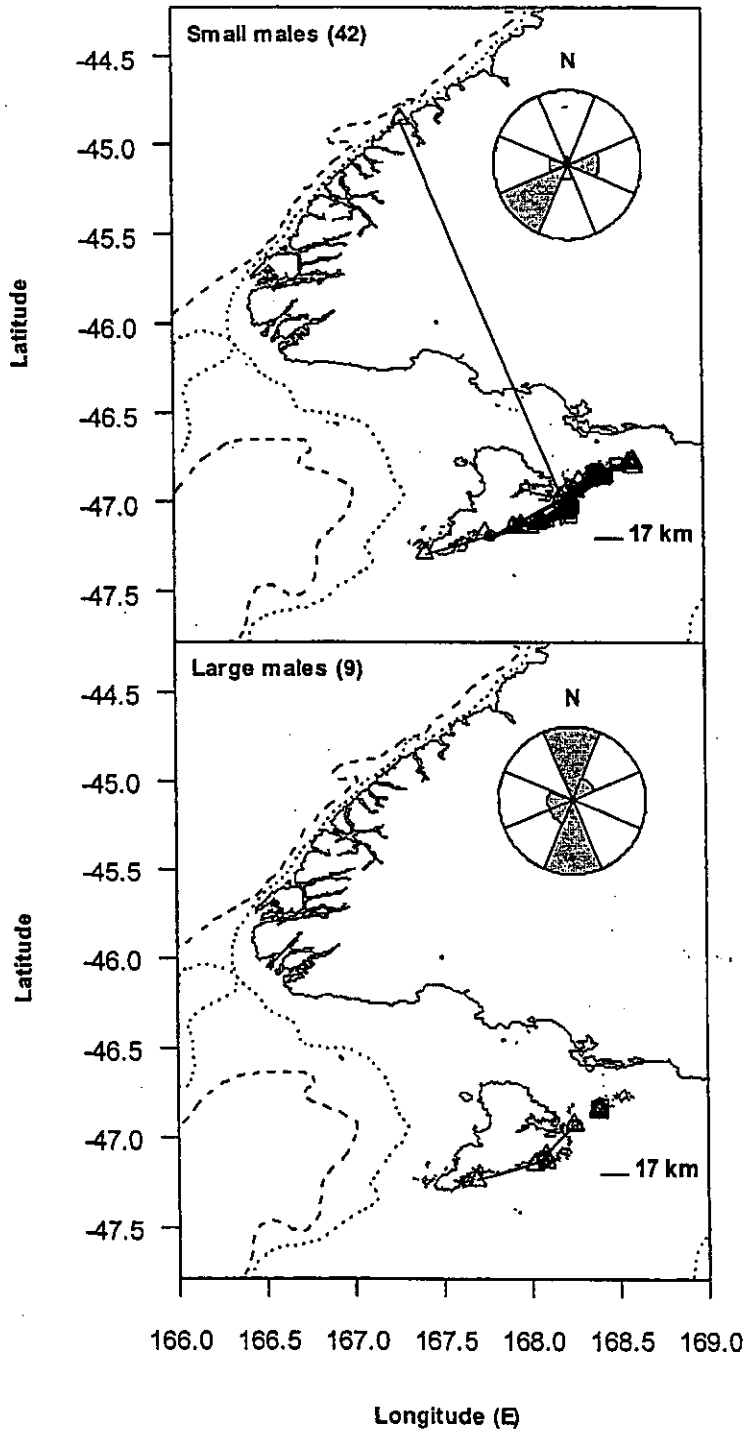


Figure 10: Movement of male (A), and female (B) lobsters initially captured, tagged, and released off the east coast of Stewart Island. Squares: initial release, circles: recapture/re-release event, triangles: last recorded recapture. To maintain fisher privacy, all positions have a random error of 1n.mile added to them. Inset plot shows the relative frequency of direction of movement, in a 45 degree quadrant. Water depths: inside dotted line, < 200 m; inside broken line, < 1000 m.

B.

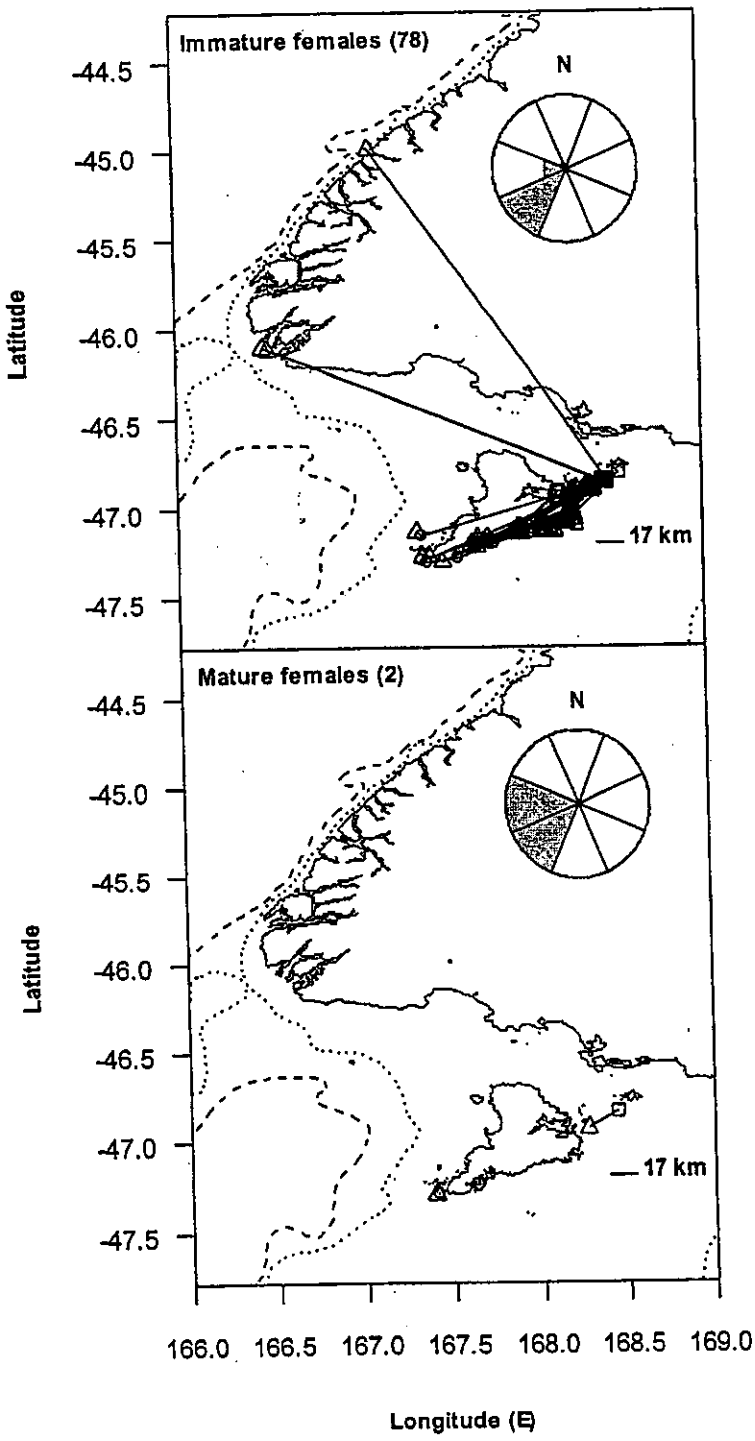


Figure 10 (cont.):

A.

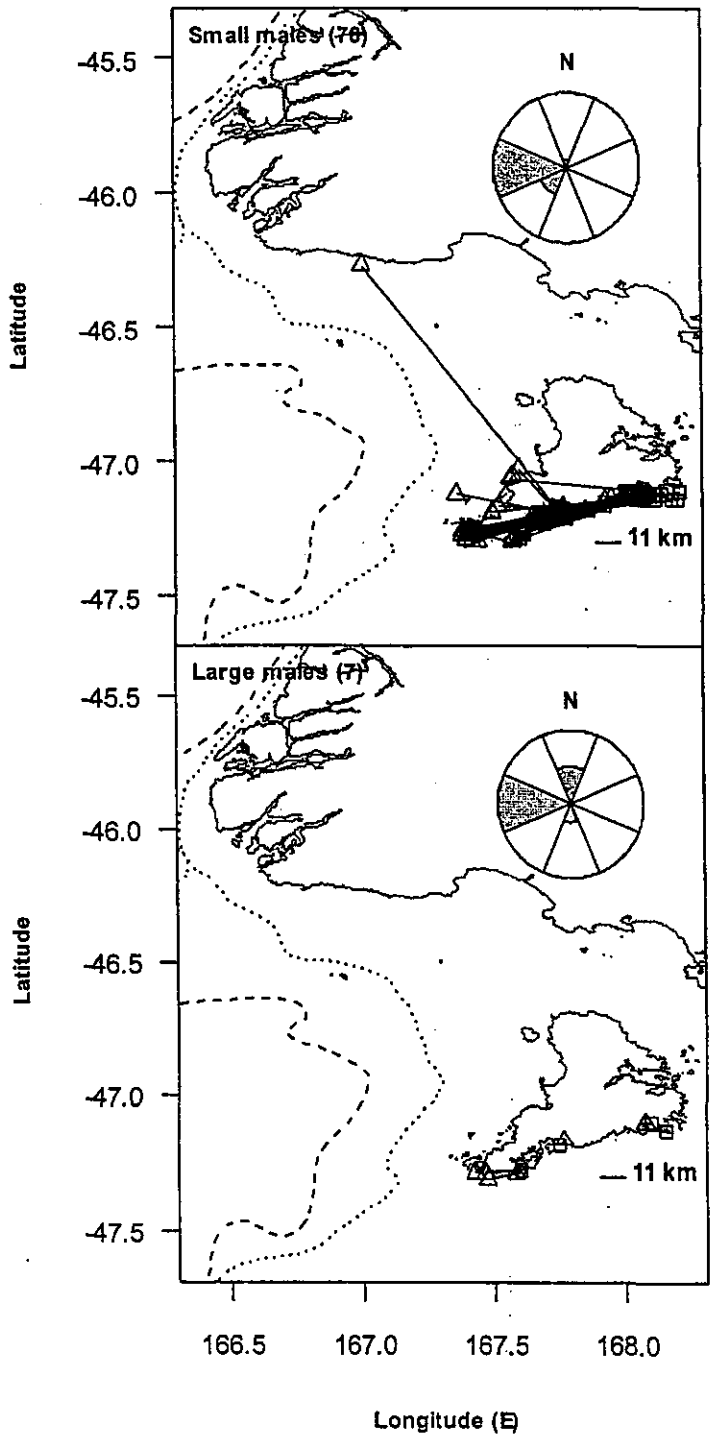


Figure 11: Movements of tagged lobsters initially captured, tagged and released along the southeast of Stewart Island. Squares: initial release, circles: recapture/re-release event, triangles: last recorded recapture. To maintain fisher privacy, all positions have a random error of 1n. mile added to them. Inset plot shows the relative frequency of direction of movement, in a 45 degree quadrant. Water depths: inside dotted line, < 200 m; inside broken line, < 1000 m.

B.

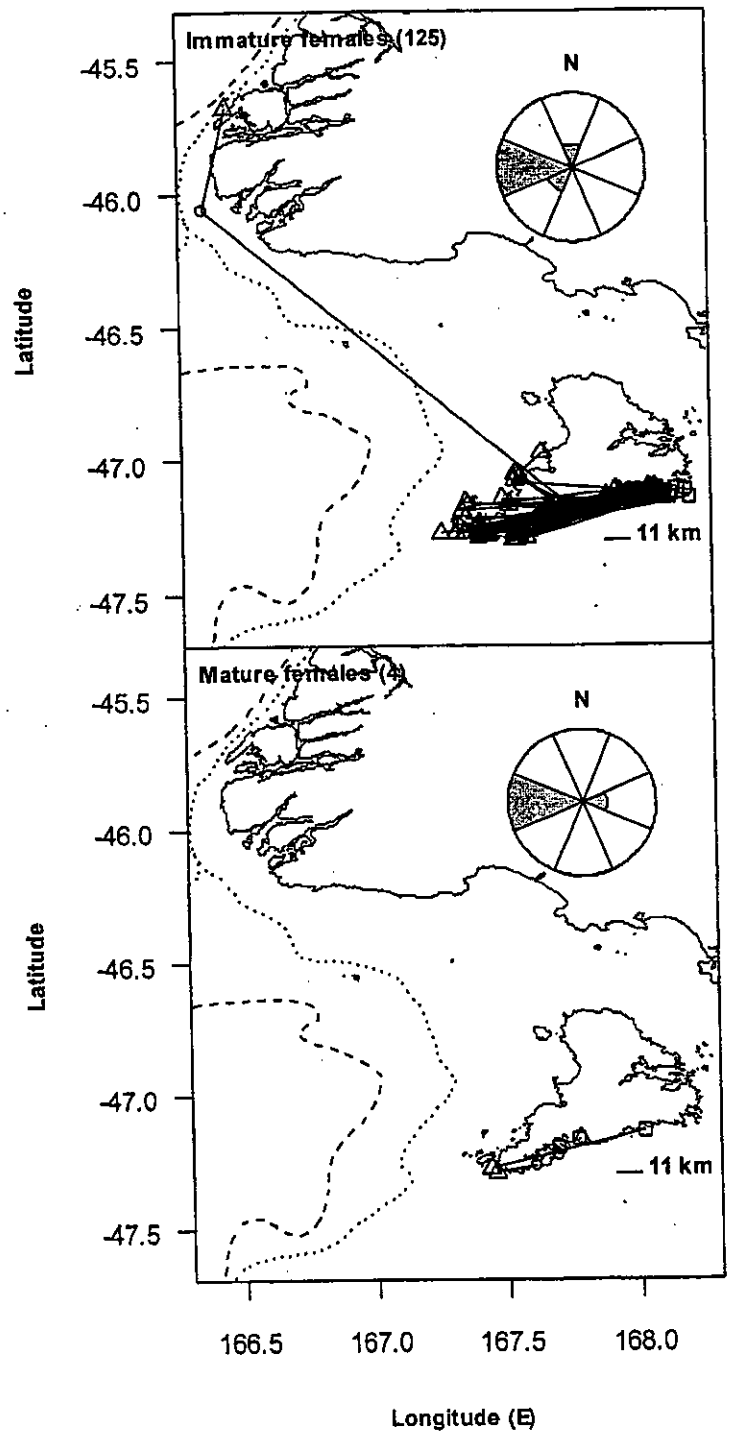


Figure 11 (cont.)

A.

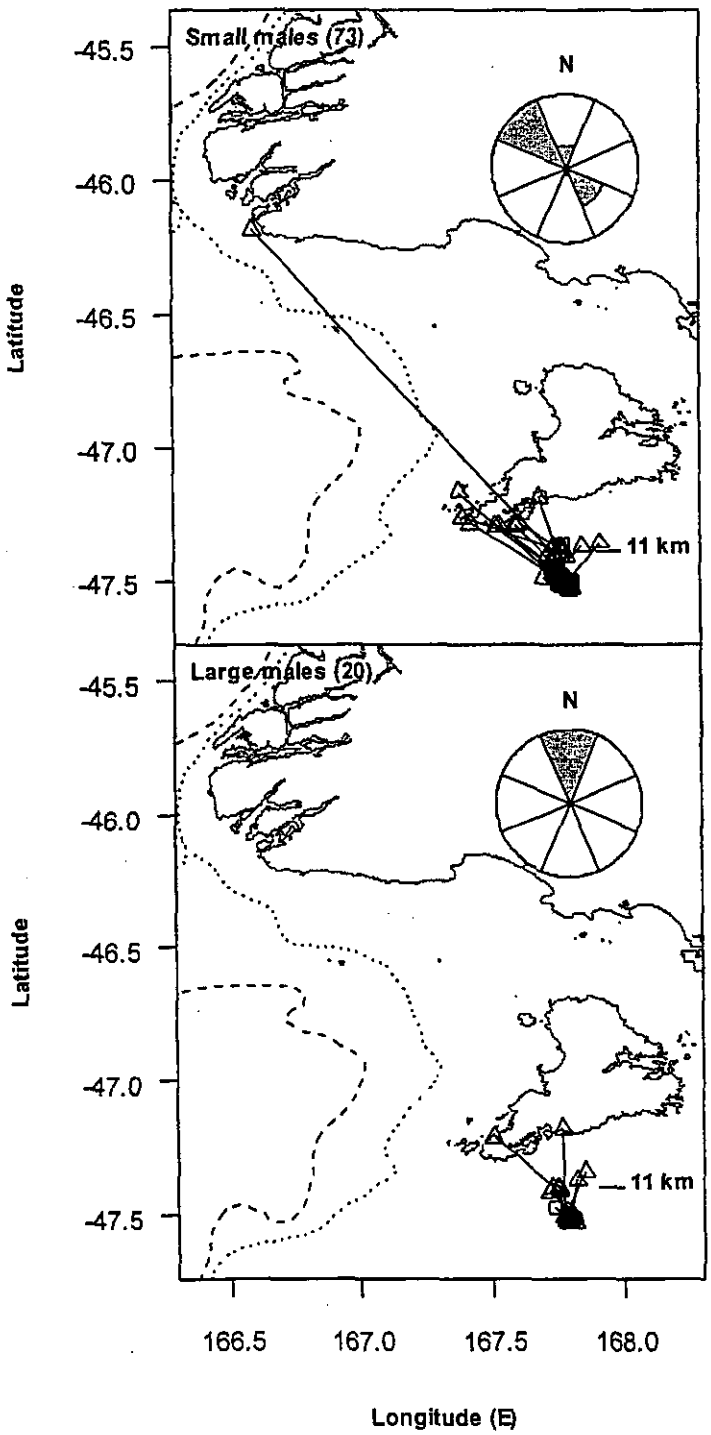


Figure 12: Movements of tagged lobsters initially captured, tagged and released near North and South Trap, south of Stewart Island. Squares: initial release, circles: recapture/re-release event, triangles: last recorded recapture. To maintain fisher privacy, all positions have a random error of 1n.mile added to them. Inset plot shows the relative frequency of direction of movement, in a 45 degree quadrant. Water depths: inside dotted line, < 200 m; inside broken line, < 1000 m.

B.

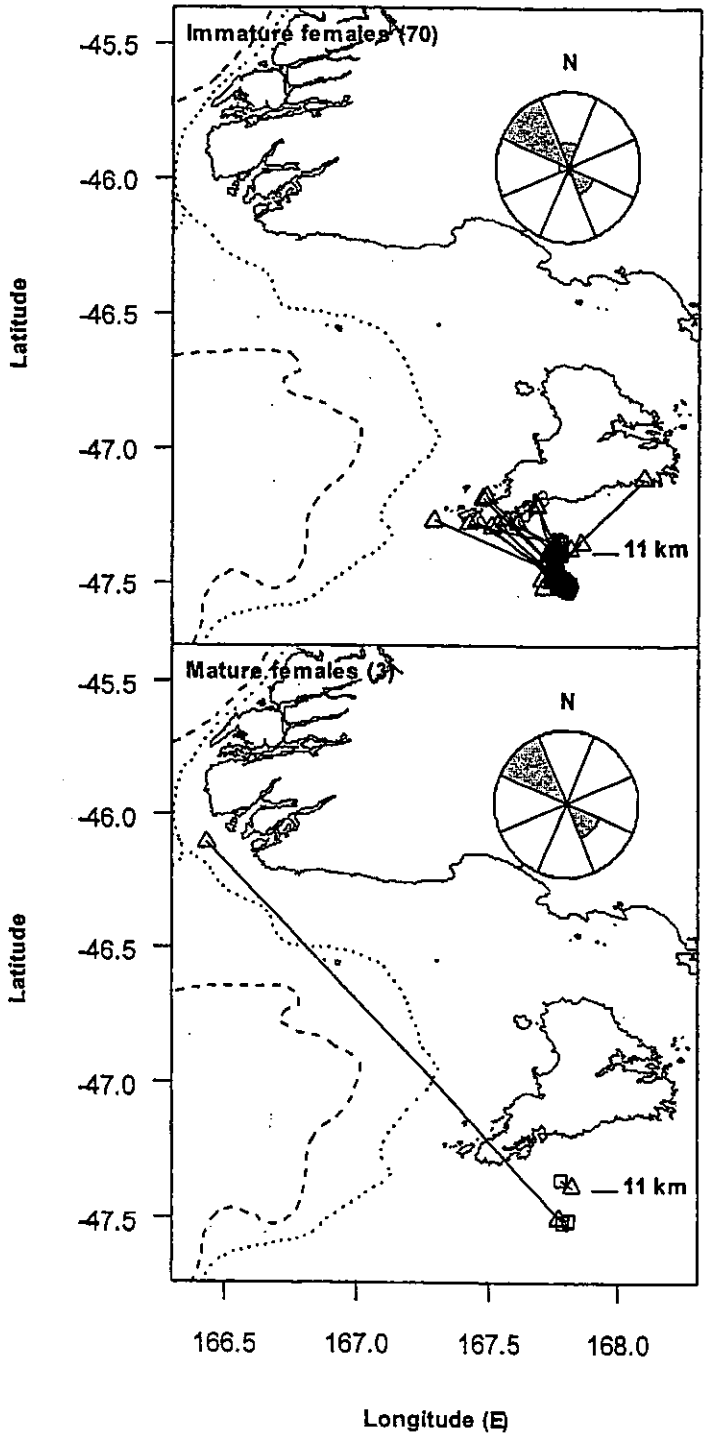


Figure 12 (Cont.)

A.

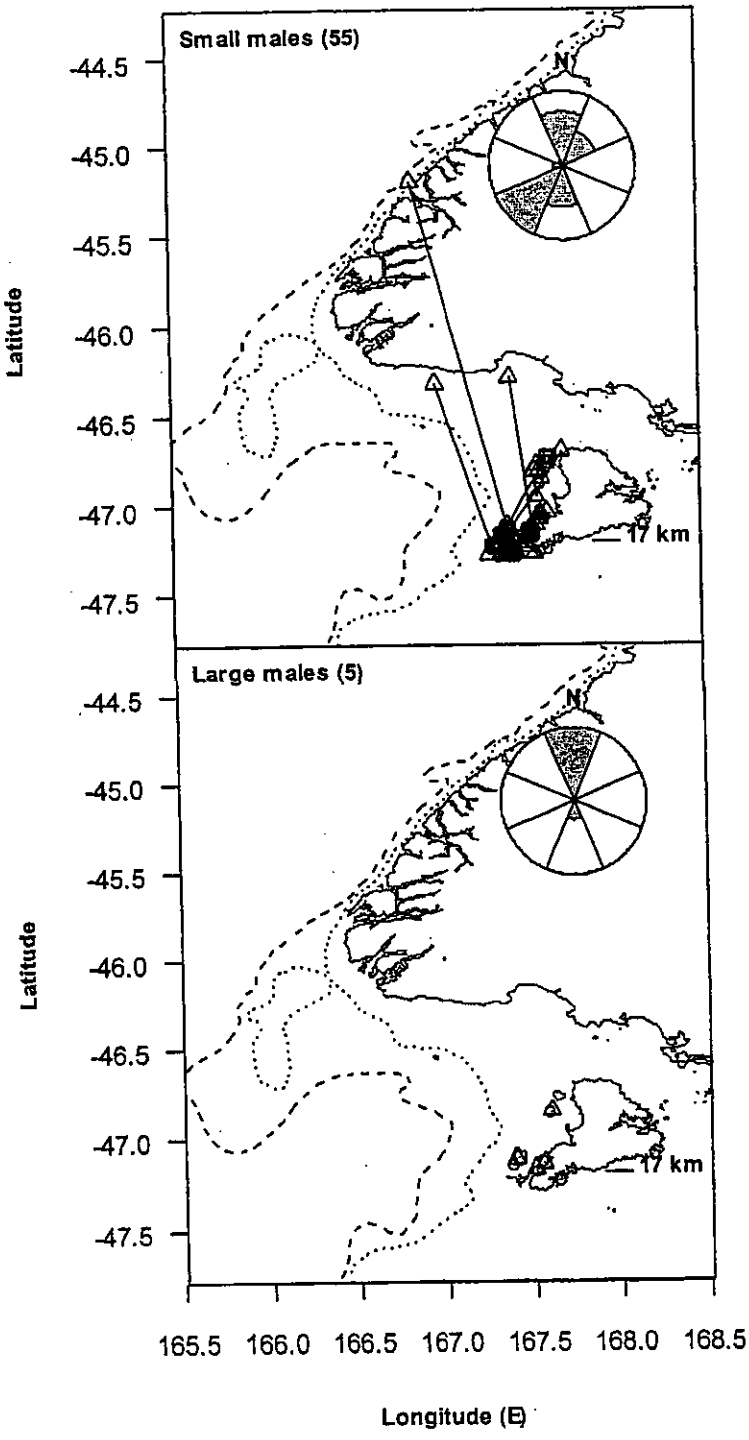


Figure 13: Movements of tagged lobsters initially captured, tagged and released on the west coast of Stewart Island. Squares: initial release, circles: recapture/re-release event, triangles: last recorded recapture. To maintain fisher privacy, all positions have a random error of 1n. mile added to them. Inset plot shows the relative frequency of direction of movement, in a 45 degree quadrant. Water depths: inside dotted line, < 200 m; inside broken line, < 1000 m.

B.

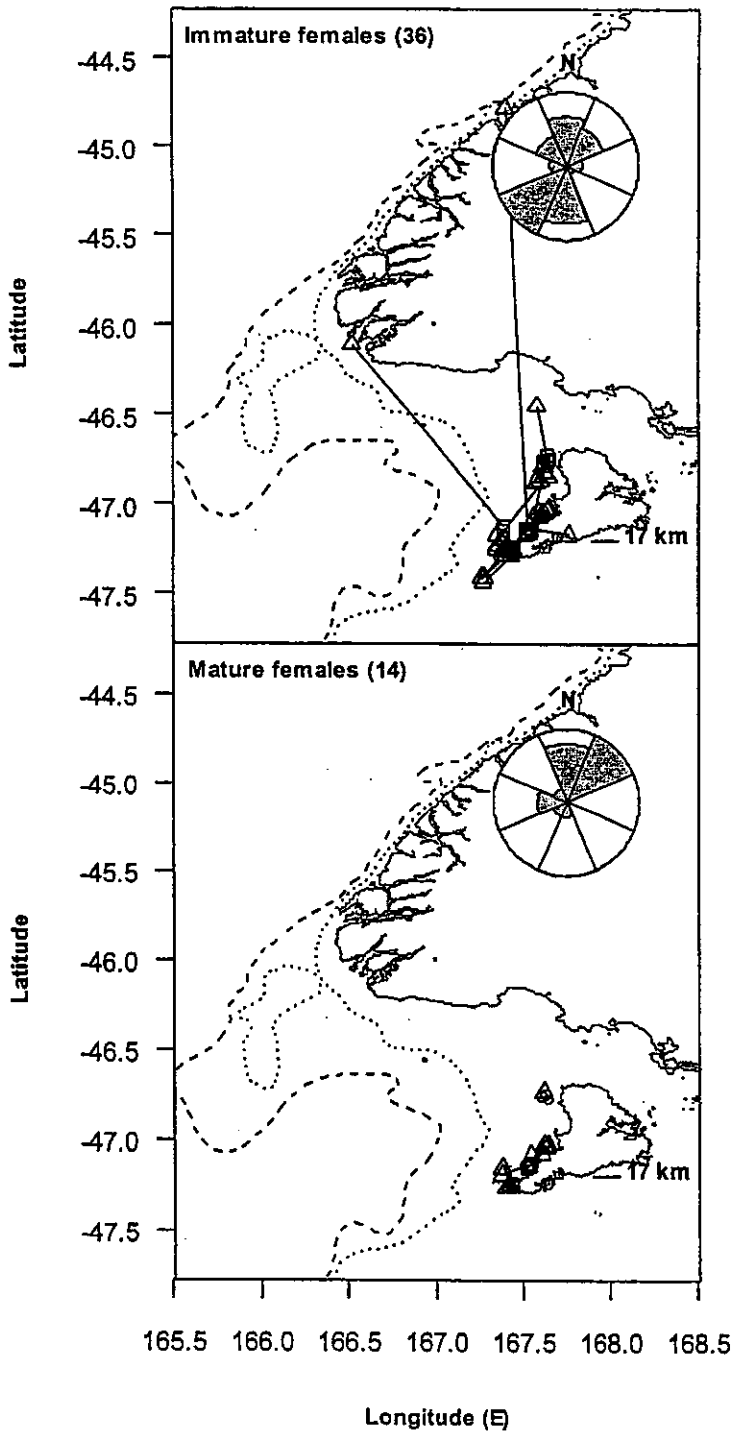


Figure 13 (Cont.)

A.

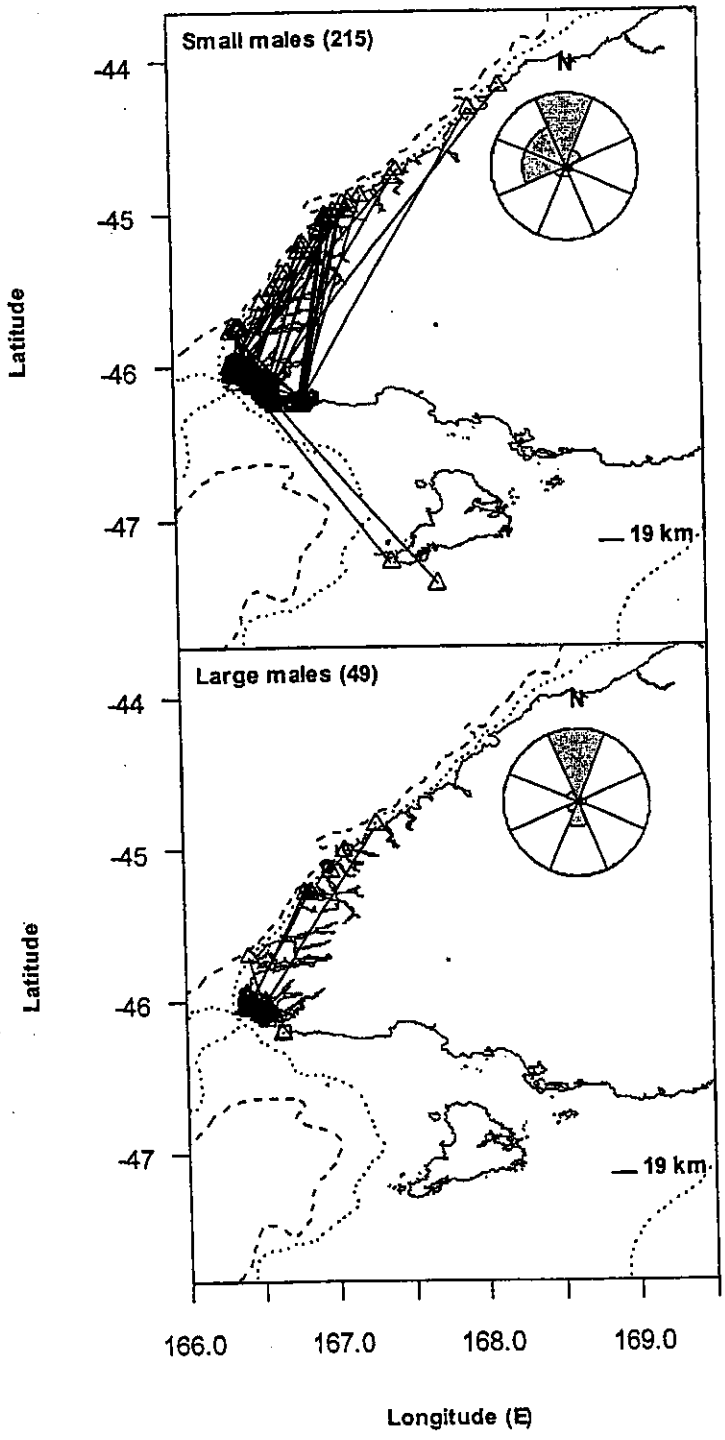


Figure 14: Movements of tagged lobsters initially captured, tagged and released near Riverton and the "South Shore" of Fiordland. Squares: initial release, circles: recapture/re-release event, triangles: last recorded recapture. To maintain fisher privacy, all positions have a random error of 1n.mile added to them. Inset plot shows the relative frequency of direction of movement, in a 45 degree quadrant. Water depths: inside dotted line,< 200 m; inside broken line, < 1000 m.

B.

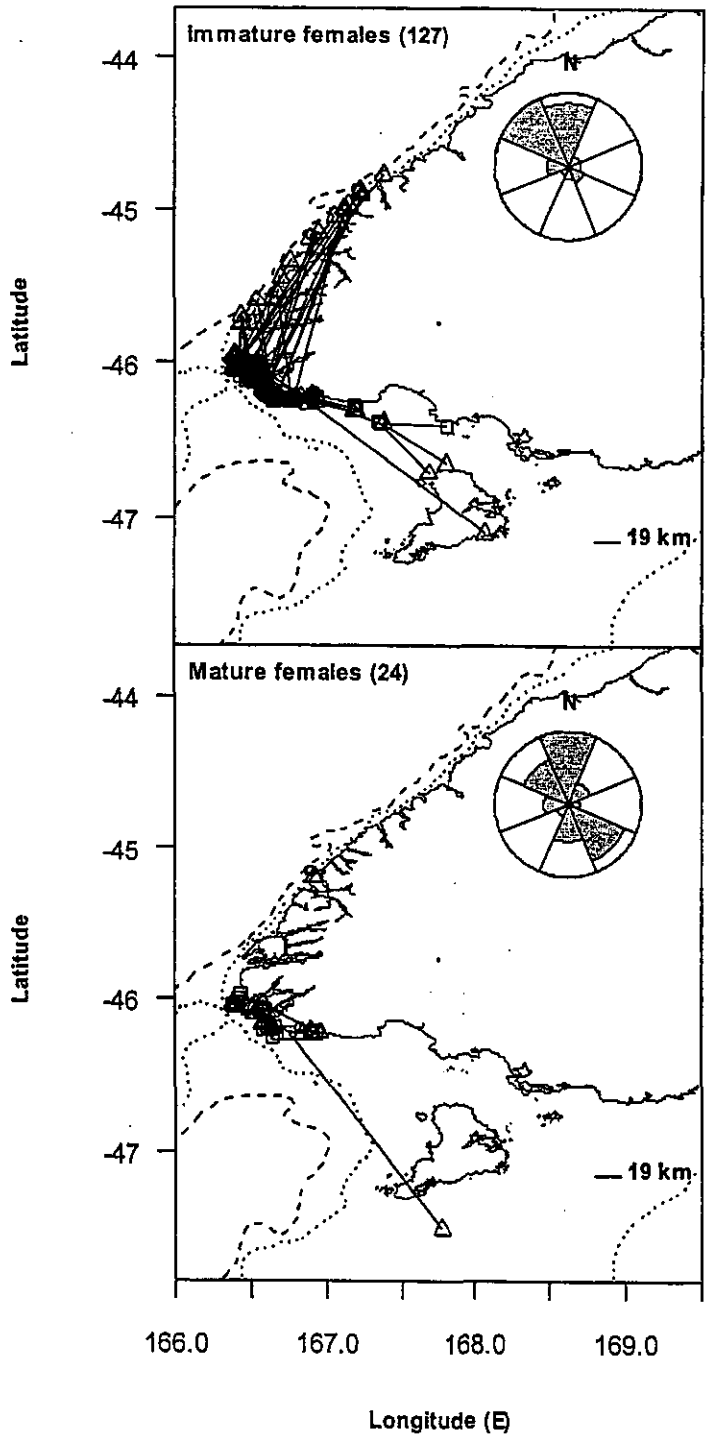


Figure 14 (Cont.)

A.

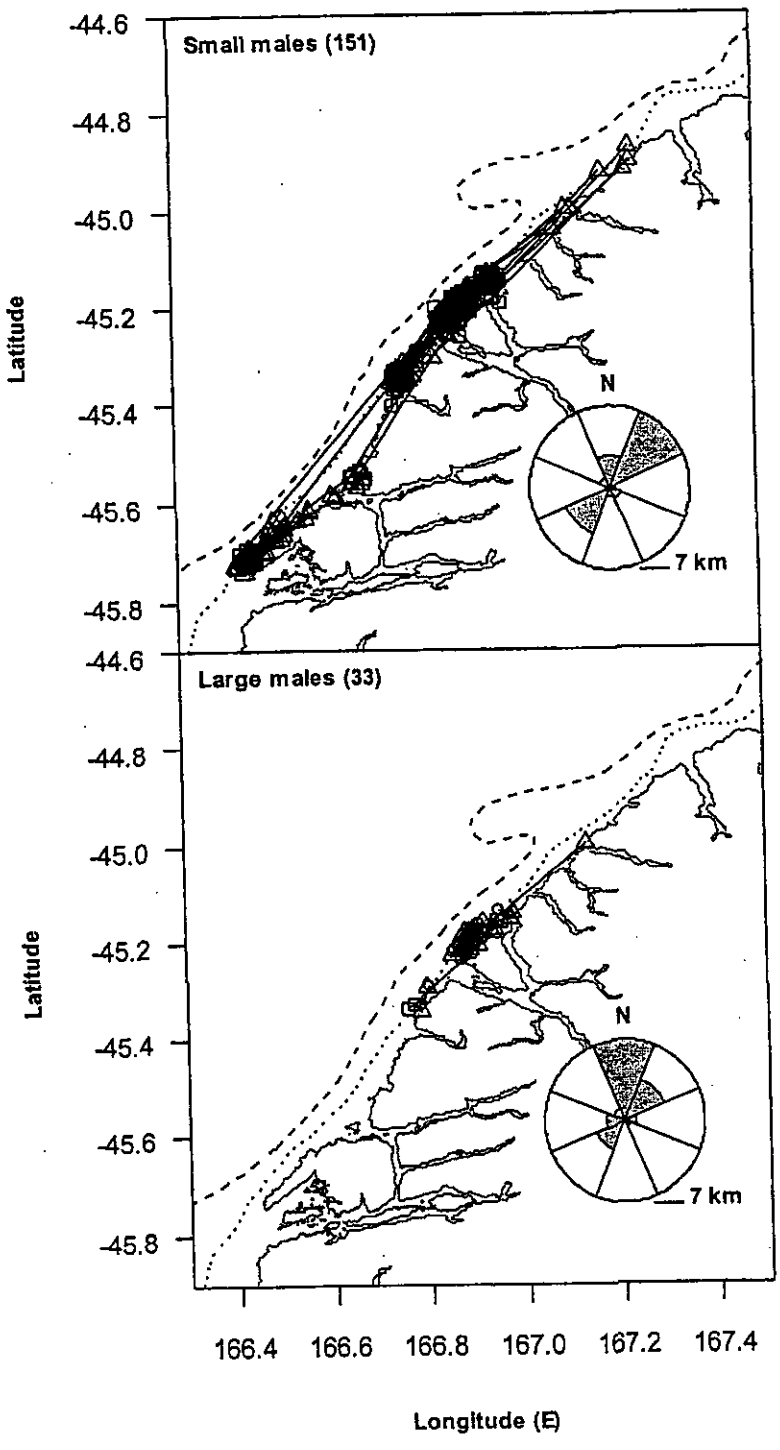


Figure 15: Movements of tagged lobsters initially captured, tagged and released between Dusky Sound and Thompson Sound, Fiordland. Squares: initial release, circles: recapture/re-release event, triangles: last recorded recapture. To maintain fisher privacy, all positions have a random error of 1n.mile added to them. Inset plot shows the relative frequency of direction of movement, in a 45 degree quadrant. Water depths: inside dotted line, < 200 m; inside broken line, < 1000 m.

B.

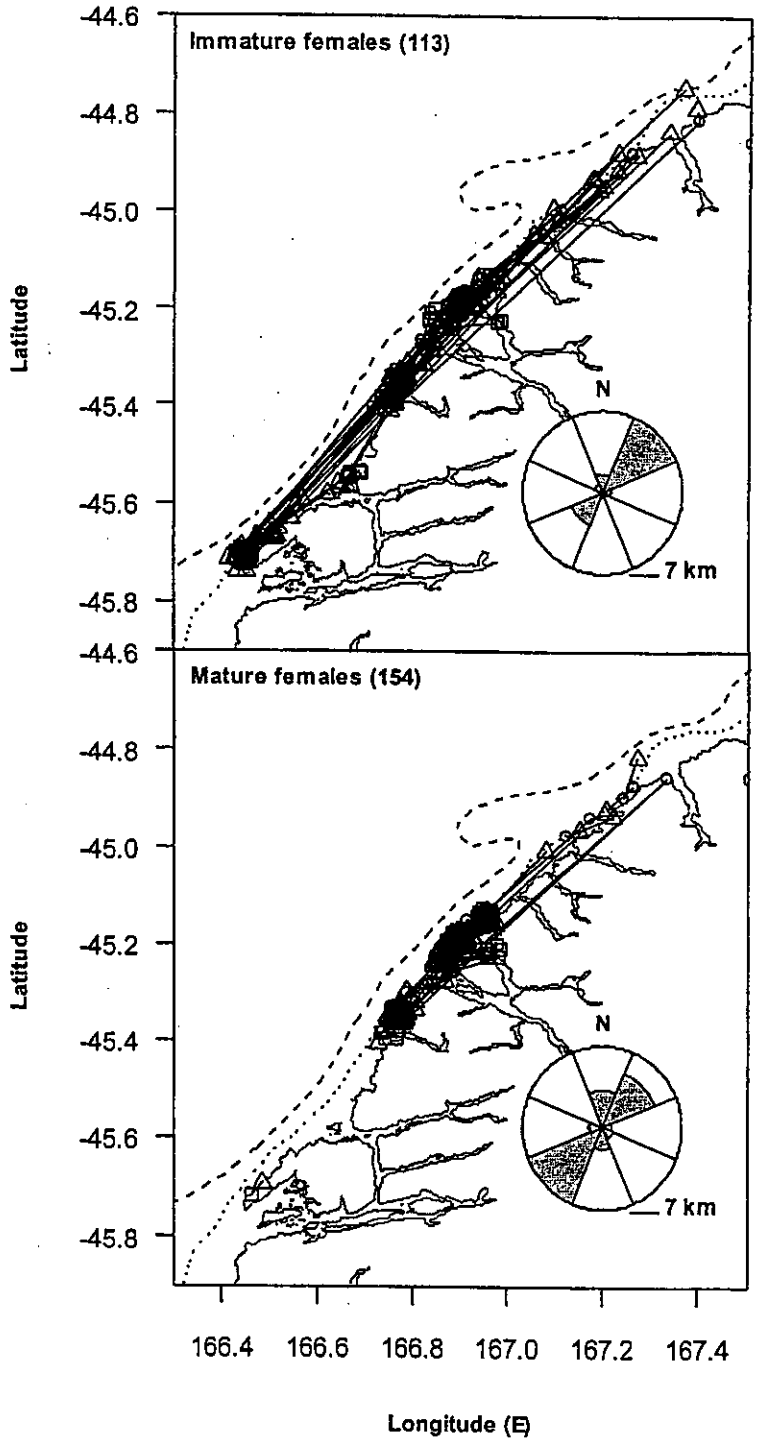


Figure 15 (Cont.)

A.

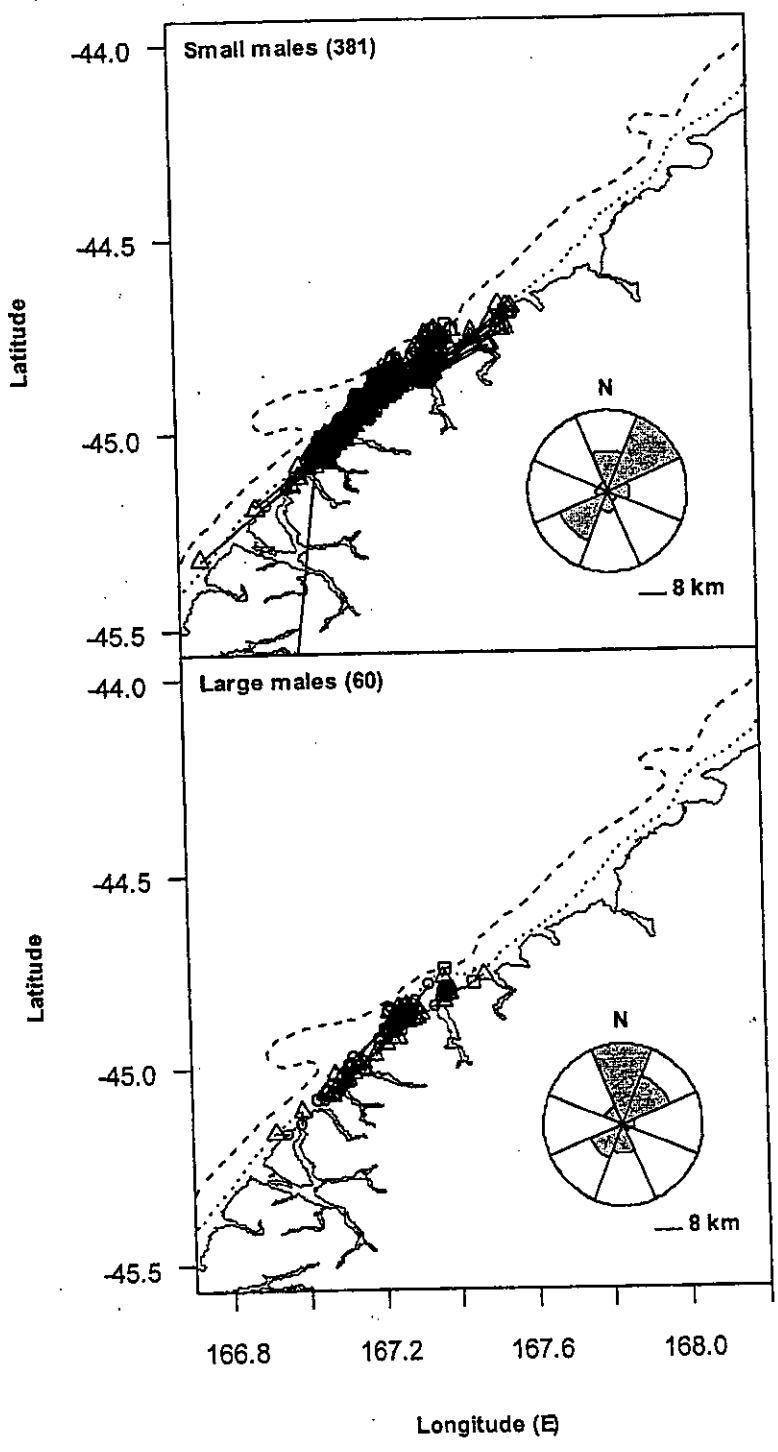


Figure 16. Movements of tagged lobsters initially captured, tagged and released between Nancy Sound and Bligh Sound, Fiordland. Squares: initial release, circles: recapture/re-release event, triangles: last recorded recapture. To maintain fisher privacy, all positions have a random error of 1n.mile added to them. Inset plot shows the relative frequency of direction of movement, in a 45 degree quadrant. Water depths: inside dotted line, < 200 m; inside broken line, < 1000 m.

B.

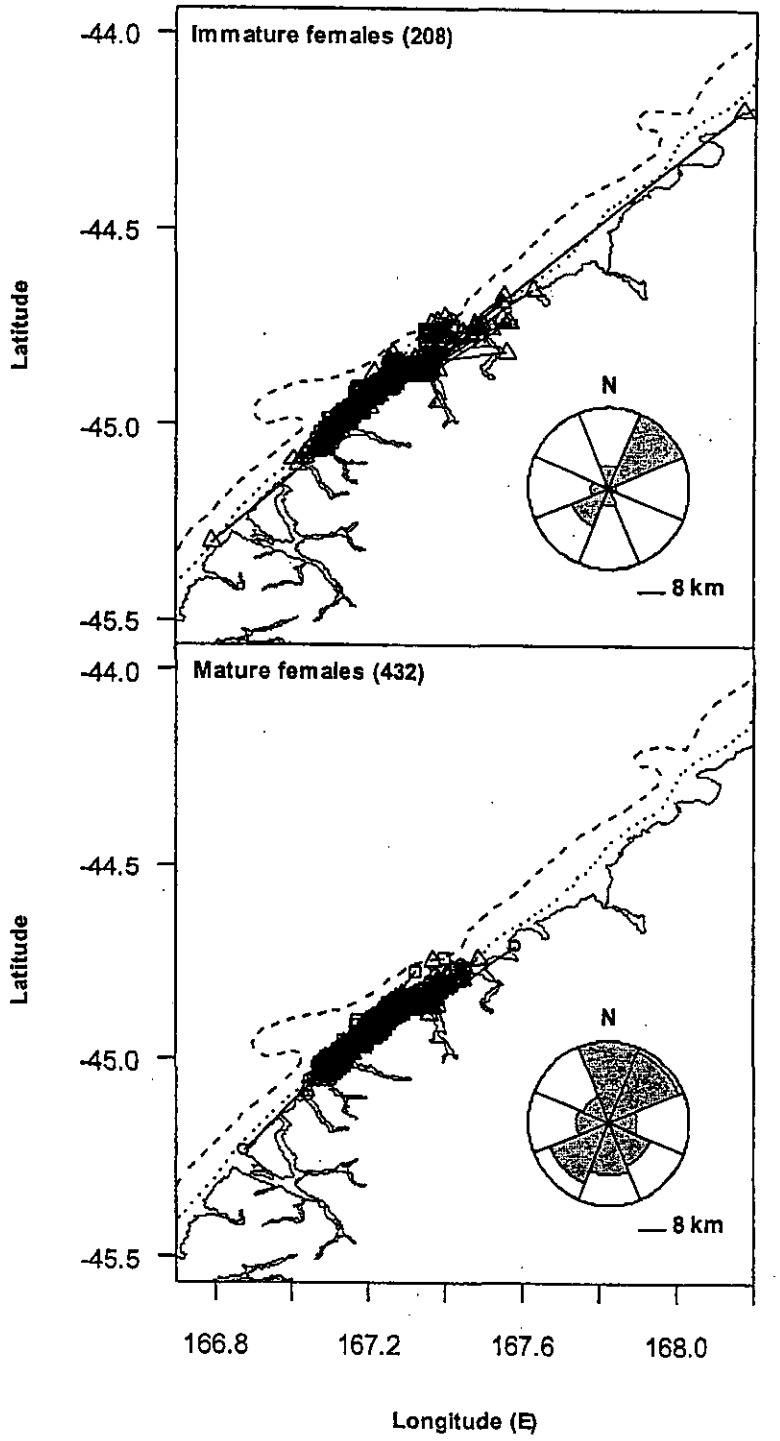


Figure 16 (Cont.)

A.

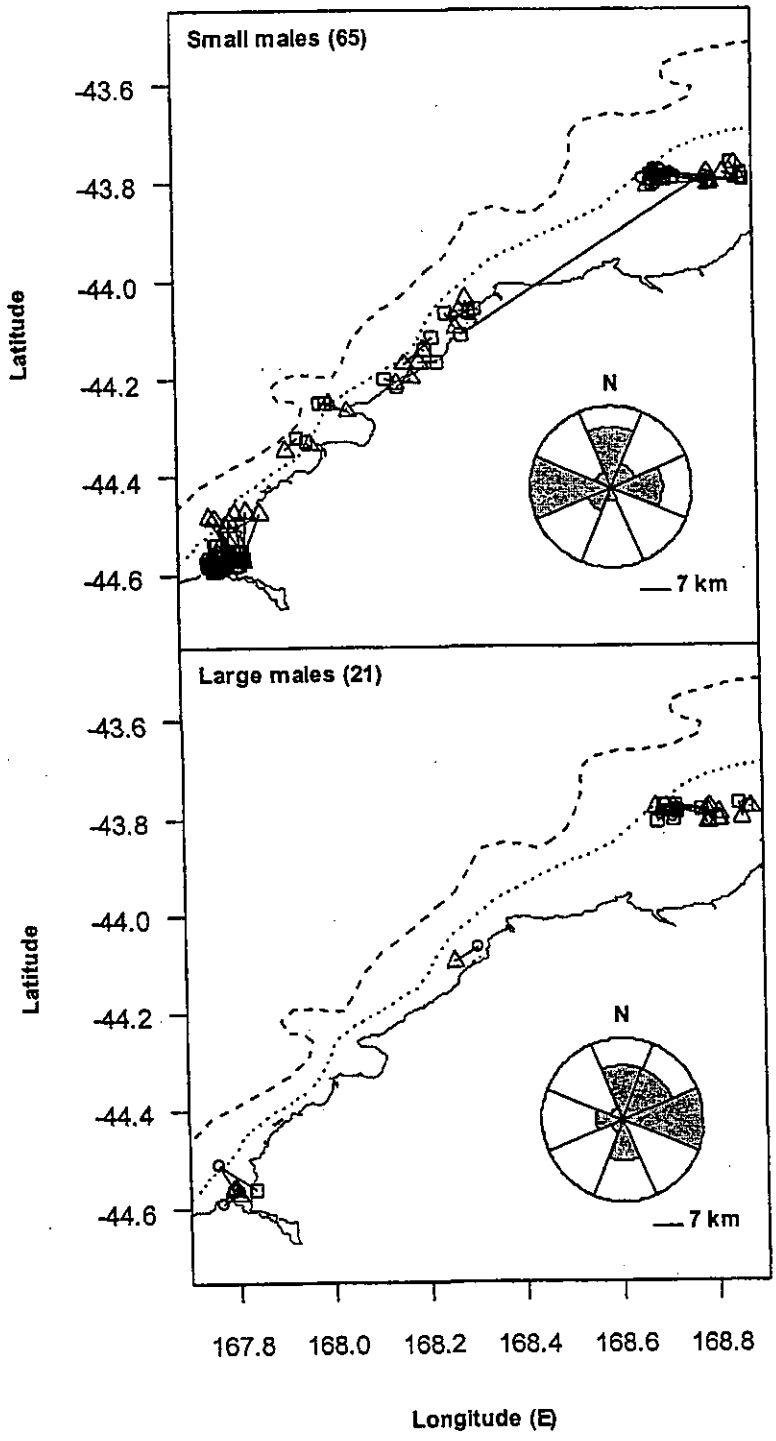


Figure 17. Movements of tagged lobsters initially captured, tagged and released between Milford Sound and the Open Bay Islands. Squares: initial release, circles: recapture/re-release event, triangles: last recorded recapture. To maintain fisher privacy, all positions have a random error of 1n.mile added to them. Inset plot shows the relative frequency of direction of movement, in a 45 degree quadrant. Water depths: inside dotted line, < 200 m; inside broken line, < 1000 m.

B.

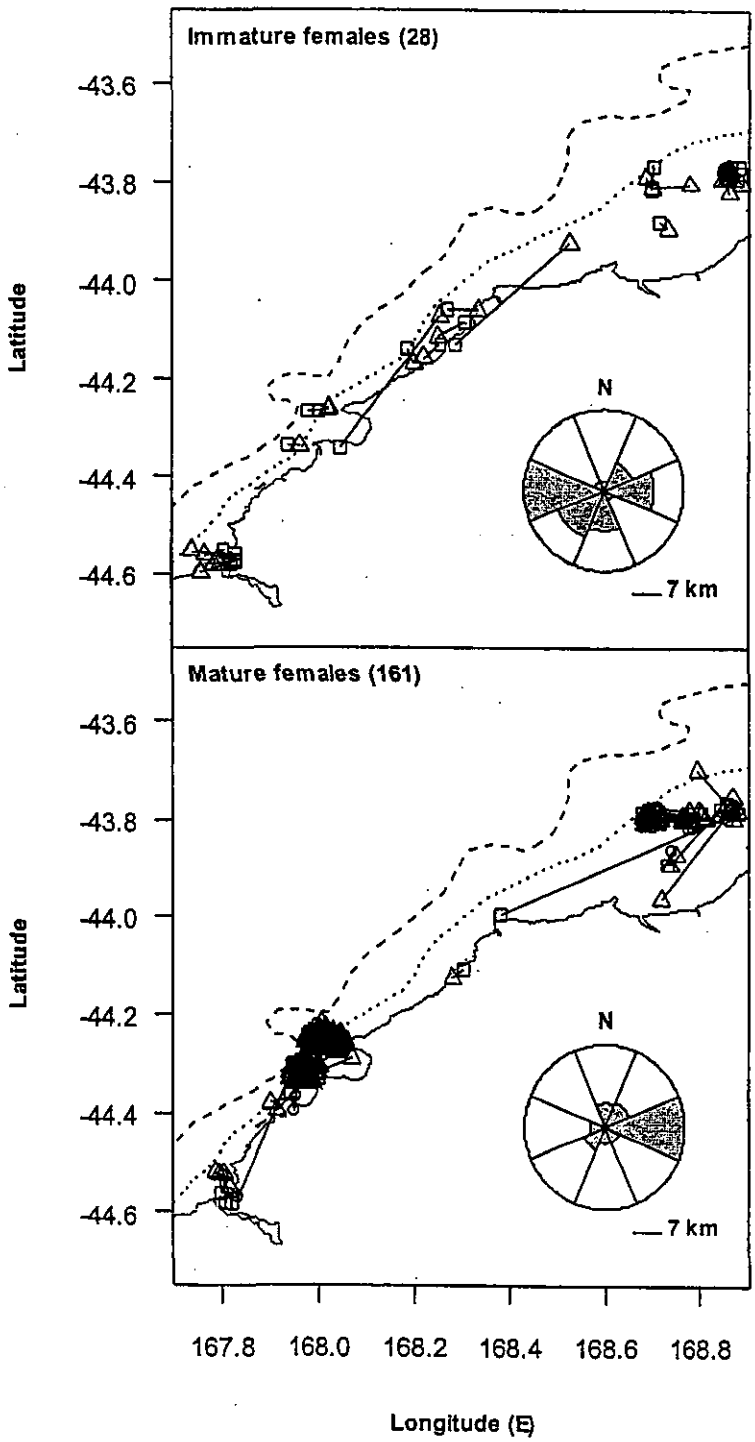


Figure 17 (Cont.)

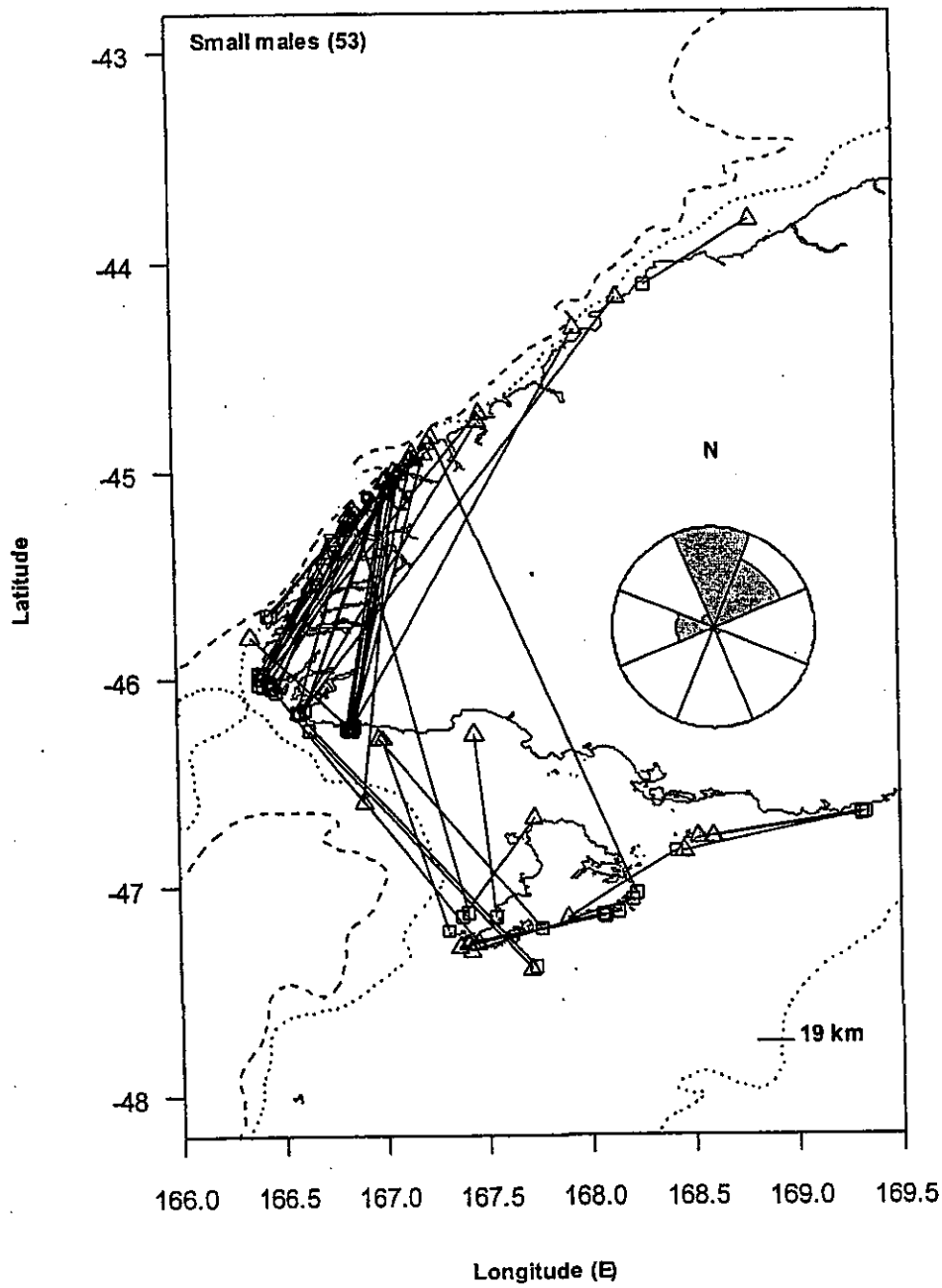


Figure 18: Movements greater than 50 km by small males in CRA 8. Squares: initial release, circles: recapture/re-release event, triangles: last recorded recapture. To maintain fisher privacy, all positions have a random error of 1n.mile added to them. Water depths: inside dotted line: < 200 m, inside broken line, < 1000 m.

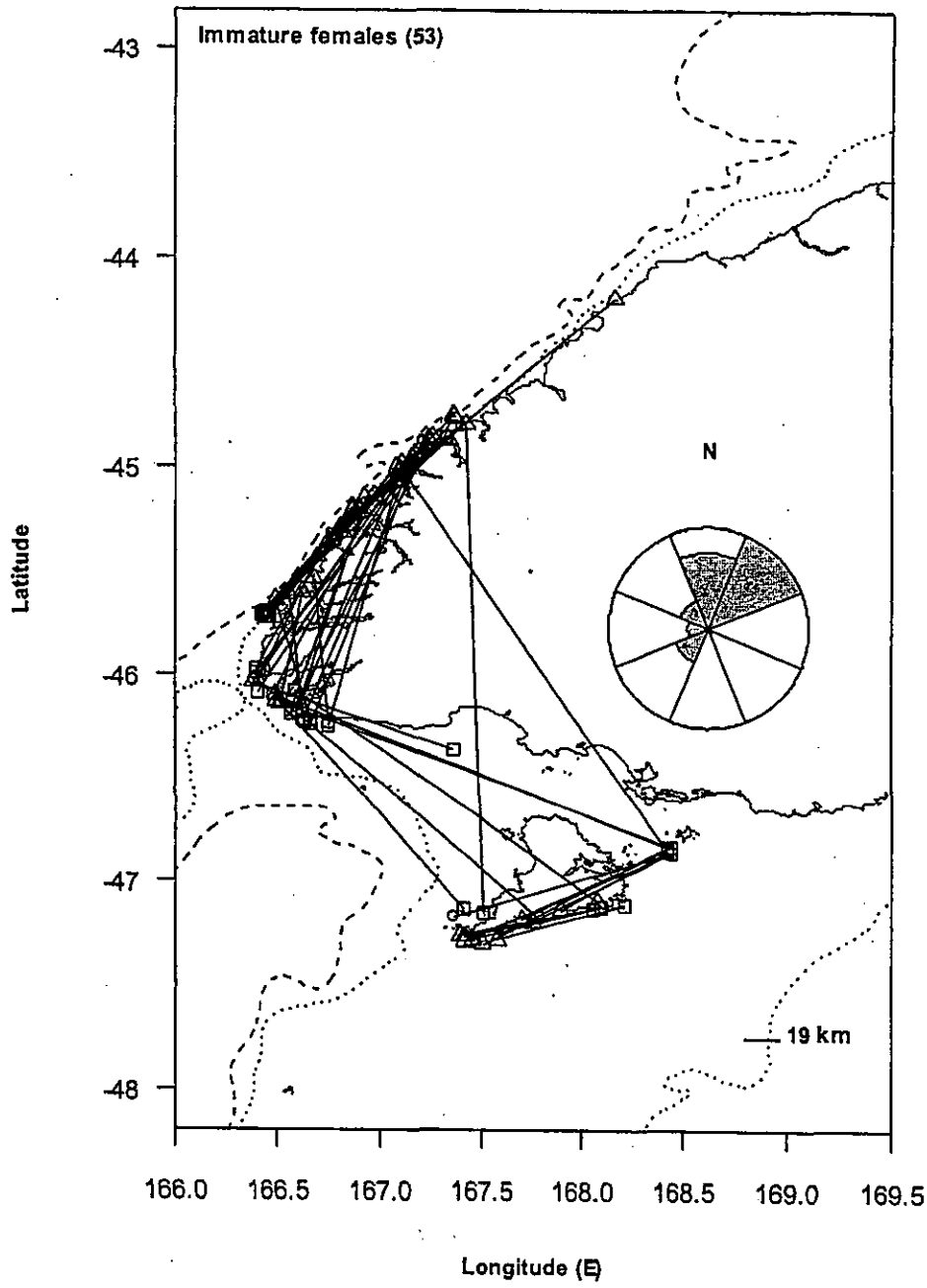


Figure 19: Movements greater than 50 km by immature females in CRA 8. Squares: initial release, circles: recapture/re-release event, triangles: last recorded recapture. To maintain fisher privacy, all positions have a random error of 1n.mile added to them. Water depths: inside dotted line: < 200 m, inside broken line, < 1000 m.

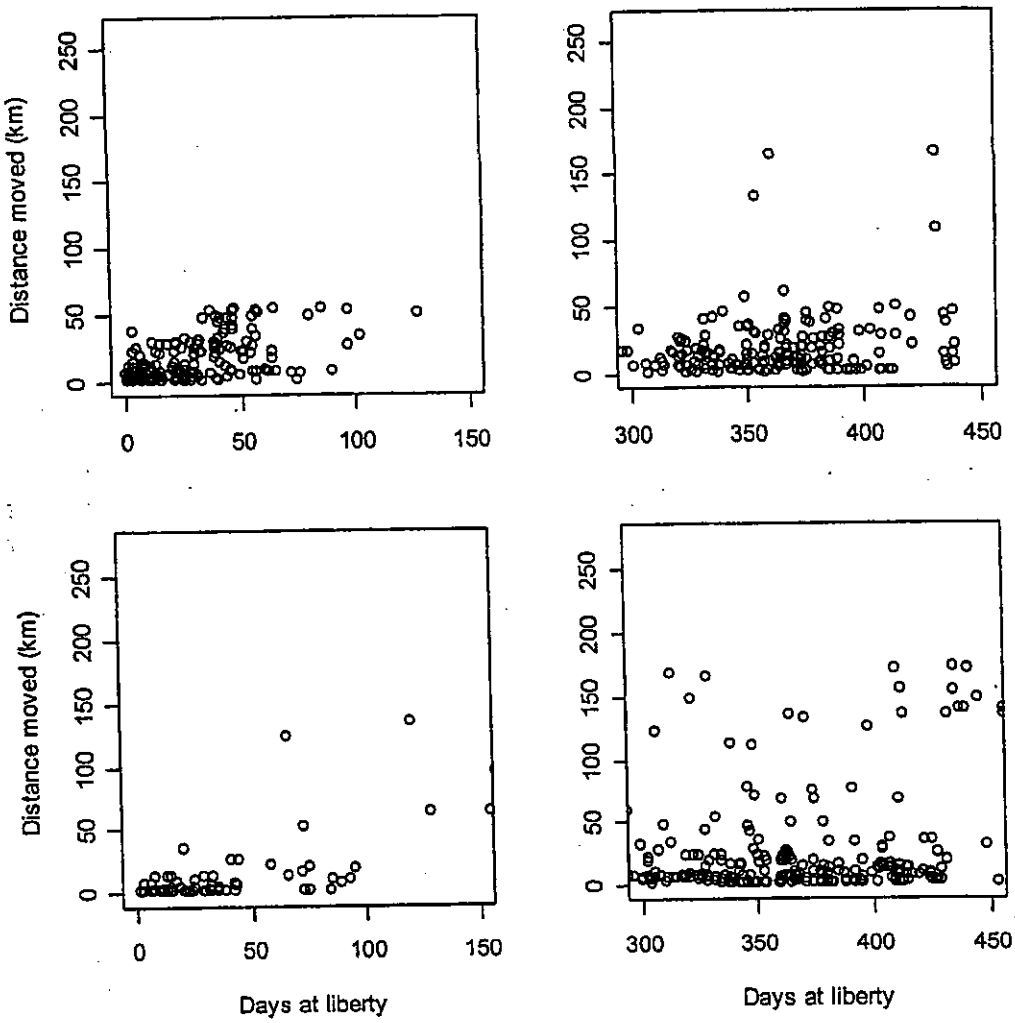


Figure 20: Distance travelled plotted against days at liberty for immature females and small males combined tagged in area 924 (top) and 926 (bottom); recaptured in the same fishing year as tagged (left), and in the following year (right).

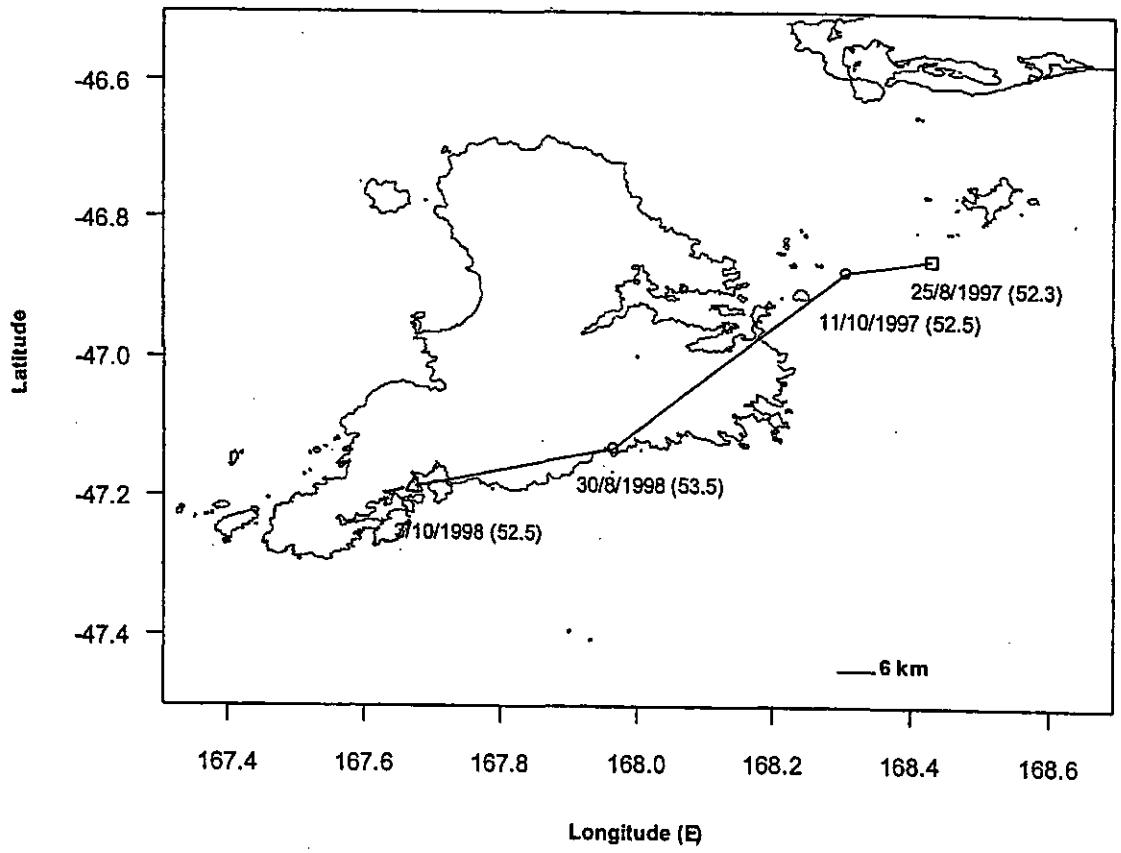


Figure 21: Release and recapture positions of an immature female tagged in August 1997, and subsequently recaptured in October 1997, August 1998 and October 1998. The capture/recapture date and the carapace length are indicated. Direction of movement was from east (right hand side) to west (left hand side). Tagging database Ref. ID: CRA8_TAG11CRA8115126

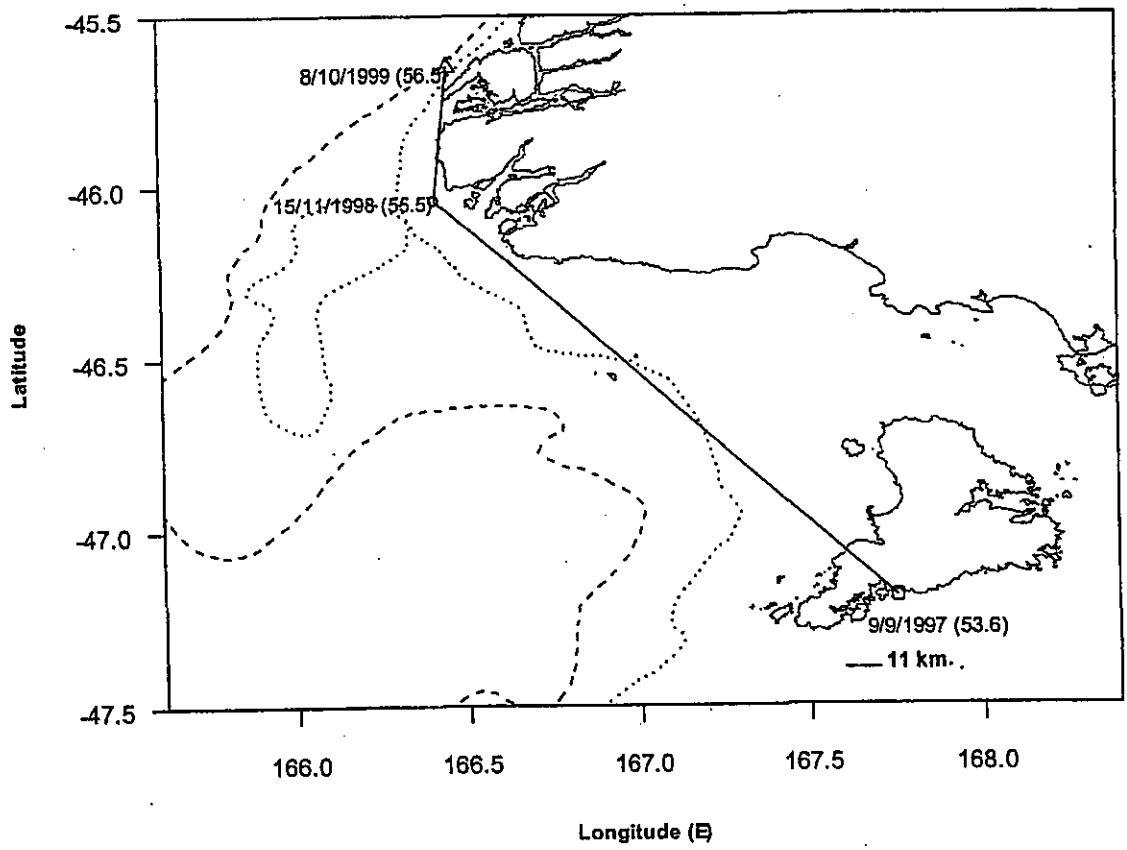


Figure 22: Release and recapture positions of an immature female tagged in September 1997, and subsequently recaptured in November 1998, and October 1999. The capture/recapture date and the carapace length are indicated. Direction of movement was from east (right hand side) to west (left hand side). Tagging database Ref. ID: CRA8_TAG11CRA8118947

4.5.7 Seasonal migration through depth (CRA 8)

There are 3258 records from CRA 8 with valid depths for both release and recapture. The fishing year is split into two 6-month periods (seasons) to coincide with the reproduction and moulting periods of both sexes, and the temporal step of the stock assessment model. 1 October to 31 March is the austral spring–summer season, and 1 April to 30 September the autumn–winter season when females tend to be in berry. The average change in depth between release and recapture was examined for each sex-maturity class and statistical area, for any systematic pattern with season.

Initially just those lobsters tagged in one season and recaptured in the subsequent one were examined. A pattern of movement, especially by large females, between greater depths in autumn–winter and shallower water in spring–summer proved to be robust across years, so tag recoveries were grouped by the season in which they were released and the season in which they were recaptured, regardless of how long they were at liberty.

Table 12 shows the median change in depth for each sex–maturity class (at release), from each CRA 8 statistical area, between being released in one season and recaptured in the other. Mature females moved into shallower water between autumn–winter and spring–summer in all areas but 924 (Stewart Island), and vice versa except in area 928 (where there was no net movement). Small females and small males generally followed the same pattern, and there was no clear pattern to the movements of large males, of which there were very few.

Table 12: Median change in recorded depth (m) between release and recapture in CRA 8 (positive numbers indicate a move into shallower water), and numbers of lobsters involved. By statistical areas in which tagged, and size-sex class. MF, mature females; LM, large males; IF, immature females; and SM, small males.

Tagged in autumn-winter, recaptured in spring-summer

Statistical area	923		924		926		927		928	
	Depth diff.	No.	Depth diff.	No.	Depth diff.	No.	Depth diff.	No.	Depth diff.	No.
LM	–	–	0	*16*	0	*13*	0	*19*	16.5	*4*
SM	-13	*8*	-9	*54*	-18	*45*	27	*145*	20	*8*
MF	15	*1*	-6	*8*	13	*10*	19	*257*	39	*62*
IF	1	*22*	-9	*108*	-6.5	*78*	28	*109*	22	*7*
Tagged in spring–summer recaptured in autumn–winter										
LM	–	–	3.5	*4*	58	*1*	0	*11*	-35	*1*
SM	-9	*1*	1.5	*50*	-17	*69*	-9	*58*	3	*7*
MF	–	–	-22	*2*	-17.5	*6*	-18	*57*	0	*12*
IF	2	*9*	0	*49*	-6	*21*	-19	*7*	-40	*3*

Figure 22 shows the change in depth between release and recapture for those lobsters tagged in autumn–winter (all CRA 8 statistical areas combined), and recaptured during the indicated six-month period after tagging. Lobsters recaptured in the same period, or in the 2nd, 4th, or 6th period after tagging, were caught in the same season as they were tagged, whereas those at liberty until the following period, or until the 3rd or 5th period after tagging were recaptured in the opposite season. Note that this is not the movement of the same animals tracked through time: each point represents the average of a different group of lobsters. They are arranged according to how many periods they were at liberty, and, from this, season is inferred. The seasonal pattern is evident regardless of how long the lobsters were at liberty.

Those tagged in autumn–winter and recaptured in spring–summer, had moved into shallower water, while those recaptured in an autumn–winter season were at or near to the depths at which they were tagged. The pattern is particularly pronounced and statistically significant for mature females, but is also evident in immature females, especially after several periods at liberty (by which time they have grown larger).

There are too few large males represented to be able to describe their behaviour, and the movement of the small males varied markedly between areas. Lobsters caught in the same period as they were tagged appear to have been on the move, and were generally recovered deeper than they were released.

The distribution of the results, numbers of lobsters, and significance of the pattern for mature female lobsters are presented graphically in Figure 23. A similar (opposite) pattern is evident for mature females tagged in spring–summer, but is not statistically significant due to low numbers.

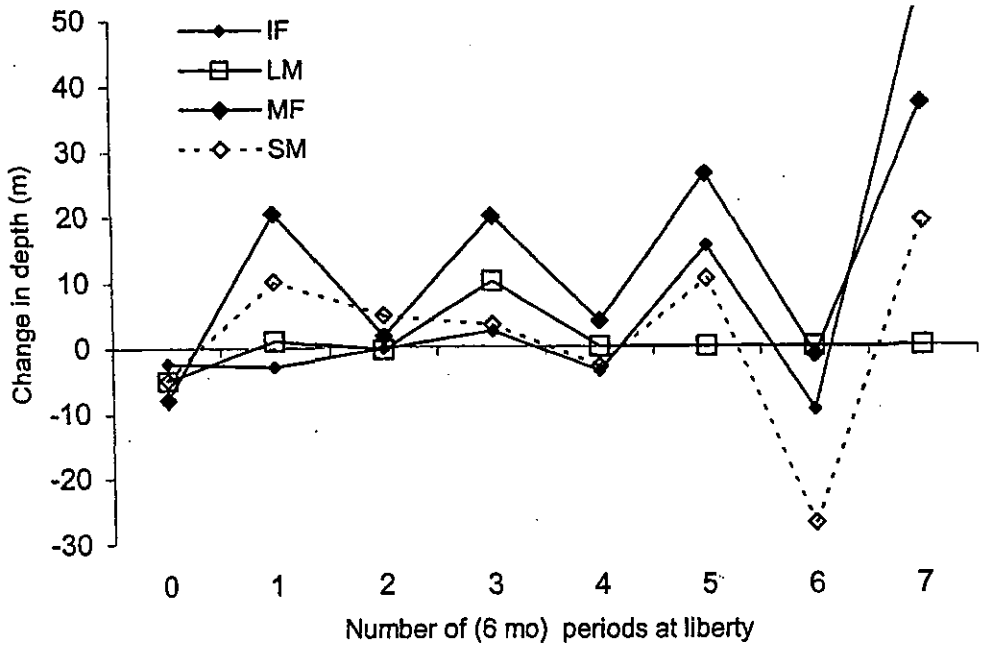
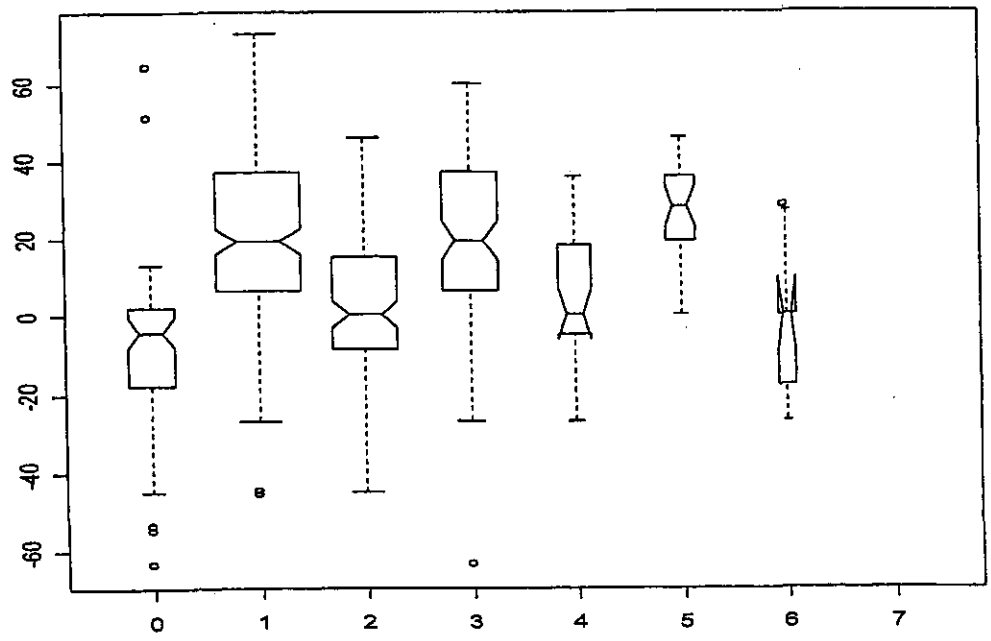


Figure 23: Average change in depth (positive numbers are towards the surface ie. shallower) between tagging and recapture, for lobsters from CRA 8 that were tagged in an autumn–winter season and recaptured after the number of 6-month periods indicated. (1, 3, & 5 are spring–summer seasons, and 2, 4, & 6 are autumn–winter seasons.



Periods at liberty	0	1	2	3	4	5	6	7
Num lobsters	103	53	76	17	20	7	2	1

Figure 24: Box-plot of change in depth (positive numbers are towards the surface ie. shallower) between tagging and recapture, for mature female lobsters from CRA 8 that were tagged in an autumn–winter season and recaptured after the number of 6-month periods indicated. (1, 3, & 5 are spring–summer seasons, and 2, 4, & 6 are autumn/winter seasons. If the notches of two plots do not overlap then the medians are significantly different at the 5% level.

4.6 Retention of immature lobsters in commercial pots

The size of lobster retained in commercial pots determines the size distribution tagged. Although this size range includes some sublegal lobsters, the degree to which it includes immature lobsters varies markedly around the country. Figure 24 is reprinted without alteration from Bentley (2001) to show the size at which 50% (M50) and 95% (M95) of females are mature in each statistical area. It is assumed that males mature at about the same size as the females in that area. Lobsters in the East Cape, Hawke Bay areas (909 to 912) are generally sublegal when they mature, so immature lobsters are not well represented in the catch of commercial pots. By contrast, the large size at which females mature in Otago and Foveaux Strait means that most of the catch is still immature. The proportion of recaptured lobsters that had moved more than 5 km varied around the coast of New Zealand corresponds closely to the proportion of immature lobsters in the tag–recapture dataset, which in turn is determined by the SOM of lobsters in the area.

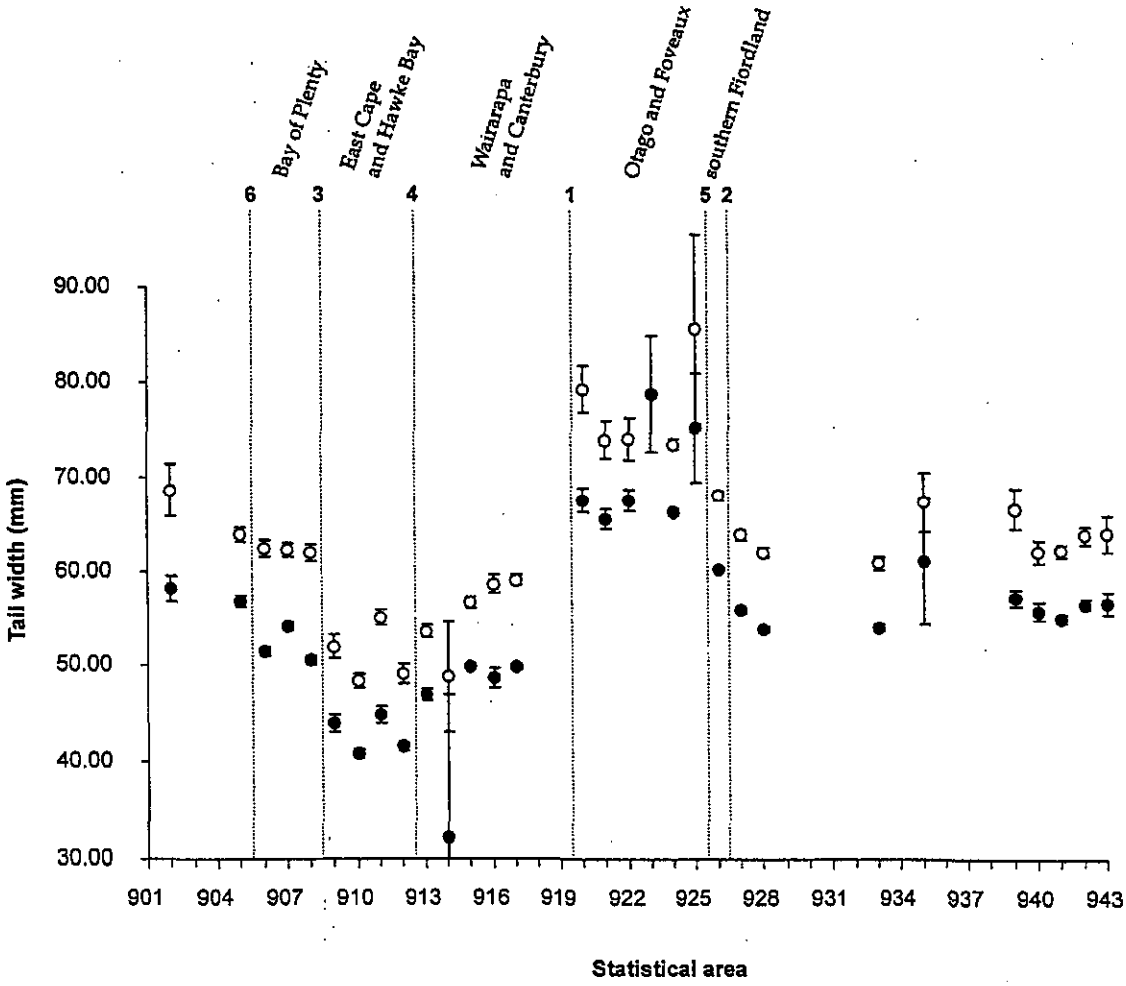


Figure 25: Estimates of M50 (closed circles) and M95 (open circles) and 95% confidence intervals by statistical areas for females. Estimate of M95 for area 923 at 133 mm TW not shown. The dotted lines and numbers refer to stock boundaries proposed in that report.

5. DISCUSSION

This study summarises results from the first (as far as we are aware) large-scale rock lobster tagging programme conducted by volunteer commercial fishers anywhere in the world. The database of tag recoveries represents extensive coverage of much of the country over one period and is therefore a neat synopsis of movement never before possible. The commitment of participating fishers has also

extended to multiple re-releases of some tagged and recovered lobsters. This will continue to offer insights into rock lobster movements. Nevertheless, return rates were very low in most areas. This may reflect limited fisher participation, low exploitation rates, high illegal removals, and/or movement of lobsters to areas that are not commercially fished. Problems with such opportunistic tagging include: the effective minimum size of lobster is determined by that retained in commercial pots movements to and from areas that are not fished commercially will go undetected; and not all size-sex classes of lobster are well represented, because of their commercial value. The seasonal pattern of tagging and recovery is also largely constrained by the fishing effort in most areas.

Short-distance movements recorded for most of *J. edwardsii* in tag release-recapture events around the country are not described in this study, and are assumed to largely represent foraging behaviour; 89 % of recoveries from CRA 2, 94% from CRA 3, 98% from CRA 4, 92% from CRA 5, and 59% from CRA 8 represented movements of less than 5 kilometres.

There are examples of longer-distance nomadism in most areas, particularly by large (mature) rock lobsters in CRA 2. Some extraordinary movements of over 100 km around the coast of New Zealand can only be described as nomadism, but deserve to be considered with caution and may result from erroneous data. The very low rates of long-distance movements in the central fishstocks, particularly in CRA 3 and CRA 4 where large numbers of tagged lobsters were recaptured, is notable and may be a function of the low size at onset of maturity (SOM) in that region. The degree to which long distance movements have been recorded around the coast of New Zealand corresponds closely to the proportion of immature lobsters in the tag-recapture dataset, and this in turn has been determined by the SOM of lobsters in the area. It is not unlikely that long-distance movements remain undetected in regions north of CRA 7 and CRA 8, because immature lobsters are not retained in large numbers in commercial pots and have not been well represented in tagging studies using this method. Anecdotal reports of migrations of small lobsters in Northland moving north and in Cook Strait moving south remain unverified.

Because of the greater SOM off Otago and in Foveaux Strait most of the catch and most lobsters tagged are immature and long-distance movements are a well-described feature of the region. Two distinct types of migration around the south coast of New Zealand are evident, the first feeding into the second and giving it destination and purpose. The first is the long-distance one-way migration of immature females and similar sized males clockwise around Stewart Island and towards Fiordland. Along the route, and particularly demonstrable on the Fiordland coast, a second type of migration is evident involving mature resident females in an annual cycle of movement out to deeper water at the end of winter at late egg-bearing, and back to shallower water in summer.

Along–shore movements

Previous tagging studies of lobsters in CRA 7 and CRA 8 have suggested that long-distance movements of *J. edwardsii* are distinctly seasonal, usually occurring off Otago and through Foveaux Strait during September–November and along the Fiordland coast during October–January (Street 1971, 1973, McKoy 1983). Commercial fishing effort in CRA8 since 1993–94 has centred almost entirely over these months of each year, and tag and recapture data collected by fishers has suggested much greater proportions of lobsters make long-distance movements than previously described.

The along-shore route of the migration of immature rock lobsters is south along the east coast of the South Island, and around the south of Stewart Island. Another very strong movement continues north along the Fiordland coast, with a small proportion of immature females and small males moving from Stewart Island across Foveaux Strait to Fiordland. Individuals from many localities along the route probably participate (McKoy 1983), moving some distance towards the Fiordland coast with no evidence of any mass return. Proportions of each size–sex class that move, and the rates of movement,decrease along the route from east to west, small males show the same patterns of movement as the immature females, but travel more slowly and cover shorter distances. The

Fiordland coast of statistical area 927 seems to be the final destination (distances moved there are smaller, and are non-directional), though it is clearly not reached by all migrating female rock lobsters.

While there is no direct evidence of individuals completing the entire route from Otago to Fiordland, it is possible, given the greater size at maturity of Otago females (Annala et al. 1980). In this study, one female and one male had moved from islands in the northeast of Foveaux Strait to area 928 in Fiordland, which is the greater part of the distance. Very little tagging (and none in this recent programme) has been carried out along the Otago coast, and tags do not always survive on a lobster for one or more moults (Booth 1997); for these reasons, it is possible that such movements might have gone undetected. The size at which an immature lobster starts its migration is not known, and evidence is presented here of immature individuals continuing to move long distances along the migration route over at least two consecutive years. It is possible that immature lobsters tagged along the Stewart Island coast had already travelled long distances.

On attaining sexual maturity, females appear to become 'resident', very rarely moving long distances, and establish themselves in populations along the route. Logbooks and catch sampling show that mature and ovigerous females contribute to the fishery in particular areas along the migration route. McKoy (1983) noted that large numbers of ovigerous females were caught in some areas around Stewart Island, including Kanetoi Island and near Rugged Islands in September and August. Booth (unpub. report to RLWG) summarising historical catch sampling, concluded that "Significant quantities of large, mature lobsters have always been present at Ruapuke and Centre Islands, North–West coast Stewart Is, and South and South–West coast of Stewart Island. Low proportions of large, mature lobsters have always been a feature of Northeast coast, Saddle Point to Port Adventure, and including Bench Island".

This study of nearly 3000 tag recoveries from the CRA 8 area adds only 16 individuals to the number reported to have crossed the western approaches to Foveaux Strait, and four of them apparently had moved from the South Island to Stewart Island. It is likely that headlands and points along the Stewart Island southwest coast are the final destination for many female lobsters.

Along the Fiordland coast north of Doubtful sound, most lobsters appeared to be resident. The movements of even the immature females was less directional, and many of the small males and females tagged further north in area 928 had moved south towards area 927.

Inshore–offshore movements

At the northern-most destination of this long-distance migration, the Fiordland coast of area 927, a second type of migration is particularly evident. It involves the mature resident females in a seasonal movement into deeper water at the end of winter, returning to shallower water in summer. This seems at first to contradict other studies that show females move inshore during autumn–winter to moult, with mating and egg extrusion taking place soon after (Street 1969), and logbook and catch sampling data from CRA 8 that confirm the proportion of berried females is greater in shallower water. However, what seems to have been described by these very seasonal data is a snapshot of mature females that are very near to, or have just completed, egg hatching. Females release their eggs between September and October. The timing of the fishery in CRA 8 neatly spans this period, with almost equal effort in both seasons, and most mature females were tagged in the three months August to October, around the time of late egg-bearing and clean-up.

This movement to the edge of very deep water may happen over a relatively brief period at the end of egg-bearing, as the distances involved are not great in spite of the dramatic changes in depth. The greatest component of many of these movements is actually along-shore in either direction, rather than obviously inshore–offshore, and is detectable not by plotting movements, but by examining changes in depth.

Ovigerous females may move out to the edge of the continental shelf to release newly hatched larvae into the stronger currents of deep water. Aggregations of late egg-bearing females at points or headlands or in areas of strong tidal currents has been documented for other *Jasus* species (Berry 1971, Herrnkind 1977), and for *J. edwardsii* in other parts of New Zealand (McKoy & Leachman 1982, Anon 1974, MacDiarmid 1991). It may be associated with egg release and has been suspected to be widespread (Booth 1997). Aggregations of large ovigerous female *J. edwardsii* were observed by divers at several places around central New Zealand (Anon 1974, McKoy & Leachman 1982, MacDiarmid 1991) typically in late winter in areas of strong tidal water movements, and often in the absence of suitable shelter. MacDiarmid (1991) reported increases in density of females at the deep (25 m) seaward edge of the coastal reef in Northland waters during the egg-bearing period. Re-sighting of tagged individuals confirmed that the observed fluctuations were caused by inshore-offshore movements at different times of the year.

Annala & Bycroft (1993) observed a 'homing' behaviour on the Fiordland coast of mature females that were recaptured at the end of egg-bearing in the same location as they were tagged, sometimes in several subsequent years.

Role of long-distance movements

Street (1971) noted that the direction of movement of migrating immature *J. edwardsii* in southern New Zealand is against the direction of the main coastal current system. McKoy (1983) observed that tidal flow in these areas is much stronger than the effect of oceanic currents and questioned whether current alone is involved in orientation. Booth (1979) suggested that migrations of *j.verreauxi* in northern New Zealand were part of a recruitment mechanism that maintained population distribution by counteracting larval drift, and concluded that this also seems to be the likely explanation of the movements of *J. edwardsii* in southern New Zealand.

It is generally accepted that the migration of immature rock lobsters around the south coast of New Zealand is against the current in order to counter larval drift. The continental shelf along the Fiordland coast is narrow, and depths exceeding the maximum recorded depth for rock lobsters of about 400 m are reached within a few kilometre offshore. For the resident female, this coast offers access within very small horizontal distances to deep water at the edge of the continental shelf and strong tidal currents to facilitate larval dispersal. It is likely that females that become sexually mature and resident before they can reach this destination seek out points and headlands in other localities at late egg-bearing (McKoy &Leachman 1982). Such movements may take place over small distances (Booth 1997), and, where changes through depth are not so great as in Fiordland, would be difficult to demonstrate with tagging data.

These data include a paucity of recoveries from Northland, where anecdotal evidence of immature females moving north (Breen & Kendrick 1994) remains unconfirmed, and from the Chatham Islands and Gisborne, both areas where lobsters are suspected to move in or out of the fishery. Recent tagging in Northland and in central areas had yielded few or no recoveries at the time that these data were extracted and these areas should be revisited later. Immature females are poorly represented in these and in most earlier tagging studies (Booth 1997) north of CRA 7 and CRA 8.

6. ACKNOWLEDGMENTS

This work was conducted under contract CRA9901 from the Ministry of Fisheries. Our thanks to Nathan Walker, Paul Breen, and John Booth who provided useful comments on earlier versions of the manuscript.

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