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To cite this article: J. L. McKoy (1983) Movements of rock lobsters, *Jasus edwardsii* (Decapoda: Palinuridae), tagged near Stewart Island, New Zealand, *New Zealand Journal of Marine and Freshwater Research*, 17:4, 357-366, DOI: [10.1080/00288330.1983.9516011](https://doi.org/10.1080/00288330.1983.9516011)

To link to this article: <http://dx.doi.org/10.1080/00288330.1983.9516011>



Published online: 30 Mar 2010.



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## Movements of rock lobsters, *Jasus edwardsii* (Decapoda: Palinuridae), tagged near Stewart Island, New Zealand

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**Abstract** A total of 4393 female and small male rock lobsters, *Jasus edwardsii*, were tagged and released near Stewart Island and in eastern Foveaux Strait between 1974 and 1978. Most recaptures had not moved more than 5 km but 16% of immature females and small males underwent highly directional movements along the southeast coast of Stewart Island, and 16 were recaptured in Fiordland. Rock lobsters which undertook long distance movements included those which were classified by fishermen as migratory animals, plus some small, local inshore animals. These observations add support to the hypothesis that a regular migration of immature rock lobsters takes place around southern New Zealand, probably with no single area of origin or destination.

**Keywords** *Jasus edwardsii*; Palinuridae; movement; tagging; migrations; Foveaux Strait; Stewart Island; Fiordland

### INTRODUCTION

This fishery for the rock lobster, *Jasus edwardsii*, around Otago, Southland, and Fiordland has recently produced at least 25% of the total New Zealand landings of rock lobsters (e.g., 1748 tonnes of a total of 4511 tonnes in 1979—Sanders 1983). An important seasonal component of this fishery is the catch of 'run' rock lobsters in some areas by

both potting and trawling (Street 1969, 1973). Fishermen identify such animals primarily by the relatively light colour of their shells, combined with the high catch rates in particular areas when they are caught. Many fishermen believe that these animals are part of a large scale, highly directional migration. This hypothesis has received limited support from tagging studies conducted in Otago and Southland in 1957-70 (Street 1969, 1971, 1973).

In view of the importance of 'run' rock lobsters to the fishery around Stewart Island and the significance of possible large scale movements for recruitment to rock lobster stocks in southern New Zealand, a tagging programme was carried out in eastern Foveaux Strait and around Stewart Island between 1974 and 1978. The aim of this study was to examine the movements of rock lobsters in the Stewart Island area, and in particular, any long distance movements or migrations they might make. The movements of rock lobsters identified by fishermen as 'run' rock lobsters were also investigated.

### METHODS

#### Tagging methods

Rock lobsters were captured by diving (in May 1977 and February 1978) or by commercial pots from local fishing vessels (for all other tagging). Most were tagged using yellow western rock lobster tags (Chittleborough 1974). Animals less than about 70 mm carapace length (CL) were tagged with Floy FTL 69 ('Sphyrion') tags. Both types of tag were inserted into the dorsal thoraco-abdominal musculature 5-10 mm to the left or right of the midline. Tagged animals were normally returned to the water, close to the area where they were taken, within 30 minutes of capture.

Information recorded for each animal tagged included sex, state of sexual maturity (for females only, see Annala et al. 1980), carapace length (CL) (measured from the antennal platform to the posterior dorsal margin of the carapace), and any damage. Animals missing more than 2 pereopods or 1 antenna were not tagged. All recaptures of tagged rock lobsters were made by commercial rock lobster fishermen.

**Table 1** Areas, dates of tagging, numbers of rock lobsters tagged near Stewart Island, total numbers returned, and numbers which had moved more than 5 km up to November 1980. Number returned includes only first recaptures and those with sufficient data to determine movements. m, male; if, immature female; mf, mature female; †, identified by fishermen as 'run' rock lobsters; ‡, caught at sites and times at which 'run' rock lobsters were expected.

Area and tagging dates	No. tagged			No. returned			No. of returns which moved more than 5 km			% of returns which moved more than 5 km			total
	m	if	mf	m	if	mf	m	if	mf	m	if	mf	
<b>Ruggedy</b>													
20-22 Sep 1976	12	5	35	5	2	4	0	0	0	0	0	0	0
9-16 Aug 1977	42	14	88	4	2	1	0	2	0	0	100	0	29
<b>Halfmoon Bay</b>													
14-15 Nov 1974 †	16	19	0	11	1	0	1	0	0	9	0	0	8
4-10 Nov 1975 †	102	187	2	54	74	1	24	30	0	44	41	0	42
3-9 Aug 1976	192	176	9	75	67	4	7	12	1	9	18	25	14
20-22 Sep 1976	75	111	17	28	33	3	2	4	0	7	12	0	9
8-16 Nov 1976 ‡	56	81	52	22	25	9	3	10	2	14	40	22	27
27-30 May 1977	101	92	0	51	38	0	2	3	0	4	8	0	6
9-16 Aug 1977	248	210	50	74	58	3	17	4	0	23	7	0	16
20-23 Feb 1978	71	74	0	26	19	0	0	0	0	0	0	0	0
<b>Port Adventure</b>													
3-9 Aug 1976	116	73	5	46	23	3	16	5	0	35	22	0	29
<b>Lords River</b>													
3-9 Aug 1976	285	197	23	145	89	4	6	7	0	4	8	0	5
8-16 Nov 1976 ‡	154	201	7	66	72	1	10	19	0	15	26	0	21
9-16 Aug 1977	226	195	24	102	82	8	7	14	0	7	17	0	11
9-10 Nov 1977 †	157	188	1	62	74	1	9	16	0	14	22	0	18
<b>Southwest Cape</b>													
- 8-16, Nov 1976	161	217	26	45	45	6	4	6	1	9	13	17	11
<b>Total</b>	<b>2014</b>	<b>2040</b>	<b>339</b>	<b>816</b>	<b>704</b>	<b>48</b>	<b>108</b>	<b>132</b>	<b>4</b>	<b>13</b>	<b>19</b>	<b>8</b>	<b>16</b>

### Tagging areas

Rock lobsters were tagged and released along the northern, northeast, and southeast coasts of Stewart Island, and in the southeastern end of Foveaux Strait between Bench Island and Ruapuke Island (Fig. 1). Release sites were grouped into 5 major areas, each of which usually represented the range of operations of a particular group of fishermen. These were: West Ruggedy Beach to Saddle Point ('Ruggedy'); Saddle Point to East Cape, including the islands off Halfmoon Bay ('Halfmoon Bay'); East Cape to Shelter Point ('Point Adventure'); Shelter Point to Kopeka River ('Lords River'); and Southwest Cape to Big Moggy Island, including the Muttonbird Islands ('Southwest Cape').

Rock lobsters were regarded as having moved if the minimum straight line sea distance between the release and recapture points was greater than 5 km. This was estimated to be the minimum distance at which recaptures could reliably be considered to have shown a nett movement from the release area.

### Tagging periods

Between November 1974 and February 1978, 4393 rock lobsters were tagged and released. The number of animals tagged in each area and for each tagging period, and numbers returned up to November 1980 from each area are summarised in Table 1. Most of the rock lobsters tagged were less than the minimum legal size (CL about 98 mm for males and 93 mm for females), in the CL range 70-100 mm. Rock lobsters tagged in November 1974, 1975, and 1977 were clearly identified as 'run' rock lobsters by fishermen. Those tagged in November 1976 were mostly caught at times and sites at which 'run' rock lobsters were expected but could not be clearly distinguished as such by fishermen.

Large numbers of ovigerous female rock lobsters are caught in some areas around Stewart Island including Kanetoi Island and near Rugged Islands (Fig. 1). Female rock lobsters tagged in those areas in September 1976 and August 1977 were mostly large ovigerous females of CL range 110-160 mm.

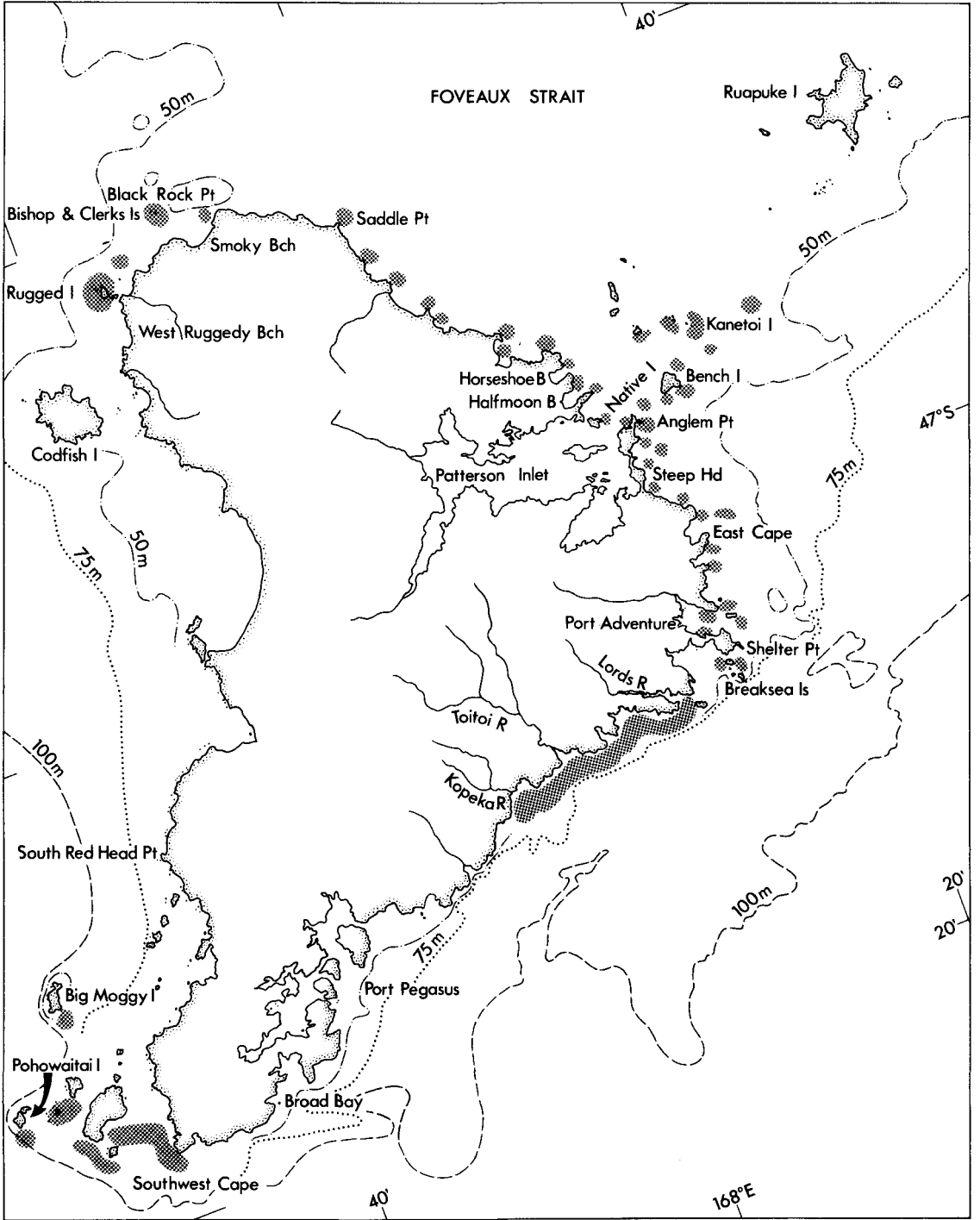


Fig. 1 Release sites (stippled areas) of tagged rock lobsters near Stewart Island, and localities mentioned in the text.

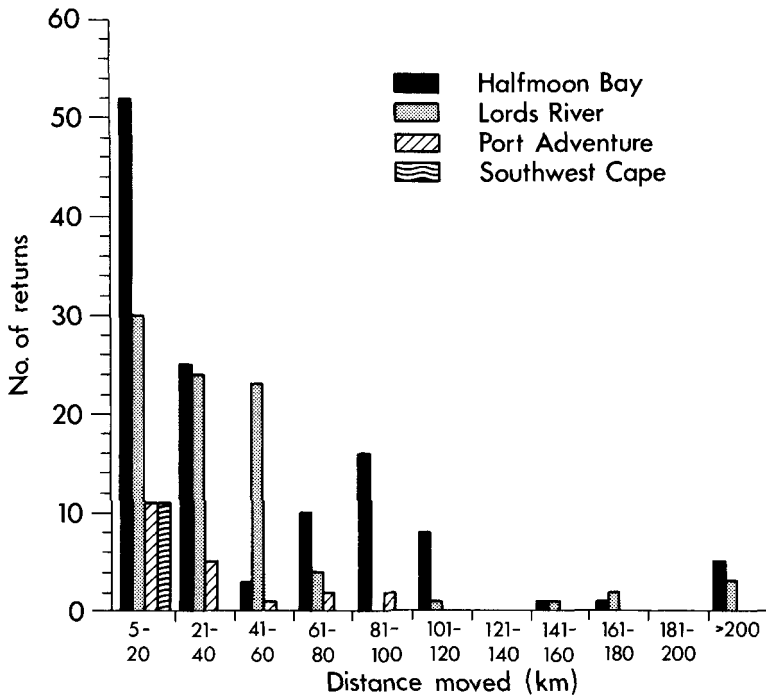


Fig. 2 Number of returns of rock lobsters tagged at Halfmoon Bay, Lords River, Port Adventure, and Southwest Cape as a function of distance travelled. Includes only rock lobsters which had moved more than 5 km.

## RESULTS

### Distance and rate of movements

Eighty-seven percent of recaptures of tagged rock lobsters were within 5 km of release sites (Table 1).

Tagged rock lobsters moved up to 350 km, but most movements were within 100 km (Fig. 2). Minimum rates of movement (minimum sea distance divided by the total number of days between release and recapture) were up to  $3.1 \text{ km d}^{-1}$ . Times over which movement took place are likely to be less, and actual distances moved and the rate of movement are likely to be greater, than those estimated here.

It is unlikely that animals took the direct route between the release and recapture points assumed by the minimum sea distances. Multiple recaptures of some animals showed that movements did not necessarily begin immediately on first release.

### Direction of movements

Most of the movements observed during this study were highly directional, and direction appeared to be independent of release site or time (Fig. 3 and

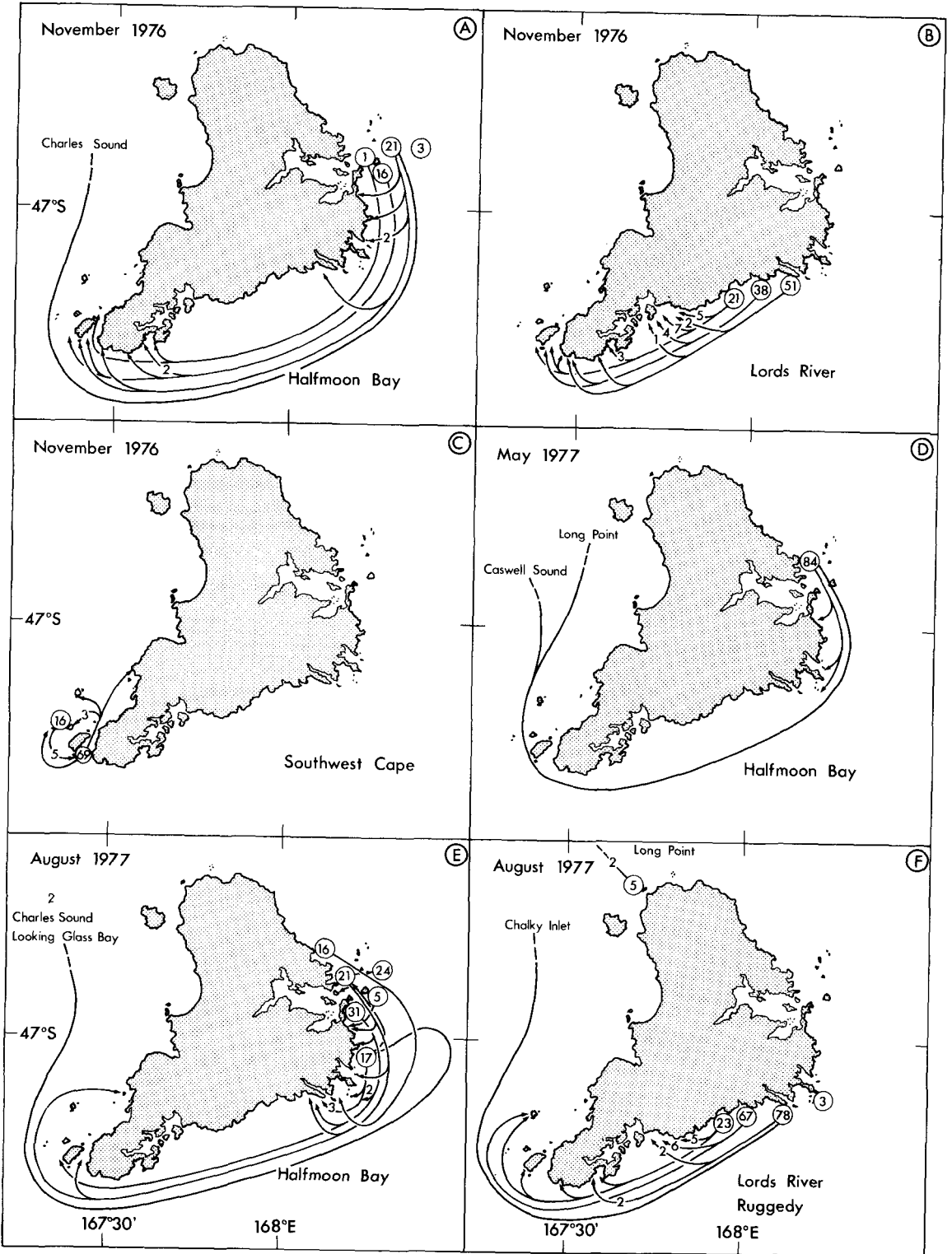
4). Almost all rock lobsters which had moved and were recaptured near Stewart Island had moved in a clockwise direction around the island. Those which moved to the coast of the South Island were all recaptured west of Tewaewae Bay (Fig. 4). No tagged rock lobsters have been returned from areas around eastern Southland, Ruapuke Island, and Otago, all of which support intensive fisheries.

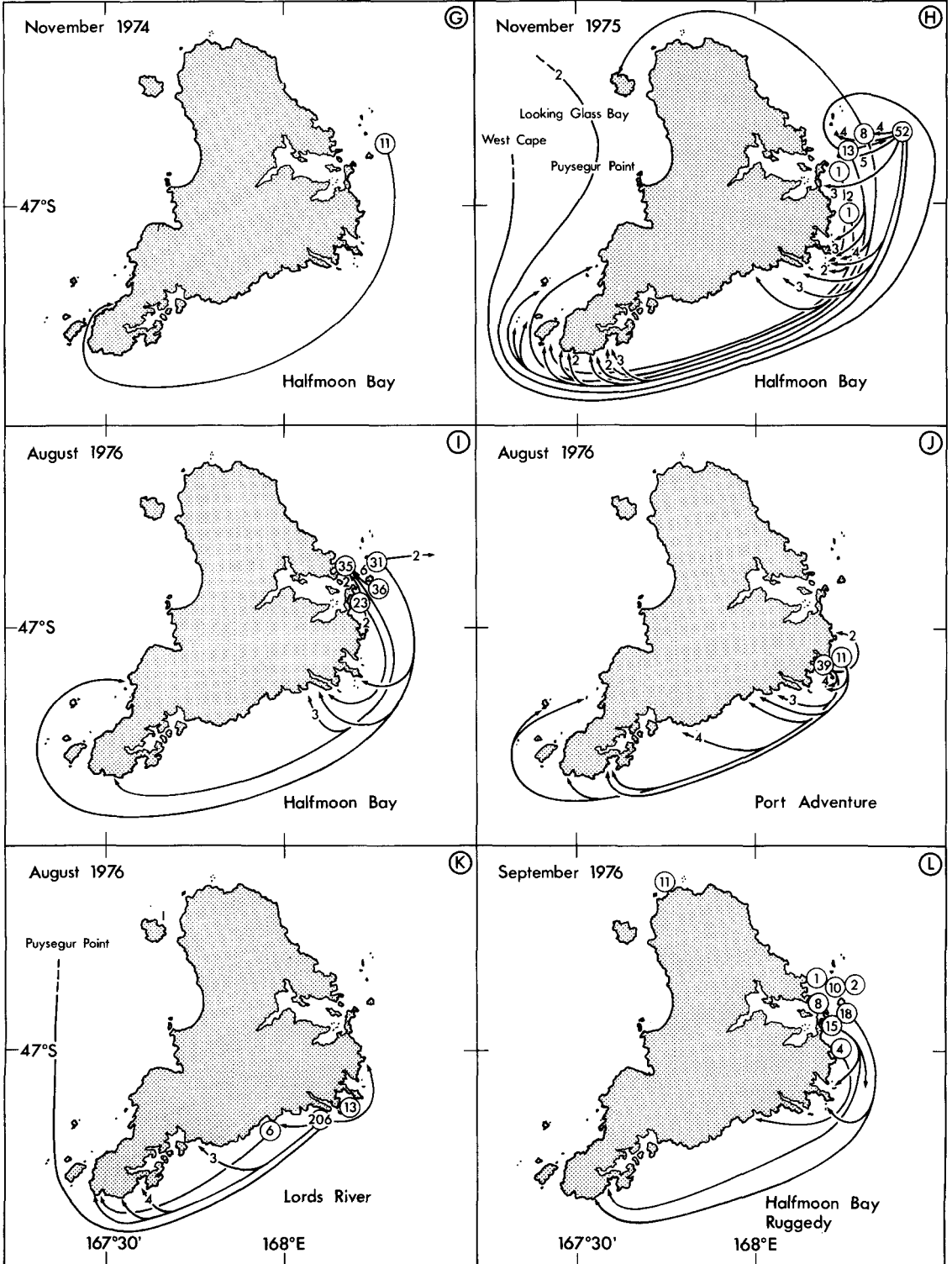
### Proportion which moved

The proportion of rock lobsters which moved varied markedly with release area and date (Table 1). Generally the most mobile groups were those tagged in November 1975, 1976, and 1977, which were either part of major catches of 'run' rock lobsters or were caught at times and at sites at which 'run' rock lobsters were expected. However, a high proportion of those tagged in August at Halfmoon Bay in 1976 and 1977, Port Adventure 1976, and Lords River 1977 also moved long distances.

### Mean velocity of displacement

A parameter which estimates the mean rate of group movement of tagged individuals in the mean direction of movement of the group, the mean velocity





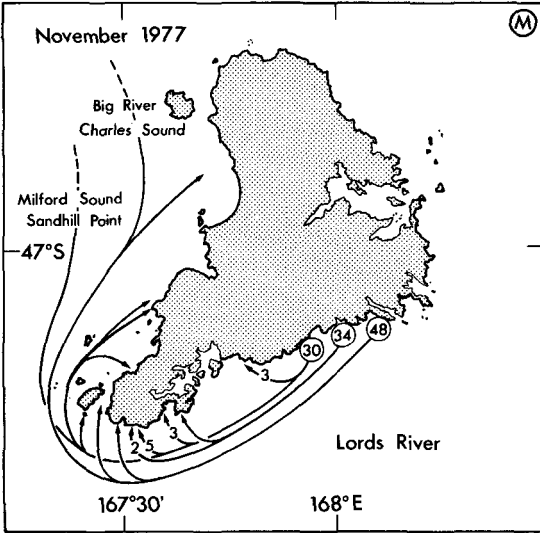


Fig. 3 (pages 361 and 362 and above) Movements of rock lobsters tagged near Stewart Island, 1974-77 and recaptured up to November 1980. The lines between release and recapture points indicate approximate suggested routes. Numbers inside circles show the number of rock lobsters recaptured from each area which had not moved. Numbers near arrows show the number of rock lobsters recaptured at each point where more than 1 animal was recaptured. Each release location shown is a combination of several release sites within each area.

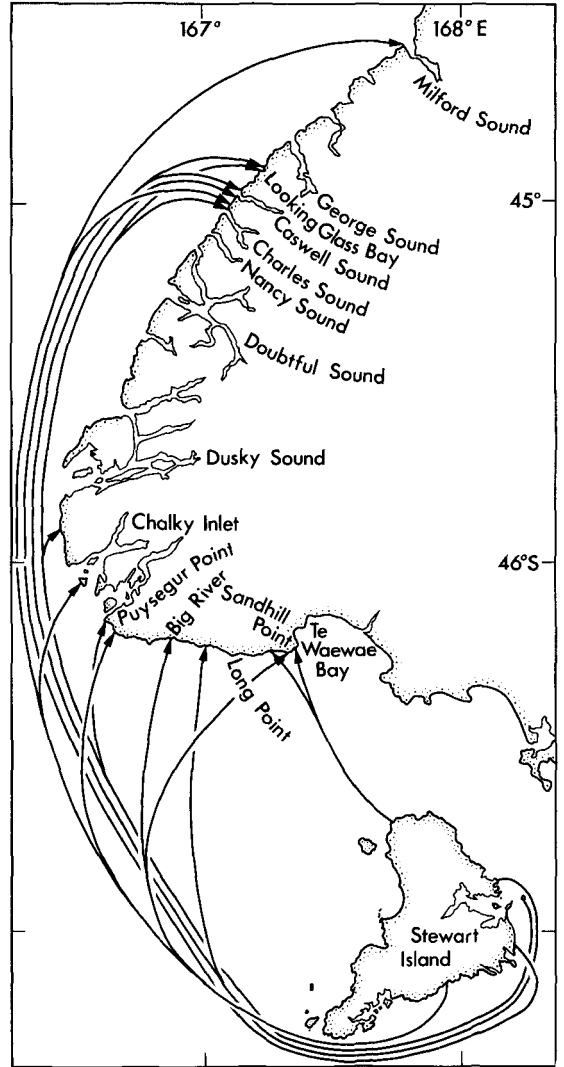


Fig. 4 Movements of tagged rock lobsters from Stewart Island to the coast of South Island up to November 1980, for all taggings combined.

of displacement ( $V$ ), was described by Jones (1966) as:

$$V = \sqrt{(\sum r \sin \sigma)^2 + (\sum r \cos \sigma)^2} / \Sigma t$$

where  $r$  = straight line distance of travel,  $t$  = time from release, and  $\sigma$  = direction of travel from any arbitrary reference point.

Unlike the simple measure of proportion which moved, used above, this parameter takes account of varying times at liberty and overcomes bias introduced by the high proportion of rock lobsters caught within a short period of tagging, not having moved. In the Stewart Island data the movements were highly directional and  $\sigma$  is therefore taken as  $0^\circ$  for all returns. Then

$$V = \sum r / \Sigma t$$

Values of  $V$  in Table 2 are grouped for each area, into males, females, and combined males and females. Mature females were not included in the

table because of the small sample size, and the narrow size range of most of the tagged rock lobsters prevents a meaningful analysis by size groups. Within each area and sex the data are grouped as 'run', November 1976 tagging (representing rock lobsters tagged at similar times and sites as 'run' animals but otherwise indistinguishable), and other tagging.

The mean velocity of displacement for 'run' rock lobsters for males and immature females combined



was considerably greater than that for non-'run' animals in the Halfmoon Bay and Lords River areas. Values of  $V$  for rock lobsters tagged in November 1976 were intermediate between values for the other 2 groups in both areas. These relationships are not, however, consistent when males and immature females are considered separately, especially at Halfmoon Bay.

### Characteristics of 'run' rock lobsters

Fishermen at Stewart Island identify 'run' rock lobsters mainly by the light colour of their shells in comparison with animals caught at other times during the season or in other areas (which are locally known as 'resident' rock lobsters). Most 'run' rock lobsters are notable for the abundance of fouling organisms (particularly barnacles) on their shells relative to 'resident' rock lobsters. The latter feature was very noticeable in the rock lobsters tagged in November 1974, 1975, and 1977 in this study. Barnacles were present on 70–80% of the animals examined, usually on the carapace but also commonly on legs, sternum, and dorsal and ventral surfaces of the abdomen. All were *Balanus decorus* which were tentatively aged at about 6 weeks (B. Foster, University of Auckland, pers. comm.) in the 1977 sample.

Other characteristics of 'run' rock lobsters are that they are usually caught in periods of 3–4 days of very high catch rates on the edge, or on shell or sand bottom near the edge, of patches of rocky bottom. The size distribution of rock lobsters caught in 'runs' is usually such that there is a higher proportion of legal sized animals (i.e., with CL greater than about 95 mm) than normal in the catch.

Although none of these features alone is sufficient to clearly distinguish these animals, the combination of several of them is regarded by fishermen as being characteristic of 'run' rock lobsters.

Preliminary morphometric data (Saila, McKoy, and Annala unpublished data) indicate that the group tagged as 'run' rock lobsters during November 1977 could be distinguished from 'resident' animals from the same general area by the relative lengths of telson and carapace. However, further sampling is necessary before this and/or other morphometric characteristics can be used reliably to distinguish the 2 groups of animals.

Fishermen believe that 'run' rock lobsters are migrating because of the apparent progression of catches of these animals through various fishing areas. However, this observation is difficult to confirm because of the short periods over which these animals are caught in any 1 area, combined with difficult weather conditions and the absence of detailed records from most boats.

### Distribution of fishing effort

The interpretation of movement patterns from tag-recapture experiments is dependent on the intensity and distribution of fishing effort. The fishing season for rock lobsters in Foveaux Strait and around Stewart Island is determined largely by seasonal changes in the catchability of rock lobsters (Street 1969) and usually extends from July to January, with most effort concentrated between September and November. Fishing on the Fiordland coast tends to begin later in the year than in Southland and to extend into February or March.

Fishing effort in southern New Zealand is geographically widespread. Most parts of the coast with suitable rock lobster habitat from Oamaru (on the east coast of the South Island at latitude 45°07'S) to about Jacksons Bay (on the west coast of the South Island at latitude 44°S) are fished to depths of 50 m or more, with fishing in some areas extending to at least 150 m depth. Some minor changes in the distribution of effort in some areas take place during periods when 'run' rock lobsters are expected, including a movement of pots to deeper water, to areas on or near the edge of rocky bottom, and to areas of 'light foul' not otherwise fished.

Some rocky areas extending to the southwest of Southwest Cape are not fished because of depth, tide, and weather factors. Fishing grounds around the Traps (20–40 km southeast of Port Pegasus) and the Snares Islands (100 km southwest of Southwest Cape) were not fished regularly at the time of this study. However, any bias in apparent directions of movements around Stewart Island coasts and the coast of the South Island caused by non-uniform distribution of fishing effort is likely to be minimal.

**Table 2** Mean velocity of displacement ( $V$ ) of rock lobsters tagged near Stewart Island. 'Run' includes November 1974, 1975, and 1977 tagging; m, male; if, immature female.

	m	if	m + if
Halfmoon Bay			
Run	0.065	0.091	0.079
November 1976	0.018	0.102	0.069
Other tagging	0.028	0.013	0.020
Lords River			
Run	0.051	0.049	0.050
November 1976	0.013	0.022	0.018
Other tagging	0.011	0.017	0.013
Port Adventure			
Other tagging	0.031	0.015	0.025
Southwest Cape			
Other tagging	0.002	0.004	0.003

## DISCUSSION

Highly directional, long distance movements of *Jasus edwardsii* in southern New Zealand were first described by Street (1969, 1971), who tagged rock lobsters in Otago, Foveaux Strait, and Fiordland between 1957 and 1970. The majority of those tagged were recaptured within 16 km of their release points, but 3 moved from Foveaux Strait to southern Fiordland within 2 years. Minimum rates of movement ranged up to about 1.4 km d<sup>-1</sup>. Street (1971) also described movements of rock lobsters tagged from trawlers off the Otago coast which indicated a migration down the east coast of the South Island to Ruapuke and Stewart Islands. Minimum rates of movement of these animals ranged up to 6.8 km d<sup>-1</sup>. In each of these studies the rock lobsters which moved long distances were males and sexually immature females of about 90–105 mm CL. Street (1969) noted that sexually mature females did not move over long distances and that their movements were primarily “random” local movements. His observations concerning the movement of sexually mature females could not be confirmed by the results of this study because of the small number of tagged mature females which were returned.

Although the rock lobsters tagged in this study were released in areas south of those used by Street (1969) the rates and general directions of movement are very similar. Most of the rock lobsters returned showed no nett movement from their release sites and many were recovered close to the area in which they were tagged after up to 2 years.

The relatively high proportion which moved and the higher mean velocity of displacement of rock lobsters tagged as ‘run’ rock lobsters in this study (Tables 1 and 2), add some support to the contention of fishermen that these animals are part of a movement into and through the Stewart Island area. However, the observation that local inshore animals at Stewart Island, which were not identified as ‘run’ rock lobsters when tagged, made long distance movements as far as the southern end of Stewart Island and the Fiordland coast suggest that there may be no single area of origin for rock lobsters making long distance movements. Rock lobsters probably make such movements from many localities around the southern New Zealand coast at various times between September and December. It seems likely that the light colour of many ‘run’ rock lobsters in the Stewart Island area is a result of environmental factors in their area of origin, different from those encountered by the local Stewart Island population.

The pattern of recaptures of tagged ‘run’ rock lobsters from this study also suggest that they do not have a single area of destination. They appear

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 Tewaewae Bay and at least as far north as Milford Sound.

### Route of moving rock lobsters

Estimates of the route taken by migrating rock lobsters are limited by the distribution of fishing effort, which is restricted mainly to rocky, coastal areas. However, migrating rock lobsters were caught by trawlers in 25–50 m depth off Otago in 1970 (Street 1971) and in similar depths in eastern Foveaux Strait in 1978 (R.J. Street, pers. comm.). ‘Run’ rock lobsters caught in pots are usually taken on or near the edge of rocky bottom in depths ranging from 40–50 m in eastern Foveaux Strait to 50–100 m near Lords River.

None of the rock lobsters tagged in the Halfmoon Bay or Lords River areas were recaptured on the coast of Stewart Island northeast of Halfmoon Bay (Fig. 3). The highly directional nature of almost all of the movements observed strongly suggests that those animals which moved to the coast of the South Island from the Halfmoon Bay to Lords River areas did so around the southern tip of Stewart Island. The absence of recaptures from areas east of Sandhill Point (Fig. 4) indicates that the route between Stewart Island and the South Island was to the southwest of Tewaewae Bay.

The general oceanic flow in the Stewart Island region is mainly water of subtropical origin which flows from west to east across the Snares Shelf (south of Stewart Island), and through Foveaux Strait, turning northeast up the Otago coast to contribute to the Southland Current (Heath 1975).

Street (1971) noted that the direction of movement of migrating *J. edwardsii* in southern New Zealand was against the direction of the main coastal current system.

Such a relationship between movements and current direction seems reasonable in terms of maintaining recruitment to areas from which larvae are released. However, it seems unlikely that the current alone is involved in orientation, since the movement of water through Foveaux Strait and around the southern shores of Stewart Island is predominantly tidal flow (Carter & Heath 1975) which is locally very strong, particularly near Southwest Cape and off East Cape (Fig. 1). There are complex local variations in the tidal flow near the coast. Migrating rock lobsters would need to be particularly sensitive to hydrological cues to respond to the oceanic currents within the strong tidal water movements in many areas through which they pass.

### Implications of long distance movements

Long distance movements of rock lobsters contribute to mixing of rock lobster populations in southern New Zealand. Rock lobsters from, or passing through, the Stewart Island area contribute to populations on the south and west coasts of Fiordland (this study) and rock lobsters from Otago contribute to the Stewart Island and Foveaux Strait populations (Street 1971).

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 sexual maturity (SOM) of females between September and February could have resulted from an influx of immature females from an area where the mean SOM is greater than in Fiordland. Such females are likely to have originated in Foveaux Strait or Otago.

Booth (1979) suggested that migrations of *J. verreauxi* in northern New Zealand were part of a recruitment mechanism which maintained population distribution by counteracting larval drift. Such an hypothesis as noted by Street (1971) seems to be the likely explanation of the movements of *J. edwardsii* observed in southern New Zealand.

### ACKNOWLEDGMENTS

I am grateful for assistance with the tagging, return of rock lobsters, advice, and hospitality of the many rock lobster fishermen at Stewart Island and in Southland who took part in this study. The assistance of the staff in processing factories and of Ministry of Agriculture and Fisheries staff at Bluff and Te Anau in handling returns is also gratefully acknowledged. Thanks also go to J.H. Annala, B.T. Hvid, J. Atkinson, S.B. Saila, and other Fisheries Research Division personnel for assistance in the field. I thank J.H. Annala, J. D. Booth, and D.B. Esterman for constructive criticism of the draft manuscript.

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