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Final Report

Southern Rock Lobster Recruitment Study

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NON TECHNICAL SUMMARY

95/018	**Southern rock lobster recruitment study**

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OBJECTIVES

1. To develop catch forecasting methods based on recruitment indices of puerulus settlement and juvenile abundance.
2. To determine the movement pattern from juvenile nurseries to commercial fishing grounds.
3. To compare the number of juveniles with the number of adults and test the assumptions of stock depletion assessments.
4. To investigate the density dependent effects on mortality at different life stages.

NON TECHNICAL SUMMARY:

The southern rock lobster (*Jasus edwardsii*) is found in Australia's southern waters from south-west Western Australia to southern New South Wales, including the waters around Tasmania. In 1996/97, 4,835 tonnes of southern rock lobster were landed in Australia with the highest catch from South Australia (52%) followed by Tasmania (37%), Victoria (10%) and Western Australia (1%) (Anon 1999). The Victorian component of this catch was 464 tonnes in 1996/97 with 403 tonnes caught in the Western and 61 tonnes in the Eastern Management Zones (Anon 1998).

The larval stages of the southern rock lobster are relatively long, ranging between 12 and 20 months from hatching of eggs to settlement of pueruli. The planktonic larvae or phyllosomas are dispersed by ocean currents; however, this process is not well understood in southern Australia. Phyllosomas metamorphose into pueruli larvae which settle on inshore reefs. The study of settlement of pueruli is being conducted in all southern Australian states.

Little is known about the relationships between larval settlement, juvenile abundance and adult abundance for *Jasus edwardsii* in Australia; however, such relationships have been determined for the western rock lobster (*Panulirus cygnus*) and used to predict catches four years in advance.

The present study aimed to establish larval and juvenile monitoring at three sites in central Victoria, Flinders, Ocean Grove and Torquay. Larval collection sites were set up and monitored monthly. Twice yearly, commercial fishers set pots (including fine-meshed research pots) in reef areas near the settlement sites to monitor juvenile and adult abundance. Extensive tagging was carried out during this fishing and movement of subsequent recaptures analysed.

Settlement of larvae was very low at all sites and showed no pattern. The study sites appear to be in a very low settlement area compared with results from other work to the southwest at Apollo Bay.

Juvenile and adult abundance was monitored at each site although some practical problems were experienced in fishing near the Flinders site. There was a lack of animals below 60 mm carapace length in the catches and further work needs to be undertaken to enable sampling of these early benthic stages.

Tagging showed that overall movement was localised with some movement occurring from inshore reefs to deeper water. A low level of movement was observed but a small proportion of immature females and one male undertook large migrations in a south-westerly direction towards King Island.

The present study has begun the process of collection of long-term data monitoring abundance of larval settlement and juvenile abundance for catch prediction. Abundance of juveniles increased during the study and based on growth data from tagging corresponded with the high larval settlement observed at Apollo Bay during 1995. It appears that catch prediction may be achievable in the study site where lobsters are recruited to the fishery at around 4-5 years. Slower growth in western Victoria with lobsters recruiting to the fishery at 5-8 years may weaken any relationships between larval settlement and recruitment. Monitoring of pre-recruits should be increased for development of indices for short-term predictions.

KEYWORDS:

Southern rock lobster; Jasus edwardsii; abundance estimation; juvenile abundance; larval settlement; tagging.

Background

The present study investigated the feasibility of commercial catch prediction based on monitoring of larval settlement and juvenile abundance.

The southern rock lobster (*Jasus edwardsii*) is found in Australia's southern waters from south-west Western Australia to southern New South Wales, including the waters around Tasmania. In 1996/97, 4,835 tonnes of southern rock lobster were landed in Australia with the highest catch from South Australia (52%) followed by Tasmania (37%), Victoria (10%) and Western Australia (1%) (Anon 1999). The Victorian component of this catch was 464 tonnes in 1996/97 with 403 tonnes caught in the Western and 61 tonnes in the Eastern Management Zones (Anon 1998).

The larval stages of the southern rock lobster are relatively long, ranging between 12 and 20 months from hatching of eggs to settlement of pueruli (Lesser 1978). The planktonic larvae or phyllosomas are dispersed by ocean currents; however, this process is not well understood in southern Australia. Phyllosomas metamorphose into the transparent puerulus stage which can actively swim to inshore reefs to settle, moult and develop into early benthic juvenile stages. Settlement of *Jasus edwardsii* pueruli is monitored in Victoria, South Australia, Tasmania and Western Australia to provide information on larval recruitment processes, provide an early warning of overfishing, and to predict trends in recruitment to the fishery. Crevice collectors which were developed in New Zealand are used to monitor *Jasus edwardsii* settlement in Australia. The first collector site in Victoria was established at Apollo Bay in 1994 and has been serviced monthly since then.

Little is known about the relationships between larval settlement, juvenile abundance and adult abundance for *Jasus edwardsii* in Australia; however, such relationships have been determined for the western rock lobster (*Panulirus cygnus*) (Phillips 1986; Phillips *et al.* 1994, Caputi *et al.* 1995a, 1995b, 1997). In order to investigate relationships between settlement and later stages, a long time series of data will be required particularly as *Jasus edwardsii* may take from 4-8 years to reach LML (Hobday *et al.* 1998).

In the original proposal for the study the completion date was December 1998; however, delays in receiving initial funds necessitated an agreed extension of the study to be completed by the end of January 99.

Need

A better understanding of relationships between larval settlement and abundance of juvenile and adult stages will enhance management of the fishery. Little is known about larval settlement and juvenile abundance in Victoria and the present study will establish the basis for long-term monitoring and progress the understanding of recruitment processes.

Catch rates in the Victorian rock lobster fishery have stabilised in the past five years at levels well below 10-15 years ago and stock assessment has shown that growth overfishing is occurring in some areas (Hobday *et al.* 1997).

The Victorian rock lobster fishery is currently managed by input controls but change to quota management has been proposed for the year 2000. Under such a system, the need for catch prediction based on various life stages would be useful for management and setting of total allowable catches whilst forecasting of catches would enable the fishing industry to plan ahead in terms of marketing and expenditure.

Objectives

1. To develop catch forecasting methods based on recruitment indices of puerulus settlement and juvenile abundance

   The study was successful in achieving this objective. The basis for long-term monitoring of larval settlement and juvenile abundance has been established and as a longer time series of data is collected, development of catch prediction models can be undertaken. The study established that the area between Flinders and Torquay is subject to relatively low larval settlement and is not likely to provide suitable data. Juvenile abundance indices from the study show some initial correlation with larval settlement and long-term data collection should continue.

2. To determine the movement pattern from juvenile nurseries to commercial fishing grounds.

   The study was successful in achieving this objective. The study showed that movement overall was localised with some movement from inshore reefs to deeper water. A low level of movement was observed where mainly immature females undertook large migrations in a south-westerly direction.

3. To compare the number of juveniles with the number of adults and test the assumptions of stock depletion assessments.

   The study was not completely successful in achieving this objective. Data collected from research fishing did not show depletion over time. The intensity of fishing needs to be much higher than that applied in the present study and should be further investigated.

4. To investigate the density dependent effects on mortality at different life stages.

   The study was not able to detect density dependence. This was because of the very low levels of settlement and the difficulty sampling animals in the stages between settlement and first capture in research pots at around 60 mm. In the initial design of the project it was thought that the entire size range could be captured. Further investigation in this area will require extensive development of alternative capture methods and/or diver surveys which was beyond the resources of the present study.

Methods

Larval settlement

Larval settlement monitoring sites were chosen in consultation with commercial fishers and placed in areas known to contain juvenile lobsters. Sites were selected within close proximity to Queenscliff for operational purposes (Table1, Figure 1). Each site was established on sand either adjacent to or within a reef structure.

At the commencement of the study three larval collector sites were established, one at Flinders, another at Point Impossible, and a third at Cinema Point (Figure 1). The Flinders site was adjacent to mussel farms inside the entrance to Western Port (Figure 1) at a depth of 9 m (Table 1) and was maintained and serviced throughout the study (Table 2). However problems were experienced with other larval collectors at the other locations established at the start of the study. Twelve collectors were deployed at Point Impossible (near Torquay, Figure 1) in August 1995 but problems were experienced locating all of the collectors during subsequent servicing months because of poor visibility and unsuitable sea conditions. In

March of the following year, collectors were moved from the Point Impossible site to a more suitable location off Torquay (Table 2). The site at Torquay was approximately 300 m offshore at 10 m depth with two groups of six collectors 40 m apart on sand within the reef structure (Table 1). More severe problems were experienced at the Cinema Point site (near Lorne) where moving sand buried the collectors. Hence, the collectors were removed and placed at Georges Point also near Lorne in May 1996 but the collectors were destroyed by a storm in July 1996 (Table 2). Some collectors were salvaged from Georges Point in August 1996 when the site was abandoned (Table 2). In order to proceed with the present study, an existing collector site at Ocean Grove established since May 1995, was used as the third site. The Ocean Grove site was initially only 3 collectors in 9 m depth, 300 m offshore but was increased to 6 in October 1995 and 12 in March 1997 (Table 2).

Settlement of pueruli was monitored at each site with twelve crevice collectors similar to those developed in New Zealand (Booth and Tarring 1986). Several collector types were evaluated in Tasmania and the crevice collector was found to be most suitable (Kennedy 1991); it is now used across the distribution of *Jasus edwardsii* to standardise and maintain consistency of settlement monitoring. Collector heads consisted of eight plates constructed from marine-grade plywood (400 x 400 x 9 mm) enclosed in a galvanised iron frame (Figure 2). A single craypot anode was attached to the lifting handle (Figure 1). Collector heads and bases were labelled using plastic cow ear tags to enable the history of individual collectors to be traced. Collector bases consisted of concrete-filled used car tyres with a vertical galvanised pole (400 mm) on which the collector head was fixed by a removable stainless steel pin (Figure 2).

Collectors were serviced monthly by divers within five days of full the moon. Servicing was initially undertaken by MAFRI staff and later by contract divers. When servicing, collector heads were covered with a fine-meshed bag to prevent escape of pueruli, removed from the collector base and raised to the surface where crevices were scraped clean (Figure 3). Pueruli and juveniles recovered from each collector were staged (Booth 1979) and the carapace length measured. External surfaces of the collector were scraped clean before being returned to the water to maintain a consistent surface.

Juvenile and adult abundance

Modified commercial lobster pots (research pots) were used to monitor abundance of late juvenile and adult stages. A total of six commercial fishers assisted the study by volunteering their time and vessels. Research pots were modified from standard commercial steel-framed lobster pots by sealing escape gaps and covering with trawl mesh which left holes of approximately 35 mm diameter. The bases of research pots were covered with black nylon protection mesh (23 mm). Ten research pots were set from commercial fishing vessels on reefs surrounding the larval collector sites during summer (January to March) and winter (July to August) for periods ranging from 6 to 11 days. All lobsters captured were sexed and had the carapace length (CL) measured, reproductive state (females) and shell state recorded. Carapace length was measured as the distance from the anterior edge of the rostral horn to the posterior edge of the carapace.

Tagging

During the juvenile and adult abundance surveys all lobsters in commercial pots measured and undersized and out of season females of CL >60 mm were tagged and released. All lobsters of CL >60 mm caught in research pots were tagged and released. Lobsters were tagged on the ventral surface of the first abdominal segment using Hallprint T-bar tags (50mm long with 23mm green identification section containing a unique 5-digit number and the lettering “MSL VIC”). As part of continuing lobster assessment, licensed commercial rock lobster fishers, recreational SCUBA dive clubs and all coastal Fisheries and Wildlife Officers were provided with tag return booklets containing 20 reply paid cards to record tag capture details including date, name and address, vessel, tag number, capture depth and position, carapace length, sex, shell colour and hardness, female reproductive state, injuries and if applicable, re-release position.

Parameters describing growth rate from tagging data (time at liberty and lengths at release and recapture) were estimated using GROTAG, a program developed by Chris Francis (NIWA, Wellington, New Zealand) following methods described in Francis (1988).

The distance moved between tag release and recapture positions was calculated by:

distance (km) = (arcos(cos(ab)cos(ac)+sin(ab)sin(ac)cos(bc))3969.665x1609.344)/1000

where: ab=((90 -release latitude)π)/180
ac=((90 -capture latitude)π)/180
bc=abs(((release longitude-capture longitude)π)/180)

Direction moved between tag release and recapture positions was calculated using the method described by Treble (1996). Fishers returning tag recapture information were sent details of the particular tag including distance and direction travelled, time at liberty and growth. The movement information given to fishers was rounded to the nearest 5 km and eight compass point categories to protect confidentiality of release positions.

Commercial catch monitoring

Commercial fishers are required to submit catch and effort returns each month. This data has been reported daily since 1978 and contains the number and weight of lobsters caught by individual fishers by depth for areas made of 10 minute longitude intervals along the Victorian coast. Data for catch and effort reporting areas containing the study sites were extracted from the Catch and Effort Database maintained at MAFRI. The Ocean Grove and Torquay sites are located in Areas 21-23 and the Flinders 25,26.

Results

Larval settlement

The larval collector sites showed poor settlement throughout the study. Initial settlement at Flinders was promising with pueruli collected in five of the first six serviced (Figure 4). Settlement then declined with none observed on collectors during 1997 and low settlement in only two months during 1998 (Figure 4). Settlement on the Ocean Grove collectors occurred during only three months during the study namely January and February 1996 and July 1998 (Figure 4). Like at Flinders, no settlement was seen during Ocean Grove during 1997 (Figure 4). Similarly, the Torquay site recorded very low settlement in only four months of the study (Figure 4).

Settlement was not consistent across the sites with the only common settlement observed during February and March 1996 at Flinders and Ocean Grove (Figures 4). The highest settlement was observed in December 1995 at Flinders which was 0.58 per collector or a total of 7 individual pueruli for the 12 collectors (Table 3). When settlement was observed, it was sporadic and at very low levels, often with only one or two pueruli collected from the twelve collectors of a site (Table 3).

Results observed in the present study were markedly different from those at an ongoing site at Apollo Bay harbour (75 Km southwest of Torquay, Figure1) where higher settlement has been recorded with peaks in mean settlement occurring consistently between July and September 1995 - 1998 (Figure 5). Spatial variability is an important factor in larval settlement monitoring. At Marengo Reef, only 2 km from Apollo Bay Harbour low level, sporadic settlement similar to that seen in the present study has been observed (Hobday *et al*. 1998). Similar work in Tasmania (Gardner *et al.* 1998) has also shown spatial variability. Further work is needed on the larval processes of *Jasus edwardsii* in south-eastern Australia to better understand the spatial and temporal variability of settlement. It is now clear from the results of the present study that the sites chosen are in a very low settlement zone, a fact that is important for understanding wider scale trends, but unfortunately of little use in testing catch prediction models.

Juvenile and adult abundance

A total of 127 days were undertaken pot fishing at the three study sites Flinders, Ocean Grove and Torquay (Table 4). Six commercial fishers set research and commercial pots on reefs adjacent to the larval collector sites and a total of 2,774 lobsters were caught and measured (Table 4). The research and commercial pots captured different size ranges with the former catching much smaller lobsters. The smallest lobster of 41 mm CL was caught in a research pot and the largest was a male of 203 mm from a commercial pot. Mean carapace length was 86 mm and 90 mm for females and males, respectively, in the research pots, and similarly 119 mm and 125 in the commercial pots. Although the research pots captured a number of relatively small individuals, the median sizes for females and males were 86 mm and 90 mm with the first quartile at 78 mm and 82 mm respectively.

Problems were experienced with juvenile potting in the area near the Flinders larval collector site. This area is within Westernport Bay and not commercially fished because of licensing restrictions. The area was surveyed as part of site selection for the larval collector site and suitable reef areas were located and seen to contain significant numbers of juvenile lobsters. However, fishing these reefs with research pots did not produce results because of sea lice attacking baits. Fishing was therefore conducted on inshore reefs in Bass Strait near entrance to Western Port but further problems were experienced with sea swell which limited access to these reefs. Catch rates in the research pots were extremely low throughout the first three sampling periods (Table 4) and it was not considered practical to fish during 1998 at Flinders. CL distributions for the Flinders area highlight the low research pot catches (Figures 6 and 7).

At Ocean Grove, despite low catches in the first sampling period (1996 Summer), catch rates were much higher with 405 lobsters captured in research and 552 in commercial pots over the 47 days fished (Table 4). The main trend from the commercial catches was the increased abundance through the study (Table 4, Figures 8 and 9). Some progression of CL classes can be seen in the length-frequency plots but no strong relationships are apparent. For males, a peak in the research pots at 75 mm CL was observed in winter 1996; 85–95 mm in the following summer 1997; 90–95 mm in winter 1997, and then increased abundance in the commercial pots during summer 1998 and winter 1998 samples (Figure 8). A similar pattern can be seen in the length-frequency plots for females at Ocean Grove and a second recruitment pulse appears in the winter 1997 sample at around 65 mm which can be followed to 70–75 mm and 80 mm in the following samples (Figure 9).

Torquay catch rates were generally higher than at Ocean Grove and were much higher during winter 1998 (Table 4, Figures 10 and 11). A peak in the length-frequency around 80–90 mm observed in research pots during summer 1997 was 5 mm higher in winter 1997 and increases in commercial catches were then seen during 1998 (Figure 10). A strong recruitment of 80–90 mm males was seen in the winter 1998 research pot sample (Figure 10). A similar pattern was observed in the female length distributions (Figure 11).

In order to gain some understanding of the possible age structure of the samples, a very rough approximation was made by applying the growth parameters derived from tagging (Table 5) to individual lengths from Ocean Grove and Torquay data and estimating age using the Bertalanffy growth relationship. Results showed a peak age in the research pots of 2.5 years for males and 2.5-3.0 years for females (Figures 12 and 13). These ages showed little modal variation but increased in abundance through the study. The highest abundance of estimated age of 2.5–3.0 year olds occurred in winter 1998 and correspond with the maximum larval settlement observed at Apollo Bay in 1995 (Figure 7).

Tagging

A total of 1,742 lobsters were tagged in the Ocean Grove, Torquay and Flinders study sites (Table 4). Differences between the number tagged and the number caught in research pots occurred when some lobsters were too small to tag or were dead due to octopus predation.

A total of 218 tagged lobsters (12.5% of releases) have been recaptured to date consisting of 100 females and 118 males. Movement was generally localised with 202 recaptures (93%) occurring within 5 km of the release position (Figure 14). Several long distance movements of >30 km were observed from the Ocean Grove and Torquay study sites (Figure 20). Recapture rates were higher from the Ocean Grove and Torquay sites (12.8%) than from the Flinders site (5.9%), probably reflecting higher fishing mortality. Similarly, male recapture rates exceeded those of female recapture rates, with 9.8% of male and 4.5% of female releases recaptured from Flinders and 15.4% of male and 10.6% of female releases from Ocean Grove and Torquay.

Distances moved by the 15 recaptured lobsters from Flinders were generally less than 2 km (mean 1.6 km, sd 2.3) with the largest movement observed being 7.6 km for males and 5.2 km for females. Of the small number of recaptures at the Flinders site, most females moved east along-shore with a mean distance travelled of 2.5 km (Figure 15) whereas the males moved mainly southwest into deeper water, averaging 7.6 km (Figures 16, 15).

Distances moved by lobsters released in the Ocean Grove study site were similar to those released in the Torquay study site, with both showing more movement than at Flinders and a strong south to southwest directional component. However, 63% of recaptures were within 400m of release and probably represent negligible movement because of limits and errors in position fixing. Females moved greater distances (mean 8.6 km, sd 27.0 km) than males (mean 2.7 km, sd 13.4 km). Of the recaptures travelling less than 5 km, the mean distances were 0.70 km and 0.60 km for females and males, respectively. Movement was generally along-shore at similar depth or offshore to deeper reefs (Figure 17). Of the 6% of recaptures from the Ocean Grove and Torquay sites which moved more than 5 km, the mean distance travelled by females was 66.7 km (sd 48.7 km) with a maximum of 143.6 km and for males a mean of 65.4 km (sd 40.0 km) and a maximum of 93.2 km. Movements for both sexes were mainly in a south and southwest direction with the mean distances travelled in these directions markedly higher (Figures 18, 19). The south–southwest movements (Figure 20) follow inshore reefs in the area with some of the recaptures occurring in the vicinity of King Island. The females which showed these large movements ranged 102-118 mm CL and most were unsetose. Size at onset of maturity has been estimated at 112 mm CL for the Eastern Management Zone (Hobday and Ryan 1997) and these movements may be related to maturation and breeding by moving closer to Southern Ocean current systems. Similar movements were observed from previous Victorian tagging, where lobsters released near the Torquay site were recaptured over 100 km near King Island (Hobday *et al*. 1998). This south-west movement follows the inshore reefs in the area and may represent breeding migrations similar to those noted in New Zealand by Booth (1997)and Booth and Stewart (1992) where migrations occur from high puerulus settlement areas in the North Island against the prevailing current southwards. Estrella (1997) found greater movement by ovigerous female American lobsters (*Homarus americanus*) suggesting that the movement was related to hatching or reproductive needs. (Campbell 1987) also working on *Homarus americanus* noted seasonal depth migrations of ovigerous females which appeared to be associated with seeking temperatures to optimise time required for egg development. Tasmanian research has shown that around 8% of tag releases from King Island consisting of immature females moved more than 8 km in a southerly direction into deeper water (Pearn 1994).

Growth derived from tag recapture data for females released at the Ocean Grove and Torquay sites during the present study show that, at LML, average female growth was 9.9 mm/year and that, at 120 mm CL, growth was 5.1 mm/year (Table 5a). The small size range of male recaptures from the Ocean Grove and Torquay sites and insufficient number of releases and subsequent recaptures at Flinders prevented further growth estimation. However, inclusion of recapture data from previous work in the study site enabled growth estimation for the Ocean Grove and Torquay study sites. At LML, males grew 14.3 mm/year and females 10.4 mm/year (Table 5b), whereas, at 140 mm CL, males grew an average of 6.2 mm/year and females, at 120 mm CL, grew 6.0 mm/year (Table 5b).

Commercial catch monitoring

The commercial catch for the Eastern Management Zone (Figure 1) in the 1997/98 fishing season was 65 tonnes with an overall catch rate of 0.31 kg/potlift (Anon 1998). Catch and effort data for the reporting area and depth resolution used in the present study are not being published to protect commercial confidentiality because in some instances there are less than five fishers represented by the data, hence only catch rate data are presented in this report.

Catch rates were calculated as number of lobsters caught per potlift from mandatory commercial returns for catch and effort reporting areas 21-23 which contained the Ocean Grove and Torquay study sites and 24-27 for the Flinders site for summer (January-March) and winter (July-August) corresponding to sampling times. Commercial catch rates at the Ocean Grove and Torquay have been about 0.15 lobster/potlift since the mid-1990s decreasing from about 0.4 lobsters/potlift in the late 1980s (Figure 21). Summer and winter catch rates at Ocean Grove and Torquay have been similar except from 1992 to 1994 when summer catch rates were higher (Figure 21). Catch rates at Flinders were more consistent and higher than from Ocean Grove and Torquay, with summer rates generally higher than winter (Figure 22). Average weight of lobster for entire fishing seasons was higher at Flinders than at Ocean Grove and Torquay (Figure 23). The lowest average weights were observed in the 1989/90 and 1990/91 fishing seasons at Flinders and 1991/92 at Ocean Grove with the 1997/98 season showing a decrease and indicating an increase in entry of small animals to the fishery (Figure 23).

Comparison of catch rates from commercial catch and effort returns with catches during the present study showed little change in commercial catch rates which were consistently lower than in the study (Figure 24). This may be partly due to the commercial catches taken from deeper reefs where fewer animals of large size are caught. Catch rates observed in winter 1997 were much higher (Figure 24). Similar results were seen at Torquay where the winter 1997 catch rate was high and the 1998 winter even higher (Figure 25). Catch rates at Flinders were very low for animals smaller than legal minimum length (LML) with those above LML similar to the commercial rates (Figure 26).

Catch prediction

The present study provides puerulus settlement data for development of catch prediction indices. However, a much longer time series of data is needed for application in predictive models and the present study has begun the collection of appropriate data. Variability of larval settlement found in the present study shows that settlement indices from the study sites would be of little use in catch prediction because of the low levels observed. However settlement at Apollo Bay was much higher and using the growth parameters derived from tagging, the peak observed in 1995 corresponded with increased abundance of pre-recruits (3+ year old) to the fishery in the 1998 juvenile samples. It is therefore important to continue monitoring larval settlement at key sites such as Apollo Bay but further settlement monitoring at the Ocean Grove, Torquay and Flinders study sites is not practical. Growth rates in the study site show that lobsters would be recruited to the fishery at around four years which is similar to that seen for *Panulirus cygnus* in Western Australia where catch forecasting from settlement and pre-recruit data has been successful (Caputi *et al*. 1995b, Anon 1987). Slower growth rates have been observed in Victoria's Western Management Zone (Hobday *et al*. 1998) and males would take about 5-6 years and females 7-8 years to reach LML. The longer time to recruit to the fishery may weaken relationships between settlement indices and catch 5-8 years later as other factors may influence recruitment. Breen and Booth (1989) found a good correlation between settlement of puerulus-stage *Jasus edwardsii* and abundance of the first three juvenile cohorts at Stewart Island, New Zealand. Puerulus settlement on subtidal collectors showed great annual variation but abundance of 2- and 3-year-olds is highly correlated with puerulus settlement 2 and 3 years previously (Breen and Booth 1989).

Estimation of juvenile abundance in the present study relied on sampling with fine-mesh research pots but the low catchability of lobsters <85 mm CL seen in the present study highlights the need for alternate sampling strategies. At present the only other method of surveying juvenile lobsters is by diver observation (Breen 1989) but development of habitat traps may be use in abundance estimation.

Further work is needed in expanding pre-fishery recruits for development of short-term prediction models. Victorian commercial lobster fishers are now required to report the number of undersized lobsters caught each day and this data along with average weight will also be valuable for short-term prediction.

References

Anon (1987). Western rock lobster: Predicting the catch. *Fins.* **20,** 20-23.
Anon (1998). Catch and effort 1998 information bulletin. Marine and Freshwater Resources Institute, Dept Natural Resources and Environment
Anon (1999). Australian Bureau of Statistics, Fish Account Australia 1997. Australian Bureau of Statistics
Booth, J. D. (1979). Settlement of the rock lobster, Jasus edwardsii (Decapoda: Palinuridae), at Castlepoint, New Zealand. *New Zealand Journal of Marine and Freshwater Research* **13,** 395-406.
Booth, J. D. (1997). Long-distance movements in Jasus spp. and their role in larval recruitment. *Bulletin of Marine Science* **61,** 111-128.
Booth, J. D. and Stewart, R. A. (1992). Distribution of phyllosoma larvae of the red rock lobster Jasus edwardsii off the east coast of New Zealand in relation to the oceanography. In 'Australian Society For Fish Biology Workshop. Larval Biology, Hobart, 20 August 1991.'. (Eds D. A. Hancock) pp. 138-148.
Booth, J. D. and Tarring, S. C. (1986). Settlement of the red rock lobster, Jasus edwardsii, near Gisborne, New Zealand. *New Zealand Journal of Marine and Freshwater Research* **20,** 291-297.
Breen, P. A. and Booth, J. D. (1989). Puerulus and juvenile abundance in the rock lobster Jasus edwardsii at Stewart Island, New Zealand. *N.Z. J. Mar. Freshwat. Res.* **23,** 519-523.
Campbell, A. (1987). Migratory movements of ovigerous lobsters, Homarus americanus , tagged off Grand Manan, eastern Canada. In 'Third Colloquium: Mediterranean Crustacea Decapoda. Barcelona, 25 March 1985..'. (Eds D. E. M. D. E. S. F. Colloquium: Crustacea Decapoda Mediterranea. Barcelona) pp. 263.
Caputi, N., Brown, R. S., Chubb, C. F. and Kittaka, J. (1995a). Regional prediction of the western rock lobster, Panulirus cygnus, commercial catch in Western Australia.
Caputi, N., Brown, R. S. and Phillips, B. F. (1995b). Predicting catches of the western rock lobster (Panulirus cygnus) based on indices of puerulus and juvenile abundance. In 'Shellfish Life Histories and Shellfishery Models. Selected Papers From a Symposium Held in Moncton, New Brunswick, 25 29 June 1990.'. (Eds D. E. Aiken, S. L. Waddy and G. Y. Conan) pp. 287-293.
Caputi, N., Chubb, C., Hall, N., Pearce (1997). Relationships between different life history stages of the western rock lobster, Panulirus cygnus, and their implications for management. In 'Developing and sustaining world fisheries resources. The state of science and management.'. (Eds D. A. e. Hancock, D. C. e. Smith, A. e. Grant and J. P. Beumer) pp. 579-585.
Estrella, B. T. and Morrissey, T. D. (1997). Seasonal movement of offshore American lobster, Homarus americanus, tagged along the eastern shore of Cape Cod, Massachusetts. *Fish. Bull.* **95,** 466-476.
Francis, R. I. C. C. (1988). Maximum likelihood estimation of growth and growth variability from tagging data. *New Zealand Journal of Marine and Freshwater Research* **22,** 395-406.
Gardner, C., Cawthorn, A., Gibson, I., Frusher, S., Kennedy, R. B. and Pearn, R. M. (1998). Review of the southern rock lobster Jasus edwardsii puerulus monitoring program: 1991-1997. Marine Research Laboratories 52
Hobday, D. K. and Ryan, T. J. (1997). Contrasting sizes at sexual maturity of southern rock lobsters (Jasus edwardsii) in the two Victorian fishing zones: implications for total egg production and management. *Marine and Freshwater Research* **48,** 1009-1014.

Hobday, D. K., Ryan, T. J., Thomson, D. R. and Treble, R. J. (1998). Assessment of the Victorian rock lobster fishery. Final report to FRDC, Project 92/104. Marine and Freshwater Resources Institute 92/104

Hobday, D. K., Smith, D. C. and (Eds.) (1997). Rock lobster - 1996. Compiled by the Rock Lobster Stock Assessment Group. *Fisheries Assessment Report (Fisheries Victoria)* **No. 11,**

Kennedy, R. B., Wallner, B., and Phillips, B.F. (1991). Preliminary investigations of puerulus settlement of the rock lobster Jasus novaehollandiae in southern Australia. *Revista De Investigaciones Marinas* **12,** 76-82.

Lesser, J. H. R. (1978). Phylosoma larvae of Jasus edwardsii (Hutton) (Crustacea: Decapoda: Palinuridae) and their distrubution off the east coast of North Isalnd, New Zealand. *New Zealand Journal of Marine and Freshwater Research* **12,** 357-370.

Pearn, R. (1994). Rock lobster tagging shows movement occurs. *Fishing Today* **7,** 27-29.

Phillips, B. F. (1986). Prediction of commercial catches of the western rock lobster Panulirus cygnus. *Can. J. Fish. Aquat. Sci.* **43,** 2126-2130.

Phillips, B. F., Cruz, R., Brown, R. S. and Caputi, N. (1994). Predicting the catch of spiny lobster fisheries. In 'Spiny Lobster Management.'. (Eds B. F. Phillips, J. S. Cobb and J. Kittaka) pp. 285-301.

Treble, R.J. 1996. The southern rock lobster (Jasus edwardsii): Fisheries biology and abundance estimation. Ph.D. Thesis, The University of Melbourne, Victoria, August 1996.

Benefits

The Victorian lobster fishing industry will benefit from a better understanding of larval settlement in central Victoria and the long-term development of catch prediction models from on-going sampling.

Intellectual Property

The value of the intellectual property will be 54% based on Part C of the FRDC project application.

Further Development

Larval settlement data should be continued at Apollo Bay and new sites established in Western Victoria. More emphasis should be placed on monitoring the life stages from settlement to the pre-recruits. At present little is known of these early benthic stages because of they are not captured by traps or pots and are difficult to locate by divers. Research in this area will be valuable in understanding recruitment processes.

Staff

David Hobday	Scientific Officer	20%	1/09/95 - 31/01/99
Rhonda Flint	Technical Officer	100%	4/09/95 – 30/11/98

Final Cost (FRDC)

Item	Expenditure
Salaries	$105,806
Travel	$2,648
Operating	$65,883
Capital	$4,576
Total	**$178,913**

Distribution

Librarian, CSIRO,
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We wish to thank commercial lobster fishers John Fisher, Glenn Pettigrove, Michael Parsons, Lee Everett, Jeff Giddins and Robert Craike for their time, support and vessels during the research and commercial potting; David Lucas. for extensive help with field work; the many MAFRI staff who assisted with servicing of puerulus collectors; and David Forbes and Bruce Waters for contract servicing of collectors.

Tables

Table 1. Larval collector sites used in the study.

	Flinders	Ocean Grove	Torquay	Apollo Bay
Latitude	38^0 27.9’	38^0 16.97’	38^0 19.04’	38^0 45.44’
Longitude	145^0 02.41’	144^0 31.05’	144^0 22.31’	143^0 40.66’
Depth	9 m	12 m	10 m	5 m
Number of collectors	12	12	12	6
Location	20 m south of mussel farm, 400 m offshore	300 m offshore from Ocean Grove Surf Life Saving Club	300 m offshore from “The Corner” Torquay	Under inside wall of jetty on north side of harbour entrance
Access	Beach launch from Flinders boat ramp	Boat launch from Queenscliff	Beach launch or boat from Queenscliff	Boat ramp in harbour or from jetty using portable winch

Table 2. Servicing history of larval collector sites.

	Flinders	**Ocean Grove**	**Torquay**	**Point Impossible**	**Cinema Point**	**Georges Point**
August 95	Dx (12)	S		Dx (12)		
September 95	NS	NS		NS	Dx (12)	
October 95	S	Dx3		NS	NS	
November 95	S	NS		NS	NS	
December 95	S	S		NS	NS	
January 96	S	S		NS	NS	
February 96	S	S		NS	NS	
March 96	S	S	Dx (12)	SC	SC	
April 96	S	S				
May 96	S	S	S			Dx (12)
June 96	S	S	S			NS
July 96	S	S	S			NS
August 96	S	S	S			SC
September 96	S	NS	S			
October 96	S	S	S			
November 96	S	S	S			
December 96	S	S	S			
January 97	S	S	S			
February 97	S	S	S			
March 97	S	S Dx (6)	S			
April 97	S	Sx6	S			
May 97	S	S	S			
June 97	S	S	S			
July 97	S	NS	S			
August 97	S	S	S			
September 97	S	S	S			
October 97	S	S	S			
November 97	S	S	S			
December 97	S	S	S			
January 98	S	S	S			
February 98	S	S	S			
March 98	S	S	S			
April 98	S	S	S			
May 98	S	S	S			
June 98	S	S	S			
July 98	S	S	S			
August 98	S	S	S			
September 98	S	S	S			
October 98	S/SC	S/SC	S/SC			

Dx (n) Collectors deployed, (number)
NS Not serviced due to bad weather or operational difficulties
S Collectors serviced
SC Site closed

Table 3. Larval settlement data for months when pueruli were observed at larval collection sites. Mean number caught per collector, total caught at site, puerulus stage (P1-P4, PP post puerulus).

	Year	Month	Number per collector	Total caught	P1	P2	P3	P4	PP
Flinders	1995	October	0.33	4				3	1
		November	0.17	2				2	
		December	0.58	7					7
	1996	February	0.17	2					2
		March	0.17	2					2
		October	0.25	3		1			2
		November	0.08	1				1	
	1998	January	0.08	1				1	
		August	0.08	1			1		
Ocean Grove	1996	February	0.17	1				1	
		March	0.17	1					1
		June	0.08	1				1	
Torquay	1997	October	0.08	1				1	
		December	0.08	1		1			
	1998	July	0.08	1			1		
		October	0.17	2		1		1	

Table 4. Juvenile and adult abundance sampling history.
(* seasonal commercial catch numbers omitted for confidentiality reasons.)

			Research Pots		Commercial Pots	
Site	**Season**	**Days Fished**	**No. caught**	**No. Tagged**	**No. caught**	**No. Tagged**
Ocean Grove	Summer 1996	6	12	11	*	5
	Winter 1996	6	59	38	*	21
	Summer 1997	9	75	72	*	35
	Winter 1997	8	102	81	*	62
	Summer 1998	11	69	66	*	36
	Winter 1998	7	88	76	*	87
		47	**405**	**344**	**552**	**246**
Torquay	Winter 1996	6	27	26	*	85
	Summer 1997	11	54	50	*	18
	Winter 1997	10	147	128	*	60
	Summer 1998	11	63	62	*	52
	Winter 1998	11	273	259	*	150
		49	**564**	**525**	**698**	**365**
Flinders	Winter 1996	10	10	9	*	57
	Summer 1997	10	12	10	*	5
	Winter 1997	11	12	10	*	161
		31	**34**	**29**	**521**	**223**
	Total	**127**	**1,003**	**898**	**1,771**	**844**

Table 5. Results of growth modelling from tag recapture data from a) Ocean Grove and Torquay releases during the study and b) all known recaptures for the Ocean Grove / Torquay study area, showing Von Bertalanffy growth parameters and average growth / year from Grotag analysis at two given lengths for each sex.
* no fit obtained

a)

	Male	Female
Number of tag recaptures	57	35
Release length range (mm CL)	60 – 109.6	64.8 – 141.1
Mean release length (mm.CL)	92.8	98.9
Average maximum length L_∞ (mm)	*	136.1
Growth constant (K)	*	0.38
Growth at 105 mm (mm/year) (95% CI)	*	9.9 (9.4 – 10.4)
Growth at 120 mm (mm/year) (95% CI)	*	5.1 (4.2 – 5.8)

b)

	Male	Female
Number of tag recaptures	109	130
Release length range (mm CL)	60 – 149.2	64.8 – 166.0
Mean release length (mm.CL)	97.9	109.4
Average maximum length L_∞ (mm)	162.7	141.1
Growth constant (K)	0.32	0.34
Growth at lower length (g_{length} mm) (mm/year) (95% CI)	g_{110} = 14.3 (13.7 – 15.0)	g_{105} = 10.4 (10.1 – 10.5)
Growth at upper length (g_{length} mm) (mm/year) (95% CI)	g_{140} = 6.2 (4.9 – 8.1)	g_{120} = 6.0 (5.9 – 6.2)

Figures

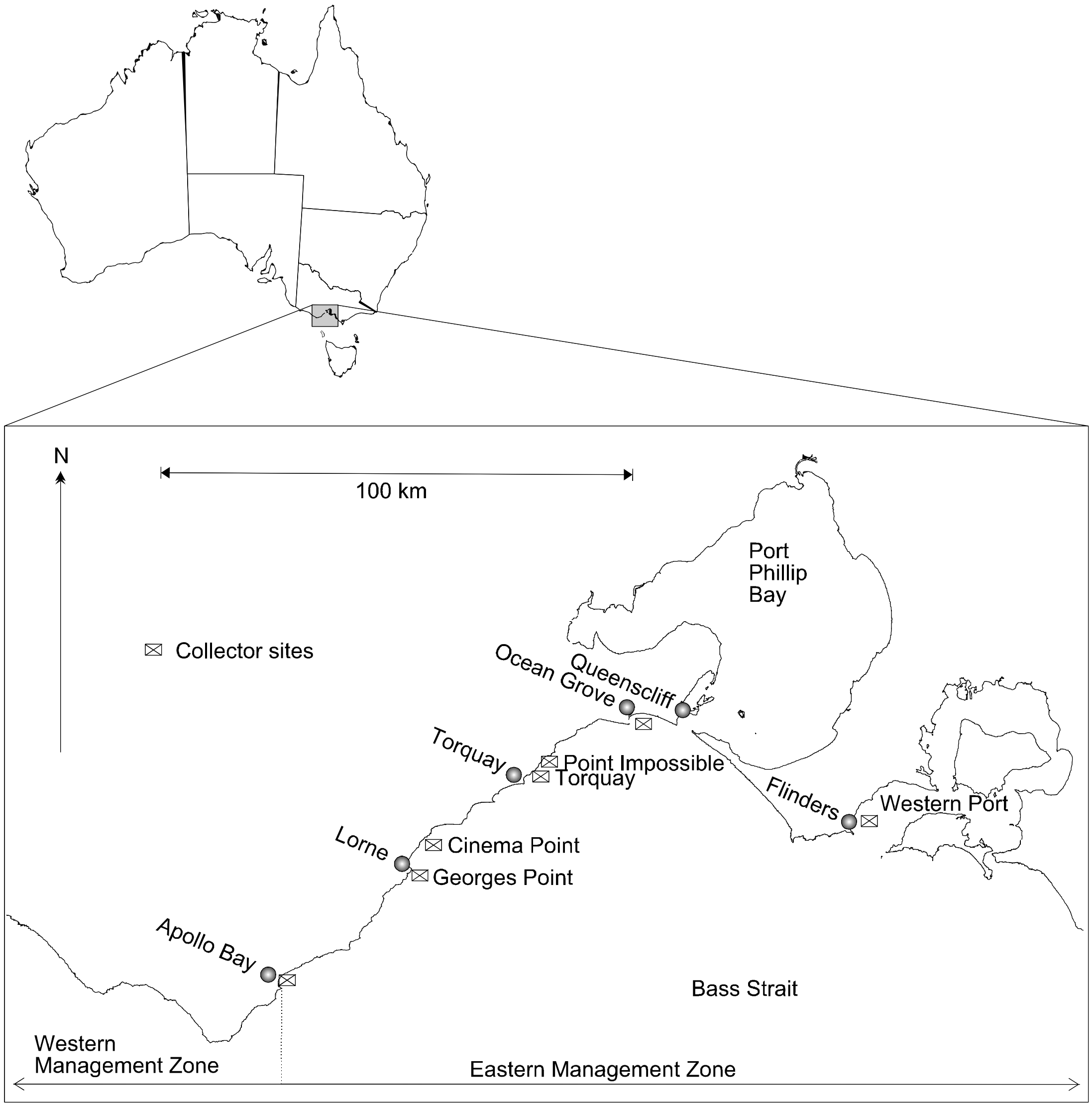


Figure 1. Map of study area showing main Victorian rock lobster fishing ports, Management Zones and larval collection sites.

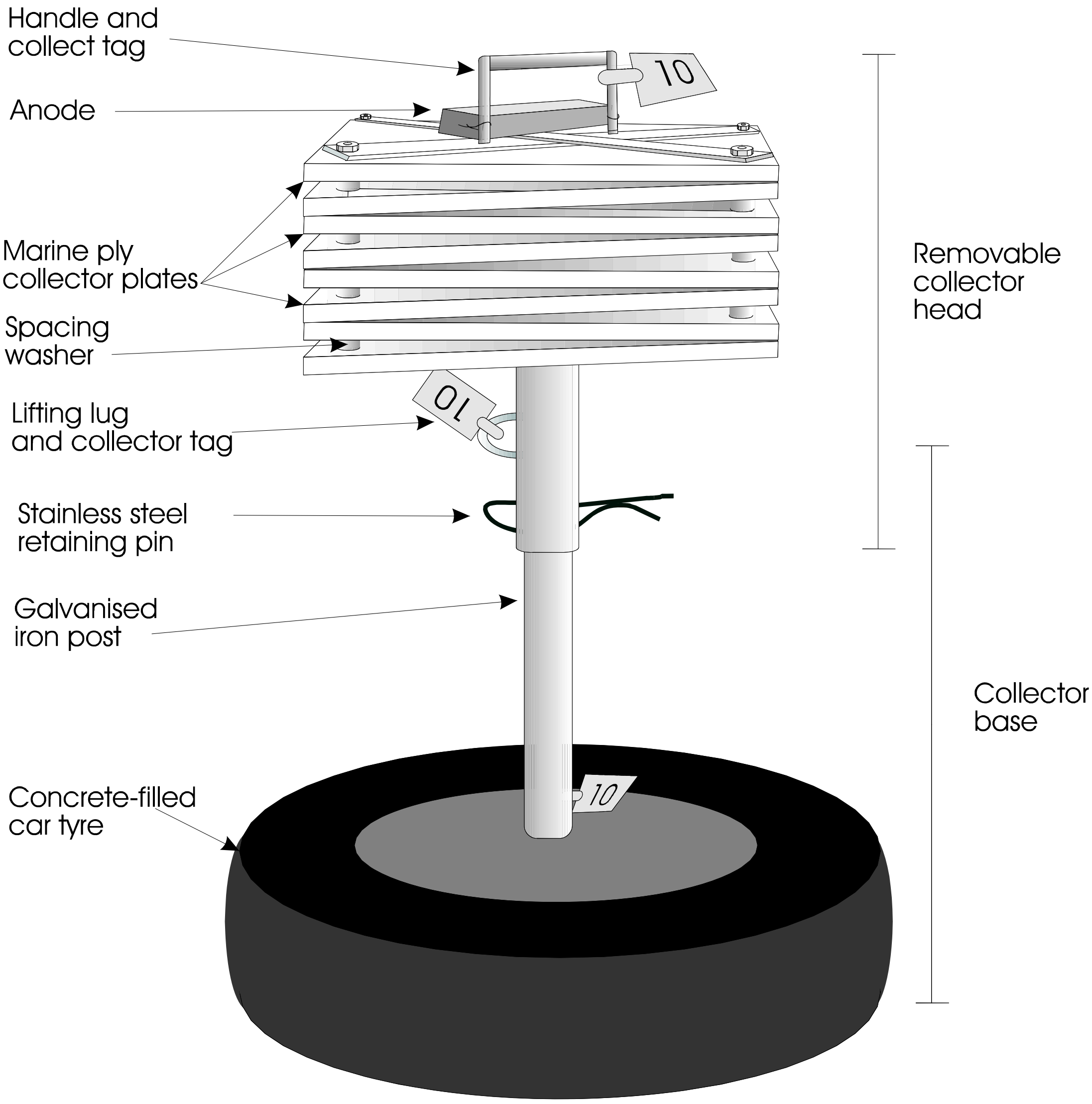


Figure 2. Crevice larval collector head in water (top) and diagram of collector (bottom).

a) b)

c) d)

Figure 3. Servicing larval collectors.
a) Retrieving collector head from diver to boat. Note mesh bag around collector.
b) Cleaning collector in fish bin to retain settled animals.
c) Detail of cleaning a collector head using PVC scraper in crevices.
d) Catch of lobster settled in a collector. Stages P1 (top right), P2 (top centre), Post Puerulus (bottom right) and early benthic juvenile (top left).

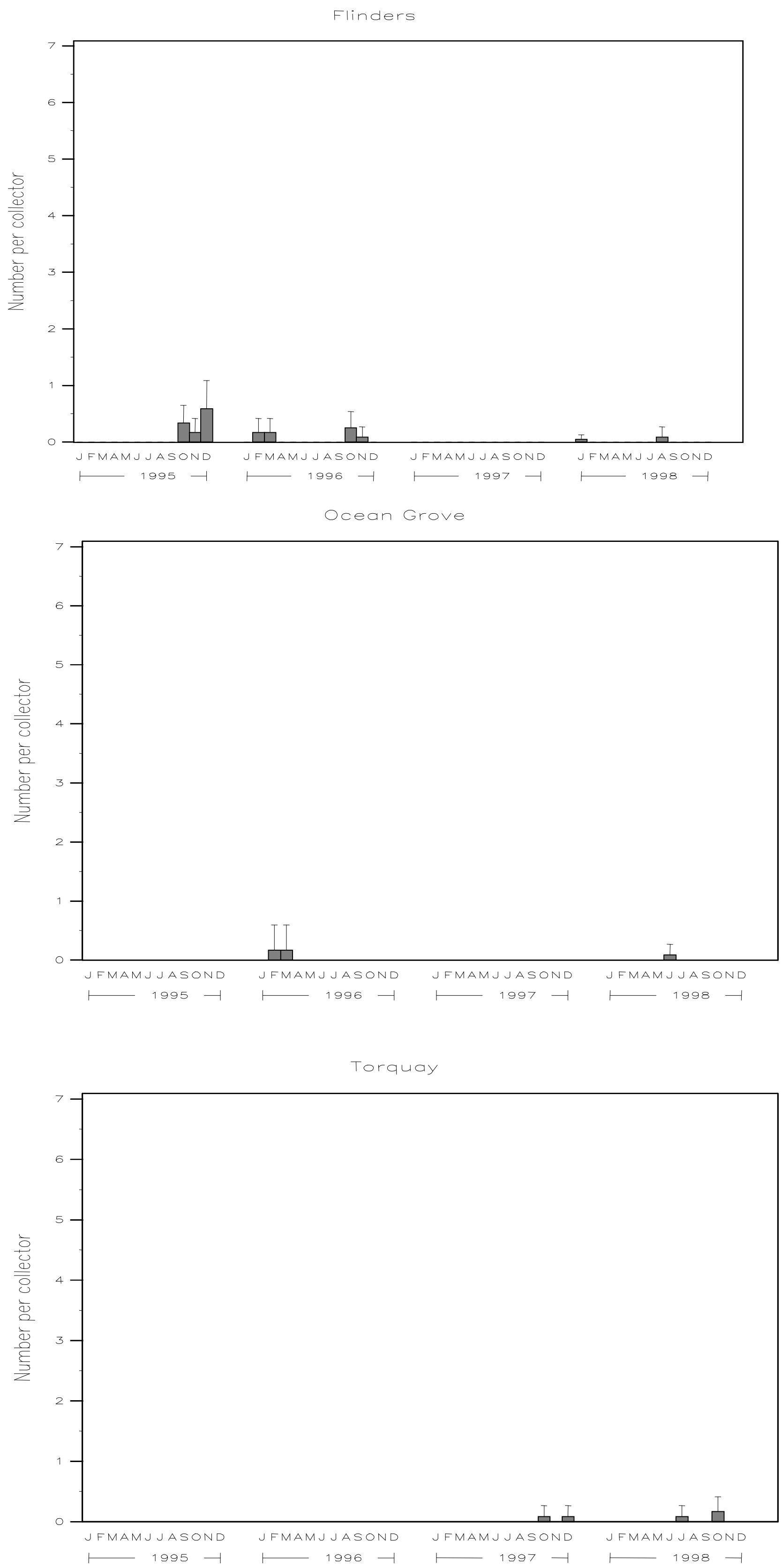


Figure 4. Mean number of pueruli per collector at Flinders (top), Ocean Grove (middle) and Torquay (bottom).

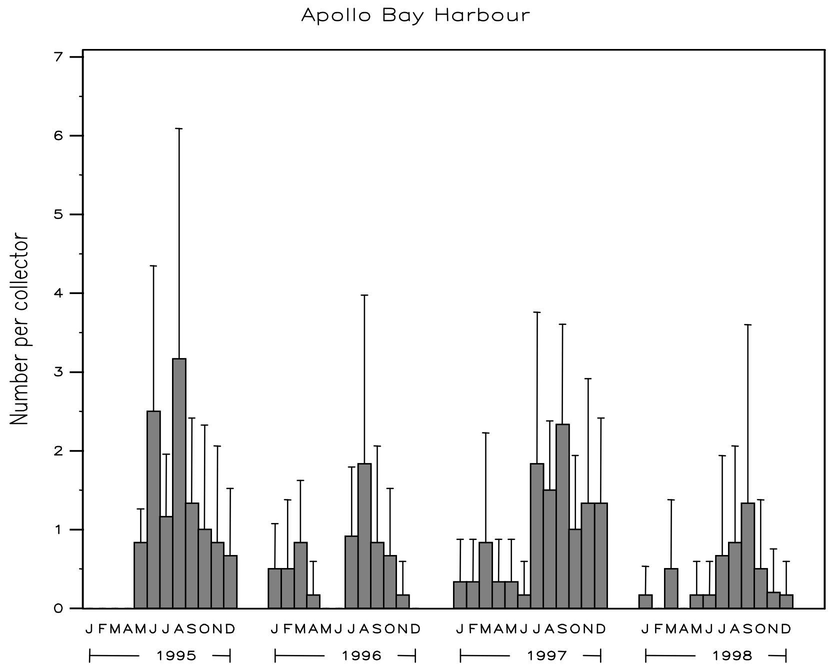


Figure 5. Mean number of pueruli per collector at Apollo Bay harbour.

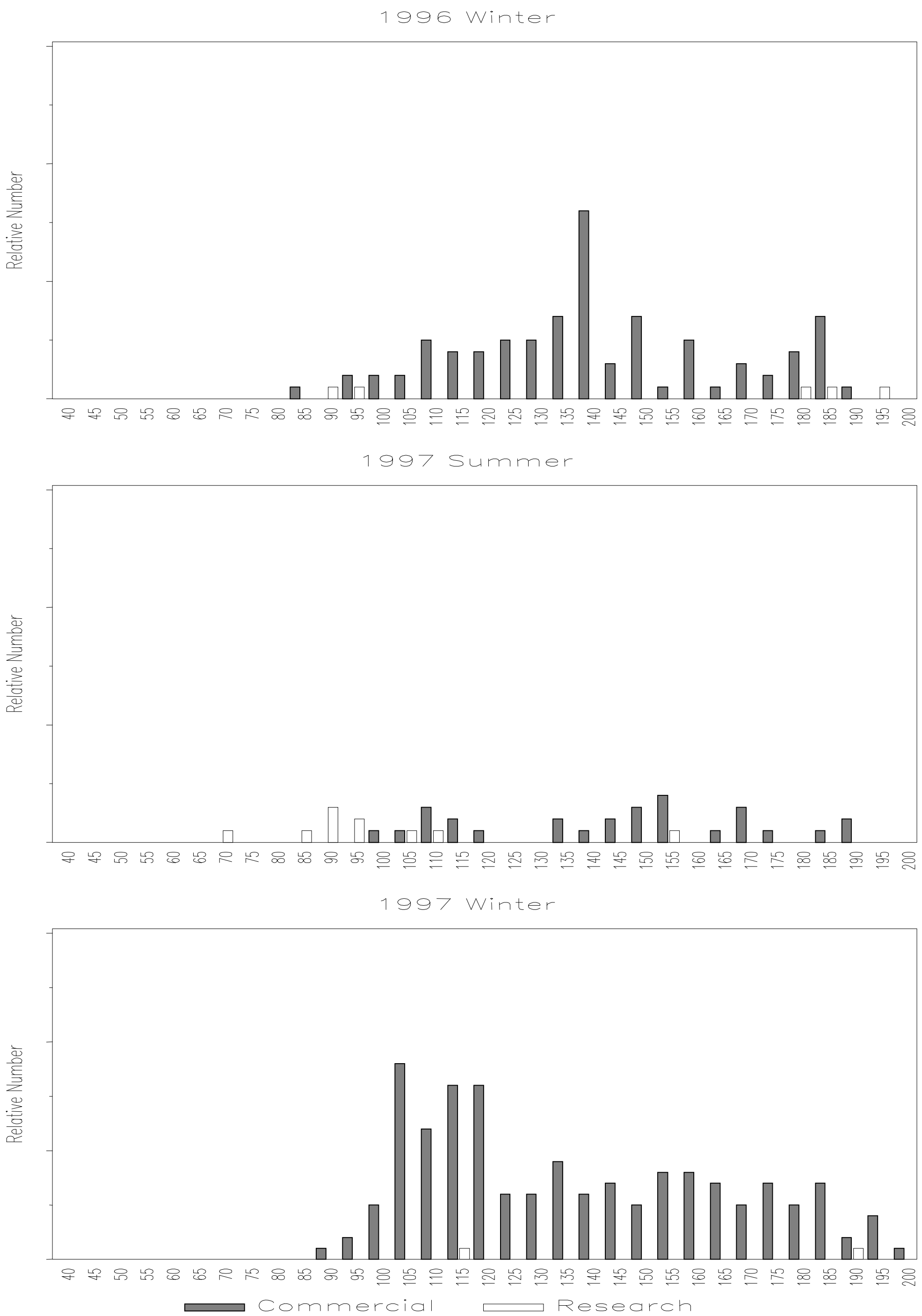


Figure 6. Length-frequency for male lobsters captured at Flinders.
(relative number used for confidentiality reasons)

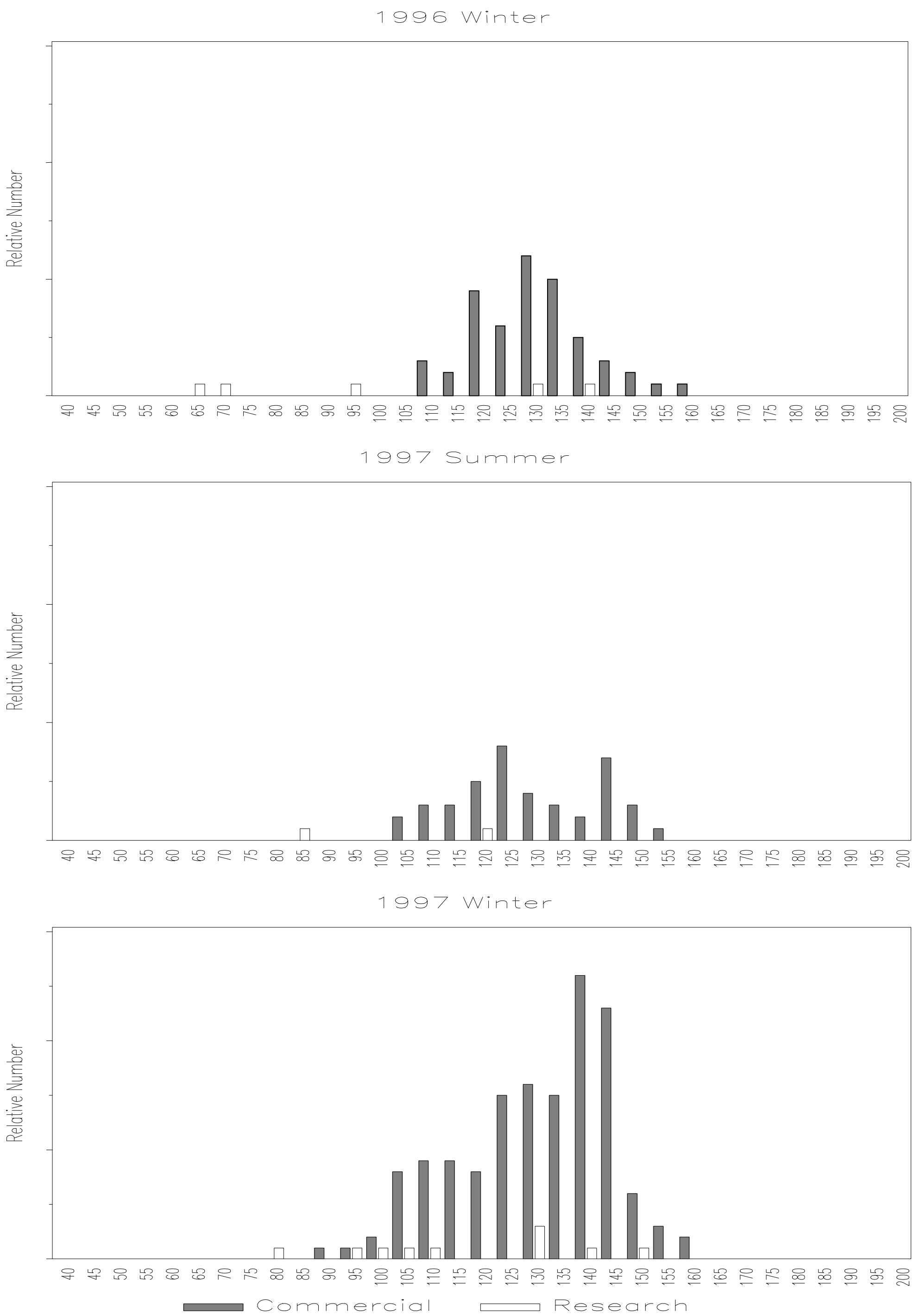


Figure 7. Length-frequency for female lobsters captured at Flinders. (relative number used for confidentiality reasons)

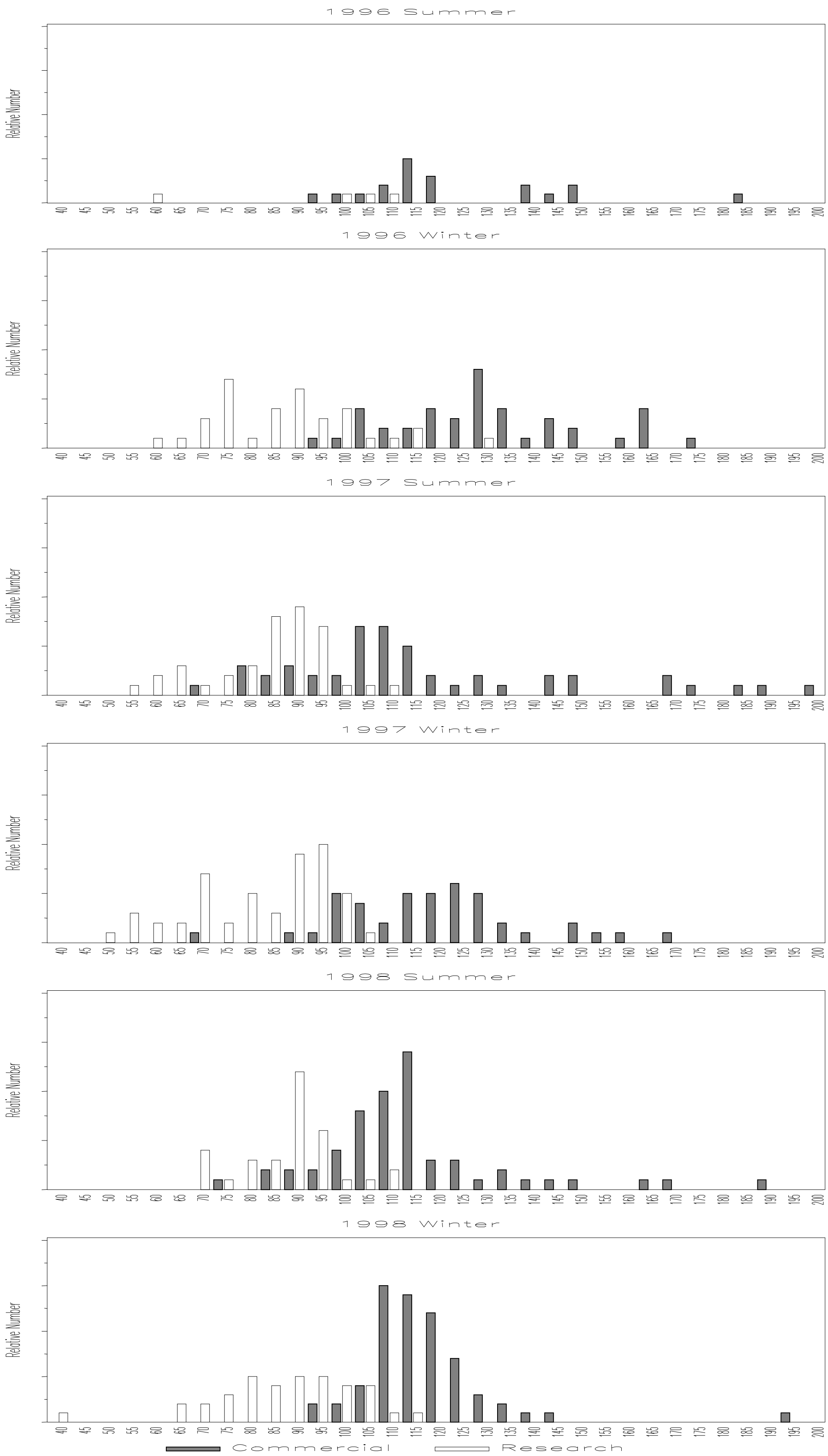


Figure 8. Length-frequency for male lobsters captured at Ocean Grove. (relative number used for confidentiality reasons)

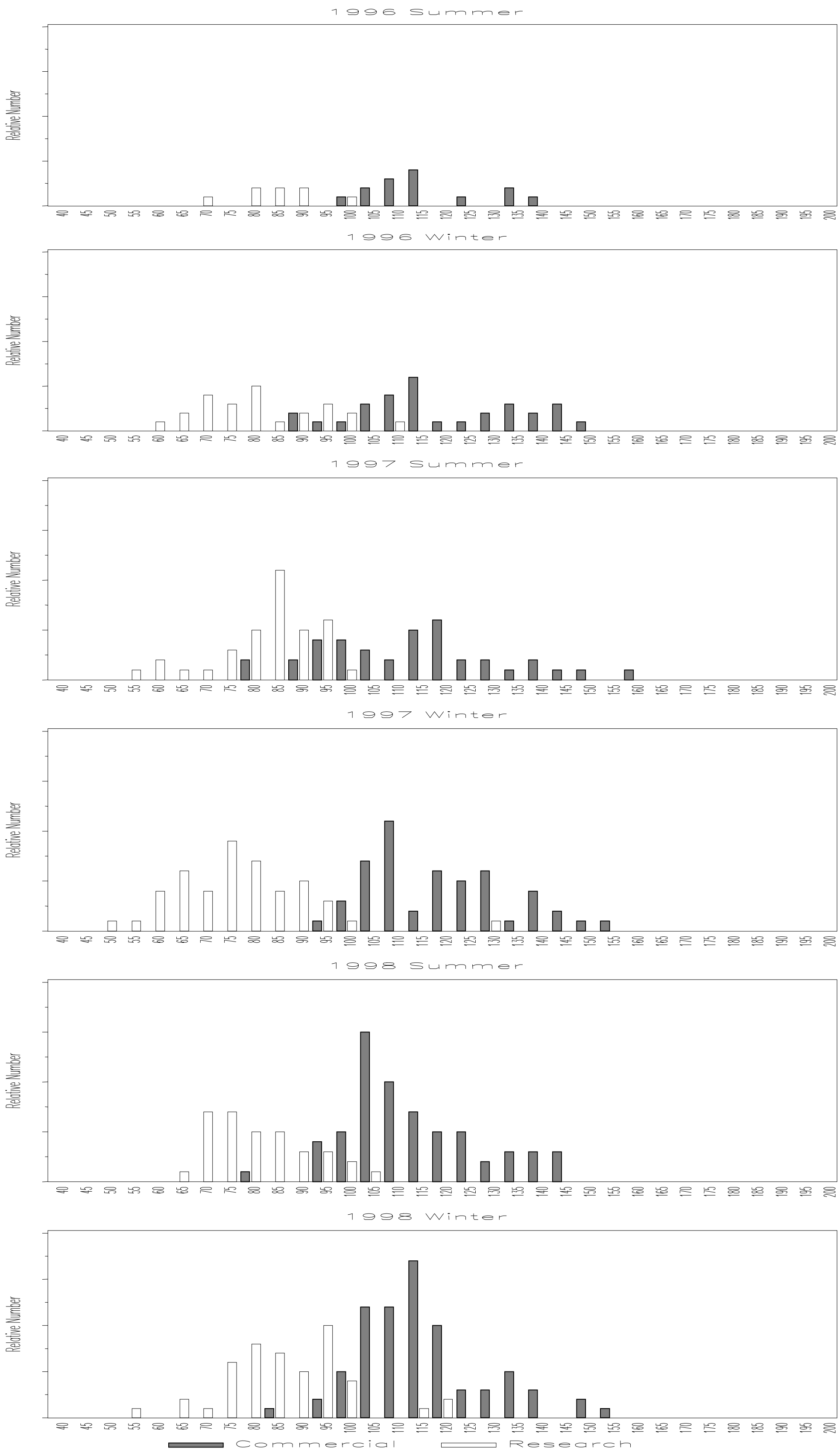


Figure 9. Length-frequency for female lobsters captured at Ocean Grove. (relative number used for confidentiality reasons)

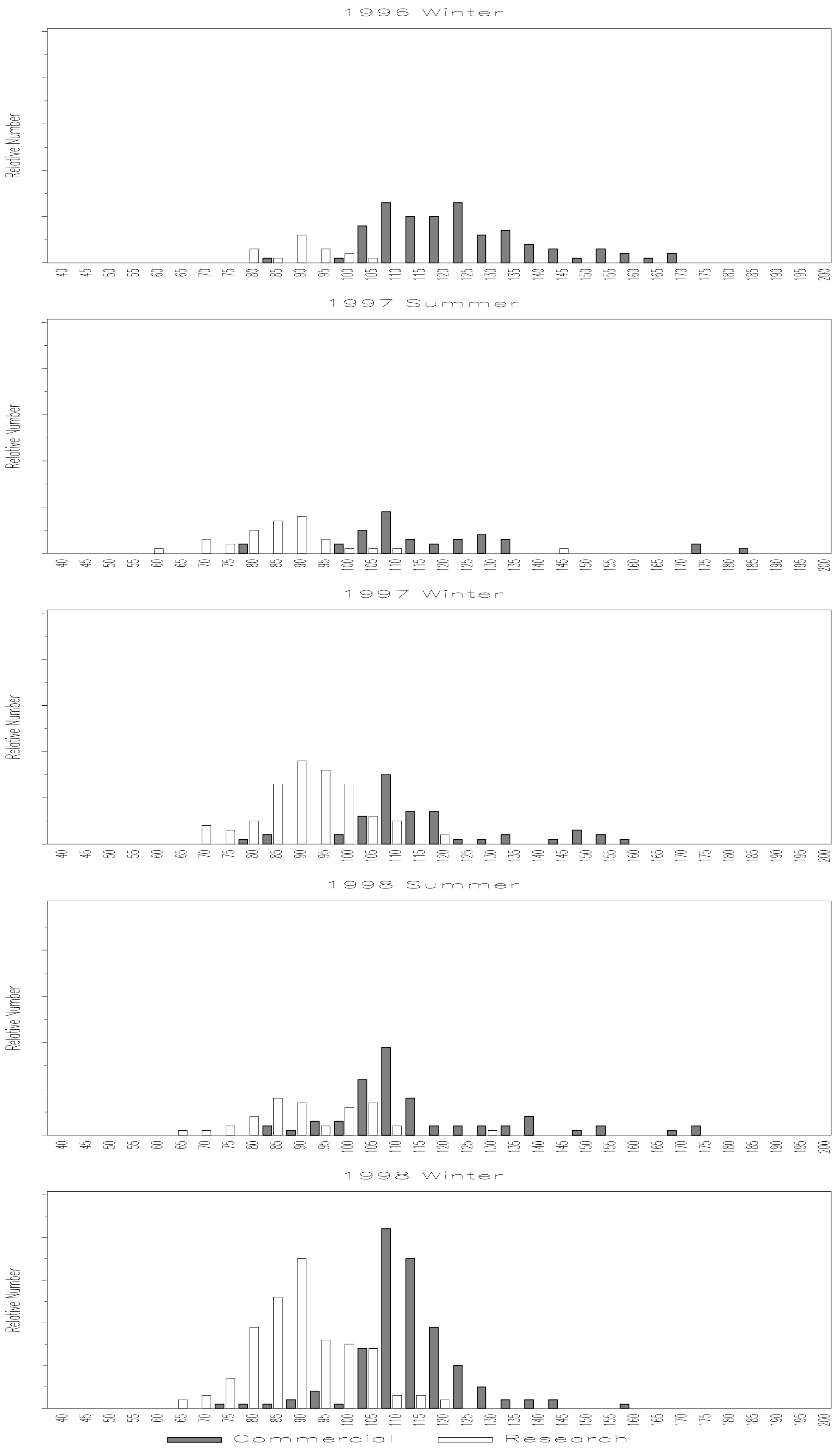


Figure 10. Length-frequency for male lobsters captured at Torquay. (relative number used for confidentiality reasons)

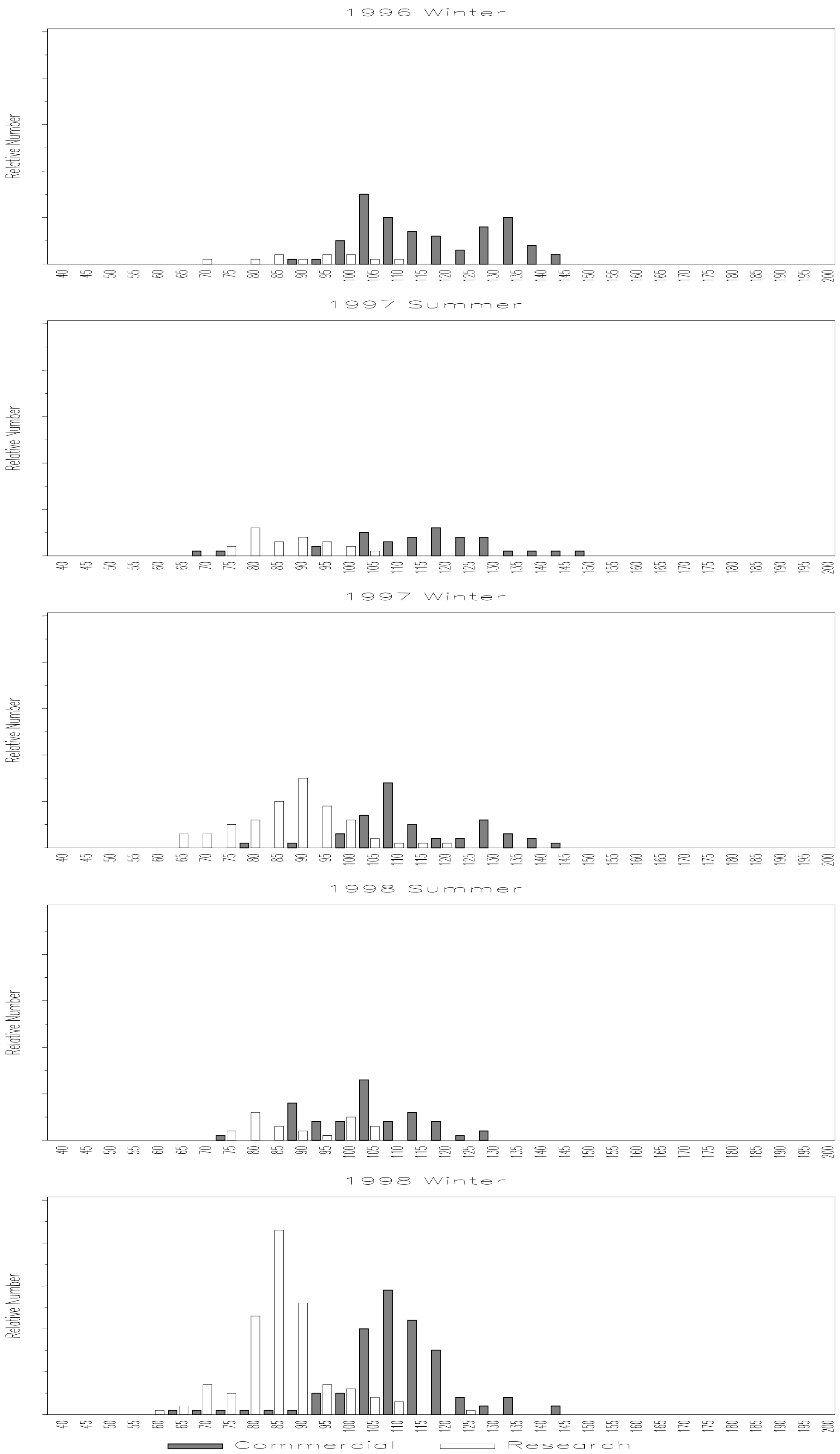


Figure 11. Length-frequency for female lobsters captured at Torquay. (relative number used for confidentiality reasons)

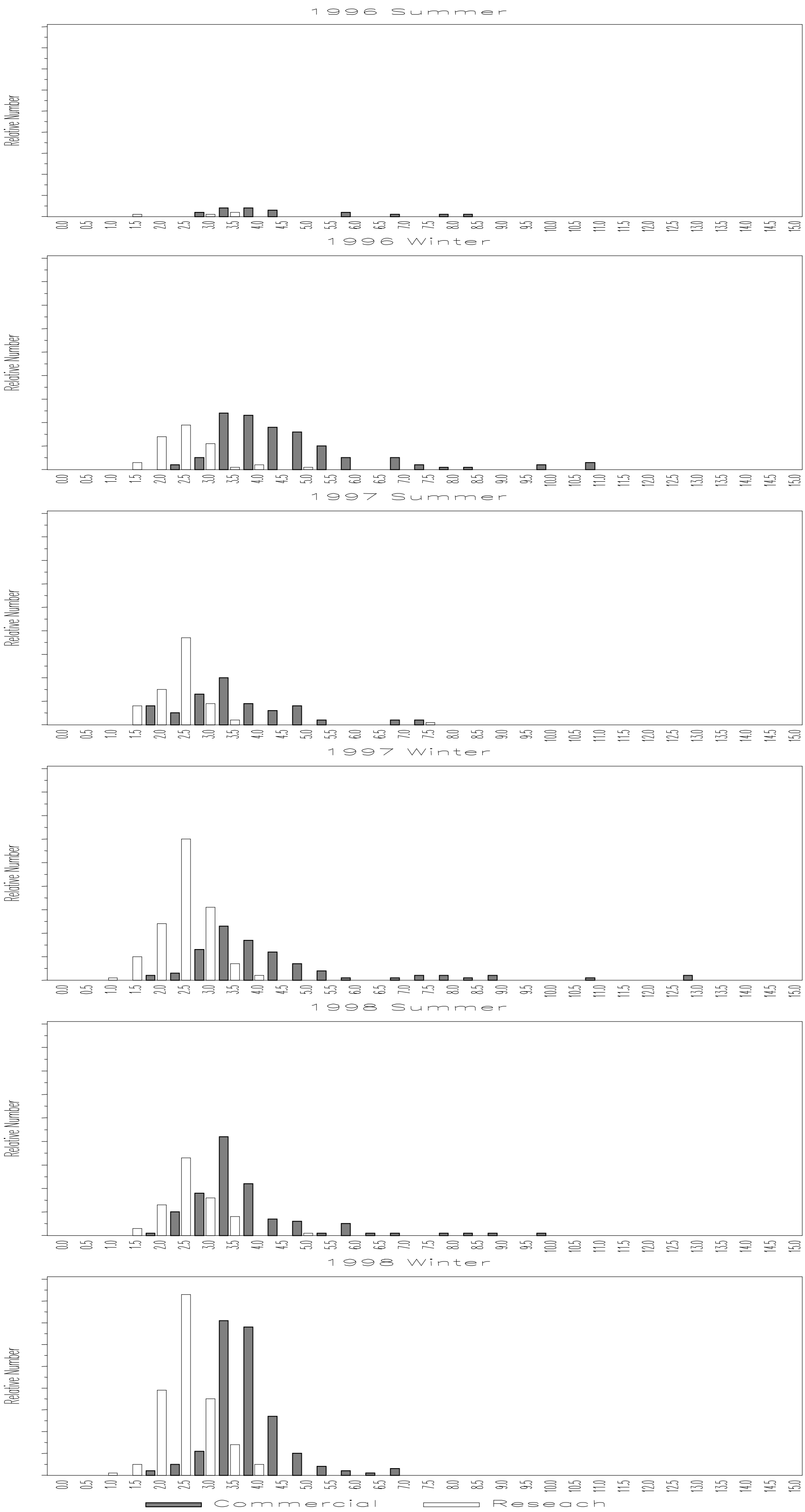


Figure 12. Relative age frequency for male lobsters captured at Ocean Grove / Torquay. (relative number used for confidentiality reasons)

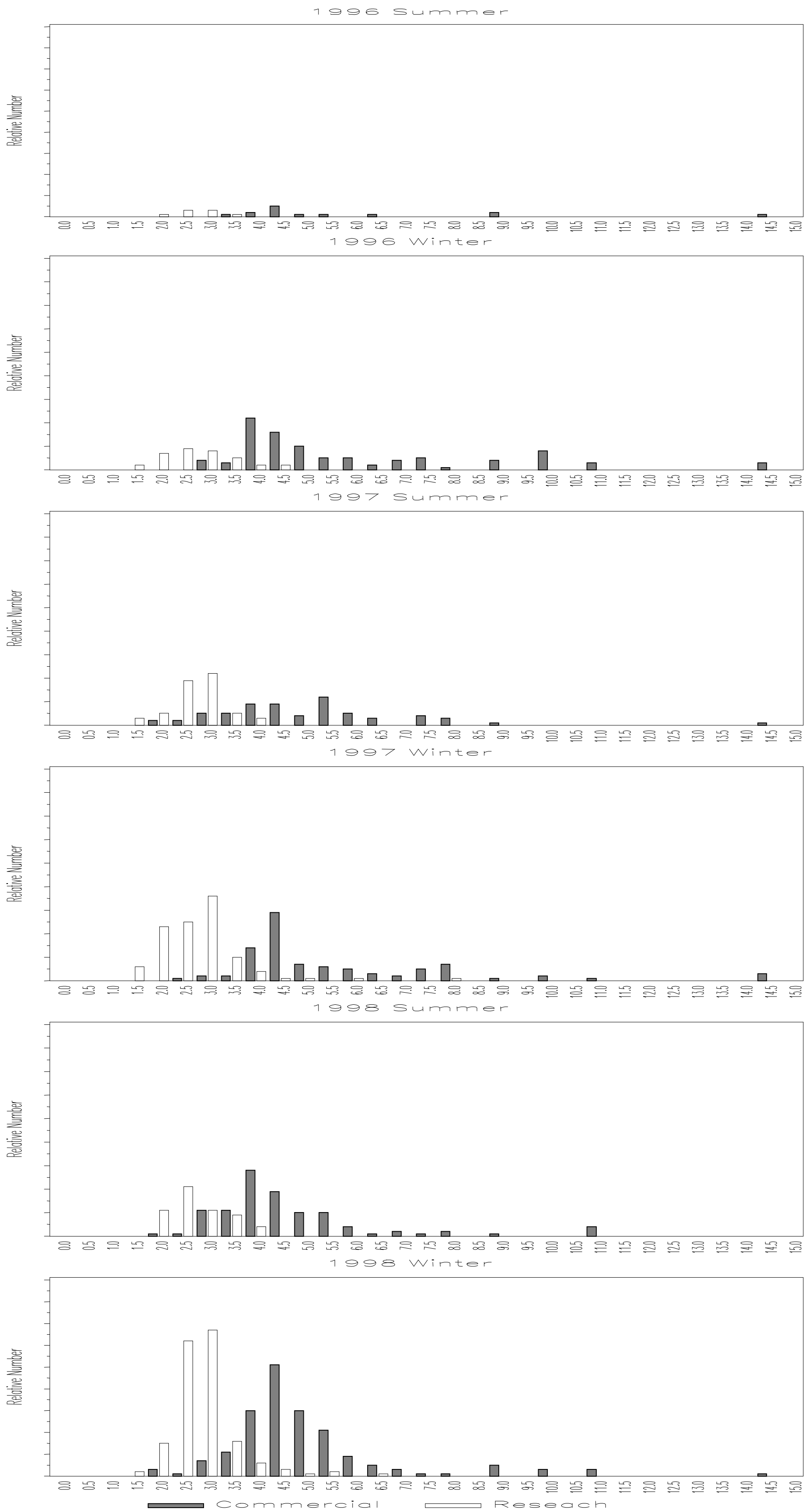
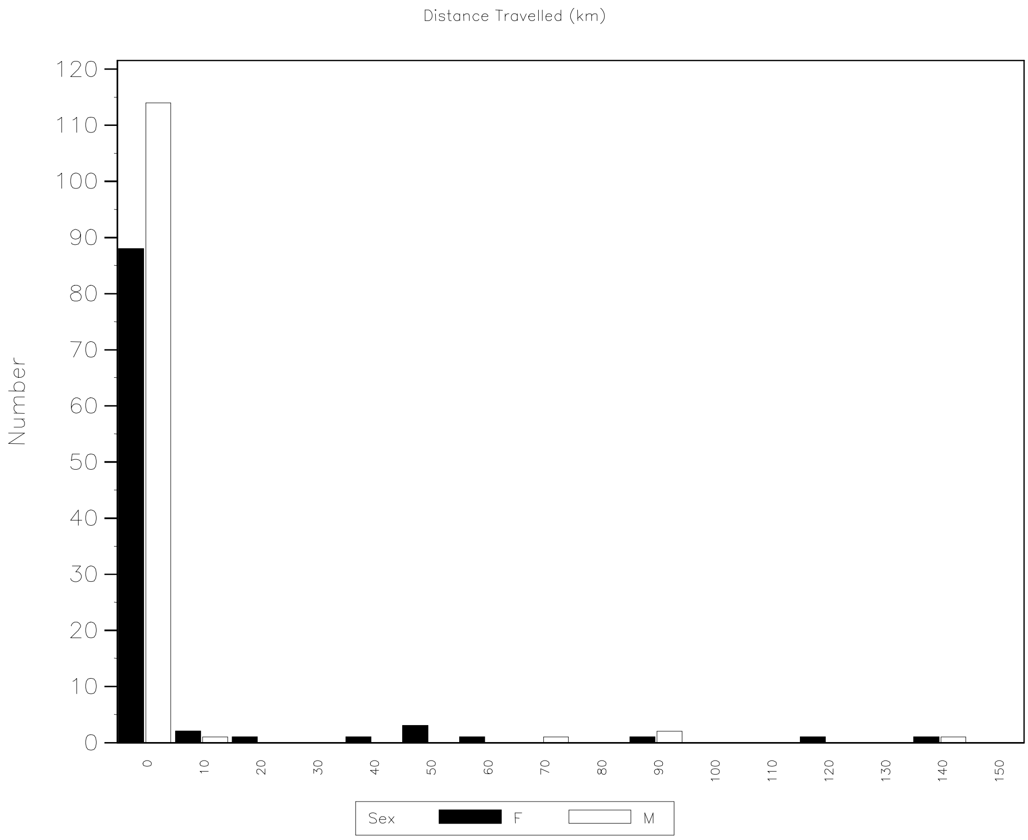


Figure 13. Relative age frequency for female lobsters captured at Ocean Grove / Torquay. (relative number used for confidentiality reasons)



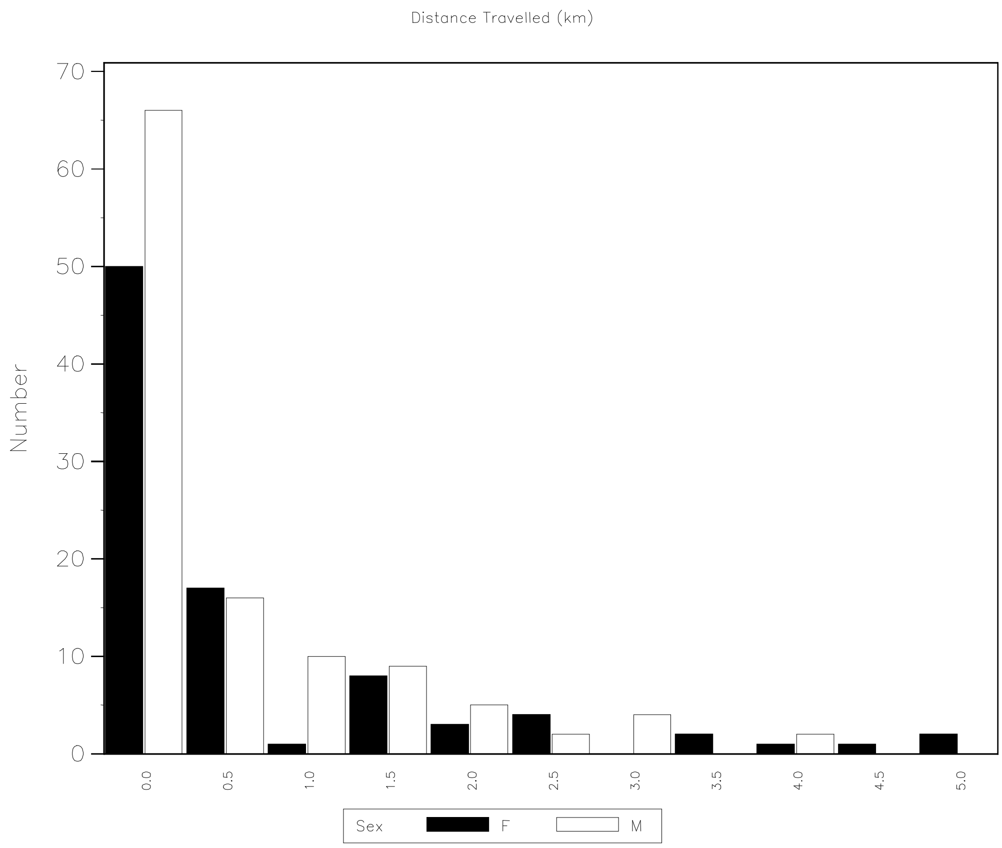


Figure 14. Distance moved between tag release and recapture positions for 0-150 km (top) and 0-5 km (bottom).

Female Tag Recaptures — Flinders

Male Tag Recaptures — Flinders

Figure 15. Movement of tag recaptures for Flinders study area releases for females (top) and males (bottom).

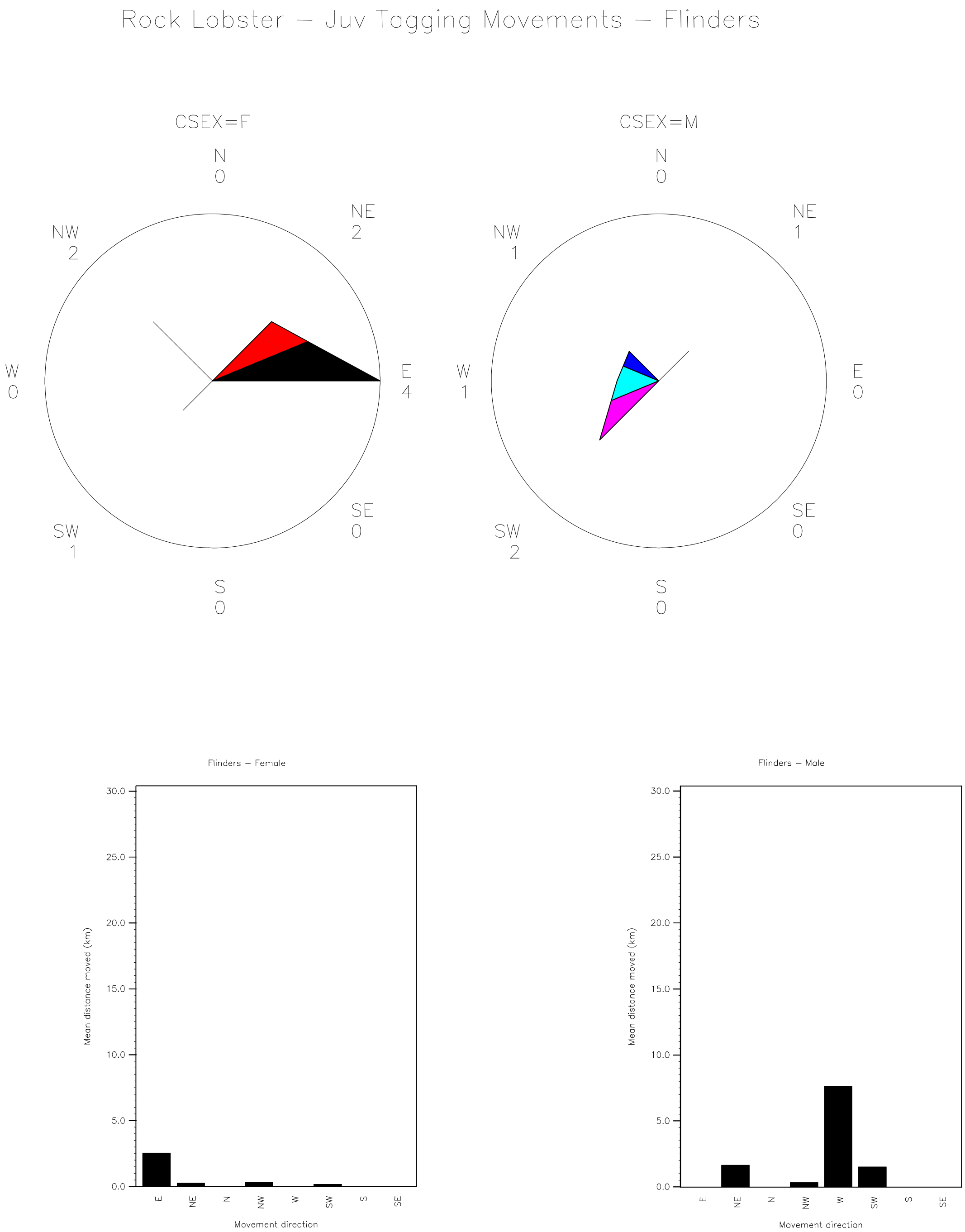
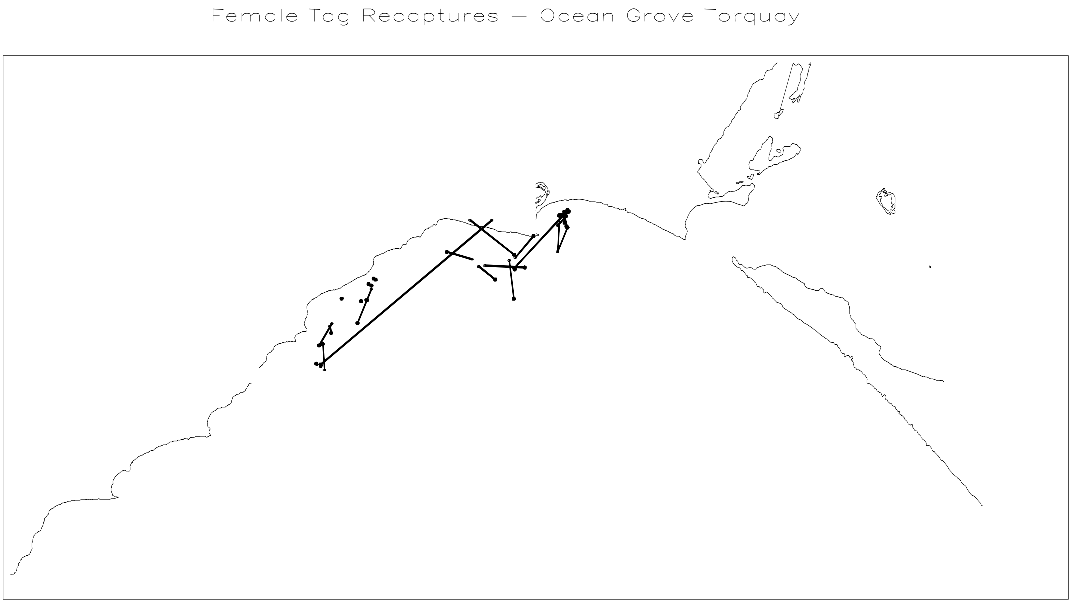


Figure 16. Movement direction frequency (top) and mean distance travelled (bottom) for Flinders recaptures for females (left) and males (right).



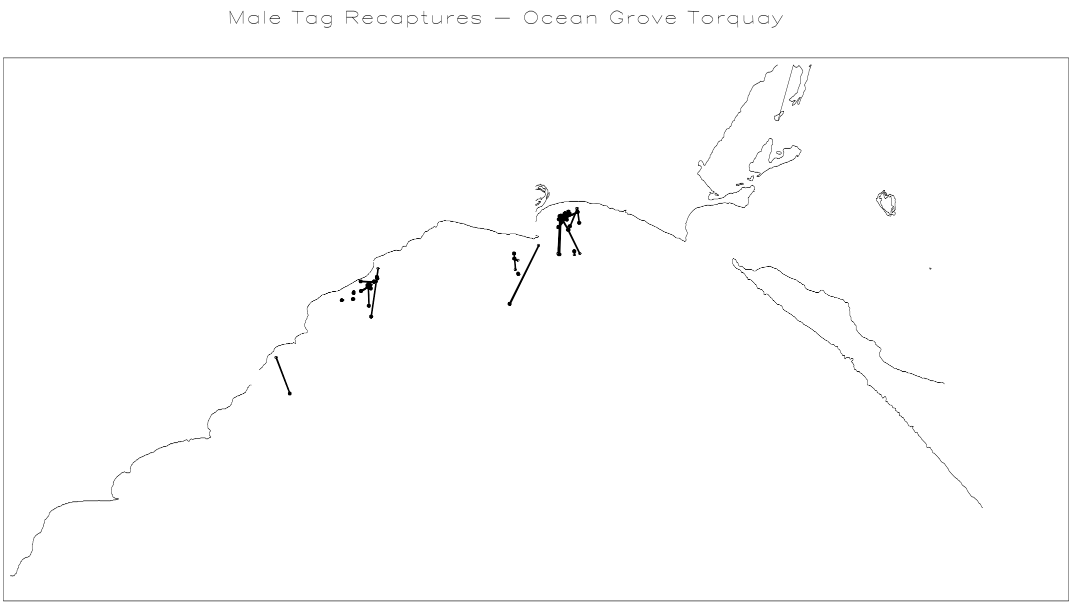


Figure 17. Movement of tag recaptures for Ocean Grove / Torquay study area releases for females (top) and males (bottom).

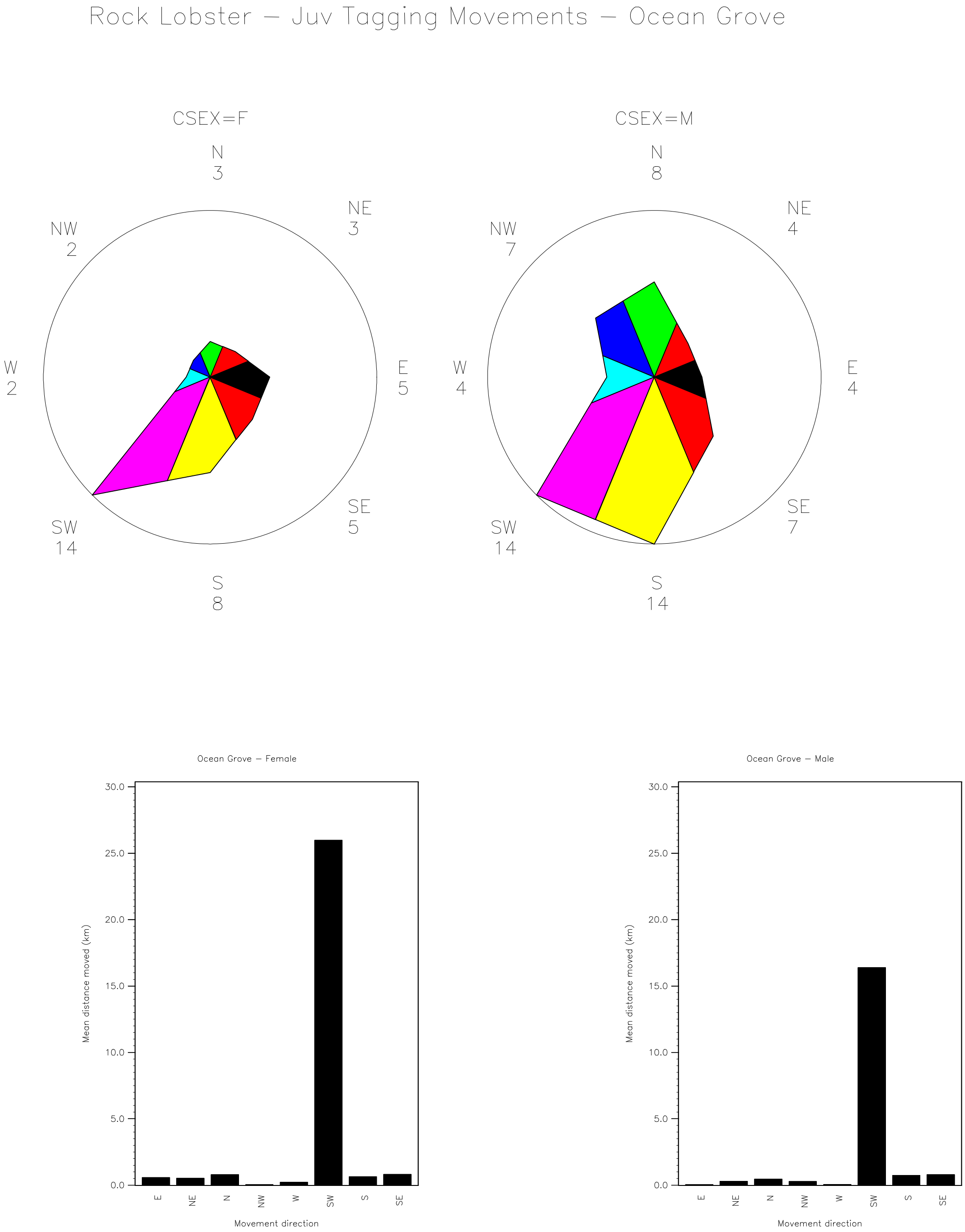


Figure 18. Movement direction frequency (top) and mean distance travelled (bottom) for Ocean Grove recaptures for females (left) and males (right).

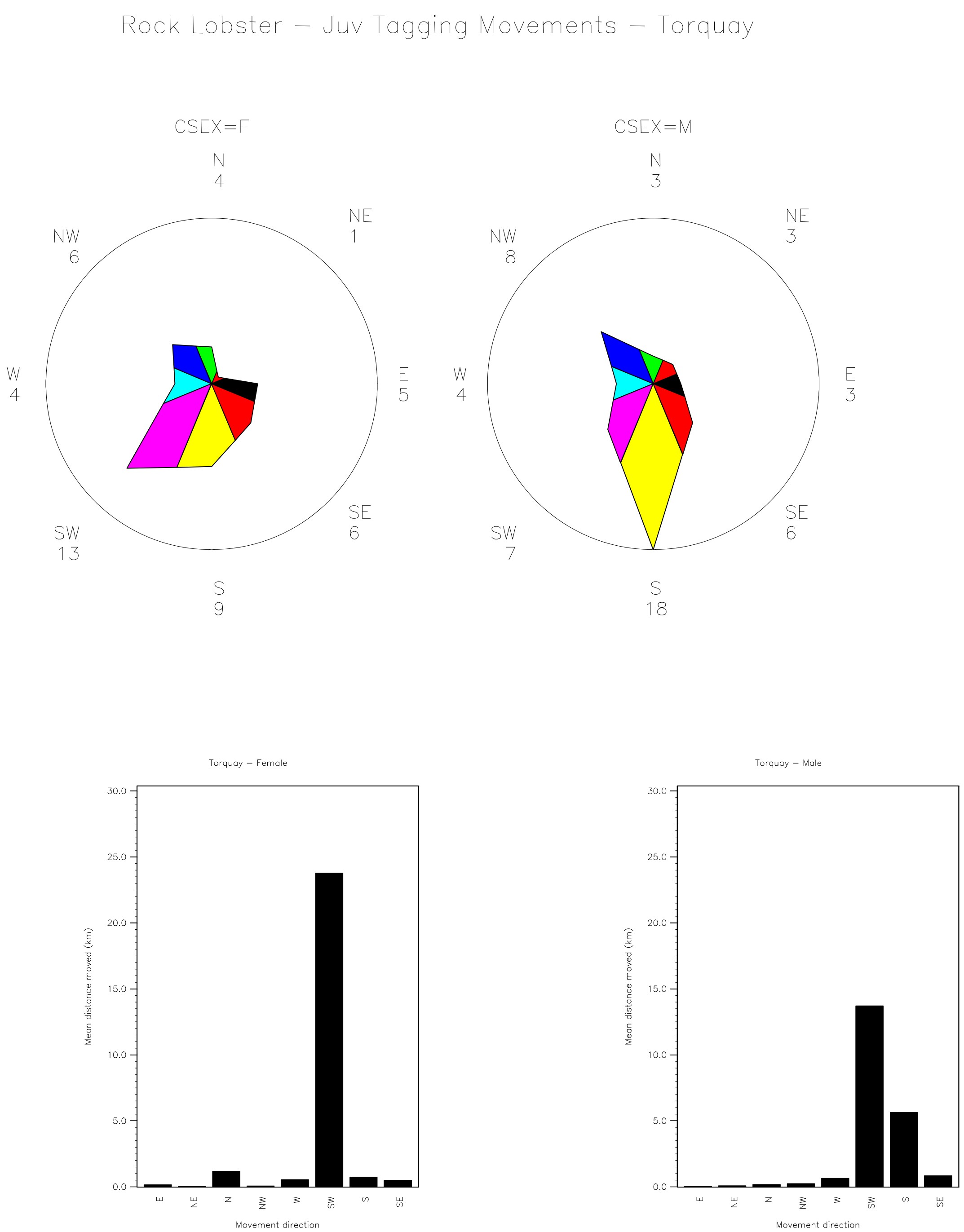


Figure 19. Movement direction frequency (top) and mean distance travelled (bottom) for Torquay recaptures for females (left) and males (right).

Female Tag Recaptures

Male Tag Recaptures

Figure 20. Large movement recaptures of female (top) and male (bottom).

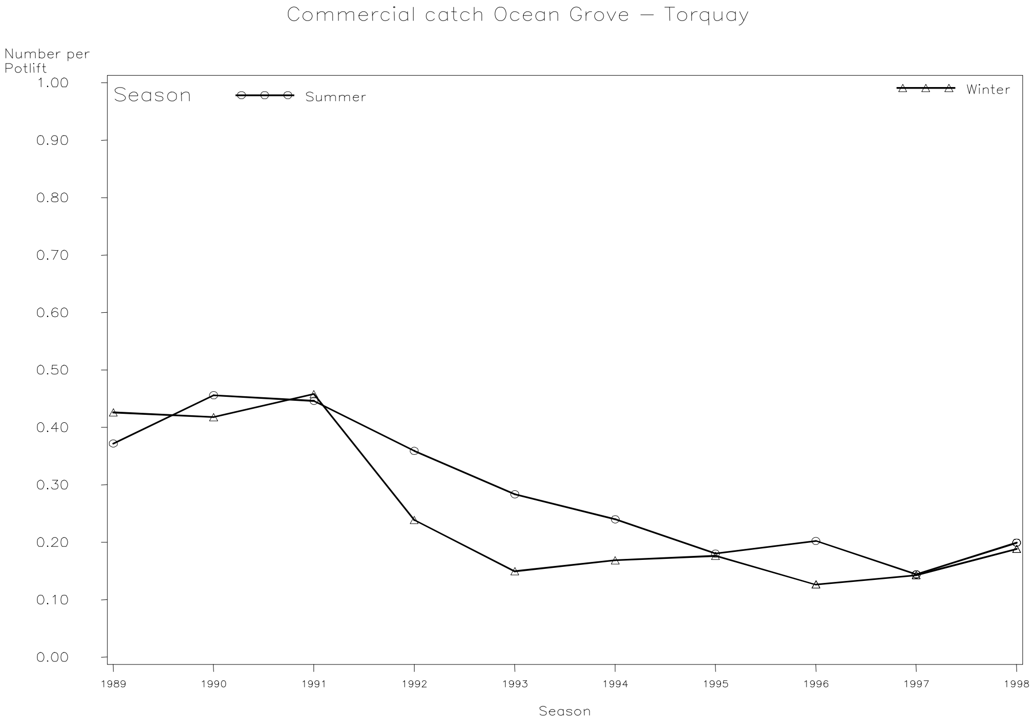


Figure 21. Commercial catch rates (number of lobsters/potlift) for summer and winter for Ocean Grove / Torquay (Catch and Effort reporting areas 21-23).

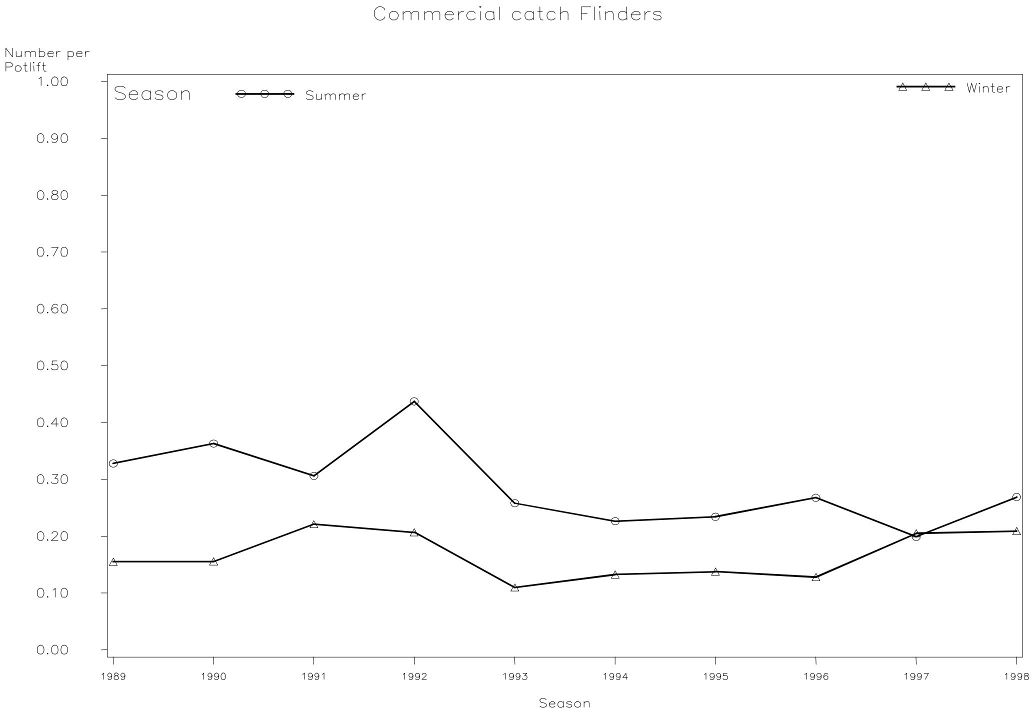


Figure 22. Commercial catch rates (number of lobsters/potlift) for summer and winter for Flinders (Catch and Effort reporting areas 25,26).

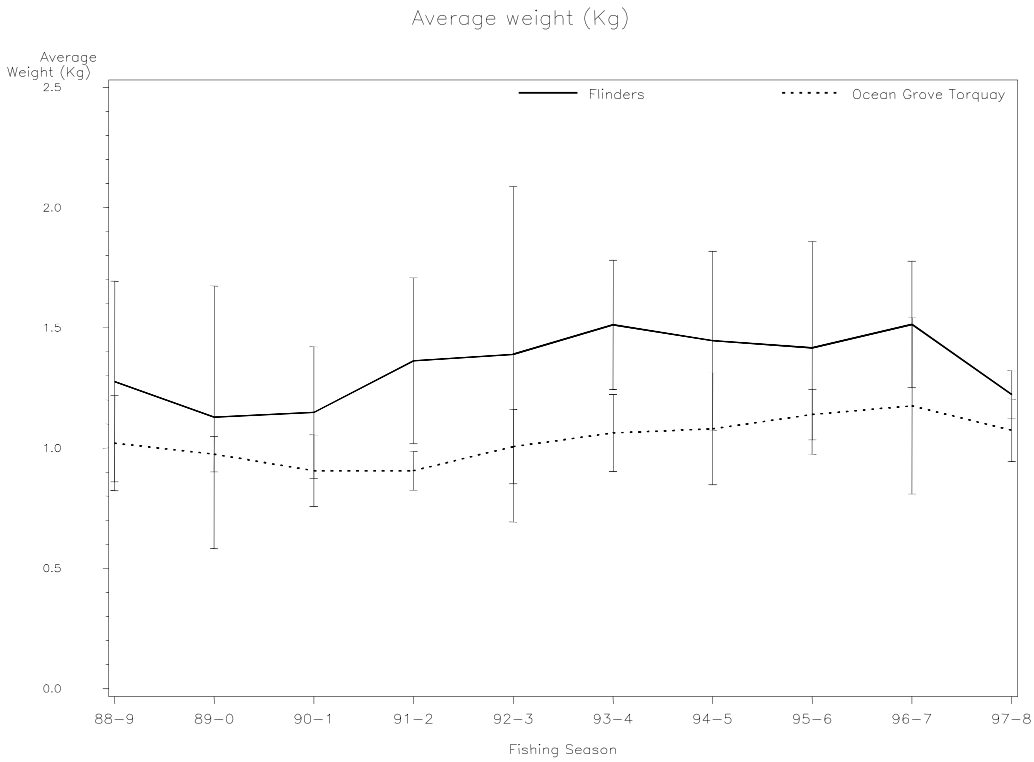


Figure 23. Average weight from commercial catch data for Ocean Grove/Torquay and Flinders.

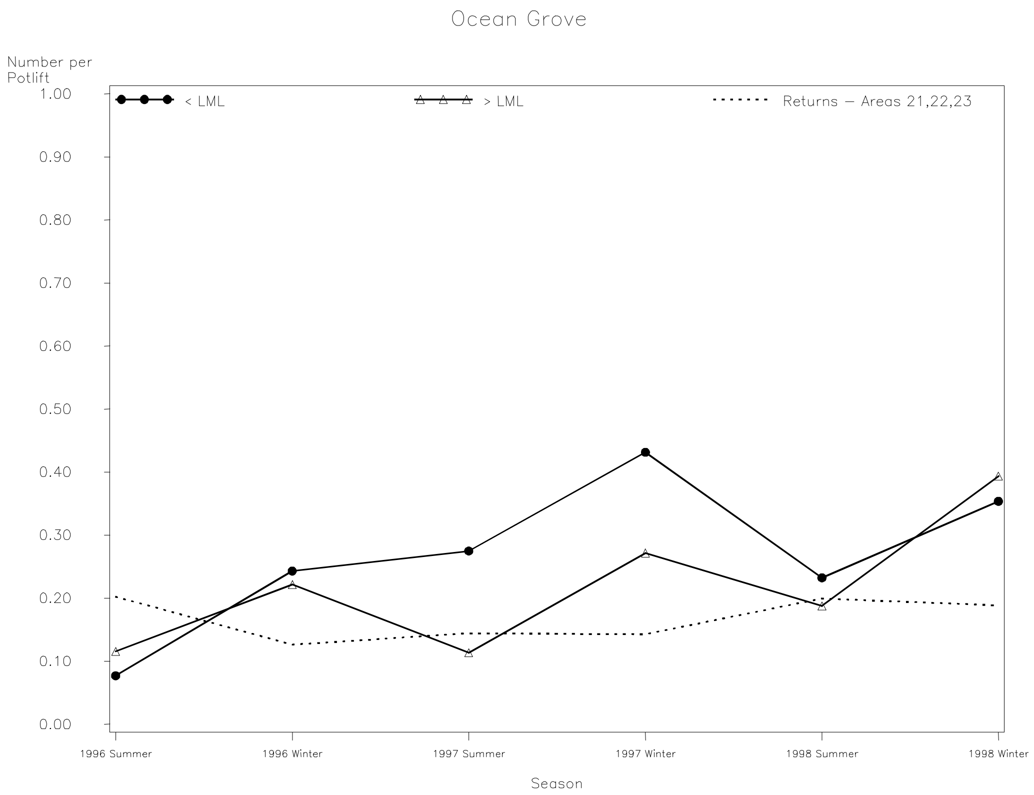


Figure 24. Catch rates from research and commercial fishing at Ocean Grove during the study for lobsters above and below legal minimum length (LML) and from commercial catch return data for the same period.

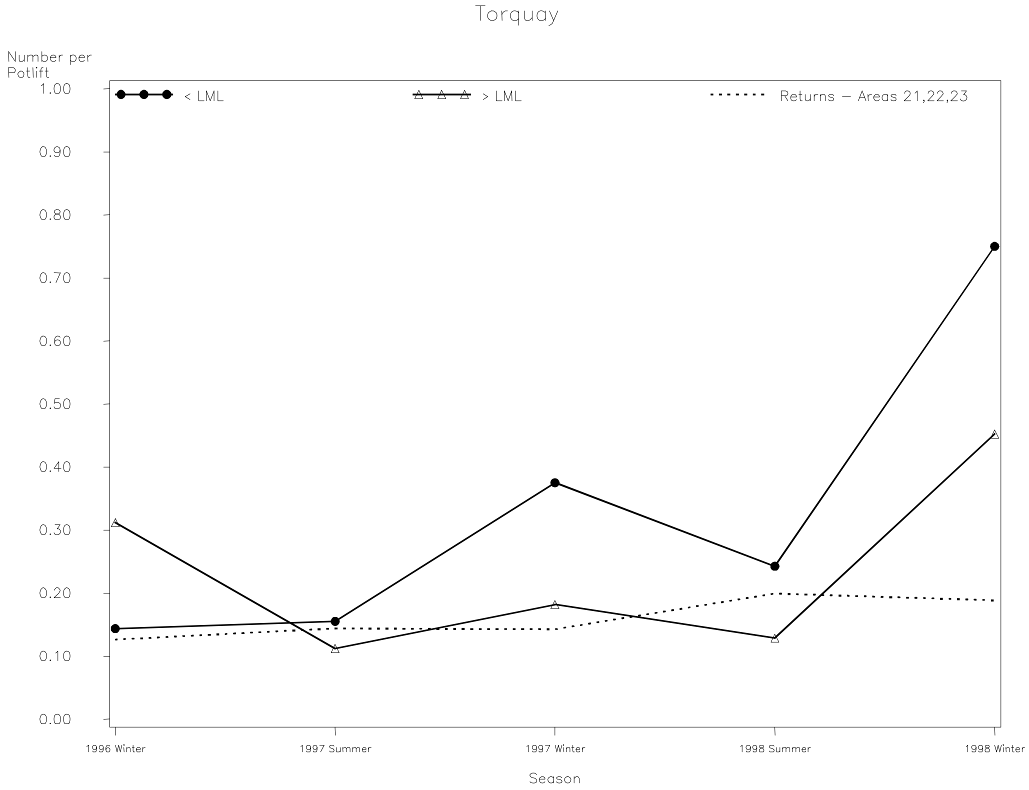


Figure 25. Catch rates from research and commercial fishing at Torquay during the study for lobsters above and below legal minimum length (LML) and from commercial catch return data for the same period.

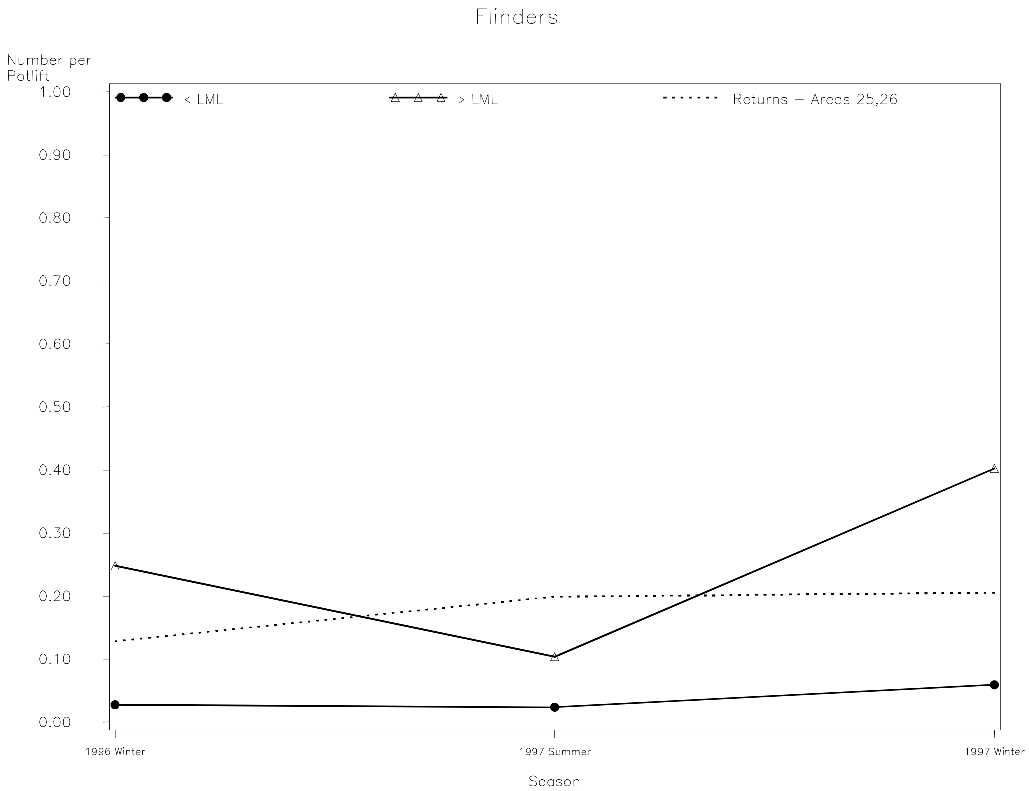


Figure 26. Catch rates from research and commercial fishing at Flinders during the study for lobsters above and below legal minimum length (LML) and from commercial catch return data for the same period.