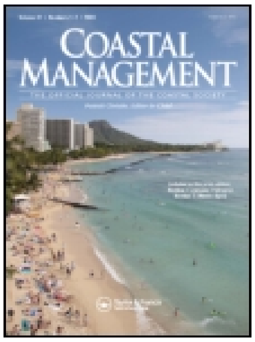

Coastal Management

ISSN: 0892-0753 (Print) 1521-0421 (Online) Journal homepage: https://www.tandfonline.com/loi/ucmg20

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To cite this article: S. Kelly , D. Scott & A. B. MacDiarmid (2002) The Value of a Spillover Fishery for Spiny Lobsters Around a Marine Reserve in Northern New Zealand, Coastal Management, 30:2, 153-166, DOI: 10.1080/089207502753504689

To link to this article: https://doi.org/10.1080/089207502753504689

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Coastal Management, 30:153–166, 2002
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The Value of a Spillover Fishery for Spiny Lobsters Around a Marine Reserve in Northern New Zealand

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The contribution that Leigh Marine Reserve in northern New Zealand makes to the local spiny lobster fishery was examined by comparing the catch characteristics of Jasus edwardsii *around the reserve boundary with those from Coastal Leigh, 0.3–2 km from the reserve, and Little Barrier Island, 22–30 km from the reserve. Seasonal trends were apparent in the reserve catch characteristics, consistent with lobster movements into and out of offshore fishing areas adjacent to the boundary. No significant difference was detected in catch per unit effort (kg.trap haul^{-1}) among locations. However, the catch around the marine reserve consisted of fewer but larger lobsters than at Little Barrier Island, while the size and number of lobsters caught per trap haul at Coastal Leigh was intermediate between the other two locations. Catch rates around the reserve were more variable than at the other sites, but on average, the amount of money made per trap haul was similar to Little Barrier Island and Coastal Leigh.*

Keywords catch, fishing, lobster, marine reserve, spillover

We would like to thank the Department of Conservation for their generous assistance in funding this project. Further funding was provided by the Graduate Research in Industry Fellowship Scheme. This work could not have been carried out without the assistance of Dave Fisher, who permitted catch sampling on board his fishing vessel, "Torai." Leigh Fisheries also assisted by providing access to their records on catch prices. Finally, we would like to thank the staff, students, and volunteers of the Leigh Marine Laboratory for the facilities they provided and their ongoing support.

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A more precautionary approach to fisheries management is increasingly being advocated as a safeguard against uncertainty in fisheries stock assessments (Ludwig, Hilborn, & Walters, 1993, Lauck et al., 1998). Within this context, marine protected areas are being promoted as an alternative or complimentary strategy for the management of marine resources (Ballantine, 1997; Allison, Lubchenco, & Carr, 1998). The potential advantages of marine reserves over other methods of fisheries management have been extensively reviewed (e.g., Attwood, Harris, & Williams, 1997), and although fishers may agree with the general concept of protected areas, opposition is still encountered whenever a specific reserve is proposed (Cocklin, Craw, & McAuley, 1998). Much of this objection stems from concern about losing spatial access to fishing grounds and hence to fish.

In New Zealand, the rock lobster (*Jasus edwardsii*) fishing industry openly opposes the establishment of marine reserves because of the possible impact reduced spatial access will have on catch rates (Sykes, 1996). However, under some circumstances it is theoretically possible for catch rates of mobile species to be maintained by animals moving out of the protected area and into the fishery (Polacheck, 1990). In most cases modeling suggests that marine reserves will lead to a reduction in yield per recruit, but a combination of moderate rates of movement and high fishing mortality may result in little, if any, loss in yield, or even slight increases (Polacheck, 1990). However, very few studies have directly examined the impact of marine reserves on the adjacent fisheries (Alcala & Russ, 1990; McClanahan & Kaunda-Arara, 1996).

This study examines how the Leigh Marine Reserve in northeast New Zealand has affected lobster catches in the adjacent fishery. Catch characteristics adjacent to the reserve were compared with those from two nearby localities and related to seasonal variations in the behavior of *J. edwardsii*. Inshore reefs within the marine reserve cannot be fished, but traps are placed along the seaward boundary and, to a lesser extent, in shallow areas at either end of the reserve. In unprotected areas there are no restrictions on where traps can be set, and both inshore and offshore areas are extensively fished. Effectively, this means that around marine reserves lobster fishers are more reliant on animals moving out from coastal reefs and into the areas where they set their traps.

Offshore movements undertaken by *J. edwardsii* are highly seasonal and associated with reproduction, molting, and foraging (Kelly, 2001). During the mating and female molting season, which in northeast New Zealand is concentrated between April and June, both male and female *J. edwardsii* accumulate on inshore reefs (MacDiarmid, 1991). Females mate within 40 days of molting and soon after extrude a brood of eggs that is carried externally for around 4 months before they hatch between September and October (MacDiarmid, 1989). Following mating, large numbers of male lobsters move offshore and aggregate in areas of sand and patch reef (Kelly, MacDiarmid, & Babcock, 1999). The timing of offshore movement is coincident with winter peaks in the feeding rates of captive males, suggesting that these movements are associated with elevated foraging. Mature males return inshore from mid-August onward and accumulate on shallow reefs, where molting takes place in October–November. Consequently, their dominance in offshore locations declines and they are replaced by females, which move offshore prior to larval release. Between September and October, females completely dominate offshore aggregations, but they return inshore after larval release and are replaced by males, which move offshore again after ecdysis. Catch characteristics around the Leigh Marine Reserve were therefore expected to be influenced by the behavior of the species to a greater extent than in the unprotected sites, and in particular to reflect seasonal variations in the movement and foraging characteristics of various population components (Kelly, 2001).

Methods

Catch sampling of a commercial fisher was conducted in three areas between 1995 and 1997. The areas sampled were (a) the boundary of the Leigh Marine Reserve (174° 47' E, 36° 16' S); (b) Coastal Leigh, 0.3 to 2 km south of the reserve; and (c) Little Barrier Island, 22 to 30 km east of the Reserve (Figure 1). The total length of coast fished at each site was 5 km, 1.7 km, and 19 km, for Leigh Marine Reserve, Coastal Leigh, and Little Barrier Island, respectively. Leigh Marine Reserve has been fully protected from all fishing activity since 1975, but commercial lobster fishing around the boundary of the reserve has occurred since the mid-1980s. The habitats found in the three areas sampled were similar, consisting of inshore areas of rocky reef surrounded by offshore sandflats with the occasional, isolated patch reef. However, apart from the small areas of coastal reef at either end of the Leigh Marine Reserve, access to inshore reefs was not available at this site. Traps around the reserve therefore tended to be set in offshore areas of sandflat and remote patch reef in about 25–35 m water depth. In contrast,

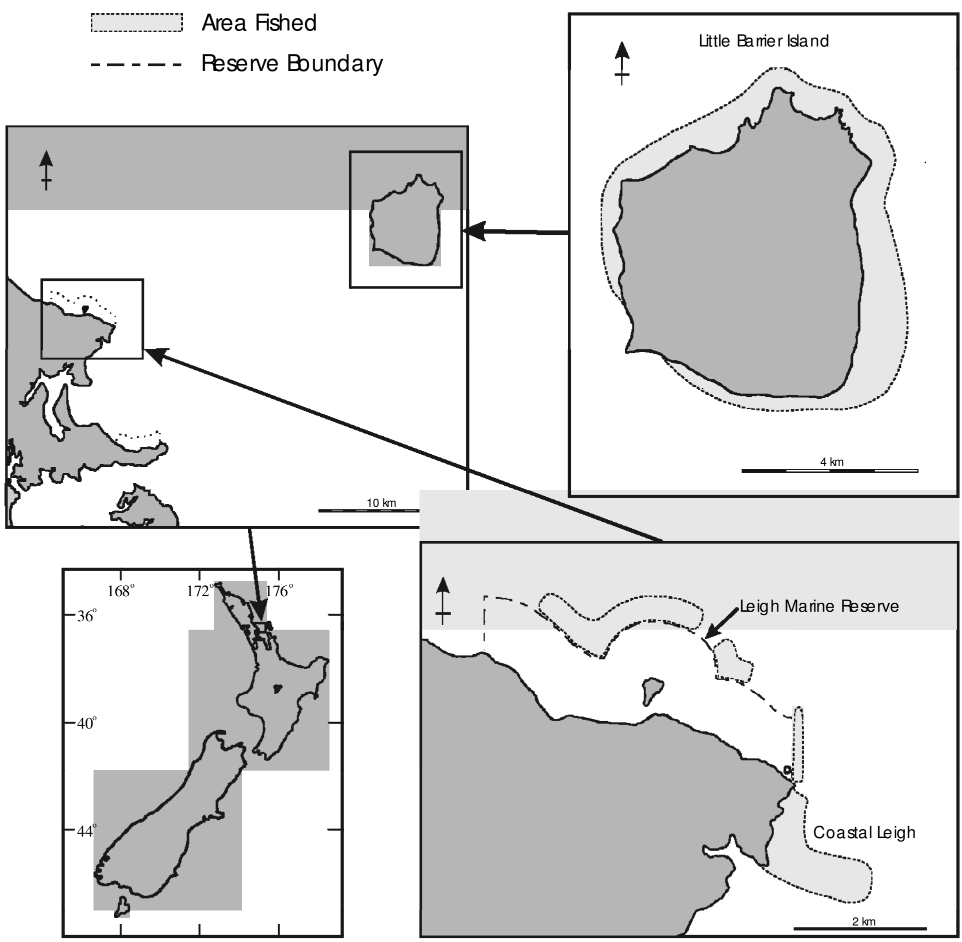

Figure 1. Map showing the areas where catch data were collected around the Leigh Marine Reserve and adjacent locations. The marine reserve boundary and total area fished at each location are also indicated.

around Little Barrier Island and Coastal Leigh, traps were predominantly set on coastal fringing reef at depths between 5 and 30 m.

Catch sampling was carried out on one of the 3 to 4 commercial lobster fishing vessels working in the Leigh area. During the fishing season an attempt was made to sample at least one trip per week. However, the number of days sampled, and the days sampling occurred each week, were essentially haphazard, depending on the amount of time available to go out on the boat, and which days the boat went out. The fisher was not directed on where fishing effort should be allocated.

Although there were no seasonal restrictions on when commercial fishing for lobsters can occur, fishing was concentrated over winter and spring, between May and November. Lobsters were caught with baited traps, which were constructed of untreated wood or steel rod, and covered with plastic mesh. Entry was through a hole in the top of the trap and legal-sized lobsters were prevented from escaping by a plastic entry funnel. Gaps at the bottom of the traps allowed the escape of undersize lobsters. Traps were hauled to the surface by a power winch where the lobsters were sorted, and the trap rebaited and returned to the water. Egg-bearing females and undersize [<50 mm tail width (~95 mm carapace length (C.L.))] for males and <54 mm tail width (~100 mm C.L.) for females) and dead lobsters were processed and returned to the sea; all other lobsters were retained.

The location of every trap, the size (mm C.L.) and sex of every lobster, the reproductive state of females, and the fate of every lobster (kept, returned) were recorded. Biomass was determined by converting length to weight after log-log transformation. Separate length-weight relationships were established for male and female lobsters (A. B. MacDiarmid, unpublished data). Occasionally lobsters could not be processed fast enough to keep up with the landing rate, so only sex data were collected. As a result, the sizes of 7% of lobsters were not measured. In these cases, size was assigned by random resampling, according to the sex of the lobster and the year and site it was obtained.

The revenue received from the catch was estimated by grading the lobsters according to criteria used by the export processors that received the lobsters. The average price paid over the fishing season for each grade of lobster was then used to estimate the dollar value of every lobster caught and retained in the catch.

Wave surge data for the reserve were obtained from meteorological data collected by the Leigh Marine Laboratory. Daily records are kept on swell amplitude, which is measured using a graduated scale marked on an exposed north-facing reef within the reserve.

Statistical Analyses

Data analyses to compare mean daily catch per unit effort (CPUE, kg.trap haul^{-1}) and the mean daily number of lobsters retained per trap haul were carried out by fitting linear models, using linear regression weighted by the number of trap hauls. A weighted analysis was used because estimates of mean CPUE (kg.trap haul^{-1}) and lobsters per trap haul were expected to improve as more traps were sampled. This expectation was supported by plots, which showed an inverse relationship between variability and the number of traps sampled. To deal with possible autocorrelation and seasonality, a sine and cosine term were fitted with a period of one year. The effect of fitting both a sine and cosine term was to incorporate a sinusoidal response with a period of one year and allow the phase of the sinusoid to be any value from 0 to 2π radians. Modeling was done by fitting predictors for location, year, wave surge with a two-day lag, all interactions, plus the sine and cosine terms, and then dropping nonsignificant terms. Linear model diagnostics were used to check the model assumptions. Plots of the residuals against fitted values, data against fitted values, normal quantile–quantile or q–q plots of residuals and the autocorrelation function of the residuals were used to check the assumption of normally distributed errors, to check for outliers, heteroscedasticity, or other problems. The value of the Akaike Information Criterion (AIC) was also considered to provide an objective means of determining the most appropriate model (Akaike, 1973). A model which has minimum AIC is considered optimal. Such a model represents a compromise between model fit and complexity. All modeling was carried out on the statistical software package SPLUS.

Results

Catch per Unit Effort

During the study a total of 802, 580, and 2387, trap hauls were sampled from the Leigh Marine Reserve, Coastal Leigh, and Little Barrier Island, respectively. The total catch obtained in each area by the fisher surveyed corresponded well with the total amount of fishing effort he exerted, although the allocation of effort was not necessarily proportional to the length of coast fished in any given year (Figure 2). Catch rates tended to increase throughout the fishing season from May to peak in September or October, and then decline (Figure 3). The increase in mean CPUE was most marked around the reserve, and this pattern was consistent for the three years that sampling took place. Catch per unit effort around Little Barrier Island followed a similar trajectory with variation of lower amplitude, but temporal trends at Coastal Leigh were less consistent. Catch rates were most variable around the reserve, and marked fluctuations in catch often occurred over relatively short periods. Overall, no lobsters were retained out of 65% of traps set around the reserve, compared with 55% at Coastal Leigh, and 45% at Little Barrier Island.

Highest daily catch rates (kg.trap haul^{-1}) were obtained from around the marine reserve where mean CPUE reached a maximum of 7.9 kg.trap haul^{-1}; however, overall catch rates for each site were relatively similar (Table 1). Linear modeling of the mean CPUE per day (weighted by the number of trap hauls) was used to test for differences between locations. The data were highly variable and contained obvious outliers. In order to obtain a fit that would satisfy the assumption of normally distributed residuals, three outlying observations had to be dropped. Although this was not ideal, it was considered preferable to having the results of the analysis dependent on a few extreme values, which can cause otherwise nonsignificant interactions to become highly significant. The choice of observations removed from the analysis was also rather subjective and needs to be considered when interpreting the results.

All three outliers dropped from the analysis represented exceptionally high catch rates of between 3.2 and 7.9 kg.trap haul^{-1}, obtained around the Leigh Marine Reserve: 2 in 1995 and 1 in 1996. With these data points removed, no significant difference in CPUE was detected between Leigh Marine Reserve, Little Barrier Island, or Coastal Leigh. However, CPUE varied significantly between years ($p < 0.0001$), and significant seasonal (indicated by a sine term in the model $p < 0.0001$) and wave surge ($p < 0.0001$) effects were detected, with high catch rates tending to be associated with high wave surge with a two-day lag (Figure 4). A significant wave surge by year interaction ($p = 0.0013$) indicated that the strength of the relationship between wave surge and CPUE varied among years.

The need to drop the marine reserve outliers from the CPUE analysis was unfortunate because the catch they represented made a substantial contribution to the overall revenue earned in 1995 and 1996. Total revenue earned on the days that sampling took

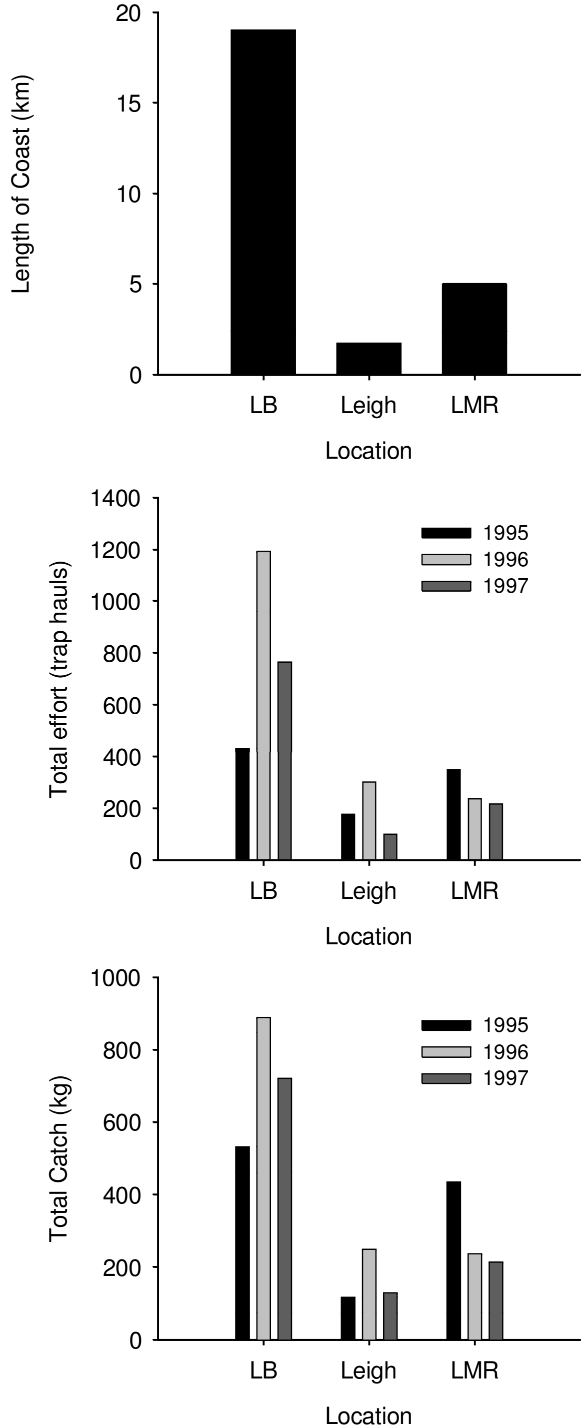

Figure 2. Length of coast fished, total fishing effort exerted by the fisher surveyed (trap hauls), and the total lobster catch of the fisher surveyed (kg) for Little Barrier Island (LB), Coastal Leigh (Leigh), and the Leigh Marine Reserve (LMR) between 1995 and 1997.

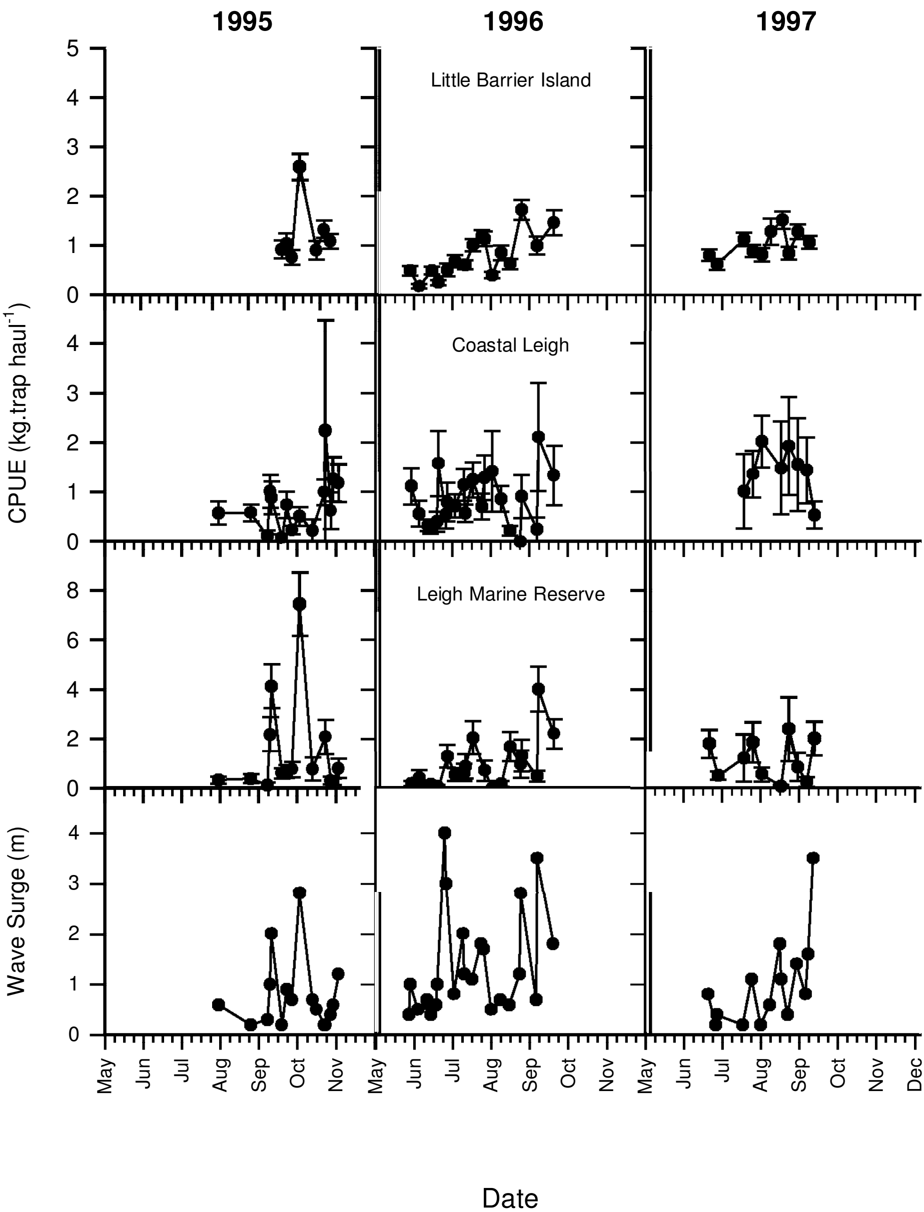

Figure 3. Catch per unit effort (CPUE) (kg.trap haul^{-1} + se) of retained lobsters around Little Barrier Island, Coastal Leigh, and Leigh Marine Reserve, and wave surge (m) data recorded at the Leigh Laboratory within the Leigh Marine Reserve. Data are presented for the three fishing seasons between 1995 and 1997.

place was estimated to be NZ$53,795 obtained from 950 trap hauls in 1995 and NZ$63,636 obtained from 1731 trap hauls in 1996. The estimated revenue earned from the two outliers dropped from the analysis in 1995 was NZ$11,612 from 42 trap hauls, or 21.6% of the total revenue for that year, and NZ$2,942 from 16 trap hauls, or 4.6% of the total revenue in 1996. Estimates of daily revenue displayed similar patterns to those of CPUE over the fishing season (Figure 4). Around Leigh Marine Reserve, periods of low or no returns were offset by days of high revenue, whereas around Little Barrier Island

Table 1
Overall CPUE [mean kg.trap haul^{-1} ($\pm$ se)] for Leigh Marine Reserve, Little Barrier Island, and Coastal Leigh between 1995 and 1997

	Leigh Marine Reserve	Little Barrier Island	Coastal Leigh
1995	1.252 (0.1571)	1.242 (0.0781)	0.654 (0.0753)
1996	1.002 (0.1257)	0.744 (0.0322)	0.825 (0.0854)
1997	1.081 (0.2115)	1.006 (0.0451)	1.421 (0.2670)

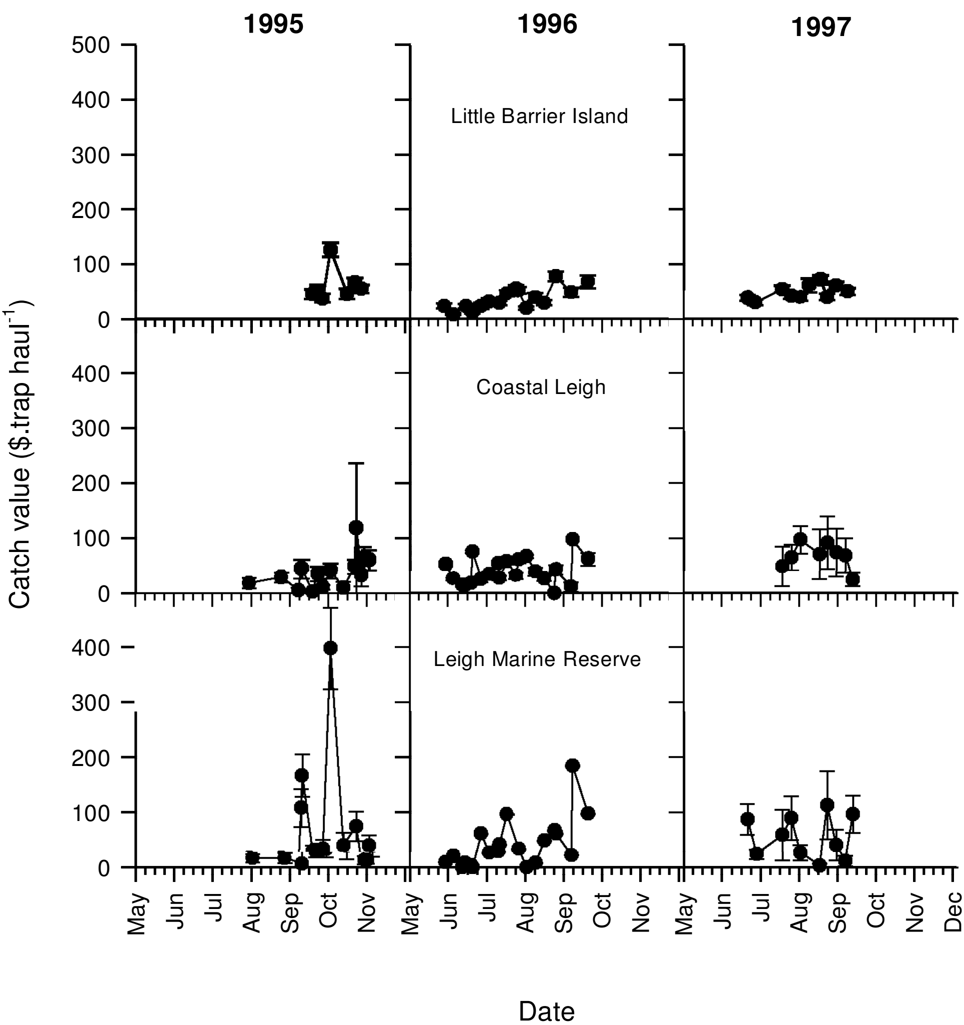

Figure 4. Variation in the mean value ($.trap haul^{-1} ± se) of the lobster catch from traps set around Little Barrier Island, Coastal Leigh, and Leigh Marine Reserve between 1995 and 1997. The figure includes the days with very high catch rates in the Leigh Marine Reserve that were dropped from the analysis of catch per unit effort.

and Coastal Leigh daily returns were less variable, and a more regular daily income was maintained over the season. As a result, overall revenue per trap haul around the Leigh Marine Reserve was comparable with the other two sites.

Catch per unit effort depends on the number and size of lobsters caught per trap haul. In order to check for differences in catch characteristics between locations, size and the number of lobsters were examined separately. An analysis of the mean number of lobsters caught per trap haul weighted by the number of trap hauls and incorporating factors for location, year, seasonal effects (cosine and sine terms), and wave surge with a two-day lag was therefore carried out. The linear model that provided the best fit based on significance values and minimum AIC values included location, year, wave surge, and the sine and cosine terms (Table 2), but no interaction terms were required. Contrasts between locations indicated that the mean number of lobsters caught per trap haul around Little Barrier Island differed significantly from Leigh Marine Reserve (p = 0.0009), but no significant differences were detected between Coastal Leigh and Leigh Marine Reserve (p = 0.2524) or Little Barrier Island (p = 0.0737). The mean size of lobsters increased significantly at all sites between 1995 and 1997, but lobsters caught around the Leigh Marine Reserve and Coastal Leigh consistently had a larger mean size than those around Little Barrier Island (Figure 5). The data therefore indicated that although CPUE was similar among the three sites surveyed, catches around the Leigh Marine Reserve were similar to Coastal Leigh but made up of fewer, larger lobsters than around Little Barrier Island.

Catch Characteristics

Marked differences were observed in the lobster catch characteristics between locations, and in particular, in the sexual composition of the total catch (i.e., all lobsters that were caught in the traps, including those that were subsequently returned). Around the marine reserve, the sex ratio of the total catch showed marked seasonality (Figure 6). The proportion of mature egg-bearing females in the total catch increased over the mating season between May and July, so that by mid-July virtually all mature females in the traps were ovigerous. Around the reserve, males dominated the total catch during, and soon after, the mating season, but there was a steady increase in the proportion of females over the egg bearing season through to October (Figure 6). Following larval release, in late October–November, there was a return to more even sex ratios. At Little Barrier Island and Coastal Leigh the sex ratios of lobsters in the total catch did not display

Table 2
Results of a linear model comparing the mean number of lobsters caught per trap haul

Term	Df	SS	MS	F value	P
Location	2	68.8310	34.4155	5.5365	0.0052
Year	2	40.5113	20.2557	3.2586	0.0423
Wave surge	1	156.2760	156.2760	25.1408	0.0000
Sine	1	232.8598	232.8598	37.4612	0.0000
Cosine	1	36.7447	36.7447	5.9113	0.0167
Residuals	107	665.1143	6.2160		

Note. Model terms used in the analysis included: location (Leigh Marine Reserve, Little Barrier Island, Coastal Leigh), year as a factor (1995, 1996, 1997), wave surge in meters measured at the Leigh marine laboratory, and sine and cosine terms for seasonal effects.

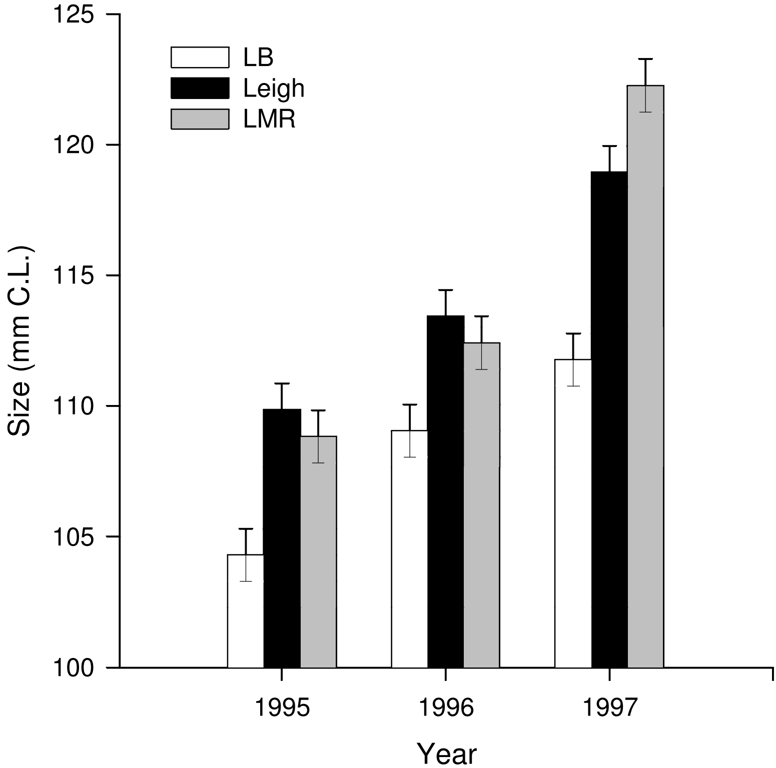

Figure 5. Changes in the mean size (mm carapace length (C.L.) + 95% CI) of lobsters in the retained catch between 1995 and 1997 at Little Barrier Island (LB), Coastal Leigh (Leigh), and Leigh Marine Reserve (LMR).

seasonality. Around Little Barrier Island the ratio remained close to unity over the fishing season for all three years of catch sampling, while at Coastal Leigh they were generally biased toward males. However, as ovigerous females were returned to the sea, seasonal patterns in the sex ratios of retained lobsters were similar between locations. At all locations the proportion of females in the retained catch declined over the mating season to approach zero during the egg bearing season between July and August. The proportion of females retained increased in September as larvae were released (Figure 6). As most fishing occurred during the period when females were ovigerous and therefore had to be returned to the sea, the overall sex ratio of the retained catch was heavily biased toward males. Furthermore, the proportion of males in the retained catch increased steadily from around 70% in 1995 to over 90% in 1997. The increase in the male component of the retained catch between 1995 and 1996 may have been an artifact of the delayed start to the fishing season in 1995. As a result, in 1995 more fishing effort was concentrated in the period after females had released their larvae and could be retained. However, the reason for continued increase in male bias in 1997 is unknown.

Discussion

Reports by local fishers of large numbers of lobsters being caught adjacent to the boundary of the Leigh Marine Reserve were supported by the catch data collected in this study. Catches around the marine reserve were characterized by a high proportion of empty

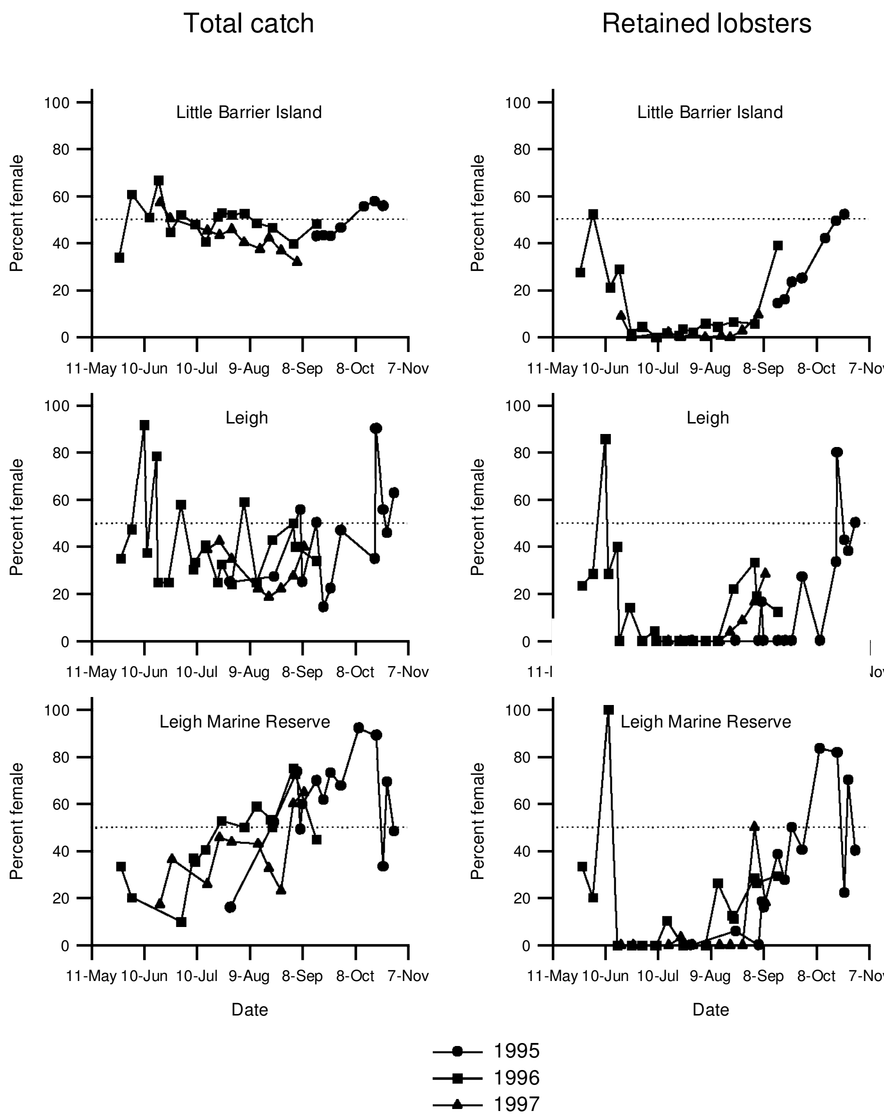

Figure 6. Variation in the sex ratio (% female) of the total (i.e., both retained lobsters and those returned to the sea) and retained catch over the fishing season around Little Barrier Island, Coastal Leigh, and Leigh Marine Reserve, between 1995 and 1997.

traps and large fluctuations in catch rates and value of the catch per trap haul over the fishing season compared to the other sites. Periods of low catch were offset by days when extremely large numbers of lobsters were caught. For example, in 1995, 21.6% of the total revenue earned from 950 trap hauls came from 42 trap hauls around the boundary of the Leigh Marine Reserve. Consequently, the total value of the catch per trap haul around the Leigh Marine Reserve was comparable with the other two sites.

The loss of spatial access to inshore reefs within marine reserves reduces the area available to set traps, and potentially the number of traps that can be set. The fisher surveyed offset the reduction in fishing ground by increasing the density of traps in the immediate vicinity of the marine reserve, thereby maintaining trapping effort, and catch per kilometer of coast around the marine reserve at similar levels to the other two locations.

Catches around the marine reserve and Coastal Leigh were maintained by fewer, but larger lobsters than around Little Barrier Island. The Coastal Leigh area is within the range of recorded movements of *J. edwardsii* tagged within the Leigh Marine Reserve (Kelly, 1999). Catches in Coastal Leigh may therefore have also been under the influence of the nearby reserve, and this could account for the large mean size and male bias in sex ratio of lobsters caught at Coastal Leigh compared to Little Barrier Island.

The larger mean size of lobsters caught around the boundary of the Leigh Marine Reserve was consistent with the pattern of lobster recovery reported for this and other marine reserves (Kelly et al., 2000). *Jasus edwardsii* have increased in both mean size and abundance within the Leigh Marine Reserve since its establishment in 1975, and although lobsters within the reserve display a high degree of site fidelity, large lobsters also undertake regular migrations of up to several kilometers that often carry them beyond the boundary of the reserve (Kelly, MacDiarmid, & Babcock, 1999). Given that lobster populations recover when protected (Kelly et al., 2000), and lobsters move from protected to fished areas where they become susceptible to capture (Kelly, 2001), the finding that CPUE around the Leigh Marine Reserve was similar to unprotected areas clearly supports the hypothesis that the spillover of lobsters from this reserve maintains catch rates at a similar level to those in the surrounding fishery. Furthermore, examination of the total catch and catch value indicate that economic returns obtained by the fisher surveyed from areas adjacent to the Leigh Marine Reserve (Figure 5) were equal to or greater than those from unprotected areas with unrestricted access to lobster habitat.

Because marine reserves remove access to inshore reefs, fishers are reliant on animals moving into the areas where their gear is set, and catch characteristics are dependent upon the behavior and ecology of a species. Traps around the Leigh Marine Reserve were predominantly set in offshore areas of sand and isolated patch reef, and the sex ratios of the catch reflected the inshore–offshore movements of *J. edwardsii*. Males dominated the total catch around the reserve following the mating season in May, coincident with the time when they move offshore and form large aggregations in areas of sand and patch reef (Kelly, MacDiarmid, & Babcock, 1999). The female component of the total catch increased over the egg-bearing season when females move offshore prior to larval release and males begin heading inshore prior to ecdysis (Kelly, 2001). Sex ratios were heavily biased toward females between September and October. This coincides with the time when females aggregate in offshore areas and release their larvae (Kelly, MacDiarmid, & Babcock, 1999). The female component of the catch declined in late October, supporting the conclusion that they return inshore following larval release. Around Little Barrier Island and Coastal Leigh, where there was no restriction on the placement of traps, fishers make greater use of inshore reefs. Fishing effort was therefore spread over the lobster population, and overall sex ratios did not reflect the movements of different components of the population into and out of particular areas.

The reliance by fishers working around the boundaries of marine reserves on lobsters moving into the areas where traps are set has several implications. First, as this study revealed, catch rates around marine reserves are likely to have a stronger seasonal component than in unprotected areas. Movement and feeding rates vary throughout the year and differ between male and female lobsters (Kelly, MacDiarmid, & Babcock, 1999; Kelly, 2001). Offshore lobster aggregations were observed over 7 months of the year, from July to January, and these periods corresponded to the times when peaks in feeding and movement activity occurred (Kelly, MacDiarmid, & Babcock, 1999). Fishers also report catching lobsters in offshore areas around the Leigh Marine Reserve in February. Lobsters are therefore likely to be available for capture in offshore areas around marine reserves over 7–8 months of the year. However, as *J. edwardsii* accumulate on inshore reefs between March and June, it is likely that catch rates in offshore areas surrounding marine reserves would be low during these months. Second, economic returns are strongly influenced by seasonal fluctuations in the prices paid for lobsters. Prices are market driven and depend on competition with other lobster producing countries, exchange rates, and demand. New Zealand fishers have no control over exchange rates and demand, but try to fill their quota as early as possible in the season, before other countries enter the global market. Maximum returns will be achieved where high lobster prices coincide with seasonal peaks in catch rates around marine reserves, while lowest returns will occur when peak prices coincide with seasonal lows in catch rates. Lobsters are graded according to size and sold by the kilogram, with the price varying according to grade. Therefore, returns will also be influenced by differences in the size characteristics of lobsters around marine reserves compared to unprotected areas. Finally, the level of spillover will depend on the size and shape of the protected area. The position of the seaward boundary and length of coast encompassed by a marine reserve should regulate the proportion of the protected lobster population moving over the boundary. Lobsters tracked acoustically for up to 12 months within the Leigh Marine Reserve and nearby Tawharanui Marine Park moved a maximum distance of 1.7 km offshore and 3.4 km from their home sites (Kelly, 2001). Greatest spillover of *J. edwardsii* would therefore be expected in short, narrow marine reserves, while least spillover would be expected in long, wide marine reserves.

Other studies examining the impact of protected areas on fishing yields have produced mixed results. Alcala and Russ (1990) found that when protective management of the Sumilon Island Marine Reserve in the Philippines broke down, the total yield of fish from the entire island dropped by 54% after 18 months, despite the fact that the reserve had previously taken up 25% of the available reef. They proposed that yields in the Sumilon Island fishery were being maintained through the emigration of adult fish from the marine reserve, but did not supply movement data to support this hypothesis. McClanahan and Kaunda-Arara (1996) found that total fish landings declined by 35% after the establishment of the Mombasa Marine Park removed access to 65% of the fishing grounds and reduced fisher numbers by a similar percentage. Although CPUE increased significantly around the Mombasa Marine Park in the first year following its establishment, catch rates declined to pre-park levels in subsequent years. This decline in yield occurred even though fish biomass within the park increased. However, the results were complicated by changes in fishing practices, such as a switch to fishing gear with reduced fishing efficiency, which occurred over the course of the study. Differences between McClanahan and Kaunda-Arara's (1996) results and those of Alcala and Russ (1990) and this study highlight the fact that the impact of marine reserves may vary from place to place, and from species to species. This is particularly important given the lack of replication in any of the studies.

It is not possible to generalize the findings of this study to other fishers or other areas, as sampling was carried out on a single fishing vessel and only one marine reserve was examined. However, all of the commercial operators fishing in the areas surveyed used similar methods, and mean catch rates for all of the locations sampled were similar to those reported for the quota management area in which this study was carried out (Vignaux & Kendrick, 1998). Furthermore, data were not available on the total effort exerted or total annual yield of all fishers in each area, so comparisons between these parameters could not be made. Nevertheless, catch rates around the nearby Tawharanui Marine Park are also known to be relatively high (S. Kelly, unpublished data), and the conclusion that marine reserves can maintain catch rates of *J. edwardsii* in the surrounding fishery through the emigration of adults is strengthened by additional data on the recovery rates (Kelly et al., 2000) and movement characteristics of this species (Kelly, 2001). These data show that protected lobster populations build up within relatively small (~400 ha) marine reserves, and adults make periodic movements that take them into the fishery.

Conclusions

This study suggests that the movement of *J. edwardsii* out of the Leigh Marine Reserve maintained catch rates around the reserve at similar levels to nearby coastal areas. However, catch characteristics around the marine reserve were more variable and reflected the movement of lobsters into and out of offshore areas where traps were set. Although the study was confined to a single marine reserve and estimates of the total yield obtained by all fishers were not available, information on the recovery and movement characteristics of *J. edwardsii*, together with the catch data obtained in this study, suggests that spillover from marine reserves may under certain circumstances greatly reduce the long-term losses of local fishers after the establishment of a marine protected area.

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