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Have changes in selectivity masked recruitment declines in crustacean trap fisheries?

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Abstract

In the Tasmanian rock lobster assessment model, as in many other assessment models, selectivity is treated as a fixed effect. The actual size composition in the population is estimated by dividing the survey catch in each size class by the size-specific selectivity. Recently, it has been found that larger lobsters tend to inhibit smaller lobsters from entering traps. We suggest that, as larger lobsters are removed from the population by harvesting, the number of smaller lobsters in the catch increases because they become more catchable. To determine the effect of a change in selectivity pattern on our perception of population composition, we applied selectivity curves that accounted for the effects of a change in size composition to sampling data from a population of lobsters that had seen a substantial decline in large legal-sized lobsters due to harvesting over the last 35 years. The results suggest that recent recruitment is lower than the recruitment that occurred in the 1960s, but this is masked in the unadjusted sampling data by changes in selectivity. This could contribute to masking of a stock–recruitment relationship. If this is a common phenomenon in crustacean trap fisheries, the assessment approaches now in use may be more risk prone than previously realised.

Keywords: Selectivity; Trap fisheries; Lobsters; Recruitment

1. Introduction

Lobster fisheries constitute major fisheries around the world and have consequently received substantial attention from managers and scientists. This has resulted in considerable literature on lobster assessment (see Breen, 1994; Addison, 1997; Hilborn, 1997 for reviews). Over the last decade most of the advances in rock lobster assessment have involved the development of new population models (Bergh and Johnstone, 1992; Walters et al., 1993, 1997; Punt and Kennedy, 1997). In summarising an international workshop on models used for assessing lobster stocks around the world, Hilborn (1997) found the general trend to be towards dynamic models fitted to observed length distributions. In Tasmania, Southern Australia, a spatially explicit, size-structured model (Punt and Kennedy, 1997) is used to undertake risk assessments of future harvest strategies for southern rock lobster (*Jasus edwardsii*) (Frusher, 1997; Frusher and Gardner, 1999).

Despite the advances in assessment models, there has been limited research directed at developing techniques to estimate the parameters used in the models (e.g. natural mortality, selectivity, catchability). Catch and effort data are used to indicate relative changes in lobster abundance in most models. However, various authors have suggested that behaviour of crustaceans can influence what is caught in a trap (Miller, 1979,

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1990; Addison, 1995), and Frusher and Hoenig (2001) demonstrated a change in selectivity as the population size structure changed. They concluded that larger lobsters tend to exclude smaller lobsters from entering the traps. Thus, as the size structure of a population is affected by fishing, the selectivity of the fishing gear changes as large lobsters are depleted. Area-specific selectivity estimates are incorporated into the Tasmanian assessment model as a fixed parameter vector that does not allow size-specific selectivity to vary temporally. This paper investigates the implications of temporally changing gear selectivity on the assessment of the fishery.

2. Methods

To determine the impact that a change in the selectivity curve could have on interpretation of historic size structure data for the southern rock lobster we chose a region in northeastern Tasmania where size structure data were available from research surveys in 1962–1964 and 1995, 1996 and 1998 from the same time of year and the same location. During each survey, all lobsters caught in each trap were sexed and measured to the nearest millimetre of carapace length (mm CL).

To standardise for different amounts of effort in each of these surveys the catch (number of lobsters caught) was converted to catch rates (number of lobsters caught per trap lift) (Fig. 1). During each survey, commercial vessels using commercial traps were chartered. The style of trap has not changed over time, although escape gaps were introduced into commercially used traps between the 1960s and 1990s. To simulate the 1960s fishing activity, we closed the escape gaps on the fisher's traps that were used in the surveys in the 1990s. In all surveys traps were set overnight with a soak time of approximately 22 h.

To account for distortions in the size frequency distributions caused by selectivity of the sampling gear, the size composition was adjusted by dividing the standardised number (number per trap lift) in each size class by an estimate of selectivity. Frusher and Hoenig (2001) obtained estimates of selectivity from fished populations in eastern Tasmania and a population in a reserve in southeastern Tasmania. Due to the fact that the reserve population had been protected from exploitation since 1970, there was a large biomass of large lobsters. The relative size structure of the catch from the reserve was the closest we could find to the relative size structure of the 1960s catch in northeastern Tasmania (Fig. 2). Selectivity of traps for the reserve population was determined by tagging and releasing lobsters of various sizes and then noting the fraction of the tags recovered from each size group during a follow-up research trapping survey. The reserve size selectivity data are for the first 4 days of follow-up sampling because trapped lobsters were removed to an aquarium facility and held until the survey was completed. This changed the composition of the remaining population in the water and thus changed

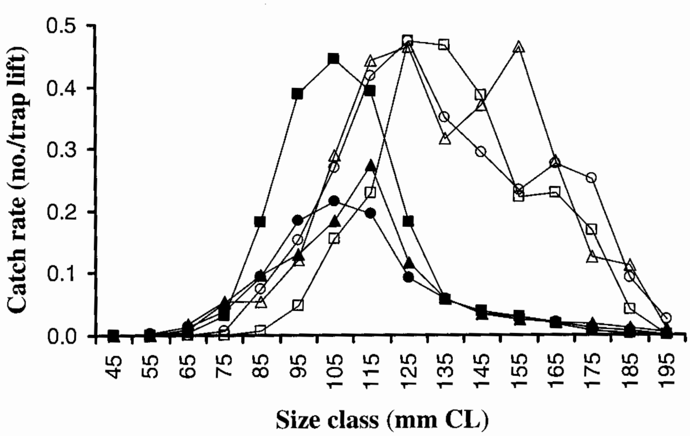

Fig. 1. Size structure of male lobster catch (unadjusted for selectivity) from research sampling surveys undertaken in northeastern Tasmania in 1962 (open square), 1963 (open circle), 1964 (open triangle), 1995 (solid circle), 1996 (solid triangle) and 1998 (solid square).

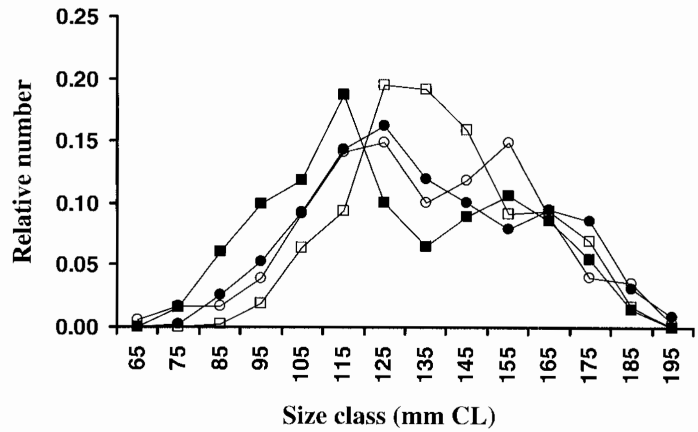

Fig. 2. Comparison of relative size structure of male lobsters caught in the reserve (first 4 days of survey) in 1999 (solid square) and in the commercial fishery in northeastern Tasmania in 1962 (open square), 1963 (closed circle) and 1964 (open circle). Relative number is obtained by dividing the number caught in each size class by the total number caught in all size classes.

the selectivity of the traps (Frusher and Hoenig, 2001). Thus we use selectivity estimates from the first 4 days of sampling in the reserve to adjust the size structure of the survey catch from the northeast in the 1960s.

The selectivity curve from the reserve has dips and crests that most likely reflect sampling variability rather than actual size-specific selectivity. To make sure that inferences did not depend critically on such local phenomena, we smoothed the selectivity curve. Smoothing was undertaken by using a LOWESS function with a smoothing fraction of 2/3 (Chambers et al., 1983). The resultant smoothed curve was standardised to the interval [0, 1] by dividing each size class estimate by the highest size class estimate obtained (Fig. 3).

The size structures in the surveys in northeastern Tasmania in the 1990s most closely resemble the size structure from surveys in the 1990s on the East Coast

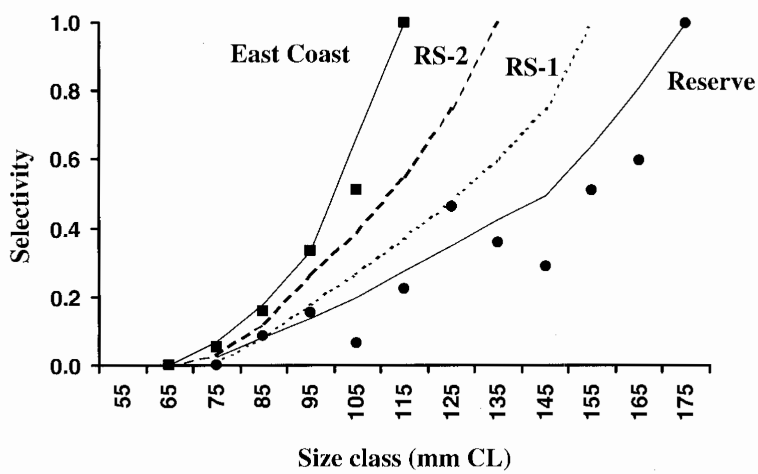

Fig. 3. Selectivity data points for 5 mm CL size class intervals for the reserve (circle) and East Coast (square). The resultant curves after smoothing with a LOWESS procedure are shown. For exploratory purposes, simulated selectivity curves (RS-1 and RS-2) have been created to peak 20 and 40 mm CL less than the reserve selectivity curve, respectively.

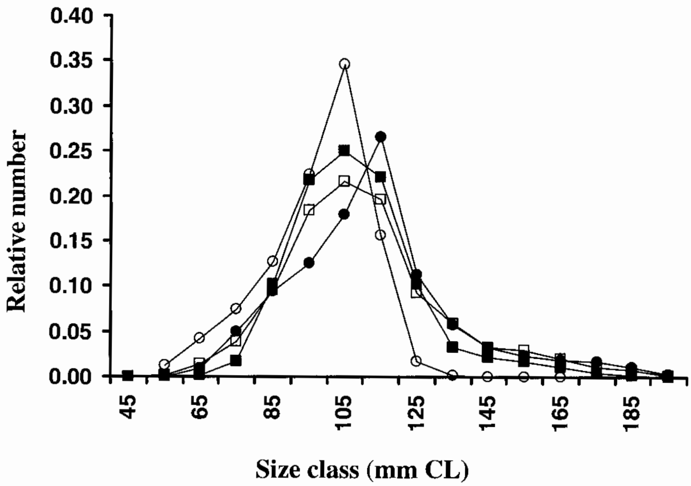

Fig. 4. Comparison of relative size structure of male lobsters caught on the East Coast from 1992 to 1999 (open circle) and in northeastern Tasmania in 1995 (open square), 1996 (solid circle) and 1998 (solid square). Relative number is obtained by dividing the number caught in each size class by the total number caught in all size classes.

(Fig. 4). Thus we used selectivity estimates obtained by Frusher and Hoenig (2001) using tag and recapture studies from the East Coast to adjust the size structure of the northeast survey catch in the 1990s. The East Coast selectivity curve was also smoothed using the LOWESS function. The size composition from the East Coast was not a perfect match to the data from northeastern Tasmania, there being a noticeable difference in the number of lobsters greater than 110 mm CL (Fig. 4). To account for this difference and to test the sensitivity of the estimated relative population structure to variation in the selectivity curve, we simulated two other selectivity curves that had reduced selectivity of the smaller lobsters and reached peak selectivity at a larger size class (Fig. 3). The curves labelled RS-1 and RS-2 fit between the reserve and East Coast curves and are simulated to have a peak selectivity 20 and 40 mm CL less than the reserve curve, respectively.

To evaluate the impact of changes in selectivity curves on the current assessment of the Tasmanian rock lobster fishery we undertook two comparisons. First, we compared selectivity curves currently used in the Tasmanian rock lobster assessment model (Punt and Kennedy, 1997) to selectivity curves obtained in this study from the reserve and East Coast populations. Due to the fact that curves generated for the assessment model are fitted to a logistic function (Punt et al., 1997), we also fitted the same function to the reserve and East Coast selectivity data to enable a more direct comparison (Fig. 5). Secondly, we compared the annual biomass estimates generated by the assessment model for different selectivity curves by adjusting the selectivity function in the model. All selectivity curves used in model runs are fitted to logistic functions.

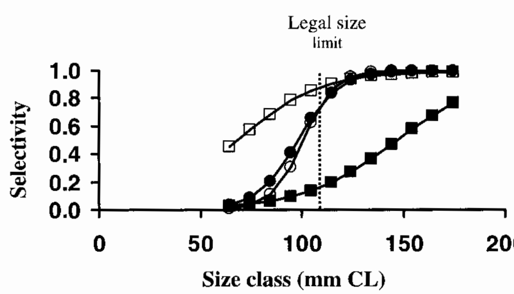

Fig. 5. Comparison of selectivity curves from the northeast coast (solid circle, Punt et al., 1997), reserve (solid square, this study) and the East Coast of Tasmania (open square, Punt et al., 1997; open circle, this study) for male lobsters. The East Coast and reserve curves for this study have been fitted to a logistic function. The dotted line is the minimum legal size limit of 110 mm CL.

3. Results and discussion

The minimum legal size limit for males has been 110 mm CL in Tasmania since 1957. In the 1960s, lobsters $\geq$125 mm CL comprised a substantial component of the legal-sized male survey catch in northeastern Tasmania (Fig. 1). By 1995 and 1996, the legal-sized catch was primarily comprised of new recruits between 110 and 125 mm CL. In 1998 the legal-sized catch still comprised smaller lobsters, but there was a substantial recruitment pulse of sublegal lobsters. This recruitment pulse corresponds to the highest index of puerulus (larval) settlement recorded for the fishery since puerulus monitoring commenced in 1991. Puerulus settlement indices have been found to correspond to commercial catches in 5 years time, and the 1995 puerulus peak resulted in a substantial increase in catch rates in eastern Tasmania (Gardner et al., 2001).

To study in a systematic way the effect of changing selectivity on the interpretation of size-specific catch rates we applied the reserve curve to the 1960s catch data, and each of the four curves (Fig. 3) was applied to the 1990s data (Fig. 6).

As the selectivity curve moves from the reserve curve to the East Coast curve there is a substantial change in the perceived relative abundance. When the reserve selectivity is applied to all years, abundance of pre-recruit lobsters less than 100 mm CL is higher in the 1990s than in the 1960s. However, as the selectivity curve moves towards the East Coast selectivity pattern, the relative abundance of pre-recruit lobsters in the 1960s becomes higher than in the 1990s. Thus, changes in the selectivity curves can lead to substantial changes in population abundance estimates. The application of selectivity curves that account for a change in selectivity as the size structure of the population changes indicate that pre-recruit biomass was substantially higher in the 1960s than the 1990s.

Concomitant with the decline in large male lobsters in northeastern Tasmania there has been a decline in catches of large female lobsters (Fig. 7). The size at which 50% of female lobsters are mature is just above the minimum legal size limit of 105 mm CL for female lobsters (Gardner et al., 2002). This reduction in legal-sized female lobsters has resulted in egg production being less than 10% of that of an unharvested population (Frusher and Gardner, 1999). We suggest that the application of selectivity curves that account for changes in selectivity due to large lobsters reducing the catchability of smaller lobsters, as demonstrated by Frusher and Hoenig (2001), indicates there has been a decline in recruitment of the Tasmanian rock lobster fishery from the 1960s to the 1990s.

Conversely, since the introduction of an individual transferable quota (ITQ) system in 1998, the fishery has seen a substantial rebuilding of legal-sized biomass (Gardner et al., 2000). As the size range and number of larger lobsters increase, these lobsters would be expected to affect the selectivity of the fishing gear by excluding smaller lobsters. For example, in the northeast of Tasmania, Punt et al. (1997) estimated a selectivity curve that is similar to the East Coast curve of Frusher and Hoenig (2001) (Fig. 5). The northeast selectivity curve estimated by Punt et al. (1997) was based on data from 1990 to 1995 when legal-sized biomass was at it lowest. With rebuilding of the legal-sized biomass we would be expecting the selectivity curve to move from a shape similar to that of the East Coast (few large lobsters) to a shape more similar to the reserve (increased number of large lobsters). If use of the East Coast selectivity curve is maintained in the stock assessments, the lower catches of undersized lobsters would be interpreted as a decline in recruitment rather than the behaviour of the increased numbers of larger lobsters excluding smaller lobsters from the fishing gear.

Legal-sized biomass estimates would be underestimated if selectivity curves were not adjusted to account for the shift in selectivity towards larger lobsters as they increase in abundance in the fishery. For example, as larger lobsters begin to accumulate in the northeast of Tasmania under the ITQ management system, we would expect the selectivity curve to move from a shape similar to the East Coast to a shape closer to the reserve population. Running the stock assessment model (Punt and Kennedy, 1997) with an East Coast selectivity curve and a reserve selectivity curve on the population in northeastern Tasmania, we find that there is a change in legal size biomass estimates of approximately 50% (Fig. 8). Maintaining the current selectivity curve in the model as the number of legal-sized lobster increases would result in legal-sized biomass estimates being underestimated.

An interesting case where large lobsters have increased in number is in recently declared marine reserves. In Tasmania, marine reserves have been shown

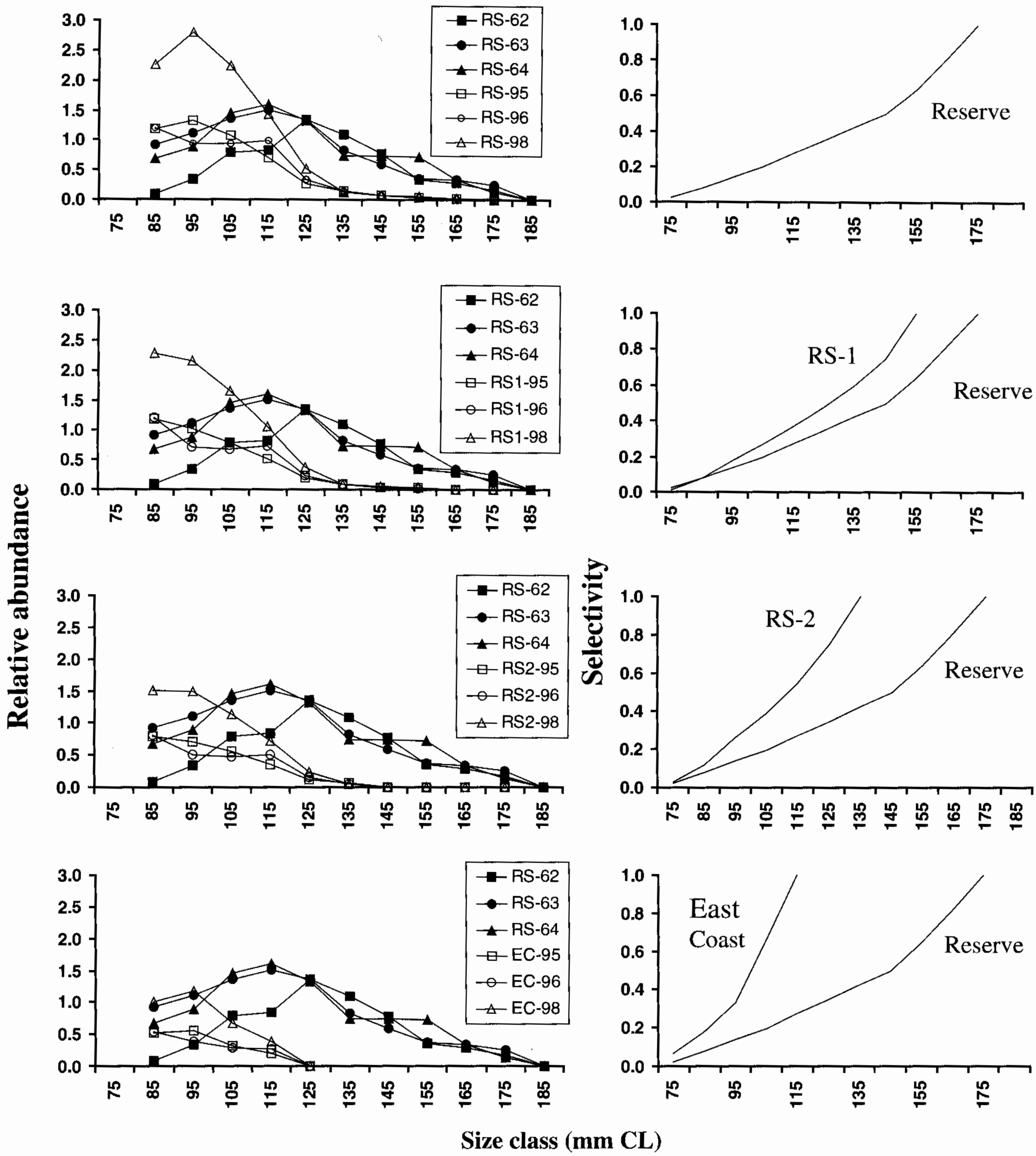

Fig. 6. Relative abundance estimates from northeastern Tasmania in 1962 (solid square), 1963 (solid circle), 1964 (solid triangle), 1995 (open square), 1996 (open circle) and 1998 (open triangle) obtained by applying a smoothed selectivity curve from the reserve surveys (RS), the East Coast (EC) surveys, and two simulated curves. The selectivity curves are shown to the right of each plot.

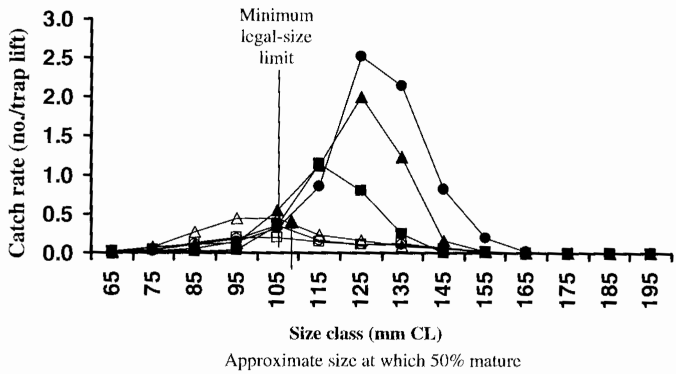

Fig. 7. Size-specific catch rates of female lobsters caught in northeastern Tasmania in 1962 (solid square), 1963 (solid circle), 1964 (solid triangle), 1995 (open square), 1996 (open circle) and 1998 (open triangle).

to have a rapid increase in the number of larger lobsters after fishing has been stopped (Edgar and Barrett, 1999). From a fisheries perspective, the potential for these reserves to be refugias for breeding populations and thus sources for future recruitment is of interest. Interpretation of the effect of these reserves is often based on the BACI (before, after, control and intervention) experimental design, which consists of comparisons of conditions before and after an intervention as well as comparisons of control and intervention sites. If trap catches are to be compared directly between surveys before (when fishing was allowed) and after (several years after fishing has ceased), or converted to size-structured population abundance estimates, then such estimates would be erroneous if changes in selectivity were not taken into account. The effect of changing selectivity on the interpretation of trapping results would depend on whether the trapping data were considered qualitative (i.e. catch composition was used to judge population composition) or quantitative (i.e. catch rates were used to judge abundance). In the former case, abundance of large lobsters relative to that of small animals would be overstated. In the latter case, the proportional change in abundance of large animals may be inferred correctly but the apparent abundance of small lobsters would be too low.

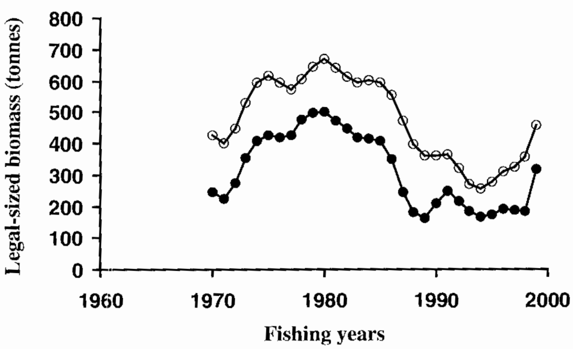

Fig. 8. Comparison of legal-sized biomass based on selectivity curves for the East Coast (solid circle) and the reserve (open circle). Both curves were fitted to a logistic function before obtaining biomass estimates.

Comparisons of size-structured population estimates from fished and marine reserve regions would need to ensure that the catches from both regions were converted to population estimates by using appropriate selectivity curves.

Gear selectivity appears to be an important component of Tasmanian lobster assessments and greater attention should be given to obtain accurate selectivity curves. Valid selectivity curves are needed to correctly interpret changes in recruitment associated with the historical exploitation of legal-sized biomass. We wish selectivity had been estimated in the 1960s. This would have strengthened our inferences. In the absence of such direct estimates, selectivity needs to be obtained for populations of lobsters from regions where the size structure most closely resembles historical size structure. Analyses based on such selectivity estimates may be exploratory in nature but are nonetheless valuable for the insights they provide concerning perceptions of recruitment and the risks of recruitment decline. We suggest that studies of other crustacean trap fisheries would be worthwhile.

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