FISHERY INDEPENDENT SURVEY OF THE BREEDING STOCK AND MIGRATION OF THE WESTERN ROCK LOBSTER (*PANULIRUS CYGNUS*)

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CONTENTS

NON-TECHNICAL SUMMARY:

The fishery for western lobster (*Panulirus cygnus*) has supported an annual catch of about 10,500 tonnes per annum over the last twenty years and is worth between $200-300 million per annum. The fishery has been experiencing increasing exploitation rates over time and estimates in the early 1990s were suggesting that the brood stock had declined to between 15-20% of unfished levels. These low levels were considered to pose a serious risk to future recruitment and resulted in a number of management measures being introduced in the 1993/94 season aimed at raising the levels of the brood stock.

In the past, the state of egg production in the stock has been estimated using data obtained from the commercial fishery. Data from this source can introduce possible bias, in that it is possible for fishers to avoid certain areas where there are large numbers of female animals in a breeding state and which under the new management measures are now required to be returned to the sea Furthermore, the effect of increases in fishing power on commercial fishing effort due to changes in gear technology, can lead to the spawning stock index being over estimated if valid measures of the increases in effectiveness are not available.

The only way of avoiding the potential biases of using commercial data, is by conducting a sampling programme independent from commercial fishing data. Such a pilot programme was undertaken at Fremantle and the Abrolhos Islands in 1991, was expanded to include Dongara and Jurien in 1992 and with the assistance of FRDC funding was continued and expanded to include Lancelin and Kalbarri from 1993 to 1996 (FRDC project 93/091). The project was further extended under FRDC funding from 1996 to 1998 (this project), in order to increase the confidence of the results and to examine the breeding stock indices over the full term of the current management package. The results from this latter survey form the basis of this report.

Commercial lobster fishing boats were chartered to do research fishing in five areas on the coast and a research vessel was assigned to the Abrolhos Islands. Fishing took place at each of these areas over ten days during the last new moon prior to the start of the commercial fishing season in mid-November. Standard commercial pots were set on the same GPS positions each year in areas that had previously been identified as localities which consistently yielded large numbers of spawning animals. All lobsters caught were measured, sexed and in the case of females particular attention was paid to their reproductive state. Environmental parameters (bottom and surface temperature, salinity, swell size) were recorded daily in each area.

Egg production indices (expressed as the mean number of eggs per pot lift) were calculated annually for each area separately and for the areas combined, based on the number of mature female animals in the catch. Analysis of the results at all the coastal sites showed significant increases in egg production since the surveys first commenced. All the survey areas have shown an upward trend in egg production since 1993 when the management changes came into effect.

Other analyses showed that there were substantial inter-annual differences in swell size as well as bottom temperature. These environmental factors did not significantly increase or decrease the egg production indices in any one year, but the analysis did suggest that swell size has an influence on the index.

The fishery independent spawning stock survey has produced results which are comparable with the long-established fishery dependent egg production index which has been used in the past in this fishery. Both indices indicate that egg production has more than doubled over the last five years.

The increased contribution made to egg production by the maximum size rule was shown to be significant (~5-10% over the last five years), but small compared to the overall improvement in the spawning stock index that has been recorded since 1993/94.

The second part of the project was aimed at examining in some detail, the migration of 'whites' lobsters and the effect this might have on the movement of those animals between zones. Legislation introduced in 1993/94, has required fishers to return all lobsters <77 mm CL to the sea from the start of the lobster fishing season on 15 November, to 31 January, at which time the legal minimum size changes to 76 mm CL. Fishers in some parts of the fishery argue that releasing 77 mm CL animals in the first part of the season, prior to the change to 76 mm CL, is inequitable because many of those are migrating 'whites'. In their opinion, releasing these animals allows them to move out of their zone into adjacent zones where they may not be permitted to fish.

Previous research (FRDC project 95/020), has shown that only a relatively small proportion of migrating lobsters undertake extensive movements. Those that did so, tended to move in a north westerly direction following the depth contours along the coastline.

Work undertaken in this study was targeted at the tagging of 'white' lobsters in areas that had either not been previously tagged (Geraldton to Port Gregory) or where recapture information was considered to be inadequate (Fremantle to Two Rocks). Recaptures in both of those areas confirmed the conclusions that had been drawn in FRDC project 95/020 about movement patterns of 'white' lobsters. In the case of animals tagged in the Geraldton to Port Gregory stretch of coastline, 15 animals (or 1.5% of those recaptured) moved from Zone B (the north coastal area) to Zone A (the Abrolhos Islands).

Tagging undertaken in December 1997/January 1998 was aimed at quantifying the tonnage of 'white' lobsters migrating across the border between zones B and C. A tag release strategy stratified by latitude and depth was established and a substantial number of animals (5.9% of those tagged) have been recaptured to date. Analysis of the data are preliminary at this stage, but approximately 5% of tagged animals recaptured from the Cervantes and Jurien release sites moved >30 nm from their release positions. Many more tags are expected to be returned in the 1998/99 fishing season and a full analysis of this dataset will take place in the second half of 1999.

BACKGROUND

This study has been the product of two earlier FRDC funded projects, namely the fishery independent study of the stock of the western rock lobster (FRDC project 93/091) and the mortality, growth and movements of the western rock lobster, *Panulirus cygnus* (FRDC 95/020)

FRDC project 93/091 was initiated in order to develop an index of egg production that was independent of commercial fishery data. At the start of the 1990s it was considered, based on commercial monitoring data, that egg production had declined to 15-20% of unfished levels (Brown, Caputi and Barker, 1995). There were real concerns as to the potential for recruitment failure at such low levels of egg production and as a result, a management package was introduced in the 1993/94 season aimed at improving the brood stock (Anon, 1993).

Some of the changes resulting from the management package introduced in 1993/94 resulted in changed commercial fishing patterns. For example, under the new management package, setose lobsters were required to be returned to the sea. This resulted in fishers avoiding certain depths at particular times of the year where large numbers of setose females were known to be available and since these areas had been fished prior to the changed management package, it was obvious that egg production indices derived from commercial monitoring data would be affected by the changed fishing arrangements. The fishery independent survey methods were seen as being a way of establishing egg production indices free of any biases that might result from changes in commercial fishing patterns.

A pilot fishery independent egg production index sampling programme was undertaken at Fremantle and the Abrolhos Islands in 1991, was expanded to include Dongara and Jurien in 1992 and with the assistance of FRDC funding was continued and expanded to include Lancelin and Kalbarri from 1993 onwards.

The most important outcomes of FRDC project 93/091 were that the fishery independent index of egg production produced similar trends to the fishery dependent index, the latter index being one based on commercial monitoring data. This gave reason for confidence in the method. Secondly, in terms of the result it was most encouraging to see evidence of a substantial improvement in the egg production indices, indicating that the management package introduced to improve egg production was achieving its aim.

It was seen as being important that, based on the success of the fishery independent spawning stock index, the project should continue for a longer period to obtain additional information on the indices. This recommendation was the prime motivation behind the continuation of this project for an additional two years under FRDC funding.

FRDC project 95/020 was a one year project that was primarily initiated to analyse tagging data that had been collected between 1988 and 1995, but which was also aimed at developing a long term strategy for future western rock lobster tagging work.

One of the changes to the regulations that came about with the introduction of the revised management package introduced in 1993/94, was that the legal minimum size was increased from 76 to 77 mm CL for the first two and a half months of the season (i.e. from 15 November to 31 January). This increase in minimum size during the 'whites' phase succeeded in transferring a substantial proportion of animals that would normally have been caught as 'whites' in the first half of the season, to be taken as more valuable 'reds' in the second half of the season (see Marec, 1997 for a more detailed discussion on this subject).

Because of the success in increasing the value of the catch made in particularly the northern part of the fishery through this small minimum size increase in the first half of the season, consideration was given to further variations to the legal minimum size at first capture. However, before further changes could be debated, it was necessary to have specific data on the movements and growth of near legal sized lobsters (70-80 mm CL) on a regional basis.

Based on this necessity, an additional two years of FRDC funding was granted for further tagging work to be undertaken on juveniles (70-80 mm CL). Though tagging work was unrelated to deriving indices for egg production, there were some overlaps in staff commitments to the two projects and for this reason they were combined in this present study (FRDC project 96/108).

NEED

(a) Unbiased data was required to measure the effects of fishing and management measures on the reproductive potential of the western rock lobster stock. Extension of the existing breeding stock survey by a further two years was considered necessary to:

(i) provide a more reliable statistical comparison of egg production indices i.e. 5 data points (rather than 3) at 6 locations. It was considered that these data would allow for a better evaluation of options for a future long-term egg production index (eg. whether to have an index based on annual surveys at 6 sites, or using a reduced number of sites, or perhaps conducting surveys at less frequent intervals).

(ii) provide a direct means of assessing the lagged (2 year) flow through of lobsters to the breeding stock over the period 1996/97 and 1997/98 at the six survey locations covering the full range of the fishery. Noting that the expected increases in breeding stock levels from the management changes starting in 1993/94 would not fully impact until the 1995/96 season, an extension to the existing survey for the years 1996/97 and 1997/98 would provide a measure of the success of the first 3 years of the new management package and would assist future management planning.

(b) Specific data on the movements and growth of the near legal sized lobsters (70-80 mm CL) on a regional basis was considered necessary so as to allow management consideration of variations in the legal size at first capture as a means of optimising the value of the catch.

Two related, though more specific needs arose during the course of this project and have been addressed by a slightly changed sampling programme (see methods and Appendices 1 and 2).

(i) In the 1996/97 season it was noted that there was a specific need to address the concerns of fishers in the Fremantle and Geraldton areas, as to the fate of 76 mm lobsters returned to the sea under the revised management regulations introduced in 1993/94 (see Appendix 1).
(ii) In the 1997/98 season there were calls by particularly Zone C fishers (i.e. fishers operating south of latitude 30°S), for researchers to quantify the tonnage of 76 mm CL lobsters moving across the border between zones B and C during the course of the annual (generally) north-westerly migration undertaken by 'whites' lobsters. These data were perceived as being particularly relevant in the light of consideration being given by the Rock Lobster Industry Advisory Committee (RLIAC) to further increasing the legal minimum size (Prokop 1997).

OBJECTIVES

1. To use independent spawning stock survey techniques to validate spawning stock indices derived from commercial fisheries data and to examine specific impacts of the current management package over its full term. Specific impacts include trends in egg production and measurement of effective effort creep by comparison of fishery independent and fishery dependent spawning stock indices.
2. To undertake pre-season tagging of juveniles in the shallow water of the limited entry fishery, to obtain more detailed information on the migration and growth of these lobsters to aid in the understanding of the effects of distributing catch more evenly throughout the season.

There was an additional objective introduced in the 1997/98 season (Appendix 2), namely:

3. To set in place a tagging strategy that will provide data capable of being utilised to model the tonnage of 'white' 76 mm CL lobsters migrating between Zones B and C.

METHODS

(a) Development of an egg production index:

(i) Sampling methods:

Six sites, covering the major portion of the commercial western lobster fishing grounds, were selected as spawning stock survey sites. The sites, Fremantle, Lancelin, Jurien, Dongara, Kalbarri and the Abrolhos Islands (Fig. 1), were believed to be wide enough apart and important enough in their own right, to provide adequate coverage of the commercial lobster grounds.

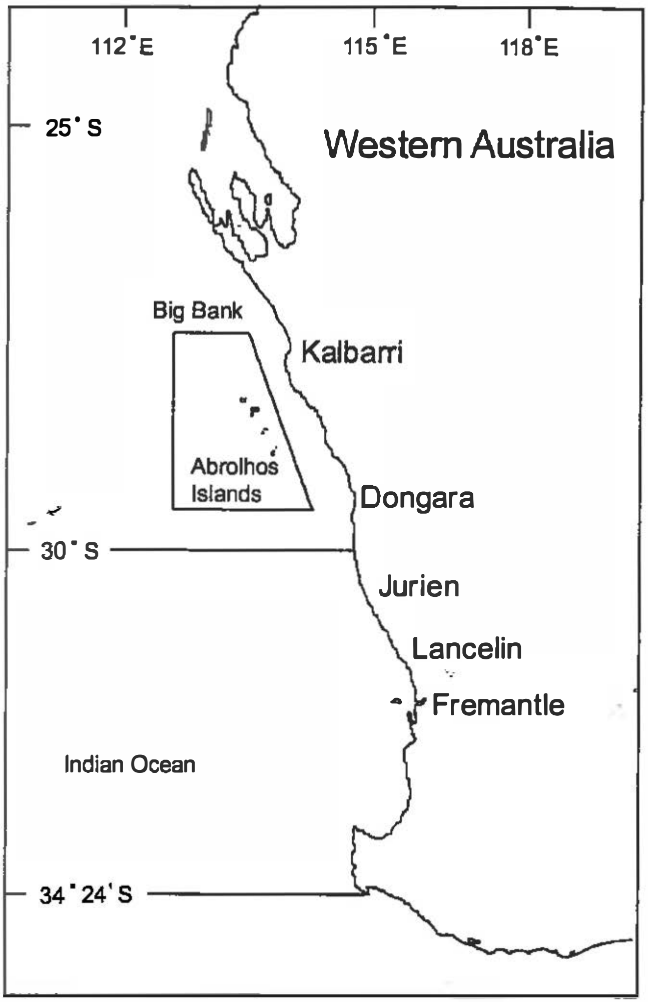

Fig. 1. Map showing the main localities along the Western Australian coast at which lobster tagging took place.

Each of the areas were visited prior to undertaking the first survey and local knowledgeable fishers were consulted as to which parts of the grounds and between what depths that they most frequently encountered mature/breeding female lobsters. Based on this information, survey sites within any one area were designed to incorporate four or five sub-areas with identified high mature-female catch rates and possibly different bottom types. The depths covered by the coastal sampling sites ranged from 15-40 fathoms, with most depths in the 20-30 fathom range. Spawning lobsters are frequently found in shallow depths at the Abrolhos Islands and consequently sampling covered a greater depth range there (5-32 fathoms).

Because the survey was to rely on chartered commercial vessels to do the catching, it was not possible to run it during the commercial fishing season (November 15-June 30). Periods outside of the fishing season are not ideal because of winter storms, but it was felt that a compromise would be to run the survey at the end of winter just prior to the start of the commercial fishing season and at the start of the spawning period which occurs from September-February (Chubb, 1991). Catch rates are best over the dark phase of the moon and it was therefore decided to conduct the annual survey during the last new moon period prior to the start of the western rock lobster commercial fishing season (i.e. November 15).

Bait for the pots was standardised in the first year of the survey. Salmon heads, North Sea herring and cow hide were chosen because of their availability and well known reliability as good bait and approximately 1kg of each fish bait per pot was used at each setting (~2kg total). All pots were soaked for one week prior to the start of the survey. This soaking period took place well away from the survey area and apart from hide that was to be used later in the survey being put into the pots to mature, no other bait was used. Soaking of pots prior to the start of the season is standard commercial fishing practice, the aim being to rid pots of any 'foreign' odour that might deter lobsters from entering.

At each of the coastal locations 160 standard commercial lobster pots with jarrah batten slats, red-necks and closed escape gaps were fished, except for the Fremantle area where large numbers of cane beehive pots are traditionally used. Because of this tradition of using substantial numbers of cane beehive pots in the Fremantle area, it was decided to use an equal number of beehive and batten pots for the survey in this particular area and to alternate the setting of the two pot types. In all the coastal survey locations, pots were set for two day soaking times with 80 pots being pulled and reset each day for the duration of the survey, however, because of occasional adverse weather conditions, some soak times were longer than two days. Two day pot soaking times were chosen because they provided better catch rates than one day soaking times during lower catchability periods. The location of each pot setting was recorded on GPS navigational equipment and the positions for each location were standardised after the first survey in each area for use as the sampling points in subsequent surveys.

Pots were set singularly, but in lines tracking what was considered by the skipper to be optimal ground. This method of setting pots in lines is a standard fishing practice and assists in the retrieval of the gear by enabling the skipper to be pulling a pot while at the same time having the float of the next pot to be pulled in sight. Since each of the areas in the survey had four or five sub-areas and since 80 pots were being hauled per day, the strategy adopted was to have either 16 or 20 pots to a line. Every day one line of pots would be pulled and reset in each sub-area, in this way spreading many of the day-to-day effects that might have otherwise influenced lobster catchability over the whole area.

The offshore Abrolhos Islands were fished in a slightly different manner to those on the mainland. All four island groups of the Houtman Abrolhos Archipelago were fished by the Fisheries Agency's research vessel *R.V. Flinders* using a combination of cane beehive and jarrah batten pots set alternatively. Because of the high catch rates in this area, it was sufficient to set the pots for 24 hour soak periods and because of the large amount of animals in the catch that were required to be measured and sampled, it was only practical to work 51 pots per day. Another difference in the fishing method was that since the island groups are relatively far apart, it was not possible to haul and set pots at all island groups on the same day. Instead, each island group was divided into three sectors, each sector (12 in total) was fished daily and sampled systematically from south to north. Within each sector three lines of 17 pots were set in different depth categories i.e. one line was set in depths ranging between 5-12 fathoms (inside line) another was set in depths ranging from 15-25 fathoms (middle line) and the other was set in depths ranging from 25-32 fathoms (outside line).

For each day of fishing and for each pot, individual rock lobsters were measured (carapace length in mm), sexed and if female assigned a breeding state. Rock lobsters were returned to the water in the vicinity of where they were caught to minimise any mortality due to translocation. Environmental data likely to affect catchability, eg water temperature (bottom and surface), swell, current, salinity and general weather conditions, were recorded on a daily basis throughout the programme.

The first year of the survey in each area provided the GPS locations for subsequent years. There is a random error associated with GPS positions of up to 100 m standard deviation (pers. comm. E. Skender, Transair Australia), which means that it is theoretically possible for a vessel returning to a GPS position to be as far as 200 m from the original GPS position. Because this error precluded the possibility of setting the gear in exactly the same position each year, a sampling strategy had to be devised to cope with the errors that would occur through using GPS positions. The strategy that has been followed when repeating the original GPS sampling points in subsequent years has been to carefully follow echo soundings and traces when steaming up to the sampling position. If the ground on the given GPS position has proved, based on the echo trace, to be unsuitable habitat for lobsters, then the boat has been required to continue on the same course for a further approximately 100m, before circling back to set the pot on the most suitable piece of ground that was covered over the 100m course that was steamed on either side of the GPS position.

As might be expected, it was found that not all of the sites that were chosen in the first couple of years of the survey produced good catches of lobsters. As a result, it was necessary to make changes to the positions of some of the lines of pots in the subsequent years. Since then though, the positions of the pots with the exception of some very minor changes have been standardised.

(ii) Data analysis:
Prior to undertaking any detailed analyses, the data were validated by generating plots showing the mid-point of each line of pots, for each year surveyed, for each of the six areas. Lines outside of the sampling areas were identified and their co-ordinates were checked for possible errors. In some cases, particularly in the first year of the survey, there were occasional lines that had been set well outside of the main sub-areas and which had then been discountinued. These lines were excluded from the analysis.

In the case of the pilot breeding stock survey conducted in the Fremantle area in 1991, the lines were not set in well-defined sub-areas. From 1992 onwards the sampling strategy changed and most of the 1991 lines were discounted. It was therefore considered appropriate to exclude the Fremantle 1991 data from the analysis.

As has been noted, for particular reasons the sampling strategy for the Abrolhos Islands has been designed differently to the coastal sites. There have been a larger range of depths fished at the Islands than at the mainland, the sub-areas have been fished sequentially each day over the survey rather than concurrently and lastly pot soaking times have been one rather than two days in duration. All of these differences have provided strong reasons for excluding the small Abrolhos Island data set from the bigger coastal data set when combining areas for analysis.

Pots with structural damage and open escape gaps, both situations which could have influenced catch rates, were omitted from the analysis. The number of eggs produced per pot in a line in each area for each year, was then calculated by estimating the number of eggs produced by each mature female sampled. This calculation used the size-fecundity relationship, percent double spawning-size relationship, and percent maturity-size relationship (Chubb *et al*. 1989). The total egg production per pot for each line was then logarithmically transformed, to take account of the skewed distribution resulting from the dependence of the index on catch rates, before being used in any of the statistical analyses.

An ANOVA was undertaken on the egg production index in each of the six areas, with main effects being year, sub-area, fishing depth (in 5 fathom depth intervals) and soak time (in days), to take into account some of the main effects which were considered might influence the index. The number of samples in the above cells was dependent on all the lines being fished each year, but since some lines were omitted in certain years due to weather conditions and minor changes to the design, this led to the ANOVA design being unbalanced. All results using these data were back transformed from mean log egg indices per pot to geometric mean number of eggs per pot before being graphed for presentation.

This ANOVA was later broadened to test the effect on the egg production index of two key environmental factors, namely swell size, and bottom temperatures. Swell size was scored in each area against a range of given categories and these have been coded numerically for analysis so that no swell=0, low=1, moderate=2 and heavy=3. Since the environmental variables were generally only measured once a day at each sampling area, there were many pot lines for which the data were missing. Missing data have been generated for those lines by assuming that they were similar to the measurements made for other lines in the same area on the same day. In a few instances this information was missing for all lines pulled on the same day and in those cases the missing variables were generated using measurements made for these sea conditions in other areas for the same day, but taking into account the average differences between locations.

Numbers of mature (setose) females by size class in the six sampling locations have been graphed in order to examine the size structure of the brood stock in the different areas. The proportion of eggs produced in each size class in each area for each year, was then calculated by estimating the number of eggs produced by each mature female sampled using the size-fecundity relationship, percent double spawning-size relationship, and percent maturity-size relationship described in Chubb *et al* (1979). These data have been presented as a series of histograms.

(b) Tagging data

(i) Sampling methods

All lobsters were tagged with individually numbered Hallprint type TBA-1 internal anchor tags, which were individually inserted into the abdominal muscle between the first and second ventral abdominal segments using a tagging gun. Lobster tagging during the 1996/97 and 1997/98 fishing seasons was undertaken from a combination of research, charter and commercial vessels. Lobsters were caught in standard commercial pots, occasionally with the escape gaps closed. The tag number, size, colour, sex, in the case of females breeding condition (i.e. presence or absence of ovigerous setae, a spermatophore or eggs), date of capture/release and position and depth of release was recorded for each tagged lobster. Similar data were recorded for each recaptured animal.

Tagged lobsters were generally recaptured by commercial fishers, although small numbers were caught by research and recreational fishers. Fishers were encouraged to surrender details of tagged lobsters by offers of a $A2 'scratch and win' instant lottery ticket for information relating to any tagged animal recaptured. Lobsters were tagged in a number of different localities and depths over the course of this project. With the exception of the tagging of 'whites' lobsters in December /January 1997/98, animals in all other tagging sessions were tagged and released as close as possible to their position of capture because there is evidence to suggest that displacing lobsters from their area of capture can affect their subsequent growth increments (Brown and Caputi, 1984), mortality rates (Chittleborough, 1974; Brown and Caputi, 1983) and can lead to nomadism (Chittleborough, 1974; Hermkind, 1980).

Many of the lobsters that were tagged were animals taken either in the course of, or in inshore fishing which followed immediately after, the fishery independent breeding stock survey, as has been fully described by Rossbach *et al*. (1997). However, in both the 1996/97 and 1997/98 seasons lobsters were tagged later in the season to provide data on specific research issues.

In the 1996/97 season 2000 'white' lobsters were tagged in the area between Fremantle and Two Rocks (a location approximately 70 km north of Fremantle) and a further 4000 were tagged between Geraldton and Port Gregory (a location approximately 70 km north of Geraldton) (Fig. 1). The aim was to obtain information on the movements of 76 mm CL lobsters in the first few months of the fishing season (see the explanation given under 'need', as well as Appendix 1).

In the 1997/98 season migrating sub-legal sized 'white' lobsters were tagged between Lancelin and Jurien (Figs. 1 and 2) to obtain data for modelling the movements of the migrating portion of the population between Zones B and C (see point 3 in 'objectives' and Appendix 2, for a more detailed explanation). Because the data collecting strategy involved tagging large numbers of lobsters in three different areas and in three different depth categories, it was not possible to do the work on the available budget by following the tagging routine that was used on all other occasions in this project and which has been described in Rossbach *et al.* (1997).

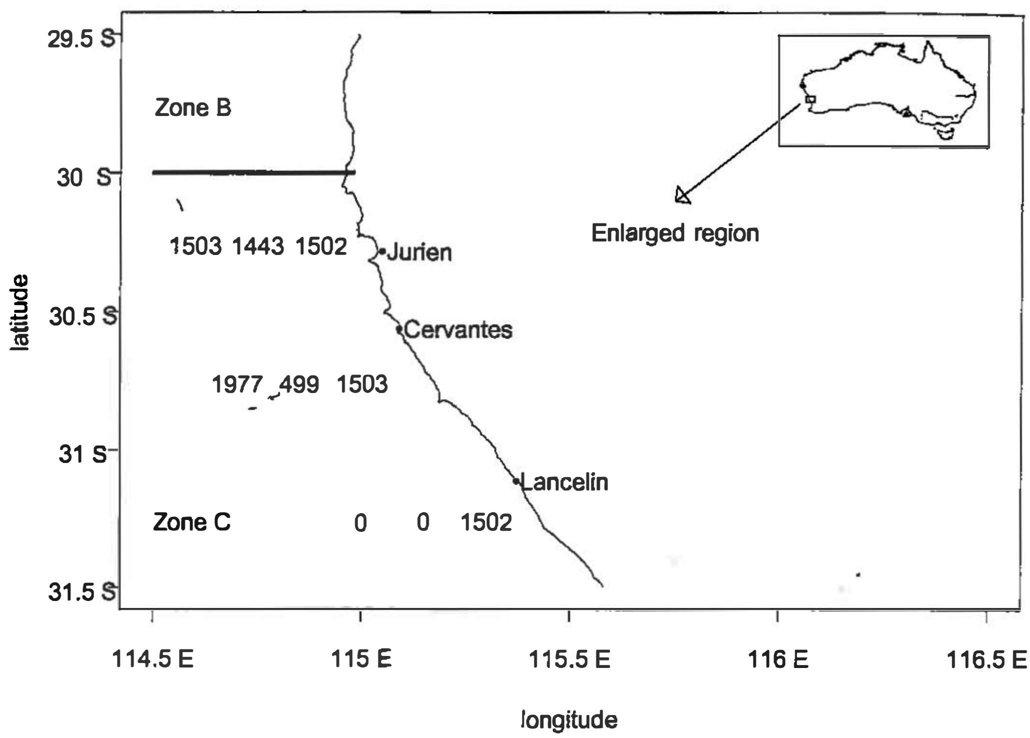

Fig. 2: Plot of the total number of western rock lobsters (carapace length < 77 mm) tagged and released in different depth among Lancelin, Cervantes and Jurien.

During this part of the work the lobsters that were used for tagging were caught at sea during the course of the day and were retained alive in deck tanks on board commercial fishing boats. When the boats returned to port at the end of the day, the sub-legal white lobsters that had been retained (n = 8,744) were tagged and kept overnight in plastic fishing baskets tied to the side of the fishing boats. The following day those lobsters were once again loaded into the deck tanks and taken out to the fishing grounds. There they were released together in a single batch, on suitable substrate and in roughly the area and depth from which they had been caught during the previous days fishing. GPS details of their release positions were recorded for future use. A number of migrating white lobsters (n = 1,175) were tagged and released at sea where they were caught. These animals will act as controls when results are compared between the migratory patterns of animals tagged ashore and at sea.

The strategy employed to collect data suitable for a simple grid pattern on which migrating lobsters would be tagged and released was defined in October 1997, well ahead of the December/January 'whites' migration (Appendix 2). The grid plan was based on area and depth of release and was established close to the 30°S parallel (the line of latitude separating Zones B and C, Fig. 2). The intended strategy was to tag lobsters in three depth strata covering the offshore extent of the western rock lobster 'whites' migration phase: approximately 1000 lobsters in the shallows (<10 fm), 1500 in mid-depths (20-40 fm) and 1500 in deep-water (>50 fm), in three areas (or correlated replicates), leading to a total of 12000 tagged animals being released over the course of the offshore migration phase (i.e. between late November and early January). The size frequency of lobsters in the catch was obtained for the three depth strata from pots with closed escape gaps.

It was considered imperative that all lobsters tagged in this experiment should be released in roughly the same depth that they were captured. To conform with this goal necessitated relying on information from fishing boat skippers on the offshore movements of the lobsters. Such movements differ from area-to-area. When the bulk of the fleet in any one of the three demarcated tagging areas (Lancelin, Cervantes or Jurien) moved into one of the target depth ranges, a tagging team was sent to that area to tag the agreed number of animals that were to be released in the particular depth range.

The sampling grid had three coastal sites south of the 30°S parallel and none to the north (Fig. 2), despite the aim being to monitor what quantity of animals was migrating across the 30°S parallel. The justification for this decision was that there were concerns that fishermen north of 30°S might, knowing the likely result of the experiment and the likely political fallout resulting from the outcome (namely that a far greater tonnage of lobsters would be moving from Zone C to B rather than B to C), be less inclined to return tagged lobsters than their more southerly counterparts. It was reasoned that since the tagged lobsters from the two southerly transects would have further to migrate before crossing the 30°S parallel, that if there was a reluctance on the part of Zone B fishers to return tagged lobsters, that this would be identified by comparisons between the numbers of animals recaptured from the three sites.

(ii) Data analysis

The analysis of tagging data collected by this project is ongoing and is taking place on a number of different levels of activity.

- In order to address the simple question posed by the Fremantle and Geraldton Fishermen's Association, namely "what is the extent of movement in the first year by 76 mm lobsters released between the start of the fishing season and the end of January?" A straightforward tabulation of numbers tagged and recaptured by distance moved as well of directional plots of those movements has been considered sufficient to illustrate the outcome of the experiment.

- Current and historic tagging data have been and are currently being systematically analysed, and whilst not *specifically* addressing the objectives of this study, such work is providing more detailed information on the growth of the lobsters (of all sizes) from year-to-year and area-to-area.

- It has not been possible in this report, to address the more complicated question raised by industry as to "what tonnage of lobsters cross the 30°S parallel from one management zone to another", because less than one season has elapsed since the animals were tagged. Clearly, more time (it is suggested at least another full season) is required for the tagged animals to distribute themselves over the grounds before any analysis of the data can be considered. A summary of the numbers of animals recaptured by depth at release and distance from release has been provided in the results section. A description of the methods that will be used to model the movement of lobsters is presented over.

Modelling the movement of product from Zone B to C:

The following assumptions will be made:

a. Each depth, in each location, represents one stratum of the open population.
b. Every animal in the population, whether marked or unmarked, has the same probability $p_i = 1 - q_i$ of being caught in the *i*th sample, given that it is alive and in the population when the sample is taken.
c. Every marked animal has the same probability ϕ_i of surviving from the *i*th to the (*i+1*)th sample and of being in the population at the time of the *i+1* sample, given that it is alive.
d. Immigration and emigration is in equilibrium.
e. The instantaneous natural mortality rate μ is constant throughout the whole experiment, and is the same for tagged and untagged animals.
f. Sampling is instantaneous, or at least takes a negligible period of time as far as population changes are concerned.

The following Statistical models will be used to interpret/present the data:

a. Rose diagrams (Fisher, 1993, Rossbach *et al*., 1997) will be used to present the directional movement of lobsters in each stratum.
b. Frequency distribution of distance moved by lobsters in each stratum will be constructed.
c. Analysis of variance (Cox, 1958) will be used to test whether there is significant difference between the distance moved from the three tagging locations and three depth strata.
d. A generalised linear model (McCullagh and Neldar,1986) will be used to predict the expected movement of the lobsters, by producing the probability of particular angular movement and distance moved.
e. Bootstrapping techniques (Efron, 1982, Efron and Gong, 1983) will be used to calculate the 95 % confidence intervals for the expected mean angular movement in each stratum.
f. Return rates of tags from the fisherman by latitude, in each season, will be used to estimate the non-return rate of tags along the margin between zone B and zone C. These analyses to be done by ANOVA and contingency table with Pearson's chi-square test.
g. Modified Jolly - Seber method (Jolly, 1965, Seber, 1965 and 1986) will be used to estimate the population size of each stratum. Assuming that immigration and emigration between strata is not negligible, moment estimates (Arnason, 1973) will be used to estimate the rate of migration.
h. Spatial simulation techniques will be used to estimate the 95% confidence intervals for the total biomass of western rock lobsters moved from zone C to Zone B. All the parameters used in the simulation will be derived in a to g (above).

DETAILED RESULTS

(a) To use independent spawning stock survey techniques to validate spawning stock indices derived from commercial fisheries data and to examine specific impacts of the current management package over its full term. Specific impacts include trends in egg production and measurement of effective effort creep by comparison of fishery independent and fishery dependent spawning stock indices

Previous analyses (Melville-Smith *et al.* 1996) showed that the main effects (year, sub-area, fishing depth, soak time and pot type) explained most of the variation in egg production indices and that interaction effects between factors were minimal. In that study (Melville-Smith *op cit*), two areas produced interactions between factors. In the Fremantle area, year and sub-area interacted, largely as a result of major changes to the survey design in that area between the first (1991) survey and those in subsequent years. Because of the major changes to the survey in Fremantle in 1991 and the influence that those changes have had on subsequent egg indices for this area, the omission of that year from the analyses undertaken in this report is considered to be justified.

The other area to show interaction effects was the Abrolhos Islands, where sub-area and depth were shown to significantly (p=0.0001) interact with each other. This interaction is not unexpected given the large depth range (0-35f), distance (~20kms) between the sub-areas (Islands) and topography and habitat types making up this area. Because of its highly significant response, the sub-area-depth interaction has been included in the summary analysis presented in (Table 1).

Given the objectives of this study, the most important outcome of the analysis has been that all six areas have shown highly significant differences in egg production in the period over which the surveys have taken place. From Figs. 3 - 9, it can be seen that in all cases egg indices have been increasing positively since the introduction of the1993/94 management package. It was noted earlier under 'methods' that where data have been grouped, the Abrolhos Island results have mostly been presented separately from coastal data due to differences in sampling strategy. In the only occasion where coastal and Abrolhos Island results have been combined in a single graph (Fig. 9), the two broad areas (Abrolhos Island and coastal areas) showed an order of magnitude difference in the recorded number of eggs per pot. These differences are attributable to high densities of lobsters at the Islands as well as a 50% size at maturity of 66 mm CL (Chubb *et al.* 1989), which is well below the 76 mm CL legal minimum size for the fishery. By contrast, size at 50% maturity on the mainland is around 93-97 mm CL (Chubb *et al.* 1989), leaving the brood stock far less protected there than at the Islands.

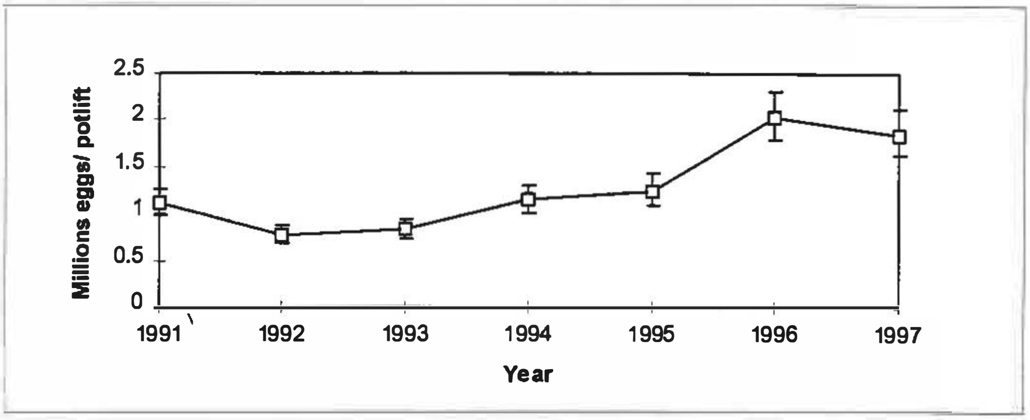

Fig. 3 Year-to-year variation in the egg production index for the Abrolhos Island area (±1 standard error of the mean), as measured by the fishery independent spawning stock survey

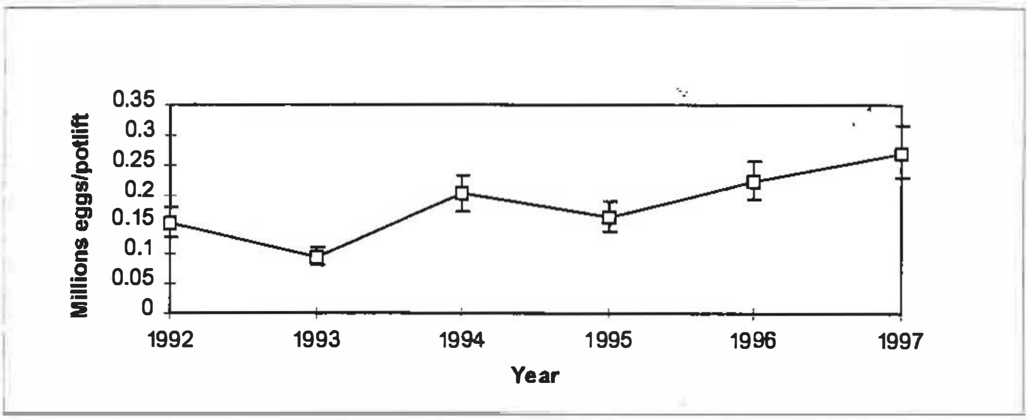

Fig. 4 Year-to-year variation in the egg production index for the Fremantle area (±1 standard error of the mean), as measured by the fishery independent spawning stock survey

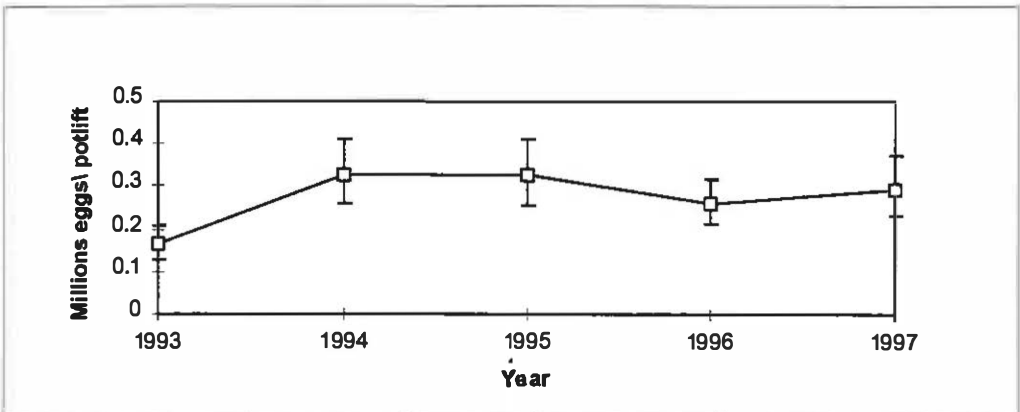

Fig. 5 Year-to-year variation in the egg production index for the Lancelin area (±1 standard error of the mean), as measured by the fishery independent spawning stock survey

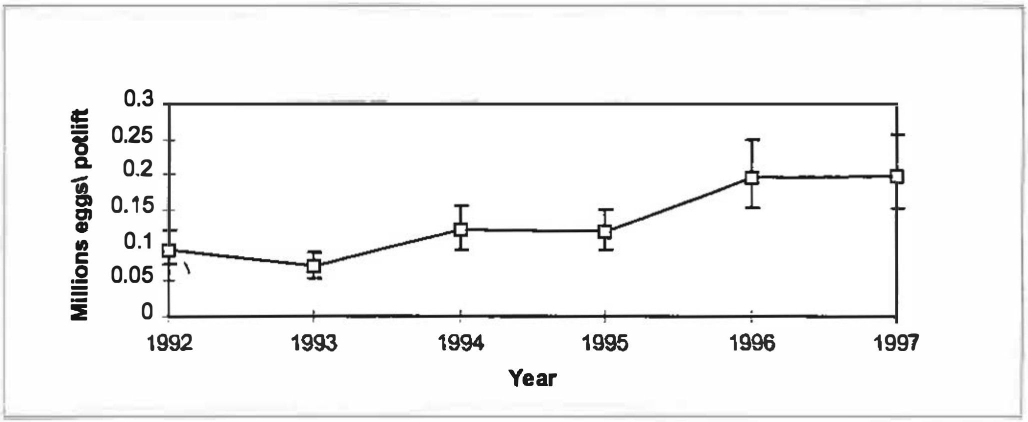

Fig. 6 Year-to-year variation in the egg production index for the Jurien area (±1 standard error of the mean), as measured by the fishery independent spawning stock survey

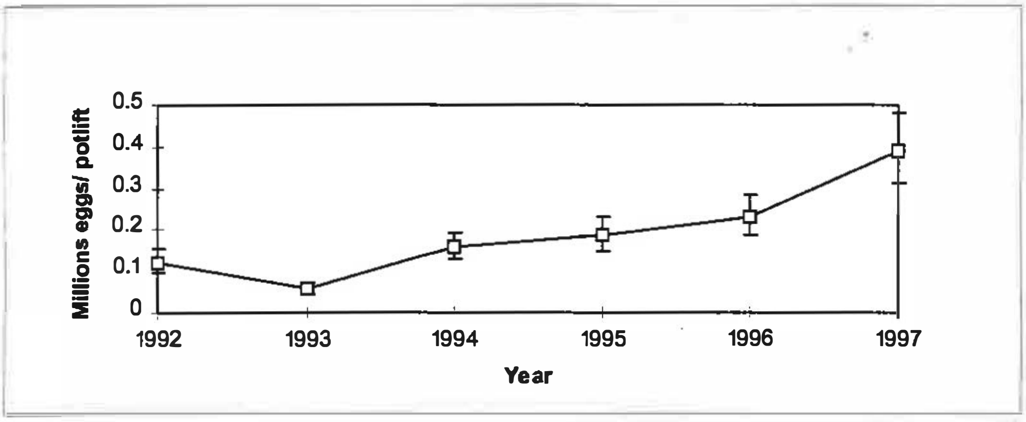

Fig. 7 Year-to-year variation in the egg production index for the Dongara area (±1 standard error of the mean), as measured by the fishery independent spawning stock survey

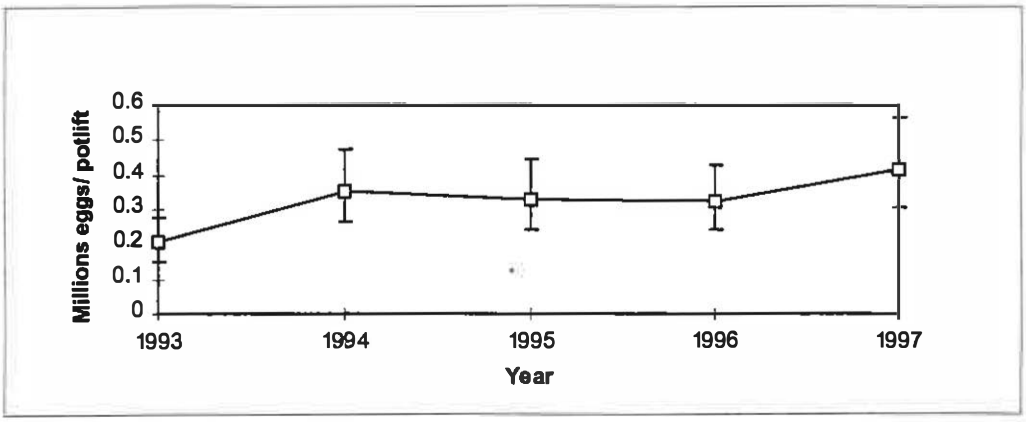

Fig. 8 Year-to-year variation in the egg production index for the Kalbarri area (±1 standard error of the mean), as measured by the fishery independent spawning stock survey

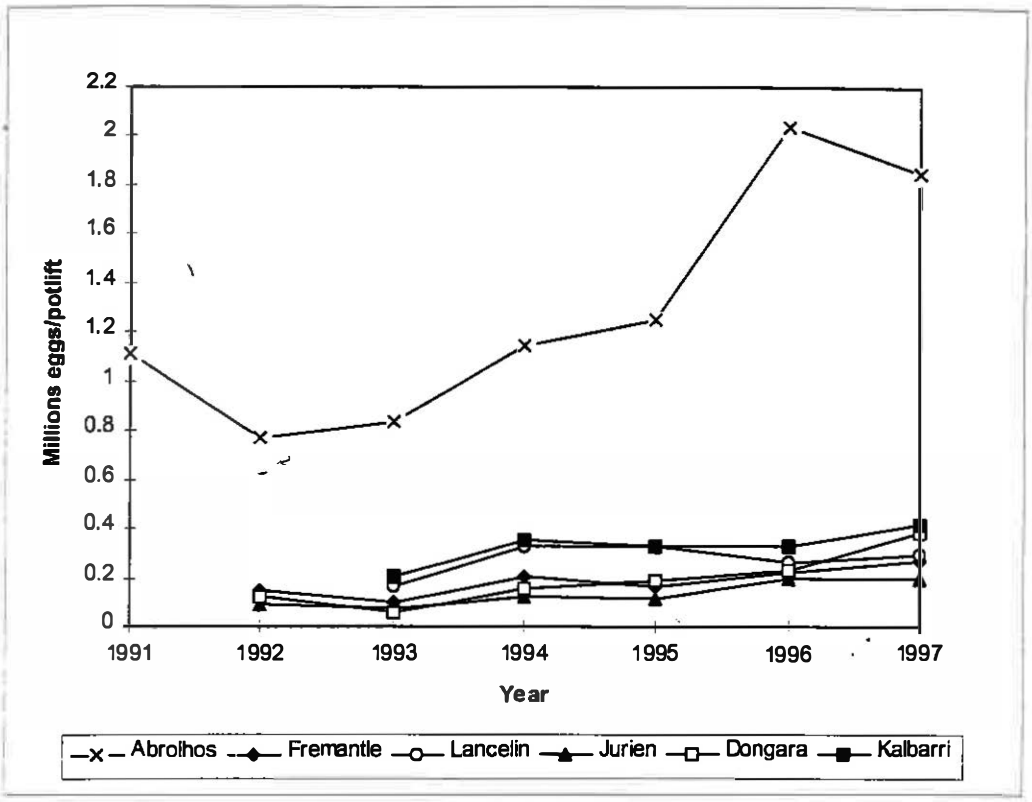

Fig. 9 Trends in egg production indices for all sites combined

Sub-area was shown to be a highly significant factor affecting the egg production index in all areas (Tables 1 - 6). This result is not unexpected because, as noted earlier, sub-areas were deliberately chosen to provide a better overall index of egg production across the areas being surveyed.

Depth was shown to be a less significant factor influencing the egg production index at the coastal sites than at the Abrolhos Islands (Tables 1 - 6). The reason for this is that the sampling strategy for the coastal survey areas has followed a fairly narrow range of depths (generally 20-30 fathoms), corresponding with the limited (20-40 fathom) depth range over which the main breeding grounds for the western rock lobsters have been shown to occur (Chubb *et al.*, 1989). Spawning grounds at the Abrolhos Islands are less well defined than on the coast and ovigerous lobsters are found at all depths in this area (Chubb *et al.* 1989). As a result, sampling at the Abrolhos Islands has been designed to cover a much wider range of depths, and as a consequence differences in catch rates (and therefore the egg production index) were more significant between depths (Table 1).

There were variable pot soaking times in all areas (Tables 1 - 6), due to pots occasionally being left for longer than the stipulated periods set out in the sampling regime. In all the coastal areas three day pulls produced more than two day pulls and though this difference was significant in a number of instances (Fremantle, Lancelin and Dongara), the results were usually only based on a relatively small number of replicates. At the Abrolhos Islands pot soaking times varied from 1 to 3 days, but in contrast to the coastal areas, longer soaking times produced significantly smaller catches/egg production indices.

Pot type was only a factor at the Abrolhos Islands and Fremantle where combinations of beehive and batten pots were used. The two pot types performed very differently in the two areas; in the Fremantle area beehive pots produced significantly more eggs per potlift than batten pots, while at the Abrolhos Islands the reverse occurred (Tables 1 and 2). The reason for the differences between the way the pots caught in the two areas is considered to be because most fishing in the Fremantle area took place in depths >20 fathoms but generally in much shallower depths at the Islands. Published data have shown that beehive pots have significantly better catch rates than batten pots in depths >37m (20 fathoms) (Brown *et al*., 1995).

Table 1. Summary of an ANOVA of log egg production indices for the Abrolhos Island area

Factors	Sum of squares	df	Mean square	*F*	*p*
Year	318.3	6	53.1	55.8	0.0001
Sub-area	659.1	3	219.7	42.4	0.0001
Depth	1445.1	5	289.0	55.8	0.0001
Soak-time	37.6	2	18.8	3.6	0.0275
Pot type	42.4	1	42.3	8.2	0.0045
Sub-area*depth	467.2	15	31.1	6.0	0.0001
Error	2052.7	396	5.2		

Table 2. Summary of an ANOVA of log egg production indices for the Fremantle area

Factors	Sum of squares	df	Mean square	*F*	*p*
Year	493.4	5	98.7	9.76	0.0001
Sub-area	329.0	4	82.3	8.13	0.0001
Depth	80.3	3	26.8	2.65	0.0485
Soak-time	50.5	1	50.5	4.99	0.0260
Pot type	82.6	1	82.6	8.17	0.0045
Error	4540.4	449	10.1		

Table 3. Summary of an ANOVA of log egg production indices for the Lancelin area

Factors	Sum of squares	df	Mean square	*F*	*p*
Year	260.9	4	65.2	6.54	0.0001
Sub-area	357.1	3	119.0	11.94	0.0001
Depth	148.3	3	49.4	4.96	0.0025
Soak-time	85.5	1	85.5	8.58	0.0038
Error	1874.1	188	10.0		

Table 4. Summary of an ANOVA of log egg production indices for the Jurien area

Factors	Sum of squares	df	Mean square	*F*	*p*
Year	554.2	5	110.8	9.28	0.0001
Sub-area	1136.2	4	284.1	23.8	0.0001
Depth	0.5	2	0.2	0.02	0.9797
Soak-time	31.1	1	31.1	2.60	0.1078
Error	3188.9	267	11.9		

Table 5. Summary of an ANOVA of log egg production indices for the Dongara area

Factors	Sum of squares	df	Mean square	*F*	*p*
Year	1317.6	5	263.5	13.94	0.0001
Sub-area	125.0	3	41.7	2.21	0.0001
Depth	44.1	2	22.1	1.17	0.3133
Soak-time	75.9	1	75.9	4.02	0.0464
Error	3779.6	200	18.9		

Table 6. Summary of an ANOVA of log egg production indices for the Kalbarri area

Factors	Sum of squares	df	Mean square	*F*	*p*
Year	210.0	4	52.5	3.74	0.0059
Sub-area	724.3	3	241.4	17.2	0.0001
Depth	47.1	1	47.1	3.36	0.0686
Soak-time	24.2	1	24.2	1.72	0.1909
Error	2638.7	188	14.0		

ANOVAs of swell size showed significant variations from year-to-year and from area-to-area (Table 7). Swell size was lowest in 1995 and highest in 1996 (Fig. 10). Data (not presented here) showed that largest swell sizes over the survey period were recorded at the Abrolhos Islands and smallest at Dongara. It should be noted that in most years the same staff have been monitoring a particular area and since swell conditions have been subjectively assigned a particular category, it is likely that personal judgements could have influenced area-to-area assessments of size.

Table 7. Summary of an ANOVA of swell size for all areas combined

Factors	Sum of squares	df	Mean square	*F*	*p*
Year	87.5	6	14.6	51.21	0.0001
Area	59.2	5	11.8	41.60	0.0001
Sub-area	3.9	20	0.2	0.69	0.8442
Error	375.9	1320	0.3		

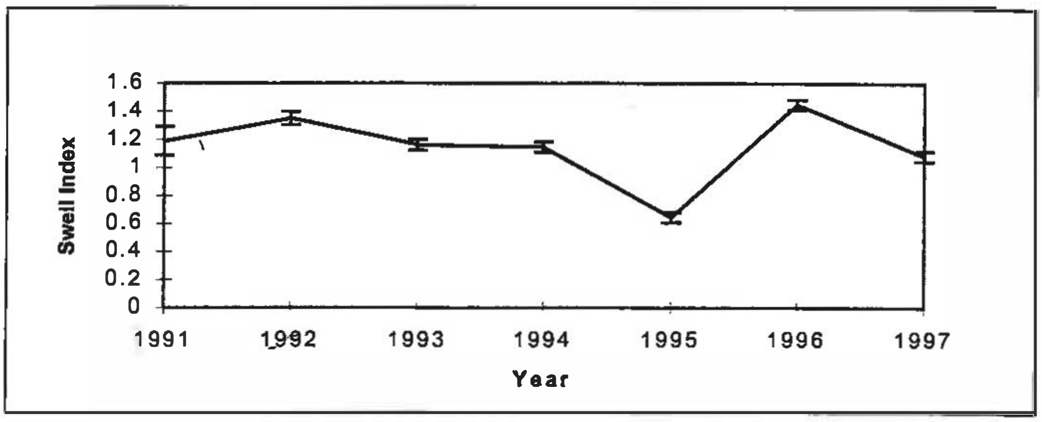

Fig. 10 Year-to-year variation in mean swell size index (±1 standard error of the mean) for the coastal areas

As with swell conditions, ANOVAs of bottom temperature showed highly significant differences from year-to-year and area-to-area (Table 8). Examination of the data (Fig. 11) showed that lowest bottom temperatures were recorded in the first three years of the seven-year data series. Data (not presented here) showed, as might have been expected, that bottom temperatures were considerably higher at the offshore Abrolhos Islands compared to the coast. The coastal sites generally fell into their latitudinal grading of warmest bottom temperatures being recorded in the north and coolest in the south.

Table 8. Summary of an ANOVA of bottom temperature for all areas combined

Factors	Sum of squares	df	Mean square	*F*	*p*
Year	135.6	6	22.6	68.60	0.0001
Area	129.2	5	25.8	78.40	0.0001
Sub-area	8.4	20	0.4	1.27	0.1947
Error	166.4	505	0.3		

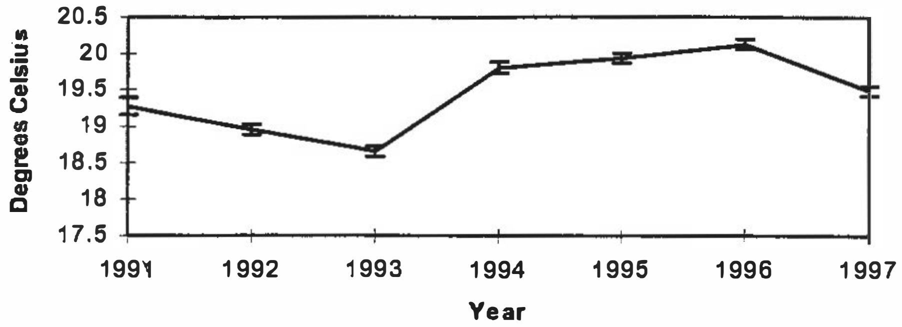

Fig. 11 Year-to-year variation in mean bottom temperature (±1 standard error of the mean) for the coastal areas

Egg production indices for the coastal and Abrolhos Island sites taking into account the effects of swell size and bottom temperature are shown in Tables 9 and 10 respectively. It should be noted, that although it has been attempted to take temperature into account in the analyses (above), it has not been fully accounted for because (in most years) there is probably more variation in temperature in a sub-area from year-to-year than within a year. The full effects of annual temperature variations will become clear as more years are added to this dataset in the future.

Swell size was shown to have a significant effect on the coastal egg production indices, but not on the Abrolhos Island indices. Temperature was not shown to significantly effect the egg production index at the coastal sites or the Abrolhos Islands. The incorporation of bottom temperature and swell size into the analysis made little difference to the significance of year-to-year effects, showing that these effects are robust to the inclusion of additional factors.

Table 9 Summary of an ANOVA of log egg production indices for the combined coastal sampling sites, taking into account swell and bottom temperature effects

Factors	Sum of squares	df	Mean square	*F*	*p*
Year	1565.4	5	313.1	24.72	0. 0001
Area	2296.3	4	574.1	45.32	0.0001
Sub-area	2695.7	17	158.6	12.52	0.0001
Depth	314.2	4	53.6	4.23	0.0021
Soak-time	239.2	1	239.2	18.88	0.0001
Pot type	82.6	1	82.6	6.52	0.0108
Swell	80.6	1	80.6	6.36	0.0118
Temperature (bottom)	15.1	1	15.1	1.19	0.2746
Error	16707.3	1319	12.7		

Table 10 Summary of an ANOVA of log egg production indices for the combined Abrolhos Island area, taking into account swell and bottom temperature effects

Factors	Sum of squares	df	Mean square	*F*	*p*
Year	186.8	6	31.1	5.93	0.0001
Sub-area	548.9	3	182.9	34.84	0.0001
Depth	1422.8	5	284.6	54.19	0.0001
Pot type	42.09	1	42.09	8.02	0.0049
Sub-area*Depth	460.3	15	30.7	5.84	0.0001
Swell	10.58	1	10.58	2.02	0.1565
Temperature (bottom)	0.03	1	0.03	0.01	0.9365
Error	2079.5	396	5.25		

It is not unexpected to find that swell height had some influence on the coastal egg production index, though it is perhaps surprising that it is more influential than bottom temperatures in explaining the year-to-year variation of the index, because foraging and therefore catchability of *P. cygnus* (the factor which would influence the egg production index), has been more frequently attributed to temperature variation than swell height (Chittleborough 1970, 1975, and Morgan 1974). It was notable that environmental effects were not significant at the Abrolhos Islands where lobster densities and pot catch rates are particularly high. It is likely that under such conditions, pot volume, soaking time and bait quantity play a bigger part in limiting the catch (and therefore the egg production index per pot).

The fact that environmental effects influence lobster catchability and therefore the egg production index, makes it necessary to include these factors when presenting data on year-to-year variation in the indices. Accordingly, these two environmental factors have been taken into account in the overall presentation of egg production data for the western rock lobster fishery over the period covered by the fishery independent spawning stock indices (Figs. 12 and 13).

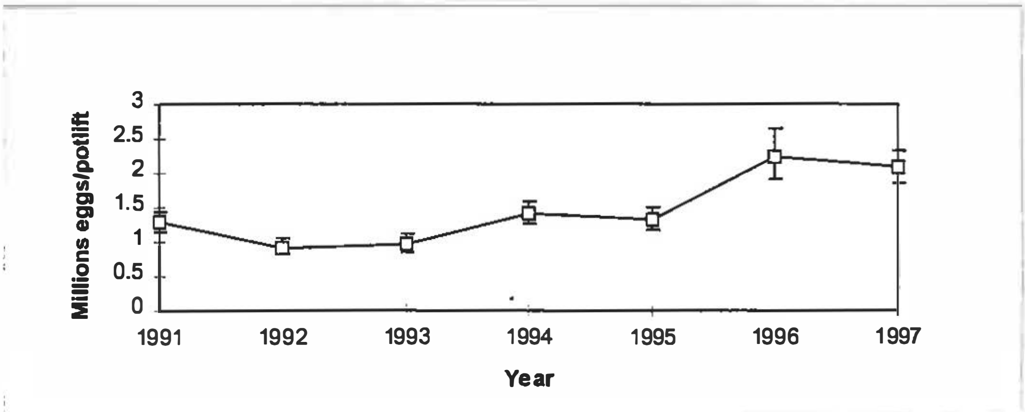

Fig. 12 Year-to-year variation in the egg production index (±1 standard error of the mean) for the egg production index for the Abrolhos Island, taking swell and bottom temperature into account

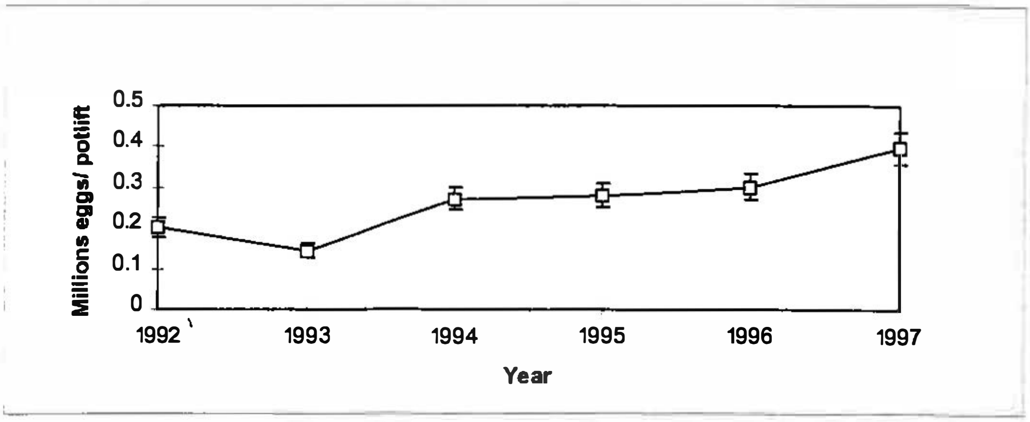

Fig. 13 Year-to-year variation in the egg production index (±1 standard error of the mean) for the egg production index for the coastal areas, taking swell and bottom temperature into account

The percentage proportion of mature (setose) lobsters in various size classes are presented by area in Figs. 14-19 and the contribution of these same size classes to total egg production within their sampling area are shown in Figs. 20-25. The two sets of figures show the importance of viewing the proportion to egg production made by different size classes in terms of reproductive contribution, rather than numerical abundance. The reason for this is that the number of eggs carried per lobster is positively related to carapace size and furthermore, large lobsters are more likely to carry more than one brood per year than small individuals (Chubb *et al.* 1989).

As was noted earlier, size at 50% maturity is very much smaller at the Abrolhos Islands than at the coast and as a consequence >90% of egg production is accounted for by lobsters <85mm CL (Fig. 20) compared to only about 20-40% for the coastal areas (Figs 21-25). Equally notable is the fact that around 70% of the contribution made to the Abrolhos Island egg production is attributable to animals below the legal minimum size (Fig. 20), while at the coast this figure is <5% (Figs. 21-25).

The contribution to egg production at the Abrolhos Islands made by lobsters less than the legal minimum size (Fig. 20), is probably an underestimate. Pots with closed escape gaps select for western rock lobsters larger than 60mm (Morgan, 1970). Because maturity can occur in lobsters as small as 44mm CL at the Abrolhos Islands (Chubb *et al.* 1989), a small quantity of egg producing animals probably escaped capture and would therefore not have been accounted for in Fig. 20. Because of the very much larger size at sexual maturity at the coastal areas, this potential problem is not considered to be of concern for those data (Figs 21 and 25).

Legislation introduced in the 1993/94 season as part of the management package aimed at increasing egg production, imposed a legal maximum size for females of ≥115 mm CL south of Wedge Island (30°50'S) and ≥105 mm CL north of this line. In more recent times (since the start of the 1997/98 season), the Wedge Island line has been moved north to the border between Zones B and C (30°S). Results (Figs. 21-25) show that the maximum size has resulted in a small, but significant (~5-10%), increase in the contribution of this size class to overall egg production in all coastal areas.

There was a marked change in the contribution made by lobsters >105 mm CL to overall egg production in the Jurien area in 1997 compared to the two previous years (Fig. 23). The reason for this is believed to be due to some unscrupulous fishers operating in this area during the 1996/97 season, retaining lobsters in the 105-115 mm CL size range despite there being a ban on landing females >105 mm in this area over that period. These fishers were able to overcome the legislation by landing the oversized lobsters south of the Wedge Island line, and this transportation of oversized lobsters across the line was a prime reason for the movement of the line to 30°S in 1997. Because the 30°S line separates Zones B and C, it is now considered to be easier for the enforcement staff to prevent any flaunting of the maximum size rule than was the Wedge Island line.

The increase in contribution to overall egg production that has resulted from the imposition of the maximum size rule is small compared to the setose rule and the raising of the legal minimum size for the first two and a half months of the season, which together have led to a doubling of overall egg production over the same period Figs. 12 and 13).

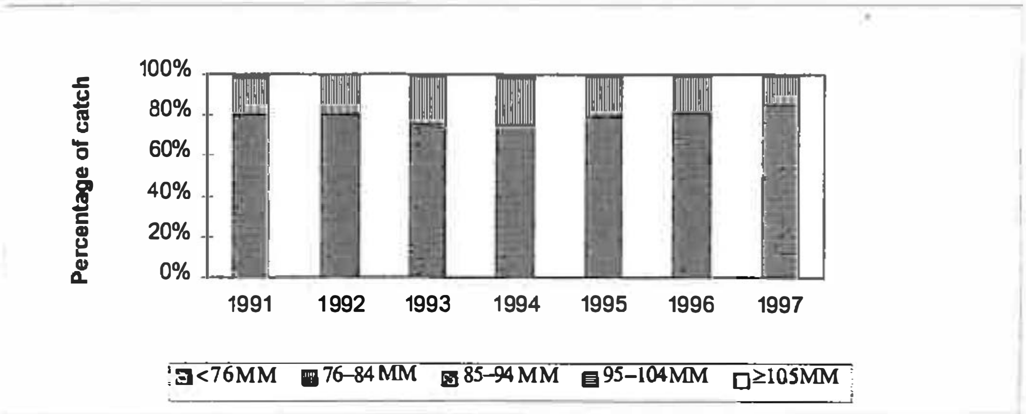

Fig. 14 Histogram showing year-to-year variation in the proportion of different size classes of mature (setose) female lobsters contributing to the Abrolhos Island catch during the fishery independent spawning stock survey 1991-1997

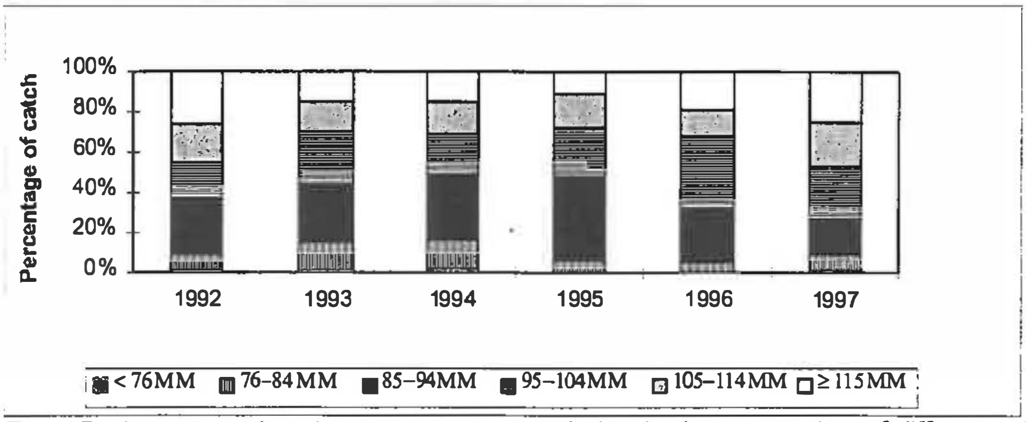

Fig. 15 Histogram showing year-to-year variation in the proportion of different size classes of mature (setose) female lobsters contributing to the catch made in the Fremantle area during the fishery independent spawning stock survey 1992-1997

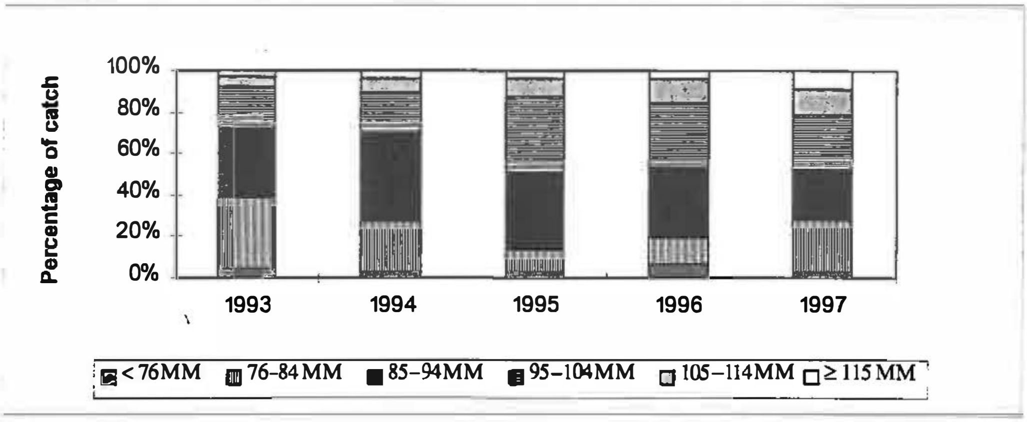

Fig. 16 Histogram showing year-to-year variation in the proportion of different size classes of mature (setose) female lobsters contributing to the catch made in the Lancelin area during the fishery independent spawning stock survey 1993-1997

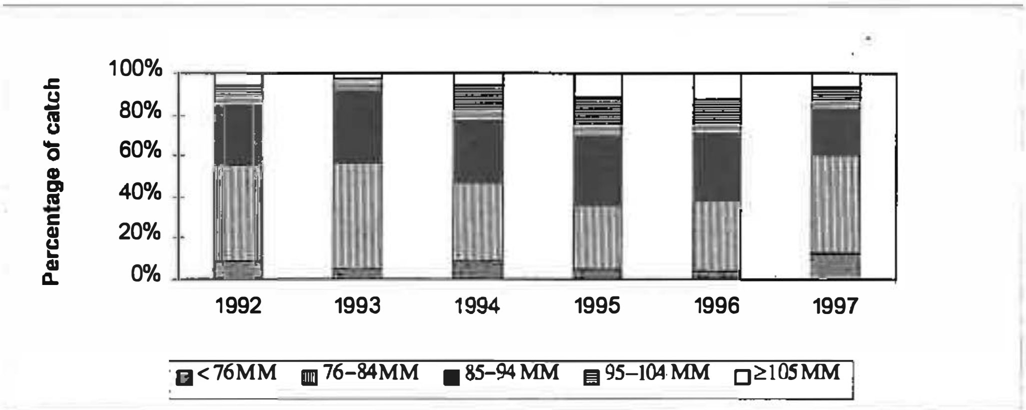

Fig. 17 Histogram showing year-to-year variation in the proportion of different size classes of mature (setose) female lobsters contributing to the catch made in the Jurien area during the fishery independent spawning stock survey 1992-1997

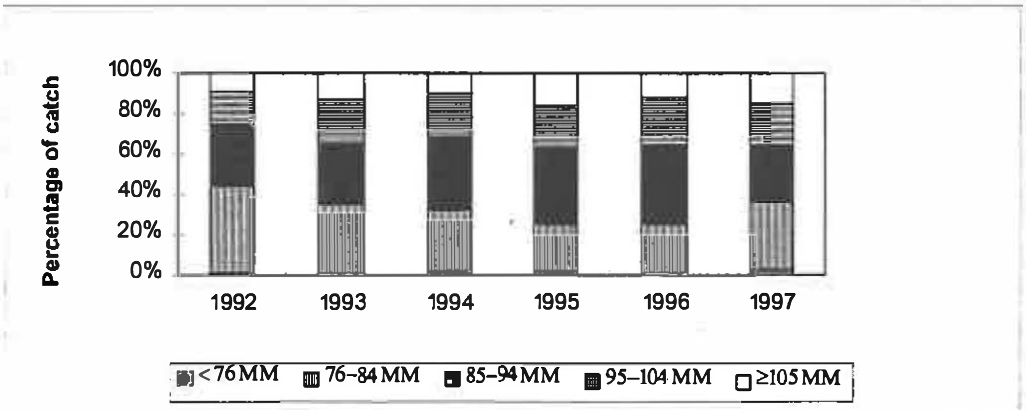

Fig. 18 Histogram showing year-to-year variation in the proportion of different size classes of mature (setose) female lobsters contributing to the catch made in the Dongara area during the fishery independent spawning stock survey 1992-1997

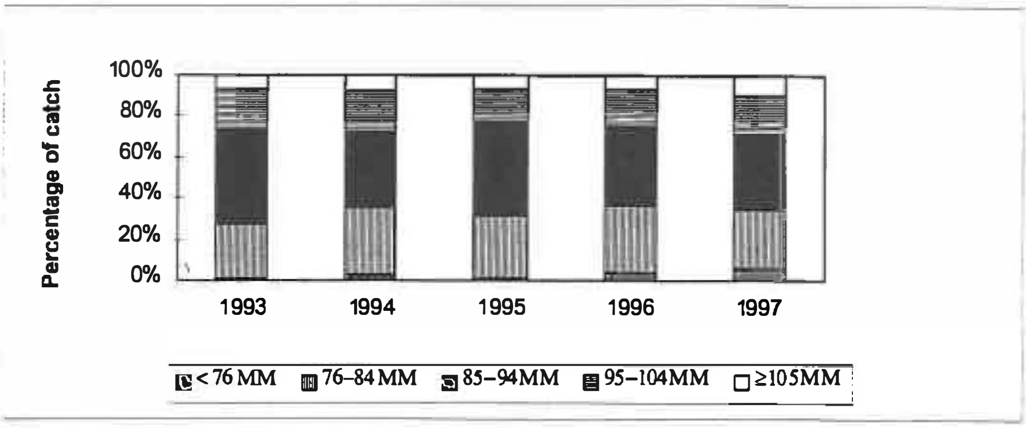

Fig. 19 Histogram showing year-to-year variation in the proportion of different size classes of mature (setose) female lobsters contributing to the catch made in the Kalbarri area during the fishery independent spawning stock survey 1993-1997

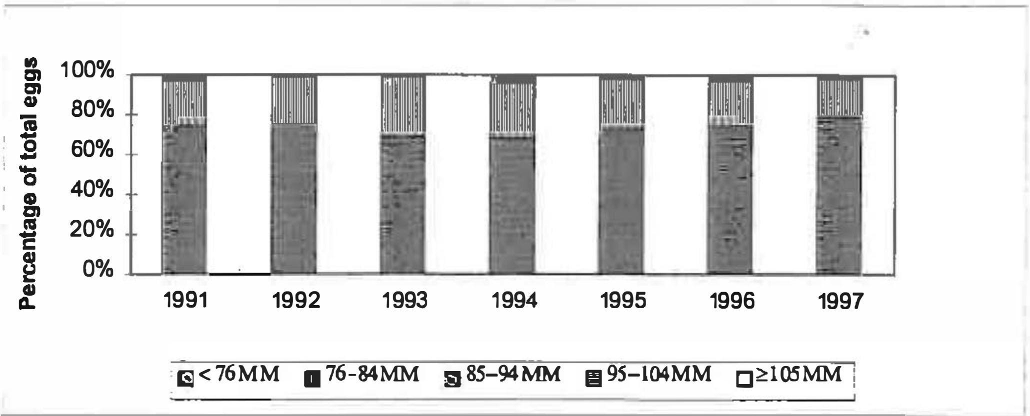

Fig. 20 Histogram showing year-to-year variation in the egg production contribution made by different size classes of female lobsters taken during the fishery independent spawning stock survey at the Abrolhos Islands 1991-1997

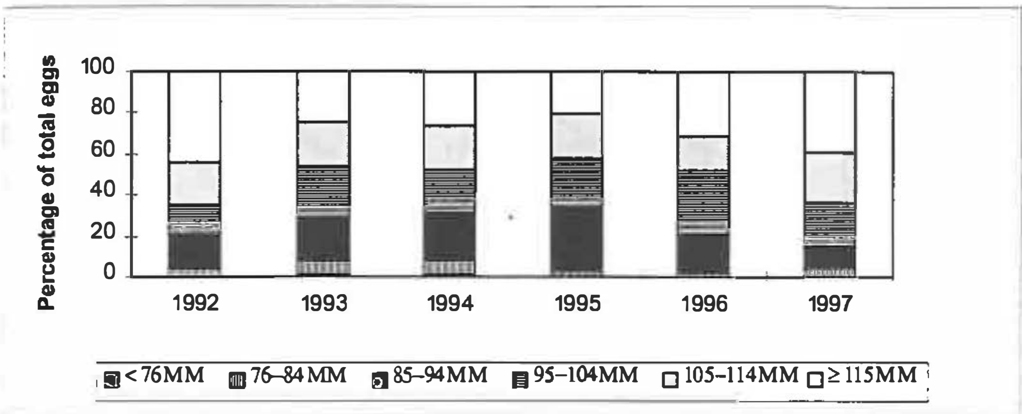

Fig. 21 Histogram showing year-to-year variation in the egg production contribution made by different size classes of female lobsters taken during the fishery independent spawning stock survey in the Fremantle area 1993-1997

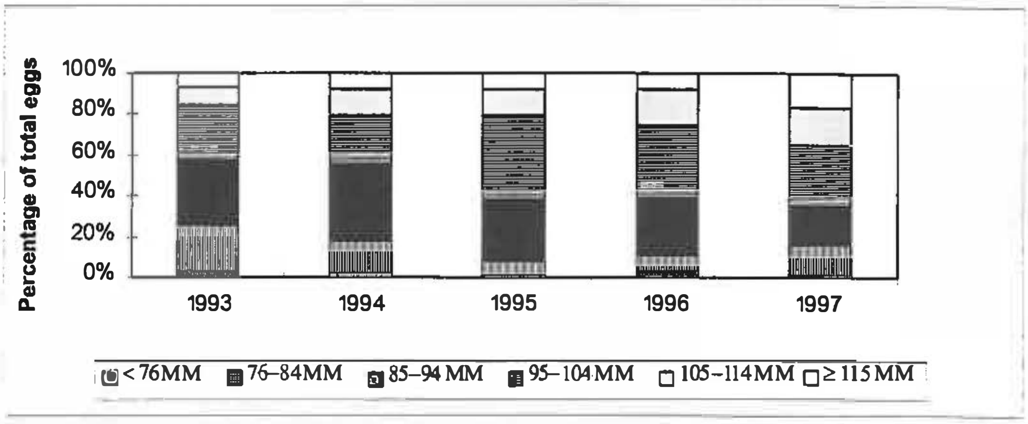

Fig. 22 Histogram showing year-to-year variation in the egg production contribution made by different size classes of female lobsters taken during the fishery independent spawning stock survey in the Lancelin area 1993-1997

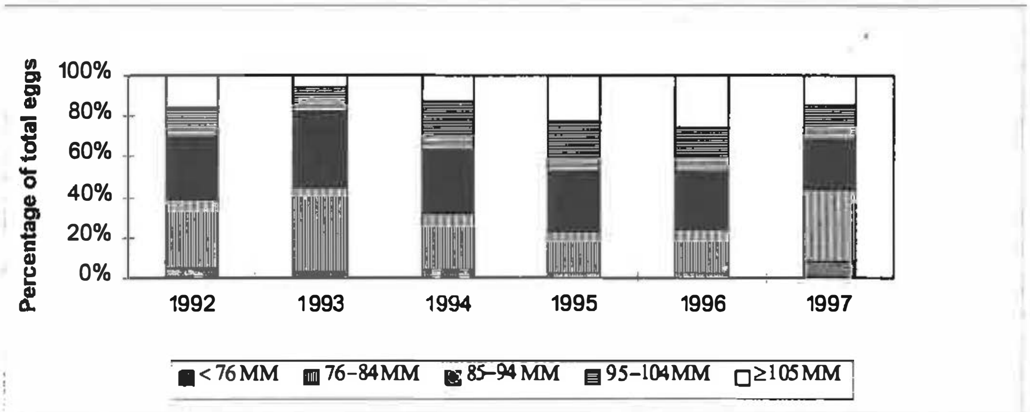

Fig. 23 Histogram showing year-to-year variation in the egg production contribution made by different size classes of female lobsters taken during the fishery independent spawning stock survey in the Jurien area 1993-1997

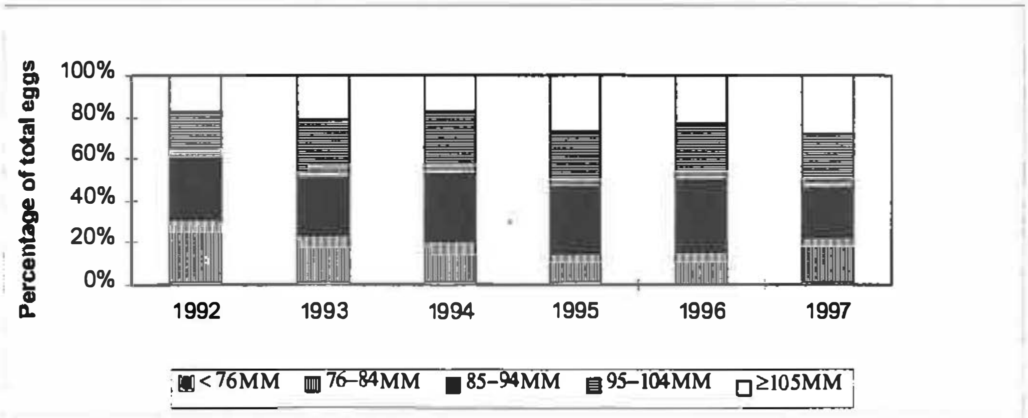

Fig. 24 Histogram showing year-to-year variation in the egg production contribution made by different size classes of female lobsters taken during the fishery independent spawning stock survey in the Dongara area 1992-1997

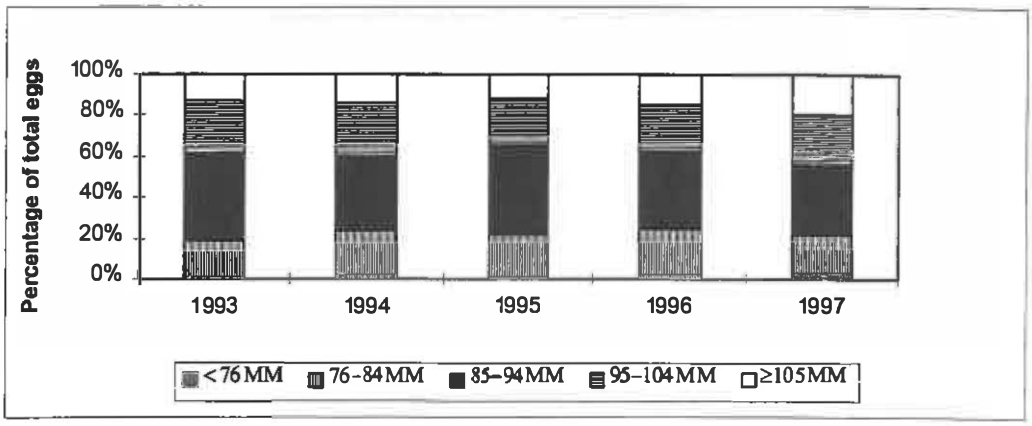

Fig. 25 Histogram showing year-to-year variation in the egg production contribution made by different size classes of female lobsters taken during the fishery independent spawning stock survey in the Kalbarri area 1993-1997

The prime reason for the initiation of the fishery independent breeding stock survey was to establish an index of egg production free from the potential biases that can be introduced through the use of commercial fishing data. Fishery dependent egg production indices have been used to monitor the state of the spawning stock in the past (Caputi et al.1995) and will continue to be updated each year in the future. That method of estimating egg production and the one developed in this study are viewed as complimenting each other. At this stage both methods are showing similar responses to trends in egg production (Figs. 26 and 27).

The egg production indices shown in Fig. 26 and 27 have been calculated using commercial fishing length monitoring data from the 20-30 fm depth range at four coastal areas (as described in Caputi et al. 1995). The indices (Figs. 26 and 27) would suggest that egg production has increased by approximately 250% in the southern area (Fig. 26) and 150% in the northern areas (Fig. 27) since the introduction of the 1993/94 management package (Anon, 1993). By comparison, the Abrolhos Island and combined coastal indices calculated from the fishery independent data presented in this study (Figs. 12 and 13), suggest that egg production has increased by 170% and 120% respectively over this same period.

It is not clear why there is such discrepancy between the fishery independent breeding stock survey and the fishery dependent breeding stock indices. Both methods are reinforcing the same conclusion, namely that egg production has shown a phenomenal increase over a relatively short period. However, it is believed that the indices derived by the fishery dependent method are less reliable than the figures that have been derived by this fishery independent study which had the specific objective of measuring changes in egg production.

Those responsible for the management of the western rock lobster resource in the early 1990s considered that having egg production levels in the fishery at an estimated 15-20% of pristine was not sufficiently cautious (Caputi et al. 1995). Management objectives (Caputi *op cit*) were to increase the breeding stock to the level that it had been in the early 1980s, which was an estimated 25% of the pristine spawning stock size. Both fishery dependent (Figs. 26 and 27) and fishery independent (Figs. 12 and 13) spawning stock indices, suggest that egg production has more than doubled over the past four years, thereby achieving and even surpassing the target levels set by managers for this resource. Management measures which might result in the utilisation of some breeding animals above the maximum size limit, without allowing egg production to fall below 'safe' egg production levels are under consideration (Donohue 1998).

(b) To undertake pre-season tagging of juveniles in the shallow water of the limited entry fishery to obtain more detailed information on the migration and growth of these lobsters to aid in the understanding of the effects of distributing catch more evenly throughout the season.

Numbers of animals tagged during the course of, and immediately following the fishery independent breeding stock survey are shown in Table 11. Recapture rates for the current (1997/98) season are low, because a substantial number of tagged animals remain at large for longer than one season before being recaptured.

It is obvious that tagged lobster recapture rates are variable from area-to-area. It is not clear to what extent these differences reflect variations in exploitation rates from one area to another, or differences in the way that fishers cooperate by returning recaptured tagged rock lobsters in one area compared to another.

Analysis of these data are ongoing. The data are viewed as a part of an unbroken long-term dataset. These and earlier data have been used to examine spatial and temporal variations in growth (Rossbach *et al.* 1997).

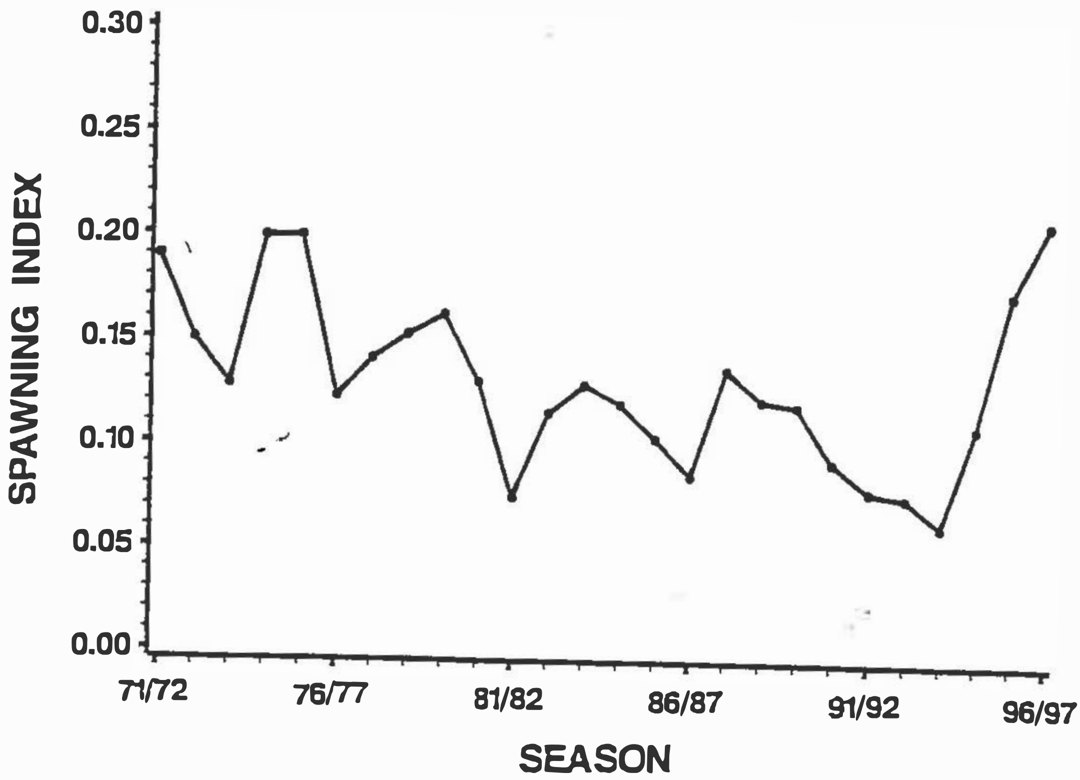

Figure 26 *Time series of monitoring of spawning stock index for south coastal region.*

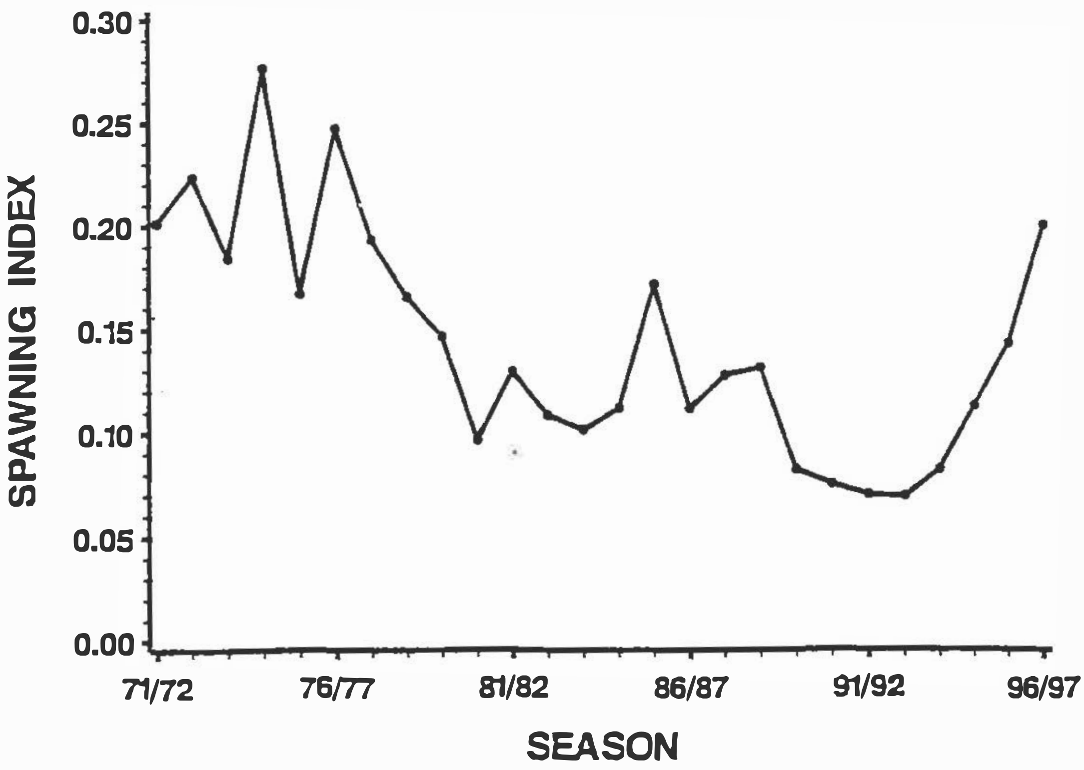

Figure 27 *Time series of monitoring of spawning stock index for north coastal region.*

Table 11. Western rock lobster tagged during the course of the fishery independent breeding stock survey. In each season and location, the top figure refers to numbers tagged, the middle to numbers recaptured and the bottom figure to percentage recapture rates.

Locations	Seasons 1996/97	1997/98	Totals
Fremantle	575	751	1326
	53	18	71
	9.2%	2.4%	5.5%
Lancelin	1631	1268	2899
	487	122	609
	29.8%	9.6%	21.0%
Jurien	2832	1094	3926
	461	231	692
	16.3%	21.1%	17.6%
Dongara	602	1124	1726
	195	155	350
	32.4%	13.8%	20.3%
Kalbarri	3699	1867	5566
	804	139	943
	21.7%	7.4%	16.9%
Abrolhos	5992	5996	11988
	867	377	1244
	14.5%	6.3%	10.4%
	15331	12100	27431
Totals	2867	1042	3909
	18.7%	8.6%	14.3%

Current as at 10/6/98

Of more significance to this project, has been the tagging work directed at addressing specific industry concerns relating to the movement patterns of migrating 'white' lobsters, in particular the 76-77 mm animals which are sub-legal sized animals from the start of the fishing season to the end of January when the legal size changes to 76 mm (see Appendices 1 and 2).

Numbers of lobsters between Fremantle and Two Rocks (hereafter referred to as Fremantle) and between Geraldton and Port Gregory (hereafter referred to as Geraldton) tagged in December/January 1996/97 and recaptured in the same and subsequent season, are presented in Table 12. As has been noted in the past (Rossbach *et al*., 1997), only a small proportion of recaptured lobsters showed major movements (Table 12, Figs. 28-31). Those that did show substantial migration (>30 nm) amounted to only 1.6% of the combined recaptures over both seasons.

Table 12. Numbers of western rock lobsters tagged in Fremantle and Geraldton in December and January during the 1996/97 season, with recapture rates for distances covered from the release position.

Location	Number tagged	Recapture season	Numbers recaptured (by distance from release position) in nm					
			0-10 nm	11-20 nm	21-30 nm	31-40 nm	>40 nm	Total
		96/97	257	2	1	0	0	260
Fremantle	2000	% recaught	12.9	0.1	<0.1	0	0	13
		97/98	31	13	12	5	13	74
		% recaught	1.6	0.7	0.6	0.25	0.65	3.7
		96/97	892	17	1	1	0	911
Geraldton	4000	% recaught	22.3	0.4	0.3	<0.1	0	22.8
		97/98	57	0	2	0	2	61
		% recaught	1.4	0	<0.1	0	<0.1	1.5

Current as at 4/6/98

Clearly this preliminary analysis of movement is an underestimate of the real movement. It does not take into account the fact that some tagged lobsters were probably (particularly in the first year after tagging) recaptured prior to having completed their migration. Nevertheless, it does emphasise that most 'white' lobsters do not undertake extensive movement.

Concerns by the Geraldton fishers as to the fate of 76-77 mm CL animals released in the first part of the fishing season (Appendix 1) were shown to be unfounded. Only 15 animals tagged as 'whites' were shown to move from Zone B to Zone A (Figs. 30 and 31).

(c) To set in place a tagging strategy that will provide data capable of being utilised to model the tonnage of 'white' 76 mm CL lobsters migrating between Zones B and C.

Recapture rates by area and depth and by area and distance moved are presented in Tables 13 and 14 respectively. The numbers tagged in the three depth ranges in the three locations are very different to the target numbers that were set prior to the commencement of the experiment. The reason for this is that the offshore component to the 'whites' migration run, which is made up of recruiting animals, was smaller than usual in 1997/98 in those locations. The smaller than usual offshore migration run was caused by the migration being unusually late (by one or two weeks) compared to normal years, as well as recruitment to the fishery in the 1997/98 season being below average. These factors, combined with the fact that fishers made exceptionally good catches in the shallow waters and unquestionably succeeded in 'thinning out' the numbers of animals migrating offshore, made it difficult for the fishing fleet to follow the migrating lobsters as they quickly (over a week or two) moved through the mid-grounds and into the deep (>50 fm) water.

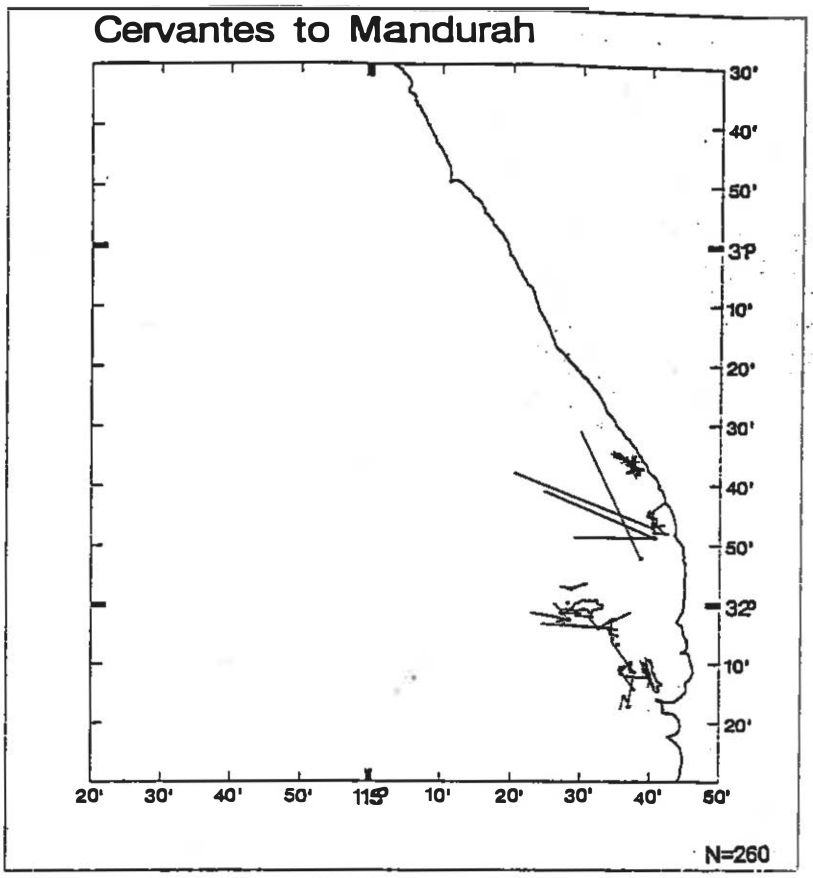

Fig. 28 Straight line plots from point of release to point of recapture for individual lobsters tagged at Fremantle in December/January 1996/97 and recaptured the same season

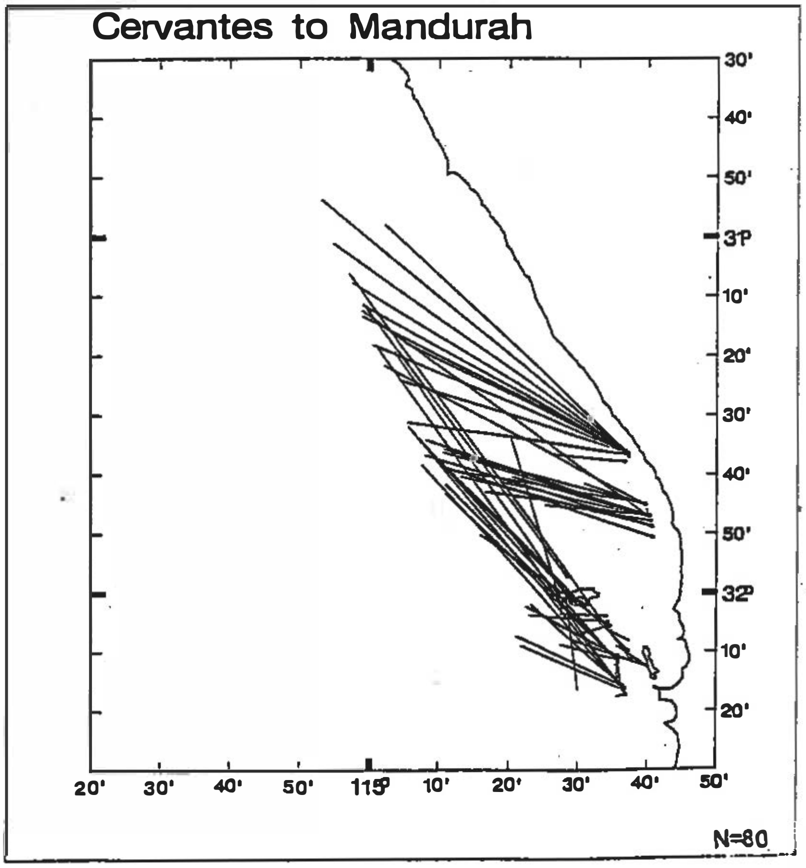

Fig. 29 Straight line plots from point of release to point of recapture for individual lobsters tagged at Fremantle in December/January 1996/97 and recaptured in the 1997/98 season

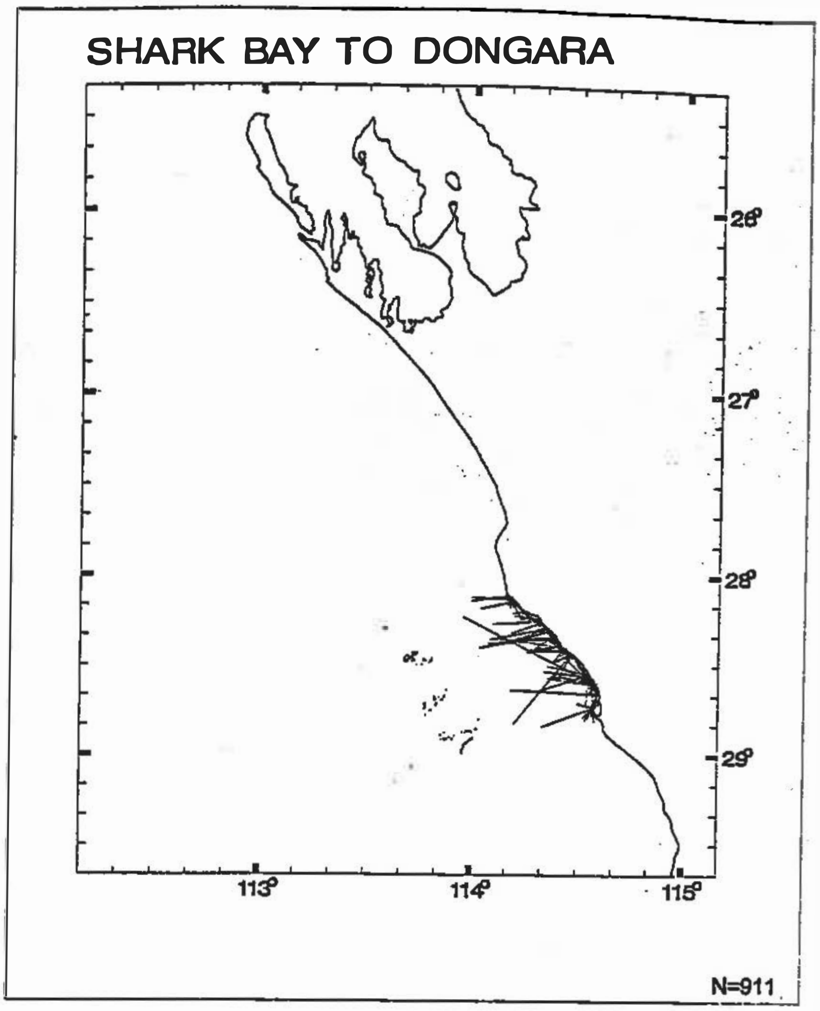

Fig. 30 Straight line plots from point of release to point of recapture for individual lobsters tagged at Geraldton in December/January 1996/97 and recaptured the same season

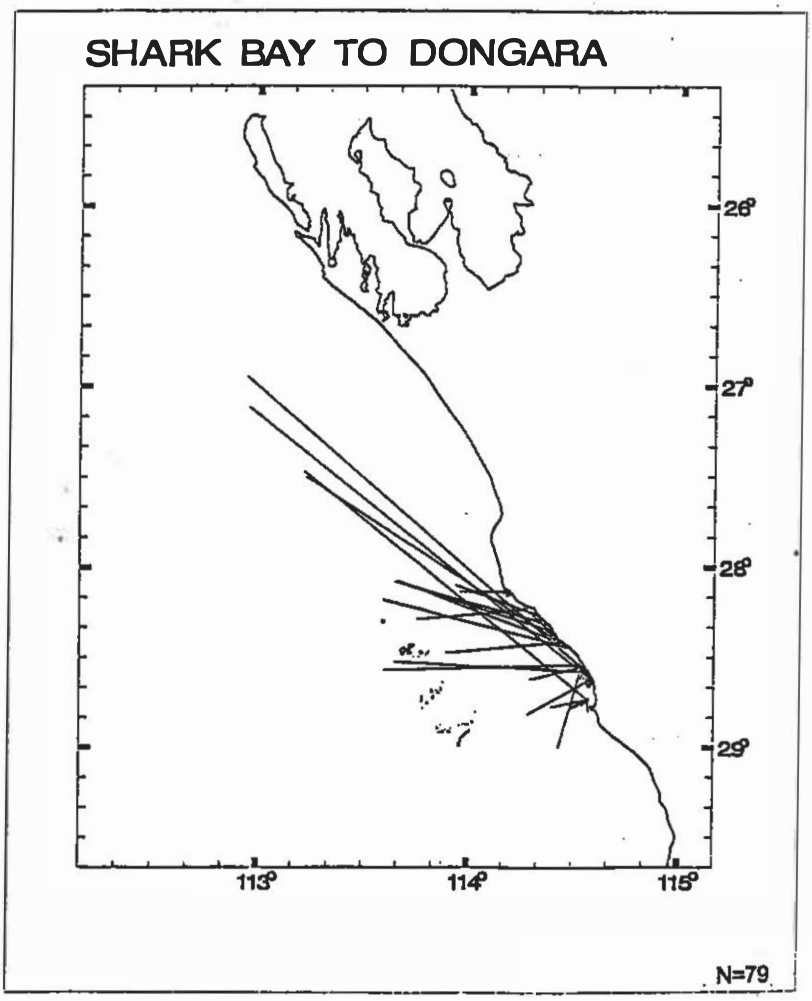

Fig. 31 Straight line plots from point of release to point of recapture for individual lobsters tagged at Geraldton in December/January 1996/97 and recaptured in the 1997/98 season

Table 13. Numbers of western rock lobsters tagged by depth interval in Lancelin, Jurien and Cervantes in 1997/98, with corresponding recapture rates.

Tagging location		No tagged 0-15fm	Recap	No tagged 20-40fm	Recap	No tagged >50+fm	Recap	Total Tagged	Total Recap
Lancelin	#	1502	196					1502	196
	%		13.0						13.0
Jurien	#	1502	106	1443	56	1503	58	4448	220
	%		7.1		3.9		3.9		4.9
Cervantes	#	1503	112	499	12	1977	49	3979	173
	%		7.5		2.4		2.5		4.3
All areas	#							9929	589
	%								5.9

Current as at 4/6/98

Table 14. Numbers of western rock lobsters tagged in Lancelin, Jurien and Cervantes in the 1997/98 season, with recapture rates for distances covered from the release position

Tagging location	Number tagged	Numbers recaptured by distance from release position (in nm) 0-10 nm	11-20nm	21-30nm	31-40nm	40+nm	Total
		196	0	0	0	0	196
Lancelin	1502	13.0	0	0	0	0	13.0
		182	17	11	5	5	220
Jurien	4448	4.1	0.4	0.2	0.1	0.1	4.9
		146	14	3	2	8	173
Cervantes	3979	3.7	0.4	0.08	<0.1	0.2	4.3

Current as at 4/6/98

Because the wave of migrating lobsters moved rapidly in a dispersed fashion over the 20-40 fm depth range, it was difficult to know when to send staff to tag at the three tagging locations (see scattered tagging dates for each location, Table 15). As a consequence, fewer lobsters than desired were tagged in the mid-depths in the Cervantes region.

Table 15. Dates when 'whites' tagging took place in 1997/98, by depth strata, by locality

Location	Tagging depth (fm)	Dates when tagging took place
JURIEN BAY	0-15 fms	3/12/97 - 5/12/97
	20-40 fms	29/12/97, 3/12/97, 4/1/97
	>50 fms	29/12/97, 31/12/97, 4/1/97
CERVANTES	0-15 fms	3/12/97 - 5/12/97
	20-40 fms	4/1/98 - 7/1/98
	>50 fms	29/12/97 - 31/12/97, 5/1/98, 6/1/98
LANCELIN	0-15 fms	3/12/97 - 5/12/97

The mid and deep-water migration of lobsters did not materialise to any degree in the Lancelin area in 1997/98 and therefore tagging was not considered feasible in these depths in this area.

A larger percentage of animals were recaptured from shallow compared to deep-water releases (Table 13), which may reflect differences in exploitation rates in the two broad depth ranges. It is encouraging that tag recapture rates across the three depth categories sampled (Table 13) were so similar for Cervantes and Jurien. It must however be borne in mind that it is very premature to be examining these data, as more tag return information for this season will undoubtedly be forthcoming from fishers who hold back submission of their tag return data to the end of the fishing season. Furthermore, recent experience has shown that around 20% of all tag recaptures are made in the years that follow the season on which tagging took place (see Table 12 and Melville-Smith and Chubb, 1997).

Direction and extent of movement show the now familiar trend of most recaptured animals migrating <10 nm from where they were tagged (Table 14). Those that migrated substantial distances (>10 nm) were generally recaptured north-west of their release location (Fig. 32).

Prior to using these data to model movements of product from Zone C to B, it will be necessary to show that lobsters that were brought ashore to be tagged behaved similarly to those that were released at sea. There are too few data at this point to provide any indication as to whether there are behavioural differences, however a comparison of recapture rates using χ^2 tables has shown that there were significant differences ($p<0.001$) between the recapture rates of animals tagged and released at sea at Cervantes, compared to those that were brought ashore to be tagged (Table 16). Differences in recapture rates between those tagged at sea compared to those tagged ashore was not significant for releases in the Jurien area (Table 16).

Table16. Recapture rates for lobsters tagged at sea compared to those tagged ashore

Location and depth	Tagged and recaptured	No. tagged at sea	No. tagged ashore
Jurien Bay		599	841
20-27fathoms	recaps	25	31
	%	4.17%	3.69%
Cervantes	#	574	1399
50+ fathoms	recaps	24	25
	%	4.18%	1.79%

Work by Chittleborough (1974), suggested that displaced lobsters show abnormal patterns of movement and he hypothesised that displacement made lobsters more vulnerable to predation. Tagging results obtained by Brown and Caputi (1983) indicated that the recapture rates of migrating lobsters were somehow affected more by displacement than were those for non-migrating animals. While there do seem to be some preliminary indications in this study (at least in the Cervantes area) that displacement may have led to lower recapture rates, the movement patterns of animals tagged at sea have yet to be compared to those tagged ashore.

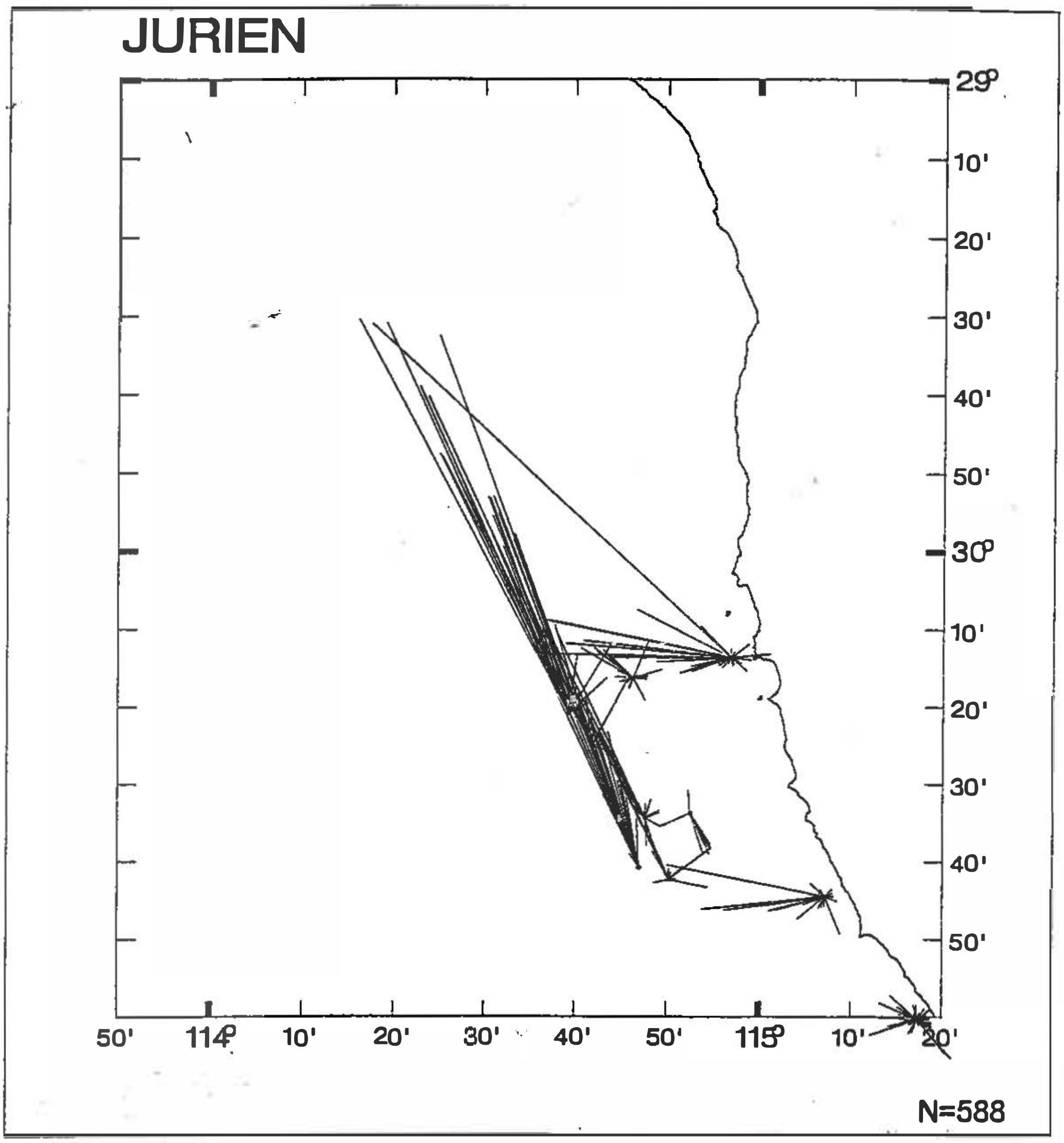

Fig. 32 Straight line plots from point of release to point of recapture for individual lobsters tagged at Lancelin, Cervantes and Jurien in December/January 1996/97 and recaptured the same season

BENEFITS

There are just over 600 boats licensed to fish in the western rock lobster fishery and the catch averages at around 10,500 tonnes per annum. The value of the fishery is estimated at between $200-300 million per annum which makes it Australia's most important single species fishery. The recreational fishery provides a pastime for between 20,000-30,000 fishers each season and this sector harvests an estimated 300-800 tonnes per season. Sound management of this fishery is critical to maintaining production, and in that way ensuring the future of the industry as well as those who depend on it for their livelihood and recreation.

It is widely accepted by researchers, managers and the fishers themselves, that the level of risk associated with egg production of 15-20% of pristine (the level at which this fishery was believed to operating in the late 1980s/early 1990s) is unacceptable. For the reasons that have been outlined earlier in some detail, it was felt in the early 1990s that there were serious downsides to using commercial fishery data to estimate egg production. This project was initiated in order to establish a fishery independent egg production index and it has achieved that aim in full. Over the last four years, the fishery dependant and independent indices have shown substantial increases and there are now no longer concerns regarding the state of the brood stock.

Beneficiaries of this research are both commercial and recreational fishers. It is felt that the current state of egg production will ensure optimal recruitment to the fishery in the future. Managers will now be able to rely on what is believed to be a reliable independent index of egg production and the focus of their endeavours will now be able to shift away from egg production concerns, towards improving the value of the fishery.

Changes to management regulations in the 1993/94 season have impacted on catches of migrating 'white' lobsters in some parts of the fishery. There was a need to obtain additional information on the movements and growth of 'whites' in the fishery, in order to address the concerns of fishers that large quantities of these animals were moving from Zones C to B and B to A. Data collected by this project will achieve these aims.

FURTHER DEVELOPMENT

Fishery independent spawning stock survey

The results of this project show it to be a useful and arguably more accurate index of egg production in this fishery than indices derived from commercial monitoring and log book data. Managers of this fishery have recognised the value of the project and have made a commitment to support the continuation of collecting fishery independent egg production indices in the future.

Future financial support for this work will be obtained from Industry under the cost recovery process. In an attempt to minimise this burden, it has been agreed to limit future surveys to three rather than six sites. It is intended to conduct an internal (Fisheries WA) workshop on the results of this project that have been obtained to date (on 22 July 1998) and to use that venue to decide which of the current sites should be continued in the future. Debate is also likely to centre on the possibility of surveying all six sites at periodic intervals. If this were considered to have merit, consideration would need to be given to the frequency with which such large-scale surveys should occur.

Finally, although it has been agreed by Industry to limit future sampling to three sites per annum, workshop members may consider the possibility of retaining the present six sampling sites, but surveying them biannually rather than annually.

Lobster tagging

A considerable tagging database has been built up over the last decade and this will be useful for many years to come.

As with the future of the fishery independent breeding stock surveys, further developments with respect to tagging of western rock lobsters will be considered by a panel of workshop participants on 22 July 1998.

It should be noted that tagging can be used to provide data on lobster movement, growth and fishing mortality and while some of these areas have been intensively researched, there are other research areas for which there are wide gaps in our knowledge.

Research areas which should be considered for future tagging research focus are:

(i) the use of biological tags (Melville-Smith *et al.* 1997) for identifying intermoult intervals.

(ii) annual monitoring of growth increments to examine the effects of density (big catch years versus average and low catch years) and possible density dependent effects on growth.

(iii) the selective use of tagging for estimating fishing mortality (eg. to record fishing mortality during the Big Bank run, or comparing differences in shallow compared to deep-water fishing mortality).

CONCLUSION

This project set out to achieve three objectives:

(i) *To use independent spawning stock survey techniques to validate spawning stock indices derived from commercial fisheries data and to examine specific impacts of the current management package over its full term. Specific impacts include trends in egg production and measurement of effective effort creep by comparison of fishery independent and fishery dependent spawning stock indices.*

This objective was fully achieved. Fisheries independent egg production indices were established separately for each of the six sampling areas spanning the main commercial distribution of the western rock lobster fishery. Five of these indices were then combined to form a coastal egg production index. Both the fisheries dependent and fisheries independent egg production indices showed these indicators to have more than doubled since the 1993/94 season when the management package aimed at improving egg production was introduced.

The maximum size rule was shown to have had a significant effect on the improvement of egg production in the fishery, but its increased contribution was small compared to the other changes that were brought about by the 1993/94 management package.

(ii) *To undertake pre-season tagging of juveniles in the shallow water of the limited entry fishery to obtain more detailed information on the migration and growth of these lobsters to aid in the understanding of the effects of distributing catch more evenly throughout the season.*

Tagging of sub-legal sized animals in the Fremantle and Geraldton areas at the request of Industry Associations, once again proved to sceptics that though some 'whites' lobsters undergo major migrations, the vast majority (>80%) move <10 nm. (18 km) from their release position. Those that do undertake major movements tend to move in a north-westerly direction, following the depth contours. Very few 'whites' (~1.5% of the tag recaptures) tagged on the coast west of the Abrolhos Islands crossed the border from Zone B to Zone A.

These results achieved their objectives, in that they have provided data on the movements of lobsters from a part of the coast (Geraldton to Port Gregory) for which there had been no previous tagging data available. Based on these results, there is now a better understanding of how the zonal distribution of the catch might be impacted by the changes to the legal minimum sizes that are currently under consideration.

Obtaining data on growth was a minor objective. No specific data were obtained in this regard, but the tag recapture information will be utilised in ongoing lobster growth studies.

(iii) *To set in place a tagging strategy that will provide data capable of being utilised to model the tonnage of 'white' 76 mm CL lobsters migrating between Zones B and C.*

The tagging strategy which will provide the data for estimating the tonnage of 'whites' moving between Zones C and B was established and executed. Information has been presented on the tag recaptures that have been made to date, but it is clearly too premature to quantify the movement between zones.

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REFERENCES CITED

Anon. (1993). Rock Lobster Industry Advisory Committee management proposals for 1993/94 and 1994/95 western rock lobster season. Fisheries Management Paper, Fisheries Department of Western Australia, No. **54**: 25 pp.

Arnason, A. N. (1973). The estimation of population size, migration rates and survival in the stratified population. *Res. Popul. Ecol.*: **15** 1-8.

Brown, R. S., and Caputi, N. (1983). Factors affecting the recapture of undersize western rock lobster *Panulirus cygnus* George returned by fishermen to the sea. *Fisheries Research* **2**: 103-128.

Brown, R.S., and Caputi, N. (1984). Factors affecting the growth of undersize western rock lobster, *Panulirus cygnus* George, returned by fishermen to the sea. *US National Marine Fisheries Service Fishery Bulletin* **83**: 567-74.

Brown, R.S., Caputi, N. and Barker, E. (1995). A preliminary assessment of increases in fishing power on stock assessment and fishing effort expended in the western rock lobster (*Panulirus cygnus*) fishery. *Crustaceana* **68** (2): 227-37.

Caputi, N., Chubb, C.F. and Brown, R.S. (1995). Relationships between spawning stock, environment, recruitment and fishing effort for the western rock lobster, *Panulirus cygnus*, fishery in Western Australia. *Crustaceana* **68** (2): 213-26.

Chittleborough, R.G. (1970). Studies on recruitment in the Western Australian rock lobster *Panulirus longipes cygnus* George: density and natural mortality of juveniles. *Aust. J. mar. Freshwat. Res.* **21**: 131-148.

Chittleborough, R.G. (1974). Development of a tag for the western rock lobster. CSIRO Division of Fisheries and Oceanography Report No. **56**: 19 pp.

Chittleborough, R.G. (1974). Home range, homing and dominance in juvenile western rock lobsters. *Aust. J. mar Freshwat. Res.* **25**: 227-234.

Chittleborough, R.G. (1975). Environmental factors affecting growth and survival of juvenile western rock lobsters *Panulirus longipes* (Milne-Edwards). *Aust. J. mar. Freshwat. Res.* **26**: 177-196.

Chubb, C.F. (1991). Measurement of spawning stock levels for the western rock lobster, *Panulirus cygnus*. *Revista Investigaciones Marinas* **12**: 223-233.

Chubb, C.F., Dibden, C. and Ellard, K. (1989). Studies on the breeding stock of the western rock lobster, *Panulirus cygnus*, in relation to stock and recruitment. FIRTA project 85/57 Final Report: 37 pp.

Cox, C.R. (1958). Planning of experiments. John Wiley, New York.

Donohue, K. (1998). Western rock lobster management - options and issues. Fisheries Management Paper, Fisheries Western Australia, No. **113**: 68 pp.

Efron, B. (1982). The Jacknife, the Bootstrap and Other Resampling Plans. CBMS-NSF Regional Conference Series in Applied Mathematics 38. S.I.A.M, Pennsylvania.

Efron, B. and Gong, G. (1983). A leisurely look at the bootstrap, the jacknife, and the cross-validation. *American Statistician*, **37**, 36-48.

Fisher, N.I.(1993). Statistical Analysis of Circular Data. Cambridge University Press, New York.

Herrnkind, W.F. (1980). Spiny lobsters: patterns of movement. In: The biology and management of lobsters, 1: Physiology and behaviour, (ed.) Cobb, J.S. & Phillips, B.F. pp. 349-407. Academic Press, New York.

Jolley, G.M. (1965). Explicit estimates from capture-recapture data with both death and immigration-stochastic model. *Biometrika*, **52**, 225-247.

Marec Pty Ltd. (1997). Optimising the worth of the lobster catch. Options and issues. Fisheries Management Paper, Fisheries Department of Western Australia, No. **101**: 86 pp.

McCullagh, P. and Nedler, J.A. (1986). Generalized Linear Models, 2nd edn, Chapman and Hall, London.

Melville-Smith, R. Caputi, N. Chubb, C.F. and Christianopoulos, D. (1996). Fishery independent study of the spawning stock of the western rock lobster. FRDC Project 93/091 Final Report: 37 pp.

Melville-Smith, R. and Chubb, C.F. (1997). Comparison of dorsal and ventral tag retention in western rock lobsters, *Panulirus cygnus* (George). *Mar. Freshwater Res.*, **48**: 577-580.

Melville-Smith, R., Jones, J.B. and Brown, R.S. (1997). Biological tags as moult indicators in *Panulirus cygnus* (George). *Mar. Freshwater Res.*, **48**: 959-965.

Morgan, G.R. (1974). Aspects of the population dynamics of the western rock lobster, *Panulirus cygnus* George. II Seasonal changes in the catchability coefficient. *Aust. J. mar. Freshwat. Res.* **25**: 249-259.

Morgan, G.R. (1977). Aspects of the population dynamics of the western rock lobster and their role in management. Ph.D. Thesis, University of Western Australia: 341 pp.

Prokop, F. (1997). Rock Lobster Industry Advisory Committee Report. Management arrangements for the western rock lobster fishery for the 1997/98 season. Fisheries Management Paper, Fisheries Department of Western Australia, No. **94**: 23 pp.

Rossbach, M., Chubb, C.F., Melville-Smith, R. and Cheng, Y.W. (1997). Mortality, growth and movement of the western rock lobster. FRDC Project 95/020 Final Report: 38 pp.

Seber, G.A.F. (1965). A note on the multiple-sample single recapture census. *Biometrika*, **52**: 249-259.

Seber, G.A.F.(1986). A review of estimating animal abundance. *Biometrika*, **42**: 267-292.

APPENDIX 1

FISHERIES DEPARTMENT
OF WESTERN AUSTRALIA

BERNARD BOWEN
FISHERIES RESEARCH INSTITUTE

Western Australian Marine
Research Laboratories

West Coast Drive
Waterman

Mr D Mahoney
Programme Manager
Fisheries Research and Development Corporation
PO Box 222
DEAKIN WEST ACT 2600

Dear Mr Mahoney

RE: Modification of sampling in Project 96/108 "Fishery Independent Survey of the Breeding Stock and Migration of the Western Rock Lobster, *Panulirus cygnus*"

It is proposed to alter slightly the sampling regime of the above project to address more directly one of the objectives; specifically the short term migration of 76mm carapace length western rock lobsters returned to the sea as part of the current management arrangements.

Justification

In most cases the fishermen are happy to accept the information based on the tagging of juvenile lobsters in shallow water at the end of the October breeding stock survey and other data. However, a more direct assessment of the movement of returned lobsters in the Fremantle and Geraldton regions is being sought by industry which they consider is essential in understanding the implications of the current management arrangements. Since this is one of the objectives of the approved project it is proposed that the two days of shallow water tagging at Fremantle and Dongara not be undertaken in October. Instead the resources will be utilised to tag 76mm lobsters returned to the sea off Fremantle and Geraldton during the "whites" fishery in December 1996. Commercial vessels operating in those areas will be used as the tagging platforms at no charge.

In the past few years, the complaint has been made that the substantial number of 76mm "white" lobsters returned to the sea around Geraldton simply migrate to the Abrolhos Islands. This is perceived to give those fishers with A Zone concessions an unfair advantage of additional catch when the Abrolhos season commences in March. While we have data from Dongara to the south of the Abrolhos and Kalbarri to the north, we have no information on the movement of lobsters from the coast directly east of the Abrolhos Islands. The proposed change to the sampling programme will rectify this situation.

The changes outlined here will address directly the short term movements of the temporarily undersized lobsters in Fremantle where a large part of fishers' incomes are

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derived from the "whites" phase of the season. Direct evidence of the migration of this specific size group of lobsters in the Fremantle and Geraldton regions will assist industry and researchers in their assessment of the current management arrangements.

I see this alteration to the programme as responding to a reasonable request by industry to provide specific information relating to the impact of current management arrangements.

Approval sought

Since the changes still address explicitly the stated objectives, they are supported by WAFIC and industry and the project will remain within budget, I seek the board's concurrence to undertake the modified programme for this year. No decision will be taken on sampling for 1997 until the results from the 1996 field work are available.

Yours sincerely

Dr C F Chubb
Senior Fisheries Research Scientist
Principal Investigator

29 August, 1996

FISHERIES DEPARTMENT
OF WESTERN AUSTRALIA

Enquiries Roy Melville-Smith ☎(09) 246 8406
our ref:
your ref

BERNARD BOWEN
FISHERIES RESEARCH INSTITUTE
Western Australian Marine
Research Laboratories
West Coast Drive
Waterman

Dr Patrick Hone.
Fisheries Research and Development Corp.
P.O. Box 222
Deakin West
ACT 2600

Dear Dr Hone,

re Modification of sampling in Project 96/108 "Fishery Independent Survey of the Breeding Stock and Migration of the Western Rock Lobster, Panulirus cygnus"

Subtle modifications were made to the above project during 1996 (your fax dated 15/10/1996 approving the changes refers) and it is proposed that changes be made to the tagging project again this year. These are that:

Instead of tagging juvenile lobsters in the shallow water at the five coastal locations of Kalbarri, Dongara, Jurien, Lancelin and Fremantle at the end of the spawning stock survey, it is now intended to tag juveniles at Jurien, Green Island and Lancelin during the commercial fishing season. The tagging of sub-legal sized "white" lobsters will take place from commercial vessels as follows: in each of the three areas approximately 1000 will be tagged and released in the shallows(<10 fm), 1500 in mid-water depths (20-40 fm) and 1500 in deep water (>50 fm), leading to a total of 12000 tagged animals being released over the course of the offshore migration phase (i.e between late November and early January).

The proposed changes to the methods outlined in Project 96/108 will still address the original objectives. It is anticipated though, that the revised tag release strategy will provide a better basis for modelling the movements of the migrating lobsters across the boundary that separates the northern from the southern coastal management zones. Though this was not identified as an objective in 96/108, the debate over what proportion of migrating "white" lobsters are 'lost' from one management zone to the other has become an increasingly controversial issue. Future management scenarios currently under discussion, do not exclude the possibility of small changes to the legal (77mm) minimum size. Since migrating "white" lobsters fall within this size range (largely 70-80mm), it is important that an attempt be made to quantify the likely changes to landings on either side of the management boundary line that would result from any such changes.

Budget implications
Your approval is sought to use the $10000 savings that would result from scrapping the pre-season inshore tagging (i.e. charter vessel costs of $2000 for the two-day tagging portion of the project in the five areas), as well as some savings on bait purchases, car hire etc to fund the costs of staff hired to undertake the amended tagging strategy outlined above. The two people employed to do the tagging in the three areas will need to spend at least 15 days in the field, spread out over three periods corresponding with the migration of lobsters from shallow inshore to deep offshore waters.

A preliminary budget would be as follows:

3 Fisheries Dept FTEs for 3 periods of 6 days @ $120/day	$6 480
3 Temporary Assistants for 3 periods of 4 days @ $100/day	$3 600
Hiring of 2 vehicles for 3 periods of 8 days each @ $70/day	$3 360
Total	$13 440

Clearly, the budget for the envisaged work will be tight and there are unlikely to be any savings made under the revised sampling regime.

Industry liaison
The need to quantify the extent of migration across the zonal management line has been discussed with fishers on the recent Rock Lobster Coastal Tour. There was widespread support for such work.

I would appreciate your earliest possible response to this request, because if there are objections to the proposed changes and we are forced to continue as outlined in the project proposal, then it will be necessary to finalise charter arrangements within the next fortnight. I look forward to your response.

Yours sincerely

Roy Melville-Smith
Senior Fisheries Research Scientist
6 October, 1997

APPENDIX 3

INTELLECTUAL PROPERTY AND VALUABLE INFORMATION

The data will be published in scientific journals in due course and in that respect remains the intellectual property of those who have participated in its collection and analysis. There is no information of a confidential or commercially sensitive nature.

APPENDIX 4

STAFF

Ms S. Anderton	Technical Officer	100%#
Mr E.H. Barker	Technical Officer	*
Mr M.J. Byrne	Technical Officer	*
Dr N. Caputi	Research Supervisor	*
Dr Y Cheng	Senior Research Scientist,	*
Mr D. Christianopoulos	Technical Officer	100%
Dr C.F. Chubb	Senior Research Scientist, Principal Investigator	*
Mr B.J.M. Davy	Technical Officer	100%#
Mr N Hall	Research Supervisor,	*
Mr W Lehre	Research Scientist,	*
Dr R. Melville-Smith	Principal Research Scientist	*
Ms S. O'Connor	Technical Officer	100%#
Mr A. Paust	Technical Officer	*
Mr M.H. Rossbach	Technical Officer	*

* Trained staff who assisted with the project using non-FRDC funds.
\# Staff employed for parts of the project under FRDC funding.