FINAL REPORT

MORTALITY, GROWTH AND MOVEMENT OF THE WESTERN ROCK LOBSTER (Panulirus cygnus).

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TABLE OF CONTENTS

95/020 Mortality, growth and movements of the western rock lobster (*Panulirus cygnus*).

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OBJECTIVES:

1. To prepare a report to industry on the migratory movements of lobsters tagged in recent programmes.
2. To estimate regional growth and mortality rates using existing data from recent programmes to assist in the experimental design of future tagging programmes.
3. To undertake tagging of juveniles in the shallower waters of the Limited Entry Western Rock Lobster Fishery to provide preliminary estimates of exploitation and growth rates and the directions and magnitude of movements.
4. To attempt to recruit and train fishing industry representatives in the procedures of data collection from recaptured tagged lobsters to improve the level of reporting by industry.
5. To prepare a longer term strategy for providing annual exploitation rates, growth and movements of western rock lobster throughout the Limited Entry Fishery.

NON-TECHNICAL SUMMARY

The very high levels of exploitation in the western rock lobster fishery have resulted in the introduction of regional or zone-specific management arrangements in recent years. This is a permanent departure from an holistic approach to the fishery's regulation. A detailed knowledge of regional variations in the growth, movement and mortality of the lobsters is required to support the models assessing regional management options.

A need was identified to supplement the Fisheries Western Australia, Research Division's resources to enable the full analysis of existing tagging data in terms of growth, movements and mortality; to undertake tagging in shallow water to assist in addressing specific management issues; to improve the level of tag recapture information from industry; and to develop a strategic approach to tagging that would assist in providing appropriate advice to management and industry, given the regional approach to the fishery's regulation.

Tagging of western rock lobsters, using "spaghetti" tags in a dorsal or ventral (or both) position, has been undertaken opportunistically for many years but this report is concerned with data collected from 1988 to 1996. Most recaptures of tagged lobsters were made during the first commercial season after release (approximately 75%), however, recaptures did occur for up to five seasons post-release.

By examining the movements of lobsters, it was found that migration is restricted to the "whites" phase of the life cycle (Nov-Jan) which occurs when immature lobsters of around 70-90 mm carapace length migrate offshore in a west to north-westerly direction. They generally move less than 50 km to recruit to the breeding stock areas (40-100 m) adjacent to the nursery grounds where they settled as pueruli. However, some white lobsters undertake long distance northerly migrations (*eg* Big Bank area north of Abrolhos Islands), usually in very deep water (greater than 100m) before settling in the breeding stock areas closer

to shore. Long distance movements of up to 438 km were undertaken by some individuals at an average rate of 1 km.d^{-1}.

A model based on the von Bertalanffy growth equation was used to describe the average growth of rock lobsters in the fishery based on tagging data. Model results demonstrated that the period of growth generally was consistent across all regions. The model's high growth rate periods of November - December and February - March were consistent with the known major moulting times for the western rock lobster population. Growth rates also were found to vary between regions within a year and significant differences in growth were found between mature and immature lobsters and sexes. The theoretical maximum carapace length to which lobsters could grow in the model ranged from about 140-200mm and 110-120mm for coastal males and females respectively. Abrolhos Islands' lobsters were significantly smaller at 100mm for males and 80mm for females. An interesting comparison between lobster populations at Fremantle and the Abrolhos Islands was noted. In both areas, lobsters grow at very similar rates for the early part of their lives, however, the theoretical maximum lengths for males and females is highest for Fremantle and lowest for the Abrolhos Islands. It is significant that the abundances of lobsters at the Abrolhos is very high and at Fremantle, very low. These differences may illustrate the dependence of growth upon density and size at maturity.

Data from the tagging experiments were used to examine their usefulness for mortality estimates. Mortality estimates obtained differed widely between each data set analysed (natural mortality, M: varied from 0.38-1.15 and fishing mortality, F from 0.12-1.35) and from estimates gained by pervious researchers (*eg* M at 0.22). Assumptions about tag loss, which is dependent on depth, location, and lobster density and non-reporting by fishers are factors that influence the mortality estimates. Considerably more work needs to be undertaken before mortality estimates from these tagging data are considered reliable, however, there is little doubt that, once validated, the mortality rates will prove valuable.

Processors nominated representatives at seven coastal locations (Kalbarri, Geraldton (also covering the Abrolhos Is.), Dongara, Jurien, Cervantes, Lancelin and Fremantle) who were instrumental in assisting skippers to complete tag return information labels and dispatching data labels regularly to research staff. These representatives were trained by research staff in a successful attempt to improve the level of tag recapture information from industry. Prior to the 1995/96 season, an average of only 11.6% of tag returns from the processing establishments contained information other than the tag number. As a direct result of the training/education programme of factory staff, that percentage jumped to 49.0% in 1995/96 and 40.3% the following season. This was a very good result, noting that factories contributed almost 14% of the tag recaptures in 1995/96. The level of information from tag returns directly from fishers also improved from 77% before 1995/96 to an average of 89% in the two seasons 1995/96 and 1996/97. The return rate of useful information was dramatically improved by this education programme, thereby increasing the cost effectiveness of the expensive tagging programmes.

This study and the use of the results in modelling exercises has indicated several areas of research that should be addressed using tagging studies. An improved understanding of growth in mature lobsters; an assessment of growth in the closed seasons of the fishery; determining the relationship of moult frequency with size, sex and location and examining the variation in inter-annual growth by

location have been identified with the last two having a relatively low priority. Likewise, the use of tagging to estimate exploitation rates is not considered a priority. Industry pressure will drive other aspects that it considers a relatively high priority, such as quantifying the rate of movement across management boundaries. Future modelling exercises and management requirements will impact on the priority setting of tagging programmes but it is likely that priority will be given to the area of growth, so vital in sophisticated models assessing management options. Timing of the future projects also will be determined by Agency priorities, the level of industry support and the source of funding to be sought to undertake them.

The project was very successful in achieving many of its objectives, or where not achieved, highlighting deficiencies in the data sets. This has led to an understanding of what tagging can achieve in the western rock lobster fishery and allowed the development of a strategic view of the application of tagging to research for management of Australia's most valuable single species fishery.

KEYWORDS: Western rock lobster, *Panulirus cygnus*, tagging, migration, growth, mortality.

BACKGROUND

Tagging of western rock lobsters was developed in the late 1960s by Chittleborough (1974) and since then has been used by numerous authors as a means of providing information on growth rates (Joll and Phillips1984, Phillips 1983, Morgan 1974 and 1977), mortality rates (Morgan 1977) and movement patterns (Chittleborough 1970 and 1974, Phillips 1983).

Before 1988, small scale tagging of western rock lobsters had occurred with only limited results being published *eg* Phillips (1983) presented results from 5,034 juvenile lobsters tagged off Cliff Head, Western Australia and Morgan (1977) results for 49,971 tagged at Rat Island in the Abrolhos group, Geraldton and Fremantle. By the early to mid-1980s, the focus of western rock lobster tagging moved away from the use of spaghetti tags and research became directed at short-term movements using sophisticated electromagnetic tags (Jernakoff and Phillips 1986, Jernakoff *et al.* 1987). In the late 1980s a tagging programme was resurrected, aimed at providing additional information on growth, mortality and movements. This tagging study was a low-budget project conducted concurrently with the FRDC funded Fishery Independent Breeding Stock Surveys (IBSS) (93/091, Melville-Smith *et al.* 1996).

The benefit of running the two projects together was that the IBSS already provided the costly at-sea research sampling by a number of vessels over a wide area of the fishery. Thus it yielded animals, that once tagged, were being returned to the sea. This strategy enabled additional information on the biology of western rock lobsters to be obtained at very little extra cost. Additionally, the spread of the breeding stock survey over the coast meant that tag releases covered the major portion of the commercial fishing grounds. Between 1988 and 1996 when funding was approved by the FRDC, over 66,000 lobsters had been tagged, but due to a lack of resources, it had not been possible to fully analyse the data and develop a strategy for tagging in the future. The approval of funding for this project focussed resources in this area.

The benefit of the recent tagging over that of earlier years was that a new insertion position was developed (Melville-Smith and Chubb, 1997). Trials had shown that the traditional dorsal insertion position generally lead to chewing and mutilation of the tags by other rock lobsters. The consequence was that many of these tags either went unnoticed by fishers or were illegible and generally did not remain in the lobsters for more than one or two moults. By comparison, ventral insertion of the tags offered far greater protection to the tags and has provided recaptures for up to four seasons.

A management initiative, introduced in 1993, required all setose and breeding females to be returned to the sea. This regulation has had positive benefits for the tagging programme since, in order to determine whether lobsters could be kept legally, it has ensured that the vast majority of rock lobsters caught in traps have had their ventral surface examined by the fishers. This, together with the longevity of the ventrally placed tags, has for the first time provided a means of gathering long term growth and mortality data.

The commercial sector, through the Western Australian Fishing Industry Council, had been particularly eager for the Research Division of the Fisheries Western Australia to expand its tagging programmes to include annual tagging in shallow and deep water in all major regions of the fishery. The fishers' interest in the tagging results was to obtain information on the movements of lobsters,

particularly those returned to the sea as a result of increases in the legal minimum length during the initial part of the season. Pressure from industry was only one reason for the revival of a tagging programme. Another more important stimulus (from a research viewpoint) was the need to provide regional management advice.

NEED

The very high levels of exploitation in the western rock lobster fishery have resulted in the introduction of regional or zone-specific management arrangements in recent years. This is a permanent departure from an holistic approach to the fishery's regulation. A detailed knowledge of regional variations in the growth, movement and mortality of the lobsters is required to support the models assessing regional management options.

In planning this project, a need was identified to supplement the Fisheries WA, Research Division's resources so as to be able to analyse fully existing tagging data, to take advantage of an existing sampling programme and to subsequently develop a strategic approach to tagging that would assist in providing appropriate advice to management and industry.

OBJECTIVES

1. To prepare a report to industry on the migratory movements of lobsters tagged in recent programmes.
2. To estimate regional growth and mortality rates using existing data from recent programmes to assist in the experimental design of future tagging programmes.
3. To undertake tagging of juveniles in the shallower waters of the Limited Entry Western Rock Lobster Fishery to provide preliminary estimates of exploitation and growth rates and the directions and magnitude of movements.
4. To attempt to recruit and train fishing industry representatives in the procedures of data collection from recaptured tagged lobsters to improve the level of reporting by industry.
5. To prepare a longer term strategy for providing annual exploitation rates, growth and movements of western rock lobster throughout the Limited Entry Fishery.

METHODS

GENERAL TAGGING PROCEDURE

Lobsters were tagged in seven different localities and depths between November 1988 and June 1996 (Fig 1 and Table 1).

Two types of tags were used: (i) the western rock lobster tag described in Chittleborough (1974) with a laminated numbered internal toggle attached to a nylon filament, and (ii) a Hallprint type TBA-1 internal anchor tag (similar to the Floy FD67 type tag in Chittleborough 1974) with an unnumbered nylon T-bar. The benefit of the first type was that it allowed the same number that appeared on the labelled portion of the tag also appeared on the internal toggle, which meant that even though the number on the filament could be illegible, the number of the tag could be read if the animal was to be sacrificed. This tag type required the tagging gun to be reloaded by hand for each lobster tagged.

Tagging was undertaken from a combination of research, charter and commercial vessels and the lobsters were caught in standard commercial pots, with the escape gaps closed. In the 1988/89 season, all tags were inserted ventrally into the muscle between the first and second abdominal segments. Between then and the 1994/95 season all lobsters were double tagged, with one tag being placed in the dorsal insertion point and a second in the ventral position. From the 1995/96 season only a single ventral tag was inserted.

For each lobster released, the tag number(s); carapace length in millimetres (measurements were accurate to 0.1mm in most cases but in some instances measurements were accurate only to the nearest millimetre); date of release; location of release; depth; colour; sex; breeding condition (presence or absence of ovigerous setae, spermatophore or eggs and their stage of development); existing limb or antennae loss or damage resulting from handling was recorded. Information labels were provided to commercial fishermen and to dive and fishing shops frequented by recreational rock lobster fishermen, and these target groups were encouraged to supply similar information to that recorded at release, for any tagged lobster that was recaptured.

Industry personnel were nominated at receival depots or factories [through kind cooperation by the WA Fishing Industry Council (WAFIC) and the Rock Lobster and Prawning Association (now WRLDA)], to query skippers on any tag return information where the data might be considered to be questionable. These nominated representatives also assisted by completing tag return information sheets and dispatching them regularly to the Western Australian Marine Research Laboratories (WAMRL) for inclusion in the data base.

Training sessions were held at WAMRL and at major centres such as Geraldton to ensure the nominated representatives were fully conversant with the required data and methods for collecting and recording it. Furthermore, printed material was provided to act as a reference for the industry representatives and fishers (Appendix 3). Regular trips along the coast were conducted to ensure effective liaison with these representatives and maintain quality control on the data being submitted.

Table 1. *Localities, depths and seasons in which western rock lobsters were tagged.*

Locality		Depth (m)	Seasons tagged
Abrolhos	Wallabi group	9-57	1992/93; 1993/94; 1994/95;1995/96
Islands	Pelsaert group	13-59	1992/93; 1993/94; 1994/95;1995/96
	Easter group	13-59	1992/93; 1993/94; 1994/95;1995/96
	North Island	11-57	1992/93; 1993/94; 1994/95;1995/96
Kalbarri		7-53	1993/94; 1994/95;1995/96
Big Bank		143-185	1992/93
Dongara		9-59	1992/93; 1993/94; 1994/95; 1995/96
Jurien		7-59	1992/93; 1993/94; 1994/95; 1995/96
Lancelin		5-73	1993/94; 1994/95; 1995/96
Fremantle		4-64	1992/93; 1993/94; 1994/95; 1995/96

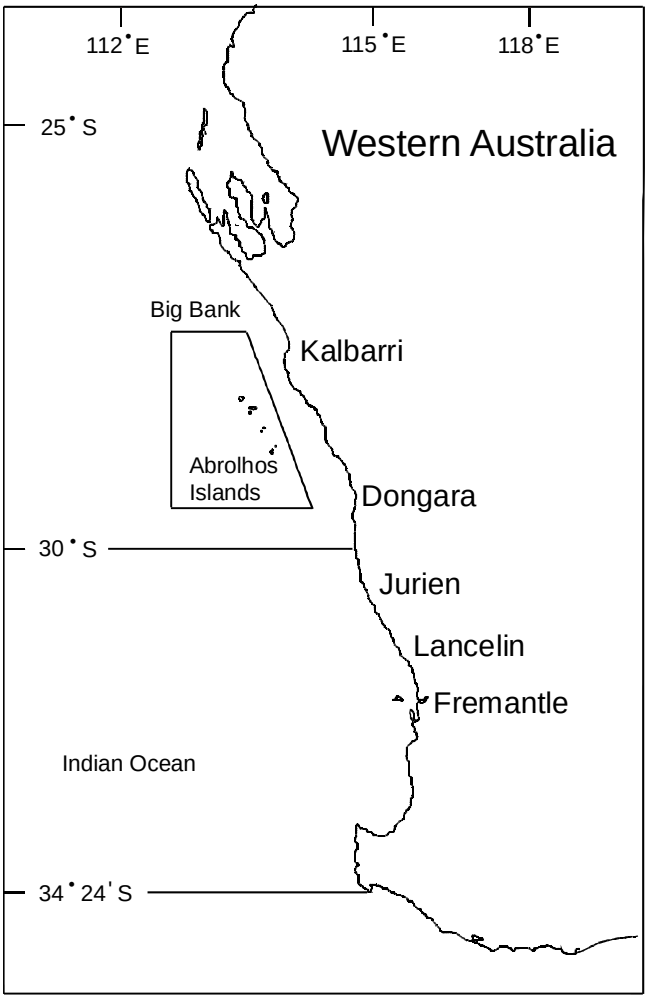

Figure 1*. Map showing the main localities along the Western Australia at which tagging took place.*

MOVEMENT/MIGRATION DATA

Data set

Existing tagging data for the period 1988 to 1996 were analysed by season, sex and size to examine the movements of recaptured tagged lobster. Frequency histograms were generated showing days at large, distance moved and growth while at large Additionally, a series of maps was generated detailing lobster movements in the waters of the limited entry west coast rock lobster fishery.

Tag release and recapture data were subjected to an intensive validation process to remove all obvious errors. The location of release was slightly problematical given that lobsters were caught in “lines” or groups of pots that might have extended for up to three nautical miles (~6 km), but the point of release was taken as the midpoint of the group or “line” of pots. This meant that a lobster released at the end of a line would, if recaptured later without moving from its point of release, have been considered as having moved relative to the central position which had been taken as the point of release. As a result of this potential for inaccuracy, all lobsters recaptured within 6km of their release position were deemed not to have moved and were not included in the directional movement analyses.

The data were analysed using an array of statistical techniques (see below) to quantify distance and direction of movement by size, sex and colour of the animals.

Statistical Analyses - Angular Movement and Distance Moved

Since the earth is spherical, it is necessary to transform that data into a planular form in order to calculate the correct angular movement and distance moved by each lobster. The Ribbons formulae (National Mapping Council of Australia, 1972) were used to calculate the angle (α_{ab}) and distance travelled (s) between the place of release a and the place of recapture b of each lobster.

Circular Mean Angle

For a sample consisting of n angles, denoted as θ_1 through θ_n, the mean of these angles, $\bar{\theta}$ is the estimate of the mean angle in the sampled population μ_θ. Complete references to this procedure can be found in Batschelet (1965), Fisher (1993), Watson (1983) and Zar (1996).

Let

$$X = \frac{\sum_{i=1}^{n} \cos\theta_i}{n}$$

and

$$Y = \frac{\sum_{i=1}^{n} \sin\theta_i}{n}.$$

Then

$$r = \sqrt{X^2 + Y^2}$$

The direction of the mean angle $\bar{\theta}$ of θ_1 ,..., θ_n is given by

cos $\bar{\theta}$ = X/r and sin $\bar{\theta}$ = Y/r

or

$$\bar{\theta} = \begin{cases} \tan^{-1}(Y/X) & Y > 0, X > 0 \\ \tan^{-1}(Y/X) + \pi & X < 0 \\ \tan^{-1}(Y/X) + 2\pi & Y < 0, X > 0 \end{cases}$$

The quantity R = nr is the resultant length of the vector resultant, and lies in the range of (0,n).

Angular Histograms

A commonly used method to present angular groups is called rose diagram. Each group is displayed as a sector. The radius of each sector is probably best taken to be proportional to the square root of the relative frequency of the group, so that the area of the sector is proportional to the group frequency.

Uniform Circular Distribution

Rayleigh's test is a common test for uniform circular distribution. Full details can be found in Fisher (1993) and Zar (1996). Let the population mean resultant length be ρ. The estimated mean resultant length from data is r. As circular uniformity implies there is no mean direction, the Raleigh test may be said to test $H_0 : \rho = 0$ vs. $H_A: \rho \neq 0$.

If H_0 is rejected by Rayleigh's test, it may be concluded that there is a mean population angular distribution and if H_0 is accepted, it would be concluded that the population angular distribution was uniform around a circle, but only if it is assumed that the angular distribution does not contain more than one mode.

Confidence Intervals

Most of the circular distributions are symmetrical in shape. For example, the Cardioid distribution, wrapped distributions, wrapped normal distribution and the von Mises distribution. Full details are to be found in Fisher (1993). Most circular distributions require parametric or non-parametric bootstrapping to construct confidence intervals because they are not symmetrical in shape. The assumption of symmetry in the angular movement of western rock lobsters may not be appropriate because parts of the lobster population were in shallow water close to the coastline. The angular distribution of western rock lobster movement is assumed to be unknown and non-symmetrical and so non-parametric boot-strapping was used to find the 95 % confidence interval for the mean angle of movement of lobsters in each region and depth. One thousand iterations were used given that, from experience, this number is large enough to guarantee numerical accuracy to one decimal place for the mean angle in degrees.

Prediction of Speed and Distance Moved Using Generalised Linear Models

Generalised linear models (GLMs) extend linear models to fit both non-normal response distributions and transformation of linearity (McCullagh and Nelder 1989). We have attempted to put the angular predictor in GLMs for the prediction of the speed and distance moved by western rock lobsters under the influence of the other predictors sex, latitude, angular direction and depth of water by Poisson link function. A Poisson link means the transformation of log in the response variable and avoids the prediction values becoming negative. Since many "white" lobsters have carapace lengths between 70 and 80 mm CL (unpublished commercial monitoring data), this size range was used to define "whites" in this analysis. To allow for movement to take place, only those lobsters that had been at liberty for more than 1 yr were included and any lobsters moving less than 6 km were omitted from the modelling. During the analyses it was found that movement greater than 400 km (for distance prediction) and 350 km (for speed prediction) invalidated the model assumptions. Since these lobsters respectively were respectively approximately 1% and less than 1% of recaptured rock lobsters, they were excluded from the analyses. The Akaike Information Criterion (AIC) (Akaike 1974) were used to select the models of best fit.

GROWTH DATA

Recapture data from 1988 to June1996 were analysed by season to gain estimates of growth and mortality. Growth was examined by region, depth and sex using regression procedures. Regional growth by sex was described using a model based on the von Bertalanffy growth model. While growth of individual rock lobsters is determined by ecdysis, it was not intended to model the growth of the individual, as it is the growth of the population that is of concern when considering management issues. However, it is recognised that there are periods within the year when animals are more likely to moult than at others, and that the months may be classified as "high growth rate" or "low growth rate" months based on the change in average length that occurs within the month for each size class of rock lobsters.

Western rock lobster have a migratory phase which may lead to individuals travelling long distances (George 1958; Phillips 1983; Chubb *et al.* 1994). It was considered that this characteristic might have had the potential to confuse growth results and so only lobsters re-caught (inshore and offshore) within the same general region where they were tagged were used to determine the growth coefficients and theoretical maximum lengths (L_∞) for the various regions. Recaptured lobsters from particular regions were combined in the analyses, despite the fact that there probably are year-to-year factors affecting growth rates. This was not considered to be an unreasonable course to take, since the objective has been to describe average seasonal growth for the population in a region for use in population modeling and not to examine inter-annual variation in growth.

A modification to the von Bertalanffy growth model was used to describe the average growth of rock lobsters through the year. It has been assumed in the model that the average asymptotic length, L_∞, is constant for all months, but that the average growth coefficient for month m, *ie* K_m, varies from month to month. Growth within the month m from length L_1 to an estimated length $\hat{L}_2$ is then described using the von Bertalannfy equation as:

$$\hat{L}_2 = L_1 + \left(L_\infty - L_1\right)\left\{1 - \exp\left[-K_m\, T_m\right]\right\},$$

where T_m is the period of growth within the month. Growth over successive months was determined by repeated application of this equation to provide an estimate of the final length, $\hat{L}_{\text{Final}}$.

At this time, it was assumed that the process is deterministic, and that all errors are observation errors for the length at recapture, L_{Final}. The errors are assumed to be independent and drawn from a normal distribution with zero mean and common standard variance. The objective function that is minimised in order to estimate L_∞ and K_m (for m=1, 2, ... 6, 11, and 12, the months of fishing) therefore is given by:

$$S = \sum_j \left[L_{\text{Final}} - \hat{L}_{\text{Final}} \right]^2,$$

where j=1,2, ... n, and n is the number of recaptured rock lobsters.

As no recapture data are available for the closed fishing season from July through to November, and only a minimal number of recaptures are made in October during the pre-season research surveys, the growth coefficient, K_m, has been assumed to be constant for the months of June through October (possibly creating a bias in the estimate for November). Also consideration needs to be given to the time of moulting (*ie* Nov-Dec and Feb-Apr depending on environmental conditions). A similar assumption has been made for the Abrolhos Islands where fishing is allowed only for three and a half months each year (March 15 to June 30). Here we have assumed that K_m, is constant for the months of June through February, again biasing the estimates, particularly for March.

The model has allowed the estimation of growth coefficients for immature and mature rock lobsters by inserting the estimated size at 50% maturity (SAM) for females and assuming a similar SAM for males. While it is known that coastal female SAM varies slightly with latitude (Chubb 1991, 1994), a single value of 90 mm CL arbitrarily was used as the SAM for the whole coastal stock of *P. cygnus* including both sexes. The size at maturity for the Abrolhos Islands is 65 mm CL and since most lobsters there are mature, the analysis comparing growth for mature and immature lobsters was not undertaken. In sites where the analysis of mature and immature lobsters was undertaken, the model selected only those lobsters that were released and recaptured with carapace lengths above or below 90 mm.

An approximation to the variance-covariance matrix of the parameters was calculated using the equation presented in Donaldson and Schnabel (1987)

$$\hat{V} = s^2\left[J\left(\hat{\theta}\right)^T J\left(\hat{\theta}\right)\right]^{-1},$$

where $J\left(\hat{\theta}\right)$ is the Jacobian matrix of the objective function at $\hat{\theta}$ and s^2 is the residual variance.

MORTALITY DATA

If fishing mortality and natural mortality are constant, and are denoted by *F* and *M* respectively, then the probability that the *j*th recapture will be made at time t_j is given by

$$p_j = F \exp\{-(M + F)t_j\}. \quad (1)$$

The probability that a tagged fish is not caught before time *T* may be calculated as

$$P\{\text{No capture}\} = 1 - \frac{F}{M+F}\{1 - \exp[-(M + F)T]\}. \quad (2)$$

For a tagging experiment where *R* tagged fish are released, the probability of recapturing *C* fish at times $t_1, t_2, \ldots\ldots, t_C$ before the end of the experiment at time *T* is therefore given by

$$P = \frac{R!}{C!(R-C)!}\left\{\prod_{j=1}^{C} p_j\right\} P\{\text{No capture}\}^{R-C}. \quad (3)$$

Where tag loss occurs, the formulae must be modified. Assuming that the instantaneous rate of tag loss, λ, is constant, then

$$p_j = F \exp\{-(M + F + \lambda)t_j\}, \quad (4)$$

and

$$P\{\text{No capture}\} = 1 - \frac{F}{M+F+\lambda}\{1-\exp[-(M + F + \lambda)T]\}. \quad (5)$$

Here, p_j is the probability that a tagged fish is recaptured with the tag still attached, and *P*{No capture} is the probability that, by time *T*, a tagged fish is not recaptured with its tag intact.

If the fish are double tagged, and the (constant) instantaneous rates of tag loss are denoted by λ_D and λ_V, then

$$P\{\text{No capture}\} = 1 - \frac{F}{M+F+\lambda_D}\{1 - \exp[-(M + F + \lambda_D)T]\}$$

$$- \frac{F}{M+F+\lambda_V}\{1 - \exp[-(M + F + \lambda_V)T]\}$$

$$+ \frac{F}{M + F + \lambda_D + \lambda_V} \{1 - \exp[-(M + F + \lambda_D + \lambda_V)T]\}. \quad (6)$$

The probability that a tag of a specific type might be lost by time t_j is

$$P\{\text{Loss of tag type D}\} = P_{L(D)} = 1 - \exp[-\lambda_D t_j] \quad (7)$$

or

$$P\{\text{Loss of tag type V}\} = P_{L(V)} = 1 - \exp[-\lambda_V t_j] \quad (8)$$

The probability that both tags will be lost is

$$P\{\text{Loss of both tags}\} = P_{L(DV)} = P_{L(D)}P_{L(V)}. \quad (9)$$

From this, the probability that a fish will be recaptured with tag D intact but tag V lost is

$$P_{D\overline{V}} = F \exp\{-(M + F)t_j\} (1 - P_{L(D)}) P_{L(V)}. \quad (10)$$

Similarly, the probability that the fish is recaptured with tag V intact but tag D lost is

$$P_{V\overline{D}} = F \exp\{-(M + F)t_j\} P_{L(D)} (1 - P_{L(V)}). \quad (11)$$

and the probability that the fish is recaptured at time t_j with both tags intact is

$$P_{DV} = F \exp\{-(M + F)t_j\}(1 - P_{L(D)})(1 - P_{L(V)}). \quad (12)$$

Where data are returned for tags of type D but no information is available for the condition of tag type V, the probability of recapturing such a fish at time t_j may be written as

$$P_{D\overline{\overline{V}}} = F \exp\{-(M + F)t_j\} (1 - P_{L(D)}). \quad (13)$$

If the status of tag type D is unknown, but tag type V is intact, the probability is given by

$$P_{V\overline{\overline{D}}} = F \exp\{-(M + F)t_j\}(1 - P_{L(V)}). \quad (14)$$

If P_R is the probability that a recaptured tagged fish is reported, then the formulae must again be modified. An instantaneous loss of tags on release of fish or instantaneous loss of tagged fish on release that arises from the tagging event will also affect the formulae. If P_S is the probability that a tagged fish will retain its tag (no initial tag loss) and survive the tagging process, then the effects of P_R and P_S may be combined as

$$P_X = P_R P_S. \quad (15)$$

Then the probability that a tagged fish is not reported to be captured by time T is given by

$$P\{\text{No reported recapture}\} = P\{\text{No capture}\} + (1 - P\{\text{No capture}\})(1 - P_X). \quad (16)$$

For an experiment using only a single tag type, the probability that a tagged fish is recaptured at time t_j with its tag intact, and reported, is calculated as

$$p_j = F \exp\{-(M + F + \lambda)t_j\} P_X. \quad (17)$$

If the experiment is a double tagging experiment, then the formulae above become

$$P_{D\overline{V}} = F \exp\{-(M + F)t_j\} (1 - P_{L(D)}) P_{L(V)} P_X ; \quad (18)$$

$$P_{V\overline{D}} = F \exp\{-(M + F)t_j\} P_{L(D)} (1 - P_{L(V)}) P_X ; \quad (19)$$

$$P_{DV} = F \exp\{-(M + F)t_j\}(1 - P_{L(D)})(1 - P_{L(V)}) P_X ; \quad (20)$$

$$P_{D\overline{\overline{V}}} = F \exp\{-(M + F)t_j\} (1 - P_{L(D)}) P_X ; \quad (21)$$

and

$$P_{V\overline{\overline{D}}} = F \exp\{-(M + F)t_j\}(1 - P_{L(V)}) P_X ; \quad (22)$$

For the double tagging experiment, the value of p_j is determined from the status of the tags as reported on recapture.

The kernel of the log likelihood function then may be calculated as

$$\text{LL} = \left\{ \sum_{j=1}^{C} \log p_j \right\} \quad (R - C) \log P\{\text{No reported recapture}\}. \quad (23)$$

Where a mixture of single and double tagging experiments have been undertaken, the combined log likelihood is calculated as the sum of the log likelihoods of the separate tagging experiments.

RESULTS AND DISCUSSION

OBJECTIVE 1. *To prepare a report to industry on the migratory movements of lobsters tagged in recent programmes*.

Verbal reports on the tagging programme were presented to industry during 1995 and 1996 with brief descriptions of the findings outlined in the 1996 Rock Lobster Industry Advisory Committee Coastal Tour document (Appendix 5). It was the intention to provide a written summary of the results of these analyses to industry, but the simplified diagrams shown to fishers, *eg* Fig. 6, highlighted an unforseen circumstance that resulted in the wrong impression being conveyed to many in industry by figures such as Fig. 6. That is, for many fishers, the eye concentrated on the lines depicting long distance movements. While such movements form only a very small percentage of the recaptures, they mask the fact that the vast majority of recaptures did not move far because they were represented in graphical form by a dot. Thus it was considered sensible to fully analyse the data, submit the results to a journal for peer review and, when accepted, summarise the paper for industry release in a form that conveyed the findings appropriately. The manuscript is in a final stage of preparation and will be submitted to a journal shortly. The major findings are presented below.

A total of 66,719 lobsters were tagged between 1988 and 1996 throughout the coastal fishery from Fremantle to Kalbarri, and at the Abrolhos Islands and Big Bank regions of the fishery (Tables 1, 2; Fig. 1; Appendix 3). An information sheet distributed to industry (see Appendix 3), is updated annually. It provides information on tagging programmes, tag number series, location and season tagged. The sheet is a handy reference for fishers to identify the release season and location of any recaptured western rock lobster.

Most recaptures were made during the first commercial season after release (approximately 75%) and good numbers of rock lobsters were recaptured in the second season (approximately 21%). Recaptures did occur for up to five seasons post-release (Fig. 2). While long distance movements in excess of 200 km (straight line distance) have been recorded for a few individuals, movements of the western rock lobster are generally less than 50 km (Fig. 2). The vast majority of recaptured lobsters (87.1-98.6% by location) were caught within 10 km of their release points. However when these data were separated into groups that had either been tagged or recaptured as ‘white’ lobsters and were compared to those that had had not been recorded as ‘whites’ or ‘reds’, it became obvious that the first group showed a far greater propensity to move than the second group of ‘reds’ (Fig 3).

Furthermore, when size at tagging was plotted against distance moved (Fig. 4), it was clear that the size of animals that had shown substantial movement prior to recapture was consistent with the size at which small red lobsters become white lobsters (*ie* around 70-90 mm carapace length (CL)).

Comparing distances moved by ‘reds’ and ‘whites’ (Fig 3), shows that 27% of ‘whites’ moved further than 10 km from their release position compared to only 9% of ‘reds’. It is believed that this difference between the two categories is likely to have underestimated the movement of ‘whites’ and inflated that of ‘reds’. On a number of occasions lobsters were recorded as being both tagged and recaptured as ‘reds’, yet their size indicated that between tagging and recapture they had probably passed through a ‘whites’ moult. This assumption, of course,

could not be tested and as a consequence the distance covered by such an animal between tagging and recapture would have had to have been attributed to ‘red’ rather than ‘white’ lobster movement (Fig. 3).

Plots of the directional movement (Fig. 5) and plots of the straight line movements of recaptured western rock lobsters (Fig. 6.) indicate the movement from the shallows to the adjacent deeper water in a west to north-westerly direction. In the deeper water (150-200 m), the general movement was to the north-north-west along the edge of the continental shelf. This movement apparently is against the flow of the Leeuwin Current, although the current is at its weakest or is absent during this migration (Nov-Jan).

***Table 2**. Numbers of western rock lobsters released and recaptured.*

Season	No. Released	No.Recaptured	Recaptures (%)
1988-91	10,613	1,613	15.2
1992/93	29,580	10,143	34.3
1993/94	9,323	2,628	28.2
1994/95	6,156	1,544	25.1
1995/96	11,047	2,888	26.1
Totals	66,719	18,816	28.2

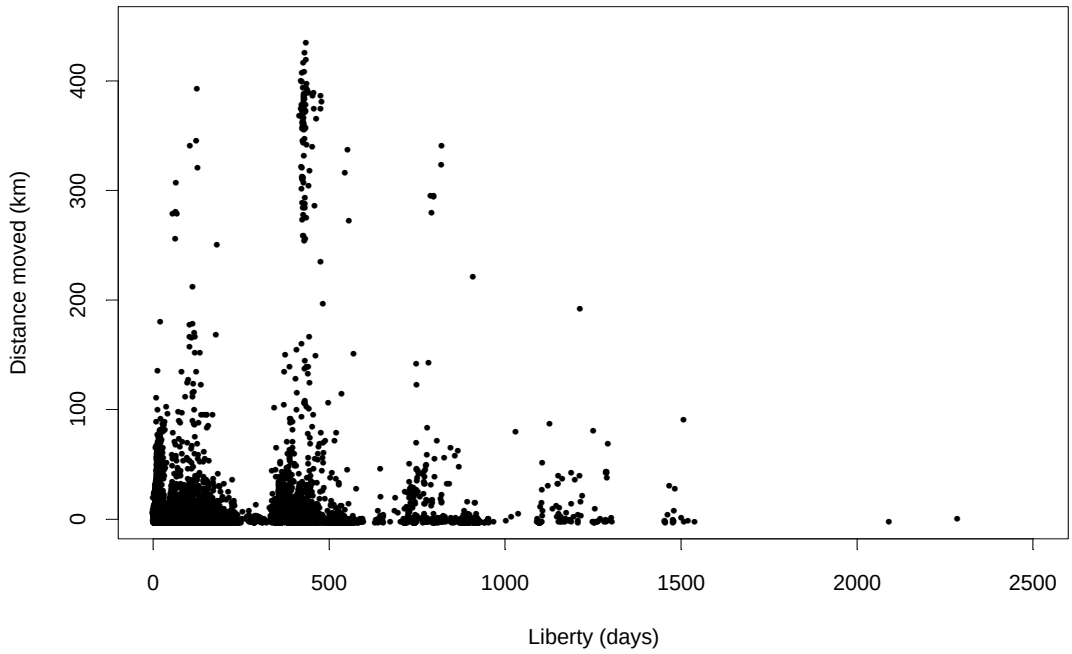

***Figure 2**. Distance moved related to days at large for recaptured western rock lobsters of both sexes.*

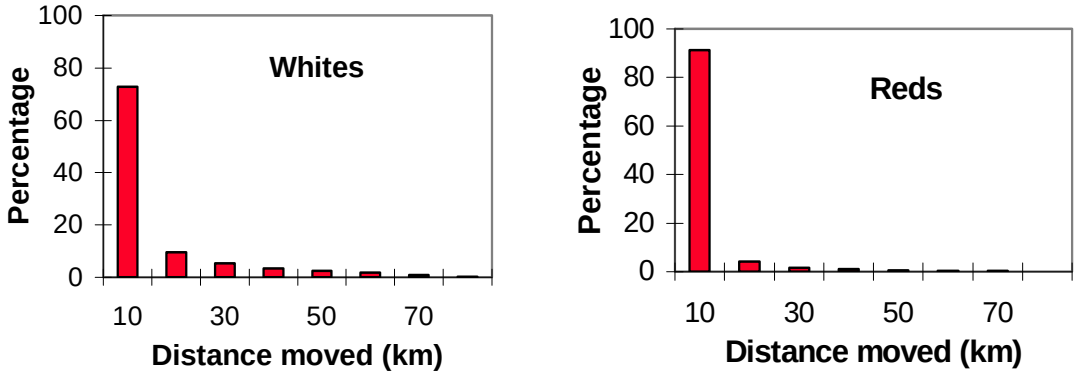

***Figure 3**. Distance moved (kilometres) by reds and whites.*

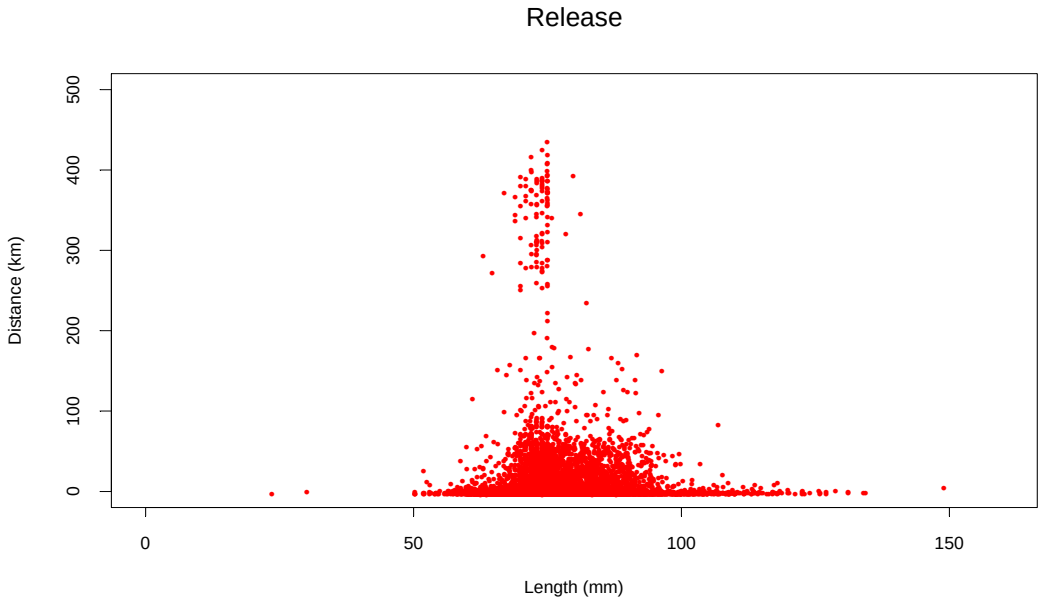

***Figure 4**. Length of rock lobsters at release and resultant distance moved.*

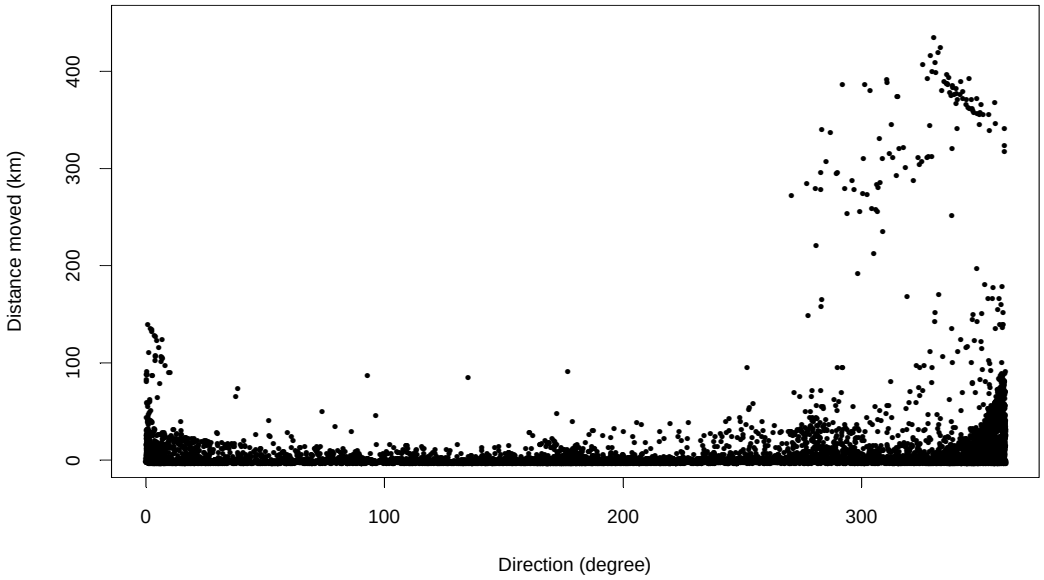

***Figure 5**. Distance moved related to the direction of movement of tagged western rock lobsters.*

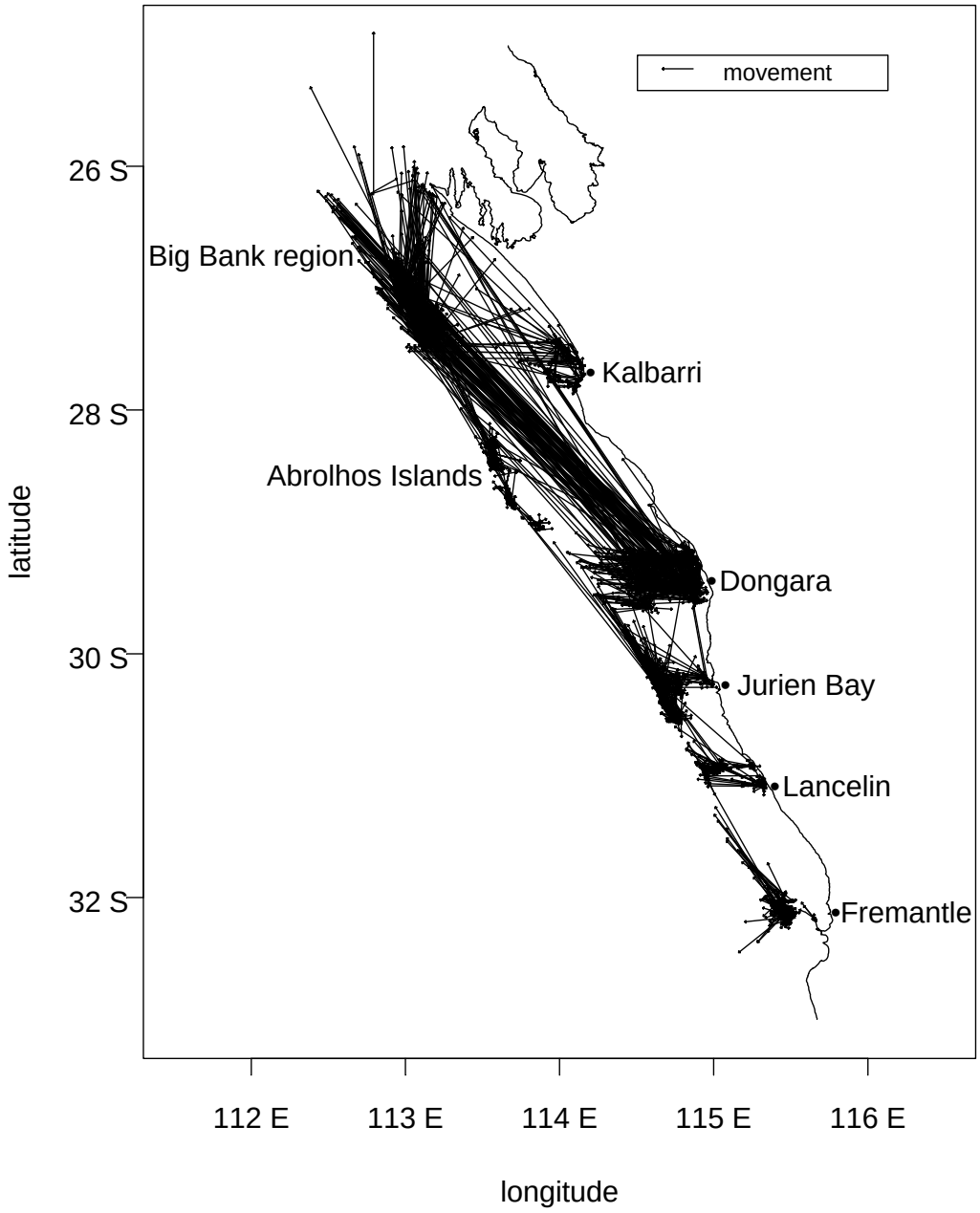

***Figure 6**. Plots of directional movement of each lobster (both sexes) in Western Australia.*

Migration is restricted to the “whites” phase of the life cycle which occurs when lobsters are ~70-90 mm CL, with those lobsters becoming residential before moulting to maturity (which occurs in most areas on the coast at 80-90 mm CL). It would appear that in most cases immature “whites” migrate offshore in a west to north-westerly direction moving less than 50 km to recruit to the breeding stock areas generally (40-100 m) adjacent to the nursery grounds where they settled as pueruli. However a small proportion of coastal lobsters (<5%) undertake long distance “northerly” migrations and comprise part of the Big Bank run (north of

Abrolhos Islands, Fig. 6), usually in very deep water (greater than 100m) before settling in the breeding stock areas.

To describe the directional movement of the western rock lobster rose diagrams were used where each petal is proportional to the frequency (Fig. 7). Rayleigh's test has shown that the hypothesis of a uniform circular distribution was rejected for each region and each depth for males and females with the exception of the males in the deep water at Lancelin (region 2) and Kalbarri (region 6). The small sample sizes, 12 and 15 respectively for these two areas, probably influenced the result.

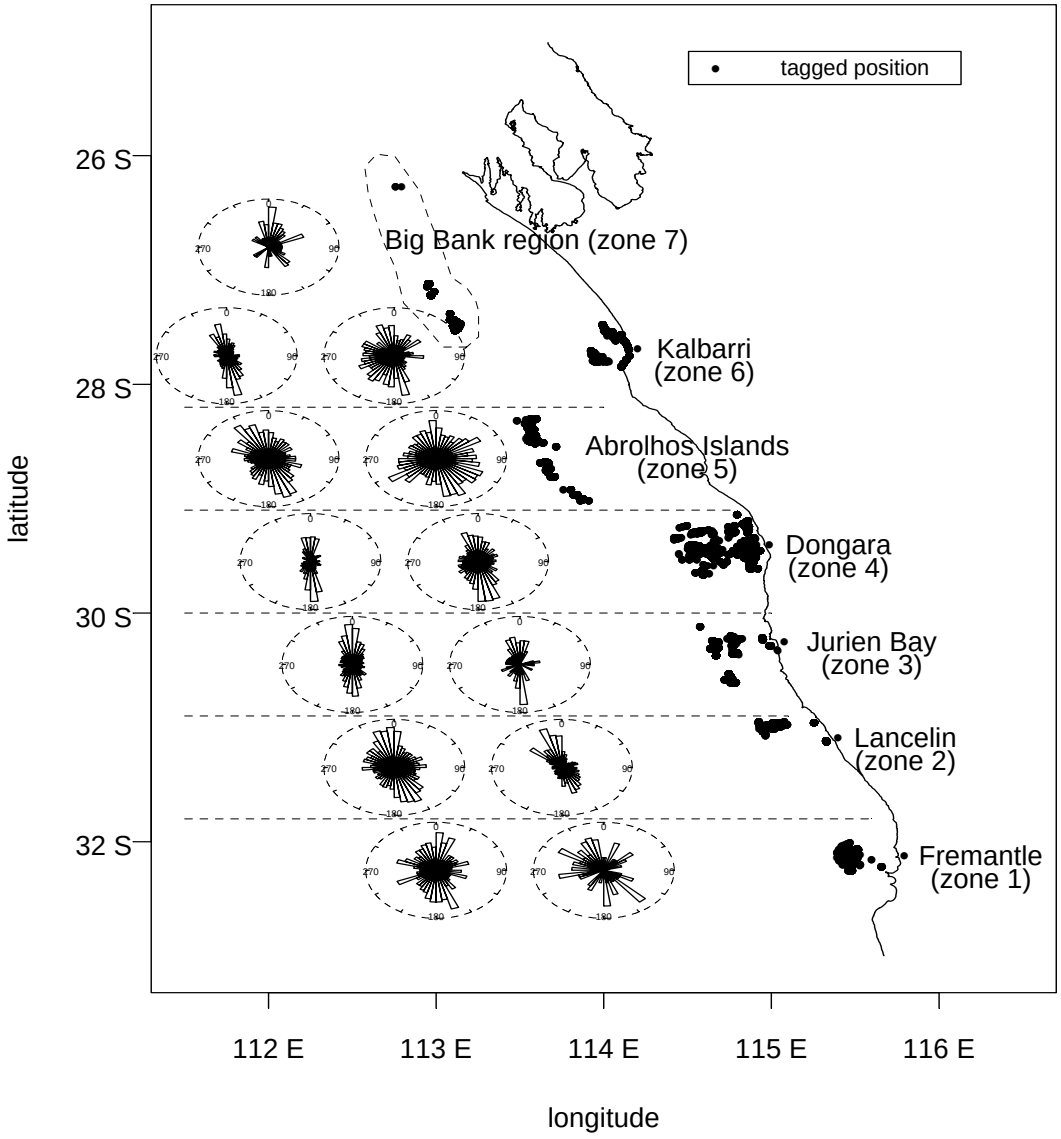

***Figure 7**. Rose diagrams of directional movement (≥6 km) of tagged male and female lobsters released in shallow (<30m,right) and deep (≥30m, left)) water in various regions of the western rock lobster fishery. Note that the Big Bank releases were only in deep water.*

Generalised linear models predicted the speed and distance of "white" lobsters. Long distance movements of up to 438 km were undertaken by some individuals

at an average rate of 1 km.d^{-1}. Since there were no significant differences (P>5%) between the directional movement of male and female lobsters at each location, data were combined to provide the mean angle of movement with 95% confidence intervals for lobsters moving greater than 6 km in both shallow and deep water in each of the regions (Fig. 8)

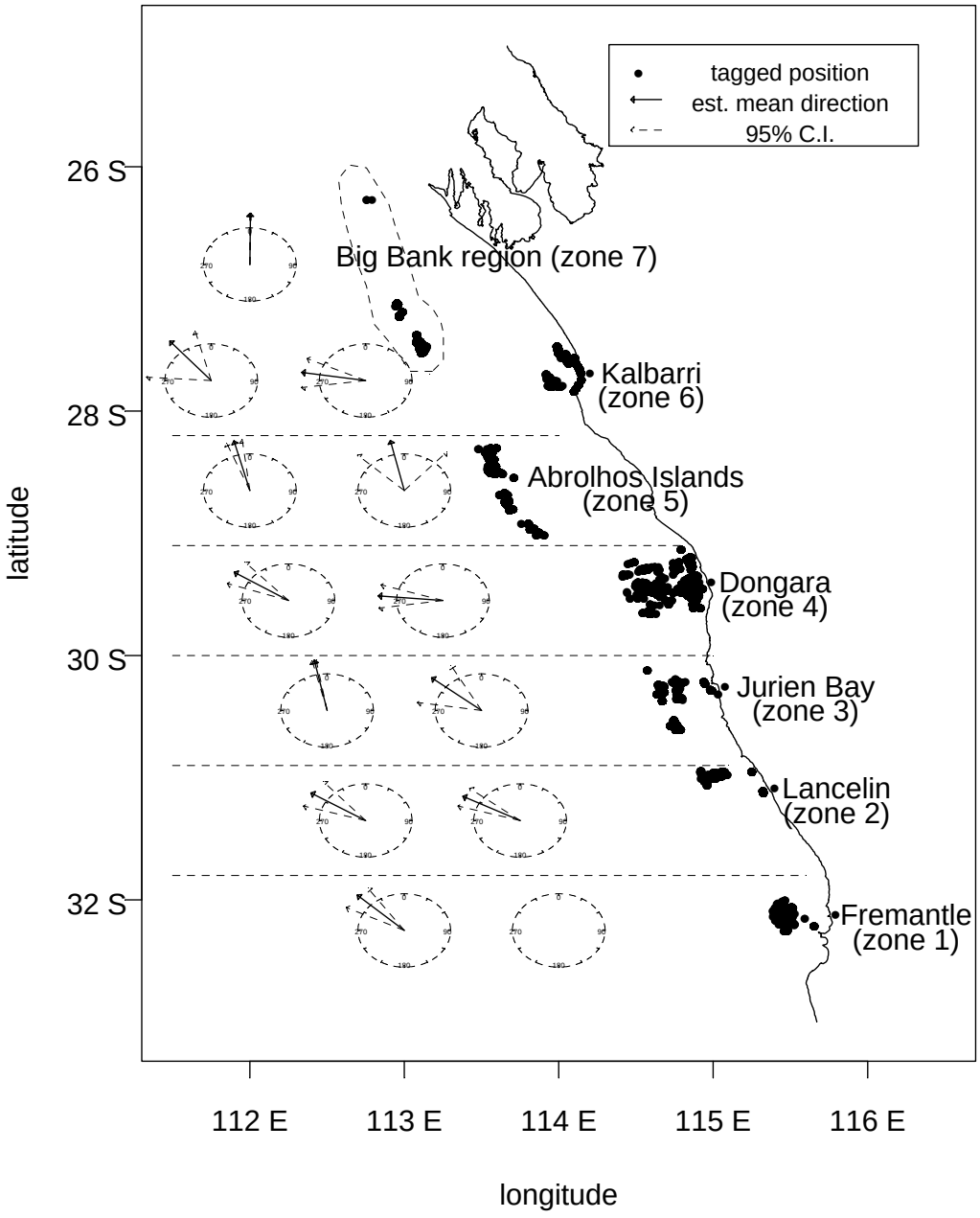

***Figure 8**. Plots of 95% confidence intervals for the estimated mean directional movement of lobsters (female and male) in Western Australia (left hand side diagrams: lobsters released in deep water; right hand side diagrams: lobsters released in shallow water).*

OBJECTIVE 2. ***To estimate regional growth and mortality rates using existing data from recent programmes to assist in the experimental design of future tagging programmes*****.**

GROWTH

A model based on the von Bertalanffy growth equation was used to describe the average growth of rock lobsters in the fishery based on tagging data. Recognising the assumptions of the model (see Methods), model results demonstrated that variable growth rates were present throughout the year but were consistent for all regions. An example of the model output is given in Fig. 9. The model's high growth rate periods of November - December and February - March were consistent with the known major moulting times for the western rock lobster population. Some of the variability in Fig. 9 can be accounted for by the inter-annual variability in growth rates, something not addressed in this project.

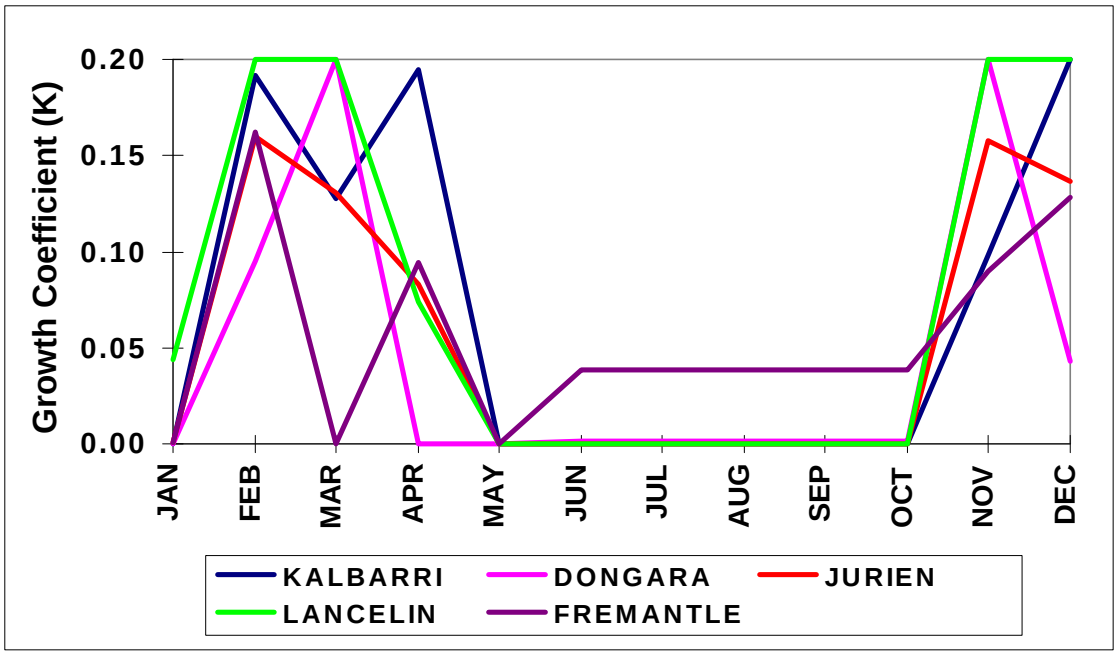

Figure 9*. Monthly values of the von Bertalanffy growth coefficient (k) for immature male western rock lobsters.*

L_∞ values from the model were very similar for all coastal sites, but significantly smaller at the Abrolhos Islands (Fig.10). They ranged from 139 to 196 mm CL for coastal males and from 109 to 122 mm for coastal females. The L_∞ values for males and females at the Abrolhos Islands were 100 and 81 mm CL respectively.

The results of likelihood ratio tests (Kimura,1980) applied to data from two localities on the coast, showed that differences between male and female growth rates were highly significant (Table 3). Females at maturity have greatly reduced growth as energy is diverted to gamete production. This leads to skewed sex ratios in favour of males at large sizes.

Likelihood ratio tests also were used to test the significance between growth rates recorded for immature and mature lobsters. The differences recorded for the two maturity states for males (Table 4) and females (not shown) at all coastal sites were highly significant.

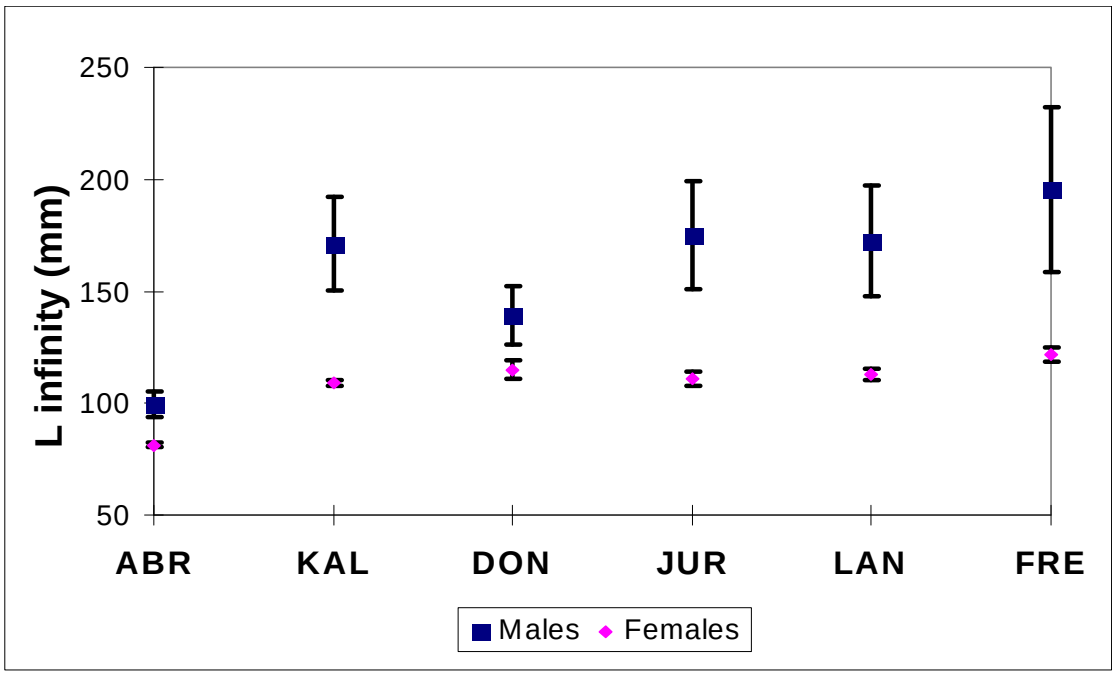

Figure 10. *The L_∞ values with 95% confidence limits estimated for western rock lobsters at five coastal sites and the Abrolhos Islands.*

Table 3. *Likelihood ratio tests on growth rates between males and females at two coastal locations.*

Location	H_{diff} SS	H_{same} SS	n	χ^2	df	Significance
Dongara	12922.4	13734.9	3212	195.840	9	P<0.001
Jurien	10566.7	11117.4	1445	73.413	9	P<0.001

Table 4. *Likelihood ratio tests on growth rates between immature and mature male lobsters on the coast.*

Location	H_{diff} SS	H_{same} SS	n	χ^2	df	Significance
Kalbarri	1916.0	2577.9	323	95.850	9	P<0.001
Dongara	3952.8	5201.9	782	214.737	9	P<0.001
Jurien	3564.9	4578.2	492	124.051	9	P<0.001
Lancelin	2705.9	5036.5	313	194.464	9	P<0.001
Fremantle	976.6	1429.6	175	66.688	9	P<0.001

The modelling results show that growth was variable between regions and sexes with rapid growth particularly at Fremantle and the Abrolhos Islands. This presents an interesting comparison. Both Fremantle and Abrolhos lobsters grow at very similar rates for the early part of their lives, however, the L_∞ for males and females is highest for Fremantle and lowest for the Abrolhos Islands.

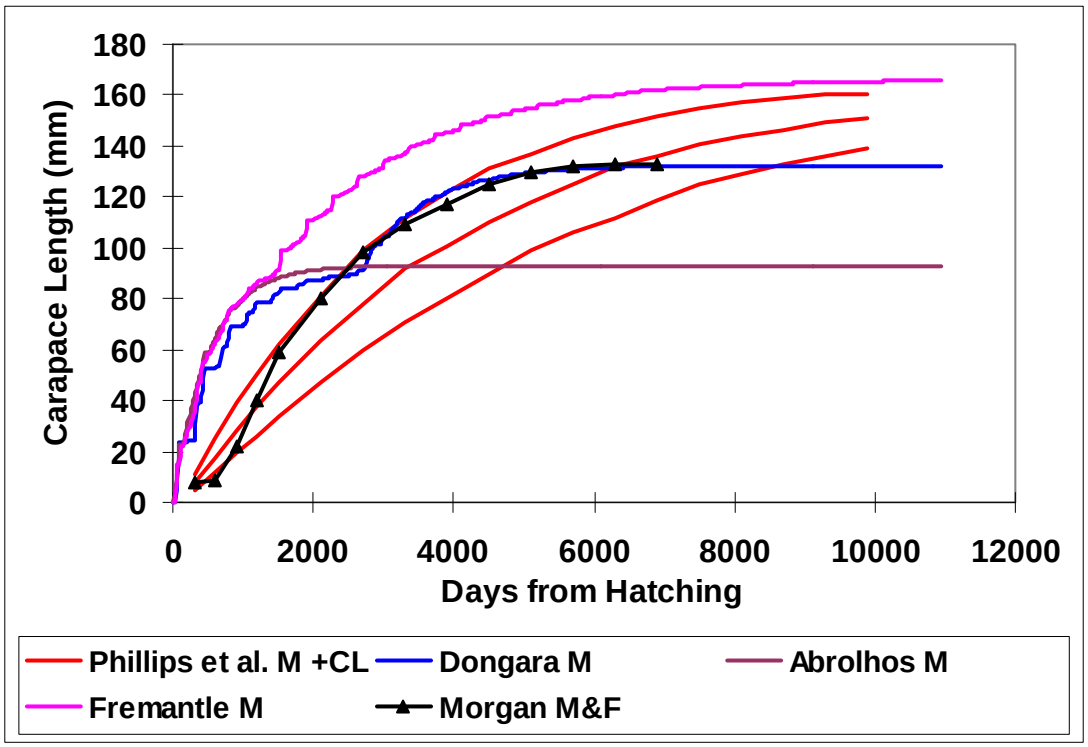

***Figure 11a**. Growth curves for male western rock lobsters compared to previous studies by Phillips et al. (1992) and Morgan (1980) (results from this study are indicated by purple and indigo lines; M, F and CL are males, females and confidence limits respectively).*

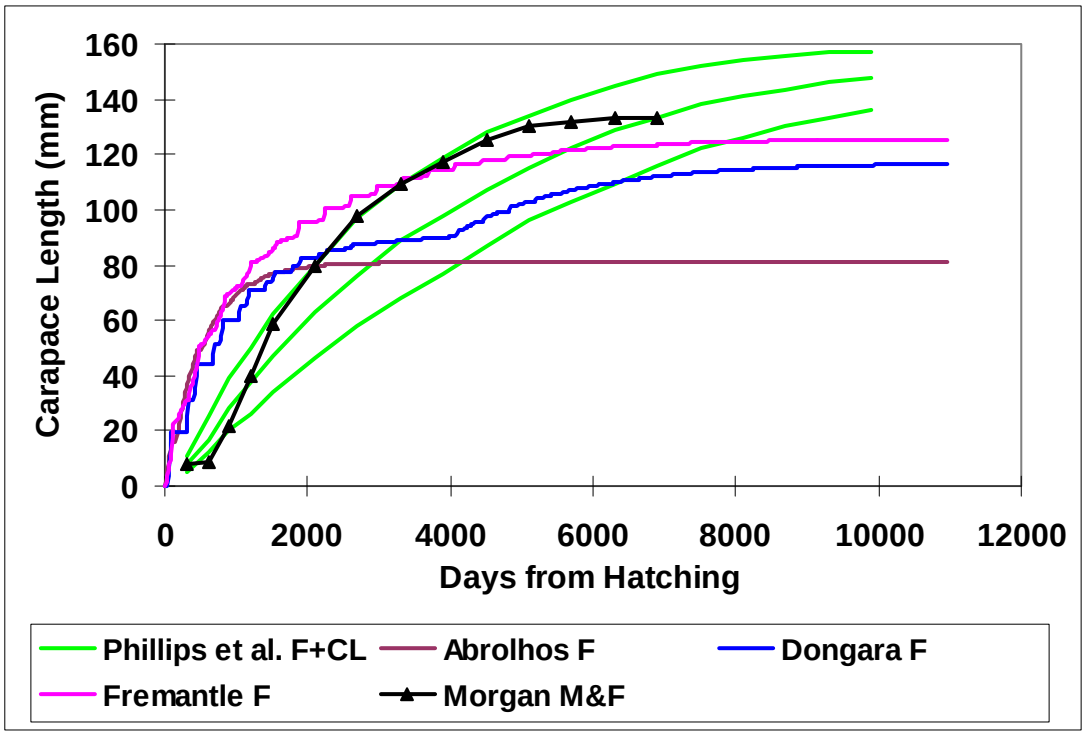

***Figure 11b**. Growth curves for female western rock lobsters compared to previous studies by Phillips et al. (1992) and Morgan (1980) (results from this study are indicated by purple and indigo lines; M, F and CL are males, females and confidence limits respectively).*

It is significant that the abundances of lobsters at the two locations are also extreme, but opposite, with the Abrolhos abundance very high and Fremantle low. These differences may illustrate the effects of density dependence upon growth, although it is also significant that Abrolhos females mature at 65mm CL (size at 50% maturity, SAM) some 30mm below the 95mm CL SAM in the Fremantle population (Chubb 1991).

Recognising that the starting point of the growth curves (t_0) is variable, the growth curves generated by the model were comparable to previously published data by Morgan 1977 and Phillips *et al.* (1992) (Figs 11a and 11b).

This study has provided, for the first time, regional estimates of growth. It has also highlighted deficiencies in the sampling that has been undertaken. For example, the number of mature lobsters available from the tagging programmes is relatively low, brought about principally by a focus of early work on juvenile to immediately pre-adult lobsters. In addition, the model assumption that the growth coefficient (k) in the four and a half month closed season is the same as June (the last month of the fishing season), needs scrutiny. Since the little research fishing that occurs is in the spring in October, nothing is known of growth over the winter closure. These deficiencies become extremely important in the assessment of management options that might include, say, winter fishing, or more sophisticated modelling processes requiring detailed growth matrices. These findings, to some extent, will determine directions for future tagging programmes (see Objective 5).

MORTALITY

Data from some tagging experiments were used to illustrate their usefulness for mortality estimates.

Estimates of *M, F,* λ_D *and* λ_V were derived from an analysis of the combination of all western rock lobster tagging experiments undertaken in the 1992/93. Rumours of the non- reporting of tag recaptures by some fishers led to an assumed reporting probability (P_R) of 0.8, and the survival (of tagged lobsters, P_S) after tagging mortality or tag loss (mutilation or shedding) was set sequentially to 1.0, 0.8 and 0.6 to assess the sensitivity of the parameter estimates to tag loss. The resulting estimates are given in Table 5

Table 5*. Estimation of M, F,* λ_D *and* λ_V *for the 1992/93 tagging programmes.*

P_R	0.8	0.8	0.8
P_S	1.0	0.8	0.6
M	1.146	0.944	0.606
F	0.810	1.012	1.350
λ_D	0.613	0.612	0.613
λ_v	0.013	0.013	0.013

A profile likelihood surface was determined for *M* and *F* by maximising the log likelihood for the tag loss rate parameters at each combination of M and F. From this surface, estimates of the bayesian posterior probabilities at each combination of parameters were determined, and approximate 95% confidence regions were calculated. Using tagging data for 1988 at Jurien and setting $P_S = 1$, the confidence regions are shown in Table 6.

***Table 6**. Jurien tagging data (1988): confidence regions for mortality estimates M and F.*

P_R	*M*	*F*
0.7	0.375-0.525	0.175-0.225
0.8	0.425-0.575	0.175-0.225
0.9	0.375-0.525	0.125-0.175

Analysis of the mortality estimates from the tagging data is continuing. It is apparent from the study by Melville-Smith and Chubb (1997) that tag loss is dependent on depth, location, and lobster density. This suggests that it is necessary to analyse the results from each tagging study separately.

Of greater concern is the discrepancy between the mortality estimates obtained from analysis of the tagging data and the value of the rate of natural mortality of 0.226 per year as derived by Morgan (1977). Also, the variation between estimates of rates of natural mortality in the analyses described above raises further concern. The dependence of the mortality estimates on assumptions of initial tagging mortality and on reporting rates requires evaluation of the validity of such assumptions before the estimates of mortality may be considered valid. Other assumptions of the models, such as constancy of rates of mortality and tag loss are being investigated. The estimates of high natural mortality rate may be associated with an increase in natural mortality of tagged lobsters associated with presence of a tag (such as mortality at moulting) which might explain the difference in the rates of natural mortality for the two sets of data discussed above, or may relate to migration from the inshore areas where fishing is now concentrated to offshore regions which are more lightly fished (again consistent with the results of the data sets above). A recent, unpublished aquarium study resulted in considerable initial mortality associated with the tagging event suggesting that lower estimates of natural mortality and higher estimates of fishing mortality might be more correct; a formal analysis of these data is still required.

It is premature to conclude that the results of the current calculations are accurate. The analysis is on-going and requires re-assessment of earlier experimental studies in order to determine estimates of mortality rates that are considered scientifically sound. There is little doubt that the information on mortality rates derived from the tagging studies will provide valuable information, but more detailed studies are required to ensure that appropriate use is made of the data. Final estimates of mortality rate are likely to have considerable impact on the management advice for the fishery.

OBJECTIVE 3. ***To undertake tagging of juveniles in the shallower waters of the Limited Entry Western Rock Lobster Fishery to provide preliminary estimates of exploitation and growth rates and the directions and magnitude of movements*****.**

This project undertook to tag lobsters in shallow water in an attempt to provide additional data from the inshore regions. This was to assist in our understanding of growth and movements and the rate of exploitation as they related to management options.

Two days of tagging juvenile rock lobsters (mostly in the size range 65-85 mm CL) in the shallow water (0-18 metres) was undertaken at the coastal locations of Fremantle, Lancelin, Jurien, Dongara and Kalbarri. In late October-early November of 1995, a total of 5,228 lobsters were tagged in the shallow water at the five locations. Of these releases, 1025 recaptures came during the 1995/96 season and 392 from season 199/97, or 19.6% and 7.5% respectively (Table 7). The rate of return was variable between locations with generally higher returns in 1995/96 and much lower rates the following season. Fremantle was the exception with a very low rate of return the first season but twice the number of returns the second season, to a rate consistent with the other locations.

Information from the 1025 recaptures during the 1995/96 season (Table 7) were included in the analyses of movement and growth, the results of which were covered under Objectives 1 and 2 in this report.

Given the time available in this one year project, preliminary estimates of exploitation rate in the shallow water were not attempted. This decision also was influenced by other factors such as the unknown rate of non-reporting of recaptures by fishers and it's variability between locations, and the highly variable and inconsistent (with previous estimates) natural mortality estimates reported under Objective 2 above.

In assessing these issues for future research, it is questionable whether the technique of tagging will provide accurate measures of exploitation rate. Other methods such as change-in-ratio techniques may be more cost effective in achieving such estimates.

Table 7*. Details of the depth range, size range (mm carapace length) and numbers of* P. cygnus *released and recaptured at the locations mentioned.*

Location	Depth (m)	Size Range (mm CL)	No. Released	No. Recaptured		% Recaptured	
				95/96	96/97	95/96	96/97
Kalbarri	7-28	41.5-97.3	2642	507	105	19.2	4.0
Dongara	9-18	41.9-90.5	1089	193	149	17.7	13.7
Jurien	3-22	53.5-87.2	399	104	28	26.1	7.0
Lancelin	5-15	56.8-88.8	692	200	68	28.9	9.8
Fremantle	3-13	51.6-124.4	406	21	42	5.2	10.3
Totals			5228	1025	392	19.6	7.5

OBJECTIVE 4. ***To attempt to recruit and train fishing industry representatives in the procedures of data collection from recaptured tagged lobsters to improve the level of reporting by industry*****.**

In previous seasons, many tag returns were from processing establishments where lobsters with tags were discovered by processing staff and it was impossible to determine from whom or which location the lobsters came. This situation arose (still arises) for three reasons; either the lobster tags genuinely were not seen by fishers (a small proportion of the returns), or, more likely, uncaring fishers or those disgruntled with management measures simply consigned the lobsters for sale, or some fishers who feel they are not paid quickly enough for lobsters returned to researchers also consigned their tagged lobsters for sale. Given the sizeable nature of the problem, it was decided to seek the assistance of processors through the kind cooperation of the Western Australian Fishing Industry Council (WAFIC) and the Rock Lobster and Prawning Association (now Western Rock Lobster Development Association) . Processors were requested to appoint an employee who would be trained and who would be the focal point for any tagged lobsters returned to the factory. This had potentially major benefits in cost savings for the payment of legal lobsters returned to research staff and the acquisition of a better level of data from consigned lobsters. Processors were happy to be involved.

The training of industry personnel took place in November 1995 and 1996. A workshop was conducted at the Western Australian Marine Research Laboratories. Here Technical Officers trained nominated representatives from various factories and receival depots in the techniques of tagged lobster measurement, sexing, determination of breeding state and the information required for the completion of the tag recapture labels. For those industry personnel unable to attend the workshop, research staff travelled to various locations to conduct training. With strategic liaison, the representatives nominated at seven coastal locations (Kalbarri, Geraldton (also covering the Abrolhos Is.), Dongara, Jurien, Cervantes Lancelin and Fremantle) were instrumental in assisting skippers to complete tag return information labels, querying skippers on any tag return information where the data might be considered questionable, and dispatching data labels regularly to research staff (Appendix 4).

Prior to the 1995/96 season an average of only 11.6% of tag returns from the processing establishments contained information other than the tag number. As a direct result of the training/education programme of factory staff, that percentage jumped to 49.0% in 1995/96 and 40.3% the following season. This is considered to be a very good result, noting also that factories contributed almost 14% of the tag recaptures in 1995/96. While the proportion of tag returns having useful data attached from the factories, at least in theory, should approach 100%, there are a few factors mitigating against achieving this rate of return. There are times when dealing with tags becomes a second priority for factory staff, such as when large volumes of lobsters are landed (*eg* December, March and April) and have to be processed. Some lobsters are not offered to factory staff by some skippers and so initially are missed but later discovered when mixed with other fisher's catches. While the level of interest shown by factory representatives is high, it does tend to wane and is maintained only with a considerable level of liaison between researchers and representatives. As an adjunct to this, the proportion of useful information in fishers' tag returns before 1995/96 averaged 77% but in the two seasons 1995/96 and 1996/97, it averaged 89%. Obviously,

the return rate of useful information was dramatically improved by this education programme, thereby increasing the cost effectiveness of tagging.

OBJECTIVE 5. ***Preparation of a longer term strategy for providing annual exploitation rates, growth and movements of western rock lobster throughout the Limited Entry Fishery*****.**

The tagging programmes in the past have been undertaken generally on an ad hoc, opportunistic basis except where tagging has been an integral part of the project, *eg* the FIRTA funded breeding stock studies of the western rock lobster (85/057). Additional tagging has been conducted where industry has lobbied government which has led to studies being undertaken. Thus the tagging programmes are driven by: the need for biological data for input into modelling processes; the deficiencies in those data as a result of modelling exercises and sensitivity analyses of assumptions; and industry pressure usually relating to lobster movements and their impacts relating to management options.

This study has shown that tagging information from the western rock lobster fishery can yield reliable information on movements and growth. Notwithstanding this, the rate of tag returns from fishers may vary enormously between seasons and regions. This is due, in part, to fishers' attitudes to the management regulations in force at the time and some fisher's general attitude to research. Another problem is the perception by some fishers that to supply information about lobsters, particularly those that move across boundaries, may have a detrimental impact on their own pecuniary interests if restrictive regulation is deemed possible (from their point of view). Given these serious considerations, it is likely that they probably preclude the estimation of mortality and exploitation rates from tagging data in this fishery from both data and cost-effectiveness viewpoints.

This study and the use of the results in modelling exercises has indicated several areas of research that should be addressed using tagging studies:

- An improved understanding of growth in mature lobsters (sample sizes currently are relatively small).
- An assessment of growth, particularly moult frequency, in the closed seasons of the fishery, ie July to November for the coastal fishery) and July to March for the Abrolhos fishery.
- Determining the relationship of moult frequency with size, sex and location.
- Examine the variation in inter-annual growth by location (a relatively low priority).

Comment from Industry has suggested that:

- Quantifying the rate of movement across management boundaries is a relatively high priority.

These objectives can be achieved using standard tagging techniques supplemented with the use of biological tagging methodology (Melville-Smith *et al*.(1997) and pleopod staging, *eg* Turnbull (1989).

Future modelling exercises and management requirements will impact on the priority setting of tagging programmes but it is likely that priority will be given to the area of growth, eg growth of mature lobsters and moult frequency of all sizes and the industry requested quantification of movement across management

boundaries. Timing of the future projects also will be determined by Agency priorities, the level of industry support and the source of funding to be sought to undertake them.

BENEFITS

The western rock lobster is managed solely by the Western Australian government and all the benefits of this research will flow directly to the State. Data from this pilot programme provides a strategy for improving stock assessment to ensure the long term viability of Australia's most important single species fisheries.

FURTHER DEVELOPMENT

None applicable.

CONCLUSION

This success of this project may be judged against the performance indicators outlined in section B12 of the original application. The first of these was the publication of an agency report on the regional movements, growth and mortality parameters. The analyses of these data have been undertaken and a very good understanding of movements in the western rock lobster has been gained. A journal manuscript is in the final stages of preparation and following peer review and acceptance, a version will be produced for industry distribution. It should be noted that much of what is reported here has been communicated to industry by presentations at a number of meetings along the coast. Analysis of the growth data has yielded some good information but also has indicated gaps in the data base. A decision was taken not to prepare a written report to industry until further work had been undertaken to improve our understanding of growth particularly in the larger size ranges and during the seasonal closures. The mortality work has indicated significant discrepancies between estimates from these data and those of earlier researchers. These discrepancies need to be investigated fully prior to reporting to industry.

The second performance indicator, the successful completion of the shallow water tagging, data entry, validation and analysis of growth, mortality and movements, was achieved. The tagging was undertaken and the data was utilised in the analyses of growth mortality and movements reported under Results and Discussion above. The third performance indicator related to the need for the selection and training of industry representatives to improve the flow of tag recapture data from the commercial fishery. This aspect of the project was a resounding success and dramatically improved, by a factor of four times, the level of meaningful data from industry. It was found that applying an appropriate degree of liaison at strategic times ensured the continuous flow of good quality data from the industry representatives. As mentioned, the achievement of this objective improved the cost-effectiveness of the expensive tagging programmes. This approach will become an integral part of future tagging projects.

The final indicator of performance was the formulation of a strategic view towards future tagging programmes. In hindsight this one year pilot programme was an ambitious undertaking, given the volume of data and level of analysis required to fulfil the objectives. Indeed this work has extended past the one year allocated to it. Nevertheless, the project has been very successful in achieving many of its objectives, or where not achieved, highlighting deficiencies in the data sets. This has led us to an understanding of what tagging can achieve in the western rock

lobster fishery and allowed us to develop a strategic view of the application of tagging to research for management of Australia's most important single species fishery.

ACKNOWLEDGEMENTS

The authors would like to thank all those at the Western Australian Marine Research Laboratories for their advice and help throughout this project.

To conduct an annual survey of this magnitude has required the cooperation and input from a large number of individuals and organisations in all sectors of the Western Rock Lobster Industry:

The following skippers and the crews of their boats are thanked for their support over the last three years. Messrs Ian Ricciardi (Costa Azzura), Nils Stokke (Viking Rose), Stephen McLeary (Whiskey & Coke II, The Edge), Bruce McAdam (Hyperion), David Ralph (Waitara, Queen of Peace), David King (Hannah-Lee), Alan Andrich (Adele-Marie), Terry Parish (Amanda Jo), Marcus Money (Blackfoot), Ross Parris (Miss Sun City II), Roger Shields (Bagheera) and Dominic Sgherza (Makeda III).

The following companies and particularly their employees provided invaluable assistance and service: Fremantle Fisherman's Co-operative Society Limited, Geraldton Fisherman's Co-operative, M.G.Kailis (1962) Pty. Ltd., Activ Industries, Cicerello & Backhouse (1974) Pty. Ltd., J.N.Taylor & Co Ltd. and MBR Fishing Company.

Staff from the Research Division of Fisheries Western Australia, in particular those in the Rock Lobster Research Unit, were instrumental in assuring the accurate collection of data. We offer our thanks in appreciation of their individual efforts to Rick Allison, Eric Barker, Michael Byrne, Jim Christianopoulos, Ben Davy, Frank Fabris, David Murphy, Tony Paust, Mark Rossbach, Craig Skepper and Ken White.

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REFERENCES CITED

Akaike, H.(1974). A new look at statistical model identification. *IEEE Transactions on Automatic Control,* AU-19**,** 716-722.

Batschelet, E. (1965). Statistical methods for the analysis of problems in animal orientation and certain other biological rhythms. Washington, D.C.: American institute of Biological Science.

Brown, R.S. and Phillips, B.F. (1994). The current status of Australia's rock lobster fisheries. pp33-63 in *Spiny Lobster Management* (B.F. Phillips, J.S. Cobb and J. Kittaka, eds). Blackwell Scientific Publications, Oxford.

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.

Chubb, C.F. (1991). Measurement of spawning stock levels for the western rock lobster, *Panulirus cygnus. Revista de Investigaciones Marinas* **12**, 223-33.

Chubb, C.F. (1994). Reproductive biology: Issues for management. *In Spiny Lobster Management* (Ed. By B.F. Phillips, J.S. Cobb & J. Kittaka) pp. 181-212. Blackwell Scientific Publications, Oxford.

Chubb, C.F., Barker, E.H. and Dibden, C.J. (1994). The Big Bank region of the limited entry fishery for the western rock lobster, *Panulirus cygnus*. *Fish. Res. Rep. Fish. Dept. West. Aust*. No. 101, 20pp.

Fisher, N.I.(1993). *Statistical Analysis of Circular Data.*USA: Cambridge Univeristy Press

George, R.W. (1958). The status of the "white" crayfish in Western Australia. *Aust. J. Mar. Freshwat. Res*. **9**, 537-545.

Jernakoff, P. and Phillips, B.F. (1986). Electromagnetic tracking of juvenile rock lobsters. *Aust. Fish*. **45**, 32-34.

Jernakoff, P. Phillips, B.F. and Maller, R.A. (1987). A quantitative study of nocturnal foraging distances of the westen rock lobster Panulirus cygnus George*. J. Exp. Mar. Biol. Ecol*. **113**, 9-21.

Joll, L.M. and Phillips, B.F. (1984). Natural diet and growth of juvenile western rock lobsters *Panulirus cygnus* George. *J. Exp. Mar. Biol. Ecol*. **75**, 145-69.

McCullagh P. and Nelder, J.A. (1989). *Generalized Linear Models*. Second Edition. 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., Jones, J.B. and Brown, R.S. (1997). Biological tags as moult indicators in Panulirus cygnus (George). *Mar. Freshwater Res*. **48**, 959-965.

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**, 577-80.

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

Morgan, G.R. (1974). Aspects of the population dynamics of the western rock lobster, *Panulirus cygnus* George. I. Estimation of population density. *Aust. J. mar. Freshwat. Res*. **25**, 235-248.

Morgan, G.R. (1980). Population dynamics of spiny lobsters. pp 189-217 in *The Biology and Management of Lobsters. Vol II: Ecology and Management* (Eds J.S. Cobb and B.F. Phillips). Academic Press, New York.

Phillips, B.F. (1983). Migrations of pre-adult western rock lobsters, *Panulirus cygnus*, in Western Australia. *Mar. Biol*. **76**, 311-318.

Phillips, B.F., Palmer, M.J., Cruz, R., and Trendall, J.T. (1992). Estimating growth of the spiny lobsters *Panulirus cygnus, P. argus* and *P. ornatus*. *Aust. J. Mar. Freshwat. Res.* **43**, 1177-88.

Turnbull, C.T. (1989). Pleopod cuticular morphology as an index of moult stage in the ornate rock lobster, *Panulirus ornatus* (Fabricius 1789). *Aust. J. Mar. Freshwat. Res.* **40**, 285-293.

Kimura,D.K. (1980). Likelihood Methods for the von Bertalanffy Growth Curve. *Fisheries Bulletin:* **77***,.* Washington Dept of Fisheries, Olympia, WA 98504.

Watson, G.S. (1983). *Statistics on Spheres*. Wiley, New York:.

Zar J. H. (1996). *Biostatistical Analysis*. Prentice Hall, New Jersey.

Appendix 1

INTELLECTUAL PROPERTY AND VALUABLE INFORMATION

There is no information of a commercial nature.

Appendix 2

STAFF

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

***** Trained staff who assisted with the project using non-FRDC funds.

Appendix 3

Tag Information

FISHERIES DEPARTMENT
OF WESTERN AUSTRALIA

BERNARD BOWEN
FISHERIES RESEARCH INSTITUTE

Western Australian Marine
Research Laboratories

West Coast Drive
Waterman

TO ALL ROCK LOBSTER PROCESSORS

The tagging of western rock lobsters will continue during the annual independent breeding stock survey to be conducted in October. This year additional funds have been granted by the Fisheries Research and Development Corporation (FRDC) to undertake tagging of lobsters in shallow coastal waters where the bulk of the juvenile lobsters reside. The objectives of this research programme are:

- To estimate regional growth and mortality rates, and rates of migration for refining our computer models of the western rock lobster fishery.
- To prepare a Departmental report to industry on the migratory movements of lobsters tagged since 1988.
- Preparation of a longer term strategy for providing annual estimates of growth, exploitation and migration throughout the limited entry fishery.

Lobsters tagged in 1995 and previous years will be caught by fishermen during the 1995/96 season.

In the past, the tagging programme has received valuable support from the processing sector and for this we are extremely grateful. Nevertheless, on many occasions over the past few years, and for a number of reasons, numerous tags with little or no recapture information attached have been returned by processors. A similar problem exists in the catching sector with some fishermen providing inadequate tag recapture details.

We would like to improve the quality of tag recapture information provided by industry by proposing that processor's establishments become the "focal point" for tag returns by the fishermen. Under this proposal each processor would nominate at least one responsible, interested person to receive tagged lobsters from fishermen at each port where product is received from the major tagging locations of Fremantle, Lancelin, Jurien, Dongara, Kalbarri, Abrolhos and Big Bank. The nominated people, perhaps including carrier boat skippers at the Abrolhos, would check recapture details immediately on receipt of a tagged lobster or, where necessary, accurately record the missing tag recapture information themselves. Information would be sent to the WA Marine Research Laboratories at regular intervals in reply paid envelopes, or be collected by Fisheries Department Technical Officers during their commercial catch monitoring operations. Your nominated staff will be considered part of our research team and will undertake specific training by the Rock Lobster Research Unit staff. The Fisheries Department will supply vernier callipers (on a loan basis) and all other data recording materials throughout the season and frequently maintain contact with your nominated staff members.

Postal: PO Box 20, North Beach WA 6020, Australia
Telephone: +61 (09) 246 8444, Fax +61 (09) 447 3062

There are a number of benefits from this initiative:

- Fishermen would get paid for their tagged lobsters by consigning them with their catch in the normal way. This would allow more of our limited resources to be spent on data analysis and provision of results to industry.

- It will hopefully entice more fishermen to report tagged lobsters rather than ignoring them.

- Your nominated staff would ensure that all details on all tag return labels were accurate and legible on the day. If they were not, the skipper could be quizzed and the details corrected on the spot or very shortly thereafter. This will save a great deal of time and money during the computer validation process.

- The quality of information from industry would be improved resulting in a better understanding of regional growth and migration, and a more timely delivery of results back to industry.

- This system would be more cost effective, provide more detailed information and allow us to more rigorously test the assumptions in our computer models, thus improving our management advice to the fishermen's associations, WAFIC, RLIAC, the general community and the Minister.

I trust you will find this proposal acceptable and become an important part of the tagging research programme by nominating responsible people who would be interested in being trained to collect these vital tag recapture data. I should mention here that it will be policy to promote the re-release of tagged lobsters at the site of capture by fishermen provided they can provide accurate recapture details such as carapace length, etc.

Since many juvenile lobsters will have been tagged in shallow water it is important that your staff be trained prior to the commencement of the 1995/96 season. Thus, we would appreciate your support and nomination(s) of responsible, motivated and interested personnel by Friday November 3, so that we can organise training in the following week and a half prior to the season's opening on November 15. Less than one half day would be required for each training session to be undertaken at each port and at the WA Marine Research Laboratories for depot and factory staff based in the Perth metropolitan area.

Once again, we look forward to your support since the data your staff will collect will be extremely important when considering the regional impacts of management in the western rock lobster fishery.

Yours sincerely

DR C F CHUBB
SENIOR FISHERIES RESEARCH SCIENTIST
ROCK LOBSTER RESEARCH UNIT

22 September, 1995

ATTENTION ABROLHOS ISLANDS FISHERMEN

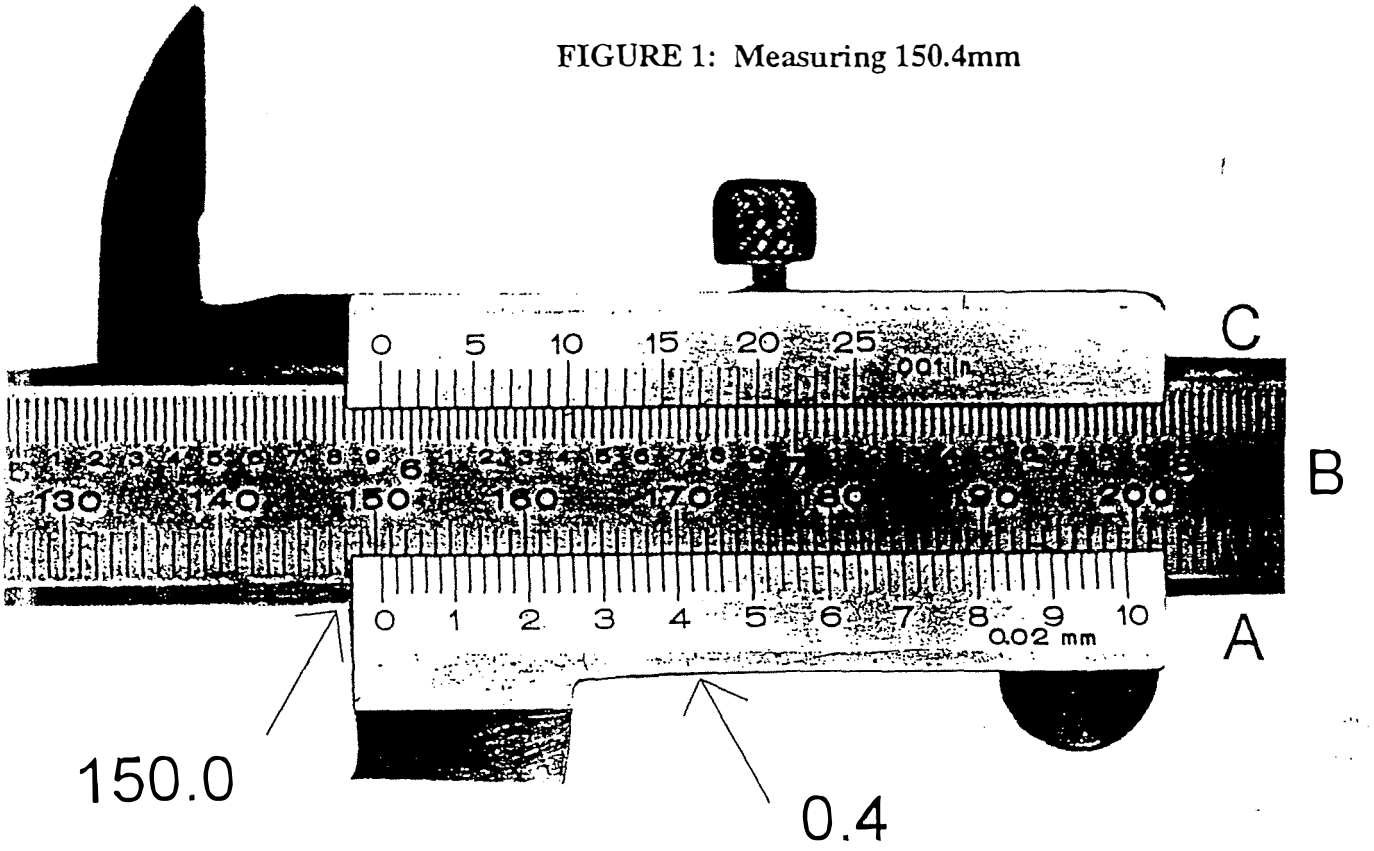
FROM FISHERIES RESEARCH

ROCK LOBSTER TAGGING PROGRAMME

The Co-operative's processing staff have found large numbers of tagged rock lobsters being consigned without any of the necessary recapture information being provided. We at Rock Lobster Research would ask fishermen to stop this practice as it results in the loss of a great deal of valuable tagging information. Remember this is YOUR industry, and it was fishermen, through their fishing associations, that requested that the tagging be undertaken! Please make your own personal contribution to your fishery, be part of the research team and spend the time to ACCURATELY record the tag numbers and carapace length (eg. 74.1 mm), date, GPS position, depth, sex, colour, breeding status (ie. spawner, tarspot and/or setose), boat name and number, and your name and postal address. Enter this information on individual plastic information labels which are available from all carrier boats. You may then re-release the tagged lobsters to the water, allowing for further recaptures. If you CANNOT accurately measure their carapace length please return ALL tagged lobsters (legal or illegal) in plastic bags (also available from carrier boats) with the completed information labels. If you wish to consign a legally-saleable, tagged rock lobster to the factory, do so, however, please provide ALL of the above recapture details, including an accurate carapace length, and ensure that you attach each lobster's tag(s) to the label with the recapture information. Return the completed labels and/or tagged lobsters to your coastal receival depot or Fisheries Office via your carrier boat. Rewards will be paid for each correctly filled-in information label and/or tagged lobster returned. In addition, the current beach price will be paid for any legal size lobsters returned. Please contact Ben Davy on (09) 246 8408 if you have any further queries.

Calipers Calipers are of the vernier type. The size of the lobster is measured along the carapace, using the same two places on the shell that you normally use to determine whether a crayfish is of legal size. An accurate measurement can only be made when the tapered face of the calipers is used anteriorly and the two antennae are spread apart. Place the calipers over the lobster as you would with a cray measure, and slide the scale of the calipers along until the jaws are a firm fit on the lobster.

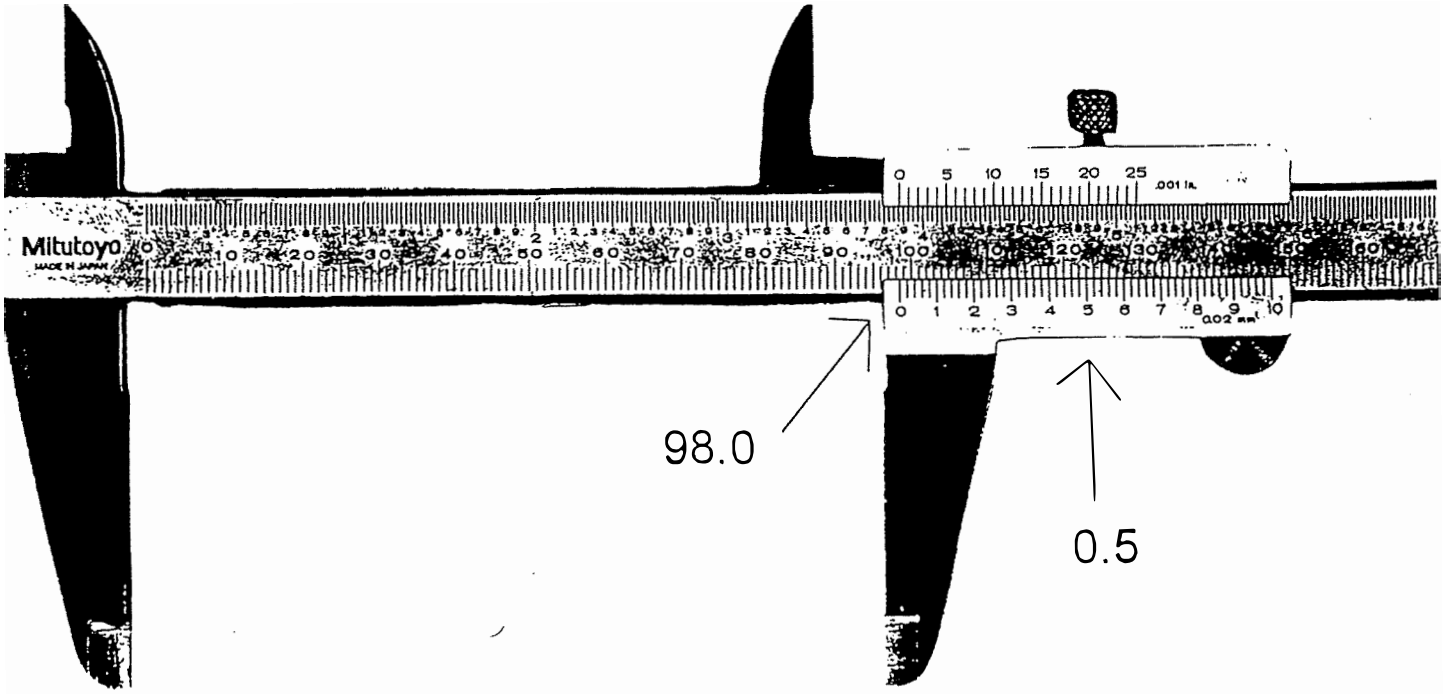
FIGURE 1: Measuring 150.4mm



Find the 0 reading on the bottom scale of the calipers (A. in figure 1). Now look above the 0 to the next scale (B. in figure 1) and look to where the 0 mark lines up on the top scale. (The scale on the very top of the calipers (C. in figure 1) is not used in the measurements). As you can see in the example, the 0 mark cuts the top scale between 150mm and 151mm. You always round down to the nearest millimeter, which in this example would be 150mm. Next step is to look along the bottom scale again, but this time you are looking to see where a whole number on the bottom scale lines up exactly with a graduation on the top scale. In this example you can see that as we move along the bottom scale the numbers are getting closer and closer to lining up until we get to 4 (on the bottom scale) which exactly lines up with a graduation (in this case 170) on the top scale. The number on the lower scale is the decimal part of a millimetre, in this case 0.4mm. The length measurement for this lobster will therefore be 150.4 mm.

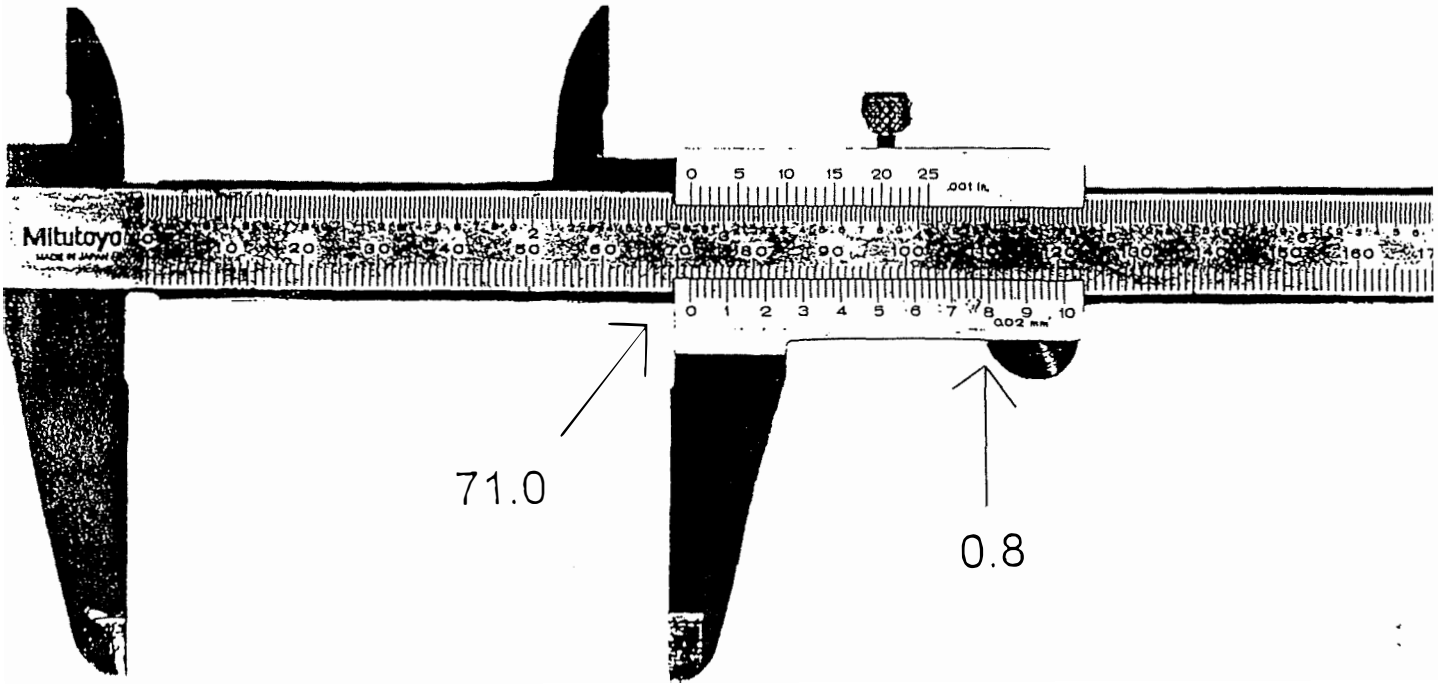
Let's look at some more examples. In Figure 2, we look at the 0 mark on the bottom scale and see that it rounds down to 98mm on the top scale. Now we look along the bottom scale again and find that 5 most closely lines up with a graduation on the top scale. The measurement is 98.5mm.

FIGURE 2: Measuring 98.5mm



In Figure 3, the 0 mark on the bottom scale rounds down to 71 mm and the decimal part of the millimetre is 0.8, as 8 lines up with a graduation on the top scale. The measurement is therefore recorded as 71.8mm.

FIGURE 3: Measuring 71.8mm



RECREATIONAL ROCK LOBSTER FISHERS

WHAT TO DO WITH TAGGED ROCK LOBSTERS

Prior to the commencement of the 1995/96 rock lobster season a large number of lobsters were tagged in shallow water (10-30 metres depth) off Fremantle, Lancelin, Jurien, Dongara and Kalbarri.

It is likely that recreational fishers operating in these areas will catch some of these tagged lobsters. Under existing regulations, some will be able to be kept and some will be illegal; ie undersize, setose, tarspotted etc.

WHAT TO DO

In **ALL** cases the following information is required:

- **TAG NUMBER(S)** - some rock lobsters may have one tag, either on its back or under its tail, others may have two tags, one in each place.
- **DATE** - the exact date is important to know how long the lobster has been at large since tagging, thus allowing calculations of rates of growth and movement.
- **LOCATION CAUGHT AND DEPTH** - this tells us if the lobster has moved since tagging and which direction it travelled.
- **SEX** - male or female and if female whether the lobster is setose, tarspotted, berried (egg carrying) and the colour of the eggs (bright orange or dull brown).
- **CARAPACE LENGTH (SIZE)** - this tells us how much the lobster has grown since it was tagged.

IT IS VITALLY IMPORTANT THAT ALL INFORMATION IS RECORDED ACCURATELY FOR EACH ROCK LOBSTER THAT IS CAUGHT.

LEGAL LOBSTERS

If you have a legal lobster that is tagged but cannot measure it properly then you can do one of two things:

- If a Fisheries Office is nearby, take the lobster there to be measured and provide all of the other details to the Fisheries Officers, who will ensure the information reaches the research team.

OR

- Freeze the head and legs (uncooked) and with the tag(s) and other information, take them to your local Fisheries Office or deliver them to the Western Australian Marine Research Laboratories, West Coast Drive, Waterman, ph: (09) 246 8444 - contact Ben Davy.

ILLEGAL LOBSTERS

If you catch a tagged lobster that would **NORMALLY NOT BE LEGALLY KEPT** then you can either:

- Accurately record all details and return the lobster to the water.

OR

- As soon as is practicable take the whole lobster to your local Fisheries Office or deliver it to the Western Australian Marine Research Laboratories together with the information on date, location, depth, etc. **DEPARTMENTAL POLICY ALLOWS YOU TO RETAIN ILLEGAL TAGGED LOBSTERS PROVIDED YOU ARE ACTING IN A RESPONSIBLE MANNER AND ENDEAVOURING TO DELIVER THE LOBSTER(S) TO FISHERIES OFFICERS OR THE RESEARCH TEAM.**

If you wish to **RETURN THE LOBSTER** (illegal or legal) **TO THE WATER**, by all means do so **IF ALL OF THE REQUIRED INFORMATION CAN BE PROVIDED ACCURATELY.**

All information is vital to the success of our research and you can act as part of the research team by providing the lobster or accurately recorded information.

For information on each tagged lobster you will be given a $2 scratch and match ticket which is a chance to win $50 000.

ROCK LOBSTER TAGGING PROGRAMMES (1991-96)
TAGGING LOCATIONS AND TAG No. SERIES

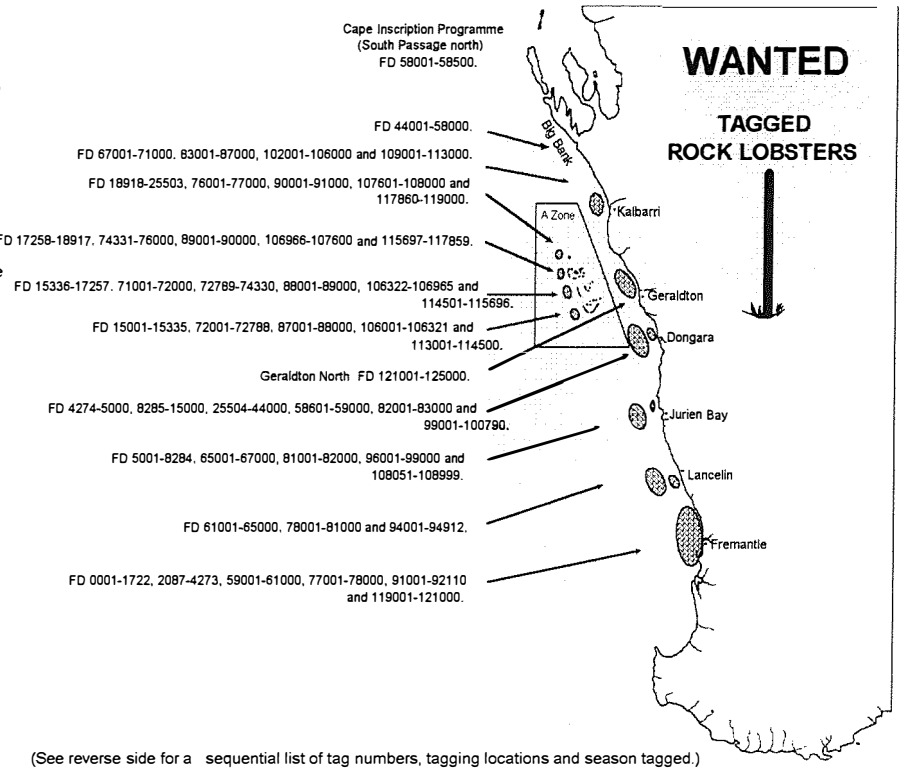
Lobsters are tagged with bright yellow spaghetti tags (eg. FD-WAMRL 106322). For each recaptured tagged lobster, please accurately record the tag number(s), date, carapace length (eg. 74.1 mm), GPS position, depth, sex, colour, female's breeding status (ie. spawner, tarspot and/or setose), boat name/no., and your name, postal address and phone no. Would you please re-release the tagged lobster where you caught it. Enter the details onto a recapture information label and return the label to your local receival depot, carrier boat or Fisheries Office, where additional labels will be available.

If you cannot accurately measure their carapace length please return all tagged lobsters (legal or illegal), with the recapture date, position and depth information, to your local receival depot, carrier boat or Fisheries Office, where help with carapace length measurements will be available.

If you bring in tagged lobsters to be measured please do not re-release any of them near your marina or anchorage unless you remove the tag(s) and attach them to their recapture labels. Lobsters with tags should only be returned to the sea exactly where they were caught.

If you wish to consign a legal tagged lobster, do so, however, please provide all of the necessary recapture details and attach each lobster's tag(s) to their recapture information label.

Rewards will be paid for each valid recapture information label and the current beach price paid for any legal lobsters returned to Rock Lobster Research, PO Box 20, North Beach 6020. If you have any queries or you require more recapture information labels please contact Sally O'Connor on (09) 246 8408.



(See reverse side for a sequential list of tag numbers, tagging locations and season tagged.)

ROCK LOBSTER TAGGING PROGRAMMES (1991-96)
TAG No. SERIES, LOCATION AND SEASON TAGGED

TAG No. SERIES	TAGGING LOCATION	SEASON TAGGED
FD 0001-1722	FREMANTLE	1991/92
FD 1725-2000	ABROLHOS	1991/92
FD 2087-4273	FREMANTLE	1992/93
FD 4274-5000	DONGARA	1992/93
FD 5001-8284	JURIEN	1992/93
FD 8285-13850	DONGARA	1992/93
FD 13851-14150	DONGARA	1993/94
FD 14151-14400	DONGARA	1992/93
FD 14401-15000	DONGARA	1994/95
FD 15001-15335	PELSART GROUP	1992/93
FD 15336-17257	EASTER GROUP	1992/93
FD 17258-18917	WALLABI GROUP	1992/93
FD 18918-25503	NORTH ISLAND	1992/93
FD 25504-42500	DONGARA	1992/93
FD 42501-43000	DONGARA	1993/94
FD 43001-44000	DONGARA	1992/93
FD 44001-58000	BIG BANK	1992/93
FD 58001-58500	CAPE INSCRIPTION	1992/93
FD 58601-59000	DONGARA	1993/94
FD 59001-61000	FREMANTLE	1993/94
FD 61001-64278	LANCELIN	1993/94
FD 64279-65000	LANCELIN	1994/95
FD 65001-67000	JURIEN	1993/94
FD 67001-71000	KALBARRI	1993/94
FD 71001-72000	EASTER GROUP	1993/94

TAG No. SERIES	TAGGING LOCATION	SEASON TAGGED
FD 72001-72788	PELSART GROUP	1993/94
FD 72789-74330	EASTER GROUP	1993/94
FD 74331-76000	WALLABI GROUP	1993/94
FD 76001-77000	NORTH ISLAND	1993/94
FD 77001-77812	FREMANTLE	1994/95
FD 77813-78000	FREMANTLE	1995/96
FD 78001-78936	LANCELIN	1994/95
FD 78937-80276	LANCELIN	1995/96
FD 81001-82000	JURIEN	1994/95
FD 82001-82530	DONGARA	1994/95
FD 82532-83000	DONGARA	1995/96
FD 83001-86738	KALBARRI	1994/95
FD 86739-87000	KALBARRI	1995/96
FD 87001-88000	PELSART GROUP	1994/95
FD 88001-89000	EASTER GROUP	1994/95
FD 89001-90000	WALLABI GROUP	1994/95
FD 90001-91000	NORTH ISLAND	1994/95
FD 91001-91529	FREMANTLE	1995/96
FD 96001-97115	JURIEN	1995/96
FD 99001-100180	DONGARA	1995/96
FD 102001-106000	KALBARRI	1995/96
FD 106001-106321	PELSART GROUP	1995/96
FD 106322-106965	EASTER GROUP	1995/96
FD 106966-107600	WALLABI GROUP	1995/96
FD 107601-108000	NORTH ISLAND	1995/96

Appendix 4

Tag Liaison Trip Report

Rock Lobster Tagging Programme
Tag Liaison Trip Report March 1996

A tag liaison trip was undertaken from 12-18 March 1996. I spent a day at the ports of Kalbarri, Geraldton, Dongara, Jurien, Lancelin and Fremantle. The objectives achieved during this trip were:

- Delivery of 1995/96 tag information sheets and recapture information labels (both attached) to rock lobster fishers, Abrolhos carrier boat skippers, processors and the Fisheries Office at each port.

- Collection of tag recapture information and tag training discussions with industry representatives.

- Recruited potential research logbook participants (x7). I delivered Commercial Fisheries Production Bulletin No 8 (attached) to non-participants as an incentive to become involved in our logbook programme.

Kalbarri: Liaison with local tackle shop owner regarding amateur tag recaptures. Delivered tag information sheets, collection of tag recapture information, logbook recruitment and liaison with rock lobster fishers at jetty (x16), processors and truck drivers. Many maximum size females and low setose numbers were frequent comments from fishers. Discussed tag training and delivered information to Kalbarri Seafoods (ie GFCoop), no problems identified.

Geraldton: Delivered tag information sheets, collection of tag recapture information and liaison with processors, Abrolhos carrier boat skippers (x5) and Fisheries Officers. Visited all processing depots and factories, including Batavia Coast Fisheries factory. The low Big Bank catch was the main topic. Discussed tag training with carrier boat skippers and industry representatives, no problems identified.

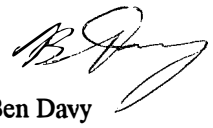
Dongara: Delivered tag information sheets, collection of tag recapture information, logbook recruitment and liaison with rock lobster fishers at jetty (x24), processors and Fisheries Officer. Big Bank and next season's predicted catch were the main topics discussed. Visited all processing depots and factory. Discussed tag training with industry representatives, no problems identified. Delivered tag information sheets to Leeman and Greenhead processing depots while on-route to Jurien.

Jurien: Delivered tag information sheets, collection of tag recapture information, logbook recruitment and liaison with rock lobster fishers at jetty (x48) and processors. The mobile fleet was the main issue discussed (ie >50 vessels). Delivered information to Fisheries Office and FFCoop factory. Discussed tag training with industry representatives, no problems identified.

Lancelin: Delivered tag information sheets, collection of tag recapture information, logbook recruitment and liaison with rock lobster fishers at jetty (x50) and processors. The mobile fleet was again the main issue discussed (ie >50 vessels). Delivered information to Fisheries Office and R&O Seafoods factory. Discussed tag training with industry representatives, no problems identified.

Fremantle: Delivered information to Fisheries Office and liaison with Fisheries Officers. Delivered tag information sheets, collection of tag recapture information, logbook recruitment and liaison with rock lobster fishers at jetty (x30) and processors. The mobile fleet and next season's predicted catch were the main topics discussed. Discussed tag training with industry representatives, no problems identified.

Abrolhos Islands: Carrier boat skippers distributed tag information sheets and recapture labels to all Abrolhos fishers prior to their season's start. However, telephone discussions with Geraldton processors and Abrolhos carrier boat skippers (21 March to 2 April 1996) found that non-reporting of recaptures was still occurring. The level of non-reporting (via GFCoop) was similar from all four island groups. Carrier boat skippers agree that large catch rates during the first two weeks of the Abrolhos season is probably the main cause of non-reporting. Therefore, the level of non-reporting should decrease significantly as catches decline.



Ben Davy
TECHNICAL OFFICER
ROCK LOBSTER RESEARCH

4 April 1996

Appendix 5

RLIAC Coastal Tour Summary Document

GROWTH AND MIGRATION

A total of 55 673 lobsters were tagged and released over the period 1988/89 to 1994/95. To the end of January 1996, 15 027 lobsters (27%) have been recaptured (Table 1)

Table 1. Rock lobster tagging programmes 1988/89 to 1995/96 -tagging locations, recapture/release numbers and percentages to 30 June 1996 inclusive.

Locations	1988-91	1992/93	1993/94	1994/95	1995/96	Totals	Secondary Recaptures (by location)
Fremantle	333 1710 (19.5%)	240 1091 (22.0%)	152 1005 (15.1%)	45 407 (11.1%)	37 712 (5.2%)	807 4925 (16.4%)	9 (0.2%)
Lancelin			673 1621 (41.5%)	194 827 (23.5%)	320 1330 (24.1%)	1187 3778 (31.4%)	129 (3.4%)
Jurien	1002 6695 (15.0%)	764 1622 (47.1%)	366 1003 (36.5%)	181 495 (36.6%)	292 1112 (26.3%)	2605 10927 (23.8%)	104 (1.0%)
Dongara		4610 12066 (38.2%)	181 600 (30.2%)	156 561 (27.8%)	268 1640 (16.3%)	5215 14867 (35.1%)	765 (5.1%)
Kalbarri			439 2003 (21.9%)	302 1865 (16.2%)	820 4252 (19.3%)	1561 8120 (19.2%)	72 (0.9%)
Abrolhos	271 2209 (12.3%)	1648 7614 (21.6%)	710 3091 (23.0%)	448 2001 (22.4%)	252 1998 (12.6%)	3329 16913 (19.7%)	194 (1.1%)
Big Bank		2822 6941 (40.7%)				2822 6941 (40.7%)	154 (2.2%)
Cape Inscription		4 246 (1.6%)				4 246 (1.6%)	
Totals	1606 10614 (15.1%)	10088 29580 (34.1%)	2521 9323 (27.0%)	1326 6156 (21.5%)	1989 11044 (18.0%)	17530 66717 (26.3%)	1427 (2.1%)
Secondary Recaptures (by season)	57 (0.5%)	994 (3.4%)	213 (2.3%)	93 (1.5%)	70 (0.6%)	1427 (2.1%)	

Note: Secondary recapture percentages are based on total numbers of releases. Secondary recaptures are included in the total number of recaptures.

Migration

Data from the recaptures over the years show that while some long distance movements up to 220 nautical miles were noted, the vast majority of lobsters moved less than 10 nautical miles with most moving 5 or less miles from their point of release. Movements were generally west to north-west with long distance migration always to the north-west. The pattern of movement is essentially the same from year to year. Detailed data will be shown on the tour.

Rock lobsters in the process of migration in very deep water were tagged at Big Bank in 1993. Some lobsters moved 80-100 nautical miles from the release point but, on the basis of earlier tagging data, had obviously travelled from the Abrolhos Islands or further from north coastal regions such as Dongara and Kalbarri prior to being tagged. The pattern of migration at Big Bank differs from the rest of the coast in that the migrating deep water "whites" move in towards the shallower breeding grounds adjacent to the shelf break and to the coast itself where suitable habitat exists. Once there they settle and become mature in a year or two.

A management issue of relevance in the Fremantle region includes transferring catch from the "whites" to the "reds" part of the fishery. Since the "whites" provide a large part of the catch of fishers operating in this region, questions about where "white" lobsters returned to the sea move to are fundamental to management discussions. From existing data rock lobsters tagged at sizes between 70 and 76mm carapace length in the breeding stock surveys at Fremantle reasonably could be expected to moult into "whites" and migrate in late November and December. Data from the Fremantle region show that 94% of this size class of lobster remained within 10 nautical miles of their release point while 6% moved between 10 and 80 nautical miles. Again the long distance movement was to the north-west.

In the Geraldton region suggestions that the 76mm animals returned to the sea in the "whites" migrate to the Abrolhos Islands can not be answered by the existing tagging data bases. However, the fact that higher catches have been taken in the "reds" suggests that many are not lost to the coastal fishery. To address both of these issues it is proposed that specific tagging of some of the 76mm "whites" returned to the sea will be undertaken at Fremantle and Geraldton in December 1996 to provide some direct evidence on the short-term movement of these lobsters in these regions.

Growth

Plots of carapace length at release and size at recapture for males and females show that different rates of growth are evident between regions and between males and females at all locations with female growth slowing after reaching maturity; 65mm at the Abrolhos Islands and 90-95mm on the coast. Detailed data will be presented on the tour.

Current Spawning Stock Indices

Spawning stock indices for the western rock lobster fishery using information derived from the commercial catch monitoring programme, had until a few years ago, been showing a gradual decline over more than a twenty year period. There was an acceptance that egg production had fallen to between 15-20% of pre-exploitation levels and that the future of the fishery was in serious danger of being adversely affected by this situation.

As a result of the low level of egg production, a management package was introduced in the 1993/94 season, aimed at reversing the declining trends in egg production. Around the same time as the introduction of the new