# Stock Assessment for the West Coast Rock Lobster Fishery

DRAFT

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*(23/09/2008)*

***This has been provided to invited Western Rock Lobster Stock Assessment and Harvest Strategy Workshop participants***

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# Acknowledgements

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# Executive Summary

The western rock lobster *Panulirus cygnus* is exploited throughout its geographic range along the lower west coast of Western Australia. The main commercial fishery exploiting *P. cygnus* is the West Coast Rock Lobster Managed Fishery (WCRLMF). This is Australia's largest single species fishery worth $250 - $400 million annually. It is important for the economy of a number of coastal towns along the west coast of Western Australia.  It also supports an important recreational fishery.



In 1963 the WCRLMF was declared a limited entry fishery, freezing pot and licence numbers. Since that time the fishery has undergone a number of management changes designed to maintain stock sustainability.  Currently there are around 490 boats catching on average of 11 million kg of western rock lobster. There is also an important recreational fishery which has about 45, 000 licences issued annually. Recreational fishing accounts for about 3% of the total catch of the fishery.

The WCRLMF was also the first fishery in the world to receive Marine Stewardship Council Certification (MSC). In 2000, certification was given on the basis of it being a sustainable fishery, and it was recertified in 2006. The ongoing accreditation requires the addressing of criteria set by the MSC, which now also include considerable research being undertaken on ecological impacts of the fishery.

The fishery is managed based on the status of the breeding stock relative to a threshold Biological Reference Point (BRP), the 1980 level.

*"Ensure the abundance of breeding lobsters is maintained or returned to, as the case may be, at or above the levels in 1980."*

The commercial fishery is managed using a total allowable effort (TAE) system as well as associated input controls. The primary control mechanism is the number of pot units, together with a proportional usage rate, which creates the TAE in pot lifts. Unitisation in the fishery and transferability provisions allow market forces to determine what is the most efficient use of licences and pot entitlements, a system now known as individually transferable effort (ITE). Management arrangements also include the protection of females in breeding condition, a variable minimum carapace length and a maximum female carapace length and gear controls, including escape gaps and a limit on the volume of pots.

The western rock lobster is an omnivorous crustacean, found predominantly along the mid and lower west coast of Western Australia in shallow and deep (> 100 m) reef habitats. After a 9-11 month plankton phase taking them off the continental shelf, they settle on shallow near-shore reefs (post larval phase - puerulus). Here they grow before undergoing an offshore migration during the juvenile stage at about four to five years of age, when they start to recruit to the fishery. Large and mature lobsters are mainly found in deep water (>40m) breeding grounds.

Department of Fisheries researchers have ongoing program to monitor settlement of puerulus, catches of the commercial fleet by onboard sampling and logbooks, the breeding stock, recreational catches, and environmental conditions. This information is used to assess changes in the stocks of the WRL, and form the basis of advice for management decisions.

Stock assessment of the fishery is based on a number of empirical and modelled indices that have been referred externally by stock assessment experts (http://www.fish.wa.gov.au/docs/op/op050/fop050.pdf). These indices include:

- Trends in fishery-dependent breeding stock indices (current basis of threshold biological reference point (BRP));
- Trends in puerulus settlement and understanding how these are affected by key factors (e.g. Leeuwin Current);
- Catch prediction 3 – 4 years in advance;
- Depletion analysis providing trends in residual legal biomass and harvest rates;
- Biological model of the fishery that integrates information on recruitment, legal-size lobsters and breeding stock.

The current state (30-June-2007) of the fishery in the three zones is as follows:

- The legal-size component of the stock in **Zone A** (Abrolhos Islands) is heavily exploited. However its breeding component is well protected as much of it matures before reaching legal size. It has achieved record catches in the last three years.

- The stock in **Zone B** (North Coastal) is heavily exploited and its breeding component is close to the breeding stock BRP threshold level. This stock is considered vulnerable, and management changes have occurred (15% effort reduction in 2005/06) to improve its status.
- The stock in **Zone C** (South Coastal) is moderately exploited and its breeding component remains well above breeding stock threshold levels. This breeding stock is considered healthy, although with four years of predicted low recruitment, pre-emptive management (5% effort reduction in 2005/06) steps have been taken to keep this stock above threshold levels.

# Background

This draft document was initiated to provide a compendium of information for the stock assessment of the West Coast Rock Lobster Fishery. It provides background information for the expert panel reviewing the stock assessment for the fishery. As such, provides information that will enable the reviews to examine:



i. The current western rock lobster stock assessment process and proposed future research;

ii. A biological model that has recently been developed by the Department of Fisheries (WA) for use in providing management advice for the western rock lobster fishery and propose future directions for that work; and

iii. The current western rock lobster harvest strategy and recommend improvements to it.

Once the reviewers' comments have been received, the report will be revised and provided to all stakeholders and made available publicly.

It should be noted, that this report does not deal with the social aspects of the fishery, or the ecological interactions of the fishery. A separate process involving two scientific reference groups (SRGs) (Sea Lion SRG and Ecosystem SRG) has been established and meets regularly to deal with the ecological issues relating to the fishery.

This document is the first production of its type for the western rock lobster fishery. It is a "living" document, with a synopsis of available biological information on *Panulirus cygnus*, a guide to on going monitoring undertaken by the Department of Fisheries, and an indication of the analyses leading to management decisions.

This document will be amended to reflect changes to procedures, and updated on a regular basis.

# 1 – The Fishery

## 1.1 – Overview



The western rock lobster (*Panulirus cygnus*) is fished by three managed fisheries, West Coast Rock Lobster Managed Fishery (WCRLMF), Augusta - Windy Harbour Managed Fishery and the South Coast Crustacean Fisheries. These fisheries extend over the entirety of the lobster's range (Figure 1.1). The WCRLMF is the major fishery exploiting the western rock lobster (WRL) as it encompasses most of its geographic range (Figure 2.1), and the most productive regions of the distribution. It is the resource located within this region that will be then focus of this report.

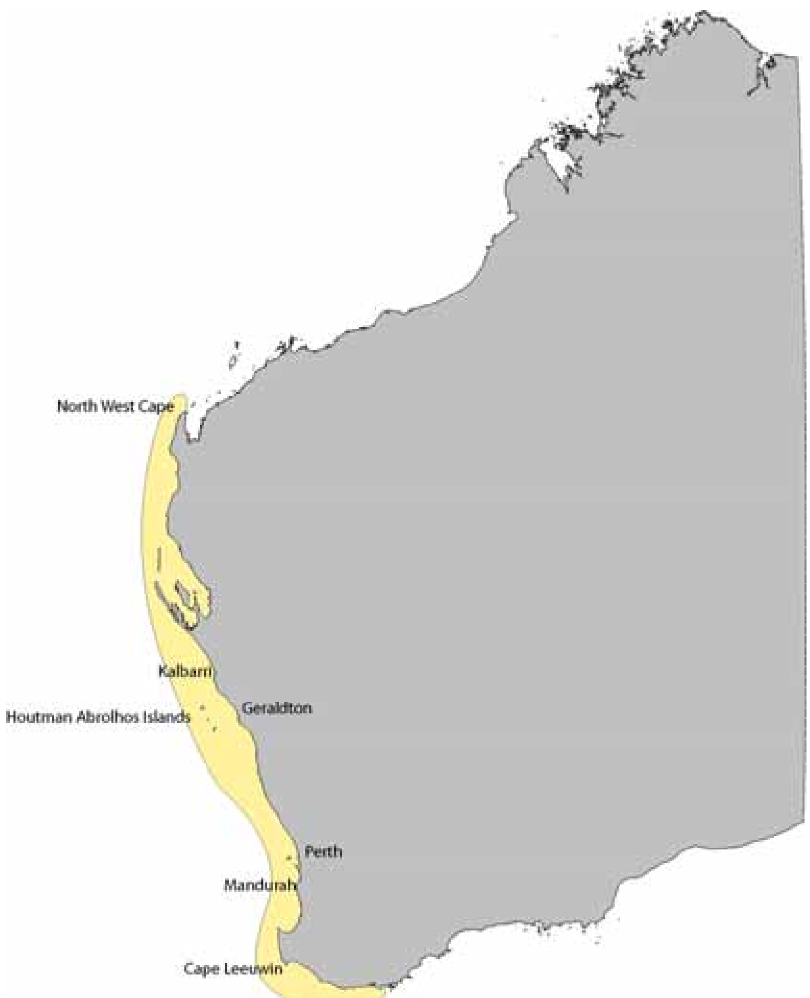



Figure 1.1 – Distribution of the Western Rock Lobster *Panulirus cygnus*

The WCRLMF fishery expanded rapidly in the 1940s and over the following 15 years achieved annual catches in excess of 8 million kg in the mid 1950s (see Gray 1999b for full details on the fishery's history). During the last 20 years the annual catch has averaged approximately 11 million kg and has varied from 8 – 14 million kg due to natural variations in the level of recruitment (Figure 1.2)



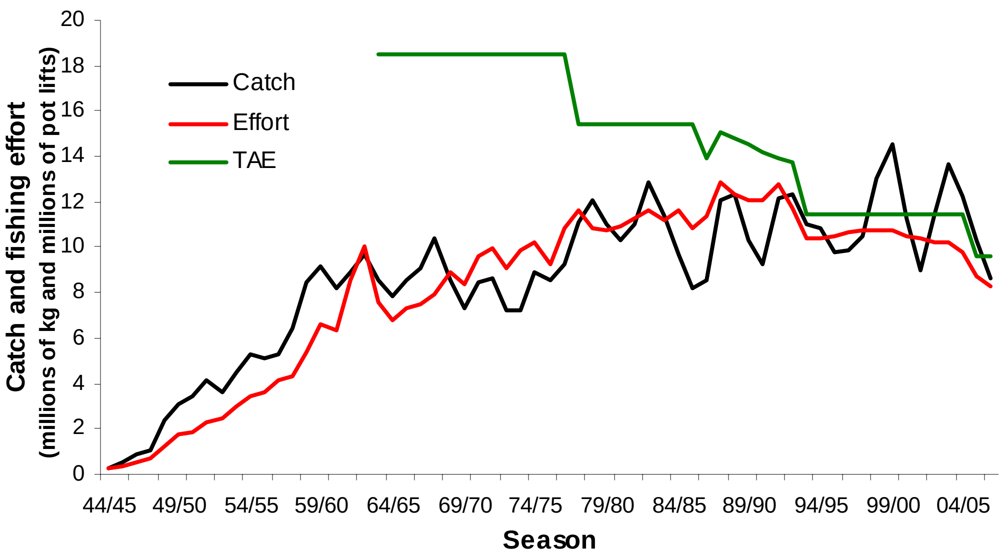



Figure 1.2 – Annual catch, effort and total allowable effort (TAE) for *Panulirus cygnus* in the WCRLMF.

## 1.2 – Commercial Fishery

The West Coast Rock Lobster Managed Fishery (WCRLMF) is the most valuable single-species wild capture fishery in Australia (with the catch worth between $A250 and $A400 million annually), representing about twenty per cent of the total value of Australia's wild capture fisheries.



The commercial fishery for Western Rock Lobster is a "potting" fishery. This activity occurs from inshore regions in shallow waters out to the edge of the continental shelf (~ 200 m depth) with the only allowable method for capture being from the use of pots (traps) of a batten design made of wood slats or plastic (Figure 1.3a), or beehive pots constructed from cane (Figure 1.3b), (for precise dimensions regulations see Section 2.3).

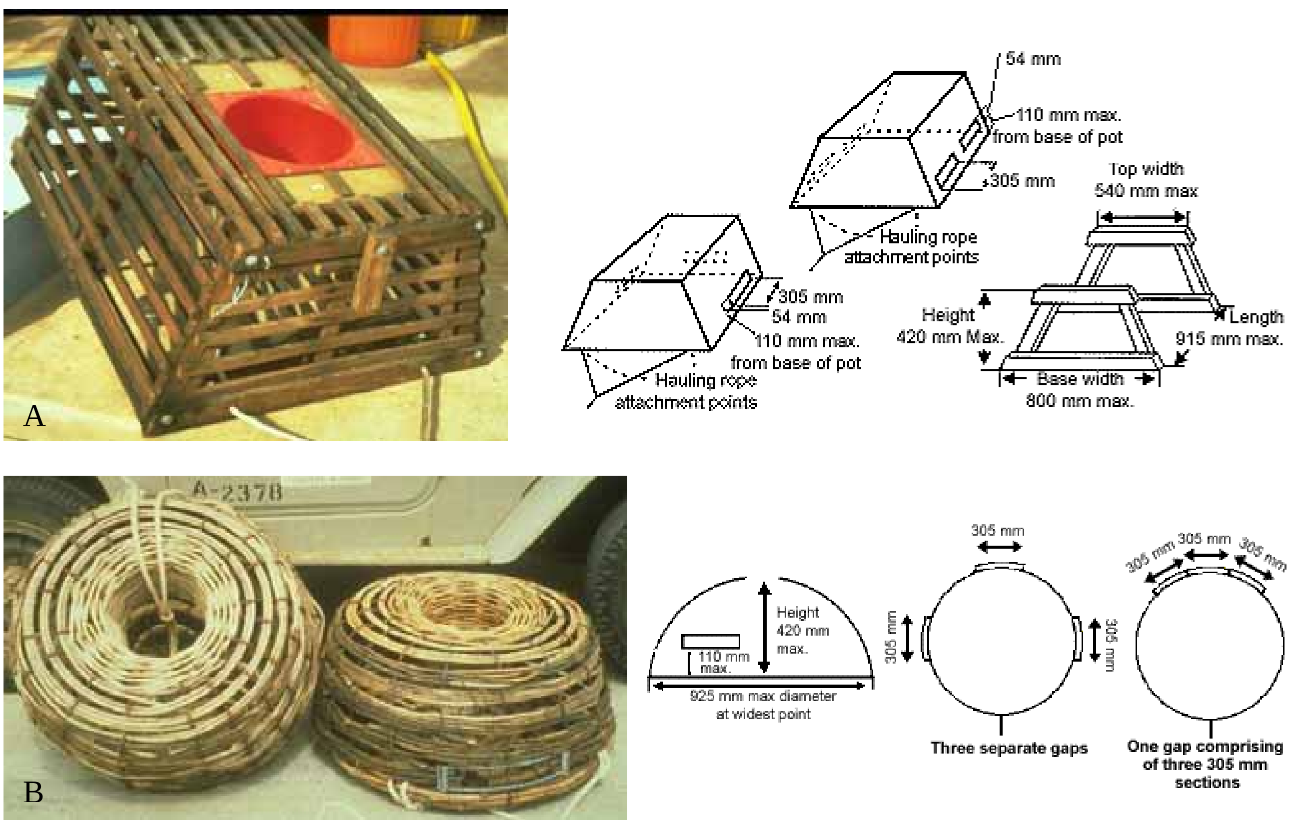



Figure 1.3 – Two main trap types used by lobster fishers and their associated size and configuration regulations a) batten design (made of wood); b) cane beehive pot (details of pot regulations; Box 2.1 and 2.2)

Baited pots are released (set) from boats near reefs where the lobsters usually reside or in regions (usually sandy bottom) thought to be on migration paths during the migration period. This is based upon a combination of information gained from depth sounders, GPS systems, previous experience and recent catch rates in the area. The pots are left overnight during which time lobsters are attracted to the baits and enter the pots. The pots are generally retrieved (pulled) the following morning, though sets of multiple days (2 or more days) do often occur, particularly during low catch rate periods. Captured lobsters of legal size and of appropriate reproductive status (e.g. not setose etc.) are placed into holding tanks and returned to on-shore processing plants where the majority are prepared for overseas markets, many as live shipments.



The rock lobster fishery was declared limited entry in March 1963 when licence and pot numbers were frozen. Since 1963, boat numbers have declined due to management changes (pot reductions etc.) from 836 to 495 (May 2007). Vessels are currently operating an average of 113 pots (2005/06). The record catch of 14,500 tonnes in the 1999/2000 season, was the second largest catch of any single species of rock lobster after *Panulirus argus*.

## 1.3 – Recreational Fishery

This fishery also supports a significant recreational fishery with about 45,000 rock lobster licences issued annually, around 80% of these being utilised, and catch approximately 400 tonnes per year (approx. 3% of the total commercial and recreational catch) (Section 4.8). Recreational fishers can catch WRL with pots (limit of two pots per licence) or by diving, using a loop or blunt hook. Other restrictions such as bag and boat limits are outlined below (Section 2.3).

## 1.4 – Illegal Catch

### *1.4.1 – Illegal fishing activities*



During the 10-15 years after limited entry was introduced (1963 to the early-1970s) some fishers adopted a cavalier approach to the regulations protecting undersize and spawning animals and to the number of traps they used.

There are, for example, anecdotal reports from the early 1960s of large numbers of undersize rock lobsters being transported out of Western Australia, under the guise of 'frozen chickens'. Fishers breaching regulations were possibly encouraged by the relaxed approach to enforcement during the early 1960s and by the limited resources available to fisheries enforcement officers at that time. In the early 1970s, better-resourced fisheries enforcement officers became more innovative and, backed by harsher penalties, were able to enforce the regulations. By the mid-1970s the regulations were generally accepted by the industry and since that time few serious breaches have been detected.

Such illegal activities in the early years of the fishery obviously affected the integrity of the data reported by fishers. Undersize rock lobsters were either not delivered to processing establishments or, if they were, they were not recorded by the processors, nor were they reported in fishers' mandatory monthly returns. The reported catch landings, therefore, were understated. Egg-bearing females were landed to processing establishments after the eggs had been removed (scrubbed) from the tails. While the females that had their eggs removed were included in the reported landings and in the monthly returns, it is of value to note the quantities landed, in order that models of the fishery make appropriate use of the data.

Use of traps in excess of the legal entitlement resulted in understated levels of effort on monthly returns.

To assess the impact of these activities interviews were conducted and a questionnaire was circulated to fishers that had fished during this period in 1985 and completed anonymously. Analysis of the responses is shown in Table 1.1. The time series of recorded catch and effort figures have then been adjusted using these estimates and the number of prosecutions, under the Fisheries Act, for various offences during this period.

Table 1.1 – Estimate of undersize rock lobsters as a percentage of the annual catch, the percentage of spawning rock lobsters in the annual catch and the percentage of traps used in excess of the licensed numbers of traps (NA: Not Available, NR: No Restriction (on trap numbers) (Caputi et al. 2000)



| Fishing Season | % Undersized | % Spawners | % Traps |
|---|---|---|---|
| 1957/58 | NA | NA | NR |
| 1958/59 | NA | 1.2 | NR |
| 1959/60 | NA | 1.1 | NR |
| 1960/61 | NA | 1.0 | NR |
| 1961/62 | NA | 0.4 | NR |
| 1962/63 | 3.6 | 0.4 | 19.4 |
| 1963/64 | 4.4 | 0.4 | 17.0 |
| 1964/65 | 4.3 | 0.4 | 21.5 |
| 1965/66 | 4.3 | 0.0 | 19.6 |
| 1966/67 | 7.6 | 0.0 | 23.8 |
| 1967/68 | 7.1 | 0.0 | 19.1 |
| 1968/69 | 7.3 | 0.0 | 14.2 |
| 1969/70 | 6.7 | 0.0 | 7.3 |
| 1970/71 | 6.4 | 0.0 | 4.7 |
| 1971/72 | 5.8 | 0.0 | 2.9 |
| 1972/73 | 5.0 | 0.0 | 1.8 |
| 1973/74 | 5.7 | 0.0 | 1.0 |
| 1974/75 | 5.4 | 0.0 | 0.0 |
| 1975/76 | 4.0 | 0.0 | 0.0 |
| 1976/77 | 2.5 | 0.0 | 0.0 |
| 1977/78 | 1.5 | 0.0 | 0.0 |
| 1978/79 | 0.7 | 0.0 | 0.0 |
| 1979/80 | 0.6 | 0.0 | 0.0 |
| 1980/81 | 0.4 | 0.0 | 0.0 |
| 1981/82 | 0.4 | 0.0 | 0.0 |
| 1982/83 | 0.3 | 0.0 | 0.0 |
| 1983/84 | 0.3 | 0.0 | 0.0 |
| 1984/85 | 0.1 | 0.0 | 0.0 |
| 1984/85 | 0.1 | 0.0 | 0.0 |
| 1985/86 + | 0.0 | 0.0. | 0.0 |

### *1.4.2 – Taxation considerations*



A source of bias has also resulted from an understatement of catch on fishers' compulsory monthly catch and effort returns, in an attempt by fishers to minimize taxation. This bias is believed to affect only the catch component of the monthly return, not the fishing effort. However, these unreported catches have been reported by most processors as cash sales although not as a catch attributed to a particular vessel, and therefore do not result in a biased measure of the total catch from this source. On average, the difference between the processors' total catch and total catch declared by fishers has been about 5%. Correction of the fishers' monthly return data for cash sales to processors has been achieved by using the ratio of landings received by processors to the total catch recorded by all licence holders.

An unquantifiable but insignificant proportion of the catch goes unrecorded through the very small local market by way of direct sales to retail outlets and consumers.

Figure 1.4 compares the catch from the original database, as obtained from fishers' monthly returns, to the catch adjusted for the illegal take of undersize rock lobsters and understated catches. Since the early 1990s processors have been required by the Australian Tax Office to record the vessel details for all lobster received and this has significantly reduced the level of unreported cash sales.

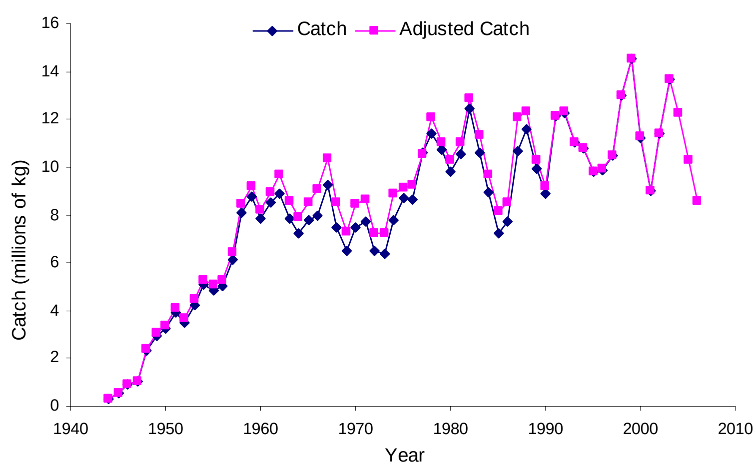



Figure 1.4 – Catch of the western rock lobster fishery from fishers' monthly returns, and that adjusted for illegal activities and under reporting (adapted from Caputi et al. 2000).

# 2 – Management

## 2.1 – Management Objective



Management regulations are aimed primarily at protection of the breeding stock with regulations continually reviewed, to ensure the breeding stock is maintained at a sustainable level, i.e. above a threshold Biological Reference Point (BRP).

The threshold BRP for a sustainable breeding stock was deemed to be the egg production in 1980. Egg production in the late 1970s and early 1980s was estimated, using a length-based assessment model, to be around 20% of the unfished level (Hall and Chubb 2001). This level was considered appropriate in the sustainability of many other invertebrate fisheries (Hall & Chubb 2001). Biologically, management measures are designed to;

"*Ensure the abundance of breeding lobsters is maintained or returned to, as the case may be, at or above the levels in 1980.*" (from Department of Fisheries 2005)

## 2.2 – History of Commercial Management Regulations

The WCRLMF was one of the first managed fisheries in Western Australia (and the world). It was declared a limited entry fishery in 1963. A timeline of management regulations that have been introduced into the WCRLMF is outlined below (Box 2.1).



Box 2.1 – Timeline of major management regulatory changes introduced into the WCRLMF.

| Year / Season | Regulation |
|---|---|
| 1897 | Minimum legal whole weight of 12 oz (340 g). This measurement is equivalent to, and eventually evolved into, the 76 mm carapace length minimum size currently in force in the fishery |
| 1899 | Females carrying spawn were given full protection by requiring them to be returned to the sea |
| 1962 | Closed seasons: coastal fishery 16 August – 14 November; Abrolhos Islands fishery 16 August – 14 March |
| 1963 | Limited entry introduced: boat numbers were fixed (858) and the number of traps per boat was limited to three per foot (0.9 mm) length of boat |
| 1965 | Boat replacement policy required a boat to be replaced with one of exactly the same length. This stopped fishers replacing a boat with a larger one and hence obtaining additional traps to use under the three traps/foot of boat length regulation. This froze the number of traps in the industry at 76 623 |
| 1966 | A 51 x 305 mm escape gap was introduced into all traps to allow sub-legal size lobsters to escape before the trap in brought to the surface |
| 1971/72 | Escape gap increased to 54 x 305 mm |
| 1973 | Multiple entrance traps were banned |
| 1977/78 | Fishing season was shortened by 6 weeks from 15 November – 15 August to 15 November – 30 June to protect newly mated females and to constrain fishing effort |
| 1979 | Boat replacement policy was changed to allow a boat's trap quota (entitlement) to vary from seven to ten traps per meter of boat length. This gave fishers the flexibility in the size of replacement boats that they could have for a given trap quota |
| 1984 | Maximum size from traps was established based on a maximum volume of $0.257m^3$ |
| 1986 | Number of escape gaps (54 x 305 mm) in traps was increased (from one) to three or four (depending on the positions of the gaps) |
| 1986 | Trap numbers of all licence holders were reduced temporarily by 10% for the 1986/7 season. Total trap numbers were reduced from 76 623 to 68 961 for one season |
| 1987 – 1991 | Trap numbers were reduced permanently by 10%, at 2% per year for 5 years |

| | |
|---|---|
| 1992/93 | 10% reduction in traps in Zone B (15 November – 9 January)<br>Closure in Zone B (10 January – 9 February)<br>Return of setose females (November – February)<br>Maximum size for females (115 mm)<br>Home porting in Zone C |
| 1993/94 | 18% reduction in traps<br>Minimum size increased to 77 mm in November – January<br>Return of females which were setose or above a maximum size (105mm Zone A and B and 115 mm Zone C)<br>Home porting in Zone C restriction lifted |
| 2003/04 | Removal of 150 pot rule |
| 2005/06 | Three year effort reduction package<br>15% effort reduction in Zone B<br>- 10% pot reduction 15 Nov – 15 Mar<br>- 10% pot reduction in Zone A 15 Mar – 15 Apr<br>- Summer closure in Zone B 15 Jan to 9 Feb<br>- Sundays off in Zone B 15 Mar – 30 Jun<br>- Closed Christmas and New Years day<br>5% effort reduction in Zone C<br>- Closed 15 Nov – 24 Nov<br>- Five three-day moon closures from 1 Feb to 30 June<br>- Closed Christmas and New Years day |

## 2.3 – Boundaries and Zoning

The boundaries of the WCRLMF are:



'*the waters situated on the west coast of the State bounded by a line commencing at the intersection of the high water mark and 21°44´ south latitude drawn due west to the intersection of 21°44´ south latitude and the boundary of the Australian Fishing Zone; thence southwards along the boundary to its intersection with 34°24´ south latitude; thence due east along 34°24´ south latitude to the intersection of 115°08´ east longitude; thence due north along 115°08´ east longitude to the high water mark; thence along the high water mark to the commencing point and divided into zones*'.

The fishery is managed in three zones: south of latitude 30° S (Zone C), north of latitude 30° S (Zone B) and, within this northern area, a third offshore zone (Zone A) around the Abrolhos Islands (Figure 2.1). This distributes effort across the entire fishery, and allows for the implementation of management controls aimed at addressing zone-specific issues, including different maximum size restrictions in the northern and southern regions of the fishery. The season is open from 15th November to 30th June annually; with the Abrolhos Islands zone operating from 15th March to 30th June.

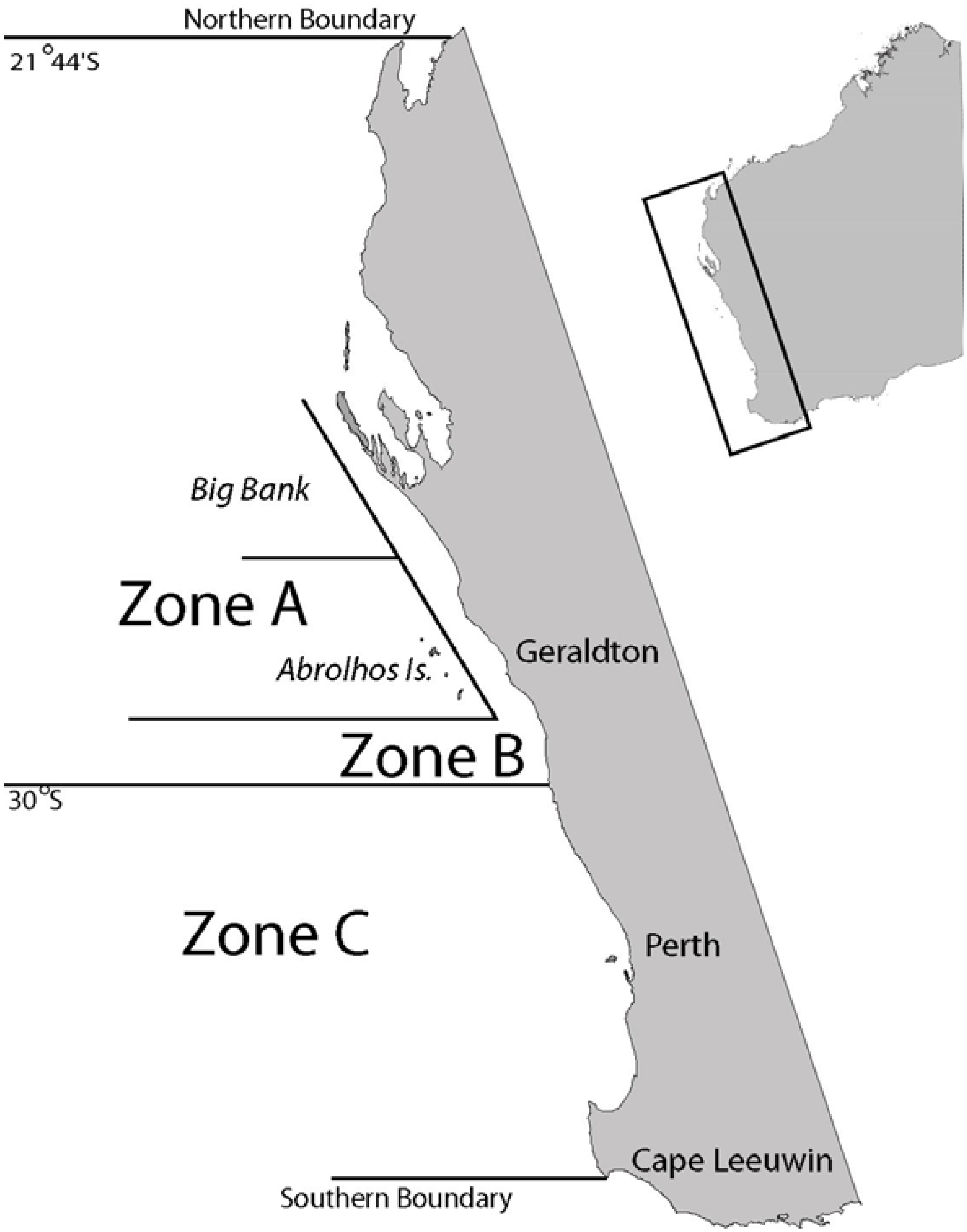



Figure 2.1 – Western Rock Lobster Fishery Management Zones

## 2.4 – Current Management Strategies

This fishery is managed using a total allowable effort (TAE) system and associated input controls. The primary control mechanism is the number of units (pots) for the fishery, together with a proportional usage rate, which creates the TAE in pot lifts. Unitisation in the fishery and transferability provisions allow market forces to determine what is the most efficient use of licences and pot entitlements. This is known as an individually transferable effort (ITE) management system. The number of units allowed in the fishery was set at 69, 000 in the early 1990s, and since 1993/94 a usage rate of 82% has operated to keep the TAE at a sustainable level.  In 2005/06 further reductions in the usage rate was introduced in zones A and B (Box 2.1).



Management arrangements also include the protection of females in breeding condition, a variable minimum carapace length and a maximum female carapace length. Gear controls, including escape gaps and a limit on the volume of pots, also play a significant role in controlling harvest rates (Box 2.2)

Box 2.2 – Summary of current (2006/07) WRL Management Arrangements (adapted from Caputi et al. 2000)

- Closed season July 1 to November 14 (Coastal Zones), July 1 to March 14 (Abrolhos Is.)
- From March 1 and March 14 all fishers holding an A concession must remain in B zone waters > 20 fm.
- A and B Zone fishers who nominate to fish the Big Bank from 10 February must remain in Big Bank until midday on the last day of February of the season. Big Bank then becomes part of the B Zone fishery and any Zone A or B fisher can go there or leave it as they please.
- Maximum number of pot entitlements allowed to be used in the fishery (56,906 pots)
- The licensee can only operate in the zone for which he/she is licensed.
- Minimum size of carapace is 77 mm from 15 November to 31 January, when it drops to 76 mm for the remainder of the season.
- It is illegal to take females with setose pleopods.
- A maximum size of 115 mm for female lobsters landed south of 30°S and 105 mm for those landed north of 30°S.
- All pots must have at least three 54 mm high and 305 mm wide escape gaps.
- Pots types have maximum size and configuration regulations (see Figure 1.3)
- Pots may only be pulled during specified daylight hours (Summer (15$^{th}$ Nov. – 31$^{st}$ Mar.) 0430 to 1930, Winter (1$^{st}$ Apr – 30$^{th}$ Jun) 0600 to 1800).

- To operate in the managed fishery, a licence must have at least 63 units of pot entitlement.
- Three-year effort reduction package (Box 2.1 – 2005/6)

### *2.4.1 Recreational Specific Management Strategies*



The recreational component of the western rock lobster fishery is managed under fisheries regulations that impose a mix of input and output controls on individual recreational fishers. These arrangements are designed to complement the management plan for the commercial fishery.

Input controls include the requirement for a recreational fishing licence (either a specific rock lobster licence or an 'umbrella' licence covering all licensed recreational fisheries). Fishers are restricted to two pots per licence holder, although the total number of licences is not restricted. The pots must meet the specific size requirements, smaller than those for the commercial fishers, and must have gaps to allow under-size rock lobsters to escape (see web site http://www.fish.wa.gov.au/docs/pub/FishingRockLobsters/FishingforRockLobstersPage06.php?0102 for specific details on recreational pot dimensions). Divers are also restricted to catching by hand, snare or blunt crook in order that lobsters are not damaged. Fishing for rock lobsters at the Abrolhos Islands is restricted to potting only.

The recreational fishing season runs from 15th November to 30th June each year, with a shorter season (15th March to 30th June) at the Abrolhos Islands. Night-time fishing for lobsters by diving prohibited.

Recreational fishers comply with the same legislation as the commercial fishers with regard to the size and condition of lobsters they can take and when, except there is a daily bag limit of 8 lobsters per fisher per day. A daily boat limit of 16 lobsters provides further control on high individual catches where there are three or more people fishing from the same boat. In the Ningaloo Marine Park and between Cape Preston and Cape Lambert in the Dampier Archipelago, the daily bag limit is 4 and the boat limit 8 lobsters. There is also a requirement for recreationally caught lobsters to be tail-clipped in order to stop these animals from being sold illegally.

## 2.5 – Marine Stewardship Council (MSC) Certification

In 2000, the West Coast Rock Lobster Managed Fishery became the world's first fishery to receive Marine Stewardship Council (MSC) certification on the basis of demonstrating the sustainability of its fishing and management operations. To achieve this, the WRL fishery was assessed by an international group of experts against the criteria set out in the MSC guidelines (see web site http://www.msc.org/ for details). A number of ongoing requirements have had to be met to continue this accreditation including an ecological risk assessment and the development and implementation of an Environmental Management Strategy (EMS). Ecological Risk Assessment (ERA) workshops have been conducted to provide a register of the potential ecological risks arising from the various activities carried out by the WCRLMF. The fishery was recertified in December 2006.

## 2.6 – Integrated Fisheries Management (IFM)

Integrated Fisheries Management (IFM) is the most recent management development in Western Australia fisheries and is designed to ensure that all sectors are taken into account in the management of the states fisheries. A core objective is to determine how to share the available fishery resource between competing users, while maintaining the fishery stock at an ecologically sustainable level. As such it requires;

- Setting an ecologically Sustainable Harvest Level (SHL) for the whole fishery
- Allocating a share of the SLH between indigenous, commercial and recreational users.
- Monitoring of each sectors catch.
- Managing each sector so as to remain within its respective catch allocation.
- Developing processes which enable re-allocation of catch shares between sectors.

The West Coast Rock Lobster Fishery was the first fishery in the state to go through the IFM process. Currently the IFM process for the WCRLMF has resulted in an allocation report (IFAAC 2007). In this, the Minister's proposed position is that the recreational and commercial allocations should be five per cent and 95 per cent respectively, and that there should be a customary fishing initial allocation of one tonne. The Minister has proposed that the allocations be implemented in 2009/10. Opportunity for submissions to these proposals closed on 23rd April 2007. Notification of final decisions has yet to be made (IFAAC 2007).

# 3 – Biology

## 3.1 – Taxonomy



The western rock lobster, *Panulirus cygnus* (George 1962), is a decapod crustacean of the family Palinuridae. The Palinuridae, or spiny lobsters, are found throughout tropical, sub tropical and temperate waters (Lipcius & Cobb 1994). The family comprises of 47 species over eight genera, with the distribution of the Australian genera shown below (Figure 3.1).

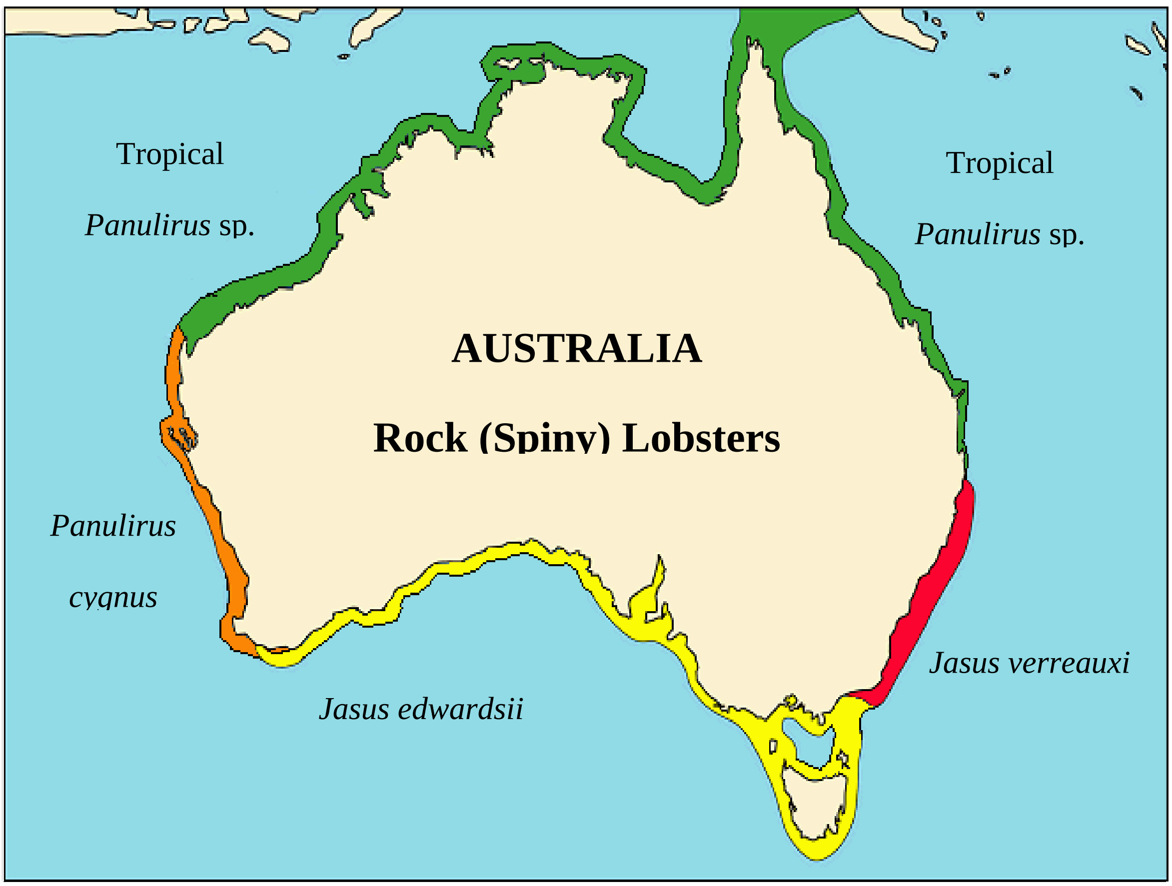



Figure 3.1 – Distribution of Palinuridae (spiny) lobsters around Australia

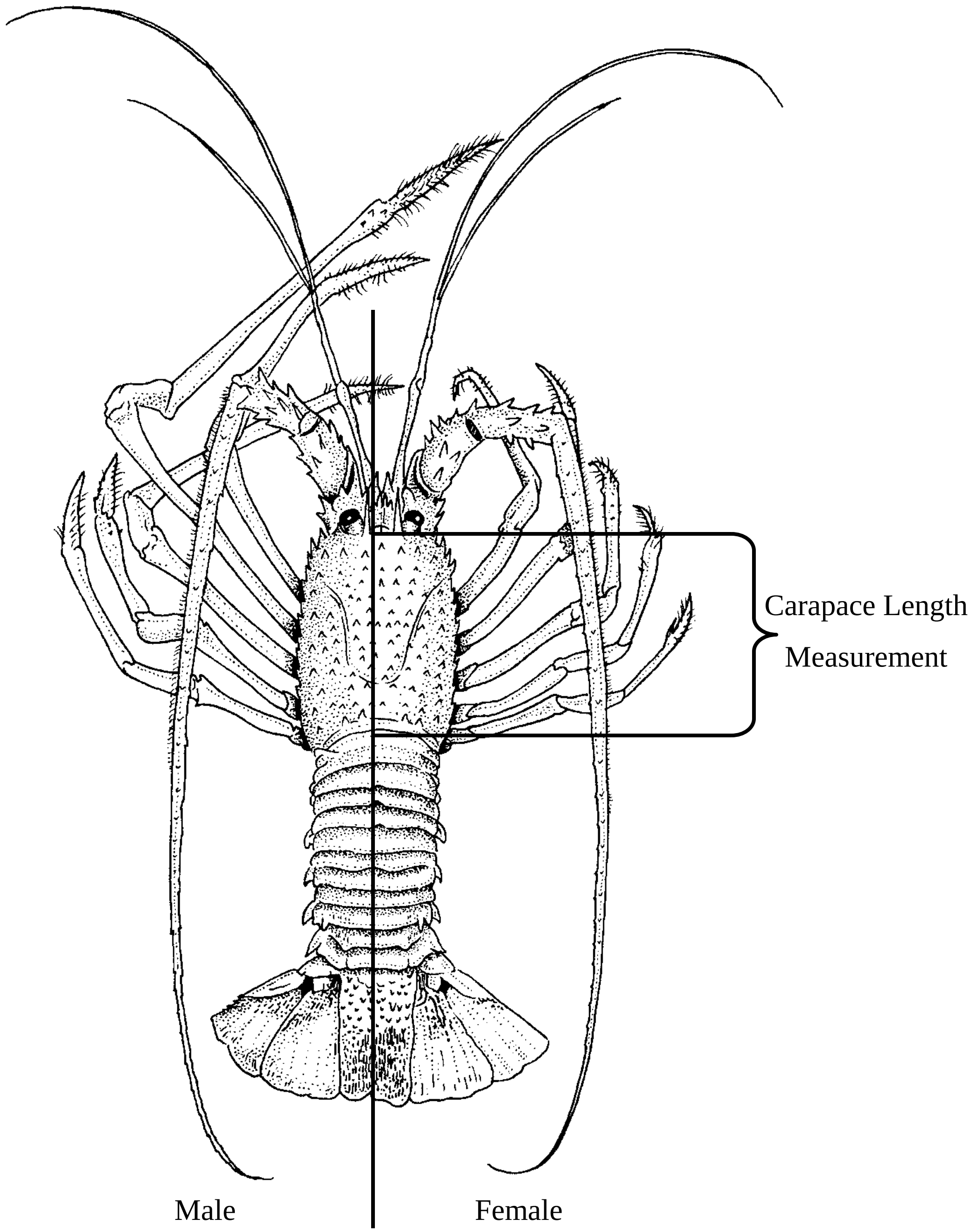



Figure 3.2 - Morphology of the *Panulirus cygnus* showing the carapace length measurement being from the anterior edge of the carapace between the preorbital spines down the mid-dorsal line to the posterior edge. The variation in morphology between males and females is also shown.

## 3.2 – Stock Structure

The stock structure of WRL has been examined genetically through allozyme electrophoresis (Thompson et al. 1996, Johnson 1999).



Samples of legal-sized lobster from 1980 (Thompson et al. 1996), and puerulus from 1995 to 1998 (Johnson 1999), showed some latitudinal and temporal variation in allelic frequencies in polymorphic loci. However the 1994 sample of Thompson et al. (1996) showed that this latitudinal variation was not persistent through years.

The overarching conclusion from both studies is that the western rock lobster is a single panmictic population, with ephemeral genetic patchiness between cohorts (Thompson et al. 1996, Johnson 1999).

However, there is variation in reproductive biology (Section 3.6) and growth (Section 3.8). At this stage there is uncertainty as to whether these observed changes in life history parameters are the result of changes in environmental conditions, a response to selective fishing practices or a combination of possibilities (Melville-Smith & de Lestang 2006). However, they do necessitate the assessment and management of the fishery in zones, so as to account for this biological variation and tailor management accordingly (Section 2).

## 3.3 – Habitats

### *3.2.1 – Oceanography*



The distributional range of *P. cygnus* (Figure 3.1) sees it restricted to the clear, warm, low nutrient waters of the west coast of Western Australia. These oceanic conditions are markedly different from those on the eastern edge of other ocean systems like the Atlantic and Pacific in the southern hemisphere. These coasts have cold, northward flowing currents (Humbolt and Benguela currents) producing nutrient rich up-wellings near the coast. In contrast the eastern coast of the Indian Ocean is dominated by a southward flowing, warm tropical water of the Leeuwin Current (Plate 3.1).

The Leeuwin Current is strongest during the southern autumn and winter (March to October) when it flows from the northwest of Australia, along the coast and around into the Great Australian Bight. Between North West Cape and Shark Bay it approaches the coast where it has a broad shallow flow, before narrowing and deepening to about 150 – 200 m and 30 km wide along the continental shelf. As it nears Cape Leeuwin it moves up onto the continental shelf and flows into the Great Australian Bight. As the current skirts the coastline it forms gyres or eddies; offshoots of the main current. These are highly variable in terms of their duration (days to months), size (some may be over a 100 km in diameter), and are usually consistent in their location (Plate 3.1).

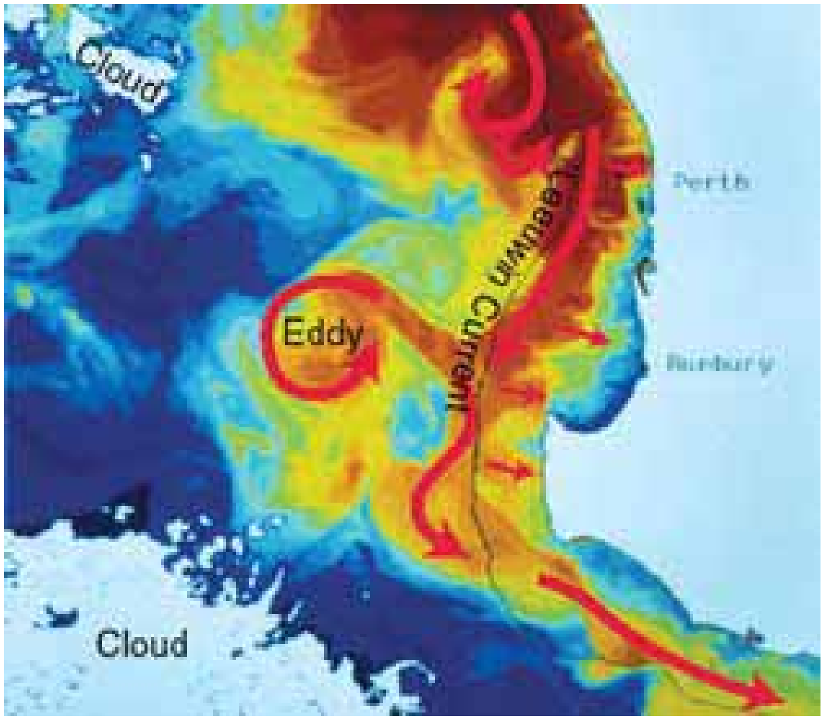



Plate – 3.1 - Thermal image showing the warm water of the Leeuwin Current (red and orange and yellow) flowing southwards and it's associated eddies. Red arrows have been added to highlight the currents path (http://www.marine.csiro.au/LeafletsFolder/44leuwin/44.html)

The Capes counter current runs inshore of the Leeuwin Current, reaching its peak in summer. Pushed by the strong south-westerly winds characteristic of the West Australian summer weather pattern, it causes cool high salinity water to flow northwards along the coast.

These contrasting oceanic conditions create a large range in temperatures experienced by *P. cygnus* throughout its range from around 27$^{o}$C at North West Cape in February to 16$^{o}$C at August near Cape Leeuwin.

Oceanographic conditions also play a vital role in the recruitment of juvenile *P. cygnus* back into the fishery after the larval phase (Section 3.5)

### *3.2.2 – Physical Habitat*

The distribution of *P. cygnus* is dominated by limestone reefs, which can extend seaward for 40 to 60 km on the continental shelf. This habitat is the almost exclusive domain of *P. cygnus* with minimal overlap of other rock lobster species (Figure 3.1).



Changes in sea levels have caused the fringing reefs associated with lower sea level shorelines to be submerged, forming long chains of ledges and banks. Also, sea level changes have created a number of mainland remnant islands with associated fringing reefs. These reefs and banks often contain a matrix of crevices and ledges, which are the primary diurnal habitat of *P. cygnus*.

Water depth, light and wave exposure influence the flora and fauna on these limestone reefs and banks. The reefs are typically covered by seagrass (*Amphibolis*), and large algae. At greater depths, and up to 50 m, large brown algae (*Ecklonia* and *Sargassum*) create “kelp” gardens covering the hard limestone bottom, while crevices, where light penetration is reduced, is often covered with seasquirts, sponges and other sessile invertebrates.

The influence of the Leeuwin Current also creates a range of habitats within the distribution of *P. cygnus*. While the limestone reefs and pavements dominate, there are some coral reefs, particularly at the Houtman Abrolhos Islands, which are important rock lobster habitats.

## 3.4 – Life History

*Panulirus cygnus* can live for over 20 years, though typically for 10 to 15 years, and reach sizes of up to 5.5 kg, with animals over 3 kg being rarely caught under current harvesting practices. When lobsters mate, the male attaches a package of sperm, which resembles a blob of tar, to the underside of the female. This spermatophore is colloquially called a "tar-spot" and remains there until the female is ready to spawn her eggs (Plate 3.2c). At spawning, the female releases eggs from gonophores located at the base of her third pereiopods. Sperm is released at the same time by the female scratching the spermatophore with a small hook attached to the tip of either fifth pereiopod. The eggs are fertilised as they are swept backwards over the opened spermatophore before becoming attached to setae along the endopodite pleopods (Plate 3.4). Females with eggs attached under their abdomen (ovigerous) are also known as "berried" females (Plate 3.2d).

The eggs hatch in about 5 - 8 weeks, depending upon water temperature ($Incubation\_time = 4412.4 \exp^{0.217*Wtemp}$ Chittleborough 1976a), releasing tiny larvae called phyllosoma (Plate 3.3a) into the water column.

The phyllosoma larvae spend 9 - 11 months in a planktonic state, carried offshore by ocean currents (Figure 3.3), where they feed on other plankton before the last phyllosoma stage moults into a free swimming puerulus stage that settles onto the inshore reefs (Plate 3.3b). However, to move from outside the continental shelf to suitable inshore reef systems requires the larvae to change into puerulus at the right times to maximise favourable currents before swimming the remaining distance to the inshore reefs. There are subsurface currents, which can return the phyllosoma to the edge of the continental shelf, and it is at this point they change to the puerulus stage.

Pueruli are capable of swimming at speeds of nearly 0.5 meters per second (Phillips & Olson 1975) which would enable them to make the 40 – 60 km swim from the shelf edge to inshore reefs in a few of days.

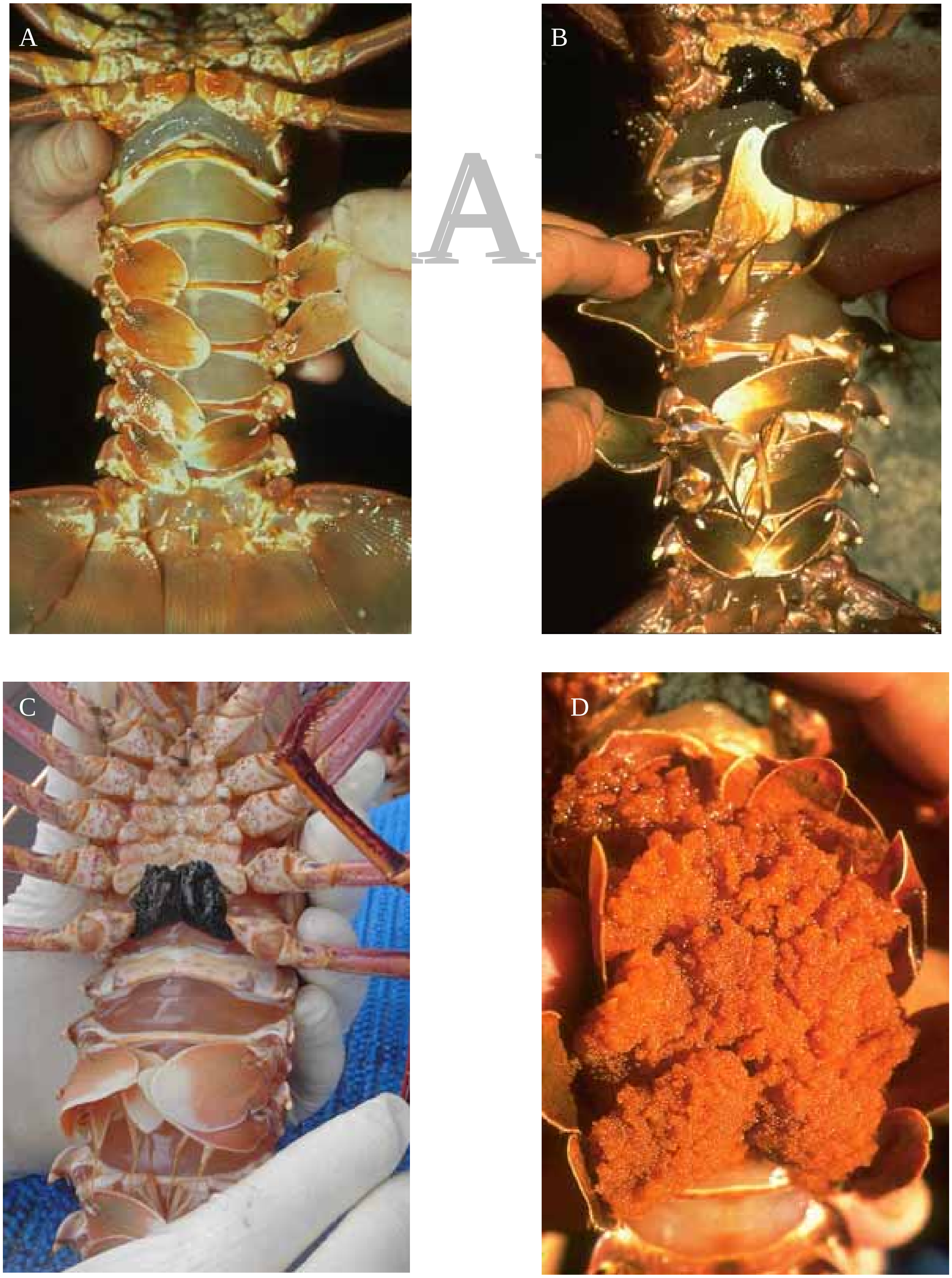



Plate 3.2 – Ventral view of a) male WRL, b) female WRL, c) tar-spotted female and d) berried female

Plate 3.3 – Life phases of the *Panulirus cygnus* a) phyllosoma (TL 20mm); b) puerulus (TL inc. outstretched antennae 35mm); c) juvenile (CL 7 – 9mm)

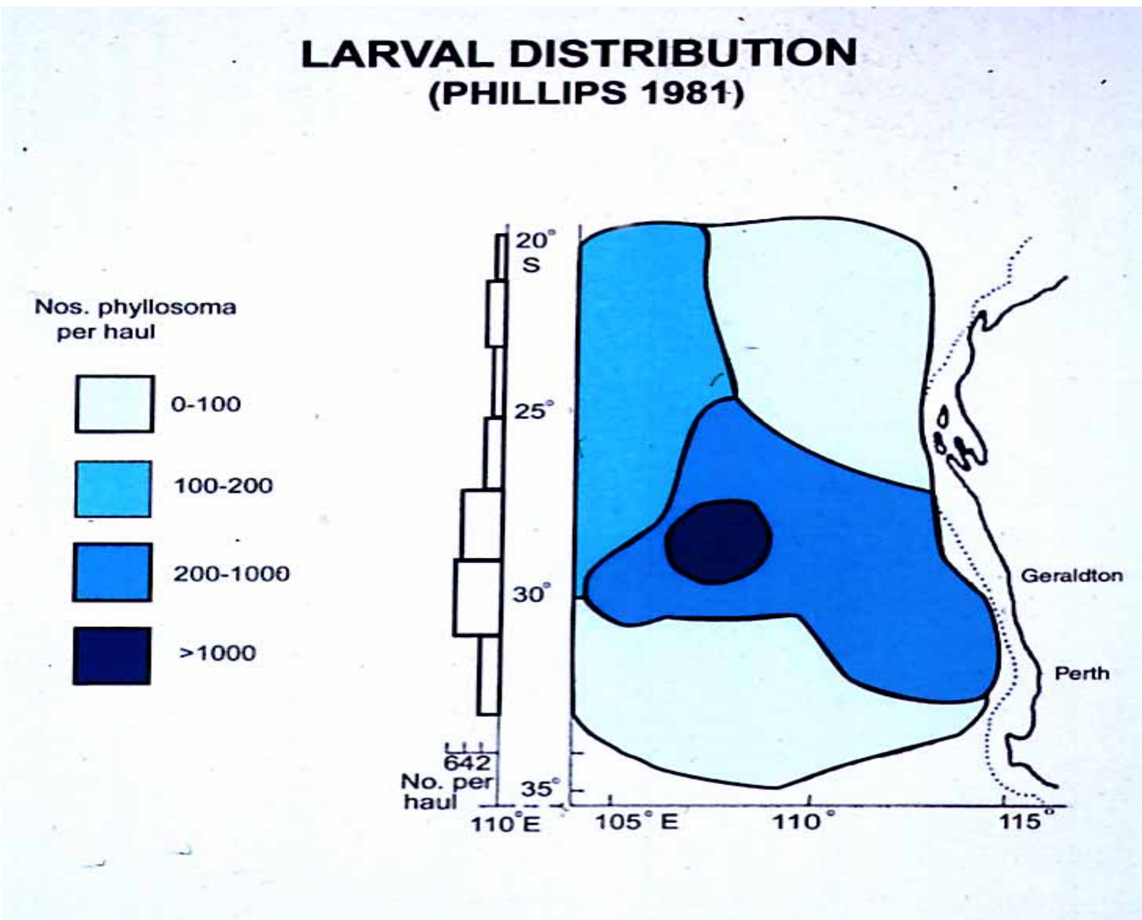



Figure 3.3 – Distribution of phyllosoma western rock lobster larvae (from Phillips 1981)

Phillips and MacMillan (1987) theorised that detection of the coast by puerulus was done by using their antennae acting as vibration receptors, detecting ocean swell noise on the coasts or offshore reefs.

Pueruli that successfully return to the coast, move close inshore, presumably in association with sea grass beds and algal meadows, before they moult into a juvenile phase (Plate 3.3c). For details of pueruli recruitment to inshore areas, see Section 3.5.



These juveniles feed and grow on the shallow inshore reefs for the next three or four years by which time they can achieve CLs up to 80mm. Three to four years after settlement, many lobsters undergo a synchronised moult in late spring when they moult from their normal red shell colour into a paler colour. These are known as "white" lobsters until they return to their normal red colour at the next moult a few months later. The "white" phase of a rock lobster's life is the migratory phase (Section 3.5.1). At this time (summer) they leave the coastal reefs and undergo a mass migration across pale white sands into deeper water breeding grounds where they become sedentary again on deeper reefs. A small percentage make far longer migrations off the edge of the continental shelf down to depths of over 200 m, before they change direction and follow the shelf in a northerly direction. Once reaching the offshore breeding grounds the "whites" undergo another synchronised moult at which time their exoskeleton becomes reds in colour (February – March). This deeper offshore ground is where the spawning stock predominantly resides (Figure 3.4).

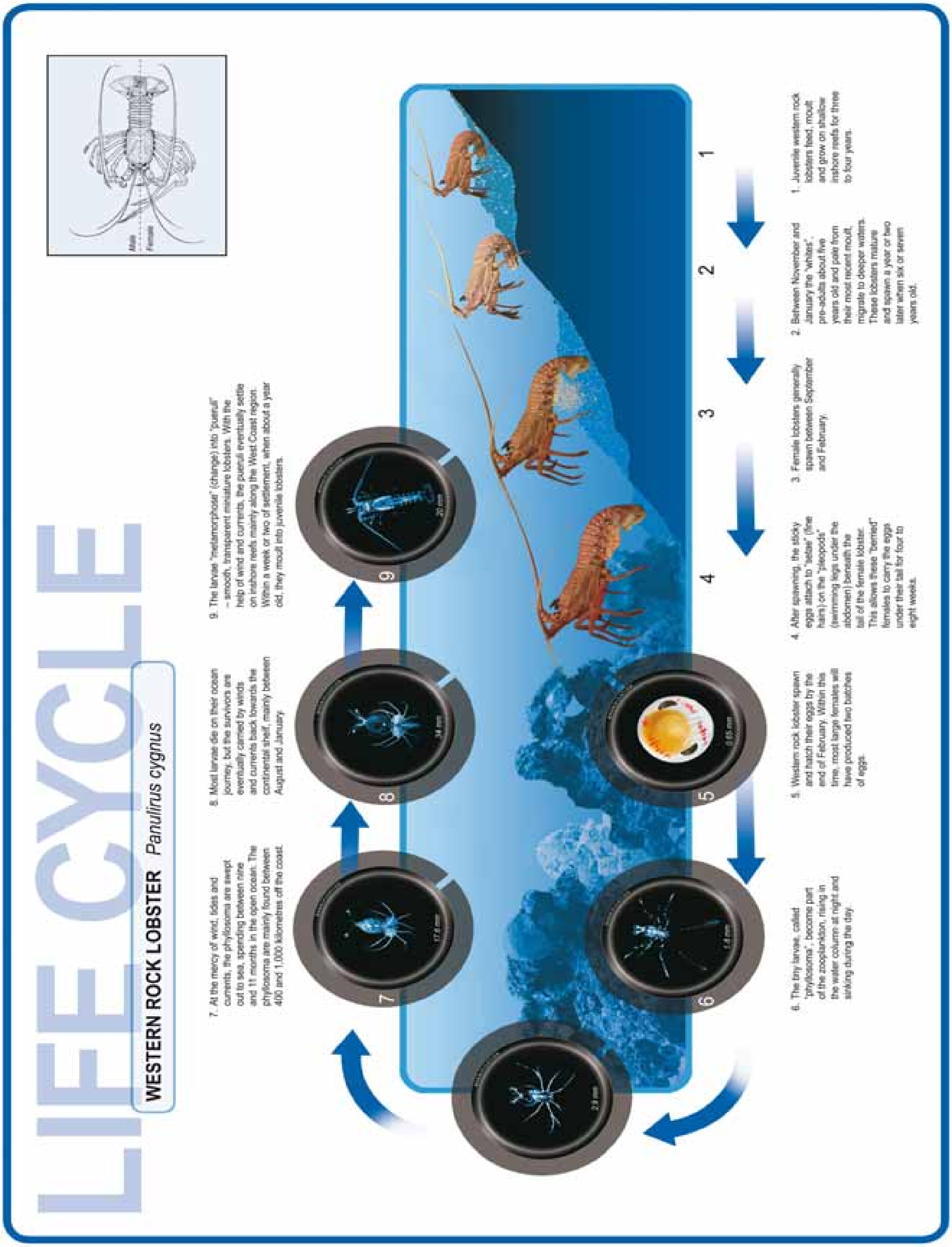



Figure 3.4 – Life history of *Panulirus cygnus* (from Community Education Branch (CEB, Department of Fisheries, Western Australia)

## 3.5 – Movement

Movement patterns of *P. cygnus* have been and continue to be studied extensively. Research has primarily focused on two aspects of the lobster's movement; namely, the "whites" migration and small-scale foraging movements.



### *3.5.1 – Migration*

The large-scale "whites" migration is a feature of this lobster's life history (Section 3.4). Tagging studies (using mainly external "T-bar" anchor tags) have been undertaken to assess this aspect of the lobster's life history (Melville-Smith et al. 1998, Chubb et al. 1999) as well as to provide growth information (Section 3.8).

Chubb et al. (1999) tagged and released over 66 500 lobster between 1988 and 1996 throughout the fishery. Approximately 75% of the recaptures were during the first season after release with around 20% the following season, though recaptures did occur up to 5 seasons after release.

While large movements (>200 km) did occur, most movements were usually west or north-westerly in direction and less than 50 km, with the vast majority (87 – 98% by location) being recaptured within 10 km of their release site.

It was found that "whites" moved considerably further than the "reds". This was also evident when movement was examined with regard to size, with those between 70 – 90 mm CL moving further. "White" movements greater than 10 km accounted for 27% of the movements, while for the "reds" they were only 9%. This is thought to be an underestimate for whites and overestimate of red movements, due to lobster being tagged and recaptured as "reds", despite their size during time at liberty indicating that they probably passed through a "whites" moult. This assumption could not be tested and therefore, neither could the suspected cause for the under or overestimation of movement be confirmed.

The timing of migration, and potential cues for it, are currently being investigated. Factors that appear to be related to lobster migration include average water temp for the 7-day period immediately before the start of migration include, the moon illumination and total sea swell levels at the start of migration. To date the best single predictor of migration has been found to be moon illumination (migration taking place close to a new or full moon). After this water temperature seemed to add further power for predicting the start of migration (warmer water temperature encouraged migration).



To this stage the lobster migration prediction model has been hampered by the lack of water temperature data at $1^o$ intervals (at the moment we are using one temperature measure for each zone but estimating 'start of migration' times at $1^o$ levels, using logbook data) to better explain the migration of animals at this level.

### *3.5.2 – Foraging*

Small-scale foraging movement patterns of juvenile *P. cygnus* have been studied using tag recapture (Chittleborough 1974a), or electromagnetic tracking (Jernakoff 1987, Jernakoff et al. 1987, Jernakoff & Phillips 1988).

Jernakoff & Phillips (1988) estimated foraging distances of ~150 m radius from dens. Jernakoff et al. (1987) also showed movements to be very variable, with distance of between 72.5 and 585 m accounting for 95% of all foraging distances in the study. One individual moved 803 m in a night within the tracking area.

These results demonstrate that juvenile *P. cygnus* forage over relatively small areas, though the extent of movement is variable.

More recently, technology has advanced allowing automated tracking of juveniles through acoustic tags (MacArthur unpublished data) and adults in deeper environment (Section 7.1.2). To date, this data has not been analysed, but will provide information on foraging distances, home ranges and habitat use of adult and juvenile *P. cygnus*.

## 3.6 – Reproduction



Adolescents, nearing maturity, undergo the "whites" migration, leaving the juveniles on the shallow inshore reefs. There are thus few mature lobsters in shallow waters (less than 40 m) with a few exceptions e.g. Houtman Abrolhos Islands, cliffs north of Kalbarri, and inshore islands and reefs in the Jurien / Cervantes, Cape Naturaliste and Cape Leeuwin regions. Ninety percent of mated ("tar-spotted") and berried females are caught in deep water (40 to 80 m) towards the edge of the continental shelf. Spawning in areas near the continental shelf may maximise larval dispersal due to the proximity of longshore ocean currents.

Sexual development is thought to begin in June when females undergo a pre-spawning moult. As a result of this moult, short fringing hairs (setae) appear on the endopodites of the swimmerets (< 5 mm). These setae elongate over a subsequent moult to become, 10 – 15mm long (Plate 3.4), and it is at this time that a female lobster is considered fully matured, being able to successfully produce and fertilise viable eggs.

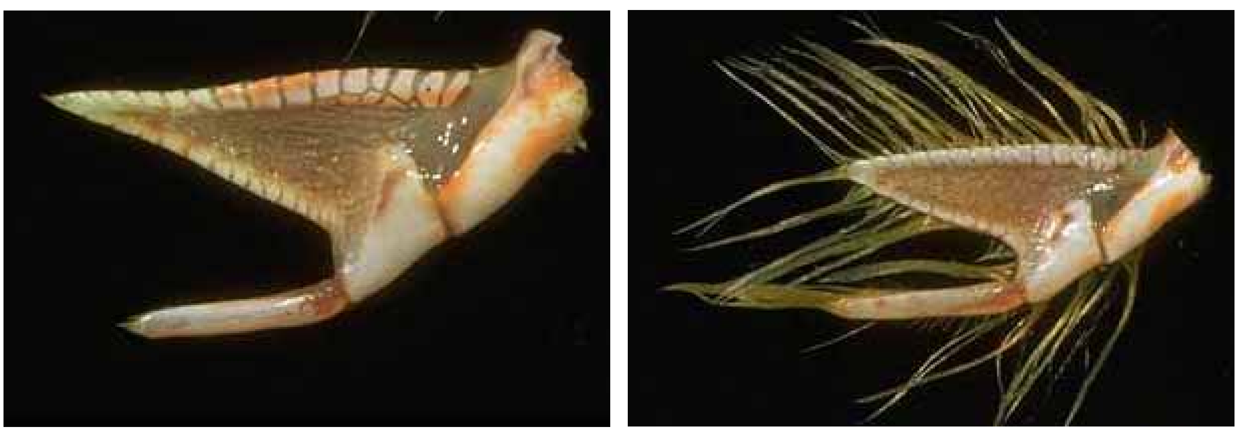


Plate 3.4 – Pleopods with a) no setae and b) mature setae.

### *3.6.1 – Size at maturity*

There is considerable variation in the size of sexual maturity ($CL_{50}$) of both male and female *P. cygnus* throughout the fishery (Figure 3.5, 3.6 & 3.7a). Size at maturity has been estimated from lobsters in deep water in coastal locations and from all depths at the Abrolhos Islands as this represents the areas of breeding. Males were found to have consistently larger $CL_{50}$s than females at the corresponding locations (Figure 3.7a). Furthermore, the size at maturity for both sexes varied similarly with latitude, being larger in the south of the fishery (Fremantle $CL_{50}$ = 87.5 mm for females) and becoming progressively smaller further north along the coast of the fishery (Dongara $CL_{50}$ = 74.9 mm for females). The offshore site of the Abrolhos Islands had the smallest $CL_{50}$ (65.0 mm for females) (Melville-Smith & de Lestang 2006).

Much of this spatial variation in size at maturity is explained by regional patterns in water temperature (Figure 3.7b), with lobster caught in warmer waters maturing at a smaller size than their colder water counterparts (Melville-Smith & de Lestang 2006).

There was also a temporal variation in the size at maturity ($CL_{50}$) at four coastal sites from Fremantle to Dongara, between 1992 and 2005 (Melville-Smith & de Lestang 2006). All sites had a larger size at maturity in 1992 and 1993, which declined in 1994 to a lower level, and remained through until 2005. However, at the Abrolhos Islands there was no noticeable change in this measure (Figure 3.8).

This reduction in the size at maturity is due in part to changes in management practices. The return of setose females which was regulated in 1993-94 (Section 2.1), would have resulted in an increase in the number of females likely to spawn in any given size class, thus biasing proportion – based estimate of size at maturity estimates.

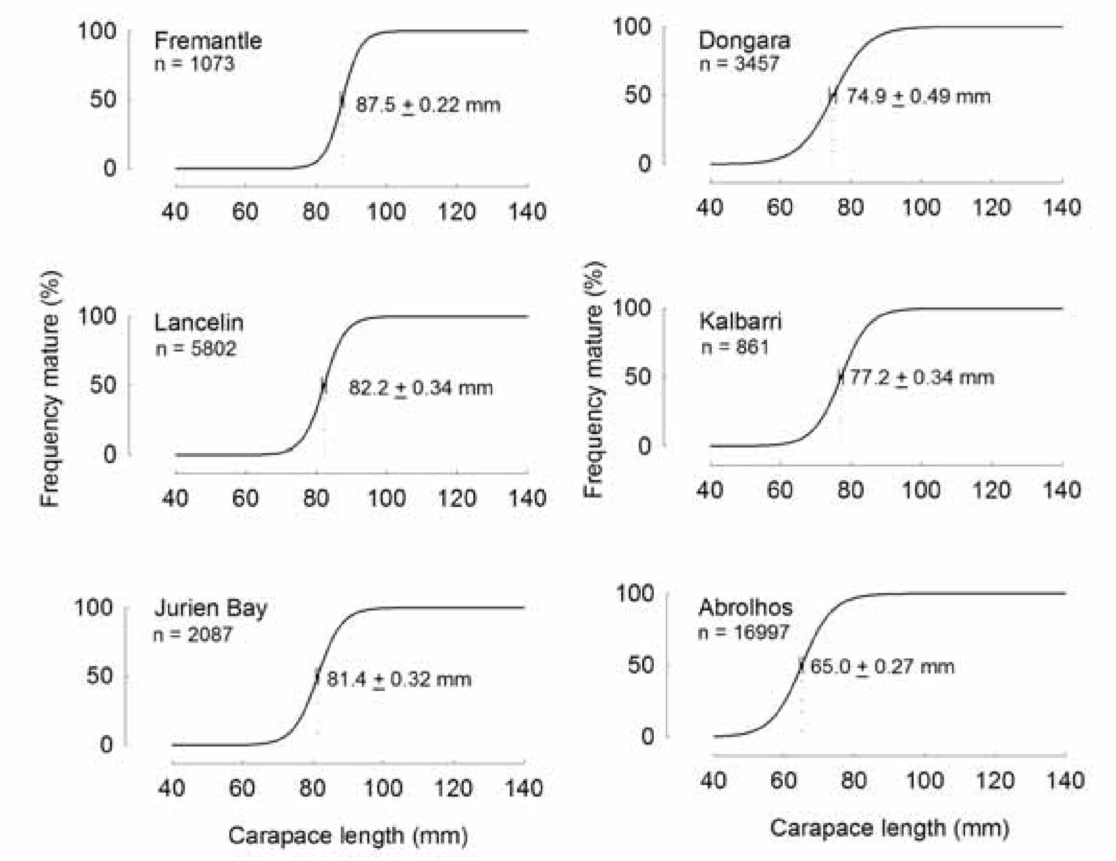



Figure 3.5 – Logistic regressions fitted to the percentage of mature female *Panulirus cygnus* at different carapace lengths in six locations in Western Australia, based on data collected during the 2002 Independent Breeding Stock Survey. $CL_{50}$ ±1 SE denotes the size at which 50% of the assemblage is mature and n the sample size (Melville-Smith & de Lestang 2006)

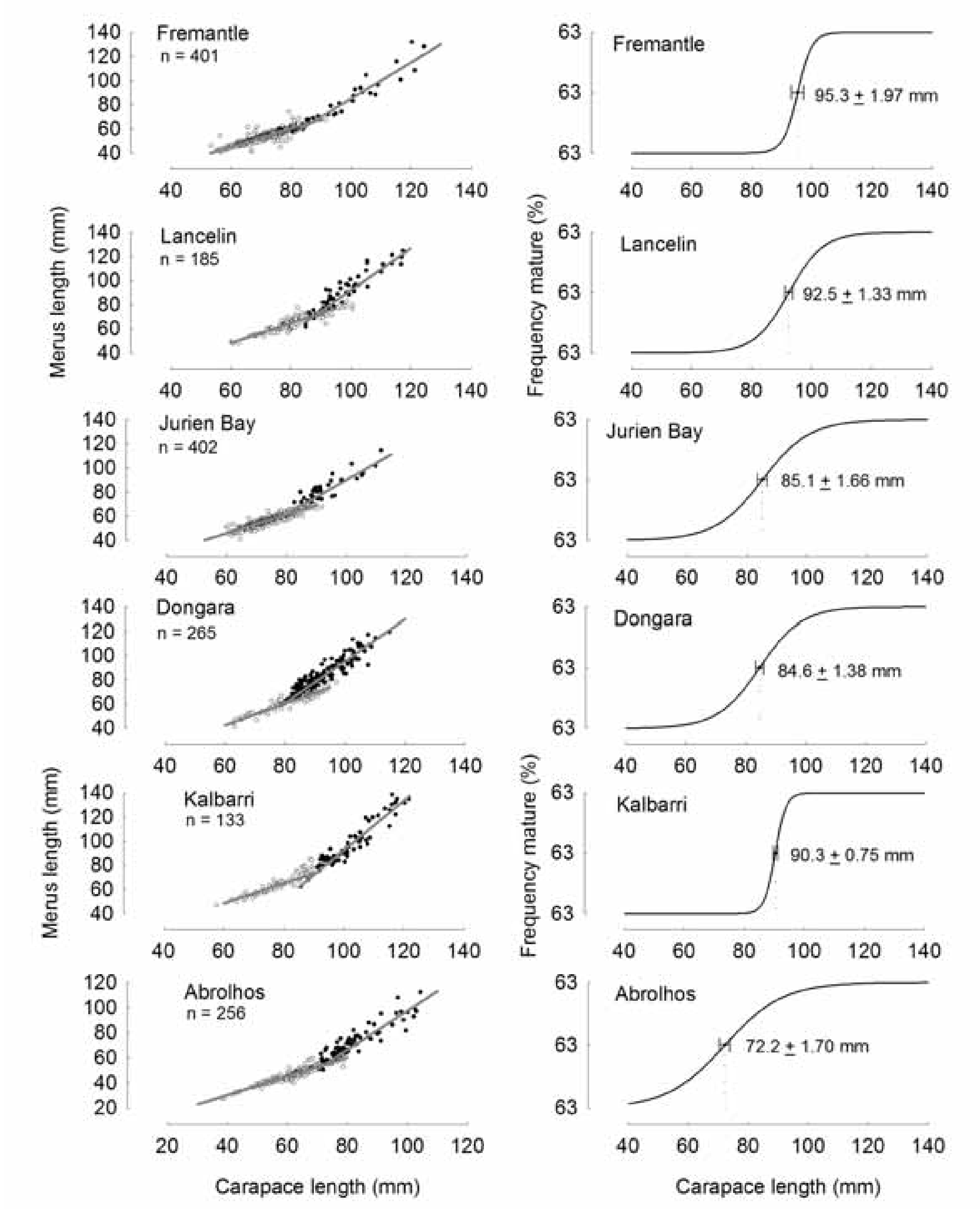
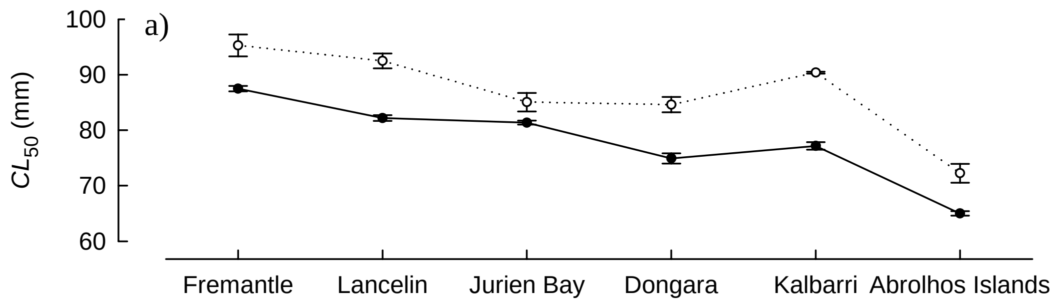



Figure 3.6 – Relationship between the merus length of the second pereiopod and carapace length of immature (open circle) and mature (filled circle) male *Panulirus cygnus* (left) and logistic regressions fitted to the percentage of morphometrically mature males at different carapace lengths (right) in six locations in Western Australia, based on data collected during the 2002 Independent Breeding Stock Survey. $CL_{50}$±1 SE denotes the size at which 50% of the assemblage is mature and n the sample size (Melville-Smith & de Lestang 2006).



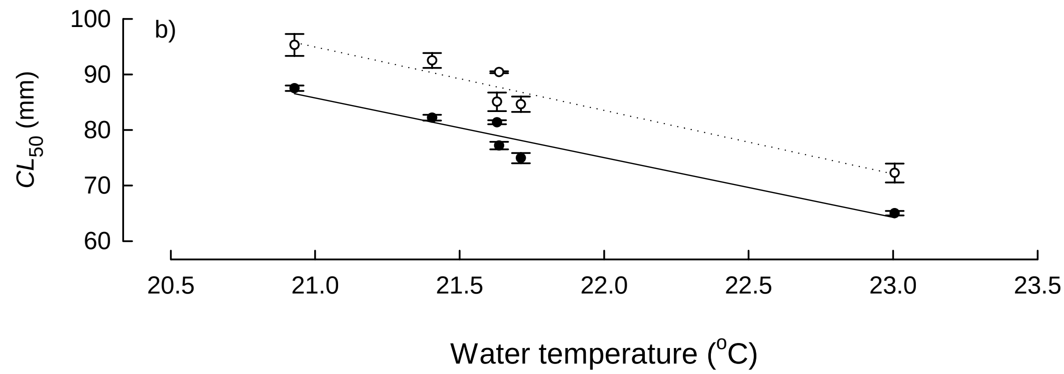




Figure 3.7 – a) Size at maturity ($CL_{50}$) ±1 SE of female (filled circle) and male (open circle) *Panulirus cygnus* at six locations and b) linear regressions fitted to the relationships between female (filled circle) or male (open circle) $CL_{50}$s at each location and the corresponding mean annual water temperature at that location (Melville-Smith & de Lestang 2006).

This was not evident at the Abrolhos Islands, as the size at maturity is below legal minimum size and as a result not subject to the bias of returning setose females.

However, the temporal change in size at maturity reported for males, which was similar to that of females, would have been unaffected by this altered management regime ("setose rule"). The lower $CL_{50}$ for males in the study of Melville-Smith & de Lestang (2006) compared with Chittleborough (1976a), implies that there must be biological or environmental factors, responsible for altering the $CL_{50}$ over this time period.

This decline over time has been further validated by analysis showing a consistent long-term decrease in mean CL of the 10% smallest mature females sampled by during commercial (Section 4.2) and independent monitoring (IBSS) (Section 4.3) programs (Figure 3.9). Although using the smallest of mature females is a crude measure for comparing size at first maturity, it does have the advantage of not being derived from ratios of immature and mature animals and as such, not being influenced by the "setose rule". The mean CLs of the 10% smallest females sampled during commercial monitoring were, in the majority of cases, larger than corresponding values determined from IBSS data. This difference is due mainly to the IBSS being conducted over the peak of the breeding season (October to November) at the point when the majority of all mature females are mated or egg bearing. The commercial monitoring on the other hand does not begin until after the IBSS and covers the subsequent decline in breeding activity when small single breeding females are no longer reproductively active and can even have moulted into their non-reproductive phase, while large double-breeding females can still be brooding eggs (de Lestang and Melville-Smith, in press). In fact, even though the IBSS is conducted over the same new moon period prior to the start of the fishing season ($15^{th}$ November), it does not always align with the peak of the breeding season. This variation between the timing of the IBSS and that of peak spawning is one factor contributing to the oscillating $CL_{50}$ estimates for the various sites each year since 1994 (Figure 3.9).

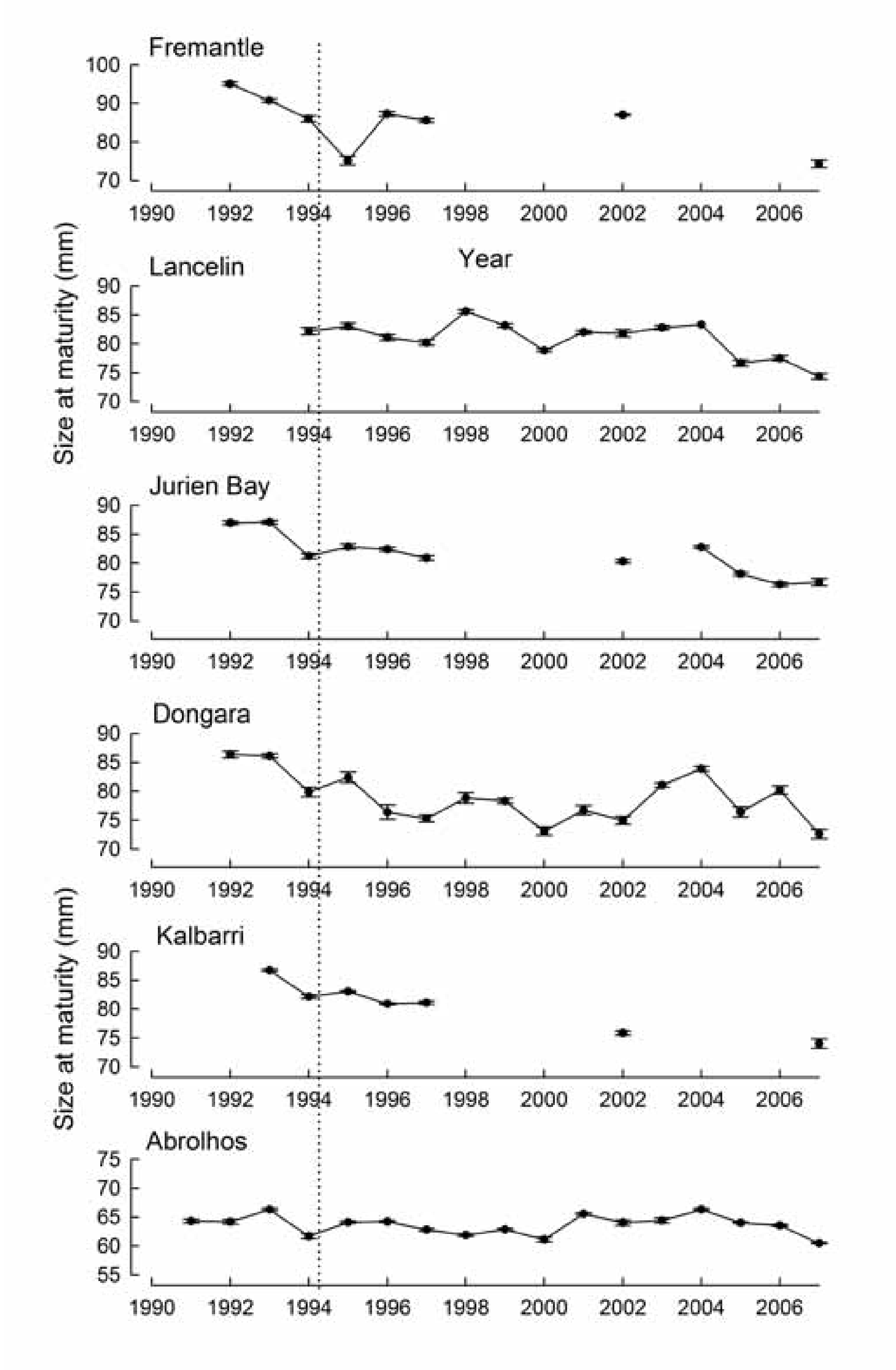



Figure 3.8 – Temporal variation in size at maturity ($CL_{50}$) ±1 SE of female *Panulirus cygnus* at six locations from the early 1990s to mid-2000s from IBSS surveys, with the vertical line representing 1994 (updated from Melville-Smith & de Lestang 2006).

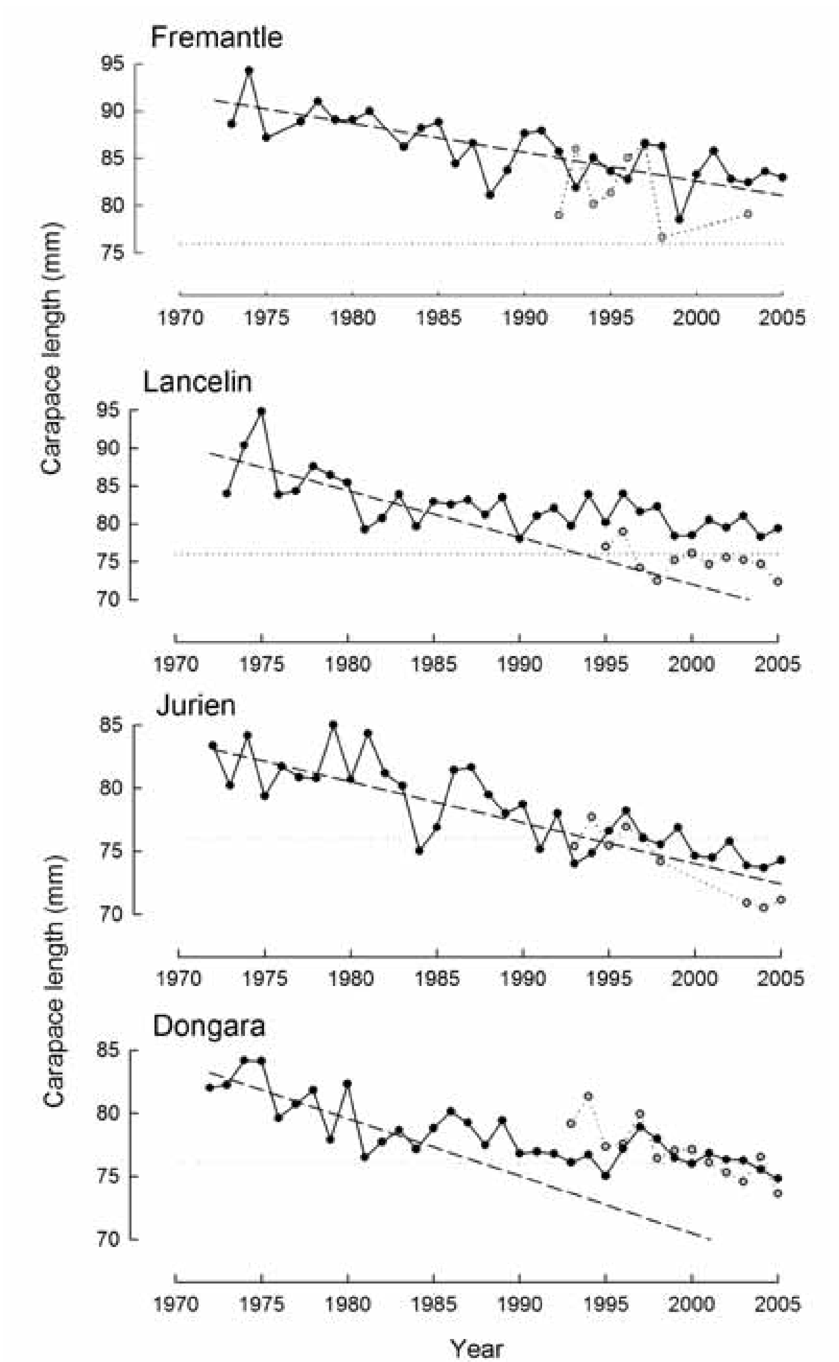



Figure 3.9 – Mean carapace lengths of the smallest 10% of mature female *Panulirus cygnus* caught in each year at four locations from 1972 to 2005 based on data collected during Fishery Dependent Commercial Catch Monitoring (filled circle) and from 1992 to 2005 based on data collected during Fishery Independent Breeding Stock Surveys (open circle). Horizontal dotted line represents 76 mm and dashed line represents a linear regression between mean carapace length and the years before 1986 (Melville-Smith & de Lestang 2006)

### *3.6.2 – Spawning Season*

Catches of berried females indicate that spawning peaks in late spring, with an increase from August/September peaking in November and tailing off in January/February, particularly on the coast. Catch rates of spawning females at the Abrolhos Islands remain high through December/January before declining in February (Chubb 1991) (Figure 3.10).



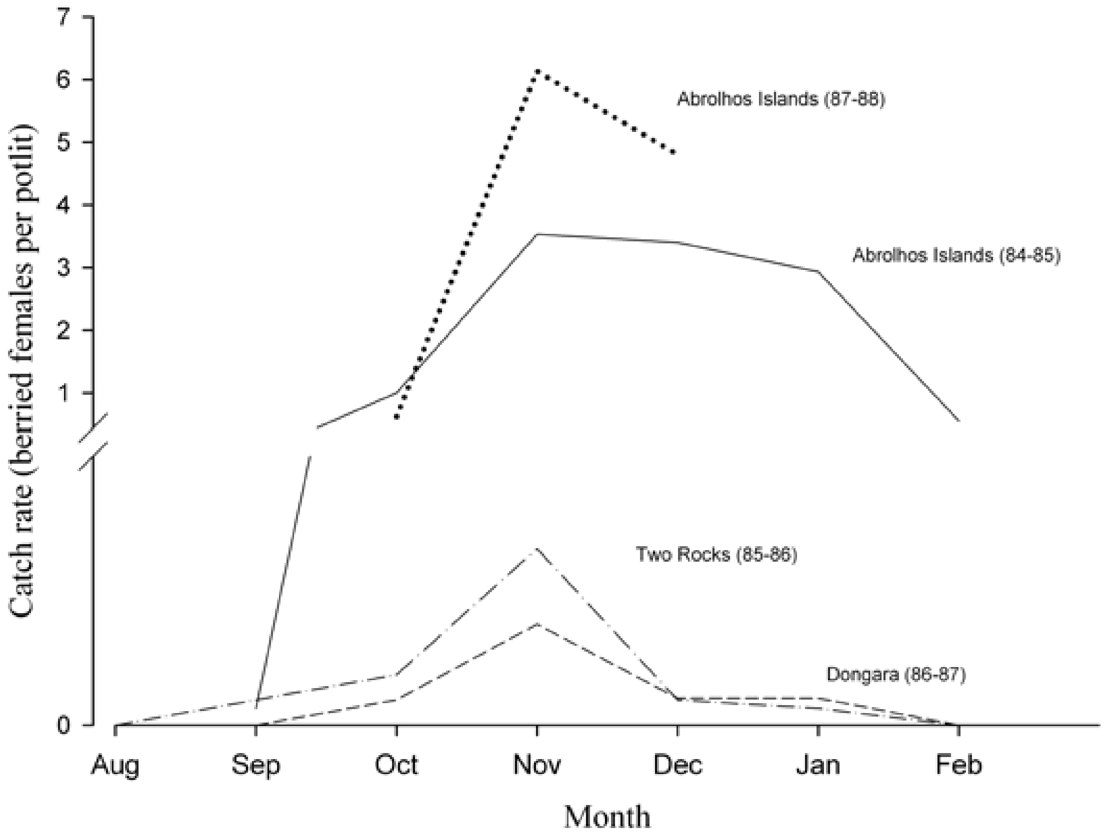



Figure 3.10 – Monthly catch rates of berried females (number per pot lift) (Adapted from Chubb 1991)

### *3.6.3 – Fecundity*

The number of eggs produced by a particular female during a spawning period depends on the size of the individual ( $Fecundity = 1.92 \times CL^{2.69}$ ) (Chubb 1991). Hence larger females produce more eggs per unit of size than smaller females with large females capable of producing a million eggs (Figure 3.11), with almost all eggs being successfully fertilised (Morgan 1972).



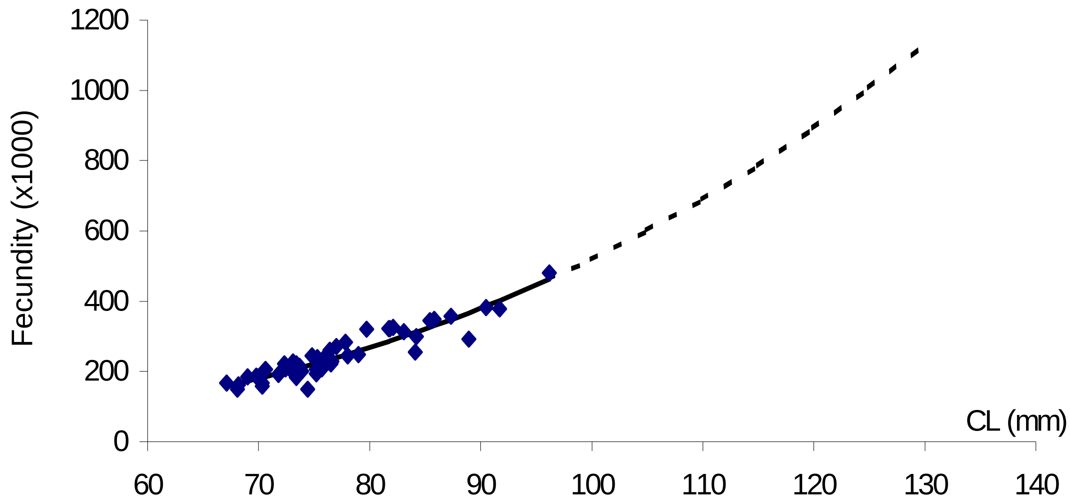



Figure 3.11 – Fecundity of *Panulirus cygnus* compared to carapace length (CL).

Increased number of eggs produced by large females was an important factor in the implementation of a maximum size for females to protect the breading stock.

While larger females have a greater egg production per brood spawned than smaller females, they also have a greater chance of spawning twice during the season (de Lestang & Melville-Smith 2006).

The size at which 50% of the lobsters, are classified as double breeders, displayed a similar spatial pattern as the various size at maturities, i.e. changing with latitude along the coast and distance off shore (Figure 3.12). Double breeding lobsters were larger at Fremantle compared with Lancelin, while Jurien Bay, Dongara and Kalbarri in the north of the fishery were all similar and smaller in comparison to the southern fishery sites. The Abrolhos Islands was smaller again than all the coastal sites. The size at double breeding was consistently ~10 mm CL larger than the size at first maturity for females at these sites (de Lestang & Melville-Smith 2006). This factor further increases larger females potential egg production during a season and supports the importance for protecting them.

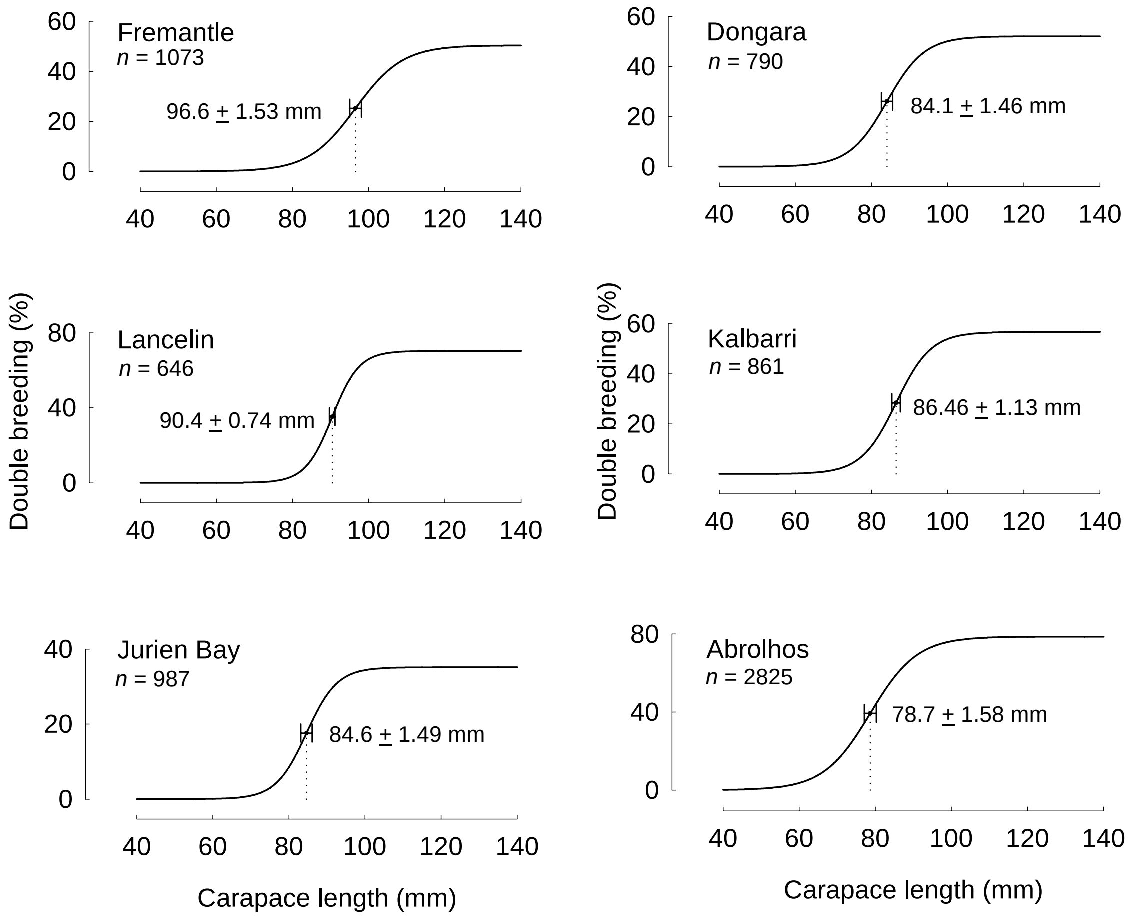



Figure 3.12 – Probability at double breeding at five coastal locations and the Abrolhos Islands (de Lestang & Melville-Smith 2006).

## 3.7 – Juvenile Recruitment

Most lobster larvae do not survive their long oceanic journey. Many are eaten by predators or are not carried close enough to the shallow reefs by the ocean currents to allow them to settle. Therefore, the number settling can vary greatly from year to year, largely as a result of changes in environmental factors (Caputi et al. 2000). When the Leeuwin Current is flowing strongly, a higher proportion of the larval lobsters return to the coast. Westerly winds at the time of year when the puerulus are ready to settle may also help more to reach the shallow reefs along the coast. One factor, which affects the strength of the Leeuwin Current (and hence the level of pueruli settlement), is the frequency of El Niños events. The occurrence of an El Niño reduces the strength of the Leeuwin Current, with strong Leeuwin Currents resulting in better settlement of puerulus (Caputi et. al. 1995b). A possible explanation for this relationship is that the warmer oceanic waters may increase the development rate and survival of phyllosoma larvae.

The settlement of pueruli occurs through out the year, with peaks occurring in late winter to mid summer (Figure 4.2), and generally at night, around each new moon.

The Department of Fisheries monitors the highly variable recruitment of puerulus to the Abrolhos Islands and the coastal reefs on a monthly basis. This data is used as an index of future stock levels providing a prediction of future catches three to four years in advance (Sections 4.1 and 5.2).

## 3.8 – Age and Growth



The first assessments of *P. cygnus* growth rates were conducted under controlled aquaria conditions (Chittleborough 1974b, 1976b) focusing on such effects as temperature, photoperiod, oxygen, food supply, crowding, autonomy of limbs, and size at maturity. Comparisons were also made between laboratory reared and wild populations (Chittleborough 1975), with wild populations being studied through tag recapture techniques (Chittleborough 1975, Morgan 1977). These data were used to attain estimates of growth parameters for use in assessment models (Phillips et al. 1992, Hall & Chubb 2001). The modeling of tagging data remains the main techniques for determining growth in western rock lobster.

Since 1992, the majority of tagging of lobsters has occurred in October and November by Department of Fisheries staff at the conclusion of the IBSS (Section 4.3). The primary focus of this tagging program has been to monitor year-to-year variability in moult increments. Additional tagging has also occurred on a far more ad-hoc basis, with the main focus being overall growth rates and movement patterns. For example in 1992, as part of a migration study, undersize lobsters were tagged during the season with most being caught soon after release. These provided little information on lobster growth.

### *3.8.1 – Methods*

Growth may be underestimated from tagging due to reduced growth from injury induced by tagging (Hunt and Lyons 1986), leg loss (Brown and Caputi 1986) or if lobsters that moult less frequently preferentially retain tags (Muller et al. 2007). In addition, if animals with very small growth increments are rejected from the analysis this may lead to overestimation of growth. Consequently, a non-aggressive approach was taken to the initial "clean-up" of the data. All data with very short times-at-liberty (< 90 days) has proven detrimental for growth determination and has been removed from the dataset. All lobsters retrieved with missing or regenerated limbs (Melville-Smith & de Lestang, 2007c) were also removed from the analysis.

The analysis by Stephenson and de Lestang (in prep) was based on the assumption that growth is different between the sexes and changes with water temperature at different locations throughout the fishery. Growth was also constricted to occur in two time steps, 15th November and 1st March. Although it is certain that small lobsters moult more than twice per year, and large lobsters, probably only once per year, bi-annual moults was considered a good assumption for the purpose of the stock assessment as the majority of the catch in this fishery is derived from lobsters entering the fishery in the "whites" (December) and the reds (March).



All lobster releases were scaled to a release date of 1st November, so that the time at liberty could be easily related to the time of year. The 1st of November was chosen, as this is the peak of the breeding season and as such considered the birth date for all lobsters during this analysis. Lobsters were then classified as 1,2,3 … according to their number of assumed moults, if they had been at liberty for between $2n-1+0\cdot 3$ and $2n-1+0\cdot 4$ years and between $2n+0\cdot 9$ and $2n+1\cdot 10$ years.

The growth for one growth increment by a lobster with carapace length *L* is denoted $I_{L,1}$ and was assumed to be the same for each growth period and given that;

$$I_1 = k + \frac{m}{1+\exp\left[\ln(19)\left(\frac{L-L_{0.5}}{L_{0.95}-L_{0.5}}\right)\right]} \qquad \text{Eq. 3.8.1}$$

where $L_{0.5}$ and $L_{0.95}$ are the 50% and 95% percentiles of the growth increment, and *m*, *k* are the maximum and minimum values of the growth increment (Figure 3.13).

The estimated $n^{th}$ growth increment is

$$I_n = k + \frac{m}{1+\exp\left[\ln(19)\left(\frac{L_{n-1}+\sum_{n=1}^{n-1} I_n - L_{0.5}}{L_{0.95}-L_{0.5}}\right)\right]} \qquad \text{Eq. 3.8.2}$$

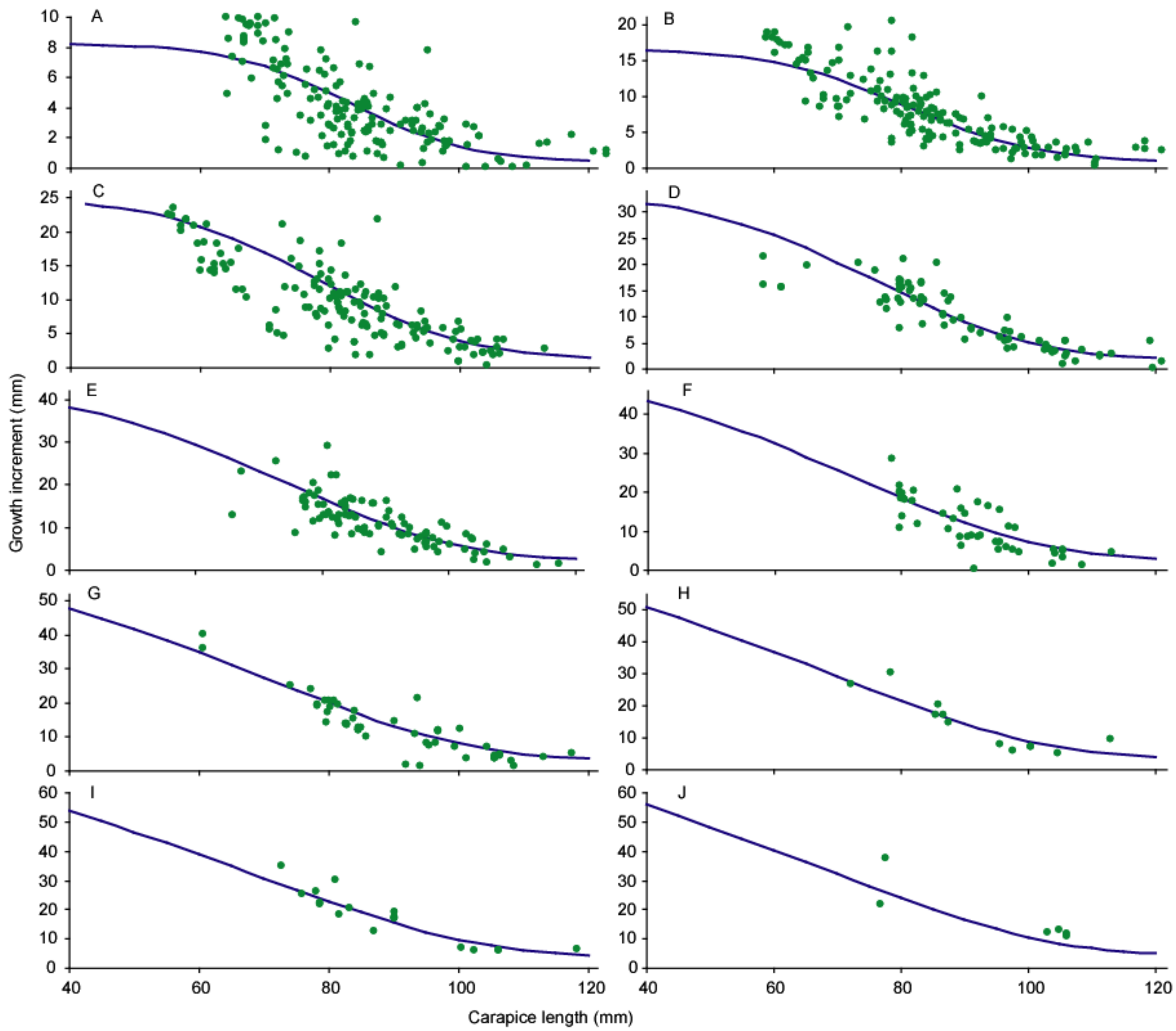



Figure 3.13 –Moult growth increments for female lobsters at Dongara with a logistic function fitted through the distribution. Figures on the left represent the growth increment estimated for the November moult for lobsters in their first (A) to fifth (I) year after release, while those on the right represent the growth increment over the March moult (Stephenson and de Lestang in prep).

Due to the large variation in growth for animals with one growth increment, the parameters of the logistic function were estimated from the observed growth for $n > 1$. It was not possible to estimate the initial growth increment as the smallest size of tagged animals was 55 - 65 mm and most of these were caught very soon after release. Thus the initial growth increment was determined from the assessment model (Section 5.4) by altering the initial increment so that the proportion of 3 to 4-year-old animals in the catch estimates, match those ratios determined from recruitment – catch relationships (de Lestang et al. submitted). These proportions are shown in Table 3.1.

Table 3.1 – Proportion and 1SE of three out of all three and four year post-puerulus lobsters in the catches at eight different locations throughout the fishery, estimated from puerulus – catch relationships (de Lestang et al., submitted).

| Region | Capes | Fremantle | Lancelin | Jurien | Dongara | Geraldton | Kalbarri | Abrolhos Is. |
|---|---|---|---|---|---|---|---|---|
| Proportion | 26.5 | 23.6 | 39.4 | 45.1 | 51.9 | 70.9 | 80.6 | 42.8 |
| Stand. error | 12.3 | 4.5 | 4.0 | 6.4 | 10.2 | 15.3 | 12.2 | 16.9 |

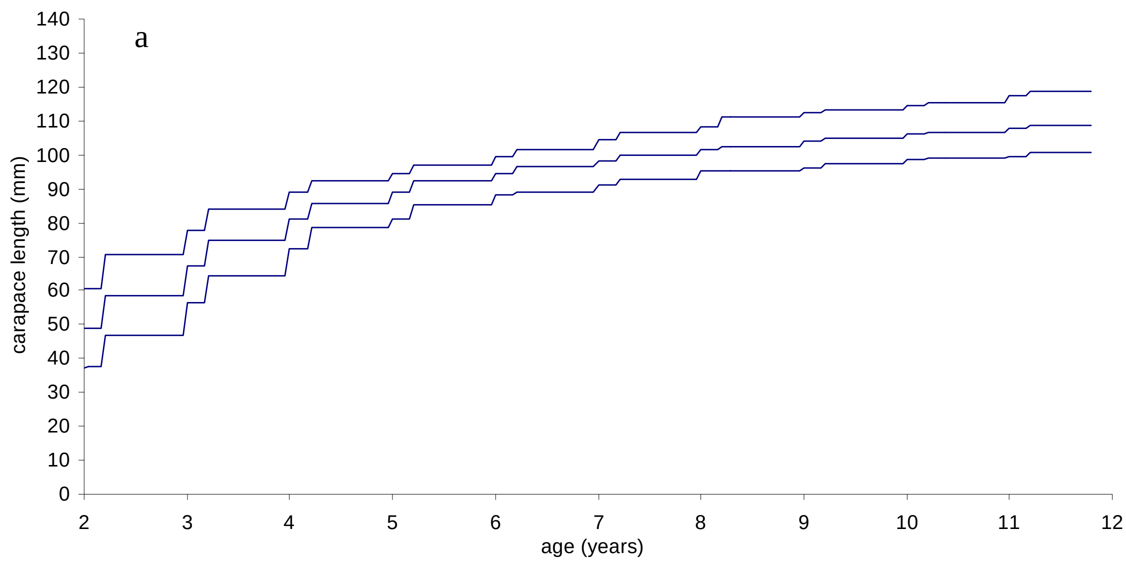


Using the estimate of initial growth increment (taken that at age 2), the $L_{0.5}$, $L_{0.95}$, and $k$ were estimated by the objective function. A stepwise growth curve was then determined using a simplified version of the method of Fogarty and Iodine (1988) and Muller et al. (1997) whereby the growth is determined in monthly time steps by determining the probability of moulting in a time step and for those animals that moulted, the growth increment is added to the length. In this assessment, the variability in growth was incorporated using the method outlined in Muller et al. (2007).

A sample of 40 lobsters was collected from Seven Mile Beach near Dongara in October 2004. These lobsters, which were assumed to be 2-years-old, had a mean carapace length of 39.8 mm and a standard deviation of 6.1 mm. Therefore in this region and for both sexes, the length of a 2-year-old lobster was assumed to be from the normal distribution $\mathrm{N}(39.8, 6.076)$. In the areas south of Dongara, a progressively smaller starting length was used, while north of Dongara and then at the Abrolhos Islands, a progressively larger starting length was used. In each case the standard deviation was determined using the same cv as the Dongara starting values.

In each time-step, lobster carapace length was determined using growth increments for each moult *n* occurring in time-step *t* =1 (November 1) and *t* =6 (March 1) given by $L_{j,t} + \mathrm{N}(I_n, s_n)$ where the standard deviation, $s_n$, for growth increments 1, 2... *n* is determined using an assumed *cv* = 0.08 and is given by $s_n = \sqrt{\sum_{n=1}^{N} (I_n \cdot cv)^2}$

A Bayesian procedure was used to model the uncertainty in growth. A joint probability distribution was generated using the Markov Chain Monte Carlo (MCMC) procedure in AD Model Builder. Saving every 500th from 1250,000 cycles of the MCMC and rejecting the first 500 generated during the burn-in period obtained a subset of 2000 values from the joint posterior distribution.  The median and the 95% confidence limits from the MCMC are shown in Figure 3.14 a & b.



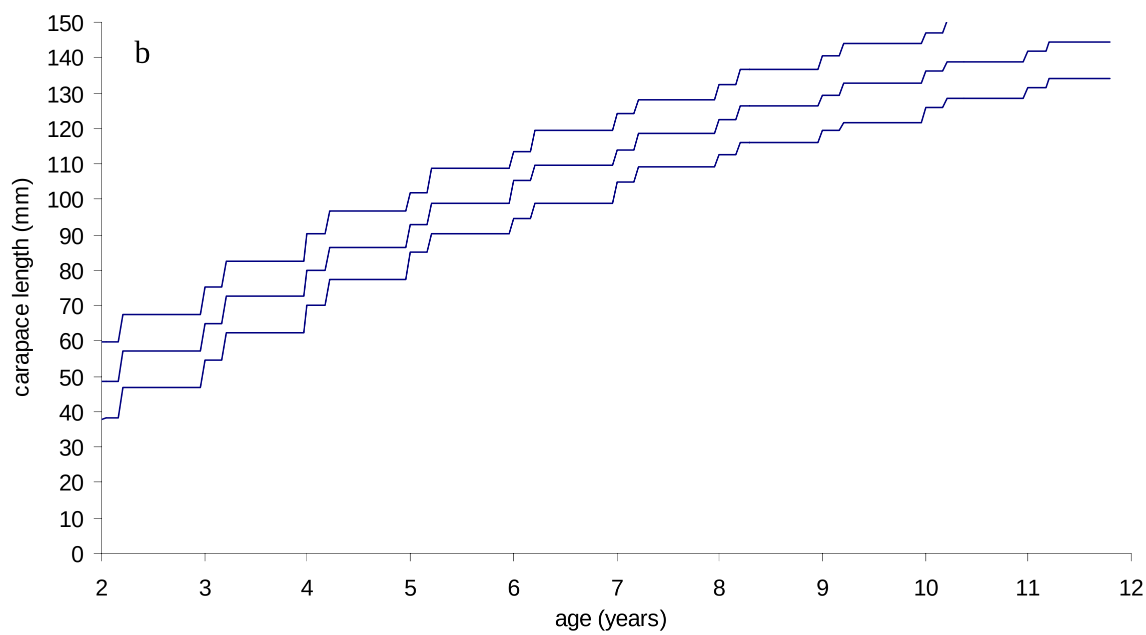




Figure 3.14 – Example of the modelled growth curves showing the median and 95% CI of a) female and, b) male western rock lobster at Dongara.

## 3.9 – Diet



The western rock lobster is an opportunistic omnivore feeding on a wide range of food items from coralline algae to molluscan and crustacean fauna (Joll & Phillips 1984, Edgar 1990) populations, which probably have high productivity, high turnover rates and short life cycles. Studies have found that juvenile rock lobsters show a range of diets and feeding strategies, varying greatly between seasons and between different habitats in the same season (Edgar 1990). Edgar (1990) reported that the diet of *P. cygnus* reflected the abundance and size distribution of benthic macrofauna available on all sampling occasions

Investigation into the diet of adult western rock lobster populations in deep coastal ecosystems (36 – 75 m) is currently underway (Waddington et al. in prep), using gut content and stable isotope analysis. Results to date suggest that lobsters are primarily carnivorous and act as secondary consumers. This same study also suggests a dietary shift occurs upon migration from an omnivorous diet in shallow inshore areas, to a primarily carnivorous diet in deep coastal ecosystems. Major prey items of lobsters in deep coastal ecosystems include crabs, amphipods and isopods, with diet largely reflecting the food availability of those taxa found free living or associated with algae on the benthos in areas lobsters are known to forage. Dietary analysis also indicated that bait (pilchards) is an important component of lobster diet at the locations investigated. Bait is available to the lobsters through discards from fishing boats and by lobsters feeding on bait in pots then exiting through the neck or through escape gaps in the case of undersize lobsters.

There is no evidence that lobster size or sex affects lobster diet or trophic position in deep coastal ecosystems (size range investigated 65 – 120 mm CL) (Waddington et al. in prep).

# 4 – Fisheries Time Series Data

## 4.1 – Puerulus



The puerulus stage of *Panulirus cygnus* settles naturally in seagrass beds or onto floating seaweed. This behaviour is exploited by artificial collectors, which mimic this habitat and thus provide a mechanism that allows relative settlement rates of puerulus throughout the fishery to be measured. Annual puerulus settlement data are used to predict future catches throughout this fishery.

### *4.1.1 – Methods*

<u>Location</u>

The first collectors were deployed in near-shore shallow waters (<5 m) in 1968 and 1969 at Seven Mile Beach, to the north of Dongara, Jurien Bay and Garden Island, as part of a CSIRO study. The first two of these sites have been monitored on a continual basis since then, with additional sites being added and removed over the years (see Table 4.1 and Figure 4.1).

Table 4.1 – Location of historical and current puerulus collector sites and the number of collectors at each site.

| Site | Initiated | No. Collectors | Status |
|---|---|---|---|
| Abrolhos Is. (Rat Is.) | 1971 | 10 | 1971 – 1978; 1984 to current |
| Alkimos | 1982 | 5 | Current |
| Cape Mentelle | 1984 | 7 | Current |
| Cervantes | 1984 | 5 | Stopped 1992 |
| Cowaramup | 2005 | 2 | Current |
| Dongara (Seven Mile) | 1968 | 6 | Current |
| Dunsborough | 1984 | 5 | 1985 |
| Garden Island | 1969 | 4 | Stopped in 1984 |
| Horrocks | 1984 | 5 | Stopped in 1991 |
| Jurien | 1969 | 5 | Current |
| Marmion | 1984 | 6 | Stopped in 1992 |
| Lancelin | 1990 | 8 | Current |
| Point Quobba | 2006 | 5 | Current |
| Port Gregory | 1995 | 5 | Current |
| Shark Bay | 1984 | 5 | Stopped in 2004 |

| | | | |
|---|---|---|---|
| Warnbro Sound | 1984 | 6 | Current |

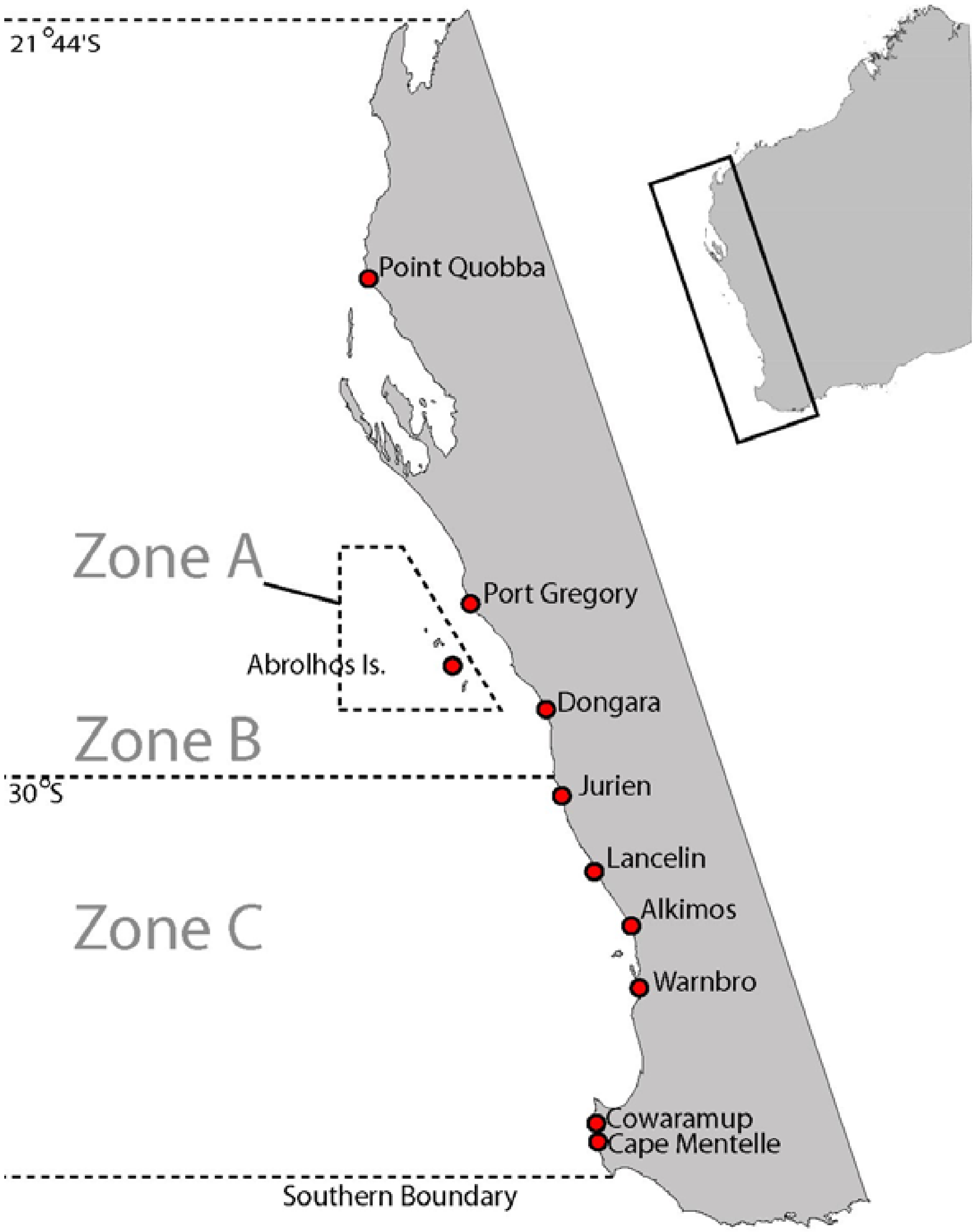



Figure 4.1 – Location of current (2007) puerulus collector sites

Puerulus collectors

The original puerulus collectors consisted of three panels each with Tanikalon tassels and a brown mesh-backing sheet (synthetic fibre) (Phillips 1972). These three panels were affixed to a stainless steal frame with two 8” floats in the centre and two 8” floats on the top of a central pole. The frame and tassels were moored to the seabed by a stainless steel chain and anchored to a large concrete block (Plate 4.1a).



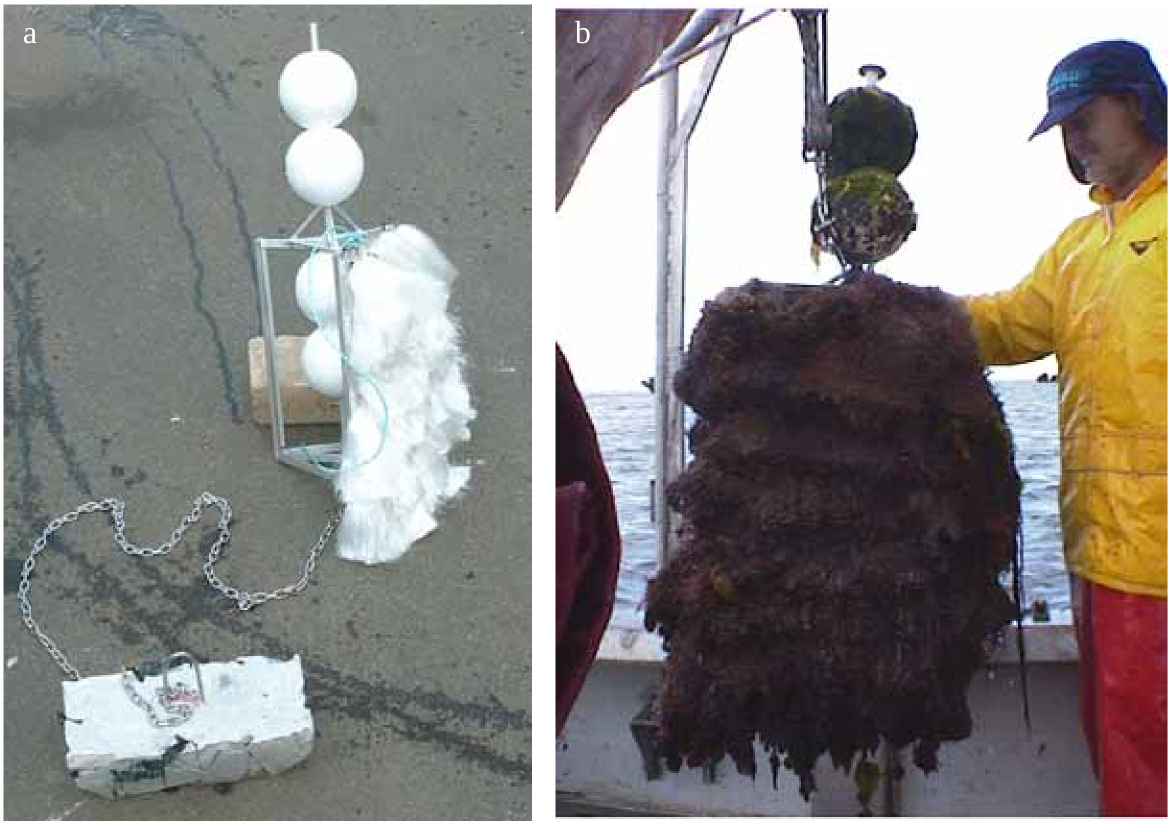



Plate 4.1 – Puerulus collectors a) design with two panels missing to show internal construction and, b) retrieved from site before being “banged”

The manufacture of Tanikalon stopped during the late 1980s and a replacement fibre had to be sourced and its efficiency for collecting puerulus compared to that of Tanikalon. The replacement fibre chosen is produced by Boral Kinnears (subsequently referred to as BK). As of 2007, BK fibre has replaced Tanikalon in all collectors used for catch prediction. From 1992 – 2006, collectors containing Tanikalon and BK were deployed in nearby “tandem” locations at the Rat Island, Seven Mile Beach and Jurien Bay sites. This has allowed for spatial and temporal comparisons to be made between fibre types.

Furthermore, the material used on the backing sheets, which originally was a brown material glued onto the external side of the plastic backing sheets to provide additional surface for puerulus to cling to, also ceased manufacture during the early 1990s, and a replacement for this has also had to be sourced.



To further address the catchability differences between the two tassel types and various backing materials, additional studies have been developed, one at Lancelin and another at Seven Mile Beach. At Lancelin three puerulus collectors were deployed in October 2004. The three panels on each collector contained different backing materials, one sheet using the traditional brown material, a second sheet using the new white material and the third sheet having no backing material. Preliminary analysis of this data indicates that the puerulus catches on sheets with BK fibre tassels and no backing are not significantly different ($p > 0.05$) from those backed with the traditional brown backing. Catches produced by sheets covered with the new white material were significantly lower ($p < 0.001$) than the other two treatments.

The second study, set up at Seven Mile Beach in July 2005 focused on both tassel types and backing material. Six Phillips collectors were set in pairs of two (making three groups). Of the six collectors, two were entirely fitted with Tanikalon fibres and brown backing, two with BK fibres and brown backing and the final two, with BK fibres and no backing material. Each month the position of each collector was randomly re-assigned to one of these six locations to provide multiple pair-wise comparisons between different collectors with different fibres in different locations. Preliminary analyses of these data indicate that tassel type ($p < 0.001$) and not backing material ($p > 0.05$) (traditional brown or no backing) significantly affects puerulus settlement rates. A conversion rate determined from this analyses suggests that Tanikalon is ~ 20% more efficient than BK. However, as this data set is relatively small, more data is being collected, and the conversion factor does not explain the differences between the puerulus catch rates from the other trials at Rat Island, Seven Mile Beach and Jurien Bay, no conversion factor is currently being used to adjust puerulus settlement rates from BK fibres for use in catch prediction. This work is on going.

Puerulus Settlement Monitoring

Collectors are sampled every full moon period (five days either side of the full moon) of the settlement season which runs from May to the following April. During each sample the collectors are removed from the water onto a boat, where each of the three sheets is removed one at a time and placed face down in a rack for shaking over a collection tray. The aluminium shaker frame is slid over the P.V.C. backing board and holding the shaker by the handles, the sheet is given 20 "shakes" before being placed on the deck, fibre side down (Plate 4.2). The contents of the shaking tray are poured through the sieve, before the sheet is shaken another 10 times over the tray. If any more pueruli appear in the tray after the second set of shaking, then the panel is given another ten shakes until no further puerulus appear. The sheet is then removed from the frame and this same process is repeated for the remaining two sheets.


Plate 4.2 – Collection of puerulus from collectors by a) shaking puerulus collector and b) sieving contents

After all three sheets have been shaken the number of puerulus and post-puerulus (similar in size to puerulus but pigmented – Plate 3.3c) are counted, with any specimens that are substantially larger than post puerulus, and may not have been shaken out during the previous collection, counted and clearly identified as having settled in the previous month. Puerulus that are returned to the water are released at some distance from the collectors to prevent contamination.

Once all three panels have been shaken, the collector is reassembled, cleaned of marine growth and checked for wear and tear. All maintenance conducted on each collector, e.g.

replacement of one or more sheets, is also recorded. Department of Fisheries staff currently conduct all servicing of the collectors from Warnbro Sound to Port Gregory, with collectors at the extreme north (Point Quobba) and south (Cape Mentelle and Cowaramup) of the fishery, being serviced by locally contracted people.



Other recordings made whilst at each site include a measure of surface water temperature at the southern and northern ends of the collectors for that site, as well as a single recording of salinity. One collector at each site is also fitted with an archival data storage logger that records water temperatures. This continually records the water temperature on an hourly basis and is removed and replaced with a new logger every second month.

The environmental data and puerulus numbers are stored in an SQL based database. This database is used to construct monthly and annual trends of puerulus settlement (Figure 4.4 and 4.5).

Analysis

Puerulus settlement indices in each management zone (Figure 2.1) are based on one or more puerulus collection site (Table 4.2). Each index is the sum of the average number of puerulus sampled per collector at each site over the settlement season (May to the following April). Since the southern zone (C) uses data from more than one puerulus location, a least squares mean estimate, standardised for location, is determined by GLM with location, season and month as factors. In cases when a location was not serviced for a given month(s), due to bad weather etc., an estimate of settlement is determined based on the proportion that month contributes on average. Actual adjustments that have been made to the data are 1988/89 Alkimos/0.64, 1989/90 Alkimos/0.97, 1989/90 Cervantes/0.77, 1968/69 Dongara/0.94, 1969/70 Cervanties/0.98 and 2000/01 Lancelin/0.82. 1968/69 Jurien is estimated from Dongara. At some locations additional collectors have been added over the years for various reasons. To maintain the consistency of the indices produced from these sites, additional collectors added over the years are not used in the analysis (Table 4.2).

Table 4.2 – Puerulus collector locations and collectors used in the development of puerulus settlement indices for the three management zones.

| Management Zone | Puerulus collector location | Collectors used |
|---|---|---|
| Abrolhos Islands (A) | Seven Mile Beach | 1 – 4 (not 5, 6) |
| Northern Coastal (B) | Seven Mile Beach | All (1 – 6) |
| Southern Coastal (C) | Alkimos | All (1 – 5) |
| | Cervantes | All (1 – 5) |
| | Garden Island | All (1 – 5) |
| | Jurien Bay | 1 – 5 (not 6) |
| | Lancelin | All (1 – 5) |
| | Warnbro Sound | All (1 – 5) |



### *4.1.2 – Results*

The puerulus settlement season runs from May to April the following year with peak settlement occurring in late winter to spring (Figure 4.2). Although the exact month of peak settlement differs slightly between years, there is always the same latitudinal progression in peak settlement time. Peak settlement always occurs earlier (~ August) in the northern locations i.e. Point Quobba and South Passage, and later in the southern locations, i.e. Cape Mentelle, (~November). Settlement occurs even later at the offshore Abrolhos Islands, peaking in ~December (Figure 4.3).

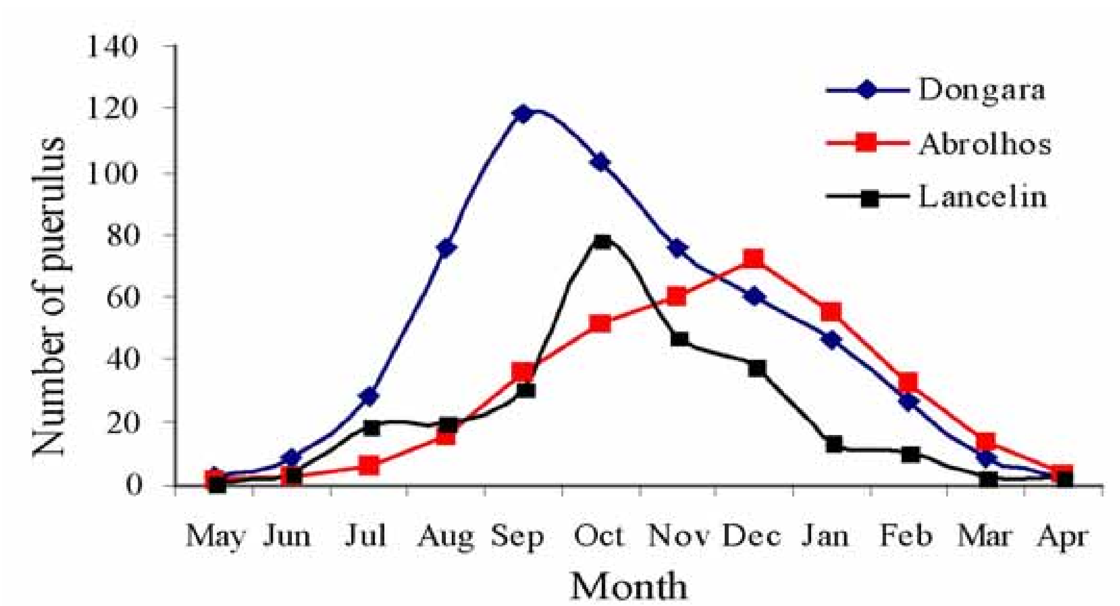



Figure 4.2 – Average puerulus settlement by month for sites in the northern (Dongara), southern (Lancelin) and offshore (Abrolhos Islands) zones of the WRL fishery.

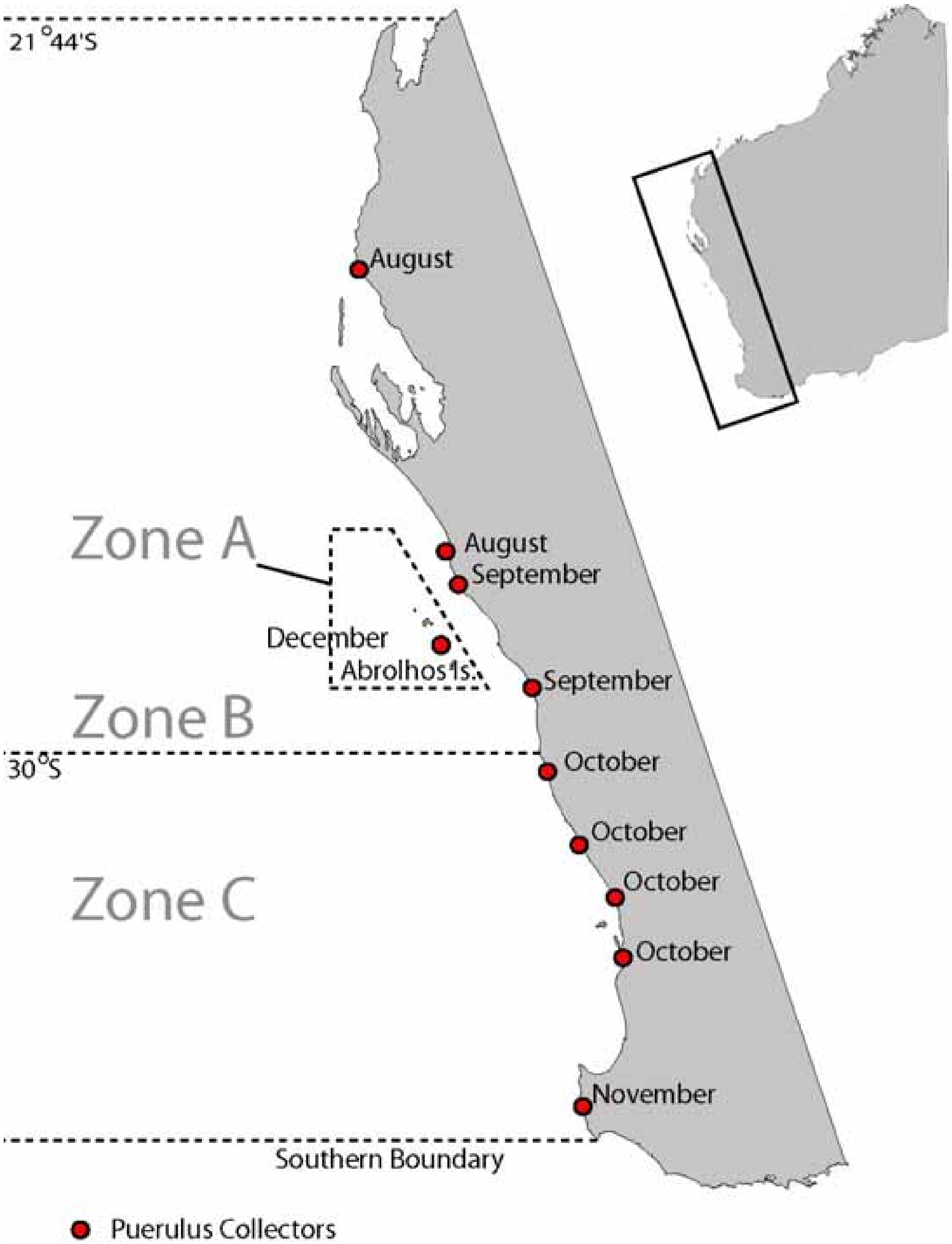



Figure 4.3 – Average month of peak puerulus settlement from current (2007) puerulus collectors throughout the WRL fishery

While there is considerable temporal variation in the number of pueruli collected, there is also considerable spatial variation (Figure 4.4). Although catches of pueruli at the various sites throughout the fishery all generally peak during the same years, the magnitude of these peaks can differ markedly. Puerulus collectors on the mid-west coast (near the centre of the fishery) record the highest numbers of pueruli. These were similar in magnitude to the offshore Abrolhos Islands (black) site when they were initially sampled (1970's), however settlement at the Abrolhos Islands site is now lower. The two metropolitan collector sites (Alkimos and Wanbro) are lower than those of the mid west, though considerably higher than the most southern collector site (Cape Mentelle). This is contrast to the most northerly collector site in Figure 4.4 (Port Gregory, light green) which has a more intermediate settlement rate compared to the high mid-west and lower metropolitan sites.



The strong correlation between years of puerulus settlement between sites is due mainly to oceanic conditions affecting survival and settlement rates on a coast wide scale. The water temperature in the area where the larvae occur in February-April (which is influenced by the strength of the Leeuwin Current) and rainfall (in October and November) from southern locations (which has been used as a proxy for the frequency of westerly winds in these months) has been shown to be significantly affect puerulus settlement (Caputi et al. 1995b).

The Leeuwin Current in June to December has also been shown to affect the spatial distribution of puerulus settlement with the mean latitude of puerulus settlement occurring further south in years of strong Leeuwin Current (Caputi et al. 2001 and Caputi in press).

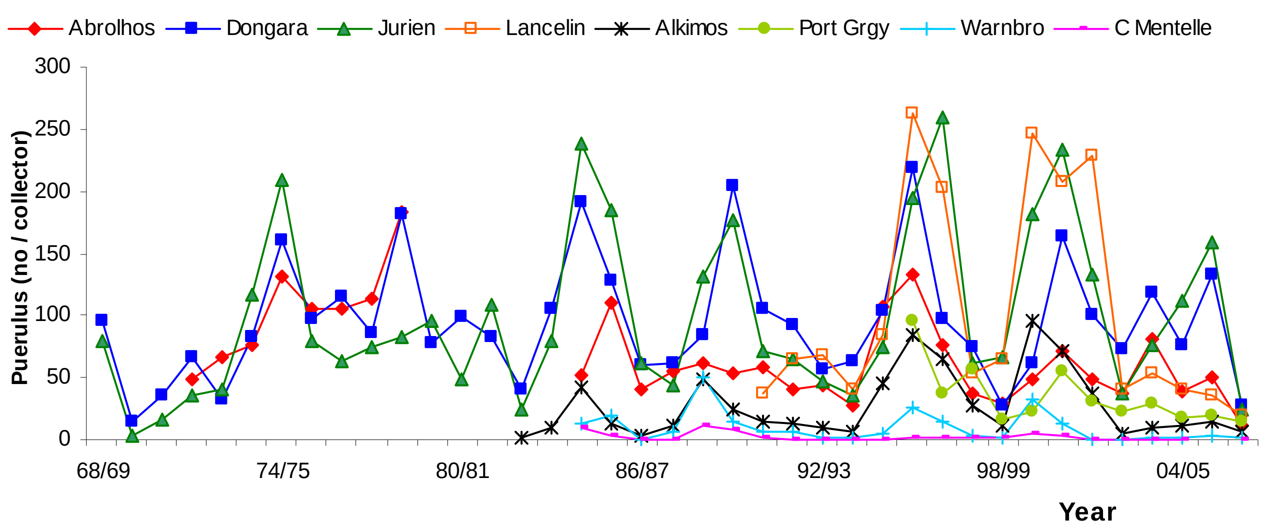



Figure 4.4 – Puerulus numbers per collector for each season at collector sites throughout the fishery.

## 4.2 – Commercial Monitoring

On-board monitoring of commercial catches by Department of Fisheries staff was initiated in 1971. This program involves members of the Research Division, making regular and detailed records of the target catch (retained and returned to the sea) and by-catch landings as well as environmental conditions and fishing activities. This program provides vital information such as juvenile (undersize) and spawning stock abundance and size at maturity on a broad temporal and spatial scale (Figure 4.5).



### *4.2.1 – Methods*

<u>Location</u>

Monitoring occurs every month throughout the fishing season (November – June) in four main localities Dongara, Jurien, Lancelin and Fremantle since 1971 and more recently in a further two locations, Kalbarri and the Abrolhos Islands (since 1985). Opportunistic monitoring also occurs in other localities such as Mandurah and the Capes region (Figure 4.5). For each locality monitoring is only conducted onboard vessels fishing within 15 nm north or south of the target port.

<u>Sampling</u>

During each month, at each location, monitoring is spread across four depth categories, i.e. <18, 18 –36, 36 – 54 and >54 m (<10, 10 – 20, 20 – 30 and >30 fathoms), with a minimum sample of 300 individuals being sought in each depth range. Sampling in some location-depth combinations in some months is missing due to vessels not fishing in that depth range due to poor catches or weather conditions.

Information is recorded on an individual lobster basis and includes carapace length to the nearest 1 mm, sex, breeding condition and colour (migratory white or sedentary red). Information is also collected on the skipper and crew as well as the fishing vessel, fishing techniques and interactions with non-target species (see Appendix1 for specifics). The data are entered and stored on an SQL based database for analysis.

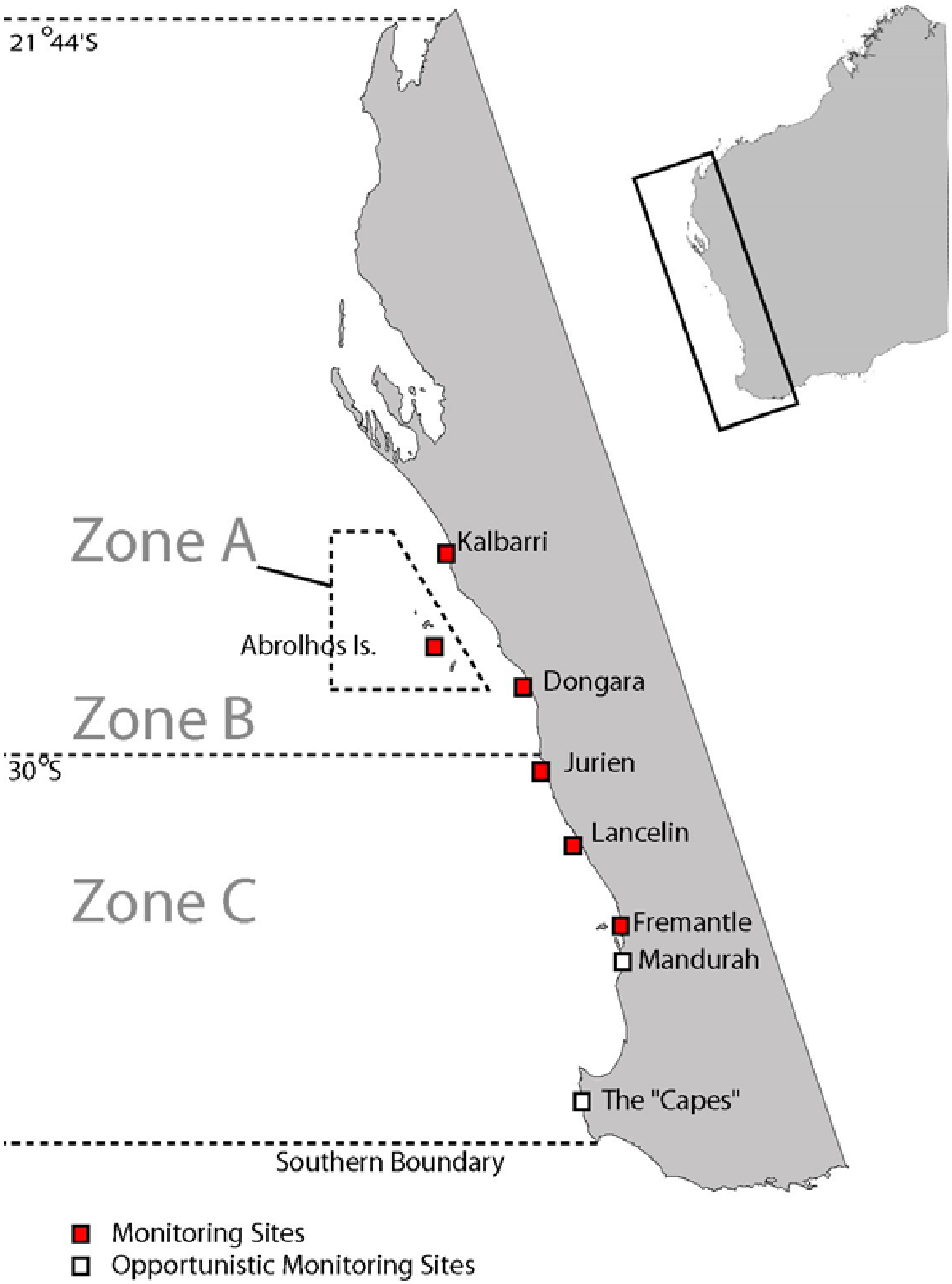



Figure 4.5 – Locations of commercial monitoring sites

Analysis

Data from commercial monitoring is used to construct a number of annual indices, used in the management of this fishery. These include breeding stock indices, a juvenile (undersize) abundance index, coast wide water temperature trends, annual mean size of the smallest 10% mature females, proportions moulting out of a setose phase each autumn, octopus catch rates, and by-catch. Of these indices, the most important for use in the management of this fishery is the breeding stock index.



*Fishery-Dependent Breeding Stock Index.*

Breeding stock indices (BSI) are produced for each of the two coastal regions, with monitoring at Dongara and Jurien used to produce the north coastal index and data from Lancelin and Fremantle used for the south coastal index. Each index is a Least Squared Mean (LSM) of eggs per pot lift in the deep-water breeding grounds of the region during the spawning season (September – February). The carapace length (CL) of each female measured during commercial monitoring in deep water (>36 m in Zone B and >18 m in Zone C) is converted to an estimated fecundity based on a size-fecundity relationship, a size-maturity relationship, and a size-double breeding relationship (equations 4.2.1-5). To account for a moult in February, the carapace lengths of all females measured after this month (March – June) are reduced by 4 mm, as this reduces them to the size they would have been during the previous spawning season (i.e. September – February). The annual estimate of egg production is a back-transformed value produced from a GLM of the logarithm of the number of eggs per pot lift, where fishing season, monitoring location, sub-location nested within location, month and pot type are all treated as factors. Water depth and water depth$^2$ are employed as covariates and the model is weighted by the number of pots sampled. A fishing efficiency of 1 – 2% pa is applied to the index to take into account increases in efficiency associated with radar, colour echo sounders, GPS, etc. (Table 5.1). Annual variations in catchability due to environmental conditions are also taken into account by applying a 3-year moving average to the time series.

The number of eggs in a single batch of eggs:

$$Fecundity = 1.92 \times CL^{2.69}. \qquad \text{Eq. 4.2.1}$$

Probability that a female is mature:



$$Pmature_{ZoneB} = 1/\left(1 + \exp\left(18.77 - 0.203 \times CL\right)\right) \qquad \text{Eq. 4.2.2}$$

$$Pmature_{ZoneC} = 1/\left(1 + \exp\left(59.51 - 0.987 \times CL + 0.0040 * CL^2\right)\right) \qquad \text{Eq. 4.2.3}$$

Probability that a female will spawn twice:

$$Pdblspawn_{ZoneB} = 1 + \left(1/\left(1 + \exp\left(4.075 - 0.0495 \times CL + 0.484\right)\right)\right) \qquad \text{Eq. 4.2.4}$$

$$Pdblspawn_{ZoneC} = 1 + \left(1/\left(1 + \exp\left(4.075 - 0.0495 \times CL - 0.484\right)\right)\right) \qquad \text{Eq. 4.2.5}$$

where $CL$ is the carapace length. * The sizes at maturity and at double breeding equations above are derived from Chubb 1991. New estimates of these parameters, reported in section 3.6, will be incorporated into the model in the near future.

*Biological Reference Points*

The Breeding Stock Index (BSI) is measured against a lower threshold (Biological Reference Point (BRP)). This point is equivalent to the BSI estimate for the 1980/81 fishing season, a period when the breeding stock was estimated by Hall and Chubb (2001) to be ~ 20% of the virgin biomass, a level substantially higher than that recorded during the early 1990s. Since, the breeding stock during the 1990s did not result in recruitment over-fishing, the higher 1980s BRP can be considered a fairly conservative level.

*Index of Juvenile Abundance*

Indices of juvenile abundance provide a qualitative assessment of recruitment to the fishery. Two indices are produced for the both north and south coastal regions, based on lobsters with carapace lengths < 68 mm and 68 – 76 mm (Figs 4.7a, b). These indices provide information relative to recruitment into the fishery two and one years in advance, respectively. These indices are Least Squared Means (LSM) of juveniles per pot lift in shallow waters (< 36 m) collected at Dongara and Jurien Bay (North Coastal region) and

Lancelin and Fremantle (South Coastal region). The indices are adjusted to account for fishing efficiency increases (Table 5.1), as well as to account for the impact of increasing the number of escape gaps (from one to three or four) in 1986/87. All data points after 1985/86 are multiplied by three and two for the < 68 mm and 68 – 76 mm indices, respectively, to account for the escape gaps.



### *4.2.2 – Results*

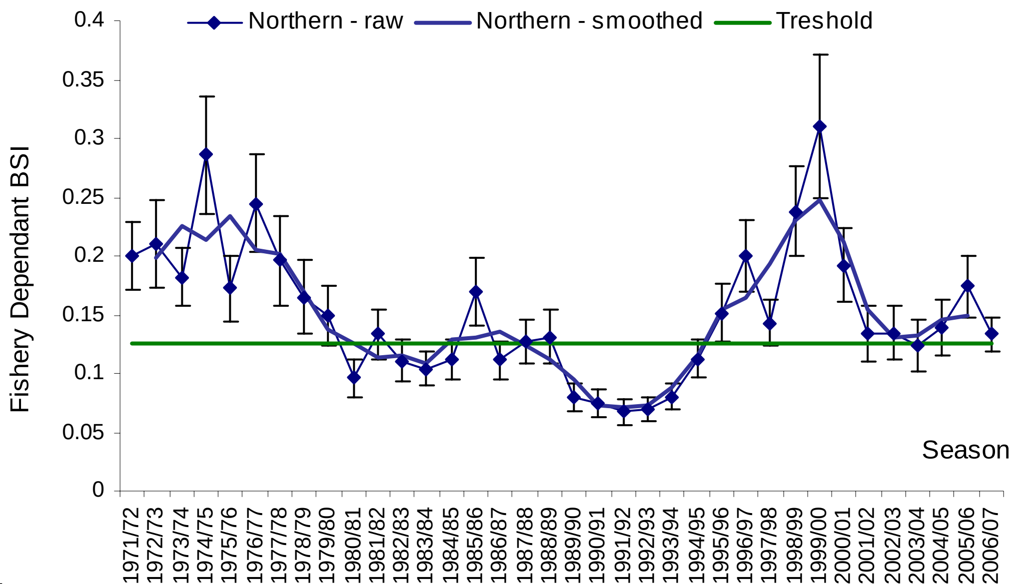
*Fishery-Dependent Breeding Stock Index.*

Monitoring of the commercial catches saw a decline in the breeding stock index from its inception in the early 1970s until 1992/93 (Figure 4.6). In the late 1980s, and early 1990s the breeding stock indices fell below their respective threshold level (Section 2). This decline prompted the introduction of the management changes designed at increasing the breeding stock (Box 2.1 – 1993/94). This and subsequent management measures have led to a recovery of the spawning stock in both the north and south of the fishery. However, there has been a more recent decline in the spawning stock, particularly in the north coastal region of the fishery, to levels just above the threshold BRP (Figure 4.6).

*Index of Juvenile Abundance*

For each coastal region the two indices of juvenile abundance (< 68 and 68-76 mm) show very similar trends as they reflect the variable puerulus settlement two and three earlier (Figs 4.7a,b). The past four seasons have shown a progressive decline in juvenile abundance, with very low levels being recorded in the 2005/06 fishing season, especially the 68 – 76 mm indices. These data suggests that commercial catches in coastal regions during 2006/07 and 2007/08 will be below average. This re-iterates the scenario estimated by the puerulus settlement indices for these seasons (Section 4.1 & 5.2).

a




b

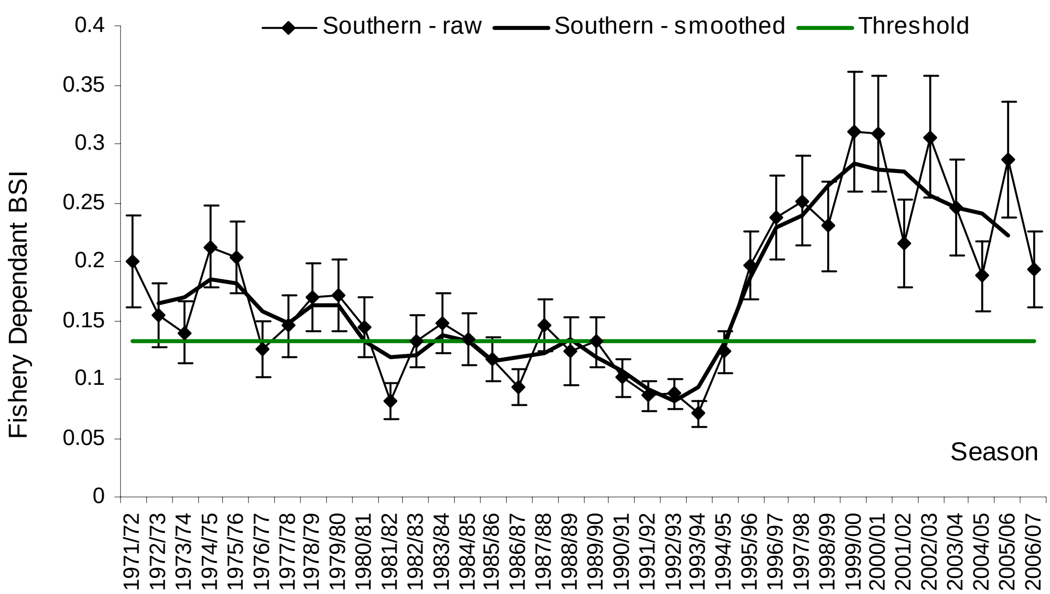



Figure 4.6 – Fishery-dependent spawning stock indices for the a) northern (Zone B) and b) southern (Zone C) regions of the fishery with a 3-year moving average. Biological Reference Point (BRP) for each area is shown (green line).

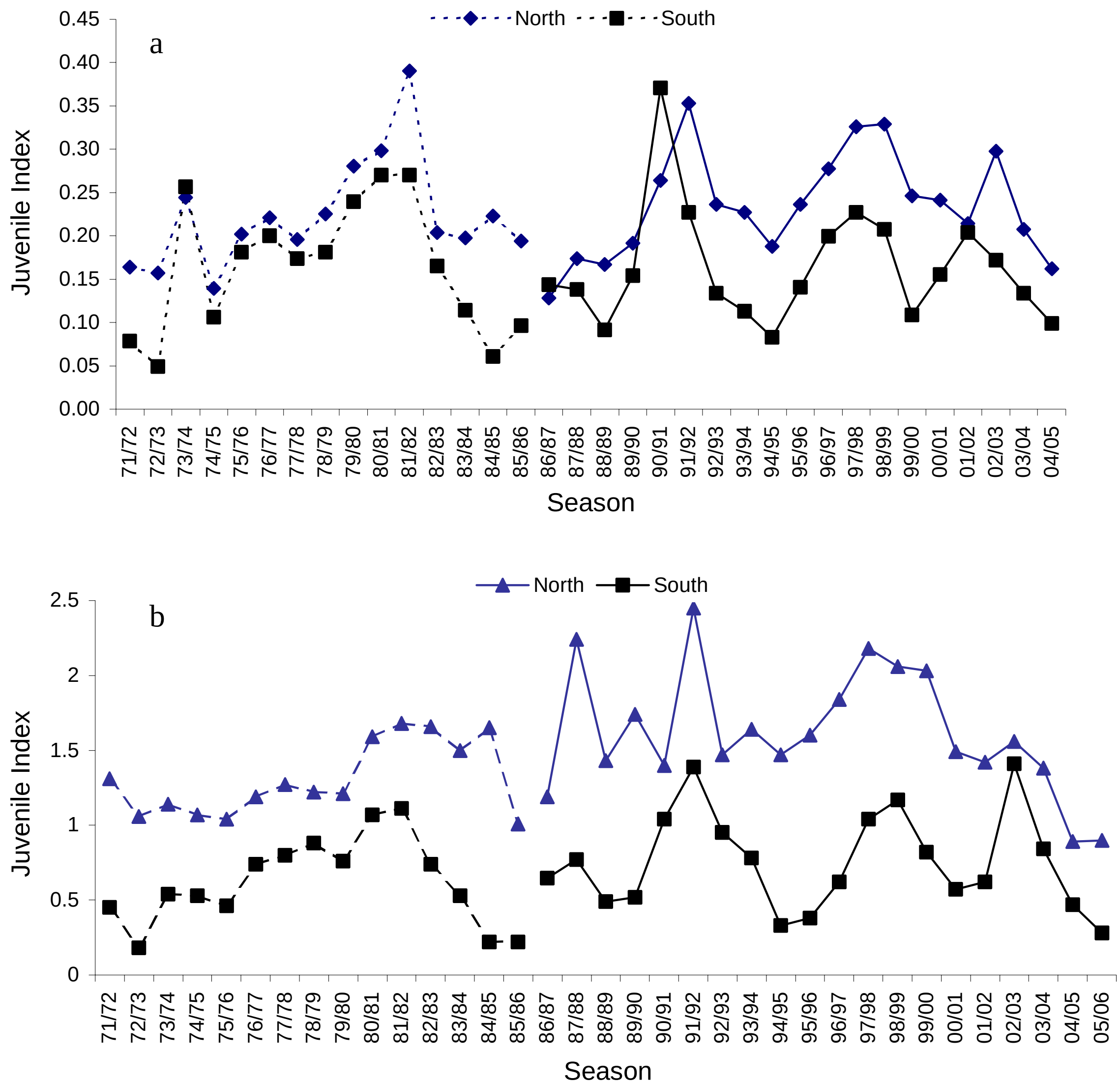



Figure 4.7 – Juvenile indices for the northern and southern regions, adjusted for escape gap changes in 1986/87 and fishing efficiency. a) Lobsters <68 mm CL and b) juveniles 68-76 mm CL. Dashed lines denote one escape gap in the pots and solid lines three or four escape gaps.

## 4.3 – Independent Breeding Stock Survey (IBSS)

Since 1991, the Research Division of the Department of Fisheries has undertaken an annual survey of the breeding stock. This survey provides fisheries managers with a measure of the breeding stock, independent of the effects of increasing fishing efficiency (Melville-Smith & de Lestang 2006) producing a cross check of the trends exhibited by the fishery-dependent breeding stock index, which is a longer time series.



### *4.3.1 – Methods*

Sampling Locations

The IBSS is conducted over ten days during the last new moon before the commencement of the fishery season (15th November). This period is also close to the annual peak of egg production, which occurs in either October or November, depending on moon phase (Chubb 1991: - Section 3.4). The IBSS involves the setting of standard fishing pots in up to five coastal sites as well as the Abrolhos Islands using the same locations each year. The survey runs annually at Dongara, Lancelin and the Abrolhos Islands, as well as intermittently (every five years) at Fremantle, Jurien and Kalbarri (Figure 4.8). Commercial WRL boats are chartered for all coastal locations, with the Department of Fisheries research vessel undertaking research at the Abrolhos Islands. For the coastal sites, surveys are undertaken at depths from 25 – 70 m while at the Abrolhos Islands the depth range surveyed is 10 – 60 m. This corresponds to the depths at which most breeding lobsters are found (Chubb 1991).

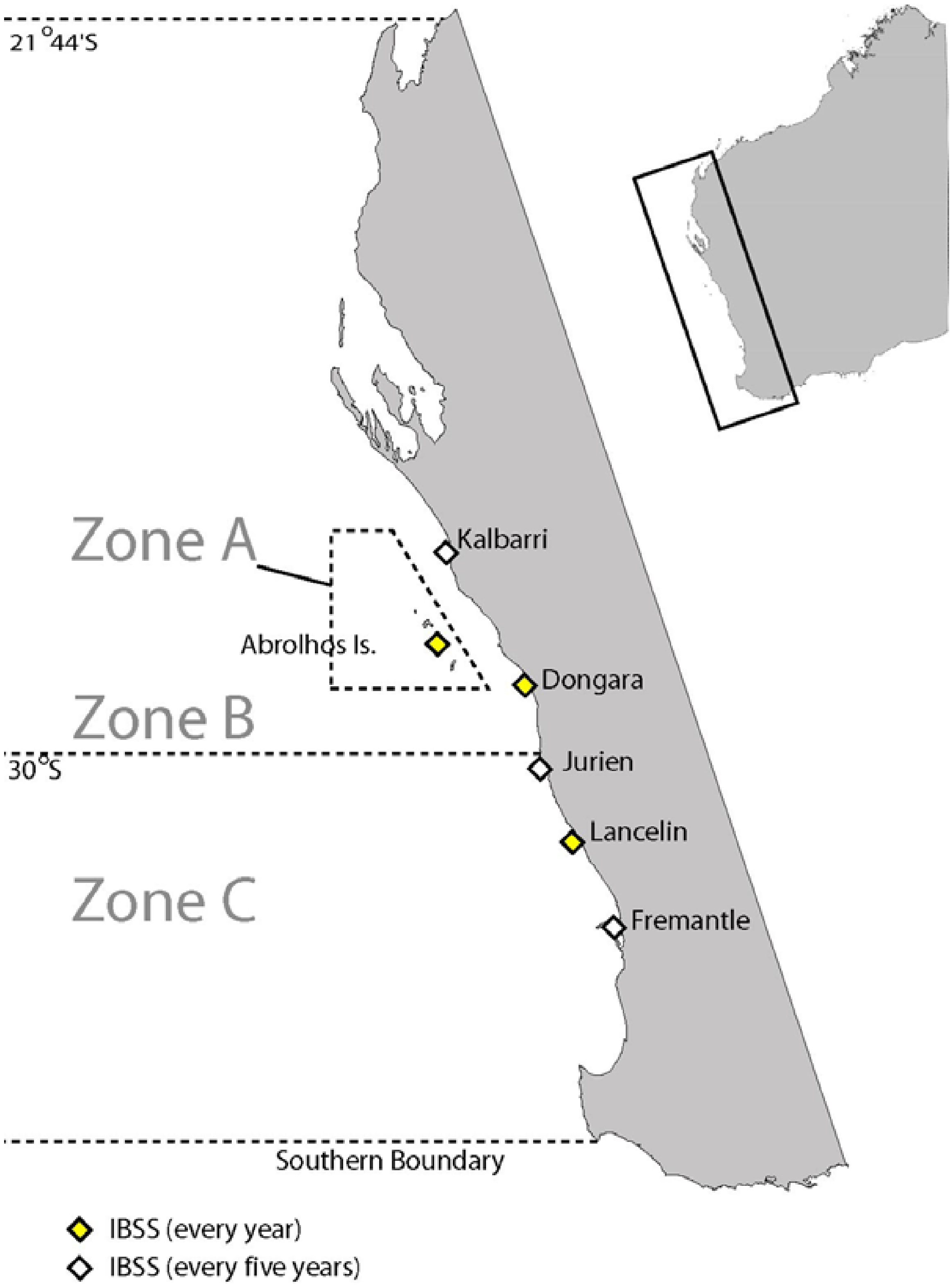



Figure 4.8 – Location of independent breeding stock survey (IBSS) sites sampled annually (yellow diamond) and every five years (white diamond).

Breeding Stock Sampling Regime

Each year 160 commercially sized batten pots, with no escape gaps, are used. These are set up for a two-day pull, with 80 pots being sampled each day during the 10-day sampling period for the coastal sites. At the Abrolhos Islands 51 pots are used with one day pulls due to the greater quantity of lobsters that are caught. Standard baits of North Sea Herring and salmon heads are used with standard amounts. Due to Australian Quarantine regulations the North Sea Herring has been substituted with local Scaly Mackerel in recent years. Anecdotal information from fishers indicates there should not be an effect on catch rates. The data recorded are shown below in Appendix 2.

Tagging

After the completion of the IBSS sampling, there is an additional two days spent in the shallows (<36 m) tagging lobster for growth and movement information. The tagging protocol is outlined below, though results in terms of movement and growth are detailed in section 3.5; 3.8).

Each year tagging in shallow waters is undertaken for two days after the IBSS at Dongara and Lancelin. During each tagging day, all male lobsters caught with a carapace between 65 and 75 mm, and without missing appendages are tagged with a Hallprint ™ "standard T-bar anchor tag" ventrally between the first and second abdominal segments (Plate 4.3).

Plate 4.3 – Tagged lobster showing location and type of tag

Ventral tagging reduces the likelihood of damage, thus increasing return and identification information Melville-Smith & Chubb (1997) .  Detailed information on each lobster is also recorded as during the IBSS (above) and each lobster is returned to its approximate location after being tagged.

Both the IBSS data and tagging data are stored in a specific SQL based database for preservation and manipulation.

Analysis

Data from the IBSS is used to construct a number of annual indices, used in the management of this fishery. These include the fishery independent BSI and, estimates of female size at maturity. Of these indices, the most important for use in the management of this fishery is the fishery independent BSI.



*Fishery Independent Breeding Stock Index (BSI)*

Breeding stock indices (BSI) are produced for the northern and southern coastal and Abrolhos regions, with coastal surveys conducted at Kalbarri, Dongara and Jurien used to produce the northern (Zone B) index and Lancelin and Fremantle used for the southern (Zone C ) index. Each index is an adjusted Least Squares Mean (LSM) of eggs per pot lift (SAS Institute Inc.). The carapace length (CL) of each "mature" female (ovigerous setae – Figure 3.7b) is converted to an estimated seasonal fecundity based on a size-fecundity relationship and a size-double breeding relationship (Chubb 1991: equations 4.3.1-4). The estimate of egg production is a back-transformed value of the LSM of the factor, year, produced from a GLM of the log (number of eggs per pot lift), where year, location, sub-location nested within location, pot type, depth category, day pull and swell range, are all treated as factors.
The number of eggs in a single batch of eggs:

$$Fecundity = 1.92 \times CL^{2.69}. \qquad \text{Eq. 4.3.1}$$

Probability that a female will spawn twice:

$$Pdblspawn_{ZoneB} = 1 + \left(1/\left(1 + \exp\left(4.075 - 0.0495 \times CL + 0.484\right)\right)\right) \qquad \text{Eq. 4.3.2}$$

$$Pdblspawn_{ZoneC} = 1 + \left(1/\left(1 + \exp\left(4.075 - 0.0495 \times CL - 0.484\right)\right)\right) \qquad \text{Eq. 4.3.3}$$

$$Pdblspawn_{ZoneA} = 1 + \left(1/\left(1 + \exp\left(6.675 - 0.1063 \times CL\right)\right)\right) \qquad \text{Eq. 4.3.4}$$

where $CL$ is the carapace length.

### *4.3.2 – Results*

*Fishery Independent Breeding Stock Index (BSI)*



All three zones within the fishery showed an increase in BSI since the inception of the IBSS in 1991, through the 1990s, reaching a peak in 1999 or 2000 (Figure 4.9 a-c). In each zone the BSI has declined throughout the following decade to levels similar to those estimated for the early 1990's. The fishery-independent BSI provides a cross check to the long-term fishery-dependent BSI that is currently the basis of the BRP. While analysis to determine the fishery-independent BSI attempts to standardize for factors affecting its variability, particularly fishing efficiency, it is difficult to standardize for annual environmental factors (e.g. water temperature) affecting catchability.

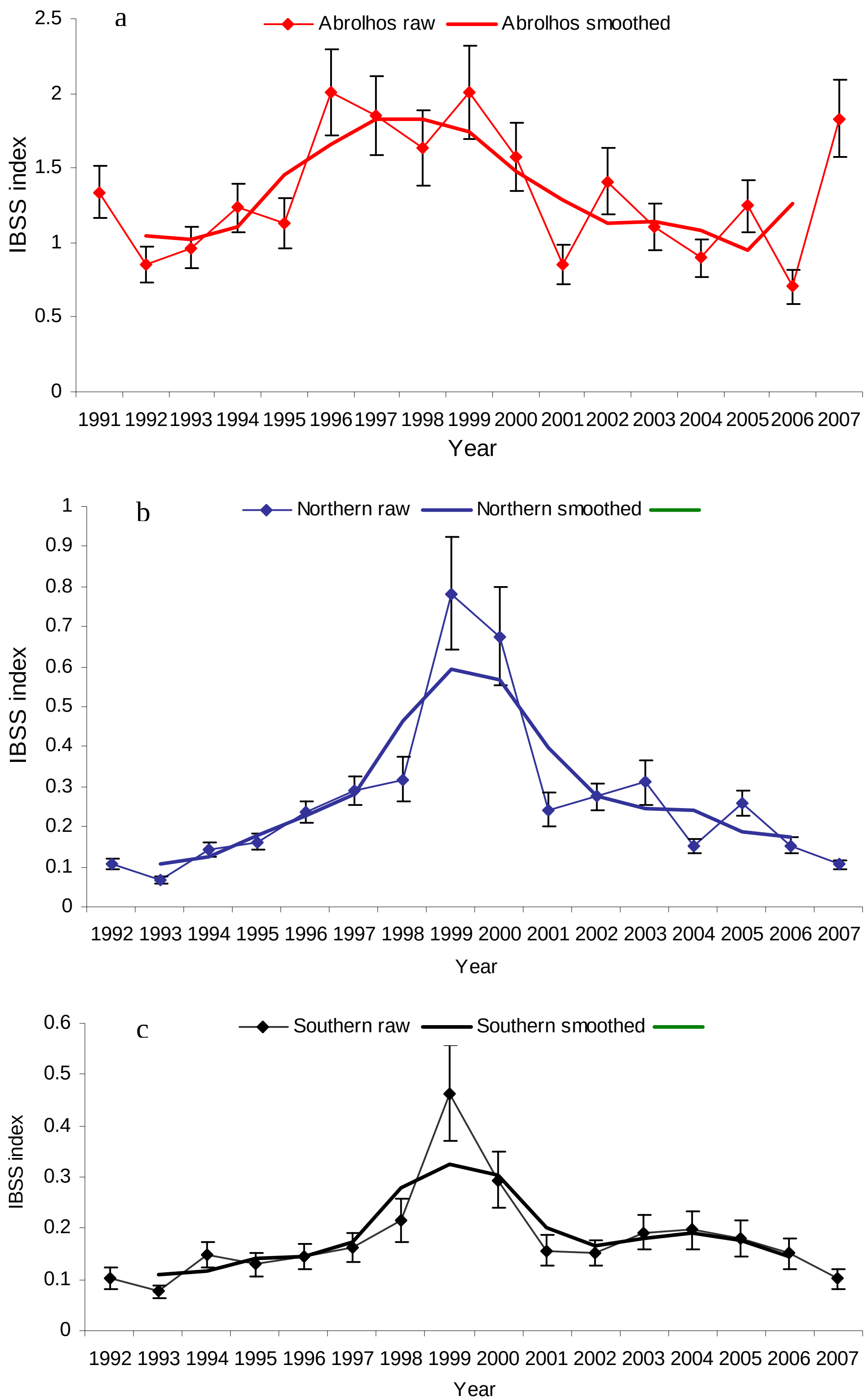



Figure 4.9 – IBSS indices (± 1 SE) and three year moving average (thick line) for; a) Zone A; b) Zone B and; c) Zone C

## 4.4 – Volunteer Research Log Books

Fisheries Research Logbooks have been issued to fishers since 1963. They are given to approximately 60% of commercial fishers each year with 30-40% of all fishers completing the logbook. Returns from fishers varied between years, from a peak in 2002/03 of 41% of the whole fleet to current levels (2006/07) of around 28%. Over the last 8 years, on average, 36% of the fleet have returned Research Logbooks, with almost all (~90%) of those returning the logbook completing the voluntary section, which provides additional information on catches and environmental conditions (Appendix 3). The research logbooks provide the Department of Fisheries with detailed information on commercial fishers' practices, daily catch and effort by depth at a higher spatial resolution than the CAES data. A summary of their catch rate is returned to individual fishers at the end of the year with a comparison to the zone average.



Key indices produced from these logbook data include;

- Logbook catch and effort by $1^{o}$ S transect in waters <20 and > 20 fm (36 m).
- Catch rate of spawners, setose and maximum size females that are returned to the sea. An estimate of the total number of setose returned is obtained by weighing up the logbook data to the total fishery (CAES data) where necessary.
- Catch rate of undersize lobsters.
- Daily index of swell height.
- Octopus catches and more recently, lobster mortalities.

### *4.4.1 – Methods*

The logbooks are divided into two sections, a core section and a voluntary section (Appendix 3). The data is stored in an SQL-based database that can be queried to produce catch and effort statistics on fine spatial and temporal scales.

## *4.4.2 – Results*

Over the last 20 years volunteer logbooks have provided data over much of the fishery (Figure 4.10). Areas of high logbook returns correspond to areas of high fishing effort, namely Big Bank (north of the Abrolhos Islands), Geraldton to Dongara, and the area around Lancelin (north of Perth). This distribution is very similar for each individual year, as shown by returns from the last fishing season (2005/06) (Figure 4.11).



The large proportion of fishers that fill out logbooks and the spatial coverage of this data means that general trends exhibited by the logbooks are representative of the general fishing patterns that occur across the fishery.  For example, the daily catch rates determined from the research logbook program, showing as series of peaks and troughs associated with changes in the fishery (whites to reds) and also lunar effects, are representative of those that occur across the entire fleet (Figure 4.12).

This fact allows logbook data, which is recorded on a fine temporal and spatial scale, to be used *pro-rata* to divide-up CAES data into finer scales than their reported monthly time steps and $1^{o}$ blocks (Section 4.5).

The logbooks also provide data additional to that recorded by other data sources, including the numbers of setose females captured and returned to the water.   The return of setose females was a management initiative introduced in 1992/93 (Box 2.1).   Since then the numbers of setose females returned have been recorded as part of the volunteer research logbook program.

These data show that there has been an overall increase in the weight of setose females returned in all three zones up until this most recent season (2006/07) (Figure 4.13). Both coastal zones peaked during 1999/00 with the recorded catches, and decreased slightly over the next few years. There was a recovery in all three zones in the early 2000s, however Zone B has declined since 2004/05, with Zones A and C falling this year, and Zone C markedly.

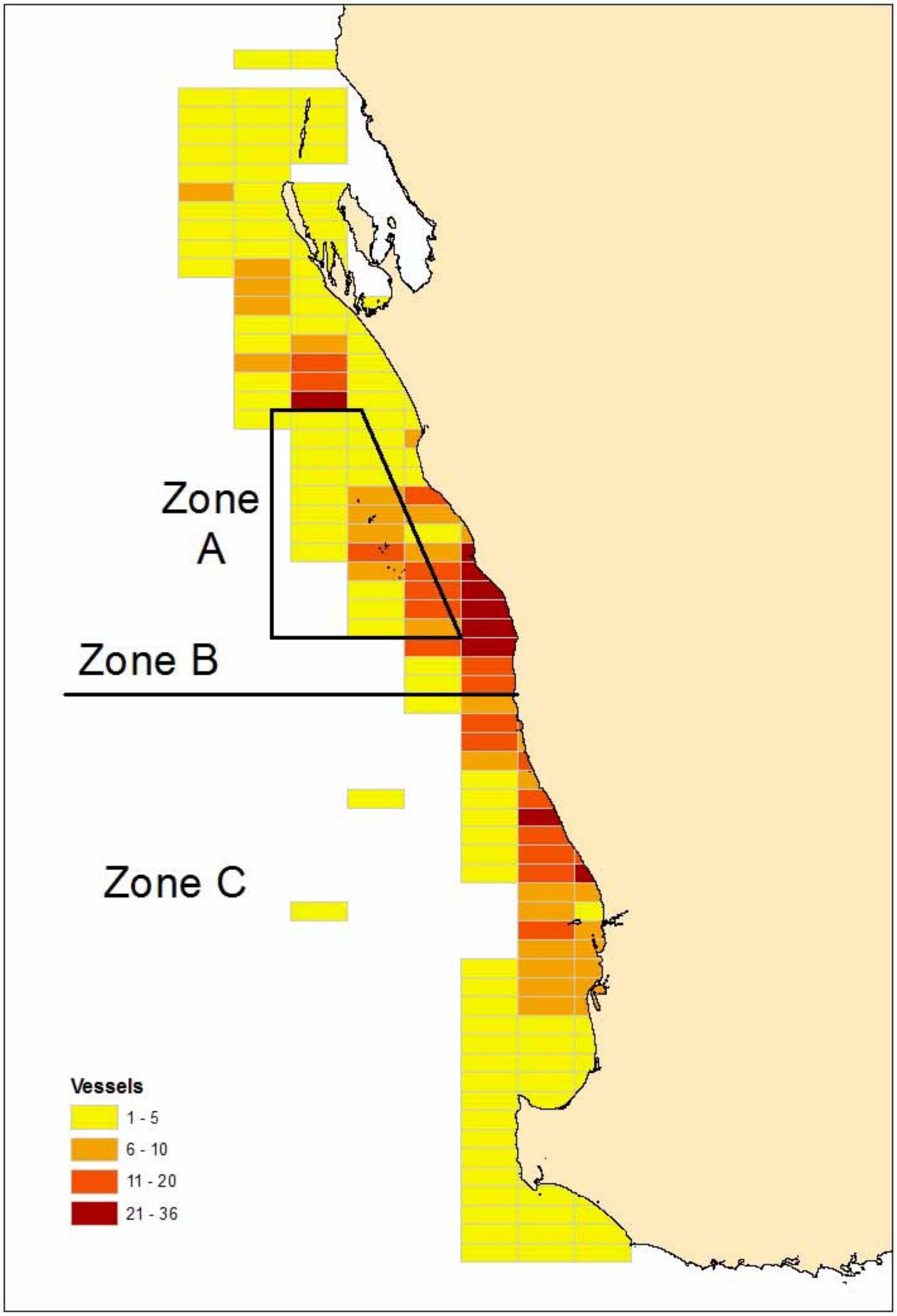



Figure 4.10 – Average number of vessels that returned logbooks for each block in seasons 1986/87 through to and including 2005/06.

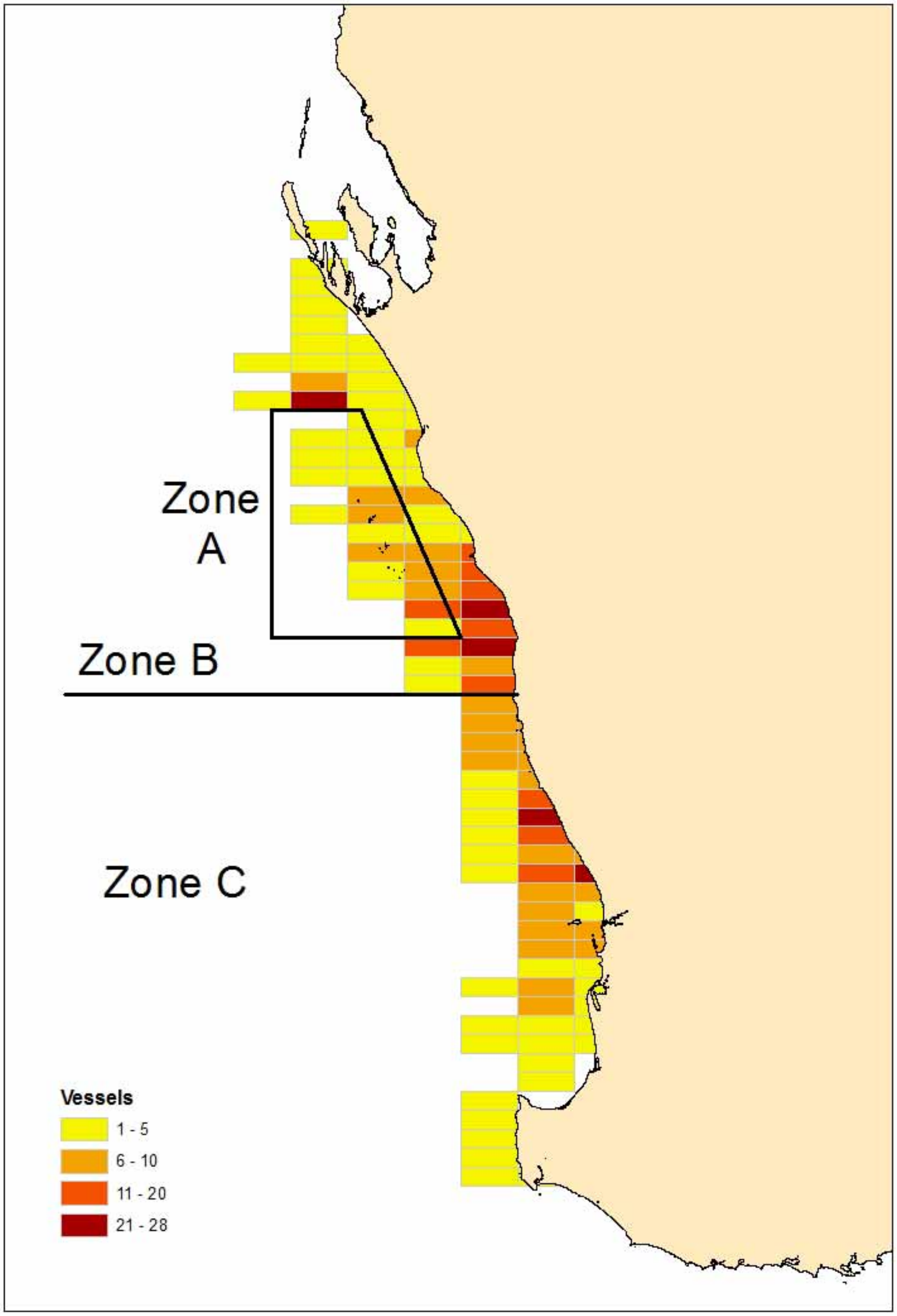



Figure 4.11 – Number of vessels that returned logbooks for each block in the 2005/06 season.

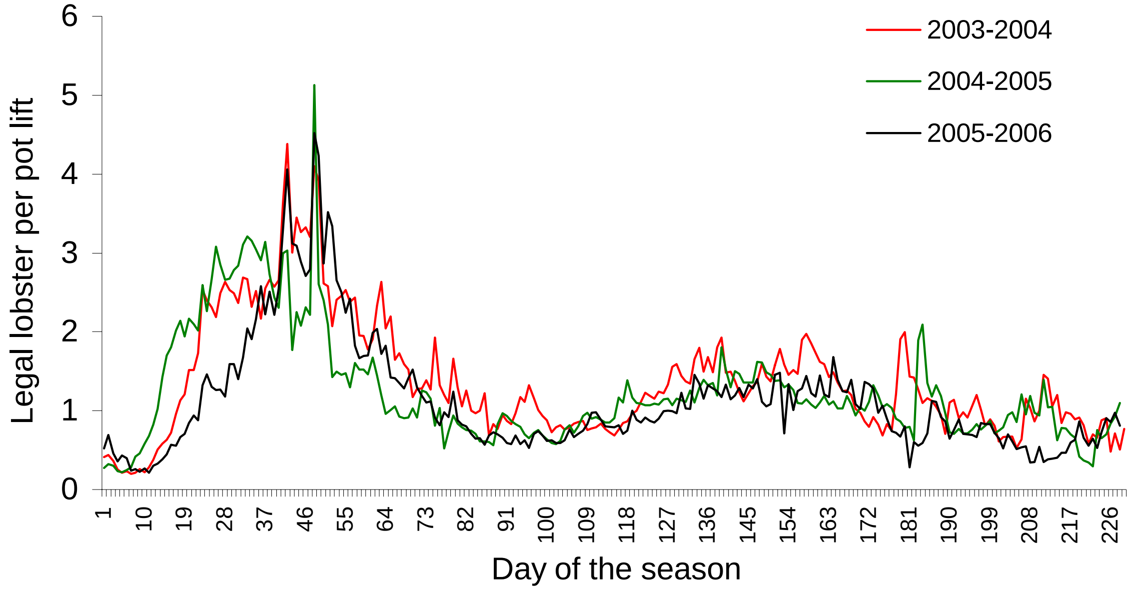



Figure 4.12 – Daily catch rate of coastal sites for last three seasons (2003/04 – 2005/06)

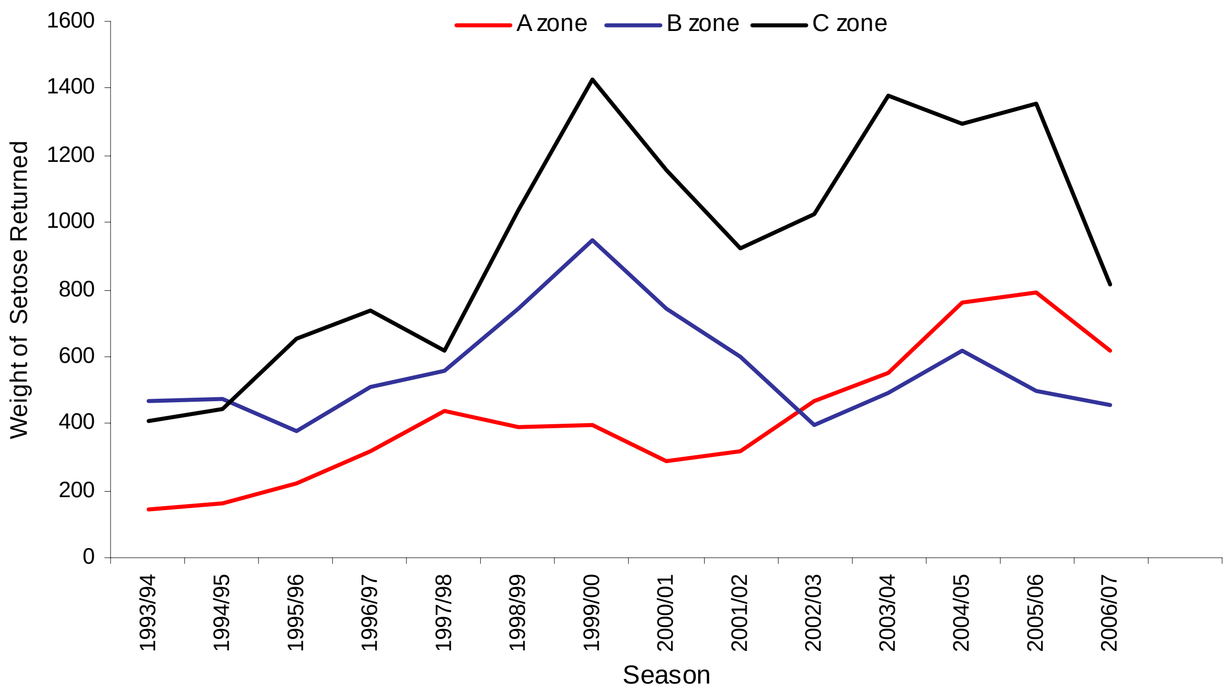



Figure 4.13 – Weight of setose females returned by fishers each season since 1992/93 in each region of the fishery

## 4.5 – Catch and Effort Statistics (CAES)

The compulsory catch and effort monthly returns from commercial fishers are used to assess the total commercial catch and effort within the fishery. This is important as it provides crucial information as to the performance of the fishery, enabling inter-annual trends in catch and effort to be examined. Additional to this is a voluntary fishing gear survey, sent out annually at the start of every season, which is designed to record technology changes occurring within the fleet. Many indices, important for management of the fisher, are produced by CAES returns, including:



- Monthly catch and nominal effort by 60 nm blocks in each management zone of lobster.
- Monthly catch and effort by 60 nm blocks in each management zone of by-catch species, i.e. octopus, deep-sea crabs.
- Interactions with threatened, endangered and protected species.

CAES data were collected by regional officers sporadically pre 1941, with the Chief Inspector in 1941 instigating a fishery statistics collection system based on $1^{o}$ latitude and longitude blocks to record fishing effort and catch which was returned to the regional officer. These were then summarised by block and sent to head office for further analysis.

In 1949 a separate cray-fisherman return was introduced to provide more information on the fishery, including gear used and the weight of the catch. This system remained in place until 1963. From 1964 a standardised Commonwealth statistic collection system was initiated under the direction of the Commonwealth Bureau of Census and Statistics, which was entered into a computer from 1967.

Issues with the method of data collection and potential inaccuracies saw a major alteration to the statistics collection in 1975, leading to an overhaul of the statistics system in terms of the data collected. Returns were stored electronically from 1975 with the system taken over by the Department of Fisheries in 1989, however there was still some ABS assistance in report production. Since 1992, all aspects of the CAES database and reporting have been the sole responsibility of the Department of Fisheries.

### *4.5.1 – Methods*

Returns from fishers are received monthly with a deadline of 15 days after the end of the month. Fishermen who are in arrears with their returns, are contacted every few months by the CAES returns officer requesting their return. Once a year a letter is sent to remind fishers of their licensing requirements to provide a return. This ultimately provides an annual return rate of around 98% by the end of the financial year.



Data collected in the returns (Appendix 4) is vetted upon its receipt. Comprehensive checks are run after data entry is completed comparing data entered to processors returns received and to details from the Fisheries Licensing system. This includes looking at irregularities in the number of days fished (if greater than is allowed) and, incorrect block numbers (fishing in a block outside the zone they are licensed for). When catches from CAES do not match that provided by lobster processors, both datasets are interrogated to determine the inconsistencies and correct where necessary. This provides a comprehensive, and largely accurate database as a baseline for comparing CAES data between blocks, zones and season.

At the end of each season, a gear survey is sent to all fishers, detailing the type of gear used, boat modifications and technology installed. This information has been collected since 1989/90 and has been used to assess changes in fishing efficiency (Section 5.1).

## 4.6 – Processor Returns

Each month, forms are returned to the Department of Fisheries from processors of western rock lobster as part of their licensing requirements. This information is collated, and provides the most accurate measure of the total catch of the fishery.



### *4.6.1 – Methods*

Processing factories deal with almost 100% of the commercial catch landed, with only occasional small domestic sales. Usually at times of low prices and high catches around Easter and Christmas (E. Barker pers. comm.) large sales are made throughout Australia, primarily to large super market chains. There are five companies that deal with the export (unrestricted) processing of western rock lobster, while a small portion of the catch goes to processors solely for the domestic market (restricted). As such there are different reporting requirements for the processor licence holders.

Unrestricted processors are required to fill out a monthly return log (Appendix 5a) and monthly breakdown of products (green tails, whole cooked, whole green and live) by grade (A – H) (Table 4.3) and market (export or local) (Appendix 5b). Restricted processors are only required to submit a monthly return log (Appendix 5a)

Table 4.3 – Processor grades for *Panulirus cygnus* showing the weight and carapace length (CL) ranges.

| Lobster Grade | Grade Weight (g) | Female CL (mm) | Male CL (mm) |
|---|---|---|---|
| A | 140 – 179 | 76 – 77 | 76 – 79 |
| B | 180 – 239 | 78 – 85 | 80 – 88 |
| C | 240 – 279 | 86 – 90 | 89 – 94 |
| D | 280 – 359 | 91 – 98 | 95 – 103 |
| E | 360 – 479 | 99 – 108 | 104 – 115 |
| F | 480 – 599 | 109 – 117 | 116 – 126 |
| G | 600 – 667 | 118 – 121 | 127 – 131 |
| H | 668 + | 122 + | 132 + |

Processor returns (grades, product lines etc. Appendix 5b) are entered into a SQL database and used to calculate the total catch by zone, product lines and grades.

Each month a breakdown by grade product line is sent to processors. Another monthly summery sheet is sent to District offices of the Department of Fisheries, and processors outlining the catch in that month for three areas Fremantle (Capes to Wedge Is.), Jurien (Green Is. to Green Head) and Geraldton (Leeman to Shark Bay). This is compared to the catch at the same time last year and also the 10-year cumulative average to give an indication of how the season is progressing.

## 4.7 – Environmental Data

Environmental conditions such as water temperatures and oceanic currents greatly influence their survival and behaviour of larval *P. cygnus*. As such, a number of environmental variables is sourced by the Department of Fisheries to determine what effects variations in climatic conditions have on the WCRLMF. Most of the data outlined below are gathered from the Australian Government's Bureau of Meteorology (BOM). These data complement environmental data collected by the Department of Fisheries during monitoring programs (see 4.1 Puerulus, 4.2 Commercial Monitoring, 4.3 IBSS, 4.4 Logbooks).



### *4.7.1 – Methods*

Rainfall

Monthly rainfall data is collated from Bunbury, Mandurah, Rockingham, Fremantle, Rottnest, Lancelin, Jurien, Dongara, Geraldton and Kalbarri (e.g. Bureau of Meteorology 2007). Rainfall is used as a proxy for westerly winds associated with storms crossing the coast in winter/spring.

Sea Level

Sea level data for the west coast is obtained from BOM recordings at Hillarys (http://www.bom.gov.au/oceanography/projects/abslmp/abslmp.shtml), and from the National Tidal Centre for Fremantle sea level. This provides hourly sea level data as well as data on Water Temperature, Air Temperature, Barometric Pressure, Wind Direction, Wind Gust, Wind Speed. Archived data is available from 1992 with current data updated monthly.

Reynolds Satellite Sea Surface Temperatures

Obtained monthly from the Commonwealth Scientific and Industrial Research Organisation (CSIRO), the Reynolds Satellite temperatures have provided sea surface temperatures since January 1982. Temperature is recorded for 1-degree blocks ranging from $10^{o}$ – $50^{o}$ S and $90^{o}$ – $130^{o}$ E.

Southern Oscillation Index (SOI)

This is calculated from the monthly air pressure difference between Tahiti and Darwin (BOM website). It is sourced from the BOM (http://www.bom.gov.au/climate/current/soi2.shtml) and provides a monthly value of the SOI, with archived values available from 1876.



The SOI reflects changes in global oceanic conditions and is usually used to denote either El Niño or La Niña weather conditions. The change in the temperature of eastern and central Pacific alters the strength of trade winds, rainfall patterns and also oceanic currents. While the majority of the impact of these climatic conditions influences the eastern seaboard of Australia (bordering the Pacific Ocean), it does impact the Leeuwin Current off the West Australia coast. Its impact on the WRL is outlined in sections 4.1 and 5.2.

### *4.7.2 – Results*

Southern Oscillation Index (SOI)

El Niño events (indicated by the SOI) affect Leeuwin Current strength, which can be measured by the mean sea level at Fremantle (Pearce & Phillips 1988). The changes between years as a result of ENSO events, has a corresponding effect of puerulus settlement (Figure 4.14).

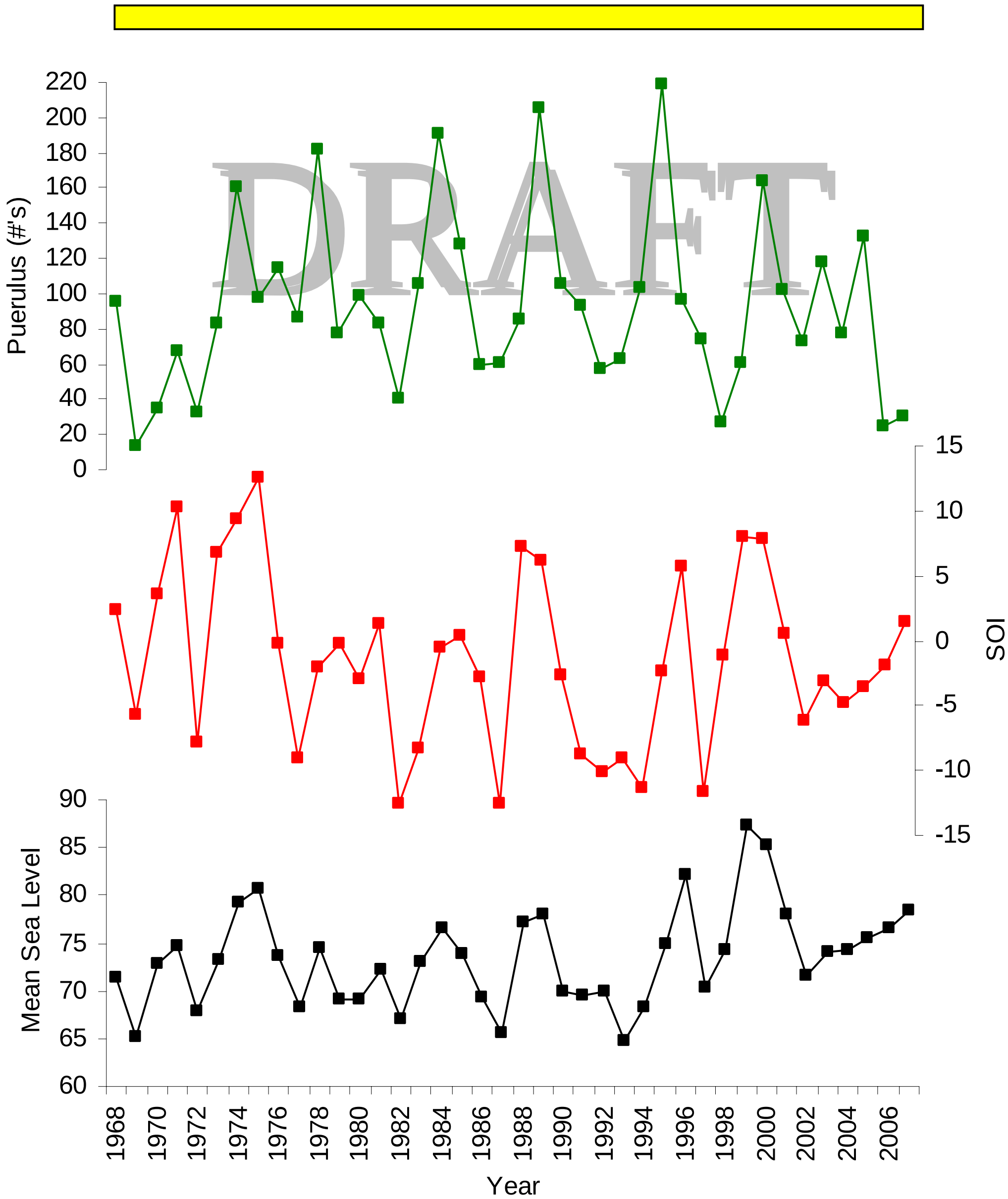



Figure 4.14 – Mean sea level for Fremantle (black), and the Southern Oscillation Index (red), puerulus settlement (green) showing the effects of El Niño events (yellow blocks) (Updated from Pearce & Phillips 1988).

## 4.8 – Recreational Fishery and Surveys

The recreational rock lobster fishery primarily targets *P. cygnus* but also takes southern and tropical rock lobster species using pots (traps) or by diving. Most of the fishing effort is focused on the *P. cygnus* and is concentrated in the Perth metropolitan area and Geraldton.



### *4.8.1 – Methods*

Mail Surveys

Information on the catch, effort and fishing characteristics of recreational rock lobster fishers has been collected in Western Australia since 1986/87 season, by an annual mail survey of randomly selected rock lobster licence holders. Initially this survey was sent out to one in four fishers with their licence expiry reminder letters, which usually went out at the start of a new season, apart from the 1988/89 season when all licence holders were sent a questionnaire.

From the 1995/96 season, a nominated quantity of licence holders has been randomly selected at the end of the fishing season from the recreational lobster licence database. These people have had the survey form mailed to them and have been encouraged to return the completed questionnaire by a post-free provision, a service provided since the initial survey in 1986/87. Questions in the survey remained relatively similar from inception up until the 1998/99 season, where additional questions were added (Appendix 6 and 7).

Questions have been assigned to a number of categories addressing:

Participant details, such as name, address and phone number. Additional data was then sought on the age, gender, main language spoken at home, highest education, email address as well as the number of years they had been recreationally lobster fishing and what licence type (rock lobster or umbrella) they used.

Fishing details, such as whether the licence holder fished that season, and if so how (methods of fishing e.g. pot, dive or other), when they fished, and how many lobsters (southern, western and tropical) they caught. This was initially examined as; which months they fished, when most of the fishing was conducted (weekend, weekdays, school holidays or annual leave) and how many days were fished, broken down by fishing method. The number of lobsters caught (also broken down by method) was recorded; as was the number of pots they pulled each day. This was further refined by getting the number of days fished for each month and the catch of that month, broken down by fishing method. This has enabled a more thorough examination of the method, fishing effort and the associated catch, to be made.



Location details of fishing effort (broken down by the methods used) were also refined in later mail surveys. Initially the location data was quite course with the location (town name) and postcodes used as identifiers for location, with an indication of the methods used at that site. This was later broken down into 23 coastal regions (Figure 4.15) with the numbers of days fished by each method in each location. The smaller blocks in the more recent surveys have allowed for a better resolution of lobster fishing along the WA coast.

While *P. cygnus* is the major targeted species, other rock lobsters taken are also surveyed with the total number of tropical or southern lobsters caught (broken down by method) recorded by the survey.

A lot of the more recent information gathered from the mail survey centres on the attributes of the fishers. This includes; if they are a boat owner and the length of boat, or if they have regular access (excluding charter boats) to a boat. Also the equipment on the boat (B/W echo, colour echo sounder, view bucket, radar, pot winch, GPS) is recorded, along with the pot types and the depth of potting.  Depth ranges of divers are also surveyed as well as the diving equipment used (e.g. SCUBA, snorkel, hookah, torch, loop, hook or dive computer) and if they have dived off charter boats (no. of days and catch). These data provide the ability to track the influence of changes in gear technology on the ability of recreational fishers to catch lobster.

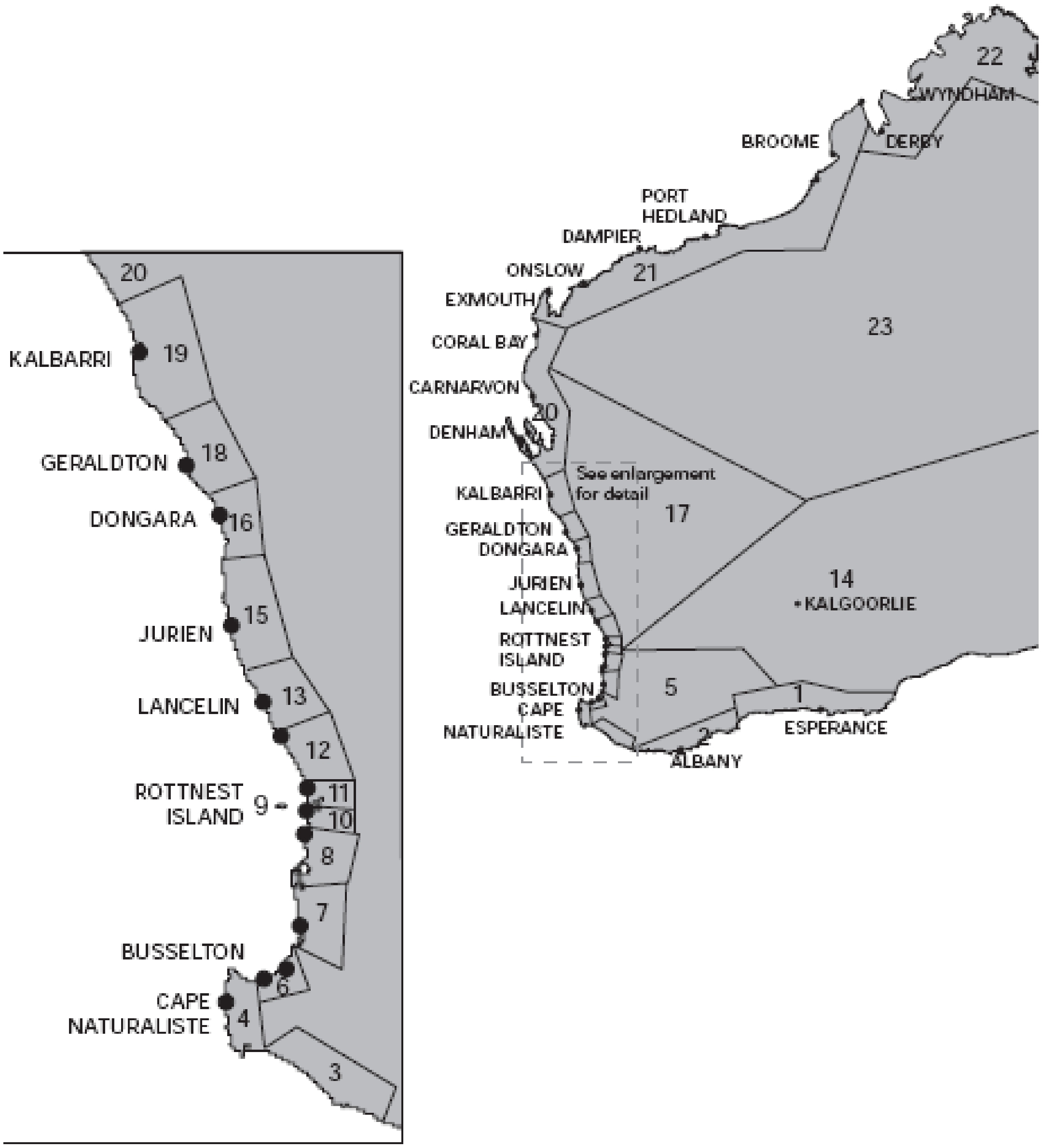



Figure 4.15 – Map codes for regions of licence holder residence and fishing effort (Melville-Smith & Anderton 2000).

One survey (1998/99), examined fisher attributes to a wide range of issues including, management effectiveness, issues with enforcement, fishery regulations (bag limit, pot limit), degree of recreation illegal fishing activities, and fishers’ knowledge of current regulations (size limits etc.)

Details of results and analysis can be found in Melville-Smith & Anderton (2000)

Telephone Diary Surveys

Telephone diary surveys of recreational rock lobster fishers have been undertaken in 2000/01 and 2001/02 and have run annually from 2004/05. This initially involved 400 to 450 people being called randomly from the licence holder database, however in the 2006/07 season it has increased to 800 participants. Participants are selected randomly from two licence types, with 50% holding a rock lobster licence and 50% hold an umbrella licence (covering all recreational licensed fisheries).



Trained interviewers initially call the randomly selected licence holders four or more times before they are deemed to be non-respondents. Respondents are sent a diary and asked to fill it out for each day they go fishing for rock lobsters. Each month (or fortnightly if they are a regular fisher), they are phoned and asked to read out from their diary the days they went fishing and their catch (Table 4.4). Over the length of the season 90 – 95% of fishing events are diarised.

Table 4.4 – Data recorded as part of the phone diary survey

| Where and When | Fishing Method | Times | Catch |
|---|---|---|---|
| Location | No. of Pots | Start time | Species |
| Date | Diving | Finish time | No. Kept / Released |

Interviewers also ask additional information such as the depth of fishing, method of diving, if it was boat or shore based, and any other comments. Location information is pooled up into regions (see Appendix 8).

In 2005/06 a phone diary survey of registered boat owners residing on the west coast also estimated the catch and fishing effort of western rock lobsters.

Boat Ramp Survey

The 2006/07 season saw for the first time, a boat ramp survey. This survey has monitored the lobster catch taken by fishers from two popular boat ramps in the northern metropolitan region (Hillarys and Ocean Reef) for 30 random days throughout December and January. These locations were chosen as they were one of the sub regions of the Telephone Diary survey and an enforcement officer was used as he had the power to demand to see the catch of fishers. The boat ramp survey will be used to validate catch rate estimates by the telephone diary survey in the Hillarys and Ocean Reef Area.

### *4.8.2 – Results*



Mail survey response rate

Prior to the 1995/96 season, when the Department of Fisheries licensing section was responsible for including survey forms in the licence reminders sent out, there is some uncertainty in the exact numbers of surveys that were dispatched due to human error. There is therefore no accurate record over this period for the exact number of surveys sent out and as a result, no way to determine response rates. However, the 1988/89 survey, which was sent to all licence holders, had a response rate of 36%. This figure is assumed to be typical of all surveys prior to 1995/96 (Figure 4.16).

There have been numerous inducements or reminders in certain years to increase survey returns. Offering an inducement or sending reminders increased return rates over those that had no inducement or reminder to the return the questionnaire (Figure 4.16).

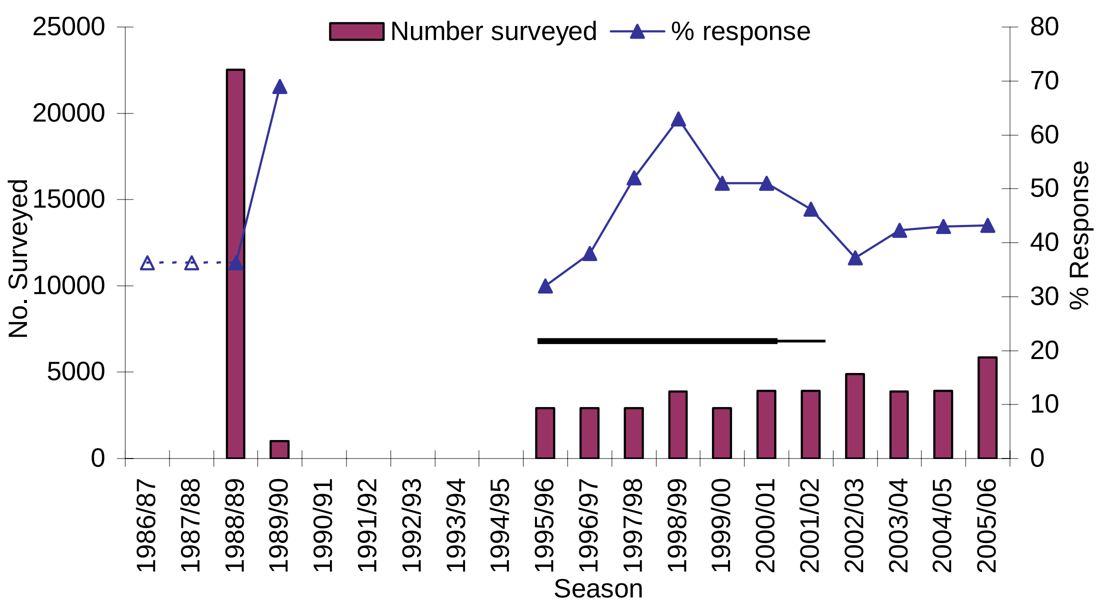



Figure 4.16 – Return rates in recreational lobster fisher mail survey. (open triangles and dashed line indicates estimated return rates from the 1998/89 survey). Thick line indicates period where inducements (with or without reminders) were offered, with the thin line being when only reminders were sent.

While inducements or reminders did alter the response rate, it did not alter the estimates of key variables such as total recreational catch. As such, response bias is standard throughout the duration of this study and not influenced by inducements (Thomson & Melville-Smith 2005).



Comparisons of survey techniques

The two major survey techniques employed to examine recreational catch and effort, have been the dedicated phone diary survey and the mail survey. There have been some major discrepancies between the catch and effort results of the two survey methods. For the four seasons that the phone diary was conducted, a direct comparison was possible with the mail survey (Table 4.5) (IFAAC 2007).

Table 4.5 – Comparison of different variable estimates using diary and mail survey data for various seasons in which both methods were performed. Adapted from IFAAC (2007)

| Variable | 2000/01 | | 2001/02 | | 2004/05 | | 2005/06 | |
|---|---|---|---|---|---|---|---|---|
| | Diary | Mail | Diary | Mail | Diary | Mail | Diary | Mail |
| Response Rate | 83% | 51% | 78% | 51% | 82% | 43% | 84% | 43% |
| Effort (days) | 15.5 | 26 | 14.4 | 27 | 10.3 | 29 | 10.3 | 25 |
| Total Recreational Catch (t) | 332 | 560 | 235 | 545 | 201 | 721 | 131 | 408 |
| CPUE (lobsters/day) | 1.81 | 1.5 | 1.63 | 1.5 | 1.95 | 1.6 | 1.64 | 1.3 |

There are two main biases inherent in the mail survey that may result in the different catch estimates of the recreational sector.

The mail survey requires respondents to recall their catch and effort over a 7.5 month period. This recall period is considerably more than the phone diary survey that requires participants to record fishing activity in a diary after each fishing event combined with monthly telephone contact.

The mail survey is also affected by non-response bias, where the fishing activity of those who return the questionnaire is different from those who do not respond. The mail survey had response rates of around 40 - 50%, compared to the phone diary survey, which had response rates of around 80% (Table 4.5).

The phone diary survey minimises both non-response and recall bias and is therefore likely to produce a more accurate estimate of recreational catch and effort than the mail survey.

There are plans to continue the phone diary survey to at least 2009/10. The mail and phone diary surveys have produced very different catch estimates to date and so there was a need to develop a conversion factor to adjust the results of the mail survey to those of the more accurate phone diary survey.



The conversion factor for adjusting total catch from the mail survey to those of the phone diary survey has only been possible for the four seasons that the phone diary survey has been conducted. The conversion ratios are shown in Table 4.6 (IFAAC 2007).

Table 4.6 - Different ratios for converting diary survey estimated total catch to that of the mail survey. Ratios have been determined using a linear model with no intercept using data for different seasons (indicated with a tick) (IFAAC 2007).

| Model | 2000/01 | 2001/02 | 2004/05 | 2005/06 | Ratio (s.e) |
|---|---|---|---|---|---|
| I | √ | √ | | | 1.90 (0.30) |
| II | √ | | √ | | 2.20 (0.84) |
| III | | √ | √ | | 2.85 (0.62) |
| IV | √ | √ | √ | | 2.23 (0.50) |
| V | √ | √ | √ | √ | 2.29 (0.42) |

Conversion factors for the four seasons in which the phone diary survey and mail survey have been conducted vary between 1.9 and 2.9 (Table 4.6). However, to maintain some consistency in conversion factors over the next few years, it has been decided to use the conversion ratio that was established for the 2000/01 and 2001/02 seasons of 1.9 (Table 4.6). When the conversion factor is applied to catch rates since the inception of the mail survey (1986), it demonstrates a much reduced recreational catch (Figure 4.17).

As such the Department of Fisheries' position on recreational catch is:

*"… the best estimates of the recreational catch of western rock lobster over the last 17 years are obtained by using the mail survey data which has been suitably adjusted using the calculated level of bias."*

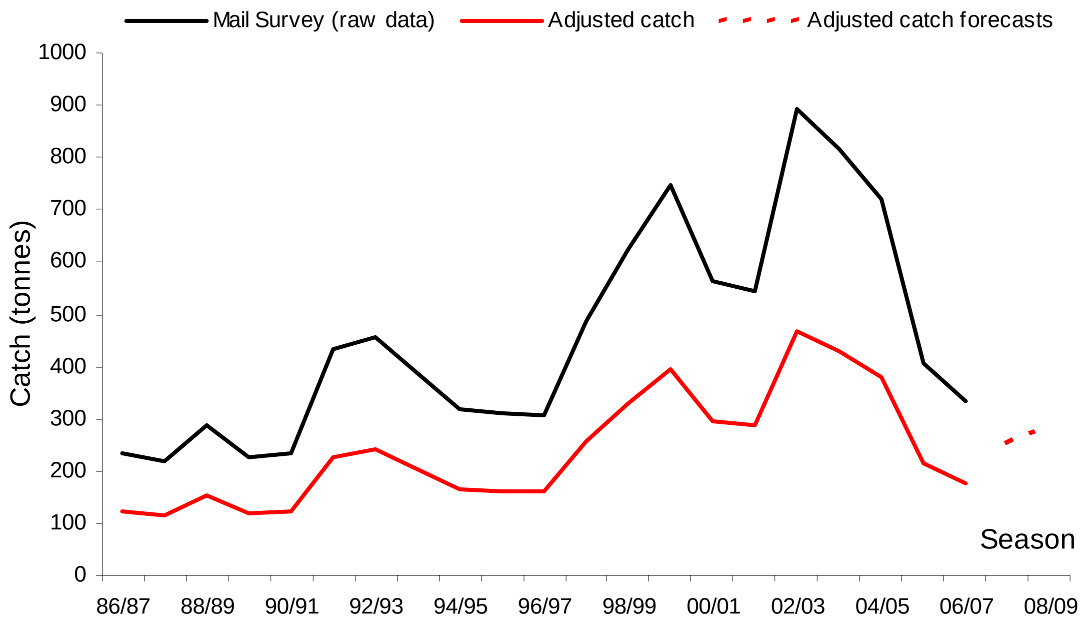



Figure 4.17 - Recreational catch estimates based on 'raw estimates' from the mail survey (black) and the adjusted estimates calculated from the 'phone diary based' correction factor (red). The forecast recreational catches for 2007/08 to 2008/09 are based on puerulus settlement during 2004/05 and 2005/06 (IFAAC 2007).

<u>Effort</u>

Most of the effort in the recreational sector is focused on just a few months near the start of the season before declining as the season progresses (Figure 4.18). The low number of days fished in November is a reflection of the season only opening in the middle of the month rather than a lower overall fishing effort (Melville-Smith & Anderton 2000). Similar results were also shown by phone diary surveys (Figure 4.19)

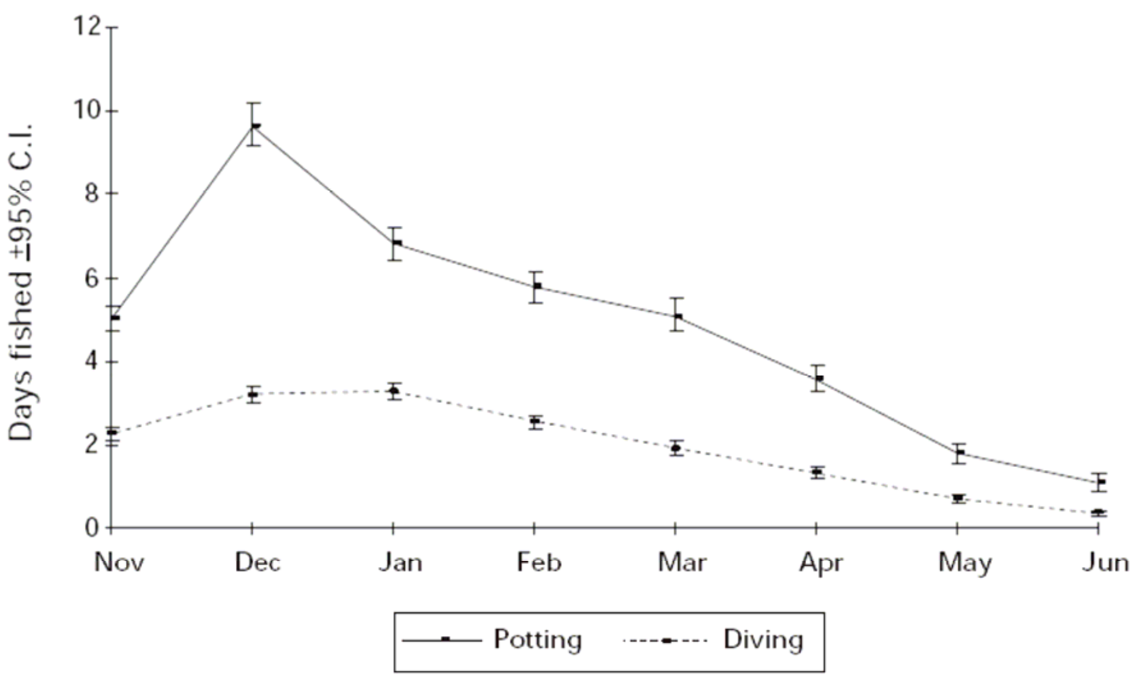



Figure 4.18 – Average number of days fished per month by recreational lobster pot and dive fishers who reported fishing in the 1998/99 survey (Melville-Smith & Anderton 2000).

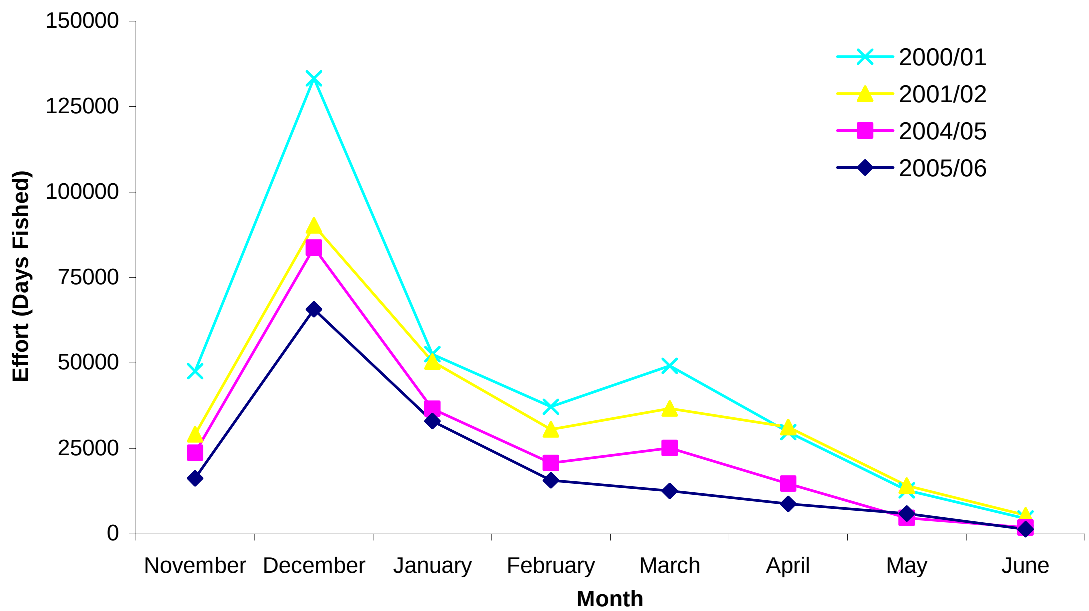



Figure 4.19 – Number of days fished by month from the phone/diary survey for the four seasons surveyed (Updated from IFAAC 2007).

Most of the fishing effort is focused in Geraldton (Zone B), Jurien Bay (Zone C) or the Metropolitan Area and surrounding areas (Mandurah – Lancelin; Zone C), with most licence holders residing in the Metropolitan Region (Figure 4.20) (Melville-Smith & Anderton 2000).



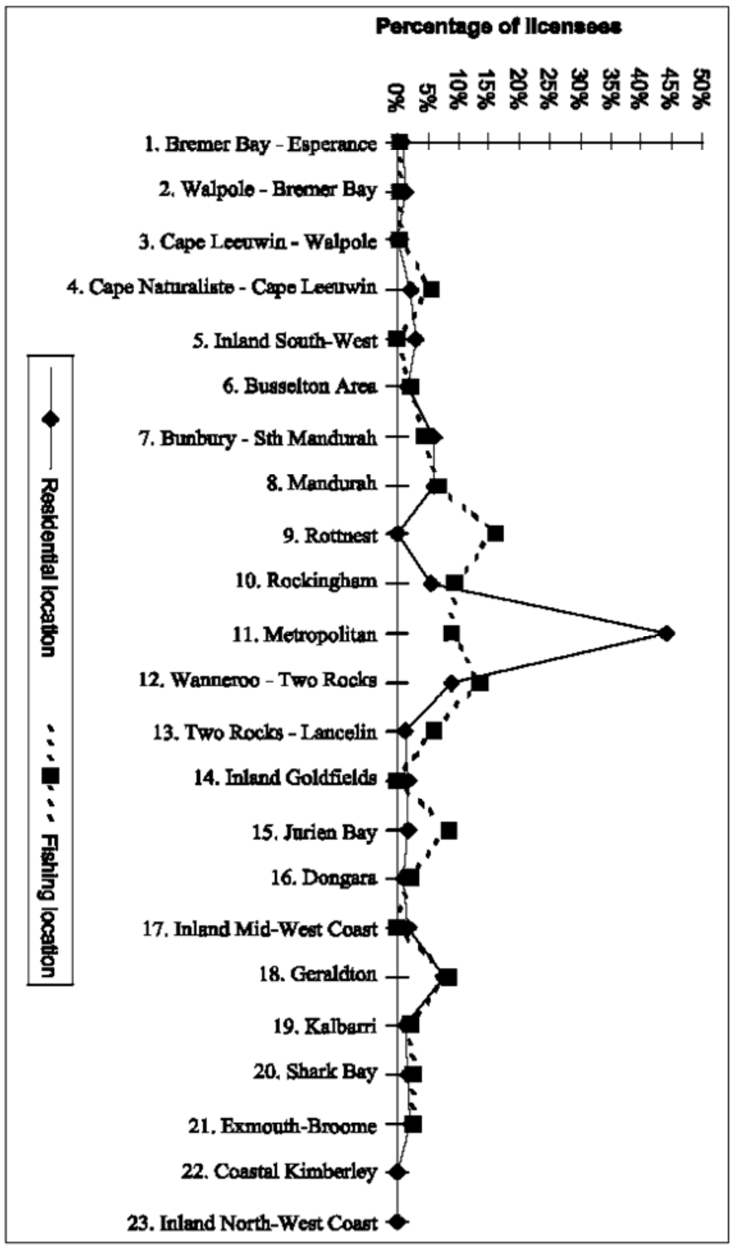



Figure 4. 20 – Location of residence and fishing for lobster licence holders (Melville-Smith & Anderton 2000)

Catch Rates

The recreational component of the total catch, based on adjusted recreational catch estimates (see Comparisons of survey techniques), differs between the northern (Zone B) and southern (Zone C) zones of the fishery. The northern zone (including zone A and B) has remained relatively stable at around 1-2%m while there are fluctuations in the southern zone (Zone C) with an overall increasing trend (Figure 4.21) (IFAAC 2007).

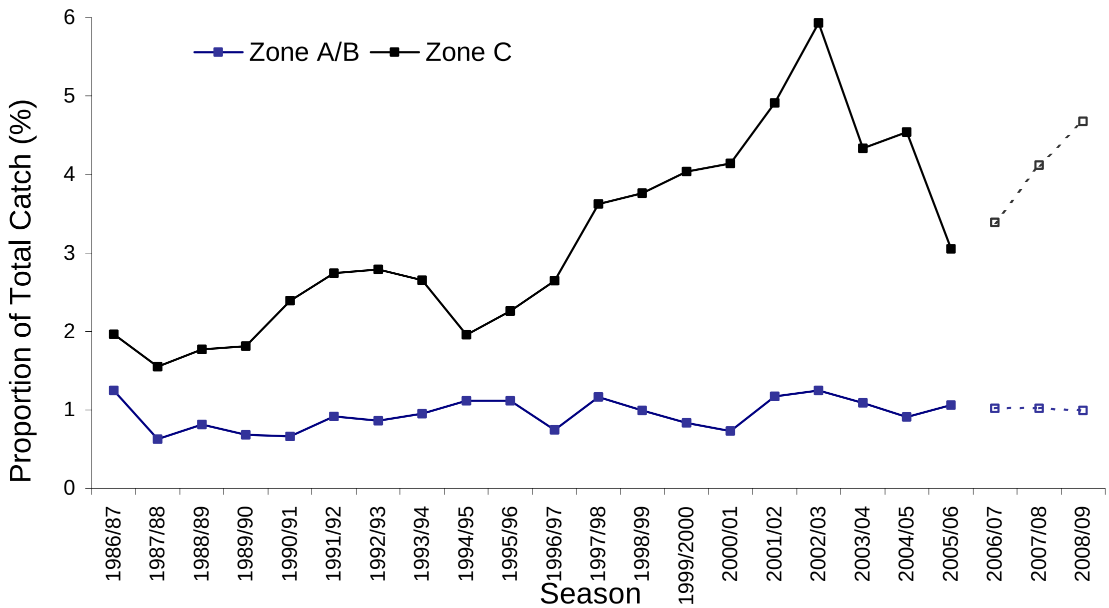



Figure 4.21 – The proportion (%) recreational catch for a zone compared with the total lobster catch in that zone (zones A/B and Zone C; using adjusted recreational catch estimates). The forecast percentages (dotted lines) are based on the expected commercial and recreational catches for the next three seasons (2004/05 to 2006/07). Note the recreational catch in Zone A is minimal and is included in Zone B (IFAAC 2007).

# 5 – Stock Assessment

## 5.1 Fishing Efficiency



Increases in fishing efficiency (fishing power) on measures of nominal fishing effort can lead to stock assessments being seriously flawed if these increases are not accounted for. The first assessment of fishing power increases in this fishery were conducted by Brown et al. (1995), who examined the impact of advances in fishing technology, such as echo sounders and Global Positioning Systems (GPS). Subsequent estimations of fishing efficiency have been made to account for more recent and subtle increases in fishing efficiency and their effects on nominal effort (Section 5.2).

See paper by Fernandez et al. (1997) for more details.

### *5.1.1 – Methods*

Changes in gear and technology

Brown et al. (1995) utilised several data sources to look at changes in gear and use of improved technologies on fishing efficiency from 1971–1992. These included;

- Compulsory monthly commercial fisher returns (Section 4.5)
- Voluntary research logbooks (Section 4.4)
- Boat gear and technology interviews (Section 4.5); plus a one off interview of 50 fishers, to account for information from 1971-1989
- Compulsory monthly processor returns (Section 4.5)

The effects of gear alterations were examined for a number of seasons in each management zone, in both shallow and deep water and during the “whites” and “reds” parts of the fishing season.

A GLM analysis was used to compare catch rates of vessels with and without the technology (e.g. GPS) after taking other factors that are likely to affect the catch rate into account (e.g. month, location of fishing).

*Soak Time*

A 48 – hour soak time (a pot that is left for 48 hours from the time that it is set, to the time that it is pulled), produced an average 20% in the catch rate in deep water (>37m). However, from 1971 – 1992 there was no significant trend in the proportion of days fished with 48 hour soaking time. Therefore this was not included in fishing efficiency calculations.



*Pot Type*

Pot type (Figure 1.3) usage did change during the period of this study, especially in the southern zone (Zone C). Logbook data showed that beehive pots produced better catch rates in deep water, while batten pots are more effective in shallow water. This was not borne out in the interview data of the 50 fishers. This efficiency change from pot type was applied to adjustments of fishing power in Zone C only, as this was the zone that showed major change in pot type usage.

### *5.1.2 – Results*

Pot type, along with increasing boat size, increasing bait use, use of plastic necks and steel bottomed traps were not included in the overall calculations of fishing power, rather they were applied separately to effort adjustments. These were combined into a "background" efficiency increase, which was subjectively assigned as an annual 1% increase.

*Colour Sounders and GPS*

Each of these technologies significantly ($p < 0.05$) increased efficiency by 29% in shallow water and 53% in deep water, over the study period 1971 – 1992. This equates to an annual increase of 0.5 – 2% increase in shallow and 1 – 4% increase in deep water.

These increases in efficiency for boats with the technology was applied to the percent of boats each year that had the technology to determine the annual increase in fishing efficiency for the whole fleet.

Standardised Effort and Nominal Effort

To standardise catch rates between seasons, measures of nominal effort are converted to effective effort by the addition of an annual efficiency increase estimate (Table 5.1, Figure 5.1).



Table 5.1 – The annual percentage increase in fishing efficiency across all zones, for both deep and shallow water, for fishing season from 1971/72

| | Annual increase in fishing efficiency (%) | |
|---|---|---|
| Fishing Season | All zones | |
| | < 20fm | > 20fm |
| 1971/72 | 1.0 | 2.0 |
| 1972/73 | 1.0 | 2.0 |
| 1973/74 | 1.0 | 2.0 |
| 1974/75 | 1.0 | 2.0 |
| 1975/76 | 1.0 | 2.0 |
| 1976/77 | 1.0 | 2.0 |
| 1977/78 | 1.0 | 2.0 |
| 1978/79 | 1.0 | 2.0 |
| 1979/80 | 1.0 | 2.0 |
| 1980/81 | 1.0 | 2.0 |
| 1981/82 | 1.0 | 2.0 |
| 1982/83 | 1.0 | 2.0 |
| 1983/84 | 1.0 | 2.0 |
| 1984/85 | 1.0 | 2.0 |
| 1985/86 | 1.5 | 2.0 |
| 1986/87 | 1.5 | 2.0 |
| 1987/88 | 1.5 | 2.5 |
| 1988/89 | 1.5 | 3.0 |

| | Annual increase in fishing efficiency (%) | |
|---|---|---|
| Fishing Season | All zones | |
| | < 20fm | > 20fm |
| 1990/91 | 1.0 | 3.0 |
| 1991/92 | 1.0 | 2.0 |
| 1992/93 | 1.0 | 2.0 |
| 1993/94 | 1.0 | 1.0 |
| 1994/95 | 1.0 | 1.0 |
| 1995/96 | 1.0 | 1.0 |
| 1996/97 | 1.0 | 1.0 |
| 1997/98 | 1.0 | 1.0 |
| 1998/99 | 1.0 | 1.0 |
| 1999/00 | 1.0 | 1.0 |
| 2000/01 | 1.0 | 1.0 |
| 2001/02 | 1.0 | 1.0 |
| 2002/03 | 1.0 | 1.0 |
| 2003/04 | 1.0 | 1.0 |
| 2004/05 | 1.0 | 1.0 |
| 2005/06 | 1.0 | 1.0 |
| 2006/07 | 1.0 | 1.0 |
| | | |

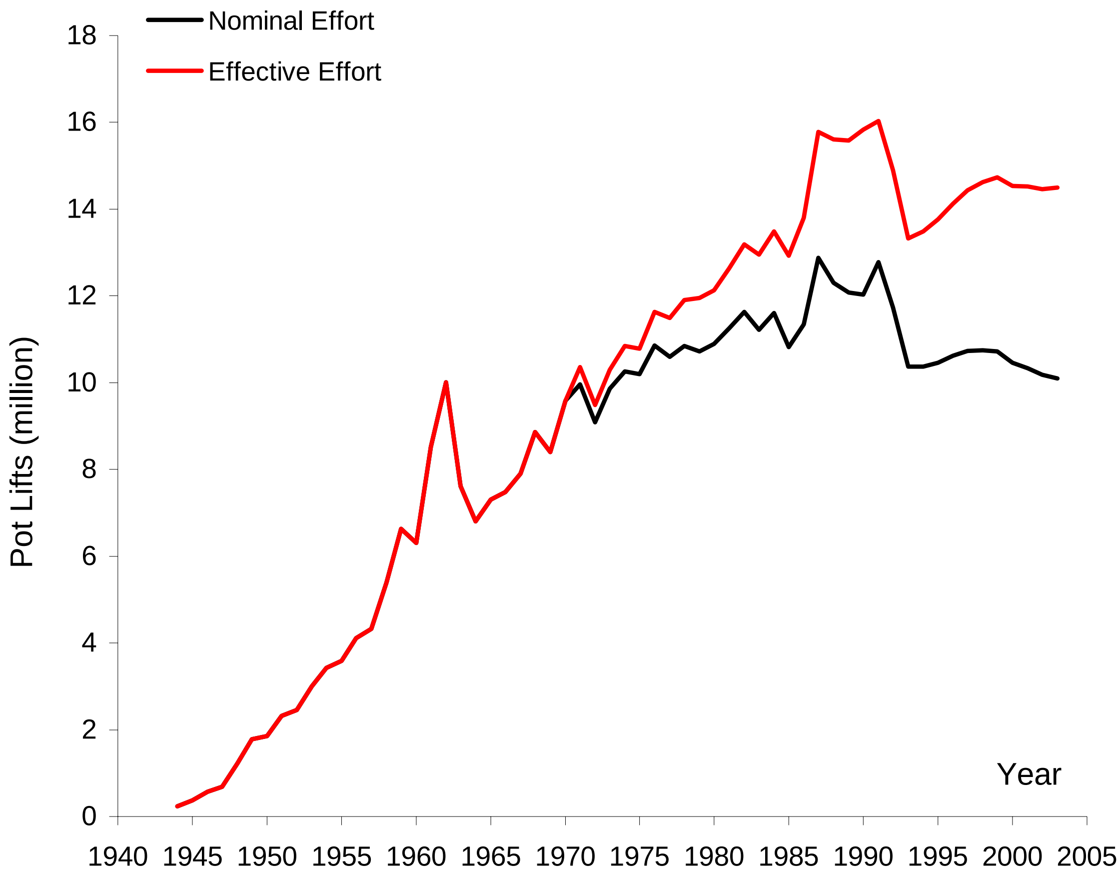



Figure 5.1 – Standardised and nominal fishing effort in the WRL fishery.

The understanding of variation in fishing effort is critical to stock assessment applicability. As such, standardised fishing effort is used in the modelling and other stock assessment analyses outlined below.

The estimates of fishing efficiency have not been reviewed since Brown et al. (1995) and Fernandez et al. (1997) and need to be reviewed based on the depletion analysis estimates and the modelling estimates of efficiency change.

## 5.2 – Catch Prediction

Catch prediction based on the level of puerulus settlement is an important tool used to sustainably manage this fishery. It requires the use of several datasets to provide an accurate prediction of the catch three to four years in advance.  This allows sufficient lead-time to implement any changes in management strategies to provide a sustainable and profitable catch of WRL.



Chittleborough and Phillips (1975) were the first to describe a relationship between the levels of puerulus settlement at the coast and variation in commercial catches.  This work soon led to the first catch predictions being produced by Morgan et al. (1982), which were based on puerulus settlement at four locations (Seven Mile Beach, Jurien Bay, Rat Island and Garden Island) and predicted the commercial catch of "whites" on a fishery-wide basis.  Predicting the whole seasons catch was then determined by Phillips (1986) and Caputi and Brown (1986) using puerulus and juvenile abundances, respectively.  The current method used for predicting catch on a regional (management zone) basis for both the whites and reds fisheries was developed by Caputi et al. (1995a) and is described in more detail in the following section.  The Department of Fisheries has recently being modifying the technique of Caputi et al. (1995a) to incorporate finer scale variation in puerulus settlement, juvenile growth rates, fishing efficiency and water temperature.

### *5.2.1 – Methods*

Commercial Catch Prediction

The prediction of catches requires the combination of a number of indices namely; puerulus settlement (Section 4.1), commercial catch and effort (Section 4.5) and estimates of efficiency increase (Section 5.1).  Catch predictions for the two coastal zones (B and C) are produced both for the whole season and split by the two main fishing periods, i.e. whites and reds (Section 3.3).  When the sum of the predicted catches for the whites and reds periods do not match that estimated for the whole season, the predictions for the two fishing periods are adjusted *pro rata* to match the whole seasons estimate.

Since the season in Zone A (Abrolhos) does not begin until the reds period, catch predictions are produced for this period only.

The general equation used to describe the relationship between puerulus settlement and commercial catch is as follows:



$$\log Catch_t = a + b \times \log Pur_{t-3} + c \times \log Pur_{t-4} + d \times Man$$

where: *Catch* is the commercial catch (tonnes) in season *t*, *Pur* is the puerulus index 3 and 4 years before season *t* and *Man* is a management dummy variable in season *t*. This dummy variable accounts for the continued impact of a management package designed to reduce harvest rates, which was introduced in the 1993/94 fishing season (Box 2.1). Parameter *a* is the intercept, *b* and *c* are measures of the density-dependent mortality experienced by lobsters between settlement and the attainment of legal size and *d* describes the relative impact of management changes. The specific factors used for catch prediction in each management zone differ slightly:

- The Zone A catch prediction equation has traditionally used an average of puerulus settlement at Rat Island lagged three and four years (Caputi et. al. 1995a). An improved estimate of the commercial catch in Zone A has recently been produced by using puerulus settlement data collected at Seven Mile Beach (Dongara), treated as two separate factors, as described in the above equation (not as an average of the settlement three and four years previously).

- The Zone B catch prediction relationship incorporates two additional variables to those represented in the above equation, namely a measure of effort and a second dummy management variable. The catch prediction in this zone includes data from the early 1970s and as such there has been an increase in nominal effort, which has significantly, affected the catch. For predicting the whole seasons and reds catches, the index of effort includes a fishing efficiency effect. This is not applied to the effort index when predicting the whites catches, as these are relatively uninfluenced by efficiency increases (Section 5.1 and Brown et. al. 1995). The second dummy variable accounts for the once off single season impact of management changes in the first season after introduction, i.e. just the 1993/94 season

- Originally, Zone C catch predictions were based on puerulus settlement data from Alkimos, as this was the only location with an expansive time series of data (Caputi et. al. 1995a). In 1997, when settlement data at other Zone C puerulus locations has sufficient temporal coverage, these were combined with the Alkimos data to produce a second, more spatially comprehensive index of settlement in Zone C (Section 4.1). Recent catch predictions for this zone have been based on same equation above, except that the dummy management variable used is the second additional dummy variable described for Zone B and not the one described in the above equation.

Catch prediction relationships are fitted using a log-transformed regression function in SAS™.

Recreational Catch and Effort Prediction

The recreational catch has increased substantially since rock lobster specific licences were first introduced in the 1986/87 fishing season. This increase, and the corresponding increases in the recreational portion of the total catch (Figure 4.21), is of particular interest in relation to the new management initiative of IFM (Section 1.4).

Recreational catch prediction utilises several fishery datasets including; recreational fishery licence numbers, estimation of participation rates and catch / effort (Section 4.7), estimation of commercial catch (Section 4.5) and, index of recruitment (Section 4.1).

Melville-Smith et al. (2001) found that a multiple regression of puerulus settlement at the Alkimos collector (Figure 4.1) for three and four years previously and seasonal license usage, best explained the recreational catch for that season as most of the recreational catch is taken in the Metropolitan area.

When examined by zone, the combined parameters of puerulus settlement at Alkimos three and four years previously and seasonal license usage in Zone C, best explained the catch within that zone. However, for Zone B, licence usage was significant in explaining the catch, while settlement at the collector for Zone B (Dongara) was not.

The predictions from this model were based on the assumption that effort levels in the future were equivalent to those in the recently completed season.

However, Melville-Smith et al. (2004) modelled future recreational effort, improving the prediction of recreational catch. Settlement rates at the Alkimos collector were found to be highly correlated with licence usage three to four years later, enabling catches to be predicted three to four years into the future.



### *5.2.2 – Results*

<u>Commercial Catch Prediction</u>

Although predicted commercial catches for each zone are all accurate, those for Zone C are generally better than for the other two zones (Figure 5.2). It is likely that lobster movement occurs between zones A and B, which reduces the models ability to always accurately estimate the commercial catch.

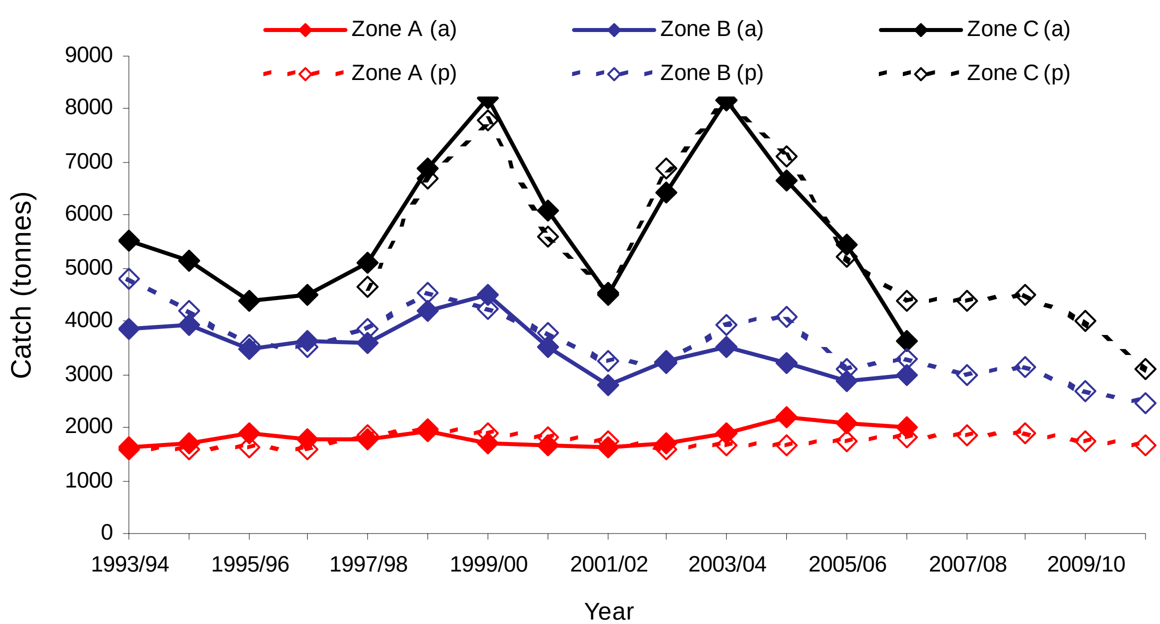



Figure 5.2 – Predicted catch (dotted line) and the actual catch (solid lines) for three management zones of the WRL commercial fishery.

The relationship between the catch in Zone A and the puerulus settlement 3 – 4 years earlier, shows that there is a strong density-dependent effect. Due to the large density of lobster at the Abrolhos compared to the coastal zones, the catch does not vary strongly with puerulus settlement.

Overall, the actual catch within zones is close to the predicted values, producing a robust indication of the catch three to four years later. This is beneficial in that it allows time for appropriate management changes to be implemented in the fishery.



<u>Recreational Catch Prediction</u>

Estimated recreational catch, utilising the model of Melville-Smith et al. (2004), incorporating forecasts of recreational licence usage, has provided good estimations of actual catch by recreational fishers (Figure 5.3) with the estimates falling within the 95% CI of the model. As for the commercial fishery, these predictions have been used for management purposes e.g. estimations of future catch shares under IFM (IFAAC 2007)

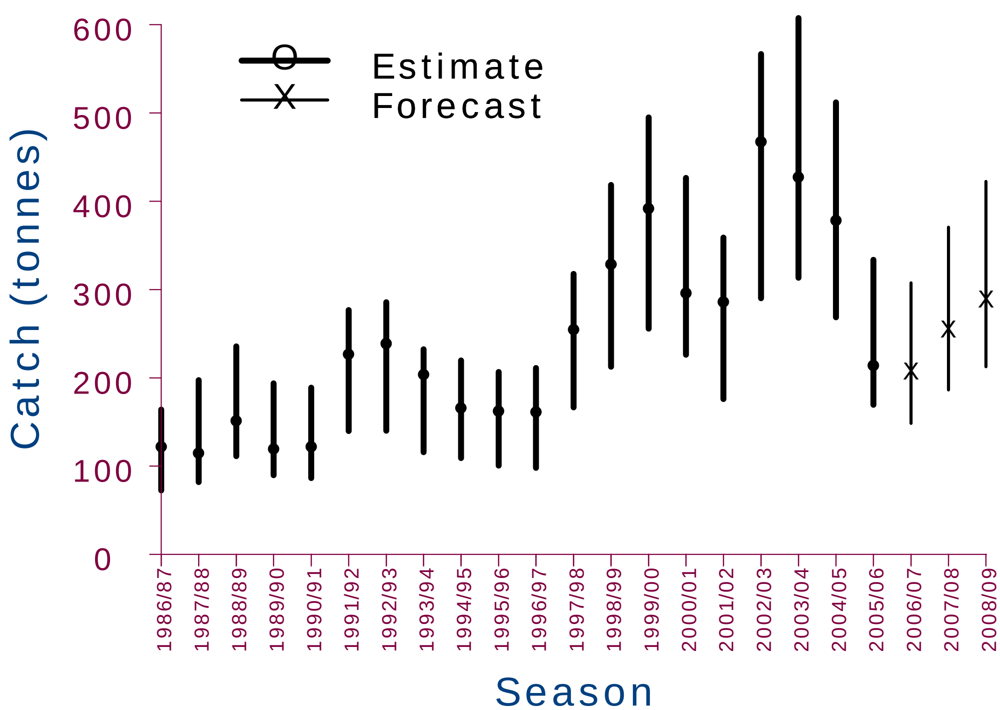



Figure 5.3 – Model predictions of recreational catch (open circle), with 95% CI (bars), with actual catches (solid circles) for season to 2002/3 Melville-Smith et al. (2004).

## 5.3 – Stock Recruitment-Environment Relationship (SRR) and Recruitment to Spawning Stock Relationship (RSR)

For complete details see Caputi et al. (1995b).



The relationship between breeding stock and recruitment (SRR) is another important relationship necessary for appropriate management of the fishery. Often these relationships have proved difficult to determine, due mainly to the long larval life of lobsters and the resulting importance of environmental conditions on recruit survival and distribution. In fact in most cases, in order to detect a SRR the stock must first be fished to a level whereby recruitment is significantly negatively affected. The construction of an SRR also requires mid – long term data sets on recruitment (e.g. puerulus settlement), abundance (Section 4.1), breeding stock (Section 4.2) and environmental measures (Section 4.7).

Recruitment to spawning stock relationships (RSR) describe the impact mortality (both natural and fishing) has on the ability of recruits to replenish the spawning stock. When combined with a SRR, the resultant model can predict equilibrium levels of stock and recruitment for different levels of effort, which is invaluable in the management of many fisheries.

### *5.3.1 – Methods*

An *SRR* and a *RSR* were determined for each of the three management zones. Puerulus settlement indices were used for each zone, with Rat Island settlement used for Zone A, Seven Mile Beach used for Zone B and Alkimos for Zone C (Section 4.1). The northern and southern coastal fishery dependant BSI (Section 4.2) was used as measures of the breeding stock in those two areas. Since no direct breeding stock index was available for the Abrolhos Islands, and the majority of the catch in this location is of a mature size, the annual commercial catch was used as a measure of the breeding stock for Zone A.

Two main environmental measures were employed for use in the SRRs, i.e. Leeuwin Current strength, as measured by the mean sea level at Fremantle and mean monthly rainfall at five locations in the southern part of the fishery over two periods (July –

September and October – November) as a proxy of westerly winds.  A unique index of westerly winds was used for the Abrolhos Islands, and was based on rainfall at three locations between Jurien and Geraldton from July – November.

SRRs were developed based on the power curve;



$$Puerulus = a\,Stock^{b}$$

where *Puerulus* is an index of puerulus settlement, *Stock* is a measure of the breeding stock and *a* and *b* are parameter estimates.

For the spawning stock relationship (RSR) nominal fishing effort (pot lifts) was obtained from CAES (Section 4.5) and standardised for increases in efficiency (Section 5.1).  The recruitment to RSR is:

$$Sn_t = 0.819\exp\left(-0.426En_{t-2}\right),\ Ss_t = 0.430\exp\left(-0.208Es_{t-2}\right),$$

where *Sn* and *Ss* are the spawning indices for the north and the south, respectively, and *En* and *Es* are the standardised effort (million pot lifts).

### *5.3.2 – Results*

<u>Stock Recruitment-Environment Relationship</u>

The strong relationship between environmental factors and puerulus settlement necessitates the incorporation of environmental variables into any examination of a stock recruitment relationship. The relationship of stock to recruitment is examined regionally due to the different environmental impacts on recruitment (Section 4.1 and 4.7).

When incorporating environmental factors into the SRR for Zone B, the combined spawning index was found to not be significant in explaining variation in puerulus settlement at Dongara. Rather it was dominated by the environmental factors, Leeuwin Current and westerly winds, with the decline in spawning stock not affecting puerulus settlement.  For the southern region, recruitment of puerulus at Alkimos was affected by rainfall (westerly winds) when environmental effects were taken into account. This also made the spawning stock index not significant in this region.

However, at the Abrolhos Islands, the spawning stock, when combined with rainfall in northern locations, was significant in explaining recruitment at the Abrolhos Islands. This may make the Abrolhos Islands more susceptible to reductions in spawning stock, as environmental factors do not dominate in the same way that they do in the coastal locations (for more detail see Caputi et al. 1995b).



<u>Recruitment to Spawning Relationship</u>

Examination of recruits into the spawning stock showed that fishing effort two years prior to spawning, when lobsters recruit into the fishery, significantly affected the spawning index, but puerulus abundance was not significant.  This indicates that the fishing effort on recruits reaching legal size is the main factor affecting the abundance of the spawning stock.  In all regions of this fishery, fishing pressure is currently at such levels that good recruitment years do not translate into good spawning stock (for more detail see Caputi et al. 1995b).

### *5.3.3 –Discussion*

As the spawning stock has generally increased since this analysis has been undertaken, the spawning stock is unlikely to have become a significant factor affecting puerulus settlement.  Therefore the focus in more recent years has been to update the environment-puerulus relationship (Section 4.7) to understand the factors affecting puerulus settlement.

However, it would be useful to update both of these relationships, particularly the RSR, to understand the effect of changes in fishing effort and other management measures (e.g. setose rule) have had on these relationships.

## 5.4 – Depletion Analysis

Depletion methods have the potential to provide an alternative approach for assessing stocks that are subject to unknown (efficiency) biases. They do this because they can estimate this efficiency changes while also producing estimates of the harvest rate and an index of abundance. Depletion-based methodology (Delury 1947, Leslie & Davis 1939) was applied to the western rock lobster fishery from 1984 – 2003, to determine the applicability of the method (Wright et al. 2006)

The basic DeLury method for estimating catchability and population size is based on a relationship between the decline in CPUE and the cumulative catch that is removed from the fishery (Ricker 1975). The slope of this (linear) relationship provides an estimate of the catchability of the unit of fishing. The extrapolation of the relationship down to the point where the CPUE is zero (Ricker 1975) provides an estimate of the population size. Assessment indices generated by this analysis include annual trends in harvest rate, total population estimate and residual biomass after the completion of fishing, and catchability of the fishing effort that reflects the efficiency of effort applied by the fleet.

The non-migratory phase "reds" provides an opportunity for using the depletion assessment as it generally satisfies the key assumptions. It has been undertaken using the monthly catch and effort of each of the three zones during the months of March – June for each fishing season since 1983/84. The migratory phase of the fishery is not suitable for a depletion analysis as migration of some of the lobsters from shallow water to deep water changes their catchability compared with the non-migrating lobsters.

### *5.4.1 - Methods*

The depletion model is based on the assumption that CPUE changes reflect changes in abundance and not environmental (Morgan 1974 , Srisurichan 2001, Srisurichan et al. 2005) or biological effects on catchability. The assessment does not produce reliable results unless any catchability changes are accounted for by standardising the CPUE for environmental and biological changes between months and years. Other complicating factors include the timing of the February moult and its impact on the availability of recruiting lobsters during March and annual variation in the spatial distribution of effort.

If the moult is late in any year the assumption of no recruitment during the period is not met and this needs to be taken into account for that year's depletion assessment. The depletion analysis also assumes that effort remains relatively constant. However, annual variations in lobster abundance within a management zone, especially Zone C, can cause effort to contract and expand. The exact influence this has on the depletion analysis needs to be investigated.



The classical DeLury depletion model has:

$C_t/F_t = q\,B_t$ Eq. 5.4.1

where $B_t$ is the biomass present at time t. For our estimation procedure we use a reformulation of this model based on the following quantities: $C_t$ = catch in month t in tones; $F_t$ = effort in month t in thousands of pot lifts; $B_t$ = average biomass in month *t*;

q = catchability standardised for temperature and swell; $B_0$ = total biomass in zone at start of harvest (March); K = scale factor that correctly sets the coefficient of variation of the monthly catches in this model and through this the standard errors in our parameter estimates. The method for determining this parameter is considered presently in the assumptions section.

Taking $B_t = B_0 + 0.5C_t - \sum_{i=1}^{t} C_i$ Eq. 5.4.2

where the index *i* ranges over the time period defined, our model becomes:

$C_t$ has the probability distribution

K Poisson $(q\,F_t\,B_t / K)$ Eq. 5.4.3

for month *t* = 1,2,3,4 (i.e. March –June).

In our initial modelling, the parameters $B_0$ and q in Equations Eq. 5.4.2 and Eq. 5.4.3 were estimated by Maximum Likelihood and by comparing the predicted and observed catch, first by using Fortran code (Numerical Recipes) and later using an Excel spreadsheet (Solver). However, since the model could be naturally formulated in a Bayesian framework, we were able to avoid optimisation fine-tuning problems (and more importantly automatically obtain standard errors) by using Bayesian estimation via the

Markov Chain Monte Carlo (MCMC) method. The rationale for using the MCMC method was the automatic estimation of standard errors for our parameters, regardless of the model type and complexity.

For each zones of the fishery, there were 20 depletions to be estimated during the period 1984-2003. For this production phase, the estimation was performed by the program BUGS 0.6 (Spiegelhalter et al. 1996) running in batch mode.



The parameter estimates were effectively the medians of a sample of 10 000 from the simulated posterior distributions based on over-dispersed priors. The priors were exponential distributions with large means.  The standard errors for the estimates were the observed standard deviations of the posterior distributions of the parameters. The sample of 10 000 consecutive simulated values used for our estimates followed a "burn-in" period of 20 000 samples. Following this burn-in we confirmed that the convergence diagnostics were comfortably within required ranges.  The parameter estimates obtained, and their standard errors and coefficients of variation, are presented in the results section for the years 2001-03, to illustrate typical values and their precision.

The MCMC methodology results in the converged Markov chains above simulating "depletion" lines with parameter values from their respective prior distributions. The intersection of these depletion lines with the vertical ordinate through each catch rate (CPUE) point realises a conditional distribution.  When there is a (linear) depletion, a plot of the medians of these conditional distributions against the cumulative catch is a straight line. In Figure 5.4, within each year, the horizontal scale uses the cumulative catch from March on as a fraction of the total March–June catch.  For Zone A, there is a very close agreement between the actual and Bayesian estimates of mean CPUE for each month. Zone C depletions also show close agreement.

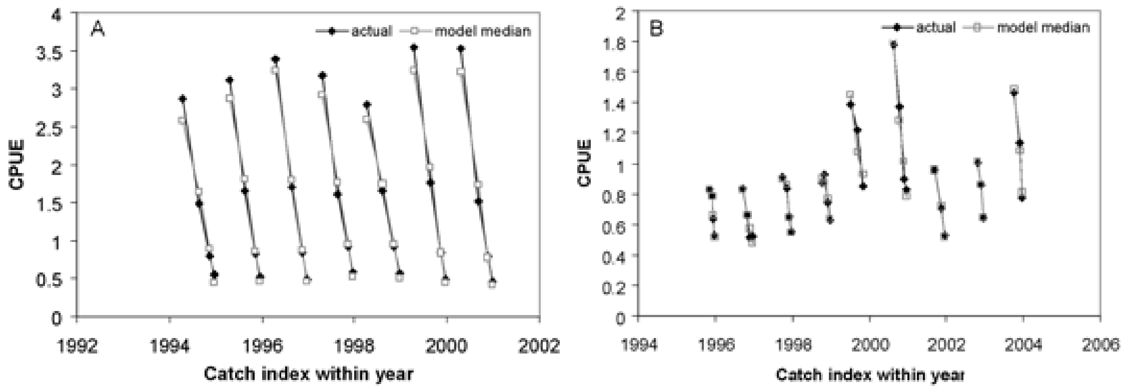



Figure 5.4 – Actual and Bayesian estimates catch per unit effort (CPUE) per month (March–June) plotted against the cumulative catch index for a number of years for: **A**, Zone A; and **B**, Zone C. Note that for the Zone C depletions for 1999 and 2001 on, the March and June CPUE values respectively have been omitted for biological reasons explained in the text (Wright et al. 2006).

<u>Assumptions and some consequences</u>

The assumptions of the depletion method are: (1) closed population : i.e., no migration, recruitment or natural mortality; and (2) sample is homogenous with effort, i.e., probability of given individual being caught when population subject to $\Delta f$ units of effort is $k\Delta f + o(\Delta f)$ where k is a constant independent of time; (3) all individuals have the same chance of being caught in the i th sample.

The result of these assumptions is that if $N_t$ is the average size of the population while the catch of the i th fisher in a specified month is being acquired through the application of effort $f_{i,t}$, then, following the standard arguments used by Cox & Miller (1965) or Ross (1985), it is readily shown that the probability distribution of $C_{i,t}$ the number caught by the i th fisher in that month has a Poisson distribution with mean $q\, f_{i,t}\, N_t$ where q is the constant catchability. In fisheries parlance q is the (constant within season) catchability of each animal in relation to one pot lift, equal to a unit of nominal effort.

If there are n fishers operating in a zone the total number of animals caught in month t is $C_t = \Sigma_i\ C_{i,t}$ and their total effort is $F_t = \Sigma_i\ f_{i,t}$ If their catches are independent, then following the standard arguments above, it follows that the total monthly catch has an approximately Poisson distribution with mean $q\, F_t\, N_t$. Conversely, if the catches are perfectly correlated (which is a much more likely scenario and which we assumed) the total monthly number of animals caught is approximately distributed as n times Poisson with mean q $F_t$ $N_t$ /n. The mean of this Poisson distribution is the average monthly catch of animals per fisher which is between 5000 in Zone C and 10 000 in Zone A. The respective distributions have coefficients of variation ranging between 1.4% and 1%, respectively.



To consider the catch for biomass (tonnes) it can be readily shown that with a conversion rate of 2000 animals per tonne, the monthly zone catch in tonnes will be distributed as K times a Poisson distribution with parameter equal to average monthly catch (tonnes) divided by K, where K is determined so that the coefficient of variation of the biomass distribution is equal to that for the distribution of animals described above. In Zone C the average monthly catch is 552 t so that K = 1/9, in Zone B the average monthly catch is 370 t so K = 1/16, whereas in Zone A the average monthly catch is 480 t so that K = 1/21. These scale factors have an important influence on the standard errors of our parameter estimates, but do not affect the median values.

When the t-th sample (zone monthly catch) represents a significant proportion of the remaining population, the value of $N_t$ is taken to be the average value of the population during the sampling period. This improvement owing to Braaten (1969) was endorsed by Ricker (1975). Our estimation process includes this feature in both its frequentist and Bayesian versions.

Environmental influence on catchability

We consider three main environmental influences on catchability: temperature, swell and moon phase.

The swell index in the zone is the average throughout the month of swell levels recorded in fishers daily logbooks (Section 4.4) on the scale: (0=none,10=Low, 20=Moderate, 30=High). The average monthly water temperature is determined by fisheries staff in conjunction with other local monitoring activities (Section 4.2 and 4.7).

We derived corrections for the impact on catchability of: temperature alone (with all other environmental variables held constant); swell alone (with all other environmental variables held constant); and temperature and swell together (with all other environmental variables held constant).

Data from Morgan (1974) for the catchability in the Abrolhos Islands (Zone A) enabled the assessment of the explicit effect of temperature alone. This was achieved using a multivariate regression model and the partial regression method of Kendall & Stuart (1973) and its modern incarnation in Johnson & Wichern (1982).



Using the Morgan (1974) observations for (natural) log catchability (logq), temperature, salinity and Pre Moult Proportions (PMP) in the March–June period we obtained the pairwise covariances between all variables (Table 5.2). The partial covariance matrix for log q and temperature (with all other variables i.e., salinity & PMP) held constant at their global average values) was determined (Table 5.3).

Table 5.2 - Covariances between log catchability (logq) and environmental variables (temperature, salinity, pre-moult proportions (PMP) for data from Morgan (1974) (Wright et al. 2006).

| | Logq | Temp. | Salin. | PMP |
|---|---|---|---|---|
| logq | 0.124 | 0.226 | 0.053 | -0.284 |
| Temp. | 0.225 | 0.985 | 0.109 | -0.222 |
| Salin. | 0.053 | 0.109 | 0.032 | -0.154 |
| PMP | -0.284 | -0.222 | -0.154 | 2.344 |

Table 5.3 – Partial covariances between log catchability and temperature for Morgan (1974) data with all other environmental variables held constant (Wright et al. 2006).

| | logq | Temp. |
|---|---|---|
| logq | 0.037 | 0.054 |
| Temp. | 0.054 | 0.559 |

From this partial covariance matrix we computed the partial regression coefficient of log catchability on temperature (with all other variables held constant), which enabled us to find the correct proportional change in catchability due to temperature.

There is widespread anecdotal evidence that the catchability of western rock lobster increases with swell. In one investigation of the question, Srisurichan (2001), Srisurichan et al. (2005) studied time series of catch rates along with corresponding swell height for six seasons of fisher's daily logbook data from 1992/93 to 1998/99. From this time series methodology we obtained estimates of the swell effect on catchability.



Unfortunately these estimates were based on the full 7.5 month fishing season rather than just the four months (March –June) of the depletion phase. In addition there was no control of temperature, so these estimates must be interpreted with caution.

In our separate investigation of the effect of swell on catchability we also used fishers daily logbook data and examined the linear regression between the daily values of the natural log of catch rate within each zone and both the swell size and moon brightness within single months between March and June, when it was reasonable to assume that the water temperature within each month was constant. The possible temperature dependence of the result was thus removed. However the results showed significant volatility in estimates of the coefficient of the swell term. For these reasons it was decided to use the zone averages of the swell coefficient over the relevant months of several years to make the swell correction of catchability needed in our depletion model.

Because we were using monthly catch and effort data, the moon phase influence on catchability was averaged across each full month and thus was not explicitly required for months where fishing takes place over the whole month. Over incomplete fishing months we needed to take the effect of reduced catchability on the full moon into account.

Having obtained estimates of the influence of temperature alone (with all other factors held constant) and of swell alone (with all other factors held constant) we derived correction formulae for the influence of both factors together, using the total differential method of the differential calculus, with partial correlations taking the roles of partial derivatives.

## Optimal Estimation of Underlying Trend.

*Centred Moving Average Estimate*

When underlying process has constant variance of its terms and a linear trend the centred moving average is an efficient estimate from an error variance standpoint, although the latest estimate is lagged by half the span of the averaging. This lag can create problems in real time process control in certain systems. Use of a three-point moving average is a reasonable compromise between timeliness and precision when incremental control measures are employed.



## Optimal Combinations of Estimators

If $E_1$ and $E_2$ are independent unbiased estimates of a parameter, the minimum variance unbiased estimate of that parameter is a weighted mean of $E_1$ and $E_2$ with weights totalling 1 and inversely proportional to the respective estimator variances.

In symbols, if E* is the minimum variance combination of the two estimators we have

$E^* = w1.E_1 + w2.E_2$ Eq. 5.4.4

Where $w1= (1/varE_1)/(1/VarE_1 + 1/VarE_2)$ Eq. 5.4.5

and

$w2 = (1/varE_2)/(1/VarE_1 + 1/VarE_2)$. Eq. 5.4.6

It is readily verified that E* is an unbiased estimator because w1+w2 =1 and these values of w1,w2 lead to a minimum point for Variance(E*). These results generalise naturally to three or more estimators.

*Weighted Moving Average Smoothing of time series data.*

One favourable aspect of our WinBugs estimation of parameters is the availability of error variances for our parameter estimates, which makes it possible to combine the moving average approach with the minimum estimator variance methodology.

Suppose our time series is written as ($X_t$, t =1..n). The smoothed time series is

($X^*_t$, t =2,n-1) where

$X^*_t = w(t-1).X_{t-1}+w(t).X_t+w(t+1).\ X_{t+1}$ Eq. 5.4.7

In which

$w(t)=1/var(X_t)/(1/var(X_{t-1})+1/var(X_t)+1/Var(X_{t+1}))$. Eq. 5.4.8



It can be shown that in the presence of autocorrelation the trend estimator $X^*_t$ has almost as small a variance as that when there is no autocorrelation, and thus is very efficient.

*Cycles in moving average smoothed series.*

In our early attempts to smooth our series of estimates we did encounter some cycles in the moving average smoothed estimates. This problem has largely disappeared when we use the weighted smoother because the large outlying values that caused the problem usually had large standard errors and so were downgraded by the weighting process. However the possibility still exists for the appearance of cycles in the smoothed series due to the operation of the Yule-Slutsky effect identified in the 1930s as an artefact of moving average smoothing.

Environmentally Corrected Catchability

Implementing the temperature and swell corrections determined provided the following temperature and swell correction formulae for our three Zones:

Zone A: $q_1= q_0 .\ \exp(\ 0.097\ .\Delta T + 0.010\ .\ \Delta S)$ Eq. 5.4.9

Zone B: $q_1= q_0 .\ \exp(\ 0.080\ .\Delta T + 0.010\ .\ \Delta S)$ Eq. 5.4.10

Zone C: $q_1= q_0 .\ \exp(\ 0.080\ .\Delta T + 0.012\ .\Delta S)$ Eq. 5.4.11

where $\Delta T$ = temperature increment above 21.4°C and $\Delta S$ = swell index increment above 9.5.

Since the moon brightness cycle has a period of c. 30 days, the average value is the same every month. Thus there is generally no need for explicit corrections for whole months. However, the combination of full moon and cold period in June may result in fishers ceasing fishing early. This can result in an elevated catch rate for the influential final catch, which may be reduced by some animals beginning to moult. Also the March catch at the Abrolhos, which covers a 17-day period, is at the start (and thus less influential part) of the depletion curve (Ricker 1975).

Diagnostics for Depletion Model Validity



The graph of CPUE against cumulative catch during each season, the depletion curve, was used to monitor our depletion estimates to ensure model assumptions remained appropriate.

Depletion based estimates for fishery harvest

Harvest rate is defined as the relative proportion of the exploited stock that is removed by the fishery, e.g., for the reds part of the fishery (March–June):

Harvest reds = (catch reds)/(Catch reds + Residual biomass in June) Eq. 5.4.12

For Zone A this definition covers the harvest of the entire season, but for Zones B and C this is effectively the harvest of legal-size rock lobsters over part of the season.

Depletion based estimates for residual biomass

Because the residual biomass estimated by our depletion procedure is always the legally-exploitable biomass of the day, the present legal biomass can only be compared with the pre-1993 biomass if we correct for the change in the definition in the legal biomass that occurred since the 1993/94 season. This change resulted in setose females and those above the maximum female size that would have been part of the catch before the 1993/94 season being returned to the sea and hence should be added to the residual biomass. An estimate of the setose and females above the maximum size that were returned to the sea was based on data collected from fishers' daily logbooks. The estimate of the June residual biomass based on the depletion analysis was adjusted to obtain an estimate of the residual biomass in the pre-1993 definition of legal biomass and hence the harvest rate based on the pre-1993 terms. These can be defined as:

Residual biomass pre 1993 = June residual biomass + mature female biomass returned

Harvest pre 1993 reds = (Catch reds)/(Catch reds + Residual biomass pre 1993).

The estimate of the harvest for the whole season was obtained by adding the whites catch during the first part of the season to the reds catch and using the total catch as follows:

Harvest pre 1993 total = (Catch total)/(Catch total + Residual biomass pre 1993)



### *5.4.2 – Results*

The depletion analysis provided estimates of the residual biomass of the legally exploited biomass at the end of the fishing season in June, the catchability and the harvest rate during March–June (reds period) for each of the three zones of the fishery. However the definition of the legally exploited biomass has changed since 1993/94 as mature females with setose pleopods and females above a certain size were required to be returned to the sea. Before 1993/94 only ovigerous females were required to be returned to sea. It is therefore important to note that the harvest rate reported here is for the whole season and it accounts for the 1993/94 management changes (Box 2.1) and the catch during the migrating whites part of the fishery.

<u>Harvest trends in Zone A</u>

Residual biomass in Zone A remained relatively constant, before steadily increasing after the introduction of management changes in 1993/94, with current estimates (2004/05) being at their highest levels (~600 t). Harvest rates also began to change in 1993/94, progressively rising to ~90% in the early 2000s. In recent seasons, the harvest rate has declined slightly to ~ 85%. Catchability, which provides an indication of changes in fishing efficiency, jumped markedly with the reduction of pots fishing in this zone with the implementation of pot reductions in 1993/94. This may reflect the effects of pot saturation. Since this rise, fishing efficiency has remained relatively constant (Figure 5.5).

<u>Harvest trends in Zone B</u>

Residual biomass in Zone B has been progressively declining since a peak in 1995/96. In the past three seasons the residual biomass has ranged between 700 and 800 t. The harvest rate in this zone has progressively increased, apart from a small decline as a result of the 1993/94 management changes, since the mid 1980s. This increase has recently levelled off, with currently estimates being around 80%. Catchability has increased rapidly since 1995/96 (Figure 5.6). While fishing efficiency affects catchability, the spatial distribution of fishing effort may also affect the catchability estimate. The effect of the 15% effort reduction in 2005/06 will be assessed in the next 2-3 years.



Harvest trends in Zone C

Residual biomass in Zone C is currently at ~ 2500 t, a similar level to the past six seasons and still far above the low years recorded during the late 1980s and early 1990s. The harvest rate in this zone is progressively increasing after it declined as a result of the 1993/94-management package. The current estimate of ~70% is well below that of zones A and B. Catchability has also increased rapidly since 1993/94 (Figure 5.7). A 5% reduction in effort was implemented in 2005/06 though the actual reduction in effort has probably been greater to the effects of the increased cost of fuel and reduced catch rates.

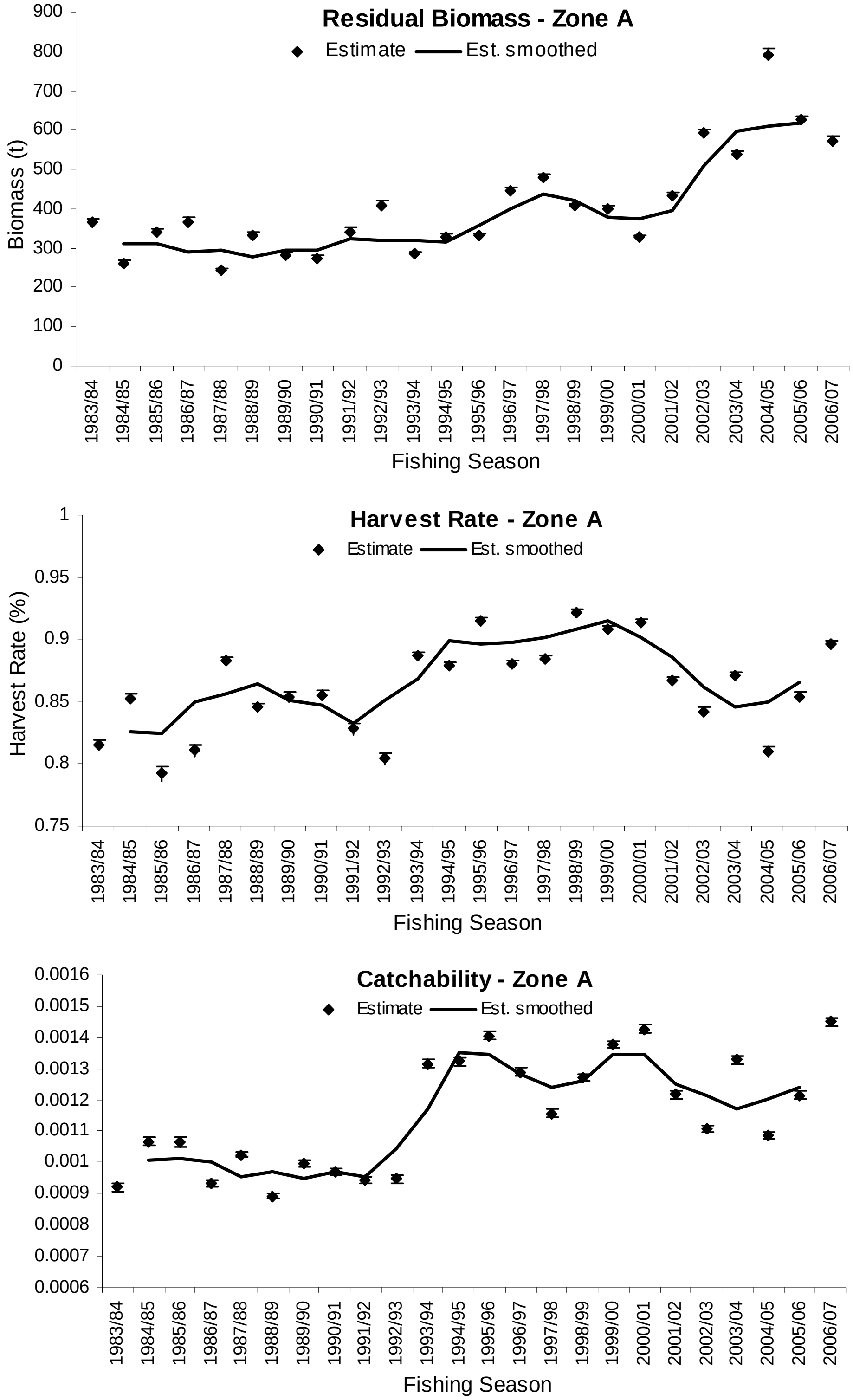



Figure 5.5 – Estimates of residual biomass, harvest rate and catchability estimates (±SD) from the depletion analysis for Zone A, with a modified three-point smoothed average (adapted from Wright et al. (2006)

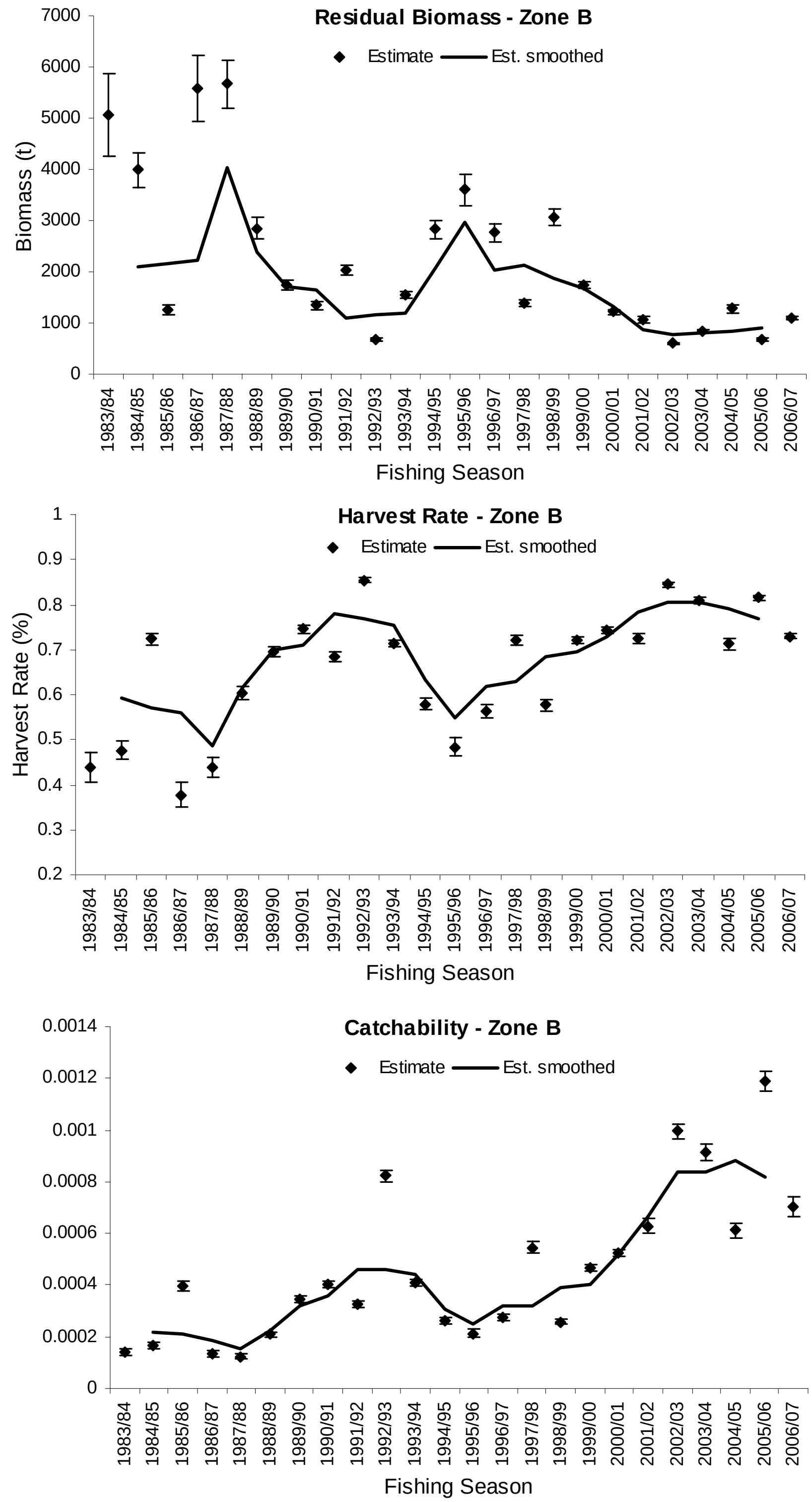



Figure 5.6 – Estimates of residual biomass, harvest rate and catchability estimates (±SD) from the depletion analysis for Zone B, with a modified three-point smoothed average (adapted from Wright et al. (2006).

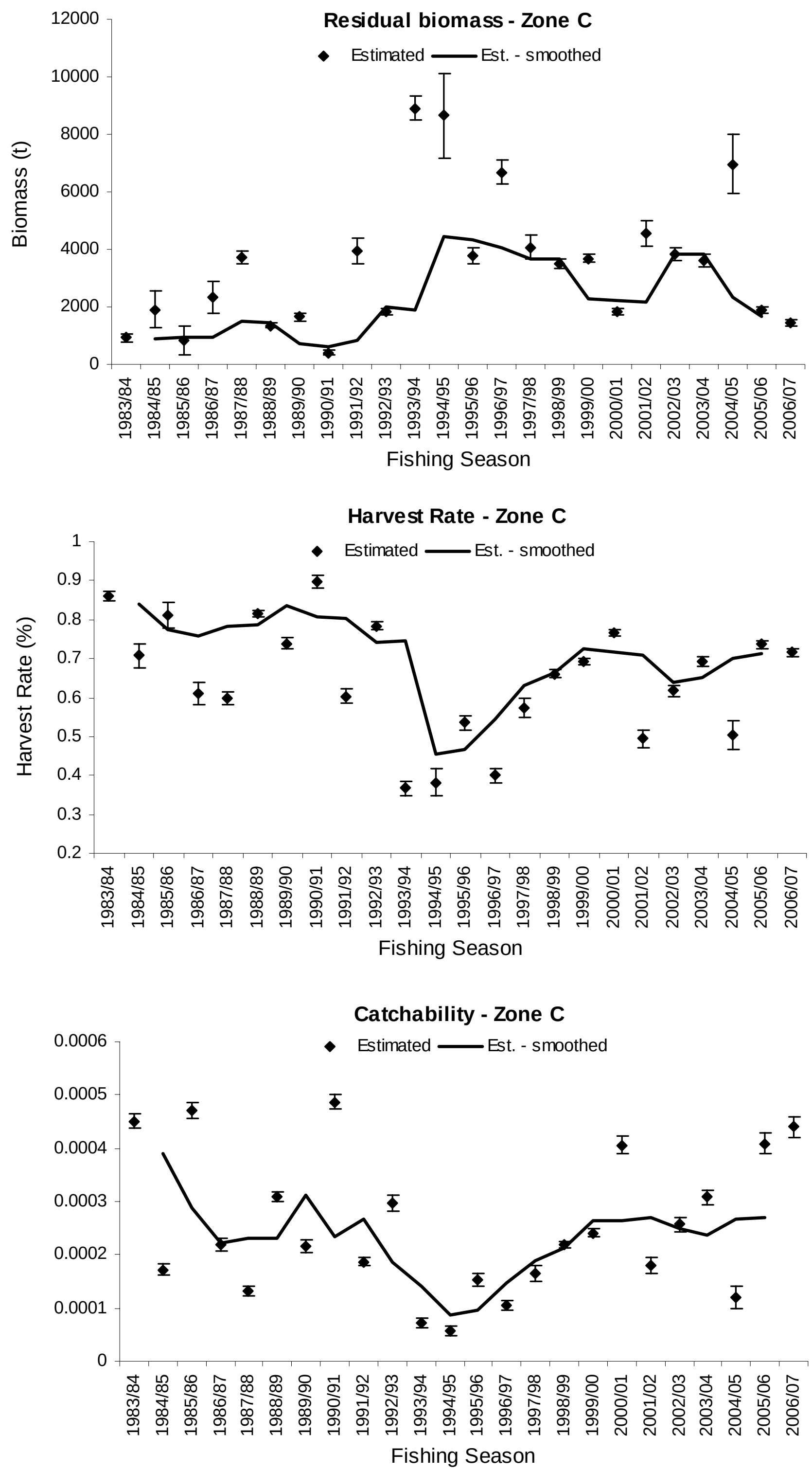



Figure 5.7 – Estimates of residual biomass, harvest rate and catchability estimates (±SD) from the depletion analysis for Zone C, with a modified three-point smoothed average (adapted from Wright et al. (2006).

## 5.5 – Biological Modelling



In modelling the recent trend is to use size-structured population models because of the inability to age rock lobsters (Hobday and Punt 2007). In the western rock lobster fishery the strong signal in the catch of lobsters with the puerulus settlement 3 and 4 years previously, enables an age-structured model to be developed in which the growth parameters in the model can be tuned so that the estimated catches are aligned with the observed catches (see Stephenson and de Lestang in prep).

In this assessment, a fine spatial scale of 8 inshore and 8 offshore areas was used to mirror the different growth and maturity characteristics both onshore-offshore and along the coast (Figure 5.8). A fine temporal scale of half monthly time steps was used to capture the synchronous migration and the distinct temporal pattern of capture. In addition, the fine temporal scale enables the evaluation of small temporal closures in the management strategies on the stock and the economics of the fishery. This model is still in the development stage and is planned for completion later this year and therefore full diagnostics are not provided and information available at the time of release is presented. The main characteristics of the new model are:

- Age/sex structured (with size composition outputs).
- Runs on a biological time scale (begins and ends with reproduction - 1st November).
- Fine temporal scale - ½ month time step (day 1 – 14 and 15 +). Incorporates the start of the season (coast and islands) and the start of the summer closure.
- Spatial scale - 16 separate transects/depth zones (<20 and 20+ fms).
- Contains a visual front end (graphics, maps and parameter estimates in Excel).
- Background programming in Ad Model Builder.
- Consists of six main sub-models and has the ability to turn these on/off.
- In the objective function contains commercial catch by year, area, and time-step (Section 4.5), fishery independent and dependent breeding stock indices in each region (Sections 4.2 and 4.3) and numbers of setose animals returned in each management zone (Section 4.4 and 4.5).

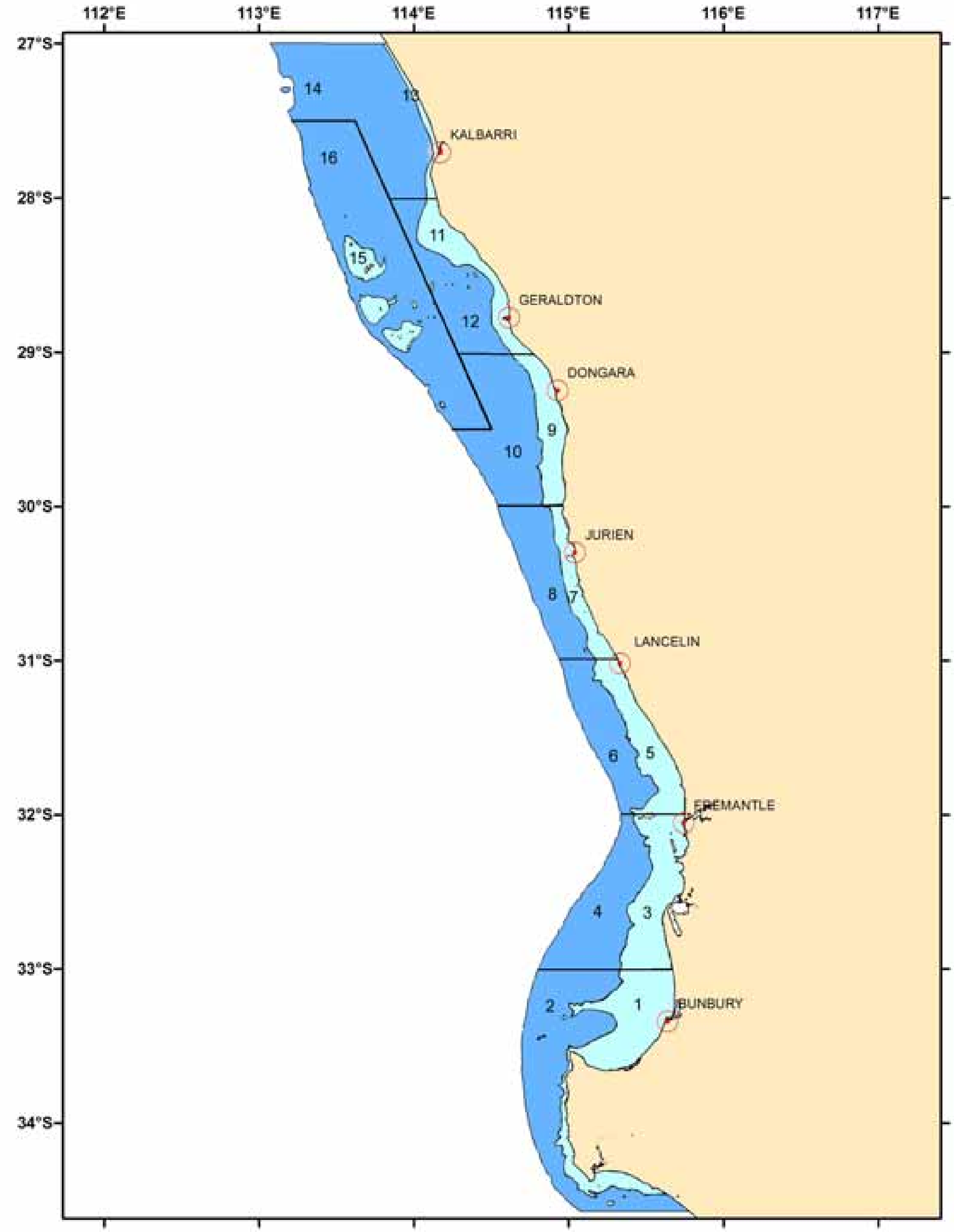



Figure 5.8 – Map of lower West Australian coast showing finer scale grids used in the modelling of the western rock lobster

## *5.5.1 – Methods*

Population dynamics model

*Recruitment*



The lobsters are assumed to have a birth data of November 1 and this is taken as the beginning of the first time step in the model. The number of lobsters (millions), $N^{s}_{r,y,2,1}$ entering the fishery in each area of fishery, $\gamma$, in each year, $y$, at time-step $t$ =1, and length, $L$ is given by

$$N^{s}_{r,y,1,L} = \begin{cases} \rho\ R_r \exp(\varepsilon^{R}_{r,y}) & s = \text{female} \\ (1-\rho)\ R_r \exp(\varepsilon^{R}_{r,y}) & s = \text{male} \end{cases} \qquad \text{Eq. 5.4.11}$$

where $R_r$ is the average recruitment in each area, $\gamma$, $\varepsilon^{R}_{r,y}$ is a recruitment deviation term, and $\rho$ is the proportion of females.

The recruits have a normally distributed length (mm) of N(36, cv×36) where cv=0.1. This length corresponds to approximately 2 years post settlement. The number of recruits are distributed into length bins (Table 5.3) at the beginning of timestep $t$= 1

Table 5.3. The lower carapace length (mm) for each length bin used to store the number of lobsters in each length class.

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 30 | 32 | 34 | 36 | 38 | 40 | 42 | 44 | 46 | 48 | 50 |
| 52 | 54 | 56 | 60 | 65 | 70 | 74 | 76 | 77 | 78 | 79 |
| 80 | 82 | 84 | 86 | 88 | 92 | 96 | 98 | 100 | 102 | 104 |
| 105 | 106 | 110 | 114 | 115 | 120 | 130 | | | | |

The annual variation in recruitment is tuned to puerulus deviation data derived from puerulus counts from the collectors at Alkimos for $\gamma = 1,3,5$; Lancelin for $\gamma = 7$, and Seven Mile Beach for $\gamma = 9,11,13,15$. The puerulus deviations are given by



$$\varepsilon^{P}_{r,y} = \omega_r \ln P_{r,y} - \frac{\sum_{y=1975}^{2006} \omega_r \ln P_{r,y}}{(2006-1975+1)}$$

The initial state in 1975 is

$$N^{s}_{r,1975,\,j+1,t+1} = \begin{cases} N^{s}_{r,1975,\,j,t}\; e^{-(j+i-1)(M+K)} & \text{for } j \le 5 \\ N^{s}_{r,1975,\,j,t}\; \dfrac{e^{-(j+i-1)(M+K)}}{1-e^{-(j+i-1)Z}} & \text{for } j > 5 \end{cases} \qquad \text{Eq. 5.4.2}$$

where K is the initial equilibrium fishing mortality in 1975.

The exploitation rate on fully selected animals is fishing mortality, $F^{s}_{r,y,t,a}$, is given by

$$F^{s}_{r,y,\,j,\,t} = E_{r,y,t}\; q_r \exp(\varepsilon^{E}_{r,y})\, \mu_{\gamma,y} \qquad \text{Eq. 5.4.3}$$

where $E_{r,y,t}$ is the effort (number of potlifts), $q_r$ is the average catchability, $\mu_y$ is the efficiency increase, and $\varepsilon^{E}_{r,y}$ is an effort deviation term.

*Availability to capture*

Lobsters are assumed to be fully vulnerable to the gear from age 2 years and lobsters that are returned to the water in accordance with the management arrangements are assumed to have zero mortality.



The availability to capture is incorporated in a series of vectors of length in size classes (Table 3) with knife-edge selection for animals above minimum size and under legal maximum size. The vectors of availability for ovigerous and setose animals are populated using the proportion of ovigerous females, $O_{r,t}$ which are discarded prior to 1993

$$O_{r,t} = \frac{1}{1+\mathrm{e}^{-\ln(19)\frac{L^{f}_{j,t}-O_{50,r}}{O_{95,r}-O_{50,r}}}} \qquad \text{Eq. 5.4.6}$$

where $O_{50,r}$, $O_{95,r}$ are values determined from maturity data (de Lestang, unpublished data) and the proportion of females that are setose, $S_{r,t}$ and discarded after 1992 is

$$S_{r,t} = \frac{1}{1+\mathrm{e}^{-\ln(19)\frac{L^{f}_{j,t}-S_{50,r}}{S_{95,r}-S_{50,r}}}} \qquad \text{Eq. 5.4.6}$$

where $S_{50,r}$, $S_{95,r}$ are fixed values determined from maturity data (de Lestang, unpublished data)

The number of lobsters captured that are above minimum legal size is given by

$$N^{G,s}_{r,y,j,t} = N^{s}_{r,y,t,j}\ \frac{G^{s}_{r,\theta,j,t}F^{s}_{r,y,j,t}}{G^{s}_{r,\theta,j,t}F^{s}_{r,y,j,t}+M}\left(1-\exp\left(G^{s}_{r,\theta,j,t}F^{s}_{r,y,j,t}+M\right)\right) \qquad \text{Eq. 5.4.6}$$

where $G^{s}_{r,\theta,j,t}$ is the proportion retained

Of the females that are above minimum legal size, setose or ovigerous animals are recorded as part of compulsory logbooks returns (see 4.4 Log books) and discarded. The estimated number of setose animals discarded is



$$N^{K,s}_{r,y,j,t} = \begin{cases} N^{G,s}_{r,y,j,t}\, S^{s}_{r,t} & \text{if } s = f \\ 0 & \text{if } s = m \end{cases} \qquad \text{Eq. 5.4.7}$$

The last stage in the discard cycle is female lobsters, which are above maximum size. In this category discards is given by

$$N^{D,s}_{r,y,t,j} = (N^{G,s}_{r,y,t,j} - N^{K,s}_{r,y,t,j})\, V^{K,s}_{r,\theta,t,j} \qquad \text{Eq. 5.4.8}$$

The number of lobsters retained is given by

$$N^{R,s}_{r,y,j,t} = N^{s}_{r,y,j,t} - N^{G,s}_{r,y,j,t} - N^{K,s}_{r,y,j,t} - N^{D,s}_{r,y,j,t} \qquad \text{Eq. 5.4.9}$$

In each subsequent time step, $t$, the number of lobsters is determined from

$$N^{s}_{r,y+1,j+1,t+1} = (N^{s}_{r,y,j,t}\exp(-F^{s}_{r,y,j,t}G^{s}_{r,\theta,j,t} - M)) \qquad \text{Eq. 5.4.10}$$

In time step $t = 4$ the lobsters migrate according to size with the proportion migrating in each odd area expressed as a logistic function with the proportion of the numbers migrating being

$$K_{r,t} = \frac{1}{1 + e^{-\ln(19)\frac{L^{f}_{j,t} - K_{50,r}}{K_{95,r} - K_{50,r}}}} \qquad \text{Eq. 5.4.6}$$

The proportion of lobsters moving into an area is shown in Table 5.4.

Table 5.4. Matrix describing the source area and proportional distribution amongst destination areas for migrating lobsters.



| | | To | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Area | 2 | 4 | 6 | 8 | 10 | 12 | 14 | 15 |
| | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | 3 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| | 5 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| | 7 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 |
| From | 9 | 0 | 0 | 0 | 0 | 0.75 | 0 | 0 | 0.25 |
| | 11 | 0 | 0 | 0 | 0 | 0 | 0.5 | 0 | 0.5 |
| | 13 | 0 | 0 | 0 | 0 | 0 | 0 | 0.75 | 0.25 |
| | 15 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

*Egg Production*

The major indicator of stock status is the egg production in regions $\delta = 1$: southern region (area 4, 6), $\delta = 2$: northern region (areas 6, 8) and $\delta = 3$: Abrolhos region (areas 15-16). For carapace length, $L^{f}_{y,12}$, the egg production in time-step *t* =12 is given by

$$\Theta_{\delta,y} = \sum_{\gamma} \left\langle \left( \frac{1}{1+\mathrm{e}^{-\ln(19)\frac{L^{f}_{j,12}-L_{50}}{L_{95}-L_{50}}}} + \frac{1}{1+\mathrm{e}^{-\ln(19)\frac{L^{f}_{j,12}-D_{50}}{D_{95}-D_{50}}}} \right) e \cdot {L^{f}_{j,12}}^{d} \cdot N^{s}_{r,y,12,j} \right\rangle \qquad \text{Eq. 5.4.11}$$

where the coefficient and power *e* = 1.92 and *d* = 2.69 (Chubb, 1991), and $L_{50}$, $L_{95}$, $D_{50}$, $D_{95}$ are constants (Caputi 1995).

The management reference point is that the median value of the egg production index,

$I_{\delta,y} = \frac{\Theta_{\delta,y}}{\Theta_{\delta,1980}}$ should be > 1

*Catches*

The catch (tonnes) in each region, year, and time-step is given by



$$\hat{C}_{r,y,t} = \sum_{s} \sum_{j=2}^{A} N_{r,y,j,t}^{R,s} \; W_{j,t}^{s} \qquad \text{Eq. 5.4.12}$$

<u>Data sources</u>

*Catch and effort*

The population model used catch and effort in the each year split into 24 half monthly time-steps) in each of the 16 model areas. This spatial and temporal detail was obtained using statuary monthly catch and effort statistics in $1^{o}$ by $1^{o}$ blocks and dividing it into the finer spatial and temporal scale using skippers detailed logbook data which is completed by 30% - 40% of the fleet. The data was also pooled in catch and effort from the whites season (November to January) and the reds season (February to June).

*Puerulus data*

The puerulus counts are available for the years 1968 to 2005, with the collector at Alkimos (Figure 1) used as an index of recruitment in areas 1,3,5, the collector at Jurien for Area 7 and the Seven Mile Beach collector used for Areas 9, 11, 13, 15 (Table 5.5). The two year lagged puerulus count in each region and year, $\theta_{r,y}$, with a puerulus power, $\omega_r$, were used to account for density dependency. The annual variation in recruitment in each area was used in the objective function to tune the recruitment deviations.

Table 5.5. Puerulus settlement indices used to determine recruitment in each area of the model.

| | Area | | |
|---|---|---|---|
| Year | 1,3,5 | 7 | 9,11,13,15 |
| 1968 | 20 | 80 | 95 |
| 1988 | 48 | 132 | 85 |

| | | | |
|---|---|---|---|
| 1969 | 1 | 4 | 14 |
| 1970 | 2 | 17 | 35 |
| 1971 | 7 | 35 | 67 |
| 1972 | 8 | 40 | 33 |
| 1973 | 30 | 117 | 83 |
| 1974 | 56 | 210 | 160 |
| 1975 | 20 | 80 | 98 |
| 1976 | 15 | 64 | 115 |
| 1977 | 18 | 74 | 86 |
| 1978 | 20 | 82 | 182 |
| 1979 | 24 | 96 | 78 |
| 1980 | 11 | 48 | 99 |
| 1981 | 28 | 108 | 83 |
| 1982 | 2 | 25 | 40 |
| 1983 | 10 | 80 | 105 |
| 1984 | 42 | 239 | 191 |
| 1985 | 13 | 185 | 128 |
| 1986 | 3 | 61 | 60 |
| 1987 | 12 | 44 | 61 |
| 1988 | 48 | 132 | 85 |
| 1989 | 25 | 177 | 205 |
| 1990 | 15 | 71 | 106 |
| 1991 | 13 | 65 | 93 |
| 1992 | 10 | 47 | 57 |
| 1993 | 7 | 35 | 63 |
| 1994 | 45 | 74 | 103 |
| 1995 | 84 | 194 | 219 |
| 1996 | 65 | 259 | 97 |
| 1997 | 27 | 62 | 74 |
| 1998 | 11 | 67 | 27 |
| 1999 | 96 | 182 | 61 |
| 2000 | 72 | 234 | 164 |
| 2001 | 37 | 133 | 101 |
| 2002 | 4.5 | 38 | 73 |
| 2003 | 10 | 77 | 118 |
| 2004 | 12 | 112 | 77 |
| 2005 | 15.88 | 90 | 92.25 |



*Breeding stock indices*

The Fisheries Dependent Breeding Stock Index (DBSI), collected since 1975 and the Fisheries Independent Breeding Stock Index (IBSI), collected since 1992, are used as indices of egg production (see sections 4.2 and 4.3).

Table 5.6. Estimates, and standard deviations of the two indices of egg production, the Fisheries Dependent Breeding Stock Index (DBSI) and the Fisheries Independent Breeding Stock Index (IBSI)

| | DBSI | | | | IBSI | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | North coastal | | South coastal | | North coastal | | South coastal | | Abrolhos | |
| Season | value | sd | value | sd | value | sd | value | sd | value | sd |
| 1975 | 0.17 | 0.03 | 0.20 | 0.03 | | | | | | |
| 1976 | 0.24 | 0.04 | 0.13 | 0.02 | | | | | | |
| 1977 | 0.20 | 0.04 | 0.15 | 0.03 | | | | | | |
| 1978 | 0.17 | 0.03 | 0.17 | 0.03 | | | | | | |
| 1979 | 0.15 | 0.03 | 0.17 | 0.03 | | | | | | |
| 1980 | 0.10 | 0.02 | 0.14 | 0.03 | | | | | | |
| 1981 | 0.13 | 0.02 | 0.08 | 0.02 | | | | | | |
| 1982 | 0.11 | 0.02 | 0.13 | 0.02 | | | | | | |
| 1983 | 0.10 | 0.01 | 0.15 | 0.03 | | | | | | |
| 1984 | 0.11 | 0.02 | 0.13 | 0.02 | | | | | | |
| 1985 | 0.17 | 0.03 | 0.12 | 0.02 | | | | | | |
| 1986 | 0.11 | 0.02 | 0.09 | 0.02 | | | | | | |
| 1987 | 0.13 | 0.02 | 0.15 | 0.02 | | | | | | |
| 1988 | 0.13 | 0.02 | 0.12 | 0.03 | | | | | | |
| 1989 | 0.08 | 0.01 | 0.13 | 0.02 | | | | | | |
| 1990 | 0.07 | 0.01 | 0.10 | 0.02 | | | | | | |
| 1991 | 0.07 | 0.01 | 0.09 | 0.01 | | | | | 1.34 | 0.18 |
| 1992 | 0.07 | 0.01 | 0.09 | 0.01 | 0.11 | 0.01 | 0.10 | 0.02 | 0.85 | 0.12 |
| 1993 | 0.08 | 0.01 | 0.07 | 0.01 | 0.07 | 0.01 | 0.08 | 0.01 | 0.96 | 0.14 |
| 1994 | 0.11 | 0.02 | 0.12 | 0.02 | 0.14 | 0.02 | 0.15 | 0.02 | 1.23 | 0.16 |
| 1995 | 0.15 | 0.02 | 0.20 | 0.03 | 0.16 | 0.02 | 0.13 | 0.02 | 1.13 | 0.17 |
| 1996 | 0.20 | 0.03 | 0.24 | 0.04 | 0.24 | 0.03 | 0.14 | 0.03 | 2.01 | 0.29 |
| 1997 | 0.14 | 0.02 | 0.25 | 0.04 | 0.29 | 0.03 | 0.16 | 0.03 | 1.85 | 0.26 |
| 1998 | 0.24 | 0.04 | 0.23 | 0.04 | 0.32 | 0.06 | 0.21 | 0.04 | 1.63 | 0.25 |
| 1999 | 0.31 | 0.06 | 0.31 | 0.05 | 0.78 | 0.14 | 0.46 | 0.09 | 2.01 | 0.31 |
| 2000 | 0.19 | 0.03 | 0.31 | 0.05 | 0.68 | 0.12 | 0.29 | 0.06 | 1.58 | 0.23 |
| 2001 | 0.13 | 0.02 | 0.22 | 0.04 | 0.24 | 0.04 | 0.16 | 0.03 | 0.86 | 0.13 |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 2002 | 0.13 | 0.02 | 0.31 | 0.05 | 0.28 | 0.03 | 0.15 | 0.03 | 1.41 | 0.22 |
| 2003 | 0.12 | 0.02 | 0.25 | 0.04 | 0.31 | 0.06 | 0.19 | 0.03 | 1.11 | 0.16 |
| 2004 | 0.14 | 0.02 | 0.19 | 0.03 | 0.15 | 0.02 | 0.20 | 0.04 | 0.90 | 0.13 |
| 2005 | 0.17 | 0.03 | 0.29 | 0.05 | 0.26 | 0.03 | 0.18 | 0.04 | 1.25 | 0.18 |
| 2006 | 0.13 | 0.01 | 0.19 | 0.03 | 0.15 | 0.02 | 0.151 | 0.03 | 0.71 | 0.11 |
| 2007 | | | | | 0.11 | 0.01 | 0.10 | 0.02 | 1.83 | 0.26 |



*Setose lobsters*

The numbers of discard lobsters from skippers logbook data was pooled into season (whites or reds) each year and each of the management zones: Zone C ($\phi = 1$, areas 1-8), Zone B ($\phi = 2$, areas 9-14) and Zone A ($\phi = 3$, areas 15-16) and denoted $\Phi_{\phi,y}$. Although not in the population model objective function, the model estimate of setose numbers, $N^{K,f}_{\phi,y}$, is compared the observed numbers to check the reliability of the model structure.

*Objective function*

The objective function incorporates information on;

- catches in half monthly time steps in each of the 16 areas,
- annual estimates of egg production in the three regions from the fishery (DBSI and IBSI),
- proportionally adjusted puerulus settlement indices.

The contribution of catches to the likelihood function is given by

$$\lambda_1 = \sum_{r,y,t} \left( \frac{1}{2\sigma^{C\ 2}} (\ln(C_{r,y,t}) - \ln(\hat{C}_{r,y,t}))^2 + \ln(\sigma^C) \right)$$

The contribution of egg production from IBSI in each region to the likelihood function is given by

$$\lambda_2 = \sum_{\delta,y} \left( \frac{1}{2\sigma_{\delta,y}^{\Omega\ 2}} (\ln(\Omega_{\delta,y} - \ln(\Theta_{\delta,y})))^2 + \ln(\sigma_{\delta,y}^{\Omega}) \right)$$



The contribution of egg production from DBSI in each region to the likelihood function is given by

$$\lambda_3 = \sum_{\delta,y} \left( \frac{1}{2\sigma_{\delta,y}^{\Psi\ 2}} (-\ln(\Psi_{\delta,y}) - \ln(\Theta_{\delta,y}))^2 + \ln(\sigma_{\delta,y}^{\Psi}) \right)$$

The contribution of puerulus settlement deviations to the likelihood is

$$\lambda_3 = \sum_{\delta,y} \left( \frac{1}{2\sigma_{\delta,y}^{\theta\ 2}} (\varepsilon_{r,y}^{P} - \varepsilon_{r,y}^{R})^2 + \ln(\sigma_{\delta,y}^{\theta}) \right)$$

The objective function, which is minimised in the model, consists of the negative of the likelihood functions, together with the penalty functions as shown:

$$\lambda = \lambda_1 + \lambda_2 + \lambda_3 \qquad \text{Eq. 5.4.13}$$

Parameter values

*Parameters assumed*

The instantaneous rate of natural mortality, *M*, is 0.22 per year (Morgan 1995) which is considerably higher than the value of 0.1 chosen by Punt and Kennedy (1997) for *Jasus edwardsii* and that estimated by Starr *et al*. (1999) for *Jasus edwardsii.*

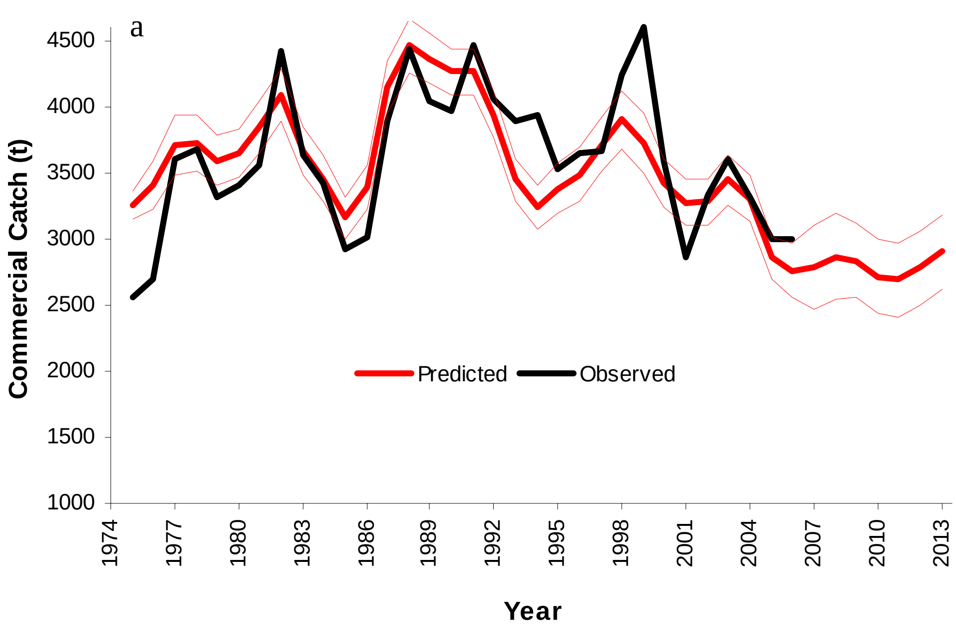
The value for the residual standard deviation of the catch data, $\sigma_C$ , was assumed to be 0.5.

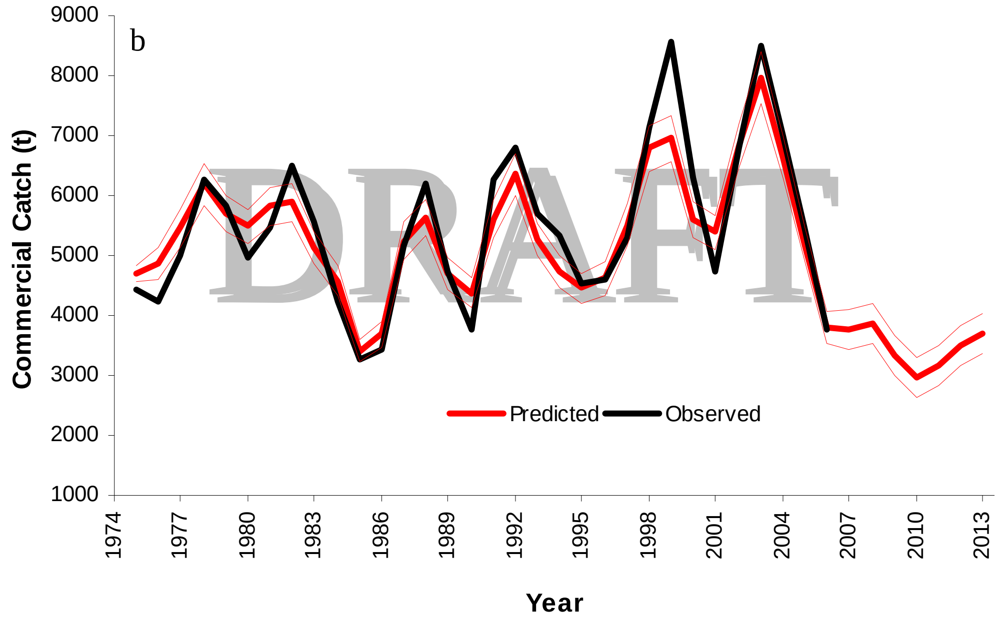
## *5.5.2 – Results*

<u>Catch estimation</u>



Catches estimated by the model matched those recorded by CAES (Section 4.5), however there is a need for further tuning. Examples of actual and estimated catches are shown for the northern and southern coastal zone where the catches have been estimated for shallow and deep water of each individual 1$^{o}$ transect and then pooled to provide regional estimates (Figures 5.9a, b). In the last five years (and 11 out of the last 12 years) the actual catch has been lower than the modelled catch and this may reflected the effect of increased migration from coastal locations to the Abrolhos (Section 7.1.4) and the increase in the minimum size during the migration period. The peak and troughs in the south coastal catch are not reached by the modelled estimates and this requires further assessment.



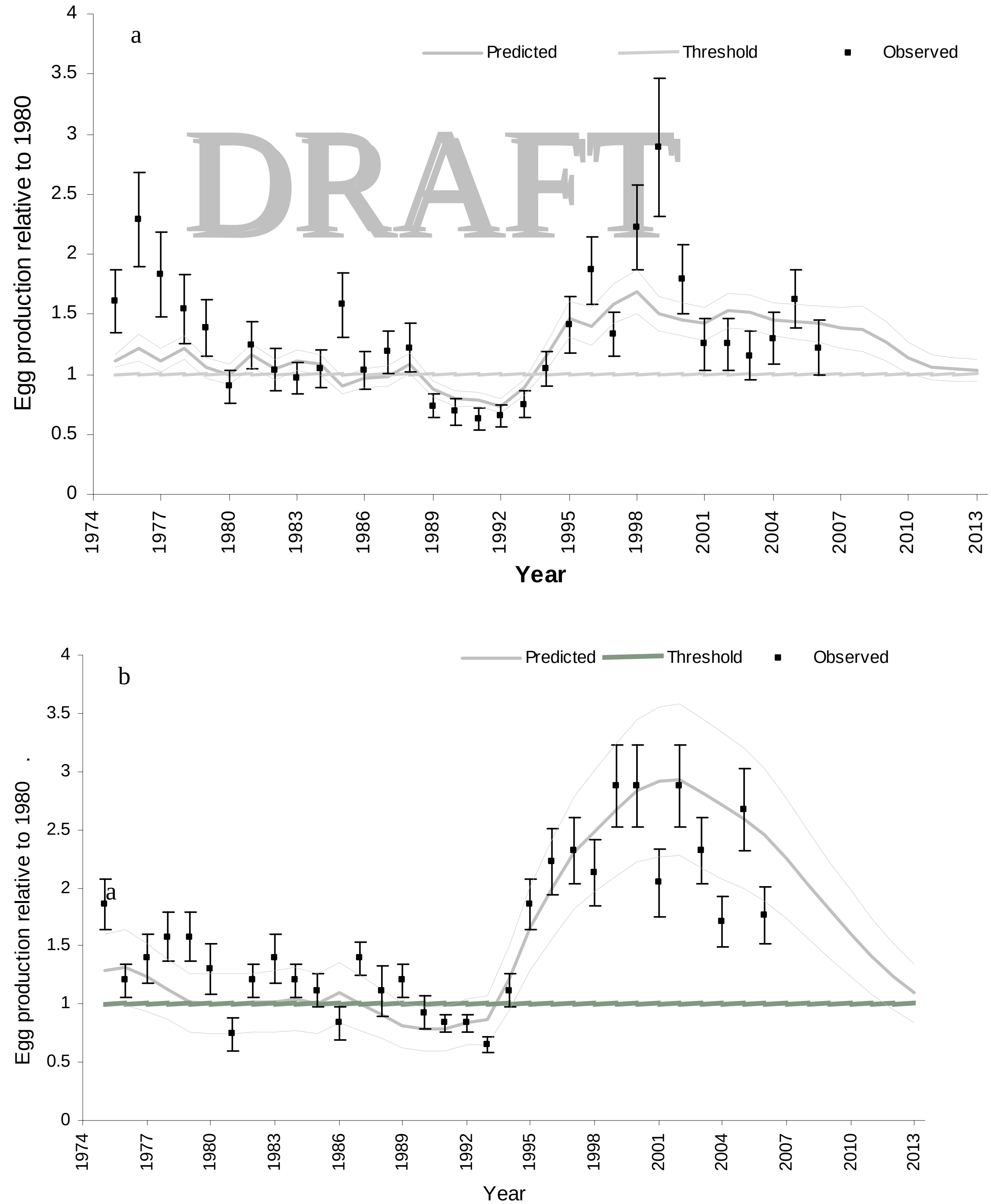



Figures 5.9 – Actual and modelled catches for the (a) northern and (b) southern coastal regions of the fishery.

<u>Model derived breeding stock indices</u>

The same spatial scale was used by the model to produce breeding stock indices (BSI) comparable to the north and south coastal fishery-dependent BSIs.  For these regions, the indices exhibited trends very similar to those produced by the fishery independent and dependent BSIs (Figures 5.10, 4.6 and 4.9).

In the southern coastal regions the model derived BSIs are currently well above the estimated 1980.  This however is not the case in the northern coastal region where the BSI is currently the same as its BRP.  This index does however appear to be trending sideways and management changes have been implemented (15% effort reduction in 2005/06) to increase the breeding stock in this zone (Box 2.1).






Figures 5.10 – Model-derived breeding stock indices (±SE) for a) northern and b) southern coastal regions (both based on data from the deep-water regions of the same

areas as the dependent BSI, respectively). Observed values are fishery dependent BSIs scaled to allow comparisons.

### *5.5.3 – Assessment of proposal management changes for the 2008/09 – 2010/11 fishing seasons*



<u>Background</u>

The draft biological model was used to assess the impact of proposed effort reductions on the catch and breeding stock in the two coastal regions of the fishery (northern and southern). Four effort reduction scenarios were examined for each of the two regions, the first two consisted of once off reductions in season one only (2008/09), the last two consisted of sequential reductions of the same magnitude in all three seasons (Table 5.7).

Table 5.7. Four effective effort reduction scenarios evaluated by the biological model for the 2008/09 – 2010/11 fishing seasons.

| Fishing season | Scenario 1 | Scenario 2 | Scenario 3 | Scenario 4 |
|---|---|---|---|---|
| 2008/09 | 30% | 20% | 10% | 5% |
| 2009/10 | 0% | 0% | 10% | 5% |
| 2010/11 | 0% | 0% | 10% | 5% |
| Total reduction | 30% | 20% | 30% | 15% |

<u>Impact of effort reduction scenarios on commercial catch</u>

The biological model was used to assess the impact of proposed effort reductions on the model predicted catch in the two coastal regions of the fishery (northern B zone and southern C zone) (Tables 5.8 and 5.9, Figures 5.11 and 5.12).

<u>Northern coastal zone (B)</u>

In the northern coastal B zone the model estimated that a 5% effective effort reduction per year will produce a negligible reduction in the predicted catch (Table 5.8, Figure 5.11). In contrast, a 30% reduction in the first year provides a substantial 18% reduction in that year and a 7% reduction in the second year of the package (Table 5.8, Figure 5.11). The 10% per year reduction affords a more moderate reduction in catch with a 5%, 6% and 7% reduction, respectively (Table 4)



Table 5.8. Model-derived impact of four-effort reduction scenarios on the predicted commercial catches in the northern B zone.

| Season | Reduction in Predicted Catch (%) | | | |
|---|---|---|---|---|
| | 5% Per Year | 10% Per Year | 20% First Year | 30% First Year |
| 2008/09 | 2 | 5 | 9 | 18 |
| 2009/10 | 1 | 6 | 4 | 7 |
| 2010/11 | 0 | 7 | 1 | 2 |

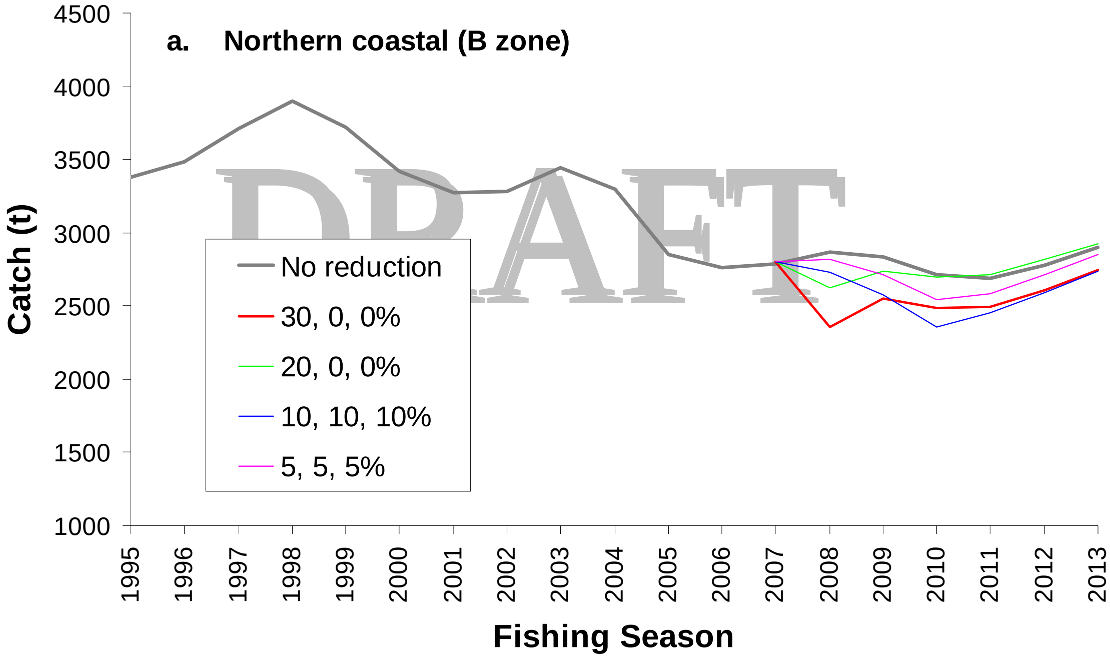



Figure 5.11 Model-derived impact of four-effort reduction scenarios on the predicted commercial catches in the northern B zone.

<u>Southern coastal zone (C)</u>

The expected percentage reductions in catch are provided in Table 5.9 and Figure 5.12. For a 5% effective effort reduction per year the actual catch is estimated to be 3%, 3% and 4% below the predicted catches for the seasons 2008/09, 2009/10 and 2010/11 respectively. A 30% reduction in the first year reduced the catch markedly (18%) in that year, while impacting years two and three only to a small extent (Table 5.9; Figure 5.12).

Table 5.9. Model-derived impact of four-effort reduction scenarios on the predicted commercial catches in the southern C zone.

| Season | Reduction in Predicted Catch (%) | | | |
|---|---|---|---|---|
| | 5% Per Year | 10% Per Year | 20% First Year | 30% First Year |
| 2008/09 | 3 | 6 | 12 | 18 |

| | | | | |
|---|---|---|---|---|
| 2009/10 | 3 | 7 | 2 | 5 |
| 2010/11 | 4 | 10 | 1 | 3 |

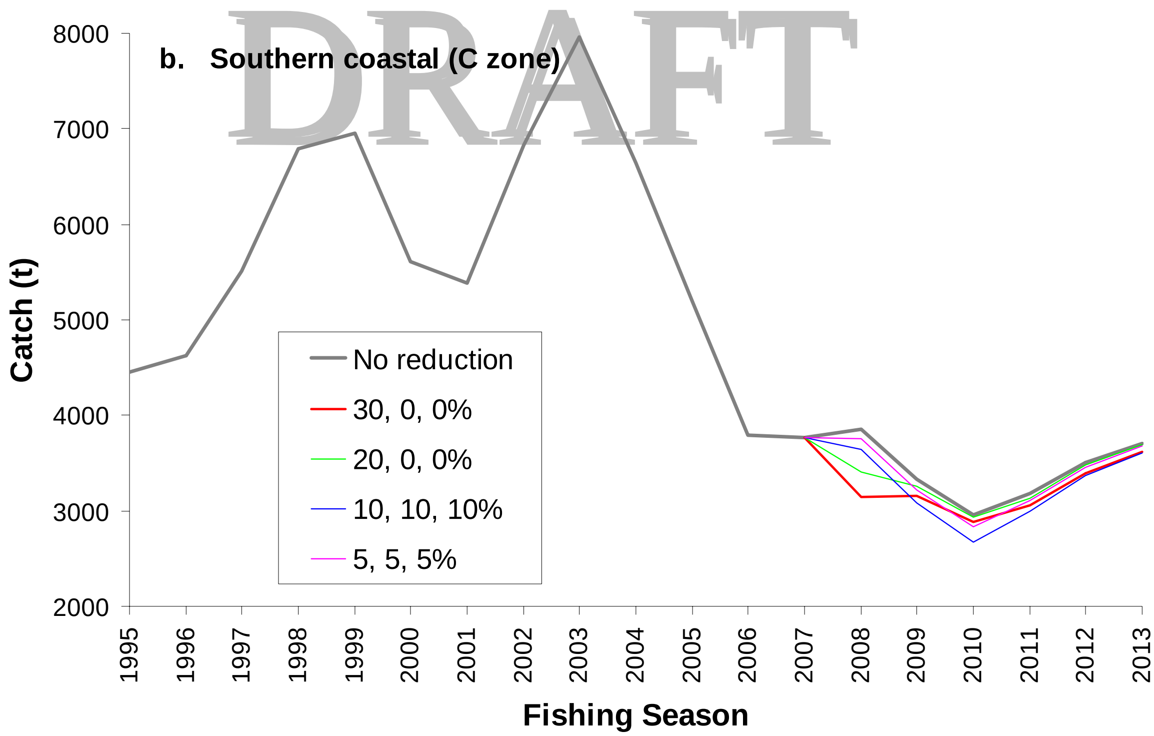



Figure 5.12. Model-derived impact of four-effort reduction scenarios on the predicted commercial catches in the southern C zone.

Impact of effort reduction scenarios on breeding stock levels

The biological model was also used to assess the impact of proposed effort reductions on the model predicted breeding stock in the two coastal regions of the fishery (northern B zone and the southern C zone) (Tables 5.8 and 5.9, Figures 5.11 and 5.12).

Northern coastal zone (B)

The impacts of the four effort reduction scenarios on the breeding stock index (BSI) are displayed (Figure 5.13). In summary a 5% reduction in effective effort each year was estimated to have no significant impact on the decline of the predicted BSI. A 10% per year reduction was estimated to provide an increase in the BSI, while the 30% reduction provides a substantial initial increase in the BSI. In the long term (2013) both the 10% effective effort reduction over three years, and the 20 and 30% effective effort once off reductions are estimated to result in similar BSI levels.



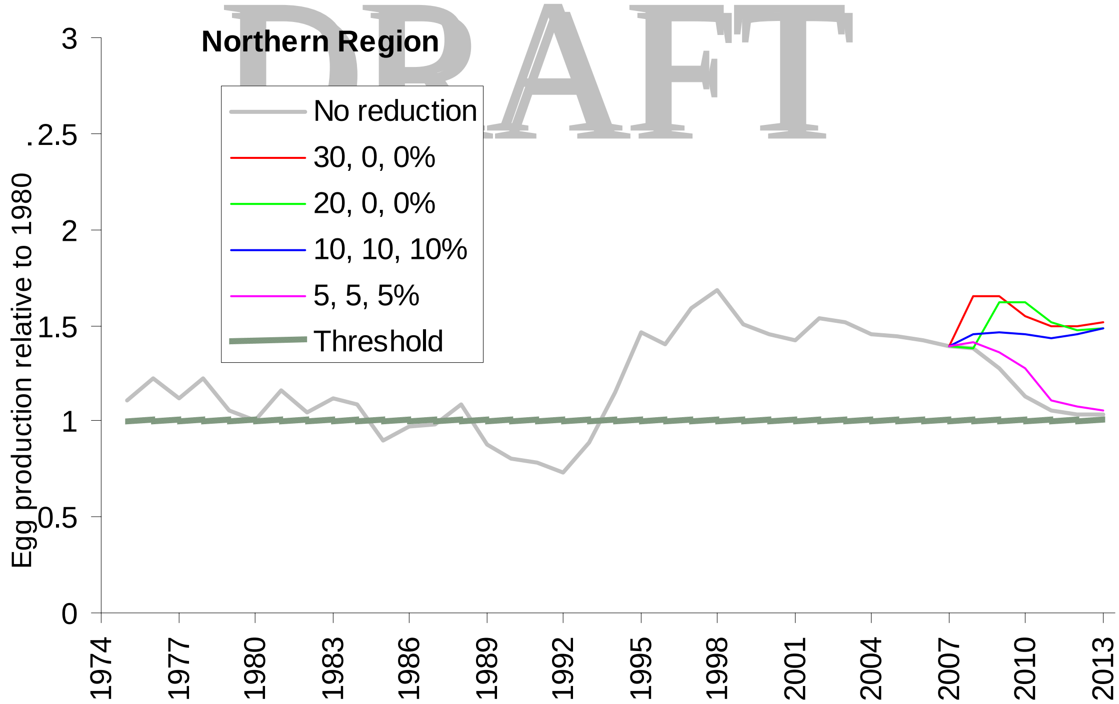



Figure 5.13. Model-derived impact of four-effort reduction scenarios on the predicted breeding stock index in the northern B zone.

<u>Southern coastal zone (C)</u>

The impacts on the BSI are displayed in Figure 5.14. In summary a 5% per year reduction in effective effort was estimated to have no significant impact on the decline of the predicted BSI. A 10% per year reduction in effective effort for 3 years was estimated to slow the decline in the BSI but the response is not as fast as either the 20 or 30% reduction. A 30% reduction in effective effort in the first year is estimated to provide a more immediate response. In the long term (2013) both the 10% effective effort reduction over three years, and the 30% effective effort one off reduction are estimated to result in a similar level BSI.

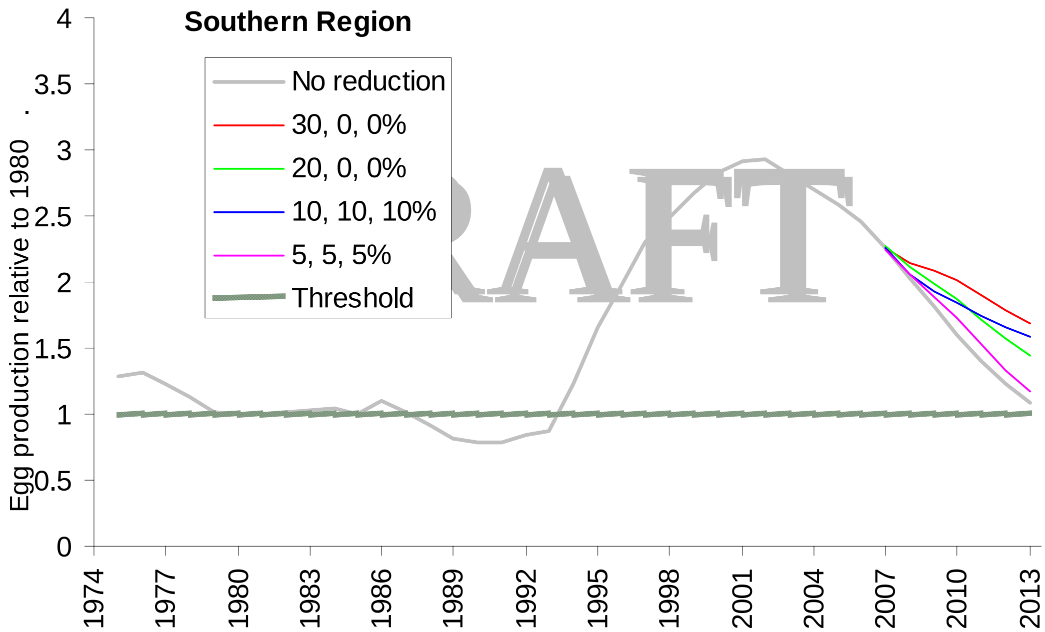



Figure 5.14. Model-derived impact of four-effort reduction scenarios on the predicted breeding stock index in the southern C zone.

## *5.5.4 – Future Directions*

There are several areas of the model that will be investigated in the future include:

- Sensitivity analyses.
- Estimates of harvest rate by area (1 – 16).
- Estimates of efficiency creep by area (1 – 16).
- Impact of a declining size at maturity.
- Impact of increasing growth rates.
- Further evaluation of management strategies.

## 5.6 – Economic Model



Effective effort reductions (TAE) of 15 and 5% were recommended in Zones B and C, respectively, for the 2005/06 to ensure breeding stock levels (Figure 4.6 and 4.8) remained above their BRPs (Section 2.0). The management options for obtaining these reductions included a number of temporal closures, legal-size changes and pot reductions, with the combination of these employed were considered by industry (Box 2.1 – 2005/06). In order to assist in the decision process an economic model was developed by the Department of Fisheries (Thomson & Caputi 2006) to assess the short-term (1-2 years) economic impacts of various effort reducing measures on the expected gross margin of fishers in each zone.

### *5.6.1 – Methods*

Three management options were considered by the model; trap reductions, seasonal or time closures and changes to the maximum size of females. These management options have differing impacts on the biological, economic and social aspects of the fishery.

This project used average costs for fishers in each of the three zones and these were obtained from the economic project evaluating input and output methods of management for the rock lobster fishery undertaken by University of WA.

The impact on catch (and hence income) of the management options was undertaken using an update of the Hall and Chubb (2001) model.

Pot Reductions

Pot reductions would achieve the required reduction in effort, with savings resulting in terms of pot and bait usage. However, numbers of days fished would remain the same, seeing little reduction, if any, in fuel costs. However, it may have longer-term effects through rationalisation of the fleet, with licences being sold and fishers leaving the industry. This may lead to improvement in the economic efficiency of the fleet, though there are likely to be considerable transitional costs associated with redundant capital.

Pot reductions for part of the season, during high catch periods, may also provide improved prices for lobster and allow more orderly processing and marketing of lobster.

Time Closures



Focused around low catch periods, time closures have considerable savings in terms of fuel and bait costs, while minimal impact on catches. Low catch periods identified were in November, January, June and over full moon periods. They also provide social benefits to the industry providing a rest period during the seven and a half month season.

Maximum Female Size Reduction

Lowering of the maximum size by 5 mm would provide direct protection for mature females and improve breeding stock. However, this would have no economic advantages in terms of operating costs.

### *5.6.2 – Results*

The economic model assessment was to show which of the management options used would provide the greatest effort reduction while minimising the short-term negative economic impact on fishers.

The economic assessment was undertaken for the first two years of any proposed management change, providing an initial impact of the management initiatives (year 1; Figure 5.11) and also looking at the flow on effects in the following year (year 2; Figure 5.12).

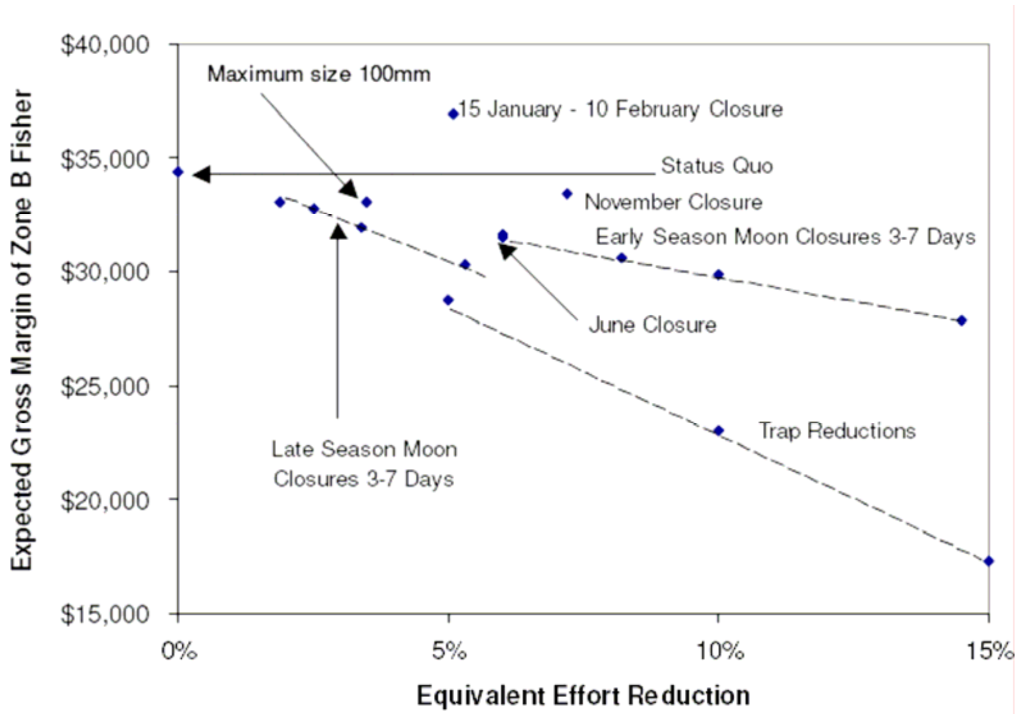



Figure 5.15 – Expected gross margin in year 1 versus the effective effort reduction for Zone B (Thomson & Caputi 2006)

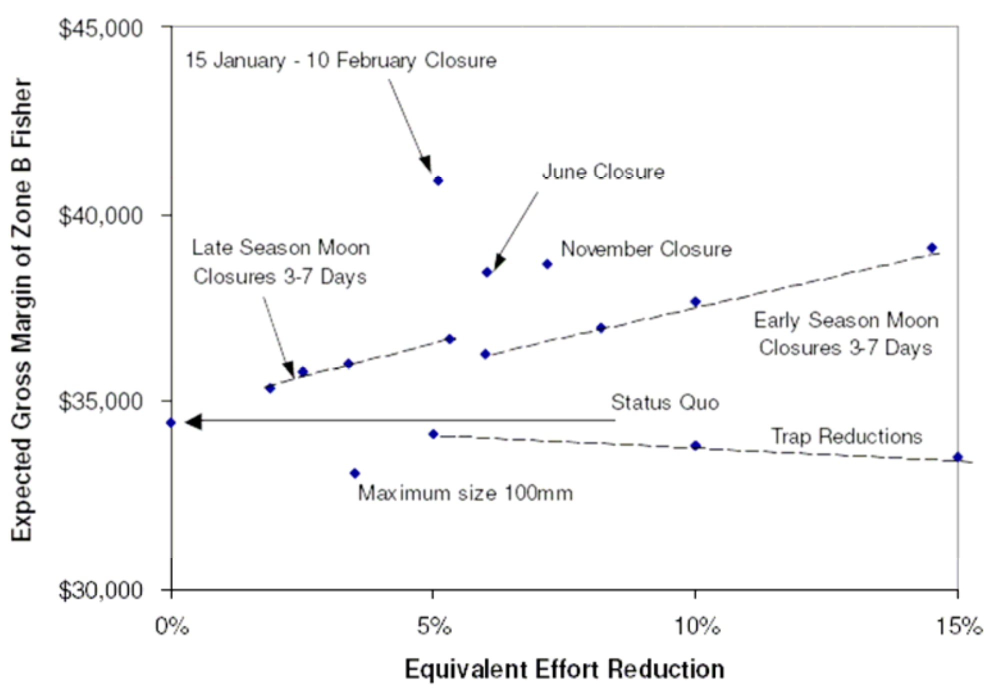



Figure 5.16 – Expected gross margin in year 2 versus the effective effort reduction for Zone B (Thomson & Caputi 2006).

Pot Reductions

As there isn't significant operational cost savings from a pot reduction, with fishers still fishing the same number of days and using similar amounts of fuel, there is a marked reduction in the gross margin in the first year (Figure 5.11). However, the impact isn't as dramatic in the second year, (Figure 5.12) as forgone catch from year one is available in year two, even with a 15% pot reduction.



Time Closures

There are several types of time closures examined, with the most beneficial being a closure from 15th January to 10th February, which resulted in an improvement in expected gross margin, with an effort reduction of 5% in the first year (Figure 5.11), and even greater fiscal benefits in year 2 (Figure 5.12).

A November closure also produced an effort reduction of 7%, with only a minimal reduction in expected gross margin in the first year (Figure 5.11), and an increase in year 2 (Figure 5.12).

Moon closures, the other major time closure considered, were not as effective as either of the more seasonal closures shown above but still showed improvements in economic performance in the second year while achieving a small effort reduction.

Maximum Female Size Reduction

Alteration to the maximum legal size for females did have an equivalent impact of 3 – 4% effort reduction on the breeding stock. However, it provided no cost savings to the fleet, and didn't provide flow over effects for stock availability in subsequent years.

Management Package Outcome

The outputs of this model were used in the construction of a suite of management initiatives designed to protect the breeding stock. They form a three-year effort reduction package that is outlined in Box 2.1 (see 2005/06). Included in the package was a "Sundays off" option that was not examined as part of this model. This was an industry-based decision as an alternative to moon closures, which provided occupational health and safety benefits through breaks during the seven and a half month season.

### *5.6.3 – Future Direction*

Currently a more-detailed economic model is being developed to assist in future management decisions.  This model should evaluate long-term (5 years) as well as the short-term economic impacts. Eventually, outputs from this model will be used, in consultation with stakeholders, to decide on the most economically and socially beneficial management package to address the biological changes in the breeding stock. It is planned that this economic model will be linked to the biological model so that there is a biological and economic assessment of any proposed management change.

# 6 – Biological Reference Points and Stock Status

## 6.1 – Management Decision Framework



In a discussion paper released in 2004, a decision framework was proposed for the WCRLMF (Bray 2004). This framework was designed to provide flexibility, transparency and accountability, and advances the concept of co-management in the management system.

### *6.1.1 – Background*

The basis of the decision framework is to address a number of objectives in bringing about changes to the management regime. The specific objectives (after Bray (2004)) are:

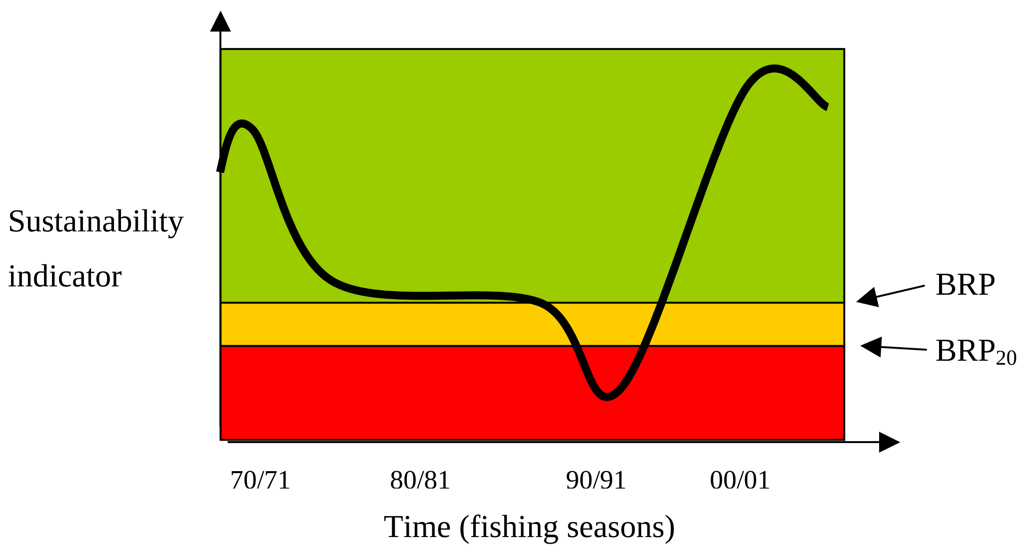
- Biological objective: That management arrangements maintain or return to, as the case may be, the abundance of breeding lobsters at or above the levels in 1980 (Biological Reference Point (BRP)).
- Ecological objective: That management arrangements are consistent with the principles of ecosystem-based fisheries management and in particular:
    - Ensure that by-catch of marine mega-fauna is minimised
    - That the effects of fishing do not result in irreversible changes to the ecological processes.
- Commercial objectives: (i) That management arrangements maximise the opportunity for optimum economic returns to the Western Australian community from the use of the western rock lobster resource. (ii) That management arrangements foster the maintenance and development of regional communities while not unnecessarily restricting normal business practices.
- Recreational objective: That management arrangements which impact upon the recreational fishery promote the fundamental ethos of recreational fishing, i.e. it is an enjoyment motivated activity.

This has lead to the design of three management decision rules, which when presented as flow diagrams, require Yes/No responses to questions within the framework to move to the appropriate management outcome (Appendix 9).



### *6.1.2 – Decision Rules*

The decision rule after Bray (2004) deals with the biological objective of sustainability, which is based on the stock status (Figure 6.1).




**Green** = healthy

**Orange** = consider stock status

**Red** = unsustainable

Figure 6.1 – Variation in WRL breeding stock abundance as a percentage of unfished biomass over time in relation to two biological reference points, the 1980 level (BRP) and 20% below this level ($BRP_{20}$) (Bray 2004). The two BRP represent different levels of management action required.

This leads to a framework of decision rules (Appendix 9)

### *6.1.3 –Future Direction*

Alterations to the current decision rules are being considered. The new framework will incorporate the breeding stock and harvest rates in the same primary assessment (Figure 6.2). The current breeding stock reference point is based on the 1980 level, while a second harvest rate reference point will be developed (reference point yet to be decided and may vary between zones), in consultation with stakeholders.



The annual estimates of breeding stock and harvest rate would quickly identify the stock status, and is required factors need attention to ensure sustainability in this fishery (Figure 6.2). For example, if the stock status is in the green square, no action is required, however if in the top orange square, adjustments to harvest rate should be considered to avoid the stock falling into the overexploited area. If the stock is in the bottom orange square then the stock is over-fished but the effort reductions are already in place for the stock to recover. If the stock status is in the red square, management measures are required to reduce harvest rate so the breeding stock is able to recover.

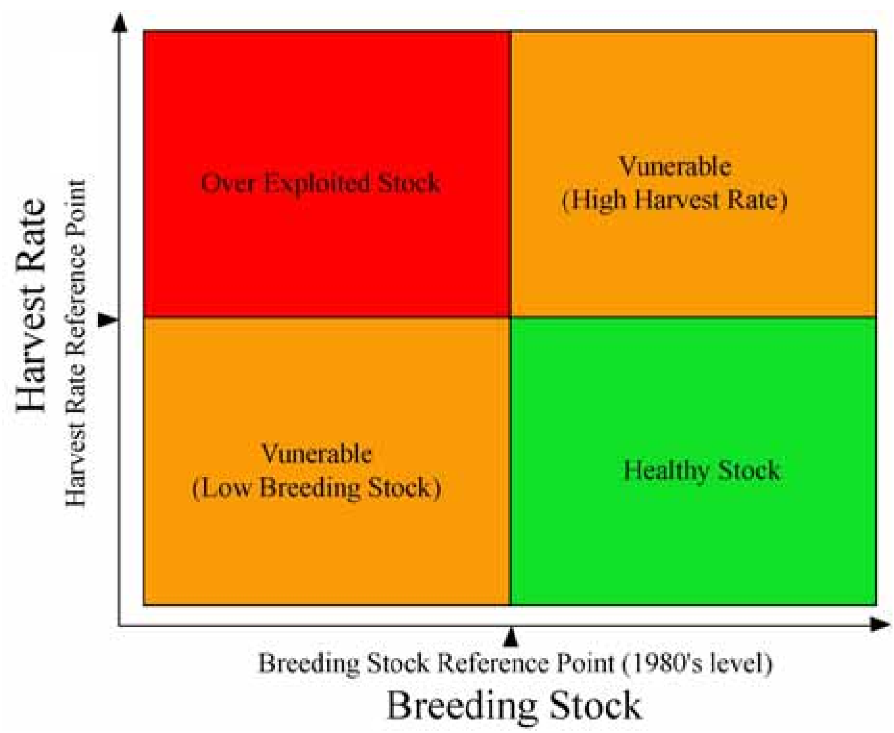



Figure 6.2 – Proposed new model assessing the stock vulnerability based on breeding stock and harvest rate levels.

## 6.2 – Stock Status

The status of the lobster stocks in each of the three management zones (A – C) is assessed annually based on trends exhibited by a number of empirical and model-derived indices. These include fishery-dependent (Section 4.2), fishery-independent (Section 4.3) and modelled (Section 5.5) indices of breeding stock (BSI), log-book estimates of the setose female biomass (Section 4.4), depletion-based estimates of residual biomass, harvest rate and efficiency increases (Section 5.4) and model-derived estimates of annual efficiency increases (Section 5.5). The primary performance indicator of stock status is currently the BSI relative to its estimate during the 1980/81 fishing season for the north and south coastal zones (Biological Reference Point - BRP). The use of multiple indices allows for the cross checking of general trends, with agreement increasing assessment confidence or disagreement highlighting areas that need further assessment.

### *6.2.1 – Stock Status by Zone (2005/06 fishing season)*

<u>Zone A</u>



- The catch in this fishery in the 2004/05 and 2005/06 season have been the two highest on record for this region. As the size at maturity is below the legal size and the fishery opens (15 March) after spawning has completed in the late spring/summer and followed by a moult in about February, catch has been used historically as an indication of the spawning stock
- The full season harvest rate is currently estimated at 85% based on the depletion analysis, which is down on the maximum of 92% recorded in the 1999/00 fishing season (Section 5.4). Although the harvest rate is high, being significantly below its maximum, suggests this level is sustainable. A BRP does not currently exist for this parameter.
- Residual legal biomass remaining at the end of the fishing season was estimated at 614 t, which in the highest level recorded (Section 5.4).
- A efficiency increase occurred after the 18% pot reduction in 1993/94 that may be due to pot saturation effect (Section 5.4).
- The numbers of setose females returned to the water has been increasing since the 1993/94, with the 2004/05 season recording the highest estimate before a slight downturn in the last season to 1.82 million (2005/06) (Section 4.4).
- The fishery-independent BSI has declined in recent years and needs to be monitored (Section 4.3).
- The model-derived BSI is currently well above the its estimated 1980 level and trending sideways (Section 5.5).

The above indices indicate that in Zone A the stock is heavily exploited, however given the trend in the catch and that spawning occurs below the size at maturity, its breeding component is considered to be at a healthy level. A BRP needs to be set for the Zone A BSI and harvest rate.

Zone B

- The full season harvest rate, adjusted for the 1993/94 package, has increased progressively since 1995/96 before levelling off at ~80% over the past the seasons (Section 5.4). This level is considered high. A BRP does not exist for this parameter.
- The residual legal biomass estimated to remain at the end of the fishing season has declined rapidly from high levels in 1995/96 (~2800t) to level off at below 800t in the last three seasons (Section 5.4). A BRP does not exist for this parameter.
- Efficiency has been increasing rapidly over the past ten years (Section 5.4).
- Approximately 0.96 million setose females were returned to the water in 2005/06. After peaking in 1999/00, numbers declined to a low in 2002/03, before recovering slightly and then declining again (Section 4.4).
- The fishery-dependent BSI is currently above its threshold BRP (1980 level), although its closeness to this level and recent downward trend warrant concern (Section 4.2).
- The fishery-independent BSI reinforces the status indicated by the fishery dependent BSI, i.e. the condition of the breeding stock is of concern (Section 4.3).
- The model-derived BSI is currently just below its estimated 1980 level, agreeing with both fishery-dependent and independent BSIs (Section 5.5).

The above indices indicate that the stock in Zone B is heavily exploited and its breeding component is close to the BRP threshold level. This stock is considered vulnerable, and management changes (15% effort reduction in 2005/06) have occurred to improve its status, however it will take 2-3 years for the effect of this to be seen in the spawning stock (Box 2.1). A BRP needs to be set for the Zone B harvest rate.

Zone C

- The full season harvest rate, adjusted for the 1993/94 package, has increased only slightly over recent seasons and currently resides at ~ 70% (Section 5.4). This level is considered sustainable. A BRP does not exist for this parameter.
- The residual legal biomass estimated to remain at the end of the fishing season declined slightly this season to 2800t but still remains above the early 1990's level (Section 5.4). A decline from this level would be of concern.
- Depletion analysis indicates that there has been an increase in fishing efficiency in this region over the past ten years but lower that zone B (Section 5.4).
- The number of setose females returned to the water in 2005/06, has increased from the previous season, and is still at almost record high levels (Section 4.4).
- The fishery-dependent BSI is currently far above its threshold BRP (1980 level) and appears relatively stable (Section 4.2).
- The fishery-independent BSI reinforces the status indicated by the fishery dependent BSI, however, it is above the BRP by a lesser amount than the dependent BSI (Section 4.3).
- The model-derived BSI is currently well above its estimated 1980 level, which supports the trends exhibited by the fishery dependent and independent BSIs (Section 5.5).

Catch in 2005/06 was below average and below-average catches are predicted until 2009/10 as a result of a series of low puerulus settlement due to weak or average Leeuwin Currents since 2000. This may result in a decline in spawning stock in the future.

The above indices suggest the Zone C stock is moderately exploited while its breeding component remains above the BRP threshold level. This stock is considered healthy, although with four years of predicted low recruitment, steps have been taken to keep this stock above threshold levels (Section 2). A BRP needs to be set for the Zone C harvest rate.

# 7 – Current Research

There are several projects that are currently at various stages of completion. These address a variety of research issues dealing with the effective management of the WCRLF. Project objectives are outlined below.  All pertinent results will be reported on in future editions of this document.



### *7.1.1 – Reproductive Biology Pertinent to Brood Stock Management*

The protection of setose females and large females through a maximum size limit (Box 2.2) may have distorted the sex ratios of breeding lobster. With a scarcity of males of similar size, maximum size females are presumably having to mate with smaller males, which has, in laboratory studies, been shown to lead to brood size reductions in other lobster species (MacDiarmid and Butler 1999). The WRL FRDC project (with Melville-Smith at Principal Investigator) aims to investigate the implications of the protection of maximum size females to provide preliminary information on possible reduced egg size at the Abrolhos Islands compared to coastal sites, and to quantify the extent of the breeding grounds to weight egg production for the stock by the three management zones based on these interactions.

### *7.1.2 – Lobster Movement Through Acoustic Tracking*

Acoustic tracking is a relatively new technique that allows detailed information on movement patterns, habitat usage and home ranges for aquatic species. This technology is currently being applied to the western rock lobster, to examine their movement behaviour in deep-water environments. Two tracking experiments have been undertaken in waters >50 m off Dongara and Jurien Bay, where 8 and 12 lobsters have been tracked for 90 and 70 days, respectively. Analysis is currently underway on both tracking sessions examining the foraging behaviour, in terms of timing and habitats utilised, as well as home range areas.

### *7.1.3 – Effects of Closed Areas*

A monitoring program has just been initiated to examine the impacts of fishing activities on WRL and their associated benthic habitats. This project will examine abundance, size and sex state compositions of lobsters inside and outside of sanctuary zones in shallow water sites in Jurien and off the Perth metropolitan coast. Monitoring consists of capturing lobsters in commercial batten lobster traps with enclosed escape gaps (Section 4.3), with lobsters sexed, measured, maturity condition recorded (i.e. external eggs) and tagged with a spaghetti tag before being returned to location of capture. Divers will conduct underwater visual surveys in the same locations to provide an alternative measure of lobster abundance and size composition. These surveys will run concurrently with benthic habitat and invertebrate/fish surveys.



Possible outcomes of this work will include;

i. An improved understanding on what virgin shallow-water lobster stocks may have been like in abundance and size structure;

ii. Information on whether no-take zones may be any use in the sustainable management of this species;

iii. Information about whether all lobsters move into deep water; and

iv. Growth rate data, unbiased by size-related catchability/reporting issues.

### *7.1.4 – Climate Change*

Environmental factors (Section 4.7) have been shown to have a significant effect on this lobster fishery. The south-flowing Leeuwin Current and the strength of westerly winds in late winter/spring have been shown to significantly affect the level of puerulus settlement (Section 4.1). The strength of the Leeuwin Current is influenced by the frequency of ENSO events. A strong Leeuwin Current is associated with warmer temperature and a strong eddy structure (which may affect primary production as measured by the chlorophyll levels) off the coast of Western Australia. Climate change may be causing an increasing trend in water temperature, a weakening of the westerly winds in winter/spring, an increase in the frequency of ENSO events, and an increase in the sea level. These factors can affect the level and spatial distribution in puerulus settlement, size at maturity, size of migrating lobsters, growth rates, catchability of the western rock lobster, numbers of mature females moulting from setose to non-setose condition, timing of moults and hence the timing of the peak catch rates. Some of these changes may have negative implications on the western rock lobster fishery but some such as increasing water temperature may have some positive influence. This project will asses the impact that climate change may be having on the environmental factors that affect the rock lobster fishery such as water temperature, frequency of ENSO events, Leeuwin Current strength, westerly winds and their implications for the western rock lobster fishery.

# 8 – Recommendations for Future Research

There are several areas that are being considered for future research. These include

- There are indications that some effects of climate change (e.g. water temperature increases) may be affecting some aspects of the biology of the WRL such as size at maturity, whites migration, setose moult, catchability, and puerulus settlement. These need to be assessed and appropriate trends built into the assessment models to assess the effect on the stock status. There is also a need to understand future trends in climate change provided by climate models and assess the implication for the lobster fishery.
- Understanding of aspects of the Leeuwin Current variability (water temperature, productivity, eddy structure) that is contributing to the variation in puerulus settlement.
- Assessment of ways to improve pot efficiency that can be used to improvement of the economic performance of the fishery and minimise the ecological impact of pot fishing
- Economic modelling to assess management measures to improve the economic performance of the fishery
- Further assessment of the biological model e.g. sensitivity analysis, assessment of management options, future projections, suitability for developing of BRP
- Testing improved escape gaps to minimise fishery-induced mortality of undersize lobsters
- Natural mortality, migration and carrying capacity (abundance and size structure) assessments in closed areas including proposed closed areas in deep water
- Review of estimates of fishing efficiency from different models
- Review and development of BRP for harvest rate and spawning stock for each region

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# 10 – Appendixes

*Appendix 1 – Header sheet used to record all ancillary data collected during the commercial monitoring program*



**W.A.M.R.L. ROCK LOBSTER LENGTH MONITORING**

Batch Data Header Sheet Coded Information
Version 3

**Header Reference Information**:

Date:( / / ) Vessel Reg. No.: ( )

Vessel Name:________________________________

Depth Category: ( ) Depth Range: ( to fms)

Sample Location: ( ) Sample Sub-Location: ( )

Latitude: ( ° 'S) Longitude: ( ° 'E)

**Catch and Effort Data**:

Total Catch Wt: ( kg) (Nearest Kg)

No. Pots Pulled: ( ) No. Pots Sampled:( )

Pot Types: ( )________________________________

No. Pots Pulled x Pot Type: (________________________________

Bait Types: ( )________________________________

Days Between Pull: ( ) 0 - 9 ( 9 day maximum).

Sample Indicator: ( ) **0** = Boat, **1** = Factory, **2** = Fishermens.

**Predation Data**:

No. Pots with Octopus Caught in Pot: ( )

Total No. Octopus Caught: ( )

No. Pots with Escaped Octopus: ( )

No. Rock Lobsters Predated by: Octopus: ( ), Unknown:( )
(Predation evident and/or dead) Cuttlefish:( ), Fish: ( )

Total No. **Dead** Rock Lobsters: ( )

No. RLs with Black-Spot: ( ) No. RLs with Microsporidiosis : ( )

**Environmental Data**:

Bottom Type:( / ) ie. **R**ock, **W**eed, **S**and, **C**oral + **L**umps.

Salinity Bottle No's: Surface = ____________, Bottom = ____________.

Surface Salinity:( ppt) Surface Temperature:( °C)

Bottom Salinity:( ppt) Bottom Temperature:( °C)

Nansen Sample Depth:( fms) Water Depth:( fms)

Bait Packaging Disposal: ( ) Used Bait Disposal: ( )

Sample Recorders Initials:( )

-2-

**Other Research Information**

Skippers Name:________________________________

Attitude to fishery management and research:________________________________

Pattern of fishing:

Use of GPS:________________________________

Use of Sounder:________________________________

Fishing lumps, setting lines etc:________________________________

**Beach Prices**:

| | | | |
|---|---|---|---|
| Whole Catch | $ . | /kg, | Company Name____________ |
| A+B's | $ . | /kg, | |
| C+D's | $ . | /kg, | |
| rest | $ . | /kg. | |

**Weather Conditions**:

Swell: m, Seas: m, Moon Phase:(Circle) New/First Q/Full/Last Q

Wind: kts., Current: kts., Tide: kts., Approx. Air Temp: °C.

**Additional Comments**: **ie.** Factors affecting catch and effort/new technology/reaction to management.

*Appendix 2 – Data recording sheet for the IBSS, showing information recorded.*

Page ______ of ______

# ROCK LOBSTER RESEARCH DATA RECORDING SHEET

Temperature: Surface ............°C — Date: ................................

Bottom .............°C @ .............Fms — Boat Name & No: ....................................

Salinity: Bot No. ...........Surface..............‰ — G.P.S..–North: ......................S/ .......................E

Bot No. ...........Bottom...............‰ @........Fms — South: ......................S/ ......................E

Swell Height & Direction: ................../ .................... — Depth: ...................Fathoms

Wind Speed & Direction: ...............kts/ .................... — Tag Series: ................................

Current Speed & Direction: ...........kts/ .................... — Line No: ................................

Cloud Cover: .........................% — Pot Pull Direction: ................................

I.B.S.S. DATA — DAY No. ........ GPS Mark Shape/Colour .............................. Location/ Sub Area ................................. Total Catch .............. Mature ♀s ..............

| TAG No. | BIO TAG | REC | POT No. | POT TYPE | DAY PULL | CARAPACE LENGTH | SEX | COLOUR | SETOSE PLEOPS | TAR SPOT | EGG STAGE | DEV. GON. | DAMAGE OLD | | DAMAGE NEW | | REGEN. | | | REMARKS |
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| D | | | | | | | | | | | | | | | | | | | | |
| V | | | | | | | | | | | | | | | | | | | | |
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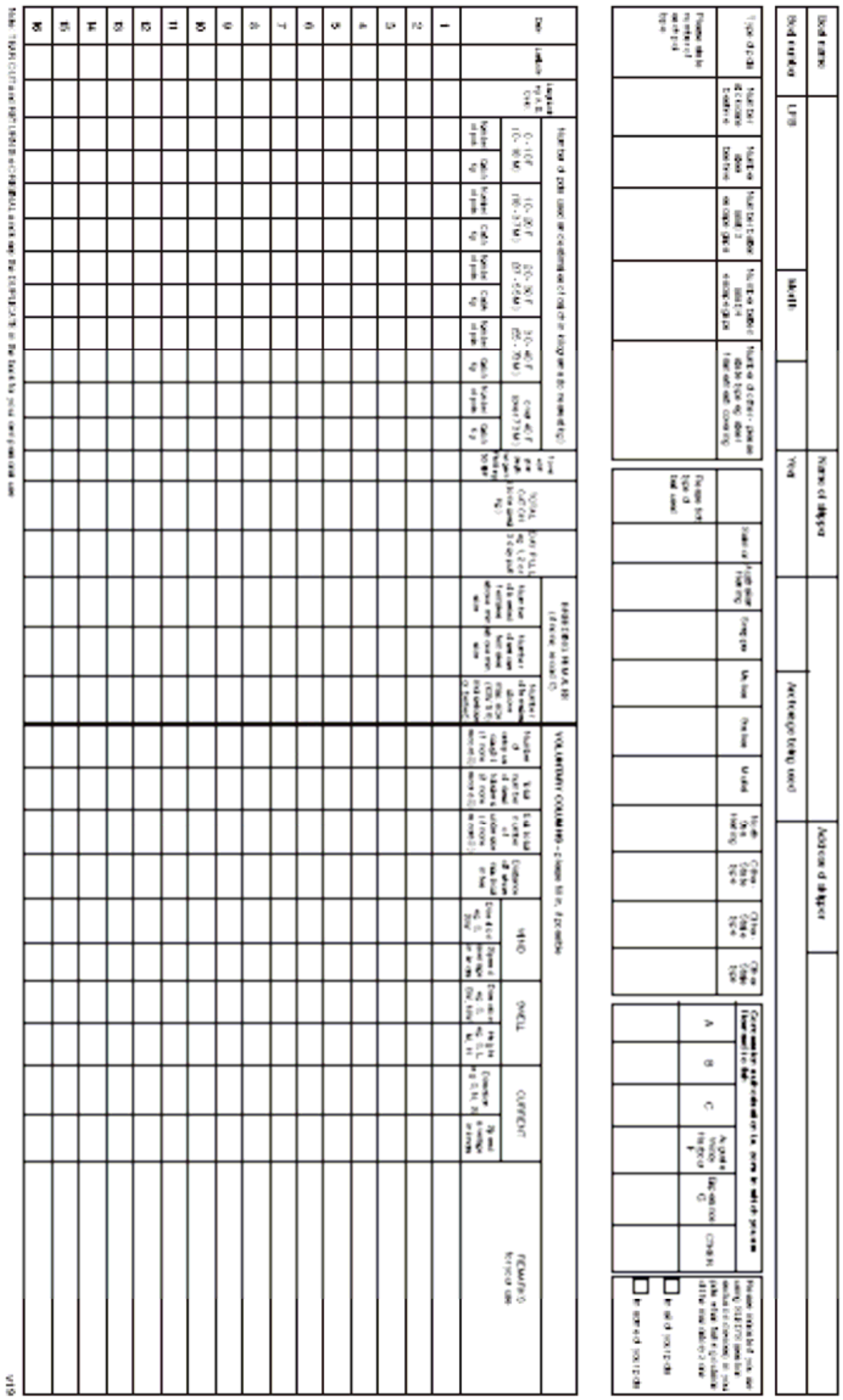
| D | | | | | | | | | | | | | | | | | | | | |
| V | | | | | | | | | | | | | | | | | | | | |
| D | | | | | | | | | | | | | | | | | | | | |

*Appendix 3 – Voluntary logbook filled in by commercial fishers.*


Boat name
Name of skipper
Address of skipper
Boat number
LFB
Month
Year
Anchorage being used
Type of pots
Please state number of each pot type
Please tick type of bait used
A
B
C
OTHER
VOLUNTARY COLUMNS - please fill in, if possible
WIND
SWELL
CURRENT
REMARKS for your use
1
2
3
4
5
6
7
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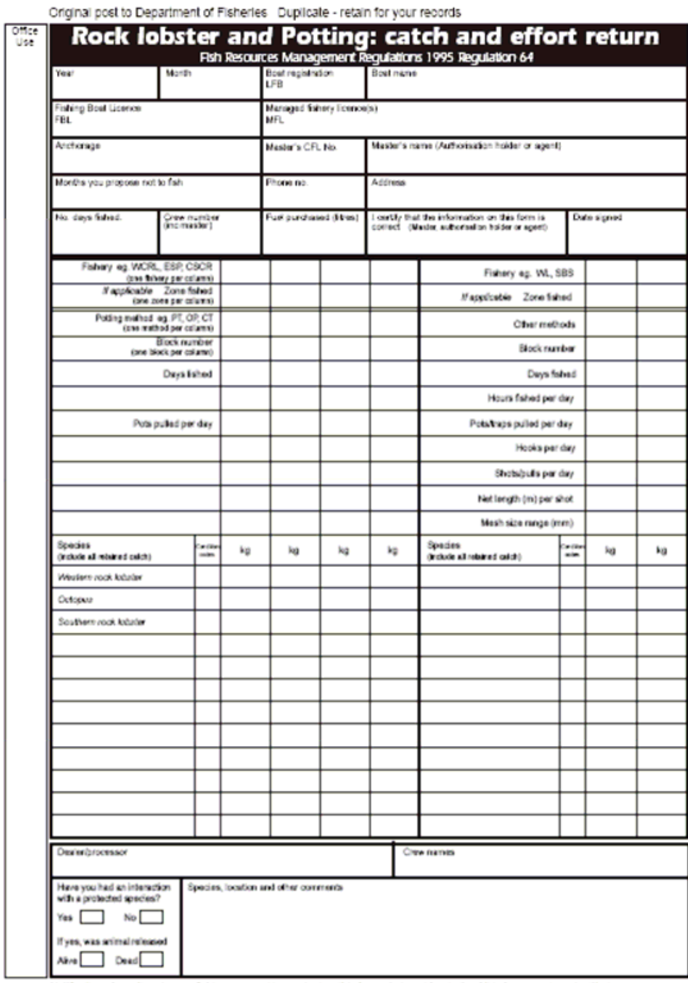
v19

*Appendix 4 – CAES logbook showing the data recorded by fishers monthly*



Original post to Department of Fisheries  Duplicate - retain for your records

Office Use

**Rock lobster and Potting: catch and effort return**

Fish Resources Management Regulations 1995 Regulation 64

| | | | |
|---|---|---|---|
| Year | Month | Boat registration LFB | Boat name |
| Fishing Boat Licence FBL | | Managed fishery licence(s) MFL | |
| Anchorage | | Master's CFL No. | Master's name (Authorisation holder or agent) |
| Months you propose not to fish | | Phone no. | Address |
| No. days fished | Crew number (inc master) | Fuel purchased (litres) | I certify that the information on this form is correct (Master, authorisation holder or agent) / Date signed |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Fishery eg. WCRL, ESP, CSCR (one fishery per column) | | | | | | Fishery eg. WL, SBS | | |
| If applicable Zone fished (one zone per column) | | | | | | If applicable Zone fished | | |
| Potting method eg. PT, OP, CT (one method per column) | | | | | | Other methods | | |
| Block number (one block per column) | | | | | | Block number | | |
| Days fished | | | | | | Days fished | | |
| | | | | | | Hours fished per day | | |
| Pots pulled per day | | | | | | Pots/traps pulled per day | | |
| | | | | | | Hooks per day | | |
| | | | | | | Shots/pulls per day | | |
| | | | | | | Net length (m) per shot | | |
| | | | | | | Mesh size range (mm) | | |
| Species (include all retained catch) | Condition codes | kg | kg | kg | kg | Species (include all retained catch) | Condition codes | kg | kg |
| Western rock lobster | | | | | | | | |
| Octopus | | | | | | | | |
| Southern rock lobster | | | | | | | | |

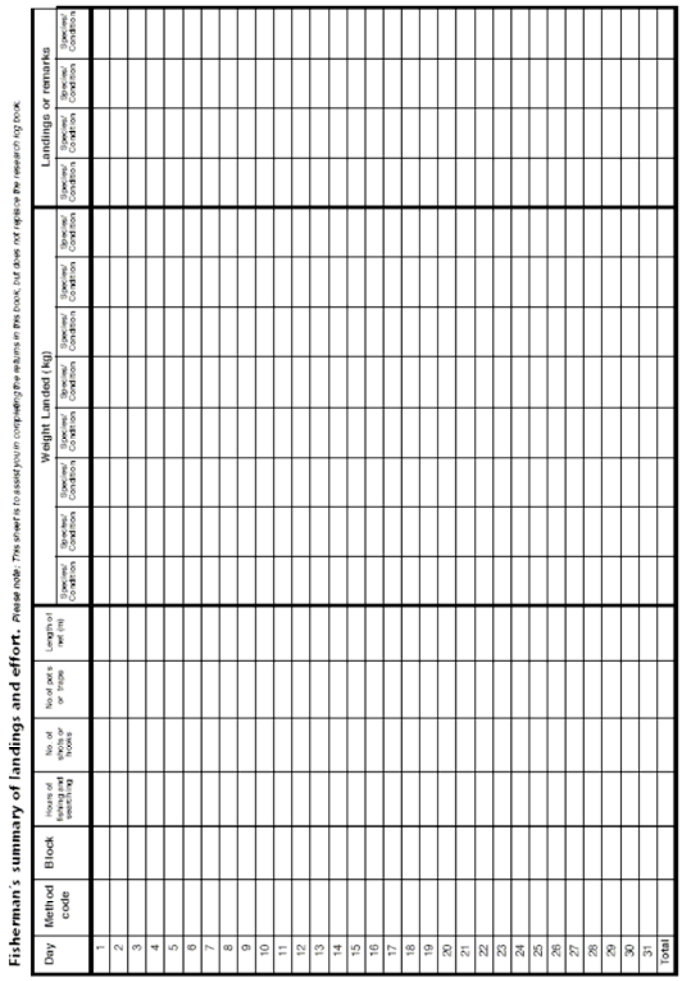
Dealer/processor | Crew names

Have you had an interaction with a protected species? Yes ☐ No ☐

If yes, was animal released Alive ☐ Dead ☐

Species, location and other comments

Notification of months when no fishing occurred is required on this form. A signed facsimile of this form may be submitted



**Fisherman's summary of landings and effort.** *Please note: This sheet is to assist you in completing the returns in this book, but does not replace the research log book.*

| Day | Method code | Block | Hours of fishing and searching | No. of shots or hooks | No of pots or traps | Length of net (m) | Weight Landed (kg): Species/Condition | Species/Condition | Species/Condition | Species/Condition | Species/Condition | Species/Condition | Species/Condition | Species/Condition | Landings or remarks: Species/Condition | Species/Condition | Species/Condition | Species/Condition |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | | | | | | | | | | | | | | | | | | |
| 2 | | | | | | | | | | | | | | | | | | |
| 3 | | | | | | | | | | | | | | | | | | |
| 4 | | | | | | | | | | | | | | | | | | |
| 5 | | | | | | | | | | | | | | | | | | |
| 6 | | | | | | | | | | | | | | | | | | |
| 7 | | | | | | | | | | | | | | | | | | |
| 8 | | | | | | | | | | | | | | | | | | |
| 9 | | | | | | | | | | | | | | | | | | |
| 10 | | | | | | | | | | | | | | | | | | |
| 11 | | | | | | | | | | | | | | | | | | |
| 12 | | | | | | | | | | | | | | | | | | |
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| 14 | | | | | | | | | | | | | | | | | | |
| 15 | | | | | | | | | | | | | | | | | | |
| 16 | | | | | | | | | | | | | | | | | | |
| 17 | | | | | | | | | | | | | | | | | | |
| 18 | | | | | | | | | | | | | | | | | | |
| 19 | | | | | | | | | | | | | | | | | | |
| 20 | | | | | | | | | | | | | | | | | | |
| 21 | | | | | | | | | | | | | | | | | | |
| 22 | | | | | | | | | | | | | | | | | | |
| 23 | | | | | | | | | | | | | | | | | | |
| 24 | | | | | | | | | | | | | | | | | | |
| 25 | | | | | | | | | | | | | | | | | | |
| 26 | | | | | | | | | | | | | | | | | | |
| 27 | | | | | | | | | | | | | | | | | | |
| 28 | | | | | | | | | | | | | | | | | | |
| 29 | | | | | | | | | | | | | | | | | | |
| 30 | | | | | | | | | | | | | | | | | | |
| 31 | | | | | | | | | | | | | | | | | | |
| Total | | | | | | | | | | | | | | | | | | |

*Appendix 5 – Forms filled out by rock lobster processors a) log of fisherman and catch for that month, and b) breakdown of product and grades of exported or sold domestically.*



**Rock Lobster Monthly Processor Return Log**

Fish Resources Management Act 1994
Regulation 64

Department of Fisheries

Return of Rock Lobsters Processed during the Month of: ________ Year: ________

Name of Firm:

Address (of processing establishment):

| Name of Fisherman: | Boat Number | Live Weight (Kg) |
|---|---|---|
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| | | |
| | TOTAL | |

Date: ___/___/___ Signature: ____________

Fish for the future

FISHERIES WESTERN AUSTRALIA

**FISHERIES WESTERN AUSTRALIA**
Fish Resources Management Act 1994,
Regulation 64

NAME OF FIRM: ____________

ADDRESS OF PROCESSING ESTABLISHMENT: ____________

FOR MONTH: ____________ YEAR: ________

| PROCESSING * See note below | WEIGHT OF CARTON (Kg) | GRADES (If the grades A, B, C, etc. have been subdivided, please specify the subdivided grade in the column provided) A | B | C | D | E | F | G | H | BAIT TAILS |
|---|---|---|---|---|---|---|---|---|---|---|
| GREEN TAILS | | TOTAL | TOTAL | TOTAL | TOTAL | TOTAL | TOTAL | TOTAL | TOTAL | |
| EXPORT | 11.34 | | | | | | | | | |
| LOCAL | 11.34 | | | | | | | | | |
| OTHER - please specify | | | | | | | | | | |
| | | | | | | | | | | |
| WHOLE COOKED | | TOTAL | TOTAL | TOTAL | TOTAL | TOTAL | TOTAL | TOTAL | TOTAL | |
| EXPORT | 10.00 | | | | | | | | | |
| LOCAL | 10.00 | | | | | | | | | |
| OTHER - please specify | | | | | | | | | | |
| | | | | | | | | | | |
| WHOLE GREEN | | TOTAL | TOTAL | TOTAL | TOTAL | TOTAL | TOTAL | TOTAL | TOTAL | |
| EXPORT | 10.00 | | | | | | | | | |
| OTHER - please specify | | | | | | | | | | |
| | | | | | | | | | | |
| LIVE | | TOTAL | TOTAL | TOTAL | TOTAL | TOTAL | TOTAL | TOTAL | TOTAL | |
| EXPORT | 8.00 | | | | | | | | | |
| OTHER - please specify | | | | | | | | | | |
| | | | | | | | | | | |
| OTHER PROCESSING (please specify) | | TOTAL | TOTAL | TOTAL | TOTAL | TOTAL | TOTAL | TOTAL | TOTAL | |
| | | | | | | | | | | |
| | | | | | | | | | | |

* Please give export and local grades separately.

DATE: ____/____/____ SIGNATURE: ____________

*Appendix 6 – Mail survey (1997/98 season) representative of those sent pre 1998*



FISHERIES WESTERN AUSTRALIA

## Recreational rock lobster fishing survey

**1997/98 season**

Please complete and return to
W.A. Marine Research Laboratories
PO Box 20, North Beach, 6020
Enquiries (08) 9246 8482 / (08) 9246 8444

***Assist us by filling in this survey form and put yourself in line for a prize***

1. Contact phone no. (to verify any entries below) ☐

Name

Address

Post Code

2. Did you fish for rock lobsters between 15 November 1997 and 30 June 1998 (please tick Yes or No below)

☐ Yes — If you answered yes, please complete this survey and return it to us.

☐ No — If you answered no, you can stop here, but **please still return** the survey form to us.

**All these questions refer to you as a single licence holder - please fill out one form for one licence.**

3. What **METHODS** did you use to fish for rock lobsters last season? (please tick) — Pots ☐ Diving ☐ Other ☐ If other, please describe.

4. How may lobster **POTS** did you pull each day you went fishing? ☐

5. During which **MONTHS** did you fish for rock lobsters? (tick more than one if appropriate) — Nov ☐ Dec ☐ Jan ☐ Feb ☐ Mar ☐ Apr ☐ May ☐ Jun ☐

6. **WHEN** did you do most of your fishing for rock lobster? (tick more than one if appropriate) — Week-ends ☐ Week-days ☐ School Holidays ☐ Annual Holidays ☐

7. On how may **DAYS** during the season did you go fishing for rock lobsters? (your best estimate of the total number for each method) — By using pots? ☐ By diving? ☐ By other methods? ☐

8. What was the total number of **LEGAL SIZE WESTERN** rock lobsters you caught during the season? (your best estimate) — By using pots? ☐ By diving? ☐ By other methods? ☐

9. **WHERE** did you do most of your fishing? (list locality or town with [1] being the most often fished. Indicate which fishing methods you used in each area)

| | Town/locality | postcode | Pots | Diving | Other |
|---|---|---|---|---|---|
| [1] | | | ☐ | ☐ | ☐ |
| [2] | | | ☐ | ☐ | ☐ |
| [3] | | | ☐ | ☐ | ☐ |

10. Total number of **TROPICAL** (green or painted) or **SOUTHERN** rock lobsters caught this season? — By using pots? ☐ By diving? ☐ By other methods? ☐ — Tropical? ☐ Southern? ☐

***Space for any further comments you'd like to make is provided overleaf***

RLsurv98.p65

### Comments (optional)

Fold 1

**Postage is Paid.**

Fold the form to show the return address - staple or tape the page and mail it.

Thank you for your input into the survey.

Fold 2

Rock Lobster Research
Western Australian Marine Research Laboratories
PO Box 20
NORTH BEACH WA 6020

**BUSINESS REPLY POST**
Permit No. 451 Issued at Perth
Postage and fee will be paid on delivery to:-

No postage stamp required if posted in Australia

**O.H.M.S.**

*Appendix 7 – Mail survey sent out in 1999, reflective of the more recent, detailed mail surveys*

# Recreational Rock Lobster Fishing Survey: 1998/99 Season

FISHERIES
WESTERN AUSTRALIA

Participating in this survey will put you in the running to win one of three cash prizes: 1st prize $500, 2nd prize $200, 3rd prize $100

Please complete and return (free postage) to:
W.A. Marine Research Laboratories
PO Box 20, North Beach, 6020
Enquires: (08) 9246 8482 or (08) 9246 8444

***Please note that all information supplied will be treated as strictly confidential***

**1.** **Contact details** in case we need to verify any information you provide. We will also contact you if you win a prize.
Name: ____________ Ph: ________
Home address: ____________
____________ Postcode: ________

**2.** How are you **licensed** to fish for rock lobster? (tick one)
☐ Rock lobster licence only
☐ Umbrella licence (all recreational fisheries)

**3.** What is your **age**? ______

**4.** What is your **gender**? Male ☐ Female ☐

**5.** What is the **main language** spoken at home?
________________

**6.** What is your highest level of **education**? (circle one)
a) Below Year 12
b) Year 12
c) Apprenticeship or TAFE certificate
d) Tertiary

**7.** **Did you fish** for rock lobster between 15 November 1998 and 30 June 1999? (tick Yes or No)

**YES** ☐ If you answered Yes, please go to **question 8**, complete this survey, and return it to us.

**NO** ☐ If you answered No, please **skip ahead to Q21**, complete the survey, and return the form to us.

**All the questions refer to you as a single licence holder - please fill out one form for one licence.**

**8.** What **methods** did you use to fish for rock lobsters last season? (please tick)
Pots ☐
Diving ☐
Other ☐
If Other, please describe:
________________

**9.** Please indicate the **approximate number of days** you fished for rock lobster in each month using the following methods:

| | Pots | Diving | Other |
|---|---|---|---|
| Nov '98 | --- | --- | --- |
| Dec '98 | --- | --- | --- |
| Jan '99 | --- | --- | --- |
| Feb '99 | --- | --- | --- |
| Mar '99 | --- | --- | --- |
| Apr '99 | --- | --- | --- |
| May '99 | --- | --- | --- |
| Jun '99 | --- | --- | --- |

**10.** **Where** did you do most of your fishing? (list locality or town with [1] being the most often fished). Please note the number of days fished using each method.

[1] Town/Locality ____________ Postcode ____ (if known)
Number of days fished at locality:
*Pots* ____ *Diving* ____ *Other* ____

[2] Town/Locality ____________ Postcode ____ (if known)
Number of days fished at locality:
*Pots* ____ *Diving* ____ *Other* ____

[3] Town/Locality ____________ Postcode ____ (if known)
Number of days fished at locality:
*Pots* ____ *Diving* ____ *Other* ____

**11.** If you used pots, **how many lobster pots** did you typically pull each day you went fishing? ______

**12.** **When** did you do most of your fishing for rock lobster? (tick more than one if appropriate)
Weekends ☐
Weekdays ☐
School Holidays ☐
Annual Holidays ☐

**13.** What was the **total number of legal size western rock lobster** you caught during the season? (your best estimate)
By using pots ______
By diving ______
By other methods ______

**14.** Please indicate the **number of legal size tropical** (green/painted) or **southern** rock lobster caught during the season:

| Lobster | Pots | Diving | Other |
|---|---|---|---|
| Tropical | --- | --- | --- |
| Southern | --- | --- | --- |

**15.** Do you own (or have regular access to) a **boat**? (tick one)
Yes ☐ **Go to Q16**
No ☐ **Skip to Q18**

**16.** What is the **length of the boat** in metres? ______ m

**17.** Please tick the equipment you used: (tick more than one if appropriate)
B/W Echo Sounder ☐
Colour Echo Sounder ☐
View Bucket ☐
Radar ☐
Pot Winch ☐
GPS ☐
None of the above ☐

**18.** In what **depth range** did you **dive** for rock lobster last season?

| Depth | Percentage of Time Diving |
|---|---|
| 0-10 m | ----- |
| 11-20 m | ----- |
| 21-30 m | ----- |
| Below 30 m | ----- |
| Didn't dive | ☐ |

**19.** In what **depth range** did you fish for rock lobster using **pots** last season?

| Depth | Percentage of Time Potting |
|---|---|
| 0-10 m | ----- |
| 11-20 m | ----- |
| 21-30 m | ----- |
| Below 30 m | ----- |
| Didn't pot fish | ☐ |

**20.** Please tick the **type(s) of pots** you used when fishing for lobster last season: (tick more than one if appropriate)
Stick/cane beehive ☐
Batten pots ☐
Plastic pots ☐
Don't use pots ☐
Other ____________ (please specify)

**21.** For **how many years** have you participated in the recreational rock lobster fishery? _____

**22.** Consider the following statement: "Fisheries management is effective in conserving rock lobster stocks". Do you: (circle one answer only)
a) Strongly agree
b) Agree
c) Not sure
d) Disagree
e) Strongly disagree

**23.** In your experience, how fair do you think fisheries officers are in dealing with infringements that they find. As far as you know, do they treat people: (circle one)
a) Always fairly
b) Sometimes fairly
c) Never fairly
d) Don't know, no contact with fisheries officers.

**24.** Consider the following statement: "**Recreational** rock lobster fishers generally abide by fisheries regulations". Do you: (circle one answer only)
a) Strongly agree
b) Agree
c) Not sure
d) Disagree
e) Strongly disagree

**25.** Please indicate the **number of contacts** you had with fisheries personnel while fishing for rock lobster in the last season: (circle one, but if greater than 1 contact please write number)
i) Fisheries officers:
a) None
b) Seen only
c) 1 contact
d) More than 1 contact _____
e) Did not fish last season

ii) Volunteer fisheries liaison officers (VFLO's):
a) None
b) Seen only
c) 1 contact
d) More than 1 contact _____
e) Did not fish last season

[Note: VFLO's are recreational fishers who donate their time to educate other fishers about conservation and fish management. They usually wear distinctive yellow shirts and hats]

**26.** How many times in total (over all your fishing years) have you come into contact with a fisheries officer (not a VFLO) while fishing for rock lobster? ________

**27.** Consider the following statement: "**Commercial** rock lobster fishers generally abide by fisheries regulations". Do you: (circle one answer only)
a) Strongly agree
b) Agree
c) Not sure
d) Disagree
e) Strongly disagree

**28.** The current **pot limit** is 2 for recreational fishers. Do you think this number is: (circle one)
a) Too low
b) About right
c) Too high
d) Don't know

**29.** The current **bag limit** is 8 lobsters per day for recreational fishers. Do you think this number is: (circle one)
a) Too low
b) About right
c) Too high
d) Don't know

**30.** In your experience, what percentage **of recreational fishers** do you think **regularly sell** some or all of their **catch?** (circle one)
a) 0%
b) 1-2%
c) 3-5%
d) 6-10%
e) More than 10%
f) Don't know

**31.** In your experience, what percentage of **recreational** fishers do you think **illegally pull other recreational** fishers' pots? (circle one)
a) 0%
b) 1-2%
c) 3-5%
d) 6-10%
e) More than 10%
f) Don't know

**32.** In your experience, what percentage of **recreational** fishers do you think **illegally pull commercial** fishers' pots? (circle one)
a) 0%
b) 1-2%
c) 3-5%
d) 6-10%
e) More than 10%
f) Don't know

**33.** In your experience, what percentage of **commercial** fishers do you think **illegally pull recreational** fishers' pots? (circle one)
a) 0%
b) 1-2%
c) 3-5%
d) 6-10%
e) More than 10%
f) Don't know

**34.** What **evidence** have you seen of **illegal pot pulling** in the rock lobster fishery?
a) None
b) Heard rumours it occurs
c) Occasionally witnessed it
d) Regularly witnessed it

**35.** If you see a recreational fisher breaking the rules, what would you do? (circle one answer only)
a) Do nothing, but feel bad about it
b) Report the illegal activity
c) Talk to the person directly
d) Ignore it
e) Don't know

**36.** What percentage of recreational fishers do you think illegally keep undersized lobster? (circle one)
a) 0%
b) 1-2%
c) 3-5%
d) 6-10%
e) More than 10%
f) Don't know

**37.** In your usual fishing area, how many times do you think you could break the size regulations without getting caught by fisheries officers? ______

**38.** What is the minimum size rules for taking western rock lobster? (tick more than 1 box if appropriate)
☐ 76 mm, 15 Nov-30 Jun
☐ 76 mm, 1 Feb-30 Jun
☐ 77 mm, 15 Nov-30 Jun
☐ 77 mm, 15 Nov-31 Jan
☐ Don't know

**39.** What percentage of days fished do you usually catch your **daily bag limit** for Western rock lobster? (circle one)
a) less than 20%
b) 20-40%
c) 41-60%
d) 61-80%
e) More than 80%
f) Don't know

**40.** In your experience, what percentage of recreational fishers do you think **fish out of season?** (circle one)
a) 0%
b) 1-2%
c) 3-5%
d) 6-10%
e) More than 10%
f) Don't know

**41.** What size fine do you think **would be imposed** on someone convicted of being in possession of 6 undersized lobster as a first offence? (circle one)
a) $200 to $500
b) $500 to $1000
c) $1000 to $2000
d) $2000 to $3000
e) More than $3000
f) Don't know

**42.** How much do think someone **should be fined** if they are caught with 6 undersized lobster (and have no previous convictions)? $_____

**43.** Among recreational rock lobster fishers you know, how would you describe their attitude towards fishers who keep undersized lobster? Would they think the practice is: (circle one)
a) Very wrong
b) Basically wrong, but OK every so often
c) Fine if you can get away with it
d) Don't know

**44.** How should recreational rock lobster fishers **be able to catch lobster**: (tick those appropriate)
Free-diving ☐
SCUBA ☐
Pots ☐
Hookah ☐
Spear ☐
Loops ☐
Shepherd's crook ☐
Other ____________ (please specify)

**45.** Consider the statement: "It doesn't hurt to keep lobsters if they are just undersize". Do you: (circle one)
a) Strongly agree
b) Agree
c) Not sure
d) Disagree
e) Strongly disagree

**46.** Do you think **the current legal size** for western rock lobster is: (circle one)
a) Too small
b) About right
c) Too large
d) Shouldn't be a limit
e) Don't know

**47.** Fishers tell us that the following issues are considered important in the recreational rock lobster fishery. Please number these according to the priority Fisheries Officers should give each issue (1 for highest priority, 8 for lowest priority).

| Issue | Priority |
|---|---|
| Divers poaching rock lobsters from pots | --- |
| Education | --- |
| Undersize lobsters | --- |
| Illegal pot-pulling of recreation pots by recreational fishers | --- |
| Oversize female lobster | --- |
| Over-potting | --- |
| Illegal pot-pulling of recreation pots by commercial fishers | --- |
| Mature female lobster | --- |
| Bag limits | --- |

**48.** Are there any issues you feel are important which were not listed in Q47?
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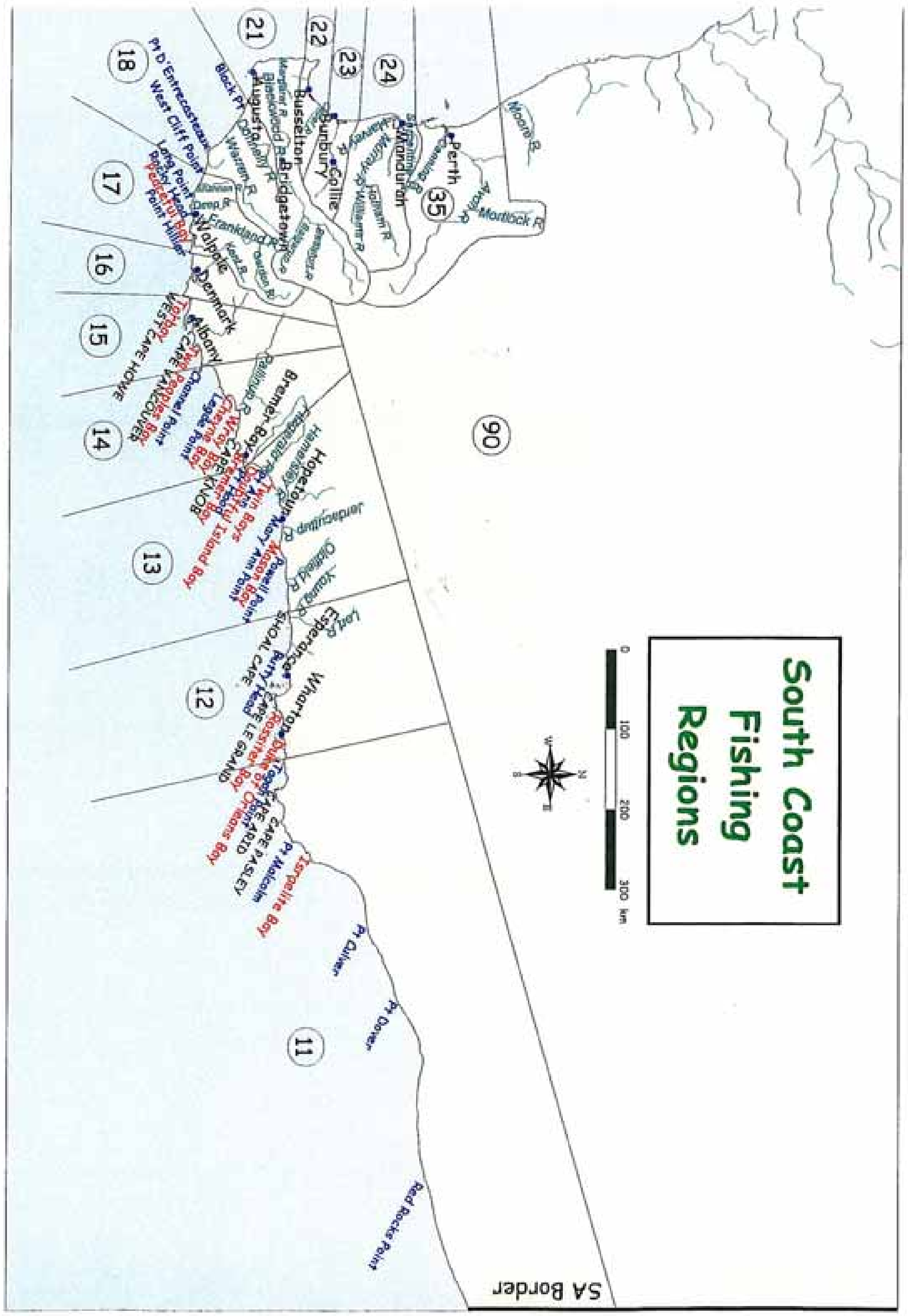
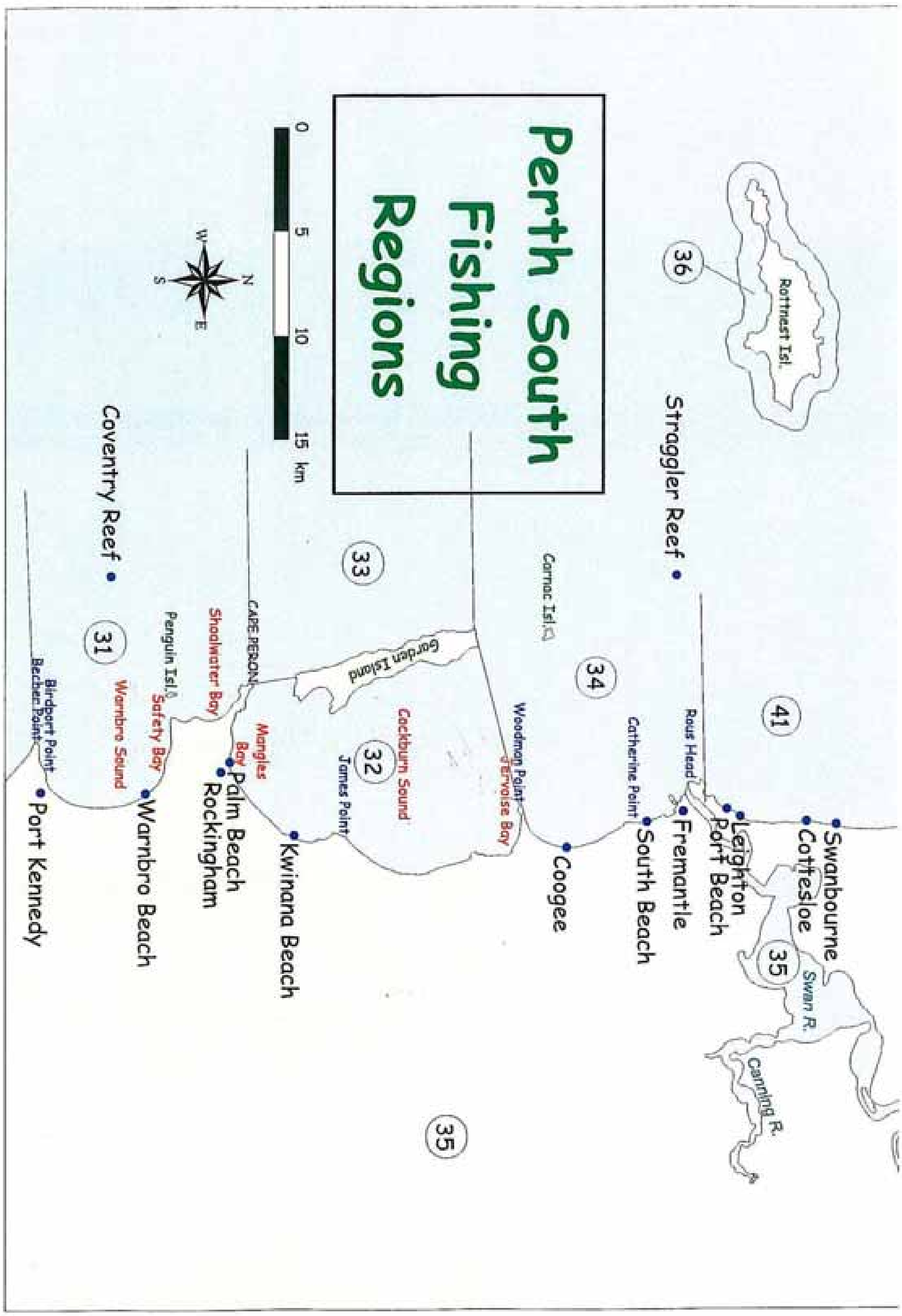
*Thankyou for taking the time to complete this survey*

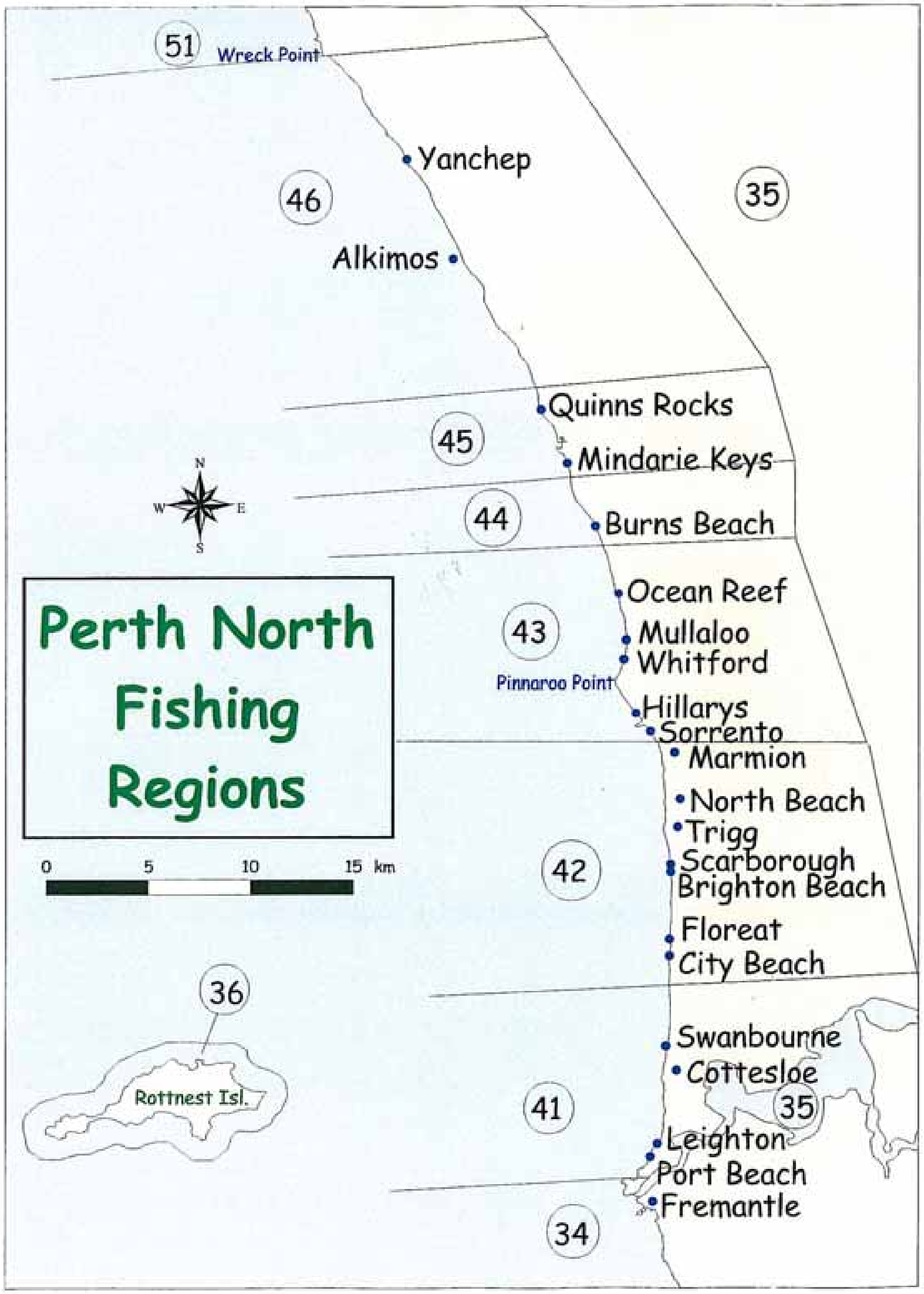
# *Appendix 8 – Location map used in the phone diary survey*



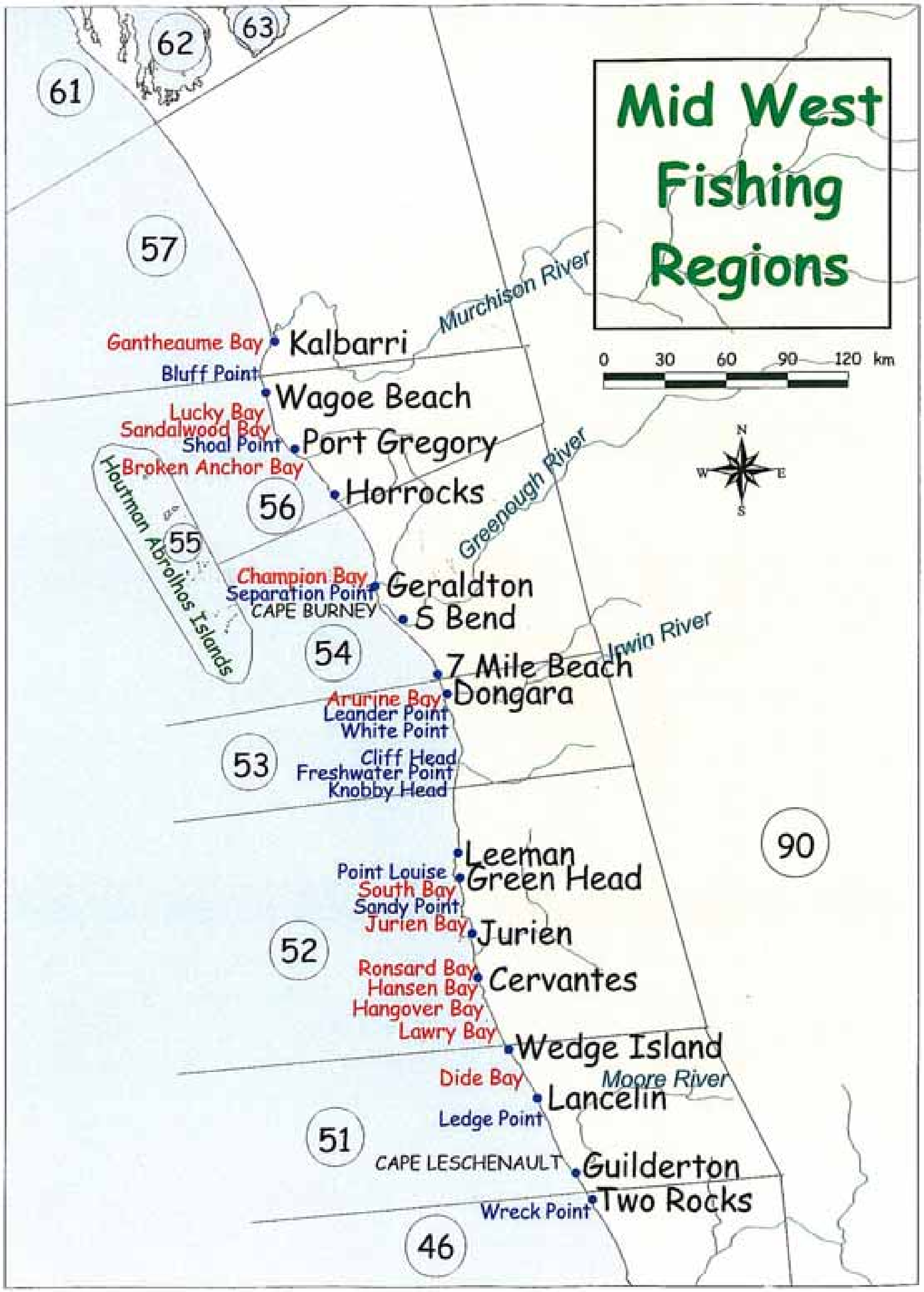
Appendix 8 cont.



Appendix 8 cont.



Appendix 8 cont.



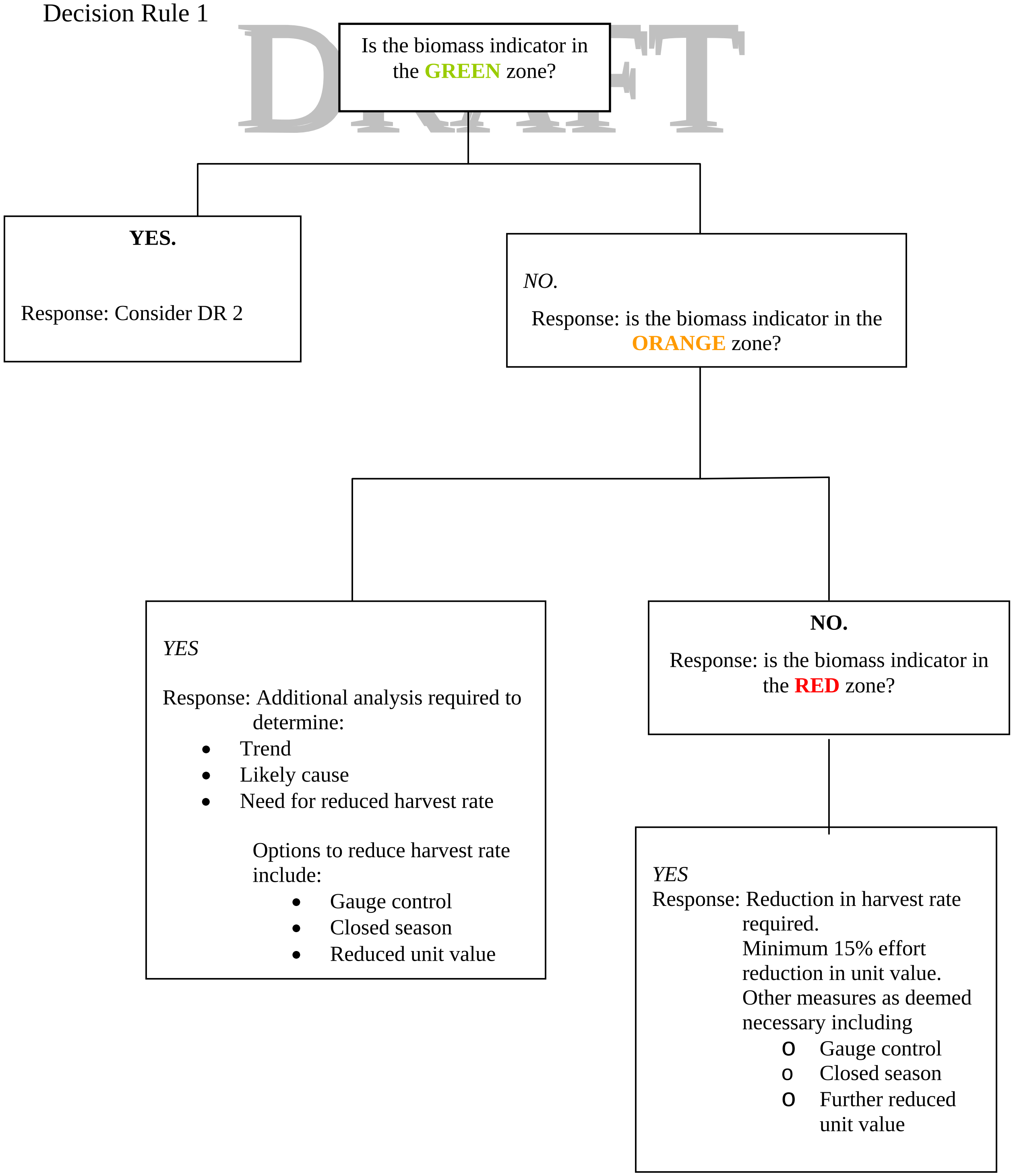
Appendix 8 cont.

*Appendix 9 – Decision rule framework from Bray (2004)*

This framework is based on Figure 6.1

Decision Rule 1





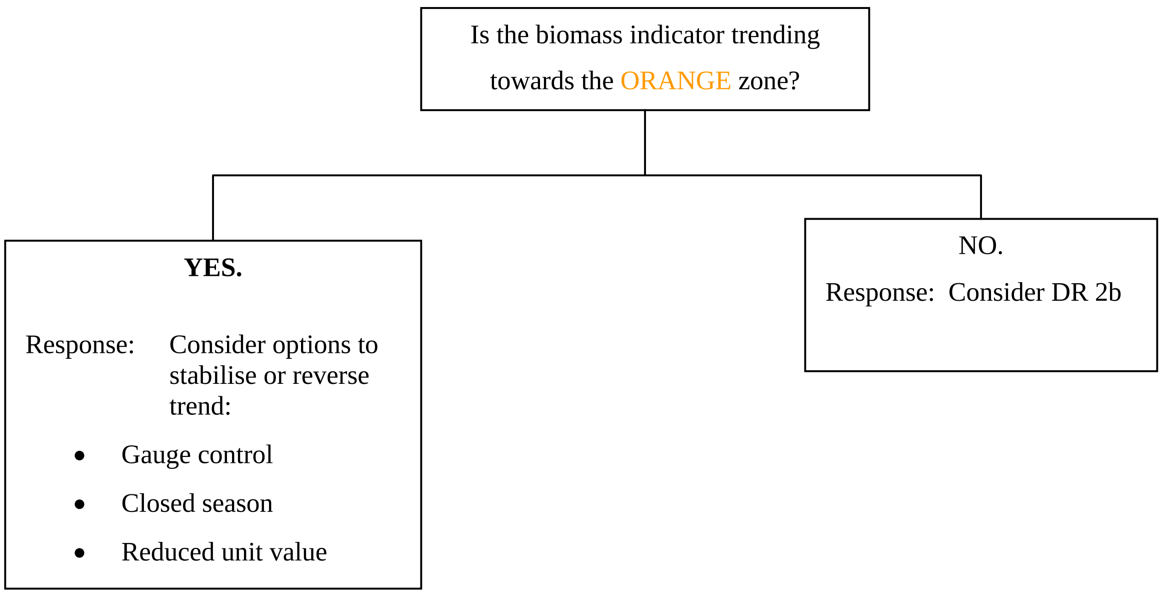
Decision Rule 2 (a-e)

The second decision rule incorporates other indicators of sustainability, when the first decision rule is in the green. These are included as a number of separate sub-rules;



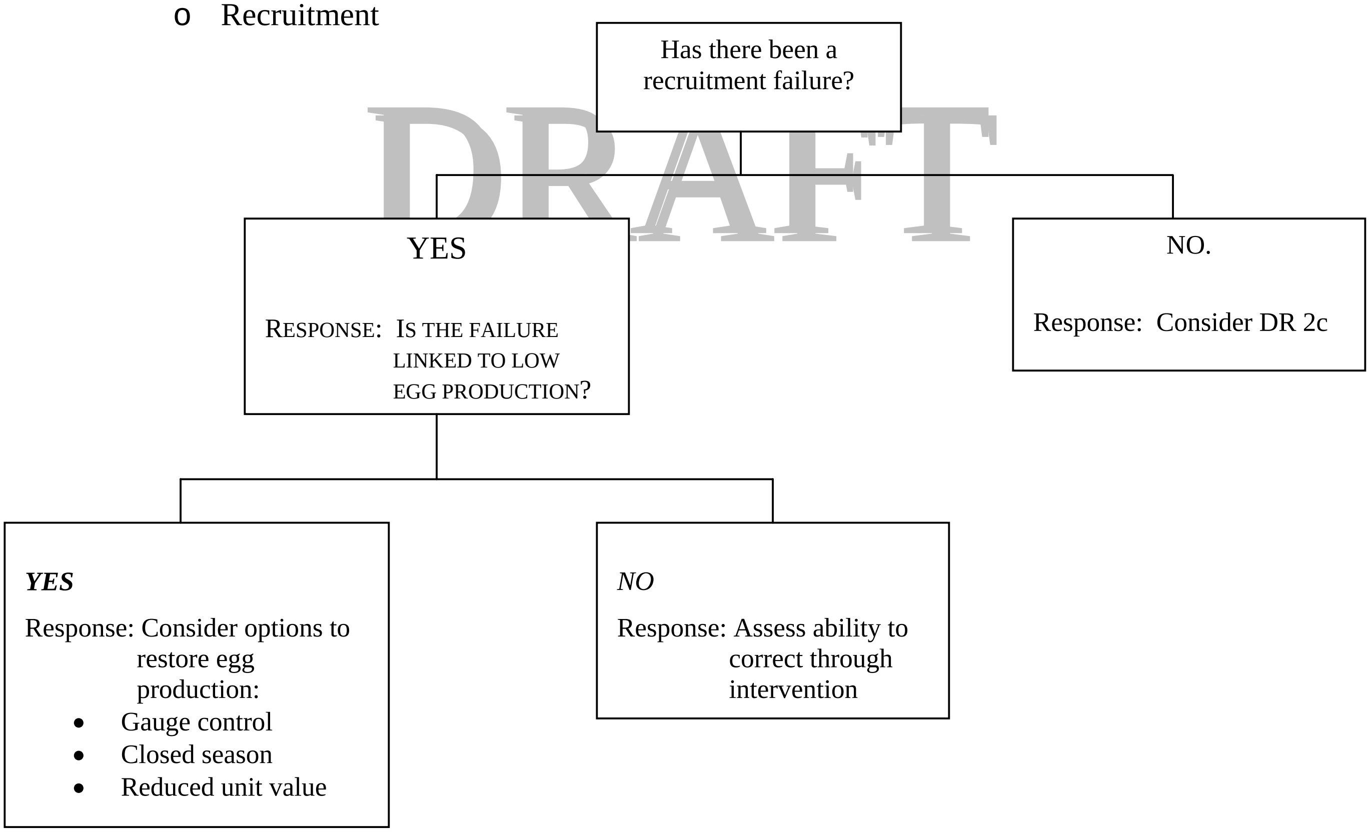
Decision Rule 2a

- o Trends in breeding biomass



Decision Rule 2b

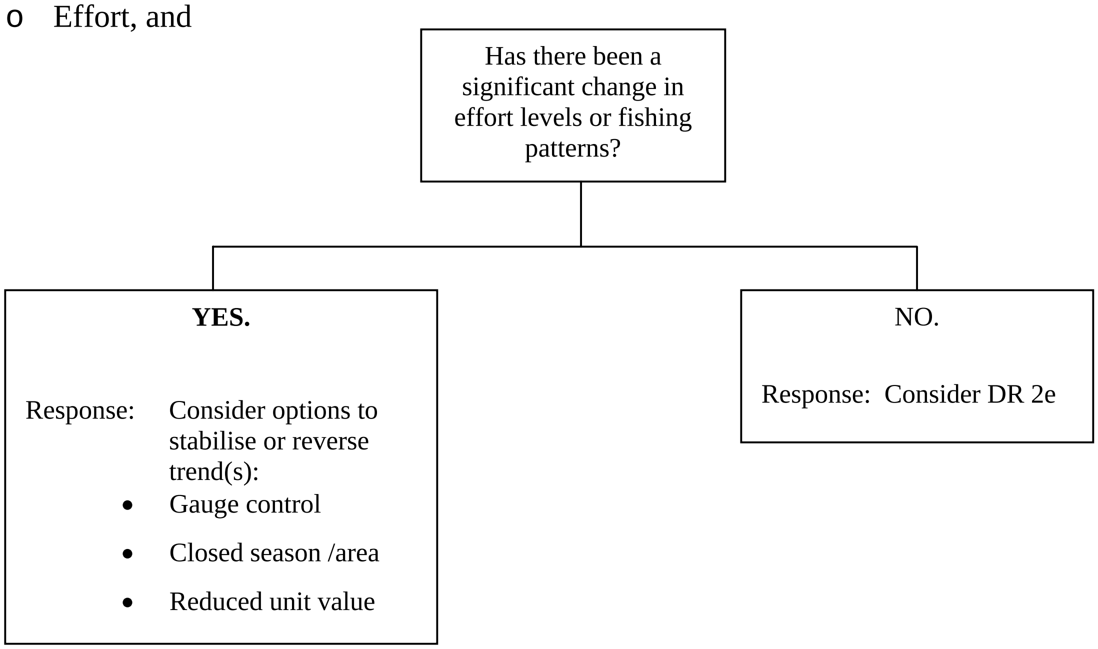
- Recruitment






Decision Rule 2d

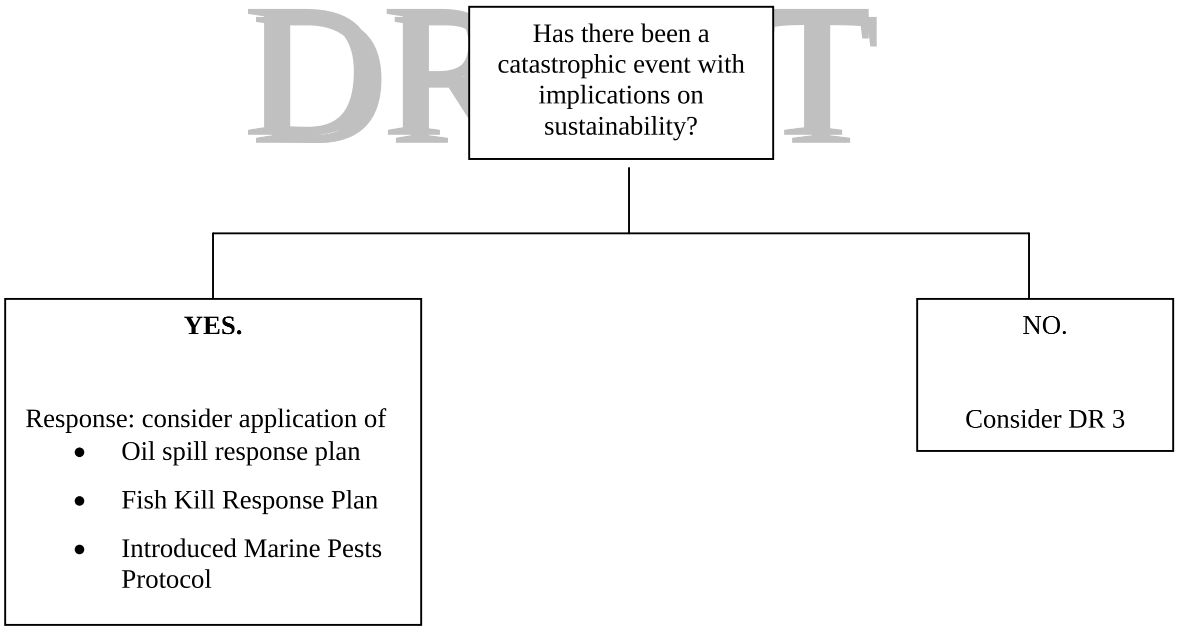
- Effort, and



Decision Rule 2e

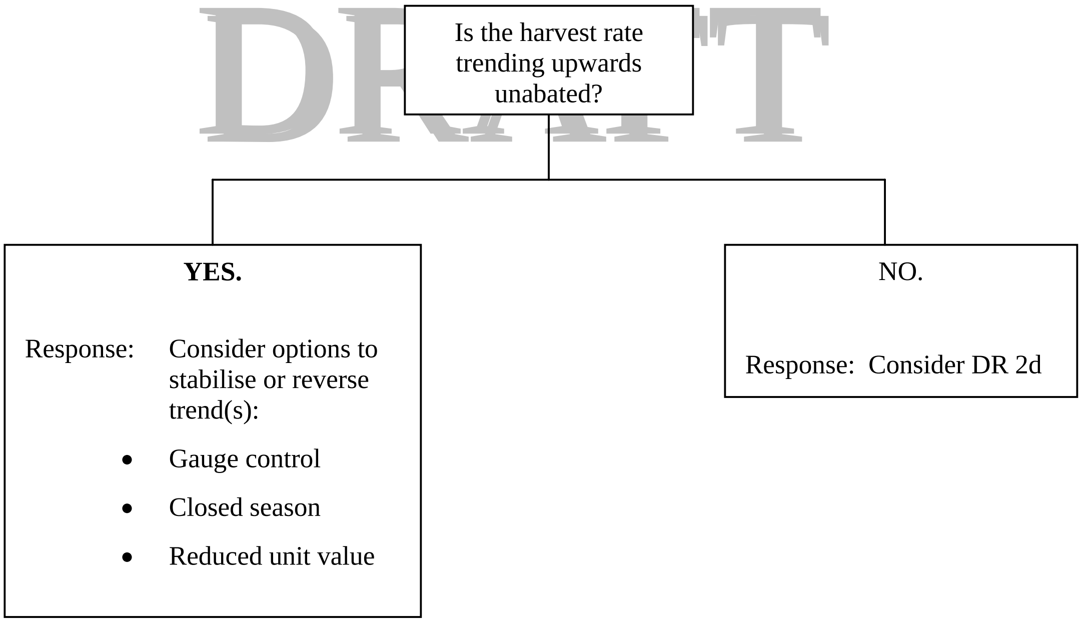
- Catastrophic events





Decision Rule 2c

- Harvest rate



Decision Rule 3

The final decision rule deals with the socio-economic aspects of the fishery. Again it begins with the primary question of decision rule one, but with an affirmative response to this question, it outlines how the industry suggested package is assessed. This provides a degree of self-determination for the industry, with a well managed resource able to have alterations to the management package assessed to provide socio-economic benefits.