Aspects of moulting of the South African West Coast rock lobster, *Jasus lalandii*.

by

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Declaration

I, ____________________, declare that **"Aspects of moulting of the South African West Coast rock lobster, *Jasus lalandii*"** is my own work and that all the sources I have used or quoted, have been indicated and acknowledged by means of complete references.

Date: December 1998

Dedication

This thesis is dedicated to my family.

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List of Figures, Tables and Plates

Table of Contents

Chapter 1- General Introduction

Chapter 2- Moult stage determination in the west coast rock lobster, *Jasus lalandii*

Chapter 3- Assessment of the use of pleopod staging in adult male *Jasus lalandii*

CHAPTER ONE

GENERAL INTRODUCTION

1.1 Introduction

The west coast of southern Africa is subject to coastal upwelling and is characterized by often dense kelp beds which can extend as far as 3 km offshore. Kelp forests create a unique ecosystem. Not only are they extremely productive, and so provide food for many animals, but they also break the force of the waves to create a sheltered habitat (Branch and Branch 1988). Some of the animals which take advantage of this environment include the commercially important rock lobsters and abalone.

There are many species of spiny lobster located around the South African coast, of which three species are exploited commercially. *Jasus lalandii* (H.Milne Edwards, 1837) (Decapoda: Palinuridae) is fished off the west coast, *Palinurus gilchristi* is caught off Port Elizabeth on the south coast and *Palinurus delagoae* is targeted in Natal and Mocambique on the east coast (Branch and Branch 1988). The most important commercial rock lobster species in southern Africa is the West Coast rock lobster, *J. lalandii*, which yields large annual catches and earns South Africa considerable foreign exchange (Branch *et al.* 1994). The fishery is valued in excess of about R150 million (Cockcroft *et al.* in press).

1.2 Distribution of *Jasus lalandii*

Jasus lalandii is distributed generally close inshore from Walvis Bay in Namibia (23°S 15°E) to East London (33°S 28°E) in the Eastern Cape Province of South Africa (Heydorn

1969). However, densities of commercial importance are encountered only along the west coast, from about 25°20'S in Namibia to roughly 34°30'S near Cape Point (Fig. 1.1).

1.3 General Biology

Jasus lalandii lives subtidally on rocky substrata, with lots of holes and crevices, and is usually found in association with the kelp species *Ecklonia maxima* and *Laminaria pallida*. Other conspicuous organisms of this environment include various mussels such as *Aulacomya ater* and *Choromytilus meridionalis*. This association with the mussels is not surprising since they form an important part of the lobster's diet (Heydorn 1969). In areas where mussel biomass is low, rock lobsters rely on other sources of food such as sea urchins, gastropods and even sponges (Pollock *et al.* 1982).

Female *Jasus lalandii* produce large numbers of eggs and this gives some indication of the high mortality rate this species experiences prior to reaching maturity. The stomach contents of longfin tuna, *Thunnus alalunga*, have frequently revealed the presence of both phyllosoma and puerulus stages (Heydorn 1969). Small rock lobsters are also common prey of young seal pups (Pollock 1989). Low rates of predation among adults are reflected by their active feeding during daylight. Predators of large lobsters are relatively scarce, but octopus, hagfish and dogsharks are known to feed on them. Cannibalism, especially among juvenile lobsters, may contribute to mortality in overcrowded areas. The natural mortality rate of post-larval rock lobsters is low, and this makes them susceptible to overfishing (Branch *et al.* 1994).

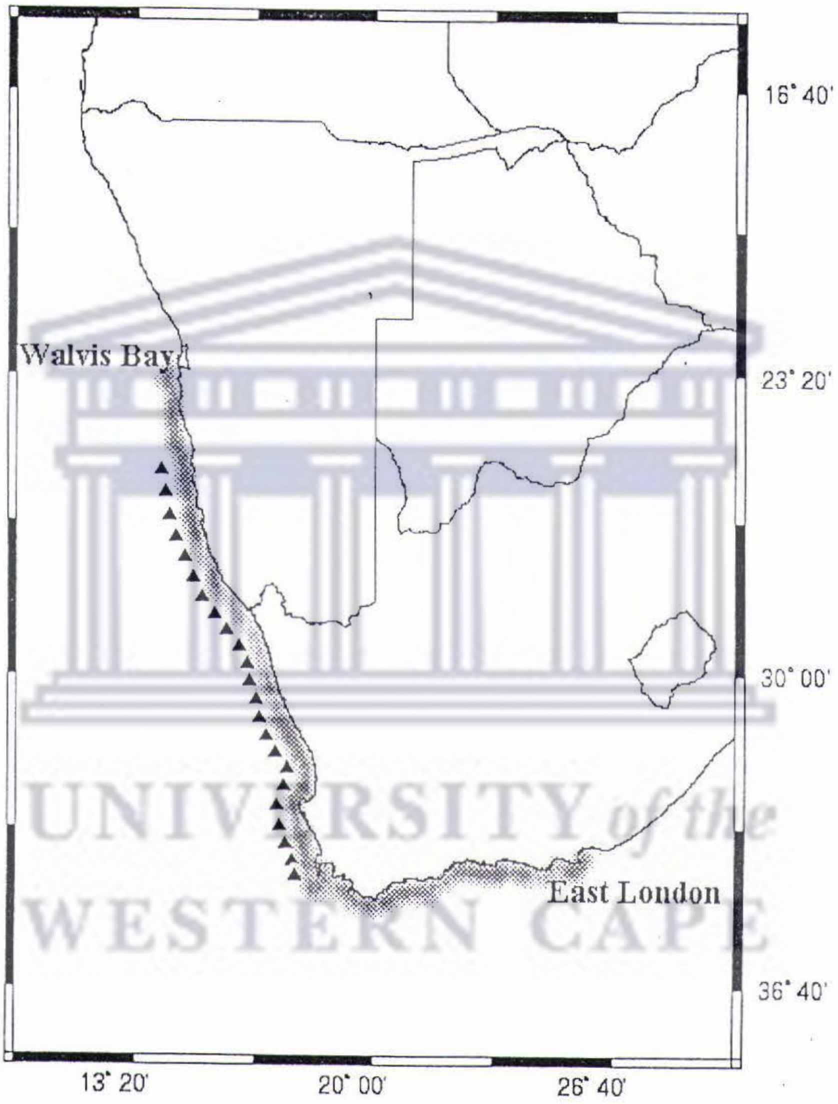

Figure 1.1. Distribution of *Jasus lalandii* along the South African and Namibian coast.

(▲ represents area of commercial importance)

The life cycle of spiny lobsters is geared to the production of large numbers of eggs and therefore larvae. Spiny lobsters are one of the organisms that makes use of ocean current systems to transport their phyllosoma larvae, away from the parent populations. These phyllosoma larvae (transparent dorsoventrally flattened body) adopt a drifting existence among the plankton and moult through thirteen larval stages before they metamorphose into a swimming stage known as a puerulus. This transparent miniature lobster then settles in shallow-water kelp beds (nursery grounds) approximately 18 months later (Pollock 1989), depending on the route taken and current velocities.

Juvenile *Jasus lalandii* moult up to four times per year (age dependent), and move progressively into deeper water as they increase in size. They are thought to arrive in the adult dominated depths (deeper than 15 m) when they reach sexual maturity which is about five years (corresponding carapace length is between 55 and 65 mm) after settlement (Pollock 1989). Relatively few rock lobsters smaller than 6 cm are found on the fishing grounds, which suggests that juveniles occupy different areas to the adult stock (Newman and Pollock 1974b).

Sexually mature rock lobsters moult once a year (Pollock 1986), and moulting of the female is followed by copulation (a male lobster in a hard shelled condition deposits sperm on the underside of a female which is in a soft shelled condition) and oviposition (Newman and Pollock 1974b). The eggs are thought to be fertilized internally (Silberbauer 1971), and attach to ovigerous setae on the underside of the abdomen on extrusion. The incubation period lasts between four to six months depending on water temperatures. Peak hatching takes place in

October and November each year, and this coincides with the onset of upwelling.

1.4 Historical development and current status of the southern African fishery for *Jasus lalandii.*

Rock lobsters form the basis of some important fisheries in the tropical and temperate coastal regions of the world (Holthuis 1991). Many of these species are either fully- or over-exploited owing to the high price they command on the international market. The commercial and recreational value of rock lobsters in many countries has led to a considerable body of scientific study aimed at improving the effective management of stocks (Booth and Phillips 1994).

Although it is distributed from Namibia to East London, the fishery for *Jasus lalandii* has been managed independently in South African and Namibian territorial waters (Pollock 1994). The fishing grounds are non-contiguous and are often separated by areas of unsuitable substrata such as sand or mud.

1.4.1 Namibia

In Namibia, Matthews (1962) has identified six fishing grounds to the north (Fig. 1.2), and six to the south, of Lüderitz (26°42'S, 15°05'E). The latter however, are not well studied and have proved extremely unproductive, since they have failed to make any major contribution towards the total catch processed (Matthews 1962, Matthews and Smit 1979).

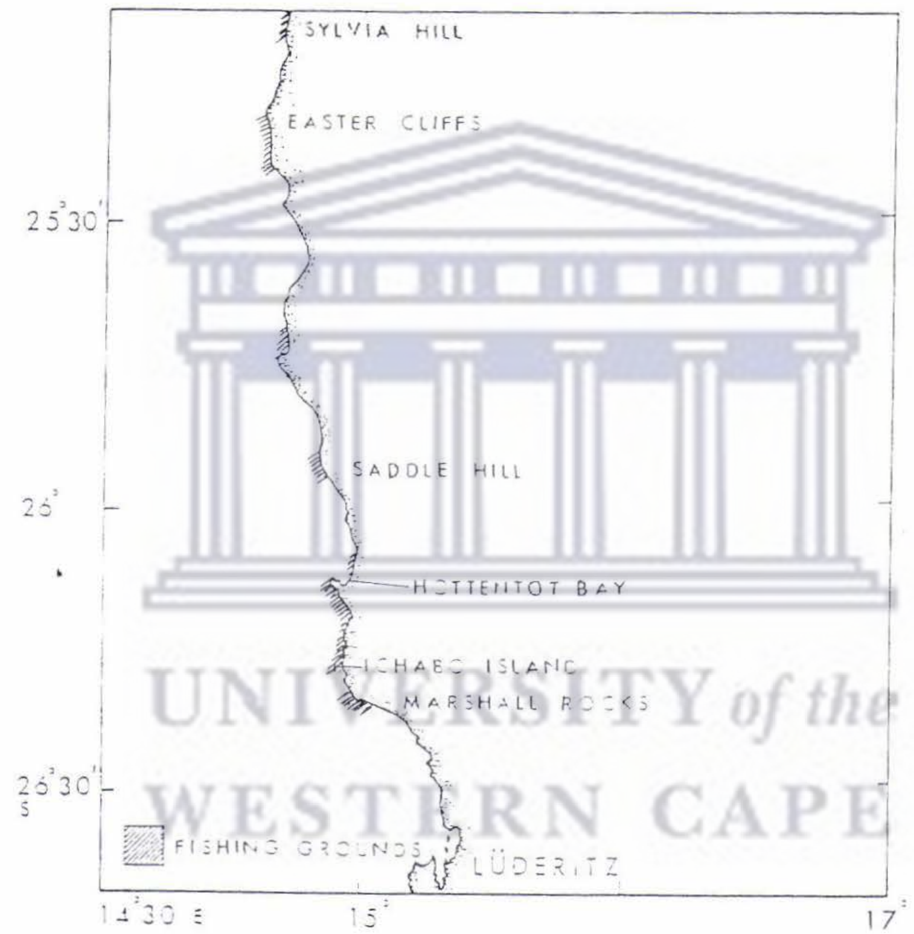

Figure 1.2. Rock lobster fishing grounds to the north of Luderitz (from Pollock and Beyers 1981).

From as early as 1886, the locals of Luderitz appreciated the abundance of rock lobster and other fish species in the area. Commercial exploitation of these resources started in 1913 when the then German government saw the potential for a fishery. The first legislation governing the harvest of rock lobsters in South West Africa (Namibia) was implemented by the Fisheries Board in 1922 and included a closed season from the 1st March to the 30th June, as well as a minimum size limit of 4 inches (~ 101 mm) (measured from the mid-rostral spine along the midline to the posterior edge of the carapace). The rationale behind these restrictive measures was to protect the stocks during the breeding season and to provide a measure of protection for the young fish. The question of a closed season received much subsequent attention, and there were regular changes to the legislation. It was decided in 1930 that the area between 60 miles north and south of Luderitz be closed from 15th May to 15th October every year. As a result of further research, the closed season was again changed in 1951, when it was decided to close the fishing area between Luderitz and Hottentot Bay Point for the period 1st June to 1st February and from Hottentot Bay Point to Saddle Hill from 1st October to 31st January. Another important change that took place was the reduction in minimum size limit to 3 inches (~ 76 mm).

As the Namibian fishery expanded in the 1950s and 1960s, the Fisheries Board made a number of other important decisions concerning the resource (Matthews 1962). A tail mass quota of 2 491 tons was instituted for the period 1964 to 1970 (Beyers 1979). As catches decreased, pressure was brought to bear on the authorities to decrease the minimum size limit, which was reduced from 82.6 mm in 1949 to 69.8 mm for the period 1964 to 1967 (Beyers 1979, Beyers and Wilke 1990). During 1968 and 1969, no size limit was enforced in Namibian waters due to a crash of the fishery in 1967. Landings increased during 1969 when a record 39 million lobsters were caught before they declined drastically again. During this period it was difficult to find a market for the small tails which comprised a large proportion of the catch. A minimum legal size limit of 63.5 mm was reintroduced in 1970. Catches of between 1 063-1 866 tons were recorded for the period 1980 to 1989 (Total Allowable Catch (TACs) = 2 200 tons). In the 1990/91 fishing season there was another drop in catches (329 tons) and catch rates due to the absence of the normal summer intrusion of oxygen-depleted waters which causes lobsters to aggregate close inshore and so become accessible to the fishery (Pollock 1994). The TAC was reduced to 100 tons for the 1991/92 season (Tomalin 1993). A fishing season for the entire Namibian coast has prevailed since 1971, and there has also been a voluntary reduction in the number of fishing vessels.The rock lobster sanctuary and the prohibition of berried females and soft-shelled animals being taken, continue to try and limit exploitation (Beyers 1979).

1.4.2 South Africa

The commercial exploitation of *Jasus lalandii* in South Africa began in the late nineteenth century and developed during the early twentieth century, before eventually levelling off at annual catches of between 10 000 to 11 000 tons for the period up to 1965 (Fig. 1.3) (Pollock 1986, Cockcroft and Payne 1997). As the fishery developed, catch quotas were granted freely and were easily filled because it was the accumulated stocks which were being exploited. However, catches from individual fishing grounds along the west coast have varied widely (Pollock 1982). With more vessels entering the fishery, an increase in fishing effort has been inevitable, and this has

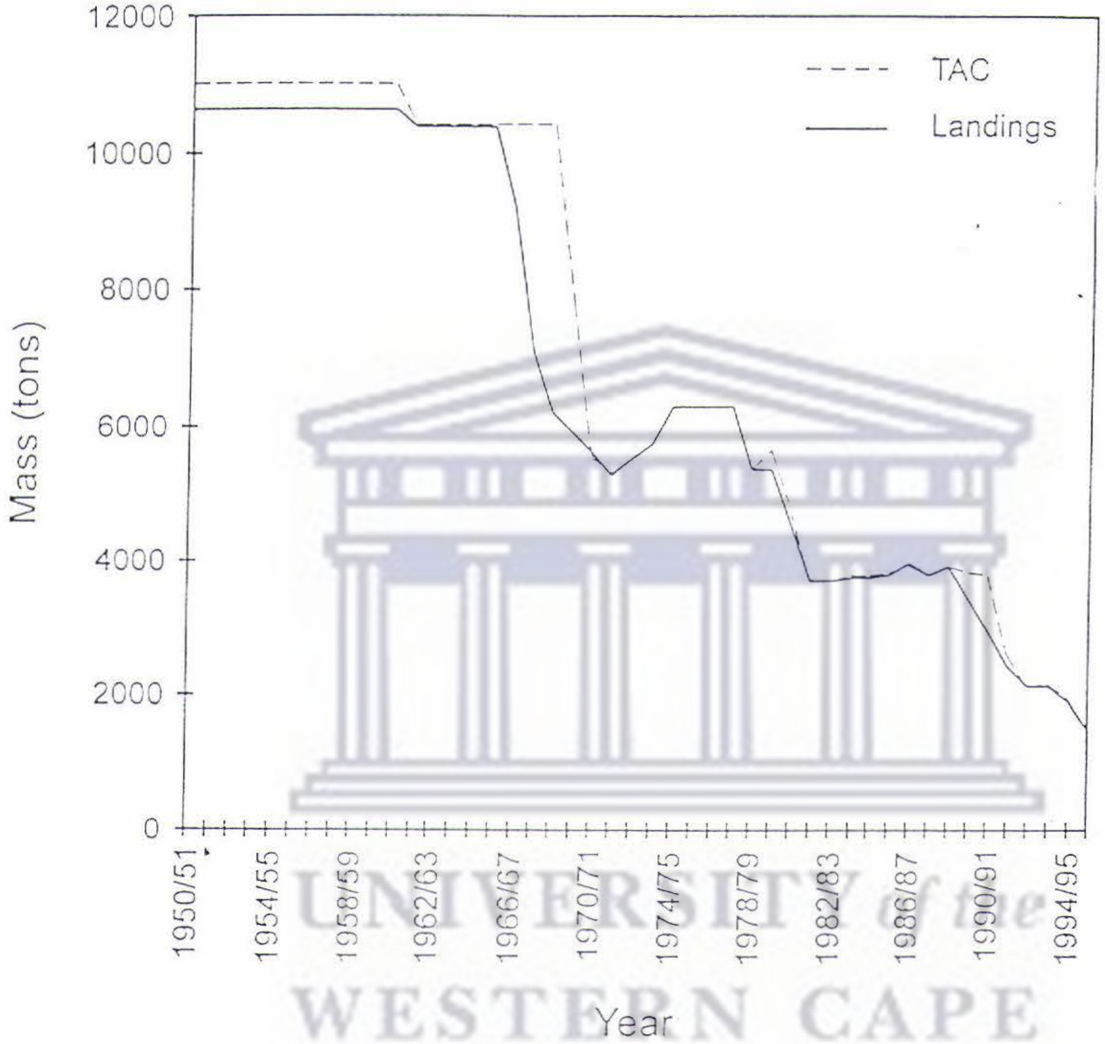

Figure 1.3. The TAC and landed catch (tons whole mass) for the period 1950/ 51 to 1995/ 96 for *Jasus lalandii* (from Cockcroft and Payne 1997).

resulted in a search for better- yielding areas (Pollock 1986). This signalled the decline of the stock available for exploitation.

From 1933 onwards, a minimum size limit of 89 mm carapace length was implemented, and a tail mass production quota was introduced in 1946 to control catches (Pollock 1986). Fishing at the northern grounds increased between the years 1918 and 1955, before declining, whereupon a reduced minimum size limit of 76 mm was implemented for the area. The smaller minimum size, and the uncontrolled exploitation at the reduced size limit after 1959, immediately improved catches in the northern areas, eg. Port Nolloth. This however was only temporary, and the fishery virtually crashed in 1969. The original size limit of 89 mm was then reinstated and applied to the entire fishing ground. Yields have since remained low (Pollock 1982). The decline in catches during the late 1960s resulted in quotas not being filled for the first time in many years (Fig. 1.3), even though appropriate control measures were in place. In 1970, the production quota was reduced to the tail-mass equivalent of ± 5 513 tons to cover both export and local markets.

As mentioned above, the management strategies used up to 1980 to control the exploitation of *Jasus lalandii* included a minimum size limit of the carapace length and a tail-mass production quota.

Since the 1970s there has also been a shift in the method of catching rock lobsters. The traditional method of capturing lobsters made use of hand-hauled baited hoopnets. These have now been replaced by rectangular metal traps covered in polyethylene netting and baited with fish.

Newman and Pollock (1969) found the traps to be 2.5 times as efficient as hoopnets.

Prior to 1980, the movement of vessels between fishing grounds (Fig. 1.4) was not restricted, although vessels tended to remain close to home ports. This situation changed when larger vessels began to move from the northern and central grounds to fish further south, particularly around Dassen Island. This movement was prompted by a decline in the availability of lobsters in the Lamberts Bay area. To prevent overfishing in the region around Dassen Island, authorities introduced a maximum allowable catch (MAC) for the 1980/81 fishing season, which was carried over to the other fishing grounds (Fig. 1.4) in subsequent years. At about the same time, the tail mass production quota system was replaced by a whole lobster mass quota. The total quota for a particular year would then be the sum of each of the eight MACs, and these are now determined annually for each of the eight fishing areas (Pollock 1986).

A number of management measures have been introduced over the years to try and protect the fishery from over-exploitation. The exact measures have varied from year to year and from area to area. These measures now include a prohibition of catching lobsters in a soft-shelled condition, berried females, a minimum legal size of 89 mm carapace length (up to 1993), bag limits for recreational fishermen, MACs and a closed fishing season. It is important to note that the above mentioned management measures should protect females from exploitation for most of their life span, and thus ensure high levels of egg and larval production. Yet, despite these measures, the numbers of rock lobsters have still decreased and this presents major problems for the sustainibility of the fishery.

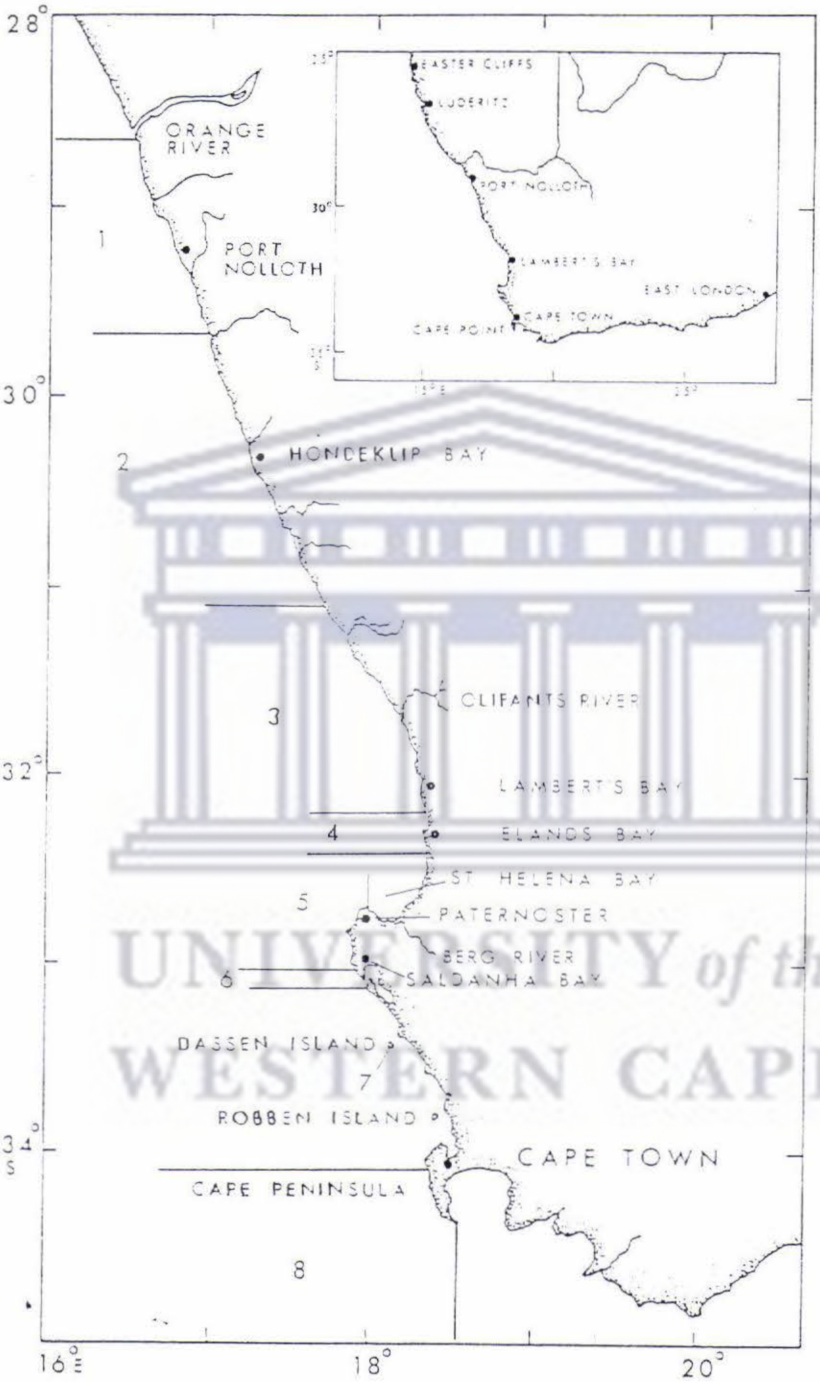

Figure 1.4. Rock lobster fishing grounds off the west coast of South Africa (from Pollock and Beyers 1981).

Between 1980 and 1989 the fishery experienced a period of stability with annual landed catches of 3 500 to 4 000 tons. Catch rates seemed to be increasing and the management measures implemented were then considered to adequately protect the resource (Cockcroft and Payne 1997). In the following years, however, the catch rates declined quite severely and quotas could not be filled (Pollock 1994). It was suggested that the decrease in catches was due to a reduction in the rock lobster somatic growth rates, which meant that fewer animals were entering the fishery. This prompted management to temporarily reduce the minimum size limit from 89 mm to 75 mm carapace length for the 1991/92 season and thereafter to reduce it permanently to 75 mm from 1993 onwards. Total allowable catches were also reduced, from 3 790 tons in 1990/91 to 2 400 tons in 1992/93, because it was predicted that recovery would be gradual. The TAC was further reduced to 1 500 tons in 1995/96 (Cockcroft and Payne 1997).

With the present *status quo*, current assessments have shown that the lobster resource is heavily depleted. The harvestable component of the population is at about five percent of its pre-exploitation level and the spawning biomass (females larger than 65 mm carapace length) is thought to be at about twenty percent of its believed pristine level. Since the mid 1980s the harvestable biomass has decreased by about 50% and the spawning biomass has been reduced by 30% (Cockcroft and Payne 1997).

The exact causes of the reduced catches is unknown, but has been linked to the severely retarded lobster growth rates on most fishing grounds (Pollock *et al.* 1997). This has resulted in a decreased recruitment of animals into the legal size range (Pollock 1994). Growth increments of ± 4 mm per moult were typical for *Jasus lalandii* in the 1970's (Pollock *et al.* 1982), but this had dropped to ± 1 mm in 1990 (Cockcroft and Payne 1997). Signs of zero growth, and even negative growth (shrinkage), at moulting have been demonstrated for this species under field conditions (Cockcroft and Goosen 1995). Zero or negative growth in crustaceans is generally associated with adverse holding or environmental conditions (Marshall 1945, Ikeda and Dixon 1982). Newman and Pollock (1971) described the disastrous effects of low oxygen water on a population of lobsters at Elands Bay and Beyers (1979), and Pollock and Beyers (1981) have concluded that poorly oxygenated water has negative effects on the growth rates of lobsters. In experiments performed by Beyers *et al.* (1994) it was demonstrated that the growth increments of individuals kept at 35.0% saturation were significantly smaller ($p<0.05$) than those kept at higher saturation levels. Although the exact causes of this slow growth phenomenon are not yet clearly understood, its widespread nature is indicative of a large scale environmental perturbation (Pollock *et al.* 1997).

To make matters worse, large numbers of lobsters have been killed by red tide events at particular areas along the west coast. Approximately 60 tons of rock lobster were washed ashore at St. Helena Bay during a black tide event in March 1994 (Matthews and Pitcher 1996). The decay of these phytoplankton blooms cause a depletion of oxygen in the water. The lobsters are generally intolerant to these anoxic conditions and seek refuge in shallower waters where they become stranded at low tide. During March and April 1997, large numbers of lobsters (mainly females and undersized lobsters), were stranded on beaches near Elands Bay due to a severe red tide (Cockcroft *et al.* in press).

1.5 Background to the research question

Over the past few years research has been under way to develop an operational management procedure (OMP) to assist with the setting of total allowable catches for the *Jasus lalandii* resource. This management procedure makes use of data gathered by resource monitoring to adjust the TAC according to the stock situation (Cockcroft and Payne 1997). As little information on rock lobster recruitment is available, research should be aimed at providing this vital information. The successful measurement of recruitment in other lobster species has been achieved by monitoring pueruli settlement. Detailed information on moult cycle provided by pleopod staging is essential for sound management of the resource on an area and global basis. This type of research, together with information on socio-economics forms part of the OMP.

The major inputs into the OMP are commercial catch per unit effort (CPUE), a fisheries independent monitoring survey (FIMS), abundance survey and information on growth rates. It is clear that the fishery for *Jasus lalandii* is influenced by factors that affect lobster growth rates. If there is insufficient growth, the number of animals that enter the legal fishery is low, and this in turn negatively affects the industry. Recent research has indicated a predictive link between lobster condition factor and growth rate (Cockcroft 1997), and modelling has highlighted the importance of growth rate in the calculations of TACs. As the condition of the lobster is closely linked to the moult cycle and could be used to predict growth increments, it would be a powerful tool in the management of the lobster resource. Conditions within the industry are constantly changing, and so the effectiveness of management decisions need be re-evaluated on an on-going basis. Similarly, aspects of the biology and ecology of *J. lalandii*, although well documented by various authors (Fielder 1964, Heydorn 1965 and 1969, Silberbauer 1971, Newman and Pollock 1974a, b), need revision and update from time to time.

Owing to the recently observed slow growth rate of *Jasus lalandii*, there is an urgent need to review the biological cycles (moulting and berry cycles) in each of the different fishing areas. Preliminary indications are that the onset and duration of these cycles may have altered from those described between 1960-1980 (Cockcroft pers. com.). Hitherto, the basic moult cycle of the west coast rock lobster has been assessed by an examination of the exoskeletal condition (shell state) according to Heydorn (1969) (Table 1.1). This technique is, however, unable to identify some key stages within the moult cycle (eg. the shift from intermoult to premoult) which are important for detailed comparisons between various fishing areas.

An accurate assessment of the moult stages would allow:

a) a detailed comparison of moult cycles between various areas,

b) a more accurate interpretation of commercial catch data on an area and monthly basis,

c) a better interpretation of behavioural and physiological studies (both laboratory and in the field) including biochemical changes during the moult cycle, and

d) a comparison with currently used moult staging method viz. exoskeletal condition.

The detailed method of staging the moult cycle is to microscopically examine the edge of the pleopod. This technique has been used to determine detailed moult stages in various

Table 1.1. Exoskeletal condition as an indicator of the basic moult cycle in the west coast rock lobster, *Jasus lalandii* (from Heydorn 1969).

SHELL STATE	CRITERIA FOR ASSESSING SHELL CATEGORIES
Soft Old Shell	carapace hard, except along ecdysial suture which is soft
Soft New Shell	carapace extremely soft; newly moulted shell
Hard New Shell	carapace not fully rigid; hardening incomplete
Hard Shell	carapace completely hard
Hard Old Shell	carapace hard, but on breaking of a section of the antenna, the new integument is seen fully developed underneath

crustaceans (Aiken 1973, Chan *et al.* 1988, Kurup 1964, Lyle and MacDonald 1983, Mills and Lake 1975, Peebles 1977; Turnbull 1989, Van Herp and Bellon-Humpert 1978). The key aim of this study has been to establish whether the pleopod staging technique can be used to determine the moult stages of *Jasus lalandii*.

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CHAPTER TWO

MOULT STAGE DETERMINATION IN THE WEST COAST ROCK LOBSTER, *Jasus lalandii*.

CHAPTER 2. Moult stage determination in the West Coast rock lobster, *Jasus lalandii.*

Abstract

A technique for determining the different stages in the moult cycle of the West Coast rock lobster *Jasus lalandii* is described. Nine stages and substages of the post-, inter- and premoult conditions have been distinguished by microscopic examination of the cuticle, epidermal retraction and setal development in the pleopods. The diagnostic features of each of the stages are described and are generally similar to those of other crustacean species.

2.1 Introduction

Like other crustaceans, the body of a lobster is encased in a fairly rigid calcified or chitinous exoskeleton, so that growth is discontinuous and can only be effected during relatively short periods when the animal sheds its outer shell and the cuticular lining of the gut, and grows a new one (Paterson 1968). Moulting includes not only the act of ecdysis itself, but also the formation of the new cuticle, apolysis, the immediate postecdysis, and tissue growth (Passano 1960).

Moulting in Crustacea is stimulated by one or more of a group of closely related steroid hormones, the ecdysteroids (Chan *et al.*1988, Skinner 1985 and Aiken 1980). The moulting hormone is usually repressed by the moult inhibiting hormone found in the X-organ sinus gland complex of the eye stalk (Skinner 1985). Ecdysone is the hormone secreted by the moult glands (Y-organ). Paterson (1968) provided a good description of the Y organ in both the puerulus and the adult of *Jasus lalandii*. Ecdysone causes apolysis and increases the rate of ecdysone hydroxylation to ecdysterone. The resultant rapid rise in ecdysterone titer is responsible for cuticle formation and the events of mid- to late premoult. High ecdysterone titer also turns off the hydroxylation process at a particular point (Aiken 1980). Thus ecdysterone levels increase rapidly during proecdysis (Skinner 1985), although precise patterns are species-specific (Chan *et al.*1988).

Distinct biochemical changes occur during the moult cycle. Most decapods accumulate organic reserves during intermoult and premoult but the specifics vary between species (Aiken 1980). The hepatopancreas (midgut gland) of decapods has long been recognized as the major site for storage of reserves during the moult cycle (Al Mohanna and Nott 1989 quoted from Cockcroft 1997). Major energy reserves are considered to be the lipids and proteins. Hepatopancreas lipid content in *Jasus lalandii* was reported to be highest during late intermoult to early premoult and then decreased rapidly. The lowest values were recorded immediately before and after moulting. Similar results have been found for other crustaceans (Cockcroft 1997).

Most decapods spend their lives in a continuous cycle of moult related events (Aiken 1980). Although macroscopic changes in the exoskeletal condition or colour have been used to 'stage' the moult cycle of lobsters (Aiken 1980, Heydorn 1969, Silberbauer 1971), they typically lack the resolution needed to identify the key stages within the moult cycle. External criteria for staging include: post moult (stage A) lobsters are uniformly soft, and the animals then progressively harden through stages B and C. Premoult lobsters are characterized by having a soft lateral margin of the carapace.

The concept of the moult cycle in crustaceans as a sequence of stages was first recognised and developed by Drach (1939 quoted from Mills and Lake 1975). Based upon integumental changes, Drach (1939 as cited by Chan *et al.* 1988) divided the crustacean cycle into four phases: (1) metecdysis (stages A, B), the period immediately following ecdysis; (2) anecdysis (stage C), a period of tissue growth and accumulation of food reserves; (3) proecdysis (stage D), a period of active morphological and physiological changes in preparation for the next moult; and (4) ecdysis (stage E), the shedding of the old cuticle. Subsequent work has seen various authors adapting this general scheme and applying it to a wide variety of crustaceans (Aiken 1973).

The premoult period has become the focus of many crustacean physiologists and has required greater subdivision than was possible with earlier criteria. Because of differences in the onset and rate of completion of different premoult events, reliability can only be achieved by basing subdivisions on changes occurring in a single developing system (Aiken 1980). The system which has proved to be the most convenient and reliable is the state of setal development, and changes associated with this have been used for moult staging in various crustacean species (Aiken 1973, Chan *et al.* 1988, Kurup 1964, Lyle and MacDonald 1983, Mills and Lake 1975, Peebles 1977; Turnbull 1989, Van Herp and Bellon-Humpert 1978). This method uses internal changes in the morphology of the developing setae of such appendages as pleopods, uropods, telson or the antennal scales, together with exoskeletal changes in order to assess moult stage (Lyle and MacDonald 1983).

2.1.1 Pleopod staging

New setae are formed in the first half of proecdysis/premoult, and the different steps in their development have been used as an aid to moult staging in the Anomura, Natantia, Brachyura and Macrura (Kurup 1964, Aiken 1973).

Aiken (1973) described the process of setal development for the American lobster

Homarus americanus. The first external morphological indication of premoult is the retraction of the epidermis and setal cores from the cuticle (Fig. 2.1A) at the tips of flattened appendages such as pleopods. When epidermal retraction is complete, papillae form around the base of each retracted seta (Fig. 2.1B). New setae then develop through epidermal growth and invagination within a cylindrical structure (Fig. 2.1C) and new setal hairs (barbules) only develop once invagination is completed (Fig. 2.1D). Barbules and setal shafts thicken and become progressively more distinct as the new epicuticle and pigmented layers are formed (Fig. 2.1E).

The general details of setal development have been shown to be similar for a variety of crustaceans. Aiken (1973) described eleven stages in the moult cycle of *Homarus americanus* while Turnbull (1989) ascribed seven relatively discrete stages and substages to the moult cycle of *Panulirus ornatus*. These stages are similar to those described by Lyle and MacDonald (1983) for *Panulirus marginatus* (eight stages and substages). The moult cycle in *Jasus edwardsii* can be divided into a total of 12 stages or substages, of which 10 are relatively easy to distinguish (Musgrove, SARDI, pers.comm.).

This study aims to establish the moult stages for the lobster, *Jasus lalandii*, using the pleopods.

2.2 Materials and Methods

Animals for this study was collected at Green Point and Cape Town Harbour Wall, on the

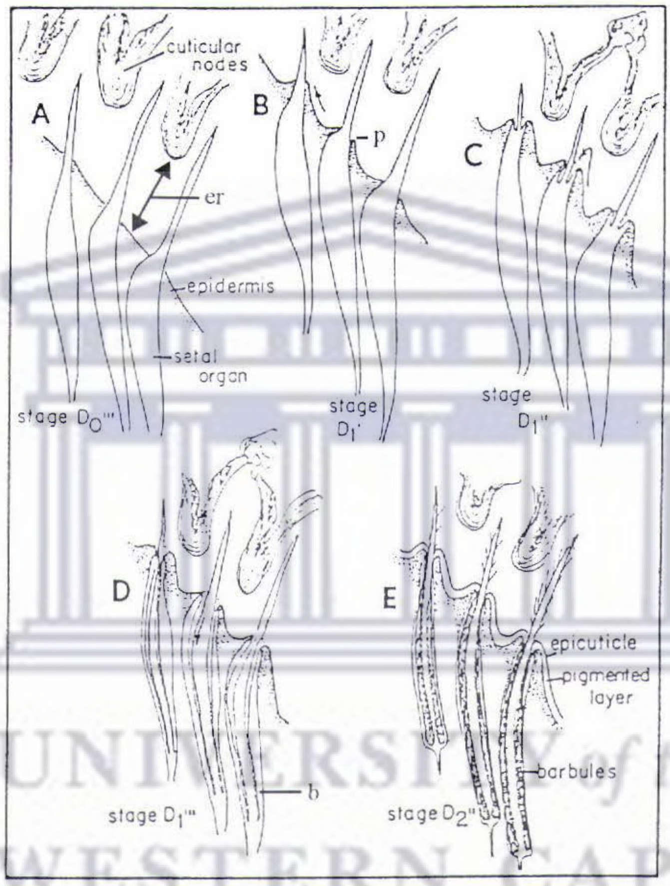

Figure 2.1. Steps in the formation of new pleopod setae during premoult (from Aiken 1980). A- epidermal retraction (er); B- papilla (p) form around the base of retracted setae; C- invagination; D- barbules (b) develop once invagination is complete; and E- epicuticle formation.

west coast of South Africa (Fig. 2.2). These sites are inhabited by a large juvenile population of *Jasus lalandii* (Pollock 1973). The reasons for using small lobsters to define the moult stages is that they moult frequently. They moult up to four times a year depending on their size. The pleopods also tend to be much thinner than those of adults which makes identification of the stages easier.

Juvenile lobsters were collected by SCUBA divers on a monthly basis during the period February 1996 to February 1997, as part of a juvenile growth project. Specimens were measured (carapace length) using vernier callipers and the exoskeletal condition (shell state) was determined using the method of Heydorn (1969). Individuals that were considered to be in premoult, and a few in intermoult, ranging in size from 20 mm - 45 mm CL, were retained for further observation. The remainder were released after measurement.

The retained lobsters were kept in aquaria at the Zoology Department of the University of Cape Town. These aquaria were supplied with constant running seawater at a temperature of between 12 - 14 °C. The lobsters in intermoult were fed a diet of fish and various invertebrates three times a week. The lobsters in premoult did not require feeding (Silberbauer 1971; Pollock 1973). Pleopods from animals in premoult were taken on alternate days to determine changes in premoult stages, whilst those of postmoult individuals were sampled daily where possible. Lobsters in intermoult were sampled on an ad-hoc basis until they entered premoult.

Pleopods were cut at their base using a pair of scissors. Severed pleopods were placed in

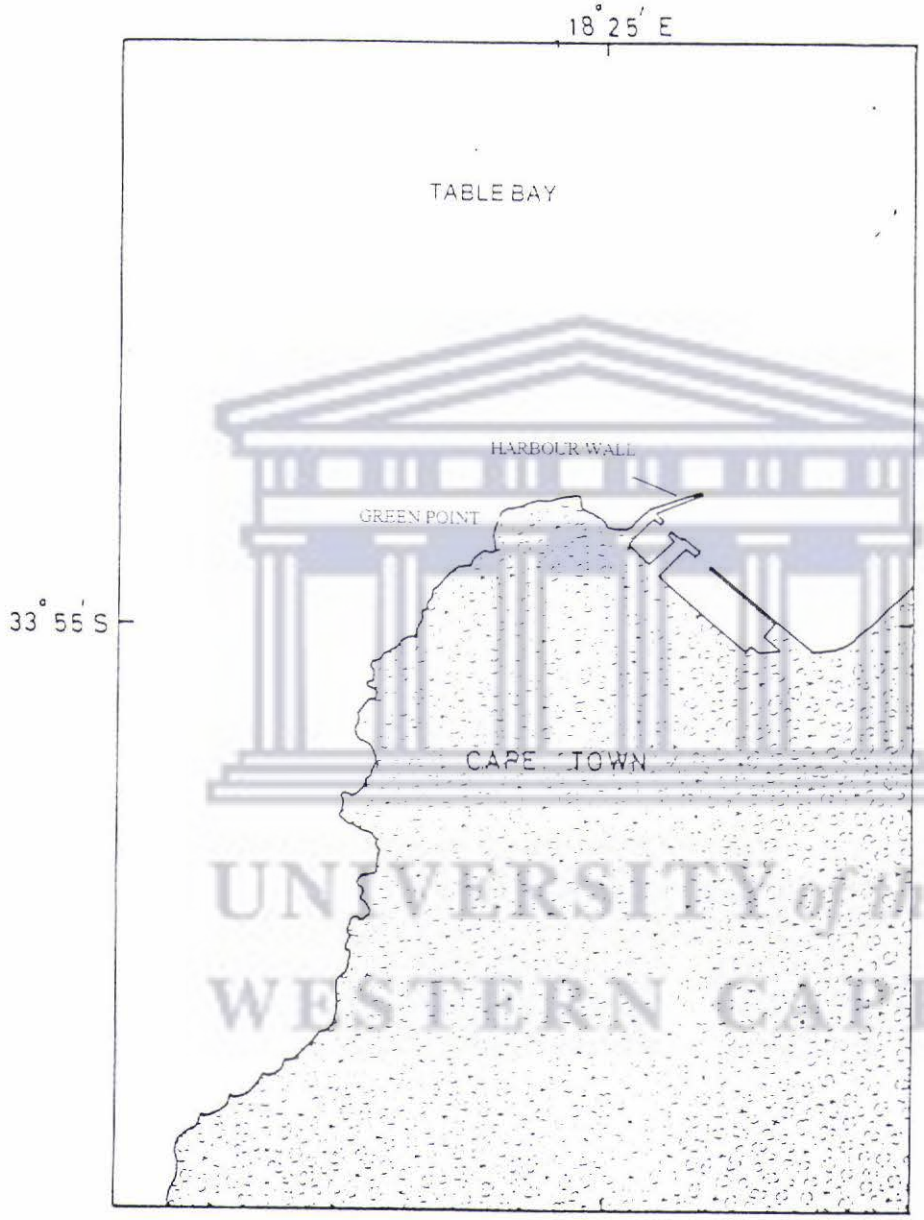

Figure 2.2. Research sites at Green point and Cape Town harbour wall (from Pollock 1973).

sea water and frozen for later examination. After thawing, the pleopod was placed in an aquaculture slide in water and examined at 63x, 100x and 160x magnification using a Zeiss IM35 inverted, phase-contrast photo-microscope. The moult stage of each pleopod was determined and photographs were taken and then used to describe the various moult stages of *Jasus lalandii*.

2.3 Results

Moulting in *Jasus lalandii* can be divided into nine stages and substages (Fig. 2.3), based on the development of setae and the degree of epidermal retraction in the pleopods.

Description of the moult stages

Postmoult

Stage A (Plate 2.1) - The setal walls show little or no thickening and the internal walls appear wavy. The setal bases are not well defined compared to those of stage B. The setal lumen is wide and granular. The entire exoskeleton is extremely soft.

Stage B (Plate 2.2) - The setal walls have begun to thicken. The setal lumen is narrower and less grainy, and the setal bases are well defined. The cuticle is relatively thin compared to stage C. The exoskeleton is starting to harden.

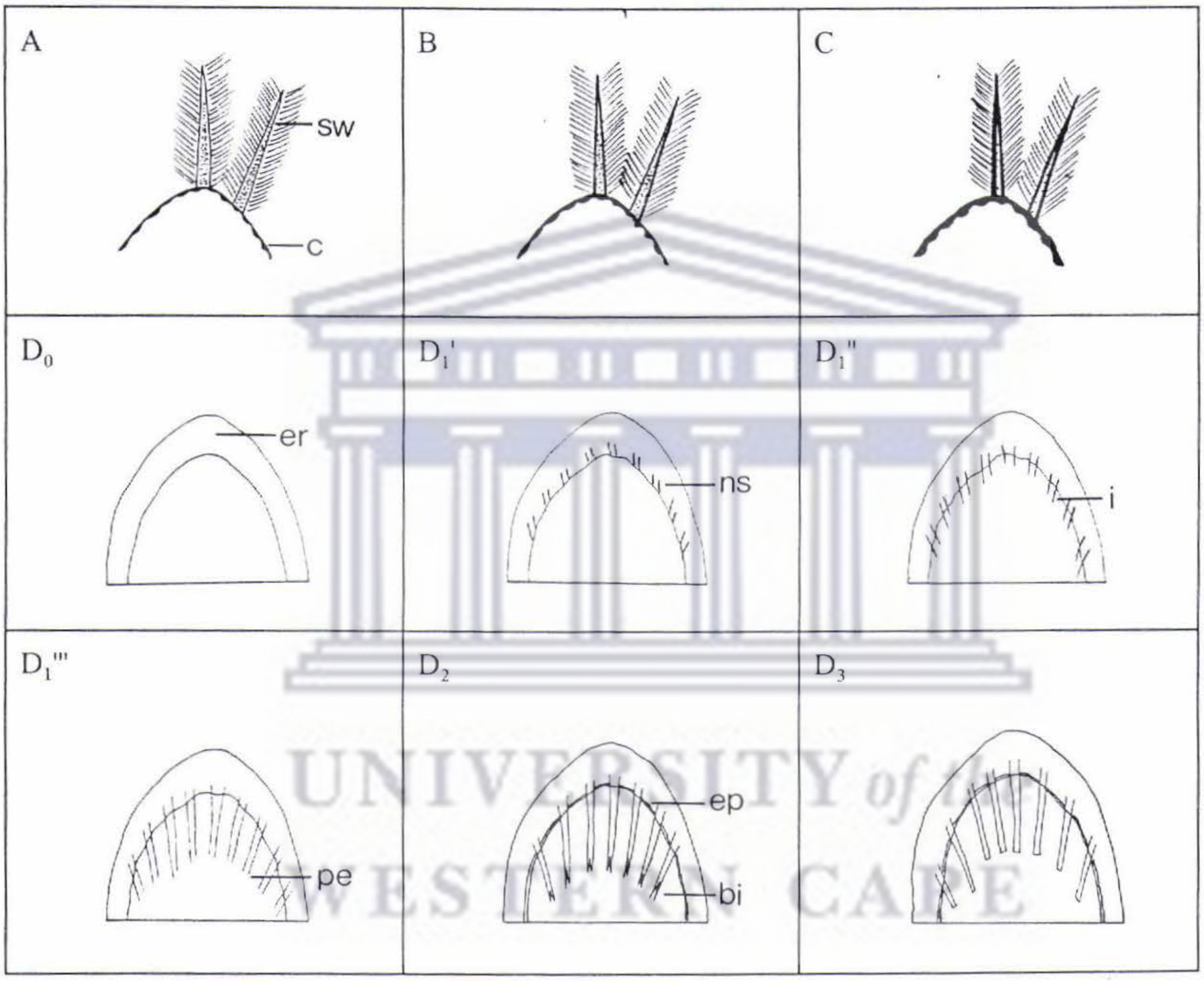

Figure 2.3. Diagrammatic representation of moult stages A to D_3.

Stage A-C showing progressive thickening of the setal walls (sw) and cuticular (c) thickening; D_0 indicating epidermal retraction (er); and D_1'-D_3 showing the various stages of setal development and epicuticle (ep) formation. i- invagination; ns- new setae; pe- proximal end; bi- bifurcate.

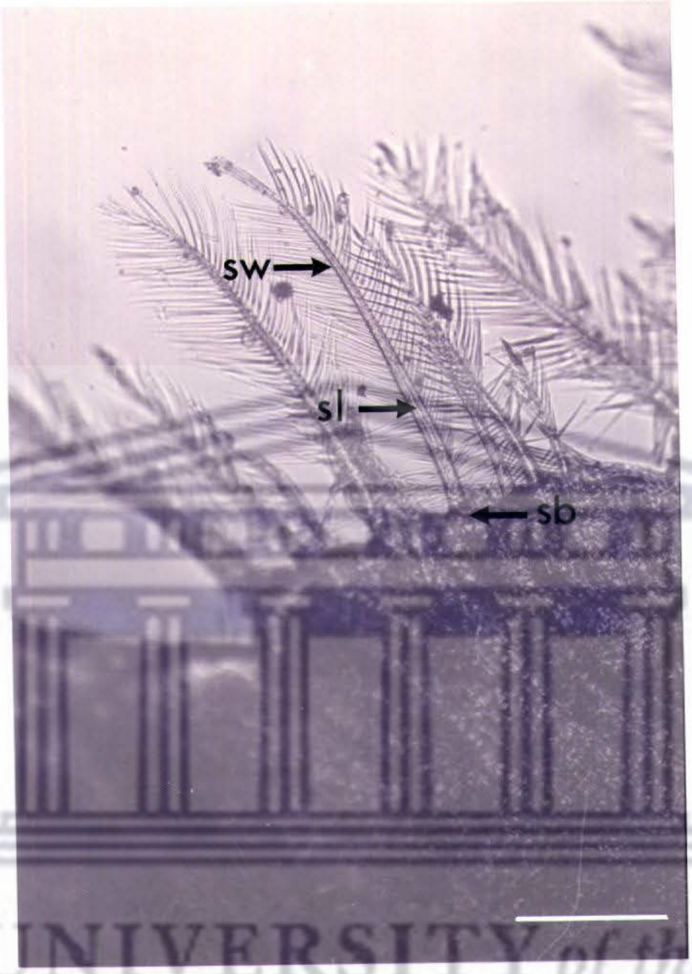

Plate 2.1. Stage A - thin setal walls (sw); setal bases (sb) are not well defined; setal lumen (sl) is wide and grainy. Scale bar = 100 μm.

Plate 2.2. Stage B - thicker setal walls (sw); setal bases (sb) are well defined; setal lumen (sl) is narrower and less grainy; cuticle (c) is thin. Scale bar = 100 μm.

Intermoult

Stage C can be divided into four substages based on shell rigidity (Aiken 1980), where the fourth stage (C_4) is referred to as intermoult.

Stage C_4 (Plate 2.3) - The setal walls have become thick. The setal lumen is narrow and sometimes non-existent due to the thick setal walls. The cuticle is thick and the epidermis lies close to it. The exoskeleton is hard throughout this stage

Premoult

The onset of premoult is often associated with a change in colour of the abdominal flesh from pink to a dark brown/black. However, the absence of a colour change does not necessarily mean that an individual has not entered the premoult stage.

Stage D_0 (Plate 2.4) - This stage is characterized by apolysis, or the retraction of the epidermis from the cuticle of the pleopod to leave a transparent gap between the two tissues. Retraction starts at the apical tip of the pleopod and works its way laterally.

Stage D_1' (Plate 2.5) - The tips of the new setae become visible in the zone of retraction, as flaccid wisps of tissue, which are small and irregular in appearance.

Stage D_1'' (Plate 2.6) - This stage commences with the invagination of the setae.

Plate 2.3. Stage C - thick setal walls (sw); setal lumen (sl) is narrow; thick cuticle (c).

Scale bar = 100 μm.

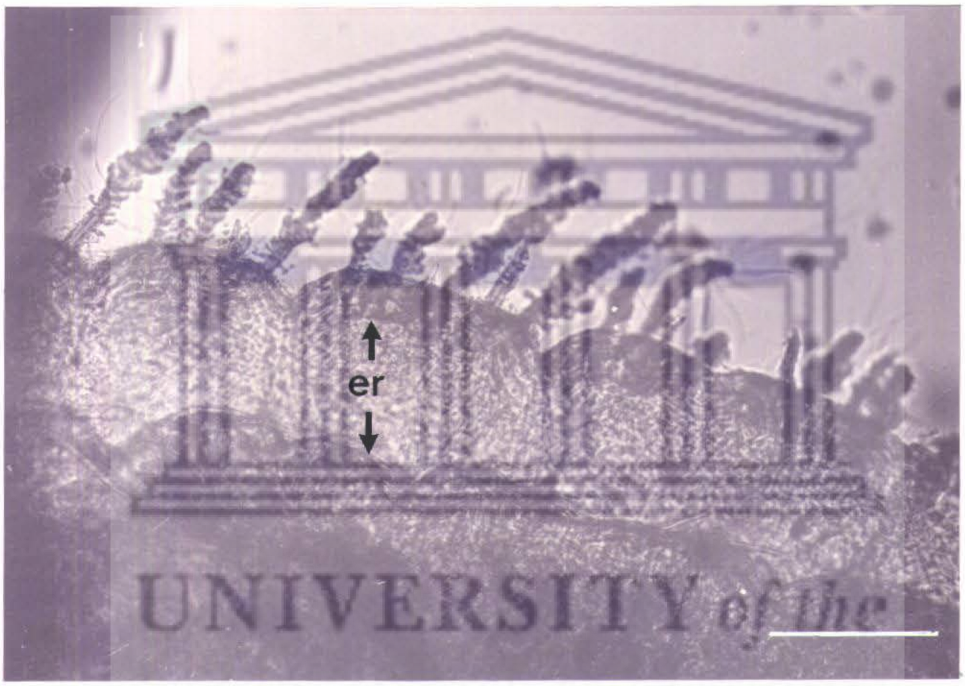

Plate 2.4. Stage D_0 - epidermal retraction (er). Scale bar = 100 μm.

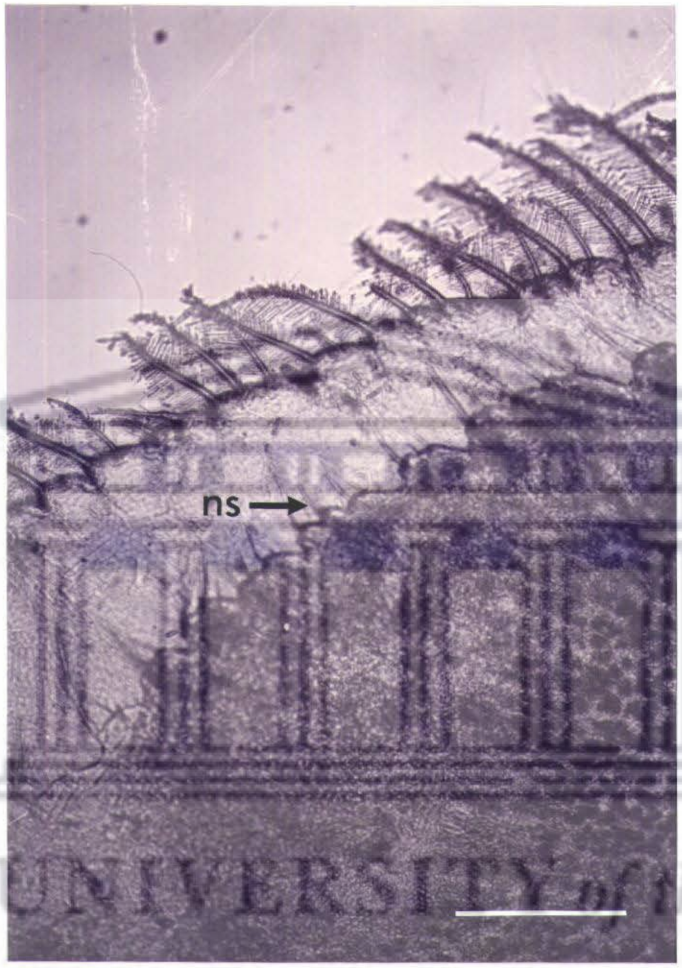

Plate 2.5. Stage D_1' - new setae (ns) visible in the retracted zone. Scale bar = 100 μm.

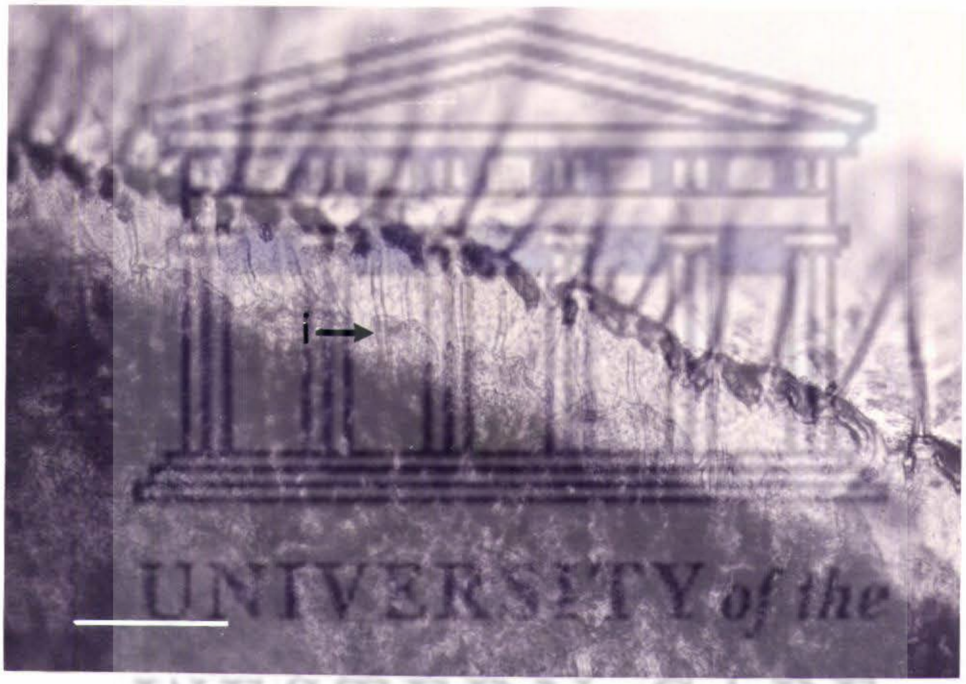

Plate 2.6. Stage D_1'' - invagination (i) of the new setae. Scale bar = 100 μm.

Stage D_1''' (Plate 2.7) - Stage D_1'' ends with the appearance of barbules along the setal axes which indicates commencing of D_1'''. The proximal ends of the setae are poorly defined. There is no epicuticle deposition.

Stage D_2 (Plate 2.8) - The proximal ends of the setae appear bifurcate and deposition of the new epicuticle has begun.

Stage D_3 (Plate 2.9) - The new exoskeleton displays folding to accommodate subsequent growth.

No further changes appeared to be visible in the pleopods until ecdysis/moult.

2.4 Discussion

The method that has been used here to determine the moult stage of *Jasus lalandii*, based on developmental changes in the setae of the pleopods, is similar to that employed by Drach and Tchernigovtzeff (cited in Lyle and MacDonald 1983), Aiken (1973) and Turnbull (1989) for a number of other lobster species. There is much variation in the developmental changes that occur in different taxonomic groups of crustaceans, and the original criteria proposed by Drach to categorize these changes have often been modified to accurately stage individual species (Stevenson *et al* 1968).

The postmoult stages of *Jasus lalandii* are characterised by a progressive thickening of

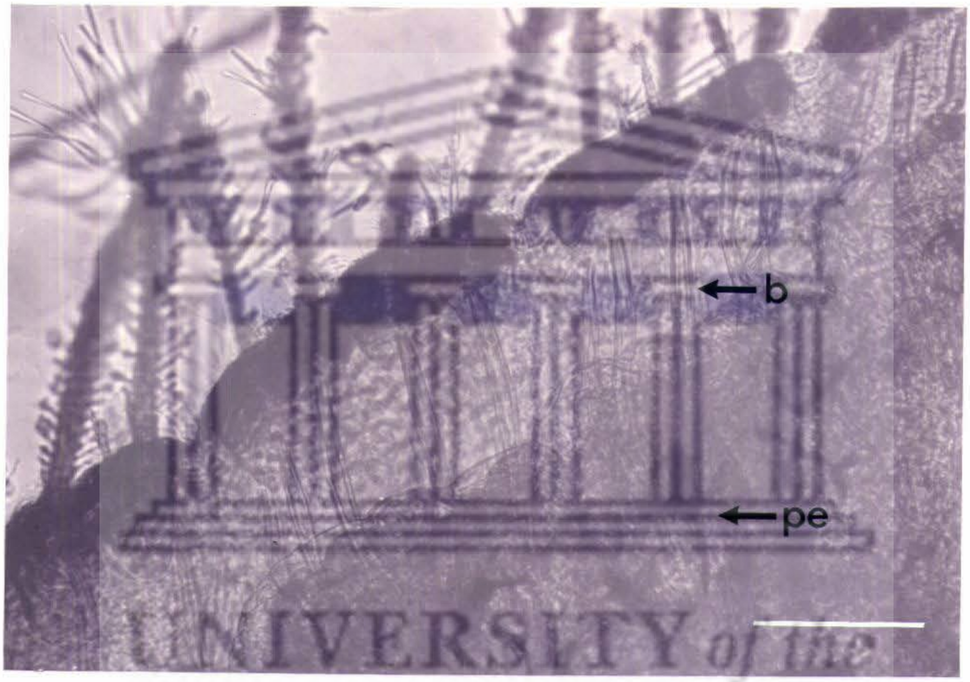

Plate 2.7. Stage D_1''' - barbules (b) along the setal axes; poorly defined proximal ends (pe).

Scale bar = 100 µm.

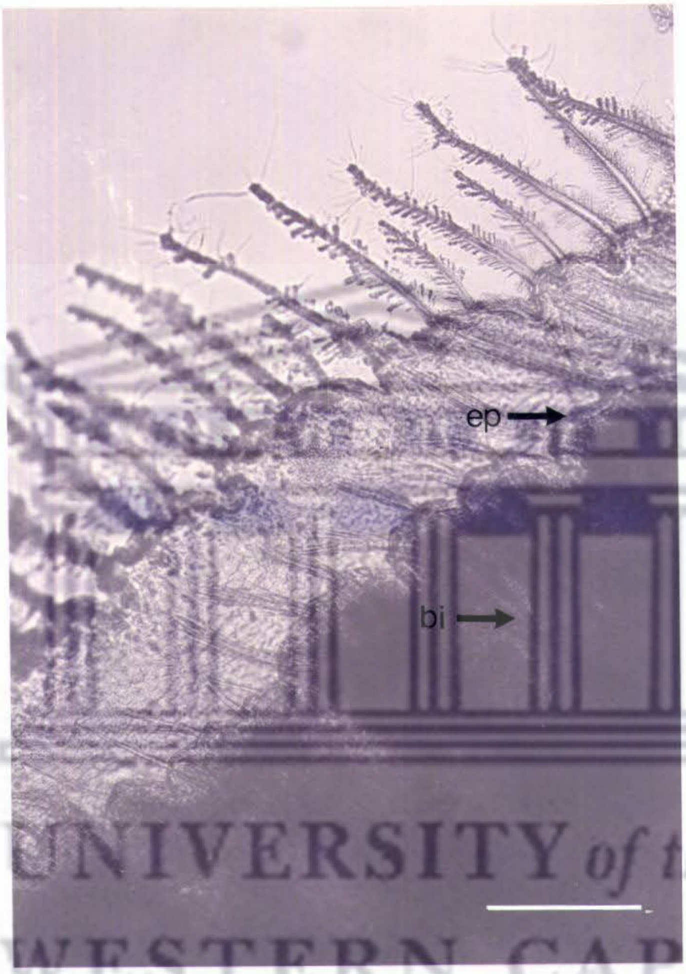

Plate 2.8. Stage D_2 - bifurcate (bi) proximal ends; new epicuticle deposition (ep).

Scale bar = 100 µm.

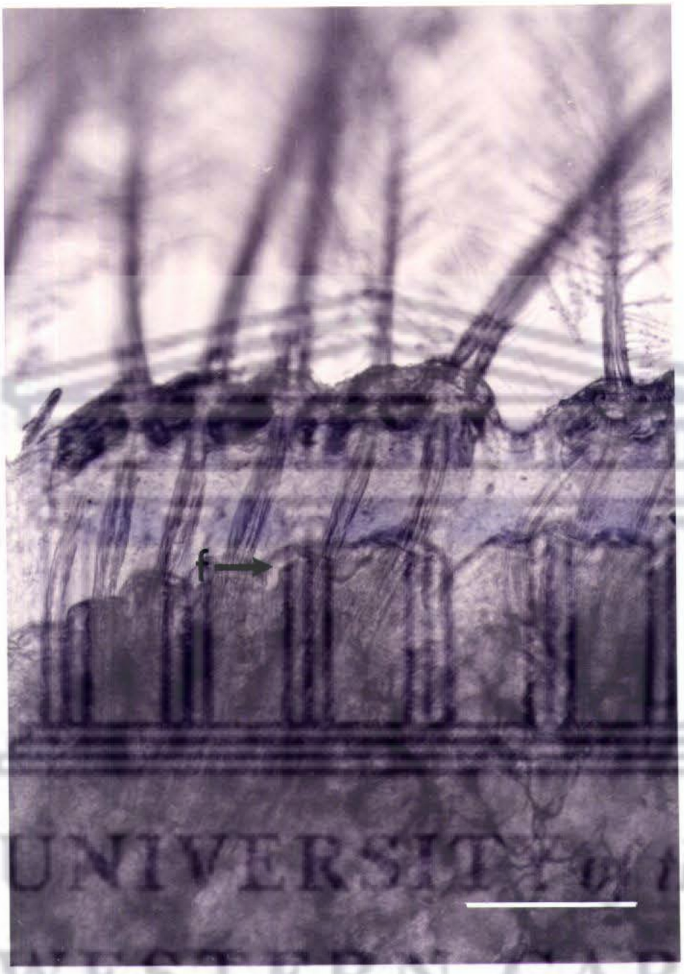

Plate 2.9. Stage D_3 - folding (f) of new exoskeleton. Scale bar = 100 µm.

the setal walls through to intermoult. Similar results were obtained by Turnbull (1989) for *Panulirus ornatus*. He also noted that the setal walls of individuals at stage A were wavy and that the setal lumen was filled with a granular protoplasm. The key features of the postmoult stages are the thickening setal walls and the wide diameter of the setal lumen which is filled with a granular protoplasm. Van Herp and Bellon-Humpert (1978) described the setae in *Astacus leptodactylus* as being filled with a fibrillar protoplasm during moult stage A, and then by a homogenous protoplasm in Stage B. Mills and Lake (1975) described these changes in the setal lumen of *Parastacoides tasmanicus* as due to the development of an internal matrix in the setae. The setae of the pleopods from many species of stomatopods have been described by Reaka (1975) as having a cellular matrix.

Lyle and MacDonald (1983) have grouped the A and B stage of postmoult together in *Panulirus marginatus* while these stages remain separate for *Panulirus ornatus*. Some authors (Kamiguchi 1968; Peebles 1977) have used the appearance of internal cones in determining the identity of postmoult stages but this feature should be approached with caution (Reaka 1975), since there is much inter- and intra-specific variation in the formation of cones (Reaka 1975).

The intermoult Stage C is characterized by thick setal walls, and a narrow, and sometimes occluded, setal lumen. The cuticle is thick. Having said that, a number of other criteria have been used to characterize this stage. Mills and Lake (1975), Reaka (1975) and Peebles (1977) stressed the use of changes associated with the internal cones as being the most useful criteria. Turnbull (1989) described setae in this stage as having narrow lumen that have lost most of their grainy appearance. He also noted thick and smooth setal walls, and a thick cuticle that extended to below the setal bases. It is not known whether the appearance of the setal lumen is due to a retraction of the cellular contents, but it does involve a thickening of the setal walls (Lyle and MacDonald 1983). Like *Panulirus marginatus* (Lyle and MacDonald 1983), stage C in *Jasus lalandii* could not be further subdivided on the basis of a microscopic examination of the pleopods.

As reported for *Homarus americanus* (Aiken 1980) and *Jasus edwardsii* (Musgrove pers. comm.), the absence of the blackened abdominal flesh colour in *Jasus lalandii* does not necessarily indicate that an individual is not in premoult.

The premoult condition in *Jasus lalandii* has been divided into stages D_0, D_1, D_2 and D_3. The onset of premoult (Stage D_0) in decapod Crustacea is identified universally by the retraction of the epidermis from the exoskeleton (Aiken 1973, Kurup 1964, Mills and Lake 1975, Turnbull 1989), and is known as apolysis (Jenkin and Hinton 1966). Aiken (1973) divided this stage into three pleopod stages (1.5-2.5) according to the varying degree of epidermal retraction, which starts at the terminal end of the pleopod and progresses laterally. It is apparent that significant epidermal retraction occurs in *J. lalandii,* before the appearance of the new setae and this possibly indicates that this is a relatively long stage. *Panulirus ornatus* (Turnbull 1989) also has a relatively long D_0,and Aiken (1973) described this stage as a 'broad transitional phase between intermoult and premoult'. This stage, however, is very short in *J. edwardsii* (Musgrove pers. comm.).

Stage D_1 in *Jasus lalandii* can be divided into three substages and this is in accordance with most other authors. Substage D_1' is characterized by the appearance of the tips of the new setae in the retracted zone. Early setal development is a feature shared with many other decapod crustaceans (Aiken 1973; Kurup 1964; Mills and Lake 1975; Stevenson et al 1968; Van Herp and Bellon-Humpert 1978). Maximum epidermal retraction in *Panulirus marginatus* is attained during D_1', and the formation of the new setae is assigned to substage D_1''. Substages D_1' and D_1'' in *P. ornatus* have been grouped, because maximal epidermal retraction and the appearance of new setae occur at approximately the same time (Turnbull 1989), however these are distinct in *J. lalandii*.

A progressive invagination of the new setae into the epidermis was characteristic of Stage D_1'' in *Jasus lalandii*. Similar observations have been made for a number of other crustaceans (Aiken 1973, Mills and Lake 1975). Some authors have found the observation of this feature to be problematic. For example, in the case of *Panulirus marginatus* (Lyle and MacDonald 1983), the pleopods are heavily pigmented and opaque, which makes consistent identification difficult.

The formation of barbules on the new setae occurs in Stage D_1''' in *Jasus lalandii*, as it does too in *Panulirus ornatus* (Turnbull 1989), *Astacus leptodactylus* (Van Herp and Bellon-Humpert 1978) and *Parastacoides tasmanicus* (Mills and Lake 1975), as well as various stomatopod crustaceans (Reaka 1975). Interestingly, this does not occur in *P. marginatus* (Lyle and MacDonald 1983) or *Homarus americanus* (Aiken 1973) where barbules only become apparent in Stage D_2.

The deposition of the new cuticle is indicative of stage D_2 in *Jasus lalandii*. This feature is widely used as the criterion to identify stage D_2 and follows the scheme of Drach and Tchernigovtzeff (in Aiken 1973), which states that D_2 is characterized by the secretion of the pigmented layer. Initially Drach was ambiguous in his definition of stage D_2, and this lead to some confusion. It was not clear whether one should place the beginning of secretion of the new cuticle in stage D_1 or D_2. Drach stated in his1944 paper that none of the general cuticle is secreted in stage D_1, and most workers have followed this statement in their use of his stages (Stevenson et al 1968).

The final stage that can be identified in *Jasus lalandii* before ecdysis is D_3. This is characterized by the development of folds in the new exoskeleton in preparation for expansion after the moult. In *Panulirus marginatus*, *Panulirus tasmanicus* (Mills and Lake 1975) and *Astacus leptodactylus* (Van Herp and Bellon-Humpert 1978) the final stage, stage $D_{3\text{-}4}$,is characterized by the extrusion of the new setae into the retracted transparent zone (Lyle and MacDonald 1983).

2.5 Conclusion

The study has shown that microscopic examination of the cuticle and setae of pleopods from *Jasus lalandii* can provide a relatively rapid and reliable index of the moult stage of the lobster. The moult stages are generally similar to those of other closely related species and conforms to the general scheme as laid down by Drach and subsequent authors. Now that these stages have been identified and described, the pleopods of lobsters from different areas can be examined to determine detailed moult cycles.

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CHAPTER THREE

ASSESSMENT OF THE USE OF PLEOPOD STAGING IN ADULT MALE *Jasus lalandii*.

Chapter 3. Assessment of the use of pleopod staging in adult male *Jasus lalandii.*

Abstract

The moult state of adult male *Jasus lalandii* was determined on a monthly basis over a three year period between January 1994 and December 1996. The study made use of the pleopod staging technique to determine when the shift from intermoult (moult Stage C) to premoult (Stage D) occurs and the results were compared with those obtained from the traditional method of staging. Results show that it is indeed possible to determine the detailed moult cycle of *Jasus lalandii* using the pleopod method of staging although a few changes in the sampling techniques are necessary. Monthly diver based sampling and a redefinition of the hard old shell state would aid in moult staging.

3.1 Introduction

The recent decline in catches of *Jasus lalandii* along the west coast of South Africa is considered to be the result of reduced somatic growth rates which has resulted in a decreased recruitment to the harvestable component of the resource. Growth is therefore an important factor influencing the determination of total allowable catches, and, together with the minimum size limit, forms the basis on which the resource is managed. An ability to predict the moult or growth increment, used in conjunction with the biochemical condition of lobsters, would therefore be very important to the rock lobster fishery (Cockcroft 1997).

As adult male rock lobsters grow much faster than females, which means that the females are protected from exploitation for most of their lifespan. The rock lobster fishery is directed mainly at males because they attain the size limit faster than females, this study focussed on the moult cycle of male lobsters (Pollock 1986).

3.1.1 The moult cycle of *Jasus lalandii* based on exoskeletal condition

Heydorn (1969) divided the moult cycle into five stages based on the hardness of specific regions of the exoskeleton. These stages were premoult, moult, postmoult, and first intermoult and second intermoult. Although Silberbauer (1971) subsequently ascribed four stages to the cycle based upon similar methods: proecdysis (= premoult), ecdysis (= moult), metecdysis (= postmoult) and anecdysis (= 1st and 2nd intermoult), the accounts are very similar.

The moult and reproductive cycles of *Jasus lalandii* are tightly coupled. Males do not moult at the same time as females for reasons of sexual compatibility. Males must be in a hard shell state to mate with females in a soft shell state (Conan 1985, Pollock 1986). The moult and berry cycles of west coast rock lobster have been well documented by various authors working along the length of the west coast of South Africa and Namibia (Heydorn 1965, 1969, Newman and Pollock 1971, 1974b, Pollock 1982, Silberbauer 1971). These authors basically agree that sexually mature rock lobsters of this species moult once a year (Pollock 1986), and that male rock lobsters moult in late Spring to early Summer and that females moult in late Autumn to early Winter.

3.1.1.1 Male moult cycle

Heydorn (1965) found evidence of moulting in both sexes during June, September, December and March, and concluded that *Jasus lalandii* moulted throughout the year. The highest percentage of moulting males was observed at Port Nolloth in September and at St. Helena Bay in December, which suggests that moulting commences earlier in the year further north (Heydorn 1965, Pollock 1982). A high incidence of moulting males (84%) was observed at Lamberts Bay and Elands Bay in October 1968, rather earlier than the peak moulting period (November/ December) at Robben Island, Dassen Island and the Cape Peninsula (Newman and Pollock 1974b). These data were confirmed in October 1975 and 1976 by Pollock (1982), which indeed suggests that the lobsters occurring in the northern latitudes of the west coast moult earlier than those further south.

3.1.1.2 Female moult and berry cycle

Heydorn (1965) recorded moulting in March at Port Nolloth, just as females were preparing for egg laying. In May 1974, Pollock (1982) found that most of the females had moulted and were already in berry. Newman and Pollock (1974b) compared data from Dassen Island, Robben Island, Springfontein and Elands Bay (Heydorn 1969) and the Cape Peninsula. Their preliminary results suggest that the females moulted earlier at the Cape Peninsula grounds than those occurring further north. Egg bearing also starts earlier on the Cape Peninsula, which ties in with the earlier onset of female moulting. However, timing of these cycles can be expected to vary from year to year. Newman and Pollock (1974b) observed that from 1963-1967, the onset of spawning and subsequent hatching varied by approximately one month at Robben Island. Over the past approximate 25 years it has been the experience of researchers who have been involved with tag recapture programs on an ongoing basis, that female moulting and spawning cycles generally commence earlier on the northern fishing grounds and become progressively later as one goes south (Goosen pers. comm.) that is the opposite of what the early findings of Newman and Pollock (1974b) seemed to indicate.

There is quite clearly a difference in the timing of the moult cycles from north to south. The shell-state method of staging the moult cycle is a very crude indicator of moult condition and cannot be used to identify the transition from intermoult to premoult stages. This shift in the moult cycle has become the focus of many scientists since it heralds many more changes in the animal's physiology (Skinner 1985). As the change from intermoult to premoult is the most important change in the moult cycle it is vital that this transition can be identified during field studies. Studies on the biochemistry of the lobsters also require a refinement of the moult cycle in order to confirm results. Lipid reserves often peak around early premoult (Stage D_0 to D_1) in adult crustaceans (Barclay *et al.* 1983 quoted from Cockcroft 1997). Cockcroft (1997) suggests that the time taken to reach peak lipid values occurs between moult stages C_4 and D_1 in *Jasus lalandii*. Pleopod examination is therefore needed to try and identify this shift between intermoult and premoult.

Being able to identify the transition from intermoult to premoult will: (1) enable the identification of any shifts in the biological cycle on a seasonal and on a long-term basis, (2) assist in the interpretation of physiological, behavioural and ecological experimental data, and (3) be of use to the industry in their live marketing of lobsters, because lobsters in an intermoult condition are likely to survive transportation to export markets better.

The aim of this study was to determine if the method of pleopod staging described in the previous chapter could be used to identify the shift from intermoult (Stage C) to premoult (Stage D) in adult male *Jasus lalandii*, using standard collection methods.

3.2 Materials and methods

Material for this study was collected as part of a study of annual biochemical changes in the rock lobster undertaken by the Sea Fisheries Research Institute. Sampling was not directed.

Male rock lobsters were sampled monthly at Olifantsbos and Hout Bay (Fig. 3.1) on the west coast of South Africa from January 1994 to December 1996. The Olifantsbos site is a commercially exploited area and the rock lobster there are characterized by slow growth rates. Hout Bay is situated within a marine sanctuary and is traditionally an area of fast growth (Cockroft and Goosen 1995). The lobsters were collected using standard commercial traps from a research vessel. The traps were constructed from a large rectangular metal frame covered with 100 mm mesh polyethylene netting and baited with fish (Pollock 1986). The collecting bag was made of 60 mm mesh netting. Sixty male lobsters in the size class 70-75 mm carapace length were collected each month and transported to the laboratory where their moult stage was assessed on the basis of shell state as defined by Heydorn (1969).

The pleopods of five randomly selected lobsters from each site were removed each month, and frozen for later examination. The shell state of these lobsters was identified using the protocols of Heydorn (1969). Pleopods 3 and 4, and 7 and 8 (Fig. 3.2) were used in the moult staging. A preliminary investigation has shown that of the eight pleopods, pleopods 3 and 4, and 7 and 8 were most useful in the analysis of the moult stages. The others did not have setae present.

For examination, the distal end of the pleopod was removed and mounted in water on an aquaculture slide and examined at 63x, 100x and 160x magnification using a Zeiss IM35 inverted, phase-contrast photo-microscope. The tip of the pleopods was examined for signs of epidermal retraction or the presence of developing setal shafts. The moult stage of each pleopod was

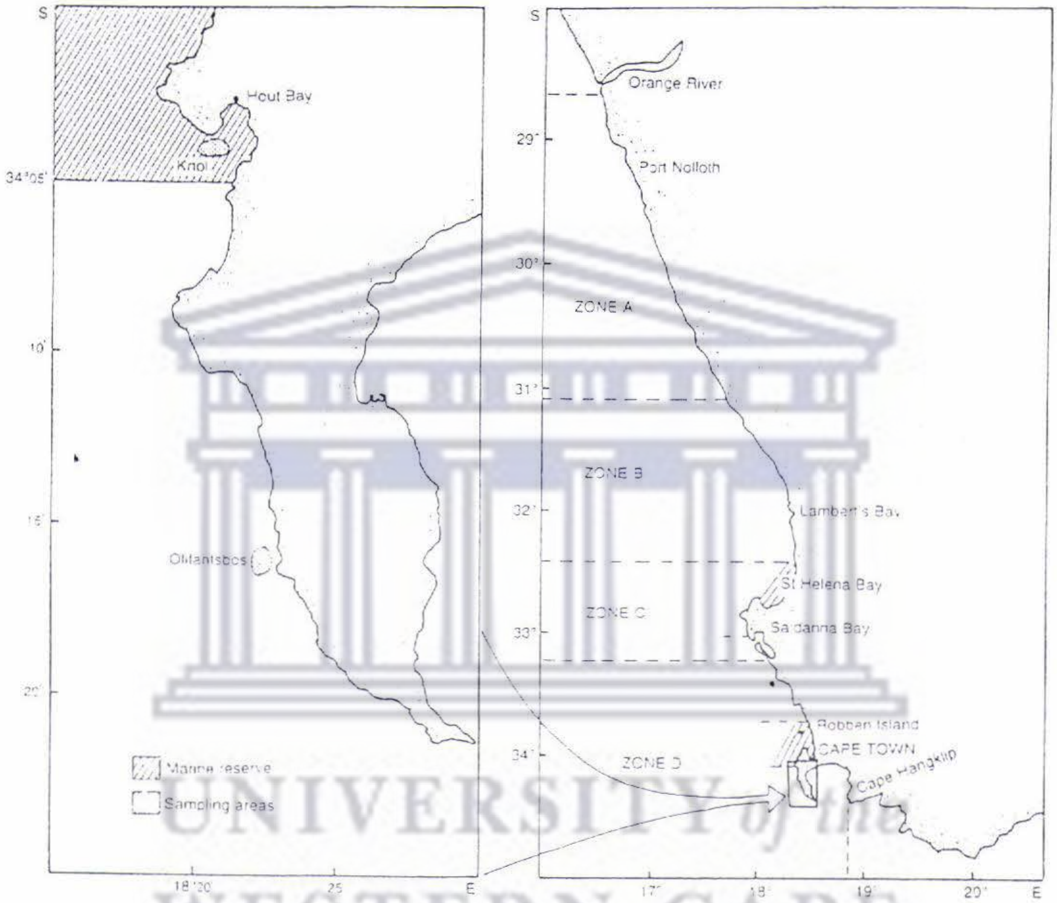

Figure 3.1. Sampling sites at Olifantsbos and Hout Bay (from Cockcroft 1997).

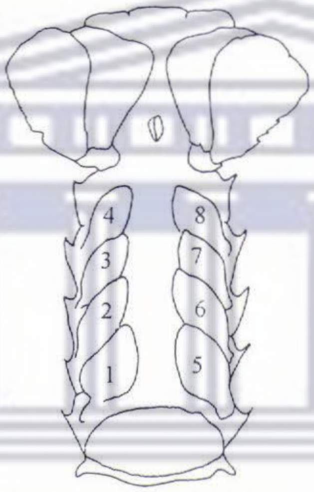

Figure 3.2. Ventral surface of abdomen of *Jasus lalandii* showing the numbering of pleopods.

determined and occasionally photographed.

3.3 Results

3.3.1 Shell state

Shell states from the monthly samples (Fig. 3.3a and 3.4a), in both areas, showed that lobsters in the premoult condition (hard old shell state) were recorded between September and October. Individuals in the postmoult/ early intermoult shell state (hard new shell state) were found between October and December, throughout the study period. This therefore suggests that moulting in males must have occurred during September and October each year. The subsamples (Fig. 3.3b and 3.4b) collected for pleopod staging also showed similar trends for the moult cycle.

3.3.2 Pleopod stage

In contrast with the results obtained using the shell state staging technique, the pleopod staging technique shows that lobsters from both areas, and for the entire sampling period were in intermoult (Stage C) (Fig. 3.3c and 3.4c). Intermoult (Stage C) is characterized by the proximity of the epidermis to the cuticle i.e. no epidermal retraction (Chapter 2).

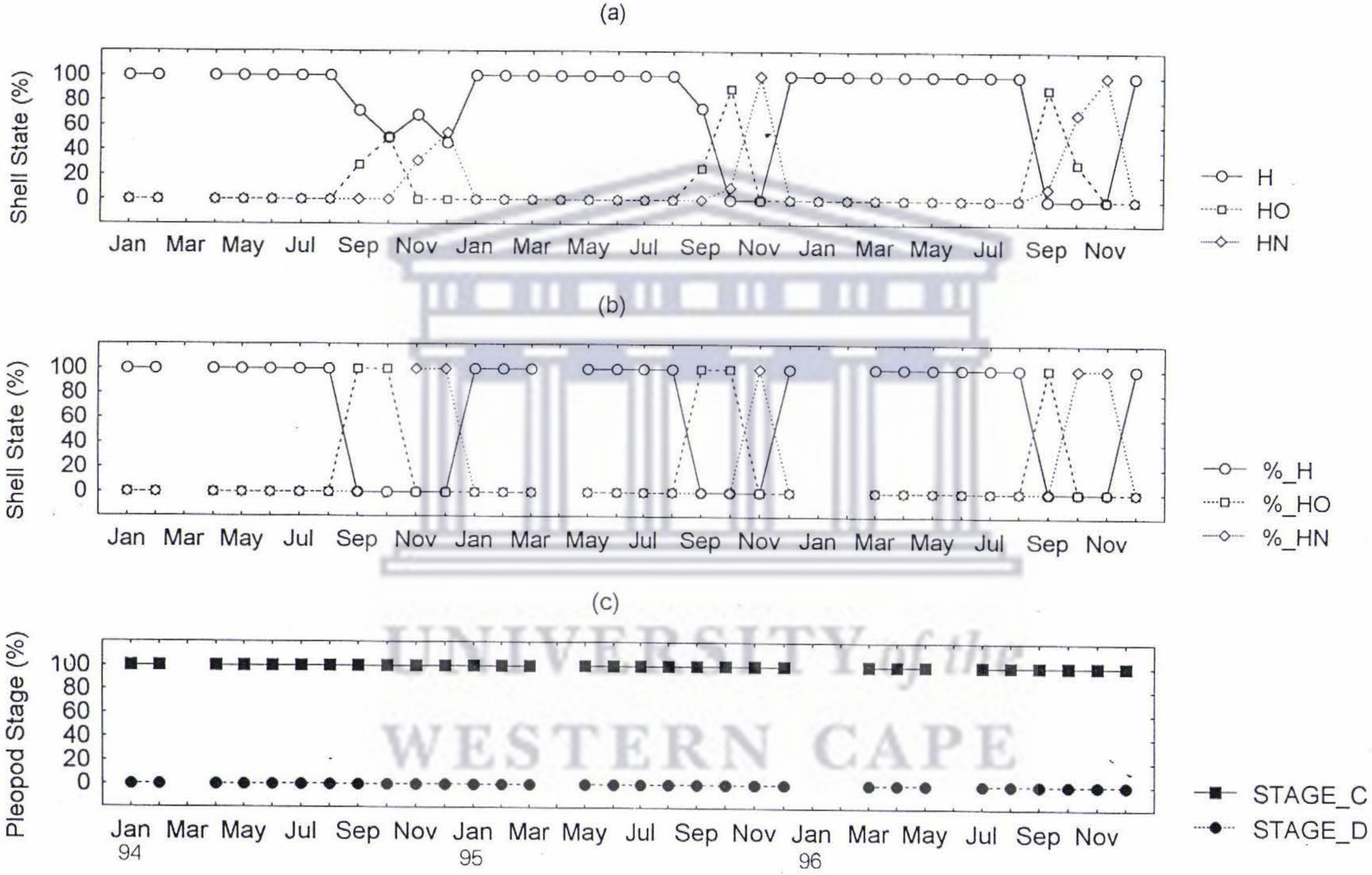

Figure 3.3. A comparison of the different moult stages as indicated by shell state in the monthly sample (a), by the shell state in the monthly subsample (b) and by the pleopod staging technique (c) for Olifantsbos.(H = hard; HO = hard old; HN = hard new)

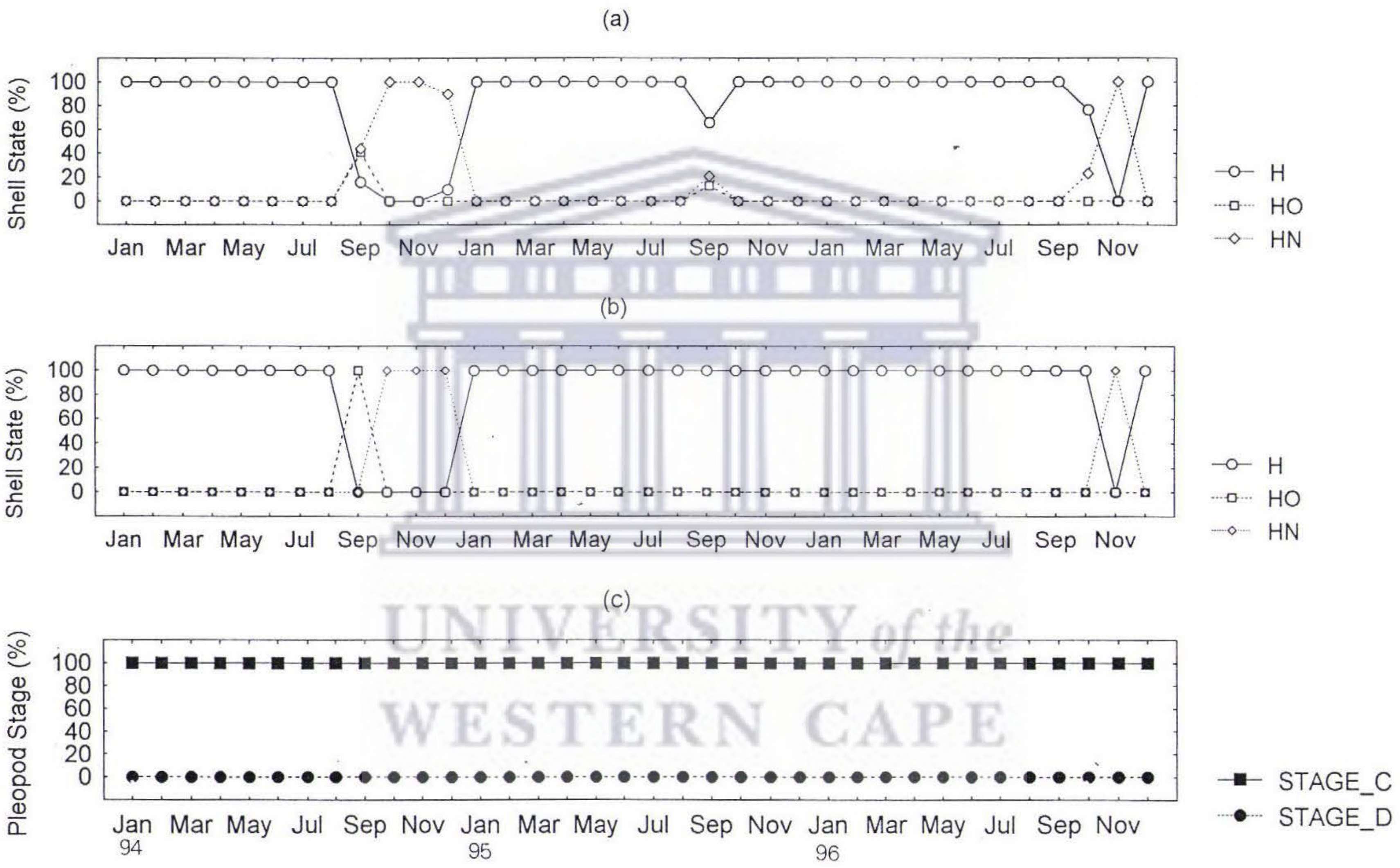

Figure 3.4. A comparison of the different moult stages as indicated by shell state in the monthly sample (a), by the shell state in the monthly subsample (b) and by the pleopod staging technique (c) for Hout Bay.(H = hard; HO = hard old; HN = hard new)

evidence of being in Stage C (intermoult) of the moult cycle, it suggests that the use of the exoskeletal condition (shell state) in moult staging during sampling overlooks other important stages, notably Stage D (premoult). It has been estimated that the intermoult period lasts between eight to ten months in sexually mature *Jasus lalandii* (Heydorn 1969). Stage C cannot be divided further in this species using the pleopod staging method and this therefore makes it difficult to determine where in the intermoult the animal actually resides.

Stage C is the period of physiological stability and the stage at which further development could be arrested for extended periods if conditions are unfavourable. In *Homarus americanus* there is a gradual transition from stage C_4 to D over a period of weeks or even months. Stage D_0 appears to be a transition period. The irreversible transition takes place between stage D_0 and D_1 (Aiken 1980). Given that a similar gradual transition period exists for *Jasus lalandii*, it is difficult to explain the absence of individuals in premoult from the samples, using the pleopod technique.

The criteria assigned to the various shell states allows for much overlap between stages (Table 3.1). The hard-old shell state probably includes both moult stages C and D. If most of the samples which were classified as hard old (HO)(refer to Table 1.1) were from the stage C group (circled in Fig. 3.5) then the results are explained. Evidence for this could be that the lobsters in stage C are still building up reserves and are thus more eager to climb into the traps to feed and thus dominate trap catches. So although they are classified as HO they are still in stage C_4.

It would be practical then to further subdivide the hard old shell state into a HO_1 and HO_2.

Table 3.1. Shell states of the west coast rock lobster *Jasus lalandii* as used by the Sea Fisheries Research Institute.

HARD: (For ± 2 months after moulting to ± 1 month before moulting

1. No give in shell when applying pressure on upper region of gill chambers.
2. Animal very hardy/robust - i.e. do not loose appendages easily.
3. Early in the stage the shell looks clean but does not appear new, while towards the latter growth (barnacles, hydroids, seaweeds, etc) are present.
4. Towards the end of the stage a brown colouration of the transparent membrane underneath the tail takes place.

HARD-OLD: (For ± 1 month before moulting)

1. Same as point number 1 and 2 for HARD.
2. Growth (barnacles, hydroids, seaweeds, etc) present on shell.
3. Brown colouration of the transparent membrane underneath the tail.
4. When an antennae is broken, a well formed "pap" new antennae pulls out.

SOFT-OLD (For <1 week before moulting)

1. Same as points 1 to 5 for HARD-OLD.
2. Carapace already broken on lines at gill chambers.
3. Old shell loose and perfectly formed new shell present under old one.
4. Not feeding - not present in catch from baited fishing gear.

SOFT-NEW: (For < 1 week after moulting)

1. New very clean shell.
2. Shell not hardened yet - like jelly.
3. Not feeding - not present in catch from baited fishing gear.
4. Prone to injury, losing appendages and dies easily.
5. White/pinkish colour to transparent membrane underneath tail.

HARD-NEW: (For ± 2 months after moulting)

1. New clean shell without any growth on it.
2. White/pinkish colour to transparent membrane underneath tail.
3. Fair amount of give to shell when pressure is applied to upper part of gill chambers - spongy feeling.
4. When applying the same pressure as for a HARD, the shell breaks.
5. Not very hardy/robust - prone to damage, injury, losing appendages, and death.

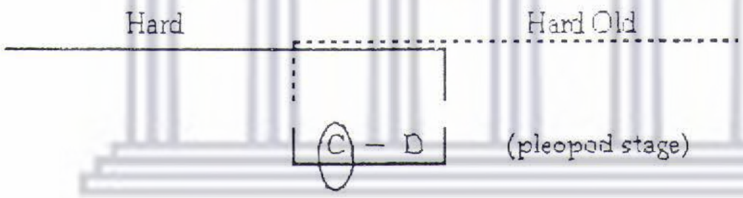

Figure 3.5. Schematic Diagram showing overlap in the shell states.

The division could possibly be the presence or absence of the new exoskeleton underneath the old. The present characteristics of the hard old shell state include: the shell is rigid on the upper region of the gill chambers when pressure is applied to it; the animal is still robust; growths such as barnacles and hydroids are present on the shell; the brown colouration on the underside of the abdomen and; the presence of the new exoskeleton underneath the old when the antenna is broken. It is the identification of the premoult stage in the moult cycle which is important to fisheries managers and which would assist them in the estimation of recruitment to the fishery.

Another possible reason for the absence of premoult lobsters from the samples, as indicated by the pleopod technique, could be attributed to the small subsample size. It is possible that individuals in a premoult condition might not have been examined. Alternatively, the absence of premoult individuals from the samples could be due to the method of sampling. To be caught, the lobsters must be attracted to the bait within the trap, and then climb into the trap to feed. Zoutendyk (1988) has shown that feeding in *Jasus lalandii* ceases for up to 44 days prior to moulting. This would mean that no animals in this condition would be caught. In order to ascertain whether this was responsible for the results, a single diver based collection was undertaken.

For the diver-based sampling, ten animals in the size range 61 mm to 88 mm carapace length were collected at an area east of Cape Hangklip during September 1998. The lobsters collected all exhibited a HO shell condition and upon breaking the antennae the new exoskeleton was visible underneath. Results of the pleopod staging (Table 3.2) clearly indicates that the entire

Table 3.2. Shell state compared to pleopod staging in diver collected samples.

Sample	n	Shell state	% in Stage C	% in Stage D
9/98	10	HO	0	100

Table 3.2. Shell state compared to pleopod staging in diver collected samples.

Sample	n	Shell state	% in Stage C	% in Stage D
9/98	10	HO	0	100

sample was in stage D_2 (setal development) of the moult cycle. This suggests that the lack of stage D (premoult) animals from the trap-collected samples is not based on an inability to detect their presence using pleopods but rather to their absence from the samples.

Evidence presented in this chapter has shown that a detailed moult cycle for adult *Jasus lalandii* can be documented with a few changes to the sampling technique which would make it more directed. A larger number of lobsters would also need to be examined. A wide range of animals of the HO shell state has to be examined to determine when the shift from stage C_4 to D_0 occurs. This would in turn allow for the precise comparison of moult cycles of animals in each of the different fishing zones.

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CHAPTER FOUR

GENERAL CONCLUSIONS

technology (Cockcroft and Payne 1997).

South Africa's new Marine Fisheries Act (White Paper) has recently become law. The Act acknowledges that marine resources should be used and maintained for long-term social and economic benefits. It promotes the sustainable utilisation and replenishment of living marine resources so that future generations may experience similar levels of catches. Everyone must also have fair access to marine resources and contribute to its management. The new policy will address the historical inequalities of fishing quotas imposed by the older order (Anon. 1997).

The work presented in this study is essential in the light of numerous requests by the rock lobster industry to have a year-round fishing season. The industry has also asked that the resource in each of the fishing areas (Fig. 1.4 of Chapter 1) be managed independently and not on a global basis (Cockcroft pers. comm.). A detailed moult cycle of animals in each of the fishing zones would provide a basis for any such proposed management decisions.

Although the condition of the shell state has been used as an indicator of the basic moult cycle in *Jasus lalandii*, this technique does not allow for the identification of important stages in the moult cycle. This is important for a detailed comparison of moult cycles between different areas. A detailed moult cycle for each of the eight fishing zones can now be compiled using the pleopod staging technique. Each fishing area can then be managed separately using its unique moult cycle, and closed seasons can be set accordingly.

Many authors around the globe have used the pleopod staging technique to determine detailed moult cycles in a number of different crustacean species. The results of this study have shown that the technique is not ineffective and that the pleopod method of staging can indeed be applied to *Jasus lalandii*. The various stages of the moult cycle have been described in juveniles using the pleopod technique (Chapter 2). Even though no shift in the moult cycle from intermoult to premoult was detected from the adult samples collected in this study, it is suggested that this method can be utilized in adults to determine detailed moult cycles if modifications to the sampling strategy are made.

The results have shown that moult staging using the shell state does not fully correspond to moult staging using the pleopod state. This confirms that the former technique is not very accurate and is too broad. There is an urgent need to refine the moult cycle of *J. lalandii* so that it can aid in other studies such as biochemical work. Once moult cycles have been determined using the pleopod staging technique, it is recommended that the shell states be reworked. At present the characteristics designating each shell state allow for a lot of overlap. This is especially so for the Hard Old shell state which is very important, since it should encompass the shift from moult stage C to stage D. As mentioned, it is the identification of this shift in the moult cycle which is crucial to scientists requiring detailed moult cycles to validate their work. The use of the moult cycle (based on pleopod staging) together with condition factor would aid in the prediction of animals that would enter the fishery. This in turn would help in setting the total allowable catch for a particular area for that year.

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