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NEW ZEALAND MARINE DEPARTMENT

FISHERIES TECHNICAL REPORT

No.29

THE NEW ZEALAND ROCK LOBSTER OR MARINE SPINY CRAYFISH *JASUS EDWARDSII* (HUTTON)

DISTRIBUTION, GROWTH, EMBRYOLOGY AND DEVELOPMENT

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SUMMARY

Intensive exploitation, from 1948 onward, particularly in southern New Zealand, of stocks hitherto largely unfished, has resulted in crayfish or rock lobster becoming the most valuable single species taken by the fishing industry. This intensive fishing, the result of a buoyant export demand for frozen tails by the United States, reached a peak in 1956. Thereafter the landings declined in volume and size of individual fish taken until huge stocks, completely unfished hitherto, were located in waters adjacent to Chatham Islands. As a result of the Chatham Islands catch of almost 41% of the gross total, a new peak record was created in 1967 when 159,012 cwt valued at $4,319,908 was recorded. Exports, principally as frozen craytails, amounted to almost 92%, and had an f.o.b. value of $6,363,130.

With a fishery of this magnitude and value it is essential that the exploitation is wisely managed so that a balance can be achieved between natural increase on the one hand, and mortality from natural causes or from exploitation on the other. Conservation regulations are important in any fishery and the protection of females carrying external eggs is essential.

The technique evolved to determine whether unlawful egg-removal has taken place is described and illustrated.

It is also important that the life-history of the species is fully understood, and published accounts and much unpublished detail are used in this paper to show the distribution, sexual dimorphism, sexual maturity, embryology, growth and development, of *Jasus edwardsii*.

Although the annual growth increment is small and, indeed, may prove to be a serious limiting factor, the initial steps taken towards laboratory rearing and "farming" are discussed and further investigation advocated.

INTRODUCTION

Before the development of the export trade in craytails really got under way in 1948, the total catch of crayfish year by year remained reasonably steady and was almost entirely consumed within New Zealand. In those days the supply at the various centres throughout the country came from small launches working their set-pots more or less regularly. Following the advent of the export market, however, there was development of more intensive fishing, especially in southern New Zealand and Fiordland, initially by trawl method and later by potting in areas newly opened up.

The total catch of crayfish in 1936 was 8,868 cwt and fluctuated between that amount and 15,777 cwt in 1946 but, thereafter, the production increased rapidly to reach a peak of 130,815 cwt in 1956, with almost three-quarters of this amount being landed at ports in the far south. From 1957 to 1960 the catch dropped to 73,904 cwt in the latter year and then increased steadily until the exploitation of hitherto unfished stocks at Chatham Islands commenced in 1965 and boosted the total catch to a new record level of 159,012 cwt in 1967. Of this latter total Chatham Islands alone contributed 65,080 cwt (almost 41%) in that year, more than double the local landings of 1966.

From the Marine Department's Report on Fisheries for 1967 the following table has been constructed to show the landed catch and value to fishermen of crayfish, and all "wet fish" over the last 10 years:

Table 1. Crayfish and "Wet Fish" catches and value 1958-1967

Year	Crayfish		Wet Fish	
	Cwt	$	Cwt	$
1958	87,351	1,457,274	494,173	3,172,600
1959	78,925	1,330,332	517,917	3,086,042
1960	73,904	1,417,550	542,506	3,350,660
1961	79,398	1,694,318	528,632	3,253,860
1962	90,018	2,141,776	554,654	3,545,256
1963	89,449	1,881,460	550,966	3,376,228
1964	90,307	2,314,976	589,384	3,779,544
1965	97,933	3,269,594	604,582	3,949,018
1966	128,981	3,844,308	666,274	4,388,116
1967	159,012	4,319,908	713,527	4,626,343

It follows that crayfish is the most valuable single species taken from New Zealand waters at the present time, its value almost equalling that obtained from the 40 or more species collectively termed "Wet Fish". The most abundant species of wet fish in 1967 was snapper, the gross take of which totalled 206,889 cwt valued at $1,248,875.

Of the 1967 crayfish production it has been calculated that 91.7% was exported, principally as frozen craytails, and having a total value f.o.b. of $6,363,130. The f.o.b. value of all other fish or fish products exported in 1967 was $1,395,643.

In view of the importance of the crayfishing industry to the New Zealand economy it is essential that the resource is managed wisely so that balance or level can be achieved between natural increase on the one hand, and mortality due to natural causes or fishing pressure on the other hand. Following the peak fishing year of 1956, southern fishermen found that not only were they faced with diminished returns, but they had to fish longer hours and closer inshore, and extend their trips over longer periods, than was the case previously. It was significant, too, that the average size of crayfish taken was considerably less than when the fishery was being developed, a fact evidenced by the tail gradings at export. It was, of course, the result of intensity of fishing on accumulated stocks, an expanding fishery made possible by the buoyant export trade in tails principally to United States markets. The Chatham Island crayfishery, so buoyant at the present time, is also fishing accumulated stocks and sooner or later can expect to reach a peak of production, followed by diminished returns, until a new balance is struck between natural increase and exploitation of the resource.

Part of the management of the New Zealand crayfisheries is achieved by regulations which specify minimum size limits, the state in which crayfish may be landed and where, prohibit the taking of females carrying eggs, the removal of eggs or the pleopods to which eggs are attached, tailing at sea (except in a defined area), marking gear, and so on. It is regrettable that a minority of fishermen, in a misguided effort to sustain the volume of former catches, have resorted to the taking crayfish of less than legal length and/or the unlawful removal of eggs from females "in berry". Many prosecutions, particularly in southern parts of New Zealand, have been undertaken in recent years for these breaches, and a technique devised for establishing whether "scrubbing" to

remove eggs has taken place.

Scientific investigation of crayfish (*Jasus edwardsii*) has been undertaken in the countries in which it occurs, notably Australia, South Africa and New Zealand. Much of the detail which follows is taken from published papers concerning the species, and is an attempt to present a balanced picture of the animal, its occurrence and importance, sexual dimorphism, reproduction, embryology, and growth, from the various investigations. Use is made, too, of some unpublished material principally on Marine Department files.

IDENTITY OF SPECIES

Taxonomy -

Order: Decapoda
Suborder: Macrura
Family: Palinuridae
Genus: *Jasus* Parker
Species: *edwardsii* (Hutton)

Valid Scientific Name -

Jasus edwardsii (Hutton)

Synonyms -

Jasus lalandii
Jasus lalandei frontalis

Common Names -

Crayfish
Marine Spiny Crayfish (or lobster)
Spiny Crayfish (or lobster)
New Zealand Rock Lobster (adoption of this as the suitable commercial name is recommended by the N.Z. Standards Institute 1965).

Two species of spiny lobsters (marine crayfish) are found in New Zealand waters, both being members of the widespread Southern Hemisphere genus *Jasus* of which the above species, *edwardsii*, is the most common and taken in greatest numbers. The less common species is *J. verreauxi*, the packhorse crayfish, green crayfish, or smooth-tailed crayfish of northern waters, and for which *J. hugelii* and *J. tumidus* are synonyms.

J. edwardsii is readily distinguished by its reddish-brown colouration, the narrow spiny carapace which is always much shorter than the abdomen or "tail", and the characteristic squamiform sculpturing of the dorsal surface of abdominal somites.

J. verreauxi, on the other hand, is easily identified by its colouration, which is green in smaller individuals and yellowish - brown in larger specimens, the wide carapace which is only slightly shorter than the abdomen, and the smooth dorsal surface of each abdominal somite.

From time to time claims have been made that the crayfish of small size which appear to be concentrated in certain localities, notably at Karitane and Stewart Island, belong to a different species. Investigations into this aspect have not revealed any evidence for such an assumption and, indeed, the studies made show that stocks in these "nursery" areas are all *Jasus edwardsii* and not specifically or racially distinct from those occurring elsewhere. The small size was more likely due to slow growth and heavy fishing. Evidence in rebuttal of the presence of a separate species, and an explanation for the regional occurrence of predominantly sub-10 inch crayfish, was given to Fishing Industry Committee (1962).

THE DISTRIBUTION OF J. EDWARDSII

According to Kensler (1967) the most northern New Zealand record for this species appears to be the Three Kings Islands where limited numbers are taken by commercial fishermen. It has not been reported from the subtropical Kermadec Islands farther north.

Kensler states it is very much more abundant on the east coast of the North Island than on the west coast. It is commonly found along all suitable rocky coastlines on the east coast and, in general, becomes more abundant with increasing distance south, i.e. from North Cape to Coromandel Peninsula, on to East Cape, Castlepoint, and the Wellington region. Distribution is sporadic along the west coast of the North Island.

Of the southern distribution Kensler records that this species is very much more common in South Island waters, and becomes increasingly so from Kaikoura to Otago Peninsula on the east coast, and from Cape Farewell to Jackson Bay on the west coast. The species reaches its South Island peak of abundance in the southwestern region, i.e. the area extending from Bluff (including Stewart Island) westward around Fiordland up to Jackson Bay.

J. edwardsii is also present at the Chatham Islands to the east of the South Island. The species is very abundant there and fishing is currently conducted on the accumulated stocks of big crayfish first exploited commercially to any extent in 1965. The huge catches landed have elevated Chatham Islands to top place in the list of producing areas. The dispersal of a large number of fishing vessels to the Chatham Islands has lessened the intensity on mainland fishing for both crayfish and wet fish.

Distributional records of J. edwardsii from New Zealand sub-antarctic islands have been reviewed and discussed by Yaldwin (1958 and 1965) who reported the species present at Snares, Bounty, Antipodes and Auckland Islands, and absent from Campbell Island. However, there is no evidence that crayfish exist in commercial quantities around these islands or that they could be economically exploited if they did.

Outside New Zealand *J. edwardsii*, or a very closely related form, occurs in South Africa, the southern coasts of Australia, Tasmania, Chile, Juan Fernandez, Tristan da Cunha, and Saint Paul (Indian Ocean).

SEXUAL DIMORPHISM

The sexes in Jasus edwardsii agree in respect of general form and colour so as to be almost indistinguishable to the unpractised eye when viewed from above, (the dorsal aspect), but they differ when more closely examined.

(a) Females are generally smaller than males of an equal age.

(b) Females are somewhat darker in colour although this may only be true in some areas.

(c) The abdomen or tail of the mature female is broader than that of a male of equal size.

(d) In the male the genital apertures are situated at the bases of last (fifth) pair of walking legs or pereiopods, while in the female they are located at the bases of the third (or middle) pair of walking legs.

(e) The female, at least when sexually mature, bears a small claw or chela at the extremity of each of the fifth pair of walking legs; no such chela appears in the male.

(f) In females the pleopods or swimmerets on the underside of the tail are "double" (biramous) and, with the exception of the first abdominal segment where both are leaf-shaped, consist of a flattened leaf-like exopodite and a rodlike endopodite. The endopodites are setose or fringed with bristles (setae) in sexually mature females and it is to these that the eggs are attached when extruded.

(g) In males the pleopods consist of the leaf-like exopodites only, the endopodites being reduced to vestiges.

These aspects are shown diagramatically in Figure 1.

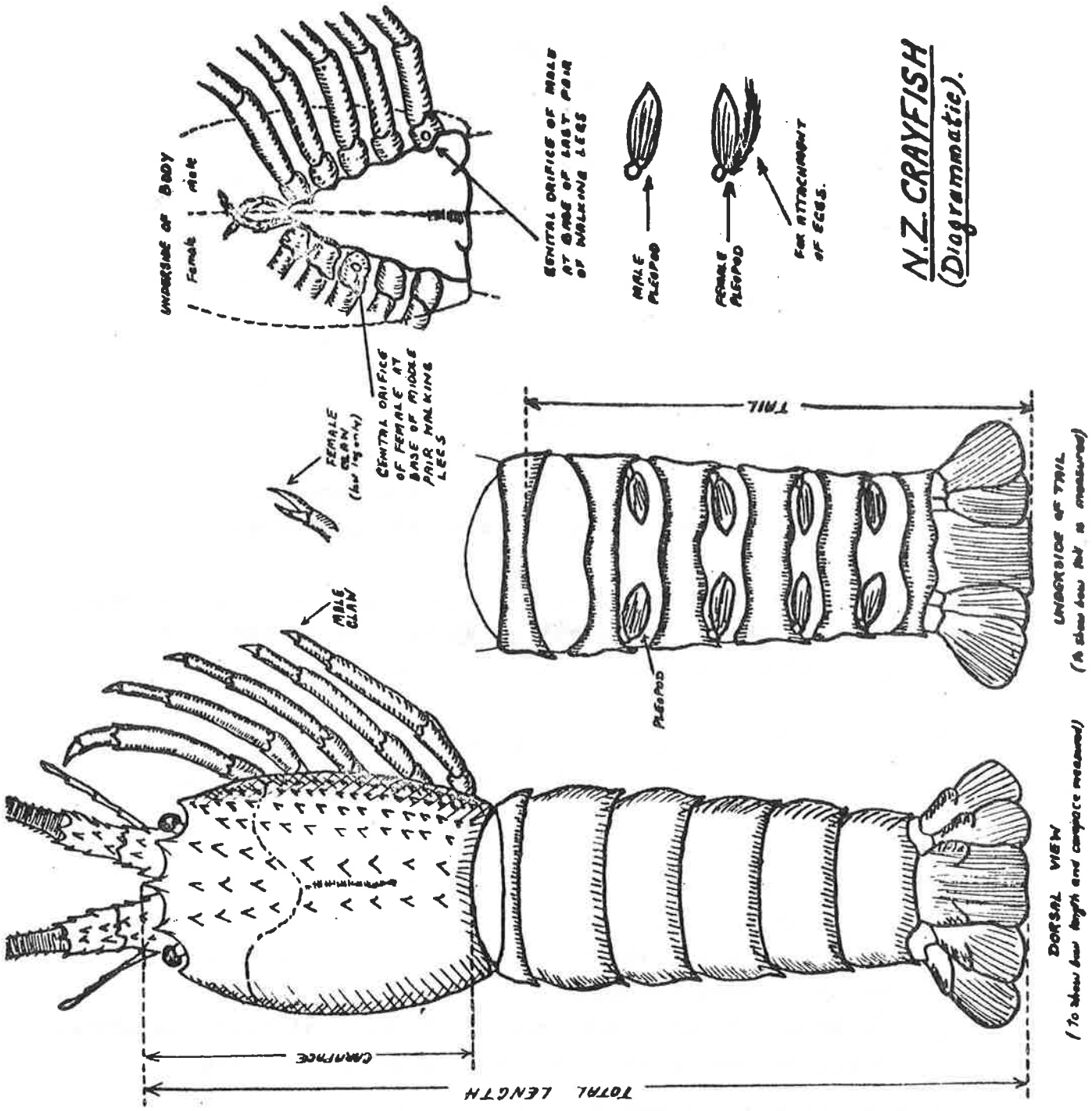

FIGURE 1.
New Zealand Crayfish (Diagrammatic)

SEXUAL MATURITY

The age of sexual maturity varies greatly in individuals and Von Bonde (1936) records that females of a carapace measurement of only one and three-quarter inches have carried "berry" on their abdomens in South Africa. Since a crayfish of this carapace size would only be a little over three inches in overall length the observation is open to question. On the other hand von Bonde states that it appears that males reach maturity after attaining a carapace measurement of three and a quarter to three and a half inches (i.e. approximately eight to nine inches overall length). (For carapace length, overall and tail length see Figure 1).

Bradstock (1950) states that in his studies on New Zealand crayfish two methods were used in an attempt to find the size at which a female becomes mature. These are:

(a) Detection of smallest female "in berry", and
(b) detection of change in the growth rate of the abdomen.

In respect of the former criterion Bradstock states that of 1,219 females examined the smallest one "in berry" was 7 cm. in carapace length (which is, therefore, equal to 7.0 inches in overall length). Of the 12 females less than 7.2 cm carapace length the balance had neither eggs or the setae to which eggs could be attached. These, and a number of others up to 9.7 cm which had no setae, or only a few fine ones, were apparently immature, since the pleopods were not ready for oviposition. The endopodites of the smaller ones were merely rod-like projections. In the larger ones (up to 9.7 cm.) the endopodites were fully developed, with a few fine setae. It appears that as the animal grows the endopodite develops, then setae begin to appear. When these are present in sufficient numbers to form a thick fringe, it is considered that the crayfish is ready, externally at least, for oviposition. Bradstock concluded that some crayfish in the Wellington area become mature when a carapace length of 7 cm. is reached, but many do not become mature until they are considerably larger. All appear to be mature by the time they are about 9.7 cm. in carapace length.

Using the second criterion (b above) Bradstock deduced that sexual maturity is achieved in some females at about 7.2 cm. carapace length. This agreed with the conclusion reached using criterion (a).

Hickman (1945) states that of 572 female Tasmanian crayfish examined, the smallest one which, by the presence of empty egg-capsules on the pleopods, gave evidence of having carried eggs, measured 7.2 cm. in carapace length. The smallest specimen actually "in berry" had a carapace length of 7.4 cm. The eggs of this specimen contained embryos at the late nauplius stage of development and therefore had been fertilised.

Street (1968) records that off the Fiordland coast the majority of females (66%) were mature at a carapace length of 8 cm. Around Ruapuke Island and the north coast of Stewart Island the majority (56%) were mature at a carapace length of 11 cm., whilst at Moeraki the majority (79%) were mature at 12 cm.

Street (1968) states that in southern waters female crayfish are first found bearing eggs in early April and egg-laying continues over two months. In Otago and Southland eggs usually begin hatching in mid-September and continues until November. This indicates, Street says, an incubation period of about five months, a period confirmed by diving operations in South Otago and tagging experiments in Chalky Inlet (Fiordland).

NUMBER OF EGGS PRODUCED

Hickman (1945) counted the number of eggs in 2-gram samples from six Tasmanian specimens and obtained an average of 8,520 (standard error 93). He used this average to obtain the total number of eggs on specimens of various sizes by multiplying this number by the total weight of eggs in the sample and dividing by two. He found that the number of eggs for a range in carapace length from 7.4 cm. to 12.4 cm. ranged from 65,170 to 413,220.

Bradstock (1950) gives an account of his repeating Hickman's work as follows (New Zealand material):

> "The whole egg-mass was stripped from the pleopods and weighed. Two grams of the mass were weighed out. The eggs, which are attached to one another by tough fibres so that the mass consists of a series of connected compact bunches, were separated from one another by hand, using a scalpel and forceps. After separation the eggs of the 2-gram sample were counted ..."
>
> "... It was found that number of eggs carried by 28 crayfish between 8.3 cm. and 13.5 cm. in carapace length, ranged from 86,000 to 549,000", (each).

(a) The Female Reproductive Organs

The ovaries are a pair of long reddish organs lying on either side of the alimentary canal in the cephalo-thoracic region and united by a median transverse bridge. From each ovary, which stretches almost the whole length of the carapace, a short straight oviduct leads downwards to open at the genital aperture situated on the base of the third pereiopod. When "ripe" the ovaries are so swollen as to fill the whole of the available space in the upper parts of the body, and when dissected at this stage the small spherical eggs are clearly seen through the thin ovarian wall which, if ruptured, permits their escape in a steady stream.

(b) The Male Reproductive Organs

The testes are a pair of elongated whitish organs connected together by a transverse bridge as in the case of the ovaries, and they occupy a similar position in the

cephalo-thoracic region. From each testis leads a thick coiled white tube or vas deferens which opens at the genital pore on the basal segment of the fifth pereiopod. The duct is composed of a proximal division which conducts the sperms from the testis, an enlarged glandular part, and a terminal muscular or ejaculatory part.

(c) The Mating of Crayfish

In respect of *J. edwardsii* fertilisation of the eggs is internal in the oviducts, maturation of the eggs being under way before extrusion. This internal fertilisation is in sharp contrast with the great majority of other sea creatures where eggs and sperms are shed into sea water by the respective sexes and fertilisation takes place externally in that medium.

The process of mating in South African crayfish has been observed and reported upon by von Bonde (1936). Apparently, about two hours after the female has cast her shell (exoskeleton), the male approaches her and manoeuvres her on to her back, head to head. He then places his sternum over the female's sternum and the sperms, in packets called spermato-phores, are extruded and appear to make their way through the female's genital apertures and so into the oviducts where fertilisation of the eggs takes place. The whole act of mating lasts from 30 to 60 seconds. Egg-laying usually follows shell-shedding (ecdysis) by about two or three days.

(d) Preparation for Egg Laying

The first step in the preparation for egg-laying consists of moulting, when the whole of the exoskeleton is shed, a process known as ecdysis. Within two or three days the eggs are laid. Before this, however, the female spends some time in cleaning the underside of her abdomen for the reception of the eggs. In this process the chelae or claws at the ends of the fifth pereiopods are used to pick the pleopod endopodites clean. This seems an unnecessary task, as the new shell is just hardening, and is probably an instinctive action.

The actual process of egg-laying in South African crayfish is described by von Bonde (1936). The abdomen is flexed under the cephalothorax and the exopodites of the pleopods are closely applied to each other so as to form a partial tunnel closed posteriorally by the telson and uropods of the tail-fan. The fertilised eggs then pass from the genital apertures in a steady stream. They pass along backward, movement being assisted by steady pulsation of the first pair of pleopods which cause a backward current of water. The eggs are free from one another but each is provided with a stalk, these stalks in turn being united together to form a main branch, much like a bunch of grapes. It is the main branch which is attached to the pleopods.

(e) Attachment of Eggs to the Abdomen

As previously stated, the eggs are laid singly with a stalk attached to each one, these stalks in turn being attached to a main branch. These branches become entwined and fixed principally to the setae of the endopodites of the second, third and fourth pleopods, a lesser quantity sometimes being fixed to the endopodites of the first pleopods. The female is then referred to as being "in berry". It takes about three to four hours for the female to lay all her eggs which, after attachment by their entwining stalks and branches, and seemingly by a "cement" secreted by tegumental glands, are not easily removed without force of some kind.

(f) First Appearance of Eggs and Duration of "Berried Season"

Bradstock (1950) stated that female crayfish may be conveniently divided into three classes:

(a) Those with eggs attached to setae on the pleopods.

(b) Those with no eggs but with setae present. This is the normal state for mature females except in the "berry" season.

(c) Those with neither eggs nor setae. These are considered to be immature.

From his study of Wellington crayfish Bradstock concluded that females carrying eggs make their first appearance in May when nearly 100% of the females caught are in this condition. It is probable that egg extrusion begins in April, but it is unlikely that it occurs earlier than this since none were observed "in berry" earlier than April. The percentage with eggs is high from May to September and a significant decrease occurs in October when the release of larvae from most females takes place leaving only a few to hatch in November and December.

The above dates agree closely with those recorded in Tasmania by Hickman (1945) who states laying takes place at Wedge Bay mainly during April, May and June, and hatching during July, August and September. He found that after September there was a rapid falling off in the number of "berried" females caught.

Bradstock (1950) records that from May to September only a small number of females are found without eggs but with setae present to which eggs are normally attached. In October there is a significant increase in females in this condition, and the increase continues through to December as a result of earlier extensive hatching leaving the pleopods free of eggs but with the setae still present. Smaller females with neither eggs nor setae are regarded as immature.

THE ANNUAL CYCLE

From the preceeding information, plus much unpublished data, the following table of the annual cycle, (Table 2), has been constructed. Whilst it will be found to cover events in New Zealand as a whole in a general way, there will be some overlapping from district to district and season to season.

Table 2. The Annual Cycle of the New Zealand Crayfish

Month	Male	Female
January	Some males, but few, in old shell	Females predominate inshore
February	Males taken in small numbers	Females coming in to shed shell
March	Males increase; mating with females commences	Females inshore shelling
April	Mating with females; few caught	Egg extrusion begins; few caught
May	Males predominate	All mature females "in berry"
June	Equal numbers of males and females	Egg hatching by early females commences
July	Equal numbers of males and females; increased number of large males	Females shedding eggs (hatching)
August	Equal numbers of males and females - further increase of large males	Female shedding eggs
September	Large males in greatest numbers	Advanced egg shedding; increase in numbers of large females
October	Males decrease in number; moult commences	Almost all females have shed eggs

Table 2. Continued

Month	Male	Female
November	Males in new shell move out	Significant number of "spent" females present
December	Any males present in new shell	Females now all free of eggs

EMBRYOLOGY

The eggs when fixed to the abdomen of the female, although fertilised, have not as yet undergone segmentation. It is possible, therefore, to trace the whole development through to the hatching of the larvae outside the body of the female by examination under the microscope of eggs from time to time.

Briefly the sequence of events, as given in von Bonde's (1936) South African observations, is as follows:

24 hours:	Eggs reach the eight cell stage.
3 days:	Ball of cells or morula stage is reached.
8 days:	The blastodermal cells increase; the egg colour changes from the bright yellow of the newly-laid condition to brick-red or cherry-red.
20 days:	The gastrula stage is reached wherein the embryo shows differentiation of the head region, the thoracic-abdominal area, and a rudimentary intestine appears.
35 days:	This stage is called the nauplius stage and the mouth and other head parts become defined, the eyes are large and compound, there is development of the thoracic appendages. The first four pairs of walking legs appear, the fifth pair come later.
50 days	A third or median eye makes its appearance and, although it persists up to and after the point of hatching, its precise significance is not known.
95 days:	Growth of the embryos has continued and they start to hatch out. Hatching is effected by rupture of the chitinous membrane along a meridian, the edges of the slit curling up and making an opening through which the larva escapes.

The empty egg shells remain attached to the pleopods of the female and are eventually cast off, the chelae assisting in clearing the appendages of the empty shells and their stalks. (See Plate 5b for presence of empty shells, infertile eggs, and one larva hatching out).

METAMORPHOSIS AND SUBSEQUENT GROWTH

The larva which emerges from the shell is quite unlike a crayfish in general appearance and habits. It is almost microscopic in size, sheds its shell many times, assuming a different form with each ecdysis, is pelagic in habitat, almost transparent, and does not assume a crayfish form until just before it settles on the sea bottom approximately twelve months later. The principal changes and names applied to the forms are, briefly, as follow:

(a) Prenaupliosoma Stage: Immediately on hatching this stage has still the bent-up appearance which it had when confined within the egg. It is nearly transparent, the only traces of pigment being in the extremities of the limbs which will become the walking legs. The eyes are large and stalked and within minutes of hatching the various appendages unfold. The third or median eye is well developed.

(b) Naupliosoma Stage: The previous form metamorphoses into this stage in about eight hours. There is development of the carapace, the eyes become more developed, and some of the appendages become more "feathery", probably as a mechanism for flotation and assistance in swimming.

(c) Phyllosoma Stage: Direct metamorphosis accompanied by another ecdysis gives rise to the first phyllosoma stage, measuring about 1.5 mm, about eight days after hatching. There is a noted decrease in length in the preceding stage and this continues until the present stage is fully developed. Thereafter growth, accompanied by an increase in length, is continuous. The phyllosoma stage is characterised by its transparent body due to the absorption of all remaining yolk. The larva now feeds on plankton. The appendages are further developed and food is taken in by mouth. (Fig 2).

(d) Later Phyllosomata: Several forms and ecdyses occur and length increases up to 35 mm have been recorded. The median eye persists until the 3.8 mm stage is reached. It then disappears. At about 4.4 mm the fourth pereiopods have developed and the fifth pair have appeared.

(e) Puerulus Stage: The most striking metamorphosis takes place when the phyllosoma of about 35 mm changes into a puerulus of about 22 mm. The latter stage appears in all essentials to be like a small adult and all the appendages, except the pleopods, are adult-like in form. The cephalic and thoracic region, which heretofore appeared as separate regions, have become fused into a single cephalothorax; the shape of the abdominal region has not changed but has grown longer. The larva at this stage is almost transparent and, at one time it was considered to be a speciesof a genus Puerulus. (Fig. 3).

At this stage the larval but recognisable crayfish ceases its pelagic life and settles to the sea bottom in shallow sheltered localities approximately twelve months after hatching.

LATER DEVELOPMENT

Following the puerulus stage a "post-puerulus" form has been described by Gilchrist (1920) for the South African "crawfish". Here the whole of the upper parts become coloured, a condition which commenced in the preceding stage, so that this increase may be regarded merely as a further development of pigment. The carapace spines become more numerous and all subsequent development is accomplished by growth of this stage accompanied by ecdysis. The deposition of lime in the cuticle results in the animal becoming more and more opaque. It now assumes the normal mode of progression, walking on the sea bottom.

GROWTH

In respect of the rate of growth von Bonde (1936) states that this is very slow but as the age advances ecdysis only occurs annually and, ".... owing to the tissues having a greater capacity for absorption of water, the growth at the moulting period is relatively greater". He did obtain a few measurements on growth from observations in South Africa of a small male with a carapace of 0.95 inches kept in a special tank from 25 January 1933. It cast its exoskeleton on 5 April 1933, the carapace measurement still being 0.95 inches. The next moult took place on 29 July 1933 and the carapace then measured 1.05 inches. The next moult was on 21 January 1934 and the carapace measured 1.15 inches. On 6 June 1934 another moult took place and the carapace was still 1.15 inches in length. The specimen died in attempting to cast its shell in December 1934. From these figures von Bonde concluded that in a space of nearly two years this specimen had grown only 0.25 of an inch.

Young (1926) captured a small crayfish in Otago waters and kept it captive at the Portobello Marine Biological Station in May 1921. He says - ".... As will be seen from the accompanying table, there is no appreciable regularity in casting, but it will be noted that the longer intervals are all in the colder months of the year, when less food is taken, or, in the case of free crayfish, available. The temperature of the water influences the feeding of the crayfish almost as much as the abundance or otherwise of its food ...." From Young's table of the growth rate in this case the accompanying stadial graph (Fig. 4) has been constructed and shows that the crayfish grew from 4.2 cm to 14.0 cm in a little over three years (1,166 days) shedding its shell eight times in the process. In other words this crayfish grew from $1\frac{7}{8}$ inches in length to $5\frac{3}{4}$ inches in approximately three years, a total gain of almost $3\frac{7}{8}$ inches at a rate of almost $1\frac{1}{3}$ inches per annum.

Fig 4.

Stadial graph of growth increment per moult of Jasus edwardsii kept in captivity at Portobello Marine Biological Station for just over three years (1166 days).

To obtain information about growth rates Street (1968) marked crayfish in southern waters with distinctive patterns of punch holes and cuts in the tail-fan. Of 3,106 crayfish marked, 306 were recovered and the following area results obtained:

(a) Stewart Island - the mean total length increase for crayfish below 9 inches overall length was 0.7 inches per moult. Crayfish 9 to 9.6 inches increased at an average of 0.6 inches per moult.

(b) George Sound - the increases in total length were calculated from tail increments and estimated to be 0.9 inches for 8.8 inch crayfish and 0.7 inches for 9.6 inch fish for one moult. After two moults the increases were 1.7 inches and 1.3 inches.

(c) Long Beach and Karitane - length increases in males ranged from 0.7 inches per moult for 6 inch fish to 0.4 inches for 10 inch fish. For female crayfish the increases per moult in these two size groups were 0.7 inches and 0.3 inches respectively.

(d) Nugget Point - length increases per moult in crayfish 7.3 inches to 12.8 inches ranged from 0.0 to 0.7 inches, with mature females showing a lower increase than males of the same size.

Sorensen (1956) examined a large number of crayfish in the Wellington area, and by means of pattern-punch marks on the tail-fan succeeded in identifying individuals recaptured. Of this latter group a number had moulted and grown between first and second taking and, for crayfish of 10 inches or slightly less overall length, an increase of 0.75 inches was recorded, all the animals being sexually mature.

LABORATORY REARING AND "FARMING"

Kensler (1967) reports in his paper that as part of a larger research programme investigating the ecology of Jasus edwardsii (Hutton) puerulus and post-puerulus specimens have been successfully reared and maintained in the laboratory for up to 12 months. In his summary he states the crayfish were reared in concrete-asbestos tanks measuring 2.4m x 37m x 23m and supplied with a continuous flow of sea water provided with constant aeration. Empty shells of paua (Halliotis iris) and rocks from the intertidal zone provided cover within the tanks. Fresh mussel (Mytilus sp.) was preferred to all other foods tried, the animals being fed every second day. The captives also "grazed" actively on the calcareous alga (Corallina officinalis L.) present on the rocks.

Kensler records that the crayfish were extremely sensitive to pollution. To reduce pollution risks all sediments were removed from the tanks as were any uneaten foods, and each tank was thoroughly cleaned every six to eight weeks. From a total of 3,300 animals collected since November 1965, over 800 remained at 15 December 1966. He concluded that the first step in raising larger adult sizes from the juvenile stages in the laboratory is clearly possible.

In his "Conclusions" on the above work Kensler states the preliminary results obtained in the first year of rearing experiments are encouraging and have direct application to the study of the ecology and biology of J. edwardsii. ".... It is evident that additional laboratory experiments are necessary to improve and perfect the simple rearing technique delineated in this paper. Further experiments to determine the most favourable temperature, salinity, and light values for maximum growth in the laboratory would have immense practical importance. The successful rearing of large numbers of juveniles indicates that the first step in raising spring lobsters to larger adult sizes in the laboratory is clearly possible."

Gilchrist (1918) conducted some investigations on the artificial rearing of "crawfish" in South Africa. He stated the hatching and rearing of crawfish had not been carried out with success in any country in which they are found. Attempts to rear them had failed because ordinary methods used for rearing lobsters could not be followed since the various stages through which the crawfish passes before reaching the adult condition are very different from those of the lobster.

Gilchrist's studies showed that the crawfish can be hatched out from the egg from its earliest stages, and the larvae procured in unlimited numbers. It was, however, found that though the young crawfish could be artificially tided over the egg stage, the free surface-swimming stage to which they could be reared was even more liable to attack by enemies. Thus when a few hundred newly-hatched larvae were placed in a large tank containing fish they were almost at once attacked by the surface-feeding mullet. The next series of experiments had, therefore, to be directed to the solution of this more serious difficulty - the possibility of protecting the surface-swimming stages of the naupliosoma and phyllosoma. It was found difficult to keep these stages alive for, after swimming about for a few days the young crawfish gradually disappeared, and the dead remains of many were seen on the bottom of the tank, the cause of death being apparently the presence of debris of seaweed, etc., in the water, clogging up the swimming appendages. Rearing in filtered sea water was tried without success as the necessary food for the young was also removed in the process. Feeding on a variety of material was also attempted without success. Finally it was found the most successful method was to partially filter the water.

Gilchrist concluded that although the experiments were not completed it had been ascertained that the whole swimming stage of the young crawfish was comparatively short, being only three or four days at most. He says - ".... After this interval of time they change their habits and, descending to the bottom, seek out the darkest corners. They then feed actively on the small animal and vegetable particles in the mud and sand, and are comparatively freefrom the attacks of their enemies."

Although Gilchrist's experiments, (necessarily carried out under somewhat artificial conditions), satisfied him that artificial cultivation is quite practicable, much more laboratory work is required on the hatching to settlement phase, especially on the duration of the phyllosoma stages and physical conditions leading to successful settlement of puerulus forms inshore. There appears to be disagreement between Gilchrist's settlement time of a few days, and the cessation of pelagic larval stages and puerulus settlement a year after hatching stated by other workers. (See preceding section on "Metamorphosis and Subsequent Growth").

No evidence has been traced to show that crayfish can be successfully reared artificially from egg to adult, and it appears that the following points must be given consideration before any trial and error "farming" is permitted:

(a) Investigations should be made to determine whether development of crayfish from egg to puerulus is feasible under artificial conditions.

(b) What survival can be expected for larvae immediately following hatching:

(i) Under laboratory conditions and confinement

(ii) When liberated in suitable natural areas

(c) Whether natural conditions suitable for maximum growth and development can be simulated in captivity.

(d) Bearing in mind that Kensler (1967) lost almost 75% of his captive stock in about 13 months, can artificial conditions be produced to prevent or lessen the pollution to which crayfish are apparently vulnerable.

(e) Because of the slow growth rate of crayfish recorded from field and laboratory conditions, experimental work should be designed to determine the time taken, at all stages, to rear crayfish to maturity.

(f) If any aquaria or holding tanks are constructed for either research or commercial crayfish rearing they should be provided with adequate cover for shelter, shielding from excessive sunlight, and especially from dilution by rain.

(g) Any or all applicants for crayfish "farms" should submit detailed plans of their proposals and be aware of the difficulties and economics of the venture.

"SCRUBBING"

Although the Fisheries (General) Regulations 1950 (Reprint) forbids the taking of female crayfish "in berry", it is during the egg-carrying period of April to October that a small number of fishermen, in a misguided effort to sustain catches, attempt to evade their responsibilities, and detection, by removing the eggs by a "plucking" and/or "scrubbing" process. Some have even severed the pleopods from the crayfish altogether. This, too, is unlawful, but so obvious that it is seldom practised today. On the other hand the removal of eggs has resulted in many prosecutions being taken particularly in the southern part of New Zealand where "tailing at sea" is permitted and the catch landed in a frozen condition. So skilful has the egg removal been in some cases that, unless an egg or eggs has been overlooked, the examining officer must search for other evidence of unlawfulness.

Although the process of egg removal is generally referred to as "scrubbing", it is more generally carried out by "plucking" with the fingers with, perhaps, a final brush over with a scrubbing brush and/or rinsing in water. However, despite the careful attention given by operators, female tails at the time of berry carrying will usually show an adherent egg or eggs if "plucking" or "scrubbing" has been carried out. Since the eggs cannot be removed without force of some kind, the presence of even one adherent egg is good evidence that the tail has been so treated. More often the plucking or scrubbing has been carried out imperfectly and remnants of egg clusters will be found, usually basally, on the pleopods endopodites. Eggs, if present, may be visible to the naked eye and show up clearly with a low power hand lens. Use of a lens, too, will reveal the state of development of the eggs, the presence or absence of eye-spots, and so on. (See Plates 3b and 4b).

In all cases where egg plucking has taken place it will be found that the pleopod setae, which are normally long and fringing, are "stubby" or truncated due to their breaking off during egg removal. This condition is good evidence of malpractice. (See Plates 1 and 2).

After normal hatching takes place the tails carry for some time the remnants of stalks and ruptured egg capsules as well as, in most cases, a few late development embryos and some infertile eggs. The latter show as more less solid opaque balls with no development of the black eye-spots. (See Plate 5b).

In 1961 the opinion that certain tails had been "scrubbed" was challenged by a prominent southern business man and fishing boat owner who requested an examination of the tails in question by scientists not employed by the Marine Department. This was arranged and the report is appended hereto, (see Appendix A). It holds the departmental view that the evidence of the eggs and truncated pleopod setae is consistent with artificial removal of eggs from mature female crayfish, and the investigators knew of no natural process which could lead to this condition.

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Appendix A

REPORT ON AN EXAMINATION OF CRAYFISH SPECIMENS AT THE FISHERIES LABORATORY, WINGFIELD STREET, WELLINGTON

On May 16 1961, we were requested by the Assistant Chief Inspector of Fisheries, Mr J.H. Sorensen, to examine a series of specimens of crayfish. These were as follows:

(a) A group of six fresh entire specimens labelled ex Wellington. Four of them, not carrying eggs, were considered by the Fisheries officers to be females of Jasus lalandii in pre-berry condition, i.e., individuals which had not yet shed the eggs. At our request, Mr Sorensen dissected two of these specimens, and we were satisfied that the ovary comprised a mass of eggs, and that the specimens were in fact in the pre-berry condition. The eggs, after removal from the ovary, were found to resemble those of other specimens in berry. Two other specimens were in the full berried condition with large clusters of eggs attached to the pleopods. One of these specimens, hereafter referred to as Control 3 was subsequently used in a more detailed examination of the pleopods.

(b) A group of two tails, labelled ex Bluff, and considered by the Fisheries officers to be from females. Neither of these was in berry. Examination of these showed that the pleopods were of the female type. One was immature, lacking the setae of the endopodite of the pleopods. The other was mature, with well-developed setae. The latter specimen, hereafter referred to as Control 2, was utilised in subsequent study of the pleopod setae.

(c) A group of three tails, labelled ex Bluff, and hereafter referred to as Bluff A, Bluff B, and Bluff C.
We were asked to express an opinion as to the sexual status of this latter group and to comment on any unusual features that might be observed.

We report as follows:

All specimens were females, as evidenced by the bifurcate abdominal appendages (pleopods). All specimens were Jasus lalandii, as evidenced by the tuberculate dorsal surface of the abdominal tergites.

A cursory macroscopic and microscopic examination of the endopodites of the specimens Bluff A, B, and C, in comparison with those of the control groups (a) and (b), suggested that some abnormal features were present in the Bluff A, B, C specimens, for the setae of the latter group appeared to be much shorter than those of the other specimens. Accordingly, a more detailed examination of these structures was undertaken. For the purpose of comparison, the middle pleopod (R3) of the right side was taken from each of the Bluff A, B, and C specimens, and compared directly with the corresponding pleopod from one of the Wellington specimens (Control 3) and one of the group (b) Bluff tails, (Control 2). We paid attention to the length of the setae, the form of the setae, and the presence or absence of eggs. All measurements were estimated with the use of an eye-piece micrometer on a dissecting microscope, and measurements were carried out by both of us, working alternately, each checking the other's results.

The results may be expressed in the following tables:

Specimen	Eggs present or absent	Length of setae on 2nd segment of endoposite R3			Condition of setae
		Average	Max.	Min.	
		mm	mm	mm	
Control 2	Unberried	12.8	17.7	1.6	Less than 5% truncated, and of these, most were from 8.5 to 10.7 mm in length. 95% elongate and tapered or frayed.
Control 3	Berried female plucked of eggs in our presence	2.1	6.0	0.54	Nearly all setae truncated abruptly at the distal end.
Bluff A	1 egg seen on R2	3.7-4.3	8.3	0.64	Nearly all setae truncated abruptly at the distal end.
Bluff B	1 egg seen on R2	3.2	9.8	0.32	Nearly all setae truncated abruptly at the distal end.
Bluff C	1 egg seen on R3, well attached by filament to seta	3.4	17.5	0.75	Most setae truncated, but the longest tapered.

The data in the foregoing table suggest that the condition of the setae in the specimens Bluff A, B, and C was substantially similar to that exhibited in Control 3, i.e., the berried specimen that had been plucked in our presence. Accordingly, further attention was directed to the endopodite of Pleopod R2 of this specimen, which had been removed by us before we asked Mr Sorensen to pluck the specimen. This pleopod therefore still retained the eggs which were originally present on all pleopods of Control 3. Examination of the endopodite of this pleopod showed that the bunches of eggs were attached to long slender setae, similar to the longest setae observed in the unberried Control 2. On a microscope stage the tufts of eggs were pulled away with a needle, and the setae were then observed to snap near their bases. The broken ends thus produced left each seta with an abrupt distal truncation, similar to the truncated setae observed on specimens Bluff A, B, and C. As it was desirable to retain this specimen without completely stripping it of eggs, no measurement could be undertaken. However, measurements were obtained from the Pleopod

R3 of the same specimen, this being one of the pleopods which Mr Sorensen had stripped at our request, and in our presence. The results are given in the table (Control 3).

The condition exhibited by the structures referred to in the foregoing paragraph may be contrasted with that of the unberried specimen, said to be from Bluff, listed as Control 2 in the table. In Control 2 the setae on the endopodite of R3 were relatively long and slender, much more so than in the other specimens submitted to us. The measurements are given in the table. It will be noted that the great majority of the setae were tapered or frayed, and truncated ends were found in less than 5% of the setae. These latter had evidently been broken in some way, either in transit, or by natural causes.

As shown in the table, some attached eggs were found in the specimens labelled Bluff A, B, and C. The eggs contained orange-coloured yolk, but showed no eyes, and were thus evidently at an early stage of development. Thus they could not have been residual unhatched eggs from a female whose eggs had all hatched out, unless they were infertile eggs. However, reference to Bradstock "Study of the Marine Spiny Crayfish", Zoology Publications Victoria University, No.7, 1950, p. 15, Fig. 7, shows that oviposition is unknown to occur earlier than April. As development of the egg requires about three months (Bradstock, loc. cit. p. 16), it is evident that the eggs observed in the Bluff A, B, and C specimens must have been quite immature eggs as, in fact, their appearance suggests. Thus the presence of the eggs on the Bluff A, B, and C specimens could be evidence that these three specimens were in berry, and that the greater part of the egg-mass had been removed before we examined the specimens. There still remains, however, a remote possibility that eggs from another female had in some way fortuitously become attached to the setae of unberried females. This supposition would not account for the condition of the setae which, as shown by the table, present an abnormal condition resembling that produced artificially when eggs are removed from a berried female, and differ markedly from the setae of a natural unberried female.

We conclude, therefore, that the specimens Bluff A, Bluff B, and Bluff C have apparently had the eggs removed, so that the setae of the endopodites of the pleopods resemble those of the control specimens from which the eggs were plucked in our presence, and contrast markedly with those of the unberried control specimen (Control 2). We know of no natural process which could lead to this condition.

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17 May 1961

ILLUSTRATIONS

Pl.1: Enlargement of a natural pleopod from an adult female crayfish showing the long setae on the endopodite to which the eggs become attached when extruded.

Pl.2: Enlargement of a pleopod from an adult female crayfish from which the eggs have been removed artificially by a plucking or scrubbing process. Note the short truncated setae which are not natural on mature crayfish.

Pl.3a: A tail from a young 8.6" female crayfish, taken on 3 October 1957, showing a normal "berried" condition.

Pl.3b: A cluster of eggs from the tail shown in Plate 3a showing the development of the embryos to a stage where the pigmented eyes are visible through the shell. Note the entwining of the egg stalks around the setae.

Pl.4a: A tail from a 9.3 inch female crayfish taken on 3 October 1957 showing the full complement of eggs carried by an adult.

Pl.4b: A sample of eggs from the tail shown in Plate 4a shortly before hatching. Development of the embryos has proceeded to a stage where the pigmented eyes and rudimentary limbs are visible. At this stage the black eye-spots can be seen with the naked eye.

Pl.5a: A tail from a 9.8 inch female crayfish taken on 14 October 1957. Egg shedding is well advanced.

Pl.5b: A sample of the "fluff" from the tail shown in Plate 5a reveals that it consists principally of ruptured capsules from which the larvae have hatched out. The sample also includes one larva and three infertile eggs.

Pl.6a: A tail from a 10.05 inch female crayfish, taken on 18 October 1957, showing natural shedding of eggs and ruptured capsules to a stage where little is left visible to the naked eye. The exopodites of the pleopods on the right side have been removed.

Pl.6b: A sample of residual material still adherent on the tail shown in Plate 6a reveals two embryos still to hatch out, two infertile eggs, and numerous empty split capsules, all attached to a single seta.

Note: All photo micrographs (1-6b) are by Fisheries Research Laboratory circa 1957.

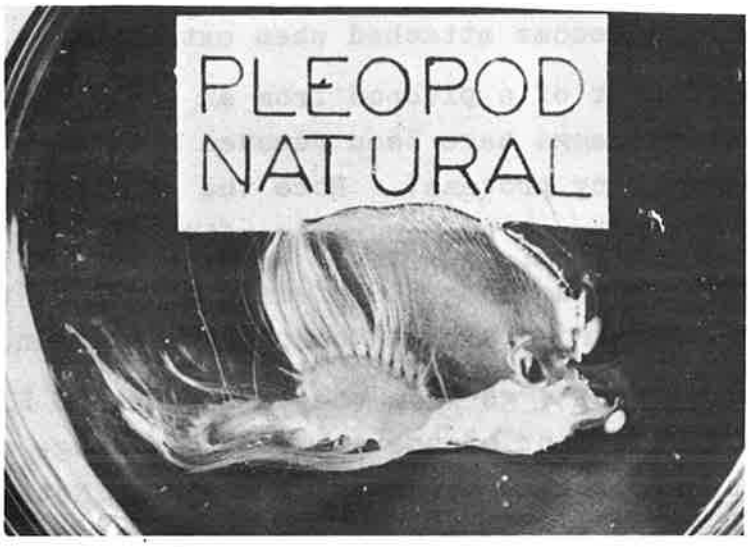


Plate 1

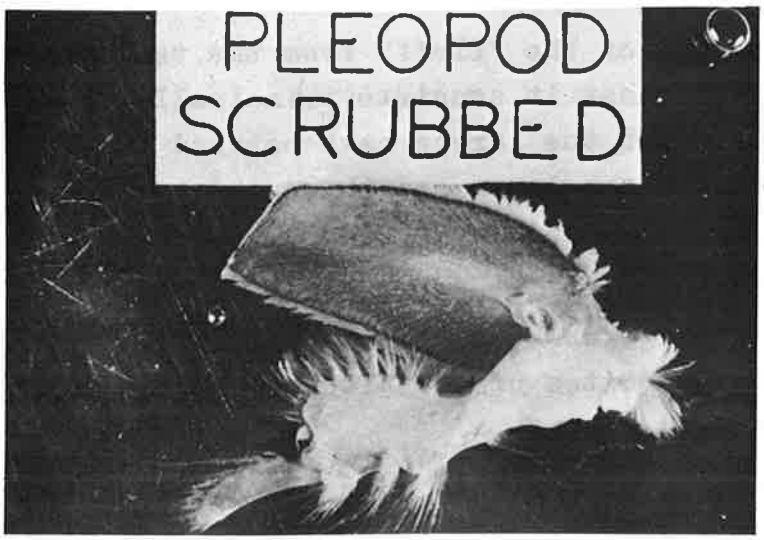


Plate 2

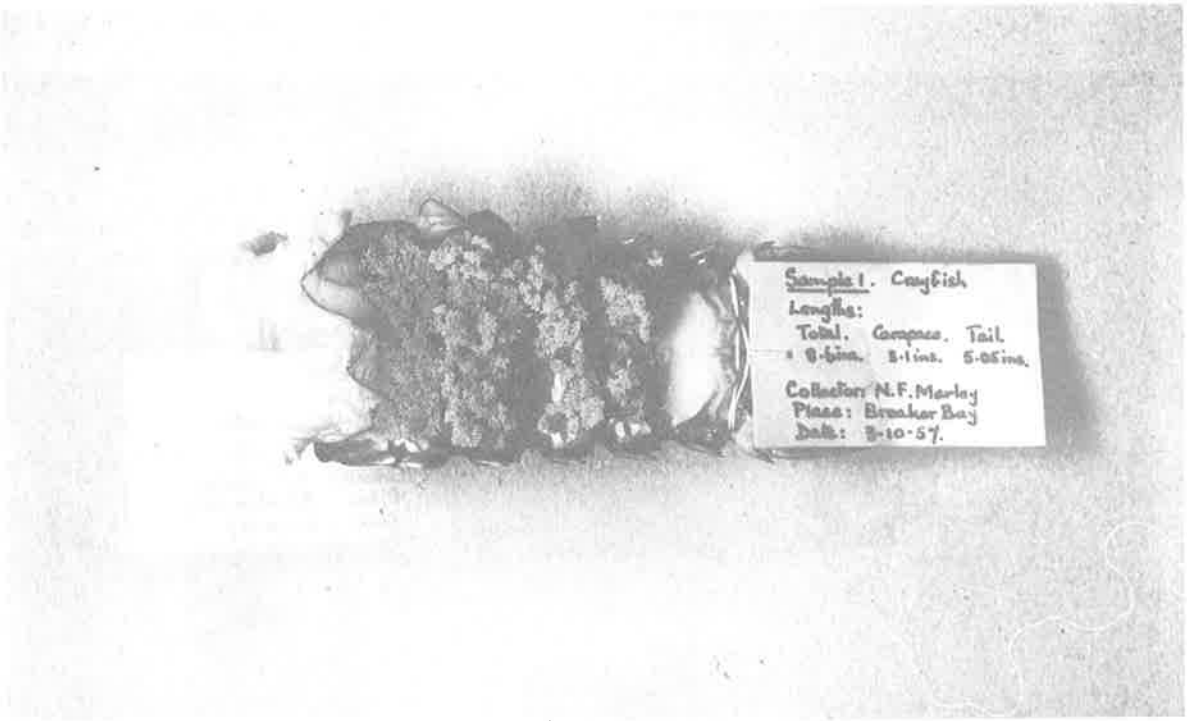


Plate 3a

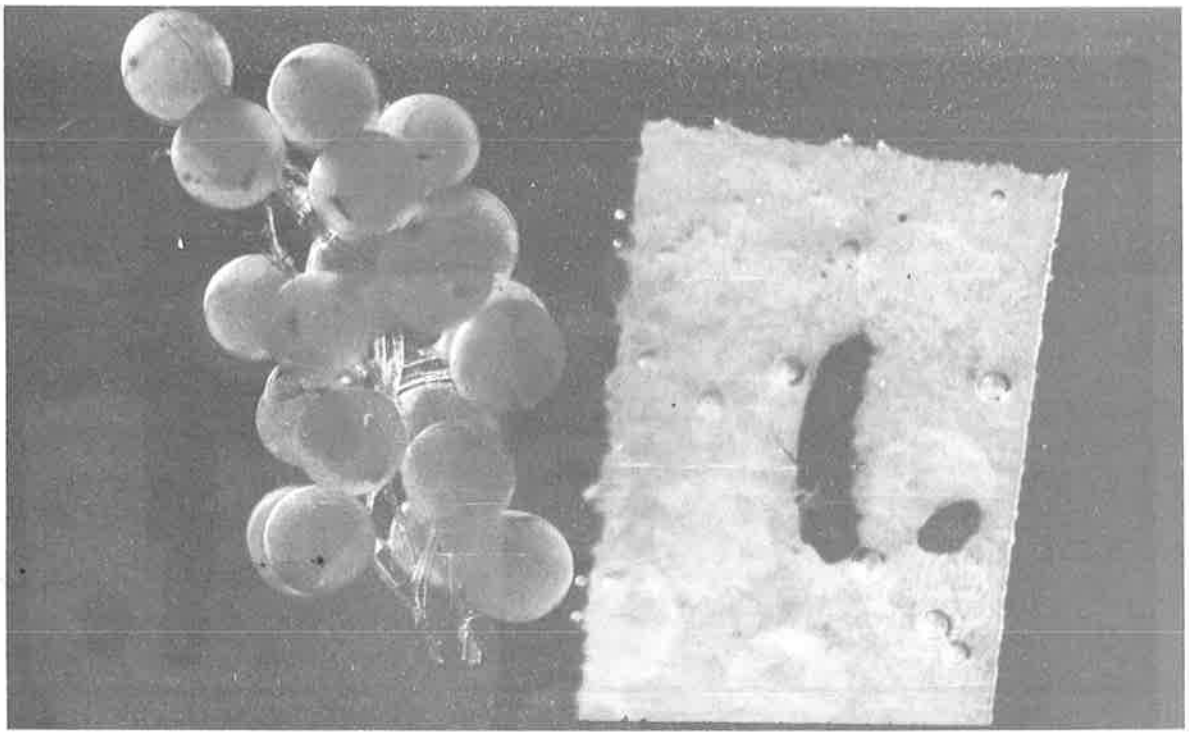


Plate 3b

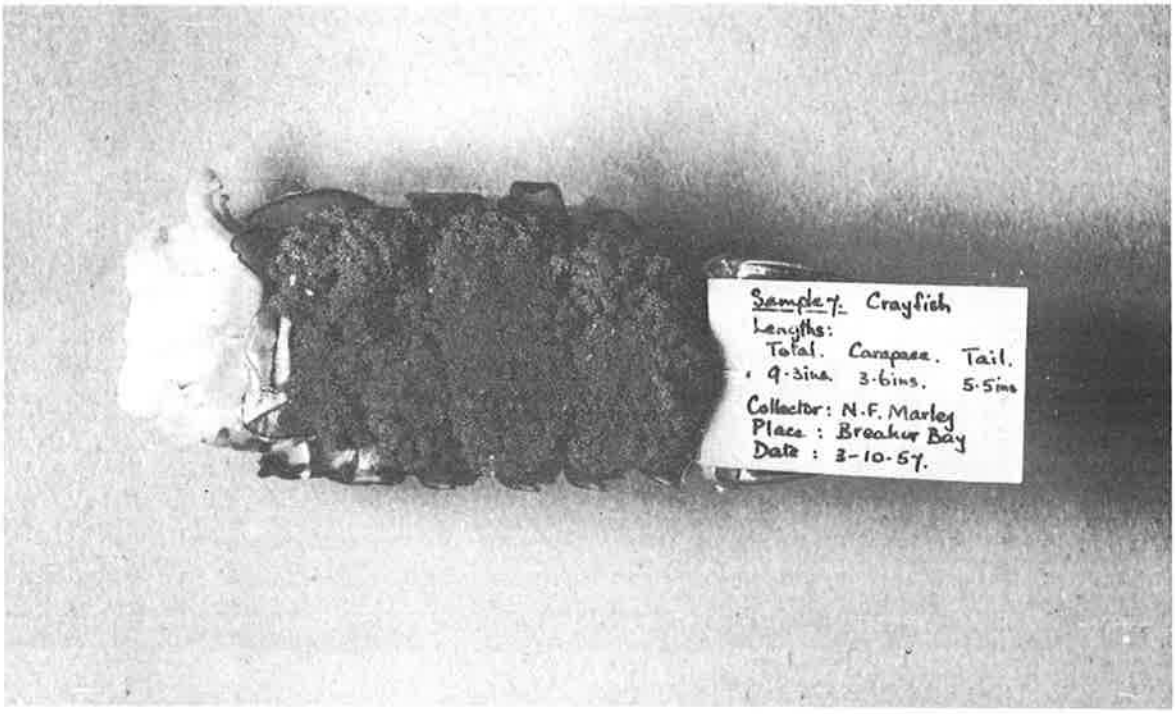


Plate 4a

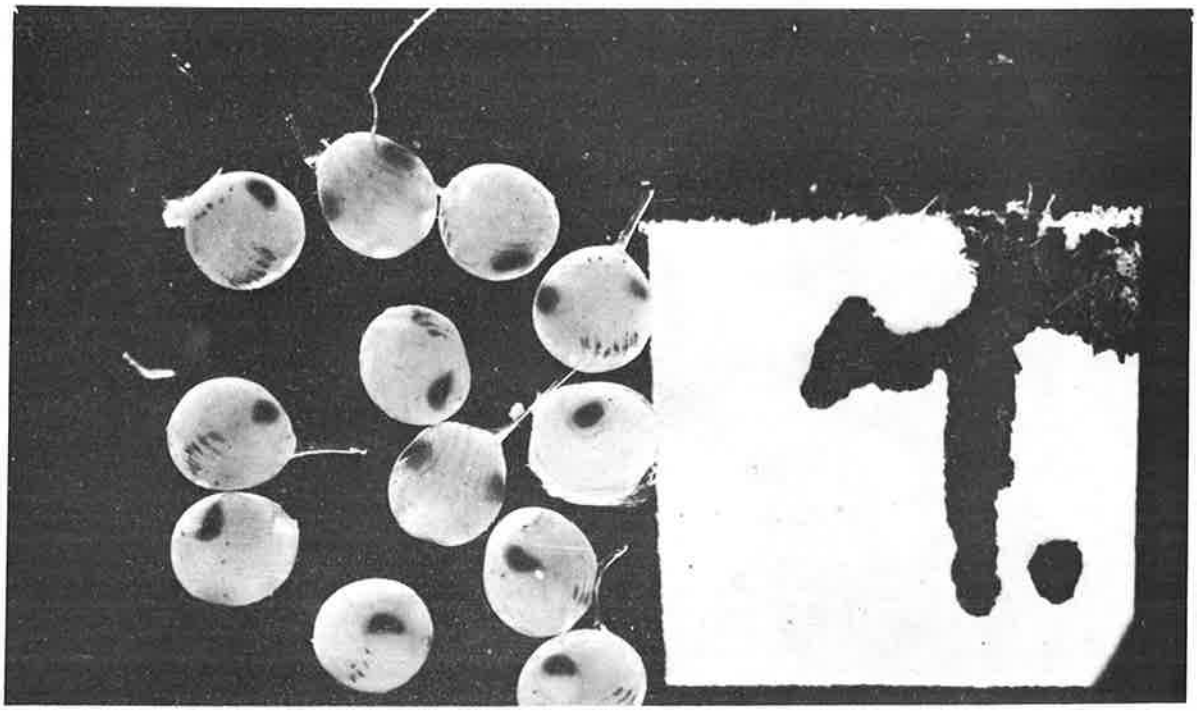


Plate 4b

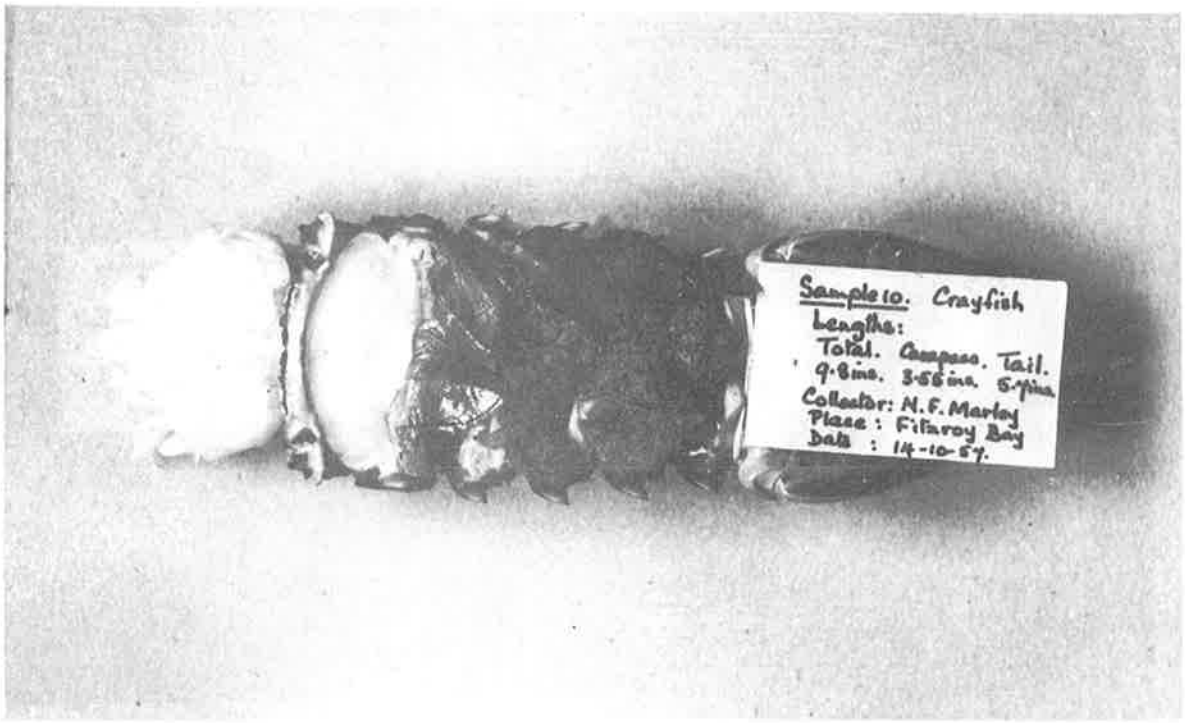


Plate 5a

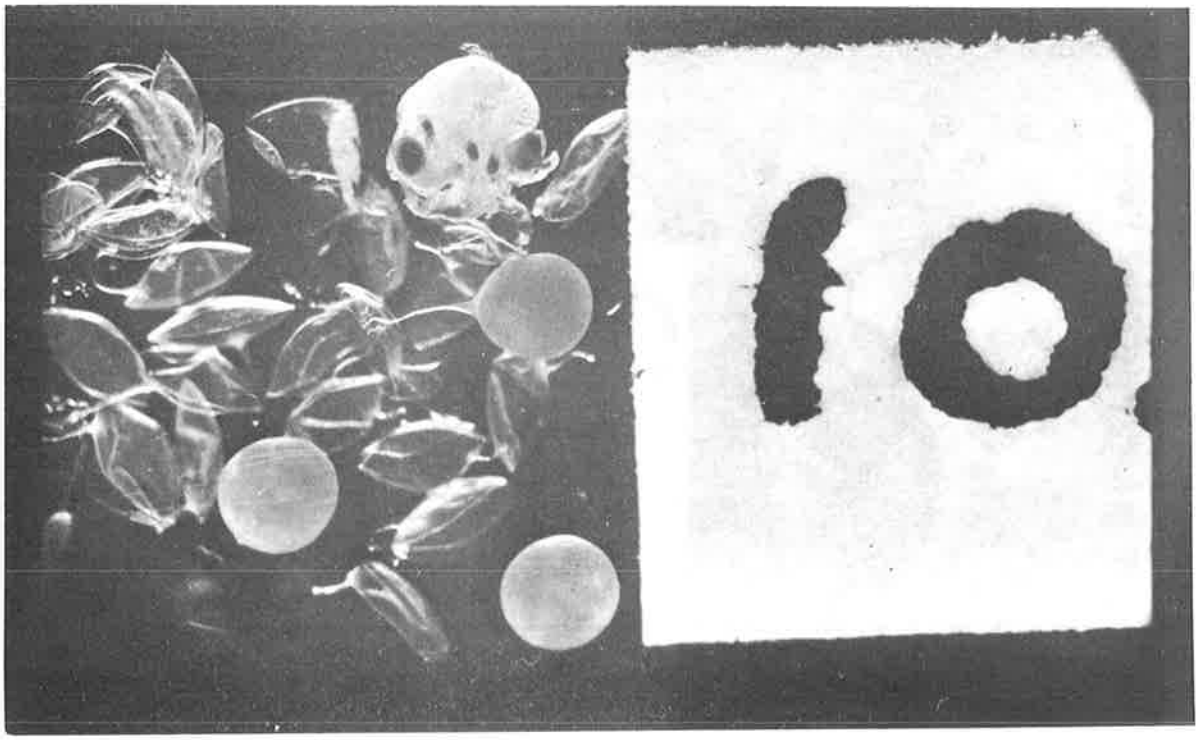


Plate 5b

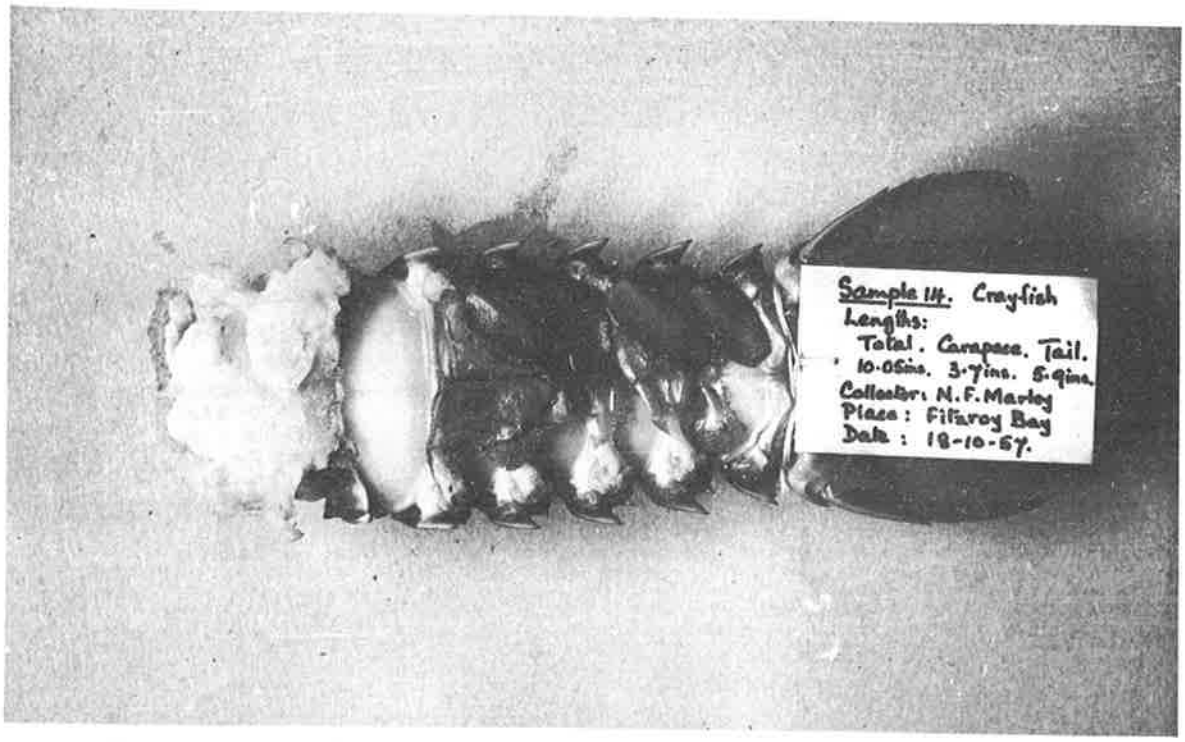


Plate 6a

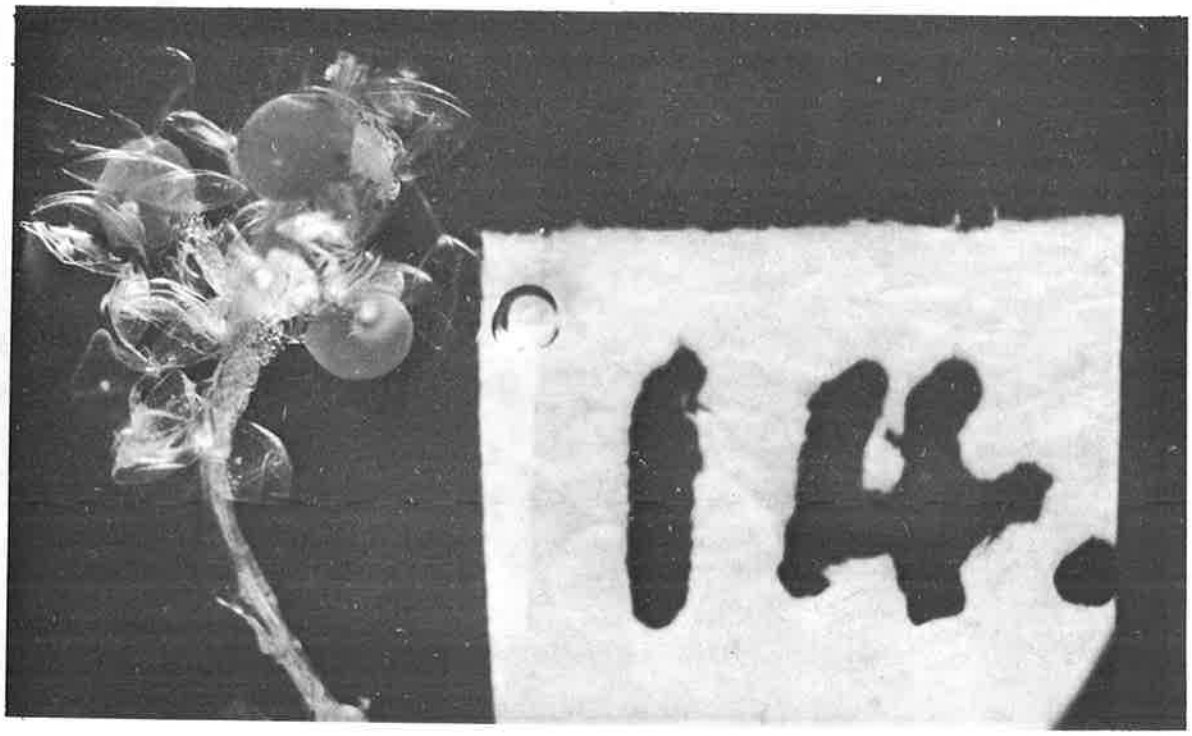


Plate 6b

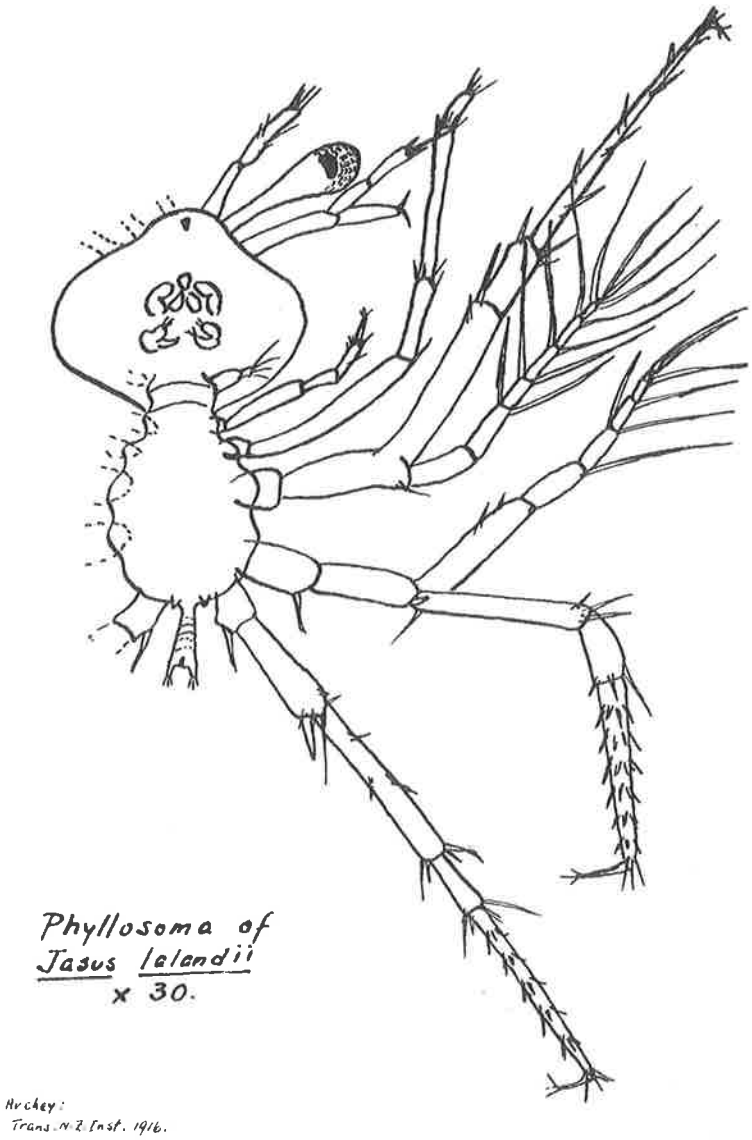
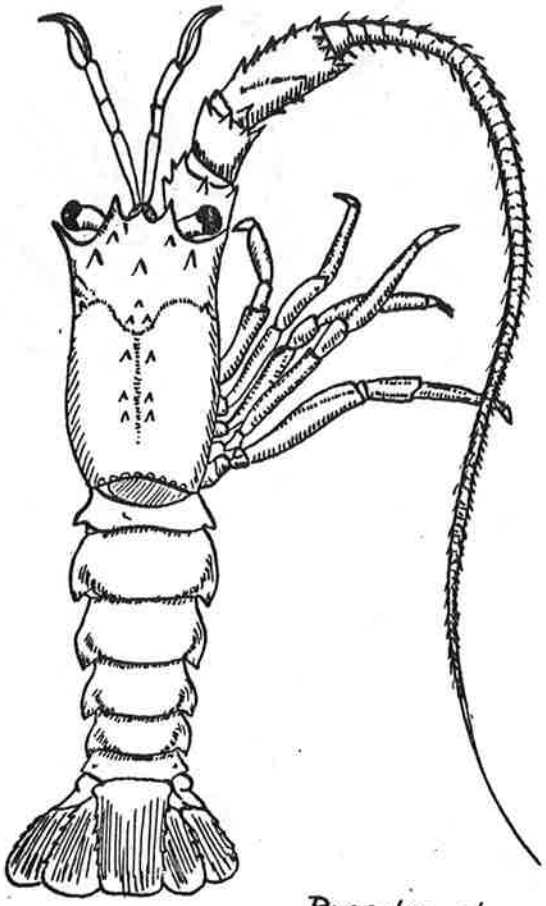


Figure 2. Phyllosoma of Jasus edwardsii
(= J. lalandii)



Puerulus of
Jasus lalandii
× 3

Archey:
Trans. N.Z. Inst. 1916.

Figure 3. Puerulus of Jasus edwardsii (= J. lalandii)

B. J. Webb

NEW ZEALAND MARINE DEPARTMENT

FISHERIES TECHNICAL REPORT

No.29

THE NEW ZEALAND ROCK LOBSTER OR MARINE SPINY CRAYFISH *JASUS EDWARDSII* (HUTTON)

DISTRIBUTION, GROWTH, EMBRYOLOGY AND DEVELOPMENT

J. H. SORENSEN

WELLINGTON, NEW ZEALAND

1969