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THE COMPLETE LARVAL DEVELOPMENT OF THE SCYLLARID LOBSTER *IBACUS ALTICRENATUS* BATE, 1888 IN NEW ZEALAND WATERS

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INTRODUCTION

Adults of three genera of the family Scyllaridae occur in New Zealand waters. These are *Scyllarus aoteanus* Powell, 1949, *Scyllarus mawsoni* Hale, 1941, and an as yet unidentified species of *Scyllarus* (J. C. Yaldwyn, pers. comm.), *Arctides antipodarum* Holthuis, 1960 and *Ibacus alticrenatus* Bate, 1888.

I. alticrenatus has been found from Cape Maria van Diemen in the north of New Zealand to the Chatham Islands and Oamaru in the south at depths of 70 to 275 meters (Dell, 1956). This species also occurs on the south-east coast of Australia (George & Griffin, 1972).

Many phyllosomae of the genus *Scyllarus* have been taken in plankton samples from New Zealand waters, but have not yet been identified to the specific level or described. Only one phyllosoma of *Arctides* has been collected; this was taken near Norfolk Island, 800 km north-west of New Zealand. The larvae of both of these genera are readily distinguished from *Ibacus* on the basis of size and general morphological characteristics. Dakin & Colefax (1940) provide a key to separate the larvae of *Ibacus* from *Scyllarus* and Michel (1971) provides a key to separate *Scyllarus* and *Arctides* phyllosomae.

Lesser (1974) has described and provided a key for the separation of the early larval stages of *I. alticrenatus* and the early larval stages of the two New Zealand Palinurid species *Jasus edwardsii* (Hutton, 1875) and *Jasus verreauxi* (H. Milne Edwards, 1851).

Descriptions of the larval stages of other species of *Ibacus* include *I. peronii* Leach from Australia by Ritz & Thomas (1973), and Harada (1958) has published a note on the naupliosoma and newly hatched phyllosomae of *I. ciliatus* (Von Siebold). Rearing experiments have been conducted with *I. ciliatus* and *I. novemdentatus* Gibbes by Dotsu et al. (1966a), and metamorphosis to the puerulus form of these two species has been described by Dotsu et al. (1966b).

This paper describes the larval development of *Ibacus alticrenatus* from individuals hatched in the laboratory and specimens taken from plankton samples. The first two post-phyllosoma stages of this species are also described from specimens reared in the laboratory from late-stage phyllosomae. Division of the development into clearly defined stages was made on the basis of morphological development and changes in total length. Seven phyllosoma stages, the puerulus and post-puerulus stages are defined and described.

A series of voucher specimens has been deposited with the National Museum, Wellington, New Zealand, registered under NMNZ Cr 2247-2255.

METHODS

A total of 98 *Ibacus alticrenatus* phyllosomae were collected by four different plankton sampling methods. Most (55%) were collected by a one square meter conical net with a 1.05 mm mesh. Tows were horizontal and up to one hour in duration at depths from 5 to 50 meters. 7% of the larvae were taken by using a 0.2 mm mesh drop-net to depths of between 50 and 100 meters. 24% of the larvae were taken by using an Isaacs-Kidd mid-water trawl (IKMT), consisting of three sections with mesh sizes of 3.8, 2.5 and 1.3 cm, fished at depths between 12 and 84 meters. (For IKMT station data, see Vooren (1972), stations J6/112/69, J6/113/69, J6/114/69 and J6/120/69). The remaining larvae (14%) were taken by a fine-meshed mid-water trawl with a gradation of mesh sizes from 10 cm at the mouth to 1 cm at the cod-end. Station data for this group of larvae are held at Fisheries Research Division, Wellington (Cruises J17/75, J4/76).

In addition, some late-stage phyllosomae were identified from the contents of albacore (*Thunnus alalunga* (Gmelin)) stomachs caught off the west coast of the South Island.

Plankton samples were preserved in approximately 10% buffered formalin, and phyllosomae were removed and examined in the laboratory. All descriptions and illustrations of larvae were made with the aid of a binocular microscope fitted with a camera lucida.

To confirm the developmental sequence of *I. alticrenatus*, berried females were held in non-circulating aerated seawater (as described by Lesser, 1974) until the larvae hatched. Some of the resulting larvae were examined under a microscope and compared with the first stage phyllosomae taken in the plankton samples. Also, three late-stage phyllosomae taken from the plankton in November 1969 were grown to metamorphosis (to the reptant form) in non-circulating, aerated seawater which was changed every three or four days. Finely chopped mussel (*Mytilus edulis aoteanus* Powell) was used as food for the phyllosomae. This was eaten and appeared as a darkened area in the digestive tract of the otherwise transparent larvae. The post-phyllosomae were not observed to feed at all.

DESCRIPTIONS OF THE STAGES

In the following descriptions, total lengths for all specimens are taken from the anterior margin of the carapace between the antennules in a mid-line to the posterior margin of the telson.

Lesser (1974) has described and illustrated the naupliosoma and first stage phyllosoma of this species.

First phyllosoma stage (fig. 1)

Mean length for seven specimens measured was 2.55 mm with a range from 2.50 to 2.60 mm. At this stage, the eyestalks are unsegmented. A stout spine

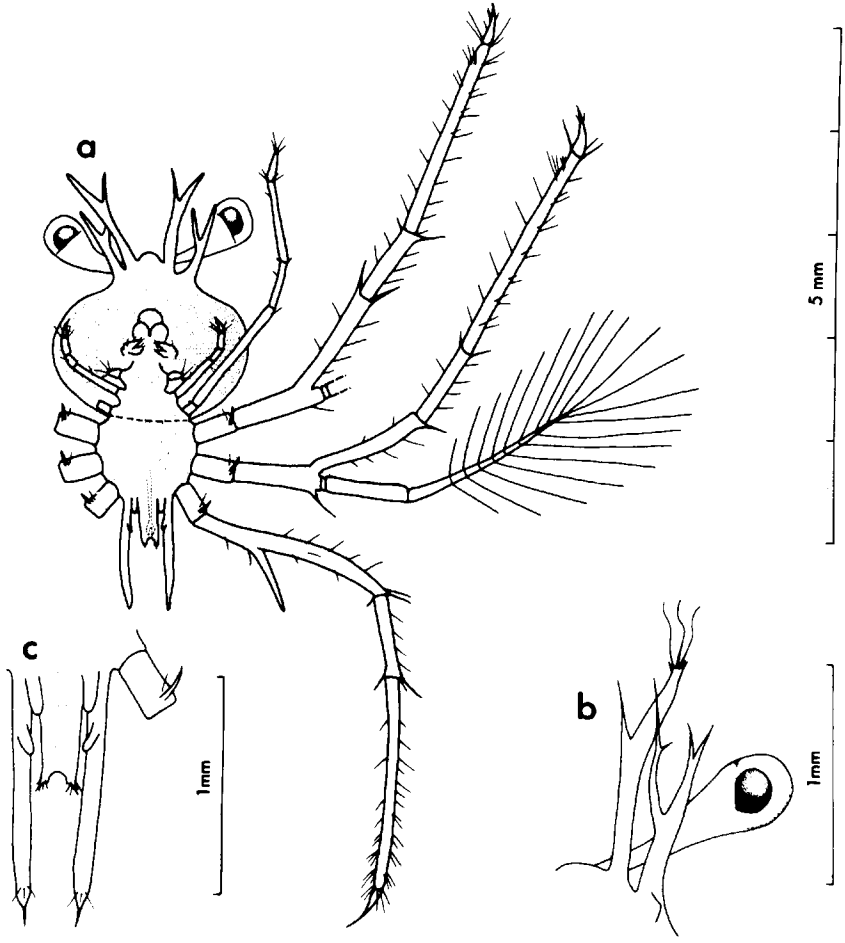

Fig. 1. *Ibacus alticrenatus* Bate, a, stage 1 phyllosoma; b, antennae and antennules; c, abdomen.

arises mid-way along the inner margin of the antennule while a forked spine and three aesthetes are present apically with a small spine sub-apically. Both rami of the antenna are of approximately equal length and bear terminal spines

(fig. 1b). The second and third maxillipeds and first three pereiopods are well developed and functional, except for the exopod of the third pereiopod which is represented as a tapered naked bud. The fourth pereiopod is simply an elongated bud with very rudimentary articulations and a small bud-like exopod near the base. The fifth pereiopod is a small undifferentiated bud. The abdomen tapers slightly and features an apex on each side of the anus, either of which bears four setae (fig. 1c).

Second phyllosoma stage (fig. 2)

Mean length for seven specimens measured was 4.0 mm with a range from 3.8 to 4.2 mm. This stage is characterised by having stalked eyes and a segmented fourth pereiopod with a rudimentary exopod bud while the fifth pereiopod is represented as an elongate undifferentiated bud. Very rudimen-

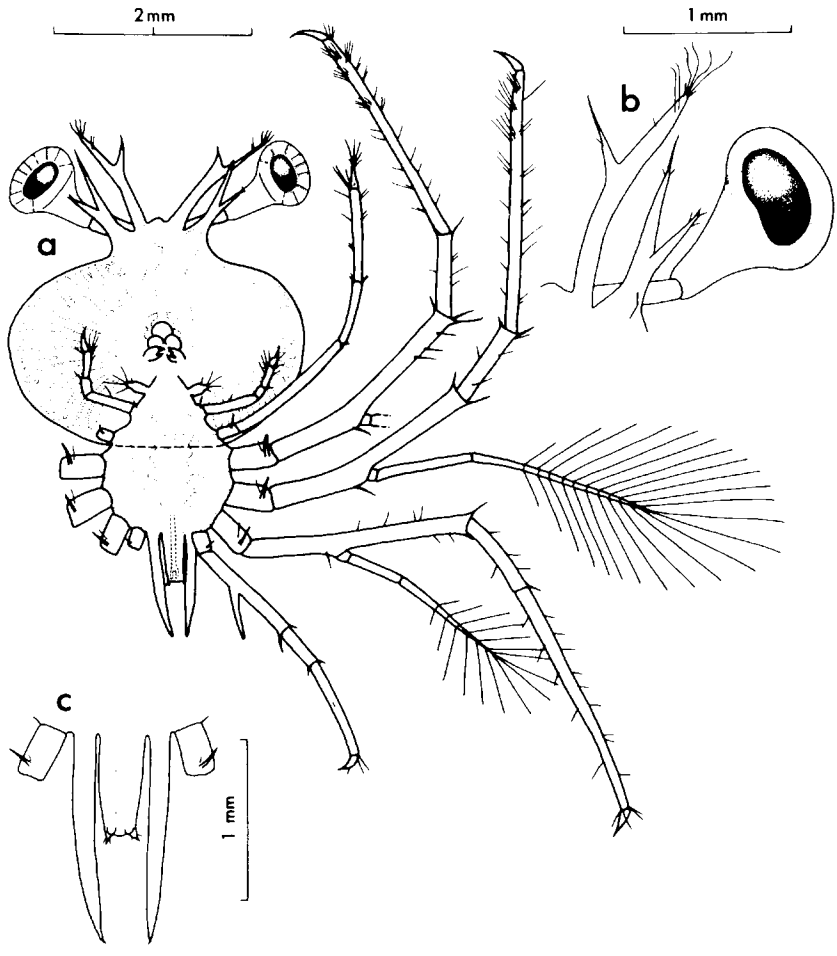

Fig. 2. *Ibacus alticrenatus* Bate, a, stage 2 phyllosoma; b, antennae and antennule; c, abdomen.

tary lobes of the uropods can be seen on the abdomen (fig. 2c). In addition, there is a rudimentary articulation at the base of the antennule, and the spine on the inner margin has become more substantial than in the previous stage. There are an additional two aesthetes sub-apically on the antennule, and the exopod of the antenna has become shorter than the endopod (fig. 2b). The endopods of the second and third maxillipeds and first three pereiopods have become more spinous in their distal portions, while the exopods bear more natatory setae than previously.

Third phyllosoma stage (fig. 3)

Mean length for 13 specimens measured was 0.6 mm with a range from 5.6 to 6.3 mm. By this stage, the fifth pereiopod has differentiated into exopod and endopod lobes, although the exopod is only a tapered naked bud. Rudimentary pleopod buds are present on the abdomen and the uropod lobes are slightly in-

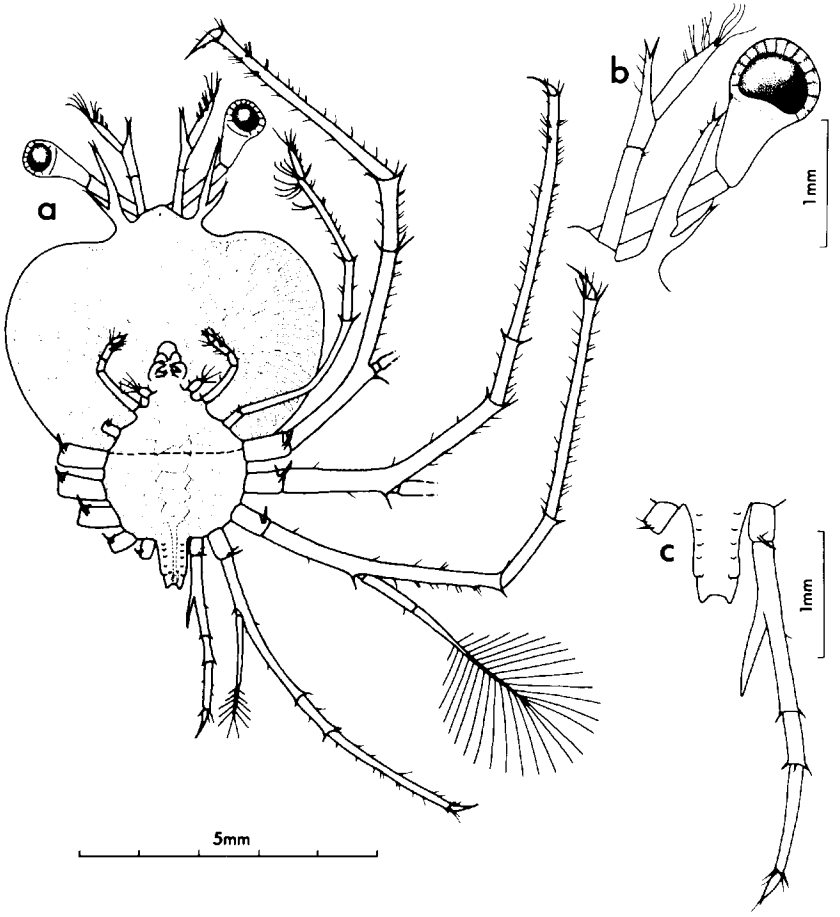

Fig. 3. *Ibacus alticrenatus* Bate, a, stage 3 phyllosoma; b, antennae and antennule; c, abdomen.

dented (fig. 3c). The peduncle of the antennule has a functional articulation at the base and a rudimentary one medially. The antennule is biramous, with the exopod bearing additional setae (fig. 3b). The exopod of the antenna has become further reduced (relative to the endopod), and the bud of a developing lateral process can be seen anteriorly to the exopod.

Fourth phyllosoma stage (fig. 4)

Mean length for 16 specimens measured was 9.3 mm with a range of 8.7 to 9.8 mm. The indentation of the anterior margin on each side of the carapace (typical for phyllosomae of this genus) is quite evident at this stage. A definite lateral process is developing anteriorly to the exopod of the antenna which is further reduced. A functional articulation is present medially on the peduncle of the antennule, and a rudimentary one is forming proximally. Spines and

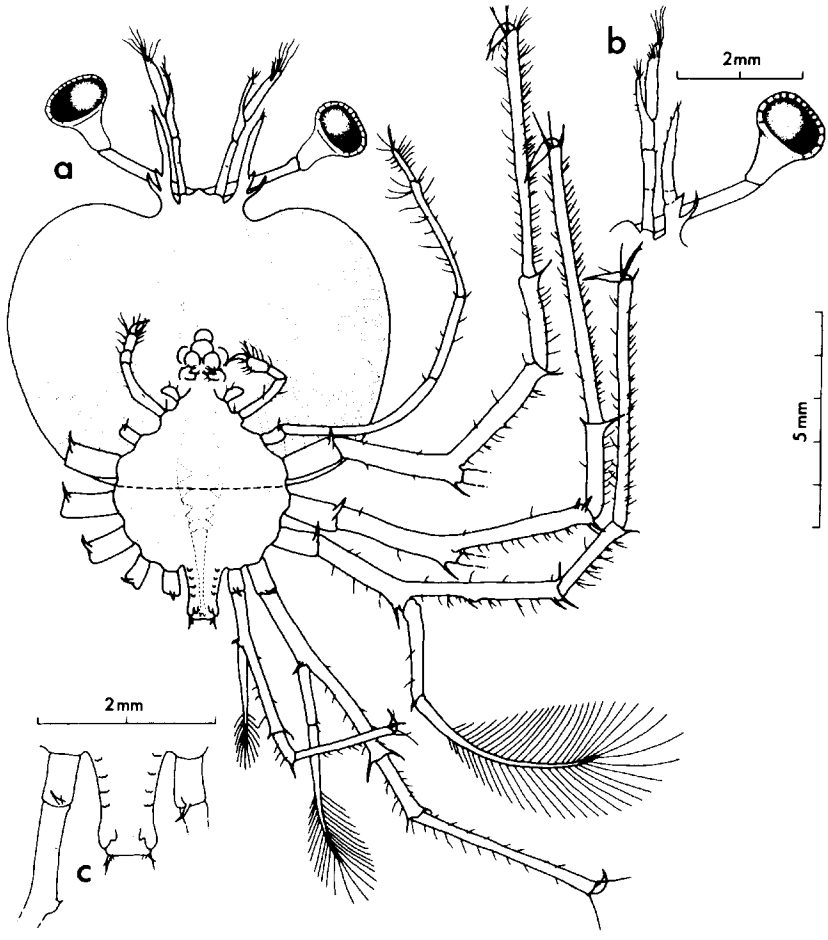

Fig. 4. *Ibacus alticrenatus* Bate, a, stage 4 phyllosoma; b, antennae and antennule; c, abdomen.

small serrations have appeared distally on both margins of the antenna (fig. 4b). The exopod of the fifth pereiopod now bears seven pairs of natatory setae and the uropods are definitely differentiated into inner and outer lobes, while the pleopod buds are slightly bifurcated (fig. 4c).

Fifth phyllosoma stage (fig. 5)

Mean length for 10 specimens measured was 14.4 mm with a range from 13.4 to 15.4 mm. This is the first stage in which a pair of spines may be seen developing dorsally on the forebody posteriorly to the eyestalks. Visible

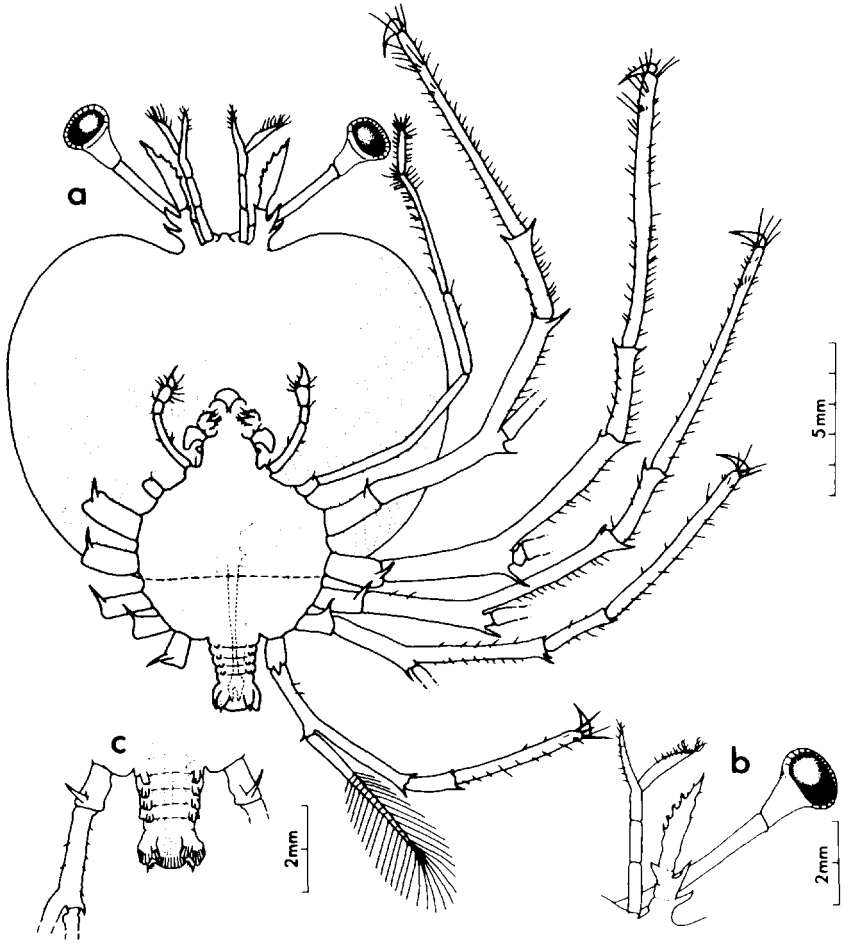

Fig. 5. *Ibacus alticrenatus* Bate, a, stage 5 phyllosoma; b, antennae and antennule; c, abdomen.

segmentation of the abdomen may also be seen for the first time in this stage. The peduncle of the antennule now has three functional articulations along its length, and the exopod bears more aesthetes than previously. The inner

margin of the antenna has developed a series of five broad serrations near the apex and a lateral process proximally. On the outer margin, the anterior lateral process has become larger, while the exopod is further reduced in size. All maxillipeds and pereiopods are better developed than in the previous stage, as are the pleopods and uropods (fig. 5c).

Sixth phyllosoma stage (fig. 6)

Mean length for 16 specimens measured was 23.9 mm with a range from 22.4 to 24.9 mm. This stage is characterised by having the posterior margin of the forebody slightly concave in shape, while exopod lobes have begun to

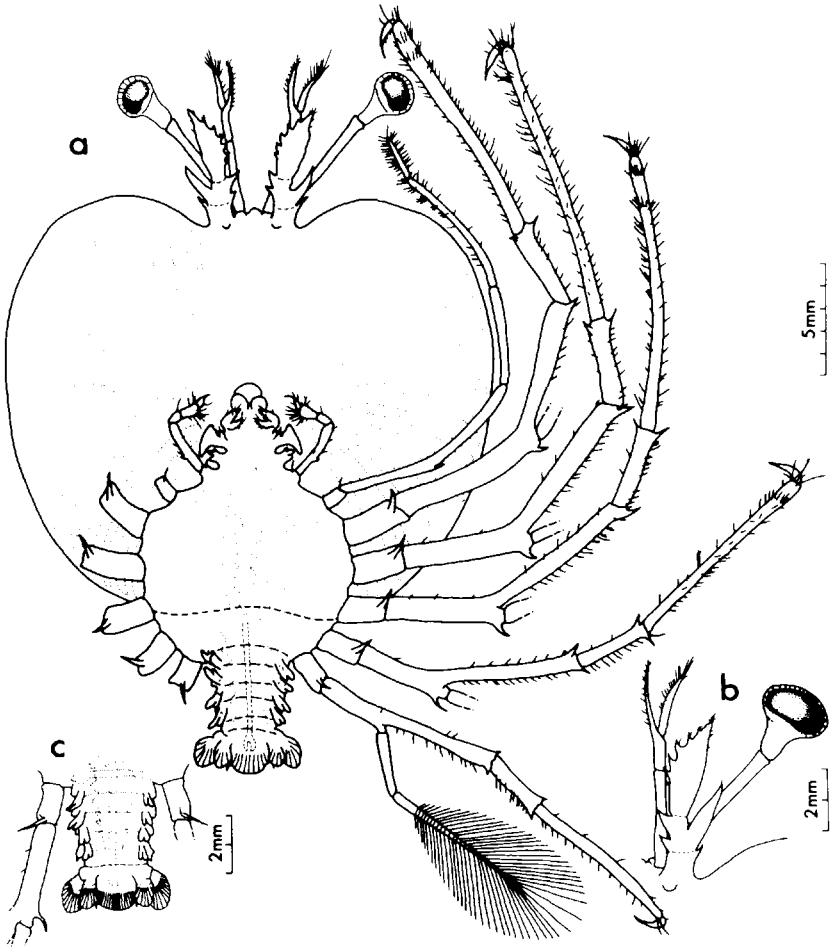

Fig. 6. *Ibacus alticrenatus* Bate, a, stage 6 phyllosoma; b, antennae and antennule; c, abdomen.

develop on the second and third maxillipeds. In addition, gill buds are beginning to form on the coxae of the second and third maxillipeds and first four pereiopods. The antennae are increasingly flattened dorso-ventrally, and the

distal serrations are more numerous and pronounced, as are the lateral processes proximally (fig. 6b). Uropods and pleopods are much better developed, although appendices internae are not evident at this stage (fig. 6c).

Seventh phyllosoma stage (fig. 7)

Mean length for 19 specimens measured was 39.7 mm with a range of 35.5 to 44.0 mm. In this stage, appendices internae are found on the pleopods, and the posteriorly directed spines on the telson are reduced (fig. 7c). The antennae are much wider than previously and the anterior margin is more serrated and

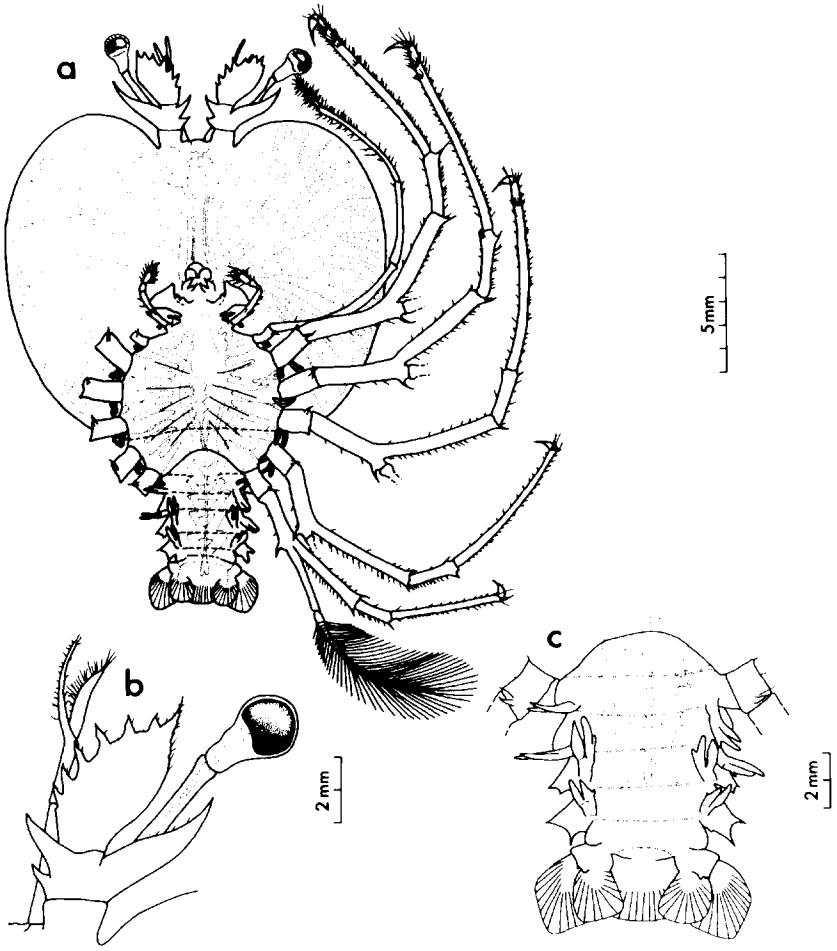

Fig. 7. *Ibacus alticrenatus* Bate, a, stage 7 phyllosoma; b, antennae and antennule; c, abdomen.

spinous (fig. 7b). The lateral process on the outer margin of the antenna is much larger and bears a few small spines on the anterior surface. Gill buds are very evident arising from the dorsal surfaces of the second and third

maxillipeds and all pereiopods. The exopod buds on the second and third maxillipeds have enlarged.

Puerulus stage (fig. 8a)

The two specimens had overall lengths of 31.5 and 36.8 mm and carapace lengths of 12.3 and 15.1 mm respectively. In the unpreserved state, they are nearly transparent, and the antennules, antennae, carapace and abdomen are as shown in fig. 8a. The mandibles are intermediate in form between those of the phyllosoma and adult forms. Both the second and third maxillipeds and all

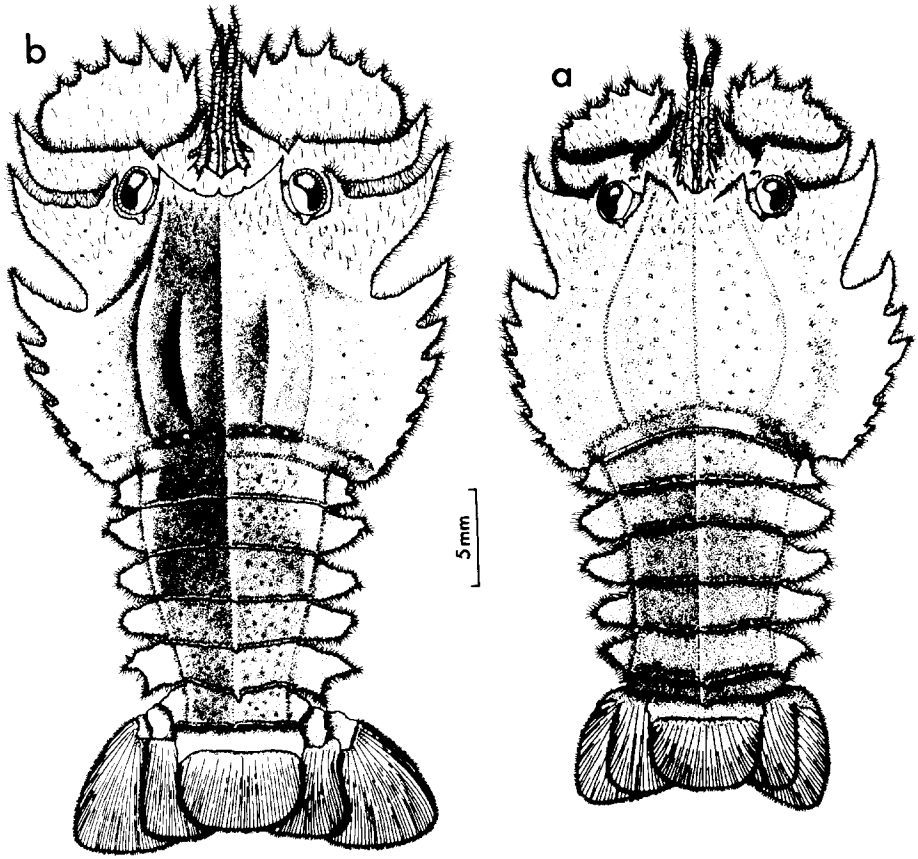

Fig. 8. *Ibacus alticrenatus* Bate, a, puerulus stage; b, post-puerulus stage.

pereiopods are shorter and stouter than in the phyllosoma form. The exopods on the maxillipeds are very small, while those on the pereiopods are vestigial (less than 1 mm in length). The pleopods are approximately 4.5 mm long, and each lobe is 1.8 to 2.1 mm in length (not including the bases) and the appendices internae are up to 1.0 mm long. The pleopods are setose and apparently functional for swimming.

Post-puerulus stage (fig. 8b)

The one specimen measured had an overall length of 34.8 mm with a carapace length of 14.7 mm. This is regarded as being a post-puerulus stage because the pleopods have become very reduced (about 1.5 mm in total length), and are of little or no use for swimming. The carapace and its features (such as antennae, carinae and dorsal spines) (fig. 8b) are much closer to the adult form. The mandibles are nearly of the adult form, with the palp just developing. The third maxilliped is broader laterally and has many serrations and rounded spines on the outer margin, while the inner margin and distal portion feature additional stout sharp spines. No vestigial exopods remain on the pereiopods.

GROWTH OF LATE-STAGE PHYLLOSOMAE IN THE LABORATORY

Three phyllosomae kept in the laboratory moulted from Stage 6 into Stage 7 before moulting to the puerulus form after a period of 25 to 29 days. After 21 and 23 days, two of these pueruli moulted into the juvenile form which were positively identified as being *Ibacus alticrenatus*. The increment of 10.9 mm total length in the case of one phyllosoma of 24.8 mm length moulting from Stage 6 to Stage 7 supports the allocation of stages on the basis of size given to the specimens collected from the plankton.

DISTRIBUTION OF PHYLLOSOMAE OF IBACUS ALTICRENATUS

Plankton samples were taken by the various methods described previously over a seven year period. Although these samples were taken all around the New Zealand coast, the bulk of the larvae were collected off the east coast of the North Island on a transect of up to 180 km due east of Castlepoint (40°54′S). Other areas yielding phyllosomae were the Bay of Islands, Bay of Plenty and East Cape areas.

Table I shows the total number of each phyllosoma stage of *I. alticrenatus* caught in plankton samples around the New Zealand coast for each month during the period from June 1969 to March 1976.

TABLE I

Stage	J	F	M	A	M	J	J	A	S	O	N	D
1			2							5		
2										5		
3										12	1	2
4										10	6	
5										6	6	1
6	(2)									10	10	1
7	(2)	(1)	(2),2								2	17

Numbers in brackets indicate phyllosomae taken from albacore stomachs off the West coast of the South Island.

DISCUSSION

To date, the only other description of the complete larval development of a species of *Ibacus* is for *I. peronii* published by Ritz & Thomas, 1973. Their illustrations and descriptions are somewhat too generalised, though, to allow the species *I. peronii* and *I. alticrenatus* to be separated solely on the basis of comparative morphological characteristics. The total length for each larval stage of *I. alticrenatus* tends to be smaller than the length of the corresponding stage of *I. peronii*. Ritz & Thomas measured fewer individuals of most stages, so the range of total lengths for *I. peronii* larvae might be extended if more specimens were available to be measured.

The puerulus stages of these two species can, however, be distinguished since the carapace of *I. peronii* is "about 1.7 times wider than long" (Ritz & Thomas, 1973). That for *I. alticrenatus* is 1.5 to 1.6 times wider than long. Moreover, the lateral serrations on the carapace are arranged differently, and there are no major indentations on the outer margin of the antennal exopod of *I. alticrenatus* while there are four in the corresponding position of *I. peronii*.

The duration of the planktonic stage of *I. alticrenatus* is estimated from table I to be four to six months. This period cannot be narrowed accurately since the catch is pooled over a seven year period during which time some seasonal variation in hatching, food abundance etc. may be expected. In addition a complex series of currents occurs off the East coast of the North Island which includes cooler sub-antarctic waters moving north and sub-tropical waters moving south from East Cape (Heath, 1973). It is possible that the phyllosomae from these different bodies of water will have different rates of development.

Although the developmental stages of *I. alticrenatus* are quite well known now, more work remains to be done to understand their distribution and ecology.

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RÉSUMÉ

Les stades phyllosome, puerulus et post-puerulus du Scyllaride *Ibacus alticrenatus* sont décrits à partir de spécimens élevés en laboratoire ou pris dans des échantillons de plancton au large des côtes de Nouvelle-Zélande. Un bref exposé de la distribution et de la durée de la phase planctonique dans le cycle de vie est également inclus.

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