

# Larvae of the Hermit Crab, *Pagurus arcuatus*, From the Plankton (Crustacea, Decapoda)

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## Abstract

Four Zoeal Stages and the megalopa of the hermit crab, *Pagurus arcuatus*, Squires, 1964, are described from the plankton and compared with *P. acadianus* Benedict, 1901, the only other species present in a small inshore area in Bonavista Bay, Newfoundland. *Pagurus arcuatus* has longer exopods than endopods of antennae in Zoeal Stages I–III, few setae on scaphognathite and medial accessory spine on inner spine of uropodal exopod in Zoea Stage IV, and in the megalopa no median posterior spine on abdominal somite 6 and no postero-lateral spurs on the telson. It has a low posterolateral spine on each side of the soft part of the carapace, also 8 setae at the posterior edge of telson. All these are different from *P. acadianus*.

Key words: Decapod crustacean larvae, Newfoundland, *Pagurus arcuatus*, *P. acadianus*, plankton, taxonomy

## Introduction

Larvae of two species of hermit crabs were collected from the plankton by G. P. Ennis and G. Dawe, Northwest Fisheries Centre, St. John's, Newfoundland, Canada, during 1971 at St. Chad's, Bonavista Bay, Newfoundland, Canada (Ennis 1983). One of the species, as described by Roberts (1973), was *Pagurus acadianus* Benedict, 1901, the other apparently undescribed. Only two species of adult hermit crabs were present in the immediate area, *P. acadianus* and *P. arcuatus* Squires, 1964, and in the general area only one additional species, *P. pubescens* Krøyer, 1838, the larvae of which were described from Ungava Bay by Squires (1993) and from the eastern Atlantic by MacDonald *et al.* (1957). The larvae of the undescribed species are therefore most likely *P. arcuatus*. The purpose of this paper is to describe the larvae of this species and to compare them with those of *P. acadianus*, as described by Roberts (1973), and observed in the plankton collection.

## Materials and Methods

The plankton were collected from St. Chad's, Bonavista Bay, Newfoundland, and the number of specimens examined at each larval stage is given in Table 1. Measurements of total length are from tip of the rostrum to the posterior end of telson without setae, carapace length from tip of the rostrum to the posterior notch of carapace. Estimates of length on a millimeter grid were made for those in good condition and not bent, and a few specimens were used for dissection and drawings. Checks for critical features were made from several stained specimens, the appendages dissected out and mounted on glass slides in glycerol and examined by light microscopy at magnifications of 100X and 430X. Drawings were done by the author.

## Results

### Description

**Stage I Zoea.** Total length 2.7–3.2 mm; carapace length 1.4–1.6 mm (Fig. 1).

Carapace (a, b): slightly shorter than rostrum, somewhat inflated in preservative, showing cervical groove where carapace bent, postero-laterally pointed, acuminate. Eyes fused with carapace.

Abdomen (a, t): first somite unarmed, others with 2 pairs of posterodorsal and 1 posterolateral spine at each side. Fifth somite with very large pair of postero-ventral spines, sixth somite fused with telson.

Telson (t): fused with 6th somite, lateral terminal process fused, others articulated, all plumodenticulate except laterals, anomuran hair or 2nd process short and tiny, seen only at 430X, 4th process longest, 7+7 processes in all.

Antennule (c): unsegmented, one aesthete and stout seta apically and a long plumose sub-apical seta.

Antenna (d): scale or exopod with long tapering terminal spur and 6 inner plumose setae; endopod or incipient flagellum appreciably shorter than scale and with strong spine at base.

Mandible (e): outer edge sharp tooth, small pointed cusp between it and molar, latter with few sharp cusps. No palp.

Maxillule (f): proximal endite with 1 seta, distal endite with 2 strong spines and small spine between them; endopod three-segmented, middle segment with one seta, 3 setae apically.

Maxilla (g): bilobed endopod with four setae, slightly longer than anterior lobe of scaphognathite, latter with 2 apical and 3 lateral setae; distal endite with 2 subequal lobes each with 2 apical setae, two proximal lobes unequal smaller with 3 apical and larger with 4 apical setae.

First maxilliped (h): endopod with 5 segments, each with 4, 2, 1, 2, and 2 setae from apex to base. No setae plumodenticulate but sparingly plumose. Exopod longer with 2 segments and apically 4 long plumose setae. Basal endite with 2 distal and 4 medial setae. Coxal endite without setae.

Second maxilliped (i): endopod with 4 segments, each with 3, 2, 1, and 2 setae from apex to base, 1 of each stout and plumodenticulate, others slender without plumes; exopod longer than endopod with 2 segments and 4 long plumose setae apically. Basal endite with 2 distal setae, 1 plumodenticulate, and 1 medial setae. Coxal endite without setae.

Third maxilliped (k): small, 2 segments only, without setae.

Pereopods (l): a bud only.

Pleopods: absent.

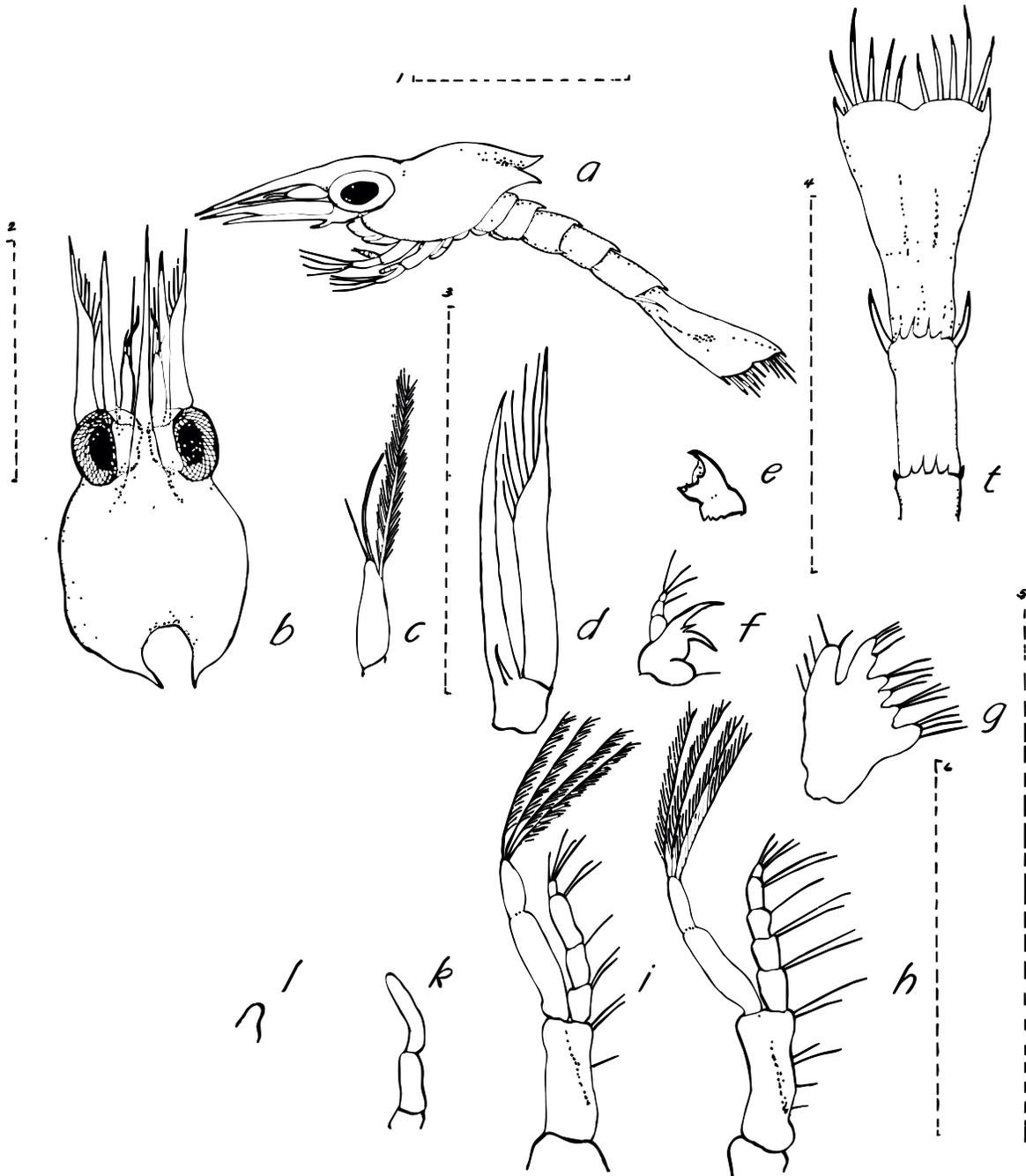


Fig. 1. *Pagurus arcuatus*. Stage 1 Zoea: a, whole zoea from left side; b, carapace in dorsal aspect; c, antennule; d, antenna; e, mandible; f, maxillule; g, maxilla; h, first maxilliped; i, second maxilliped; k, third maxilliped; l, pereopod bud; t, telson and abdominal somites 4 and 5. Scales (broken line = 1 mm): 1 = a; 2 = b; 3 = c, d; 4 = t; 5 = e-g; 6 = h-l.

**Stage II Zoea.** Total length 3.7–4.4 mm; carapace length 1.8–2.1 mm (Fig. 2).

Carapace (a, b): Eyes moveable, ridge over and behind eye, slight middorsal ridge behind rostrum extending less than half carapace; rostrum about as long as carapace.

Abdomen (a, t): narrow, each somite, except first, with 2 pairs of dorsal and 1 pair of ventrolateral spines, and 5th with pair of very large ventrolateral spines. The 6th somite still fused with telson.

Telson (t): shows early formation of uropods and has 8 + 8 terminal processes centre pair quite short, all plumodenticulate except fused lateral pair. Anomuran hair very tiny, difficult to see even at 430X.

Antennule (c): now two-segmented, has one aesthete plus stout seta apically and long subapical plumose seta on developing endopod.

Antenna (d): scale with long apical spur still longer than endopod and has 7 inner setae, basis has lower large spine curved forward.

Mandible (e): molar with low cusps, separated from pointed incisor by two short teeth.

Maxillule (f): proximal endite about as large as distal and with 4 curved setae; distal with 4 strong spine-like setae; endopod with 3 segments, distal segment with 3 and medial segment with 2 setae.

Maxilla (g): coxal endite with unequal lobes, proximal with 5 setae and distal with 3 setae; basal endite with subequal lobes one with 2 and other 4 setae; endopod longer than anterior lobe of scaphognathite, latter with 4 plumose setae. Endopod bilobed with 4 distal and 2 proximal setae.

First maxilliped (h): basal endite with 6 setae, endopod with 5 segments and 4, 2, 1, 2, 2 setae from apex, lightly plumose, none plumodenticulate. Exopod with 6 long plumose apical setae.

Second maxilliped (i): basal endite with 2 distal setae (one plumodenticulate) and 1 medial setae; endopod with 4 segments and 4, 2, 1, 2 setae from apex; 1 each of segmental setae stout and plumodenticulate, others with few short plumes. Exopod with 6 long plumose setae.

Third maxilliped (k): endopod small, inserted on basal endite and with apical seta, bi-segmented exopod much larger but smaller than in other maxillipeds and with 5 plumose apical setae.

Pereopods (l, m, n): buds only but 1st larger and showing claw formation.

Pleopods: none.

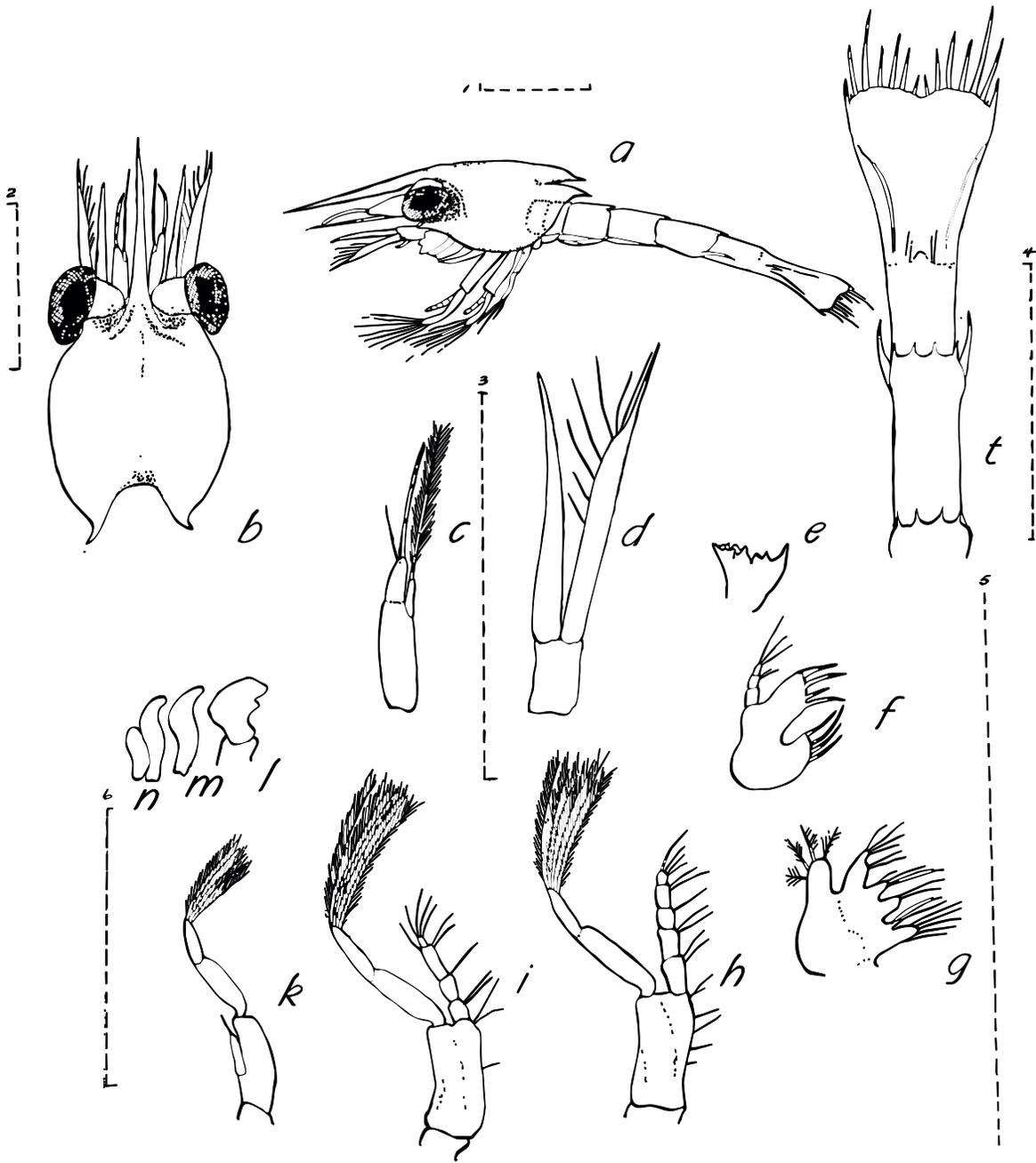


Fig. 2. *Pagurus arcuatus*. Stage II Zoea: a, whole zoea from left side; b, carapace in dorsal aspect; c, mandible; d, antennule; e, antenna; f, maxillule; g, maxilla; h, first maxilliped; i, second maxilliped; k, third maxilliped; l, m, n, peropodal buds; t, telson and abdominal somites 4 and 5. Scales (broken line = 1 mm): 1 = a; 2 = b; 3 = c, d; 4 = t; 5 = e-g; 6 = h-n.

**Stage III Zoea.** Total length 4.5–5.0 mm; carapace length 2.3–2.5 mm (Fig. 3).

Carapace (a, b): with short median carina behind rostrum and curved ridge behind eyes as in Stage II Zoea. Rostrum about as long as carapace and descending, reaching just beyond antennal endopod.

Abdomen: as in Stage II Zoea with two pairs of dorsolateral spines and 1 pair of small ventrolateral spines on somites 2 to 4; 5th somite has 2 very large ventrolateral spines. Sixth somite clearly separated from the telson.

Telson (t): now has uropods. Latter has short endopod and exopod reaching about two-thirds length of telson; exopod sharply pointed with 2 apical spines, inner short, 5 inner setae. Terminal spines of telson as in Stage II Zoea, plumodenticulate except laterals, anomuran hair not seen.

Antennule (c): has unsegmented peduncle with long seta at apex, the exopod with two aesthetes apically and a long seta beside it, endopod short with long plumose seta apically and long seta beside it on the peduncle.

Antenna (d): scale about equal in length to endopod. Spine present at base of scale and long curved spine at base of endopod.

Mandibles (e): right and left slightly different (as in other stages), incisor sharper on right and with double edge on left; molars with three serrate ridges, sharper on right.

Maxillule (f): same as in Stage II Zoea.

Maxilla (g): endopod as in Stage II Zoea, slightly longer than anterior lobe of scaphognathite, latter with 6 setae, sparingly plumose but edge also with short plumes. Basal endite with two equal lobes with 3 apical setae each, coxal endite with unequal lobes with 2 distal and 4 proximal setae.

First maxilliped (h): basal endite with 2 distal and 4 medial setae; five-segmented endopod with 4, 2, 1, 2 and 2 setae from apex, no setae plumodenticulate but some with short plumes; exopod longer than endopod, with 6 long apical plumose setae.

Second maxilliped (i): basal endite with 2 distal setae (1 plumodenticulate) and 1 medial seta; four-segmented endopod with 3, 2, 1 and 2 setae from apex (1 of each segmental setae stout and plumodenticulate, others slender and with few plumes); exopod longer, with 6 long plumose setae.

Third maxilliped (k): two-segmented endopod about as long as and fused with basal endite and with 2 apical setae; exopod about as long as endopod and with 5 apical plumose setae.

Pereopods (l, m, n): I chelate, II and III slightly longer, IV short, V behind IV but slightly longer; faint segmentation.

Pleopods (a): still enclosed under cuticle as buds or absent.

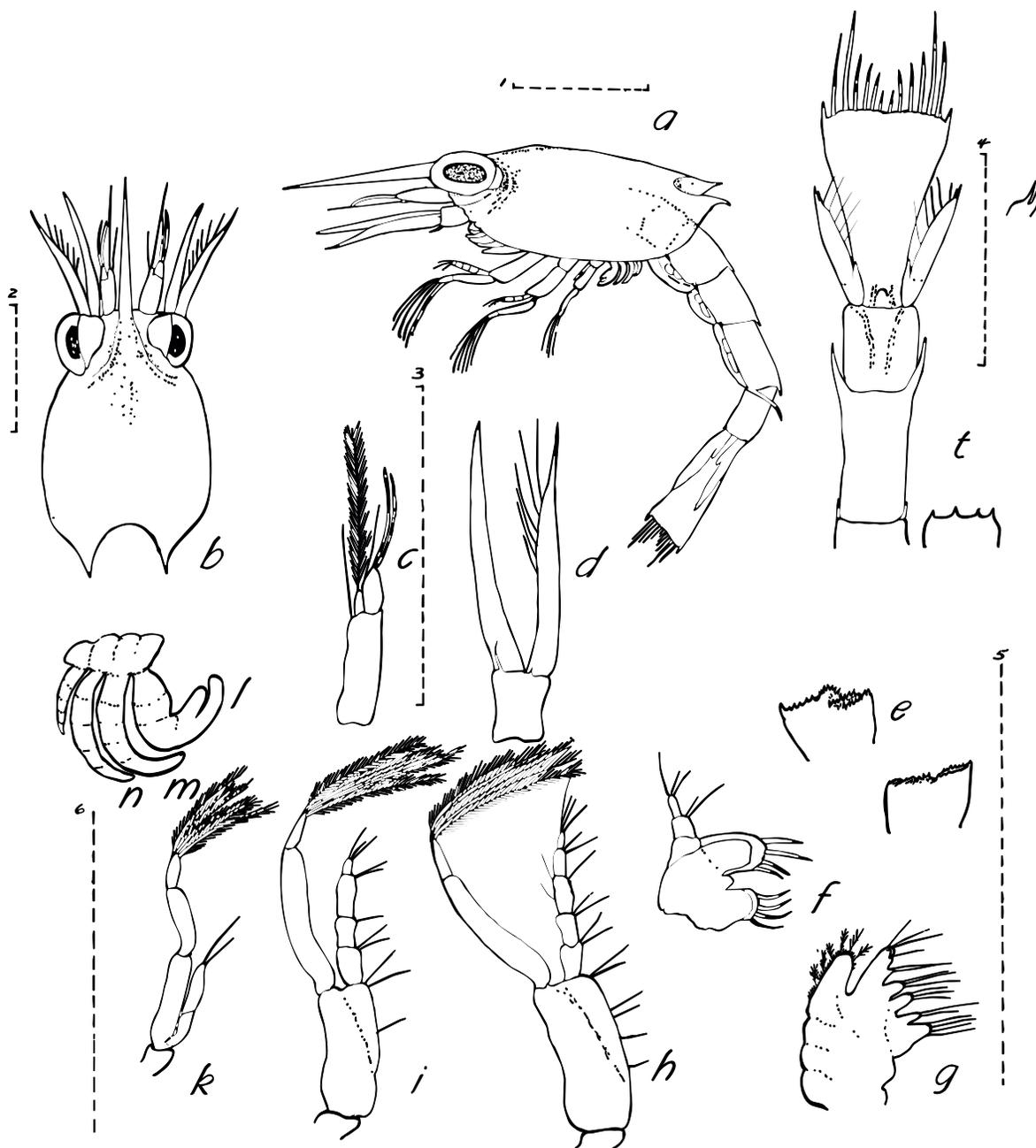


Fig. 3. *Pagurus arcuatus*. Stage III Zoea: a, whole zoea from left side; b, carapace in dorsal aspect; c, antennule; d, antenna; e, mandible; f, maxillule; g, maxilla; h, first maxilliped; i, second maxilliped; k, third maxilliped; l, m, n, pereopods; t, ventral view of telson and somites 5 and 6 (edge of 4 dorsally). Scales (broken line = 1 mm): 1 = a; 2 = b; 3 = c, d; 4 = t; 5 = e-g, 6 = h-n.

**Stage IV Zoea.** Total length 5.3–6.3 mm; carapace length 3.0–3.2 mm (Fig. 4).

Carapace (a, b): with dorsal carina more pronounced than in Stage III Zoea but not reaching more than half of carapace.

Abdomen (a): as in other stages but uniramous pleopods present.

Telson (t): with fully segmented uropods, exopod reaching about two-thirds of telson, with apically 2 subequal spines (inner spine has inner medial accessory spine) and 5 inner lateral setae, endopod fused with basal segment about one-quarter length of exopod. Telson spines all plumodenticulate except lateral pair which is reduced in comparison with length of other spines. Terminal edge of telson also plumodenticulate as in other zoeae.

Antennule (c): peduncle faintly divided into 3 segments; exopod with 3 apical and 3 medial aesthetes and a long seta at its base, endopod with one apical plumose seta and another long seta at its base inside.

Antenna (d): endopod now longer than reduced (thinner) scale and with one definite and several faint annulations; exopod (scale) has 7 setae.

Mandible (e): as in other stages but now with palp bud, unsegmented.

Maxillule (f): as in other stages but basal endite has 6 spinous setae.

Maxilla (g): as in other stages but scaphognathite has about 8 plumose setae on anterior lobe and narrow posterior lobe now in evidence.

First maxilliped (h): basal endite with 2 distal setae and 3 lateral seta; endopod with 4, 2, 1, 2, 2 setae from apex, none plumodenticulate but sparingly plumose; exopod with 7 long plumose setae.

Second maxilliped (i): basal endite with 2 apical setae (1 plumodenticulate) and 1 medial seta; endopod with 4, 2, 1, 2 setae from apex, one of each pair stout and plumodenticulate; exopod with 7 long plumose setae.

Third maxilliped (k): endopod has additional distal segment and now exceeds basal endite to which it is proximally attached; exopod has 5 long plumose setae.

Pereopods (l, m, n, ñ): I large with evidence of chela, II and III long slender, segmented, IV and V short.

Pleopods (o): uniramous but small bud of endopod beside exopod.

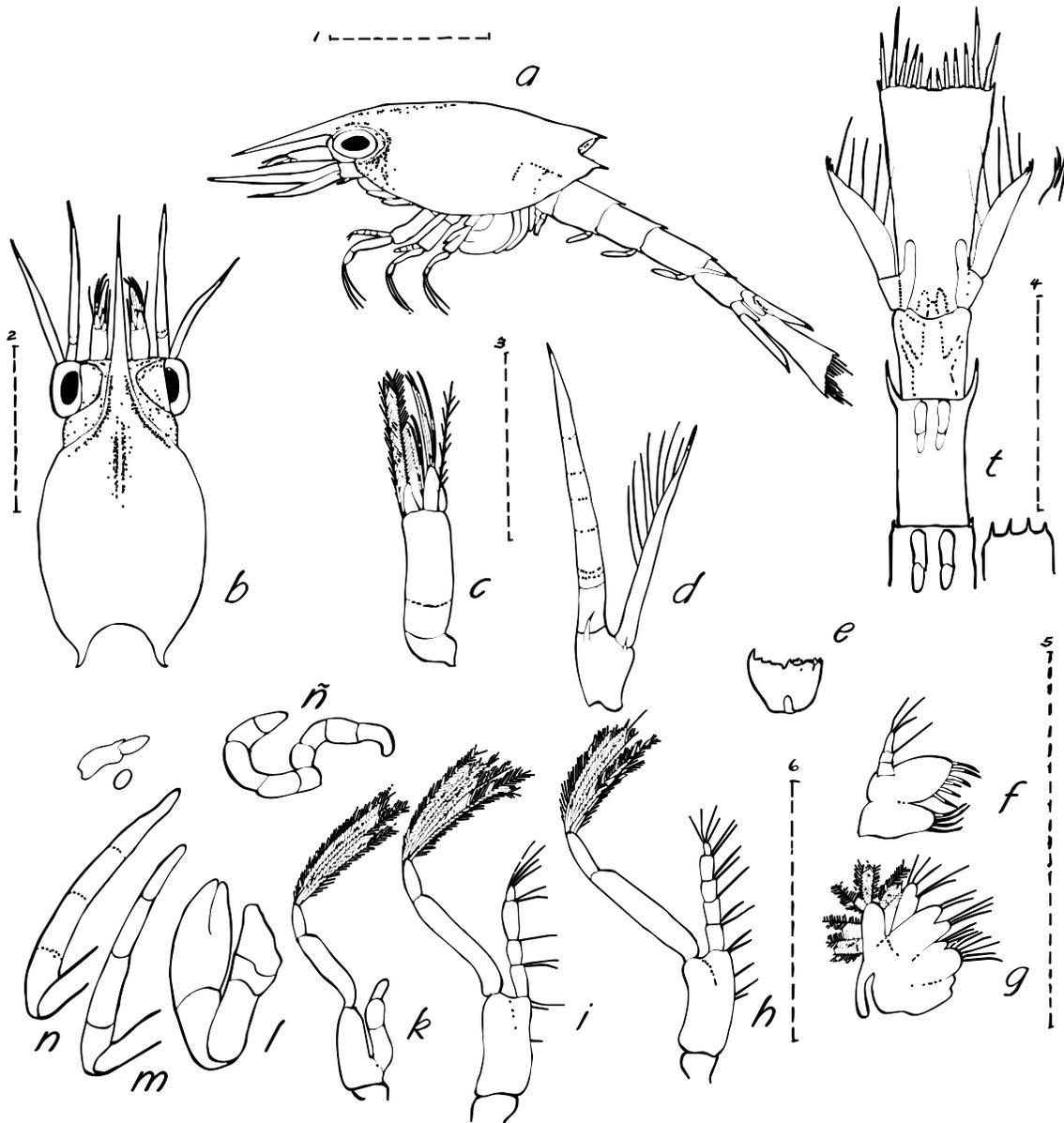


Fig. 4. *Pagurus arcuatus*, Stage IV Zoea: a, whole zoea from left side; b, carapace in dorsal aspect; c, antennule; d, antenna; e, mandible; f, maxillule; g, maxilla; h, 1st maxilliped; i, 2nd maxilliped; k, 3rd maxilliped; l, m, n, n̄ pereopods; o, pleopod; t, telson and abdominal somites 4-6 in ventral view (dorsal edge of 4). Scales (broken line = 1 mm): 1 = a; 2 = b; 3 = c, d; 4 = t; 5 = e-g; 6 = h-o.

**Megalopa.** Total length 3.2–3.3 mm; carapace length 1.3–1.6 mm (Fig. 5).

Carapace (a, b): shield separated by grooves from posterior carapace, latter with small projection or low spine at each side of pleura posteriorly. Mid-dorsal low carina on front half of shield. Rostrum short, rounded, descending. Corneas slightly less wide than stalks, latter almost as long as shield; small ocular acicles narrow, anteriorly pointed and with 2 short inner setae.

Abdomen (a) and Telson (t): with seven somites including telson, latter rounded posteriorly and with 8 long terminal plumose setae but no lateral spurs as in *P. acadianus* (Roberts 1973), also with two clumps of long dorsal setae. Biramous uropods on 6th somite, endopod short unsegmented with few short stout spines apically; right exopod with 2 segments and 9 short stout spines along outer edge and covered with numerous rasp scales among setae on expanded terminal segment, left exopod with 10 short stout spines along outer edge and numerous rasp scales. Right and left subequal.

Antennule (c): peduncle of 3 segments; exopod (outer flagellum) of 4 segments and three groups of 4 aesthetes each and apically with 1 long and 3 short setae. Endopod (inner flagellum) of 2 segments with few apical setae; one seta on proximal segment.

Antenna (d): three-segmented peduncle with one seta on segments 1 and 3, scale reduced to stout spike with 2 setae; long flagellum with 19 setose articles.

Mandible (e): incisor a thin rounded blade, molar a shelf behind it and palp with three segments.

Maxillule (f): coxal endite with 4 setae, basal with 7, unsegmented endopod with apical seta.

Maxilla (g): endites subequal pairs with few setae, endopod reduced not reaching beyond anterior lobe of scaphognathite, latter with long posterior lobe and fringe of about 32 plumose setae.

First maxilliped (h): coxal endite small with few setae, basal endite large with many setae, endopod unsegmented, exopod of 2 segments with 2 apical setae and 4 setae on proximal segment.

Second maxilliped (i): endopod with 5 segments, apically 5 setae; exopod 3-segmented with 5 long setae apically.

Third maxilliped (k): endopod 5-segmented, distal segments setose, apical one with long curved terminal spine; exopod 3-segmented with 5 long setae terminally.

Pereopods: I (l): large stout chela, setose; II and III (m) long and slender, dactyl long, sharp, setose; IV (n) pseudo-chelate, dactyl curved, sharp, propodus inflated and with rows of rasp scales; V ( $\bar{n}$ ) with small setose dactyl, propodus expanded slightly and with several rows of scales.

Pleopods (o): biramous, endopod small without setae, exopod with many setae.

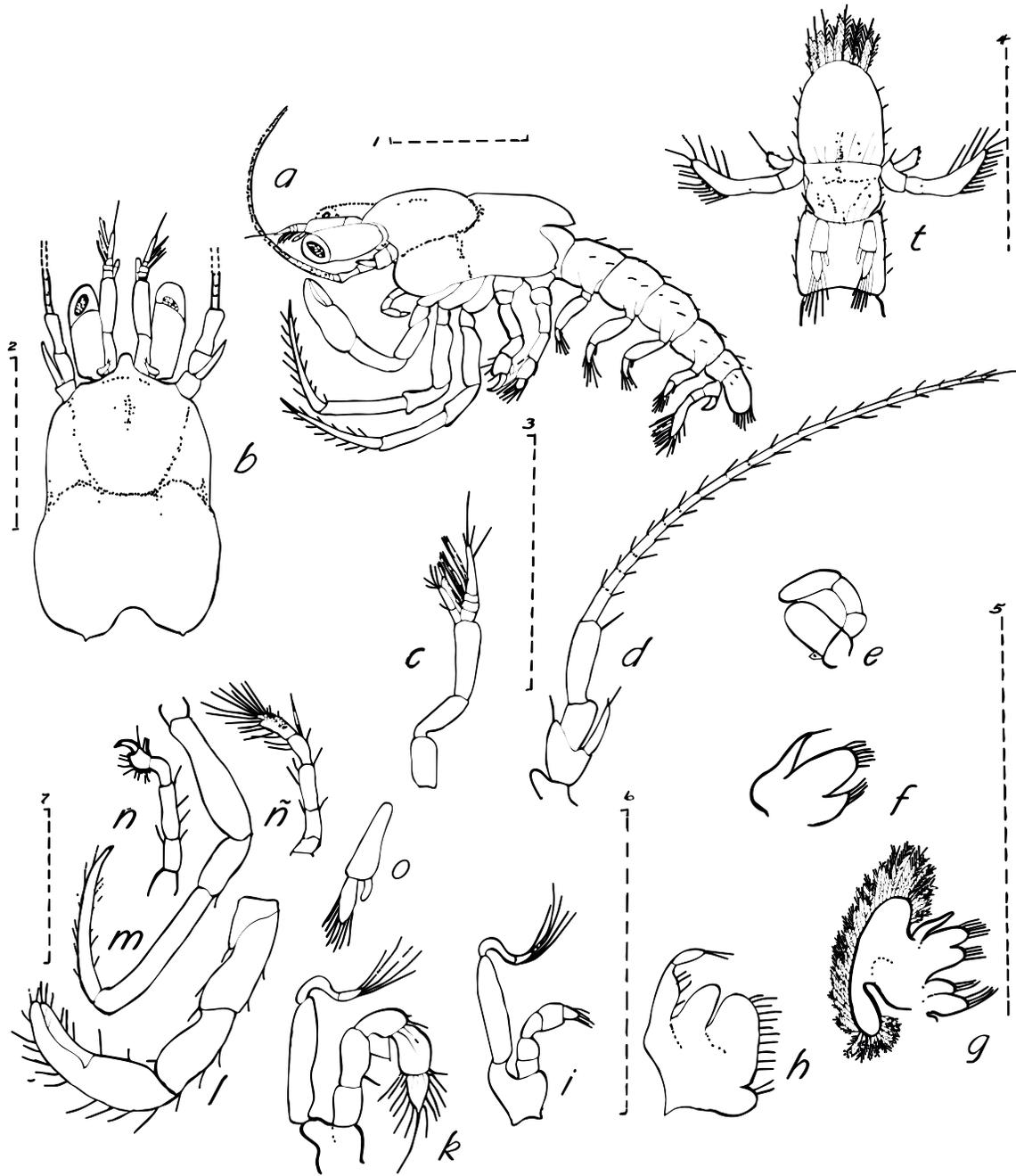


Fig. 5. *Pagurus arcuatus*. Megalopa: a, whole megalopa from left side; b, carapace in dorsal aspect; c, antennule; d, antenna; e, mandible; f, maxillule; g, maxilla; h, first maxilliped; i, second maxilliped; k, third maxilliped; l, m, n, n̄, pereopods; o, pleopod; t, telson and abdominal somites 5 and 6 in ventral view. Scales (broken line = 1 mm): 1 = a; 2 = b; 3 = c, d; 4 = t; 5 = e-h; 6 = i-k; 7 = l-o.

### Discussion

Differences between larvae of *Pagurus acadianus* Benedict, 1901, and *P. arcuatus* Squires, 1964, are based on observations of laboratory cultured specimens of *P. acadianus* (Roberts 1973) and on specimens of both species from the plankton for the present paper. An exception is the Megalopa, for which only specimens of one species, *P. arcuatus*, were obtained from the plankton at St. Chad's, and these were compared with the specimens described for *P. acadianus* by Roberts (1973). Specimens of larval stages of *P. acadianus* from the plankton appeared somewhat different from those described by Roberts (1973). For example, the numbers of aesthetes on antennules were less in those from the plankton in Stages I–III Zoeae (Table 1). However both species were similar in size (Table 2).

TABLE 1. Comparison between larval stages of *Pagurus acadianus* and *P. arcuatus* from observations based on specimens from the plankton at St. Chad's, Newfoundland, Canada, and on laboratory cultured specimens of *P. acadianus* (c.f. Roberts 1973).

Larval stages	<i>P. acadianus</i>					<i>P. arcuatus</i>				
	I	II	III	IV	M	I	II	III	IV	M
Number of specimens examined	25	8	31	2	0	52	19	65	41	20
Aesthetes on antennules (Roberts 1973)	4	4	5	8	9	1	1	2	6	12
Present study	1	2	4							
Antennal endopod longer than scale	Yes	Yes	Yes	Yes	Yes	No	No	No	Yes	Yes
Spine at each side of carapace posteriorly	Not present in Megalopa (Roberts 1973)					Present in Megalopa				
Mid-dorsal spine posteriorly on 6th somite	Present in Megalopa (Roberts 1973)					Not present in Megalopa				
Telson with postero-lateral spur at each side	Present in Megalopa (Roberts 1973)					Not present in Megalopa				
Inner spine of 2 at tip of exopod of uropod with medial spine in Stage IV Zoea	Not present (Roberts 1973)					Present				
Setae at posterior edge of telson in megalopa	10 (Roberts 1973)					8				

TABLE 2. Comparison of total lengths (mm) of *Pagurus* species from different areas and from laboratory cultured (Lc) specimens or specimens from the plankton (Ps). N is the number observed.

	Zoea				Author
	Stage I	Stage II	Stage III	Stage IV	
<i>P. pubescens</i> Krøyer (Lc) N	2.9–3.3 –	3.7–4.2 –	4.0–5.3 –	4.9–5.9 –	MacDonald <i>et al.</i> , 1957 Eastern Atlantic
<i>P. pubescens</i> Krøyer (Ps) N	3.9–4.5 142	4.3–5.7 87	5.3–7.5 74	6.8–8.4 27	Squires, 1993 Western Atlantic, Arctic
<i>P. acadianus</i> Benedict (Lc) N	2.9–3.2 23	3.4–3.9 39	4.2–4.8 24	5.3–6.2 19	Roberts, 1973
<i>P. acadianus</i> Benedict (Ps) N	2.7–3.1 10	3.7–4.0 8	4.3–4.8 20	5.3 1	This paper
<i>P. arcuatus</i> Squires (Ps) N	2.7–3.2 11	3.7–4.4 23	4.5–5.0 17	5.3–6.3 24	This paper

A summary of the differences at larval stages is as follows (Table 1):

1. The number of aesthetes on the antennules in Zoel Stages I–IV is less in *P. arcuatus* than in *P. acadianus* as indicated by Roberts (1973), but appears somewhat similar in specimens from the plankton.
2. The antennal scale is longer than the endopod in Stages I–III Zoeae and slightly shorter in Stage IV Zoa of *P. arcuatus*, while in *P. acadianus* (and in *P. pubescens* (Squires 1993)) it is always shorter.
3. In Stage III Zoa of *P. arcuatus* the outer antennular flagellum has 2 apical aesthetes only while in *P. acadianus* there are also 2 medial aesthetes.
4. In Stage IV Zoa the anterior lobe of the scaphognathite in *P. arcuatus* has only 4–8 setae while in *P. acadianus* there are 15 (Roberts 1973).
5. There is a low spine posteriorly at each side of the soft part of the carapace in the Megalopa of *P. arcuatus* but not in *P. acadianus* (Roberts 1973).
6. In the Megalopa there is no mid-dorsal spine posteriorly on the 6th somite of *P. arcuatus* which is clearly shown in *P. acadianus* by Roberts (1973).
7. There are no postero-lateral spurs on the telson and 8 setae at posterior edge in the Megalopa of *P. arcuatus*, but spurs are present and 10 setae in *P. acadianus* (Roberts 1973).

Random sampling effort resulted in considerably fewer specimens of *Pagurus acadianus* than of *P. arcuatus* being collected from the plankton. This could be accounted for by the lower occurrence of adults of the former species in the area (G. P. Ennis, DFO, Northwest Atl. Fish Centre, St. John's, NF, pers. comm.).

### Comparisons with *Pagurus pubescens*

Larvae of both *P. arcuatus* and *P. acadianus* are similar in size to each other and to *P. pubescens* from the eastern Atlantic. However, larvae of *P. pubescens* from plankton in Ungava Bay are much larger (Table 2), presumably an adaptation to Arctic conditions. In spite of this larval development proceeds in the usual way (Squires 1993) as in other areas or in laboratory culture.

Zoel Stages from I to IV (the Megalopa was not taken in Ungava Bay) have characteristics similar to such Stages from other areas, although they are larger.

The species *P. arcuatus* and *P. acadianus* are limited in their distribution to no farther north than the Straits of Belle Isle, Newfoundland. There is an overlap in distribution with *P. pubescens* which extends as far south as Georges Bank and north to the high Arctic but the latter species is found in deeper water to the south (Squires 1990).

Specimens of larval stages of *Pagurus arcuatus* are deposited at the Atlantic Reference Centre, Huntsman Marine Science Centre, St. Andrews, N. B., Canada, E0G 2X0, (Catalogue Nos. ARC9560896 – 9560900), and representative samples at the Canadian Museum of Nature, Zoology Division, P.O. Box 3443, Station D, Ottawa, Ontario, Canada, K1P 6P4.

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