

# PARASITISM OF GALATHEID CRUSTACEANS FROM THE NORFOLK CANYON AND MIDDLE ATLANTIC BIGHT BY BOPYRID ISOPODS<sup>1, 2</sup>)

BY

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## INTRODUCTION

Examination of 12 species of galatheid and one species of chirostyliid Crustacea, collected in the vicinity of Norfolk Canyon, showed that several species were infested by epibranchial isopods (Epicaridea, Bopyridae). Although the bopyrid parasites of galatheids have been reviewed taxonomically (Hansen, 1897; Richardson, 1904, 1905, 1910; Boone, 1927; Shiino, 1934; Bourdon, 1968, 1972; Markham, 1973, 1975), little quantitative information on these parasites and host species exists. Bourdon (1968) examined parasitism of several galatheids from the eastern Atlantic, and Délye (1955) studied the effects of parasitism by *Pleurocrypta intermedia* Bonnier and *Pseudione* sp. on the sexual morphology of *Munida iris ruttlandi* Zariquiey. Williams & Brown (1972) noted frequency of occurrence of bopyrid isopods and the possibility of sexual modification in parasitized *M. iris iris* A. Milne Edwards from one collection on the outer continental shelf-upper slope margin off North Carolina. This paper documents frequency of occurrence, depth distribution, sex ratios and size frequency of parasitized galatheids from the Norfolk Canyon area and the adjacent continental slope of the Middle Atlantic Bight. Some data on morphology and fecundity of the bopyrid parasites are also presented.

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## METHODS AND MATERIALS

Specimens were collected from the continental shelf, slope, and rise in the immediate vicinity of the Norfolk Canyon (36°56.0'-37°09.0'N 75°06'-74°33'W)

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and from a similar area south of the canyon ( $36^{\circ}36.4'-36^{\circ}45.7'N$   $74^{\circ}42'-74^{\circ}44'W$ ) during June 1973 (R/V "Columbus Iselin"), November 1974, September 1975 and January 1976 (R/V "James M. Gilliss").

Sampling was conducted between 75 and 3000 m with a 13.7 m (head-rope) semi-balloon, four-seam otter trawl. A detailed description of the net is found in Musick, Wenner & Sedberry (1975). Tow duration was 0.5 hr in depths less than 2000 m and 1 hr in water deeper than 2000 m.

All galatheid and chirostylid crustaceans were examined for infestation by epicaridean isopods during November, January and June cruises. During September sampling, all specimens were examined except *Munida iris iris* from four stations. Estimates of total number and incidence of parasites were made from subsamples at these four stations.

Among host species, sex of both parasitized and non-parasitized individuals was determined by an examination of the second pleopods (Williams & Brown, 1972). Short carapace length (SCL: the distance from the posterior edge of the right orbit to the posterior margin of the carapace) was measured on all infested individuals. Note was made of which host branchial chamber contained isopods, and orientation of the male and female parasites. Total length (TL) of female isopods was measured from the anterior cephalic region to the posterior margin of the uropods. Total length of males was measured from the anterior cephalic region to the tip of the pleon.

Fecundity of female *Anuropodione carolinensis* Markham from *Munida i. iris* was estimated volumetrically. Eggs were stripped from marsupial pouches of six individuals with forceps and suspended in a 100 ml volumetric flask filled with water. Eggs in three 1 ml aliquots of the suspensions were counted in a Sedgewick-Rafter slide under a binocular microscope.

## RESULTS

### Incidence of Infestation

The depth distribution of galatheoidean crustaceans collected during this study is shown in table I. Among them, *Munida i. iris*, *M. microphthalmal* A. Milne Edwards, *M. longipes* A. Milne Edwards and *Munidopsis rostrata* (A. Milne Edwards) were found to be infested with epibranchial bopyrid parasites. Infestation of the galatheids, *M. i. iris*, *M. microphthalmal* and *M. longipes* is not new (Markham, 1973, 1975), but *Munidopsis rostrata* has not been previously noted as a host for bopyrids.

*Munida i. iris*, infested with *A. carolinensis* Markham, was the most heavily parasitized host species (table II). Although infestation appeared to increase with sample size, the incidence of parasitism for this species was fairly constant (2.0-5.0%). There was no relationship between the number of parasitized individuals and depth of capture.

TABLE I

Depths of capture for galatheoidean crustaceans collected during June, September, November and January sampling in Norfolk Canyon area

Species	Depth (m)	No. collected
<i>Eumunida picta</i> Smith	269-625	19
<i>Munida iris iris</i> A. Milne Edwards	83-662	19, 148
	(based on subsample estimate)	
<i>Munida longipes</i> A. Milne Edwards	175-325	82
<i>Munida valida</i> Smith	313-819	33
<i>Munida forceps</i> A. Milne Edwards	260	1
<i>Munida microphthalmalma</i> A. Milne Edwards	1408-1698	17
<i>Munidopsis curvirostra</i> Whiteaves	1408-2642	20
<i>Munidopsis bairdii</i> (Smith)	2100-2933	12
<i>Munidopsis rostrata</i> (A. Milne Edwards)	1876-2427	70
<i>Munidopsis bermudezi</i> Chace	2575-2933	4
<i>Munidopsis sundi</i> Sivertsen & Holthuis	2933	2
<i>Munidopsis</i> sp.	2680	1
<i>Munidopsis similis</i> Smith	2291	2

TABLE II

Incidence of parasitism by bopyrid isopods according to months of capture. Data estimated from subsamples are indicated by \*

Host species	Months of collection			
	January	June	September	November
<i>Munida i. iris</i>				
Total no.	535	174	15,419*	3017
No. parasitized	18	4	717*	163
% parasitized	3.0	2.0	5.0*	5.0
<i>Munida longipes</i>				
Total no.	56	1	10	18
No. parasitized	0	0	0	1
% parasitized	0	0	0	5.5
<i>Munida microphthalmalma</i>				
Total no.	0	0	1	17
No. parasitized	0	0	0	1
% parasitized	0	0	0	5.8
<i>Munidopsis rostrata</i>				
Total no.	17	2	0	53
No. parasitized	0	0	0	1
% parasitized	0	0	0	1.8

Only single occurrences of bopyrids were observed on *M. longipes*, *M. microphthalmalma* and *Munidopsis rostrata*, and these were noted only during November sampling (table I). One female *Munida microphthalmalma*, 14.7 mm SCL, was parasitized with *Bonnieria americana* Markham. *Munidopsis longipedis* Markham was found on a male *Munida longipes*, 13.2 mm SCL. A male and a female bopyrid, thought to be an undescribed genus (J. Markham, pers. comm.) were found on a 36.8 mm female *Munidopsis rostrata*.

Size and Sex Ratio of Host *Munida i. iris*

One hundred and sixty-five male *Munida i. iris*, 9-23 mm SCL, were infested with *A. carolinensis* while 68 females 10-25 mm were parasitized (fig. 1). One ovigerous female, 22 mm SCL, was parasitized. Chi-square analysis using Yate's correction (Woolf, 1968) was calculated to determine if sex ratios of parasitized individuals and the total sample were significantly different from 1 : 1. Chi-square

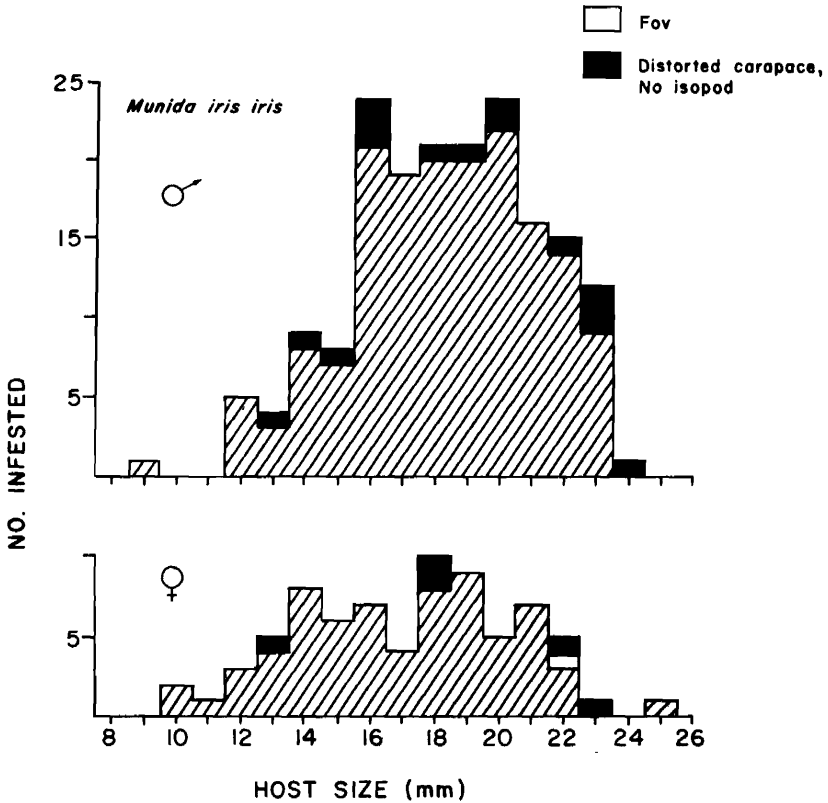


Fig. 1. Length frequency distribution of parasitized male and female *Munida iris iris* from all months of capture. Overigerous females (Fov) and individuals of both sexes found with distorted carapaces but no isopods, are also indicated.

analysis showed that incidence of infestation of males was significantly greater than females during January, November and September (table III). This is not necessarily an indication of a sexual preference by the parasite, however, since within the total sample males were significantly more numerous than females for each month of capture (table III). Contingency tables ( $2 \times 2$ ) were calculated for each month of capture with sex ( $\delta$  and  $\text{♀}$ ) as columns and condition (parasitized and non-parasitized) as rows. They revealed no significant association between sex and condition, except for the month of September ( $\chi^2 = 23, P < 0.01$ ).

TABLE III

Sex ratios for total sample and parasitized *Munida i. iris* during months of capture. Statistically significant deviation from 1 : 1 ratio indicated by \*

Month of capture	Male: female sex ratio		Chi-square	Chi-square
	parasitized	total sample	parasitized	total sample
June	1 : 1	2.3 : 1	—	27.36 *
November	2.4 : 1	1.9 : 1	26.72 *	274.96 *
September (subsampled)	3.5 : 1	1.1 : 1	25.69 *	v 3.68 *
January	3.5 : 1	3.3 : 1	4.50 *	153.39 *

An additional 5 female and 15 male *M. i. iris* had a distorted carapace but no isopod parasites. Individuals with bulges were apparently not associated with a particular size group but were found in individuals >13 mm SCL (fig. 1). The gills under the distorted carapace appeared flattened, which may indicate recent loss of the parasite.

#### Location of Bopyrids

Female bopyrid parasites were always located beneath the branchiostegite of the host, with the cephalon toward the posterior of the host and the dorsal side against the gills of the host. Gills from individuals with large parasites and distorted carapaces were flattened, but they appeared normal in *M. i. iris* with little carapace distortion. In most cases, only one male *Anuropodione carolinensis* was present per female parasite and was attached among her uropods. A pair of males was found on each of 2 female isopods (both 13 mm TL) and 26 females (5 to 16 mm TL) had no males associated with them. *Anuropodione carolinensis* were equally frequent ( $\chi^2 = 0.003$ ) in right and left branchial chambers of *M. iris iris*.

#### Pleonal variation in male *Anuropodione carolinensis*

The pleon of male *A. carolinensis* varied in shape. The allotype male described by Markham (1973) has a triangular fused abdomen, similar to that of 50 males within our samples (fig. 2A). However, no variation of the pleon in *A. carolinensis* is noted by Markham (1973). We found slight lateral undulations of the pleon in 93 individuals (fig. 2B) and pronounced lateral undulations in which three abdominal segments were visible in 2 males (fig. 2C). Thirty-eight males had six distinct pleomeres (fig. 2D).

Analysis of variance revealed a statistically significant difference ( $F = 22.6$ ;  $df$  2/178) among total lengths of male isopods with fused, undulate and segmented pleons. Scheffé's multiple mean comparison test (Snedecor & Cochran, 1967) showed males with segmented pleons to be significantly longer ( $\bar{x} = 3.4$  mm) than either males with fused ( $\bar{x} = 2.2$  mm) or undulate pleons ( $\bar{x} = 2.2$  mm).

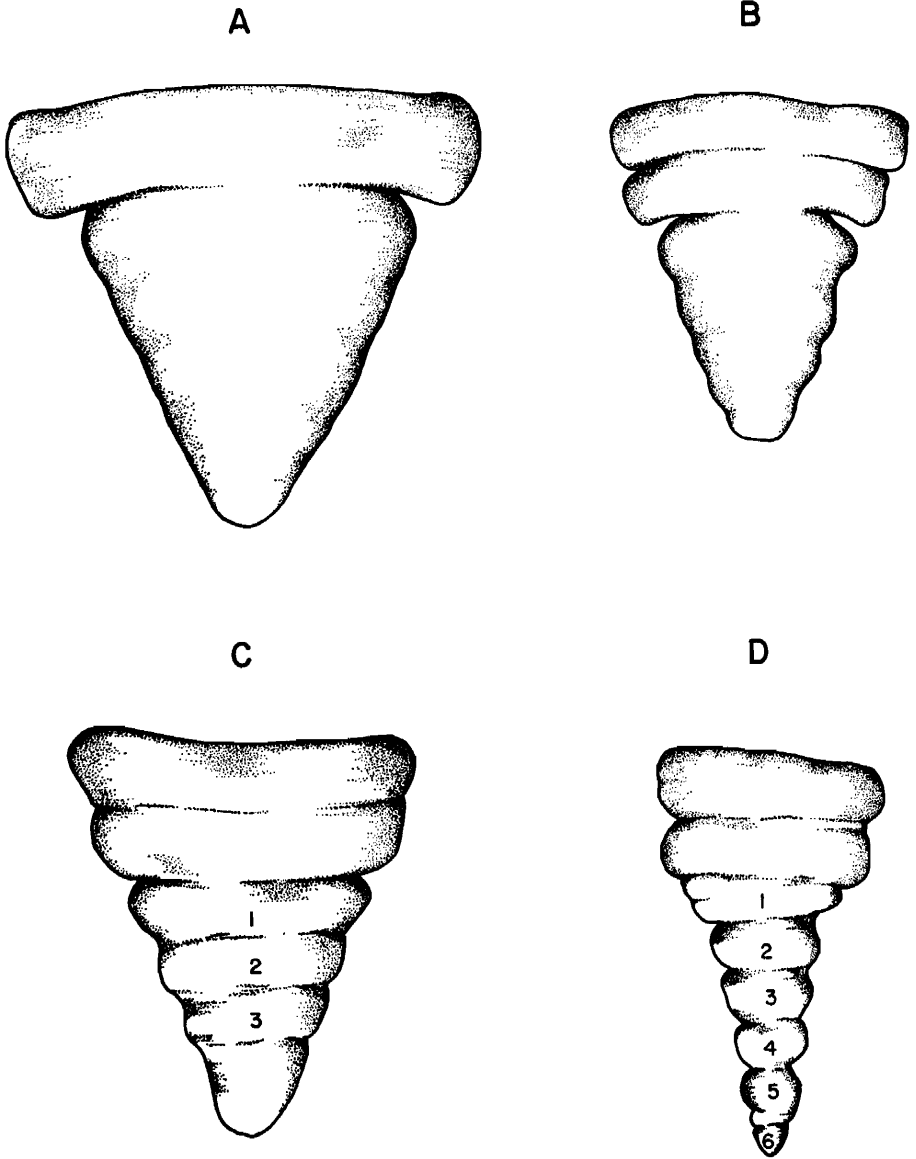


Fig. 2. Pleonal variation of male *Anuropodione carolinensis*. A, fused triangular pleon; B, slightly undulate pleon; C, pronounced undulation of pleon with three apparent pleomeres; D, pleon with six distinct pleomeres.

#### Size Composition of *Anuropodione carolinensis*

The 237 female *Anuropodione carolinensis* collected ranged from 5 to 16 mm TL (fig. 3) while 209 males ranged from 1 to 8 mm TL. A scatter diagram of parasite size (TL) against host size (SCL) showed that the size of female *A.*

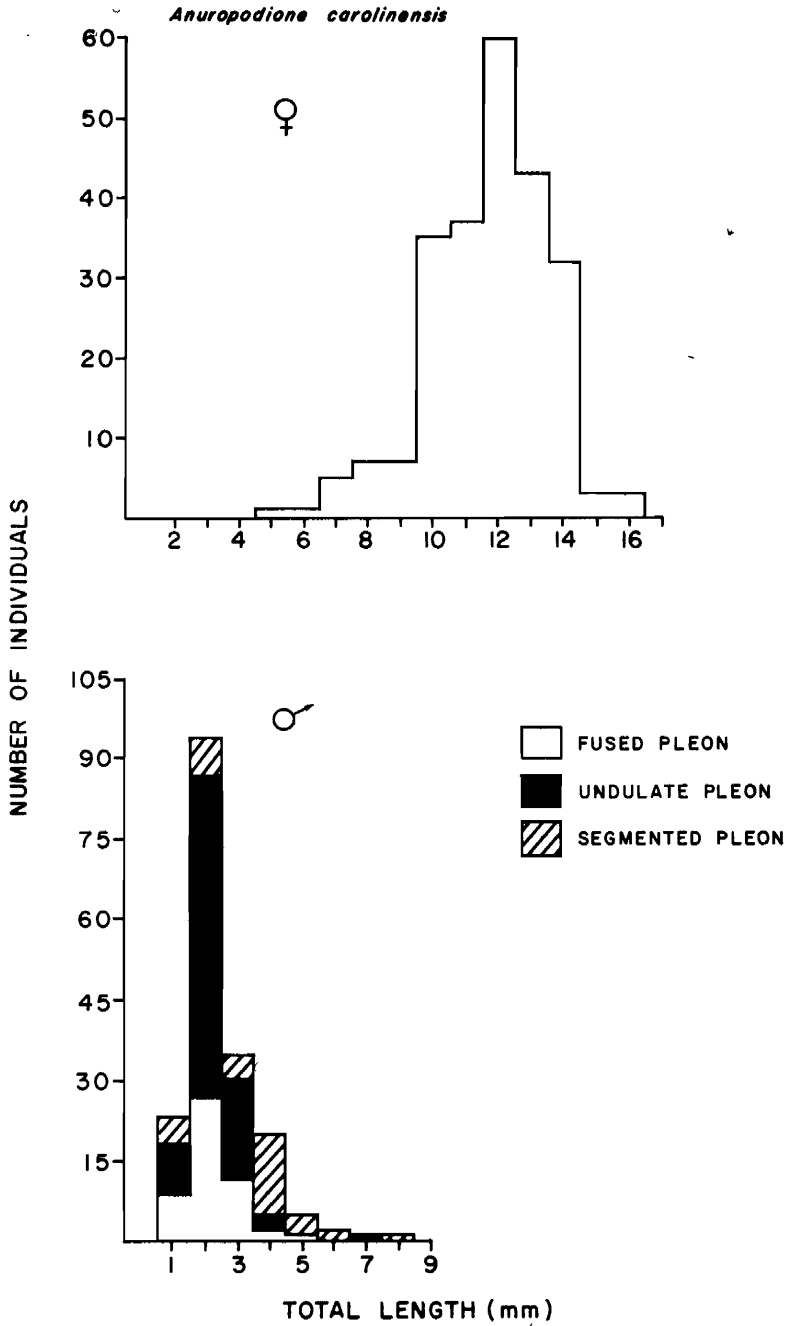


Fig. 3. Size composition of *Anuropodione carolinensis* from parasitized *Munida iris iris*. The size frequency of male isopods with fused, undulate and segmented pleons is indicated.

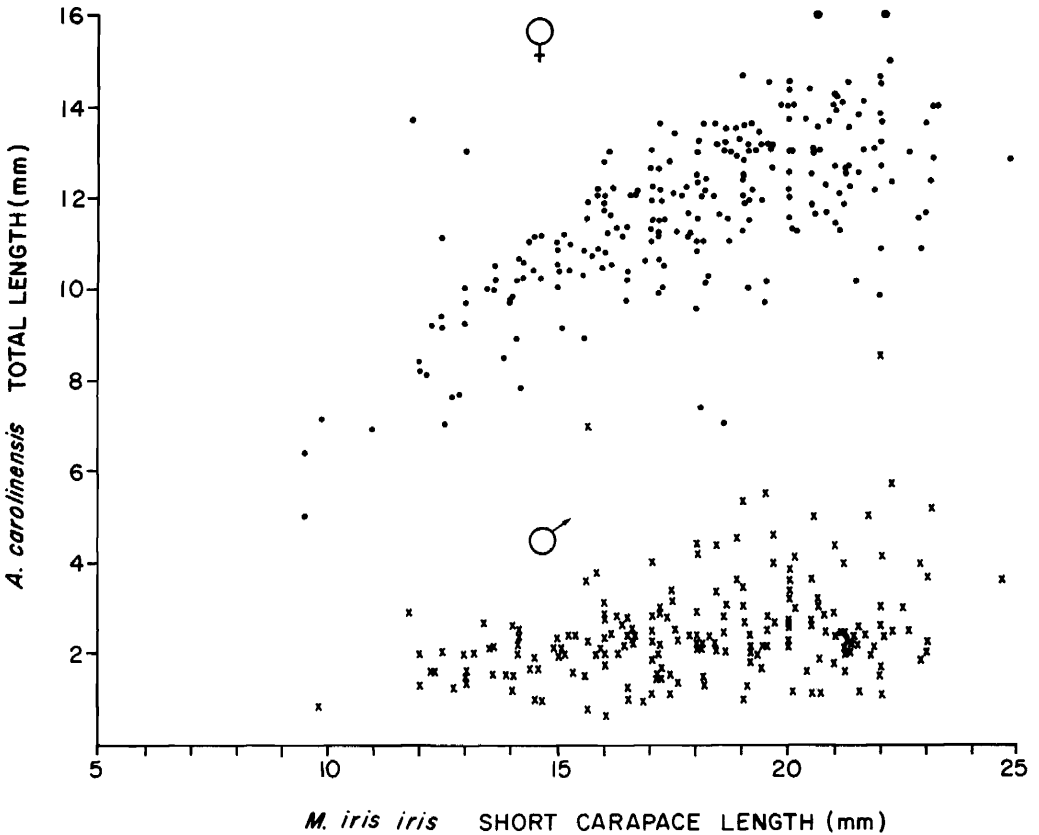


Fig. 4. Relationship of host (*Munida iris iris*) size to male (x-marks) and female (dots) parasite (*Anuropodione carolinensis*) size.

*carolinensis* was directly related to size of the host, *M. i. iris* (Fig. 4). The relation between host size and female parasite size was determined by linear least squares regression to be:

$$Y = 4.343 + 0.411 X$$

where  $Y$  = host size and  $X$  = female bopyrid size;

$$r^2 = 0.47, n = 234.$$

Although the slope of the regression of host size on size of male *A. carolinensis* was significantly different from zero, only 12% ( $r^2 \times 100$ ) of the variation in host size is due to linear regression. Therefore, no regression equation is given for these data.



## Fecundity

Fecundity estimates of six female *A. carolinensis* ranged from 9,500 to 28,000 eggs with a diameter of 140-147  $\mu\text{m}$ . Eggs were spherical in shape and appeared to be in early development with large yolk granules present. The relationship between total egg number and size of the female isopod was determined by linear least squares regression:

$$Y = -22938 + 3822 X$$

where  $Y$  = egg number and  $X$  = female SCL;

$$r^2 = 0.8.$$

The marsupium of one female, 13.7 mm TL, was filled with epicaridium larvae representative of the first stage in metamorphosis, as designated by Gilson (1909). Larvae measured 206  $\mu\text{m}$  to 252  $\mu\text{m}$  in length (from cephalon to telson).

## DISCUSSION

The frequency of parasitism of *M. i. iris* was first documented by Williams & Brown (1972), who reported a 10% incidence. The incidence in our study was markedly lower, ranging from 2.2-5.0%. There are several possible reasons for this difference; it probably occurs because the sample size ( $N = 251$ ) used by Williams & Brown (1972) was small and consisted of data from only one trawl haul. Size and age of the host may also affect incidence of parasitism among decapod crustaceans. Pike (1960) found that incidence of bopyrid parasitism increased with age in laboratory reared shrimp, *Pandalus bonnierii* Caullery and *Spirontocaris lilljeborgii* (Danielssen). The sample of *M. i. iris* studied by Williams & Brown (1972) was composed of larger and presumably older individuals, all, except one, being 15 mm short carapace length, whereas the size frequency distribution of *M. i. iris* in our study included smaller individuals. Williams & Brown (1972) also showed the first occurrence of bopyrids on males at 20 mm SCL and on non-ovigerous females at 17 mm. We found males as small as 9 mm and females 10 mm to be parasitized by *A. carolinensis*.

Williams & Brown (1972) found a significantly greater number of females than males, whereas males were significantly more numerous during each season of capture for our study. Males have also been reported to be more numerous among non-parasitized populations of *Munida sarsi* Brinkman (52.9% M : 47.1% F) and *M. tenuimana* M. Sars (53.5% M : 46.5% F) (Reverberi, 1942). Disagreement in sex ratios is probably a result of a small sample size and lack of replicate samples.

The position of *A. carolinensis* within the host and the equal occurrence on the left and right gills is consistent with observations by Williams & Brown (1972).

An increase in female parasite size with host size suggests simultaneous molts for both host and parasite since growth of the isopod would be unlikely to occur when the carapace of the host is hard. Pike (1960) confirmed for *Pandalus* that an impression was made on the soft gill covers soon after entry of the larval

parasite, but he doubted that an impression could be made on stronger gill covers of an adult prawn by a larval parasite. Larval parasites apparently infected *Pandalus* in early larval life and matured with the host. However, we have found small *A. carolinensis* on large *M. i. iris* with no apparent carapace distortion present, which shows that infestation of adult galatheids can occur.

Variability of the pleon has been documented for other Bopyridae parasitic on galatheids (Markham, 1973; Bourdon, 1968) but has never been reported for *Anuropodione carolinensis*. Bourdon (1968) suggested that pleonal variation in *Pleurocrypta porcellanae* Hesse was related to feminization of the males with pleonal metamerization suggesting an impending sex change. Bourdon (1968) also found that males of *P. porcellanae* with six distinct segments were larger than individuals with whole or laterally undulated abdomens. Results from our study are in agreement and suggest that male *A. carolinensis* with separate pleomeres may indicate impending feminization.

#### SUMMARY

Among twelve species of galatheid and one species of chirostylid Crustacea collected in the vicinity of Norfolk Canyon off eastern U.S.A., four galatheids, *Munida iris iris*, *M. longipes*, *M. microphthalmia* and *Munidopsis rostrata* were found to be infested with bopyrid isopod parasites. *Munida iris iris* was the most heavily parasitized host species with incidence of infestation by *Anuropodione carolinensis* ranging from 2.0-5.0%.

Male *M. iris iris* were significantly more numerous than females and also had a greater incidence of infestation by bopyrids than females. The size of female *A. carolinensis* was found to be related to size of the host, which suggests simultaneous molts for both species. Male *A. carolinensis* were found to have pleons which were either fused, completely segmented, partly segmented or with slight lateral undulations. Significant size differences between males with fused, undulate, and segmented pleons may indicate impending feminization of males with segmented pleons.

Single occurrences of bopyrids were observed on the other host species. *Munida microphthalmia* was infested with *Bonnieria americana*. *Munidion longipedis* was found on *Munida longipes* and an undescribed bopyrid was found on *Munidopsis rostrata*.

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