

Some Pearlfishes from Guam, with Notes on Their Ecology

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ABSTRACT: From October, 1960, to July, 1961, 230 specimens of pearlfishes were collected on the fringing reefs of Guam. Four forms are represented and their distinguishing features are discussed. These specimens were taken from four species of holothurians and from the armless starfish, *Culcita novaguineae*. *Carapus mourlani* was found only in *Culcita*; the other three occurred in two or more hosts. *Theleota ananas*, *Stichopus chloronotus*, and an unidentified *Holothuria* contained only one species each, but *Holothuria argus* served as host of three pearlfish species. Sea cucumbers that produce adhesive threads as well as those that do not were utilized as hosts. Over 100 specimens of *Holothuria atra* were opened without finding a single pearlfish. Although this species has been reported as a host, it is probably not a preferred one.

The most common species is *Carapus homei*, its usual host is *Stichopus chloronotus*. Tenuis larvae were collected from October through February. Repeated collections in the same area of Tumon Bay indicated that there was a decrease in the infestation rate after February. *C. homei* probably spawns in late summer, and the larvae assume the inquiline habit during the fall and winter months. Small samples from other parts of the island indicate that infestation rates vary with the locality.

It is unusual to find more than one pearlfish in a single host, and the fish are not confined to the respiratory trees but are often found free in the body cavity. During the period when the tenuis larvae are present *C. homei* often feeds on the larvae of its own species, perhaps indicating that there is competition for hosts. This could account for the infrequent occurrence of more than one fish per host. *Carapus homei* also eats shrimp. *Encheliophis gracilis*, however, seems to feed on the gonads of its host. *C. homei* leaves the host at night and on four occasions was seen some distance from any probable hosts.

The form called *Carapus mourlani* is structurally very similar to *C. homei* but differs in having superficial melanophores. Since *mourlani* occurs only in *Culcita* and *homei* never does, there is a possibility that the observed differences are due to the effects of the host. Until this can be demonstrated experimentally it seems desirable to retain the name *mourlani*.

IT IS WELL KNOWN that some pearlfishes (family Carapidae) dwell within the bodies of echinoderms and other invertebrates, although

few of the recognized species have been studied in detail. Arnold (1956) revised the family and thoroughly surveyed the literature but some nomenclatural problems remain, owing to the unavailability of the types of certain nominal forms. Schultz (1960:393) has emphasized the need for studies of series of specimens from various hosts ". . . in order to furnish sufficient

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information on habits and characters for proper identification of species."

Much of the difficulty in identifying pearlfishes lies in the fact that they undergo dramatic metamorphoses during their life history. Although the life histories of most pearlfishes are unknown, it is generally assumed that they are similar to that of *Carapus acus* (Brunnich), which has been studied in detail by Emery (1880) and others. The floating eggs hatch into pelagic larvae characterized by a caudal filament (Parr, 1927:133) and a remarkable dorsal appendage, the vexillum. At the end of the first (vexillifer) stage, these appendages are lost and the larva, now called a tenuis, assumes the inquiline habit. The tenuis is elongate with short rounded pectoral fins and has the anus at the rear of the body cavity. As the pearlfish transforms into its definitive form, here called the adult, the pectoral become longer, the anus moves forward, and there are marked changes in body proportions accompanied by a drastic reduction in total length. Thus, at some sizes, a given fish may be in the vexillifer or early tenuis stage, the late tenuis, or the adult stage. (See Arnold, 1956: fig. 1, and Fig. 2 of the present discussion.) Several specimens collected in Guam that seemed at first to represent a distinct species were found to be the late tenuis stages of *Carapus homei*.

In October, 1960, I found pearlfishes inhabiting the holothurian *Stichopus chloronotus* Brandt in certain areas of the fringing reefs of Guam. Periodic collections of this and other echinoderms until July, 1961, yielded 230 specimens from 567 possible hosts. Four species of carapids were represented as follows (numbers and sizes in parentheses):

<i>Encheliophis gracilis</i>	
(Bleeker)	(15, 167–220 mm)
<i>Carapus homei</i>	
(Richardson)	(208, 68–197 mm)
<i>Carapus mowlani</i> (Petit)	(5, 74–94 mm)
<i>Carapus parvipinnis</i>	
(Kaup)	(2, 63–238 mm)

Schultz (1960:392) reported *Encheliophis vermicularis* Müller from Guam, but since I have not collected it, it will be omitted in the following discussion.

NOMENCLATURE

The form referred to here as *Carapus mowlani* was considered by Arnold (1956:274) to be the same as *C. homei*. In structural features it seems to be nearly identical with *homei*, but it differs in having superficial melanophores on the head and body and it lives in the starfish *Culcita novaguineae* Müller and Troschel instead of in holothurians. If the differences are due to the effects of the different hosts these forms may be the same species, although there is still the possibility that they are reproductively isolated through active host selection. It is perhaps significant that only the *mowlani* form seems to occur in Hawaiian waters; however this could be due to the scarcity of suitable holothurian hosts. For the moment it seems preferable to follow Schultz (1960:393) in recognizing two species, although he used the name *mowlani* with some hesitation since he did not see the type which came from Madagascar. The nomenclature of other species is that of Arnold (1956).

It is usually stated that carapids have no pelvic girdles, but alizarin staining reveals the presence of small rodlike bones between the lower ends of the cleithra. These resemble the pelvic bones of *Dinematichthys* (Gosline, 1960: fig. 3b) except that there are no pelvic fins.

Alizarin staining also reveals a row of deeply imbedded plaques along the lateral line. These seem to be vestigial scales and are found in *Encheliophis gracilis*, *Carapus mowlani*, *C. homei*, and in a slightly different form in *C. parvipinnis*.

The five species reported from Guam can be distinguished by means of the following key and the features summarized in Table 1.

HOSTS

Pearlfishes were found in four species of holothurians and in the pillow starfish, *Culcita novaguineae*. Occasional sampling of nine other species of holothurians revealed no inquilines but the numbers sampled (except *Holothuria atra*, see below) were small and low incidences could have been missed. The numbers of hosts examined and inquilines found are summarized in Table 2.

KEY TO THE PEARLFISHES OF GUAM

- A. Maxilla adnate to the suborbital.....*Encheliophis* B
 Maxilla not adnate to the suborbital; separated from it by a deep groove.....*Carapus* C
- B. Pectoral fins absent.....*Encheliophis vermicularis*
 Pectoral fins present.....*Encheliophis gracilis*
- C. Body everywhere covered with fine punctulations, each a single melanophore. These are in several layers and are present in the skin covering the eye. Pectoral fins reduced, almost vestigial, less than $\frac{1}{3}$ head length.....*Carapus parvipinnis*
 Melanophores not as above. Pectoral well-developed, more than $\frac{1}{3}$ the head length.....D
- D. Body without superficial melanophores, although the meninges and peritoneum are pigmented and there is a row of deep melanophores along the base of the anal fin and on the back of the skull, the nasal capsule, the lower and upper jaws. There are usually one or two conspicuous melanophores near the upper end of the ceratohyal....*Carapus homei*
 Body with definite but sparse superficial melanophores in addition to those of the meninges and the peritoneum. Melanophores of the head not as above.....*Carapus mourlani*

TABLE 1^a

DISTINGUISHING CHARACTERISTICS OF FOUR SPECIES OF PEARLFISHES FROM GUAM

CHARACTER	<i>Encheliophis gracilis</i>	<i>Carapus parvipinnis</i>	<i>Carapus homei</i>	<i>Carapus mourlani</i>
Maxillary bone	adnate	free	free	free
Eye	large	tiny	moderate	moderate
Pectoral fins	large, $\frac{1}{3}$ head	tiny, $\frac{1}{4}$ – $\frac{1}{3}$ head	large, $\frac{1}{2}$ head	large, about $\frac{1}{2}$ head
Reverted lower lip	absent	present	present	present
Gill membranes	broadly united	slightly united	slightly united	slightly united
Gill opening extends above pectoral base	no	yes	yes	yes
Body shape	slightly compressed	terete	compressed	compressed
Superficial melanophores	present, 1 layer	present, several layers	absent	present, 1 layer
Countershading	present	absent	absent	present
Head pigment:				
cornea	no	yes	no	no
nasal capsule	no	no	yes	no
occiput	not definite	not definite	definite	not definite
lower jaw	yes	yes	no	no
ceratohyal	absent	absent	present	absent
Teeth on jaws	1 row	2 series	2 series	2 series
Host	Holothurians	Holothurians	Holothurians	<i>Culcita</i>

It is of interest that only *Carapus mourlani* enjoyed an exclusive relationship with its host. All of the other three species occurred in two or more hosts. Perhaps this indicates that the utilization of a starfish as a host is a recent development and only this form has been able to make the necessary physiological adjustments. Other aspects of this relationship will be discussed later.

Stichopus chloronotus Brandt probably serves normally as host of only *Carapus homei*. The

single specimen of *Encheliophis* found in this species could have come from a *Holothuria argus* Jaeger that had been placed in the same container with the *Stichopus*. There is no doubt, however, that *H. argus* serves as host to three species (*E. gracilis*, *C. homei*, and *C. parvipinnis*) since some of the collections contained only this host.

Holothuria sp. (a stout-bodied, thread producing, burrowing form, whitish in color with two broad brownish transverse bands on the

TABLE 2
HOST SPECIFICITY IN SOME GUAM PEARLFISHES

INQUILINE	N	HOST SPECIES				
		<i>Stichopus chloronotus</i>	<i>Thelenota ananas</i>	<i>Hol. argus</i>	<i>Hol. species</i>	<i>Calcuta novaguineae</i>
<i>Encheliophis gracilis</i>	15	1	—	12	2	—
<i>Carapus parvipinnis</i>	2	—	1	1	—	—
<i>Carapus homei</i>	208	187	—	21	—	—
<i>Carapus mourlani</i>	5	—	—	—	—	5
None	—	196	0	17	17	9
Total	230	384	1	51	19	14

dorsal surface) harbored only *Encheliophis gracilis*. *Thelenota ananas* (Jaeger) contained only *Carapus parvipinnis*, although in the latter case only one specimen was examined. Both of these hosts have habits that may impose limits on the species of inquilines inhabiting them; *Thelenota* lives in deeper water off the edge of the reef and the *Holothuria* burrows in sandy areas of the moat.

Holothuria atra has been reported as a pearlfish host but it seems to be, at best, a second choice. In Tumon Bay, Guam, I examined 107 *atra* without finding any pearlfishes, although more than 80% of the *Stichopus chloronotus* from the same part of the bay contained *Carapus homei*. There is some difference in the habitats of these two holothurians; *atra* is most abundant in quiet, shallow, sandy parts of the moat, whereas *Stichopus* lives on harder bottom near the edge of the reef where there is a good flow of fresh sea water. The ranges of the two overlap, however, and I have observed *C. homei* at night in places where *atra* was more common than *Stichopus*. The suggestion that *H. atra* is not a preferred host is supported by Bonham's statement (1960:255) that no pearlfishes were found in several hundred *atra* from the Marshall Islands, although there was a *Carapus homei* in the single *Stichopus* he examined. Strasburg (1961:479) also reported a low incidence of *Encheliophis gracilis* in *H. atra* from Hawaii (one pearlfish in 114 *atra* examined).

The ability of some holothurians to produce adhesive threads when molested might be pos-

tulated as a factor in their suitability as a pearlfish host. *Holothuria argus* and *Holothuria* sp. are thread producers; *Thelenota ananas* and *Stichopus chloronotus* are not. Thus, it appears that *Carapus homei* and *C. parvipinnis* are found in both types but *Encheliophis gracilis* shows a preference for thread producers. *Holothuria atra*, occasionally reported as the host of *Encheliophis gracilis* (Strasburg, 1961:479; Schultz, 1960:393) and *E. vermicularis* (Schultz, 1960:393), is not a thread producer but the incidence of pearlfishes in that species is low.

When the host is cut open the violent movements of the fish make it difficult to determine the original location of the fish within the host. Most individuals seemed to be free in the body cavity but a few were in the respiratory trees and some of these became so wedged in that the section with the fish could be removed and preserved in formalin without the fish freeing itself. Bonham (1960:255) carefully floated the host into a plastic bag and froze it before opening so as to avoid any disturbance. With these precautions he found the fish free in the body cavity. Some species of pearlfishes appear to feed on the viscera of the holothurian and therefore must leave the respiratory trees. *Carapus mourlani* is found free in the coelom of its starfish host which, of course, has no respiratory trees. Thus, it appears that these species, at least, are not confined to the respiratory tubes but are able to insinuate themselves into the body cavity.

Aronson and Mosher (1951:489) reported

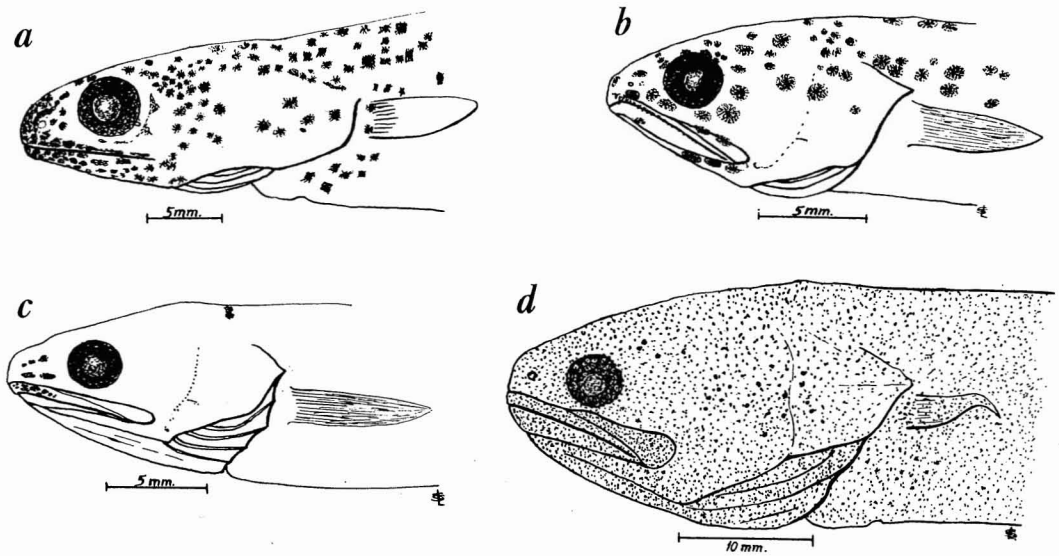


FIG. 1. Heads of four species of pearlfishes from Guam. *a*, *Encheliophis gracilis*, total length 182 mm. *b*, *Carapus mourlani*, 91 mm. *c*, *Carapus homei*, 113 mm. *d*, *Carapus parvipinnis*, 238 mm.

finding as many as five *Carapus (bermudensis)* in a single holothurian host in the Bahamas, but I have never seen more than two in an individual host. Moreover, the total number of inquilines never exceeded the total number of hosts in any one collection. It is possible, then, that some of the few "twins" observed may have been postcapture transfers.

SEASONAL VARIATIONS

Repeated collections in Tumon Bay indicate that there is a decrease in rate of infestation from November to June (Table 3). It is suggested that this is not due to sampling error alone, because only the collections made from November to February contained tenuis larvae. This would seem to indicate that the tenuis enter the host during the late fall and winter months and at that time there is a high rate of infestation. As the season progresses there is loss through mortality and the incidence decreases. It would be of interest to follow this through several complete cycles to obtain data on recruitment and mortality rates.

There are also different rates of infestation in different areas of the reefs (Table 4). This variation is not correlated with the abundance

of the hosts because all areas have approximately the same density of hosts except Asan. The Asan area is peculiar in that there is a very strong flow of water over the edge of the reef and a dense population of *Stichopus chloronotus*. Aronson and Mosher (1951:489) also reported different levels of pearlfish infestation in different parts of the Bimini harbour.

ACTIVITY OUTSIDE OF THE HOST

It has been suggested that some pearlfishes never leave the host unless it eviscerates, but this is certainly not true of *Carapus homei* or *Encheliophis gracilis*. *C. homei* seems to leave the host regularly during the night and on four occasions I observed free swimming individuals between 9 and 11 P.M. One of these was taken in a commercial fisherman's beach seine; the others were seen hovering about 18 inches above the bottom in water 3 or 4 ft deep. The fish, observed as I swam along with an underwater flashlight and a face mask, remained motionless until I came within a foot or two of them. I was able to catch one in a hand net; the others escaped. In neither of the latter cases was there a *Stichopus* host nearby and my efforts to chase one into a host were unsuccessful.

TABLE 3

SEASONAL VARIATION IN RATES OF INFESTATION OF TUMON BAY *Stichopus chloronotus* (All hosts were collected in the same part of the bay.)

MONTH	NUMBER OF <i>Stichopus</i>	% WITH <i>Carapus homei</i>
November 1960	24	88
December 1960	102	84
January 1961	14	71
February 1961	37	76
March 1961	10	80
April 1961	—	—
May 1961	25	16
June 1961	16	31

An individual removed from its host during daylight hours attempted to re-enter the slit and eviscerated body of the holothurian. It was easily captured by hand and made no effort to escape from my closed fist. The observations of pearlfish out of the hosts at night did not seem to be related to any unusual conditions, and the scarcity of such observations is probably due to the limited time spent on the reefs at night.

On one occasion I was told of an *Encheliophis gracilis* observed entering an unidentified sea cucumber about three o'clock in the afternoon. The host was opened and the fish was recovered.

LIFE HISTORY

Arnold (1956) has summarized the life history of *Carapus acus* and the observations recorded here only serve to indicate that the life history of *C. homei* is generally similar. Tenuis larvae of *homei* were found in *Stichopus chloronotus* from October to February, and posttenuis stages were collected until May. None of the

TABLE 4

VARIATION IN INFESTATION RATE BY LOCALITY

LOCALITY	DATE	NO. <i>Stichopus chloronotus</i>	% WITH <i>Carapus homei</i>
Tumon Bay	Nov.—June	228	av. 63
Piti	Mar. 18	22	0
Asan	Feb. 28	89	9
Merizo	Jan. 28	29	14
Togcha	Dec. 23	5	av. 46
	May 14	8	

homei taken during this study (October to July) had maturing gonads, indicating that spawning takes place during the summer months as in the case of *C. acus*.

Transformation from the tenuis to the adult form is accompanied by a considerable reduction in total length. The longest tenuis was 197 mm, the shortest adult 69 mm, suggesting that they may lose as much as 65% of their length during transformation. Figure 5 shows the changes in head length—body length ratio accompanying the transformation from tenuis to adult.

Two female *Encheliophis gracilis* with nearly ripe ovaries were collected February 23 and May 26. The February specimen, 217 mm long, had a single developed ovary 16 × 11 × 6.5 mm. A rough count places the number of oocytes of the largest class at approximately 14,000. Several other size classes are distinguishable. The May specimen is 186 mm long, its ovary is 11.6 × 7.5 × 3.6 mm. In view of the structural distinctness of *Encheliophis* it is unfortunate that its life history remains unknown.

FOOD HABITS

Stomachs of 185 pearlfishes were examined with the following results:

<i>Encheliophis gracilis</i>	11 examined
empty	6
holothurian viscera	4
unidentified remains	1
<i>Carapus parvipinnis</i>	1 examined
empty	1
<i>Carapus mourlani</i>	5 examined
empty	5
<i>Carapus homei</i>	168 examined
empty	127 (75.6%)
<i>C. homei</i> tenuis	19 (11.3%)
shrimp	12 (7.2%)
unidentified fish	5 (3.0%)
<i>C. homei</i> adult	1 (.6%)
shrimp and fish	2 (1.2%)
unidentified remains	2 (1.2%)

The stomachs of *Encheliophis gracilis* that contained what appeared to be holothurian viscera were very full and considerably distended. This threadlike material has been identified from histological sections as testis tissue. Stras-

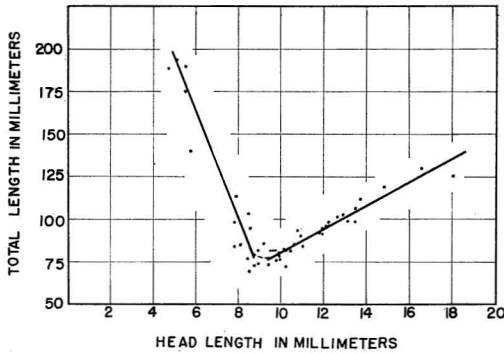


FIG. 2. Relationship between body length and head length in *Carapus homei*. Straight lines have been fitted by inspection, considering the late tenuis and definitive forms as discrete growth stanzas.

burg (1961:479) found similar material in the stomachs of Hawaiian specimens.

Neither Strasburg nor I found any food in the stomachs of the *Carapus* recovered from the pillow starfish. The specimens from Guam all appeared emaciated, leading one to wonder if *Culcita* could be an abnormal host which is frequently though accidentally invaded and from which there is no escape. If this is so, perhaps the distinctive melanophore pattern of *C. mourlani* is merely part of a starvation syndrome and the "species" *mourlani* is nothing more than those individuals of *C. homei* that chance to enter the wrong host. The simple experiments necessary to confirm or reject this hypothesis have yet to be performed.

All of the *Carapus homei* with tenuis larvae in their stomachs were collected from November through February, when the larvae are assuming the inquiline habit. Eight out of 15 specimens collected November 25 had fed on tenuis larvae. Apparently there is intense competition for hosts at that time and any larva that enters an occupied host may be eaten. The presence of an adult in another's stomach indicates that even the later stages are subject to this hazard.

Since the larva is longer than the adult, stomachs containing larvae were greatly distended. The head usually appeared to be in a more advanced stage of digestion, indicating that consumption of the larva requires a considerable period of time. One specimen had 29 mm of the tail of the larva still protruding from its mouth.

The presence of shrimp in the stomachs of *C. homei* is further evidence that this species leaves the host to feed.

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