

S. RADHAKRISHNAN, N.B. NAIR

Parasitology

NATURE OF CRUSTACEAN INFESTATION
OF FISHES ALONG THE SOUTH-WEST COAST OF INDIA
I. DISTRIBUTION, MODE OF ATTACHMENT TO THE HOST TISSUE
AND INCIDENCE AND INTENSITY OF INFESTATION

WŁAŚCIWOŚCI ZARAŻENIA SKORUPIAKAMI RYB
U WYBRZEŻY POŁUDNIOWO-ZACHODNICH INDII
I. ROZPRZESTRZENIENIA, SPOSÓB ATAKOWANIA TKANEK ŻYWICIELA,
EKSTENSYWNOŚĆ I INTENSYWNOŚĆ ZARAŻENIA

Department of Aquatica Biology and Fisheries
University of Kerala, Trivandrum, India

The distribution of the parasites on the host, their mode of attachment to the host tissue, and the incidence and intensity of infestation of 17 species of copepods belonging to eight families and of four species of isopods belonging to the family *Cymothoidae* infesting 12 species of marine fishes along the South-west (Trivandrum) coast of India are described.

The parasites show host specificity and they are highly selective as to the of attachment on the host. Incidence and intensity of infestation of the majority of the parasites examined are higher in the female fish than in the male.

INTRODUCTION

Crustaceans as parasites of fishes received scientific attention quite early in the history of fish parasitology. The works of parasitologists have revealed that crustaceans, in

particular the members of the order *Copepoda*, play a major double role, as obligatory parasites and as intermediate hosts of a wide spectrum of other fish parasites, both in the wild and in captive fish populations. Much emphasis has been placed on copepod parasites, probably because they represent a major group of parasites of commercially important fishes. The order *Copepoda* is rich not only in the number of species represented but also in the number of individuals, in all aquatic habitats. It is, therefore, not surprising that a large number of parasites occur among them.

While *Copepoda*, undoubtedly, is the largest group of crustacean parasites of fishes, members of other groups such as *Branchiura*, *Cirripedia*, *Isopoda* and *Amphipoda* also have parasitic representatives. Kabata (1970) has given an account of the different crustacean parasites of fishes and has discussed the 'role of Crustacea as enemies of fishes'.

The large volume of literature accumulated around the crustacean parasites of fishes has until recently been purely taxonomical in nature. As Kabata (loc. cit.) has rightly put it "...next to nothing is known about their biology and about the most important factors regulating their relationships with the fish hosts". It is now established that crustacean parasites have severe effects on their hosts. Meyer (1966) was emphatic in stating that "...few, if any, groups of parasites cause greater economic losses to the American fish farmer than parasitic copepods". Fish pathologists, world over, have, during the past few decades, done commendable work in assessing the nature of attack of crustacean parasites on fishes. In India even preliminary work on fish pathology is yet to pick up pace, not to speak of the several aspects of crustacean infestations alone.

From India the pioneer contribution towards an understanding of the host-parasite relationship between copepod parasites and their marine fish hosts along the South-west coast has been that of Natarajan (1975). In the present work Natarajan's study is extended to other species of copepods as well as to some isopod species.

MATERIALS AND METHODS

The following species of fishes were collected from the major landing centres along the South-west coast of India.

Diodon hystrix Linnaeus; *Trichiurus lepturus* Cuvier; *Saurida tumbil* (Bloch); *Chirocentrus dorab* (Forsk.); *Parastromateus niger* (Bloch); *Hemirhamphus xanthopterus* (Val.); *Hemirhamphus far* Forskal; *Mugil cunnesius* Smith; *Epinepheles malabaricus* (Val.); *Nemipterus japonicus* (Bloch); *Narcine tinglei* (Bloch & Schn.); *Himantura bleekeri* (Blyth).

The standard length, the weight and the sex of the fishes were recorded. A thorough examination of the skin, fins, branchial cavity, gills and the buccal cavity of the specimens was then made. The number, position of attachment, and the orientation of the parasites on the body of the fish were recorded for each kind of parasite on each fish. The data thus obtained were later processed for calculating the incidence and intensity of

infestation. The mature of attachment of the parasites to the host tissue was studied with the aid of whole mounts as well as from serial sections of the concerned tissue with the parasite *in situ*.

RESULTS

During the present study 21 species of crustacean parasites – 17 species of copepods and four of isopods – were collected from 12 species of fishes (Table 1). Ten species of copepods confined their attack to the gills – five each to the gill filaments and the gill arches. Three species were found to penetrate into the body of the hosts, two were collected from the buccal cavity while two were noted on the fins. Of the four species of isopods, two were collected from the buccal cavity, one from the branchial chamber and one from the body surface.

Nature of distribution and mode of attachment of copepods parasitic on gill filaments

Ergasilus sp. (lizae?)

A large number of *Ergasilus sp.* was obtained from the gills of *Mugil cunnesius*. The outer lateral narrow margins* of both the outer and the inner gill filaments of all the holobranchs on both sides harboured the parasite. However, the incidence was more on the outer gill filaments. Even though the parasites attach to any part along the length of the narrow margin of the filaments, they showed an affinity to the middle region – both the extreme base and extreme tip being free from infestation. Save a few scattered ones on the filaments of the buccal half of the gills, all parasites were found attached to those of the pharyngeal half. Except in a few cases of heavy infestation, the fourth holobranch on both sides was found to be free of parasites.

Usually specimens of *Ergasilus sp.* attach to the narrow lateral margins of the gill filaments. Very rarely, however, in our collection, the parasites were found to attach to the broad margins also.

The attachment of *Ergasilus sp.* is accomplished with the aid of the second antennae which are modified into stout, curved, prehensile claws. The hook-like claws, with their distal segments twisted slightly inwards, are thrust between the gill filaments and the distal pointed segments are hooked on to the broad margins of the filament. The parasite thus seems to be embracing the gill filament with outstretched claws (Fig. 1). The parasite

* Throughout the text the outer lateral narrow margin of the primary gill filament refers to that margin bearing the efferent filamentar blood vessel and the inner lateral narrow margin refers to that margin bearing the afferent filamentar blood vessel. Thus the inner lateral narrow margins of the outer and the inner gill filaments face each other.

Table 1

Crustacean parasites collected during the present study with their host fish and site of infestation

Sl. No.	Parasite	Host fish	Site of infestation
COPEPODS			
1	<i>Ergasilus</i> sp.	<i>Mugil cunnesius</i>	Gill filaments
2	<i>Lernathropus gibbosus</i>	<i>Saurida tumbil</i>	"
3	<i>Lernanthropus koenigii</i>	<i>Parastromateus niger</i>	"
4	<i>Taeniocanthus narcini</i>	<i>Narcine timlei</i>	"
5	<i>Bomolochus hemirhamphi</i>	<i>Hemirhamphus xanthopterus</i>	"
6	<i>Thysanote appendiculata</i>	<i>Parastromateus niger</i>	Gill arch
7	<i>Isobranchia appendiculata</i>	<i>Chirocentrus dorab</i>	"
8	<i>Brachiella trichiuri</i>	<i>Trichiurus lepturus</i>	"
9	<i>Pseudocharopinus narcinae</i>	<i>Narcine timlei</i>	"
10	<i>Paenodes mugilis</i>	<i>Mugil cunnesius</i>	"
11	<i>Caligus uruguayensis</i>	<i>Trichiurus lepturus</i>	Buccal cavity
12	<i>Synestius caliginus</i>	<i>Parastromateus niger</i>	"
13	<i>Lernaeenicus hemirhamphi</i>	<i>Hemirhamphus xanthopterus</i>	Body proper
14	<i>Lernaeenicus</i> sp. (R.N.-1)	<i>Epinephelus malabaricus</i>	"
15	<i>Peniculus trichiuri</i>	<i>Trichiurus lepturus</i>	"
16	<i>Peniculisa wilsoni</i>	<i>Diodon hystrix</i>	Fin
17	<i>Pseudocharopinus dasyaticus</i>	<i>Himantura bleekeri</i>	Body margin
ISOPODS			
1	<i>Cymothoa eremita</i>	<i>Parastromateus niger</i>	Buccal cavity
2	<i>Codonophilus</i> sp. (R.N.-2)	<i>Hemirhamphus xanthopterus</i>	"
3	<i>Irona far</i>	<i>Hemirhamphus far</i>	Branchial chamber
4	<i>Livoneca</i> sp.	<i>Nemipterus japonicus</i>	Body proper

is often found attached at an angle to the long axis of the filament — its head pointing to the base of the filament — so that the anterior two thirds of the parasite is closely applied to the lateral narrow margin of the gill filament.

As many as four parasites were found to attack the same gill filament, at different levels along its length. No single parasite was seen to attach to more than one filament at a time.

Lernanthropus gibbosus Pillai and *L. koenigii* Stp. & Lutk.

L. gibbosus is parasitic on the gill filaments of *Saurida tumbil* and *L. koenigii* of *Parastromateus niger*. *L. gibbosus* attaches itself to the inner narrow margins of the inner gill filaments. The parasite was found to show preference for the basal on third portion of the gill filaments of all holobranchs, with preference for the first and second holobranchs. Usually the long egg sacs, and occasionally the modified third and fourth legs, of the parasite are seen projecting beyond the gill filament. Two adjacent parasites on any holobranch were seen to be separated by as many as 7 to 15 gill filaments (Fig. 5).

The second antennae are the main organs of attachment. These are assisted by the maxillipeds. The second antennae are thrust through the broad margins of the gill filaments and they pierce the gill ray. The lateral extension of the carapace, which are folded over and gripped on to the broad margins of the gill filament, also assist in attachment (Figs. 2 & 3).

The distribution of the parasites on the gills is in such a way that one gill filament harbours only one parasite.

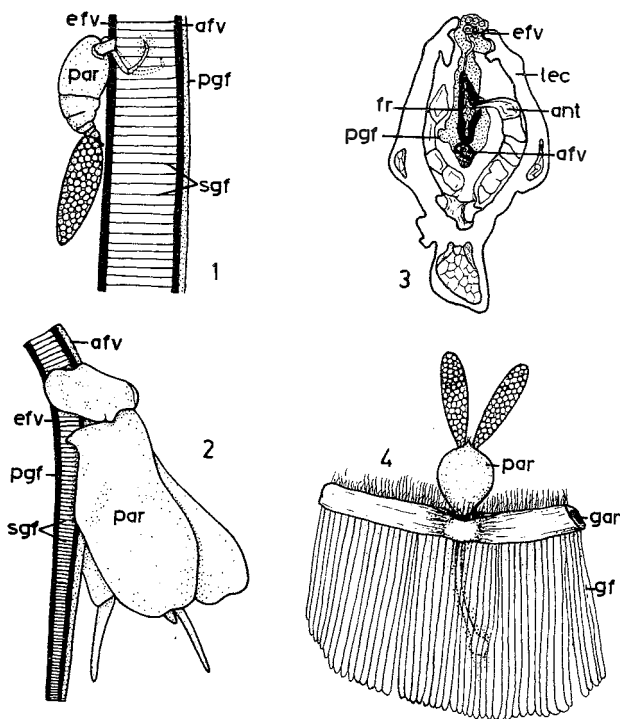
L. koenigii attaches itself to the outer narrow margins of the outer as well as the inner narrow margins of the inner gill filaments. Incidence was more on the first and second holobranchs. One gill filament was seen to be attacked by only one parasite. However, unlike *L. gibbosus*, specimens of *L. koenigii* were found attached at various levels along the length of the gill filament, and a sort of crowding was discernible, as adjacent gill filaments are attacked by the parasite (Fig. 6). Organs and mode of attachment of *L. koenigii* are similar to those of *L. gibbosus*.

Taeniacanthus narcini Pillai

Four specimens of *T. narcini* were collected from the gills of *Narcine timlei*. These parasites were found very loosely attached to the broad margin of the gill filament. The triangular, cup-like carapace acts as an efficient sucking disc which ensures a firm grip by assisting the prehension by the second antennae.

Bomolochus hemirhamphi (Pillai)

Three specimens of *B. hemirhamphi* were obtained from the gills of *Hemirhamphus xanthopterus*. This is reported to be a parasite in the branchial chamber (Pillai, 1967). During the present study the three specimens were recovered from the gill filaments of the first holobranch on the left side of the fish. Since the parasites could not be obtained intact with the gill filaments, the nature of attachment could not be studied. The



Figs. 1–4. Semidiagrammatic sketches showing attachment of *Ergasilus* sp. (1), *Lernanthropus gibbosus* (2,3), and *Paeonodes mugilis* (4).

afv – afferent filamentar vessel; ant – second antenna; efv – efferent filamentar vessel; fr – filamentar ray; gar – gill arch; gf – gill filament; lec – lateral extension of carapace; par – parasite; pgf – primary gill filament; sgf – secondary gill filament.

hemispherical carapace and the strongly curved accessory process of the claw of the maxilliped are the organs of attachment.

Nature of distribution and mode of attachment of copepods parasitic on the gill arch

Thysanote appendiculata (Stp. & Lutk.), *Isobranchia appendiculata* Heegaard, *Brachiella trichiuri* Gnanamuthu, *Pseudocharopinus narcinae* (Pillai) and *Paeonodes mugilis* Jayasree and Pillai 1978, are the copepods recovered from the gill arches of fishes during the present study.

The mode of attachment of the first three parasites has been studied in detail by Natarajan (1975). Since significant differences from Natarajan's observations as to the nature of distribution of these parasites were noticed by us, this aspect is presented below.

Thysanote appendiculata (Stp. & Lutk.)

T. appendiculata was found to infest all along the length of the gill arch of *P. niger*, no preference to any particular region of the gill arch being evident. Highest incidence was on the first gill arch and some specimens were found attached to the inner wall of the operculum.

Isobranchia appendiculata Heegaard

Specimens of *I. appendiculata* were obtained solely from the gill arch of *C. dorab*, none being found in the buccal cavity. The parasite showed preference for the second and third gill arches; the first and the fourth being free from attack. Unlike *T. appendiculata*, these parasites were highly selective for the site of attachment on the gill arch since they restricted their attack exclusively to the middle part of the gill arch at the region of the bend of the gill.

Brachiella trichiuri Gnanamuthu

Except for two specimens on the buccal floor, specimens of *B. trichiuri* were found attached exclusively to the symphyses of the gills of *Trichiurus lepturus*. Even though both the lower and upper symphyses are invaded by the parasite, the latter showed higher incidence.

The mode of attachment of these three parasites is similar. The second maxillae are greatly enlarged and modified into the so-called arms bearing a bulla at their tips. The size of the second maxillae and the size shape of the bullae of the three parasites differ as observed by Natarajan (1975). The bulla is injected into the soft tissue of the host and the irritation caused by this results in the formation of a tumour of attachment in the host tissue, which grows over the bulla providing additional anchorage to the parasite (Figs. 11, 12, & 13). The size of the bulla is small in *T. lepturus* while it is large and conspicuous in *C. dorab* and *P. niger*.

Pseudocharopinus narcinae (Pillai)

P. narcinae attaches itself usually to the gill arch of *Narcine timlei*. Occasionally, however, the gill filaments are also invaded. No preference for any particular gill arch or for any particular site on the gill arch was observed. On the gill filaments, the parasite prefers to attach towards the base nearer to the gill arch. The second maxillae are very long, united at their tips, bearing a boat-shaped bulla. The tumour of attachment is quite conspicuous (Fig. 14).

Paenonodes mugilis Jayasree and Pillai

Four specimens of *P. mugilis* were collected from the first and second gill arches of a specimen of *Mugil cunnesius*. The parasite has a very long neck, nearly three times as long as the body. The head penetrates the soft tissue of the gill arch and it is anchored at the basal part of the gill filaments, only the body proper with the egg sacs protruding beyond the gill arch (Fig. 4). The diameter of the hole bored through the soft tissue of the gill

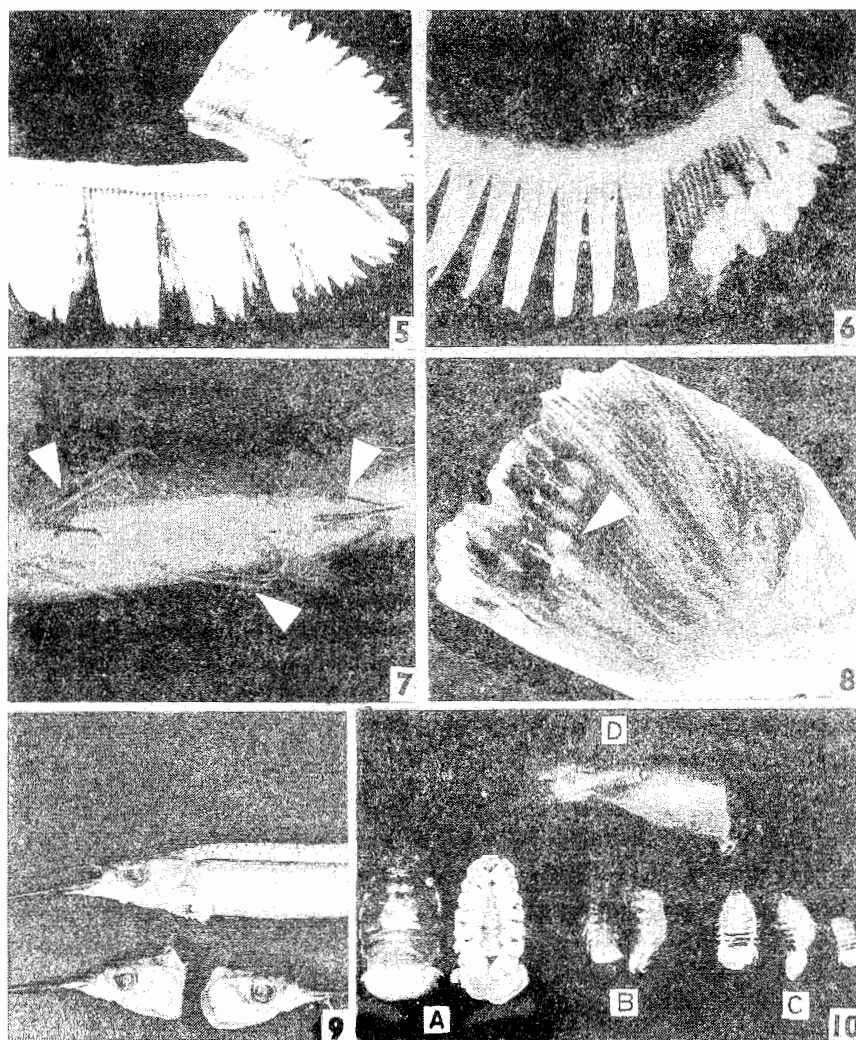


Fig. 5. Gill of *Saurida tumbil* infested by *Lernanthropus gibbosus*

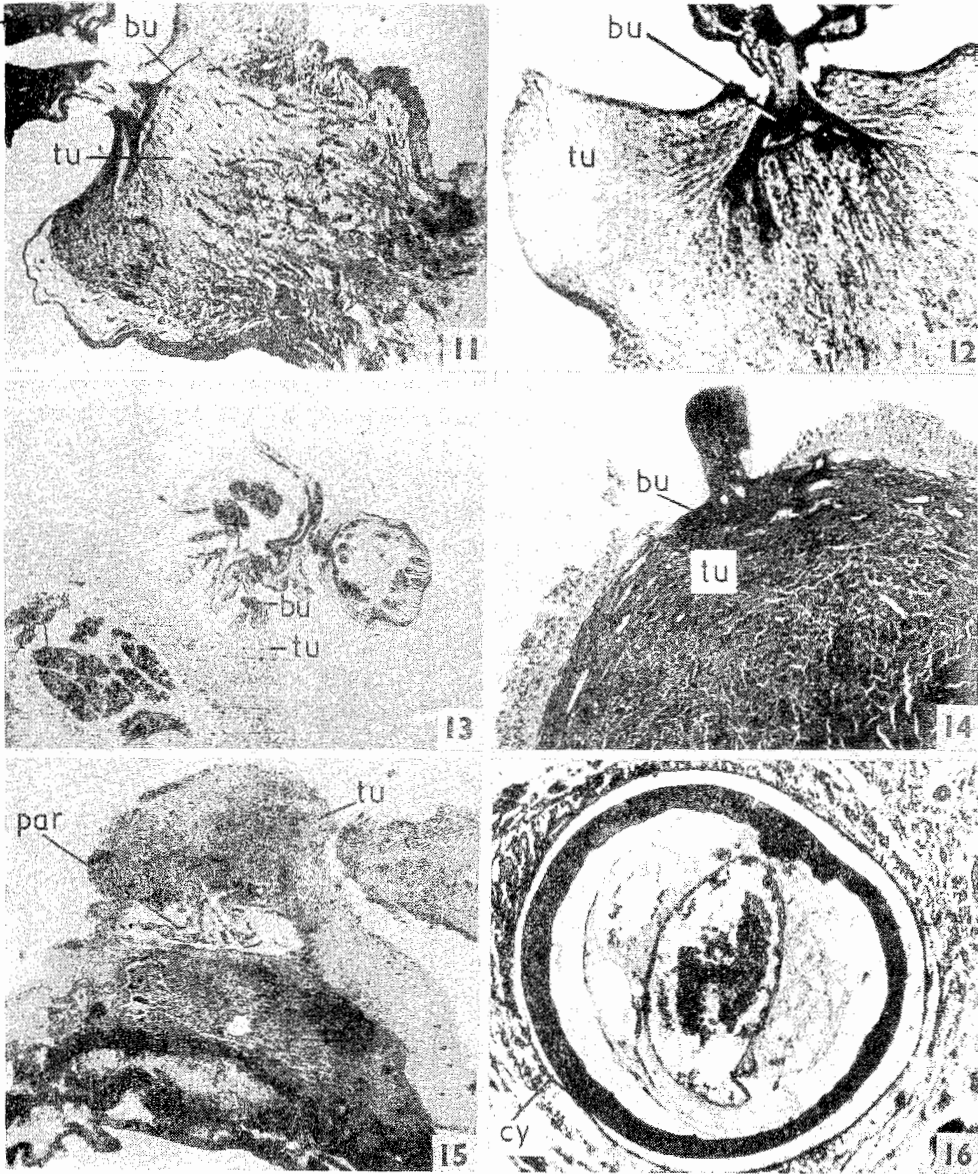
Fig. 6. Gill of *Parastromateus niger* infested by *Lernanthropus koenigii*.

Fig. 7. Ventral view of the body of *Hemirhamphus xanthopterus* infested by *Lernaeenicus hemirhamphi* (arrow heads)

Fig. 8. Anal fin of *Diodon hystrix* infested by *Peniculisa wilsoni*. Note tumorous growth (arrow head) at the site of attachment of the parasite

Fig. 9. Lateral view of *Hemirhamphus far* infested by a female *Irona far*, in the branchial cavity

Fig. 10. Isopod parasites – A – *Cymothoa eremita*, B – *Codonophilus* sp., C – *Irona far* (two females and a male), D – *Livoneca* sp. at the tail region of *Nemipterus japonicus*.



Figs. 11–14. Photomicrographs showing bulla (bu) and tumour of attachment (tu) of *Thysanote appendiculata* (11) x 60; *Isobranchia appendiculata* (12) x 60; *Brachiella trichiuri* (13) x 40 and *Pseudoscharopinus narcinae* (14) x 60

Fig. 15. Section of the tumorous growth (tu) induced by *Caligus uruguayensis* (par) on the buccal mucosa of *Trichiurus lepturus* x 40

Fig. 16. Section of the kidney of *Hemirhamphus xanthopterus* showing the cyst (cy) formed around the cephalothorax of *Lernaeenicus hemirhamphi* x 100

arch, accommodating a part of the neck of the parasite, is much smaller than that of both the head and the trunk. This helps to hold the parasite in position on the gill. The second antennae are stout and, as in ergasilids, these are the chief, if not the only, prehensile organs. Whether or not the parasite shifts the position of its head on the gill filament is not clear. Since the neck of the parasite is capable of easy to and fro movement within the burrow in the soft tissue of the gill arch it seems reasonable to assume that the parasite may shift the position of its head on the gill filament. It is noteworthy in this context that in all the four parasites, the anterior tip of the trunk was in close contact with the outer margin of the gill arch and that the head was attached at the maximum distance determined by the length of the neck of the parasite.

Nature of distribution and mode of attachment of copepods parasitic in the buccal cavity

Caligus uruguayensis Thomsen and *Synestius caliginus* (Stp. & Lutk.) were found to invade the buccal cavity of *T. lepturus* and *P. niger* respectively. Two specimens of *Brachiella trichiuri* Gnanamuthu, which normally attach themselves to the gill arch, were also obtained from the buccal cavity of *T. lepturus*.

Caligus uruguayensis Thomsen

Specimens of *C. uruguayensis* were found attached to the floor of the buccal cavity of *T. lepturus*, with the cephalothorax directed towards the anterior end of the fish. The second antennae and the maxillipeds are the main organs of attachment. The carapace, acting like a sucking disc, also helps in the attachment of the parasite. Penetration of the antennae and maxillipeds into the buccal mucosa irritates the host tissue, which proliferates to form a tumorous growth, ranging in size from a slight thickening to a conspicuous bulge. Occasionally the anterior part of the cephalothorax of the parasite becomes embedded in the tumour (Fig. 15).

Synestius caliginus (Stp. & Lutk.)

Specimens of *S. caliginus* were found embedded in the brushlike pads on the roof of the buccal cavity of *P. niger*. The parasites were seen buried among the bristles of the pad. The maxillipeds, which are unusually large, serve to cling on to the bristles.

Brachiella trichiuri Gnanamuthu

The mode of attachment of *B. trichiuri* to the buccal roof is similar to that to the gill arch. The tumour of attachment induced on the buccal roof is, however, small as noted by Natarajan (1975).

Nature of distribution and mode of attachment
of copepods parasitic on the body proper

Lernaeenicus hemirhamphi Kirtisinghe, *Lernaeenicus* sp. (R.N.1)* and *Peniculus trichiuri* Gnanamuthu were collected from the body surface of *Hemirhamphus xanthopterus* and *H. far*, *Epinepheles malabaricus* and *Trichiurus lepturus* respectively.

Lernaeenicus hemirhamphi Kirtisinghe

L. hemirhamphi infests the body of *H. xanthopterus* and *H. far*, showing preference for the lateral and ventral (especially the base of the pelvic fins) sides of the body (Fig. 7). The modified cephalothorax of the parasite is embedded in some important visceral organ of the fish – the point of anchoring of the cephalothorax always being anterior to the point of penetration on the body wall. A part of the neck, genital segment, abdomen and the egg strings of the parasite project out of the body surface of the host.

The organ of attachment is the modified cephalothorax, which is triangular in shape and provided with three identical horns. The cephalothorax with the horns functions as an anchor which anchors itself in any vital visceral organ or in the muscle. A fibrous connective tissue cyst formed around the cephalothorax, as a defense mechanism of the host, adds to the firm anchorage of the parasite to the host tissue (Fig. 16).

Lernaeenicus sp. (R.N.1)

Two specimens of *Lernaeenicus* sp. were obtained from the body surface of a specimen of *E. malabaricus*. The parasites, one adult female and one juvenile, were found attached to the posterior, dorso-lateral surface on the right side of the host. The head of the parasite, provided with branched horns, is embedded in the trunk muscle of the fish. The parasite thus attached to the host, like a plant rooted in soil, establishes such a firm foot-hold that even when carefully pulled out of the host tissue it carries the surrounding muscle tissue also of the host.

Peniculus trichiuri Gnanamuthu

Only one instance of parasitisation by *P. trichiuri* of *T. lepturus* was noted during the present study. The parasite was found attached to the postero-lateral side of the host. Details regarding the nature of attachment of the parasite could not be studied.

* According to the Zoological Nomenclature Code, the appearance of *Lernaeenicus* n.sp. in the text as used by the authors, without giving the full name and description, would result in a *nomen nudum*. Therefore the Editor has decided to use only the name of *Lernaeenicus* sp. (R.N.-1), thus announcing the future description of the species as the new one by the authors.

Nature of distribution and mode of attachment
of copepods parasitic on fins

Peniculisa wilsoni Radhakrishnan

Heavy infestation by *P. wilsoni* was observed on the caudal and pectoral fins of *Diodon hystrix*. The most preferred site of attachment is the thin distal part of the fin (Fig. 8).

The second antennae, which grip the fin ray like a vice are the main organs of attachment (Fig. 17). A chitinous, globular thickening develops around the tip of each antenna and the distal end of the thickenings fuse with the outer surface of the fin ray. The soft tissue of the host around the point of attachment proliferates to form a

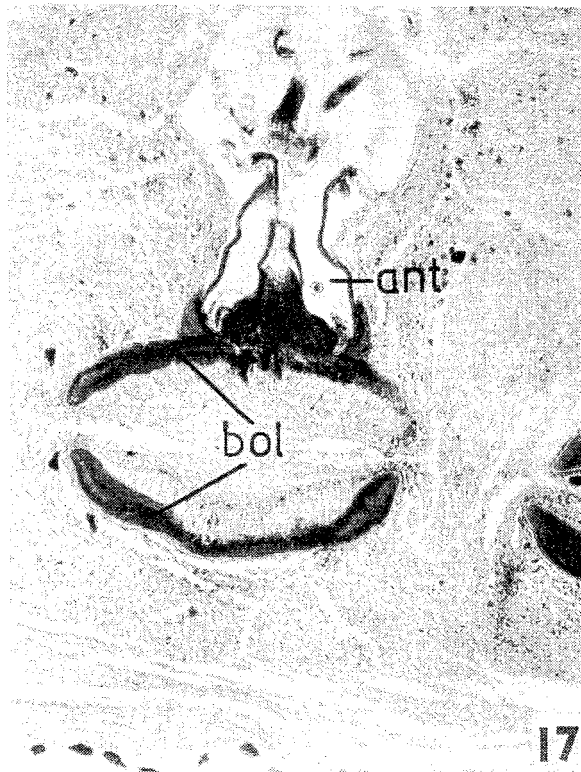


Fig. 17. T.S. of the fin of *Diodon hystrix* showing attachment of *Peniculisa wilsoni*. Note the second antenna (ant) of the parasite gripping the bone lamella (bol) of the fin ray x 100

tumorous growth enveloping the head and a part of the neck of the parasite. Invariably the heads of the parasites are directed towards the base of the fin.

Pseudocharopinus dasyaticus (Pillai)

One specimen of *P. dasyaticus* was obtained from the margin of the body of *Himantura bleekeri*. Since this region of the fish is equivalent to the pectoral fin of other fishes, the parasite is here considered as a fin parasite.

The mode of attachment is typically of the lernaeopodid type. The distal end of each modified maxilliped is enlarged into a semicircular, cup-shaped structure flanked with two wings. The bulla is button-shaped and is seen embedded in the soft tissue of the host and glued to one of the cartilagenous rays along the margin of the body of the fish. The tumour of attachment induced by the parasite is small.

Nature of distribution and mode of attachment of isopods infesting
the buccal cavity, branchial chamber and the body surface of fishes

Four species of isopod parasites were collected from four species of fishes. The parasites are *Cymothoa eremita* (Bruennich), and *Codonophilus* sp.(R.N.-2)* invading the buccal cavity of *Parastromateus niger* and *Hemirhamphus xanthopterus* respectively, *Irona far* Nair invading the branchial chamber of *H. far* and *Livoneca* sp. infesting the body surface of *Nemipterus japonicus* (Fig. 10).

Cymothoa eremita (Bruennich) and *Codonophilus* sp. (R.N.-2)

Mode of attachment of these parasites is identical. The stout thoracic legs, provided with pointed, claw-like dactyli, are thrust deep into the soft tissue of the host to establish a strong foot-hold. The attachment of the isopods invading the buccal cavity does not seem to be very strong and permanent since they are often seen freely moving inside the buccal cavity. Nevertheless, some small open sores found in the buccal mucosa suggest that the dactyli of the legs of the parasite do penetrate the host tissue.

Both *C. eremita* and *Codonophilus* sp. (R.N.-2) are comparatively large parasites which almost fill the buccal cavity of their hosts. The size of *C. eremita* is more or less directly proportional to the size of the host — large specimens being always present in large fish and vice versa. Invariably only one parasite infests a host. since in two cases two specimens of *Codonophilus* n. sp. of different sizes were collected from each host.

Irona far Nair

Male, female and intermediate stages of *I. far*, a protandrous hermaphrodite, were collected from *H. far*. Female stage predominated. Females and intermediate stages were

* According to the Zoological Nomenclature Code the appearance of *Codonophilus* n.sp. in the text as used by the authors, without giving the full name and description, would result in a nomen nudum. Therefore the Editor has decided to use only the name of *Codonophilus* sp. (R.N.-2), thus announcing the future description of the species as the new one by the authors.

present invariably in the branchial chamber, attached to the floor towards the pharyngeal side (Fig. 9). Male stage was present on the body surface attached to the body wall on the ventral side of the buccal cavity or rarely on the ventro-lateral aspect, close to the margin of the branchial chamber.

Unlike *C. eremita* and *Codonophilus* sp. (R.N.-2), *I. far* was found to establish a firm attachment to the host, the dactyli of the legs being thrust deep into the host tissue. Small, open, bleeding sores were observed on the body surface at the site of penetration of the legs of the male *I. far*.

The female stage of *I. far* is provided with large brood sacs loaded with eggs and young ones. The pressure exerted by the brood sac on the floor of the buccal chamber leads to the formation of a deep concavity directed towards the heart of the host. The brood sacs of larger specimens may hence, exert considerable pressure on the heart of the fish.

Livoneca sp.

One specimen of *Livoneca* was obtained from the body surface on the postero-lateral side of *Nemipterus japonicus*. The mode of attachment is similar to that of the other isopods already mentioned. The attachment is, however, weak when compared to that of *I. far*. The dactyli of the legs are thrust between adjacent scales and are hooked on to the muscle. Actual penetration of the scales was not observed.

Incidence and intensity of infestation

The results of a host-wise and parasite-wise analysis of the incidence and intensity of different crustacean infestations are given in Table 2.

Among the different copepod parasites the highest incidence of infestation (98.17%) was recorded for *Ergasilus* sp. and the lowest (0.08%) for *Paeonodes mugilis*, both infesting *Mugil cunnesius*. Considering total copepod infestation the highest (98.17%) was in *M. cunnesius* and the lowest (5.0%) in *Himantura bleckeri*.

In regard to isopod infestation, the highest percentage incidence (53.09) (barring the case of *Livoneca* sp. on *Nemipterus japonicus*) was noted for *Irona far* on *Hemirhamphus far* and the lowest (3.62) for *Codonophilus* sp. (R.N.-2) on *Hemirhamphus xanthopterus*.

Considering crustacean parasites as a whole, the highest incidence of infestation (98.17%) was noted in *Mugil cunnesius* and the lowest (28.22%) in *Diodon hystrix* — the former harbouring two species, and the latter one species of parasite.

Regarding intensity of copepod infestation the highest intensity of infestation was noted in the case of *Ergasilus* sp. (141.26) and the second highest in the case of *Peniculisa wilsoni* (48.57). In the case of all other parasites the average intensity of infestation was invariably less than ten, of which the highest was noted for *Synestius caliginus* (8.07). *Bomolochus hemirhamphi*, *Pseudocharopinus dasyaticus* and *Peniculus trichiuri* had an average intensity of 1.0.

The highest intensity of isopod infestation (2.20) was noted for *Irona far* on *Hemirhamphus far* and the lowest (1.00) for *Cymothoa eremita* and *Livoneca* sp. on

Table 2

Incidence and intensity of different crustacean infestations, and the maximum number of different parasites on male and female fishes collected along the South-west coast of India

Sl. No.	Host fish	Parasite	Number of fish examined			Incidence of infestation (per cent)			Intensity of infestation			Maximum number of parasites on	
			Male	Female	Total	Male	Female	Total	Male	Female	Total	Male	Female
1	<i>Diodon hystrix</i>	<i>Peniculus wilsoni</i>	98	189	287	24.49	30.16	28.22	50.25	47.86	48.57	83	90
2	<i>Trichiurus lepturus</i>	<i>Caligus uruguayensis</i>	142	223	365	55.63	61.44	59.18	1.89	1.73	1.79	8	8
		<i>Brachiella trichiuri</i>				33.80	41.26	38.36	1.60	1.61	1.61	3	4
		<i>Peniculus trichiuri</i>				0.70	—	0.27	1.00	—	1.00	1	—
		Total				63.38	70.40	67.67	2.52	2.45	2.48	8	10
3	<i>Saurida tumbil</i>	<i>Lernanthropus gibbosus</i>	107	163	270	46.73	52.76	50.37	1.54	1.89	1.76	3	4
4	<i>Chirocentrus dorab</i>	<i>Isobranchia appendiculata</i>	51	42	93	33.33	52.38	41.94	1.59	1.77	1.69	7	9
5	<i>Parastromateus niger</i>	<i>Lernanthropus koenigii</i>	37	63	100	51.35	36.51	42.00	1.47	2.04	1.79	3	3
		<i>Thysanote appendiculata</i>				40.54	23.81	30.00	1.53	1.27	1.40	3	2
		<i>Syneustius caliginus</i>				70.27	68.25	69.00	8.81	7.63	8.07	22	19
		Total (Copepods)				86.49	79.37	82.00	8.75	7.88	8.22	22	19
		<i>Cymothoa eremita</i>				37.84	44.44	42.00	1.00	1.00	1.00	1	1
6	<i>Hemirhamphus xanthopterus</i>	Total (Crustaceans)				97.30	93.65	95.00	8.17	7.15	7.54	22	19
		<i>Lernaeenicus hemirhamphi</i>	57	81	138	36.84	48.15	43.48	2.52	2.03	2.20	8	6
		<i>Bomolochus hemirhamphi</i>				1.75	2.47	2.17	1.00	1.00	1.00	1	1
		Total (Copepods)				36.84	48.15	43.48	2.57	2.08	2.25	8	6
		<i>Codonophilus</i> sp.				3.51	3.70	3.62	1.00	1.67	1.40	1	2
		Total (Crustaceans)				36.84	49.38	44.20	2.67	2.15	2.33	8	6

Table 2 c. d.

Sl. No.	Host fish	Parasite	Number of fish examined			Incidence of infestation (Per cent)			Intensity of infestation			Maximum number of parasites on	
			Male	Female	Total	Male	Female	Total	Male	Female	Total	Male	Female
7	<i>Hemirhamphus far</i>	<i>Lernaeenicus hemirhamphi</i>				29.73	30.61	30.29	1.20	1.73	1.72	4	6
		<i>Irona far</i>	111	196	307	49.55	55.10	53.09	2.29	2.15	2.20	5	6
		Total				56.76	65.31	62.22	2.89	2.64	2.70	7	7
8	<i>Mugil cunnesius</i>	<i>Ergasilus</i> sp.				95.50	99.50	98.17	112.63	155.00	141.26	379	383
		<i>Paenodes mugilis</i>	400	800	1200	—	0.13	0.08	—	4.00	4.00	—	4
		Total				95.50	99.50	98.17	112.63	155.01	141.26	379	383
9	<i>Epinepheles malabaricus</i>	<i>Lernaeenicus</i> sp.	1	2	3	—	50.00	33.33	—	2.00	2.00	—	2
10	<i>Nemipterus japonicus</i>	<i>Livoneca</i> sp.	—	1	1	—	100.00	100.00	—	1.00	1.00	—	1
	<i>Narcine timlei</i>	<i>Pseudocharopinus narcinae</i>				62.50	60.00	60.87	1.80	3.56	2.93	4	15
		<i>Taeneacanthus narcini</i>	8	15	23	—	20.00	13.04	—	1.33	1.33	—	2
		Total				62.50	60.00	60.87	1.80	4.00	3.21	4	15
12	<i>Himantura bleekeri</i>	<i>Pseudocharopinus dasyaticus</i>	5	20	25	—	5.00	4.00	—	1.00	1.00	—	1

Parastromateus niger and *Nemipterus japonicus* respectively. Considering total crustacean infestation, the picture of the intensity of infestation was similar to that for copepod infestation.

The highest number of copepods on any fish (383) was noted for *Ergasilus* sp. In the case of *Peniculisa wilsoni* it was 90. The highest number of isopod on any fish (6) was noted for *Irona far*.

The crustacean parasite fauna was the most diverse for *Parastromateus niger*, the fish harbouring four (three copepods and one isopod) different species of crustacean parasites. *Trichiurus lepturus* and *Hemirhamphus xanthopterus* had three different species in each, whereas *Hemirhamphus far*, *Mugil cunnesius* and *Narcine timlei* had two species in each.

It is noticeable from the results presented in Table 2 that in general, both the incidence and intensity of infestation in female fish were higher than in the male. Of the 22 cases of parasitic infestations studied, in 17 (77.27%) the percentage incidence was higher in females. Similarly, in 12 cases (54.55%) the intensity of infestations also was higher in female. In two cases (9.09%) the intensity was the same in male and female fish and in eight cases (36.36%) it was higher in the males.

It is a generally accepted fact that female vertebrates are less infested by parasites except at the time of breeding when, the lowering of oestrogen level in the females makes them, somehow or other, more susceptible to parasitic infestations (Thomas, 1964). The high incidence and intensity of infestation in the female fish observed during the present study could be the result of the large number of gravid females in the collections, which are prone to be more infested.

DISCUSSION

The ubiquitous crustaceans, particularly copepods, live in intimate association with all vertebrates and invertebrates except protozoans. Among vertebrates, fishes harbour an incredibly large number of copepod associates ranging from commensals like some bomolochids to endoparasites like philichthyids, in addition to a varied spectrum of isopods.

On fishes copepods are abundant on the body surface, on the fins, on the inner wall of the operculum, floor and roof of the buccal cavity, on the gill filaments and on the gill arches. They are also found inside the spiracles and cloacal aperture. A few aberrant bomolochids are reported to live beneath the adipose eye lids. Bomolochids, taeniacanthids and caligids remain attached to the host by the suctional action of the cephalothorax. They can move about also. Caligids are usually found on the surface of the body or on the inner side of the operculum. Bomolochids and taeniacanthids need more protection and hence occupy mainly the opercular wall or the gills. Pandarids are exclusively parasites of sharks and barring a few genera, are found on the body surface; often in large numbers on the fins. Euryphorids are like caligids in habit. Anthosomatids, dichelesthids, eudactylinids and pseudocycnids are exclusively gill parasites. Lerna-

eocerids and lernaepodids are the most modified of the caligoid parasites. Members of the genus *Lernaenicus* penetrate deep into the body of the host while those of the genera *Pennella* and *Peniculisa* remain attached to various parts of the body, including the fins, of the host with the help of the antennae. Lernaepodids are permanently attached with the help of the bulla, which may sometimes get fused with some skeletal part of the host, preferably, the inner side of the opercula, wall of the buccal cavity and gill arch (Yamaguti, 1963; Cressy, 1967; Kabata, 1970; Mann, 1970; Ho, 1971; Izawa, 1974 and Pillai, pers. comm.).

Seventeen species of copepod parasites collected during the present study come under the following eight families.

- 1) *Ergasilidae* (*Ergasilus* sp.)
- 2) *Taeniacanthidae* (*Taeniacanthus narcini*)
- 3) *Bomolochidae* (*Bomolochus hemirhamphi*)
- 4) *Therodamasidae* (*Paeonodes mugilis*)
- 5) *Caligidae* (*Caligus uruguayensis*, *Syneustius caliginus*)
- 6) *Anthosomatidae* (*Lernanthropus gibbosus*, *L. koenigii*)
- 7) *Lernaoceridae* (*Lernaenicus hemirhamphi*, *Lernaenicus* sp. (R.N.-1) *Peniculus trichiuri*, *Peniculisa wilsoni*)
- 8) *Lernaepodidae* (*Thysanote appendiculata*, *Isobranchia appendiculata*, *Brachiella trichiuri*, *Pseudocharopinus dasyaticus*, *P. narcinae*)

Though the collection included parasites invading body proper, fins, gill filament, gill arch, inner side of operculum and wall of the buccal cavity, those invading the gill predominated – ten out of the 17 species being collected from the gills. Eight species out of these are purely gill parasites invading either the gill filament or the gill arch. *Thysanote appendiculata* and *Brachiella trichiuri*, though typically parasitic on the gill arch, are found to extend their attack, very rarely, to other regions of their host – the former to the inner side of the operculum and the latter to the roof of the buccal cavity of *Parastromateus niger* and *Trichiurus lepturus* respectively.

Ergasilus spp. are typically parasitic on the gill filaments of fishes. However, on several occasions they have been recorded from the skin and the fins of their hosts (Abrosova and Bauer, 1962; Kabata, 1970), especially at times of heavy infestation. During the present study *Ergasilus* sp. was seen to restrict its attack solely to the gill filaments of *Mugil cunnesius* even when the infestation was comparatively heavy (383 parasites per fish).

No host specificity is exhibited by the members of the genus *Ergasilus*. They are of quite wide-spread and cosmopolitan distribution with a wide range of host fishes, from the marine, freshwater and brackishwater habitats of different geographical regions, to their credit. During the present study *Ergasilus* sp. was obtained only from *Mugil cunnesius*. However, since not many other species of fishes from the same habitat as that of *M. cunnesius* were examined, positive conclusions, either in favour or against the host specificity of this parasite, are difficult to arrive at.

Fryer (1965) observed that *Ergasilus kandti* usually showed preference for the basal portion of the gill filaments of the host fish, while *E. megacheir* always settled near the

tip of the gill filament. Even in cases of combined infestation of the same fish by these two parasites, he could notice that the two parasites strictly adhered to their specific preferences with respect to their site of attachment. On *Mugil cunnesius*, *Ergasilus* sp. was found to avoid both the extreme base and the extreme tip of the gill filaments, but it always preferred to crowd towards the pharyngeal half, both on the outer and inner sides of the gills.

Lernanthropus gibbosus and *L. koenigii* are more adapted than the members of the family *Ergasilidae* for a parasitic mode of life by virtue of the highly specialised nature of their structural modifications, mode of attachment to the host tissue and the nature of distribution on the gills. *L. gibbosus* and *L. koenigii* are closely related species. But they infest two different host fishes, *Saurida tumbil* and *Parastrumateus niger* respectively, which co-exist along the South-west coast of India.

According to Natarajan (1975) *Lernanthropus gibbosus* and *L. koenigii* infest both the outer and the inner gill filaments of their hosts, with higher incidence on the inner filaments. The results of the present study show that *L. gibbosus* is highly selective for the inner narrow lateral margins (see foot note on page 5) of the inner gill filaments, unlike *L. koenigii* which infests both the outer narrow margin of the outer and the inner narrow margin of the inner gill filaments.

The nature of distribution on the gill filaments and the mode of attachment of *Lernanthropus gibbosus* and *L. koenigii* are similar to that described by Natarajan (1975). However, Natarajan failed to notice the fact that the second antennae of the parasite penetrate into the filamentar ray. Besides, the fact that the lateral extensions of the carapace of *L. gibbosus* may occasionally extend the whole width of the fill filament and grip the broad margin of the inner gill filament at the outer margin over the efferent filamentar blood vessel, was not observed by Natarajan. The present observations are significant since, the combined effect of the fracture of the filamentar ray and the simultaneous destruction of the afferent filamentar vessel by the feeding activity of the parasite and of the efferent filamentar vessel collapsing under the strong grip by the carapace, is prone to adversely affect the respiratory function of the affected gill filament (see Radhakrishnan and Nair, 1981c).

Owing to lack of sufficient number of specimens, details regarding the infestation of the gill filaments of *Narcine timlei* and *Hemirhamphus xanthopterus* by *Taëniacanthus narcini*, and *Bomolochus hemirhamphi* respectively could not be studied. [The structure of these parasites definitely points to the fact that both, like *Ergasilus* spp., are on the lower rungs, if not on the lowest, of the ladder of parasitism].

Five species (under four genera) of parasitic copepods belonging to the family *Lernaeopodidae* were collected during the present study, from five species of fishes – two elasmobranchs and three teleosts. All these parasites are not only specific to their hosts, but are also quite selective for the site of attachment on their hosts. However, the common feature observed in all cases is that all parasites preferred to attach to the host's soft tissue which is supported by a hard structure (for eg., the gill arch), though the bulla does not enter into a permanent fusion with the hard structure of the host. In the case of

Pseudocharopinus dasyaticus infesting the body margin of *Himantura bleekeri*, the bulla, however, was seen in close contact with, rather glued to, the cartilagenous ray supporting the body margin. All these parasites are highly modified for a parasitic mode of life.

The mode of attachment is similar in all cases though differences in the shape and size of the organs of attachment are discernible. In all cases the bulla is injected into the soft tissue of the host and it soon becomes enclosed by the so-called tumour of attachment (Kabata, 1970) produced by the host as a result of the irritation caused by the parasite.

Except for *Pseudocharopinus dasyaticus* invading the body margin of *Himantura bleekeri*, all others were found to be typically parasitic on the gill arch. However, *P. narcinae*, *Thysanote appendiculata* and *Brachiella trichiuri* were found to extend their attack, very rarely, to other parts of the host's body – gill filament, opercular covering and buccal cavity respectively.

Isobranchia appendiculata and *Brachiella trichiuri* showed very distinct preference in regard to their site of attachment on the gill arch of *Chirocentrus dorab* and *Trichiurus lepturus* respectively, unlike the condition reported by Natarajan (1975).

Isobranchia appendicula (= *Clavellopsis appendiculata*.) is reported to have an equal distribution over the first and fourth gill arches of *Chirocentrus dorab* (Natarajan *loc. cit.*). Quite curiously, in the present study, this parasite was collected exclusively from the second and third gill arches of *C. dorab*, that too only from the middle part of the arches at the region of the bend. Similarly, *Brachiella trichiuri*, attacking the gill arch, were seen to be confined to the upper and lower symphyses; the former being the more preferred site. Chandran's (pers. comm.) observation on the site of attachment of *Isobranchia appendiculata* and *B. trichiuri* is in conformity with the present findings. Natarajan observed that when the parasites (*B. trichiuri*) infected the gill arches they seemed to prefer the first gill arch. During the present study, all specimens of *B. trichiuri*, except two, were obtained from the symphyses of the gill arches. Earlier reports, however, show that this is primarily a parasite of the buccal cavity (Pillai, 1967; Natarajan, 1975).

Copepods belonging to the family *Lernaeoceridae* are also well adapted for a parasitic mode of life though they have not reached the status of the family *Laernaeopodidae* in this respect (Kabata, 1970). Two species of the genus *Lernaeenicus* of the family *Lernaeoceridae* were collected from the body proper of the host during the present study. The mode of attachment and pathology of *Lernaeenicus hemirhamphi* infection have been studied in detail by Natarajan (1975). The present observations are in conformity with those of Natarajan. Even though detailed studies on the histopathology of infestation by *Lernaeenicus* sp. (R.N.-1) have not been made it seems that of the two species *L. hemirhamphi* is more deleterious than *L. ramosus*, to the host.

Kabata (1970), while assessing the role of *Crustacea* as enemies of fishes, totally ignored the genera *Peniculus* and *Peniculisa*, (family *Lernaeoceridae*) which form potent parasites of marine fishes. At least some of the members of the genus *Peniculisa* (for eg., *P. wilsoni*) retain semblance to copepods. But their mode of attachment to the host has progressed to, though not equalled, the level of that of lernaeopodids as is evident from the present study on *Peniculisa wilsoni* infestation of the fins of *Diodon hystrix*.

Peniculus trichiuri and *Peniculisa wilsoni* were obtained during the present study. While not much information could be gathered regarding *P. trichiuri* infestation, a fairly good picture of the nature of parasitisation by *P. wilsoni* could be drawn.

Peniculisa wilsoni is apparently specific to the fins of *Diodon hystrix*. The infestation seems to be confined to fishes collected from the rocky coast of Kovalam, Trivandrum. Though no conclusive explanation for this is possible now, it is quite likely that the fish in the rocky area of Kovalam form an isolated population not mixing with the neighbouring populations.

Radhakrishnan and Nair (1981a,b) have given detailed information on the nature of distribution mode of attachment and histopathology of *P. wilsoni* infestation of *D. hystrix*. The salient observations are (1) *P. wilsoni* is highly specific to the fins of *D. hystrix*, (2) the mode of attachment of this parasite has a lot to share with that of the highly advanced lernaeopodids and (3) *P. wilsoni* shows distinct gregariousness, which is unusual for lernaeocerid parasites.

The site of attachment of *Syneustius caliginus* in the buccal cavity of *Parastromateus niger* seems to be somewhat atypical for a typical parasite. No doubt, this site, the brushlike pads on the roof of the buccal cavity, renders much protection to the parasite. The threat of being washed into the oesophagus with the incoming water current, which parasites of the buccal cavity have overcome by resorting to firm attachment to the host tissue (for eg., *Caligus uruguayensis* and *Brachiella trichiuri* in the present study) is no more a major problem for *S. caliginus* embedded among the bristles of the prickly patches. But how far this site will provide other facilitates essential for the existence of a parasite has to be determined.

From the results of the present study it is quite clear that copepod parasites of fishes do show not only host specificity but also specific preferences as far as the site of attachment on the host is concerned. Accordingly they have developed modifications in their structure so as to achieve firm attachment to the host tissue. Those which chose to attach to the 'hard parts' (gill arch, fin ray etc.), though at the expense of their freedom for movement, have undoubtedly progressed much along the path of parasitism. Those which chose to attach to other parts of the host's body have proceeded at least along two paths of development.

Except for the systematics only very little information is available regarding the isopod parasites of fishes. Four species of isopods showing varied host preferences and also specific selection for the site of attachment on the host body were obtained.

The males and females of *Irona far* show distinct preference in regard to the site of infestation, the latter infests the branchial chamber and the former the body surface. A similar observation by Kabata (1970) is that the males of *Livoneca convexa* always occur in the gill chamber of *Chloroscombrus orqueta* whereas the females are invariably found in the buccal cavity.

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S. Radhakrishnan, N.B. Nair

WŁAŚCIWOŚCI ZARAŻENIA SKORUPIAKAMI RYB
U WYBRZEŻY POŁUDNIOWO-ZACHODNICH INDII

I. ROZPRZESTRZENIENIE, SPOSÓB ATAKOWANIA TKANEK ŻYWICIELA,
EKSTENSYWNOŚĆ I INTENSYWNOŚĆ ZARAŻENIA

STRESZCZENIE

Przebadano występowanie widłonogów pasożytniczych (*Copepoda parasitica*) i równonogów (*Isopoda*) na 12 gatunkach ryb. Badano skórę, płetwy, jamę skrzelową i ustną rejestrując szczegółowo liczbę gatunków pasożytów i sposób ich umocowania do żywiciela. Opisano 17 gatunków widłonogów i 4 gatunki równonogów. 10 gatunków widłonogów występowało na skrzelach, przy czym 5 z nich bezpośrednio na listkach skrzelowych i łukach. Dwa gatunki występowały w jamie gębowej, również dwa na płetwach. Trzy gatunki przebijały się bezpośrednio przez skórę.

Znaleziono również 4 gatunki równonogów z rodziny *Cymothoidae*, 2 w jamie gębowej i po jednym w jamie skrzelowej i na powierzchni ciała.

Wszystkie gatunki wykazują znaczną specyfikę zarówno co do atakowanego gatunku jak i sposobu uciepu.

Stwierdzono lekką przewagę zarażenia osobników samiczych ryb.

S. RADHAKRISHNAN, N.B. NAIR

СВОЙСТВА ИНФЕКЦИИ РЫБЫ ЮГО-ЗАПАДНОГО ПОБЕРЕЖЬЯ ИНДИИ РАКООБРАЗНЫМИ

1. РАСПРОСТРАНЕНИЕ, СПОСОБ РАЗРУШЕНИЯ ТКАНЕЙ ХОЗЯИНА, ЭКСТЕНСИВНОСТЬ
И ИНТЕНСИВНОСТЬ ИНФЕКЦИИ

Р Е З Ю М Е

Исследованы наличие паразитных веслоногих рачков -(*Copepoda parasitica*) и равноногих ракообразных (*Isopoda*) у 12 видов рыбы. Исследовались: кожа, ласты, жаберная и ротовая полости. Подробно регистрировались количество видов паразитов и способ прикрепления их к хозяину. Дается описание 17 видов веслоногих рачков и 4 видов равноногих ракообразных.

На жабрах присутствовали 10 видов веслоногих рачков, среди которых 5 видов установлено непосредственно на жаберных листках и дугах. Два вида присутствовали в ротовой полости и два на ластах. Три вида пробивались непосредственно через кожу.

Установлено также наличие 4 видов равноногих ракообразных из семейства *Cymothoidae*. Два вида наблюдались в ротовой полости и по одному в жаберной полости и на поверхности тела.

Все исследованные виды отличались специфичностью по отношению к хозяину и специфичностью способов укреплению.

Установлено небольшое превосходство в инфицировании самок рыбы.

Authors address:

Dept. of Aquatic Biology and Fisheries
The Aquarium, University of Kerala
Trivandrum 695 007
Kerala State, India

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