

Community structure of helminth parasites of the tuna, *Euthynnus affinis*, from the Visakhapatnam coast, Bay of Bengal

R. Madhavi* and B.K. Sai Ram

Department of Zoology, Andhra University, Visakhapatnam 530003, India

Abstract

An analysis is made of the community structure of the helminth parasites of the tuna *Euthynnus affinis* collected off the coast of Visakhapatnam, Bay of Bengal. The helminth fauna comprised 23 species, consisting of two monogeneans, 18 digeneans, one larval cestode, one nematode and one acanthocephalan. Didymozoids, represented by 14 species, were the dominant members of the parasite spectrum. The parasite assemblage is characterized by species richness as well as a high diversity. Most of the parasites found, the didymozoids in particular, were host specialists, exhibiting a high degree of host specificity. The fauna comprised three core species, four satellite species and many secondary species, with no potential for interaction among them but the degree of predictability is high in that each infracommunity comprised two or three core species superimposed by a few secondary species. Many host factors such as the varied diet, high vagility, long life span and endothermy appear to have contributed to the development of the species rich and diverse parasite communities in the tuna. There was evidence for a decrease in parasite density and an increase in diversity with increase in host size, indicating that host size has a profound influence on the component community structure.

Introduction

In recent years, investigations dealing with the community structure of helminth parasites of vertebrates and the factors that contribute to its organization at different hierarchical levels, have received considerable attention (Esch *et al.*, 1990; Bush *et al.*, 1990; Rohde, 1993). However, much of the work amongst lower groups of vertebrates is concerned with helminth parasites of freshwater fish whereas their counterparts in marine fish have received little attention. Kennedy *et al.* (1986) hypothesized that marine fish parasite communities should have greater species richness and numbers of individuals per host because of their greater vagility and wider breadth of diet as compared with freshwater fish. This hypothesis found

support from subsequent investigations on marine fish helminth communities by Kennedy & Williams (1989) on *Raja batis*, Holmes (1990) on *Sebastes nebulosus* and Thoney (1991, 1993) on the spot *Leiostomus xanthurus* and Atlantic croaker, *Micropogonias undulatus*. On the other hand, Cisló & Cairn (1993) found the parasite assemblage in the spiral intestine of the shark *Mustelus canis* to be depauperate, resembling in this respect the helminth communities of freshwater fish. In a recent paper Rohde *et al.* (1994), from an analysis of the data on ectoparasite communities of marine fish, concluded that community richness varies greatly between localities and is dependent on such factors as temperature, host diet, host size and latitude of the locality. Overall, they concluded that most metazoan ectoparasite communities of marine fishes are nonsaturated and little organized. It is evident that in order to understand precisely the characteristics of marine fish helminth communities at infra and

* Fax: (0891) 555547

component community levels, more species of marine fish need to be studied, especially from tropical countries, from where little quantitative information is available.

Along the coast of Visakhapatnam, Bay of Bengal, the tuna *Euthynnus affinis* (Cantor, 1849), locally known as little tunny, occurs commonly in fish catches. The tunas are known for their high vagility, varied diet, long life span and endothermy caused by the presence of a counter current heat exchange system. All these features render them most suitable hosts for helminth parasites. An investigation was therefore undertaken during 1989–1990 to study the community organization of the helminth parasite assemblage of the little tunny, *E. affinis*. Unlike earlier studies on marine fish which concentrated only on intestinal helminth parasites (Kennedy & Williams, 1989; Holmes, 1990; Cislo & Cairn, 1993) or gill parasites (Rohde *et al.*, 1994; Hayward *et al.*, 1998), the present study, like that of Thoney (1991, 1993), considered all the helminth parasites within and on the fish host. This was necessary as the parasite fauna of the tuna is comprised largely of didymozoids occurring free or encapsulated in tissues. However, the didymozoids encountered during the present study are to a large extent localized in tissues that are closely associated with the digestive tract.

The present study therefore considers the community structure of the helminth parasite fauna of the tuna, *E. affinis* and in particular the effects of host size on this parasite community.

Materials and methods

One hundred and ten tuna fish, *E. affinis*, with a size range of 150–600 mm, comprising juveniles and adults, were collected during January 1989 to December 1990, from the fish landing centres along the coast of Visakhapatnam, Bay of Bengal (17° 44'N and 83° 23'E). Individual fish were covered in ice, wrapped in polythene bags, and taken to the laboratory where they were measured and sexed. All the organs of the fish were examined for parasites which were counted and identified using specimens that were fixed and prepared as permanent whole mounts. Each didymozoid cyst, irrespective of whether enclosing two separate or fused worms, was counted as representing two worms. Tetraphyllid and didymozoid larvae were not included in the counts.

Data were analysed for calculation of parasite community parameters such as species richness, mean intensity and diversity. Diversities were calculated for each infracommunity using both Shannon-Wiener's and Brillouin's indices. Prevalence and mean intensity of infection with individual parasite species were also calculated.

The terms infra and component communities were used according to Esch *et al.* (1990). Each parasite species was characterized as core, secondary and satellite species following the criteria of Hanski (1982). The ecological terms were adopted from Bush *et al.* (1997). Correlation between community parameters and host size were tested by using Pearson's correlation coefficient and wherever necessary, the data were log transformed. Rejection of null hypothesis was $P > 0.05$. Values are expressed as mean (\pm SD). Host fish were divided into five size groups: 150–200 mm, 201–300 mm, 301–400 and > 400 mm.

Results

Helminth parasite communities

Twenty three species of helminths were recorded, including two monogeneans, 18 digeneans, one larval cestode, one larval nematode and one acanthocephalan (table 1). Digeneans dominated the parasite spectrum and among them the didymozoids, represented by 14 species, were the most important components of the helminth fauna. Numerically also the didymozoids were the most abundant contributing 96.4% of the total helminth individuals.

All 110 *E. affinis* examined were infected, each harbouring 1–16 parasite species with a mean of 8.6 (\pm 3.13). Up to 50% of fish, however, harboured 7–11 species of parasites (fig. 1). The number of individuals of parasites in a host ranged from 6 to 1197 with a mean of 296 (\pm 254.5). The fauna comprised three core species, namely *Pseudocolocynthotrema yaito*, *Opephercystis kawakawa* and *Neonematobothrium dorsale*. Four species, *Didymozoon diverticulatum*, *Kamegaia kawakawa*, *Lobatocystis bengalensis* and *Hirudinea ventricosa*, occurring with prevalence values of less than 10%, constituted the satellite species. The remaining 16 helminths could be categorized as secondary species and some, including *Melanocystis kawakawa*, *Didymocystis exiguus* and *Opepherotrematoides multitubularis*, occurred with prevalences greater than 50%. In the case of *D. exiguus* the mean intensity of infection was also high. Among the core species, *P. yaito* was the most dominant species. *Neonematobothrium dorsale* also occurred with a high prevalence but the mean intensity of infection with this species was low. The three core species co-occurred frequently but there was no evidence for any interaction between them, presumably because they were encapsulated and occupied different niches. There was also no evidence for interaction among other helminth species, indicating the community to be isolationist in nature. In each infracommunity, the two core species, *P. yaito* and *O. kawakawa*, occurred in large numbers whereas the remaining species occurred in small numbers. The diversity values (H') were, therefore, not as high as expected and ranged from 0 to 2.58 with a mean of 1.33.

Comparison with other marine fish parasite communities

The diversity parameters of the helminth communities of the different marine fish so far investigated are given in table 2. Since some authors used the Shannon Wiener's diversity index and others the Brillouin's index, both the indices were calculated for the helminth infracommunities of the tuna (table 2). It should be noted that previous studies, with the exception of the elasmobranch fish *Raja bates* and *Mustelus canis*, considered the total helminth fauna for the estimation of diversity values. However, in elasmobranch fish, where the majority of helminths occur in the spiral intestine, the diversity values, based on intestinal helminths, might also apply to the total helminth load. The values of mean number of parasite species and the mean intensity of infection recorded for the tuna are much higher than those recorded for other species of marine fish (table 2). The diversity values (H') are higher than those recorded for elasmobranch fish and

Table 1. Prevalence (%), mean intensity (mean \pm SD) and site of infection of helminth parasites of the tuna, *Euthynnus affinis* from the Visakhapatnam coast, Bay of Bengal.

Helminth species	Site	Prevalence	Mean intensity
Monogenea			
<i>Capsala gouri</i> Chauhan, 1952	Gills, operculum	16.4	1.55 \pm 0.51
<i>Homostoma chura</i> Unnithan, 1958	Gills	43.6	4.5 \pm 2.8
Digenea			
Bucephalidae			
<i>Rhipidocotyle pentagonum</i> Ozaki, 1924	Intestine	43.6	4.5 \pm 3.3
<i>Phyllodistomum lancea</i> Mamaev, 1968	Urinary bladder	15.5	2.0
Didymozoidae			
<i>Didymozoon divorticulatum</i> Yamaguti, 1970	Hepatic caeca	4.5	6.6
<i>Didymocystis exiguus</i> Yamaguti, 1970	Intestinal mucosa	57.3	52.2 \pm 71.1
<i>Kamegaia kawakawa</i> Yamaguti, 1970	Duodenum	6.4	2.0
<i>Lobatocystis yaito</i> Yamaguti, 1970	Gills	22.7	4.96 \pm 1.5
<i>L. bengalensis</i> Hussain, Rao & Shyamasundari, 1985	Gills	1.8	2.0
<i>Melanocystis kawakawa</i> Yamaguti, 1970	Oesophagus	50.0	52.7 \pm 57.9
<i>Neonematobothrium dorsale</i> Yamaguti, 1970	Dorsal fin fold	89.1	3.8 \pm 2.9
<i>N. kawakawa</i> Yamaguti, 1965	Opercular muscles	59.1	5.3 \pm 3.8
<i>Metanematobothrium bivittellatum</i> Mamaev, 1968	Mandibular tissue	35.4	4.8
<i>Opepheroctysis kawakawa</i> Yamaguti, 1970	Hepatic caeca	85.5	113.1 \pm 150.7
<i>Pseudocolococytotrema yaito</i> Yamaguti, 1970	Rectum	91.8	131.6 \pm 176.6
<i>Opepherotrematoides multitubularis</i> Yamaguti, 1970	Submucosa of stomach wall	57.3	14.8 \pm 14.3
<i>Allopseudocolococytotrema claviforme</i> Yamaguti, 1970	Rectum	15.4	6.35 \pm 4.2
<i>Didymocodium euthynni</i> Yamaguti, 1970	Hepatic caeca	24.5	9.6 \pm 2.4
Hemiuridae			
<i>Plerurus longicaudatus</i> Yamaguti, 1953	Stomach	41.8	5.4 \pm 4.5
Hirudinellidae			
<i>Hirudinella ventricosa</i> Pallas, 1774	Stomach	2.7	2.3
Cestoda (larva)			
<i>Callotetrarhynchus gracilis</i> Rudolphi, 1819	Stomach wall	32.7	3.97 \pm 3.5
Nematoda			
<i>Spinitectus mollis</i> Mamaev, 1985	Intestine and viscera	10.7	2.25
Acanthocephala			
<i>Rhadinorhynchus ganapatii</i> Chandra, Rao & Shyamasundari, 1985	Intestine	39.1	5.1 \pm 6.1

other species of tuna, but lower than those of other teleost fish.

Host specificity

The helminth species exhibited varying degrees of specificity. All the didymozoids were host specialists except *M. kawakawa*, *D. exiguus* and *O. kawakawa*. These didymozoids as well as the cestode larva, the monogeneans and the acanthocephalan infected, apart from *E. affinis*, other species of tunas in the locality. All the non-didymozoid digeneans including the bucephalids, gorgoderids and hemiurids were found to be host generalists.

Effects of host size

The prevalence and mean intensity of infection with various parasite species were found to be low in the host size group 150–200 mm where the recruitment of

helminth parasites had just commenced (table 3). In the remaining size groups, the helminth parasite intensities showed a significant decrease with an increase in fish size ($r = -0.55$). An increase in species richness and diversity, on the other hand, occurred with an increase in host size ($r = 0.585$ and 0.7 respectively). A reduction in the abundance of two core species, *P. yaito* and *O. kawakawa*, and the appearance of certain parasite species as components of the parasite fauna of larger fish, seem to have caused the observed changes in the community structure of the parasite fauna with size of the fish. An analysis of the data on the occurrence of individual parasite species in different size groups of fish revealed that trends varied in different species and the following three patterns were recognized:

1. Species showing a decrease in abundance with an increase in host size e.g. *P. yaito*, *O. kawakawa* and *Allopseudocolococytotrema claviforme*.

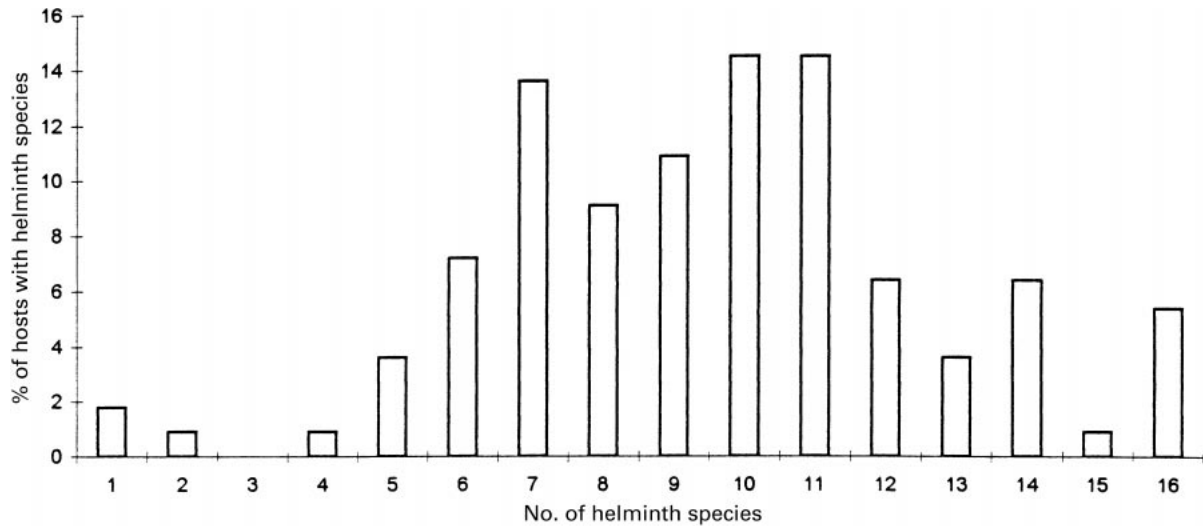


Fig. 1. Frequency (%) of the number of helminth species in *Euthynnus affinis*.

Table 2. Comparison of helminth diversity parameters of different species of marine fish (SW = Shannon Wiener index; BI = Brillouin's diversity index).

Fish species	Mean number of helminth species	Mean number of individuals	Diversity index		Author
			SW	BI	
<i>Raja batis</i>	2.94 ± 1.14	44.7 ± 57.3		0.595 ± 0.075	Kennedy & Williams, 1989
<i>Mustelus canis</i>	2.2 ± 0.7	34.3 ± 32.0	0 to 1.1		Cislo & Cairn, 1993
<i>Leiostomus xanthurus</i>	6.0 ± 1.9	142 ± 187.1	1.4 ± 0.69		Thoney, 1993
<i>Micropogonias undulatus</i>	7.0 ± 2.3	150 ± 444.2	1.8 ± 0.63		Thoney, 1993
<i>Euthynnus affinis</i>	9.52 ± 3.2	305 ± 254.5	1.33 ± 0.5	1.12 ± 0.19	Present study
<i>Auxis thazard</i>	6.3 ± 1.64	124.4 ± 39.5	1.22 ± 0.62		Madhavi <i>et al.</i> (unpublished)
<i>Katsuwonus pelamis</i>	5.8 ± 2.5	39.3 ± 13.95	1.28 ± 0.16		Madhavi <i>et al.</i> (unpublished)
<i>Thunnus albacares</i>	3.0 ± 0.96	44.35 ± 17.4	0.77 ± 0.40		Madhavi <i>et al.</i> (unpublished)

Table 3. Diversity parameters of helminth communities of *Euthynnus affinis* relative to host size.

Host size group (mm)	Host sample size	Mean no. of helminth species	Shannon Wiener index (H')	Mean no. of parasites
≤ 200	8	5.25 ± 2.86	0.76 ± 0.56	260.3 ± 270.4
201–300	60	8.58 ± 2.66	1.09 ± 0.41	411.7 ± 458.3
301–400	22	10.6 ± 1.9	1.59 ± 0.36	251.8 ± 210.3
> 400	20	12.9 ± 2.1	1.92 ± 0.38	196.6 ± 134.9

2. Species showing an increase in abundance with increase in host size e.g. *Homostoma chura*, *D. exiguus*, *Metanematobothrium bivoitellatum* and *Plerurus longicaudatus*.
 3. Species uniformly distributed in all host size groups e.g. *Lobatocystis yaito*, *N. dorsale*, *Melanocystis kawakawa* and *N. kawakawa*.

Discussion

The present study revealed the helminth infracommunities of the tuna, *E. affinis*, to be species rich and diverse and dominated by didymozoid trematodes. Altogether 23

species of helminths were recorded from the tuna. Most of these species have previously been recorded from the tuna from other localities, but represent new records for the Bay of Bengal. The community comprised three core species, many secondary species and a few satellite species. There was little evidence for interaction among the species and the community structure was essentially similar to that reported for other marine fish except for slight differences.

Information available on helminth communities of marine fish, although still scanty, indicates wide variation among different species of fish, ranging from depauperate

in a few (Cislo & Cairn, 1993) to species rich communities reported for many species (Kennedy & Williams, 1989; Holmes, 1990; Thoney, 1991, 1993). The helminth community structure of the tuna, while not deviating greatly from that reported for other marine fishes, is remarkable in the very high values of community parameters, and also in the host specialist nature of the many species in the parasite spectrum. In these specific features, helminth communities of the tuna reflect similarities to those of aquatic birds (Kennedy *et al.*, 1986). A comparison with the data provided by Kennedy *et al.* (1986) for the intestinal helminth community parameters of different species of birds reveals that the species richness as determined by the mean number of parasite species approaches that recorded for the willet, *Catoptrophorus semipalmatus*, but the mean intensity of helminth parasites in the tuna is very low as compared to that of the willet. The community parameters of the tuna thus seem to be intermediate between those of marine fish and aquatic birds. The values recorded for tuna and birds are not strictly comparable, in that the total parasites were included in the fish analysis in contrast to intestinal helminths in birds, and this would tend to bias the results in favour of birds. However, in spite of this bias, the community parameters in tuna remained lower than those in birds, thus giving support to the above conclusion.

Factors responsible for the development of rich parasite communities in marine fish are considered to be their varied diet, high vagility and long life span (Kennedy & Williams, 1989). The tuna, known for its high vagility, is capable of undertaking migrations across oceans. Another factor unique to the tuna is the presence of a counter current heat exchange system which keeps the body temperature higher than that of the ambient medium. The high vagility and endothermy require high metabolic energy which is met through foraging on large quantities of food items comprising crustaceans, fish, molluscs and polychaetes that serve as intermediate and paratenic hosts for didymozoid and other helminth parasites. The development of the rich and diverse parasite communities in the tuna is therefore likely to be due to its high vagility and endothermy.

Another reason for the high diversity of parasite fauna in the tuna seems to be the long life span of this fish, permitting accumulation of parasites with age. Apart from this, the didymozoid trematodes also have a long life span (Lester *et al.*, 1985) and, once established, these parasites remain in the host for many years. In its high vagility and endothermy, the tuna resembles avian hosts, hence it is not surprising that this similarity is also reflected in the organization of the parasite communities, the composition and diversity of which is dependent on a wide range of physiological and ecological host factors.

Studies by Holmes (1990) emphasize that undisturbed highly productive ecosystems are required for the development of rich parasite communities in marine fish. While this is true, it should be noted that the productivity of an ecosystem shows seasonal fluctuations and, in order for the development of a species rich parasite fauna, the peak in seasonal productivity should coincide with the period when the fish is most vulnerable to infection, which is usually the post spawning period when the young as well as the spent fish feed voraciously and are

highly susceptible to infection. Knowledge of seasonal changes in the productivity of the ecosystem, migratory movements and the maturity cycle of the host fish and the period of recruitment of the parasites into the host population is required in order to provide authentic support to this view.

Leong & Holmes (1981) have stressed the composition of the host fauna is a factor which influences the fish helminth communities, and parasites which inhabit the dominant host will also dominate the parasite fauna. This view finds support from the observations made on the parasite fauna of the tuna in the Bay of Bengal. Five species of tuna occur along the coast, of which *E. affinis* is the most dominant (Sai Ram, 1993). A comparison of helminth parasites of the tunas of the coast revealed that *E. affinis* harbours the most species rich and diverse helminth communities (table 2). Although requiring additional data, it seems logical at this stage to suggest that in an ecosystem, it is the most dominant host species that carries the richest parasite communities. However, it should be emphasized that apart from phylogeny, other factors such as host ecology and the abundance and latitude of the locality also play important roles in the structuring of parasite communities (Rohde & Heap, 1998). These observations suggest that the facts established here for helminth parasite communities of *E. affinis* may not apply to other species of tuna in the Bay of Bengal and even the same species of tuna in other localities.

The parasite community of *E. affinis* is characterized by the presence of three core species which co-occurred in most hosts sampled. The parasite fauna thus consists of a predictable group of core species which was accompanied by subordinate less predictable species. In view of the presence of core species and species that are highly host specialists, the predictability as well as the similarity of the parasite fauna of different individuals of host fish are high. Despite this high host specificity, there is little evidence for parasite species interaction, differing from parasite communities of homeotherms in this regard. It seems therefore pertinent to conclude that parasite infra-communities of the tuna are predominantly the result of the chance assemblage of species.

Size related changes in marine fish helminth communities have previously received little attention. The present findings revealed the larger fish to possess richer and more diversified parasite communities than smaller fish, although there is a reduction in the total parasite load. This trend seems to have been brought about by changes in the population density of the two core parasite species *P. yaiko* and *O. kavakava* and the restriction of some parasite species to larger fish. Furthermore, the distribution of individual parasite species in different size groups of fish followed different patterns, some species showing preference for smaller fish. There are parasite species which show decreasing abundance with an increase in host size or the opposite trend. Some species were uniformly distributed in all size groups. In view of these differences, it can be concluded that the age structure of the fish has a profound influence on the community structure of its parasite fauna.

Finally, we agree with the viewpoints expressed by Bush *et al.* (1990) and Poulin & Rohde (1997) that although host phylogeny is obviously important, ecological events

can be equally important, if not overriding, in determining the composition and structure of helminth communities. Overall, the observations presented here provide support to the view of Rohde *et al.* (1994) that most parasite communities are non-structured and little ordered.

Acknowledgements

The financial assistance for carrying out this work was provided by the Council of Scientific and Industrial Research, New Delhi. Our grateful thanks are due to Professor Klaus Rohde for his valuable comments on the manuscript of the paper, as a referee.

References

- Bush, A.O., Aho, J.M. & Kennedy, C.R.** (1990) Ecological versus phylogenetic determinants of helminth parasite community richness. *Evolutionary Ecology* **4**, 1–20.
- Bush, A.O., Lafferty, K.D., Lotz, T.M. & Shostak, A.W.** (1997) Parasitology meets ecology on its own terms: Margolis *et al.* revisited. *Journal of Parasitology* **83**, 575–583.
- Cislo, P.R. & Cairn, J.N.** (1993) The parasite assemblage in the spiral intestine of the shark *Mustelus canis*. *Journal of Parasitology* **79**, 886–899.
- Esch, G.W., Bush, A.O. & Aho, J.M.** (1990) *Parasite communities: patterns and processes*. London, Chapman & Hall.
- Hanski, I.** (1982) Dynamics of regional distribution: the core and satellite species hypothesis. *Oikos* **38**, 210–211.
- Hayward, C.J, Perera, K.M.L. & Rohde, K.** (1998) Assemblage of ectoparasites of a pelagic fish, slimy mackerel (*Scomber australasicus*), from south-eastern Australia. *International Journal for Parasitology* **28**, 263–273.
- Holmes, J.C.** (1990) Helminth communities in marine fishes. pp. 101–130 in Esch, G.W., Bush, A.O. & Aho, J.M. (Eds) *Parasite communities: patterns and processes*. London, Chapman & Hall.
- Kennedy, C.R., Bush, A.O. & Aho, J.M.** (1986) Patterns in helminth communities: why are birds and fish different? *Parasitology* **93**, 205–215.
- Kennedy, C.R. & Williams, H.H.** (1989) Helminth community diversity in a marine fish, *Raja batis* L. *Journal of Fish Biology* **34**, 971–972.
- Leong, T.S. & Holmes, J.C.** (1981) Communities of metazoan parasites in open water fishes of Cold Lake, Alberta. *Journal of Fish Biology* **18**, 693–713.
- Lester, R.J.G., Barnes, A. & Habib, G.** (1985) Parasites of skipjack tuna, *Katsuwonus pelamis*: fishery implications. *Fishery Bulletin* **83**, 343–357.
- Poulin, R. & Rohde, K.** (1997) Comparing the richness of metazoan ectoparasite communities of marine fishes: controlling for host phylogeny. *Oecologia* **110**, 278–283.
- Rohde, K.** (1993) *Ecology of marine parasites*. 2nd edn. Wallingford, Oxon, CAB International.
- Rohde, K. & Heap, M.** (1998) Latitudinal differences in species and community richness and in community structure of metazoan endo- and ectoparasites of marine teleost fish. *International Journal for Parasitology* **28**, 461–474.
- Rohde, K., Hayward, C., Heap, M. & Gosper, D.** (1994) A tropical assemblage of ectoparasites: gills and head parasites of *Lethrinus miniatus* (Teleostei, Lethrinidae). *International Journal for Parasitology* **24**, 1031–1053.
- Sai Ram, B.K.** (1993) Some aspects of biology of scombrid fishes and host-parasite relationships of tunas of Visakhapatnam coast, Bay of Bengal. PhD thesis, Andhra University.
- Thoney, D.A.** (1991) Population dynamics and community analysis of the parasite fauna of juvenile spot, *Leiostomus xanthurus* (Lacépède) and Atlantic croaker, *Micropogonias undulatus* (Linnaeus), (Sciaenidae) in two estuaries along the middle Atlantic coast of the United States. *Journal of Fish Biology* **39**, 515–534.
- Thoney, D.A.** (1993) Community ecology of the parasites of adult spot, *Leiostomus xanthurus*, and Atlantic croaker, *Micropogonias undulatus* (Sciaenidae) in the Cape Hatteras region. *Journal of Fish Biology* **43**, 781–804.

(Accepted 13 April 2000)
© CAB International, 2000