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Some notes on the population dynamics of the monogenean gill parasite *Gastrocotyle indica*

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Abstract

The fish *Caranx kalla* of different size groups (2 to 18 cm body length) is present during various calender months of the year off the Madras coast (S. India). *C. kalla* displays a definite progressive shift in growth during successive months; the fish grows from 2 cm (September) to about 18 cm (August) over a period of 12 months. The highest (47%) or lowest (11%) incidence of a monogenean gill parasite *Gastrocotyle indica* has been observed in the *C. kalla* size groups 2.0 to 3.9 cm or 16.0 to 17.9 cm; however, the maximum specific density of 10.9 parasite/infested fish was observed in the size group 14.0 to 15.9 cm. Small fish (2.0 to 3.9 cm) carry only larvae (58/100 fish); larger hosts (4.0 to 5.9 cm) larvae (45/100 fish) and juveniles (8/100 fish); individuals of the 6.0 to 15.9 cm size group harbour larval, juvenile and adult stages of *G. indica*. Fishes of more than 16 cm carry only adult parasites. The level of parasitization is higher on the male hosts (30% incidence; 5 parasites/infested male) than on the females (25% incidence; 4 parasites/infested female). The highest incidences of larval, juvenile and adult *G. indica* occur in September, February, and May, respectively; the parasite seems to live for 1 year. The host requires a period of about 8 months to acquire immunity against infestation by *G. indica* or copepod parasites.

Introduction

Studies on population dynamics of monogenean parasites with reference to age, size and season of the year have been made on *Gastrocotyle trachurus* and *Pseudaxine trachuri*, parasitic on *Trachurus trachurus* (LLEWELLYN, 1962); *Gyrocotylus elegans*, parasitic on *Gillichthys mirabilis* (NOBLE et al., 1963); and *Discocotyle sagittata*, parasitic on *Salmo trutta* (PALING, 1965). Similar studies on population dynamics of monogenean parasites of tropical waters are wanting. Information on composition of parasitic fauna, its age, dynamics, and seasonal fluctuations, can indeed be suggestive of not only its own biology, but also of that of its host. The present paper reports on the population dynamics of *Gastrocotyle indica*, parasitic on *Caranx kalla*.

Material and methods

Caranx kalla CUVIER and VALENCIES (family Carangidae), the specific host of *Gastrocotyle indica* SUBHAPRADHA, is a tropical fish occurring in the Indian Ocean; its distribution extends from the Red Sea to the Malayan Islands. In the present study, *C. kalla* specimens hauled by local fishermen of the Madras coast were used; the investigation lasted over a period of 3 years, from January, 1964 to December, 1966. During this period, regular monthly samples of about 30 fishes were collected, covering 2 to 18 cm body length groups. Observation of the fishes in fresh condition was possible, as the site of fish landing is very close to the laboratory. Total length of the fish was taken in all cases as an indication of the age of the host. Gill arches were removed and placed in separate petri dishes containing sea water ($35^0/_{00}$ S). The gill filaments were examined under a binocular microscope; details regarding parasitic incidence, with reference to the number and stage of the parasite, were noted.

Results

Availability and growth of the host fish Caranx kalla

During the period of investigation, as many as 591 fishes were examined; based on body length, they were classified into 8 different groups (Table 1). Percentage of each size group was calculated considering the total number of fishes (which were randomly selected for examination) to be 100. The values thus obtained for each size group for a particular calender month of the year 1964 have been pooled with those obtained for the same size group for the corresponding month in the years 1965 and 1966. The relative proportion of different size groups examined in each month was taken as typical of the inshore population. Calculation of the monthly sample population with respect to size groups showed a definite progressive shift in the mode over successive months (Fig. 1). From such modal shift, it can be said that the fish takes about 12 months to grow from 2 to 18 cm.

Table 1. *Caranx kalla. Monthly fluctuations in the abundance of different size groups*

Size group (cm)	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	March	April	May	June	July	Total
2.0— 3.9	5	13	16	0	0	0	0	4	0	0	0	0	38
4.0— 5.9	5	22	20	0	0	0	0	4	0	0	0	0	51
6.0— 7.9	0	8	10	10	12	15	17	2	0	0	0	0	73
8.0— 9.9	0	0	0	2	4	18	22	26	16	6	4	0	98
10.0—11.9	2	2	0	0	4	8	20	28	26	16	12	4	122
12.0—13.9	2	0	0	0	0	4	9	23	31	30	23	4	126
14.0—15.9	4	0	0	0	0	2	2	7	10	16	14	10	65
16.0—17.9	4	3	2	0	0	0	0	0	0	0	4	5	18
Totals	22	48	48	12	20	47	69	94	83	68	57	23	591

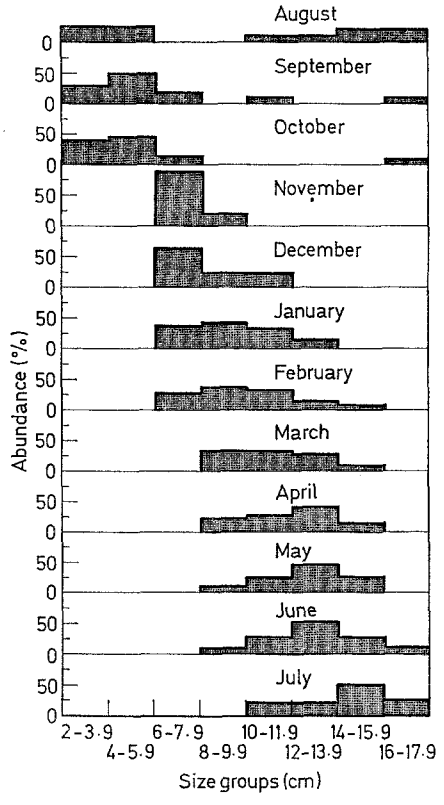

Fig. 1. Percentage abundance of different size groups during the year of the host fish *Caranx kalla*

Level of parasitization of Gastrocotyle indica on Caranx kalla

Incidence of the parasite *Gastrocotyle indica* on the gills of the juvenile fishes *Caranx kalla* was quite frequent, i.e. out of 38 juveniles (2.0 to 3.9 cm body length) examined, the parasite was found on 18 (47.3% incidence; Table 2). The incidence decreased to about 25% in the next 3 size groups (4.0 to 9.9 cm); it then decreased to 39.3% and 36.5% in the 10.0 to 11.9 cm and 12.0 to 13.9 cm size groups, respectively; however, the largest hosts examined (14.0 to 17.9 cm body length) seem to have been less susceptible to infection; only 11% of the individuals measuring more than 16 cm body length were infested by the parasite.

Table 2. *Level of parasitization (Gastrocotyle indica) on different size groups of the fish Caranx kalla*

Size group of host (cm)	No. of hosts examined	No. of hosts infested	Incidence (%)	Mean specific density (parasites/ infested fish)
2.0— 3.9	38	18	47.3	1.22
4.0— 5.9	51	13	25.5	2.07
6.0— 7.9	73	18	24.6	2.50
8.0— 9.9	98	26	26.5	2.35
10.0—11.9	122	48	39.3	5.35
12.0—13.9	126	46	36.5	5.46
14.0—15.9	65	9	13.8	10.88
16.0—17.9	18	2	11.1	2.00

Mean specific density of *Gastrocotyle indica* amounted to 1.22 parasites/infested fish of the 2.0 to 3.9 cm size group (Table 2); this steadily increased to 5.4 parasites/infested fish in the 12.0 to 13.9 cm size groups. The size group of 14.0 to 15.9 cm body length harboured the maximum of 11 parasites/infested fish. Individuals of more than 16 cm body length carried only 2 parasites/infested fish.

From the point of level of parasitization of parasitic load on the host population, which may be regarded as the cumulative effect of both incidence and density of parasitic infection, *Caranx kalla* belonging to the 10.0 to 13.9 cm size group are heavily susceptible to infestation by *Gastrocotyle indica* (Table 2).

Level of parasitization by different life stages of Gastrocotyle indica on different size groups of Caranx kalla

A total of 765 individuals of *Gastrocotyle indica* were collected from the host fish *Caranx kalla* examined during the period of investigation. The parasites collected in the monthly samples were classified into the following stages: (1) larvae — individuals without clamps (0.36 to 0.78 mm length); (2) juveniles — individuals possessing 1 to 16 clamps (0.32 to 1.81 mm length); (3) adults — individuals with more than 17 clamps (1.85 to 5.05 mm length; RADHA, 1971a, b; see also PALING, 1965). As the total number of individuals of any one size group of *C. kalla* examined varied from 12 to 94 (Table 1), the data obtained on the number of parasites found as larvae, juveniles or adults on the host have been calculated and expressed as number of parasites present/100 host fish of the given size group.

Table 3. *Level of parasitization by different life cycle stages of Gastrocotyle indica on Caranx kalla of different size groups*

Size group of host (cm)	No. of larvae/ 100 fish	No. of juveniles/ 100 fish	No. of adults/ 100 fish
2.0— 3.9	57.9	0.0	0.0
4.0— 5.9	45.1	7.8	0.0
6.0— 7.9	15.1	38.4	8.2
8.0— 9.9	10.2	23.5	28.6
10.0—11.9	11.5	16.4	182.8
12.0—13.9	9.5	14.3	175.4
14.0—15.9	3.1	0.0	147.7
16.0—17.9	0.0	0.0	0.2

None of the *Caranx kalla* individuals examined from the 2.0 to 3.0 cm size group harboured juvenile or adult parasites (Table 3). The next size group (4.0 to 5.9 cm body length) carried larvae and juveniles, but no adults. The third size group (6.0 to 7.9 cm) harboured all 3 stages of the parasite. This observation suggests that individuals belonging to the 2.0 to 3.9 cm body length group are the smallest fish size group, susceptible to larvae, and that these larvae grow to juvenile and adult stages, when the fish attains 4 and 6 cm body length, respectively. *C. kalla* belonging to the 6.0 to 13.9 cm body length size group harboured all 3 stages of the parasite, indicating that these hosts are subjected to continuous infestation by freshly hatched larvae of the parasite. However, fish of more than 16 cm body length were no longer susceptible to larval infestation.

The earliest stage of the fish (2.0 to 3.9 cm body length) seems to be heavily susceptible to infestation; 100 individuals of this size group carried as many as 58 larvae (Table 3). Although also the larger fishes were susceptible to larval infestation, the degree of susceptibility to larval infestation progressively decreases; only about 3 larvae were collected in 100 individuals of the size group measuring 14.0 to 15.9 cm body length; once *Caranx kalla* attains a body length of 16 cm, it is no longer susceptible to larval infestation.

The number of juvenile *Gastrocotyle indica* found per 100 host fish increased from 7.8 in the size group 4.0—5.9 cm, to 38.4 in the 6.0—7.9 cm size group; the number of juveniles then continuously decreased, and *Caranx kalla* individuals longer than 14 cm body length carried no juveniles. The corresponding number for the adult parasite was 8.2 in the size group of 6.0 to 7.9 cm body length, and attained a peak of about 183 in the size group measuring 10.0 to 11.9 cm body length (Table 3); subsequently, infestation decreased to 0.2 in fish of 16.0 to 17.9 cm body length.

Table 4. *Level of parasitization (Gastrocotyle indica) on males and females of the host fish Caranx kalla*

No. and sex of host fish examined	No. of fish infested	Incidence (%)	Total No. of parasites	Mean specific density (parasites/ infested fish)
313 ♂♂	93	29.7	508	5.46
199 ♀♀	51	25.6	208	4.08

Levels of Gastrocotyle indica infestation on male and female Caranx kalla

Sex determination was uncertain in fish of 2.0 to 5.9 cm body length; therefore, in the following analyses of the data on the incidence and density of parasitic infestation in relation to sex of the host, only *Caranx kalla* measuring over 6.0 cm body length have been considered. Of the 313 males examined, 93 were infested by 508 *Gastrocotyle indica*, i.e. on an average, 5 parasites/1 infested male (Table 4). Likewise, 25% of the females examined were infested by the parasite (4 parasites/1 infested female).

Fig. 2 shows the specific density of larva, juvenile and adult stages of *Gastrocotyle indica* on male and female hosts of *Caranx kalla*. Irrespective of sex, each small individual of *C. kalla* carried about 1 to 2 larvae and juvenile *G. indica*. Both male and female *C. kalla* of the 6.0 to 7.9 cm size group carried no adult parasite. Average specific density of the adult parasites increased to 13.5 for male and 8.3 for female *C. kalla* in the 14.0 to 15.9 cm size group; in the next size group (16.0 to 17.9 cm), it dropped sharply to 2 in the former, and 0 in the latter.

Life span of Gastrocotyle indica

The percentage occurrence of larval, juvenile and adult stages of *Gastrocotyle indica* was separately calculated for each month, considering the total number of parasites collected in that month to be 100. The fish sample collected in May revealed no larvae (Fig. 3), and only a few (4 laravae/100 parasites) in June. One might, therefore, assume that the larvae, which hatched earlier and were swimming freely in the bottom waters, first infected the fish in June of each year. The number of larvae collected from the *Caranx*

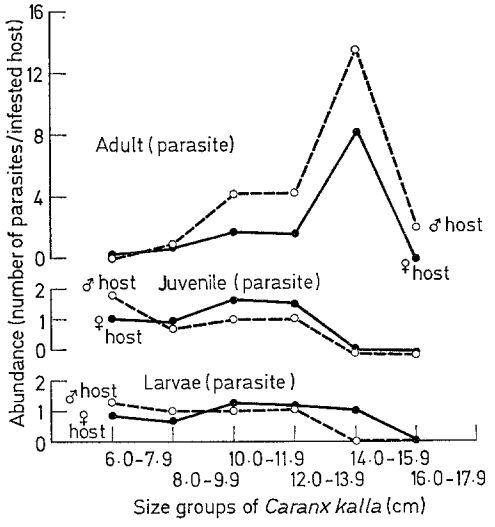

Fig. 2. *Gastrocotyle indica.* Abundance (specific density) of larval, juvenile or adult stages as functions of sex and size of the host fish *Caranx kalla*

kalla samples increased and reached a peak in September (21 to 28 larvae/100 parasites in various years). It is by this time that the most susceptible size groups (2.0 to 5.9 cm body length) of the host fish are abundant (Table 1), recording the highest total occurrence of 50 to 60% of the sample population (Fig. 1). The number of larvae of *G. indica* encountered thereafter steadily decreased each month (e.g. about 11 larvae/100 parasites in January) until they ceased to occur altogether in May.

Juvenile parasites first appeared in the July samples (about 3 juveniles/100 parasites) and then progressively increased during the subsequent months. More than 22 juveniles/100 parasites were recorded during the period January to March. Thereafter, occurrence began to decrease and, in June, no juvenile was recorded.

Adult *Gastrocotyle indica*, however, occurred throughout the year; their abundance ranged from 55 to 100/100 parasites, indicating that more than $^2/_3$ of the *G. indica* population consisted of adult individuals. The 3 year average occurrence amounted to 95 adults/100 parasites during May.

Since the incidence of *Gastrocotyle indica* larvae reaches a maximum in September (or October, as in 1965) and that of juveniles a maximum in February (Fig. 3), it is reasonable to infer that the larvae attain the juvenile stage in a period of about 5 months. The peak incidence of adults is recorded in May (or June, as in 1965) and hence it may also be inferred that juveniles grow into sexually mature adults in about 3 months. As the eggs are likely to have been shed in maximum numbers in June (RADHA, 1971a), when the adults are abundant, and as the maximum incidence

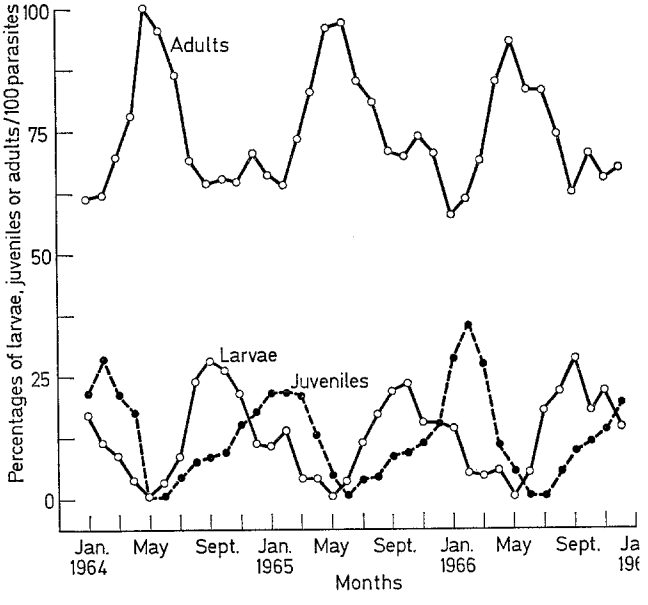

Fig. 3. *Gastrocotyle indica.* Percentage abundance of larval, juvenile and adult stages on *Caranx kalla* during various months of the years 1964, 1965 and 1966

of larva occurs in September, one may infer that the eggs require about 1 month to develop into infestive larvae. This 12 month period, i.e. from June to May, represents a single generation of the parasite and covers the egg-to-egg period of their life history. The total life span of *G. indica*, i.e. from egg to death of the parasite may be longer, as mature adults are found throughout the year, particularly in May when no larvae occur.

Other gill parasites of Caranx kalla

The gill surface of *Caranx kalla* seems to offer one of the best ecological niches, especially for ectoparasites. Along with *Gastrocotyle indica*, copepod parasites were found to occur on the gills of *C. kalla*; sporadic incidences of a hemiurid, an intestinal digenetic trematode, and isopod parasites were also

not uncommon. As recurring incidences of copepod parasites were realized at a very late stage of the investigation, a detailed species record of copepod parasites has not been made. Nevertheless, the available data on the incidence and density of a 'copepod parasite complex' on *C. kalla* seem to reveal some interesting information.

For purposes of comparison, I have given in Fig. 4 the incidence and density of *Gastrocotyle indica* and 'the copepod parasite complex' on *Caranx kalla* as a function of the body size of the host. Two remarkable features can be noted. (1) The copepods, which are relatively larger in size, infested the fish only when the latter measured more than 6 cm in body length; the incidence of copepod infestation steadily increased from 5% in the 6.0 to 7.9 cm size group to 60% in the size group 14.0 to 17.9 cm body length. On the other hand, *G. indica* infestation was very high (47%) even in the smallest fishes (2.0 to 3.9 cm), which they first infested; after decreasing to about 25%, it increased to a second maximum of 39% incidence in the 10.0 to 11.9 cm size group. Thus, the maxima of incidences of copepod and *G. indica* infestations are seen on hosts of different size groups, and also during different months (*G. indica* — 2nd peak in March; copepods — August; see also Figs. 1 and 4). Incidence began to rapidly decrease in fish of more than 14 cm for *G. indica* and 18 cm for the copepods. Thus, the host fish *Caranx kalla* seems to require a period of about 8 months to develop immunity against the respective parasites (Figs. 1 and 4). (2) Specific density of *G. indica* progressively increased from 1.2 parasites/infected fish of the size group 2.0 to 3.9 cm body length to 10.88 parasites/infected fish of the size group 14.0 to 15.9 cm. The specific density of copepods was less than 2 parasites/infested fish in any one of the size groups which they infested. Although the maximum incidence of copepods was higher than that of *G. indica*, the density of copepods is far lower than that observed for *G. indica*.

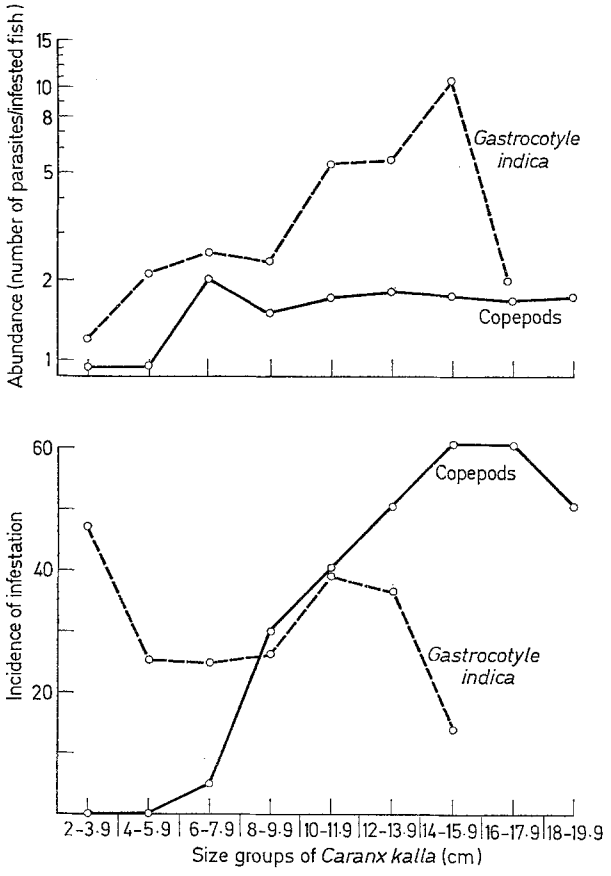

Fig. 4. Levels of parasitization by *Gastrocotyle indica* and copepods on different size groups of the fish *Caranx kalla*

Discussion

The foregoing observations on the incidence of *Gastrocotyle indica* on *Caranx kalla* suggests the following pattern of parasitization: nearly half (Table 2) of the juvenile fish (2.0 to 3.9 cm body length) become infested by onchomiracidia of *G. indica* when the young fish apparently descend to the sea bottom during the period from August to October (Fig. 3). This is immediately preceded by the peak incidence (90 to 100 adults/100 parasites in May) of the adult parasites, which carry fully ripened eggs. A reasonable inference is that the maximum number of eggs may have been shed by the adults sometime in June. The eggs of *Gastrocotyle trachuri* and *Discocotyle sagittata* have been observed to take a 4 day period to reach the bottom waters (LLEWELLYN, 1957; PALING, 1965). The duration of the embryonic period so far estimated for eggs of different monogeneans varies from 2 to 32 days, depending upon the species, and the temperature of the water in which they are laid (FRANKLAND, 1955). *G. trachuri* eggs require a period of about 28 days to hatch (LLEWELLYN, 1957). *G. indica* eggs shed in June or early July probably require a period of 1 month to hatch, and by August and early September they begin to infect the then juvenile *C. kalla*.

The maximum incidence of *Gastrocotyle indica* on *Caranx kalla* was about 47% (Table 2). This is a relatively lower value than the values reported for a number of temperate fishes. For instance, nearly all (98 to 100%) the scad *Trachurus trachurus* of the age groups 0^+ and 1^+ were found to have been infested by *G. trachuri* (LLEWELLYN, 1962); the incidence reported by PALING (1965) for *Discocotyle sagittata* of 5^+ and 6^+ age groups was about 77%. The reason for such a poor incidence of *G. indica* on *C. kalla* is not known; since the duration of free swimming larval stage of monogeneans do not exceed 4 to 6 days (FRANKLAND, 1955),

it may be due to lack of precise synchronization of time and space of hatching onchomiracidia and availability of the suitable host, viz. *C. kalla*.

Regarding density, my data on specific density (parasites/infested fish) are not strictly comparable with the density data (parasites/fish) reported by LLEWELLYN (1962) and PALING (1965). With the exception of 11 parasites/infected fish of 14 cm, the maximum number of parasites carried by *Caranx kalla* was about 5.4 parasites/infested fish. The scad, on the other hand, harboured about 11 parasites/fish during the year 0^+ and 13 parasites/fish during 1^+ years of their life. The low parasite density observed on *C. kalla* seems to be due to the fact that *C. kalla* bears only 1 generation of *Gastrocotyle indica*, whereas *Trachurus trachurus* harbours 2 generations of *G. trachuri*.

The degree of susceptibility to infestation by *Gastrocotyle indica* decreases with increase in size of *Caranx kalla* (Table 3); individuals measuring more than 16 cm were no longer susceptible to infestation, and even juvenile and adult parasites were found to be completely absent on these larger host fishes. The cause for the failure of the larvae to establish themselves on older fish may be due to one or more of the following reasons: changes in the habitat of the host fish (LLEWELLYN, 1962) and/or increased natural resistance, or previous infection which may have produced sufficient immunity against fresh larval infection (DOGIEL, 1958). The complete absence of juvenile and adult parasites on the older fish may be due to age immunity (DOGIEL, 1958) or to the hardness of the gill (BYCHOWSKY, 1957). Only further experimental work can reveal which is the cause for the failure of *G. indica* to establish on older *C. kalla*.

Incidence and specific density of *Gastrocotyle indica* on male *Caranx kalla* were greater than on female individuals (Table 4). Differences in the parasitic burdens of male and female trout *Salmo trutta* infested by *Discocotyle sagittata* were observed by PALING (1965), and led him to suggest that, for some unknown reason, the male is more attractive or less repulsive to parasites than the female. Working on the trout, THOMAS (1964) also observed the parasitization level of helminthic fauna to be similar on male and female trout less than 3 years old; the older males, however, showed an appreciably higher level of parasitization than corresponding female individuals. There is considerable circumstantial evidence to indicate that the female hormone in vertebrate animals increases resistance to parasitization (HALEY, 1958; BULL, 1959; HICKMAN, 1960; LEES and BASS, 1960; DOBSON, 1961a, b; LEES, 1962). It is interesting to cite the experimental evidence given by LEES and BASS (1960) in support of this suggestion. They injected male frogs with estrodiol benzonate at the rate of 100 mg/day over a period of 12 days. After a period of 3 weeks, the levels of parasitization by trematodes and nematodes on the males were found to be far lower than those of control males, which received no estrodiol benzonate. It may be presumed, therefore, that the female hormone of *C. kalla* may have a similar deterrent effect upon the monogeneans.

On the basis of the observations made in the present studies, the life span of *Gastrocotyle indica* from egg-to-egg stage has been inferred to be about 1 year. This is further supported by the following facts. (1) The life span of the closely related European species *G. trachuri* has been shown to be 1 year (LLEWELLYN, 1962); generally, the life span of most tropical species is known to be shorter than that of the closely related species inhabiting temperate zones (KINNE, 1963); (2) Although not much is known about the bionomics of the fish *Caranx kalla* (BAPAT and PRASAD, 1952), the growth pattern observed in the present investigation suggests that the life span of the fish is about 1 year and, hence, that of its parasite *G. indica* is also likely to be 1 year.

The gills of fishes are soft and richly vasculated, and constitute a favourable substratum for the attachment of parasitic copepods and helminths; the branchial chamber, which is well ventilated by respiratory currents, but sheltered from the disturbing environmental factors outside the fish, proves to be a highly suitable ecological niche for many free living (sessile filter-feeders such as ciliates) and semi-parasitic forms. Monogeneans seem to be the first to establish themselves on the gills of fishes; *Gastrocotyle indica* is the first one to settle on the gills of *Caranx kalla*; it is followed by copepods. RADHA (1971c) observed that the first parasite to settle successfully on the gills of different species belonging to the Carangidae is a monogenean, the second a copepod, and the third again a monogenean which infests sexually matured fishes. For instance, *Bilaterocotyloides carangis* is the first member of the parasitic complex of the fish *Caranx rotteleri*, the second copepods, and the third *B. madrasensis*. Likewise, the monogeneans *Allodiscocotyle* sp. and *Vallisia* sp. are the first to establish themselves on the fish *Chorinesmus lysan*; they are followed by copepods, and then by the monogeneans *Heterapta* sp. and *Dioncus* sp.

Summary

1. Levels of parasitization of the monogenean *Gastrocotyle indica* on the gills of the fish *Caranx kalla* were studied as functions of season, size, and sex, of the host; the observations were based on 765 specimens of *G. indica* collected from 591 *C. kalla* over a 3 year period, from January, 1964 to December, 1966.

2. Fishes of different size groups (2 to 18 cm body length), available during the different months, showed a definite progressive shift in growth rate during the successive months; it suggested that

C. kalla grows from 2 cm (September) to 18 cm (August) in about 12 months.

3. The highest (47.3%) or lowest (11.1%) parasitic incidence was observed on *C. kalla* size groups 2.0 to 3.9 cm or 16.0 to 17.9 cm; however, the maximum number (10.88) of parasites/infected fish was seen on the size group 14.0 to 15.9 cm.

4. Smaller *C. kalla* (2.0 to 3.9 cm) carried only *G. indica* larvae (58/100 fish); larger hosts carried larvae (45/100 fish) and juveniles (8/100 fish); individuals belonging to the 6.0 to 15.9 cm size group harboured larvae, juveniles and adults; fish of more than 16 cm carried only adult parasites.

5. The level of parasitization was higher on the male hosts (30% incidence; 5 parasites/infected male) than the females (25% incidence; 4 parasites/infected female).

6. The highest incidences of larvae, juveniles and adults were found to occur in September, February and May, respectively; the life span of the parasite is apparently about 1 year.

7. The copepod parasites, found to occur along with *G. indica* on *C. kalla*, infected fish of the 6 cm size group; copepod incidence increased to 60% in size groups of 14.0 to 17.9 cm; in all the size groups of the host fish, specific density of copepods was less than 2 parasites/infected host.

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