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TEMPORAL PATTERNS OF THE METAZOAN PARASITES IN THE WHITE MULLET, *MUGIL CUREMA* VALENCIENNES FROM JOYUDA LAGOON, PUERTO RICO*

by

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ABSTRACT

Monthly prevalence, incidence and intensity of metazoan parasites from the white mullet, *Mugil curema* Valenciennes, were examined from February 1979 to April 1980.

Variations in the prevalence and incidence percentages displayed by external parasites suggest patterns of periodical occurrence. The periodicity of different parasitic populations is related to the changes in relative abundance and sexual maturity of mullet, short-term salinity variations and interspecific associations of parasites.

Four new host-parasite associations were noted in *Mugil curema*: *Pseudohaliotrema mugilinus* Hargis, 1955, *Metamicrocotylea macracantha* Alexander, 1954, *Lernaeenicus longiventris* Wilson, 1917, and *Trachelobdella lugubris* Grube, 1840.

ACKNOWLEDGMENTS

I am indebted to the Marine Ecology Division of the Center for Energy and Environment Research for providing the cooperative personnel and research facilities for this investigation. I am specially grateful to Dr. Ernest H. Williams, Dr. José M. López, Dr. Luis R. Almodovar and Dr. Paul Yoshioka for the revision of this work. I would also like to acknowledge the technical assistance provided by Carlos Bonafé, Edwin González, Pablo Cabassa and Miguel Nieves. Also for Roberto Castro, Mario Perez, and Luis Negron for their cooperation and interest in this investigation. Finally, but most important I am very grateful to my parents and to my wife for their economic and moral support.

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INTRODUCTION

The importance of ecological studies in fish parasite populations has been increased by the development of aquaculture programs with freshwater and marine fishes. Artificial culture conditions enhance the direct transfer of some parasitic species and usually reduces the natural defense mechanisms of the hosts against parasitic infections.

Knowledge about fish-parasite interactions in their natural ecosystem provides useful baseline information for aquaculture research. The present study was conducted to provide such baseline information in a fish which has potential for aquaculture. The specific objectives in this study were:

1) To study the periodic occurrence and intensity of infection by metazoan parasites in the white mullet, occurring in Joyuda Lagoon.

2) To examine the influence that changes in the external environment have on the parasitic fauna of the white mullet.

3) To determine the effect that spawning and possible migrations of the fish have on its parasitic composition.

4) To add some ecological and biological information about the white mullet.

5) To present a general description of the study site, Joyuda Lagoon, and to evaluate the role of this particular ecosystem in the life cycle of the white mullet.

The white mullet is the most abundant among four species of mullet reported in Puerto Rico. A typical inhabitant of estuaries and brackish-water systems, the white mullet is the most common representative of gray mullet in the Caribbean coast. Anderson (1957) described the early development, spawning, growth and occurrence of the white mullet along the south Atlantic Coast of the United States. Yanez-Arancibia (1976) studied the feeding habits, growth, spawning behavior and trophic relations of the white mullet in the lagoonal system of Guerrero, on the Pacific Coast of Mexico.

Because of its size and abundance the white mullet, locally known as "jarea", is a prominent commercial fish in Puerto Rico. Besides being a common food item in some parts of the island, mullet are highly prized as bait for sport fishing. White mullet are specially important because of their potential for culture (Yashouv 1972, Tang 1975, Sebastian and Nair 1975, De Silva and Wijeyaratne 1977).

LITERATURE REVIEW

The general biology and ecology, as well as some parasitological information, is available concerning the striped mullet, Mugil cephalus. This species has gained much attention since it is more broadly distributed and commercially important in the United States (Anderson 1957). Rawson (1976) studied the population biology of parasites of Mugil cephalus in a temperate area and found that the number of parasite species increased with the age of the host and that initial infection was influenced by closeness of association of mullet age-classes. Skinner (1975) surveyed the parasites of Mugil cephalus in Biscayne Bay.

Recent studies have approached some ecological aspects of fish parasite populations in natural ecosystems. However, most of this work has been done in sub-tropical and temperate areas. Overstreet (1968) calculated significant correlations between monthly means of temperature, salinity and size of the fish with mean number of parasites infecting the inshore lizardfish, Synodus foetens, from an estuarine canal in South Florida. Williams (1979) studied the seasonal incidence of the cestode Isoglaridacris wisconsensis in its fish host, Hypentelium nigricans and associated low incidence of the parasite with cold winter temperatures and decreased feeding by the fish. Evans (1978) described an annual cycle of occurrence and maturation in the "roach" Rutilus rutilus by the cestode Asymphylodora kubanicum in the Worcester-Birmingham channel in England. Meskal (1966) reported seasonal variations of parasites from the cod in coastal waters of

Norway and related fluctuations in the trematode population with the seasonal abundance of a copepod, apparently acting as an intermediate host. Grimmes and Miller (1976) suggested a "temperature dependent rejection response" as a possible factor involved in the seasonal periodicity of three species of caryophyllaeid cestodes in the creek chubsucker, Erimozon oblongus, in North Carolina. Rawson (1972) reported seasonal abundance of monogenetic trematodes in the bluegill, Lepomis macrochirus, in a reservoir in Alabama. Other studies demonstrate that differences in the habitat and geographic location are more important than seasonal variables in the parasitic composition of some fishes (Shroeder 1970, Dowgiallo 1979).

Paperna (1975) stated that mortalities of gray mullet cultured in brackish and freshwater ponds which have resulted from massive infections by parasites, appear to be coupled with environmental stresses such as, declines in oxygen, critical changes in temperature or salinity, or pollution.

Taxonomical references on parasites infecting the white mullet are scattered in the literature. Table I presents a list of parasites which have been noted previously.

TABLE I

Parasites of the white mullet, Mugil curema, from Joyuda Lagoon

SPECIES	LOCALITY	REFERENCE
Monogenea:		
Pseudohaliotrema mugilinus	Puerto Rico	Present Study
Metamicrocotyla macracantha	Puerto Rico	Present Study
Digenea:		
Haplosplanchnus mugilis	Curacao	Nahhas and Cable, 1963
Schikhobalotrema elongatum	Curacao	Nahhas and Cable, 1963
Rhipidocotyle lepisostei	U.S. A. Atlantic	Hopkins, 1964
Acanthocephala:		
Floridosentis elongatus	U.S.A., Gulf of Mexico	Williams and Gaines, 1974
Copepoda:		
Ergasilus lizae	U.S.A. Atlantic	Krøyer, 1863
Ergasilus mugilinus	U.S.A. Atlantic	Vogt, 1877
Ergasilus nanus	Atlantic, Mediterranean and Black Sea	Beneden, 1870
Bomolochus concinnus	Puerto Rico	Present Study
Lernaeenicus longiventris	Puerto Rico	Present Study
Hirudinea:		
Trachelobdella lugubris	Puerto Rico	Present Study

MATERIALS AND METHODS

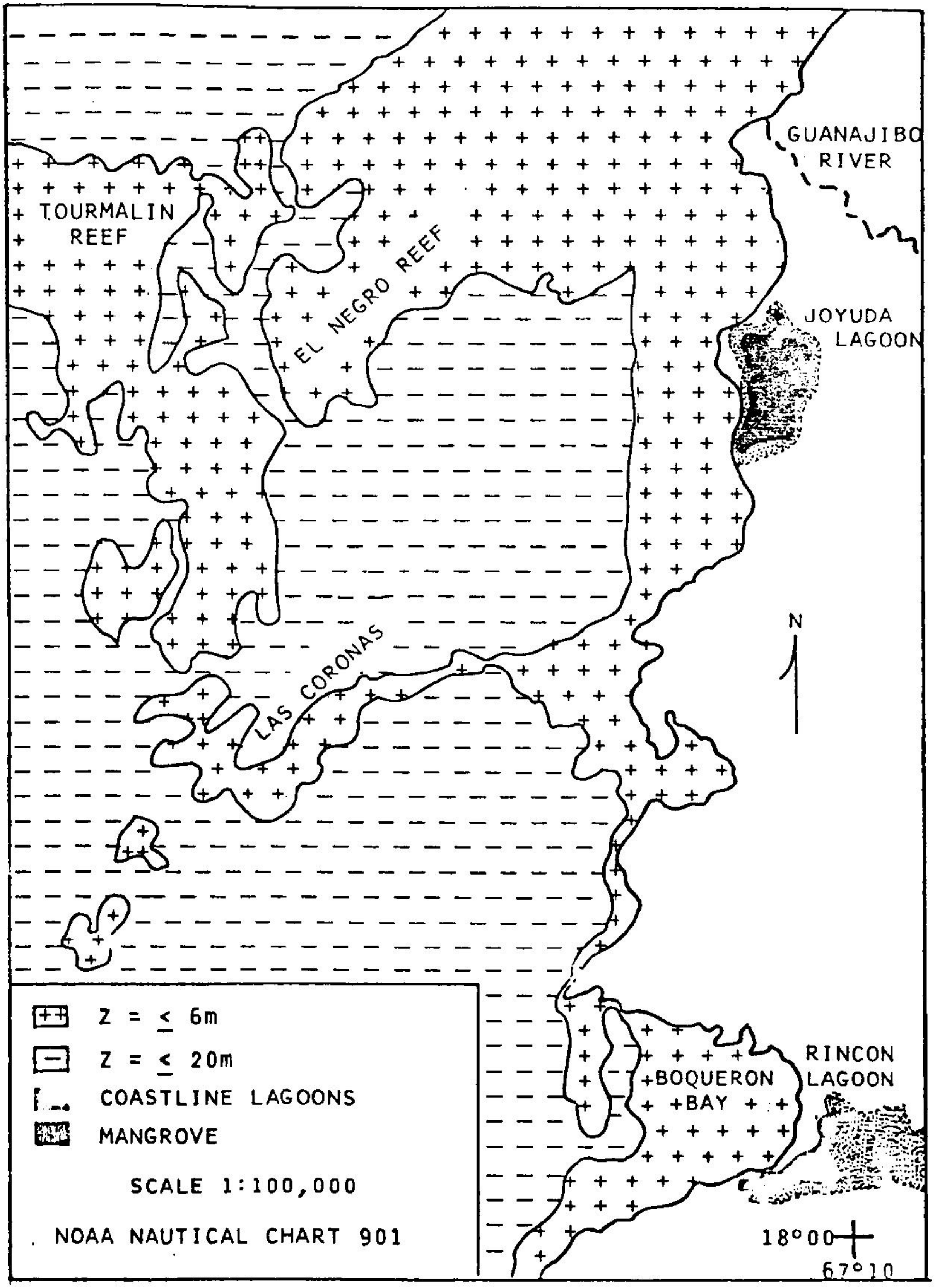
The Study Area

Joyuda Lagoon (Figure I) is a coastal brackish water system located on the southwestern coast of Puerto Rico. The lagoon is approximately 1.6 km long and 0.8 km wide, covering an area of 121 hectares. A conspicuous band of the red mangrove, *Rhizophora mangle*, borders the lagoon. There is also some development of the black mangrove, *Avicenia nitida*, and white mangrove, *Laguncularia racemosa*, on the western section. Water exchange between the lagoon and the sea occurs along a small channel bordered by mangrove which opens seaward into a sandy patch area of turtle grass with scattered coral growth. The average water depth of the lagoon is 1.3 m, with a maximum depth of approximately 4 m. The bottom substrate is composed of soft mud sediments and organic detritus, mainly derived from the mangroves.

Sampling Procedures

Monthly samples of ten mullet from Joyuda Lagoon were examined for metazoan parasites during the period of February 1979 through March 1980. Most of the collections were made with monofilament and nylon bottom gill nets 60 m long and 2.5 m high, with a square mesh diameter of 3.9 cm. Some individuals were captured with cast nets. All the sampling was done from a 13'6" fiberglass boat powered by a small outboard motor. The nets were set at sunset and recovered at dawn. Fish were placed in individual plastic bags and taken directly to the laboratory for examination.

Figure I. Joyuda Lagoon and adjacent coastal features


GUANAJIBO
RIVER
TOURMALIN
REEF
EL NEGRO REEF
JOYUDA
LAGOON
N
LAS CORONAS
BOQUERON
BAY
RINCON
LAGOON
Z = ≤ 6m
Z = ≤ 20m
COASTLINE LAGOONS
MANGROVE
SCALE 1:100,000
NOAA NAUTICAL CHART 901
18°00
67°10

Hydrological Measurements

Salinity, temperature and dissolved oxygen measurements were obtained every month at five stations in the lagoon. These data were recorded on sampling days at the time of setting the nets with YSI meters from Yellow Springs Instruments Co. Model 33 S-C-T was used to measure salinity (to the nearest ± 0.5°/₀₀) and temperature (to the nearest ± 0.6 °C). Model 57 was used to measure dissolved oxygen (to the nearest ± 0.2 ppm). The instruments were calibrated according to the instruction manual at least once a month.

Laboratory Procedures

The fish samples were taken directly from the field to the laboratory facilities at CEER and examined within a few hours of collection. All fish were weighed and measured (standard length) and the gonads were removed from the fish and weighed.

Parasitological examinations were limited to metazoan (multicellular) species and included the body surface, gills and alimentary tract of the fish. Gill arches were removed and placed in separate dishes. Numbers and species of parasites present were recorded for each gill arch. An incision was made on the right side of each fish and the different organs separated into petri dishes. Each organ was studied as a whole unit for metazoan parasites. A saline solution was added to the dishes to avoid drying and facilitate the examination. Observations and separation of parasites were made with a dissecting microscope.

The relaxation, fixation and preservation of parasites followed standard procedures for each group. Crustacean parasites were removed from the fish and placed into six-dram vials with 70% ethanol. Monogenetic trematodes were relaxed in 1/4000 formalin, preserved in 10% formalin and mounted on microscopic slides with glycerine jelly. Nematodes and digenetic trematodes were relaxed and preserved in hot 10% formalin. Leeches were pressed between two microscopic slides in a 10% formalin bath, then transferred to vials with 10% formalin. Acanthocephalans were relaxed in cold, distilled water and later preserved in 10% formalin. Internal worms and leeches were stained with semichon's carmine and mounted in permount.

Statistical Analysis

The incidence percentage and intensity of infection by the different parasitic species were noted as monthly values for the 15 month period. Incidence percentages represent the proportion of fishes infected by a particular parasite. Intensity of infection values represent a proportion between the total number of individuals of a parasitic species and the total number of mullet examined in a month. A logarithmic transformation (Log_{10} N) was applied to the monthly values of intensity of infection. Prevalence represents the presence of a parasite in a monthly sample. Simple and multiple regression analysis between the temperature and salinity means and the intensity of infection values were calculated for every species except for the leech, *Trachelobdella lubrica*, which only occurred once during the study period. The correlation coefficients were obtained from a program of an Apple II computer, which also calculated the standard error of estimate.

Possible interrelations between parasitic groups were tested for significance in 2X2 contingency tables. The exact probabilities were calculated by the formula $Po = \frac{(A+B)!(C+D)!(A+C)!(B+D)!}{N!A!B!C!D!}$ as suggested by Tate and Clelland (1957) for small N values of less than 40 and expected frequencies of less than 5.

Data on the stage of sexual maturity were obtained by using an index of gonad development previously reported by Orange (1961) for several species of tunas. This index is a numerical relationship between the weight of the fish and the weight of both ovaries. It is expressed as:

$$G.I. = \frac{w}{W} \times 100$$

where G.I. = Gonad Index

w = Weight of both ovaries in grams

W = Weight of fish in grams

The relative abundance of white mullet in Joyuda Lagoon was expressed as a proportion between the number of individuals of white mullet and the total collection of fishes in the month, following standard collection procedures.

RESULTS AND DISCUSSION

Hydrological Parameters

Salinity - The average salinity in Joyuda Lagoon for the period between February 1979 and April 1980 was 19.9 ppt. Monthly mean values ranged between a minimum of 12.0 ppt in October 1979 to a maximum of 30.0 ppt in April 1980. Figure II presents the monthly fluctuations in salinity during the study period. Summer months (May-October) averaged lower salinity values ($\bar{X}$=18.6) while the winter period (November-April) presented a higher average value ($\bar{X}$=20.8).

Monthly mean values indicate that the salinity pattern in the lagoon is unstable and that moderate variability can occur in short time intervals of less than one month. Salinity is mostly determined by the amount of precipitation and runoff, the temperature and wind effect on evaporation and the intrusion of sea water during high tides.

Temperature - The average water temperature was 27.7°C. Monthly mean values ranged between a maximum of 30.0°C in May and July 1979 and a minimum of 24.7°C in February 1980. Figure III presents the monthly variation in mean temperature values. The average water temperature was higher during the summer months (May-October) with $\bar{X}$=28.8°C as compared to the winter months (November-April) with $\bar{X}$=27.0°C. The gradual decrease of water temperature started in September and reached its lowest point by February. The pattern of water temperature is affected by air temperature because of the shallow nature of the lagoon and relatively stagnant condition of the

Figure II. Monthly means and range of salinity measurements at Joyuda Lagoon, between the period of February 1979 through April 1980.

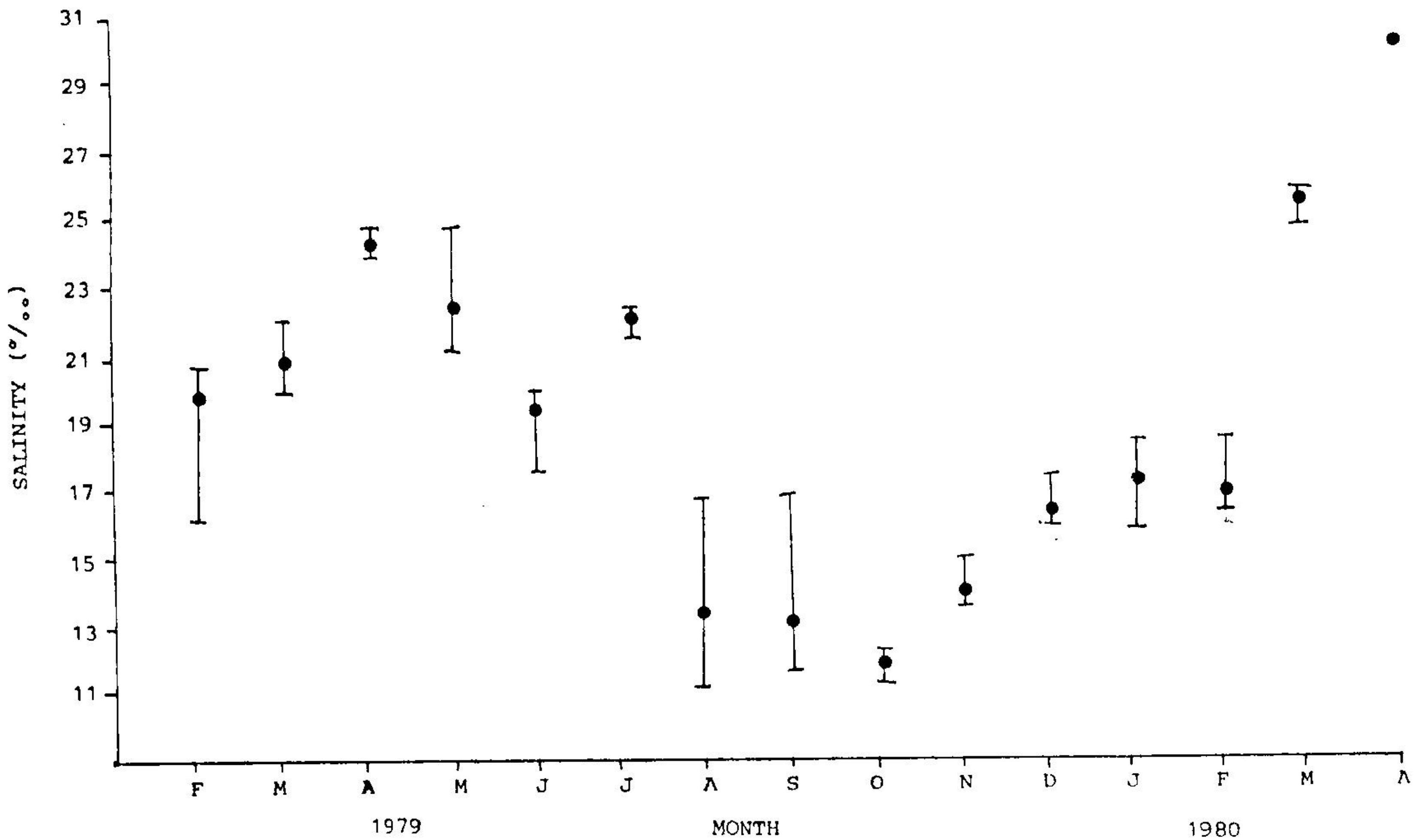
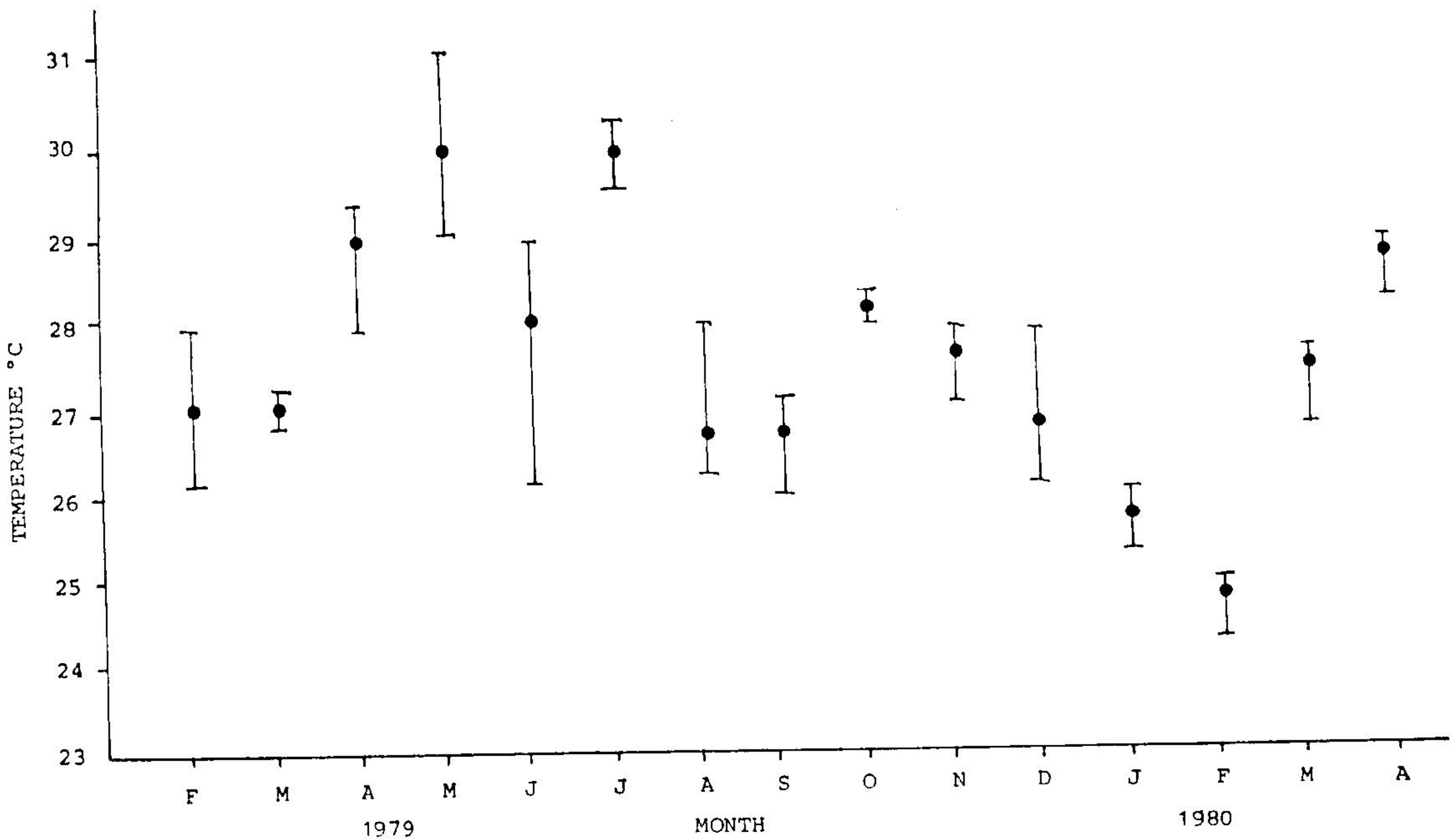


Figure III. Monthly means and range of water temperature measurements at Joyuda Lagoon between the period of February 1979 through April 1980.



water. Short term variation in water temperature may occur as a result of heavy precipitation and the drain of cold freshwater from the runoff of adjacent mountains.

Dissolved Oxygen - The content of dissolved oxygen in the water ranged from 4.7 ppm in March 1980 and 7.2 ppm in April and December 1980. Although moderate variation occurred on a monthly basis, the summer period registered a rather stable content of O_2 in the water as compared to the winter months in which the degree of variation from month to month was high (see Figure IV). If we account for the temperature and salinity effect on the different expected levels of O_2 saturation, the variation in the monthly percentages of O_2 saturation must be related to biological processes occurring in the lagoon. Table II presents the monthly values of the percentages of O_2 saturation.

Relative Abundance of White Mullet in Joyuda Lagoon

The relative abundance of white mullet in monthly samples indicated a peak in February 1979 with 41% of the total capture in a sample size of 193 individuals. Another high value was recorded in September 1979 with 32% in a sample size of 49 individuals. Figure V presents the monthly variation in relative abundance of white mullet. The sudden decrease in abundance of white mullet after February tends to support the theory of an offshore spawning migration of this fish, as has been already suggested by Anderson (1957), Moore (1974) and Yanez (1976). Index of gonad maturity (see Table III) indicated that 80% of the mullet examined in February 1979 had an advanced stage of gonad development. In March 1979, all the individuals examined were sexually mature. The following months presented some mature indi-

Figure IV. Mean and range of dissolved oxygen values at Joyuda Lagoon, for the period between February 1979 and April 1980.

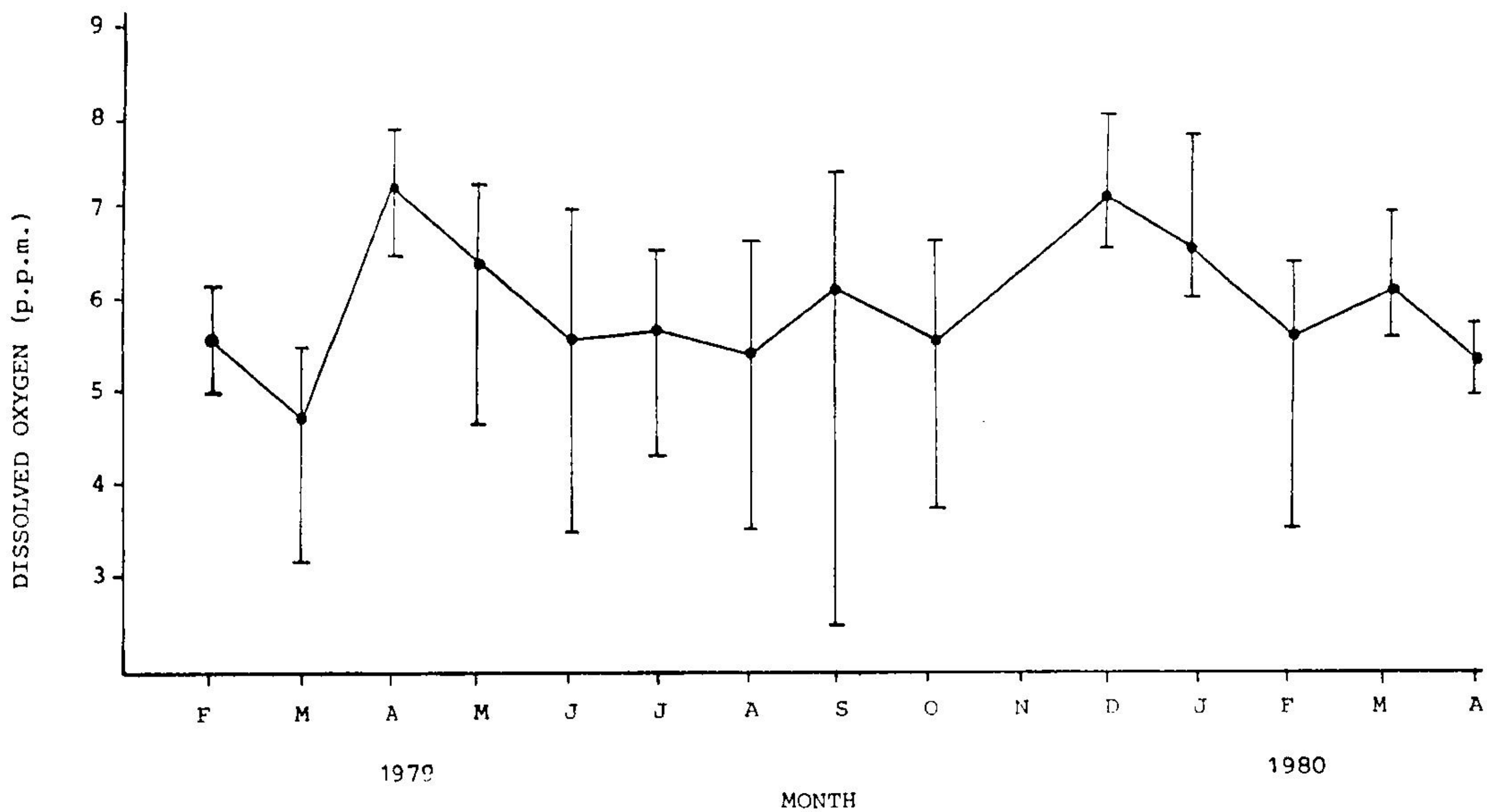


TABLE II

Monthly distribution of salinity (°/₀₀), temperature and dissolved oxygen (p.p.m.) values from Joyuda Lagoon during the period between February 1979 and April 1980

MONTH	SALINITY p.p.t.	TEMPERATURE °C	D.O. p.p.m.	D.O. SATURATION (p.p.m.)	% D.O. SATURATION
FEB	20.0	27.1	5.6	7.3	76.7
MAR	20.9	27.1	4.7	7.3	64.4
APR	24.2	28.9	7.2	6.8	> sat. point 113.5%
MAY	22.7	30.0	6.4	6.8	94.7
JUN	19.3	28.0	5.6	7.1	78.9
JUL	22.3	30.0	5.7	6.9	82.6
AUG	13.8	26.7	5.5	6.5	84.6
SEP	13.2	26.6	6.1	7.7	79.2
OCT	12.0	28.4	5.6	7.5	74.7
NOV	14.5	27.7	-	7.1	-
DEC	16.4	26.8	7.2	7.3	98.6
JAN	17.6	25.7	6.7	7.4	90.5
FEB	17.0	24.7	5.7	7.6	75.0
MAR	25.7	27.5	6.1	6.9	88.4
APR	30.0	28.8	5.4	6.6	81.8

Figure V. Relative abundance of Mugil curema in monthly samples at Joyuda Lagoon, with confidence limits to the 95%.

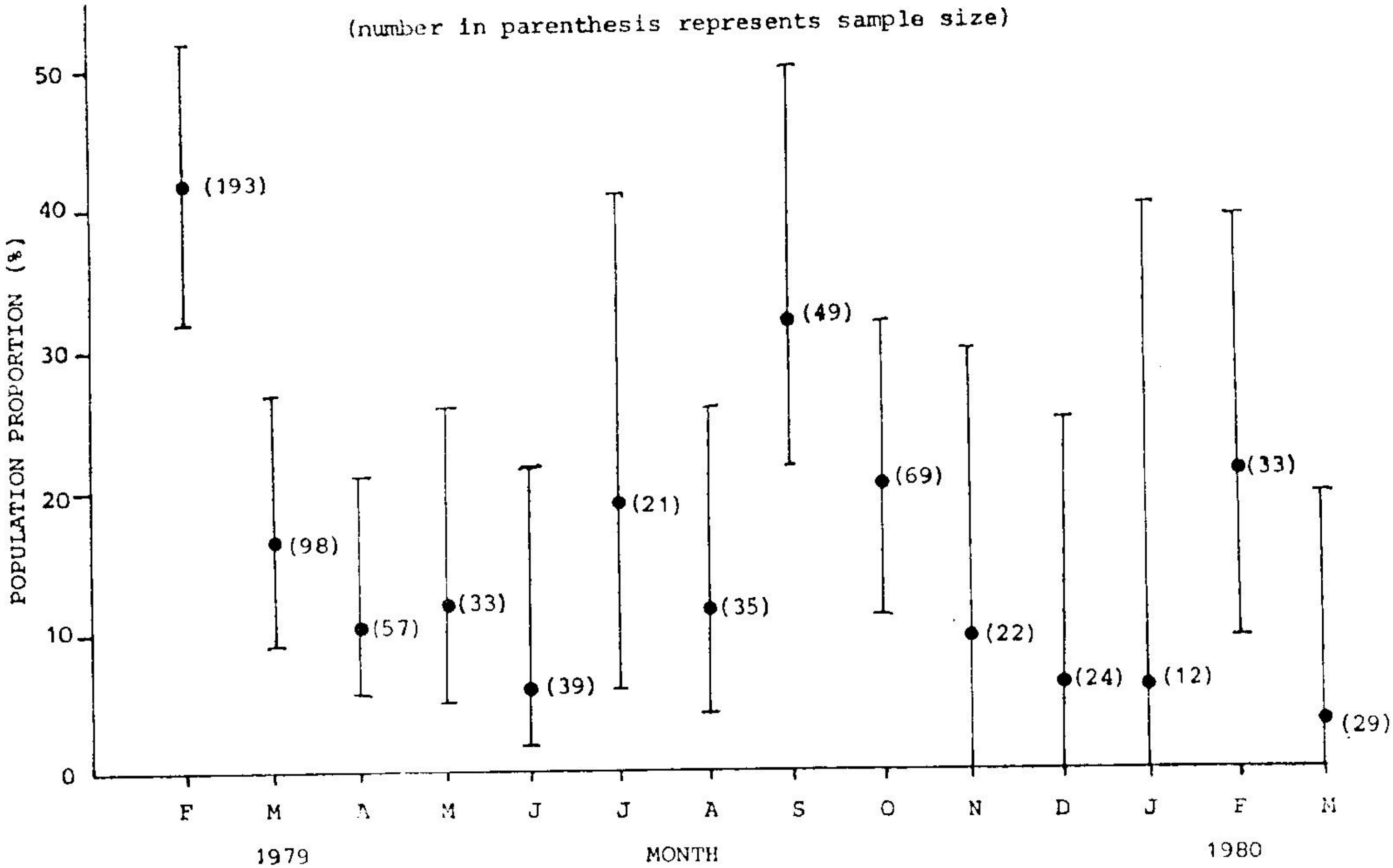


TABLE III

Index of gonad development in *Mugil curema* for the period between February 1979 and April 1980

1979								
FEBRUARY	MARCH	APRIL	MAY	JUNE	JULY	AUGUST	SEPTEMBER	OCTOBER
1.38	5.12	0.54	5.90	1.26	0.62	5.03	0.66	0.35
8.15	3.60	10.72	0.32	0.31	0.39	0.43	0.48	0.22
0.73	3.94	5.40	0.11	0.46	0.57	0.36	0.49	1.53
2.47	9.05	6.90	0.32	0.73	0.84	0.49	0.28	0.20
4.76	6.20	0.44	0.49	0.23	0.25		0.23	0.37
3.18	3.94	0.61	0.18	0.32	0.31		0.40	0.81
0.24	2.17	0.25	0.11	0.31	0.54		0.15	0.39
1.76	6.83	0.20	0.93	0.48	8.22		0.63	0.17
3.63	8.18	0.52	0.48	0.23	2.35		0.38	3.18
3.92	6.30	0.86		0.48	0.82		0.40	6.74
$\bar{X}$=3.02	5.53	2.64	0.88	0.48	1.49	1.58	0.41	2.20

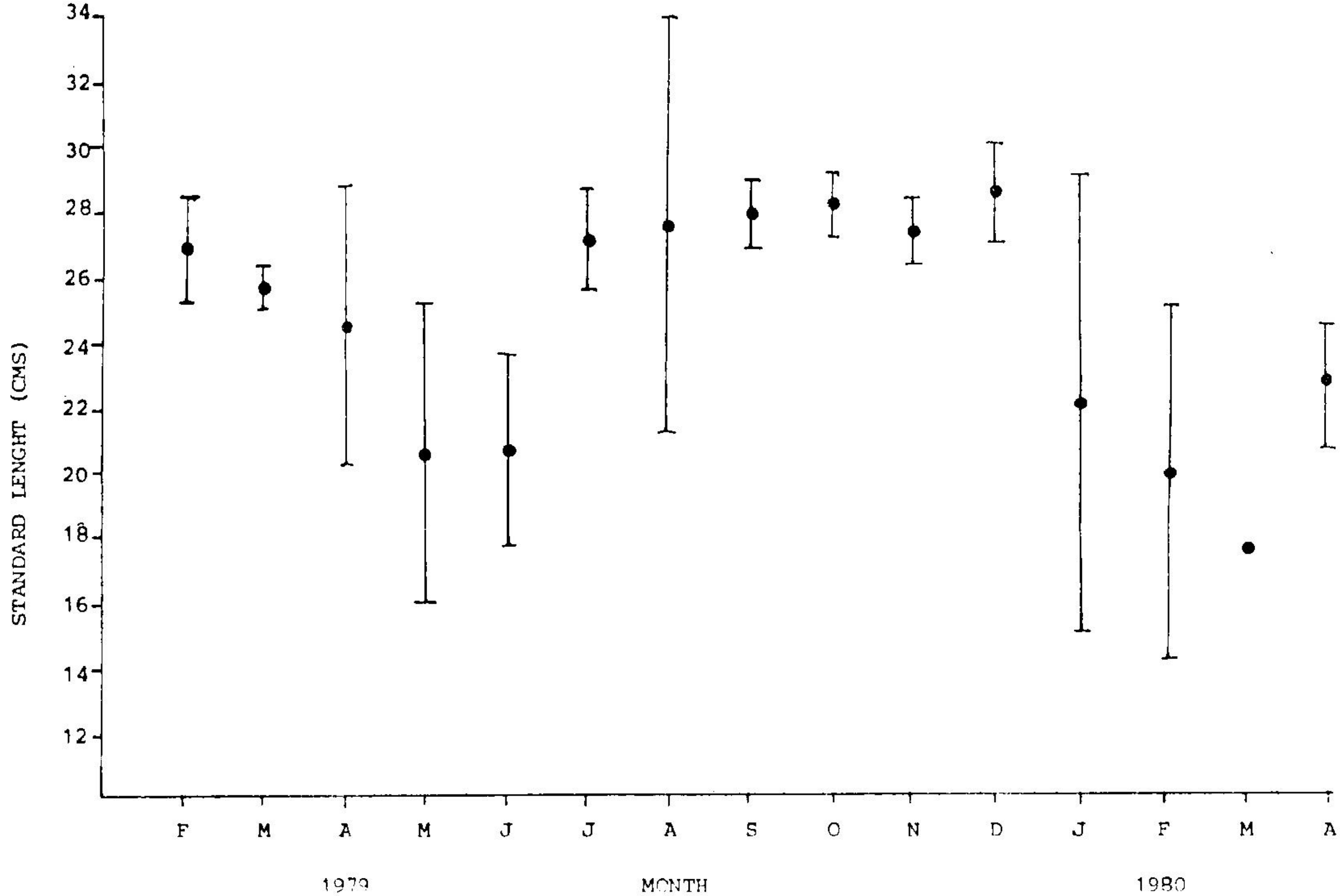
1980					
NOVEMBER	DECEMBER	JANUARY	FEBRUARY	MARCH	APRIL
3.00	1.40	0.43	2.70	0.09	0.17
2.32	6.32	0.24	0.11		0.31
	9.01		1.18		0.23
			0.09		
			0.09		
			0.09		
			8.06		
$\bar{X}$=2.66	5.58	0.34	1.76	0.09	0.24

viduals in the collections until September, in which no individuals were found to be sexually mature. The peak of adult white mullet in September with reduced gonad development may be indicative of a return, in part, of the white mullet population after the spawning had taken place in offshore waters. The overlapping data for the months of February and March 1980, are not significant in this matter because the individuals examined were not adult fishes (see Figure VI). The low values in relative abundance after October 1979 may be indicative of the detrimental effect of hurricanes David and Frederick in September 1979, or to over-fishing of the adult mullet population in the lagoon during their period of pre-spawning in February and March 1979 by local and commercial fishermen.

Host - Parasite Interactions

Six species of metazoan parasites were found to infect the white mullet during the study period at Joyuda Lagoon. Temporal patterns of incidence percentages must be interpreted with caution due to small sample size numbers. The Acanthocephalian parasite, Floridosentis mugilis (Machado - Filho 1951) which is an internal parasite, localized always in the intestine of the fish, was present at least once in every monthly sample. Floridosentis mugilis registered a peak of incidence in monthly collections of March 1979, and then in December 1979, January and March 1980. Figure VII presents the monthly fluctuations in incidence percentages for this species. The pattern of incidence percentages does not seem to be directly determined by any external factor related to the water quality of the lagoon. The fact that F. mugilis is transmitted by an intermediary host is indicative

Figure VI. Standard lenght distribution of *Mugil curema* in monthly samples at Joyuda Lagoon.



of the apparent availability of this intermediate host throughout most of the year in the lagoon. Further studies on the life cycle of this parasite must be assessed before any conclusive statements can be drawn about the short term variability in the incidence percentages of this species.

Two monogenean trematodes parasitized the gill filament of the white mullet in Joyuda Lagoon. Pseudohaliotrema mugilinus Hargis 1955 presented peaks in incidence percentages in February and March 1979, and then in March and April 1980. This monogenean parasite was absent from August to October 1979. Nevertheless, it appeared with moderately high incidence percentages throughout the study, specially during the winter period (Figure VIII). Low salinities, or perhaps the sudden decrease in salinity from August to September, continuing into October 1979, could have caused the absence of this parasite during these months.

Metamicrocotylea macracantha Alexander 1954 another monogenetic trematode which infects the gill filaments peaked in November 1979 and March 1980, and was also common in July and September 1979 and February 1980. Metamicrocotylea macracantha can withstand short time salinity variations and was present in September 1979 (see Figure IX) when salinity reached its lowest point during the study (approx. 12 ppt). The presence of this monogenetic trematode in Mugil curema was first noted in May 1979, but continued to appear in the rest of the study. This strongly suggests that the parasite either entered the lagoon after a sand bar formation opened in April-May with early spawned adult females, or with juvenile mullet which were probably new re-

Figure VII. Monthly variation in the incidence percentage of the Acanthocephalian parasite, *Floridosentis mugilis*, occurring in white mullet.

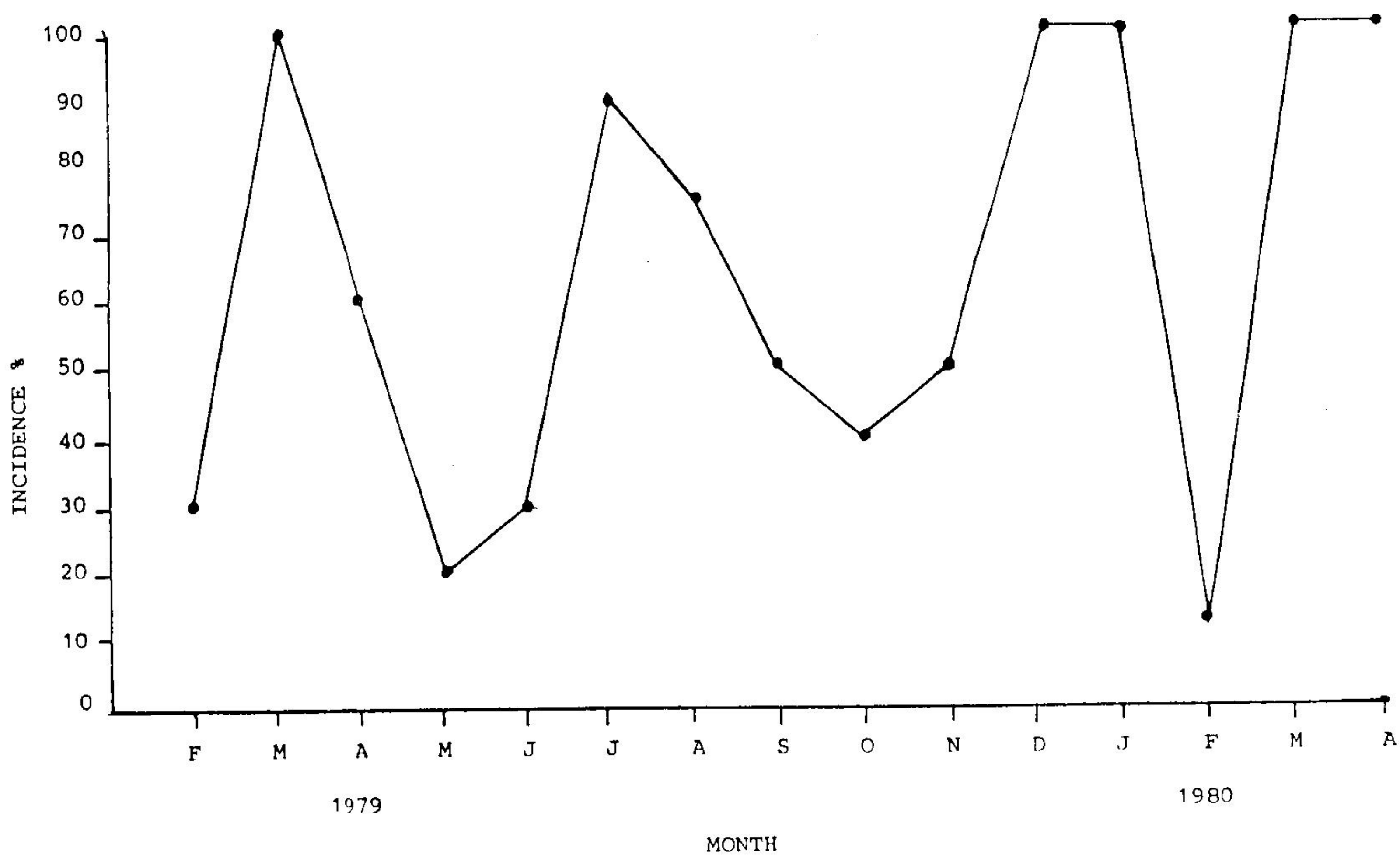


Figure VIII. Monthly variation in the incidence percentages of the monogenean trematode *Pseudohaliotrema mugilis*, parasitic in white mullet.

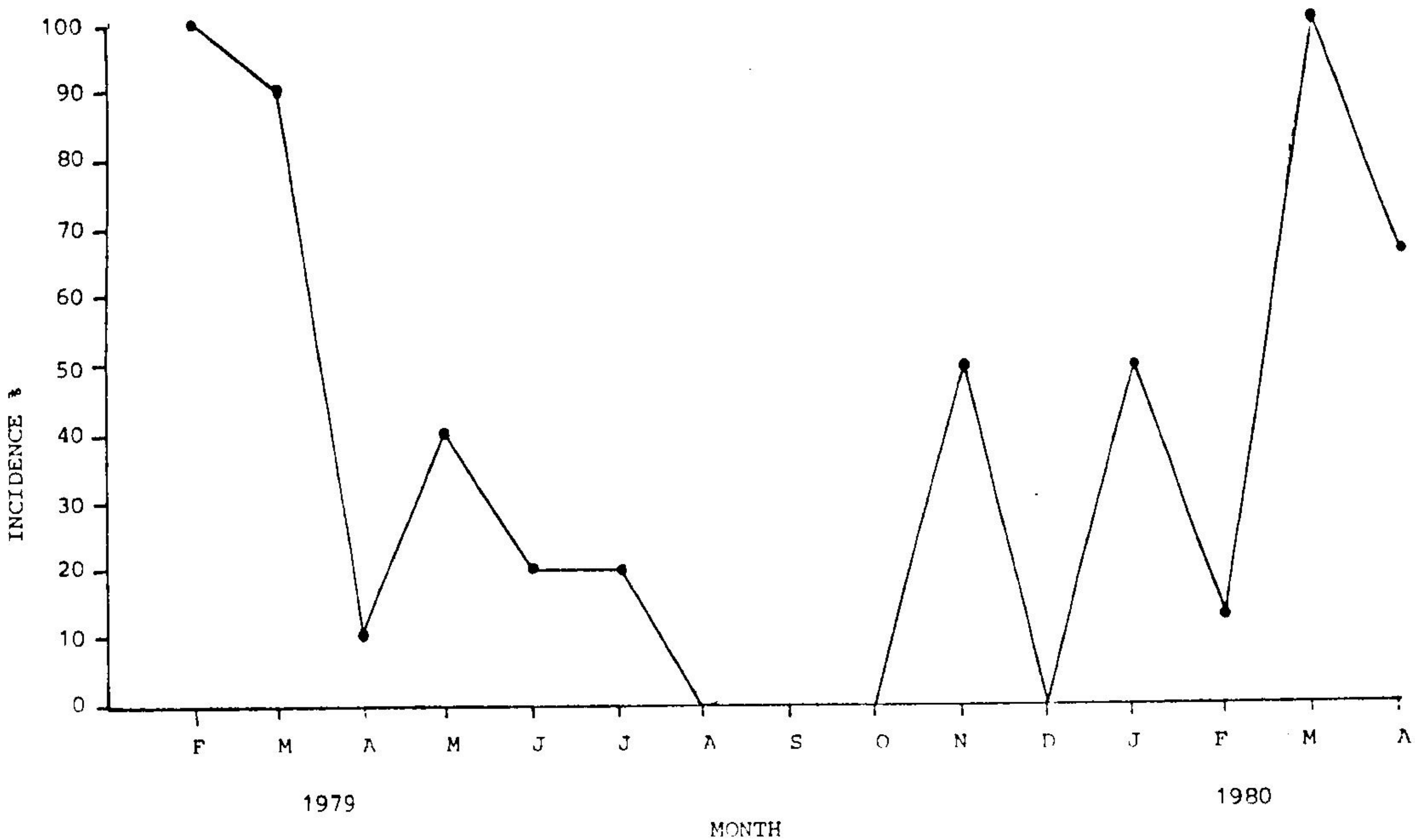
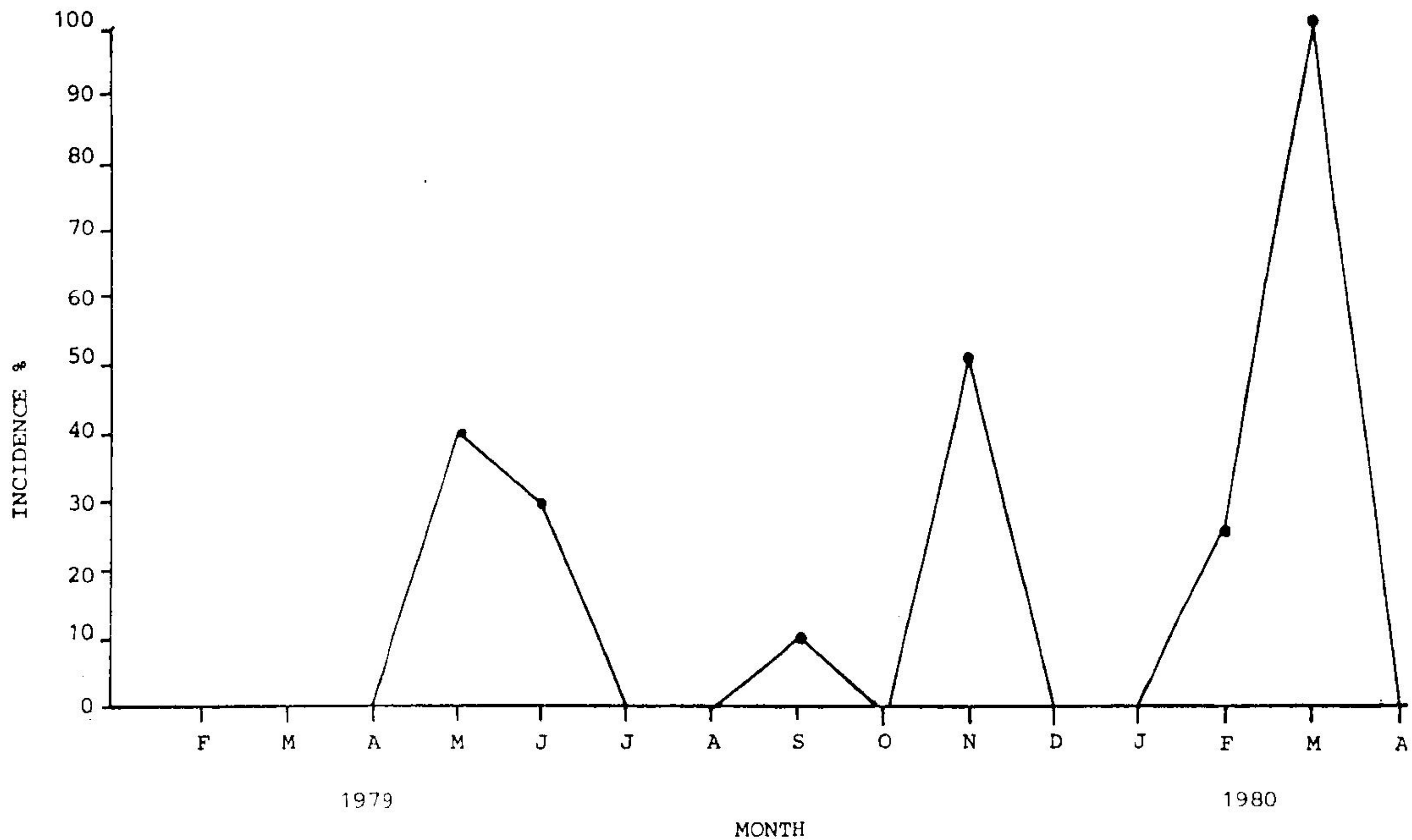


Figure IX. Monthly variation in the incidence percentage of the monogenetic trematode, *Metamicrocotylea macracantha*, parasitic in white mullet.



cruitments in the lagoon. However, after May, the short term variations of incidence on the host may be related to other factors, either environmental, biological or both.

Three species of copepods of different genera were found on the white mullet. Ergasilus lizae Krøyer 1864 which occurred only in the gill filaments of the fish was more abundant in February 1979. It prevailed until March 1979 and then disappeared until October 1979 reaching another high incidence value during January 1980 (see Figure X). Although E. lizae occurred during the winter period, its incidence in the white mullet seems to be more related to the migratory pattern of the adult fish than to seasonally related hydrological conditions. Ergasilus lizae survived in a wide range of temperature and salinity variations in Joyuda Lagoon. Its absence after March 1979 could be due to the migration of adult mullet to offshore waters. As a consequence of this migration, the individuals examined during the remaining summer months, did not possess this parasite because they were new recruitments composed mostly of juvenile fish. With the next immigration of adult mullet after September 1979, the parasite became again a regular component of the parasitic population of the mullet in Joyuda Lagoon.

The parasitic copepod, Lernaeenicus longiventris Wilson 1917 was found partially embedded in the fins and body surface of the white mullet. Its prevalence and incidence percentages show a clear peak during summer with consistently high incidence percentages for the months of July, August and September 1979 (see Figure XI). After a lag period of two months, the parasite appeared again in the collec-

Figure X. Monthly variation in the incidence percentages of the copepod, *Ergasilus lizae*, parasitic in white mullet.

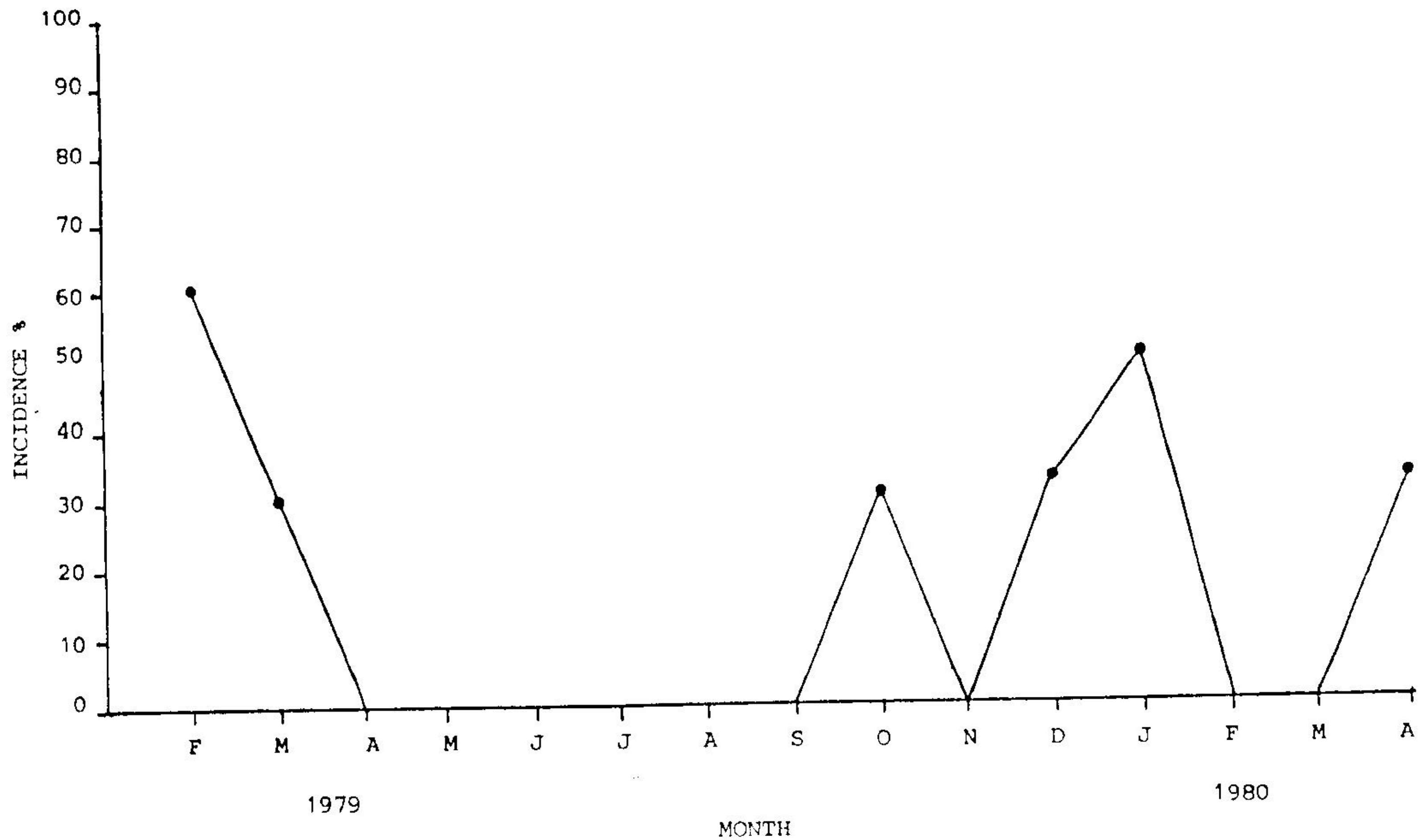
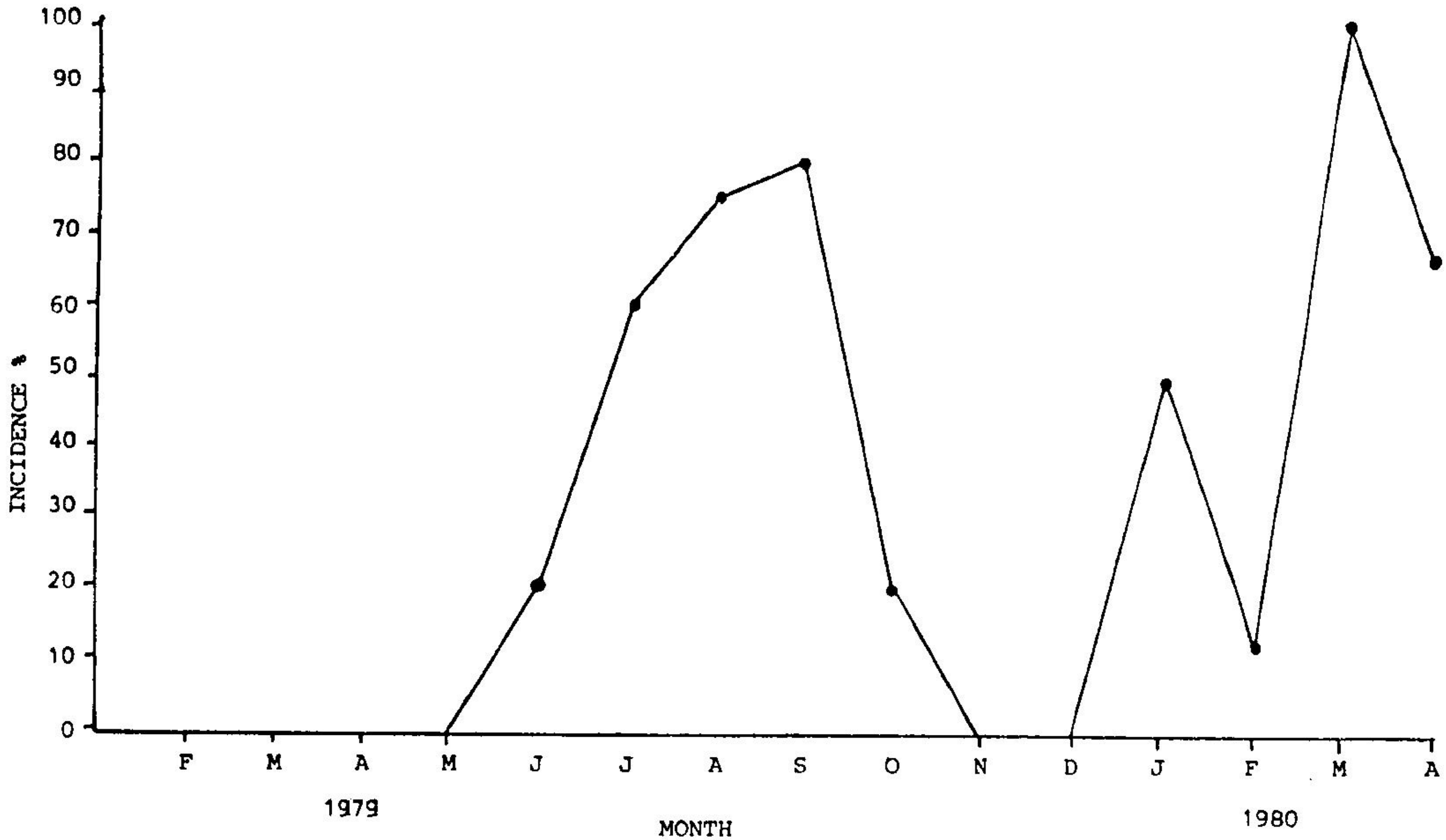


Figure XI. Monthly variation in the incidence percentages of the copepod *Lernaeenicus longiventris*, parasitic in white mullet.



tions, reaching another peak during March 1980. The pattern of occurrence of this parasitic species is again indicative of the different populations of mullet which were sampled during the study period. The parasite first appeared in monthly collections from June 1979, one month after the migration of the fish, and then showed reduced incidence percentages in October 1979, probably as a result of non-infected adult mullet examined in that particular monthly sample. Apparently, after being introduced by new recruitment into the lagoon during the summer period, the parasite adapted well to the strongly variable hydrological conditions in the lagoon and persisted in the samples despite a change of 17 ppt in salinity between October 1979 and April 1980.

Bomolochus concinnus Wilson 1911 occurred mostly in the mucus of the branchiostegal cavity with occasional presence in the branchiostegal filaments. *Bomolochus concinnus* appeared in nine out of 15 monthly samples, but did not show any distinct peak of abundance based on reasonable sample size numbers. Its abundance during the rainy period in summer (see Figure XII) from August to October 1979 may be indicative of low tolerance to the sudden salinity decrease associated to hurricanes David and Frederick.

Interactions Between Parasitic Species

Six species of external parasites and one endoparasite were present in white mullet at different time periods throughout the study. The prevalence of these species in the white mullet is presented in Table IV. It was observed that ectoparasites which occupied similar microhabitats within the fish such as *Metamicrocotylea*

Figure XII. Monthly variation in the incidence percentages of the copepod *Bomolochus concinnus*, parasitic in white mullet.

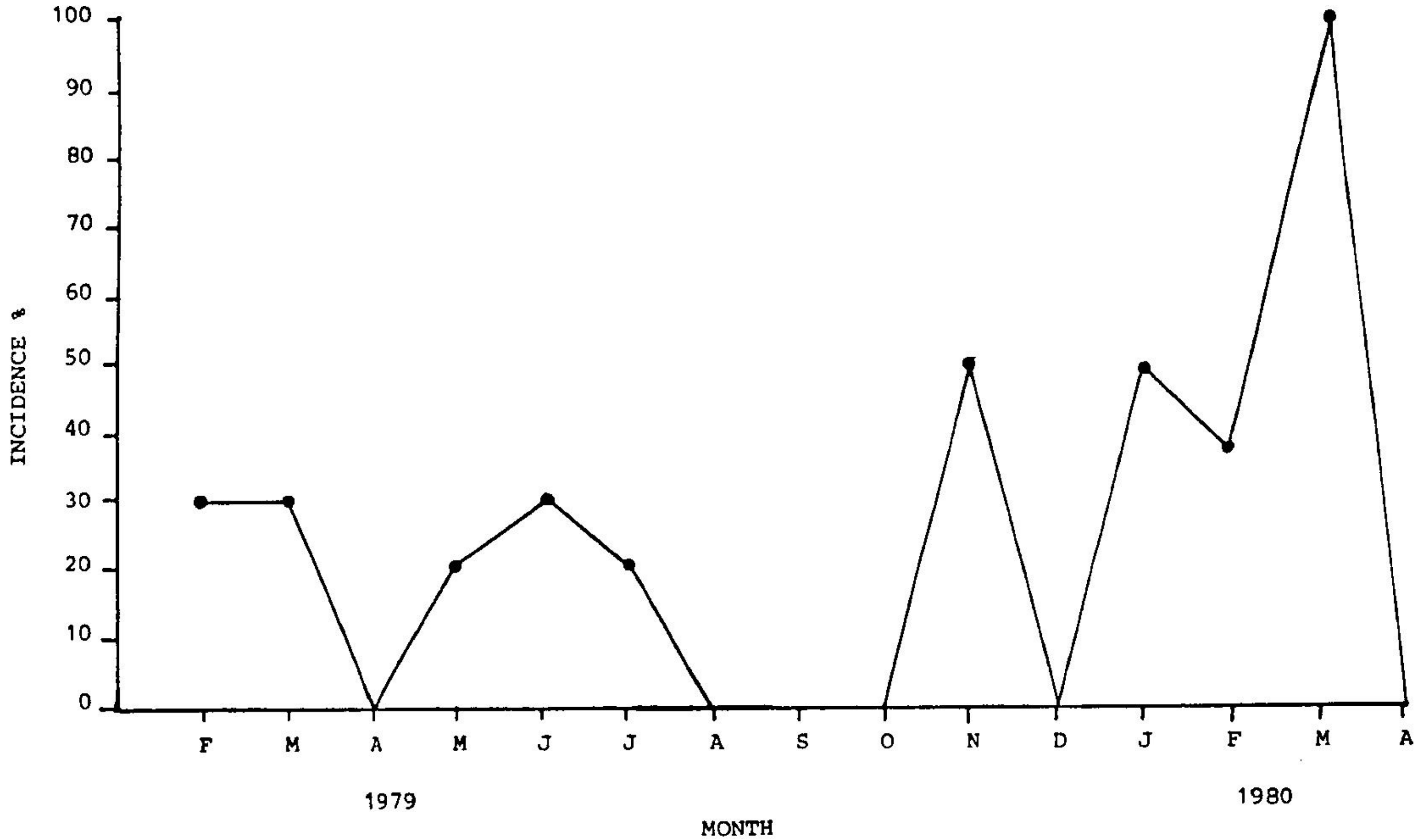


TABLE IV

Monthly prevalence of parasitic species in the white mullet from Joyuda Lagoon, during the period between February 1979 and April 1980

MONTH	Sp 1	Sp 2	Sp 3	Sp 4	Sp 5	Sp 6
FEB	+	-	+	+	-	+
MAR	+	-	+	+	-	+
APR	+	-	-	-	-	+
MAY	+	+	+	-	-	+
JUN	+	+	+	-	+	+
JUL	+	-	+	-	+	+
AUG	-	-	-	-	+	+
SEP	-	+	-	-	+	+
OCT	-	-	-	+	+	+
NOV	+	+	+	-	-	+
DEC	-	-	-	+	-	+
JAN	+	-	+	+	+	+
FEB	+	+	+	-	+	+
MAR	+	+	+	-	+	+
APR	-	-	-	+	+	+

\- Absence
\+ Presence

Sp. 1 - Pseudohaliotrema mugilinus

Sp. 2 - Metamicrocotylea macracantha

Sp. 3 - Bomolochus concinnus

Sp. 4 - Ergasilus lizae

Sp. 5 - Lernaeenicus longiventris

Sp. 6 - Floridosentis mugilis

macracantha and Ergasilus lizae, did not occur together in monthly samples. Both species are specialized parasites of the gill filaments. Table V details the presence-absence display of both species in monthly samples. These species show a significant negative association (p=0.017). Possibly one of these parasites is excluding the other in competition for food and/or space. Their mutual exclusion in monthly samples could be affected by the seasonal periodicity of one species or the other, their adaptations to withstand environmental stress, chance, or actual interspecific interactions between both species.

The association between Pseudohaliotrema mugilinus and Bomolochus concinnus also suggests possible interactions between different parasitic populations. In this case, a positive association resulted between both parasites (see Table VI), the probability of association was highly significant (p=0.002). Pseudohaliotrema mugilinus and B. concinnus are exposed to similar environmental conditions, as both are parasitic in the branchiostegal cavity, however, each species occupied different niches or microhabitats within the fish. Bomolochus concinnus was always found in the mucus layer of the branchiostegal flap, while Pseudohaliotrema mugilinus was always parasitic in the gill filaments. Different food and space requirements can permit both species to co-exist together in the host.

Floridosentis mugilis, an acanthocephalian worm, was the only internal parasite observed and it prevailed consistently in every monthly sample (see Table IV). The presence of other endoparasites in the alimentary tract is probably limited by the lack of intermediate

TABLE V

Contingency table representing the negative interspecific association between the monogenetic trematode Metamicrocotylea macracantha and the copepod Ergasilus lizae

Metamicrocotylea macracantha

Ergasilus lizae	Present	Absent	
Present	0	6	6
Absent	6	3	9
	6	9	15

Probability of association by chance (p) = 0.017

TABLE VI

Contingency table representing the positive interspecific association between the monogenetic trematode *Pseudohaliotrema mugilinus* and the copepod *Bomolochus cocinnus*

Pseudohaliotrema mugilinus

Bomolochus cocinnus	Present	Absent	
Present	9	0	9
Absent	1	5	6
	10	5	15

Probability of association by chance (p) = 0.002

hosts such as mollusks, which are rare in Joyuda Lagoon. The possibility of competitive exclusion by the acanthocephalian is contradicted by the presence of digenetic trematodes which occur along with *E. mugilis* in collections of mullet examined in La Parguera, Puerto Rico (Williams, E.H., unpubl. data).

The consistent patterns of association between parasites constitutes evidence that their temporal occurrence is real and not an artifact of sampling variability.

Parasite-Ecosystem Interactions

Simple and multiple regression analyses between monthly means of temperature and salinity and the intensity of infection by parasitic species were non-significant at the 0.05 level. Evidently, most ectoparasitic species in *Mugil curema* withstand some degree of variation in salinity and temperature (see Tables VII, VIII and IX). Consequently the spread of points in both sides of the regression lines result in high standard error and low correlation coefficients. Deterministic effects of hydrological parameters on the parasite composition of *Mugil curema* were observed for abrupt salinity variations in August through October 1979. Most species of external parasites presented low incidence or were absent during this period. The effect of short term variation is probably more important in determining the prevalence of some parasitic species than seasonally related variations which are gradually experienced by external parasites. If we consider the wide range of tolerance that mullet have for salinity variations it is suggestive that the external parasitic fauna has also adapted to variable salinities.

TABLE VII

Analysis of simple linear regressions between monthly means of salinity and intensity of parasitization by metazoan species of parasites in white mullet

Parasite Species	Coefficient of Determination (r^2)	Coefficient of Correlation (r)	Standard Error of Estimate	Significance of Correlation Coefficient to the 95% Level for n=14, r=.497
Pseudohaliotrema mugilinus	.016	.126	1.067	P> .05, N.S.
Metamicrocotylea macracantha	.013	.116	.539	P> .05, N.S.
Ergasilus lizae	6.15×10^{-3}	.078	.557	P> .05, N.S.
Lernaeenicus longiventris	.063	.251	.654	P> .05, N.S.
Bomolochus concinnus	5.12×10^{-3}	.072	.545	P> .05, N.S.
Floridosentis mugilis	.046	.214	.442	P> .05, N.S.

TABLE VIII

Analysis of simple linear regressions between monthly means of temperature and intensity of parasitization by metazoan species of parasites in white mullet

Parasite Species	Coefficient of Determination	Coefficient of Correlation	Standard Error of Estimate	Significance of Correlation Coef-ficient to the 95% Level for n=14, r=.497
Pseudohaliotrema mugilinus	.045	.212	1.051	P> .05, N.S.
Metamicrocotylea macracantha	4.62×10^{-6}	2.15×10^{-3}	.543	P> .05, N.S.
Ergasilus lizae	5.89×10^{-3}	.077	.558	P> .05, N.S.
Lernaeenicus longiventris	.054	.232	.658	P> .05, N.S.
Bomolochus concinnus	.172	.414	.497	P> .05, N.S.
Floridosentis mugilis	.012	.111	.449	P> .05, N.S.

TABLE IX

Multiple linear regression analysis between monthly means of salinity and temperature and intensity of parasitization by metazoan species of parasites in white mullet

Parasite Species	Coefficient of Determination	Coefficient of Correlation	Standard Error of Estimate	Significance of Correlation Coefficient to the 95% Level for n=14, r=.497
Pseudohaliotrema mugilinus	.047	.216	1.093	P> .05, N.S.
Metamicrocotylea macracantha	.016	.126	.560	P> .05, N.S.
Ergasilus lizae	.021	.143	.576	P> .05, N.S.
Lernaeenicus longiventris	.083	.288	.674	P> .05, N.S.
Bomolochus concinnus	.243	.493	.494	P> .05, N.S.
Floridosentis mugilis	.094	.307	.447	P> .05, N.S.

The periodic occurrence of parasitic species such as the copepods *Lernaeenicus longiventris* and *Ergasilus lizae* is explained by the migratory behavior and relative abundance of adult mullet in Joyuda Lagoon rather than seasonally determined by temperature and/or salinity. The influence of monthly variations in water temperature and salinity may play an important role in particular interspecific interactions between two species in competition for similar habitats in the fish. For example, *E. lizae* presented higher intensity of parasitization during the winter period (see Figure XIII), while *M. macracantha* had high intensity of infection in two monthly collections in summer and also prevailed in samples from September 1979 (see Figure XIV). This suggests that *M. macracantha* is more tolerant to high temperatures than *E. lizae* in Joyuda Lagoon. *L. longiventris* also displayed a trend of occurrence during the summer months with high intensity of parasitization in higher water temperatures than the average for the ecosystem (see Figure XV).

ure XIII. Monthly variation in the intensity of parasitization of the copepod *Ergasilus lizae*, on white mullet.

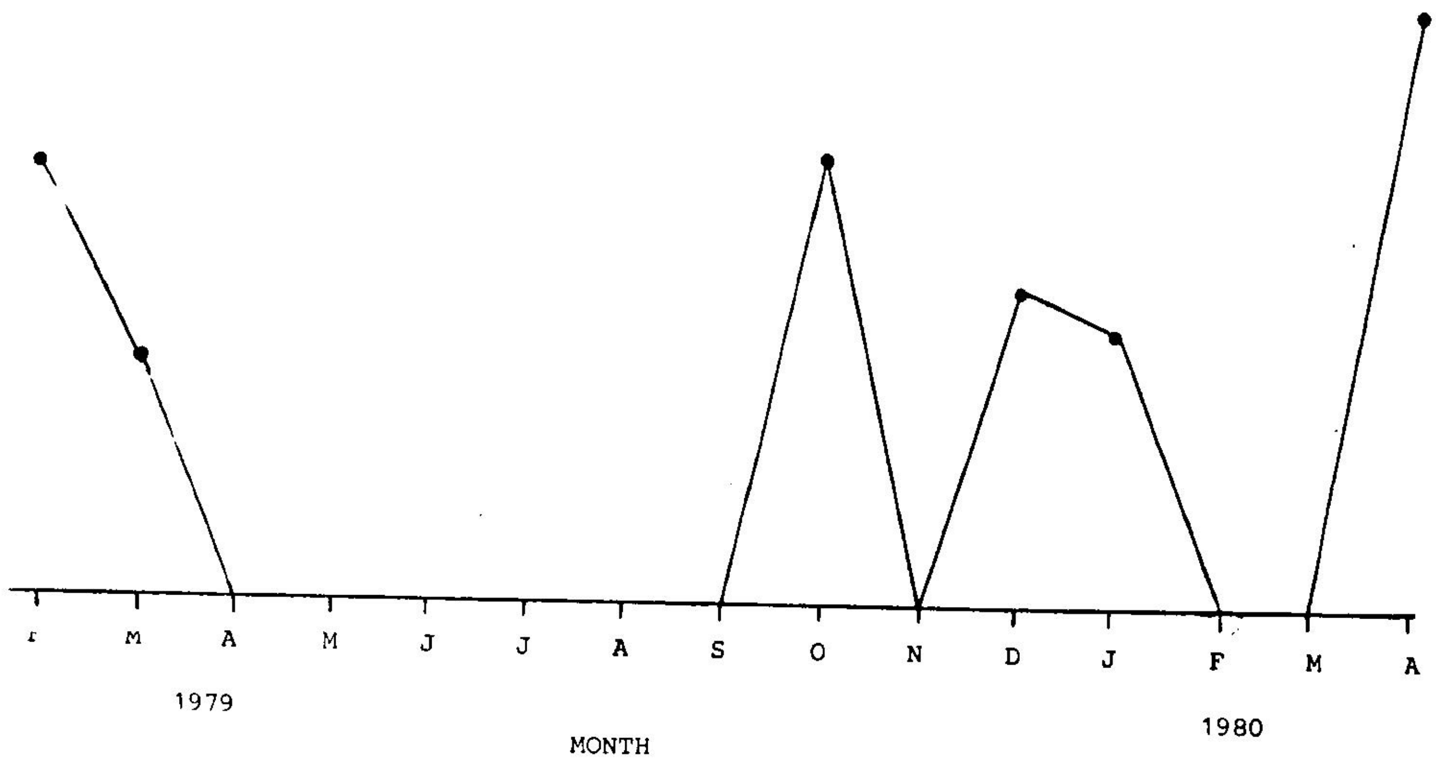


Figure XIV. Monthly variation in the intensity of parasitization of the monogenetic trematode, *Metamicrocotylea macracantha*, on white mullet.

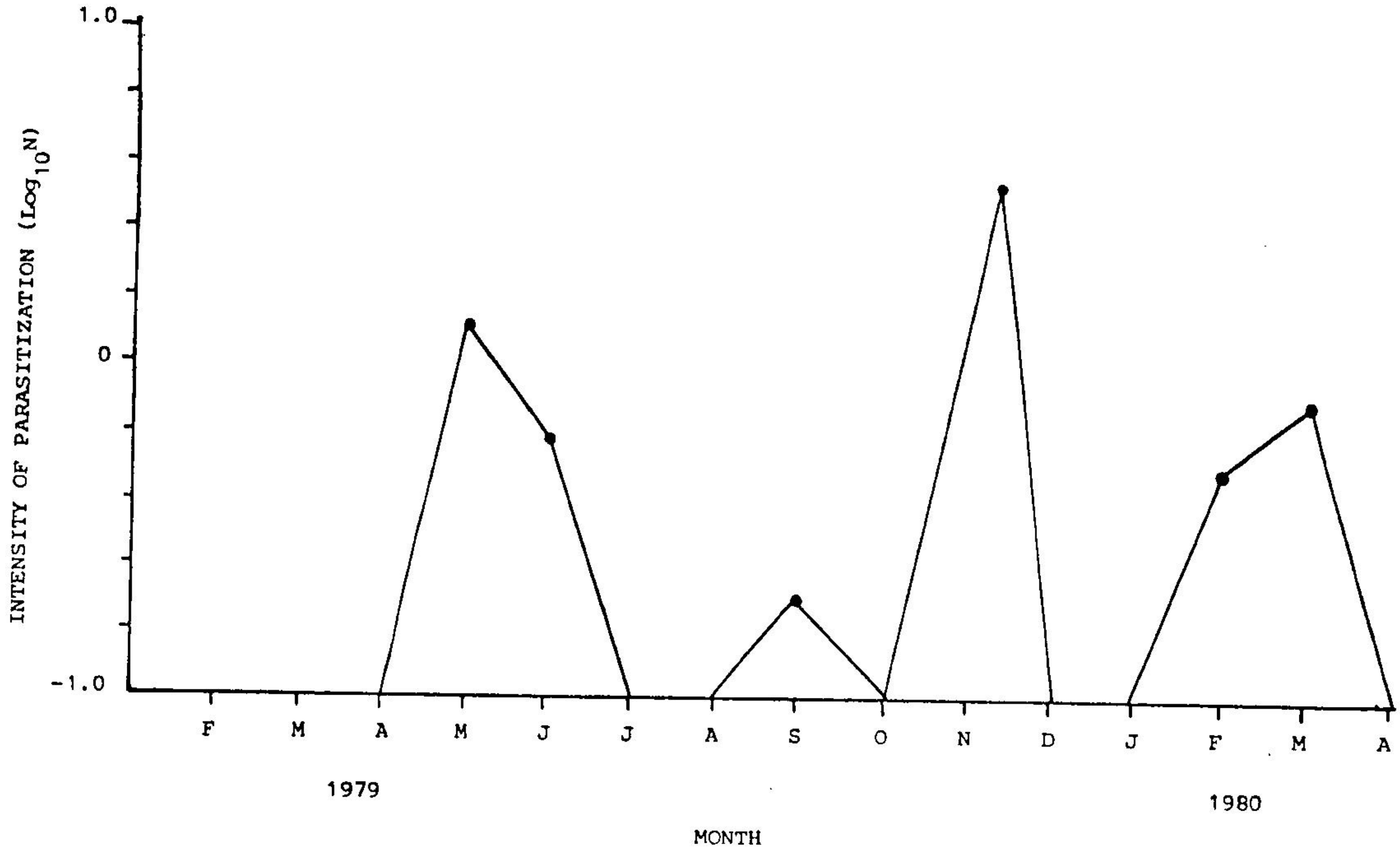
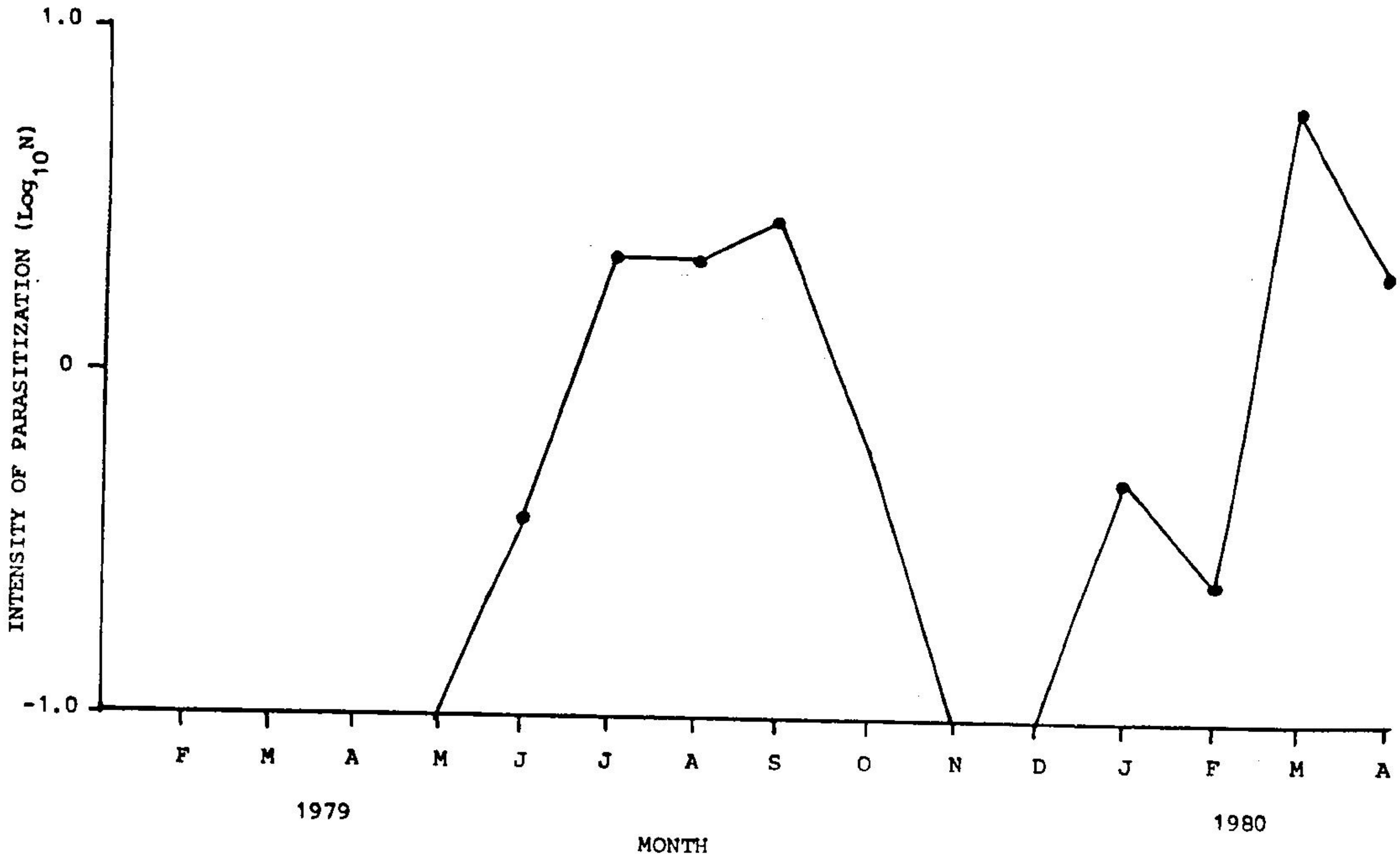


Figure XV. Monthly variation in the intensity of parasitization of the copepod *Lernaeenicus longiventris*, on white mullet.



CONCLUSIONS

The range of tolerance observed by parasitic species to temperature and salinity variations in Joyuda Lagoon is indicative of the adaptations that these parasites have developed in order to withstand similar environmental gradients to which the host is adapted.

The migratory behavior of adult mullet to offshore waters and their eventual return to the lagoon accounts for much of the variability observed in the periodic occurrence of some parasitic species in white mullet.

Seasonally related variations in water temperature and salinity are not related to the incidence and intensity of infection by parasitic species. Nevertheless, sudden salinity variations are detrimental to some ectoparasitic populations which are apparently less tolerant than their host to rapid, low salinity stress.

Negative interspecific interactions between parasitic species occurred between populations which occupy similar microhabitats within the host. This type of association was significant for the copepod *Ergasilus lizae* and the monogenetic trematode *Metamicrocotylea macracantha*. Their actual competition and mutual exclusion may explain the short-term variations that these species present in their patterns of occurrence.

Joyuda Lagoon is a detritus-based ecosystem which provides high food availability and protection for juvenile and adult mullet. The population proportion of adult mullet is higher during the winter period prior to their peak of sexual maturity. This fact suggests that the mullet concentrate in the lagoon in order to feed extensively and storage enough energy for their spawning migration. Joyuda Lagoon may also function as shelter to juvenile and adult mullet during periods of high wave energy and low food availability in the coast.

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