EFFECTS OF STOCKING DENSITY AND POLYCULTURE ON GILL ECTOSYMBIONT LOADS IN CAGE CULTURED CHANNEL CATFISH AND TILAPIA AUREA

By

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EFFECTS OF STOCKING DENSITY AND POLYCULTURE

ON GILL ECTOSYMBIONT LOADS IN CAGE

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PREFACE

This study was concerned with the effects of stocking density and polyculture on gill ectosymbiont loads in cage cultured fish. The primary objectives were to observe temporal variations among the ectosymbionts and to determine if an increase in stocking density or the addition of a second culture species produced a change in the gill ectosymbiont community.

The author wishes to express her appreciation to her major adviser, Dr. Rudy Miller, for his guidance and assistance throughout this study. Appreciation is also expressed to the other committee members, Dr. Eugene Maughan and Dr. Margaret Ewing for their invaluable assistance throughout the course of this study.

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CHAPTER I

INTRODUCTION

Fish diseases and their control are of great economic importance to fish hatcheries, freshwater and marine fisheries, aquaculture operations, and the ornamental fish trade. To the layman, the mere presence of these disease agents is cause for alarm but to specialists, parasites are considered fish pathogens only if functions are impaired (Snieszko, 1975).

The role of symbiotic algae in fish disease is particularly difficult to interpret. Oodinium limneticum was the first freshwater alga identified as parasitic (Jacobs, 1946). However, it is often unclear whether the association is parasitic. Vinyard (1953) found Cladophora spp. deeply penetrating the bone in largemouth bass (Micropterus salmoides) and smallmouth buffalo (Ictiobus bubalus) and Edwards (1978) found carp (Cyprinus carpio) infected with Cladophora spp. In contrast, Tsuda et al, (1972) found Cladophora spp. epizoophytic on the teeth of parrot fish (Scaridae) and all fish appeared healthy.

In any community a large percentage of healthy and normal individuals harbor potentially pathogenic organisms without suffering any symptoms or lesions. A disease occurs only if a susceptible host is exposed to a virulent pathogen under the proper environmental conditions (Snieszko, 1975). These proper "environmental conditions" usually involve some form of stress (Snieszko, 1958, 1975; Wedemeyer, 1970).

Some of the factors which are known to act as stressors and influence infection or the course of a disease in fish include temperature, host density, inter- and intraspecific interaction and oxygen deficiency. These factors are especially important in intensive culture where fish are constantly subjected to environmental fluctuations and potentially stressful management practices such as hauling, crowding and drug treatments (Snieszko, 1958; Allison, 1963; Wedemeyer et al, 1976; Walters and Plumb, 1980).

Disease incidence in culture conditions has been shown to vary seasonally, with the highest incidence in April when almost 50% more cases occurred than in July, the month of next highest incidence. The April peak is probably due to increased water temperature and handling (Meyer, 1970; Plumb, 1975). As water temperature approaches the upper or lower tolerance limits for fish, normally nonpathogenic bacteria become pathogenic.

There are also strong correlations between optimum temperatures for multiplication of parasites and outbreaks of disease (Roberts, 1975). Furthermore, changes in water temperature alter dissolved oxygen concentrations, biological oxygen demand, toxicity of pollutants, the host's metabolic rate with subsequent changes in the excreted metabolites, and the speed of antibody formation (Snieszko, 1974).

Low dissolved oxygen concentrations are a common problem in catfish culture. The frequency of dissolved oxygen concentrations below 2 mg/L at dawn is greatest during the summer when water temperatures are above 26C. Concentrations often fall below 2 mg/L but seldom harm the fish as long as the period of low dissolved oxygen concentration is not prolonged (Boyd et al, 1979). However, the effects of hypoxia on disease

resistance are not clear. Such stress did not appear to enhance disease or parasite problems in a study conducted by Andrews et al (1973), who concluded that poor survival in commercial culture during hypoxic periods was probably due to exposure to lethal levels for very brief periods. In contrast, Scott and Rogers (1980) found that fish exposed to hypoxia were predisposed to diseases because the necessary physiological adjustments and damage to the immune system reduced the fish's ability to combat bacterial, viral or parasitic infections. Gill tissues are especially sensitive to sublethal hypoxia, and lesions may result, reducing the efficiency of the gills in respiratory exchange. The residual effects of hypoxia place fish at an adaptive disadvantage if the fish are exposed to additional stresses.

Crowding in an environment that is enriched through supplemental feeding and fertilization is another important environmental stressor which predisposes fish to disease problems in intensive culture. Mortalities can be related directly to detrimental environmental changes or to diseases resulting from physiological disturbances associated with these environmental changes (Wedemeyer et al, 1976; Scott and Rogers, 1980). High metabolite levels among confined fish create an ideal situation for the development of parasitic populations (Allison, 1963). For example, bacterial gill disease can become a chronic problem at the high population densities needed for efficient salmonid fish culture but can be eliminated if densities are reduced (Wedemeyer, 1970; Wedemeyer, et al, 1976).

Though infectious diseases can often be controlled with drugs, chemotherapy generally offers only temporary control. More extensive reduction in mortality in high density culture can be achieved in several

ways:

1. Proper diagnosis of the disease.
2. Maintenance of the natural balance between pathogen and host.
3. Practice of sanitation procedures.
4. Prophylaxis only when a specific disease occurs with some regularity at a location or if part of the establishment is already contaminated.

(Snieszko, 1958)

Long range disease control can best be accomplished by increasing the resistance of the host through selective breeding. A number of biochemical components of both hosts and parasites are genetically linked and therefore potential resistance or susceptability to infectious diseases or parasites can be inherited (Snieszko, 1958). Because more than one pair of genes may be involved in inheriting disease resistance and differences between stocks exist, development of a pure line is time consuming and demanding. One currently promising approach is to develop fish which can tolerate a greater range of temperatures, or dissolved oxygen/carbon dioxide levels. Resistance of this type ensures that these fish will be less easily stressed and therefore be more resistant to invasion by parasites (Wolf, 1954).

Cage Culture

Catfish culture is restricted generally to the southeastern United States because of the need for a long growing season and warm water temperatures are required. The principal markets for cultured catfish, also located within these areas, are processing plants (27% of the market), recreational use (greater than 40%), local markets (approximately

31%) and restaurants. The four basic methods of intensive commercial culture are pond, tank, raceway and cage culture.

Cage culture of fish has been defined as the raising of fish stocked at high densities from fingerlings to marketable size in cages. Fish are fed at the surface of the water in cages enclosed on all sides and bottom by wooden slats, hardware cloth, netting, or other materials that allow free circulation of water (Schmittou, 1970; Collins, 1970; Douglass and Lackey, 1974).

Some of the advantages of cage culture include:

1. All types of water environments including farm ponds, rivers, and irrigation canals can be used.
2. Intensive culture and polyculture can be practiced.
3. Fish can be observed closely during feeding and their general health evaluated. Parasites and diseases can be treated easily and economically.

(Schmittou, 1970; Douglass and Lackey, 1974; Newton, 1980)

Some of the disadvantages of cage culture include:

1. A nutritionally complete floating feed is required.
2. Aeration equipment may be necessary.
3. The incidence of bacterial disease is high and the possibility of parasite epizootics in both the native and caged fish is increased as a result of crowding.

(Aldridge and Loyacano, 1973; Douglass and Lackey, 1974; Collins, 1978)

Generally culture operations in the United States involve channel catfish as the principal culture species and much information exists on channel catfish culture. Marketable-size channel catfish can be produced in one growing season provided the initial stocking size is at

least 150mm (Holmes et al, 1974). Stocking density is also an important consideration. Increase in stocking density from 500 to 900 fish per cage has been correlated with a decrease in weight per fish (Pennington and Strawn, 1978). This decrease was due either to deteriorating water quality in the cages or to some minimal space requirement of channel catfish that must be met for normal growth. Despite the decrease in mean fish weight, total production increases until carrying capacity is reached.

A relatively new approach in fish culture is polyculture, defined as the combined cultivation of two or more species of fish (Allen and Carter, 1976). Some authors have reported synergistic relationships between polycultured species. For example, it has been found that the addition of small numbers of Tilapia aurea increased the individual weight gains as well as the percent harvestable channel catfish in cages in small shallow ponds. It has been suggested that Tilapia stimulated catfish to eat more or to convert food more efficiently (Clady, 1981; Williams, 1982).

In contrast, Wilson and Hilton (1981) found that as the density of Tilapia aurea increased, the growth of the channel catfish decreased. The catfish stocked alone gained approximately 49% of initial body weight, whereas the polycultured catfish lost approximately 22% of initial body weight.

Cage cultured fish would seem predisposed to high disease incidence because fish are stocked at higher densities than in pond culture. Ectoparasites are present on virtually all fish under natural conditions, but crowding increases the potential for parasite epidemics. The rate of parasite transmission may increase because the parasite has a better

chance of finding a host if the host density is high (DeBach and Smith, 1941; Allison, 1963; Crofton, 1971). Evidence from terrestrial situations is seen in the 92% increase in Trichomonas among crowded ground squirrels (Noble, 1961, 1962).

Most parasitic epidemics among fish result from contact transfer of external protozoans and helminths with simple life cycles (Allison, 1963). In an 11-year survey of fish diseases at the Southeastern Fish Disease Laboratory, 59% of cases with parasites involved protozoans and 14.5% involved multiple parasitic species (Plumb, 1975).

Nevertheless, some investigators maintain that parasites do not present a greater threat to caged fish than to other fish in the pond. Certain aspects of cage culture may actually reduce the potential of epidemics. Bottom muds generally have higher densities of pathogenic organisms than the surface water and fish in cages generally do not come in contact with this bottom mud. Also, fish feces fall through the cage and are not consumed when the fish are feeding (Schmittou, 1970).

Support for this position is provided by a study of parasite loads of fish found near cages and fish located away from cages (Aldridge and Loyacano, 1973). No significant differences between locations in number of fish harboring monogenetic trematodes, copepods, or both were observed. Neither was there a significant difference in the number of fish with these parasites during pre-culturing, culturing, or post-culturing periods.

It appears that, as Collins (1978) suggested, if water quality is adequate and feed meets the nutritional requirements of the fish, then disease seldom reaches epidemic proportions in cage culture. However, the effects of moderate increases in stocking density upon symbiont populations in caged fish are unknown.

Objectives

The major objectives of this study were to:

1. Determine whether an increase in stocking density was associated with an increase in the gill ectosymbiont density of cage cultured channel catfish, Ictalurus punctatus.

2. Determine whether the addition of Tilapia aurea as a second species caused a difference in the gill ectosymbiont community of cage cultured channel catfish, Ictalurus punctatus.

3. Observe any seasonal variations in ectosymbiont incidence in an effort to separate the direct effects of increased stocking densities and the natural seasonal cycling of ectosymbiont populations.

CHAPTER II

METHODS AND MATERIALS

Preliminary Study 1981

A preliminary stocking density study was conducted in the summer of 1981 (Appendix A). Three one-m^3 plastic mesh cages were suspended at 1m in a 0.4-hectare Oklahoma State University pond located 15.3 kilometers northwest of O. S. U. in the southern tip of Noble County. Stocking densities were 375, 425, and 475 age-I channel catfish per m^3.

Two privately owned farm ponds also were used for a preliminary polyculture study of channel catfish and blue tilapia. The Buntin pond was 1.7 hectares and the Kolb pond was 2.4 to 4.0 hectares, depending on water level fluctuations during the sampling period. Both ponds are located 22.6 kilometers southwest of Stillwater, Oklahoma in Payne County. In each pond three one-m^3 cages were anchored to a cable at approximately 8.8-meter intervals. Stocking density was 400 fish/m^3 in the following proportions: 400 channel catfish, 390 catfish and 10 tilapia, and 350 catfish and 50 tilapia.

The ponds were stocked in late April 1981 with catfish from the Tishomingo National Fish Hatchery and Tilapia from Horseshoe Lake. The fish were generally fed a 32%-protein commercial floating catfish feed six days a week and received as much feed as they would consume in 10 minutes.

Each pond was sampled twice a month for two months (Appendix A).

Five catfish were removed from each cage in the stocking density pond for each sample. Five catfish from each cage and one tilapia from the cage containing 50 tilapia were sampled from each of the two farm ponds in the polyculture study. The fish were transported to the laboratory in 11.3 liter pails where they remained in aerated pond water until examined.

The first three gill arches on the right side of each fish were examined for ectosymbionts. The filaments were removed as close as possible to the arch and large filaments were cut into sections facilitating examination. A wet mount was made of each section and the filaments scanned at a magnification of 200X on a Nikon phase contrast microscope. The ectosymbionts were identified, counted and recorded.

The results were analyzed using the Statistical Analysis Systems program (SAS). The results of the stocking density study were tested using an ANOVA, (Analysis of Variance), to determine whether significant differences between cages and between sampling dates existed for a variety of variables. Data from the polyculture study were analyzed similarly for significant differences between the ponds, cages within the ponds, and sampling dates. Where significant differences were found, the data were then analyzed using Duncan's Multiple Range Test.

1982 Study

The experiments were repeated in 1982. The stocking density study was conducted in a 0.1-hectare pond on O. S. U. property located 4.96 kilometers west of Stillwater. Stocking densities and sampling procedure were the same as in 1981 except that sampling was extended from June to October.

The polyculture experiment was repeated in the Buntin and Kolb ponds. Stocking densities and proportions were: 400 catfish, 400 catfish: 25 tilapia, and 400 catfish: 50 tilapia.

Catfish were again obtained from Tishomingo National Fish Hatchery. The tilapia were the same fish used in the preliminary study that had overwintered in holding tanks. The ponds were stocked in late May and fish removed for sampling were replaced to maintain the initial stocking densities. The replacement fish were marked by clipping the right pectoral spine or dorsal fin and were not used for data collection. The fish were transported and maintained in the lab as in the preliminary study except that larger volumes of water were used to reduce crowding. Prior to stocking and after harvest in 1982 a sample of 15 catfish from Tishomingo and 10 wild fish from each of the three ponds were examined for parasites.

Dissolved oxygen concentration and water temperature were measured every two weeks at 0930 using a Yellow Springs Instrument oxygen and temperature probe. Readings were taken at the surface, middle and bottom of the cage. The mean of surface, mid-cage, and bottom cage readings were used in analysis of data.

Individual weights to the nearest 0.01 gram measured on an Ohaus balance and total lengths to the nearest millimeter were recorded at the time of examination. Length and weight were used to calculate individual condition, (R) (Bennett, 1970).

Data from 1982 were analyzed in the same manner as the preliminary data. Comparisons made are summarized in Appendix B. Correlation coefficients were determined for length, weight, R, temperature and

dissolved oxygen to determine whether a relationship existed between these variables and ectosymbiont parameters.

CHAPTER III

RESULTS

1981 Preliminary Study

Mean gill ectosymbiont density increased (A=0.05) as stocking density decreased (Table I). A sharp increase in the number of ectosymbionts per gill arch also was observed in the middle of the sampling season (Figure 1).

In the Kolb pond, fish from the cage containing 50 Tilapia had the highest average ectosymbiont density (27.9 per gill arch) but in the Buntin pond fish from the cage containing only catfish had the highest average density (15.6 per gill arch). For fish from the Buntin pond the average ectosymbiont density decreased as the number of Tilapia increased but for those from the Kolb pond the average density increased with an increase in Tilapia. No significant difference was found between the mean ectosymbiont densities of fish from the Buntin and Kolb ponds nor was there a significant difference in means for fish from different cages.

Colonial algae were the dominant ectosymbionts in the Kolb pond, and Trichophrya was dominant in the Buntin pond (Tables II and III). Other organisms occuring frequently in both ponds were Oodinium, Trichodina and monogentic flukes (either Cleidodiscus or Dactylogyrus).

Temporal variation in ectosymbionts was observed in the polyculture study. Variation existed between ponds but also between sample dates,

(Figure 2), and cages (Figure 3). In both the Buntin and Kolb ponds, the Tilapia which were examined had very few gill ectosymbionts.

TABLE I

MEAN ECTOSYMBIONT DENSITIES PER GILL ARCH FOR CHANNEL CATFISH IN THE STOCKING DENSITY POND 1981

Ectosymbiont	Stocking Density 375	425	475
Trichodina	285.7	206.7	78.7
Scyphidia	196.3	216	68
Glossatella		0.$\overline{3}$	
U.I.D. ciliates	0.$\overline{3}$		
Trichophrya	601.$\overline{3}$	393	466.$\overline{3}$
Myxosporidian Spores	*	*	*
Myxosporidian Cysts	*	*	*
Oodinium	458	152.7	60.$\overline{3}$
Ceratium			
Colonial algae	38.7	26	10.$\overline{3}$
Peridinium			
U.I.D. cysts		0.$\overline{3}$	
Monogenean Flukes	124.7	115	67.$\overline{3}$
TOTAL	1705	1110	750.9
AVERAGE	85.3	55.5	41.7

*Organisms observed but not counted.

Figure 1. Temporal Variation in Mean Densities of Ectosymbionts of Fish from Stocking Density Pond 1981

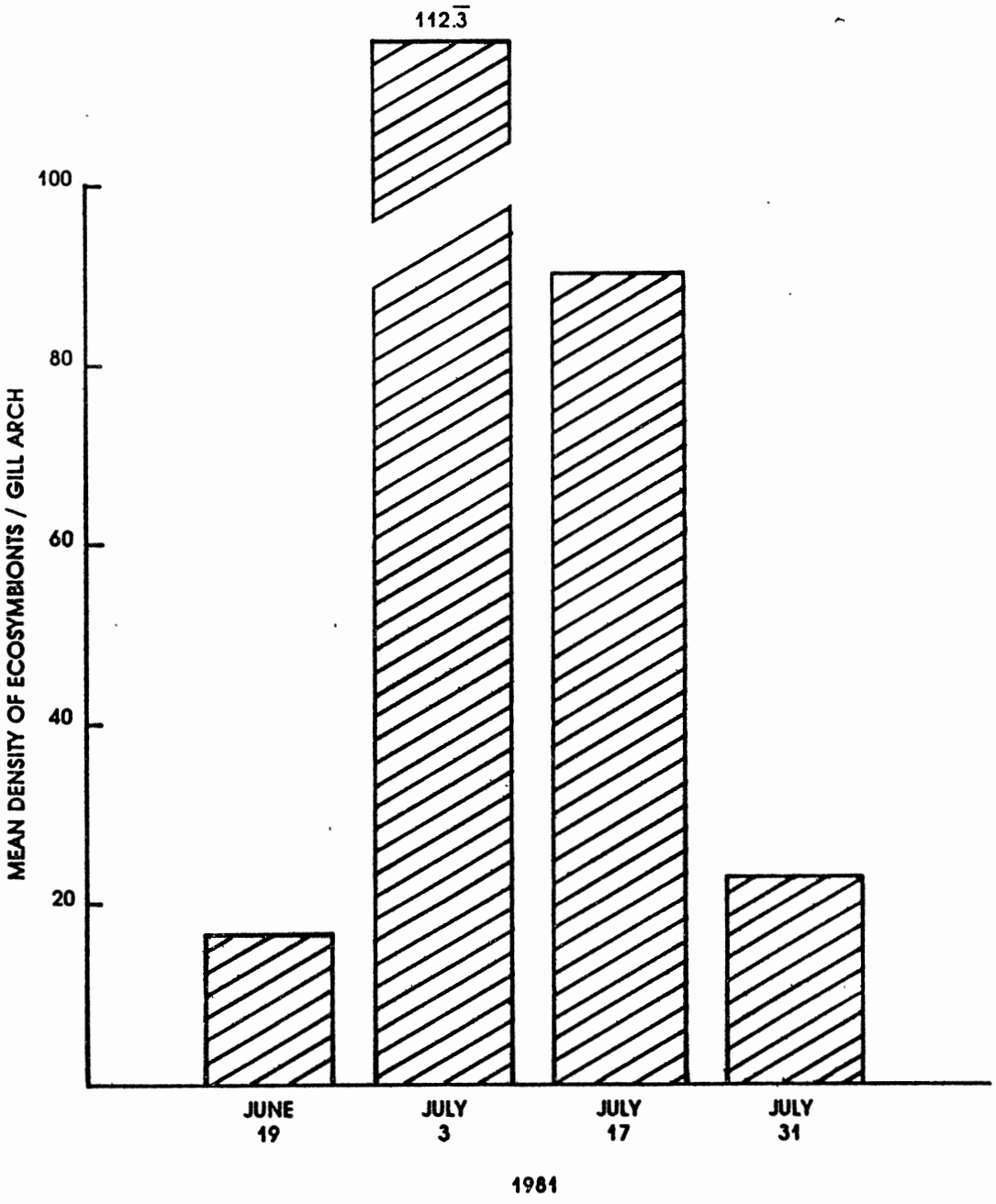

112.3
100
80
60
40
20
MEAN DENSITY OF ECOSYMBIONTS / GILL ARCH
JUNE 19
JULY 3
JULY 17
JULY 31
1981

TABLE II

MEAN ECTOSYMBIONT DENSITIES PER GILL ARCH FOR CHANNEL CATFISH FROM THE KOLB POND 1981

Ectosymbiont	Cage Density: 400 Catfish + 0 Tilapia	390 Catfish + 10 Tilapia	350 Catfish + 50 Tilapia
Trichodina	21.7	33	122.7
Scyphidia	1	1.$\overline{3}$	48.7
Glossatella			
U.I.D. ciliates	5		0.7
Trichophrya	7.7	2.$\overline{3}$	19.7
Myxosporidian Spores	*	*	*
Myxosporidian Cysts	*	*	*
Oodinium	25.$\overline{3}$	14	64
Ceratium	2	0.$\overline{3}$	1
Colonial algae	95.7	91	96.$\overline{3}$
Peridinium			0.$\overline{3}$
U.I.D. cysts			
Monogenean Flukes	29.7	18	30.7
Lernea			7.$\overline{3}$
TOTAL	188.1	159.9	391.4
AVERAGE	12.6	20	28

*Organisms observed but not counted.

TABLE III

MEAN ECTOSYMBIONT DENSITIES PER GILL ARCH FOR CHANNEL CATFISH FROM THE BUNTIN POND 1981

Ectosymbiont	Cage Density		
	400 Catfish	390 Catfish 10 Tilapia	350 Catfish 50 Tilapia
Trichodina	34.7	88.7	6
Scyphidia	0.$\overline{3}$	10	1.7
Glossatella			
U.I.D. ciliates	1.7	0.7	0.7
Trichophrya	118	48	36.7
Myxosporidian Spores	*	*	*
Myxosporidian Cysts	*	*	*
Oodinium	61.$\overline{3}$	74.$\overline{3}$	19.$\overline{3}$
Ceratium	1	0.$\overline{3}$	
Colonial algae	2	9.7	0.7
Peridinium	*	*	
U.I.D. cysts		5.7	
Monogenean Flukes	92.$\overline{3}$	46.$\overline{3}$	17.$\overline{3}$
TOTAL	311.3	283.7	82.4
AVERAGE	15.6	14.2	6.$\overline{3}$

*Organisms observed but not counted.

Figure 2. Temporal Variation in Gill Ectosymbiont Densities for Fish from Polyculture Ponds in 1981

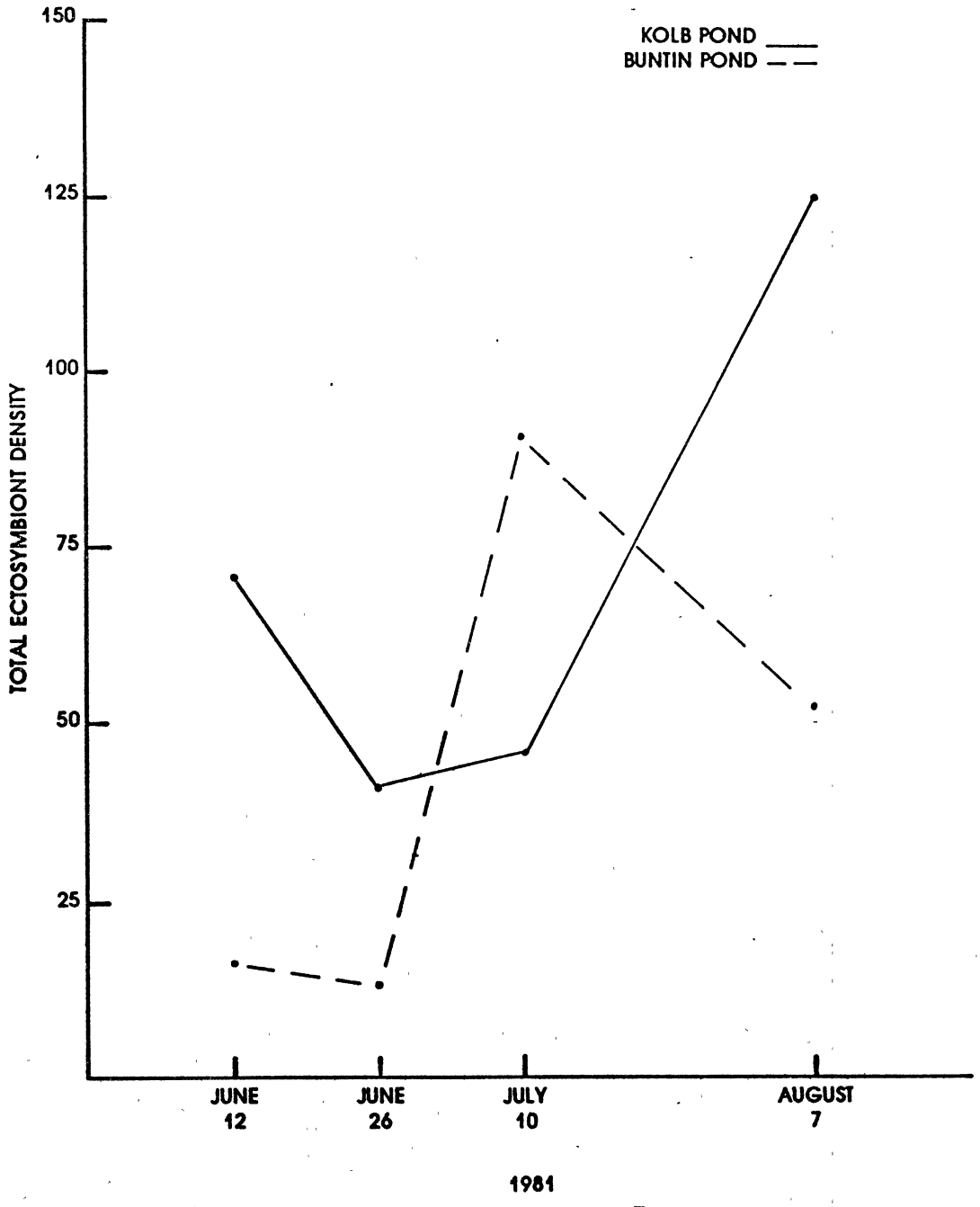
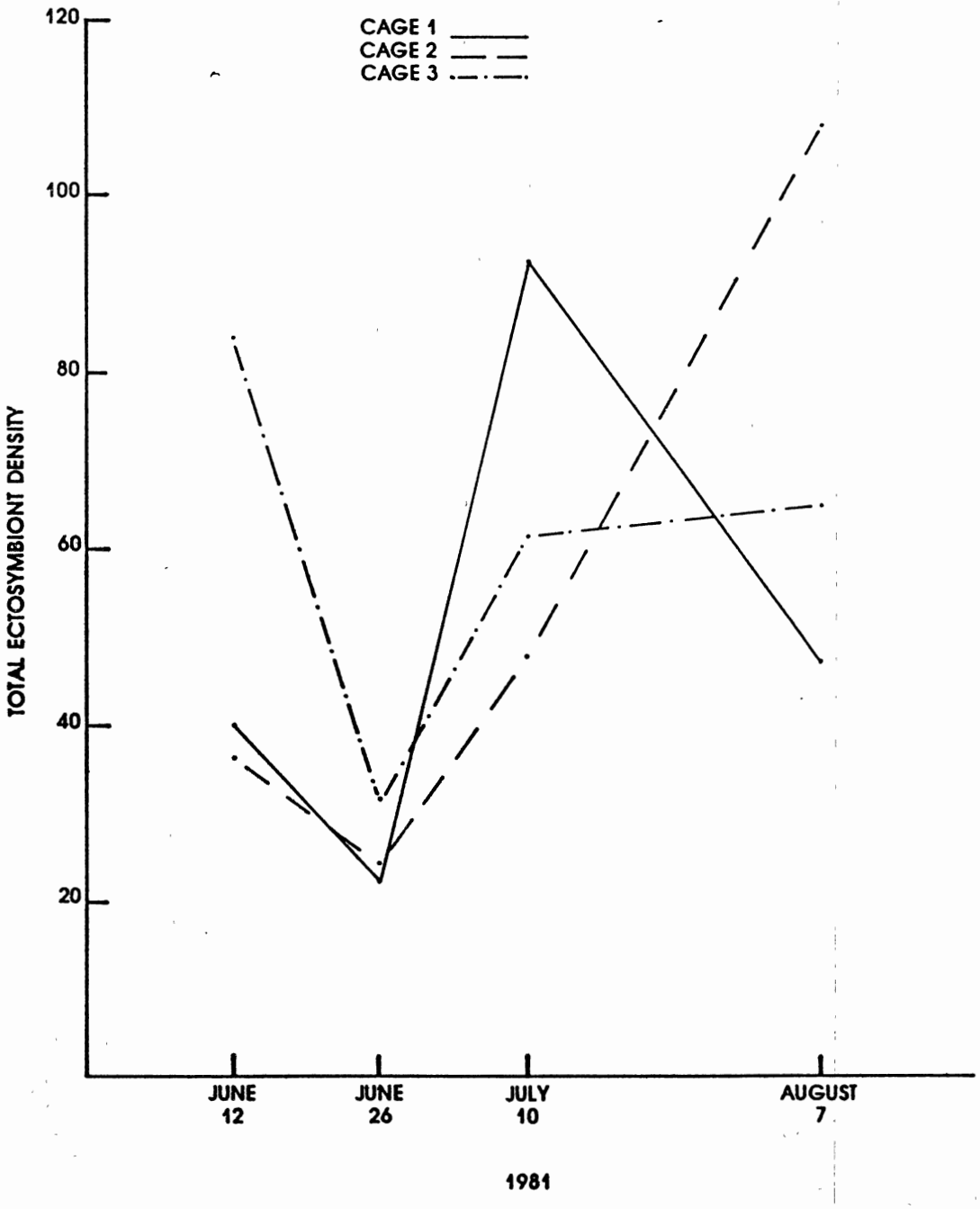

KOLB POND
BUNTIN POND
150
125
100
75
50
25
TOTAL ECTOSYMBIONT DENSITY
JUNE 12
JUNE 26
JULY 10
AUGUST 7
1981

Figure 3. Temporal Variation in Gill Ectosymbiont Densities for Fish Grouped by Cage from Polyculture Ponds in 1981


CAGE 1
CAGE 2
CAGE 3
120
100
80
60
40
20
TOTAL ECTOSYMBIONT DENSITY
JUNE 12
JUNE 26
JULY 10
AUGUST 7
1981

1982 Experiments

Stocking Density

The water temperature in the stocking density pond rose steadily from June 4 (20.8C) until July 16 (28.4C) (Figure 4). For the next month temperatures remained between 23.6C and 25.0C, peaked at 26.0C, and declined to the end of the study. The dissolved oxygen concentration remained above 4 mg/L throughout the study except on June 24 when it dropped to 2.6 mg/L and September 16 when it was 1.6 mg/L (Personal communication, Aecio DaSilva, 1982). Following September 16, the dissolved oxygen concentration rose until the end of the sampling period.

All fish examined from the wild population before stocking were channel catfish (Table IV). The total number of ectosymbionts varied per gill arch and all fish examined appeared to be in good health. A total of 10 bluegill (Lepomis macrochirus), channel catfish (Ictalurus punctatus), and green sunfish (Lepomis cyanellus) collected from the wild population post-harvest had very few ectosymbionts (Table V). In contrast, the last sample of caged fish had a mean ectosymbiont density of 99.7 per gill arch for 15 fish.

The 15 channel catfish from Tishomingo examined prior to stocking had relatively light densities of gill ectosymbionts. Trichodina was the most abundant of the ectosymbionts observed, ranging from 1.3 to 163.6 per gill arch (Table VI). One fish had 55 Scyphidia but all other fish had less than 16.6 per gill arch.

When the ectosymbiont populations were grouped, there were no significant differences in the mean ectosymbiont densities between cages

at different stocking densities (Table VII). However, when each group of ectosymbionts was considered separately, Staurastrum was significantly more abundant in fish from cage 1 than in fish from the other two cages. It is doubtful that the difference in Staurastrum was biologically significant since the number observed was very small.

Significant (A=0.05) temporal variations were observed in mean ectosymbiont densities as well as in individual densities of eight groups of ectosymbionts (Table VIII). The maximum mean density on August 13 was due primarily to a large number of spores. Analysis of variations between cages by date showed few differences in the total community. The mean ectosymbiont density of fish from cage 2 on August 13 was significantly higher (A=0.05) than those of fish from other cages on that date. When the ectosymbiont groups were considered individually, all showed significant variations between cages at different stocking densities by date (Table IX).

The occurrence of most ectosymbiont groups was correlated, either positively or negatively, with at least one variable. Positive correlations with temperature were most common. Only mean ectosymbiont density and occurrence of spores were positively correlated with dissolved oxygen concentration. Ceratium was consistently correlated negatively with all variables except dissolved oxygen concentration (Table X).

Polyculture Study

The water temperature patterns in the Buntin and Kolb ponds were similar (Figure 5). Temperatures increased until July 23 when both

Figure 4. Average Water Temperature and Dissolved Oxygen Concentration in 1982 for Stocking Density Pond

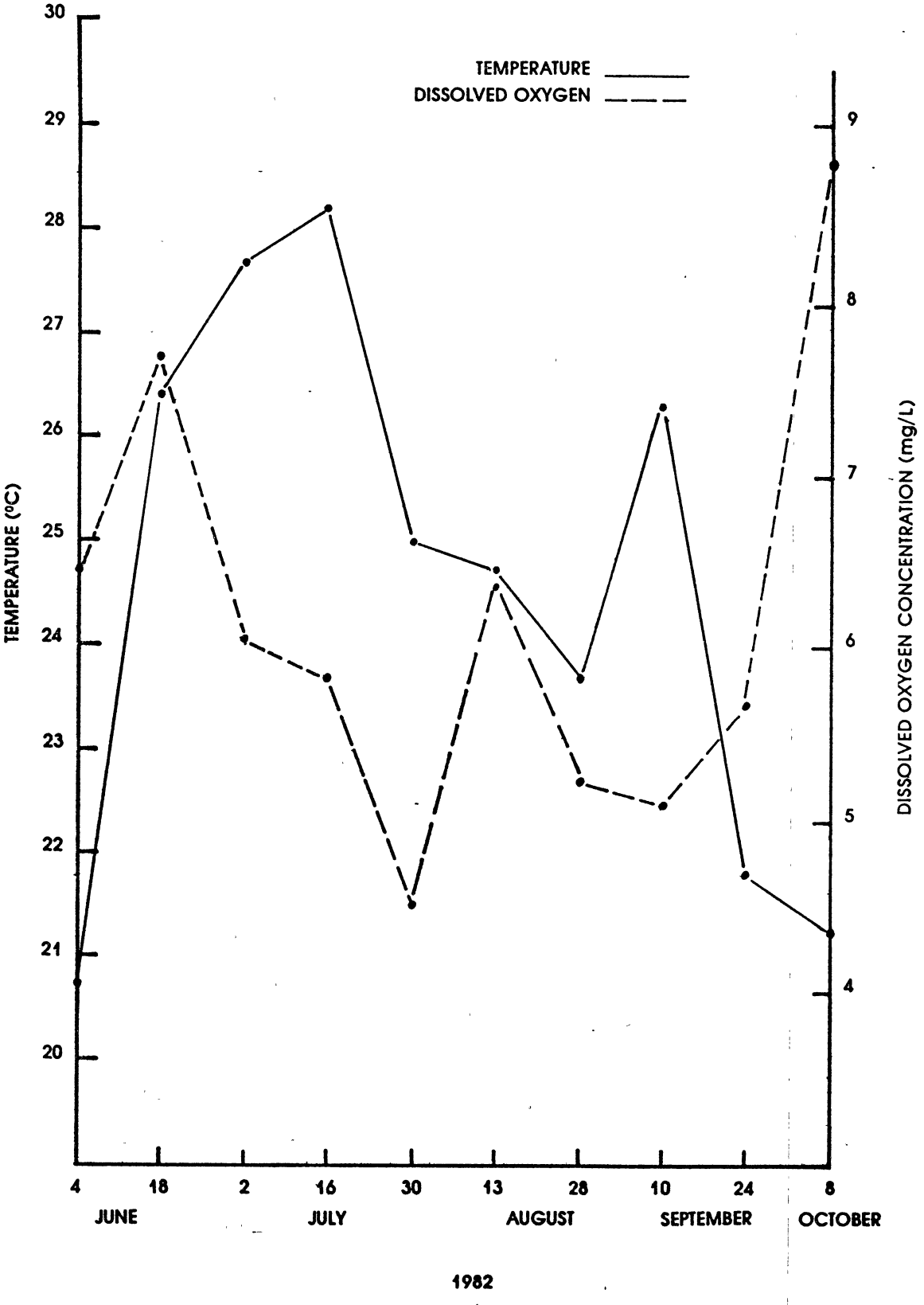

TEMPERATURE
DISSOLVED OXYGEN
TEMPERATURE (°C)
DISSOLVED OXYGEN CONCENTRATION (mg/L)
30
29
28
27
26
25
24
23
22
21
20
9
8
7
6
5
4
4
18
2
16
30
13
28
10
24
8
JUNE
JULY
AUGUST
SEPTEMBER
OCTOBER
1982

TABLE IV

MEAN ECTOSYMBIONT DENSITIES PER GILL ARCH FOR WILD POPULATIONS OF THE STOCKING DENSITY POND PRIOR TO STOCKING

Ectosymbiont	Mean Density/Gill Arch
Trichodina	510.6
Scyphidia	0.6
Trichophrya	67.$\overline{3}$
Myxosporidian Spores	*
Myxosporidian Cysts	173
Oodinium	231
Ceratium	1
Staurastrum	5
Gloeocystis	0.$\overline{3}$
U.I.D. Cysts	1
Monogenean Flukes	8.$\overline{3}$
Rotifer	1.$\overline{3}$
TOTAL	999.4

N=8 Fish

*Organisms observed but not counted.

TABLE V

MEAN ECTOSYMBIONT DENSITIES PER GILL ARCH FOR WILD POPULATIONS OF THE STOCKING DENSITY POND AFTER CAGE HARVEST

Ectosymbiont	Mean Density
Myxosporidian Cysts	1
Colonial algae	0.3
Monogenean Flukes	18.6
TOTAL	19.9

N=10 Fish

TABLE VI

MEAN ECTOSYMBIONT DENSITIES PER GILL ARCH OF STOCKING SOURCE CHANNEL CATFISH PRIOR TO STOCKING

Ectosymbiont	Mean Density
Trichodina	871
Scyphidia	242
U.I.D. ciliates	1
Myxosporidian Cysts	290
Oodinium	24
Ceratium	11
Colonial algae	13
Monogenean Flukes	110
TOTAL	1562

N=15 Fish

TABLE VII

MEAN ECTOSYMBIONT DENSITIES PER GILL ARCH FOR FISH FROM THE STOCKING DENSITY CAGES

Ectosymbiont	Cage Density 375	425	475
Trichodina	105	95.7	105.7
Scyphidia	55.7	23.7	59.7
Glossatella	1.7	2	0
U.I.D. ciliates	0.7	0	0.7
Trichophrya	116	111.$\overline{3}$	95.$\overline{3}$
Myxosporidian Spores	727	4166.$\overline{3}$	330.$\overline{3}$
Myxosporidian Cysts	495.7	754.7	248.7
Oodinium	31.7	15.7	30
Ceratium	12	9	7.$\overline{3}$
Colonial algae	13.7	5	4
Staurastrum	1	0	0
Monogenean Flukes	105	95.7	105.7
TOTAL	1799.5	5547.7	1290.7
AVERAGE	37.5	118	27.5
	N = 48	47	47

TABLE VIII

TEMPORAL VARIATION IN MEAN ECTOSYMBIONT DENSITIES
PER GILL ARCH IN THE STOCKING DENSITY POND

Ectosymbiont	June 4	June 18	July 2	July 16	July 30	August 13	August 28	September 10	September 24	October 8
Trichodina	1.2^{B}	1^{B}	26^{A}	29.9^{A}	3.1^{B}	4.3^{B}	2.8^{B}	3.2^{B}	0.4^{B}	0.5^{B}
Scyphidia	5.07^{A}	0.07^{B}	1.8^{B}	0.4^{B}	0.1^{B}	0.2^{B}	0.1^{B}	1.7^{B}	0.0^{B}	0.02^{B}
Trichophrya	0.0^{B}	5.0^{A}	6.3^{A}	3.9^{AB}	0.07^{B}	5.6^{A}	1^{B}	0.2^{B}	0.7^{B}	0.0^{B}
Myxosporidian Spores	2.6^{B}	7.4^{B}	18.9^{B}	0.2^{B}	9.2^{B}	223.7^{A}	12.9^{B}	4.4^{B}	0.02^{B}	91.2^{AB}
Oodinium	0.15^{B}	0.9^{AB}	2.1^{A}	0.6^{AB}	1.1^{AB}	0.2^{B}	0.1^{B}	0.03^{B}	0.07^{B}	0.0^{B}
Ceratium	1.4^{A}	0.5^{B}	0.0^{C}	0.0^{C}	0.0^{C}	0.0^{C}	0.0^{C}	0.0^{C}	0.0^{C}	0.0^{C}
Colonial algae	0.0^{B}	0.0^{B}	0.6^{A}	0.5^{AB}	0.1^{AB}	0.2^{AB}	0.0^{B}	0.0^{B}	0.03^{AB}	0.07^{AB}
Monogenean Flukes	1.6^{C}	1.5^{C}	1.5^{C}	2.2^{ABC}	2^{BC}	3.2^{AB}	2.1^{BC}	2.1^{BC}	3.4^{A}	2^{BC}
TOTAL	14^{B}	32.9^{B}	59^{B}	68.9^{AB}	29.4^{B}	267.8^{A}	21.6^{B}	12^{B}	6.9^{B}	99.7^{AB}

Means with the same letter are not significantly different.

N=142

TABLE IX

TEMPORAL VARIATION IN MEAN ECTOSYMBIONT DENSITIES PER GILL ARCH OF FISH GROUPED BY STOCKING DENSITY IN THE STOCKING DENSITY POND FOR 1982

	Stocking Density														
	June									July					
Ectosymbiont	375	4/425	475	375	18/425	475	375	2/425	475	375	16/425	475	375	30/425	475
Trichodina	2.9^{CD}	0.9^{D}	0.0^{D}	0.7^{D}	1.4^{D}	0.8^{D}	23.5^{BCD}	33.2^{B}	21.4^{BCD}	5.4^{CD}	29.3^{BC}	61.2^{A}	5.6^{CD}	0.8^{D}	3^{CD}
Scyphidia	8.7^{A}	0.3^{C}	6.2^{AB}	0.16^{C}	0.13^{C}	0.0^{C}	1.1^{C}	1.4^{BC}	3.0^{BC}	0.0^{C}	1.4^{BC}	0.0^{C}	0.5^{C}	0.0^{C}	0.06^{C}
Glossatella	0.0^{B}	0.0^{B}	0.0^{B}	0.0^{B}	0.0^{B}	0.0^{B}	0.3^{A}	0.06^{B}	0.0^{B}	0.0^{B}	0.4^{A}	0.0^{B}	0.0^{B}	0.0^{B}	0.0^{B}
U.I.D. ciliates	0.0^{B}	0.0^{B}	0.06^{B}	0.0^{B}	0.0^{B}	0.0^{B}	0.1^{A}	0.0^{B}	0.0^{B}	0.0^{B}	0.0^{B}	0.0^{B}	0.0^{B}	0.0^{B}	0.06^{B}
Trichophrya	0.0^{B}	0.0^{B}	0.0^{B}	2.3^{AB}	4.5^{AB}	7.7^{AB}	3.3^{AB}	7.5^{AB}	8.1^{AB}	8.5^{A}	1.9^{AB}	0.2^{B}	0.07^{B}	0.0^{B}	0.2^{B}
Myxosporidian Spores	0.0^{B}	7.9^{B}	0.0^{B}	0.2^{B}	16.7^{B}	3.9^{B}	6^{B}	32.2^{B}	18.5^{B}	0.6^{B}	0.0^{B}	0.0^{B}	6.5^{B}	19.5^{B}	1.8^{B}
Myxosporidian Cysts	1.8^{C}	2.0^{C}	1.7^{C}	0.5^{C}	39.5^{BC}	6.1^{C}	0.1^{C}	2.7^{C}	2.2^{C}	70.5^{AB}	5.6	6.4^{C}	3.8^{C}	16.4^{C}	20.4^{C}
Oodinium	0.3^{C}	0.2^{C}	0.0^{C}	3.1^{AB}	0.13^{C}	0.0^{C}	0.3^{C}	2.1^{ABC}	3.9^{A}	1.1^{BC}	0.2^{C}	0.3^{C}	1.4^{BC}	0.3^{C}	1.6^{BC}
Ceratium	1.9^{A}	1.1^{AB}	1.3^{AB}	0.7^{BC}	0.7^{BC}	0.1^{C}	0.0^{C}	0.0^{C}	0.0^{C}	0.0^{C}	0.0^{C}	0.0^{C}	0.0^{C}	0.0^{C}	0.0^{C}
Colonial algae	0.0^{B}	0.0^{B}	0.0^{B}	0.0^{B}	0.0^{B}	0.0^{B}	1.5^{A}	0.26^{B}	0.0^{B}	0.53^{B}	0.7^{AB}	0.4^{B}	0.0^{B}	0.13^{B}	0.2^{B}
Staurastrum	0.07^{AB}	0.0^{C}	0.0^{C}	0.0^{C}	0.0^{C}	0.0^{C}	0.0^{C}	0.0^{C}	0.0^{C}	0.0^{C}	0.0^{C}	0.0^{C}	0.06^{AB}	0.0^{C}	0.0^{C}
Monogenean Flukes	1.5^{ABC}	1.9^{ABC}	1.3^{BC}	2.3^{ABC}	1.3^{BC}	1.1^{C}	1.3^{BC}	1.7^{ABC}	1.5^{ABC}	2.5^{ABC}	1.8^{ABC}	2.4^{ABC}	2.0^{ABC}	1.1^{C}	2.9^{ABC}
TOTAL	17.1^{B}	14.2^{B}	10.7^{B}	9.9^{B}	64.5^{B}	19.8^{B}	37.5^{B}	81.1^{B}	58.5^{B}	89.1^{B}	42.4^{B}	71.1^{B}	19.9^{B}	38.2^{B}	30.2^{B}

TABLE IX (Continued)

Ectosymbiont	Stocking Density														
	August						September						October		
	375	13/425	475	375	28/425	475	375	10/425	475	375	24/425	475	375	8/425	475
Trichodina	7.9^{CD}	5^{CD}	0.8^{D}	1.9^{CD}	2.5^{CD}	4.1^{CD}	0.9^{D}	8.1^{CD}	2.5^{CD}	0.7^{D}	0.0^{D}	0.53^{D}	0.06^{D}	1.1^{D}	0.2^{D}
Scyphidia	0.0^{C}	0.7^{C}	0.0^{C}	0.06^{C}	0.3^{C}	0.3^{C}	0.7^{C}	1.2^{BC}	3.3^{BC}	0.0^{C}	0.0^{C}	0.0^{C}	0.0^{C}	0.06^{C}	0.0^{C}
Glossatella	0.0^{B}	0.0^{B}	0.0^{B}	0.06^{B}	0.0^{B}	0.0^{B}	0.0^{B}	0.0^{B}	0.0^{B}	0.0^{B}	0.0^{B}	0.0^{B}	0.0^{B}	0.0^{B}	0.0^{B}
U.I.D. ciliates	0.0^{B}	0.0^{B}	0.0^{B}	0.0^{B}	0.0^{B}	0.0^{B}	0.0^{B}	0.0^{B}	0.0^{B}	0.13^{B}	0.0^{B}	0.0^{B}	0.0^{B}	0.0^{B}	0.3^{B}
Trichophrya	7.2^{AB}	6.9^{AB}	2.9^{AB}	2.9^{AB}	0.07^{B}	0.0^{B}	0.5^{B}	0.0^{B}	0.0^{B}	0.3^{B}	1.7^{AB}	0.0^{B}	0.0^{B}	0.0^{B}	0.0^{B}
Myxosporidian Spores	44.8^{b}	565.4^{A}	25.3^{B}	11.13^{B}	10.9^{B}	16.6^{B}	10.5^{B}	0.0^{B}	0.0^{B}	0.06^{B}	0.0^{B}	0.0^{B}	74.6^{B}	180.7^{B}	0.0^{B}
Myxosporidian Cysts	7.7^{C}	77.4^{A}	7^{C}	1.8^{C}	4.2^{C}	1.5^{C}	0.9^{C}	0.1^{C}	0.06^{C}	4.3^{C}	0.9^{C}	1.7^{C}	9.3^{C}	3.3^{C}	4.7^{C}
Oodinium	0.6^{BC}	0.0^{C}	0.0^{C}	0.3^{C}	0.13^{C}	0.0^{C}	0.06^{C}	0.0^{C}	0.0^{C}	0.0^{C}	0.0^{C}	0.2^{C}	0.0^{C}	0.0^{C}	0.0^{C}
Ceratium	0.0^{C}	0.0^{C}	0.0^{C}	0.0^{C}	0.0^{C}	0.0^{C}	0.0^{C}	0.0^{C}	0.0^{C}	0.0^{C}	0.0^{C}	0.0^{C}	0.0^{C}	0.0^{C}	0.0^{C}
Colonial algae	0.7^{AB}	0.0^{B}	0.0^{B}	0.0^{B}	0.0^{B}	0.0^{B}	0.0^{B}	0.0^{B}	0.0^{B}	0.13^{B}	0.0^{B}	0.0^{B}	0.0^{B}	0.0^{B}	0.3^{B}
Staurastrum	0.06^{A}	0.0^{C}	0.0^{C}	0.0^{C}	0.0^{C}	0.0^{C}	0.0^{C}	0.0^{C}	0.0^{C}	0.0^{C}	0.0^{C}	0.0^{C}	0.0^{C}	0.0^{C}	0.0^{C}
Monogenean Flukes	4^{A}	3.5^{AB}	2.2^{ABC}	0.9^{C}	2.8^{ABC}	2.7^{ABC}	2.1^{ABC}	2.1^{ABC}	2.1^{ABC}	3.6^{AB}	2.7^{ABC}	3.9^{A}	2.2^{ABC}	1.5^{ABC}	2.4^{ABC}
TOTAL	73.2^{B}	658.9^{A}	38.1^{B}	19.1^{B}	20.9^{B}	24.9^{B}	15.6^{B}	11.2^{B}	8^{B}	9.1^{B}	5.3^{B}	6.4^{B}	86.2^{B}	186.7^{B}	7.7^{B}

Means with the same letter are not significantly different.

N=142

TABLE X

CORRELATION TESTS FOR STOCKING DENSITY STUDY*

Ectosymbiont	R	Length	Weight	Temperature	Dissolved Oxygen Concentration
Trichodina				+	
Scyphidia	-				
Glossatella				+	
U.I.D. ciliates					
Trichophrya				+	
Oodinium				+	
Ceratium	-	-	-	-	
Colonial algae				+	
Staurastrum					
U.I.D. Spores					+
U.I.D. Cysts				+	
Monogenean Flukes	+	+	+		
TOTAL					+

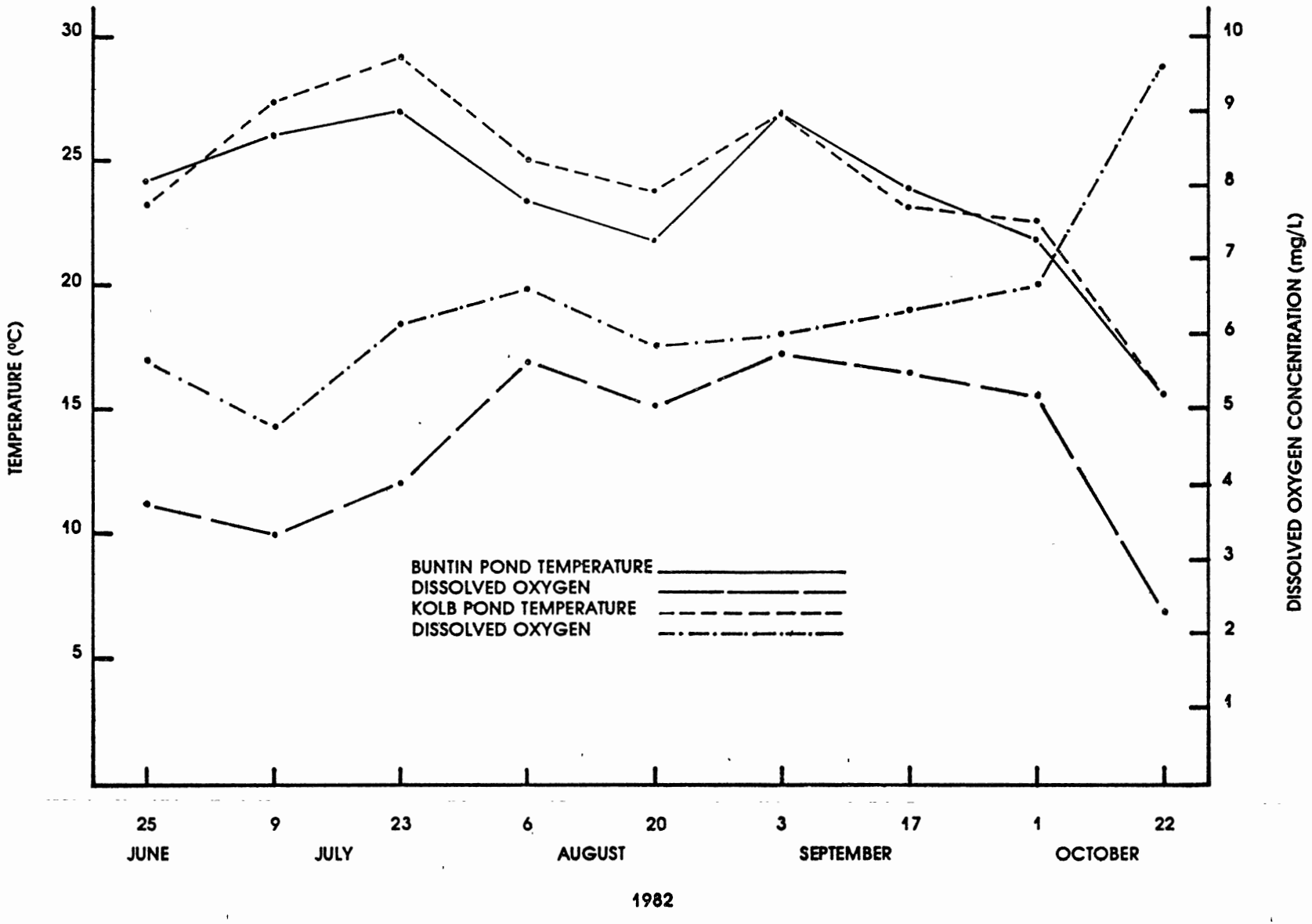
N=142

+Positive correlation.

-Negative correlation.

*Variables indicated either positively or negatively are statistically significant at A=0.05.

Figure 5. Average Water Temperature and Dissolved Oxygen Concentrations in the Kolb and Buntin Ponds in 1982.


TEMPERATURE (°C)
30
25
20
15
10
5
DISSOLVED OXYGEN CONCENTRATION (mg/L)
10
9
8
7
6
5
4
3
2
1
BUNTIN POND TEMPERATURE
DISSOLVED OXYGEN
KOLB POND TEMPERATURE
DISSOLVED OXYGEN
25
9
23
6
20
3
17
1
22
JUNE
JULY
AUGUST
SEPTEMBER
OCTOBER
1982

ponds cooled briefly, then warmed to 27 C in early September. In both ponds water temperatures declined thereafter.

Dissolved oxygen concentration in the Kolb pond remained above 4 mg/L throughout the entire sampling period with a sharp increase observed in October. Dissolved oxygen concentration in the Buntin pond was below 4 mg/L in late June and early July and also fell below 4 mg/L in October. The decrease at the end of the sampling period could be due to the development of a high biological oxygen demand throughout the season because this pond received large amounts of organic materials.

All wild fish taken from the Kolb pond before stocking were bulegill (Lepomis macrochirus). The fish appeared to be in good condition and a smaller variety of ectosymbionts was found than in fish from the Buntin pond (Table XI). Bluegill (Lepomis macrochirus) and channel catfish (Ictalurus punctatus) were collected from the latter and 4 of the 10 fish died before they were examined. All fish appeared to be in slightly poorer condition. The bluegill, (Lepomis macrochirus), green sunfish, (Lepomis cyanellus), and white crappie (Pomoxis annularis) collected from the Buntin pond post-harvest had relatively few ectosymbionts (Table XII). This sample was taken considerably later than the last sample of caged fish (late October) which had a mean ectosymbiont density of 544 per gill arch. Relatively few ectosymbionts were seen in the bluegill (L. macrochirus) taken from the Kolb pond post-harvest. The last sample of caged fish taken from this pond in late October had a mean ectosymbiont density of 371.9 per gill arch.

Among Tilapia examined, no significant differences were found between ponds or sampling dates with regard to mean density of individual groups or combined groups of ectosymbionts. Relatively few

TABLE XI

MEAN ECTOSYMBIONT DENSITIES PER GILL ARCH ON SAMPLED WILD POPULATIONS FROM BUNTIN AND KOLB PONDS PRIOR TO STOCKING

Ectosymbiont	Mean Density Buntin Pond	Kolb Pond
Trichodina	50.3	0.3
Scyphidia	1.3	
Glossatella	0.7	
U.I.D. ciliates	0.3	
Trichophrya	3.7	
Myxosporidian Spores	11,748	
Myxosporidian Cysts	38.3	0.3
Oodinium	102.7	
Colonial algae	2.7	3.3
U.I.D. Flagellates		0.3
Monogenean Flukes	9	10.7
Rotifer	2.3	
TOTAL	11,959.3	14.9
	N = 6	10

TABLE XII

MEAN ECTOSYMBIONT DENSITIES PER GILL ARCH ON WILD POPULATIONS FROM THE BUNTIN AND KOLB PONDS AFTER HARVESTING

Ectosymbiont	Mean Density Buntin Pond	Kolb Pond
Trichodina	0.3	3.6
Scyphidia		1.0
Trichophrya		0.3
Colonial algae	0.6	76.6
U.I.D. Cysts	5.6	0.3
Monogenean Flukes	24.0	22.3
TOTAL	30.5	104.1
	N = 10	10

ectosymbionts were found on Tilapia (Table XIII). Mean ectosymbiont density was correlated positively with weight, owing primarily to Ceratium and colonial algae, which both were positively correlated with R and weight (Table XIV).

Among catfish sampled, Trichodina, Scyphidia and myxosporidian spores were the dominant ectosymbiont groups. Cysts occurred in large numbers in fish from cage 1 (Table XV). Mean ectosymbiont densities of combined taxa showed no differences between ponds. However, densities of colonial algae and Ergasilus were significantly higher (A=0.05) on fish from the Buntin pond and the density of Trichophrya was significantly higher on fish from the Buntin pond (Figure 6).

No differences in mean ectosymbiont densities were observed between fish from cages at varying stocking densities. However, mean density of Oodinium was significantly higher (A=0.05) in catfish from cage 1 without Tilapia than from cage 3 and mean density of cysts was also higher in fish from cage 1 than from cages 2 or 3 (Figure 7). Analysis of mean ectosymbiont densities for fish from cages at identical stocking densities revealed no significant differences. In the Kolb pond, mean densities of both colonial algae and Scyphidia were higher in fish from cage 3 than from cage 2. Mean densities of rotifers and Ergasilus on fish from cage 1 were higher than on fish from other cages (Figure 8).

Mean ectosymbiont densities from catfish on October 22 were significantly higher (A=0.05) than on any other sampling date. Mean densities of 11 taxa varied by date (Table XVI and Figure 9). Considerable variation with regard to mean ectosymbiont densities from fish occurred when analysis was made of both the ponds combined by date and between cages by date. In both cases the mean ectosymbiont

TABLE XIII

MEAN ECTOSYMBIONT DENSITIES PER GILL ARCH ON *TILAPIA AUREA* IN THE POLYCULTURE STUDY

Ectosymbiont	Mean Density
Trichodina	19.3
Myxosporidian Cysts	0.3
Ceratium	0.3
Colonial algae	271.7
TOTAL	291.6

N=18

TABLE XIV

CORRELATION TESTS FOR *TILAPIA AUREA* IN POLYCULTURE STUDY

Ectosymbiont	Correlations R	Length	Weight	Temperature	Dissolved Oxygen Concentration
Trichodina					
Myxosporidian Cysts					
Ceratium	+		+		
Colonial algae	+		+		
TOTAL	+		+		

N=18

+Positive correlation.

-Negative correlation.

*Variables indicated either positively or negatively are statistically significant at A=0.05.

TABLE XV

MEAN ECTOSYMBIONT DENSITIES PER GILL ARCH
ON CATFISH IN THE POLYCULTURE STUDY*

Ectosymbiont	Density 400 Catfish 0 Tilapia	 400 Catfish 25 Tilapia	 400 Catfish 50 Tilapia
Trichodina	4283.3	3579.3	5022.7
Scyphidia	1257.7	1356.3	1768.3
Glossatella	4.3	0.3	0
U.I.D. ciliates	0	0.7	0.3
Trichophrya	177.7	123	94.3
Myxosporidian Spores	2310	240.7	478.7
Myxosporidian Cysts	1123.7	242.3	150.3
Oodinium	47.3	26.3	5.3
Ceratium	3.3	0	0.3
Colonial algae	85.7	9.3	79
Peridinium	0	0	0.3
U.I.D. Flagellates	5	1	0
Monogenean Flukes	268.7	162.3	184
Ergasilus	2.7	0.3	0
Rotifer	0	0.3	0
TOTAL	9569.4	5742.1	7783.5

N=144

*August 20 sample omitted because all catfish died prior to examination.

Figure 6. Pond Variation in *Ergasilus*, *Trichophrya* and Colonial Algae Densities Per Gill Arch from Channel Catfish in 1982 Polyculture Study

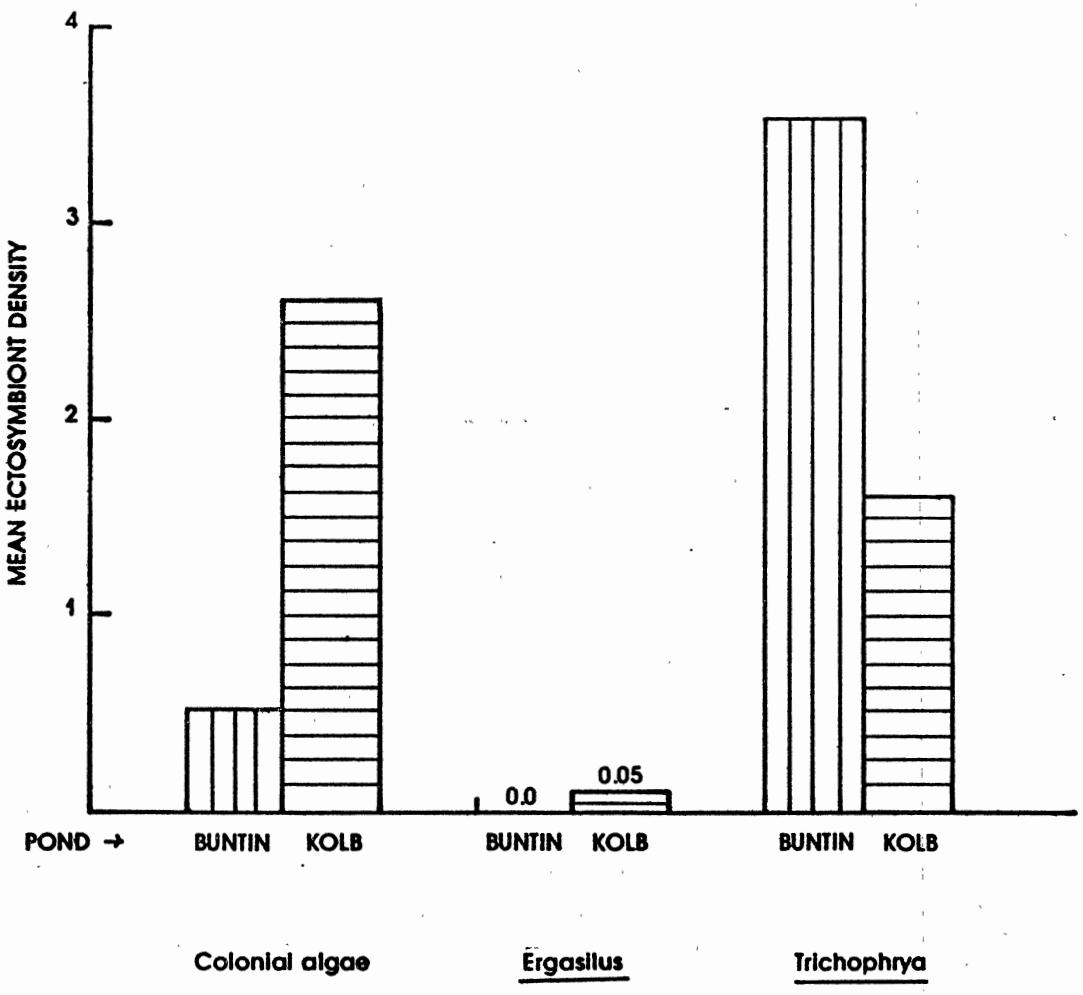

MEAN ECTOSYMBIONT DENSITY
4
3
2
1
0.0
0.05
POND →
BUNTIN
KOLB
BUNTIN
KOLB
BUNTIN
KOLB
Colonial algae
Ergasilus
Trichophrya

Figure 7. Variation in Oodinium and Cyst Densities Per Gill Arch on Channel Catfish Grouped by Stocking Density in 1982 Polyculture Study

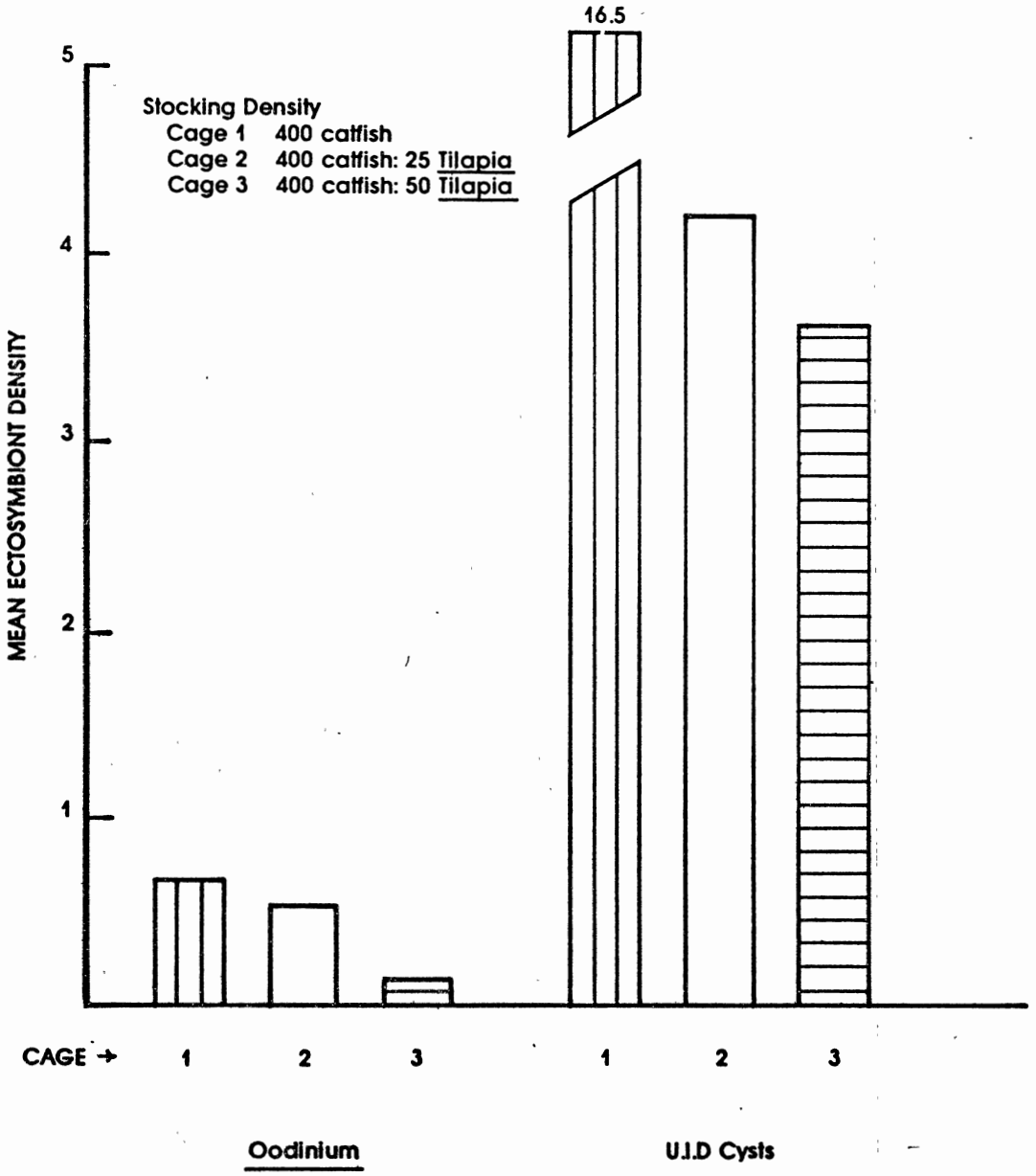

16.5
5
4
3
2
1
Stocking Density
Cage 1 400 catfish
Cage 2 400 catfish: 25 Tilapia
Cage 3 400 catfish: 50 Tilapia
MEAN ECTOSYMBIONT DENSITY
CAGE →
1
2
3
1
2
3
Oodinium
U.I.D Cysts

Figure 8. Variation in Scyphidia, Ergasilus, Rotifer and Colonial Algae Densities Per Gill Arch on Channel Catfish Grouped by Stocking Density in 1982 Polyculture Study

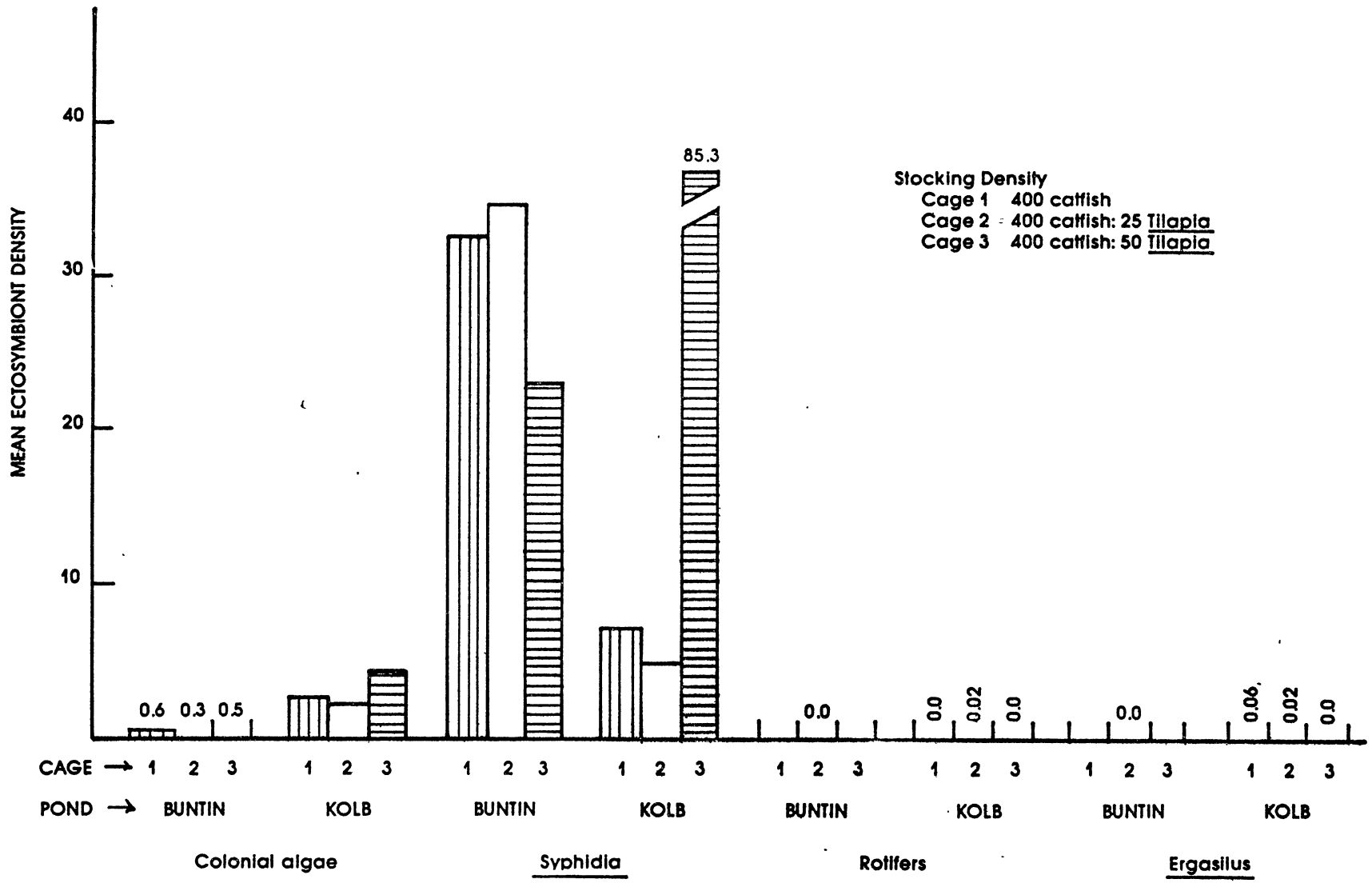

MEAN ECTOSYMBIONT DENSITY
40
30
20
10
85.3
Stocking Density
Cage 1 400 catfish
Cage 2 400 catfish: 25 Tilapia
Cage 3 400 catfish: 50 Tilapia
0.6 0.3 0.5
0.0
0.0 0.02 0.0
0.0
0.06 0.02 0.0
CAGE → 1 2 3 1 2 3 1 2 3 1 2 3 1 2 3 1 2 3 1 2 3 1 2 3
POND → BUNTIN KOLB BUNTIN KOLB BUNTIN KOLB BUNTIN KOLB
Colonial algae
Syphidia
Rotifers
Ergasilus

TABLE XVI

TEMPORAL VARIATION IN MEAN ECTOSYMBIONT DENSITIES PER GILL ARCH ON CATFISH IN THE POLYCULTURE STUDY*

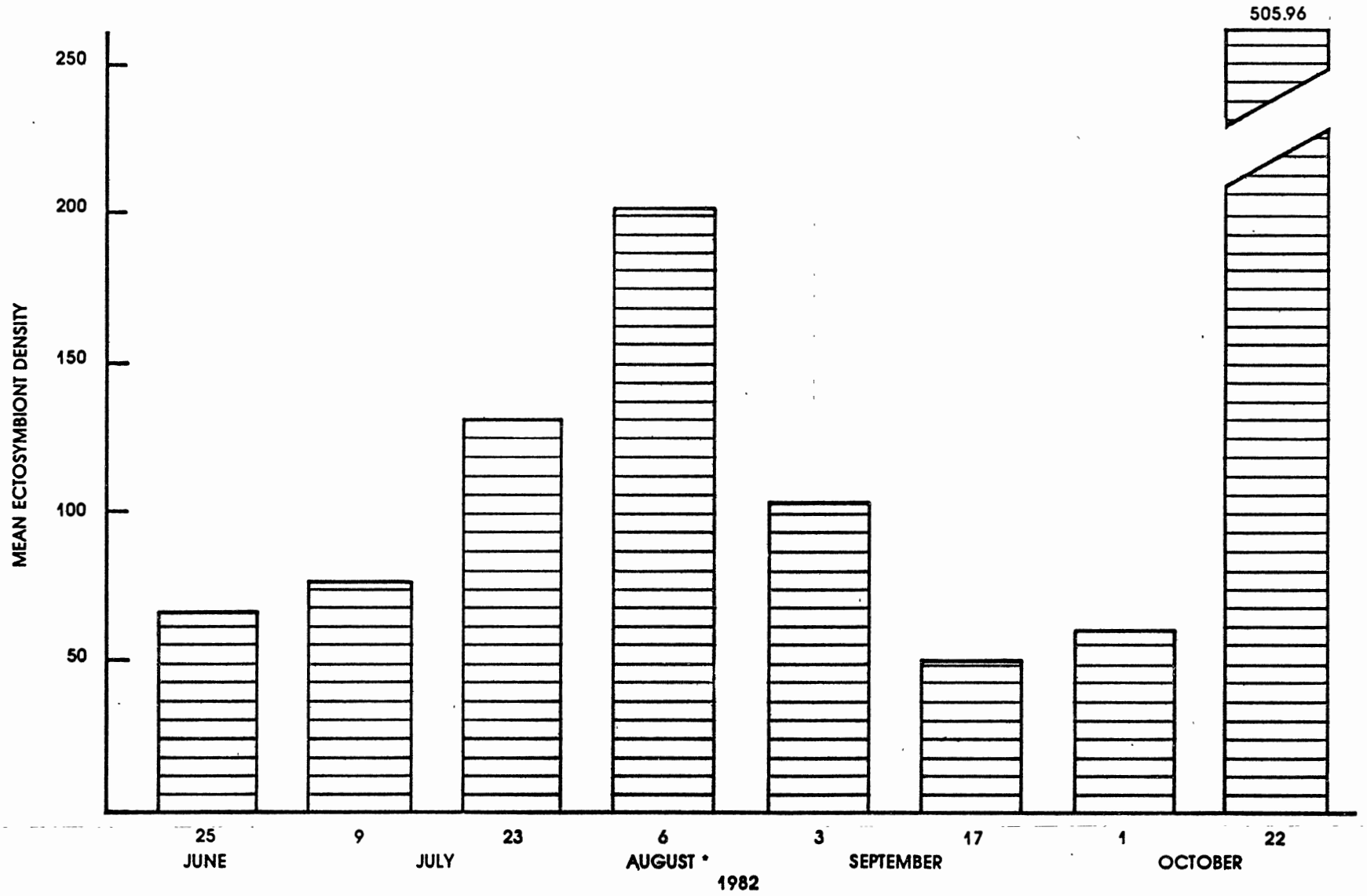
Ectosymbiont	June 25	July 9	July 23	August 6	September 3	September 17	October 1	October 22
Trichodina	16.5^{B}	42.7^{B}	58.5^{B}	70.5^{B}	64.6^{B}	36.2^{B}	33.6^{B}	331.2^{A}
Scyphidia	0.4^{B}	0.3^{B}	0.4^{B}	1.4^{B}	0.2^{B}	2.7^{B}	0.2^{B}	149.4^{A}
Glossatella	0.01^{B}	0.0^{B}	0.0^{B}	0.5^{A}	0.03^{B}	0.0^{B}	0.0^{B}	0.0^{B}
U.I.D. ciliates	0.0^{B}	0.0^{B}	0.0^{B}	0.0^{B}	0.0^{B}	0.03^{A}	0.02^{B}	0.0^{B}
Trichophrya	2.0^{CD}	5.4^{B}	0.4^{D}	10.4^{A}	2.0^{BCD}	4.9^{BC}	1.8^{CD}	0.5^{D}
Myxosporidian Cysts	9.4^{B}	7.9^{B}	37.5^{A}	25.3^{AB}	2.3^{B}	1.7^{B}	0.9^{B}	4.7^{B}
Oodinium	0.03^{D}	0.7^{BCD}	1.1^{BC}	4.4^{A}	0.03^{CD}	1.3^{B}	0.02^{D}	0.0^{D}
Colonial algae	0.2^{B}	0.2^{B}	0.3^{B}	0.0^{B}	0.6^{B}	0.4^{B}	2.0^{B}	4.96^{A}
Peridinium	0.0^{B}	0.0^{B}	0.0^{B}	0.0^{B}	0.0^{B}	0.0^{B}	0.02^{A}	0.0^{B}
Monogenean Flukes	1.8^{C}	4.0^{B}	4.1^{B}	4.9^{AB}	4.5^{AB}	5.2^{AB}	3.6^{B}	6.3^{A}
Rotifers	0.0^{B}	0.0^{B}	0.0^{B}	0.0^{B}	0.0^{B}	0.0^{B}	0.02^{A}	0.0^{B}
TOTAL	66.4^{B}	73.8^{B}	122.1^{B}	203.2^{B}	101.4^{B}	52.5^{B}	61.9^{B}	505.9^{A}

Means with the same letter are not significantly different.

*August 20 sample omitted because all catfish died prior to examination.

N=144

Figure 9. Temporal Variation in Gill Ectosymbiont Densities Per Gill Arch on Channel Catfish in 1982 Polyculture Study



* AUGUST 20 SAMPLE OMITTED BECAUSE ALL CATFISH DIED PRIOR TO EXAMINATION.

densities were significantly higher (A=0.05) on October 22. The mean densities of all taxa except myxosporidian spores and rotifers showed significant temporal differences for fish from both ponds (Table XVII). When the ectosymbiont taxa were considered separately, all but Ergasilus showed significant temporal differences at different stocking densities (Table XVIII).

Mean ectosymbiont density from catfish was positively correlated with length and weight and negatively correlated with temperature (Table XIX). Mean densities of some taxa were positively correlated with length and weight and negatively correlated with temperature. Cysts were slightly positively correlated with temperature but not significant at the 0.05 level.

There was no difference between ponds in mean ectosymbiont density of pooled Tilapia and catfish. Mean densities of colonial algae and Ergasilus were significantly higher (A=0.05) in fish from the Kolb pond and the mean density of Trichophrya was significantly higher in fish from the Buntin pond (Figure 10). These densities are identical to those for catfish considered alone.

There were no differences in mean ectosymbiont densities in pooled Tilapia and catfish from cages at varying stocking densities. However, five individual parasitic taxa showed significant (A=0.05) differences in mean density (Table XX). There was no difference between ponds in mean ectosymbiont densities of fish at identical stocking densities but six individual parasitic taxa showed significant (A=0.05) differences in mean density (Table XXI).

The mean ectosymbiont density of pooled Tilapia and catfish was significantly higher (A=0.05) on October 22 than on any other sampling

TABLE XVII

POND VARIATIONS IN MEAN ECTOSYMBIONT DENSITIES PER GILL ARCH OF CATFISH GROUPED BY DATE IN THE POLYCULTURE STUDY

Ectosymbiont	June 25 B*	June 25 K*	July 9 B	July 9 K	July 23 B	July 23 K	August[o] 6 B	August[o] 6 K
Trichodina	17.3^{C}	15.6^{C}	56.0^{C}	24.6^{C}	82.4^{BC}	31.2^{C}	3.5^{C}	204.6^{ABC}
Scyphidia	0.8^{C}	0.0^{C}	0.4^{C}	0.1^{C}	0.5^{C}	0.3^{C}	0.6^{C}	3.0^{BC}
Glossatella	0.02^{B}	0.0^{B}	0.0^{B}	0.0^{B}	0.0^{B}	0.0^{B}	0.8^{A}	0.0^{B}
U.I.D. ciliates	0.0^{B}	0.0^{B}	0.0^{B}	0.0^{B}	0.0^{B}	0.0^{B}	0.0^{B}	0.0^{B}
Trichophrya	1.6^{C}	2.4^{C}	7.9^{B}	1.96^{C}	0.6^{C}	0.06^{C}	15.6^{C}	0.2^{C}
Oodinium	0.06^{B}	0.0^{B}	0.4^{B}	1.1^{B}	1.8^{B}	0.3^{B}	0.6^{B}	12.2^{A}
Ceratium	0.2^{A}	0.0^{B}	0.0^{B}	0.03^{B}	0.0^{B}	0.0^{B}	0.0^{B}	0.0^{B}
Colonial algae	0.3^{C}	0.03^{C}	0.06^{C}	0.4^{C}	0.3^{C}	0.2^{C}	0.0^{C}	0.0^{C}
Peridinium	0.0^{B}	0.0^{B}	0.0^{B}	0.0^{B}	0.0^{B}	0.0^{B}	0.0^{B}	0.0^{B}
U.I.D. Flagellates	0.3^{A}	0.03^{AB}	0.0^{B}	0.0^{B}	0.0^{B}	0.0^{B}	0.0^{B}	0.0^{B}
U.I.D. Cysts	15.3^{BC}	2.5^{C}	5.1^{C}	11.8^{BC}	37.8^{AB}	37.3^{AB}	6.1^{C}	63.8^{A}
Monogenean Flukes	1.4^{D}	2.2^{CD}	3.2^{BCD}	5.03^{ABCD}	4.4^{ABCD}	3.7^{ABCD}	5.2^{ABCD}	4.3^{ABCD}
Ergasilus	0.0^{B}	0.03^{B}	0.0^{B}	0.03^{B}	0.0^{B}	0.16^{A}	0.0^{B}	0.0^{B}
TOTAL	83.2^{B}	29.2^{B}	76.8^{B}	69.7^{B}	139.9^{B}	101.8^{B}	97.0^{B}	415.5^{AB}

TABLE XVII (Continued)

Ectosymbiont	September 3 B	September 3 K	September 17 B	September 17 K	October 1 B	October 1 K	October 22 B	October 22 K
Trichodina	7^{C}	114^{BC}	36.2^{C}		19.7^{C}	50.4^{C}	380.3^{A}	264.3^{AB}
Scyphidia	0.4^{C}	0.0^{C}	2.7^{C}		0.2^{C}	0.2^{C}	168.4^{A}	123.6^{AB}
Glossatella	0.0^{B}	0.06^{B}	0.0^{B}		0.0^{B}	0.0^{B}	0.0^{B}	0.0^{B}
U.I.D. ciliates	0.0^{B}	0.0^{B}	0.05^{B}		0.0^{B}	0.04^{AB}	0.0^{B}	0.0^{B}
Trichophrya	2.4^{C}	1.7^{C}	4.9^{BC}		0.3^{C}	3.6^{BC}	0.8^{C}	0.0^{C}
Oodinium	0.0^{B}	0.06^{B}	1.3^{B}		0.03^{B}	0.0^{B}	0.0^{B}	0.0^{B}
Ceratium	0.0^{B}	0.0^{B}	0.0^{B}		0.03^{B}	0.0^{B}	0.0^{B}	0.0^{B}
Colonial algae	0.8^{BC}	0.4^{BC}	0.4^{C}		0.6^{BC}	3.6^{B}	1.1^{BC}	10.3^{A}
Peridinium	0.0^{B}	0.0^{B}	0.0^{B}		0.03^{A}	0.0^{B}	0.0^{B}	0.0^{B}
U.I.D. Flagellates	0.2^{AB}	0.0^{B}	0.0^{B}		0.0^{B}	0.0^{B}	0.0^{B}	0.0^{B}
U.I.D Cysts	4.1^{C}	0.8^{C}	1.7^{C}		1.6^{C}	0.06^{C}	7.9^{C}	0.5^{C}
Monogenean Flukes	3.0^{BCD}	5.8^{ABC}	5.2^{ABCD}		4.2^{ABCD}	2.9^{BCD}	6.6^{A}	5.9^{AB}
Ergasilus	0.0^{B}	0.06^{AB}	0.0^{B}		0.0^{B}	0.0^{B}	0.0^{B}	0.0^{B}
TOTAL	65.6^{B}	132.0^{B}	52.5^{B}	+	56.3^{B}	68.7^{B}	580.3^{A}	404.6^{AB}

*B=Buntin pond K=Kolb pond N=144

+ The Kolb pond on September 17 shows no values due to death of all catfish prior to examination.

o August 20 sample omitted because all catfish died prior to examination.

Means with the same letter are not significantly different.

TABLE XVIII

VARIATION ATTRIBUTED TO STOCKING DENSITY FOR MEAN ECTOSYMBIONT DENSITIES PER GILL ARCH OF CATFISH GROUPED BY DATE IN THE POLYCULTURE STUDY

Ectosymbiont	June 25			July 9			July 23			August+ 6		
	1	2	3	1	2	3	1	2	3	1	2	3
Trichodina	30.7^{CD}	2.8^{D}	18.0^{CD}	53.5^{CD}	44.6^{CD}	21.6^{CD}	55.5^{CD}	19.0^{CD}	133.3^{BCD}	77.6^{CD}	35.0^{CD}	
Scyphidia	0.0^{B}	0.9^{B}	0.2^{B}	0.06^{B}	0.6^{B}	0.0^{B}	0.2^{B}	0.8^{B}	1.2^{B}	1.3^{B}	2.3^{B}	
Glossatella	0.03^{B}	0.0^{B}	0.0^{B}	0.0^{B}	0.0^{B}	0.0^{B}	0.0^{B}	0.0^{B}	0.0^{B}	0.6^{A}	0.0^{B}	
U.I.D. ciliates	0.0^{C}	0.0^{C}	0.0^{C}	0.0^{C}	0.0^{C}	0.0^{C}	0.0^{C}	0.0^{C}	0.0^{C}	0.0^{C}	0.0^{C}	
Trichophrya	3.1^{CD}	1.5^{C}	1.3^{D}	7.6^{BC}	2.7^{CD}	6.2^{BCD}	0.5^{D}	0.0^{D}	0.2^{D}	12.5^{B}	0.3^{D}	
Oodinium	0.1^{B}	0.0^{B}	0.0^{B}	0.4^{B}	1.2^{B}	0.4^{B}	1.4^{B}	0.1^{B}	1.0^{B}	5.3^{A}	0.0^{B}	
Ceratium	0.3^{A}	0.0^{B}	0.0^{B}	0.03^{B}	0.0^{B}	0.0^{B}	0.0^{B}	0.0^{B}	0.0^{B}	0.0^{B}	0.0^{B}	
Colonial algae	0.2^{BC}	0.2^{BC}	0.0^{C}	0.0^{C}	0.5^{BC}	0.0^{C}	0.2^{BC}	0.1^{BC}	0.8^{BC}	0.0^{C}	0.0^{C}	
Peridinium	0.0^{B}	0.0^{B}	0.0^{B}	0.0^{B}	0.0^{B}	0.0^{B}	0.0^{B}	0.0^{B}	0.0^{B}	0.0^{B}	0.0^{B}	
U.I.D. Flagellates	0.5^{A}	0.0^{B}	0.0^{B}	0.0^{B}	0.0^{B}	0.0^{B}	0.0^{B}	0.0^{B}	0.0^{B}	0.0^{B}	0.0^{B}	
U.I.D. Spores	102.8^{A}	0.2^{B}	0.0^{B}	28.5^{AB}	3.7^{B}	0.8^{B}	24.2^{AB}	6.5^{B}	16.0^{AB}	87.1^{AB}	77.0^{AB}	
U.I.D. Cysts	24.0^{AB}	2.1^{B}	1.1^{B}	15.8^{B}	1.8^{B}	5.0^{B}	50.2^{A}	7.8^{B}	18.8^{AB}	25.8^{AB}	23.0^{AB}	
Monogenean Flukes	1.9^{CD}	1.3^{D}	2.3^{CD}	4.4^{BCD}	3.6^{CD}	3.9^{BCD}	4.4^{BCD}	3.3^{CD}	3.6^{CD}	5.3^{BCD}	3.0^{CD}	
Rotifers	0.0^{B}	0.0^{B}	0.0^{B}	0.0^{B}	0.0^{B}	0.0^{B}	0.0^{B}	0.0^{B}	0.0^{B}	0.0^{B}	0.0^{B}	
TOTAL	163.9^{CD}	9.0^{D}	22.9^{D}	110.3^{CD}	58.9^{D}	37.9^{D}	136.9^{CD}	37.6^{D}	175.0^{CD}	215.6^{CD}	140.6^{CD}	*

TABLE XVIII (Continued)

Ectosymbiont	September 3 1	3 2	3 3	17 1	17 2	17 3	October 1 1	1 2	1 3	22 1	22 2	22 3
Trichodina	70.9^{CD}	178.3^{BCD}	3.6^{CD}	15.3^{CD}	6.1^{CD}	47.1^{CD}	39.6^{CD}	30.1^{CD}	24.9^{CD}	207.1^{BC}	387.0^{AB}	421.8^{A}
Scyphidia	0.0^{B}	0.2^{B}	0.3^{B}	1.5^{B}	2.2^{B}	4.3^{B}	0.2^{B}	0.3^{B}	0.2^{B}	123.9^{A}	150.9^{A}	174.1^{A}
Glossatella	0.2^{B}	0.0^{B}	0.0^{B}	0.0^{B}	0.0^{B}	0.0^{B}	0.0^{B}	0.0^{B}	0.0^{B}	0.0^{B}	0.0^{B}	0.0^{B}
U.I.D. ciliates	0.0^{C}	0.0^{C}	0.0^{C}	0.0^{C}	0.3^{A}	0.0^{C}	0.0^{C}	0.0^{C}	0.06^{B}	0.0^{C}	0.0^{C}	0.0^{C}
Trichophrya	0.5^{D}	3.4^{BCD}	2.4^{CD}	0.8^{D}	26.8^{A}	0.2^{D}	0.03^{D}	0.5^{D}	6.5^{BCD}	0.0^{D}	2.1^{CD}	0.0^{D}
Oodinium	0.0^{B}	0.1^{B}	0.03^{B}	0.2^{B}	7.2^{A}	0.13^{B}	0.0^{B}	0.06^{B}	0.0^{B}	0.0^{B}	0.0^{B}	0.0^{B}
Ceratium	0.0^{B}	0.0^{B}	0.0^{B}	0.0^{B}	0.0^{B}	0.0^{B}	0.0^{B}	0.0^{B}	0.06^{B}	0.0^{B}	0.0^{B}	0.0^{B}
Colonial algae	0.2^{BC}	0.5^{BC}	0.9^{BC}	0.06^{BC}	1.6^{ABC}	0.2^{BC}	1.3^{BC}	1.5^{BC}	3.9^{ABC}	6.7^{A}	3.4^{ABC}	4.2^{AB}
Peridinium	0.0^{B}	0.0^{B}	0.0^{B}	0.0^{B}	0.0^{B}	0.0^{B}	0.0^{B}	0.0^{B}	0.06^{A}	0.0^{B}	0.0^{B}	0.0^{B}
U.I.D. Flagellates	0.0^{B}	0.3^{AB}	0.0^{B}	0.0^{B}	0.0^{B}	0.0^{B}	0.0^{B}	0.0^{B}	0.0^{B}	0.0^{B}	0.0^{B}	0.0^{B}
U.I.D. Spores	15.4^{AB}	17.4^{AB}	39.0^{AB}	0.0^{B}	0.0^{B}	0.0^{B}	24.9^{AB}	10.1^{B}	18.8^{AB}	8.9^{B}	4.2^{B}	11.4^{B}
U.I.D. Cysts	0.8^{B}	2.6^{B}	3.2^{B}	1.2^{B}	1.2^{B}	2.5^{B}	1.5^{B}	0.06^{B}	0.7^{B}	0.9^{B}	12.4^{B}	3.96^{B}
Monogenean Flukes	5.5^{BCD}	7.0^{BC}	2.6^{CD}	2.5^{CD}	13.0^{A}	4.6^{BCD}	3.7^{CD}	2.5^{CD}	4.5^{BCD}	6.3^{BC}	7.8^{B}	5.5^{BCD}
Rotifers	0.0^{B}	0.0^{B}	0.0^{B}	0.0^{B}	0.0^{B}	0.0^{B}	0.0^{B}	0.06^{A}	0.0^{B}	0.0^{B}	0.0^{B}	0.0^{B}
TOTAL	93.6^{CD}	210.1^{CD}	52.2^{D}	21.6^{D}	113.3^{CD}	59.1^{D}	71.2^{D}	45.3^{D}	59.8^{D}	353.9^{BC}	567.9^{AB}	620.9^{A}

Means with the same letter are not significantly different.

*Cage 3 on August 6 shows no values since all catfish died prior to examination.

+August 20 sample omitted since all catfish died prior to examination.

TABLE XIX

CORRELATION TESTS FOR CATFISH ONLY IN THE POLYCULTURE STUDY*

Ectosymbiont	Correlations R	Length	Weight	Temperature	Dissolved Oxygen Concentration
Trichodina		+	+	-	
Scyphidia		+	+	-	
Glossatella					
U.I.D. ciliates		+	+		
Trichophrya					
Oodinium					
Ceratium					
Colonial algae		+	+	-	+
Peridinium					
U.I.D. Flagelates					
U.I.D. Spores					
U.I.D. Cysts					
Monogenean Flukes	+	+	+	-	
Ergasilus					
Rotifers					
TOTAL		+	+	-	

N=144

*Variables indicated either positively or negatively are statistically significant at A=0.05.

Figure 10. Pond Variation in *Ergasilus*, *Trichophrya* and Colonial Algae Densities Per Gill Arch in Pooled *Tilapia* and Catfish in 1982 Polyculture Study

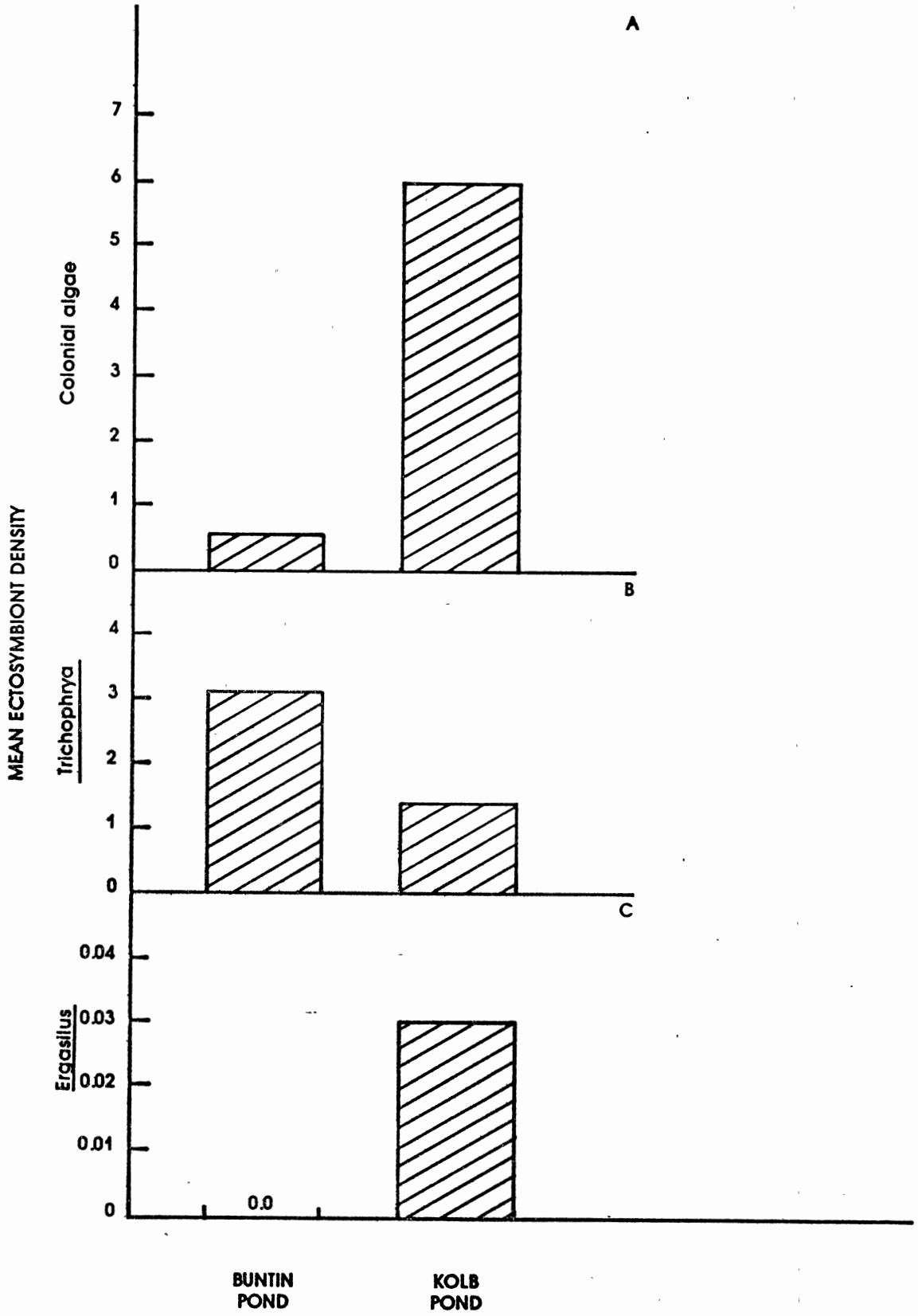

A
MEAN ECTOSYMBIONT DENSITY
Colonial algae
7
6
5
4
3
2
1
0
B
Trichophrya
4
3
2
1
0
C
Ergasilus
0.04
0.03
0.02
0.01
0
0.0
BUNTIN POND
KOLB POND

TABLE XX

VARIATION ATTRIBUTED TO STOCKING DENSITY FOR MEAN ECTOSYMBIONT DENSITIES PER GILL ARCH OF POOLED TILAPIA AND CATFISH IN 1982 POLYCULTURE STUDY

Ectosymbiont	Density 400	425	450
Myxosporidian Spores	36.0^{A}	6.6^{B}	8.1^{B}
Myxosporidian Cysts	16.5^{A}	4.2^{B}	2.5^{B}
Oodinium	0.7^{A}	0.6^{A}	0.06^{B}
Colonial algae	1.3^{B}	1.0^{B}	5.8^{A}
Monogenean Flukes	4.2^{A}	4.2^{A}	2.8^{B}

N=162

Means with the same letter are not significantly different.

TABLE XXI

VARIATION ATTRIBUTED TO STOCKING DENSITY AND POND, (COMBINED), FOR MEAN ECTOSYMBIONT DENSITIES PER GILL ARCH OF POOLED TILAPIA AND CATFISH IN 1982 POLYCULTURE STUDY

Ectosymbiont	400		425		450	
	B*	K*	B	K	B	K
Glossatella	0.1^{A}	0.02^{AB}	0.0^{AB}	0.0^{B}	0.0^{B}	0.0^{B}
Trichophrya	4.5^{A}	0.9^{B}	3.6^{AB}	2.1^{AB}	1.6^{AB}	1.6^{AB}
Myxosporidian Cysts	18.0^{A}	14.4^{AB}	4.5^{AB}	3.8^{AB}	2.3^{B}	3.0^{AB}
Colonial algae	0.6^{B}	2.2^{B}	0.2^{B}	2.1^{B}	0.6^{B}	14.0^{A}
Ergasilus	0.0^{B}	0.06^{A}	0.0^{B}	0.02^{AB}	0.0^{B}	0.0^{B}
Rotifers	0.0^{B}	0.0^{B}	0.0^{B}	0.02^{AB}	0.0^{B}	0.0^{B}

N=162

Means with the same letter are not significantly different.

*B=Buntin pond

K=Kolb pond

date. Ten ectosymbiont taxa showed significant temporal differences in mean density (Table XXII). The ectosymbionts of catfish showed no temporal variation and Peridinium from catfish and Tilapia combined showed no temporal differences. Considerable variation in mean ectosymbiont densities from fish was shown in analysis both of ponds compared by date and of cages compared by date (Tables XXIII and XXIV). In both cases the mean ectosymbiont densities were significantly higher (A=0.05) on October 22. The mean densities of all ectosymbiont taxa except Ceratium and myxosporidian spores showed significant temporal differences for the ponds compared (Table XXIII). When the ectosymbiont taxa were considered separately, all but Ergasilus showed significant temporal differences in fish from cages at different stocking densities (Table XXIV).

Mean ectosymbiont densities from pooled Tilapia and catfish were positively correlated with length and weight and negatively correlated with temperature (Table XXV). Mean densities of three taxa were negatively correlated with temperature. Mean densities of cysts were slightly positively correlated with temperature but not significantly at the 0.05 level.

TABLE XXII

TEMPORAL VARIATION IN MEAN ECTOSYMBIONT DENSITIES PER GILL ARCH OF POOLED TILAPIA AND CATFISH IN 1982 POLYCULTURE STUDY

Ectosymbiont	June 25	July 9	July 23	August 6	August 20	September 3	September 17	October 1	October 22
Trichodina	15.4^{B}	39.7^{B}	52.0^{B}	53.4^{B}	1.5^{B}	56.2^{B}	31.1^{B}	30.5^{B}	307.5^{A}
Scyphidia	0.4^{B}	0.2^{B}	0.4^{B}	1.1^{B}	0.0^{B}	0.13^{B}	2.3^{B}	0.2^{B}	138.8^{A}
Glossatella	0.01^{B}	0.0^{B}	0.0^{B}	0.4^{A}	0.0^{B}	0.03^{B}	0.0^{B}	0.0^{B}	0.0^{B}
U.I.D. ciliates	0.0^{B}	0.0^{B}	0.0^{B}	0.0^{B}	0.0^{B}	0.0^{B}	0.03^{A}	0.01^{AB}	0.0^{B}
Trichophrya	1.8^{B}	4.9^{A}	0.3^{B}	4.7^{A}	0.0^{B}	1.8^{B}	4.2^{AB}	1.6^{B}	0.4^{B}
Myxosporidian Cysts	8.7^{B}	7.3^{B}	33.1^{A}	19.0^{AB}	0.0^{B}	2.03^{B}	1.5^{B}	0.8^{B}	4.4^{B}
Oodinium	0.03^{D}	0.6^{BCD}	0.96^{BC}	3.3^{A}	0.0^{D}	0.03^{CD}	1.1^{B}	0.01^{D}	0.0^{D}
Colonial algae	0.1^{C}	0.2^{C}	0.3^{C}	0.0^{C}	0.0^{C}	0.9^{C}	15.5^{A}	3.5^{B}	5.1^{B}
Monogenean Flukes	1.6^{C}	3.7^{B}	3.6^{BC}	3.7^{BC}	0.0^{C}	3.9^{AB}	4.4^{AB}	3.3^{BC}	5.9^{A}
Rotifers	0.0^{B}	0.0^{B}	0.0^{B}	0.0^{B}	0.0^{B}	0.0^{B}	0.0^{B}	0.01^{A}	0.0^{B}
TOTAL	61.6^{B}	68.6^{B}	103.2^{B}	152.9^{B}	1.5^{B}	88.5^{B}	60.3^{B}	58.0^{B}	470.3^{A}

N=162

TABLE XXIII

POND VARIATION BY DATE OF MEAN ECTOSYMBIONT DENSITIES PER GILL ARCH OF POOLED TILAPIA AND CATFISH IN 1982 POLYCULTURE STUDY

Ectosymbiont	June 25		July 9		July 23		August 6		August 20	
	13*	K*	B	K	B	K	B	K	B	K
Trichodina	16.2^{C}	14.4^{C}	52.5^{C}	22.6^{C}	73.3^{BC}	28.1^{C}	2.8^{C}	137.8^{ABC}	1.3^{C}	1.6^{C}
Scyphidia	0.7^{B}	0.0^{B}	0.3^{B}	0.1^{B}	0.5^{B}	0.3^{B}	0.5^{B}	0.2^{B}	0.0^{B}	0.0^{B}
Glossatella	0.02^{B}	0.0^{B}	0.0^{B}	0.0^{B}	0.0^{B}	0.0^{B}	0.6^{A}	0.0^{B}	0.0^{B}	0.0^{B}
U.I.D. ciliates	0.0^{B}	0.0^{B}	0.0^{B}	0.0^{B}	0.0^{B}	0.0^{B}	0.0^{B}	0.0^{B}	0.0^{B}	0.0^{B}
Trichophrya	1.5^{C}	2.2^{C}	7.4^{AB}	1.8^{C}	0.5^{C}	0.06^{C}	12.5^{A}	0.1^{C}	0.0^{C}	0.0^{C}
Oodinium	0.06^{B}	0.0^{B}	0.4^{B}	1.0^{B}	1.6^{B}	0.2^{B}	0.5^{B}	8.1^{A}	0.0^{B}	0.0^{B}
Colonial algae	0.3^{C}	0.02^{C}	0.06^{C}	0.3^{C}	0.5^{C}	0.2^{C}	0.0^{C}	0.0^{C}	0.0^{C}	0.0^{C}
Peridinium	0.0^{B}	0.0^{B}	0.0^{B}	0.0^{B}	0.0^{B}	0.0^{B}	0.0^{B}	0.0^{B}	0.0^{B}	0.0^{B}
U.I.D. Flagellates	0.3^{A}	0.03^{AB}	0.0^{B}	0.0^{B}	0.0^{B}	0.0^{B}	0.0^{B}	0.0^{B}	0.0^{B}	0.0^{B}
U.I.D. Cysts	14.3^{AB}	2.3^{AB}	4.7^{AB}	10.8^{AB}	33.6^{A}	32.6^{A}	4.9^{AB}	42.5^{A}	0.0^{B}	0.0^{B}
Monogenean Flukes	1.3^{D}	2.0^{CD}	3.0^{BCD}	4.6^{ABC}	3.9^{ABCD}	3.3^{ABCD}	4.2^{ABCD}	2.9^{BCD}	0.0^{D}	0.0^{D}
Ergasilus	0.0^{B}	0.03^{B}	0.0^{B}	0.03^{B}	0.0^{B}	0.2^{A}	0.0^{B}	0.0^{B}	0.0^{B}	0.0^{B}
Rotifers	0.0^{B}	0.0^{B}	0.0^{B}	0.0^{B}	0.0^{B}	0.0^{B}	0.0^{B}	0.0^{B}	0.0^{B}	0.0^{B}
TOTAL	91.7^{B}	26.96^{B}	72.1^{B}	63.9^{B}	124.5^{B}	89.9^{B}	77.6^{B}	278.3^{AB}	1.3^{B}	1.6^{B}

TABLE XXIII (Continued)

Ectosymbiont	September 3 B	September 3 K	September 17 B	September 17 K	October 1 B	October 1 K	October 22 B	October 22 K
Trichodina	6.3^{C}	99.9^{BC}	33.4^{C}	1.0^{C}	18.1^{C}	45.4^{C}	356.5^{A}	242.2^{AB}
Scyphidia	0.3^{B}	0.0^{B}	2.5^{B}	0.0^{B}	0.0^{B}	0.3^{B}	157.9^{A}	113.3^{A}
Glossatella	0.0^{B}	0.06^{B}	0.0^{B}	0.0^{B}	0.0^{B}	0.0^{B}	0.0^{B}	0.0^{B}
U.I.D. ciliates	0.0^{B}	0.0^{B}	0.05^{A}	0.0^{B}	0.0^{B}	0.03^{AB}	0.0^{B}	0.0^{B}
Trichophrya	2.03^{C}	1.5^{C}	4.5^{BC}	0.0^{C}	0.23^{C}	3.2^{BC}	0.8^{C}	0.0^{C}
Oodinium	0.0^{B}	0.06^{B}	1.3^{B}	0.0^{B}	0.03^{B}	0.0^{B}	0.0^{B}	0.0^{B}
Colonial algae	1.6^{C}	0.4^{C}	0.6^{C}	209.0^{A}	0.6^{C}	7.1^{B}	1.0^{C}	10.5^{B}
Peridinium	0.0^{B}	0.0^{B}	0.0^{B}	0.0^{B}	0.03^{A}	0.0^{B}	0.0^{B}	0.0^{B}
U.I.D. Flagellates	0.13^{AB}	0.0^{B}	0.0^{B}	0.0^{B}	0.0^{B}	0.0^{B}	0.0^{B}	0.0^{B}
U.I.D. Cysts	3.5^{AB}	0.7^{AB}	1.6^{AB}	0.0^{B}	1.5^{AB}	0.06^{B}	7.4^{AB}	0.4^{B}
Monogenean Flukes	2.6^{BCD}	5.06^{ABC}	4.8^{ABC}	0.0^{D}	3.8^{ABCD}	2.6^{BCD}	6.2^{A}	5.4^{AB}
Ergasilus	0.0^{B}	0.06^{AB}	0.0^{B}	0.0^{B}	0.0^{B}	0.0^{B}	0.0^{B}	0.0^{B}
Rotifers	0.0^{B}	0.0^{B}	0.0^{B}	0.0^{B}	0.0^{B}	0.03^{B}	0.0^{B}	0.0^{B}
TOTAL	57.5^{B}	115.6^{B}	48.8^{B}	210.3^{AB}	51.6^{B}	65.6^{B}	544.0^{A}	371.9^{A}

Means with the same letter are not significantly different.

*B=Buntin pond

K=Kolb

TABLE XXIV

VARIATION ATTRIBUTED TO STOCKING DENSITY FOR MEAN ECTOSYMBIONT DENSITIES PER GILL ARCH IN POOLED TILAPIA AND CATFISH GROUPED BY DATE IN 1982 POLYCULTURE STUDY

	June			July						August					
		25			9			23			6			20	
Ectosymbiont	400	425	450	400	425	450	400	425	450	400	425	450	400	425	450
Trichodina	30.7^{BC}	2.8^{C}	14.0^{BC}	53.5^{BC}	44.6^{BC}	16.3^{BC}	55.5^{BC}	19.0^{BC}	68.3^{BC}	77.6^{BC}	35.0^{BC}	2.0^{C}			1.5^{C}
Scyphidia	0.0^{B}	0.96^{B}	0.13^{B}	0.06^{B}	0.6^{B}	0.0^{B}	0.2^{B}	0.8^{B}	0.6^{B}	1.3^{B}	2.3^{B}	0.0^{B}			0.0^{B}
Glossatella	0.03^{B}	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.6^{A}	0.0^{B}	0.0^{B}			0.0^{B}
U.I.D. ciliates	0.0^{B}	0.0^{B}	0.0^{B}	0.0^{B}	0.0^{B}	0.0^{B}	0.0^{B}	0.0^{B}	0.0^{B}	0.0^{B}	0.0^{B}	0.0^{B}			0.0^{B}
Trichophrya	3.1^{C}	1.5^{C}	1.03^{C}	7.6^{BC}	2.7^{C}	4.6^{BC}	0.5^{C}	0.0^{C}	0.06^{C}	12.5^{B}	0.03^{C}	0.0^{C}			0.0^{C}
Oodinium	0.1^{B}	0.0^{B}	0.0^{B}	0.4^{B}	1.2^{B}	0.3^{B}	1.4^{B}	0.1^{B}	0.5^{B}	5.3^{A}	0.0^{B}	0.0^{B}			0.0^{B}
Ceratium	0.3^{A}	0.0^{B}	0.0^{B}	0.03^{B}	0.0^{B}	0.0^{B}	0.0^{B}	0.0^{B}	0.0^{B}	0.0^{B}	0.0^{B}	0.0^{B}			0.0^{B}
Colonial algae	0.2^{B}	0.2^{B}	0.0^{B}	0.0^{B}	0.5^{B}	0.03^{B}	0.2^{B}	0.1^{B}	0.8^{B}	0.0^{B}	0.0^{B}	0.0^{B}			0.0^{B}
Peridinium	0.0^{B}	0.0^{B}	0.0^{B}	0.0^{B}	0.0^{B}	0.0^{B}	0.0^{B}	0.0^{B}	0.0^{B}	0.0^{B}	0.0^{B}	0.0^{B}			0.0^{B}
U.I.D. Flagellates	0.5^{A}	0.0^{B}	0.0^{B}	0.0^{B}	0.0^{B}	0.0^{B}	0.0^{B}	0.0^{B}	0.0^{B}	0.0^{B}	0.0^{B}	0.0^{B}			0.0^{B}
U.I.D. Spores	102.8^{A}	0.2^{B}	0.0^{B}	28.5^{B}	3.7^{B}	0.6^{B}	24.2^{B}	6.5^{B}	8.0^{B}	87.1^{AB}	77.0^{AB}	0.0^{B}			0.0^{B}
U.I.D. Cysts	24.0^{B}	2.1^{B}	0.8^{B}	15.8^{B}	1.8^{B}	3.7^{B}	50.2^{A}	7.8^{B}	9.4^{B}	25.8^{AB}	23.0^{B}	0.0^{B}			0.0^{B}
Monogenean Flukes	1.9^{CD}	1.3^{D}	1.8^{D}	4.4^{BCD}	3.6^{CD}	2.4^{CD}	4.4^{BCD}	3.3^{CD}	1.8^{CD}	5.3^{BCD}	3.0^{CD}	0.0^{D}			0.0^{D}
Rotifers	0.0^{B}	0.0^{B}	0.0^{B}	0.0^{B}	0.0^{B}	0.0^{B}	0.0^{B}	0.0^{B}	0.0^{B}	0.0^{B}	0.0^{B}	0.0^{B}			0.0^{B}
TOTAL	163.9^{BC}	9.0^{C}	17.8^{C}	110.3^{BC}	58.9^{C}	28.6^{C}	136.9^{BC}	37.6^{C}	89.6^{BC}	215.6^{BC}	140.6^{BC}	2.0^{C}	*	*	1.5^{C}

TABLE XXIV (Continued)

Ectosymbiont	September 3 400	September 3 425	September 3 450	September 17 400	September 17 425	September 17 450	October 1 400	October 1 425	October 1 450	October 22 400	October 22 425	October 22 450
Trichodina	70.9^{BC}	178.3^{ABC}	3.1^{BC}	15.3^{BC}	61.0^{BC}	33.9^{BC}	39.6^{BC}	30.0^{BC}	17.8^{BC}	207.1^{AB}	387.2^{A}	351.5^{A}
Scyphidia	0.0^{B}	0.2^{B}	0.2^{B}	1.5^{B}	2.2^{B}	3.0^{B}	0.2^{B}	0.3^{B}	0.13^{B}	123.9^{A}	150.9^{A}	145.0^{A}
Glossatella	0.0^{B}	0.0^{B}	0.0^{B}	0.0^{B}	0.0^{B}	0.0^{B}	0.0^{B}	0.0^{B}	0.0^{B}	0.0^{B}	0.0^{B}	0.0^{B}
U.I.D. ciliates	0.0^{B}	0.0^{B}	0.0^{B}	0.0^{B}	0.3^{A}	0.0^{B}	0.0^{B}	0.0^{B}	0.03^{B}	0.0^{B}	0.0^{B}	0.0^{B}
Trichophrya	0.5^{C}	3.4^{C}	1.8^{C}	0.8^{C}	26.8^{A}	0.13^{C}	0.03^{C}	0.5^{C}	4.6^{BC}	0.0^{C}	2.1^{C}	0.0^{C}
Oodinium	0.0^{B}	0.1^{B}	0.03^{B}	0.2^{B}	7.2^{A}	0.06^{B}	0.0^{B}	0.06^{B}	0.0^{B}	0.0^{B}	0.0^{B}	0.0^{B}
Ceratium	0.0^{B}	0.0^{B}	0.0^{B}	0.0^{B}	0.0^{B}	0.03^{B}	0.0^{B}	0.0^{B}	0.03^{B}	0.0^{B}	0.0^{B}	0.0^{B}
Colonial algae	0.2^{B}	0.5^{B}	1.4^{B}	0.06^{B}	1.6^{B}	30.5^{A}	1.3^{B}	1.5^{B}	8.2^{B}	6.7^{B}	3.4^{B}	4.6^{B}
Peridinium	0.0^{B}	0.0^{B}	0.0^{B}	0.0^{B}	0.0^{B}	0.0^{B}	0.0^{B}	0.0^{B}	0.03^{A}	0.0^{B}	0.0^{B}	0.0^{B}
U.I.D. Flagellates	0.0^{B}	0.3^{AB}	0.0^{B}	0.0^{B}	0.0^{B}	0.0^{B}	0.0^{B}	0.0^{B}	0.0^{B}	0.0^{B}	0.0^{B}	0.0^{B}
U.I.D. Spores	15.4^{B}	17.4^{B}	29.3^{AB}	0.0^{B}	0.0^{B}	0.0^{B}	24.9^{B}	10.0^{B}	13.4^{B}	8.9^{B}	4.2^{B}	9.5^{B}
U.I.S. Cysts	0.8^{B}	2.6^{B}	2.4^{B}	1.2^{B}	1.2^{B}	1.7^{B}	1.5^{B}	0.06^{B}	0.6^{B}	0.9^{B}	12.4^{B}	3.3^{B}
Monogenean Flukes	5.5^{BCD}	7.0^{BC}	2.0^{CD}	2.5^{CD}	13.0^{A}	3.3^{CD}	3.7^{CD}	2.5^{CD}	3.2^{CD}	6.3^{BC}	7.8^{B}	4.6^{BCD}
Rotifers	0.0^{B}	0.0^{B}	0.0^{B}	0.0^{B}	0.0^{B}	0.0^{B}	0.0^{B}	0.06^{A}	0.0^{B}	0.0^{B}	0.0^{B}	0.0^{B}
TOTAL	93.6^{BC}	210.1^{BC}	40.3^{C}	21.6^{C}	113.3^{BC}	72.8^{BC}	71.2^{C}	45.3^{C}	48.2^{C}	353.9^{AB}	567.9^{A}	518.5^{A}

Means with the same letter are not significantly different.

*Cages 1 and 2 (denisty 400 and 425 respectively) on August 20 show no values since all catfish died prior to examination.

N=162

TABLE XXV

CORRELATION TESTS FOR POOLED TILAPIA AND CATFISH DATA IN 1982 POLYCULTURE STUDY*

Ectosymbiont	Correlations R	Length	Weight	Temperature	Dissolved Oxygen Concentration
Trichodina		+	+	-	
Scyphidia		+	+	-	
Glossatella					
U.I.D. ciliates		+	+		
Trichophrya					
Oodinium					
Ceratium					
Colonial algae	+		+		+
Peridinium					
U.I.D. Flagellates					
U.I.D. Spores					
U.I.D. Cysts					
Monogenean Flukes	-	+	+	-	
Ergasilus					
Rotifers					
TOTAL		+	+	-	

N=162

*Variables indicated either positively or negatively are statistically significant at A=0.05.

CHAPTER IV

DISCUSSION

There appeared to be no correlation between mean gill ectosymbiont densities among caged channel catfish and different stocking densities. There were also no differences in the mean gill ectosymbiont densities between fish in cages containing both catfish and Tilapia and fish in cages containing only catfish. The presence of T. aurea as a second species at the stocking densities used did not affect total gill ectosymbiont densities of catfish either positively or negatively. For those individual taxa of ectosymbionts showing a significant difference, only an increase in colonial algae appeared to be associated with the presence of Tilapia.

Stocking Density

The high mean ectosymbiont density of 269.8 per gill arch on August 13 might appear to have been associated with high water temperature or some other seasonal effect. However, spores, an important part of the ectosymbiont community, generally are more prevalent in the first six to seven months of the year (Meyer, 1970). The observed peak probably should be attributed to overdispersion of myxosporidian spores (thought to be Henneguya spp.) within the host population. The uneven distribution was likely due to a difference in susceptibility among hosts (Crofton, 1971). Overdispersion was further substantiated on both August 13 and October 8 (means of 223.7 and 91.2

per gill arch respectively) by the small number of fish harboring spores. Of fourteen fish examined on August 13, only 6 had spores; one had 2654.3 per gill arch and others ranged from 17.6 to 179.3 per gill arch. Of fourteen fish examined on October 8, only four had spores; one fish had 783.3 per gill arch. The number of spores appears to have been so large as to strongly influence the ectosymbiont density correlation with dissolved oxygen concentration.

Monogenetic flukes (thought to be Cleidodiscus or Dactylogyrus) increased in mean densities as the season progressed and the highest mean (3.4 per gill arch) occurred in late September. This trend is in contrast to that reported by Meyer (1970) who observed a sharp decrease in the number of monogenean flukes after July. The mean densities of flukes on fish were positively correlated with length, weight and condition factor (R). These data suggest that as the fish increased in size, the density of flukes increased. The incidence of parasitism has been reported to increase with the age of the host (Dogiel et al. 1958) among fish observed five or more years; however, it would be difficult to attribute the increase seen over one growing season to the effects of age. These monogenetic flukes deposit eggs daily under optimum envionrmental conditions so fluke populations tend to build up as the summer progresses. This aspect of their life cycle is bound to influence temporal variations (Schmidt and Roberts, 1977).

Trichodina was most abundant in July but was also common in August. The mean density of Trichophrya was highest in July but also was high in late June and into the middle of August. Mean densities of Scyphidia were highest in June but there was no extension into August. Meyer (1970) reported large numbers of cases of Scyphidia and Trichophrya in

July and Trichodina in June, all three then dropping to zero or very low in August. The occurrence of both Trichodina and Trichophrya was positively correlated with temperature. However, this trend did not extend as late as September 10 when increased water temperature (26.0C) was not correlated with an increase in mean ectosymbiont densities.

The high density of Trichodina on July 2 could be due to over-dispersion since densities ranged from 77.3 to 123.0 per gill arch among three fish and from 3.3 to 24.0 per gill arch among all other fish. Scyphidia was negatively correlated with the coefficient of condition (R). Deteriorating water quality with a corresponding increase in bacteria may result in an increase in densities of both Trichodina and Scyphidia (Plumb, 1979). However, the dissolved oxygen concentration remained between 5.8 and 7.6 mg/L during the period. It is therefore unlikely that low dissolved oxygen was the cause of the high densities of ectosymbionts.

Oodinium and Ceratium, both dinoflagellates, were observed on the gills of channel catfish. Ceratium was seen only in June and its occurrence was negatively correlated with the length, weight and R of the host. The high densities of Oodinium occurred in late June and July. Its occurrence was positively correlated with temperature; however, there were not correspondingly high densities associated with the high water temperature on September 10.

There appeared to be no difference in mean gill ectosymbiont densities in fish from cages stocked at varying densities; however, densities in fish at different stocking densities varied a great deal from date to date. The mean density of ectosymbionts considered as one group was significantly higher (658.9 per gill arch) in fish from cage 2

(density=425) than in those from cage 1 (375) and cage 3 (475) (73.2 and 38.1 per gill arch respectively) on August 13. This difference appeared to have resulted mostly from a high density of spores and cysts on fish in cage 2 (425). The mean density of myxosporidian spores was 565.4 per gill arch and of cysts was 77.4 per gill arch.

Mean monogenetic fluke densities were significantly higher (A=0.05) on August 13 and September 24 than on any other sampling dates; however, density did not appear to be of much influence. The mean density (4 per gill arch) for fish from the cage containing 375 catfish was significantly higher (A=0.05) on August 13 than other sampling dates although the mean density (3.9 per gill arch) for fish from the cage containing 475 catfish was significantly higher (A=0.05) on September 24 than on other sampling dates.

Mean densities of both Trichodina and Trichophrya were highest on July 16 but the trends in the cages were exactly opposite. The mean density of Trichodina was highest (61.2 per gill arch) in fish from the cage containing 475 catfish and mean density was lowest (5.4 per gill arch) in fish from the cage containing 375 catfish. The mean density of Trichophrya was highest (8.5 per gill arch) in the cage containing 375 catfish and the mean density was lowest (0.2 per gill arch) in the cage containing 475 catfish. The mean density of Scyphidia was highest in the cage containing 375 catfish on June 4 but the trend between cages on this date was different from that for either Trichodina or Trichophrya.

The ectosymbionts as a whole and as individual groups showed significant differences between cages stocked at different densities. However, those differences probably were not caused by differences in the stocking density because no consistent trend between cages over the

season was seen for the ectosymbionts considered either as a single group or separately. Even the monogenetic flukes, which were found at significantly higher (A=0.05) mean densities on two dates, showed different trends on those two dates.

Many of the ectosymbionts found on caged fish throughout the sampling season were present in fish sampled from the pond prior to stocking. Only Glossatella and colonial algae were found on the catfish obtained from Tishomingo. There were far fewer numbers and types of ectosymbionts found on the last sample of caged fish than on the wild populations at the end of the season. Although the ectosymbiont densities in the wild populations were not monitored throughout the sampling season, it is possible that the gill ectosymbiont densities on the wild fish decreased before those of the caged population. The wild fish were found at much lower population densities and therefore had smaller chances of ectosymbiont transmission than the caged fish.

Polyculture

Ectosymbionts of Tilapia

No significant differences were found between the mean densities of ectosymbionts considered as a group or separate groups from Tilapia analyzed alone. Relatively few ectosymbionts were found on these fish. Paperna (1980) has reported Glossatella, Scyphidia, Trichodina, Trichophrya, monogenetic flukes as well as other protozoans from Tilapia found in Africa.

Tilapia are extremely hardy above 20C. However below 17C their metabolism slows and they cease to feed; below 15C they become weakened and stressed (Paperna, 1980). The temperature in this study remained

above 20C at all times except in late October when it fell to between 15C and 16C. Because lethal protozoan infections have been reported in the winter months (Paperna, 1980) it is possible that increased gill ectosymbiont densities might have been observed had this study been extended through a period of cooler water temperatures.

Ectosymbionts of Catfish

There was no variation in ectosymbionts of fish from different ponds when the ectosymbiont densities were considered for the group as a whole. Mean densities of colonial algae and Ergasilus were higher in fish from the Kolb pond although Ergasilus is probably unimportant because only six fish with a total of 9 organisms were found. The mean density of colonial algae was positively correlated with dissolved oxygen concentration. The dissolved oxygen concentration in the Kolb pond was consistently higher than that in the Buntin pond, and it remained above 4 mg/L the entire season although the concentration in the Buntin pond was often less than 4 mg/L. No apparent reason could be found for the higher mean density of Trichophrya in the Buntin pond.

No significant differences in mean total ectosymbiont densities were found in fish grouped by stocking density and proportion, but the mean densities of both unidentified cysts, and Oodinium were higher in cage 1 (400 catfish) than in other cages. Although fish in cage 1 had higher densities of cysts than fish from other cages, there were six fish which had very high densities (54.3 to 251.3 per gill arch); therefore, overdispersion could have contributed to the difference. No explanation could be found for the higher mean density of Oodinium in cage 1.

No significant difference in ectosymbiont densities was found

between fish in cages stocked at the same density when the ectosymbionts were considered as a group. The mean densities of both Scyphidia and colonial algae were higher from fish in cage 3 (400 catfish: 50 Tilapia) in the Kolb pond than in cage 3 in the Buntin pond. The mean density of Scyphidia was positively correlated with length and weight. The catfish in cage 3 in both ponds appeared to grow at approximately the same rate during the first half of the season but by the end of the season the catfish in cage 3 in the Kolb pond were larger than the catfish in cage 3 in the Buntin pond. The positive correlation with length and weight could account for the higher mean densities of Scyphidia in cage 3 in the Kolb pond since the catfish in that cage were larger. Overdispersion could also have contributed to the higher densities of Scyphidia on October 22 because one fish had 647.6 per gill arch. No explanation could be found for the cage difference with respect to colonial algae.

A significantly higher mean density of 505.9 per gill arch on October 22 for the ectosymbionts as a group suggests that more ectosymbionts occur later in the season than earlier. Mean ectosymbiont density was positively correlated with length and weight as well as negatively correlated with temperature. Monogenean flukes, Trichodina, Scyphidia and colonial algae all were similarly correlated. The lowest recorded water temperature for the season occurred on October 22 which coincided with the highest mean densities of Scyphidia and Trichodina.

The mean density of monogenean flukes was negatively correlated with temperature but there was also a trend toward higher mean densities of flukes as the season progressed which suggests that increases in length and weight also had an influence on the ectosymbiont density. It should

be remembered, however, that fluke populations normally increase later in the season due to their normal life cycle. Colonial algae also tended to increase in density as the fish grew. It would appear that the combination of a size increase and lower water temperatures contributed to an increase in the gill ectosymbiont density late in the season.

The temporal variation for the above-mentioned ectosymbionts is in contrast to that reported by Meyer, 1970. With the exception of colonial algae, not surveyed in the Meyer study, all ectosymbionts in his study showed a higher incidence in the first half of the year and a sharp decrease in August which continued to the end of the year.

The mean Oodinium density on August 6 was significantly higher (A=0.05) than that on any other sampling date; however, it is doubtful that it represented a trend. More likely, overdispersion was responsible because one fish had a mean density of 24.3 per gill arch on August 6. No reasonable explanation can be offered for the high density of Trichophrya on August 6 or the higher densities of unidentified cysts on July 23 and August 6. There was a positive correlation between temperature and cysts but it was not significant at the A=0.05 level.

When fish from the two ponds were compared, differences were found for only three ectosymbionts; however, when temporal variation was taken into consideration there were significant differences between ponds for the ectosymbionts as a group and for thirteen individual groups.

When considered as a whole group the mean ectosymbiont density in fish from the Buntin pond on October 22 was significantly higher (A=0.05) than on any other sampling date in either pond. Two-thirds of the groups

were found in higher densities on fish from the Buntin pond than from the Kolb pond although the dates varied for each. Only Oodinium, unidentified cysts, colonial algae and Ergasilus were higher from fish in the Kolb pond. The higher density of ectosymbionts on October 22 was most likely due to the high densities of flukes, Trichodina and Scyphidia which occurred on that date in the Buntin pond.

No reasonable explanation could be found for the differences between ponds with respect to ectosymbionts. The mean densities of flukes, Trichodina, colonial algae and Scyphidia as well as the ectosymbionts as a group were negatively correlated with water temperature. Although the Buntin pond was lower in temperature than the Kolb pond, it is not known if this temperature difference was enough to cause an increase in the ectosymbiont densities among fish.

When the ectosymbiont densities of fishes at different stocking densities were compared, Oodinium and unidentified cysts showed the only differences. However, when temporal variation was taken into consideration only Ergasilus failed to show any difference between cages.

The mean ectosymbiont density as a group (620.9 per gill arch) in fish from cage 3 (400 catfish +50 Tilapia) on October 22 was significantly higher ($A=0.05$) than in fish from any other cage on any other sampling date. It is probable that the high density for ectosymbionts as a group was affected mostly by the high densities of Trichodina and Scyphidia, (421.8 and 174.1 per gill arch respectively), which occurred in fish from cage 3 on October 22.

The mean densities of unidentified cysts, spores and colonial algae were significantly higher in fish from cage 1 (400 catfish). Densities

of flukes, Trichophrya and Oodinium in fish from cage 2 (400 catfish +25 Tilapia) on September 17 were all significantly higher (A=0.05) than in fish from any other cage on other sampling dates. The trends seen in the ectosymbiont densities between cages on September 17 were not consistent throughout the season.

Ectosymbionts of Catfish and Tilapia

The statistical tests of data for catfish and Tilapia combined revealed numerous significant differences. Most results were similar to those for the catfish-only experiments except that the means were slightly different due to the different number of fish examined.

Spore densities were significantly different in fish from cages stocked at different densities when the catfish and Tilapia results combined were analyzed; however, there was no such difference in spore densities when only the catfish results were analyzed. Since no spores were found on the Tilapia examined, it was only the addition of the Tilapia to the number of fish examined which reduced the means in cage 3 enough to produce a statistical difference. Trichophrya also showed a significant variation on fish in cages stocked at the same densities, but again it was the addition of Tilapia data that reduced the means in cage 3. In both cases, there was no biological difference. Although the densities of ectosymbionts considered as a whole group and of 14 of 15 taxa considered separately showed differences between cages, the presence of Tilapia as a second species had little or no influence on the gill ectosymbiont densities of caged channel catfish at the stocking densities and proportions used in this study.

Many of the ectosymbionts found on the caged fish throughout the

sampling season were present on the wild population before the cages were stocked. Only Ceratium, Ergasilus, and Peridinium were observed solely on caged fish. These three organisms were observed at very low densities and their distribution among the caged fish was irregular. It is conceivable that the ectosymbionts also were present at low densities among the wild population. Ceratium was also found on the catfish from Tishomingo and was, therefore, subsequently introduced into the ponds.

There was a noticeable difference in number and types of ectosymbionts found in the final samples of the caged fish and in samples of the wild population post-harvest. In all the samples there were far fewer ectosymbionts in both wild populations than in the cages. The fact that the caged fish were maintained under higher densities with high chances of ectosymbiont transmission could have contributed to the higher gill ectosymbiont densities among the caged fish.

Fish-Algal Association

The channel catfish (Ictalurus punctatus) examined in the stocking density study were found to harbor algae representing three genera and a group designated colonial algae. Colonial algae were found on 16 fish at densities varying from 0.3 to 6.3 per gill arch. The only other alga found in relatively large numbers was Oodinium sp., (quite possibly Oodinium limneticum), which was found on 40 of the fish examined. Densities on these fish varied from 0.3 to 15.6 per gill arch.

The other two genera observed were thought to be Ceratium spp. and Staurastrum spp. During June Ceratium densities varied from 0.3 to 6.0

per gill arch. Only three fish harbored Staurastrum on the gills and each fish had only one group of cells.

The channel catfish (Ictalurus punctatus) and Tilapia aurea examined in the polyculture study also harbored algae representing the same taxa as those from fish in the stocking density study. Colonial algae were found on 37 catfish at densities varying from 0.3 to 13.0 per gill arch and on 7 Tilapia at densities of 0.3 to 209.0 per gill arch. Oodinium sp. was found on 27 catfish. Densities varied from 0.3 to 24.3 per gill arch. Oodinium was not found on any of the Tilapia examined. The other two genera observed are thought to be Ceratium sp. and Peridinium sp., both found at very low densities. Ceratium was found on only four fish including both catfish and Tilapia. One catfish was found to have one Peridinium cell on its gill.

In both the stocking density and polyculture studies it is not known if the algae were behaving as true parasites. The small numbers on many fish could indicate that the algae had been taken in during feeding and then expelled out over the gills. In a few instances, when high densities were observed, algae may have been established and utilized the gills as a substrate. All fish examined appeared to be in good condition.

Oodinium sp. was the only alga observed in these studies which is known to be almost exclusively parasitic on animals. The other genera of algae observed are generally free-living and symbiotic relationships with animals have not been established, although commensal relationships might be possible (Smith, 1950).

Throughout these studies, overdispersion often was postulated to be the cause of a significant difference, but it should be remembered that

overdispersion is a fact of parasitic life. Large numbers of ectosymbionts on a few fish can produce statistically significant differences between the samples; however, differences which are due to overdispersion mask what is happening in the whole sample. The presence of numerous spores on a few fish does not imply numerous spores on all fish in the sample.

Many different ectosymbionts were observed in these studies but it is quite possible that not all were suitable indicators of the stress experienced by the fish. Although high numbers of myxosporidian spores were encountered, they probably had little or no effect on the fish and tended to skew the results due to overdispersion. Although monogenetic flukes may be a better indicator of stress, the results may not appear immediately, but may be delayed until some time after the stressful condition because the number of flukes normally increases more slowly. It is possible that a protozoan such as Trichodina or Scyphidia which reproduces by simple fission and has a shorter life cycle would be a more accurate indicator of stress.

Conclusions

The mean gill densities for ectosymbionts as a group were not correlated with stocking density among caged channel catfish tested. Of the individual ectosymbiont groups only monogenean fluke and Ceratium population levels were correlated (positively and negatively respectively) with weight or condition of the fish. Flukes appear to be more prevalent on larger fish, and Ceratium may affect smaller fish. It appears that temperature controls the presence of Ceratium.

At stocking densities higher than those tested, the positive

correlation between temperature and many ectosymbiont densities as well as the stress evoked by suboptimal physical conditions could result in an increase in the ectosymbiont densities.

The presence of Tilapia aurea as a second species at the stocking densities used did not affect the gill ectosymbiont densities of catfish. It is difficult to determine if production or weight gain was affected. The occurrence of ectosymbionts as a group as well as that of populations of five individual taxa were positively correlated with weight; however, the fish appeared in good condition and behaved normally.

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APPENDIXES

APPENDIX A

STOCKING DENSITIES AND SAMPLING DATES FOR 1981 AND 1982 STUDIES

Stocking Density Study

Pond

Cage 1	Cage 2	Cage 3
375 catfish	425 catfish	475 catfish

Sampling Dates: 1981 - June 19 July 3, 17, 31
1982 - June 4, 18 July 2, 16, 30 August 13, 28
September 10, 24 October 8

Polyculture Study

1981 Preliminary Pond*

Cage 1	Cage 2	Cage 3
400 catfish	390 catfish	350 catfish
+	+	+
0 Tilapia	10 Tilapia	50 Tilapia

1982 Pond*

Cage 1	Cage 2	Cage 3
400 catfish	400 catfish	400 catfish
+	+	+
0 Tilapia	25 Tilapia	50 Tilapia

Sampling Dates: Preliminary - June 12, 26 July 10 August 7
1982 - June 25 July 9, 23 August 6, 20
September 3, 17 October 1, 22

*Cages in both the Buntin and Kolb ponds had the same stocking densities and proportions.

APPENDIX B

STATISTICAL TESTS AND COMPARISONS OF THE 1982 DATA

Results of 1982 were analyzed using SAS. ANOVA's were made to determine whether any significant differences existed. If differences were found then a Duncan's Multiple Range test was used. All tests were made for the ectosymbionts as a total and then for each group of ectosymbionts. All tests run on the polyculture study were done on the catfish and Tilapia combined, then on the catfish alone and on the Tilapia alone.

Comparisons made in stocking density study

1. Differences between cages.
2. Differences between dates.
3. Differences between cages on different dates.

Comparisons made in polyculture study

1. Differences between ponds.
2. Differences between cages.
3. Differences between dates.
4. Differences between cages in different ponds.
5. Differences between ponds on different dates.
6. Differences between cages on different dates.

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