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Feasibility of increasing striped bass populations by stocking of underutilized nursery grounds : Completion report 1970-1973

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COMPLETION REPORT

ANADROMOUS FISH PROJECT

(embodying annual progress report for AFS 6-3)

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PROJECT NUMBER: FA-Virginia AFS 6

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ABSTRACT

The research program at VIMS concerning striped bass in the Virginia tributaries of Chesapeake Bay is summarized in this report. Results herein presented represent a completion report relative to the contract with the Bureau of Sport Fisheries and Wildlife; but they are only a progress report of the assessment and management program for striped bass in Virginia waters.

Striped bass harvested in Virginia tributaries by the sport and commercial fisheries are predominantly Age II fish unless a strong year class makes large numbers of Age I fish available. Older fish are taken by all segments of the fishery in Virginia but the incidence of fish greater than 4 years of age is low.

Tagging and recapture data from striped bass in the Virginia tributaries of Chesapeake Bay indicate that the commercial fishery is the major component of fishing mortality in these rivers. The recreational fishery exerts a greater fishing pressure on Ages I through III in the York River than the fishery in the Rappahannock River. Striped bass have become increasingly scarce in the James River since 1970. Tag returns from outside of the river of origin demonstrate that the migratory component of the intrariver population may approximate 30-50% of the river stock annually. Loss of tags and nonreporting of recaptures are considered as substantial sources of error leading to unrealistically high mortality estimates for Age II and older striped bass in Virginia waters.

Beach seine and trawl indices of yearclass strength indicated poor year classes in 1971 and 1972 in Virginia tributaries. We expect local stocks of striped bass to decrease in abundance in 1973 and 1974 due to the low 1971 and 1972 year classes.

The Piankatank River and the Mobjack Bay system were sampled to determine their suitability as receiving waters for a stocking of striped bass. The Ware River was selected and received two plantings of young striped bass. Fish, benthic and epibenthic faunas were surveyed before and after stocking. Faunal assessment indicated suitable food for the stocked fish and a low incidence of piscivorous predators/ competitors.

Recoveries of striped bass in the stocked waters did not suggest a successful stocking. Young striped bass from the Mobjack Bay system are believed to join the York River population and thus be lost from the stocked area on an annual cycle.

Results of closed system rearing tests suggest this technique as an effective and efficient method for the production of fingerling striped bass. Our study of fish age, temperature, and salinity revealed a greater hardiness of young striped bass than previously reported. Stocking site selection and time of release were shown to be flexible if the biotic and abiotic factors in the stocking area approximate natural nursery ground levels.

A preliminary assessment of stocking underutilized nursery grounds suggested that a program utilizing striped bass less than 100 days old would not be a cost effective means of increasing the local populations at the present time. Stocking programs to restore a spawning run of striped bass, however, may be successful. A full understanding of the expected natural mortality and carefully controlled fishing are major factors determining the success of given stocking programs.

COMPLETION REPORT

ANADROMOUS FISH PROJECT AFS 6

FEASIBILITY OF INCREASING STRIPED BASS POPULATIONS BY STOCKING UNDERUTILIZED NURSERY GROUNDS

INTRODUCTION

This report summarizes information obtained by project personnel during the agreement period July 1, 1970 to June 30, 1973. It serves as a completion report for that work accomplished in the contract period but represents only a progress report for our studies of the striped bass in Virginia waters. Several jobs within the project were designed to terminate after a three year study. Our research pertaining to population monitoring, evaluation of culture techniques, and experimental studies with YOY was not expected to terminate with project AFS 6.

Job 1 is a continuing effort of the project designed to provide information on the age composition and mortality rates of striped bass in the lower Chesapeake Bay and to assess yearclass strength in the Virginia tributaries of Chesapeake Bay. The value of such a monitoring program to management of the species increases in proportion to the number of years data available for analysis. We expected to follow several yearclasses as they passed through the fishery and determine the contribution to the fishery made by each.

Job 2, 3, 5 and 6 were concerned with the selection of a tributary for stocking, assessment of the stocking, and evaluation of the techniques as a management tool for estuarine situations. These jobs were designed to terminate with the contract pending documentation of successful stocking.

Job 4 was designed as a continuing investigation of techniques employed in the culture of striped bass. Our results to date are promising, but continued study of controlled variables in the culture of striped bass is needed. The order of presentation for material in this report is by job. Within each job the objectives are stated, a short summary of our findings is given, followed by detailed results and discussion of our research program for that job. Pagination is consecutive with figures and tables following the text for each job.

Job 1. - Monitoring of Population Parameters

The objectives of the research performed under this job include monitoring programs to ascertain the age composition, mortality rates, and year class strength of striped bass in the Virginia tributaries of Chesapeake Bay. Continuation of monitoring programs of this type is important in providing the data base for regional comparisons and historical analysis of year class contribution to the fishery. Termination of this study by BSF&W in 1973 will result in a serious data gap for the striped bass resource of the Chesapeake Bay.

Striped bass taken in Virginia estuarine waters by the sport and commercial fisheries are predominantly Age II unless a strong year class makes large numbers of Age I fish available. Older striped bass are taken by all segments of the fishery in Virginia waters but the incidence of fish greater than 4 years of age is low. The winter gill net fishery typically harvests older striped bass than taken by other commercial gears or the sport fishery. Striped bass have become increasingly scarce in the James River since the inception of this project, and the 1972-1973 year was the least productive year to date.

Tag and recapture studies on striped bass in Virginia tributaries of Chesapeake Bay demonstrated that the commercial fishery is the major component of fishing mortality in these waters. The recreational fishery exerts a greater fishing pressure on Age I through III striped bass in the York River than in the Rappahannock River. Tag returns from outside of the river of origin conclusively demonstrate that the migratory component of this intra-river population is substantial and may approximate 30 to 50% of the river stock yearly. Mortality estimates developed from the tag return data are felt to be unrealistically high for striped bass of Age II and older. Loss of tags and nonreporting of recaptures are considered substantial sources of errors in the population mortality estimates. Exploitation rates in Virginia can not be used to estimate the spawning runs in each river nor the population in the rivers.

Beach seine and trawl indices of year class strength indicated poor year classes in 1971 and 1972 in the Virginia tributaries. We expect local stock of striped bass to decrease in abundance in 1973 and 1974 due to the low abundance of 1971 and 1972 year classes.

Age composition of striped bass

Age analysis data for three years from Virginia estuarine waters allow several important conclusions independent of other sections.

1. Age 0 striped bass do not enter the commercial or sport catch to any significant degree.
2. The majority of all striped bass captured in Virginia estuarine waters are Age II unless a strong year class makes large numbers of Age I fish available.
3. The winter gill net fishery typically captures older fish than the other commercial fisheries or the sport fishery.
4. The James River has become unproductive for striped bass and 1972-1973 was the most unproductive year to date.

5. Striped bass greater than 4 years of age are taken by all portions of the fishery but their incidence is low.

6. The sport fishery typically utilizes the same stock and age groups as the commercial fishery.

In 1972-1973 the methods of sampling striped bass in Virginia waters remained unchanged from those described in the 1970-1971 annual report, FA Virginia-AFS-6-1. Essentially it is a scale sampling routine with 50 samples gathered semimonthly from each river. For this final report, the data from the current year will be discussed first. Then, conclusions and calculations from the three-year study will be given where appropriate with the accompanying data.

The 1970 year class entered the commerical fishery at age II[1] in spring of 1972, and continued as the dominant year class in the 1972-1973 fall and spring fishery. This year class contributed 79.6 to 94.3% of all fish in 1971-1972 and in 1972-1973 it made up 72.4 to 78.9% of the catch (Table 1.1). The 1971 year class entered the fishery in 1972-1973 with a contribution of 18.1 to 25.9% to the catch, far below the 1970 year class of a year earlier. This percentage is below all previous years for age I+ fish and suggests, but does not necessarily mean a poor year class. The percent composition data are biased in favor of the strong 1970 year class moving through the fishery. The high catch of two-year-old fish as they are recruited to the river fishery is not uncommon, (Raney, 1952; Vladykov and Wallace, 1952; Mansueti, 1961; Clark, 1968). Striped bass older than IV were rare in commercial samples from Virginia rivers.

(1) The assumed birthday is January 1 every year.

The York and Rappahannock rivers produced practically all striped bass caught by pound and fyke nets in Virginia. Totals of 1,474 and 1,199 fish from each river, respectively, were obtained for age analysis in 1972-1973 compared to 1,915 and 1,174 in 1971-1972. Only nine bass were obtained from the James River compared to 98 a year before. The James River now appears very unproductive for striped bass. The 1972-1973 data substantiate a 6-year downward trend in landings and our indices of juvenile abundance reveal very weak year classes since 1966. When all gear is considered, the James River samples fell from 183 fish in 1971-1972 to 43 in 1972-1973 (Table 1.2) with 24 of the 1972-1973 samples being Age I. The 1970 year class was present in the James River catches as indicated by 13 fish in the samples, but the 1971 year class was absent. Studies by Raney (1952), Lewis (1957) and Massmann and Pacheco (1961) indicated the James River once supported a distinct bass population with little migratory movement. This population is now nearly extinct.

The winter gill net fishery in the Rappahannock River relied heavily on the strong 1970 year class in the 1973 season. These fish (Age III) made up 90% of the catch whereas in most years only one-third of the catch is this age (Table 1.3). Fish above age IV were practically absent in the samples. The strong 1966 year class was represented by only one specimen. The winter gill net fishery does not harvest many bass below Age III (Grant et al., 1970) as do the pound and fyke net fisheries.

The sport fishery, as measured by samples from the York River, also relied heavily on the 1970 year class but younger bass still made up 29.9% of the total (Table 1.4). No fish of the 1972 year class were obtained and striped bass older than III were rare. Fish of age I were abundant in sport catches in 1972 and continued to contribute to the catch in 1973 as age II. However the strong 1970 year class which contributed the majority of samples in 1972, was absent the following spring as age III (Table 1.4). This, plus the commercial samples, indicates an exodus of Age III bass from the rivers. These fish probably migrate to the lower bay and become part of the migrating coastal population (Merriman, 1941; Nichols and Miller, 1967; Grant et al., 1969).

Calculation of mortality rates from age composition of striped bass in Virginia rivers is not possible because (a) recruitment is highly variable and directly dependent on year class strength, (b) the bass are not fully recruited until age II or III, (c) at age III the bass begin leaving the river systems to join other populations, and (d) our samples are not proportional to the actual catch of the fishermen. Grant et al. (1969) presented values of 0.23 to 0.83 using the Jackson method and we have calculated values of 0.32 to 0.91 using catch curve analysis. We feel it is not possible to speculate on the total mortality of striped bass, since our values for mortality did not stabilize around some mean, and mortality rates for age groups across several year classes were not consistent in trend. The age extinction between I and III indicates substantial loss of fish, but data presented in following sections demonstrate only a small part of this loss is due to fishing mortality.

Tagging and Exploitation of Striped Bass

Fewer bass were tagged during this contract year than in previous years. The numbers tagged in the York and Rappahannock rivers during 1972-1973 were 373 and 465 fish, respectively, compared to nearly 2,000 in each river in previous years (Table 1.5). Equal trawl time has been allocated to the tagging program in each year, thus it was low availability of suitable size fish during the winter of 1972-1973 which resulted in low numbers of tagged fish. The 1970 year class (age II in 1973) was very scarce when compared to age II abundance in previous years. This further confirms our belief from age composition analysis, that the 1971 year class was very low. Overall the age IIs seemed about one-third to one-fourth their normal abundance in the York and Rappahannock and there was practically no production in the James. Discussion related to these phenomena is reserved for later sections.

Returns from the winter tagging program in 1973 demonstrate that commercial gear took over 90% of the recaptured tags through June 30, 1973 (Table 1.6). On yearly basis, commercial gear contributed 75.6 to 91.6% of the total recaptures in the Rappahannock River; and 32.3 to 87.6% in the York River. The sport fishery caught the remainder when only those tags captured within river of origin are considered. The York River seems to have greater sport fishing pressure (impact) on the bass (age I-III) than the Rappahannock sport fishery, when both are compared to the active commercial fishery.

Commercial gear therefore represents the major component of striped bass fishing mortality in Virginia rivers. However, we have no way of estimating population size because there are no measures of total bass catch (sport or commercial) by river or by gear. The State of Virginia may institute a reporting system of commercial catches. Data obtained in that program will prove invaluable in resource management by allowing estimates of total population size, escapement, etc.

Only by calculating these basic parameters can the contribution to Atlantic stock be properly determined. We know the Chesapeake Bay stock contributed heavily to the coastal stock in some years (Koo, 1970; Raney, 1952) and various studies have shown extensive coastal migration of Chesapeake Bay fish with increasing age (Mansueti, 1961; Chapoton and Sykes, 1961; Grant et al., 1969). Since numbers can be easily converted to pounds by incorporating a growth function, and determining age composition of the Atlantic catch, a program rigidly designed to answer the key questions of abundance and recruitment should be undertaken.

The complete history of the tagging program and tag returns by year class and area is given in Tables 1.7 and 1.8. In the 1973 program, through June 30th, of the 48 tags returned from the York River striped bass, 10 fish were captured outside of the river of release. Data after a full year at large are shown in the 1972 tagging summary. Of 289 tags returned from fish tagged in the Rappahannock River, 47 tags (16.3%) were returned outside of the river of release. Similarly, of 188 tag returns from fish tagged in the York River, 49 tags (26.1%) were returned from outside the river of release.

Grant et al. (1969) received only 3.7% tags returned from outside the York and 0.8% from outside the Rappahannock. Similarly, Massmann and Pacheco (1961) found a very low percentage of tags were returned from outside the river of release, and Nichols and Miller (1967) found only 2.0% of all tags were returned from outside the area of release in Maryland waters. Our returns conclusively demonstrate that the migratory component was substantial in every year (Table 1.7 and 1.8). The 4-year average for the York was 22.2% and 10.0% for the Rappahannock.[(2)] Since we tag in winter (January-March) the younger fish (usually age I-III), and the most intense river fishery for striped bass is in spring and early summer; the returns from within the river of origin are biased upward. We suspect that the true proportion of fish which leave the river stock yearly approximates 30-50%. This would be the older individuals. Koo (1970) has shown that the Chesapeake Bay stocks contribute significantly to the Atlantic stock between age II and III, and the predominant variations in the Atlantic stock can be attributed to the recruitment potential of the Chesapeake Bay fish.

The New York and New Jersey striped bass population (younger fish) originates primarily from the Hudson River and older members migrate north in summer and south in winter (Clark, 1968). Bass from southern locations mix with the New York stock and the winter distribution shows definite concentrations in Delaware Bay and Chesapeake Bay. These fish probably spawn in the southern bays in early spring and may rejoin the north bound stock in late spring or early summer. New York and New Jersey land only 16.5% of the striped

(2) Includes 1/2 year of returns for the 1973 tagging season.

bass along the Atlantic, whereas Virginia and Maryland land 67.0% (Koo, 1970).

The Hudson River spawning stock is positively correlated (R = 0.97) with the mid-Atlantic catch 4-6 years later suggesting a near perfect parent-progeny relationship (Atomic Energy Commission, 1972). Since this stock is mainly nonmigratory up to age III-V, it is surprising that the escapement from any year is not proportional to the abundance of the Atlantic stock the following year. Or, that the Atlantic stock in year X cannot be used to predict the Hudson River spawning run in year X + 1, because the Atlantic stock is composed mainly of mature fish. Koo (1970) has shown the abundance of Chesapeake Bay fish could, with few exceptions,be used to predict the mid-Atlantic catches two years later. While only questioning the inferences made by AEC, we strongly reject the expansion of these comments by Glowka (1973) who concluded "... the Hudson River is the most important source for striped bass along the entire East Coast ...". The AEC report included only mid-Atlantic landing, not the entire East Coast.

The basic premise of non-loss of tags and complete reporting of returns must be investigated before calculation of mortality and exploitation rates. We do not have the information that would allow a direct estimation of these effects, such as capture of scarred fish or collection of tags previously ignored. The extremely high natural mortality rates presented in previous reports (Grant and Merriner, 1971; Merriner and Hoagman, 1972) have cast suspicion on the original formula and method adopted to evaluate mortality.

The survival formula used in previous years was

$$s_1 = \frac{R_{12} M_2}{M_1 (R_{22} + 1)}$$

where

s_1 = survival rate in first year

R_{12} = recapture of first year marks in year 2

M_2 = tagged fish in year 2

M_1 = tagged fish in year 1

R_{22} = recaptures of second year marks in year 2

Source: Ricker (1958, p 128).

This formula uses the exploitation rate in year 2 to determine the number of fish at large in year 2 from the recaptures of first year marks in year 2. Since the number of marked fish in year 1 is known, s_1 can be generated. In a closed system nearly all tagged fish can be accounted for over the years; but the estuarine system is not closed and there are few returns after the first year. The model assumes only mortality acting to reduce M_1 numbers, not migration or differential natural mortality of tagged fish.

Our tagging data indicate light exploitation of striped bass in Virginia because the total tag returns have averaged only 12.4% from the York River and 21.3% from the Rappahannock River (Table 1.9). There has been no trend of increasing returns with years at large. Returns in the second year (1-2) have been negligible in both rivers (Table 1.10 and Fig. 1.1), and the returns soon diminish to zero. The Ricker formula for survival depends primarily on second year returns and our data thus do not seem appropriate for its use. Use of the formula has resulted in estimated natural mortality rates of 85-97% per year which are, in our opinion, entirely unrealistic for striped bass of age II or above.

Application to the 1972 data gives a survival of 0.0219 in the York River for 1971 and 0.1472 for the Rappahannock River in 1971. After subtracting apparent fishing mortality of 0.102 and 0.259, this results in a natural mortality estimate of 87.6% and 59.4% annually. The 1970 estimates for the same rivers were 0.068 and 0.144 for annual survival, 0.099 and 0.315 for fishing mortality and 0.842 and 0.561 for natural mortality. Table 1.9 of Merriner and Hoagman (1972) summarized the mortality estimates for the entire project. These estimates were based on the Ricker formula, which because of its unsuitability, has not been applied to the 1972-1973 data to extend Table 1.9. Emigration of tagged fish from the river increases the estimate of total mortality but not fishing mortality (Gulland, 1969). Holland and Yelverton (1973) found an overall exploitation rate of 11.2% for striped bass in North Carolina. Their estimated natural mortality rates were 90-96% per year. They rejected these high estimates and attributed the bias to loss of tagged fish to the general population. From monthly tag return data they calculated a yearly fishing mortality of 35% per year, which is probably more realistic for striped bass.

Loss of tags and nonreporting must be sources of substantial error in the population mortality estimates. Migration outside of the river of tagging is extensive in some years and these striped bass probably go to areas where tags are not returned. Approximately one-fourth of all returns are from outside the river of tagging (Tables 1.7 and 1.8). Commercial gear during early spring and summer accounts for the majority of all tags returned. If we assume the tags are not lost before five months at large, then exploitation rates of 10.2% and 25.9% in the York and Rappahannock rivers do not seem unusually high. As the striped bass grow they become more heavily exploited (usually above 25% after age IV).

For all years combined, the first year returns averaged 11.3% from the York River and 14.8% from the Rappahannock River. In a closed system these rates converted to instantaneous and combined with an assumed natural mortality rate of 0.20, would give a stable age distribution (assuming 1,000 fish fully recruited each year at age II) of

1,000	of age II
710	of age III
504	of age IV
357	of age V
254	of age VI
180	of age VII
128	of age VIII
90	of age IX
64	of age X
45	of age XI
33	of age XII
23	of age XIII
16	of age XIV

After age IV striped bass have few natural predators because they average 17-20 inches (Mansueti, 1961). Since we know many bass reach age X but after age IV are rare in the rivers, we must conclude the calculated mortality rates shed no information on the actual annual survival. The age composition data presented earlier in this section, do not follow the theoretical, nor can we postulate any source of high natural mortality in the rivers.

Between age II and III in 1971 and 1972 combined (from age composition data of Table 1.2) the total survival was only 10.1% annually. If the calculated exploitation rates apply and natural mortality was 0.20 (instantaneous) the survival should be 71.3%. We conclude that approximately one-third of all young bass are captured or die naturally within the system of origin. The remainder migrate to Chesapeake Bay and the Atlantic Ocean to join the coastal stocks. A small percentage of the migratory stock return to the river of origin to repeat the cycle.

Exploitation rates in Virginia cannot be used to estimate the spawning runs in each river or the river population because catch and effort data reports have not been mandatory, nor do independent estimates exist. Additionally, we have tagged only the younger bass, and therefore the exploitation rates do not apply to mature bass returning to spawn. River escapement based on these exploitation rates (even if total catch and effort were available)would be in serious error.

Year Class Strength Abundance Indices

Beach Seine Index

Young-of-the-year striped bass were sampled semimonthly by a 100 ft minnow seine at 8 stations in the James River, 21 stations in the York River and 6 stations in the Rappahannock River for 4 months (July-October). Reduced to catch per unit effort (one unit = one haul), the 1972 indices were 0.29 for the James River, 0.52 for the York River and 0.71 for the Rappahannock River. These values are lower than any year since 1967 (Table 1.11). They represent the poorest catch of striped bass in Virginia that we have monitored (Fig. 1.2). The James River has declined since 1970 and now appears to be an insignificant contributor to striped bass stocks of the Chesapeake Bay area. All rivers combined represent a 65% decline from 1971 and a 89% decline from 1970. Since we have no measure of the spawning run in each river, we cannot at this time determine the cause of the low year class strength. Hurricane Agnes struck on June 19-21, 1972 and caused widespread flooding in Virginia tributaries causing changes in their seasonal, chemical and planktonic characteristics of the areas affected. It is possible the young striped bass were negatively affected by Agnes.

The James had a very small run of adults during the spawning season as evidenced by our inability to obtain samples from the commercial fishery (Tables 1.1 and 1.2). The York and Rappahannock had normal spawning runs it seemed. For these latter two rivers the small year class must be an expression of high egg or larva mortality, but we cannot determine the reason at this time. The spring of 1972 was normal in most respects except hurricane Agnes caused heavy flooding between June 22 and 30. Massive amounts of fresh water and the resultant turbidity, displacement, and plankton mortality may have sufficiently stressed the nursery zone to produce the smallest year class on record. However Turner and Chadwick (1972) showed that high river flow usually resulted in significantly stronger year classes of striped bass in the Sacramento-San Joaquin estuary. Analysis of a plankton collection made during Agnes may eventually clarify the situation of 1972.

Winter Trawling Index

The second annual winter census was conducted during January and February, 1973 in the James, York, Rappahannock and Potomac rivers. As in the previous year, a 30 ft bottom otter trawl with one-fourth inch cod end was towed four times at each 5-mile interval in mainstream. All tows were one-fourth mile (nautical) long and two were made with the tide and two against. The water temperatures were similar to 1972, but the salinity was approximately 20% lower at most stations compared to last year. The average catch per tow and bottom salinity are given in Table 1.12.

The overwintering population of young striped bass in the James River was negligible in 1973 as it was in 1972. The York and Rappahannock rivers also contained a very small overwintering population compared to 1972. Of all stations that yielded bass in the York River, the grand average catch per tow was 5.52 in 1972 but only 0.5 in 1973. For the Rappahannock River the 1972 index was 4.87 but in 1973 was only 1.33. These indices represent a 91% and 73% reduction in abundance of striped bass respectively and indicate the 1971 year class was probably very poor. The age II's (1971 year class in 1973) usually make up 85% of the midwinter trawl catch. Age I's (1972 year class) were practically nonexistant, confirming the low beach seine index. The small mesh trawl has always captured age I bass where they existed.

In 1972 the preferred salinity of striped bass in the York River in February was 14-21‰. This salinity zone was further downstream during the 1973 survey with 14-18‰ found from mile 17 to the river mouth. In the Rappahannock River the salinities of 9-16‰ held the highest concentration of striped bass in 1972 and in 1973 this zone was between mile 23 and the river mouth, again several miles downstream. Thus, adequate salinity existed in both rivers in 1973 but striped bass were practically absent. Since water temperatures were the same in both years, the young striped bass probably were not on the shoals in colder water, but merely very low in abundance.

From the two indices of year class strength we conclude that striped bass had poor year classes in 1971 and 1972. We can expect the local stocks to decrease in abundance in 1973 and continue low through 1974. Since only a small fraction of any year class returns to spawn we can further expect reduced abundance of large bass through 1977 in the Virginia rivers. The 1973 year class may reverse the downward trend because preliminary data suggest it was fairly strong. If it was, the young bass would enter the fishery in mid 1974 and 1975 and replenish the low abundance of the pre-migratory stocks.

The striped bass is a very important commercial and sport species. Koo (1970) gave the east coast landings by states from 1930-1966, but did not include the catch value. To complete this section we provide in Table 1.13 the entire catch history of striped bass in Virginia and Maryland, and its exvessel value (unadjusted dollars) from 1887-1973. Fluctuations in abundance are obvious in Figure 1.3 and over the last 16 years the Virginia catch has oscillated at regular 3-year intervals. The catches for both states apparently have approached the sustained yield. From 1963 to 1973 there has been a general decline in Virginia and if this continues it indicates overfishing by sport and commercial interests, for the reproductive capability of the present stock. The environment may have deteriorated in some spawning areas and this would allow a lower MSY statewide. Between 1960 and 1972 the stock was healthy, had rapid growth and reproduced successfully. If conditions were stabilized at the 1960 to 1970 levels, striped bass will remain an integral component of the Virginia fishery through time.

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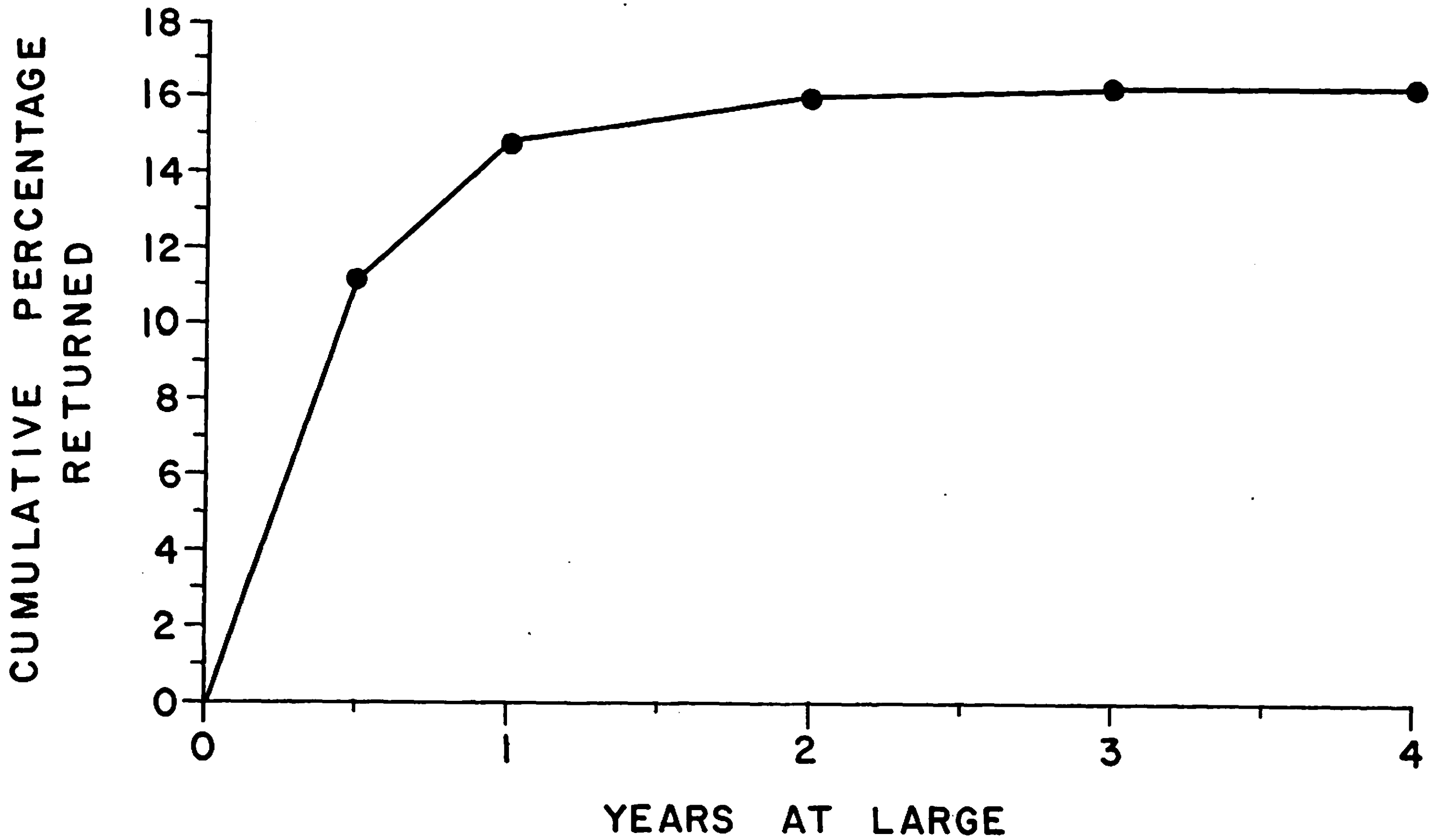

Figure 1.1. Cumulative percent returned for striped bass tagged and released in Virginia tributaries of Chesapeake Bay relative to years at large.

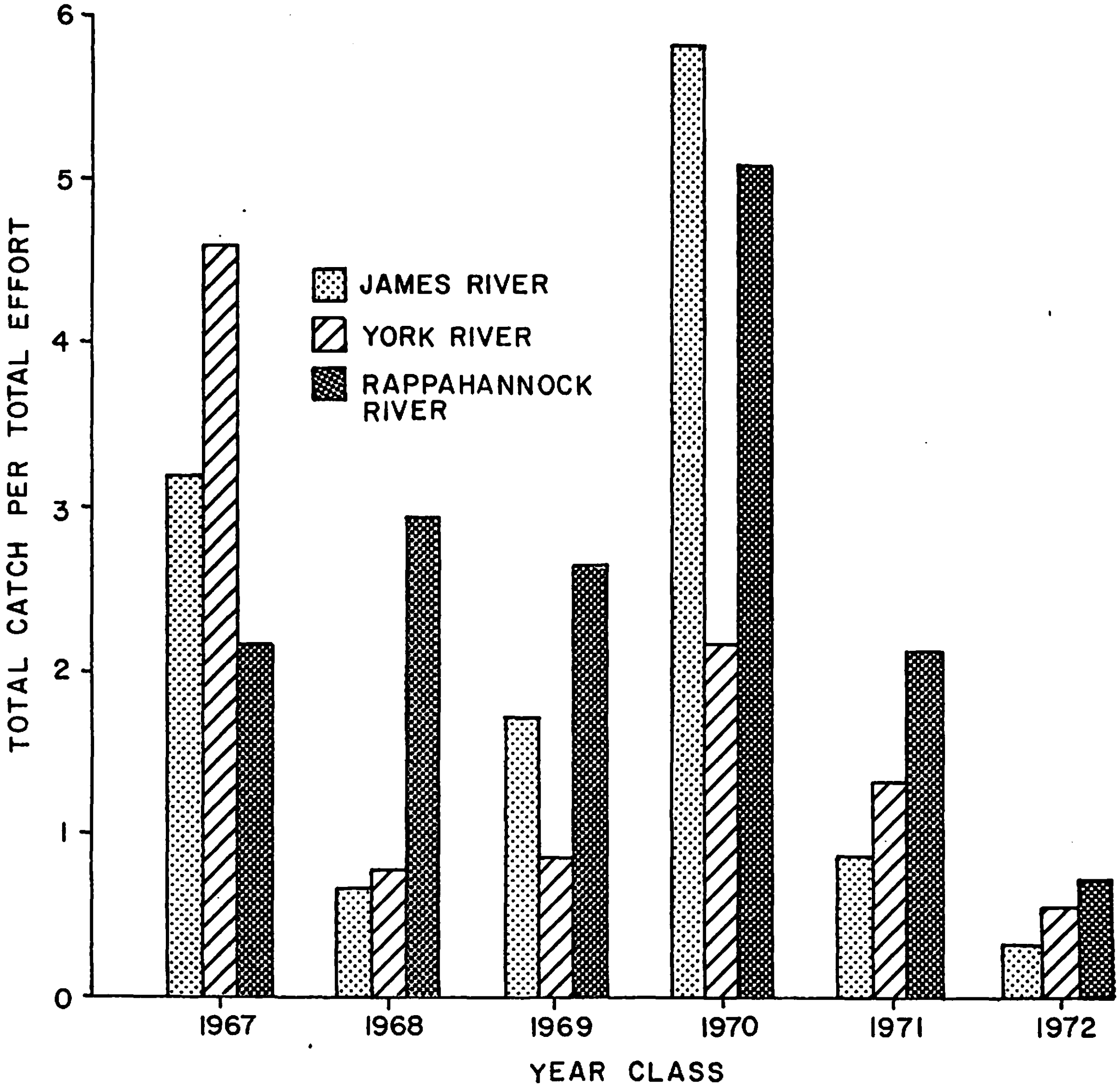

Figure 1.2. Young-of-year indices for striped bass taken by beach seine during July through October in Virginia tributaries to Chesapeake Bay 1967 through 1972.

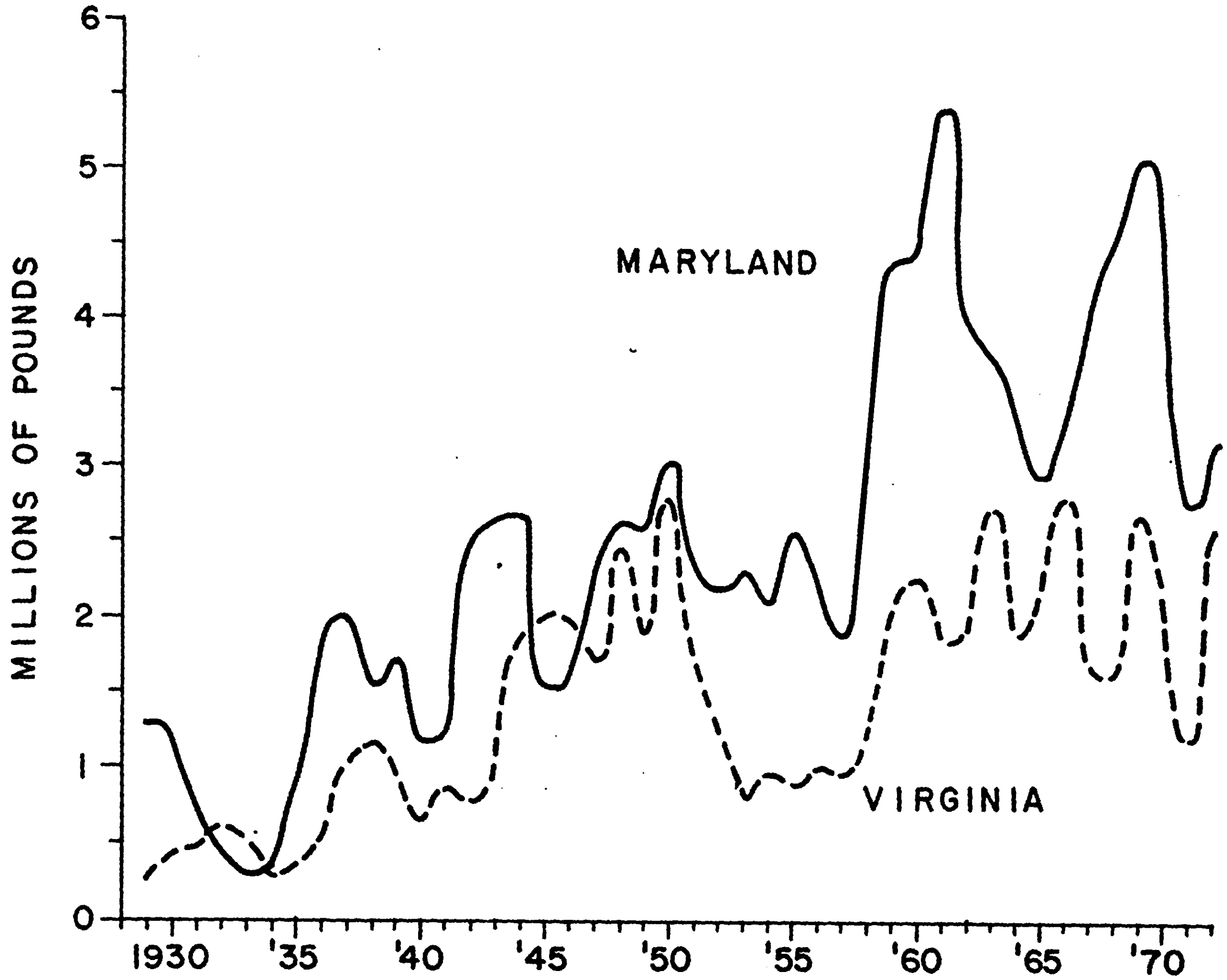

Figure 1.3. Landings of striped bass by Virginia and Maryland commercial fisheries (1929 through 1972) from NMFS Fishery Statistics.

Table 1.1. Percent composition by year classes of the striped bass caught in non-selective gear for the contract year July 1971 - June 1972 and July 1, 1972 to June 30, 1973.

River System	Percent of Sample in Year Class											
	1972	1971	1970	1969	1968	1967	1966	1965	1964	1963	1962	Total
<u>July 1971-June 1972</u>												
James (no samples Dec 71-Feb 72)		0	79.6	7.1	6.1	4.1	0	0	-	-	-	98
York		1.8	84.9	9.7	1.3	0.5	0.8	0.3	-	-	-	1915
Rappahannock		0.3	94.3	3.3	0.6	0.3	0.3	0	-	-	-	1174
<u>July 1972-June 1973</u>												
James			100.0									9
York	0.1	18.1	78.9	1.5	0.1		0.6	0.2	0.4	0.1	0.1	1474
Rappahannock	0.1	25.9	72.4	0.6	0.3	0.3	0.2	0.1	0.3	-	-	1199

Table 1.2. Age composition of striped bass sampled from Virginia rivers. All gears combined.

	Year Classes										
1970-71	1973	1972	1971	1970	1969	1968	1967	1966	1965	1964	Total**
York	-	-	-	217	1347	190	43	11	1	2	1890
Rapp.	-	-	-	135	789	367	80	84	4	7	1481
James	-	-	-	1	131	65	67	12	2	1	279
1971-72											
York	-	-	95	2248	225	25	10	15	6	5	2640
Rapp.	-	-	112	1286	90	28	8	6	4	14	1562
James	-	-	53	111	7	6	3			1	183
1972-73*											
York	6	90	409	1470	30	0	1	9	3	6	2028
Rapp.	0	34	312	1007	10	5	7	4	2	6	1388
James	0	24	0	13	0	1	1	2	0	2	43

* Through 30 June 1973.

** Totals include several fish older than 1964 year class.

Table 1.3. Age compositon of winter gill-net catches of striped bass, through 30 June 1973, Rappahannock River.

Month	Year Classes 1970	1969	1968	1967	1966	1965	1964	1958	Total
March	94	1	1	2	0	1	1	0	100
April	41	2	1	2	1	0	2	1	50
Seasonal Total	135	3	2	4	1	1	3	1	150
Percent of Total	90.0	2.0	1.33	2.67	0.67	0.67	2.0	0.67	

Table 1.4. Age composition of striped bass from sport catches in the York River, July 1972 - June 1973.

Month	Year Classes 1972	1971	1970	1969	1968	1967	Total
Jul	0	15	70	2	0	1	88
Aug	0	17	58	1	0	0	76
Sep	0	18	32	1	0	0	51
Oct	0	43	36	1	0	0	80
Nov	0	16	8	0	0	0	24
Dec	0	9	49	0	0	0	58
Jan	---- No sample obtained ----						
Feb	---- No sample obtained ----						
Mar	0	0	1	0	0	0	1
Apr	0	2	2	0	0	0	4
May	0	4	36	0	0	0	40
Jun	0	0	5	0	0	0	5
Total	0	124	297	5	0	1	427
Percent of Total	0	29.0	69.6	1.2	0	0.2	

Table 1.5. Age distribution and returns by gear of striped bass tagged in the York and Rappahannock rivers in 1970-71, 1971-1972 and 1972-1973.

	Year Class								
	1972	1971	1970	1969	1968	1967	1966	1963	Totals
York River									
Number tagged									
Winter 1971		0	204	1493	79	8	0	1	1785
Number returned in 1971									
Commercial gear		-	3	175	16	2	0		196
Sport gear		-	2	25	2	0	-		29
Unknown gear		-	0	5	1	0	-		6
Total		-	5	205	19	2	-		231
Number tagged									
Winter 1972		135	1691	14	0	0	0		1840
Number returned									
Commercial gear		1	107	3	-	-	-		111
Sport gear		9	66	0	-	-	-		75
Unknown gear		0	8	1	-	-	-		9
Total		10	181	4	-	-	-		195
Number tagged									
Winter 1973	-	77	296	-	-	-	-		373
Number returned*									
Commercial gear	-	9	34	-	-	-	-		43
Sport gear	-	-	5	-	-	-	-		5
Unknown gear	-	-	3	-	-	-	-		3
Total	-	9	42	-	-	-	-		51

Table 1.5. Continued

	Year Class								
	1973	1972	1971	1970	1969	1968	1967	1966	Totals
Rappahannock River									
Number tagged									
Winter 1971			0	204	432	136	26	11	809
Number returned									
Commercial gear	]		-	21	98	47	14	6	186
Sport gear		-	-	2	15	5	0	0	22
Unknown gear		-	-	0	2	0	0	-	2
Total		-	-	23	115	52	14	6	210
Number tagged									
Winter 1972	-	-	22	1997	6	-	-	-	2025
Number returned									
Commercial gear	-	-	2	208	2	0	0	0	212
Sport gear	-	-	0	55	1	0	0	0	56
Unknown gear	-	-	0	21	0	0	0	0	21
Total	-	-	2	284	3	0	0	0	289
Number tagged									
Winter 1973	0	5	298	162	-	-	-	-	465
Number returned*									
Commercial gear	-	-	20	23	-	-	-	-	43
Sport gear	-	-	4	2	-	-	-	-	6
Unknown	-	-	3	2	-	-	-	-	5
Total	-	-	27	27	-	-	-	-	54

* Up to June 30, 1973.

Table 1.6. Percentage return of tagged striped bass from different gear types in the York and Rappahannock rivers. Returns from outside river of origin not included. Tags out over one year not included.

	Tagging Period							
	Winter 1970		Winter 1971		Winter 1972		Winter 1973*	
	York	Rapp.	York	Rapp.	York	Rapp.	York	Rapp.
Pound nets	6.7	45.1	0.5	74.3	2.0	68.5	2.6	47.6
Gill nets	21.4	32.9	78.9	16.5	24.8	8.7	50.0	31.0
Haul seine	4.5	6.8	4.9	0.5	30.9	7.9	39.5	11.9
Peeler traps	---	0.8	---	0.5	---	0.4	---	---
Fyke nets	1.1	---	3.2	---	12.1	---	---	---
Sport gear	67.7	14.4	12.4	8.4	29.5	14.1	7.9	9.5
Crab pots	---	---	---	---	0.7	---	---	---
Dip Net	---	---	---	---	---	0.4	---	---
Total returns	90	237	185	214	149	241	38	42

* Up to June 30, 1973.

Table 1.7. Numbers of striped bass tagged and tag returns by year class and year in the York River, all gears combined. Number of returns outside of river given in parentheses below each entry.

Winter 1969	1968	67	66	65	64	63	62	61	Total
No. tagged in year class	9	594	259	15	3	3	1	1	885
No. returned in 1969		57	16	-	-	-	-	-	73
		(16)	(17)						(33)
No. returned in 1970		1	4	-	-	1	-	-	6
		(3)	(5)						(8)
No. returned in 1971		1	2	-	-	-	-	-	3
No. returned in 1972		-	-	-	-	-	-	-	0
Total									123

Winter 1970	1969	68	67	66	65	64	63	62	Total
No. tagged in year class	352	621	42	4	-	-	1	-	1020
No. returned in 1970	16	50	8	3	-	-	-	-	77
	(10)	(12)	(2)						(24)
No. returned in 1971	3	5	-	-	-	-	-	-	8
		(1)							(1)
No. returned in 1972	0	1	-	-	-	-	-	-	1
	(1)								(1)
Total									112

Winter 1971	1970	69	68	67	66	65	64	63	Total
No. tagged in year class	204	1493	79	8	-	-	-	1	1785
No. returned in 1971	3	184	15	1	-	-	-	-	203
	(3)	(20)	(4)	(1)					(28)
No. returned in 1972	-	4	-	-	-	-	-	-	4
Total									235

Winter 1972	1971	70	69	68	67	66	Total
No. tagged in year class	135	1691	14	-	-	-	1840
No. returned in 1972	8	129	2	-	-	-	139
	(2)	(46)	(1)				(49)
No. returned in 1973*	-	12	-	-	-	-	12
		(7)					(7)
Total							207

Table 1.7. Continued

<u>Winter 1973</u>

	1972	71	70	69	68	67	66	Total
No. tagged in year class	-	77	296	-	-	-	-	373
No. returned in 1973*		8 (1)	30 (9)	-	-	-	-	38 (10) 48

* Through 30 June 1973.

Table 1.8. Numbers of striped bass tagged and tag returns by year class and year in the Rappahannock River, all gears combined. Number of returns outside of river given in parentheses below each entry.

Winter 1969

	1968	67	66	65	64	63	62	UNK	Total
No. tagged in year class	128	922	108	1	-	-	-	2	1161
No. returned in 1969	11	128	28	1	-	-	-	-	168
		(10)	(2)						(12)
No. returned in 1970	1	6	1	-	-	-	-	-	8
		(2)	(2)						(4)
No. returned in 1971	-	1	-	-	-	-	-	-	1
No. returned in 1972	1	1	-	-	-	-	-	-	2
									195

Winter 1970

	1969	68	67	66	65	64	Total
No. tagged in year class	29	388	186	143	4	1	751
No. returned in 1970	5	86	61	67	-	-	219
	(1)	(4)	(7)	(6)			(18)
No. returned in 1971	2	12	5	6	-	-	25
		(3)	(2)	(1)			(6)
No. returned in 1972		2	1	1	-	-	4
							272

Winter 1971

	1970	69	68	67	66	65	Total
No. tagged in year class	204	432	136	26	11	-	809
No. returned in 1971	23	108	52	14	6	-	203
		(7)					(7)
No. returned in 1972	1	6	7	3		-	17
							227

Winter 1972

	1971	70	69	68	67	Total
No. tagged in year class	22	1997	6	0	0	2025
No. returned in 1972	2	238	2	-	-	242
		(46)	(1)			(47)
No. returned in 1973*		4	-	-	-	4
						293

Table 1.8. Continued

Winter 1973	1972	71	70	69	68	67	Total
No. tagged in year class	5	298	162	-	-	-	465
No. returned in 1973*		23 (1)	19 (6)	-	-	-	42 (7) 49

* Through 30 June 1973.

Table 1.9. Total returns from striped bass tagging program in Virginia waters. All fish tagged in winter of year indicated. All returns included.

	York River				Rappahannock River		
Tagging Season	Total years at large	Number tagged	Number returned	Percent returned	Number tagged	Number returned	Percent returned
1969	4.5	885	123	13.9	1161	199	17.1
1970	3.5	1020	112	11.0	751	272	36.2
1971	2.5	1785	234	13.1	809	227	28.1
1972	1.5	1840	207	11.3	2025	293	14.7
1973[a]	0.5	373	48	12.9	465	49	10.5
Totals		5903	724		5211	1040	
Average percentage return for 1969-72				12.4			21.3

[a] Up to June 30, 1973

Table 1.10. Tag return data grouped by year at large and summed across all years for the York and Rappahannock rivers.

	York			Rappahannock			
Years at large	Number tagged at start[b]	Number returned	Percent returned	Number tagged	Number returned	Percent returned	Grand average[c]
3-4	885	0	0.0	1161	2	0.17	-
2-3	1905	5	0.26	1912	5	0.26	0.26
1-2	3690	27	0.73	2721	60	2.2	1.26
0-1	5530	625	11.3	4746	916	19.3	14.76
0-1/2[a]	5903	530	9.0	5211	727	13.6	11.06

(a) To June 30, of each tagging year.

(b) Tagging seasons combined, e.g. for 2-3 years at large, total tagged fish from 1969 and 1970 combined and returns from 1971 and 1972 combined, respectively.

(c) Geometric mean.

Table 1.11. Beach seine indices of abundance for young-of-the-year striped bass in the principal Virginia rivers.

Year	James	York	Rappahannock	Average
1967	3.21	4.65	2.19	3.35
1968	0.71	0.79	2.94	1.48
1969	1.75	0.88	2.69	1.77
1970	5.88	2.26	5.16	4.43
1971	0.83	1.31	2.10	1.41
1972	0.29	0.52	0.71	0.51
6-year river average	2.11	1.74	2.63	

Table 1.12. Striped bass catch from winter survey 1973 with R/V *Langley* in Virginia rivers. Four tows made at each five mile station. Forty eight tows made in each river to mile indicated.

River mile	James Av/Tow	James Salinity ‰	York Av/tow	York Salinity ‰	Rappahannock Av/tow	Rappahannock Salinity ‰
00	0.3	17.6	0	18.1	0	11.9
05	0	13.6	0	18.0	0	13.1
10	0	13.6	0	16.2	4.5	13.3
15	0.5	8.1	0	14.5	0.2	10.9
20	0	2.3	0	12.7	0.8	10.1
25	0	0.3	0	9.1	1.5	8.3
30	0	0.2	0.5	7.6	0.5	4.4
35	0	0.1	0.5	3.7	0	1.8
40	0	0.1	0	0.5	0.5	0.3
45	0	0.1	0	0.1	0	-
50	0	0.1	0	0.1	0	0.1
55	0	0.1	0	0.1	0	0.1
Bottom temp. range	4.2-5.7		3.5-7.8		4.6-6.3	

Table 1.13. Commercial catch of striped bass for Maryland and Virginia from 1887 to 1973, in thousands of pounds and dollars (from NMFS Fishery Statistics).

	Maryland		Virginia		Total	
Year	Pounds	Value	Pounds	Value	Pounds	Value
1973[1]	2,824	880	1,862	503	4,686	1,383
1972	3,175	917	2,604	555	5,779	1,472
1971	2,743	862	1,183	280	3,926	1,142
1970	4,017	878	1,787	372	5,804	1,250
1969	5,088	910	2,671	517	7,759	1,427
1968	4,532	922	1,614	293	6,146	1,215
1967	4,150	675	1,677	260	5,827	935
1966	3,347	604	2,803	526	6,150	1,130
1965	2,949	542	2,213	433	5,162	975
1964	3,300	538	1,889	301	5,189	839
1963	3,749	534	2,747	356	6,496	890
1962	3,979	642	1,944	279	5,932	921
1961	5,408	612	1,854	290	7,262	902
1960	4,409	675	2,278	316	6,687	991
1959	4,349	744	2,097	330	6,446	1,074
1958	3,105	716	1,317	211	4,422	927
1957	1,859	459	929	149	2,788	608
1956	2,150	542	995	161	3,145	703
1955	2,572	643	894	177	3,466	820
1954	2,108	525	951	146	3,059	671
1953	2,303	555	803	121	3,106	676

(1) Through June 1973.

Table 1.13. (Cont)

	Maryland		Virginia		Total	
Year	Pounds	Value	Pounds	Value	Pounds	Value
1952	2,171	536	1,242	192	3,413	728
1951	2,336	586	1,804	276	4,140	862
1950	3,038	578	2,796	370	5,884	948
1949	2,629	540	1,913	234	4,542	774
1948	2,650	487	2,452	333	5,102	820
1947	2,338	444	1,725	329	4,063	773
1946	1,615	344	2,084	313	3,699	656
1945	1,545	338	2,119	339	3,664	677
1944	2,681	460	1,864	227	4,545	687
1943	No data available					
1942	2,508	254	778	74	3,286	325
1941	1,223	107	865	78	2,089	185
1940	1,180	110	659	64	1,839	174
1939	1,729	142	964	79	2,692	222
1938	1,714	140	1,155	91	2,869	232
1937	2,011	157	1,044	63	3,016	220
1936	1,864	140	20	35	2,384	176
1935	928	79	375	39	1,303	118
1934	333	37	10	29	643	66
1933	314	38	519	63	833	101
1932	433	56	594	71	1,028	128
1931	635	97	481	62	1,116	159
1930	1,228	204	425	67	1,653	271

Table 1.13. (Cont)

	Maryland		Virginia		Total	
Year	Pounds	Value	Pounds	Value	Pounds	Value
1929	1,292	217	290	55	1,581	272
1928-1926	No data available					
1925	1,414	240	821	151	2,235	391
1924-1921	No data available					
1920	1,040		380		1,420	
1919 1909	No data available					
1908	640		504		1,144	
1907-1905	No data available					
1904	721		451		1,172	
1903-1902	No data available					
1901	824	69	528	45	1,352	114
1900-1898	No data available					
1897	935		576		1,511	
1896-1892	No data available					
1891	1,265		483		1,748	
1890	1,366		529		1,895	
1889	No data available					
1888	1,123		779		1,902	
1887	1,140		505		1,645	

Job 2. Selection of Tributary to be Stocked.

The Piankatank River and the Mobjack Bay system were sampled to determine their suitability as receiving waters for a stocking of striped bass. Parameters examined during 1970-1971 included hydrographic factors (depth, temperature, salinity, and dissolved oxygen) and fishes (species abundance, community characteristics, and availability of forage species for striped bass after stocking). Data for the Piankatank River are summarized in the attached manuscript entitled "Seasonality, abundance, and diversity of fishes in the Piankatank River, Virginia, 1970-1971." Data for the Mobjack Bay system were presented in the text and appendices of progress report AFS 6-1. Biological data collected from the Mobjack Bay system between 1970-1973 are summarized under Job 3 of this report.

All areas surveyed as latent nursery areas and potential receiving waters for striped bass represented meso-polyhaline habitat (5 to 30 ppt salinity). Within the upper reaches of each stream the transition from 5 ppt to fresh water was rather abrupt. The transition occurred over a distance of approximately 200 yards. Stocking striped bass within habitats having a rapid change in salinity could represent a stress to the planted fish and affect the success of our stocking in a detrimental fashion (Albrecht, 1964 and Bayless, 1973). We designed a series of laboratory experiments to determine the response of striped bass at various ages (= sizes) to abrupt changes in salinity and temperatures. We could then select stocking sites within the estuary which approximate the experimentally defined acceptable ranges of temperature and salinity. In this manner adverse effects of temperature and salinity on stocking success would be minimized. Results of our laboratory study are presented in Job 4.

The Ware River (Mobjack Bay system) was selected as the initial area to receive an experimental planting of striped bass. The factors considered in the selection of this stream were the likelihood of successful stock relative to hydrographic factors, absence of a natural population of striped bass, abundance of forage organisms for the fish after stocking, and accessibility of the area for sampling after stocking.

The East River (Mobjack system) was selected as a control area of similar physical, chemical, and biological characteristics. The results of our post-stocking monitoring program are described in Job 3 of this report and in annual progress reports AFS 6-1 and 6-2.

Literature Cited

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Seasonality, Abundance, and Diversity of Fishes in the Piankatank River, Virginia (1970-1971)

Abstract

Bimonthly trawl catches of seven stations in the Piankatank River, Virginia included 3,417 specimens representing 41 species. Numeric and species abundance in the river reflected a seasonal pattern of species specific migrations with peak numerical abundance in September and a decline in marine fishes during winter.

The effects of seasonal migrations by marine fishes and their interaction with resident fishes are reflected in diversity indices. Bimodality in diversity was shown with highest diversity occurring at the upper and the lower stations and is attributed to stability of hydrographic factors in these two areas. Results are related to other areas of the East Coast.

Introduction

Numerous studies have been conducted to clarify the tolerance of various fishes to stress factors, i.e., pollutants and natural factors (Doudoroff and Warren, 1957). As a general rule, invertebrates and phytoplankters have been emphasized as indicator species for stressed environments while fishes have been avoided because of either sampling problems or fish mobility. Dahlberg and Odum (1970), Bechtel and Copeland (1970), and McErlean, O'Connor and Mihursky (Ms) have presented fish diversity data for areas in Georgia, Texas, and Maryland, respectively.

Trawl collections of fishes taken in alternate months throughout an annual cycle in an undisturbed estuary, the Piankatank River, Virginia are analyzed by abundance, diversity, and migratory tendency.

Materials and Methods

The Piankatank River is a small undisturbed tributary of Chesapeake Bay lying between the York and Rappahannock rivers. Little development has occurred in the drainage basin. Waters are darkened by tannins from the swamps along the river.

From July 1970 through May 1971 seven stations were sampled bimonthly with a semiballon trawl (Fig. 2.1). All trawls were of 7.5 minutes duration.

Temperature, salinity and dissolved oxygen were measured at the surface and bottom immediately before each trawl. The total number of each species and fork lengths from up to 25 specimens per species were recorded for each trawl. The diversity formulation for H' presented by Lloyd, Zar and Karr (1968) was used:

$$H' = \frac{c}{N} (N \log_{10} N - \Sigma n_i \log_{10} n_i)$$

where N is the total number of individuals in the sample, n_i is the number of individuals in the ith species, and c is the conversion factor from base 10 to base e (2.302585). Diversity indices using numeric ratios are independent of sample size (Wilhm and Dorris, 1968) and therefore are applicable to our trawl data.

Results

Average salinity decreased from the mouth upstream (PK-1 = 16.28, PK-7 = 4.27‰) (Fig. 2.1). Seasonal decrease in rainfall allowed higher salinity (13‰) to encroach to PK-7 in November 1970 and with spring rains salinities were as low as 2.04‰ at PK-6 (May 1971). Stations in the lower reaches of the river had similar seasonal trends but salinity remained above 10‰. Salinities above 5‰ extended to PK-7 from July through November while the transition zone (1‰ or less) was between PK-6 and PK-7 from January through May.

Dissolved oxygen content of the water exceeded 3 ppm at all stations and depths except at the bottom at PK-3 in July 1970 (0.8 ppm).

Temperatures at each station reflected no distinct stratification. Surface water temperatures ranged from 29.7 C at PK-7 in July to 2.9 C at PK-1 in January and bottom water temperatures from 28.9 C to 2.6 C for the same stations and dates. The maximum temperature range in the river for a given sampling period occurred in May (13.7 C to 20.3 C).

Seasonal variation of fishes for all stations pooled showed a peak numerical abundance in September with 1931 individuals captured and a pattern of species specific migrations (Table 2.1). A decline occurred in the marine fauna in winter (January and March) with a persistence of the resident species and occurrence of winter or early spring migrants such as winter flounder (Pseudopleuronectes americanus) and alosids. A total of 3417 specimens including 41 species were taken during the year. A maximum of 21 species (535 individuals) was obtained in the July trawls. The number of species taken declined to six by January and increased to 13 in May.

Individual stations exhibited a similar variation in species abundance. Seasonally migrant, saltwater species such as weakfish, croaker, silver perch and spotted hake dominated the lower reaches (PK-1) while upstream the saltwater migrants are gradually replaced by the resident fishes (hogchoker and sunfish) and seasonal forage species (silversides and bay anchovy). At PK-7 the forage species and freshwater fishes such as yellow perch and sunfishes, assumed dominance. The seasonal abundance of the bay anchovy, Anchoa mitchilli, greatly exceeded that of the hogchoker, Trinectes maculatus, a continual resident within the estuary. Freshwater gill net collections in March and April 1971 added chain pickerel, Esox niger; adult alewife, Alosa pseudoharengus; adult hickory shad, Alosa mediocris; European carp, Cyprinus carpio; gizzard shad, Dorosoma cepedianum; longnose gar, Lepisosteus osseus; largemouth bass, Micropterus salmoides; and golden shiner, Notemigonus chrysoleucas, to the species assemblage found in the river.

A seasonal trend of declining diversity was evident for the total collections (PK 1-7) from a high in July of 2.355 (H') to a low in November of 0.95 (H') (Fig. 2.2). This decline is assumed to be due to water temperature and its effect upon migrant fishes. Annual diversity (H') ranged from 0.814 at PK-4 to 2.799 at PK-1. Average annual diversities are probably more representative of a given station or general area than indices based upon individual trawl collections since each species actually encountered in that area is included in the index (Bechtel and Copeland, 1970).

The freshwater and saltwater reaches of the river have different seasonal pulses in diversity index (Fig. 2.2). Diversity at PK-1 is high throughout the summer and fall (H' above 1.44) and declines during the winter and early spring. This pulse in diversity is also shown at PK-7 though peaks are evident both in summer (July, H' = 2.722) and winter (January, H' = 1.499). Stations in the middle reaches of the river (PK-3 through PK-5) generally were low in diversity. For the total river collection in a given month (Fig. 2.3, PK 1-7) diversity is highest in January (H' = 2.957) and lowest in November (H' = 0.959).

Average diversity indices (H') by month indicate summer as the period of highest diversity (Fig. 2.4 A). Average diversity indices (H') by station indicate two areas of high diversity, the lower saltwater reach and PK-7 (Fig. 2.4 B). Stations PK 4-6 had average diversity values less than 0.5.

Discussion

Fish populations in estuarine waters are characterized by resident and migrant marine components. The migrant component of the fish fauna may use the estuary as a spawning area (striped bass and alosids), feeding area for adults and/or juveniles (spot, weakfish, kingfish, menhaden, etc.) or a combination of uses (anchovy, sciaenids, striped bass). Several species such as spot, croaker, menhaden, weakfish and silver perch migrate into the estuary as larval and postlarval fish and migrate out after one or more year's growth. These migrating species may be very abundant at times, and trawl collections are often dominated by them (Table 2.1).

Peak abundance and diversity occur during the summer months (Table 2.1 and Fig. 2.4 A) when recruited marine and resident juveniles are utilizing the estuary as a nursery ground. Sciaenids and other summer migrants leave the river as winter approaches and are replaced by winter migrants such as spotted hake and winter flounder. Winter catches were greater in the upper reaches (PK-7 and above)than summer catches. This increased catch is assumed to reflect the congregation of fishes in the deeper waters rather than dispersal in shoal areas during cold weather. In the spring and summer most fresh and saltwater fishes disperse into shallower water where forage and/or cover are more readily available. High abundance of migratory life stages of a given species, or wintertime congregation of certain species, would decrease the diversity value at that station (Bechtel and Copeland, 1970). Such fluctuations in species abundance may thus distort the diversity values from individual collections. Assessment of an area, in the sense of environmental stress reflected by the fish species assemblage, should be based upon mean annual values derived from individual stations. In this way effects of seasonal migrants and congregation are minimized.

Our data are reasonably in accord with those for fish populations in Georgia sounds, creeks and rivers where diversity index values (species richness) ranged from 0.8 to 1.8 (Dahlberg and Odum, 1970). Small marsh creeks had higher diversity than rivers or sounds in Georgia and seasonal variation in diversity was less evident in the marsh creeks than in the sounds. At the upper station in the Piankatank River a rather pronounced seasonal trend was observed and highest diversity was found for the high salinity area.

Pollution or alteration of natural waters would be expected to decrease the diversity. Evidence of stress effects upon fish diversity is presented by Bechtel and Copeland (1970) for Galveston Bay, Texas. Reductions in the total number of species present and an increase in the planktivorous species abundance is expected with stress conditions.

Valid application of diversity indices as indicators of stressed or unstressed habitat must consider the biology of species encountered, season in which samples are obtained, and hydrographic factors in the area. The variations shown in our data reveal the magnitude of this "background noise" in an undisturbed system. Latitudinal variations must also be defined in undisturbed estuaries. We recommend use of the diversity concept coupled with community ecology in future evaluations of stressed habitats.

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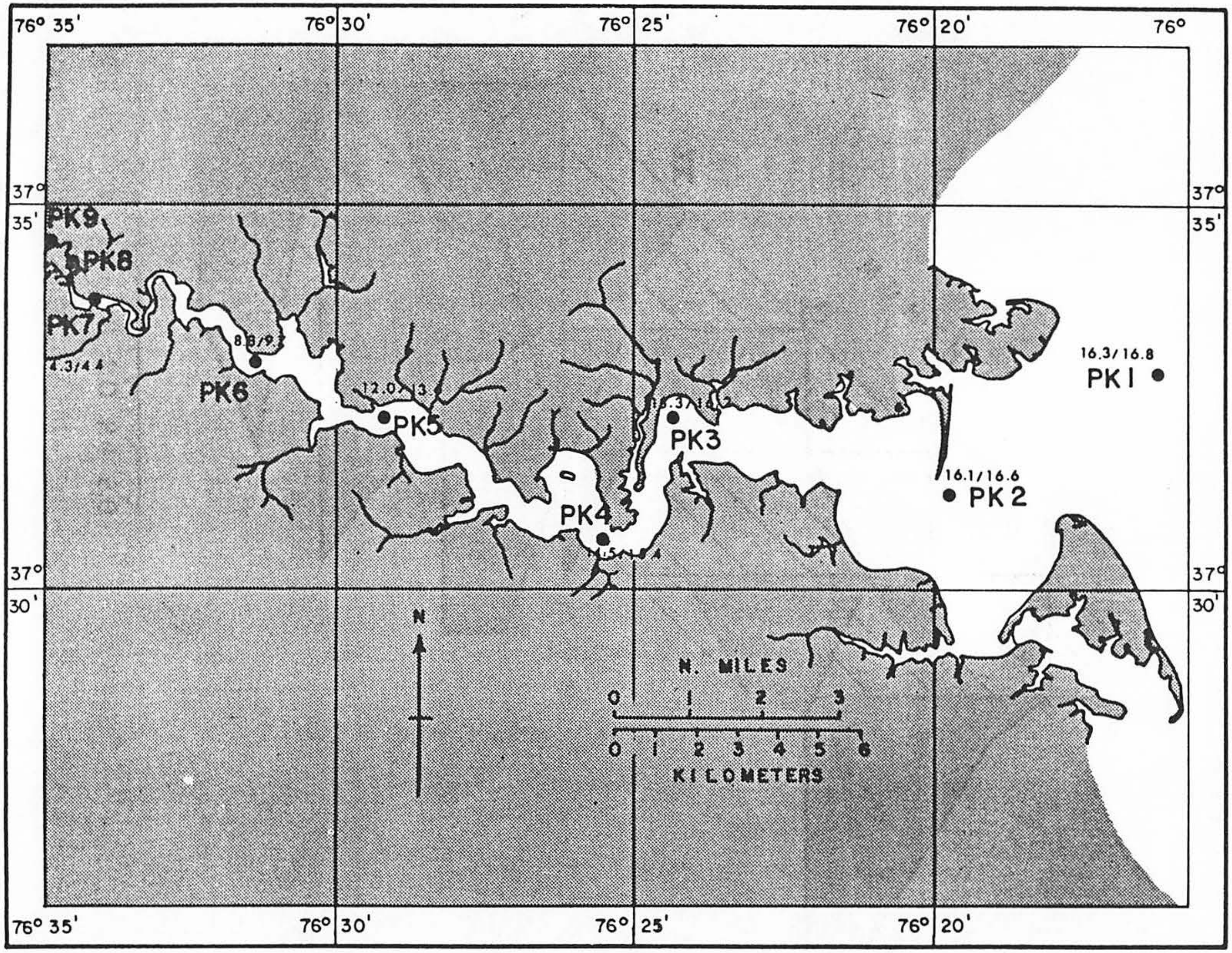

Figure 2.1. Station locations within the Piankatank River, 1970-1971, and average annual salinity at each station (surface ‰/ bottom ‰).

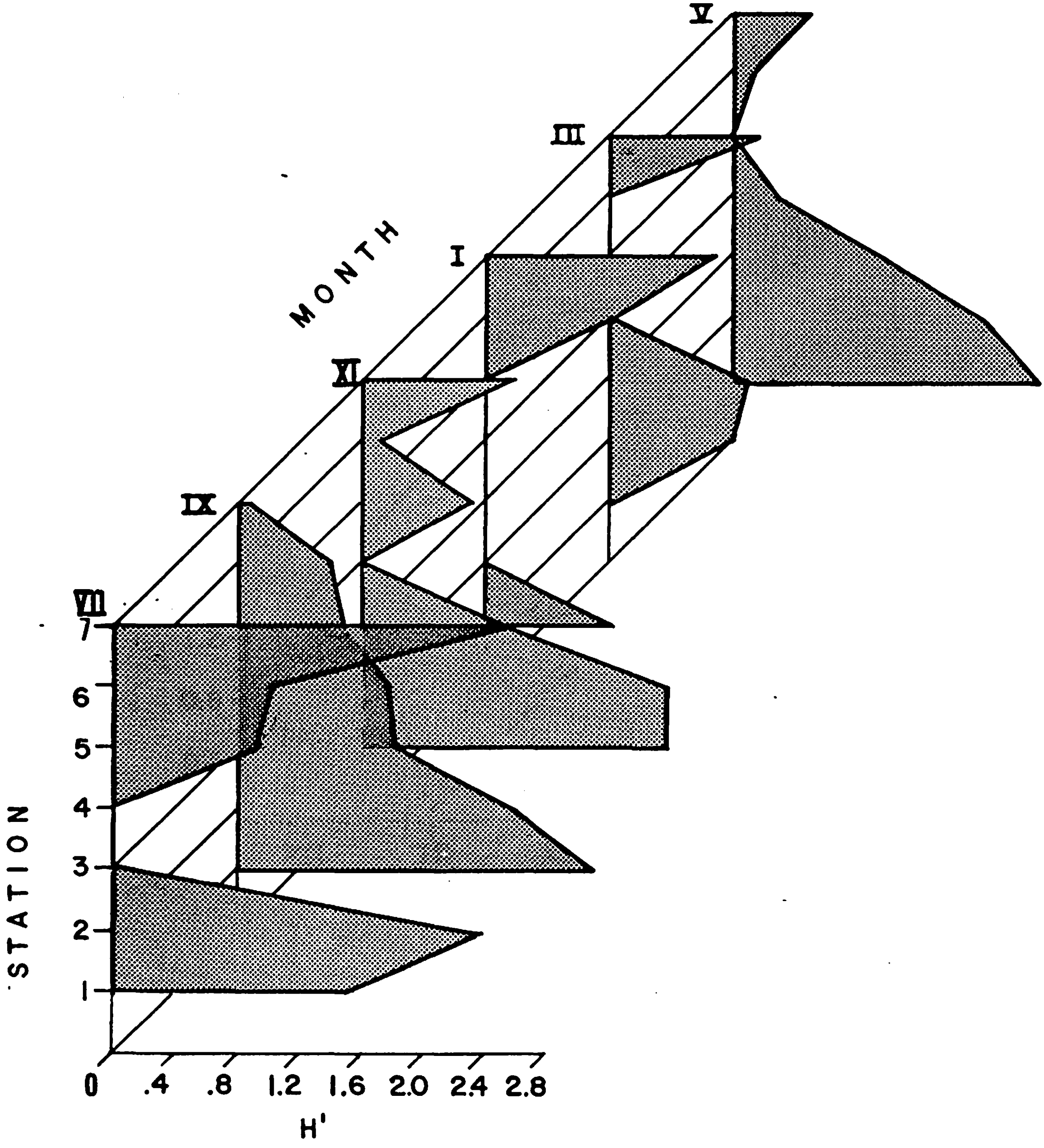

Figure 2.2. Diversity values (H') by month and station derived from trawl collections in the Piankatank River, Virginia.

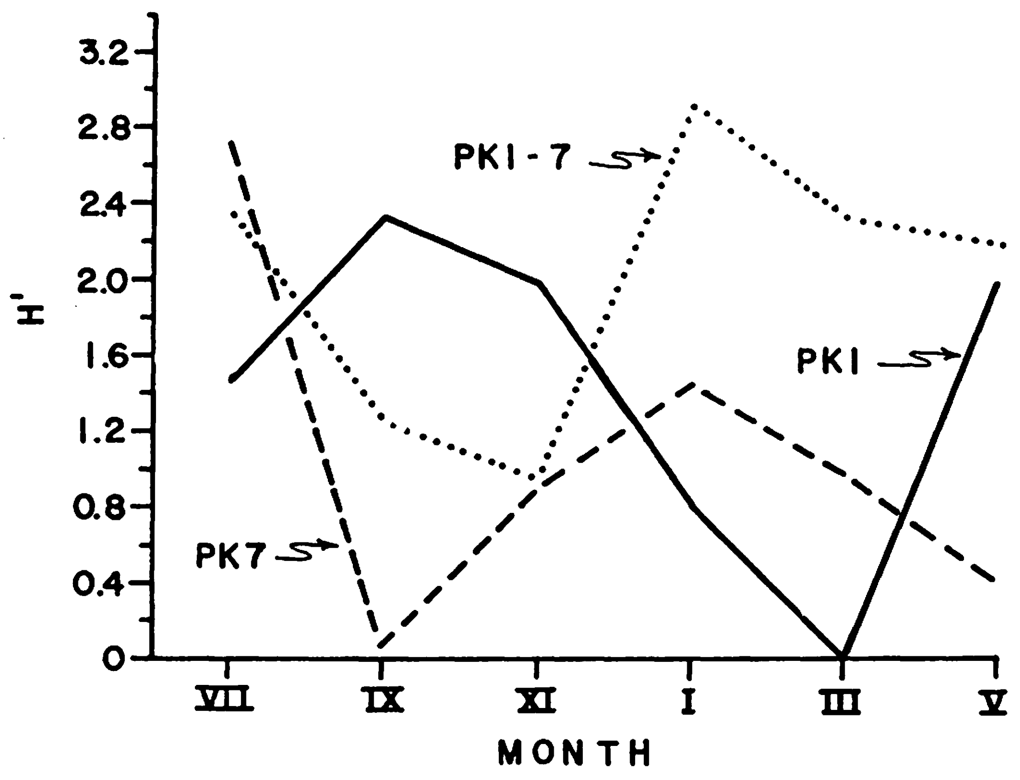

Figure 2.3. Diversity indices (H') by month for PK-1, PK-7 and the combined collections (PK-1 through PK-7) in the Piankatank River, Virginia (1970-1971).

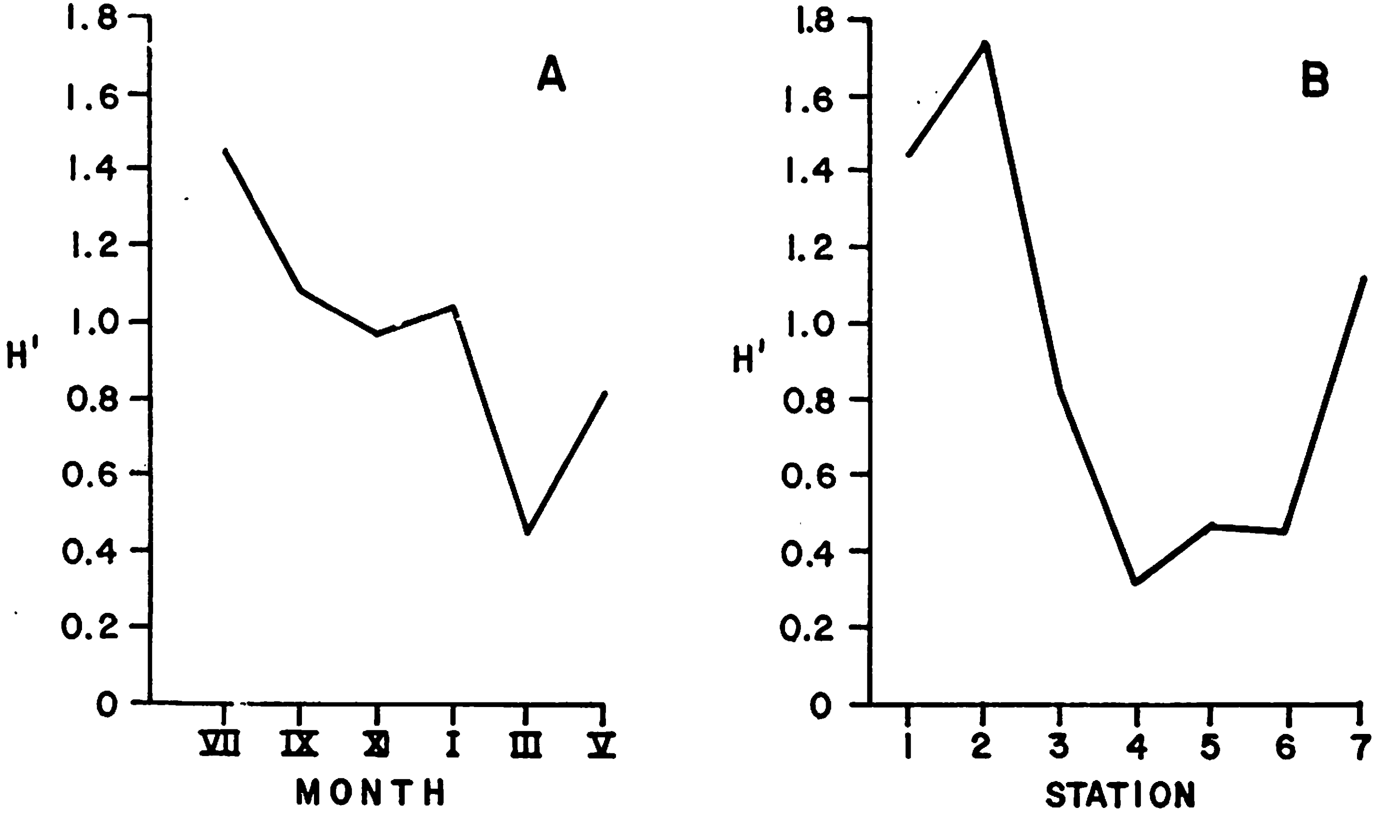

Figure 2.4. Average diversity indices (H') for trawl collections in the Piankatank River, Virginia (1970-1971), by month (A) and by station (B).

Table 2.1. Species list and abundance for all trawl stations in the Piankatank River, 1970-71.

Species	1970 July	1970 Sept.	1970 Nov.	1971 Jan.	1971 March	1971 May	Total
Alosa aestivalis	5				17		22
Alosa pseudoharengus	4				14		18
Alosa sapidissima					1		1
Anchoa hepsetus		1					1
Anchoa mitchilli	54	866	34	1	158	5	1118
Anguilla rostrata						3	3
Apeltes quadracus					1		1
Bairdiella chrysura	26	343	215				584
Centropristis striatus	1						1
Chasmodes bosquianus			2				2
Cynoscion nebulosus			1				1
Cynoscion regalis	160	100	3				263
Etropus microstomus			1				1
Gobiesox strumosus			1			1	2
Gobiosoma bosci						2	2
Hippocampus hudsonius			1				1
Hypsoblennius hentzi			1				1
Ictalurus catus	1					1	2
Leiostomus xanthurus	9	26					35
Lepomis gibbosus				1		1	2
Lepomis macrochirus	1			1	2		4
Menidia menidia	146			3			149
Menticirrhus americanus		45	16				61
Menticirrhus saxatilis	1						1
Microgobius thalassinus						1	1
Micropogon undulatus		68	59				127
Morone americana	13	2				2	17
Morone saxatilis	25		15				40
Notropis hudsonius	24	2			2		28
Opsanus tau	4		2			2	8
Paralichthys dentatus		1	1			1	3
Peprilus alepidotus		5					5
Perca flavescens	1			2			3
Pomatomus saltatrix		1					1
Pseudopleuronectes americanus					2		2
Prionotus carolinus	7						7
Prionotus evolans	1						1
Scophthalmus aquosus	1						1
Sphoeroides maculatus	6	240				1	247
Trinectes maculatus	45	231	130	4	5	224	639
Urophycis regius						11	11
Total Fish	535	1931	482	12	202	255	3417
Number of Species	21	14	15	6	9	13	41

Job 3. Stocking of Selected Tributary and Post-stocking Assessement.

The stocking and ecological assessment operations conducted during project AFS 6 shall be described as sections within this job. General topics for these subunits include A) sources and distribution of stocked fish, B) fish community monitoring in the Mobjack Bay system, C) benthic invertebrates of the Mobjack Bay system, D) epibenthic faunal survey in the Mobjack Bay system, and E) biology of striped bass in the Mobjack Bay system.

Natural spawning within the Ware River does not occur as shown by gill net and plankton net surveys during spawning season. Thus, this system was selected to receive a stocking of striped bass. Two releases of young striped bass into the Ware River, Virginia were accomplished in the course of the project. Stocking rates in the Ware River (4,209 surface acres) were low relative to that required for successful reservoir stocking in the southeastern states: in 1971, a maximum of 25,000 two-week-old striped bass released = 6 per acre; in 1972, 4,000 juvenile striped bass (20 to 65 mm FL) released = 0.95 per acre. Plankton net, beach seine, and trawl net surveys in the receiving waters after each stocking provided incomplete data for assessment of the stocking success.

The 1972-1973 trawl survey in the Ware River, East River, and Mobjack Bay yielded no striped bass juveniles. Trophic composition of the fish fauna during 1972-1973 in the Mobjack Bay system revealed a low incidence of piscivorous fishes. Data suggest that food (forage fishes) would not be a limiting factor for survival of striped bass in the Mobjack Bay system. The pattern of species occurrence and abundance within the system during 1972-1973 demonstrates the significance of the study area as a summer nursery for important commercial, sport, and forage (prey) fishes.

The 1972 beach seine survey in the Mobjack Bay system from the Guinea Marshes into the freshwater portions of the Ware and East rivers did not yield any juvenile striped bass. Our increased sampling effort in the Ware River did not provide positive data for evaluation of stocking success. It is concluded that either no striped bass survived from the 1972 stocking, survival of stocked striped bass was so low that the probability of recapture was very small, or our sampling effort was insufficient.

The fish fauna of the Mobjack Bay system may be grouped into a summer contingent (May to October) and a winter contingent (November to April). The summer fauna is dominated by anchovies, sciaenids, and resident benthic fishes. Differences in dominant species lists between areas in a given year and between years are attributable to climatic factors and fluctuations in year class strength. In general, the fish community within the various portions of the system is quite similar during the summer months. The winter fish fauna is low in species and abundance. It is dominated by anchovies, gobies, pipefishes, blennies, and silversides. Winter immigrants to lower Chesapeake Bay are often taken in Mobjack Bay. The tributary streams are more sparcely populated and less diverse than the deeper, more saline portions of the system. Beach seine data revealed no nearshore movement of striped bass from the York

River into Mobjack Bay or in the opposite direction. Diversity (H'), species richness (R), and evenness (J') statistics for the fish community within the Ware and East rivers did not change as a result of our stocking program. The species list developed during our trawl and beach seine surveys in the Mobjack Bay system included a total of 64 species. The trawl survey produced 44 species and the beach seine survey produced 53 species. Thirty-three species were taken in both the trawl and beach seine surveys, 20 species were taken only in the beach seine, and 11 were taken only with trawls. The Mobjack Bay system possesses a benthic macroinvertebrate fauna similar to that of the meso-polyhaline areas within Chesapeake Bay which support natural populations of striped bass. Seasonal changes within the benthic community were related to shifts in dominant species between summer and winter rather than replacement of loss of species from the area. We conclude that the benthic macroinvertebrate fauna in Mobjack Bay is sufficiently similar to other striped bass nursery grounds as to expect no effect upon survival of stocked fish from the benthos.

Qualitative epibenthic collections in the Mobjack Bay system at 20 stations in AFS 6-1 and 11 stations in AFS 6-2 were made between August, 1970 and June, 1972 using a sled-mounted plankton net (D-Net). A total of 186 samples were taken to assess food availability for striped bass young, presence of striped bass eggs or larvae, and presence of predator or competitor fishes in the system. Hydrographic data indicated relatively uniform salinity, temperature and dissolved oxygen throughout the sampling area. Over 155 different species of epibenthic fauna were identified from the collections. The list included representatives of 12 phyla. Arthropoda was the most speciose phylum and were the most abundant group of organisms. The species list and abundance data suggest an adequate epibenthic food supply for young striped bass. Seasonality of the epibenthic fauna parallels that presented for fishes with a greater abundance and species list during the warm seasons. Winter conditions result in fewer species with certain species reaching maximum abundance (Ctenophores, Cyanea, Crangon larvae).

Striped bass utilization of habitats similar to Mobjack Bay is seasonal and parallels that pattern shown by sciaenids. Deep water sections of the York River are the most likely sites of winter residence for striped bass reared in Mobjack Bay. Thus production within the underutilized nursery grounds as a result of stocking would be lost from the immediate area in an annual migration. It remains to be shown if the striped bass stocked in Mobjack Bay will return to that area upon reaching sexual maturity.

Data herein represent summaries of our field program. Raw data for selected species, discrete station collection data, and reference collections have been stored at the Virginia Institute of Marine Science and are available for use by other researchers upon request. Several manuscripts are in preparation which utilize data obtained within this job.

A. Sources and distribution of stocked fish.

Striped bass utilized in the pursuit of our stocking program were obtained from the Virginia Commission of Game and Inland Fisheries, Striped Bass Hatchery at Brookneal, Virginia. The cooperation of this state agency is gratefully acknowledged.

The parental stock from which these striped bass were derived is that of the Roanoke River.

1971 Stocking. The first stocking of one million striped bass was made in the Ware River on June 4, 1971. Three-day-old sac fry were transported by truck to VIMS and distributed among three stocking sites: Beaverdam Creek (7×10^5 fry), Cow Creek (1×10^5 fry) and Fox Mill Creek (2×10^5 fry). All locations were in the freshwater portions of the streams.

The condition of the fish and the stocking procedure were suboptimal. The fish experienced a 3.6 C temperature rise in the shipping containers during transport from the hatchery. Water temperatures at the stocking sites ranged from 22 to 24.5 C. A brief thermal acclimation period (15 to 20 minutes) preceeded the release of fish at each site. A subsample of the fry in creek water was returned to the laboratory and placed in an acquarium to assess initial mortality due to handling and thermal shock. The effective stocking of striped bass was estimated at 570,000 sac fry after the first day mortality of the fish in the subsample in aerated creek water. Mortality reached 97.5% after 2 weeks for the subsample maintained and fed in the lab. Thus, we estimate a maximum stocking of 25,000 two-week-old striped bass into the Mobjack Bay system in 1971. This represents a stocking rate of approximately 6 fish per acre.

We were unable to confirm the success of our stocking program in the field during June, 1971, despite the estimated survival of 25,000 two-week-old striped bass. D-net collections were made in the freshwater (less than 1‰ salinity) and oligohaline (up to 5‰ salinity) areas of the Ware and East rivers preceeding our stocking operation and during the three weeks thereafter. These efforts produced no striped bass eggs or larvae though forage organisms were abundant throughout the areas sampled. Details of the sampling were presented in the progress report AFS 6-2.

<u>1972 Stocking</u>. A prestocking gill net survey to assess natural spawning by striped bass in the Ware and East rivers between 7 March and 27 April revealed the presence of mature male striped bass but no mature female striped bass. Gill net sets in the East River produced 26 striped bass with 17 net-days of effort. Gill net sets in the Ware River produced 40 striped bass with 25 net-days of effort. A total of seven ripe-running male striped bass were taken. A ripe female striped bass was caught by a sportfisherman on 7 May near the mouth of Wilson Creek (Ware River). This was the only report we received of a ripe female striped bass taken in either river during the 1972 spawning season. Species lists and data from the striped bass taken during this survey were presented in the progress report AFS 6-2.

A prestocking survey with a D-net to assess natural spawning produced no striped bass eggs or larvae. A total of 126 samples were taken between 7 March and 23 May in the Ware and East rivers and their tributaries. Potential food organisms for striped bass were abundant in the samples.

Three-day-old sac fry were obtained from the Brookneal Hatchery on 26 May, 1972. A total of 3.25 million young fish were received. Initial mortality due to shipping and handling was estimated at 33%.

These fish were used in our temperature and salinity experiments and were reared in the laboratory and in cages. Details of the rearing and experimental procedures employed are presented in Job 4 of this report.

On July 29, 1972 we stocked 4,000 fingerling striped bass (20 to 65 mm FL) into the Ware River system at Ware House Landing and Pig Hill. This represents a stocking rate of approximately one fish per acre. The fish were transported from our rearing facilities in plastic containers, acclimated at the stocking site, and released. The fish did not appear stressed by the handling. After release, the fish dispersed into the surrounding water rapidly and showed no signs of stress, such as erratic swimming, nosing the surface, blanched coloration, or loss of equilibrium. We assumed a successful transfer had been accomplished.

Post-stocking study of the waters for survivors included beach seine and trawl sampling of the river, its tributaries, and Mobjack Bay through October, 1972. The beach seine survey was terminated after October, but trawling continued through June, 1973. The data from these programs are summarized in section B of this job.

Summary of Job 3 A:

1. Natural spawning within the Ware River does not occur as shown by gill net and plankton net surveys during spawning season.
2. Two releases of young striped bass into the Ware River, Virginia were accomplished in the course of the project.
3. Stocking rates in the Ware River (4,209 surface acres) were low relative to that required for successful reservoir stocking in

the southeastern states: in 1971, a maximum of 25,000 two-week-old striped bass released = 6 per acre; in 1972, 4,000 juvenile striped bass (20 to 65 mm FL) released = 0.95 per acre.

4. Plankton net, beach seine, and trawl net surveys in the receiving waters after each stocking provided incomplete data for assessment of the stocking success.

B. Fishes of the Mobjack Bay System.

1972-1973 Trawl Survey. Trawl stations were continued in the Ware and East rivers (four in each) and station MJ3 was retained in Mobjack Bay during the AFS 6-3 contract year (Fig. 3.1). Hydrographic data, fish species, enumeration of fish and fish lengths were recorded in the manner described in progress report AFS 6-1. A 16-ft semiballoon trawl with a 1/4-inch bar mesh cod end was the sampling device.

Temperature, salinity, and dissolved oxygen data for 1972-1973 followed the seasonal trends previously described. Hurricane Agnes caused a slight reduction in salinity during July (range 13.4 to 14.4 ppt in the East River and 12.4 to 14.4 in the Ware River).

Collections during 1972-1973 at the Mobjack Bay station (MJ3) yielded a total of 1,575 fish representing 14 species (Table 3.1). Anchovy, Anchoa mitchilli, (980 individuals) was the most abundant species followed by spot, Leiostomus xanthurus, (522 individuals); weakfish, Cynoscion regalis, (35 individuals); and croaker, Micropogon undulatus, (15 individuals). The winter decline in both total abundance and species occurrence was consistent with earlier data (AFS 6-1 and 6-2 progress reports). No striped bass were taken during the project year at station MJ3).

Trawl collections in the East River (four stations) during 1972-1973 yielded 3,734 fish representing 19 species (Table 3.2).

Anchovy (2,115 individuals) was the most abundant species followed by spot (1,053 individuals); silver perch, Bairdiella chrysura, (187 individuals); menhaden, Brevoortia tyrannus, (161 individuals); and blueback herring, Alosa aestivalis (127 individuals). The remaining 14 species represented only 2.4% of the total number of fishes taken. The cyclical pattern of species occurrence and abundance duplicates that shown by earlier data. No striped bass were taken by trawl in the 1972-1973 collections in the East River.

Trawl collections in the Ware River (four stations) during 1972-1973 yielded 5,667 fish representing 19 species (Table 3.3). Anchovy (3,220 individuals) was the most abundant species followed by spot (2,225 individuals), silver perch (86 individuals), and weakfish (33 individuals). The remaining 15 species represented only 1.82% of the total number taken. A similar pattern of seasonality in species occurrence and abundance to that described in earlier reports was evident. No striped bass were taken by trawl in the 1972-1973 samples from the Ware River. This suggests marginal survival, if any, from our stocking operations in 1972. However, these stations are in deeper water (channel area) and juvenile striped bass are typically distributed over shoal areas during the warmer months.

Trophic composition of the fish fauna in the Mobjack Bay system reveals a low percentage of piscivorous fishes (Table 3.4). Piscivores were less abundant in each area during 1972-1973 than in 1971-1972. Forage fishes represented 57 to 64% of the fauna and secondary carnivores 34 to 42%. These data suggest that food (forage fishes) would not be a limiting factor for striped bass over 200 mm FL in the Mobjack Bay system.

1972 Beach Seine Survey. Beach seine collections in the Mobjack Bay system from 30 May through 12 October 1972 did not yield striped bass juveniles which survived from our stocking operations. A total of 120 seine hauls were undertaken during this period in the area from the Guinea Marshes to the freshwater portions of the Ware and East rivers. All seines were 1/4-inch bar mesh by 6 ft deep and lengths were 30, 50, and 100 ft. The length used at a given station was dependent upon stream width and depth of water nearshore. All tows were made in a quarter circle fashion. A general summary of beach seine information (1971 and 1972) will be presented rather than detailed species lists and abundance data. The survey was unproductive in our search for juvenile striped bass survivors from our stocking.

Our increased sampling effort in the Ware River in 1972-1973 (79 seine hauls) over that in 1971-1972 (37 seine hauls) did not provide positive data for evaluation of stocking success. From this information we must conclude that either 1) the fingerling striped bass planted in July of 1972 did not survive, 2) sampling effort was insufficient, or 3) survivors were in such low abundance that the likelihood of capture was very small. On the basis of our field data these possibilities can not be separated. Item 2 above is least likely since our 1971-1972 results yielded an average of 0.67 striped bass per tow in the river.

The three striped bass captured in the Ware River in 1972 were larger than the expected size of stocked fish (288, 346, and 369 mm FL). We conclude that they were strays from the York River population.

Trawl Survey Summary 1970 through 1973. The fish community within the Mobjack Bay system is dominated by seasonal species. Sampling within the bay and tributary streams has been continuous throughout the project. Gear used, station locations, and detailed lists of fishes taken during July, 1970 through June, 1973 are found in progress reports AFS 6-1 and 6-2 and in the preceeding section of this report. The calendar year is divisable into summer (May through October) and winter (November through April) seasons which have consistent fish species aggregations and abundance.

Data collected at individual stations within each area were pooled across the time frames cited above. The five most abundant species at each station in each month were assigned ranks (5 = most abundant to 1 = fifth most abundant). These ranks were summed across all collections within the interval for each area and each species. The summation of ranks divided by the total number of stations gives the statistic called mean biological index. Incidence is defined as the number of times a given species occurred in the samples during the interval.

A general rank based upon the mean biological index was assigned to signify the importance of individual species in the system within a time-frame (1 = highest biological index).

The fish community in Mobjack Bay and its tributaries during May through October includes 26 to 28 species each year from the total of 44 species taken by trawl during the entire project period (Tables 3.5-3.7). Dominant species in 1970 were *Anchoa mitchilli*, *Bairdiella chrysura*, *Cynoscion regalis*, *Trinectes maculatus*, *Leiostomus xanthurus*, and *Opsanus tau* (Table 3.5). The uniformity between areas in species ranks reflects the high degree of similarity in hydrographic factors throughout the entire Mobjack Bay system. During 1971 these same species were dominant in the tributary streams (Table 3.6), but the Mobjack Bay stations shared only *Anchoa* and *Leiostomus*. *Urophycis*, *Prionotus*, *Syngnathus*, and *Sphoeroides* assumed dominance at the bay stations. The dominance of winter forms at the bay stations is attributed to a slower on-set of summer conditions in 1971. During 1972 *Anchoa*, *Leiostomus*, *Cynoscion*, and *Bairdiella* were dominant at the bay and tributary stations (Table 3.7). Other fishes such as *Centropristis*, *Peprilus*, *Brevoortia*, and *Gobiosoma* were among the five most dominant fishes for certain locations but were inconsistent in occurrence. Passage of the flood waters from Hurricane Agnes did not appreciably alter the dominance relationships within the system herein described.

The summer fish fauna in the Mobjack Bay system and other poly-mesohaline environments of Chesapeake Bay may be characterized as anchovy, sciaenid, and resident benthic fish communities. Differences in species dominance between areas in a given year and between years are attributable to climatic factors and fluctuations in yearclass strength. The significance of shallow, moderate salinity habitat in Chesapeake Bay as a nursery area for juvenile sciaenids and other summer immigrants is clearly shown by the overall dominance ranks.

The fish fauna within Mobjack Bay and its tributaries between November and April includes 17 to 27 species each year (Tables 3.8-3.10). Discrete year to year differences, i.e. 1971-1972 relative to other years, are attributable to the severity of winter in Tidewater, Virginia. It is of particular interest to note the paucity of species in tributary streams relative to Mobjack Bay. Tributary streams are dominated by resident benthic fishes (blennies and gobies) and the anchovy. Species which frequent the shoal areas during the warmer months move into deeper water for the winter season (such as Menidia, Fundulus, Syngnathus, and Lucania). Winter immigrants into Chesapeake Bay such as Pseudopleuronectes americanus, Urophycis regius, Raja eglanteria, and Micropogon undulatus assume dominance in Mobjack Bay. As a general rule, these species do not penetrate into the tributary streams in large numbers. Species which leave the estuarine area during the fall and early winter (sciaenids and clupeids) may stay in Mobjack Bay during mild winter thus inflating the species list and distorting ranks, as occurred in 1971-1972 (Table 3.9).

In winter the fish community of the Mobjack Bay system and similar areas in lower Chesapeake Bay is poor in species and sparce in abundance. Resident gobies, blennies, silversides, pipefishes, and anchovy predominate the fauna. Other seasonal forms such as sciaenids and clupeids may be locally abundant during atypical winters. Tributary streams become even more sparcely populated and less diverse than the deeper, saline portions of the system.

It is likely that striped basswithin the Mobjack Bay system during summer (either stocked or products of natural spawning) would leave the rigors of the tributary streams and migrate to deeper, more saline waters in the winter season.

Beach Seine Survey Summary 1971-1972. Nearshore, shoal areas serve as nursery habitat for more species of fish than do channel areas in the Mobjack Bay system. Beach seine samples within the system included 53 species of fish spanning marine, estuarine, and freshwater forms. A total of 207 tows at several stations were completed in 1971 and 1972.

Samples from the Ware River in 1971 (42 tows) yielded 32 species (Table 3.11 and Fig. 3.2). The ten most dominant species in descending order of biological index included five species which are common food items for striped bass, two benthic feeders which would compete with striped bass juveniles up to 200 mm FL, and three piscivorous species which would compete with striped bass over 200 mm FL and possibly prey upon striped bass less than 200 mm FL. The shore zone fauna is thus quite diverse in prey species available to piscivorous fishes. Thirty-three species were taken in the Ware River on 71 tows during 1972 (Table 3.12). Seven of the ten most dominant forms during 1971 repeated in 1972. Brevoortia tyrannus, Lucania parva, and Menidia beryllina replaced Bairdiella chrysura, Hyporhamphus unifasciatus, and Cynoscion nebulosus in the dominant list. The consistency of these two data set signifies the widespread use of shoal habitat by juvenile marine species and resident estuarine species.

Collections in Beaverdam Creek in 1971 and 1972 (Tables 3.13 and 3.14) reveal an increase in species with increased effort and the downstream displacement of freshwater fishes by Hurricane Agnes in 1972. Even in the freshwater reaches sampled, forage fishes were quite abundant.

Fishes taken in the beach seine survey of the East River were similar in species dominance in 1971 and 1972 (Tables 3.15 and 3.16 and Fig. 3.3). Six species of the ten most dominant forms in each year were dominant in both collection periods. Decreased effort is the most likely cause of the smaller number of species in 1972. As in the Ware River, potential prey for striped bass abounds in the East River during the summer months. In both years, eight out of the ten most dominant species were shared by the two rivers. Our selection of the East River as a control stream to monitor the impact of striped bass stocking on prey populations appears to have been appropriate due to the high number of shared dominant fishes in the nearshore area. Our examination of the data to date does not indicate prey stock reduction in the Ware River. The survival of significant numbers of striped bass, however, would be required before any change in the forage fish crop due to predation could be ascertained. As described earlier, we do not have strong evidence of a significant survival of striped bass from our stocking operations.

Beach seine collections in Mobjack Bay proper (22 tows) produced a species list (29 species) and incidence record which was very similar to that of the East and Ware rivers (Table 3.17). This was the only area in which Orthopristis chrysoptera, Stenostomus chrysops, and Eucinostomus argenteus were taken by beach seine. These data indicate the general shorewide dispersion of juvenile marine and estuarine fishes and the significance of these areas as nurseries for many commercial and sport species. Of primary significance also is the absence of striped bass in the species list. If juvenile striped bass were to migrate from the York River system into the Mobjack Bay system or vice versa, then shoreline dispersion is highly likely. They should have appeared in our samples. However, fall migrations of striped bass into deeper, more saline waters in response to colder temperatures on the shoals would not be detected in our seine survey (due to time of samples and depth of water at the sample sites). The trawl survey was to demonstrate the winter movements of striped bass within the Mobjack Bay system.

Diversity values for beach seine collections in the Mobjack Bay system approximated those we reported for the Piankatank River and were equivalent in the two years of sampling (Table 3.18). Diversity (H') is a statistic which embodies both the abundance and species composition aspects of the community. Though its use as a general descriptor of habitat and biota has come under scrutiny recently, it is a useful tool for comparative purposes within defined geographic regions. Species richness (R) and evenness (J') are the secondary statistics used to evaluate the fluctuations in H'. They are measures of the number of species within a community and the distribution of individuals among species within the community, respectively. The data collectively do not show a response in the fish community to our stocking of striped bass in the Ware River, nor a difference between the Ware and East River communities.

C. Benthic Invertebrates in Mobjack Bay.

INTRODUCTION

Many small embayments, minor rivers, and creeks are found in the lower Chesapeake Bay region of Virginia. The biology of these smaller systems is relatively unknown compared to major river systems such as the James, York, and Rappahannock rivers.

Mobjack Bay and its tributaries are located just north of the York River mouth and exemplify the smaller systems in lower Chesapeake Bay (Fig. 3.1). Attributes of the system include: total surface area of 121 km^2 (26.7 $mile^2$); tributary surface areas of 14.2 km^2 in the Severn River, 17 km^2 in the Ware River, 17.6 km^2 in the North River, and 7.1 km^2 in the East River; maximum depth of 11.5 m; depths in tributary rivers range from 3-7 m in the channels with broad flats to either shore; and depths in the bay range from 6-9 m. The drainage basin is primarily swampy in the tributary headwaters. Most property contiguous to the system is in larger tracts with farms, estates, and single family dwellings predominating shoreline development.

This report stems from an evaluation of Mobjack Bay as a nursery ground for stocked striped bass, _Morone saxatilis_, and summarizes results of benthic surveys of the system conducted in 1970-1971. These data provide substantial information for the meso-polyhaline zone of lower Chesapeake Bay and are expected to aid management agencies in their evaluation of proposed developments in habitats of this type.

MATERIALS AND METHODS

Twenty sampling stations were selected in the Mobjack Bay system: 6 in the bay proper, 3 in the Severn River, 4 in the Ware River, 4 in the North River, and 3 in the East River (Fig. 3.1). R/V Pathfinder and several smaller vessels belonging to the Virginia Institute of Marine Science served as platforms for collections during cruises.

Salinity, temperature and dissolved oxygen at the surface and bottom of the water column were determined monthly at each station from July 1970 through June 1971. Water samples were returned to the laboratory for analysis of salinity by an induction salinometer and dissolved oxygen by the modified Winkler method.

Faunal and sediment samples were obtained with a modified Peterson grab (0.067 m^2). Three replicate bottom samples were taken at each station in August,1970. One of these samples was returned to the laboratory for analysis of particle size using the methods of Folk (1961). The two remaining samples in August collections and the two replicates at each station taken in February 1971 were analyzed separately for benthic macrofauna. Each sample was washed through a 1 mm mesh sieve in the field. Materials retained in this sieve were preserved in 5% formalin and returned to the laboratory for sorting, identification (to species where possible) and enumeration.

Dominant faunal species were defined for the pooled replicates from each station and each collection period by a biological index (Fager, 1957). The biological index (BI) was computed by assigning rank values (5 to 0) to all species in the order of decreasing abundance at each station. Species received an average rank value in cases of equal abundance among two or more species. Average BI per species per collection period was obtained by summation of rank values across all stations and division by the number of stations sampled (20).

Homogeneity of faunal distribution within the study area was evaluated by dominance affinity indices between all possible station pairs (Saunders, 1960). Percent composition of the fauna at given station pairs were inspected, the lesser percent for each co-occurring species was tabulated, and the summation of these percentages in the index value for that pair of stations. Station similarity was considered high when the index was $\geq$ 40%. Data were summarized in a trellis diagram for each collection period.

Diversity of the benthic macroinvertebrate fauna in the Mobjack Bay system was expressed as H'. The formula for H' in the units of information bits per individual is defined by

$$-\Sigma p_i \log_2 p_i,$$

where p_i is the proportion of the total individuals in a sample belonging to the i-th species. The working formula, which closely approximates Shannon's H', presented by Lloyd, Zar, and Karr (1968) was used:

$$H' = -\frac{c}{N}(N \log_{10} N - n_i \log n_i)$$

where N is the total number of individuals in the i-th species, and c is a constant for conversion of $\log_{10}$ to $\log_2$ (=3.322).

Species richness and evenness were calculated since H' diversity may reflect the number of species in a sample, distribution of individuals among the species in a sample or both. Species richness was calculated as d = S-1/ln N after Margalef (1958) and evenness was calculated as $J' = H'/\log_2 S$ after Pielou (1969), where S is the number of species in the sample and N is the total number of individuals in a sample.

RESULTS

Monthly values and seasonal trends in salinity and temperature were similar for stations in the bay proper and in all four tributaries (Table 3.19). The average monthly range in bottom salinity was 3.95 o/oo. Greatest variation of bottom salinity between stations occurred in March (20.41 o/oo at MJ1 and 13.25 o/oo at MN4). The minimum ranges in bottom salinity occurred in January (20.55 o/oo at MJ3 and 19.21 o/oo at MW4). The average monthly range in water temperature was 4 C. The greatest range in water temperature occurred in April (7.0 to 12.0 C) and the minimal range occurred in August (25.6 to 26.8 C). Dissolved oxygen remained near saturation except during summer months. Lowest DO values were obtained in July.

Most stations in the study area were in the silty clay category relative to sediment particle sizes, but four of the more exposed sites were quite high in sand content (Fig. 3.4 and Table 3.20). Silt and clay fractions exceeded 88% of the sediment at all stations in the tributary streams except station MN1 which had 88.7% sand. Stations within Mobjack Bay were more variable in sediment particle size than were stations in tributaries. Stations MJ1, MJ4, and MJ6 contained over 75% sand; station MJ5 had a rather even mixture of sediment particle sizes; station MJ2 was classified as a clayey sand station; and station MJ3 approximated the sediment type found at tributary stations.

The species complement and density of organisms in the study area on a station to station basis revealed a more speciose fauna in summer and a greater density of animals in winter (Table 3.20). Average number of species encountered in summer (August = 17.9) was greater than that during the winter (February = 14.6). The average density of organisms per station was approximately two times higher in winter than in summer (2192 versus 1150 individuals m^{-2}). The number of species per station ranged from 7 to 30 in February and from 5 to 32 in August. Density of organisms ranged from 361 to 18,186 individuals m^{-2} in February and 97 to 4147 individuals m^{-2} in August. A decreasing or equal number of species was present at seven stations from the August to February collections. Density of organisms at 13 stations, however, was lower in August than in February.

Ninety-nine different organisms, representing eight phyla, were identified from the samples in the Mobjack Bay system (Table 3.21). August samples contained a total of 75 species while February samples contained a total of 76 species.

Fifty-two species were taken during both sampling periods. Annelida was the most speciose phylum encountered (35 species), followed by Mollusca (29 species: 12 Pelecypoda and 17 Gastropoda) and Arthropoda (26 species). A total of 80 species were found in the combined river samples and 74 species were present only in the samples from the bay stations. The bay and tributary habitat shared 55 species in the combined summer and winter collections.

Habitat characterization of the benthic invertebrate fauna in the Mobjack Bay system was adequately described by species dominance lists (Table 3.22). Eighty percent of all organisms collected in August belonged to the ten dominant species. Faunal composition at individual stations ranged from 32 to 99% of the samples belonging to the dominant species in August collections. The 10 dominant species included 93% of all organisms in the February collections and ranged from 63 to 99% for individual stations (Table 3.23).

Ampelisca abdita (amphipod) and *Paraprionospio pinnata* (polychaete) were the most dominant (B.I. = 3.88 and 3.43 in winter and 3.08 and 2.80 in summer, respectively) and widespread (occurred at 19 stations) species in the invertebrate fauna of the Mobjack Bay system during both seasons. *A. abdita* (identification tentative; see Mills, 1964 and Feely and Wass, 1971) accounted for 19.5% of all organisms in summer collections and 35% of all organisms in winter collections. The high percentage for *A. abdita* in winter collections was attributed to the capture of 2199 individuals at station MJ4. *P. pinnata* represented 28% of the total individuals present in February collections and 21% of the total individuals in the August collections. P. pinnata and Ampelisca spp. represented over 20% of the fauna at 12 and 14 stations respectively in the February collections. The range in percent composition at individual stations was broad for both species: 0 to 79% for P. pinnata and 0 to 90.2% for Ampelisca spp. These two organisms represented over 50% of the fauna at 15 stations in February. The range of percent composition at individual stations in the August collections was 0 to 95.2% for P. pinnata and 0.2 to 55.6% for Ampelisca spp. During August six station samples contained over 20% P. pinnata and nine contained over 20% Ampelisca spp. At nine stations over 50% of the organisms present were P. pinnata and Ampelisca spp.

Affinity indices suggested greater uniformity of benthic fauna within the Mobjack Bay system in winter than in summer (Figs. 3.5 and 3.6). Station similarity was presented in the form of a trellis diagram with shaded blocks representing station pairs with index values $\geq$ 40 and individual index values for station pairs entered below the diagonal of the matrix. The overall mean index value for August collections was 31.1. Three stations (MJ1, MJ6, and MW4) were not highly similar to any other station in the system (Fig. 3.5). Stations MW1, MW2, MW3, MN4, ME1, ME2, M51, M52, and MJ4 were highly similar to each other in species composition (index values ranged from 40 to 76). Station MJ5 was highly similar to all of the above stations except MW1 (index = 36). The overall mean index of similarity for February collections was 42.4 (Fig. 3.6). Significant similarity existed in 57% of the possible station comparisons. Stations MN3 and MW1 were similar to 16 other stations in the system. Only station MJ6 lacked high affinity with all other stations (index values from 2 to 27).

Diversity (H') was lower in winter than in summer and appeared to reflect evenness to a greater extent than species richness (Fig. 3.7). Mean H' value for the combined sampling periods was 2.43 bits/individual. The mean H' for August collections was 2.68 bits/individual (range = 0.47 to 4.03) and equalled 2.19 bits/individual in February collections (range = 0.74 to 3.49). Highest diversity was obtained at station MS3 in August (H' = 4.03) and had a species richness value in excess of 6.0. The lowest diversity occurred at station MN3 in August (H' = 0.37) and was accompanied by very low richness and evenness values.

DISCUSSION

The Mobjack Bay system has the characteristics of a meso-polyhaline habitat (Carriker, 1967). The salinity gradient in the study area is similar to that found in the York River between its mouth and the confluence of the Mattaponi and Pamunkey rivers (VIMS, unpublished data). Steep salinity gradients exist in the area of the meso-oligohaline interface in the York River and the tributary rivers of Mobjack Bay. Smaller size of Mobjack tributaries results in an abbreviated transition zone relative to salinity. The oligohaline zone appears to be virtually nonexistent in the Mobjack system. Axial transects indicate salinity changes from 7 o/oo to 1 o/oo in less than 200 m.

Seasonal changes in species occurrence and abundance coupled with hydrographic parameters resulted in low faunal affinity between stations within given tributaries and shifts in station affinities between the two sampling periods. The total species complement encountered in the August and February samples was nearly equal. However, February samples had a greater proportion of the total number of organisms belonging to a few species than did samples taken in August. Affinity relationships shown by the winter collections probably represented stable portions of the benthic faunal community in the Mobjack Bay system more accurately than did summer collections.

Seasonal differences in station affinities represent changes in abundance of dominant organisms rather than community or species changes. The winter and summer matrices representing station affinity suggested different areas of similarity with season. But only nine station pairs having high affinity in August fall into the nonsignificant affinity category in February. Six out of the ten dominant species occurred on this list for both seasons. The average BI of these shared dominant species was 1.66 while the average BI of single season dominants was 0.51. Incidence of encounter was also higher for the shared dominant species (average = 15.75 stations) than for single season dominants (average = 10.5 stations). Differences in total BI for shared dominant species between seasons was not great (winter = 10.28 versus summer = 9.67). Similarly, total BI for single season dominant species were in close agreement (winter = 2.10 versus summer = 2.01).

Differences in species dominance between our data for the Mobjack Bay system and that of Boesch (1971a) for the York River were attributed to water depth in the study area. The occurrences of more abundant species in the Mobjack Bay system conforms to their position within the salinity gradient predicted from Boesch's results. However, dominant species in our samples are different from those in the meso-polyhaline zone of the York River (Boesch's station numbers 3 through 8). The high degree of dominance shown by P. pinnata, Retusa canaliculatum, and Leucon americanus was similar to data from the York River. But dominance of Ampelisca in the Mobjack Bay system was not expected. Orth (1971), however, reported dominance of Ampelisca in collections from shallow water in the York River. Stations in the Mobjack Bay system did not exceed 7.5 m (average depth = 4.4 m) while stations in the York River reported by Boesch were deeper. Substrate types were very similar in the York River and Mobjack system with the exception of four Mobjack stations which had high sand content in the sediments. Thus, differences in water depth at sampling sites could account for the variations in faunal dominance in the Mobjack Bay system relative to that in the York River.

The meso-polyhaline interface was confirmed as an area of declining informational diversity from higher levels in the polyhaline zone to lower values in the oligohaline zone. H' values for stations in the Mobjack Bay system were lower than those of the Chesapeake Bay-York River polyhaline zone but higher than those of the York-Pamunkey River meso-oligohaline zone reported by Boesch (1972). The Mobjack Bay study area included two salinity divisions found in the York River-lower Chesapeake Bay system and had intermediate diversity values for the benthic invertebrate fauna.

The benthic invertebrate fauna in the Mobjack Bay system was generally similar to that reported for Hampton Roads in the James River (Boesch, 1971b) and the Elizabeth River (Richardson, 1971) with the exception of the high dominance of *Ampelisca* in the Mobjack Bay system. *Paraprionospio pinnata* assumed greater importance in faunal abundance for Mobjack Bay system although it was one of the dominant species in the fauna of the York, James, and Elizabeth rivers.

The benthic invertebrate community of the Mobjack Bay system and probably most other small meso-polyhaline subsystems in the lower Chesapeake Bay contains elements which would classify it as a mildly polluted habitat although its shoreline is relatively free of development. Selection and use of indicator organisms representative of degrees of habitat pollution is a desirable goal for management and monitoring coastal waters. Richardson (1971) and Boesch (1972) attempted this for the lower Chesapeake Bay. Low dissolved oxygen has been recorded during early summer at the mouths of tributary streams and in Mobjack

Bay (VIMS, unpublished data). The major river tributaries to lower Chesapeake Bay characteristically experience the same phenomenon near the mouth of the river in early summer. Thus benthic fauna is subjected to oxygen stress conditions on an annual basis. Given these conditions, only highly tolerant, pioneer, or mobile forms would be expected to assume dominance in affected areas. Two such tolerant forms are Paraprionospio and Ampelisca. The abundance of these forms in the benthic invertebrate fauna of the Mobjack Bay system, however, does not connote pollution stress of the type found in metropolitan or industrialized areas. Rather, the interaction of natural factors can produce environmental conditions and changes in the fauna which mimic pollution stress. We consider the species associations herein described as representative of the numerous shallow, polyhaline systems of Chesapeake Bay which are relatively nondisturbed.

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D. Epibenthic Faunal Survey in the Mobjack Bay System.

Successful stocking of striped bass sac fry and juveniles is dependent upon an adequate supply of preferred food organisms in the area stocked. Young striped bass feed upon copepods, cladocerns, mysids, decapods, and polychaetes to varying degrees and preferences change as the fish grow (Meshaw, 1969 and Markle and Grant, 1970). Species lists of food items suggest that young striped bass feed mostly on or near the bottom. We undertook a qualitative survey of epibenthic fauna within the Mobjack Bay system to assess food availability for stocked fish, presence of naturally spawned eggs or larvae of striped bass, and presence of competitor or predator fishes.

Methods

Samples were obtained by towing a sled and secured to have a D-shaped opening lowered to the bottom and towed for five minutes. Tows were repeated if the gear rose off the bottom or dug deeply into the sediments. Upon retrieval, the net was washed down and the concentrated sample was transferred from the net to a quart jar. The sample was then fixed with 5% formalin and returned to the laboratory for analysis. Hydrographic data for near bottom water (temperature, dissolved oxygen, and salinity) were recorded before each sample.

Station locations for the epibenthic survey were the same as those of the trawl survey (Fig. 3.1). Twenty stations were sampled every other month during the contract year 1970-1971. Eleven stations were sampled every second month during 1971-1972 (stations in the Severn and North rivers as well as MJ 4-6 were deleted during AFS 6-2).

Sample analysis was completed in the laboratory. Rough sorting divided the epibenthic samples into major taxa (i.e., crustaceans, molluscs, fishes, etc.). Final sorting, identification, and enumeration of the major groups were completed during contract year AFS 6-3. Identification was to species, where possible. A reference collection for epifauna was developed as sample sorting proceeded. Data were entered on sorting logs, summarized by collection period on tally sheets, and compiled as an overall species list.

Results and Discussion

Hydrographic data for nearbottom water in the Mobjack Bay system were very consistent across stations for a given collection period. Temperatures during the study period ranged from a high 28.1 C (MN 3 and MW 4 in August, 1970) to a low of 2.2 C (MJ 2 in February, 1971). Seasonal trends reveal highest average water temperatures in August (26 C) and lowest values in February (4-5 C) (Table 3.24). Dissolved oxygen was generally 5 ppm or greater at all stations when we sampled epibenthic fauna. Lower DO values were typically obtained during June and August than during other sampling periods. Salinity was higher during the fall and winter seasons than in spring and summer (Table 3.25). Variation in salinity between stations in a given sample interval was typically less than 5%.

The species list developed from the epibenthic data included over 155 species representing 12 phyla (Table 3.26). Cnidarians were represented by a total of 19 species: 14 species of Hydrozoa, 3 species of Scyphozoa, and 2 species of Anthozoa. Two species of Ctenophora were collected: Mnemiopsis leidyi and Beroe ovata. Several species of Platyhelminthes and Nematoda were encountered but are unidentified at the present time. Rhynchocoela were represented by Cerebratulus sp and several unidentified forms. Electra crustulenta and several unidentified forms represented the Ectoprocta. Annelida species encountered in the Mobjack Bay system were listed in Job 3 C (benthic infauna). The phylum Mollusca was represented by over 12 species, larval forms were not identified. Arthropoda was the most speciose phylum in the collections (3 classes, 11 orders, and 79 species). Copepoda (7 species), Isopoda (6 species), Amphipoda (20 species), and Decapoda (34 species) were the most abundant and speciose orders of Arthropoda. Chaetognatha was represented by four species. Echinodermata was represented by three species and several unidentified larval forms. Chordata representatives included Mogula larvae and 23 species of fish.

Seasonality of the epibenthic fauna abundance and species occurrence parallels that of the fish fauna with greatest abundance and diversity during summer and low abundance and diversity in winter. Summer collections (June and August were dominated by copepods, decapod larvae, anchovy eggs, and fish larvae with relatively low numbers of cnidarians. October collections contained large numbers of copepods, cnidarians, and decapod larvae but very few fishes. Winter and spring collections were poor in a species sense with mysids, cumacians, Crangon, and *Sagitta elegans* reaching their greatest abundance. In February and April ctenophores and *Cyanea* reached their peak abundance and most other organisms were very low in abundance.

The extensive species list and abundance of Copepoda, Isopoda, Amphipoda, and Decapoda (larvae) suggest adequate food reserves within the Mobjack Bay system to support a stocked population of striped bass during the first year of life.

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E. Biology of Striped Bass in the Mobjack Bay System.

Adult striped bass enter Mobjack Bay during the spring spawning migration but do not successfully reporduce in that area. Gill net collections in the Ware and East rivers confirm the presence of mature male striped bass. Food items in the stomach contents of these fish verify their penetration into freshwater. However, we have not taken any mature female striped bass in these collections. The only reported capture of a mature female striped bass was at the mouth of Wilson Creek, Ware River. Discussions with local residents and sportfishermen, however, confirm an occasional capture of "large striped bass" (= mature females?) in the Mobjack Bay system during the spring migration. Our data (gill net, D-net, beach seine, and trawl) do not substantiate a successful natural spawning of striped bass in the system.

We consider the adult striped bass in the Mobjack Bay system to be strays from the spawning population in the York River. Attributes of the rivers in the Mobjack Bay system (flow, bottom, and size of freshwater zone) would effectively limit successful spawning even if mature individuals of both sexes were present. Those few striped bass juveniles which were obtained in the Mobjack Bay system prior to our 1971 stocking program could have originated in the York River and dispersed into the study area since there was a strong year class of striped bass in the York River in 1970. Food supply was not considered to be a factor limiting the success of stocking young striped bass since forage organisms for juvenile striped bass(decapod larvae, mysids, isopods, and fishes) are abundant during the summer months throughout the Mobjack Bay system. Trawl and D-net collections

(Job 3 C and D) produced large numbers and diversity of prey organisms in the tributary streams and few predatory species. Young striped bass are known to feed upon zooplankton, epibenthic crustaceans, and small fishes during their first year of life. Thus we had high hopes for the survival of striped bass placed in the Mobjack Bay system by project personnel.

Too few juvenile striped bass were taken in the Ware and East rivers of Mobjack Bay after our stocking programs of 1971 and 1972 to reliably compare growth and condition of stocked fish to fish from the York River (Table 3.27). A total of nine juvenile striped bass up to 96 mm FL (x = 85.2 mm) were captured in the Ware River during the 1971 and 1972 beach seine surveys (3 August 1971 at station MW 68). Striped bass young-of-the-year in the York River during the first half of August, 1971 ranged from 67 to 88 mm FL ($\bar{x}$ = 75.0 mm, n = 9). Comparison by student's t test for equal sample size, unequal variance (Steel and Torrie, 1960) indicates that striped bass in Mobjack Bay were significantly larger than in the York River (t = 3.14, df 8). We consider this difference to be attributable to sampling site differences in forage availability and density of competitor fishes. The York River series included six fish from Mile 43 in the Mattaponi River (freshwater) while the Mobjack Bay sample was from an area of over 10% salinity. Striped bass from the York River during this period in an area of comparable salinity (i.e., Y 19 and Y 28) averaged 83 mm FL (N=3). Thus growth of striped bass in the Mobjack Bay and the York River was more nearly equal when salinity in the areas of capture was considered.

Seasonal utilization of the Mobjack Bay system by striped bass seems to parallel that shown by other fishes. Juvenile striped bass disperse into a mesohaline area (salinity 5-19 where food supply and food item diversity is great during the summer months. Growth of striped bass in Mobjack Bay during the summer is equivalent to that of striped bass in the mesohaline zone of the York River. With the approach of winter, declining water temperatures in the shoal areas prompt a general movement of fishes to deeper waters of higher salinity and temperature. Striped bass behavior in the York River follows this pattern, thus the fish would be expected to respond similarly in Mobjack Bay. Our samples in the deeper areas of Mobjack Bay, however, have produced very few fish during the winter months and no striped bass. Striped bass, therefore, appear to leave the Mobjack system in cold weather. The most probable fate of striped bass leaving the Mobjack Bay system during the winter months would be to mix with and join the York River population. In this manner stocked fish would be lost from the system on an annual basis. It is unlikely that those immigrant fish in the York River would leave their new area of residence with the advent of the spring season since food would be plentiful there also. The migratory patterns of stocked fish upon attainment of sexual maturity, however, may bring them back to the Mobjack Bay system. An evaluation of this will be made by reported captures of sexually mature striped bass in the Mobjack Bay system during the 1974 and 1975 spawning seasons.

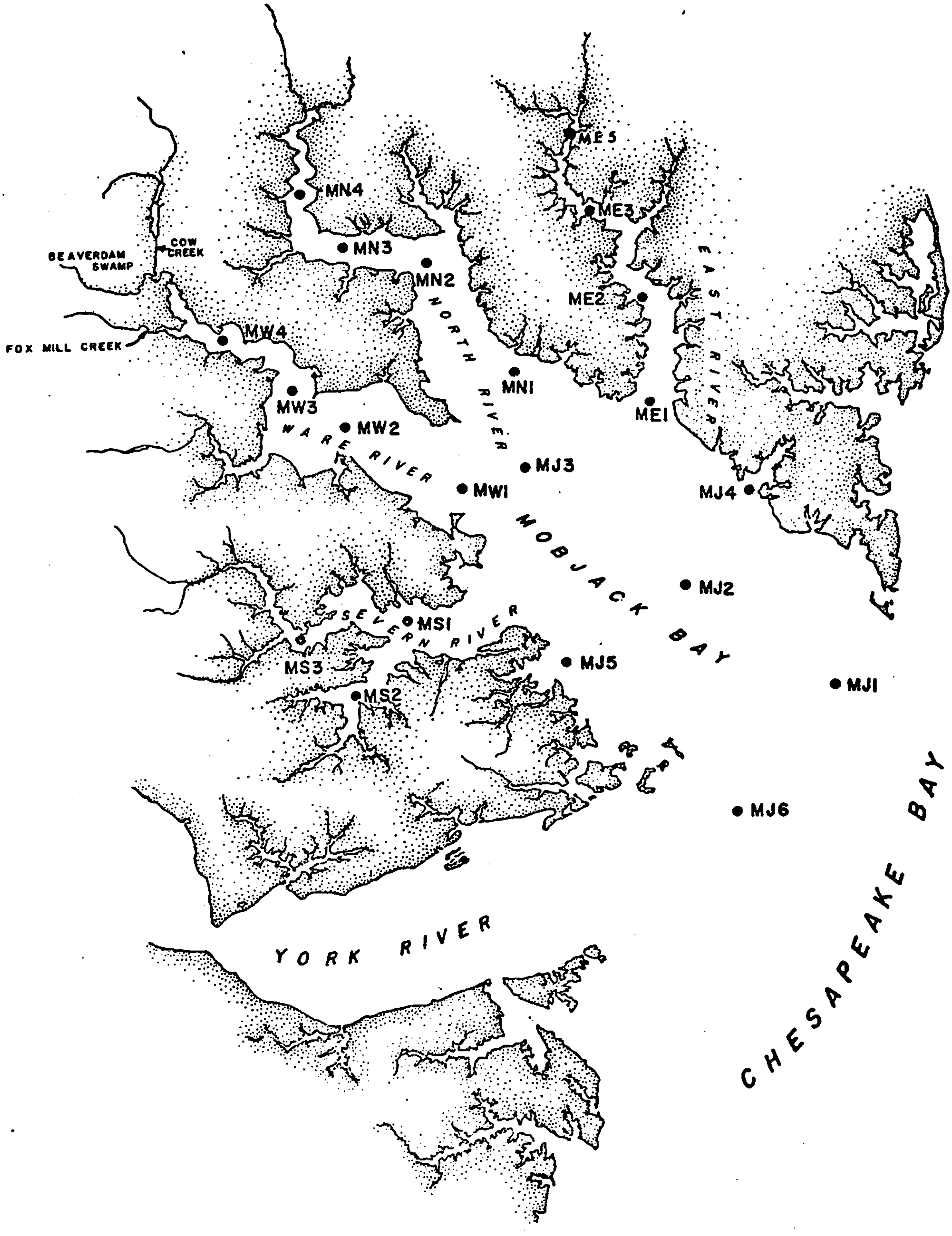

Figure 3.1. Mobjack Bay and tributary streams showing station locations for trawl samples 1970-1973.

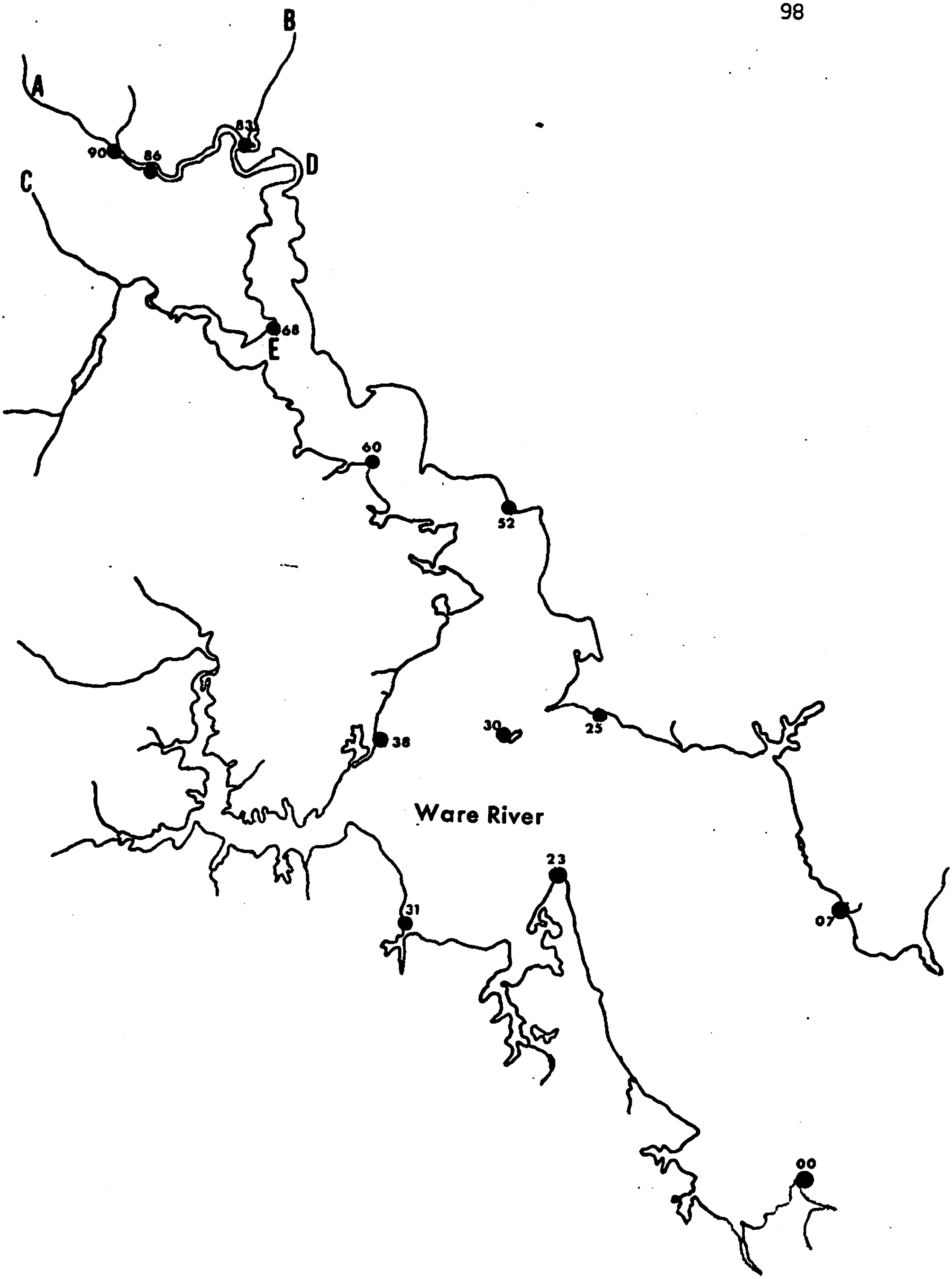

Figure 3.2. Detailed sketch of the Ware River, Mobjack Bay showing beach seine stations and stocking sites for 1971 and 1972.

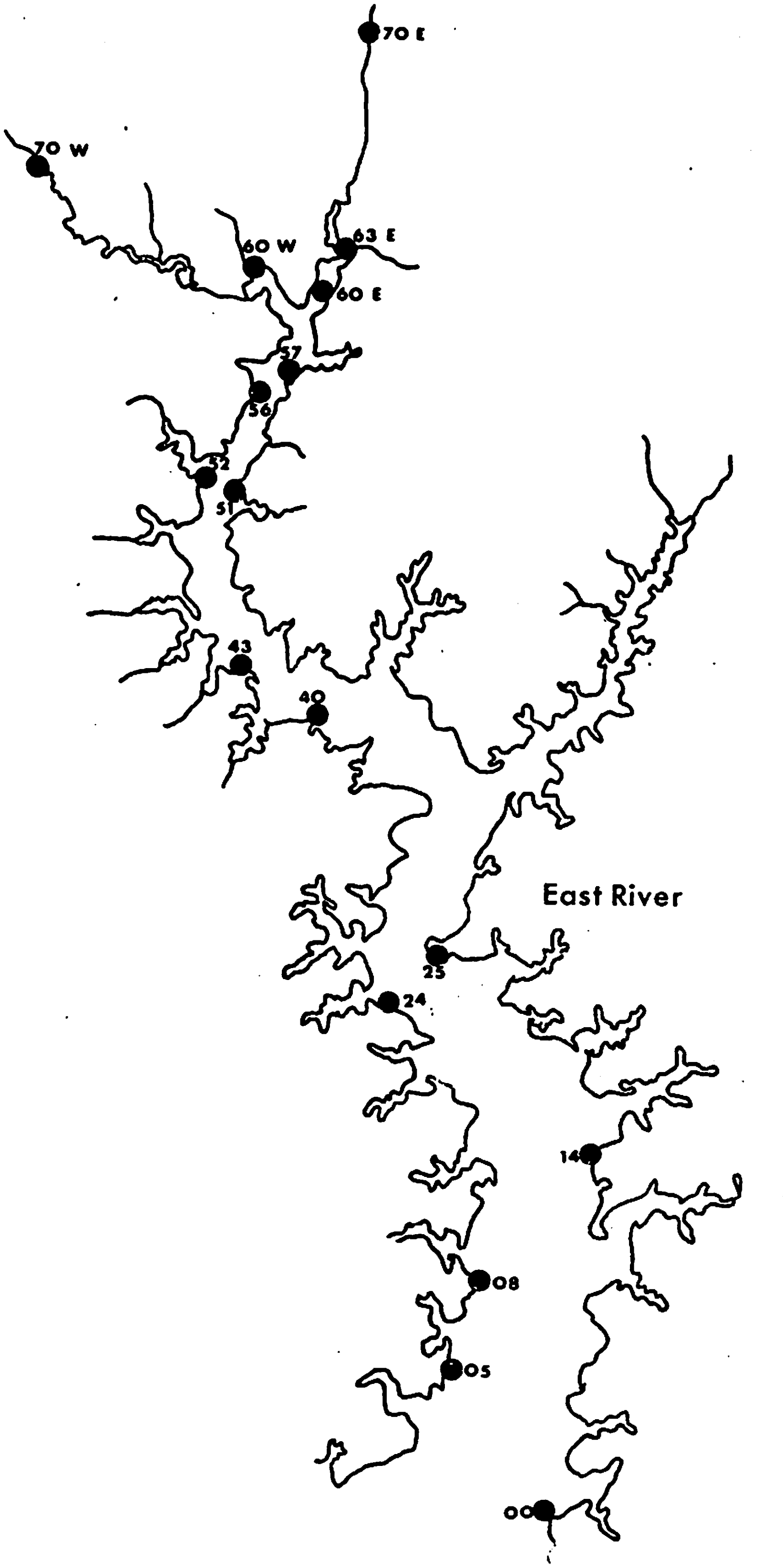

Figure 3.3. Detailed sketch of the East River, Mobjack Bay showing beach seine stations occupied in 1971 and 1972.

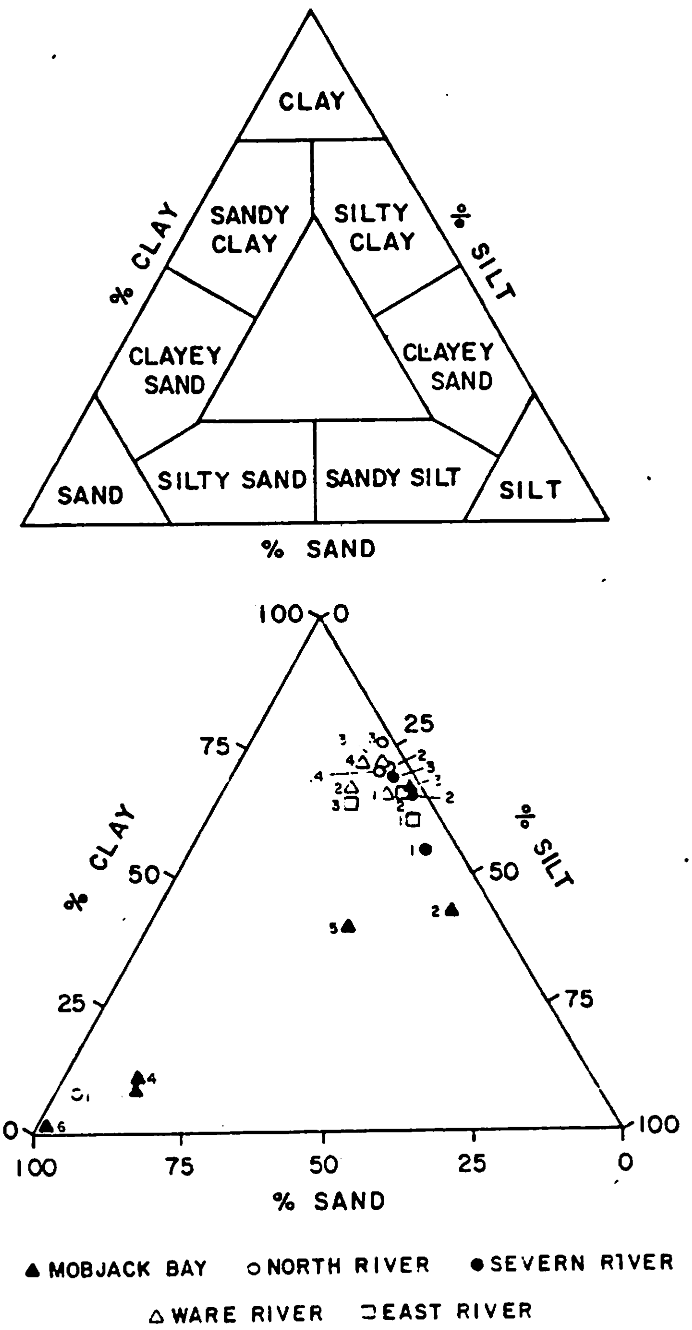

Figure 3.4. Sediment particle size classification for stations within the Mobjack Bay system.

	MW1	MN4	MJ4	MW2	MW3	ME2	ME1	MS2	MS1	MJ5	MJ3	MN2	MN3	MJ1	MJ2	MW4	MS3	ME3	MJ6	MN1
MW1		*	*	*	*	*	*	*	*		*	*	*							
MN4	67		*	*	*	*	*	*	*	*										
MJ4	55	56		*	*	*	*	*	*	*										
MW2	57	70	71		*	*	*	*	*	*										
MW3	51	45	48	58		*	*	*	*	*										
ME2	49	48	59	69	63		*	*	*	*										
ME1	44	49	48	51	48	58		*	*	*										
MS2	47	53	45	52	53	51	49		*	*					*			*		
MS1	46	48	76	71	44	63	49	40		*										
MJ5	36	45	64	63	45	63	50	41	62											
MJ3	47	22	30	36	37	35	27	32	22	17		*	*							
MN2	50	22	31	37	32	32	24	37	24	23	64									
MN3	41	16	14	25	26	23	17	22	12	10	64	21								
MJ1	5	5	16	7	8	10	11	5	10	8	20	14	2		*					
MJ2	17	18	30	21	19	31	26	40	37	24	36	26	9	50						*
MW4	22	34	27	28	27	31	36	30	32	28	22	28	13	12	19		*			
MS3	24	37	30	31	21	30	28	36	30	34	21	27	12	10	17	43				
ME3	36	37	31	25	27	34	29	41	26	22	20	29	22	2	9	36	30			
MJ6	18	27	30	14	23	20	16	28	20	16	17	14	4	17	19	23	14	24		
MN1	31	29	29	17	9	15	11	17	23	10	26	21	4	36	46	17	13	7	22	

* $\geq$ 40

Figure 3.5. Trellis diagram of affinity indices for station pairs during August collections (= summer) in Mobjack Bay system.

	MN3	MW1	MS1	MN2	ME2	MS2	ME3	MJ3	MW3	MN4	MJ1	MN1	MJ5	MJ4	MS3	MW2	ME1	MW4	MJ2	MJ6
MN3		*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*			
MW1	76		*	*	*	*	*	*	*	*	*	*	*	*	*	*	*			
MS1	74	59		*	*	*	*	*	*	*	*	*	*	*						
MN2	73	58	73		*	*	*	*	*	*	*	*	*	*	*				*	
ME2	74	58	85	74		*	*	*	*	*	*	*	*	*					*	
MS2	67	73	44	55	46		*	*	*	*					*	*	*	*	*	
ME3	61	57	55	58	49	71		*	*	*	*	*			*	*	*	*	*	
MJ3	67	70	49	59	49	68	53		*						*	*	*			
MW3	65	85	46	47	46	76	60	68		*					*	*	*	*		
MN4	68	52	68	78	68	42	47	38	40		*	*	*	*						
MJ1	49	44	52	51	46	36	49	33	31	47		*	*	*					*	
MN1	46	43	46	49	44	32	40	31	32	52	52		*	*						
MJ5	55	41	48	61	58	32	34	30	30	63	45	45		*						
MJ4	54	42	67	58	75	27	31	32	28	62	47	47	87							
MS3	57	67	34	45	35	78	57	69	76	32	25	24	20	17		*	*	*		
MW2	49	70	32	31	32	61	41	53	72	23	15	14	12	13	66		*			
ME1	55	62	37	32	36	65	45	54	64	25	17	16	14	15	69	65			*	
MW4	34	36	30	28	23	50	58	33	40	16	25	11	8	8	43	37	36			
MJ2	38	37	38	41	35	48	41	35	38	20	41	32	22	25	36	29	50	28		
MJ6	3	2	2	4	2	10	10	27	6	2	5	21	3	3	20	4	4	7	10	

* $\geq$ 40

Figure 3.6. Trellis diagram of affinity indices for station pairs during February collections (= winter) in Mobjack Bay system.

Table 3.1. Species list and abundance of fishes taken by trawl in Mobjack Bay from July 1973 through June 1973.

Species	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Total
Anchoa mitchilli	218	9	190	Boat Inoperable	53	3	1	No Fish	Boat Inoperable	374	Boat Inoperable	132	980
Bairdiella chrysura		1	3										4
Brevoortia tyrannus										7			7
Cynoscion regalis	3	2	30										35
Leiostomus xanthurus	23	29	40									430	522
Micropogon undulatus		2	13										15
Paralichthys dentatus			1									1	2
Peprilus alepidotus		3											3
Peprilus triacanthus		2											2
Pseudopleuronectes americanus												1	1
Syngnathus floridae						1							1
Syngnathus fuscus					1								1
Trichiurus lepturus		1				1							1
Urophycis regius										1			1
Total fish	244	49	277	-	54	4	1	0	-	382	-	564	1575
# Species	3	8	6	-	2	2	1	0	-	3	-	4	14

Table 3.2. Species list and abundance of fishes taken by trawl at 4 stations in the East River, Virginia from July 1972 through June 1973.

Species	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Total
Alosa aestivalis				B		91	N	N	B	36	B		127
Alosa pseudoharengus				o			o	o	o		o	1	1
Anchoa mitchilli	472	225	513	a	444	2			a	126	a	333	2115
Auguilla rostrata		1		t					t		t	2	3
Bairdiella chrysura	8	35	144				F	F					187
Brevoortia tyrannus	1			I			i	i	I	88	I	72	161
Centropristis striata	1			n			s	s	n		n		1
Chasmodes bosquianus			1	o			h	h	o		o		1
Cynoscion regalis	3	11	10	p					p		p	2	26
Gobiosoma bosci				e					e		e	1	1
Leiostomus xanthurus	297	230	103	r	1				r		r	422	1053
Menidia menidia				a		1			a	11	a		12
Microgobius thallassinus			1	b					b		b		1
Micropogon undulatus		13		l	1				l		l		14
Opsanus tau	3	1	4	e					e		e	4	12
Paralichthys dentatus												1	1
Peprilus alepidotus		4											4
Trichiurus lepturus	1												1
Trinectes maculatus	1	6	6										13
Total Fish	787	526	782	-	446	94	0	0	-	261	-	838	3734
# Species	9	9	8	-	3	3	0	0	-	4	-	9	19

Table 3.3. Species list and abundance of fishes taken at 4 stations in the Ware River, Virginia from July 1972 through June 1973.

Species	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Total
Alosa aestivalis										7			7
Alosa pseudoharengus		1						12					13
Alosa sapidissima				B			N		B	1	B		1
Anchoa mitchilli	456	99	647	o	1308		o		o	237	o	473	3220
Anguilla rostrata		3		a					a		a	1	4
Bairdiella chrysura	2	47	37	t					t		t		86
Brevoortia tyrannus							F			1		6	7
Cynoscion nebulosus		1		I			i		I		I		1
Cynoscion regalis	3	5	25	n			s		n		n		33
Gobiosoma bosci		1		o			h		o		o		1
Hypsoblennius hentzi		1		p					p		p		1
Leiostomus xanthurus	100	254	110	e					e		e	1761	2225
Menidia menidia				r		6			r		r		6
Micropogon undulatus	1	4	29	a					a		a		34
Opsanus tau		3	4	b					b		b	2	9
Paralichthys dentatus			2	l					l		l		2
Peprilus alepidotus		5	3	e					e		e		8
Pomatomus saltatrix		1	1										2
Trinectes maculatus	1		6										7
Total Fish	563	425	864	-	1308	6	0	12	-	246	-	2243	5667
# Species	6	13	10	-	1	1	0	1	-	4	-	5	19

Table 3.5. Fish species list with incidence and dominance ranking (mean Biological Index) developed from 16' semi-balloon trawl catches in Mobjack Bay and its tributaries, May to October 1970.

Species	Mobjack Bay			Severn River			Ware River			North River			East River		
	I	B.I.	R	I	B.I.	R	I	B.I.	R	I	B.I.	R	I	B.I.	R
Anchoa mitchilli	10	3.0	1	6	4.17	1	8	4.81	1	6	2.94	2	6	3.50	2
Bairdiella chrysura	6	2.0	2	5	3.83	2	6	2.69	2	6	3.25	1	6	4.00	1
Cynoscion regalis	7	1.96	3	5	2.50	3	3	1.44	3	3	1.00	3	6	2.33	4
Trinectes maculatus	6	1.33	4	1	0.17	5	2	0.50	5	2	0.44	6	4	0.83	5
Leiostomus xanthurus	7	1.28	5							2	0.31	8	2		
Menticirrhus americanus	3	0.50	6							2	0.50	5	1	0.33	7
Paralichthys dentatus	4	0.40	7							1					
Micropogon undulatus	4	0.38	8				1	0.38	6	2	0.44	7	2		
Anchoa hepsetus	1	0.33	9	1	0.17	8	1	0.31	7						
Prionotus carolinus	1	0.17	10												
Chaetodipterus faber	1	0.13	11	1	0.17	7							1		
Syngnathus fuscus	1	0.08	12				1	0.19	8						
Sphoeroides maculatus	1	0.08	13												
Pseudopleuronectes americanus	1	0.08	14	1	0.17	6									
Monacanthus hispidus	1	0.08	15												
Opsanus tau	2	0.03	16	5	1.83	4	2	0.88	4	4	0.81	4	5	2.83	3
Gobiesox strumosus	1														
Gobiosoma bosci	1			1						1	0.28	9	3		
Peprilus triacanthus	1														
Hypsoblennius hentzi	1														
Urophycis regius	1														
Morone saxatilis				1			1	0.19	9	1			2	0.83	6
Peprilus alepidotus				1											
Anguilla rostrata										1	0.06	10	1		
Chasmodes bosquianus										1			2		
Microgobius thalassinus													2	0.17	8

Table 3.6. Fish species list with incidence and dominance ranking (mean Biological Index) developed from 16' semi-balloon trawl catches in Mobjack Bay and its tributaries, May to October 1971.

Species	Mobjack Bay I	Mobjack Bay B.I.	Mobjack Bay R	Severn River I	Severn River B.I.	Severn River R	Ware River I	Ware River B.I.	Ware River R	North River I	North River B.I.	North River R	East River I	East River B.I.	East River R
Anchoa mitchilli	4	2.75	1				12	2.75	2	2	1.88	2	12	2.37	2
Urophycis regius	5	2.70	2				2	0.45	8	1	1.13	5	1	0.05	14
Leiostomus xanthurus	3	1.92	3	2	2.25	3	13	2.83	1				18	3.76	1
Prionotus carolinus	4	1.58	4												
Syngnathus fuscus	3	1.33	5							1	1.13	6	1	0.21	11
Sphoeroides maculatus	4	0.95	6							1	0.88	7			
Centropristis striata	1	0.83	7	1	1.00	5	1	0.12	12				1	0.11	13
Menidia menidia	1	0.75	8												
Bairdiella chrysura	1	0.67	9				9	1.33	3				12	1.40	4
Gobiosoma bosci	1	0.25	10	2	1.35	4	2	0.38	9	3	2.75	1	5	0.42	9
Etropus microstomus	1	0.17	11												
Trinectes maculatus	1	0.03	12	3	2.35	2	4	0.48	6				12	0.83	7
Paralichthys dentatus	1	0.03	13							1	0.75	8			
Microgobius thalassinus	1	0.03	14	2	0.75	6	2	0.32	10				5	0.63	8
Opsanus tau				3	3.43	1	9	1.03	5	1	1.25	4	15	2.03	3
Anguilla rostrata				2	0.17	7	2	0.04	15	2	1.50	3	1		
Apeltes quadracus				1											
Peprilus alepidotus							6	0.46	7				6	0.84	6
Peprilus triacanthus							1	0.12	11						
Morone saxatilis							2	0.11	13				4	0.22	10
Chasmodes bosquianus							1	0.04	14				1		
Anchoa hepsetus							1								
Chaetodipterus faber							2						1		
Cynoscion nebulosus							1								
Cynoscion regalis							8	1.13	4				11	1.29	5
Menticirrhus americanus							1						2	0.02	15
Synodus foetens							2						2	0.13	12

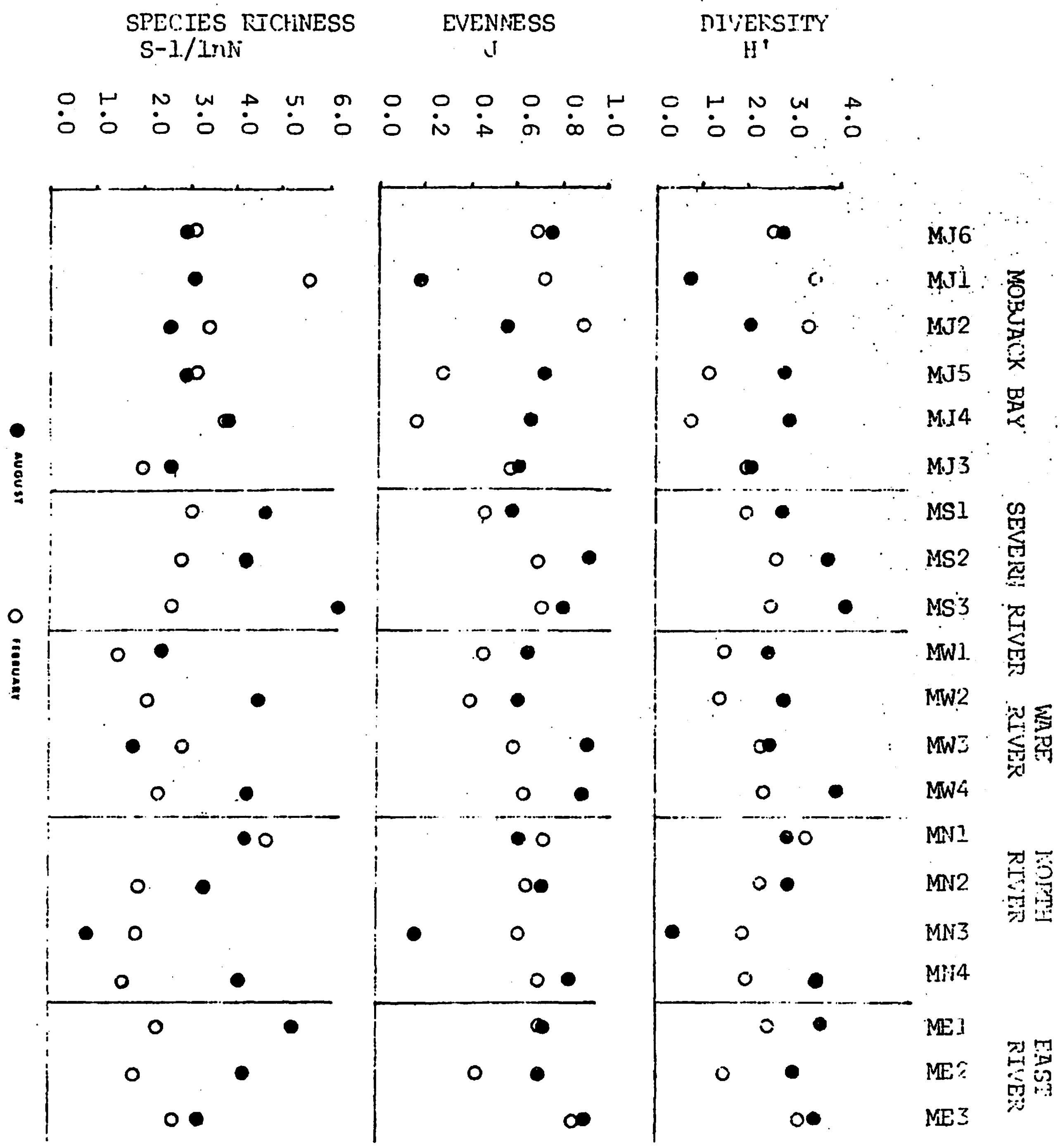

Figure 3.7. H' diversity, evenness, and species richness of benthic invertebrates for August and February collections in the Mogjack Bay system.

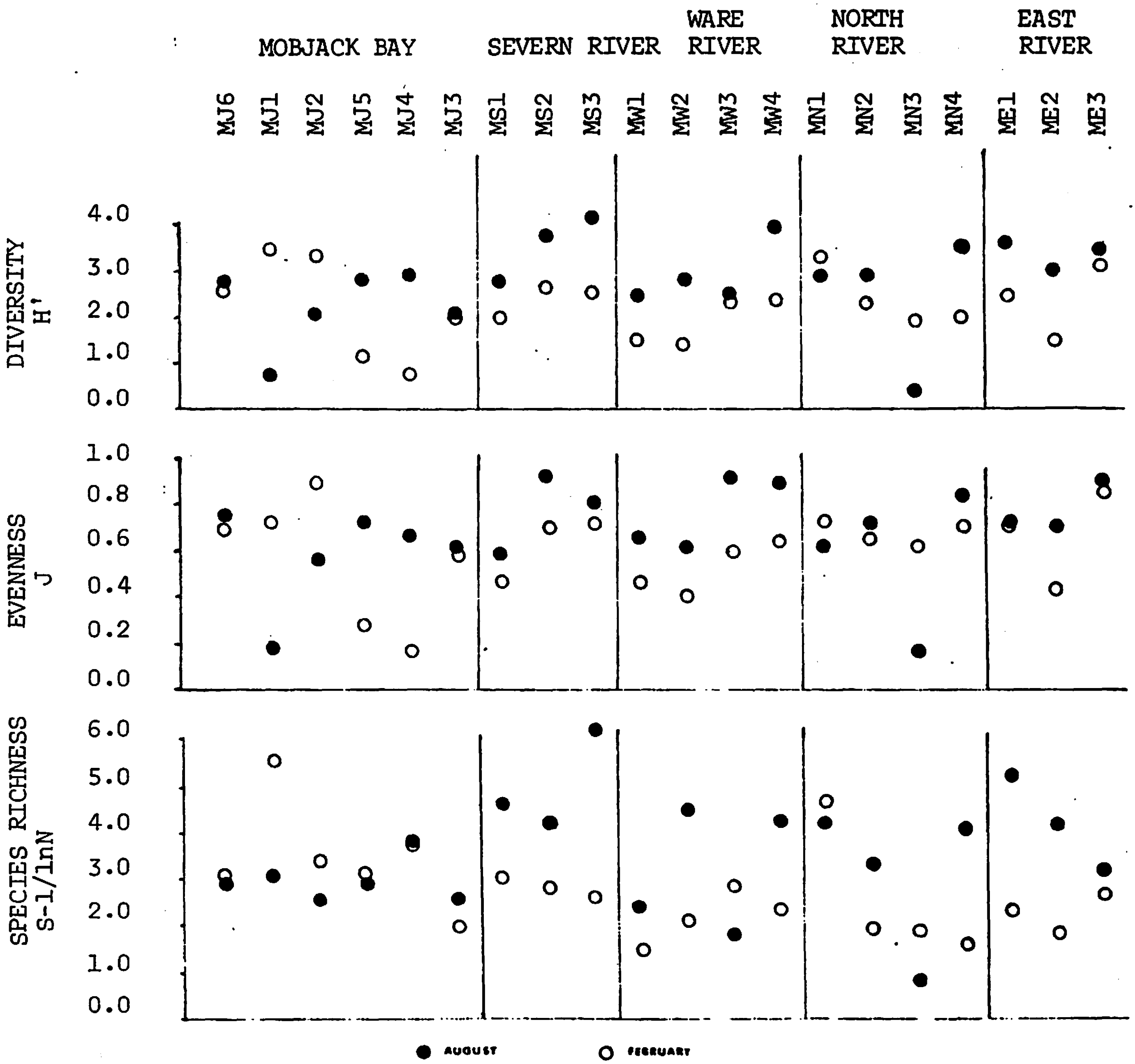

Figure 3.7. H' diversity, evenness, and species richness of benthic invertebrates for August and February collections in the Mogjack Bay system.

Table 3.7. Fish species list with incidence and dominance ranking (mean Biological Index) developed from 16' semi-balloon trawl catches in Mobjack Bay and its tributaries, May to October 1972.

Species	Mobjack Bay			Ware River			East River			York River		
	I	B.I.	R	I	B.I.	R	I	B.I.	R	I	B.I.	R
Anchoa mitchilli	7	3.67	1	19	4.63	1	20	4.48	1	6	2.94	1
Leiostomus xanthurus	5	2.44	2	16	3.28	2	16	3.43	2	3	0.69	5
Cynoscion regalis	4	0.96	3	7	0.60	5	6	0.53	5	3	0.50	7
Bairdiella chrysura	4	0.57	4	6	0.70	4	9	1.43	3			
Centropristis striata	1	0.44	5	1	0.08	14	1	0.02	15			
Peprilus alepidotus	1	0.33	6	4	0.30	6	3	0.17	12			
Micropogon undulatus	2	0.33	7	6	0.70	3	3	0.22	9	4	2.25	2
Prionotus carolinus	1	0.28	8	1	0.03	13	1	0.13	13			
Syngnathus fuscus	1	0.18	9									
Peprilus triacanthus	1	0.11	10									
Brevoortia tyrannus				2	0.28	7	3	0.58	4			
Trinectes maculatus				3	0.23	8	6	0.25	8	4	2.00	3
Opsanus tau				2	0.15	9	7	0.29	7	2	0.50	6
Syngnathus floridae				1	0.13	10						
Pomatomus saltatrix				3	0.13	11						
Gobiosoma bosci				2	0.13	12	2	0.30	6			
Anguilla rostrata				1	0.08	15	1	0.02	16			
Paralichthys dentatus				1	0.03	16						
Alosa pseudoharengus				1								
Cynoscion nebulosus				1								
Hypsoblennius hentzi				1								
Trichiurus lepturus							2	0.19	11			
Microgobius thalassinus							2	0.20	10			
Etropus microstomus							1	0.05	14			
Chasmodes bosquianus							1					
Ictalurus catus										3	1.06	4
Symphurus plagiusa										1	0.25	8
Morone americana										2	0.06	9

Table 3.8. Fish species list with incidence and dominance ranking (mean Biological Index) developed from 16' semi-balloon trawl catches in Mobjack Bay and its tributaries, November 1970 to April 1971.

Species	Mobjack Bay			Severn River			Ware River			North River			East River		
	I	B.I.	R	I	B.I.	R	I	B.I.	R	I	B.I.	R	I	B.I.	R
Anchoa mitchilli	4	3.08	1	1	1.67	3	2	2.50	1	2	2.50	1			
Micropogon undulatus	5	2.83	2							2	1.50	3			
Menticirrhus americanus	2	0.87	3												
Cynoscion regalis	1	0.58	4							1	0.75	4			
Gobiesox strumosus	1	0.50	5												
Menidia menidia	1	0.42	6	1	1.67	1	1	1.25	3						
Membras martinica	1	0.42	7												
Raja eglanteria	2	0.28	8												
Urophycis regius	1	0.25	9												
Opsanus tau	1	0.03	10				1	1.25	2						
Hypsoblennius hentzi	1	0.03	11												
Bairdiella chrysura	1	0.03	12	1	1.67	2				2	1.56	2	1	1.67	2
Morone saxatilis				1	1.33	4							1	1.33	3
Syngnathus fuscus							1	1.00	4	1	0.56	5			
Gobiosoma bosci										1	0.56	6	1.	1.67	1
Chasmodes bosquianus										1	0.56	7			
Alosa sapidissima													1	1.00	4

Table 3.9. Fish species list with incidence and dominance ranking (mean Biological Index) developed from 16' semi-balloon trawl catches in Mobjack Bay and its tributaries, November 1971 to April 1972.

	Mobjack Bay			Severn River			Ware River			North River			East River		
Species	I	B.I.	R	I	B.I.	R	I	B.I.	R	I	B.I.	R	I	B.I.	R
Anchoa mitchilli	3	1.13	1	2	0.92	3	5	1.57	1				8	2.75	1
Menidia menidia	2	0.83	2	1	0.83	4							1	0.32	9
Syngnathus floridae	2	0.63	3	1	0.75	5				1	0.56	4	3	0.79	3
Gobiosoma bosci	2	0.58	4	2	1.22	2	4	1.17	2	1	0.38	7	3	0.75	4
Anguilla rostrata	1	0.42	5												
Alosa aestivalis	1	0.42	6	1	0.58	9							1	0.36	7
Urophycis regius	1	0.25	7												
Apeltes quadracus	1	0.25	8										2	0.18	12
Microgobius thalassinus				3	2.42	1	3	0.90	3	4	2.44	1	3	1.07	2
Fundulus majalis				1	0.58	6									
Fundulus diaphanus				1	0.58	7									
Alosa pseudoharengus				1	0.58	8									
Pseudopleuronectes americanus				1	0.38	10	1	0.33	7	3	1.63	2			
Chasmodes bosquianus				1	0.25	12									
Hypsoblennius hentzi				1	0.38	11									
Micropogon undulatus							3	0.80	4				2	0.57	5
Leiostomus xanthurus							2	0.47	5						
Trinectes maculatus							1	0.33	6				2	0.39	6
Morone saxatilis							1	0.33	8						
Opsanus tau							1	0.30	9						
Lucania parva							1	0.30	10	1	0.56	5	1	0.18	10
Cynoscion regalis							2	0.27	11						
Bairdiella chrysura							2	0.10	12						
Paralichthys dentatus							2	0.03	13						
Syngnathus fuscus										1	0.63	3	1	0.32	8
Gobiesox strumosus										1	0.44	6			
Cyprinodon variegatus													2	0.18	11

Table 3.10. Fish species list with incidence and dominance ranking (mean Biological Index) developed from 16' semi-balloon trawl catches in Mobjack Bay and its tributaries, November 1972 to April 1973.

Species	Mobjack Bay I	Mobjack Bay B.I.	Mobjack Bay R	Ware River I	Ware River B.I.	Ware River R	East River I	East River B.I.	East River R
Anchoa mitchilli	8	2.82	1	4	0.81	1	7	1.40	1
Menidia menidia	3	0.89	2	1	0.21	5	1	0.15	8
Syngnathus fuscus	2	0.64	3				1	0.17	6
Prionotus carolinus	2	0.52	4				1	0.21	4
Alosa pseudoharengus	2	0.50	5						
Syngnathus floridae	1	0.29	6	1	0.21	3			
Alosa aestivalis	1	0.29	7				2	0.42	3
Pseudopleuronectes americanus	1	0.21	8						
Urophycis regius	1	0.16	9						
Microgobius thalassinus	1	0.16	10						
Trinectes maculatus				1	0.21	2			
Opsanus tau				1	0.21	4			
Apeltes quadracus				1	0.19	6			
Brevoortia tyrannus							2	0.42	2
Cyprinodon variegatus							1	0.21	5
Micropogon undulatus							1	0.15	7
Leiostomus xanthurus							1	0.15	9

Table 3.11. Species list, incidence, and dominance ranking (mean B.I.) for fishes in Ware River taken by beach seine during July to November 1971. (Total number of stations = 42)

Species	Incidence	Mean B.I.
Menidia menidia	40	4.24
Fundulus majalis	35	2.17
Leiostomus xanthurus	28	1.93
Fundulus heteroclitus	25	1.55
Anchoa mitchilli	10	.69
Bairdiella chrysura	13	.65
Hyporhampus unifasciatus	14	.35
Strongylura marina	17	.33
Cyprinodon variegatus	4	.27
Cynoscion nebulosus	14	.26
Brevoortia tyrannus	11	.12
Lucania parva	8	.11
Chasmodes bosquianus	6	.10
Gobiesox strumosus	6	.08
Apeltes quadracus	2	.08
Morone americana	2	.07
Menidia beryllina	1	.05
Opsanus tau	4	.05
Chaetodipterus faber	1	.05
Syngnathus floridae	4	.04
Gobiosoma bosci	6	.03
Sciaenops ocellata	3	.02
Syngnathus fuscus	2	.02
Sphoeroides maculatus	3	.02
Syngnathus spp.	2	.01
Fundulus diaphanus	1	
Hypsoblennius hentzi	1	
Microgobius thallassinus	1	
Morone saxatilis	6	
Peprilus alepidotus	3	
Trinectes maculatus	4	
Anguilla rostrata	3	
Paralichthys dentatus	2	

Table 3.12. Species list, incidence, and dominance ranking (mean B.I.) for fishes in the Ware River taken by beach seine during May to October 1972. (Total number of stations = 71)

Species	Incidence	Mean B.I.
Menidia menidia	69	4.03
Fundulus heteroclitus	45	1.97
Leiostomus xanthurus	48	1.90
Fundulus majalis	48	1.87
Anchoa mitchilli	32	1.11
Brevoortia tyrannus	14	0.75
Menidia beryllina	17	0.42
Cypinodon variegatus	14	0.37
Lucania parva	14	0.20
Strongylura marina	8	0.11
Trinectes maculatus	5	0.10
Gobiosoma bosci	5	0.08
Cynoscion nebulosus	15	0.08
Anchoa hepsetus	2	0.08
Synodus foetens	3	0.06
Morone saxatilis	3	0.06
Mugil cephalus	3	0.05
Syngnathus fuscus	2	0.04
Mugil curema	2	0.04
Elops saurus	3	0.04
Pomatomus saltatrix	1	0.02
Membras martinica	2	0.02
Opsanus tau	3	0.01
Chasmodes bosquianus	2	0.01
Bairdiella chrysura	3	
Apeltes quadracus	2	
Gobiesox strumosus	2	
Menticirrhus saxatilis	1	
Micropogon undulatus	1	
Syngnathus floridae	1	
Peprilus triacanthus	1	
Morone americana	1	
Sciaenops ocellata	1	

Table 3.13. Species list, incidence, and dominance ranking (mean B.I.) for fishes in the upper Ware River (Beaverdam Creek) taken by beach seine during July to November 1971. (Total number of stations = 5)

Species	Incidence	Mean B.I.
Menidia beryllina	4	3.10
Fundulus diaphanus	4	2.90
Fundulus heteroclitus	4	2.85
Brevoortia tyrannus	2	0.85
Leiostomus xanthurus	1	0.45
Anchoa mitchilli	1	0.45
Notropis hudsonius	1	0.20
Bairdiella chrysura	1	0.10
Morone saxatilis	1	
Strongylura marina	1	

Table 3.14. Species list, incidence, and dominance ranking (mean B.I.) for fishes in Beaverdam Creek (upper Ware River) taken by beach seine during May to October 1972. (Total number of stations = 8)

Species	Incidence	Mean B.I.
Menidia beryllina	6	2.95
Anchoa mitchilli	2	1.19
Fundulus diaphanus	3	0.90
Notemigonus crysoleucas	2	0.88
Leiostomus xanthurus	2	0.88
Morone americana	2	0.75
Fundulus heteroclitus	1	0.63
Menidia menidia	2	0.58
Brevoortia tyrannus	1	0.50
Trinectes maculatus	1	0.20
Etheostoma nigrum	1	0.20
Apeltes quadracus	2	0.13
Lepomis gibbosus	1	
Enneacanthus gloriosus	1	
Micropterus salmoides	1	
Umbra pygmaea	1	

Table 3.15. Species list, incidence, and dominance ranking (mean B.I.) for fishes in the East River taken by beach seine during July to November 1971. (Total number of stations = 40)

Species	Incidence	Mean B.I.
Menidia menidia	36	3.54
Fundulus heteroclitus	25	2.10
Leiostomus xanthurus	28	1.94
Fundulus majalis	26	1.74
Bairdiella chrysura	8	.55
Opsanus tau	10	.49
Anchoa mitchilli	9	.33
Cyprinodon variegatus	7	.25
Trinectes maculatus	8	.21
Strongylura marina	13	.18
Anchoa hepsetus	4	.15
Brevoortia tyrannus	4	.13
Peprilus alepidotus	2	.13
Syngnathus fuscus	2	.12
Lucania parva	5	.12
Menidia beryllina	2	.11
Morone saxatilis	9	.11
Fundulus diaphanus	4	.10
Hyporhampus unifasciatus	1	.08
Gobiosoma bosci	8	.08
Cynoscion nebulosus	3	.08
Chasmodes bosquianus	1	.03
Alosa pseudoharengus	2	.01
Syngnathus floridae	2	.01
Microgobius thalassinus	1	.01
Morone americanus	2	.01
Apeltes quadracus	1	.01
Sciaenops ocellata	1	

Table 3.16. Species list, incidence, and dominance ranking (mean B.I.) for fishes in the East River taken by beach seine during May to October 1972. (Total number of stations = 19)

Species	Incidence	Mean B.I.
Fundulus heteroclitus	13	2.79
Menidia menidia	15	2.57
Leiostomus xanthurus	9	1.92
Fundulus majalis	10	1.55
Anchoa mitchilli	6	1.05
Cyprinodon variegatus	2	0.55
Brevoortia tyrannus	1	0.26
Menidia beryllina	2	0.24
Gobiosoma bosci	2	0.21
Sciaenops ocellata	1	0.16
Lucania parva	2	0.16
Trinectes maculatus	1	0.12
Eucinostomus argenteus	1	0.12
Anchoa hepsetus	3	0.08
Apeltes quadracus	1	
Bairdiella chrysura	1	
Mugil curema	1	

Table 3.17. Species list, incidence, and dominance ranking (mean B.I.) for fishes in the lower Mobjack Bay taken by beach seine during July to November 1972. (Total number of stations = 22)

Species	Incidence	Mean B.I.
Menidia menidia	18	3.57
Leiostomus xanthurus	17	2.73
Fundulus majalis	18	2.27
Fundulus heteroclitus	15	1.57
Anchoa mitchilli	12	0.93
Menidia beryllina	10	0.70
Cyprinodon variegatus	6	0.52
Hyporhampus unifasciatus	6	0.45
Strongylura marina	8	0.23
Sphoeroides maculatus	2	0.14
Syngnathus fuscus	4	0.11
Lucania parva	3	0.07
Cynoscion nebulosus	5	0.05
Alosa pseudoharengus	1	0.05
Chasmodes bosquianus	1	0.02
Anchoa hepsetus	1	
Anguilla rostrata	4	
Apeltes quadracus	3	
Bairdiella chrysura	2	
Brevoortia tyrannus	1	
Gobiesox strumosus	2	
Menticirrhus saxatilis	1	
Opsanus tau	1	
Orthopristis chrysoptera	1	
Paralichthys dentatus	3	
Pomatomus saltatrix	1	
Stenotomus chrysops	1	
Syngnathus floridae	2	
Eucinostomus argenteus	1	

Table 3.18. Summary of Mobjack Bay beach seine data for stations made in July to November 1971 and May to October 1972. (S_D = Standard deviation, S_M = Standard error)

			H'					
Sample Area	Date	Stations	$\bar{H}'$	S_D	S_M	Range	$\bar{R}$	$\bar{J}'$
Ware River (MW00-MW70)	1971	41	1.53	0.64	0.10	0.15-2.71	1.21	0.60
Upper Ware (Beaverdam Creek)	1971	5	1.38			0.36-2.43	0.90	0.77
East River (ME00-ME63E)	1971	39	1.54	0.86	0.14	0.03-3.02	1.22	0.61
Lower Mobjack	1972	21	1.40	0.78	0.17	0.14-2.91	1.20	0.59
Ware River (MW00-MW70)	1972	71	1.38	0.58	0.07	0.08-2.44	1.04	0.60
Upper Ware (Beaverdam Creek)	1972	6	1.50			0.73-2.31	1.45	0.72
East River (ME00-ME63E)	1972	19	1.38	0.77	0.18	0.09-3.46	0.93	0.69

$H' = - \quad p_i \log_2 P_i$; $R = (S-1)/\log_E N$, and $j' = H'/\log_2 S$

Table 3.19. Summary of bottom hydrographic data for stations in the Mobjack Bay system between July 1970-June 1971.

		Temperature (°C)	Salinity (‰)	Dissolved Oxygen (ppm.)
Mobjack Bay	High	27.3 (MJ5,Sept.)	23.3 (MJ1,Aug.)	12.2 (MJ5,Jan.)
	Low	0.0 (MJ4,Jan.)	15.3 (MJ6,June)	2.9 (MJ1,July)
	Mean	14.9	18.4	8.1
Severn River	High	27.3 (MS3,Sept.)	22.3(MS1,Nov.)	11.9 (MS2,Jan.)
	Low	0.0 (MS2-3,Jan.)	12.8 (MS2,June)	2.7 (MS1,Sept.)
	Mean	15.2	18.2	8.0
Ware River	High	28.3 (MW4,Sept.)	21.9 (MW1,Nov.)	12.4 (MW3,Jan.)
	Low	0.5 (MW4,Jan.)	14.8 (MW4, March)	3.0 (MW2, July, Sept.)
	Mean	15.1	18.1	8.2
North River	High	28.1 (MN3,Aug.)	22.2 (MN2,Nov.)	12.1 (MN1-4,Jan.)
	Low	0.5 (MN3,Jan.)	13.3 (MN4, March)	3.4 (MN3,June)
	Mean	16.0	18.4	7.9
East River	High	27.9 (ME3,Aug.Sept)	22.1 (ME1-2,Nov.)	12.2 (ME2,Jan.)
	Low	1.0 (ME1-2-3,Jan.)	15.0 (ME3,June)	4.7 (ME2,Aug.)
	Mean	14.9	18.6	8.1

Table 3.20. List of stations, water depth, sediment type, shell, number of species and number of individuals per square meter in the Mobjack Bay system during February and August collection periods.

		Sediments				February		August	
Station	Depth m	% Sand	% Silt	% Clay	Other	Species	Ind/m^2	Species	Ind/m^2
MS1	7.0	5.2	39.8	55.0	shell+	19	3149	27	2231
MS2	2.0	2.0	32.0	66.1	shell	13	567	17	351
MS3	2.5	3.3	27.0	69.8	shell	11	388	32	1194
MW1	5.5	6.7	27.5	66.3	shell	10	4828	13	1202
MW2	5.0	11.5	21.5	67.0	shell++	11	970	24	1306
MW3	3.0	3.7	23.9	72.4		14	761	6	127
MW4	2.0	7.1	20.1	72.8	shell	12	858	20	701
MN1	2.5	88.7	3.3	8.0	shell+	24	1134	26	2366
MN2	7.0	3.4	25.7	70.9	shell+	11	1559	17	1045
MN3	3.5	1.3	22.8	76.0		9	658	5	1082
MN4	2.5	4.5	25.0	70.5	shell	7	1470	19	641
ME1	8.0	4.1	34.5	61.5	shell	10	403	27	1164
ME2	5.5	2.8	30.9	66.2	shell	11	1962	20	739
ME3	3.5	13.2	22.1	64.7		13	761	16	447
MJ1	7.5	78.6	12.9	8.5		29	1238	20	4149
MJ2	5.5	7.1	50.0	42.9		13	361	14	1126
MJ3	7.0	1.0	32.2	66.8		11	1216	11	403
MJ4	3.0	77.3	11.4	11.3		30	18186	22	1955
MJ5	2.5	25.8	33.7	40.3		19	2839	14	671
MJ6	3.0	98.0	0.4	0.6		14	522	8	97
					Mean	14.6	2192	17.9	1150

Table 2.21. List of species from benthic collections in Mobjack Bay, Virginia. Incidence of encounter is given for bay stations (B) and for each tributary (S,W,N, and E) during August 1970 and February 1971.

		Incidence of Encounter									
		August					February				
Phylum	Species	B	S	W	N	E	B	S	W	N	E
CNIDARIA	Edwardsia elegans	5	2		2	1	2	3	2		2
	Diadumene leucolena	1	2	2		1				1	1
RHYNOCHOCOELA	spp.	1		1		2	3	1		1	
PHORONIDA	Phoronis architecta	4	3	2	3	2	2	2	1		2
ANNELIDA	Capitella capitata						1				
	Cirriformia filigera						2				
	Clymenella torquata		1	1	2					1	
	Eteone heteropoda						1				
	Glycera americana		2	1	3	2					
	Glycera dibranchiata	1				1	1				
	Glycera robusta		1								
	Glycinde solitaria	4	3	2	3	3	3	3	4	2	2
	Gyptis vittata		1			2					
	Heteromastus filiformis	1					1				
	Hydroides hexagona		2	1						1	
	Lumbrinereis tenuis		1		1						
	Maldanopsis elongata	1		1		2		1	3		
	Melinna maculata	2	2	3		1	2			1	
	Nephtys incisa	3		1		2	2			1	1
	Nephtys picta		1				1		1		
	Nereis succinea	3	3	2	3	3	6	3	4	4	1
	Notomastus latericus	1				1	2				
	Paranaitis speciosa			1							
	Paraprionospio pinnata	5	3	4	4	3	5	3	4	4	3
	Pectinaria gouldii		1				1				
	Phyllodoce arenae						3	1			
	Phyllodoce sp.					1	1			1	1
	Polydora ligni						2	1		1	
	Polynoidae sp.	1	1	1		1	1	1			
	Potamilla neglecta		1	1		1					
	Pseudeurythoe paucibranchiata	2	2	1		2	2		1	1	1
	Sabella microphthalma		1					1		1	
	Sabellaria vulgaris	1									
	Scale worm A		1						1		
	Scale worm B				1		1				
	Scolopolos robustus	2	2	2	2		1		2		1
	Sigambra tentaculata	2		2		1					
	Spiochaetopterus costarum oculatus	1		1	1		1				
	Spiophanes bombyx	1			1		1			1	

Table 3.21 (Continued)

		Incidence of Encounter									
		August					February				
Phylum	Species	B	S	W	N	E	B	S	W	N	E
MOLLUSCA Pelecypoda	Amygdalium papyria		1		1						
	Anadara ovalis						2			1	
	Crassostrea virginica			1							
	Ensis sp.									1	
	Gemma gemma	1	1		2		1				
	Macoma tenta	1					1				
	Mulinia lateralis	3	2	1	3	2	1	1	3	1	
	Mya arenaria	1							1	1	
	Nucula proxima						1				
	Tagelus plebeius				1						
	Tellina agilis				2		1	1		1	
	Venus mercenaria					1		1			
Gastropoda	Bittium sp.	1	1			2					
	Crepidula convexa	1	1		1		1				
	Corambella depressa						1				
	Elysia sp.						1				
	Epitonium rupicolum	2	3	1			1				
	Eupleura caudata			1		1					
	Haminoea solitaria	1			1						
	Mangelia plicosa	1	1		1						
	Mitrella lunata		1								
	Nassarius obsoletus						1				
	Nassarius trivittatus		1				1				
	Nassarius vibex	3	2	3	3		1				
	Odostomia bisuturalis	2	2	1	2					1	
	Odostomia impressa		1	1		1					
	Retusa canaliculatum	6	3	4	3	2	3	2	1	2	2
	Turbonilla interrupta	4		1	2						
	Urosalpinx cinerea		2								
ARTHROPODA Cirrepedia	Balanus improvisus						1				
Mysidacea	Mysidiopsis bigelowi	1	1		1	1					
Cumacea	Leucon americanus	1	2		1	1	3	3	4	3	3
	Oxyurostylus smithi	1		1	1		6	2	1	2	3
Isopoda	Cyathura polita		3	1			1				
	Edotea triloba	3	2	2	1	2	3	1	2		1

Table 3.21 (Continued)

Phylum	Species	Incidence of Encounter									
		August					February				
		B	S	W	N	E	B	S	W	N	E
Amphipoda	Ampelisca spp.				1						
	Ampelisca spp.	6	3	4	4	3	5	3	4	4	3
	Caprella geometrica							1			
	Corophium tuberculatum	1			1						
	Corophium simile						1				
	Elasmopus pocillimanus		1				1				
	Erichthonius brasiliensis						1				
	Gammarus mucronatus						2			1	
	Leptocheirus plumulosus						2	3	3	3	1
	Listriella barnardi			1	1	1	1			2	
	Listriella clymenellae	1			2		1				
	Melita nitida		1							1	
	Monoculodes edwardsi						2				
	Paraphoxus epistomus						2				
	Unciola irrorata						2				
Caridea	Alpheus heterochaelus		1								
	Ogyrides limnicola	5	2	4	2	2	3	1	2	1	2
Brachyura	Callinectes sapidus						2				
	Pinnotheres sp.									1	
	Xanthidae sp.						1				
ECHINODERMATA	Amphiodia atra	1	1	1		2	1				3
	Cucumaria pulcherrima		1	2	1	2	1	1	1		1
	Mellita quinquiesperforata						1				
CHORDATA	Molgula manhattensis			2		1	2	1			
	Microgobius thalassinus	2	1			2			1		

Table 3.22. Ten most dominant species during the February sampling period with average biological index (B.I.) and incidence of encounter.

Species	Average B.I.	Incidence of Encounter
Ampelisca abdita	3.88	19
Paraprionospio pinnata	3.43	19
Leucon americanus	1.60	16
Nereis succinea	1.08	18
Ogyrides limnicola	0.78	10
Oxyurostylus smithi	0.70	14
Retusa canaliculatum	0.63	10
Cucumaria pulcherrima	0.50	3
Glycinde solitaria	0.48	14
Leptocheirus plumulosus	0.30	12

Table 3.23. Ten most dominant species during the August sampling period with average B.I. and incidence of encounter.

Species	Average B.I.	Incidence of Encounter
Paraprionospio pinnata	3.08	19
Ampelisca abdita	2.80	20
Retusa canaliculatum	1.98	18
Phoronis architecta	0.93	14
Nereis succinea	0.78	14
Glycinde solitaria	0.58	15
Ogyrides limnicola	0.45	13
Scolopolus robustus	0.43	8
Nephtys incisa	0.35	6
Mulinia lateralis	0.30	11

Table 3.24. Average nearbottom water temperatures (C) and ranges by month in the Mobjack Bay system based upon data taken during an epibenthic survey (August, 1970 through June, 1972).

	1970			1971		
	Aug.	Oct.	Dec.	Feb.	Apr.	Jun.
Mean	26.6	23.2	10.4	4.4	9.6	24.9
Range	28.1- 19.7	24.1- 22.5	12.3- 9.3	6.2- 2.2	13.0- 7.0	27.1- 23.4
Number of Stations	20	20	20	20	20	20
	1971			1972		
	Aug.	Oct.	Dec.	Feb.	Apr.	Jun.
Mean	26.4	18.8	7.3	5.6	14.8	25.4
Range	27.2- 25.8	19.2- 18.4	9.0- 6.1	8.0- 4.3	18.2- 12.5	27.5- 23.5
Number of Stations	11	11	11	11	11	11

Table 3.25. Average nearbottom salinity (ppt) and ranges by month in the Mobjack Bay system based upon data taken during an epibenthic survey (August, 1970 through June, 1972).

	1970			1971		
	Aug.	Oct.	Dec.	Feb.	Apr.	Jun.
Mean	19.6	21.8	21.5	18.7	17.3	15.7
Range	23.3- 17.8	23.1- 20.1	22.0- 20.3	20.1- 15.9	18.5- 15.7	16.5- 12.8
Number of Stations	20	20	20	20	20	20
	1971			1972		
	Aug.	Oct.	Dec.	Feb.	Apr.	Jun.
Mean	19.3	19.2	18.4	18.2	16.2	15.1
Range	20.8- 13.6	20.6- 17.4	20.6- 15.2	21.6- 14.8	16.8- 15.1	17.5- 13.3
Number of Stations	11	11	11	11	11	11

Table 3.26. Taxonomic list of organisms taken during epibenthic collections in Mobjack Bay, Virginia between August, 1970 and June, 1972.

Phylum Cnidaria
- Class Hydrozoa
  - hydromedusae
    - Bougainvillia carolinensis
    - Bougainvillia rugosa
    - Cunina octonaria
    - Dipurena strangulata
    - Eucheilota ventricularis
    - Eutima mira
    - Liriope tetraphylla
    - Nemopsis bachei
    - Obelia spp.
    - Phialucium carolinae
    - Rathkea octopunctata
    - Turritopsis nutricula
  - hydroids
    - Dynamena cornicina
    - Sertularia argentea
- Class Scyphozoa
  - Aurelia aurita
  - Chrysaora quinquecirrha
  - Cyanea capillata
- Class Anthozoa
  - Diadumene leucolena
  - Edwardsia (elegans?)

Phylum Ctenophora
- Mnemiopsis leidyi
- Beroe ovata

Phylum Platyhelminthes
- Unidentified spp.

Phylum Rhynchocoela
- Cerebratulus fragments
- Unidentified spp.

Phylum Nematoda
- Unidentified spp.

Phylum Ectoprocta
- Electra crustulenta
- Unidentified spp.

Table 3.26 (Continued)

Phylum Annelida
- Class Polychaeta*
  - Autolytus sp.
  - Nereis epitokes

*Infaunal and epifaunal polychaete species listed in Job 3C (benthic infauna)

Phylum Mollusca
- Class Gastropoda
  - Bittium spp.
  - Crepidula convexa
  - Mitrella lunata
  - Pyramidellidae (several species)
  - Retusa canaliculata
  - Turbonilla spp.
  - Unidentified larvae
- Class Pelecypoda
  - Anadara spp.
  - Gemma gemma
  - Mulinia spp.
  - Mya arenaria
  - Tellina agilis
  - Tagelus plebeius
  - Unidentified larvae

Phylum Arthropoda
- Class Arachnida
  - Unidentified spp.
- Class Pycnogonida
  - Callipalene brevirostris
- Class Crustacea
  - Order Cladocera
    - Unidentified spp.
  - Subclass Ostracoda
    - Sarsiella spp.
    - Cyprideis spp.
  - Subclass Copepoda
    - Paracalanus parvus
    - Eurytemora affinis
    - Centropages hamatus
    - Acartia clausi
    - Acartia tonsa
    - Oithona brevicornis
    - Argulus spp.
  - Subclass Cirrepedia
    - Balanus spp. (cypris larvae)
  - Subclass Malacostraca
  - Order Mysidacea
    - Neomysis americana
    - Mysidopsis bigelowi
  - Order Cumacea
    - Leucon americanus
    - Oxyurostylis smithi
  - Order Isopoda
    - Cyathura polita
    - Edotea triloba
    - Erichsonella attenuata

Table 3.26 (Continued)

Class Crustacea (Continued)
- Idotea baltica
- Lironeca ovalis
- Sphaeroma quadridentatum

Order Amphipoda
- Ampelisca abdita
- Ampithoe longimana
- Batea catharinensis
- Cerapus tubularis
- Corophium acherusicum
- Corophium tuberculatum
- Corophium lacustre
- Cymadusa compta
- Elasmopus pocillimanus
- Gammarus mucronatus
- Jassa falcata
- Listriella barnardi
- Lysianopis alba
- Melita appendiculata
- Melita nitida
- Monoculodes edwardsi
- Stenothoe minuta
- Unciola irrorata
- Caprella geometrica
- Paracaprella tenuis

Order Decapoda
- Acetes americanus (L)
- Alpheus heterochaelis (L)
- Alpheus normanni (L)
- Callinectes sapidus (young crab)
- Crangon septemspinosa (L&A)
- Dissodactylus mellitae (L)
- Emerita talpoida (L)
- Euceramus praelongus (L)
- Eurypanopeus depressus (L)
- Hexaponopeus angustifrons (L)
- Hippolyte pleuracantha (L&A)
- Libinia spp. (L)
- Lucifer faxoni (L&A)
- Neopanope texana sayi (L)
- Ogyrides limnicola (L&A)
- Pagurus longicarpus (L)
- Pagurus pollicaris (L)
- Palaemonetes spp. (L)
- Palaemonetes pugio (A)
- Palaemonetes vulgaris (A)
- Panopeus herbstii (L)
- Pinnixa chaetopterana (L)
- Pinnixa cylindrica (L)
- Pinnixa sayana (L)
- Pinnotheres maculatus (L)
- Pinnotheres spp. (small crab)
- Polyonyx gibbesi (L)
- Rithropanopeus harrisii (L)

Table 3.26 (Continued)

Class Crustacea (Continued)
- Sesarma cinereum (L)
- Sesarma reticulatatum (L)
- Squilla empusa (L)
- Uca spp. (L)
- Upogebia affinis (L)
- Xanthidae spp. (small crab and megalops)

Phylum Chaetognatha
- Sagitta elegans
- Sagitta emflata
- Sagitta hispida
- Sagitta tenuis

Phylum Echinodermata
- Class Holothuroidea
  - Cucumaria pulcherrima
  - Thyone briareus
  - Unidentified larvae
- Class Ophiuroidea
  - Amphiodia atra
  - Unidentified larvae

Phylum Chordata
- Subphylum Urochordata
  - Molgula spp. larvae
- Subphylum Vertebrata
  - Anchoa hepsetus (E&L)
  - Anchoa mitchilli (E,L,&A)
  - Anguilla rostrata (elver)
  - Bairdiella chrysura (L)
  - Brevoortia tyrannus (L)
  - Chasmodes bosquianus (L)
  - Cynoscion nebulosus ? (L)
  - Cynoscion regalis ? (L)
  - Gobionellus spp. ? (L)
  - Gobiosoma spp. (= bosci) (L)
  - Gobiosoma bosci (A)
  - Gobiesox strumosus (L)
  - Hippocampus erectus (L)
  - Hysoblennius hentzi (L)
  - Menidia menidia (L)
  - Microgobius thalassinus (L)
  - Peprilus alepidotus (L)
  - Pseudopleuronectes americanus ? (L)
  - Sciaenidae (E&L)
  - Sphoeroides maculatus (L)
  - Syngnathus floridae (L)
  - Syngnathus fuscus (L)
  - Trinectes maculatus (E&L)

Note: A = adult, L = larvae.

Table 3.27. Length (mm FL) of striped bass taken by beach seine in the Ware and York Rivers during the first two weeks of August, 1971.

Ware River			York River		
Date	Station	Length	Date	Station	Length
3 Aug	MW 68	76	13 Aug	Y 28	88
		96			81
		87	13 Aug	Y 19	80
		79	12 Aug	M 43	75
		95			69
		82			73
		81			74
		77			68
		84			67
	Σx	757		Σx	675
	$\bar{x}$ =	85.2		$\bar{x}$ =	75.0
	s =	7.29		s =	6.93
	$s_{\bar{x}}$ =	0.81		$s_{\bar{x}}$ =	0.77

Job 4. <u>To Define and Adapt Existing Techniques for Rearing Striped Bass Larvae, with an Assessment of Optimum Size for Stocking</u>.

To date research on rearing striped bass larvae to fingerling size has centered on the use of ponds, raceways, and cages. These techniques, however, require a considerable land area, capital outlay, and personnel commitment. We have experimentally assessed cage culture and closed-system tanks or pools as methods for the rearing of striped bass. Our goals in this research were to develop a system for rearing which was of low construction cost, required little physical space, and was not as labor intensive as existing techniques. At the same time, we sought to maximize control of water quality, feeding, and disease in the culture system.

An experimental study of the effects of temperature, salinity, and age on growth and survival of striped bass was conducted to provide an insight into optimal rearing conditions and optimum stocking conditions.

Closed-system rearing facilities appear to be better than cage or pond culture facilities for striped bass. Results of our preliminary tests indicated fiberglass tanks and plastic pools can be utilized as effective and efficient rearing facilities for both experimental and large scale production of striped bass fingerlings.

The factorial experiment evaluating age, temperature, and salinity demonstrated a considerable hardiness of young striped bass. Striped bass less than two months old had over 80% survival during seven days subsequent to acute introduction from an average ambient condition of 21 ± 3 C at 0.2 to 4.8% into temperatures of 18 C and 24 C and salinities of 4 and 12%. These results suggest a greater flexibility in an estuarine stocking program as to site selection and time of release than previously known.

Cage Culture. Open-flow cage culture was attempted during 1972 in the Ware River, Mobjack Bay, Virginia. The cages were of plywood and plastic screen construction (4x2x1-1/2 ft deep) with centered lids for access. These were placed in the river and allowed to develop natural communities of aquatic invertebrates on the screens. Natural foods would then be available to striped bass in the cages and we would supplement with prepared foods as needed. In this manner labor for feeding would be reduced, natural foods would provide inputs of required dieting constituents which might be lacking in prepared foods, and the fish would have "experienced" natural forage before release into the estuary which laboratory reared fish (using prepared foods) would not have been exposed to prior to stocking.

Approximately 500 2-week-old striped bass were placed in each of 3 cages. The initial response of the fish appeared favorable in that they did not go into a shock posture and could be seen darting about in apparent feeding behavior. Examination of the cages one week later revealed no survivors in any of the cages. Food organisms were present in the cages and water was flowing through the cages. The utility of cage culture in an open estuarine system can not be concluded from our data, but it is less applicable than other methods tested particularly for very young fish.

Fiberglass Tanks - Closed System. Striped bass sac fry were successfully reared in 180 gallon fiberglass tanks of a circular design. The details of the system's construction and feeding were provided in progress report AFS 6-2 and are similar to those described for the swimming pool system. Results of these experiments indicate that they would be useful as rearing systems for production of up to 1,000 fish per tank. Tank systems of this type would be optimal for batch production of experimental animals of known history as needed for bioassay, temperature tolerance or preference, salinity tolerance or preference etc. Overcrowding of fish is considered the major problem with this tank system. The number of sac fry placed in a system of this type should not exceed 10,000 to optimize survival and growth of the fish during the rearing period.

Plastic Pool - Closed System. The following description summarizes the results of our recommended method for rearing striped bass in the laboratory.

A PRELIMINARY REPORT ON CLOSED SYSTEM REARING OF STRIPED BASS SAC FRY TO FINGERLING SIZE

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CONTROLLED REARING OF STRIPED BASS has become the subject of considerable research in recent years. This has resulted from successful introductions of this important species into freshwater impoundments and estuaries which are considerably removed from its natural habitat. Reproducing populations now exist in reservoirs, Pacific coast estuaries (Sacramento-San Joaquin Delta, California), and the U.S.S.R. [*2*]. Additional interest in the potential of *Morone* hybrids as introduced fishes has developed [*1, 3*].

Successful rearing facilities described to date are elaborate and expensive. We are investigating the possibility of rearing fish in inexpensive closed systems, primarily for experimental purposes. Closed system culture of striped bass (*Morone saxatilis*) also appears promising for larger scale rearing. Our preliminary results are the subject of this report.

FISH

Three-day-old sac fry, of Roanoke River parental stock, were obtained from the Virginia Commission of Game and Inland Fisheries Hatchery at Brookneal, Va., on May 26, 1972. The fry were transported in an oxygen atmosphere in sealed plastic bags within styrofoam shipping containers. Water temperature in the shipping bags was 19°C at the time of packaging and also on arrival at the culture facility 4 hours later. The sealed bags were floated in a culture pool until the water temperature in the bags was lowered to that of the pool, 17°C. Mortality due to shipping and handling was estimated at 33 percent; approximately one million live sac fry were released into the pool.

CULTURE SYSTEM

On a concrete floor, we assembled a circular wading pool with steel wall and blue[1] vinyl liner, 10 feet in diameter by 2 feet deep. The vinyl liner was thoroughly scrubbed without detergent or soap, rinsed, and filled with well water to 18 inches or about 900 gallons. Airstones were spaced around the periphery of the pool. A submersible pump maintained a constant clockwise movement of the water.

Filters fabricated from plastic dish pans (18- by 12- by 8-inches deep) were suspended over the pool. The bottoms of the pans were drilled with approximately 150 ¼-inch holes and lined with a thin but continuous layer of fiberglass filter wool and activated charcoal. Water was circulated through the filters by submersible pumps (capacity about 200 gal pump^{-1} hour^{-1}). Pumps were placed in a cage of 1- by ½-millimeter-rectangular mesh netting to exclude larvae from the intake. A single pump serviced three filter pans. When two pumps were used, the maximum filtration rate was 400 gallons per hour.

Water quality remained good throughout the study. Occasional cloudiness caused by overfeeding was corrected by intensive filtration for

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The use of trade names in the manuscript is not intended as an endorsement of products, but only as identification of materials used in this study.

[1] Bayless [1] and others have found that survival of larval striped bass is best when the holding facility has a dark-colored interior.

24 to 48 hours. The normal daily replacement of water was approximately 25 gallons—the amount removed when siphoning dead fish and uneaten food from the bottom.

Fry were held in well water (0.2%, pH 7.6) for the first 2 weeks. Salinity was raised to 4.7 during the third week of the rearing operation by adding prepared salts and to 5.6 during the eighth week. The pH of the pool water ranged from 8.3 to 8.6 (see table).

No temperature control was employed. The volume of the system acted as a damper against rapid fluctuations in atmospheric temperature. Mean weekly temperatures, ranges, and maximum change, over a 24-hour period are listed in the table.

No evidence of fungus or epizootics was observed during the rearing interval. Regular dosages of a prepared fungus remedy (Wardley's Stainless) were administered for preventive purposes. A sample of fish removed during the eighth week and examined by the parasitology section of VIMS was free of parasites.

FEEDING

The striped bass larvae began taking brine shrimp nauplii at 5 days of age. Small quantities of Tetramin were offered in addition to brine shrimp. The behavior of the fish and subsequent examination of their stomachs indicated that some fish were ingesting Tetramin. However, quantities fed were not increased due to the water fouling tendency of the flakes. The fish were fed 50 percent Tetramin and 50 percent brine shrimp (see table) from age 42 days through age 67 days.

SURVIVAL AND GROWTH

Mortality rates are based upon the estimated number of dead fish removed from the pool during cleaning operations. The initial mortality rate was estimated to be 10 to 13 percent per week or 100,000 fish per week through day 25 (see table). From day 26 to day 32 heavy mortalities of 96 percent per week reduced the number of healthy fish to about 24,000 or 2.4 percent of the initial number (8-10 mm FL). The mortality rate was about 1,000 fish per week (5%) from day 35 through day 53.

Fish growth rate in our system was retarded relative to reported growth rate of young striped bass in the wild [4]. The weekly increase in fork length was about 10 percent of the starting length through day 34 (see table). An average weekly increase of 33 percent fork length was obtained from day 34 until day 53, and the population was rather uniform in size.

Cannibalism was first evident at 18 days, however it did not appear to be a significant mortality factor until the latter part of the ninth week. A growth differential between individuals became evident by day 53. Although

Weekly summary of physical and biological parameters in the rearing facility

	Week									
	I	II	III	IV	V	VI	VII	VIII	IX	X
Dates	24-27 May	28 May-3 June	4-10 June	11-17 June	18-24 June	25 June-1 July	2-8 July	9-15 July	16-22 July	23-29 July
Fish age (days)[1]	4	11	18	25	32	39	46	53	60	67
Temperature (°C):										
Mean	17.0	19.5	21.5	22.5	23.0	21.5	21.5	22.5	26.0	27.0
Range	17-17.5	17.5-21	21-22	19-25.5	19-25	19.5-23.5	21-23	21-24	24-28	25.8-28
Maximum change/24 hours	0.5	1.5	1.0	2.5	2.0	2.5	1.0	1.5	1.0	1.0
Salinity	0.2	0.2	4.7	4.8	4.8	4.7	4.8	5.6	5.6	5.6
Food:										
Percent brine shrimp = BS	—	BS90	BS90	BS90	BS90	BS70	BS70	BS50	BS50	BS50
Percent Tetramin = TM	—	TM10	TM10	TM10	TM10	TM30	TM30	TM50	TM50	TM50
Estimated number of fish (thousands)[1]	950	850	750	650	24	20	19	18	12	4
Fork length (mm):[2]										
Mean[1]	6.4	7.0	7.9	8.7	9.8	—	15.8	—	23.0	27.6
Range[1]	6.1-6.6	6.8-7.4	6.9-9.0	7.8-9.9	9.3-10.5		14.5-17.9	- -	20.0-26.5 [3](50)	24.0-40.5 [3](65)

[1] At end of week.

[2] Fork lengths are based on samples of 10 fish removed from the population at the end of each week.

[3] Estimated fork length of largest fish not included in measured sample.

most of the fish were approximately 20 millimeters fork length (15-25 mm), at least 50 larger fish were evident (estimated 30-40 mm FL). We observed the larger fish (30-50 mm) actively feeding on the smaller fish near the end of week nine. Cannibalism was most severe during the 10th week. During this period 1,000 larger striped bass, a few exceeding 60 mm, reduced the remaining stock to 3,000 fingerlings (20 to 25 mm), in addition to themselves.

DISCUSSION

The objective of this report is to point out the potential of a closed system for rearing striped bass. The advantages of a simple, economical system of maintaining animals for experimental purposes are obvious. More important, however, is the potential of the closed systems for rearing sac fry to fingerling size for stocking. We estimate that the system contained 12 to 15 thousand fish, 20 to 25 millimeters long, before cannibalism became critical. This number compares favorably to production in the more elaborate rearing facilities that are now in operation [5, 6]. A substantially lower cost per fingerling is incurred. The closed system is inexpensive and versatile; it may be set up in an area to be stocked, thus eliminating most transportation problems encountered in moving fry or fingerlings to and from established rearing facilities.

We consider overcrowding to be the major cause of the high mortality rate and slow growth encountered during the first 4 weeks of rearing. Fish were removed from the culture tank and placed in gallon jars (8 to 10 fish/jar) at 4% during the second and third week of the operation. In all cases survival within the jars exceeded that within the culture pool and fish growth was rapid—up to 100 percent increase in fork length during the third week. The reduced mortality and increased growth rate after the 32d day also suggests that overcrowding may have been an initial problem.

Our observations suggest that the following procedural modifications would increase the efficiency of the described system:

1. Initial numbers of sac fry should not exceed 100,000 per 10-foot diameter pool (900-gallon capacity).
2. Salinity of the culture water should be increased from 0.2% to 4% within a few days after the fish begin feeding on brine shrimp. The fish appear healthier and this enhances survival of *Artemia* nauplii and therefore food availability.
3. Brine shrimp nauplii appear to be an acceptable food for larvae and juveniles up to 25 millimeters; however, other supplementary foods, living or prepared, would be desirable for the older fish.
4. Larger, potentially cannibalistic fish should be removed and isolated from the population.

With the above conditions the described system should produce between 15 and 20 thousand 20- to 25-millimeter fingerlings in shorter time than was required in this study and would probably extend the production potential with respect to fish size.

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OPTIMUM AGE, TEMPERATURE, AND SALINITY FOR ESTUARINE STOCKING OF JUVENILE STRIPED BASS, MORONE SAXATILIS (Walbaum)

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Abstract

A 3n factorial design to evaluate the effects of an abrupt introduction of striped bass, Morone saxatilis from a closed system rearing facility into a variety of experimental temperature and salinity combinations has demonstrated a considerable hardiness of juvenile fish. Striped bass less than two months old had over 80.0% survival during seven days subsequent to acute introduction from an average ambient condition of 21.0 + 3 C at 0.20 to 4.8% into temperatures of 18 C and 24 C and salinities of 4.0% and 12.0%. Relative growth in these treatments was significantly greater than in the 12 C treatment at all salinities. These results lend a degree of flexibility to the stocking program as to site selection and time of release, both of which should be governed by food types and quantities available, and the concentration and activity of predators.

Introduction

Striped bass, *Morone saxatilis*, are anadromous coastal fish which usually spawn in oligohaline to freshwater reaches of estuarine tributaries. Striped bass use these and other estuarine areas of higher salinity as nursery grounds (Talbot, 1967). Many suitable nursery grounds are underutilized presently and may be in the future due to natural variability in year class strength (Raney, 1952), environmental degradation of upstream spawning areas (Dovel and Edmunds, 1971; Radtke and Turner, 1967; Talbot, 1967), and overfishing (SFI Bulletin, 1973). The success of stocking freshwater rivers, ponds, and lakes with striped bass fry and improvement and expansion of hatchery facilities have been documented (Humphries and Cummings, 1973). Estuarine stockings similarly might be established or augmented by the introduction of striped bass fry and fingerlings into rivers that are normally not utilized or are underutilized as nursery grounds. Stocking striped bass in these areas would be of value in reestablishing populations, maintaining populations which no longer have suitable spawning grounds, or in strengthening weak year classes. The estuarine environment, however, presents a number of difficulties that are not encountered in landlocked systems. Fluctuations in temperature and salinity in estuaries are known to interact to govern spawning and survival of striped bass (Talbot, 1967).

Therefore, it is advantageous in planning a stocking program for latent estuarine nursery areas to know what environmental parameters could affect its success both during and after introduction of the stock. The purpose of this study was to determine the optimum temperature and salinity for stocking juvenile striped bass relative to age, rearing cost, and stresses encountered after introduction. The temperature and salinity combination yielding lowest mortality with highest relative growth of the youngest fish was defined as the optimum stocking combination.

Materials and Methods

Three-day-old striped bass prolarvae[1] were obtained from the Brookneal Hatchery, Brookneal, Virginia on May 26, 1972. The fish were shipped in plastic bag/styrofoam containers and were placed in the closed-system culture facilities at VIMS laboratories. One million fish were placed in a 900 gallon pool (10' x 2.5') which will henceforth be referred to as the ambient. Water temperature within the ambient pool was allowed to fluctuate with air temperatures. Fluctuations were partially buffered due to the large volume-to-surface area ratio in the pool. Salinity in the ambient pool was 0.20 ppt (ppt=‰) initially and was raised to 4.0‰ when the fish were three weeks old. Experimentation began 48 hours after arrival of the fish at VIMS laboratories. Closed-system filtration, water analysis, and mortality rates of striped bass in the pool were described by Rhodes and Merriner (1973).

The experimental design was a 3^n factorial, Model I, complete randomization with three replications of each combination. Three temperatures, 12, 18, and 24 C and three salinities, 4, 12, and 20‰ were tested at six age levels, 5, 13, 21, 28, 43, and 63 days old. The experimental design allows examination of main effects (salinity, temperature, and age) and interactions between factors.

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[1]Descriptive terminology for juvenile striped bass is that presented by Mansueti (1958) and adopted by Bayless (1973). The terms 'fry' and 'juvenile' will be used in general reference to striped bass less than two months old.

Temperature was maintained in three soft drink coolers of a water circulation type modified for laboratory use (Fig. 4.1). Each water bath was equipped with a Ranco thermostat (0-30 C range) and a Honeywell switch for control of water temperatures. One water bath (24 C) was further modified to provide heating capacity by addition of three aquarium heaters. All water baths were located in an air conditioned room. Vibrations were lessened by foam rubber shock absorbers placed between the compressors and unit frames.

Test salinities of 4 and 12‰ were established by dilutions of filtered water (pore size = 1 micron) from the York River with well water (0.20‰). The 20‰ salinity was achieved by addition of artificial marine salts to the filtered river water. Each salinity mixture was placed in a 3.5 liter glass test vessel. Test vessels were wrapped with black plastic to prevent visual contact with neighboring vessels, and to aid in food recognition by providing background contrast. Each vessel was also capped with clear plastic wrap to prevent increases in salinity due to evaporation. Test vessels were then partially submerged in the water baths for the designed temperature and salinity combinations (Fig. 4.2).

Dissolved oxygen and water circulation in each test vessel was maintained by an air stone. A "silent giant" air pump aerated nine test vessels. Lighting was not controlled. Test fish were exposed to artificial lighting during observation periods which occasionally occurred at night.

The six age groups of fish constituted six individual experiments and test levels of the age factor in the factorial design. Each experiment lasted for seven days (Table 4.1).

Temperature and salinity combinations were established in the test vessels, then ten fish were introduced per vessel. Only five fish per vessel were used in experiment VI due to heavy mortalities and high incidence of cannibalism in the ambient stock. All fish were randomly chosen from the ambient stock. Fish with gross anomalies were not included in the experiments. Fish were not acclimatized prior to the transfer. Methods of introduction and transportation assured complete submersion of the fish at all times.

Data obtained were percent mortality and relative growth during the seven day experiment. Relative growth is the fork length attained at the end of the experiment expressed as a percent of the initial length (Ricker, 1958). Arcsin transformation was applied to all percentage data to maintain normality. Factorial analysis of variance (α=0.05) evaluated statistical significance of treatment effects. Tukey's multiple comparison test was used to distinguish significant mean differences.

Avoidance behavior and swimming activity of test fish were monitored in daily observations periods and compared among treatments. No quantitative measurements were applied to behavioral and feeding differences. Artemia salina nauplii were the primary food source during all experiments. Tetramin, an artificial food supplement, was discontinued after experiment II due to its water fouling tendency and poor acceptance by the test fish. The feeding regime assured equivalent food availability among treatments during the entire experimental period.

Waste materials consisting largely of dead brine shrimp were siphoned from each test vessel daily. Dissolved oxygen, pH, and salinity were initially monitored daily. Stability of these parameters during experiment I and the increased mechanical agitation caused by sampling for these characteristics led to adoption of an initial and final sampling schedule for these parameters during experiments II through VI. Temperatures were recorded at least three times daily.

Dead fish were removed from the vessel, measured, and examined for physical defects and presence of food in stomachs. One hundred percent mortality in less than 48 hours was considered equivalent to zero growth.

Bioassay tests for water toxicity were conducted in all instances of one hundred percent mortality in the test vessels.

The water temperature in the vessel was raised to ambient and ten additional striped bass added. No bioassay produced positive toxic results over a 48 hour test period.

Each experiment terminated after seven days of observations. The surviving fish were removed, examined, and preserved. Temperature and salinity combinations were reestablished and the next experiment began.

A control was maintained to indicate stress and mortality due to transfer technique and vessel confinement. The control included fish of the same age, transferred in the same manner, and housed in the same type of test vessel. Nine vessels were placed in a closed water bath (Fig. 4.2) in which no temperature control was maintained. The control bath did not have the temperature buffering capacity of the pool because of its smaller volume. All maintenance and observations described for experimental vessels were also conducted for the controls.

Results

Temperature and salinity combinations in the experimental vessels did not change appreciably during the experiments. Temperature variation in specific water baths rarely exceeded ± 1 C. The extreme variation in the 24 C bath of ± 2 C during experiment III was corrected within 24 hours. The plastic cover over each vessel resulted in a salinity change of less than +1% during an experiment. All pH and dissolved oxygen values were within the limits of previously predicted optima (Bogdanov et al., 1967; Chittenden, 1971; Davies, 1970; Krouse, 1968).

The recorded thermal conditions and salinity in the ambient holding facility gradually increased during the study period. Temperature changes in the ambient pool were slow from May 26 until August but were constantly increasing. Temperature changes in control facilities were more rapid, paralleling diurnal fluctuations in air temperatures. Daily mean temperatures in the ambient pool for the day prior to experiments I through VI were 18.8, 22.0, 21.0, 24.5, and 28.0 C respectively.

Mortality

Analysis of mortality data revealed significant effects at all levels of the factorial (Table 4.2). Temperature was the most significant main effect ($F=124.49$, df 2,108). The mean mortality of fish introduced into 12 C exceeded 50%, while mortalities at 18 C and 24 C were 3.5% and 7.2% respectively (mean percentages are retransformed arcsin values). The salinity main effect was less significant (F=6.47, df 2,108). Mortality in the 20‰ treatment was only slightly higher than that at 4‰ and 12‰. The age main effect was significant (F=24.58, df 5,108) but presented a complicated series of mean differences in which two distinct groups were apparent. Fish younger than one month (experiments I through III) had mortality values ranging from 11.0% to 3.6%. Older fish (experiments IV through VI) had mortality values greater than 20% and as high as 40.2% (Fig. 4.3)

All first order interactions were significant except that of temperature x salinity (TxS) (Fig. 4.4 and Table 4.3). The synergistic effect of TxS did not exceed the effects attributed to either temperature or salinity alone. Similarly the graphed results suggest no interaction and a high degree of additivity with temperature as the dominant factor. A lethality of 20% resulted at the temperature extremes.

Interaction of temperature x age (TxA) was significant (F=34.25, df 10,108), but temperature x salinity (TxS) was non-significant (F=1.87, df 4,108). Lethality of the 12 C treatment for older fish (experiments IV through VI) indicates the importance of thermal history on the response of the fish to experimental conditions. The fifteen remaining TxA combinations yielded mean mortalities from 0% to 22%. This stratification of response by age is also present in the significant salinity x age interactions (SxA) (F=2.52, df 10,108). Mortalities attributable to SxA increased with age. The change of the ambient pool salinity

(0.20‰ to 4.0‰) prior to experiment III had no apparent effect on experimental results. Five of the six SxA combinations with 20‰ produced mean mortalities ranging from 17.0% to 41.3%.

TxSxA was a significant second order interaction (F=1.79, df 20,108) with a complex pattern present in mean differences (Fig. 4.5). No significant differences resulted in comparison of 27 cell mean values (0% to 35.0%) of the 36 possible combinations. Tukey's test and comparisons were based upon transformed data before conversion to final percentages. Eight of the nine significant combinations included 12 C treatment values with 100% mortality. The effect of temperature differences in the experimental baths increased with the age of the test fish.

Extraneous factors causing mortalities were limited. One case of cannibalism occurred during experiment III (21-28 days old) in 24 C at 4‰. Food availability was adequate in all test vessels during all experiments. Disease occurred only once in the controls during experiment V. External symptoms suggested a bacterial infection, tail rot (Snieszko and Axelrod, 1971). The high mortalities in experiment VI at 24 C were attributed to foreign debris falling into one vessel of one replication each of 4‰ and 20‰ treatments.

Growth

Relative growth rates were different for the different factorial combinations. Factorial analysis of relative growth revealed significant effects on all levels (Table 4.4 and Fig. 4.6). Temperature again was the most significant main effect

(F=3242.26, df 2,108). The mean relative growth during a seven day experiment at 24 C exceeded 20%, equalled 14.6% at 18 C, and was less than 1% at 12 C. The salinity main effect was less significant (F=10.39, df 2,108). Growth in 12‰ (10.7%) was significantly higher than in 4‰ (9.84%) and 20‰ (9.35%). The age main effect was significant (F=424.95, df 5,108) but yielded a complex pattern of mean differences in which two distinct groups were evident. Fish less than one month old (experiments I through III) experienced mean relative growth of 15.2% to 18.0%. Older fish (experiments IV through VI) grew between 4.5% to 5.8% of their initial length.

All first order interactions were significant (Table 4.5 and Fig.4.7). Temperature x salinity (TxS) was the least significant interaction and the mean differences suggest temperature as the dominant factor affecting growth. The greatest mean relative growth of 29.2% occurred in 24 C and 12‰. The temperature x age interaction (TxA) separated mean differences into three groups. Greatest mean relative growth, 19.7% to 31.6%, occurred in 18 C and 24 C treatments with younger fish (experiments I through III). Mean relative growth of 8.9% to 17.0% occurred in 18 C and 24 C treatments with older fish (experiments IV through VI). Mean relative growth of less than 7.0% occurred in 12 C across all age levels. The salinity x age interaction (SxA) yielded a pattern of mean relative growth with two different groups. Age was the dominant stratifying factor in SxA. Relative growth of younger fish (experiments I through

III) in all salinities ranged from 13.6% to 20.1%. The second group included older fish (experiments IV through VI) in all salinities and relative growth ranged from 2.8% to 6.8%.

The second order interaction (TxSxA) was significant (F=19.39, df 20,108) (Fig. 4.8). Temperature was the major factor in mean differences but the effect of temperature on relative growth decreased with age of the test fish. There was no pattern apparent which was attributable to salinity. The greatest mean relative growth (37.4%) occurred at 24 C and 4‰ for five-day-old fish. The complex pattern of mean differences in the TxSxA interaction is resolvable into five percentage groupings (Table 4.6).

Behavior and Feeding

Fish of the same age behaved differently when exposed to different temperatures. A temporary "shock" response occurred at the beginning of each experiment as fish were introduced into 12 C water. Upon contact with 12 C water the fish went into a shivering, downward-spiraling swim which ended in a momentary motionless posture on the bottom of the vessel. All fin and opercular movements ceased in experiments I and II. Opercular motion was detected in older fish in experiments III and IV. The time required for the fish to recover from this numbed condition ranged from thirty seconds in experiment I to ten minutes in experiment IV. No fish recovered from this condition in experiment IV at 20‰ or in experiments V and VI at all salinities.

Fish remained demersal and in a lethargic state after recovery.

No behavioral peculiarities were observed in 18 C and 24 C. Fish in these treatments were very active and became more so with age. Their activity in the later experiments was inhibited by the test vessel as evidenced by side-to-side swimming. Rapid, jerking changes in the swimming patterns were scored as "avoidance" reactions to changes in light and sound. At 12 C only mechanical agitation of fish with a glass probe resulted in a sluggish avoidance reaction. There were no peculiarities in fish activity in the control.

The striped bass larvae were not observed to eat dead or dying fish and only one instance of cannibalism occurred during the experiments. Striped bass preferred the mobile planktonic _Artemia salina_ nauplii over the dry artificial food supplement, TetraMin. The fish were not observed feeding on dead _Artemia_.

Food type and availability are not considered as confounding factors in the mortality and growth results described earlier. Larvae were five days old with functional mouth parts and the major portion of the yolk-sac had been absorbed at the beginning of experiment I. Feeding commenced within 24 hours after introduction of the larvae to the test vessels. Feeding activity of test fish increased with test temperature. Salinity had no apparent effect on the appetite of test fish. Feeding activity and intensity also increased with age. Feeding activity of the control fish was comparable to that in 18 C and 24 C treatments.

Controls

Controls during experiments I, IV, and VI suggest that a mean percent mortality within the range of 12% to 20% can be expected due to the effects of vessel confinement and transfer stress (Table 4.7). Excessive mortalities in the remaining controls (experiments I, II, and V) were caused by certain extraneous factors. The mean relative growth in the controls supports these conclusions (Table 4.8). Experimental results in excess of this predicted range of expected mortality should indicate a definite adverse treatment effect. Results within or below the expected ranged should indicate favorable conditions.

Comparison of mortalities and relative growth in the controls with that in the experimental treatments revealed a direct effect of prior environmental history or exposure on experimental results after acute introduction of the fish into the test vessels. Increased temperature in the ambient pool during the later experiments had a definite effect on the results since mortalities in 12 C increased to 100%. Mortality in 18 C and 24 C decreased with increasing ambient temperatures. Controls showed no significant change in average mortality at the higher ambient temperatures (Table 4.7).

The change of salinity in the ambient pool from 0.20‰ to 4.0‰ prior to experiment III had no detrimental effect on the experimental results. Control data suggest that the increase in salinity was advantageous to growth and survival. Mortality in the control group decreased from 71.0% and 79.0% to less than 20.0%, and mean relative growth increased from 8.8% and 7.6% to over 10.9% (Table 4.8).

Discussion

The survival of striped bass subsequent to release into the estuary depends on three essential factors: adaptation to physical-chemical conditions, food availability, and predator avoidance. The age of striped bass upon stocking will determine their response to these factors. These factors and their inter-relation with age need to be examined before large scale estuarine stocking is successful.

This study provides laboratory evidence for predicting stocking success given fish age and the temperature-salinity conditions in the stocking area. Striped bass less than two months old had over 80% survival during seven days subsequent to acute introduction from an average ambient condition of 21.0 ± 3 C at 0.20 to 4.8‰ into temperatures of 18 and 24 C and salinities of 4.0‰ and 12.0‰. Relative growth in these treatments was significantly greater than in the 12 C treatment at all salinities tested. These results lend a degree of flexibility to the stocking program as to site selection and time of release, both of which should be governed by the food types and quantities available, and the concentration and activity of predators.

Evaluation of mortality and relative growth of striped bass from a known age group following acute introduction is the unique feature of this study. Expenses incurred in rearing striped bass may be reduced by an early release time and minimization of equipment. Striped bass can be reared for several months in relatively inexpensive facilities (Rhodes and Merriner, 1973). Temperature acclimation prior to stocking is not mandatory, if temperature and salinity values in the rearing facility and the area to be stocked are within the range found in this study. All phases of acclimation should not be dismissed. A water-mixing procedure at the stocking site is customary and probably beneficial. However, juvenile striped bass require several hours to several days for complete reacclimation depending upon the previous environmental history of the fish (Davies, 1970).

The environmental history of the striped bass affected its response to the experimental conditions. Increasing mortalities in 12 C treatments during experiments I through VI may not connote an increase in thermal sensitivity with age, rather it is probably an artifact due to increasing water temperatures in the ambient holding facility. Increasing temperatures in the ambient pool altered the measured survival and growth response in the direction of the warmer experimental temperatures, 18 and 24 C. The fish response was altered in the direction of acclimation and reacclimation was more successful in the warmer temperatures. Tagatz (1961) found that juvenile striped bass could survive a temperature change from 45 F (7.2 C) to 70 F (21.1 C), but mortalities occurred in changes from 70 F to 55 F (12.8 C).

The present data indicates no significant difference in thermal requirements for survival of striped bass less than two months old. Davies (1970) found that striped bass fry (less than 10 days old = 0.1 inch) acclimated to higher and lower temperatures more rapidly than did fingerlings (=1.0 to 2.46 inches). However, his data revealed a more restricted range of temperature tolerance for fry than for fingerlings.

Thermal requirements for growth were more variable than for survival. Mortalities in the 12 C treatment were lower during experiments I through III when water temperatures in the ambient pool were low, but mean relative growth was less than 1.0%. Mean relative growth was significantly different among tested temperatures with a general decrease in relative growth with increasing age of the fish in the experiment. The markedly different growth during experiment III and IV (age 21 to 28 days) characterizes a "critical period" of life for striped bass post-larvae. In a review of striped bass fingerling cultures Humphries and Cummings (1973) noted that these fish begin to die in large numbers during their transformation to young adults (21 to 30 days). This phenomenon may be the result of nutritional deficiency at this developmental stage, which may be caused by a shift in the metabolic rate or efficiency. Crowding may be correlated with the variable growth response. This "critical period" (21 to 30 days old) may be the best time to release striped bass to avoid high mortalities and stunting of the fish in the culture facilities, unless diets can be improved. However, this period may coincide with a period of low natural food availability or high predator concentration in the estuary. Thus the striped bass could be highly vulnerable to predation or starvation if stocked at this age. The flexibility in the diet of the striped bass with age needs to be examined relative to food type availability before releasing the fish at this age.

Temperature is more limiting than salinity to growth and survival of striped bass. Krouse (1968) found better survival of striped bass at 5‰ and 15‰ than at 25‰. Similarly, the present data indicate some lethality for 20‰ at 12 C and 24 C. Salinity effects on growth were less significant as a main effect and in interaction than temperature and age. Direct influence of salinity on survival appears to be less important in selection of a stocking location than indirect effects such as predator avoidance via lower salinities and presence of particular food types in areas of specific salinity.

Age of striped bass at stocking is the most difficult parameter to assess. Rising costs of culture operations require production of a stockable fish in a swift, efficient program. The ideal approach to maximize production with minimum cost would be to stock fertilized eggs. High natural mortalities, silt suffocation, improper stripping techniques, etc. have resulted in marginal success with such programs (Bayless, 1967 and 1973; Tatum et al., 1965). Bayless (1973) suggests holding striped bass at least four days post-hatching prior to stocking. Prolarval striped bass at this age can swim freely in the water column thereby avoiding sediment suffocation. However, these fish would be vulnerable to even the most lethargic of predators. Changes in water currents in the estuary with tides would take their toll. Shell (1972) attempted stocking striped bass which he had reared past the 10th day critical phase. These post-larval fish had functional mouth parts, were freely swimming and were actively feeding. However, the benefits of increased survival after stocking did not compensate for the high mortalities incurred in the longer rearing period before stocking.

The key to success seems to be intensive culture of striped bass to fingerling size. Striped bass between one and two months old range from 20 mm to 40 mm in fork length depending on the culture facility (Humphries and Cummings, 1973). Striped bass at this size have advanced to the young adult stage, having their full complement of fin elements and scales are beginning to form (Mansueti, 1958; Pearson, 1938). Such fish have a strong swimming capability for predator avoidance and they feed voraciously (Humphries, 1971; Rhodes and Merriner, 1973).

Logically, life expectancy subsequent to stocking should increase with age. The older striped bass should be able to cope with environmental stress more effectively than the young fish as evident from the successful stocking of yearling striped bass in the lower Sacramento River, California in 1879 (Raney, 1952; Radovich, 1961). But, in a culture operation production costs may greatly exceed the benefits attributable to increased survival after stocking. Also, the fish may become "environment-dependent" on the culture system, since near constant temperatures, controlled salinities, saturated food source, and waste elimination could weaken the fish's ability to survive under natural conditions.

An efficient stocking program will assure highest survival of the youngest fish possible. However, to define a successful stocking age with sole reference to favorable physical-chemical conditions is fallacious. The remaining problems of natural food availability and predator avoidance must be considered. These conditions will vary with season in different estuarine systems and subsystems. Therefore, no one particular stocking age has universal application. The age at stocking and the production cost as measured against benefits is environmentally dependent.

In summary, juvenile striped bass between 5 days and two months of age, reared in culture conditions of 21.0 ± 3 C at 0.20‰ to 4.8‰, demonstrate considerable hardiness for stocking in estuarine waters ranging from 18 C to 24 C and 4.0‰ to 12.0‰. This conclusion is formulated from experimental results following acute introduction. These results lend flexibility to the stocking program as to site selection and time of release, both of which should consider food availability and predator concentration.

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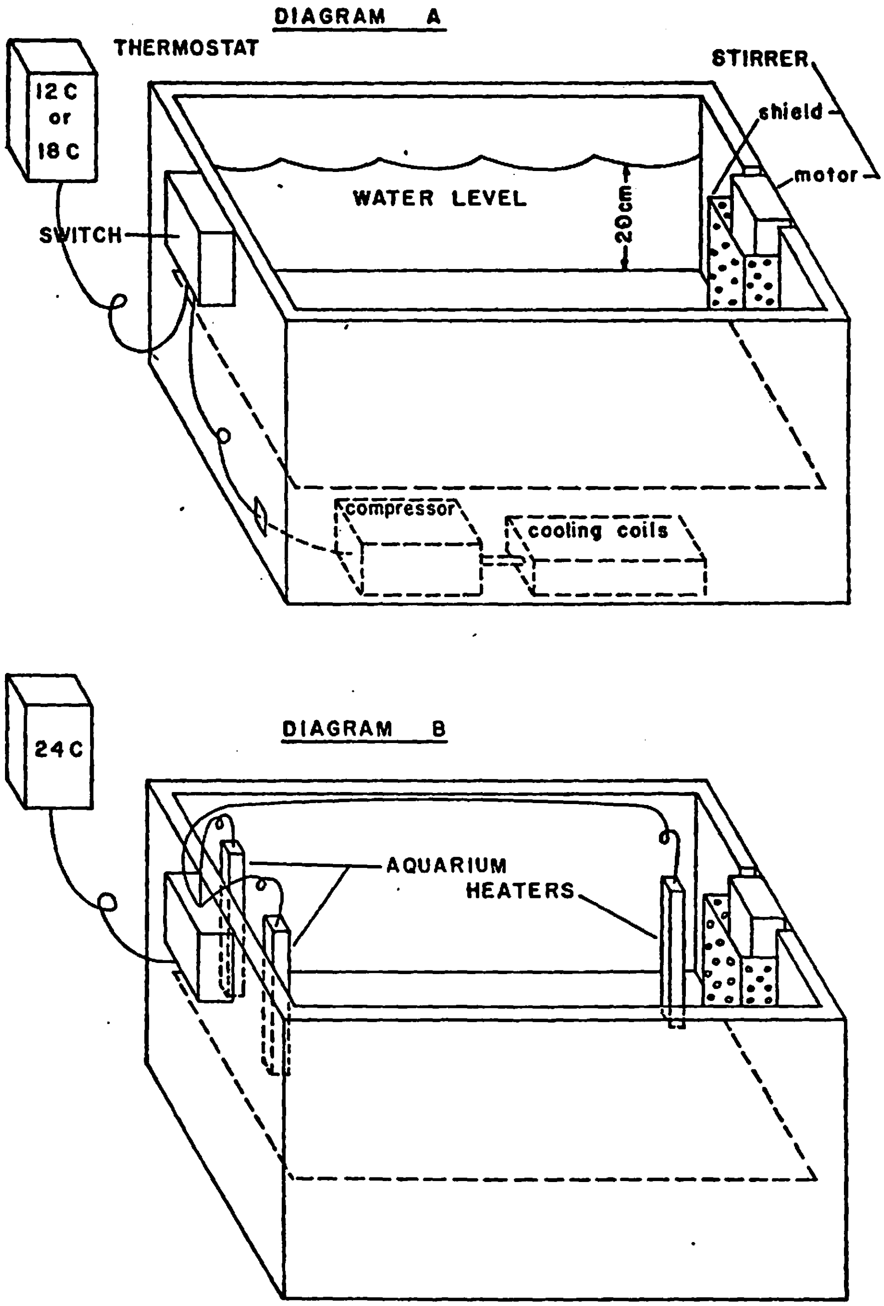


Fig. 4.1. Water baths -- soft drink coolers modified for laboratory use (water circulation type). Diagram A. Typical construction for water baths 12 C and 18 C. Diagram B. Additional modification for water bath 24 C.

Fig. 4.2. Experimental design -- three water baths with nine vessels per bath form nine temperature and salinity combinations with three replications of each combination. One control per experiment consist of nine vessels per bath.

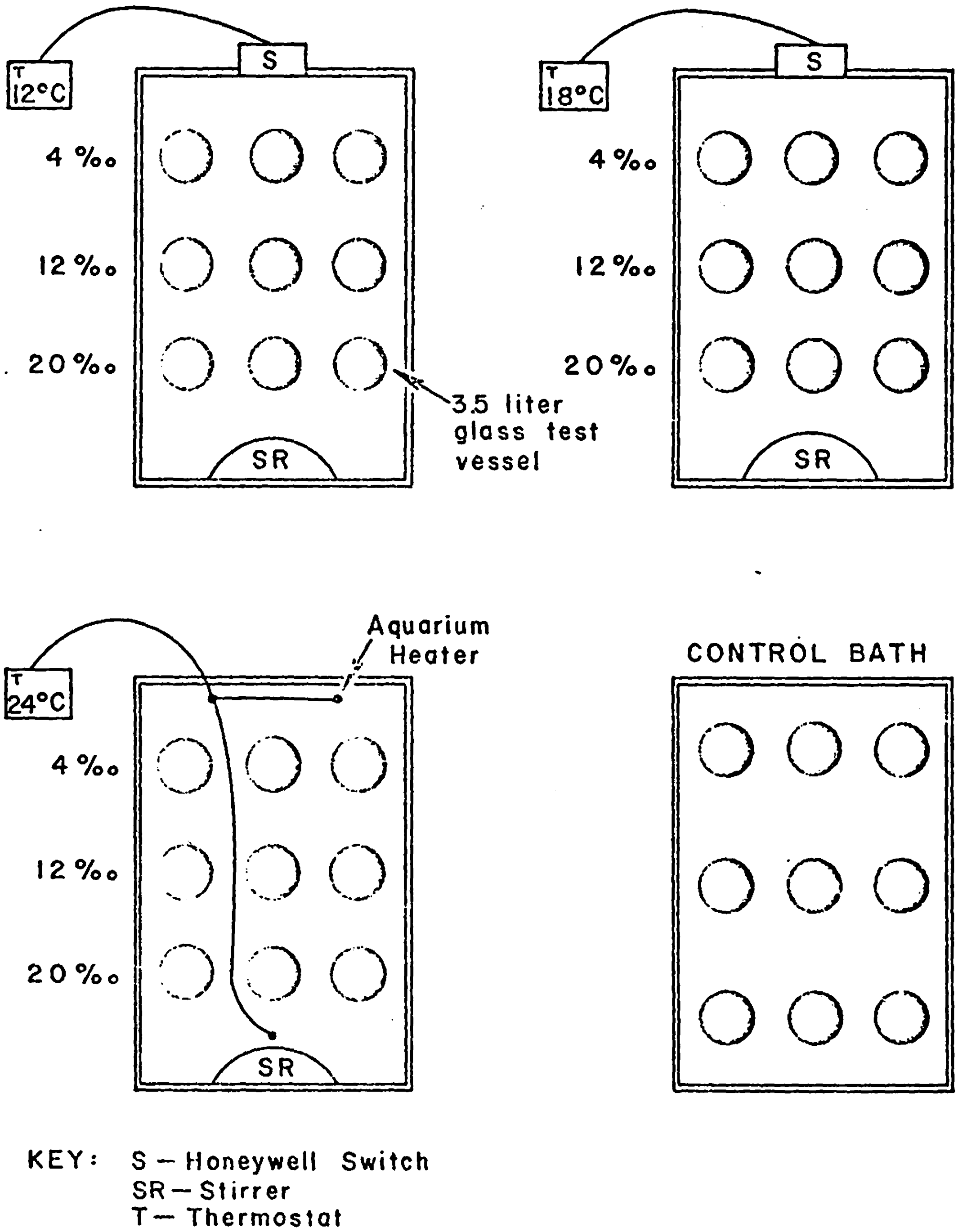
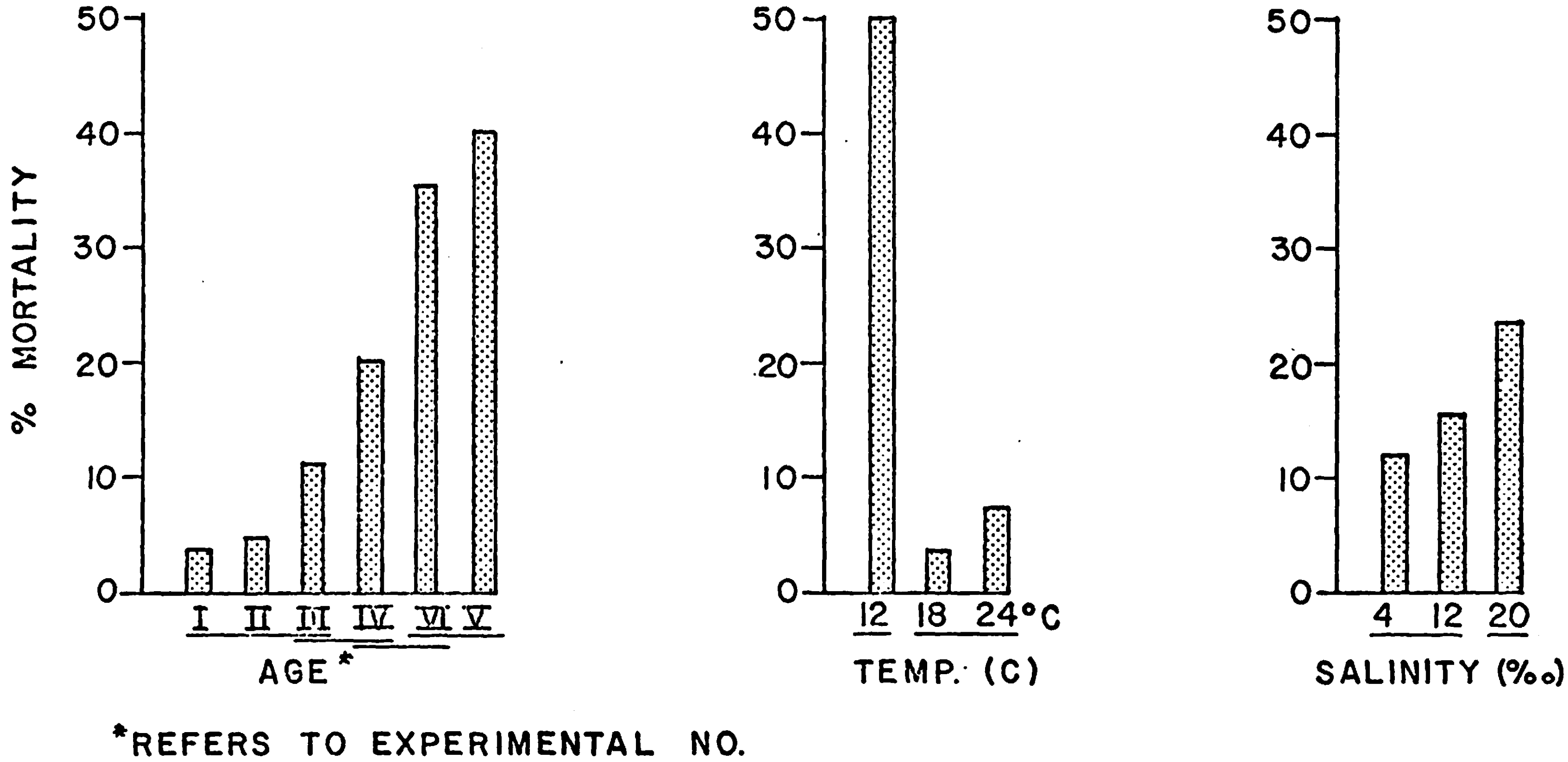


Fig. 4.3. Mean percent mortality of striped bass under the main effects of age, temperature, and salinity. (The significant mean differences resulting from Tukey's test for comparison of means are indicated on the horizontal axis. Any two means not scored by the same line are significantly different).



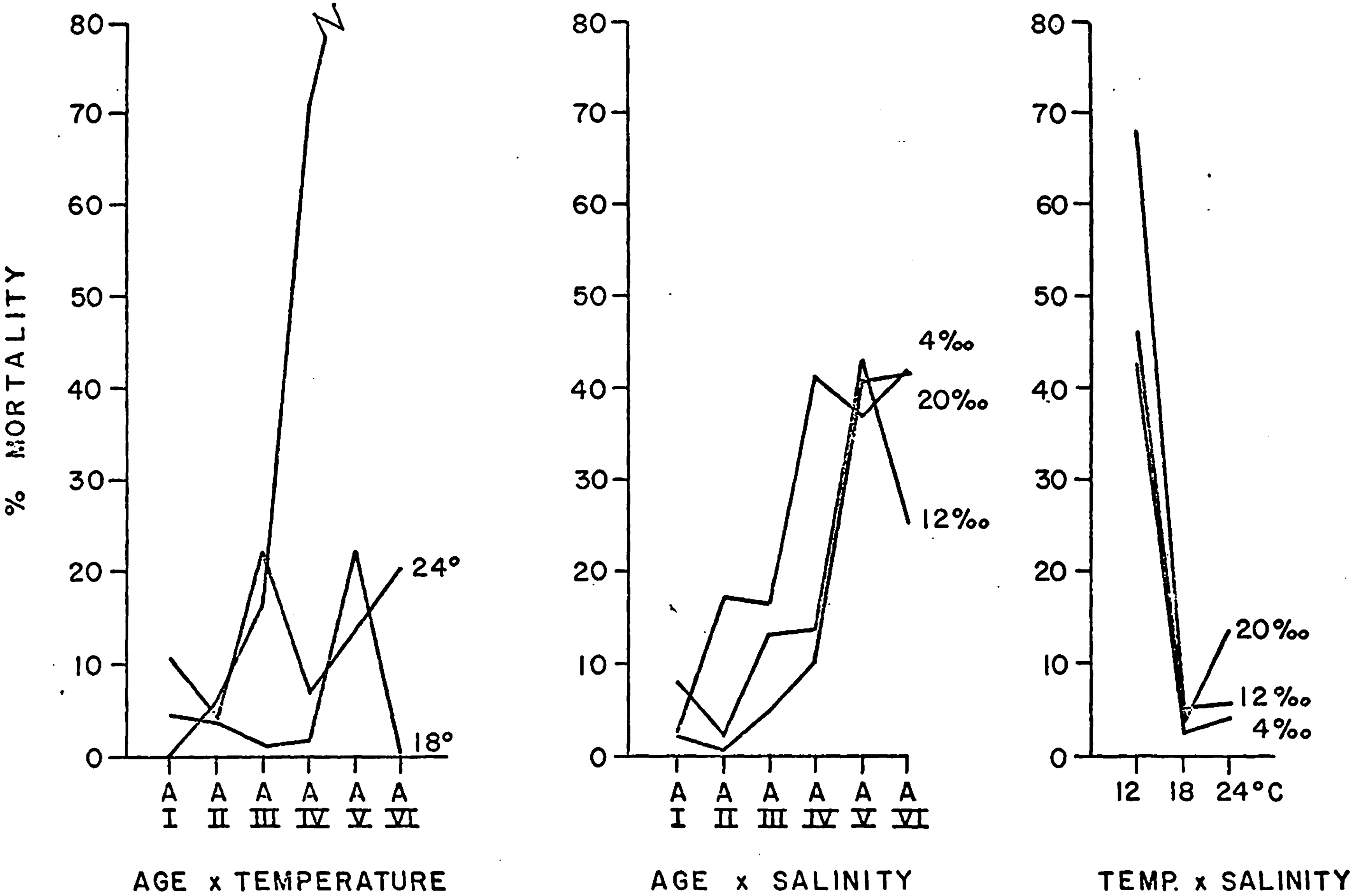


Fig. 4.4. Mean percent mortality of striped bass in 1st Order interactions.

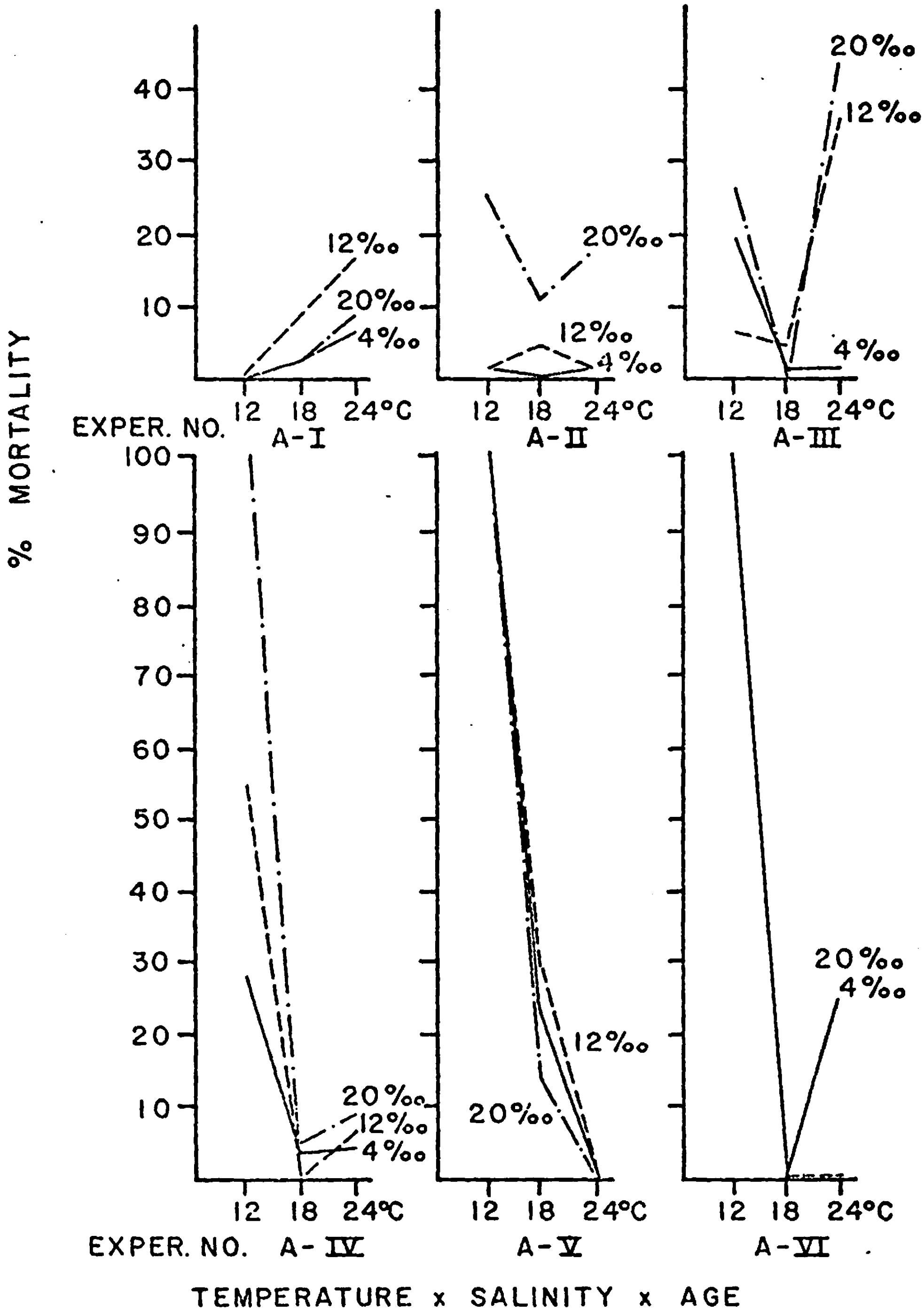


Fig. 4.5. Mean percent mortality of striped bass in 2nd Order interactions.

Fig. 4.6. Mean relative growth of striped bass under the main effects of age, temperature, and salinity. (The significant mean differences resulting from Tukey's test for comparison of means are indicated on the horizontal axis. Any two means not scored by the same line are significantly different).

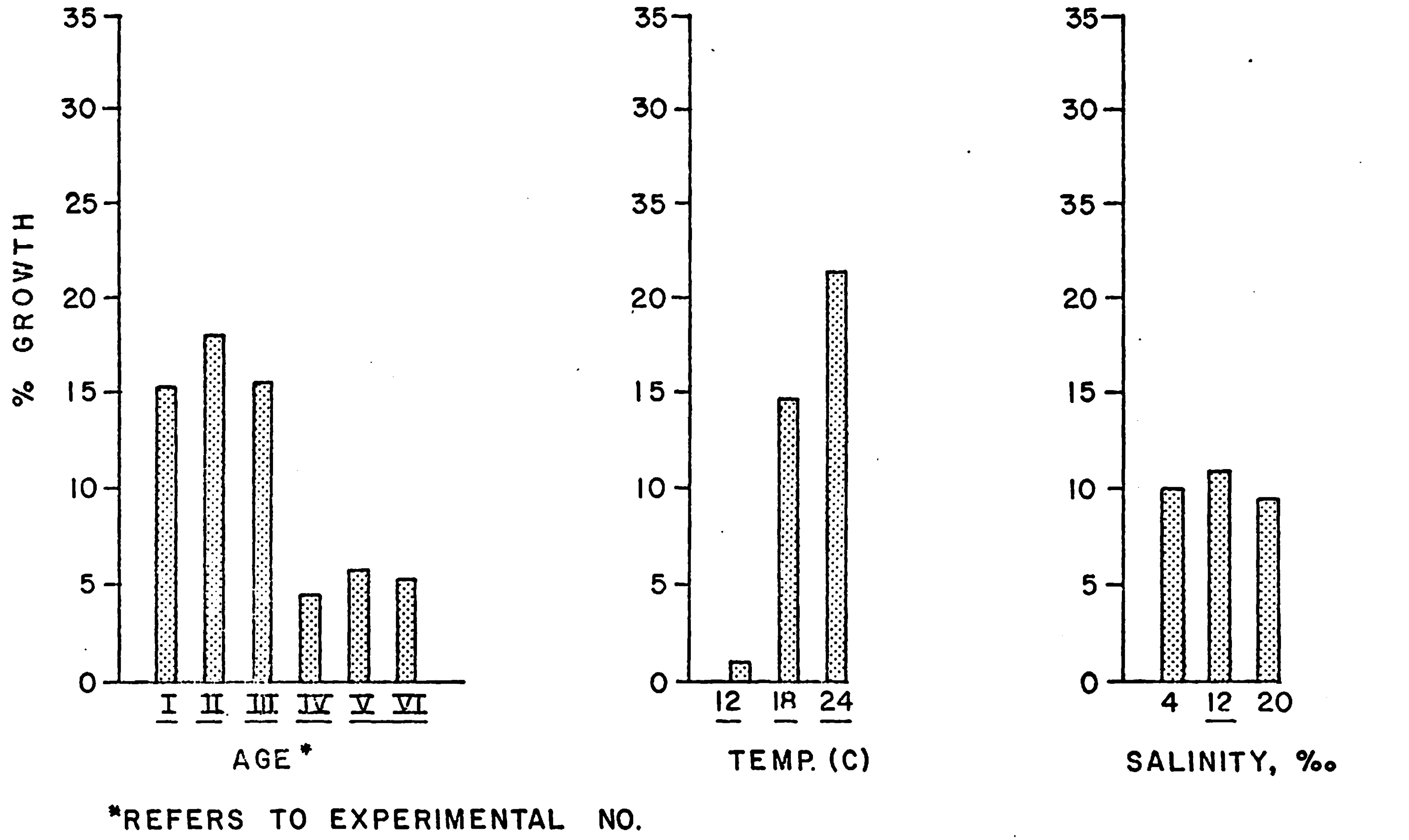
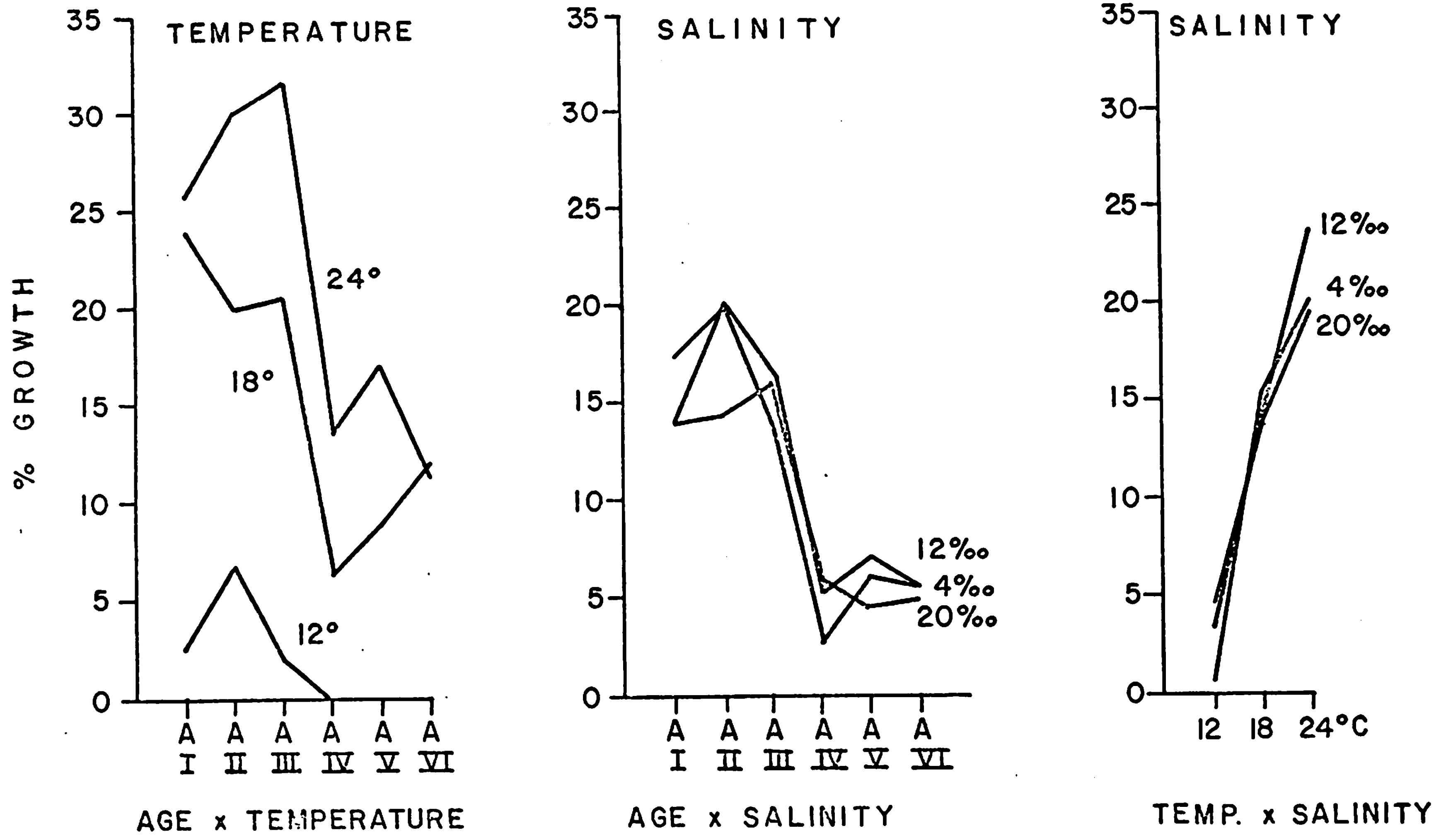


Fig. 4.7. Mean relative growth of striped bass in 1st Order interactions.



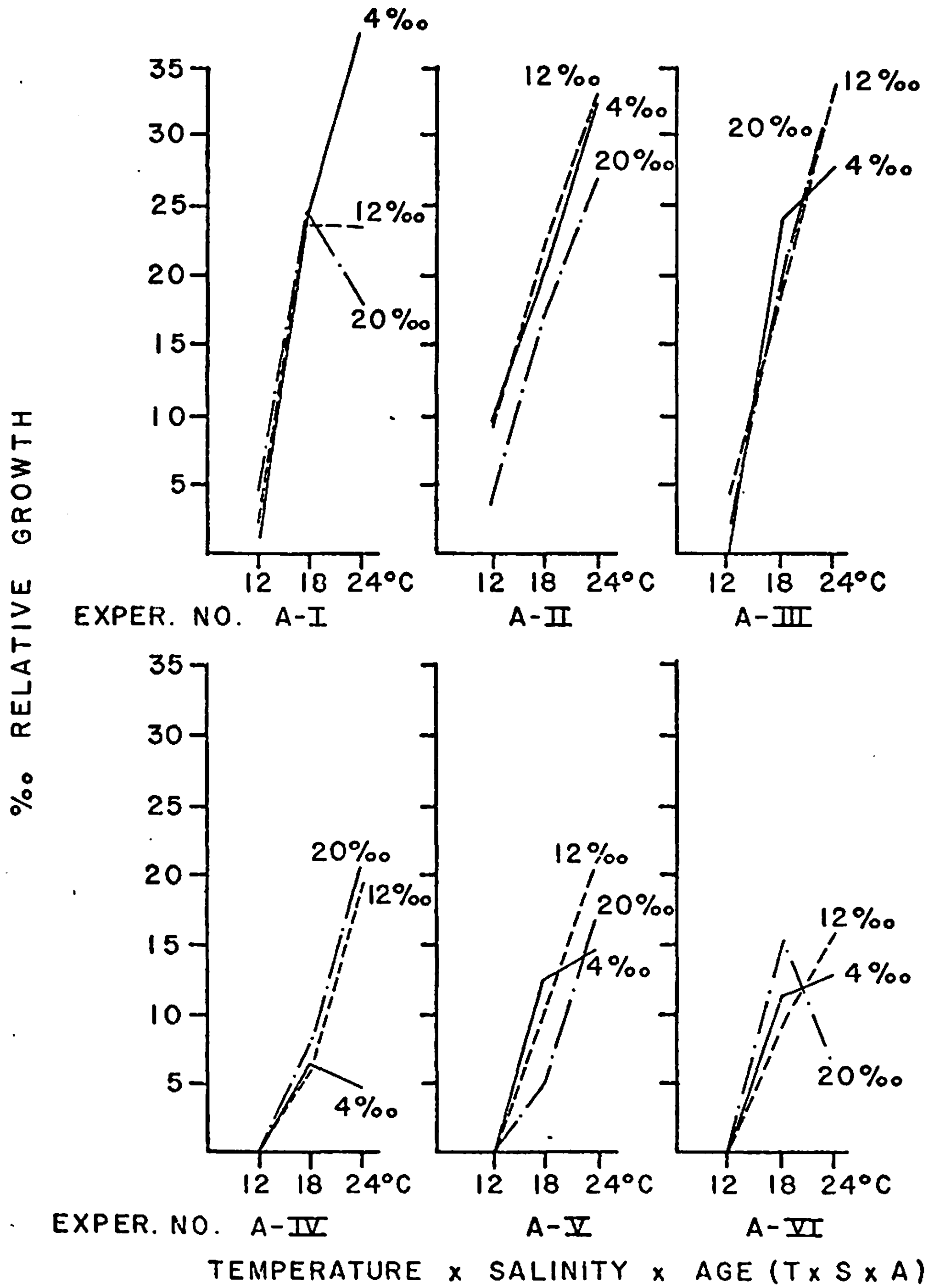


Fig. 4.8. Mean relative growth of striped bass in 2nd Order interactions.

Table 4.1. Age of test fish in temperature and salinity experiments

Experiment	I	II	III	IV	V	VI
Initial age (days)	5	13	21	28	43	63
Length of Experiment	7	7	7	7	7	7
Final age (days)	12	20	28	34	49	69

TABLE 4.2

Analysis of variance illustrating significant treatment effects on mortality of striped bass.

Source of Variation	df	ss	ms	F
Age	5	19762.67	3952.53	24.5794**
Temperature	2	40037.35	20018.68	124.4892**
Salinity	2	2080.52	1040.26	6.4690*
T x A	10	55079.76	5507.98	34.2522**
S x A	10	4052.31	405.23	2.5199*
T x S	4	1200.10	300.03	1.8657n.s.
T x S x A	20	5770.98	288.55	1.7943*
Error	108	17367.10	160.81	
Total	161	145350.79		

Table 4.3

Results of Tukey's test for comparison of means and significant differences in mean percent mortality of striped bass in 1st Order interactions. (Any two means not scored by the same line are significantly different).

Temperature X Age

AGE*	C	MEAN % MORTALITY
V	12	100.0
VI	12	100.0
IV	12	71.0
III	24	22.1
V	18	22.0
III	12	16.5
VI	24	11.7
I	24	10.3
IV	24	6.6
II	12	6.0
I	18	4.4
II	24	4.2
II	18	3.5
IV	18	1.8
III	18	1.1
I	12	0.1
V	24	0.0
VI	18	0.0

Salinity X Age

AGE*	‰	MEAN % MORTALITY
V	12	43.2
VI	4	41.3
VI	20	41.3
IV	20	41.0
V	4	40.6
V	20	36.7
VI	12	25.0
II	20	17.2
III	20	16.5
IV	12	13.6
III	12	13.3
IV	4	10.1
I	12	7.7
III	4	4.9
I	20	2.3
II	12	2.0
I	4	1.9
II	4	0.5

* Age refers to experimental number

Table 4.4

Analysis of variance illustrating significant treatment effects on relative growth of striped bass.

Source of Variation	df	ss	ms	
Age	5	4664.52	932.90	424.9549**
Temperature	2	14235.46	7117.73	3242.2595**
Salinity	2	45.64	22.82	10.3945*
T x A	10	462.19	46.22	21.0535*
S x A	10	285.35	28.53	12.9980*
T x S	4	82.35	20.59	9.3776*
T x S x A	20	851.17	42.56	19.3447*
Error	108	237.10	2.20	
Total	161	20863.78		

Table 4.5

Results of Tukey's test for comparison of means and significant differences in mean relative growth of striped bass in 1st Order interactions. (Any two means not scored by the same line are significantly differnt).

Temperature X Age

AGE*	C	RELATIVE GROWTH
III	24	31.63
II	24	30.01
I	24	25.69
I	18	23.86
III	18	20.44
II	18	19.73
V	24	17.00
IV	24	13.58
VI	18	11.92
VI	24	11.32
V	18	8.86
II	12	6.75
IV	18	6.24
I	12	2.49
III	12	2.07
IV	12	0.01
V	12	0.00
VI	12	0.00

Salinity X Age

AGE*	‰	RELATIVE GROWTH
II	12	20.07
II	4	19.80
I	4	17.27
III	12	16.69
III	20	16.05
II	20	14.36
I	12	14.16
I	20	14.12
III	4	13.62
V	12	6.81
V	4	6.07
IV	20	5.89
VI	12	5.55
VI	4	5.50
IV	12	5.17
VI	20	4.81
V	20	4.51
IV	4	2.64

* Age refers to experimental number

Temperature X Salinity

C	‰	RELATIVE GROWTH
24	12	23.83
24	4	20.20
24	20	19.45
18	4	15.54
18	20	14.10
18	12	13.95
12	12	4.60
12	20	3.31
12	4	0.75

T x S x A INTERACTIONS			RELATIVE GROWTH	PERCENTAGE GROUPINGS
C	‰	AGE*		
24	4	I	37.40	
24	20	III	33.85	>25%
24	12	III	33.71	
24	12	II	33.31	24 C - Younger Fish
24	4	II	32.95	(Exper. Nos. I-III)
24	4	III	27.73	
24	20	II	26.98	
18	20	I	24.40	
18	4	I	24.03	
18	4	III	23.25	<25% >20%
24	12	I	23.19	
18	12	I	23.16	18 & 24 C - Predominantly
18	12	II	21.83	Younger Fish
24	12	V	20.50	
24	20	IV	20.20	
18	4	II	20.19	
18	20	III	19.94	
24	12	IV	18.70	
18	12	III	18.03	
24	20	I	17.70	<20% >15%
18	20	II	17.29	
24	20	V	16.26	18 & 24 C - All Age Fish
18	20	VI	15.61	
24	12	VI	15.60	
24	4	V	14.45	
24	4	VI	12.73	<15% >10%
18	4	V	12.24	
18	4	VI	11.47	18 & 24 C - Older Fish
18	12	V	10.04	
18	12	VI	9.15	
12	4	II	9.08	
12	12	II	8.26	
18	20	IV	7.10	<10% >5%
24	20	VI	6.52	
18	4	IV	5.97	All Temps. - All Ages
18	12	IV	5.69	
18	20	V	5.18	
24	4	IV	4.70	
12	20	I	4.15	
12	12	III	4.11	<5%
12	20	II	3.60	
12	12	I	2.33	
12	20	III	2.32	12 C - All Age Fish
12	4	I	1.32	
12	4	III	0.58	
12	4	IV	0.06	
12	4	V	0.00	
12	4	VI	0.00	
12	12	IV	0.00	
12	12	V	0.00	
12	12	VI	0.00	
12	20	IV	0.00	
12	20	V	0.00	
12	20	VI	0.00	

KEY:
> GREATER THAN
< LESS THAN
*Age refers to Experiment No.

Table 4.6. Results of Tukey's test for comparison of means and significant differences in mean relative growth of striped bass in 2nd Order interactions. (Any two means not scored by the same line are significantly different).

Table 4.7. Mean percent mortality of striped bass in controls and experimental temperature and salinity treatments by experiment.

Exper.	Initial Ambient		Controls(1.)	Treatments - % Mortality								
				12 C			18 C			24 C		
No.	C	‰	% Mortality	4‰	12‰	20‰	4‰	12‰	20‰	4‰	12‰	20‰
I	18.8	.20	71.0	0.0	3.3	0.0	6.7	10.0	6.7	10.0	16.7	13.3
II	21.5	.20	79.0	3.3	3.3	26.7	0.0	6.7	16.7	3.3	3.3	16.7
III	21.0	4.1	20.0	20.0	10.0	26.7	3.3	6.7	0.0	3.3	36.6	43.3
IV	24.2	4.6	12.0	30.0	56.7	100.0	10.0	0.0	6.7	6.7	10.0	13.3
V	22.0	4.7	100.0*	100.0	100.0	100.0	23.3	30.0	20.0	0.0	0.0	0.0
VI	28.0	4.8	13.0	100.0	100.0	100.0	0.0	0.0	0.0	33.3**	0.0	33.3**

*-- Disease; epidemic level

**- Mortalities occurred on the sixth day of experimentation due to foreign debris entering the vessels.

1. % Mortality in the controls is the mean of nine test vessels.

Table 4.8. Mean relative growth of striped bass in controls and experimental temperature and salinity treatments per experiment.

Exper. No.	Initial Ambient		Controls Relative Growth(%)(1.)	Treatments - Relative Growth(mean percent)								
				12 C			18 C			24 C		
	C	‰		4‰	12‰	20‰	4‰	12‰	20‰	4‰	12‰	20‰
I	18.8	.20	8.8	1.40	2.37	4.03	24.05	23.18	24.41	37.46	23.21	17.84
II	21.5	.20	7.4	9.09	8.31	3.88	20.22	21.84	17.03	32.93	33.32	27.08
III	21.0	4.1	10.9	0.79	4.16	2.69	23.26	16.98	19.97	27.81	33.76	33.92
IV	24.2	4.6	19.2	0.00	0.00	0.00	6.07	5.66	7.11	4.76	18.79	20.22
V	22.0	4.7	0.15*	0.00	0.00	0.00	12.28	10.32	5.16	14.56	20.52	16.37
VI	28.0	4.8	12.0	0.00	0.00	0.00	11.52	11.15	15.58	12.68	15.76	6.41

*-- Disease; epidemic level

1. Relative growth in the controls is the mean of nine test vessels.

Job 5. To Experimentally Stock Additional Tributaries.

Stocking of additional tributaries was proposed contingent upon demonstrable success in the stocking program for the Ware River. Extensive field studies conducted during this project did not provide conclusive evidence of a successful stocking for 1971 in the Ware River. Our efforts were, therefore, diverted toward an indepth assessment of the Ware River rather than a less complete study involving stocking in two tributaries. This decision was reasoned to provide the most efficient and effective utilization of personnel and funds in our assessment of the feasibility of stocking underutilized nursery areas with striped bass. The results of our investigations have been presented in Job 3 of this report.

Job 6. Evaluation of Striped Bass Stocking as a Management Procedure and an Estimate of Benefits.

A. Computation of Survival of Juveniles.

This section analyzes several basic aspects of the population dynamics of juvenile striped bass and describes the relationship between age and stocking density necessary to achieve various densities at the end of 6 months.

Stocking of eyed eggs and sac fry was in vogue from 1860 to 1940 until several investigators began suspecting the fallibility of this approach (Hile, 1936; Van Oosten, 1941; Christie, 1963, and Walburg and Nichols, 1967). Pond, lake and stream stocking has been moderately successful in controlling the species-types after reclamation (e.g. elimination of rough fish) but overall increases in stock are usually not expected. A separate and specific management technique has been the recent development of put and take fishing.

The put and take technique has circumvented high juvenile mortality by raising the fish artificially to a size where mortality losses become tolerable, thereby giving a fair return for the number and cost of rearing. The entire Great Lakes fisheries rehabilitation program, has been based on this concept and it has been extremely successful in its initial years, Tody (1973), SCOL (1972).

To boost natural stocks requires successive introductions into environments that have natural spawning (not a factor in put and take or the Great Lakes salmon fishery); but the introductions must be made with full cognizance of fish size versus mortality rate. Such information allows estimates of the proper stocking density based on size (and age) of fish to achieve the target density at some later date.

If the natural stock densities can be measured at comparable dates, then the contribution of the stocked segment can be calculated. Further, by comparing costs with return, a rational decision of stocking any area can be attempted.

In the absence of data from Virginia waters, we must incorporate mortality data for juvenile striped bass from other areas and make several assumptions. These are shown to be acceptable and to approximate the Virginia population quite closely.

Turner and Chadwick (1972) have studied striped bass in the Sacramento-San Joaquin estuary of California for 11 years. From their serial survey and estimate of year class abundance the mean (11 year) daily mortality for bass between 1.0 and 1.6 inches was 5.2%. Within this size range, the grand average growth rate was 0.0289 inches/day. The slopes of the serial abundance estimates reveal the same rates for young bass between 0.8 and 2.0 inches. Within the first growing season, young bass growth is linear soon after yolk absorption (Humphries and Cumming, 1973), so we can assume the daily growth rate holds at least up to 200 days.

The mortality rate applies strictly to bass 0.8-2.0 inches long; however, a first approximation is to consider it as the daily rate from hatching (or at yolk absorption = 5 days) to the 200th day. The possible error introduced for bass larger than 2 inches (ca 65-70 days old) is negligible as shown below. If bass 0.2 to 0.8 inches have a higher mortality rate (very likely), then our estimates will be somewhat conservative.

A daily mortality rate (a) of 5.2% converts to an instantaneous rate (Z) of 0.053. For each 30 days we, therefore, expect a 79.61% reduction in abundance.

$$1 - s = e^{-0.053(30)}$$

Since yolk absorption is complete at 0.2 inches, the age of young bass at 1 inch becomes

$$\frac{1.0 \text{ inch} - 0.2 \text{ inch}}{0.0289 \text{ inch/day}} = 27.7 \text{ days}$$

plus 5 days with yolk = 32.7 days

By a similar procedure, age at 1.6 inches is 53.4 days. Expirically, these sizes compare closely with the graph of Humphries and Cumming (1973). We, therefore, have at least two known points and the corresponding mortality from field data. The loss of fish between these sizes occurs over 21 days, therefore, the 21 day loss is 67.2% of N at 1 inch.

Setting the population of 1 inch fish at 1,000, we can compute the numbers alive at any day after the 33rd, and at any day younger than this. This gives the following hypothetical population:

Age in Days	Number Alive	Percentage of Original
5	4,405	100.0
10	3,389	76.9
20	1,992	45.2
33	1,000	22.7
38	768	17.3
43	588	13.3
48	452	10.3
54	328	7.4
67	160	3.63
85	63	1.43
100	38	0.64
120	10	0.23
160	1	0.023
200	0.1	0.0031

We can consider this as the standard population and carry the computations through the 120th day (Fig. 6.1). From the derived relationship it is possible to determine stocking rate versus age for any desired density in suitable habitat at some particular age. By December of each year the year class of striped bass has been established. Between June 1 and December 16, there are 200 days. By 16 December natural mortality is rapidly decreasing and from the following spring onward, fishing mortality represents the greatest cause of death (see Job 1 of this report).

We do not have estimates of striped bass density in suitable habitat during October-December. We consider suitable habitat for the YOY as that area less than 18 ft deep for the period before winter water temperatures prompt a movement of young bass to deeper channels. From our beach seine and trawling program the density is estimated at between 2 and 30 bass/acre. Therefore, we have selected this as an operational range to calculate stocking rates.

The number of bass necessary to achieve any selected density depends primarily on size of bass stocked. The complete 200 day matrix is given in Table 6.1 for various densities. To "insure" a density of 4 bass/acre in December, 129,800 sac-fry would need to be stocked per acre on June 5. If the young bass were held until the 50th day (fish about 37 mm) then only 11,344/acre would be necessary. By the 85th day the mortality curve has for the most part leveled out and 98% of the mortality in the wild has already occurred (Fig. 6.1). Turner and Chadwick's mortality rate holds at least through the 70th day of life. If bass older than 70 days have lower mortality, the differences in the final densities are negligible compared to the extremely high early mortality effects.

An estimate of stocking rate versus size and desired density after any elapsed period may also be obtained from Table 6.1. For example, if a program to achieve 10 bass/acre on September 8 (100th day) is desired, the managers have the choice of stocking sac fry or any age up to 100 days old. If they could only stock sac fry, 2000/acre are necessary. If they could hold the fish until the 50th day, then only 140/acre would be necessary.

The optimum density of striped bass in any area depends on a multitude of factors collectively termed carrying capacity. Whatever these factors may be, intense experimental sampling could determine density at several periods within the first year of life. Once the range has been determined this should provide some estimate of the greatest density when strong year classes occur. It seems improbable that any stocking program could contribute to densities which exceed the overall carrying capacity. However when natural densities are below the maximum at any point in time, stocking the correct number of the correct size could boost the density by a predictable amount. To this end Table 6.1 provides an estimate of the choice matrix in quantitative terms derived from the population dynamics of striped bass. If a greater number of studies were available, a more refined table could be prepared. The best estimate for any area, whether estuary or reservoir would be based upon site specific population dynamics.

In the absence of natural spawned fish, surveys of natural stock are unnecessary to compute necessary additions. The desired goal is always catchable size bass (say 12+ inches). To achieve the desired stocking rate, the mortality from December to the 12 inch size needs to be computed and applied to the expected density in December. For example, if 4 bass/acre (12 inches) represents a reasonable fishing density, and if the mortality is 70% between 6 inches (200 days old) and 12 inches (about 630 days old), then there should be 13.3 bass/acre on the 200th day. From Table 6.1 we see that to have 15 fish per acre on the 200th day required a 3000/acre stocking rate of 100 day old fish, or 42,540/acre of 50 day old fish. Of course each situation and rate depends on the derived total mortality rate, so the above is only an example of computations.

Comparison of numerical extinction in the wild with some rearing operation coupled with the economics of the rearing operation would allow a rational choice of optimum stocking size. When the stocking density is further extrapolated to total return from the commercial and sport fishery, a reasonable cost-benefit relationship can be estimated. For the Great Lakes salmon program, the State of Michigan has estimated a 11 to 1 return (in dollars) to the state when the fish are raised to 5-8 inches before release (Tody, 1973). Stream fisheries seldom have such high ratios but most are positive. Stocking of eyed-eggs or sac fry usually produces negative ratios and for the most part have been abandoned by the U. S. and Canada.

B. Evaluation of Striped Bass Stocking in the Mobjack Bay.

A total of 1 million sac fry striped bass were stocked at three locations in the Mobjack Bay (Table 6.2 and Fig. 3.2) in 1971. Between the low water mark and the 18 ft contour, there are 24,667 acres in Mobjack Bay (Table 6.3). We consider this area as suitable habitat for young bass since they have seldom been found in water deeper than 18 ft during our experimental trawling. There is little imigration of York River or Piankatank River striped bass YOY to Mobjack Bay except in years of very high abundance. The rivers and creeks of Mobjack Bay do not serve as spawning grounds for striped bass (see previous sections). We can, therefore, apply stocking density calculations from part A and determine if the number stocked was adequate to contribute measurably to this underutilized nursery area.

The 1 million fish stocked in 1971 could migrate throughout Mobjack Bay, so the effective stocking density was 40.5 sac fry/acre. After 200 days this density would be approximately 0.0013 juveniles per acre, or approximately one juvenile bass for ever 1.2 $miles^2$. To obtain one juvenile bass per acre in December, 32,500 sac fry per acre would be the correct stocking rate. The total number necessary for the entire Mobjack Bay system would be close to 800 million, stocked at various points.

The 1 million sac fry stocked, contributed approximately 31 bass to the population of Mobjack Bay by December. If the mortality rate in Mobjack Bay was only half that of the California population (2.6%/day instead of 5.2%/day) the contribution by December would have been 6,700 young fish. This value converts to only 0.25 bass per acre. The more realistic approach is to assume a mortality rate close to the derived rate for California fry.

With the conservative 4% daily mortality rate, a density of 10 striped bass per acre by December 16 would require stocking 33 thousand sac fry/acre in Mobjack Bay. At the higher mortality rate of 5.2%/day, 325 thousand sac fry/acre would be necessary. These two examples can be summarized as follows:

To get in Dec.	With a Mortality of	Sac Fry Stocking/Acre	Total Needed for Mobjack Bay
1/acre	5.2%/day	32,500	800 million
1/acre	4.0%/day	3,300	82 million
10/acre	5.2%/day	325,000	8 billion
10/acre	4.0%/day	33,300	821 million

The number of young bass we were able to obtain for stocking in 1971 was entirely inadequate to satisfy the objective of utilizing the nursery grounds in Mobjack Bay. Between 20 and 500 bass may have survived to December, but compared to suitable habitat these numbers are infinitely small. If the Mobjack Bay mortality rate is the same as that in California, only 31 bass survived until December. The total value contributed would be less than $100 at the present market value, assuming all continue to live and are caught as 2-year-olds.

In 1972 the fish were reared in the laboratory from the yolk sac stage to about 35 mm. From 2.1 million bass as sac fry, we raised 4,000 to a mean size of 35.3 mm FL. If the mortality rate in "nature" applied to the reared fish about 35 thousand would have survived, but crowding and cannibalism caused a higher mortality.

The reared fish grew more slowly than normal, being only 38 mm (average) by the 11th week, whereas they should have averaged near 58 mm (in the wild). Thus for stocking computations, we must use size rather than age. This would be about 50 days old (Table 6.1).

The 4,000 fingerlings stocked in 1972 represent 0.16/acre for the Mobjack Bay to depths of 18 ft. If the same mortality of 5.2%/day applied from the 50th to the 200th day, the total contribution to the bay was approximately 1.4 fish, or 0.00035 of the stocked number. A target density of 1 juvenile/acre in December would require stocking 2,800 bass/acre at 35 mm. For Mobjack Bay, this would be approximately 69 million young bass 50 days old. If the actual death rate was 4.0%/day; nine bass would have survived from the 4,000. One would need to stock 454/acre as 50-day-old fish or 11.2 million for the bay to obtain 1/acre in December.

The mortality of bass 51 mm (2 inch) from stocking to December may be less than 5.2%/day. However, the extinction curve beyond 80 days (about 60 mm) represents only a slight change compared to the impact of mortality at smaller sizes (Fig. 6.1). The 4.0%/day mortality rate would compensate for reduced mortality beyond 51 mm, and as such can be considered a fair estimate.

For both years of stocking in Mobjack Bay, even using the 4.0% rate, the number stocked was inadequate to significantly increase the population of bass. In 1971 we may have increased the population by 300 fish, and in 1972 by 10 fish. If several million 50-day-old fish could have been stocked, Mobjack could have produced about 20,000 striped bass by December. If the fish could be raised to 65-75 mm, then 1.5 million would be necessary to produce 20,000 fish.

We must conclude that stocking striped bass to augment or utilize some available nursery area has little hope of success with existing economic conditions and status of striped bass in Tidewater Virginia. A massive input into an area without a natural spawned population of YOY (such as Mobjack Bay) would boost the utilization of these waters by bass, but the benefit-cost ratio would be less than one. If the striped bass were raised to 6-10", then released, stocking to augment may have some merits in selected locations of limited size. The small number and size available to us for Mobjack Bay precluded success based purely on theoretical grounds (as presented in the foregoing calculations).

Stocking may functionally restore a spawning run of striped bass to some area previously altered by pollution or damming,but the expected loss of stocked fish needs to be appreciated and fishing must be carefully controlled. If the natural population has access to these areas, then through normal dispersal phenomena, they will soon capitalize on the increased spawning or nursery zone.

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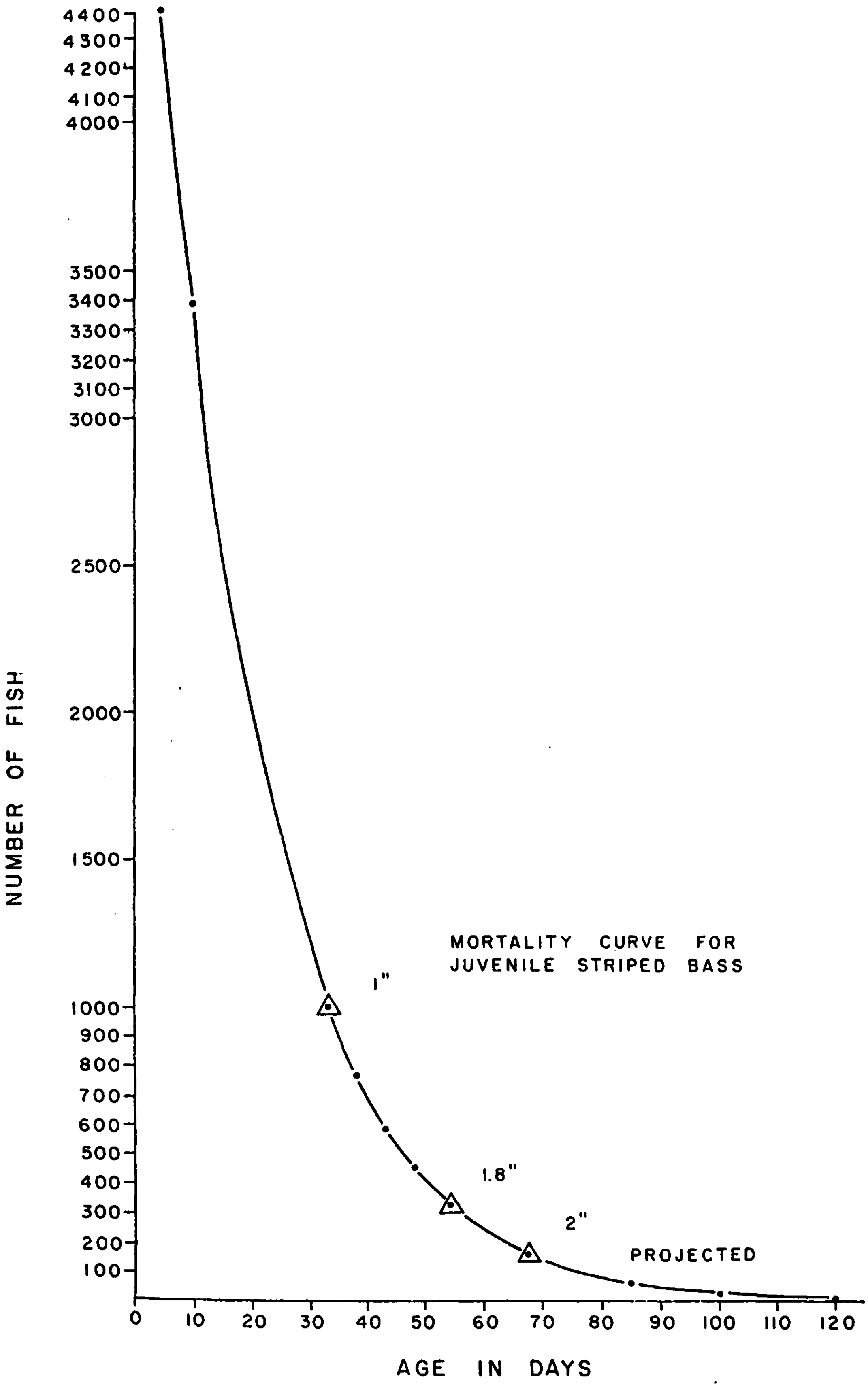

Figure 6.1. Mortality curve of young striped bass based on a daily rate of 5.2% per day for fish 1 inch to 2 inches and extrapolated to other ages.

Table 6.1. Estimated stocking rate per acre of striped bass to achieve a desired density on December 16. For the 200 day matrix, all fish assumed stocked on June 5 if sac fry, June 20 if 20 days old, August 10 if 40 days old, etc.

Age of fish and	Approx. size[a] in mm (FL)[b]	Desired density of striped bass per acre on 200th day								
		1	2	4	6	8	10	15	20	30
Fert. eggs		40,144	80,288	160,576	240,864	321,152	401,440	602,160	802,880	1,204,320
5 days	3.7 mm	32,467	64,434	129,868	194,802	259,736	324,670	487,005	649,340	974,010
10	7.3	23,677	47,354	94,708	142,062	189,416	236,770	355,155	473,540	710,310
15	11.0	18,160	36,320	72,640	108,960	145,280	181,600	272,400	363,200	544,800
20	14.7	13,204	26,408	52,816	79,224	105,632	132,040	198,060	264,080	396,120
25	18.3	10,730	21,460	42,920	64,380	85,840	107,300	160,950	214,600	321,900
30	22.0	8,182	16,364	32,728	49,092	65,456	81,820	122,730	163,640	245,460
35	25.7	6,310	12,620	25,240	37,860	50,480	63,100	94,650	126,200	189,300
40	29.6	4,818	9,636	19,277	28,908	38,544	48,180	72,270	96,360	144,540
45	33.0	3,715	7,430	14,860	22,290	29,720	37,150	55,725	74,300	111,450
50	36.7	2,836	5,672	11,344	17,016	22,688	28,360	42,540	56,720	85,080
55	40.4	2,187	4,374	8,748	13,122	17,496	21,870	32,805	43,740	65,610
60	44.0	1,672	3,344	6,688	10,032	13,376	16,720	25,080	33,440	50,160
65	47.7	1,286	2,572	5,144	7,716	10,288	12,860	19,290	25,720	38,580
70	51.4	982	1,964	3,928	5,892	7,856	9,820	14,730	19,640	29,460
75	55.1	756	1,512	3,024	4,536	6,048	7,560	11,340	15,120	22,680
80	58.7	577	1,154	2,308	3,462	4,616	5,770	8,655	11,540	17,310

Table 6.1. Continued

Age of fish and	Approx. size[a] in mm (FL)[b]	Desired density of striped bass per acre on 200th day								
		1	2	4	6	8	10	15	20	30
85	62.4	441	882	1,764	2,646	3,528	4,400	6,615	8,820	13,230
90	66.1	390	780	1,560	2,340	3,120	3,900	5,850	7,800	11,700
95	69.7	259	518	1,036	1,554	2,072	2,590	3,885	5,180	7,770
100	73.4	200	400	800	1,200	1,600	2,000	3,000	4,000	6,000
125	91.8	53	106	212	318	424	530	795	1,060	1,590
150	110.1	14	28	56	84	112	140	210	280	420
175	128.6	4	8	16	24	32	40	60	80	120
200	146.8	1	2	4	6	8	10	15	20	30

(a) Fish size in wild computed from 0.0289 inch/day (0.7340 mm/day) from Turner and Chadwick.

(b) For pond reared fish, multiply sizes by 1.08.

Table 6.2. Striped bass stocked in Virginia waters 1971 and 1972 by Virginia Institute of Marine Science.

Location	Index Letter on Fig. 3.2	Date	Salinity	Number	Size
Beaverdam Creek at Rt 14 Bridge	A	4 June 71	Fresh	700,000	3 day Sac Fry
Cow Creek at 14 Bridge	B	4 June 71	Fresh	100,000	3 day Sac Fry
Foxmill Creek at U.S. 17 Bridge	C	4 June 71	Fresh	200,000	3 day Sac Fry
Pighill Bend, Ware River	D	29 June 72	10‰	2,000	20-65[1] mm
Warehouse Landing, Ware River	E	29 June 72	10‰	2,000	20-65[1] mm

(1) $\bar{x}$ = 35.3 mm FL

Table 6.3. Areal statistics of the striped bass nursery zones in the major Virginia rivers. Upper limit defined as five miles beyond the point where the 0.5 ppt isohaline intersects bottom between high and low tide (summer and fall average). Area is at mean low water, including offshore shoals and all small creeks and bays within tributary.

System	Area of 0-12' interval in hectares	Area of 0-18' interval in hectares	Acreage of 0-18' interval	Boundary Points
Mobjack Bay	6,222	9,982	24,667	All areas northwest of a line connecting New Point Comfort and the east tip of Guinea Marshes.
Back Creek	579	610	1,506	Area west of line connecting east Bay Tree Point and east Tue Point
Poquoson River	2,333	3,011	7,441	Tue Point to Marsh Point, not including that of Back Creek
Back River	1,739	1,789	4,420	Plumtree Point to Northend Point
York River	10,420	12,474	30,823	Tue Point to tip of Guinea Marshes
Great Wicomico	2,416	3,096	7,650	Fleet Point to tip of Dameron Marsh
Piankatank	2,992	3,819	9,436	Stingray Point to Cherry Point
Rappa-hannock	22,106	26,449	65,355	Windmill Point to Stingray Point
James[(1)]	33,418	39,743	98,205	Old Point Comfort to Willoughby Spit
		Total	249,000	

(1) Elizabeth River included to 2nd lift bridge.

Publications from FA - Virginia - AFS 6 Contract

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