PROCEEDINGS OF THE THIRTY-SECOND ANNUAL CONFERENCE SOUTHEASTERN ASSOCIATION OF FISH AND WILDLIFE AGENCIES

NOVEMBER 5-8, 1978
HOT SPRINGS, VIRGINIA

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BEACH ZONE FISH COMMUNITY STRUCTURE IN THE JAMES RIVER, VIRGINIA[a]

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Abstract: A seining survey of the fish fauna of the beach zone in the James River, Virginia, was conducted from July to December 1977. Weekly collections were made at 4 stations resulting in the capture of 17,602 individuals representing 36 species. Abundance and diversity were influenced by large catches of schooling and migratory species utilizing nearshore areas as a nursery ground. Freshwater species diversity peaked in August and September, while mesohaline species diversity peaked in July, September, and November. Cluster analysis was used to define 3 freshwater station groups representing warm, moderate, and cool water temperatures, but was not helpful in analyzing mesohaline stations.

Proc. Ann. Conf. S.E. Assoc. Fish & Wildl. Agencies 32: 639-647

The beach or shore zone is a rather extensive and physically well defined habitat which is not only economically important as a recreational area but also is significant as nursery grounds for several species: *Alosa pseudoharengus*, *A. aestivalis*, *A. sapidissima* (Hoagman et al. 1974); *Morone saxatilis* (Raney 1952); *Brevoortia tyrannus* (June and Chamberlin 1959) and *Trinectes maculatus* (Dovel et al. 1969). Faunal surveys also revealed that the fish components utilize the estuary as a feeding area for adults and juveniles, and as a spawning area. (Moore et al. 1977; Merriner et al. 1976). Other workers who have reported on James River beach seining are: Haven (1957), Hoagman et al. (1974), Jensen (1974), Loesch and Kriete (1976), and Dias et al. (1977).

Our objective was to understand the dynamics of the fish populations inhabiting the beach zone. Weekly daytime collections of ichthyofauna were taken from 2 salinity regimes of the beach zone in the James River, Virginia. The fish species taken in the samples were subsequently analyzed for abundance, diversity and clustering tendencies. This project was supported by funds from the Anadromous Fish Act (P.L. 89-304) through the National Marine Fisheries Service, Northeast and Southeast Regions, and the U.S. Fish and Wildlife Service, Southeast Region.

We are grateful to J. G. Loesch for his helpful comments and critical review of the manuscript. We also wish to thank E. Foell and W. Kriete for their help with the data analysis and W. Blystone for his assistance with the computer programs. J. Zernes, J. Gartner, and J. Gourley assisted in the data collection. B. Taylor typed the manuscript.

METHODS AND MATERIALS

Data Collection

From July 1977 through December 1977 four stations in the James River, Virginia, were sampled weekly using a 27.5 m beach seine with a 2.4 m bag of 1.2 cm stretched mesh. The seine was set 30 m from shore and approximately parallel to the shoreline. Two consecutive sets were made at each station.

Surface temperature and salinity were measured at each location. The total number and total weight of each fish species were recorded after each seine sample.

The 2 upriver stations, Wilcox Wharf (JA-2) and Maycocks Point (JA-3) located at river kilometer 90 and 95, respectively, are in tidal freshwater (Fig. 1). The downriver, mesohaline stations, Tribell Shoal (JA-5) and Hog Point (JA-4), are on opposite sides of the river at kilometer 47.

[a]Contribution No. 900 from Virginia Institute of Marine Science, Glou- cester Point, VA 23062.

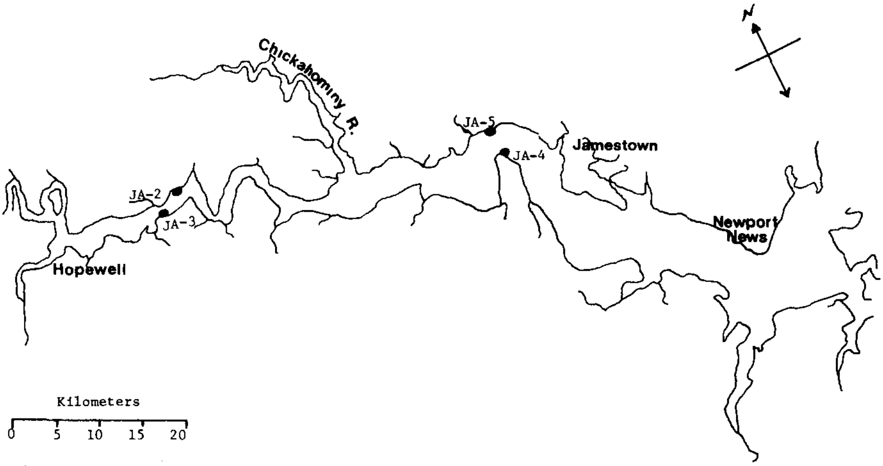


Fig. 1. Beach seine station locations in the James River, 1977.

Data Analysis

An index of species diversity H' was computed by the formula:

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

where N is the total number of individuals in the sample, n_i is the number of individuals in the *i*th species, and c is the conversion factor (= 2.302585) from base 10 to base e (Lloyd et al. 1968). This measure of diversity is affected by both the numer of species present (species richness component) and their relative abundance (species evenness component). Species richness was measured by the ratio $(S-1)/\log_e N$ where S is the number of species and $\log_i N$ is the natural logarithm of the number of individuals of all species in the sample. Evenness was measured by Pielou's (1969) measure J which is the ratio $H'/\log_2 S$ where H' is the diversity index and S is the total number of species.

Species and stations were grouped by the Canberra Metric dissimilarity coefficient. This coefficient minimizes the effect of extremely large catches of a species on group formation (Boesch 1977). Comparison of station groups with species groups by constancy and nodal fidelity analysis can reveal if clusters represented natural cohesive groups or were excessively divisive or agglomerative. The constancy index (C_{ij}) is computed by formula:

$$C_{ij} = a_{ij}/(n_i n_j)$$

Where a_{ij} is the number of occurrences of members of species group i in station group j, and n_i and n_j are the number of entities in the respective groups. The constancy index takes a value of 1 when all species in the species group occur at all stations in the station group and 0 when none of the species occur in the station group.

Fidelity (F_{ij}) is an expression of the constancy of species in a station group compared to the constancy over all station groups and is computed as:

$$F_{ij} = (a_{ij}\sum_j n_j)/(n_j \sum_j a_{ij})$$

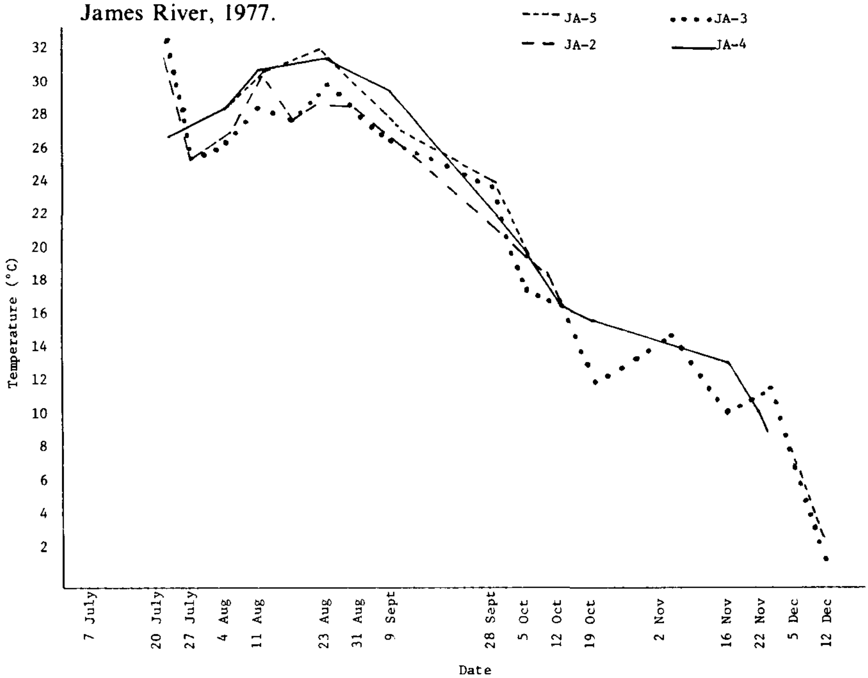
Fidelity is an indication to what degree species select, avoid, or are limited to stations. Fidelity is greater than 1 when constancy in a station group is greater than its constancy in all groups (species group preference of a station group) and less than 1 when constancy in the station group is less than its overall constancy (species avoidance of a station group). Chi-square ($\alpha = 0.05$) analysis was used to determine if the corresponding fidelity values were significantly different from unity.

If less than 10 individuals of a species were caught over the entire sampling period they were considered rare and dropped from the analysis. The following species were rare: *Notropis analostanus, Membras martinica, Alosa sapidissima, A. pseudoharengus, Perca flavescens, Lepomis macrochirus, Pomatomus saltatrix, Cyprinus carpio, Opis[thonema oglinum, Noturus gyrinus,* and *Anchoa hepsetus.*

RESULTS

Salinity of the lower river stations (JA-4, JA-5) ranged from 10 to 17 0/00 and for the upper river stations (JA-2, JA-3), 0 to 0.5 0/00. Surface water temperature ranged from 32.0 C at station JA-3 in July to 3.0 C at station JA-5 in December (Fig. 2).

Fig. 2. Surface water temperatures recorded at individual beach seine stations in the James River, 1977.



A total of 17,602 individuals comprising 36 species was taken during the 23 week sampling period. A complete list of all fish obtained in this study can be obtained from the authors. On a sample basis, numbers of both species and specimens were erratic and influenced greatly by the densely schooling species, *Brevoortia tyrannus,* and to a lesser degree by *Dorosoma petenense.* On a seasonal basis, higher numbers of species were collected during summer and early fall prior to a surface water temperature drop of 6.1 C (average for all stations) observed on the October 5 sampling trip.

Seasonally migratory species such as *Brevoortia tyrannus* and *Leiostous xanthurus* utilize the estuary as a nursery ground and were abundant at both the upper and lower river stations. Prey fishes (*Menidia menidia* and *Anchoa mitchilli*) were also dominant fishes at stations JA-5, JA-4. Upstream, *Notropis hudsonius amarus* and *Morone americana* were dominant species. *Dorosoma petenense* was the only dominant species found at all stations (Table 1). Diversity for all stations changed from a highest in early September to a lowest in November and December (Table 2). The decline in diversity was attributed to the decrease in water temperatures forcing some species to migrate to deeper waters.

Table 1. Percent total catch (by number) of dominant species for the sampling period July through December.

Station	*Species*	*% Total Catch*
JA-2:	*Dorosoma petenense*	20.3
	Notropis hudsonius amarus	17.8
	Morone americana	17.6
	Brevoortia tyrannus	16.9
	Leiostomus xanthurus	6.8
JA-3:	*Brevoortia tyrannus*	80.5
	Notropis hudsonius amarus	5.6
	Dorosoma petenense	2.7
	Morone americana	2.4
JA-4:	*Menidia menidia*	26.0
	Leiostomus xanthurus	22.7
	Dorosoma petenense	21.5
	Brevoortia tyrannus	19.0
	Anchoa mitchilli	2.5
JA-5:	*Menidia menidia*	56.5
	Leiostomus xanthurus	13.5
	Anchoa mitchilli	7.5
	Dorosoma petenense	5.4
	Dorosoma cepedianum	3.7

Table 2. Diversity indices (H'), evenness (J), and species richness (d) for individual beach seine collections in the James River.

JA-2	Date:	20 July	27 July	4 Aug	11 Aug	23 Aug	31 Aug	7 Sept	28 Sept	5 Oct	12 Oct	TOTAL
H'		1.77	2.03	1.86	2.14	0.93	1.48	1.54	1.84	1.18	1.37	2.20
J		0.49	0.53	0.48	0.55	0.40	0.40	0.39	0.51	0.34	0.33	0.47
d		2.13	2.76	2.43	2.68	0.92	2.10	2.31	2.04	1.94	2.72	3.06

JA-3	Date:	20 July	27 July	4 Aug	23 Aug	31 Aug	7 Sept	28 Sept	5 Oct	12 Oct	19 Oct	2 Nov	16 Nov	22 Nov	5 Dec	12 Dec	TOTAL
H'		0.57	1.23	2.08	2.31	0.62	2.41	1.84	1.95	1.82	1.23	0.20	1.74	0.85	1.28	0	0.94
J		0.16	0.30	0.53	0.58	0.15	0.65	0.50	0.54	0.46	0.39	0.06	0.55	0.30	0.46	-	0.20
d		1.51	2.33	2.35	2.93	2.23	2.18	1.88	2.07	3.33	1.42	1.28	1.52	1.36	1.78	0	2.58

JA-4	Date:	7 July	25 July	4 Aug	11 Aug	23 Aug	7 Sept	5 Oct	12 Oct	19 Oct	2 Nov	16 Nov	22 Nov	1 Dec	TOTAL
H'		1.26	1.55	0.88	1.08	0.48	0.54	1.21	0.40	1.40	0.81	0.93	1.08	1.41	1.80
J		0.49	0.41	0.31	0.34	0.17	0.19	0.47	0.17	0.39	0.35	0.28	0.42	0.50	0.40
d		1.01	1.96	1.31	1.54	1.19	0.93	1.17	1.03	1.88	0.96	1.32	1.15	1.40	2.69

JA-5	Date:	4 Aug	11 Aug	23 Aug	7 Sept	28 Sept	5 Oct	12 Oct	19 Oct	2 Nov	22 Nov	12 Dec	TOTAL
H'		0.66	1.46	0.44	1.57	1.92	1.22	0.61	1.67	0.48	1.56	0.41	1.62
J		0.33	0.56	0.22	0.56	0.61	0.38	0.26	0.58	0.30	0.56	0.41	0.41
d		1.05	1.29	0.82	1.91	2.46	1.61	0.86	1.93	0.42	1.76	0.51	2.49

Diversity at JA-2 and JA-3 peaked during August and September while the mesohaline stations showed pulses in diversity in July, September, and November.

Evenness indices, which measure the distribution of individuals among species, were relatively constant over the entire sampling period (Table 2). Upriver stations showed erratic decreases in evenness which were attributed to large catches of *Brevoortia* *tyrannus*. Large catches of *Menidia menidia, Leiostomus xanthurus* and *Dorosoma petenense* resulted in an erratic depression of evenness at the downriver stations.

Species richness for all stations was highest in summer and early fall and decreased in November and December.

Table 3. Species groups determined by cluster analysis of James River beach seine fish catch data.

Grouping	*Explanation*
Group A	
Notropis hudsonius *Menidia beryllina* *Etheostoma olmstedi* *Trinectes maculatus* *Ictalurus punctatus*	Eurythermal, mainly fresh-water
Group B	
Morone saxatilis *Lepomis gibbosus*	Warm water, euryhaline
Group C	
Hybognathus regius *Notemigonus crysoleucas* *Fundulus diaphanus*	Warm to moderate water temperature, mainly fresh-water
Group D	
Anchoa mitchilli *Menidia menidia* *Mugil cephalus*	Eurythermal, mesohaline regime
Group E	
Leiostomus xanthurus *Morone americana* *Dorosoma petenense* *Dorosoma cepedianum* *Brevoortia tyrannus* *Alosa aestivalis*	Euryhaline, common down-stream migration and decline in abundance with falling water temperature in fall
Group F	
Strongylura marina *Stenotomus chrysops*	Mesohaline regime only, appear in fall
Group G	
Fundulus heteroclitus *Micropogon undulatus*	Euryhaline, prefer Hog Point

Cluster analysis was interpreted at the 7 species groups (Table 3) and 10 station groups level (Table 4). Results of the nodal analysis are presented in Figs. 3 & 4.

The three freshwater station groups (VIII, IX, X) represented three temperature regimes with average temperatures of 26.7 C (warm), 20.1 C (moderate), and 7.0 C (cold), respectively. A station at Wilcox Wharf on August 23 had an unusually small catch causing it to cluster with group X (cool freshwater) so it was dropped from the analysis.

Warm and moderate water temperature station groups VIII and IX, respectively, had a high constancy for species groups A, B, C, and E, but only slightly positive fidelity. Constancy decreased at the coldwater station group X for all species groups found in

Table 4. Station groups determined by cluster analysis of James River beach seine data. JA-2 (Wilcox Wharf), JA-3 (Maycocks Point), JA-4 (Hog Point), JA-5 (Tribell Shoal).

Station Group	*Sampling Areas Included*	*Average Temperature (C)*	*Salinity Regime*
I	JA-4	29.5	Mesohaline
II	JA-5	28.9	Mesohaline
III	JA-4, JA-5	24.8	Mesohaline
IV	JA-4	21.3	Mesohaline
V	JA-4, JA-5	16.5	Mesohaline
VI	JA-4, JA-5	10.7	Mesohaline
VII	JA-4, JA-5	9.5	Mesohaline
VIII	JA-2, JA-3	26.7	Freshwater
IX	JA-2, JA-3	20.1	Freshwater
X	JA-2, JA-3	7.0	Freshwater

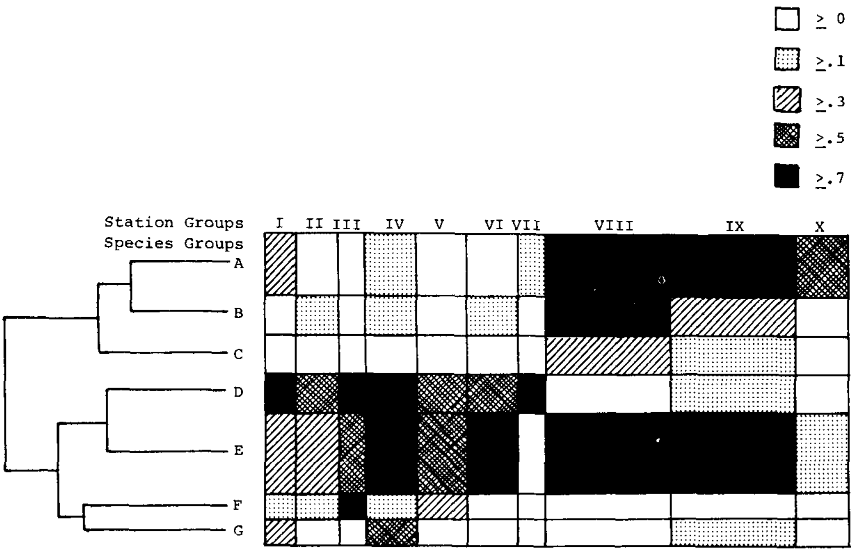


Fig. 3. Nodal constancy in a two-way table of species in station groups (see tables 3 and 4) for James River beach seine data.

freshwater. Constancy decreased from station groups VIII to IX for species groups A, B, and C but increased for species group E. *Anguilla rostrata* clustered with group B, but unlike *Morone saxatilis* and *Lepomis gibbosus, A. rostrata* were never found in the beach zone at the downriver stations.

Cluster analysis of the downriver stations was complicated primarily by spotty appearances of freshwater groups and by faunal differences between opposite sides of the river; thus, these station groups did not lend themselves to labeling strictly by temperature regime as did the freshwater stations. Species group A was highly constant at all freshwater station groups. Downriver, group A was more common at moderate and warm water Hog Point station groups (I, IV) than at Tribell Shoal stations. The moderate

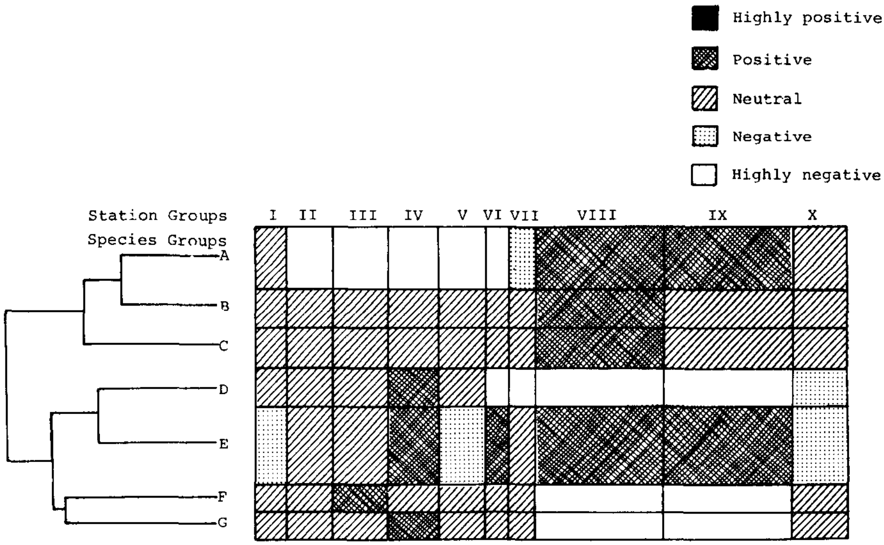


Fig. 4. Chi-Square nodal fidelity analysis of James River beach seine data.

to coolwater groups (V, VI, VII) contained stations from both sides of the river, which indicated that faunal differences were linked to water temperature.

Species group D was exclusively found downriver except for *Anchoa mitchilli*, which was taken in the moderate temperature freshwater station group (IX). Species group D had a slightly positive fidelity with station group IV.

Species group F was exclusively found downriver but excluded from the coldwater stations (VI, VII). Group F had slightly positive fidelity with station group III.

Species group G had a low constancy in warm freshwater (VIII). Downriver, this group had high constancy at only moderate to warm Hog Point stations (IV, VI), and its positive fidelity was limited to station group IV.

Group E was the modal group with 6 species. In freshwater their constancy was high at both station groups VIII and IX, but declined at the cold water group X. In general at the downriver stations, group E's constancy increased from warm to moderate to cool water temperature; however, it declined to near zero on December 12, the termination date of sampling, when water temperature was 3.0 C.

DISCUSSION

The schooling and migrating species of the daytime ichthyofauna of the beach zone were very abundant at times and dominated particular seine catches. As a result total numbers were heavily influenced by these species over the sampling period. These migrant species, represented by group E, which consists of 4 species of clupeids, spot, and white perch, were dominant species at all 4 of the sampling areas (Table 1). Peak abundance occurred in August and September when the juveniles of these species utilize the nearshore areas as feeding grounds. When water temperature fell sharply in October, so did fish abundance. This is the result of group E species migrating downriver and to deeper areas in the estuary. Subsequently, abundance reached a low in December at all stations.

Summarizing fish community structure using 1 parameter, such as species diversity, severely limits the ability of the researcher to describe the community. Often the values are erratic or are heavily influenced by a single component of the system. Diversity values of equal magnitude can represent totally different faunal compositions. Cluster analysis, in conjunction with diversity indices can be a useful tool in analyzing fish community structure. Our freshwater sampling stations clustered clearly into three temperature regimes each with a unique faunal composition. Clustering of the downriver stations, however, was complicated by the spotty appearance of freshwter groups and possibly by the physical and hydrographic differences between the downriver sites. These clustering tendencies were reflected in the diversity indices. Upriver diversity peaked once, but downriver it peaked several times during the sampling period and over a wide range of temperatures. Constancy decreased with falling temperatures upriver, but increased with falling temperatures downriver.

Differences found in the fish community structure emphasize the need for further surveys of the beach zone. Explanations of the changes in community structure are intimately linked to the common traits of the members that form a group. In particular, there is a need to investigate physical features of the habitat as well as diurnal and annual differences.

This study did reveal however, the dynamic nature of the beach zone fish community. Over the sampling period, the changes in fish community structure for the freshwater stations were strongly linked to changes in water temperature. Associated with these temperature regimes was a specific faunal composition.

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