NOAA's Estuarine Biogeography Program

U.S. East Coast Estuaries and Inlets
Analysis of Physical and Hydrodynamic Characteristics

EBP Technical Report Number 1

May 1995

U.S. Department of Commerce
National Oceanic and Atmospheric Administration
National Ocean Service

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The Strategic Environmental Assessments (SEA) Division of NOAA's Office of Ocean Resources Conservation and Assessment (ORCA) was created in response to the need for comprehensive information on the effects of human activities on the nation's coastal ocean. The SEA Division performs assessments of the estuarine and coastal environments and of the resources of the U.S. Exclusive Economic Zone (EEZ).

In 1990, NOAA began a program to evaluate the Nation's estuarine resources in the context of the estuaries they depend. The Estuarine Biogeography program has been conducted jointly by SEAD's Biogeographic Characterization Branch and Physical Environments Characterization Branch. These analyses use SEAD's recently compiled physical, hydrologic, and biologic data sets which were compiled for the explicit purpose of promoting inter-estuarine analyses. The insights gained from these analyses improve the scientific foundation for managing the Nation's estuarine resources. The objectives of this program are to stimulate further inter-estuarine analyses by demonstrating the utility of SEAD data sets, creating the necessary inter-estuarine methodologies, and advocating the use of inter-estuarine analyses in support of estuarine management and assessment.

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NOAA/NOS SEA Division, N/ORCA1
1305 East-West Hwy., 9th Floor
Silver Spring, Maryland 20910
Phone (301) 713-3000
Fax (301) 713-4384

U.S. East Coast Estuaries and Inlets
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Tony A. Lowery and Mark E. Monaco
Biogeographic Characterization Branch
Strategic Environmental Assessments Division
Office of Ocean Resources Conservation and Assessment
National Ocean Service
Silver Spring, MD 20910

and

C. John Klein, S. Paul Orlando and Miranda Harris
Physical Environments Characterization Branch
Strategic Environmental Assessments Division
Office of Ocean Resources Conservation and Assessment
National Ocean Service
Silver Spring, MD 20910

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CHAPTER 1- Assemblages of U.S. East Coast Estuaries Based on Physical and Hydrodynamic Characteristics

Introduction

Traditionally, estuarine characterizations are based on geomorphology or hydrodynamic regimes. Drowned river valley, coastal plain, riverine, lagoon, fjord, etc., describe geomorphology. Likewise, salt-wedge, highly stratified, moderately stratified, vertically homogeneous, etc., describe hydrodynamics. However, the influence of tides, freshwater input, and mixing energetics on estuarine water masses complicates the use of hybrid geomorphologic/hydrodynamic characterizations of estuaries. In the past, this complexity thwarted development of a unified geomorphologic/hydrodynamic characterization of U.S. East Coast estuaries.

With the aid of Principal Component Analysis (PCA) and cluster analysis, the complexity reduces and more objectivity can be brought to bare on developing an empirically based characterization. Given the East Coast estuaries diverse geomorphology and hydrodynamic regimes, 21 descriptive characteristics were included in analysis of 41 National Estuarine Inventory estuaries (Buzzards Bay, Massachusetts to Biscayne Bay, Florida). PCA was applied to the 21 by 41 matrix to identify inter-variable (via rotated loadings) and variable/estuary associations (via factor scores). The PCA's factor scores were subjected to cluster analysis generating assemblages of similar estuaries. To sum, the analysis presented in this report uses estuarine geomorphology and hydrodynamics to identify groups of similar U.S. East Coast estuaries found in the Virginian and Carolinian Provinces.

The purpose of this chapter is to document the analytical techniques and to disseminate results of the first of four analyses, and to define coupling of estuarine and marine environments. This chapter supports an ongoing cooperative study between the University of Virginia and the SEA Division entitled the *Analysis of East Coast Inlet, Estuarine, and Climate Characteristics and Their Impact on the Exchange of Organisms through Inlets Study*. The impetus for this work stems from NOAA's Strategic Environmental Assessments Division's ongoing estuarine characterization efforts in support of improved management of the nation's estuarine resources and inter-estuarine research. Also, the analysis stems from previous success in its application to U.S. West Coast estuaries in identifying estuarine types based on geomorphology/hydrodynamics and species assemblages (Horn and Allen 1976; Monaco et al. 1991; Monaco et al. 1992).

Methods

Estuary Selection. The selection of estuaries to include in the analysis was based on the following. NEI estuaries were selected to take advantage of their previously compiled physical and hydrodynamic data summaries. Estuaries (41) below Cape Cod (Table 1) were included in the analysis due to their overall (geomorphological and hydrodynamic) similarity.

Estuaries north of Cape Cod (northern embayments) were excluded from the analysis based on the following. The northern embayments are radically different (geomorphologically and hydrodynamically) from the estuaries in the Virginian and Carolinian Provinces (south of Cape Cod). The northern embayments sedimentary budgets do not support secondary coastal features (such as spits, pennisulas, barrier islands, etc.) nor allow for bathymetric equilibriums. Therefore, these embayments strictly reflect a sea level/coastal topography intersection. This low sedimentary geomorphology and associated hydrodynamics are fundamentally different from those of the estuaries below Cape Cod. Geomorphologically, the Virginian and Carolinian estuaries have ample sedimentary budgets that maintain bathymetric equilibriums and secondary coastal features. Bathymetric equilibriums and secondary coastal features heavily impact estuarine hydrodynamics (e.g., bathymetry impacts estuary volume, and spits restrict tidal exchange). Preliminary (PCAs and Cluster Analyses) test runs on matrices including northern embayments and southern estuaries indicated that northern embayments group together and that their inclusion diluted discrimination among southern estuaries. This confusion is understandable since some of the northern embayments resemble riverine estuaries geomorphologically, but don't resemble them hydrodynamically. As a result, the inclusion of the northern embayments adds an unnecessary level of confusion into the analysis.

Variable Selection. A major assumption of this analysis was that the estuary's geomorphology and hydrodynamics are intrinsically linked. Variables included in the analysis were based on the following. The patterns of these dynamic linkages makes identification of similarly behaving estuaries possible. Therefore, variables directly affected by these dynamic linkages will be (with analysis) the most useful in identifying the patterns of the interactions and provide the basis for identifying similar estuaries. Evaluations of potential variables, to be included in the final matrix, were carried out by including them in test matrices and running

Table 1. The following East Coast NEI estuaries (Virginian and Carolinian Provinces) were included in the analysis.

Buzzards Bay
Narragansett Bay
Gardiners Bay
Long Island Sound
Connecticut River
Great South Bay
Hudson River/Raritan Bay
Barnegat Bay
New Jersey Inland Bays
Delaware Bay
Delaware Inland Bays
Chinoteaque Bay
Chesapeake Bay
Patuxent River
Potomac River
Rappahannock River
York River
James River
Chester River
Choptank River
Tangier/Pocomoke Sound
Albemarle/Pamlico Sound
Pamlico & Pungo Rivers
Neuse River
Bogue Sound
New River
Cape Fear River
Winyah Bay
Charleston Harbor
North & South Santee Rivers
St. Helena Sound
Broad River
Savannah River
Ossabaw Sound
St. Catherines/Sapelo Sound
Altamaha River
St. Andrew/St. Simons Sound
St. Marys River
St. Johns River
Indian River
Biscayne Bay.

Table 2. Variables selected for analysis.

estuary length
estuary width
maximum width
minimum width
average depth
depth to width ratio
tidal fresh surface area
mixing zone surface area
seawater zone surface area
tidal prism volume
tidal fresh volume
mixing zone volume
seawater volume
daily flow rate
50 year flood
100 year flood
low flow period
high flow period
percent water mass fresh water
dissolved concentration potential
tidal flushing

PCA on the matrices. These alternate matrices' PCA runs consistently identified similar component patterns. This occurrence of similar component patterns for various matrices suggests that the underlying geomorphologic/hydrodynamic relationships were adequately represented by the variables tested. With this in mind, the 21 variables presented in Table 2 were selected for inclusion in the analysis. These variables were taken or developed from NOAA's Physical Environments Characterization Branch (PECB) (1993) unpublished physical and hydrodynamic data sets, for methods see NOAA (1985). The resulting variables/estuaries matrix is presented in Table 3.

Statistical Protocol. SAS version 6.04 was used to carry out the PCA and Factor Score manipulations (SAS Institute 1988). The PCA on the 21 by 41 variables/estuaries matrix was carried out using SAS's Factor procedure with the varimax option and nfactor instruction set the number of components to be generated. Component number selection was based on the following. Component eigenvalues accounted for ≥75% of the variance in the matrix, and individual component eigenvalues must be ≥1 and account for ≥8% of the variance in the matrix. Based on the above criteria, a truncated 5 component PCA was selected. The criterion for assigning variables to membership in the resulting components follows. Variables were assigned membership in a component if the variable's rotated loading were ≥ 0.5 or ≤ -0.5 SAS's Score procedure was used to generate the factor scores. These factor scores indicate an individual estuary's strength of association with the components generated by the PCA.

Factor scores provide the basis for evaluating similarity/dissimilarity as follows. Each estuary has a set of 5 factor scores associated with it. The factor scores were placed into a 41 (number of estuaries) by 5 (number of components) matrix and subjected to cluster analysis as follows. Systat version 5.2.1 Cluster procedure (with the Join, Pearson, and Average Linkage options invoked) was used to carry out the cluster analysis and produce the dendrogram (Systat 1992). The dendrogram groups estuaries with similar factor score patterns into clusters. Therefore, the dendrogram groups the estuaries into clusters based on degree of similarity. The criterion for selecting the number of clusters to consider was based on the following. In order to maintain continuity with the PCA's identification of 5 components, the dendrogram's branching that provided 5 clusters was selected. The estuaries within

Table 3. Variables (21)/estuaries (41) matrix selected to perform PCA and cluster analysis on.

Estuary name	length	avg width	min width	max width	avg depth	depth width ratio	avg daily flow	50 year flood	100 year flood	high flow ratio	low flow ratio	tidal prism vol.	tidal fresh zone vol.	mixing zone vol	seawater zone vol.	tidal fresh zone area	mixing zone area	seawater zone area	per. water mass fresh water	diss conc poten	tidal prism flush.
	m	m	m	m	m	none	cms	cms	cms	none	none	m^3	m^3	m^3	m^3	m^2	m^2	m^2	%	mg/l	tidal cycles
Buzzards Bay	48109	11102	1123	20273	10.3	0.0009	3.4	6.3	79.3	0.003	0.001	6.80E+03	0.00E+00	2.20E+07	6.10E+09	0.00E+00	5.18E+03	5.85E+03	12.3	1.04	8.93
Narragansett Bay	47144	14642	805	20595	9.2	0.0003	90.3	96804	1093	0.014	0.003	4.90E+03	4.10E+07	2.70E+03	3.60E+09	7.77E+03	5.18E+07	3.88E+03	18.33	0.52	9
Gardiners Bay	49879	13993	1809	22043	6.2	0.0004	19.3	5.7	5.7	0.003	0.003	3.30E+03	0.00E+00	8.30E+03	3.10E+09	0.00E+00	5.18E+03	5.05E+03	12.22	1.77	9.85
Long Island Sound	98149	50684	1123	36363	18.9	0.0004	849.5	8311.3	662803	0.013	0.004	3.70E+09	2.40E+03	4.30E+09	5.70E+10	2.85E+07	4.22E+03	2.82E+09	15.95	0.05	16054
Connecticut River	89300	483	322	1443	3.3	0.0079	59403	3998.2	4137	1.937	0.459	2.60E+07	1.80E+03	1.60E+07	0.00E+00	4.68E+07	5.18E+03	0.00E+00	96.24	0.47	7.63
Great South Bay	11263	42064	322	9010	2.7	0.0001	1903	42.5	4801	0.012	0.011	7.50E+07	0.00E+00	4.70E+03	5.80E+03	0.00E+00	2.02E+03	1.89E+03	34.23	4.97	14.13
Hudson River/Raritan Bay	257440	2735	161	18021	6.3	0.0023	753	5414	5759.5	0.077	0.021	7.40E+07	5.10E+03	2.90E+09	1.40E+09	9.58E+07	4.35E+03	2.41E+03	50.87	0.19	66.34
Barnegat Bay	33789	17699	483	10619	1.4	0.0001	65.1	100204	120603	0.044	0.024	8.60E+07	0.00E+00	1.40E+03	2.40E+03	0.00E+00	7.77E+07	1.86E+03	3003	1.34	4.43
New Jersey Inland Bays	24940	16090	50	6900	3	0.0002	31.1	25.2	30	0.012	0.003	8.00E+07	0.00E+00	5.50E+07	2.20E+03	0.00E+00	1.18E+07	1.26E+03	21.85	3.17	3.43
Delaware Bay	222042	24135	6753	45693	6.4	0.0003	560.7	7438.3	8302.3	0.013	0.005	2.90E+09	4.20E+03	2.80E+09	9.40E+09	5.98E+07	5.18E+03	1.41E+09	26.02	0.13	4.39
Delaware Inland Bays	19303	2893	150	5500	1.3	0.0004	9.3	8.3	11.2	0.039	0.007	1.60E+07	0.00E+00	1.90E+07	8.60E+07	0.00E+00	1.55E+07	6.73E+07	20.99	6.27	5.84
Chincoteaque Bay	51483	7241	1609	10619	1.3	0.0002	11.3	9	4	0.015	0.011	4.70E+07	0.00E+00	0.00E+00	6.40E+03	0.00E+00	0.00E+00	3.55E+03	12.12	3.03	13063
Chesapeake Bay	318582	24779	5149	55993	8.1	0.0003	2429.5	58722	75114	0.1	0.029	8.70E+03	1.00E+09	5.70E+10	2.90E+09	2.75E+03	6.89E+09	2.98E+03	59.63	0.07	69.63
Patuxent River	75600	1609	30	2900	5.9	0.0037	26.3	360.7	437.3	0.055	0.023	3.00E+07	5.00E+03	7.10E+03	0.00E+00	3.63E+03	1.18E+03	0.00E+00	61.85	8.93	2387
Potomac River	188253	10293	2574	17860	5.9	0.0003	450.2	9188.5	10749	0.095	0.027	3.40E+03	4.50E+07	7.50E+09	0.00E+00	1.30E+07	1.27E+09	0.00E+00	61.59	0.39	2217
Rappahannock River	158647	3701	644	5149	4.9	0.0013	82.1	1936.3	2129.4	0.043	0.017	1.20E+03	2.90E+07	1.80E+09	0.00E+00	7.77E+03	3.88E+03	0.00E+00	61.93	2.17	15.91
York River	78841	3379	644	6597	4.3	0.0014	70.3	2755.1	3681.1	0.043	0.013	1.10E+03	6.70E+07	8.50E+03	0.00E+00	1.81E+07	1.74E+03	0.00E+00	64.13	2.61	8.3
James River	162187	5149	483	9654	4.2	0.0003	354	10213	11799	0.084	0.023	2.80E+03	2.80E+03	2.30E+09	0.00E+00	8.29E+07	5.28E+03	0.00E+00	65.53	0.53	9.02
Chester River	61100	2300	160	7080	4.2	0.0013	1403	114.7	153	0.032	0.013	3.30E+07	2.70E+07	8.00E+03	0.00E+00	1.42E+07	1.34E+03	0.00E+00	7193	1.43	18.95
Choptank River	80500	6900	320	19800	4	0.0003	29.1	119.3	12607	0.03	0.003	7.20E+07	2.50E+07	1.10E+09	0.00E+00	7.77E+03	2.78E+03	0.00E+00	82.2	6.32	15079
Tangier/Pocomoke Sound	91700	5600	10	25400	33	0.0007	83.3	5004	59.5	0.017	0.003	3.80E+03	8.80E+03	4.50E+09	0.00E+00	9.32E+03	1.18E+09	0.00E+00	81.45	2.15	12003
Albemarle/Pamlico Sound	186644	21073	1443	47623	4.1	0.0002	130205	6507	7506.3	0.313	0.187	8.20E+03	1.10E+09	2.60E+10	3.10E+03	5.72E+03	6.01E+09	1.74E+03	62.34	0.14	33.63
Pamlico/Pungo Rivers	67573	5632	1443	9332	2.9	0.0005	130.3	1228.9	1362	0.117	0.053	6.50E+07	0.00E+00	1.20E+09	0.00E+00	0.00E+00	4.30E+03	0.00E+00	61.33	1.33	18.63
Neuse River	80450	6597	1443	12223	3.5	0.0005	175.3	1568.7	1795.2	0.193	0.064	6.90E+07	0.00E+00	1.60E+09	0.00E+00	0.00E+00	4.48E+03	0.00E+00	61.33	1.01	22.92
Bogue River	15283	17699	965	4023	1.4	0.0001	36.3	404.9	472.9	0.015	0.003	1.40E+03	1.60E+03	4.60E+07	3.20E+03	2.59E+03	5.44E+07	2.07E+03	18.67	1.43	2.73
New River	39903	2735	644	3379	1.3	0.0003	22.7	569.2	679.3	0.03	0.04	1.70E+07	0.00E+00	1.40E+03	6.90E+03	0.00E+00	7.77E+07	5.18E+03	59.03	7.5	8.51
Cape Fear River	83663	1123	483	3862	3.5	0.0031	283	4043.5	4779.7	0.224	0.072	1.00E+03	5.80E+07	2.20E+03	6.90E+07	1.30E+07	6.99E+07	1.55E+07	5964	0.3	3.43
Winyah Bay	82059	1123	483	6919	3.4	0.003	57703	664001	765905	0.493	0.143	8.60E+07	1.10E+03	1.60E+03	0.00E+00	2.33E+07	5.44E+07	0.00E+00	7663	0.33	3.03
North & South Santee Rivers	88817	1123	322	3213	2.5	0.0022	76.5	2619.2	2639.1	0.303	0.05	2.50E+07	2.40E+07	3.60E+07	0.00E+00	1.04E+07	1.30E+07	0.00E+00	76079	2.89	2.33
Charleston Harbor	65647	3862	644	5792	5.3	0.0014	45509	1161	117709	0.201	0.112	1.40E+03	1.00E+03	4.30E+03	0.00E+00	1.55E+07	8.03E+07	0.00E+00	68.52	0.43	3.95
St Helena Sound	54703	6753	483	14642	3.9	0.0003	130.3	91403	100502	0.024	0.01	3.90E+03	3.20E+07	4.70E+03	3.70E+03	7.77E+03	1.06E+03	1.06E+03	42	0.93	2.2
Broad River	53253	6275	1123	10459	7.3	0.0012	25.5	314.3	359.3	0.004	0.001	5.40E+03	4.70E+07	1.10E+09	7.50E+03	1.04E+07	1.45E+03	1.04E+03	4263	4.82	3.5
Savannah Sound	46339	2735	483	10459	4.3	0.0017	362.4	2069.9	2262.4	0.137	0.065	1.80E+03	2.20E+07	2.90E+03	8.00E+07	7.77E+03	5.96E+07	1.61E+07	5351	0.42	2.23
Ossabaw Sound	49075	1770	322	6753	4.4	0.0025	84.9	2055.7	2489	0.059	0.013	1.80E+03	1.00E+07	3.20E+03	3.70E+07	5.18E+03	7.25E+07	7.77E+03	5749	1.95	2.12
St Catherines/ SapeloSound	39903	5149	322	56637	4.4	0.0009	2207	36801	45301	0.004	0.001	4.20E+03	1.20E+07	7.80E+03	8.50E+07	5.18E+03	1.79E+03	1.04E+07	58.14	7.33	2.03
Altamaha River	43443	2735	644	4663	3.1	0.0011	421.9	344601	3681.1	0.557	0.117	6.70E+07	1.40E+07	7.60E+07	3.10E+07	1.04E+07	2.07E+07	7.77E+03	52.99	0.33	1.81
St. Andrews/ St Simmons Sound	83663	8689	805	47623	4.4	0.0005	70.3	1543.2	1577.2	0.014	0.005	3.90E+03	8.10E+03	7.50E+03	5.70E+07	2.59E+03	1.76E+03	7.77E+03	58.31	2.37	2.09
St Marys River	51500	480	60	2300	3	0.0125	23104	52502	57201	0.164	0.119	7.00E+07	3.60E+03	1.30E+07	3.90E+03	2.07E+05	5.18E+03	8.11E+07	17.5	0.22	5.83
St. Johns River	197907	3701	1123	11585	37	0.001	220.9	1090.2	127104	0.252	0.125	5.30E+07	9.90E+03	8.00E+03	6.60E+03	3.08E+03	2.46E+03	1.14E+03	6333	0.83	45083
Indian River	4827	55023	161	9010	2	0	39.3	16701	192.5	0.044	0.013	6.50E+07	0.00E+00	5.60E+07	1.40E+03	0.00E+00	2.85E+07	6.97E+03	14	1.02	22057
Biscayne Bay	15283	45052	965	17377	23	0.0001	9003	60003	66803	0.021	0.007	3.00E+03	0.00E+00	1.70E+07	1.60E+03	0.00E+00	1.55E+07	6.61E+03	1282	0.4	5.45

the 5 clusters were assigned to estuarine groups according to their membership in a common cluster. This identified estuaries with similar characteristics based on the original 21 by 41 variables/estuaries matrix.

PCA Results

The PCA identified 5 components that account for 82.1% of the variance in the 21 by 41 variables/estuary matrix. Descriptions of the components follow. The PCA's rotated loadings are presented in Table 4. The PCA's factor scores are presented in Table 5. See Appendix 1 for SAS programming, log, and detailed output of PCA.

Component 1- System Magnitude Function. This component accounted for 26.8% of the variance in the matrix. The following parameters dominated this component (rotated loading in parenthesis): 100 year flood (0.97223); 50 year flood (0.97056); mixing zone volume (0.87872); daily flow rate (0.81285); mixing zone surface area (0.73312); length (0.63239); and tidal prism flushing (0.51662). Estuaries with factor scores ≥1.0: Chesapeake Bay; and Potomac River.

Component 2- Seawater Function. This component accounted for 18.3% of the variance in the matrix. Parameters that dominated this component: seawater volume (0.92650); tidal prism (0.91136); seawater surface area (0.87441); and average depth (0.88561). Estuaries with factor scores ≥1.0: Long Island Sound; and Delaware Bay.

Component 3- Mixing Function. This component accounted for 15.3% of the variance in the matrix. Parameters that dominated this component: tidal fresh surface area (0.90541); tidal fresh volume (0.82607); tidal prism flushing (0.57741); mixing zone surface area (0.57653); and length (0.51983). Estuaries with factor scores ≥1.0: Albemarle/Pamlico Sound; St. Johns River; and Hudson River/Raritan Bay.

Component 4- Stratification Function. This component accounted for 13.2% of the variance in the matrix. Parameters that dominated this component: high flow period (0.92147); low flow period (0.90114); depth to width ratio (0.69186); and dissolved concentration potential (-0.49484). Estuaries with factor scores ≥1.0: Connecticut River; St. Mary's River; Winyah Bay; and Altamaha River.

Table 4. PCA's rotated loadings for 5 components. Rotated loadings ≥0.5 or ≤-0.5 (bold) indicate variables that are highly associated with the component.

	Rotated Loadings				
	Component1	**Component2**	**Component3**	**Component4**	**Component5**
	System Magnitude Function	Seawater Function	Mixing Function	Strat. Function	Width Function
estuary length	**0.63239**	0.21157	**0.51983**	0.05810	-0.29696
avg. estuary width	0.10305	0.34508	0.11090	-0.17072	**0.80765**
min. estuary width	**0.65684**	0.29652	0.12469	-0.11902	0.15102
max. estuary width	0.43767	0.40497	0.40237	-0.31782	0.03545
avg. depth	0.19827	**0.88561**	-0.00532	0.00166	-0.07083
depth/width ratio	-0.03296	-0.01055	-0.24935	**0.69186**	-0.28788
daily flow	**0.81285**	0.21961	0.40943	0.26009	0.03215
fifty year flood	**0.97056**	0.06031	0.13742	0.04034	-0.01021
hundred year flood	**0.97223**	0.04186	0.12988	0.02580	-0.00664
high flow	-0.01566	-0.08815	0.07813	**0.90114**	-0.12800
low flow	-0.02925	-0.11561	0.24388	**0.92147**	-0.11261
tidal prism volume	0.18128	**0.91136**	0.11225	-0.08004	0.18661
tidal fresh volume	0.46774	0.12146	**0.82607**	0.13265	-0.00318
mixing zone volume	**0.87872**	0.00799	0.39684	-0.02889	0.04985
seawater zone volume	-0.00870	**0.92650**	0.00834	0.00136	0.19122
tidal fresh area	0.31311	-0.01542	**0.90541**	0.13308	0.04127
mixing zone area	**0.73312**	-0.02681	**0.57653**	-0.01298	0.06317
seawater zone area	0.02848	**0.87441**	0.02606	-0.06437	0.44057
percent water mass fresh water	0.11701	-0.23857	0.23721	0.34965	**-0.70481**
dissolved conc. potential	-0.28488	-0.20124	-0.12235	**-0.49484**	-0.35716
tidal prism flushing	**0.51662**	0.01875	**0.57741**	-0.05407	-0.07523

Table 5. PCA's factor scores for 5 components. Estuaries with higher factor scores have strongest association with components. Further, factor scores ≥1.0 indicate estuaries representing the component.

Component 1 Estuaries	Compt Factor Scores	Component 2 Estuaries	Comp2 Factor Scores	Component 3 Estuaries	Comp3 Factor Scores	Component 4 Estuaries	Comp4 Factor Scores	Component 5 Estuaries	Comp5 Factor Scores
Chesapeake Bay	5.87781	**Long Island Sound**	5.38919	**Albemarle/Pamlico Sound**	4.74406	**Connecticut River**	4.84227	**Indian River**	3.00781
Potomac River	0.99559	**Delaware Bay**	2.13401	**St. Johns River**	3.0594	**St. Marys River**	1.88039	**Biscayne Bay**	2.66941
Delaware Bay	0.84473	Buzzards Bay	0.92099	**Hudson River/Raritan Bay**	1.42021	**Winyah Bay**	1.36424	**Bogue River**	1.45762
James River	0.35874	Narragansett Bay	0.52623	Chesapeake Bay	0.41528	**Altamaha River**	1.08173	**Great South Bay**	1.39138
Winyah Bay	0.21268	Hudson River/Raritan Bay	0.2995	Tangier/Pocomoke Sound	0.18311	Charleston Harbor	0.67539	**Barnegat Bay**	1.14172
St. Marys River	0.14218	Broad River	0.29535	St. Catherines/Sapelo Sound	0.17765	Cape Fear River	0.67065	Albemarle/Pamlico Sound	0.86889
Hudson River/Raritan Bay	0.11182	St Catherines/Sapelo Sound	0.25492	Choptank River	0.17631	Albemarle/Pamlico Sound	0.57792	Long Island Sound	0.84528
Cape Fear River	0.08787	Gardiners Bay	0.22824	James River	0.13596	Savannah Sound	0.38111	New Jersey Inland Bays	0.83786
Neuse River	0.0096	St Andrews/St. Simmons Sound	0.13281	Long Island Sound	0.0686	St. Johns River	0.35329	Chincoteaque Bay	0.76175
Altamaha River	-0.00705	St Marys River	0.11058	Delaware Bay	0.06379	North & South Santee Rivers	0.27616	Gardiners Bay	0.73929
Pamlico/Pungo Rivers	-0.03911	Patuxent River	0.0254	Indian River	0.01536	Long Island Sound	0.20045	Narragansett Bay	0.55556
Albemarle/Pamlico Sound	-0.04072	Potomac River	0.00887	Great South Bay	-0.01073	Neuse River	0.07247	Delaware Bay	0.55198
Rappahannock River	-0.04388	Connecticut River	-0.0674	St. Andrews/ St.Simmons Sound	-0.01179	James River	-0.00112	Buzzards Bay	0.31737
Savannah Sound	-0.04693	Rappahannock River	-0.07889	Connecticut River	-0.0745	Ossabaw Sound	-0.04076	Altamaha River	0.30057
York River	-0.09648	Charleston Harbor	-0.0881	Chester River	-0.08443	Pamlico/Pungo Rivers	-0.06577	Chesapeake Bay	0.17236
Ossabaw Sound	-0.11622	Tangier/Pocomoke Sound	-0.14367	Neuse River	-0.08871	Indian River	-0.07969	St. Helena Sound	0.16974
Charleston Harbor	-0.14791	Choptank River	-0.16039	Rappahannock River	-0.12324	Biscayne Bay	-0.11536	Delaware Inland Bays	0.06744
St. Andrews/St. Simmons Sound	-0.16195	St. Johns River	-0.17078	Pamlico/Pungo Rivers	-0.15615	Hudson River/Raritan Bay	-0.12456	St. Marys River	-0.06363
Gardiners Bay	-0.18674	York River	-0.17655	New River	-0.17527	Chester River	-0.17209	Savannah Sound	-0.08824
Narragansett Bay	-0.18804	St. Helena Sound	-0.18111	Charleston Harbor	-0.21093	Potomac River	-0.19055	Pamlico/Pungo Rivers	-0.15252
Chincoteaque Bay	-0.1954	Ossabaw Sound	-0.19596	Patuxent River	-0.2213	Barnegat Bay	-0.1964	Neuse River	-0.16775
North & South Santee Rivers	-0.19713	Savannah Sound	-0.19837	York River	-0.28783	St. Helena Sound	-0.24689	Cape Fear River	-0.32772
St. Helena Sound	-0.20583	James River	-0.20574	Biscayne Bay	-0.29036	Bogue River	-0.25216	Charleston Harbor	-0.36077
Tangier/Pocomoke Sound	-0.2192	Chester River	-0.24006	Barnegat Bay	-0.3098	York River	-0.27863	Winyah Bay	-0.44782
Bogue River	-0.22383	Chesapeake Bay	-0.25997	Delaware Inland Bays	-0.31697	Narragansett Bay	-0.2878	St. Johns River	-0.50278
Buzzards Bay	-0.24121	Winyah Bay	-0.2799	St. Helena Sound	-0.31861	Chesapeake Bay	-0.30083	Potomac River	-0.50371
Barnegat Bay	-0.24937	Cape Fear River	-0.28996	Chincoteaque Bay	-0.33823	Rappahannock River	-0.30814	Ossabaw Sound	-0.52155
Biscayne Bay	-0.25011	North & South Santee Rivers	-0.34568	Potomac River	-0.34187	Buzzards Bay	-0.34954	Connecticut River	-0.52955
Connecticut River	-0.26792	Albemarle/Pamlico Sound	-0.35655	New Jersey Inland Bays	-0.3429	Delaware Bay	-0.45793	James River	-0.55024
Broad River	-0.26889	Neuse River	-0.36039	North & South Santee Rivers	-0.36487	New Jersey Inland Bays	-0.48615	Tangier/Pocomoke Sound	-0.61752
Chester River	-0.32296	Pamlico/Pungo Rivers	-0.44654	Broad River	-0.39363	Gardiners Bay	-0.51203	St. Andrews/St. Simmons Sound	-0.66229
Patuxent River	-0.37559	Biscayne Bay	-0.4489	Gardiners Bay	-0.40671	Patuxent River	-0.5355	Broad River	-0.72229
Long Island Sound	-0.39553	Altamaha River	-0.47775	Narragansett Bay	-0.42257	Chincoteaque Bay	-0.58755	York River	-0.75389
New Jersey Inland Bays	-0.40455	Chincoteaque Bay	-0.50756	Winyah Bay	-0.44935	Tangier/Pocomoke Sound	-0.60182	Chester River	-0.76095
Choptank River	-0.43399	New River	-0.52651	Bogue River	-0.47832	Great South Bay	-0.63976	North & South Santee Rivers	-0.90099
New River	-0.44046	New Jersey Inland Bays	-0.57587	Savannah Sound	-0.49758	Broad River	-0.70121	New River	-0.91296
Indian River	-0.4414	Great South Bay	-0.67318	Altamaha River	-0.51074	New River	-0.75495	Rappahannock River	-0.94449
Great South Bay	-0.47018	Barnegat Bay	-0.69464	Buzzards Bay	-0.54269	St. Andrews/St. Simmons Sound	-0.79705	Hudson River/Raritan Bay	-1.08282
Delaware Inland Bays	-0.47036	Delaware Inland Bays	-0.7044	Cape Fear River	-0.58568	Delaware Inland Bays	-0.83481	Choptank River	-1.15888
St. Catherines/Sapelo Sound	-0.48058	Indian River	-0.71418	Ossabaw Sound	-0.60469	Choptank River	-1.01498	St. Catherines/Sapelo Sound	-1.46924
St. Johns River	-1.01149	Bogue River	-0.75708	St. Marys River	-1.49931	St. Catherines/Sapelo Sound	-1.44207	Patuxent River	-1.65343

Component 5- Width Function. This component accounted for 8.5% of the variance in the matrix. Parameters that dominated this component: estuary width (0.80765); and percent water mass fresh water (-0.70481). Estuaries with factor scores ≥1.0: Indian River; Biscayne Bay; Bogue Sound; Great South Bay; and Barnegat Bay.

Dendrogram Results

The dendrogram (Figure 1) of the clustered factor scores (Table 6) identified the following estuarine groups based on similarities of geomorphology and hydrodynamic characteristics. Descriptions of the groups follow. *Caveat: the preliminary interpretation of the groups' descriptive characteristics will need further evaluation (ranges should be presented where possible at a later date). However, the descriptive characteristics used below are the obvious ones to start with.*

The dendrogram groups (branches) are presented below in order of strength of their association versus the other branches relative to the 0.75 cut distance. In other words, the first cluster links (+) to the left of the 0.75 cut distance identify the dendrogram groups and their strength of association. Therefore, the strongest dendrogram group is presented as Dendrogram Group 1 and the second strongest is presented as Dendrogram Group 2 and so on.

Dendrogram Group 1- Large Drowned River Valleys Assemblage. This group contains: Chesapeake Bay; and Potomac River. Descriptive characteristics of group: large volumetrically and surficially; mixing zone dominates; moderately stratified; large watersheds; tidal prism; and freshwater input dominate hydrodynamic regime. This group of estuaries most closely matched the characteristics identified by the PCA's Component 1- (System Magnitude Function). Overlap of the component's estuaries with factor scores ≥1.0 and the estuaries presence in the dendrogram group was 100%.

Dendrogram Group 2- Lagoons and Shallow Bays Assemblage. This group contains: Gardiners Bay; St. Helena Sound; Barnegat Bay; Bogue Sound; Biscayne Bay; New Jersey Inland Bays; Indian River; Great South Bay; Chincoteaque Bay; and Delaware Inland Bays. Descriptive characteristics of group: small volumetrically; shallow; tidal prism dominates hydrodynamic regime; large seawater zone; small watersheds; reduced freshwater inputs; and vertically homogeneous. This group of estuaries most closely matched the characteristics identified by the PCA's Component 5 (Width Function). Overlap of the component's estuaries with factor scores ≥1.0 and the estuaries presence in the dendrogram group was 100%.

Dendrogram Group 3- Sounds and Deep Bays Assemblage. This group contains: Long Island Sound; Buzzards Bay; Narranagsett Bay; Delaware Bay; and Broad River. Descriptive characteristics of group: tidal prism dominates hydrodynamic regimes; vertically homogenous; large seawater zones and volumes; mixing zones present; small watersheds; and proportionately small freshwater inputs. This group of estuaries most closely matched the characteristics identified by the PCA's Component 2 (Seawater Function). Overlap of the component's estuaries with factor scores ≥1.0 and the estuaries presence in the dendrogram group was 100%.

Dendrogram Group 4- Riverine Estuaries Assemblage. This group contains: Pamlico/Pungo Rivers; Neuse River; Altamaha River; St. Mary's River; Savannah River; Cape Fear River; Winyah Bay; Connecticut River; Charleston Harbor; North and South Santee River; and Ossabaw Sound. Descriptive characteristics of group: small volumetrically; mixing and tidal fresh zones dominate; and freshwater input dominates hydrodynamic regime. This group of estuaries most closely matches the characteristics identified by the PCA's Component 4- (Stratification Function). Overlap of the component's estuaries with factor scores ≥1.0 and the estuaries presence in the dendrogram group was 100%.

Dendrogram Group 5- Moderately Sized Drowned River Valleys Assemblage. This group contains: Albemarle/Pamlico Sound; St. John's River; St. Andrew/St. Simons Sound; St. Catherines/Sapelo Sound; Choptank River; Tangier/Pocomoke Sound; New River; Hudson River/Raritan Bay; Chester River; Patuxent River; Rappahannock River; York River; and James River. Descriptive characteristics of group: mid-sized volumetrically; large mixing zones; and tidal prism and fresh water input dominates hydrodynamic regime. This group of estuaries most closely matches the characteristics identified by the PCA's Component 3- (Mixing Function). Overlap of the component's estuaries with factor scores ≥1.0 and the estuaries presence in the dendrogram group was 100%.

Summary

The PCA identified the following components based on the estuaries' physical and hydrodynamic variables: (1) System Magnitude Function; (2) Seawater Function; (3) Mixing Function; (4) Stratification Function; and (5) Width Function. Cluster analysis of the PCA's factor scores identified the following estuarine assemblages: 1) Large Drowned River Valleys; 2) Lagoons

Table 6. Factor score matrix on which cluster analysis was based. Same factor scores as in Table 2, but sorted alphabetically by Estuary instead of sorted to show top estuary/factor score per component.

Estuary	Comp1	Comp2	Comp3	Comp4	Comp5
Albemarle/Pamlico Sound	-0.04072	-0.35655	4.74406	0.57792	0.86889
Altamaha River	-0.00705	-0.47775	-0.51074	1.08173	0.30057
Barnegat Bay	-0.24937	-0.69464	-0.3098	-0.1964	1.14172
Biscayne Bay	-0.25011	-0.4489	-0.29036	-0.11536	2.66941
Bogue River	-0.22383	-0.75708	-0.47832	-0.25216	1.45762
Broad River	-0.26889	0.29535	-0.39363	-0.70121	-0.72229
Buzzards Bay	-0.24121	0.92099	-0.54269	-0.34954	0.31737
Cape Fear River	0.08787	-0.28996	-0.58568	0.67065	-0.32772
Charleston Harbor	-0.14791	-0.0881	-0.21093	0.67539	-0.36077
Chesapeake Bay	5.87781	-0.25997	0.41528	-0.30083	0.17236
Chester River	-0.32296	-0.24006	-0.08443	-0.17209	-0.76095
Chincoteaque Bay	-0.1954	-0.50756	-0.33823	-0.58755	0.76175
Choptank River	-0.43399	-0.16039	0.17631	-1.01498	-1.15888
Connecticut River	-0.26792	-0.0674	-0.0745	4.84227	-0.52955
Delaware Bay	0.84473	2.13401	0.06379	-0.45793	0.55198
Delaware Inland Bays	-0.47036	-0.7044	-0.31697	-0.83481	0.06744
Gardiners Bay	-0.18674	0.22824	-0.40671	-0.51203	0.73929
Great South Bay	-0.47018	-0.67318	-0.01073	-0.63976	1.39138
Hudson River/Raritan Bay	0.11182	0.2995	1.42021	-0.12456	-1.08282
Indian River	-0.4414	-0.71418	0.01536	-0.07969	3.00781
James River	0.35874	-0.20574	0.13596	-0.00112	-0.55024
Long Island Sound	-0.39553	5.38919	0.0686	0.20045	0.84528
Narragansett Bay	-0.18804	0.52623	-0.42257	-0.2878	0.55556
Neuse River	0.0096	-0.36039	-0.08871	0.07247	-0.16775
New Jersey Inland Bays	-0.40455	-0.57587	-0.3429	-0.48615	0.83786
New River	-0.44046	-0.52651	-0.17527	-0.75495	-0.91296
North & South Santee Rivers	-0.19713	-0.34568	-0.36487	0.27616	-0.90099
Ossabaw Sound	-0.11622	-0.19596	-0.60469	-0.04076	-0.52155
Pamlico/Pungo Rivers	-0.03911	-0.44654	-0.15615	-0.06577	-0.15252
Patuxent River	-0.37559	0.0254	-0.2213	-0.5355	-1.65343
Potomac River	0.99559	0.00887	-0.34187	-0.19055	-0.50371
Rappahannock River	-0.04388	-0.07889	-0.12324	-0.30814	-0.94449
Savannah Sound	-0.04693	-0.19837	-0.49758	0.38111	-0.08824
St. Andrews/St. Simmons Sound	-0.16195	0.13281	-0.01179	-0.79705	-0.66229
St. Catherines/Sapelo Sound	-0.48058	0.25492	0.17765	-1.44207	-1.46924
St. Helena Sound	-0.20583	-0.18111	-0.31861	-0.24689	0.16974
St. Johns River	-1.01149	-0.17078	3.0594	0.35329	-0.50278
St. Marys River	0.14218	0.11058	-1.49931	1.88039	-0.06363
Tangier/Pocomoke Sound	-0.2192	-0.14367	0.18311	-0.60182	-0.61752
Winyah Bay	0.21268	-0.2799	-0.44935	1.36424	-0.44782
York River	-0.09648	-0.17655	-0.28783	-0.27863	-0.75389

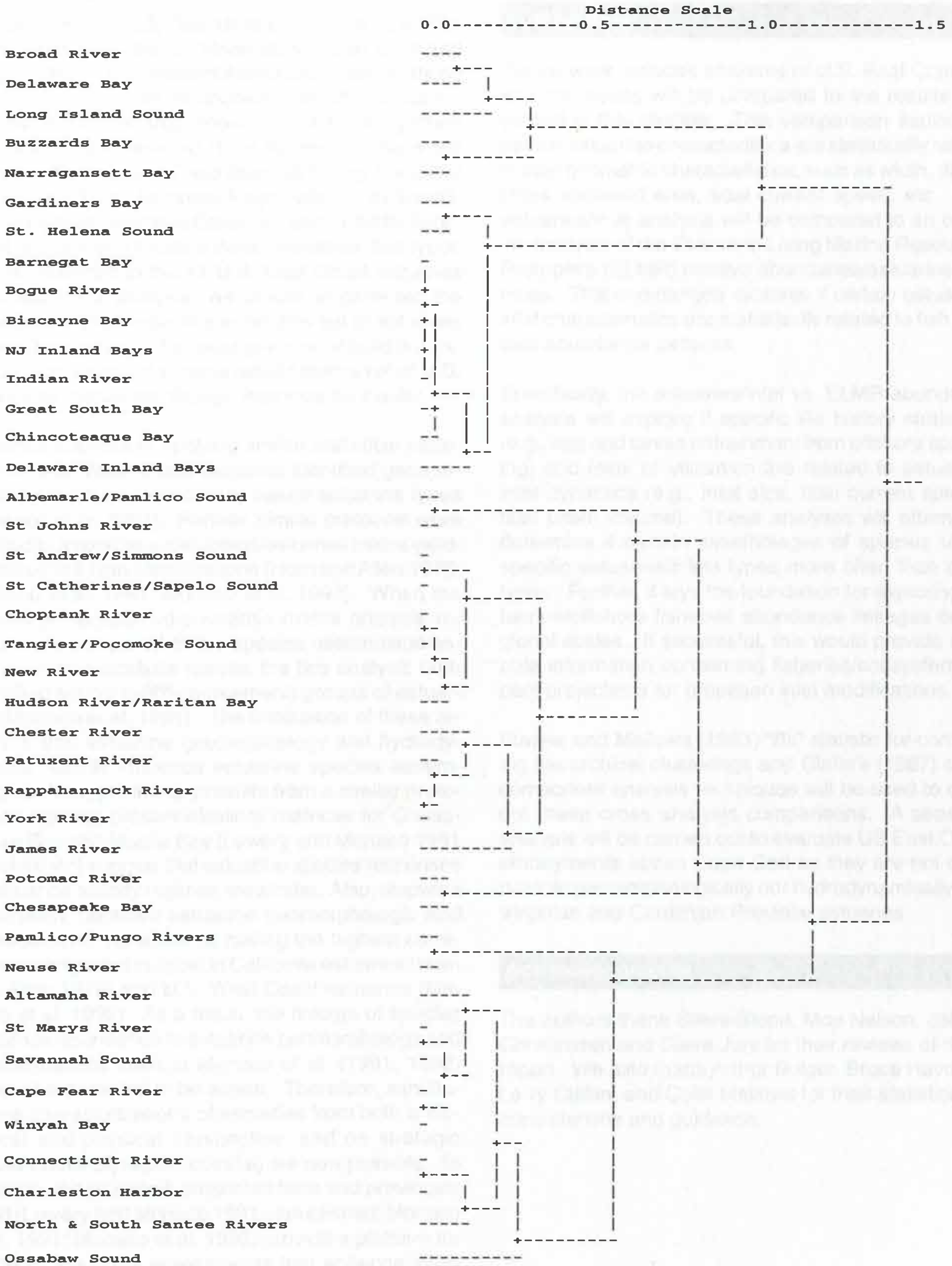

Figure 1. Dendrogram of clustered factor scores. Distance of cluster linkages (indicated by (+)) indicates strength of association between the estuaries or groups of estuaries linked together. Shorter distances indicate stronger associations among the members of the cluster (branch). Based on the PCA's identification of 5 significant components, the dendrogram's branching was cut at a distance of 0.75 to produce 5 dendrogram clusters that were comparable to the PCA components.

and Shallow Bays; 3) Sounds and Deep Bays; 4) Riverine Estuaries; and 5) Moderately Sized Drowned River Valleys. Component/Assemblage associations based on factor score/component strengths versus assemblage membership follow: 1) System Magnitude Function/Large Drowned River Valleys; 2) Seawater Function/Sounds and Deep Bays; 3) Mixing Function/ Moderately Sized Drowned River Valleys ; 4) Stratification Function/Riverine Estuaries; and 5) Width Function/Lagoons and Shallow Bays. However, this typology is restricted to the 41 U.S. East Coast estuaries included in this analysis. As should be expected the differences and similarities within this set of estuaries drives the typology. For example, one should not expect to find exactly the same results from a set of U.S. Gulf Coast estuaries, though they may be similar.

Previous success in applying similar statistical protocols to U.S. West Coast estuaries identified geomorphologically/hydrodynamically based estuarine types (Monaco et al. 1991). Further, similar protocols were applied to a species assemblage/estuaries matrix yielding estuarine type identifications (Horn and Allen 1976; Monaco et al. 1991; Monaco et al. 1992). When the geomorphological/hydrodynamic matrix analysis results were compared to the species assemblage/estuaries matrix analysis results, the two analysis both identified similar (>80% agreement) groups of estuaries (Monaco et al. 1991). The implication of these results is that estuarine geomorphology and hydrodynamics heavily influence estuarine species assemblages. Also, preliminary results from a similar protocol on species presence/salinity matrices for Chesapeake Bay and Mobile Bay (Lowery and Monaco 1991 unpublished) suggest that estuarine species responses to estuarine salinity regimes are similar. Also, stepwise regression identified estuarine geomorphologic and hydrodynamic variables as having the highest correlation with species number in California estuaries (Horn and Allen 1976) and U.S. West Coast estuaries (Monaco et al. 1992). As a result, the linkage of species presence/abundance to estuarine geomorphology and hydrodynamics seen in Monaco et al. (1991, 1992) should be expected to be similar. Therefore, simultaneous characterizations of estuaries from both a biological and physical perspective, and on strategic scales (national, region, coastal) are now possible. To reiterate, the protocols presented here and previously used (Lowery and Monaco 1991 unpublished; Monaco et al. 1991; Monaco et al. 1992) provide a platform for strategic estuarine assessments that enhance inter-estuarine comparisons. These improved capabilities facilitate improvements in regional ecosystems management.

Future Work

Future work includes analyses of U.S. East Coast inlets. Its results will be compared to the results presented in this chapter. This comparison explores if certain estuarine characteristics are statistically related to inlet geometric characteristics, such as width, depth, cross sectional area, tidal current speed, etc. This estuaries/inlet analysis will be compared to an ongoing analysis of the Estuarine Living Marine Resources Program's (ELMR) relative abundance/estuaries matrices. This comparison explores if certain estuarine/ inlet characteristics are statistically related to fish species abundance patterns.

Specifically, the estuaries/inlet vs. ELMR abundance analysis will explore if specific life history strategies (e.g., egg and larvae entrainment from offshore spawning) and level of utilization are related to estuarine/ inlet dynamics (e.g., inlet size, tidal current speeds, tidal prism volume). These analyses will attempt to determine if certain assemblages of species utilize specific estuaries/inlets types more often than other types. Further, it lays the foundation for exploring estuarine/offshore fisheries abundance linkages on regional scales. If successful, this would provide valuable information concerning fisheries/ecosystem impact projections for proposed inlet modifications.

Fowles and Mallows (1983) "Bk" statistic for comparing hierarchical clusterings and Clafin's (1987) cross component analysis techniques will be used to carry out these cross analysis comparisons. A separate analysis will be carried out to evaluate US East Coast embayments above Cape Cod as they are not comparable geomorphologically nor hydrodynamically with Virginian and Carolinian Province estuaries.

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Appendix 1. Complete SAS PCA program, log, and results.

```
libname elmo ‘h:/tony/data’;
options pagesize=66 linesize=120;
PROC PRINT DATA=elmo.ESTUARY;
PROC FACTOR nfactor=5 ROTATE=VARIMAX DATA=elmo.ESTUARY
score outstat=fact;
PROC SCORE DATA=elmo.ESTUARY SCORE=Fact OUT=elmo.SCORES;
PROC SORT DATA=elmo.SCORES;
BY DESCENDING FACTOR1;
PROC PRINT DATA=elmo.SCORES;
VAR esty FACTOR1;
PROC SORT DATA=elmo.SCORES;
BY DESCENDING FACTOR2;
PROC PRINT DATA=elmo.SCORES;
VAR esty FACTOR2;
PROC SORT DATA=elmo.SCORES;
BY DESCENDING FACTOR3;
PROC PRINT DATA=elmo.SCORES;
VAR esty FACTOR3;
PROC SORT DATA=elmo.SCORES;
BY DESCENDING FACTOR4;
PROC PRINT DATA=elmo.SCORES;
VAR esty FACTOR4;
PROC SORT DATA=elmo.SCORES;
BY DESCENDING FACTOR5;
PROC PRINT DATA=elmo.SCORES;
VAR esty FACTOR5;
run;
```

```
51    libname elmo ‘h:/tony/data’;
NOTE: Libref ELMO was successfully assigned as follows:
      Engine:      V604
      Physical Name: h:/tony/data
52    options pagesize=66 linesize=120;
53    PROC PRINT DATA=elmo.ESTUARY;
NOTE: The PROCEDURE PRINT used .71 seconds.
54    PROC FACTOR nfactor=5 ROTATE=VARIMAX DATA=elmo.ESTUARY
55    score outstat=fact;
NOTE: The data set WORK.FACT has 47 observations and 23 variables.
NOTE: The PROCEDURE FACTOR used 1.62 seconds.
56    PROC SCORE DATA=elmo.ESTUARY SCORE=Fact OUT=elmo.SCORES;
NOTE: No VAR statement is given.  All numeric variables in the SCORE= data set will be used to compute the scores.
NOTE: The data set ELMO.SCORES has 41 observations and 27 variables.
NOTE: The PROCEDURE SCORE used .75 seconds.
57    PROC SORT DATA=elmo.SCORES;
58    BY DESCENDING FACTOR1;
NOTE: SAS sort was used.
NOTE: The data set ELMO.SCORES has 41 observations and 27 variables.
NOTE: The PROCEDURE SORT used .40 seconds.
59    PROC PRINT DATA=elmo.SCORES;
60    VAR esty FACTOR1;
NOTE: The PROCEDURE PRINT used .20 seconds.
61    PROC SORT DATA=elmo.SCORES;
62    BY DESCENDING FACTOR2;
NOTE: SAS sort was used.
NOTE: The data set ELMO.SCORES has 41 observations and 27 variables.
NOTE: The PROCEDURE SORT used .40 seconds.
63    PROC PRINT DATA=elmo.SCORES;
64    VAR esty FACTOR2;
NOTE: The PROCEDURE PRINT used .22 seconds.
65    PROC SORT DATA=elmo.SCORES;
66    BY DESCENDING FACTOR3;
NOTE: SAS sort was used.
NOTE: The data set ELMO.SCORES has 41 observations and 27 variables.
NOTE: The PROCEDURE SORT used .40 seconds.
67    PROC PRINT DATA=elmo.SCORES;
68    VAR esty FACTOR3;
NOTE: The PROCEDURE PRINT used .19 seconds.
69    PROC SORT DATA=elmo.SCORES;
70    BY DESCENDING FACTOR4;
NOTE: SAS sort was used.
NOTE: The data set ELMO.SCORES has 41 observations and 27 variables.
NOTE: The PROCEDURE SORT used .40 seconds.
71    PROC PRINT DATA=elmo.SCORES;
72    VAR esty FACTOR4;
```

```
NOTE: The PROCEDURE PRINT used .19 seconds.
73    PROC SORT DATA=elmo.SCORES;
74    BY DESCENDING FACTOR5;
NOTE: SAS sort was used.
NOTE: The data set ELMO.SCORES has 41 observations and 27 variables.
NOTE: The PROCEDURE SORT used .46 seconds.
75    PROC PRINT DATA=elmo.SCORES;
76    VAR esty FACTOR5;
77    run;
NOTE: The PROCEDURE PRINT used .22 seconds.

  OBS  ESTY        LENGT     ESTWI     MINWI     MAXWI     ADEPT      DPWR     DYFLR     FIFYR     HUNYR     HIFLW     LWFLW
    1  buzz      48109.1   11102.1    1126.3   20273.4   10.3022   0.00093   33.9792   67.9584   79.2848     0.003     0.001
    2  narr      47143.7   14641.9     804.5   20595.2   9.20496   0.00063   90.6112   968.407      1093     0.014     0.003
    3  gard        49879   13998.3      1609   22043.3   6.15696   0.00044   19.8212    5.6632    5.6632     0.003     0.003
    4  lisd        98149   50683.5    1126.3   36363.4   18.9281   0.00037    849.48   6311.64   6628.78     0.018     0.004
    5  conn      89299.5     482.7     321.8    1448.1      3.81   0.00789   594.636   3998.22   4136.97     1.937     0.459
    6  grts        11263   42063.9     321.8    9010.4   2.71272   0.00006   19.8212    42.474   48.1372     0.012     0.011
    7  huds       257440    2735.3     160.9   18020.8   6.33984   0.00232   756.037   5414.02   5759.47     0.077     0.021
    8  barn        33789     17699     482.7   10619.4   1.43256   0.00008   65.1268   1002.39   1206.26     0.044     0.024
    9  njby      24939.5     16090        50      6900         3   0.00019     31.14   25.2296    30.015     0.012     0.006
   10  deby       222042     24135    6757.8   45695.6   6.37032   0.00026   560.657   7438.61   8302.25     0.013     0.005
   11  dein        19308    2896.2       150      5500   1.28016   0.00044       9.6      8.55     11.24   0.03859   0.00715
   12  chnq        51488    7240.5      1609   10619.4   1.79832   0.00025   11.3264         3         4     0.015     0.011
   13  ches       318582   24778.6    5148.8   55993.2   8.10768   0.00033   2429.51   58721.7   75113.9       0.1     0.029
   14  patx        75600      1609        30      2900   5.88264   0.00366   26.5604   360.718   437.341     0.055     0.023
   15  poto       188253   10297.6    2574.4   17859.9   5.88264   0.00057   450.224   9188.54   10748.8     0.095     0.027
   16  rapp       158647    3700.7     643.6    5148.8   4.93776   0.00133   82.1164   1936.81   2129.36     0.048     0.017
   17  york        78841    3378.9     643.6    6596.9   4.75488   0.00141     70.79   2755.15   3681.08     0.046     0.016
   18  jams       162187    5148.8     482.7      9654   4.17576   0.00081    353.95   10216.4   11799.3     0.084     0.028
   19  chst        61100      2300       160      7080   4.20624   0.00183   14.7526    114.68   156.021     0.032     0.013
   20  chop        80500      6900       320     19800   3.99288   0.00058   29.1088    119.55   126.686      0.03     0.008
   21  tang        91700      5800        10     25400      3.81   0.00066   83.3057   50.4308   59.4636     0.017     0.006
   22  a1pm       186644   21077.9    1448.1   47626.4    4.1148    0.0002   1302.54   6507.02   7506.57     0.318     0.187
   23  paml        67578    5631.5    1448.1    9332.2   2.86512   0.00051   130.254   1228.91      1362     0.117     0.053
   24  neus        80450    6596.9    1448.1   12228.4    3.5052   0.00053   175.559   1568.71   1795.23     0.198     0.064
   25  boge      15285.5     17699     965.4    4022.5   1.40208   0.00008   36.8108   404.919   472.877     0.015     0.008
   26  nwri      39903.2    2735.3     643.6    3378.9   1.76784   0.00065   22.6528   569.152   679.584      0.08      0.04
   27  cpfr        83668    1126.3     482.7    3861.6    3.5052   0.00311   285.992   4043.52   4779.74     0.224     0.072
   28  winy        82059    1126.3     482.7    6918.7    3.3528   0.00298   577.646    6640.1   7659.48     0.498     0.148
   29  nssn      88816.8    1126.3     321.8      3218   2.52984   0.00225   76.4532   2619.23   2639.05     0.306      0.05

  OBS    TPRSM      TFVOL      MXVOL      SWVOL      TFSUR      MXSUR      SWSUR      FWFRC      DCPTL      TPFLUSH
    1  6.797E8          0    2.195E7    6.067E9          0      51800    5853400    0.12299    1.04119   8.95802688
    2  4.928E8    4.074E7    2.669E8    3.632E9      77700     518000    3677800    0.16357    0.51929    7.9956533
    3   3.26E8          0    6316130    3.141E9          0      51800    5050500     0.1222    1.77348   9.65341081
    4  3.738E9    2.371E8     4.35E9    5.72E10     284900    4221700    2.815E7    0.15948      0.054    16.539622
    5   2.58E7    1.819E8    1.563E7          0     466200      51800          0    0.96245     0.4656   7.65647191
    6  7.476E7          0    4.742E8    5.821E8          0    2020200    1890700    0.34227    4.96728    14.128224
    7  7.363E7    5.083E8    2.945E9    1.432E9     958300    4351200    2408700    0.50871    0.19356   66.3387973
    8  8.553E7          0    1.397E8    2.387E8          0     777000    1864800      0.303      1.338   4.42546522
    9  7.969E7          0    5.476E7    2.224E8          0     118192    1257913    0.21851    3.17116   3.47755378
   10  2.889E9    4.249E8    2.826E9    9.423E9     595700    5180000    1.412E7    0.26023    0.13352   4.38775951
   11    1.8E7          0    1.895E7    8.621E7          0     155400     673400    0.20994     6.2728     5.841944
   12  4.673E7          0          0    6.382E8          0          0    3548300    0.12121    3.07848   13.6570368
   13  8.694E8    1.013E9    5.67E10    2.851E9    2745400    6.889E7    2978500    0.59679    0.07066   69.6556646
   14      3E7    4972992    7.111E8          0      36260    1181040          0     0.6165      6.959   23.8696064
   15  3.398E8     4.54E7     7.49E9          0     129500    1.267E7          0    0.61592    0.39353   22.1728531
   16  1.167E8    2.913E7    1.827E9          0      77700    3677800          0    0.61958    2.17045   15.9116645
   17  1.062E8    6.742E7    8.464E8          0     181300    1735300          0    0.64159    2.60715   8.60438938
   18  2.829E8    2.804E8    2.271E9          0     828800    5283600          0    0.65527    0.53255   9.01820195
   19   3.31E7     2.73E7    5.998E8          0     142450    1344210          0     0.7198      1.462   18.9462511
   20   7.22E7    2.511E7    1.115E9          0      77700    2776480          0      0.622      6.319    15.786478
   21   3.77E8    8810352    4.526E9          0      93240     1.18E7          0     0.6145      2.153   12.0274439
   22  8.213E8    1.117E9    2.64E10    3.067E8    5723900    6.014E7    1735300    0.62341    0.13768    33.877931
   23  6.542E7          0    1.232E9          0          0    4299400          0    0.61364     1.3552   18.8311688
   24  6.853E7          0    1.571E9          0          0    4480700          0    0.61364    1.00547   22.9173554
   25  1.354E8    1579033    4.642E7    3.221E8      25900     543900    2072000    0.18669    1.45893   2.73418283
   26  1.725E7          0    1.397E8    6947743          0     777000      51800    0.59031    7.49625   8.50542975
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    27  1.003E8    5.763E7    2.174E8     6.916E7      129500      699300      155400    0.59639    0.59987    3.43361085
    28  8.609E7    1.052E8    1.559E8           0      233100      543900           0    0.76625    0.38159      3.031776
    29  2.509E7    2.369E7    3.554E7           0      103600      129500           0    0.76788    2.88922    2.36049661

   OBS  ESTY       LENGT     ESTWI     MINWI     MAXWI     ADEPT      DPWR     DYFLR     FIFYR     HUNYR     HIFLW     LWFLW
    30  char     65647.2    3861.6     643.6    5792.4   5.57784   0.00144   455.888   1160.96   1177.95     0.201     0.112
    31  sthe       54706    6757.8     482.7   14641.9   3.93192   0.00058   130.254   914.607   1005.22     0.024      0.01
    32  brri     53257.9    6275.1    1126.3   10458.5    7.3152   0.00117   25.4844   314.308   359.613     0.004     0.001
    33  sava     46339.2    2735.3     482.7   10458.5   4.63296   0.00169   362.445    2069.9   2262.45     0.137     0.065
    34  ossa     49074.5    1769.9     321.8    6757.8   4.35864   0.00246    84.948   2055.74   2488.98     0.059     0.013
    35  casa     39903.2    5148.8     321.8   56636.8    4.4196   0.00086   22.6528   368.108   453.056     0.004     0.001
    36  alta       43443    2735.3     643.6    4666.1   3.10896   0.00114   421.908   3446.06   3681.08     0.557     0.117
    37  ansi       83668      8689     804.5   47626.4   4.35864    0.0005     70.79   1543.22    1577.2     0.014     0.005
    38  mycb       51500       480        60      2300   6.00456   0.01251    231.37   525.205   572.096     0.164     0.119
    39  john      197907    3700.7    1126.3   11584.8    3.6576   0.00099   220.865   1090.17   1271.39     0.252     0.125
    40  indn        4827   55027.8     160.9    9010.4   2.01168   0.00004   39.6424   167.064   192.549     0.044     0.013
    41  bisc     15285.5     45052     965.4   17377.2   2.34696   0.00005   90.6112   600.299   668.258     0.021     0.007

   OBS    TPRSM      TFVOL      MXVOL       SWVOL       TFSUR       MXSUR       SWSUR      FWFRC      DCPTL       TPFLUSH
    30  1.351E8    1.009E8    4.332E8           0      155400      802900           0    0.68519    0.43235     3.9538234
    31  3.936E8    3.221E7    4.694E8     3.658E8       77700     1061900     1061900    0.42004    0.92765    2.20339642
    32  5.409E8    4.706E7    1.092E9     7.548E8      103600     1450400     1036000     0.4268    4.81763     3.5012935
    33  1.753E8    2.203E7    2.942E8     8.014E7       77700      595700      181300    0.53512    0.42471    2.26089771
    34  1.759E8    1.026E7     3.25E8     3.719E7       51800      725200       77700    0.57491    1.94682    2.11759119
    35  4.163E8      1.2E7     7.79E8     6.537E7       51800     1787100      103600    0.58136    7.38249    2.05712248
    36  6.684E7    1.358E7    7.643E7     3.103E7      103600      207200       77700     0.5299    0.36129    1.81091471
    37   3.88E8    8132018    7.463E8     5.661E7       25900     1761200       77700    0.58306    2.36933    2.09026952
    38      7E7    3599472    1.325E7     3.936E8        2072       51800      611240    0.17499      0.217    5.86430331
    39  5.324E7    9.865E8     7.95E8      6.6E8     3082100     2460500     1139600    0.63356    0.82518    45.8584851
    40  6.457E7          0    5.558E7     1.402E9           0      284900     6967100    0.13999    1.01585    22.5692766
    41  3.002E8          0    1.658E7      1.62E9           0      155400     6811700     0.1262    0.40065     5.4504902
Initial Factor Method: Principal Components

                                          Prior Communality Estimates: ONE

                              Eigenvalues of the Correlation Matrix:  Total = 21  Average = 1
                                    1            2            3            4            5            6            7
            Eigenvalue         8.1646       4.4133       2.4554       1.1582       1.0573       0.8829       0.8325
            Difference         3.7513       1.9579       1.2972       0.1009       0.1745       0.0503       0.2293
            Proportion         0.3888       0.2102       0.1169       0.0552       0.0503       0.0420       0.0396
            Cumulative         0.3888       0.5989       0.7159       0.7710       0.8214       0.8634       0.9031
                                    8            9           10           11           12           13           14
            Eigenvalue         0.6032       0.4934       0.3133       0.2235       0.1451       0.1056       0.0666
            Difference         0.1098       0.1801       0.0898       0.0783       0.0395       0.0390       0.0238
            Proportion         0.0287       0.0235       0.0149       0.0106       0.0069       0.0050       0.0032
            Cumulative         0.9318       0.9553       0.9702       0.9808       0.9878       0.9928       0.9960
                                   15           16           17           18           19           20           21
            Eigenvalue         0.0428       0.0203       0.0115       0.0063       0.0033       0.0006       0.0000
            Difference         0.0225       0.0088       0.0052       0.0030       0.0027       0.0006
            Proportion         0.0020       0.0010       0.0005       0.0003       0.0002       0.0000       0.0000
            Cumulative         0.9980       0.9990       0.9995       0.9998       1.0000       1.0000       1.0000

                                    5 factors will be retained by the NFACTOR criterion.


                           Factor Pattern
             FACTOR1   FACTOR2   FACTOR3   FACTOR4   FACTOR5
  LENGT      0.81685   0.22604   0.00506   0.07434   0.28736
  ESTWI      0.30108  -0.64550  -0.01879  -0.33981  -0.44755
  MINWI      0.68369  -0.20004  -0.09683   0.19774  -0.12631
  MAXWI      0.67402  -0.29217  -0.17778  -0.04183   0.21611
  ADEPT      0.43070  -0.56987   0.40248   0.25351   0.30358
  DPWR      -0.15410   0.39534   0.60419   0.27815  -0.04950
  DYFLR      0.93568   0.17144   0.14039   0.09208  -0.11039
  FIFYR      0.85662   0.16851  -0.14037   0.37235  -0.21381
  HUNYR      0.84785   0.17201  -0.16179   0.37498  -0.22212
  HIFLW      0.02442   0.55110   0.71727  -0.04498  -0.14745
  LWFLW      0.09299   0.60762   0.71441  -0.18613  -0.11233
  TPRSM      0.50224  -0.71794   0.33749   0.04915   0.18235
  TFVOL      0.84159   0.23432   0.03335  -0.37743   0.16365
  MXVOL      0.90416   0.18940  -0.22111   0.10316  -0.14176
  SWVOL      0.30664  -0.74713   0.45755   0.03387   0.17997
  TFSUR      0.72055   0.30487  -0.00804  -0.54914   0.15401
  MXSUR      0.87325   0.23162  -0.20520  -0.11132  -0.06342
  SWSUR      0.34421  -0.84174   0.36185  -0.07797  -0.01720
  FWFRC      0.10143   0.71865   0.15673   0.14985   0.41488
  DCPTL     -0.39664   0.00171  -0.44361   0.09911   0.38094
  TPFLUSH    0.70597   0.20686  -0.16992  -0.14625   0.13339

              Variance explained by each factor
```

```
         FACTOR1   FACTOR2   FACTOR3   FACTOR4   FACTOR5
        8.164560  4.413288  2.455429  1.158228  1.057321

Initial Factor Method: Principal Components

                                         Final Communality Estimates: Total = 17.248825
           LENGT     ESTWI     MINWI     MAXWI     ADEPT      DPWR     DYFLR     FIFYR     HUNYR     HIFLW     LWFLW
        0.806462  0.823445  0.571884  0.619723  0.828674  0.624913  0.945267  0.966245  0.964557  0.842549  0.935485
           TPRSM     TFVOL     MXVOL     SWVOL     TFSUR     MXSUR     SWSUR     FWFRC     DCPTL  TPFLUSH
        0.917260  0.933531  0.933006  0.895119  0.937467  0.874731  0.964326  0.745890  0.509059  0.609232

Rotation Method: Varimax

              Orthogonal Transformation Matrix
                   1         2         3         4         5
       1     0.78841   0.31867   0.51982   0.03720   0.07252
       2     0.16292  -0.71526   0.22071   0.46178  -0.44712
       3    -0.20323   0.49614  -0.05283   0.84213  -0.02405
       4     0.47686   0.13952  -0.74487  -0.02654  -0.44452
       5    -0.28838   0.34820   0.35135  -0.27476  -0.77243

                   Rotated Factor Pattern
               FACTOR1   FACTOR2   FACTOR3   FACTOR4   FACTOR5
  LENGT        0.63239   0.21157   0.51983   0.05810  -0.29696
  ESTWI        0.10305   0.34508   0.11090  -0.17072   0.80765
  MINWI        0.65684   0.29652   0.12469  -0.11902   0.15102
  MAXWI        0.43767   0.40497   0.40237  -0.31782   0.03545
  ADEPT        0.19827   0.88561  -0.00532   0.00166  -0.07083
  DPWR        -0.03296  -0.01055  -0.24935   0.69186  -0.28788
  DYFLR        0.81285   0.21961   0.40943   0.26009   0.03215
  FIFYR        0.97056   0.06031   0.13742   0.04034  -0.01021
  HUNYR        0.97223   0.04186   0.12988   0.02580  -0.00664
  HIFLW       -0.01566  -0.08815   0.07813   0.90114  -0.12800
  LWFLW       -0.02925  -0.11561   0.24388   0.92147  -0.11261
  TPRSM        0.18128   0.91136   0.11225  -0.08004   0.18661
  TFVOL        0.46774   0.12146   0.82607   0.13265  -0.00318
  MXVOL        0.87872   0.00799   0.39684  -0.02889   0.04985
  SWVOL       -0.00870   0.92650   0.00834   0.00136   0.19122
  TFSUR        0.31311  -0.01542   0.90541   0.13308   0.04127
  MXSUR        0.73312  -0.02681   0.57653  -0.01298   0.06317
  SWSUR        0.02848   0.87441   0.02606  -0.06437   0.44057
  FWFRC        0.11701  -0.23857   0.23721   0.34965  -0.70481
  DCPTL       -0.28488  -0.20124  -0.12235  -0.49484  -0.35716
  TPFLUSH      0.51662   0.01875   0.57741  -0.05407  -0.07523

             Variance explained by each factor
          FACTOR1   FACTOR2   FACTOR3   FACTOR4   FACTOR5
         5.644898  3.842050  3.201159  2.774365  1.786353

                                         Final Communality Estimates: Total = 17.248825
           LENGT     ESTWI     MINWI     MAXWI     ADEPT      DPWR     DYFLR     FIFYR     HUNYR     HIFLW     LWFLW
        0.806462  0.823445  0.571884  0.619723  0.828674  0.624913  0.945267  0.966245  0.964557  0.842549  0.935485
           TPRSM     TFVOL     MXVOL     SWVOL     TFSUR     MXSUR     SWSUR     FWFRC     DCPTL  TPFLUSH
        0.917260  0.933531  0.933006  0.895119  0.937467  0.874731  0.964326  0.745890  0.509059  0.609232

         Scoring Coefficients Estimated by Regression
         Squared Multiple Correlations of the Variables with each Factor
          FACTOR1   FACTOR2   FACTOR3   FACTOR4   FACTOR5
         1.000000  1.000000  1.000000  1.000000  1.000000

Rotation Method: Varimax

  Standardized Scoring Coefficients
               FACTOR1   FACTOR2   FACTOR3   FACTOR4   FACTOR5
  LENGT        0.03903   0.09986   0.11088  -0.04727  -0.25416
  ESTWI       -0.01104  -0.07575   0.05711   0.05147   0.52563
  MINWI        0.18251   0.02176  -0.13353  -0.02273   0.04367
  MAXWI       -0.00715   0.10387   0.13084  -0.14367  -0.10450
  ADEPT        0.00881   0.32101  -0.07189  -0.00433  -0.26146
  DPWR         0.07773   0.06920  -0.19837   0.25437  -0.11793
  DYFLR        0.15308   0.01184  -0.03078   0.09693   0.03487
  FIFYR        0.31218  -0.04780  -0.24453   0.02042   0.00521
  HUNYR        0.31658  -0.05546  -0.24890   0.01550   0.01005
  HIFLW       -0.01497   0.00259  -0.00639   0.34312   0.06234
  LWFLW       -0.07372  -0.00991   0.10332   0.34247   0.08577
  TPRSM       -0.03543   0.27012   0.01780  -0.00560  -0.07819
  TFVOL       -0.11287   0.01004   0.36170   0.00591   0.00871
  MXVOL        0.19374  -0.07434  -0.04165  -0.01742   0.05498
  SWVOL       -0.07098   0.28885   0.01034   0.03260  -0.07054
  TFSUR       -0.18659  -0.03834   0.46563   0.00499   0.07384
  MXSUR        0.08133  -0.07921   0.12211  -0.02313   0.07535
```

```
  SWSUR       -0.05519     0.20791     0.01646     0.04385
0.12728
  FWFRC      -0.02811     0.07384     0.08052     0.01817   -
0.43404
  DCPTL      -0.06462     0.03200     0.04723   -0.25504   -
0.31569
  TPFLUSH    -0.00672    -0.01399     0.19733   -0.06473   -
0.05434

 OBS    ESTY          FACTOR1
   1    ches          5.87781
   2    poto          0.99559
   3    deby          0.84473
   4    jams          0.35874
   5    winy          0.21268
   6    mycb          0.14218
   7    huds          0.11182
   8    cpfr          0.08787
   9    neus          0.00960
  10    alta         -0.00705
  11    paml         -0.03911
  12    alpm         -0.04072
  13    rapp         -0.04388
  14    sava         -0.04693
  15    york         -0.09648
  16    ossa         -0.11622
  17    char         -0.14791
  18    ansi         -0.16195
  19    gard         -0.18674
  20    narr         -0.18804
  21    chnq         -0.19540
  22    nssn         -0.19713
  23    sthe         -0.20583
  24    tang         -0.21920
  25    boge         -0.22383
  26    buzz         -0.24121
  27    barn         -0.24937
  28    bisc         -0.25011
  29    conn         -0.26792
  30    brri         -0.26889
  31    chst         -0.32296
  32    patx         -0.37559
  33    lisd         -0.39553
  34    njby         -0.40455
  35    chop         -0.43399
  36    nwri         -0.44046
  37    indn         -0.44140
  38    grts         -0.47018
  39    dein         -0.47036
  40    casa         -0.48058
  41    john         -1.01149

 OBS    ESTY          FACTOR2
   1    lisd          5.38919
   2    deby          2.13401
   3    buzz          0.92099
   4    narr          0.52623
   5    huds          0.29950
   6    brri          0.29535
   7    casa          0.25492
   8    gard          0.22824
   9    ansi          0.13281
  10    mycb          0.11058
  11    patx          0.02540
  12    poto          0.00887
  13    conn         -0.06740
  14    rapp         -0.07889
  15    char         -0.08810
  16    tang         -0.14367
  17    chop         -0.16039
  18    john         -0.17078
  19    york         -0.17655
  20    sthe         -0.18111
  21    ossa         -0.19596
  22    sava         -0.19837
  23    jams         -0.20574
  24    chst         -0.24006
  25    ches         -0.25997
  26    winy         -0.27990
  27    cpfr         -0.28996
  28    nssn         -0.34568
```

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  29    alpm         -0.35655
  30    neus         -0.36039
  31    paml         -0.44654
  32    bisc         -0.44890
  33    alta         -0.47775
  34    chnq         -0.50756
  35    nwri         -0.52651
  36    njby         -0.57587
  37    grts         -0.67318
  38    barn         -0.69464
  39    dein         -0.70440
  40    indn         -0.71418
  41    boge         -0.75708

 OBS    ESTY          FACTOR3
   1    alpm          4.74406
   2    john          3.05940
   3    huds          1.42021
   4    ches          0.41528
   5    tang          0.18311
   6    casa          0.17765
   7    chop          0.17631
   8    jams          0.13596
   9    lisd          0.06860
  10    deby          0.06379
  11    indn          0.01536
  12    grts         -0.01073
  13    ansi         -0.01179
  14    conn         -0.07450
  15    chst         -0.08443
  16    neus         -0.08871
  17    rapp         -0.12324
  18    paml         -0.15615
  19    nwri         -0.17527
  20    char         -0.21093
  21    patx         -0.22130
  22    york         -0.28783
  23    bisc         -0.29036
  24    barn         -0.30980
  25    dein         -0.31697
  26    sthe         -0.31861
  27    chnq         -0.33823
  28    poto         -0.34187
  29    njby         -0.34290
  30    nssn         -0.36487
  31    brri         -0.39363
  32    gard         -0.40671
  33    narr         -0.42257
  34    winy         -0.44935
  35    boge         -0.47832
  36    sava         -0.49758
  37    alta         -0.51074
  38    buzz         -0.54269
  39    cpfr         -0.58568
  40    ossa         -0.60469
  41    mycb         -1.49931

 OBS    ESTY          FACTOR4
   1    conn          4.84227
   2    mycb          1.88039
   3    winy          1.36424
   4    alta          1.08173
   5    char          0.67539
   6    cpfr          0.67065
   7    alpm          0.57792
   8    sava          0.38111
   9    john          0.35329
  10    nssn          0.27616
  11    lisd          0.20045
  12    neus          0.07247
  13    jams         -0.00112
  14    ossa         -0.04076
  15    paml         -0.06577
  16    indn         -0.07969
  17    bisc         -0.11536
  18    huds         -0.12456
  19    chst         -0.17209
  20    poto         -0.19055
  21    barn         -0.19640
  22    sthe         -0.24689
  23    boge         -0.25216
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```
  24    york         -0.27863
  25    narr         -0.28780
  26    ches         -0.30083
  27    rapp         -0.30814
  28    buzz         -0.34954
  29    deby         -0.45793
  30    njby         -0.48615
  31    gard         -0.51203
  32    patx         -0.53550
  33    chnq         -0.58755
  34    tang         -0.60182
  35    grts         -0.63976
  36    brri         -0.70121
  37    nwri         -0.75495
  38    ansi         -0.79705
  39    dein         -0.83481
  40    chop         -1.01498
  41    casa         -1.44207

 OBS    ESTY          FACTOR5
   1    indn          3.00781
   2    bisc          2.66941
   3    boge          1.45762
   4    grts          1.39138
   5    barn          1.14172
   6    alpm          0.86889
   7    lisd          0.84528
   8    njby          0.83786
   9    chnq          0.76175
  10    gard          0.73929
  11    narr          0.55556
  12    deby          0.55198
  13    buzz          0.31737
  14    alta          0.30057
  15    ches          0.17236
  16    sthe          0.16974
  17    dein          0.06744
  18    mycb         -0.06363
  19    sava         -0.08824
  20    paml         -0.15252
  21    neus         -0.16775
  22    cpfr         -0.32772
  23    char         -0.36077
  24    winy         -0.44782
  25    john         -0.50278
  26    poto         -0.50371
  27    ossa         -0.52155
  28    conn         -0.52955
  29    jams         -0.55024
  30    tang         -0.61752
  31    ansi         -0.66229
  32    brri         -0.72229
  33    york         -0.75389
  34    chst         -0.76095
  35    nssn         -0.90099
  36    nwri         -0.91296
  37    rapp         -0.94449
  38    huds         -1.08282
  39    chop         -1.15888
  40    casa         -1.46924
  41    patx         -1.65343
```

CHAPTER 2- Assemblages of U.S. East Coast Inlets Based on Physical and Hydrodynamic Characteristics

Introduction

Inlet dimensions heavily impact estuarine hydrodynamic regimes and estuarine/marine exchanges. Therefore an understanding of the influence of inlets is crucial to developing an understanding of estuaries abiotically and biotically. Traditionally, inlet studies have focused on evaluating the relationships between inlet dimensions and hydrodynamic variables (e.g., cross sectional area, depth, width, current speed, etc.) (Jarrett 1976, O'Brien 1931, Vincent and Corson 1980a). The impetus for these studies has been to improve the information available to assess potential impacts of channellization and inlet stabilization projects, since modifying inlet dimensions can radically alter estuarine hydrodynamic regimes to the detriment of established ecosystems (e.g., Great South Bay's inlet modification driven oyster industry demise (Schubel et al. 1991)). The Strategic Environmental Assessments Division (SEAD) Inlet Analysis presented in this chapter carries out a similar analysis on U.S. East Coast Inlets from Buzzards Bay, Massachusetts to Biscayne Bay, Florida. The objectives of this U.S. East Coast Inlet Analysis are to: 1) identify the most important physical and hydrodynamic inlet relationships, 2) use these important physical and hydrodynamic relationships' variables to group similar inlets, 3) develop inlet information to assess fisheries species inlet usage regionally.

The purpose of this chapter is to document analytical techniques and to disseminate results of the second of four analyses to define coupling of estuarine and marine environments. This chapter supports an ongoing cooperative study between the University of Virginia and the SEA Division entitled the *Analysis of East Coast Inlet, Estuarine, and Climate Characteristics and Their Impact on the Exchange of Organisms through Inlets Study.* The impetus for this work stems from NOAA's Strategic Environmental Assessments Division's ongoing estuarine characterization efforts in support of improved management of the nation's estuarine resources and inter-estuarine research. Also, the analysis stems from previous success in its application to U.S. inlets in identifying inlet types based on geomorphology and hydrodynamics (Vincent and Corson 1980b.).

Methods

Variable Selection. Variables included in this analysis were based on the following. A major assumption of this analysis was that inlet geomorphology and hydrodynamics are intrinsically linked. The patterns of these dynamic linkages makes identification of similar inlets possible. Therefore, variables directly affected by these dynamic linkages will be (with analysis) the most useful in identifying patterns of interactions, and provide the basis for identifying similar inlets.

Inlet Selection. The selection of estuarine-inlets to include in this Analysis was based on the following. Inlets of National Estuarine Inventory (NEI) (NOAA 1985) estuaries were selected to take advantage of their previously compiled physical and hydrodynamic data summaries. Inlet information was compiled for 41 estuaries from Buzzards Bay, Massachusetts to Biscayne Bay, Florida. This range of estuaries was selected to make this inlet analysis comparable to the previously completed estuaries analysis in chapter 1 and Estuarine Living Marine Resources (ELMR) Program's estuarine fisheries abundance data set.

Individual-Inlet Analysis. This Individual-Inlet analysis evaluates inlets independent of their estuarine associations. The rationale for this Individual-Inlet Analysis is that some fisheries species (e.g., red drum, blue crab, American eel, striped bass, Atlantic salmon, etc.) rely on specific hydrodynamic regimes to trigger spawning, stimulate upstream migration, facilitate egg/larvae entrainment, etc. Since these inlet sensitive species rely on specific inlet hydrodynamic regimes, some inlets are more important to a particular species than others. This Individual-Inlet Analysis will be used in combination with ELMR's Life History Tables (currently under development) and an analysis of ELMR's fisheries abundance data set to evaluate "inlet hydrodynamic regime/species utilization patterns" for U.S. East Coast Inlets. As a result, assessments of inlet utility to inlet sensitive species will be evaluated from a regional perspective instead of the current *ad hoc* provincial assessments. The individual inlets, individual inlet variables, and individual inlet data matrix are presented in Tables 1, 2, and 3.

Estuarine-Inlet Analysis. This part of the inlet analysis will be used to evaluate inlet/estuarine linkages. Therefore, to make this inlet analysis comparable to the previously completed Estuaries Analysis in chapter 1 and yet to be completed ELMR Fisheries Abundance Analysis, composite inlet variable values for estuaries with multiple inlets (Table 4) were developed by the use of sums and weighted averages (Table 5). As a result, the Estuarine-Inlet Matrix (Table 6) contains composite inlet information for estuaries with multiple inlets, and non-composite inlet information for estuaries with single inlets. The estuarine-inlets, estuarine-inlets variables, and estuarine-inlets data matricies are presented in Tables 4, 5, and 6.

Statistical Protocol. The same statistical protocol was applied to the individual-inlet data matrix (Table 3) and estuarine-inlet data matrix (Table 6). Systat version 5.2.1 was used to carry out truncated PCA and Factor Score manipulations (Systat 1992). Systat's *Factor* procedure's *Principal Component* procedure with *correlation* option, *varimax* option, and *Num Factor* instruction invoked were used to carry out the PCAs'. Component number selection was based on the following: 1) component eigenvalues account for ≥75% of the variance in the matrix, and 2) individual component eigenvalues ≥1.0 and account for ≥8% of the variance in the matrix. Based on the above criteria, truncated PCAs were selected. The criterion for assigning variables to membership in the resulting components follows: variables were assigned membership in a component if the variable's rotated loading was ≥0.5. Systat's *Principal Component's save file* option with the *scores* option invoked was used to retrieve the PCA run's factor scores. These factor scores indicate an individual estuary's strength of association with the PCA generated components. These factor scores provided the basis for evaluating similarity/dissimilarity.

These factor scores were subjected to cluster analysis as follows. Systat Incorporated's Systat version 5.2.1 *Cluster* procedure (with *Join, Pearson*, and *Average Linkage* options invoked) was used to carry out cluster analysis and produce dendrograms (Systat 1992). The dendrogram grouped inlets with similar factor score patterns into clusters. Therefore, the dendrogram grouped the inlets into clusters based on degree of similarity. The criterion for selecting the number of clusters to consider was based on the following. In order to maintain continuity with the previously completed Estuaries Analysis in chapter 1, the dendrogram's branching was cut to provide the number of clusters equal to the number of clusters selected in the Estuaries Analysis. Given the selection of number of clusters to consider is somewhat subjective, the selection of 5 clusters facilates our cross analyses comparisons (yet to be completed). However, the decision to cut the dendrograms into 5 branches is preliminary and other cuts may prove more useful with further analysis. The inlets within these clusters were assigned to inlet groups according to their membership in a common cluster. This identifies inlets with similar characteristics based on the variables/inlet matrix.

Test runs (PCA and factor score clustering) on Tables 3, Table 6 and their sub-matrices were used to determine the most important variables and final matrix structures (i.e., matrices on which the inlets would be clustered) for the Individual-Inlet Analysis and Estuarine-Inlet Analysis. Variables that did not generate strong PCA rotated loadings (≥0.5) and/or caused the test runs to yield egregiously spurious factor score

Table 1. The following 69 individual inlets included in the Individual-Inlet Analysis.

Inlet Abbrev.	Inlet Name	Estuary Affiliation
buzz	mouth of Buzzards Bay	Buzzards Bay
buzzqkhl	Quicks Hole	
narrnpbp	Narrows Point-Brenton Point	Narragansett Bay
narrspbp	Sachuest Point-Breakwater Point	
gardnogi	north mouth of Gardiners Bay	Gardiners Bay
gardsogi	south mouth of Gardiners Bay	
lisoprp	Orient Point - Race Point	Long Island Sound
lisepnp	East Point - Napatree Point	
conn	Connecticut River entrance	Connecticut River
gsberoc	East Rockaway Inlet	Great South Bay
gsbjone	Jones Inlet	
gsbfris	Fire Island Inlet	
huds	Hudson River entrance	Hudson River
njinbinj	Barnaget Inlet (jetty)	Barnegat Bay
njinlteg	Little Egg Inlet	
njinbrig	Brigatine Inlet	New Jersey Inland Bays
njinabsj	Absecon Inlet (jetty)	
njingreg	Great Egg Inlet	
njincors	Corsons Inlet	
njintown	Towsends Inlet	
njinhere	Hereford Inlet	
njincpmj	Cape May Inlet (jetty)	
dela	mouth of Delaware Bay	Delaware Bay
delainrj	Indian River Inlet (jetty)	Delaware Inland Bays
chinsine	mouth of Sinapuxent Bay	Chincoteague Bay
chin	Chincoteague Inlet	
ches	mouth of Chesapeake Bay	Chesapeake Bay
paxt	mouth of Patuxent River	Patuxent River
poto	mouth of Potomac River	Potomac River
rapp	mouth of Rappahannok River	Rappahannok River
york	mouth of York River	York River
jame	mouth of James River	James River
chst	mouth of Chester River	Chester River
chop	mouth of Choptank River	Choptank River
tgpk	mouth of Tangier/Pocomoke Sound	Tangier/Pocomoke Sound
almaorgn	Oregon Inlet	Albamarle/Pamlico Sound
almahatt	Hatteras Inlet	
almaocrk	Ocracoke Inlet	
almadrum	Drum Inlet	
pamrppgr	mouth of Pamlico/Pungo River	Pamlico/Pungo River
neunuri	mouth of Neuse River	Neuse River
bogubard	Barden Inlet	Bogue Sound
bogubeau	Beauford Inlet	
bogu	Bogue Inlet	
newnrii	New River Inlet	New River
capecpfr	mouth of Cape Fear River	Cape Fear River
winy	mouth of Winyah Bay	WInyah Bay
santnsan	mouth of North Santee River	N/S Santee River
santssan	mouth of South Santee River	
charchhj	Charleston Harbor (jetty)	Charleston Harbor
helesthl	mouth of St. Helena Sound	St. Helena Sound
helefrin	Fripp Inlet	
broaprse	mouth of Port Royal Sound	Broad River
sava	mouth of Savannah River	Savannah River
ossa	mouth of Ossabaw Sound	Ossabaw Sound
cathdymo	mouth of Doboy Sound	St. Catherine/Sapelo Sound
cathspmo	mouth of Sapelo Sound	
cathctmo	mouth of St. Catherine Sound	
alta	mouth of Altamaha River	Altamaha River
andranso	mouth of St. Andrew Sound	St. Andrew/St. Simon Sound
andrsimo	mouth of St. Simon Sound	
marvmvit	mouth of St. Mary's River (jetty)	St. Mary's River
johnjjet	mouth of St. John's River (jetty)	St. John's River
indifpjt	Fort Pierce Inlet (jetty)	Indian River
indisebj	Sebastian Inlet (jetty)	
biscmikb	Miami Beach - Key Biscayne	Biscayne Bay
biscskkb	Soldier Key - Key Biscayne	
biscsksk	Sand Key - Soldier Key	
biscbacr	Broad/Angelfish Creek	

clusterings (e.g., Long Island Sound and Chincoteaque Bay grouping together, Chesapeake Bay and Connecticut River grouping together, etc.) were not included in the final matrix. Also, variables that appeared to duplicate each other (i.e., PCA rotated loadings within .01 of each other in the same component) where tested to determine if they were interchangeable within the matrix. That is a matrix containing one or the other variable yields similar PCA and factor score clusterings. If the variables were interchangeable then one was not included in the final matrix.

Results

Important Variables Identified. Test runs on Tables 3, Table 6 and their sub-matrices yielded concurrent re

Table 2. Individual inlet variables included in the Individual-Inlet Analysis.

Variables	Methods Used to Develop Variables
width	This parameter is based upon the minimum width of the NEI cross section. In cases where there is a jetty, the width was determined at the terminus of the jetties or shorter jetty if one side was longer than the other. In areas where a tidal flat was exposed at the inlet mouth, a measurement was taken half way between the water line and the shoreline in order to account for the width at mid-tide level.
average depth	This parameter was taken by applying a dot grid approach along the cross section. The depths were averaged and converted from lower low water to mid-tide level depths by adding to the average depth the mean tide level recorded in NOAA's Tide Tables, High and Low Predictions.
maximum depth	This is the maximum depth found in between the borders of the thalweg. The depth only incorporates the natural channel and not random holes on the inlet bottom. The depth parameter was adjusted to reflect mid-tide depths.
cross sectional area	This was derived from multiplying the inlet width by the average depth.
distance to the continental shelf	This was measured on 1:1,200,000 scale NOS nautical charts that give depths in fathoms. The 100 (approx. 200m) bathymetric contour line was used to represent the continental shelf break. The measurements for distance were taken from the middle of the inlet cross section and followed out to the closest point of the shelf, regardless of angle.
mean tide level	This was acquired from NOAA's Tide Tables 1992, High and Low Predictions, East Coast of North and South America. The tidal range measurement closest to the NEI or jettied cross sections were recorded in the matrix and the location was marked on a nautical chart.
spring tide level	same as above
flood current speed	This is obtained from NOAA's Tidal Current Table 1992, Atlantic Coast of North America. The measurements closest to both the NEI or jettied cross sections were recorded in the matrix and the location was marked on the nautical charts. For those that do not have gages, the speed was interpolated from the closest inlet with same physical characteristics (especially depth).
ebb current speed	same as above
flood tidal excursion	This was calculated from the equation: fte = 3.95 * flood current speed
ebb tidal excursion	This was calculated from the equation: ete = 3.95 * ebb current speed
flood volume	This was calculated from the equation: flood current speed * cross sectional area
ebb volume	This was calculated from the equation: ebb current speed * cross sectional area

sults. Matrices that excluded any of the 5 important variables (listed in Table 7) produced egregiously spurious factor score clusterings of the inlets. Inclusion of tidal prism volume (estuarine-inlet matrices only), flood volume, ebb volume, flood excursion, ebb excursion, and max depth to matrices containing the 5 important variables did not alter the PCA's identification of a recurring component pattern (Table 7). Max depth, flood volume, and ebb volume usually associated (strongly) with the first component (Table 7). Flood and ebb excursions usually associated (strongly) with the second component (Table 7). Flood and ebb excursions were found to be interchangeable with flood and ebb current speed. Inclusion of average tidal height, spring tidal height, and distance to shelf caused egregiously spurious factor score clusterings of the inlets, and these variables didn't associate strongly with any component (based on their low rotated loadings). Conversely, the variables listed in Table 7 were the most important variables tested (for both the individual-inlet test runs and estuarine-inlet test runs) based on their consistently high rotated loadings (> 0.8), their consistent presence in the significant components (i.e., eigenvalues $\geq$1 and $\geq$8% variance), and their required presence to maintain the recurrent component pattern. As a result, the following variables were excluded from further consideration and removed from the individual-inlet matrix and estuarine-inlet matrix: tidal height, spring tidal height, distance to shelf, max depth, flood volume, ebb volume, flood excursion, ebb excursion, tidal prism volume. The following important variables remained in the individual-inlet's (final) data matrix (Table 8) and estuarine-inlet's (final) data matrix (Table 9): cross sectional area, depth, width, flood current speed, ebb current speed. These final data matrices were evaluated further using PCA and factor score clustering protocols.

Improving Robustness of Analysis. The PCA and factor score clusterings of the individual-inlet (final) data matrix (Table 8) and estuarine-inlet (final) data matrix (Table 9) produced a minor mis-alignment of the inlets. To be specific, Long Island Sound grouped with the Chesapeake Bay Sub-estuaries. This groupment was deemed to be unrealistic given disparities in cross section and current speed within this group. After some thought, it was realized that clustering factor scores from a 3 component PCA was not very robust analytically (i.e., clustering 3 x 41 and 3 x 69 matrices). Conversely, clustering the variables of Table 8 and Table 9 would produce substainally more robust analyses (i.e., clustering 5 x 41 and 5 x 69). Therefore, Table 8 and Table 9's variables were: standardized (using Systat 5.2.1 *data* module) to compensate for the disparate units, and the resulting standardized data *Join Clustered* using *Euclidean Distance* and *Average Linkage*. The resulting dendrograms are presented in Figure 1 and Figure 2.

Individual-Inlet Dendrogram Results. The Individual-Inlet cluster analysis (Figure 1) identified five groups of inlets. Long Island Sound's-Orient Point - Race Point Inlet is its own group based on its large size (cross sectionally) and swift currents. This combination is opposite the trend in the other inlets which is characterized by slower currents speeds associated with larger cross sectional areas and vice versa. The Delaware Bay, Potomac River, and Chesapeake Bay Inlets make up a slow (current speeds) and large (cross section) group. Indian River's-Sebastian Inlet (jetty), and New Jersey Inland Bay's-Absecon Inlet (jetty) make an exceptional fast (current speeds) group. Buzzards Bay's-mouth of Buzzards Bay, Narragansett Bay's-Narrows Point to Breton Point, Narragansett Bay's-Sachuest Point to Breakwater Point, Gardiners Bay's-south mouth of Gardiners Bay, and Paxtuent River Inlets make up another moderately sized (cross sectional area) / slow (current speed) group. The other 58 inlets fall into a small to moderately sized (cross section) group (group 5). One subsection of group 5 consist of moderately sized and slow inlets: New Jersey Inland Bay's-Corson's Inlet, Chester River, Choptank River, Rappahanock River, Pamilico/Pungo River, Biscayne Bay's-Solder Key to Biscayne Key, Biscayne Bay's-Sand Key to Solder Key, and Neuse River Inlets. A second subsection of group 5 consist of moderately large / swift inlets: Savannah River, St. Helena Sound's-mouth of St. Helena Sound, Hudson River, Gardiners Bay's-north mouth of Gardiners Bay. The remaining 46 inlets fall into a moderate to small group.

Estuarine-Inlet Cluster Analysis Results. The Estuarine-Inlet cluster analysis identified five groups. Long Island Sound is its own group, which makes sense since it is so large and swift. This break out also occurred in the Individual Inlet dendrogram (Figure 1). Biscayne Bay is also its own group, which makes sense since it is so wide, shallow, and slow. Narragansett Bay, Buzzards Bay, Delaware Bay, Gardiners Bay, Potomac River, Chesapeake Bay make up a "slow current speed and large cross sectional area" group. The members of this group showed a similar grouping in Figure 1. Neuse, Pamilico, Rappahannock, Choptank, Chester, Connecticut, Altama, Tangier, York, and Patuxent Rivers make up a "small cross sectional area and slow to moderate current speed" group. A similar groupment was seen in Figure 1. The rest of the inlets (23) fell within a swift current speed group.

Table 3. Individual inlet data matrix for variables tested in Individual-Inlet Analysis.

inlet	width m	avdep m	mxdep m	crsec m2	dshlf m	atide m	sptid m	fcurr m/s	ecurr m/s	flexc m	ebexc m	fvol m3/s	evol m3/s
buzz	10424	14.9	21.3	155051.5	149850	1.04	1.28	0.31	0.26	2028.12	1701.01	48065.95187	40313.37899
buzzqkhl	1289	6.6	14.5	8449.1	150000	0.76	0.94	0.98	1.03	6411.49	6738.61	8280.085633	8702.538982
narrnpbp	7041	19.4	33.1	136595.4	150000	1.07	1.31	0.21	0.31	1373.89	2028.13	28685.034	42344.574
narrspbp	3859	15.1	16.3	58270.9	150000	0.94	1.19	0.21	0.21	1373.89	1373.89	12236.889	12236.889
gardnogi	9354	12.9	18.0	120605.5	144000	0.79	0.94	0.62	0.93	4056.25	6084.37	74775.42165	112163.1325
gardsogi	10250	14.6	21.3	149967.8	137000	0.64	0.79	0.15	0.15	981.35	981.35	22495.17049	22495.17049
lisoprp	18974	29.0	73.8	549983.7	150000	0.67	0.79	1.70	1.60	11121.97	10467.74	934972.2462	879973.8788
lisepnp	3383	9.2	61.9	31246.1	150000	0.79	0.98	0.98	1.13	6411.49	7392.84	30621.15785	35308.06977
conn	1399	2.7	7.9	3777.3	165000	0.98	1.16	0.46	0.36	3009.48	2355.24	1737.558	1359.828
gsberoc	741	3.4	5.5	2483.3	176000	1.25	1.52	1.13	1.18	7392.84	7719.96	2806.127033	2930.291946
gsbjone	640	3.5	10.4	2240.3	167000	1.10	1.31	1.60	1.34	10467.74	8766.73	3584.448	3001.9752
gsbfris	878	5.1	8.7	4476.9	154000	0.79	0.94	1.24	1.24	8112.50	8112.50	5551.358976	5551.358976
huds	9135	8.4	14.1	76289.9	189000	1.43	1.71	0.82	0.88	5364.72	5757.26	62557.74472	67135.14067
njinbinj	347	2.9	3.5	1007.7	141000	0.94	1.16	1.13	1.29	7392.84	8439.62	1138.665744	1299.892752
njinlteg	3264	3.6	6.4	11840.4	133000	1.13	1.37	1.03	1.08	6730.76	7067.29	12181.40305	12790.4732
njinbrig	366	3.9	7.0	1438.1	132000	1.10	1.30	0.98	1.03	6394.22	6738.61	1405.579591	1481.283231
njinabsj	662	5.5	9.8	3632.1	134000	1.19	1.43	2.10	2.49	13738.91	16290.42	7627.488229	9044.021757
njingreg	1463	5.7	11.5	8383.6	139000	1.16	1.40	1.03	1.08	6730.76	7065.72	8625.017155	9054.255956
njincors	777	0.6	7.3	497.4	139000	1.19	1.43	0.05	0.10	336.54	673.08	25.58798438	51.17596877
njintown	274	3.2	4.3	877.8	139000	1.16	1.40	0.87	0.93	5721.14	6057.68	767.5835648	812.7355392
njinhere	892	2.3	4.9	2050.5	122000	1.25	1.52	0.82	0.87	5384.61	5691.83	1687.678088	1783.97154
njincpmj	251	6.9	10.1	1731.9	144000	1.34	1.62	0.93	1.13	6084.37	7392.84	1610.667	1957.047
dela	18197	12.6	30.8	228508.0	137000	1.25	1.49	0.72	0.67	4710.48	4383.37	164525.784	153100.3823
delainrj	152	4.5	5.0	685.8	118000	0.82	0.98	0.93	1.10	6084.37	7196.57	637.794	754.38
chinsine	247	3.0	4.7	741.0	109000	1.00	1.30	0.87	0.93	5721.14	6057.68	647.98968	686.10672
chin	4695	3.4	8.9	16099.2	93000	0.67	0.79	0.82	0.87	5384.61	5721.14	13250.24853	14078.38906
ches	17730	7.8	15.7	137806.3	120000	0.85	1.04	0.41	0.62	2682.36	4056.25	56500.59564	85439.92512
paxt	1509	13.1	17.6	19767.9	269900	0.37	0.43	0.21	0.21	1373.89	1373.89	4151.259	4151.259
poto	17775	9.1	12.8	161752.5	231000	0.37	0.43	0.36	0.26	2355.24	1701.01	58230.9	42055.65
rapp	6096	5.5	10.0	33528.0	188450	0.37	0.43	0.36	0.26	2355.24	1701.01	12070.08	8717.28
york	4541	7.9	20.8	35873.9	160700	0.67	0.79	0.52	0.46	3402.02	3009.48	18654.428	16501.994
jame	3683	9.1	21.5	33515.3	147750	0.76	0.91	0.77	0.77	5037.60	5037.60	25806.781	25806.781
chst	1196	5.8	9.7	6936.8	351250	0.34	0.40	0.21	0.21	1373.89	1373.89	1456.728	1456.728
chop	1322	6.2	16.7	8196.4	297600	0.40	0.46	0.31	0.26	2028.12	1701.01	2540.884	2131.064
tgpk	4617	6.5	24.5	30010.5	206950	0.49	0.58	0.57	0.57	3729.13	3729.13	17105.985	17105.985
almaorgn	1582	2.9	4.0	4587.5	59000	0.58	0.70	1.10	0.62	7196.57	4056.25	5046.29928	2844.277776
almahatt	880	1.5	2.8	1319.5	47000	0.61	0.73	1.10	1.00	7196.57	6542.34	1451.42712	1319.4792
almaocrk	2057	2.7	14.0	5643.9	59000	0.58	0.70	0.88	1.20	5757.26	7850.81	4966.596518	6772.631616
almadrum	604	1.3	3.3	754.4	64000	0.61	0.73	0.93	0.57	6084.37	3729.13	701.5734	429.9966
pamrppgr	6309	4.5	7.0	28390.5	99700	0.00	0.00	0.10	0.15	673.08	1009.61	2920.81464	4381.22196
neunuri	10058	4.4	7.6	44255.2	110800	0.00	0.00	0.10	0.15	673.08	1009.61	4552.974976	6829.462464
bogubard	777	1.7	3.0	1303.0	65000	1.13	1.34	0.98	1.03	6411.49	6738.61	1276.905833	1342.05409
bogubeau	1054	7.7	14.2	8098.1	80000	0.98	1.16	0.62	0.88	4056.25	5757.26	5020.797638	7126.293422
bogu	1554	1.7	3.1	2642.6	106000	0.67	0.79	0.51	0.57	3336.59	3701.92	1347.73416	1495.297837
newnrii	1006	1.9	3.5	1901.0	111000	0.91	1.10	0.51	1.13	3336.59	7403.83	969.529176	2151.366231
capecpfr	2114	1.6	3.8	3286.3	100000	1.31	1.49	1.10	1.50	7196.57	9813.51	3614.946473	4929.472464
winy	1975	3.4	10.0	6742.5	93000	1.16	1.34	0.98	1.00	6411.49	6542.34	6607.68041	6742.531031
santnsan	572	3.4	5.3	1968.4	90000	1.37	1.62	0.77	0.93	5037.60	6084.37	1515.655033	1830.596339
santssan	562	1.9	2.8	1045.6	89000	1.25	1.46	0.77	0.82	5037.60	5364.72	805.094493	857.3733562
charchhj	914	7.8	13.8	7135.0	103000	1.51	1.80	0.93	0.93	6084.37	6084.37	6635.506729	6635.506729
helesthl	12349	4.7	11.0	57588.7	121000	1.89	2.23	0.77	0.82	5037.60	5364.72	44343.29129	47222.72579
helefrin	1381	5.9	8.3	8206.6	117000	1.92	2.23	0.62	0.62	4056.25	4056.25	5088.085824	5088.085824
broaprse	4206	10.5	17.1	44163.0	126000	2.01	2.23	0.93	0.93	6084.37	6084.37	41071.59	41071.59
sava	9400	5.9	13.1	55870.0	134000	2.07	2.44	0.93	1.60	6084.37	10467.74	51959.12808	89392.04831
ossa	5395	4.8	7.5	25817.0	137000	2.13	2.50	0.82	1.18	5364.72	7719.96	21169.9541	30464.0803
cathdymo	2016	6.4	13.9	12844.2	137000	2.10	2.44	0.82	0.93	5364.72	6084.37	10532.21976	11945.07851
cathspmo	4065	5.8	13.6	23414.5	137000	2.10	2.47	0.88	1.13	5757.26	7392.84	20604.75342	26458.37655
cathctmo	2652	8.2	14.9	21663.2	141000	2.16	2.53	0.93	0.88	6084.37	5757.26	20146.80695	19063.64529
alta	3667	2.3	6.0	8493.9	134000	2.04	2.38	0.57	0.62	3729.13	4056.25	4841.54531	5266.242267
andranso	4398	6.6	16.9	28822.7	134000	2.01	2.35	1.10	1.13	7196.57	7392.84	31704.97401	32569.65512
andrsimo	1911	9.0	12.4	17242.1	135000	2.01	2.38	1.60	1.13	10467.74	7392.84	27587.2976	19483.52893
marymyjt	1166	11.9	14.7	13873.7	128000	1.77	2.07	1.13	1.40	7392.84	9159.27	15677.31942	19423.2276
johnjjet	471	13.9	19.8	6530.9	117000	1.48	1.74	0.97	1.19	6346.07	7785.38	6334.925911	7771.713231
indifpjt	206	6.0	8.7	1236.0	40000	0.79	0.95	1.34	1.59	8766.73	10402.32	1656.24	1965.24
indisebj	180	1.9	4.0	342.0	55000	0.64	0.76	2.11	2.78	13804.33	18187.70	721.62	950.76
biscmikb	4171	0.8	12.3	3178.7	6800	0.66	0.87	0.62	0.46	4038.45	3028.84	1962.134056	1471.600542
biscskkb	8230	2.1	5.4	17558.7	10200	0.58	0.70	0.10	0.15	673.08	1009.61	1806.436439	2709.654658
biscsksk	8120	1.5	4.4	12127.2	10800	0.49	0.58	0.10	0.15	673.08	1009.61	1247.645434	1871.468151
biscbacr	2414	1.1	5.1	2722.4	15600	0.37	0.43	0.62	0.93	4056.25	6084.37	1687.907024	2531.860536

Table 4. The following 41 estuarine-inlets included in the Estuarine-Inlet Analysis. "Composite Inlets" denotes estuaries with multiple inlets. "Non-Composite Inlet" denotes estuaries with single inlet.

Esty-Inlet Abbrev.	Composite Inlet or Non-Composite Inlet	Estuary
buzz	Composite Inlet	Buzzards Bay
narr	Composite Inlet	Narragansett Bay
gard	Composite Inlet	Gardiners Bay
lisd	Composite Inlet	Long Island Sound
conn	Non-composite Inlet	Connecticut River
grts	Composite Inlet	Great South Bay
huds	Non-composite Inlet	Hudson River
barn	Composite Inlet	Barnegat Bay
njby	Composite Inlet	New Jersey Inland Bays
deby	Non-composite Inlet	Delaware Bay
dein	Non-composite Inlet	Delaware Inland Bays
chnq	Composite Inlet	Chincoteague Bay
ches	Non-composite Inlet	Chesapeake Bay
patx	Non-composite Inlet	Patuxent River
poto	Non-composite Inlet	Potomac River
rapp	Non-composite Inlet	Rappahannok River
york	Non-composite Inlet	York River
jams	Non-composite Inlet	James River
chst	Non-composite Inlet	Chester River
chop	Non-composite Inlet	Choptank River
tang	Non-composite Inlet	Tangier/Pocomoke Sound
alpm	Composite Inlett	Albamarle/Pamlico Sound
paml	Non-composite Inlet	Pamlico/Pungo River
neus	Non-composite Inlet	Neuse River
boge	Composite Inlet	Bogue Sound
nwri	Non-composite Inlet	New River
cpfr	Non-composite Inlet	Cape Fear River
winy	Non-composite Inlet	WInyah Bay
nssn	Composite Inlet	N/S Santee River
char	Non-composite Inlet	Charleston Harbor
sthe	Composite Inlet	St. Helena Sound
brri	Non-composite Inlet	Broad River
sava	Non-composite Inlet	Savannah River
ossa	Non-composite Inlet	Ossabaw Sound
casa	Composite Inlet	St. Catherine/Sapelo Sound
alta	Non-composite Inlet	Altamaha River
ansi	Composite Inlet	St. Andrew/St. Simon Sound
mycb	Non-composite Inlet	St. Mary's River
john	Non-composite Inlet	St. John's River
indn	Composite Inlet	Indian River
bisc	Composite Inlet	Biscayne Bay

Discussion

First and foremost, these inlet analyses identify the following variables as being the most important in characterizing the interaction of inlet geomorphology and inlet hydrodynamics: 1) cross sectional area; 2) depth; 3) width; 4) flood current speed; and 5) ebb current speed. The interaction of these variables reasonably define inlet types based primarily on cross sectional area and current speeds, and secondarily on depth and width. This appraisal is based on test runs on both the Individual-Inlet and Estuarine-Inlet data matrices (Table 3, Table 6, and their sub-matrices) which consistently identified a recurrent PCA component pattern seen in Table 7. Cross sectional area recurrently occurred in the first component with rotated loadings >0.9. Flood current speed and ebb current speed recurrently occurred in the second component with rotated loadings >0.9. Width or depth recurrently occurred in the first component with rotated loadings <0.9, and one or the other occurred in component 3 at a higher rotated load value than it had in component one. These findings agree with those of Vincent and Corson's (1980b) identification of cross section and current speed as the most important variables defining inlets.

Estuarine inlets come into existance in three basic ways: 1) primary inlets- sea level intersects the coastal topography and drowns the subaqueous topography in such a way as to create a basin incisied into the coastline (e.g., drowned river valleys, coastal plain estuaries, fjords, large sounds, etc.), 2) secondary inlets- sea level positioning in combination with adequate coastal sedimentary budgets maintain barrier islands, pennisulas,spits, etc. while the subaqueous topography behind these secondary coastal features become lagoons and small sounds, 3) hybrid inlets come into existance when primary inlets are modified by secondary coastal features (e.g., Sandy Hook Pennisula as headland for Raritan Bay, barrier islands as headlands for Almarle/Pamlico Sound). These estuarine inlets are maintained around some dynamic equilibrium by the interaction of their estuary's geomorphology, volumetrics, and sedimentary budgets.

Future Work

Future work includes cross analyses of the U.S. East Coast Inlets Analysis results and the previously completed U.S. East Coast Estuaries Analysis results. This comparison explores if certain estuarine characteristics are statistically related to inlet geometric characteristics, such as width, depth, cross sectional area, tidal current speed, etc. This estuaries/inlet analysis

Table 5. Estuarine-inlet variables included in the Estuarine-Inlet Analysis.

Variables	Methods Used to Develop Variables
width	sum of (individual inlet width) inlet widths taken from Table 2
average depth	sum of (individual inlet average depth * proration) proration based on: (inlet cross sectional area) / (sum of (estuary's inlets cross sectional area)) inlet average depth taken from Table 2
maximum depth	sum of (individual inlet maximum depth * proration) proration based on: (inlet cross sectional area) / (sum of (estuary's inlets cross sectional area)) inlet average depth taken from Table 2
cross sectional area	sum of (individual inlet cross sectional area) inlet cross sectional area taken from Table 2
distance to the continental shelf	average of distance to the continental shelf distances inlet distance to shelf taken from Table 2
mean tide level	sum of (individual inlet mean tide level)/ number of inlets inlet mean tide level taken from Table 2
spring tide level	sum of (individual inlet spring tide level) / number of inlets inlet spring tide level taken from Table 2
flood current speed	sum of (individual inlet flood current speed * proration) proration based on: (inlet cross sectional area) / (sum of (estuary's inlets cross sectional area)) inlet flood current speed taken from Table 2
ebb current speed	sum of (individual inlet ebb current speed* proration) proration based on: (inlet cross sectional area) / (sum of (estuary's inlets cross sectional area)) inlet ebb current speed taken from Table 2
flood tidal excursion	This was calculated from the equation: fte = 3.95 * flood current speed flood current speed taken from Table 5
ebb tidal excursion	This was calculated from the equation: ete = 3.95 * ebb current speed ebb current speed taken from Table 5
flood volume	This was calculated from the equation: flood current speed * cross sectional area flood current speed & cross sectional area taken from Table 5
ebb volume	This was calculated from the equation: ebb current speed * cross sectional area ebb current speed & cross sectional area taken from Table 5
tidal prism volume	Taken directly from NEI.

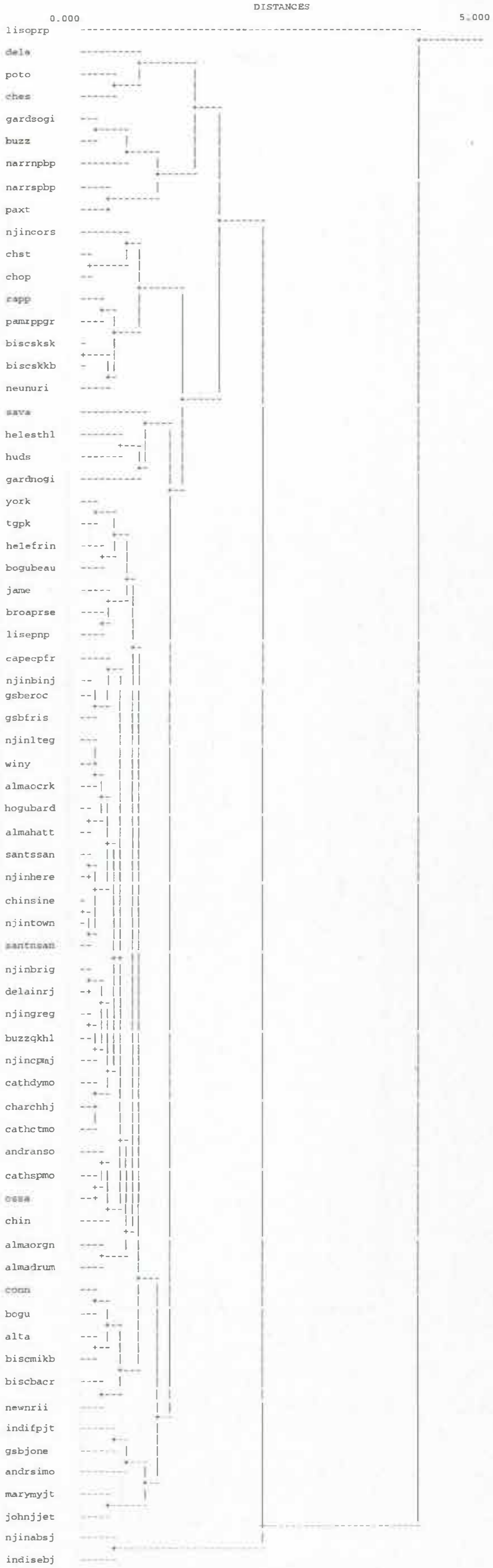

Figure 1. Individual-inlet dendrogram of standardized data in Table 8.

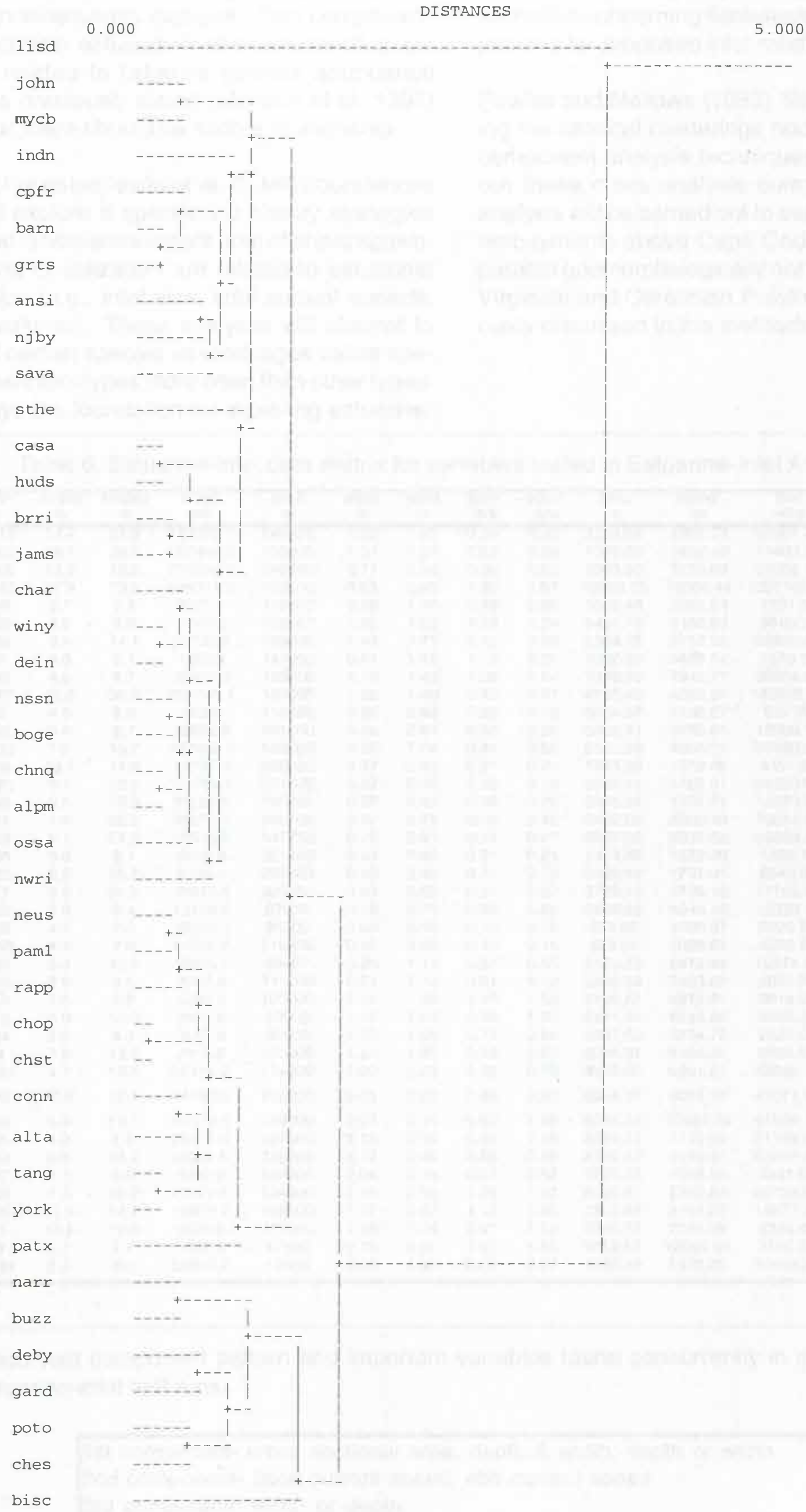

Figure 2. Estuarine-inlet dendrogram of standardized data in Table 9.

will be compared to an ongoing analysis of the Estuarine Living Marine Resources Program's (ELMR) relative abundance/estuaries matrices. This comparison explores if certain estuarine/inlet characteristics are statistically related to fisheries species abundance patterns. As previously stated (Monaco et al. 1991) indicates that there should be such a relationship.

Specifically, the estuaries/inlet vs. ELMR abundances analysis will explore if specific life history strategies (e.g., egg and larvae entrainment from offshore spawning) and level of utilization are related to estuarine/inlet dynamics (e.g., inlet size, tidal current speeds, tidal prism volume). These analyses will attempt to determine if certain species assemblages utilize specific estuaries/inlets types more often than other types. Further, it lays the foundation for exploring estuarine/offshore fisheries abundance linkages on regional scales. If successful, this would provide valuable information concerning fisheries/ecosystem impact projections for proposed inlet modifications.

Fowles and Mallows (1983) "Bk" statistic for comparing hierarchical clusterings and Clafin's (1987) cross component analysis techniques will be used to carry out these cross analysis comparisons. A separate analysis will be carried out to evaluate U.S. East Coast embayments above Cape Cod as they are not comparable geomorphologically nor hydrodynamically with Virginian and Carolinian Province estuaries as previously discussed in the methods section.

Table 6. Estuarine-inlet data matrix for variables tested in Estuarine-Inlet Analysis.

esty	width m	avdep m	mxdep m	crsec m2	dshlf m	atide m	sptid m	fcurr m/s	ecurr m/s	flexc m	ebexc m	fvol m3/s	evol m3/s	tprsm m3
buzz	11713	14.4	21.0	169192.1	149925	1.02	1.26	0.34	0.30	2254.64	1961.33	58307.49	50722.20	6.80E+08
narr	10900	18.1	28.1	197444.5	150000	1.01	1.25	0.21	0.28	1373.89	1832.49	41463.34	55303.60	4.93E+08
gard	19605	13.9	19.8	271643.0	140500	0.71	0.86	0.36	0.50	2351.96	3255.98	97655.14	135190.65	3.26E+08
lisd	22357	27.9	73.1	624314.6	150000	0.68	0.80	1.66	1.57	10868.75	10302.44	1037169.96	983129.07	3.74E+09
conn	1399	2.7	7.9	3777.3	165000	0.98	1.16	0.46	0.36	3009.48	2355.24	1737.56	1359.83	2.58E+07
grts	1829	4.2	8.0	7700.0	165667	1.02	1.23	1.28	1.24	8491.75	8165.85	9840.31	9548.26	7.48E+07
huds	9135	8.4	14.1	76732.8	189000	1.43	1.71	0.82	0.88	5364.72	5757.26	62920.89	67524.86	7.36E+07
barn	347	4.0	3.1	1389.9	141000	0.94	1.16	1.13	1.29	7392.84	8439.62	1570.57	1792.96	8.55E+07
njby	7949	4.9	8.7	38951.6	135250	1.19	1.43	1.35	1.54	7376.95	7943.77	52694.96	59867.75	7.97E+07
deby	18197	12.6	30.8	229276.7	137000	1.25	1.49	0.72	0.67	4710.48	4383.37	165079.19	153615.36	2.89E+09
dein	152	4.5	5.0	685.8	118000	0.82	0.98	0.93	1.10	6084.37	7196.57	637.79	754.38	1.80E+07
chnq	4942	3.4	8.7	16852.8	101000	0.69	0.81	0.83	0.88	5399.41	5735.95	13908.70	14775.61	4.67E+07
ches	17730	7.8	15.7	137806.3	120000	0.85	1.04	0.41	0.62	2682.36	4056.25	56500.60	85439.93	8.69E+08
patx	1509	13.1	17.6	19767.9	269900	0.37	0.43	0.21	0.21	1373.89	1373.89	4151.26	4151.26	3.00E+07
poto	17775	9.1	12.8	161752.5	231000	0.37	0.43	0.36	0.26	2355.24	1701.01	58230.90	42055.65	3.40E+08
rapp	6096	5.5	10.0	33528.0	188450	0.37	0.43	0.36	0.26	2355.24	1701.01	12070.08	8717.28	1.17E+08
york	4541	7.9	20.8	35873.9	160700	0.67	0.79	0.52	0.46	3402.02	3009.48	18654.43	16501.99	1.06E+08
jams	3683	9.1	21.5	33515.3	147750	0.76	0.91	0.77	0.77	5037.60	5037.60	25806.78	25806.78	2.83E+08
chst	1196	5.8	9.7	6936.8	351250	0.34	0.40	0.21	0.21	1373.89	1373.89	1456.73	1456.73	3.31E+07
chop	1322	6.2	16.7	8196.4	297600	0.40	0.46	0.31	0.26	2028.12	1701.01	2540.88	2131.06	7.22E+07
tang	4617	6.5	24.5	30010.5	206950	0.49	0.58	0.57	0.57	3729.13	3729.13	17105.99	17105.99	3.77E+08
alpm	5122	2.6	8.4	13199.6	57250	0.59	0.71	0.99	0.92	6468.24	6043.16	13050.13	12192.50	8.21E+08
paml	6309	4.5	7.0	28390.5	99700	0.00	0.00	0.10	0.15	673.08	1009.61	2920.81	4381.22	6.54E+07
neus	10058	4.4	7.6	44255.2	110800	0.00	0.00	0.10	0.15	673.08	1009.61	4552.97	6829.46	6.85E+07
boge	3386	5.4	10.0	18245.1	83667	0.95	1.12	0.67	0.85	4153.15	5412.44	12274.88	15500.85	1.35E+08
nwri	1006	2.0	3.5	2007.4	111000	0.91	1.10	0.51	1.13	3336.59	7403.83	1023.80	2271.78	1.72E+07
cpfr	2114	1.6	3.8	3286.3	100000	1.31	1.49	1.10	1.50	7196.57	9813.51	3614.95	4929.47	1.00E+08
winy	1975	5.0	10.0	9821.8	93000	1.16	1.34	0.98	1.00	6411.49	6542.34	9625.36	9821.80	8.61E+07
nssn	1134	2.9	4.4	3281.8	90000	1.33	1.56	0.77	0.89	5037.60	5834.72	2527.01	2926.87	2.51E+07
char	914	7.8	13.8	7135.0	103000	1.51	1.80	0.93	0.93	6084.37	6084.37	6635.51	6635.51	1.35E+08
sthe	13730	4.7	10.5	65144.3	119000	1.90	2.23	0.75	0.78	4915.20	5201.51	48646.13	50752.28	3.94E+08
brri	4206	10.5	17.1	44163.0	126000	2.01	2.23	0.93	0.93	6084.37	6084.37	41071.59	41071.59	5.41E+08
sava	9400	5.9	13.1	55870.0	134000	2.07	2.44	0.93	1.60	6084.37	10467.74	51959.13	89392.05	1.75E+08
ossa	5395	4.8	7.5	25817.0	137000	2.13	2.50	0.82	1.18	5364.72	7719.96	21169.95	30464.08	1.76E+08
casa	8733	6.8	14.2	59352.0	138333	2.12	2.49	0.89	0.99	5792.56	6490.97	52550.01	58886.00	4.16E+08
alta	3667	2.3	6.0	8493.9	134000	2.04	2.38	0.57	0.62	3729.13	4056.25	4841.55	5266.24	6.68E+07
ansi	6309	7.5	15.2	47177.0	134000	2.01	2.36	1.29	1.13	8420.97	7392.84	60723.88	53310.00	3.88E+08
mycb	1166	11.9	14.7	13873.7	128000	1.77	2.07	1.13	1.40	7392.84	9159.27	15677.32	19423.23	7.00E+07
john	471	13.9	19.8	6530.9	117000	1.48	1.74	0.97	1.19	6346.07	7785.38	6334.93	7771.71	5.32E+07
indn	386	4.7	7.7	1832.6	47500	0.76	0.91	1.51	1.85	9858.53	12089.64	2761.37	3393.65	6.46E+07
bisc	22935	2.3	6.0	52807.7	10850	0.56	0.69	0.26	0.27	1232.49	1578.20	13658.31	14444.95	3.00E+08

Table 7. Recurrent component pattern and important variables found concurrently in the individual-inlet test runs and estuarine-inlet test runs.

1st component- cross sectional area, depth & width; depth or width
2nd component- flood current speed, ebb current speed
3rd component- width or depth

Table 8. Individual-inlet data (final) matrix on which dendrogram (Figure 1) was based.

inlet	width	avdep	crsec	fcurr	ecurr
buzz	10424	14.9	155051.5	0.31	0.26
buzzqkhl	1289	6.6	8449.1	0.98	1.03
narrnpbp	7041	19.4	136595.4	0.21	0.31
narrspbp	3859	15.1	58270.9	0.21	0.21
gardnogi	9354	12.9	120605.5	0.62	0.93
gardsogi	10250	14.6	149967.8	0.15	0.15
lisoprp	18974	29.0	549983.7	1.70	1.60
lisepnp	3383	9.2	31246.1	0.98	1.13
conn	1399	2.7	3777.3	0.46	0.36
gsberoc	741	3.4	2483.3	1.13	1.18
gsbjone	640	3.5	2240.3	1.60	1.34
gsbfris	878	5.1	4476.9	1.24	1.24
huds	9135	8.4	76289.9	0.82	0.88
njinbinj	347	2.9	1007.7	1.13	1.29
njinlteg	3264	3.6	11840.4	1.03	1.08
njinbrig	366	3.9	1438.1	0.98	1.03
njinabsj	662	5.5	3632.1	2.10	2.49
njingreg	1463	5.7	8383.6	1.03	1.08
njincors	777	0.6	497.4	0.05	0.10
njintown	274	3.2	877.8	0.87	0.93
njinhere	892	2.3	2050.5	0.82	0.87
njincpmj	251	6.9	1731.9	0.93	1.13
dela	18197	12.6	228508.0	0.72	0.67
delainrj	152	4.5	685.8	0.93	1.10
chinsine	247	3.0	741.0	0.87	0.93
chin	4695	3.4	16099.2	0.82	0.87
ches	17730	7.8	137806.3	0.41	0.62
paxt	1509	13.1	19767.9	0.21	0.21
poto	17775	9.1	161752.5	0.36	0.26
rapp	6096	5.5	33528.0	0.36	0.26
york	4541	7.9	35873.9	0.52	0.46
jame	3683	9.1	33515.3	0.77	0.77
chst	1196	5.8	6936.8	0.21	0.21
chop	1322	6.2	8196.4	0.31	0.26
tgpk	4617	6.5	30010.5	0.57	0.57
almaorgn	1582	2.9	4587.5	1.10	0.62
almahatt	880	1.5	1319.5	1.10	1.00
almaocrk	2057	2.7	5643.9	0.88	1.20
almadrum	604	1.3	754.4	0.93	0.57
pamrppgr	6309	4.5	28390.5	0.10	0.15
neunuri	10058	4.4	44255.2	0.10	0.15
bogubard	777	1.7	1303.0	0.98	1.03
bogubeau	1054	7.7	8098.1	0.62	0.88
bogu	1554	1.7	2642.6	0.51	0.57
newnrii	1006	1.9	1901.0	0.51	1.13
capecpfr	2114	1.6	3286.3	1.10	1.50
winy	1975	3.4	6742.5	0.98	1.00
santnsan	572	3.4	1968.4	0.77	0.93
santssan	562	1.9	1045.6	0.77	0.82
charchhj	914	7.8	7135.0	0.93	0.93
helesthl	12349	4.7	57588.7	0.77	0.82
helefrin	1381	5.9	8206.6	0.62	0.62
broaprse	4206	10.5	44163.0	0.93	0.93
sava	9400	5.9	55870.0	0.93	1.60
ossa	5395	4.8	25817.0	0.82	1.18
cathdymo	2016	6.4	12844.2	0.82	0.93
cathspmo	4065	5.8	23414.5	0.88	1.13
cathctmo	2652	8.2	21663.2	0.93	0.88
alta	3667	2.3	8493.9	0.57	0.62
andranso	4398	6.6	28822.7	1.10	1.13
andrsimo	1911	9.0	17242.1	1.60	1.13
marymyjt	1166	11.9	13873.7	1.13	1.40
johnjjet	471	13.9	6530.9	0.97	1.19
indifpjt	206	6.0	1236.0	1.34	1.59
indisebj	180	1.9	342.0	2.11	2.78
biscmikb	4171	0.8	3178.7	0.62	0.46
biscskkb	8230	2.1	17558.7	0.10	0.15
biscsksk	8120	1.5	12127.2	0.10	0.15
biscbacr	2414	1.1	2722.4	0.62	0.93

Table 9. Estuarine-inlet data (final) matrix on which dendrogram (Figure 2) was based.

esty	width	avdep	crsec	fcurr	ecurr
buzz	11713	14.4	169192.1	0.34	0.30
narr	10900	18.1	197444.5	0.21	0.28
gard	19605	13.9	271643.0	0.36	0.50
lisd	22357	27.9	624314.6	1.66	1.57
conn	1399	2.7	3777.3	0.46	0.36
grts	1829	4.2	7700.0	1.28	1.24
huds	9135	8.4	76732.8	0.82	0.88
barn	347	4.0	1389.9	1.13	1.29
njby	7949	4.9	38951.6	1.35	1.54
deby	18197	12.6	229276.7	0.72	0.67
dein	152	4.5	685.8	0.93	1.10
chnq	4942	3.4	16852.8	0.83	0.88
ches	17730	7.8	137806.3	0.41	0.62
patx	1509	13.1	19767.9	0.21	0.21
poto	17775	9.1	161752.5	0.36	0.26
rapp	6096	5.5	33528.0	0.36	0.26
york	4541	7.9	35873.9	0.52	0.46
jams	3683	9.1	33515.3	0.77	0.77
chst	1196	5.8	6936.8	0.21	0.21
chop	1322	6.2	8196.4	0.31	0.26
tang	4617	6.5	30010.5	0.57	0.57
alpm	5122	2.6	13199.6	0.99	0.92
paml	6309	4.5	28390.5	0.10	0.15
neus	10058	4.4	44255.2	0.10	0.15
boge	3386	5.4	18245.1	0.67	0.85
nwri	1006	2.0	2007.4	0.51	1.13
cpfr	2114	1.6	3286.3	1.10	1.50
winy	1975	5.0	9821.8	0.98	1.00
nssn	1134	2.9	3281.8	0.77	0.89
char	914	7.8	7135.0	0.93	0.93
sthe	13730	4.7	65144.3	0.75	0.78
brri	4206	10.5	44163.0	0.93	0.93
sava	9400	5.9	55870.0	0.93	1.60
ossa	5395	4.8	25817.0	0.82	1.18
casa	8733	6.8	59352.0	0.89	0.99
alta	3667	2.3	8493.9	0.57	0.62
ansi	6309	7.5	47177.0	1.29	1.13
mycb	1166	11.9	13873.7	1.13	1.40
john	471	13.9	6530.9	0.97	1.19
indn	386	4.7	1832.6	1.51	1.85
bisc	22935	2.3	52807.7	0.26	0.27

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CHAPTER 3- Comparison of U.S. East Coast Estuarine and Inlet Assemblages Based on Physical and Hydrodynamic Characteristics.

Introduction

Previous analyses of U.S. East Coast estuaries in chapter 1 and inletsin chapter 2 have identified assemblages of estuaries and inlets based on their physical and hydrodynamic characteristics. Given an estuary's hydrodynamic impact on its inlet(s) and vice versa, it is reasonable to assume that estuaries of a specific type possess complementary inlets. Therefore, comparisons of inlet assemblages from chapter 2 versus estuarine assemblages from chapter 1 provides a means of evaluating these estuarine/inlet relationships.

The purpose of this chapter is to document the analytical techniques and to disseminate results of the third of four analyses to define coupling of estuarine and marine environments. Thischapter supports an ongoing cooperative study between the University of Virginia and the SEA Division entitled the *Analysis of East Coast Inlet, Estuarine, and Climate Characteristics and Their Impact on the Exchange of Organisms through Inlets Study*. The impetus for this work stems from NOAA's Strategic Environmental Assessments Division's ongoing estuarine characterization efforts in support of improved management of the nation's estuarine resources and inter-estuarine research. Also, the analysis stems from previous success in its application to U.S. West Coast estuaries in identifying estuarine types based on geomorphology/hydrodynamics and species assemblages (Horn and Allen 1976; Monaco et al. 1991; Monaco et al. 1992).

Methods

Fowlkes and Mallows' (1983) Bk statistic (Table 1) was used to determine the similarity of the estuaries dendrogram (Figure 1) versus the inlet dendrogram (Figure 2). Based on previous analyses (chapters 1 and 2) the estuaries and inlet dendrograms were cut to produce a five cluster configuration for comparative purposes. These clusters were used to develop the comparison matrix on which the Bk statistic's components were based (Table 1). As per Fowlkes and Mallows (1983), if the Bk statistic is above the 95% confidence interval for Bk, then the dendrograms are similar at the five cluster cut. If the Bk statistic is below the 95% confidence interval for Bk, then the dendrograms are not similar at the five cluster cut.

The Bk statistic was determined to be 0.3906 for the comparison matrix (Table 1). The Bk value was above the 95% confidence interval (0.3394) for Bk indicating that the estuaries dendrogram and inlet dendrogram were similar according to the Bk statistic procedure used here.

Discussion

This analysis of the U.S. East Coast Inlets Analysis (chapter 1) and the U.S. East Coast Estuaries Analysis (chapter 2) indicates that the assemblages of inlets and estuaries identified by Principal Component Analysis (PCA) and Cluster Analysis are statistically similar. This is especially interesting since no variables are common between the U.S. East Coast Inlets Analysis (chapter 1) and the U.S. East Coast Estuaries Analysis (chapter 2). These results significantly reinforce the premise that specific estuary types are associated with complementary inlet types.

Future Work

The next step in this series of estuarine inlet analyses will subject a combined estuaries/inlet variables matrix to the above statistical protocols (chapters 1 and 2). The estuaries/inlet results will be compared to the previous estuaries results (chapter 1) and inlet results (chapter 2). This will be done to: 1) investigate intercorrelations within the combined estuaries and inlet variable matrix; and 2) evaluate the similarity of the resulting dendrograms to the previous dendrograms (chapters 1 and 2).

These estuarine inlet analyses will be compared to an ongoing analysis of the Estuarine Living Marine Resources Program's (ELMR) relative abundance/estuaries matrices. This ELMR vs. inlet/estuaries analysis explores if certain estuarine/inlet characteristics are statistically related to fish species abundance patterns. Fowles and Mallows (1983) "Bk" statistic for comparing hierarchical clusterings and Clafin's (1987) cross component analysis techniques will be used to carry out these cross analysis comparisons.

The estuaries/inlet vs. ELMR abundance analysis will explore if specific life history strategies (e.g., egg and larvae entrainment from offshore spawn

Table 1. Estuaries dendrogram (tree1) versus inlet dendrogram (tree2), comparison matrix and Bk statistic components.

Inlet vs. Estuaries- 5 cluster comparison

Comparison matrix

		tree1 branch1	tree1 branch2	tree1 branch3	tree1 branch4	tree1 branch5	*sum cells across rows*
tree2	branch1	1	0	0	0	0	***1***
tree2	branch2	1	8	7	0	7	***23***
tree2	branch3	0	0	6	0	4	***10***
tree2	branch4	3	1	0	2	0	***6***
tree2	branch5	0	1	0	0	0	***1***
sum cells	down columns	5	10	13	2	11	**41**

Bk statistics components for above comparison matrix

values	**component**
41	mij=matrix cells e.g. above 1+1+3+8+1+7+6+2+7+4
231	mij squared e.g. above 1squared+1squared+3squared+8squared+7squared+6squared+2squared+7squared+4squared
41	mi.=sum bottom e.g. above 5+10+13+2+11
419	mi. squared e.g. above 5squared+10squared+13squared+2squared+11squared
41	m.j=sum side e.g. above 1+23+10+6+1
667	m.j squared e.g. above 1squared+23squared+10squared+6squared+1squared
41	n=mij
5	k=number of clusters
25	c=number of cells in comparison matrix
190	Tk=mij squared - n
378	Pk=mi. squared-n
626	Qk=m.j squared-n
3486	Pk'=mi.(mi.-1)(mi.-2) e.g. mi. values of 5,10,13,2,11 Pk'=5*4*3+10*9*8+13*12*11+0+*11*10*9
11466	Qk'=m.j(m.j-1)(m.j-2) e.g. for values of 1,23,10,6,1 Qk'=0+23*22*21+10*9*8+6*5*4+0
0.3906	Bk=Tk/square root of Pk*Qk
0.296612	E(Bk)=Bk mean= (square root of Pk*Qk)/(n*(n-1)
0.0006	var(Bk)=2/[n(n-1)]+[4(Pk'Qk')/n(n-1)*(n-2)*PkQk]+[{(Pk-2-4Pk'/Pk)*(Qk-2-4Qk'/Qk)/n(n-1)(n-2)(n-3)}] continued from above: -PkQk/[n squared (n-1)squared]
0.3394	upper 95%Confidence Interval= E(Bk) + t-value for n * square root of var(Bk)

If Bk less than upper 95% Confidence interval
Then clusters are not similar

ing) and level of utilization are related to estuarine/inlet dynamics (e.g., inlet size, tidal current speeds, tidal prism volume). These analyses will attempt to determine if certain assemblages of species utilize specific estuaries/inlets types more than other types. Further, it lays the foundation for exploring estuarine/offshore fisheries abundance linkages on regional scales. If successful, this would provide valuable information concerning fisheries/ecosystem impact projections for proposed inlet modifications.

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```
                                                        Distance Scale
                              0.0------------0.5-------------1.0-------------1.5

Broad River                   ----
                                 +---
Delaware Bay                  ----  |
                                    +----
Long Island Sound             -------   |
                                        +----------------------
Buzzards Bay                  ---       |                     |
                                +--------                     |
Narragansett Bay              ---                             |
                                                              +------------
Gardiners Bay                 ---                             |           |
                                +----                         |           |
St. Helena Sound              ---   |                         |           |
                                    +--------------------------           |
Barnegat Bay                  -     |                                     |
                              |     |                                     |
Bogue River                   +     |                                     |
                              +-    |                                     |
Biscayne Bay                  +|    |                                     |
                              ||    |                                     |
NJ Inland Bays                +|    |                                     |
                              ||    |                                     |
Indian River                  -|    |                                     |
                               +--- |                                     |
Great South Bay               -+  | |                                     |
                               |  | |                                     |
Chincoteaque Bay              --  | |                                     |
                                  +--                                     |
Delaware Inland Bays          -----                                       |
                                                                          +---
Albemarle/Pamlico Sound       --                                          |
                               +-------------------                       |
St Johns River                --                  |                       |
                                                  +------                 |
St Andrew/Simmons Sound       -                   |     |                 |
                              +----               |     |                 |
St Catherines/Sapelo Sound    -   |               |     |                 |
                                  +-------        |     |                 |
Choptank River                -   |      |        |     |                 |
                              +-  |      |        |     |                 |
Tangier/Pocomoke Sound        -|  |      |        |     |                 |
                               +- |      |        |     |                 |
New River                     --| |      |        |     |                 |
                                +--      |        |     |                 |
Hudson River/Raritan Bay      ---        |        |     |                 |
                                         +---------     |                 |
Chester River                 -----      |              |                 |
                                  +----  |              |                 |
Patuxent River                --  |   |  |              |                 |
                               +---   |  |              |                 |
Rappahannock River            -|      |  |              |                 |
                              +-      |  |              |                 |
York River                    -       |  |              |                 |
                                      +---              |                 |
James River                   ---------                 |                 |
                                                        +-----------      |
Potomac River                 ---                       |          |      |
                                +------------------------          |      |
Chesapeake Bay                ---                                  |      |
                                                                   +-------
Pamlico/Pungo Rivers          --                                   |
                               +-----------------                  |
Neuse River                   --                |                  |
                                                +-------------------
Altamaha River                -----             |
                                  +---          |
St Marys River                -   |  |          |
                              +-- |  |          |
Savannah Sound                - | |  |          |
                                +--  |          |
Cape Fear River               - |    |          |
                              +--    |          |
Winyah Bay                    -      |          |
                                     +--        |
Connecticut River             -      | |        |
                              +----  | |        |
Charleston Harbor             -   |  | |        |
                                  +---  |        |
North & South Santee Rivers   -----    |        |
                                       +---------
Ossabaw Sound                 ----------
```

Figure 1. Dendrogram of estuaries (chapter 1).

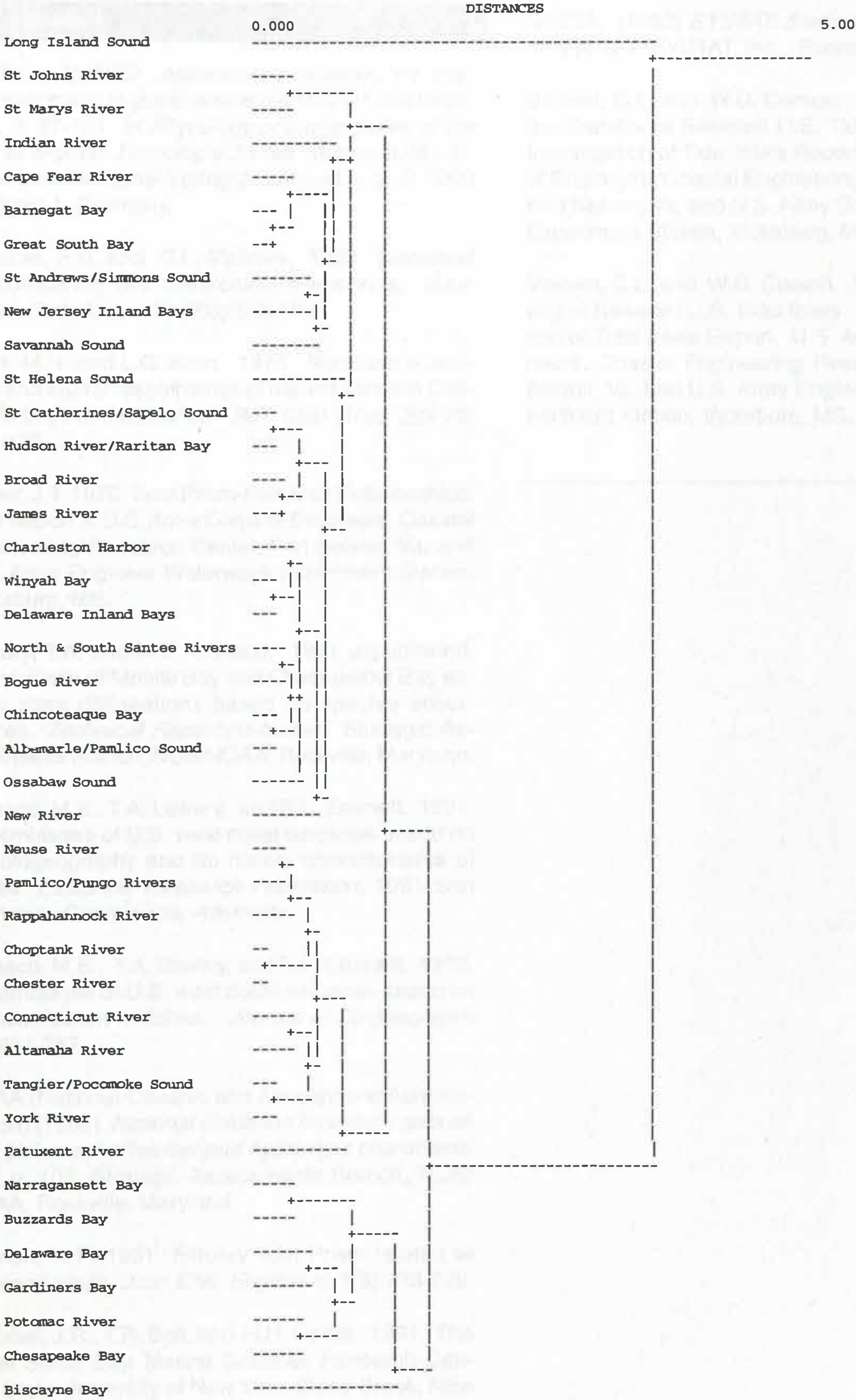

Figure 2. Dendrogram of Inlets (chapter 2).

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CHAPTER 4- Comparison of U.S. East Coast Estuarine and Inlet Assemblages Evaluation of Physical and Hydrodynamic Interactions

Introduction

Three previous analyses (chapters 1, 2 and 3) indicate that assemblages of estuaries (based on estuarine geomorphology and hydrodynamics variables) are statistically similar to assemblages of inlets (based on inlet geomorphology and hydrodynamics). Now that estuaries/inlets similarity has been established, the next set of analyses investigates the nature of the relationships responsible for the observed estuaries/inlets similarity. The geomorphologic and hydrodynamic variables from the previous estuaries (chapter 1) and inlet (chapter 2) analyses were combined here for further evaluation. The resulting 26 variable by 41 estuaries/inlet matrix (Table 3) was subjected to Principal Component Analysis (PCA) and cluster analysis to identify assemblages of estuaries. The resulting hybrid estuaries/inlet assemblages were compared to the previous estuaries (chapter 1) and inlet (chapter 2) assemblages by the use of Bk statistics and cross component analysis.

The purpose of this chapter is to document the analytical techniques and to disseminate results of this fourth of four analysis to define coupling of estuarine and marine environments. This chapter supports an ongoing cooperative study between the University of Virginia and the SEA Division entitled the *Analysis of East Coast Inlet, Estuarine, and Climate Characteristics and Their Impact on the Exchange of Organisms through Inlets Study.* The impetus for this work stems from NOAA's Strategic Environmental Assessments Division's ongoing estuarine characterization efforts in support of improved management of the nation's estuarine resources and inter-estuarine research. Also, the analysis stems from previous success in its application to U.S. West Coast estuaries in identifying estuarine types based on geomorphology/hydrodynamics and species assemblages (Horn and Allen 1976; Monaco et al. 1991; Monaco et al. 1992).

Methods

Estuary Selection. Forty one NEI estuaries (Table 1) were selected to take advantage of previous analyses of their geomorphologic and hydrodynamic variables (chapter 1 and 2). The analyses reported here are a continuation of the previous analyses (chapters 1, 2 and 3).

Variable Selection. Previous evaluations of estuarine and inlet variables identified 21 important estuarine variables and 5 important inlet variables (chapter 1, 2 and 3). These important variables were combined to create a 26 variables by 41 estuaries/inlets matrix (Tables 2,3).

Table 1. East Coast NEI estuaries were included in analyses.

Buzzards Bay
Narragansett Bay
Gardiners Bay
Long Island Sound
Connecticut River
Great South Bay
Hudson River/Raritan Bay
Barnegat Bay
New Jersey Inland Bays
Delaware Bay
Delaware Inland Bays
Chincoteaque Bay
Chesapeake Bay
Patuxent River
Potomac River
Rappahannock River
York River
James River
Chester River
Choptank River
Tangier/Pocomoke Sound
Albemarle/Pamlico Sound
Pamlico & Pungo Rivers
Neuse River
Bogue Sound
New River
Cape Fear River
Winyah Bay
Charleston Harbor
North & South Santee Rivers
St. Helena Sound
Broad River
Savannah River
Ossabaw Sound
St. Catherines/Sapelo Sound
Altamaha River
St. Andrew/St. Simons Sound
St. Marys River
St. Johns River
Indian River
Biscayne Bay.

Table 2. Estuaries/inlets variables selected for analyses.

estuary length
estuary width
maximum width
minimum width
average depth
depth to width ratio
tidal fresh surface area
mixing zone surface area
seawater zone surface area
tidal prism volume
tidal fresh volume
mixing zone volume
seawater volume
daily flow rate
50 year flood
100 year flood
low flow period
high flow period
percent water mass fresh water
dissolved concentration potential
tidal flushing
cross sectional area at mouth
mouth width
mouth depth
flood current speed
ebb current speed

Statistical Protocol. Systat version 5.2.1 was used to carry out truncated PCA and Factor Score manipulations (Systat 1992). Systat's *Factor* module's *Principal component* procedure (with *correlation*, *varimax*, and *Num Factor* options invoked) was used to carry out the PCAs. Component number selection was based on the following: 1) component eigenvalues account for ≥75% of the variance in the matrix; and 2) individual component eigenvalues ≥1.0 and account for ≥7% of the variance in the matrix. Based on the above criteria, truncated PCAs were selected. The criterion for assigning variables to membership in the resulting components follows: variables were assigned membership in a component if the variable's rotated loadings were ≥0.5. Systat's *Principal component's save file* option (with *scores* option invoked) was used to retrieve the PCA's factor scores. The factor scores indicate an estuary's strength of association to the PCA components. These estuarine factor scores provide the basis for evaluating similarity/dissimilarity as follows. For a PCA with 5 components selected, each estuary had a set of 5 factor scores associated with it. This results in a 41 estuaries by 5 factor scores matrix.

These 41 by 5 matrices were subjected to cluster analysis as follows. Systat version 5.2.1 *Cluster* procedure (with the Join, Pearson, and Average Linkage options invoked) was used to carry out cluster analysis and produce dendrograms (Systat 1992). Dendrograms group estuaries with similar factor score patterns into clusters. The criteria for selecting the number of clusters to consider was based on the following. In order to maintain continuity with the PCA's identification of 5 components, The dendrogram's branching that provided 5 clusters was selected. The estuaries within the 5 clusters were assigned to estuarine groups according to their membership in a common cluster. This identifies estuaries with similar characteristics based on the original 26 by 41 variables/estuaries matrix.

Systat's *Correlation module's Pearson* procedure was used to carry out the cross component analysis (Claflin 1987). The factor scores of the components of the PCAs of the estuaries variables matrix, inlet variables matrix, and Estuaries and Inlet variables combined matrix were sorted by estuary and merged in to a single matrix. This matrix was subjected to correlation analysis. Correlation coefficients greater ≥0.5 identified component pairs that were highly similar.

Fowlkes and Mallows' (1983) Bk statistic (Tables 6,7.8) was used to determine similarity of estuarine dendrogram, inlet dendrogram, and estuaries and inlet dendrogram (Figures 2,3,4). Based on previous analyses (chapters 1, 2 and 3) the estuaries, inlet, and estuaries and inlet dendrograms were cut to produce a five cluster configuration for comparative purposes. These clusters were used to develop the comparison matrix on which the Bk statistic's components were based (Table 6,7,8). As per Fowlkes and Mallows (1983), if the Bk statistic is above the 95% confidence interval for Bk, then the dendrograms are similar at the five cluster cut. If the Bk statistic is below the 95% confidence interval for Bk, then the dendrograms are not similar at the five cluster cut.

Estuaries/Inlets PCA Results

PCA identified 5 components that account for 79.7% of the variance in the 26 by 41 estuaries/inlets matrix. Descriptions of the components follow. The PCA's rotated loadings are presented in Table 4. The PCA's factor scores are presented in Table 5. See Appendix 1 for SAS programming, log, and detailed output of PCA.

Component 1- System Magnitude and Mixing Function. This component accounted for 29.4% of the variance in the 26 by 41 estuaries/inlets matrix. The following parameters (rotated loading in parenthesis) dominated this component: mixing zone volume (0.932); mixing zone surface area (0.925); daily flow rate (0.896); tidal fresh volume (0.884); 50 year flood

Table 3. 26 variables by 41 estuaries/inlets matrix selected to perform PCA and cluster analysis on.

esty	lengt m	estwi m	minwi m	maxwi m	adept m	dpwr none	dyflr cms	fifyr cms	hunyr cms	hiflw none	lwflw none	tprsm m3	tfvol m3
buzz	48109.1	11102.1	1126.3	20273.4	10.3	0.00093	33.98	67.96	79.28	0.003	0.001	6.80E+08	0.00E+00
narr	47143.7	14641.9	804.5	20595.2	9.2	0.00063	90.61	968.41	1093	0.014	0.003	4.93E+08	4.07E+07
gard	49879	13998.3	1609	22043.3	6.2	0.00044	19.82	5.66	5.66	0.003	0.003	3.26E+08	0.00E+00
lisd	98149	50683.5	1126.3	36363.4	18.9	0.00037	849.48	6311.64	6628.78	0.018	0.004	3.74E+09	2.37E+08
conn	89299.5	482.7	321.8	1448.1	3.8	0.00789	594.64	3998.22	4136.97	1.937	0.459	2.58E+07	1.82E+08
grts	11263	42063.9	321.8	9010.4	2.7	0.00006	19.82	42.47	48.14	0.012	0.011	7.48E+07	0.00E+00
huds	257440	2735.3	160.9	18020.8	6.3	0.00232	756.04	5414.02	5759.47	0.077	0.021	7.36E+07	5.08E+08
barn	33789	17699	482.7	10619.4	1.4	0.00008	65.13	1002.3864	1206.2616	0.044	0.024	8.55E+07	0.00E+00
njby	24939.5	16090	50	6900	3	0.00019	31.14	25.23	30.015	0.012	0.006	7.97E+07	0.00E+00
deby	222042	24135	6757.8	45695.6	6.4	0.00026	560.66	7438.61	8302.25	0.013	0.005	2.89E+09	4.25E+08
dein	19308	2896.2	150	5500	1.3	0.00044	9.6	8.55	11.24	0.039	0.007	1.80E+07	0.00E+00
chnq	51488	7240.5	1609	10619.4	1.8	0.00025	11.33	3	4	0.015	0.011	4.67E+07	0.00E+00
ches	318582	24778.6	5148.8	55993.2	8.1	0.00033	2429.51	58721.72	75113.85	0.1	0.029	8.69E+08	1.01E+09
patx	75600	1609	30	2900	5.9	0.00366	26.56	360.72	437.34	0.055	0.023	3.00E+07	4.97E+06
poto	188253	10297.6	2574.4	17859.9	5.9	0.00057	450.22	9188.54	10748.75	0.095	0.027	3.40E+08	4.54E+07
rapp	158647.4	3700.7	643.6	5148.8	4.9	0.00133	82.12	1936.81	2129.36	0.048	0.017	1.17E+08	2.91E+07
york	78841	3378.9	643.6	6596.9	4.8	0.00141	70.79	2755.15	3681.08	0.046	0.016	1.06E+08	6.74E+07
jams	162187.2	5148.8	482.7	9654	4.2	0.00081	353.95	10216.41	11799.28	0.084	0.028	2.83E+08	2.80E+08
chst	61100	2300	160	7080	4.2	0.00183	14.75	114.68	156.02	0.032	0.013	3.31E+07	2.73E+07
chop	80500	6900	320	19800	4	0.00058	29.11	119.55	126.69	0.03	0.008	7.22E+07	2.51E+07
tang	91700	5800	10	25400	3.8	0.00066	83.31	50.43	59.46	0.017	0.006	3.77E+08	8.81E+06
alpm	186644	21077.9	1448.1	47626.4	4.1	0.0002	1302.54	6507.02	7506.57	0.318	0.187	8.21E+08	1.12E+09
paml	67578	5631.5	1448.1	9332.2	2.9	0.00051	130.25	1228.91	1362	0.117	0.053	6.54E+07	0.00E+00
neus	80450	6596.9	1448.1	12228.4	3.5	0.00053	175.56	1568.71	1795.23	0.198	0.064	6.85E+07	0.00E+00
boge	15285.5	17699	965.4	4022.5	1.4	0.00008	36.81	404.92	472.88	0.015	0.008	1.35E+08	1.58E+06
nwri	39903.2	2735.3	643.6	3378.9	1.8	0.00065	22.65	569.15	679.58	0.08	0.04	1.72E+07	0.00E+00
cpfr	83668	1126.3	482.7	3861.6	3.5	0.00311	285.99	4043.52	4779.74	0.224	0.072	1.00E+08	5.76E+07
winy	82059	1126.3	482.7	6918.7	3.4	0.00298	577.65	6640.1	7659.48	0.498	0.148	8.61E+07	1.05E+08
nssn	88816.8	1126.3	321.8	3218	2.5	0.00225	76.45	2619.23	2639.05	0.306	0.05	2.51E+07	2.37E+07
char	65647.2	3861.6	643.6	5792.4	5.6	0.00144	455.89	1160.96	1177.95	0.201	0.112	1.35E+08	1.01E+08
sthe	54706	6757.8	482.7	14641.9	3.9	0.00058	130.25	914.61	1005.22	0.024	0.01	3.94E+08	3.22E+07
brri	53257.9	6275.1	1126.3	10458.5	7.3	0.00117	25.48	314.31	359.61	0.004	0.001	5.41E+08	4.71E+07
sava	46339.2	2735.3	482.7	10458.5	4.6	0.00169	362.44	2069.9	2262.45	0.137	0.065	1.75E+08	2.20E+07
ossa	49074.5	1769.9	321.8	6757.8	4.4	0.00246	84.95	2055.74	2488.98	0.059	0.013	1.76E+08	1.03E+07
casa	39903.2	5148.8	321.8	56636.8	4.4	0.00086	22.65	368.11	453.06	0.004	0.001	4.16E+08	1.20E+07
alta	43443	2735.3	643.6	4666.1	3.1	0.00114	421.91	3446.06	3681.08	0.557	0.117	6.68E+07	1.36E+07
ansi	83668	8689	804.5	47626.4	4.4	0.0005	70.79	1543.22	1577.2	0.014	0.005	3.88E+08	8.13E+06
mycb	51500	480	60	2300	6	0.01251	231.37	525.21	572.1	0.164	0.119	7.00E+07	3.60E+06
john	197907	3700.7	1126.3	11584.8	3.7	0.00099	220.86	1090.17	1271.39	0.252	0.125	5.32E+07	9.87E+08
indn	4827	55027.8	160.9	9010.4	2	0.00004	39.64	167.06	192.55	0.044	0.013	6.46E+07	0.00E+00
bisc	15285.5	45052	965.4	17377.2	2.3	0.00005	90.61	600.3	668.26	0.021	0.007	3.00E+08	0.00E+00

Table 3. continued.

esty	mxvol m3	swvol m3	tfsur m2	mxsur m2	swsur m2	fwfrc %	dcptl mg/1	tpflush tidal cycles	iwidth m	iavdep m	icrsec m2	ifcurr m/s	iecurr m/s
buzz	2.20E+07	6.07E+09	0	51800	5853400	0.123	1.041	8.96	11713	14.4	169192.1	0.34	0.3
narr	2.67E+08	3.63E+09	77700	518000	3677800	0.1636	0.519	8.00	10900	18.1	197444.5	0.21	0.28
gard	6.32E+06	3.14E+09	0	51800	5050500	0.1222	1.773	9.65	19605	13.9	271643	0.36	0.5
lisd	4.35E+09	5.72E+10	284900	4221700	28153300	0.1595	0.054	16.54	22357	27.9	624314.6	1.66	1.57
conn	1.56E+07	0.00E+00	466200	51800	0	0.9624	0.466	7.66	1399	2.7	3777.3	0.46	0.36
grts	4.74E+08	5.82E+08	0	2020200	1890700	0.3423	4.967	14.13	1829	4.2	7700	1.28	1.24
huds	2.95E+09	1.43E+09	958300	4351200	2408700	0.5087	0.194	66.34	9135	8.4	76732.8	0.82	0.88
barn	1.40E+08	2.39E+08	0	777000	1864800	0.303	1.338	4.43	347	4	1389.9	1.13	1.29
njby	5.48E+07	2.22E+08	0	118192	1257913	0.2185	3.171	3.48	7949	4.9	38951.6	1.35	1.54
deby	2.83E+09	9.42E+09	595700	5180000	14115500	0.2602	0.134	4.39	18197	12.6	229276.7	0.72	0.67
dein	1.90E+07	8.62E+07	0	155400	673400	0.2099	6.273	5.84	152	4.5	685.8	0.93	1.1
chnq	0.00E+00	6.38E+08	0	0	3548300	0.1212	3.078	13.66	4942	3.4	16852.8	0.83	0.88
ches	5.67E+10	2.85E+09	2745400	68894000	2978500	0.5968	0.071	69.66	17730	7.8	137806.3	0.41	0.62
patx	7.11E+08	0.00E+00	36260	1181040	0	0.6165	6.959	23.87	1509	13.1	19767.9	0.21	0.21
poto	7.49E+09	0.00E+00	129500	12665100	0	0.6159	0.394	22.17	17775	9.1	161752.5	0.36	0.26
rapp	1.83E+09	0.00E+00	77700	3677800	0	0.6196	2.17	15.91	6096	5.5	33528	0.36	0.26
york	8.46E+08	0.00E+00	181300	1735300	0	0.6416	2.607	8.60	4541	7.9	35873.9	0.52	0.46
jams	2.27E+09	0.00E+00	828800	5283600	0	0.6553	0.533	9.02	3683	9.1	33515.3	0.77	0.77
chst	6.00E+08	0.00E+00	142450	1344210	0	0.7198	1.462	18.95	1196	5.8	6936.8	0.21	0.21
chop	1.12E+09	0.00E+00	77700	2776480	0	0.622	6.319	15.79	1322	6.2	8196.4	0.31	0.26
tang	4.53E+09	0.00E+00	93240	11802630	0	0.6145	2.153	12.03	4617	6.5	30010.5	0.57	0.57
alpm	2.64E+10	3.07E+08	5723900	60139800	1735300	0.6234	0.138	33.88	5122	2.6	13199.6	0.99	0.92
paml	1.23E+09	0.00E+00	0	4299400	0	0.6136	1.355	18.83	6309	4.5	28390.5	0.1	0.15
neus	1.57E+09	0.00E+00	0	4480700	0	0.6136	1.005	22.92	10058	4.4	44255.2	0.1	0.15
boge	4.64E+07	3.22E+08	25900	543900	2072000	0.1867	1.459	2.73	3386	5.4	18245.1	0.67	0.85
nwri	1.40E+08	6.95E+06	0	777000	51800	0.5903	7.496	8.51	1006	2	2007.4	0.51	1.13
cpfr	2.17E+08	6.92E+07	129500	699300	155400	0.5964	0.6	3.43	2114	1.6	3286.3	1.1	1.5
winy	1.56E+08	0.00E+00	233100	543900	0	0.7663	0.382	3.03	1975	5	9821.8	0.98	1
nssn	3.55E+07	0.00E+00	103600	129500	0	0.7679	2.889	2.36	1134	2.9	3281.8	0.77	0.89
char	4.33E+08	0.00E+00	155400	802900	0	0.6852	0.432	3.95	914	7.8	7135	0.93	0.93
sthe	4.69E+08	3.66E+08	77700	1061900	1061900	0.42	0.928	2.20	13730	4.7	65144.3	0.75	0.78
brri	1.09E+09	7.55E+08	103600	1450400	1036000	0.4268	4.818	3.50	4206	10.5	44163	0.93	0.93
sava	2.94E+08	8.01E+07	77700	595700	181300	0.5351	0.425	2.26	9400	5.9	55870	0.93	1.6
ossa	3.25E+08	3.72E+07	51800	725200	77700	0.5749	1.947	2.12	5395	4.8	25817	0.82	1.18
casa	7.79E+08	6.54E+07	51800	1787100	103600	0.5814	7.382	2.06	8733	6.8	59352	0.89	0.99
alta	7.64E+07	3.10E+07	103600	207200	77700	0.5299	0.361	1.81	3667	2.3	8493.9	0.57	0.62
ansi	7.46E+08	5.66E+07	25900	1761200	77700	0.5831	2.369	2.09	6309	7.5	47177	1.29	1.13
mycb	1.33E+07	3.94E+08	2072	51800	611240	0.175	0.217	5.86	1166	11.9	13873.7	1.13	1.4
john	7.95E+08	6.60E+08	3082100	2460500	1139600	0.6336	0.825	45.86	471	13.9	6530.9	0.97	1.19
indn	5.56E+07	1.40E+09	0	284900	6967100	0.14	1.016	22.57	386	4.7	1832.6	1.51	1.85
bisc	1.66E+07	1.62E+09	0	155400	6811700	0.1262	0.401	5.45	22935	2.3	52807.7	0.26	0.27

Table 3. 26 variables by 41 estuaries/inlets matrix selected to perform PCA and cluster analysis on.

esty	lengt m	estwi m	minwi m	maxwi m	adept m	dpwr none	dyflr cms	fifyr cms	hunyr cms	hiflw none	lwflw none	tprsm m3	tfvol m3
buzz	48109.1	11102.1	1126.3	20273.4	10.3	0.00093	33.98	67.96	79.28	0.003	0.001	6.80E+08	0.00E+00
narr	47143.7	14641.9	804.5	20595.2	9.2	0.00063	90.61	968.41	1093	0.014	0.003	4.93E+08	4.07E+07
gard	49879	13998.3	1609	22043.3	6.2	0.00044	19.82	5.66	5.66	0.003	0.003	3.26E+08	0.00E+00
lisd	98149	50683.5	1126.3	36363.4	18.9	0.00037	849.48	6311.64	6628.78	0.018	0.004	3.74E+09	2.37E+08
conn	89299.5	482.7	321.8	1448.1	3.8	0.00789	594.64	3998.22	4136.97	1.937	0.459	2.58E+07	1.82E+08
grts	11263	42063.9	321.8	9010.4	2.7	0.00006	19.82	42.47	48.14	0.012	0.011	7.48E+07	0.00E+00
huds	257440	2735.3	160.9	18020.8	6.3	0.00232	756.04	5414.02	5759.47	0.077	0.021	7.36E+07	5.08E+08
barn	33789	17699	482.7	10619.4	1.4	0.00008	65.13	1002.3864	1206.2616	0.044	0.024	8.55E+07	0.00E+00
njby	24939.5	16090	50	6900	3	0.00019	31.14	25.23	30.015	0.012	0.006	7.97E+07	0.00E+00
deby	222042	24135	6757.8	45695.6	6.4	0.00026	560.66	7438.61	8302.25	0.013	0.005	2.89E+09	4.25E+08
dein	19308	2896.2	150	5500	1.3	0.00044	9.6	8.55	11.24	0.039	0.007	1.80E+07	0.00E+00
chnq	51488	7240.5	1609	10619.4	1.8	0.00025	11.33	3	4	0.015	0.011	4.67E+07	0.00E+00
ches	318582	24778.6	5148.8	55993.2	8.1	0.00033	2429.51	58721.72	75113.85	0.1	0.029	8.69E+08	1.01E+09
patx	75600	1609	30	2900	5.9	0.00366	26.56	360.72	437.34	0.055	0.023	3.00E+07	4.97E+06
poto	188253	10297.6	2574.4	17859.9	5.9	0.00057	450.22	9188.54	10748.75	0.095	0.027	3.40E+08	4.54E+07
rapp	158647.4	3700.7	643.6	5148.8	4.9	0.00133	82.12	1936.81	2129.36	0.048	0.017	1.17E+08	2.91E+07
york	78841	3378.9	643.6	6596.9	4.8	0.00141	70.79	2755.15	3681.08	0.046	0.016	1.06E+08	6.74E+07
jams	162187.2	5148.8	482.7	9654	4.2	0.00081	353.95	10216.41	11799.28	0.084	0.028	2.83E+08	2.80E+08
chst	61100	2300	160	7080	4.2	0.00183	14.75	114.68	156.02	0.032	0.013	3.31E+07	2.73E+07
chop	80500	6900	320	19800	4	0.00058	29.11	119.55	126.69	0.03	0.008	7.22E+07	2.51E+07
tang	91700	5800	10	25400	3.8	0.00066	83.31	50.43	59.46	0.017	0.006	3.77E+08	8.81E+06
alpm	186644	21077.9	1448.1	47626.4	4.1	0.0002	1302.54	6507.02	7506.57	0.318	0.187	8.21E+08	1.12E+09
paml	67578	5631.5	1448.1	9332.2	2.9	0.00051	130.25	1228.91	1362	0.117	0.053	6.54E+07	0.00E+00
neus	80450	6596.9	1448.1	12228.4	3.5	0.00053	175.56	1568.71	1795.23	0.198	0.064	6.85E+07	0.00E+00
boge	15285.5	17699	965.4	4022.5	1.4	0.00008	36.81	404.92	472.88	0.015	0.008	1.35E+08	1.58E+06
nwri	39903.2	2735.3	643.6	3378.9	1.8	0.00065	22.65	569.15	679.58	0.08	0.04	1.72E+07	0.00E+00
cpfr	83668	1126.3	482.7	3861.6	3.5	0.00311	285.99	4043.52	4779.74	0.224	0.072	1.00E+08	5.76E+07
winy	82059	1126.3	482.7	6918.7	3.4	0.00298	577.65	6640.1	7659.48	0.498	0.148	8.61E+07	1.05E+08
nssn	88816.8	1126.3	321.8	3218	2.5	0.00225	76.45	2619.23	2639.05	0.306	0.05	2.51E+07	2.37E+07
char	65647.2	3861.6	643.6	5792.4	5.6	0.00144	455.89	1160.96	1177.95	0.201	0.112	1.35E+08	1.01E+08
sthe	54706	6757.8	482.7	14641.9	3.9	0.00058	130.25	914.61	1005.22	0.024	0.01	3.94E+08	3.22E+07
brri	53257.9	6275.1	1126.3	10458.5	7.3	0.00117	25.48	314.31	359.61	0.004	0.001	5.41E+08	4.71E+07
sava	46339.2	2735.3	482.7	10458.5	4.6	0.00169	362.44	2069.9	2262.45	0.137	0.065	1.75E+08	2.20E+07
ossa	49074.5	1769.9	321.8	6757.8	4.4	0.00246	84.95	2055.74	2488.98	0.059	0.013	1.76E+08	1.03E+07
casa	39903.2	5148.8	321.8	56636.8	4.4	0.00086	22.65	368.11	453.06	0.004	0.001	4.16E+08	1.20E+07
alta	43443	2735.3	643.6	4666.1	3.1	0.00114	421.91	3446.06	3681.08	0.557	0.117	6.68E+07	1.36E+07
ansi	83668	8689	804.5	47626.4	4.4	0.0005	70.79	1543.22	1577.2	0.014	0.005	3.88E+08	8.13E+06
mycb	51500	480	60	2300	6	0.01251	231.37	525.21	572.1	0.164	0.119	7.00E+07	3.60E+06
john	197907	3700.7	1126.3	11584.8	3.7	0.00099	220.86	1090.17	1271.39	0.252	0.125	5.32E+07	9.87E+08
indn	4827	55027.8	160.9	9010.4	2	0.00004	39.64	167.06	192.55	0.044	0.013	6.46E+07	0.00E+00
bisc	15285.5	45052	965.4	17377.2	2.3	0.00005	90.61	600.3	668.26	0.021	0.007	3.00E+08	0.00E+00

Table 3. continued.

esty	mxvol m3	swvol m3	tfsur m2	mxsur m2	swsur m2	fwfrc %	dcpt1 mg/1	tpflush tidal cycles	iwidth m	iavdep m	icrsec m2	ifcurr m/s	iecurr m/s
buzz	2.20E+07	6.07E+09	0	51800	5853400	0.123	1.041	8.96	11713	14.4	169192.1	0.34	0.3
narr	2.67E+08	3.63E+09	77700	518000	3677800	0.1636	0.519	8.00	10900	18.1	197444.5	0.21	0.28
gard	6.32E+06	3.14E+09	0	51800	5050500	0.1222	1.773	9.65	19605	13.9	271643	0.36	0.5
lisd	4.35E+09	5.72E+10	284900	4221700	28153300	0.1595	0.054	16.54	22357	27.9	624314.6	1.66	1.57
conn	1.56E+07	0.00E+00	466200	51800	0	0.9624	0.466	7.66	1399	2.7	3777.3	0.46	0.36
grts	4.74E+08	5.82E+08	0	2020200	1890700	0.3423	4.967	14.13	1829	4.2	7700	1.28	1.24
huds	2.95E+09	1.43E+09	958300	4351200	2408700	0.5087	0.194	66.34	9135	8.4	76732.8	0.82	0.88
barn	1.40E+08	2.39E+08	0	777000	1864800	0.303	1.338	4.43	347	4	1389.9	1.13	1.29
njby	5.48E+07	2.22E+08	0	118192	1257913	0.2185	3.171	3.48	7949	4.9	38951.6	1.35	1.54
deby	2.83E+09	9.42E+09	595700	5180000	14115500	0.2602	0.134	4.39	18197	12.6	229276.7	0.72	0.67
dein	1.90E+07	8.62E+07	0	155400	673400	0.2099	6.273	5.84	152	4.5	685.8	0.93	1.1
chnq	0.00E+00	6.38E+08	0	0	3548300	0.1212	3.078	13.66	4942	3.4	16852.8	0.83	0.88
ches	5.67E+10	2.85E+09	2745400	68894000	2978500	0.5968	0.071	69.66	17730	7.8	137806.3	0.41	0.62
patx	7.11E+08	0.00E+00	36260	1181040	0	0.6165	6.959	23.87	1509	13.1	19767.9	0.21	0.21
poto	7.49E+09	0.00E+00	129500	12665100	0	0.6159	0.394	22.17	17775	9.1	161752.5	0.36	0.26
rapp	1.83E+09	0.00E+00	77700	3677800	0	0.6196	2.17	15.91	6096	5.5	33528	0.36	0.26
york	8.46E+08	0.00E+00	181300	1735300	0	0.6416	2.607	8.60	4541	7.9	35873.9	0.52	0.46
jams	2.27E+09	0.00E+00	828800	5283600	0	0.6553	0.533	9.02	3683	9.1	33515.3	0.77	0.77
chst	6.00E+08	0.00E+00	142450	1344210	0	0.7198	1.462	18.95	1196	5.8	6936.8	0.21	0.21
chop	1.12E+09	0.00E+00	77700	2776480	0	0.622	6.319	15.79	1322	6.2	8196.4	0.31	0.26
tang	4.53E+09	0.00E+00	93240	11802630	0	0.6145	2.153	12.03	4617	6.5	30010.5	0.57	0.57
alpm	2.64E+10	3.07E+08	5723900	60139800	1735300	0.6234	0.138	33.88	5122	2.6	13199.6	0.99	0.92
pam1	1.23E+09	0.00E+00	0	4299400	0	0.6136	1.355	18.83	6309	4.5	28390.5	0.1	0.15
neus	1.57E+09	0.00E+00	0	4480700	0	0.6136	1.005	22.92	10058	4.4	44255.2	0.1	0.15
boge	4.64E+07	3.22E+08	25900	543900	2072000	0.1867	1.459	2.73	3386	5.4	18245.1	0.67	0.85
nwri	1.40E+08	6.95E+06	0	777000	51800	0.5903	7.496	8.51	1006	2	2007.4	0.51	1.13
cpfr	2.17E+08	6.92E+07	129500	699300	155400	0.5964	0.6	3.43	2114	1.6	3286.3	1.1	1.5
winy	1.56E+08	0.00E+00	233100	543900	0	0.7663	0.382	3.03	1975	5	9821.8	0.98	1
nssn	3.55E+07	0.00E+00	103600	129500	0	0.7679	2.889	2.36	1134	2.9	3281.8	0.77	0.89
char	4.33E+08	0.00E+00	155400	802900	0	0.6852	0.432	3.95	914	7.8	7135	0.93	0.93
sthe	4.69E+08	3.66E+08	77700	1061900	1061900	0.42	0.928	2.20	13730	4.7	65144.3	0.75	0.78
brri	1.09E+09	7.55E+08	103600	1450400	1036000	0.4268	4.818	3.50	4206	10.5	44163	0.93	0.93
sava	2.94E+08	8.01E+07	77700	595700	181300	0.5351	0.425	2.26	9400	5.9	55870	0.93	1.6
ossa	3.25E+08	3.72E+07	51800	725200	77700	0.5749	1.947	2.12	5395	4.8	25817	0.82	1.18
casa	7.79E+08	6.54E+07	51800	1787100	103600	0.5814	7.382	2.06	8733	6.8	59352	0.89	0.99
alta	7.64E+07	3.10E+07	103600	207200	77700	0.5299	0.361	1.81	3667	2.3	8493.9	0.57	0.62
ansi	7.46E+08	5.66E+07	25900	1761200	77700	0.5831	2.369	2.09	6309	7.5	47177	1.29	1.13
mycb	1.33E+07	3.94E+08	2072	51800	611240	0.175	0.217	5.86	1166	11.9	13873.7	1.13	1.4
john	7.95E+08	6.60E+08	3082100	2460500	1139600	0.6336	0.825	45.86	471	13.9	6530.9	0.97	1.19
indn	5.56E+07	1.40E+09	0	284900	6967100	0.14	1.016	22.57	386	4.7	1832.6	1.51	1.85
bisc	1.66E+07	1.62E+09	0	155400	6811700	0.1262	0.401	5.45	22935	2.3	52807.7	0.26	0.27

(0.848); 100 year flood (0.845); length (0.830); tidal fresh surface area (0.806); tidal prism flushing (0.773); maximum estuary width (0.583); and minimum estuary width (0.553). Estuaries with factor scores ≥1.0: Chesapeake Bay; Albemarle/Pamilico Sound; St Johns River; and Hudson River.

Component 2- Seawater Function. This component accounted for 22.4% of the variance in the estuaries/inlets matrix. Parameters that dominated this component: inlet cross sectional area (0.940); average estuarine depth (0.923); inlet average depth (0.905); seawater volume (0.900); seawater surface area (0.856); tidal prism volume (0.849); and inlet width (0.588). Estuaries with factor scores ≥1.0: Long Island Sound; Delaware Bay; Buzzards Bay; and Narragansett Bay.

Component 3- Freshwater Inflow Function. This component accounted for 11.4% of the variance in the estuaries/inlets matrix. Parameters that dominated this component: low flow period (0.933); and high flow period (0.919). Estuaries with factor scores ≥1.0: Connecticut River; St Marys River; Winyah Bay; and Altamaha River.

Component 4- Inlet Current Speed Function. This component accounted for 9.4% of the variance in the estuaries/inlets matrix. Parameters that dominated this component: inlet flood current speed (0.940); and inlet excursion current speed (0.930). Estuaries with factor scores ≥1.0: Indian River; Long Island Sound; Albemarle/Pamilico Sound; Great South Bay; New Jersey Inland Bays; Barnegat Bay; St Johns River; and St Marys River.

Component 5- Width Function. This component accounted for 7.3% of the variance in the estuaries/inlets matrix. Parameters that dominated this component: estuary width (0.593); and inlet width (0.524). Estuaries with factor scores ≥1.0: Biscayne Bay; Delaware Bay; Chesapeake Bay; and Indian River.

Estuaries/Inlets Dendrogram Results

Dendrogram (Figure 1) of estuaries/inlets factor scores (Table 5) identified the following estuarine groups based on similarities. Descriptions of the groups follow. The dendrogram groups (branches) are presented below in order of strength of their association versus the other branches. In other words, the first cluster links (+) to the left of the cut identify the dendrogram groups and their strength of association. Therefore,

Table 4. PCA's rotated loadings for 5 components. Rotated loadings ≥0.5 or ≤-0.5 (bold) indicate variables that are highly associated with the component.

Variable	Component 1	Component 2	Component 3	Component 4	Component 5
LENGT	**0.830**	0.200	0.098	-0.206	-0.146
ESTWI	0.106	0.351	-0.273	0.397	**0.593**
MINWI	**0.553**	0.267	-0.117	-0.274	0.459
MAXWI	**0.583**	0.359	-0.292	0.005	0.170
ADEPT	0.174	**0.923**	0.023	-0.065	-0.067
DPWR	-0.136	-0.004	0.699	0.021	-0.243
DYFLR	**0.896**	0.185	0.246	0.033	0.198
FIFYR	**0.848**	0.047	0.022	-0.131	0.260
HUNYR	**0.845**	0.031	0.006	-0.133	0.259
HIFLW	0.035	-0.137	**0.919**	-0.059	0.050
LWFLW	0.132	-0.156	**0.933**	0.047	-0.035
TPRSM	0.209	**0.849**	-0.063	0.121	0.263
TFVOL	**0.884**	0.117	0.129	0.162	-0.128
MXVOL	**0.932**	-0.003	-0.053	-0.050	0.188
SWVOL	0.012	**0.900**	0.003	0.236	0.119
TFSUR	**0.806**	-0.020	0.124	0.213	-0.156
MXSUR	**0.925**	-0.045	-0.033	0.005	0.123
SWSUR	0.025	**0.856**	-0.094	0.242	0.353
FWFRC	0.277	-0.325	0.451	-0.266	-0.434
DCPTL	-0.262	-0.242	-0.440	0.000	-0.397
TPFLUSH	**0.773**	0.075	-0.072	-0.066	-0.214
IWIDTH	0.211	**0.588**	-0.216	-0.311	**0.524**
IAVDEP	0.023	**0.905**	-0.102	-0.037	-0.190
ICRSEC	0.073	**0.940**	-0.106	-0.039	0.218
IFCURR	-0.033	0.156	0.006	**0.940**	0.018
IECURR	-0.048	0.023	-0.019	**0.930**	0.025

Table 5. PCA's factor scores for 5 estuaries/inlets components. Estuaries with higher factor scores have strongest associations with components. Factor scores ≥1.0 indicate estuaries representing the component.

esty	comp1	esty	comp2	esty	comp3	esty	comp4	esty	comp5
ches	4.875	lisd	5.185	conn	4.932	indn	2.542	bisc	2.805
alpm	2.84	deby	1.632	mycb	1.673	lisd	1.778	deby	1.881
john	1.168	buzz	1.202	winy	1.43	alpm	1.555	ches	1.583
huds	1.102	narr	1.167	alta	1.058	grts	1.481	indn	1.451
deby	0.549	gard	0.915	char	0.733	njby	1.389	boge	0.97
poto	0.462	huds	0.456	cpfr	0.709	barn	1.14	alta	0.802
jams	0.413	mycb	0.35	alpm	0.516	john	1.022	gard	0.725
tang	-0.037	poto	0.297	nssn	0.425	mycb	1	barn	0.671
winy	-0.057	patx	0.267	john	0.391	cpfr	0.918	sthe	0.612
ansi	-0.071	brri	0.242	sava	0.385	dein	0.711	chnq	0.599
rapp	-0.085	john	0.199	lisd	0.234	sava	0.647	conn	0.573
lisd	-0.123	casa	-0.059	neus	0.108	ansi	0.646	grts	0.523
casa	-0.152	ansi	-0.101	jams	0.057	winy	0.326	poto	0.515
neus	-0.162	york	-0.121	ossa	0.018	ossa	0.268	njby	0.479
chop	-0.166	rapp	-0.122	paml	-0.031	char	0.262	neus	0.367
cpfr	-0.191	jams	-0.133	huds	-0.07	boge	0.24	sava	0.298
char	-0.197	char	-0.162	chst	-0.087	chnq	0.238	lisd	0.266
york	-0.221	sthe	-0.176	poto	-0.109	brri	0.172	paml	0.21
paml	-0.226	tang	-0.222	rapp	-0.183	casa	0.157	cpfr	0.092
chst	-0.283	sava	-0.225	york	-0.184	nwri	0.115	winy	0.08
patx	-0.288	ches	-0.246	sthe	-0.252	huds	0.046	buzz	0.061
conn	-0.298	chst	-0.258	deby	-0.28	nssn	0.027	narr	-0.051
nssn	-0.298	conn	-0.277	barn	-0.353	jams	-0.081	ossa	-0.214
sava	-0.314	chop	-0.291	patx	-0.398	sthe	-0.233	ansi	-0.228
brri	-0.351	neus	-0.309	buzz	-0.402	alta	-0.349	char	-0.334
nwri	-0.36	bisc	-0.319	narr	-0.403	tang	-0.408	dein	-0.364
ossa	-0.387	ossa	-0.327	boge	-0.477	deby	-0.651	nssn	-0.429
alta	-0.393	paml	-0.421	tang	-0.485	conn	-0.678	alpm	-0.461
grts	-0.394	winy	-0.433	ches	-0.496	york	-0.689	tang	-0.527
sthe	-0.418	njby	-0.515	bisc	-0.506	bisc	-0.764	jams	-0.579
chnq	-0.42	alpm	-0.539	indn	-0.56	ches	-0.807	rapp	-0.629
barn	-0.424	chnq	-0.567	brri	-0.59	chop	-0.86	york	-0.632
indn	-0.424	nssn	-0.591	ansi	-0.598	buzz	-1.055	mycb	-0.67
dein	-0.509	cpfr	-0.603	nwri	-0.607	chst	-1.07	nwri	-0.672
njby	-0.525	alta	-0.615	gard	-0.612	gard	-1.089	brri	-0.805
narr	-0.532	boge	-0.628	njby	-0.626	rapp	-1.108	chst	-0.826
gard	-0.592	indn	-0.67	chnq	-0.689	patx	-1.137	casa	-0.831
buzz	-0.595	grts	-0.697	chop	-0.829	narr	-1.19	chop	-1.16
boge	-0.595	dein	-0.738	grts	-0.855	paml	-1.387	huds	-1.727
mycb	-0.622	barn	-0.754	dein	-0.863	neus	-1.499	patx	-2.088
bisc	-0.702	nwri	-0.795	casa	-1.123	poto	-1.627	john	-2.339

the strongest dendrogram group is presented as Dendrogram Group 1 and the second strongest is presented as Dendrogram Group 2 and so on.

Dendrogram Group 1. This group contains: Long Island Sound; Broad River; and St. Catherines/Sapelo Sound. This group of estuaries did not clearly align with the PCA's Components based on review of factor scores.

Dendrogram Group 2. This group contains: Bogue River; Chincoteaque Bay; Barnegat Bay; Indian River; New Jersey Inland Bays; Great South Bay; St. Andrews/Simmons Sound; Delaware Inland Bays; and New River. This group of estuaries most closely matches the characteristics identified by PCA Component 4 (Inlet Current Speed Function). Overlap of the component's estuaries with factor scores ≥1.0 and the estuaries presence in the dendrogram group is 57%.

Dendrogram Group 3. This group contains: Altamaha River; Connecticut River; St. Marys River; Charleston Harbor; North and South Santee Rivers; Winyah Bay; Cape Fear River; Ossabaw Sound; and Savannah Sound. This group of estuaries most closely matches the characteristics identified by PCA Component 3 (Freshwater Inflow Function). Overlap of the component's estuaries with factor scores ≥1.0 and the estuaries presence in the dendrogram group is 100%.

Dendrogram Group 4. This group contains: Narragansett Bay; Buzzards Bay; Gardiners Bay; Delaware Bay; Potomac Bay; Neuse River; Pamilico/Pungo Rivers; Biscayne Bay; andSt. Helena Sound. This group of estuaries most closely matches the characteristics identified by PCA Component 2- (Seawater Function). Overlap of the component's estuaries with factor scores ≥1.0 and the estuaries presence in the dendrogram group is 75%.

Dendrogram Group 5. This group contains: Chesapeake Bay; Albemarle/Pamlico Sound; St. Johns River; Hudson River/Raritan Bay; James River; Choptank River; Tangier/Pocomoke Sound; Patuxent River; York River; Chester River; and Rappahannock River. This group of estuaries most closely matches the characteristics of identified by PCA Component 1- (System Magnitude Function). Overlap of the component's estuaries with factor scores ≥1.0 and the estuaries presence in the dendrogram group is 100%.

Bk Statistic Comparisons

Statistical comparisons of the estuaries/inlets dendrogram (above), estuaries dendrogram (chapter a), and inlets dendrogram (chapter 2) against each other were carried out by Fowlkes and Mallows (1983) Bk statistic. The Bk statistic determines if two dendrograms are statistically similar. Since the three dendrograms contain the same 41 estuaries/inlet members and have been cut into five clusters, the Bk statistic can be applied to all combinations of the dendrograms.

The dendrogram comparisons of interest here were the estuaries/inlets dendrogram vs. estuaries dendrogram, and estuaries/inlets dendrogram vs. inlet dendrogram. The estuaries/inlets dendrogram was based on variables that were common to the estuaries dendrogram (i.e., 21 estuarine variables (chapter 1) and inlet dendrogram (i.e., 5 inlet variables (chapter 2)). If these estuaries/inlets variables were intrinsically aligned based on estuarine/inlet dynamics, then these variables should produce an estuarine/inlets dendrogram that is statistically similar to the previous estuaries dendrogram (chapter 1) and inlet dendrogram (chapter 2). This estuarine/inlet alignment has been previously established (chapter 3) and this series of dendrogram comparisons was to further evaluate the alignment.

The Bk statistic's comparison of the estuaries/inlets dendrogram versus estuaries dendrogram (Table 6) indicates that these dendrograms were statistically similar at a significance level of 0.05. Given the two dendrograms share 21 common variables, this was no surprise. These results indicate that adding the 5 inlet variables to the estuaries/inlets dendrogram's matrix did not disrupt the underlying alignments found in the estuaries dendrogram.

The Bk statistic's comparison of the estuaries/inlets dendrogram versus inlet dendrogram (Table 7) indicates that these dendrograms were statistically similar at a significance level of 0.05. Given the two dendrograms share only 5 common variables, this reinforces the indication of an estuarine/inlet alignment. These results indicate that adding the 21 estuarine variables to the estuaries/inlets dendrogram's matrix did not disrupt the underlying alignments found in the inlet dendrogram.

Previous Bk statistic analysis (chapter 3) of the inlet dendrogram vs. estuaries dendrogram (Figure 4, Table 8) indicates that these two dendrograms were statistically similar at a significance level of 0.05. This verifies there are strong linkages between estuaries and their inlets. This is especially impressive given that these two dendrograms were based on matrices which contained no common variables. The estuaries dendrogram was based strictly on non-inlet (estuarine) variables while the inlet dendrogram was based strictly on non-estuarine (inlet) variables (chapters 1 and 2).

Cross Component Results

Claflin's (1987) cross component analysis uses correlation analysis of PCA component factor scores to reveal similarities between the components of different PCAs. So long as the PCAs have common members, their components factor scores can be merged into a single matrix and that matrix subjected to correlation analysis. The component combinations (between the two PCAs) with the higher correlation coefficients indicate similarity between the components. Therefore, this analysis identifies components that are similar to components of a different PCA. The primary purpose of using cross component analysis here is to identify correlations between: 1) estuaries/inlets variables (Table 3) based components (Table 11) and inlet variables based components (Tables 9, 10, 11 (Lowery 1994b)) (Tables 12 and 13); 2) estuaries/inlets variables based components and estuaries variables based components (Table 11 (chapter 1)) (Tables 12 and 13); and 3) estuaries variables based components and inlet variables based components (Tables 12 and 13). These correlated components provide an opportunity to identify alignments of inlet and estuarine variables. Hence, these cross component analyses were to reveal underlying relationships between the inlet and estuarine variables that were linked. Since the inlet variables PCA had not been included in any previous report it is presented in Appendix 2, same methods as previously employed with the exception that 3 components were selected based on the component number selection criteria (see above methods section).

Based on the inlet PCA, three components occur (Table 10, Appendix 2): 1) Cross Sectional Area-Depth Function correlated with inlet average depth (0.972), and inlet cross section (0.742 rotated loading), accounting for 31% of the variance in the data set; 2) Inlet Current

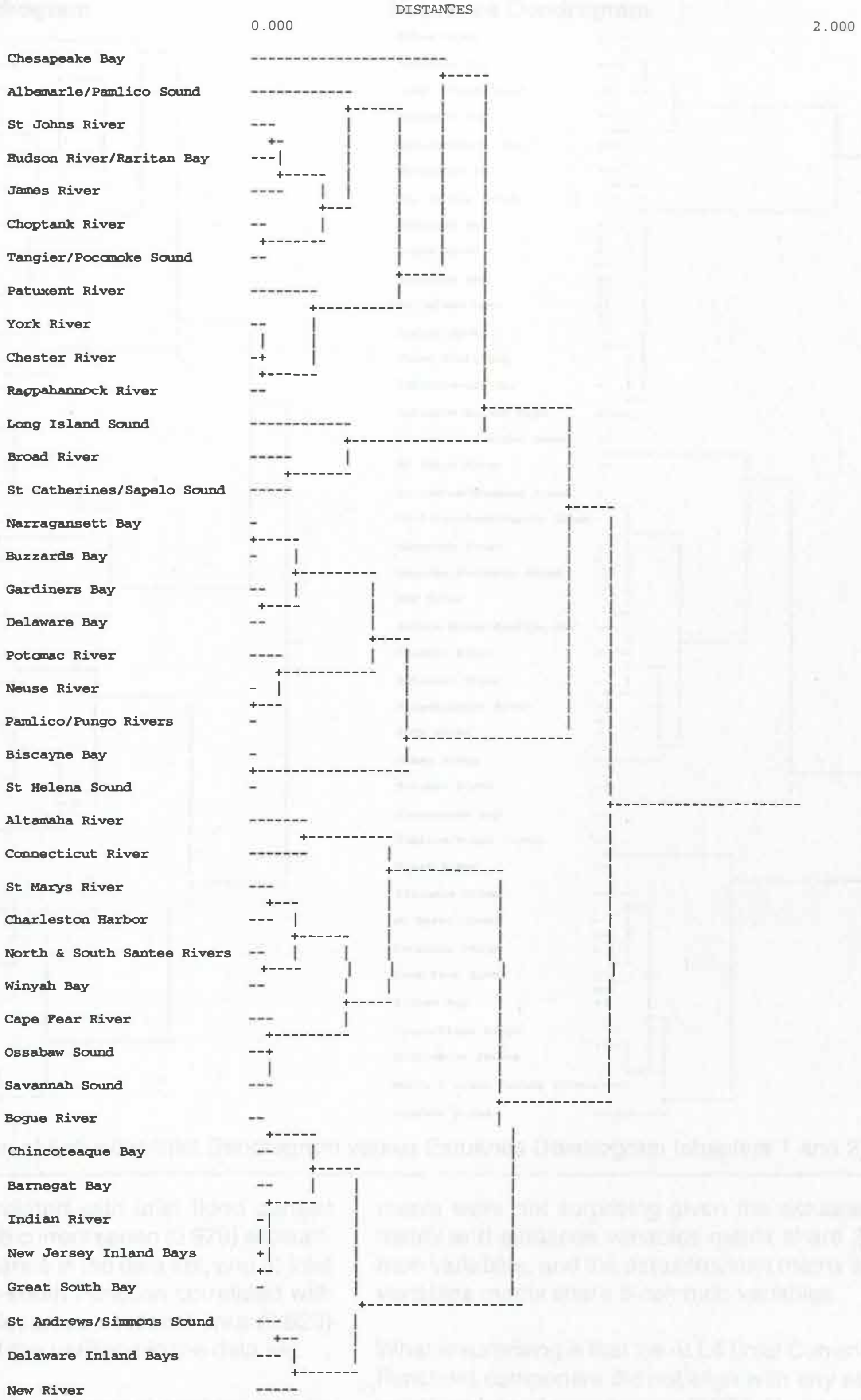

Figure 1. Dendrogram of clustered factor scores. Distance of cluster linkages (indicated by (+)) indicates strength of association between the estuaries or groups of estuaries linked together. Shorter distances indicate stronger associations among the members of the cluster (branch). Based on the PCA's identification of 5 significant components, the dendrogram's branching was cut at a distance of 0.75 to produce 5 dendrogram clusters that are comparable to the PCA components.

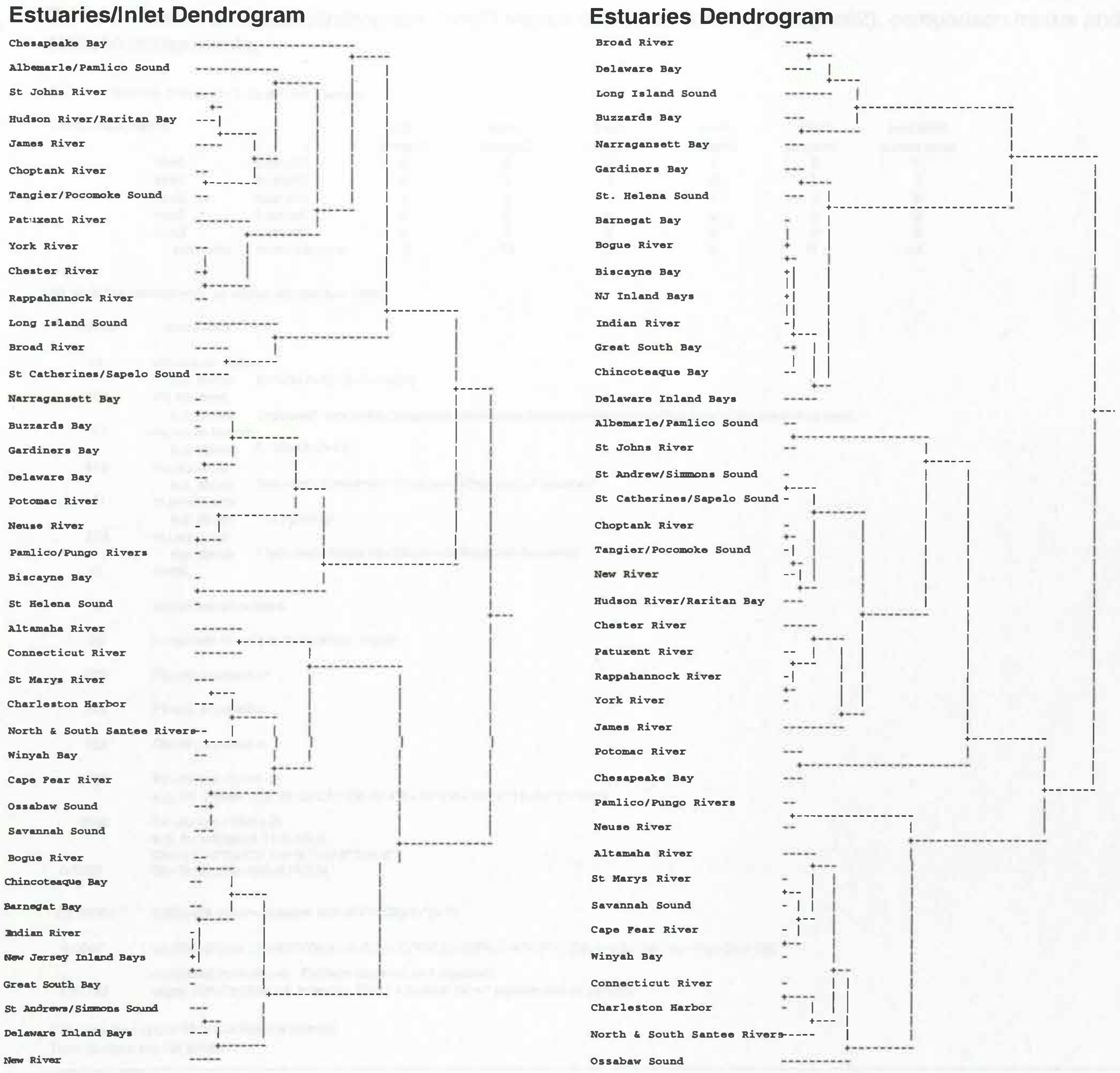

Figure 2. Comparision of Estuaries/Inlet Dendrogram versus Estuaries Dendrogram (chapters 1 and 2).

Speed Function correlated with inlet flood current speed (0.976), inlet ebb current speed (0.979) accounting for 39% of the variance in the data set; and 3) Inlet Cross Sectional Area-Width Function correlated with inlet width (0.947), inlet cross sectional area (0.629) accounting for 27% of the variance in the data set.

The results of the cross component analysis reveals that there was a high degree of similarity between the estuaries/inlets variables PCA's components (ALL1,2,3,5) and the estuaries variables PCA's components (EST1-5). Likewise, estuaries/inlets variable based components (ALL 2,4,5) aligned with the inlet variables based components (INLET1-3). These alignments were not surprising given the estuaries/inlets matrix and estuaries variables matrix share 21 common variables, and the estuaries/inlet matrix and inlet variables matrix share 5 common variables.

What is surprising is that the ALL4 (Inlet Current Speed Function) component did not align with any estuaries variables based components (EST1-5). Its only alignment was with the INLET2 (Inlet Current Speed Function) component. This indicates that the Inlet Current Speed Function was not aligning with any of the other components. This finding suggests: 1) the Inlet variables matrix data and/or the Estuaries variables matrix data were inadequate for the task of identifying

Table 6. Estuaries/inlets dendrogram (tree1) versus estuaries dendrogram (tree2), comparison matrix and Bk statistic components.

Estuaries/Inlet vs. Estuaries- 5 cluster comparison

Comparison matrix

		tree1 branch1	tree1 branch2	tree1 branch3	tree1 branch4	tree1 branch5	sum cells across rows
tree2	branch1	0	0	10	1	0	11
tree2	branch2	2	0	1	0	0	3
tree2	branch3	3	3	0	1	2	9
tree2	branch4	0	0	0	0	9	9
tree2	branch5	0	7	2	0	0	9
sum cells	down columns	5	10	13	2	11	41

Bk statistics components for above comparison matrix

values	component
41	mij=matrix cells e.g. above 2+3+3+7+10+2+1+1+2+9
263	mij squared e.g. above 1squared+1squared+3squared+8squared+7squared+6squared+2squared+7squared+4squared
41	mi.=sum bottom e.g. above 5+10+13+2+11
419	mi. squared e.g. above 5squared+10squared+13squared+2squared+11squared
41	m.j=sum side e.g. above 11+3+9+9+9
373	m.j squared e.g. above 11squared+3squared+9squared+9squared+9squared
41	n=mij
5	k=number of clusters
25	c=number of cells in comparison matrix
222	Tk=mij squared - n
378	Pk=mi. squared-n
332	Qk=m.j squared-n
3486	Pk'=mi.(mi.-1)(mi.-2) e.g. mi. values of 5,10,13,2,11 Pk'=5*4*3+10*9*8+13*12*11+0+*11*10*9
2508	Qk'=m.j(m.j-1)(m.j-2) e.g. for values of 11,3,9,9,9 Qk'=11*10*9+3*2*1+9*8*7+9*8*7+9*8*7
0.6267	Bk=Tk/square root of Pk*Qk
0.216009	E(Bk)=Bk mean= (square root of Pk*Qk)/(n*(n-1)
0.0007	var(Bk)=2/[n(n-1)]+[4(Pk'Qk')/n(n-1)*(n-2)*PkQk]+[{(Pk-2-4Pk'/Pk)*(Qk-2-4Qk'/Qk)/n(n-1)(n-2)(n-3)}] continued from above: -PkQk/[n squared (n-1)squared]
0.26193	upper 95%Confidence Interval= E(Bk) + t-value for n * square root of var(Bk)

If Bk less than upper 95% Confidence interval
Then clusters are not similar

estuarine vs. inlet relationships concerning current speed; and or 2) no clear relationships exist between estuaries and their inlets current speeds. The authors feel that the data was inadequate and that there are definable estuarine to inlet current speed relationships. Additional effort will be required to delineate these relationships based on improved data sets.

Concerning the overall relationship of estuaries to their inlets in terms of their geomorphology, one pairing of components occurs between the estuaries variables based components (EST1-5) and the inlet variables based components (INLET1-3). This pairing aligns the EST2 (Seawater Function) component with the INLET1 (Cross Sectional Area-Depth Function) component. The Seawater Function's dominant variables were: seawater volume; tidal prism; seawater surface area; and average depth of estuary. The Cross Sectional Area-Depth Function's dominant variables were: average depth of inlet; and cross sectional area of inlet. The Cross Sectional Area-Depth Function indicates that the cross sectional area generally increases with increasing inlet depth. Since the Seawater Function has average estuarine depth as one of its dominant variables, it makes sense that deeper estuaries have deeper inlets, and that inlet depth accounts for a large

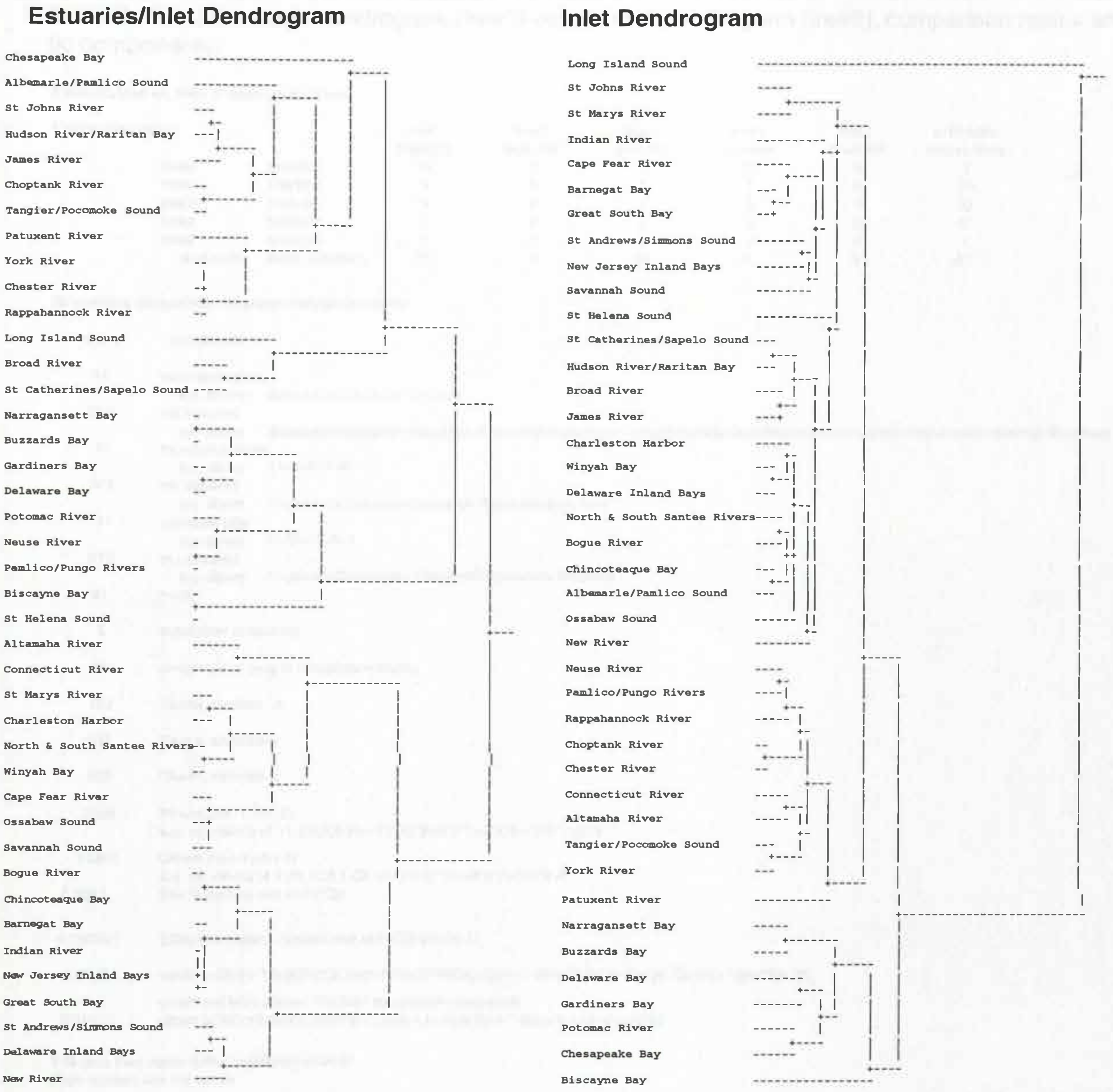

Figure 3. Comparision of Estuaries/Inlet Dendrogram versus Inlet Dendrogram (chapters 1 and 2).

portion of the inlets cross sectional area. This estuarine depth to inlet depth relationship was also seen in the estuaries/inlets PCA's Seawater Function (Table 4). The estuaries/inlets Seawater Function's dominant variables are: 1) inlet cross sectional area (rotated loading .940); 2) average estuarine depth (.923); 3) inlet average depth (.905); 4) seawater volume (.900); 5) seawater surface area (.856); 6) tidal prism volume (.849); and 7) inlet width (.588). Here the top three variables driving the component were average estuarine depth, average inlet depth, and inlet cross sectional area. Clearly, this estuarine depth to inlet depth/cross sectional area linkage is the most important geomorphological relationship based on our analyses of the available data.

Summary

Bk statistical analysis of the inlet and estuarine dendrograms indicates that estuarine/inlet linkages exist for the 41 estuary/inlets evaluated. Cross component analysis identified cross component pairing of estuaries Seawater Function and the inlets' Cross Sectional Area-Depth Function. These findings establish geomorphic linkage of estuaries and inlets via their estuarine depth with inlet depth and inlet cross sectional area intra-relationships. Based on these intra-relationships, estuarine depth is positively correlated to inlet depth and inlet cross sectional area (i.e., deeper estu-

Table 7. Estuaries/inlets dendrogram (tree1) versus inlet dendrogram (tree2), comparison matrix and Bk statistic components.

Estuaries/Inlet vs. Inlet- 5 cluster comparison

Comparison matrix		tree1 branch1	tree1 branch2	tree1 branch3	tree1 branch4	tree1 branch5	sum cells across rows
tree2	branch1	0	1	0	0	0	1
tree2	branch2	4	2	1	7	9	23
tree2	branch3	6	0	2	2	0	10
tree2	branch4	1	0	5	0	0	6
tree2	branch5	0	0	1	0	0	1
sum cells	down columns	11	3	9	9	9	41

Bk statistics components for above comparison matrix

values	component	
41	mij=matrix cells	
	e.g. above	4+6+1+1+2+1+2+5+1+7+2+9
223	mij squared	
	e.g. above	4squared+6squared+1squared+1squared+2squared+1squared+2squared+5squared+1squared+7squared+2squared+9squared
41	mi.=sum bottom	
	e.g. above	11+3+9+9+9
373	mi. squared	
	e.g. above	11squared+3squared+9squared+9squared+9squared
41	m.j=sum side	
	e.g. above	1+23+10+6+1
677	m.j squared	
	e.g. above	1squared+23squared+10squared+6squared+1squared
41	n=mij	
5	k=number of clusters	
25	c=number of cells in comparison matrix	
182	Tk=mij squared - n	
332	Pk=mi. squared-n	
636	Qk=m.j squared-n	
2508	Pk'=mi.(mi.-1)(mi.-2)	
	e.g. mi. values of 11,3,9,9,9 Pk'=11*10*9+3*2*1+8*7*6+*9*8*7+9*8*7	
11466	Qk'=m.j(m.j-1)(m.j-2)	
	e.g. for values of 1,23,10,6,1 Qk'=0+23*22*21+9*8*7+6*5*4+0	
0.3961	Bk=Tk/square root of Pk*Qk	
0.280191	E(Bk)=Bk mean= (square root of Pk*Qk)/(n*(n-1)	
0.0005	var(Bk)=2/[n(n-1)]+[4(Pk'Qk')/n(n-1)*(n-2)*PkQk]+[{(Pk-2-4Pk'/Pk)*(Qk-2-4Qk'/Qk)/n(n-1)(n-2)(n-3)}]	
	continued from above: -PkQk/[n squared (n-1)squared]	
0.31913	upper 95%Confidence Interval= E(Bk) + t-value for n * square root of var(Bk)	

If Bk less than upper 95% Confidence interval
Then clusters are not similar

aries have deeper inlets and that increases the inlets cross sectional area accordingly).

The cross component analysis and Principal Components Analysis revealed that inlet current speed does not correlate with any estuarine variables or combination of estuarine variables evaluated. This indicates that further work will be required to determine the hydrodynamic relationships of estuarine/marine exchanges through the inlets. Based on the results obtained from the estuaries data (chapter 1) versus those obtained from the inlet data (chapter 2), the estuaries data generated highly credible results while the inlet data did not.

Efforts to improve data should focus on the inlet data. For example, the demarcation and measurement of the inlets may need refinement. The inlets could be measured at the choke point (or manifold section) which most heavily restricts tidal exchange. This choke point (section) could be based on the cross sectional area of the inlet instead of the narrowest distance between the inlets shores. Perhaps, characterizations of the flows passing through the inlets could be developed (e.g., velocity and volumetric time series per tide cycle). No doubt it will take time and effort to compile an improved inlet data set, but it may be the only means of determining the hydrodynamic/geomorphologic relationships controlling estuarine/marine exchanges for strategic purposes.

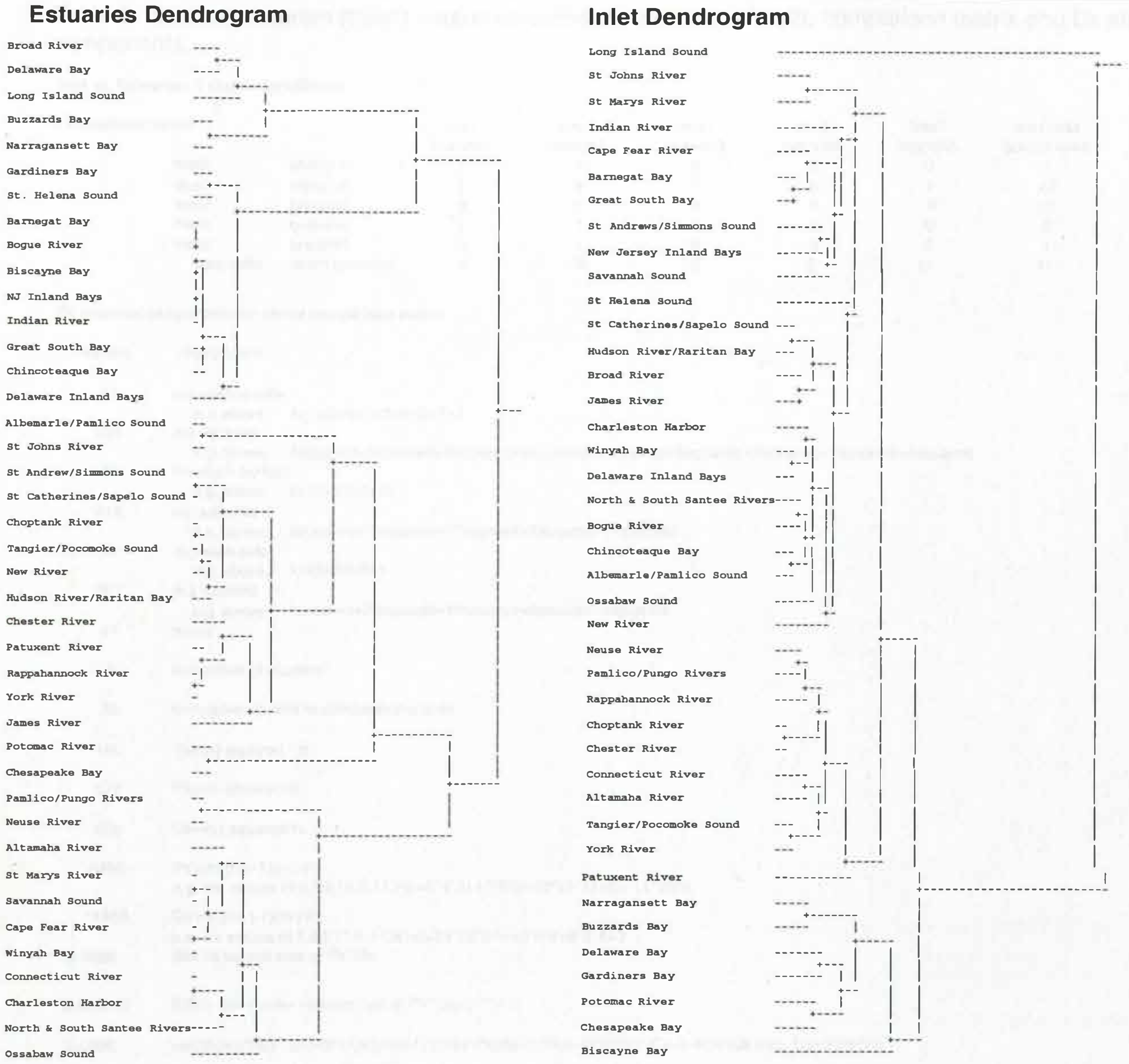

Figure 4. Comparision of Estuaries Dendrogram versus Inlet Dendrogram (Lowery et. al. 1993a, b).

Future Work

The U.S. East Coast Estuaries Analysis (chapter 1) will be compared to an ongoing analysis of the Estuarine Living Marine Resources Program's (ELMR) relative abundance/estuaries matrices. This comparison explores if certain estuarine/inlet characteristics are statistically related to fisheries species abundance patterns. Further refinements and re-evaluation of the inlet/estuarine relationships will be undertaken in the future. These relationships are believed to be paramount to understanding estuarine/marine exchanges and their discernment are crucial to SEAD's ongoing East Coast Assessment.

Acknowledgments

The authors thank Steve Stone, Moe Nelson, John Christensen and Steve Jury for their reviews of this chapter. We also thank Arthur Bulger, Bruce Hayden, Larry Claflin and Colin Mallows for their statistical consultations.

Table 8. Inlet dendrogram (tree1) versus estuaries dendrogram (tree2), comparison matrix and Bk statistic components.

Inlet vs. Estuaries- 5 cluster comparison

Comparison matrix

		tree1 branch1	tree1 branch2	tree1 branch3	tree1 branch4	tree1 branch5	sum cells across rows
tree2	branch1	1	0	0	0	0	1
tree2	branch2	1	8	7	0	7	23
tree2	branch3	0	0	6	0	4	10
tree2	branch4	3	1	0	2	0	6
tree2	branch5	0	1	0	0	0	1
sum cells	down columns	5	10	13	2	11	41

Bk statistics components for above comparison matrix

values	component
41	mij=matrix cells
	e.g. above 1+1+3+8+1+7+6+2+7+4
231	mij squared
	e.g. above 1squared+1squared+3squared+8squared+7squared+6squared+2squared+7squared+4squared
41	mi.=sum bottom
	e.g. above 5+10+13+2+11
419	mi. squared
	e.g. above 5squared+10squared+13squared+2squared+11squared
41	m.j=sum side
	e.g. above 1+23+10+6+1
667	m.j squared
	e.g. above 1squared+23squared+10squared+6squared+1squared
41	n=mij
5	k=number of clusters
25	c=number of cells in comparison matrix
190	Tk=mij squared - n
378	Pk=mi. squared-n
626	Qk=m.j squared-n
3486	Pk'=mi.(mi.-1)(mi.-2)
	e.g. mi. values of 5,10,13,2,11 Pk'=5*4*3+10*9*8+13*12*11+0+*11*10*9
11466	Qk'=m.j(m.j-1)(m.j-2)
	e.g. for values of 1,23,10,6,1 Qk'=0+23*22*21+10*9*8+6*5*4+0
0.3906	Bk=Tk/square root of Pk*Qk
0.296612	E(Bk)=Bk mean= (square root of Pk*Qk)/(n*(n-1)
0.0006	var(Bk)=2/[n(n-1)]+[4(Pk'Qk')/n(n-1)*(n-2)*PkQk]+[{(Pk-2-4Pk'/Pk)*(Qk-2-4Qk'/Qk)/n(n-1)(n-2)(n-3)}]
	continued from above: -PkQk/[n squared (n-1)squared]
0.3394	upper 95%Confidence Interval= E(Bk) + t-value for n * square root of var(Bk)

If Bk less than upper 95% Confidence interval
Then clusters are not similar

Table 9. Inlet variables matrix from Lowery et. al. 1993b.

esty	width	avdep	crsec	fcurr	ecurr
buzz	11713	14.4	169192.1	0.34	0.30
narr	10900	18.1	197444.5	0.21	0.28
gard	19605	13.9	271643.0	0.36	0.50
lisd	22357	27.9	624314.6	1.66	1.57
conn	1399	2.7	3777.3	0.46	0.36
grts	1829	4.2	7700.0	1.28	1.24
huds	9135	8.4	76732.8	0.82	0.88
barn	347	4.0	1389.9	1.13	1.29
njby	7949	4.9	38951.6	1.35	1.54
deby	18197	12.6	229276.7	0.72	0.67
dein	152	4.5	685.8	0.93	1.10
chnq	4942	3.4	16852.8	0.83	0.88
ches	17730	7.8	137806.3	0.41	0.62
patx	1509	13.1	19767.9	0.21	0.21
poto	17775	9.1	161752.5	0.36	0.26
rapp	6096	5.5	33528.0	0.36	0.26
york	4541	7.9	35873.9	0.52	0.46
jams	3683	9.1	33515.3	0.77	0.77
chst	1196	5.8	6936.8	0.21	0.21
chop	1322	6.2	8196.4	0.31	0.26
tang	4617	6.5	30010.5	0.57	0.57
alpm	5122	2.6	13199.6	0.99	0.92
paml	6309	4.5	28390.5	0.10	0.15
neus	10058	4.4	44255.2	0.10	0.15
boge	3386	5.4	18245.1	0.67	0.85
nwri	1006	2.0	2007.4	0.51	1.13
cpfr	2114	1.6	3286.3	1.10	1.50
winy	1975	5.0	9821.8	0.98	1.00
nssn	1134	2.9	3281.8	0.77	0.89
char	914	7.8	7135.0	0.93	0.93
sthe	13730	4.7	65144.3	0.75	0.78
brri	4206	10.5	44163.0	0.93	0.93
sava	9400	5.9	55870.0	0.93	1.60
ossa	5395	4.8	25817.0	0.82	1.18
casa	8733	6.8	59352.0	0.89	0.99
alta	3667	2.3	8493.9	0.57	0.62
ansi	6309	7.5	47177.0	1.29	1.13
mycb	1166	11.9	13873.7	1.13	1.40
john	471	13.9	6530.9	0.97	1.19
indn	386	4.7	1832.6	1.51	1.85
bisc	22935	2.3	52807.7	0.26	0.27

Table 10. Rotated loadings of Inlet variable matrix (Table 9). Rotated loadings in bold identify variables that are highly associated with the PCA components (Comp1-3).

Variable	Comp1	Comp2	Comp3
WIDTH	0.256	-0.153	**0.947**
AVDEP	**0.972**	0.022	0.189
CRSEC	**0.742**	0.087	**0.629**
FCURR	0.093	**0.976**	-0.057
ECURR	-0.024	**0.979**	-0.078

Table 11. Factor scores from PCA of estuaries/inlets variables matrix (ALL1-5), estuaries variables matrix (EST1-5), and inlet variables matrix (Inlet1-3).

Estuary	ALL1	ALL2	ALL3	ALL4	ALL5	Est1	EST2	EST3	EST4	EST5	Inlet1	Inlet2	Inlet3
Albemarle/Pamlico Sound	2.840	-0.539	0.516	1.555	-0.461	-0.041	-0.357	4.744	0.578	0.869	-0.897	0.490	0.119
Altamaha River	-0.393	-0.615	1.058	-0.349	0.802	-0.007	-0.478	-0.511	1.082	0.301	-0.794	-0.402	-0.198
Barnegat Bay	-0.424	-0.754	-0.353	1.140	0.671	-0.249	-0.695	-0.310	-0.196	1.142	-0.481	1.011	-0.665
Biscayne Bay	-0.702	-0.319	-0.506	-0.764	2.805	-0.250	-0.449	-0.290	-0.115	2.669	-1.803	-1.006	2.675
Bogue River	-0.595	-0.628	-0.477	0.240	0.970	-0.224	-0.757	-0.478	-0.252	1.458	-0.291	-0.065	-0.449
Broad River	-0.351	0.242	-0.590	0.172	-0.805	-0.269	0.295	-0.394	-0.701	-0.722	0.617	0.291	-0.663
Buzzards Bay	-0.595	1.202	-0.402	-1.055	0.061	-0.241	0.921	-0.543	-0.350	0.317	1.346	-1.114	0.212
Cape Fear River	-0.191	-0.603	0.709	0.918	0.092	0.088	-0.290	-0.586	0.671	-0.328	-1.051	1.267	-0.128
Charleston Harbor	-0.197	-0.162	0.733	0.262	-0.334	-0.148	-0.088	-0.211	0.675	-0.361	0.241	0.290	-1.009
Chesapeake Bay	4.875	-0.246	-0.496	-0.807	1.583	5.878	-0.260	0.415	-0.301	0.172	-0.339	-0.516	1.722
Chester River	-0.283	-0.258	-0.087	-1.070	-0.826	-0.323	-0.240	-0.084	-0.172	-0.761	0.046	-1.410	-1.019
Chincoteaque Bay	-0.420	-0.567	-0.689	0.238	0.599	-0.195	-0.508	-0.338	-0.588	0.762	-0.718	0.213	0.000
Choptank River	-0.166	-0.291	-0.829	-0.860	-1.160	-0.434	-0.160	0.176	-1.015	-1.159	0.099	-1.230	-1.011
Connecticut River	-0.298	-0.277	4.932	-0.678	0.573	-0.268	-0.067	-0.075	4.842	-0.530	-0.555	-0.867	-0.664
Delaware Bay	0.549	1.632	-0.280	-0.651	1.881	0.845	2.134	0.064	-0.458	0.552	0.746	-0.092	1.642
Delaware Inland Bays	-0.509	-0.738	-0.863	0.711	-0.364	-0.470	-0.704	-0.317	-0.835	0.067	-0.340	0.529	-0.803
Gardiners Bay	-0.592	0.915	-0.612	-1.089	0.725	-0.187	0.228	-0.407	-0.512	0.739	1.043	-0.739	1.770
Great South Bay	-0.394	-0.697	-0.855	1.481	0.523	-0.470	-0.673	-0.011	-0.640	1.391	-0.498	1.159	-0.435
Hudson River/Raritan Bay	1.102	0.456	-0.070	0.046	-1.727	0.112	0.300	1.420	-0.125	-1.083	0.065	0.190	0.330
Indian River	-0.424	-0.670	-0.560	2.542	1.451	-0.441	-0.714	0.015	-0.080	3.008	-0.483	2.000	-0.563
James River	0.413	-0.133	0.057	-0.081	-0.579	0.359	-0.206	0.136	-0.001	-0.550	0.413	-0.081	-0.694
Long Island Sound	-0.123	5.185	0.234	1.778	0.266	-0.396	5.389	0.069	0.201	0.845	3.984	2.000	2.000
Narragansett Bay	-0.532	1.167	-0.403	-1.190	-0.051	-0.188	0.526	-0.423	-0.288	0.556	2.126	-1.366	-0.184
Neuse River	-0.162	-0.309	0.108	-1.499	0.367	0.010	-0.360	-0.089	0.073	-0.168	-0.607	-1.489	0.517
New Jersey Inland Bays	-0.525	-0.515	-0.626	1.389	0.479	-0.405	-0.576	-0.343	-0.486	0.838	-0.756	1.643	0.554
New River	-0.360	-0.795	-0.607	0.115	-0.672	-0.441	-0.527	-0.175	-0.755	-0.913	-0.826	0.074	-0.482
North & South Santee Rivers	-0.298	-0.591	0.425	0.027	-0.429	-0.197	-0.346	-0.365	0.276	-0.901	-0.621	0.126	-0.566
Ossabaw Sound	-0.387	-0.327	0.018	0.268	-0.214	-0.116	-0.196	-0.605	-0.041	-0.522	-0.552	0.531	0.032
Pamlico/Pungo Rivers	-0.226	-0.421	-0.031	-1.387	0.210	-0.039	-0.447	-0.156	-0.066	-0.153	-0.411	-1.532	-0.098
Patuxent River	-0.288	0.267	-0.398	-1.137	-2.088	-0.376	0.025	-0.221	-0.536	-1.653	1.321	-1.528	-1.601
Potomac River	0.462	0.297	-0.109	-1.627	0.515	0.996	0.009	-0.342	-0.191	-0.504	0.063	-0.993	1.601
Rappahannock River	-0.085	-0.122	-0.183	-1.108	-0.629	-0.044	-0.079	-0.123	-0.308	-0.945	-0.235	-1.098	-0.158
Savannah Sound	-0.314	-0.225	0.385	0.647	0.298	-0.047	-0.198	-0.498	0.381	-0.088	-0.602	1.175	0.711
St. Andrews/St. Simmons Sound	-0.071	-0.101	-0.598	0.646	-0.228	-0.162	0.133	-0.012	-0.797	-0.662	-0.071	1.049	0.015
St. Catherines/Sapelo Sound	-0.152	-0.059	-1.123	0.157	-0.831	-0.481	0.255	0.178	-1.442	-1.469	-0.268	0.415	0.400
St. Helena Sound	-0.418	-0.176	-0.252	-0.233	0.612	-0.206	-0.181	-0.319	-0.247	0.170	-0.851	0.081	1.300
St. Johns River	1.168	0.199	0.391	1.022	-2.339	-1.012	-0.171	3.059	0.353	-0.503	1.249	0.524	-1.566
St. Marys River	-0.622	0.350	1.673	1.000	-0.670	0.142	0.111	-1.499	1.880	-0.064	0.842	1.010	-1.201
Tangier/Pocomoke Sound	-0.037	-0.222	-0.485	-0.408	-0.527	-0.219	-0.144	0.183	-0.602	-0.618	-0.055	-0.511	-0.391
Winyah Bay	-0.057	-0.433	1.430	0.326	0.080	0.213	-0.280	-0.449	1.364	-0.448	-0.328	0.492	-0.572
York River	-0.221	-0.121	-0.184	-0.689	-0.632	-0.097	-0.177	-0.288	-0.279	-0.754	0.233	-0.722	-0.544

Table 12. Cross component analysis, Pearson correlation matrix of component factor scores from Table 10. Correlation coefficients in bold identify component pairs that are highly correlated. Estuaries/inlets variables matrix (ALL1-5), estuaries variables matrix (EST1-5), and inlet variables matrix (Inlet1-3)

	ALL1	ALL2	ALL3	ALL4	ALL5	EST1	EST2	EST3	EST4	EST5
EST1	**0.778**	-0.006	-0.021	-0.236	0.339					
EST2	0.017	**0.972**	0.036	0.067	0.024					
EST3	**0.619**	-0.008	0.010	0.242	-0.304					
EST4	0.002	-0.020	**0.987**	0.055	0.092					
EST5	-0.069	0.041	-0.141	0.401	**0.756**					
INLET1	-0.031	**0.865**	-0.040	-0.028	-0.308	-0.073	**0.782**	-0.002	-0.066	-0.124
INLET2	-0.026	0.086	-0.015	**0.944**	0.074	-0.136	0.164	0.068	0.024	0.325
INLET3	0.214	0.407	-0.197	-0.173	**0.665**	0.378	0.402	-0.046	-0.166	0.387

Table 13. Summary of cross component analysis (Table 12).

1st half of cross component pair	2nd half of cross component pair	correlation
ALL1 (System Magnitude & Mixing Function)	EST1 (System Magnitude Function;)	0.778
ALL1 (System Magnitude & Mixing Function)	EST3 (Mixing Function)	0.619
ALL2 (Seawater Function)	EST2 (Seawater Function)	0.972
ALL2 (Seawater Function)	INLET1 (Cross Sectional Area-Depth Function)	0.865
ALL3 (Freshwater Inflow Function)	EST4 (Stratification Function)	0.987
ALL4 (Inlet Current Speed Function)	INLET2 (Inlet Current Speed Function)	0.944
ALL5 (Width Function)	EST5 (Width Function)	0.756
ALL5 (Width Function)	INLET3 (Cross Sectional Area-Width Function)	0.665
EST2 (Seawater Function)	INLET1 (Cross Sectional Area-Depth Function)	0.782

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Appendix 1. Estuaries & Inlet variable matrix PCA.

```
SYSTAT 5.2.1
Principal Components
5 Components Selected
Varimax Rotation Selected
Scores Saved Selected

LATENT ROOTS (EIGENVALUES)

                       1          2          3          4          5
                   8.821      5.786      2.657      2.269       1.25

                       6          7          8          9         10
                   1.073      0.925      0.751      0.612      0.515

                      11         12         13         14         15
                   0.361      0.262      0.229      0.142      0.092

                      16         17         18         19         20
                   0.083      0.058      0.034      0.030      0.017

                      21         22         23         24         25
                   0.013      0.008      0.004      0.003      0.001

                      26
                   0.000

COMPONENT LOADINGS

                       1          2          3          4          5
      LENGT        0.746      0.408      0.019     -0.147      0.242
      ESTWI        0.421     -0.492     -0.092      0.379     -0.382
      MINWI        0.709      0.024     -0.226     -0.191     -0.294
      MAXWI        0.719     -0.083     -0.224      0.071      0.055
      ADEPT        0.607     -0.529      0.275     -0.291      0.287
       DPWR       -0.208      0.223      0.666     -0.168      0.053
      DYFLR        0.863      0.386      0.169      0.074     -0.099
      FIFYR        0.780      0.400     -0.127      0.005     -0.151
      HUNYR        0.769      0.405     -0.146      0.010     -0.151
      HIFLW       -0.079      0.440      0.736     -0.213     -0.288
      LWFLW       -0.031      0.507      0.778     -0.103     -0.201
      TPRSM        0.679     -0.594      0.190     -0.058     -0.007
      TFVOL        0.746      0.429      0.133      0.218      0.222
      MXVOL        0.809      0.453     -0.181      0.119     -0.065
      SWVOL        0.506     -0.705      0.339     -0.017      0.108
      TFSUR        0.604      0.479      0.114      0.290      0.211
      MXSUR        0.764      0.489     -0.148      0.172     -0.017
      SWSUR        0.553     -0.751      0.210      0.036     -0.097
      FWFRC       -0.068      0.682      0.241     -0.238      0.247
      DCPTL       -0.412     -0.040     -0.382      0.102      0.389
    TPFLUSH        0.625      0.392     -0.109      0.042      0.316
     IWIDTH        0.618     -0.429     -0.200     -0.338     -0.297
     IAVDEP        0.452     -0.620      0.200     -0.261      0.412
     ICRSEC        0.608     -0.705      0.148     -0.243      0.043
     IFCURR        0.050     -0.319      0.360      0.821      0.058
     IECURR       -0.029     -0.240      0.294      0.851      0.025

VARIANCE EXPLAINED BY COMPONENTS

                       1          2          3          4          5
                   8.821      5.786      2.657      2.269      1.254
```

Appendix 1.- continued.

```
PERCENT OF TOTAL VARIANCE EXPLAINED

                        1            2            3            4            5
                       33.926       22.253       10.220       8.727        4.824




ROTATED LOADINGS

                        1            2            3            4            5

     LENGT              0.830        0.200        0.098       -0.206       -0.146
     ESTWI              0.106        0.351       -0.273        0.397        0.593
     MINWI              0.553        0.267       -0.117       -0.274        0.459
     MAXWI              0.583        0.359       -0.292        0.005        0.170
     ADEPT              0.174        0.923        0.023       -0.065       -0.067
      DPWR             -0.136       -0.004        0.699        0.021       -0.243
     DYFLR              0.896        0.185        0.246        0.033        0.198
     FIFYR              0.848        0.047        0.022       -0.131        0.260
     HUNYR              0.845        0.031        0.006       -0.133        0.259
     HIFLW              0.035       -0.137        0.919       -0.059        0.050
     LWFLW              0.132       -0.156        0.933        0.047       -0.035
     TPRSM              0.209        0.849       -0.063        0.121        0.263
     TFVOL              0.884        0.117        0.129        0.162       -0.128
     MXVOL              0.932       -0.003       -0.053       -0.050        0.188
     SWVOL              0.012        0.900        0.003        0.236        0.119
     TFSUR              0.806       -0.020        0.124        0.213       -0.156
     MXSUR              0.925       -0.045       -0.033        0.005        0.123
     SWSUR              0.025        0.856       -0.094        0.242        0.353
     FWFRC              0.277       -0.325        0.451       -0.266       -0.434
     DCPTL             -0.262       -0.242       -0.440        0.000       -0.397
   TPFLUSH              0.773        0.075       -0.072       -0.066       -0.214
    IWIDTH              0.211        0.588       -0.216       -0.311        0.524
    IAVDEP              0.023        0.905       -0.102       -0.037       -0.190
    ICRSEC              0.073        0.940       -0.106       -0.039        0.218
    IFCURR             -0.033        0.156        0.006        0.940        0.018
    IECURR             -0.048        0.023       -0.019        0.930        0.025

VARIANCE EXPLAINED BY ROTATED COMPONENTS

                        1            2            3            4            5

                        7.647        5.819        2.968        2.449        1.904

PERCENT OF TOTAL VARIANCE EXPLAINED

                        1            2            3            4            5

                       29.413       22.381       11.415       9.420        7.322
```

Appendix 2. Inlet variable matrix PCA.

```
SYSTAT 5.2.1
Principal Components
3 Components Selected
Varimax Rotation Selected
Scores Saved Selected


LATENT ROOTS (EIGENVALUES)

                        1           2           3           4           5

                        2.360       1.973       0.516       0.082       0.068

COMPONENT LOADINGS

                        1           2           3

     WIDTH              0.842      -0.116       0.514
     AVDEP              0.833       0.232      -0.484
     CRSEC              0.948       0.234       0.003
     FCURR             -0.116       0.973       0.059
     ECURR             -0.215       0.951       0.120

VARIANCE EXPLAINED BY COMPONENTS

                        1           2           3

                        2.360       1.973       0.516

PERCENT OF TOTAL VARIANCE EXPLAINED

                        1           2           3

                       47.207      39.466      10.328

ROTATED LOADINGS

                        1           2           3

     WIDTH              0.256      -0.153       0.947
     AVDEP              0.972       0.022       0.189
     CRSEC              0.742       0.087       0.629
     FCURR              0.093       0.976      -0.057
     ECURR             -0.024       0.979      -0.078

VARIANCE EXPLAINED BY ROTATED COMPONENTS

                        1           2           3

                        1.571       1.942       1.338

PERCENT OF TOTAL VARIANCE EXPLAINED

                        1           2           3

                       31.413      38.837      26.751
```