

1990

## Comparative community structure of surf-zone fishes in the Chesapeake Bight and southern Brazil

Cassiano Monteiro-Neto

*College of William and Mary - Virginia Institute of Marine Science*

Follow this and additional works at: <https://scholarworks.wm.edu/etd>



Part of the [Ecology and Evolutionary Biology Commons](#), [Fresh Water Studies Commons](#), and the [Oceanography Commons](#)

---

### Recommended Citation

Monteiro-Neto, Cassiano, "Comparative community structure of surf-zone fishes in the Chesapeake Bight and southern Brazil" (1990). *Dissertations, Theses, and Masters Projects*. William & Mary. Paper 1539616781.

<https://dx.doi.org/doi:10.25773/v5-7des-zm75>

This Dissertation is brought to you for free and open access by the Theses, Dissertations, & Master Projects at W&M ScholarWorks. It has been accepted for inclusion in Dissertations, Theses, and Masters Projects by an authorized administrator of W&M ScholarWorks. For more information, please contact [scholarworks@wm.edu](mailto:scholarworks@wm.edu).

## **INFORMATION TO USERS**

The most advanced technology has been used to photograph and reproduce this manuscript from the microfilm master. UMI films the text directly from the original or copy submitted. Thus, some thesis and dissertation copies are in typewriter face, while others may be from any type of computer printer.

**The quality of this reproduction is dependent upon the quality of the copy submitted.** Broken or indistinct print, colored or poor quality illustrations and photographs, print bleedthrough, substandard margins, and improper alignment can adversely affect reproduction.

In the unlikely event that the author did not send UMI a complete manuscript and there are missing pages, these will be noted. Also, if unauthorized copyright material had to be removed, a note will indicate the deletion.

Oversize materials (e.g., maps, drawings, charts) are reproduced by sectioning the original, beginning at the upper left-hand corner and continuing from left to right in equal sections with small overlaps. Each original is also photographed in one exposure and is included in reduced form at the back of the book.

Photographs included in the original manuscript have been reproduced xerographically in this copy. Higher quality 6" x 9" black and white photographic prints are available for any photographs or illustrations appearing in this copy for an additional charge. Contact UMI directly to order.

# **U·M·I**

University Microfilms International  
A Bell & Howell Information Company  
300 North Zeeb Road, Ann Arbor, MI 48106-1346 USA  
313. 761-4700 800 521-0600



**Order Number 9025870**

**Comparative community structure of surf-zone fishes in the  
Chesapeake Bight and southern Brazil**

**Monteiro-Neto, Cassiano, Ph.D.**

**The College of William and Mary, 1990**

**U·M·I**

300 N. Zeeb Rd.  
Ann Arbor, MI 48106



COMPARATIVE COMMUNITY STRUCTURE OF SURF-ZONE FISHES  
IN THE CHESAPEAKE BIGHT AND SOUTHERN BRAZIL

---

A Dissertation

Presented to

The Faculty of the School of Marine Science  
The College of William and Mary in Virginia

in Partial Fulfillment  
of the Requirements For the Degree of  
Doctor of Philosophy

---

by

Cassiano Monteiro-Neto

1990

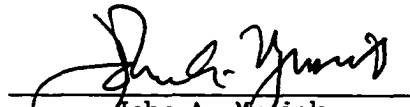
APPROVAL SHEET

This Dissertation is submitted in partial fulfillment of  
the requirements for the degree of


Doctor of Philosophy

  
Cassiano Monteiro-Neto

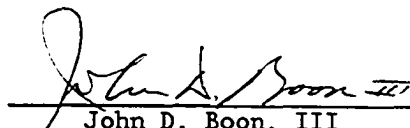
Approved, March 1990

  
John A. Musick  
Committee Chairman

  
James A. Colvocoresses

  
Ning Labbish Chao

  
Mark E. Chittenden, Jr.

  
John D. Boon, III

Dedicated to the memory of my father  
Daniel Monteiro



## TABLE OF CONTENTS

	Page
ACKNOWLEDGMENTS .....	vi
LIST OF TABLES .....	viii
LIST OF FIGURES .....	xii
ABSTRACT .....	xv
INTRODUCTION .....	2
STUDY AREA .....	6
Western South Atlantic (WSA) .....	6
Physical Environment .....	6
Zoogeography .....	12
Western North Atlantic (WNA) .....	13
Physical Environment .....	13
Zoogeography .....	20
MATERIAL AND METHODS .....	22
Definition of the surf-zone .....	22
Collecting Techniques .....	22
Data Analysis .....	27
Numerical Classification .....	27
Dominance .....	32
Analysis of Covariance .....	32
Community Structure Indices .....	34
Species Rarefaction .....	36
K-dominance Curves .....	37
Faunal and Ecological Affinities .....	37
Taxonomic Comparison .....	38
RESULTS .....	41
Within Habitat - Cassino (WSA) .....	41
Species Abundance .....	41
Numerical Classification .....	45
Normal Analysis .....	45
Inverse Analysis .....	48
Nodal Analysis .....	52
Dominance .....	54
Analysis of Covariance .....	56
Community Structure Indices .....	61
Species Rarefaction .....	64
Taxonomic Comparison (WSA) .....	67

Within Region - Chesapeake Bight (WNA) .....	71
Species Abundance .....	71
Numerical Classification .....	75
Normal Analysis .....	75
Inverse Analysis .....	78
Nodal Analysis .....	80
Dominance .....	82
Analysis of Covariance .....	84
Community Structure Indices .....	90
Species Rarefaction .....	90
Taxonomic Comparison (WNA) .....	95
Within the western Atlantic - Cassino x Chesapeake Bight ..	99
DISCUSSION .....	104
Within Habitat Scale - Cassino (WSA) .....	104
Within Region Scale - Chesapeake Bight (WNA) .....	112
Within the western Atlantic - Cassino x Chesapeake Bight ..	118
CONCLUSIONS .....	123
APPENDIX A .....	126
LITERATURE CITED .....	139
VITA .....	150

## ACKNOWLEDGMENTS

I would like to thank my major professor Dr. John A. Musick for his support throughout the course of this study. To all members of my committee, I also thank for their critical review of the manuscript. Their patience of reviewing the manuscript written in 'translated portuguese style' was greatly appreciated. Specially I thank Dr. James A. Colvocoresses for his assistance and guidance through the intricacies of cluster analysis, and Dr. Labbish N. Chao for introducing me into the wonders of the fish world during my undergraduate years. I am also grateful to Robert K. Dias and Dr. Luis Paulo R. Cunha for providing the data sets in which I based this work.

It was through many discussions with fellow brazilian friends at VIMS that most of this work took shape. Due to his common interest in community ecology, Joao Vieira more than anybody had to listen my questions and doubts (some of them probably became part of his own comparative study of estuarine fish communities). Together we tried to find reasonable answers to many of those problems. Luiz Barbieri provided insights and suggestions concerning several aspects of statistical analysis and ecological interpretation. Lauro Calliari and I started the graduate work at VIMS at the same time, and we probably will not forget those class days when we could not even understand what the lecture was all about due to 'communication problems'. Thank you all for your friendship and support throughout these years.

To the graduate students, faculty and staff at Jefferson Hall I express my appreciation for their friendship and encouragement. Special thanks goes to Gloria Rowe and Kim Callis for helping me, among other things, to fill in travel vouchers, T & E sheets, and reimbursement forms to which I will never be familiar with.

Many hours I spent at the user's room trying to 'communicate' with the PRIME computer, and spooling more than enough copies of my text and figures (which always needed improvements). I would like to thank Gary Anderson, Pat Hall, Kevin Kiley, David Boughan, and Lyn McCarthy for their patience and helpful advice in several computer matters. To fellow students I apologyze for the monopoly of the graphics terminal, sometimes for weeks in a row. To the art and word processing departments and photo lab I express my deepest gratitude for helping with the final figures, text, and slides.

This work was made possible and supported by Conselho Nacional de Desenvolvimento Cientifico e Tecnologico - CNPq, Brazil, which granted me a four year full time scholarship. I thank Drs.

John A. Musick, James A. Colvocoresses, and Mark E. Chittenden for providing assistantships when funds from Brazil were not available. I also thank Dr. Frank O. Perkins, director of the School of Marine Science, for supporting my participation in the XVI Brazilian Congress of Zoology in Joao Pessoa, Brazil. This gratitude is also extended to Sarah Hamrick for helping me with the necessary paperwork to travel in and out of the country.

I would like to thank my mother for taking care of my interests in Brazil during the last few years. Thanks to the people and the community of Gloucester Point for their friendly attitude with us, newcomers in a strange land.

Finally, to my wife and daughter, I would like to express my gratitude and love for their understanding and support. It was not an easy task to manage family and graduate school at the same time, but without their love and affection things would probably be much harder. Thank you.

# LIST OF TABLES

Table	Page
1. Mean, standard deviation (SD), maximum (Max) and minimum (Min) air temperature, water temperature and salinity at Cassino. Total rainfall (mm/month) in the city of Rio Grande (IPA-SA, 1980, 1981, 1982). YR1=March 1980 - February 1981; YR2=March 1981 - February 1982 .....	9
2. Mean, standard deviation (SD), maximum (Max) and minimum (Min) air temperature, water temperature and salinity at Sandbridge (VA) and Cape Hatteras (NC). Air temperatures are monthly averages of daily observations (mean, maximum and minimum), taken at Back Bay Wildlife Refuge and Cape Hatteras Coast Guard stations along with total rainfall (mm/month) (NCDC, Virginia and North carolina, 1973 and 1974) ....	16
3. Wilcoxon Matched-Pairs Signed-Ranks comparisons of mean monthly temperatures and salinities between years (Cassino) and localities (Chesapeake Bight) YR1=March 1980 - February 1981; YR2=March 1981 - February 1982; CH=Cape Hatteras; SB=Sandbridge; Z-standardized score; P-probability level .....	19
4. Characterization of sampling stations at Cassino (WSA). Distance readings are referred to the jetties at the mouth of Patos Lagoon, increasing towards the south (Cunha, 1981) .....	24
5. Selected bibliography from localities in the western South (WSA) and North (WNA) Atlantic used for taxonomic comparison of surf-zone fish communities within hemispheres .....	39
6. Numerical abundance (Abund.), percent (%a) and cumulative percent (Cum.) abundance, frequency (Freq.) and percent frequency (%f) of occurrence of fish species in the surf-zone at Cassino. March 1980 to February 1982 .....	42
7. Numerical abundance (Abund.), percent (%a) and cumulative percent (Cum.) abundance, frequency (Freq.) and percent frequency (%f) of occurrence of fish species in the surf-zone at Cassino. YR1=March 1980 -	

February 1981 .....	43
8. Numerical abundance (Abund.), percent (%a) and cumulative percent (Cum.) abundance, frequency (Freq.) and percent frequency (%f) of occurrence of fish species in the surf-zone at Cassino. YR2=March 1981 - February 1982 .....	44
9. Summary of environmental and catch data within seasonal groups derived from normal cluster analysis at Cassino. YR1=March 1980 - February 1981; YR2=March 1981 - February 1982; $\bar{X}$ - Mean; SD - Standard Deviation .....	47
10. Species within groups of inverse cluster analysis at Cassino and their faunal affinity (TR-tropical; ST-sub-tropical; TE-temperate), habitat affinity (SZ-surf-zone oriented; CM-coastal marine; ER-estuarine related), ecological role (SW-shallow water; BO-bottom oriented; PE-pelagic), feeding mode (BE-benthivore; PL-planktivore; OM-omnivore; PR-predator), and spawning season (SP-spring; SU-summer; FL-fall; WN-winter) .....	49
11. Species dominance indicated by percent frequency (%) and average percent abundance ( $\bar{X}$ ) of species within seasonal groups at Cassino. Only species included on numerical classification are reported .....	55
12. ANCOVA model for $\log_{10}$ (total CPUE+1) at Cassino. Degrees of freedom (df), sums of squares (SS), standardized F distribution scores (F), probability ( $P > F$ ), significance level (* - significant; ** - highly significant), and correlation coefficient ( $r^2$ ) .....	57
13. Total number of species, genera, and families collected at Cassino and selected localities of the western South Atlantic; number of shared species, genus and families (commonality), and faunal similarities (Jaccard) among these localities and Cassino (CA), at each taxonomic level. Effort=number of samples taken .....	68
14. Pooled number of species, genus and families collected at selected localities of the western South Atlantic, and the proportions in which taxa occurred within the patterns indicated by the	

stars (*). 'No Pattern'-occurrences did not follow any of the proposed patterns .....	69
15. Numerical abundance (Abund.), percent (%a) and cumulative percent (Cum.) abundance, frequency (Freq.) and percent frequency (%f) of occurrence of fish species in the surf-zone of the Chesapeake Bight (July 1973 - June 1974) .....	72
16. Numerical abundance (Abund.), percent (%a) and cumulative percent (Cum.) abundance, frequency (Freq.) and percent frequency (%f) of occurrence of fish species in the surf-zone at Cape Hatteras (July 1973 - June 1974) .....	73
17. Numerical abundance (Abund.), percent (%a) and cumulative percent (Cum.) abundance, frequency (Freq.) and percent frequency (%f) of occurrence of fish species in the surf-zone at Sandbridge (July 1973 - June 1974) .....	74
18. Summary of environmental and catch data within seasonal groups derived from normal cluster analysis in the Chesapeake Bight. $\bar{X}$ - Means, SD - Standard Deviation .....	77
19. Species within groups of inverse cluster analysis in the Chesapeake Bight and their faunal affinity (TR-tropical; ST-sub-tropical; TE-temperate), habitat affinity (SZ-surf-zone oriented; CM-coastal marine; ER-estuarine related), ecological role (SW-shallow water; BO-bottom oriented; PE-pelagic), feeding mode (BE-benthivore; PL-planktivore; OM-omnivore; PR-predator), and spawning season (SP-spring; SU-summer; FL-fall; WN-winter) .....	79
20. Species dominance indicated by percent frequency (%) and average percent abundance ( $\bar{X}$ ) of species within seasonal groups in the Chesapeake Bight. Only species included on numerical classification are reported .....	83
21. ANCOVA model for $\log_{10}$ (total CPUE+1) at the Chesapeake Bight. Degrees of freedom (df), sums of squares (SS), standardized F distribution scores (F), probability ( $P > F$ ), significance level (* - significant; ** - highly significant), and	

correlation coefficient ( $r^2$ ) .....	85
22. Total number of species, genera, and families collected at selected localities of the western North Atlantic; number of shared species, genus and families (commonality), and faunal similarities (Jaccard) among these localities and the Chesapeake Bight (CB), at each taxonomic level. Effort=number of samples taken .....	96
23. Pooled number of species, genera and families collected in the Chesapeake Bight and at selected localities of the western North Atlantic, and the proportions in which taxa occurred within the patterns indicated by the stars (*). 'No Pattern'-occurrences did not follow any of the proposed patterns .....	97
24. Total and mutually exclusive (ME) number of species, genera, and families collected at Cassino and the Chesapeake Bight; number of shared species, genus and families (common.), and similarity between faunas (Jaccard) at each taxonomic level .....	101
25. Shared genera and families between Cassino and the Chesapeake Bight, number of species and percent abundance (%a) per genus and family .....	102



## LIST OF FIGURES

Figure	Page
1. Circulation patterns of the western South (WSA) and North (WNA) Atlantic (Adapted from Pickard and Emery, 1982), and geographic location of study areas (CA-Cassino, CB-Chesapeake Bight, and left inset) and selected surf-zone studies (SC-Laguna, SP-Santos, FL-Sebastian, SC-Folly Beach, NC-Beaufort, CT-Morris Cove) .....	7
2. Monthly means for air and water temperature ( $^{\circ}\text{C}$ ) at Cassino. YR1=March 1980 - February 1981; YR2=March 1981 - February 1982 .....	10
3. Total rainfall (mm/month) in the city of Rio Grande, and mean salinity (0/00) per month at Cassino. YR1=March 1980 - February 1981; YR2=March 1981 - February 1982 .....	11
4. Monthly means for air and water temperature ( $^{\circ}\text{C}$ ) at Cape Hatteras (CH) and Sandbridge (SB), in the Chesapeake Bight (July 1973 - February 1974) .....	17
5. a) Total rainfall (mm/month); b) mean salinity ( $^{\circ}/\text{oo}$ ) per month at Cape Hatteras (CH) and Sandbridge (SB) (July 1973 - February 1974) .....	18
6. Map of the western South Atlantic showing the sampled area at Cassino. Insets represent the geographical location in South America (top left) and sampling stations (1-8) (bottom right) .....	23
7. Map of the western North Atlantic (top inset) and the Chesapeake Bight, indicating both sampling locations (Cape Hatteras and Sandbridge) .....	26
8. Dendrogram of normal cluster analysis at Cassino (WSA) .....	46
9. Nodal constancy (top) and fidelity (bottom) diagrams showing inter-relations between seasonal groups (spring to winter) and species groups (A to G) at Cassino. Rows and columns were drawn proportionally	

to the number of group members .....	53
10. Scatter plot of the $\log_{10}$ (CPUE+1) for individual samples against water temperature by season, and fitted regression lines for each year at Cassino .....	58
11. Scatter plot of the $\log_{10}$ (CPUE+1) against water temperature by season, of the five most abundant species on YR1 (March 1980 - February 1981) at Cassino .....	59
12. Scatter plot of the $\log_{10}$ (CPUE+1) against water temperature by season, of the five most abundant species on YR2 (March 1981 - February 1982) at Cassino .....	60
13. Mean number of species (S), Shannon-Wiener diversity ( $H'$ ), equitability ( $J'$ ) and species richness (D) per sample (point diversity) by season by year at Cassino. Spring (Sp), summer (Su), fall (Fl), winter (Wn). Bars indicate 95% confidence intervals for the mean .....	62
14. Mean number of species (S), Shannon-Wiener diversity ( $H'$ ), equitability ( $J'$ ) and species richness (D) per sample (point diversity) by sampling station (1-8) by year at Cassino. Bars indicate 95% confidence intervals for the mean .....	63
15. Rarefaction curves by season by year at Cassino indicating the total number of species (endpoint) and the back calculated values for different sample sizes (number of individuals). Spring (Sp), summer (Su), fall (Fl), winter (Wn) .....	65
16. Rarefaction curves by sampling station (1-8) by year at Cassino indicating the total number of species (endpoint) and the back calculated values for different sample sizes (number of individuals) ....	66
17. Dendrogram of normal cluster analysis in the Chesapeake Bight (WNA) .....	76
18. Nodal constancy (top) and fidelity (bottom) diagrams showing inter-relations between seasonal groups (spring to winter at Cape Hatteras - CH, and Sandbridge - SB), and species groups (A to G) in the Chesapeake Bight .....	81

19. Scatter plot of the $\log_{10}$ (CPUE+1) for individual samples against water temperature by season, and fitted regression lines for each locality in the Chesapeake Bight .....	86
20. Scatter plot of the $\log_{10}$ (CPUE+1) against water temperature by season, of the five most abundant species at Cape Hatteras in the Chesapeake Bight .....	87
21. Scatter plot of the $\log_{10}$ (CPUE+1) against water temperature by season, of the five most abundant species at Sandbridge in the Chesapeake Bight .....	88
22. Mean number of species (S), Shannon-Wiener diversity (H'), equitability (J') and species richness (D) per sample (point diversity) by season by locality in the Chesapeake Bight. Spring (Sp), summer (Su), fall (Fl), winter (Wn). Bars indicate 95% confidence intervals for the mean .....	91
23. Mean number of species (S), Shannon-Wiener diversity (H'), equitability (J') and species richness (D) per sample (point diversity) by diel period by locality in the Chesapeake Bight. Dawn (6:00); mid-day (12:00) dusk (18:00); mid-night (24:00). Bars indicate 95% confidence intervals .....	92
24. Rarefaction curves by season by locality in the Chesapeake Bight indicating the total number of species (endpoint) and the back calculated values for different sample sizes (number of individuals). Spring (SP), summer (SU), fall (FL), winter (WN) .....	93
25. Rarefaction curves by diel period by locality in the Chesapeake Bight indicating the total number of species (endpoint) and the back calculated values for different sample sizes (number of individuals). 6:00, dawn (DA); 12:00, mid-day (MD); 18:00, dusk (DU); 24:00, mid-night (MN) .....	94
26. K-dominance curves comparing community dominance-richness patterns from Cassino (WSA) and the Chesapeake Bight (WNA) .....	100

## ABSTRACT

The structure of surf-zone fish communities at Cassino (western South Atlantic, WSA) and the Chesapeake Bight (western North Atlantic, WNA) is described using historical beach seine data, to examine similarities between geographically isolated fish communities. Numerical classification, ANCOVA, Shannon-Wiener diversity and its components, and species rarefaction are used to describe fish community structure: a) within habitat (community analysis within a nearly homogeneous habitat - Cassino), with emphasis on the characterization of seasonal patterns; b) within region (the study of seasonal and large scale spatial variations in fish communities from separate localities (Cape Hatteras and Sandbridge, Chesapeake Bight) within the same zoogeographical region); c) within the western Atlantic (comparison of patterns of community structure and faunal affinities between Cassino and the Chesapeake Bight).

The surf-zone fish community at Cassino had a low diversity and was dominated by a few species. Seasonal periods identified by cluster analysis correlated well with seasonal environmental changes. The seasonal occurrence, abundance and diversity of fish species reflected recruitment patterns of juveniles, and seasonal variation in the marine and estuarine circulation patterns. Fish species associations usually fitted into three broad categories: year-round surf-zone residents (Trachinotus marginatus, Menticirrhus littoralis, Oncopterus darwini, Odonthestes bonariensis, Mugil platanus); b) spring to fall, estuarine related, pelagic planktivores (Ramnogaster arcuata, Brevoortia pectinata) or shallow water omnivores (Xenomelaniris brasiliensis, Jenynsia lineata, Mugil spp.); c) summer to fall coastal marine occasionals (Porichthys porosissimus, Umbrina canosai, Chloroscombrus chrysourus, Caranx latus). Water temperature probably played an important role determining the time of the spawning migration and reproduction of adult fish. Faunal similarity between Cassino and other selected locations of the WSA, decreased towards lower latitudes due to faunal replacements.

In the Chesapeake Bight community structure was determined by differences between sampled localities. The community at Sandbridge was characterized by estuarine related species (Leiostomus xanthurus, Bairdiella chrysoura, Micropogonias undulatus, Syngnathus spp.) associated with the Chesapeake Bay. Sub-tropical coastal marine species (Monacanthus hispidus, Caranx hippos, Trachinotus spp.) at Cape Hatteras indicated influence of Gulf Stream waters. A few species dominated fish communities both at Sandbridge and Cape Hatteras. The seasonal species occurrence, abundance and diversity was determined by an enhanced seasonal migration along the coast, juvenile recruitment, and the thermal

regime of the Chesapeake Bight. Species assemblages showed considerable seasonality and ubiquitous surf-zone residents were replaced by a wintering group in the colder months. The diversity of estuarine related species at Sandbridge indicated that locally the surf-zone acted as a peripheral habitat for migratory estuarine dependents and estuarine residents. Faunal similarities between the Chesapeake Bight and other WNA localities decreased both northward and southward due to faunal replacements.

Similarities between surf-zone fish communities within the western Atlantic (Cassino x Chesapeake Bight) were correlated with the temperature range and habitat structure. However, data did not provide enough evidence to characterize either convergence or parallel evolution of communities.

COMPARATIVE COMMUNITY STRUCTURE OF SURF-ZONE FISHES  
IN THE CHESAPEAKE BIGHT AND SOUTHERN BRAZIL

## INTRODUCTION

The concept of equivalent species (those that occupy similar roles in geographically isolated communities) has brought up discussion in the literature for many years (Ekman, 1953; Johnson, 1973; Cody and Mooney, 1978). This similarity between species may be explained either through common ancestry and parallel evolution of closely related groups, or through convergent evolution of distantly related groups living under similar environmental conditions (Johnson, 1973). A general hypothesis may be formulated in which 'animal or plant communities living in separate but environmentally similar areas will develop analogous structural patterns' (Johnson, 1973; Sage, 1973).

Land ecologists have compared patterns of community variation, and mechanisms of selection and adaptation to determine predictive evolutionary pathways. Cody (1975) working with bird communities, and Whittaker (1977) with birds and vascular plants have compared mediterranean climate ecosystems from North America, South America and Africa. Pianka (1975) working with desert lizards, Schall and Pianka (1978) with terrestrial vertebrates, and Morton and Davidson (1988) with harvester ant communities have compared North America and Australia. Mares (1976) compared desert rodents between North and South America.

Their conclusions were that: a) communities were comparable by their species pairs (similar species occupied nearly the same niche in each separate system); b) the species pair relationship was not always a one to one ratio but several species in one system may have filled the niche space of a single species in the other; c) communities converged in several aspects of their diversity and dominance patterns, but these convergences were often ill-defined and did not yield predictable relationships among communities.

Comparative ecological hypotheses have seldom been tested among fish communities. However some studies have concentrated on the taxonomic distribution of anti-tropical groups (e.g., Nelson, 1985; Andriyashev, 1987) or the comparison and distinction between Atlantic and Pacific faunas (Gladfelter et al., 1980; Parrish, 1987; Thresher, 1987).

Chao and Musick (1982) compared fish faunas of two large estuaries of the temperate West Atlantic (Patos Lagoon, Brazil and Lower Chesapeake Bay, U.S.A.), and suggested that these estuaries shared several equivalent species assemblages. Causes of such similarities, though not fully evaluated, may be related to the temperate latitudinal positioning of both areas and related environmental regimes. The availability of historical data sets on surf-zone fish communities near these two estuarine systems offered the opportunity to compare further the structure of fish communities in these two areas.



Geographic comparisons of surf-zone fish faunas are few, mostly due to incompatible sampling methodologies among studies (Dahlberg, 1972; Peters and Nelson, 1987; McLachlan 1983; Ross et al., 1987). Gunter (1945, 1958) pointed out that the species composition of surf-zone fish communities was similar along the Texas Gulf coast and the Atlantic coast of North America up to New England. Differences appeared mainly as the replacement of species in one region by closely related species or species pairs in the other (e.g. Brevoortia patronus - gulf menhaden, and B. tyrannus - atlantic menhaden) (Gunter, 1958; Fox and Mock, Jr., 1968). More recently, DeLancey (1984) concluded that the most abundant fish species in the surf-zone in South Carolina were typical of the surf-zone ichthyofauna from North Carolina through Georgia and in the northwestern Gulf of Mexico.

The present comparison of surf-zone fish communities from the western South and North Atlantic involves three scales of analysis.

1. Within habitat - community analysis within a nearly homogeneous habitat (Cassino, Brazil, western South Atlantic-WSA), placing emphasis on characterizing seasonal patterns of community structure.
2. Within region - study of communities not contiguously located, but within the same zoogeographical region (Cape Hatteras and Sandbridge in the Chesapeake Bight, U.S.A., western North Atlantic-WNA), focusing on seasonal and large scale spatial variations in structure and organization.

The following objectives apply to both:

- a. describe species composition and relative abundance.
  - b. characterize species associations within the surf-zone fish assemblage, and their temporal patterns.
  - c. examine factors responsible for variations in overall relative abundance.
  - d. characterize temporal and spatial changes of fish communities through the analysis of community structure indices (community diversity).
  - e. compare taxonomic similarities among surf-zone fish assemblages within hemispheres.
3. Within the western Atlantic - the direct comparison between Cassino (WSA) and the Chesapeake Bight (WNA). At this scale the structural characteristics of communities derived from the above analysis, total diversity of each locality and matching species pairs are compared, in order to:
- a. Test for similarities in faunal assemblages between surf-zone fish communities of the western South and North Atlantic.
  - b. Determine whether communities are undergoing convergent or parallel evolution.

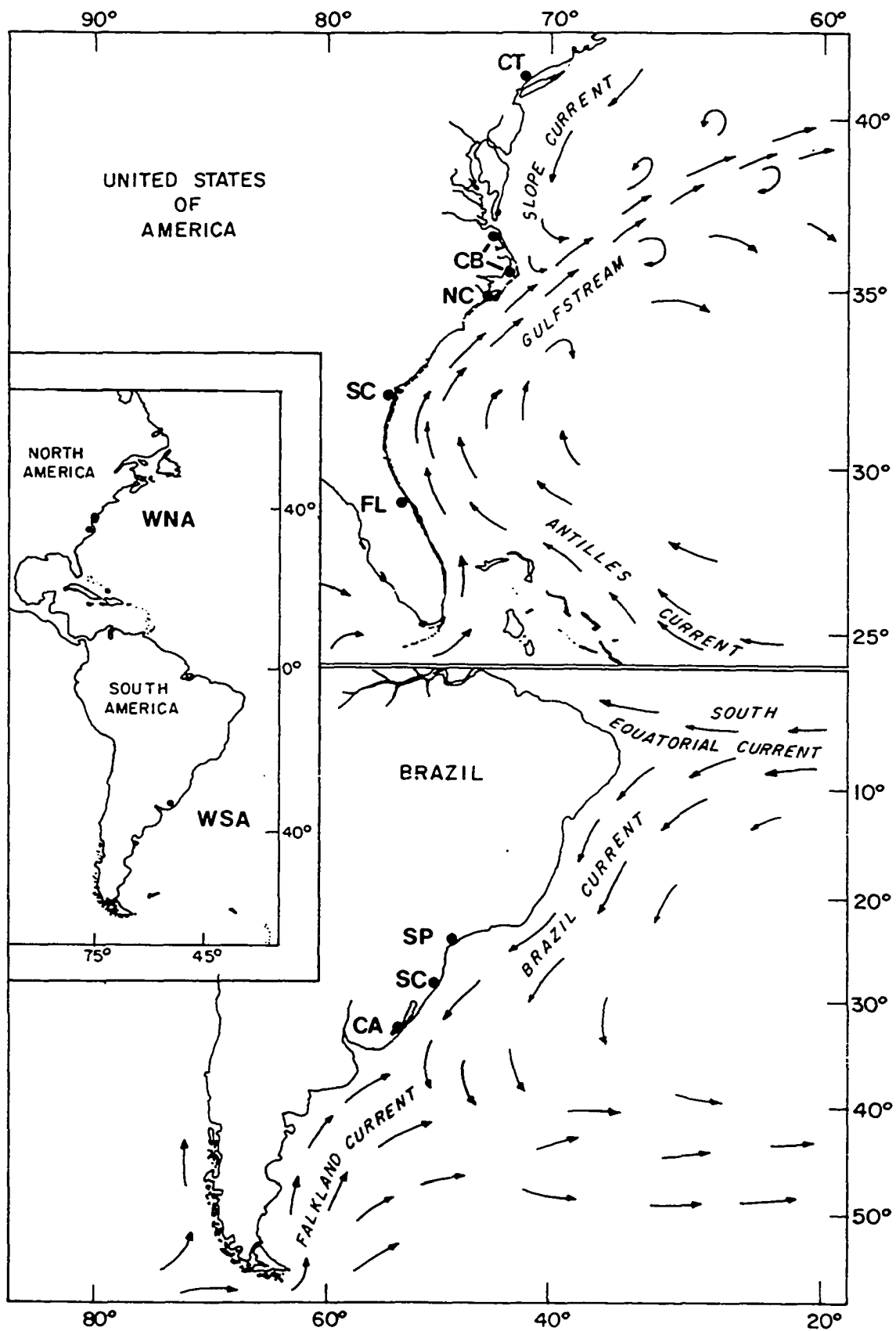
## STUDY AREA

### Western South Atlantic (WSA)

Physical environment - The beach at Cassino ( $32^{\circ}$  S) is located south of the mouth of Patos Lagoon estuary and is part of the coastal plain of Rio Grande do Sul, Brazil (Fig. 1 and 6), a sandy area characterized by broad flat lowlands, numerous lakes, coastwise terraces and aeolian land forms. One of the world's longest uninterrupted sandy beaches (640 km) extends from the coastal town of Torres ( $29^{\circ}20'$  S, Brazil) south to Uruguay at  $34^{\circ}$  latitude (Gierloff-Emden, 1975). The beaches are open to the sea, subjected to moderate to strong wave action, and have fine to very fine well-sorted quartz sand. The slope is gentle ( $1/30$  -  $1/50$ ) but the intertidal zone is small since tidal range is only about 0.5 m (Gianuca, 1983, 1985).

The hydrography of the WSA has been reviewed by Castello and Moller (1977), Hubold (1980a and b) and Martins (1984). In general, tropical oceanic water is transported southward by the Brazil Current flowing along the continental slope. This current meets the sub-antarctic Falkland Current off the La Plata estuary (Fig. 1) at  $35$ - $40^{\circ}$  S (Hubold, 1980a; Martins, 1984). The meeting zone of these currents is considered the western extreme of the subtropical

Figure 1: Circulation patterns of the western South (WSA) and North (WNA) Atlantic (adapted from Pickard and Emery, 1982), and geographic locations of study areas (CA-Cassino, CB-Chesapeake Bight, and left inset) and selected surf-zone studies (SC-Laguna, SP-Santos, FL-Sebastian, SC-Folly Beach, NC-Beaufort, CT-Morris Cove) (references in Table 5).



convergence, with a major penetration into Brazilian waters in the winter (June - August) and a minor incursion during the fall (March - May) and spring (September - November), and reaching its southernmost limit in the summer (December - February) (Castello and Moller, 1977). Coastal waters are strongly influenced by the outflow of the La Plata River, and less so by the outflow of Patos Lagoon (Castello and Moller, 1977). Long-shore currents are important and generally move southward due to the prevailing southerly winds (Gianuca, 1985).

Air and water temperature ( $^{\circ}\text{C}$ ), and salinity ( $^{\circ}/\text{oo}$ ) were measured concurrently with field work at Cassino from March 1980 to February 1982. Rainfall data (mm/month) in the city of Rio Grande near the study area was compiled from "Boletim de Observacoes Meteorologicas" (IPA-SA 1980, 1981, 1982).

Water temperature ranged from  $12.0^{\circ}\text{C}$  in July and October, 1980, to  $27.7^{\circ}\text{C}$  in December 1981 (Table 1). Monthly means followed the seasonal cycle of air temperature (Table 1, Fig. 2) with means near  $26^{\circ}\text{C}$  in summer (December - February) and  $12^{\circ}\text{C}$  in winter (June - August). The non-parametric Sign-Rank test indicated that yearly differences in water temperatures within months were non-significant between years ( $P=0.784$ ) (Table 3).

Salinity in the surf-zone ranged between  $5.0^{\circ}/\text{oo}$  (December, 1980) and  $36.0^{\circ}/\text{oo}$  (March, April, September and December, 1980).

**Table 1:** Mean, standard deviation (SD), maximum (Max.) and minimum (Min.) air temperature, water temperature and salinity at Cassino. Total rainfall (mm/month) in the city of Rio Grande (IPA-SA, 1980, 1981, 1982). YR1=March 1980 - February 1981; YR2=March 1981 - February 1982.

	AIR TEMPERATURE (°C)				WATER TEMPERATURE (°C)				SALINITY (‰)				RAIN
MONTH	Mean	SD	Max.	Min.	Mean	SD	Max.	Min.	Mean	SD	Max.	Min.	(mm)
YR1													
March	26.1	1.6	28.0	23.5	23.7	4.3	27.3	12.4	30.0	4.1	36.0	26.0	284
April	21.6	4.1	26.5	14.2	21.1	2.9	24.5	15.0	30.0	5.4	36.0	19.0	187
May	21.2	3.0	28.0	15.9	19.4	0.9	21.9	17.8	26.0	4.5	33.0	14.0	70
June	16.2	1.3	18.8	14.6	14.7	0.5	15.7	13.9	22.0	6.3	33.0	13.0	117
July	11.8	1.5	14.9	9.8	13.1	0.8	14.6	12.0	21.0	4.8	28.0	11.0	159
August	16.9	3.3	21.8	12.5	14.6	0.8	16.5	13.0	24.0	3.7	34.0	19.0	40
September	16.6	2.9	22.3	11.5	15.0	1.5	19.4	12.6	22.0	7.0	36.0	9.0	44
October	17.0	2.9	22.0	12.5	17.4	2.3	21.1	12.0	20.0	5.0	31.0	11.0	208
November	21.6	0.9	23.7	20.0	21.2	1.3	23.4	19.1	22.0	5.8	33.0	7.0	145
December	25.3	2.7	30.0	21.2	23.3	1.5	26.3	20.5	25.0	1.2	36.0	5.0	39
January	26.5	2.2	30.0	22.7	24.7	1.1	27.0	23.0	28.0	3.0	33.0	21.0	101
February	27.3	2.3	30.9	23.2	25.3	1.1	27.2	23.2	28.0	5.6	35.0	14.0	156
YR2													
March	24.8	1.6	27.0	21.9	23.4	1.2	24.7	21.8	32.0	1.0	34.0	31.0	30
April	20.5	1.9	22.9	18.0	21.3	1.4	23.1	18.7	31.0	0.9	32.0	30.0	34
May	19.9	2.3	25.0	17.0	20.5	0.5	21.8	19.9	31.0	1.6	33.0	26.0	85
June	14.6	1.2	17.0	13.1	14.6	0.9	16.0	12.1	27.0	4.5	32.0	14.0	118
July	16.5	0.7	17.6	15.0	14.2	0.3	15.0	13.8	26.0	1.3	28.0	24.0	128
August	15.9	1.3	18.0	13.6	14.5	0.9	15.9	13.6	27.0	1.5	30.0	24.0	15
September	15.4	1.3	18.0	13.0	15.1	0.9	17.7	14.0	30.0	2.5	34.0	27.0	92
October	20.9	2.0	24.2	19.2	19.2	1.0	21.0	18.2	29.0	3.4	32.0	21.0	18
November	19.6	0.4	20.0	18.8	20.6	1.3	22.8	19.1	29.0	2.5	32.0	25.0	76
December	23.3	1.0	24.8	21.5	23.6	1.2	27.7	22.7	31.0	2.5	33.0	26.0	61
January	24.1	0.8	25.0	22.5	23.2	0.7	24.1	22.0	33.0	1.1	35.0	32.0	30
February	26.5	1.0	28.3	25.3	24.6	0.7	25.6	23.6	34.0	0.8	35.0	33.0	46

Figure 2: Monthly means for air and water temperature ( $^{\circ}\text{C}$ ) at Cassino. YR1=March 1980 - February 1981; YR2=March 1981 - February 1982.



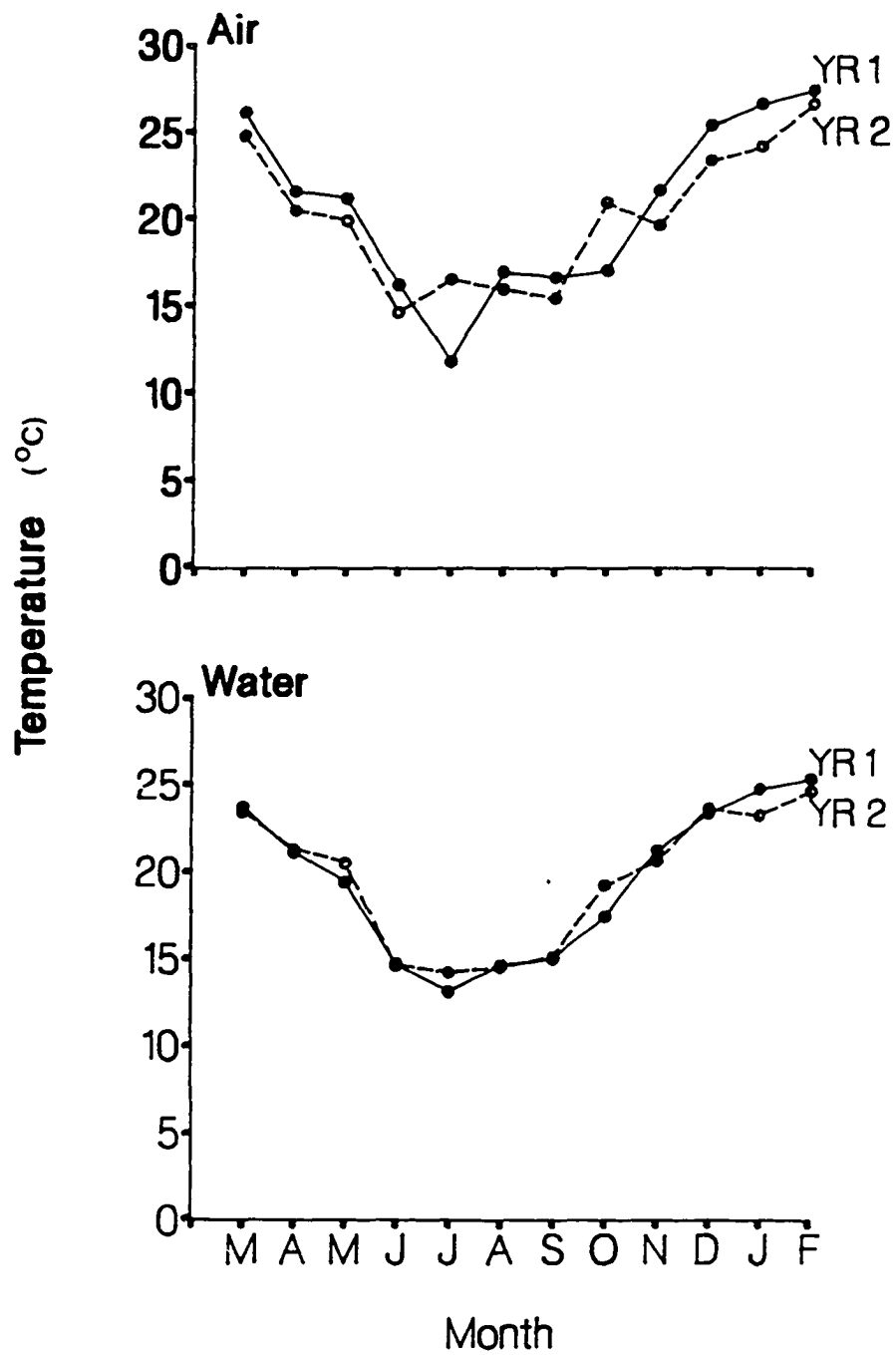
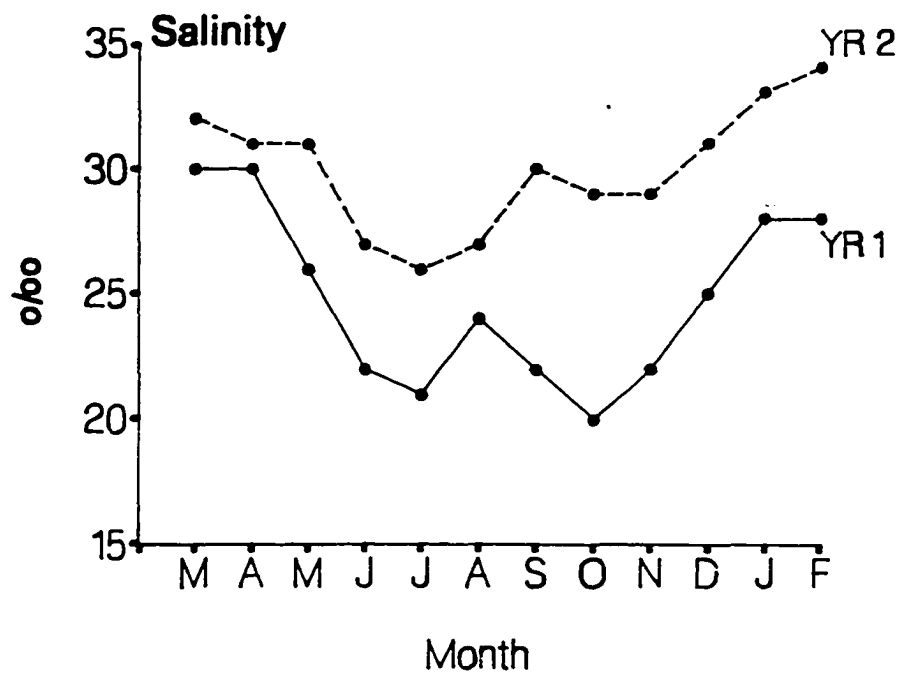
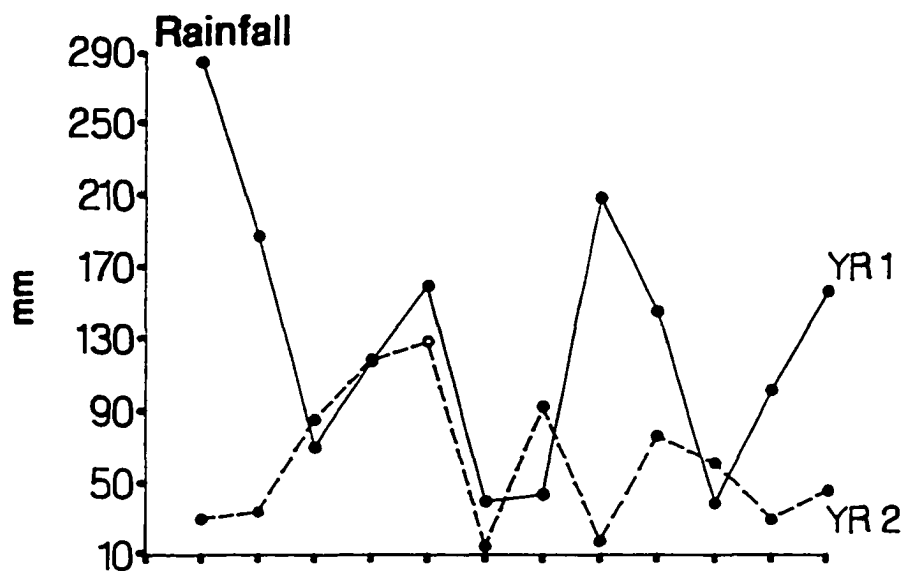


Figure 3: Total rainfall (mm/month) in the city of Rio Grande,  
and mean salinity (0/00) per month at Cassino.  
YR1=March 1980 - February 1981; YR2=March 1981 -  
February 1982.



Mean monthly values were lower from May to November and increased in summer (Table 1, Fig. 3). Total rainfall was highly variable, so average salinity and total rainfall were usually not correlated within periods (Figs. 3). However, significant differences among yearly salinity regimes (Wilcoxon Sign-Rank test,  $P=0.002$ , Table 3), with higher salinities occurring from March 1981 to February 1982 (YR2), were probably related to reduced rainfall that year (Fig. 3).

Zoogeography - Many authors have proposed zoogeographical classification schemes for the WSA. Palacio (1982), working with cephalopods, recognized the Paulistan province ( $22-24^{\circ}$  to  $32^{\circ}$  S), whose northern limit is the  $23^{\circ}$  C isotherm near Espirito Santo and Rio de Janeiro, and southern limit is the  $23^{\circ}$  C isocrime (lines of mean temperature of the coldest 30 consecutive days of the year) between Rio Grande do Sul and Uruguay. His province is a broad faunal transition zone, characterized by complex seasonal environmental fluctuations due to the alternate influence of the Brazil and Falkland currents at the western margin of the sub-tropical/sub-antarctic convergence (Fig. 1). The fauna is composed of a significant portion of endemic elements as well as members of the adjacent Caribbean and Patagonian faunas.

Lopez (1964), studying marine fishes, proposed a broad warm-temperate region, the Argentinean province ( $23-41^{\circ}$  S). Figueiredo (1981), looking at the distribution of endemic demersal marine

fishes, recognized the Argentinean province, and suggested that sub-regions and boundaries within this warm temperate province were poorly defined due to the mobility of fishes, in contrast to less motile marine groups. Endemic fish species showed affinities with three basic non-endemic groups: a) tropical elements; b) temperate groups that also occur in the western North Atlantic; and c) South Atlantic cold water forms (Figueiredo, 1981).

Applying Briggs (1974) zoogeographic system, Coelho and Dos Santos (1980) recognized a transition between tropical and warm temperate zones near Cananeia, Sao Paulo ( $25^{\circ}$  S), and between warm and cold temperate zones near Maldonado, Uruguay ( $35^{\circ}$  S).

Despite variation among authors regarding the limits and number of faunal provinces in the South Atlantic, the zoogeographic boundary between tropical and warm temperate regions is usually recognized at  $22-24^{\circ}$  S (Lopez, 1964; Briggs, 1974; Coelho and Dos Santos, 1980; Figueiredo, 1981). Warm and cold temperate regions overlap between  $35-41^{\circ}$  S, but faunal components within the warm temperate WSA are transitional (Palacio, 1982).

#### Western North Atlantic (WNA)

Physical Environment - In the WNA, the beaches considered for this study, Cape Hatteras (NC,  $35^{\circ}$  N), and Sandbridge (VA,  $37^{\circ}$  N),

are located south of the Chesapeake Bay (Figs. 1 and 7) in the southern Chesapeake Bight (Cape Henlopen (DE) to Cape Hatteras (NC)).

The Chesapeake Bight coastline is characterized by low-lying barrier islands with broad, sandy, gently-sloping beaches (Harrison et al., 1967) and well developed surf-zones. Just south of the Chesapeake Bay the barrier island system is absent creating a mainland beach which becomes gradually separated by the presence of coastal lagoons (Back Bay, Currituck Sound and Pamlico Sound) which widen to the South towards Cape Hatteras (Pierce and Colquhoun, 1970, 1971).

The water within the 183 m isobath from Cape Cod to Cape Hatteras (the Middle Atlantic Bight), is called Coastal Water. It is influenced by discharge from estuaries such as Delaware and Chesapeake Bays, and exhibits pronounced seasonality (Harrison et al., 1967). Oceanographic features of this region have been described by Beardsley et al. (1976) and Pocklington and Trembley (1987). The surface circulation of shelf water is a predominantly southwestern flow of cool water derived from the Labrador Current (Fig. 1). The alongshore flow turns seaward at Cape Hatteras and becomes entrained in the Gulf Stream (Pocklington and Trembley, 1987). Harrison et al. (1967) observed a seasonal component varying with river discharge, local winds, and less so with instability of the water column. Southwesterly flow dominates most of the year, but northerly surface flows may develop within a few miles of the

beach, especially in summer when the water column is strongly stratified.

Water temperature ( $^{\circ}\text{C}$ ) and salinity ( $^{\circ}/\text{oo}$ ) were recorded in the field at Cape Hatteras and Sandbridge (Chesapeake Bight). Data on air temperature ( $^{\circ}\text{F}$ , monthly averages of daily observations), and rainfall (in/month), were measured at Back Bay Wildlife Refuge and Cape Hatteras Coast Guard Station and gathered from Climatological Data for Virginia and North Carolina (NCDC, 1973, 1974).

Temperature and precipitation data were converted to  $^{\circ}\text{C}$  and mm/month respectively.

Water temperature at Cape Hatteras ranged between  $9.3^{\circ}\text{C}$  in January 1974 and  $26.0^{\circ}\text{C}$  in June 1973, whereas at Sandbridge temperature ranged between  $5.0^{\circ}\text{C}$  in December and  $23.8^{\circ}\text{C}$  in September, both in 1973 (Table 2). Water temperatures were significantly different between Cape Hatteras and Sandbridge within months (Wilcoxon Sign-Rank test,  $P=0.012$ ). Monthly means were usually  $2\text{--}5^{\circ}\text{C}$  higher at Cape Hatteras (Tables 2 and 3). Air and water temperature showed similar seasonal patterns (Fig. 4), mean monthly temperatures being about  $25^{\circ}\text{C}$  in summer (June - August) and  $10^{\circ}\text{C}$  in winter (December - February) (Table 2, Fig. 4).

Salinity at Cape Hatteras ranged between  $28.0^{\circ}/\text{oo}$  in June 1974

**Table 2:** Mean, standard deviation (SD), maximum (Max.) and minimum (Min.) air temperature, water temperature and salinity at Sandbridge (VA) and Cape Hatteras (NC). Air temperatures are monthly averages of daily observations (mean, maximum and minimum), taken at Back Bay Wildlife Refuge and Cape Hatteras Coast Guard Station along with total rainfall (mm/month) (NCDC, Virginia and North carolina, 1973, 1974)

	AIR TEMPERATURE (°C)			WATER TEMPERATURE (°C)				SALINITY (‰)				RAIN
MONTH	Mean	Max.	Min.	Mean	SD	Max.	Min.	Mean	SD	Max.	Min.	(mm)
C. HATTERAS												
July	26.2	31.1	21.3	24.3	1.7	26.0	22.0	32.0	0.0	32.0	32.0	100
August	26.4	30.3	22.6	24.0	0.4	24.4	23.5	29.8	1.0	31.0	29.0	163
September	25.1	28.9	21.2	23.6	0.5	24.1	23.0	33.3	0.5	34.0	33.0	144
October	19.6	24.0	15.2	23.2	1.0	24.5	22.2	31.0	0.0	31.0	31.0	24
November	13.6	18.9	8.2	14.3	1.1	15.8	13.2	33.8	1.5	36.0	33.0	27
December	9.9	15.4	4.4	13.6	1.6	15.8	12.2	33.8	1.9	35.0	31.0	210
January	11.8	15.9	7.6	11.2	2.1	13.2	9.3	31.8	1.5	33.0	30.0	75
February	8.9	14.4	3.5	-	-	-	-	-	-	-	-	100
March	13.1	18.4	7.7	15.1	0.8	15.8	14.2	35.0	0.0	35.0	35.0	90
April	17.3	23.3	11.2	14.8	1.5	16.0	13.0	32.0	3.5	35.0	29.0	104
May	20.2	25.1	15.4	-	-	-	-	-	-	-	-	119
June	23.3	27.6	19.1	21.0	0.7	21.8	20.2	28.0	0.0	28.0	28.0	223
SANDBRIDGE												
July	25.0	29.2	20.7	20.7	1.8	22.2	18.5	29.6	1.9	31.0	27.0	132
August	25.6	29.4	21.7	19.9	2.2	22.4	18.0	30.0	2.5	32.0	27.0	119
September	24.4	28.4	16.0	23.0	0.8	23.8	22.2	25.0	0.0	25.0	25.0	43
October	18.7	23.5	13.9	15.3	0.7	16.1	14.5	28.8	1.0	30.0	28.0	22
November	12.6	18.0	7.0	12.2	1.4	13.9	10.8	30.5	3.0	33.0	27.0	26
December	9.1	13.7	4.3	5.8	0.6	6.2	5.0	26.5	0.6	27.0	26.0	148
January	10.5	15.6	5.4	8.0	0.1	8.1	8.0	18.3	0.5	19.0	18.0	95
February	7.4	12.1	2.8	-	-	-	-	-	-	-	-	124
March	11.8	17.4	6.1	6.5	0.4	7.0	6.0	24.8	1.0	26.0	24.0	120
April	15.8	21.8	10.0	-	-	-	-	-	-	-	-	49
May	19.4	24.1	14.7	18.6	1.6	19.8	16.2	24.8	4.4	31.0	21.0	94
June	23.0	26.9	19.1	21.0	0.2	21.3	20.7	22.0	0.8	23.0	21.0	145



Figure 4: Monthly means for air and water temperature ( $^{\circ}\text{C}$ ) at Cape Hatteras (CH) and Sandbridge (SB), in the Chesapeake Bight (July 1973 - February 1974).

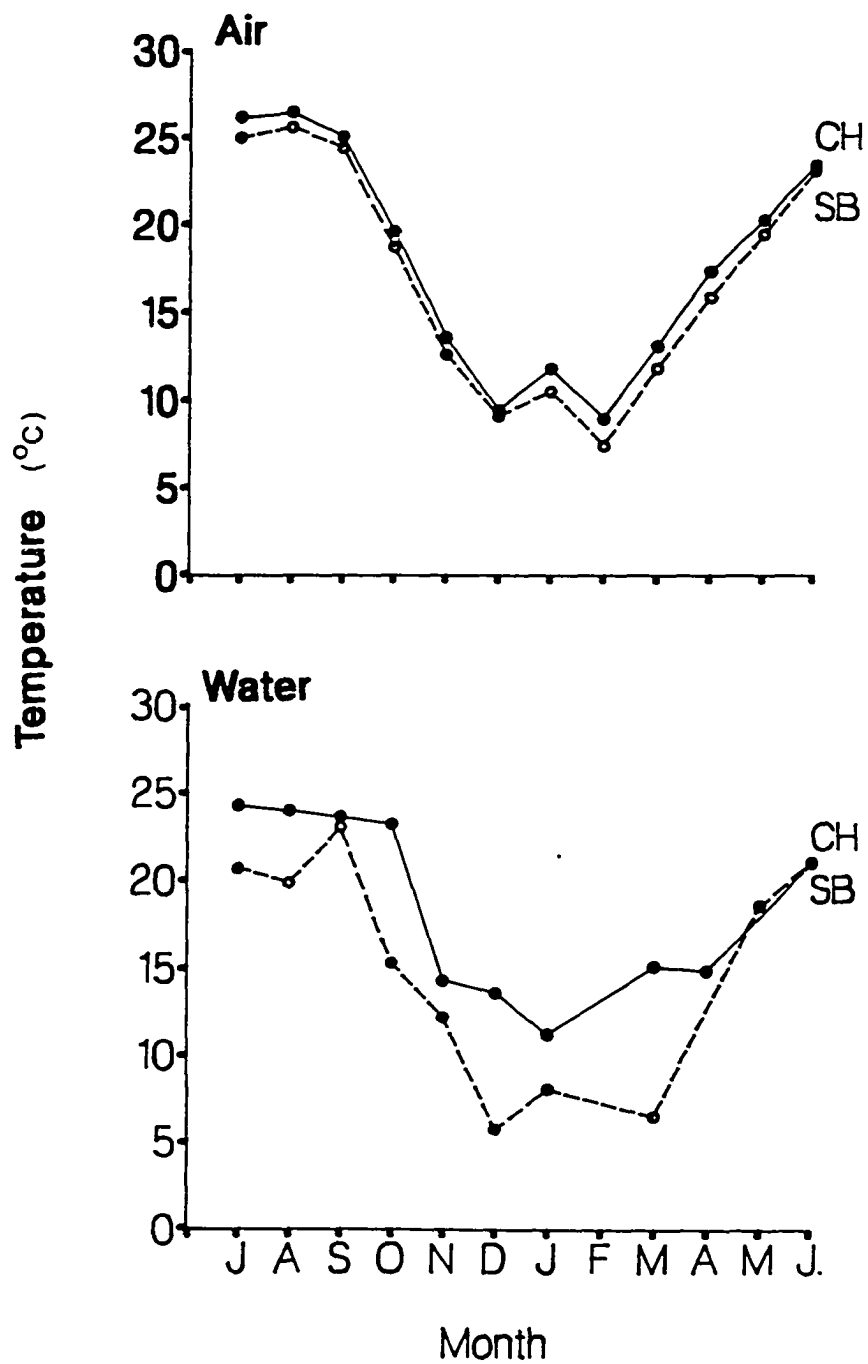
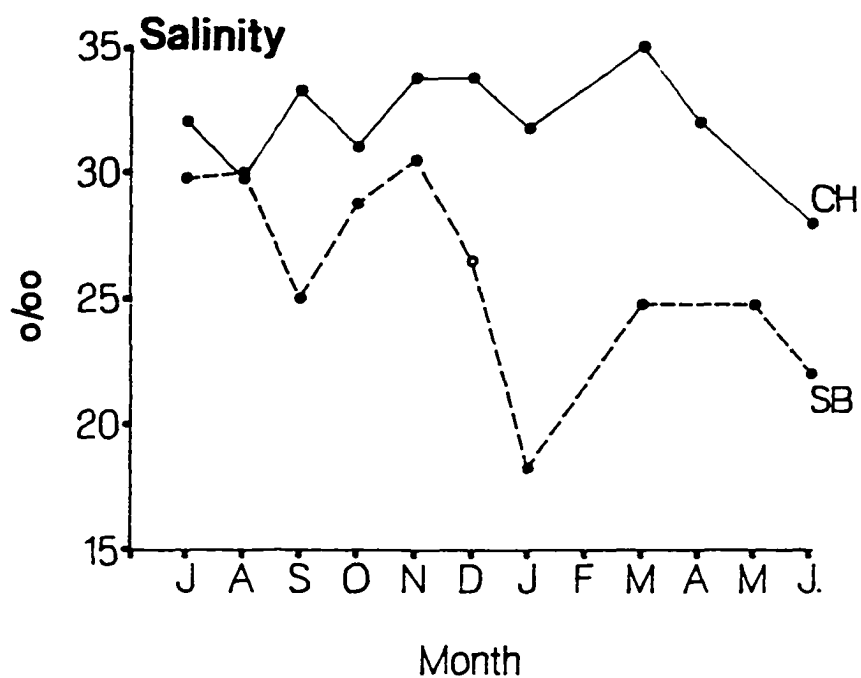
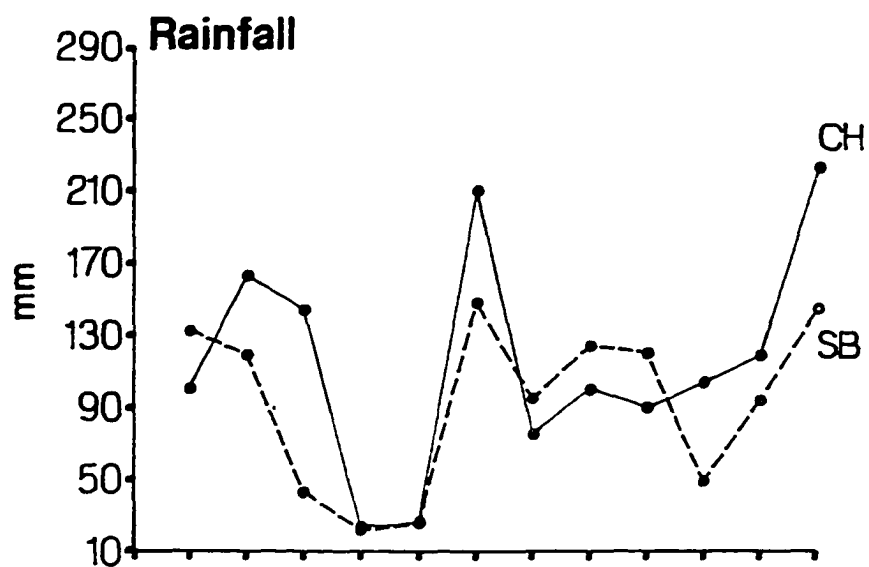


Figure 5: Total rainfall (mm/month) and mean salinity ( $^{\circ}$ /oo) per month at Cape Hatteras (CH) and Sandbridge (SB) (July 1973 - February 1974).



**Table 3:** Wilcoxon Matched-Pairs Signed-Ranks comparisons of mean monthly temperatures and salinities between years (Cassino) and localities (Chesapeake Bight). YR1=March 1980 - February 1981; YR2=March 1981 - February 1982; CH=Cape Hatteras; SB=Sandbridge; Z-standardized score; P-probability level.

-----					
CASSINO					
Comparison	YR2<YR1	YR2>YR1	YR2=YR1	Z	<u>P</u>
-----					
Temperature	7	5	0	-0.275	0.784 NS
Salinity	0	12	0	-3.059	0.002 **
-----					
CHESAPEAKE BIGHT					
Comparison	SB<CH	SB>CH	SB=CH	Z	<u>P</u>
-----					
Temperature	8	0	1	-2.520	0.012 *
Salinity	8	0	0	-2.547	0.011 *
-----					

and 36.0 ‰ in November 1973. At Sandbridge, salinity ranged from 18.0-33.0 ‰ in November, 1973 and January, 1974 respectively (Table 2). Monthly means showed a lagged negative correlation with total rainfall. High precipitation in one month usually preceded lower salinities in the following month such as in December 1973 and January 1974 (Figs. 5). significant differences ( $P=0.011$ ) in mean salinity between Cape Hatteras and Sandbridge within months were found (Table 3), with averages about 5 ‰ higher in Cape Hatteras, indicating the reduced influence of estuarine waters at this beach.

Zoogeography - Zoogeography of the WNA has been well studied (e.g. Cerame-Vivas and Gray, 1966; Briggs 1974; Pocklington and Trembley, 1987). The Middle Atlantic Bight between Cape Cod and Cape Hatteras is the southern limit of a cold-temperate fauna but has a large number of tropical and warm temperate organisms in the summer (Briggs, 1974). Colvocoresses and Musick (1984), studying demersal fishes, found that boreal and warm-temperate migrants were dominant, and that resident species played a minor role in this region.

The Chesapeake Bight is the southern half of the Virginian zoogeographic province (Musick et al., 1985. Pocklington and Trembley, 1987). Cape Hatteras, the southern limit of this province, has been a well recognized barrier for many invertebrate groups (Cerame-Vivas and Gray, 1966; Pocklington and Trembley,

1987). Parr (1933) recognized a strong latitudinal gradient in winter temperatures near Cape Hatteras as a faunal barrier for fishes. Phoel (1985), studying inshore fishes, showed that the biogeographic boundary at Cape Hatteras was effective not also effective in the fall when the temperature gradient was 4-8° C.

The two areas in this study share geological, hydrographical, and zoogeographical features as follows:

1. Low gradient, fine-sand beaches, located on a barrier island-type environment.
2. Well developed surf-zones exposed to moderate wave action.
3. Parallel circulation patterns with convergence zones of warm and cold water masses with seasonally fluctuating boundaries.
4. Estuaries such as Patos Lagoon (WSA) and the Chesapeake Bay (WNA) playing an important role in determining coastal water characteristics.
5. Both are transition zones for marine organisms, although Cassino (WSA) has been classified as warm temperate and the Chesapeake Bight (WNA) as cold temperate.
6. Fish faunas in these regions are characterized by a seasonal mixture of cold and warm-water species.

## MATERIALS AND METHODS

### Definition of the Surf-zone

The surf-zone is the area between the breaker zone and the shore face on a beach (Carter, 1988), the area influenced by breaking waves. Its width varies from tens to hundreds of meters, depending upon wave regime, and beach state (Wright and Short, 1984). Difficulties of sampling this entire zone with a beach seine have led many biologists to consider the surf-zone a more restricted area, without admitting the sampling limitations.

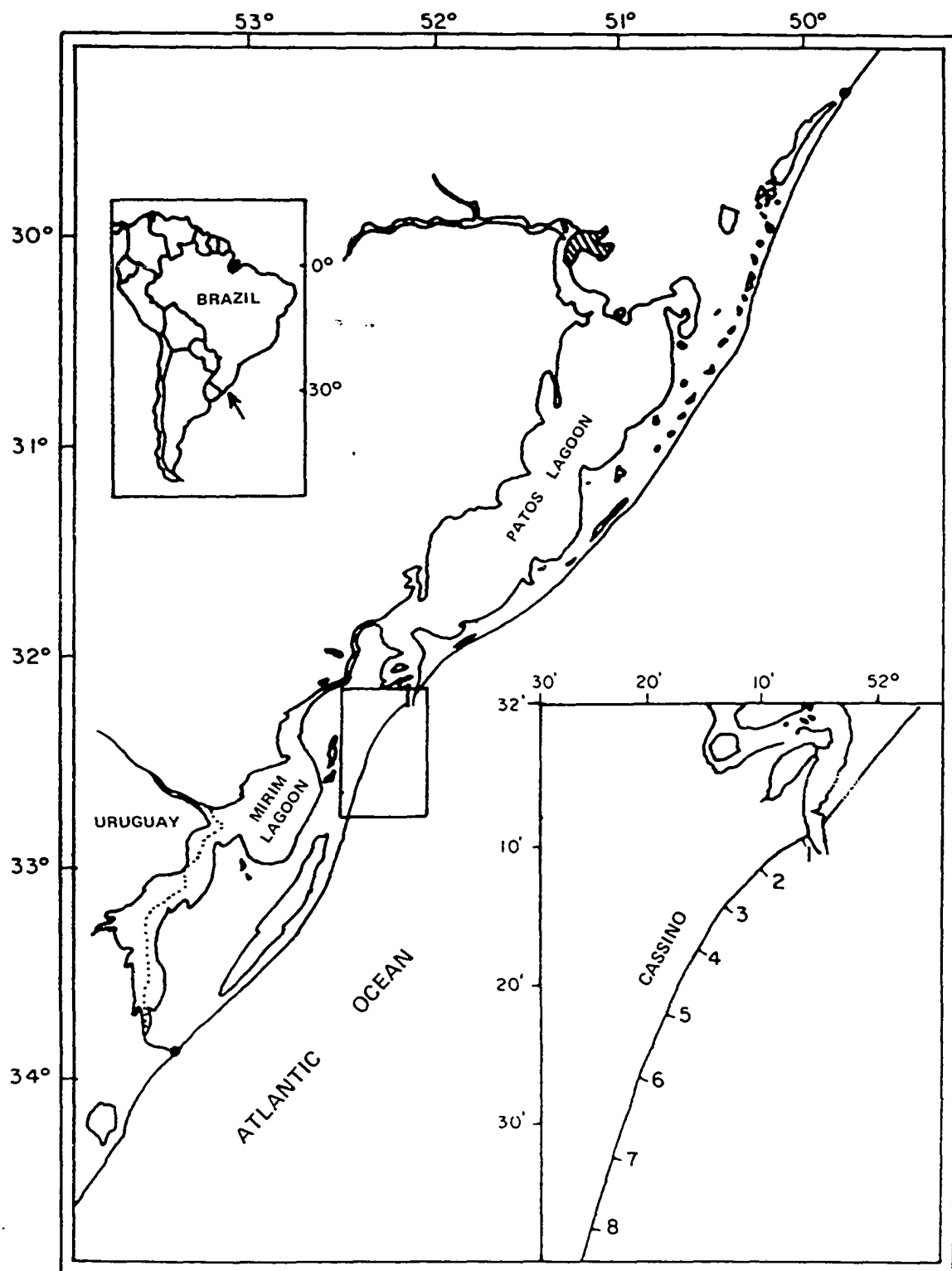
The surf-zone in the present study is defined by the maximum depth of gear operation and extends from the shore face (0 m) to 1.2 m depth. Average width of this limited surf-zone is 15-20 m, but it could exceed 30 m at Cassino, depending upon conditions.

### Collecting Techniques

Cassino (WSA), was sampled from March 1980 to February 1982 by the Laboratorio de Ictiologia, Universidade do Rio Grande, RS, Brazil at eight fixed stations along a 67 km beach extending south of the jetties at the mouth of the Patos Lagoon estuary (Fig. 6). Stations separated by 8 km on average (Fig. 6) are referred to by



Figure 6: Map of the western South Atlantic showing the sampled area at Cassino. Insets represent the geographical location in South America (top left) and sampling stations (1-8) (bottom right).



**Table 4:** Characterization of sampling stations at Cassino (WSA). Distance readings are referred to the jetties at the mouth of Patos Lagoon, increasing towards the South (Cunha, 1981).

Station Number	Distance (Km)	Physical and ecological characteristics
1	1	resort area
2	8	resort area, beach creek
3	16	resort area, periodic mud washes
4	24	uninhabited, near a shipwreck
5	34	uninhabited
6	44	uninhabited, shipwreck at mean high tide
7	56	fisherman ranch, beach creek
8	67	Sarita lighthouse

sequential numbering (1-8) and distance from the mouth of the Patos Lagoon (Table 4) (Cunha, 1981).

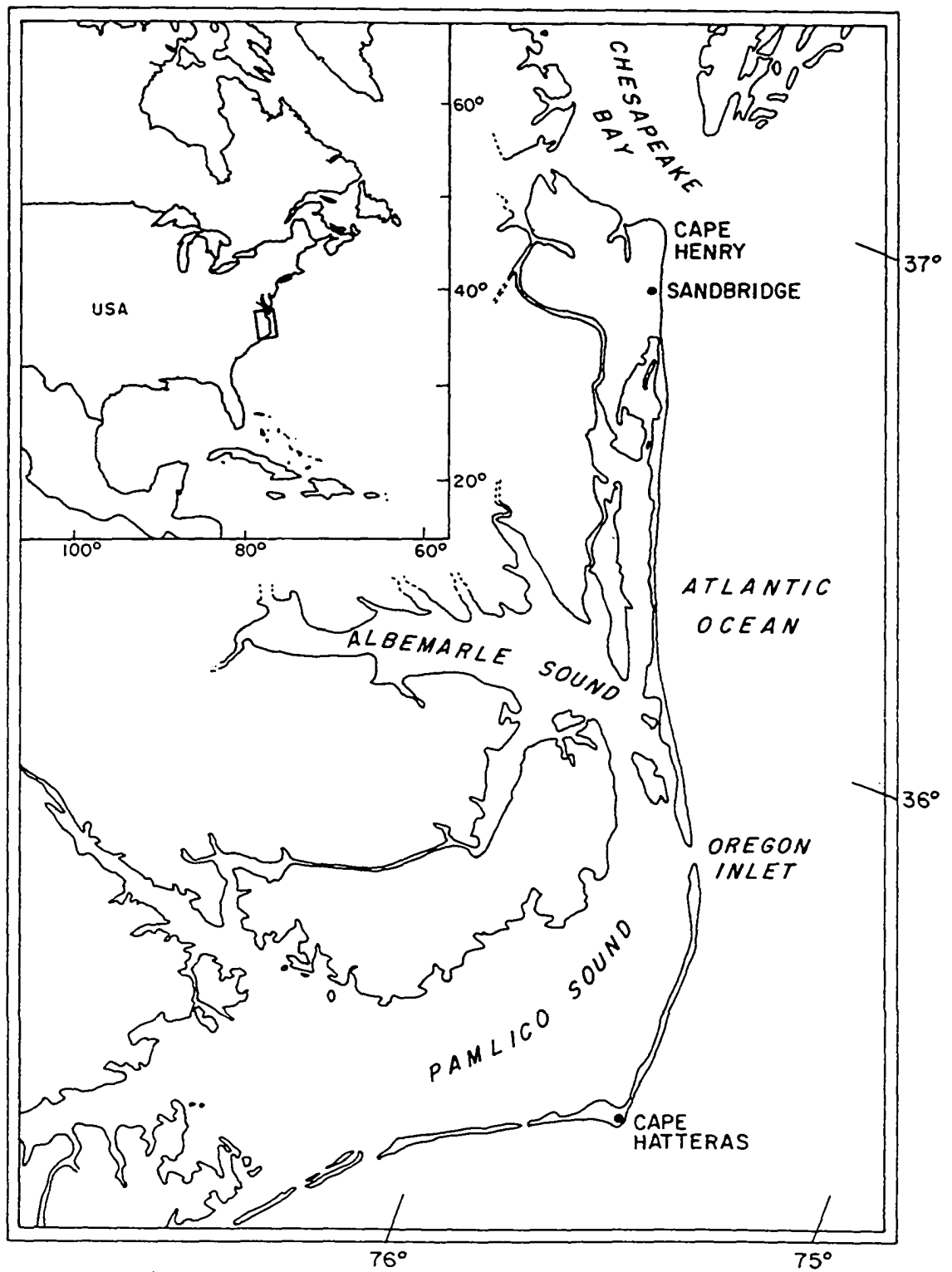
The beach seine used was 9 m long and 1.2 m deep, and constructed from three equal length (3 m) panels. The two wing panels had 15 mm bar mesh and the center panel 5 mm mesh. Three hauls, each covering an area of approximately  $100 \text{ m}^2$ , were made at each station each visit and pooled into one catch (a sample). Stations were visited two to five times a month whenever beach conditions permitted, from March 1980 to February 1981 (year 1 - YR1), and twice a month from March 1981 to February 1982 (year 2 - YR2).

The Chesapeake Bight (WNA) was sampled by R.K. Dias and co-workers from the Virginia Institute of Marine Science, at Cape Hatteras, NC, and Sandbridge, VA (Fig. 7) once a month from July 1973 to June 1974 at four times (dawn, 600; midday, 1200; dusk, 1800; midnight, 2400) whenever beach conditions permitted.

The beach seine used was made of DELTA material, was 15.2 m wing to wing and 1.8 m deep, had a center bag (1.8 m x 1.8 m x 1.8 m), and 6.35 mm (1/4") bar mesh in the wings and 4.76 mm (3/16") in the bag. Four hauls were made following the current direction, covering an area of about  $500 \text{ m}^2$  each, and pooled into one catch (a sample).

**Figure 7: Map of the western North Atlantic (top inset) and the Chesapeake Bight, indicating sampling locations (Cape Hatteras and Sandbridge).**

- . .



Fish collected in both studies were preserved in 10% formalin : 90% seawater. Fishes were identified, measured and counted in the laboratory and total species recorded. Fish abundance is expressed as catch per haul (CPUE - catch per unit effort).

#### Data Analysis

Data were pre-screened for extremely variant catches and abnormal sampling to remove sources of bias from analysis and interpretation, as other authors have done (Fox and Mock, Jr., 1968). An exceptional catch of mugilids in February, 1981 at Cassino station eight, made up twice the number of individuals as all other species collected in the two year survey, and was not considered in the analysis.

Similarly, two large catches of Anchoa hepsetus at Sandbridge in August were excluded. Due to the small number of samples, values of one were used for the species in data analysis on these two occasions. This reduced the effect of large catches on CPUE, but maintained useful information for species occurrence. While CPUE calculations based on this procedure were biased, this bias probably had a much smaller effect on data analysis than if both large catches had remained (Saloman and Naughton, 1979).

Numerical Classification - Data from each geographical area were analyzed by cluster and nodal analysis using the biotic

classification approach to identify patterns among the biological variables (species abundances) and interpret them against environmental data (Fields et al., 1982). Cluster analysis is a multivariate technique to order entities into groups on the basis of pre-established criteria to simplify complex data sets (Boesch, 1977).

Species that occurred no more than twice during the entire survey either at Cassino or the Chesapeake Bight were eliminated from cluster analysis due to lack of information. A total of 24 species in each data set were maintained for numerical classification.

CPUE data for each species were log-transformed [ $\log_{10}$  (CPUE+1)] to reduce the effects of contagion, compress the upper end of the measurement scale, and reduce the relative importance of large values (Clifford and Stephenson, 1975; Boesch, 1977; Digby and Kempton, 1987).

Both normal and inverse analysis were performed. In normal analysis a similarity matrix comparing pairs of samples is calculated. Derived sample groups reflect the similarity in the distribution patterns between species. In inverse analysis the similarity matrix is calculated between pairs of species and derived species groups express the degree of overall "likeness" between assemblages of organisms (Boesch, 1977; Digby and Kempton, 1987). In either case, cell entries were species  $\log_{10}$  (CPUE+1) per sample.



The similarity used to calculate the square similarity matrices (normal and inverse) was the complement of the Canberra-Metric dissimilarity coefficient:

$$S_{jk} = 1 - D_{jk} ;$$

$$D_{jk} = \frac{1}{m} \sum_i \frac{|X_{ij} - X_{jk}|}{(X_{ij} + X_{ik})}$$

$m$  - total number of attributes (species in normal analysis),  
 $X_{ij}$  - value of entity (collection site)  $j$  for attribute (species)  $i$ ,  
 $X_{ik}$  - value of entity  $k$  for attribute  $i$ .

The clustering strategy was flexible with  $\beta = -0.25$  (Clifford and Stephenson 1975, Boesch 1977). Flexible sorting eliminates the excessive chaining of rare species on to groups of abundant species. A variable stopping rule was employed to determine groups, since resemblance between less common species is much lower than between abundant ones (Boesch, 1977). Calculations were performed using the COMPAH (Combinatorial Polythetic Agglomerative Hierarchical Program) software.

Data matrices (species  $\log_{10} (CPUE+1)$  by sample) were reduced into fewer dimensions of variability to enhance biotic

discontinuities along a predominant gradient (Boesch, 1977). A preliminary classification of all samples yielded results that were very difficult to interpret due to great amount of variation. The initial matrix was reduced by averaging CPUE by station by month by year at Cassino, and by station by month by geographical location within the Chesapeake Bight. Values were log-transformed and a second classification run. Results of the second classification were still difficult to interpret, but they showed strong evidences of group homogeneity within seasons at either location. Data sets were then pooled by month and by year (Cassino) or geographical location (Chesapeake Bight) following the procedure above, to further define seasonal groupings. These groupings were used in the subsequent data analysis which included seasons as a unit of community variation (unless otherwise indicated).

To facilitate cluster interpretation (Boesch, 1977), and determine species-collections coincidences (Lambert and Williams, 1962), normal and inverse classifications were related to each other using nodal analysis, performed using the following concepts:

- a. Constancy - the frequency of occurrence of species groups within a designated group of collections.

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

$a_{ij}$  - actual number of occurrences of members of  
species group i in collection group j;

$n_i$  ,  $n_j$  - number of entities in the respective groups.

The index has a value of one when all members of a species group occur in all collections in a collection group, and zero when a species group does not occur in a given collection group (Clifford and Stephenson, 1975; Boesch, 1977).

- b. Fidelity - the degree to which species 'select' or are limited to collection groups (Lambert and Williams, 1962; Boesch, 1977). The fidelity index used was the constancy of a species group within a collection group divided by the average constancy over all collection groups.

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

The index uses the same notation as the constancy index. It has a value of one when the constancy of a species group in a collection group is equivalent to its overall constancy, greater than one when its constancy in the collection groups is greater than that overall, and between zero and one when its constancy is less than its overall constancy (Clifford and Stephenson, 1975; Boesch, 1977).

Dominance - Species dominance has been used to characterize fish communities, and changes in dominance often reflect faunal changes (Musick et al., 1985). Dominant species may exert a powerful control over the occurrence of other species (Krebs, 1985). Patterns of numerically dominant species were compared among collection groups for all species used in numerical classification. Dominance was assessed by percent occurrence (percent of stations in each collection group that a given species occurred) and average percent abundance (average percent that individuals of each species contributed to stations in each collection group). For a species to be considered a numerical dominant, it had to have occurred in at least 20% of all samples in a collection group, and the average percentage the species contributed towards total abundance within the site group had to be equal to or greater than 2.0% (Phoel, 1985).

Analysis of Covariance - Temporal and spatial changes in total CPUE per sample were assessed using analysis of covariance to explain total community relative abundance patterns as a function of multiple environmental variables. This technique combines the methods of regression analysis and analysis of variance (Underwood, 1981) in order to increase precision and remove potential sources of bias (Winer, 1971; Freund et al., 1986).

The following experimental structure was used to build the analysis model with multiple treatments and covariates:

- a. Block - the analysis was blocked by year (YR1, YR2) at Cassino to reduce effects of varying sampling effort between years. In the Chesapeake Bight, each locality (Cape Hatteras - CH, Sandbridge - SB) was used as a block in order to account for geographical variation.
- b. Covariates - the model was adjusted for variation in water temperature and salinity.
- c. Treatments - seasons, four levels, according to seasonal group criteria derived from cluster analysis; sampling stations, one to eight at Cassino reflecting a spatial gradient and one to four in the Chesapeake Bight reflecting diel variation; and the interaction among different levels of those treatments were used as the main factors of interest in the analysis.

Normality was assessed by fitting a normal curve against the frequency distribution for total CPUE, and homogeneity of variance was tested by the observation of the residuals against predicted variable plots (Draper and Smith, 1981), and Cochran's C test. A logarithmic transformation [ $\log_{10}(\text{CPUE}+1)$ ] was applied in order to meet the model assumptions.

Due to unequal replication within cells, parameter estimates and tests were calculated using the type III estimation hypothesis, since it does not depend upon cell sizes but only on which cells are observed, thus providing unbiased estimates for the parameters (Miliken and Johnson, 1984).

Regression lines may differ in slope and y intercepts. One assumption of ANCOVA is that fitted regression lines need to be parallel to each other (homogeneous slopes) so that the main significance test becomes one of homogeneity of the 'y'-intercepts (Underwood, 1981; Sokal and Rohlf, 1981). Homogeneity of slopes was tested by introducing first degree treatments/covariates interaction terms in the model. Non-significant treatments/covariates interactions indicate that regression lines are parallel to each other (Freund et al., 1986).

Community Structure Indices - The number of species, the Shanon-Wiener Diversity ( $H'$ ), and related parameters (Evenness -  $J'$ , and Species Richness -  $D$ ) were used to further characterize community structure. Calculations were based on the following expressions:

$$H' = - \sum_i^S (P_i) (\log_2 P_i)$$

$H'$  - Shanon-Wiener diversity (bits/individuals);

$S$  - number of species;

$P_i$  - proportion of total sample belonging  
to  $i^{\text{th}}$  species;

$$J' = H' / H'_{\max}$$

$J'$  - equitability or evenness;

$H'$  - observed Shanon-Wiener diversity;

$H'_{\max} = \log_2 S$ ;

$$D = (S - 1) / \ln N$$

$S$  - number of species;

$N$  - number of individuals.

Community structure indices depend on relative abundance and number of species. As the sample size increases, individuals are added at a constant rate, but species accumulate at a decreasing logarithmic rate (Sanders, 1968). Thus, the application of these indices to estimate diversity within units of unequal sample size would provide biased estimates of the actual diversity or species richness in the community (Magurran, 1988). In order to overcome this problem, community structure indices were calculated for each sample (pooled catch of three tows at Cassino, and four tows in the Chesapeake Bight) and averaged within seasons (seasonal groups criteria) as an estimate of point diversity (Magurran, 1988).

Community structure indices were also averaged at stations (Cassino: one - eight; Chesapeake Bight: dawn - midnight) to explore possible spatial (Cassino) or diel (Chesapeake Bight) trends in community structure not fully evaluated previously by cluster analysis.

Species Rarefaction - Comparisons of total or alpha diversity (Magurran, 1988) among seasons and stations (following the above approach) were made using the rarefaction technique proposed by Sanders (1968) and modified by Hurlbert (1971), which enables comparisons of the species richness among samples of uneven size. Collections were pooled by season, following the seasonal groups criteria obtained from numerical classification, and by station. The total number of species and the number of individuals within each species within each pooled sampling unit were subjected to rarefaction. The method uses the percentage composition of the component species within the original sample to estimate the number of species that would have been obtained had smaller samples with the identical faunal composition been taken (Sanders, 1968; Hurlbert, 1971).

The usefulness of the rarefaction method for comparing samples of different sizes relates to the fact that it depends solely [A the shape of the species abundance curve rather than the absolute number of specimens per sample (Sanders, 1968)]. When interpreting the curves generated by the rarefaction method, curves that are displaced furthest from the x-axis have a larger number of species per unit number of individuals, therefore higher the diversity. When the curves are flattened and close to the x-axis, the smaller the number of species per unit of individuals, the lower is the diversity.



k-Dominance Curves - Diversity profiles at Cassino and the Chesapeake Bight were compared against each other using k-dominance curves (Lambshead et al., 1983) in order to look at their relationships. This graphical technique is based on the analysis of the combined dominance of the k most abundant species (Lambshead et al., 1983; Shaw et al., 1983). Species ranked by their numerical dominance are plotted on the x-axis on a log scale, from the first most dominant to the k<sup>th</sup> dominant species. The cumulative percent abundance is plotted on the y-axis (Lambshead et al., 1983).

Since dominance is the reverse of equitability and has an inverse relationship with diversity, a community is more diverse than another if the k-dominance of one is less than or equal to the other for all values of k from one to whatever is the smaller total number of species (Lambshead et al., 1983).

Faunal and Ecological Affinities - Published records of the species considered for classification were examined to determine their geographical ranges, and establish their faunal affinities in Briggs' (1974) zoogeographic system. Information on juvenile stages was compiled to determine habitat occurrence, ecological roles (Day et al., 1989), feeding modes, and spawning period. This compilation is listed on Appendix A.

Based on the above information, species were fitted into the following categories:

- a. Faunal affinity - (TR) Tropical; (ST) Sub-Tropical (between warm temperate and tropical); (WT) Warm Temperate.
- b. Habitat Affinity - (SZ) surf-zone oriented; (ER) estuarine related (estuarine resident or estuarine dependent); (CM) coastal marine (shallow bays, reefs, rocky bottoms, near bulkheads, excluding the surf-zone and estuaries).
- c. Ecological role - (SW) shallow water - species inhabiting estuarine edges, marshes and grassbeds; (BO) bottom oriented - epibenthic or demersal species that frequently feed and swim in the water column near the bottom; (PE) pelagic - species that swim freely throughout the water column, usually in schools at the surface.
- d. Feeding mode - (BE) benthivore; (PL) planktivore; (OM) omnivore; (PR) predator.
- e. Spawning period - (SP) spring; (SU) summer; (FL) fall; (WN) winter.

Taxonomic Comparisons - Information about species occurrence in the surf-zone of the western South and North Atlantic was compiled from similar studies (fig. 1, Table 5), and compared with the present data in order to examine similarities and variabilities in community composition at the species, genus, and family levels over a latitudinal gradient within hemispheres.

Faunal comparisons were conducted by calculating the Jaccard

**Table 5:** Selected bibliography from localities in the western South (WSA) and North (WNA) Atlantic, used for taxonomic comparisons of surf-zone fish communities within hemispheres.

Locality		Latitude	Authors	Year
WSA				
Laguna	SC	29° 00' S	Monteiro-Neto et al.	in press
Santos	SP	24° 00' S	Paiva Filho and Toscano	1987
WNA				
Sebastian	FL	28° $\pm$ 30' N	Peters and Nelson	1987
Folly Beach	SC	32° 38' N	Anderson et al.	1977
Beaufort	NC	34° 40' N	Tagatz and Dudley	1961
Morris Cove	CT	41° 15' N	Warfell and Merriman	1944

index for presence/absence data:

$$J = \frac{a}{a + b + c}$$

a - number of co-occurrent taxa;

b - number of exclusive taxa in locality 1;

c - number of exclusive taxa in locality 2;

The index is equal to one when taxonomic composition of two samples or localities are exactly the same, and zero when they have no elements in common (Clifford and Stephenson, 1975).

The total number of species, genus and families occurring among all of the above studies within hemisphere was tabulated, and the percentage of taxa occurring in accordance with proposed patterns of consecutive latitudinal distributions calculated in order to examine the proportion of taxa with restricted or widespread distribution.

Similar tabulations and similarity indices were calculated for taxonomic comparisons between Cassino and the Chesapeake Bight. Also, information on the number of species per genus, and number of species per family among those groups shared between hemispheres, as well as their percent contribution to total abundance, were compared in order to examine richness and dominance patterns.

## RESULTS

### Within Habitat - Cassino, WSA

#### Species Abundance

Forty-three species totaling 75,888 individuals were collected in 459 samples taken from March 1980 to February 1982 (Table 6). Fish species were represented in the majority by juveniles ranging in size between 15-150 mm TL (Cunha, 1981). Eleven species comprised over 99% of the total catch in numbers, while the remaining 32 species usually represented less than 0.1% of the total catch each. Trachinotus marginatus, Mugil platanus, Menticirrhus littoralis, Mugil curema and Mugil gaimardianus were the five most abundant species captured. In terms of percent frequency, Mugil curema and Mugil gaimardianus were replaced in the top five by Odonthestes bonariensis and Oncopterus darwini. Nineteen species occurred in less than three samples (Table 6).

Forty species and about 50,000 individuals were captured in 283 samples in YR1 (Table 7). With a reduction of 37.8% in effort, slightly over half as many species (22) and about half the number of individuals were taken in YR2 (Table 8). Trachinotus marginatus, Mugil platanus and Mugil curema occurred among the five most

**Table 6:** Numerical abundance (Abund.), percent (%a) and cumulative percent (Cum.) abundance, frequency (Freq.) and percent frequency (%f) of occurrence of fish species in the surf-zone at Cassino. March 1980 to February 1982.

Species	Abund.	%a	Cum.	Freq.	%f
<u>Trachinotus marginatus</u>	29490	38.9	38.9	316	68.8
<u>Mugil platanus</u>	16674	22.0	60.9	375	81.7
<u>Menticirrhus littoralis</u>	7249	9.5	70.4	222	48.4
<u>Mugil curema</u>	6800	9.0	79.4	133	29.0
<u>Mugil gaimardianus</u>	3984	5.2	84.6	111	24.2
<u>Odonthestes bonariensis</u>	3604	4.7	89.3	227	49.5
<u>Brevoortia pectinata</u>	2965	3.9	93.2	157	34.2
<u>Lycengraulis grossidens</u>	1521	2.0	95.2	89	19.4
<u>Oncopterus darwini</u>	1156	1.5	96.7	203	44.2
<u>Xenomelaniris brasiliensis</u>	1101	1.4	98.1	92	20.0
<u>Anchoa marinii</u>	829	1.1	99.2	22	4.8
<u>Ramnogaster arcuata</u>	160	< 1		40	8.7
<u>Micropogonias furnieri</u>	123	< 1		36	7.8
<u>Caranx latus</u>	89	< 1		24	5.2
<u>Umbrina canosai</u>	30	< 1		4	< 1
<u>Sardinella brasiliensis</u>	27	< 1		7	1.5
<u>Jenynsia lineata</u>	22	< 1		13	2.8
<u>Chloroscombrus chrysourus</u>	9	< 1		4	< 1
<u>Trachinotus carolinus</u>	7	< 1		6	1.3
<u>Parona signata</u>	5	< 1		3	< 1
<u>Paralonchurus brasiliensis</u>	5	< 1		1	< 1
<u>Abudefduf saxatilis</u>	4	< 1		4	< 1
<u>Syngnathus folletti</u>	3	< 1		3	< 1
<u>Porichthys porossissimus</u>	3	< 1		3	< 1
<u>Paralichthys orbignyana</u>	3	< 1		3	< 1
<u>Netuma barba</u>	3	< 1		2	< 1
<u>Menticirrhus americanus</u>	3	< 1		1	< 1
<u>Trichiurus lepturus</u>	2	< 1		2	< 1
<u>Trachinotus falcatus</u>	2	< 1		2	< 1
<u>Epinephelus itajara</u>	2	< 1		2	< 1
<u>Urophycis brasiliensis</u>	1	< 1		1	< 1
<u>Ulaema lefroi</u>	1	< 1		1	< 1
<u>Selene vomer</u>	1	< 1		1	< 1
<u>Pomatomus saltatrix</u>	1	< 1		1	< 1
<u>Poecilia vivipara</u>	1	< 1		1	< 1
<u>Lagocephalus laevigatus</u>	1	< 1		1	< 1
<u>Genidens genidens</u>	1	< 1		1	< 1
<u>Epinephelus nigritum</u>	1	< 1		1	< 1
<u>Cheirodon interruptus</u>	1	< 1		1	< 1
<u>Characidium sp</u>	1	< 1		1	< 1
<u>Leptocephalli</u>	1	< 1		1	< 1
<u>Harengula sp</u>	1	< 1		1	< 1
<u>Gobiesox sp</u>	1	< 1		1	< 1
43 Species	75,888 individuals		459 samples		

Table 7: Numerical abundance (Abund.), percent (%a) and cumulative percent (Cum.) abundance, frequency (Freq.) and percent frequency (%f) of occurrence of fish species in the surf-zone at Cassino. YR1=March 1980 - February 1981.

Species	Abund.	%a	Cum.	Freq.	%f
<u>Trachinotus marginatus</u>	17022	33.4	33.4	191	67.5
<u>Mugil platanus</u>	12862	25.2	58.6	240	84.8
<u>Menticirrhus littoralis</u>	6058	11.9	70.5	160	56.5
<u>Mugil curema</u>	5231	10.3	80.8	85	30.0
<u>Odonthestes bonariensis</u>	2239	4.4	85.2	141	49.8
<u>Mugil gaimardianus</u>	2178	4.3	89.5	60	21.2
<u>Lycengraulis grossidens</u>	1475	2.9	92.4	66	23.3
<u>Xenomelaniris brasiliensis</u>	1094	2.1	94.5	86	30.4
<u>Oncopterus darwini</u>	857	1.7	96.2	142	50.2
<u>Anchoa marinii</u>	768	1.5	97.7	16	5.6
<u>Brevoortia pectinata</u>	761	1.5	99.2	84	29.7
<u>Micropogonias furnieri</u>	118	< 1		31	10.9
<u>Ramnogaster arcuata</u>	89	< 1		20	7.1
<u>Caranx latus</u>	82	< 1		17	6.0
<u>Sardinella brasiliensis</u>	27	< 1		7	2.5
<u>Jenynsia lineata</u>	19	< 1		11	3.9
<u>Parona signata</u>	5	< 1		3	1.1
<u>Paralonchurus brasiliensis</u>	5	< 1		1	< 1
<u>Trachinotus carolinus</u>	4	< 1		3	1.1
<u>Chloroscombrus chrysourus</u>	4	< 1		3	1.1
<u>Abudefduf saxatilis</u>	4	< 1		4	1.4
<u>Syngnathus folletii</u>	3	< 1		3	1.1
<u>Porichthys porossissimus</u>	3	< 1		3	1.1
<u>Paralichthys orbignyana</u>	3	< 1		3	1.1
<u>Menticirrhus americanus</u>	3	< 1		1	< 1
<u>Trichiurus lepturus</u>	2	< 1		2	< 1
<u>Netuma barba</u>	2	< 1		2	< 1
<u>Epinephelus itajara</u>	2	< 1		2	< 1
<u>Urophycis brasiliensis</u>	1	< 1		1	< 1
<u>Ulaema lefroii</u>	1	< 1		1	< 1
<u>Trachinotus falcatus</u>	1	< 1		1	< 1
<u>Poecilia vivipara</u>	1	< 1		1	< 1
<u>Lagocephalus laevigatus</u>	1	< 1		1	< 1
<u>Genidens genidens</u>	1	< 1		1	< 1
<u>Epinephelus nigritum</u>	1	< 1		1	< 1
<u>Cheirodon interruptus</u>	1	< 1		1	< 1
<u>Selene vomer</u>	1	< 1		1	< 1
<u>Characidium sp</u>	1	< 1		1	< 1
<u>Gobiesox sp</u>	1	< 1		1	< 1
<u>Leptocephalli</u>	1	< 1		1	< 1
40 Species	50,932 individuals			283 samples	

**Table 8:** Numerical abundance (Abund.), percent (%a) and cumulative percent (Cum.) abundance, frequency (Freq.) and percent frequency (%f) of occurrence of fish species in the surf-zone at Cassino. YR2-March 1981 - February 1982.

Species	Abund.	%a	Cum.	Freq.	%f
<u>Trachinotus marginatus</u>	12468	49.9	49.9	125	71.0
<u>Mugil platanus</u>	3812	15.3	65.2	135	76.7
<u>Brevoortia pectinata</u>	2204	8.8	74.0	73	41.5
<u>Mugil gaimardianus</u>	1806	7.2	81.2	51	29.0
<u>Mugil curema</u>	1569	6.3	87.5	48	27.3
<u>Odonthestes bonariensis</u>	1365	5.5	93.0	86	48.9
<u>Menticirrhus littoralis</u>	1191	4.8	97.8	62	35.2
<u>Oncopterus darwini</u>	299	1.2	99.0	61	34.6
<u>Ramnogaster arcuata</u>	71	< 1		20	11.4
<u>Anchoa marinii</u>	61	< 1		6	3.4
<u>Lycengraulis grossidens</u>	46	< 1		23	13.1
<u>Umbrina canosai</u>	30	< 1		4	2.3
<u>Xenomelaniris brasiliensis</u>	7	< 1		6	3.4
<u>Caranx latus</u>	7	< 1		7	4.0
<u>Micropogonias furnieri</u>	5	< 1		5	2.8
<u>Chloroscombrus chrysourus</u>	5	< 1		1	< 1
<u>Trachinotus carolinus</u>	3	< 1		3	1.7
<u>Jenynsia lineata</u>	3	< 1		2	1.1
<u>Trachinotus falcatus</u>	1	< 1		1	< 1
<u>Pomatomus saltatrix</u>	1	< 1		1	< 1
<u>Netuma barba</u>	1	< 1		1	< 1
<u>Harengula sp</u>	1	< 1		1	< 1
22 Species	24,956 individuals		176 samples		



abundant and frequent species both years. Menticirrhus littoralis and Odontesthes bonariensis completed the five most abundant species during YR1, whereas Brevoortia pectinata and Mugil gaimardianus so qualified during YR2 (Tables 7 and 8). Ranks of abundance and frequency varied considerably from year to year.

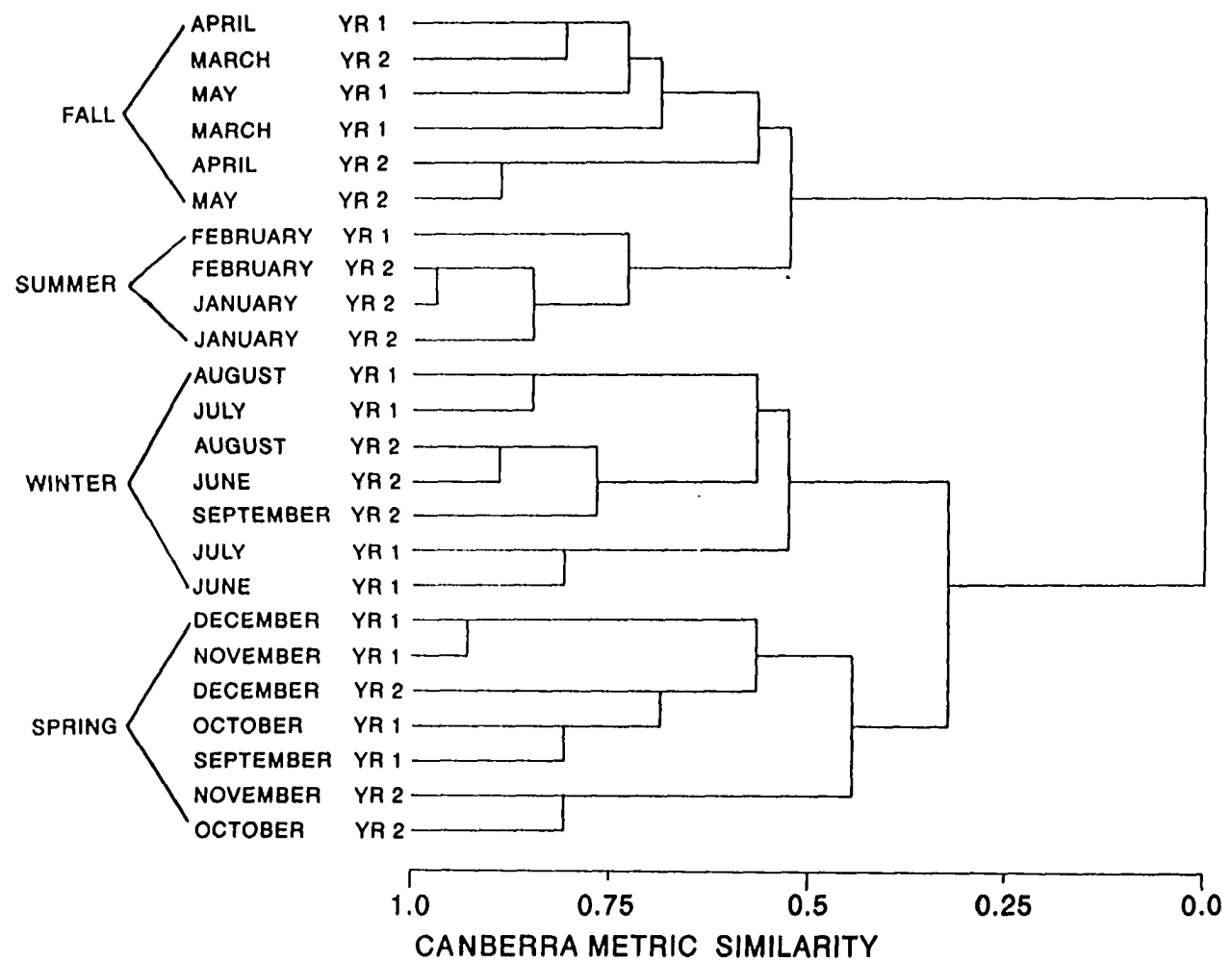
#### Numerical Classification

Normal analysis - Pooled data on species abundance [ $\log_{10}$  (CPUE+1)] by month within years, resulted in cluster groups which could be characterized into the following seasonal groups: spring (YR1: September - December; YR2: October - December); summer (YR1, YR2: January - February); fall (YR1, YR2: March - May); winter (YR1: June - August; YR2: June - September) (Fig. 8).

Table 9 summarizes environmental and catch data within seasonal groups. Water temperature ranged between 22-27° C in the summer group, and 12-18° C in the winter. Wide temperature ranges were observed in the spring and fall groups with minimum and maximum temperatures encompassing the entire range observed (12-27° C). Mean water temperature was considerably lower in the winter than in the other seasons.

Salinity was highly variable and usually ranged between 14-35 ‰ within seasonal groups (Table 9). Even lower minimum salinities were encountered in spring (5.0 ‰) and winter

**Figure 8: Dendrogram of normal cluster analysis at Cassino (WSA).**



**Table 9:** Summary of environmental and catch data within seasonal groups of normal cluster analysis at Cassino. YR1=March 1980 - February 1981; YR2=March 1981 - February 1982;  $\bar{X}$  - mean; SD - standard deviation.

SEASONAL GROUP		SPRING	SUMMER	FALL	WINTER
Months	YR1 YR2	Sep.-Dec. Oct.-Dec.	Jan.-Feb. Jan.-Feb.	Mar.-May Mar.-May	Jun.-Aug. Jun.-Sep.
Number of Samples		166	82	108	103
Temperature (°C)	Range	12.0-27.7	22.0-27.2	12.4-27.3	12.0-17.7
	$\bar{X}$	20.3	24.6	21.2	14.3
	SD	3.6	1.2	2.5	1.0
Salinity (‰)	Range	5.0-36.0	14.0-35.0	14.0-36.0	11.0-34.0
	$\bar{X}$	24.0	30.0	29.0	25.0
	SD	7.4	4.7	4.3	4.8
Number of Species		24	26	27	13
CPUE	range	0.0-445.3	2.0-816.7	1.0-1102.0	1.0-213.3
	$\bar{X}$	23.8	126.9	84.6	14.4
	SD	51.3	141.2	149.1	26.8

(11.0 ‰). Mean salinity was higher in summer and fall than in winter and spring. The widest range and largest variations occurred in spring.

Mean total CPUE was highest in summer and fall, with averages near 130 and 80 fishes per haul respectively. In the winter and spring means were much lower averaging only 14 and 24 fishes per haul (Table 9). Total number of species captured was nearly the same from spring to fall (between 24 and 27), but decreased to 13 species in the winter (Table 9).

Inverse analysis - Inverse cluster analysis identified seven species groups at Cassino, ranging in content from two to five species (Table 10).

Species groups A through C were composed of estuarine related species (Table 10). In group A, juveniles of Ramnogaster arcuata and Anchoa marinii, are common pelagic planktivores of the Patos Lagoon estuary (Appendix A). Xenomelaniris brasiliensis and Jenynsia lineata of group B are omnivorous shallow water residents in the estuary occupying similar niches in vegetated areas. Lycengraulis grossidens and Micropogonias furnieri (group C), although not competing at the niche level, show similar recruitment peaks usually in the summer, after spring spawning (Appendix A, Table 10).

Most species of group D (e.g., Porichthys porossissimus, Sardinella brasiliensis, Umbrina canosai, and Parona signata) are

**Table 10:** Species within groups of inverse cluster analysis at Cassino and their faunal affinity (TR-tropical; ST-sub-tropical; WT-warm temperate), habitat affinity (SZ-surf-zone oriented; CM-coastal marine; ER-estuarine related), ecological role (SW-shallow water; BO-bottom oriented; PE-pelagic), feeding mode (BE-benthivore; PL-planktivore; OM-omnivore; PR-predator), and spawning season (SP-spring; SU-summer; FL-fall; WN-winter).

SPECIES	Fauna	Habitat	Ecol.	Feeding	Spawning
		Afinity	Role	Mode	Season
GROUP A					
<u>Ramnogaster arcuata</u>	WT	ER	PE	PL	?
<u>Anchoa marinii</u>	WT	ER	PE	PL	?
GROUP B					
<u>Xenomelaniris brasiliensis</u>	WT	ER	SW	OM	SP/SU
<u>Jenynsia lineata</u>	WT	ER	SW	OM	SU
GROUP C					
<u>Lycengraulis grossidens</u>	WT	ER	PE	PL	FL/SP
<u>Micropogonias furnieri</u>	WT	ER	BO	BE	WN/SP
GROUP D					
<u>Porichthys porossissimus</u>	WT	CM	BO	BE	?
<u>Sardinella brasiliensis</u>	WT	CM	PE	PL	SP/SU
<u>Syngnathus folletti</u>	WT	ER	SW	PL	?
<u>Umbrina canosai</u>	WT	CM	BO	BE	WN?
<u>Parona signata</u>	WT	CM	PE	PR	?
GROUP E					
<u>Chloroscombrus chrysourus</u>	ST	CM	PE	PL	?
<u>Paralychthys orbignyana</u>	WT	ER	BO	BE	?
<u>Trachinotus carolinus</u>	WT	SZ	PE	BE	SU
<u>Abudefduf saxatilis</u>	TR	CM	BO	OM	?
<u>Caranx latus</u>	ST	CM	PE	BE	?
GROUP F					
<u>Brevoortia pectinata</u>	WT	ER	PE	PL	?
<u>Mugil gaimardianus</u>	WT	ER	BO	OM	SP/SU?
<u>Mugil curema</u>	WT	ER	BO	OM	SU?
GROUP G					
<u>Odontesthes bonariensis</u>	WT	ER	SW	OM	WN/SP
<u>Menticirrhus littoralis</u>	WT	SZ	BO	BE	SP?
<u>Trachinotus marginatus</u>	WT	SZ	PE	BE	SP/SU
<u>Oncopterus darwinii</u>	WT	SZ	BO	BE	?
<u>Mugil platanus</u>	WT	ER	BO	OM	FL/WN

common in coastal waters of the WSA, with juvenile stages eventually penetrating the estuaries (Appendix A, Table 10). Syngnathus folletti, although generally regarded as estuarine resident, is also common in coastal waters at depths less than 30 m (Appendix A).

Group E was composed of an assemblage of species with various habitat affinities. Juvenile Paralichthys orbignyana are common in the Patos Lagoon estuary, whereas Abudefduf saxatilis, Caranx latus and Chloroscombrus chrysourus are usually found in structurally complex coastal marine habitats (rocks, reefs, bulkheads) year round in lower latitudes (Appendix A). Trachinotus carolinus, a common surf-zone species, also has its peak abundance at lower latitudes in the WSA (Appendix A).

Group F was constituted of Brevoortia pectinata and two mugilids (Mugil curema and Mugil gaimardianus). Although juveniles of these species are frequent in coastal waters and the surf-zone, the estuary appears to be their major nursery area (Appendix A).

Species within group G were the most frequently occurring, and among the most abundant in the surf-zone of Cassino (Table 6). Trachinotus marginatus, Menticirrhus littoralis and Oncopterus darwini use the surf-zone as a regular nursery area, seldom being found in estuarine waters (Appendix A). Odonthestes bonariensis, a resident species in the estuary, and juvenile Mugil platanus (estuarine dependent) also belonged to this group (Appendix A, Table 10).

Twenty-three species were representative of the warm temperate fauna of the WSA. One tropical species (Abudefduf saxatilis) and two sub-tropical species (Caranx latus, Chloroscombrus chrysourus) have their center of distribution north of the area (Table 10, Appendix A), and occurred occasionally at Cassino. Of 24 species, only four are primarily associated with the surf-zone (Trachinotus carolinus, Trachinotus marginatus, Oncopterus darwinii and Menticirrhus littoralis), with juveniles using the system as a preferred nursery (Appendix A). According to the literature, 13 species can be characterized as estuarine related and seven as coastal marine, but they occur in the surf-zone uncommonly (Appendix A). Bottom oriented and pelagic species were equally represented (10 species each) and four species were shallow water inhabitants (Odonthestes bonariensis, Xenomelaniris brasiliensis, Jenynsia lineata, and Syngnathus folletti).

According to their feeding mode, species were nearly equally partitioned among benthivores (9), planktivores (7), and omnivores (7) (Appendix A, Table 10). Pelagic species such as Trachinotus spp. and Caranx latus have been reported to feed on the bottom. The shallow water estuarine residents (Odonthestes bonariensis, Xenomelaniris brasiliensis, Jenynsia lineata) and the mullets comprised the omnivores in the surf-zone habitat.

Analysis of the literature indicated that most species spawn in late winter (August) and spring (September - November), but



information about the life history of many species is unavailable (Appendix A).

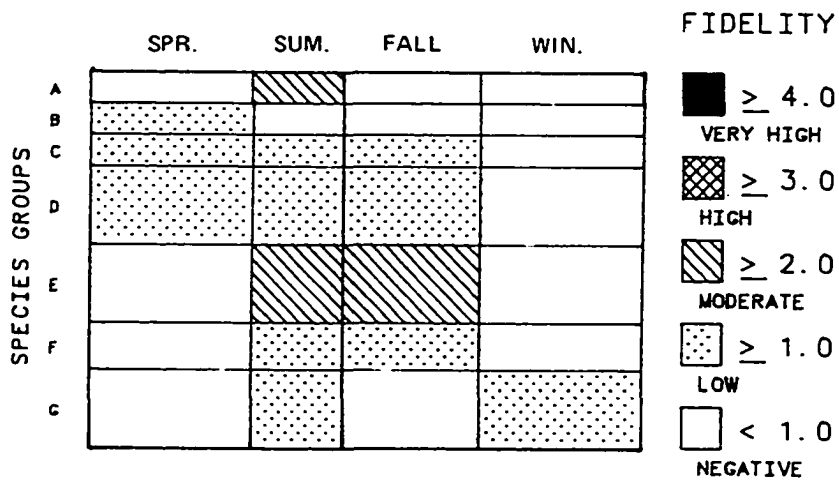
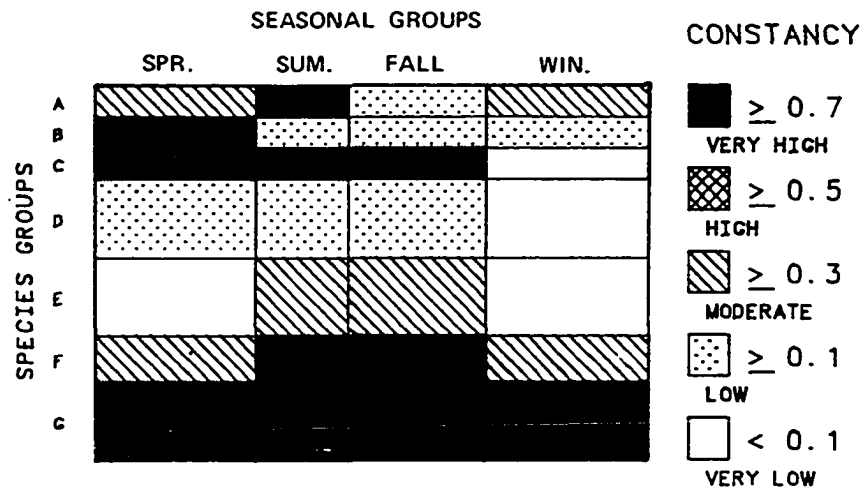
Nodal Analysis - Nodal analysis indicated that species group G was highly constant within seasonal groups. Species within this group occurred every month of the year, often in considerable abundance. High constancy and low fidelity throughout the sampling period at Cassino, characterized group G as ubiquitous surf-zone residents (Fig. 9).

Species groups A through F usually occurred in the surf-zone with moderate to very high constancy on a seasonal basis, but fidelities were usually low, indicating the absence of a strong association of any of the species groups with any particular one of the seasonal groups derived from normal classification (Fig. 9).

Species groups A through C, constituted of estuarine related species, usually showed higher constancy during the warmer months. Group A had a very high constancy and moderate fidelity in the summer, group B was highly constant in the spring, and constancy of group C remained very high from spring to fall, with negative fidelity in the winter (Fig. 9).

Both constancy and fidelity of group D were low (Fig. 9). Species within this group are common in shallow waters of the WSA, but in the surf-zone, they usually represented less than 1% of the total catch individually, and occurred in less than 1% of the

Figure 9: Nodal constancy (top) and fidelity (bottom) diagrams showing inter-relations between seasonal groups (spring to winter) and species groups (A to G) at Cassino. Rows and columns were drawn proportionally to the number of group members.



- CASSINO BEACH -

samples (Table 6), indicating that they occurred as occasional visitors usually in low abundances.

Group E occurred with moderate constancy and fidelity during the summer and fall (Fig. 9), but species within the group were nearly absent from beach seines during the rest of the year. Group F also showed very high constancy during the summer and fall, due to peak abundance of both mugillid species at this time of the year (Vieira, in press b).

#### Dominance

Species of group G were usually among the top five dominants in all seasonal groups, occurring in over 50% of the samples with an average percent abundance greater than 7% (Table 11). Trachinotus marginatus most strongly dominated the community in the summer and fall, Odontesthes bonariensis was the top dominant in the spring, and Mugil platanus was the most dominant in the winter occurring in 100% of the samples (Table 11). Oncopterus darwinii was most dominant in the winter and spring.

In the winter, only the species from group G remained dominant, with each occurring in at least in 50% of the samples and contributing more than 11% of total numerical abundance. Species within group F were among the dominants during the summer and fall (Table 11). Other species occurred sporadically as dominants on a seasonal basis (Xenomelaniris brasiliensis - spring, fall; Micropogonias furnieri, Lycengraulis grossidens - summer, fall;

**Table 11:** Species dominance indicated by percent frequency (%) and average percent abundance ( $\bar{X}$ ) of species within seasonal groups at Cassino. Only species included in numerical classification are reported.

	SPRING		SUMMER		FALL		WINTER	
	%	$\bar{X}$	%	$\bar{X}$	%	$\bar{X}$	%	$\bar{X}$
GROUP A								
<u>Ramnogaster arcuata</u>	18	2.4	56	5.4	4	0.6	11	1.9
<u>Anchoa marinii</u>	7	0.9	28	2.3	4	0.6	2	0.3
GROUP B								
<u>Xenomelaniris brasiliensis</u>	41	7.2			40	4.5	9	1.5
<u>Jenynsia lineata</u>	18	2.2	3	0.3			2	0.3
GROUP C								
<u>Lycengraulis grossidens</u>	29	3.7	78	7.4	31	3.6		
<u>Micropogonias furnieri</u>	16	2.4	28	1.9	22	2.2		
GROUP D								
<u>Porichthys porosissimus</u>	2	0.2	3	0.2			2	0.3
<u>Sardinella brasiliensis</u>			19	1.2				
<u>Syngnathus folletti</u>	4	0.3			2	0.2		
<u>Umbrina canosai</u>	2	0.2	9	1.1				
<u>Parona signata</u>	2	0.2			4	0.4		
GROUP E								
<u>Chloroscombrus chrysourus</u>			3	0.3	7	0.6		
<u>Paralichthys orbignyana</u>			6	0.5	2	0.2		
<u>Trachinotus carolinus</u>	4	0.4	6	0.6	4	0.5		
<u>Abudefduf saxatilis</u>			6	0.4	2	0.1		
<u>Caranx latus</u>			13	0.8	36	3.8		
GROUP F								
<u>Brevoortia pectinata</u>	46	8.1	88	8.2	78	10.4	9	1.9
<u>Mugil gaimardianus</u>	2	0.2	88	8.7	73	10.3	13	2.9
<u>Mugil curema</u>	4	0.4	91	9.5	84	10.6	6	1.1
GROUP G								
<u>Odontesthes bonariensis</u>	93	18.1	97	9.6	64	8.1	54	11.2
<u>Menticirrhus littoralis</u>	46	7.0	100	11.7	69	8.5	57	11.7
<u>Trachinotus marginatus</u>	64	12.4	100	13.2	100	17.6	93	22.8
<u>Oncopterus darwini</u>	82	14.4	38	3.9	24	2.4	85	18.9
<u>Mugil platanus</u>	88	17.6	97	11.2	98	12.9	100	25.0

Caranx latus - fall), but the magnitude of both abundance and occurrence were usually much lower when compared with dominant species from groups F and G (Table 11).

#### Analysis of Covariance

The ANCOVA model, blocked by year (YR1/YR2) at Cassino was highly significant ( $P < 0.01$ ) and explained 53% of the total variation in total  $\log_{10}$  (CPUE+1) (Table 12). Block effects need not be associated with any significant probability levels, primarily because they are known sources of variation that need to be excluded from the error term. Nevertheless, a highly significant block effect at Cassino (Table 12) further supported the apriori hypothesis that yearly variations in abundance do occur.

Significant interaction between seasons and water temperature (Table 12) indicate regression slopes non-homogeneous, that both factor and covariate are interdependent, and that changes in total community abundance occur among seasons and within seasons with water temperature.

Figure 10 shows plots of total  $\log_{10}$  (CPUE+1) against water temperature within each season, along with fitted regression lines by year. Differences in the magnitude of observed total CPUE values were apparent between seasons, with larger catches occurring in the summer.

Regression lines are parallel to the x axis during summer and

**Table 12:** ANCOVA model for  $\log_{10}$  (total CPUE+1) at Cassino.

Degrees of freedom (df), sums of squares (SS), standardized F distribution scores (F), probability ( $P > F$ ), significance level (\* - significant; \*\* - highly significant), and correlation coefficient ( $r^2$ ).

SOURCE	df	SS	F	$P > F$		$r^2$
MODEL	54	88.522	8.15	0.000	**	0.53
ERROR	395	79.435				
BLOCK						
Year (YR1/YR2)	1	4.769	23.71	0.000	**	
COVARIATES						
Salinity (SL)	1	0.560	2.79	0.096		
Water Temp. (WT)	1	1.153	5.74	0.017	*	
FACTORS						
Season (SS)	3	1.863	3.09	0.027	*	
Station (ST)	7	1.056	0.75	0.629		
INTERACTIONS						
SS*ST	21	5.853	1.39	0.120		
WT*SS	3	1.604	2.66	0.048	*	
WT*ST	7	1.078	0.77	0.616		
SL*SS	3	1.208	2.00	0.113		
SL*ST	7	0.656	0.47	0.859		

Figure 10: Scatter plot of the  $\log_{10} (\text{CPUE}+1)$  for individual samples against water temperature by season, and fitted regression lines for each year at Cassino.



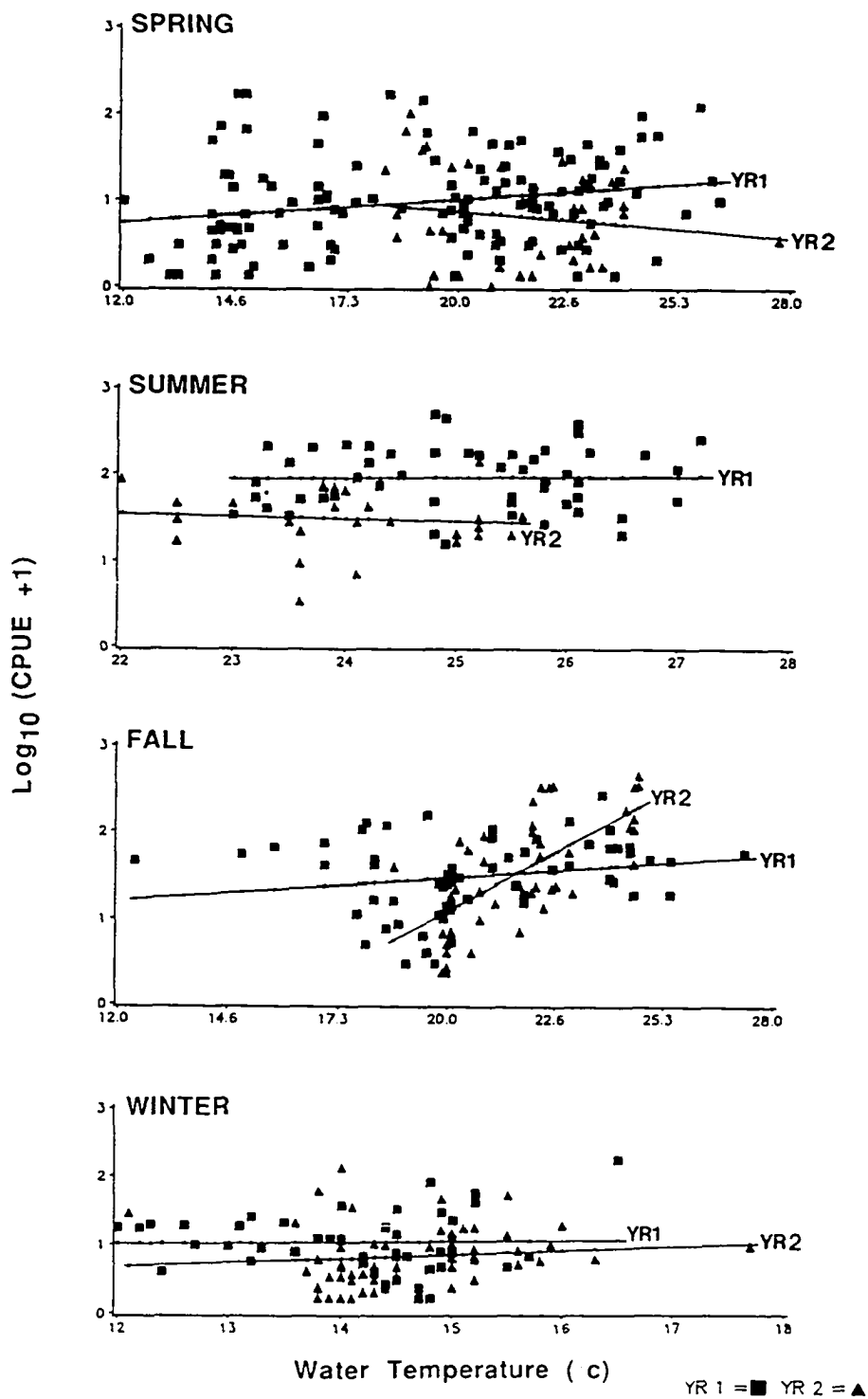


Figure 11: Scatter plot of the  $\log_{10} (\text{CPUE}+1)$  against water temperature by season, of the five most abundant species on YR1 (March 1980 - February 1981) at Cassino.

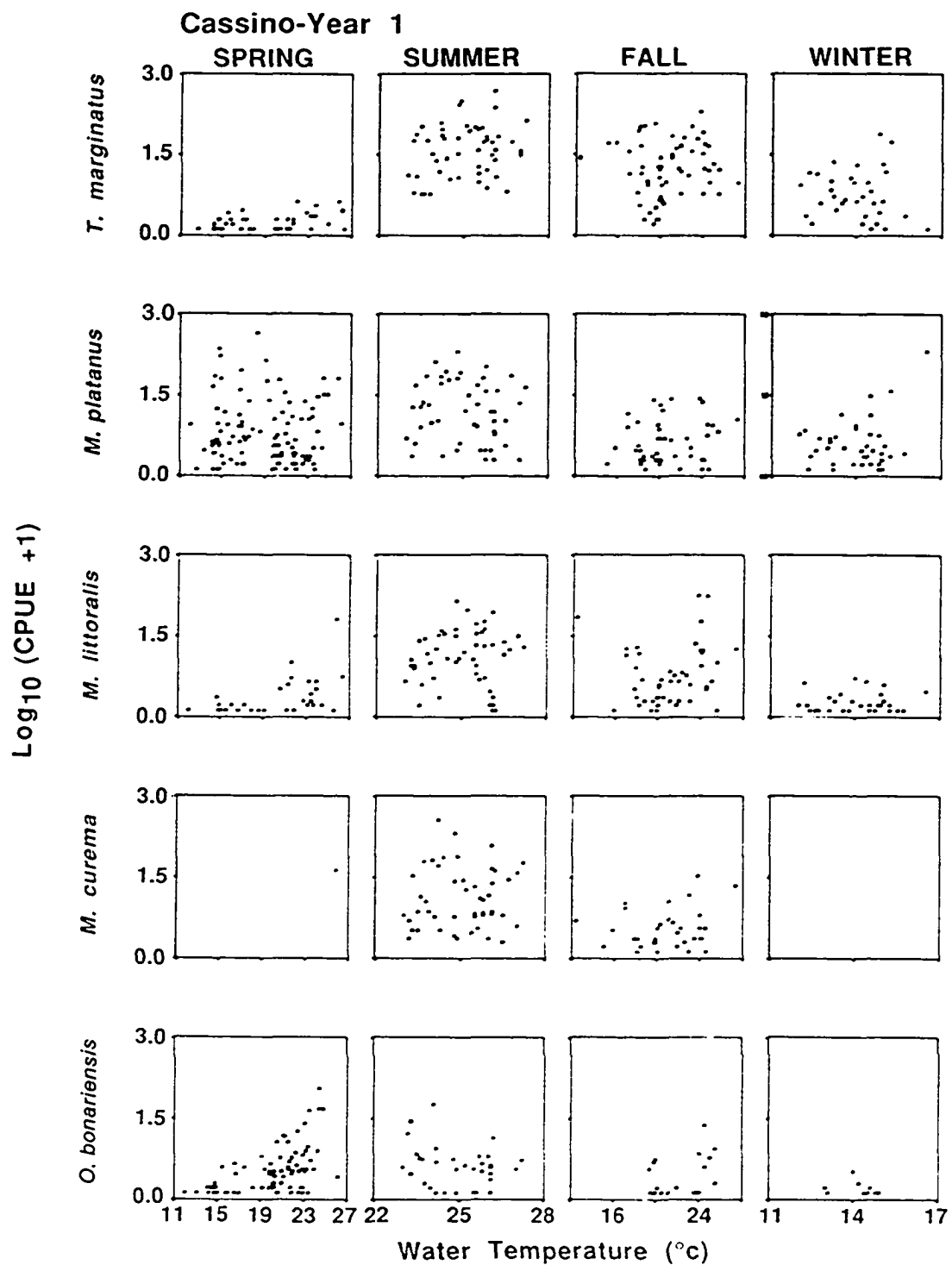
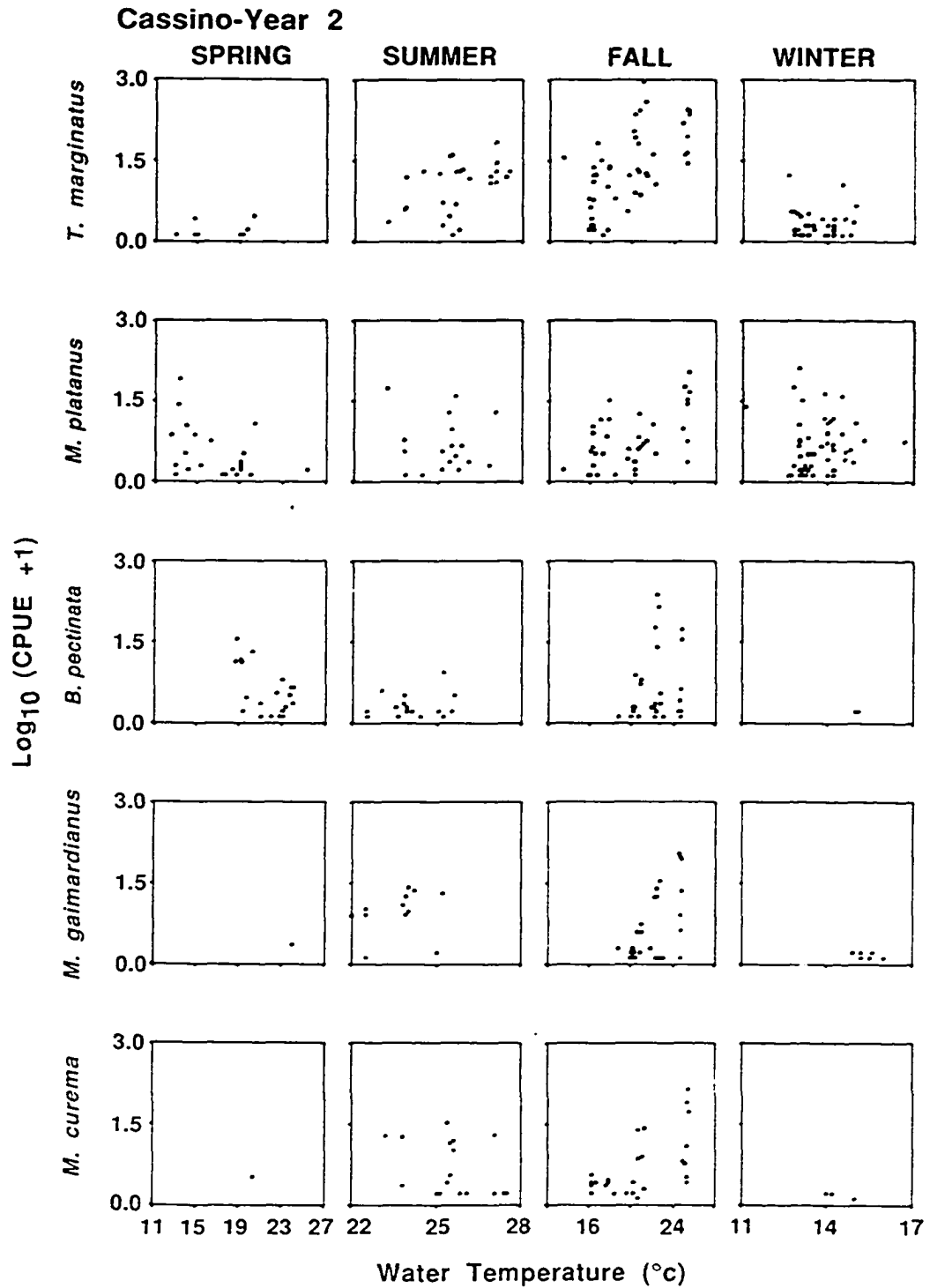


Figure 12: Scatter plot of the  $\log_{10} (\text{CPUE}+1)$  against water temperature by season, of the five most abundant species on YR2 (March 1981 - February 1982) at Cassino.



winter indicating the absence of any relationship between abundance and water temperature (Fig. 10).

In spring and fall regression lines crossed each other. In the spring the abundance trend was positive in YR1 (total CPUE increased at higher water temperatures), and negative in YR2. In the fall, a trend towards large catches at higher water temperatures was evident especially during YR2 (Fig. 10).

Trends for one or more dominant species may influence community abundance, but most of the top five abundant species show little relationship between temperature and abundance, and much variation within a season (figures 11 and 12).

Considerable changes in abundance occur among seasons, and CPUE values tend to be higher during the summer and fall for all species. Only Trachinotus marginatus and Mugil platanus were caught in reasonable numbers during the winter of both years (Figs. 11 and 12).

#### Community Structure Indices

The analysis of community structure indices at Cassino was segregated by yearly period (YR1/YR2) because of the variation in community abundance and composition determined above. All community structure indices affected by the number of species (S, H', D), showed a characteristic trend each year of lowest mean values in the spring and winter, a peak in the summer, and intermediate values in

Figure 13: Mean number of species (S), Shannon-Wiener diversity ( $H'$ ), equitability ( $J'$ ) and species richness (D) per sample (point diversity) by season by year at Cassino. Spring (Sp), summer (Su), fall (Fl), winter (Wn). Bars indicate 95% confidence intervals for the mean.

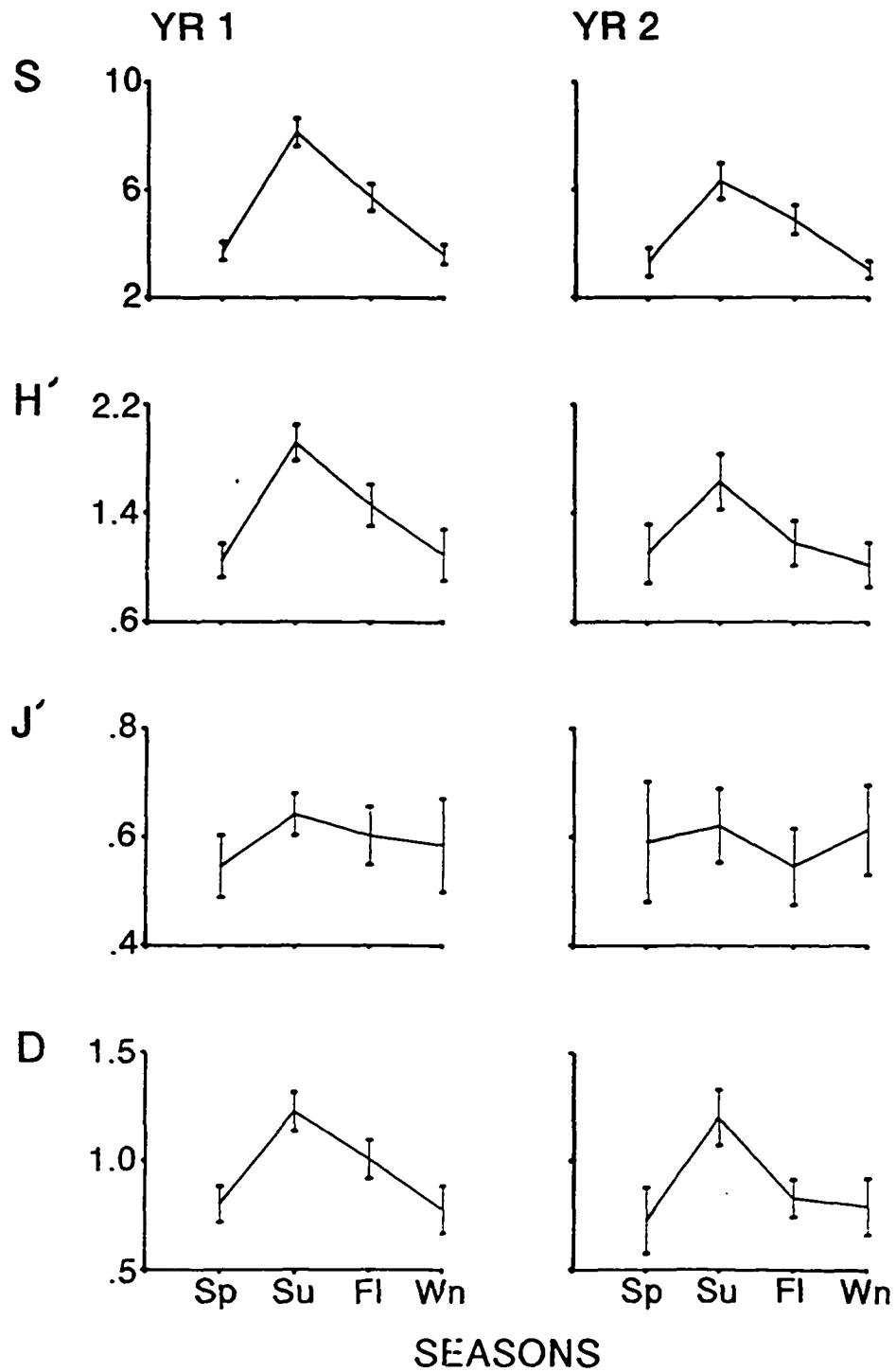
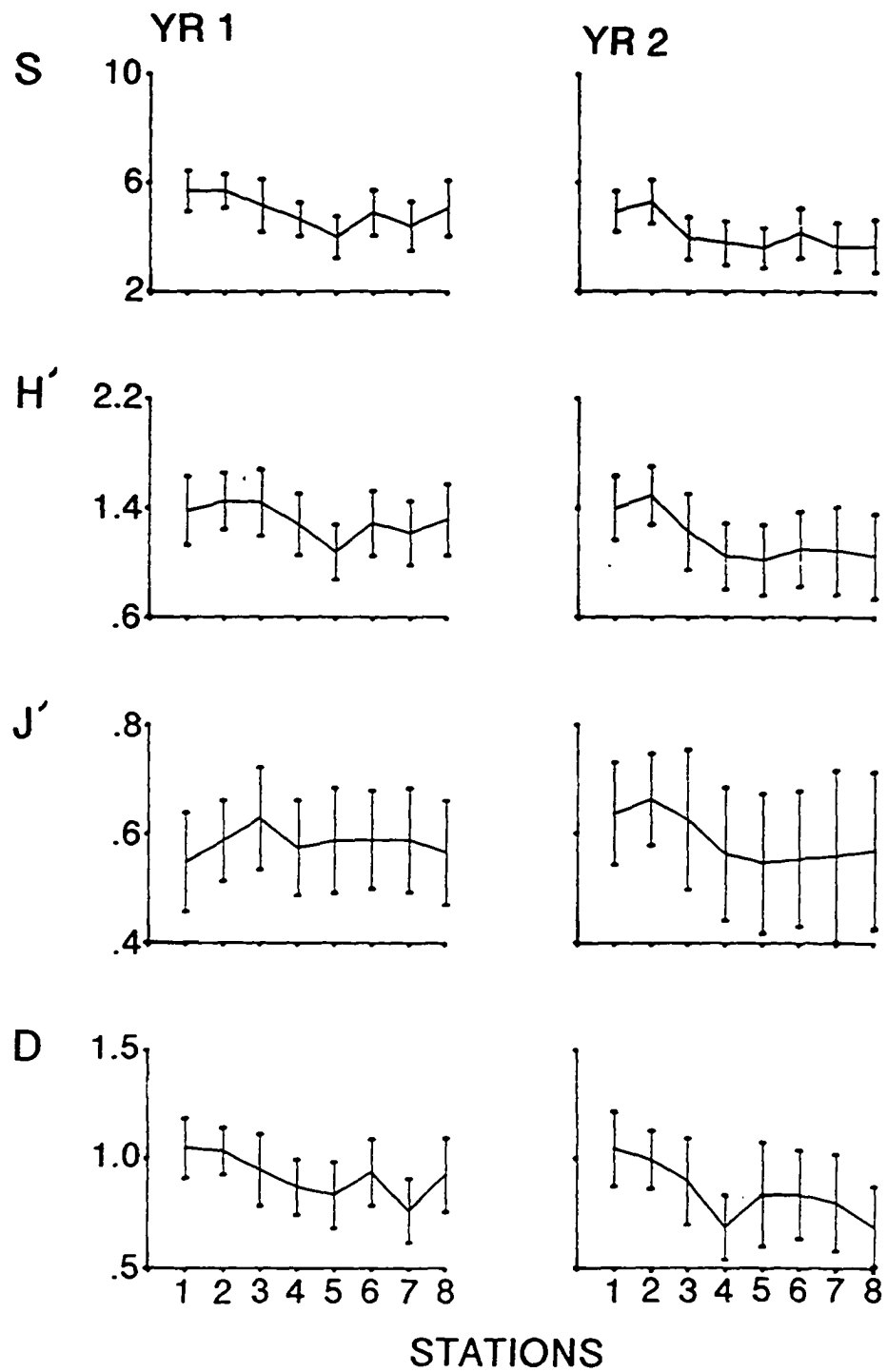




Figure 14: Mean number of species (S), Shannon-Wiener diversity ( $H'$ ), equitability ( $J'$ ) and species richness (D) per sample (point diversity) by sampling station (1-8) by year at Cassino. Bars indicate 95% confidence intervals for the mean.



the fall (Fig. 13). In contrast, average equitability ( $J'$ ) showed high variability within seasons and non-consistent seasonal patterns between years. The low average sample equitability in the fall of YR2 influenced both the Shannon-Wiener diversity and the Richness functions (Fig. 13).

Community structure indices were highly variable among sampling stations at Cassino (Fig. 14). Mean number of species, Shannon-Wiener diversity and species richness tended to be higher at stations near the estuary (1-3), decreased at intermediate stations (4-5), and became less stable at the furthest stations (6-8). Mean equitability showed a similar patterns in YR2, but in YR1 it was lower near the estuary, increased in the mid-point, and decreased towards the furthest stations (Fig. 14).

Overlapping confidence intervals among concomitant sampling sites suggested no significant spatial patterns, but the above trends were consistent from year to year, especially for the number of species (Fig. 14).

#### Species Rarefaction

Seasonally, species rarefaction curves (Fig. 15) were strongly influenced by abundance. Peak recruitment of Trachinotus marginatus, occurred in the summer of YR1 and fall of YR2, and probably accounted for most of the variation encountered, and the lower richness during both of the periods. Lowest richness occurred in the winter of each year.

Figure 15: Rarefaction curves by season by year at Cassino indicating the total number of species (endpoint) and the back calculated values for different sample sizes (number of individuals). Spring (SP), summer (SU), fall (FL), winter (WN).

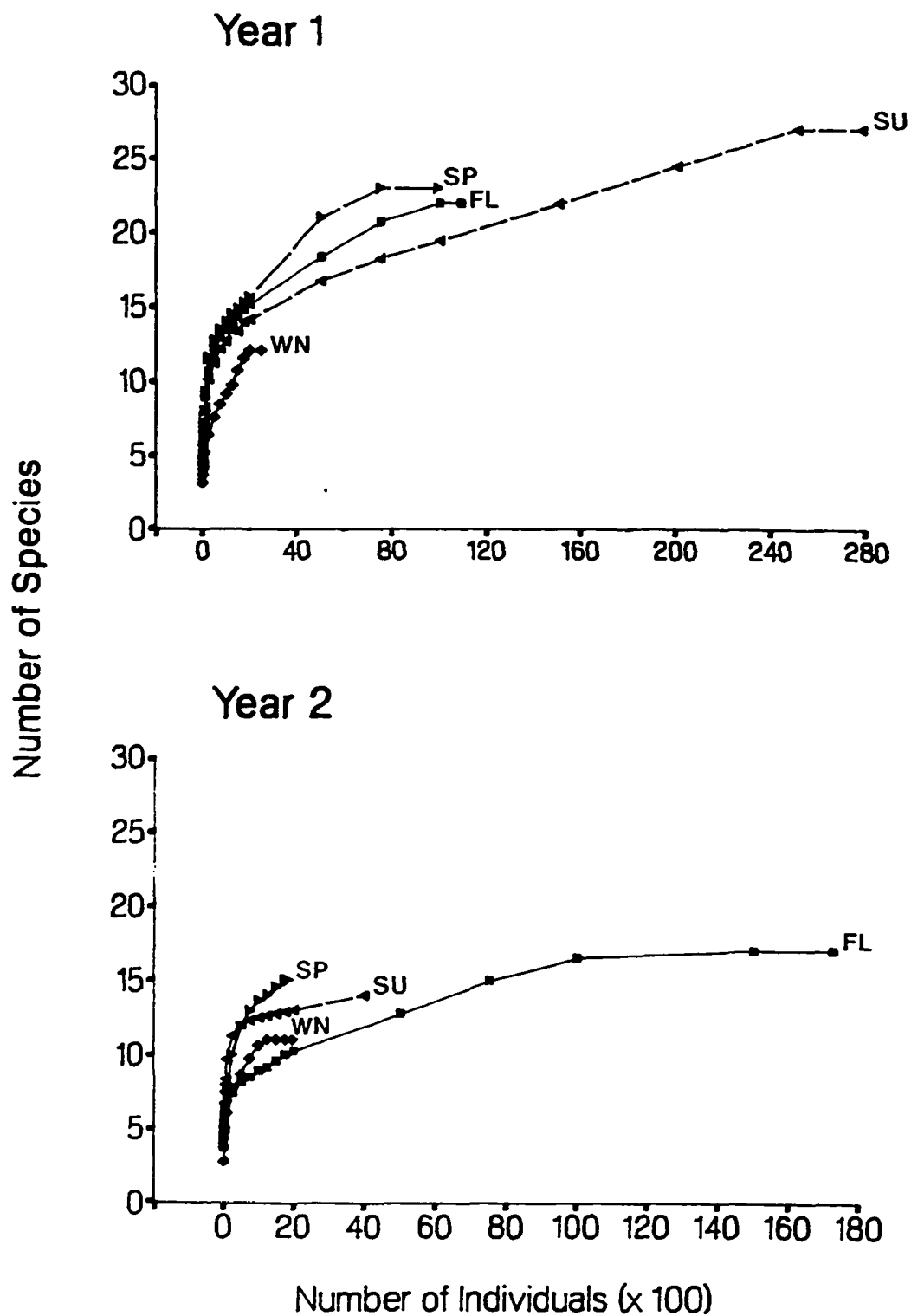
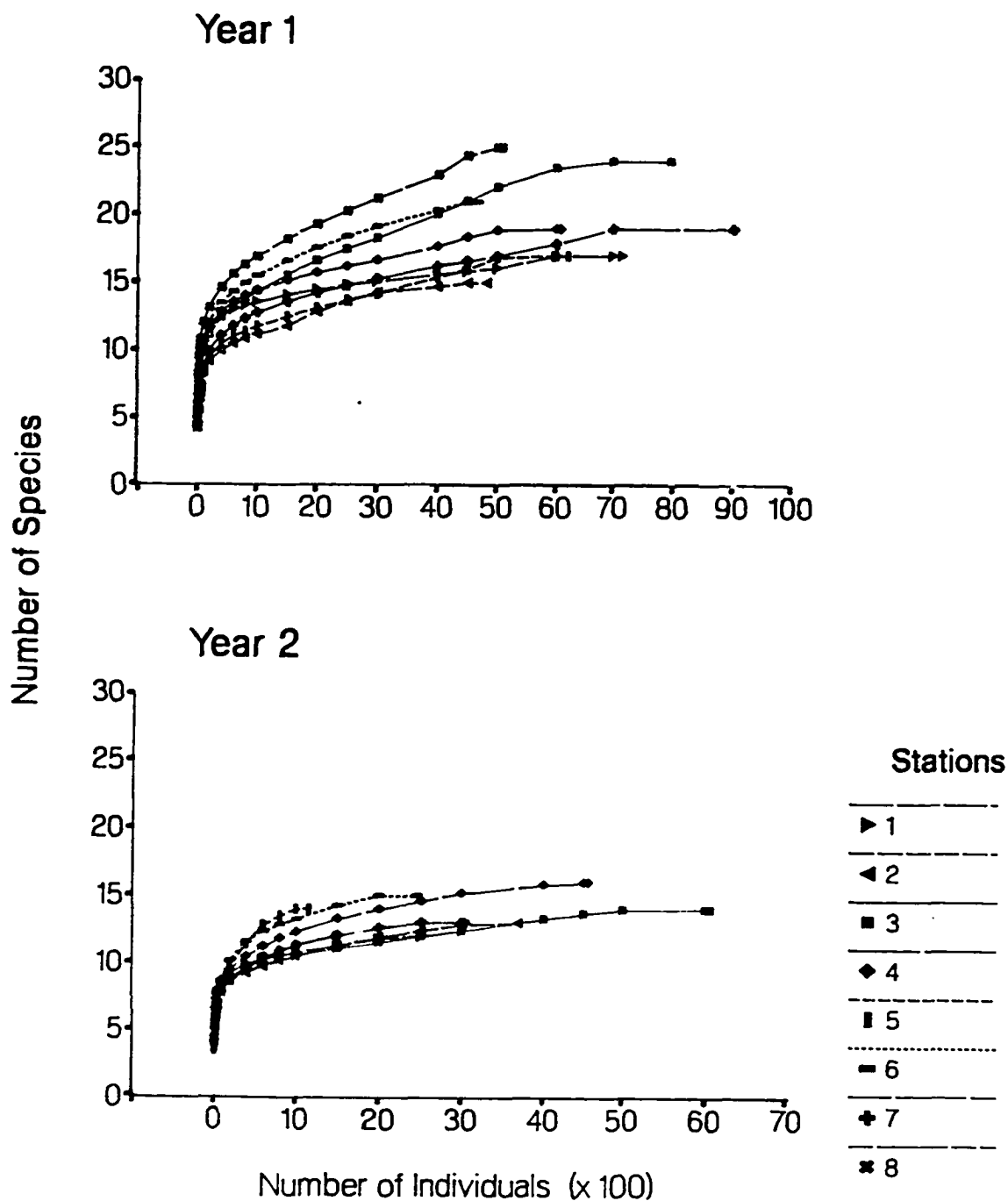


Figure 16: Rarefaction curves by sampling station (1-8) by year at Cassino indicating the total number of species (endpoint) and the back calculated values for different sample sizes (number of individuals).



Species richness at each sampling station varied randomly among stations and among yearly periods, and conclusive patterns were not apparent (Fig. 16).

#### Taxonomic Comparison (WSA)

The total number of taxa at each selected location in the WSA was greatest at Cassino (CA), lowest at Laguna (SC) and intermediate at Santos (SP), and probably reflected differences in sampling effort (Table 13). Within the same taxonomic level (species, genus or family) faunal similarities decreased from Laguna (SC) towards Santos (SP). Across taxonomic levels within locality, similarity increased from species to family (Table 13).

A total of 64 species, 48 genera, and 30 species occurred among all the above selected locations (Table 14). Cassino (CA) had the greatest percentage (> 40%) and Laguna the lowest percentage (< 6%) of mutually exclusive taxa. Mutually exclusive species were usually occasional in occurrence and often represented by one or two individuals (e.g., Cheirodon interruptus, CA; Anchoa tricolor, SC; Polydactylus oligodon, SP). However, species occurring at Santos (SP) tended to be of sub-tropical and tropical distribution.

About 17% of the species, 17% of the genera and 23% of the families were found in all locations (Table 14), and shared taxa were often numeric dominants in the surf-zone (e.g., Menticirrhus littoralis, Mugil spp., Odontesthes bonariensis, Trachinotus spp.).



**Table 13:** Total number of species, genera, and families collected at Cassino and selected localities of the western South Atlantic; number of shared species, genus and families (commonality), and faunal similarities (Jaccard) among these localities and Cassino (CA), at each taxonomic level. Effort=number of samples taken.

	CA	SC	SP
Total Species	43	25	28
commonality	-	17	11
Jaccard	-	0.33	0.18
Total Genera	36	15	21
commonality	-	12	9
Jaccard	-	0.31	0.19
Total Families	23	11	15
commonality	-	10	8
Jaccard	-	0.42	0.27
Effort (samples)	459	24	63

CA = Casino, RS, Brazil (32° S), present data;

SC = Laguna, SC, Brazil (29° S), Monteiro-Neto et al., (in press);

SP = Santos, SP, Brazil (24° S), Paiva Filho and Toscano (1987).

**Table 14:** Pooled number of species, genera, and families collected at Cassino and selected localities of the western South Atlantic, and the proportions in which taxa occurred within the patterns indicated by the stars (\*). 'No Pattern'-occurrences did not follow any of the proposed patterns.

CA	SC	SP	% species	% genus	% family
*			40.6	47.9	40.0
	*		6.3	0.0	0.0
		*	20.3	18.8	20.0
* --- *			9.4	8.3	10.0
* --- *	* --- *		17.2	16.7	23.3
	* --- *		6.3	6.3	3.3
-No Pattern-			0.0	2.1	3.3
Pooled Number (100%)			64	48	30

CA = Cassino, RS, Brazil (32° S), present data;

SC = Laguna, SC, Brazil (29° S), Monteiro-Neto et al., (in press);

SP = Santos, SP, Brazil (24° S), Paiva Filho and Toscano (1987).

Co-occurrences between two geographically adjacent localities indicated that more taxa were shared between Cassino (CA) and Laguna (SC) than Laguna (SC) and Santos (SP) (Table 14).

## Within Region - Chesapeake Bight, WNA

Species Abundance

Eighty samples (40 at Cape Hatteras and 40 at Sandbridge) comprising 40 species and 4,491 individuals (18-210 mm TL) were collected from July 1973 to June 1974 (Table 15). Menticirrhus littoralis, Trachinotus carolinus, Menidia menidia, Syngnathus fuscus and Membras martinica, were the five most abundant species comprising more than 70% of the total catch in numbers. In terms of percent frequency, Syngnathus fuscus was replaced in the five most frequent by Mugil curema. Ten species accounted for nearly 90% of the total abundance, while 27 species each comprised less than 1% of the total numerical abundance (Table 15). Collections at Cape Hatteras yielded a total of only 18 species and 1,590 individuals, whereas at Sandbridge, twice as many species and almost twice as many individuals (2,901) were captured during the same period with the same effort (Tables 16 and 17). Trachinotus carolinus, Menticirrhus littoralis, Membras martinica, Monacanthus hispidus and Trachinotus goodei were respectively the five most abundant and frequent species in beach seine catches at Cape Hatteras (Table 16), and Menticirrhus littoralis, Trachinotus carolinus, Menidia menidia, Syngnathus fuscus and Bairdiella chrysoura were the most abundant in decreasing order at Sandbridge (Table 17). The last two species were replaced by Mugil curema and Mugil cephalus in terms of percent

**Table 15:** Numerical abundance (Abund.), percent (%a) and cumulative percent (Cum.) abundance, frequency (Freq.) and percent frequency (%f) of occurrence of fish species in the surf-zone of the Chesapeake Bight (July 1973 - June 1974).

Species	Abund.	%a	Cum.	Freq.	%f
<u>Menticirrhus littoralis</u>	1616	36.0	36.0	47	58.7
<u>Trachinotus carolinus</u>	943	21.0	57.0	33	41.2
<u>Menidia menidia</u>	291	6.5	63.5	19	23.7
<u>Syngnathus fuscus</u>	227	5.0	68.5	7	8.7
<u>Membras martinica</u>	217	4.8	73.3	18	22.5
<u>Bairdiella chrysoura</u>	217	4.8	78.1	9	11.2
<u>Mugil curema</u>	199	4.4	82.5	18	22.5
<u>Micropogonias undulatus</u>	160	3.6	86.1	6	7.5
<u>Anchoa hepsetus</u>	114	2.5	88.6	7	8.7
<u>Monacanthus hispidus</u>	93	2.1	90.7	12	15.0
<u>Anchoa mitchilli</u>	70	1.6	92.3	9	11.2
<u>Trachinotus goodei</u>	63	1.4	93.7	12	15.0
<u>Mugil cephalus</u>	51	1.1	94.8	15	18.7
<u>Leiostomus xanthurus</u>	43	< 1		7	8.7
<u>Pomatomus saltatrix</u>	41	< 1		5	6.2
<u>Menticirrhus saxatilis</u>	32	< 1		7	8.7
<u>Selene vomer</u>	22	< 1		5	6.2
<u>Syngnathus floridae</u>	17	< 1		4	5.0
<u>Caranx hippos</u>	14	< 1		6	7.5
<u>Brevoortia tyrannus</u>	14	< 1		3	3.7
<u>Sphaeroides maculatus</u>	6	< 1		5	6.2
<u>Ophidion marginatum</u>	6	< 1		3	3.7
<u>Syngnathus louisianae</u>	5	< 1		5	6.2
<u>Trachinotus falcatus</u>	4	< 1		3	3.7
<u>Paralichthys squamilentus</u>	4	< 1		1	1.2
<u>Chaetodon ocellatus</u>	4	< 1		1	1.2
<u>Paralichthys dentatus</u>	2	< 1		1	1.2
<u>Lutjanus griseus</u>	2	< 1		2	2.5
<u>Astroscopus guttatus</u>	2	< 1		1	1.2
<u>Aluterus schoepfi</u>	2	< 1		1	1.2
<u>Tylosurus acus</u>	1	< 1		1	1.2
<u>Sphyræna borealis</u>	1	< 1		1	1.2
<u>Prionotus tribulus</u>	1	< 1		1	1.2
<u>Gasterosteus aculeatus</u>	1	< 1		1	1.2
<u>Fundulus heteroclitus</u>	1	< 1		1	1.2
<u>Cyprinodon variegatus</u>	1	< 1		1	1.2
<u>Cynoscion regalis</u>	1	< 1		1	1.2
<u>Chilomicterus schoepfi</u>	1	< 1		1	1.2
<u>Chaetodipterus faber</u>	1	< 1		1	1.2
<u>Caranx latus</u>	1	< 1		1	1.2
40 Species	4,491 individuals			80 samples	

**Table 16:** Numerical abundance (Abund.), percent (%a) and cumulative percent (Cum.) abundance, frequency (Freq.) and percent frequency (%f) of occurrence of fish species in the surf-zone at Cape Hatteras (July 1973 - June 1974).

Species	Abund.	%a	Cum.	Freq.	%f
<u>Trachinotus carolinus</u>	622	39.1	39.1	20	50.0
<u>Menticirrhus littoralis</u>	611	38.4	77.5	28	70.0
<u>Membras martinica</u>	95	6.0	83.5	8	20.0
<u>Monacanthus hispidus</u>	92	5.8	89.3	11	27.5
<u>Trachinotus goodei</u>	63	4.0	93.3	12	30.0
<u>Mugil curema</u>	37	2.3	95.6	7	17.5
<u>Menidia menidia</u>	36	2.3	97.9	5	12.5
<u>Caranx hippos</u>	12	< 1		4	10.0
<u>Mugil cephalus</u>	5	< 1		4	10.0
<u>Sphaeroides maculatus</u>	4	< 1		3	7.5
<u>Paralichthys squamilentus</u>	4	< 1		1	2.5
<u>Trachinotus falcatus</u>	2	< 1		1	2.5
<u>Menticirrhus saxatilis</u>	2	< 1		2	5.0
<u>Tylosurus acus</u>	1	< 1		1	2.5
<u>Sphyraena borealis</u>	1	< 1		1	2.5
<u>Lutjanus griseus</u>	1	< 1		1	2.5
<u>Leiostomus xanthurus</u>	1	< 1		1	2.5
<u>Anchoa mitchilli</u>	1	< 1		1	2.5
18 Species	1,590 individuals			40 samples	

Table 17: Numerical abundance (Abund.), percent (%a) and cumulative percent (Cum.) abundance, frequency (Freq.) and percent frequency (%f) of occurrence of fish species in the surf-zone at Sandbridge (July 1973 - June 1974).

Species	Abund.	%a	Cum.	Freq.	%f
<u>Menticirrhus littoralis</u>	1005	34.6	34.6	19	47.5
<u>Trachinotus carolinus</u>	321	11.1	45.7	13	32.5
<u>Menidia menidia</u>	255	8.8	54.5	14	35.0
<u>Syngnathus fuscus</u>	227	7.8	62.3	7	17.5
<u>Bairdiella chrisoura</u>	217	7.5	69.8	9	22.5
<u>Mugil curema</u>	162	5.6	75.4	11	27.5
<u>Micropogonias undulatus</u>	160	5.5	80.9	6	15.0
<u>Membras martinica</u>	122	4.2	85.1	10	25.0
<u>Anchoa hepsetus</u>	114	3.9	89.0	7	17.5
<u>Anchoa mitchilli</u>	69	2.4	91.4	8	20.0
<u>Mugil cephalus</u>	46	1.6	93.0	11	27.5
<u>Leiostomus xanthurus</u>	42	1.4	94.4	6	15.0
<u>Pomatomus saltatrix</u>	41	1.4	95.8	5	12.5
<u>Menticirrhus saxatilis</u>	30	1.0	96.8	5	12.5
<u>Selene vomer</u>	22	< 1		5	12.5
<u>Syngnathus floridae</u>	17	< 1		4	10.0
<u>Brevoortia tyrannus</u>	14	< 1		3	7.5
<u>Ophidion marginatum</u>	6	< 1		3	7.5
<u>Syngnathus louisianae</u>	5	< 1		5	12.5
<u>Chaetodon ocellatus</u>	4	< 1		1	2.5
<u>Trachinotus falcatus</u>	2	< 1		2	5.0
<u>Sphaeroides maculatus</u>	2	< 1		2	5.0
<u>Paralichthys dentatus</u>	2	< 1		1	2.5
<u>Caranx hippos</u>	2	< 1		2	5.0
<u>Astroscopus guttatus</u>	2	< 1		1	2.5
<u>Aluterus schoepfi</u>	2	< 1		1	2.5
<u>Prionotus tribulus</u>	1	< 1		1	2.5
<u>Monacanthus hispidus</u>	1	< 1		1	2.5
<u>Lutjanus griseus</u>	1	< 1		1	2.5
<u>Gasterosteus aculeatus</u>	1	< 1		1	2.5
<u>Fundulus heteroclitus</u>	1	< 1		1	2.5
<u>Cyprinodon variegatus</u>	1	< 1		1	2.5
<u>Cynoscion regalis</u>	1	< 1		1	2.5
<u>Chilomicterus schoepfi</u>	1	< 1		1	2.5
<u>Chaetodipterus faber</u>	1	< 1		1	2.5
<u>Caranx latus</u>	1	< 1		1	2.5
36 Species	2,901 individuals			40 samples	

frequency. Seven species at Cape Hatteras and 14 species at Sandbridge occurred only once in the collections (Tables 16 and 17).

#### Numerical Classification

Normal analysis - Eight cluster groups reflected seasonal patterns, and a geographical variation between Cape Hatteras and Sandbridge, since pooled monthly collections from the same period at each of the two localities never clustered together within the same group (Fig. 17). Seasonal groups in Cape Hatteras were defined as: spring (March, April), summer (June - August), fall (September - October), winter (November - January); and in Sandbridge as: spring (May - June), summer (July - August), fall (September - October), winter (November - March).

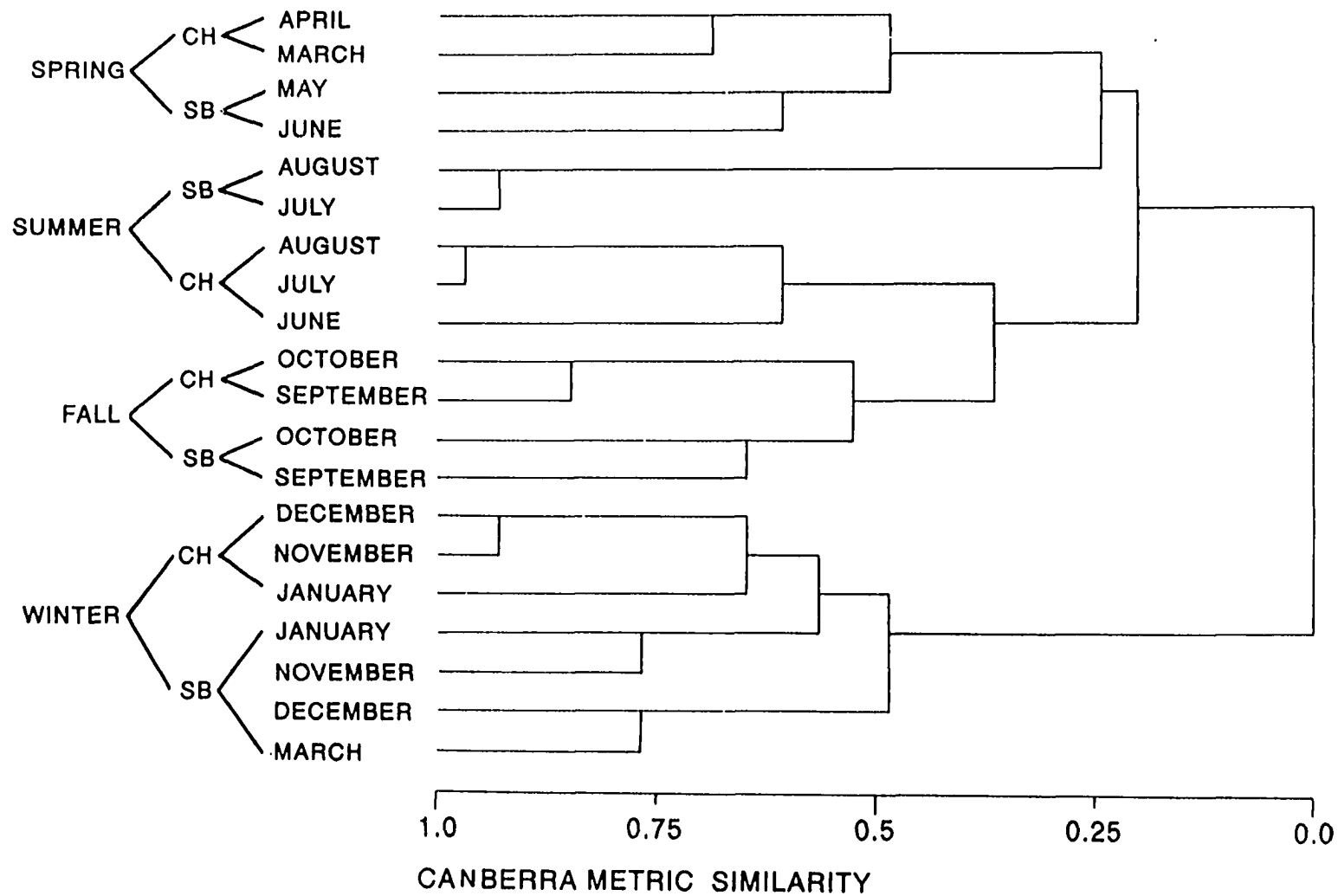
There was also an evident seasonal offset between localities. The winter was longer at Sandbridge than at Cape Hatteras, and the summer of the two localities did not constitute a separate branch in the dendrogram (Fig. 17).

Average water temperature within seasonal groups was usually 3-5° C higher at Cape Hatteras than at Sandbridge, except in the spring (Table 18). Wider ranges in temperature (9° C) occurred in the winter at Cape Hatteras and Sandbridge.

Mean salinity remained near 30-34 ‰ during all seasons at Cape Hatteras, whereas in Sandbridge averages were usually well



Figure 17: Dendrogram of normal cluster analysis in the Chesapeake Bight (WNA).



**Table 18:** Summary of environmental and catch data within seasonal groups of normal cluster analysis in the Chesapeake Bight.  $\bar{X}$  - means, SD - standard deviation.

SEASONAL GROUP		C A P E H A T T E R A S				S A N D B R I D G E			
		SPRING	SUMMER	FALL	WINTER	SPRING	SUMMER	FALL	WINTER
Months		Mar.-Apr.	Jun.-Aug.	Sep.-Oct.	Nov.-Jan.	May-Jun.	Jul.-Aug.	Sep.-Oct.	Nov.-Mar.
Number of Samples		8	12	8	12	8	8	8	16
Temperature (°C)	Range	13.0-16.0	20.2-26.0	22.2-24.5	9.3-15.8	16.2-21.3	18.0-22.4	14.5-23.8	5.0-13.9
	$\bar{X}$	14.9	23.0	23.4	13.0	19.8	20.3	19.1	8.1
	SD	1.1	1.8	0.7	2.0	1.7	1.9	4.2	2.6
Salinity (‰)	Range	29.0-35.0	28.0-32.0	31.0-34.0	30.0-36.0	21.0-31.0	27.0-32.0	25.0-30.0	18.0-32.0
	$\bar{X}$	33.5	29.9	32.1	33.1	23.4	29.9	26.9	25.0
	SD	2.8	1.8	1.2	1.8	3.2	2.0	2.1	4.8
Number of Species		4	10	9	6	12	28	10	8
CPUE	Range	0.0- 1.7	1.7-57.2	2.0-42.0	0.0- 5.2	0.0-46.7	14.5-104.7	7.2-63.2	0.0-30.0
	$\bar{X}$	0.5	20.4	15.4	2.2	16.5	29.0	34.8	5.1
	SD	0.7	16.9	16.2	1.8	17.3	30.8	23.3	7.7

below 30.0 ‰. Wider ranges in salinity occurred in the spring and winter at both locations (Table 17).

Total number of species captured was highest in the summer at both locations (dramatically so at Sandbridge), and lowest in the spring at Cape Hatteras and winter at Sandbridge (Table 17). total CPUE remained high in the summer and fall and decreased in the winter and spring at both localities in the Chesapeake Bight (Table 17).

Inverse analysis - Seven species groups were recognized in the Chesapeake Bight (Table 19). Group A comprised three species, Monacanthus hispidus, Trachinotus goodei, Caranx hippos, and group C two (Spheroides maculatus, Trachinotus falcatus). All of which except Spheroides maculatus (warm temperate) have a sub-tropical distribution, and are usually common in warm coastal marine waters (Appendix A).

Group B was comprised of four species: two surf-zone oriented (Menticirrhus littoralis and Trachinotus carolinus), and two estuarine related (Membras martinica, Mugil curema) species (Table 19), resembling group G at Cassino (Table 10).

Groups D (Menidia menidia and Mugil cephalus) and G (Bairdiella chrysoura, Syngnathus fuscus, Anchoa mitchilli and A. hepsetus) were characterized by estuarine related species (Table 19).

Groups E and F were represented mostly by coastal marine species (Ophidion marginatum, Pomatomus saltatrix), as well as

**Table 19:** Species within groups of inverse cluster analysis in the Chesapeake Bight and their faunal affinity (TR-tropical; ST-sub-tropical; WT-warm temperate), habitat affinity (SZ-surf-zone oriented; CM-coastal marine; ER-estuarine related), ecological role (SW-shallow water; BO-bottom oriented; PE-pelagic), feeding mode (BE-benthivore; PL-planktivore; OM-omnivore; PR-predator), and spawning season (SP-spring; SU-summer; FL-fall; WN-winter).

SPECIES	Fauna	Habitat	Ecol.	Feeding	Spawning
		Occurr.	Role	Mode	Season
GROUP A					
<u>Monacanthus hispidus</u>	ST	CM	PE	BE	?
<u>Trachinotus goodei</u>	ST	SZ	PE	BE	SU?
<u>Caranx hippos</u>	ST	CM	PE	BE	?
GROUP B					
<u>Menticirrhus littoralis</u>	WT	SZ	BO	BE	SU
<u>Trachinotus carolinus</u>	WT	SZ	PE	BE	SU/FL
<u>Membras martinica</u>	WT	ER	SW	OM	?
<u>Mugil curema</u>	WT	ER	BO	OM	SP
GROUP C					
<u>Spheroides maculatus</u>	WT	CM	PE	BE	SP
<u>Trachinotus falcatus</u>	ST	SZ	PE	BE	SP
GROUP D					
<u>Menidia menidia</u>	WT	ER	SW	OM	SP
<u>Mugil cephalus</u>	ST	ER	BO	OM	FL/WN
GROUP E					
<u>Menticirrhus saxatilis</u>	WT	SZ	BO	BE	SU
<u>Leiostomus xanthurus</u>	WT	ER	BO	BE	WN
<u>Brevoortia tyrannus</u>	WT	ER	PE	PL	SP/FL
<u>Ophidion marginatum</u>	WT	CM	BO	BE	?
GROUP F					
<u>Micropogonias undulatus</u>	WT	ER	BO	BE	FL
<u>Syngnathus louisianae</u>	ST	ER	SW	PL	?
<u>Syngnathus floridae</u>	WT	ER	SW	PL	SU
<u>Pomatomus saltatrix</u>	WT	CM	PE	PR	SU
<u>Selene vomer</u>	WT	CM	PE	BE	?
GROUP G					
<u>Bairdiella chrysoura</u>	WT	ER	BO	BE	SP/SU
<u>Syngnathus fuscus</u>	WT	ER	SW	PL	SU
<u>Anchoa mitchilli</u>	WT	ER	PE	PL	SU
<u>Anchoa hepsetus</u>	WT	ER	PE	PL	SU

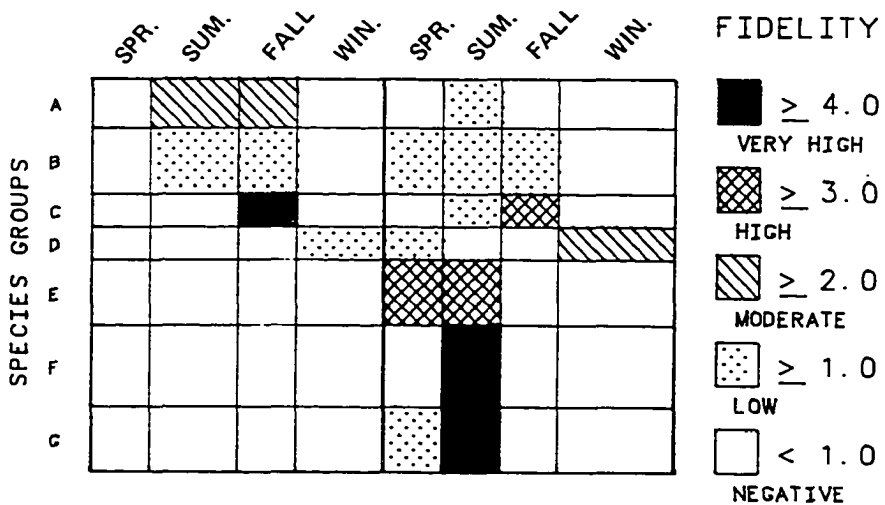
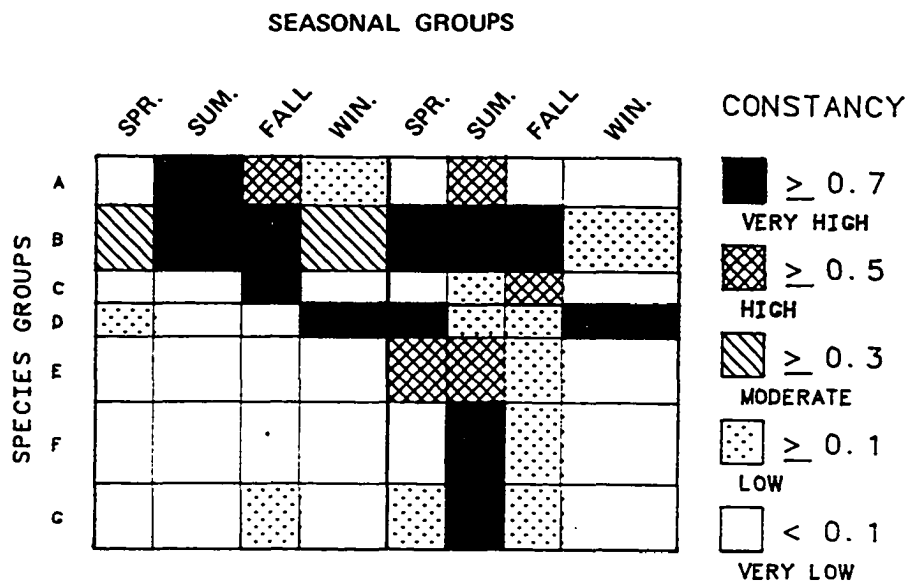
estuarine related ones such as the sciaenids Leiostomus xanthurus and Micropogonias undulatus (Appendix A, Table 19).

Eighteen species were characteristic of warm temperate latitudes. The 6 remaining species were of sub-tropical distribution, and three of them occurred in group A (Table 19). Similarly to what was observed in Cassino, only a few species (5) were strongly associated with the surf-zone habitat, and more than half (13) of the species were represented by juveniles of estuarine resident or dependent fishes (Appendix A, Table 19). Eleven pelagic and eight bottom oriented species, along with a 5 species shallow water fish assemblage (syngnathids - 3 species, atherinids - 2 species), utilized the surf-zone of the Chesapeake Bight. Thirteen and six species have been reported to be benthic and plankton feeders respectively (Appendix A, Table 19). According to the literature, peak spawning for most species usually occurs in the summer (June - August) south of Cape Hatteras (Appendix A, Table 19).

Nodal Analysis - Nearly every group identified in the Chesapeake Bight portion of this study used the surf-zone on a seasonal basis. Both groups A and C, characterized by species of sub-tropical distribution, showed high constancy and moderate to very high fidelity respectively in the summer and fall at Cape Hatteras, but not as much in the Sandbridge area (Fig. 18).

Group B had very high constancy in the summer and fall at Cape Hatteras, and from spring to fall at Sandbridge. Constancy was

Figure 18: Nodal constancy (top) and fidelity (bottom) diagrams showing inter-relations between seasonal groups (spring to winter in Cape Hatteras, and Sandbridge), and species groups (A to G) in the Cheasapeake Bight. Rows and columns were drawn proportionally to the number of group members.



C. HATTERAS

SANDBRIDGE



moderate to low in the other periods at both locations (Fig. 18). While none of the groups in the Chesapeake Bight could be characterized as ubiquitous surf-zone residents year-round, the species composition of group B was similar to that of group G at Cassino, and probably is the closest match to a surf-zone resident group (as defined previously). For instance, Menticirrhus littoralis and Trachinotus carolinus have been considered annual residents of the surf-zone south of Cape Hatteras (Anderson et al., 1977, Modde, 1980; Peters and Nelson, 1987).

Group D primarily occupied the habitat in the colder months, since it showed a high constancy during this period, and can be characterized as a wintering group (Fig. 18). Groups E through G occurred almost exclusively at Sandbridge in the warmer seasons, with high to very high constancy and fidelity in the summer. Many species within these groups did not occur at all in beach seines at Cape Hatteras (Table 16).

#### Dominance

Species within group B (Menticirrhus littoralis, Trachinotus carolinus, Membras martinica) were usually among the dominants from spring to fall in both areas of the Chesapeake Bight. Menticirrhus littoralis remained dominant in the winter as well. Mugil curema dominated the community in the spring and fall, but not in the summer at Sandbridge (Table 20).

Table 20: Species dominance indicated by percent frequency (%) and average percent abundance ( $\bar{x}$ ) of species within seasonal groups in the Chesapeake Bight. Only species included in numerical classification are reported.

	C A P E				H A T T E R A S				S A N D B R I D G E							
	SPRING		SUMMER		FALL		WINTER		SPRING		SUMMER		FALL		WINTER	
	%	$\bar{X}$	%	$\bar{X}$	%	$\bar{X}$	%	$\bar{X}$	%	$\bar{X}$	%	$\bar{X}$	%	$\bar{X}$	%	$\bar{X}$
GROUP A																
<u>Monacanthus hispidus</u>			75	14.4	63	14.0					13	0.7				
<u>Trachinotus goodei</u>	13	2.5	13	2.5	88	20.2	30	17.0								
<u>Caranx hippos</u>	13	3.1	38	6.2							25	2.4				
GROUP B																
<u>Menticirrhus littoralis</u>	50	27.5	100	24.8	100	24.4	80	51.7	14	2.4	88	8.7	100	45.4	23	8.3
<u>Trachinotus carolinus</u>	50	23.7	100	24.8	100	24.4			57	20.5	88	8.7	25	6.7		
<u>Membras martinica</u>	38	25.0	50	10.4	13	2.1			43	8.8	38	2.7	50	11.0		
<u>Mugil curema</u>	13	2.5	38	6.7	25	4.2	10	2.0	86	23.6			50	11.6	8	3.8
GROUP C																
<u>Sphaeroides maculatus</u>					38	6.2					25	2.1				
<u>Trachinotus falcatus</u>					13	2.5							25	9.4		
GROUP D																
<u>Menidia menidia</u>	13	6.3					40	13.7	29	5.2	13	0.7			85	40.4
<u>Mugil cephalus</u>							40	13.7	14	3.6			13	1.8	69	32.7
GROUP E																
<u>Menticirrhus saxatilis</u>			25	5.0							63	5.3				
<u>Leiostomus xanthurus</u>							10	2.0	29	16.7	50	3.9				
<u>Brevoortia tyrannus</u>									29	6.4	13	1.6				
<u>Ophidion marginatum</u>									14	2.4			13	2.5	8	7.7
GROUP F																
<u>Micropogonias undulatus</u>											38	4.0	38	7.4		
<u>Syngnathus louisianae</u>											63	4.8				
<u>Syngnathus floridae</u>											50	3.4				
<u>Pomatomus saltatrix</u>											63	5.0				
<u>Selene vomer</u>											63	5.0				
GROUP G																
<u>Bairdiella chrysoura</u>									14	2.9	100	9.7				
<u>Syngnathus fuscus</u>											88	8.8				
<u>Anchoa mitchilli</u>					13	2.1			14	2.9	63	5.7	13	1.8	8	2.6
<u>Anchoa hepsetus</u>											88	8.3				

Geographical differences in terms of dominance within seasons in the Chesapeake Bight were evident. Coastal sub-tropical marine species of groups A and C (Monacanthus hispidus, and carangids), dominated the fish community in the summer and fall at Cape Hatteras, whereas at Sandbridge, an array of estuarine related species (Bairdiella chrysoura, Leiostomus xanthurus, Micropogonias undulatus, Syngnathus fuscus, Anchoa hepsetus, and Anchoa mitchilli) were the dominants, particularly in the summer (Tables 20). In the winter, Menidia menidia and Mugil cephalus, species of low abundance and occurrence throughout most of the year were, along with Menticirrhus littoralis, the dominant species in the surf-zone of the Chesapeake Bight (Table 20), although to a much greater degree at Sandbridge.

#### Analysis of Covariance

The ANCOVA model blocked by geographical location (CH/SB) at the Chesapeake Bight was highly significant ( $P < 0.01$ ) and explained 81% of the variability in total  $\text{Log}_{10}$  (CPUE+1) (Table 21).

Similarly to what occurred at Cassino, highly significant block effects also supported the apriori hypothesis of variations in abundance between localities (Table 21). Also, a significant interaction between the seasonal effect and water temperature was found indicating heterogeneity of slopes among regressions.

Regression lines did not indicate any relationship among total

**Table 21:** ANCOVA model for  $\log_{10}$  (total CPUE+1) at the Chesapeake Bight. Degrees of freedom (df), sums of squares (SS), standardized F distribution scores (F), probability ( $P > F$ ), significance level (\* - significant; \*\* - highly significant), and correlation coefficient ( $r^2$ ).

SOURCE	df	SS	F	$P > F$	$r^2$
MODEL	30	15.543	6.99	0.000 **	0.81
ERROR	48	3.555			
BLOCK					
Area (CH/SB)	1	1.272	17.18	0.000 **	
COVARIATES					
Salinity (SL)	1	0.026	0.35	0.556	
Water Temp. (WT)	1	0.257	3.48	0.068	
FACTORS					
Season (SS)	3	0.197	0.89	0.454	
Station (ST)	3	0.255	1.15	0.339	
INTERACTIONS					
SS*ST	9	1.014	1.52	0.168	
WT*SS	3	1.132	5.10	0.004 **	
WT*ST	3	0.220	0.99	0.406	
SL*SS	3	0.191	0.86	0.467	
SL*ST	3	0.032	0.15	0.932	

Figure 19: Scatter plot of the  $\log_{10} (\text{CPUE}+1)$  for individual samples against water temperature by season, and fitted regression lines for each locality in the Chesapeake Bight.

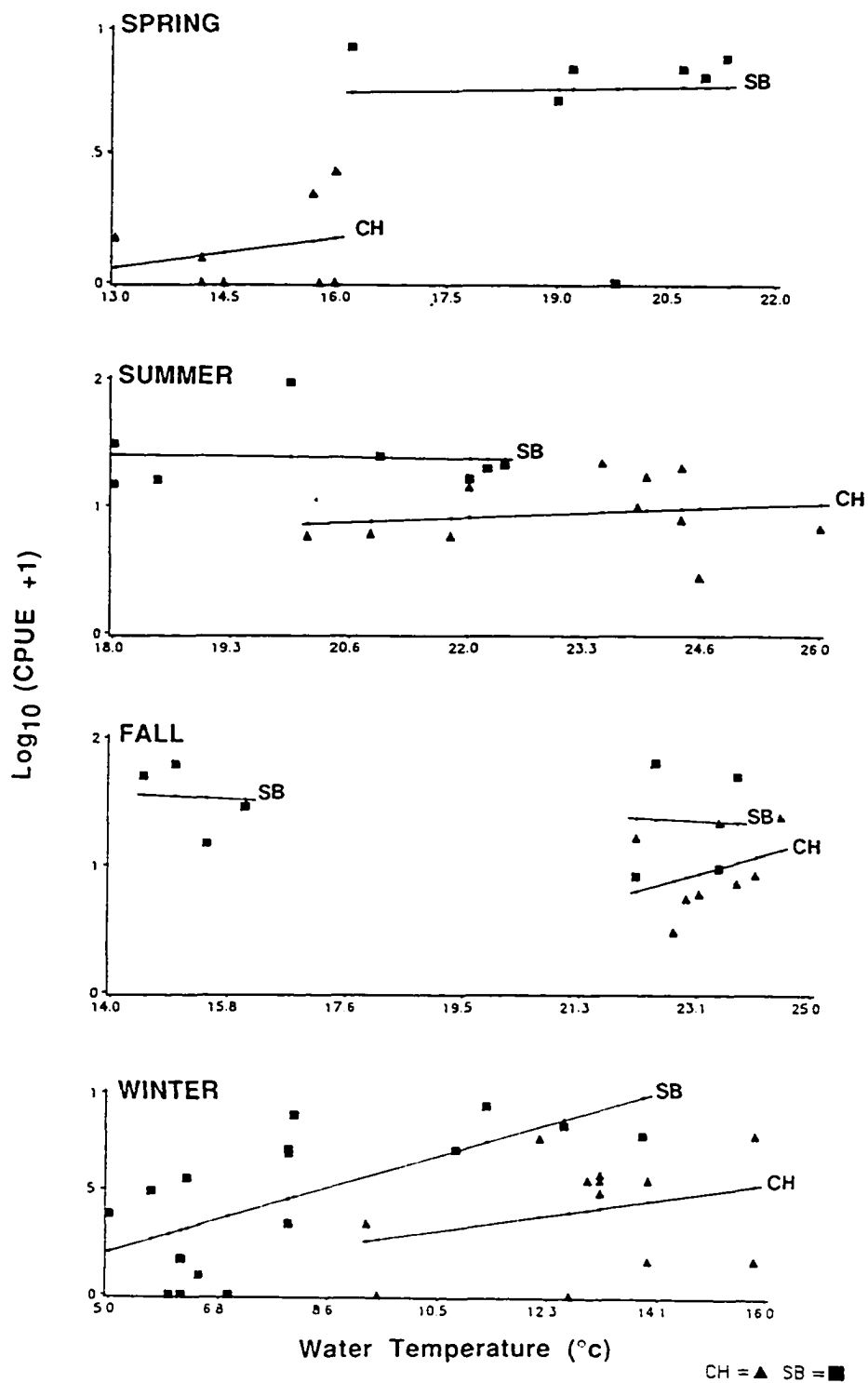


Figure 20: Scatter plot of the  $\log_{10} (\text{CPUE}+1)$  against water temperature by season, of the five most abundant species at Cape Hatteras in the Chesapeake Bight.

# Cape Hatteras

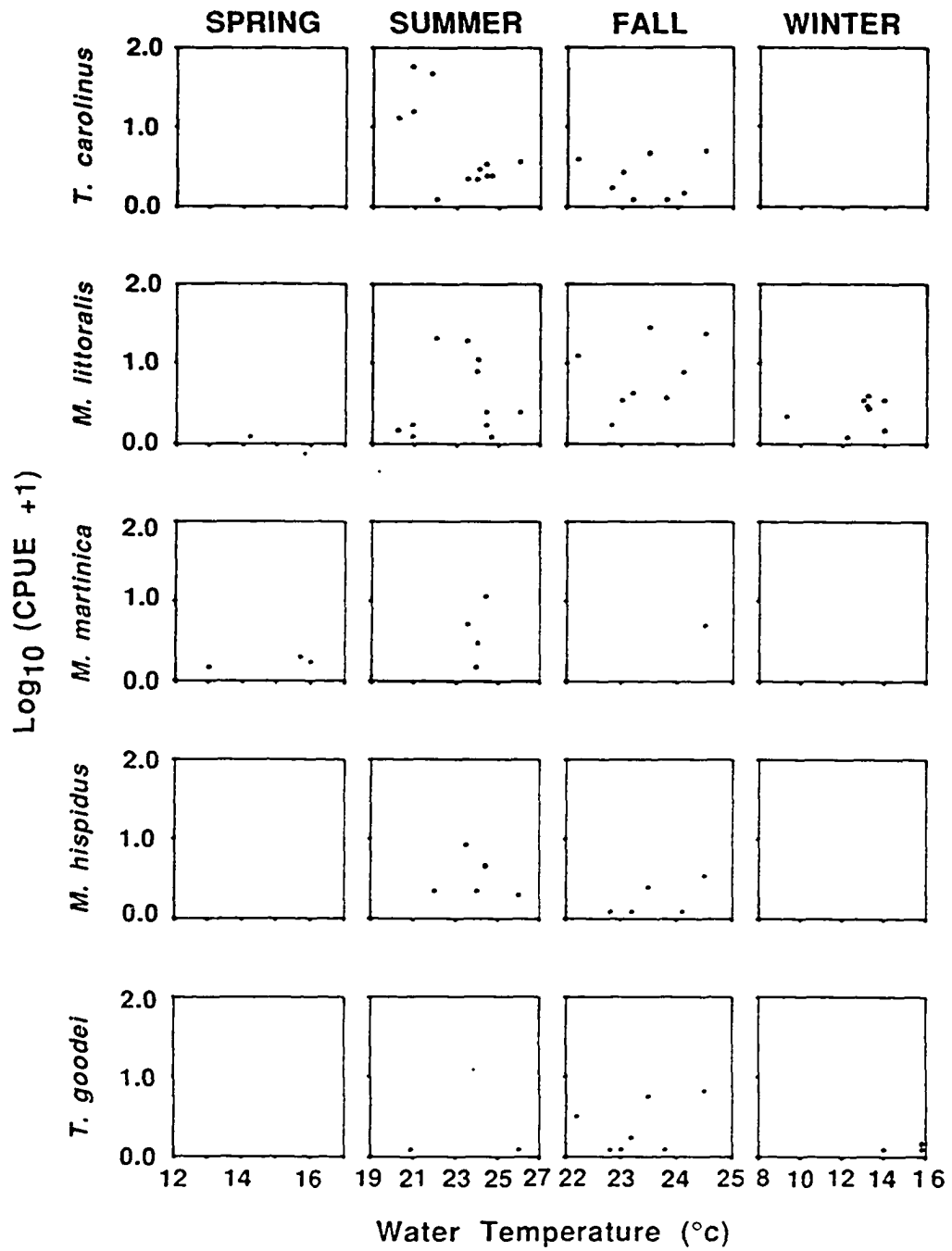
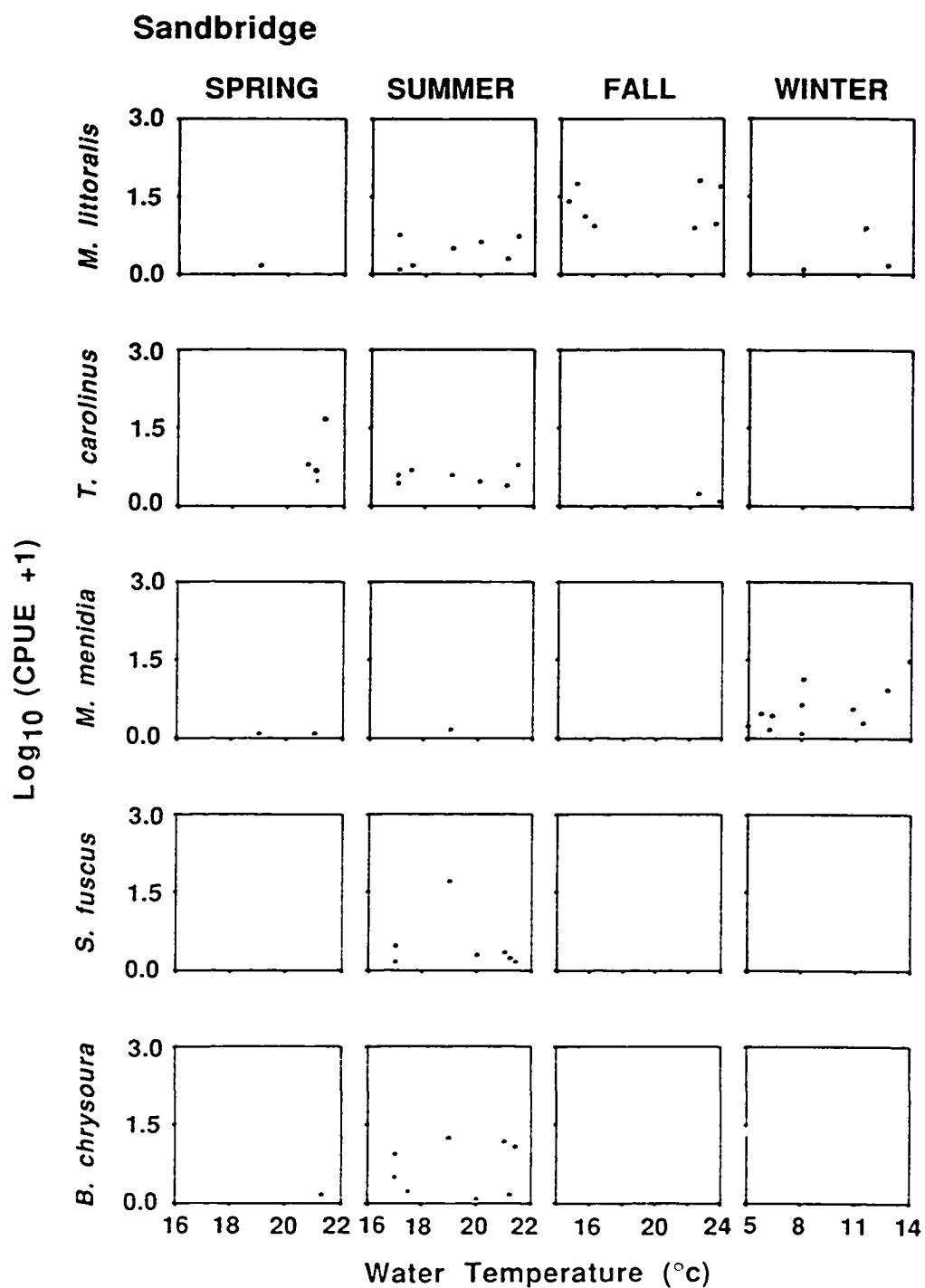




Figure 21: Scatter plot of the  $\log_{10} (\text{CPUE}+1)$  against water temperature by season, of the five most abundant species at Sandbridge in the Chesapeake Bight.



$\log_{10} (\text{CPUE}+1)$  and water temperature in spring or summer at either location (Fig. 19). In the fall, the regression line at Sandbridge was also parallel to the x axis (Fig. 19), but the data is discontinuous along the temperature axis, as sampling periodicity was not intense enough to entirely cover the rapid onset of cold water temperatures in the fall. Nevertheless, total abundance was approximately constant both at low and high water temperatures, at least during the period covered by sampling (Fig. 19). At Cape Hatteras, total abundance correlated with water temperature, and lower abundances were observed as temperature started to drop (Fig. 19). Catches in the winter were usually very low as compared to other seasons and within the winter lower CPUE values were always associated with low water temperatures (Fig. 19).

Plots of individual dominant species abundance against water temperature within seasons were based on limited data and did not show any evident relationships among these variables (Figs. 20 and 21). Differences across seasons indicated that in Cape Hatteras, higher catches occurred mostly in the summer and fall for all of the five species considered (Fig. 20). In Sandbridge, catches of Trachinotus carolinus peaked in the summer, Menticirrhus littoralis in the fall, and Menidia menidia in the winter, while the last two species, Syngnathus fuscus and Bairdiella chrysoura, occurred primarily in the summer (Fig. 20).

### Community Structure Indices

The community structure indices indicated contrasting patterns of seasonal variation between localities in the Chesapeake Bight (Fig. 22). While the average number of species per sample ( $S$ ) remained approximately the same in the winter and spring at both localities, mean number of species in the summer at Sandbridge were nearly twice the magnitude to that observed at Cape Hatteras (Fig. 22). The pattern was consistent also for Shanon-Wiener diversity ( $H'$ ) and species richness ( $D$ ). Mean equitability at Sandbridge appeared to increase slightly during the winter, but overlapping confidence intervals suggested that differences were non-significant from fall to spring (Fig. 22).

Small variability among sampling periods and large variations within periods indicated that diel patterns in surf-zone fish communities at Cape Hatteras and Sandbridge were non-significant at the sample level (Fig. 23).

### Species Rarefaction

Patterns of species richness in the Chesapeake Bight as evidenced by species rarefaction curves were different between geographical locations. Richness was slightly higher in the summer and fall at Cape Hatteras, and lower in the winter, but the curves ran very close to each other (Fig. 24). The small number of species (4) and individuals (15) in the spring make further data interpretation for this period tenuous. In Sandbridge, however, a

Figure 22: Mean number of species (S), Shannon-Wiener diversity ( $H'$ ), equitability ( $J'$ ) and species richness (D) per sample (point diversity) by season by locality in the Chesapeake Bight. Spring (Sp), summer (Su), fall (Fl), winter (Wn). Bars indicate 95% confidence intervals for the mean.

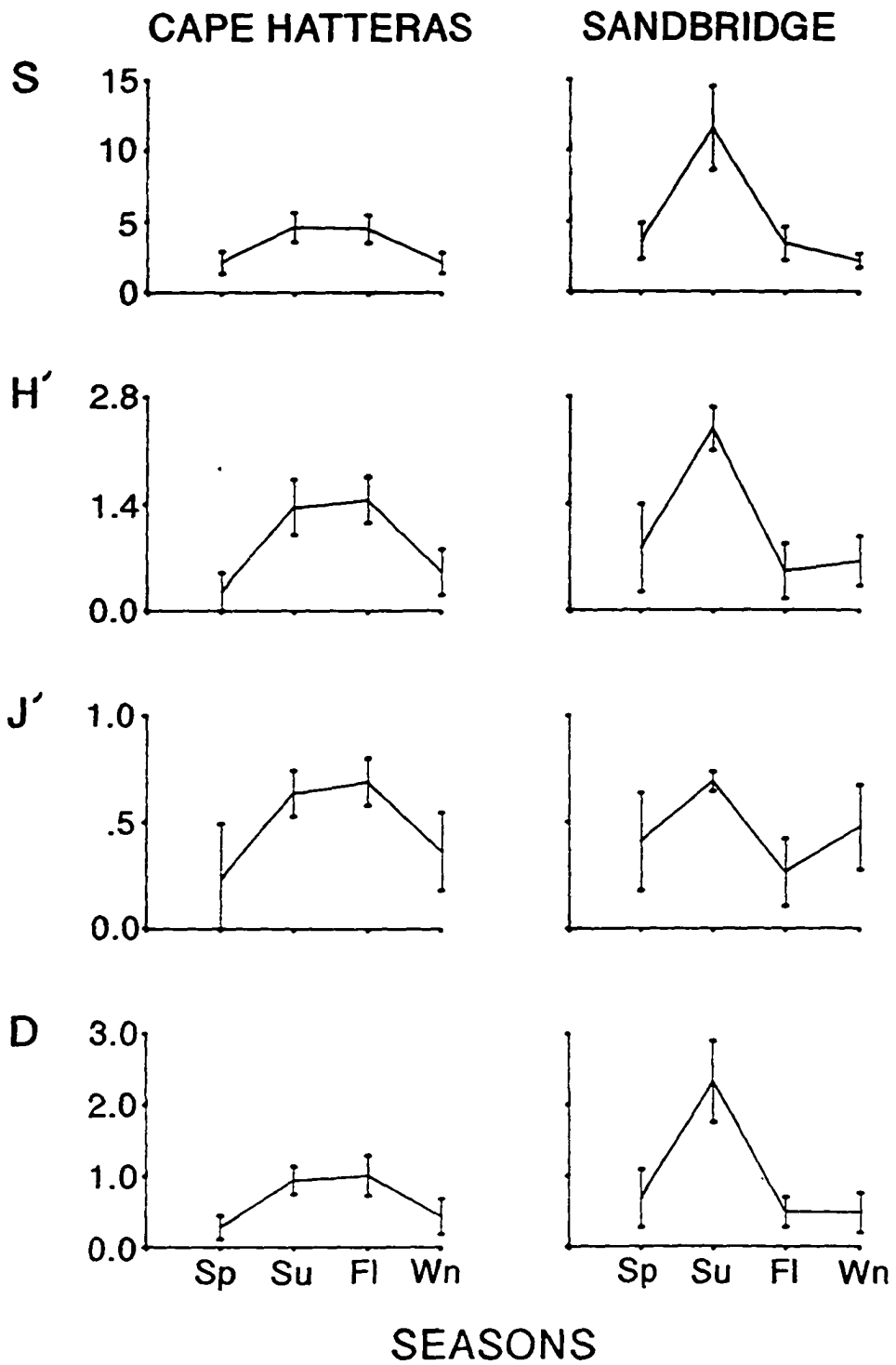


Figure 23: Mean number of species (S), Shannon-Wiener diversity ( $H'$ ), equitability ( $J'$ ) and species richness (D) per sample (point diversity) by diel period by locality in the Chesapeake Bight. Bars indicate 95% confidence intervals for the means.

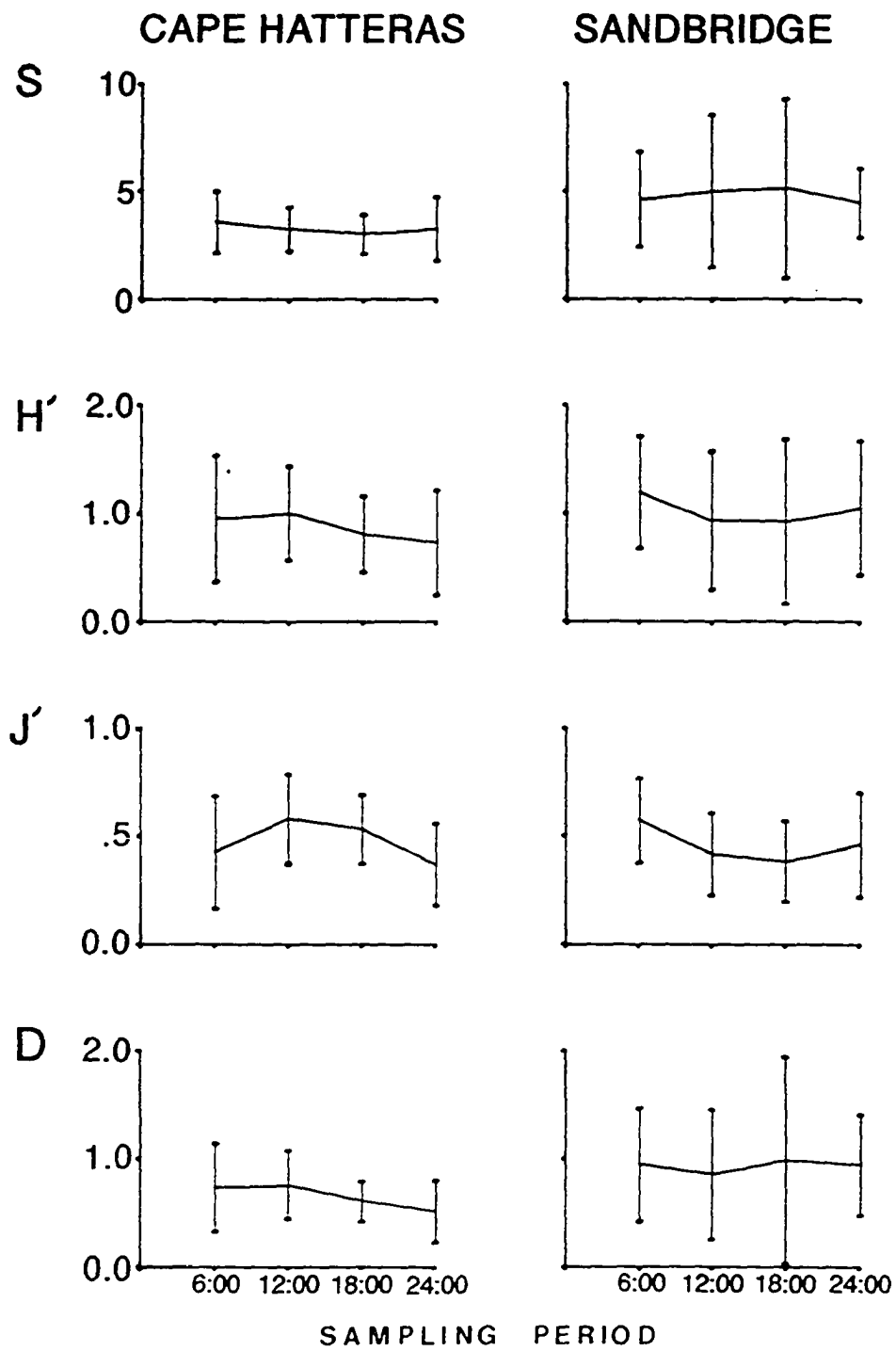
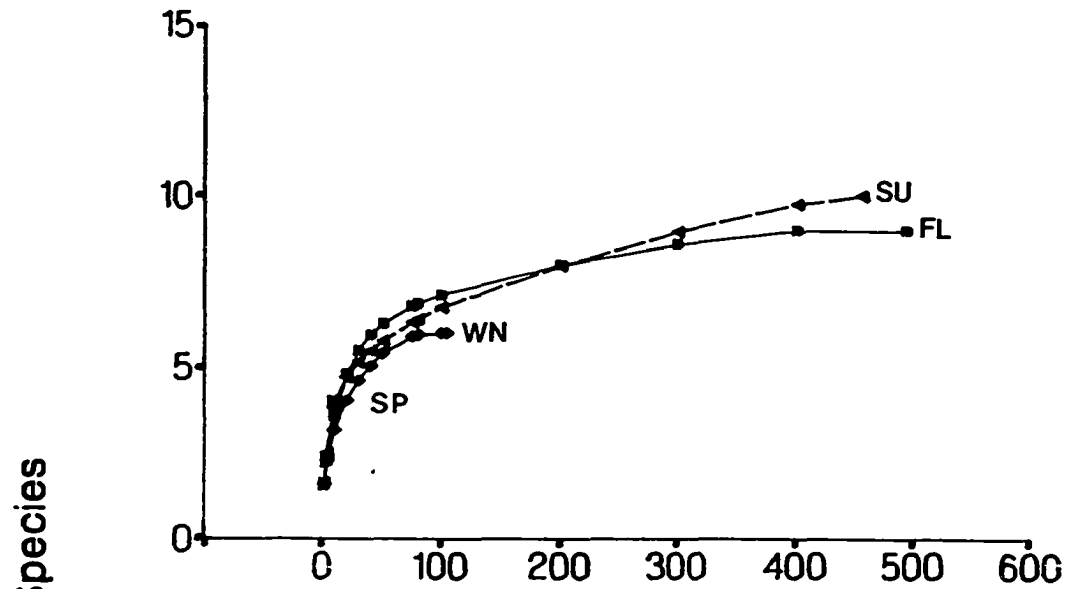




Figure 24: Rarefaction curves by season by locality in the Chesapeake Bight indicating the total number of species (endpoint) and back calculated for different sample sizes (number of individuals). Spring (SP), summer (SU), fall (FL), winter (WN).

## Cape Hatteras



## Sandbridge

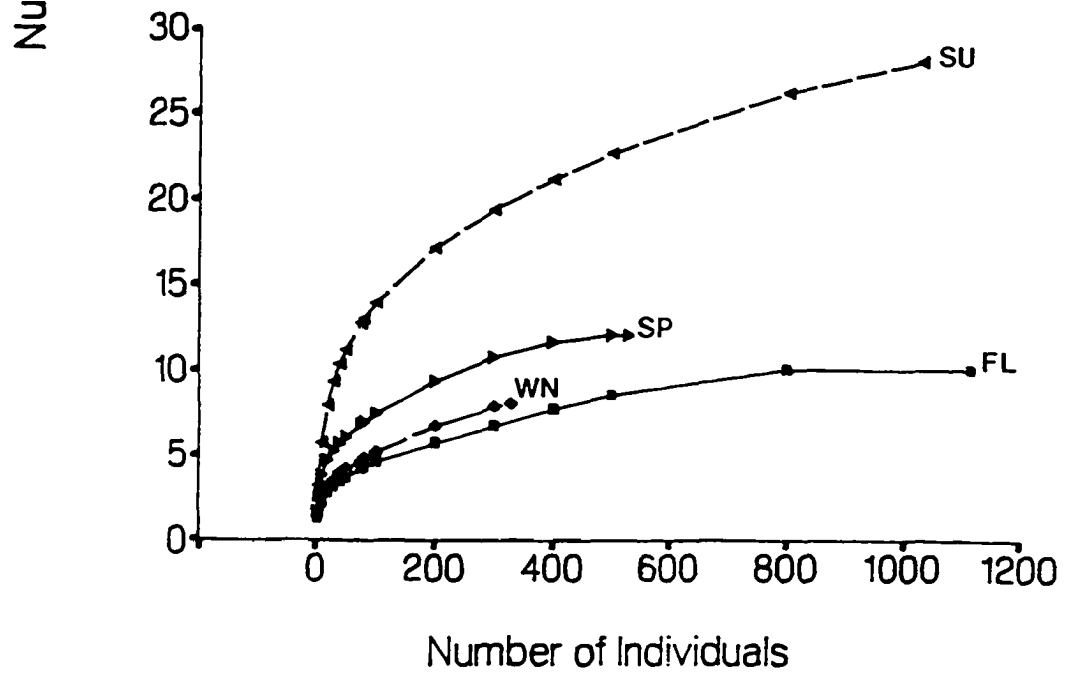
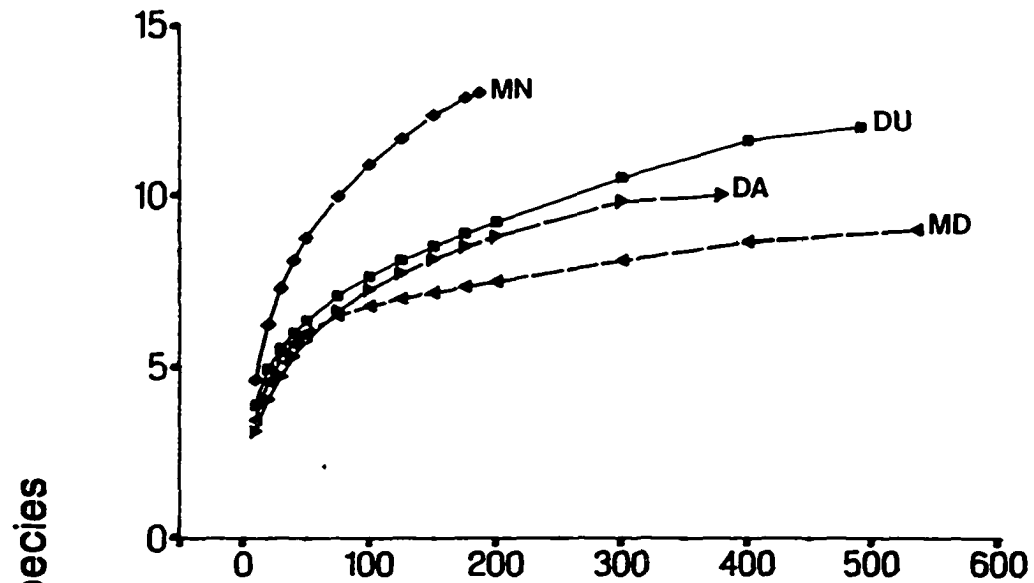
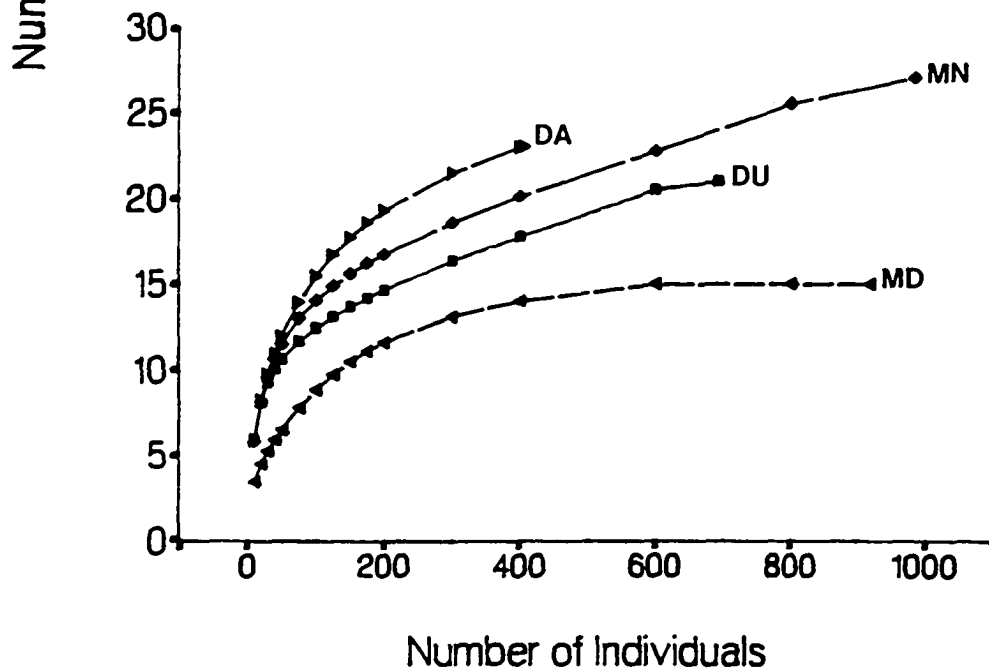


Figure 25: Rarefaction curves by diel period by locality in the Chesapeake Bight indicating the total number of species (endpoint) and back calculated for different sample sizes (number of individuals). 6:00, dawn (DA); 12:00, mid-day (MD); 18:00, dusk (DU); 24:00, mid-night (MN).

## Cape Hatteras



## Sandbridge



strong seasonality was evident, with species richness by far highest in the summer, lowest in the fall and winter, and intermediate in the spring (Fig. 24).

The analysis of diel patterns of species richness through rarefaction indicated that highest richness was attained from dusk (18:00) to dawn (6:00), and lowest at noon (12:00). Highest richness occurred at midnight at Cape Hatteras, and at dawn at Sandbridge (Fig. 25).

#### Taxonomic Comparison (WNA)

The total number of species, genera, and families reported for each selected location in the WNA was smallest at Morris Cove (CT), nearly the same (40 spp.) from the Chesapeake Bight (CB) to Folly Beach (SC), and increased at Sebastian (FL) (Table 22).

Faunal similarities of these localities with the Chesapeake Bight increased towards the family level (Table 22). Across localities within taxonomic levels, faunistic similarity to the Chesapeake Bight was lowest at Morris Cove (CT), higher at Beaufort (NC) and decreased towards Sebastian (FL) (Table 22).

A total of 106 species, 75 genera and 43 families occurred among the selected locations pooled together. The percentages of taxa found exclusively at Morris Cove (CT) and Sebastian (FL) were highest than in any other area (Table 23). At Morris Cove mutually exclusive species were represented by boreal forms of the families

**Table 22:** Total number of species, genera, and families collected in the Chesapeake Bight and at selected localities of the western North Atlantic; number of shared species, genus and families (commonality), and faunal similarities (Jaccard) among these localities and the Chesapeake Bight (CB), at each taxonomic level. Effort=number of samples taken.

	CT	CB	NC	SC	FL
Total Species	28	40	41	41	54
commonality	10	-	22	21	21
Jaccard	0.17	-	0.38	0.35	0.29
Total Genera	26	30	31	32	42
commonality	11	-	19	17	19
Jaccard	0.24	-	0.45	0.38	0.36
Total Families	16	21	22	19	26
commonality	9	-	15	12	14
Jaccard	0.32	-	0.54	0.43	0.42
Effort	26	80	74	51	40

CT = Morris Cove, CT, USA (41°15' N), Warfell and Merriman (1944);

CB = Chesapeake Bight, USA (37°- 35° N), present data;

NC = Beaufort, NC, USA (34°40' N), Tagatz and Dudley (1961);

SC = Folly Beach, SC, USA (32°38' N), Anderson et al. (1977);

FL = Sebastian, FL, USA (28°± 30' N)  
Peters and Nelson (1987).

**Table 23:** Pooled number of species, genera, and families collected in the Chesapeake Bight and at selected localities of the western North Atlantic, and the proportions in which taxa occurred within the patterns indicated by the stars (\*). 'No Pattern'-occurrences did not follow any of the proposed patterns.

CT	CB	NC	SC	FL	% species	% genus	% family
*					13.2	16.0	11.6
	*				9.4	8.0	7.0
		*			6.6	2.7	2.3
			*		6.6	6.7	7.0
				*	18.9	13.3	11.6
* -- *					0.9	0.0	2.3
* -- * -- *					0.0	0.0	0.0
* -- * -- * -- *					0.9	2.7	0.0
* -- * -- * -- * -- *					6.6	9.3	16.3
	*	-- *	-- *	-- *	7.5	6.7	7.0
		*	-- *	-- *	1.9	4.0	7.0
			*	-- *	5.7	6.7	2.3
- -	No Pattern			- -	23.6	24.0	25.6
Pooled Number (100%)					106	75	43

CT = Morris Cove, CT, USA ( $41^{\circ}15' N$ ), Warfell and Merriman (1944);

CB = Chesapeake Bight, USA ( $37^{\circ}$ -  $35^{\circ}$  N), present data;

NC = Beaufort, NC, USA ( $34^{\circ}40' N$ ), Tagatz and Dudley (1961);

SC = Folly Beach, SC, USA ( $32^{\circ}38' N$ ), Anderson et al. (1977);

FL = Sebastian, FL, USA ( $28^{\circ} \pm 30' N$ ), Peters and Nelson (1987).

Osmeridae (Osmerus mordax), Pleuronectidae (Pseudopleuronectes americanus), and Gadidae (Pollachius virens, Microgadus tomcod, Urophycis spp.). At Sebastian (FL) sub-tropical and tropical species (e.g., Eucinostomus spp., Anisotremus surinamensis, Abudefduf saxatilis, and Diplodus holbrooki) comprised the majority of exclusive taxa.

Sixteen percent of the families were widely distributed throughout these selected localities of the WNA, but fewer genera and species showed such a wide distribution (Table 23). Species of widespread distribution included several sciaenids (Bairdiella chrysoura, Leiostomus xanthurus, Menticirrhus saxatilis), Anchoa mitchilli, Brevoortia tyrannus, and Menidia menidia, which are commonly found in estuaries throughout the WNA. Taxa occurred more frequently at consecutive adjoining locations south of the Chesapeake Bight than to the north. Common surf-zone species (Trachinotus spp., and Menticirrhus littoralis) occurred at all locations from the Chesapeake Bight (CB) down to Sebastian (FL).

About 23% to 25% of the taxa were distributed irregularly and could not fit into the patterns herein depicted (Table 23). While many of the species included into this category were of occasional occurrence, Syngnathus fuscus, numerically dominant at Sandbridge (CB) was also included among them.



### Within the western Atlantic - Cassino x Chesapeake Bight

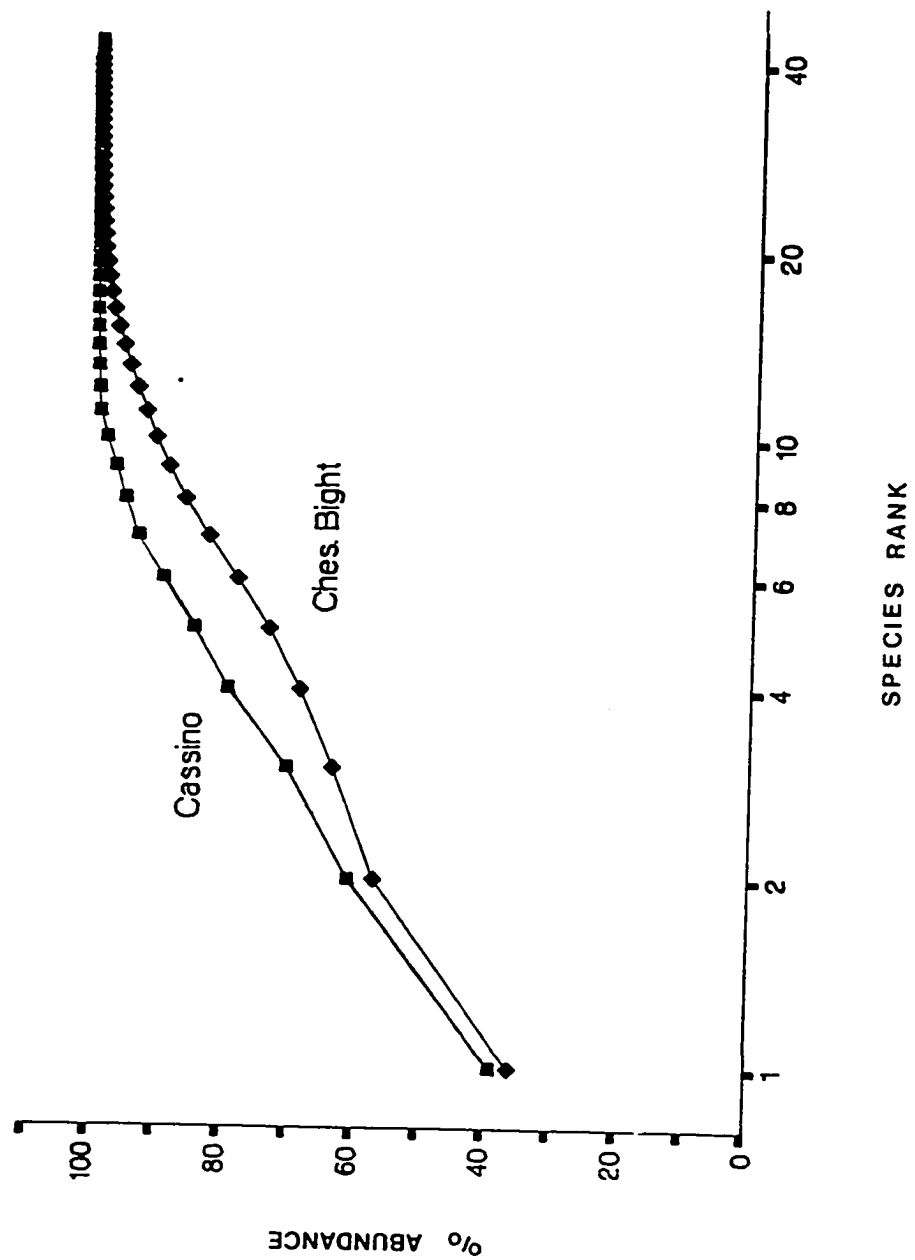
The total number of species (43 and 40) and families (23 and 22) represented at Cassino and the Chesapeake Bight respectively, were about the same with the number of genera being greater at Cassino (37) than in the Chesapeake Bight (31) (Table 24). K-Dominance curves were very similar in shape, but the lowest curve for the Chesapeake Bight at any k species rank indicated that the community in this locality was slightly more diverse than at Cassino (Fig. 26).

Faunal similarities at the species level were quite small (0.09) and only seven species were common to both regions (Table 23). At the family level, however, faunal similarities were around 0.3 with 10 families being common to both locations (Table 24).

Seventy-six species, 57 genera and 35 families were compiled for the surf-zone in the two primary studies pooled together (Cassino-WSA and Chesapeake Bight-WNA), but most of them occurred exclusively in each hemisphere (Table 24).

Eleven genera comprising one to three species per genus were shared between Cassino and the Chesapeake Bight. Trachinotus, Menticirrhus and Mugil dominated the catches in abundance at both locations (Table 25), but dominance was usually a product of high abundance and frequency of occurrence of solely one species (e.g., Trachinotus carolinus in the Chesapeake Bight and Trachinotus marginatus at Cassino). Shared genera showed a greater ratio of

Figure 26: K-dominance curves comparing community dominance-richness patterns from Cassino (WSA) and the Chesapeake Bight (WNA).



**Table 24:** Total and mutually exclusive (ME) number of species, genera, and families collected in each locality of the temperate West Atlantic; number of shared species, genera and families (common.) and similarity between faunas (Jaccard) at each taxonomic level.

	Cassino		Cheasapeake Bight		Pool	Common.	Jaccard
	Total	ME	Total	ME			
SPECIES	43	36	40	33	76	7	0.09
GENERA	37	26	31	20	57	11	0.19
FAMILY	23	13	22	12	35	10	0.29

**Table 25:** Shared genera and families between Cassino and the Chesapeake Bight, number of species and percent abundance (%a) per genus and family.

	Cassino		Chesapeake Bight	
	species	%a	species	%a
<b>GENUS</b>				
<u>Trachinotus</u>	3	38.9	3	22.5
<u>Mugil</u>	3	36.2	2	5.6
<u>Menticirrhus</u>	2	9.6	2	36.7
<u>Syngnathus</u>	1	< 1	3	5.5
<u>Anchoa</u>	1	1.1	2	2.5
<u>Caranx</u>	1	< 1	2	< 1
<u>Paralichthys</u>	1	< 1	2	< 1
<u>Brevoortia</u>	1	3.9	1	< 1
<u>Micropogonias</u>	1	< 1	1	3.6
<u>Selene</u>	1	< 1	1	< 1
<u>Pomatomus</u>	1	< 1	1	< 1
<b>FAMILY</b>				
Carangidae	7	39.0	6	23.3
Sciaenidae	5	9.8	6	43.1
Mugilidae	3	36.0	2	5.6
Clupeidae	3	4.1	1	< 1
Atherinidae	2	6.2	2	11.3
Engraulidae	2	3.1	2	2.5
Syngnathidae	1	< 1	3	5.5
Bothidae	1	< 1	2	< 1
Tetraodontidae	1	< 1	1	< 1
Pomatomidae	1	< 1	1	< 1

species per genus in the Chesapeake Bight. Syngnathus and Anchoa were represented in the surf-zone respectively by three and two species, and were relatively important faunal components in terms of abundance, occurring almost exclusively at Sandbridge (Table 25).

Ten families were common between both hemispheres, and the families Carangidae and Sciaenidae were represented by the greatest number of species, outnumbering the next family by two or more species (Table 25). Abundance ranks varied however, and Carangidae, Mugilidae and Sciaenidae were more important at Cassino, whereas Sciaenidae, Carangidae and Atherinidae dominated the catches in the Chesapeake Bight (Table 25).

## DISCUSSION

### Within Habitat - Cassino, WSA

Despite considerable sampling effort at Cassino (WSA) over two years covering an extensive nearly homogeneous habitat, only a relatively small number of fish species were collected. Also, a few species such as Trachinotus marginatus, Menticirrhus littoralis and Mugil platanus numerically dominated the community, whereas a larger number of less abundant species occurred occasionally. Thus the community was characterized by relatively low diversity. In fact, the dominant species at Cassino were often found to be dominant in other surf-zone areas of the WSA (Paiva Filho and Toscano, 1987; Monteiro-Neto et al., in press), indicating that these results were very much in accordance with previous studies (DeLancey, 1984; Ross et al., 1987) which have suggested that the above characteristics are common among surf-zone fish communities.

Comparisons between years were limited due to the survey characteristic which was not aimed to address questions about yearly variations in community organization and structure. However, the observed differences in both the total number of species collected and abundance ranks among species between years probably resulted from variations in the sampling effort, and year class strength.

The species composition among the top 10 dominants was similar in both years despite changes in abundance ranks, thus indicating that dominant fish species assemblage in the surf-zone remained approximately the same, at least within the two year time frame herein considered. In support of this conclusion, a study comparing the dominant species composition at Folly Beach, SC, USA with previously reported data for nearly the same area has also yielded similar results (DeLancey, 1984).

Numerical classification of all samples (non-pooled data) resulted in cluster groups that did not provide evidence of possible spatial variations in the community, indicating that surf-zone fishes at Cassino were probably widely distributed throughout the habitat. Community structure indices and rarefaction also did not indicate significant patterns of community variation among sampling stations suggesting that the previous conclusion of within habitat homogeneity was valid. These results were supported by Cunha (1981) who suggested that the surf-zone fish fauna at Cassino was widely distributed throughout the entire surveyed area, despite small variations on individual species abundance. However, the analysis at the sample level (community structure indices) suggested that diversity patterns were affected by the influence of the Patos Lagoon estuary, and that the probability of catching more species per sample apparently decreased as distance away from the estuary increased.



Normal cluster analysis of pooled species abundances by month by year resulted in cluster groups that identified four annual seasons, but these did not always agree with the commonly adopted seasonal definitions, either with respect to the usual nominal periods or the common convention of seasons of equal duration. Nevertheless, the seasonal periods identified in this analysis reflected similarities among pooled monthly species compositions and correlated well with the major seasonal environmental changes characterized by water temperature and salinity variations. Water temperature ranges were small within both the summer and winter groups, whereas much wider variations were observed during the transitional spring and fall groups, in accordance with expected patterns. Also, the passage of climatic fronts and predominant NE winds favoring the outflow of Patos Lagoon estuarine waters from June to November (Castello and Moller, 1978), were largely reflected in salinity variations in the surf-zone during the spring.

The seasonal occurrence, abundance and diversity of fish species in the surf-zone reflected recruitment patterns of juveniles determined by both the seasonality of reproduction and seasonal variations in the circulation patterns, both marine and estuarine. Estuarine dependent species recruiting from offshore spawning grounds to estuarine nursery grounds usually in the spring and summer (Micropogonias furnieri, Ramnogaster arcuata, Anchoa marinii), spent time in the surf-zone before penetrating into the

estuary, whereas estuarine residents (Xenomelaniris brasiliensis, Jenynsia lineata) occurred mostly in the spring, perhaps following the estuarine front in times of greater runoff. Also, sub-tropical (Caranx latus, Chloroscombrus chrysourus) and tropical species (Abudefduf saxatilis) strayed into the surf-zone habitat during the summer, reflecting both recruitment from spring-summer spawning (Phonlor, 1973) and the greatest influence of warm tropical waters of the Brazil Current at this time of the year (Cunha, 1981). These results were consistent with previous surf-zone fish studies (Gunter, 1945, 1958; Modde and Ross; 1981; Ross et al., 1987; Monteiro-Neto et al., in press), and supported those of Lenanton and Potter (1987), which indicated that species abundant in estuaries during one stage of their life cycle could also be found along coastal marine environments.

Community diversity patterns derived from community structure indices (Shanon-Wiener Diversity and its components) and the rarefaction method showed seasonal variations consistent with the results presented above, and similar to previously reported surf-zone fish studies in other areas (Anderson et al., 1977; Hillman et al., 1977; Monteiro-Neto et al., in press). Greatest diversity occurred usually in the summer due to recruitment of juveniles. However, diversity and species richness indices can be adversely affected by high degrees of unevenness, and the rarefaction method in particular was largely affected by species dominance patterns and year-class variations. The community became less diverse in the

summer of YR1 and fall of YR2 when extremely high recruitment of Trachinotus marginatus occurred and overwhelmed the fact that there was also a high number of species. Sanders (1968), pointed out that such problems occurred when species in the community are not evenly distributed but strongly aggregated.

Species classified within the seven groups derived from inverse cluster analysis were in the majority typical representatives of the temperate fish fauna of the WSA (Figueiredo and Menezes, 1978, 1980; Menezes and Figueiredo, 1980, 1985), and usually fit into broad categories which reflected similar seasonal patterns of distribution and abundance, and similar faunal and ecological characteristics shared among species. However, despite the usually higher constancy of species groups at specific seasons from spring to fall, weak associations of any particular species group to any particular season indicated that most groups were at least present throughout the year.

Estuarine related groups (A, B, C and F), frequent in the surf-zone at times from spring to fall comprised several pelagic planktivores (Ramnogaster arcuata, Brevoortia pectinata) and shallow water omnivores (Xenomelaniris brasiliensis, Jenynsia lineata, and Mugil spp.) which often dominated estuarine beach seine catches at Patos Lagoon (Chao et al., 1985).

Groups D and E tended to be less homogeneous with regard to faunal associations, but were constituted in the majority by

summer-fall occasional coastal marine species of temperate (Porichthys porossissimus, Umbrina canosai) sub-tropical (Chloroscombrus chrysourus, Caranx latus) and tropical (Abudefduf saxatilis) distribution.

Ubiquitous group G, which can be characterized as year-round surf-zone resident, was composed of the only truly surf-zone oriented species (Trachinotus marginatus, Menticirrhus littoralis, and Oncopterus darwini), and also two estuarine related species. Juvenile Mugil platanus may have stayed in the surf-zone for several months without showing any considerable growth, waiting for appropriate conditions to recruit to estuarine nurseries (Vieira, in press a and b), whereas Odontesthes bonariensis, an ubiquitous species in the lower Patos Lagoon estuary (Bemvenuti, 1987), also included the surf-zone at Cassino within its normal range of spatial distribution (Cunha, 1981; Bemvenuti, 1987).

The present study in the surf-zone at Cassino suggested that variations in total community abundance occurred not only between but also within seasons, and apparently were correlated with changes in water temperature. While the analysis indicated that the two variables were not significantly correlated in the summer and winter, positive (increasing abundance and water temperature) or negative (decreasing abundance at higher water temperatures) relationships in the remaining seasons were also non-conclusive.

Water temperature probably played an important role in setting the time of spawning migration and reproduction of adult fish, thus determining seasonal abundance variations in surf-zone fish assemblages through the recruitment of juveniles. Some previous surf-zone fish studies have suggested that seasonal abundance peaked in the summer (McFarland, 1963; Hillman et al., 1977; Naughton and Saloman, 1978; Ross et al., 1987) probably because of increased temperature which, directly or indirectly, affected reproduction (and recruitment), or prey availability, or both (Gunter, 1945). At least for Mugil platanus, water temperature appeared to be an important factor determining the time of the species' reproductive migration at Patos Lagoon (Vieira, in press a and b). Similar correlation may occur with other temperate species in the WSA, either with temperature or other seasonal abiotic factors (photoperiod, light intensity) not taken into account in this study.

Taxonomic comparisons between the published information on surf-zone fish communities of the WSA and data from Cassino indicated that faunal similarities decreased towards lower latitudes at any of the examined taxonomic levels, due to a greater contribution of tropical and sub-tropical taxa at lower latitudes. In fact, more taxa were shared between Cassino and Laguna (SC) than between Laguna (SC) and Santos (SP), further indicating that the greatest faunal changes occurred near the transition between

temperate and tropical zoogeographic provinces in the WSA (Figueiredo, 1981).

Faunal replacements occurred faster among species than among genera or families. This was very consistent with Cunha's (1987) results, which had previously observed that the surf-zone oriented Trachinotus marginatus was gradually replaced by T. carolinus northward of Cassino. Also, previous taxonomic work in the WSA (Figueiredo and Menezes, 1978, 1980; Menezes and Figueiredo, 1980, 1985) indicated that several species varied considerably in their ranges of occurrence, but the families were usually widely represented throughout tropical and temperate waters.

### Within Region - Chesapeake Bight, WNA

The study of surf-zone fish communities in the Chesapeake Bight (WNA), indicated that within-region differences in community structure were primarily determined by large scale environmental and habitat differences between sampled localities. The surf-zone fish community at Sandbridge was strongly influenced by the proximity of the Chesapeake Bay estuary and species composition among the top 10 dominants comprised several estuarine related species such as Syngnathus fuscus, Bairdiella chrysoura, and Micropogonias undulatus. At Cape Hatteras, however, the surf-zone fish community reflected in great part the influence of Gulf Stream waters as characterized by the occurrence of several fish species with sub-tropical distribution (Monacanthus hispidus, Trachinotus spp., and Caranx hippos) among the dominants. Nevertheless, Surf-zone fish communities in the Chesapeake Bight (WNA) were dominated numerically by few species, whether Cape Hatteras and Sandbridge were treated separately or if samples were pooled and the Bight treated as a unit. This suggested that dominance by a few species shaped surf-zone fish communities not only within habitats, but also within regions.

The seasonal occurrence, abundance, and diversity of fish species in the surf-zone of the Chesapeake Bight was largely determined by seasonal species migrations along the WNA, the

development of a thermal barrier at Cape Hatteras during the colder months (Phoel, 1985), as well as recruitment patterns of juveniles. These conclusions were supported by previous surf-zone fish studies (Warfel and Merriman, 1944; Anderson et al. 1977; Peters and Nelson, 1987) which have observed considerable seasonal migration among species in the WNA. Several estuarine dependent (*Sciaenidae* and *Brevoortia tyrannus*) and surf-zone oriented species (*Trachinotus spp.*) spawn in the spring and summer (usually south of Cape Hatteras), and juveniles migrate northward as water temperature at higher latitudes progressively rise in the summer, and then recruit into the estuarine nurseries including the Chesapeake Bay (Appendix A). When the temperature drops in the fall migration patterns are reversed and the same species move offshore and south back to warmer waters south of Cape Hatteras (Musick, 1972; Chao and Musick, 1975).

The strong effects of the thermal regimes upon surf-zone fish communities in the Chesapeake Bight were further evidenced when seasonal groups derived from normal cluster analysis indicated that the length of the 'biological' winter was slightly shorter at Cape Hatteras than at Sandbridge, and monthly collections grouped within the same season were offset between localities. These differences can be attributed in most part to the later warming of the northern end of the Bight, and the buffering effect of the warm Gulf Stream near Cape Hatteras.

The analysis of variations in total community abundance in relation to several abiotic factors also suggested that water



temperature in the winter near the lower limit of the tolerable range for many species forced fish assemblages out of the surf-zone, either to deeper waters, or south of Cape Hatteras.

Inverse cluster analysis identified seven species assemblages in the Chesapeake Bight which clearly showed specific spatial associations between areas, and considerable seasonal changes in community structure in which none of the groups remained resident through the whole year, but were replaced by a wintering fish assemblage.

Sub-tropical groups A and C were characterized by pelagic benthivore species (Monacanthus hispidus, Trachinotus spp., and Caranx hippos) which were frequent in the summer or fall, or both primarily at Cape Hatteras and associated with warm Gulf Stream waters. Estuarine related groups (E, F, and G) almost exclusively occupied the habitat at Sandbridge either in the spring, or summer, or both, and was comprised of mostly bottom oriented benthivores (Leiostomus xanthurus, Bairdiella chrysoura and Micropogonias undulatus), and pelagic (Anchoa spp.) and shallow water (Syngnathus spp.) planktivores that were common in estuarine waters of the Chesapeake Bay (Musick, 1972; Chao and Musick, 1975).

Ubiquitous species of group B, which included surf-zone oriented (Trachinotus carolinus and Menticirrhus littoralis) and estuarine related (Membras martinica, and Mugil curema) species, often remain year-round in the surf-zone south of Cape Hatteras

(McFarland, 1963; Anderson et al., 1977; Modde and Ross, 1981), but in the Chesapeake Bight they were replaced in the winter by estuarine related Mugil cephalus and Menidia menidia).

The winter occurrence of these species in the surf-zone may be respectively explained by timing of reproduction and avoidance of colder temperatures in shallow estuarine waters, but their faunistic relationships contrasted with previous demersal fish community studies in the Chesapeake Bight in which winter assemblages were dominated by boreal fish species (Musick et al., 1985). One possible explanation for these differences was that demersal fish studies analyzed both adult and sub-adult populations over broad ranges of spatial distribution, whereas this study was limited to the analysis of the juvenile fish population in a restricted habitat. Previous surf-zone fish studies have indicated that boreal species such as Urophycis spp. become more important in localities to the north of the studied portion of the Chesapeake Bight (Warfel and Merriman, 1944).

Differences in community diversity between localities in the Chesapeake Bight, as indicated by community structure indices and rarefaction, suggested that the assumption of low diversity (Gunter, 1945, 1958; McFarland, 1963; Modde and Ross, 1981) among surf-zone fish communities may be valid within habitats, but may not be broadly applied within regions.

A higher diversity at Cape Hatteras was expected, due to the proximity of the Gulf Stream (which should transport warm temperate, sub-tropical and tropical species into the area) and the fact that this area constitutes a major faunal border zone. Despite the previously observed higher association of tropical species with Cape Hatteras, the greatest community diversity was observed at Sandbridge in the summer due largely to the occurrence of a much higher number of estuarine related species in the surf-zone. This indicates that locally the surf-zone may function either as a buffer system for migrating estuarine dependent species, or an extension of the Chesapeake Bay estuarine realm for estuarine residents in the warmer months.

The community structure indices and the rarefaction method yielded different diel patterns. Differences were largely attributable to the level of organization at which each technique evaluated surf-zone fish communities. Community structure indices were based on sample diversity (point diversity; Whittaker, 1977), whereas the rarefaction method provided information on the overall diversity pooled across units of community variation (four units over a diel cycle).

The species rarefaction indicated that fish community diversity in the surf-zone was usually higher at night and lowest at noon at both locations in the Bight. These patterns may reflect gear avoidance by fish when light penetration made the seine more

conspicuous, or onshore-offshore migrations for the purpose of feeding or predator avoidance, or both (Modde and Ross, 1981). The community structure indices, however, were highly variable suggesting that diel variations at the sample level did not occur accross sampling periods.

Taxonomic comparison between several surf-zone fish studies in the WNA and data from the Chesapeake Bight indicated that the greatest faunal similarity occurred with Beaufort (NC), a fact that correlated well with the spawning grounds for several WNA temperate species (Appendix A). However, there is also the fact that Beaufort is much closer to the Chesapeake Bight than any other locality compared. Similarities decreased both northward due to increased participation of boreal species within the surf-zone fish fauna at Morris Cove (CT), and southward due to the gradual increase in the number of tropical and sub-tropical elements at both, Folly Beach (SC) and Sebastian (FL). Gunter (1945, 1958) suggested that surf-zone fish faunas from the Gulf of Mexico all the way up to New England were very similar in their species composition. The results herein presented indicate that considerable faunal replacement occur. At any given location, faunal change is inversely proportional to taxonomic level.

Within the western Atlantic - Cassino x Chesapeake Bight

The comparison of surf-zone fish communities at Cassino (WSA) and the Chesapeake Bight (WNA) indicated considerable similarities between them in respect to several aspects of their structure. Within broad limits, community structure patterns were correlated with seasonal temperature effects, and with the positioning of large estuarine systems.

Both communities were numerically dominated by a few species, a characteristic that is also shared by temperate estuarine fish assemblages (Weinstein and Brooks, 1983; Chao et al., 1985). Surf-zone fish communities, however, also had relatively low diversity, a pattern probably derived from the nature of the physically controlled surf-zone environment (DeLancey, 1984; Lasiak, 1984a and b), which prevents the development of more stable and diverse fish communities in this habitat.

The seasonal patterns of species occurrence abundance and diversity were associated with recruitment of juveniles and reproduction of adult fish. These patterns were also shared by temperate surf-zone fish communities in the Gulf of Mexico (Ross et al., 1987). The reproductive migration of temperate fish species is usually determined by seasonal changes in environmental factors such as water temperature, light intensity, and photoperiod (Gunter, 1945; Vieira, in press a). A fish community dominated by juveniles would certainly be affected by seasonal recruitment waves. As

larvae and juveniles move inshore from spawning grounds they are transported along shore by coastal currents while recruiting into the estuarine nurseries. The seasonal cycles in diversity showed very similar patterns with peaks in the summer, at least when the community was looked at the level of point diversity. However, the results of pooled diversity could not be compared since highly aggregated species distributions at Cassino apparently affected the results of the rarefaction method.

The close association with estuaries also contributed to the similarities in the community structure of surf-zone fishes between both regions. The influence of the Chesapeake Bay estuary clearly played a much more important role in determining community structure at Sandbridge than at the more distant Cape Hatteras (Chesapeake Bight). At Cassino, the greater number of estuarine related species as compared to the relatively small number of surf-zone oriented ones also supported the importance of estuarine proximity. Data also suggested that the extent to which the estuarine fauna is distributed within habitats may also be limited to areas near the estuary. At Cape Hatteras the estuarine influence was not evident and the surf-zone fish community was less diverse due to relatively few estuarine related species. Therefore, on a local scale, estuaries and the surf-zone habitat are part of an integrated system in which the surf-zone acted mostly as an interface coupling oceanic and estuarine habitats for estuarine related species.

The main difference between communities at Cassino and the Chesapeake Bight was related to the intensity of seasonal changes. The ubiquitous surf-zone group at Cassino remained resident throughout the year, whereas in the Chesapeake Bight the assemblage was replaced in the colder months by a wintering group.

Tyler (1971) observed that the proportion of regular (year-round) and seasonal species in fish communities changed with latitude and temperature range, and that seasonal species predominated over regular ones in conjunction with the increase in the annual temperature range in temperate latitudes. At Cassino, where seasonal variations in water temperature were less pronounced, species groups tended to remain throughout the year in the surf-zone. The increased temperature range in the Chesapeake Bight was correlated with seasonal migration of species and changes in surf-zone fish communities.

The comparison of dominance richness patterns of fish communities at Cassino and the Chesapeake Bight through k-dominance curves indicated that the community in the Chesapeake Bight was slightly more diverse than at Cassino. There are two possible explanations for that. The first may be due to the distance between the two sample sites in the Chesapeake Bight, where the rate of species turnover and differences in beta diversity might have contributed to a high pooled diversity gradient (Whittaker, 1977), or in a greater habitat diversity. The second hypothesis is that

communities in the WNA are closer to centers of faunal diversity in the Caribbean and Gulf of Mexico and that the effects of the Gulf Stream provided more effective means of transport of sub-tropical and tropical species to higher latitudes.

The most striking aspect of similarity between communities was the degree to which almost every important species in one hemisphere was matched by one or more comparable species (usually in the same taxon) with a similar broadly defined niche in the other. Among several examples, the pelagic planktivores, Anchoa marinii and Lycengraulis grossidens in the WSA were matched by Anchoa hepsetus and Anchoa mitchilli in the WNA; the bottom oriented benthivore Micropogonias furnieri matched with Micropogonias undulatus; the shallow water omnivores Xenomelaniris brasiliensis and Odontesthes bonariensis matched Menidia menidia and Membras martinica; and the surf-zone oriented species Trachinotus marginatus matched Trachinotus carolinus, respectively at Casino and the Chesapeake Bight; Menticirrhus littoralis occurred in both localities.

While the close taxonomic relationship between pairs of species suggested the occurrence of parallel evolution and speciation in geographically isolated systems rather than convergence, the question is not that simple to answer.

Faunistic comparisons within hemispheres indicated that the extensive temperate components of the fauna at Cassino and the Chesapeake Bight were being gradually replaced by sub-tropical and



tropical species at lower latitudes. However, the distribution ranges of dominant surf-zone taxa shared between regions indicated that they were usually widely distributed and often dominant also accross the tropics. Therefore, there may be a continuity within surf-zone fish communities in which dominant fish assemblages, characterized by eurythermic warm temperate taxa, extend into tropical regions, while occasional components are replaced by tropical elements.

Future comparative surf-zone fish studies should concentrate on the comparison between temperate and tropical faunas including more detailed analysis of niche dimensions and resource partitioning. The use of tropical surf-zone fish communities as a possible out-group for comparisons might provide the basis upon which to test hypotheses concerning the maintainance and evolution of temperate surf-zone fish communities in the western South and North Atlantic.

## CONCLUSIONS

### Within Habitat - Cassino, WSA

1. The total number of fish species collected was relatively small, a few species numerically dominated the community and a larger number of less abundant species occurred occasionally. This resulted in low species diversity.
2. Spatial variation in community diversity was not significant supporting the assumption of within-habitat homogeneity at Cassino.
3. Seasonality was the primary factor shaping the community structure of surf-zone fishes at Cassino, and the biotic identification of seasonal periods correlated well with the abiotic seasonal changes in water temperature and salinity.
4. The seasonal occurrence, abundance and diversity of fish species in the surf-zone reflected recruitment patterns of juveniles determined by the seasonal reproduction of adult fish, and seasonal variations in the circulation patterns, both marine and estuarine.
5. Fish assemblages reflected similar seasonal patterns, faunal affinities, and ecological characteristics and usually fitted into three broad categories: a) year-round surf-zone residents; b) spring to fall, estuarine related, pelagic planktivores or shallow water omnivores; and c) summer to fall coastal marine occasionals.
6. Seasonal variations in water temperature probably played a more important role by determining the time of the spawning migration and reproduction of adult fish, than direct effects on the distribution of juvenile fishes which dominated this community.
7. Similarities between the surf-zone fish fauna at Cassino and that of selected locations of the WSA, decreased towards lower latitudes due to faunal replacements by tropical and sub-tropical taxa.

Within Region - Chesapeake Bight, WNA

1. The structure of surf-zone fish communities in the Chesapeake Bight was primarily determined by large scale habitat heterogeneity between sampled localities, related with the proximity of the Chesapeake Bay estuary at Sandbridge, and the influence of Gulf Stream waters at Cape Hatteras.
2. Surf-zone fish communities in the Chesapeake Bight were also numerically dominated by a few species, either if Sandbridge and Cape Hatteras were treated separately or if samples were pooled and the Bight treated as a unit.
3. Seasonal species migration along the WNA associated with the thermal regime of the Chesapeake Bight, the development of a thermal barrier at Cape Hatteras, and recruitment patterns of juveniles were responsible for high seasonal patterns of species occurrence, abundance and diversity in the surf-zone fish community.
4. Species assemblages showed specific spatial associations, and considerable seasonal patterns in which ubiquitous surf-zone residents were replaced by a wintering group in the colder months.
5. The greater diversity of estuarine related species at Sandbridge indicated that locally, the surf-zone habitat functioned either as a buffer system for migratory estuarine dependents, or an extension of the estuarine realm for estuarine residents.
6. Taxonomic similarities between the surf-zone fish fauna in the Chesapeake Bight and that of the WNA decreased both northward and southward due to the replacement of the warm temperate fauna by boreal and tropical faunas respectively
7. The greatest faunal similarity was with North Carolina and this coincided with spawning areas of several temperate WNA.

#### Within the western Atlantic - Cassino x Chesapeake Bight

Similarities between surf-zone fish communities in geographically isolated systems of the western Atlantic were observed, and within broad limits, community patterns were correlated with the temperature range and habitat structure. The following characteristics were shared between both:

1. The community was numerically dominated by a few species, and a larger number of less abundant species occurred occasionally.
2. Seasonal patterns of species occurrence, abundance and diversity were associated with juvenile recruitment in turn derived from the seasonal reproduction of adult fish and changes in circulation patterns.
3. Seasonal cycles in abundance and diversity showed highly similar patterns, with peaks in the summer and lowest values in winter and spring.
4. The fish fauna was mostly of warm temperate elements which are not contiguously distributed but gradually replaced at lower latitudes by tropical elements.
5. Several species in one system closely matched one or more species in the other in terms of their faunal and ecological relationships.

Communities differed between them in relation to the intensity of seasonal changes. At Cassino, ubiquitous species remained in the surf-zone throughout the year, whereas in the Chesapeake bight a comparable group was replaced by a wintering assemblage when temperatures got too low. It appears that an increased temperature stress in the WNA determined a pronounced seasonal species migration along the Chesapeake Bight.

Faunal replacements at lower latitudes indicate ultimate geographical isolation and parallel evolution of communities under similar environmental conditions. However, the distribution of dominant eurythermic warm temperate taxa into the tropical regions suggests some continuity into the tropics.

Future studies of surf-zone fish communities should compare tropical and temperate faunas to better define faunal replacements and the effects of the degree of seasonality on community structure and function.

## A P P E N D I X   A

Annotated list of species classified by cluster analysis at Cassino and the Chesapeake Bight, indicating their faunal affinity, distribution range, habitat occurrence, reproduction and spawning, and feeding habits. Species are listed by alphabetical order.

Abudefduf saxatilis (Pomacentridae)

Range: North Carolina to SE Brazil (Rio Grande, RS - Chao et al., 1982), common in NE Brazil (Menezes and Figueiredo, 1985).

Occurrence: shallow waters, over reef tops less than 15 m deep, juveniles occur in tidal pools or offshore as part of the Sargassum weed community (Robins et al., 1986). Food and Feeding: plankton, benthic invertebrates, and plants (Robins et al., 1986).

Anchoa hepsetus (Engraulidae)

Range: Massachusetts through the West Indies and southward as far as Montevideo, rare in Florida Keys (Robinette, 1983). Occurrence: coastal and shelf waters (Robinette, 1983); common to locally abundant in the lower Chesapeake Bay from spring to fall (Musick, 1972). Spawning: in estuaries, but also observed along the outer banks less than 16 km offshore at Beaufort, NC (Robinette, 1983); Food and Feeding: adults - plankton and benthic invertebrates (Fischer, 1978).

Anchoa mitchilli (Engraulidae)

Range: Cabo Frio (Rio de Janeiro, Brazil) to Argentina, more common in the southern part of its range (Figueiredo and Menezes, 1978). Occurrence: abundant in the winter at Patos Lagoon (RS, Brazil) usually associated with salt water intrusions (Buckup, 1984); estuarine dependent (Chao et al., 1985); individuals 15 to 30 mm TL occurred from December to February at Cassino (Cunha, 1981). Food and Feeding: zooplankton.

Anchoa mitchilli (Engraulidae)

Fauna: Warm temperate (Phoel, 1985). Range: Along the Atlantic and Gulf of Mexico coasts, from Cape Cod (MA) to Yucatan, Mexico, apparently absent from the Florida Keys; abundant at many localities off New Jersey and in the Chesapeake Bay (Morton, 1989). Occurrence: pelagic, shallow-water, eurihaline, usually schooling along beaches, more common in brackish waters and muddy bottoms (Fischer, 1978); abundant in the lower Chesapeake Bay, from spring to fall, and in deeper bay waters in the winter (Musick, 1972). Spawning: May through September in the Chesapeake Bay (Musick, 1972). Food and Feeding: copepods (preferred), mysids, small crustaceans and molluscs, larval fish, (Morton, 1989).

Bairdiella chrysoura (Sciaenidae)

Fauna: Warm temperate (Musick et al., 1985). Range: Atlantic coast of the U.S. - Connecticut to South Florida; Gulf of Mexico - Rio Grande (Mexico boarder) to Florida. Occurrence: coastal waters over sandy and muddy bottoms (Fischer, 1978); abundant on pound-nets in the Chesapeake Bay in October (Hildebrand and Schroeder, 1928), in deep flats and channels in the lower Bay from spring to fall, in deep channels in the winter, and out of the bay in cold winters (Musick, 1972). Spawning: late spring and early summer (May to June); juveniles and adults move to the nursery and feeding grounds in the estuaries in the summer (Hildebrand and Schroeder, 1928). Food and Feeding: crustaceans, worms, and occasionally fish (Fischer, 1978).

Brevoortia pectinata (Clupeidae)

Range: Sao Paulo (Brazil) to Argentina (Figueiredo and Menezes, 1978). Occurrence: it is the Largest sardine species in SE Brazil (Figueiredo and Menezes, 1978), found year-round on estuarine beach seines at Patos Lagoon (Chao et al., 1982); summer recruitment (December through February) of fish 20 to 80 mm TL at Cassino (Cunha, 1981). Food and Feeding: plankton (Figueiredo and Menezes, 1978).

Brevoortia tyrannus (Clupeidae)

Fauna: Warm temperate (Musick et al., 1985). Range: Nova Scotia to Jupiter Inlet (Florida); Occurrence: coastal, pelagic, forming large schools, adults migrate into deeper water in the winter in the northern part of the range, less so occurs in the South (Fischer, 1978); undergoes extensive North-South, inshore-offshore seasonal migration along the Atlantic seaboard, abundant year-round in the South Atlantic Bight (Rogers and Van Den Avyle, 1983); abundant to common from spring to fall in the Chesapeake Bay (Musick, 1972). Spawning: November through March, starting just South of Cape Hatteras (NC) in shelf waters (100-200 meters); adults move inshore and northward in the spring, separating by age and size, larger fish migrating furthest North; larvae enter estuaries after 1 to 3 months at sea, juveniles emigrate from the estuaries between August and November at 55 to 150 mm TL. Food and Feeding: juveniles and adults are filter feeders (Rogers and Van Den Avyle, 1983).

Caranx hippos (Carangidae)

Range: Nova Scotia to Argentina (Fischer, 1978). Occurrence: common in tropical coastal waters at the surface; young are common in shallow brackish waters, near river mouths (Wheeler, 1975); occasional to common in the summer and fall in the lower Chesapeake

Bay (Musick, 1972). Food and Feeding: invertebrates and fish (Fischer, 1978).

Caranx latus (Carangidae)

Range: New Jersey to Tramandai, (Menezes and Figueiredo, 1980) and Rio Grande (Chao et al., 1982), RS, Brazil; Occurrence: marine pelagic, juveniles usually in brackish water of mud flats (Menezes and Figueiredo, 1980); fishes 30 to 40 mm TL caught at Cassino from February to May near the mouth of Patos Lagoon (Cunha, 1981); rare in the lower Chesapeake Bay from summer to fall (Musick, 1972). Food and Feeding: fish, shrimp, and invertebrates (Menezes and Figueiredo, 1980).

Chloroscombrus chrysourus (Carangidae)

Range: Massachusetts to Argentina (Menezes and Figueiredo, 1980). Occurrence: pelagic, schooling in coastal marine waters, bays and estuaries, most abundant in tropical America (Robins et al., 1986); occasional from fall to spring at Patos Lagoon and nearby coastal waters (Cunha, 1981; Chao et al., 1982); rare in the summer and fall in the lower Chesapeake Bay (Musick, 1972). Food and Feeding: planktonic crustaceans (Menezes and Figueiredo, 1980).

Jenynsia lineata (Jenynsiidae)

Range: Widely distributed in southern Brazil, Uruguay and Argentina, near the mouth of La Plata River (Wheeler, 1975). Occurrence: dominant in shallow estuarine waters (Betito, 1984); occasional from October to December at Cassino, near the mouth of Patos Lagoon (Cunha, 1981). Spawning: live bearer, wide reproductive cycle (peak in the summer). Food and Feeding: omnivorous, phytobenthic feeding (Betito, 1984).

Leiostomus xanthurus (Sciaenidae)

Fauna: Warm temperate (Phoel, 1985). Range: Cape Cod to the Bay of Campeche (Mexico), uncommon in the Florida Keys (Phillips et al., 1989). Occurrence: estuarine and coastal waters, abundant in estuaries in the summer and fall (Phillips et al., 1989); abundant from spring to fall in the Chesapeake Bay, migrating out and south of the bay during winter (Musick, 1972). Spawning: offshore from October to March, mostly off the coast of North Carolina; larvae transported inshore entering the estuaries up to tidal and marsh creeks over seagrass meadows; young remain until September/October (Phillips et al., 1989). Food and Feeding: copepods, ostracods,



polychaetes, larval pelecypods, bivalve siphons, benthic grazing generalists (Phillips et al., 1989).

Lycengraulis grossidens (Engraulidae)

Range: Venezuela to Trinidad and Guianas, southward to Argentina (Figueiredo and Menezes, 1978). Occurrence: euriotic, common in shallow coastal waters, river mouths, estuaries and freshwater, resident at Patos Lagoon (Chao et al., 1985); young-of-the-year ( $\geq 20$  mm TL), occurred at Cassino from December to February (Cunha, 1981). Spawning: fall (March to May) and spring (September to November) in high salinity waters; juveniles recruit to the estuary in December (Buckup, 1984). Food and Feeding: adults - small crustaceans and fishes (Fischer, 1978); juveniles - zooplankton.

Membras martinica (Atherinidae)

Range: New York to Florida, northern Gulf of Mexico to Florida and North Mexico (Robins et al., 1986). Occurrence: along shore, bays and inlets of the Texas Gulf coast, in higher salinity waters in the winter and spring (Gunter, 1945); common in grass flats, and channel edges in the summer in the Chesapeake Bay; winter habitat unknown (Musick, 1972).

Menidia menidia (Atherinidae)

Fauna: Warm temperate (Fay et al., 1983). Range: just north of 47° N (New Brunswick, Nova Scotia) south to Volusia County, Florida (Fay et al., 1983). Occurrence: coastal waters, shore-zone of salt marshes, estuaries and tidal creeks over the entire range; geographically, winter ecology and habitat vary from rare or absent in shore zone or shallow waters in midwinter, moving into deeper areas in populations from Chesapeake Bay northward, to usually abundant throughout the winter in estuaries of South Carolina (Fay et al., 1983). Spawning: in estuaries from late March through June, and probably determined by water temperature, photoperiod, in conjunction with high tide and appropriate lunar phase in the spring. Food and Feeding: copepods, mysids, amphipods, cladocerans, fish eggs, squid, worms, molluscan larvae, insects, algae, detritus; opportunistic, omnivorous (Fay et al., 1983).

Menticirrhus littoralis (Sciaenidae)

Range: Chesapeake Bay to SE Brazil and Rio Grande, usually absent from the Caribbean islands (Fischer, 1978; Menezes and Figueiredo,

1980; Chao et al., 1982). Occurrence: coastal waters over sandy and muddy bottoms, juveniles abundant in the surf-zone, rare at salinities lower than 21 ‰ (Fischer, 1978); small fish (20 to 70 mm TL) recruit in the summer (December to February) at Cassino, adults are caught in the winter (June to August) on deeper water by commercial beach seines (Cunha, 1981); rare in the lower Chesapeake Bay during summer and fall (Musick, 1972), fairly common south of Cape Hatteras (Fischer, 1978). Spawning: WNA - near Cape Lookout (NC) from May through August (Anderson et al., 1977). Food and Feeding: bottom dwelling organisms (polychaetes, *Emerita* spp, *Donax* spp) (Fischer, 1978).

Menticirrhus saxatilis (Sciaenidae)

Fauna: Warm temperate (Phoel, 1985). Range: Gulf of Maine to south Florida and Gulf of Mexico (Fischer, 1978). Occurrence: shallow coastal waters, with sandy and muddy bottoms, rather common in the surf-zone and estuaries; juveniles may enter tidal creeks of low salinities (Fischer, 1978); common in the lower Chesapeake Bay in the summer and fall, migrating south in winter (Musick, 1972); spawns from June to August in New Jersey (Hildebrand and Schroeder, 1928). Food and Feeding: feeds on bottom dwelling organisms such as worm and crustaceans (Fischer, 1978).

Micropogonias furnieri (Sciaenidae)

Range: Atlantic coast of South America from Costa Rica to Argentina, and most of the Antilles and southern Caribbean (Fischer, 1978). Occurrence: coastal waters (<60 m) over sandy and muddy bottoms (Fischer, 1978); juveniles and adults enter estuaries for feeding and nursery; it is the most abundant sciaenid in Patos Lagoon (Barbieri, 1986); occasional at Cassino (Cunha, 1981). Spawning: offshore in the spring, near the mouth of Patos Lagoon, juveniles recruit in the summer through the deeper channels and later spreading into the shallow nursery areas of the estuary; a small late winter recruitment is related to an estuarine spawning stock (Barbieri, 1986). Food and Feeding: bottom dwelling organisms (worms, crustaceans) and small fishes (Fischer, 1978).

Micropogonias undulatus (Sciaenidae)

Fauna: Warm temperate (Musick et al., 1985). Range: Cape Cod, Massachusetts, to the Bay of Campeche, Mexico, uncommon north of New Jersey, common along the Gulf of Mexico coast off Louisiana and Mississippi (Lassuy, 1983). Occurrence: coastal waters (<100 m) over sandy and muddy bottoms, estuarine dependent (Lassuy, 1983); adults

are rare to abundant in the summer and fall in the Chesapeake Bay, migrating south in the winter; juveniles may remain in the bay during mild winters (Musick, 1972). Spawning: near estuaries, shallow bays and lagoons or in offshore waters (8 to 80 m) from August (Chesapeake Bay) to June (Louisiana), with peak spawning in October/November (Hildebrand and Schroeder, 1928; Lassuy, 1983). Food and Feeding: mysids, decapods, amphipods, copepods and polychaetes, molluscs, finfishes and detritus (Lassuy, 1983).

Monacanthus hispidus (Balistidae)

Fauna: Warm temperate (Phoel, 1985). Range: Cape Cod to Cuba (abundant from Georgia to the Florida Keys) southward through the West Indies to northern Brazil (Robins et al., 1986). Occurrence: inshore seagrass beds, seawalls and wharves of harbors, coral reefs and deeper rocky slopes; on continental coasts rather than the islands of the Caribbean (Robins et al., 1986); Monacanthus spp. are very numerous in warm seas (Jordan and Evermann, 1898). Food and Feeding: sponges, sea whips, hydroids and soft-bodied invertebrates (Robins et al., 1986).

Mugil cephalus (Mugilidae)

Range: in the western Atlantic from Nova Scotia to Brazil, abundant in South Florida (Coolins, 1985b); Cited for SE Brazil, but probably does not occur in the WSA (Menezes and Figueiredo, 1985). Occurrence: cosmopolitan in tropical and temperate coastal waters, estuaries and brackish lagoons; eurihaline Juveniles (>35 mm) spend their first year in coastal waters, salt marshes and estuaries, often moving into deeper waters in the fall (Coolins, 1985b); occasional to common in the Chesapeake Bay in the summer and fall, rare in the winter at the lower bay (Musick, 1972). Spawning: offshore in the fall and winter (October to February, peak in November/December) (Coolins, 1985b). Food and Feeding: small algae, organic matter both living and detrital, taken in with sand and mud (Fischer, 1978).

Mugil curema (Mugilidae)

Range: New England to South Brazil (Menezes and Figueiredo, 1985). Occurrence: coastal and estuarine waters (Fischer, 1978); juveniles in shallow waters along beaches and coastal lagoons at high temperatures (Coolins, 1985a); at Patos Lagoon, juveniles are most abundant from mid-summer to early winter, but adults are not found near the estuary (Vieira, in press b); juveniles are occasional to common in the summer and fall in the lower Chesapeake Bay (Musick, 1972). Spawning: WSA - offshore, to the North of Patos Lagoon

(Vieira, in press b); WNA - offshore at the surface, from April through June (peak - March through September), along the Florida coast; juveniles carried North by the Gulf Stream enter estuaries and remain through the summer (Coolins, 1985a). Food and Feeding: small algae, organic matter both living and detrital, taken in with sand and mud (Fischer, 1978), illiophagous (Vieira, in press b).

Mugil gaimardianus (Mugilidae)

Range: Antilles and Florida to SE Brazil (Menezes and Figueiredo, 1985), and Rio Grande, RS, (Chao et al., 1982; Vieira, in press b). Occurrence: juveniles in shallow waters along beaches and coastal lagoons at high temperatures and higher salinities, small fish (30 to 40 mm TL) recruit in the estuary from January through May; absent from the estuary in the winter and spring (Vieira, in press a and b). Spawning: offshore to the north of Patos Lagoon (Vieira, in press a and b). Food and Feeding: illiophagous feeding, near the bottom (Vieira, in press b).

Mugil platanus (Mugilidae)

Fauna: endemic to the WSA (Menezes and Figueiredo, 1985). Range: Rio de Janeiro to Argentina (Menezes and Figueiredo, 1985). Occurrence: coastal waters and estuaries (Menezes and Figueiredo, 1985); very abundant in the Patos Lagoon estuary and Tramandai; juveniles may be retained in coastal waters long after reproduction due to adverse conditions for penetrating the estuaries (Vieira, in press a). Spawning: between May and June (occasionally July and August), roughly in offshore waters off Santa Catarina, SE Brazil (Vieira, in press a).

Odontesthes bonariensis (Atherinidae)

Range: Santos (Sao Paulo, Brazil) to Uruguay (Figueiredo and Menezes, 1978). Occurrence: coastal waters, lagoons, and estuaries (Figueiredo and Menezes, 1978); abundant in late winter and spring at Patos Lagoon, juveniles found in the lower estuary during the whole year (Bemvenuti, 1987). Spawning: late winter (July-August), peak in September, in calm estuarine bays with vegetation (Bemvenuti, 1987). Food and Feeding: plant detritus, small crustaceans and fish (Bemvenuti, 1987).

Oncopterus darwinii (Pleuronectidae)

Range: Rio Grande do Sul (Brazil) to San Mathias Bay, south of Patagonia in Argentina (Roux, 1973). Occurrence: peak recruitment

of 15-105 mm TL fish at Cassino occurred in November and December (Cunha, 1981). Food and Feeding: Juvenile - crustaceans (amphipods, *Emerita* sp.).

Ophidion marginatum (Ophidiidae)

Range: New York to Pensacola and the coast of Texas (Hildebrand and Schroeder, 1928). Occurrence: sandy shores, not very common (Hildebrand and Schroeder, 1928); nocturnal habits, marine, polyhaline, occasional from spring to fall in the lower Chesapeake Bay, burrows in the bottom (Musick, 1972). Food and Feeding: small crustaceans and occasionally fish (Hildebrand and Schroeder, 1928).

Paralichthys orbignyana (Bothidae)

Range: coast of Brazil all the way to Argentina (Roux, 1973). Occurrence: juveniles year-round in shallow waters of the Patos Lagoon (Chao et al., 1982); occasional in the surf-zone at Cassino (Cunha, 1981).

Parona signata (Carangidae)

Range: Rio de Janeiro (Brazil) to the north of Patagonia (Argentina). Occurrence: abundant in Uruguay and Argentina, common in Brazil at certain times of the year. Food and Feeding: small fishes, squid and crustaceans over the entire water column (Menezes and Figueiredo, 1980).

Pomatomus saltatrix (Pomatomidae)

Fauna: Warm temperate (Musick et al., 1985). Range: on the Atlantic coast, from Nova Scotia to SE Brazil (Menezes and Figueiredo, 1980). Occurrence: coastal, pelagic, cosmopolitan, abundant in the lower Chesapeake Bay, adults in the spring, young in summer; all sizes migrate offshore and south in the winter (Musick, 1972). Spawning: probably an offshore spawner in the summer (Hildebrand and Schroeder, 1928). Food and Feeding: predator, carnivore, young hunting in schools, attack shoals of mullets, menhaden and other pelagic fishes (Hildebrand and Schroeder, 1928).

Porichthys porossissimus (Batrachoididae)

Range: Argentina up to at least Rio de Janeiro (Brazil); the northern range of the species has not been well determined yet (Figueiredo and Menezes, 1978). Occurrence: nocturnal, common near

the Patos Lagoon estuary (Chao et al., 1982), in shallow water over sandy and muddy bottoms; one specimen collected by Cunha (1981) at Cassino. Food and Feeding: small crustaceans; coastal spawning (Figueiredo and Menezes, 1978);

Ramnogaster arcuata (Clupeidae)

Range: Rio Grande, Brazil (Chao et al., 1982) and Uruguay, to Terra del Fuego, Argentina (Roux, 1973). Occurrence: year-round in the shallow waters of Patos Lagoon (Chao et al., 1982); in the surf-zone at Cassino individuals 25 to 30 mm TL occurred with peak abundance in November (Cunha, 1981). Food and Feeding: planktonic organisms.

Sardinella brasiliensis (Clupeidae)

Range: Espirito Santo (Brazil) to Uruguay, apparently replacing S. aurita in the southern coast of Brazil (Fischer, 1978). Occurrence: coastal, pelagic, schooling (Figueiredo and Menezes, 1978). Spawning: spring and summer, mostly between December and January, usually at night (Matsuura, 1977). Food and Feeding: planktonic organisms (filter feeding), both phyto and zooplankton (Figueiredo and Menezes, 1978).

Selene vomer (Carangidae)

Range: Maine to Uruguay, rare in the West Indies and Bermuda (Fischer, 1978). Occurrence: Pelagic, in shallow coastal waters, usually over hard or sandy bottoms, around piling and bridges (Fischer, 1978); occasional to common in the lower Chesapeake Bay, during the summer and fall (Musick, 1972). Food and Feeding: small crabs, shrimp, fish and worms (Fischer, 1978).

Spheroides maculatus (Tetraodontidae)

Fauna: Warm temperate (Musick et al., 1985). Range: Cape Ann to Florida on the Atlantic coast of the U.S; the only species within the genus outside the tropics (Jordan and Evermann, 1898). Occurrence: marine, abundant from spring to fall in the channel edges and flats of the lower Chesapeake Bay, migrating south in the winter (Musick, 1972). Spawning: May in the Chesapeake Bay, and July/August in N.Jersey (Hildebrand and Schroeder, 1928). Food and Feeding: small crustaceans (crabs, shrimp, isopods amphipods), small molluscs, annelids (Hildebrand and Schroeder, 1928).

Syngnathus floridae (Syngnathidae)

Range: Chesapeake Bay, Bermuda, Bahamas, North Gulf of Mexico to Panama (Robins et al., 1986). Occurrence: seagrass beds, bays and coastal lagoons (Robins et al., 1986); abundant in deeper grass flats in the summer, and channels in winter in the lower bay (Musick, 1972). Spawning: May to October in the Chesapeake Bay (Hildebrand and Schroeder, 1928);. Food and Feeding: small crustaceans (schizopods, isopods, amphipods) by suction (Hildebrand and Schroeder, 1928).

Syngnathus folletti (Syngnathidae)

Range: Sao Paulo (Brazil) to Uruguay (Figueiredo and Menezes, 1980). Occurrence: shallow coastal waters of SE Brazil usually associated with reefs and submerged vegetation; abundant at depths between 10-30 m in Rio Grande do Sul (Figueiredo and Menezes, 1980); resident in grass beds at Patos Lagoon (Chao et al., 1982). Food and Feeding: copepod crustaceans, plankton suction.

Syngnathus fuscus (Syngnathidae)

Fauna: Warm temperate (Phoel, 1985). Range: Gulf of St. Lawrence to northeast Florida, and northwest Gulf of Mexico from Louisiana to Texas (Robins et al., 1986). Occurrence: seagrass beds in bays and estuaries (Robins et al., 1986); abundant over the entire Chesapeake Bay, in shallow grass flats in the summer, and channels in the winter (Musick, 1972). Spawning: April to October, peaks between April and July (Hildebrand and Schroeder, 1928). Food and Feeding: small crustaceans (copepods, amphipods), fish larvae, insects, plankton suction (Robins et al., 1986).

Syngnathus louisianae (Syngnathidae)

Range: Virginia, Bermuda, north Gulf of Mexico to Campeche and Jamaica (Robins et al., 1986). Occurrence: marine, rare in the lower Chesapeake Bay, over the grass beds in the summer (Musick, 1972); widely captured in the bays along with other Syngnathus species (Gunter, 1945).

Trachinotus carolinus (Carangidae)

Range: Cape Cod (Massachusetts) to Rio Grande do Sul (Brazil); especially common along the Florida and the warm SE Brazil coast (Menezes and Figueiredo, 1980; Cunha, 1987; Gilbert, 1989). Occurrence: surf-zone off sandy beaches (Cunha, 1987; Gilbert, 1989); WSA - juveniles recruited in the summer in the coast of Sao Paulo (SE Brazil), rare at Cassino, from December to February

(Cunha, 1981, 1987); WNA - common in the summer and fall in shallow sandy beaches in the lower Chesapeake Bay (Musick, 1972). Spawning: WSA - probably a spring spawner in the coast of Sao Paulo, SP, Brazil (Cunha, 1987); WNA - offshore, near the Gulf Stream, from April through June and September/October, larvae dispersed along the U.S. Atlantic seaboard (Gilbert, 1989). Food and Feeding: amphipods, bivalve molluscs, crab larvae, copepods, isopods and eggs (Gilbert, 1989).

Trachinotus falcatus (Carangidae)

Range: Massachusetts to SE Brazil (Rio Grande, RS - Chao et al., 1982, 1985), throughout the West Indies and Bermuda (Fischer, 1978). Occurrence: adults - pelagically and epibenthically in shallow water, frequently in channels or holes, over sandy flats, around reefs; juveniles - in large schools in the summer in the surf-zone of sandy beaches (Fischer, 1978), occasionally near vegetated bottoms around mangroves (Cunha, 1987); rare in SE Brazil in the summer (Cunha, 1987); rare to occasional in the lower Chesapeake Bay during summer and fall (Musick, 1972). Spawning: WNA - probably offshore in the spring, near the Gulf Stream (Cunha, 1987). Food and Feeding: adults - molluscs and crustaceans (crabs and shrimps); juveniles - benthic invertebrates (worms, copepods, amphipods) (Fischer, 1978).

Trachinotus goodei (Carangidae)

Fauna: Tropical (Fischer, 1978). Range: Massachusetts to Argentina, through the West Indies and Bermuda (Fischer, 1978). Occurrence: pelagic, on high salinity waters, schooling in the surf-zone of sandy beaches, but also around reef and rocky areas; recruitment occurs in the summer in Florida, developing young move northward along the Atlantic seaboard, less common in Georgia waters and further north (Fischer, 1978); rare in the lower Chesapeake Bay in the summer (Musick, 1972). Food and Feeding: small invertebrates and fish (Fischer, 1978).

Trachinotus marginatus (Carangidae)

Fauna: endemic to the WSA (Figueiredo, 1981). Range: Rio de Janeiro (Brazil) to Uruguay, not common in the warmer SE Brazil (Menezes and Figueiredo, 1980; Figueiredo, 1981). Occurrence: juveniles - surf-zone off sand beaches; at Cassino, fish ranged from 13 to 170 mm TL, 93% of the fish were between 15-60 mm TL (Cunha, 1981, 1987). Spawning: probably from late spring to early fall with peak in the summer (Cunha, 1981, 1987). Food and Feeding: benthic invertebrates, crustaceans (Emerita brasiliensis, copepods,



amphipods), polychaetes, and bivalve molluscs (Monteiro-Neto and Cunha, 1989).

Umbrina canosai (Sciaenidae)

Range: SE Brazil to Argentina. Occurrence: coastal waters over sandy and/or muddy bottoms in the continental shelf (Menezes and Figueiredo, 1980); juveniles are caught in bottom and mid-water trawls in the Patos Lagoon, from spring to fall (Chao et al., 1982).

Xenomelaniris brasiliensis (Atherinidae)

Range: Venezuela to Rio Grande do Sul (Figueiredo and Menezes, 1978). Occurrence: estuarine resident in the Patos Lagoon and apparently the most common species in SE Brazil (Chao et al., 1985); peak abundance at Cassino, occurred in April and November, with smaller individuals (20 to 90 mm TL) recruiting in April (Cunha, 1981). Spawning: as early as October (peak in December-January) in shallow bays, over vegetated bottom, juveniles appear in the summer in the upper estuary and adults stay near the mouth (Bemvenuti, 1987). Food and Feeding: plant detritus, small crustaceans and fish (Bemvenuti, 1987).

## LITERATURE CITED

- Anderson, W.D., Jr; J.K. Dias; R.K. Dias; D.M. Cupka and N.A. Chamberlain 1977. The macrofauna of the surf-zone off Folly Beach, South Carolina. NOAA Tech. Rep. NMFS SSRF-704, 23 p.
- Andriyashev, A.P. 1987. Development of L.S. Berg's concept of the bipolarity of marine fauna. Soviet J. Mar. Biol. 13(2): 114-120.
- Barbieri, L.R.R. 1986. Distribuicao espacial e temporal dos sciaenideos juvenis no estuario da Lagoa dos Patos, RS, Brasil. MS thesis, Universidade do Rio Grande, RS, Brasil.
- Beardsley, R.C.; W.C. Boicourt and D.V. Hansen 1976. Physical oceanography of the Middle Atlantic Bight. Limnol. and Oceanogr. Spec. Symp., 2:20-34.
- Bemvenuti, M.A. 1987. Abundancia, distribuicao e reproducao de peixes-rei (Atherinidae) na regio estuarina da Lagoa dos Patos, RS, Brasil. Atlantica 9(1): 5-32.
- Betito, R. 1984. Dinamica da populacao de Jenynsia lineata (Ciprinodontiformes, Anablepidae) na restinga de Rio Grande, estuario da Lagoa dos Patos. MS thesis, Universidade do Rio Grande, RGS, Brasil.
- Boesch, D.F. 1977. Application of numerical classification in ecological investigations of water pollution. E.P.A., Ecol. Res. Series, EPA-600/3-77-033. 115 p.
- Briggs, J.C. 1974. Marine zoogeography. McGraw-Hill Inc.
- Buckup, P.A. 1984. Distribuicao e abundancia de Engraulideos (Osteichthyes, Clupeiformes) na regio estuarial da Lagoa dos Patos, RS, Brasil. MS thesis, Universidade do Rio Grande, RGS, Brasil.
- Carter, R.W.G. 1988. Coastal Environments. An introduction to the physical, ecological and cultural systems of coastlines. Academic Press.
- Castello, J.P. and O.O. Moller, Jr. 1977. On the oceanographic conditions in the Rio Grande do Sul state. Atlantica 2(2):25-110.

- Castello, J.P. and O.O. Moller, Jr. 1978. On the relationship between rainfall and shrimp production in the estuary of the Patos Lagoon (Rio Grande do Sul, Brazil). *Atlantica* 3:67-74.
- Cerame-Vivas, M.J. and I.E. Gray 1966. The distributional pattern of benthic invertebrates of the continental shelf off North Carolina. *Ecology* 47(2):261-270.
- Chao, L.N. and J.A. Musick 1975. Life history, feeding habits, and functional morphology of juvenile sciaenid fishes in the York River estuary, Virginia. *Fish. Bull* 75(4): 657-702.
- Chao, L.N. and J.A. Musick 1982. Faunal and ecological affinities of fish communities in the estuary of Lagoa dos Patos (30 S), Brazil, and lower Chesapeake Bay (37 N), USA. Paper presented at "International Symposium on Utilization of Coastal Ecosystems: Planning, Pollution and Productivity. Rio Grande, RS, Brazil.
- Chao, L.N.; L.E. Pereira; J.P. Vieira; M.A. Bemvenuti and L.P.R. Cunha 1982. Relacao preliminar dos peixes estuarinos e marinhos da Lagoa dos Patos e regioa costeira adjacente, Rio Grande do Sul, Brasil. *Atlantica*, Rio Grande, 5(1): 67-75.
- Chao, L.N.; L.E. Pereira and J.P. Vieira 1985. Estuarine fish community of the Patos Lagoon, Brazil - a baseline study. In: Yanez-Arancibia (ed.), *Fish Community Ecology in Estuaries and Coastal Lagoons - Towards an Ecosystem Integration*. UNAM, Mexico.
- Clifford, H.T. and W. Stephenson 1975. An introduction to numerical classification. Academic Press, N.Y. 229 p.
- Cody, M.L. 1975. Towards a theory of continental species diversities. In: M.L. Cody and J.M. Diamond (eds.), *Ecology and evolution of communities*, 214-257.
- Cody, M.L. and H.A. Mooney 1978. Convergence versus non-convergence in mediterranean climate ecosystems. *Ann. Rev. Ecol. Syst.*, 9: 265-321.
- Coelho, P.A. and M.F.B.A Dos Santos 1980. Zoogeografia marinha do Brasil. I. Consideracoes gerais sobre o metodo e aplicacao a um grupo de crustaceos (Paguros: Crustacea, Decapoda, super-familias Paguroidea e Coenobitoidea). *Bol. Inst. Oceanogr. S. Paulo* 29(2): 139-144.
- Colvocoresses, J.A. and J.A. Musick 1984. Species associations and community composition of the Middle Atlantic Bight continental shelf demersal fishes. *Fish. Bull.* 82(2): 295-313.

- Coolins, M.R. 1985a. Species Profiles: Life histories and environmental requirements of coastal fishes and invertebrates (South Florida) -- white mullet. U.S. Fish and Wildl. Serv. Biol. Rep. 82(11.39). U.S Army Corps of Engineers, TR EL-82-4. 7 pp.
- Coolins, M.R. 1985b. Species Profiles: Life histories and environmental requirements of coastal fishes and invertebrates (South Florida) -- striped mullet. U.S. Fish and Wildl. Serv. Biol. Rep. 82(11.34). U.S Army Corps of Engineers, TR EL-82-4. 11 pp.
- Cunha , L.P.R. 1981. Variacao sazonal da distribuicao, abundancia e diversidade dos peixes na zona de arrebentacao da praia do Cassino, RS Brasil. M.S. thesis, Museu Nacional do Rio de Janeiro, UFRJ., Brazil. 47 p.
- Cunha , L.P.R. 1987. Importancia da zona de arrebentacao de praias para o desenvolvimento dos juvenis de Trachinotus (Pisces, Carangidae): Aspectos da bioecologia e distribuicao geografica do genero, com enfase as especies que ocorrem no litoral sul/sudeste do Brasil e no Atlantico Ocidental. Ph.D. dissertation, Instituto de Biociencias da USP, Sao Paulo, Brazil.
- Dahlberg, M.D. 1972. An ecological study of Georgia coastal fishes. Fish. Bull., 70(2): 323-353.
- Day, J.D., Jr.; C.A.S. Hall; W.M. Kemp; A. Yanes-Arancibia and L.A. Deegan 1989. Nekton, the free-swimming consumers. In: Day, J.D., Jr.; C.A.S. Hall; W.M. Kemp; A. Yanes-Arancibia (Eds.), Estuarine Ecology, John Wiley and Sons. pp: 377-437.
- DeLancey, L.B. 1984. An ecological study of the surf-zone at Folly Beach, South Carolina. M.S. Thesis, College of Charleston, S.C.
- Diaz, R.J. 1982. Habitat suitability index models: Juvenile Atlantic croaker. U.S. Dept. Int. Fish Wildl. Serv. FWS/OBS-82/10.21. 22 pp.
- Digby P.G.N. and R.A. Kempton 1987. Multivariate analysis of ecological communities. Chapman Hall, N.Y.
- Draper, N. and H. Smith 1981. Applied regression analysis, 2<sup>nd</sup> ed. John Wiley and Sons.
- Ekman, S. 1953. Zoogeography of the sea. Sidgwick and Jackson LTD, London.

- Fay, C.W., R.J. Neves, and G.B. Pardue. 1983. Species Profiles: Life histories and environmental requirements of coastal fishes and invertebrates (Mid-Atlantic) -- Atlantic silverside. U.S. Fish and Wildlife Service, Division of Biological Services, FWS/OBS-82/11.10. U.S. Army Corps of Engineers, TREL-82-4. 15 pp.
- Fields, J.G.; K.R. Clarke and R.M. Warwick 1982. A practical strategy for analysing multispecies distribution patterns. Mar. Ecol. Prog. Ser., 8: 37-52.
- Figueiredo, J.L. 1981. Estudo das distribuicoes endemicas de peixes da Provincia Zoogeografica Marinha Argentina. Ph.D. dissertation, Instituto de Biociencias da Universidade de Sao Paulo, 121 p.
- Figueiredo, J.L. and N.A. Menezes 1978. Manual de peixes marinhos do sudeste brasileiro: II - Teleostei (1). Museu de Zoologia da USP.
- Figueiredo, J.L. and N.A. Menezes 1980. Manual de peixes marinhos do sudeste brasileiro: III - Teleostei (2). Museu de Zoologia da USP.
- Fischer, W. (ed.). 1978. FAO species identification sheets for fishery purposes. Western Central Atlantic (fishing area 31). Vols. 1-7. FAO, Rome, Italy.
- Fox, L.S. and W.R. Mock, Jr. 1968. Seasonal occurrence of fishes in two shore habitats in Barataria Bay, Louisiana. Louisiana Acad. Sci. 31: 43-53.
- Freund, R.J.; R.C. Littell and P.C. Spector 1986. SAS system for linear models. SAS Institute Inc.
- Gilbert, C. 1989. Species Profiles: Life histories and environmental requirements of coastal fishes and invertebrates (South Florida) -- Florida pompano. U.S. Fish and Wildl. Serv. Biol. Rep. 82(11.42). U.S. Army Corps of Engineers, TR EL-82-4. 14 pp.
- Gianuca, N.M. 1983. A preliminary account of the ecology of sandy beaches in southern Brazil. In: A. McLachlan and T. Erasmus (ed). Sandy beaches as ecosystems. Junk, The Hague, 413-419.
- Gianuca, N.M. 1985. The ecology of a sandy beach in southern Brazil. Ph.D. Dissertation, Dept. Oceanography, Univ. South Hampton, U.K.

- Gierloff-Emden, H.G. 1975. Water-body of a lagoon consisting of turbid water masses having no transparency. Lagoa dos Patos, Brazil, Coast of Atlantic Ocean, orbital remote sensing from Apollo and Skylab missions - comparison and evaluation. NASA, Apollo mission 7, no. 4 - 1594.
- Gladfelter, W.B., J.C. Ogden and E.H. Gladfelter 1980. Similarity and diversity among coral reef fish communities: a comparison between tropical western Atlantic (Virgin Islands) and tropical central Pacific (Marshall Islands) patch reefs. *Ecology* 61(5): 1156-1168.
- Gunter G. 1945. Studies on marine fishes from Texas. Publ. Inst. Mar. Sci., Univ. of Texas, 1(1): 1-190.
- Gunter G. 1958. Population studies of the shallow water fishes of an outer beach in south Texas. Texas Inst. Mar. Sci. Publ. 5: 186-193.
- Harrison, W.; J.J. Norcross; N.A. Pore and E.M. Stanley. 1967. Circulation of shelf waters off the Chesapeake Bight. Surface and bottom drift of continental shelf waters between cape henlopen, Delaware, and Cape Hatteras, North Carolina, June 1963 - December 1964. ESSA professional paper 3.
- Hildebrand, S.F. and W.C. Schroeder 1928. Fishes of Chesapeake Bay. U. S. Fish and Wildl. Serv. Fish. Bull. 53(1). Neptune, N.J., T.F.H. Publ. Inc.
- Hillman, R.E.; N.W. Davis and J. Wennemer 1977. Abundance, diversity and stability in shore-zone fish communities in an area of Long Island Sound affected by the thermal discharge of a nuclear power station. *Est. Coast. Mar. Sci.* 5:355-381.
- Hubold, G. 1980a. Hydrography and plankton off southern Brazil and Rio de La Plata, August - November 1977. *Atlantica* 4:1-22.
- Hubold, G. 1980b. Second report on hydrography and plankton off southern Brazil and Rio de La Plata; Autumn cruise: April - June 1978. *Atlantica* 4:23-42.
- Hurlbert, S.H. 1971. The non-concept of species diversity: a critique and alternative parameters. *Ecology* 52: 577-586.
- IPA-SA 1980. Boletim meteorologico para a cidade de Rio Grande. Instituto de Pesquisas Agronomicas, Secretaria da Agricultura, Porto Alegre, Brasil.

- IPA-SA 1981. Boletim meteorologico para a cidade de Rio Grande. Instituto de Pesquisas Agronomicas, Secretaria da Agricultura, Porto Alegre, Brasil.
- IPA-SA 1982. Boletim meteorologico para a cidade de Rio Grande. Instituto de Pesquisas Agronomicas, Secretaria da Agricultura, Porto Alegre, Brasil.
- Johnson, A.W. 1973. Historical view of the concept of ecosystem convergence. In: Mediterranean Type Ecosystems. F. DiCasteri and H.A. Mooney (eds.). Springer Verlag, N.Y. pp 1-7.
- Johnson, R.A. and D.W. Wichern 1988. Applied multivariate statistical analysis, 2<sup>nd</sup> ed. Prentice Hall, N.J.
- Jordan, D.S. and B.W. Evermann 1898. The fishes of North and Middle America: A descriptive catalogue of the species of fish-like vertebrates found in the waters of North America, north of the isthmus of Panama. Bull. of U.S. Nat. Museum, parts I-III.
- Krebs, C.J. 1985. Ecology: the experimental analysis of distribution and abundance (3<sup>rd</sup> ed.). Harper and Row Publ.
- Lambert, J.M. and W.T. Williams 1962. Multivariate methods in plant ecology: IV - Nodal Analysis. J. Ecol. 50: 775-802.
- Lasiak, T. 1984a. Structural aspects of the surf-zone fish assemblage at King's Beach, Algoa Bay, South Africa: Long-term fluctuations. Est. Coast. Shelf Sci., 18: 459-483.
- Lasiak, T. 1984b. Structural aspects of the surf-zone fish assemblage at King's Beach, Algoa Bay, South Africa: Short-term fluctuations. Est. Coast. Shelf Sci., 18: 347-360.
- Lassuy, D.R. 1983. Species Profiles: Life histories and environmental requirements (Gulf of Mexico) -- Atlantic croaker. U.S. Fish and Wildlife Service, Division of Biological Services, FWS/OBS-82/11.3. U.S. Army Corps of Engineers, TREL-82-4. 12 pp.
- Lenanton, R.C.J. 1982. Alternative non-estuarine nursery habitats for some commercially and recreationally important fish species of Southwestern Australia. Aust. J. Mar. Freshw. Res., 33: 881-900.
- Lenanton, R.C.J and I.C. Potter 1987. Contribution of estuaries to commercial fisheries in temperate western Australia and the concept of estuarine dependence. Estuaries 10(1): 28-35.

- Lopez, R.B. 1964. Problemas de la distribucion geografica de los peces marinos suramericanos. Bol. Inst. Biol. Mar. Mar del Plata 7: 57-63.
- MacFarland, W.N. 1963. Seasonal change in the number and biomass of fishes from the surf at Mustang Island, Texas. Publ. Inst. Mar. Sci., Univ. of Texas , 9: 91-105.
- Magurran, A.E. 1988. Ecological diversity and its measurement. Princeton University Press, N.J.
- Mares, M.A. 1976. Convergent evolution of desert rodents: multivariate analysis and zoogeographic implications. Paleobiol. 2: 39-63.
- Martins, I. da R. 1984. Aspectos da oceanografia fisica do Atlantico Sul. Pesquisas 16:76-90.
- Matsuura, Y. 1977. O ciclo de vida da sardinha verdadeira. (Introducao a oceanografia pesqueira). Publ. Esp. Inst. Oceanogr. S. Paulo 4: 1-146.
- McLachlan, A. 1983. Sandy beach ecology - A review. In: A. McLachlan and T. Erasmus (ed). Sandy beaches as ecosystems. Junk, The Hague, 321-380.
- Menezes, N.A. and J.L. Figueiredo 1980. Manual de peixes marinhos do sudeste brasileiro: IV - Teleostei (3). Museu de Zoologia da USP.
- Menezes, N.A. and J.L. Figueiredo 1985. Manual de peixes marinhos do sudeste brasileiro: V - Teleostei (4). Museu de Zoologia da USP.
- Miliken, G.A. and D.A. Johnson 1984. Analysis of messy data. Van Nostrand and Reinholds Co., N.Y.
- Modde, T. 1980. Growth and residency of juvenile fishes within a surf-zone habitat in the Gulf of Mexico. Gulf Res. Rep. 6:377-385.
- Modde, T. and S.T. Ross 1981. Seasonality of fishes occupying a surf-zone habitat in the northern Gulf of Mexico. Fish. Bull. 78(4): 911-922.
- Monteiro-Neto, C. and L.P.R. Cunha 1989. Seasonal and ontogenetic changes in the food habits of juvenile Trachinotus marginatus (Teleostei, Carangidae) in the surf-zone of Cassino Beach, RS, Brazil. Atlantica 11(2): 45-54, Rio Grande.



- Monteiro-Neto, C.; C. Blacher; A.A.S. Laurent; F.N. Snizek; M.B. Canozzi and L.L.C. de A. Tabajara (in press). Estrutura da comunidade de peixes em aguas rasas no estuario de Laguna, SC, Brasil. *Atlantica* 12(1), 1990, Rio Grande.
- Morton, T. 1989. Species Profiles: Life histories and environmental requirements of coastal fishes and invertebrates (Mid-Atlantic) -- bay anchovy. U.S. Fish and Wildl. Serv. Biol. Rep. 82(11.97). 13 pp.
- Morton, S.R. and D.W. Davidson 1988. Comparative structure of harvester ant communities in arid Australia and North America. *Ecol. Monogr.*, 58(1): 19-38.
- Musick, J.A. 1972. Fishes of the Chesapeake Bay and adjacent coastal plain. In: A checklist of the biota of lower Chesapeake Bay. M.L. Wass (ed.). VIMS, Spec. Scient. Rep. 65.
- Musick, J.A.; J. Colvocoresses and E.J. Foel 1985. Seasonality and the distribution, availability and composition of fish assemblages in Chesapeake Bight. In: A. Yanez Arancibia (ed.), *Fish Community Ecology in Estuaries and Coastal Lagoons: Towards an Ecosystem Integration*, UNAM Press, Mexico.
- Naughton, S.P. and C.H. Saloman 1978. Fishes of the nearshore zone of St. Andrew Bay, Florida, and adjacent coast. *Northeast Gulf Sci.* 2(1): 43-55.
- NCDC-National Climatic Data Center 1973. *Climatological Data - Virginia*, vol. 83, no. 7 to 12.
- NCDC-National Climatic Data Center 1974. *Climatological Data - Virginia*, vol. 84, no. 1 to 6.
- NCDC-National Climatic Data Center 1973. *Climatological Data - North Carolina*, vol. 78, no. 7 to 12.
- NCDC-National Climatic Data Center 1974. *Climatological Data - North Carolina*, vol. 79, no. 1 to 6.
- Nelson, G. 1985. A decade of challenge the future of biogeography. In: A.E. Leviton and M.L. Aldrich (eds). *Earth sciences history* (J. Hist. Sci. Soc.), 4(2): 187-196.
- Paiva Filho, A.M. and A.P. Toscano 1987. Estudo comparativo e variacao sazonal da ictiofauna na zona entremares do Mar Casado-Guaruja, e Mar Pequeno-Sao Vicente, SP. *Bolm. Inst. Oceanogr. S.Paulo* 35(2): 153-165.

- Palacio, F.J. 1982. Revision zoogeografica marina del sur del Brasil. Bolm. Inst. Oceanogr., S. Paulo, 31(1):69-92.
- Parr, A.E. (1933) A geographic ecological analysis of the seasonal changes in temperature conditions in shallow water along the Atlantic coast of the U.S. Bull. Bingham Oceanogr. Collect., Yale Univ. 4: 1-90.
- Parrish, J.D. 1987. Characteristics of fish communities on coral reefs and in potentially interacting shallow habitats in tropical oceans of the world. In: Comparison between atlantic and pacific tropical marine coastal ecosystems: community structure, ecological processes, and productivity. C. Birkland (ed.). UNESCO Rep. Mar. Sci. 46, pp. 171-218.
- Peters, D.J. and W.G. Nelson 1987. The seasonality and spatial patterns of juvenile surf-zone fishes of the Florida east coast. Fla. Scient. 50(2): 85-99.
- Phillips, J.M., M.T. Huish, J.H. Kerby, and D.P. Moran. 1989. Species Profiles: Life histories and environmental requirements of coastal fishes and invertebrates (Mid-Atlantic) -- spot. U.S. Fish and Wildl. Serv. Biol. Rep. 82(11.98). U.S Army Corps of Engineers, TR EL-82-4. 13 pp.
- Phoel, W.C. 1985. Community structure of demersal fishes on the inshore U.S. Atlantic Continental Shelf: Cape Ann, MA. to Cape Fear, N.C. Ph.D. dissertation, VIMS, Gloucester Point, VA.
- Phonlor, G. 1973. Estudo preliminar do ictioplankton. Publ. Esp. Inst. Oceanogr. Sao Paulo, 3(1): 427-464.
- Pianka, E.R. 1975. Niche relations of desert lizards. In: M.L. Cody and J.M. Diamond (eds.), Ecology and evolution of communities, 214-257.
- Pickard, G.L. and W.J. Emery 1982. Descriptive physical oceanography: an introduction (4<sup>th</sup> ed.). Pergamon Press.
- Pierce, J.W. and D.J. Colquhoun 1970. Holocene evolution of a portion of the North Carolina coast. Geol. Soc. Amer. Bull., 81:3697-3714.
- Pierce, J.W. and D.J. Colquhoun 1971. Configuration of the holocene primary barrier chain, Outer Banks, N.C. Southeastern Geology 2(4): 231-236.

- Pocklington, P. and M.J. Tremblay 1987. Faunal zones in the northwestern atlantic based on polychaete distribution. *Can. J. Zool.* 65:391-402.
- Robinette, H.R. 1983. Species Profiles: Life histories and environmental requirements of coastal fishes and invertebrates (Gulf of Mexico) -- bay anchovy and striped anchovy. U.S. Fish and Wildlife Service, Division of Biological Services, FWS/OBS-82/11.14. U.S. Army Corps of Engineers, TREL-82-4. 15 pp.
- Robins, C.R.; G.C. Ray; J. Douglass and R. Freund 1986. A field guide to Atlantic coast fishes of North America. Houghton Mifflin Co., Boston.
- Rogers, S.G., and M.J. Van Den Avyle. 1983. Species Profiles: Life histories and environmental requirements of coastal fishes and invertebrates (South Atlantic) -- Atlantic menhaden. U.S. Fish and Wildlife Service, Division of Biological Services, FWS/OBS-82/11.11. U.S. Army Corps of Engineers, TREL-82-4. 20 pp.
- Ross, S.T.; R.H. McMichael, Jr. and D.L. Ruple 1987. Seasonal and diel variation in the standing crop of fishes and macro-invertebrates from a Gulf of Mexico surf-zone. *East. Coast. Shelf. Sci.* 25: 391-412.
- Roux, C. 1973. Resultats scientifique des campagnes de la Calypso. Fasc. X, poisons teleostiens du plateau continental bresilien. *An. Inst. Oceanogr. Monaco*, 49(suppl.): 23-207.
- Schall, J.J. and E.R. Pianka 1978. Geographical trends in number of species. *Sci.* 201(4357): 679-686.
- Sage, R.D. 1973. Ecological convergence of the lizard faunas of the Chaparral communities in Chile and California. In: *Mediterranean Type Ecosystems*. F. DiCasteri and H.A. Mooney (eds.). Springer Verlag, N.Y. pp 1-7.
- Saloman, C.H. and S.P. Naughton 1979. Fishes of littoral zone, Pinellas County, Florida. *Fla. Sci.* 42(2): 85-93.
- Sanders, H.L. 1968. Marine benthic diversity: a comparative study. *Am. Nat.* 102(925): 243-282.
- Sokal R.R. and F.J. Rohlf 1981. *Biometry*, 2<sup>nd</sup> ed. W.H. Freeman & Co, N.Y.

- Tagatz, M.E. and D.L. Dudley 1961. Seasonal occurrence of marine fishes in four shore habitats near Beaufort, NC, 1957-1960. U.S. Fish. Wildl. Serv., Spec. Sci. Rep. Fish. 390. 19 p.
- Thresher, R.E. 1987. Interoceanic and regional differences in the reproductive biology of reef associated fishes. In: Comparison between atlantic and pacific tropical marine coastal ecosystems: community structure, ecological processes, and productivity. C. Birkland (ed.). UNESCO Rep. Mar. Sci. 46, pp. 219-238.
- Tyler, A.V. 1971. Periodic and resident components in communities of atlantic fishes. J. Fish. Res. Bd. Canada, 27(7): 935-946.
- Underwood, A.J. 1981. Techniques of analysis of variance in experimental marine biology and ecology. Oceanogr. Mar. Biol. Ann. Rev., 19: 513-605.
- Vieira, J.P. (in press a) Migracao reprodutiva da "Tainha" (Mugil platanus Günther, 1880) no sul do Brasil. Anais do Simposio de Pesquisa Pesqueira da Fundacao Universidade do Rio Grande.
- Vieira, J.P. (in press b) Juvenile mullets (Pisces, Mugilidae) in the estuary of Lagoa dos Patos, RS, Brazil.
- Warfel, H.E. and D. Merriman 1944. Studies on the marine resources of southern New England. I- An analysis of the fish population of the shore zone. Bull. Bingh. Oc. Coll. 9(2): 1-91.
- Winer, B.J. 1971. Statistical principles in experimental design, 2<sup>nd</sup> ed. McGraw-Hill Book Co.
- Wheeler, A. 1975. Fishes of the world: an illustrated dictionary. Macmillan Publishing Co. Inc., New York.
- Whittaker, R.H. 1977. Evolution of species diversity in land communities. In: M.K. Hecht, W.C. Steere, and B. Wallace (Eds.), Evolutionary Biology, Vol. 10. Plenum, New York, pp: 1-67.
- Wright, L.D. and A.D. Short 1984. Morphodynamic variability of surf-zone and beaches: a synthesis. Mar. Geol. 56: 93-118.

## VITA

Cassiano Monteiro-Neto

Born in Porto Alegre, Rio Grande do Sul, Brazil, 11 February 1956. Received a BS degree in Oceanology (major in Biological Oceanography) from Fundacao Universidade do Rio Grande, RS, Brazil, in 1982. Received a a fellowship from the Brazilian government (CIRM) to take a two month extension course in Marine Science at Instituto Oceanografico da Universidade de Sao Paulo, SP, Brazil, in 1983. Entered the Masters program at the School of Marine Science, College of William and Mary in January 1985, and latter bypassed to the PhD program. Granted a 4 year full time scholarship from Brazil (CNPq) to complete graduate work in Marine Science.