A Proposed Estuarine Classification: Analysis of Species Salinity Ranges

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Introduction

This report presents results of a statistical analysis of the salinity ranges of fish and invertebrates that use estuaries in the Mid-Atlantic Region. The analysis was conducted jointly by NOAA's Strategic Assessment Branch and the University of Virginia's Department of Environmental Sciences. The project was undertaken to provide additional information to NOAA's Estuarine Living Marine Resources (ELMR) project (see inside front cover). This project uses salinity zones to organize information on the spatial and temporal distribution of species within estuaries. The results presented will aid in the interpretation of the ELMR information under development, and may provide an improved framework to organize information on estuarine species distributions.

Data were compiled and analyzed on the salinity ranges of 317 species/life stage combinations in the Mid-Atlantic Region. Results indicate that five overlapping salinity zones (freshwater to 4 parts per thousand (ppt), 2-15 ppt, 11-19 ppt, 15-28 ppt, and 23 ppt to marine waters) can be used to represent how fish and invertebrates are distributed within estuaries in this region. Species assemblages were also identified based on the salinity zones they use in common. The scheme presented is an attempt to develop an estuarine salinity classification based on a multivariate statistical analysis of reported field distributions of species. The analysis is compared to the Venice System (Symposium 1959) of estuarine salinity classification.

Rationale

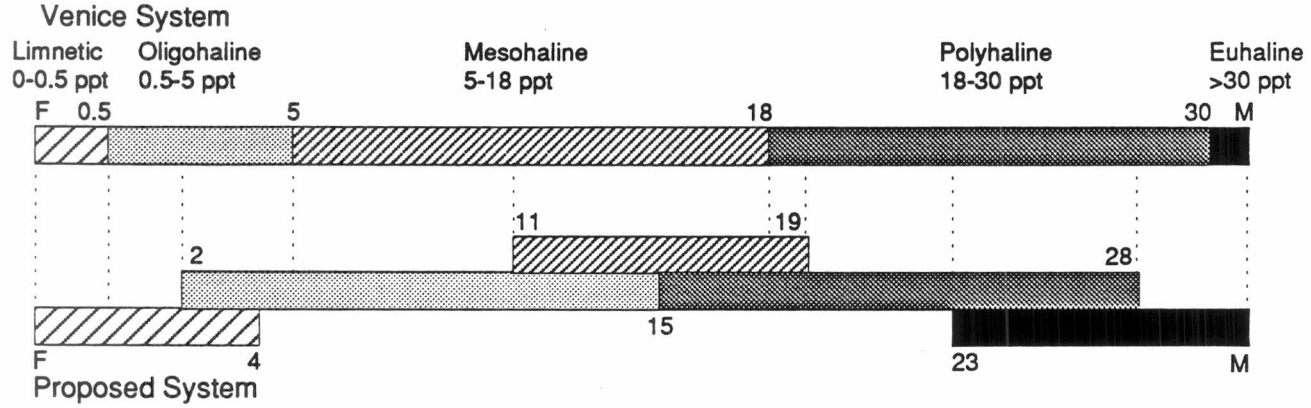
Estuaries are transitional environments in which salinity ranges between freshwater and seawater (Moyle and Cech 1982). The important role that these environments play in sustaining the health and abundance of marine fishes, shellfish, and other animals has long been recognized. Salinity is an important determinant of the distribution of estuarine flora and fauna. Consequently, efforts to subdivide estuaries on the basis of salinity have long been based on the observation that estuarine species are not evenly distributed across estuarine salinity gradients. (Segerstråle 1959; Remane and Schlieper 1971). Although descriptions of the distributions of estuarine species have yielded more than a dozen salinity classification schemes, recurring patterns across taxa and geographic regions have also been recognized.

One of the most well-known estuarine classification schemes is the "Venice System" (Symposium 1959), which has largely superseded earlier schemes. The Venice System has gained wide application in describing the patterns of distribution among estuarine organisms. Describing and summarizing these patterns is one important and practical function of classification schemes; another is to help understand the linkages between ecological processes and species distributions.

Existing classification schemes have been based primarily on subjective or qualitative assessments of how animals use estuaries. For example, the Venice System of estuarine salinity gradients (Figure 1) was the result of an informal analysis which was crafted from the observation, judgement, and experience of scientists of the day (Symposium 1959).

As nationwide estuarine degradation continues, and management and mitigation strategies become more complex, improved and more adaptable schemes are necessary to organize our knowledge of estuaries. Development of a statistically-based classification scheme as attempted here may provide new insights into how species utilize estuaries.

Figure 1. Comparison of Venice and Proposed Classification System.



Study Design

This study was designed to derive an ecological salinity classification for estuaries based on biological responses to salinity gradients. In developing the classification, it was hypothesized that species tend to have common or similar salinity ranges, and that the number of common ranges are small. Estuarine zones can be identified from these ranges to produce a biogeographic estuarine salinity classification.

The analysis of community structure across environmental gradients has a long history and has resulted in the evolution of ecological concepts such as continuum, ecotone, limiting factors, and optimum conditions. Ecologists use the term ordination for gradient analysis (Gauch 1982; Legendre and Legendre 1983). Recently, multivariate ordination methods have been used to examine community structure across environmental gradients. These techniques and tests of statistical significance have begun to replace more subjective methods, such as overlaying maps, to reveal subtle or complex patterns of variation.

The multivariate technique, *Principal Component Analysis* (PCA), was used in this study to explore species distributions across estuarine salinity gradients (Wilkinson 1987). The analysis was applied to known salinity ranges of organisms from the Mid-Atlantic Bight with emphasis on the Chesapeake Bay.

The PCA technique attempts to reduce the dimensionality of a data set into a small number of variables that explain most of the variation in the original data set. Thus, the major result of applying this technique to data on species salinity ranges was identification of a limited number of overlapping zones and their associated species. Results were used to propose an alternative classification of estuarine salinity zones. These zones were then compared to the Venice System.

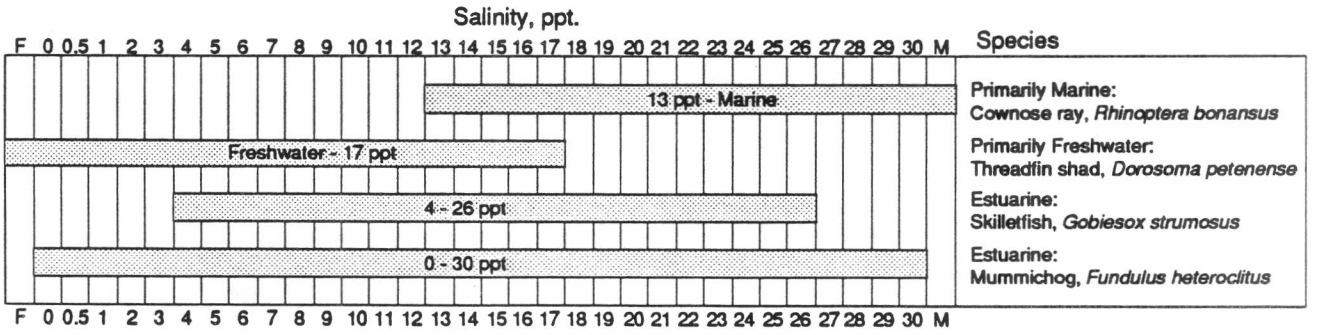
Analytical Framework

Estuaries link marine to freshwater environments, and within estuaries salinity ranges from full seawater to freshwater. An analytical framework consisting of a gradient of 34 salinity increments was constructed to compile information on the salinity ranges of organisms. The first increment in the gradient, labelled F (Freshwater) in Figure 2, was scored as present for all organisms which are normally part of freshwater communities. The last increment, labelled M (Marine), was scored as present for all organisms which are normally part of marine communities. Between these extremes, organisms were scored as present only in those increments corresponding to their published salinity ranges. These increments are the integer values of salinity between 0 ppt and 30 ppt, plus 0.5 ppt. Fractional salinity values in the literature were rounded to the nearest increment. Examples of the salinity increments scored for two estuarine species, a primarily freshwater species, and a primarily marine species are shown in Figure 2.

Thirty ppt was chosen as the upper boundary of the estuarine salinity gradient because it corresponds to the maximum isohaline typically found in Chesapeake Bay (Lippson 1973). The 0.5 ppt value was included because it is a boundary in the Venice System. Since an objective of this study was to compare results with the Venice System, all the Venice boundaries (0.5 ppt, 5 ppt, 18 ppt, 30 ppt) were included as increments in this study.

Estuarine species which normally tolerate salinities over 30 ppt (such as the mummichog, *Fundulus heteroclitus*) were not scored as present in the M increment since they are not normally part of marine communities. Estuarine species which tolerate 0 ppt were likewise not scored as present in the F increment since they are not typically part of freshwater communities. Although the majority of species found in estuaries are of either freshwater or marine origin,

Figure 2. Examples of salinity ranges of adult fishes.



the F and M increments were retained to permit investigation of biological linkages between estuaries and freshwater or marine ecosystems.

Note: The method used here to formulate an estuarine classification system does not take into account the relative abundance or frequency of occurrence of a species at salinities within its range. Such information is available for only a few species. The result of scoring each species as simply present at each salinity increment is to assume that each species is evenly distributed within its salinity range.

Data Sources

The Chesapeake Bay/Mid-Atlantic region was selected for study because of the large amount of available field data on species salinity ranges. Most of the data analyzed were extracted from four sources. Invertebrate ranges came from Gosner (1979), *A Field Guide to the Atlantic Seashore from the Bay of Fundy to Cape Hatteras* (from which only Mid-Atlantic ranges were taken) and Wass (1972), *A Checklist of the Biota of Lower Chesapeake Bay with Inclusions from the Upper Bay and Virginian Sea.* The latter document also contained a chapter on fishes (Musick 1972) which included data on fishes from the entire Bay. *Development of Fishes of the Mid-Atlantic Bight* (DFMAB 1978) provided salinity ranges for many larval and juvenile stages of Chesapeake Bay fishes, as well as additional species from the adjacent coastal waters. The data are presented and the data sources compared in Appendix 3.

The data set developed comprises salinity ranges for 242 species of fishes and invertebrates. Some of the 175 fish species are represented in the data set by multiple life stages: 47 species are represented by 2 life stages, and 14 species by 3 life stages. There are therefore 250 cases representing fish salinity ranges: 124 adult ranges, 83 juvenile ranges, and 43 larval salinity ranges. The 67 invertebrate cases represent adult salinity ranges. The total number of cases is therefore 317. The term *cases* is used throughout this report to refer to the 317 salinity ranges in the data set; the term *species* is not used in this sense because some of the species appear in the data set more than once as different life stages.

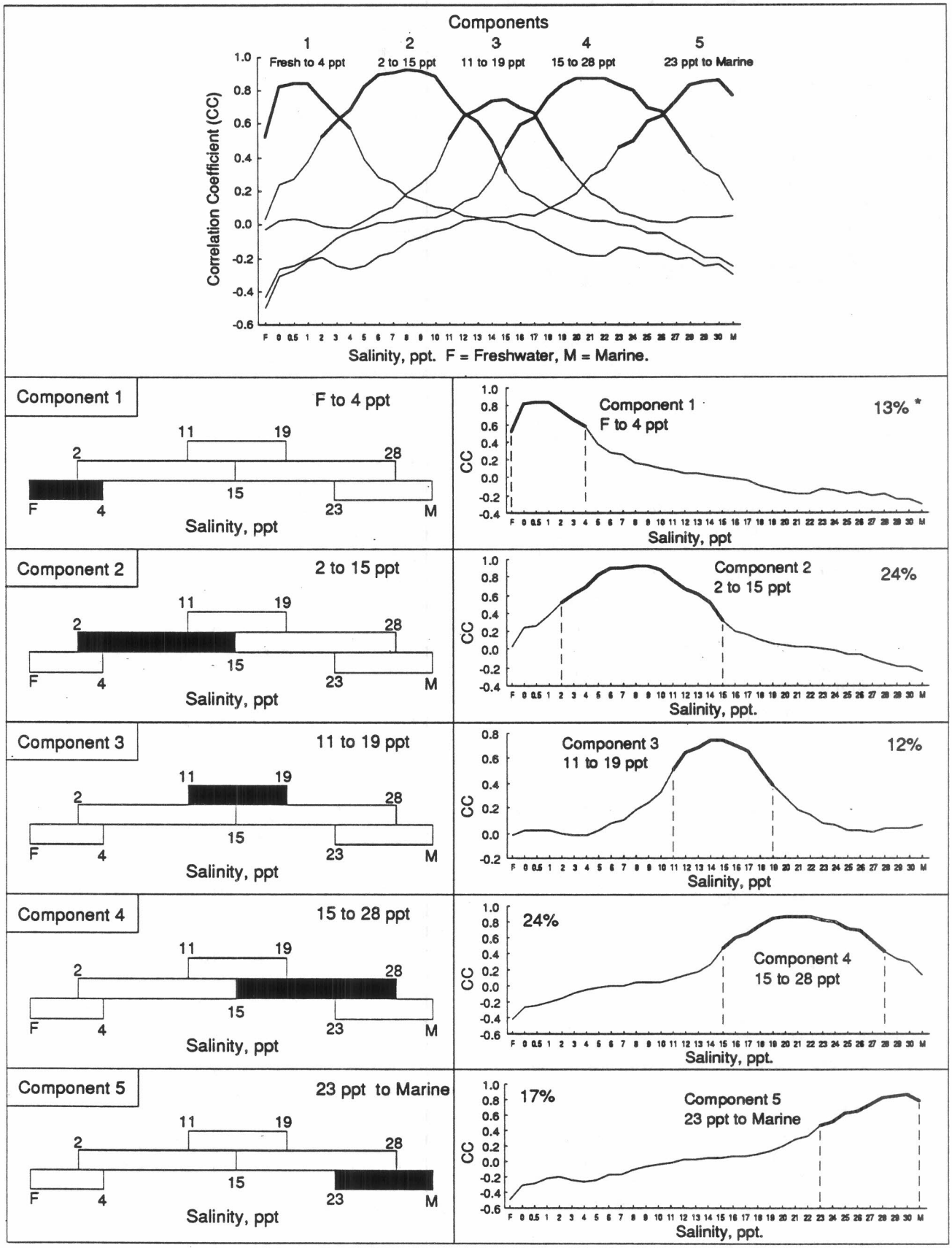
The purpose of combining data for these groups of organisms was to develop a data set large enough to produce a robust analysis that was not limited to a single taxonomic group or life history stage. Although fishes represent 79 percent of the cases, the invertebrates included are a diverse group and belong to 12 phyla. Certainly, additional salinity ranges exist in the literature as individual records, but the resulting data set of salinity ranges is the most comprehensive available for Chesapeake Bay/Mid-Atlantic organisms. Analysis of subsets of the 317 cases produced results very similar to the patterns based on the analysis of the full data set, suggesting that it would take the addition of a large number of very different salinity ranges to alter the fundamental results of the analysis.

The term *range* is used to refer to the published salinities reported for the 317 cases, and to the corresponding salinity increments used in this study. The term *zone* is used to refer to the five salinity regions identified in the analysis. The terms *limit* or *salinity range limit* are used to refer to the high and low salinity increments which enclose the salinity range of an individual case. The terms *end point* or *zone end point* are used to refer to the high and low salinity increments which enclose each of the five salinity zones identified.

Fishes. One hundred twenty four salinity ranges for adult fishes were taken from Musick (1972). These data were collected by the staff of Virginia Institute of Marine Sciences, and are based primarily on monthly trawl surveys, supplemented by gill net and seine surveys. The data therefore reflect the salinity ranges in which fishes are actually collected in Chesapeake Bay, rather than laboratory determinations of salinity tolerances. The data included in this analysis were numeric salinity ranges such as "freshwater to 17 ppt and "4-26 ppt" (Figure 2). Other species listed in Musick (1972) were excluded from this analysis because their numeric salinity ranges were not reported.

The same numerical range criteria were applied to include 126 juvenile and larval fishes. These salinity ranges were primarily obtained from the 6-volume work, Development of Fishes of the Middle Atlantic Bight (DFMAB 1978), which is a compilation based on a large number of primary literature sources. Only those ranges that appeared to be based on field observations were included. The geographic scope of DFMAB includes Chesapeake and Delaware Bays, plus coastal waters to 100 fathoms, between the North Carolina-Virginia border and Sandy Hook, New Jersey. Although broader in geographic scope than Musick (1972), there is substantial overlap between the two publications in species coverage. A few additional salinity ranges were obtained from two other sources. Ranges for larval alewife, hickory shad, bay anchovy, and blueback herring were obtained from "Habitat requirements for Chesapeake Bay living resources (1987). Ranges for larval and juvenile Atlantic tomcod came from Stewart and Auster (1987).

Figure 3. Correlation coefficients (rotated loadings) of salinity increments on Principal Components.



* Percent of the total variance explained by each Principal Component.

Invertebrates. Adult salinity ranges for 42 invertebrates, representing occurrence in nature, were taken from Gosner (1979); only mid-Atlantic species were included. An additional 25 invertebrate salinity ranges were taken from Wass (1972), which is a compilation of a large number of primary sources; the criteria for establishing the salinity ranges reported in Wass is not always stated explicitly. Only those numerical records which appeared to be based on field observations from Gosner and Wass were included. Since the invertebrate data emphasizes lower Chesapeake Bay (Wass 1972) and coastal marine and estuarine waters (Gosner 1979), freshwater and upper estuarine invertebrates may be underrepresented.

Results and Interpretation

Application of Principal Components Analysis to the salinity range data indicated that the underlying structure of salinity distributions can be represented by five new variables, or Principal Components. These new components explain 89 percent of the variance in the original data set. In this PCA, the original 34 salinity increments were considered as 34 variables (see Appendix 2) which naturally explained 100 percent of the variance in the data set. Thus, PCA provided considerable power of summary with little information loss.

Figure 3 displays the relationship between salinity and the new Principal Components, along with the percent of the total variance explained by each. Each Component explained a significant (at the 0.05 level) percent of the total variance, using the N-rule of Overland and Prisendorfer (1982). The N-rule is derived from Monte Carlo PCA simulations on random number matrices. Each of the five Components in this study explained more variance than 95 percent of the Monte Carlo runs with random number matrices of the size used in this study.

The Principal Components identify salinity zones used in common by many species. Each of the five Components has a suite of salinity increments with which it is most highly associated (i.e., with which it has its highest correlation coefficients). Figure 3 displays plots of the correlation coefficients between each the five Principal Components and the original 34 salinity increments. The regions between the broad peaks of the curves represent transition areas between zones. Many species' salinity range limits fall in these transition areas where the curves cross, as opposed to the zones under the peaks, where relatively few salinity range limits fall.

While the Components identify zones used in common by many species, the Components in themselves do not actually define end points for their associated salinity zones. Three kinds of analyses were used to establish the zone end points shown in Figure 3. These analyses used 1) the relationship between the Principal Components and the original salinity increments, 2) the salinity range limits for the cases most strongly associated with each of the Components (Appendix 1) , and 3) the frequency distribution of the salinity range limits for all 317 cases.

Analysis 1. This analysis identified the salinity increments with which each Component is most strongly correlated (Figure 3). Correlation coefficients are equivalent to varimax rotated loadings (see Appendix 2) in this analysis. Component 1 is most highly correlated ($r > 0.5$) with the salinity increments from F to 4 ppt. Component 2 is most highly correlated ($r > 0.5$) with 2 to 14 ppt, Component 3 with 11 to 18 ppt, Component 4 with 16 to 27 ppt, and Component 5 with 24 ppt to M. These were taken as first approximations of the end points for the five zones associated with the Principal Components.

Analysis 2. This analysis supported the approximate bounds identified above, and involved plotting the actual salinity range limits (high and low) for all 317 cases against the factor score for each Component (see Appendix 1). The resulting plots showed that cases with the highest factor scores (i.e., those most strongly associated) for Component 1 hada peak number of high range limits at 4-5 ppt. Cases with the highest factor scores for Component 2 showed a peak number of low salinity range limits at 3 ppt, and a peak number of high limits at 13 ppt. By this analysis, Components 3's approximate end points were 10-11 and 19 ppt, Components 4's were 15-16 and 27-28, and Component 5's were 23-24 and M. Thus, the cases with the highest factor scores for each Component are valuable in defining salinity zone end points. Appendix 3 lists the factor scores of each case and the percentage of its range enclosed by each salinity zone.

Analysis 3. This analysis established the boundaries for the five zones by examining the frequency distributions of all high and low salinity range limits. It indicated which of the candidate end points identified by the two previous analyses were the most representative. This analysis takes advantage of the fundamental finding of the Principal Components analysis, that salinity range limits are not randomly distributed, i.e., there are more range limits in the transition areas where the curves cross (Figure 3). This procedure identified the low end points of 2, 11,

15, and 23, and high end points of 4, 15,19 and 28. These end points are considered representative for their respective zones because more than 97 percent of of all the low range limits in the data set are within 3 ppt of these, and more that 98 percent of all high limits are within 3 ppt of the high zone end points. The resulting classification system, shown in Figure 3, reflects the convergence of the three analyses.

The Components. In the discussion which follows, the organisms associated with each zone are characterized, using the cases with the highest factor scores for each Component as indicators. In Appendix 1, Figures 1a through 5a display the species that are most important in identifying the zones in the classification, i. e., the species with the highest factor scores for each zone. Appendix 1 Figures 1b through 5b display the species for which ach zone is most important, i. e., the species with the highest percent of their range enclosed by each of the five zones. It is important to remember that the analysis recognizes similarities in salinities where organisms occur, not the salinities to which they are limited.

Component 1 identifies the Freshwater to 4 ppt (F-4 ppt) Zone 1, which overlaps with Zone 2 (2-15 ppt). The cases most strongly associated by their factor scores with Component 1 have their lower salinity limits in increments as F or 0 ppt, and extend variously into higher salinities. This is a heterogeneous group in terms of the breadth of their salinity ranges, but all occur in very low salinities, and stenohaline freshwater fishes are uniquely associated with Component 1. Invertebrates are not strongly associated with this Component, with only two cases among the highest 25 percent of factor scores; this is in part explained by the underrepresentation of the salinity ranges of freshwater invertebrates in the literature sources. The cases having the top 10 percent of factor scores for Component 1 all occur in the salinity increments 0-4 ppt.

Component 2 identifies the 2-15 ppt inner-estuarine Zone 2, which overlaps with Zone 1 (F- 4 ppt) on the freshwater side, and Zone 3 (11-19 ppt) on the seaward side of the estuary. The cases most strongly associated with Component 2 include a) larval and juvenile fishes plus adults of estuarine resident fishes, b) euryhaline freshwater fishes with upper limits as high as 13 ppt, and c) very euryhaline marine invertebrates and fishes which penetrate the estuary to salinities as low as 2 ppt. The cases having the top 10 percent of factor scores for Component 2 all occur in the salinity increments 5-10 ppt.

Component 3 identifies the 11-19 ppt mid-estuarine Zone 3, which overlaps with Zone 2 on the freshwater side, and Zone 4 on the marine side of the estuary. The cases most strongly associated with Component 3 include invertebrates as well as immature and adult fishes which have broad representation in the center of the estuarine salinity gradient. This group includes freshwater forms with salinity ranges as high as 20 ppt, as well as marine forms with salinity ranges as low as 9 ppt. The cases having the top 10 percent of factor scores for Component 3 all occur in increments 11-17 ppt.

Component 4 identifies the 15 to 28 ppt outer estuarine Zone 4, which overlaps with Zone 3 (11-19 ppt) and Zone 5 (23-M). The cases most strongly associated with Component 4 are a) estuarine fishes (adults, juveniles, and larvae) absent from increment M, and b) euryhaline marine invertebrates and fishes occurring in increment M and extending into the estuary as far as 15-17 ppt. The cases with the top 10 percent of factor scores for Component 4 all occur in the salinity increments 19-24 ppt.

Component 5 identifies the Marine to 23 ppt (23 ppt-M) Zone 5, which overlaps with Zone 4 (15-28 ppt). The cases most strongly associated with Component 5 all occur in increment M, and penetrate variously into the estuary. Stenohaline marine cases are uniquely associated with Component 5. Thus Component 5 represents a group of cases complementary to that of Component 1. There are certain highly euryhaline cases (notably those with salinity ranges of 0 ppt to M) which in fact have high factor scores for both Component 1 and Component 5, emphasizing again that this analysis groups cases by the salinities in which they co-occur, not the salinities to which they are limited. The cases with the top 10 percent of factor scores for Component 5 all occur in the salinity increments 26 ppt-M.

Unique features of the estuarine classification presented here are 1) low end points are in some case different from the high end points of adjacent zones, and 2) the zones identified by the Principal Components overlap, which may better reflect biological utilization.

Species/Life Stage Analyses. In addition to the PCA on all 317 cases, 3 separate PCA's were performed: a) 124 adult fish salinity ranges, b) 126 immature (larvae and juvenile) fish salinity ranges, and c) 67 invertebrate salinity ranges which together made up the complete data set. Their purpose was to determine how these subgroups might depart from the patterns observed with the complete data set. There was substantial agreement between the sepa-

rate analyses and the aggregate analysis, with minor exceptions. Both the invertebrate and adult fishes analysis produced a five-Component solution, with peaks in the same regions as resulted from the complete data set.

There were, however, small differences in the variances associated with the the Components. The PCA on the immature fishes yielded a 4-Component solution. The "absent" peak corresponded to the mid-estuarine peak found in the other analyses. The four peaks in this analysis were somewhat broader as well. Nevertheless,the classification scheme in Figure 3 is based on the complete data set and incorporates the information derived from all 317 cases because herein lies the greatest generality and power of summary of the results.

Comparison to the Venice System

The Venice System of estuarine classification has been widely used to describe the distribution of estuarine organisms with respect to salinity. One of its advantages is its simplicity; it is made of non-overlapping zones with discrete boundaries (Figure 1). However, criteria for establishing boundaries at 0.5, 5, 18, and 30 ppt are not defined beyond the statement that the subdivisions are based on "biological observations" (Symposium 1959). This means that the assumptions and information used to construct the system are not available for subsequent analysis or interpretation.

In contrast, the classification presented here is based on analysis of a defined data set, and the methods used to establish the boundaries are stated. The data set, the analysis, and the interpretation are open to re-examination, and can be used to generate alternate hypotheses about the structure presented. Additional information can be incorporated, or the procedure can be applied to different data sets. These advantages contribute to the utility and flexibility, but also the complexity, of the proposed classification.

While the classification system presented shares some similarities to the Venice classification, it yields a different perspective on the significance of the boundaries used to separate estuarine zones. Especially noteworthy is the ability to distinguish upper from lower boundaries. A major difference between the classifications is that this analysis did not identify major estuarine boundaries at 0.5 and 30 ppt (Figure 1), although these salinity range limits were included for some organisms in the study.

Lower Boundary Differences. In the description of the salinity limits of freshwater organisms in the literature, a boundary a 0.5 ppt may be implied, especially in the absence of field records. This boundary may represent a barrier to organisms that never enter estuaries, but this analysis based on actual field records can neither refute nor support this boundary as an upper limit for stenohaline freshwater organisms. The empirical basis for the boundary at 4 ppt in the proposed classification rests largely on the salinity ranges of the most stenohaline freshwater penetrants included in the analysis. Thus, 4 ppt may be a better representation for the upper limit of freshwater penetrants than 0.5 ppt. The boundary at 4 ppt is quite close the Venice boundary at 5 ppt, but we do not know the basis for the establishment of that boundary in the Venice System. The two classifications could possibly reflect the same underlying phenomenon.

Upper Boundary Differences. Likewise, this analysis did not identify a major boundary at 30 ppt, despite a small potential bias of recording it as the nominal salinity maximum for some estuarine organisms; this salinity (30 ppt) does not appear to represent a significant barrier to marine penetrants. This analysis suggests that the lower boundary for Zone 5 at 23 ppt may have greater significance than 30 ppt, at least with regard to marine penetrants. Twenty-three ppt may better reflect the lower salinity limit for marine species regarded as stenohaline. Most marine fishes enter estuaries at least occasionally (Cronin and Mansueti 1971), and indeed, 63 percent of the marine fishes collected in 270 trawls in a four-season survey of the Mid-Atlantic region are also found in Chesapeake Bay (Foell and Musick 1979). This information suggests that a 30 ppt boundary may be biologically invisible to marine penetrants.

In summary, this analysis indicates that 0.5 is not an upper limit to freshwater stenohaline forms, and that 30 ppt is not a lower limit to stenohaline marine forms. It is possible that the Venice boundaries at 0.5 ppt and 30 ppt are convenient and legitimate hydrographic, rather than biogeographic, boundaries (as, for example, 30 ppt is the typical maximum salinity isohaline in Chesapeake Bay, Lippson 1976). An alternative interpretation is that 0.5 is a *lower* limit to very euryhaline marine organisms, and that 30 ppt is an *upper* limit to some freshwater and estuarine organisms; this is supported by the present analysis which identifies 2 ppt as a lower limit and 28 ppt as an upper limit; these are close to the Venice boundaries of 0.5 and 30 ppt.

These results support the use of 25 ppt as a boundary in NOAA's ELMR project (Monaco et al. 1990). Twenty-three ppt was identified as an important lower boundary in this survey, and 28 ppt was identified as an upper limit (Zone 4) for estuarine and freshwater organisms. Twenty-three and 28 ppt bracket the upper estuarine zone limit of 25 ppt.

Mesohaline/Polyhaline Boundary. This analysis also identified an upper boundary (Zone 3) at 19 ppt. Therefore, the boundary at 15 ppt (Zone 2-4) and the upper boundary at 19 ppt (Zone 3) bracket the Venice mesohaline-polyhaline boundary at 18 ppt. The agreement between the two classifications, which are based on such different methods, on the boundary in the 15-19 ppt range suggests a phenomenon of generality and importance. An osmoregulatory hypothesis regarding marine-penetrant fishes may be one component of the explanation for a significant estuarine boundary at 15-18 ppt identified in both classifications.

Inner Estuary Boundaries. The lower boundaries at 2 (for Zone 2) and 11 (for Zone 3) ppt identified in this analysis do not correspond to major boundaries in the Venice System. However, the original Venice System document (as well as some later citations) does mention minor breaks within the oligohaline at 3 ppt, and within the mesohaline at 10 ppt. If these genuinely represent biotic boundaries, they are close to those identified here.

Limits of Marine Species. The end point at 15 ppt identified in the present analysis represents the lower salinity limit of estuarine penetration for many marine fishes in this study. A direct physiological basis for a salinity limit at approximately this salinity may be hypothesized. Many marine teleost fishes have body fluids which are isosmotic with seawater of 11- 14 ppt. This means that in full seawater, they tend to gain salts across their body surfaces, and to dehydrate as well. The lost water must be replaced by drinking seawater, which adds to the salt gain, which must be actively excreted across the gills. The rates of water loss and salt gain are dependent on the concentration differences between the body fluids and seawater. Because the salinity is lower in the estuary than the open sea, and therefore closer to the blood osmolality of the fishes, the rates of water loss across and salt gain are actually smaller in estuaries than the open sea, so at least the outer estuary may not represent an osmoregulatory stress (Bulger, in prep.). Consequently, it comes as no surprise that most oceanic fishes enter estuaries at least occasionally (Cronin and Mansueti 1971).

For marine teleost fishes to penetrate estuaries beyond isosmotic salinities (11-14 ppt), however, they must be able to reverse the direction of salt transport, decrease drinking rate, and increase urine production, since at these salinities they gain rather than lose water. Stenohaline teleosts cannot do these things. Consequently, while the outer estuary may be an osmoregulatory refuge from the high cost seawater existence, the inner estuary is guarded by an isosmotic boundary for some fishes.

Concluding Comments

The results of this multivariate analysis of the salinity ranges of Mid-Atlantic Bight/Chesapeake Bay organisms support an estuarine classification which summarizes the salinity distributions of these organisms in only a few general patterns. Among this diversity of organisms there is apparently great commonality in salinity distributions.

The salinity zone boundaries in this classification showed some similarities to the Venice System. However, the five zones in this classification overlap and not exclusive. The overlapping zones in the new classification probably better represent the way that species use estuaries. The new classification is more flexible in that it can be easily updated as new information becomes available, and the analytical basis for its boundaries can be reexamined. As a result, it can be used to formulate hypotheses regarding the ecological significance of the boundaries. For some boundaries, salinity may act as a proxy variable for habitat characteristics which covary with salinity (e.g., substrate, turbidity, etc.). For other boundaries, direct effects of salinity upon organisms may be suggested.

This analytical framework supports ongoing NOAA efforts to better understand how species utilize estuaries. A logical next step would be to apply this analysis to data sets from other estuaries to determine the generality of the new classification. In addition, this classification, now based only on salinity, may be expanded to include information on other important habitat parameters such as substrate, temperature or hydrographic features.

Further development of this work will provide managers and scientists an improved framework to integrate and summarize a vast amount of estuarine information.

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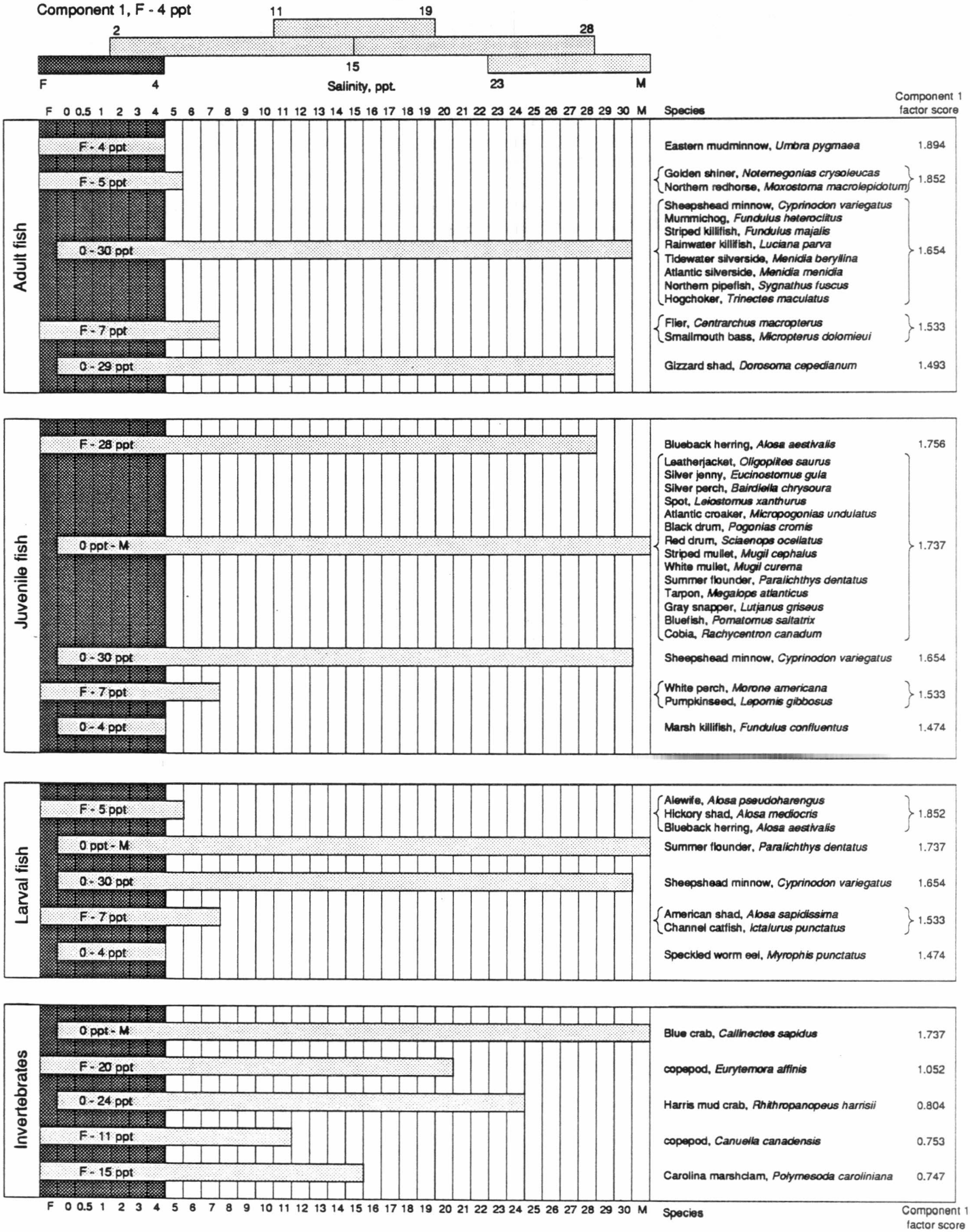
Appendix 1. Salinity ranges of species associated with each salinity zone

The figures in Appendix 1 display the salinity ranges of species associated with each salinity zone.

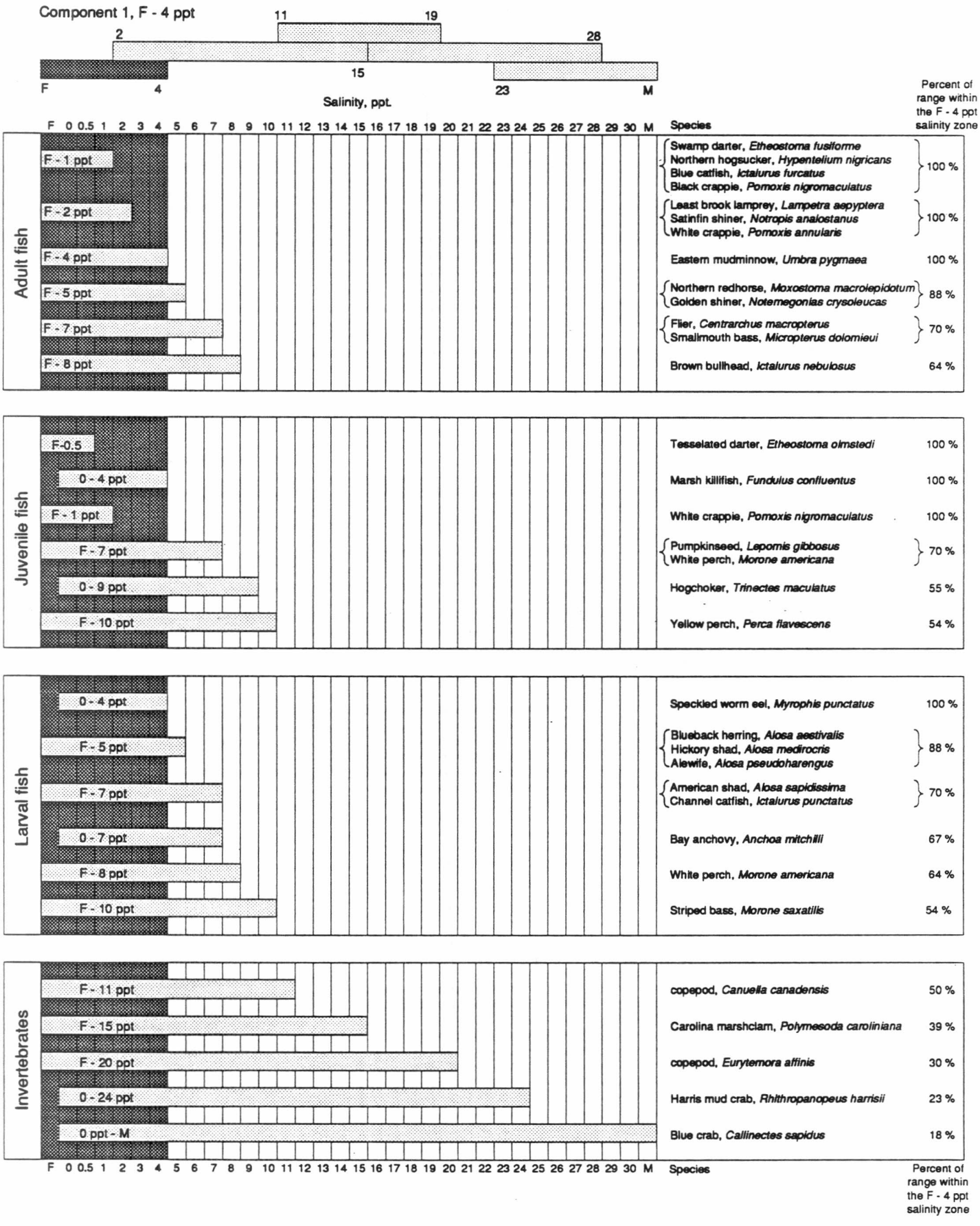
A) Figures 1a through 5a display the species that are most important in identifying the zones in the estuarine classification, i. e., the cases with the highest factor scores for each of the five Principal Components. These cases often have salinity range limits that coincide with one or both of the zone end points.

B) Figures 1b through 5b display the species for which each zone is most important, i. e., the cases with the highest percent of their range enclosed by each of the five zones.

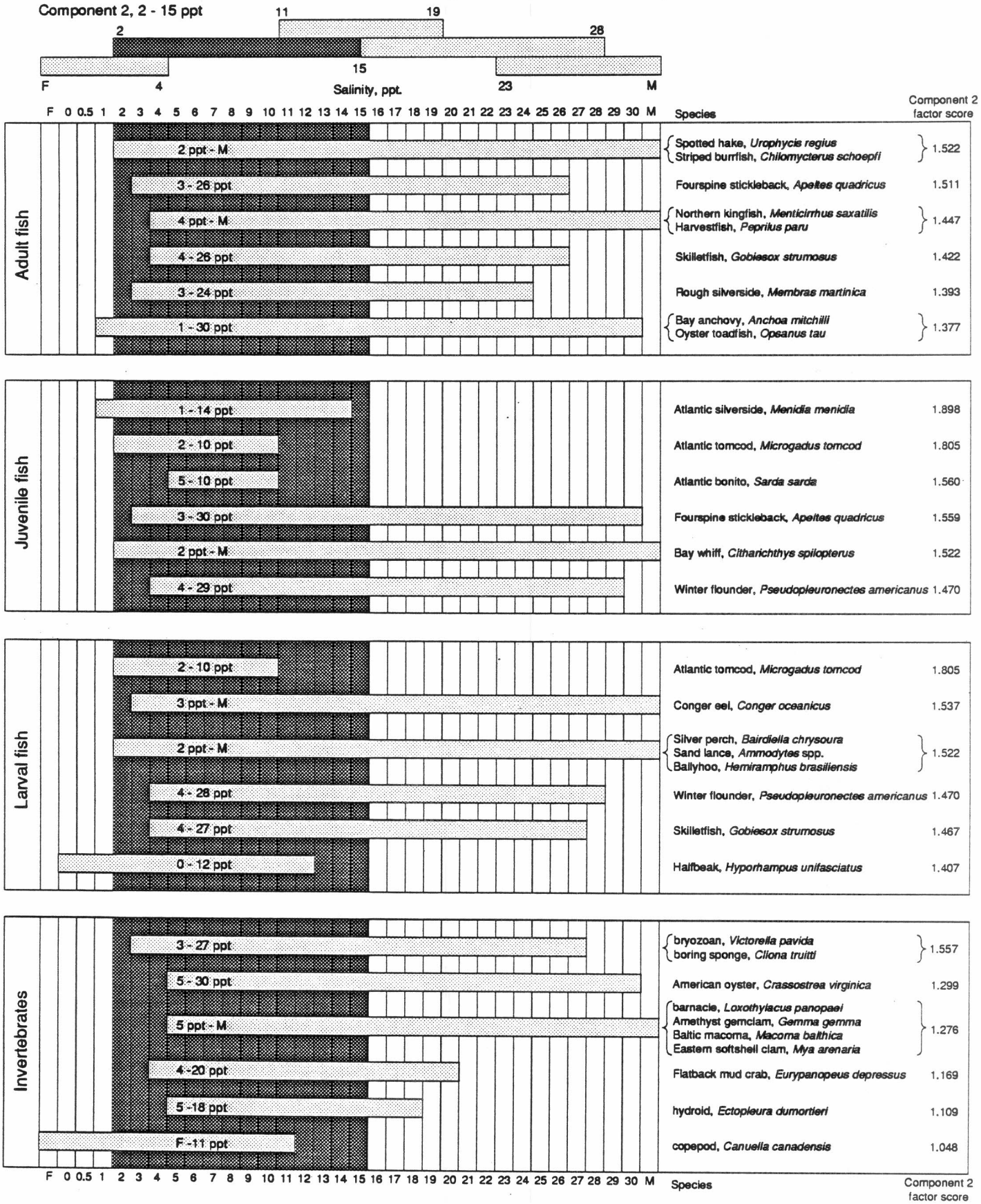
Appendix 1, Figure 1a. Species important for defining the Freshwater to 4 ppt salinity zone (Component 1). These are the cases with high factor scores for Component 1.



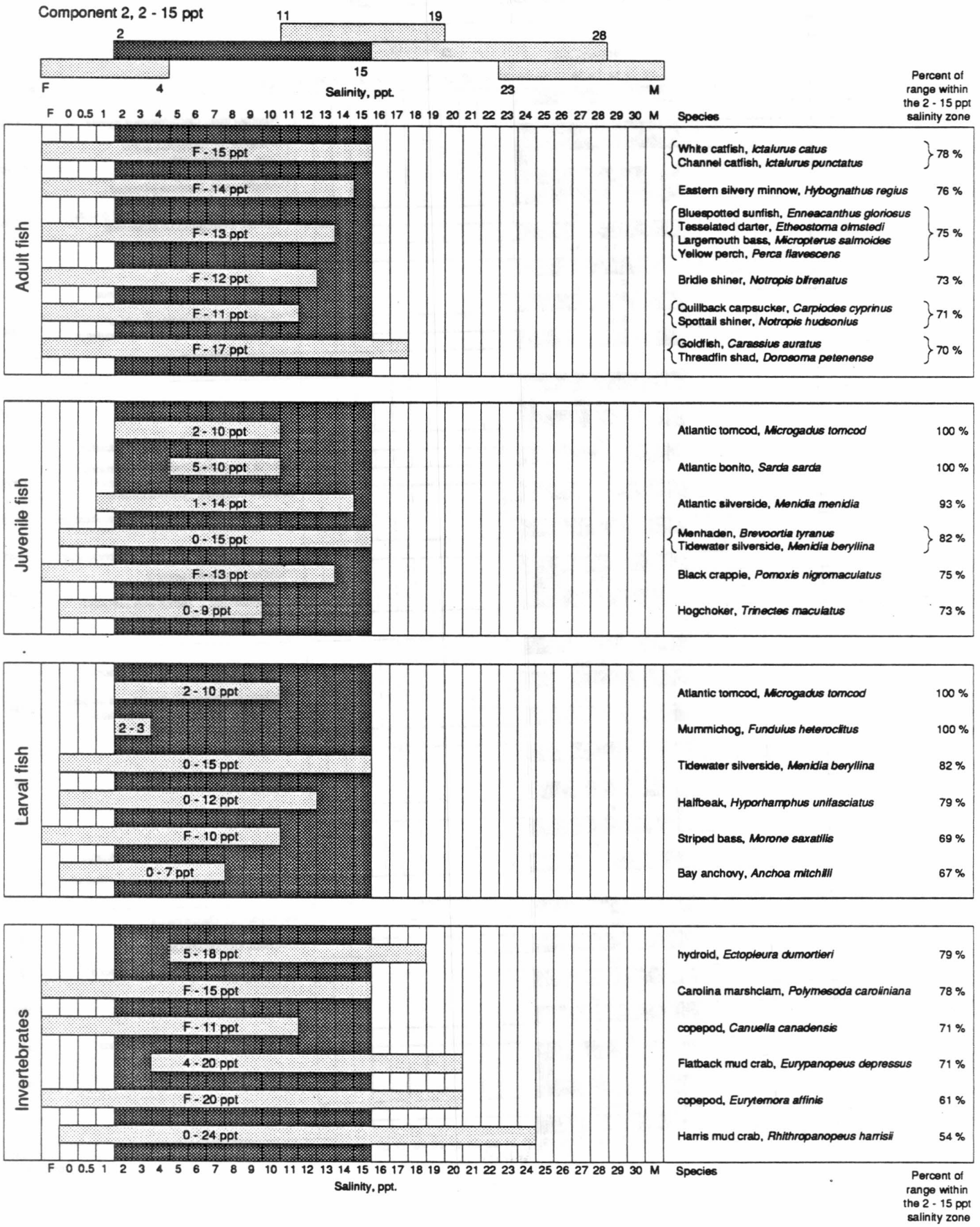
Appendix 1, Figure 1b. Species for which the Freshwater to 4 ppt salinity zone (Component 1) is most important. These are the cases with a high proportion of their range enclosed by Zone 1.



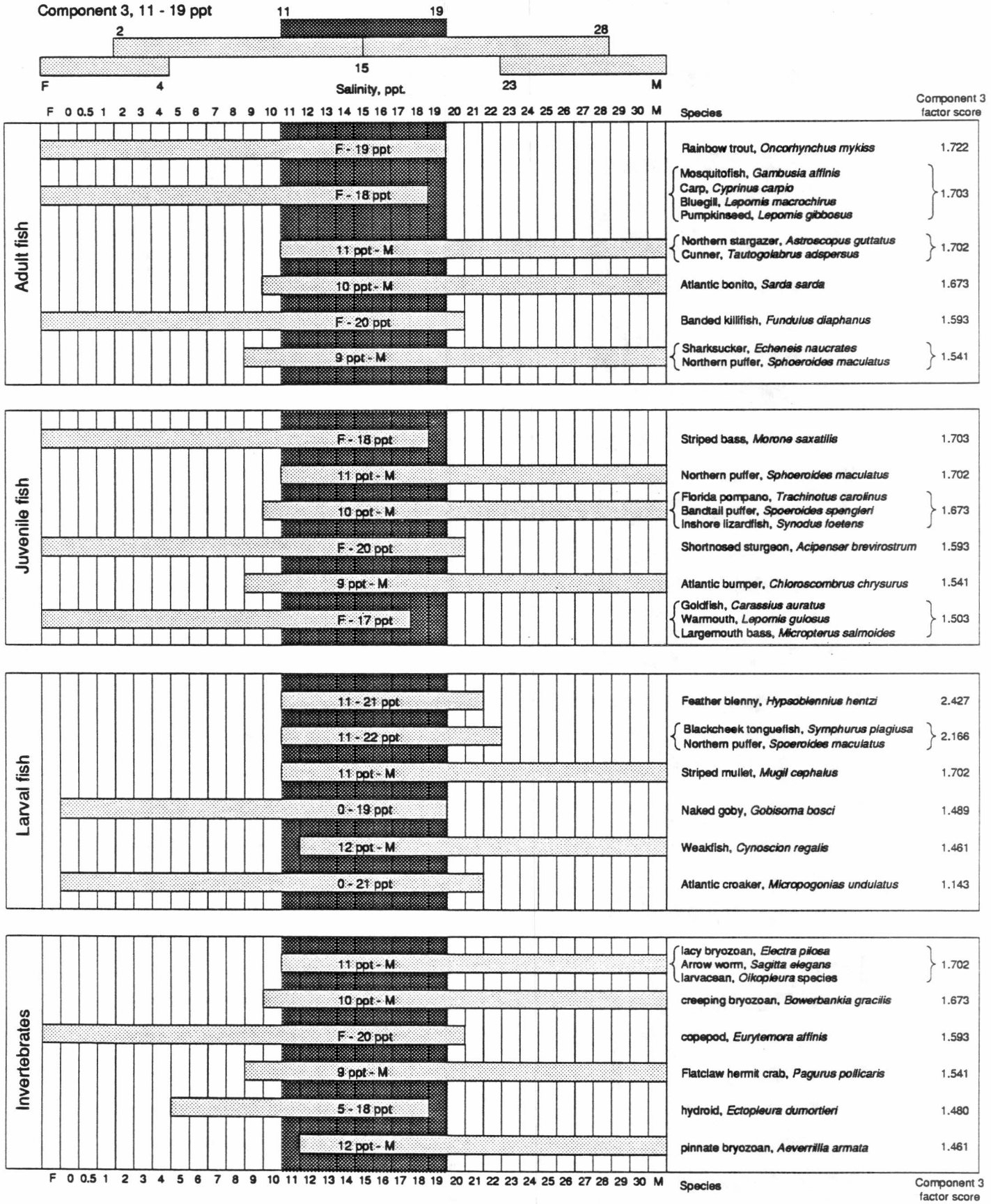
Appendix 1, Figure 2a. Species important for defining the 2 to 15 ppt salinity zone (Component 2). These are the cases with the highest factor scores for Component 2.



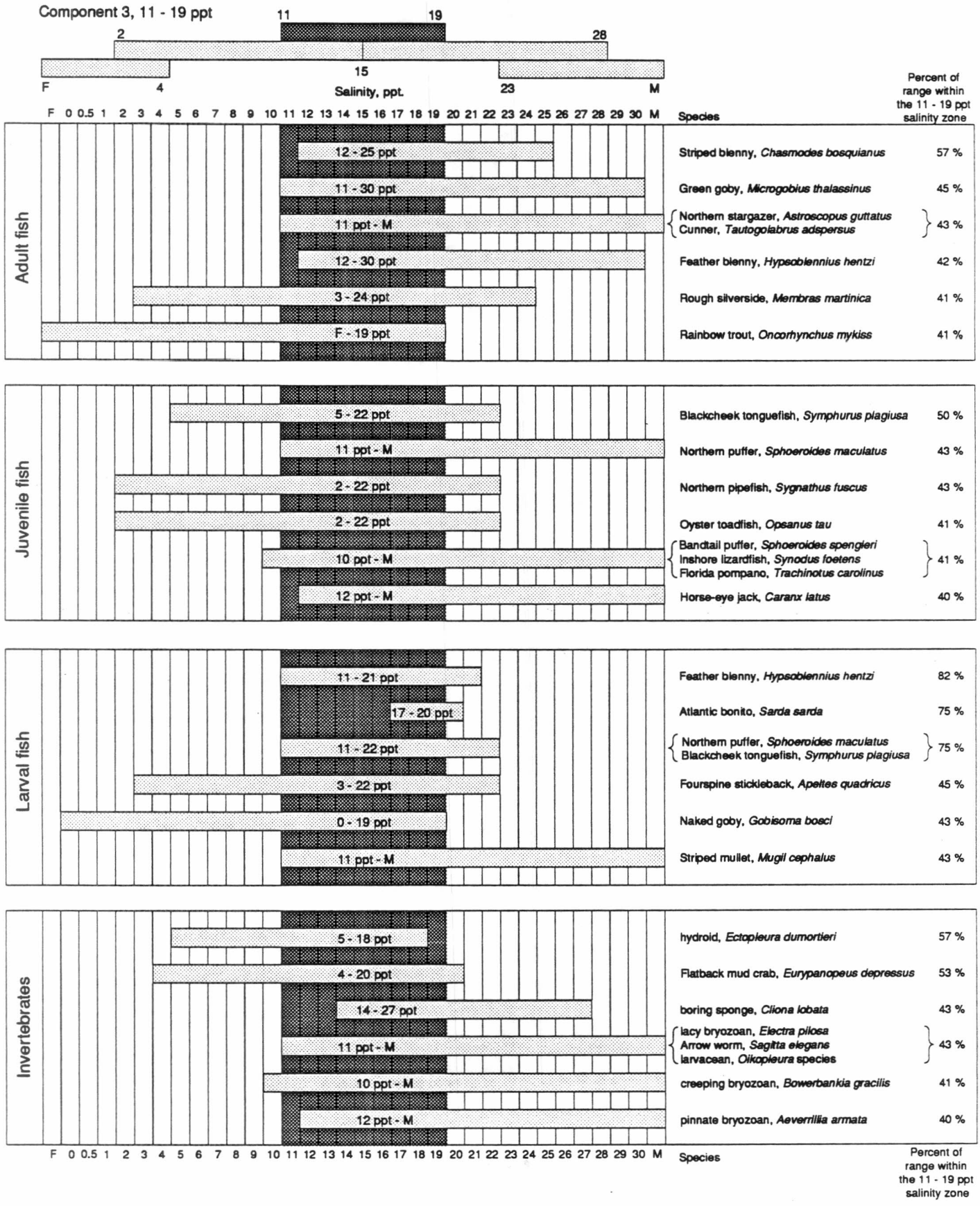
Appendix 1, Figure 2b. Species for which the 2 to 15 ppt salinity zone (Component 2) is most important. These are the cases with a high proportion of their range enclosed by Zone 2.



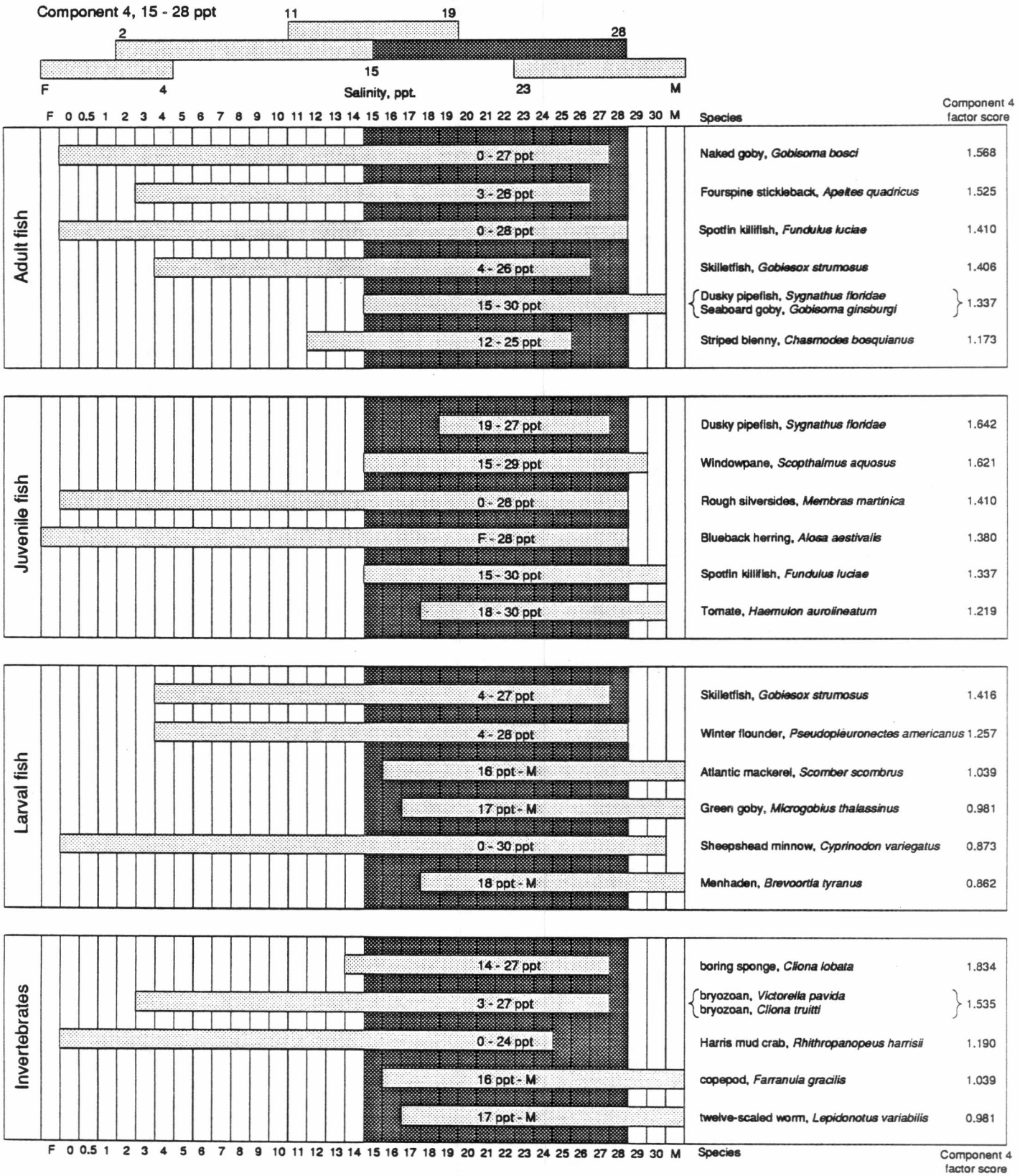
Appendix 1, Figure 3a. Species important for defining the 11 to 19 ppt salinity zone (Component 3). These are the cases with the highest factor scores for Component 3.



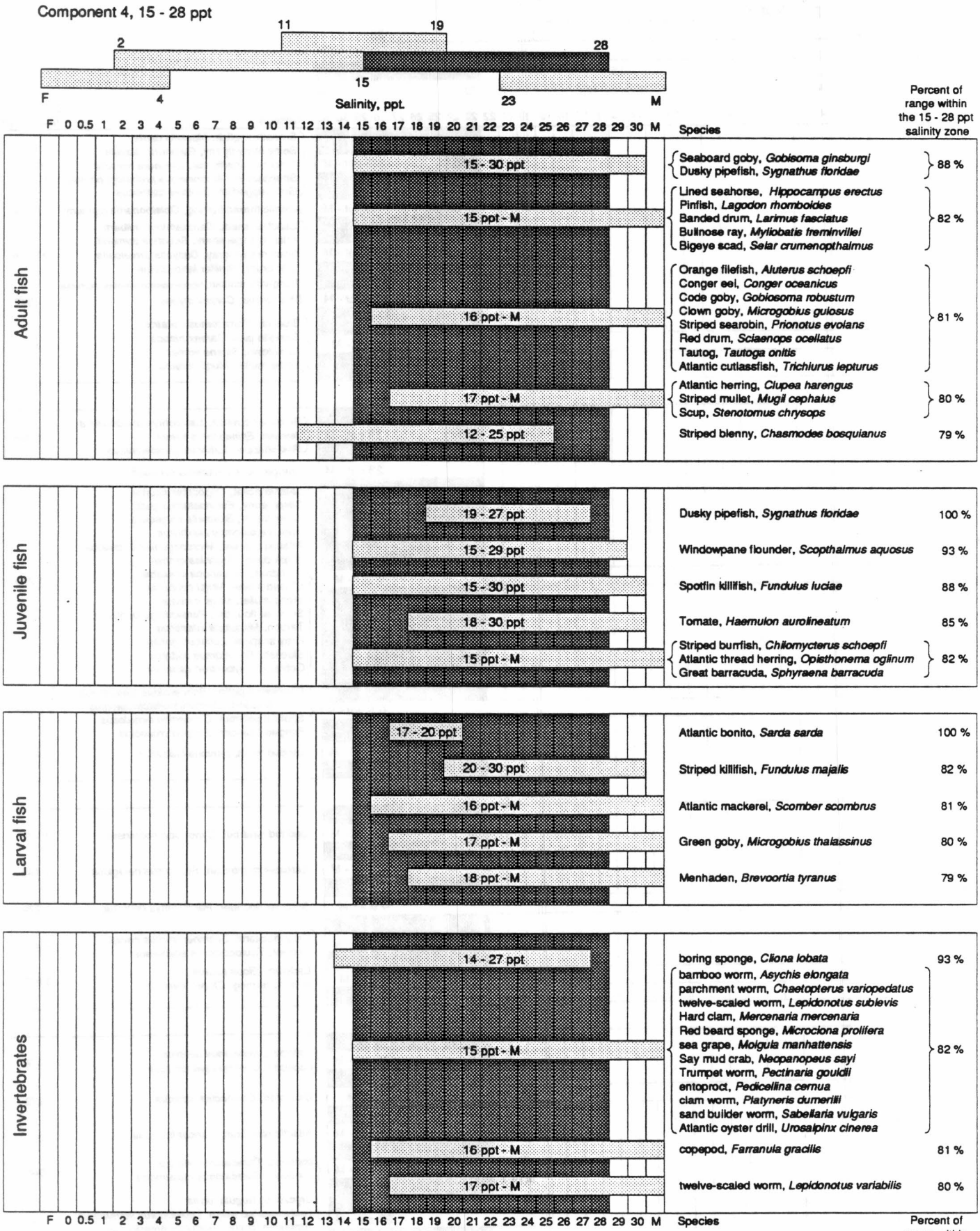
Appendix 1, Figure 3b. Species for which the 11 to 19 ppt salinity zone (Component 3) is most important. These are the cases with a high proportion of their range enclosed by Zone 3.



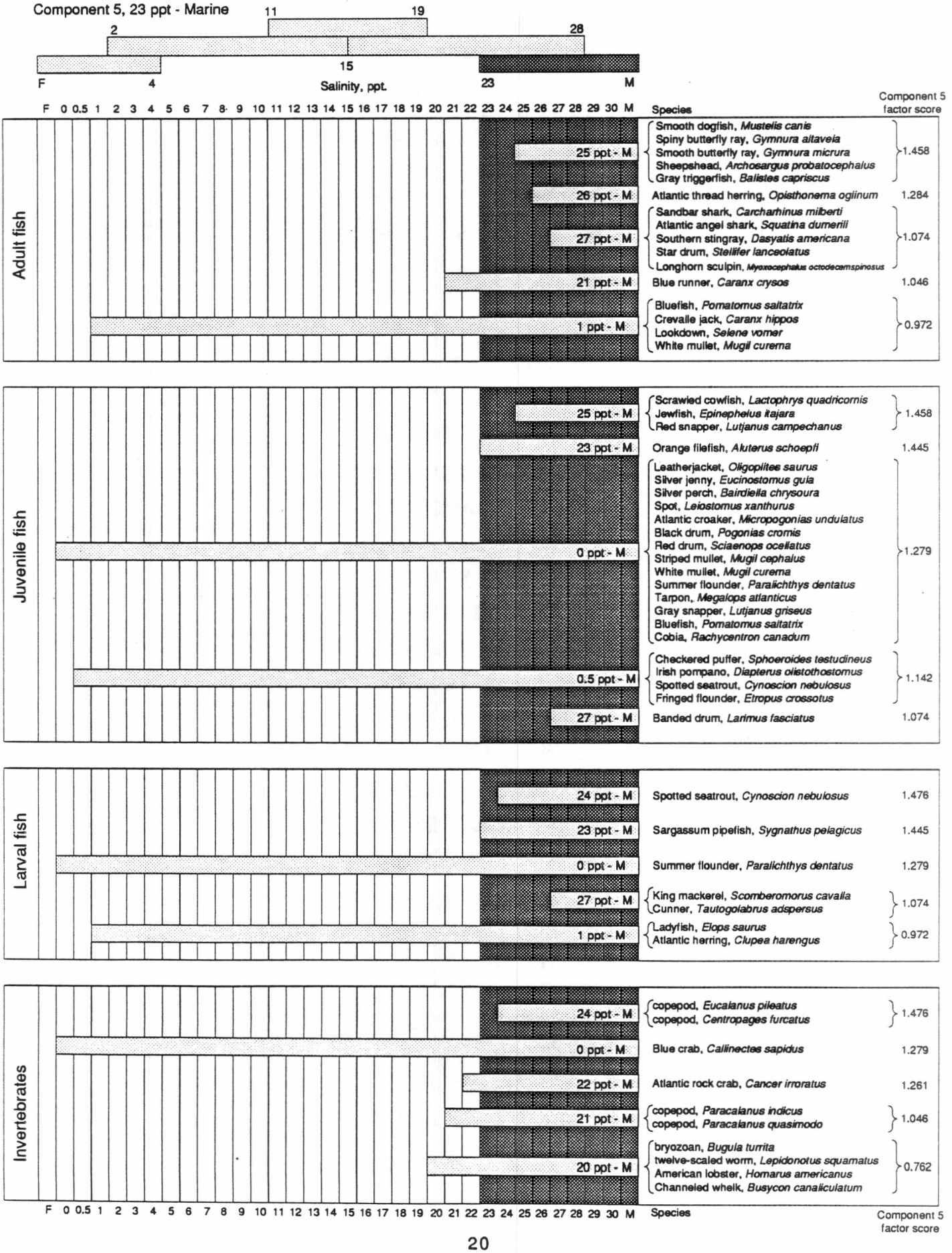
Appendix 1, Figure 4a. Species important for defining the 15 to 28 ppt salinity zone (Component 4). These are the cases with the highest factor scores for Component 4.



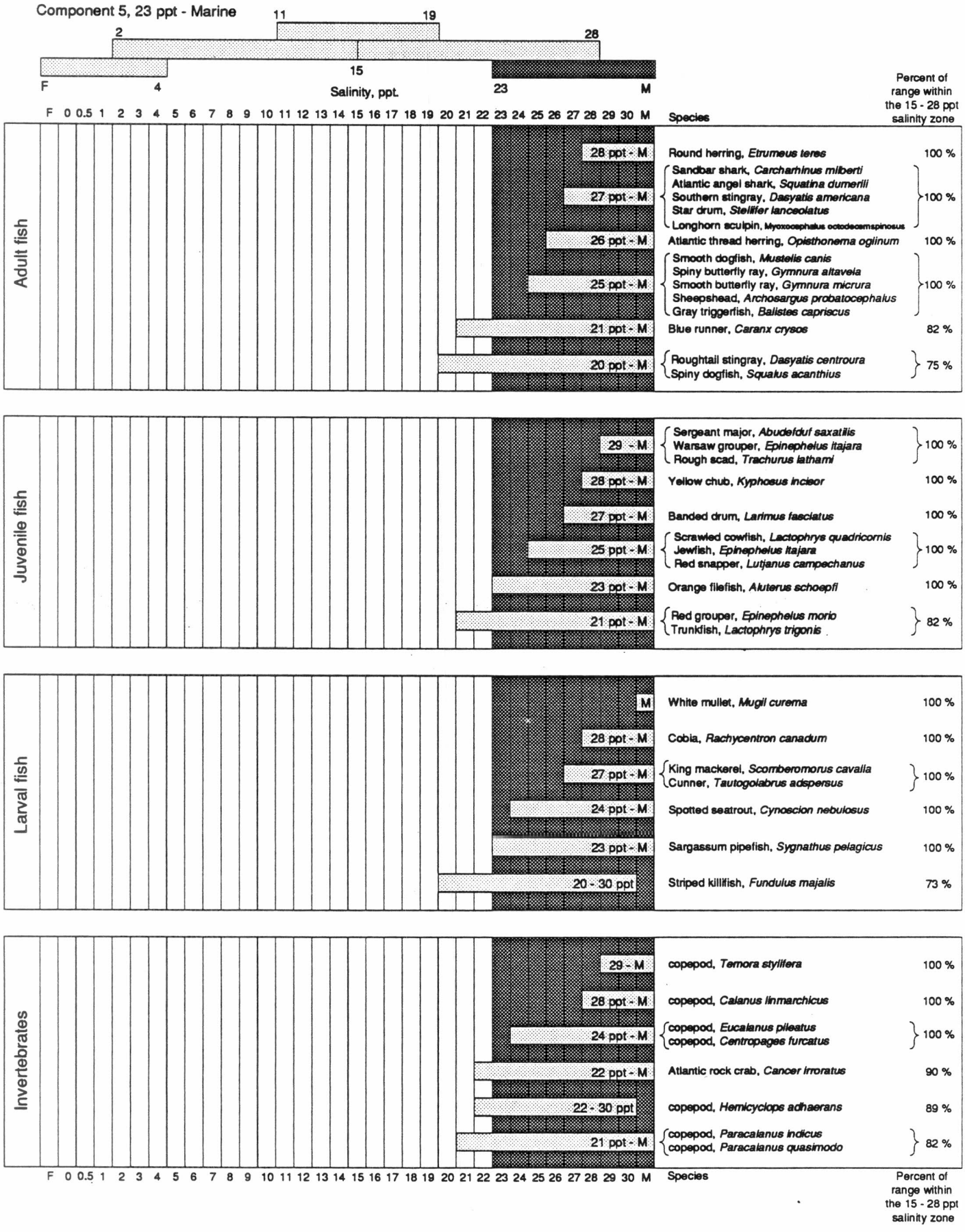
Appendix 1, Figure 4b. Species for which the 15 to 28 ppt salinity zone (Component 4) is most important. These are the cases with a high proportion of their range enclosed by Zone 4.



Appendix 1, Figure 5a. Species important for defining the 23 ppt to marine salinity zone (Component 5). These are the cases with the highest factor scores for Component 5.



Appendix 1, Figure 5b. Species for which the 23 ppt to marine salinity zone (Component 5) is most important. These are the cases with a high proportion of their range enclosed by Zone 5.



Appendix 2. Glossary

Case: One of the 317 salinity ranges used as the data in this study. Some fish species are present as juveniles or larvae as well as adults, and therefore are represented by more than one case.

End point: The high and low salinity values that enclose each of the five Zones defined in this study.

Factor analysis. A group of statistical methods that extract a few factors from a large correlation matrix. The most frequently used of these methods is *Principal Components Analysis* (PCA) (Legendre and Legendre 1983), in which the variance of a large and complex data set is represented by a few new Principal Components.

Factor scores: The coordinates of the original cases projected on to the several Principal Component axes. A high factor score indicates a strong association between a case and one of the Components.

Ordination: The analysis of variation across gradients. Ecologists use multivariate ordination procedures in the analysis of community structure across environmental gradients. Ordination is widely regarded as a valuable exploratory tool for hypothesis generation (Gauch 1982). However, with the development of tests of statistical significance, hypothesis testing is now feasible. Multivariate ordination techniques generally are within a class of statistical methods called *Factor Analysis*.

Principal Component: One of the new variables resulting from a multivariate Principal Components Analysis, representing an axis through the data matrix. Also called a *Factor* or *Eigenvector*.

Principal Components Analysis (PCA): A multivariate statistical technique in which a set of many intercorrelated variables is transformed into a set of a few independent variables, or Principal Components. PCA creates a new coordinate system in which the axes are mutually orthogonal linear combinations of the original variables. The Principal Components clarify the underlying patterns of covariation within the original set of variables, and they retain most of the variance of the original data. In this study, the 34 salinity increments were considered to be 34 intercorrelated variables. For each of these variables, each case was scored as 0 or 1. Thus, the analysis was performed on a 34 x 317 incidence (presence/absence) matrix.

Range: The salinity values reported for a given species/life stage, based on actual field data.

Rotated Loading: The correlation coefficient between one of the original variables and one of the derived Principal Components. For example, the 1 ppt salinity increment has a high correlation coefficient with Component 1, F - 4 ppt (Figure 3).

Salinity increment: One of the 34 original variables used in this analysis, each representing a particular salinity: Freshwater, 0 ppt, 0.5 ppt, 1 through 30 ppt, and Marine.

Salinity range limit: The high and low salinity increments that enclose the salinity range of a case.

Varimax Rotation: A rigid orthogonal rotation of the Principal Component axes, such that the variance explained is optimized for all Principal Components retained in the analysis. Varimax rotations are applied because they improve the resolution of transitions between one zone and the next.

Zone: One of the five estuarine regions identified in this analysis, and associated with one of the five Principal Components.

Appendix 3. Table of salinity ranges and factor scores.

For each of the 317 cases, Appendix 3 lists the data source, salinity range , factor score for each of the five Principal Components, and percent of salinity range enclosed by each of the five salinity zones.

Comparison of the data sources

In addition to providing the larval and juvenile fish salinity ranges used in this study, DFMAB (1978) also listed numeric salinity ranges for 88 of the 124 adult salinity ranges from Musick (1972) which were used in this study. This provided the opportunity to compare the adult fish salinity ranges against another source. The data from the two sources were compared over the range of salinities used in this study. This comparison resulted in an average difference in salinity range of 4.4 ppt for these 88 pairs. In 30 of the 88 species, the ranges were identical over the salinities used in this analysis; 19 of these resulted from the use of the same primary sources by Musick and DFMAB. In 51 of the 58 cases where the sources differed, the range reported in DFMAB was broader than that in Musick. Although only Mid-Atlantic species are included in DFMAB, the salinity range records for some of these species came from as far away as the Gulf of Mexico and the Black Sea, whereas Musick limited information to that obtained in Chesapeake Bay. Therefore, the broader ranges in DFMAB may reflect geographic variation on a larger scale. The adult salinity ranges in DFMAB were used only as a check, and were not included in the analysis.

Only six invertebrate species had numerical salinity ranges in both Wass (1972) and Gosner (1979). There was good agreement between the sources on these six; their reported salinity ranges differed by an average of 2.8 ppt. For these six, the ranges in Wass were used in the analysis.

The major difference between the fish and invertebrate data sets is that the fishes are representative of the entire salinity spectrum (Musick 1972, DFMAB 1978), while the invertebrate data emphasizes Lower Chesapeake Bay (Wass 1972) and coastal marine and estuarine waters (Gosner 1979). Therefore, freshwater and upper estuarine invertebrates may be underrepresented in the compiled data set.

Appendix 3. Table of salinity ranges, factor scores, and percent of range enclosed by each salinity zone.

Case #	Common name	Latin name	Salinity range, ppt.	Component factor scores: 1	2	3	4	5	Percent of range enclosed by each zone: F-4	2-15	11-19	15-28	23-M
Invertebrates from Wass (1972):													
1	bryozoan	*Victorella pavida*	3 - 27	1.535	1.557	-0.578	-1.364	-1.761	8	52	36	52	20
2	boring sponge	*Cliona celata*	14 - M	0.782	-1.232	0.551	-0.031	0.152	0	11	33	78	50
3	boring sponge	*Cliona lobata*	14 - 27	1.834	-1.213	-0.016	-0.624	-2.212	0	14	43	93	36
4	boring sponge	*Cliona truitti*	3 - 27	1.535	1.557	-0.578	-1.364	-1.761	8	52	36	52	20
5	boring sponge	*Cliona vastifica*	14 - M	0.782	-1.232	0.551	-0.031	0.152	0	11	33	78	50
6	lacy bryozoan	*Electra crustulenta*	6 - M	0.075	0.963	0.744	-1.241	0.656	0	38	35	54	35
7	copepod	*Calanus finmarchicus*	28 - M	-2.153	-0.662	-0.042	-0.954	0.695	0	0	0	25	100
8	copepod	*Eucalanus pileatus*	24 - M	-1.450	-0.451	-0.810	-0.527	1.476	0	0	0	63	100
9	copepod	*Paracalanus crassirostris*	14 - M	0.782	-1.232	0.551	-0.031	0.152	0	11	33	78	50
10	copepod	*Paracalanus indicus*	21 - M	-0:221	-0.364	-1.551	-0.441	1.046	0	0	0	73	82
11	copepod	*Paracalanus quasimodo*	21 - M	-0.221	-0.364	-1.551	-0.441	1.046	0	0	0	73	82
12	copepod	*Pseudocalanus minutus*	8 - M	-0.063	0.195	1.337	-0.922	0.723	0	33	38	58	38
13	copepod	*Temora longicornis*	19 - M	0.590	-0.474	-1.661	-0.427	0.495	0	0	8	77	69
14	copepod	*Temora stylifera*	29 - M	-1.994	-0.665	-0.101	-1.145	0.148	0	0	0	0	100
15	copepod	*Eurytemora affinis*	F - 20	-0.393	0.297	1.593	1.052	-1.534	30	61	39	26	0
16	copepod	*Centropages furcatus*	24 - M	-1.450	-0.451	-0.810	-0.527	1.476	0	0	0	63	100
17	copepod	*Centropages hamatus*	8 - M	-0.063	0.195	1.337	-0.922	0.723	0	33	38	58	38
18	copepod	*Canuella canadensis*	F - 11	-0.916	1.048	-1.418	0.753	-0.930	50	71	7	0	0
19	copepod	*Euterpina acutifrons*	19 - M	0.590	-0.474	-1.661	-0.427	0.495	0	0	8	77	69
20	copepod	*Hemicyclops adhaerans*	22 - 30	-0.298	-0.356	-1.570	-0.520	0.680	0	0	0	78	89
21	copepod	*Farranula gracilis*	16 - M	1.039	-1.016	-0.553	-0.136	0.053	0	0	25	81	56
22	barnacle	*Loxothylacus panopaei*	5 - M	0.204	1.276	0.428	-1.283	0.589	0	41	33	52	33
23	mud crab	*Neopanope texana sayi*	6 - M	0.075	0.963	0.744	-1.241	0.656	0	38	35	54	35
24	Atlantic mud crab	*Panopeus herbstii*	6 - M	0.075	0.963	0.744	-1.241	0.656	0	38	35	54	35
25	Harris mud crab	*Rhithropanopeus harrisii*	0 - 24	1.190	0.707	0.358	0.804	-1.848	23	54	35	38	8
Adult fish from Musick (1972):													
26	Least brook lamprey	*Lampetra aepyptera*	F - 2	-1.097	-1.604	0.054	1.382	-1.090	100	20	0	0	0
27	Sandbar shark	*Carcharhinus milberti*	27 - M	-2.143	-0.616	-0.134	-0.821	1.074	0	0	0	40	100
28	Smooth dogfish	*Mustelus canis*	25 - M	-1.775	-0.498	-0.548	-0.614	1.458	0	0	0	57	100
29	Spiny dogfish	*Squalus acanthias*	20 - M	0.217	-0.391	-1.679	-0.452	0.762	0	0	0	75	75
30	Atlantic angel shark	*Squatina dumerili*	27 - M	-2.143	-0.616	-0.134	-0.821	1.074	0	0	0	40	100
31	Southern stingray	*Dasyatis americana*	27 - M	-2.143	-0.616	-0.134	-0.821	1.074	0	0	0	40	100
32	Bluntnose stingray	*Dasyatis sayi*	18 - M	0.862	-0.614	-1.460	-0.368	0.270	0	0	14	79	64
33	Spiny butterfly ray	*Gymnura altavela*	25 - M	-1.775	-0.498	-0.548	-0.614	1.458	0	0	0	57	100
34	Smooth butterfly ray	*Gymnura micrura*	25 - M	-1.775	-0.498	-0.548	-0.614	1.458	0	0	0	57	100
35	Bullnose ray	*Myliobatis freminvillei*	15 - M	0.980	-1.186	0.007	-0.036	0.048	0	6	29	82	53
36	Cownose ray	*Rhinoptera bonasus*	13 - M	0.541	-1.198	1.037	-0.072	0.295	0	16	37	74	47
37	Longnose gar	*Lepisosteus osseus*	F - 23	0.836	0.384	0.853	1.138	-1.964	27	54	35	35	4
38	Conger eel	*Conger oceanicus*	16 - M	1.039	-1.016	-0.553	-0.136	0.053	0	0	25	81	56
39	Atlantic herring	*Clupea harengus*	17 - M	0.981	-0.816	-1.032	-0.257	0.135	0	0	20	80	60
40	Gizzard shad	*Dorosoma cepedianum*	0 - 29	1.157	0.874	0.036	1.493	0.067	19	45	29	45	23
41	Threadfin shad	*Dorosoma petenense*	F - 17	-1.476	0.548	1.503	0.978	-0.758	35	70	35	15	0
42	Round herring	*Etrumeus teres*	28 - M	-2.153	-0.662	-0.042	-0.954	0.695	0	0	0	25	100
43	Atlantic thread herring	*Opisthonema oglinum*	26 - M	-1.972	-0.553	-0.339	-0.715	1.284	0	0	0	50	100
44	Striped anchovy	*Anchoa hepsetus*	5 - M	0.204	1.276	0.428	-1.283	0.589	0	41	33	52	33
45	Bay anchovy	*Anchoa mitchilli*	1 - 30	0.873	1.377	-0.183	0.276	0.391	13	47	30	47	27
46	Rainbow trout	*Salmo gairdneri*	F - 19	-0.831	0.324	1.722	1.063	-1.250	32	64	41	23	0
47	Eastern mudminnow	*Umbra pygmaea*	F - 4	-0.818	-1.343	-0.385	1.894	-1.077	100	43	0	0	0
48	Redfin pickerel	*Esox americanus*	F - 9	-0.616	0.516	-1.630	1.088	-1.143	58	67	0	0	0
49	Chain pickerel	*Esox niger*	F - 22	0.472	0.351	1.116	1.045	-1.933	28	56	36	32	0
50	Goldfish	*Carrassius auratus*	F - 17	-1.476	0.548	1.503	0.978	-0.758	35	70	35	15	0
51	Carp	*Cyprinus carpio*	F - 18	-1.204	0.408	1.703	1.038	-0.983	33	67	38	19	0
52	Eastern silvery minnow	*Hybognathus regius*	F - 14	-1.595	1.119	0.036	0.647	-0.536	41	76	24	0	0
53	Golden shiner	*Notemigonus crysoleucas*	F - 5	-0.689	-1.030	-0.701	1.852	-1.144	88	50	0	0	0
54	Satinfin shiner	*Notropis analostanus*	F - 2	-1.097	-1.604	0.054	1.382	-1.090	100	20	0	0	0
55	Bridle shiner	*Notropis bifrenatus*	F - 12	-1.156	1.131	-0.994	0.682	-0.783	47	73	13	0	0
56	Spotail shier	*Notopis hudsonius*	F - 11	-0.916	1.048	-1.418	0.753	-0.930	50	71	7	0	0
57	Quillback carpsucker	*Carpiodes cyprinus*	F - 11	-0.916	1.048	-1.418	0.753	-0.930	50	71	7	0	0
58	Northern redhorse	*Moxostoma macrolepidotum*	F - 5	-0.689	-1.030	-0.701	1.852	-1.144	88	50	0	0	0
59	Northern hogsucker	*Hypentelium nigricans*	F - 1	-1.137	-1.589	0.104	0.904	-1.248	100	0	0	0	0
60	White catfish	*Ictalurus catus*	F - 15	-1.653	0.949	0.595	0.747	-0.541	39	78	28	6	0
61	Blue catfish	*Ictalurus furcatus*	F - 1	-1.137	-1.589	0.104	0.904	-1.248	100	0	0	0	0
62	Brown bullhead	*Ictalurus nebulosus*	F - 8	-0.561	0.135	-1.498	1.314	-1.193	64	64	0	0	0
63	Channel catfish	*Ictalurus punctatus*	F - 15	-1.653	0.949	0.595	0.747	-0.541	39	78	28	6	0
64	Inshore lizardfish	*Synodus foetens*	12 - M	0.302	-1.115	1.461	-0.142	0.441	0	20	40	70	45
65	Oyster toadfish	*Opsanus tau*	1 - 30	0.873	1.377	-0.183	0.276	0.391	13	47	30	47	27
66	Skilletfish	*Gobiesox strumosus*	4 - 26	1.406	1.422	-0.306	-1.819	-2.186	4	52	39	52	17
67	Goosefish	*Lophius americanus*	14 - M	0.782	-1.232	0.551	-0.031	0.152	0	11	33	78	50
68	Red hake	*Urophycis chuss*	7 - M	-0.007	0.583	1.053	-1.093	0.697	0	36	36	56	36
69	Spotted hake	*Urophycis regius*	2 - M	0.523	1.522	-0.061	-0.293	0.760	10	47	30	47	30
70	Silver hake	*Merluccius bilinearis*	12 - M	0.302	-1.115	1.461	-0.142	0.441	0	20	40	70	45

Appendix 3, continued. Table of salinity ranges, factor scores, and percent of range enclosed by each salinity zone.

Case #	Common name	Latin name	Salinity range, ppt.	Component factor scores: 1	2	3	4	5	Percent of range enclosed by each zone: F-4	2-15	11-19	15-28	23-M
Adult fish from Musick (1972), continued:													
71	Striped cusk-eel	*Rissola marginata*	14 - M	0.782	-1.232	0.551	-0.031	0.152	0	11	33	78	50
72	Halfbeak	*Hyporhamphus unifasciatus*	12 - M	0.302	-1.115	1.461	-0.142	0.441	0	20	40	70	45
73	Sheepshead minnow	*Cyprinodon variegatus*	0 - 30	0.873	0.873	0.182	1.654	0.698	19	44	28	44	25
74	Banded killifish	*Fundulus diaphanus*	F - 20	-0.393	0.297	1.593	1.052	-1.534	30	61	39	26	0
75	Mummichog	*Fundulus heteroclitus*	0 - 30	0.873	0.873	0.182	1.654	0.698	19	44	28	44	25
76	Spotfin killifish	*Fundulus luciae*	0 - 28	1.410	0.874	-0.089	1.336	-0.538	20	47	30	47	20
77	Striped killifish	*Fundulus majalis*	0 - 30	0.873	0.873	0.182	1.654	0.698	19	44	28	44	25
78	Rainwater killifish	*Lucania parva*	0 - 30	0.873	0.873	0.182	1.654	0.698	19	44	28	44	25
79	Mosquitofish	*Gambusia affinis*	F - 18	-1.204	0.408	1.703	1.038	-0.983	33	67	38	19	0
80	Rough silverside	*Membras martinica*	3 - 24	1.157	1.393	-0.072	-1.705	-2.524	9	59	41	45	9
81	Tidewater silverside	*Menidia beryllina*	0 - 30	0.873	0.873	0.182	1.654	0.698	19	44	28	44	25
82	Atlantic silverside	*Menidia menidia*	0 - 30	0.873	0.873	0.182	1.654	0.698	19	44	28	44	25
83	Fourspine stickleback	*Apeltes quadracus*	3 - 26	1.525	1.511	-0.486	-1.497	-2.140	8	54	38	50	17
84	Lined seahorse	*Hippocampus erectus*	15 - M	0.980	-1.186	0.007	-0.036	0.048	0	6	29	82	53
85	Dusky pipefish	*Sygnathus floridae*	15 - 30	1.337	-1.164	-0.229	-0.119	-0.533	0	6	31	88	50
86	Northern pipefish	*Sygnathus fuscus*	0 - 30	0.873	0.873	0.182	1.654	0.698	19	44	28	44	25
87	Black sea bass	*Centropristes striata*	12 - M	0.302	-1.115	1.461	-0.142	0.441	0	20	40	70	45
88	Flier	*Centrarchus macropterus*	F - 7	-0.551	-0.262	-1.294	1.533	-1.212	70	60	0	0	0
89	Bluespotted sunfish	*Enneacanthus gloriosus*	F - 13	-1.396	1.166	-0.509	0.642	-0.640	44	75	19	0	0
90	Bluegill	*Lepomis macrochirus*	F - 18	-1.204	0.408	1.703	1.038	-0.983	33	67	38	19	0
91	Pumpkinseed	*Lepomis gibbosus*	F - 18	-1.204	0.408	1.703	1.038	-0.983	33	67	38	19	0
92	Smallmouth bass	*Micropterus dolomieui*	F - 7	-0.551	-0.262	-1.294	1.533	-1.212	70	60	0	0	0
93	Largemouth bass	*Micropterus salmoides*	F - 13	-1.396	1.166	-0.509	0.642	-0.640	44	75	19	0	0
94	White crappie	*Pomoxis annularis*	F - 2	-1.097	-1.604	0.054	1.382	-1.090	100	20	0	0	0
95	Black crappie	*Pomoxis nigromaculatus*	F - 1	-1.137	-1.589	0.104	0.904	-1.248	100	0	0	0	0
96	Swamp darter	*Etheostoma fusiforme*	F - 1	-1.137	-1.589	0.104	0.904	-1.248	100	0	0	0	0
97	Tessellated darter	*Etheostoma olmstedi*	F - 13	-1.396	1.166	-0.509	0.642	-0.640	44	75	19	0	0
98	Yellow perch	*Perca flavescens*	F - 13	-1.396	1.166	-0.509	0.642	-0.640	44	75	19	0	0
99	Bluefish	*Pomatomus saltatrix*	1 - M	0.516	1.354	0.053	0.360	0.972	13	45	29	45	29
100	Sharksucker	*Echeneis naucrates*	9 - M	-0.053	-0.202	1.541	-0.703	0.705	0	30	39	61	39
101	Blue runner	*Caranx fuscus*	21 - M	-0.221	-0.364	-1.551	-0.441	1.046	0	0	0	73	82
102	Crevalle jack	*Caranx hippos*	1 - M	0.516	1.354	0.053	0.360	0.972	13	45	29	45	29
103	Bigeye scad	*Selar crumenophthalmus*	15 - M	0.980	-1.186	0.007	-0.036	0.048	0	6	29	82	53
104	Lookdown	*Selene vomer*	1 - M	0.516	1.354	0.053	0.360	0.972	13	45	29	45	29
105	Rough scad	*Trachurus lathami*	14 - M	0.782	-1.232	0.551	-0.031	0.152	0	11	33	78	50
106	Pigfish	*Orthopristis chrysoptera*	14 - M	0.782	-1.232	0.551	-0.031	0.152	0	11	33	78	50
107	Scup	*Stenotomus chrysops*	17 - M	0.981	-0.816	-1.032	-0.257	0.135	0	0	20	80	60
108	Pinfish	*Lagodon rhomboides*	15 - M	0.980	-1.186	0.007	-0.036	0.048	0	6	29	82	53
109	Sheepshead	*Archosargus probatocephalus*	25 - M	-1.775	-0.498	-0.548	-0.614	1.458	0	0	0	57	100
110	Spotted seatrout	*Cynoscion nebulosus*	5 - M	0.204	1.276	0.428	-1.283	0.589	0	41	33	52	33
111	Banded drum	*Larimus fasciatus*	15 - M	0.980	-1.186	0.007	-0.036	0.048	0	6	29	82	53
112	Southern kingfish	*Menticirrhus americanus*	14 - M	0.782	-1.232	0.551	-0.031	0.152	0	11	33	78	50
113	Northern kingfish	*Menticirrhus saxatilis*	4 - M	0.364	1.447	0.169	-1.094	0.556	4	43	32	50	32
114	Red drum	*Sciaenops ocellata*	16 - M	1.039	-1.016	-0.553	-0.136	0.053	0	0	25	81	56
115	Star drum	*Stellifer lanceolatus*	27 - M	-2.143	-0.616	-0.134	-0.821	1.074	0	0	0	40	100
116	Atlantic spadefish	*Chaetodipterus faber*	12 - M	0.302	-1.115	1.461	-0.142	0.441	0	20	40	70	45
117	Tautog	*Tautoga onitis*	16 - M	1.039	-1.016	-0.553	-0.136	0.053	0	0	25	81	56
118	Striped mullet	*Mugil cephalus*	17 - M	0.981	-0.816	-1.032	-0.257	0.135	0	0	20	80	60
119	White mullet	*Mugil curema*	1 - M	0.516	1.354	0.053	0.360	0.972	13	45	29	45	29
120	Northern stargazer	*Astroscopus guttatus*	11 - M	0.110	-0.924	1.702	-0.265	0.568	0	24	43	67	43
121	Feather blenny	*Hypsoblennius hentzi*	12 - 30	0.659	-1.093	1.225	-0.225	-0.140	0	21	42	74	42
122	Striped blenny	*Chasmodes bosquianus*	12 - 25	1.173	-1.204	1.191	-0.974	-2.511	0	29	57	79	21
123	Naked goby	*Gobiosoma bosci*	0 - 27	1.568	0.871	-0.149	1.145	-1.085	21	48	31	45	17
124	Seaboard goby	*Gobiosoma ginsburgi*	15 - 30	1.337	-1.164	-0.229	-0.119	-0.533	0	6	31	88	50
125	Code goby	*Gobiosoma robustum*	16 - M	1.039	-1.016	-0.553	-0.136	0.053	0	0	25	81	56
126	Clown goby	*Microgobius gulosus*	16 - M	1.039	-1.016	-0.553	-0.136	0.053	0	0	25	81	56
127	Green goby	*Microgobius thalassinus*	11 - 30	0.466	-0.902	1.466	-0.349	-0.013	0	25	45	70	40
128	Atlantic cutlassfish	*Trichiurus lepturus*	16 - M	1.039	-1.016	-0.553	-0.136	0.053	0	0	25	81	56
129	Atlantic bonito	*Sarda sarda*	10 - M	0.002	-0.583	1.673	-0.477	0.655	0	27	41	64	41
130	King mackerel	*Scomberomorus cavalla*	14 - M	0.782	-1.232	0.551	-0.031	0.152	0	11	33	78	50
131	Harvestfish	*Peprilus paru*	4 - M	0.364	1.447	0.169	-1.094	0.556	4	43	32	50	32
132	Butterfish	*Peprilus triacanthus*	5 - M	0.204	1.276	0.428	-1.283	0.589	0	41	33	52	33
133	Northern searobin	*Prionotus carolinus*	5 - M	0.204	1.276	0.428	-1.283	0.589	0	41	33	52	33
134	Striped searobin	*Prionotus evolans*	16 - M	1.039	-1.016	-0.553	-0.136	0.053	0	0	25	81	56
135	Longhorn sculpin	*Myoxocephalus octodecemspinosus*	27 - M	-2.143	-0.616	-0.134	-0.821	1.074	0	0	0	40	100
136	Fringed flounder	*Etropus crossotus*	18 - M	0.862	-0.614	-1.460	-0.368	0.270	0	0	14	79	64
137	Smallmouth flounder	*Etropus microstomus*	7 - M	-0.007	0.583	1.053	-1.093	0.697	0	36	36	56	36
138	Summer flounder	*Paralichthys dentatus*	6 - M	0.075	0.963	0.744	-1.241	0.656	0	38	35	54	35
139	Winter flounder	*Pseudopleuronectes americanus*	5 - 30	0.560	1.299	0.192	-1.366	0.008	0	42	35	54	31

Appendix 3, continued. Table of salinity ranges, factor scores, and percent of range enclosed by each salinity zone.

Case #	Common name	Latin name	Salinity range, ppt.	Component factor scores: 1	2	3	4	5	Percent of range enclosed by each zone: F-4	2-15	11-19	15-28	23-M
Adult fish from Musick (1972), continued:													
140	Hogchoker	*Trinectes maculatus*	0 - 30	0.873	0.873	0.182	1.654	0.698	19	44	28	44	25
141	Blackcheek tonguefish	*Symphurus plagiusa*	7 - M	-0.007	0.583	1.053	-1.093	0.697	0	36	36	56	36
142	Orange filefish	*Aluterus schoepfi*	16 - M	1.039	-1.016	-0.553	-0.136	0.053	0	0	25	81	56
143	Gray triggerfish	*Balistes capriscus*	25 - M	-1.775	-0.498	-0.548	-0.614	1.458	0	0	0	57	100
144	Planehead filefish	*Stephanolepsis hispidus*	19 - M	0.590	-0.474	-1.661	-0.427	0.495	0	0	8	77	69
145	Northern puffer	*Sphoeroides maculatus*	9 - M	-0.053	-0.202	1.541	-0.703	0.705	0	30	39	61	39
146	Striped burrfish	*Chilomycterus schoepfi*	2 - M	0.523	1.522	-0.061	-0.293	0.760	10	47	30	47	30
147	Roughtail stingray	*Dasyatis centroura*	20 - M	0.217	-0.391	-1.679	-0.452	0.762	0	0	0	75	75
148	Cunner	*Tautogolabrus adspersus*	11 - M	0.110	-0.924	1.702	-0.265	0.568	0	24	43	67	43
149	Windowpane	*Scophthalmus aquosus*	13 - M	0.541	-1.198	1.037	-0.072	0.295	0	16	37	74	47
Invertebrates from Gosner (1979):													
150	entoproct	*Pedicellina cernua*	15 - M	0.980	-1.186	0.007	-0.036	0.048	0	6	29	82	53
151	bryzoan	*Anguinella palmata*	13 - M	0.541	-1.198	1.037	-0.072	0.295	0	16	37	74	47
152	creeping bryozoan	*Bowerbankia gracilis*	10 - M	0.002	-0.583	1.673	-0.477	0.655	0	27	41	64	41
153	Red beard sponge	*Microciona prolifera*	15 - M	0.980	-1.186	0.007	-0.036	0.048	0	6	29	82	53
154	pinnate bryozoan	*Aeverrillia armata*	12 - M	0.302	-1.115	1.461	-0.142	0.441	0	20	40	70	45
155	bryozoan	*Crisia eburnea*	18 - M	0.862	-0.614	-1.460	-0.368	0.270	0	0	14	79	64
156	lacy bryozoan	*Electra pilosa*	11 - M	0.110	-0.924	1.702	-0.265	0.568	0	24	43	67	43
157	bryozoan	*Bugula turrita*	20 - M	0.217	-0.391	-1.679	-0.452	0.762	0	0	0	75	75
158	red bryozaon	*Schizoporella unicornis*	18 - M	0.862	-0.614	-1.460	-0.368	0.270	0	0	14	79	64
159	Arrow worm	*Sagitta elegans*	11 - M	0.110	-0.924	1.702	-0.265	0.568	0	24	43	67	43
160	phoronid worm	*Phoronis architecta*	18 - M	0.862	-0.614	-1.460	-0.368	0.270	0	0	14	79	64
161	Atlantic oyster drill	*Urosalpinx cinerea*	15 - M	0.980	-1.186	0.007	-0.036	0.048	0	6	29	82	53
162	American oyster	*Crassostrea virginica*	5 - 30	0.560	1.299	0.192	-1.366	0.008	0	42	35	54	31
163	Carolina marshclam	*Polymesoda caroliniana*	F - 15	-1.653	0.949	0.595	0.747	-0.541	39	78	28	6	0
164	Hard clam	*Mercenaria mercenaria*	15 - M	0.980	-1.186	0.007	-0.036	0.048	0	6	29	82	53
165	Amethyst gemclam	*Gemma gemma*	5 - M	0.204	1.276	0.428	-1.283	0.589	0	41	33	52	33
166	Baltic macoma	*Macoma baltica*	5 - M	0.204	1.276	0.428	-1.283	0.589	0	41	33	52	33
167	Softshell clam	*Mya arenaria*	5 - M	0.204	1.276	0.428	-1.283	0.589	0	41	33	52	33
168	twelve-scaled worm	*Lepidonotus squamatus*	20 - M	0.217	-0.391	-1.679	-0.452	0.762	0	0	0	75	75
169	twelve-scaled worm	*Lepidonotus sublevis*	15 - M	0.980	-1.186	0.007	-0.036	0.048	0	6	29	82	53
170	twelve-scaled worm	*Lepidonotus variabilis*	17 - M	0.981	-0.816	-1.032	-0.257	0.135	0	0	20	80	60
171	fifteen-scaled worm	*Harmothoe imbricata*	18 - M	0.862	-0.614	-1.460	-0.368	0.270	0	0	14	79	64
172	fifteen-scaled worm	*Harmothoe extenuata*	18 - M	0.862	-0.614	-1.460	-0.368	0.270	0	0	14	79	64
173	clam worm	*Platynereis dumerilii*	15 - M	0.980	-1.186	0.007	-0.036	0.048	0	6	29	82	53
174	bamboo worm	*Asychis elongata*	15 - M	0.980	-1.186	0.007	-0.036	0.048	0	6	29	82	53
175	Parchment worm	*Chaetopterus variopedatus*	15 - M	0.980	-1.186	0.007	-0.036	0.048	0	6	29	82	53
176	sand-builder worm	*Sabellaria vulgaris*	15 - M	0.980	-1.186	0.007	-0.036	0.048	0	6	29	82	53
177	Trumpet worm	*Pectinaria gouldii*	15 - M	0.980	-1.186	0.007	-0.036	0.048	0	6	29	82	53
178	American lobster	*Homarus americanus*	20 - M	0.217	-0.391	-1.679	-0.452	0.762	0	0	0	75	75
179	Longwrist hermit crab	*Pagurus longicarpus*	18 - M	0.862	-0.614	-1.460	-0.368	0.270	0	0	14	79	64
180	Flatclaw hermit crab	*Pagurus pollicaris*	9 - M	-0.053	-0.202	1.541	-0.703	0.705	0	30	39	61	39
181	Atlantic rock crab	*Cancer irroratus*	22 - M	-0.655	-0.379	-1.334	-0.437	1.261	0	0	0	70	90
182	Green crab	*Carcinus maenas*	6 - M	0.075	0.963	0.744	-1.241	0.656	0	38	35	54	35
183	Blue crab	*Callinectus sapidus*	0 - M	0.517	0.851	0.418	1.737	1.279	18	42	27	42	27
184	mud crab	*Neopanopeus sayi*	15 - M	0.980	-1.186	0.007	-0.036	0.048	0	6	29	82	53
185	Flatback mud crab	*Eurypanopeus depressus*	4 - 20	-0.516	1.169	1.111	-2.199	-2.158	6	71	53	35	0
186	hydroid	*Ectopleura dumortieri*	5 - 18	-1.488	1.109	1.480	-2.403	-1.574	0	79	57	29	0
187	Channeled whelk	*Busycon canaliculatum*	20 - M	0.217	-0.391	-1.679	-0.452	0.762	0	0	0	75	75
188	acorn worm	*Saccoglossus kowalewskii*	19 - M	0.590	-0.474	-1.661	-0.427	0.495	0	0	8	77	69
189	Golden star tunicate	*Botryllus schlosseri*	18 - M	0.862	-0.614	-1.460	-0.368	0.270	0	0	14	79	64
190	sea grape	*Molgula manhattensis*	15 - M	0.980	-1.186	0.007	-0.036	0.048	0	6	29	82	53
191	larvacean	*Oikopleura species*	11 - M	0.110	-0.924	1.702	-0.265	0.568	0	24	43	67	43
Juvenile fish from DFMAB (1978):													
192	Winter flounder	*Pseudopleuronectes americanus*	4 - 30	0.721	1.470	-0.067	-1.177	-0.024	4	44	33	52	30
193	Hogchoker	*Trinectes maculatus*	0 - 9	-0.587	0.792	-1.863	0.667	-1.045	55	73	0	0	0
194	Blackcheek tonguefish	*Symphurus plagiusa*	5 - 22	0.189	1.052	0.893	-2.396	-2.524	0	61	50	44	0
195	Scrawled cowfish	*Lactophrys quadricornis*	25 - M	-1.775	-0.498	-0.548	-0.614	1.458	0	0	0	57	100
196	Trunkfish	*Lactophrys trigonis*	21 - M	-0.221	-0.364	-1.551	-0.441	1.046	0	0	0	73	82
197	Northern puffer	*Sphoeroides maculatus*	11 - M	0.110	-0.924	1.702	-0.265	0.568	0	24	43	67	43
198	Checkered puffer	*Sphoeroides testudineus*	0.5 - M	0.513	1.107	0.234	1.057	1.142	16	44	28	44	28
199	Striped burrfish	*Chilomycterus schoepfi*	15 - M	0.980	-1.186	0.007	-0.036	0.048	0	6	29	82	53
200	Oyster toadfish	*Opsanus tau*	13 - 29	1.182	-1.175	0.655	-0.316	-0.916	0	18	41	82	41
201	Atlantic tomcod	*Microgadus tomcod*	2 - 10	-0.688	1.805	-2.372	-1.574	-1.476	33	100	0	0	0
202	Horse-eye jack	*Caranx latus*	12 - M	0.302	-1.115	1.461	-0.142	0.441	0	20	40	70	45
203	Atlantic bumper	*Chloroscombrus chrysurus*	9 - M	-0.053	-0.202	1.541	-0.703	0.705	0	30	39	61	39
204	Leatherjacket	*Oligoplites saurus*	0 - M	0.517	0.851	0.418	1.737	1.279	18	42	27	42	27

Appendix 3, continued. Table of salinity ranges, factor scores, and percent of range enclosed by each salinity zone.

Case #	Common name	Latin name	Salinity range, ppt.	Component factor scores: 1	2	3	4	5	Percent of range enclosed by each zone: F-4	2-15	11-19	15-28	23-M
Juvenile fish from DFMAB (1978), continued:													
205	Lookdown	*Selene vomer*	8 - M	-0.063	0.195	1.337	-0.922	0.723	0	33	38	58	38
206	Florida pompano	*Trachinotus carolinus*	10 - M	0.002	-0.583	1.673	-0.477	0.655	0	27	41	64	41
207	Permit	*Trachinotus falcatus*	1 - M	0.516	1.354	0.053	0.360	0.972	13	45	29	45	29
208	Rough scad	*Trachurus lathami*	29 - M	-1.994	-0.665	-0.101	-1.145	0.148	0	0	0	0	100
209	Irish pompano	*Diapterus olisthostomus*	0.5 - M	0.513	1.107	0.234	1.057	1.142	16	44	28	44	28
210	Spotfin mojarra	*Eucinostomus argenteus*	4 - 29	1.005	1.470	-0.213	-1.338	-0.655	4	46	35	54	27
211	Silver jenny	*Eucinostomus gula*	0 - M	0.517	0.851	0.418	1.737	1.279	18	42	27	42	27
212	Tomtate	*Haemulon aurolineatum*	18 - 30	1.219	-0.592	-1.696	-0.451	-0.311	0	0	15	85	62
213	Yellow chub	*Kyphosus incisor*	28 - M	-2.153	-0.662	-0.042	-0.954	0.695	0	0	0	25	100
214	Sargeant major	*Abudefduf saxatilis*	29 - M	-1.994	-0.665	-0.101	-1.145	0.148	0	0	0	0	100
215	Atlantic bonito	*Sarda sarda*	5 - 10	-1.007	1.559	-1.882	-2.564	-1.647	0	100	0	0	0
216	Spanish mackerel	*Scomberomorus maculatus*	13 - M	0.541	-1.198	1.037	-0.072	0.295	0	16	37	74	47
217	White perch	*Morone americana*	F - 7	-0.551	-0.262	-1.294	1.533	-1.212	70	60	0	0	0
218	Striped bass	*Morone saxatilis*	F - 18	-1.204	0.408	1.703	1.038	-0.983	33	67	38	19	0
219	Blueback herring	*Alosa aestivalis*	F - 28	1.380	0.598	0.144	1.756	-0.636	23	45	29	45	19
220	Menhaden	*Brevoortia tyranus*	0 - 15	-1.624	1.224	0.362	0.327	-0.443	35	82	29	6	0
221	Atlantic thread herring	*Opisthonema oglinum*	15 - M	0.980	-1.186	0.007	-0.036	0.048	0	6	29	82	53
222	Silver perch	*Bairdiella chrysoseura*	0 - M	0.517	0.851	0.418	1.737	1.279	18	42	27	42	27
223	Spotted seatrout	*Cynoscion nebulosus*	0.5 - M	0.513	1.107	0.234	1.057	1.142	16	44	28	44	28
224	Banded drum	*Larimus fasciatus*	27 - M	-2.143	-0.616	-0.134	-0.821	1.074	0	0	0	40	100
225	Spot	*Leiostomus xanthurus*	0 - M	0.517	0.851	0.418	1.737	1.279	18	42	27	42	27
226	Atlantic croaker	*Micropogonias undulatus*	0 - M	0.517	0.851	0.418	1.737	1.279	18	42	27	42	27
227	Black drum	*Pogonias cromis*	0 - M	0.517	0.851	0.418	1.737	1.279	18	42	27	42	27
228	Northern Kingfish	*Menticirrhus saxatilis*	6 - M	0.075	0.963	0.744	-1.241	0.656	0	38	35	54	35
229	Great barracuda	*Sphyraena barracuda*	15 - M	0.980	-1.186	0.007	-0.036	0.048	0	6	29	82	53
230	Red drum	*Sciaenops ocellata*	0 - M	0.517	0.851	0.418	1.737	1.279	18	42	27	42	27
231	Striped mullet	*Mugil cephalus*	0 - M	0.517	0.851	0.418	1.737	1.279	18	42	27	42	27
232	White mullet	*Mugil curema*	0 - M	0.517	0.851	0.418	1.737	1.279	18	42	27	42	27
233	Rough silversides	*Membras martinica*	0 - 28	1.410	0.874	-0.089	1.336	-0.538	20	47	30	47	20
234	Tidewater silverside	*Menidia beryllina*	0 - 15	-1.624	1.224	0.362	0.327	-0.443	35	82	29	6	0
235	Atlantic silverside	*Menidia menidia*	1 - 14	-1.566	1.898	-0.563	-1.151	-0.745	29	93	29	0	0
236	Bay whiff	*Citharichthys spilopterus*	2 - M	0.523	1.522	-0.061	-0.293	0.760	10	47	30	47	30
237	Summer flounder	*Paralichthys dentatus*	0 - M	0.517	0.851	0.418	1.737	1.279	18	42	27	42	27
238	Windowpane	*Scophthalmus aquosus*	15 - 29	1.621	-1.163	-0.375	-0.280	-1.163	0	7	33	93	47
239	Fringed flounder	*Etropus crossotus*	0.5 - M	0.513	1.107	0.234	1.057	1.142	16	44	28	44	28
240	Orange filefish	*Aluterus schoepli*	23 - M	-1.086	-0.417	-1.073	-0.434	1.445	0	0	0	67	100
241	Bandtali puffer	*Sphoeroides spengleri*	10 - M	0.002	-0.583	1.673	-0.477	0.655	0	27	41	64	41
242	Shortnosed sturgeon	*Acipenser brevirostrum*	F - 20	-0.393	0.297	1.593	1.052	-1.534	30	61	39	26	0
243	Ladyfish	*Elops saurus*	17 - M	0.981	-0.816	-1.032	-0.257	0.135	0	0	20	80	60
244	Tarpon	*Megalops atlantica*	0 - M	0.517	0.851	0.418	1.737	1.279	18	42	27	42	27
245	Inshore lizardfish	*Synodus foetens*	10 - M	0.002	-0.583	1.673	-0.477	0.655	0	27	41	64	41
246	Goldfish	*Carrassius auratus*	F - 17	-1.476	0.548	1.503	0.978	-0.758	35	70	35	15	0
247	White catfish	*Ictalurus catus*	F - 11	-0.916	1.048	-1.418	0.753	-0.930	50	71	7	0	0
248	Channel catfish	*Ictalurus punctatus*	F - 11	-0.916	1.048	-1.418	0.753	-0.930	50	71	7	0	0
249	Sheepshead minnow	*Cyprinodon variegatus*	0 - 30	0.873	0.873	0.182	1.654	0.698	19	44	28	44	25
250	Marsh killifish	*Fundulus confluentus*	0 - 4	-0.788	-1.067	-0.618	1.474	-0.979	100	50	0	0	0
251	Spotfin killifish	*Fundulus luciae*	15 - 30	1.337	-1.164	-0.229	-0.119	-0.533	0	6	31	88	50
252	Striped killifish	*Fundulus majalis*	20 - 30	0.574	-0.368	-1.915	-0.536	0.181	0	0	0	82	73
253	Spotted hake	*Urophycis regius*	5 - M	0.204	1.276	0.428	-1.283	0.589	0	41	33	52	33
254	Fourspine stickleback	*Apeltes quadracus*	3 - 30	0.840	1.560	-0.247	-0.855	0.021	7	46	32	50	29
255	Dusky pipefish	*Sygnathus floridae*	19 - 27	1.642	-0.455	-2.228	-1.020	-1.869	0	0	11	100	56
256	Northern pipefish	*Sygnathus fuscus*	2 - 22	0.508	1.297	0.403	-1.406	-2.353	14	67	43	38	0
257	Rock sea bass	*Centropristes philadephica*	7 - M	-0.007	0.583	1.053	-1.093	0.697	0	36	36	56	36
258	Jewfish	*Epinephelus itajara*	25 - M	-1.775	-0.498	-0.548	-0.614	1.458	0	0	0	57	100
259	Red grouper	*Epinephelus morio*	21 - M	-0.221	-0.364	-1.551	-0.441	1.046	0	0	0	73	82
260	Warsaw grouper	*Epinephelus nigritus*	29 - M	-1.994	-0.665	-0.101	-1.145	0.148	0	0	0	0	100
261	Tripletail	*Lobotes surinamensis*	1 - M	0.516	1.354	0.053	0.360	0.972	13	45	29	45	29
262	Mutton snapper	*Lutjanus analis*	5 - M	0.204	1.276	0.428	-1.283	0.589	0	41	33	52	33
263	Red snapper	*Lutjanus campechanus*	25 - M	-1.775	-0.498	-0.548	-0.614	1.458	0	0	0	57	100
264	Cubera snapper	*Lutjanus cyanopterus*	4 - M	0.364	1.447	0.169	-1.094	0.556	4	43	32	50	32
265	Gray snapper	*Lutjanus griseus*	0 - M	0.517	0.851	0.418	1.737	1.279	18	42	27	42	27
266	Pumpkinseed	*Lepomis gibbosus*	F - 7	-0.551	-0.262	-1.294	1.533	-1.212	70	60	0	0	0
267	Warmouth	*Lepomis gulosus*	F - 17	-1.476	0.548	1.503	0.978	-0.758	35	70	35	15	0
268	Largemouth bass	*Micropterus salmoides*	F - 17	-1.476	0.548	1.503	0.978	-0.758	35	70	35	15	0
269	White crappie	*Pomoxis annularis*	F - 1	-1.137	-1.589	0.104	0.904	-1.248	100	0	0	0	0
270	Black crappie	*Pomoxis nigromaculatus*	F - 13	-1.396	1.166	-0.509	0.642	-0.640	44	75	19	0	0
271	Tessellated darter	*Etheostoma olmstedi*	F - 0.5	-1.130	-1.421	-0.010	0.251	-1.460	100	0	0	0	0
272	Yellow perch	*Perca flavescens*	F - 10	-0.724	0.858	-1.659	0.876	-1.056	54	69	0	0	0
273	Bluefish	*Pomatomus saltatrix*	0 - M	0.517	0.851	0.418	1.737	1.279	18	42	27	42	27
274	Cobia	*Rachycentron canadum*	0 - M	0.517	0.851	0.418	1.737	1.279	18	42	27	42	27

Appendix 3, continued. Table of salinity ranges, factor scores, and percent of range enclosed by each salinity zone.

Case #	Common name	Latin name	Salinity range, ppt.	Component factor scores: 1	2	3	4	5	Percent of range enclosed by each zone: F-4	2-15	11-19	15-28	23-M
Larval fish from DFMAB (1978):													
275	Winter flounder	*Pseudopleuronectes americanus*	4 - 28	1.257	1.470	-0.339	-1.495	-1.260	4	48	36	56	24
276	Blackcheek tonguefish	*Symphurus plagiusa*	11 - 22	0.095	-1.149	2.166	-1.378	-2.545	0	42	75	67	0
277	Skilletfish	*Gobiesox strumosus*	4 - 27	1.416	1.467	-0.398	-1.686	-1.807	4	50	38	54	21
278	Northern puffer	*Sphoeroides maculatus*	11 - 22	0.095	-1.149	2.166	-1.378	-2.545	0	42	75	67	0
279	Atlantic tomcod	*Microgadus tomcod*	2 - 10	-0.688	1.805	-2.372	-1.574	-1.476	33	100	0	0	0
280	Alewife	*Alosa pseudoharengus*	F - 5	-0.689	-1.030	-0.701	1.852	-1.144	88	50	0	0	0
281	Hickory shad	*Alosa mediocris*	F - 5	-0.689	-1.030	-0.701	1.852	-1.144	88	50	0	0	0
282	Bay anchovy	*Anchoa mitchilli*	0 - 7	-0.521	0.014	-1.527	1.113	-1.113	67	67	0	0	0
283	Atlantic bonito	*Sarda sarda*	17 - 20	0.100	-1.094	-0.089	-1.363	-2.579	0	0	75	100	0
284	Atlantic mackerel	*Scomber scombrus*	16 - M	1.039	-1.016	-0.553	-0.136	0.053	0	0	25	81	56
285	King mackerel	*Scomberomorus cavalla*	27 - M	-2.143	-0.616	-0.134	-0.821	1.074	0	0	0	40	100
286	White perch	*Morone americana*	F - 8	-0.561	0.135	-1.498	1.314	-1.193	64	64	0	0	0
287	Striped bass	*Morone saxatilis*	F - 10	-0.724	0.858	-1.659	0.876	-1.056	54	69	0	0	0
288	Blueback herring	*Alosa aestivalis*	F - 5	-0.689	-1.030	-0.701	1.852	-1.144	88	50	0	0	0
289	American shad	*Alosa sapidissima*	F - 7	-0.551	-0.262	-1.294	1.533	-1.212	70	60	0	0	0
290	Menhaden	*Brevoortia tyranus*	18 - M	0.862	-0.614	-1.460	-0.368	0.270	0	0	14	79	64
291	Silver perch	*Bairdiella chrysoseura*	2 - M	0.523	1.522	-0.061	-0.293	0.760	10	47	30	47	30
292	Spotted seatrout	*Cynoscion nebulosus*	24 - M	-1.450	-0.451	-0.810	-0.527	1.476	0	0	0	63	100
293	Weakfish	*Cynoscion regalis*	12 - M	0.302	-1.115	1.461	-0.142	0.441	0	20	40	70	45
294	Atlantic croaker	*Micropogonias undulatus*	0 - 21	0.070	0.588	1.143	0.627	-1.651	26	61	39	30	0
295	Cunner	*Tautogolabrus adspersus*	27 - M	-2.143	-0.616	-0.134	-0.821	1.074	0	0	0	40	100
296	Sand lance	*Ammodytes sp.*	2 - M	0.523	1.522	-0.061	-0.293	0.760	10	47	30	47	30
297	Striped mullet	*Mugil cephalus*	11 - M	0.110	-0.924	1.702	-0.265	0.568	0	24	43	67	43
298	White mullet	*Mugil curema*	M - M	-1.458	-0.665	-0.373	-1.464	-1.087	0	0	0	0	100
299	Tidewater silverside	*Menidia beryllina*	0 - 15	-1.624	1.224	0.362	0.327	-0.443	35	82	29	6	0
300	Summer flounder	*Paralichthys dentatus*	0 - M	0.517	0.851	0.418	1.737	1.279	18	42	27	42	27
301	Naked goby	*Gobiosoma bosci*	0 - 19	-0.802	0.600	1.489	0.643	-1.152	29	67	43	24	0
302	Green goby	*Microgobius thalassinus*	17 - M	0.981	-0.816	-1.032	-0.257	0.135	0	0	20	80	60
303	Ladyfish	*Elops saurus*	1 - M	0.516	1.354	0.053	0.360	0.972	13	45	29	45	29
304	Atlantic herring	*Clupea harengus*	1 - M	0.516	1.354	0.053	0.360	0.972	13	45	29	45	29
305	Channel catfish	*Ictalurus punctatus*	F - 7	-0.551	-0.262	-1.294	1.533	-1.212	70	60	0	0	0
306	Conger eel	*Conger oceanicus*	3 - M	0.483	1.537	-0.011	-0.771	0.602	7	45	31	48	31
307	Speckled worm eel	*Myrophis punctatus*	0 - 4	-0.788	-1.067	-0.618	1.474	-0.979	100	50	0	0	0
308	Ballyhoo	*Hemiramphus brasiliensis*	2 - M	0.523	1.522	-0.061	-0.293	0.760	10	47	30	47	30
309	Halfbeak	*Hyporhamphus unifasciatus*	0 - 12	-1.126	1.407	-1.227	0.262	-0.685	43	79	14	0	0
310	Sheepshead minnow	*Cyprinodon variegatus*	0 - 30	0.873	0.873	0.182	1.654	0.698	19	44	28	44	25
311	Mummichog	*Fundulus heteroclitus*	2 - 3	-0.943	-0.567	-0.839	-0.746	-1.464	100	100	0	0	0
312	Striped killifish	*Fundulus majalis*	20 - 30	0.574	-0.368	-1.915	-0.536	0.181	0	0	0	82	73
313	Fourspine stickleback	*Apeltes quadracus*	3 - 22	0.468	1.312	0.454	-1.884	-2.511	10	65	45	40	0
314	Northern pipefish	*Sygnathus fuscus*	2 - 22	0.508	1.297	0.403	-1.406	-2.353	14	67	43	38	0
315	Sargassum pipefish	*Sygnathus pelagicus*	23 - M	-1.086	-0.417	-1.073	-0.434	1.445	0	0	0	67	100
316	Cobia	*Rachycentron canadum*	28 - M	-2.153	-0.662	-0.042	-0.954	0.695	0	0	0	25	100
317	Feather blenny	*Hypsoblennius hentzi*	11 - 21	-0.337	-1.187	2.427	-1.375	-2.362	0	45	82	64	0