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Estimation of Relative Abundance of Recreationally Important Finfish in the Virginia Portion of Chesapeake Bay

U. S. Fish and Wildlife Service

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TABLE OF CONTENTS

PREFACE ii

ACKNOWLEDGEMENTS iii

LIST OF TABLES iv

LIST OF FIGURES v

SUMMARY vii

INTRODUCTION 1

METHODS 4

RESULTS 11

DISCUSSION 25

LITERATURE CITED 34

APPENDIX 63

PREFACE

This document is a revised edition of an original manuscript presented to the U.S. Fish and Wildlife Service and the Virginia Marine Resources Commission in partial fulfillment of contract obligations (Sportfish Restoration Project F104R2). After its submittal and acceptance in September 1993, data from the period December 1987, to April 1988, were discovered that dramatically altered some of the results presented. These data concern only the tributaries (James, York, and Rappahannock Rivers), for the months January through March 1988. These samples were funded from internal sources to provide a continuous database for striped bass. All protocol were identical to that routinely used on the VIMS Trawl Survey. These data have been verified and incorporated into the VIMS Fisheries Database. Results presented here reflect the changes these data have caused.

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LIST OF TABLES

Table 1. Numbers of potential trawl sites and approximate areas of sampling strata 37

Table 2. Assignment of fixed tributary stations to potential random strata 38

Table 3. Spatial, temporal and length criteria used to calculate juvenile indices . . . 39

Table 4. Paired t-test statistics of geometric mean catch difference between the Research Vessels *Captain John Smith* and *Fish Hawk*, August 1990 40

Table 5. T-test statistics for door comparisons based on data pooled as aggregates, April 1991 to June 1992 41

Table 6. Juvenile abundance indices for key recreational species 42

Table 7. Mean geometric catch per tow for Atlantic Croaker in the tributaries and mainstem Bay during months of peak abundance 45

LIST OF FIGURES

Figure 1. Chesapeake Bay trawl survey strata 46

Figure 2. Geometric mean catch per tow of spot, Atlantic croaker and weakfish by month on the primary nursery grounds 47

Figure 3. Annual juvenile abundance indices with 95% confidence intervals for spot, Atlantic croaker and weakfish 48

Figure 4. Geometric mean catch per tow of summer flounder, black sea bass and scup by month on the primary nursery grounds 49

Figure 5. Annual juvenile abundance indices with 95% confidence intervals for summer flounder, black sea bass and scup 50

Figure 6. Length cutoff values used to separate y-o-y white perch from age 1+ components 51

Figure 7. Geometric mean catch per trawl by month for white perch y-o-y and age 1+ components 52

Figure 8. Composite length frequencies by month for white perch, VIMS trawl survey data base, 1955-1991 54

Figure 9. Geometric mean catch per tow of age 1+ white perch, y-o-y white perch and striped bass by month on the primary nursery grounds 55

Figure 10. Annual juvenile abundance indices with 95% confidence intervals for age 1+ white perch, y-o-y white perch and striped bass 56

Figure 11. Length cutoff values used to separate y-o-y striped bass from older year classes 57

Figure 12. Composite length frequencies by month for striped bass, VIMS trawl survey data base, 1957-1991 58

Figure 13. Annual juvenile abundance indices for initial key species based on tributary data only and on expanded sampling program 59

Figure 14. Annual juvenile abundance indices for white perch (y-o-y and age 1+) and striped bass based on historic tributary data (1979-1987), and the expanded sampling program (1988-1993) 60

Figure 15. Geometric mean catch per trawl by month for striped bass y-o-y and age 1+ components 61

SUMMARY

Project Objectives

1 & 2: Provisional annual indices of juvenile abundance have been generated from trawl survey data for six species of key recreational importance in the Virginia portion of Chesapeake Bay (spot, croaker, weakfish, summer flounder, black sea bass and striped bass) and two species of secondary importance (scup and white perch) for the period 1988-1992. No species has shown a continuous trend during the five year period, although several species have revealed declines (spot, scup and y-o-y white perch) or increases (Atlantic croaker and striped bass) in recent years. Spot has shown the largest decline from a high geometric mean catch per trawl of 68 (1988) to a low (1992) of 2. Atlantic croaker showed the greatest variability between years, with the 1989 index of 65 being 4 to 7 times higher than that seen in the other four years. The weakfish and striped bass indices reversed a downward trend in 1992 exhibiting values of 7 and 2.2 respectively (a historical high for striped bass). Summer flounder in 1992 declined significantly to near the historic low experienced in 1988. Black sea bass and scup juvenile recruitment to lower Chesapeake Bay showed no evidence of a trend over the five year period.

3: Analysis of vessel comparisons indicates little if any difference for the species of importance, with only marginal significance ($P < 0.1$) for other species of interest. Gear comparisons between different door types had little effect on the fishing power of the gear. There appeared to be no size selectivity for the gears, although further investigation is necessary to resolve statistical aberrations associated with large sample sizes. A longer time series of data will be needed in order to determine the best area/time combinations for juvenile index calculations and to establish a baseline for categorizing trends and assessing relative annual recruitment success.

4: Analysis and summary of data continues to be routinely produced and available in the form of an annual data summary report. These summaries allow for detailed comparisons and contrasts of annual results with previous surveys.

Since most of the species concerned are highly migratory and utilize widespread nursery areas, a multi-state effort will be required to fully evaluate their relative annual reproductive success.

With the recent discovery of tributary data from January to March 1988, an index for white perch and striped bass can be generated for the 1987 year class. This data supports other sampling programs indicating these two species having very successful year classes in 1987. The addition of finfish catch information from the VIMS Crustaceology Department's historical data sets for the years 1973-1978, provides a continuous 39 year dataset of fixed station transects of Virginia's major tributaries. Work is presently underway to analyze gear differences during this period, as well as other years, to provide a historical perspective.

INTRODUCTION

Measures of juvenile abundance are presently in wide use as a key element in the management of the Atlantic States' coastal fishery resources. Estimates of the relative interannual abundance of early juveniles (age-0) generated from scientific survey programs have been found to provide a reliable and early estimator of future year class strength (Goodyear 1985, Lipcius and Van Engel 1990). After a review of previously available indices of juvenile abundance for important fishery resource species in the Chesapeake Bay, the Chesapeake Bay Stock Assessment Committee (CBSAC), a federal/state committee sponsored and funded by the National Oceanic and Atmospheric Administration (NOAA), recommended that " a unified, consistent trawl program should be one of the primary monitoring tools for finfish and crab stock assessment." (Chesapeake Bay Program Stock Assessment Plan, Chesapeake Executive Council 1988). In order to facilitate the implementation of such a program, CBSAC directly supported pilot studies directed at developing a comprehensive trawl survey for Chesapeake Bay. In the Virginia portion of the bay the primary focus of this support was the initiation in 1988 of a monthly trawl survey of the mainstem portion of the lower Bay. This survey served to compliment and greatly expand the monthly trawl surveys of the major Virginia tributaries (James, York and Rappahannock rivers) which have been conducted by the Virginia Institute of Marine Science (VIMS) as part of a long-term effort to monitor and assess the condition of fishery stocks in the lower Chesapeake Bay and its tributaries. The primary intent of the present project is to assure that this expanded sampling effort be continued on a long-term basis as well.

The expanded sampling program is a particularly vital component to insure that data will be of sufficient geographic resolution for the generation of annual relative estimates of recruitment success of recreationally important finfish species of Chesapeake Bay. An analysis of the Virginia portion of the National Marine Fisheries Service (NMFS) Marine Recreational Fisheries Statistics Survey (MRFSS) (VMRC 1985), showed Virginia marine recreational catches were dominated by six species (spot, croaker, weakfish, black sea bass, summer flounder, and bluefish) constituting over 85% of the total estimated catch by both numbers caught and weight landed. All of these species heavily use the lower Chesapeake Bay and its tributaries as a nursery area, with all but bluefish highly vulnerable to bottom trawls. In addition to the five key species cited above, past survey results indicate other species of recreational interest, including scup, white perch, striped bass, white and channel catfish, kingfish, and others, are taken with sufficient regularity during trawling operations as to provide data sets suitable for the generation of useful indices of juvenile abundance.

The project also seeks to facilitate the further development of a comprehensive trawl survey program through gear evaluations and comparison studies which will serve to unify current trawling efforts while maximizing continuity with historical data sets. Although the primary focus of the project is the generation of annual indices of juvenile (young-of-year) abundance of recreationally and ecologically important marine and estuarine finfish, survey results can also be used to address other aspects of the population biology of these species, such as habitat utilization, early growth and survival, climate and pollutant interactions, etc.

The development of juvenile indices requires considerable continuous time series of data in order to determine the proper area-time sequences best used in index calculations. Since results from the pilot survey spans only five full years of the expanded data, the calculation of abundance indices possible at present can only be performed on a preliminary and tentative basis. In view of the fact that even very short term trends in juvenile abundance may be of interest for the five key species identified above, during the report for the first project segment (Colvocoresses and Geer 1991), provisional annual juvenile abundance indices were calculated for these species. In the fourth year of the expanded survey (second project segment), a provisional index was developed for a sixth species, scup (Colvocoresses et al. 1992). In the present report provisional indices have been developed for two more species of interest; striped bass and white perch. The striped bass is considered by many to be the most important finfish both recreationally and commercially in Virginia, with management plans encompassing the entire eastern seaboard. The white perch is of secondary importance to the Virginia recreational fisheries in terms of numbers caught, but is still a highly prized food fish for the angler fishing the upper estuary regions. Calculations of abundance indices for other species of interest will be deferred until a sounder basis for their calculation can be generated. The provisional nature of the reported values is emphasized by the fact that all of the abundance indices for the initial five species reported during previous segments have undergone some minor modifications since then.

In the present report an attempt is also made to relate the juvenile indices developed herein with a longer term series based on the traditional tributary sampling. In some cases this appears to provide a historical context in which to place recent project results, while in others it only emphasizes the need for the expanded sampling program. Overall data summaries for data collected in the mainstem bay sampling in 1988 (Chittenden 1989) and for both the bay and river sampling in 1989 (Geer et al. 1990), 1990 to 1992 (Bonzek et al. 1991, 1992, 1993) have been previously prepared and distributed.

METHODS

Field Sampling

All collections were made with a lined 30' (9.14m) semi-balloon otter trawl (38.1mm stretched mesh, 6.35mm cod liner) and towed along the bottom for a period of five minutes during daylight hours. No effort was made to consistently trawl with or against the tidal flow since wind was often a more important factor. However, tows were made parallel to isobaths at constant depth. Catches were sorted to species, enumerated and individual lengths recorded. Relevant hydrographic and atmospheric parameters including depth, salinity, temperature and dissolved oxygen were recorded with each collection. Details of sampling protocols, gear specifications and specific collection information have been summarized in the reports for previous segments and the data report series cited above.

Sampling has been performed monthly using a random stratified sampling design in the mainstem bay and a fixed transect design in the tributaries. Exceptions include the winter months of January through March, when very few fish are present in the mainstem waters and only a single cruise in the bay has been conducted since 1991. Preliminary analysis on the five years of expanded data suggests no significant difference in samples of important species during this period (Geer, unpublished). Stratification in the mainstem bay is based on depth and latitudinal zones (Fig . 1). Trawling sites within strata are selected randomly from the National Ocean Service's Chesapeake Bay bathymetric grid, a data base containing depth records measured or calculated at 15 cartographic second intervals. Two to four trawling sites are randomly selected for each strata each month, the number chosen varying seasonally according to observed changes in distribution, with sampling intensity being highest in the most heavily utilized strata. The number of potential sites and approximate areas of each strata, which are subsequently used as weighting factors in the calculation of abundance indices, are given in Table 1. Latitudinal strata were slightly different, and overall coverage greater during the first year's (1988) sampling, but for the purpose of juvenile index calculation 1988 data was post-stratified into, and restricted to, those strata which have been continually sampled (1-12).

Sampling in the tributaries is performed at fixed sites located in the river channels and spaced at approximately 5 mile intervals from the river mouths up to approximately the fresh water interface in each system. These stations have been sampled on a monthly basis almost continuously since 1980 with the present sampling gear, and were previously used in monthly surveys using an unlined 30' trawl beginning in the mid-1950's (York R.) or early-1960's (James and Rappahannock) through 1972 (during 1973-79 semi-annual random stratified sampling was performed by the Ichthyology Department). This sampling effort has been supported by VIMS internal funds until budget cuts in mid 1980's. Since the data collected in the tributaries is highly relevant to juvenile abundance estimates it will be reported here as well. Areal weightings for the tributaries were assigned by dividing each river into two approximately equal length "strata" and assuming that the stations in each strata are representative of the channel areas in those reaches (Table 2). In general the channel areas were arbitrarily considered to be those areas greater than 12 ft. deep (Table 1). The exception was the lower Rappahannock, where the fixed stations were referred only to depths greater than 30' feet. The lower Rappahannock is generally deeper than the other two tributaries and is hydrographically quite dissimilar. A shallow sill at the river's mouth greatly reduces deep circulation, which results in severe anoxic conditions being typically encountered in the deeper portions of the lower reaches of this river during the warmer months. No sampling was performed in the tributaries in December 1987, or April of 1988.

It would perhaps be preferable that the mainstem and tributaries be monitored using the same sampling design, and the random stratified design offers numerous advantages over the fixed station design. Although a random stratified sampling scheme has been conceptually developed for the tributaries, before it can replace the fixed station surveys comparability of results must be established in order to assure continuity with the historical data set. To that end, during the first project segment a pilot random, stratified design survey in one of the Virginia tributaries (the York system, for logistical reasons) was initiated and is being conducted in a parallel manner with the fixed transect survey. Gear and sampling protocol are identical. The parallel survey was conducted throughout the second and third segments. The data collected during the first two years of parallel sampling (June 1991-May 1993) are presently being evaluated as to the need for further parallel sampling and as to whether the fixed-transect sampling can be phased out. Preliminary analysis indicates a good correlation between the deep water strata of the random stratified design with those stations of the fixed transect (Bonzek, per. comm.).

Gear Comparisons

Supplementary sampling and analysis were completed this segment in order to assure a minor gear modification associated with a change in sampling platform did not impact survey results. In August of 1990 a new, dedicated trawling vessel, the R/V *Fish Hawk* was placed in service and the former sampling platform, the R/V *Captain John Smith* was subsequently taken out of service. Side by side comparisons between vessels was performed during the August 1990 tributary survey resulting in 21 paired tows for analysis.

Because the *Fish Hawk* is a much more compact vessel with limited deck space, it was decided that for safety reasons the large wooden trawl doors (otter boards) used previously should be replaced with smaller but more hydrodynamically efficient metal china-v style doors. For continuity of the annual data base, this change was delayed until January of 1991. A series of comparison tows utilizing the different doors initiated during the first segment were concluded in the second segment, (April 1991 to June 1992). Comparisons were made by towing each gear twice at a given location, once upstream and then downstream, to negate any affects of tide and current. These four tows represented a set with a total of fifteen sets being completed during the two segments. Unfortunately, differences in gear configuration during the April 1991 comparisons, (unrelated to the doors), forced the removal of the first 12 samples for purposes of analysis. This in turn decreased the total number of samples to 48. An additional drawback is the lack of samples for two key species, striped bass and white perch. Most comparison work was performed in the lower York River for both logistic reasons and the fact catches are typically clean of debris and provide a good representation of many key species. Further work will be necessary in areas of striped bass and white perch abundance if these gear changes indicate significant statistical differences for other key species.

Juvenile Index Computations

Measuring the abundance of migratory species (as are many of the key target species in this project) presents special difficulties, particularly if the timing and duration of migratory behavior is not constant from year to year. Juvenile fishes which use estuarine nursery areas are especially vulnerable to the vagaries of climate, as many rely upon climatically dependent wind driven and tidal circulation patterns for semi-passive transport into the estuaries as larvae and early juveniles, and later key their outward migration from the nursery areas on such annually variable environmental cues as temperature changes. Ideally the abundance of a juvenile finfish population should be measured at that point when it is most fully recruited to the nursery area being monitored. However, in practicality this can only be accomplished if the time of maximal abundance and size of recruitment to the gear can be predicted (and surveys timed accordingly), or surveys can be conducted on such an intense periodicity over the season of potential maximal abundance as to be certain of reasonable temporal coincidence. Neither of these two approaches is possible in the present case. The period of recruitable maximal abundance and the scope of the area being surveyed has proved to be variable between years within species. Couple this with the multi-specific monitoring objectives, precludes temporally intense surveys in the face of finite resources. As further knowledge of the interannual variability of recruitment patterns of the target species in Chesapeake Bay is accumulated it may be possible to adjust survey timing in order to maximize the usefulness of the data collected. However, until a sufficient body of information is available upon which to base such decisions the survey will have to be conducted on a regular periodicity and juvenile indices constructed as best possible from this data.

In the previous and present reports the following approach was used for juvenile index calculation. Trawl catches of target species were first separated into young-of-year and older components by applying a cutoff value to the length frequency information collected with each catch. Cutoff values vary among months for each species and were based on modal analyses of historical composite monthly length frequency data and reviews of ageing studies for each species. For the earlier months of the biological year cutoff values are usually arbitrary values which fall in between completely discrete modal size ranges. In the later part of the biological year, when early spawned, rapidly growing individuals of the most recent year class may overtake late spawned and slowly growing individuals of the previous year class, cutoff values are selected so as to preserve the correct numeric proportionality between year classes despite the misclassification of individuals (Table 3). The extent of the zone of overlapping lengths and the proportion within that range attributable to each year class is estimated based on the shapes of each modal curve during the months prior to overlap occurring. A length value is then selected from within that range which will result in the appropriate proportional separation. Although this process involves considerable subjectivity and ignores possible interannual variability in average growth rates, there is little likelihood that any significant error will be introduced, as only a very small fraction of the total number of young-of-the-year individuals fall within the zone of overlap and most of the data used to construct juvenile indices is drawn from months when no overlap at all is present.

After partitioning out non-young-of-the-year individuals, monthly catch rates of the target species are map-plotted and strata-specific abundances and occurrence rates calculated. Numbers of individuals caught are logrithmetically transformed (ln(n+1)) prior to abundance calculations, as this transformation has repeatedly been shown to best normalize collection data for contagiously distributed organisms such as fishes (Taylor 1953) and has been verified as the best suited transformation for Chesapeake Bay trawl collections (Chittenden 1991). Resultant average catch rates (and the 95% confidence intervals as estimated by ± 2 standard errors) are then back-transformed to the geometric means. Plots and data matrices are then examined for the area-time combinations which appear to provide the best basis for juvenile index calculations. Criteria applied during the selection process include identification of maximal abundance levels, uniformity of distribution, minimization of overall variance and avoidance of periods which indicated distribution patterns suggesting migratory behavior was occurring. Although identification of areas most suitable for index calculations (primary nursery zones) is generally clear, selection of appropriate time windows has proven a more complex issue. Surveys are timed on regular period intervals which might or might not coincide with periods of maximal recruitment to the nursery areas. Using very limited portion of the overall data set would decrease sample sizes, increasing both confidence intervals, and the risk of sampling artifacts influencing results. As a result, the use of a single (maximal) month's survey results was deemed inappropriate. Conversely, a conscious effort is made not to incorporate any longer temporal series of data into index calculations than is necessary in order to capture the period of maximal juvenile utilization of the nursery area. It is believed indices calculated over longer time periods run the risk of confounding temporal persistence on the nursery area with maximal utilization levels. Using this approach it has been possible to identify three or four month periods which consistently capture the months of highest abundance for the species thus far examined (Table 3).

After area-time combinations are selected, annual juvenile indices are calculated as the weighted geometric mean catch per tow. Strata-specific means and variances are calculated and then combined, weighting by stratum areas according to the formulae supplied by Cochran (1977). Since stratum areas are quite variable, use of a weighted mean will provide an index that more closely mirrors actual population sizes than will a simple mean.

RESULTS

Gear and Vessel Comparisons

There appears to be minimal differences associated with the change in vessels. Mean catch rates and total number of fish for each species were statistically similar. Data were compared statistically using a paired t-test after $\ln(x + 1)$ transformation of individual catches. Differences between that of the R/V *Captain John Smith* and the R/V *Fish Hawk* were obtained and back transformed to the geometric mean difference. There were no significant differences for those species presented here, however, there were minor significance for several other species of related interest. (Table 4). Length data collected during these vessel comparisons were evaluated for homoscedasticity of variance using the t-test statistic. No significant differences were found for species with sufficient length samples. The comparison tows involving the different types of trawl doors indicate that this gear change had negligible effect on the fishing power of the net (Table 5). Mean catch rates were examined both with a geometric mean differences between paired tows, and a pooled aggregate by each gear type.

Minor significance $P < 0.1$, was found for two species (spot and croaker) using the paired statistic method, but all were statistically indistinguishable when data were pooled (Table 5). Size selectivity was suggested for only summer flounder when length information were separated into year classes (Y-O-Y and age 1+), $P < 0.05$. However, this was not the case when pooled length data for abundant species was examined.

Conclusions regarding differences, or the lack thereof, are much more difficult to draw than those establishing differences, but the general similarity of the mean catch rates observed coupled with the lack of any trend across a number of paired comparisons suggest that if any gear differences do exist they are small in magnitude compared to the very high variability of the field collections. Preparations are underway for a more detailed summary of all comparisons in a VIMS internal scientific report which will be available in the near future.

Juvenile Index Calculations

Spot (*Leiostomus xanthurus*) - This has typically been the most abundant, widely, and consistently distributed of the finfish recreational resource species taken. Young-of-the-year individuals usually first recruit into the survey area during April, so for the purposes of year class index calculation this month was taken as the beginning of the biological year. Slight modifications were made during the second project segment (1991-1992) to the length-based cutoff values used to separate the nominal young-of-the-year and older fractions of the total catches (Table 5). This resulted in slightly altered index values reported in the first segment report. A few errors in the data base have also been subsequently identified and corrected, also resulting in some changes in previously reported values.

In contrast to the first four years of sampling, early 1992 spot young-of-the-year abundances were extremely low until September, differing from previous years when abundance was high and distribution wide by June (Appendix Figs. 1 a-b). During 1992 sampling, average catch rates were highest during September, A bimodal peak in abundance evident in three of the five years, was absent in 1992 as well as 1990 (Fig. 2). The period of July through October captures both peaks during the three years when catch rates dipped during September as well as the unimodal peak seen in that month during 1990 and 1992, and has therefore been chosen to this point as the temporal window for index calculation. Since during this period spot were strongly distributed throughout the survey area for all five years, all strata have been included in the calculations.

The weighted geometric mean catch per tow for juvenile spot has declined considerably from a high of 68 for the 1988 year class to a low of 2 in 1992 (Table 6, Fig. 3), with the latter two years having discrete confidence intervals from the previous three years, as well as each other.

Atlantic Croaker (*Micropogonias undulatus*) - This species, like the spot, displays high levels of abundance in the trawl catches but presents much more complex patterns of recruitment and distribution. Spawning in this species takes place on a much more protracted basis than for the other species considered here and small early juveniles (<30mm) have been found to be present in the catches on a year around basis (Norcross 1983; Colvocoresses and Geer 1991; Colvocoresses et al. 1992). During the first three years of the expanded survey and throughout most of the earlier surveys, peak recruitment of early juveniles clearly took place during the fall months. For the purposes of separating size cohorts on an annual basis, September was chosen as the most appropriate month to designate as the first month of 'new' recruitment. The months of October through December were the three months of highest juvenile abundance during the first three years and the vast majority of juveniles captured were taken during this season. A completely anomalous pattern observed in 1991, (when highest abundance occurred during June), caused concern for the temporal selection for index calculations (Fig. 2). Length frequency data suggested these spring peaks were the result of returning individuals from the previous year class and not a new cohort of early juveniles. Recent ageing studies supports this theory, indicating these spring recruits are in the process of laying down an annulus and therefore are considered as age-1 individuals (Barbieri 1993). The 1992 data showed similar high values for June and July, with both months having larger values than the index month of October. However, an average length of 155.6 and 161.7mm respectively indicate these specimens to be part of the age-1 year class.

Fall recruitment of early 1992 year class individuals seemed as complex as that of the 1991 year class. Previous years (1988 - 1990), showed high utilization in the tributaries while 1991 and 1992 indicated a more even distribution between the tributaries and the mainstem bay with exception of November 1992 (Table - 7, Appendix Figs. 2 a & b).

Since a comparison of monthly average catch rates between the mainstem and tributary sites continues to show (with the exception of December of 1989) average catch rates 1-2 orders of magnitude higher in the tributaries (Table 7) during the fall months of peak juvenile abundance, the juvenile index for Atlantic croaker will continue to be based solely on the tributary data. Choice as to what temporal period to use for index calculation was considered straightforward, as maximal young-of-the-year abundances were observed during November for the first three years, with the next highest value occurring during the preceding or following month, and the third highest value being recorded during the remaining month of the October-December period. Obviously, 1991 with a peak abundance in June, and to a lesser extent, 1992 with a peak in December, throws these premises into question, but does not suggest any clear alternatives. Therefore, until further investigation reveals a clear understanding of the spatial and temporal utilization of age-0 individuals, the tributary strata and the months October through December will be maintained for index calculations.

The anomalous 1991 data notwithstanding, survey results clearly indicate a much stronger year class of croaker in lower Chesapeake Bay in 1989 than during the other four years sampled. The calculated index for 1989 (65, Table 6 and Fig. 3) was four to seven times that seen in other years, when results were similar and statistically indistinguishable.

Weakfish (*Cynoscion regalis*) - This species, while considerably less abundant than the other two sciaenid species discussed above, is still one of the dominant species of the trawl collections. Juveniles occasionally have first occurred in the catches as early as late June, which is taken as the beginning of the biological year, but most new recruitment to the nursery areas takes place in July, August and September. As during the previous four years, July young-of-the-year weakfish were found primarily in the tributaries. However, by August and for the ensuing summer and fall months they had dispersed into the mainstem bay as well (Appendix Figs. 3 a & b). The three months of highest juvenile abundances were observed during the same three month period during all five years, August-October (Fig. 2). Index calculations were therefore based on data from all strata collected during these months.

The weakfish juvenile abundance index for 1992 was significantly higher than that of the previous year class, ending a two year period of decline. The 1988 and 1989 values were similar (9 and 12, respectively, Table 6 and Fig. 3) and had broadly overlapping confidence intervals, as did the two lower 1990 (5) and 1991 (4) values. These 1992 results show marginal overlap with the former and considerable overlap for only the year 1990 of the latter, revealing three distinct groupings.

Summer Flounder (*Paralichthys dentatus*) - This species is generally taken in much lower numbers than the three sciaenid species above but is still a regularly occurring component of the trawl catches. Small juveniles can first appear in the catches as early as late March, which for the current purposes is used as the beginning of the biological year; but in 1992, as during most years were not taken in appreciable numbers until June (Appendix Figs. 4 a & b). As in the previous four years, young-of-the-year summer flounder abundance continued to increase steadily throughout the summer and early fall towards a late fall peak (November in this case) and then show clear evidence of emigration during December (Fig. 4). As was the case with weakfish, a single three month period, September to November, encompassed the three months of greatest abundance for all years sampled but 1992, when August had slightly higher values than October. However, until this anomaly can be explained further, the original three month period of September to November will continue to be used for index calculations. During this time period juvenile flounder are broadly distributed across the mainstem bay and are commonly taken in the lower rivers, but only rarely appear in catches in the upper tributaries. Index calculations therefore include all bay strata and the lower river strata.

The 1992 juvenile index for summer flounder reversed a four year trend of increasing values, declining significantly to near the survey's record low recorded in 1988 (1992: 0.91, 1988: 0.53). This 1992 value is significantly different from both the previous two years, but is indistinguishable from the first two years of the expanded survey (Table 6, Fig. 5). The index doubled during each of the first three years, rising from a weighted geometric mean catch of 0.5 per tow in 1988 to 2.5 per tow in 1990, with all three years having discrete confidence intervals.

Black Sea Bass (*Centropristis striata*) - Like summer flounder, black sea bass are seldom taken in large numbers but still regularly occur in the catches. Small juveniles first appear in low numbers in August, which is used as the initial month for year class separation. When present, young-of-the-year sea bass occur throughout the bay strata but do not appear to penetrate into most of the tributaries on a regular basis except the lower James River, a pattern which held in 1992 (Appendix Figs. 5 a & b). Index calculations have thus been based on all bay strata and the lower James stratum. Choice of the appropriate time period for index calculation is less obvious though, as young-of-the-year black sea bass appear to use Chesapeake Bay as a nursery area in a more complicated manner. Although some early juveniles appear in the bay during their first summer and fall and then emigrate out with the onset of winter, a much larger number of young-of-the-year enter the estuary during the following spring (Fig. 4). During some years, including 1992, there is virtually no recruitment to the Chesapeake Bay by early juveniles spawned the same calendar year. Since abundances are higher and distribution much more consistent during the late spring and early summer, juvenile index calculations have been based on the months of May through July. This period encompasses the three months of highest abundance for all years except 1992. Mild winter temperatures resulting in warmer spring waters allowed April abundances to be slightly higher than May. The 1992 data is similar to 1991, when maximal abundance was seen in June rather than July as seen in the previous three years.. However, the general window of maximal utilization was clearly the same. Since this index is calculated from the middle portion of the calendar year but the very end of the biological year, the resultant index is for the year class spawned the previous calendar year, i.e. the 1988 index is for the 1987 year class. It is conceivable that an earlier, fall based "preindex" could also be generated, but because of the very low abundances and erratic distribution seen in the fall no confidence can be placed in such an index until a relationship can demonstrated with the much more statistically robust summer index. Fall abundances were much lower in 1988 than 1989 with an intermediate value in 1990. The same pattern was seen for these year classes the following spring and summer, but several more years of data will be required to determine if a consistent relationship exists.

Thus far the annual juvenile indices for black sea bass have shown no evidence of any pattern (Fig. 5), ranging from 0.8 (1988 year class) to 2.4 (1989 year class). This minimum value in addition to that of 1990, are the only values without overlapping confidence intervals with the 1989 year class (Table 6). The intermediate years of 1987 (1.6), 1990 (1.1), and 1991 (1.3) are statistically indistinguishable from any of the other years sampled.

Scup (*Stenotomus chrysops*) - Like the black sea bass, the scup is a primarily marine and summer spawning species and appears to use the Chesapeake Bay in much the same way as black sea bass; i.e. there is minimal usage of the estuary as a nursery area by early juveniles but a very significant use by older juveniles during their second summer. Early juvenile scup (25-40mm FL) occasionally appear in the catches in June, but rapidly disappear after that if they do indeed appear at all (almost all of the early juveniles taken thus far were captured in a single year, 1989). Older scup first appear in the catches in May, and by June there are clearly three distinct size classes present which can easily be assigned as the age-0, age-1 and age-2+ year classes based on previous ageing studies (Morse 1978). Since the age-0 component is annually variable and not persistent, and the largest size class is only taken in very small numbers, index calculations are performed on age-1 individuals. This component clearly remains present in the bay and available to the gear for the remainder of the summer and early fall. Thus, while the data collected are obviously not amenable to the construction of a true young-of-the-year juvenile index, it is suitable for assessing juvenile scup abundance just as they enter their second year.

Distributional data for 1992 (Appendix Figs. 6 a-b) supports previous findings that the early age-1 nursery area is largely restricted to the two lower mainstem segments. Catch rates for age-1 scup in this area peaked in July during three of the five years thus sampled (1989-1991) and essentially showed a July-August dome during the other two years (1988 and 1992)(Fig. 4). With the exception 1988, when age-1 scup were not taken until July, there were also sizable numbers of late juveniles taken during the months of June and September. These months were therefore chosen as the temporal basis for index calculation.

No trend is evident in the scup age-1 index to this point. The high value (4.9) recorded for the 1989 year class is marginally different from the 1990 year class index (1.9) with only slightly overlapping confidence intervals for the 1987 year class (Table 6, Fig. 5). The present year class of 1991 is considerably different from high index years, (1988 and 1989), and marginal different for the remaining two (1987 and 1990). However the values for the three years other than 1989 and 1991 are essentially indistinguishable.

White Perch (*Morone americana*) - The semi-anadromous white perch is taken in large numbers in different spatial and temporal frames than those species previously mentioned. Spawning occurs in the upper tributaries from March to July with a peak occurring from late April to early May. Low numbers of early juveniles first appear in the size range $\leq$ 35 mm in May, the initial month for year class separation (Figure 6). Interestingly, several year classes are captured in high enough abundance for evaluation, (Figure 7). The historical length frequency data suggests there might be three distinct size classes available to the gear (Figure 9). However, since white perch populations from various tributaries can exhibit significantly different growth rates (Bowen, 1987; Setzler-Hamilton, 1991), and those separations are not clear at this point, for purposes of this analysis all specimens were categorized as either age-0 or age-1+. Examination of distributional data (Appendix Figures 7 a-j, 8 a-j), reveals neither year class of white perch are found in the main-stem bay, with the highest abundances found in upper portions of each tributary. As a result, index calculations are confined to the upper stratum of each tributary. Determining the temporal stratification was confounded by several factors. Basing an index on the beginning or middle of the biological year will exclude upstream river stations added exclusively to look at such anadromous species. Using the final period of the biological year would result in calculations over two calendar years. In addition, the month of peak abundance for age-1+ individuals ranged from December to February, with complimenting months of abundance from November to March (Figure 9). A bimodal peak in 1988 for y-o-y individuals from November through March clouded what appeared to be clearly a December to February peak of abundance for all other years. Analysis of variance on total monthly catch rates indicates no significant difference for the periods November to February for age-1+, and December to February for age-0 individuals. However, the periodic abundance shown in March for age-1+ individuals, and November and March for age-0 specimens, indicates the nature of these indices as provisional and subject to change if these months prove pragmatic. With the exception of December 1989, January has consistently had the highest geometric mean for age 0 fish during this period. Since the index is calculated from the end of the biological year and across calendar years, values are for the previous year class, i.e. the 1989 and 1990 data form the 1989 index. A note of concern involves the 1988 sampling season. The tributaries were sparsely sampled from December 1987 to April 1988, with samples only being collected in January, February, and part of March.

To date, the annual juvenile indices for white perch have shown no evidence of any trend (Fig. 10, Table 6), ranging from 42.1 for the 1987 year class to 1.21 (1992 year class). The resulting confidence intervals are significantly different for the year 1989 with 1990 through 1992, and 1987 is significantly different from all years.

The age-1+ indices have complimented that of the Y-O-Y indices. A peak in the 1987 and 1989 age-0 fish were slightly evident in the 1988 and 1990 age-1+ populations. The 1990 peak has been followed by two years of decline, resulting in 1992 having the lowest value of the five years studied, (15.8) (Figure 10, Table 6). Although abundance seems on the decline, values of age-1+ fish are nearly ten times higher than the juvenile counterparts. This is possibly due to the fact sampling is being performed over as many as six year classes.

Striped Bass -(*Morone saxatilis*) - Like the white perch, the striped bass is an anadromous species utilizing the upper tributaries for spawning and nursery grounds. Spawning in the Chesapeake Bay region takes place from early to mid-April through the end of May, primarily in tidal freshwater areas just above the salt wedge. Young-of-the-year striped bass first appear in the samples in May in the size class less than 50 mm, (start of biological year, Figure 11), although index calculations are developed on older individuals (November). There appears to be a minor peak that occurs immediately following spawning from June to July consisting mainly of individuals less than 75mm (Figure 12). This season of abundance is quickly followed by a period of minimal catches which continues through November (Figure 9). This peak and following trough can possibly be due to the migration of the fish beyond the sampling area. After spawning and during larval development, striped bass are subject to transport by water circulation in the tributaries. This could transport the fish within the sampling area and subject to the gear. As the water warms and growth increases, the fish migrate to shallower waters and further up the estuary, both beyond the sampling region (Colvocoresses and Austin, 1987).

A second, stronger, and more consistent period of abundance occurs in December and continues through to February the following year. This period is better fitted for abundance estimates because sampling is routine performed further upriver during these months. For this reason, December to February have been chosen as provisional temporal period for y-o-y calculations. As in white perch, only the upper river strata were used in calculations, (Appendix Figures - 9 a-j).

The young of year index of striped bass had shown a consistently downward trend from its historical high of 3.6 in 1987 to 1991, (1.0) increasing to 2.2 in 1992 (Figure 10). However, with the exception of the very large 1987 year class, there appears to be no significant difference in the weighted geometric means from the lowest value in 1991, (1.02), to the highest in 1992. These overlapping confidence intervals seem larger than some of the other species examined, possibly due to the limited number of annual samples involved in calculations. The 1987 year class would seem an anomaly in the data. However, other measures of striped bass year class strength indicate and support 1987 to be one of the strongest on record, (Colvocoresses et al. 1993; Austin 1993). As with white perch the sampling associated with this year class excluded December results due to limited sampling during that period.

DISCUSSION

Although the Virginia Institute of Marine Science has been conducting a trawl survey dating back to 1955, changes in both gear and sampling protocol limit the "usuable" data at this time to the years since 1979. A major portion of the collections performed from 1973-1978 involved semi-annual random stratified surveys. Although sampling was quite intense, it was generally concentrated within a short period, drastically effecting the ability to detect changes in temporal abundance. In addition, a smaller size net was used for much of this period, making comparisons with the 30' nets difficult. This introduces serious doubts concerning its usefulness in the present method of estimating abundance. However, recently discovered data from the VIMS Crustaceology Department revealed fish catches were routinely recorded during its monthly fixed station survey during this same period. Unfortunately only total numbers of each species were recorded. The possibility of generating length frequencies based on known proportions from previous years (1955-1972) and similar gear type appears promising (Bonzek, personal comm.). With reliable length frequency proportions, y-o-y cutoffs can be applied and juvenile indices generated. This would provide a contiguous 39 year data base for the fixed station transects of the major Virginia tributaries, with the only difference related to sampling gear. During the initial segment objectives were established to investigate these different gears and how they relate to the present gears and sampling protocol. However, a vessel replacement and subsequent door change force the postponement of historical gear comparisons in favor of those of a more immediate concern.

The results presented here indicate little if any difference between vessels relative to abundance, with any minor differences in size probably a result of high variability associated with such sampling. Although the sample size was small, (N = 21), the lack of any clear pattern provides confidence that the vessel change had little impact on survey results. The 48 samples taken for door comparisons seem to have found little difference in the means or variance of the two gear types. The lack of striped bass and white perch samples for these comparisons (due to spatial and seasonal preclusion), might be of concern, but the generally high probability of accepting the null hypothesis (variances are equal), for those species captured in high abundance provide assurance against any significant difference. Presently, comparisons are being performed with a similar sized gear without a cod-end liner nor a tickler chain. At present there have been nearly 80 samples collected. However, the importance of these early dataset to the compatibility of the present database requires considerably more sampling and analysis before results can be considered acceptable.

It appears the analysis of length data from such comparisons will prove problemsome, since the large N values associated with these data will invariably find significant differences. Logically, comparisons between vessels or trawl doors that reveal little difference in catch rates, should not find statistical differences in size of individuals, except possibly near the extremes.

A unique situation became available to the Institute in recent months with the visits of several prominent fisheries scientists. Drs. Louis Rugolo (Maryland Department of Natural Resources), Ronald Thresher (CSIRO, Australia Division of Fisheries), Michael Pennington (NMFS, Northeast Fisheries Center), and Barry Smith (Canadian Department of Fisheries and Oceans), were all presented with this problem independently. The consensus was to randomly select a small sample size for each species' length data (N=50), for each class of analysis, then perform the necessary analysis on that subset and repeat the process numerous times. This process of analysis is presently being evaluated and will be available in the near future. This concern needs to be addressed prior to analysis of the lined for unlined sampling gears since differences in size of individuals is expected for this type of comparison.

The annual juvenile abundance indices presented here should still be regarded as strictly provisional. Five years of expanded data have undoubtedly not captured all of the interannual variability in nursery area utilization, as is clearly suggested by the fact that the 1991 and 1992 croaker data showed a distinctly different pattern from that observed during the first three years of sampling. A larger data set may well suggest different area-time combinations for juvenile index calculations than those used here. Likewise, it will take a considerably longer period of data collection in order to place the present results in a proper population trend context. It may be advantageous to develop a variable time/abundance window for certain species to capture fluctuations in period of abundance and spatial distributions. The historical VIMS tributary data does provide some basis for comparison, but comparison of this data to that reported here clearly shows that the degree to which this information will augment current survey results can be expected to significantly vary between species. Tributary-only based juvenile and age-1+ indices for the first five species as well as white perch and striped bass are plotted along with the indices developed for the expanded sampling program in Figures 13 and 14. The tributary-only data begins with the 1979 sampling year; prior to that time there were either differences in sampling design (1973-78) or significant differences in sampling gear and protocol (1955-72) which have yet to be resolved. Agreement of the two time series for croaker, striped bass, and white perch are of course essentially perfect since the same data set was used for both, but the agreement of the other four species ranges greatly.

In terms of general trends the tributary and complete data sets for spot produced similar results for the five years sampled, but it is evident that there is considerable interannual variability in the relative utilization of mainstem and tributary waters as nursery areas. During 1988, 1991, and 1992 the tributary and combined indices were essentially identical, indicating a very uniform distribution of juveniles. But during 1989 abundances were clearly higher in the tributaries with 1988 having opposite results. Within this possible limitation, comparison of recent results to the longer time series suggests that the downward trend in spot juvenile recruitment in Chesapeake Bay over the past five years has spanned a range of values comparable to that seen over the past 13 years; i.e. 1988 was probably a year of very successful recruitment by these standards, but 1992 recruitment was at historic lows. This decline in recruitment is possibly caused by variations in wind direction and timing during spawning and larval transport (Austin and Bodolus, per. comm.).

The initial 1989 year class of croaker was obviously much stronger than those immediately preceding or following it (at least on the Chesapeake Bay nursery grounds), and it also appears to be a strong year class on a historical basis based on the tributary results (Figure 13). However, the 1992 data again suggests (as did some of the 1989 results), that even though utilization rates of the tributary waters as nursery areas often seems much higher than that for the mainstem, significant use of the mainstem may occur during some periods. Considering it's much greater area, a large enough portion of the juvenile croaker population may reside in the mainstem to warrant consideration in index calculations. The thus far unique use of the bay as a nursery area for late age-0's also raises interesting questions as to alternative ways of calculating a juvenile index for croaker. Since abundances of 1990 year class individuals were higher during the summer of 1991 than during early recruitment in the fall of 1990, it is evident that the summer immigrants must have included (or even been entirely composed of) juveniles which had initially recruited to different nursery areas. The fact juveniles which recruit to one estuary as early juveniles and then out-migrate over winter may return to a different estuary the next spring is supported by the fact the large 1989 year class showed little evidence of return during 1990 sampling.

The lack of agreement between the tributary and combined indices for weakfish (Figure 13) clearly illustrates the need for the expanded sampling program. Juvenile weakfish juvenile densities are consistently several times higher in the tributaries than in the mainstem, but the degree of relative utilization can vary dramatically between years. Tributary catch rates peaked in 1990 when overall catch rates dropped, as there was a much lower utilization of the mainstem than during the prior two years. Since the combined index should be much more representative of actual population levels, there is little reason to believe that the tributary only series provides a meaningful measure of overall reproductive success in Chesapeake Bay. Further investigation is necessary, possibly with North Carolina trawl data of Pamlico Sound, to validate these findings.

Even though the present flounder and sea bass indices are primarily based on the mainstem data (where abundances are clearly higher), and there is little reason to believe that the tributary abundances will necessarily reflect overall abundances, for the five years sampled there is reasonably good coherence (Figure 13), particularly for summer flounder. These two species may occupy lower riverine nursery areas in a much more proportional manner to their overall abundance than do weakfish. If this proves to hold true the tributary data can provide a historical context for the upward trend in summer flounder seen from 1988 to 1991, and the observed rise covers only a range from a record low to still sub-average levels of recruitment. Black sea bass recruitment to the Chesapeake nursery areas would appear to have been near a historical high as well for the 1989 year class and about average the other four years. The tributary based values of 1992 are a historical high, with the combined index simply near the median for the five years studied. This provides strength for the inclusion of the tributaries in an overall index, refuting previous results that questioned the usefulness of the rivers based on 1987 findings.

The juvenile and age 1+ indices of white perch have been on the decline in recent years (Figure 14). Although the age 1+ specimens have remained at relatively high values in relation to the Y-O-Y counterparts, this can probably be due to the fact sampling is over several year classes. Piavis (1993) suggests a strong year-class is necessary only every several years (10 to 14) to support the Maryland fishery. Correlation data between Age-0 and one year lagged age-1+ specimens reveals a poor r-value of 0.33, ($P < 0.3896$, df=9,14), providing evidence that the age 1+ index does indeed include more than one year class. It also supports Piavis' findings since age 1+ values remain relatively high and stable while young-of-the-year abundance has been variable and on the recent decline. Environmental factors effecting growth can vary from river to river resulting in different size distributions with age for each system. Future efforts might attempt to examine the length at age relationship for each system to determine if index calculation methods need to be modified. The absence of Y-O-Y indices for the years 1979 to 1983 can be explained by the fact that sampling during that period was routinely performed from May through November, and only up to mile 35 on each river. Presently the survey samples at the fringe of the juveniles habitat, with presumably higher concentrations located above mile 40 of the tributaries. Increasing winter sampling further upriver would vastly enhance the precision and accuracy of the estimates. Supporting these findings for the y-o-y data are the results from the summer seine survey, ($r=0.94$, $P < 0.0001$). Preliminary results from the 1993 beach seine sampling season indicate a y-o-y geometric mean per haul of 13.12 (Seaver, personal communication). The resulting regression formula would suggest a trawl index of 37.42 for the 1993 year class, second only to that of 1987.

The 1992 striped bass Y-O-Y index increased dramatically over recent years, but has still not matched that of 1987. Unfortunately, since sampling was routinely performed only during the months of May to November, there are no supporting data for the 1979 to 1982 year classes. Also of concern is the lack of data from December 1987 (Figure 14). This month would have been part of the largest year class on record. Without it there might always be questions to its validity. The VIMS beach seine survey supports 1987 as a very successful year class (Colvocoresses et al, 1993; Austin 1993). Correlation between the beach seine and trawl surveys is fairly good for the years 1983 to 1992 ($r = 0.871$ $P < 0.001$ $df = 10,9$). Preliminary results from the 1993 beach seine survey would expect the 1993 trawl survey index to be the largest ever recorded. But further investigation is necessary to develop a sound relationship. As mentioned previously, large confidence intervals can possibly be attributed to the small number of trawls upon which the index is based, averaging 34 the past six years. The possibility of extending the survey an additional five to ten miles upstream during the winter months when these anadromous species are abundant exists, and would probably aid in developing a more precise and accurate measure of abundance. In addition, replicate trawls could be performed at index stations to better provide information for a particular area of the tributary. Like many other species routinely found in the upper tributary, several year classes of striped bass are caught in large enough quantities for index consideration (Figure 15). Future efforts will be directed at producing indices for other year classes similar to that of age 1+ white perch.

The extreme rarity of scup in the tributary collections precludes a similar exercise for that species.

The juvenile indices presented here must be kept in a geographic context. This is evidenced by their absence during the winter months, as the first six species discussed here are highly migratory and only use the Bay nursery grounds during the summer months. Chesapeake Bay does constitutes a major nursery area for all of them (with the possible exception of black sea bass and scup) but is certainly only one of several along the Atlantic seaboard for these stocks. With the exception of weakfish and the anadromous species, all of the juveniles recruited to the Chesapeake Bay nursery areas are the result of spawning activities which take place outside of the Bay. Early juveniles of the three sciaenid species are thought to be estuarine dependent, but black sea bass young of year also utilize nearshore continental shelf waters (Musick and Mercer 1977) and juvenile summer flounder also frequent shallow, high salinity coastal lagoons (Wyanski 1989). Scup do not appear in the bay in appreciable numbers until they are a year old. Conceivably, Chesapeake Bay nursery zone abundances may well be reflective of overall reproductive success, but this will only be able to be verified through comparisons with recruitment in other nursery areas. Assessment of annual recruitment success for coastal Atlantic finfish populations as a whole will require multi-state monitoring efforts, as may complete validation of area-specific juvenile indices.

A random stratified sampling approach, if coupled with knowledge of gear efficiencies and physical sampling frames, can be used to provide absolute population estimates as well as relative indices of abundance. In the present study this is not yet possible even using efficiency and sample area approximations, since the tributary sampling frame does not meet the assumptions of this design. Hopefully the pilot random survey being conducted in the York system will provide the basis for replacing the fixed tributary sampling with a random sampling design, but additional resources may have to be identified in order to establish the random stratified design in all three tributaries.

LITERATURE CITED

Austin, H.M., 1993. Evidence for a strong 1987 year class of striped bass in Virginia. Virginia Marine Resource Commission Report 93-07. 22 p.

Barbieri, L.R. 1993. Life history, population dynamics and yield-per-recruit modeling of the Atlantic croaker, *Micropogonias undulatus*, in the Chesapeake Bay area. Phd Dissertation. College of William and mary. Williamsburg, VA. 139p.

Bonzek, C. F., P. J. Geer, J. A. Colvocoresses and R. E. Harris, Jr. 1991. Juvenile finfish and blue crab stock assessment program bottom trawl survey annual data summary report series. Volume 1990. Va. Inst. Mar. Sci. Spec. Sci. Rpt. No. 124. Virginia Institute of Marine Science, Gloucester Pt. VA 23062. 206 p.

Bonzek, C. F., P. J. Geer, J. A. Colvocoresses and R. E. Harris, Jr. 1992. Juvenile finfish and blue crab stock assessment program bottom trawl survey annual data summary report series. Volume 1991. Va. Inst. Mar. Sci. Spec. Sci. Rpt. No. 124. Virginia Institute of Marine Science, Gloucester Pt. VA 23062. 213 p.

Bonzek, C. F., P. J. Geer, J. A. Colvocoresses and R. E. Harris, Jr. 1993. Juvenile finfish and blue crab stock assessment program bottom trawl survey annual data summary report series. Volume 1992. Va. Inst. Mar. Sci. Spec. Sci. Rpt. No. 124. Virginia Institute of Marine Science, Gloucester Pt. VA 23062. 206 p.

Bowen, B.W. 1987. Population structure of the white perch, *Morone americanus*, in the lower Chesapeake Bay as inferred from mitochondrial DNA restriction analysis. Master's Thesis. College of William and Mary, Williamsburg, VA. 33 p.

Chesapeake Executive Council. 1988. Chesapeake Bay Program Stock Assessment Plan. Agreement Commitment Report. Annapolis, MD. 66 p.

Colvocoresses, J.A. and H.M. Austin, 1987. Development of an index of juvenile striped bass abundance for the Chesapeake Bay System. I. An evaluation of present measures and recommendations for future studies. Va. Inst. Mar. Sci. Spec. Sci. Rep. No. 120. Virginia Institute of Marine Science, Gloucester Pt., VA, 23062. 108 p.

Colvocoresses, J. A. and P. J. Geer. 1991. Estimation of relative juvenile abundance of recreationally important finfish in the Virginia portion of Chesapeake Bay. Annual report to VMRC/USFWS. Virginia Institute of Marine Science, Gloucester Pt. VA 23062. 64 p.

Colvocoresses, J. A., P. J. Geer and C.F. Bonzek. 1992. Estimation of relative juvenile abundance of recreationally important finfish in the Virginia portion of Chesapeake Bay. Annual report to VMRC/USFWS. Virginia Institute of Marine Science, Gloucester Pt. VA 23062. 53 p.

Colvocoresses, J.A., A.D. Estes and D.M. Seaver. 1993. Estimation of juvenile striped bass relative abundance in the Virginia Portion of Chesapeake Bay. Annual report to VMRC/USFWS. Virginia Institute of Marine Science, Gloucester Pt. VA, 23062. 24 p.

Chittenden, M. E., Jr. 1989. Initiation of trawl surveys for a cooperative research/assessment program in the Chesapeake Bay. Final report to Chesapeake Bay Stock Assessment Committee & NOAA/NMFS. Virginia Institute of Marine Science, Gloucester Point, VA. 123 p.

Chittenden, M. E., Jr. 1991. Evaluation of spatial/temporal sources of variation in nekton catch and the efficacy of stratified sampling in the Chesapeake Bay. Final report to Chesapeake Bay Stock Assessment Committee & NOAA/NMFS. Virginia Institute of Marine Science, Gloucester Point, VA. 254 p.

Cochran, W. G. 1977. Sampling techniques. John Wiley & Sons. New York, NY. 428 p.

Geer, P. J., C. F.Bonzek, J. A. Colvocoresses and R. E. Harris, Jr. 1990. Juvenile finfish and blue crab stock assessment program bottom trawl survey annual data summary report series. Volume 1989. Va. Inst. Mar. Sci. Spec. Sci. Rpt. No. 124. Virginia Institute of Marine Science, Gloucester Pt. VA 23062. 211 p.

Goodyear, C. P. 1985. Relationship between reported commercial landings and abundance of young striped bass in Chesapeake Bay, Maryland. Trans. Amer. Fish. Soc. 114(1): 92-96.

Lipcius, R. N. and W. A. Van Engel. Blue crab population dynamics in Chesapeake Bay: variation in abundance (York River, 1972-1988) and stock-recruit functions. Bull. Mar. Sci. 46(1): 180-194.

Morse, W. W. 1978. Biological and fisheries data on scup, *Stenotomus chrysops* (Linnaeus). National Marine Fisheries Service, Sandy Hook Laboratory, Tech. Series Rept. No. 12. 41p.

Musick, J. A. and L. P. Mercer. 1977. Seasonal distribution of black sea bass, Centropristis striata, in the Mid-Atlantic Bight with comments on the ecology and fisheries of the species. Trans. Amer. Fish. Soc. 106(1): 12-25.

Piavis, P. 1993. Review of white perch status in Maryland. Tidal fisheries technical report series No. 7. 21pp.

Norcross, B.L. 1983. Climate scale environmental factors affecting year-class fluctuations of Atlantic croaker, *Micropogonias undulatus* in the Chesapeake Bay, VA. Ph.D Dissertation. College of William and Mary, Williamsburg, VA, 388 p.

Setzler-Hamilton, E.M. 1991. Chapter 12; White perch. in Habitat requirements for Chesapeake Bay living resources, ed., S.L. Funderburk, J.A. Mihursky, S.J. Jordan, and D. Reiley. Prepared for Living Resources Subcommittee Chesapeake Bay Program.

Taylor, C. C. 1953. Nature of variability in trawl catches. Fish. Bull. 54: 142-166.

Virginia Marine Resources Commission. 1985. Marine recreational fisheries in Virginia. Newport News, VA.

Wyanski, D. M. 1989. Depth and substrate characteristics of age-0 summer flounder, (Paralichthys dentatus) in Virginia estuaries. Master's Thesis. College of William & Mary. Williamsburg, VA. 54 p.

Table 1. Numbers of potential trawl sites and approximate areas of sampling strata.

Area	Stratum	Name	No. of Points	Sq. Naut. Miles
Bottom Bay	ST01	Bottom WS, 12-30'	1740	112.33
	ST02	Bottom ES, 12-30'	863	55.72
	ST03	Bo. Plain, 30-42'	910	58.75
	ST04	Bottom Deep, >42'	386	24.92
			3899	251.72
Lower Bay	ST05	Lower WS, 12-30'	1027	66.30
	ST06	Lower ES, 12-30'	398	25.69
	ST07	Lo. Plain, 30-42'	1756	113.37
	ST08	Lower Deep, >42'	684	44.16
			3865	249.52
Upper Bay	ST09	Upper WS, 12-30'	768	49.58
	ST10	Upper ES, 12-30'	632	40.80
	ST11	Up. Plain, 30-42'	2197	141.84
	ST12	Upper Deep, >42'	844	54.49
			4441	286.71
James River	JA01	Lower James, >12'	687	44.35
	JA02	Upper James, >12'	364	23.50
			1051	67.85
York River	YK01	Lower York, >12'	372	24.02
	YK02	Upper York, >12'	184	11.88
			556	35.90
Rappahannock River	RA01	Lower Rapp., >30'	283	18.27
	RA02	Upper Rapp., >12'	190	12.26
			473	30.53

Table 2. Assignment of fixed tributary stations to potential random strata.

River	Lower	Upper
James	J01, J05, J13, J17	J24, J27, J35, J40
York	Y02, Y05, Y10, Y15	Y20, Y25, Y30, Y35, Y40
Rappahannock	R02, R10, R15, R20	R25, R30, R35, R40

Table 3. Spatial, temporal and length criteria used to calculate juvenile indices.

Species	Strata Included	Months Included
Spot	Bay 1-12, J1-2, Y1-2, R1-2	July-October
Atlantic Croaker	J1-2, Y1-2, R1-2	October-December
Weakfish	Bay 1-12, J1-2, Y1-2, R1-2	August-October
Summer Flounder	Bay 1-12, J1, Y1, R1	September-November
Black Sea Bass	Bay 1-12, J1	May-July
Scup	Bay 1-8	June-September
White Perch Age 1+	J2, Y2, R2	November-February (Year + 1)
White Perch Age 0	J2, Y2, R2	December-February (Year + 1)
Striped Bass	J2, Y2, R2	December-February (Year + 1)

Species	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Spot	≤200	≤200	≤200	≤75	≤100	≤135	≤160	≤180	≤200	≤200	≤200	≤200
Atlantic Croaker	≤100	≤100	≤100	≤110	≤135	≤160	≤180	≤220	≤50	≤80	≤100	≤100
Weakfish	≤200	≤200	≤200	≤225	≤240	≤90	≤120	≤150	≤180	≤200	≤200	≤200
Summer Flounder	≤290	≤290	≤60	≤100	≤140	≤170	≤200	≤225	≤250	≤275	≤290	≤290
Black Sea Bass	≤110	≤110	≤110	≤110	≤110	≤150	≤175	≤70	≤85	≤100	≤105	≤110
Scup	90-170	90-170	90-170	90-170	35-90	40-100	50-125	60-145	75-160	85-170	90-170	90-170
White Perch Age 1+	>85	>85	>85	>95	>35	>65	>73	>80	>85	>85	>85	>85
White Perch Age 0	≤85	≤85	≤85	≤95	≤35	≤65	≤73	≤80	≤85	≤85	≤85	≤85
Striped Bass	≤200	≤200	≤200	≤200	≤50	≤80	≤100	≤120	≤135	≤150	≤175	≤190

Table 4. Paired t-test statistics of geometric mean catch difference between the Research Vessels *Captain John Smith* and *Fish Hawk*, August 1990.

	Geometric Mean Difference	Standard Error	N	t	Prt
Spot	0.1614	0.237	17	0.63	0.5349
Atlantic Croaker	0.3950	0.204	6	1.64	0.1176
Weakfish	0.2570	0.066	16	0.49	0.6305
Summer Flounder	0.0836	0.083	4	0.97	0.3439
Black Sea Bass	0.0195	0.010	2	0.19	0.8482
Scup	0.1307	0.094	2	1.30	0.2068
White Perch All	0.0118	0.066	4	0.18	0.8611
Striped Bass	0.0682	0.046	1	1.45	0.1623
White Catfish	0.0852	0.100	4	0.89	0.3855
Channel Catfish	0.0027	0.068	3	0.04	0.9683
Bay Anchovy	1.9817	0.347	10	3.15	0.0051
Silver Perch	0.6193	0.245	5	1.96	0.0635

N represents the number of occurrences in 21 paired tows.

Table 5. T-test statistics for door comparisons based on data pooled as aggregates, April 1991 to June 1992.

Species	F'	DF	Prob.
Spot	1.15	23,23	0.7404
Atlantic Croaker	1.15	23,23	0.7482
Weakfish	1.25	23,23	0.6003
Summer Flounder	1.14	23,23	0.7631
Black Sea Bass	1.60	23,23	0.2671
Scup	*	23,23	*
White Perch - All	**	**	**
Striped Bass	**	**	**

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* All Specimens captured were from the same class (gear type).

** No specimens collected.

Table 6. Juvenile abundance indices for key recreational species.

Species	Year Class	Weighted Geo. Mean CPUE	95% C. I.	N
Spot	1988	67.5	47.0 - 96.7	231
	1989	32.3	25.4 - 41.0	252
	1990	44.6	32.4 - 61.2	248
	1991	16.6	12.6 - 21.7	238
	1992	1.95	1.48 - 2.51	239
Atlantic Croaker	1988	9.0	6.0 - 13.4	65
	1989	64.8	37.9 -110.2	65
	1990	13.1	8.9 - 19.2	60
	1991	9.6	5.9 - 15.3	63
	1992	14.0	7.96 - 24.1	68
Weakfish	1988	8.9	5.9 - 13.1	173
	1989	12.2	8.6 - 17.2	189
	1990	4.8	3.3 - 6.6	184
	1991	3.6	2.6 - 4.7	179
	1992	6.87	4.86 - 9.58	179
Summer Flounder	1988	0.53	0.35 - 0.74	143
	1989	1.22	0.93 - 1.56	162
	1990	2.54	2.07 - 3.09	162
	1991	2.78	2.26 - 3.38	153
	1992	0.91	0.70 - 1.15	154

cont.

Table 6. (cont.).

Species	Year Class	Weighted Geo. Mean CPUE	95% C. I.	N
Black Sea Bass	1987	1.57	1.07 - 2.19	124
	1988	0.83	0.58 - 1.12	138
	1989	2.36	1.70 - 3.17	138
	1990	1.12	0.78 - 1.52	128
	1991	1.29	0.91 - 1.74	129
Scup	1987	2.07	1.24 - 3.21	92
	1988	3.06	2.05 - 4.41	112
	1989	4.86	3.07 - 7.42	112
	1990	1.90	1.11 - 2.99	103
	1991	0.65	0.41 - 0.93	104
White Perch Age 1+	1987	21.9	12.6 - 37.5	36
	1988	35.1	21.6 - 56.7	46
	1989	25.9	15.4 - 43.0	46
	1990	32.0	20.1 - 50.4	45
	1991	29.5	20.4 - 42.5	44
	1992	15.8	9.55 - 25.7	48

cont.

Table 6. (cont.).

Species	Year Class	Weighted Geo. Mean CPUE	95% C. I.	N
White Perch Age 0	1987	42.1	25.1 - 70.4	20
	1988	5.26	2.31 - 10.9	35
	1989	13.3	7.23 - 14.9	37
	1990	3.31	1.56 - 6.26	36
	1991	2.30	0.93 - 4.67	36
	1992	1.21	0.48 - 2.31	39
Striped Bass	1987	3.62	1.88 - 6.44	20
	1988	1.93	0.96 - 3.36	35
	1989	1.59	0.81 - 2.70	37
	1990	1.14	0.50 - 2.06	36
	1991	1.02	0.52 - 1.68	36
	1992	2.15	1.30 - 3.32	39

Table 7. Mean geometric catch per tow for Atlantic Croaker in the tributaries and mainstem Bay during months of peak abundance.

Year	Month	Tributaries	Bay	Ratio
1988	Oct.	10.86	0.22	48.50
	Nov.	21.32	0.41	51.61
	Dec.	13.14	1.02	12.92
1989	Oct.	117.75	6.26	18.82
	Nov.	169.82	3.65	46.59
	Dec.	27.89	31.62	0.88
1990	Oct.	11.49	0.08	143.65
	Nov.	32.00	0.23	138.55
	Dec.	30.03	2.41	12.45
1991	June	35.19	1.02	34.37
	July	19.17	5.74	3.34
	Aug.	8.61	18.58	0.46
	Oct.	6.52	0.12	56.16
	Nov.	14.36	1.64	8.76
	Dec.	18.08	3.34	5.41
1992	Jun.	8.11	0.17	46.90
	Jul.	20.34	0.80	25.46
	Aug.	9.68	3.19	3.03
	Oct.	3.57	1.69	2.11
	Nov.	27.93	1.40	19.95
	Dec.	67.38	21.79	3.09

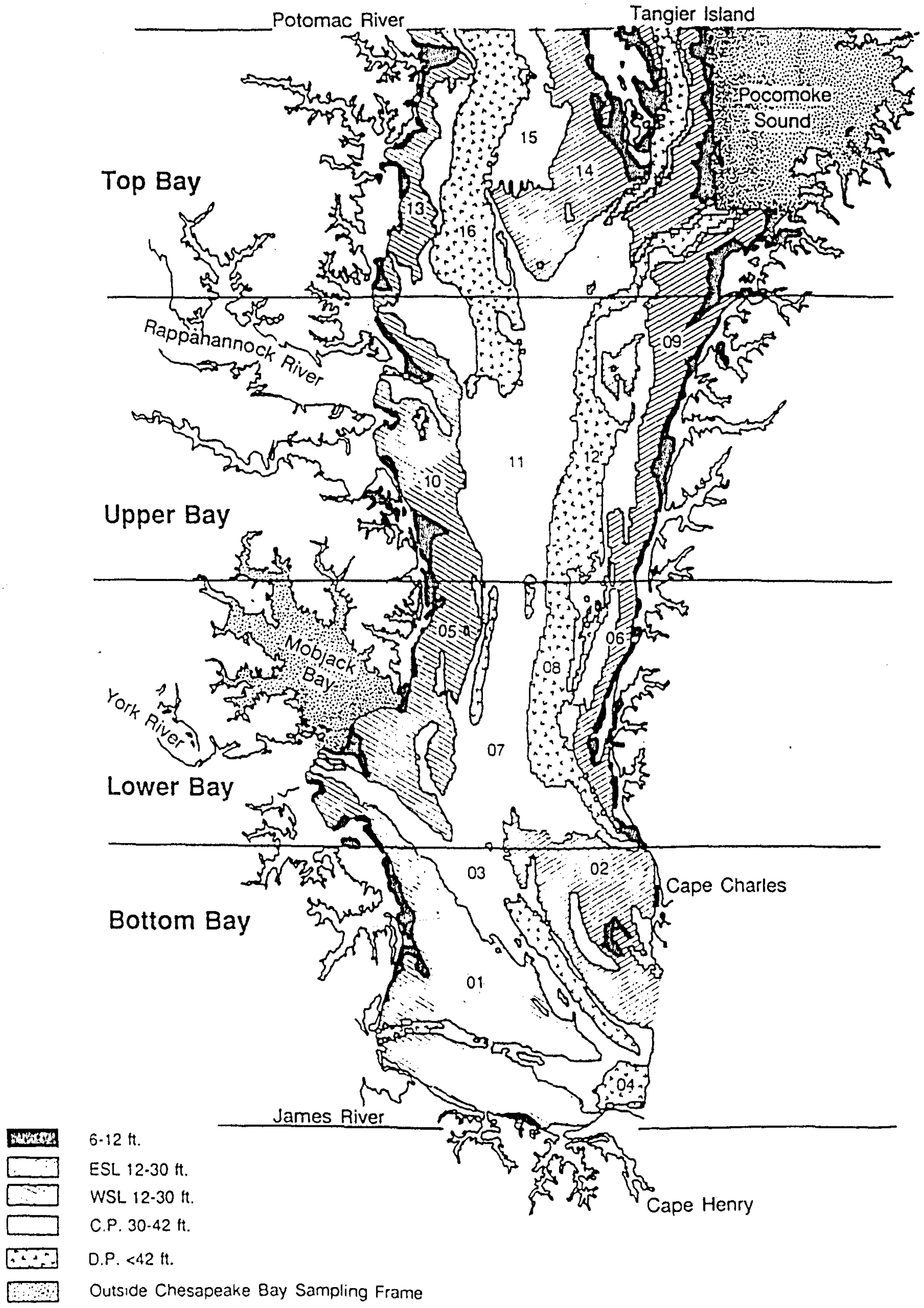


Figure 1. Chesapeake Bay trawl survey strata.

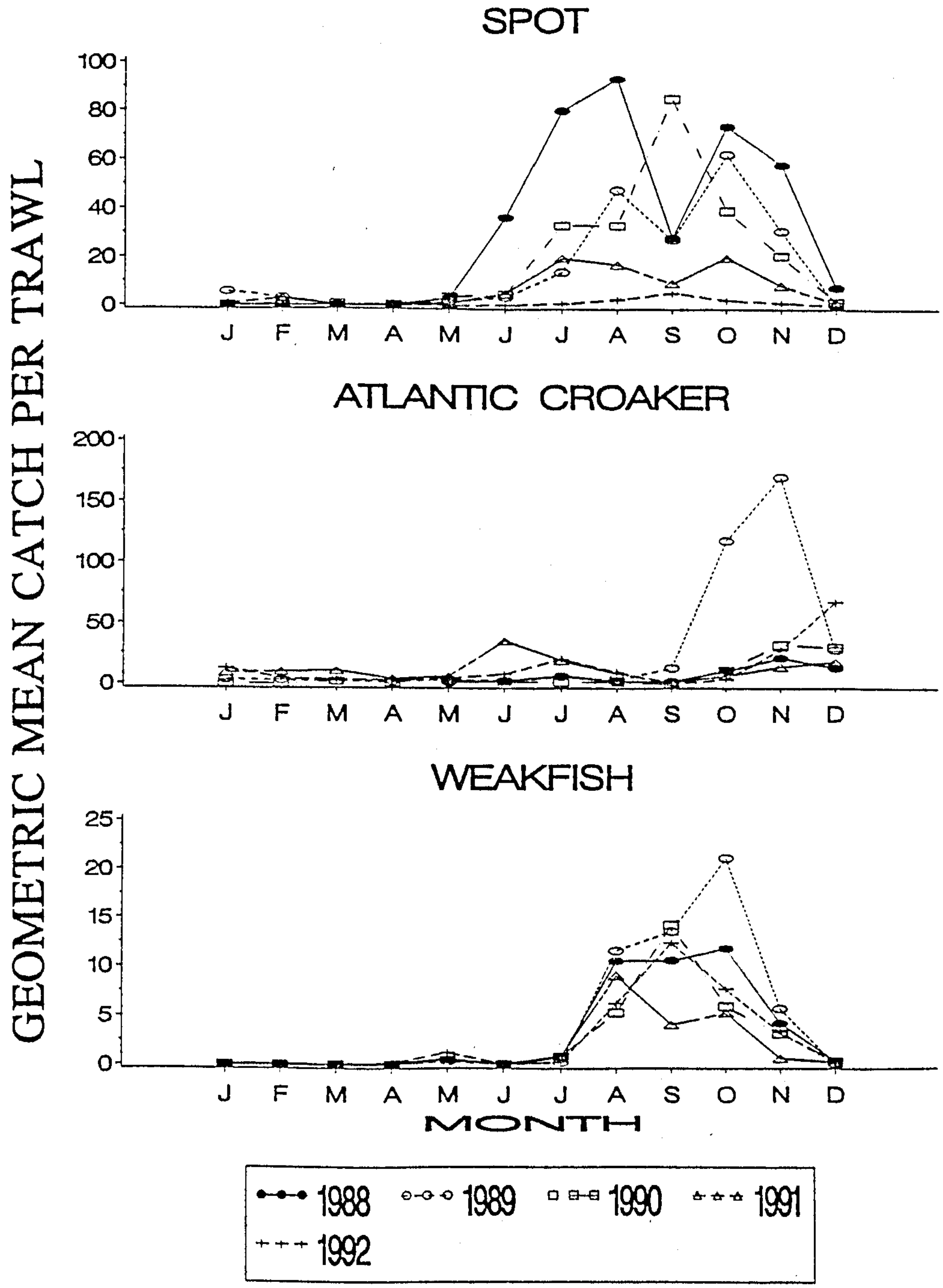


Figure 2. Geometric mean catch per tow of spot, Atlantic croaker and weakfish by month on the primary nursery grounds.

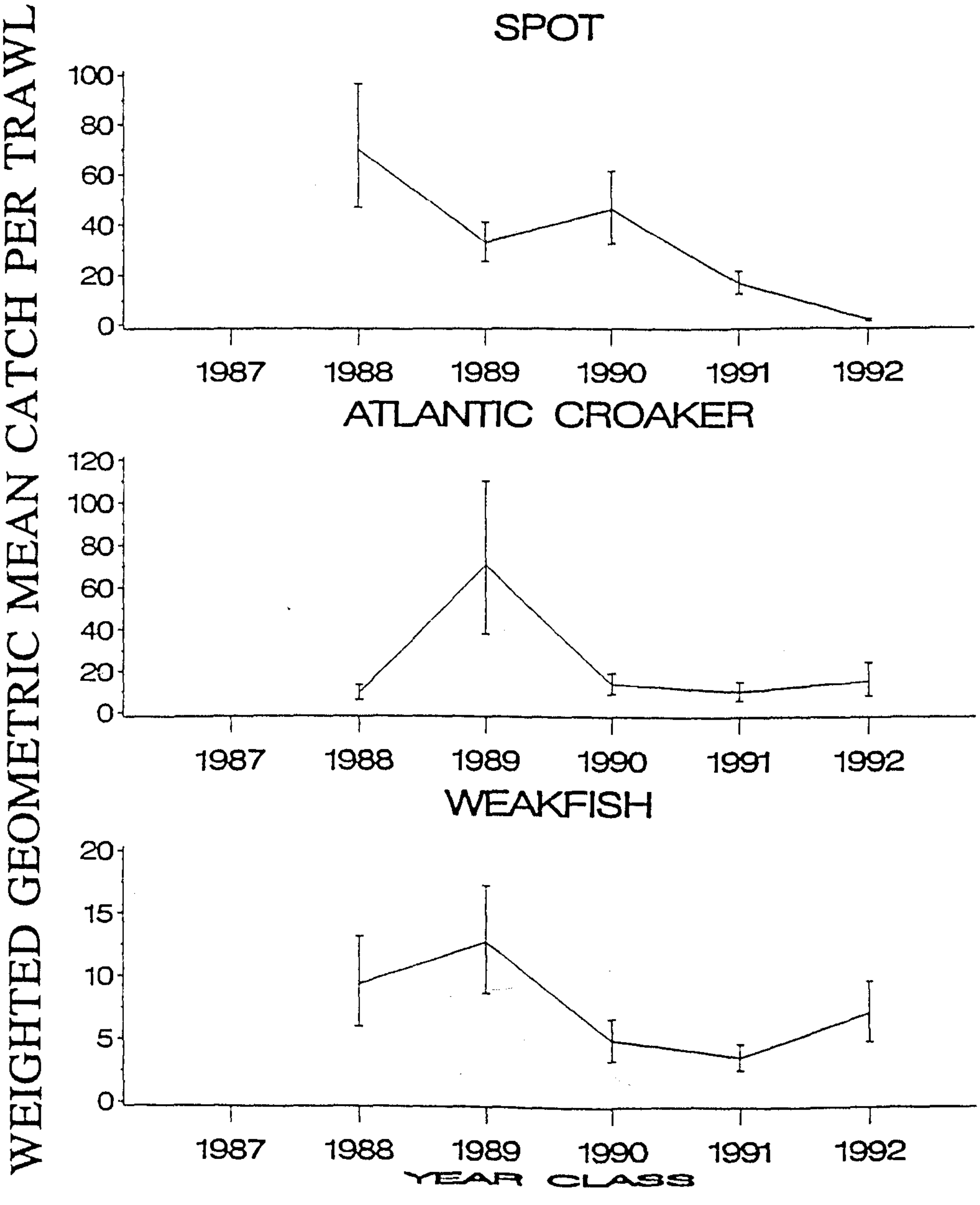


Figure 3. Annual juvenile abundance indices with 95% confidence intervals for spot, Atlantic croaker and weakfish.

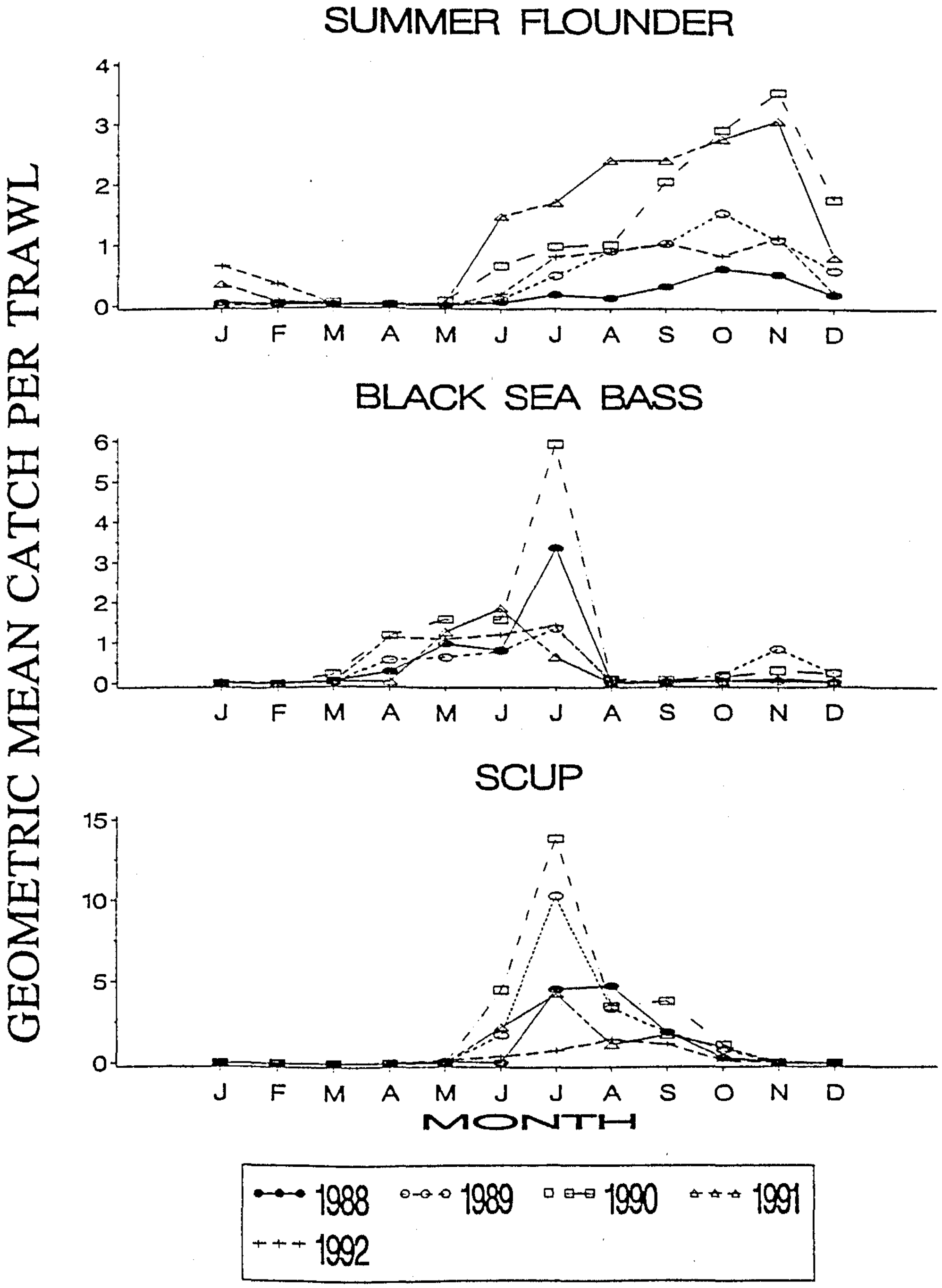


Figure 4. Geometric mean catch per tow of summer flounder, black sea bass and scup by month on the primary nursery grounds.

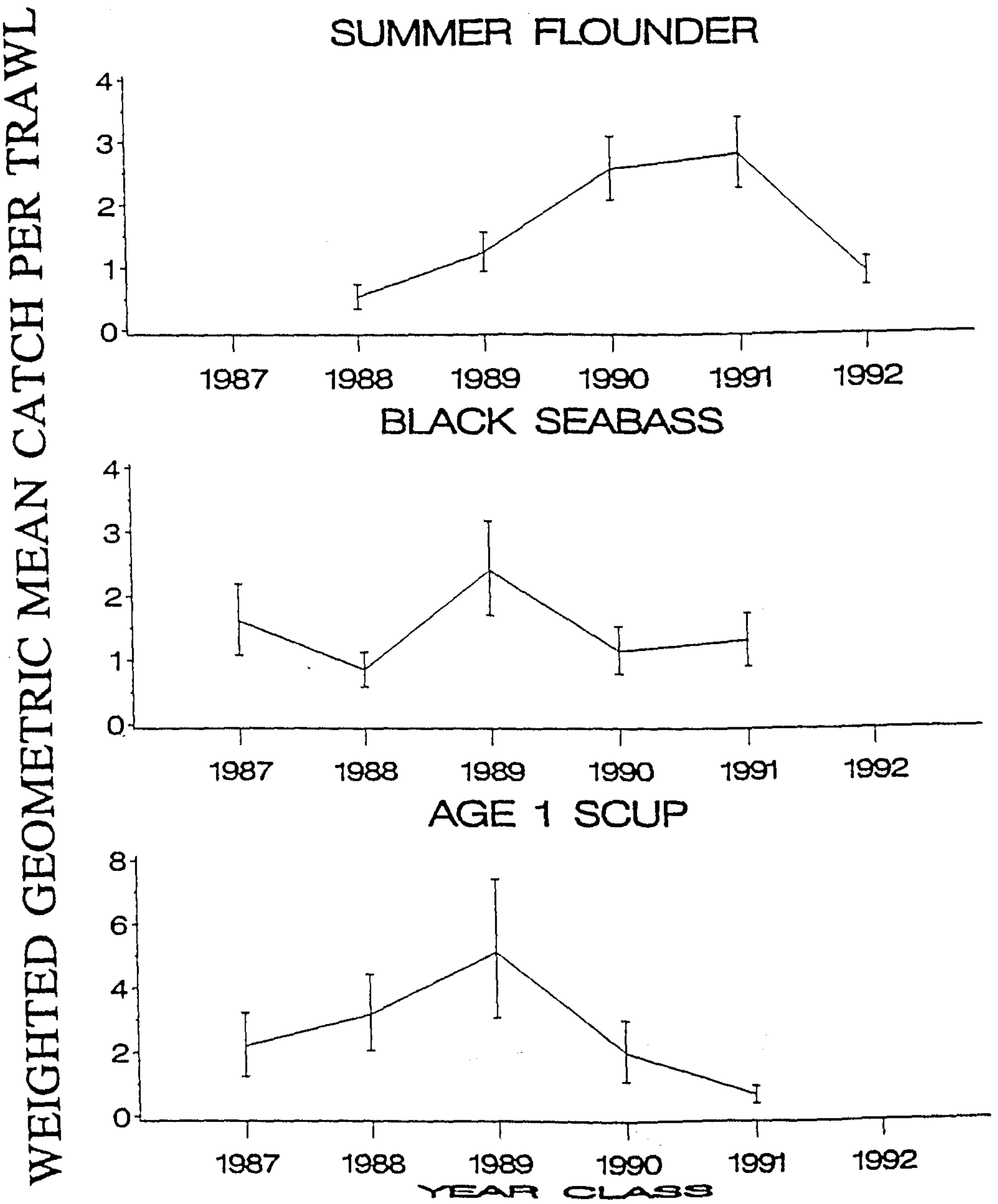


Figure 5. Annual juvenile abundance indices with 95% confidence intervals for summer flounder, black sea bass and scup.

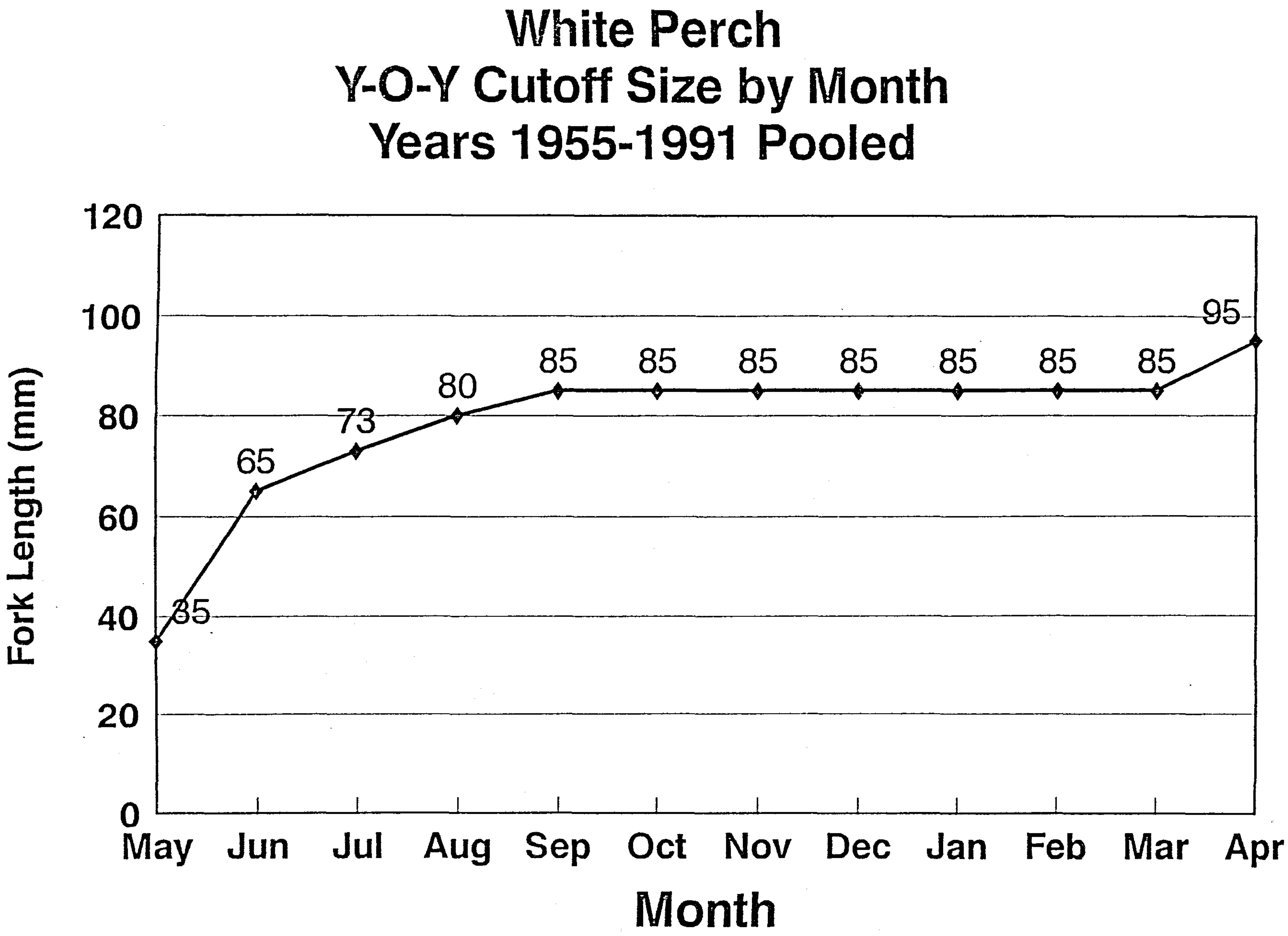
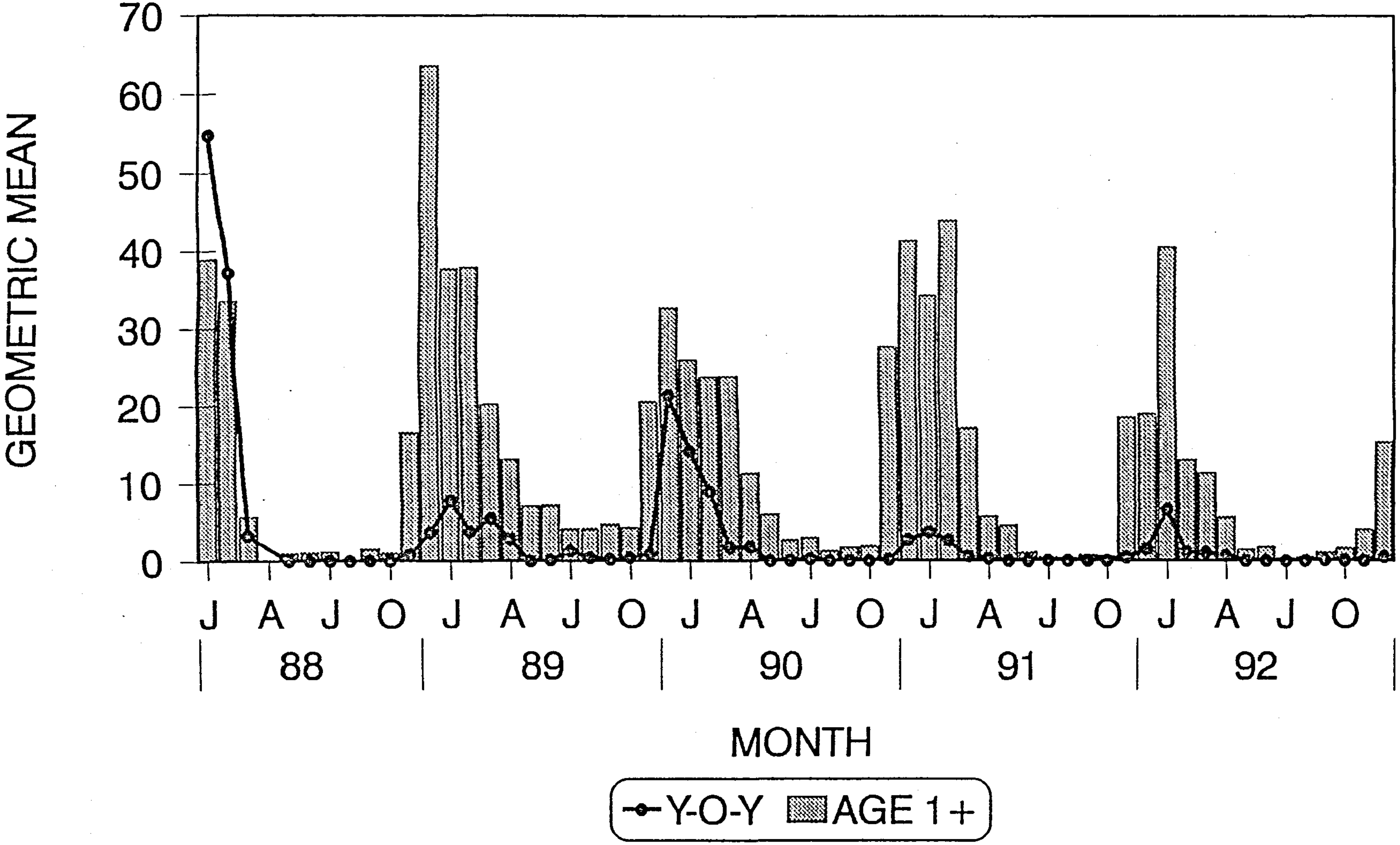


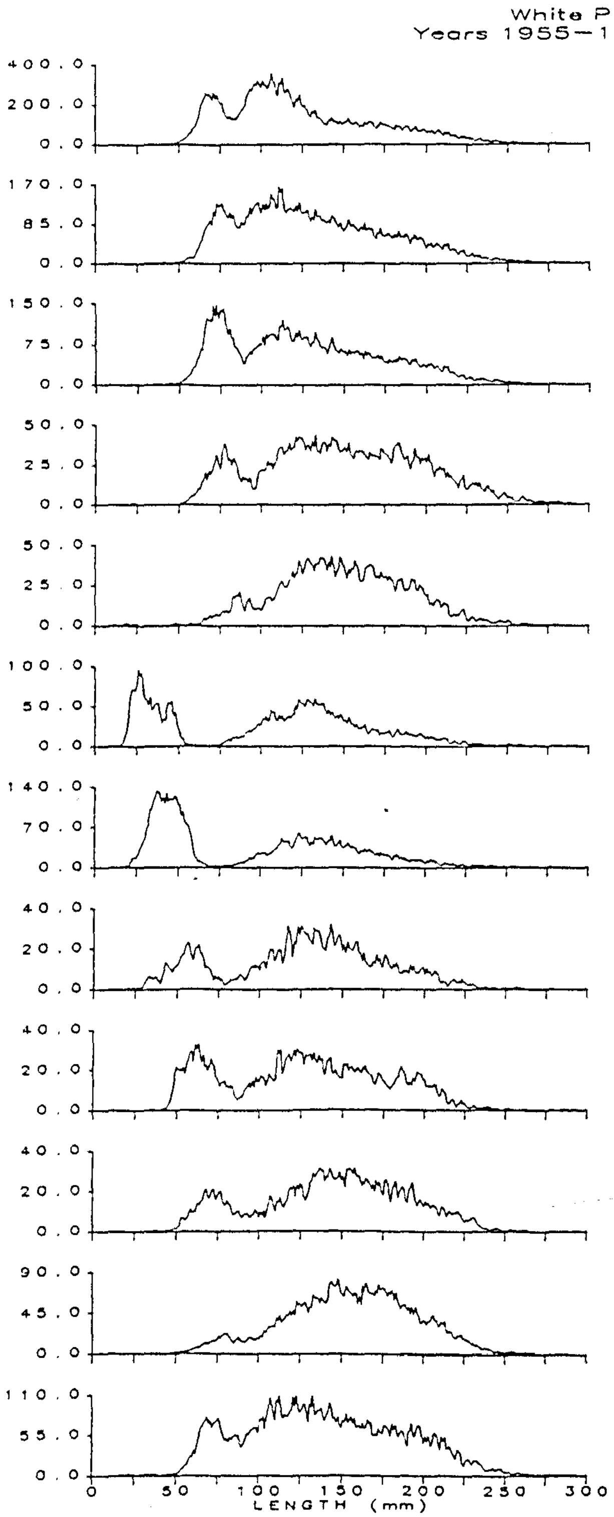
Figure 6. Length cutoff values used to separate y-o-y white perch from age 1+ components.

Figure 7. Geometric mean catch per trawl by month for white perch y-o-y and age 1+ components.

White Perch

Y-O-Y and Age 1+ Monthly Geometric Mean





```
JANUARY      570114  -   910135
NO. CGHT.   -137182  MEAN SIZE  -120.9
NO. MEAS.   - 25645  S.E. SIZE  -   0.3
NO. HAULS   -  1703  MIN. SIZE  -    22
CAT./HAUL   -  80.6  MAX. SIZE  -   362

FEBRUARY     550214  -   910218
NO. CGHT.   - 90810  MEAN SIZE  -129.3
NO. MEAS.   - 14013  S.E. SIZE  -   0.4
NO. HAULS   -  1490  MIN. SIZE  -    24
CAT./HAUL   -  60.9  MAX. SIZE  -   445

MARCH        550310  -   910326
NO. CGHT.   - 40641  MEAN SIZE  -125.2
NO. MEAS.   - 11449  S.E. SIZE  -   0.4
NO. HAULS   -  1362  MIN. SIZE  -    18
CAT./HAUL   -  29.8  MAX. SIZE  -   365

APRIL        550419  -   910423
NO. CGHT.   - 11443  MEAN SIZE  -146.9
NO. MEAS.   -  5002  S.E. SIZE  -   0.7
NO. HAULS   -   802  MIN. SIZE  -    19
CAT./HAUL   -  14.3  MAX. SIZE  -   309

MAY          550501  -   910513
NO. CGHT.   -  8788  MEAN SIZE  -147.8
NO. MEAS.   -  3801  S.E. SIZE  -   0.6
NO. HAULS   -  1043  MIN. SIZE  -    15
CAT./HAUL   -   8.4  MAX. SIZE  -   420

JUNE         550606  -   910618
NO. CGHT.   - 11334  MEAN SIZE  -103.6
NO. MEAS.   -  3458  S.E. SIZE  -   0.8
NO. HAULS   -  1219  MIN. SIZE  -    15
CAT./HAUL   -   9.8  MAX. SIZE  -   368

JULY         550706  -   910722
NO. CGHT.   - 16046  MEAN SIZE  -  94.4
NO. MEAS.   -  6981  S.E. SIZE  -   0.7
NO. HAULS   -  2929  MIN. SIZE  -    16
CAT./HAUL   -   5.5  MAX. SIZE  -   370

AUGUST       550801  -   910820
NO. CGHT.   -  7478  MEAN SIZE  -125.4
NO. MEAS.   -  2669  S.E. SIZE  -   0.9
NO. HAULS   -  1218  MIN. SIZE  -    19
CAT./HAUL   -   6.1  MAX. SIZE  -   274

SEPTEMBER    550906  -   910930
NO. CGHT.   -  9837  MEAN SIZE  -128.1
NO. MEAS.   -  3138  S.E. SIZE  -   0.9
NO. HAULS   -  1068  MIN. SIZE  -    33
CAT./HAUL   -   9.2  MAX. SIZE  -   290

OCTOBER      561015  -   911022
NO. CGHT.   -  7011  MEAN SIZE  -142.1
NO. MEAS.   -  3054  S.E. SIZE  -   0.8
NO. HAULS   -  1129  MIN. SIZE  -    15
CAT./HAUL   -   6.2  MAX. SIZE  -   346

NOVEMBER     561112  -   911121
NO. CGHT.   - 16277  MEAN SIZE  -153.9
NO. MEAS.   -  7088  S.E. SIZE  -   0.5
NO. HAULS   -   990  MIN. SIZE  -    25
CAT./HAUL   -  16.4  MAX. SIZE  -   305

DECEMBER     561210  -   911222
NO. CGHT.   - 52290  MEAN SIZE  -138.4
NO. MEAS.   - 11510  S.E. SIZE  -   0.4
NO. HAULS   -   977  MIN. SIZE  -    16
CAT./HAUL   -  53.5  MAX. SIZE  -   308
```

Figure 8. Composite length frequencies by month for white perch, VIMS trawl survey data base, 1955-1991.

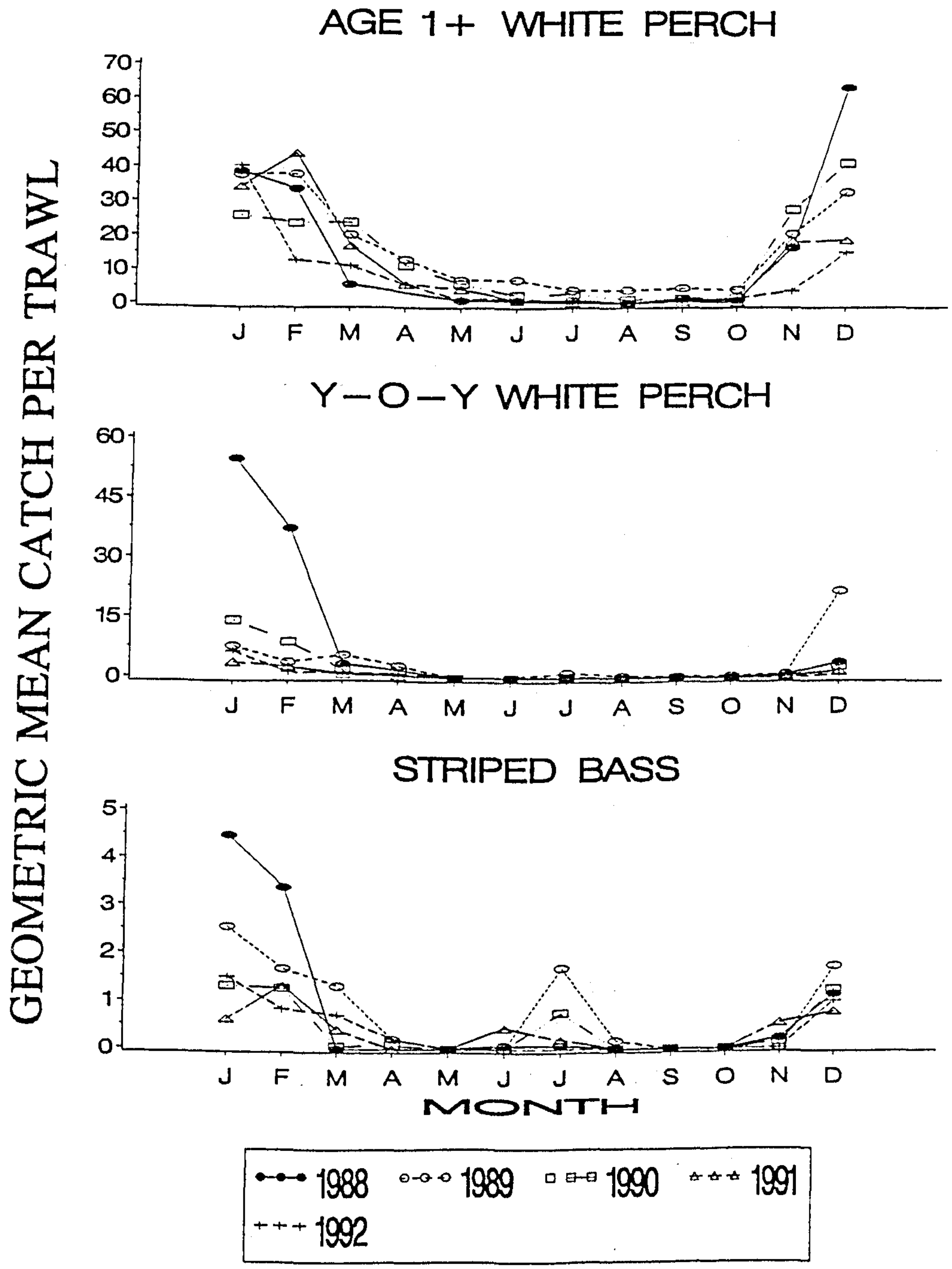


Figure 9. Geometric mean catch per tow of age 1+ white perch, y-o-y white perch and striped bass by month on the primary nursery grounds.

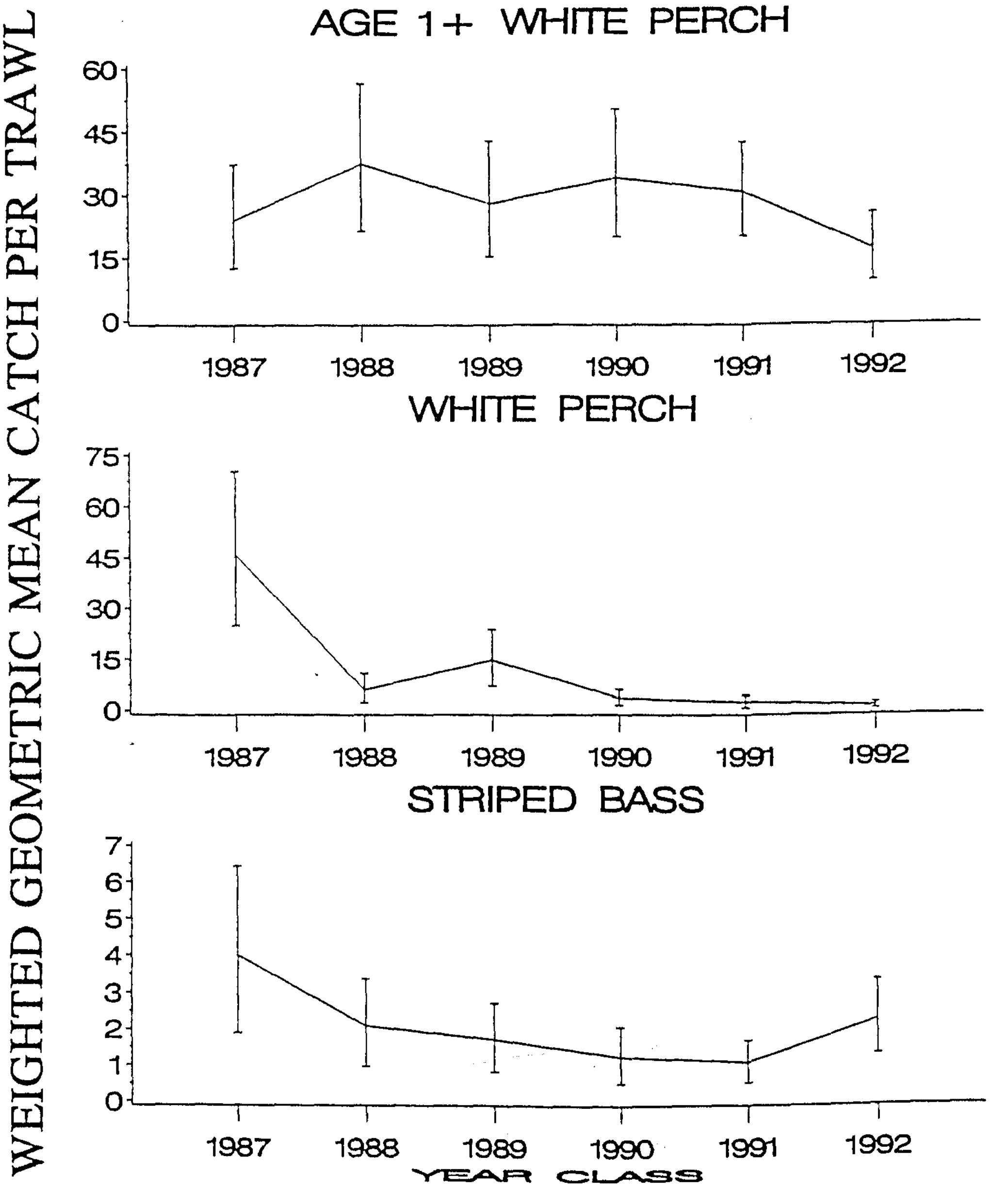


Figure 10. Annual juvenile abundance indices with 95% confidence intervals for age 1+ white perch, y-o-y white perch and striped bass.

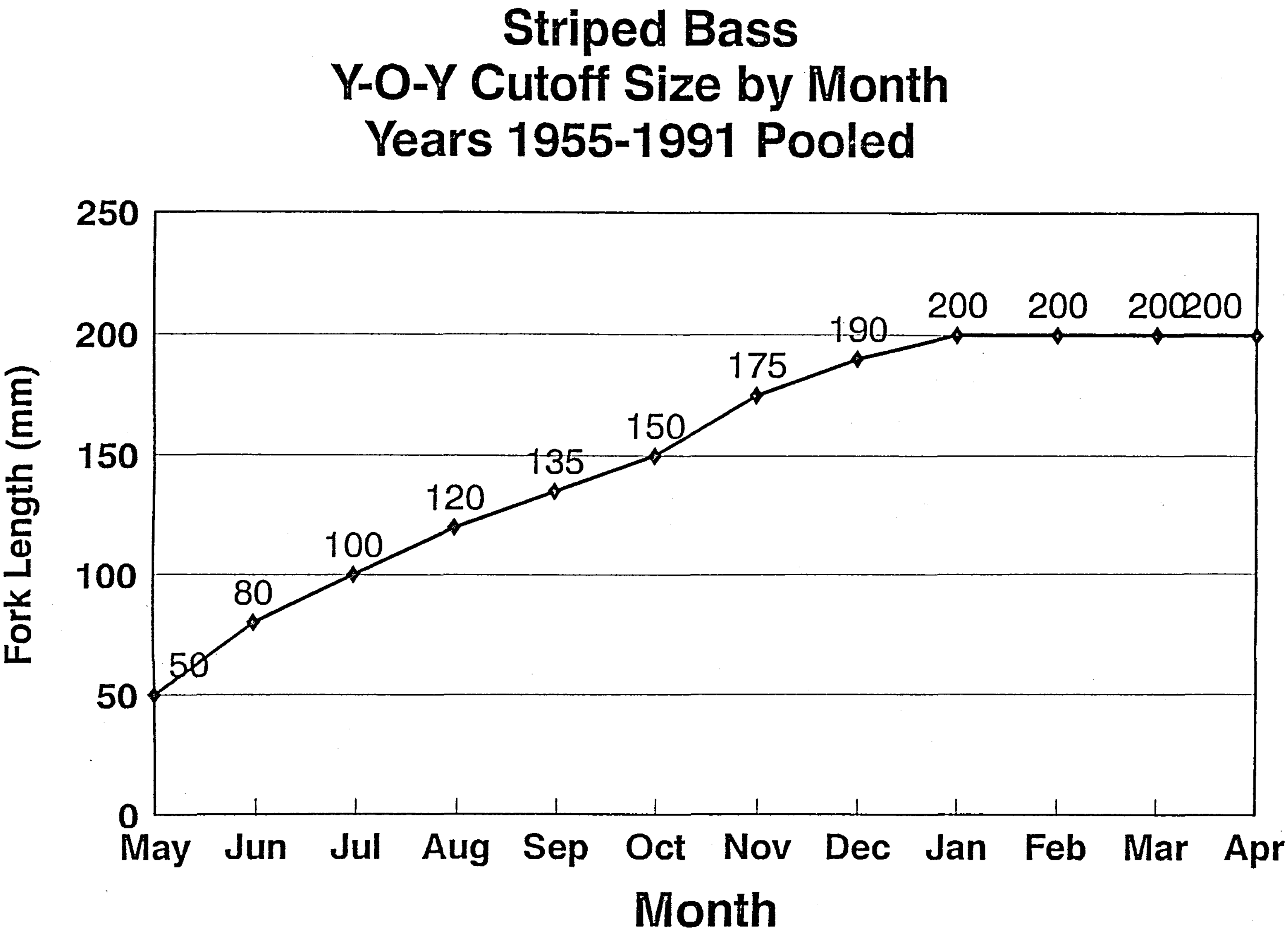
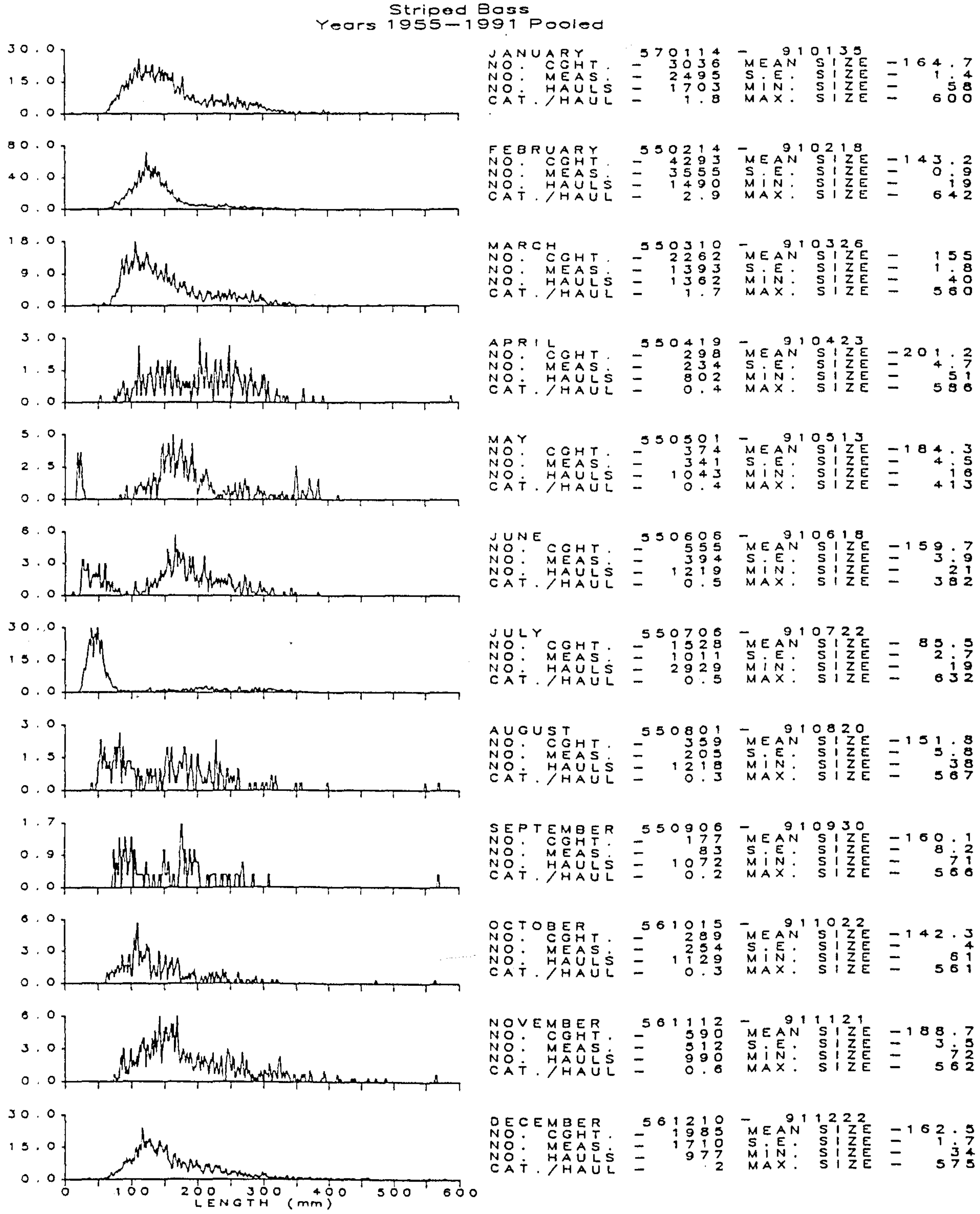


Figure 11. Length cutoff values used to separate y-o-y striped bass from older year classes.



```
JANUARY        570114 -   910135
NO. CGHT.   -    3036  MEAN SIZE  -164.7
NO. MEAS.   -    2495  S.E. SIZE  -    1.4
NO. HAULS   -    1703  MIN. SIZE  -     58
CAT./HAUL   -     1.8  MAX. SIZE  -    600

FEBRUARY       550214 -   910218
NO. CGHT.   -    4293  MEAN SIZE  -143.2
NO. MEAS.   -    3555  S.E. SIZE  -    0.9
NO. HAULS   -    1490  MIN. SIZE  -     19
CAT./HAUL   -     2.9  MAX. SIZE  -    642

MARCH          550310 -   910326
NO. CGHT.   -    2262  MEAN SIZE  -    155
NO. MEAS.   -    1393  S.E. SIZE  -    1.8
NO. HAULS   -    1362  MIN. SIZE  -     40
CAT./HAUL   -     1.7  MAX. SIZE  -    560

APRIL          550419 -   910423
NO. CGHT.   -     298  MEAN SIZE  -201.2
NO. MEAS.   -     234  S.E. SIZE  -    4.7
NO. HAULS   -     802  MIN. SIZE  -     51
CAT./HAUL   -     0.4  MAX. SIZE  -    586

MAY            550501 -   910513
NO. CGHT.   -     374  MEAN SIZE  -184.3
NO. MEAS.   -     341  S.E. SIZE  -    4.5
NO. HAULS   -    1043  MIN. SIZE  -     16
CAT./HAUL   -     0.4  MAX. SIZE  -    413

JUNE           550606 -   910618
NO. CGHT.   -     555  MEAN SIZE  -159.7
NO. MEAS.   -     394  S.E. SIZE  -    3.9
NO. HAULS   -    1219  MIN. SIZE  -     21
CAT./HAUL   -     0.5  MAX. SIZE  -    382

JULY           550706 -   910722
NO. CGHT.   -    1528  MEAN SIZE  -   85.5
NO. MEAS.   -    1011  S.E. SIZE  -    2.7
NO. HAULS   -    2929  MIN. SIZE  -     19
CAT./HAUL   -     0.5  MAX. SIZE  -    632

AUGUST         550801 -   910820
NO. CGHT.   -     359  MEAN SIZE  -151.8
NO. MEAS.   -     205  S.E. SIZE  -    5.8
NO. HAULS   -    1218  MIN. SIZE  -     38
CAT./HAUL   -     0.3  MAX. SIZE  -    567

SEPTEMBER      550906 -   910930
NO. CGHT.   -     177  MEAN SIZE  -160.1
NO. MEAS.   -      83  S.E. SIZE  -    8.2
NO. HAULS   -    1072  MIN. SIZE  -     71
CAT./HAUL   -     0.2  MAX. SIZE  -    566

OCTOBER        561015 -   911022
NO. CGHT.   -     289  MEAN SIZE  -142.3
NO. MEAS.   -     254  S.E. SIZE  -      4
NO. HAULS   -    1129  MIN. SIZE  -     61
CAT./HAUL   -     0.3  MAX. SIZE  -    561

NOVEMBER       561112 -   911121
NO. CGHT.   -     590  MEAN SIZE  -188.7
NO. MEAS.   -     512  S.E. SIZE  -    3.5
NO. HAULS   -     990  MIN. SIZE  -     72
CAT./HAUL   -     0.6  MAX. SIZE  -    562

DECEMBER       561210 -   911222
NO. CGHT.   -    1985  MEAN SIZE  -162.5
NO. MEAS.   -    1710  S.E. SIZE  -    1.7
NO. HAULS   -     977  MIN. SIZE  -     34
CAT./HAUL   -       2  MAX. SIZE  -    575
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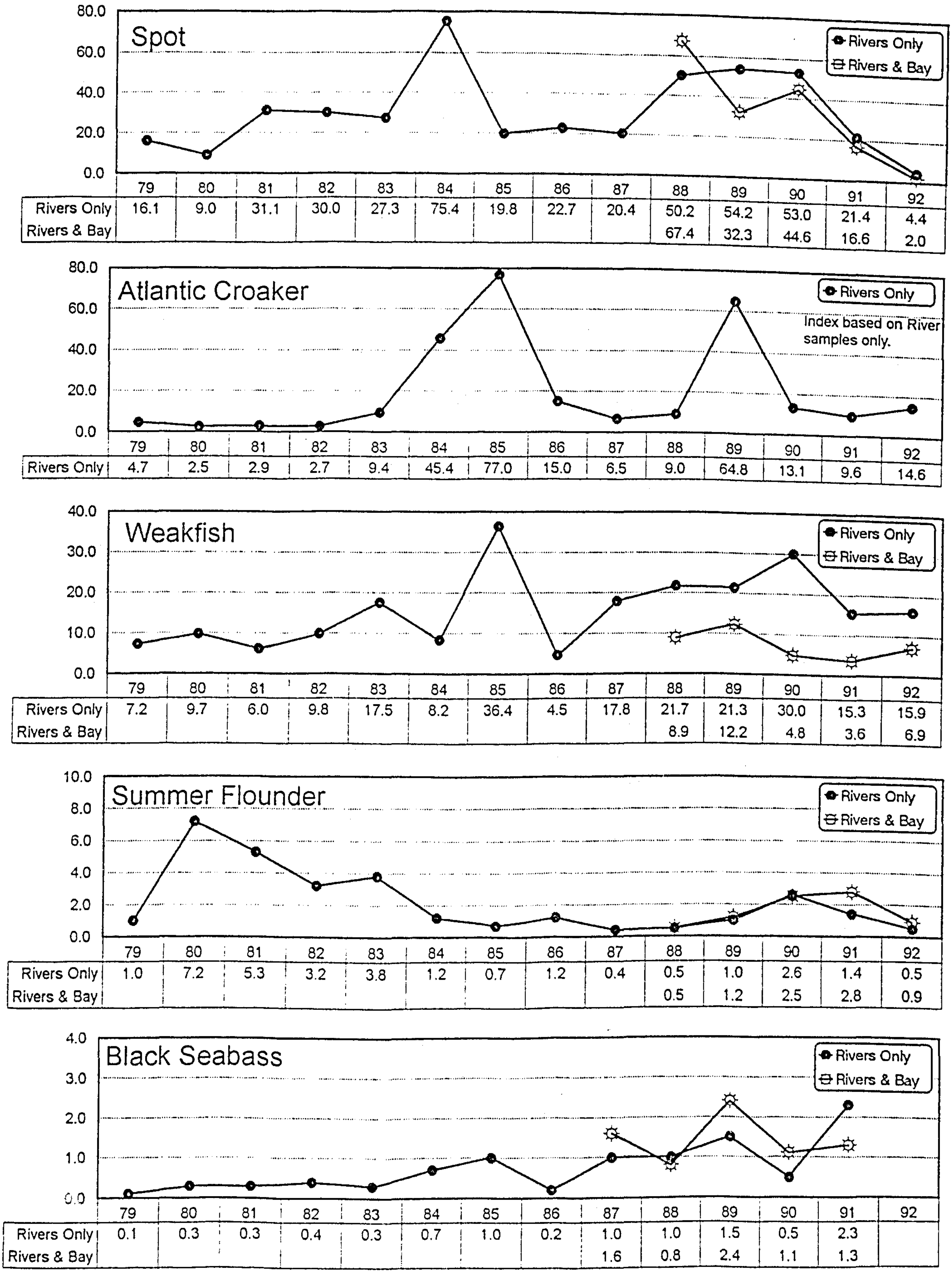
Figure 12. Composite length frequencies by month for striped bass, VIMS trawl survey data base, 1957-1991.



	79	80	81	82	83	84	85	86	87	88	89	90	91	92
Rivers Only	16.1	9.0	31.1	30.0	27.3	75.4	19.8	22.7	20.4	50.2	54.2	53.0	21.4	4.4
Rivers & Bay										67.4	32.3	44.6	16.6	2.0

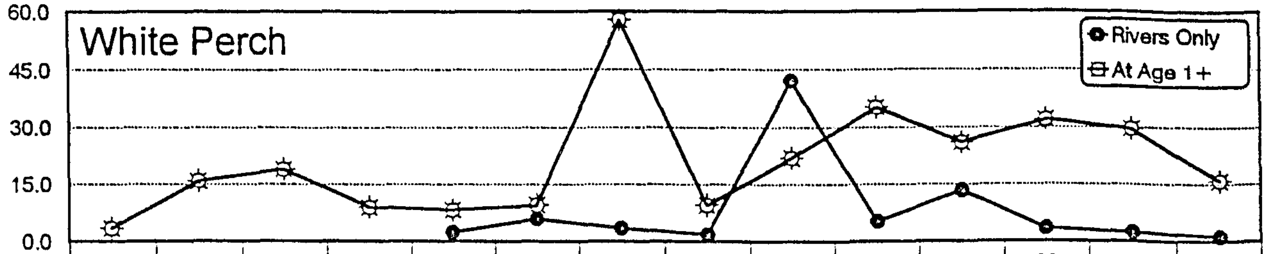
	79	80	81	82	83	84	85	86	87	88	89	90	91	92
Rivers Only	4.7	2.5	2.9	2.7	9.4	45.4	77.0	15.0	6.5	9.0	64.8	13.1	9.6	14.6

	79	80	81	82	83	84	85	86	87	88	89	90	91	92
Rivers Only	7.2	9.7	6.0	9.8	17.5	8.2	36.4	4.5	17.8	21.7	21.3	30.0	15.3	15.9
Rivers & Bay										8.9	12.2	4.8	3.6	6.9

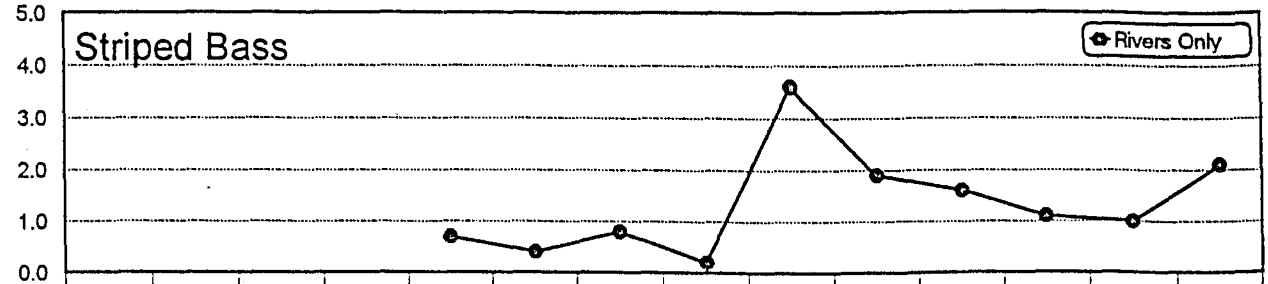
	79	80	81	82	83	84	85	86	87	88	89	90	91	92
Rivers Only	1.0	7.2	5.3	3.2	3.8	1.2	0.7	1.2	0.4	0.5	1.0	2.6	1.4	0.5
Rivers & Bay										0.5	1.2	2.5	2.8	0.9

	79	80	81	82	83	84	85	86	87	88	89	90	91	92
Rivers Only	0.1	0.3	0.3	0.4	0.3	0.7	1.0	0.2	1.0	1.0	1.5	0.5	2.3	
Rivers & Bay									1.6	0.8	2.4	1.1	1.3	

Figure 13. Annual juvenile abundance indices for initial key species based on tributary data only and on expanded sampling program.



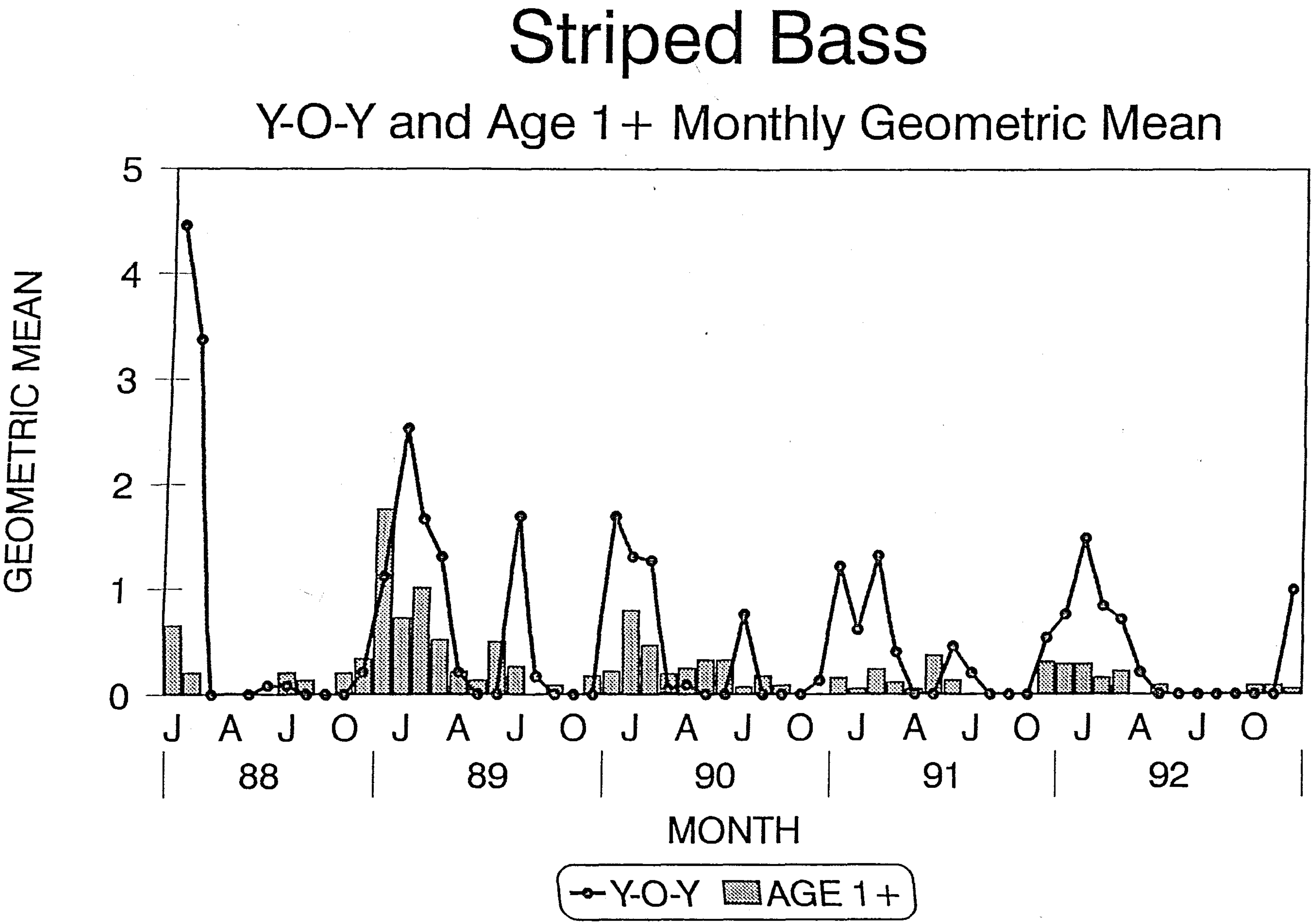
	79	80	81	82	83	84	85	86	87	88	89	90	91	92
Rivers Only					2.4	5.9	3.3	1.8	42.1	5.3	13.3	3.3	2.3	1.2
At Age 1+	3.3	15.8	18.9	8.9	8.3	9.5	57.8	9.5	21.9	35.1	25.9	32.0	29.5	15.8



	79	80	81	82	83	84	85	86	87	88	89	90	91	92
Rivers Only					0.7	0.4	0.8	0.2	3.6	1.9	1.6	1.1	1.0	2.1

Figure 14. Annual juvenile abundance indices for white perch (y-o-y and age 1+) and striped bass based on historic tributary data (1979-1987), and the expanded sampling program (1988-1993).

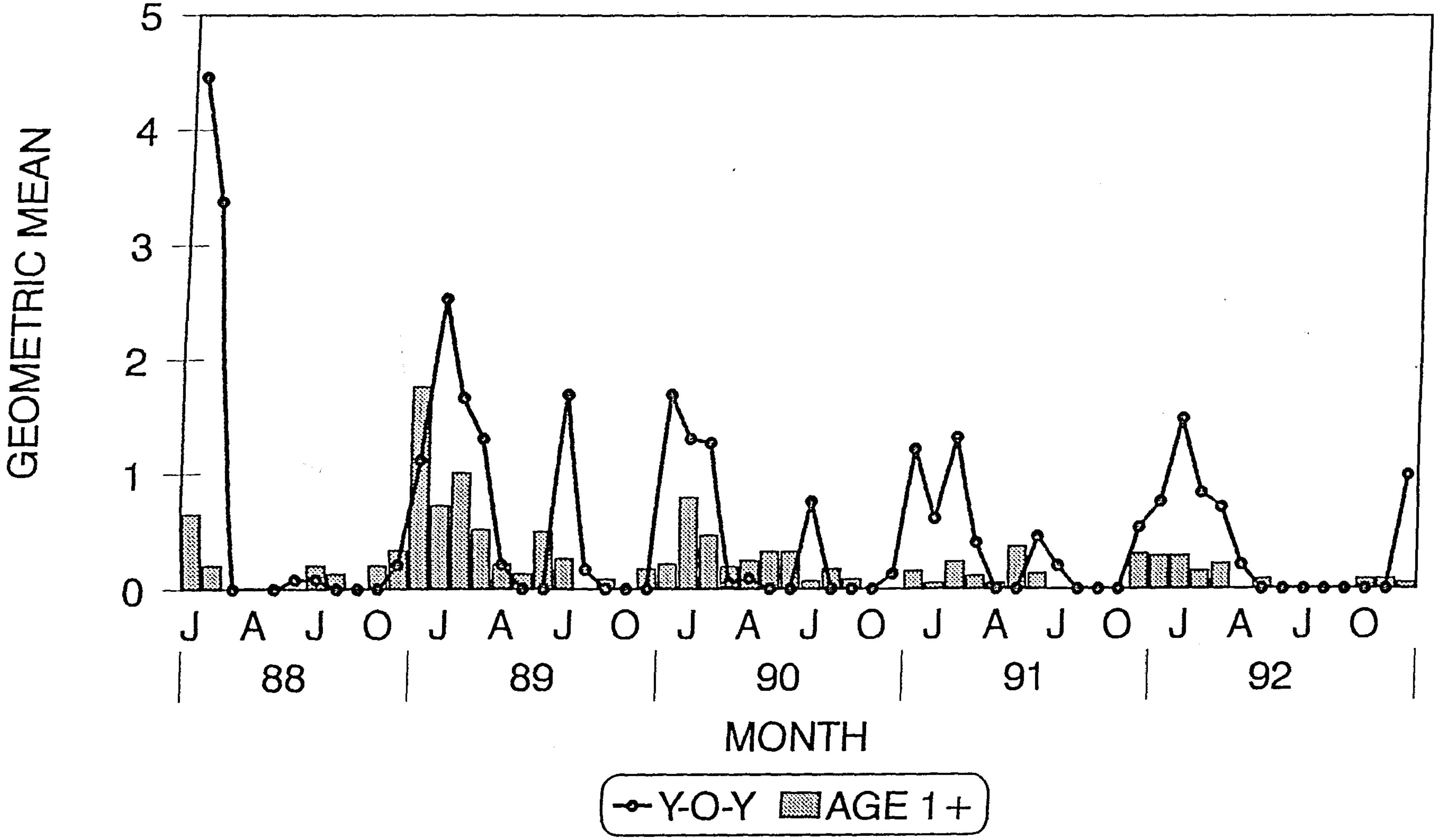
Figure 15. Geometric mean catch per trawl by month for striped bass y-o-y and age 1+ components.


Striped Bass
Y-O-Y and Age 1+ Monthly Geometric Mean
GEOMETRIC MEAN
0
1
2
3
4
5
J
A
J
O
J
A
J
O
J
A
J
O
J
A
J
O
J
A
J
O
88
89
90
91
92
MONTH
Y-O-Y
AGE 1+

Appendix Figures 1-9. Trawl catches (numbers of individuals) of young-of-the-year of 1, spot; 2, Atlantic croaker; 3, weakfish; 4, summer flounder; 5, black sea bass; and 6, early age-1 scup plotted by month for 1992. Plots are arranged chronologically (a, Jan.-June; b, July-Dec). Also catches of age 1+ white perch (7); y-o-y white perch (8) and striped bass (9) for 1988-1992. Plots are arranged chronologically (a, Jan.-June 1988; b, July-Dec. 1988; c, Jan.-June 1989; d, July-Dec. 1989; e, Jan.-June 1990; f, July-Dec. 1990; g, Jan.-June 1991; h, July-Dec. 1991; i, Jan.-June 1992; j, July-Dec. 1992).

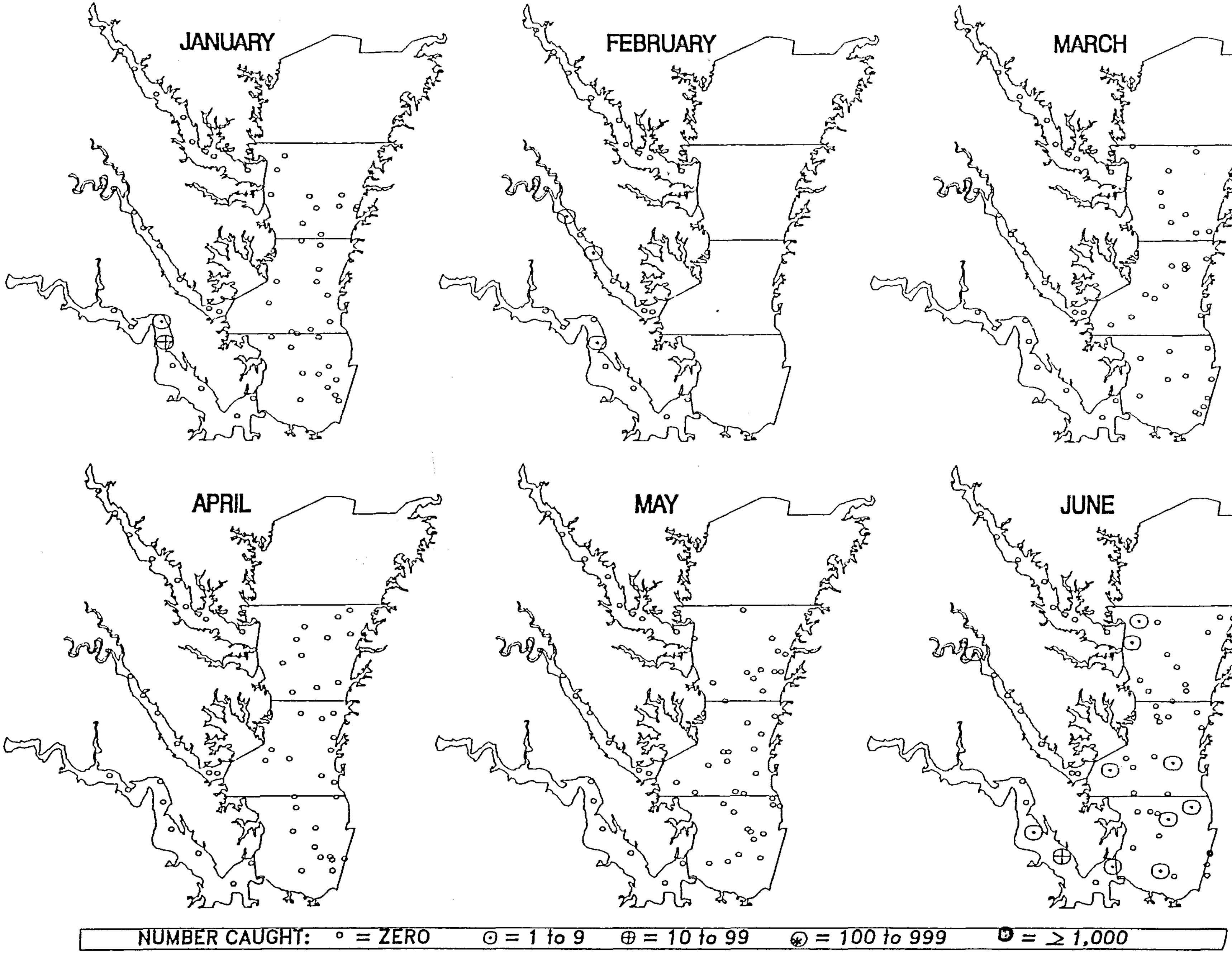
Striped Bass

Y-O-Y and Age 1+ Monthly Geometric Mean



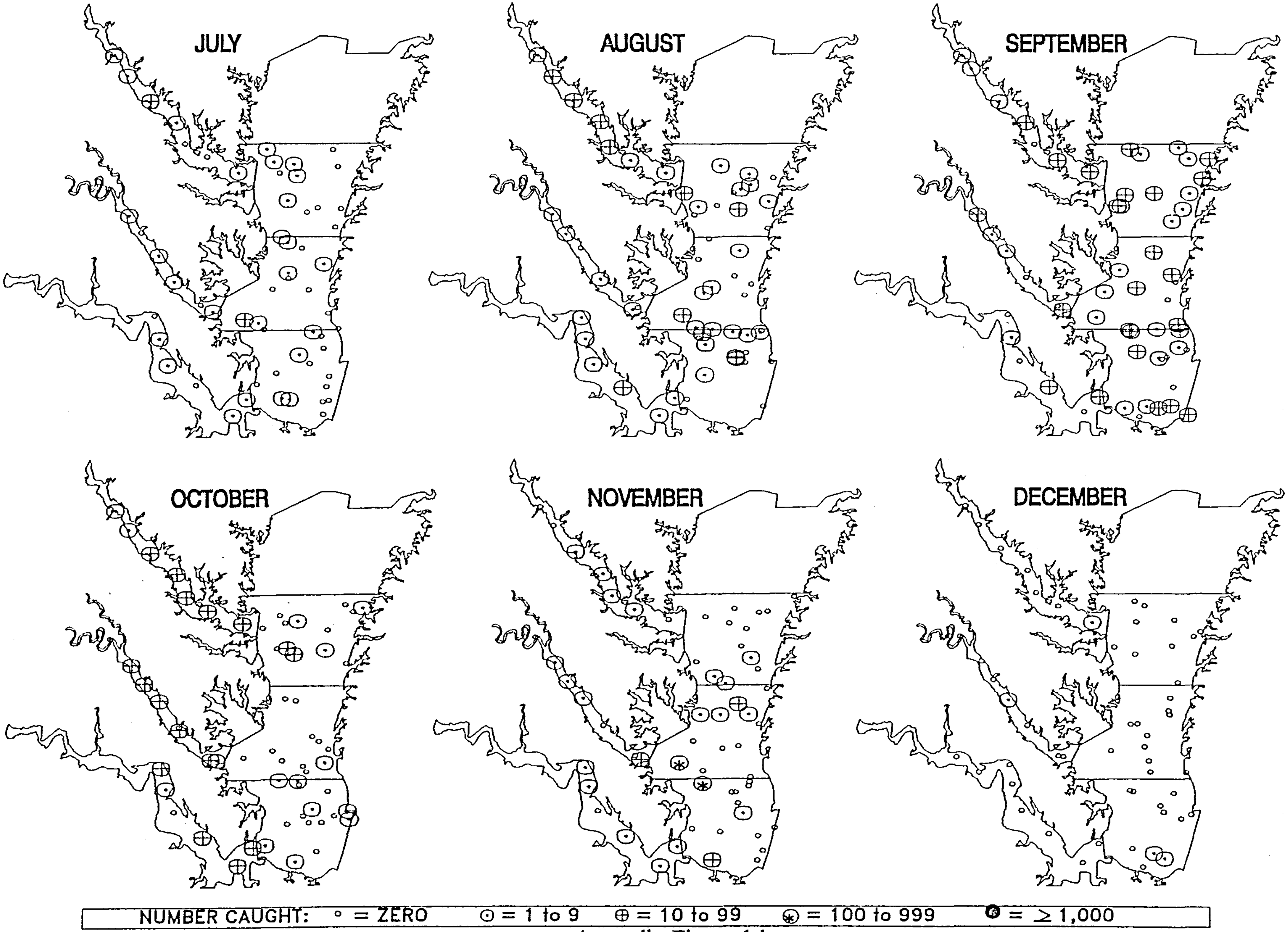
Appendix Figures 1-9. Trawl catches (numbers of individuals) of young-of-the-year of 1, spot; 2, Atlantic croaker; 3, weakfish; 4, summer flounder; 5, black sea bass; and 6, early age-1 scup plotted by month for 1992. Plots are arranged chronologically (a, Jan.-June; b, July-Dec). Also catches of age 1+ white perch (7); y-o-y white perch (8) and striped bass (9) for 1988-1992. Plots are arranged chronologically (a, Jan.-June 1988; b, July-Dec. 1988; c, Jan.-June 1989; d, July-Dec. 1989; e, Jan.-June 1990; f, July-Dec. 1990; g, Jan.-June 1991; h, July-Dec. 1991; i, Jan.-June 1992; j, July-Dec. 1992).

Y–O–Y SPOT 1992



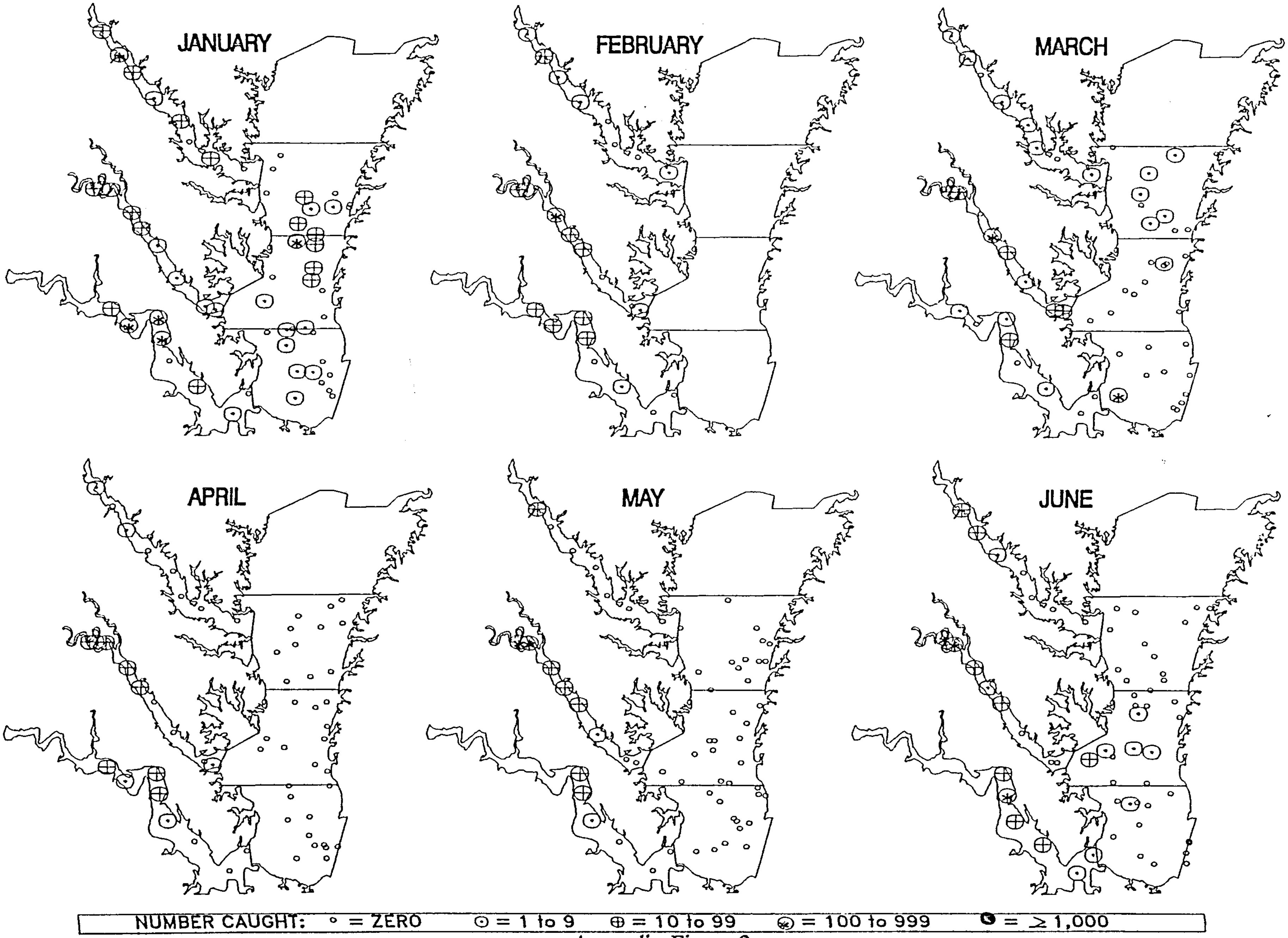
Appendix Figure 1-a.

Y-O-Y SPOT 1992



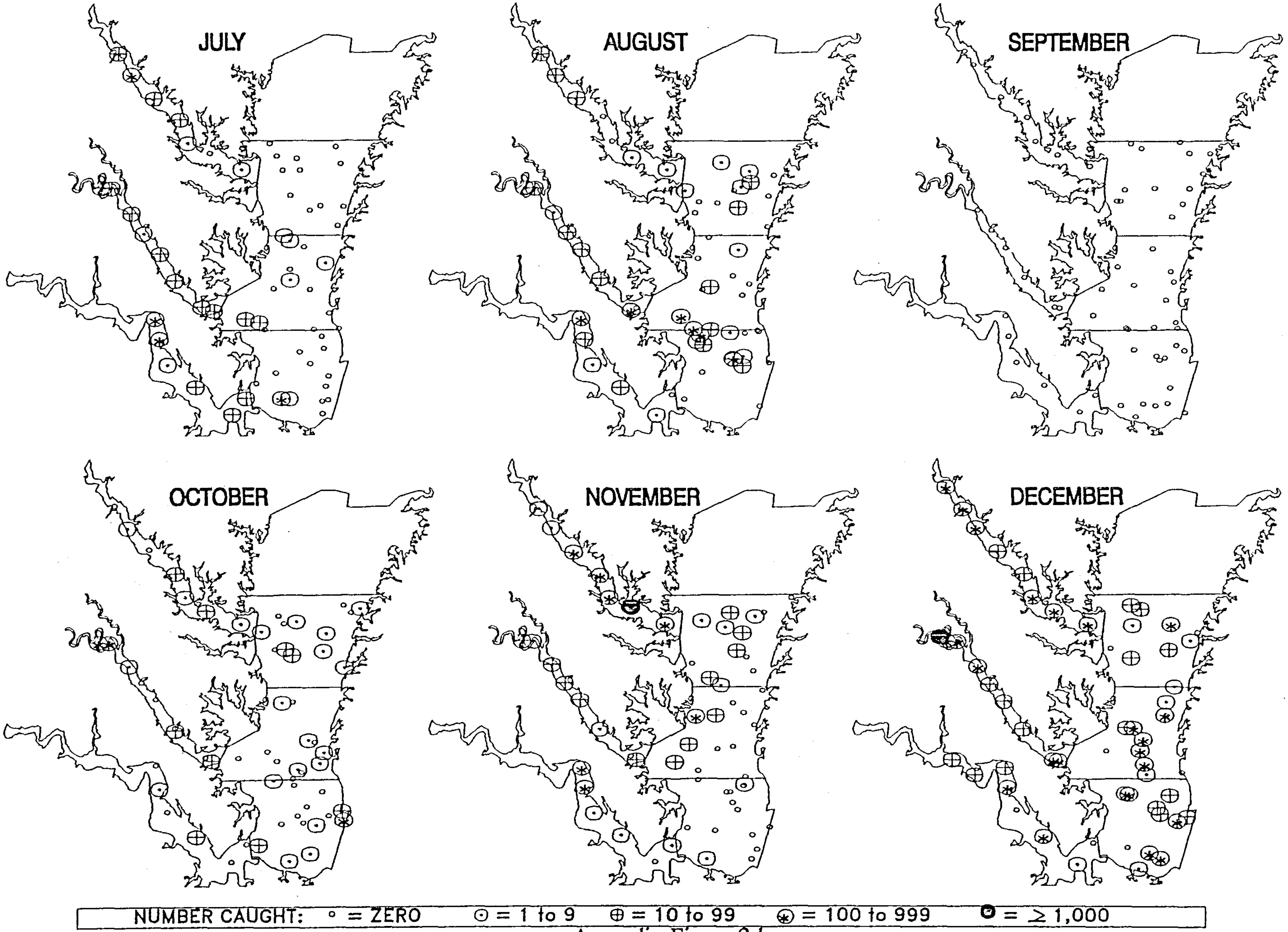
Appendix Figure 1-b.

Y–O–Y Atlantic Croaker 1992



Appendix Figure 2-a.

Y—O—Y Atlantic Croaker 1992



JULY

AUGUST

SEPTEMBER

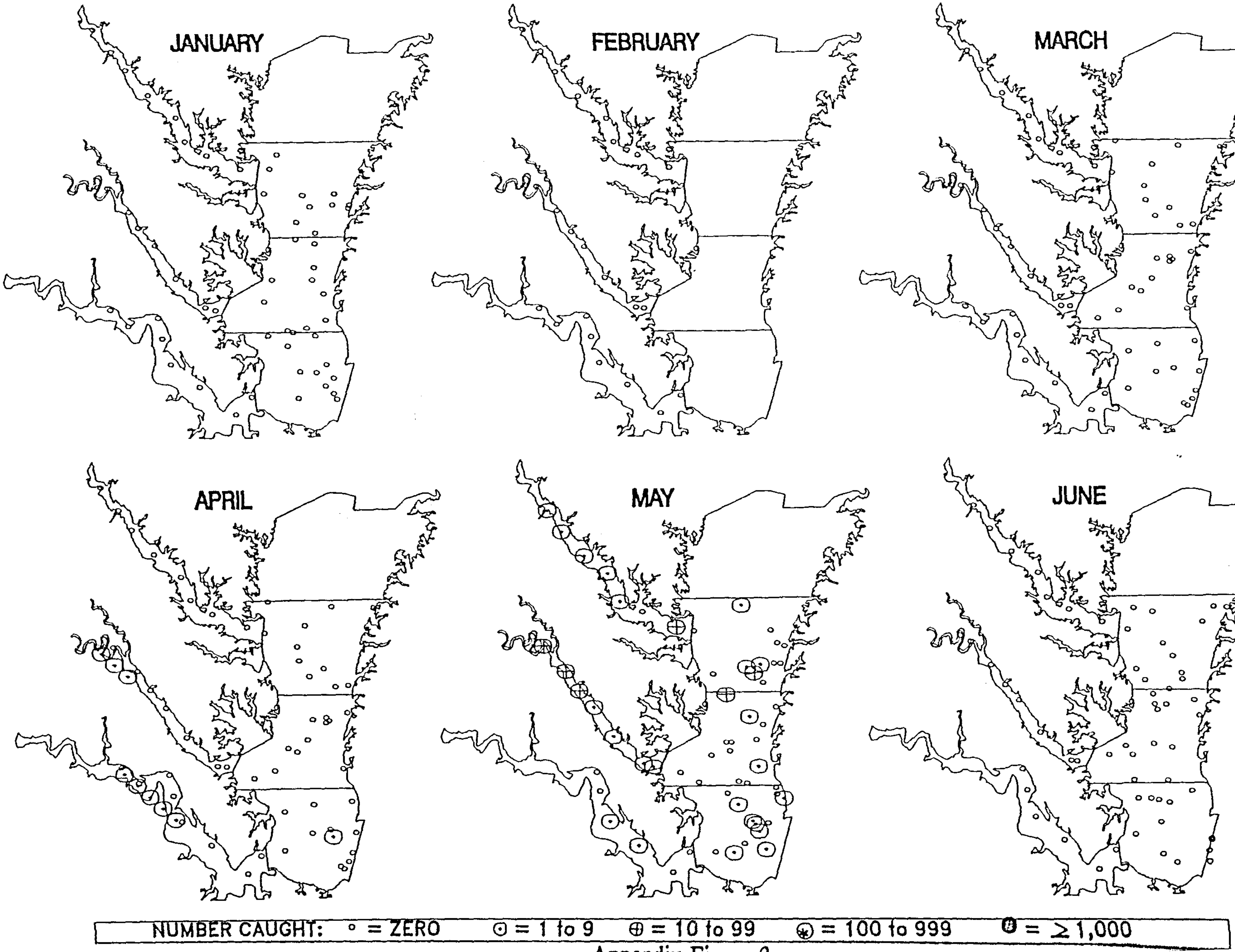
OCTOBER

NOVEMBER

DECEMBER

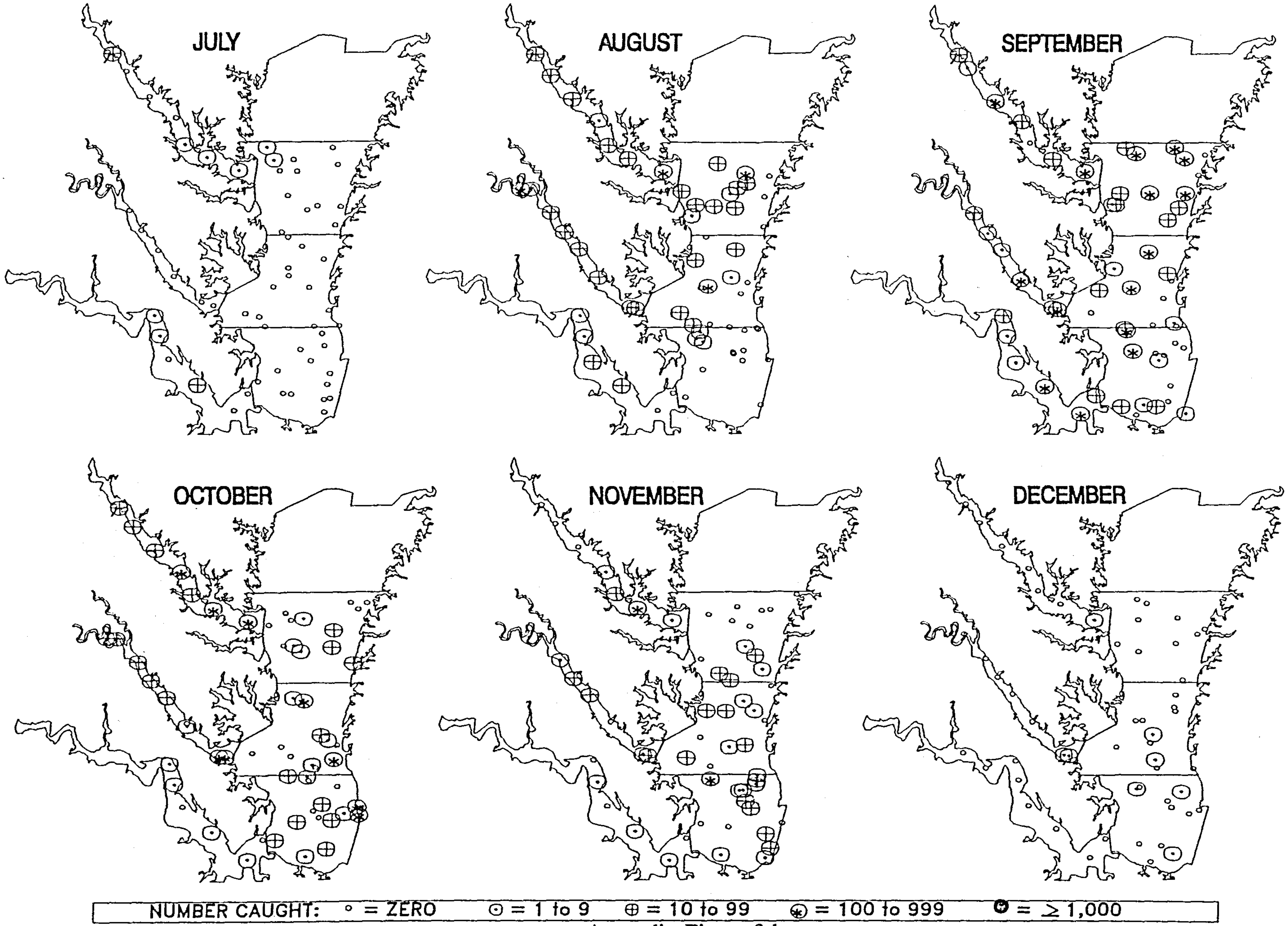
Appendix Figure 2-b.

Y–O–Y Weakfish 1992



Appendix Figure 3a

Y−O−Y Weakfish 1992



JULY

AUGUST

SEPTEMBER

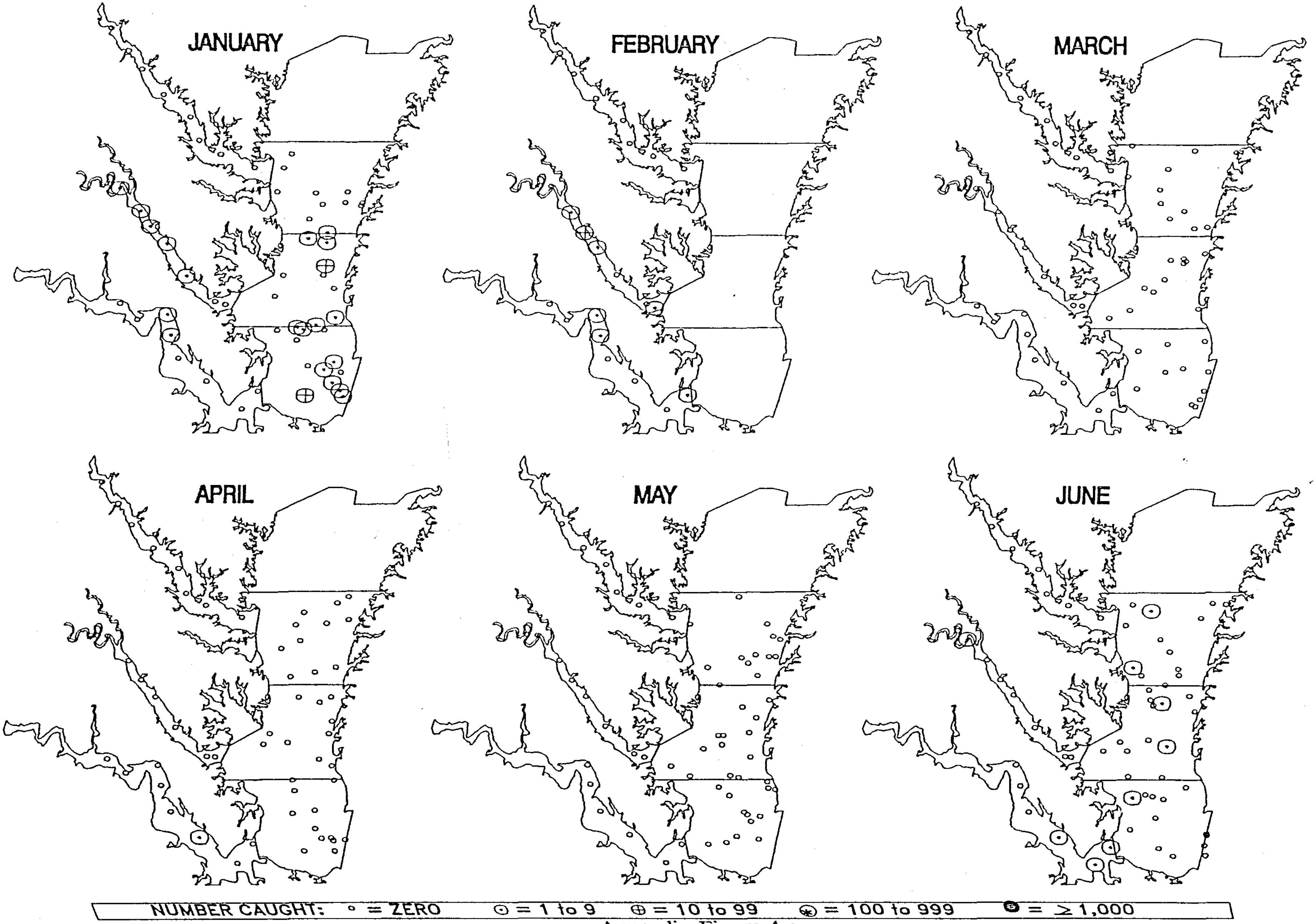
OCTOBER

NOVEMBER

DECEMBER

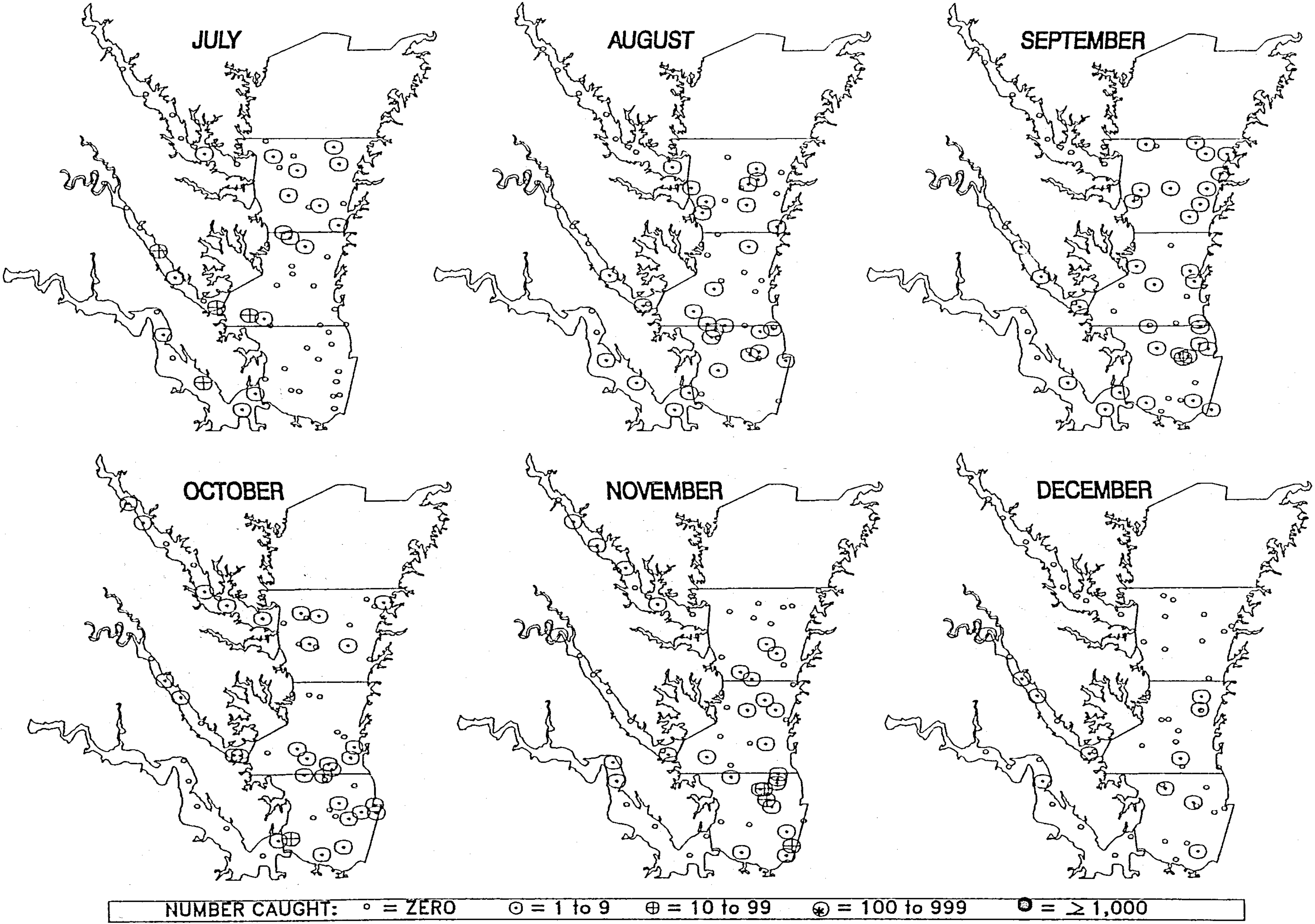
Appendix Figure 3-b.

Y–O–Y Summer Flounder 1992



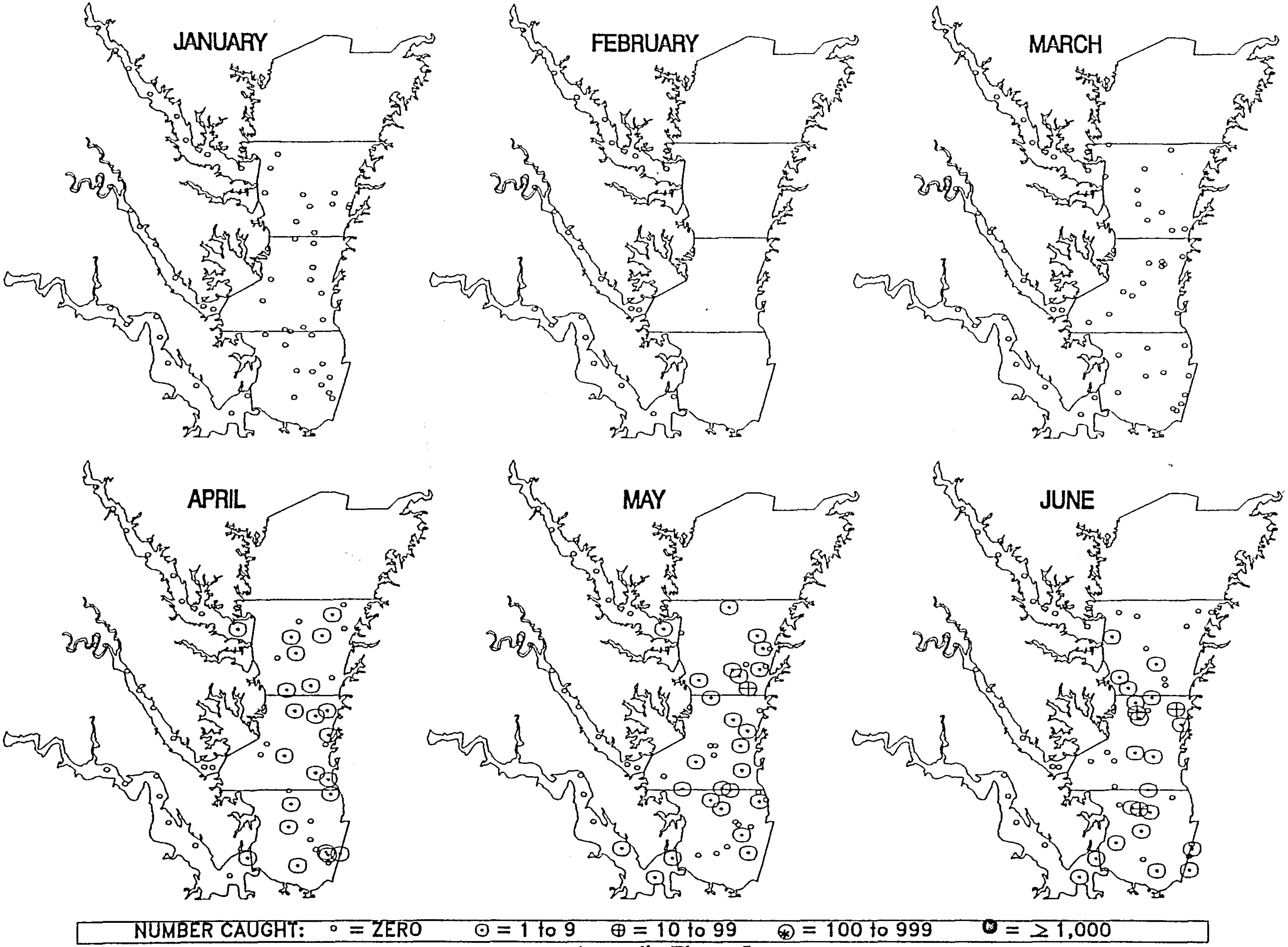
Appendix Figure 4-a.

Y—O—Y Summer Flounder 1992



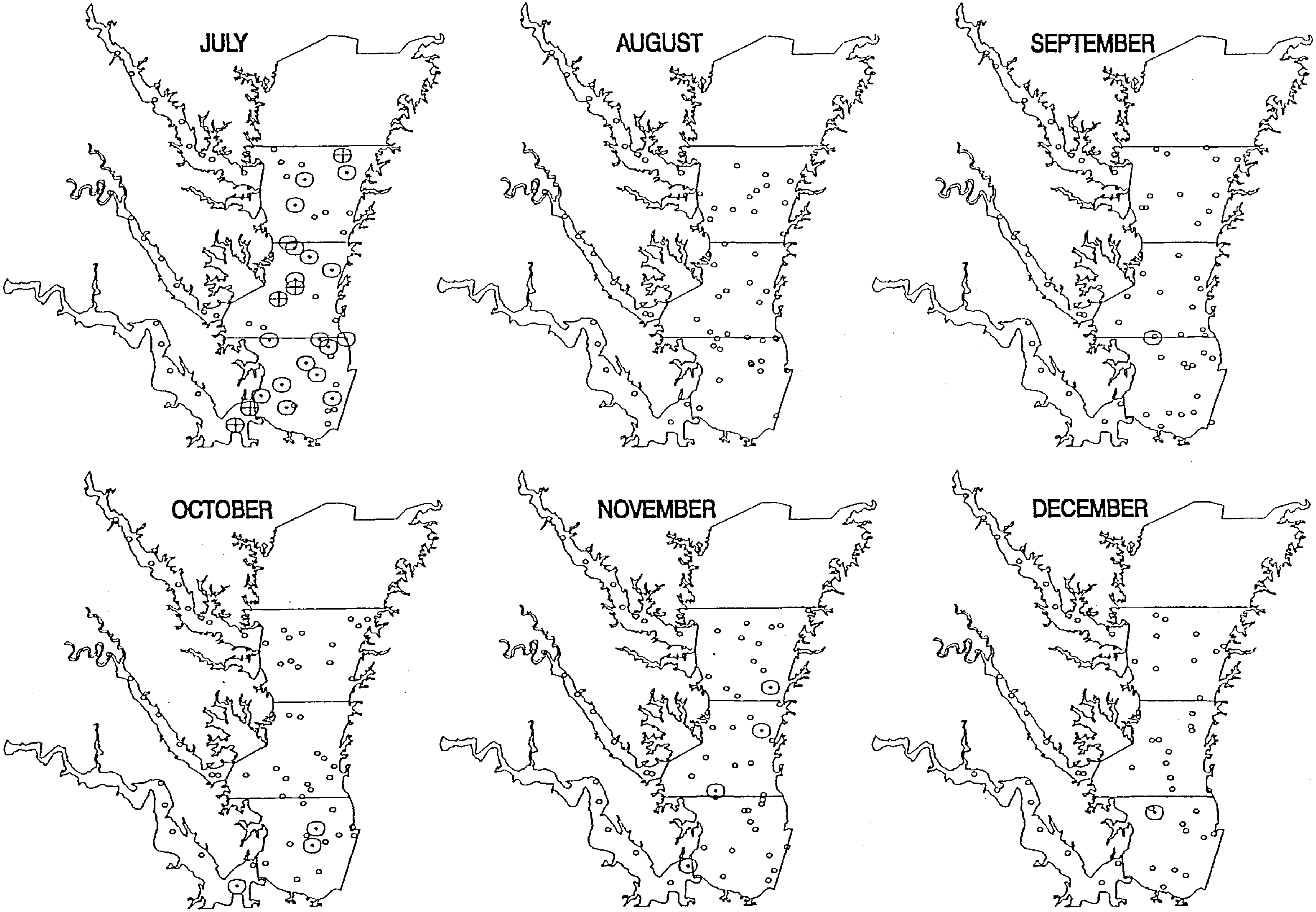
Appendix Figure 4-b.

Y-O-Y Black Sea Bass 1992



Appendix Figure 5-a.

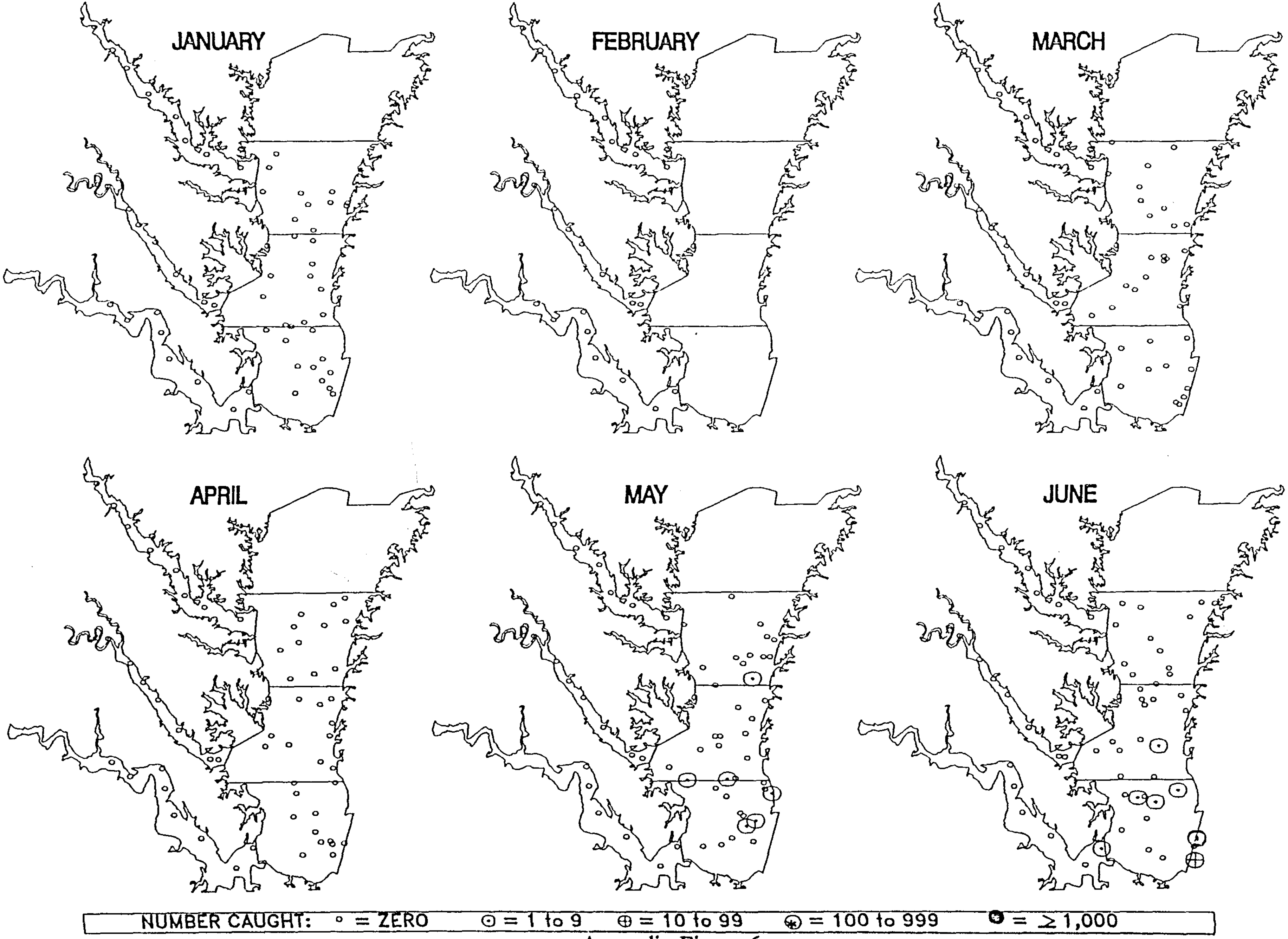
Y-O-Y Black Sea Bass 1992



NUMBER CAUGHT: ○ = ZERO ⊙ = 1 to 9 ⊕ = 10 to 99 ⊛ = 100 to 999 ● = ≥ 1,000

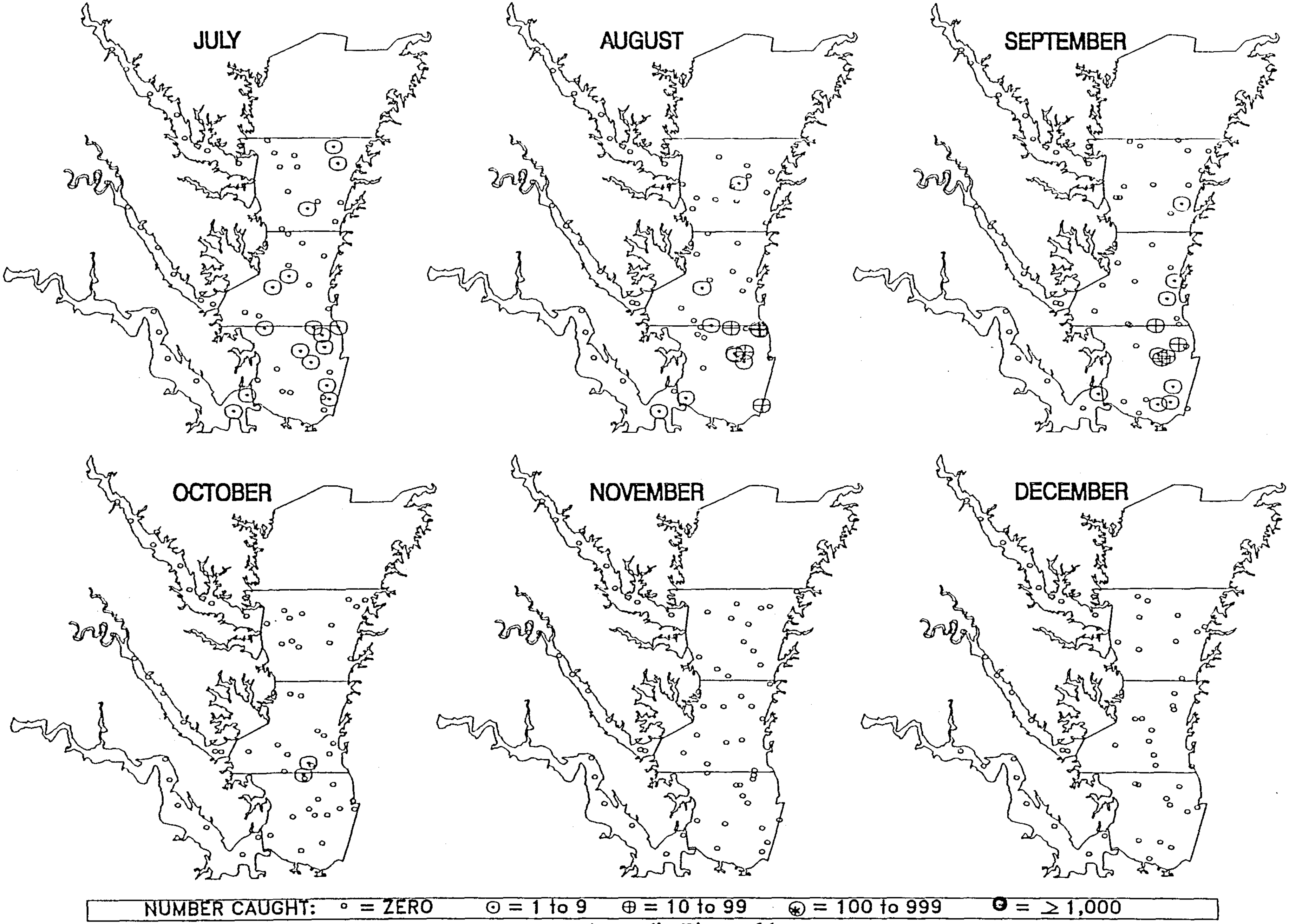
Appendix Figure 5-b.

AGE 1 Scup 1992

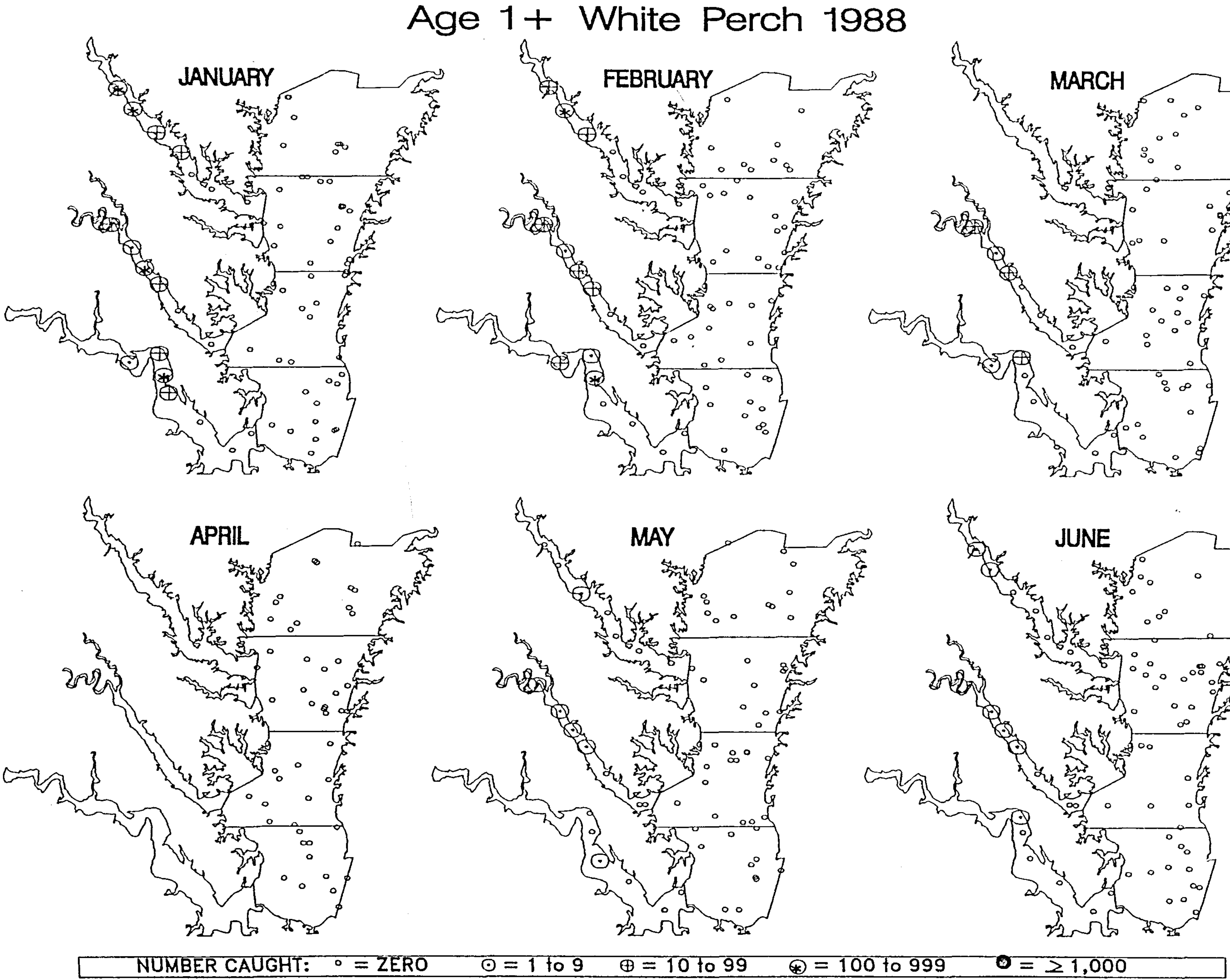


Appendix Figure 6-a.

AGE 1 Scup 1992

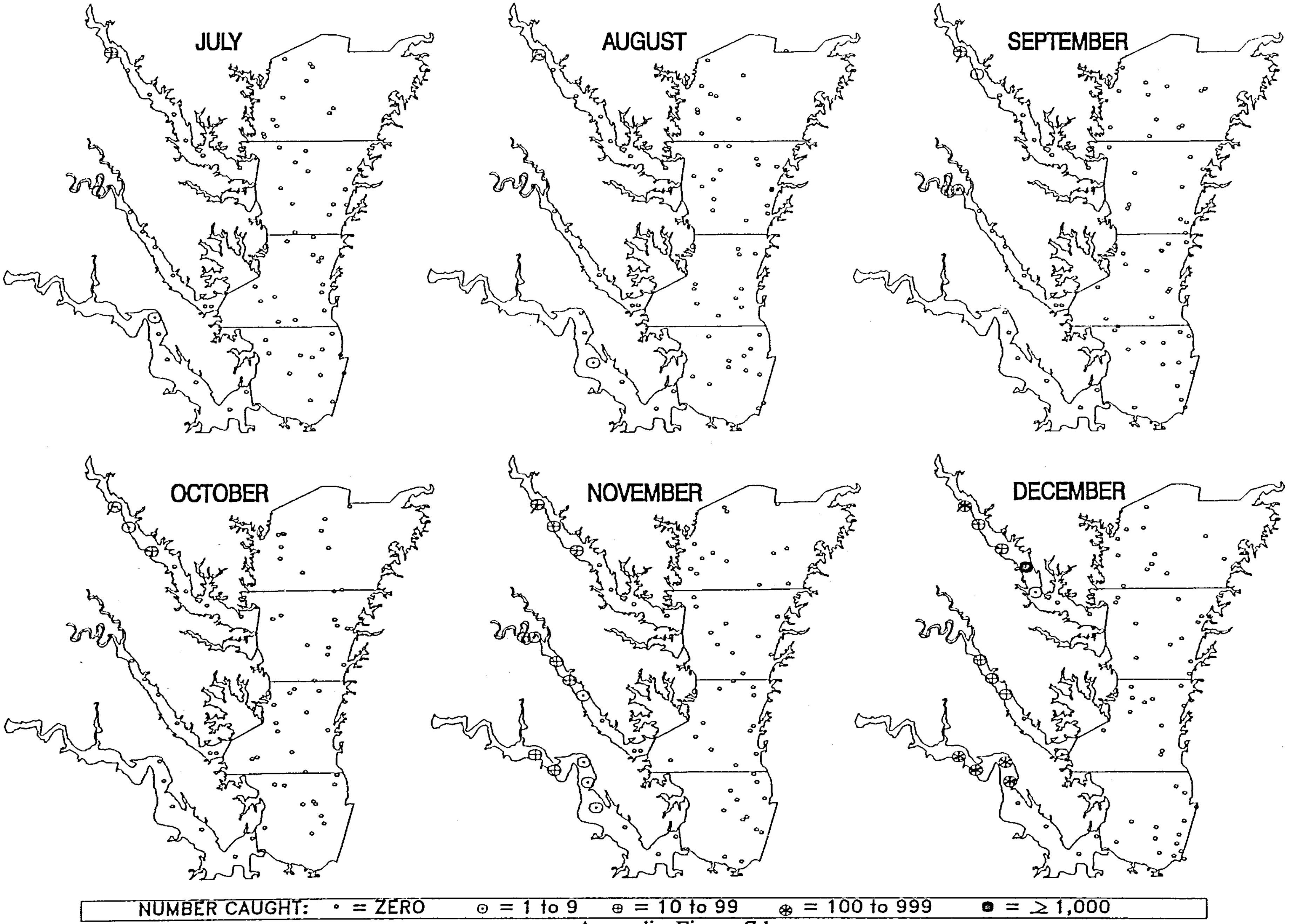


Appendix Figure 6-b.



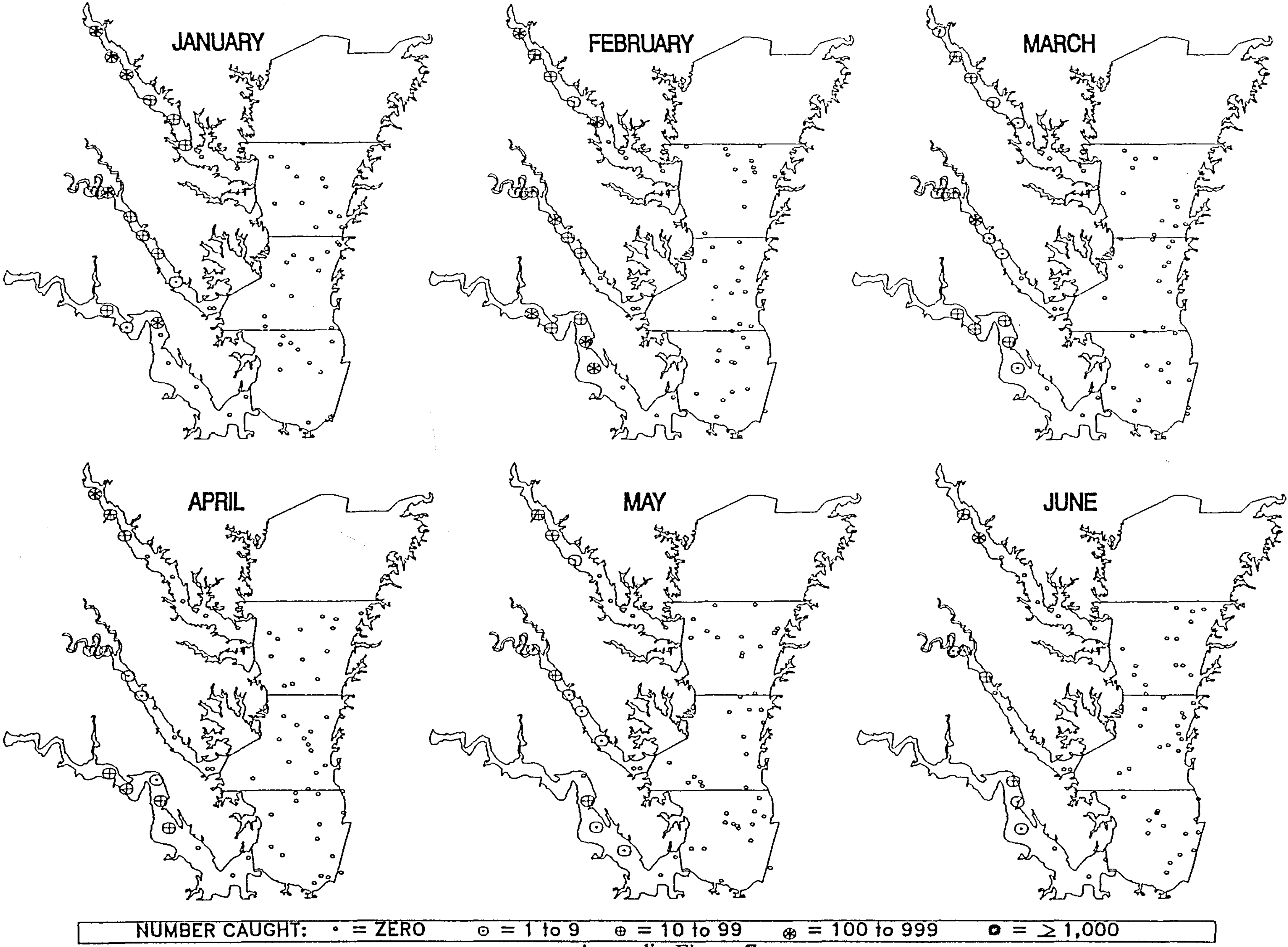
Age 1+ White Perch 1988

Appendix Figure 7-a.


AGE 1+ White Perch 1988

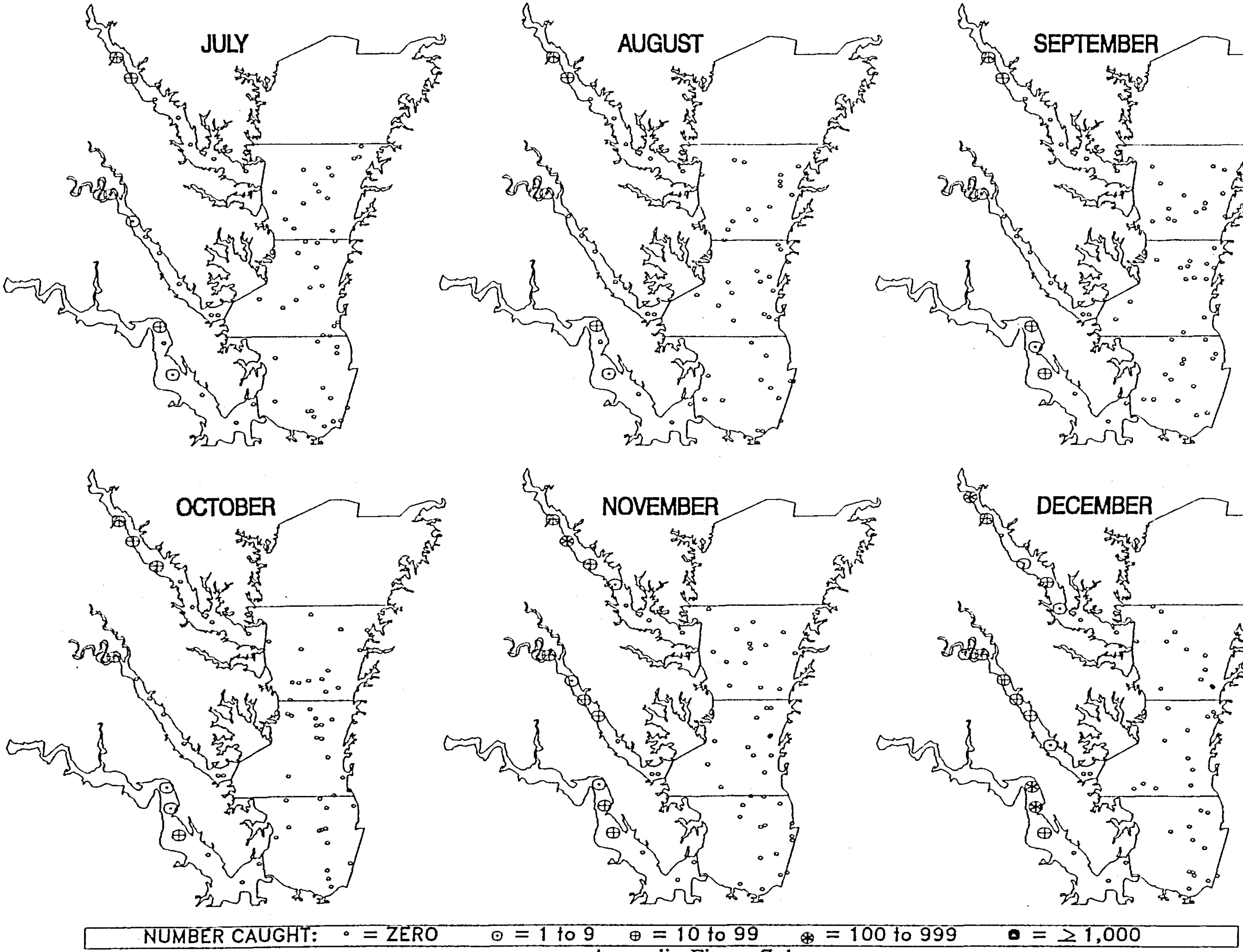
Appendix Figure 7-b.

AGE 1+ White Perch 1989



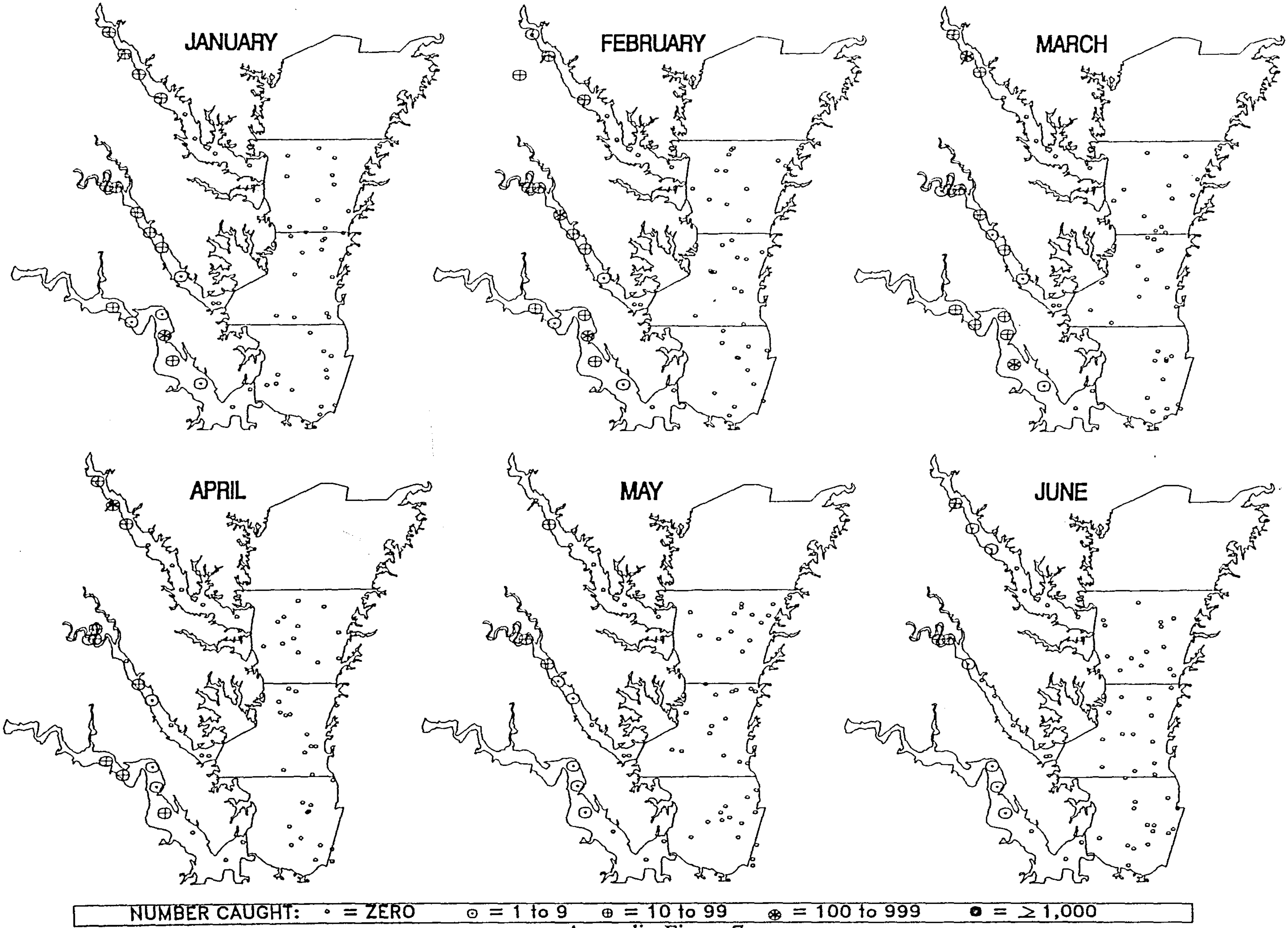
Appendix Figure 7-c.

AGE 1+ White Perch 1989



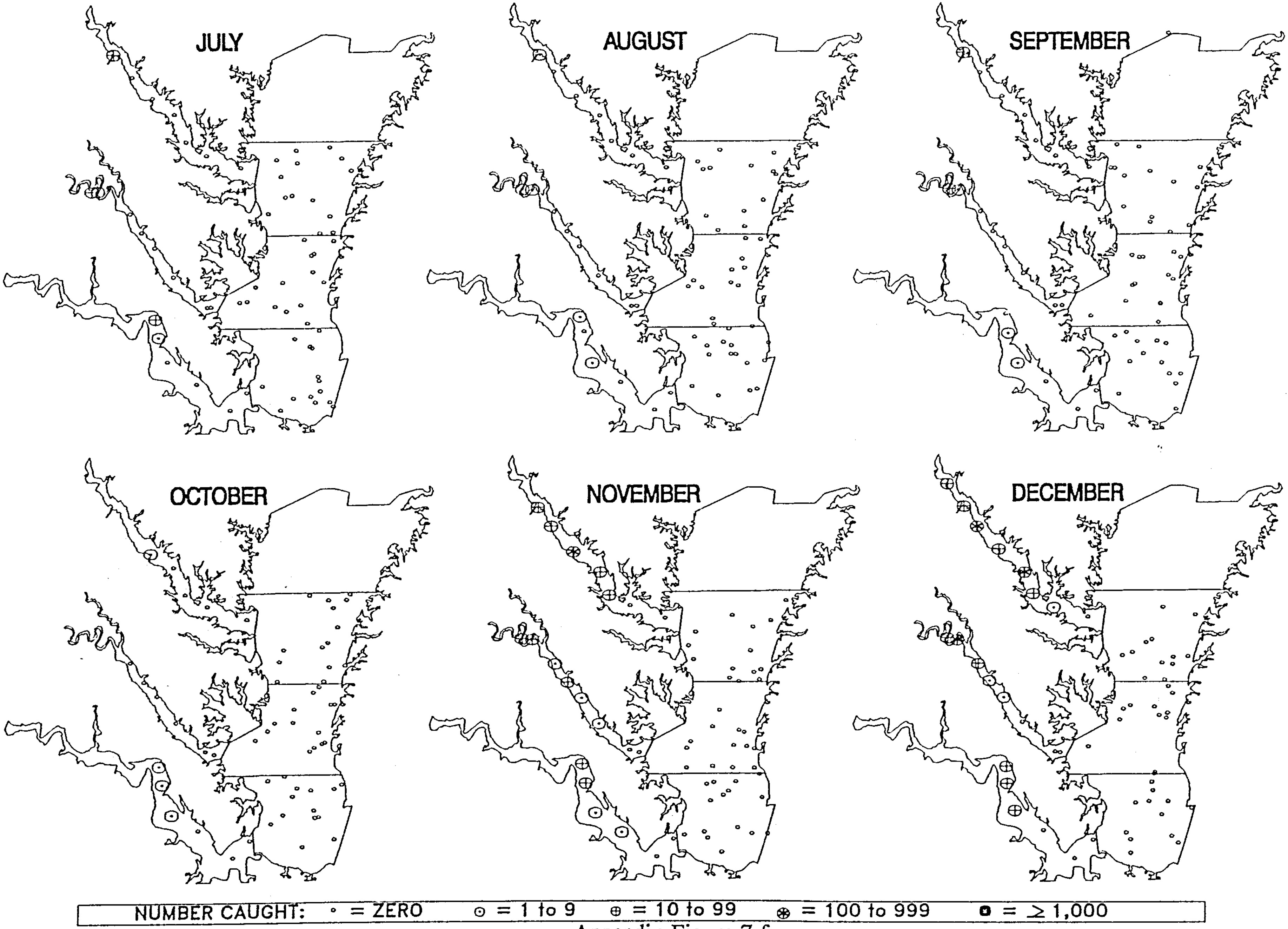
Appendix Figure 7-d.

AGE 1+ White Perch 1990



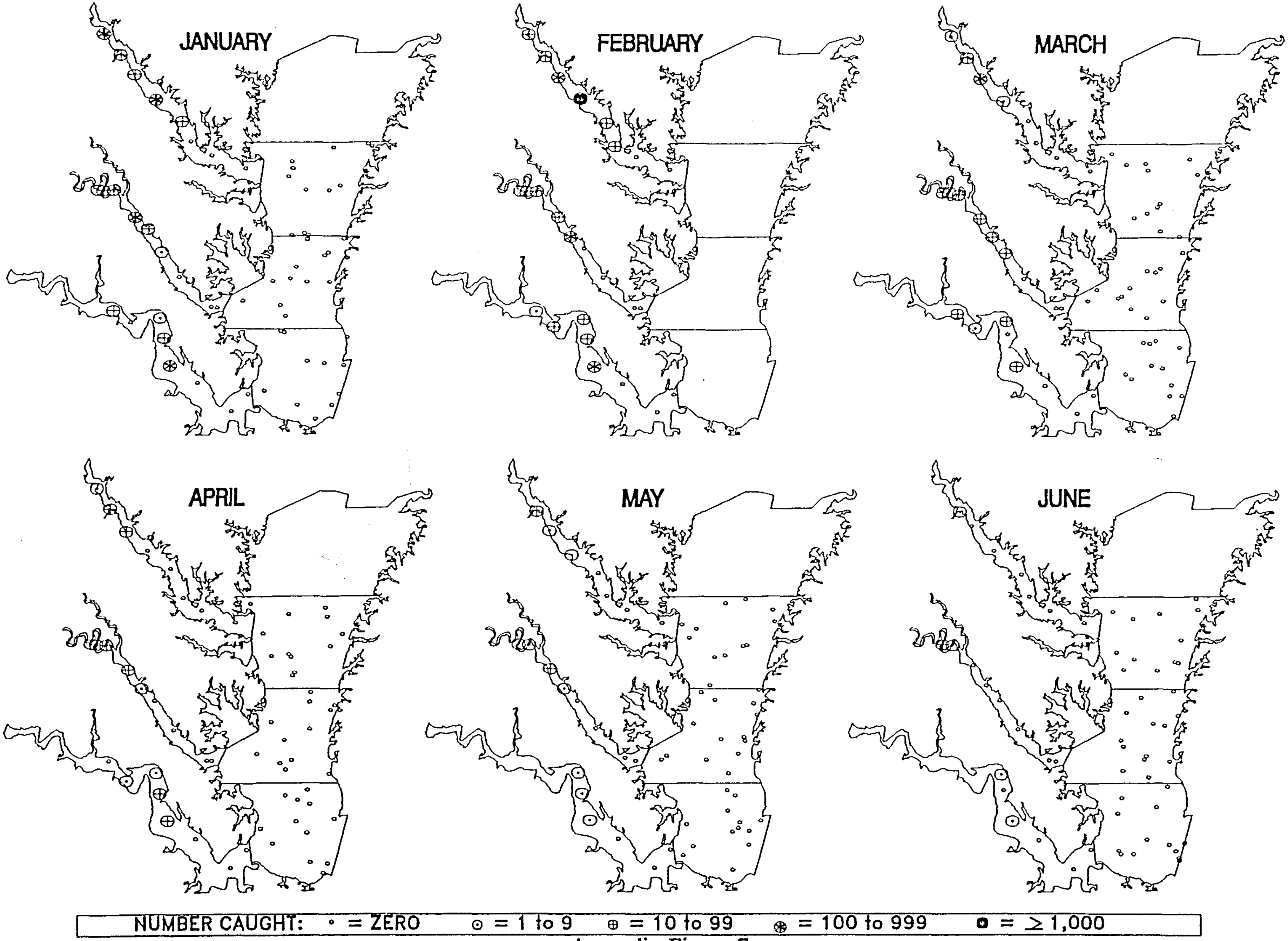
Appendix Figure 7-e.

AGE 1+ White Perch 1990



Appendix Figure 7-f.

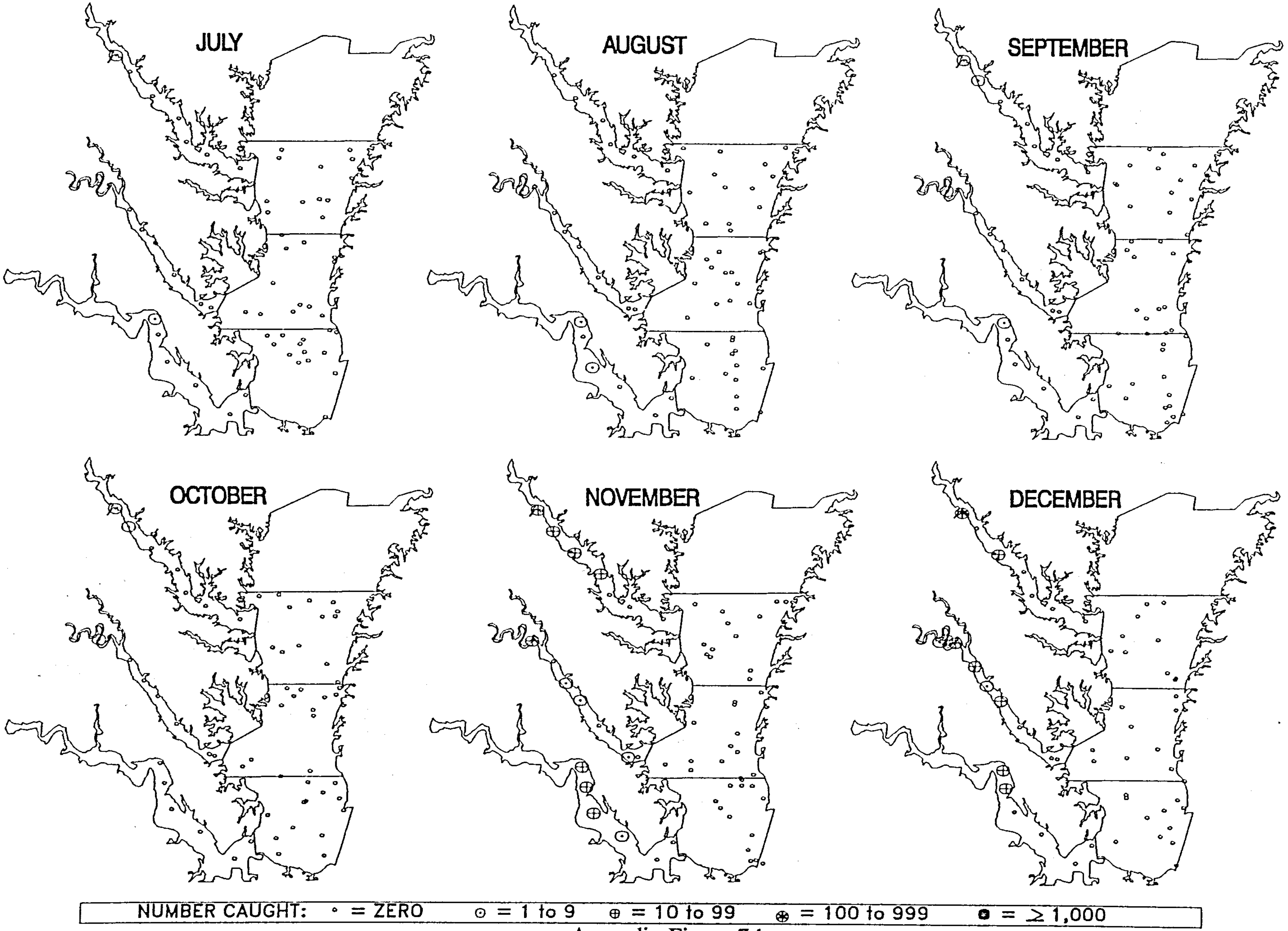
AGE 1+ White Perch 1991



NUMBER CAUGHT: • = ZERO ⊙ = 1 to 9 ⊕ = 10 to 99 ⊛ = 100 to 999 ● = ≥ 1,000

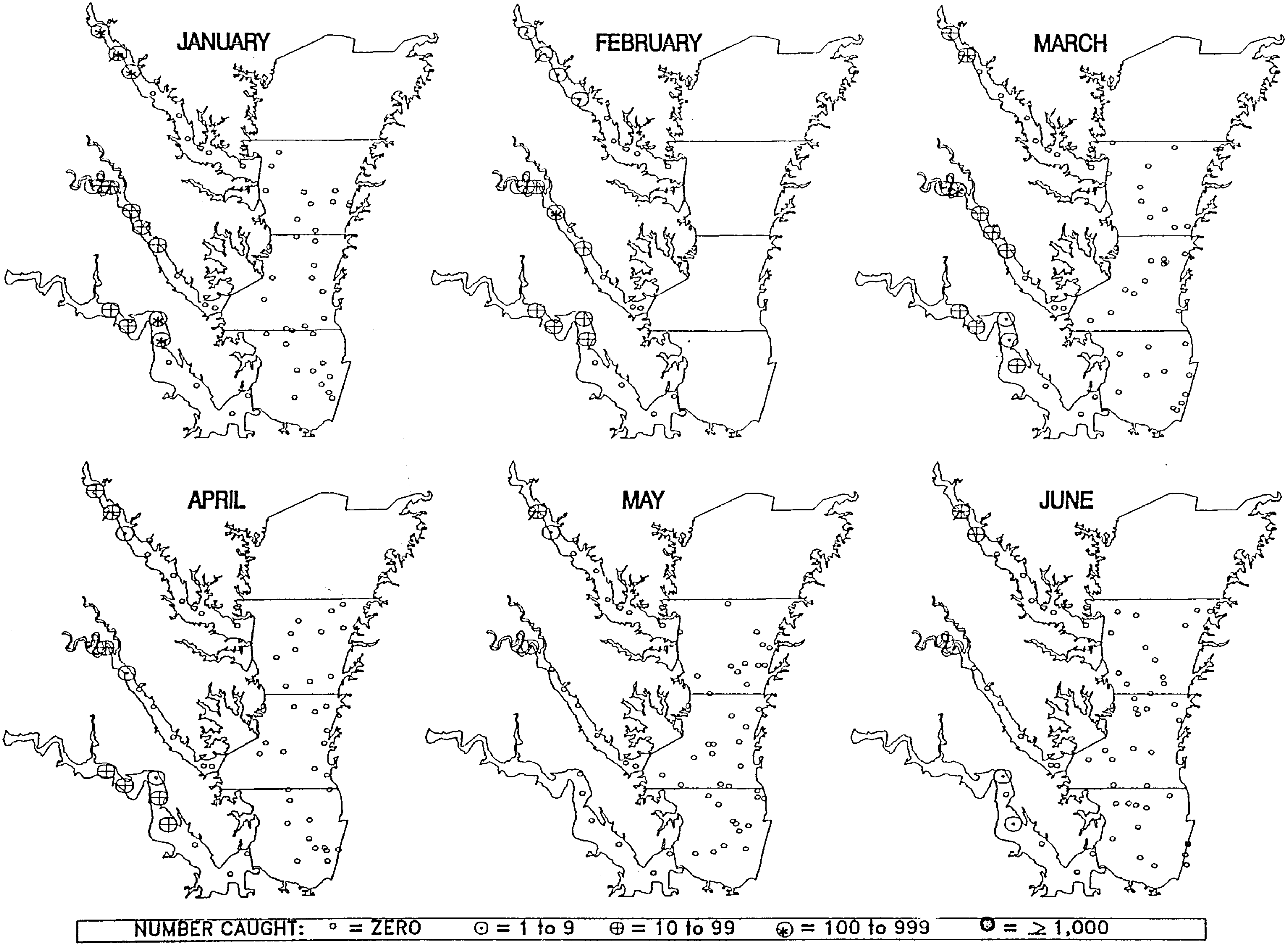
Appendix Figure 7-g.

AGE 1+ White Perch 1991



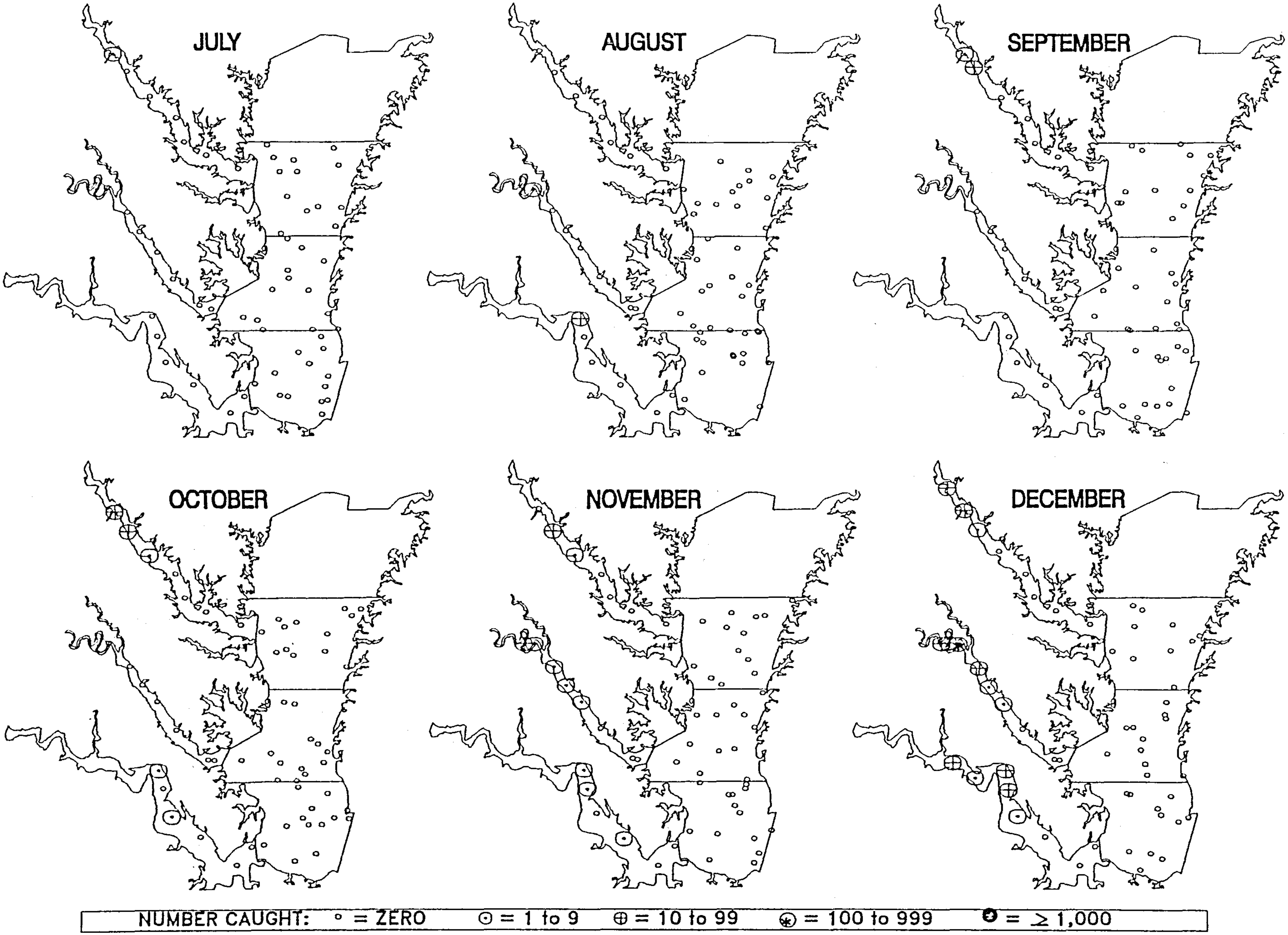
Appendix Figure 7-h.

AGE 1+ White Perch 1992



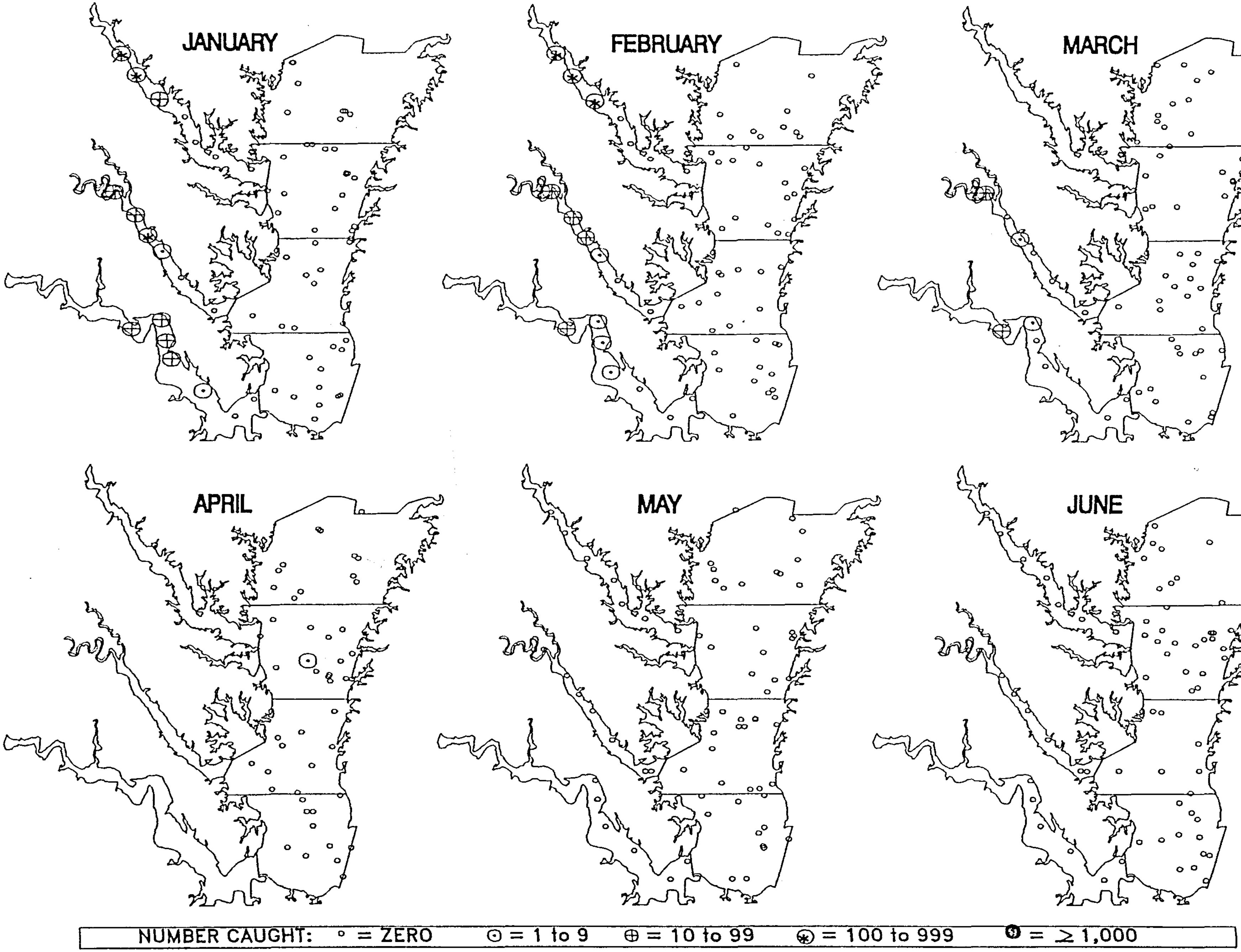
Appendix Figure 7-i.

AGE 1+ White Perch 1992



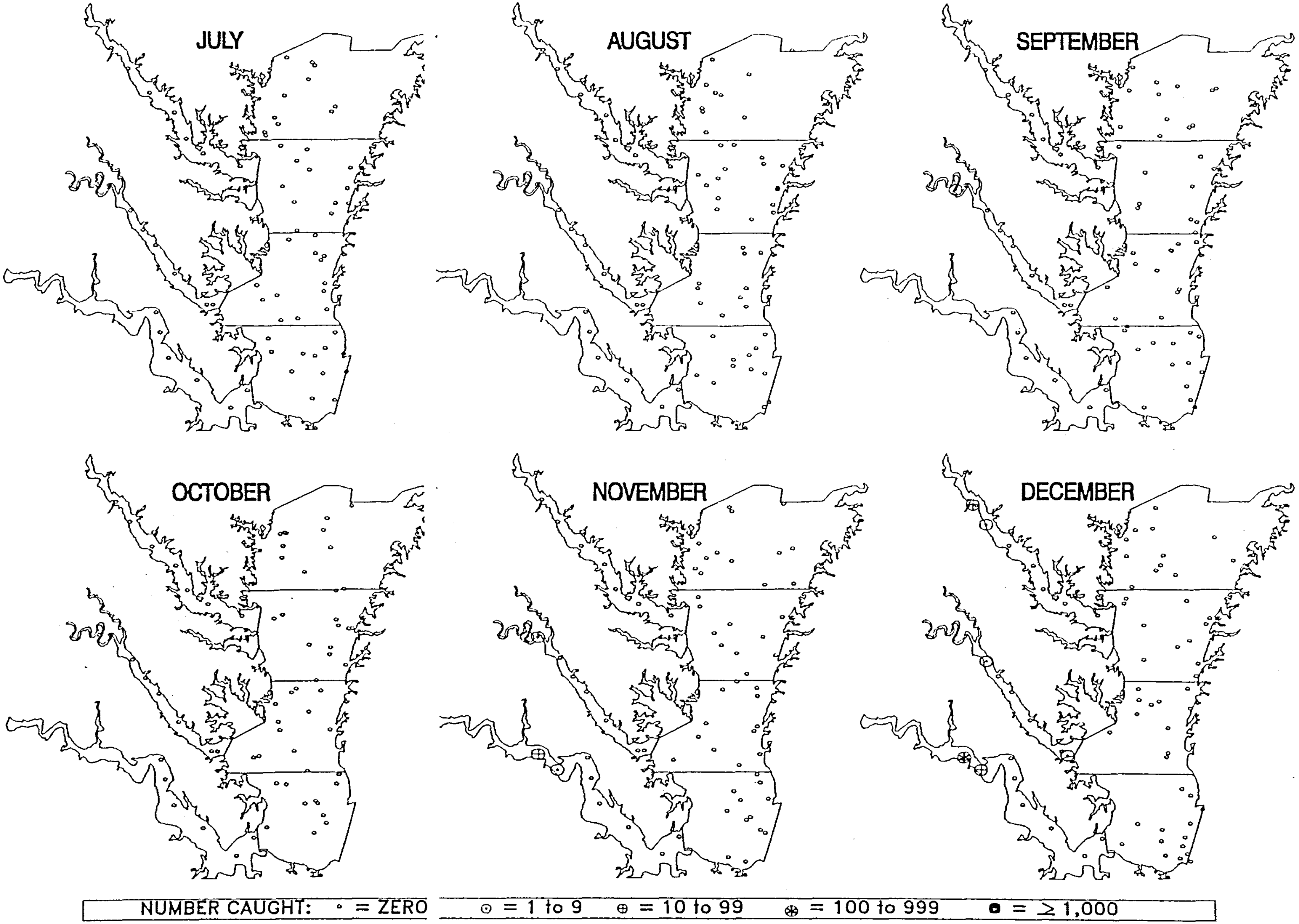
Appendix Figure 7-j.

Y–O–Y White Perch 1988



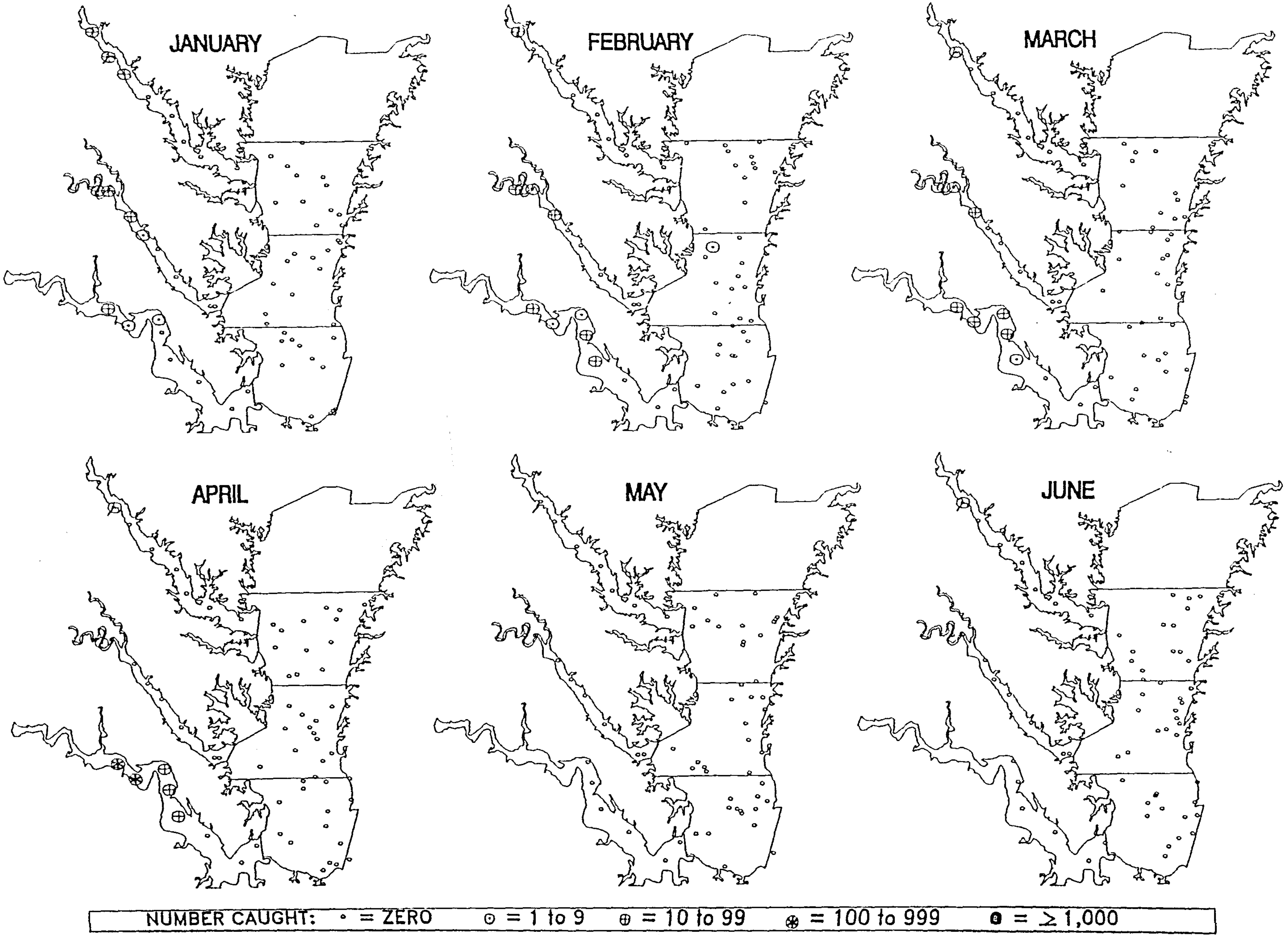
Appendix Figure 8-a.

Y—O—Y White Perch 1988



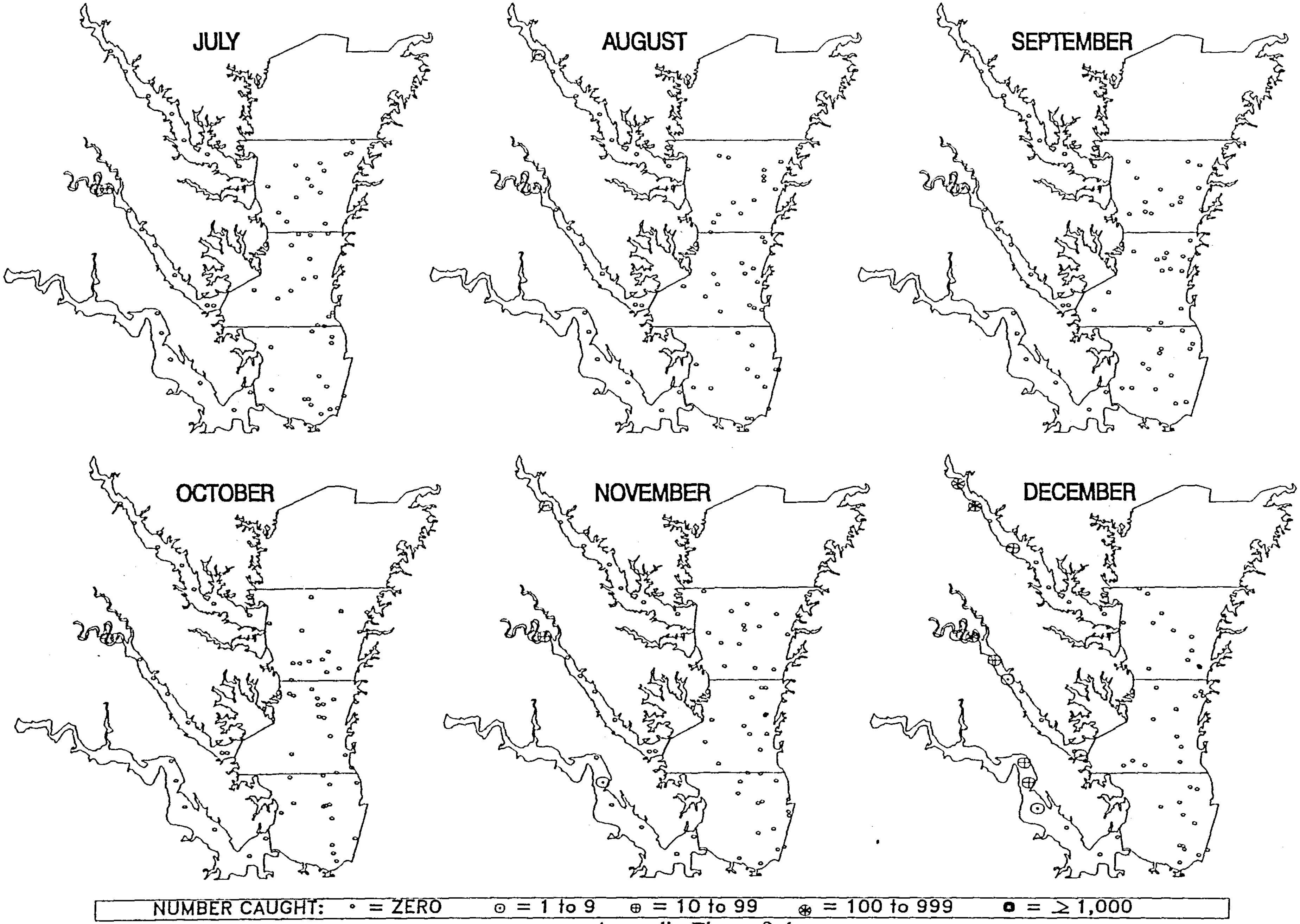
Appendix Figure 8-b.

Y-O-Y White Perch 1989



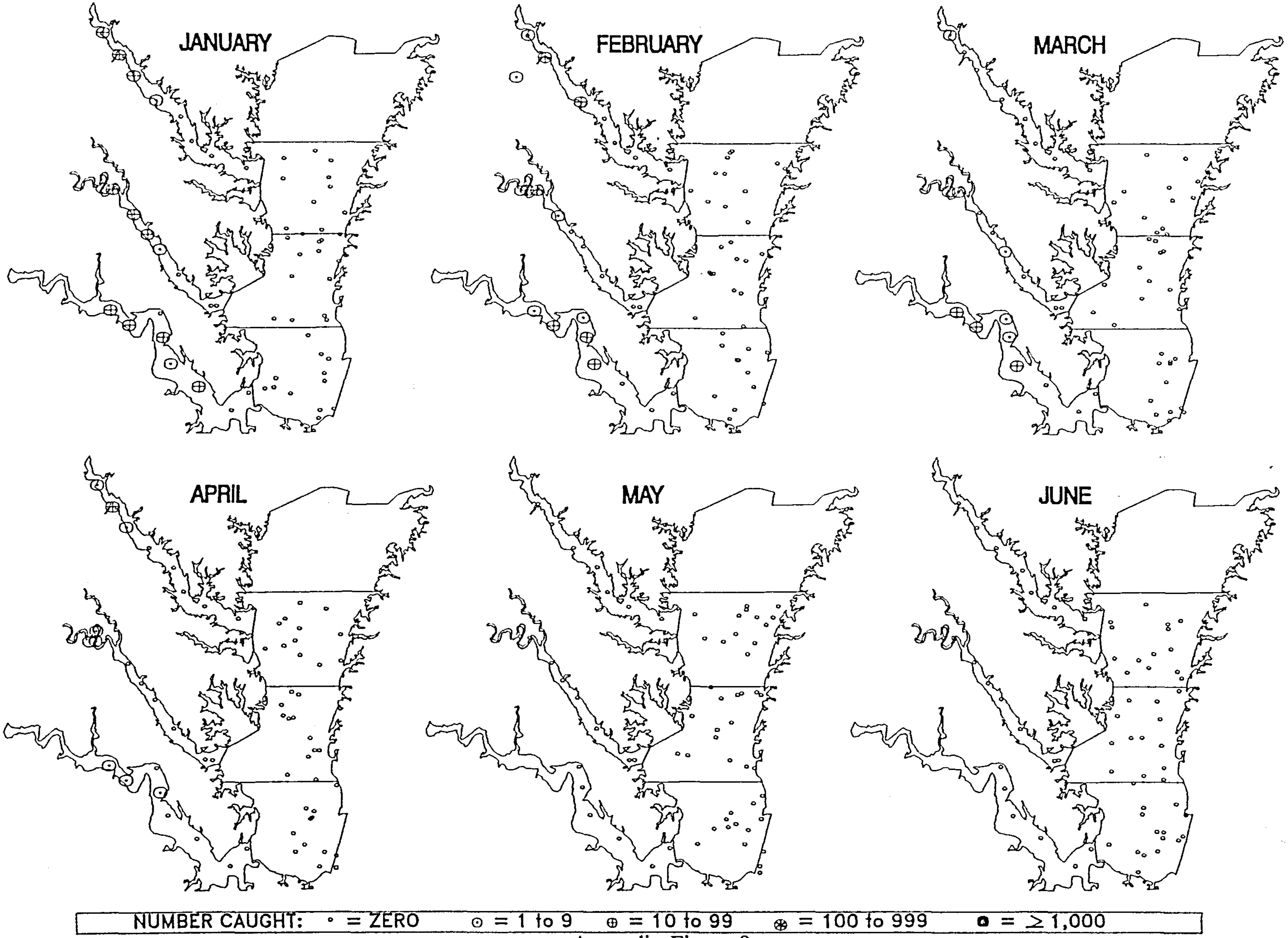
Appendix Figure 8-c.

Y–O–Y White Perch 1989



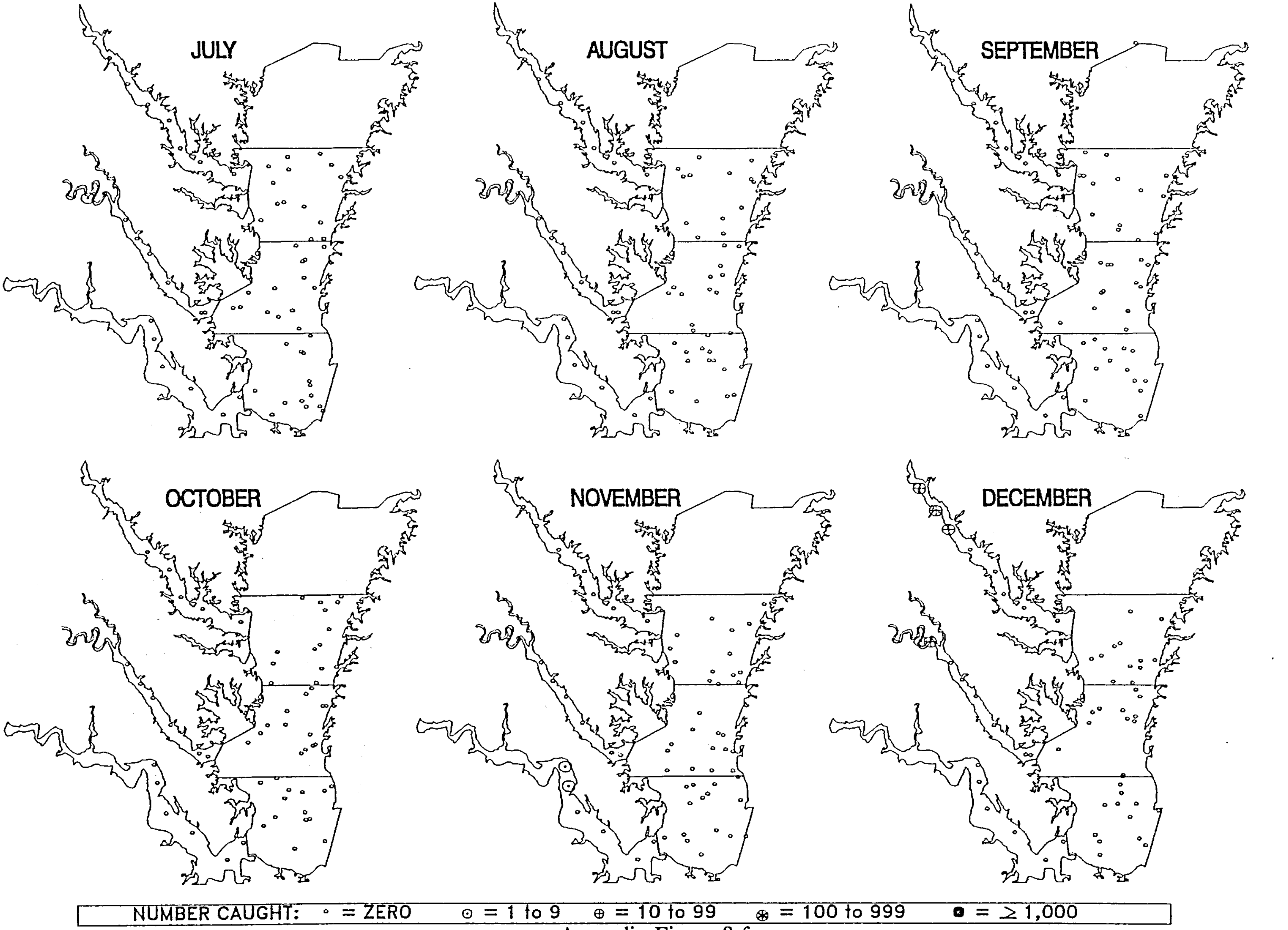
Appendix Figure 8-d.

Y–O–Y White Perch 1990

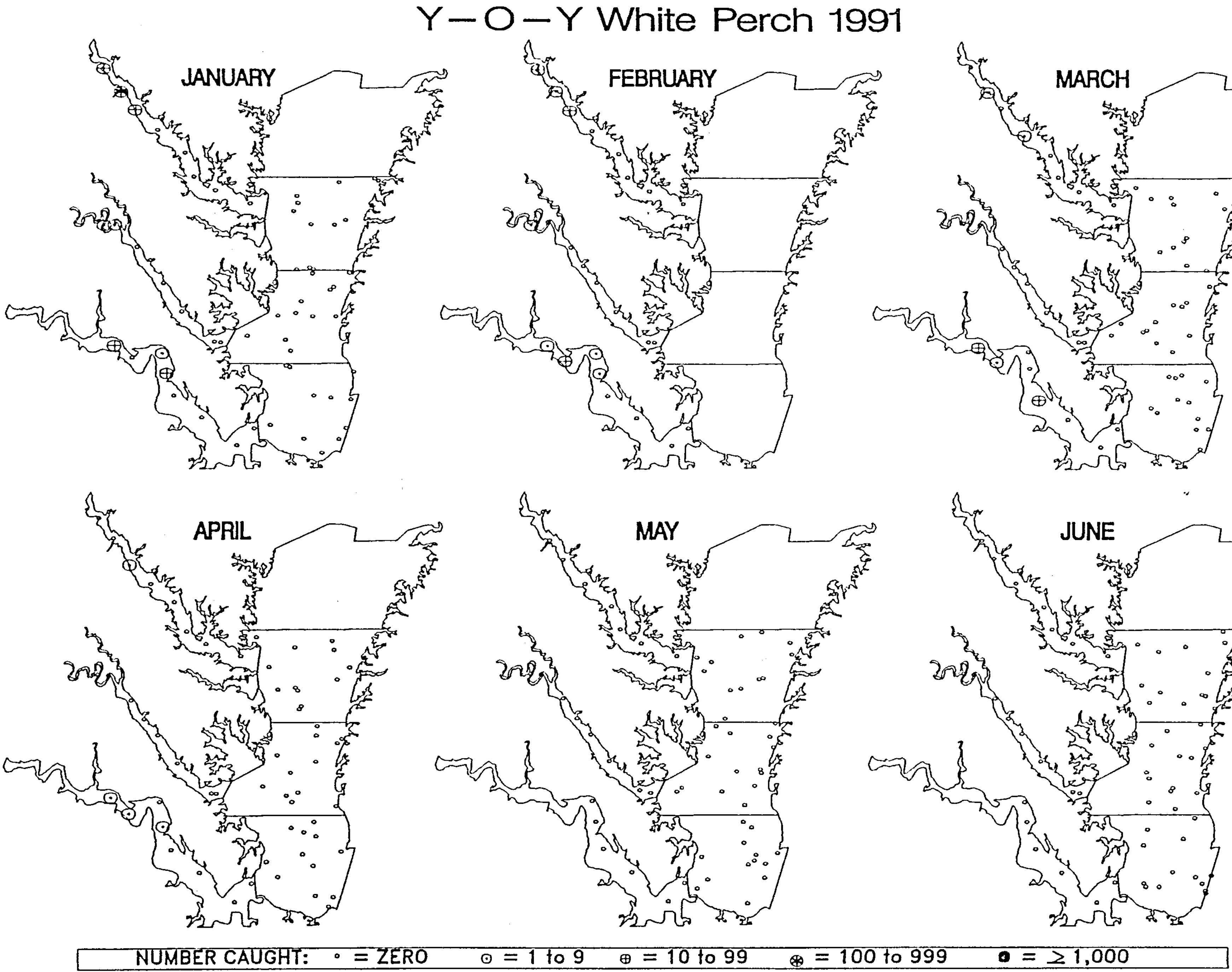


Appendix Figure 8-e.

Y-O-Y White Perch 1990



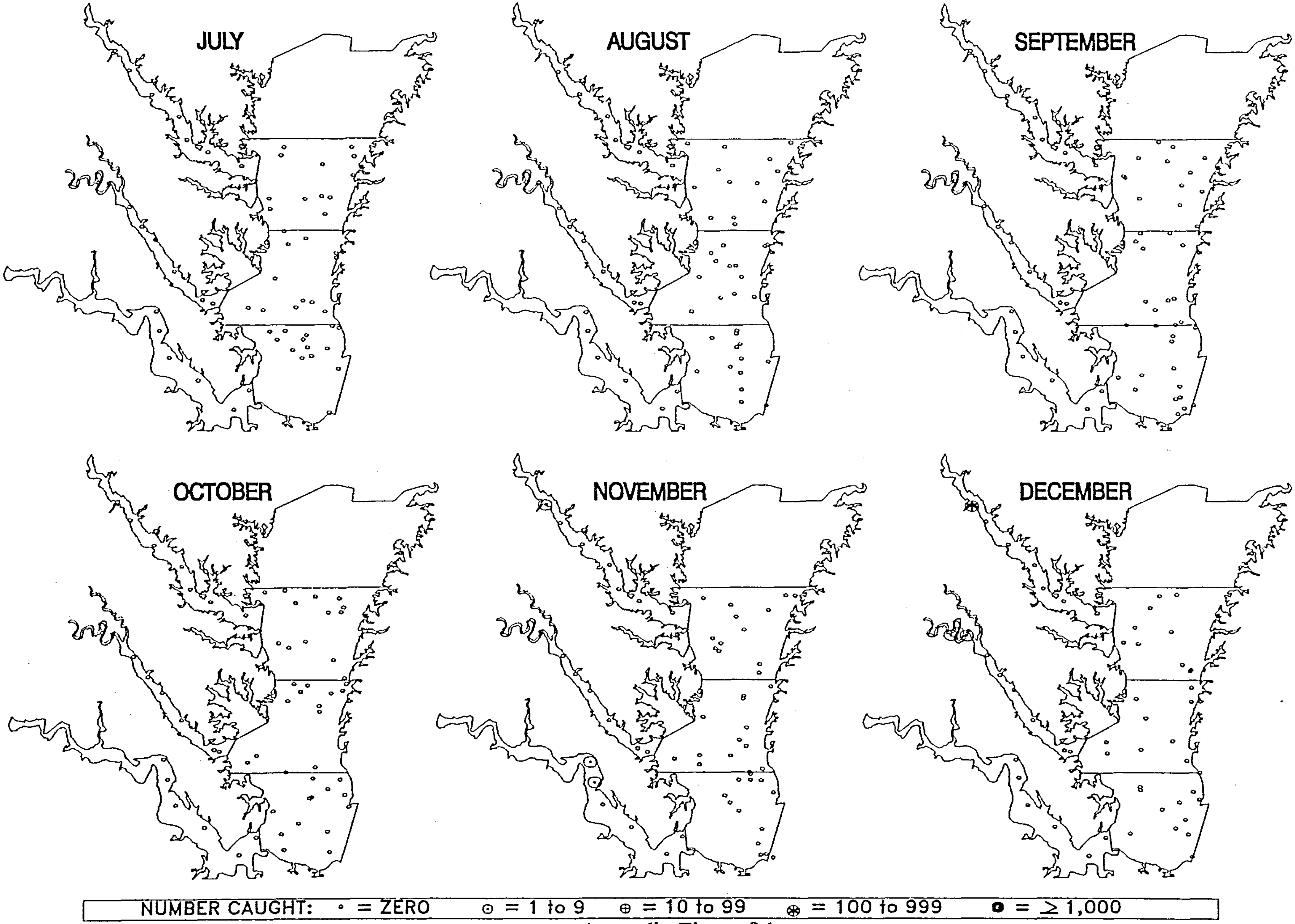
Appendix Figure 8-f.



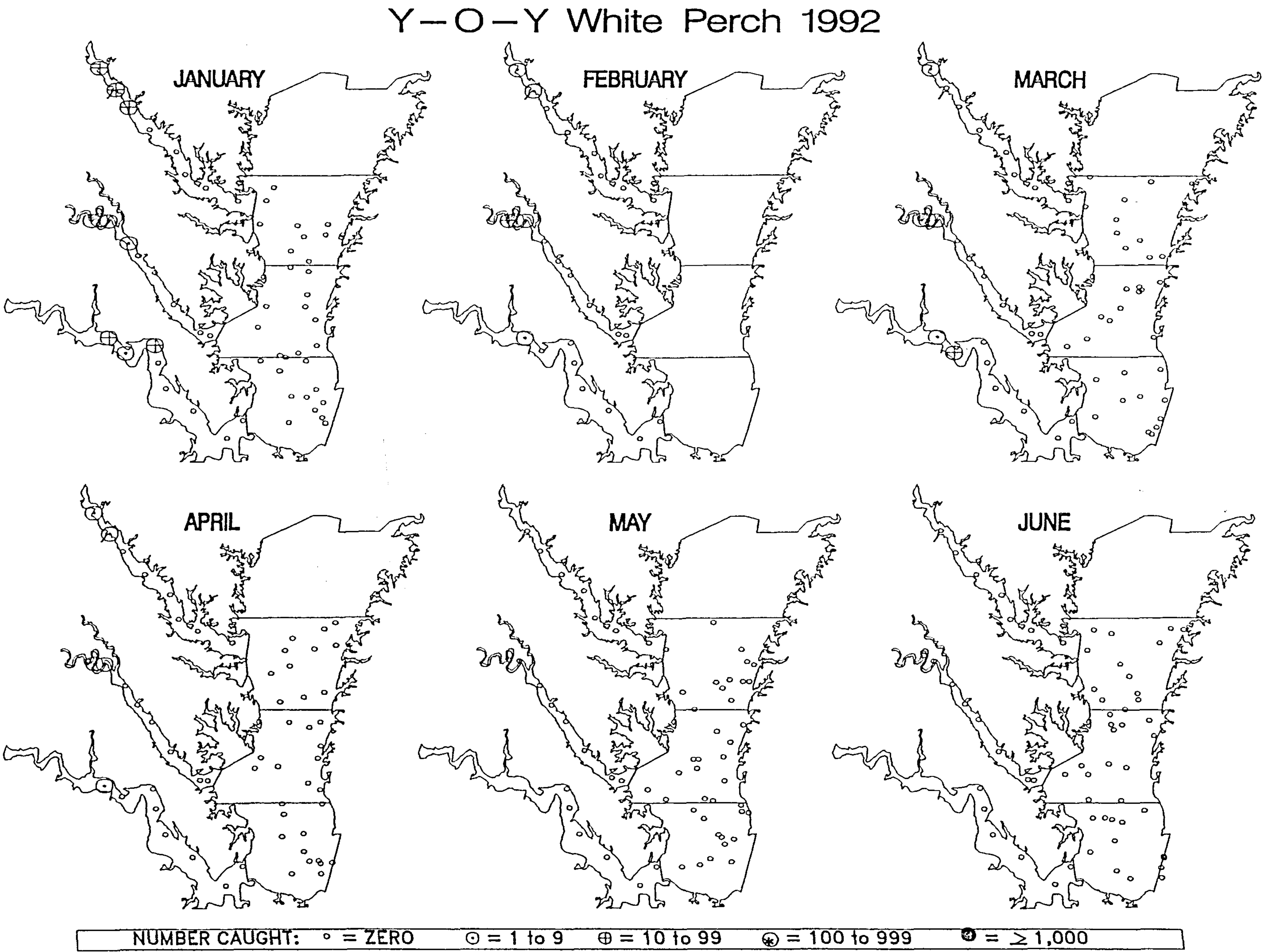
Y–O–Y White Perch 1991

Appendix Figure 8-g.

Y-O-Y White Perch 1991

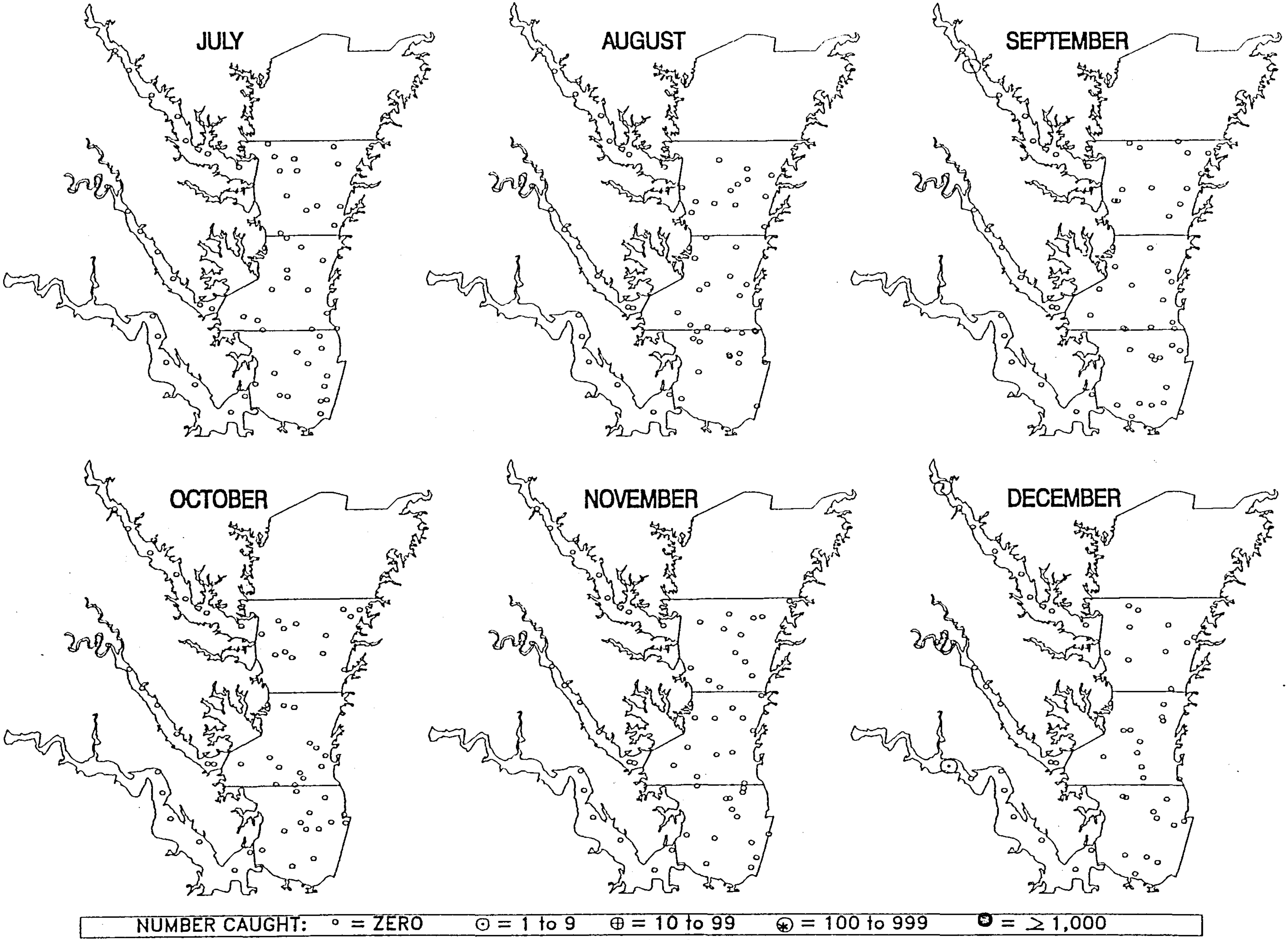


Appendix Figure 8-h.



Appendix Figure 8-i.

Y–O–Y White Perch 1992



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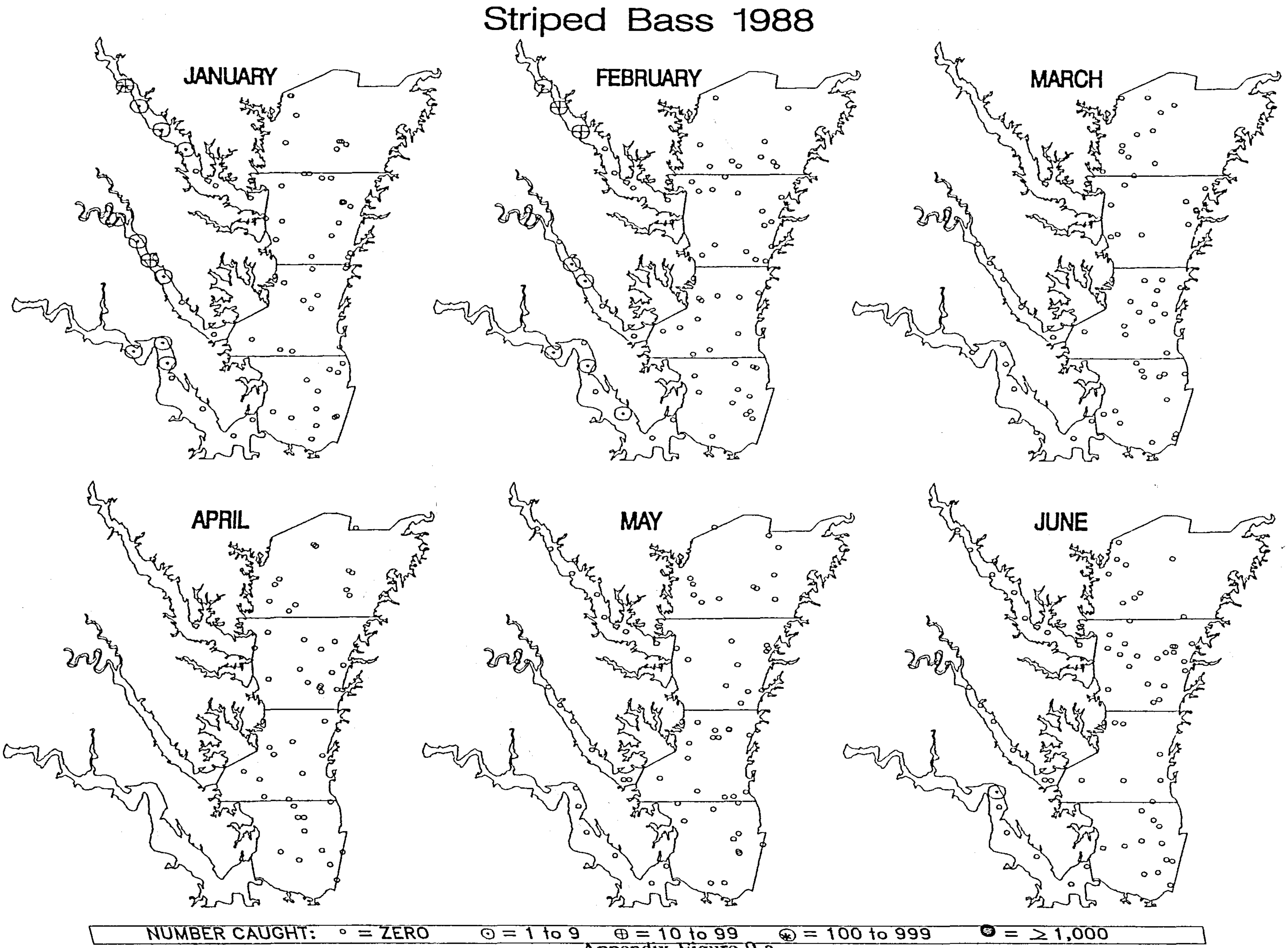
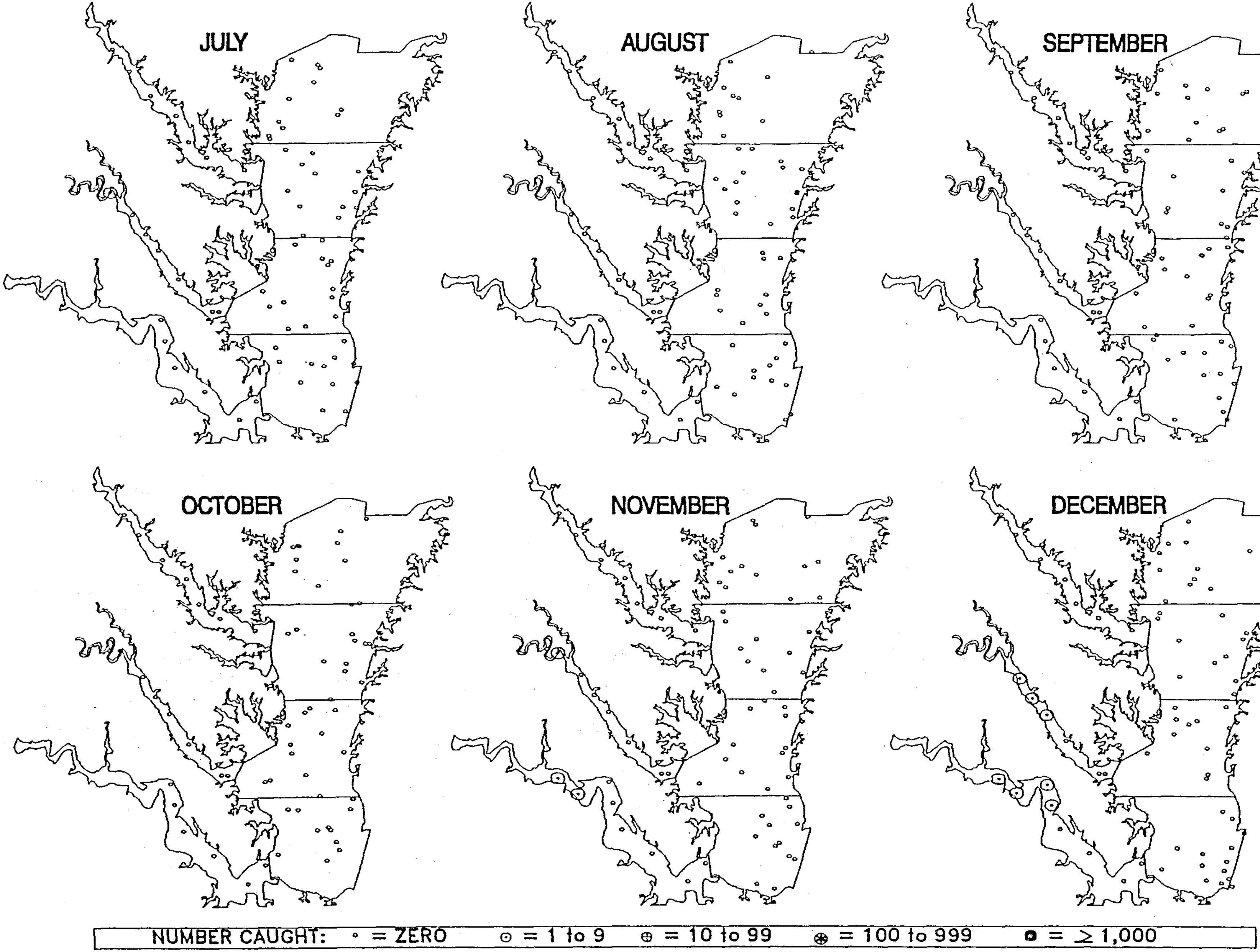


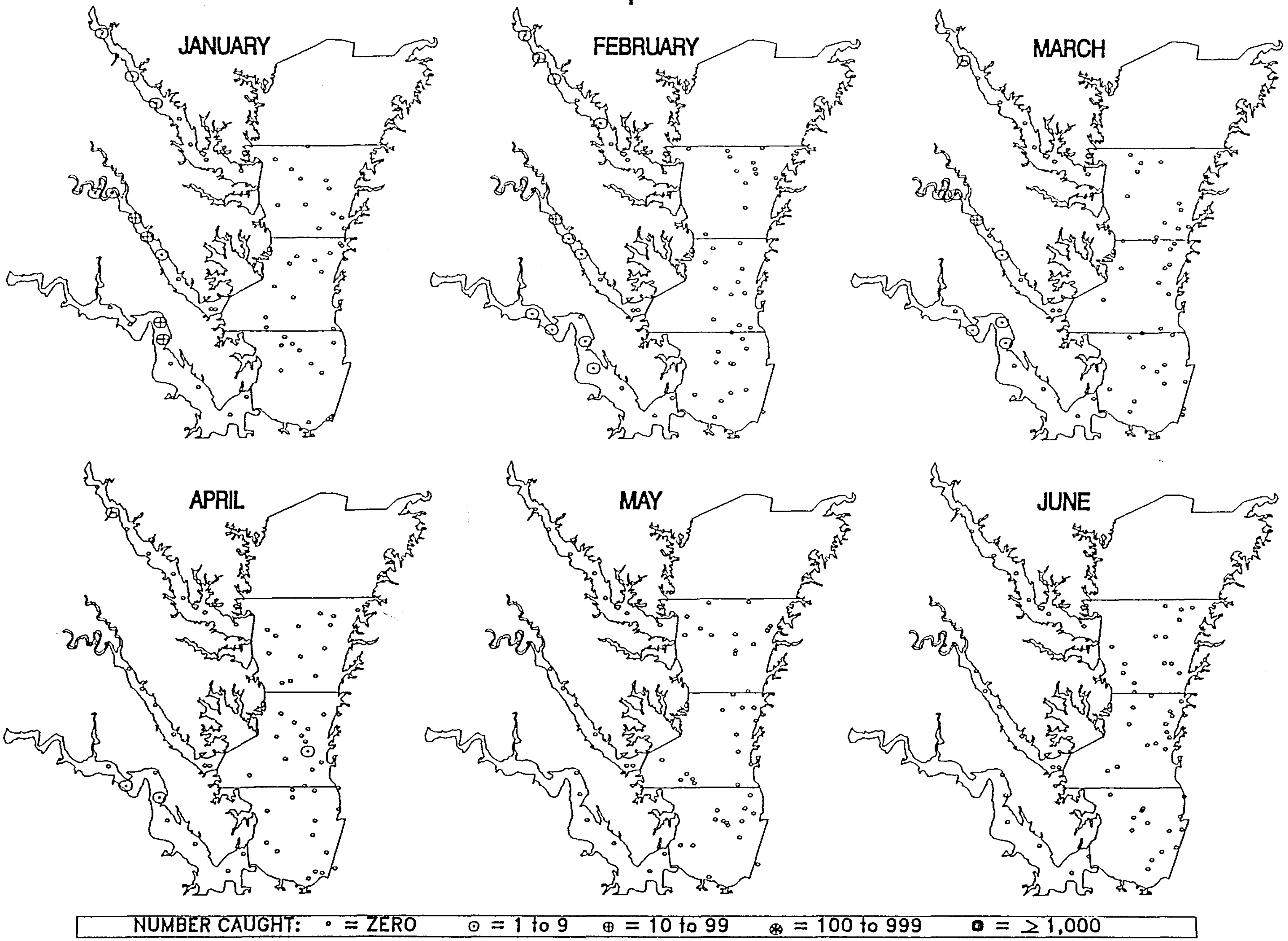
Appendix Figure 9-a.



Y—O—Y Striped Bass 1988

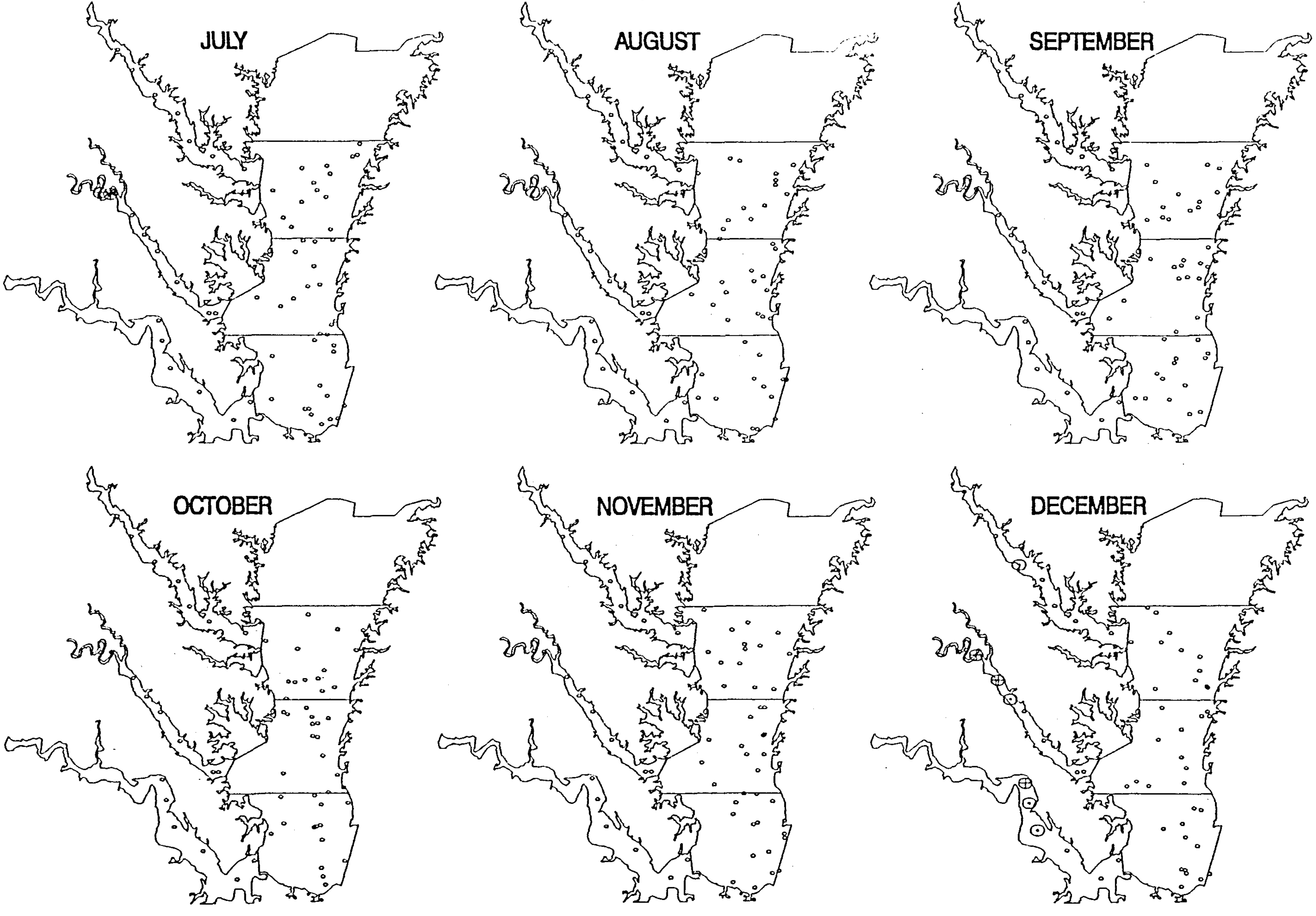
Appendix Figure 9-b.

Y–O–Y Striped Bass 1989



Appendix Figure 9-c.

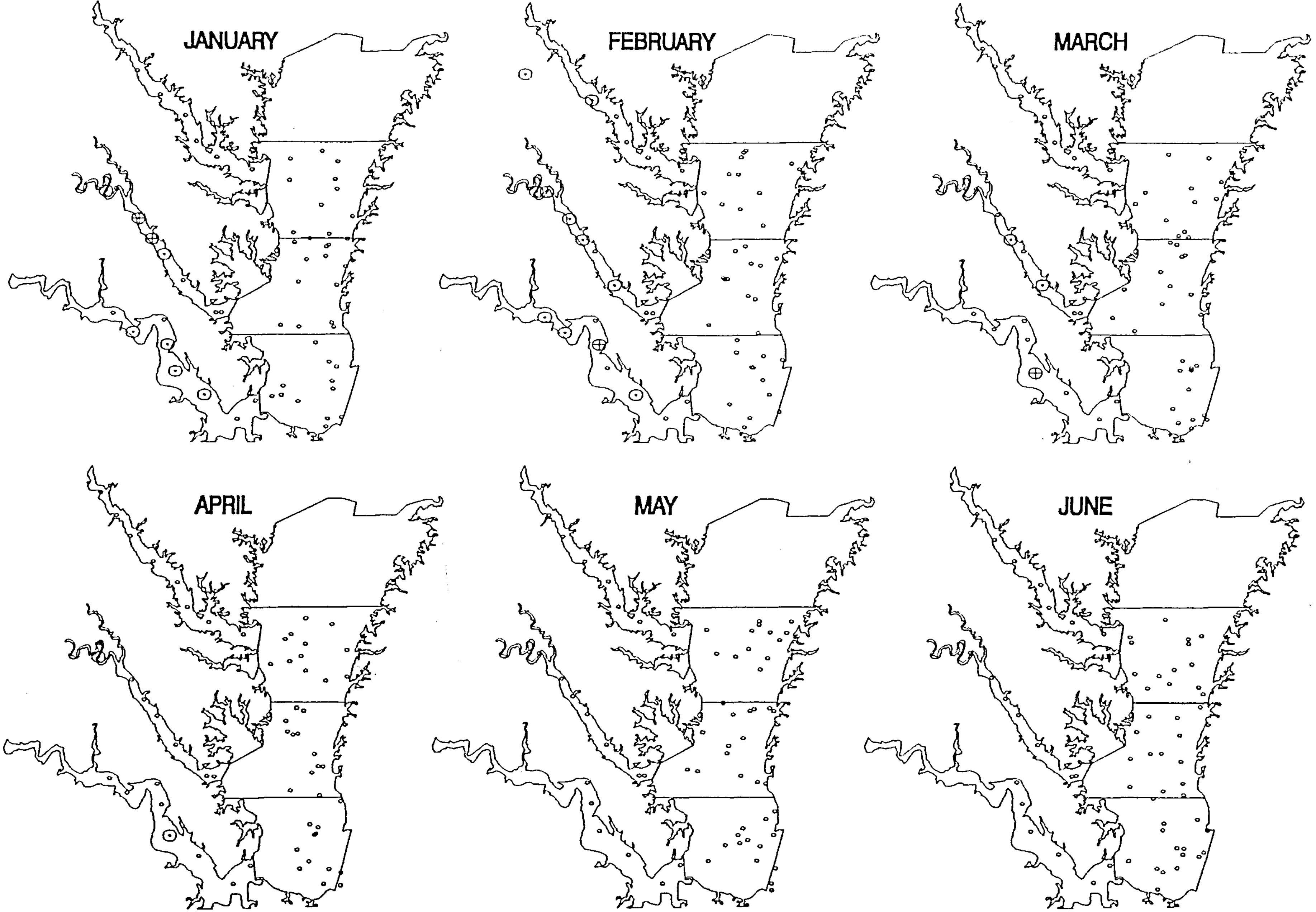
Y – O – Y Striped Bass 1989



NUMBER CAUGHT: ∘ = ZERO ⊙ = 1 to 9 ⊕ = 10 to 99 ⊛ = 100 to 999 ● = ≥ 1,000

Appendix Figure 9-d.

Y–O–Y Striped Bass 1990



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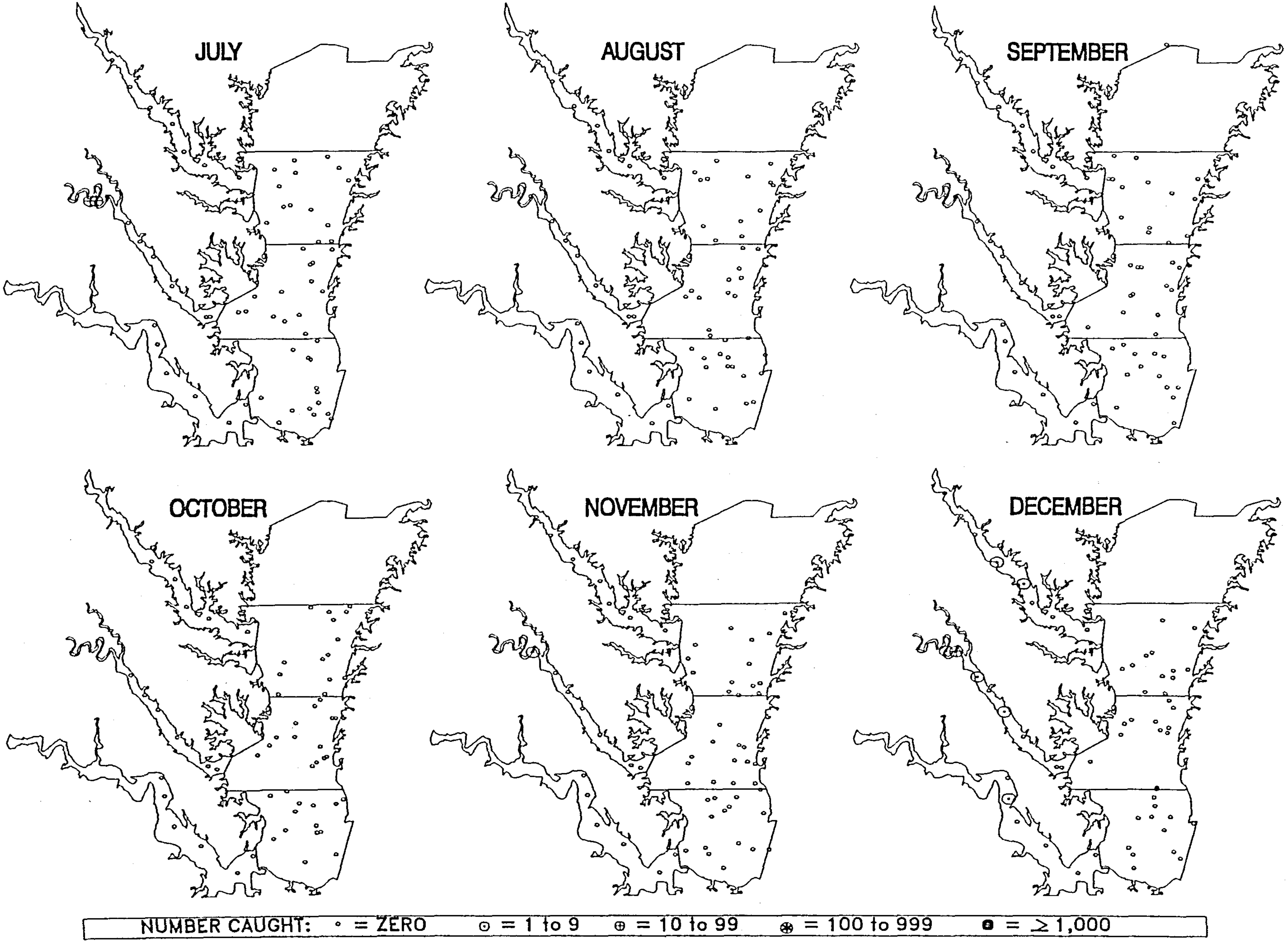
Appendix Figure 9-e.

Y-O-Y Striped Bass 1990



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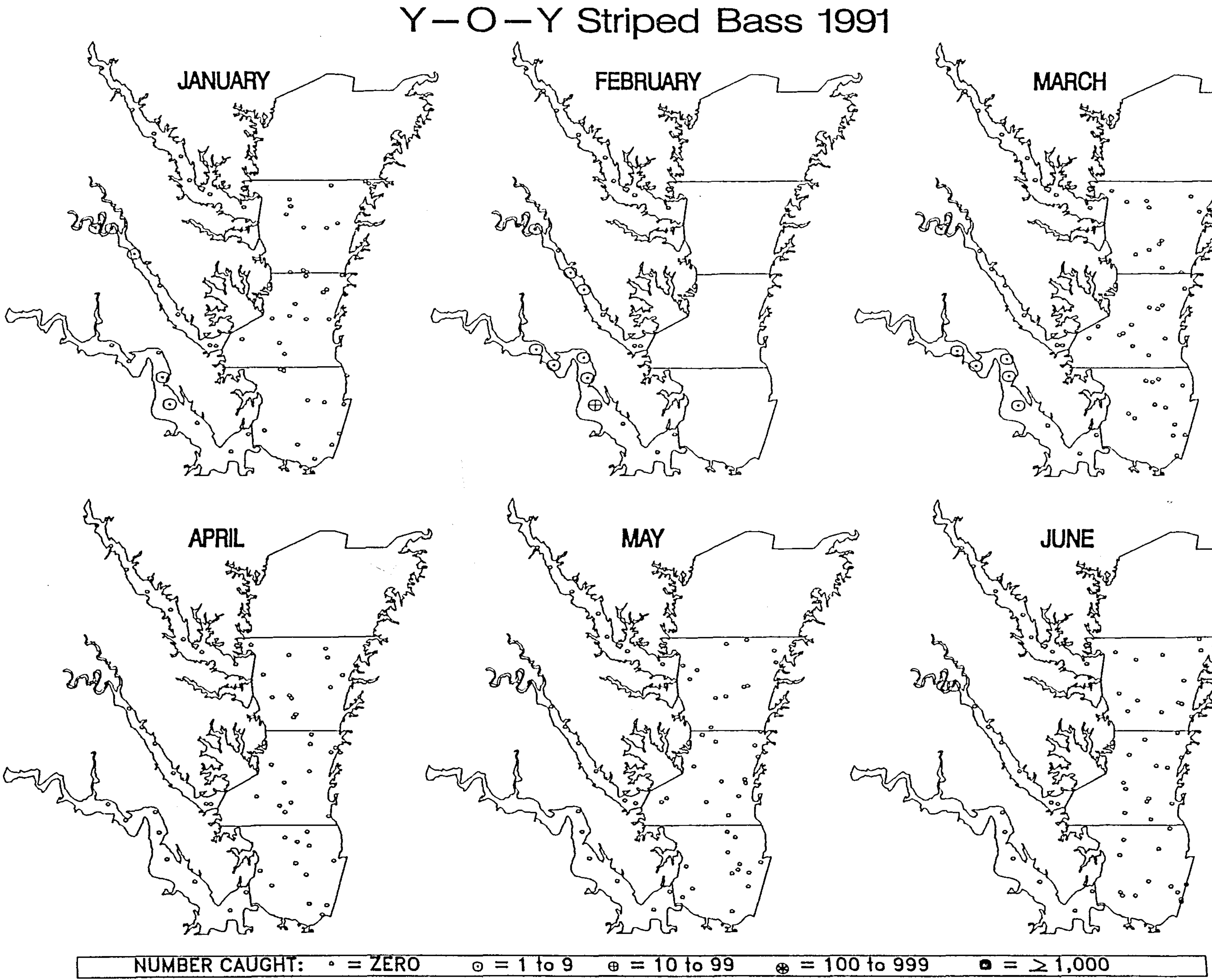
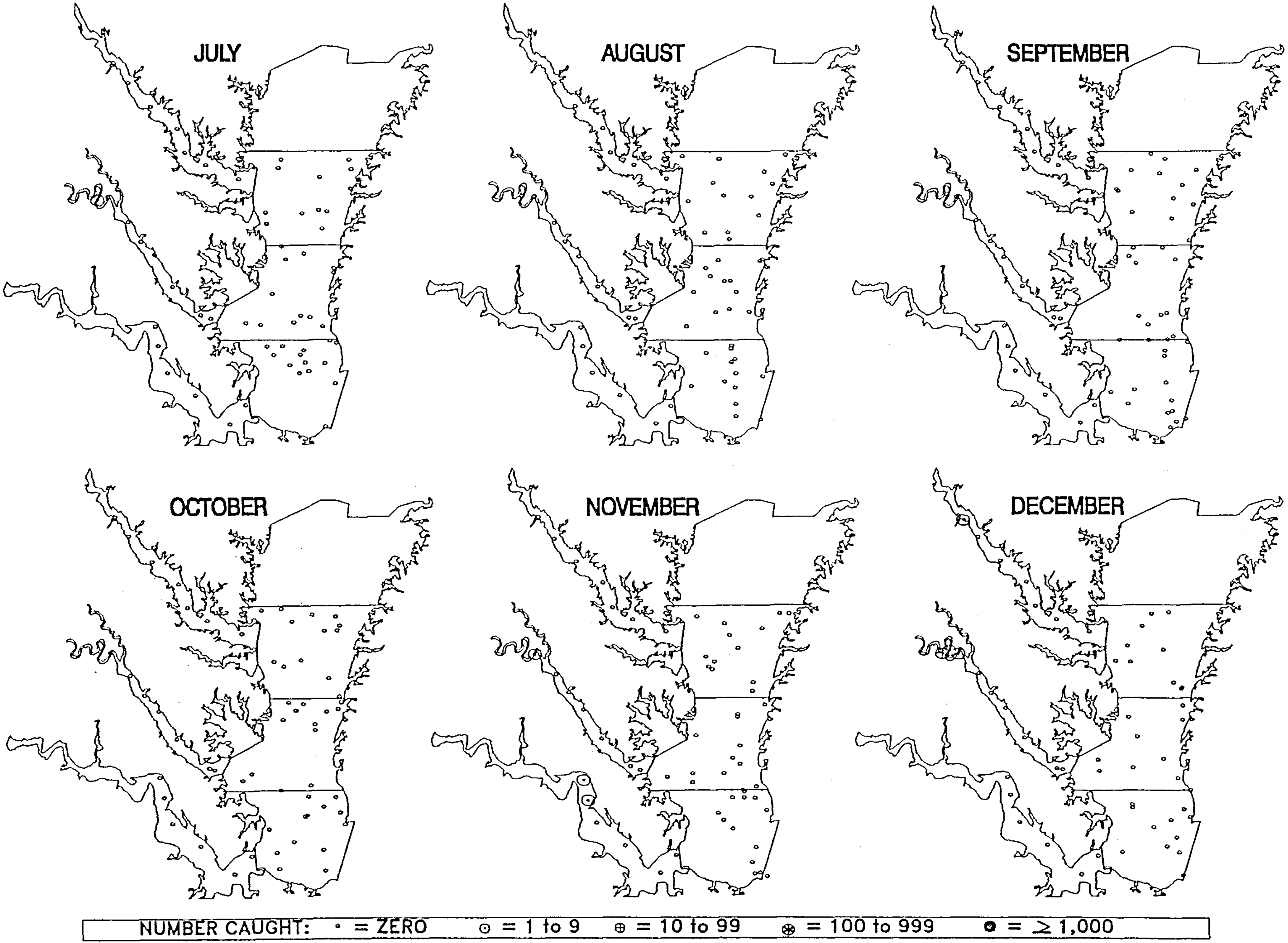
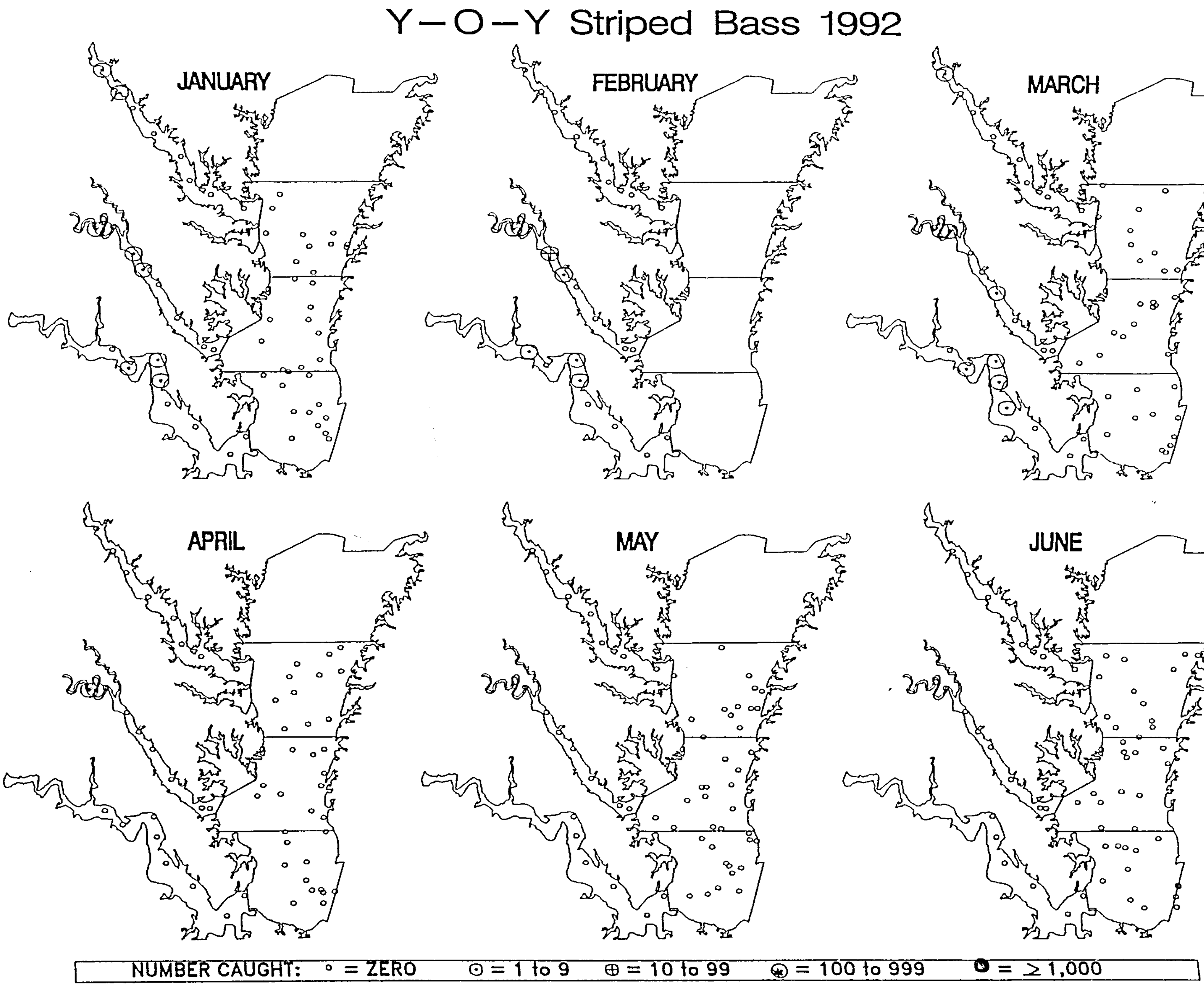


Appendix Figure 9-g.

Y–O–Y Striped Bass 1991



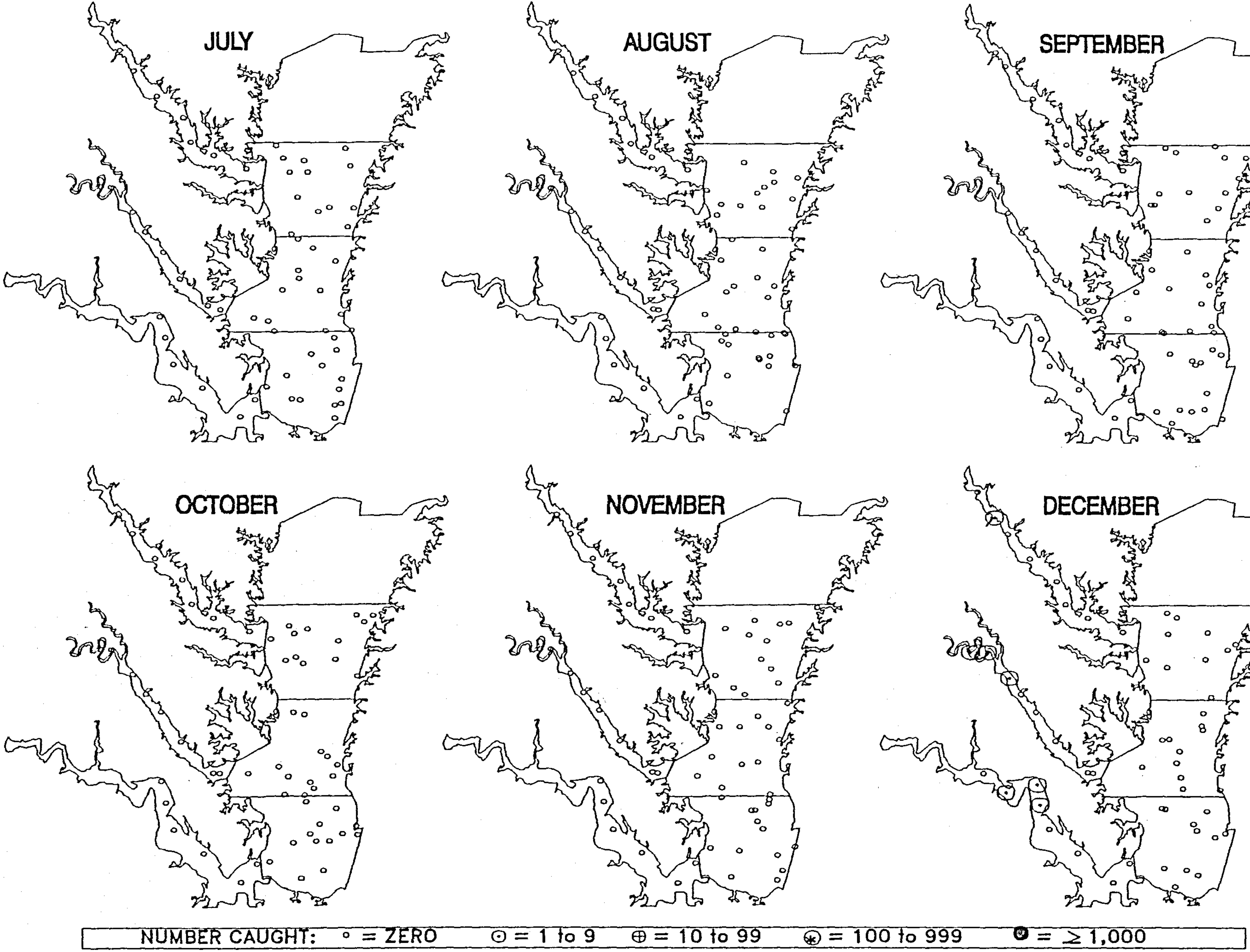
Appendix Figure 9-h.



Appendix Figure 9-i.

Appendix Figure 9-i.

Y–O–Y Striped Bass 1992



Appendix Figure 9-j.