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Estimation of Relative Abundance of Recreationally Important Finfish in the Virginia Portion of Chesapeake Bay: Annual Progress Report 1991-1992

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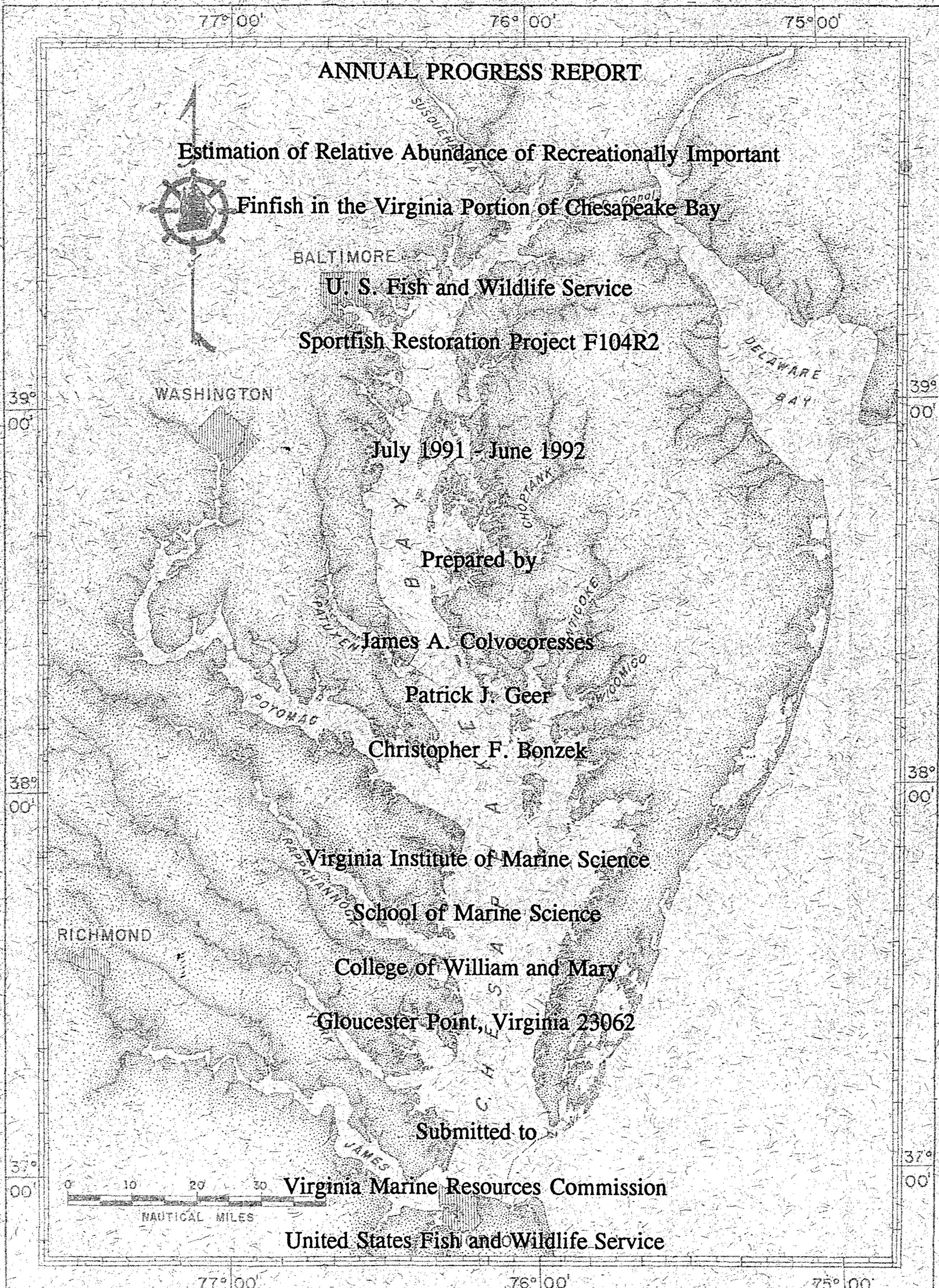

ANNUAL PROGRESS REPORT

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

U. S. Fish and Wildlife Service

Sportfish Restoration Project F104R2

July 1991 - June 1992

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Submitted to

Virginia Marine Resources Commission

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SUMMARY

1. Provisional annual indices of juvenile abundance have been generated from trawl survey data for five species of key recreational importance in the Virginia portion of Chesapeake Bay (spot, croaker, weakfish, summer flounder and black sea bass) and one species of secondary importance (scup) for the period 1988-1991. Only summer flounder catches resulted in an index that showed a consistent (upward) trend over the four years sampled, but the maximal value recorded for 1991 (2.8) was not statistically significantly higher than the prior year, in contrast to the previous increases observed. Atlantic croaker showed the greatest variability between years, with the 1989 index of 65 being 5 to 7 times higher than that seen in the other three years. The spot and weakfish indices both exhibited minimal values in 1991 (17 and 4 respectively) and suggested a declining trend, but there was considerable overlap of confidence intervals between years and the pattern was not definitive. Black sea bass and scup juvenile recruitment to lower Chesapeake Bay showed no evidence of a trend over the four year period.

2. Comparison of these indices to a longer time series (1979-1991) based solely on tributary data suggests that the recent rise in summer flounder recruitment probably represents only a partial recovery from a historically low value, and that the 1989 croaker year class in Chesapeake Bay was probably an exceptionally strong one. Comparisons involving the other species are of questionable value, as there is either highly variable or very sparse usage of tributary waters as nursery areas.

3. 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. Since all 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.

INTRODUCTION

Measures of juvenile abundance are presently widely utilized 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 subsequently encouraged and 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 in order for the trawl surveys to produce data that will be of sufficient quality for the generation of annual relative estimates of recruitment success of recreationally important finfish species for the major Virginia nursery areas of Chesapeake Bay. An analysis of the Virginia portion of the National Marine Fisheries Service Marine Recreational Fisheries Statistics Survey (VMRC 1985) showed that Virginia marine recreational catches were dominated by six species (spot, croaker, weakfish, black sea bass, summer flounder, and bluefish) which constituted over

85% of the total estimated catch by both numbers caught and weight landed. All of these species except bluefish heavily utilize the lower Chesapeake Bay as a nursery area for early juveniles which are highly vulnerable to bottom trawls. In addition the five key species cited above, past survey results indicate that other species of recreational interest, including scup, white perch, striped bass, white and channel catfish and southern kingfish 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.

Since the development of juvenile indices requires considerable continuous time series of data in order to determine the proper area-time sequences to be best utilized in index calculation and to allow proper validation, and since including the results from the pilot surveys only four full years of the expanded data set have been collected to this point, the calculation of abundance indices possible at present can only be done 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 present report a provisional index has also been developed for a sixth species, scup. The scup is of secondary importance to the Virginia recreational fishery in terms of number caught, but is still a highly prized food fish for the local angler and is a species of coastwide management concern. 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 the previous segment 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 and 1991 (Bonzek et al. 1991, 1992) have been previously prepared and distributed.

METHODS

Field Sampling

All collections were made with a lined 30' semi-balloon otter trawl towed along the bottom for a period of five minutes during daylight hours. 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 report for the previous segment and the data report series cited above.

Sampling has been performed monthly utilizing a random stratified sampling design in the mainstem bay and a fixed transect design in the tributaries, with the exception of the winter months of January and February, when very few fish are present in the mainstem waters and only a single cruise in the bay has been made since 1991. Stratification in the 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 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 done at fixed sites located in the river channels and spaced at about 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). While this sampling effort is technically supported by VIMS internal funds, 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 in general deeper than the other two tributaries and is hydrographically quite dissimilar. A shallow sill at the river's mouth greatly reduces deep circulation, with the result that severe anoxic conditions are typically encountered in the deeper portions of the lower reaches of this river during the warmer months. No sampling was done in the tributaries during January through April of 1988.

It would obviously 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 segment. The data collected during the first year of parallel sampling (June 1991-May 1992) is presently being evaluated as to the need for further parallel sampling and as to whether the fixed-transect sampling can be phased out.

Supplementary sampling was also conducted in this segment in order to assure a minor gear change 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. 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. A series of comparison tows utilizing the different doors initiated during the first segment was concluded in this segment, with no discernable differences in catch rates between gears being observed.

Juvenile Index Computations

Measuring the abundance of migratory species (as are all 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 depend 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, but in practicality this can only be accomplished if the time of maximal abundance 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, as the period of maximal abundance has proved to be variable between years within species and the geographic scope of the nursery area being surveyed and the multi-specific monitoring objectives preclude 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, but 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 prior and present report 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 between months for each species and were based upon 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. 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 $\pm$ 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 evidenced distribution patterns which suggested 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. Since surveys are timed on regular period intervals which might or might not coincide with periods of maximal recruitment to the nursery areas, and use of a very limited portion of the overall data set would decrease sample sizes (and hence increase confidence intervals) and increase the risk of sampling artifacts influencing results, 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, as 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.

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

Field Sampling

All survey field sampling was conducted as scheduled during the current project segment. 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. Mean catch rates were statistically indistinguishable across all abundant species, and there was no evidence of size selectivity. Absolute statistical conclusions regarding lack of differences 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 very large 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.

Juvenile Index Calculations

Spot (*Leiostomus xanthurus*) - This has been the most abundant and 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 to be the beginning of the biological year. With the addition of another year of data some slight modifications were made to the length-based cutoff values used to separate the nominal young-of-the-year and older fractions of the total catches (Table 3), resulting in slight modifications to the 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 reported values. The most notable change resulting from error corrections is a change in sample size for 1990. Four tows made as special replicate tows for the blue crab sampling program during the tributary surveys were previously inadvertently coded as regular 'fish' tows.

As in the first three years of sampling, during early 1991 spot young-of-the-year abundances were relatively low and distribution was erratic until the new year class strongly recruited to the area in June, after which juvenile spot were again abundant and widely distributed throughout the survey area until the onset of winter (Appendix Figs. 1 a-b). During 1991 sampling average catch rates were highest during July and October, continuing a pattern of bimodal peaks in abundance seen in two of the previous three years (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 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 during all four years, all strata have been included in the calculations.

The weighted geometric mean catch per tow for juvenile spot has declined from a high of 68 for the 1988 year class to a low of 17 for the 1991 year class (Table 4, Fig. 3), with the latter value showing confidence intervals which are discrete from all of those of the previous three years.

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 (Colvocoresses and Geer 1991). 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, and 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 all three years and the vast majority of juveniles captured were taken during this season. During 1991, however, a completely anomalous pattern was observed, with the highest abundance of nominal young-of-the-year croaker occurring in June, a month of extremely low abundance the previous three years (Fig. 2, Appendix Figs.

2 a & b). Examination of the length frequency data (Fig. 4) shows clearly that this peak is attributable to returning 1990 year class individuals and not to a new cohort of early juveniles. Fall recruitment of early 1991 year class individuals continued to take place primarily in the tributaries, but returning 1990 year class individuals only showed the usual much higher utilization of the tributaries during the initial month of June, with an increasing use of the mainstem bay occurring as the summer progressed (Table 5, Appendix Figs. 2 a & b).

Since a comparison of monthly average catch rates between the mainstem and tributary sites showed that (with the exception of December of 1989) average catch rates were always 1-2 orders of magnitude higher in the tributaries (Table 5) during the fall months of peak juvenile abundance, the initial juvenile index for Atlantic croaker was based solely on the tributary data, subject to latter revision if further sampling supported the December 1989 results (Colvocoresses and Geer 1991). 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 of all three prior 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, the 1991 data throws these premises into serious question, but does not suggest any clear alternatives. Therefore, until an adequate time series of data can be collected to determine whether the summer utilization of the bay as a nursery ground for late age-0 individuals was an event unique to 1991 or a periodically occurring phenomena which should be considered in juvenile index development, the previous basis for index calculation will be maintained.

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 three years sampled. The calculated index for 1989 (65, Table 4 and Fig. 3) was five to seven times that seen in the other three 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. New juveniles occasionally have 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 three years, in July young-of-the-year weakfish were found primarily in the tributaries, but 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 four years, August-October (Fig. 2). Index calculations were therefore based on data from all strata collected during these months.

The weakfish juvenile abundance indices observed for the past two years have been considerably lower than those recorded during the first two years of the expanded survey. The 1988 and 1989 values were similar (9 and 12, respectively, Table 4 and Fig. 3) and had broadly overlapping confidence intervals, as did the two lower 1990 (5) and 1991 (4) values. The 1990 index had slightly overlapping confidence intervals with the 1988 index, but the four numbers still readily group into two pairs.

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 1991 as during most years were not taken in appreciable numbers until June (Appendix Figs. 4 a & b). As in the previous three 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. 5). As was the case with weakfish, a single three month period, September to November, encompassed the three months of greatest abundance for all four years sampled and therefore chosen as the period for index calculation. 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.

While the 1991 juvenile index for summer flounder was the highest for the four years sampled (2.8), it was statistically indistinguishable from the previous year's value of 2.5 (Table 4, Fig. 6). During the prior three years the index had more than doubled during each successive year, 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 occur often in the catches. Small early juveniles first appear in the catches 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 any of the tributaries except the lower James River on a regular basis, a pattern which was seen again in 1991 (Appendix Figs. 5 a & b). Index calculations have thus ben based on all bay strata and the lower James strata. Choice of the appropriate time period for index calculation is less obvious than for the prior four species, 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. 5). During some years, including 1991, there is virtually no use of the Chesapeake Bay as nursery area for 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, a period which has encompassed the three months of highest abundance during all four years sampled. The 1991 data differed slightly from the previous three years in that maximal abundance was seen in June rather than July, but 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 "pre-index" 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 and 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. 6), ranging from 0.8 (1988 year class) to 2.4 (1989 year class). Only these two extreme values do not have overlapping confidence intervals (Table 3), with the intermediate years of 1987 (1.6) and 1991 (1.1) being 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 (Fig. 7), but rapidly disappear after that if they do indeed appear at all (almost 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). As noted above, the age-0 component is annually variable and not persistent, while the largest size class is only taken in very small numbers. The age-1 component, however, 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 is 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. This is only marginally different from the black sea bass index, which is estimated during the end of the first year of life, but computationally different in that both minimal and maximal cutoff values are needed to partition the year class out of the total catches based on the length frequency data (Fig. 8).

Examination of the distributional data (Appendix Figs. 6 a-h) clearly shows that the utilization of the Chesapeake Bay as an early age-1 nursery area is largely restricted to the lower mainstem. Juvenile scup are occasionally taken in the river mouths and the upper segments of the mainstem survey area, but catch rates are always many times higher in the two lower mainstem segments so these have been provisionally chosen as the geographic basis for index calculation. Catch rates for age-1 scup in this area peaked in July during three of the four years thus sampled (1989-91) and essentially showed a July-August dome during the fourth (1988)(Fig. 5). 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. The months of June through September were therefore chosen as the temporal basis for initial index calculation, but this may be subject to later modification if June proves to be a consistently problematic month.

No trend is evident in the scup juvenile index to this point. The high value (4.9) recorded for the 1989 year class index is marginally statistically different from the 1990 year class index (1.9) and has only slightly overlapping confidence intervals with the 1987 year class (Table 4, Fig. 6), but the values for the three years other than 1989 are essentially indistinguishable.

DISCUSSION

The annual juvenile abundance indices presented here should still be regarded as strictly provisional. Four years of data has undoubtedly not captured all of the interannual variability in nursery area utilization, as is clearly suggested by the fact that the 1991 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. 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 indices for the first five species considered here are plotted along with the indices developed here for the expanded sampling program in Figure

9. 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 is of course essentially perfect since the same data set was used for both (the minor differences are due to slightly varying areal weighting factors between tributaries), 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 four years thus 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 and 1991 the tributary and combined indices were essentially identical, indicating a very uniform distribution of juveniles, but during 1989 and 1990 abundances were clearly much higher in the tributaries. 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 four 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 1991 recruitment was near historic lows.

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 (Fig. 9). The 1991 data, however, again suggests (as did some of the 1989 results) that even though utilization rates of the tributary waters as nursery areas is usually much higher than the for the mainstem, significant use of the mainstem may occur during some periods and that considering it's much greater area, a large enough portion of the juvenile croaker population may reside there 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 that 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 that the large 1989 year class showed little evidence of return during 1990 sampling.

The extreme lack of agreement between the tributary and combined indices for weakfish (Fig. 9) clearly illustrate the need for the expanded sampling program. 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 but overall catch rates dropped sharply, 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.

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 four years thus sampled there is reasonably good coherence (Fig. 9), 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 1990, 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 three years, but if the lack of coherence between the tributary and combined data seen for the 1987 year class proves not to be an exception, the usefulness of the tributary data may be open to question. 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 as well. As is evidenced by their absence during the winter months, all six of the species discussed here are highly migratory. 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 to many along the Atlantic seaboard for these populations.

With the exception of weakfish, 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 as 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.

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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

Length Cutoff Values (mm Fork Length or Total Length if caudal not forked)

	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

Table 4. 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
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
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
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

(cont.)

Table 4. (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
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

Table 5. 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.	10.9	0.2	48.5
	Nov.	21.3	0.4	51.9
	Dec.	13.1	1.0	13.1
1989	Oct.	117.8	6.3	18.8
	Nov.	169.8	3.6	46.6
	Dec.	27.9	31.6	0.9
1990	Oct.	11.5	0.1	143.7
	Nov.	32.0	0.2	138.5
	Dec.	30.0	2.4	12.4
1991	June	35.2	1.0	34.4
	July	19.2	5.7	3.3
	Aug.	8.6	18.6	0.5
	Oct.	6.5	0.1	56.2
	Nov.	14.4	1.6	8.8
	Dec.	18.1	3.3	5.4

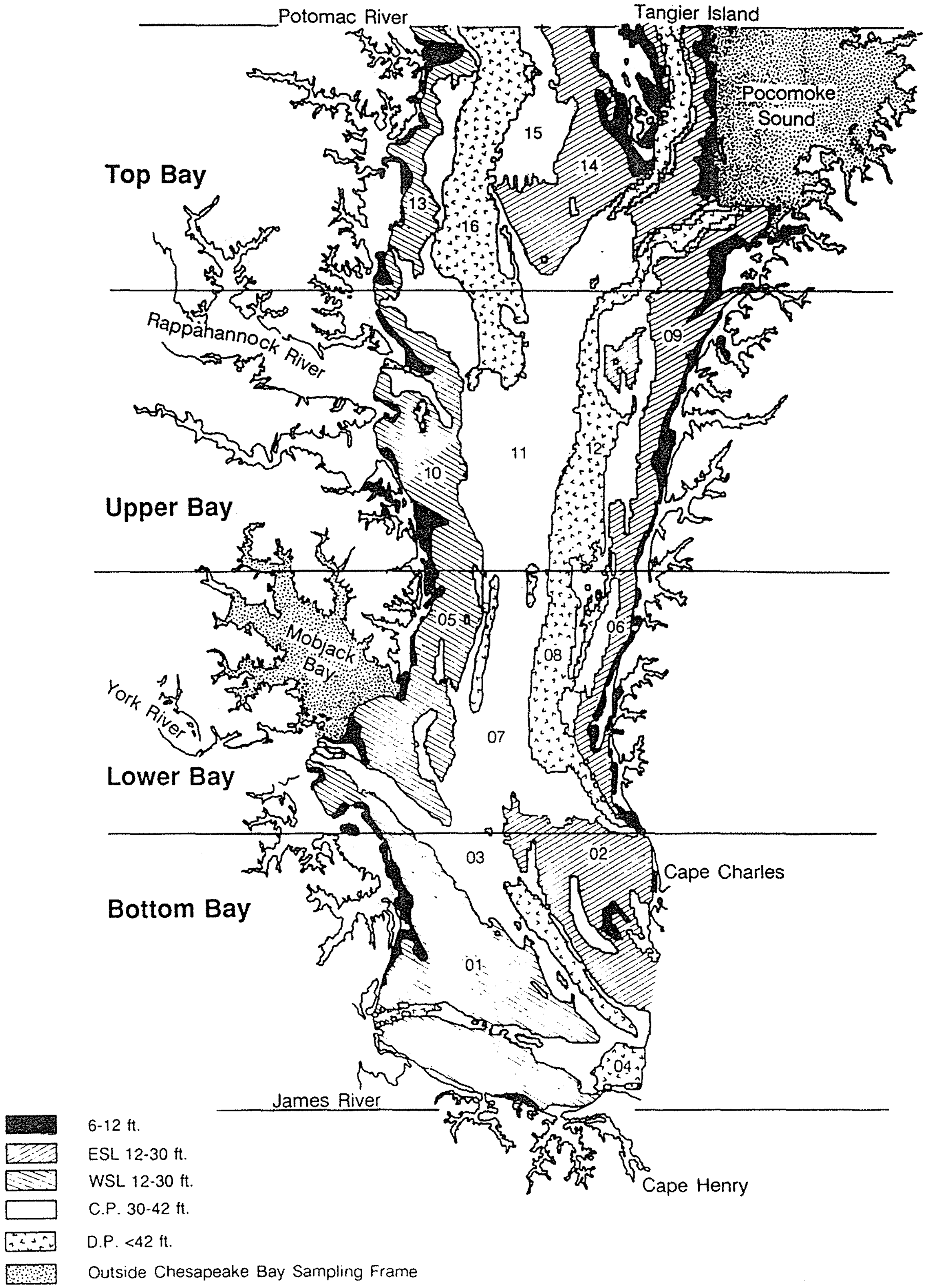


Figure 1. Chesapeake Bay trawl survey strata.

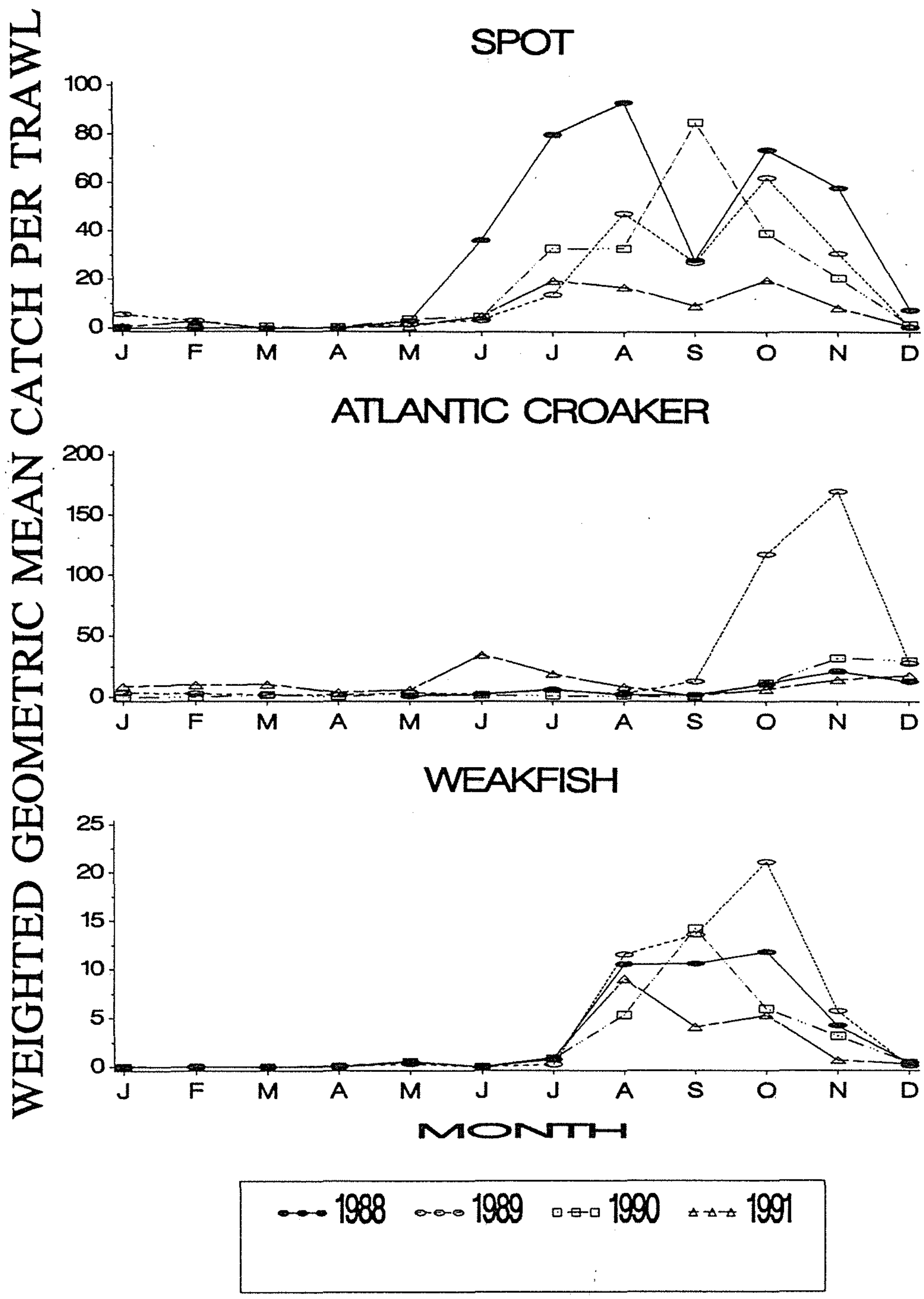


Figure 2. Geometric mean catch per tow of spot, Atlantic croaker and weakfish by month on the primary nursery grounds.

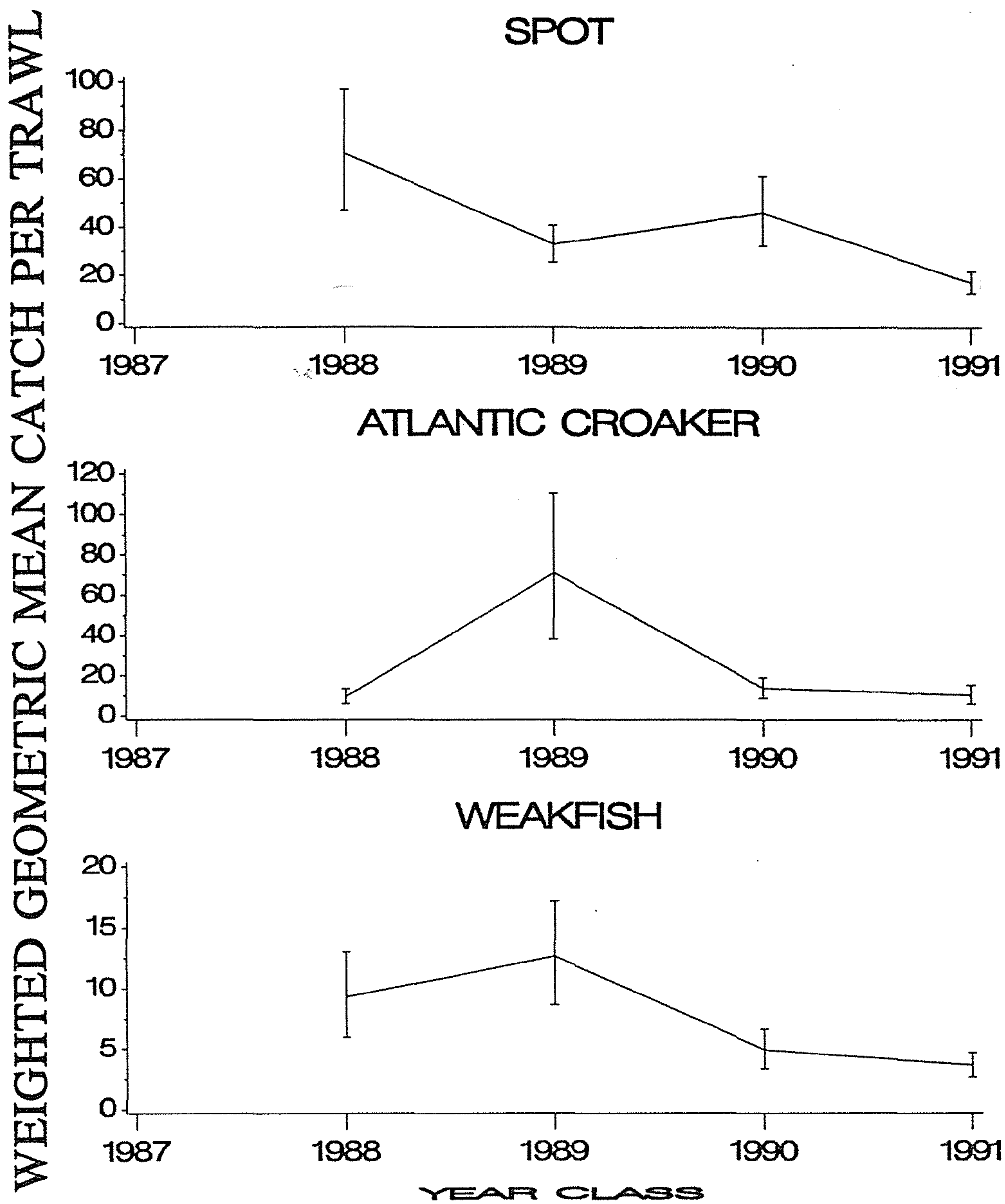


Figure 3. Annual juvenile abundance indices with 95% confidence intervals for spot, Atlantic croaker and weakfish.

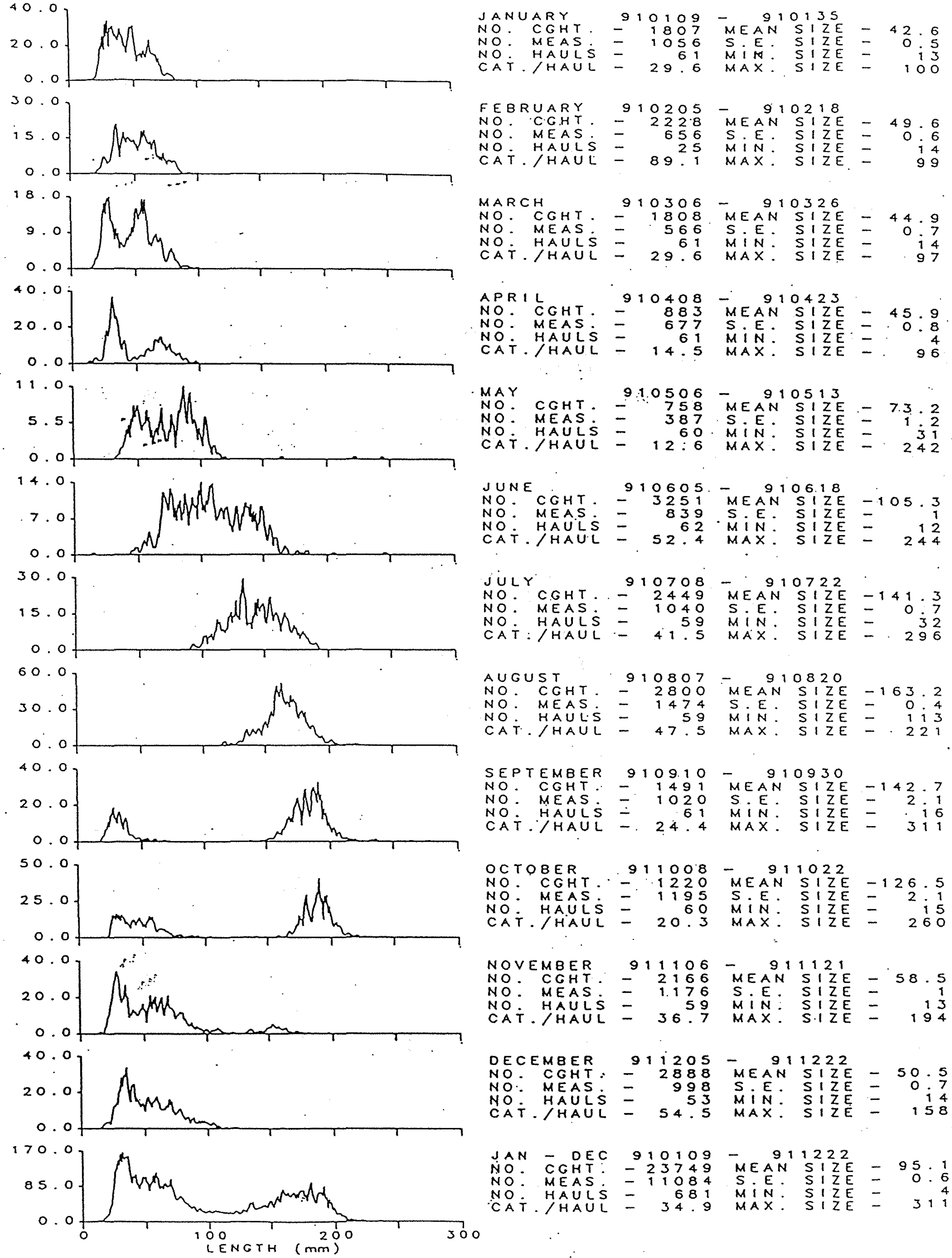


Figure 4. Composite length frequencies by month for Atlantic croaker, VIMS trawl survey data base, 1991.

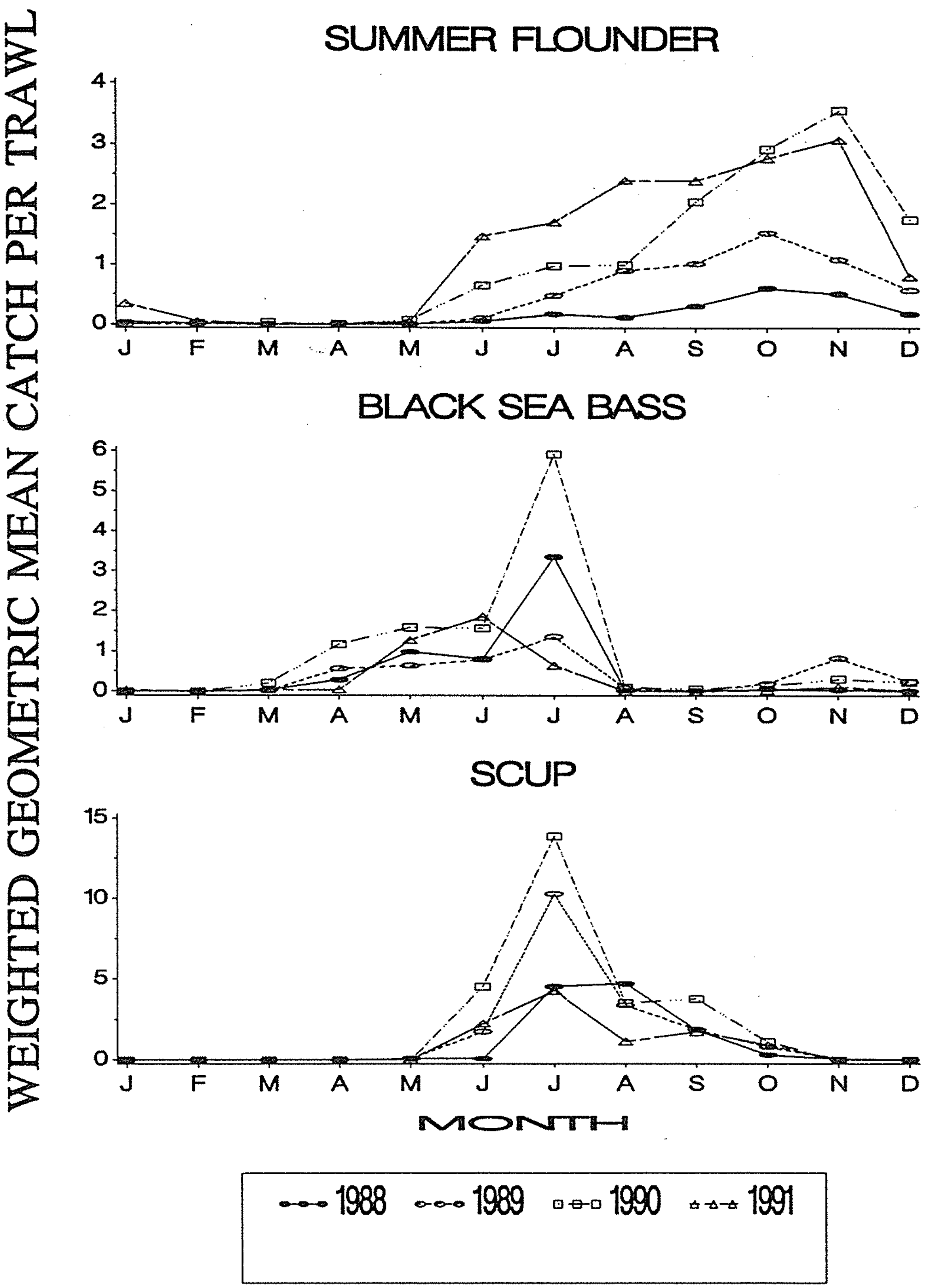


Figure 5. Geometric mean catch per tow of summer flounder, black sea bass and scup by month on the primary nursery grounds.

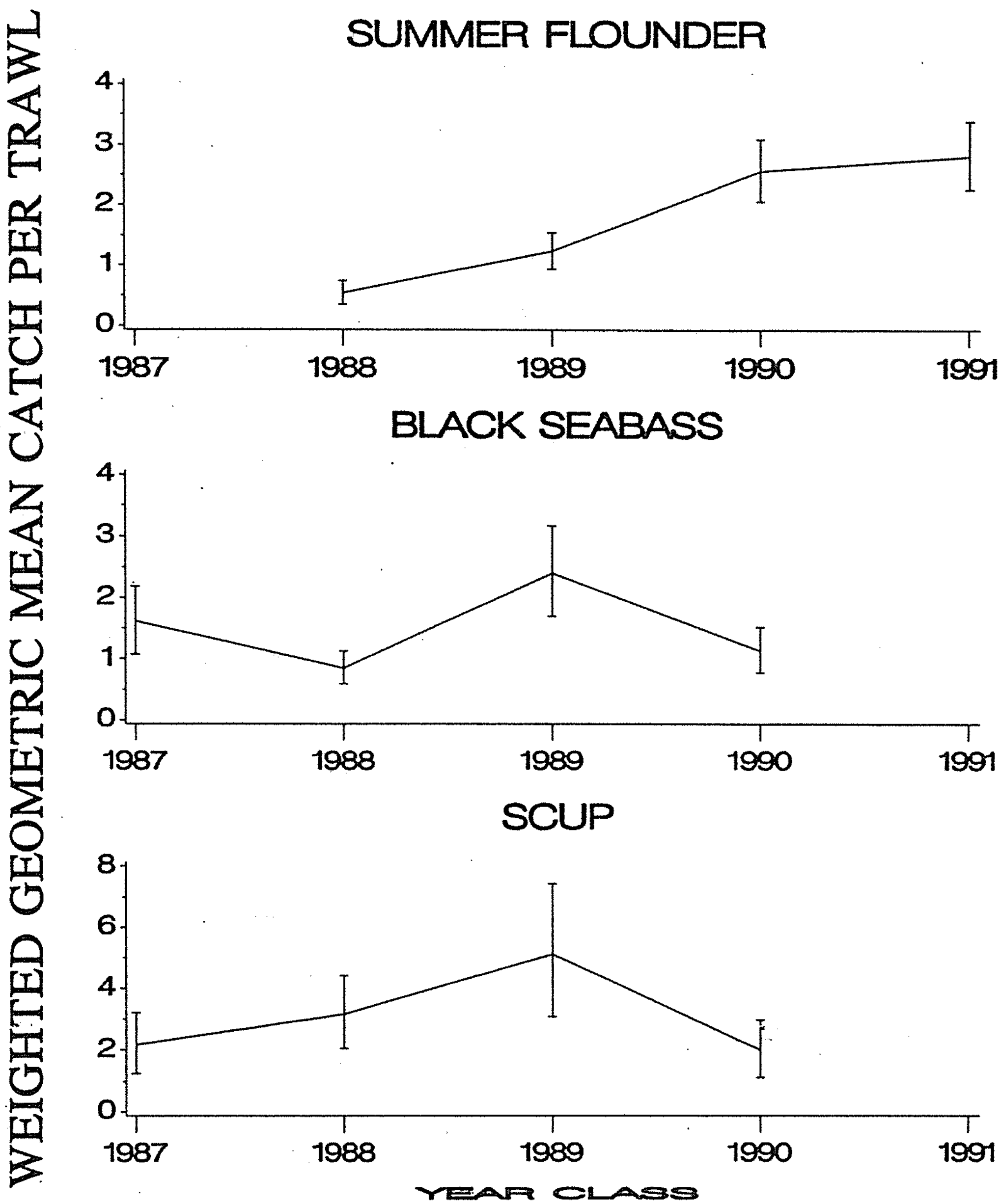


Figure 6. Annual juvenile abundance indices with 95% confidence intervals for summer flounder, black sea bass and scup.

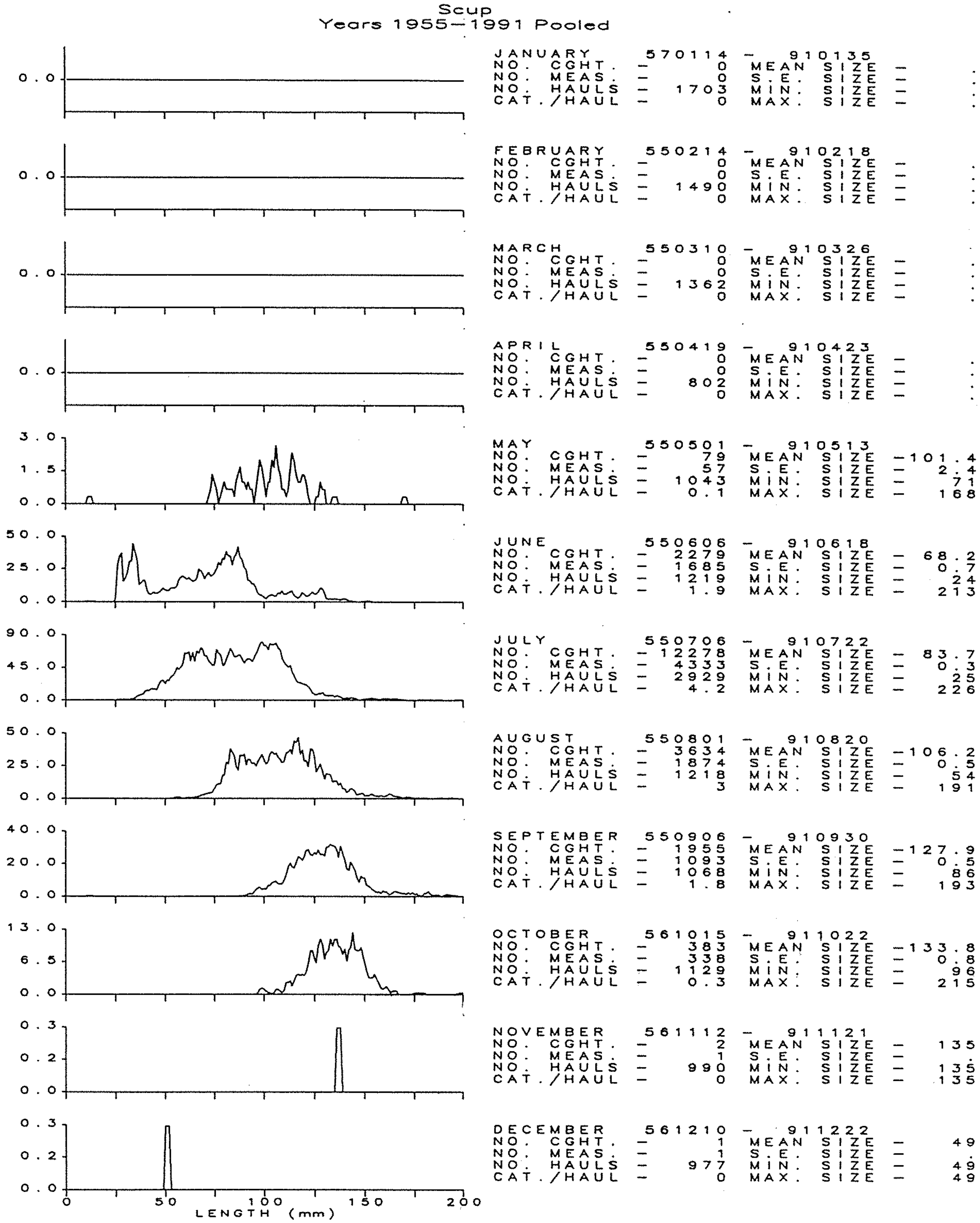


Figure 7. Composite length frequencies by month for scup, VIMS trawl survey data base, 1957-1991.

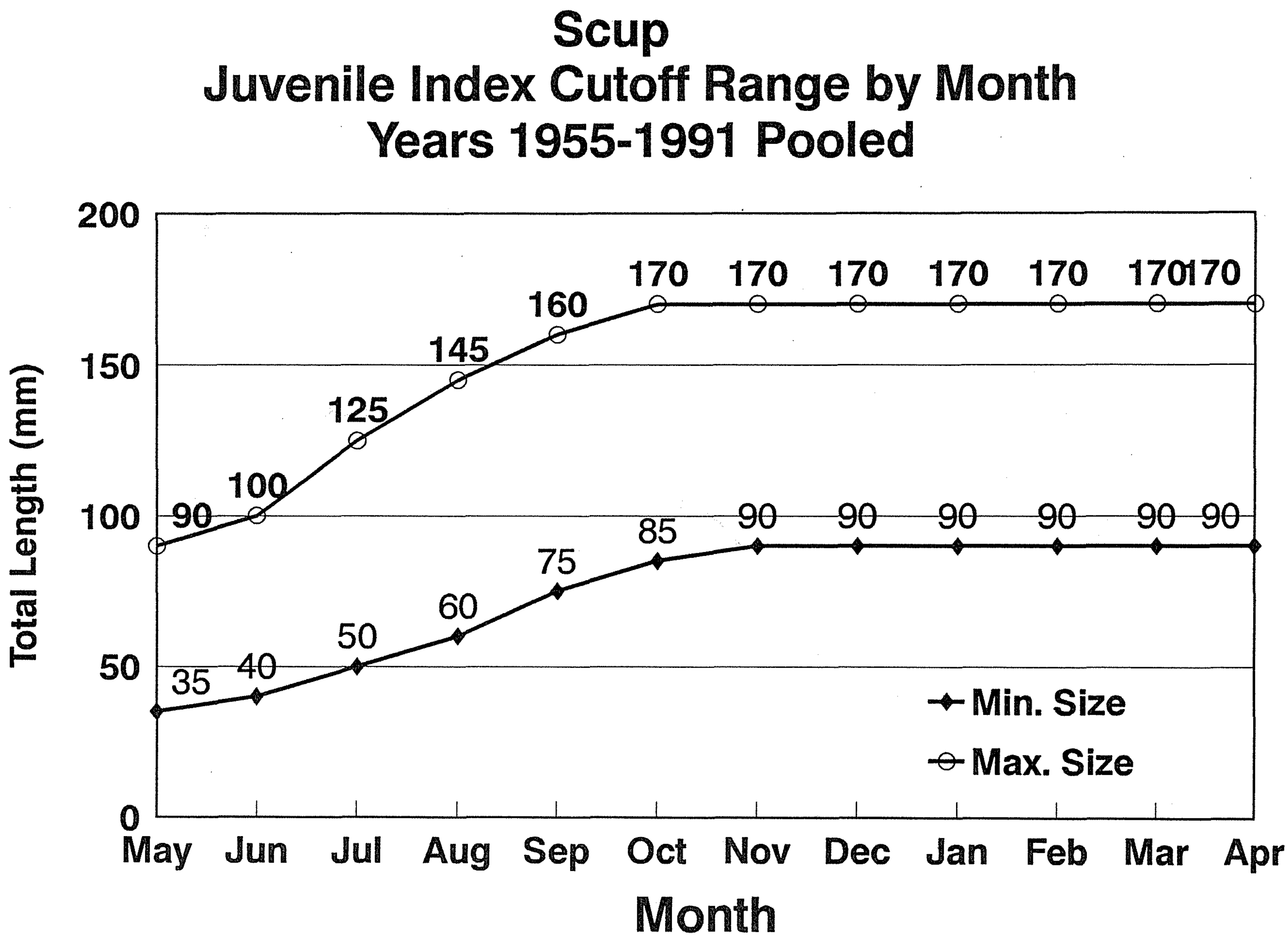


Figure 8. Length cutoff values used to separate early age one scup from the prior and following year classes.

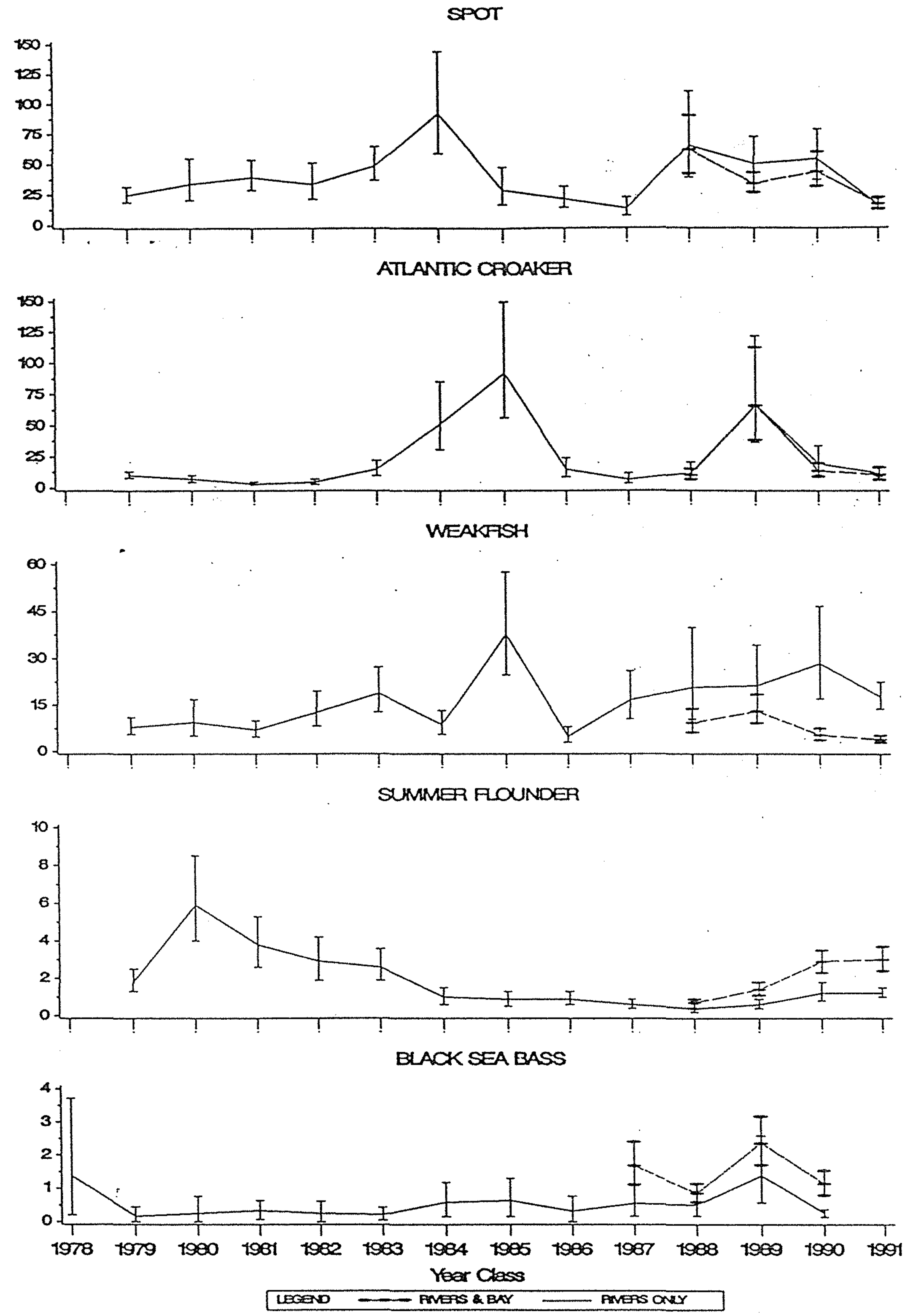
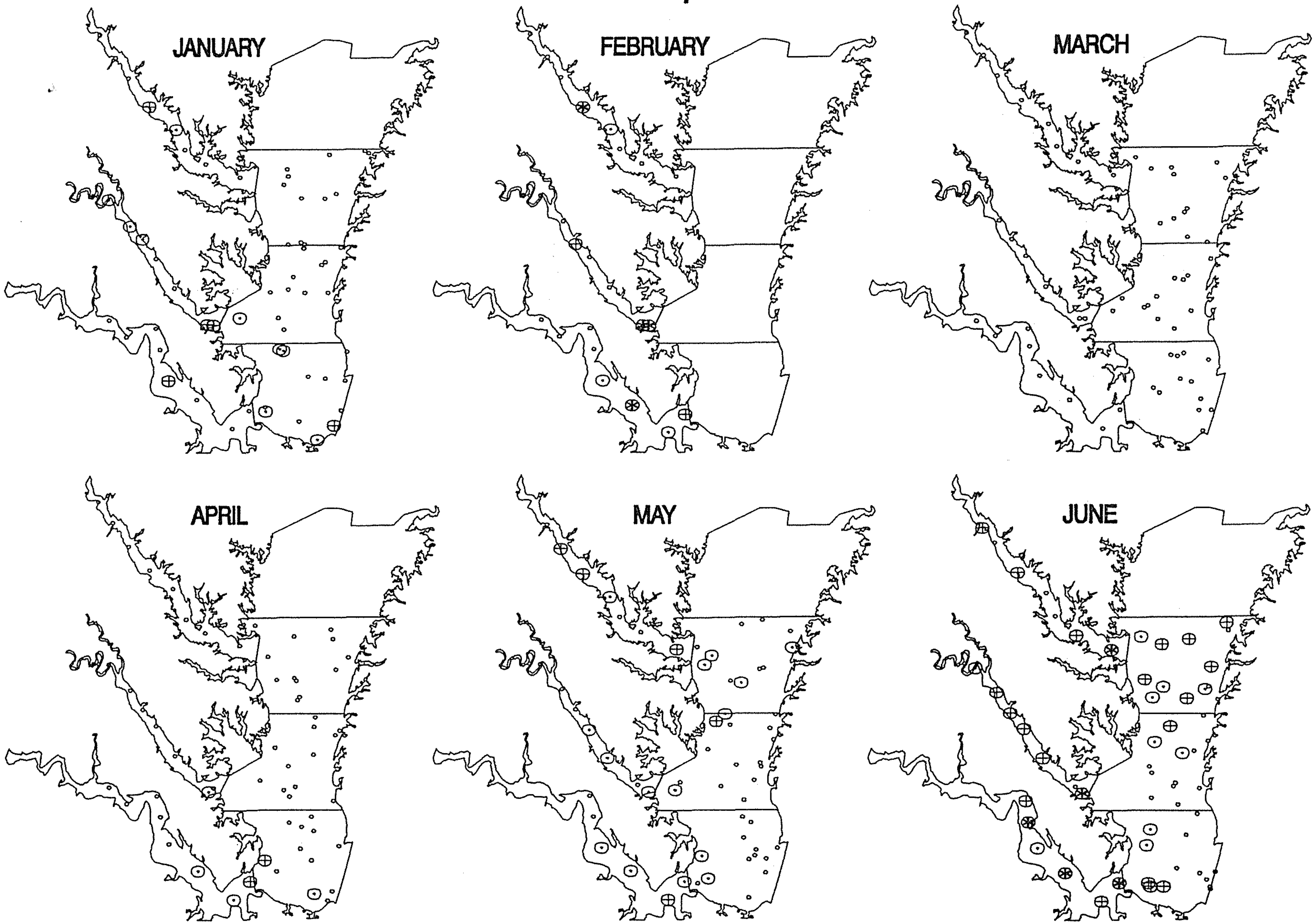


Figure 9. Annual juvenile abundance indices with 95% confidence intervals for key species based on tributary data only (solid line) and based on expanded sampling program (dashed line).

Appendix Figures 1-6. Trawl catches (numbers of individuals) of young-of-the-year of 1, spot; 2, Atlantic croaker; 3, weakfish; 4, summer flounder; and 5, black sea bass plotted by month for 1991. Plots are arranged chronologically (a, Jan.-June; b, July-Dec). Also catches of early age-1 scup (6) for 1988-1991. 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).

Appendix Figure 1-a.

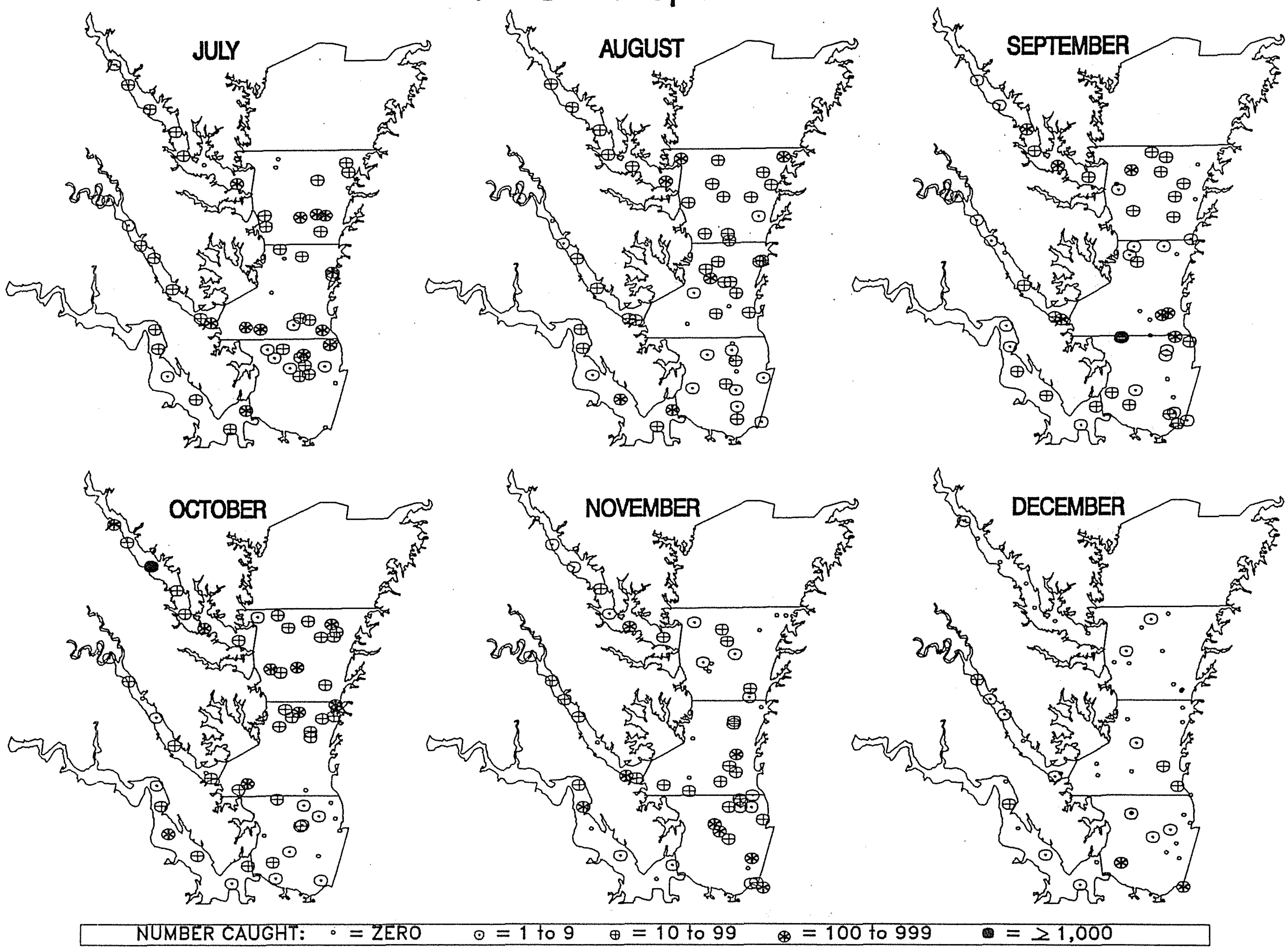
Y — O — Y Spot 1991



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

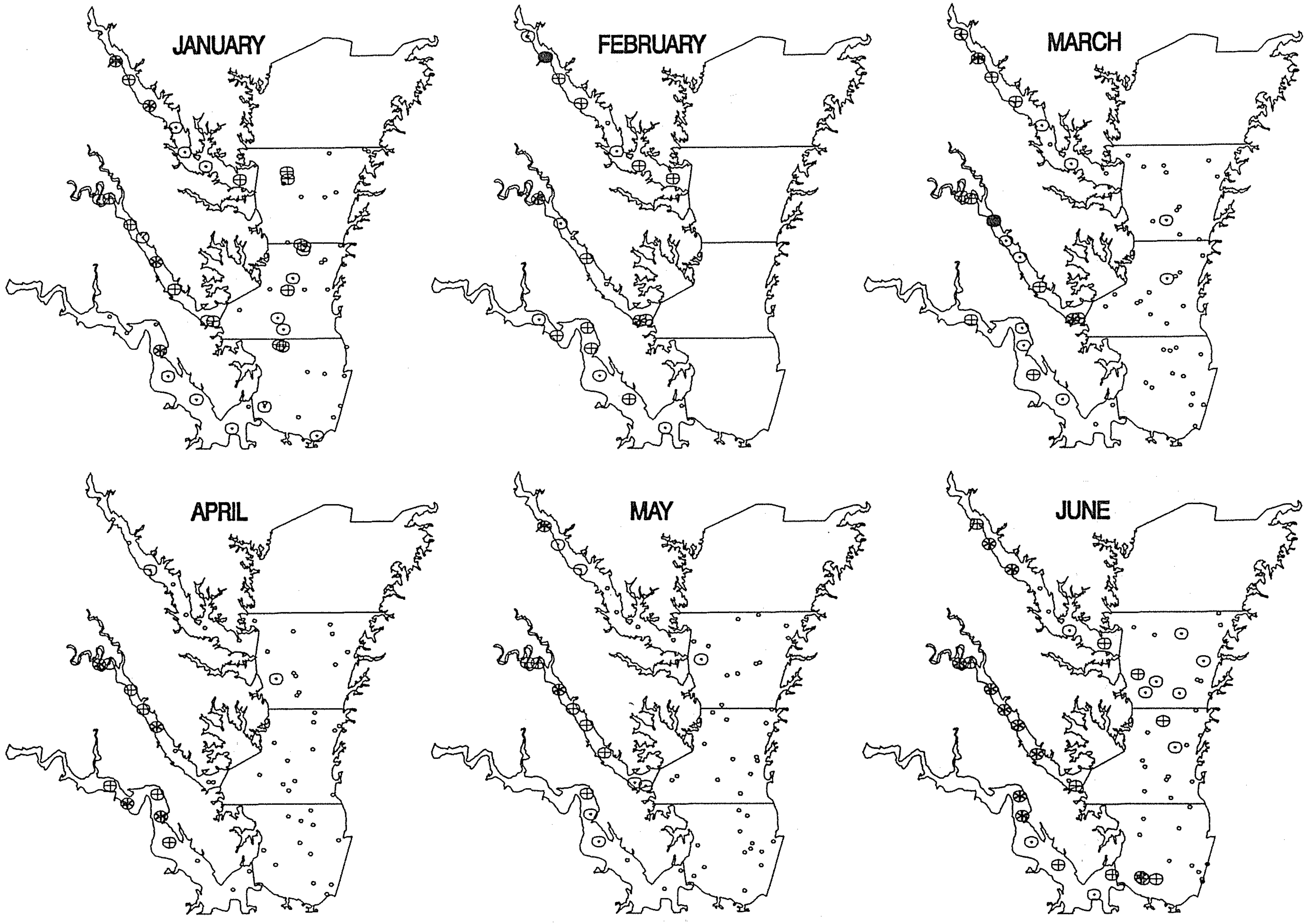
Appendix Figure 1-b.

Y-O-Y Spot 1991



Appendix Figure 2-a.

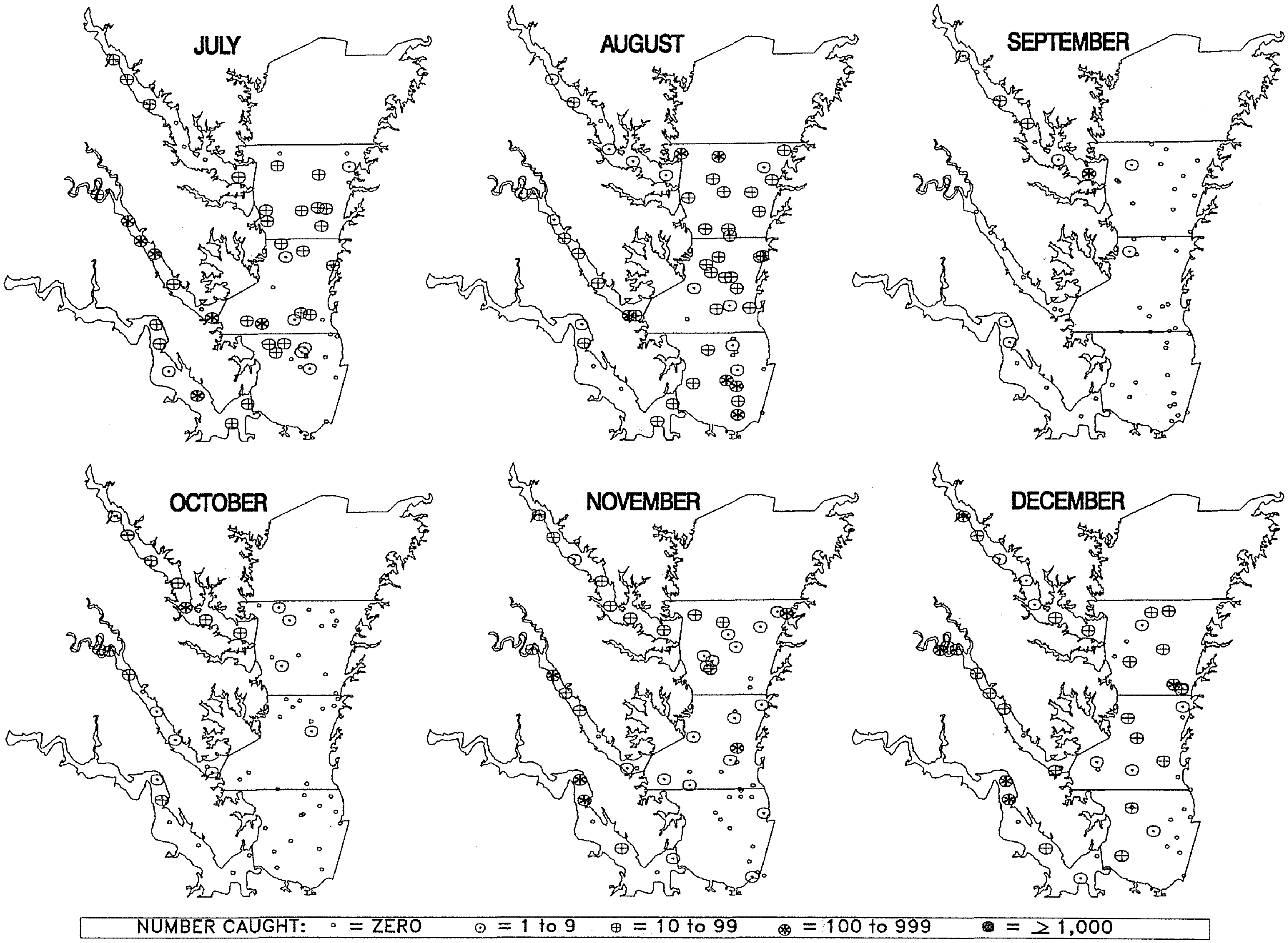
Y-O-Y Atlantic Croaker 1991



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

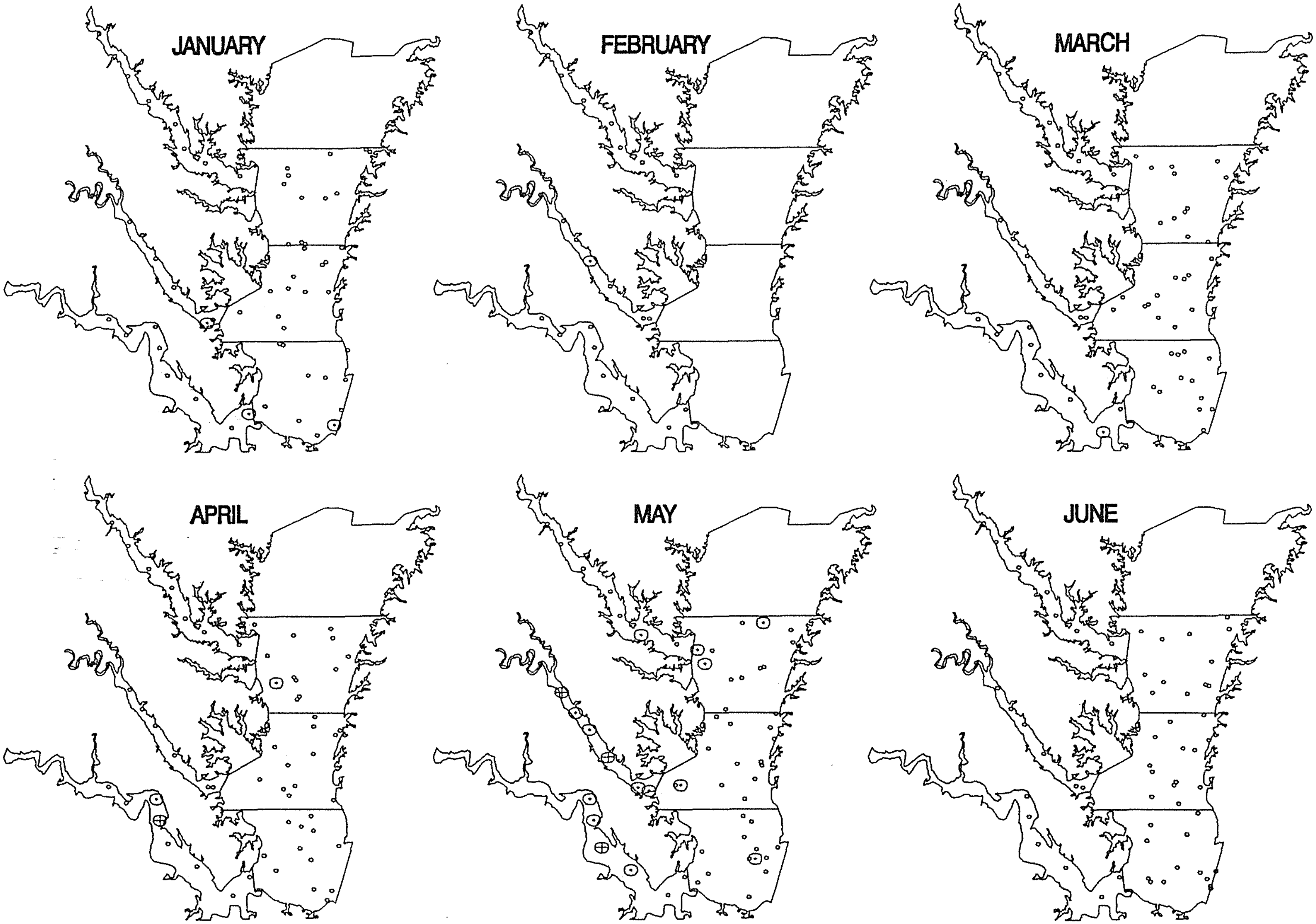
Appendix Figure 2-b.

Y-O-Y Atlantic Croaker 1991



Appendix Figure 3-a.

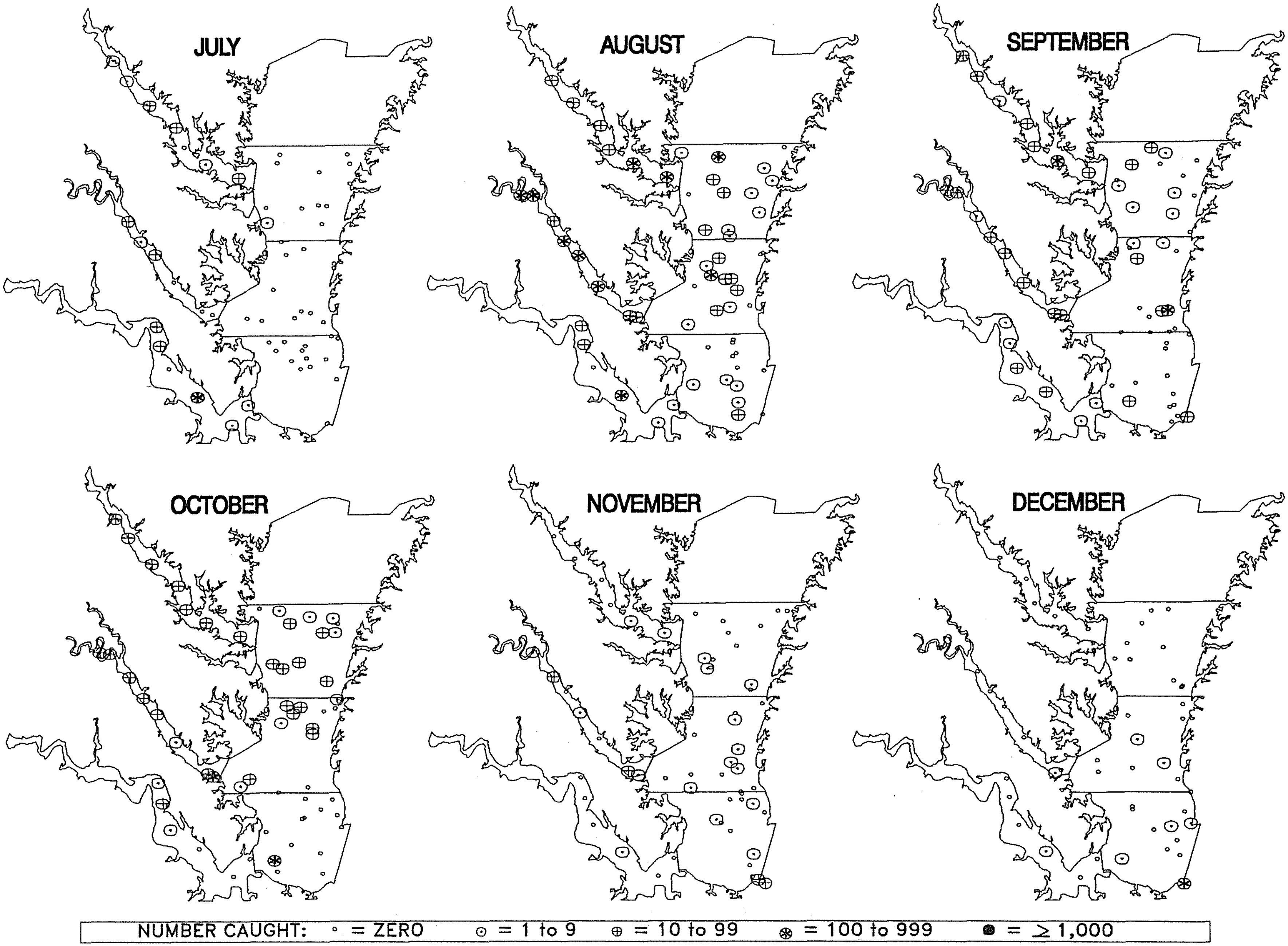
Y-O-Y Weakfish 1991



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

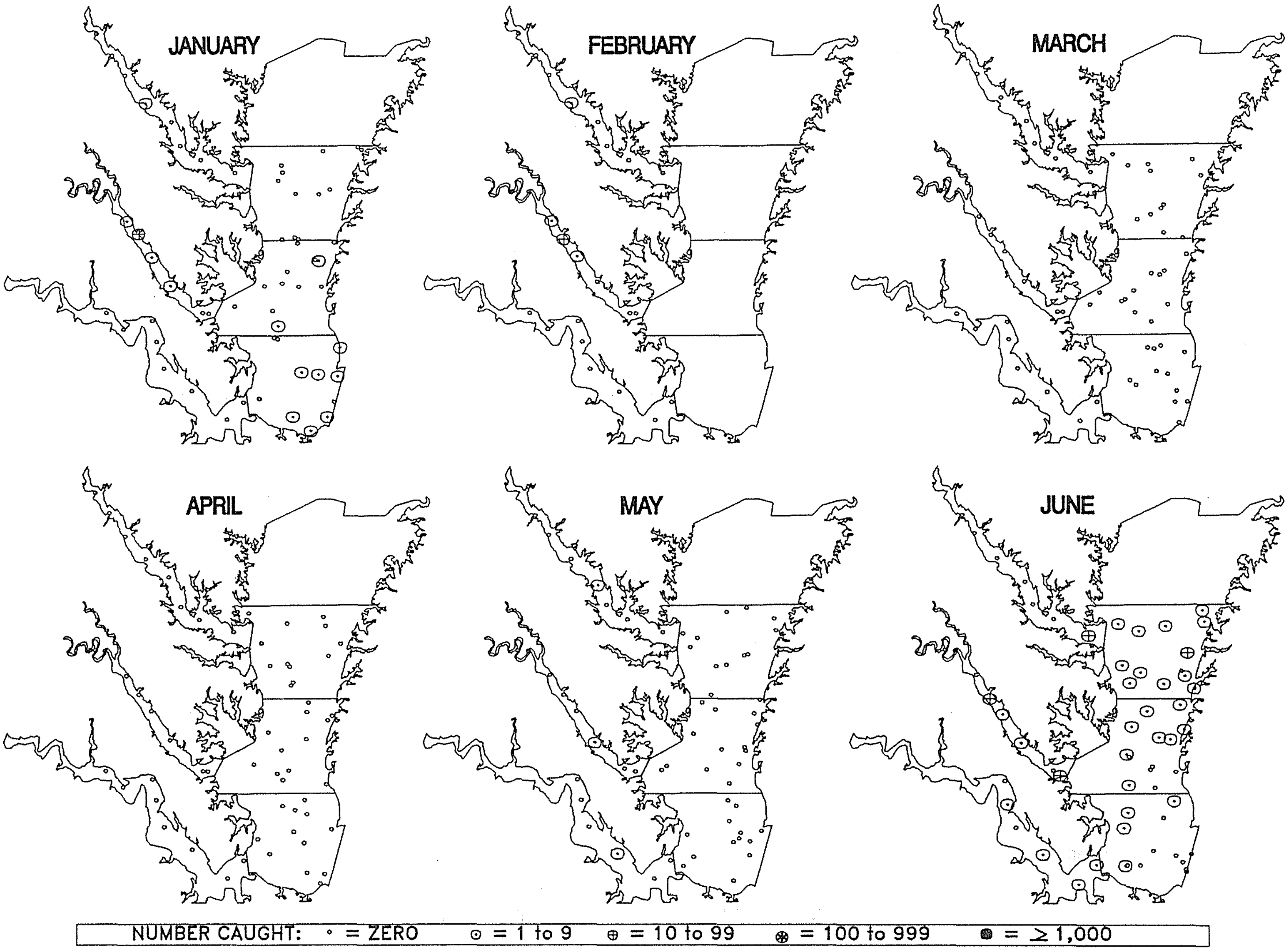
Appendix Figure 3-b.

Y-O-Y Weakfish 1991



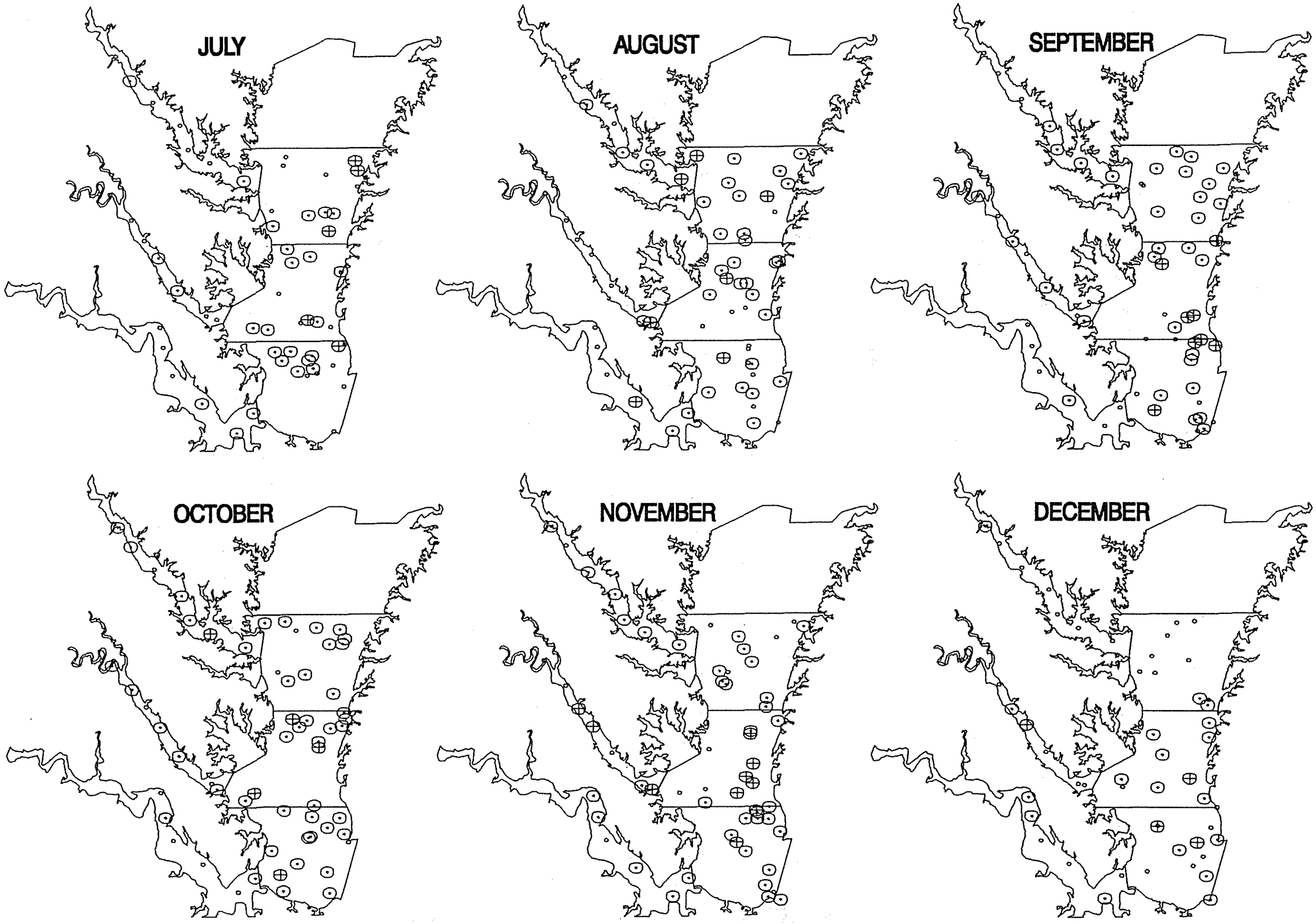
Appendix Figure 4-a.

Y-O-Y Summer Flounder 1991



Appendix Figure 4-b.

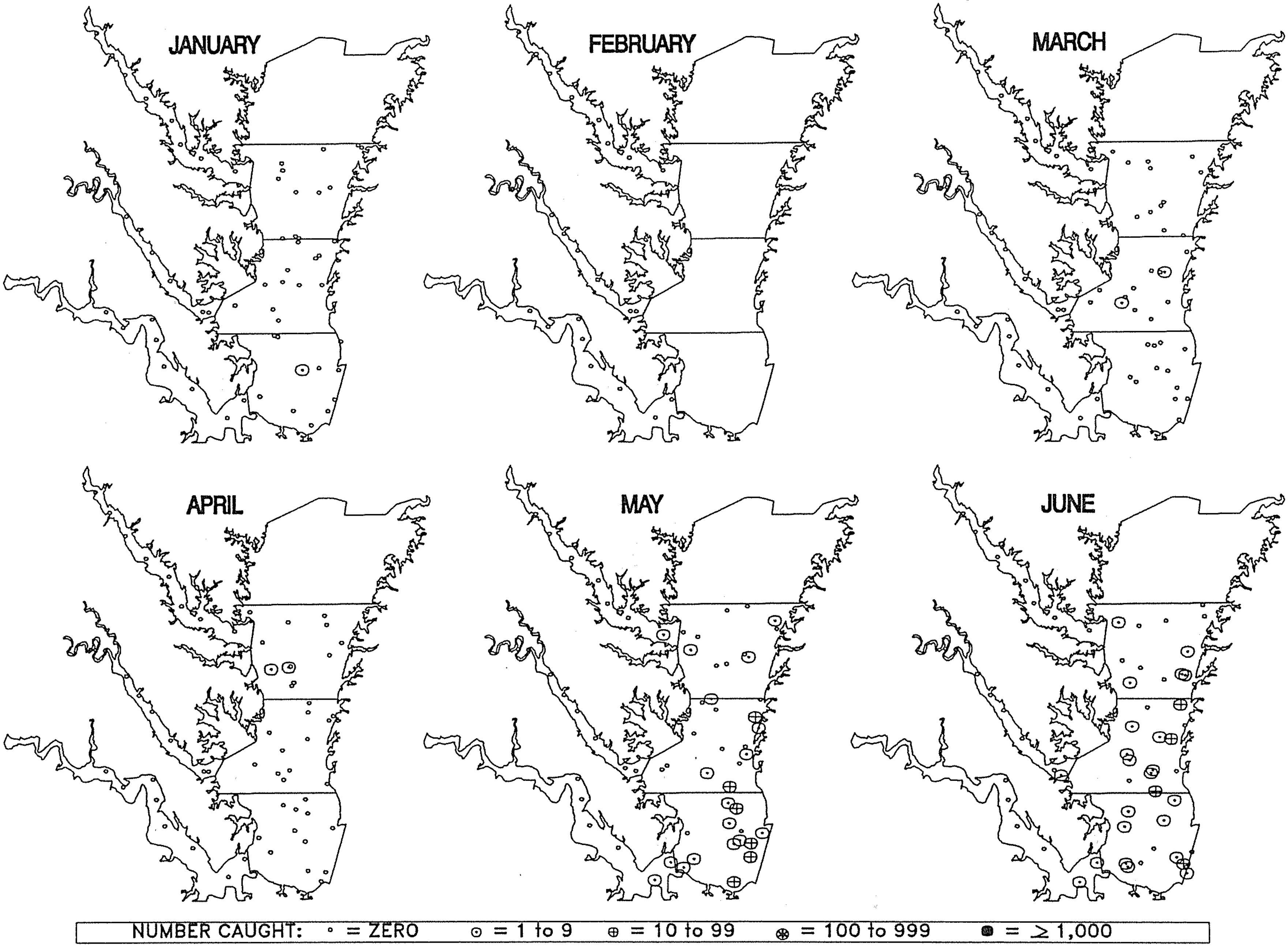
Y-O-Y Summer Flounder 1991



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

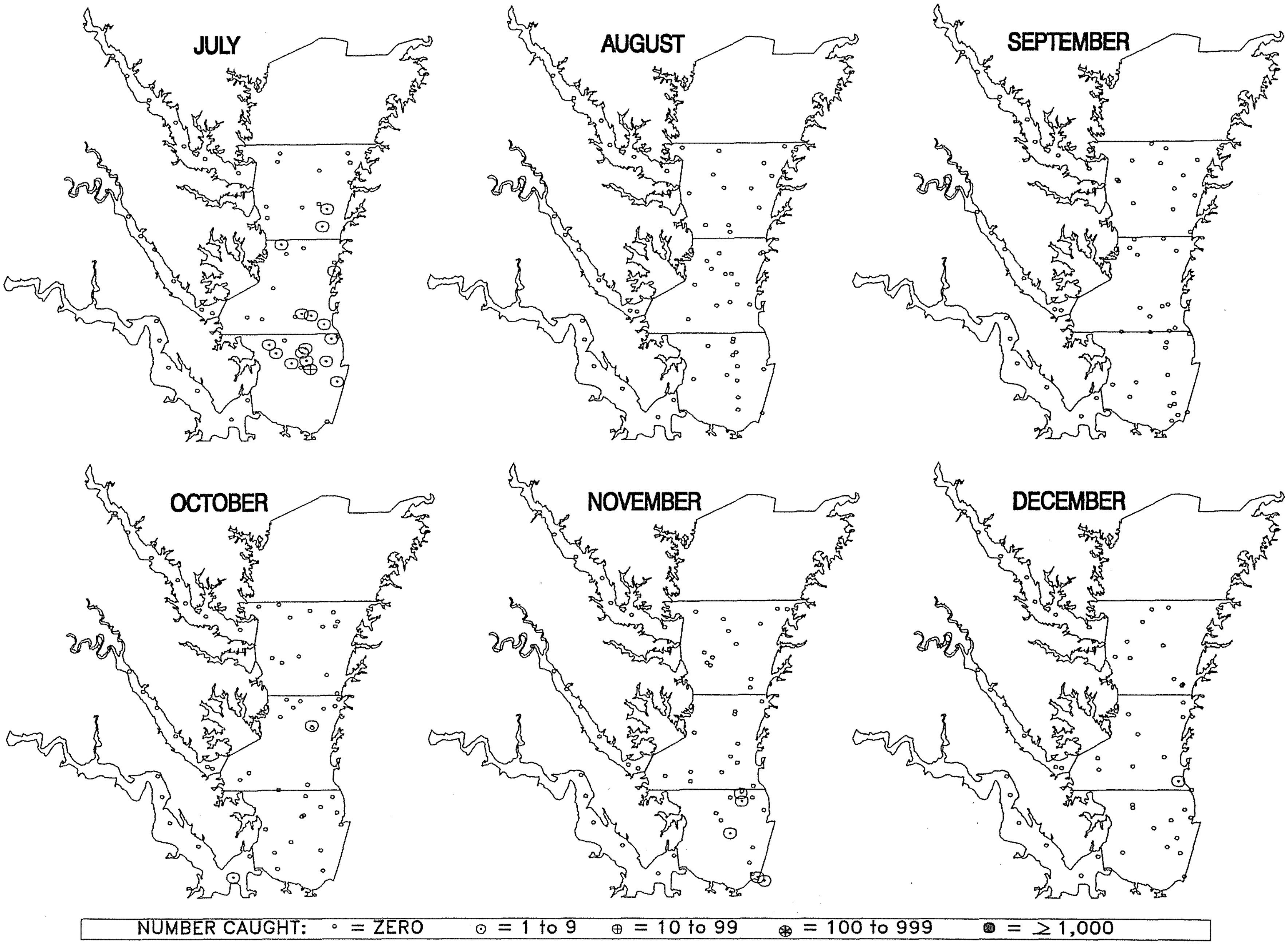
Appendix Figure 5-a.

Y-O-Y Black Sea Bass 1991



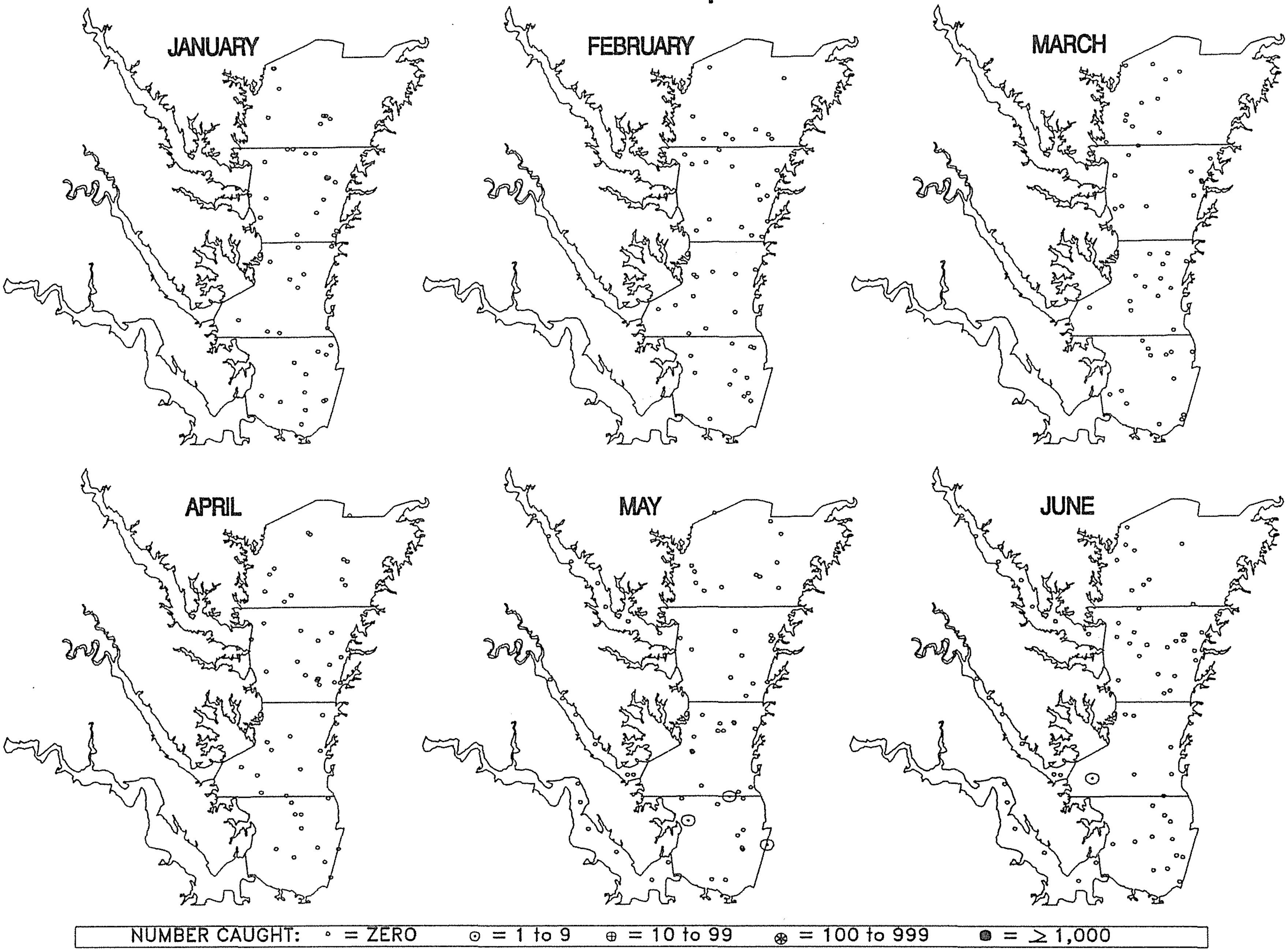
Appendix Figure 5-b.

Y-O-Y Black Sea Bass 1991



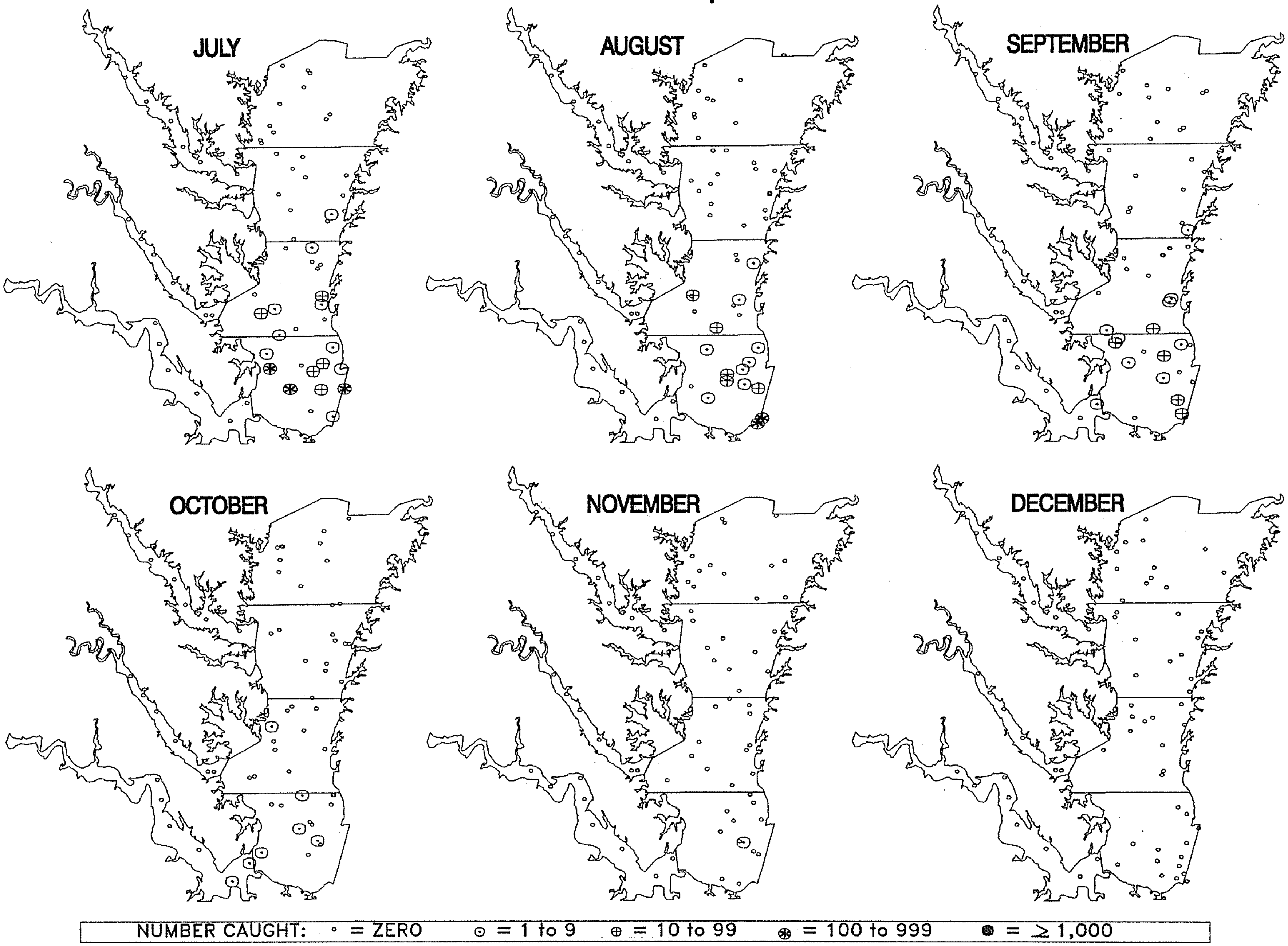
Appendix Figure 6-a.

AGE — 1 Scup 1988



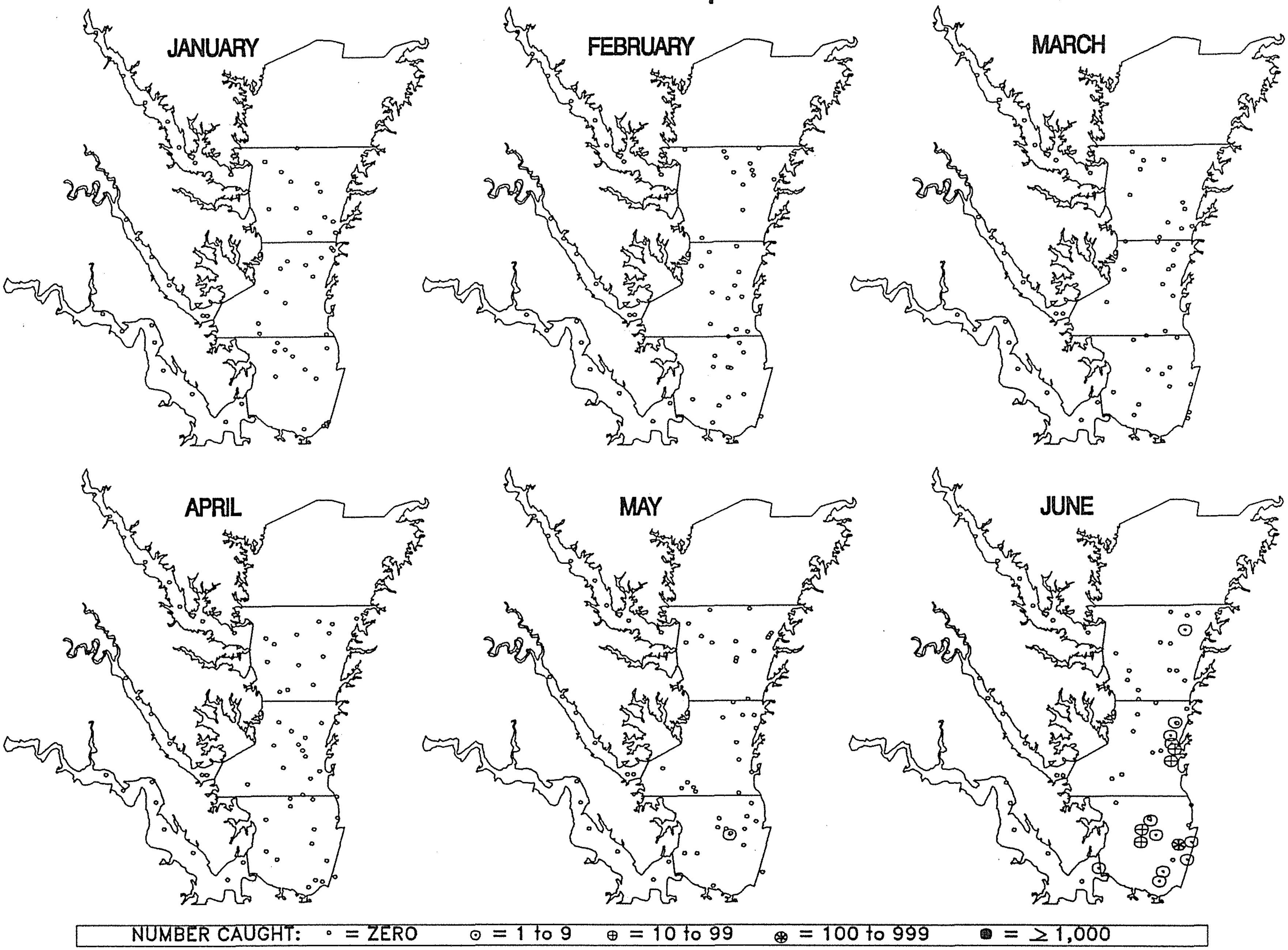
Appendix Figure 6-b.

AGE — 1 Scup 1988



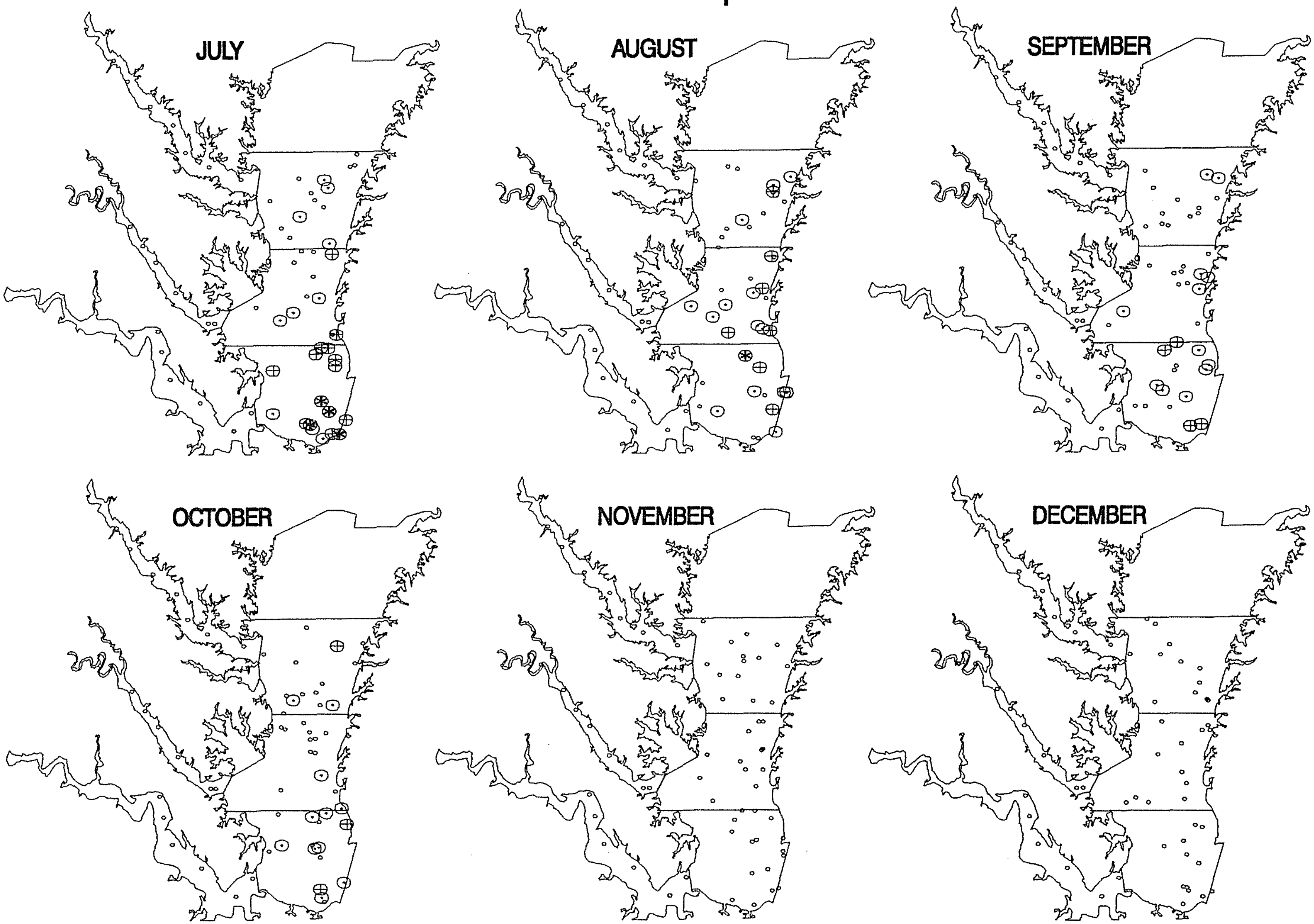
Appendix Figure 6-c.

AGE – 1 Scup 1989



Appendix Figure 6-d.

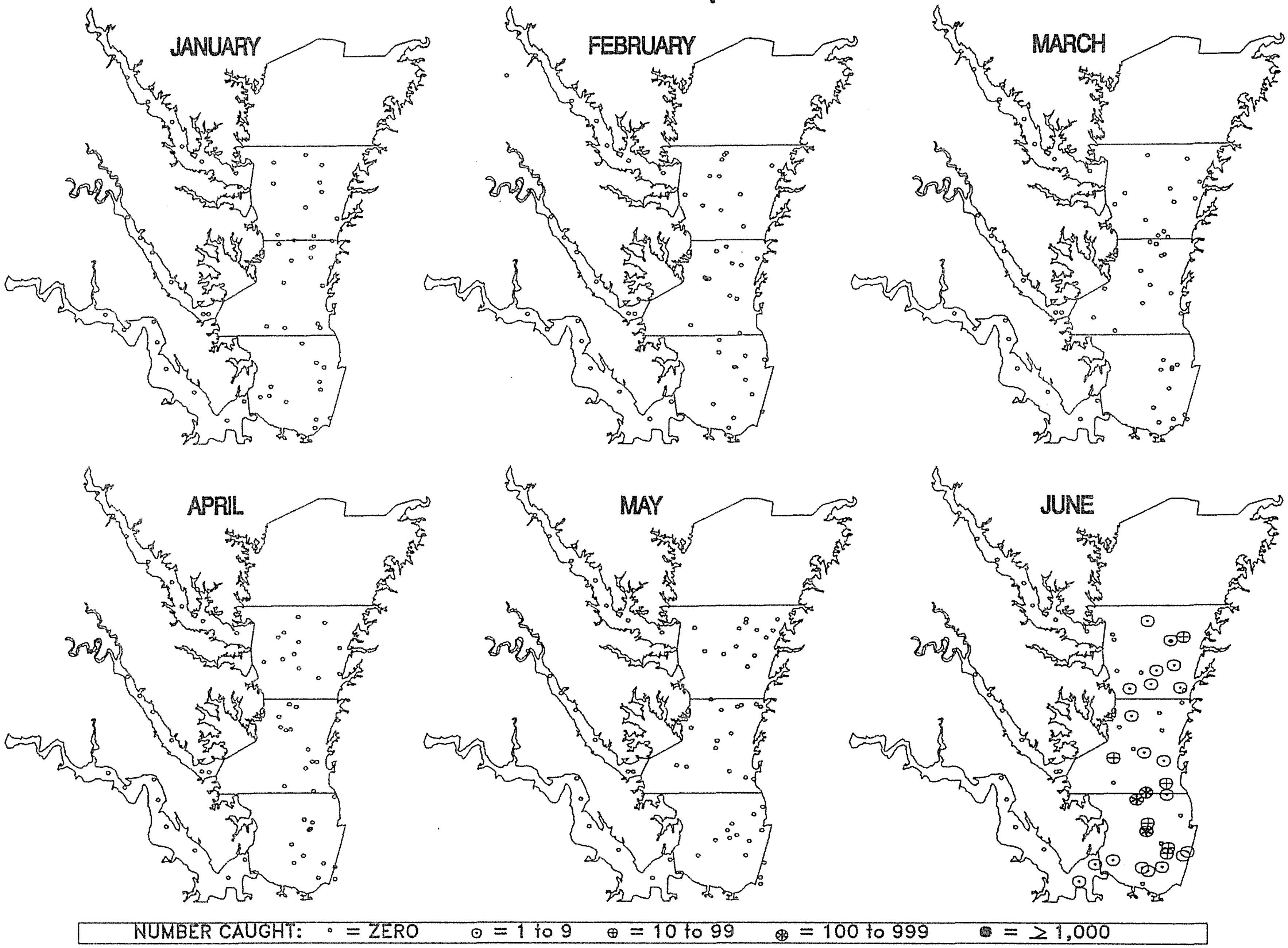
AGE – 1 Scup 1989



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

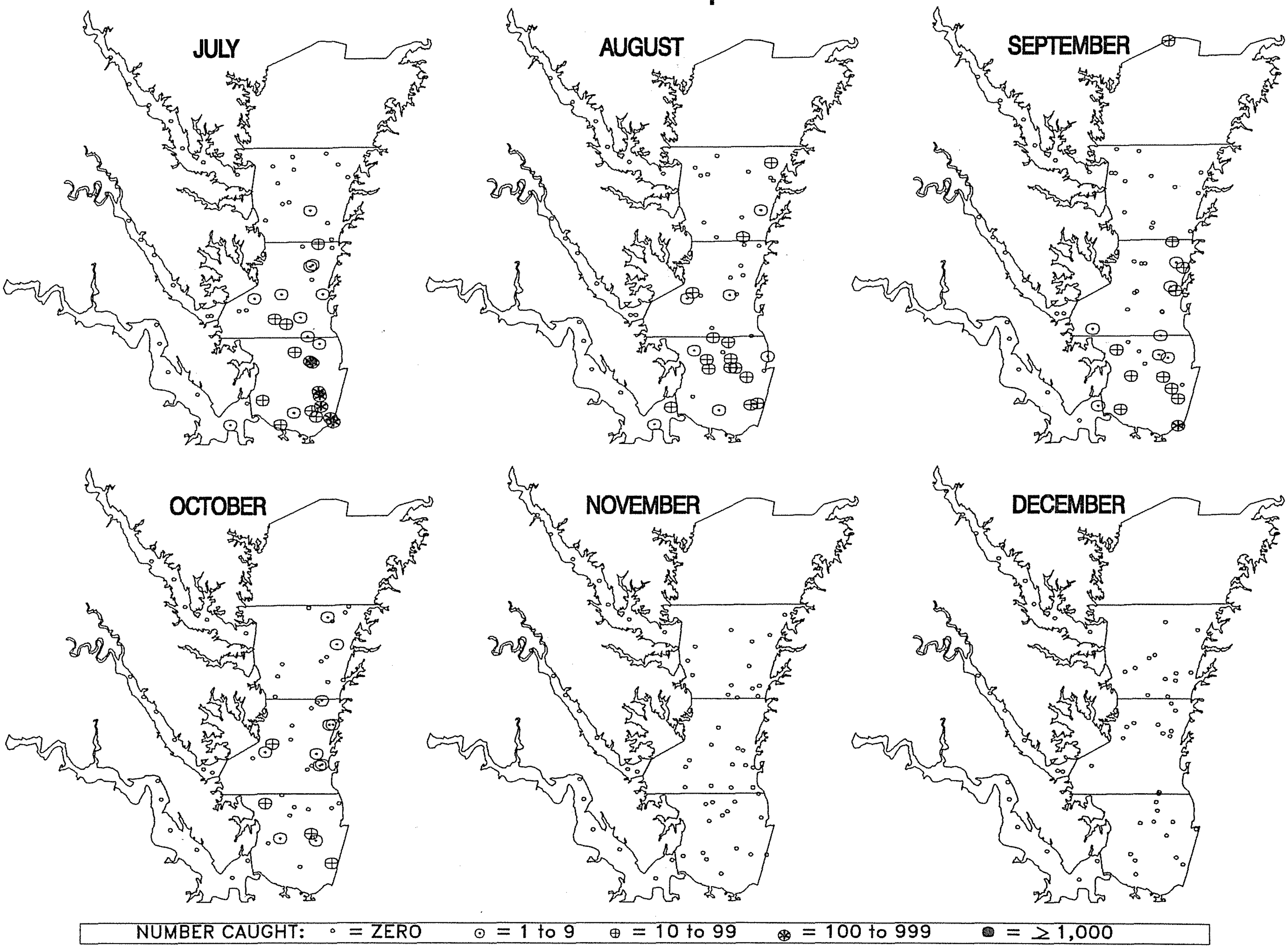
Appendix Figure 6-e.

AGE — 1 Scup 1990



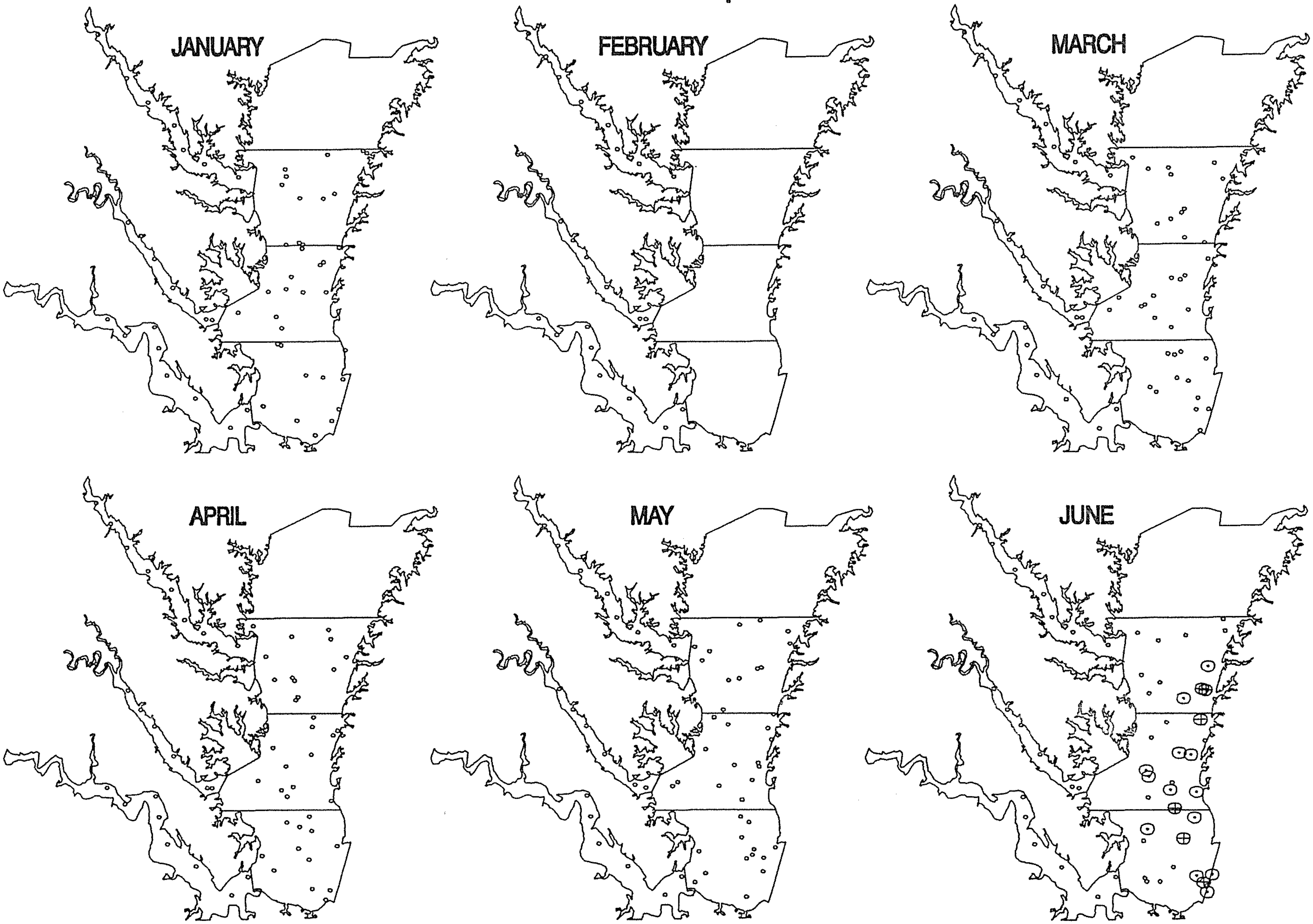
Appendix Figure 6-f.

AGE - 1 Scup 1990



Appendix Figure 6-g.

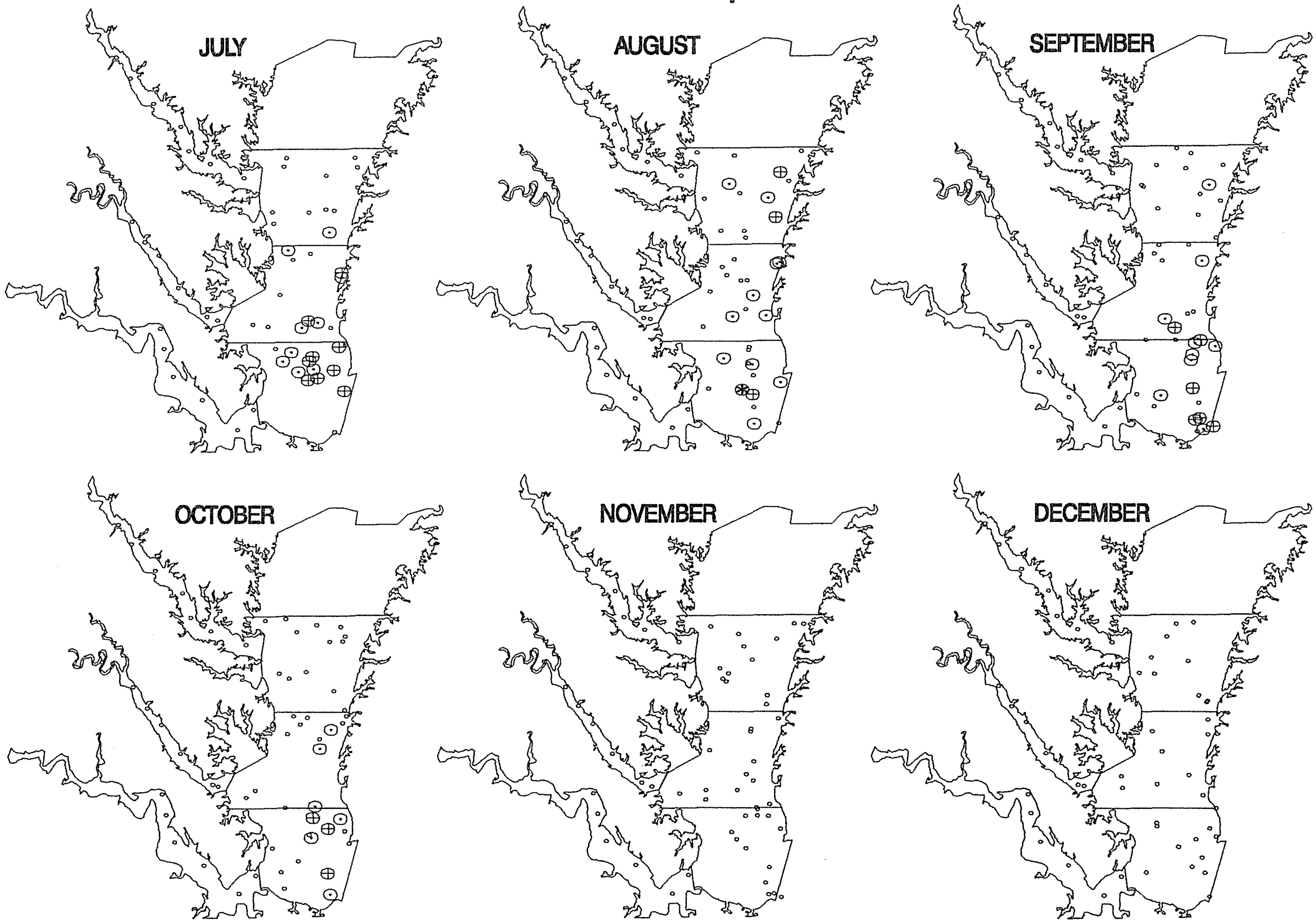
AGE – 1 Scup 1991



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

Appendix Figure 6-h.

AGE – 1 Scup 1991



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