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Estimation of Relative Abundance of Recreationally Important Finfish in the Virginia Portion of Chesapeake Bay: Annual Progress Report 1990-1991

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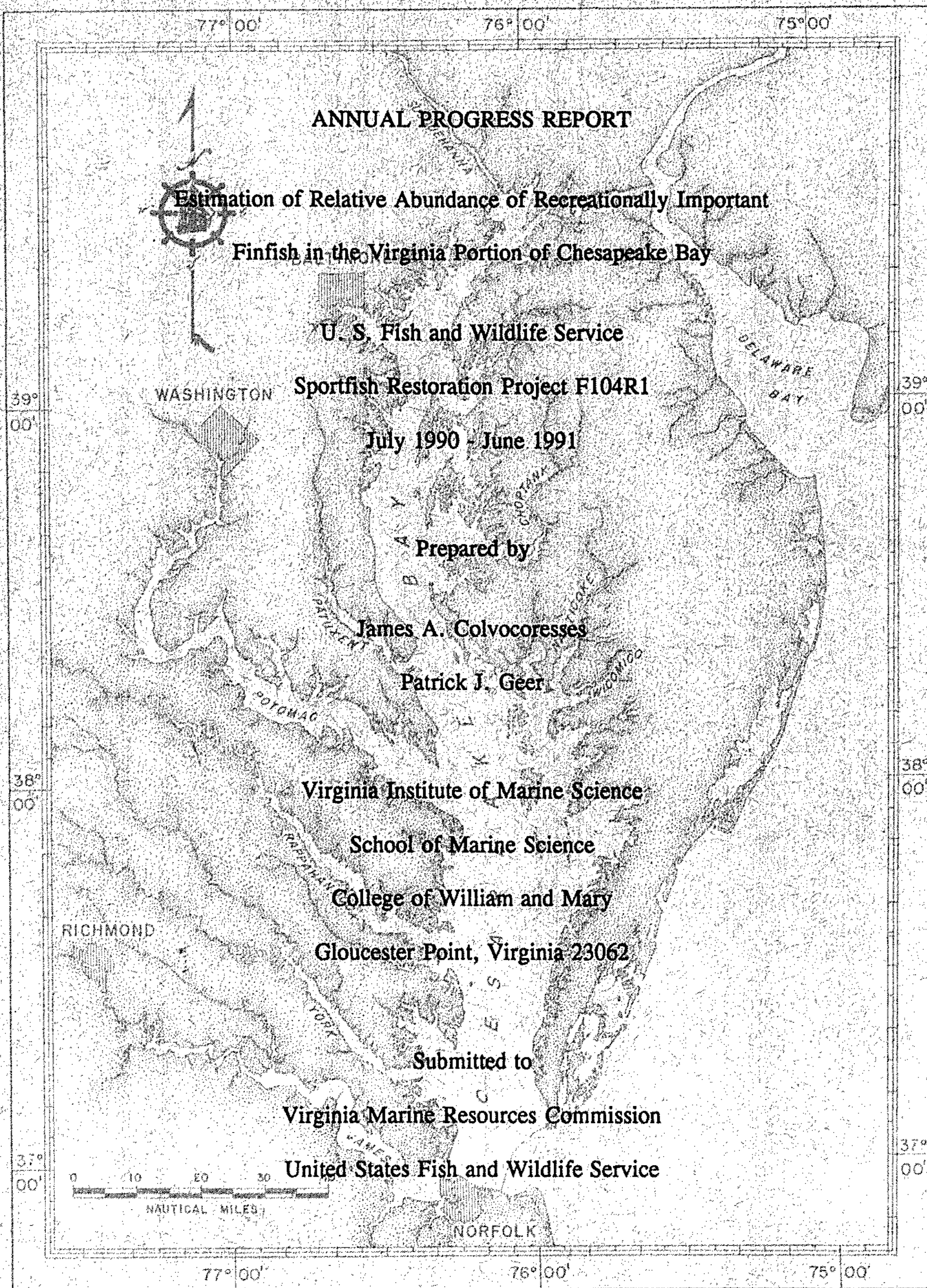

ANNUAL PROGRESS REPORT

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U. S. Fish and Wildlife Service

Sportfish Restoration Project F104R1

July 1990 - June 1991

Prepared by

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SUMMARY

1. Provisional annual indices of juvenile (young-of-the-year) abundance were 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) for the period 1988-1990. Only summer flounder catches resulted in an index that showed a consistent trend and was significantly different during all three years, with the index rising from 0.7 in 1988 to 2.9 in 1990. Atlantic croaker showed the greatest variability between years, with the 1989 index of 66 being 5 to 7 times higher than that seen in the next and prior year, respectively. The other three species showed only a two- to three-fold range of index values and considerable overlap of confidence intervals between years. The highest juvenile spot index (62) was calculated for the 1988 year class, while weakfish and black sea bass both showed maximal values in 1989 (13 and 2.4 respectively).

2. 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.

3. 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

A recent 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.

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). A review of previously available indices of juvenile abundance for important fishery resource species in the Chesapeake Bay by the Chesapeake Bay Stock Assessment Committee (CBSAC), a federal/state committee sponsored and funded by the National Oceanic and Atmospheric Administration (NOAA), resulted in the recommendation 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). A major impact of the lack of such a program was that the information on juvenile abundance needed to manage those species which utilize the deeper and more saline portions of the Chesapeake Bay as nursery areas (such as the five species of high recreational importance in Virginia waters cited above) has either been fragmentary or lacking.

In order to facilitate the implementation of such a program, CBSAC has subsequently encouraged and directly supported pilot studies directed at developing a comprehensive Bay-wide trawl survey. In the Virginia portion of Chesapeake Bay the primary focus of this support was the initiation, beginning in January of 1988, of a monthly trawl survey of the mainstem portion of the lower bay which 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 through the use of scientific trawl surveys. The primary intent of the present project is to assure that the comprehensive sampling program established by the CBSAC-funded pilot study be continued as well on a long-term basis. The expanded sampling program is a 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 that will be adequate for management purposes. The project also seeks to facilitate the further development of a comprehensive Bay-wide trawl survey through gear evaluations and comparison studies which will serve to unify current trawling programs 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 three 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 key species identified above, in the present report provisional annual juvenile abundance indices have been calculated for them. Calculations of abundance indices for other species of interest will be deferred until a sounder basis for their calculation can be generated. 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) and 1990 (Bonzek et al. 1991) have been previously prepared and distributed.

METHODS

Field Sampling

All collections were made with a 30' semi-balloon otter trawl (Gulf Shrimp Trawl) with a 1 1/2" stretch mesh body and a cod end fitted with a 1/2" stretch mesh liner, fished with a tickler chain along the bottom for a period of five minutes at a vessel speed of approximately 2 1/2 knots. Sampling was done during daylight hours from either the R/V Captain John Smith or the R/V Fish Hawk. Catches were sorted to species, enumerated and individual lengths recorded. In the cases of extremely large catches representative subsamples were taken for length frequencies. Relevant hydrographic and atmospheric parameters including depth, salinity, temperature and dissolved oxygen were recorded with each collection.

Sampling was performed monthly utilizing a random stratified sampling design in the mainstem bay and a fixed transect design in the tributaries. Stratification in the Bay was based on depth and latitudinal zones (Fig. 1). Trawling sites within strata were 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 were selected for each strata each month, the number chosen seasonally varying from 2 (colder months, December to April) to 3 (warmer months) in the shoal strata and remaining a constant four in other 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 was 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 second half of this first project segment a pilot random, stratified design survey in one of the Virginia tributaries (the York system, for logistical reasons) was implemented and is being conducted in a parallel manner with the fixed transect survey. Sampling for the two surveys is being conducted as synoptically as feasible each month (complete same-day sampling is not possible as the fixed-transect sampling is much less intense and requires only a single day's sampling per tributary, the random survey requires at least two). Gear and sampling protocol are identical. The parallel survey will be continued into the second segment until it has been conducted for a period of one year, at which point the data will be evaluated and a decision made 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 order to assure that a sampling platform and associated gear change 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 scheduled to be subsequently taken out of service. Both vessels performed all of the August tributary surveys in tandem, making parallel simultaneous tows at each station. Subsequent to this 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 was also conducted, this time on an alternating basis from the same vessel (Fish Hawk). Additionally, a short series of alternate tows were made using the standard Virginia 30' trawling gear and a 20' custom high-rise trawl which has been the most recently used gear in a pilot survey in the Maryland portion of Chesapeake Bay.

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 (i.e. monthly) and juvenile indices constructed as best possible from this data.

In the 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 varied 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 were usually arbitrary values which fell 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 overtook late spawned and slowly growing individuals of the previous year class, cutoff values were 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 was estimated based on the shapes of each modal curve during the months prior to overlap occurring. A length value was then selected from within that range which would result in the appropriate proportional separation. Although this process involved considerable subjectivity and ignored possible interannual variability in average growth rates, there is little likelihood that any significant error was introduced, as only a very small fraction of the total number of young-of-the-year individuals fell within the zone of overlap and most of the data used to construct juvenile indices was drawn from months when no overlap at all was present.

After partitioning out non-young-of-the-year individuals, monthly catch rates of the target species were map-plotted and strata-specific abundances and occurrence rates calculated. Numbers of individuals caught were 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) were then back-transformed to the geometric means. Plots and data matrices were then examined for the area-time combinations which appeared to provide the best basis for juvenile index calculations. Criteria applied during the selection process included 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) was generally clear, selection of appropriate time windows proved a more complex issue. Since surveys were 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 was made not to incorporate any longer temporal series of data into index calculations than was 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 was possible to identify three-month periods which captured the two months of highest abundance during all three years sampled for four of the five species examined, while for the fifth a four month period was required.

After area-time combinations were selected, annual juvenile indices were calculated as the weighted geometric mean catch per tow. Strata-specific means and variances were calculated and then combined, weighting by stratum areas according to the formulae supplied by Cochran (1977). Since stratum areas were 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 supplementary sampling involving vessel comparisons strongly indicated that the change of sampling platforms will have no impact whatsoever on catch rates. Mean catch rates were very consistent and statistically indistinguishable across all abundant species. Comparison tows involving the different types of trawl doors also did not suggest that this gear change will significantly effect catches, but these comparisons were conducted at a time of year (spring) when diversity and abundances were relatively low so additional comparisons have been scheduled for the second project segment during the period of maximal abundance and diversity (fall) prior to statistical analysis of this data. A small set (6 tows each) of trawl gear comparisons involving the gear used on the present project and a custom-built 20' high rise trawl recently used in a Maryland pilot survey showed considerably higher catch rates with the presently used gear, but this was to be expected as virtually all of the fishes taken by either net were small in size and the Maryland net had a smaller sweep and larger mesh size. A more extensive set (20 pairs) of earlier comparison tows involving a larger (30') version of the high rise failed to demonstrate whether one gear offered a significant advantage over the other, with differences in catches not being large and variability sufficiently high to preclude absolute statistical conclusions within the given sample size, but catch rates in that series as well were consistently somewhat higher for the trawl presently being used in the Virginia survey, particularly for smaller sized individuals.

Juvenile Index Calculations

Spot (*Leiostomus xanthurus*) - This was the most abundant and widely and consistently distributed of the finfish recreational resource species taken. Young-of-the-year individuals first recruit into the survey area during April (Fig. 2), so for the purposes of year class index calculation this was taken to be the beginning of the biological year. Except for the months of April through June catches were almost completely dominated by the most recent year class. In April and May young-of-the-year are completely segregated by size from the previous year class. A very slight degree of size overlap is present in June, after which larger individuals are virtually absent from the catches (Fig. 2), presumably due to decreased vulnerability to the gear with increased size and/or reduced abundances due to fishing mortality or emigration. Young-of-the-year abundances were relatively low and distribution was spotty until May or June, after which spot were abundant and widely distributed throughout the survey area until the onset of winter (Appendix Figs. 1 a-f). During 1988 sampling average catch rates were highest during July and August and showed a secondary peak in October, while in 1989 catch rates peaked in August and October and in 1990 showed a single peak in September (Fig. 4). The period of August through October was therefore chosen as the temporal window for index calculation, as this period essentially encompassed the three months of highest abundance during all three years sampled. Since during this period spot were distributed throughout the survey area, all strata were included in the calculations.

The weighted geometric mean catch per tow for juvenile spot ranged from 34 (1989) to 62 (1988) individuals (Table 3, Fig. 5), with the latter value exhibiting only slightly overlapping confidence intervals with the former. The catch data for 1990 exhibited an intermediate index value (44) which had confidence intervals which broadly overlapped both of the other two years.

Atlantic Croaker (*Micropogonias undulatus*) - This species, like the spot, displayed high levels of abundance in the trawl catches but presented 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) were present in the catches on a year round basis (Fig. 6). Peak recruitment of early juveniles, however, clearly took place during the fall months and for the purposes of separating size cohorts on an annual basis September was obviously the most appropriate month to designate as the first month of 'new' recruitment, and length cutoff values (Fig. 7) were designated accordingly. Distribution of new juveniles was very uneven and variable between years. Early recruitment took place primarily in the rivers during September (1988 and 1989) or October (1990), and subsequent distribution of young-of-the-year was largely centered in the tributaries for the remainder of the calendar year during two of the three years sampled (1988 and 1990). During 1989, however, significant numbers of new juveniles were also taken in the mainstem bay throughout the fall and early winter (Appendix Figs. 2 a-f). 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 4) during the months of peak juvenile abundance. It was therefore decided to base this initial juvenile index solely on the tributary data, subject to latter revision if further sampling supports the December 1989 results. Choice as to what temporal period to use for index calculation was, on the other hand, very straightforward. Maximal young-of-the-year abundances were observed during November of all three years, with the next highest value occurring during the preceding (1989) or following (1988 and 1990) month and the third highest value being recorded during the remaining month of the October-December period (Fig. 4), outside of which relatively few young-of-year were taken.

Survey results indicated a much stronger year class of croaker in 1989 than during the other two years sampled. The calculated index for 1989 (66, Table 3 and Fig. 5) was over five times that seen in the other two 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, was still one of the dominant species of the trawl collections. New juveniles occasionally have occurred in the catches as early as late June (Fig. 8), which was taken as the beginning of the biological year (Fig. 9), but most new recruitment to the nursery areas took place in July, August and September. During July young-of-the-year weakfish were found primarily in the tributaries, but by August and for all ensuing summer and fall months they were widespread and fairly evenly distributed throughout the entire survey area (Appendix Figs. 3 a-f). As was the case with croaker, peak abundances were observed during the same three month period during all three years, August-October (Fig. 4). Index calculations were therefore based on data from all strata collected during these months.

The weakfish juvenile abundance indices for 1988 and 1989 were similar (9 and 13, respectively, Table 3 and Fig. 5) and had broadly overlapping confidence intervals. The 1990 index was considerably lower (5), and was statistically discrete from the 1989 index and had only slightly overlapping confidence intervals with the 1988 index.

Summer Flounder (*Paralichthys dentatus*) - This species was generally taken in much lower numbers than the three sciaenid species above but was still a regularly occurring component of the trawl catches. Small juveniles first appeared in the catches in March (Fig. 10), which for the current purposes was used as the beginning of the biological year (Fig. 11), but were not taken in appreciable numbers until June (Appendix Tables 4 a-f). Young-of-the-year abundance continued to increase gradually throughout the summer and early fall, peaking in either October (1988 and 1989) or November (1990, Fig. 4). By December of each year emigration from the bay was clearly taking place. Near-peak abundances were recorded in September of each of the first two years, while in 1990 September catch rates were very close to also being the third highest. September through November were therefore chosen as the period for index calculation. During this time period juvenile flounder were broadly distributed across the mainstem bay and were commonly taken in the lower rivers, but only rarely appeared in catches in the upper tributaries. Index calculations therefore included all bay strata and the lower river strata.

The resultant summer flounder index showed a distinct upward trend during the three years sampled, rising from a weighted geometric mean catch of 0.7 individuals per tow in 1988 to almost 3 per tow in 1990, with all three years having discrete confidence intervals (Table 3 and Fig.5).

Black Sea Bass (*Centropristis striata*) - Like summer flounder, black sea bass were seldom taken in large numbers but still occurred often in the catches. Small early juveniles first appeared in the catches in August (Fig. 12), which was used as the initial month for year class separation (Fig. 13). When present, young-of-the-year sea bass occurred throughout the bay strata but did not appear to penetrate into any of the tributaries except the lower James River on a regular basis (Appendix Figs. 5 a-f). Index calculations were thus based on all bay strata and the lower James strata. Choice of the appropriate time period for index calculation was 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. 4). Since abundances are highest and distribution much more consistent during the late spring and early summer, initial juvenile index calculations were based on the months of May through July, a period which encompassed the three months of highest abundance during all three years sampled. 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 and the same pattern was seen for the year classes the following spring and summer, but several more years of data will be required to determine if a consistent relationship exists.

The annual juvenile indices for black sea bass ranged from 0.9 (1988 year class) to 2.4 (1989 year class). As was the case for weakfish, the intermediate index of the three (1.5, 1987 year class) had overlapping confidence intervals with both of the other two years while the high and low values were statistically different (Table 3, Fig. 5).

DISCUSSION

The annual juvenile abundance indices presented here should be regarded as strictly provisional. Three years of data will undoubtedly not capture all of the interannual variability in nursery area utilization, and 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 population trend context. The 1989 year class of croaker was obviously much stronger than that preceding or following it, at least on the Chesapeake Bay nursery grounds, but whether it was a strong year class on a historical basis will require comparison with a much longer time series. Towards that end there is currently an internal VIMS effort underway to construct and validate statistically sound juvenile indices using the historical VIMS tributary data, and as these indices become available they will be interrelated and compared to the present ones. The degree to which this effort will augment current survey results can be expected to vary between species. The present sea bass index is almost strictly based on the mainstem data, and there is little reason to believe that the historical tributary data will be particularly useful in interpreting it. The present croaker index, on the other hand, is based solely on the tributary data and therefore is directly calculable for the more recent historical data using the same gear (1981-on), which will be done in connection with the analysis of the second segment data. The present indices for the other three species are based on both mainstem and tributary data, and will probably demonstrate varying degrees of coherence with the historical data. A provisional summer flounder index for 1981-1990 based upon the tributary data agrees well with the present one for the three common years and provides a context for the upward trend seen for this species in Fig. 5. In the longer time series 1988 is the lowest value of record and the seemingly high 1990 value represents only a return to the historical average.

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 five of the species discussed here are highly migratory. Chesapeake Bay does constitutes a major nursery area for them 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). 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.

Comparison tows using the high-rise trawl gears used in the pilot surveys in the Maryland portion of the bay and other trawling gears tested during the Virginia pilot program (Chittenden 1989) have not indicated that any meaningful increase in trawling efficiency would be obtained by a change in nets. Since the statistical quantification of a change in trawl gears would require an extremely large set of comparison tows in order to maintain continuity with present and past results, further comparisons will be deferred until the need for them is established. Unless future recommendations regarding the development of a Bay-wide trawl survey suggest a gear change or more gear comparisons, project gear comparison studies will continue to focus on intercalibration of gears which have already contributed significant bodies of data to the historical set.

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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. Juvenile abundance indices for key recreational species.

Species	Year Class	Weighted Geo. Mean CPUE	95% C. I.	N
Spot	1988	62.4	42.5 - 91.4	231
	1989	34.3	27.0 - 43.5	252
	1990	44.5	32.3 - 61.2	252
Atlantic Croaker	1988	10.1	6.6 - 15.2	65
	1989	66.0	38.4 -113.0	65
	1990	13.5	9.0 - 19.8	60
Weakfish	1988	9.3	6.2 - 13.8	173
	1989	13.0	9.2 - 18.4	189
	1990	5.3	3.7 - 7.5	188
Summer Flounder	1988	0.66	0.44 - 0.91	143
	1989	1.40	1.07 - 1.78	162
	1990	2.86	2.32 - 3.48	164
Black Sea Bass	1987	1.68	1.11 - 2.41	124
	1988	0.85	0.59 - 1.14	138
	1989	2.36	1.70 - 3.18	138

Table 4. 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.	14.5	0.3	59.1
	Nov.	21.3	0.4	51.9
	Dec.	13.1	1.0	13.1
1989	Oct.	120.4	6.5	18.5
	Nov.	172.9	3.8	45.5
	Dec.	27.9	31.7	0.9
1990	Oct.	11.8	0.1	147.5
	Nov.	33.0	0.2	143.5
	Dec.	30.0	2.4	12.5

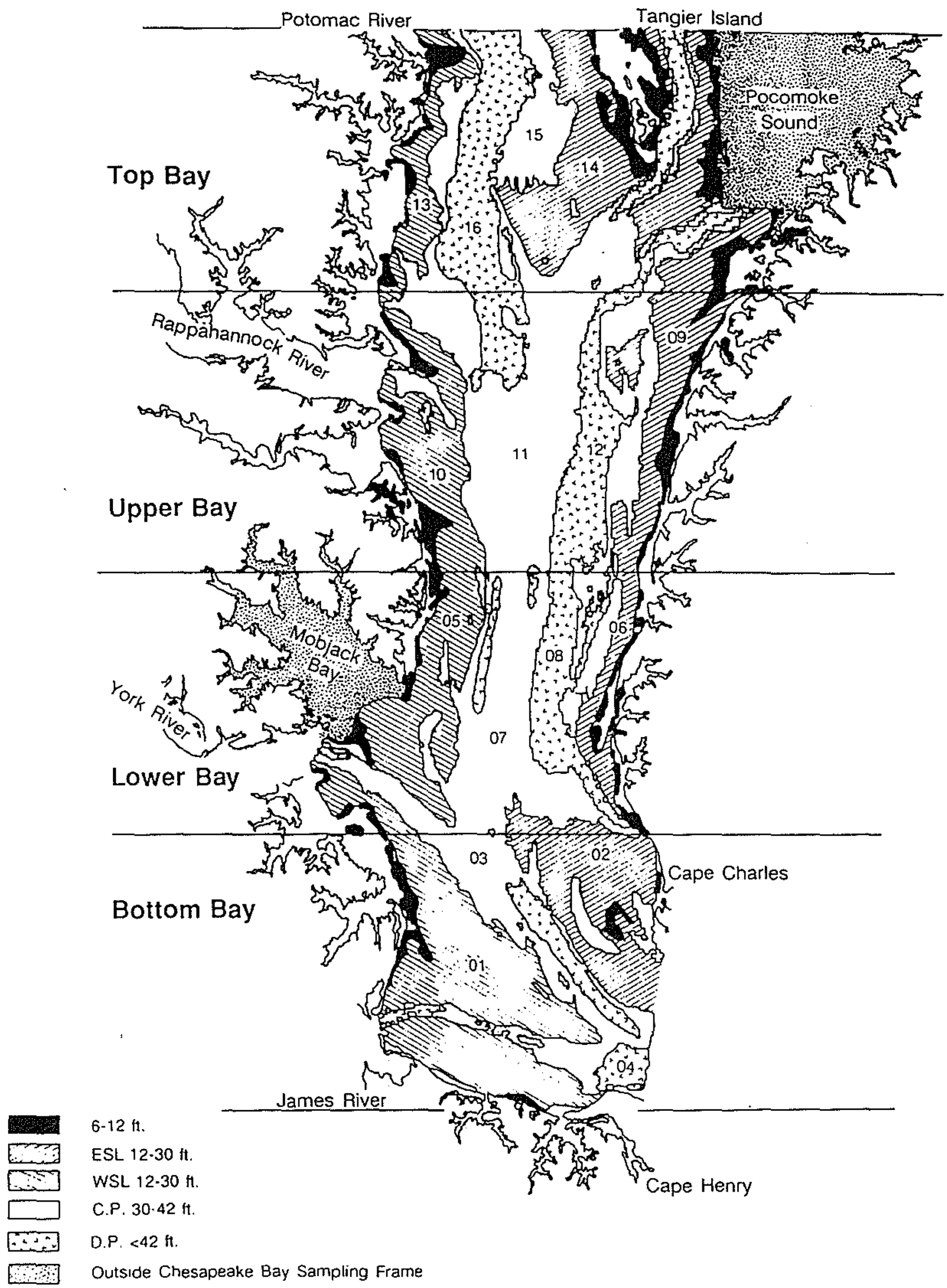


Figure 1. Chesapeake Bay trawl survey strata.

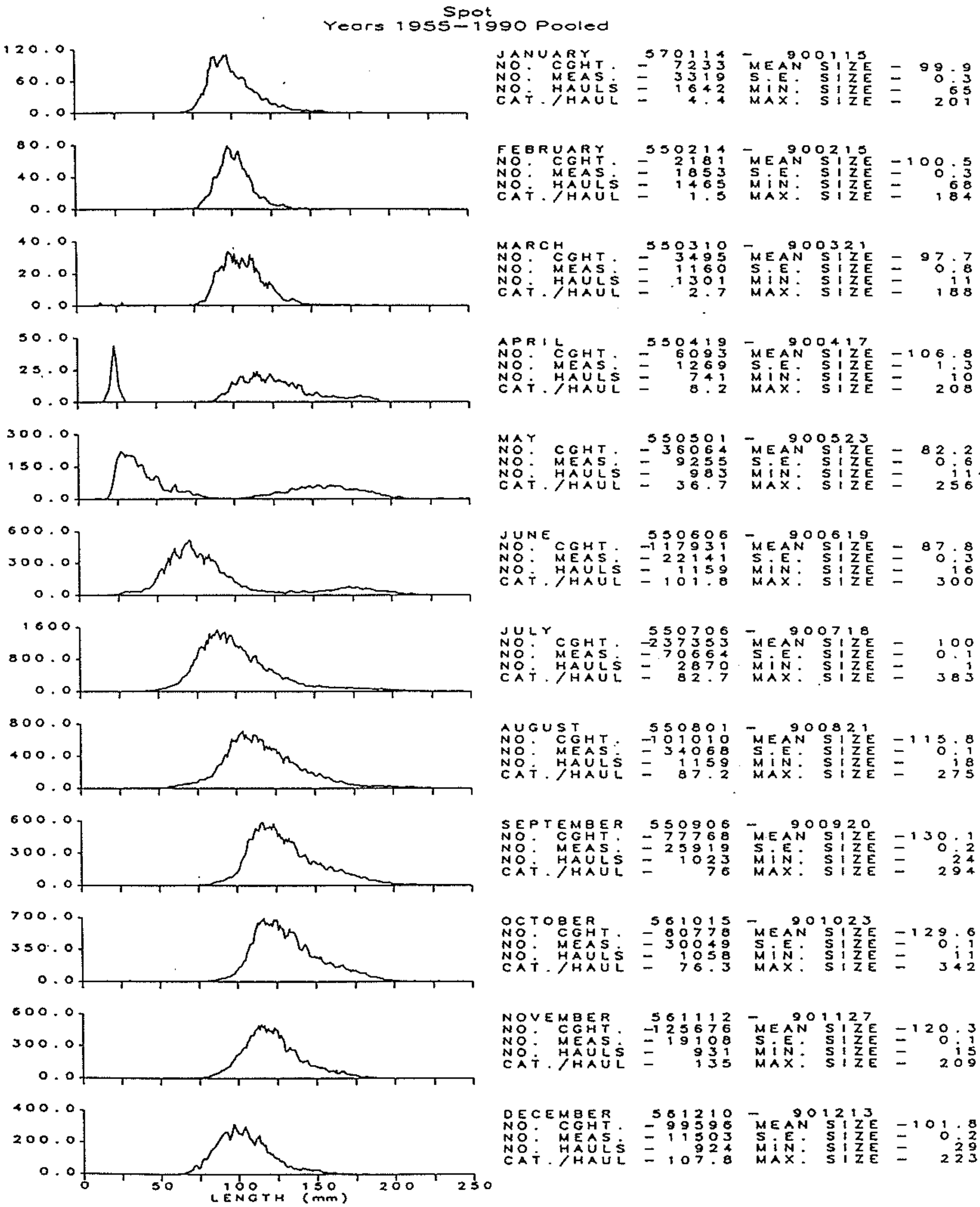


Figure 2. Composite length frequencies by month for spot, VIMS trawl survey data base, 1957-1990.

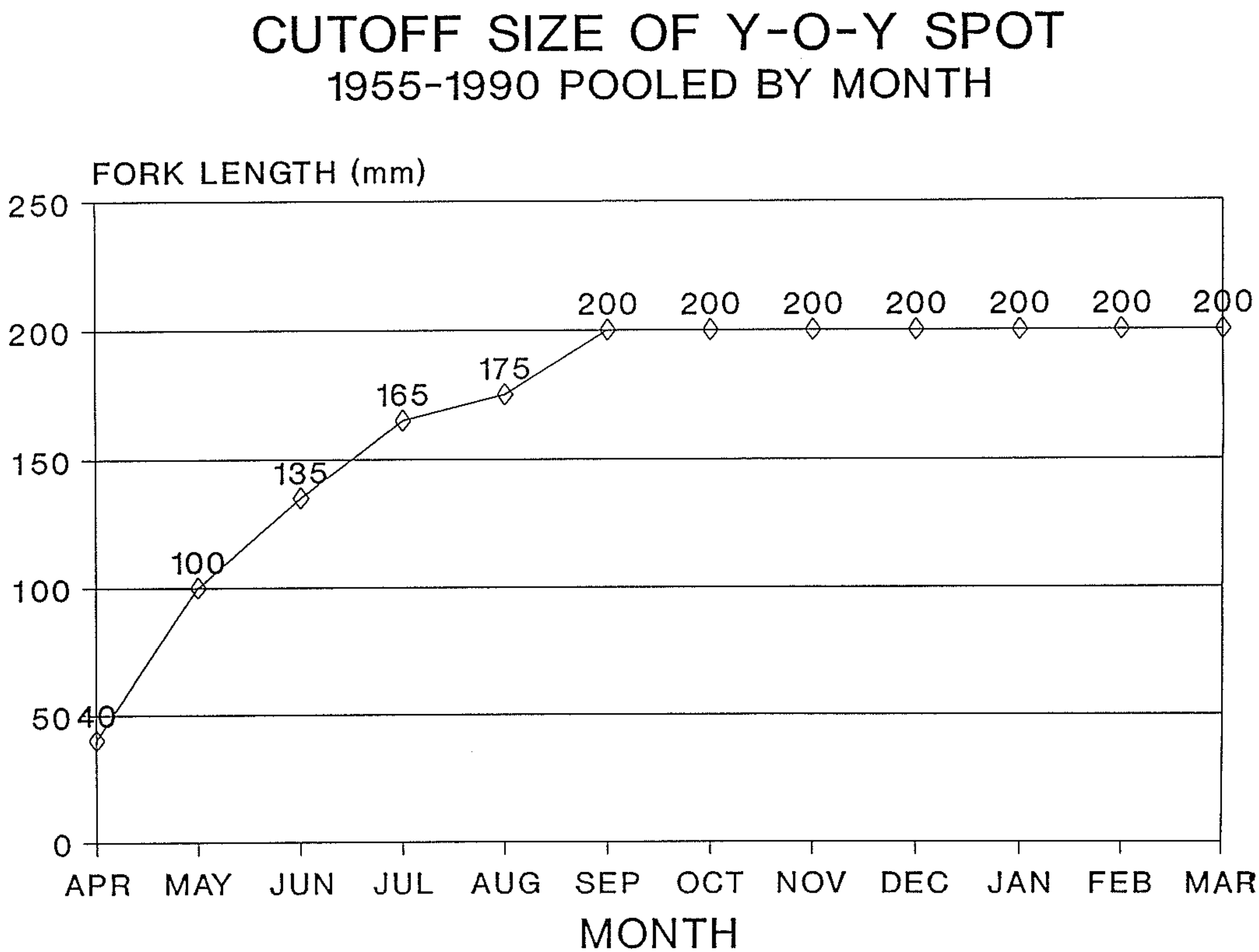


Figure 3. Length cutoff values used to separate spot young-of-the-year from older year classes.

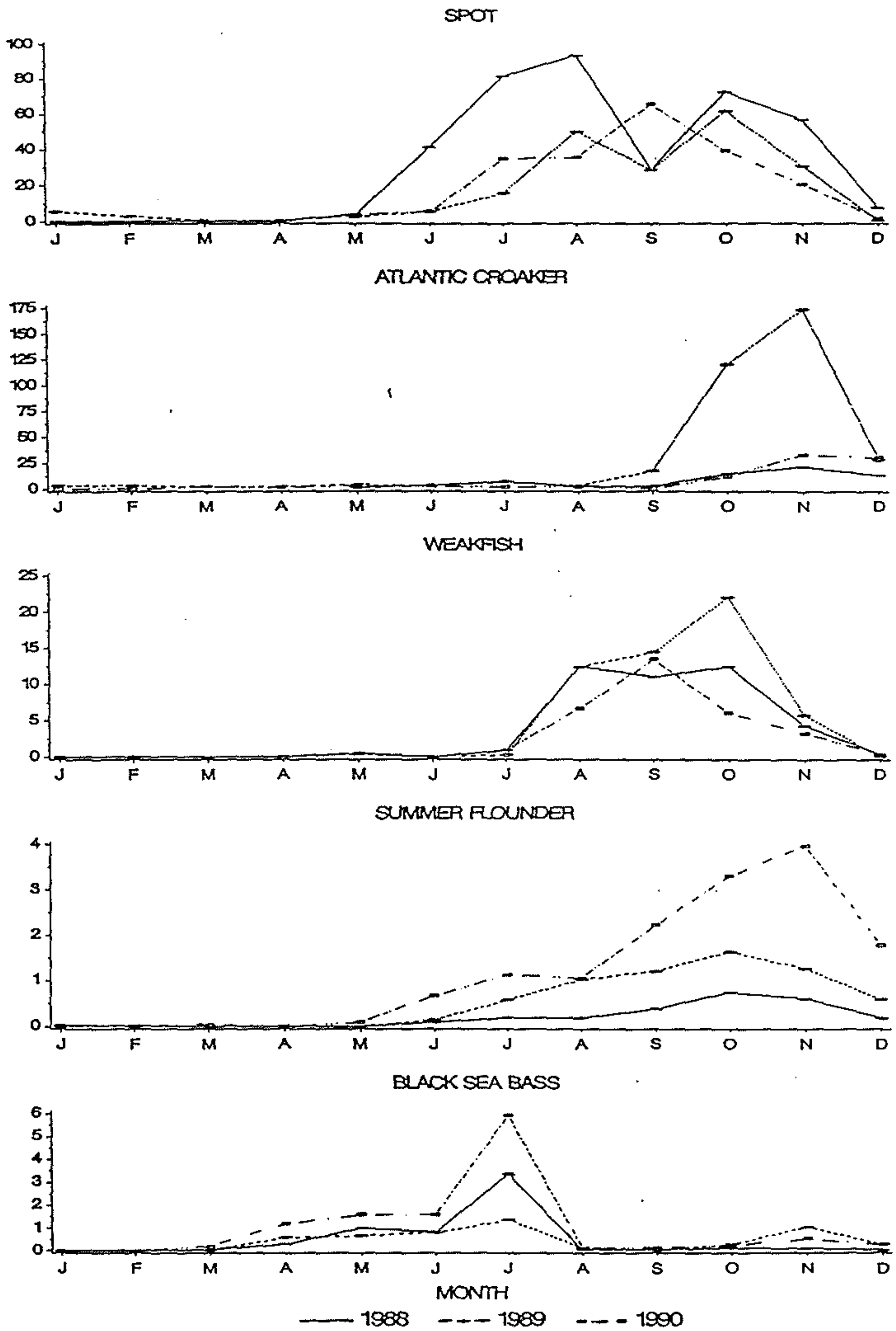


Figure 4. Geometric mean catch per tow of key species by month on the primary nursery grounds.

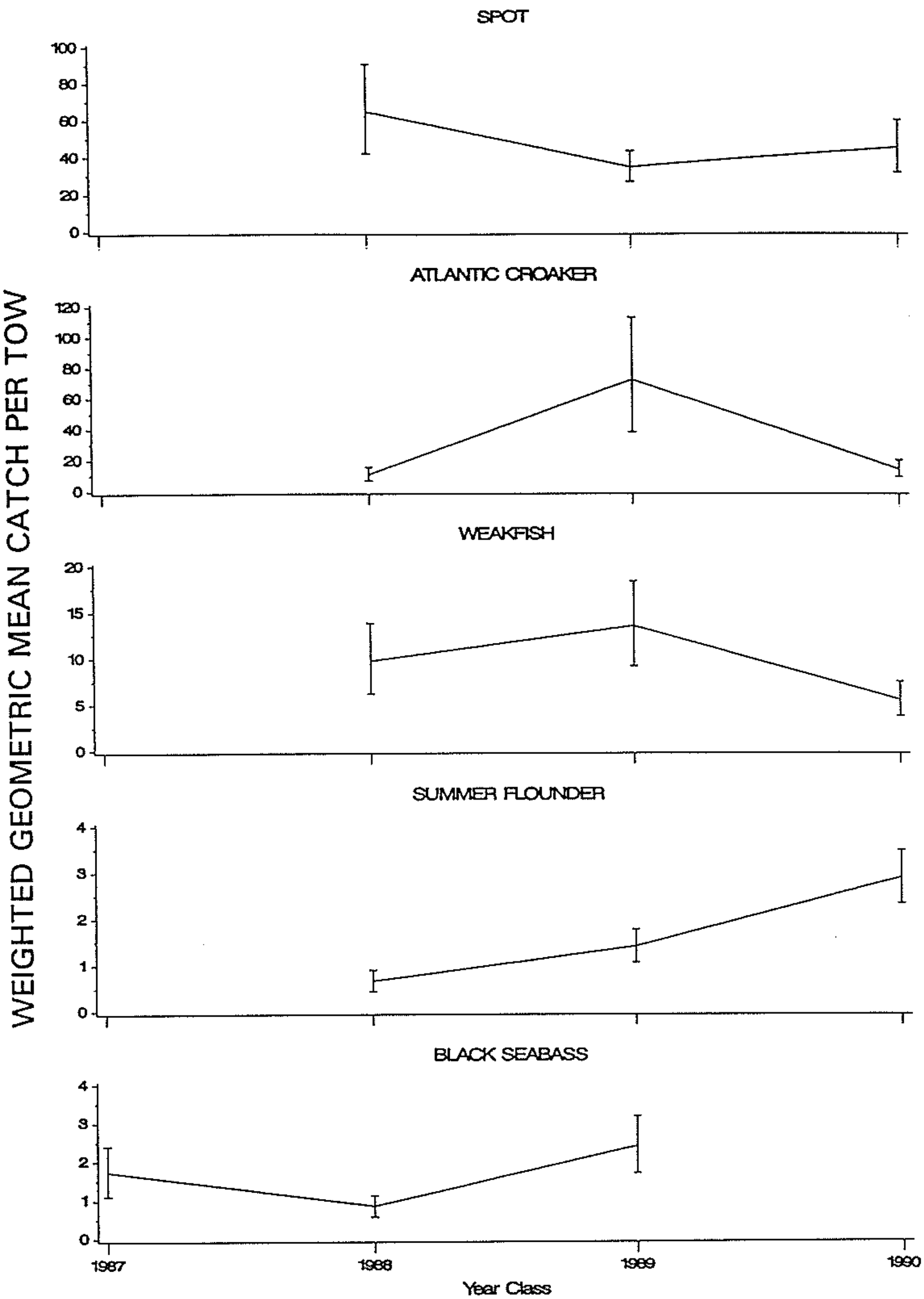


Figure 5. Annual juvenile abundance indices with 95% confidence intervals for key species.

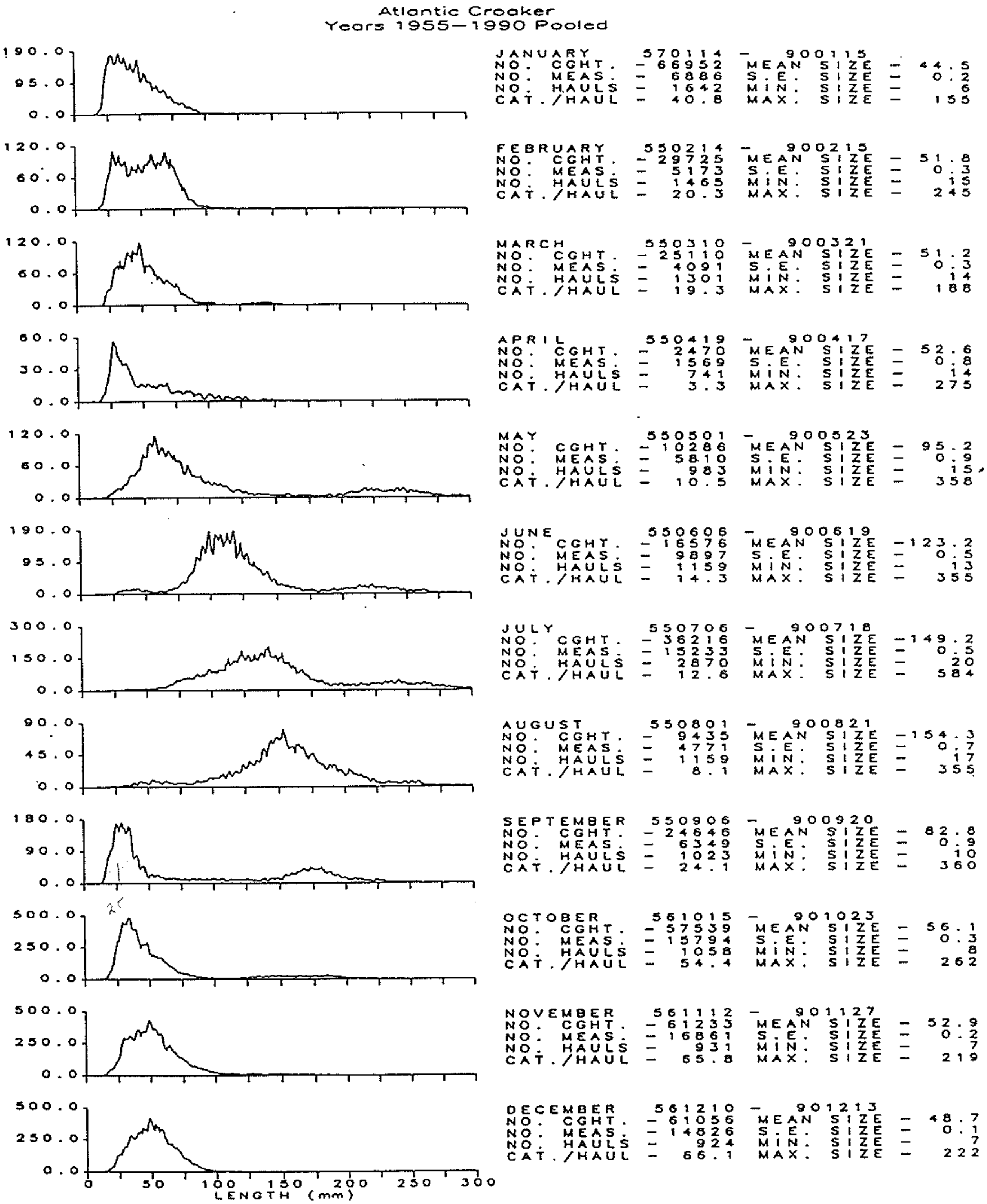


Figure 6. Composite length frequencies by month for Atlantic croaker, VIMS trawl survey data base, 1957-1990.

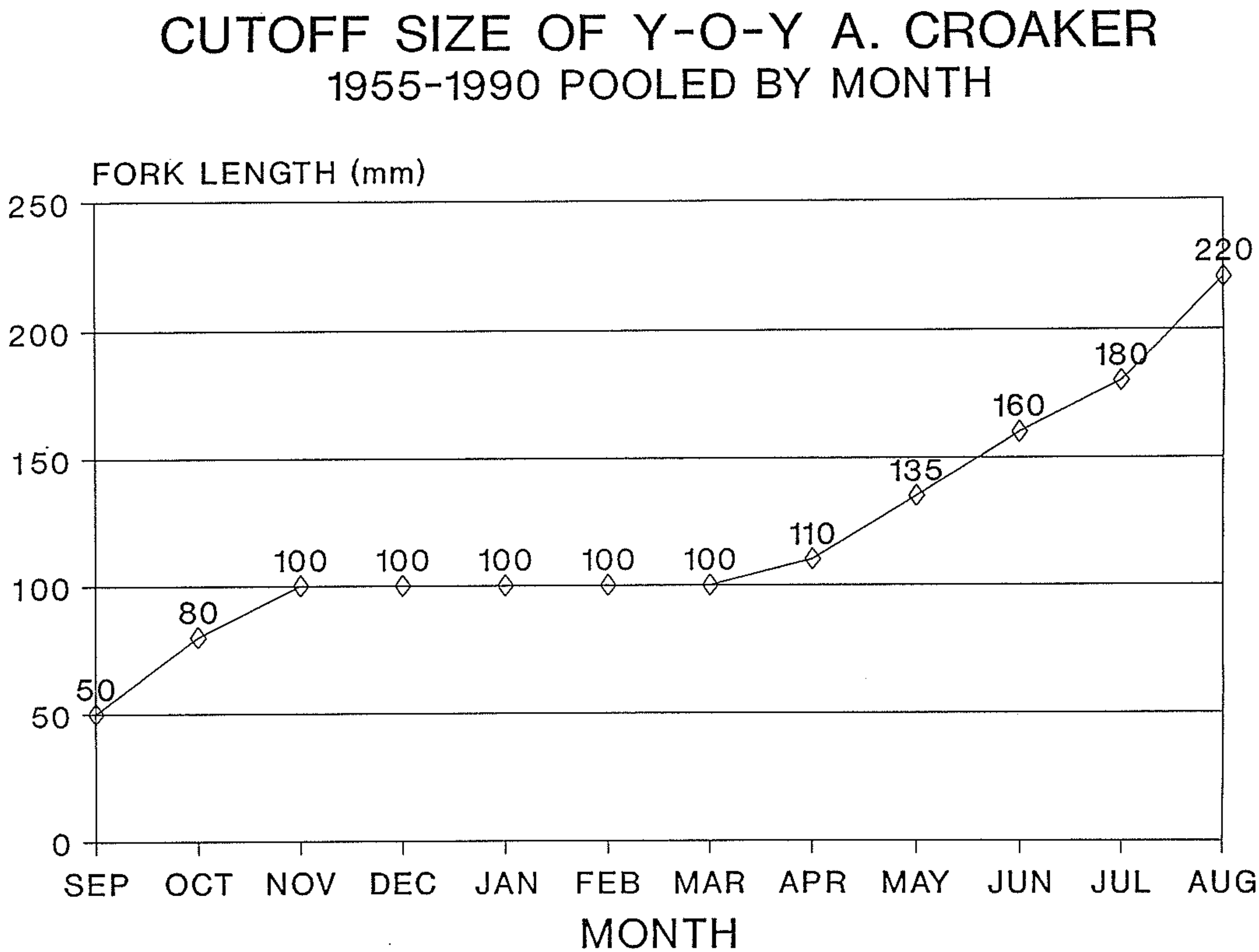


Figure 7. Length cutoff values used to separate Atlantic croaker young-of-the-year from older year classes.

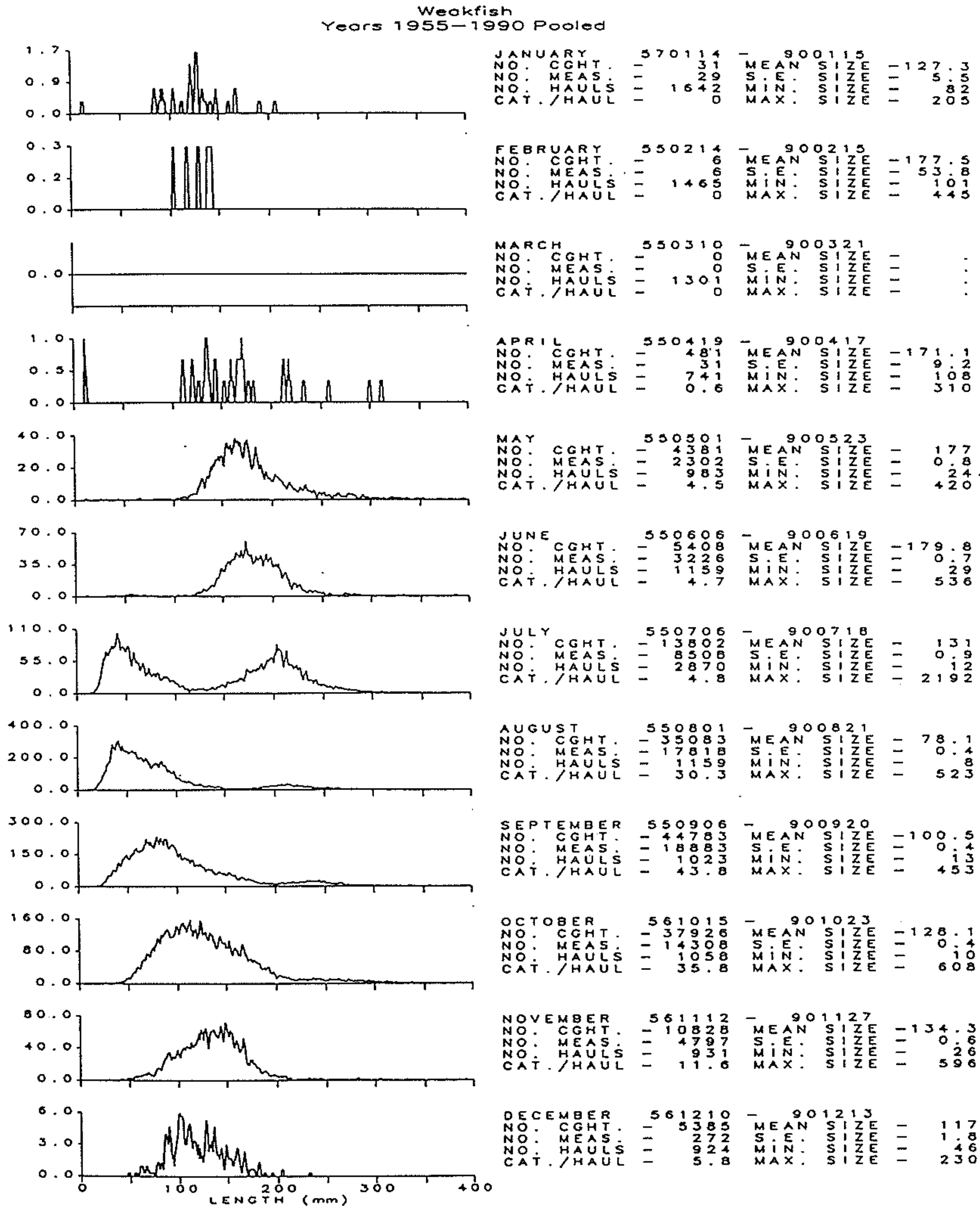


Figure 8. Composite length frequencies by month for weakfish, VIMS trawl survey data base, 1957-1990.

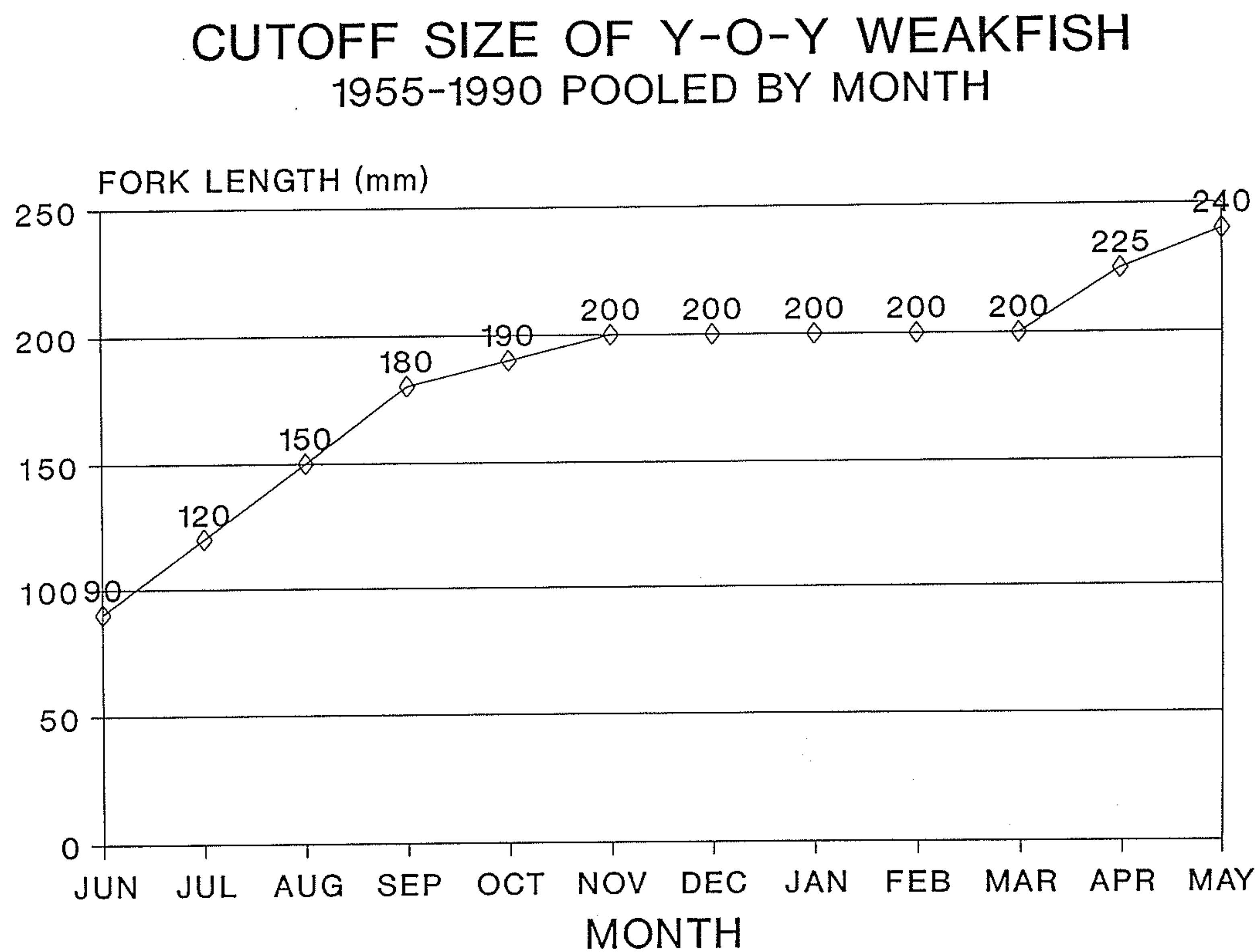


Figure 9. Length cutoff values used to separate weakfish young-of-the-year from older year classes.

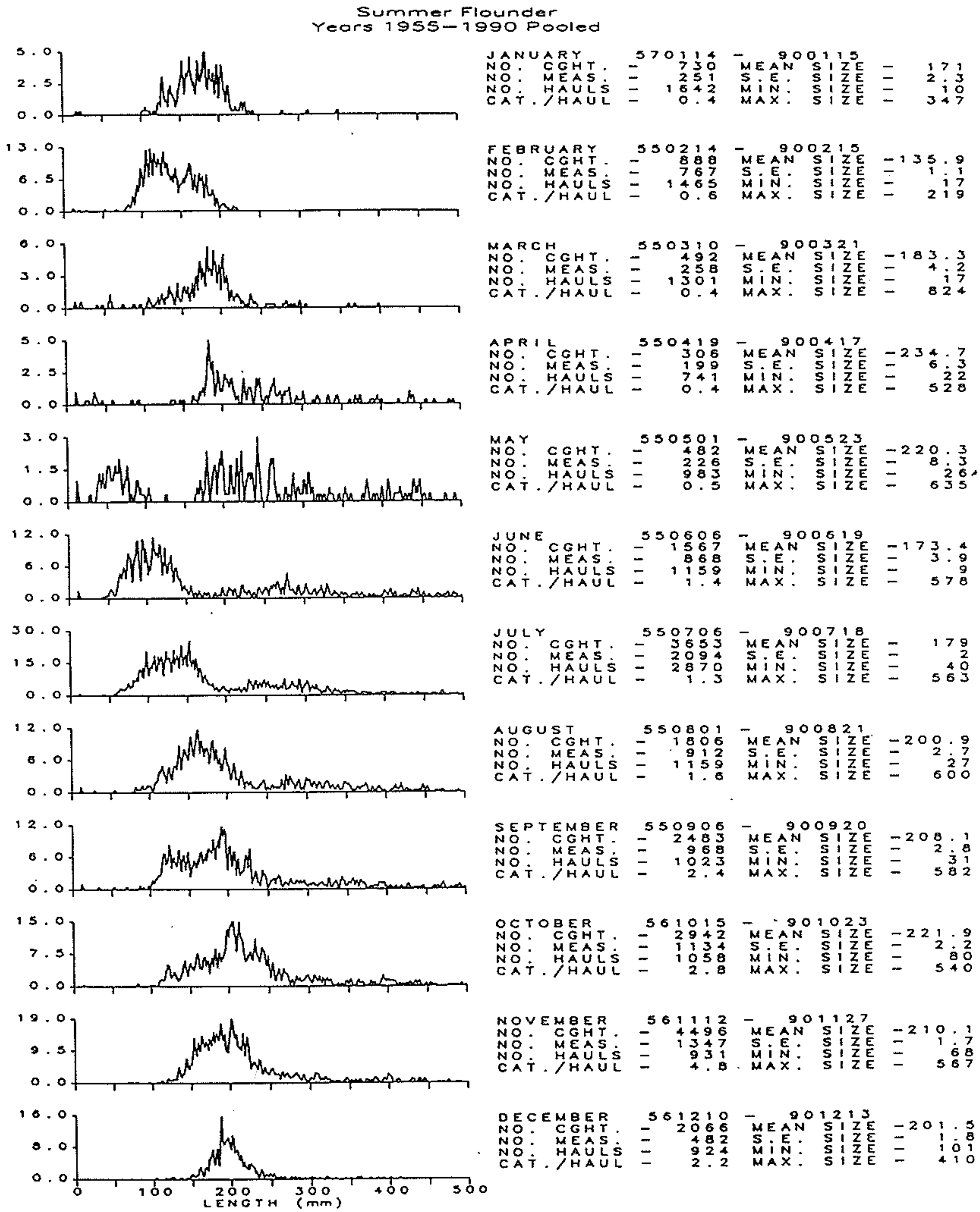


Figure 10. Composite length frequencies by month for summer flounder, VIMS trawl survey data base, 1957-1990.

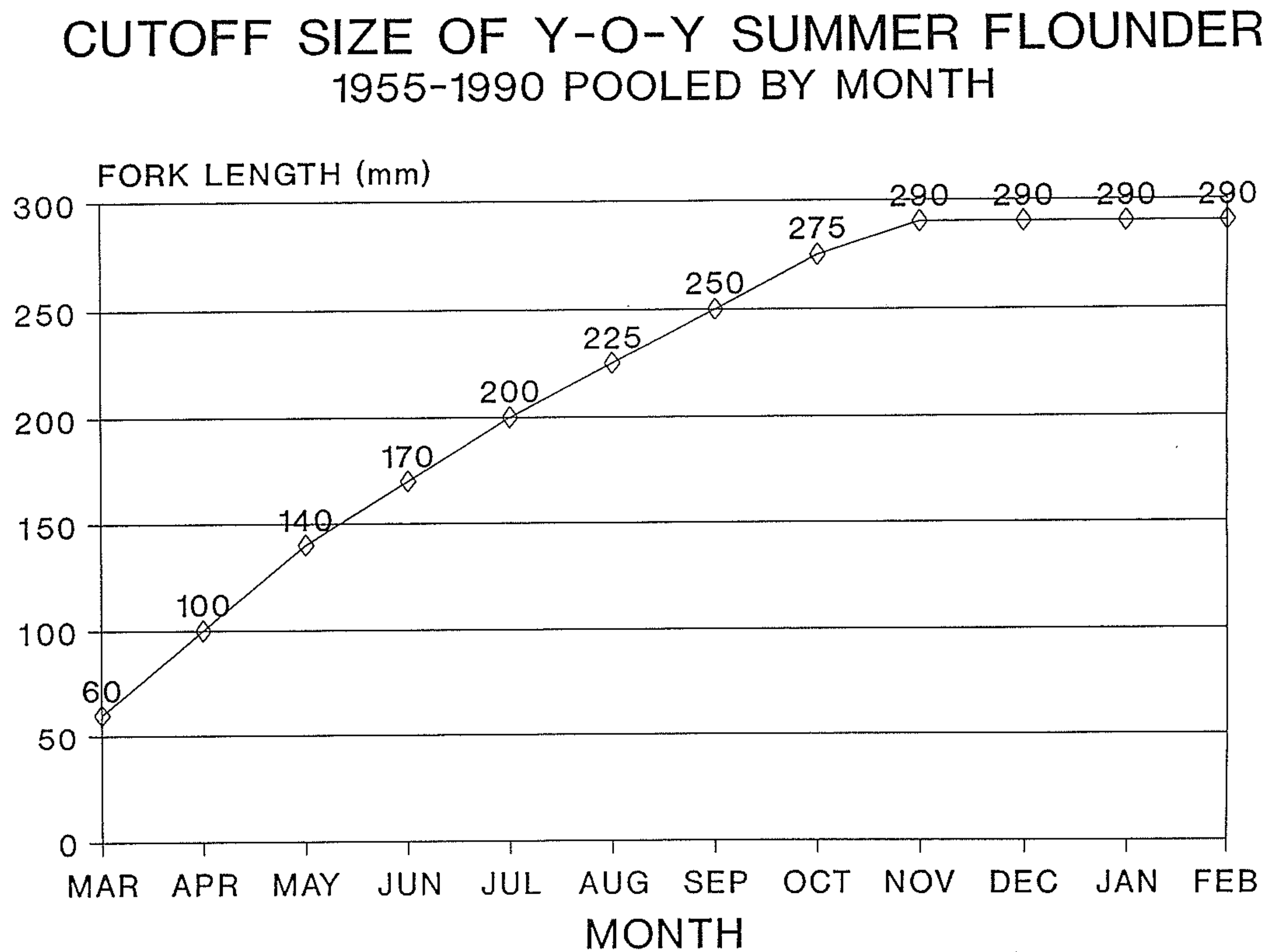


Figure 11. Length cutoff values used to separate summer flounder young-of-the-year from older year classes.

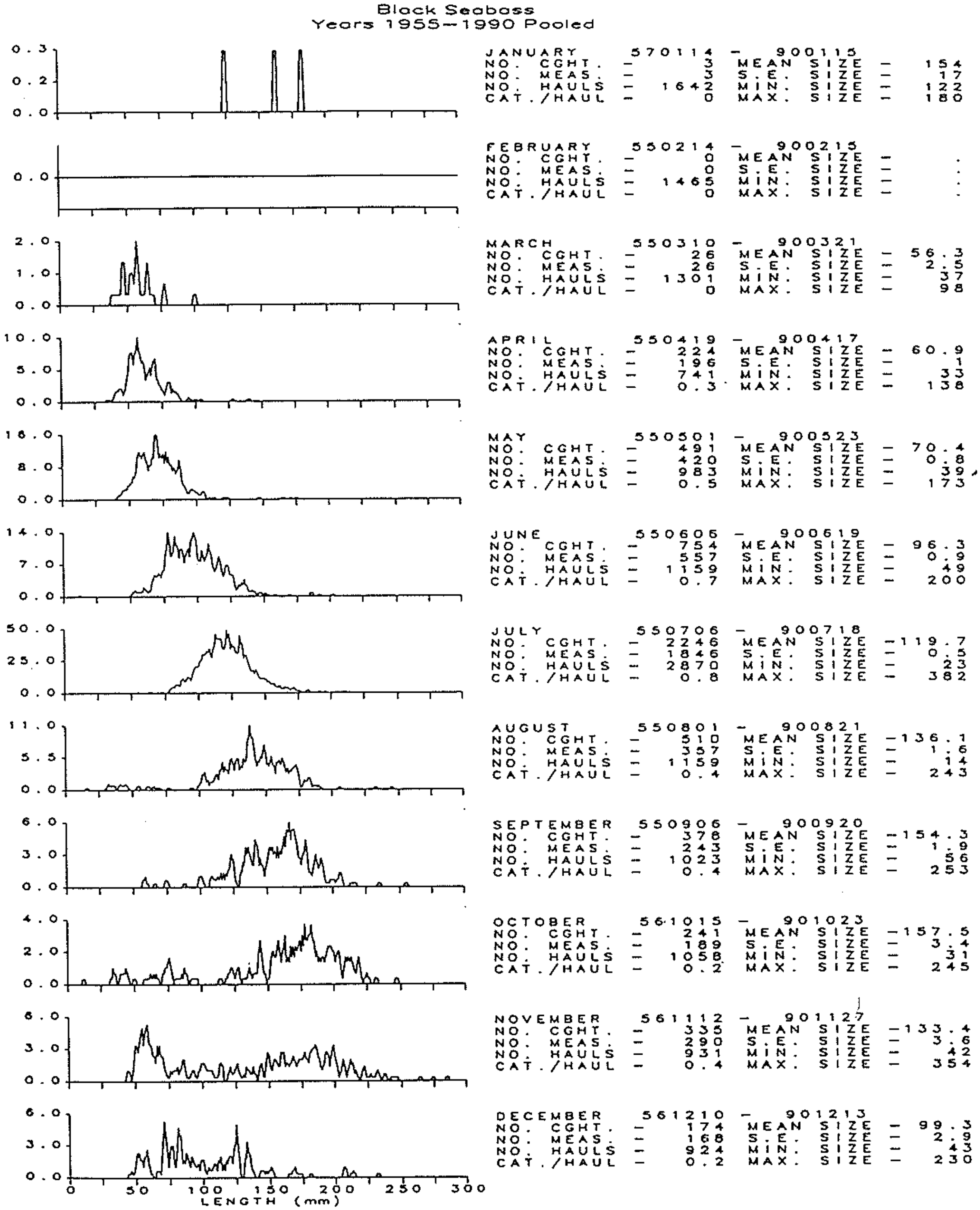
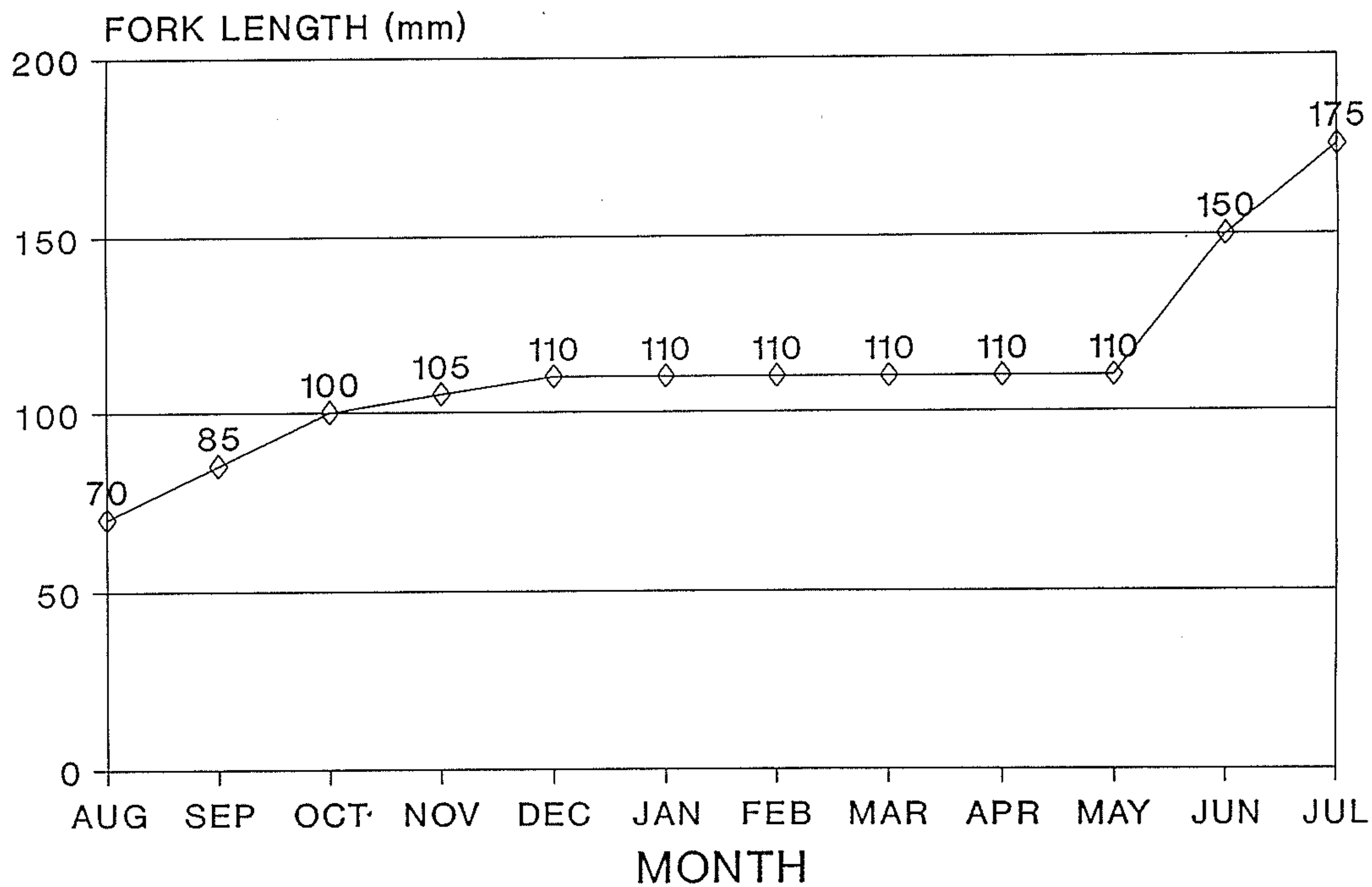


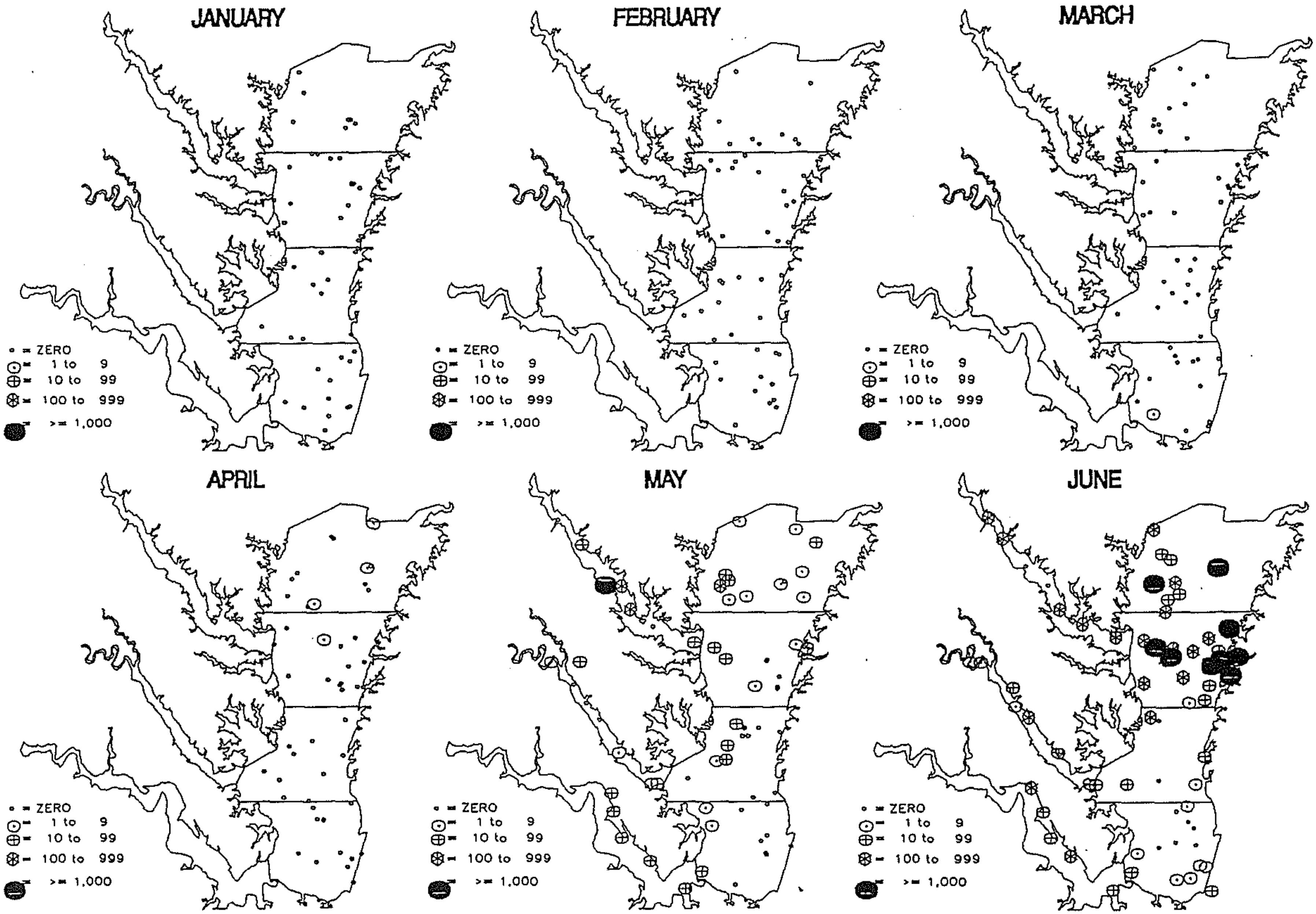
Figure 12. Composite length frequencies by month for black sea bass, VIMS trawl survey data base, 1957-1990.

CUTOFF SIZE OF Y-O-Y BLACK SEABASS
1955-1990 POOLED BY MONTH



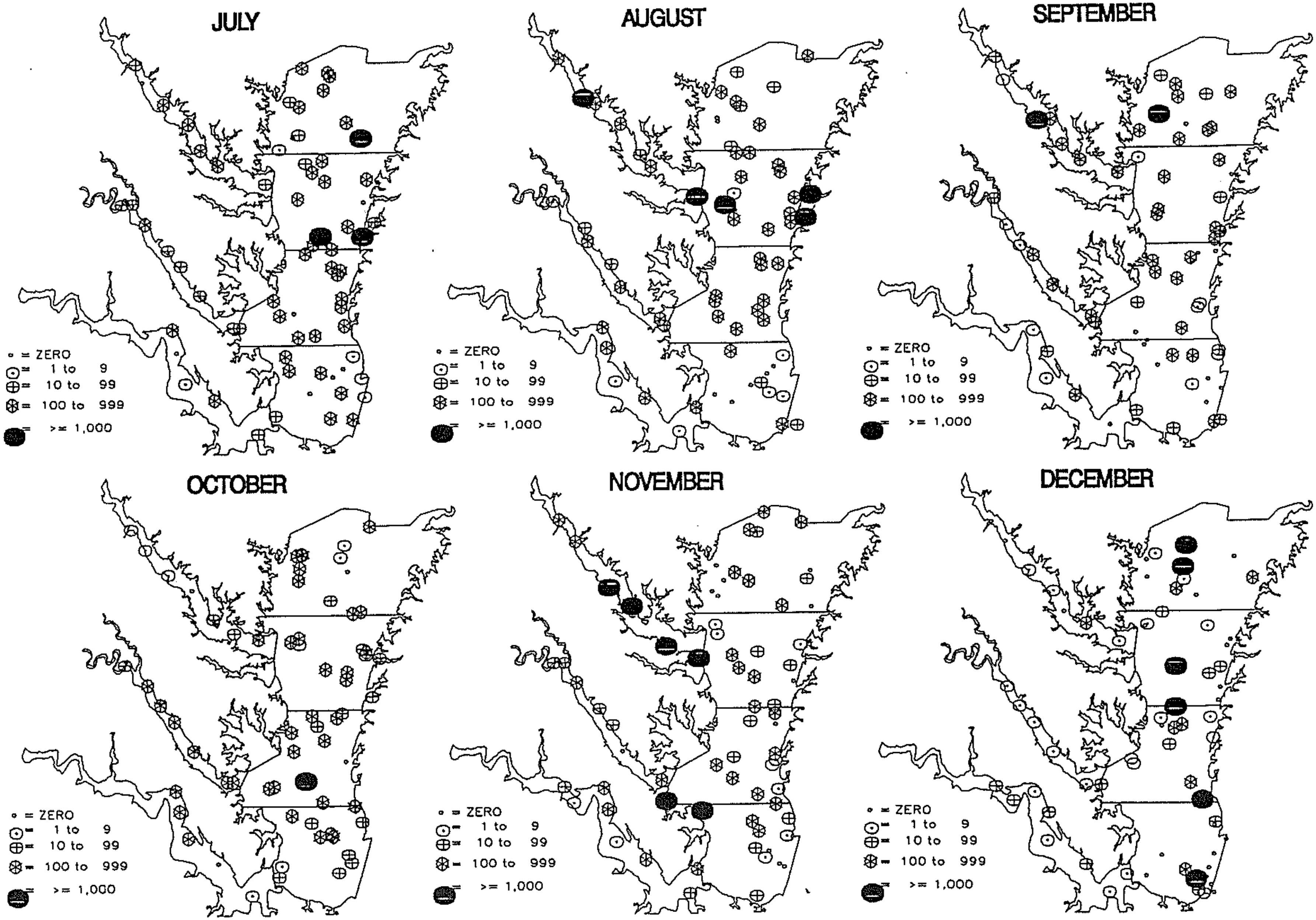
Appendix Figures 1-5. Trawl catches (numbers of individuals) of young-of-the-year of key species plotted by month. Plots are arranged chronologically (a, Jan.-June 1988; b, July-Dec. 1988; c, Jan.-June 1989; d, July-Dec. 1989; e, Jan.-June 1990; f, July-Dec. 1990;) by species (1, spot; 2, Atlantic croaker; 3, weakfish; 4, summer flounder; 5, black sea bass).

Y-O-Y SPOT 1988



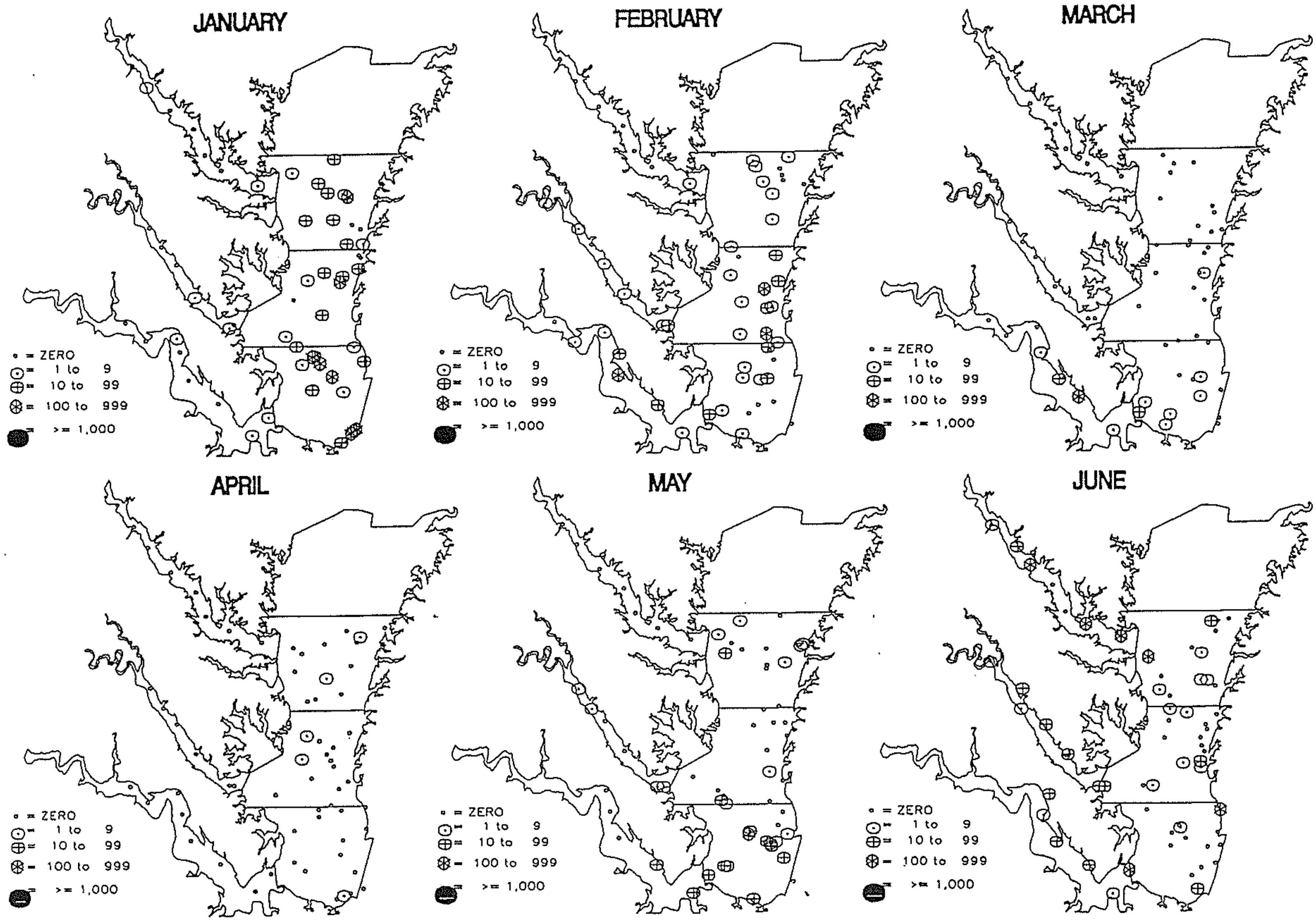
Appendix Figure 1-a.

Y-O-Y SPOT 1988



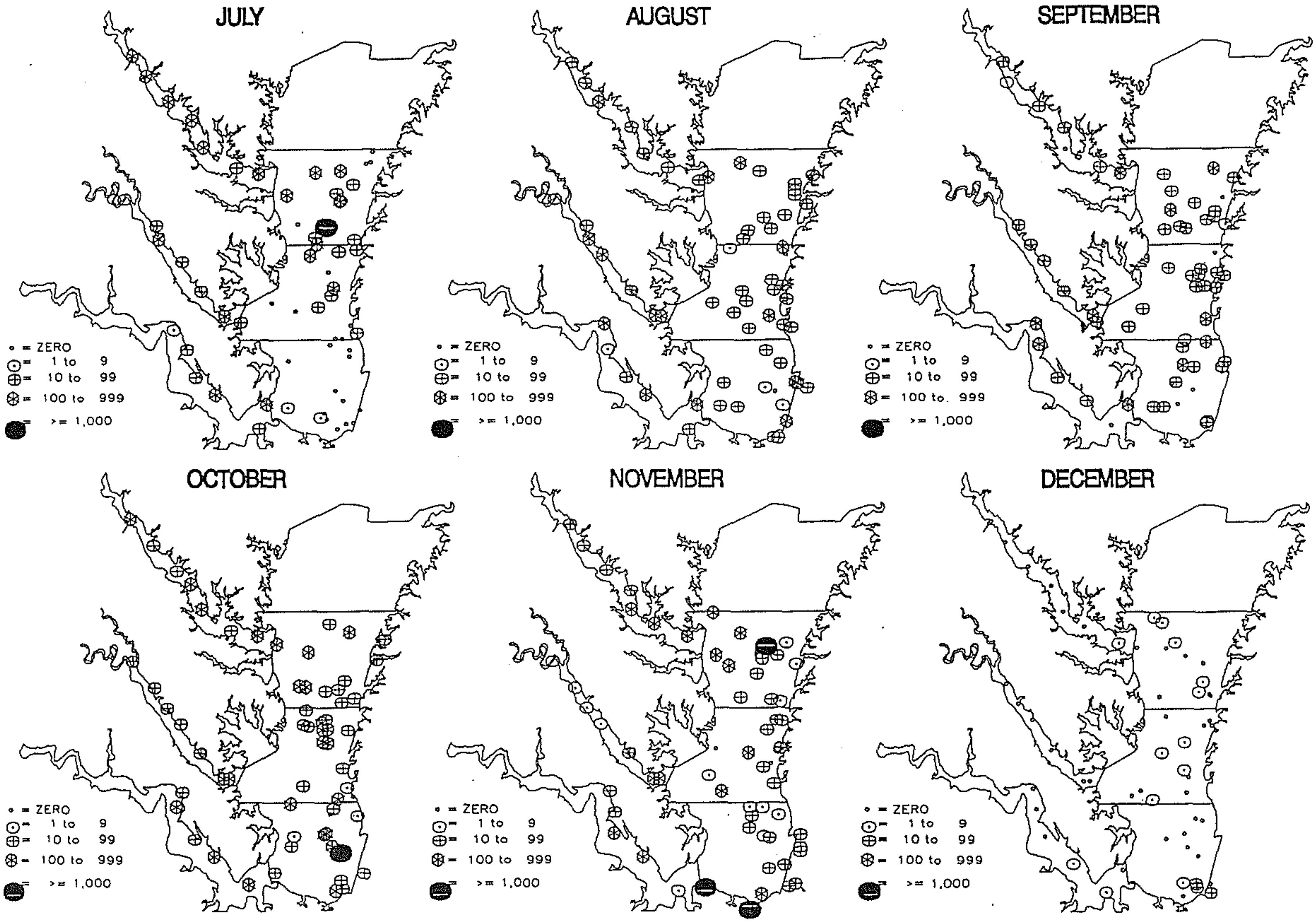
Appendix Figure 1-b.

Y-O-Y SPOT 1989



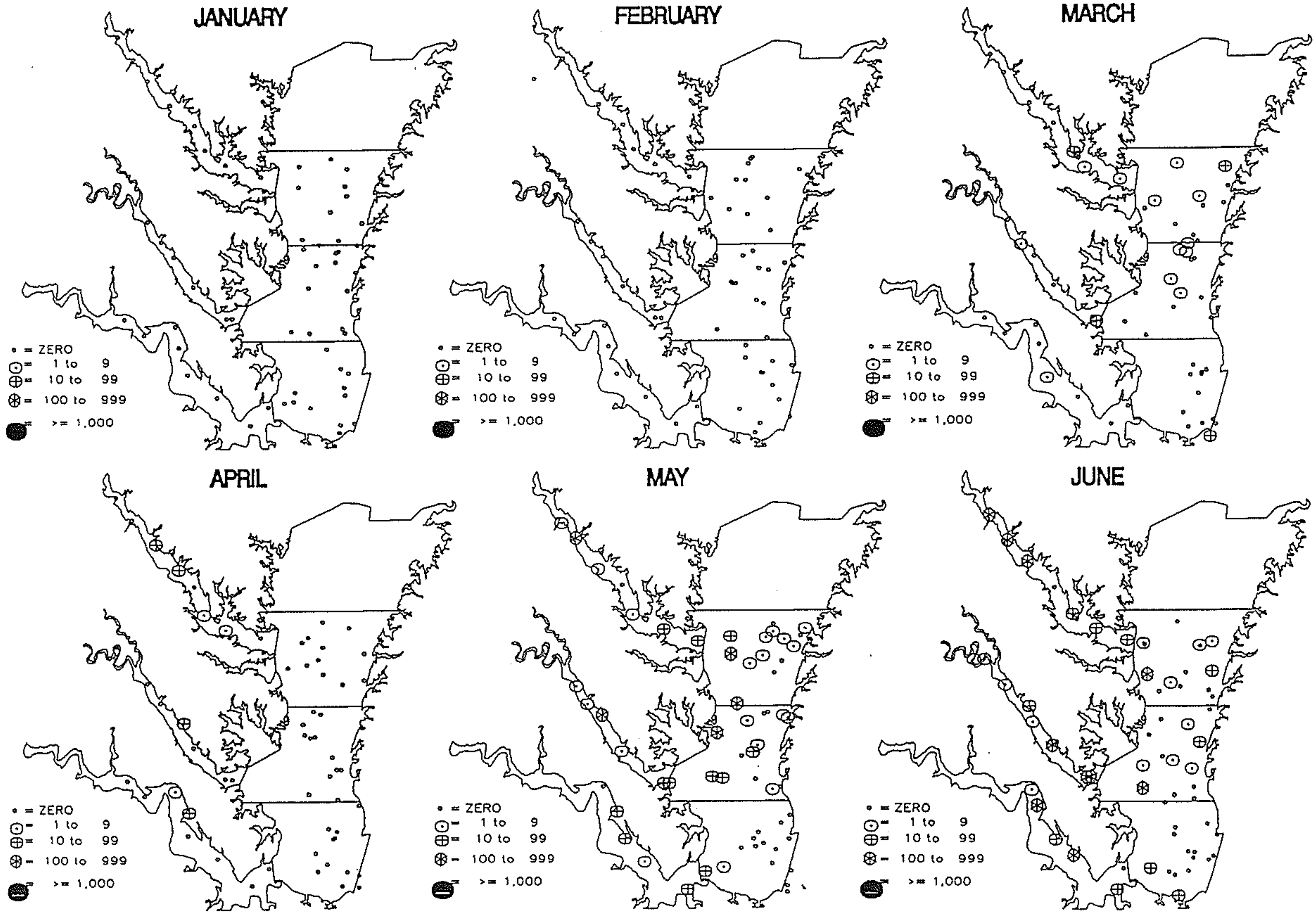
Appendix Figure 1-c.

Y-O-Y SPOT 1989



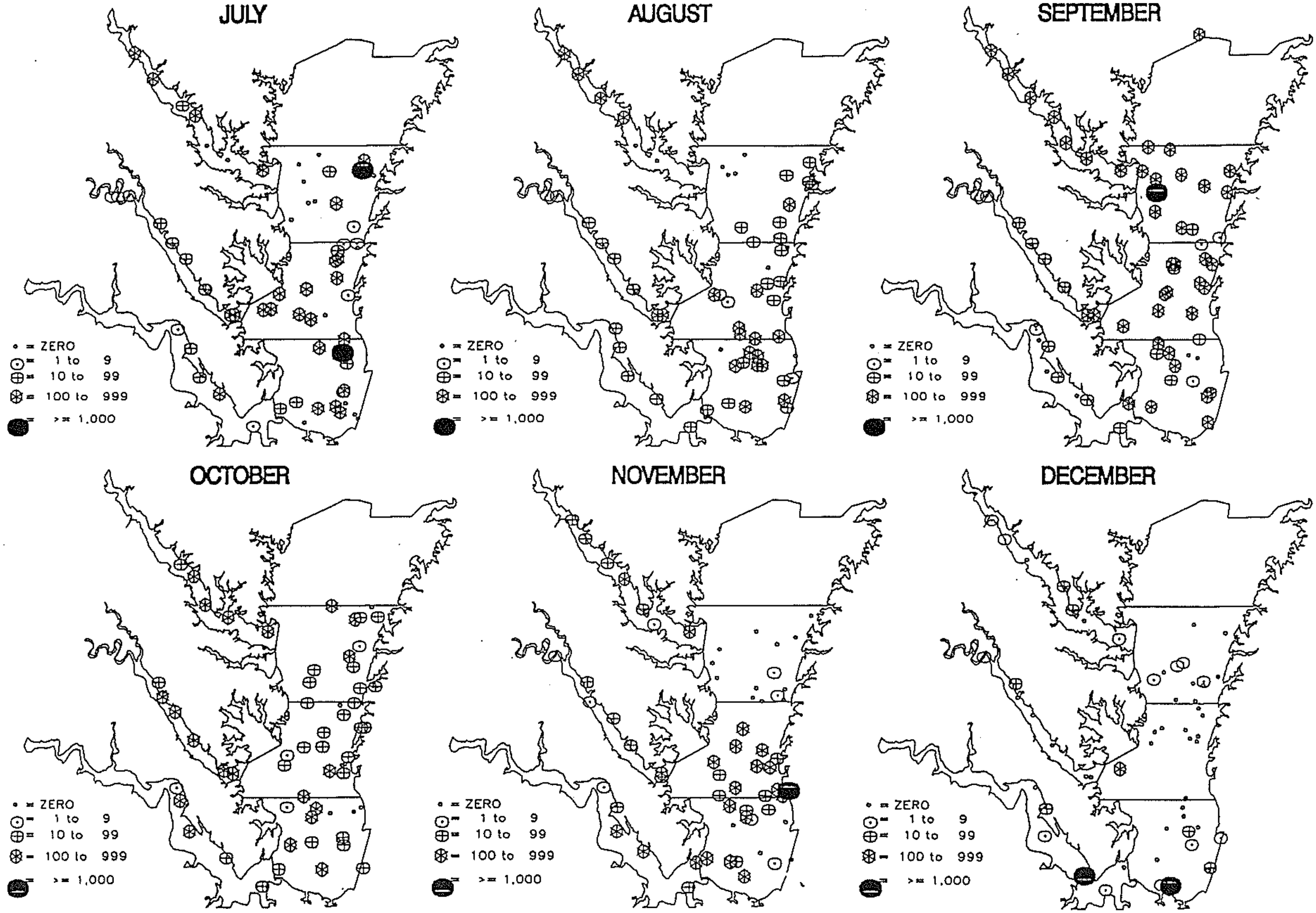
Appendix Figure 1-d.

Y-O-Y SPOT 1990



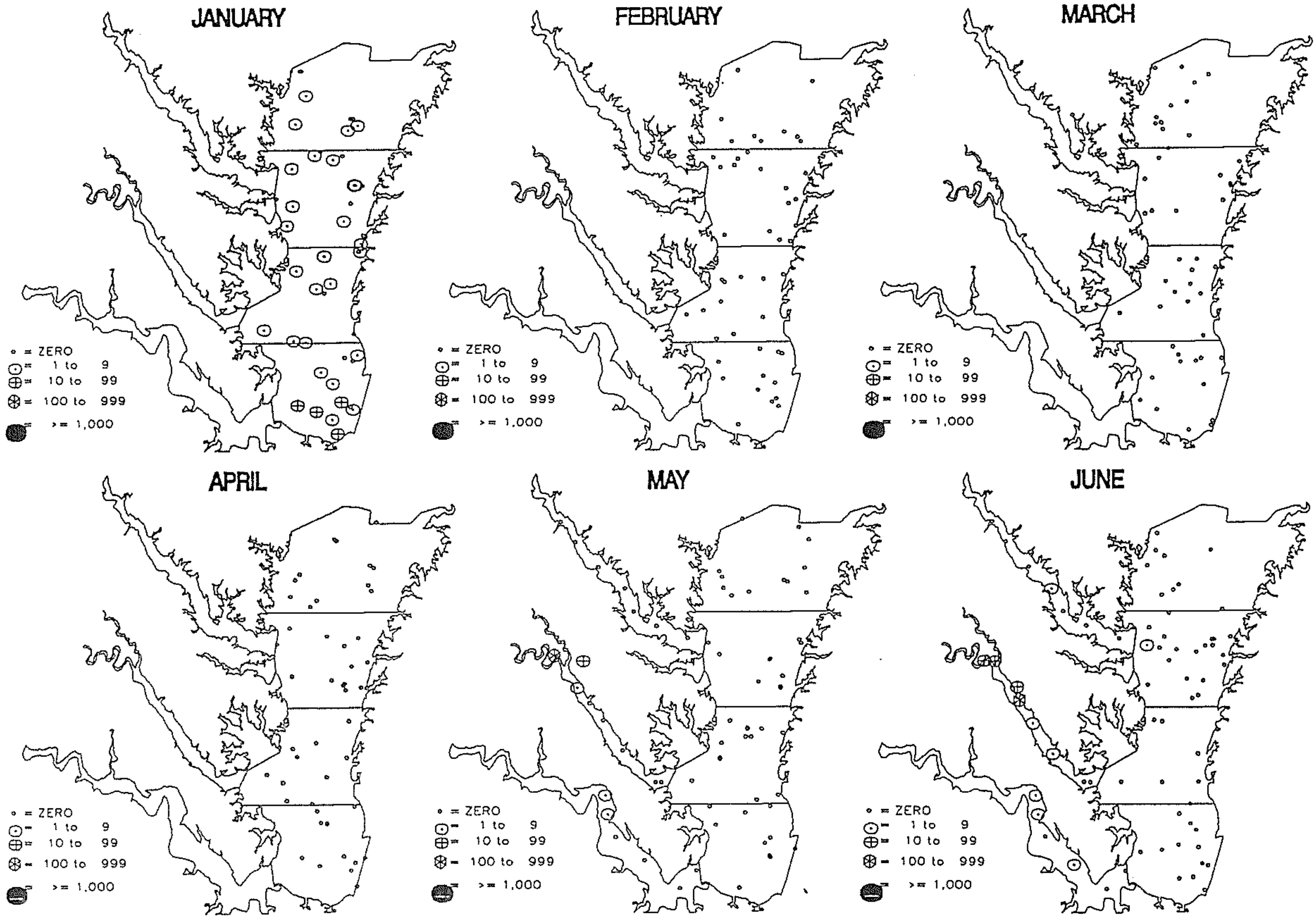
Appendix Figure 1-e.

Y-O-Y SPOT 1990



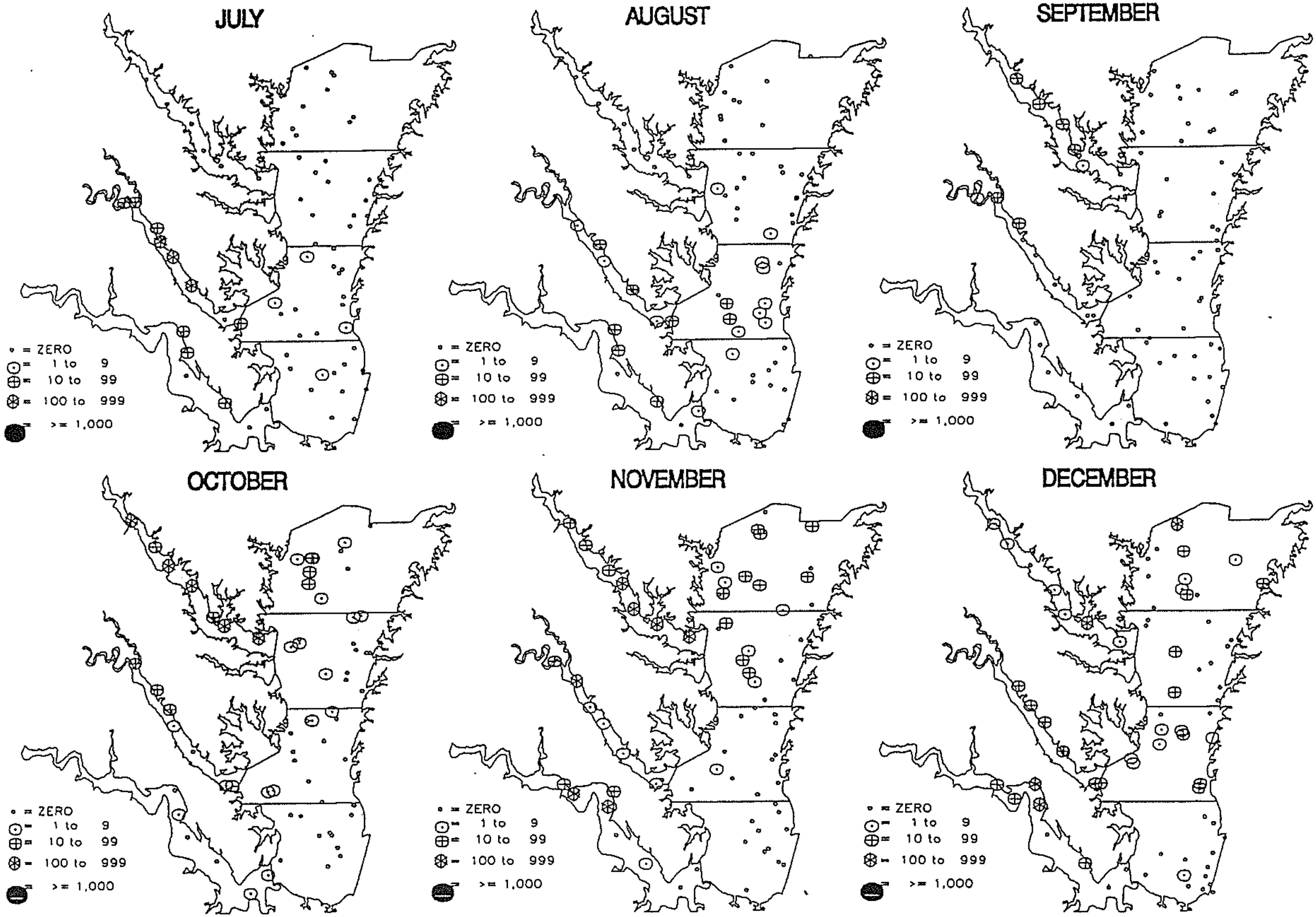
Appendix Figure 1-f.

Y-O-Y ATLANTIC CROAKER 1988



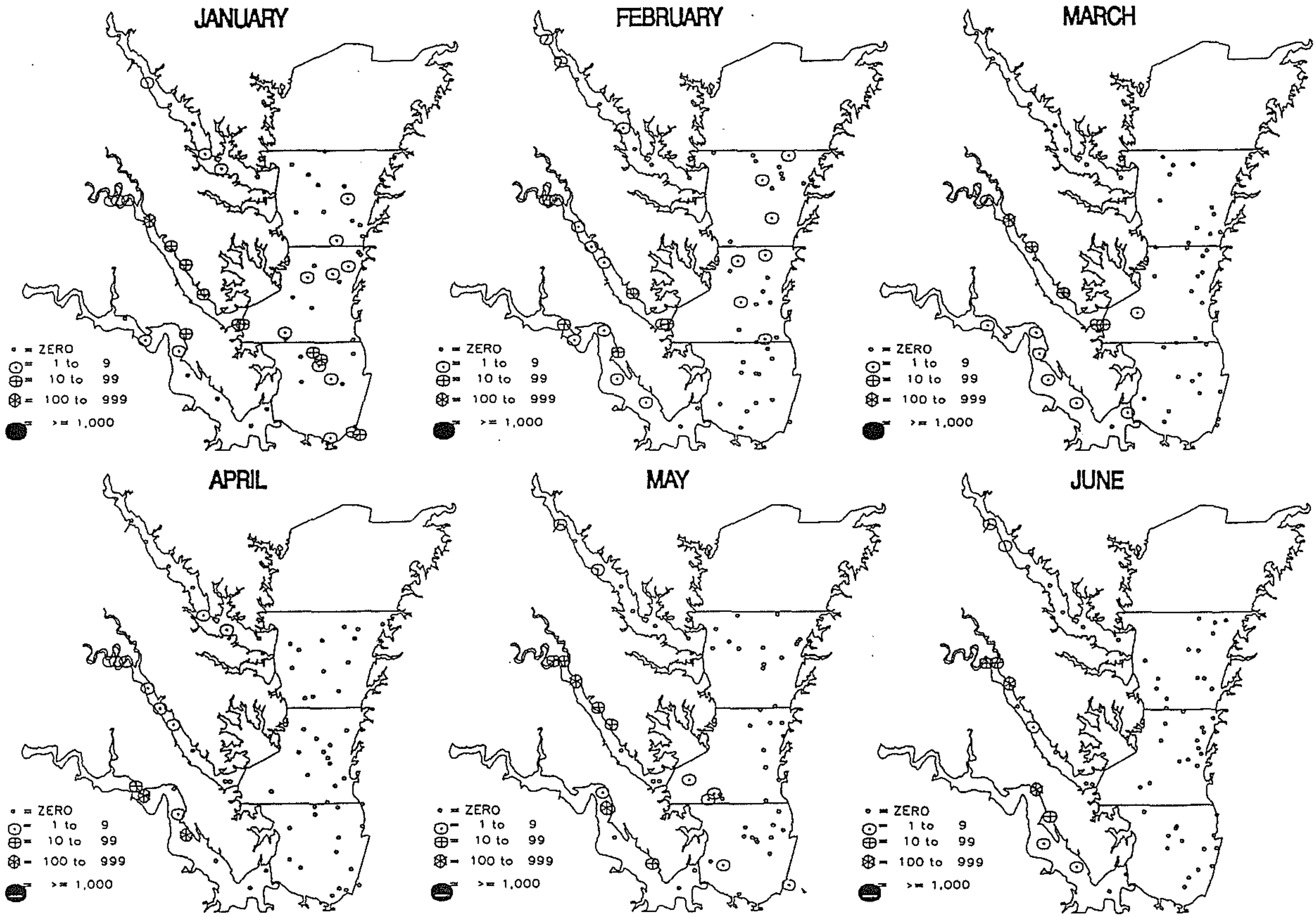
Appendix Figure 2-a.

Y-O-Y ATLANTIC CROAKER 1988



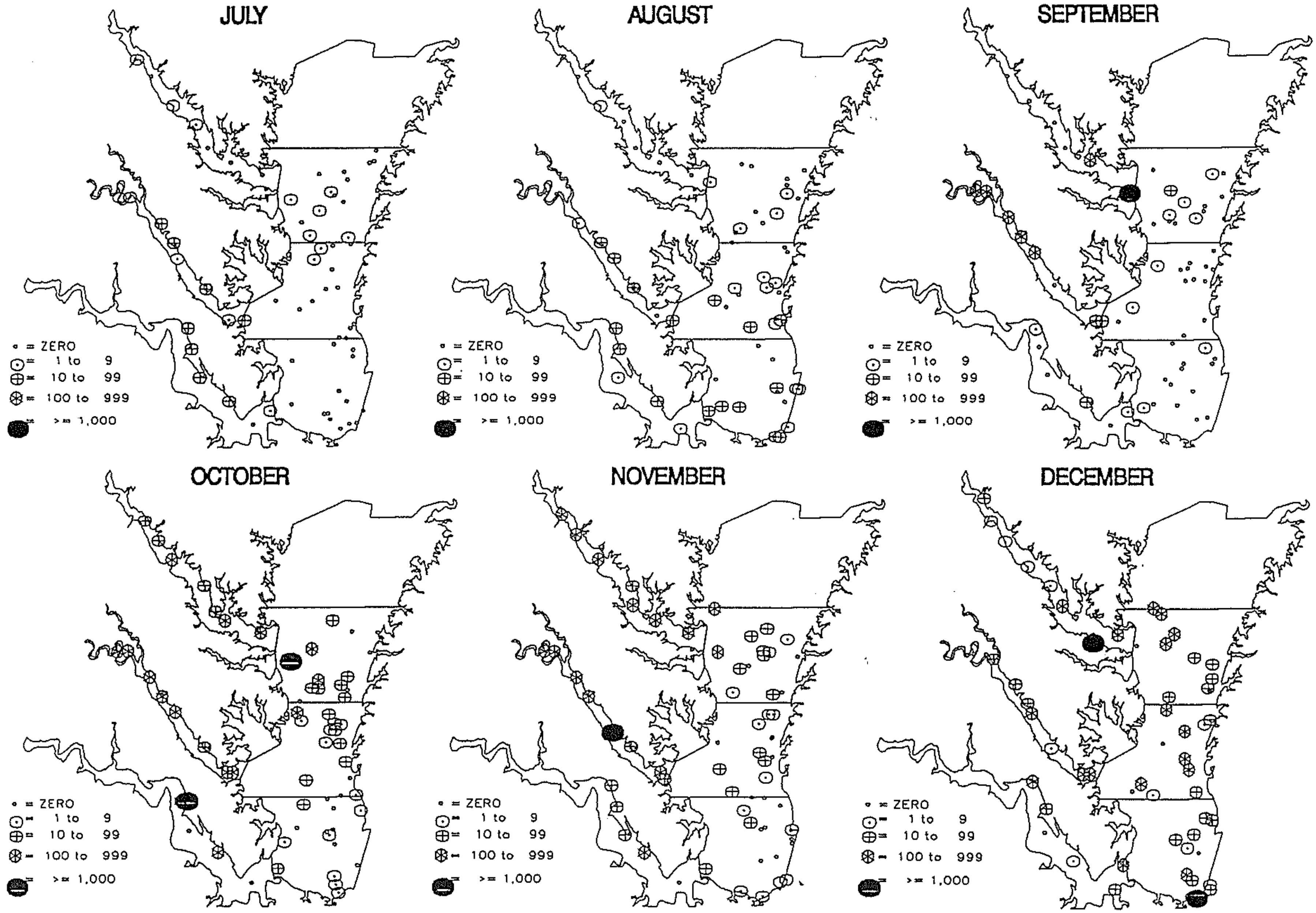
Appendix Figure 2-b.

Y-O-Y ATLANTIC CROAKER 1989



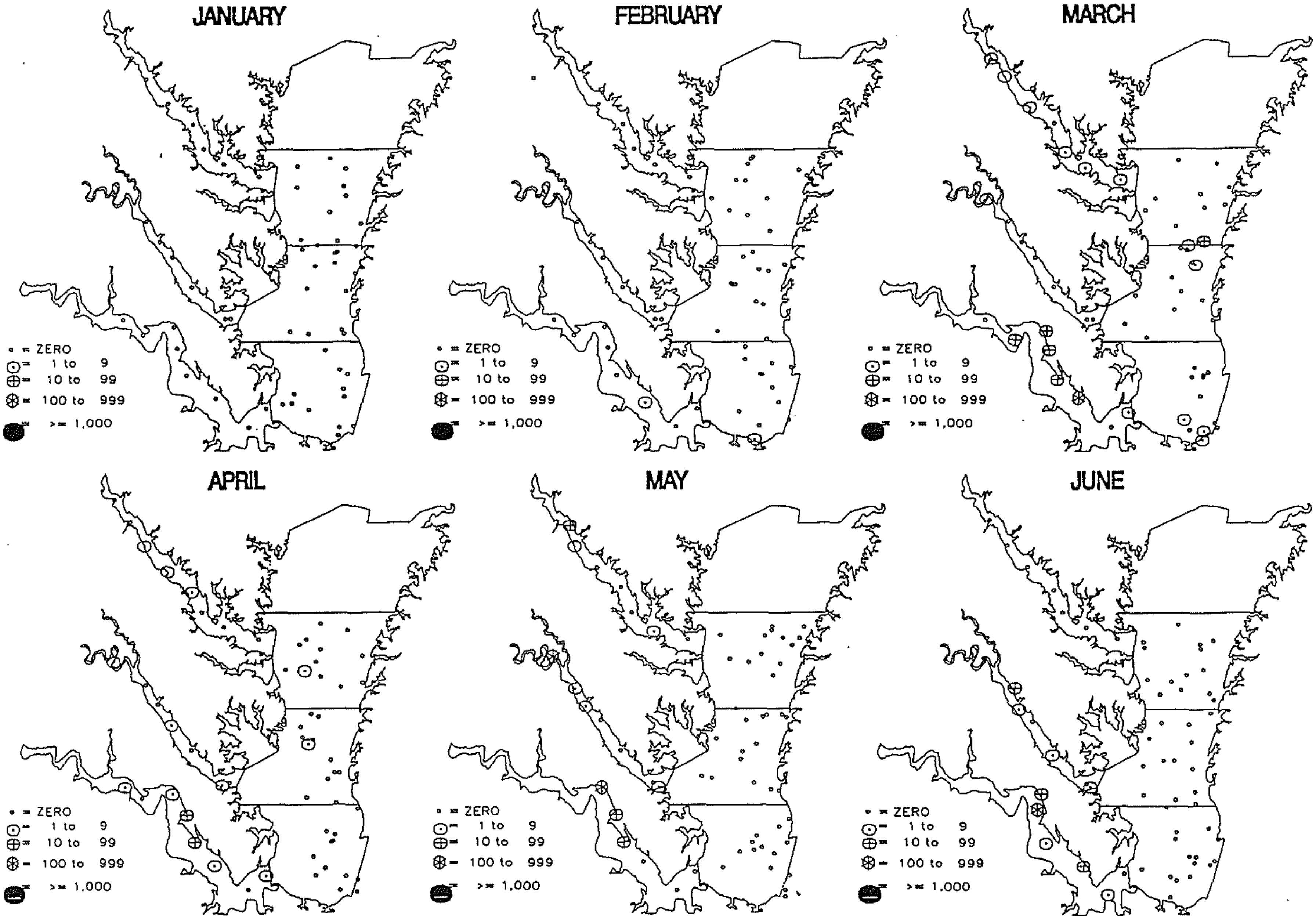
Appendix Figure 2-c.

Y-O-Y ATLANTIC CROAKER 1989



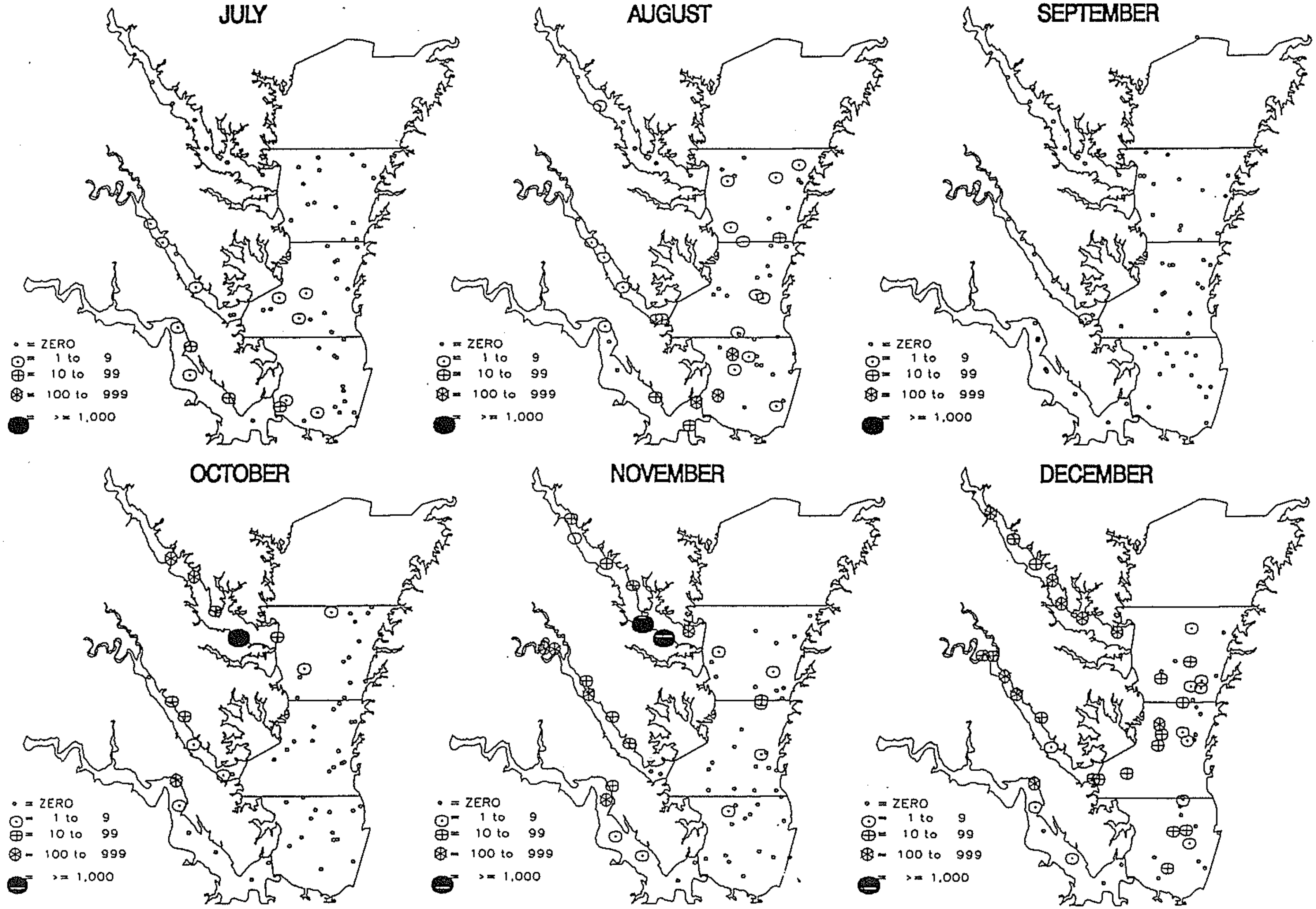
Appendix Figure 2-d.

Y-O-Y ATLANTIC CROAKER 1990



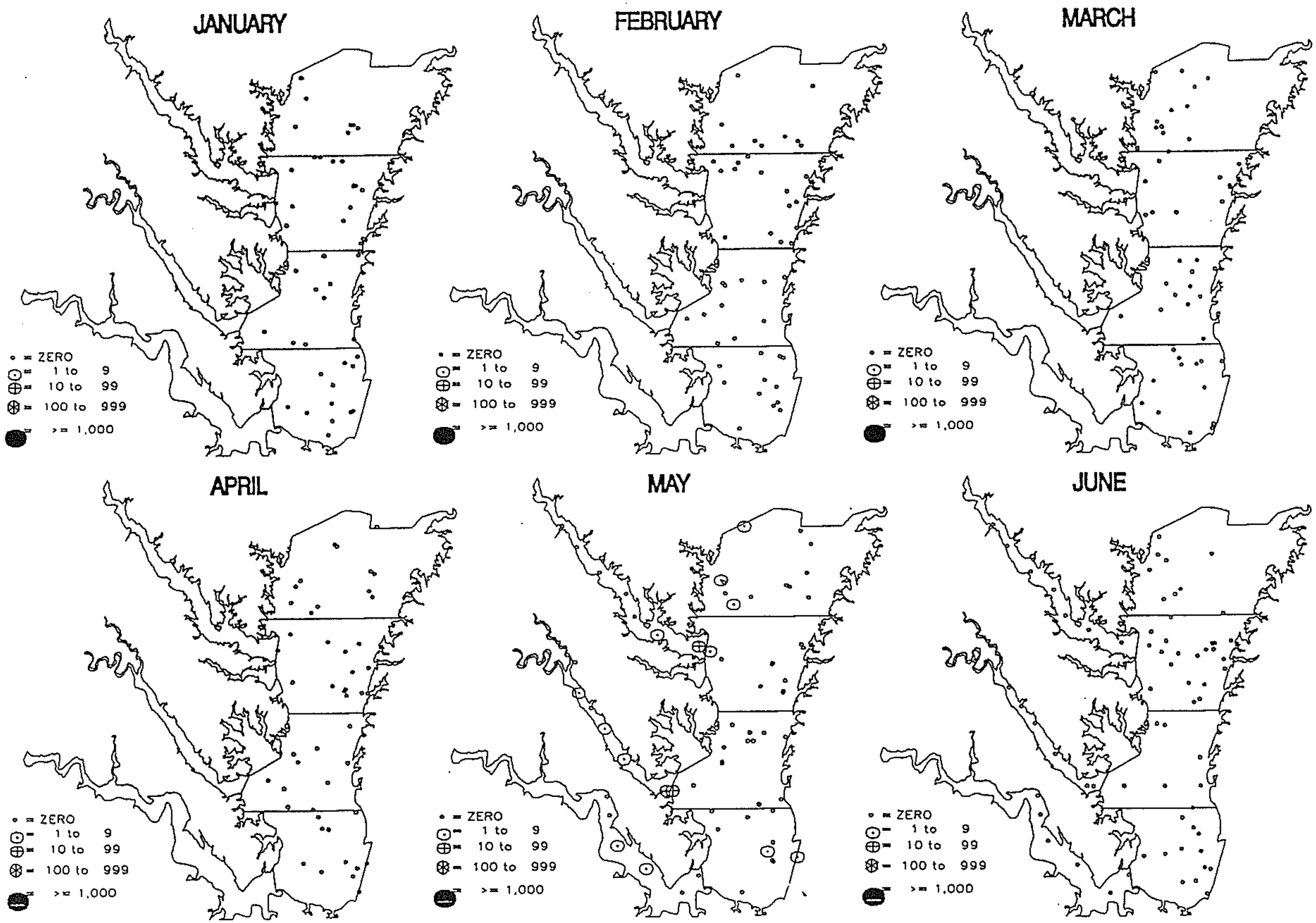
Appendix Figure 2-e.

Y-O-Y ATLANTIC CROAKER 1990



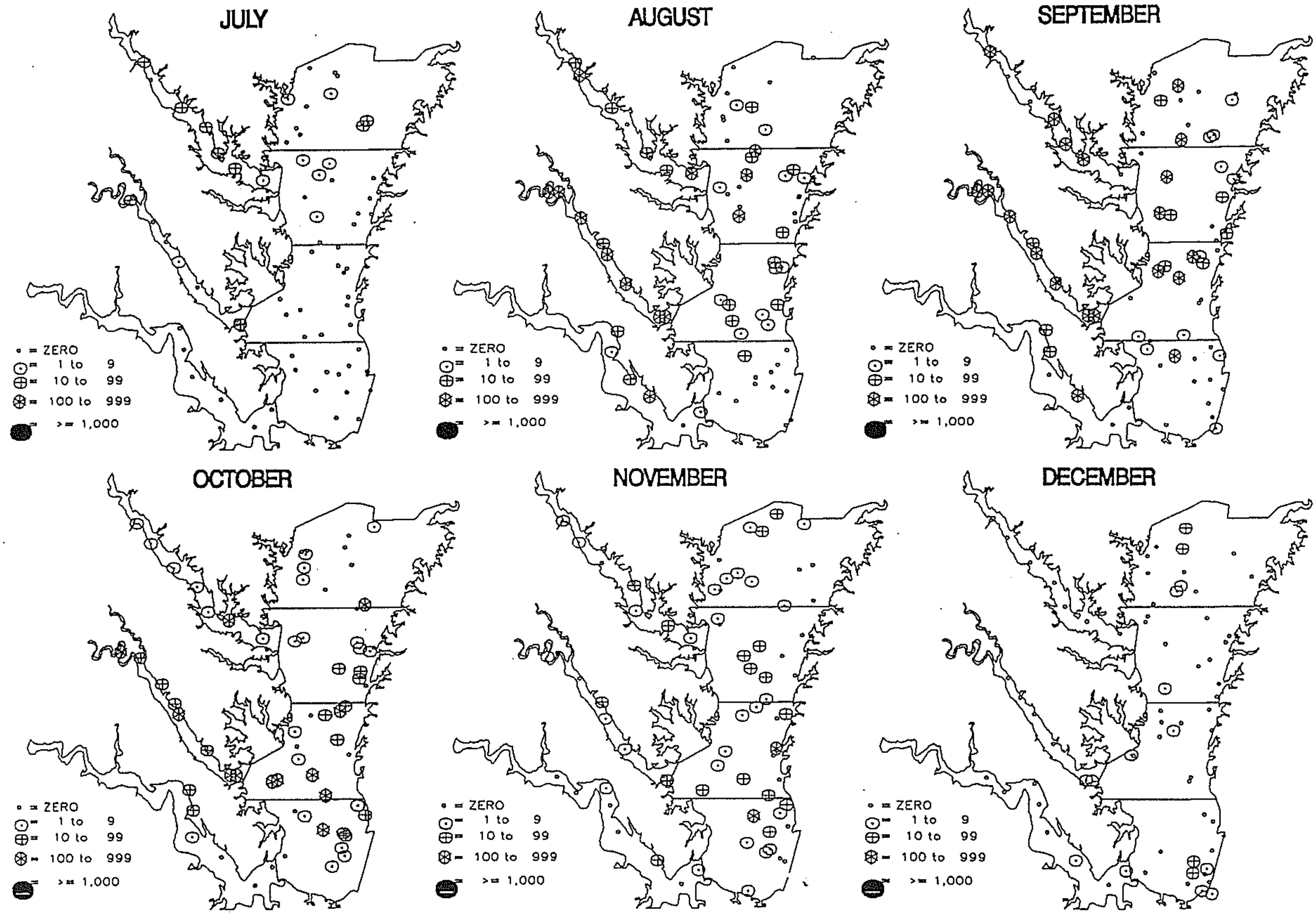
Appendix Figure 2-f.

Y-O-Y WEAKFISH 1988



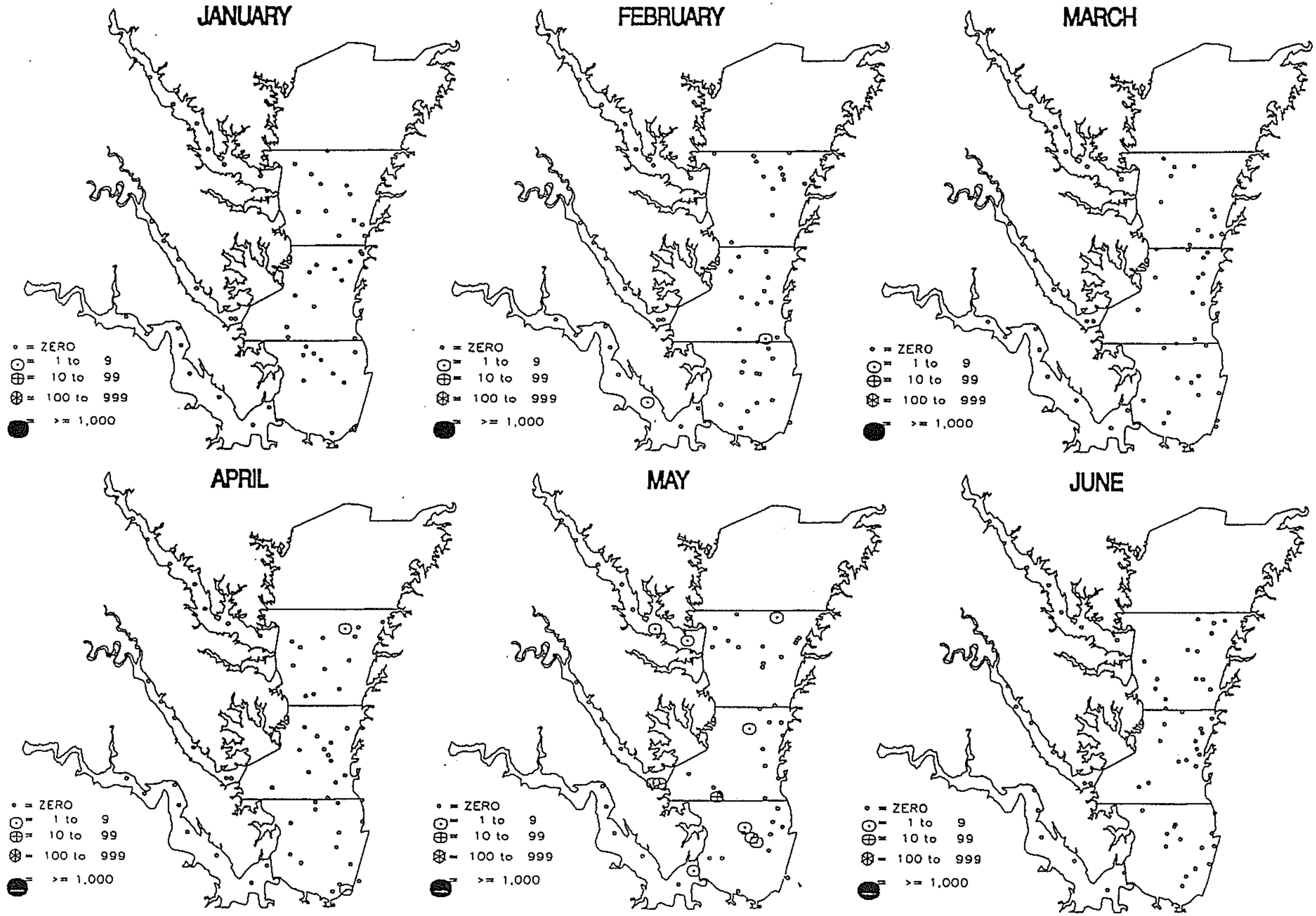
Appendix Figure 3-a.

Y-O-Y WEAKFISH 1988

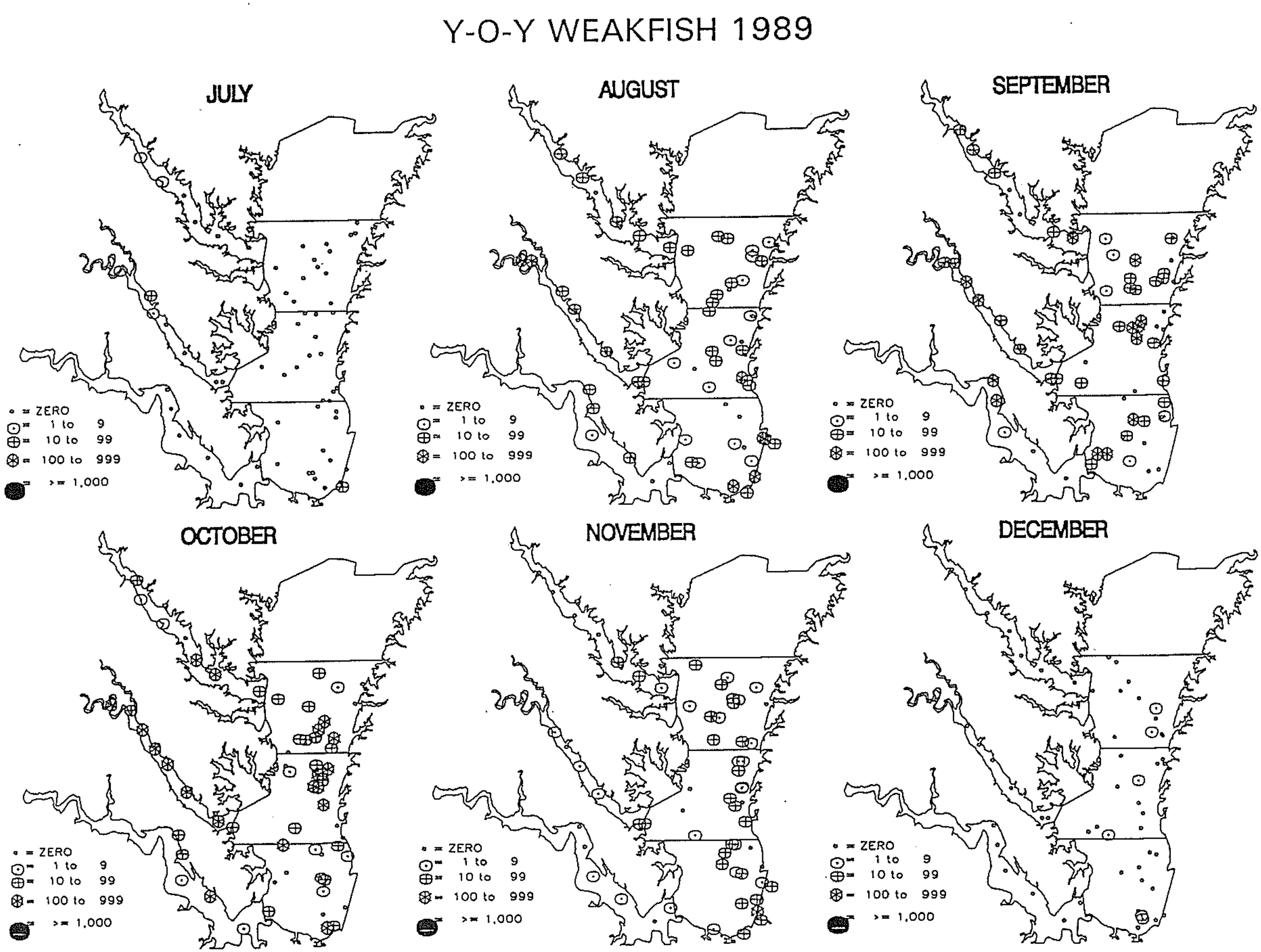


Appendix Figure 3-b.

Y-O-Y WEAKFISH 1989

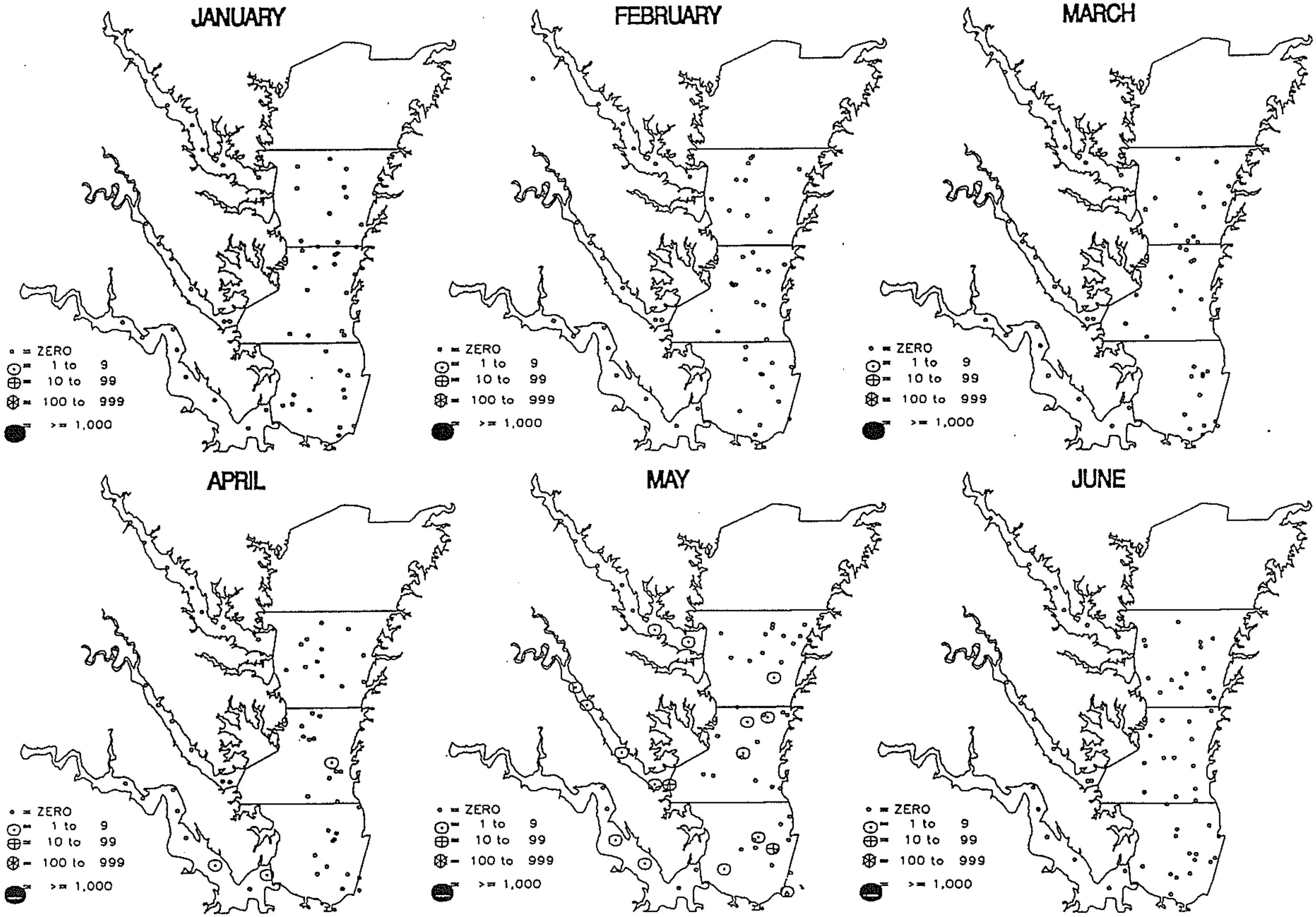


Appendix Figure 3-c.



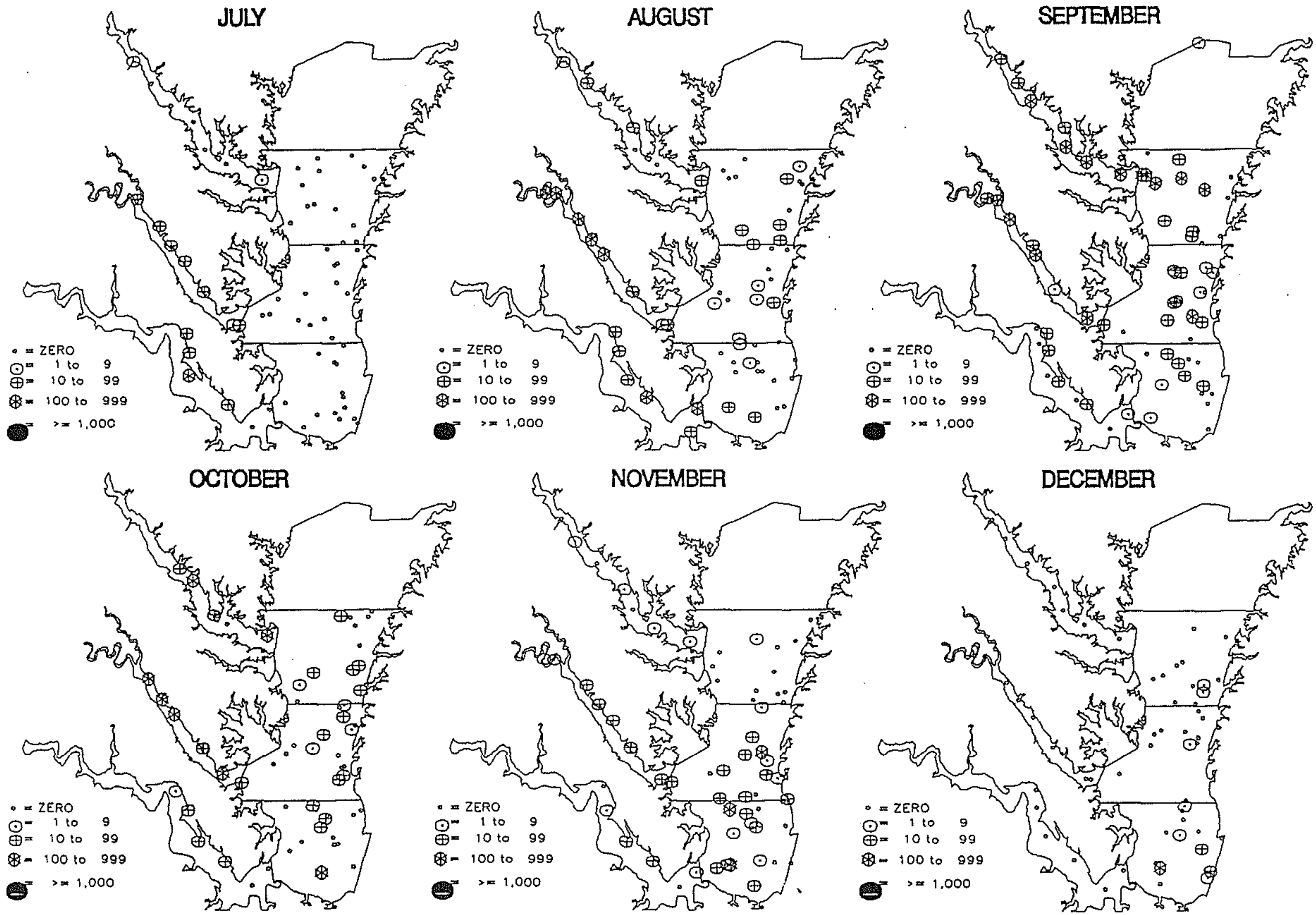
Appendix Figure 3-d.

Y-O-Y WEAKFISH 1990



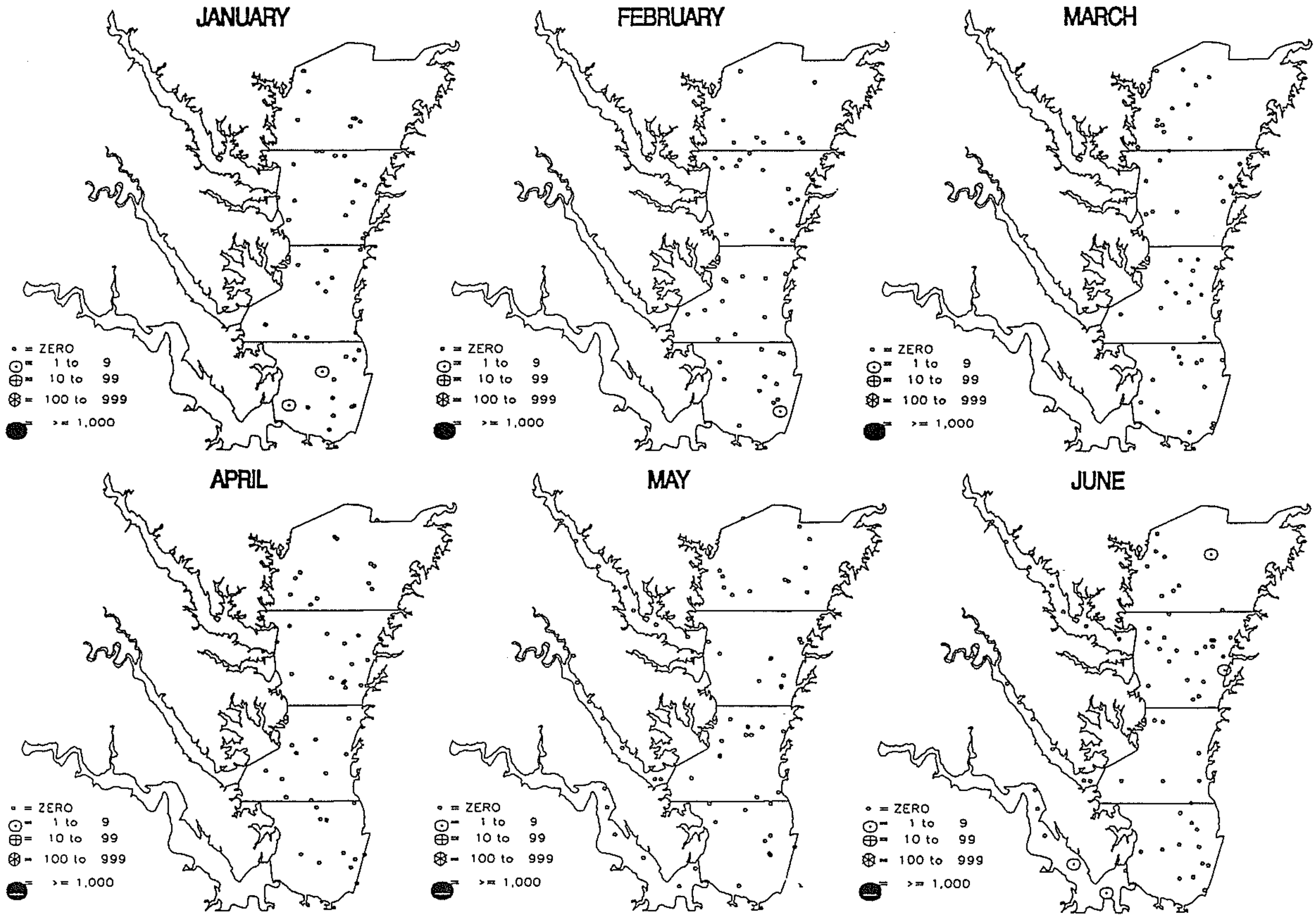
Appendix Figure 3-e.

Y-O-Y WEAKFISH 1990



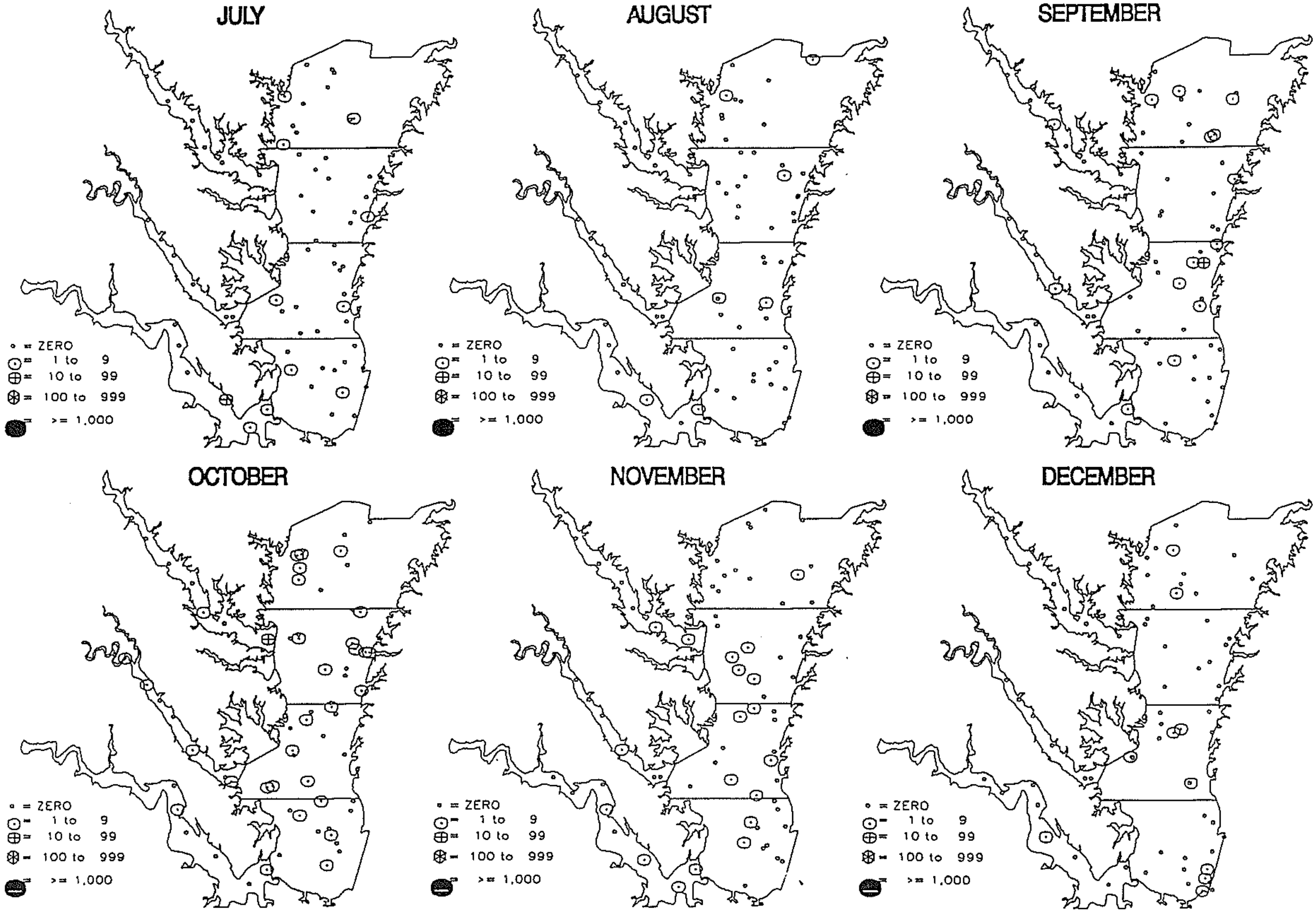
Appendix Figure 3-f.

Y-O-Y SUMMER FLOUNDER 1988



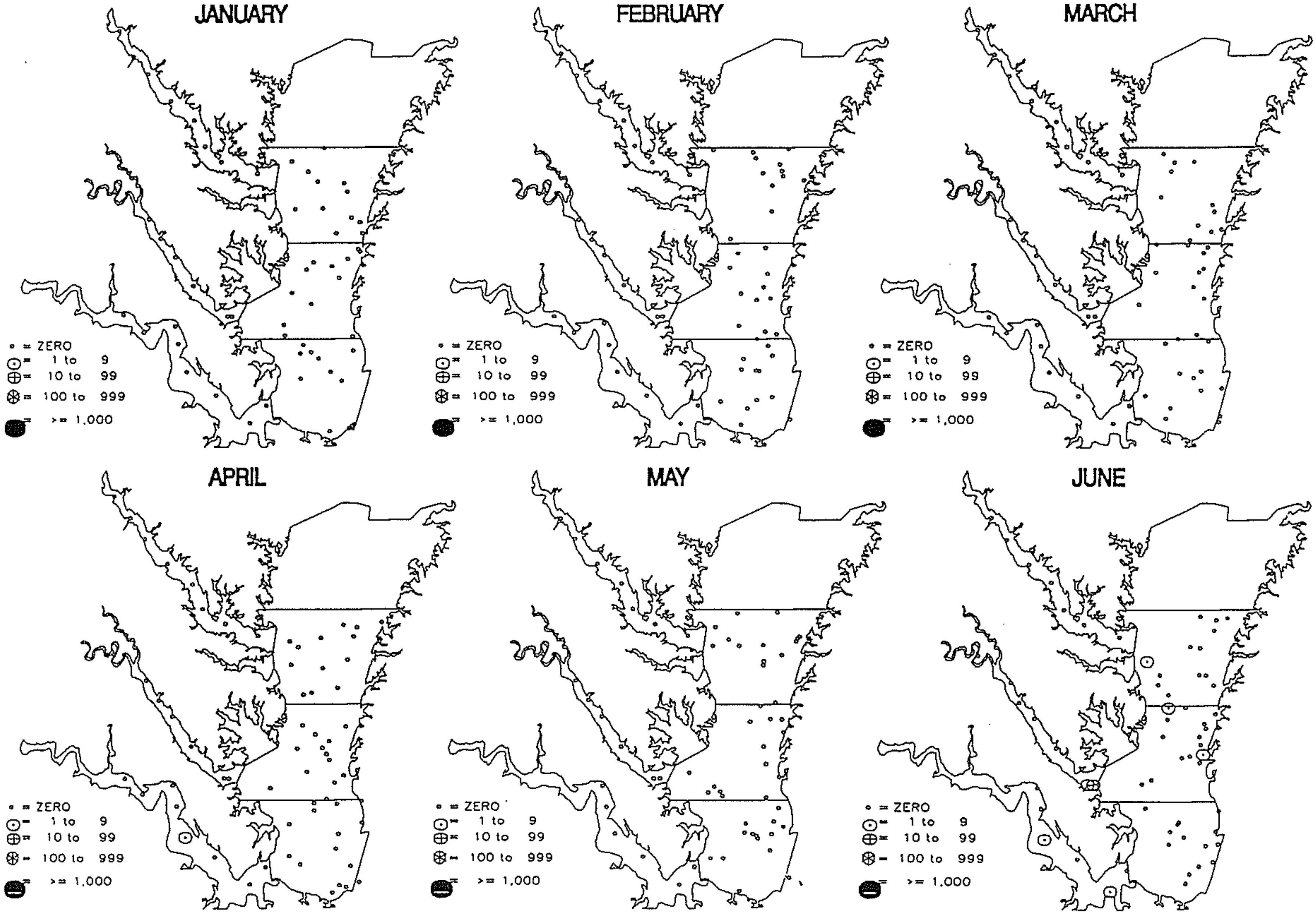
Appendix Figure 4-a.

Y-O-Y SUMMER FLOUNDER 1988



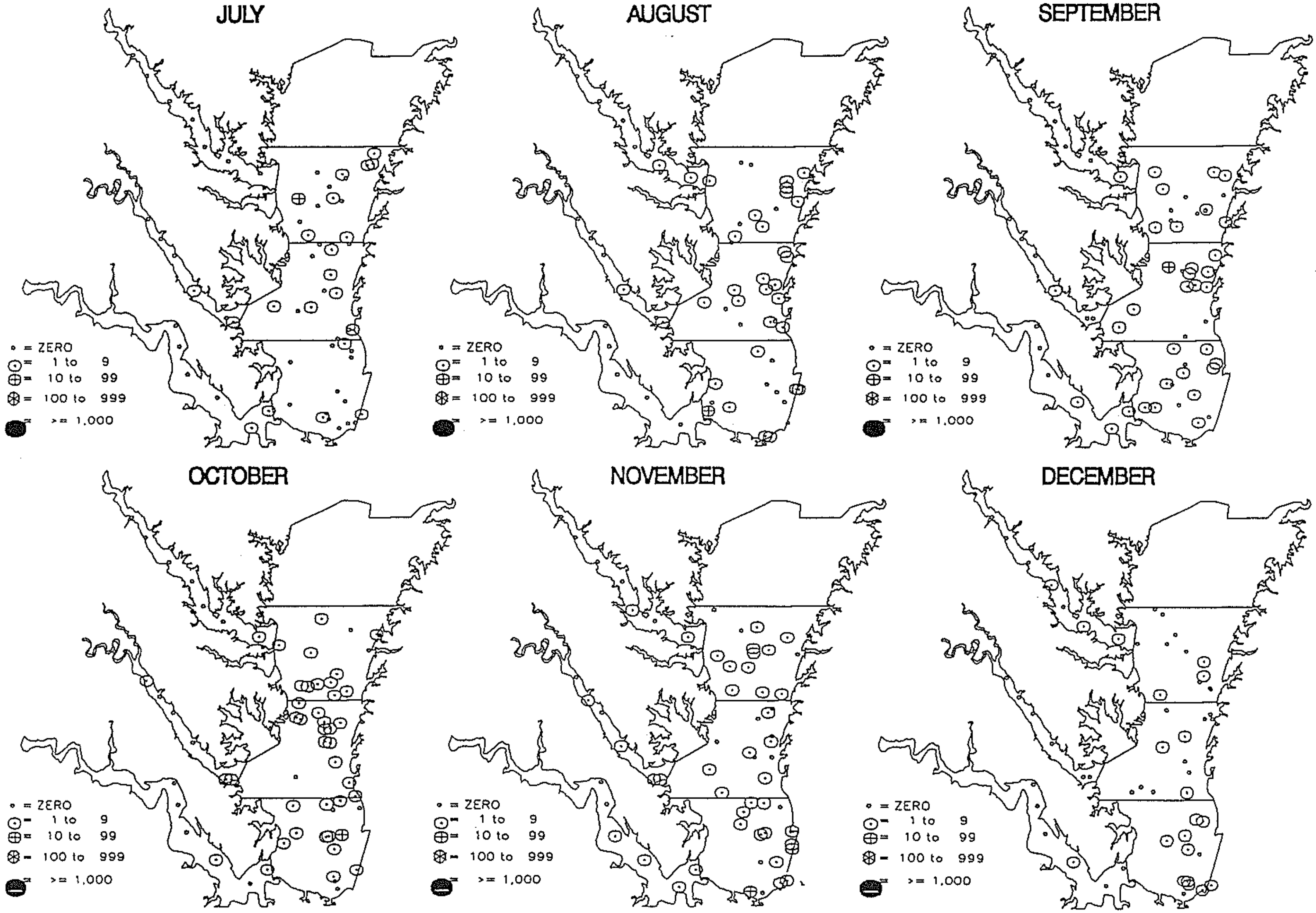
Appendix Figure 4-b.

Y-O-Y SUMMER FLOUNDER 1989



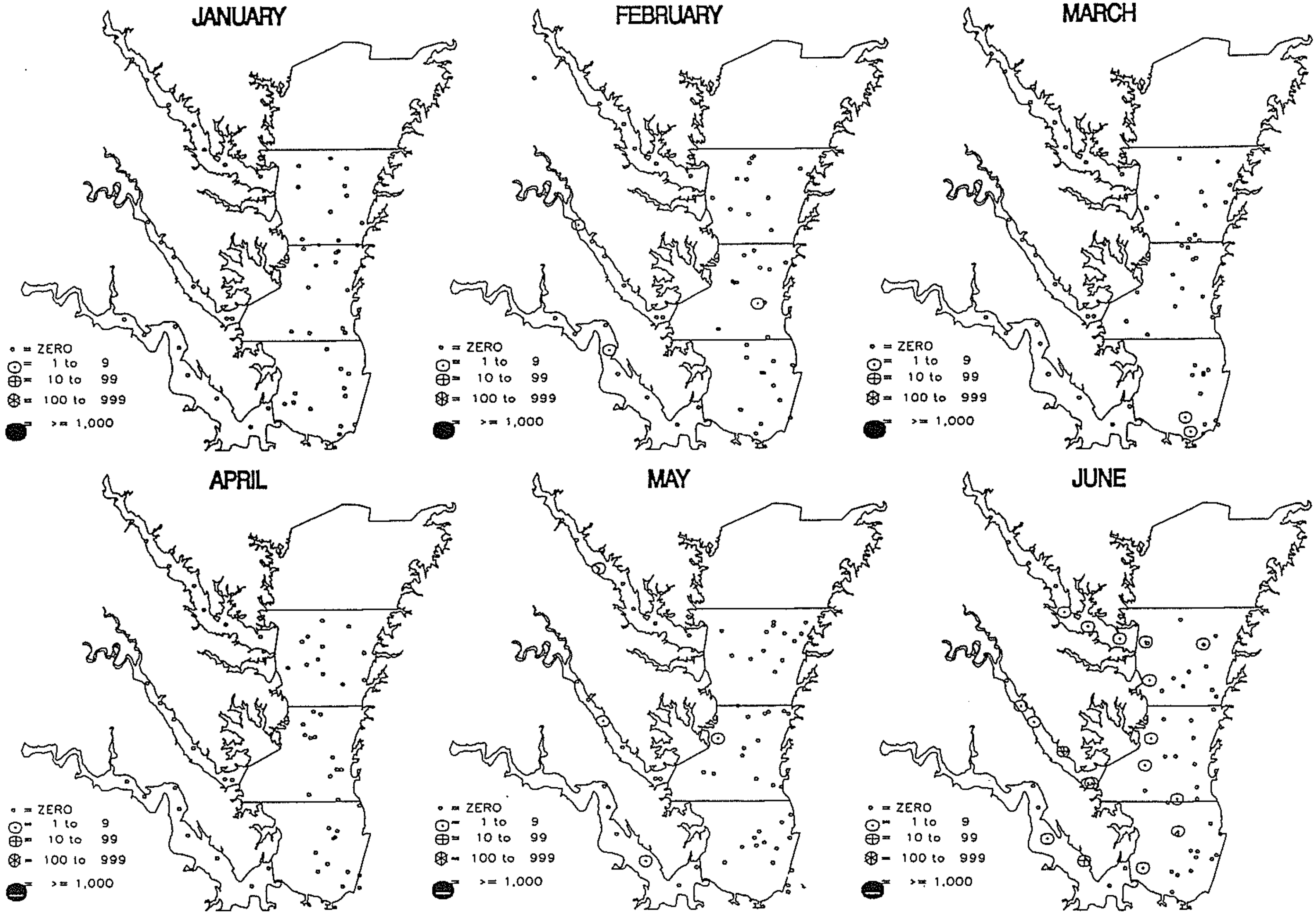
Appendix Figure 4-c.

Y-O-Y SUMMER FLOUNDER 1989



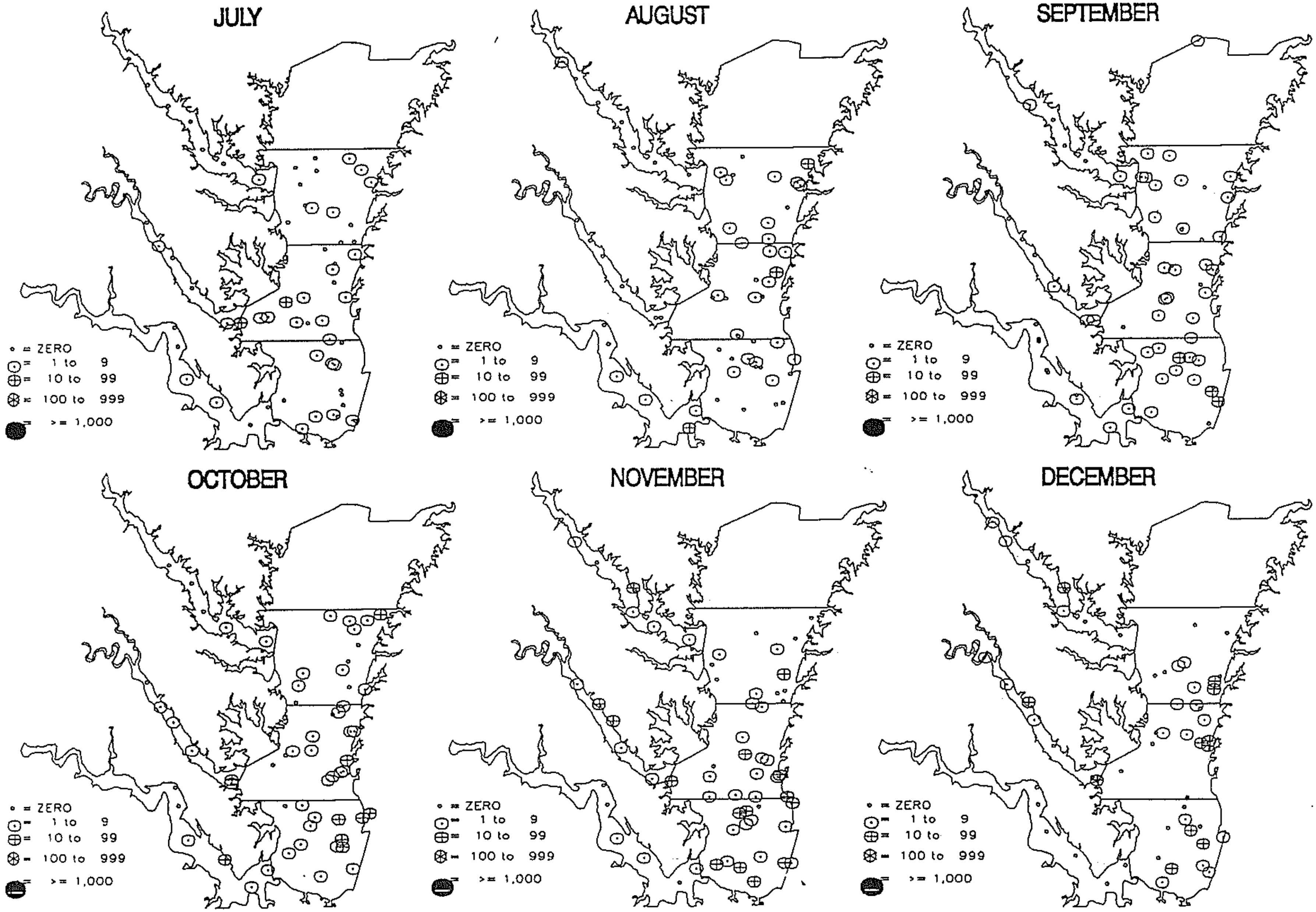
Appendix Figure 4-d.

Y-O-Y SUMMER FLOUNDER 1990



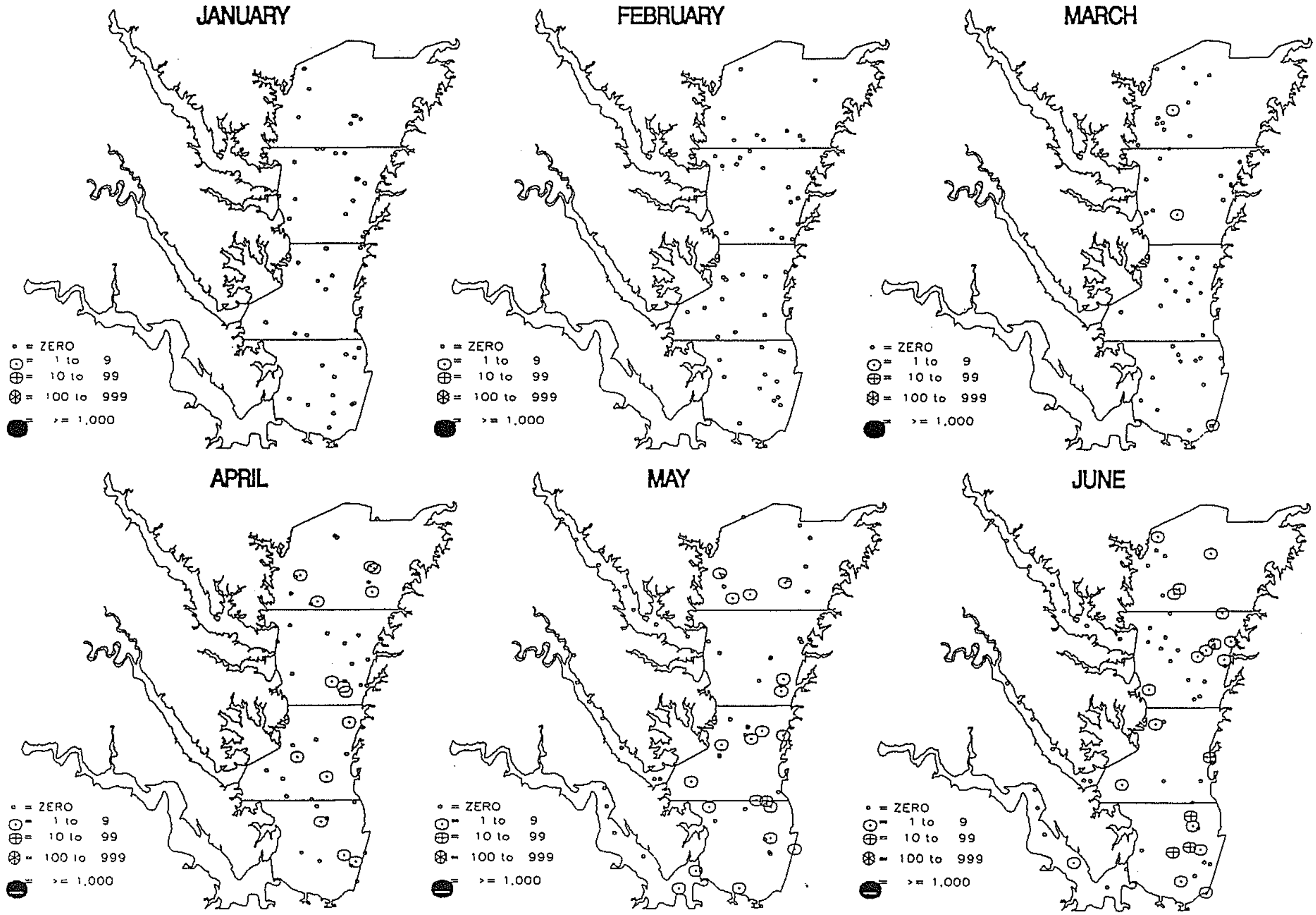
Appendix Figure 4-e.

Y-O-Y SUMMER FLOUNDER 1990



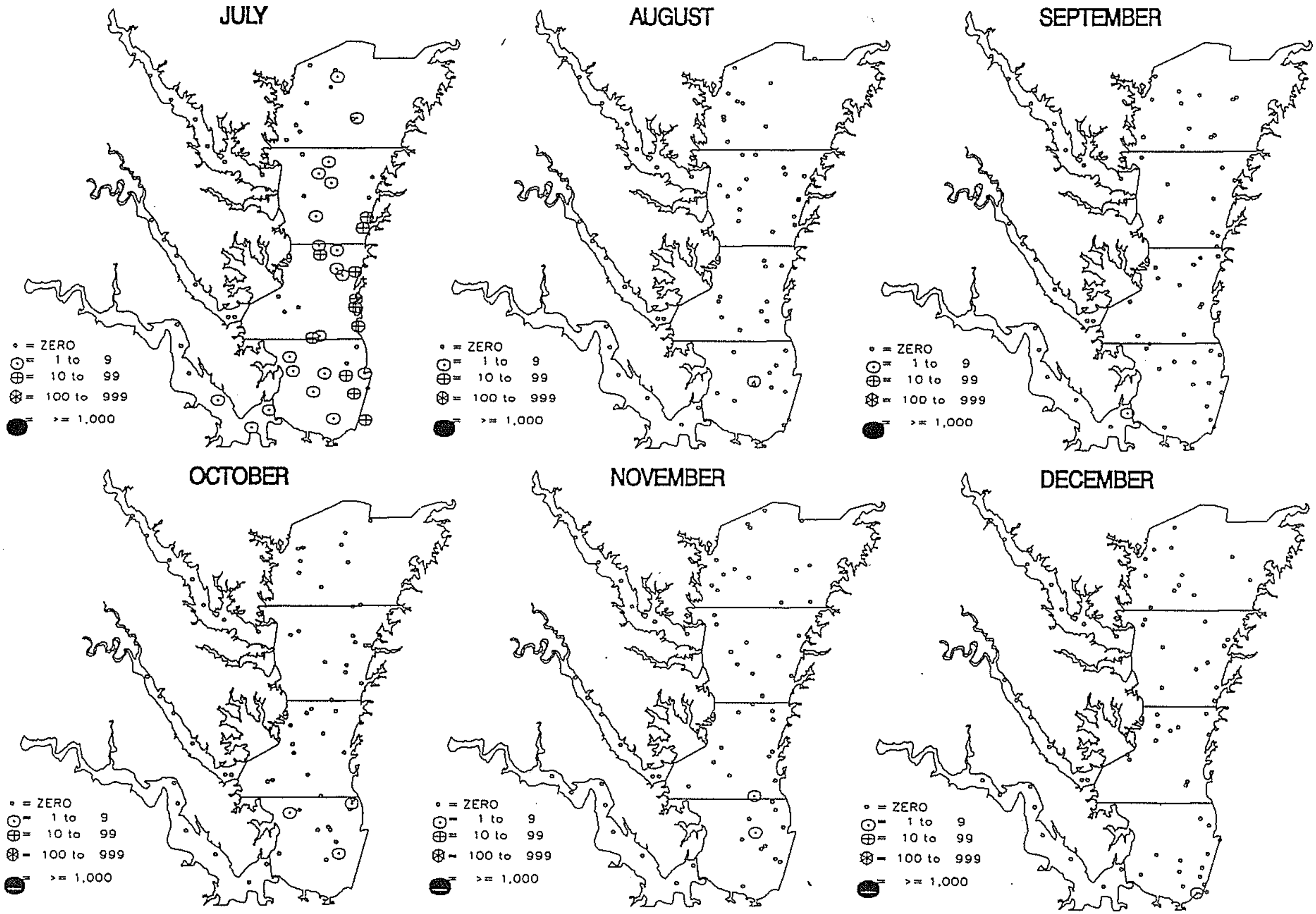
Appendix Figure 4-f.

Y-O-Y BLACK SEA BASS 1988



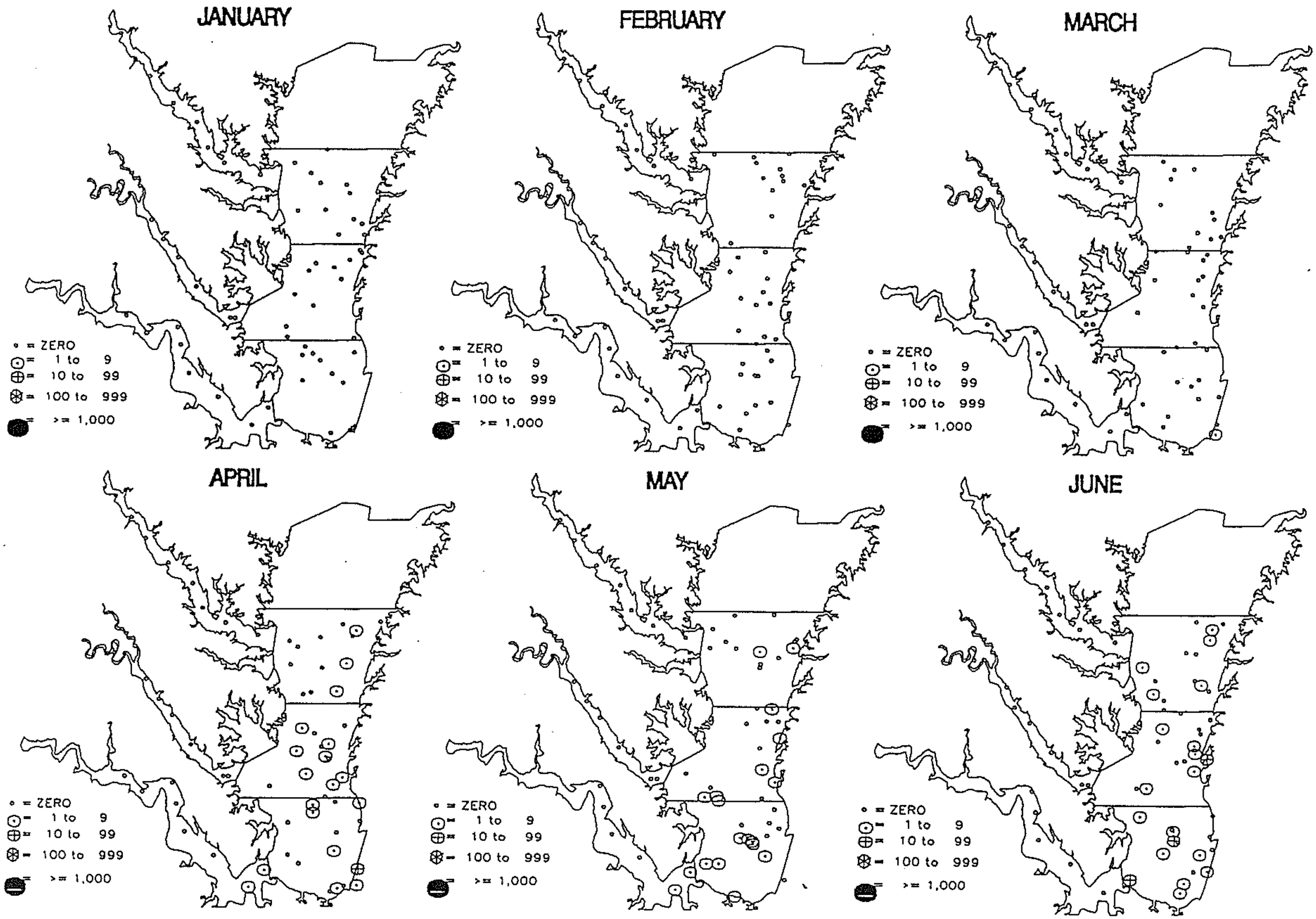
Appendix Figure 5-a.

Y-O-Y BLACK SEA BASS 1988



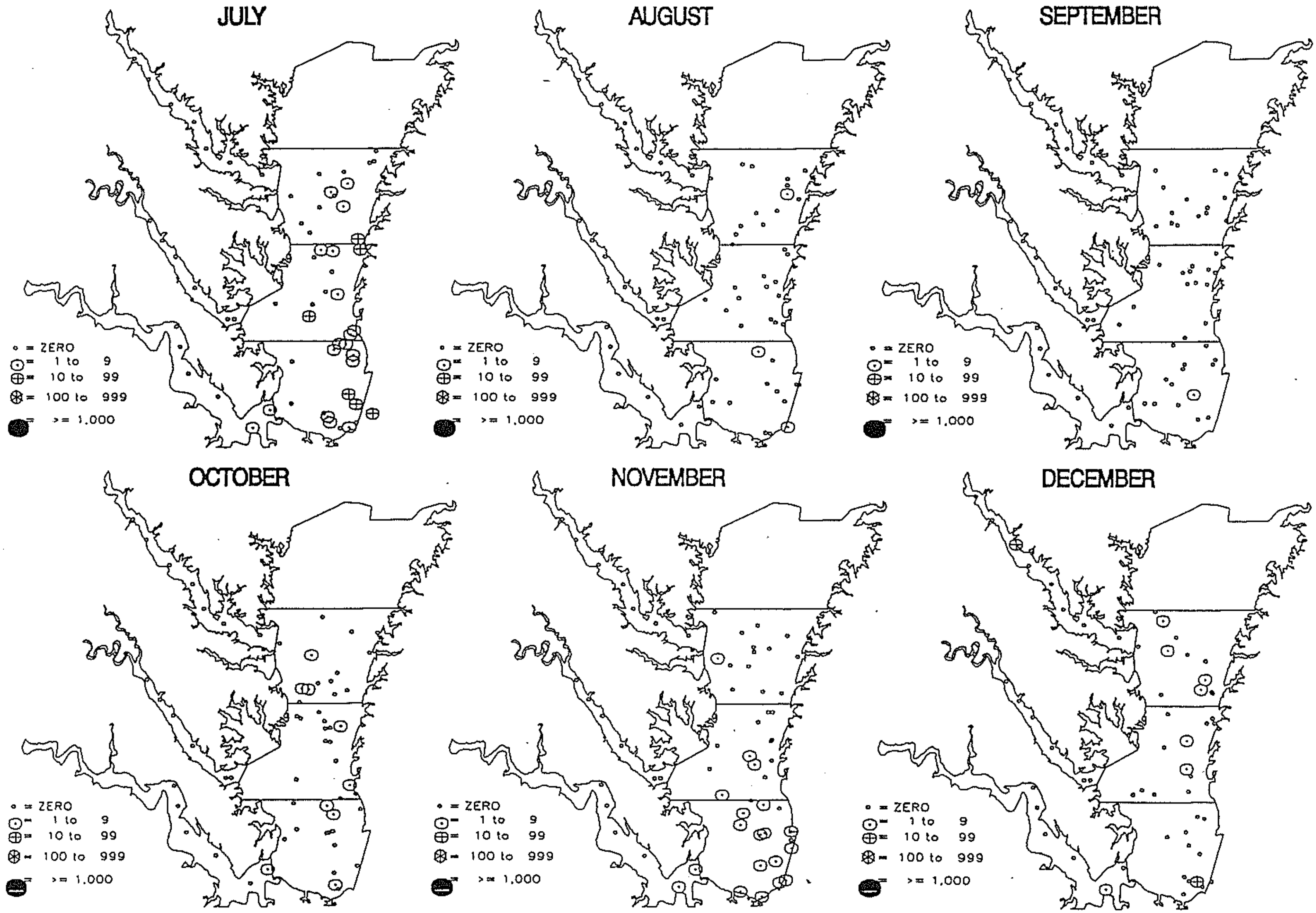
Appendix Figure 5-b.

Y-O-Y BLACK SEA BASS 1989



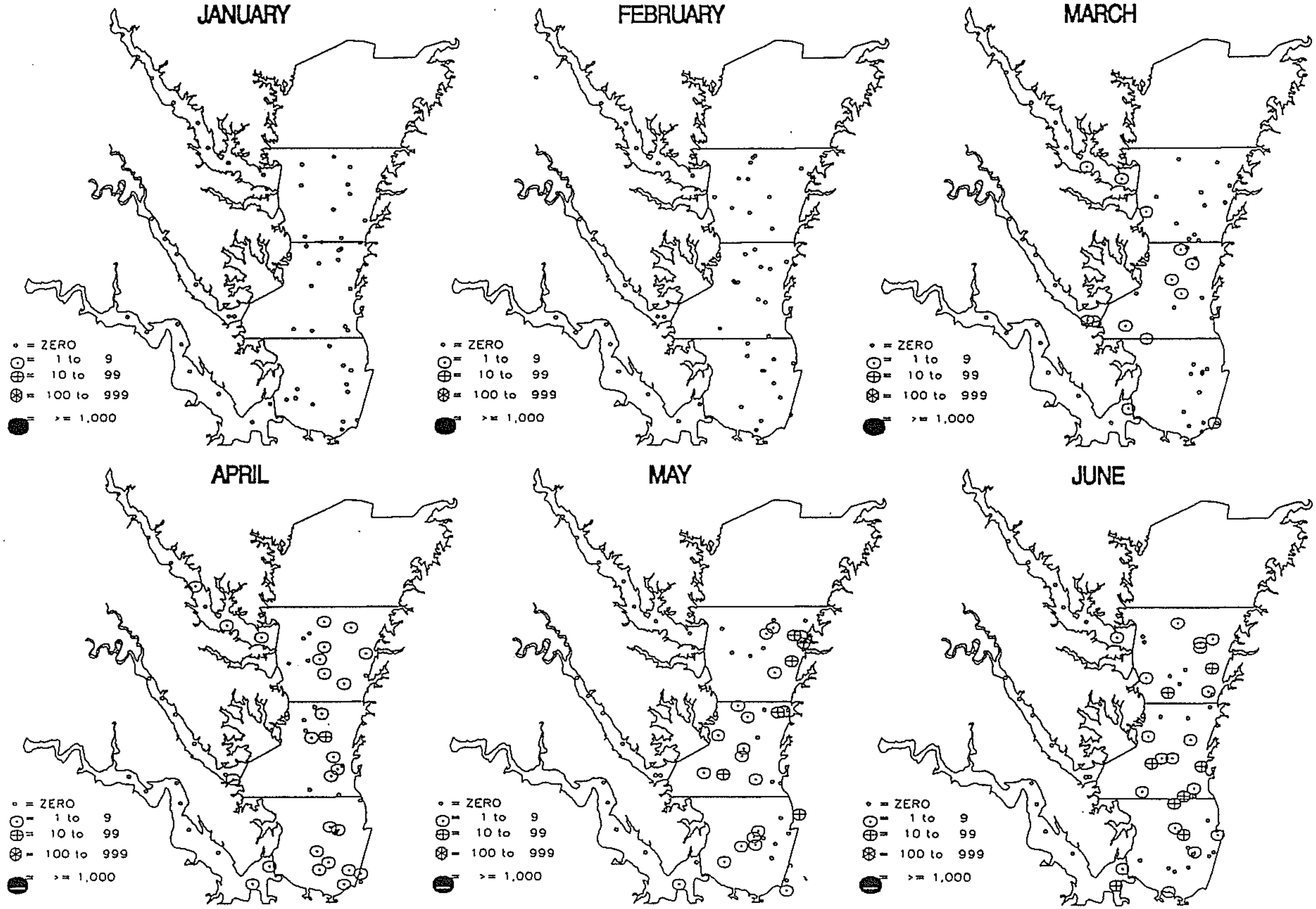
Appendix Figure 5-c.

Y-O-Y BLACK SEA BASS 1989



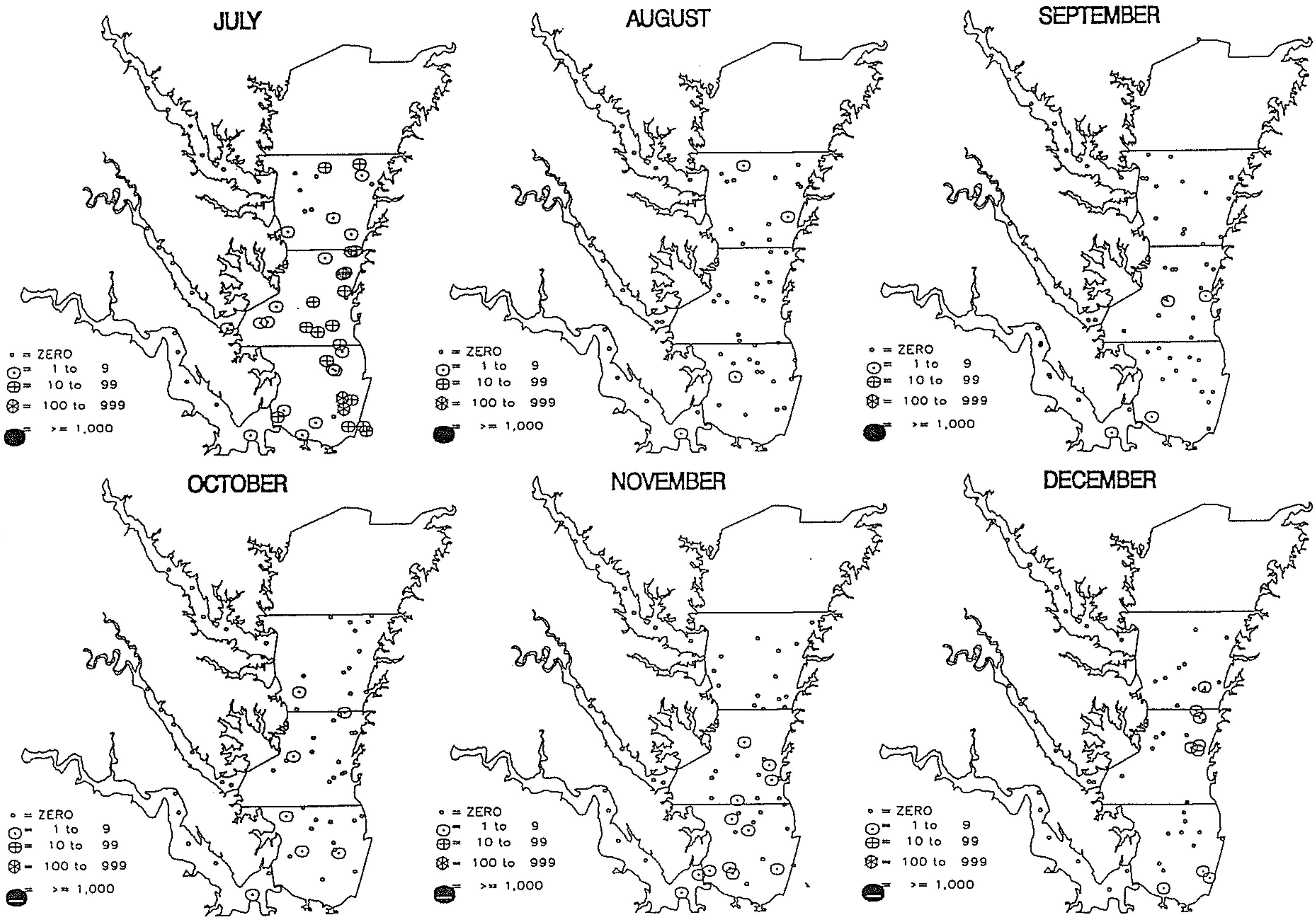
Appendix Figure 5-d.

Y-O-Y BLACK SEA BASS 1990



Appendix Figure 5-e.

Y-O-Y BLACK SEA BASS 1990



Appendix Figure 5-f.