CHAPTER 4
SPATIOTEMPORAL DISTRIBUTION OF SELECTED SPECIES OF HUDSON RIVER ESTUARY FISHES

4.1 FISH COMMUNITY

4.1.1 General Description of the Fish Community

The fish community of the Hudson River estuary reflects the convergence of the two primary fish habitats: fresh water and salt water. Fish are generally confined to one or the other habitat, but a relatively small number of estuarine and migratory species can pass from one to the other, or live in the narrow zone where there is a gradient between fresh and salt water. As a result of this convergence of different habitats in estuaries such as the Hudson, many species can be found in a relatively small area. The Hudson River estuary's species diversity is enhanced by its mid-latitude location on the Atlantic Coast. Southern tropical marine forms enter the Hudson River during the summer, and a number of northern fishes are near their southern limit.

Smith and Lake (1990) documented the Hudson River fish fauna, including the river upstream of the dam at Green Island and the Mohawk River subsystem. They report 201 species, including 3 known from contiguous waters but not yet reported from the Hudson. Beebe and Savidge (1988), based on sampling through 1980, reported 140 fish species in the Hudson south of the dam at Green Island. Smith and Lake (1990) classified the probable origin of each species, showing that the fish community, particularly in the estuarine reach, is a mixture of both temperate and tropical marine forms, freshwater forms, and intentional and accidental introductions.

The estuary and its tributary streams provide a wide range of chemical, physical, and biological habitat conditions. This diversity is reflected in the range of migratory and movement patterns, reproductive strategies, and food preferences among the members of the fish community. Daniels and Lawrence (1991) grouped 71 Hudson River estuary fish species collected in a variety of sampling programs from 1936 through 1991 into 8 trophic categories (feeding behavior) developed by Grossman et al. (1982): surface feeders, water column feeders, soft-bottom benthic feeders, rocky-bottom feeders, ooze feeders, algae feeders, macrocarnivores, and omnivores. Although this analysis did not include all recorded fish species from the estuary, it illustrates the broad range of feeding behaviors among the members of the Hudson River estuary fish community. Such an array of feeding behaviors reflects a diversity of habitat conditions.

Carlson (1986) identified assemblages of fish species based on 6 habitat types for the freshwater portion of the Hudson River estuary: vegetated backwaters, tributaries, rock pile, shore, offshore shoals and channel, and tailwater. Carlson's assemblages illustrate the diversity of physical habitats in the estuary. A similar analysis for the middle and lower regions of the estuary would show additional physical habitat types, including man-made habitats such as riprap shoreline, bulkheading, and piling clusters associated with piers and docking facilities.

Because many fish species are tolerant of a wide range of habitat conditions and because there are no well-defined boundaries between habitat types, it is useful to classify the fish community into assemblages based on migratory behavior (anadromous and catadromous) and salinity preference (freshwater, estuarine, and marine). In the Hudson River, only the American eel is catadromous; thus discussion is focused on the other four assemblages.

4.1.2 Species Occurrence Through Time

The Hudson River estuary's fish community is species rich. The total number of fish species collected in the Utilities' monitoring program in the Hudson River estuary has varied from 64 to 104 between 1974 and 2000 (Table 4-1). Such high levels of species richness are often used as an indicator of a healthy ecosystem in which habitat and other water quality conditions allow a wide variety of species to occupy the habitat.

Despite the large number of species which can occasionally be found in the estuary, most of the fish are from a limited number of species. In fact, only 10 – 15 percent of the species collected typically account for more than 99 percent of the catch. In an environmentally stable system, low species diversity is often associated with environmental stress. However in highly dynamic and unstable systems like the Hudson River estuary, the biological communities are typically dominated by a few species well adapted to such naturally dynamic systems. Most of the energy in estuaries is directed towards production of a few species, many of which have considerable commercial and recreational importance to man.

In each of the four major fish assemblages (anadromous, freshwater, estuarine, and marine), the persistence of most of the species over long periods of time shows broad-scale suitability of the environment for each assemblage. The fish community in brackish areas of the estuary is dominated by marine species whereas in tidal freshwater areas the fish community is dominated by anadromous species as larvae and young of year and by freshwater and estuarine species as yearling and older. Marine species appear largely limited to areas with salinities greater than 1 ppt, which in the Hudson River typically includes areas downstream from Region 6, the Cornwall region. Most of the fish production in low salinity brackish and freshwater areas of the estuary during spring and summer is directed towards anadromous species including river herring (alewife and blueback herring), striped bass, and American shad. These anadromous fish leave the estuary in fall of their first year of life leaving the community of older individuals consisting primarily of resident species.

Although the estuarine and anadromous assemblages have fluctuated very little over time, there have been some minor changes in the freshwater and marine assemblages. The disappearance or appearance of species may indicate some change has taken place, such as degradation or improvement of environmental conditions, introduction of competing or exotic species, and overexploitation or proper fisheries management. In the Hudson River estuary, significant changes in habitat (expansion of water chestnut beds), water quality (improvement in New York City wastewater treatment), and fisheries management practices (striped bass) may have contributed to changes in fish assemblages.

The freshwater assemblage has shown fewer species in recent years compared to the years from 1974 to 1980 (Table 4-1). However, the fewest species in this assemblage occurred in 1982 and 1983, and numbers have increased slowly since then. When the individual species in the freshwater assemblage are examined, there are several species that occurred consistently in the early years and not in the later years, such as cutlips minnow, common shiner, blacknose dace, redfin pickerel, longnose dace, and trout perch. Conversely, there are several species that were not present in the early years but have been recorded recently, such as brook silverside, channel catfish, and freshwater drum. The cause for the decline in the number of freshwater species sampled in the estuary since the 1970s is not clear, and in fact may be due to changes in the temporal extent of the sampling. In the 1970s, the BSS program began in April and continued through November. In the early 1980s, the shortened program typically ran from July or August to October. Beginning in the late 1980s and continuing to the present, the BSS program covered the period from mid-June through October. Alternatively, the expansion of water chestnut beds following cessation of herbicide treatments in the 1970s may have changed the availability of preferred habitat for some species in shallow freshwater areas of the estuary, which may have been a contributing factor to the apparent decline in species richness.

The dominant freshwater species collected in the Utilities' monitoring program were spottail shiner and tessellated darter (Appendix Tables C-1 through C-3). These two species also dominated the freshwater assemblages of near-shore collections in fisheries surveys conducted in 1936 and 1990 (Daniels and Lawrence 1991), but ranked density for these species especially from upper regions of the Hudson River has been lower in recent years than in the earlier years of the monitoring program (Pace et al. 1993). However, further analysis of the abundance levels of seven species from the Utilities' monitoring data concluded that there was no general pattern of abundance over time, suggesting that there has been no river wide fish decline (Pace et al. 1993).

The number of species in the marine assemblage shows more year-to-year variation, but overall there is a trend toward more marine species (Table 4-1). As expected, the largest increase in marine species occurred in the downstream sampling regions. Among the recent recruits to the marine assemblage are cunner, grubby, spotted hake, fourbeard rockling, yellowtail flounder, and naked goby. The opposing trends in the number of freshwater and marine species could be related to the shift in annual freshwater inflow. During the 1970s, when the number of freshwater species was relatively high, freshwater flow was higher than normal. In the 1980s and 1990s, freshwater flow was typically below normal, and freshwater species declined while the number of marine species increased. Additionally, due to increased treatment of sewage in New York City, dissolved oxygen levels have increased at the mouth of the Hudson, increasing the potential for movement of marine fish into the estuary. Extension of the LRS sampling program in 1988 and the FSS sampling program in 1996 into the more saline portion of the Hudson River estuary, the Battery region, also increased the possibility of collecting more marine species.

The dominant marine species collected in the Utilities' monitoring program was bay anchovy (Appendix Tables C-1 through C-3). Likewise, in 1968, bay anchovy was the principal species in trawl collections south of the Indian Point region (RM 40) (Carlson and McCann 1969). Overall abundance has increased in brackish areas of the estuary since the monitoring program began in 1974, largely as a result of recent increases in the abundance of bay anchovy and Atlantic silverside, both important prey species in inshore marine systems. Reasons for these apparent changes are unknown. However, much of the change appears to have occurred since 1990, a date which coincides with completion of major wastewater treatment facility upgrades in New York City. Perhaps improvements in water quality contributed to increased overall abundance of these two species.

Estuarine species are generally euryhaline, year-round residents of the Hudson River fish community. Dominant species in the estuarine assemblage as collected in the Utilities' monitoring program included white perch, banded killifish, Atlantic silverside, and hogchoker (Appendix Tables C-1 through C-3). White perch and banded killifish were also dominant in near-shore collections in 1936 and 1990 (Daniels and Lawrence 1991) as well as 1966 (Carlson and McCann 1969). Abundance of Atlantic silverside, as noted above, has been increasing in recent years, whereas banded killifish have been found in lower abundance in recent years (Pace et al. 1993).

Perhaps the most important fish assemblage in the Hudson River estuary is composed of the anadromous species, which use the estuary as spawning and nursery grounds. Adult fish enter the estuary in the spring and migrate upstream to low salinity brackish and freshwaters areas to spawn. The young fish then use the near-shore shoal areas for food and habitat as they make their way downstream and generally leave the estuary in the fall. Most of the energy in the Hudson River estuary is directed towards the production of these anadromous species: striped bass, blueback herring, alewife, American shad, and Atlantic tomcod. The early life stages of these species have dominated catches in the Utilities' monitoring program (Appendix Tables C-1 through C-3). Other investigators have noted that these ubiquitous species, especially blueback herring, comprise the numerically most important species in their study areas (MRL 1970; Heller et al. 1969; Carlson and McCann 1969; Daniels and Lawrence 1991). Curiously, Daniels (undated), in summarizing a 1936 fisheries survey in the Hudson River, noted the near absence of blueback herring from the sampling sites. In the last three decades, blueback herring have been the numerical dominant in most of the summer catches at near-shore sites.

Other species of the anadromous assemblage have shown fluctuations in abundance over the years. Striped bass and perhaps American shad appear to have increased over the period 1974-1989, especially at the larval stage (Pace et al. 1993). Despite their numerical dominance in catches, the overall abundance of blueback herring has declined since the early years of the monitoring program. Declines in the abundance of this anadromous species appear to have occurred to all stocks throughout their geographic range and appear a result of factors outside of the Hudson River, including overfishing in open ocean waters.

In all, it appears that the Hudson River estuary has a healthy and robust fish population. Species richness is high for all life stages as a result of the estuary serving as an interface between fresh and saltwater and between warmer and temperate climatic conditions. On the other hand, species diversity is relatively low reflecting the fact that the individual members of this community are comprised primarily of a limited number of species which are well adapted to the highly dynamic estuarine conditions. Spatially, the composition and abundance of the fish community is largely influenced by salinity with the interface between a marine-dominated and a freshwater-dominated fish community occurring in the reach of the estuary through the Hudson Highlands. However, considerable overlap in the spatial distribution of individual species occurs. There is no evidence of any substantial long-term changes in composition or abundance of the fish community over the 27-year period, 1974-2000.

4.1.3 Species Collected in 2000

Of the 94 species of fish collected in 2000, 29 were freshwater species, which is consistent with the number of freshwater species collected since the late 1980s (Table 4-1). The marine species in 2000 numbered 46, continuing the trend begun in the early 1990s of higher numbers of marine species. The estuarine and diadromous assemblages in 2000 were nearly identical to similar assemblages collected since 1974, with 7 to 11 species in each. A new species, cusk, a marine inhabitant, was collected in 2000.

Each of the surveys sampled a different habitat within the Hudson River estuary and, therefore, collected different assemblages of fish. More freshwater taxa were collected in the BSS than in the other two surveys and more marine species were captured in the LRS (Table 4-2). Thirty-one of the 94 species recorded during 2000 were collected in all three sampling surveys, while

44 of the remaining 63 species were collected in only one of the surveys. Of the 29 freshwater species, 12 (41 percent) of them were collected only in the BSS. Likewise, 15 (33 percent) of the 46 marine species were only collected in the LRS.

The dominant species in the monitoring program since the mid-1980s, when the spatial and temporal extent of the surveys has been relatively uniform, have remained relatively stable (Appendix Tables C-1 through C-3). The early life stages of bay anchovy, striped bass, *Alosa* spp., and white perch dominated the 2000 LRS, as they have in previous years (Appendix Table C-1). Striped bass, winter flounder, yellow perch, and Atlantic croaker were more abundant in the 2000 LRS than in previous years whereas Atlantic tomcod and bay anchovy were less abundant. The 2000 FSS was dominated by bay anchovy, hogchoker, and weakfish (Appendix Table C-2). Compared to previous years, weakfish, Atlantic menhaden, and Atlantic croaker were more abundant in the 2000 FSS, but blueback herring were less abundant than in the past. Catches of several species, namely rainbow smelt, American eel, Atlantic sturgeon, and hogchoker, have been markedly reduced since the mid-1990s than in earlier years of the FSS. Atlantic menhaden was the dominant species in the 2000 BSS, with blueback herring and Atlantic silverside also prevalent (Appendix Table C-3). Other species that were collected in large numbers in the BSS since 1985 included American shad, spottail shiner, white perch, and striped bass. Atlantic menhaden were more abundant in the 2000 BSS than in previous years.

4.2 STRIPED BASS

Striped bass (*Morone saxatilis*) are anadromous (i.e., they spend most of their life in the marine environment but return to fresh water to reproduce) members of the temperate bass family (the Percichthyidae). They are native to North America and range along the Atlantic Coast from the St. Lawrence River in Canada to the St. Johns River in northern Florida and from western Florida to Louisiana along the coast of the Gulf of Mexico. They were introduced in the Sacramento-San Joaquin River system in 1879 and are now found from British Columbia to Ensalada, Mexico. Striped bass have also been successfully introduced into the inland waters of at least 24 states. The U.S. East Coast rivers and bays that support the principal spawning populations are the Hudson River; Delaware Bay and Delaware River; Chesapeake Bay and tributaries; the Roanoke and Chowan rivers and Albermarle Sound, North Carolina; the Santee River, South Carolina; and the St. Johns River, Florida. Small spawning populations also occur in several river systems in eastern Canada. From 1983 to 1995, the Utilities' striped bass hatchery provided larvae for rearing and stocking by the State of Maine in its efforts to establish striped bass in the Kennebec River.

On the Atlantic Coast adult striped bass, which commonly reach 30 lb and can weigh over 50 lb, feed in nearshore waters from summer through late winter. During the warmer months fish typically travel north and return south as the coastal waters cool in the fall. Northward migration of Hudson River fish extends as far north as the Bay of Fundy, Nova Scotia, and older fish tend to travel farther north. Over the winter adult striped bass tend to aggregate near the mouths of their natal rivers. Once water temperatures rise in the spring, native adults (ages 4 and older) begin moving upriver to spawning areas in the freshwater portions of the estuaries.

Spawning begins in the spring when water temperatures are rising rapidly and reach about 57°F. Peak spawning occurs at about 60-65 °F in freshwater areas where currents are moderate to swift (Albrecht 1964; Setzler et al. 1980). In the Hudson River spawning occurs primarily between mid-May and mid-June in the middle portion of the Hudson River estuary. Depending on their age and size, females produce up to several million semibuoyant eggs that are suspended by currents. The eggs are relatively large (average 1/10 in. in diameter after water hardening), but vary with the size of the female. Older, larger females tend to have larger eggs.

In 1-4 days, depending on temperature, YSL hatch from the eggs. Typically 1/8 in. long, they initially drift with the current but can swim for short bursts. During the YSL stage the eyes become pigmented, the jaws and digestive tract form, fin buds appear, and they at least partially absorb the yolk-sac and oil globule. Older YSL are mobile and exhibit a positive phototaxis, or movement toward light (Doroshev 1970). The end of the yolk-sac stage is marked by the completion of the digestive tract, although some of the yolk-sac and oil globule may still remain.

During 2000, striped bass YSL were most abundant in mid-river, slightly downriver of the location of egg abundance (Figure 4-1; supporting density and standing crop tables for striped bass are presented in Appendix Tables D-1 through D-24). In other years in the Hudson River, however, the peak in yolk-sac abundance was often further upriver than the peak in eggs. The difference in distribution may mean that YSL migrate upriver using tidal currents, although other explanations have been proposed (Polgar et al. 1976; Fay et al. 1983).

Transformation to the PYSL stage occurs from 4 to 9 days after hatching, when the larvae are 1/4 in. long. The remainder of the yolk-sac and oil globule is absorbed, body pigmentation becomes noticeable, fins begin to form, the gas bladder is inflated, and larvae begin to feed actively on zooplankton. This stage lasts approximately one month or longer, ending when the fin rays are fully developed, which occurs when the fish are just over 1/2 in. long. During 2000, striped bass PYSL were most abundant in the lower section of the estuary (Figure 4-1), but typically they are found throughout the estuary.

Toward the end of the PYSL stage, young striped bass begin moving out of the middle estuary into the lower estuary, which is broader, shallower, and may be more productive, and they feed on copepods and amphipods. This downriver movement of YOY is evident in the 2000 spatiotemporal distribution pattern seen in the LRS, FSS, and BSS (Figure 4-2). Larger juveniles, over 2-1/2 in. long, feed on insect larvae, worms, opossum shrimps, crabs, and small fish (Gardinier and Hoff 1982). Low numbers of yearling and older-than-yearling striped bass were collected in the LRS, FSS, and BSS throughout the estuary during 2000 (Figures 4-3 and 4-4).

Comparing the temporal distribution of early life stages of striped bass in 2000 with previous years (1974-1999), peak egg density in 2000 was one week earlier but still within the historical pattern of peak occurrence in mid- to late May (Figure 4-5). YSL and PYSL abundance in 2000 was also earlier than the historical peak in early to mid-June. YOY were collected later than the temporal limits (Weeks 18-26) of this comparison in 2000.

Striped bass eggs in the 2000 LRS were most abundant in the Cornwall and Kingston regions, consistent with the historical pattern, but ranged from West Point to Saugerties (Figure 4-6). The YSL and PYSL distribution in 2000 was downriver from the long-term pattern of greatest distribution in the middle estuary with YSL most abundant in Indian Point and West Point and PYSL most abundant in Yonkers and Tappan Zee. The 2000 geographical distribution of YOY, or juvenile, striped bass in the BSS was consistent with the long-term trend (based on data from 1974 to 1999), with the main distribution centered in the Tappan Zee and Croton-Haverstraw regions and a secondary distribution in the upper river near Saugerties and Catskill (Figure 4-7). At the end of their first summer, many of the juvenile striped bass move to the southern extreme of the estuary and are found in New York Harbor, western Long Island Sound, and along the south shore of Long Island (McKown 1992). Yearling striped bass in the 2000 BSS were also prevalent in the lower estuary whereas older-than-yearling were found primarily in the middle estuary (Figure 4-7).

Weekly length statistics for young-of-year striped bass collected in 2000 show relatively steady growth from mid-June through late October and a decrease in size of fish collected through the end of FSS collections in November (Figure 4-8, supporting length frequency tables for striped bass are presented in Appendix Tables E-1 through E-3). Slight variances in the growth curve may reflect size selectivity of the various gears used in the surveys. As striped bass grow, fish become an increasingly important component of their diet. Juvenile striped bass are also preyed upon by some marine and estuarine predator species.

At age 2 or 3, striped bass leave Atlantic Coast estuaries and begin the typical seasonal migration, northward during the spring and summer and southward during the fall. Adult striped bass are at the top of the food chain and have few natural enemies other than man. Since they rarely go more than 10 mi offshore, they are typically available to sport and commercial fishermen all along their migration route.

4.3 WHITE PERCH

White perch (*Morone americana*) resemble the closely related striped bass in general form and structure but are deeper bodied, more laterally compressed, and have no stripes. Adult white perch are much smaller than adult striped bass, averaging less than 10 in. in length and less than 3 lb in weight. Coloration ranges from dark olive to dark gray on the dorsal surface, shading to silvery white on the belly.

The natural range of this species extends along the Atlantic Coast of North America from the southern Maritime Provinces of Canada and the St. Lawrence River to South Carolina in brackish and freshwater areas near the Coast. White perch are essentially estuarine, but landlocked populations exist in fresh water throughout their range (Mansueti 1964). Freshwater populations predominate in the northern part of the range and white perch are uncommon in salt water north of Cape Cod (Rounsefell 1975). Probably as a result of dispersal through canals, they are now found in Lakes Ontario and Erie (Hubbs and Lagler 1958). They have also been introduced accidentally into the Missouri River drainage (Hergenrader and Bliss 1971).

Coastal populations overwinter in the deeper waters of middle and lower estuaries (Mansueti 1957; Markle 1976). White perch spawn in shallow water following upstream migrations to areas of fresh or slightly brackish waters during the spring and early summer. Spawning also occurs in tributary streams. After spawning, adult white perch generally return to the lower reaches of estuaries. In the Hudson River estuary, spawning occurs from early May to early July, primarily north of Croton Bay. After spawning, many adults move downriver to areas of higher salinity in Haverstraw Bay and the Tappan Zee region.

Female Hudson River white perch produce from 16,000 to 161,000 eggs (Bath and O'Connor 1982). White perch eggs do not contain an oil globule and are small, 1/16 in. in diameter. They sink to the bottom and, because they are very adhesive, stick to each other and to anything else they contact (Mansueti 1964). In the Hudson River during 2000, white perch eggs were most abundant in the upper estuary, but extended to the West Point region (Figure 4-9, Appendix Tables D-25 through D-48).

Hatching occurs in 1.5 to 6 days, with development occurring faster at higher temperatures. Newly hatched YSL are from 1/16 to 1/8 in. long. They remain on or near the bottom for 3-5 days and do not move about actively until the yolk-sac is absorbed (Mansueti 1964). White perch YSL were abundant in the upper and middle estuary during 2000, in the same areas that eggs were most abundant but also extending downriver (Figure 4-9). The yolk-sac is completely absorbed when the larvae are a little over 1/8 in. long; the end of the PYSL stage occurs when the adult fin complement develops, usually about one month after hatching and when the young white perch are about 1 in. in length. During 2000, white perch PYSL were most abundant in the middle and lower estuary (Figure 4-9) where they co-occur extensively with striped bass PYSL.

White perch reach the juvenile stage beginning in mid-June; and during 2000, YOY fish were found throughout the entire estuary (Figure 4-10). Juvenile white perch are about 3 in. long by the end of their first summer (Klauda et al. 1988a). They are prey for larger predators (including adult white perch and striped bass). Yearling and older-than-yearling white perch were also distributed throughout the Hudson River based on the 2000 monitoring program (Figures 4-11 and 4-12). In the Hudson River estuary some white perch of both sexes become sexually mature at age 2, but all males and females are mature by ages 4 and 5, respectively (Klauda et al. 1988a).

Comparing the temporal distribution of early life stages of white perch in 2000 with previous years (1974-1999), the 2000 distribution was very similar to the long-term record. The majority of eggs occurred in May, YSL were present in May and early June, and PYSL peaked in late May, slightly earlier than previous years (Figure 4-13). Most YOY white perch collected in the 2000 LRS occurred beyond the temporal limits of this comparison.

White perch eggs in the 2000 LRS were primarily in the Catskill region which is consistent with the historical trend (Figure 4-14). YSL were distributed mainly in the middle and upper regions of the estuary in 2000, and PYSL were found throughout the estuary, notably in the Yonkers and Tappan Zee regions which diverges from the historical trend. Historically as well as in 2000, the geographical distribution of YOY, yearling, and older-than-yearling white perch in the BSS has shown two distribution centers, one in the Tappan Zee and Croton-Haverstraw regions and the other in the upriver regions of Saugerties and Catskill (Figure 4-15). In previous years, the lower distribution center was primary, but in 2000 more YOY and yearling white perch were located in the upper distribution area.

Weekly length statistics for young-of-year white perch collected in 2000 show increasing growth from July through September with only a slight increase through the fall months (Figure 4-16, Appendix Tables E-4 through E-6). The zigzag pattern in the growth curve may reflect size selectivity of the various gears used in the surveys.

4.4 ATLANTIC TOMCOD

Nineteen members of the codfish family (Gadidae) are found along the Atlantic Coast of Canada and the United States, but only the Atlantic tomcod (*Microgadus tomcod*), an inshore species that ranges from Labrador to the Chesapeake Bay, is anadromous; the southern limit of its spawning range is the Hudson River (Grabe 1978). In Canada, the Atlantic tomcod occurs in the mid- to lower St. Lawrence River and is landlocked in at least two freshwater lakes (Scott and Crossman 1973).

Atlantic tomcod enter coastal estuaries and rivers to spawn in shallow fresh or brackish water during mid-winter. In the Hudson River estuary, adult Atlantic tomcod occur at least as far north as the Saugerties region during spawning runs; the largest concentrations, however, are consistently found in the middle estuary between West Point and Poughkeepsie. After spawning in late December or early January, Atlantic tomcod return to coastal waters.

The Hudson River population is the southernmost major breeding population (Dew and Hecht 1976). No spawning has been documented in either the Connecticut River (Marcy 1976) or Long Island Sound (Richards 1959), and limited spawning may occur in the Raritan River and/or Raritan Bay (IA 1977). Unlike more northern populations, age 1 fish constitute most of the Hudson River spawning stock.

Atlantic tomcod eggs are about 1/16 in. in diameter and non-adhesive. The average number of eggs per female in the Hudson River population has ranged from 12,400 to 22,500 eggs at age 1 and from 32,500 to 53,100 eggs at age 2 (NAI 1992). In the Hudson River water temperatures are generally less than 37°F when spawning occurs, and the eggs take at least a month to hatch.

Atlantic tomcod larvae are about 1/5 in. long at hatching. YSL are pelagic and move downstream as they develop. The yolk-sac is absorbed by 1/4 in., and onset of feeding by PYSL may depend on water temperatures. In the Hudson River, the abundance of YSL peaks in March. YSL are found throughout the lower half of the estuary, whereas PYSL are concentrated in the Yonkers and Tappan Zee regions.

Early March sampling in the 2000 LRS collected YSL from the Tappan Zee to Cornwall regions, the northern extent of sampling in March (Figure 4-17, Appendix Tables D-49 through D-66). PYSL were collected in March and April predominantly in the Yonkers and Tappan Zee regions, but ranging as far north as Cornwall (Figure 4-17). Juvenile Atlantic tomcod collected in the LRS were most abundant in April in the Battery region but ranged as far north as Hyde Park (Figure 4-18). Although some juvenile tomcod remain in the Hudson River throughout the summer, some proportion of the population may move out of the lower estuary into New York Bay and Raritan Bay when water temperatures rise during late May and June. The 2000 FSS collected juvenile Atlantic tomcod primarily in the middle estuary during July and the 2000 BSS collected Atlantic tomcod in the lower estuary throughout the summer (Figure 4-18). A few yearling and older Atlantic tomcod were collected in the FSS during the fall (Figure 4-19).

Comparing the temporal distribution of early life stages of Atlantic tomcod in 2000 with the long-term database (beginning in early May) available from previous years (1974-1999), the 2000 PYSL distribution was consistent with the long-term record showing that most PYSL were collected in early May (Figure 4-20). Peak occurrence of YOY in 2000 was similar to the historical trend in mid-May, but also extended to late June in 2000.

The geographical distribution of PYSL in the 2000 LRS was further upriver, in the Indian Point region, than the long-term pattern. YOY occurrence in 2000 was similar to the historic distribution in the lower estuary (Figure 4-21). However, the geographical distribution index based on the 2000 FSS for YOY Atlantic tomcod showed the primary peak in the middle estuary (Figure 4-22). No yearling and older Atlantic tomcod were collected within the temporal limits of this index in 2000.

Juvenile growth slows or ceases in summer (Grabe 1978; Klauda et al. 1988b). Growth slows at temperatures above 66°F and essentially stops in early July when temperatures exceed 71°F. It begins again when water temperatures fall below 77°F during late August and early September (TI 1978). During 2000, the weekly length statistics obtained from the monitoring program exemplified this pattern, showing more rapid growth in the spring and fall than during the summer (Figure 4-23, Appendix Tables E-7 through E-9). Juvenile tomcod generally double their summer length by December to a mean total length approximately 6 in. Most of the juvenile Atlantic tomcod in the Hudson River are sexually mature by the end of December and reproduce in early January. Following the period of rapid growth during the fall, mature YOY migrate upriver to spawn.

4.5 BAY ANCHOVY

Bay anchovy (*Anchoa mitchilli*) is a small, slender fish, from 1.5- to 4-in. long, that is ubiquitous in shallow coastal waters of North America from southern Maine to the Yucatan Peninsula. They have a wide salinity tolerance from fresh water to more than twice the salinity of normal sea water, but they prefer salinities found at seaward ends of estuaries. Where temperatures do not drop below 41°F during the winter, bay anchovy remain in the estuaries throughout the year (Wang and Kernehan 1979).

However, north of Delaware Bay, where water temperatures go below 41°F during the winter, National Marine Fisheries Service trawl data indicate a movement of bay anchovy out of coastal estuaries and southward during the fall, resulting in an overwintering distribution ranging from Cape Hatteras to Delaware Bay and the virtual absence of bay anchovy from the inshore continental shelf of New York and New Jersey during the winter months (Vouglitois et al. 1987).

Bay anchovy school in large numbers and feed on plankton as they swim. Their mouths are large relative to their small size, which enables them to pass relatively large quantities of water through their gill rakers (long, slender projections on their gills) and filter out their prey. They feed throughout the water column and primarily eat invertebrates. Larval bay anchovy feed on a variety of microzooplankton, including the larval stages of crustaceans and mollusks. Juvenile and adult bay anchovy feed on larger macro-zooplankton, including copepods, cladocerans, amphipods, and mysids.

Bay anchovy rarely survive more than 2 years. They grow rapidly and mature at a size of 1-2 inches. In warm waters, they may mature within 3 months of hatching, but in cooler, northern waters they usually mature in their second summer, 11-14 months after hatching. They are also very prolific; individual females may spawn 50 or more times per year, averaging about 1,100 eggs per spawn (Houde and Zastrow 1991). Partially as a result of this early maturity and high fecundity, bay anchovy may be the most abundant fish species in the western north Atlantic (McHugh 1967).

Bay anchovy spawn in lower estuarine and inshore coastal waters throughout the warmer months of the year. In the New York Bight spawning occurs from May through September, with peak egg abundance occurring in late June or early July when water temperatures exceed 70°F. Adults spawn in areas where the salinity is greater than 10 ppt. Egg abundance is typically highest in waters with salinities greater than 20 ppt, and egg viability apparently declines at salinities lower than 8 ppt. Spawning occurs throughout all areas of the Hudson-Raritan Bay complex, including Raritan and Newark bays, Arthur Kill, Kill Van Kull, and the Upper and Lower New York bays as well as throughout Long Island Sound.

Within the Hudson River, bay anchovy eggs are most abundant in the Battery through Tappan Zee regions (Figure 4-24, Appendix Tables D-67 through D-84). The eggs, which are about 1/16 in. long, are transparent and initially buoyant, but sink after 12-16 hours of floating. Hatching occurs approximately 24 hours after spawning. Newly hatched YSL are approximately 1/16-1/8 in. long, transparent, and drift along the bottom with the tidal currents. The YSL stage is very brief, and typically lasts less than 1 day. Due to their small size, short duration, and epibenthic nature, few YSL are collected in the Utilities' ichthyoplankton samples. The PYSL stage is longer and lasts about a month. In the Hudson River the peak abundance of PYSL occurs during the summer and the center of their distribution shifts slightly upriver compared to that of eggs and YSL (Figure 4-24).

Bay anchovy are about 1/2 in. long at the beginning of the juvenile stage. Juvenile bay anchovy are found in the Hudson River estuary from mid-August through October and as far upriver as Albany (Schmidt 1992). During 2000, most of the YOY population was located downstream of the Cornwall region (Figure 4-25). Yearling and older bay anchovy were much less abundant in collections than YOY (Figure 4-26). They were caught more frequently in the summer than during fall in the lower estuary.

Comparing the temporal distribution of early life stages of bay anchovy in 2000 with the years when LRS sampling included the Battery region (1988-1999), the 2000 egg distribution peaked in mid-July which is later and more concentrated in a single week than the long-term trend (Figure 4-27). PYSL and YOY distribution in 2000 also occurred later than the long-term pattern with PYSL peaking in late July and YOY temporal distribution extending into October (Figure 4-27).

The geographical distribution of bay anchovy early life stages in 2000 was very consistent with the distribution pattern seen over the 1988-1999 period (Figure 4-28). The 2000 YOY geographical distribution from the LRS was similar to the historic pattern with peak abundance in the Tappan Zee region. The 2000 geographical distribution of YOY and yearling and older bay anchovy in the BSS also showed peak abundance in the Tappan Zee region. While similar to the 1974-1999 long-term trend for YOY, this distribution was slightly upriver of the historical trend for yearling and older bay anchovy (Figure 4-29).

Weekly length statistics for bay anchovy juvenile life stage collected in 2000 showed an overall increase in growth throughout the summer and a leveling off of growth in the fall as the fish were recruited to the adult stage (Figure 4-30, Appendix Tables E-10 through E-12). The wide range in size (up to 2.5 in.) during a collection period reflects the protracted spawning period of bay anchovy.

4.6 AMERICAN SHAD

American shad (*Alosa sapidissima*) are the largest of the North American species of anadromous herrings. They range from Newfoundland to northern Florida along the Atlantic Coast and over the continental shelf. They may live to 13 years, attain a length of 30 in., and weigh up to 12 lb. American shad usually become sexually mature after 3-6 years at sea, although some males may mature within 2 years. Most females mature by their fourth or fifth year.

American shad, like many anadromous herrings, have well-developed homing abilities and are capable of returning to their natal rivers and tributaries from far off the Coast. After spawning, the adults soon return to the ocean. They can repeat their annual spawning sequence up to eight times. In more southerly rivers along the Atlantic Coast, increasing percentages of the adult population die after spawning; south of Cape Fear, North Carolina, all spawners die on their first run.

In the spring, American shad migrate north, and by summer they are feeding in the Gulf of Maine, the Bay of Fundy, Georges Bank, and the Gulf of the St. Lawrence (Neves and Depres 1979; Dadswell et al. 1987). In fall they move south again along the perimeter of the Gulf of Maine and Georges Bank at depths greater than 60 m (Neves and Depres 1979); by winter they may congregate along the edge of the continental shelf. Based on tagging experiments conducted in 1950 and 1951, Talbot (1954) reported that American shad of Hudson River origin were recaptured from Maine to North Carolina. Most recaptured fish were from the fishery along the New Jersey Coast in spring. Pre-spawning adults move along the Coast in the spring to their natal rivers (Dadswell et al. 1987), which they enter as river temperatures reach 50-60 °F.

Peak spawning activity for American shad in the Hudson River occurs during May in the upper estuary. Shad have been reported to spawn on dark afternoons or evening hours over shallow, broad flats washed by moderate currents in the main body of coastal rivers (Leggett 1976). At present shad are not known to utilize Hudson River tributaries, the Mohawk River, or the upper Hudson River for spawning (Schmidt et al. 1988), although historically the Mohawk and upper Hudson may have been part of the shad spawning and nursery range. During 2000, the bulk of American shad eggs were collected from Saugerties to Albany during May (Figure 4-31, Appendix Tables D-85 through D-102).

American shad produce 116,000-468,000 eggs per female. The eggs are 1/16-1/8 in. in diameter, semibuoyant, and non-adhesive. They hatch in 3-12 days, depending upon water temperature. Newly hatched YSL are approximately 1/4 in. long and grow very rapidly. They absorb the yolk-sac within 1 week and are approximately 1/2 in. long at the beginning of the PYSL stage. Larval shad alternately swim toward the surface and passively sink (Chittenden 1969), but behavior has not been completely described. Although downriver dispersal was apparent during 2000, both YSL and PYSL American shad were found primarily in the upper estuary between Kingston and Albany (Figure 4-31).

During 2000 YOY shad appeared to have been fully recruited to the beach seine gear by early July with the highest catch effort evident in the middle estuary, but in the upper estuary for the LRS and FSS gear (Figure 4-32). Few yearling and older American shad were collected in 2000 (Figure 4-33), since adult spawning fish (3- to 6-year-old fish) effectively avoid the juvenile gear.

Comparing the temporal distribution of early life stages of American shad in 2000 with previous years (1974-1999), the 2000 distributions were very similar to the historic pattern (Figure 4-34). Eggs peaked in early May with YSL abundance peaking one week later followed by a protracted occurrence of PYSL into late June. YOY also occurred in late June. The geographical distribution of American shad early life stages in 2000 was generally consistent with the long-term record with greatest distribution in the upper estuary (Figure 4-35).

The long-term geographical distribution of YOY American shad in the BSS showed tri-modal peaks in the lower estuary (Tappan Zee and Croton-Haverstraw), mid-estuary (Cornwall and Poughkeepsie), and upper estuary (Saugerties, Catskill, and Albany) (Figure 4-36). The 2000 geographical distribution data supported the mid- and upper estuary peaks, with fewer YOY found in the lower estuary in 2000.

Weekly length statistics for YOY American shad collected in 2000 showed steady growth from June through October (Figure 4-37, Appendix Tables E-13 through E-15). At the time they emigrate from the Hudson River at the end of the summer, juvenile shad range from 3 to 4 in.

long. This emigration is triggered by declining water temperatures and may be related to size (Schmidt et al. 1988); larger juveniles may tend to emigrate earlier. The shad emigration is a gradual movement of the population seaward over several months. Shad emigrate from the estuary earlier than either of the other two anadromous herrings commonly found in the Hudson River, alewife and blueback herring; and Schmidt et al. (1988) speculated that the earlier migration might be a behavioral adaptation that reduces competition with juveniles of the other two herring species.

4.7 RIVER HERRINGS (*Alosa* spp.)

Blueback herring (*Alosa aestivalis*) and its congener, alewife (*A. pseudoharengus*), are similar in general form to American shad, but are much smaller and not as deep bodied when adult. Blueback herring and alewife are very much alike in external appearance, especially as larvae, but older alewife have proportionately larger eyes and deeper bodies than blueback herring. In Hudson River sampling, eggs and larvae of alewife and blueback herring are not differentiated because of the similarity in appearance. Any references in this document to eggs and larvae pertain to the combined numbers from both species, referred to as *Alosa* spp. When juveniles of these two species reach sufficient size, they are differentiated by the size of the eyes and the mouth morphology. The differentiated juveniles are discussed separately below. Occasionally other members of the Clupeidae family, such as Atlantic menhaden, which are also difficult to distinguish during the early life stages may be included in this *Alosa* spp. grouping.

Of the three anadromous herring species that spawn in the Hudson River estuary, blueback herring are the last to begin their spring spawning run, preferring warmer water than American shad or alewife. Alewife spawning activity is most intense when water temperatures are 51-71°F, which results in slightly earlier spawning than that of blueback herring. Blueback herring peak spawning activity occurs near the end of May. Spawning activity occurs within the river, but preferred spawning habitat for blueback herring is in fast-flowing tributaries, where eggs are released over hard substrates (Loesch and Lund 1977). In the Hudson River, blueback herring travel through the locks and spawning occurs within the Mohawk River and upper Hudson River. Alewife prefer ponds and slow-moving streams for their spawning habitat.

Alewife eggs are semidemersal, slightly adhesive, but easily torn free and carried by currents. The egg diameter is about 1/16 in. Hatching takes 2-15 days depending upon temperature (Smith 1985). Blueback herring produce 45,000-350,000 eggs per female. The eggs are 1/16 in. in diameter and adhesive upon release, but they may later become dislodged and be pelagic. Development proceeds rapidly and hatching occurs in 2-3 days. Newly hatched blueback herring are 1/8 in. long and the yolk-sac is absorbed in about 4 days. At the beginning of the PYSL stage, the larvae are about 3/16 in. long.

In the Hudson River during 2000, peak abundance of *Alosa* spp. eggs occurred in the upper estuary, mainly in the Albany region during mid-May (Figure 4-38, Appendix Tables D-103 through D-114). YSL and PYSL were also most abundant in the upper estuary but PYSL were found throughout the estuary by early June (Figure 4-38). YOY *Alosa* spp. were found mainly in the upper and middle estuary from June through July (Figure 4-39).

Comparing the temporal distribution of early life stages of *Alosa* spp. in 2000 with previous years (1974-1999), the 2000 abundance periods for eggs, YSL, and PYSL were within the historical range but larval stages were slightly later in 2000. YOY distributions were much earlier than the long-term peak although most YOY were collected beyond the temporal limits of this comparison (Figure 4-40). Most eggs were collected in mid-May in 2000, YSL and PYSL in late May and early June, and YOY in late May.

The geographical distribution of *Alosa* spp. early life stages showed that most of the *Alosa* spp. eggs are found in the Catskill and Albany regions and the larvae gradually disperse downriver throughout the estuary (Figure 4-41). The 2000 distribution is consistent with this long-term record, except that the early catch of YOY was found exclusively in Poughkeepsie (Figure 4-41). Geographic distribution of YOY *Alosa* spp. from the BSS also indicated abundance in the upper estuary in the historic record, as well as in the 2000 data (Figure 4-42).

4.8 ALEWIFE

Alewife are usually anadromous and inhabit coastal waters from Newfoundland to South Carolina but they have also been introduced into the upper Great Lakes and inland lakes in Rhode Island, Maine, New Hampshire, Virginia, Ontario, and New York, where they provide forage for large predatory species. Anadromous alewife spend most of their lives in salt water and return to fresh water to spawn in lakes and quiet stretches of rivers (Scott and Crossman 1973). They are capable of homing to their natal rivers after they mature at ages 3 or 4, even though substantial numbers may not return and considerable mixing of river stocks may occur (reviewed in Fay et al. 1983). Adults are typically about 10- to 12 in. long and have a maximum life span of about 9 years.

Alewife is chiefly a plankton feeder; copepods, amphipods, shrimps, and appendicularians are the chief diet. However, they also take small fish, such as herring, eels, lance, cunners, and their own species, as well as fish eggs. Upon returning to the lower estuary after spawning, alewife feed heavily on shrimp (Bigelow and Schroeder 1953).

Alewife assume adult characteristics at about one month of age and about 0.5 in. long. At this stage they tend to move inshore during the day and offshore into deeper waters at night. They remain in estuaries until water temperatures begin declining in the fall, when they move into coastal waters. Their emigration pattern is prolonged, like that of American shad. Timing of migration may also be related to size, and larger juveniles migrate earlier (Schmidt et al. 1988). Little is known about the migration patterns at sea. The presence of alewife and blueback herring in the Bay of Fundy has led to speculation that these species have an oceanic migratory pattern similar to American shad, although that has not been confirmed (Harris and Rulifson 1989).

YOY alewife began appearing in the 2000 LRS in mid-July mainly in the middle estuary as no LRS sampling was conducted in the upper estuary at this time of year (Figure 4-43, Appendix Tables D-115 through D-126). YOY alewife captured in the 2000 FSS and BSS were found throughout the estuary but were most abundant in the upper estuary in the FSS and in the middle regions in the BSS (Figure 4-43). The yearling and older alewife collected in the 2000 monitoring program were found throughout the estuary during the sampling season. Those found in the spring were presumably on their spawning migration (Figure 4-44).

Comparing the geographical distribution of YOY alewife based on the 2000 BSS with previous years (1974-1999), the 2000 distribution of juveniles differed from the long-term pattern of a tri-modal peak in distribution in that most of the YOY alewife were found in the upper estuary (Figure 4-45).

Weekly length statistics for YOY alewife collected in 2000 showed steady growth during the summer and an a leveling off of growth beginning in late October (Figure 4-46, Appendix Tables E-16 and E-17).

4.9 BLUEBACK HERRING

Blueback herring range from southern New Brunswick and Nova Scotia southward to northern Florida. Although they are caught as far as 70-80 miles offshore, little is known about the oceanic migration patterns. The presence of blueback herring and alewife in the Bay of Fundy has led to speculation that these species have an oceanic migratory pattern similar to that of American shad, although that has not been confirmed (Harris and Rulifson 1989). The degree to which river herring of Hudson River origin return to the Hudson River is not known nor is the degree to which spawning stocks from different river systems mix. Blueback herring grow to a maximum length of 15 in. and a weight of about 1 lb and live for up to 8 or 9 years (Scott and Crossman 1973).

Within a month of hatching the young blueback herring assume adult characteristics and are about 0.5 in. long. Juvenile blueback herring remain in upper estuaries throughout the summer. During this period they are about 10 times more abundant than juvenile alewife. Juvenile blueback herring grow more slowly than juvenile alewife and begin their downriver migration later than the other herring species. It has been reported that blueback herring exhibit a tendency to spend their first year or two in the lower reaches of estuaries (Hildebrand 1963).

In the Hudson River during 2000, early juveniles collected in the LRS were found in the middle estuary beginning in mid-July (Figure 4-47, Appendix Tables D-127 through D-138). YOY blueback herring began appearing in the 2000 BSS and FSS in late July and were present in the upper and middle estuary to early October with collections gradually increasing in downriver regions by October, reflecting the downriver migration. A few yearling and older blueback herring were collected throughout the estuary with one large catch in March in Yonkers (Figure 4-48).

Comparing the geographical distribution of juvenile blueback herring based on the 2000 BSS with previous years (1974-1999), the 2000 distribution of YOY resembled the long-term record with most of the population located in the upper estuary from Kingston to Catskill and some of the population in the middle region of Poughkeepsie (Figure 4-49).

Weekly length statistics for juvenile blueback herring collected in 2000 showed only a slight increase in growth from July to October and no apparent growth in the fall (Figure 4-50, Appendix Tables E-18 and E-19).

4.10 GIZZARD SHAD

Gizzard shad (*Dorosoma cepedianum*) is a freshwater herring that sometimes ranges into brackish water and seawater along the Coast. It is an open-water species, usually living at or near the surface, and is found in large rivers, reservoirs, lakes, swamps, bays, borrow pits, bayous, estuaries, temporary floodwater pools along large river courses, sloughs, and similar quiet open waters. The geographic range of the gizzard shad includes the Great Lakes, except Lake Superior; the Hudson River south to the U.S. Gulf Coast and west to the Dakotas, Texas, and New Mexico; and along the Gulf Coast south to Rio Panuco in eastern Mexico. The northern extent of the range along the Atlantic Coast is Sandy Hook, the Hudson River, and

Long Island (Smith 1985). Gizzard shad can grow to a length of 19 in., but the usual adult size is 10-14 in. and 1-3 lb in weight (Miller 1960).

Gizzard shad spawn when the water temperature reaches 50-70°F (April-June, depending upon the location). Adults mill near the surface and spawning sometimes takes place in water less than a foot deep. The eggs sink slowly and adhere to the bottom. The eggs are less than 1/16 in. in diameter and the number of eggs produced by adult females ranges from 59,000 to almost 400,000. Hatching occurs from 1-1/2 to 7 days, depending upon the temperature. Gizzard shad larvae are generally pelagic and widely distributed in many types of habitat. They begin to eat by the fifth day after hatching and feed on microzooplankton until they are about 1 in. long. At that point the digestive system begins to change and the young shad become herbivorous and eat phytoplankton, algae, and microscopic bottom plants (Scott and Crossman 1973).

Growth during the first 5 or 6 weeks is typically rapid, but then slows. By the end of the first summer, gizzard shad are generally between 4 and 5 in. long. Young gizzard shad tend to school and prefer clear, slow-moving water. They sometimes move into small streams and can tolerate high turbidity. However, they do not usually move into brackish waters.

Gizzard shad typically mature at age 2 or 3, and the life span is about 7 years in northern populations and less in southern ones. In estuarine populations gizzard shad move into waters of higher salinities as they age; spring spawning runs have been reported in some instances (Miller 1960). Young gizzard shad are eaten by most predatory fish, but adults are generally too large to be eaten easily.

Gizzard shad occur primarily in the Mohawk River drainage. The early life stages of this species have been caught only occasionally in the Utilities' river surveys. A few YOY gizzard shad were collected in the 2000 FSS and BSS predominantly in the middle estuary during the summer (Figure 4-51, Appendix Tables D-139 through D-146). However, adult gizzard shad appear regularly in winter impingement samples at all of the power plants on the Hudson River. These fish may be emigrants from established populations located in the Mohawk River (Smith 1985) or there may be a small resident population in the lower Hudson River. The few yearling and older gizzard shad recorded in river surveys in 2000 were collected in beach seines throughout the estuary (Figure 4-52).

Comparing the geographic distribution of gizzard shad during the 2000 BSS with the long-term record (1974-1999), peak 2000 distribution for YOY was similar to the historic pattern of greatest distribution in the middle estuary region of Poughkeepsie, but additional YOY were found further downriver than in the historic pattern (Figure 4-53). Likewise, yearling and older gizzard shad in 2000 were found in the lower estuary, not the middle estuary as in the long-term pattern.

4.11 RAINBOW SMELT

Rainbow smelt (*Osmerus mordax*) are greenish, slender, salmon-like fish with deeply forked tails. They occur along the Atlantic Coast from Labrador to the Delaware River, along the Arctic Coast, and along the coasts of Alaska and British Columbia. They are landlocked naturally in many lakes and ponds in Canada, Maine and New Hampshire and have been introduced to other landlocked fresh waters. Within New York State rainbow smelt are found in the Hudson River, Long Island streams, several Adirondack lakes, and the Great Lakes (Smith 1985).

Anadromous rainbow smelt may spend the whole year in or near estuaries. In the fall they move into the bays and estuaries. Rainbow smelt spawn in tributaries in spring when the water temperature reaches 48°F. Even landlocked populations continue to migrate from their lake habitats to tributary streams to spawn. Spawners move into the lower reaches of streams in the evening, spawn at night, and move out in the day. Adult rainbow smelt leave the tributaries immediately after spawning. They spawn where water velocities are high, and larval survival decreases where water velocities are low (Buckley 1989). In the summer adults move to deeper, cooler water just outside bays and estuaries.

Adult smelt usually average 7-8 in. in total length, but occasionally reach lengths of 13-14 in. Female smelt grow faster than males and may reach maturity as early as age 1 along the southern edge of their range. However, maturity occurs more commonly at ages 2 through 5. The number of eggs produced by an adult smelt may range from 7,000 to 70,000.

The eggs are approximately 1/16 in. or less in diameter and sink to the bottom, where they stick in clusters to pebbles or whatever they happen to touch (Bigelow and Schroeder 1953). Rainbow smelt eggs hatch in about a week to almost a month, depending on temperature and, historically, eggs have been present in the Hudson River ichthyoplankton catches for about two weeks, which suggests a short spawning period. No rainbow smelt eggs were collected in 2000.

Newly hatched larvae are about 1/5 in. long. These larvae are carried downstream and out of the tributaries by current flows. In the Hudson River, YSL have been found in late April throughout the upper half of the Hudson River estuary but none were collected in 2000. The yolk-sac is absorbed when the fish are about 1/4 in. in length. PYSL in the Hudson River were commonly found in the upper and middle estuary and were abundant from late April through June but none were collected in 2000. As rainbow smelt larvae grow, they move closer to the bottom during the day and move back toward the surface at night, probably to feed on zooplankton, which exhibit similar vertical migrations in the water column.

Juvenile rainbow smelt were historically found in the Hudson River from mid-June to August in the middle and lower estuary but, again, none were collected in 2000. Juvenile smelt are exceedingly slender and nearly transparent. At about 3/4 in. they begin to school. Juvenile rainbow smelt move into shallow water at night and back to deep channels during the day (Buckley 1989). These movement patterns were reflected in BSS and FSS collections where beach seines conducted during the day collected no rainbow smelt and fall shoals sampling conducted at night collected juveniles primarily in the middle estuary regions in the early summer. By late summer the young smelt leave the estuary. The only collection of yearling and older rainbow smelt in the Hudson River in 2000 occurred in the Saugerties region during late May (Figure 4-54, Appendix Tables D-147 through D-152). Historically they were found mainly in the Indian Point through Hyde Park regions.

The long-term distribution record (1974-1999) of the early life stages of rainbow smelt in the Hudson River shows a short occurrence of eggs and YSL in early May and a protected occurrence of PYSL throughout May and June (Figure 4-55). The historical geographic distribution (1974-1999) of the early life stages of rainbow smelt demonstrate a downriver migration from peak egg abundance in Saugerties to middle and lower estuary occurrence by YOY (Figure 4-56). The long-term distribution record (1979-1999) from the FSS indicated that most YOY and yearling and older smelt were found in the middle estuary (Figure 4-57).

4.12 HOGCHOKER

Hogchoker (*Trinectes maculatus*) inhabit estuaries and nearshore coastal waters and range from Massachusetts Bay to the Atlantic Coast of Panama. They can tolerate a wide range of salinities and are found from marine waters up into fresh water, although older individuals tend to be found in more saline waters. Hogchoker reach a length of 2-3 in. in their first year, mature at about 4.5 in., and obtain a maximum size of about 8 in. (Bigelow and Schroeder 1953). This small flatfish is very abundant in the Hudson River estuary and its adjacent bays and coastal waters.

Adult hogchoker overwinter in low salinity regions of estuaries (Koski 1973) and spawn in the lower regions of estuaries and offshore from estuary mouths during the spring and summer. In some areas (eastern Chesapeake Bay) spawning appears to be restricted to sandy substrates. Dovel et al. (1969) reported that the hogchoker population in the Patuxent River was a resident population confined for the most part to that estuary in the Chesapeake Bay complex and concluded that the hogchoker population in the Chesapeake Bay system was probably composed of subpopulations that were generally confined to the bay and various tributaries. The relationship of Hudson River hogchoker to Atlantic coastal populations is unknown.

Individual hogchoker produce from 11,000 to 54,000 eggs, depending upon the size of the female. In the Hudson River estuary hogchoker spawning occurs from May to October, although eggs are more commonly collected from the last week in May through July in the more saline areas of the lower estuary, such as the Battery and Yonkers regions. During 2000 hogchoker eggs were collected primarily in the Battery and Yonkers regions in June and July (Figure 4-58, Appendix Tables D-153 through D-170).

After hatching, the YSL move upstream from the spawning areas and may use the net upstream flows in the deeper saline waters of the estuary. However in 2000, YSL and PYSL were collected in the same regions as eggs (Figure 4-58). YOY hogchoker in 2000 were found primarily in the middle estuary during late summer and fall (Figure 4-59). Yearling and older hogchoker were collected throughout the Hudson River in 2000 but were most abundant in the lower and middle estuary (Figure 4-60).

The 2000 geographical distribution of YOY hogchoker in the FSS is generally consistent with the long-term trend (1979-1999) showing a presence in most regions of the estuary, except in 2000 more YOY were found in the middle estuary (Figure 4-61). Yearling and older hogchoker were also found throughout the estuary but were more prevalent in the lower and middle estuary (Figure 4-61).

In the Hudson River, hogchoker generally reached sexual maturity at age 2, although some males were mature at age 1 (about 3 in. long). The oldest males in the Hudson River were age 4 while the oldest females were age 6. Hogchoker feed near the bottom on a variety of benthic invertebrates, including annelid worms and smaller crustaceans.

4.13 SPOTTAIL SHINER

Spottail shiner (*Notropis hudsonius*) is a small, silvery, freshwater minnow that reaches a maximum total length of over 5 in. in the Hudson River. It is usually recognizable by a large oval spot at the base of the tail, but in large individuals the spot is sometimes small and somewhat masked by silvery pigment. It occurs in a variety of freshwater habitats from large lakes and rivers to small streams and is widely distributed in Canada and the United States (Smith 1985). Spottail shiner is a freshwater species and does not enter marine coastal waters.

Thus, the Hudson River population is probably isolated from those in other coastal rivers along the East Coast of the United States.

Adult spottail shiner may form large spawning aggregations over sand or gravel substrates in shallow water or at the mouths of tributaries. In the Hudson River adult spottail shiner appear in the ichthyoplankton samples from the upper, freshwater regions of the estuary during April. Spottail shiner produce from 100 to 2,600 eggs, depending upon the age and size of the female. Very few eggs and larvae have been collected during the LRS, which is probably a reflection of the fact that this species spawns in shallow-water habitats that are not sampled efficiently during the ichthyoplankton surveys.

Juvenile spottail shiner first appeared in the 2000 BSS during June and were most abundant in the shorezone above the Croton-Haverstraw region (Figure 4-62, Appendix Tables D-171 through D-182), which is also the portion of the estuary with the greatest number of tributaries. Yearling and older spottail shiner were also found throughout the middle and upper Hudson River above Croton-Haverstraw (Figure 4-63).

Comparing the geographical distribution of YOY and yearling and older spottail shiner based on BSS in 2000 with previous years (1974-1999), the 2000 distribution of these life stages was consistent with the long-term record except that more spottail shiner were found downriver in Saugerties and Catskill than in Albany as in the long-term record (Figure 4-64).

Weekly length statistics for juvenile spottail shiner collected in 2000 show a steady increase in length from June to mid-October and a leveling off of growth in the fall as the fish were recruited to the adult stage (Figure 4-65, Appendix Tables E-20 and E-21).

In general, spottail shiner are opportunistic predators that feed on aquatic insect larvae, zooplankton, benthic invertebrates, and the eggs and larvae of fish, including their own species. The smaller fish eat the smaller organisms and zooplankton (Scott and Crossman 1973).

4.14 ATLANTIC STURGEON

Atlantic sturgeon, *Acipenser oxyrhynchus*, has two recognized subspecies, *A. o. oxyrhynchus* and *A. o. desotoi*. The former ranges from Hamilton River, Labrador, and George River, Ungava Bay, to northeastern Florida, while the latter is confined to the northeastern Gulf of Mexico (Gruchy and Parker 1980a). Atlantic sturgeon are anadromous with spawning occurring in freshwater, but most of their life is spent in marine waters, often undertaking long distance migrations along the Atlantic Coast (Bain 1997). Tagging studies reported by Dovel and Berggren (1983) indicate that Atlantic sturgeon disperse over great distances and spend at least part of their lives in other estuary systems. Atlantic sturgeon tagged in the Hudson River have been recaptured as far north as Marblehead, Massachusetts, and as far south as Ocracoke, North Carolina. Many of the tags were returned by Delaware Bay and Chesapeake Bay commercial fisherman. Presumably, Atlantic sturgeon that spawned in other rivers and estuaries find their way into the Hudson River.

Atlantic sturgeon are long-lived, slow-maturing, large fishes. Dovel and Berggren (1983) reported that by age 29, Atlantic sturgeon averaged 7.8 ft. The largest known Atlantic sturgeon was a 14-ft specimen weighing 811 lb from Saint John River, New Brunswick (Van Den Avyle 1984). While in the Hudson River the maximum reported age is 36 (Van Eenennaam et al. 1996), the oldest known Atlantic sturgeon is a 60-year-old individual from the St. Lawrence River (Gilbert 1989). Adults are large fishes with barbels extending across most of the width of the snout, heavy bony plates (called scutes) covering the body, and an extended upper lobe of the tail fin.

Male Atlantic sturgeon reach maturity at about 12 years and females at 18-19 years (Dovel and Berggren 1983), although some females may reach maturity at 15 years (Van Eenennaam et al. 1996). They are believed to spawn at intervals ranging from 1 to 5 years (Bain 1997); however, males may possibly have an annual spermatogenic cycle (Van Eenennaam et al. 1996). Mature male Atlantic sturgeon enter the Hudson estuary by early April, before water temperatures rise above 43°F while mature females do not arrive until several weeks later (Dovel and Berggren 1983). Spawning occurs from May through July. Telemetry studies in 1994 and 1995 suggest that spawning occurs in concentration areas near Hyde Park (RM 80) and Clinton Point (RM 70) (Nack and Bain 1996). Other studies have identified an additional concentration area near Catskill (RM 113) (Van Eenennaam et al. 1996). After spawning, males and females were tracked to a congregation site at Con Hook (RM 48) where the estuary is deep (up to 120 ft). Post-spawning adults were joined at this site by marine-migrant juveniles and this large population of Atlantic sturgeon remained at Con Hook throughout most of the summer. A gradual emigration of adults to marine waters began in August and was completed by October (Nack and Bain 1996).

Atlantic sturgeon produce large numbers of eggs. Fecundity estimates derived from a number of river systems indicate that Atlantic sturgeon produce between 0.8 and 3.75 million eggs per female and that the number of eggs is closely related to the weight of the fish. During spawning, eggs are presumably broadcast into flowing water, becoming widely dispersed after fertilization. There is no evidence of parental care. The eggs are demersal and become strongly adhesive after about 20 minutes and attach to rocks, weeds, and other submerged objects (Gilbert 1989). Hatching time ranges from about 4 days at about 20 C (Dean 1895) to 7 days at 17.8 C (Vladykov and Greeley 1963).

Larvae of Atlantic sturgeon, as all life stages, are oriented on the bottom of deep channel habitats (Bain 1997). Based on capture locations of larval and juvenile sturgeon from early Hudson River studies, the nursery region for sturgeon is believed to be located between RM 43 and RM 118 from May through mid-July (Hoff et al. 1977, in Hoff et al. 1988). More recent data collected during the LRS from 1974 through 1994 show a concentration area (RM 43-100) of larvae and early juveniles between mid-May and mid-July that may correspond to the distribution of Atlantic sturgeon early life stages (Con Edison 1997a).

Juvenile Atlantic sturgeon remain in the Hudson estuary for 2-6 years before migrating to marine waters. During the first 3 years of life, they quickly grow to over 2 ft (Bain 1997). From July through September, juvenile Atlantic sturgeon are distributed over much of the Hudson estuary (Bain 1997), but one section of the estuary (RM 43-48) contained high numbers of juveniles (Haley et al. 1996). As water temperatures drop in the fall, juveniles form an overwintering congregation in deep waters (>25 ft) between the Bear Mountain Bridge and the George Washington Bridge (Dovel and Berggren 1983).

Sturgeon feed by rooting along the bottom and "vacuuming" with their protrusible mouths. This leads to a large amount of non-food matter, mostly mud, in the stomach. Actual food items include mollusks, polychaete worms, gastropods, shrimp, isopods, amphipods, and small benthic fishes.

The Atlantic sturgeon has been an important commercial species in the Hudson estuary, prized for its flesh and caviar. Commercial landings peaked at 7 million pounds at the turn of the 19th century, but the fishery crashed within a 10-year period due to over-exploitation of a slow-growing, slow-maturing fish (Field 1996). Since then, coast-wide landings hovered around 200,000 lb. In 1990, the Atlantic States Marine Fisheries Commission adopted a management plan for Atlantic sturgeon establishing a minimum size limit for the commercial fishery. Recent annual landings in New York State have ranged from 17,000 to 36,000 lb (McKown 1996). However, in 1996, the Atlantic States Marine Fisheries Commission recommended a 2-year fishery moratorium based on recent scientific analyses of the Hudson River Atlantic sturgeon which indicated a collapsing population (Field 1996).

Evidence of a decline in the Hudson River estuary stock of Atlantic sturgeon in recent years comes from two population estimates. The population of immature Atlantic sturgeon in the Hudson River estuary was estimated at 14,500 to 36,000 fish for the 1976 year class at age one (Dovel and Berggren 1983). Kahnle and Hattala (1998) estimated that there were 4,600 age zero Atlantic sturgeon in the estuary in 1994, a substantial decline from the abundance of the 1976 year class.

Some Atlantic sturgeon were collected in the Utilities' monitoring program in 2000. One juvenile and four yearling and older Atlantic sturgeon were caught in the FSS between West Point and Poughkeepsie (RM 47 to 68) from July to November (Figure 4-66, Table 4-3, and Appendix Tables D-183 through D-188).

4.15 SHORTNOSE STURGEON

Shortnose sturgeon, *Acipenser brevirostrum*, are less widespread than the Atlantic sturgeon, ranging from the St. John River, New Brunswick, to the St. Johns River, Florida (Gruchy and Parker 1980b). Nineteen distinct stocks of shortnose sturgeon are recognized, ranging in size from less than about 100 adults in the Merrimack River, Massachusetts to greater than about 38,000 (now 60,000 [Bain et al*.* 1998]) adults in the Hudson River, New York (NMFS 1998). Shortnose sturgeon are amphidromous, using mainly fresh and brackish waters, and only occasionally marine waters, during its life cycle (Bain 1997). Shortnose sturgeon presumably from the Hudson River have been caught in Sandy Hook Bay, New Jersey just off the mouth of the Hudson (Dovel et al. 1992), but most seem to remain within the Hudson estuary. Forty-four shortnose sturgeon tagged in the Hudson River between 1979 and 1980 were recaptured in the Hudson River by researchers from 1993 to 1995, from 14 to 17 years after tagging (Bain et al. 1996).

Like Atlantic sturgeon, shortnose sturgeon are long-lived, slow-maturing fishes. In the Hudson River the maximum reported age for shortnose sturgeon is 37 years, however, the oldest known shortnose sturgeon is a 67-year-old female from St. John River, Canada (Gilbert 1989). The largest shortnose sturgeon reported for the Hudson River was almost 4 ft long (Geoghegan et al. 1992), considerably smaller than that reported for Atlantic sturgeon. However, both the Atlantic and the shortnose sturgeons are similar in appearance. As adults, shortnose sturgeon can be distinguished from the Atlantic sturgeon by a shorter and blunter snout, wider mouth, and smaller size of the anal fin.

Male shortnose sturgeon in the Hudson River do not reach sexual maturity until age 3-5 and females at age 6-7 (Dadswell et al. 1984). The first spawning, however, may follow maturation in males by 1-2 years, while in females spawning may be delayed for up to 5 years (Dadswell 1979). Spawning appears to be a non-annual event. Based on the percentage of fish examined from August to March that were developing sexually, Dadswell (1979) suggested that females spawn once every third year and males every other year. Other evidence (annuli of the pectoral ray) suggests a 5- to 11-year interval between spawnings (Dadswell 1979). However, annual spawning has been suggested by tagging studies on the Hudson River that tracked shortnose sturgeon to the spawning grounds in successive years (Dovel et al. 1992).

During their spawning migrations, shortnose sturgeon move upriver as far as accessible habitat permits (Dovel et al. 1992). In the Hudson River, adult shortnose sturgeon reach the spawning grounds between Coeymans and Troy (RM 124-153) as early as the first week of April and spawning occurs from late April to early May (Bain 1997). After spawning, adults move downriver to feed and disperse over the tidal portion of the Hudson estuary, but are primarily south of Kingston (Bain 1997). From October through March, pre-spawning adults concentrate near Esopus Meadows (RM 87) (Dovel et al. 1992). Non-spawning adults may inhabit another winter concentration area located near Croton Point (RM 34) (Geoghegan et al. 1992; Bain 1997).

Shortnose sturgeon are broadcast spawners with external fertilization of eggs (NMFS 1987). Similar to Atlantic sturgeon, the eggs are demersal and adhere to objects on the river bottom within minutes of fertilization. Between 8 and 12 C, eggs hatch 13 days after fertilization. At 17 C, hatching occurs in 8 days (Buckley and Kynard 1981).

Recent research on shortnose sturgeon larval behavior indicates that hatchlings are photonegative and vigorously seek cover under any available structure immediately after hatching (Richmond and Kynard 1995). During the first 1-2 days following hatch, larvae denied or dislodged from cover will exhibit “swim-up and drift” behavior, which in the wild allows them to move short distances to seek available cover. At 9-12 days post hatch, larvae are 15 mm long (TL), the yolk sac is completely absorbed, and the fry are feeding on zooplankton (Buckley and Kynard 1981; Washburn and Gillis Associates 1981). By about 14-17 mm TL, shortnose sturgeon, resembling miniature adults, become photopositive and leave cover to swim in the water column, although remaining bottom oriented. In the wild, larvae of this size probably migrate downstream (Richmond and Kynard 1995).

Little information is available on the actual distribution of the early life stages of Hudson River sturgeon during their first growth season because of the infrequency of their capture and the difficulty in distinguishing between the two species of sturgeon. Data from 21 years of the LRS (1974-1994) document the collection of 186 larvae and early juveniles of both species (Con Edison 1997a). These data show two concentration areas of sturgeon larvae and early juveniles in the Hudson River estuary. Based on spawning ground identification by Dovel et al. (1992), the concentration area from RM 120 to RM 150 during May may correspond to the distribution of shortnose sturgeon larvae and early juveniles in the Hudson River.

Early growth is rapid. For shortnose sturgeon, larvae are approximately 0.7 in. in total length at the end of May and from 4.9 to 5.1 in. by the end of July. By the end of their second summer, they average approximately 11.5 in. (Dovel et al. 1992). After about the third year of life, growth slows considerably. Greeley (1937) reported a maximum size of about 34 in. at 15 years for shortnose sturgeon, while Dadswell et al. (1984) reported a maximum of approximately 35 in. at age 40, but shortnose sturgeon over 39 in. have been captured in the Hudson River (Hoff and Klauda 1979).

Juvenile shortnose sturgeon use a large portion of the Hudson estuary as nursery ground (Bain 1997). During the summer, more juvenile shortnose sturgeon were found in the relatively shallow, freshwater zone of the estuary around Poughkeepsie (RM 67-86) than in the deeper, more saline zone near West Point (RM 42-56) (Haley et al. 1996). By late fall and early winter, most juveniles occupy the broad region of the Hudson River near Haverstraw (RM 34-39) (Bain 1997). Juvenile shortnose sturgeon typically prey on benthic crustaceans and insect larvae, whereas adults will feed on larger items with mollusks being a major component of their diet (Bain 1997).

Although numerous studies summarized the life history of Atlantic sturgeon since the late 1800s, little attention was paid to shortnose sturgeon, likely because of its limited commercial importance. With the listing of shortnose sturgeon as an endangered species in the United States and its classification as rare in Canada (Gorham and McAllister 1974), more effort has been directed toward understanding this species. Current research efforts have focused on the ecology of juveniles and on the population status of shortnose sturgeon in the Hudson River. Trends in the relative abundance of shortnose and Atlantic sturgeon have shown an increase in shortnose sturgeon and a decline in Atlantic sturgeon (Bain 1996). Dovel et al. (1992) observed that in 1984 equal numbers of juvenile Atlantic and shortnose sturgeon were collected; while during earlier years (1975-1980), the ratio of Atlantic to shortnose sturgeon was 10:1 in the Hudson River. Other evidence of an increasing population of shortnose sturgeon over its range is that the National Marine Fisheries Service has recommended that the status of the Connecticut, Delaware, and Hudson rivers' populations of shortnose sturgeon be changed from endangered to threatened (NMFS 1998).

The Hudson River estuary appears presently to contain the largest stock of shortnose sturgeon that has been reported anywhere. In the late 1970's, Dovel (1979) estimated the shortnose sturgeon population in the Hudson River estuary at 13,000 fish. Bain et al. (1995) estimated the adult population size to be 38,024, with lower and upper 95% confidence intervals of 26,427 and 55,072, respectively. This latter population estimate suggests a 2- to 4-fold increase in abundance since the late 1970's (NMFS 1998). Further refined analytical techniques indicate that the most appropriate population estimate based on this most recent study is 61,057 fish, 1-year-old and older (Bain et al. 1998). These estimates reflect those fish in the overwintering and spawning concentration areas and, thus are likely just a subset of the total adult population. Additionally, because shortnose sturgeon do not appear to spawn every year, the majority of the population may be non-spawners and, thus, not included in this population estimate.

The Utilities' monitoring program conducted during 2000 resulted in a total of 56 shortnose sturgeon, including PYSL and YOY, collected in the LRS, FSS, and BSS from Yonkers to Albany (RM 17 to 136) from May though November, with most captured in August and September in the middle estuary (Figures 4-67 and 4-68, Table 4-4, and Appendix Tables D-189 through D-198).

4.16 WHITE CATFISH

White catfish (*Ameiurus catus*) occur in freshwater lakes and ponds and have been introduced widely on the West Coast and into the Northeast. The natural distribution was originally from the Chesapeake Bay region in coastal streams southward to Texas. They are found in estuaries all along the Atlantic Coast from the Hudson River to Florida and west along the Gulf of Mexico to Mobile Bay. White catfish prefer fresh and slightly brackish waters and moderate water currents, however, they do not tolerate high salinity, and so estuarine populations generally remain in their natal systems.

In southern waters young white catfish are about 3 in. long at the end of the first growing season. White catfish generally do not mature until they are 3-4 years old and 7-8 in. long.

They continue to grow slowly, attaining lengths of 17 in. at age 8 and 22 in. at age 11. This species seldom exceeds 3 lb in weight.

White catfish move upstream to spawn. In spring white catfish have been reported in tidal creeks and shallow marsh habitats. Like the other members of the catfish family, the white catfish is a nest builder, and the male guards the young for some time after they hatch. Both parents participate in the construction of a nest up to 3 ft in diameter on sand and gravel bars. White catfish spawn when water temperatures reach about 70°F, i.e., in late June and early July in the Hudson River. An 11- to 12-in. female carries only 3,200-3,500 eggs, but the eggs are large, approximately 1/4 in. in diameter. The male (or less often both parents) protects and fans water over the eggs in the nest.

White catfish eggs and larvae were rarely collected during the Utilities' ichthyoplankton surveys. However, the 2000 FSS consistently captured low numbers of YOY white catfish primarily in the upper estuary during the summer, then after migration, in the middle estuary by fall (Figure 4-69, Appendix Tables D-199 through D-210). Yearling and older white catfish were captured in the 2000 surveys throughout the estuary (Figure 4-70).

The 2000 geographical distribution of YOY and yearling and older white catfish in the FSS is consistent with the 1979-1999 long-term trend (Figure 4-71). Juveniles occurred in the mid- to upper Hudson River with the bulk of the distribution in 2000 in the Saugerties region, slightly downriver of the historical trend. Yearling and older white catfish were found throughout the estuary, but with a larger distribution in the lower and middle estuary in 2000 than in the past (Figure 4-71). After moving into the deeper river strata during September and October, yearling and older white catfish migrate downstream to overwinter in the lower estuary when temperatures in the upper estuary drop below 59°F (NAI 1985a).

Small white catfish feed on midge larvae until they become large enough to eat fish. Larger white catfish have a diverse diet that includes midge larvae, crustaceans, algae, fish eggs, and a variety of fish (Smith 1985).

Weekly length statistics for juvenile white catfish collected in 2000 showed rapid growth from July through October with a decline in size during the late fall as larger fish were able to avoid the sampling gear (Figure 4-72, Appendix Tables E-22 and E-23).

4.17 WEAKFISH

Weakfish (*Cynoscion regalis*) is a member of the drum family commonly inhabiting nearshore waters from North Carolina to New York and occasionally straying as far as Nova Scotia or the eastern Gulf of Mexico. Weakfish overwinter in deeper waters of the continental shelf, generally between Chesapeake Bay and Cape Fear, North Carolina. When inshore waters begin to warm each spring, older weakfish begin to move toward shore and then head north along the Coast. These older individuals are followed by successively younger groups of adult weakfish. During warmer months of the year, weakfish are found throughout inshore waters in their geographic range, with larger individuals the most abundant in northern areas. As water temperatures decline in the fall, weakfish begin to migrate southward and return to offshore overwintering areas.

Spawning occurs in nearshore coastal and marine waters in spring and summer, depending upon geographic location. Extensive spawning occurs in the south and in the New York Bight. Weakfish eggs are buoyant and hatch in about 2 days. The newly hatched larvae, which are less than 1/8 in. long, are weak swimmers and move shoreward up into the bays and estuaries. Duration of the larval stage appears to depend partially on prey density. In the nursery areas young weakfish feed on invertebrates and grow rapidly. They reach a length of 3-6 in. by the end of the first summer. Young weakfish can be found throughout the saline and brackish areas of estuaries but tend to be most common in areas where salinities are over 10 ppt. As water temperatures decline in fall, juvenile weakfish begin to leave these nursery areas and move toward southern overwintering areas.

In the New York Bight spawning typically occurs from May to mid-July, and there are two spawning peaks. Weakfish larvae are rarely encountered north of the George Washington Bridge, preferring more saline waters. Weakfish juveniles typically first enter the areas north of the George Washington Bridge during July and most have emigrated from the estuary by mid-August. During the 2000 LRS, YOY weakfish were present from July through August from the Battery to Indian Point regions with greatest abundance in early August (Figure 4-73, Appendix Tables D-211 through D-216). In the 2000 FSS YOY weakfish abundance peaked in late July but they were found through October, gradually emigrating from the Hudson estuary. Few yearling and older weakfish are collected in the monitoring program, indicating that these life stages rarely enter the Hudson above Yonkers.

The 2000 geographical distribution of YOY weakfish in the FSS is consistent with the 1979-1999 long-term trend in which the majority of juveniles were found in the lower estuary regions of Yonkers and Tappan Zee (Figure 4-74).

Weekly length statistics for juvenile weakfish collected in 2000 showed an overall increase in growth from July to early October, then very gradual growth through November (Figure 4-75, Appendix Tables E-24 and E-25). The erratic increases in growth were the result of the size selectivity of the various gears employed in the FSS and BSS.

4.18 BLUEFISH

Bluefish (*Pomatomus saltatrix*) is a predaceous oceanic fish species; in the western Atlantic Ocean its range is from Argentina to Maine and occasionally to Nova Scotia. In the New York Bight bluefish is a common inshore inhabitant that arrives in May and usually departs by November. North Atlantic bluefish migrate from New England to Cape Hatteras, North Carolina in summer and to the Florida area and the southern Gulf Stream in winter, but migration patterns have not been positively identified. During migrations, smaller fish migrate closer to shore than larger fish.

There are two major spawning aggregations in the mid-Atlantic: a spring spawning stock and a summer spawning stock. The degree to which the stocks are isolated is not known, but consistent morphological differences suggest some isolation of the stocks (Pottern et al. 1989). Most of the bluefish population in the New York Bight probably originates from the spring-spawning stock (Chiarella and Conover 1990). The spring spawners move into the waters where the Gulf Stream and the continental shelf water meet between northern Florida and Cape Hatteras. Bluefish spawn as they migrate northward. North of Cape Hatteras the adults move shoreward. The smaller spent bluefish may spend summers in the Chesapeake and Delaware bays and Albemarle Sound. Larger fish move north longer than the smaller bluefish and migrate farther. Some move into Long Island Sound and more northern areas. In autumn, bluefish migrate back to the wintering areas off south Florida and the south Atlantic (Pottern et al. 1989).

The juvenile bluefish produced in the spring travel north with the Gulf Stream and migrate across the continental shelf to the mid-Atlantic bays and estuaries, which act as productive nursery areas. Spring-spawned juveniles spend most of their first summer in estuaries (Kendall and Walford 1979). In fall they migrate southward along the Coast to winter off south Florida. The following spring, yearlings migrate north along the Coast and return to the mid-Atlantic bays and estuaries and, to a lesser extent, the sounds of North Carolina (Pottern et al. 1989). The spring-spawning bluefish stock that contributes most to Hudson River fish ranges along most of the Atlantic Coast.

Some summer-spawned larvae have also been reported in the more saline parts of estuaries in the mid-Atlantic Bight. Summer-spawned juveniles may spend only about a month in estuaries, but most are found along the shore (Kendall and Walford 1979). The summer-spawning adults start from the southern wintering areas, but they migrate north to the outer half of the continental shelf between Cape Hatteras and Cape Cod and spawn there. Spent spawners then move west, and show up in coastal waters, particularly along Long Island. Most of the juveniles from the summer spawn remain offshore during the summer. In fall the adults and juveniles migrate south. Juveniles from the summer spawn may spend the winter farther out to sea than juveniles from the spring spawning. Juveniles from the summer spawn migrate north the next spring and most of these juveniles may spend the summer in the sounds of North Carolina and may not return to their original nursery areas (Pottern et al. 1989).

Bluefish eggs are buoyant and pelagic and hatch in about 2 days. The newly hatched larvae are also pelagic and remain in offshore waters for 1-2 months before migrating shoreward toward shallow-water nursery areas. In the New York Bight, YOY bluefish enter the shallow-water nursery areas as two groups. The first, from the spring spawning in the south Atlantic, are about 1-2 in. long when they enter the nursery areas in June or early July to feed and grow rapidly. The second, from the summer spawning in the mid-Atlantic Bight, are larger when they arrive in September.

YOY bluefish typically first enter areas north of the George Washington Bridge in early June and remain at least until early October. They are most common in shallow, more saline areas of the estuary, including the Tappan Zee and Haverstraw Bay, but typically range as far upriver as the Cornwall region. During 2000 YOY bluefish were collected as far north as the Indian Point region in July, but most had emigrated from the Hudson River above the George Washington Bridge by October (Figure 4-76, Appendix Tables D-217 through D-222). Salinity intrusions into the estuary appear to be a major determinant of geographic distribution within the estuary. YOY bluefish are also abundant in areas of the estuary south of the George Washington Bridge and adjacent waterways, which are part of the larger, coastal distribution.

The 2000 geographical distribution of YOY bluefish in the BSS is consistent with the 1974-1999 long-term trend with the majority of fish collected in the lower estuary (Figure 4-77).

In the Hudson River YOY bluefish aggressively feed on a variety of macroinvertebrates and fish and grow rapidly to a size of 3-6 in. by the time they begin to leave the estuary in late summer. Older bluefish, including adults, occasionally enter the lower estuary during summer and feed on available forage fish such as bay anchovy, Atlantic silverside, and young menhaden and river herrings. Bluefish reach sexual maturity during their second year of life. Annual fecundities range from 600,000 to 1,400,000 eggs per female, depending upon size. The maximum size of bluefish has been reported to be 45 in. and 30 lb. All ages of bluefish often travel in schools and are voracious feeders that commonly destroy more than they can eat.

Link to References

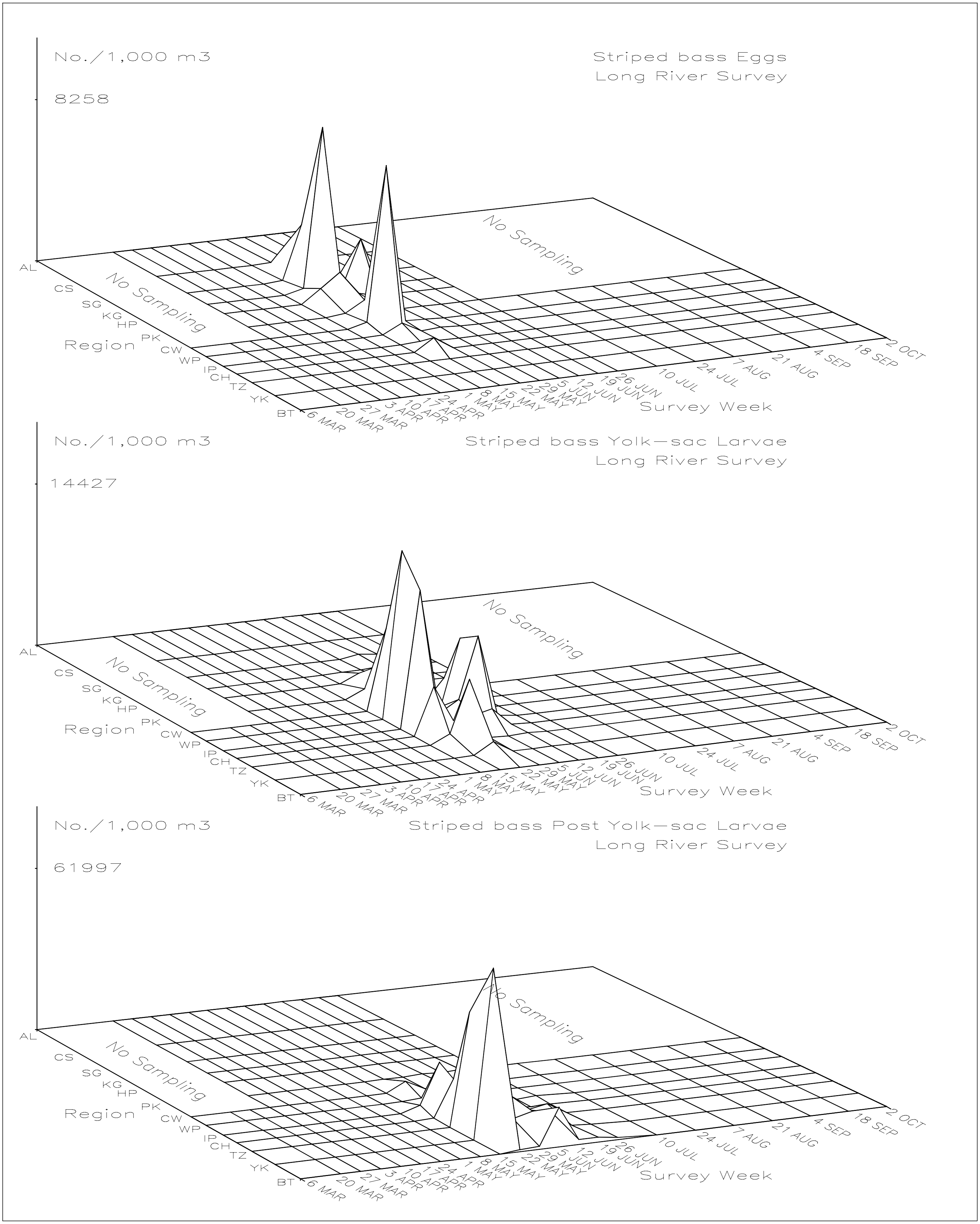

Figure 4-1. Spatiotemporal distribution of eggs, yolk-sac, and post yolk-sac larval striped bass in the Hudson River estuary based on the 2000 Long River Survey.

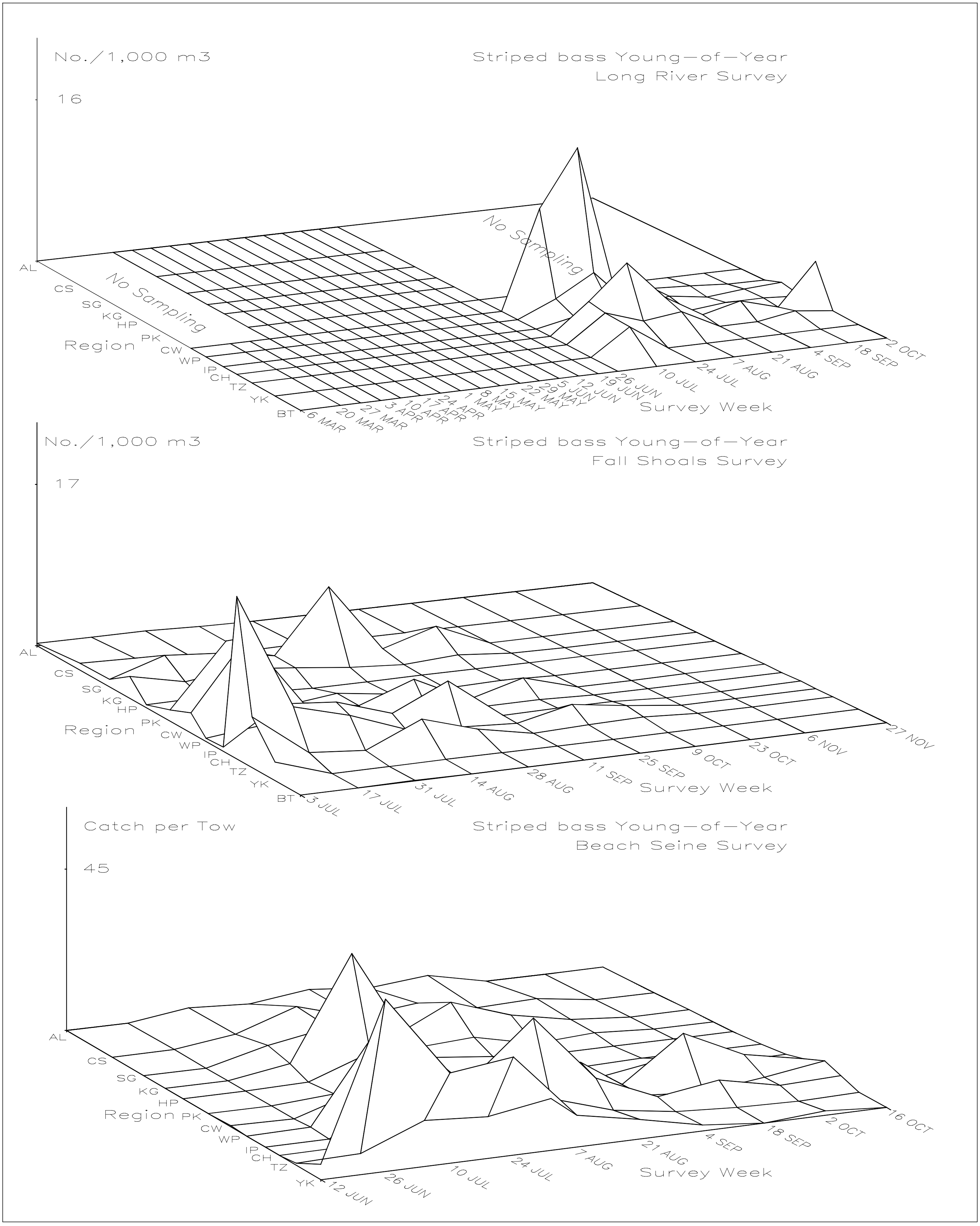

Figure 4-2. Spatiotemporal distribution of young-of-year striped bass in the Hudson River estuary based on the 2000 Long River, Fall Shoals, and Beach Seine surveys.

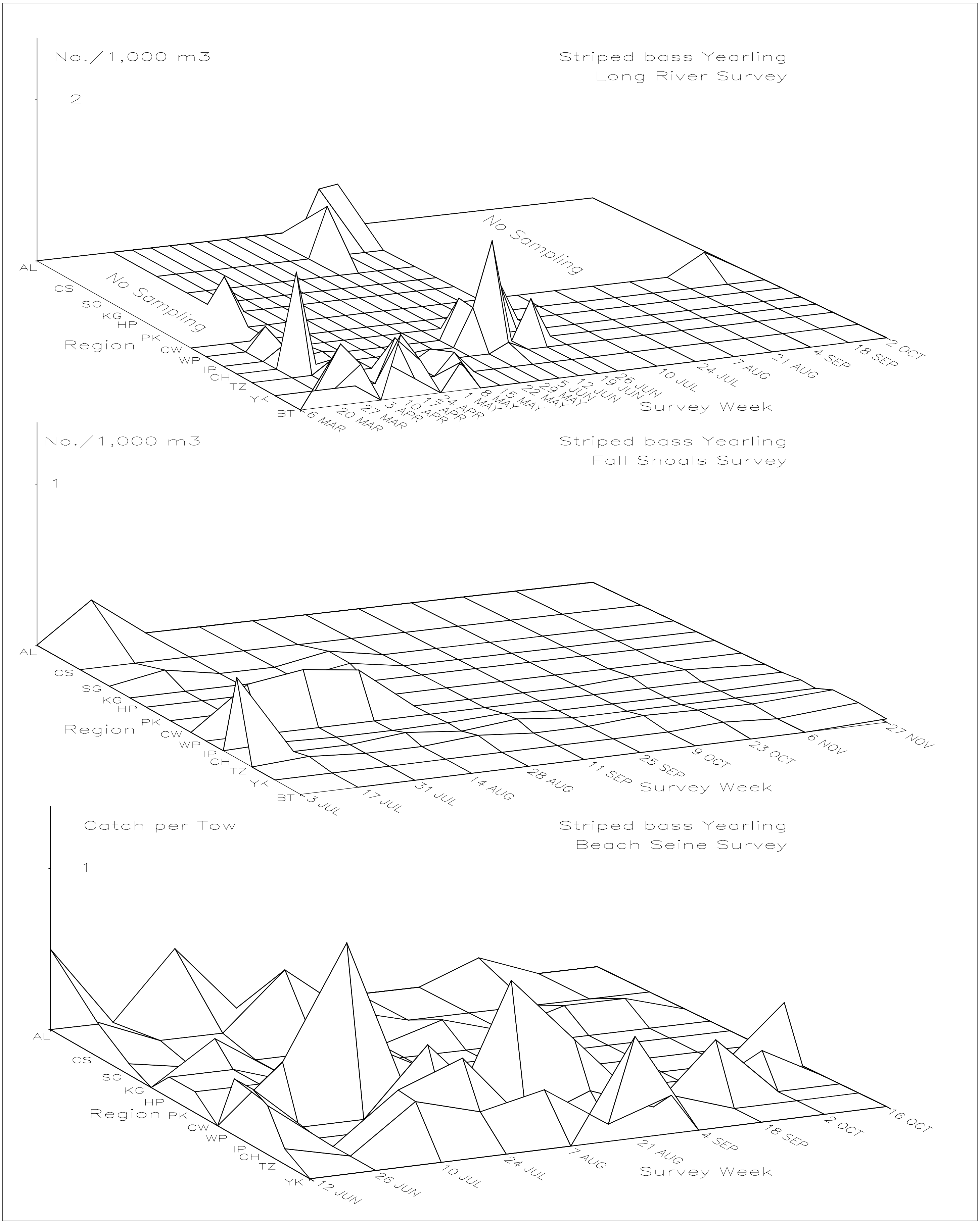

Figure 4–3. Spatiotemporal distribution of yearling striped bass in the Hudson River estuary based on the 2000 Long River, Fall Shoals, and Beach Seine surveys.

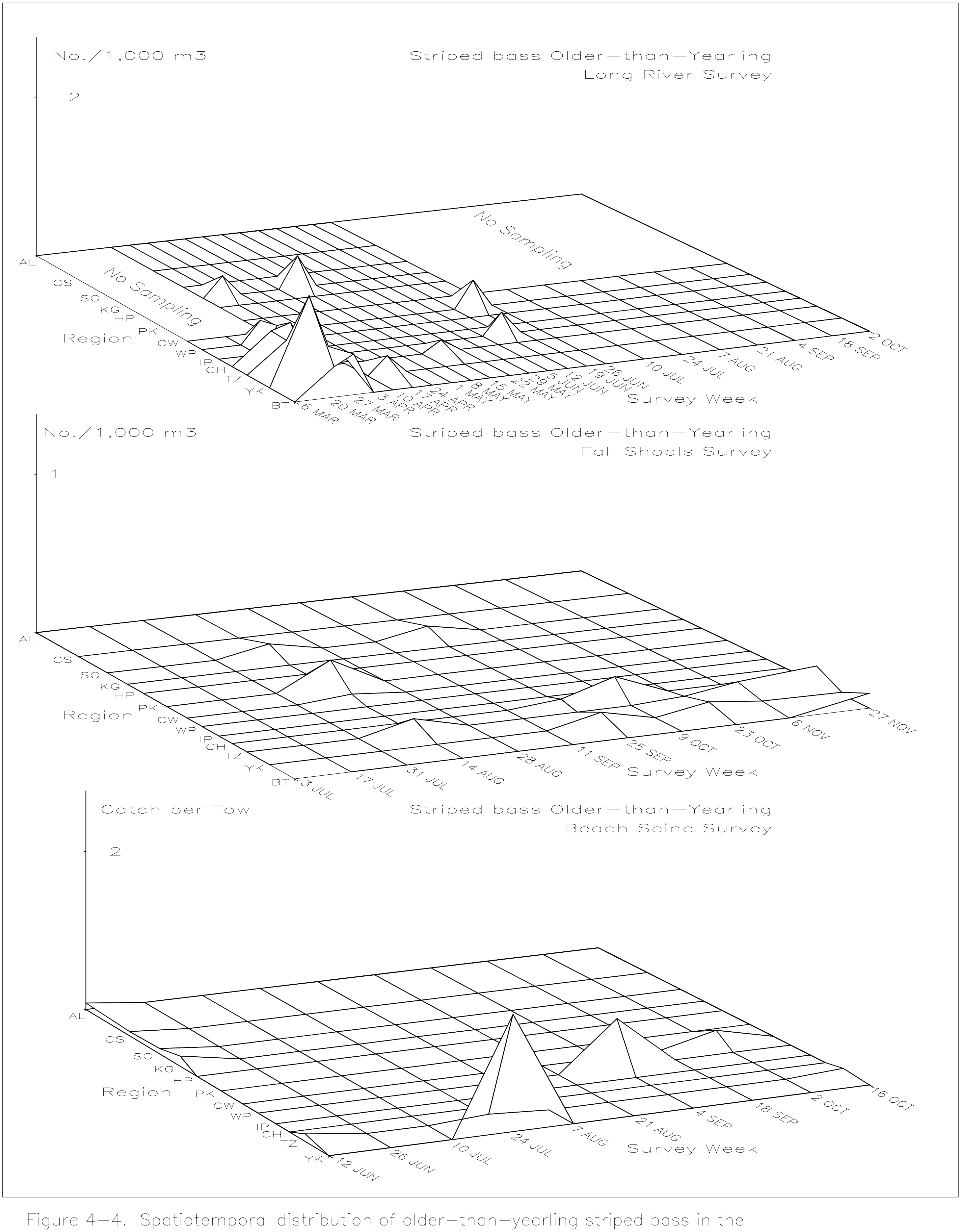

Figure 4-4. Spatiotemporal distribution of older-than-yearling striped bass in the Hudson River estuary based on the 2000 Long River, Fall Shoals, and Beach Seine surveys.

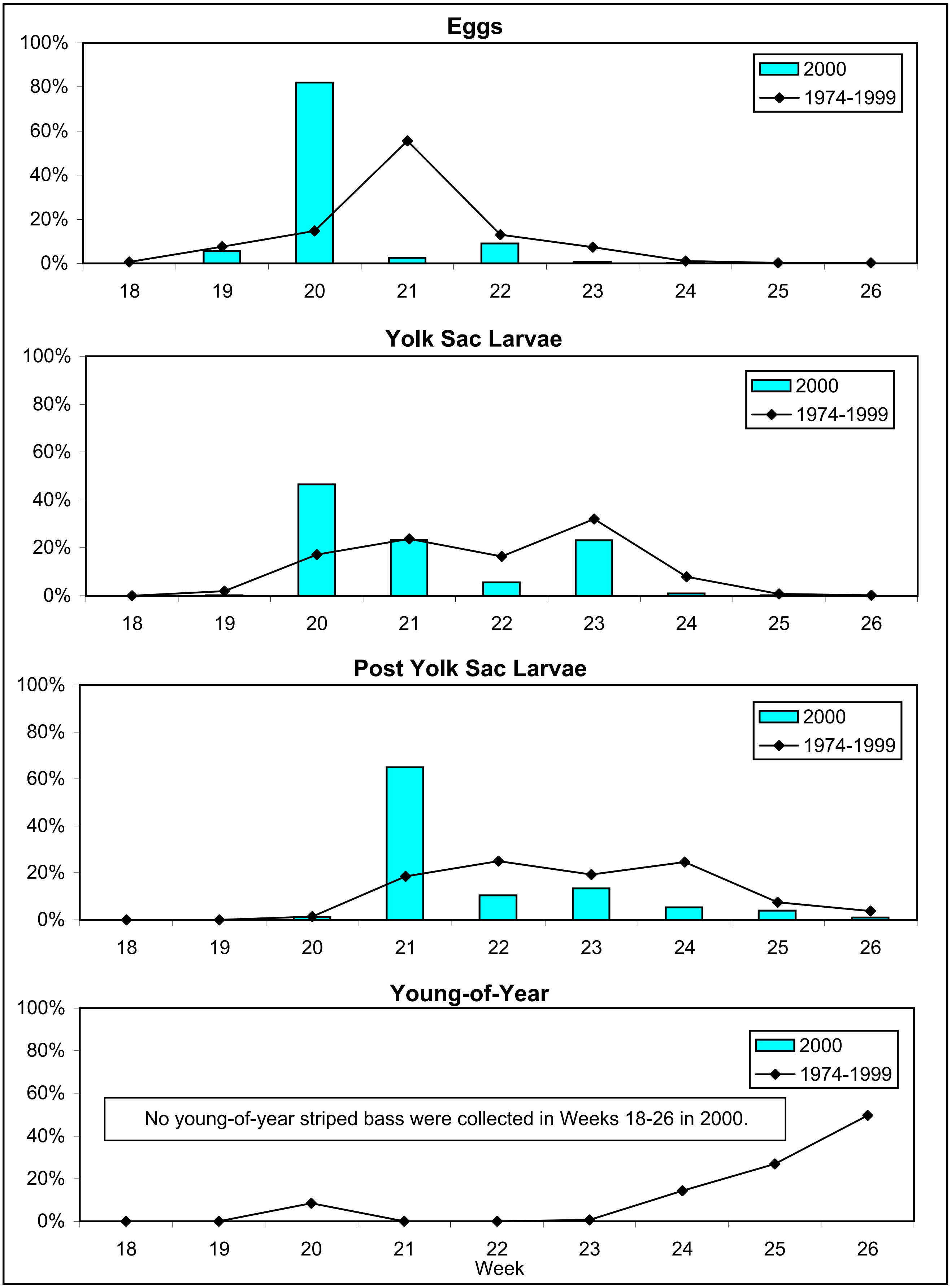

Figure 4-5. Temporal distribution indices for striped bass collected during Long River surveys of the Hudson River estuary, 1974-2000.

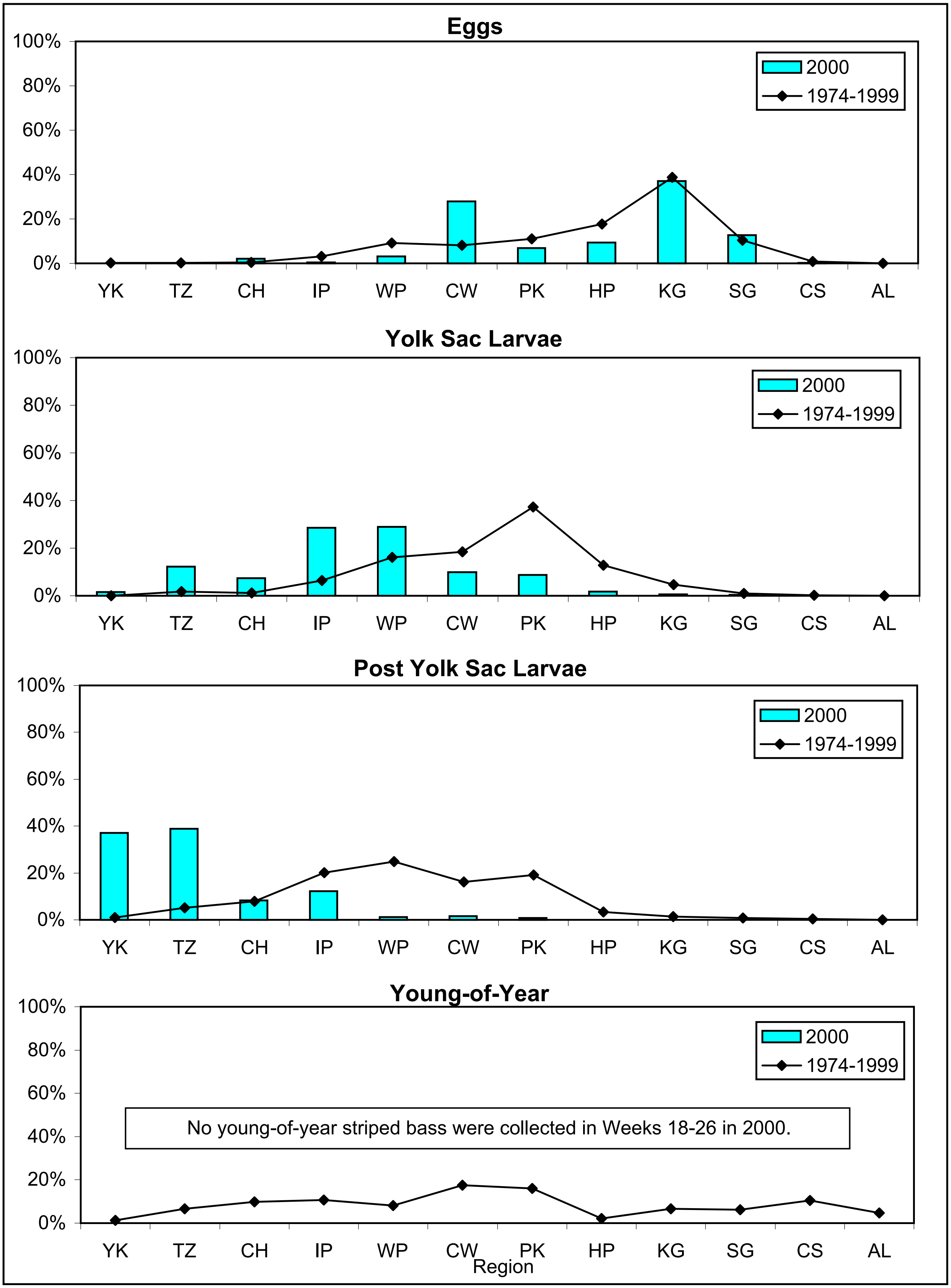

Figure 4-6. Geographic distribution indices for striped bass collected during Long River surveys of the Hudson River estuary, 1974-2000.

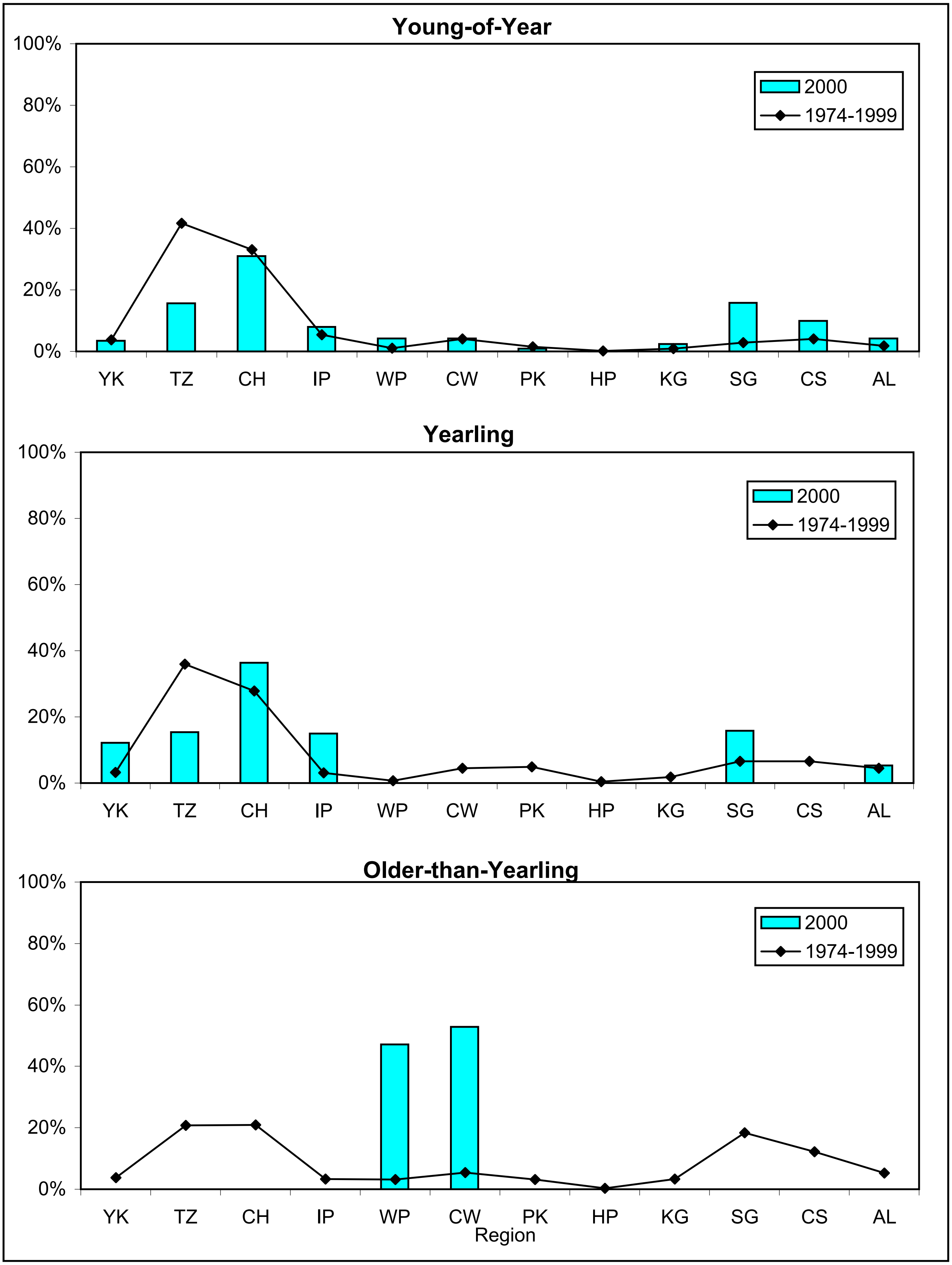

Figure 4-7. Geographic distribution indices for striped bass collected during Beach Seine surveys of the Hudson River estuary, 1974-2000.

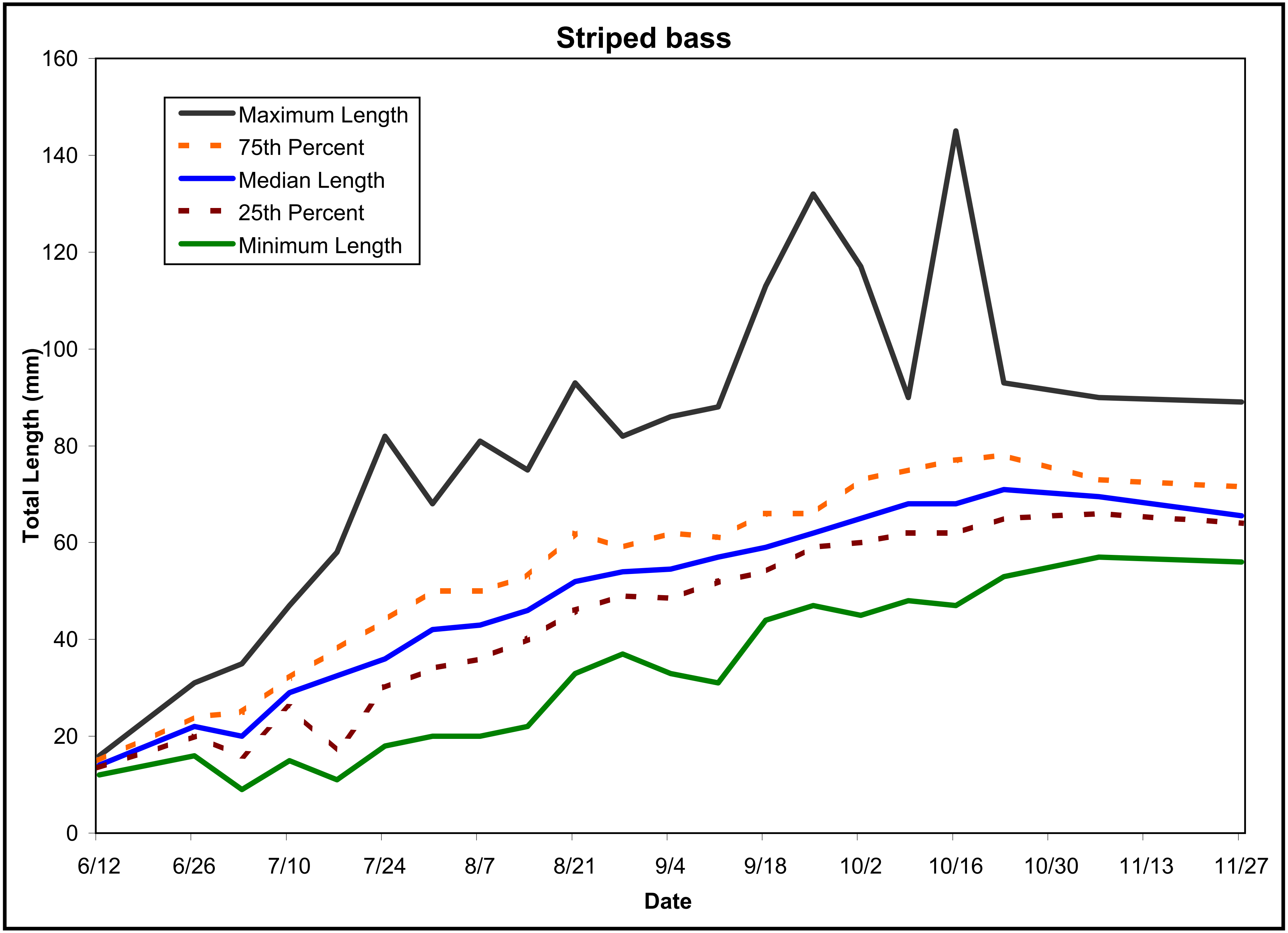

Figure 4-8. Weekly length statistics for young-of-year striped bass in the Hudson River estuary, 2000.

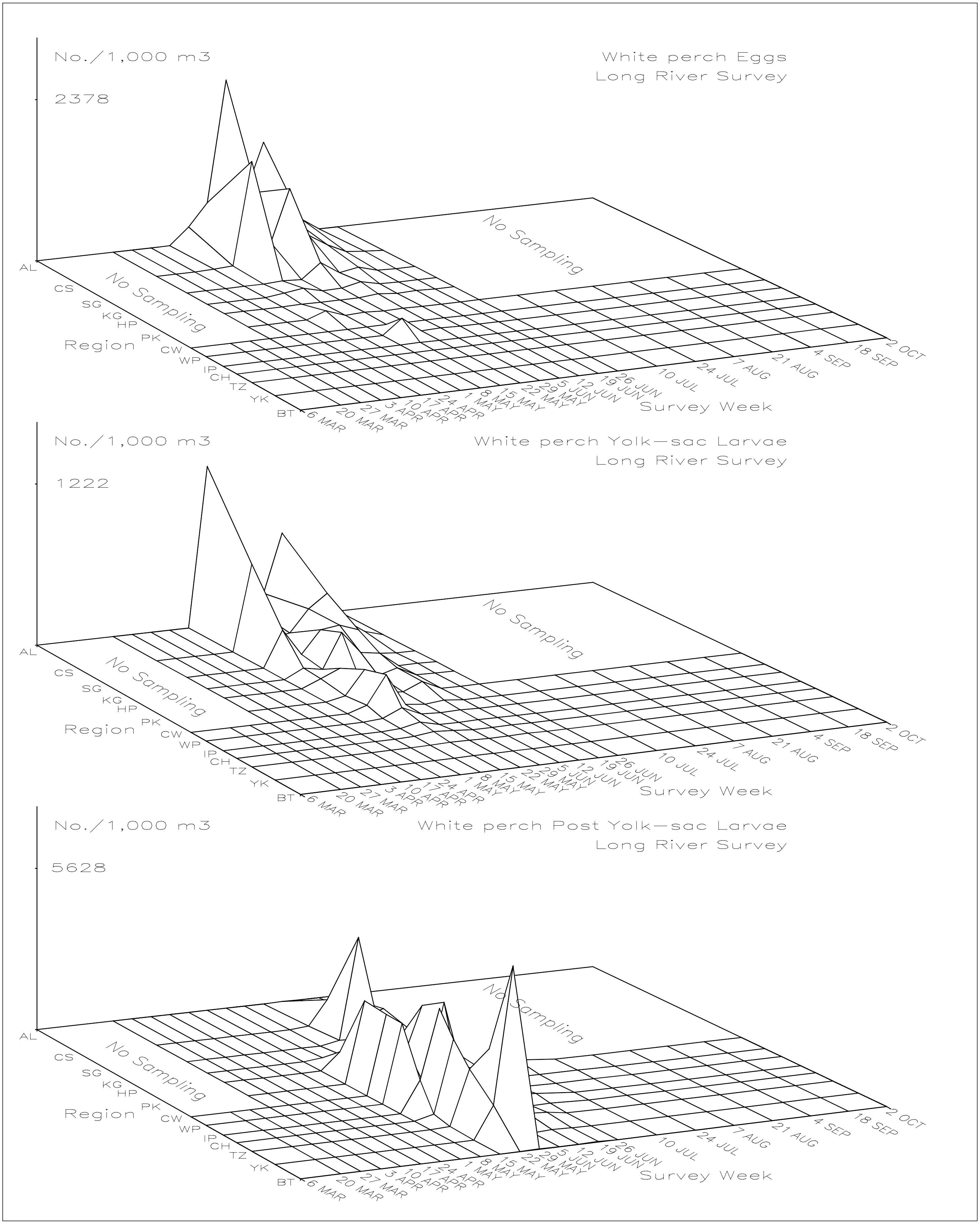

Figure 4-9. Spatiotemporal distribution of eggs, yolk-sac, and post yolk-sac larval white perch in the Hudson River estuary based on the 2000 Long River Survey.

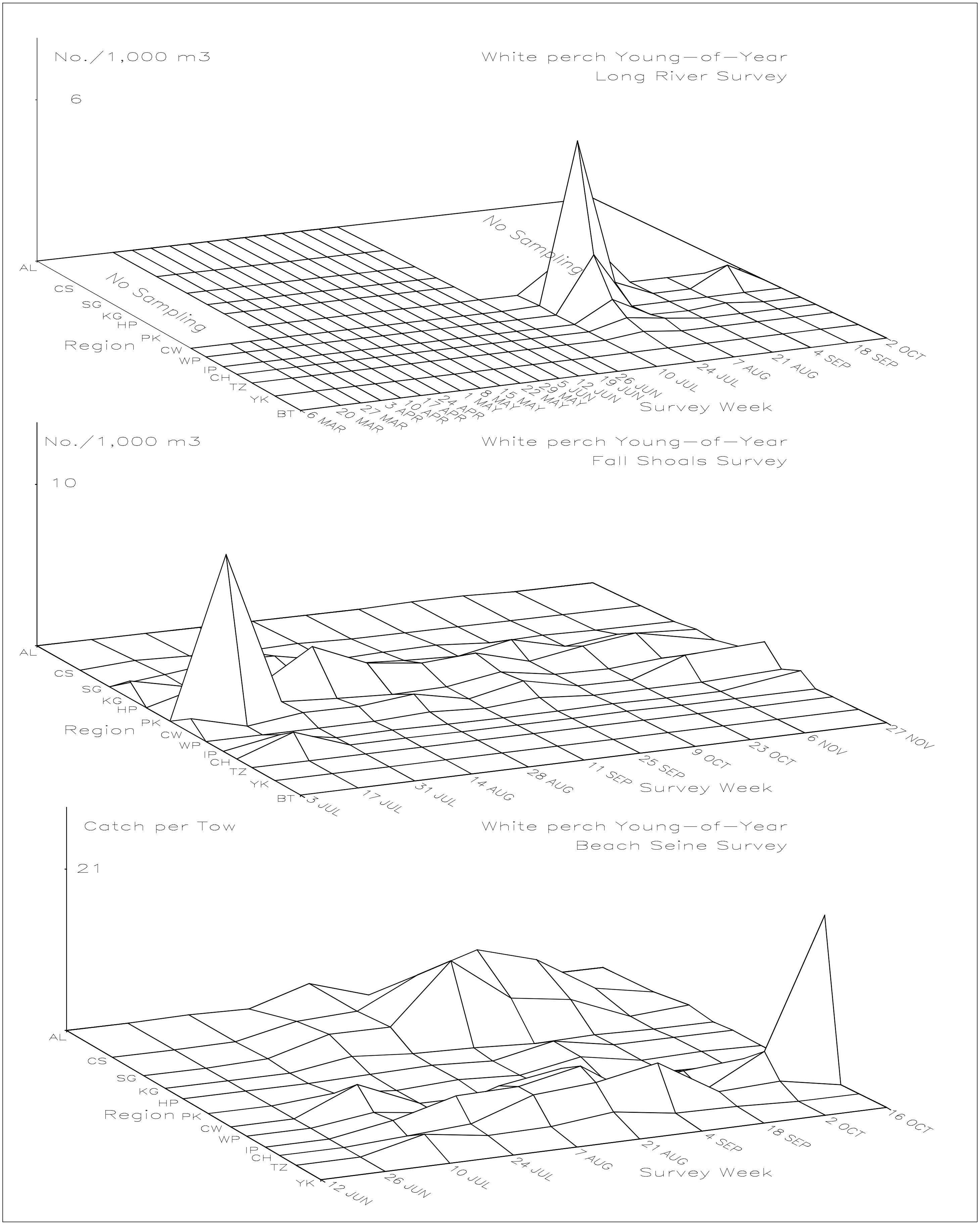

Figure 4-10. Spatiotemporal distribution of young-of-year white perch in the Hudson River estuary based on the 2000 Long River, Fall Shoals, and Beach Seine surveys.

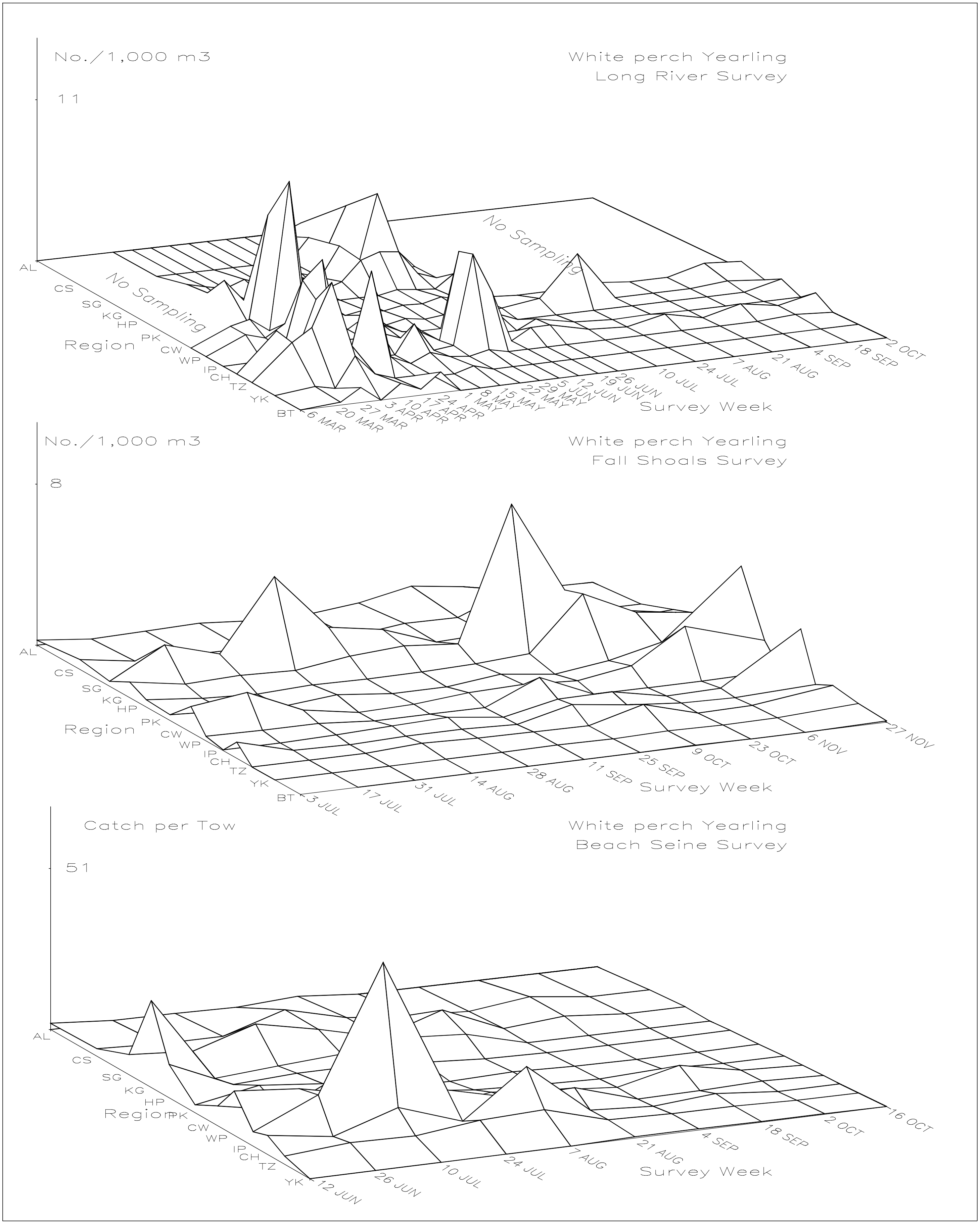

Figure 4–11. Spatiotemporal distribution of yearling white perch in the Hudson River estuary based on the 2000 Long River, Fall Shoals, and Beach Seine surveys.

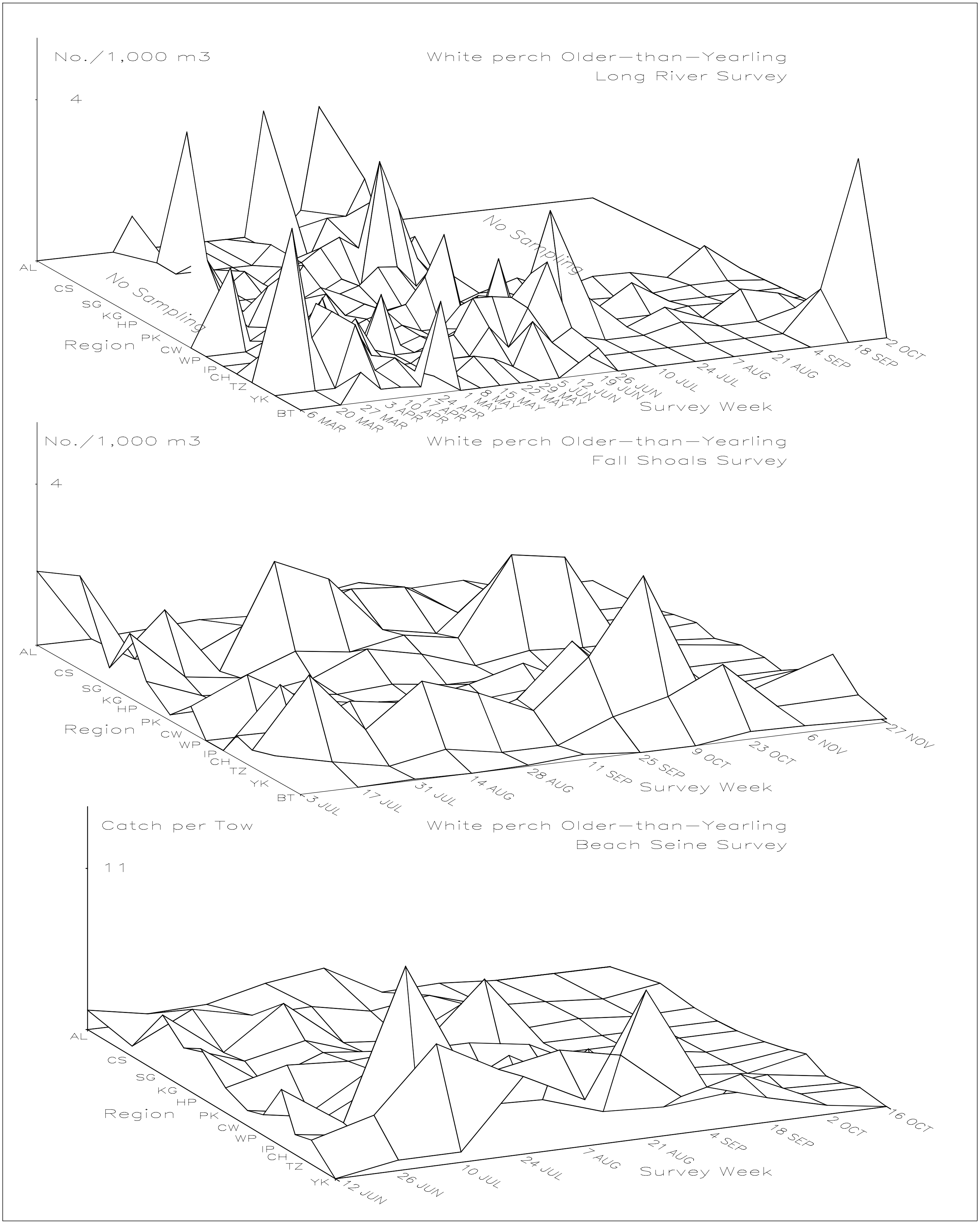

Figure 4—12. Spatiotemporal distribution of older—than—yearling white perch in the Hudson River estuary based on the 2000 Long River, Fall Shoals, and Beach Seine surveys.

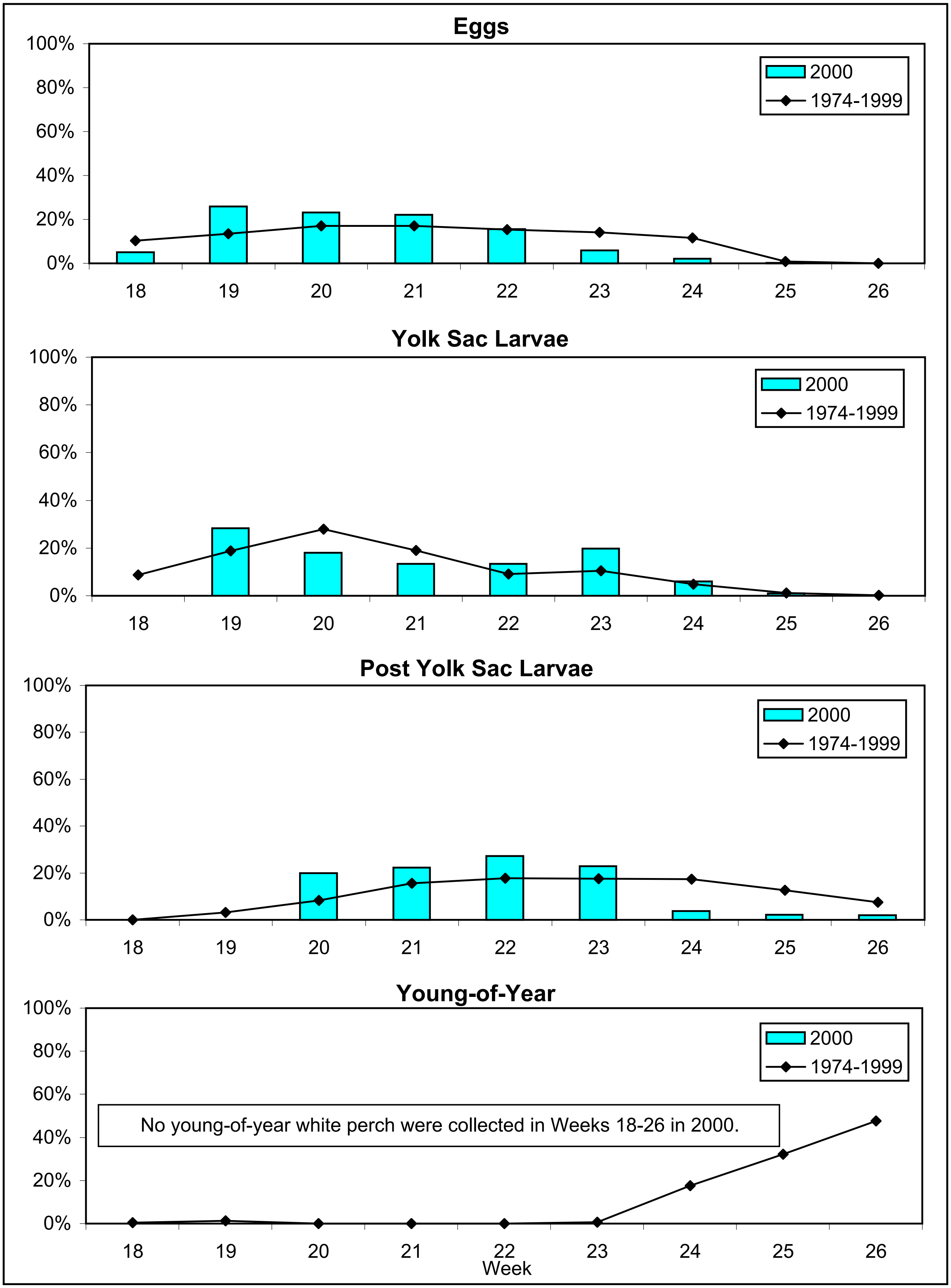

Figure 4-13. Temporal distribution indices for white perch collected during Long River surveys of the Hudson River estuary, 1974-2000.

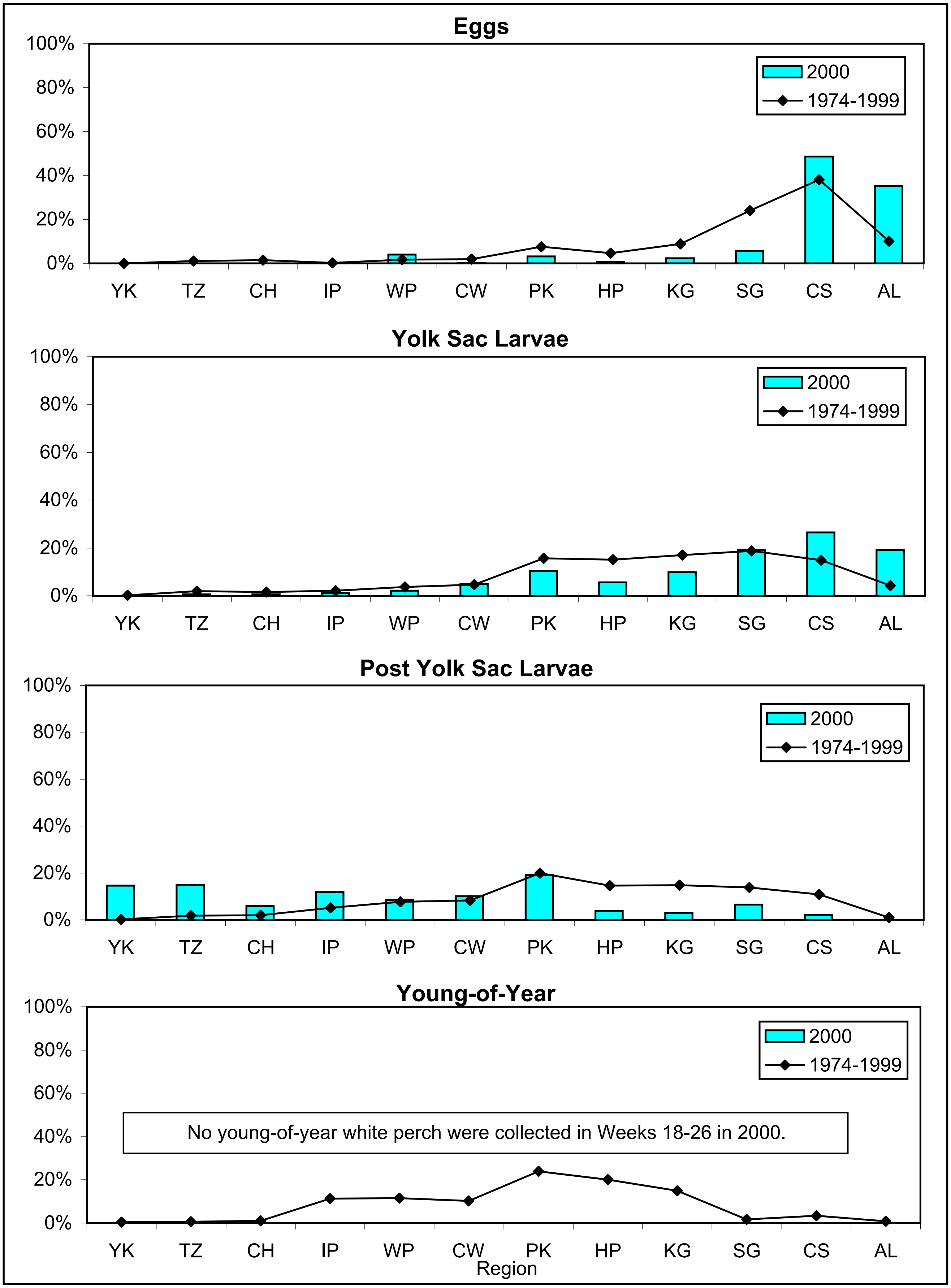

Figure 4-14. Geographic distribution indices for white perch collected during Long River surveys of the Hudson River estuary, 1974-2000.

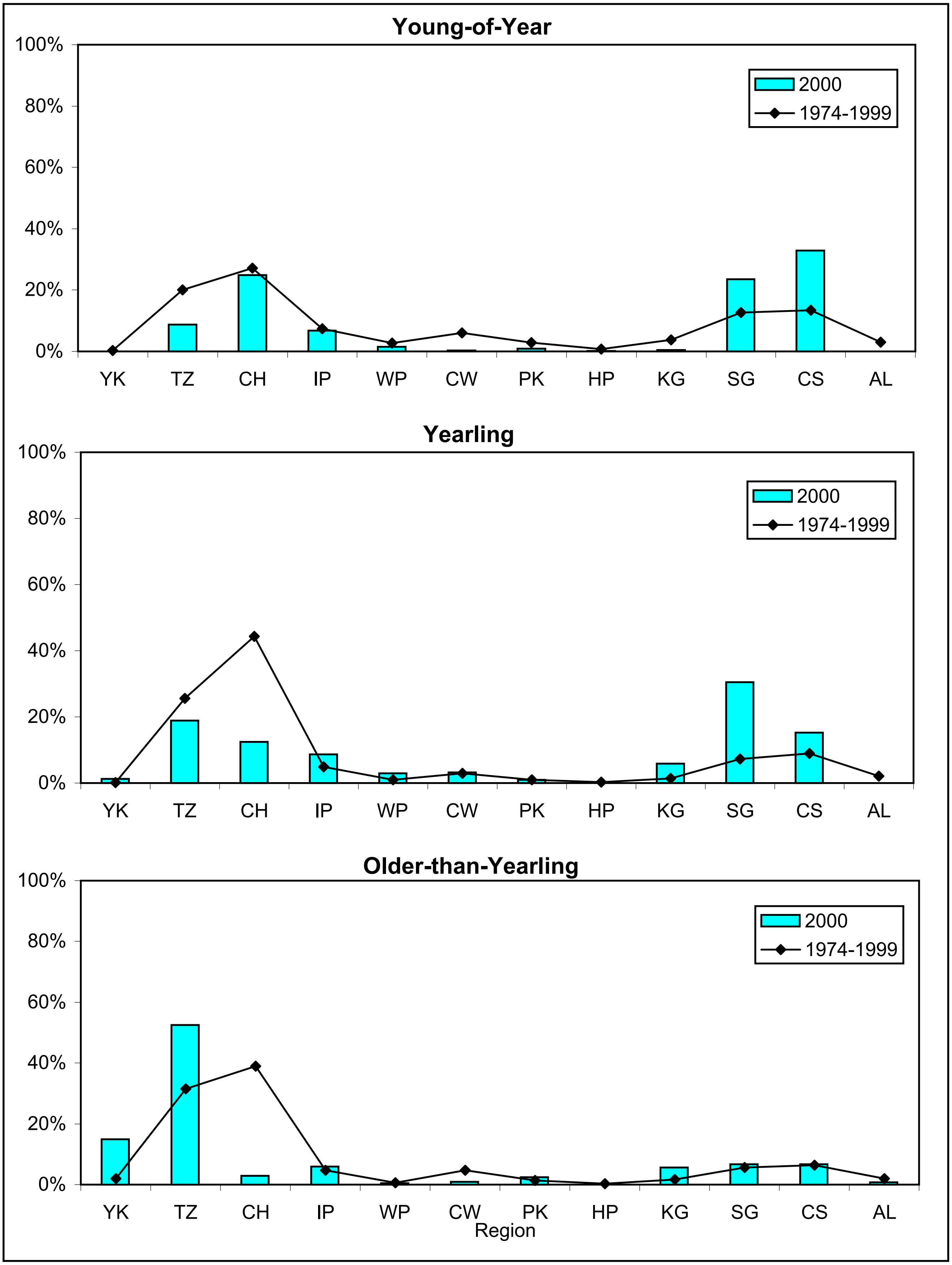

Figure 4-15. Geographic distribution indices for white perch collected during Beach Seine surveys of the Hudson River estuary, 1974-2000.

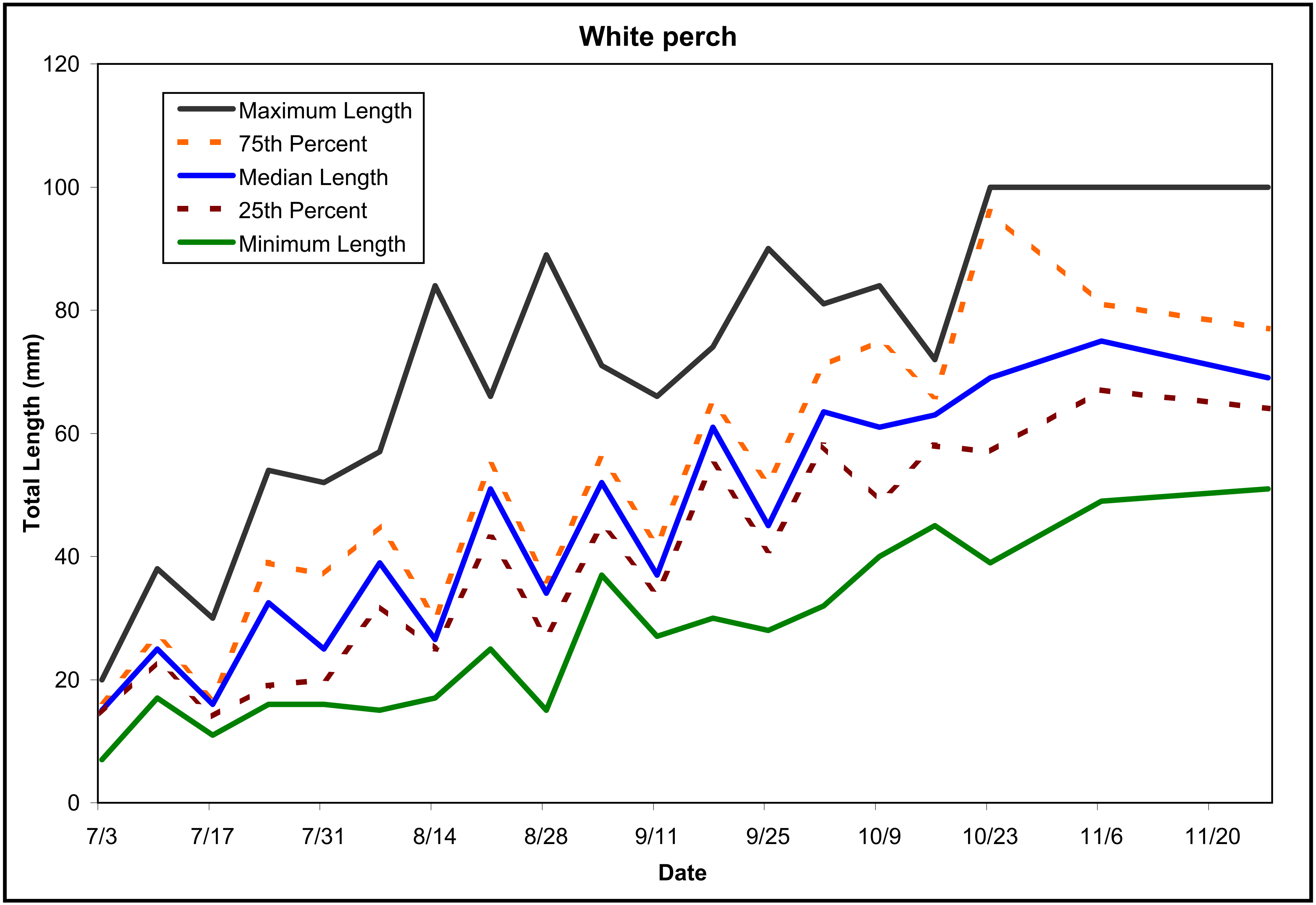

Figure 4-16. Weekly length statistics for young-of-year white perch in the Hudson River estuary, 2000.

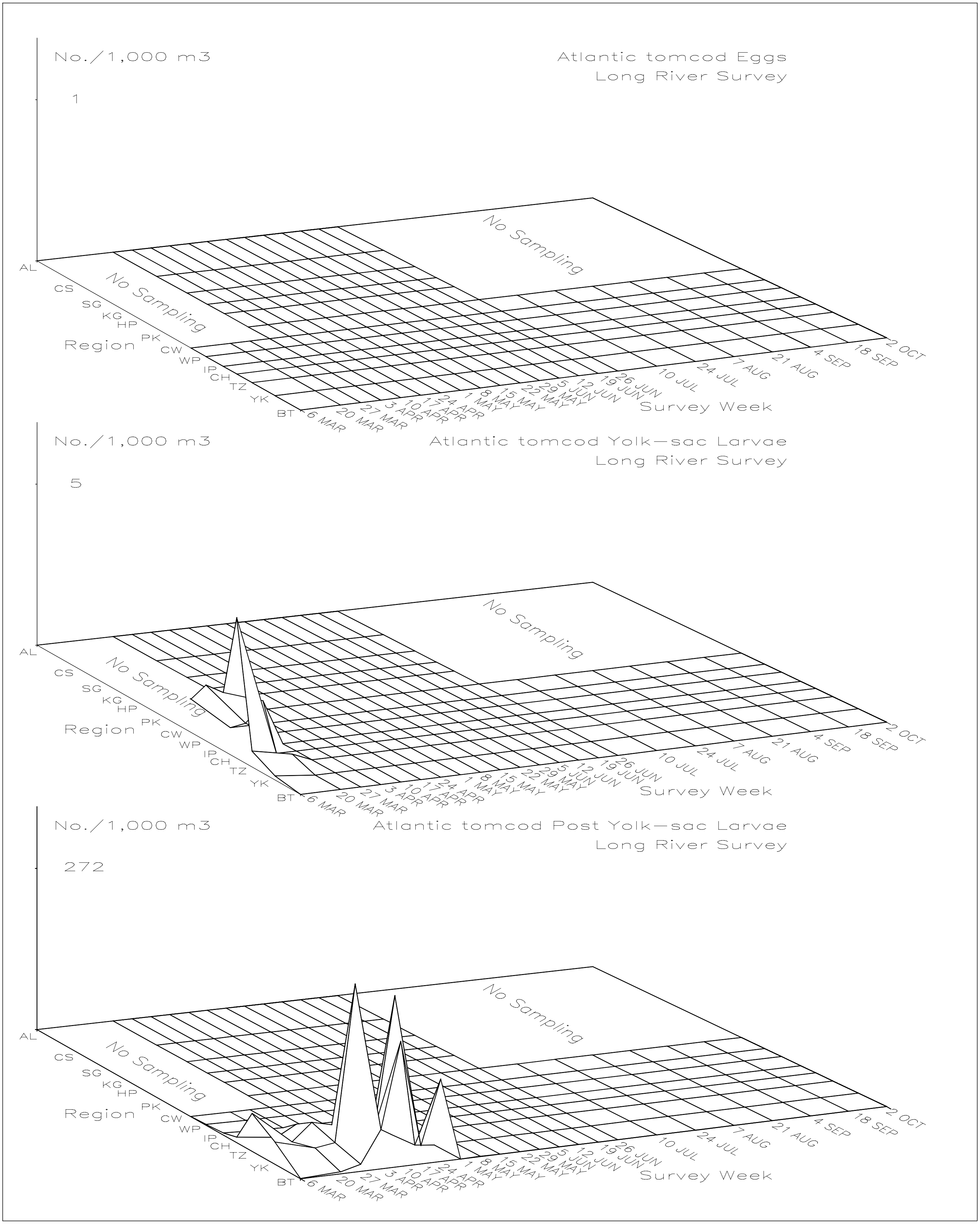

Figure 4–17. Spatiotemporal distribution of eggs, yolk–sac, and post yolk–sac larval Atlantic tomcod in the Hudson River estuary based on the 2000 Long River Survey.

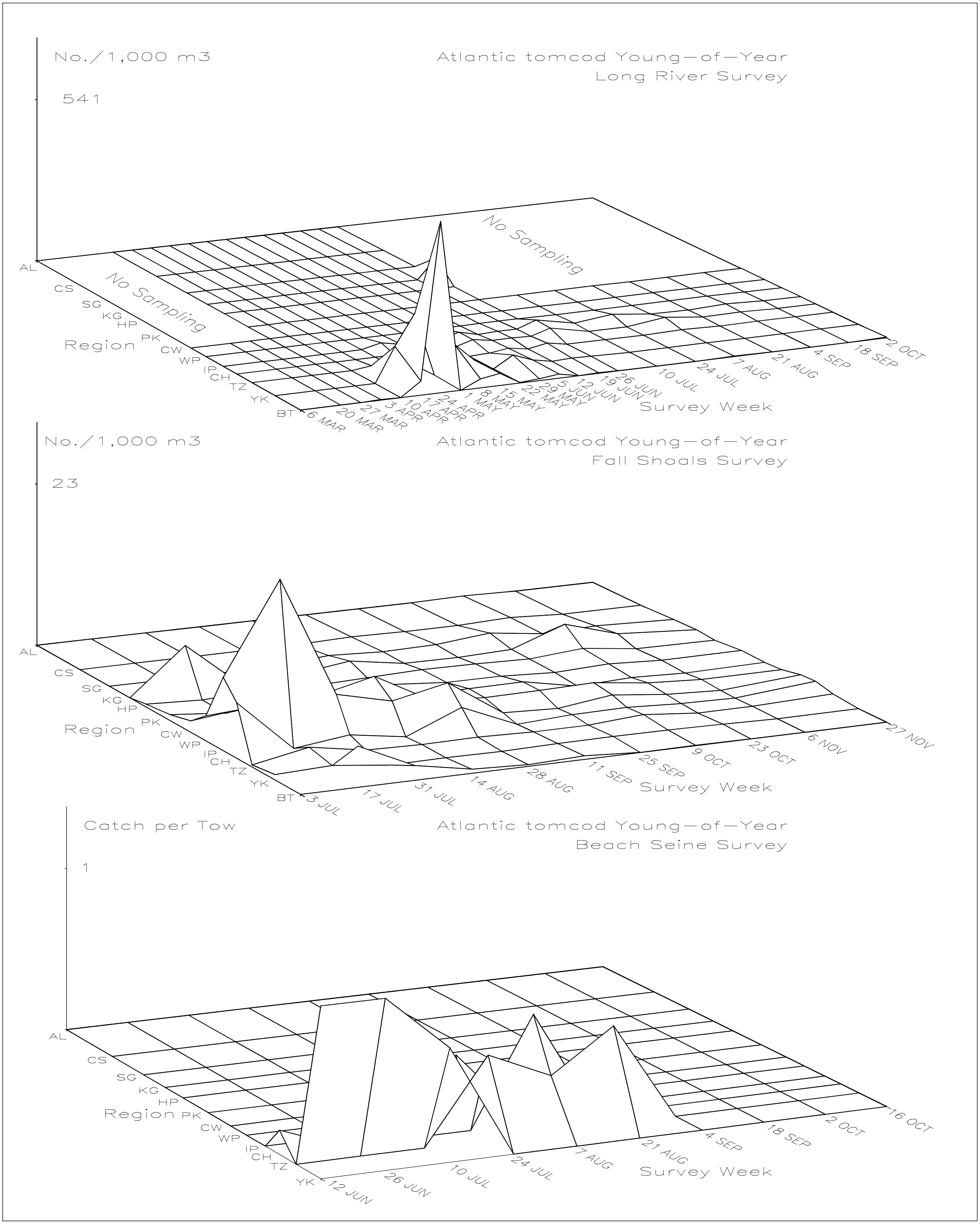

Figure 4-18. Spatiotemporal distribution of young-of-year Atlantic tomcod in the Hudson River estuary based on the 2000 Long River, Fall Shoals, and Beach Seine surveys.

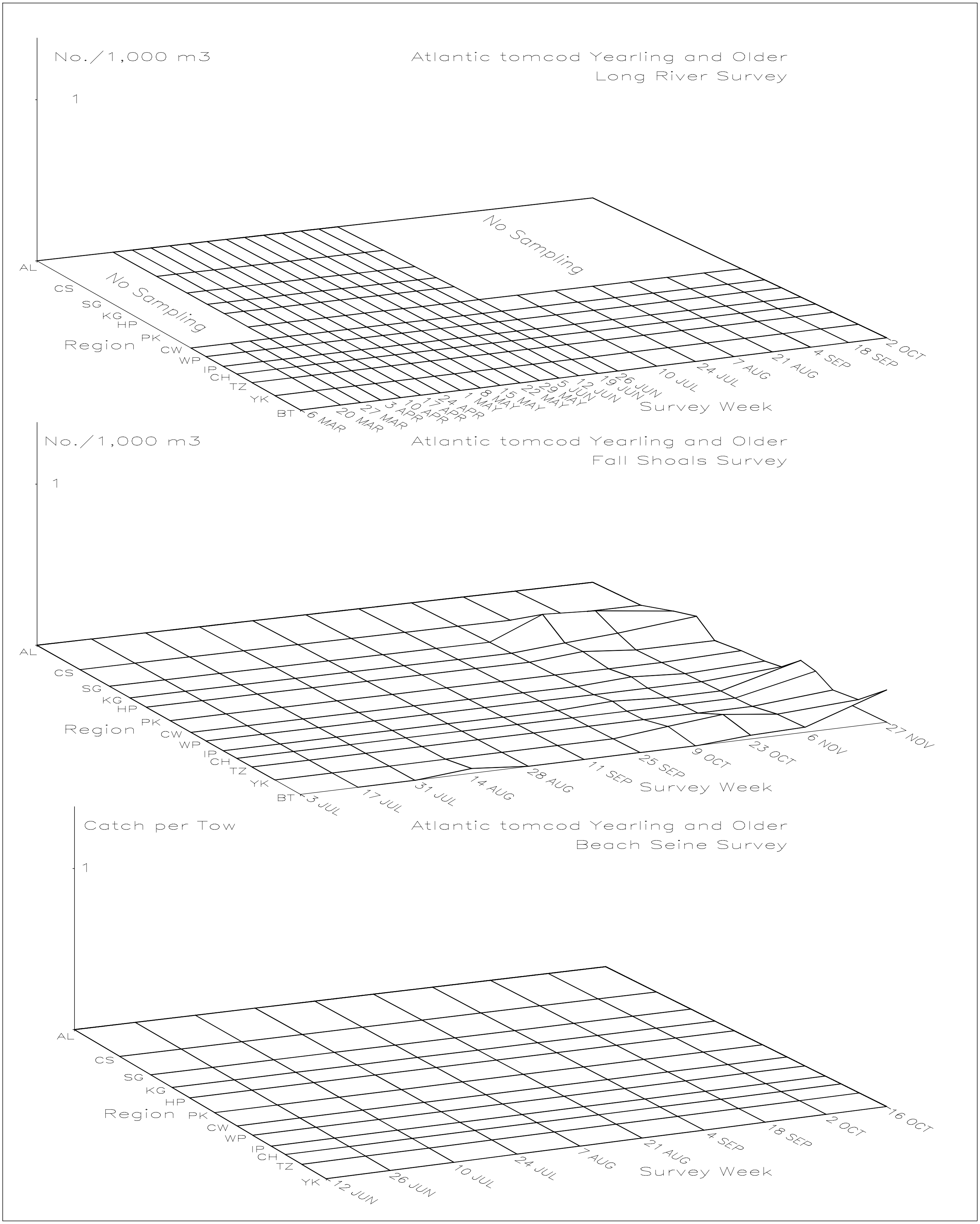

Figure 4–19. Spatiotemporal distribution of yearling and older Atlantic tomcod in the Hudson River estuary based on the 2000 Long River, Fall Shoals, and Beach Seine surveys.

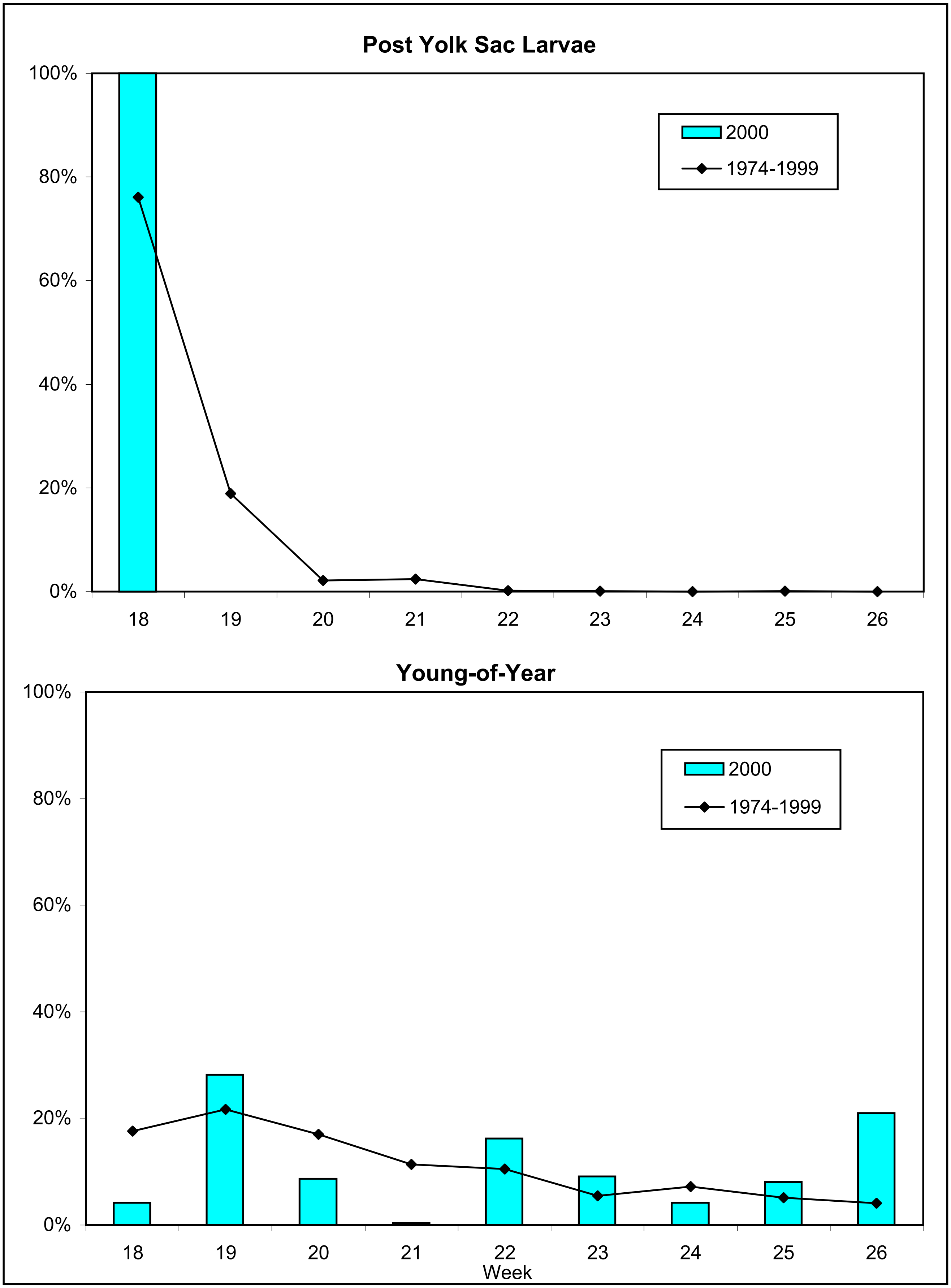

Figure 4-20. Temporal distribution indices for Atlantic tomcod collected during Long River surveys of the Hudson River estuary, 1974-2000.

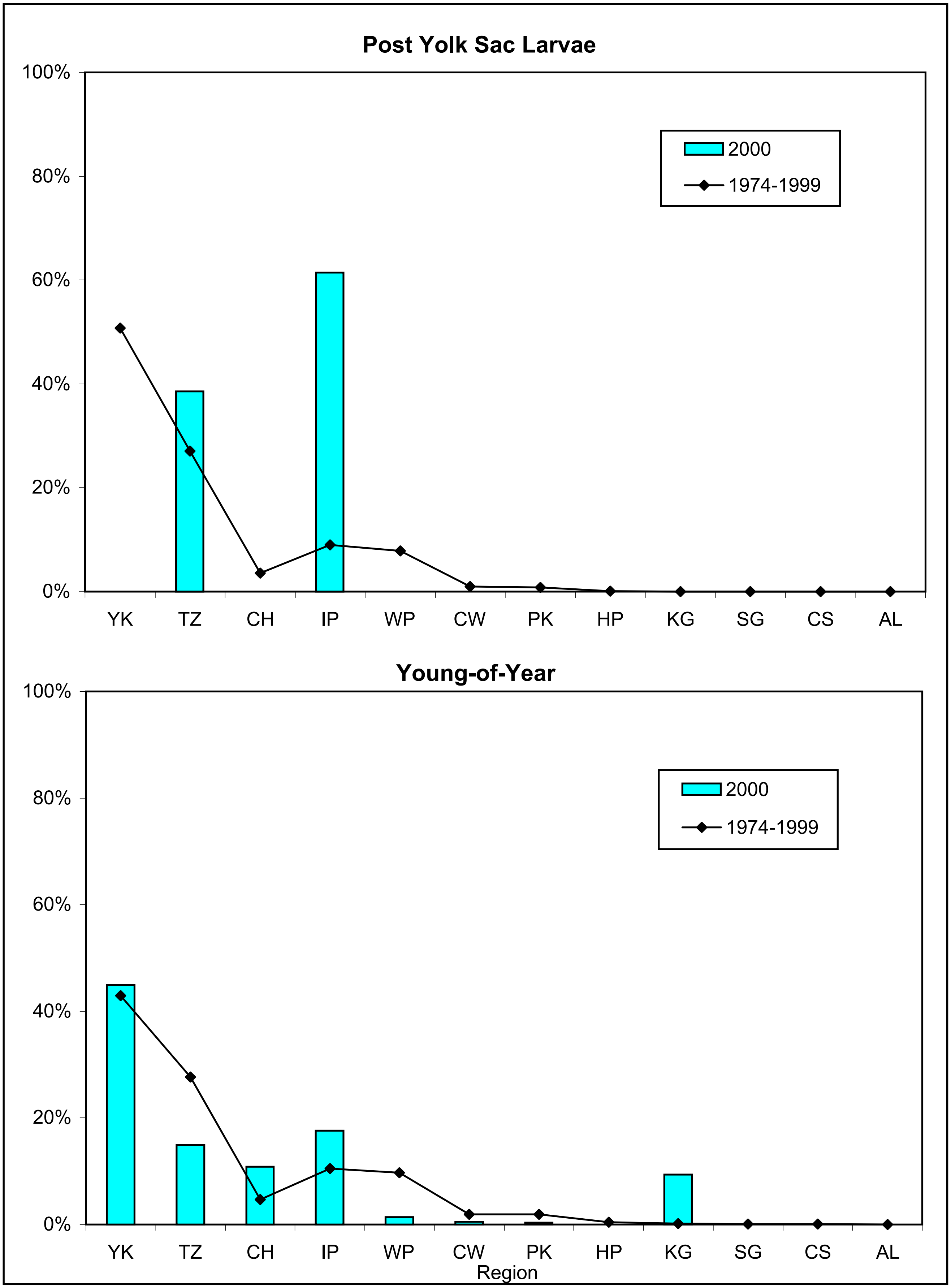

Figure 4-21. Geographic distribution indices for Atlantic tomcod collected during Long River surveys of the Hudson River estuary, 1974-2000.

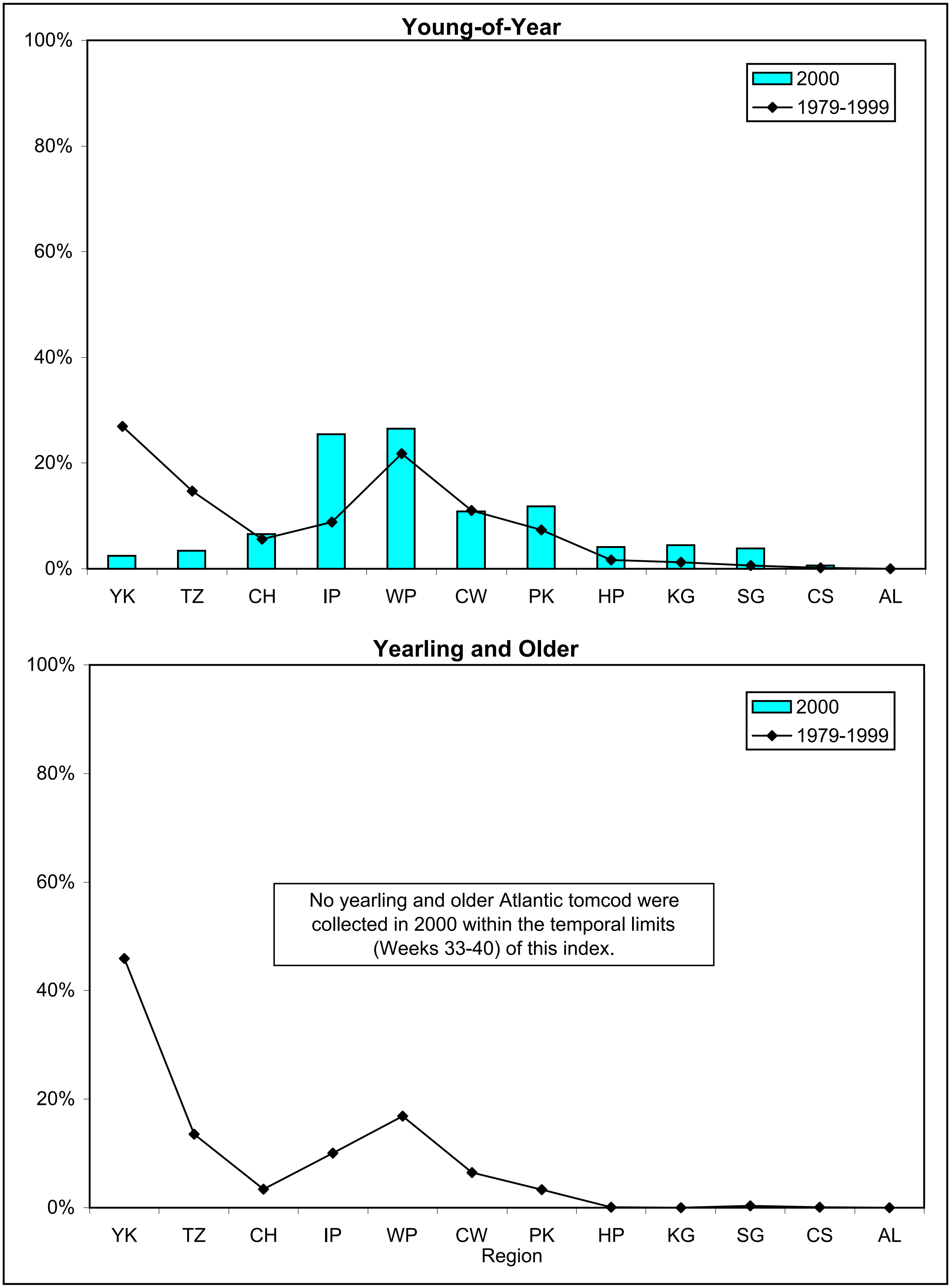

Figure 4-22. Geographic distribution indices for Atlantic tomcod collected during Fall Shoals surveys of the Hudson River estuary, 1979-2000.

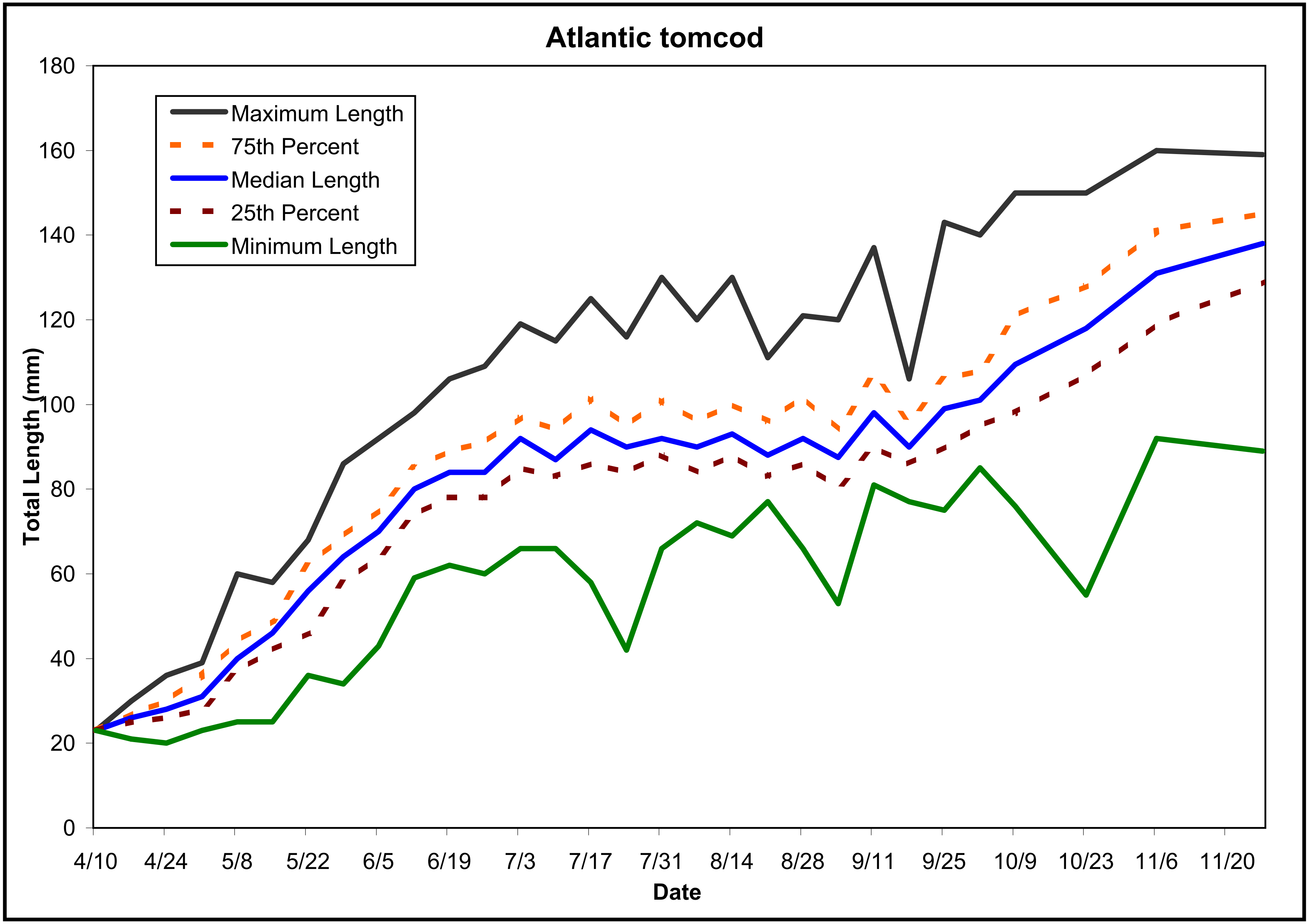

Figure 4-23. Weekly length statistics for young-of-year Atlantic tomcod in the Hudson River estuary, 2000.

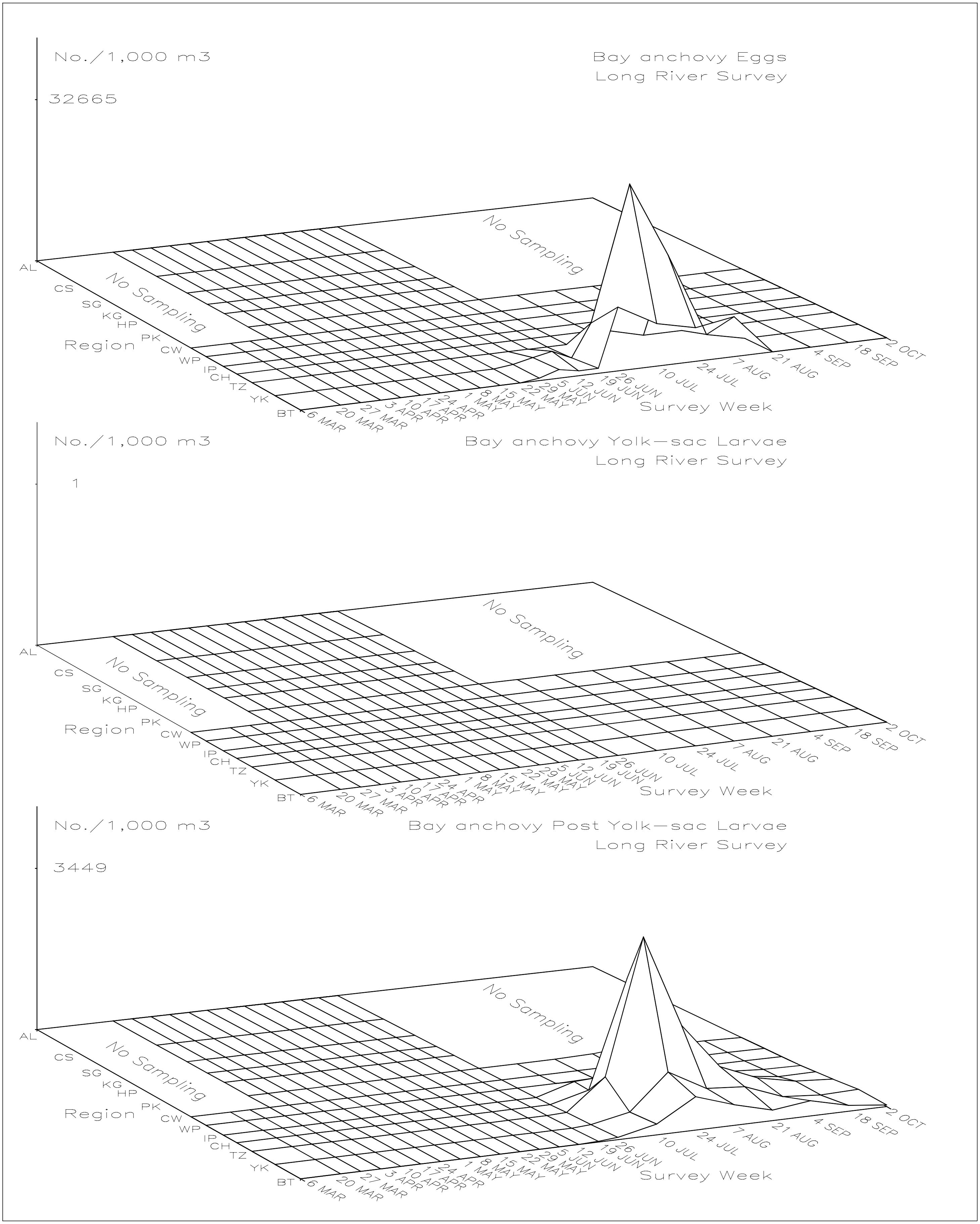

Figure 4-24. Spatiotemporal distribution of eggs, yolk-sac, and post yolk-sac larval bay anchovy in the Hudson River estuary based on the 2000 Long River Survey.

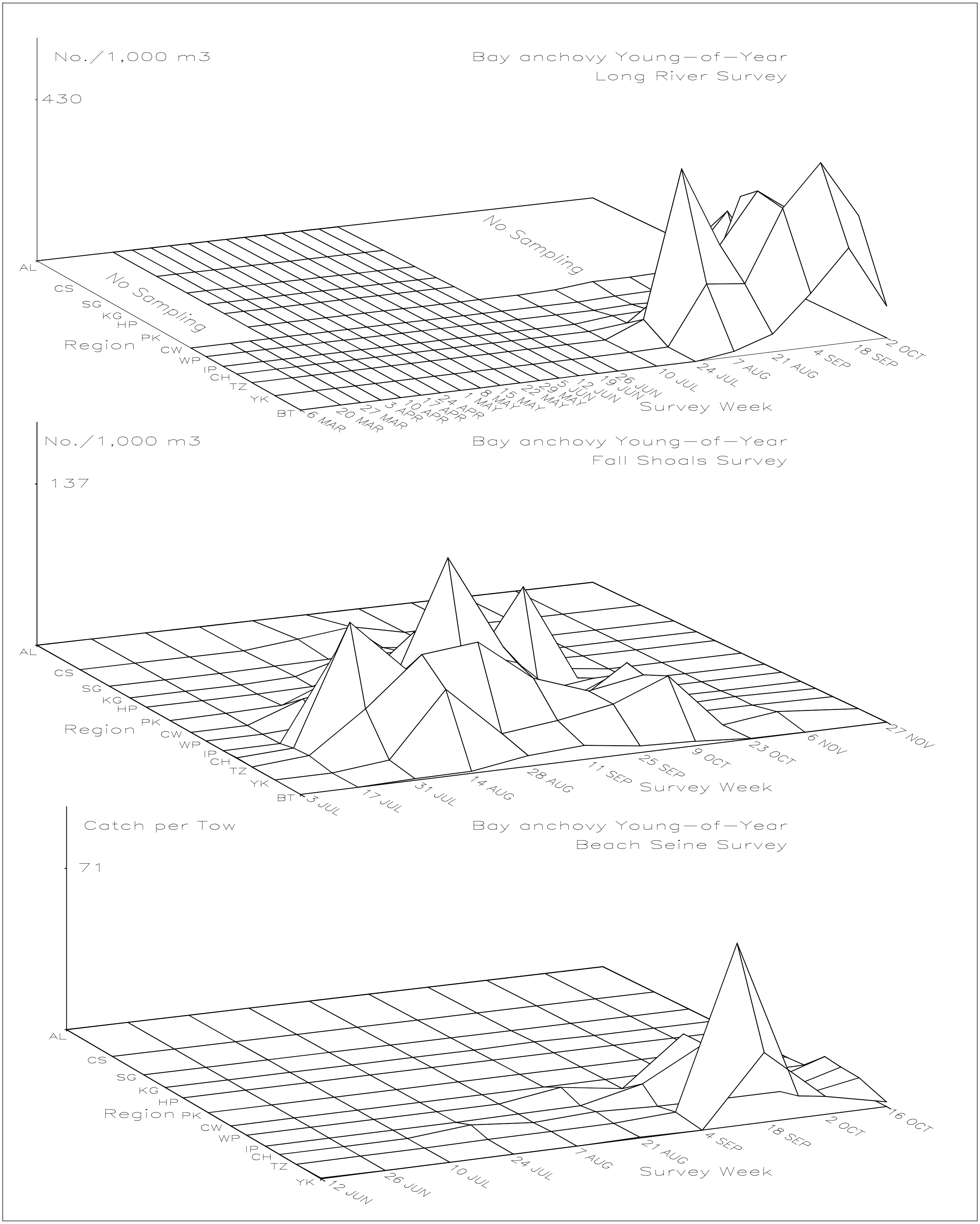

Figure 4-25. Spatiotemporal distribution of young-of-year bay anchovy in the Hudson River estuary based on the 2000 Long River, Fall Shoals, and Beach Seine surveys.

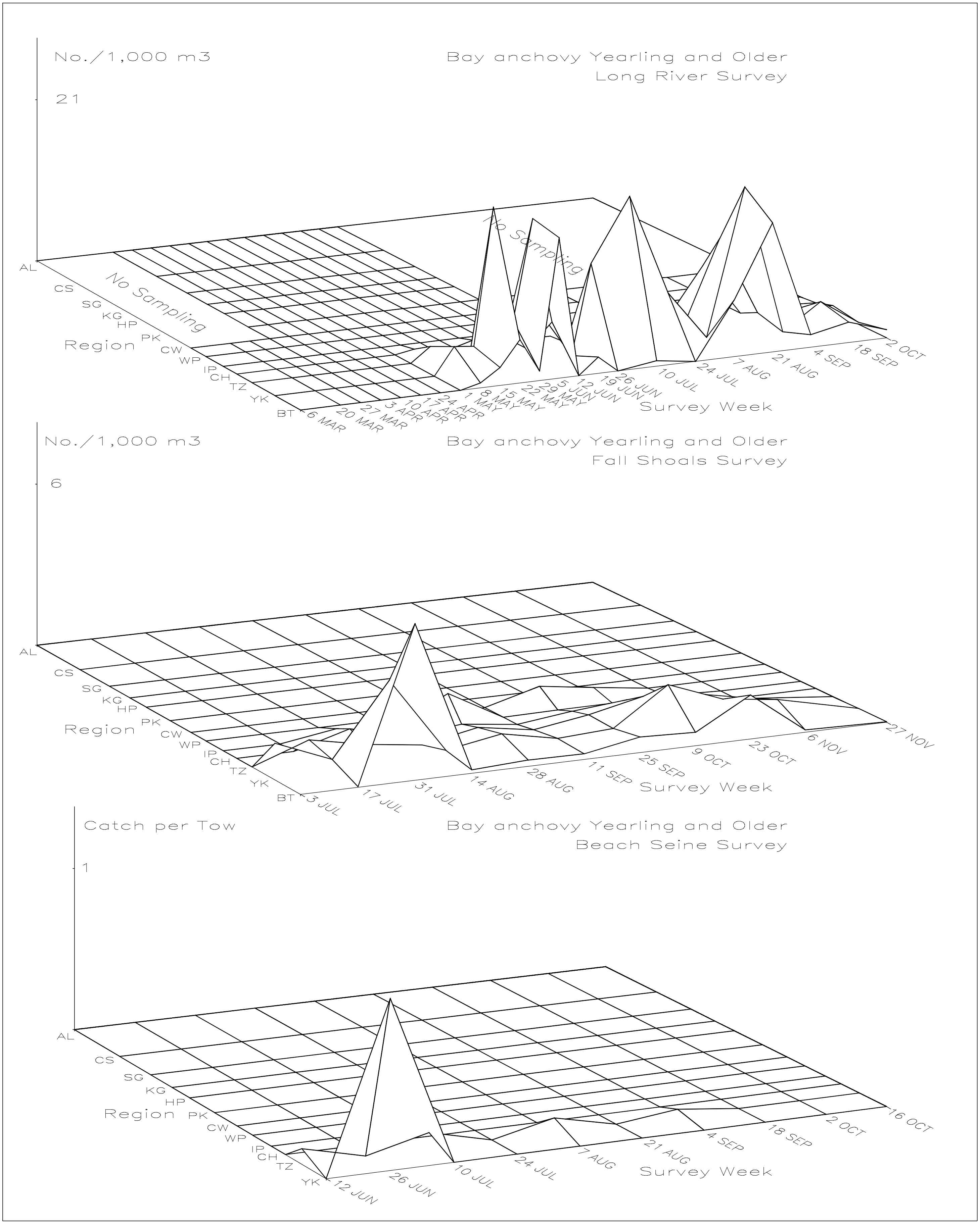

Figure 4–26. Spatiotemporal distribution of yearling and older bay anchovy in the Hudson River estuary based on the 2000 Long River, Fall Shoals, and Beach Seine surveys.

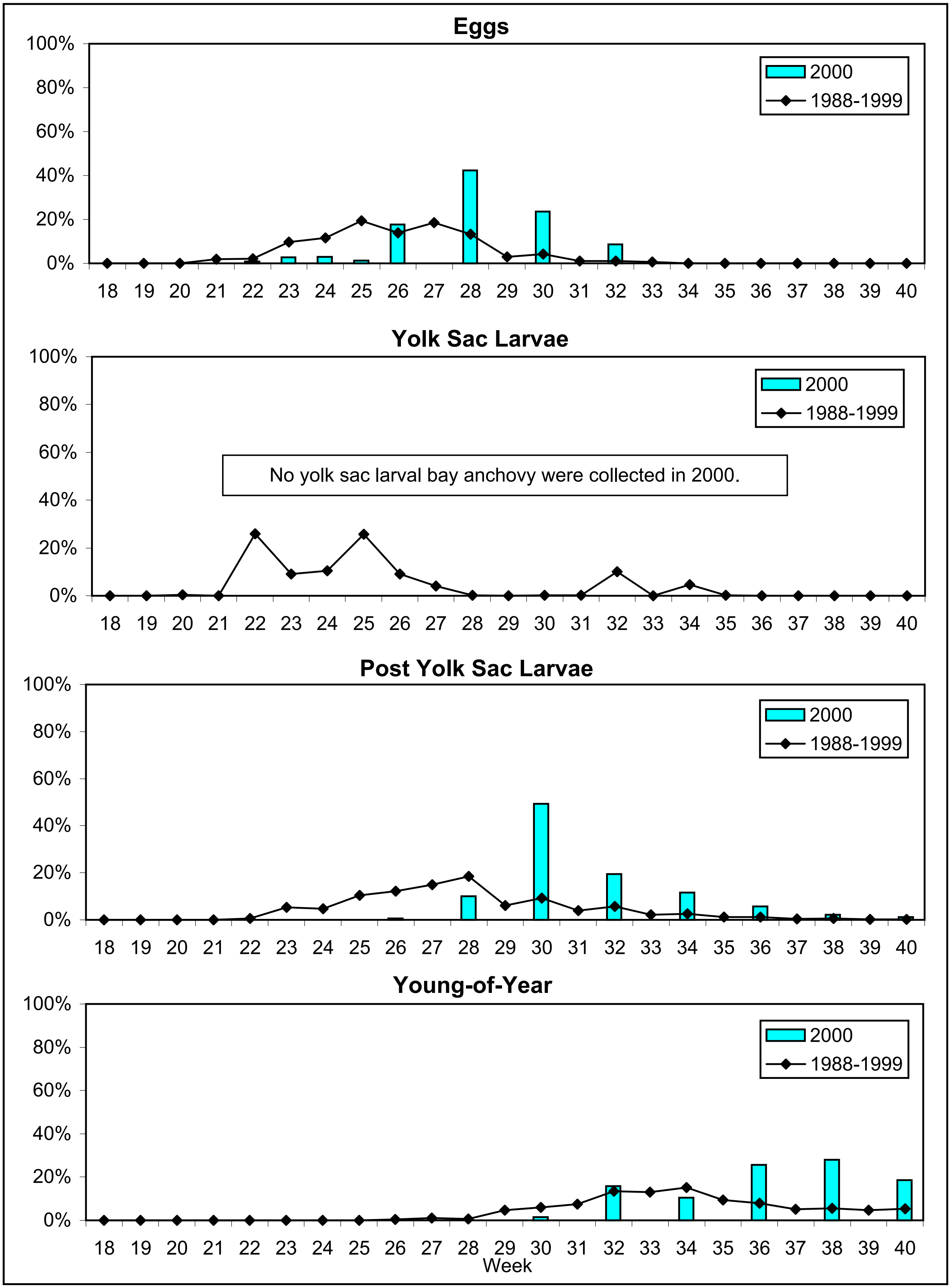

Figure 4-27. Temporal distribution indices for bay anchovy collected during Long River surveys of the Hudson River estuary, 1988-2000.

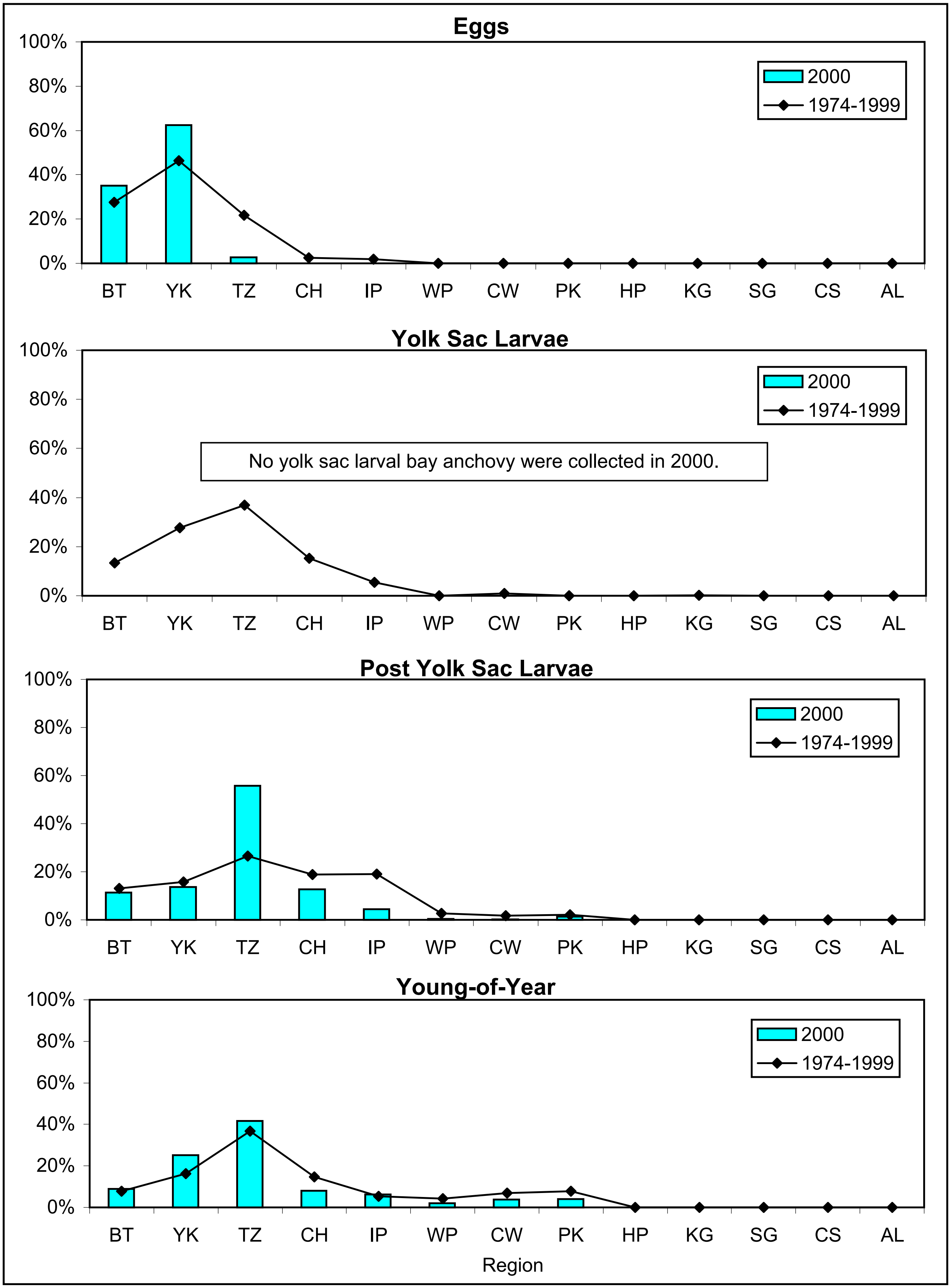

Figure 4-28. Geographic distribution indices for bay anchovy collected during Long River surveys of the Hudson River estuary, 1988-2000.

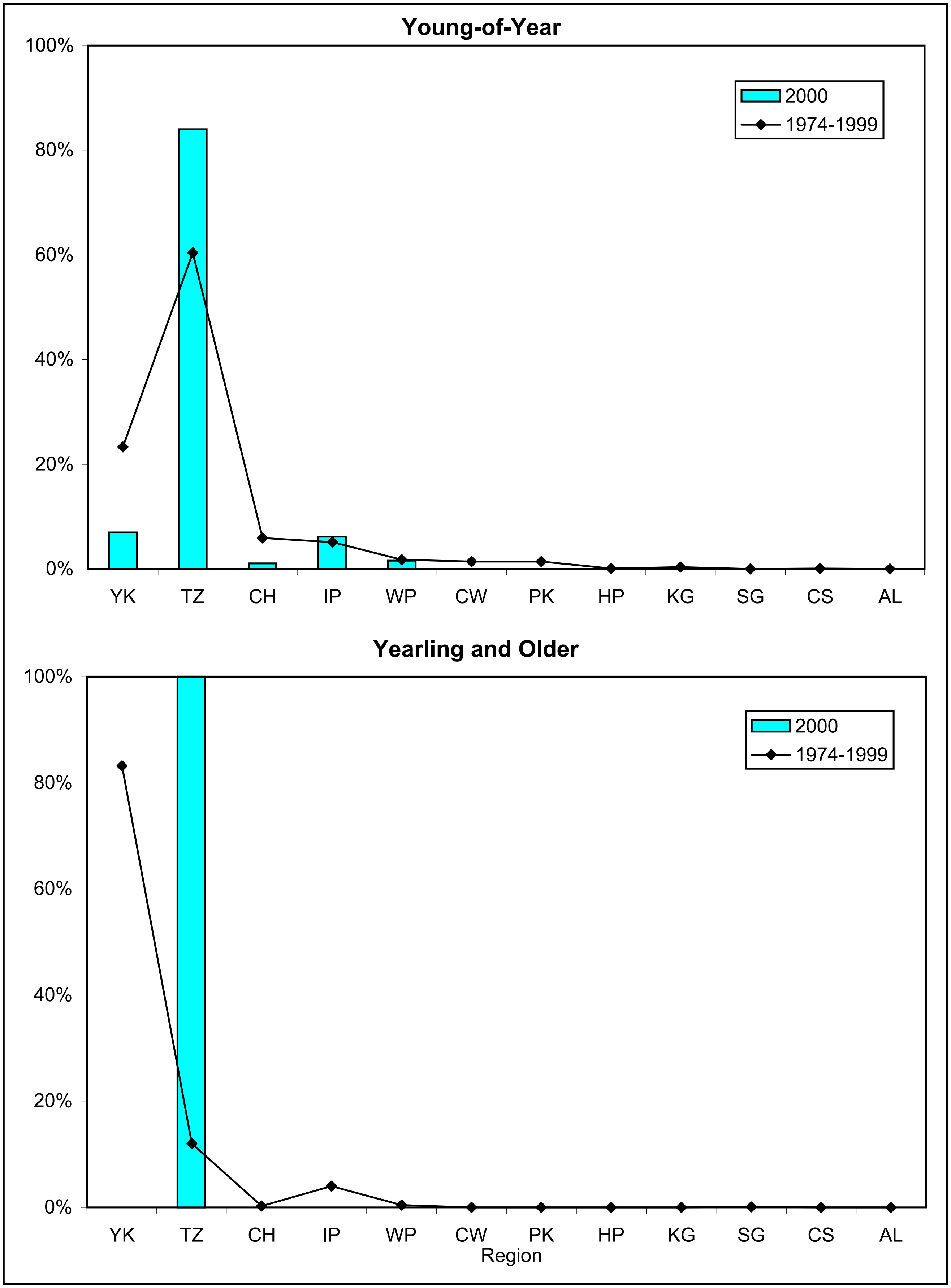

Figure 4-29. Geographic distribution indices for bay anchovy collected during Beach Seine surveys of the Hudson River estuary, 1974-2000.

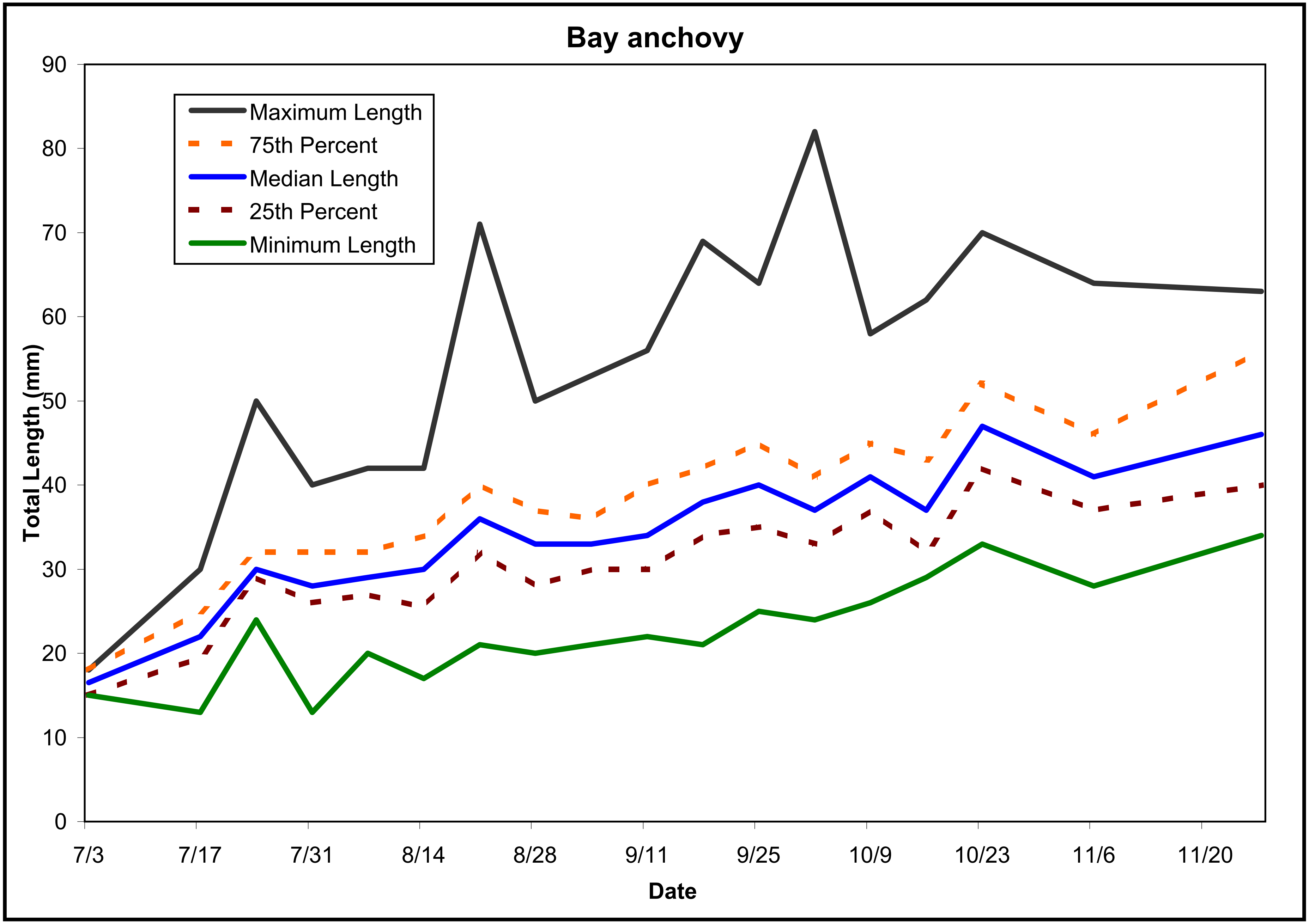

Figure 4-30. Weekly length statistics for young-of-year bay anchovy in the Hudson River estuary, 2000.

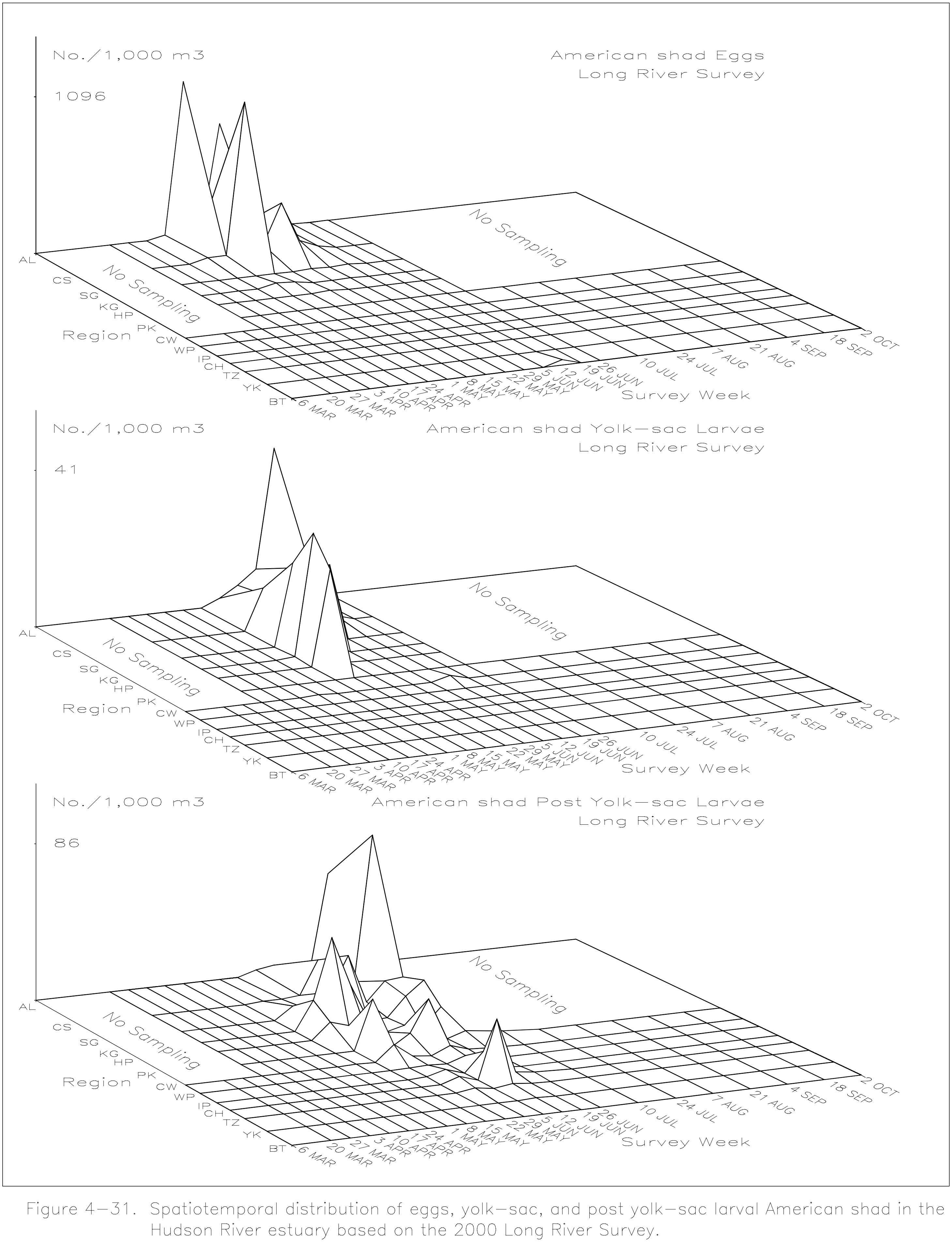

Figure 4-31. Spatiotemporal distribution of eggs, yolk-sac, and post yolk-sac larval American shad in the Hudson River estuary based on the 2000 Long River Survey.

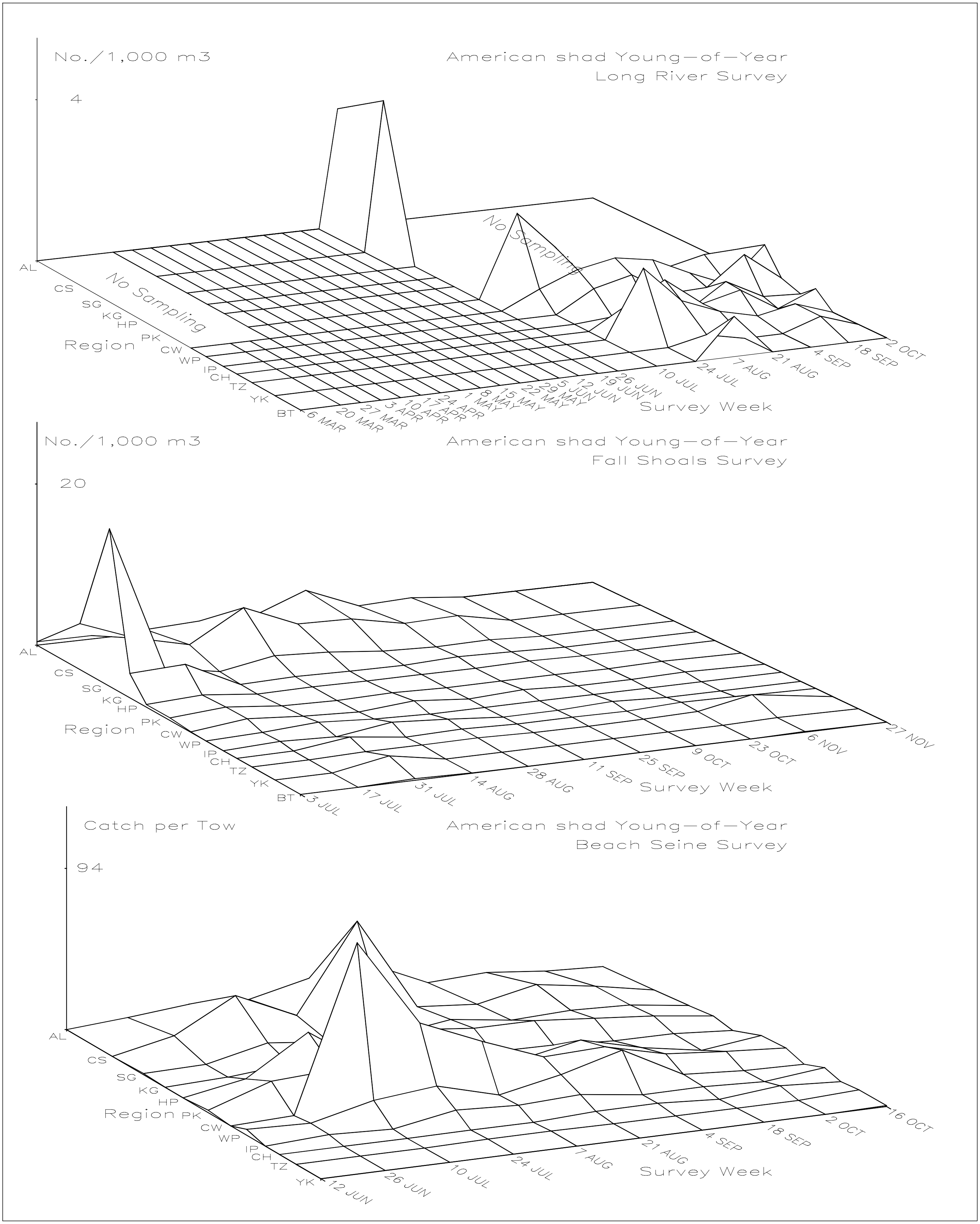

Figure 4–32. Spatiotemporal distribution of young-of-year American shad in the Hudson River estuary based on the 2000 Long River, Fall Shoals, and Beach Seine surveys.

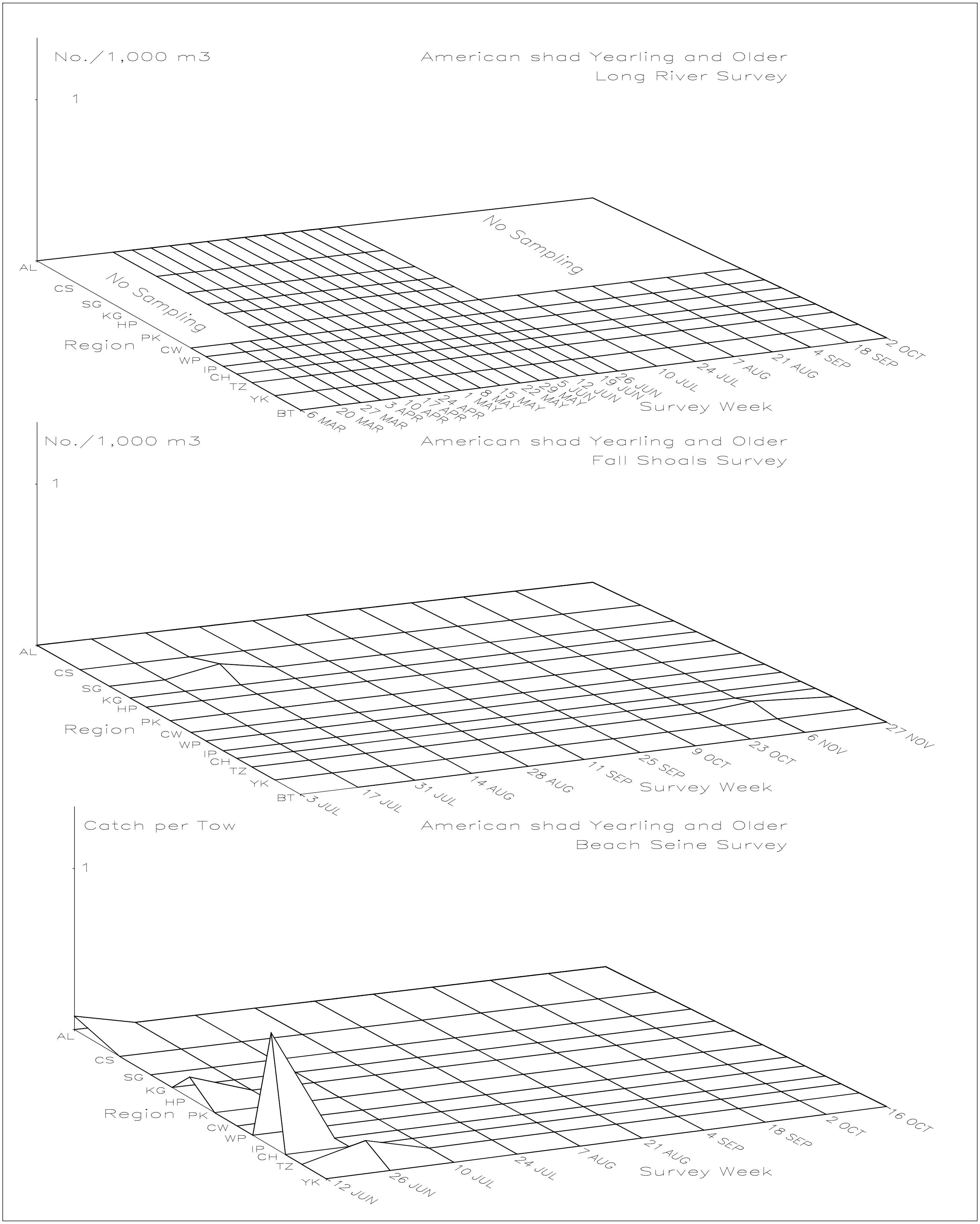

Figure 4–33. Spatiotemporal distribution of yearling and older American shad in the Hudson River estuary based on the 2000 Long River, Fall Shoals, and Beach Seine surveys.

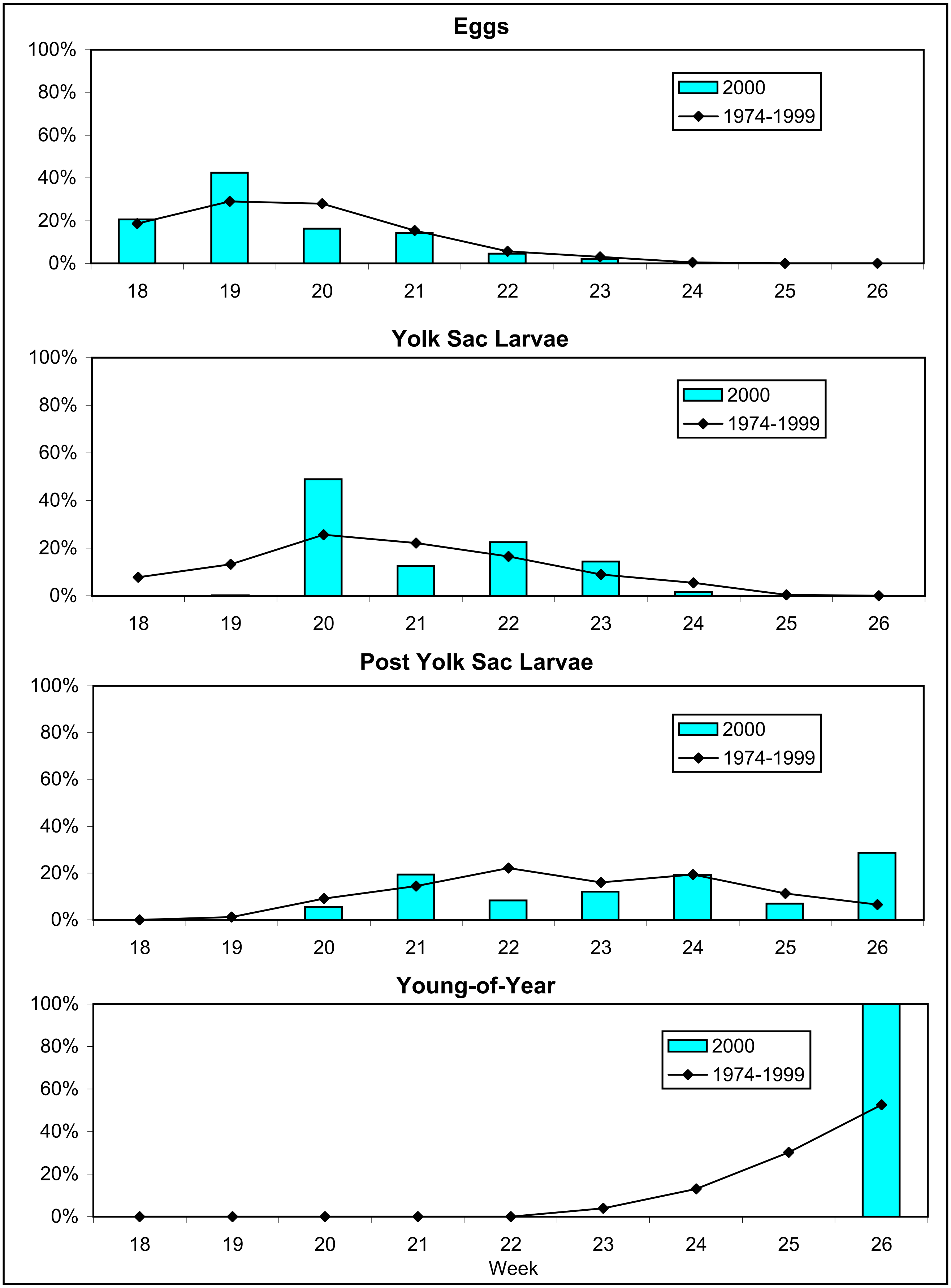

Figure 4-34. Temporal distribution indices for American shad collected during Long River surveys of the Hudson River estuary, 1974-2000.

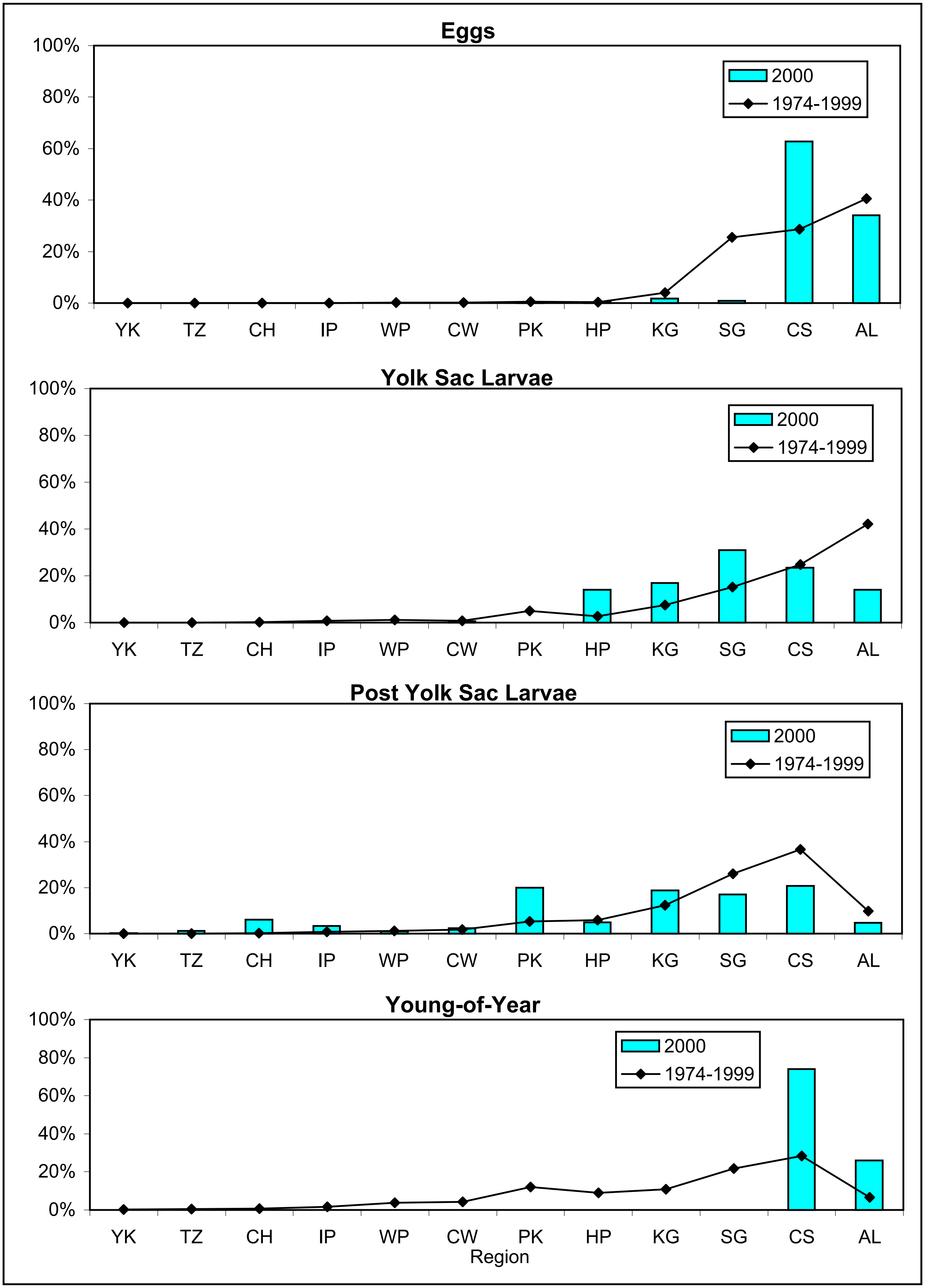

Figure 4-35. Geographic distribution indices for American shad collected during Long River surveys of the Hudson River estuary, 1974-2000.

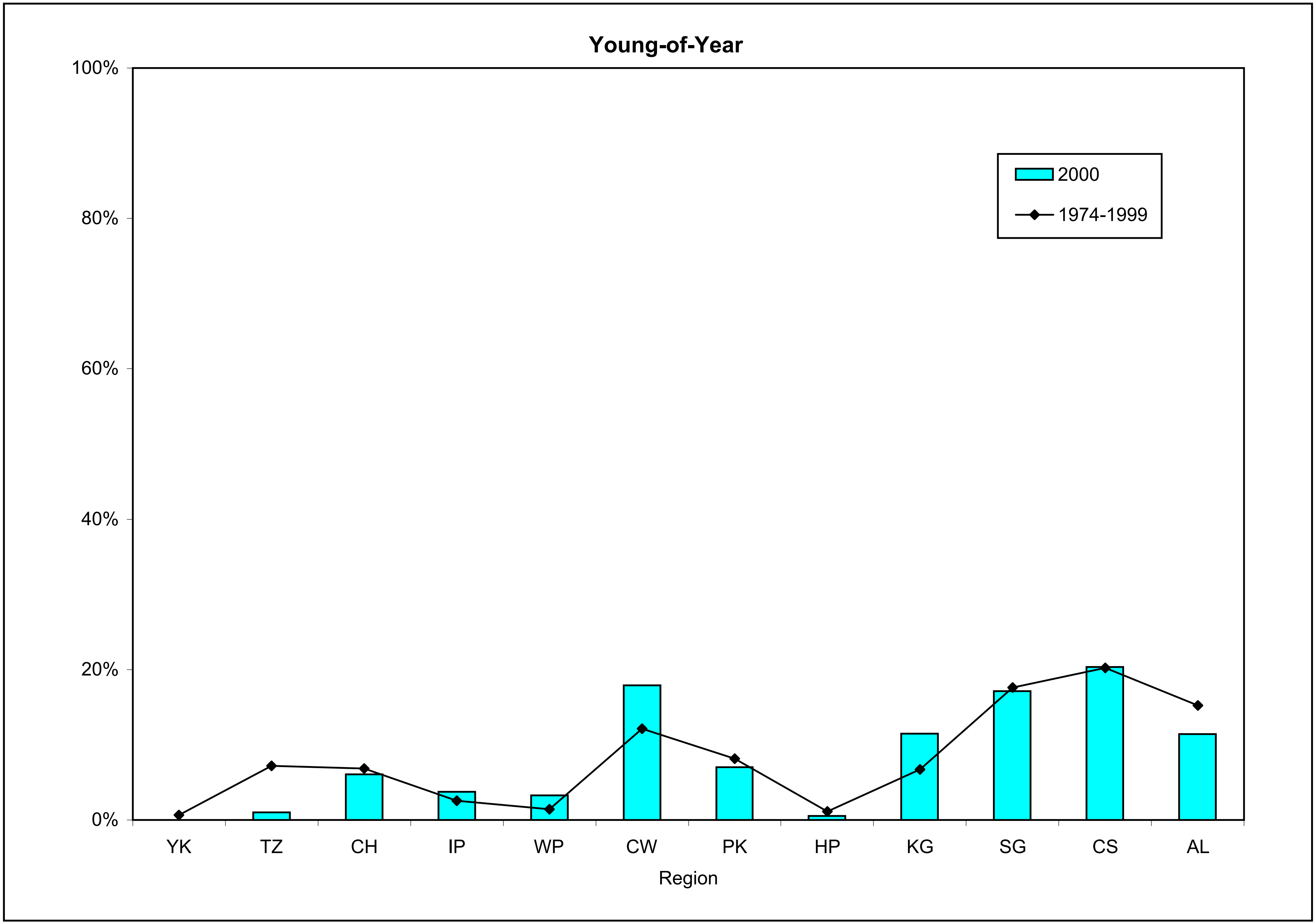

Figure 4-36. Geographic distribution indices for American shad collected during Beach Seine surveys of the Hudson River estuary, 1974-2000.

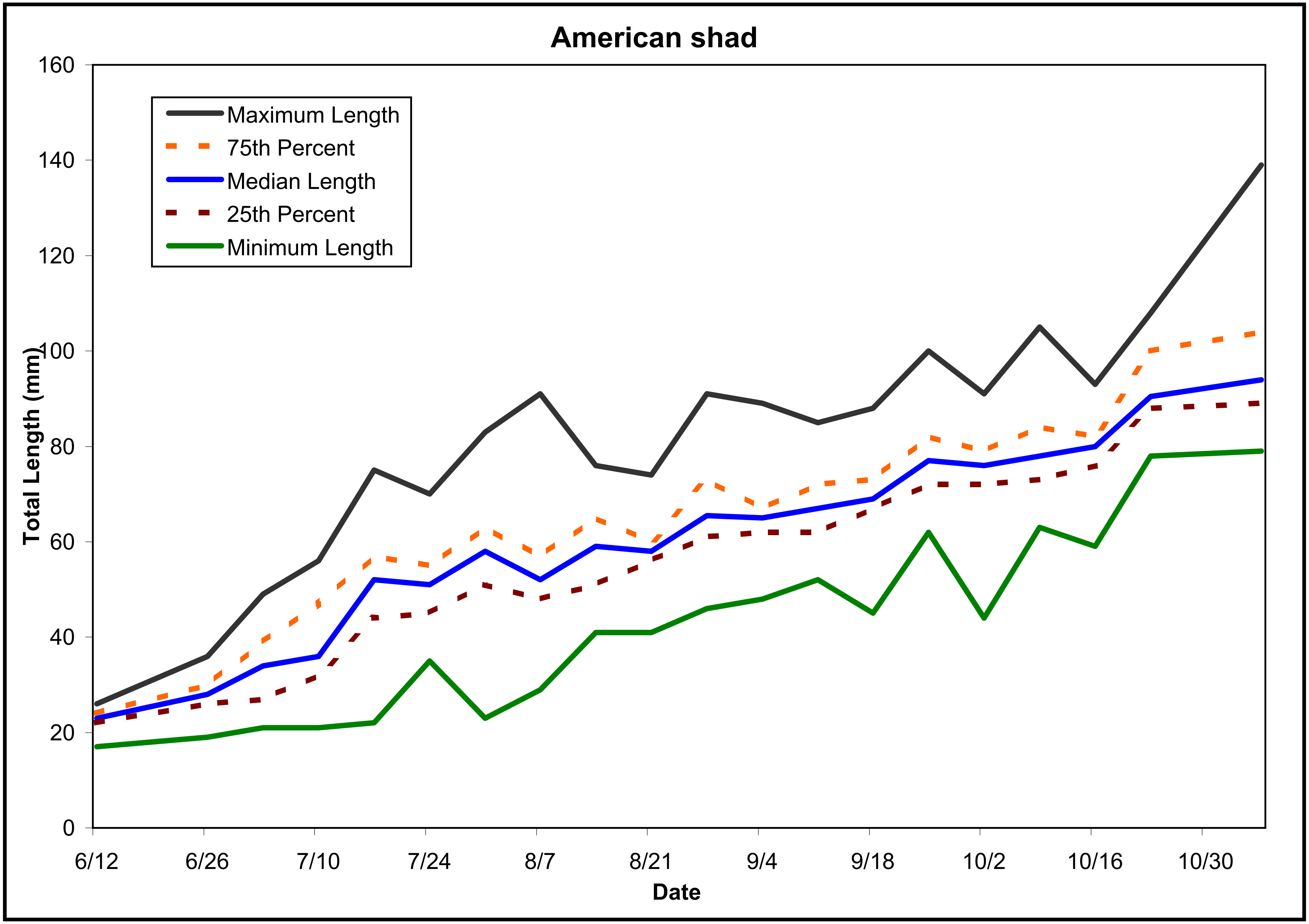

Figure 4-37. Weekly length statistics for young-of-year American shad in the Hudson River estuary, 2000.

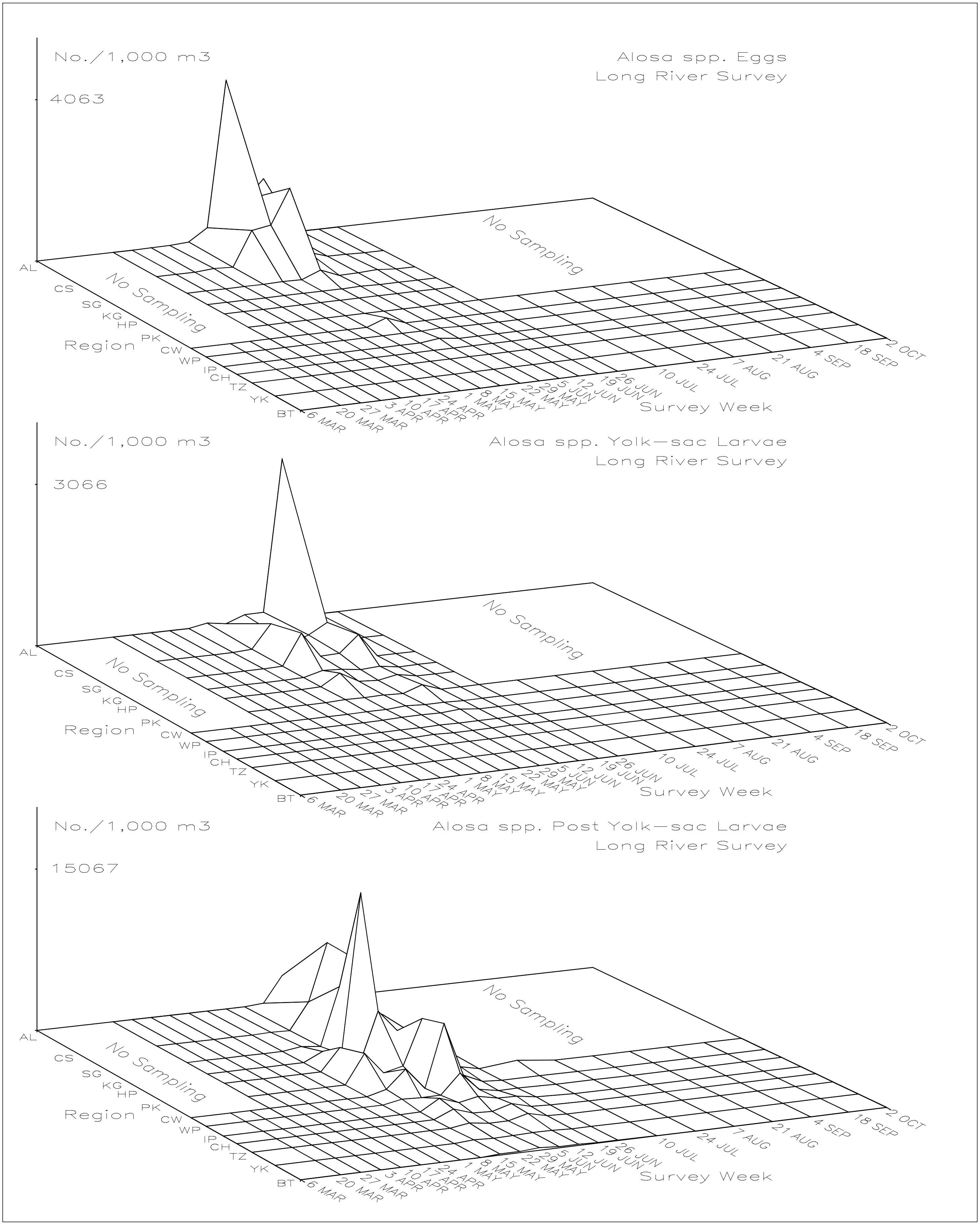

Figure 4-38. Spatiotemporal distribution of eggs, yolk-sac, and post yolk-sac larval Alosa spp. in the Hudson River estuary based on the 2000 Long River Survey.

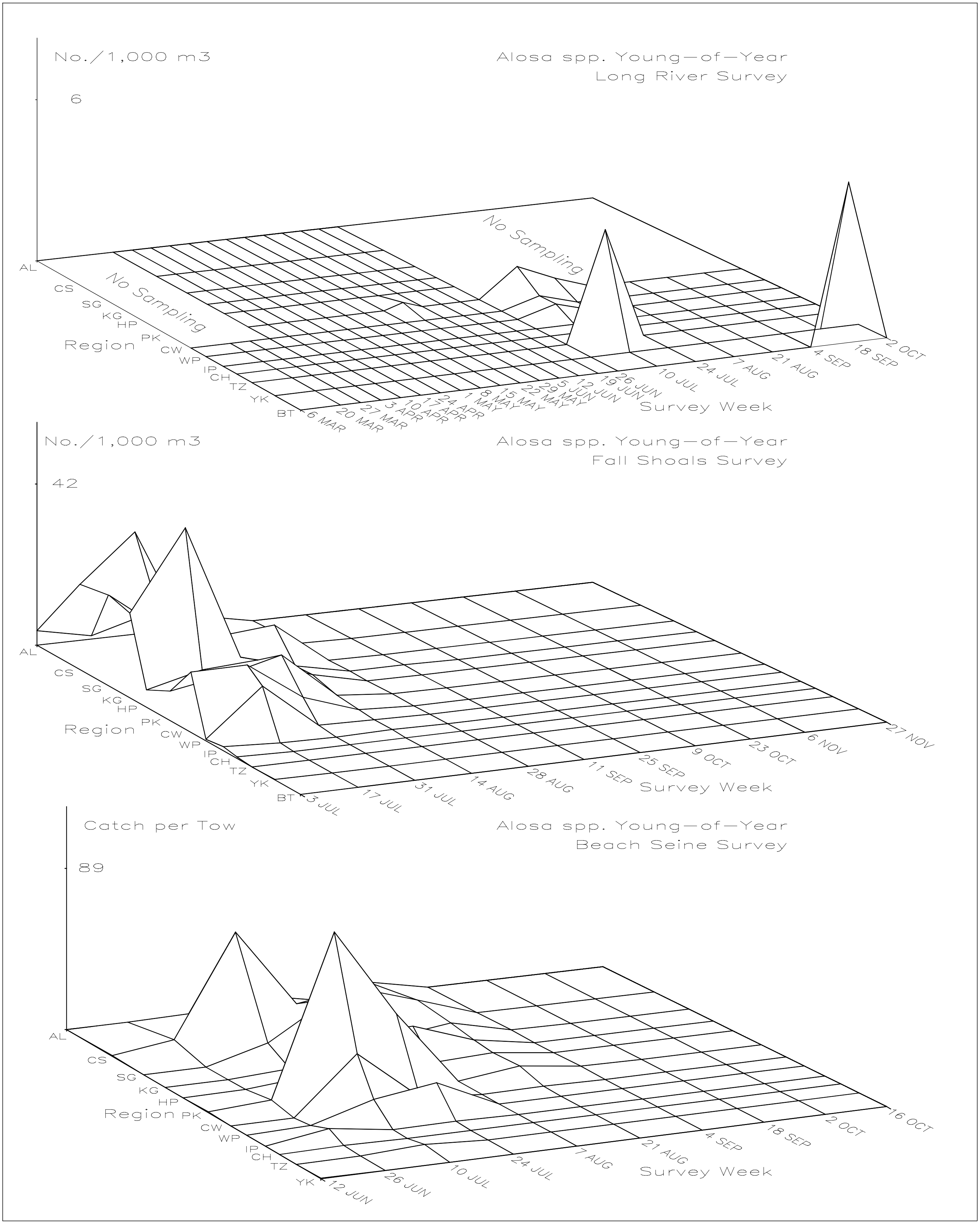

Figure 4-39. Spatiotemporal distribution of young-of-year Alosa spp. in the Hudson River estuary based on the 2000 Long River, Fall Shoals, and Beach Seine surveys.

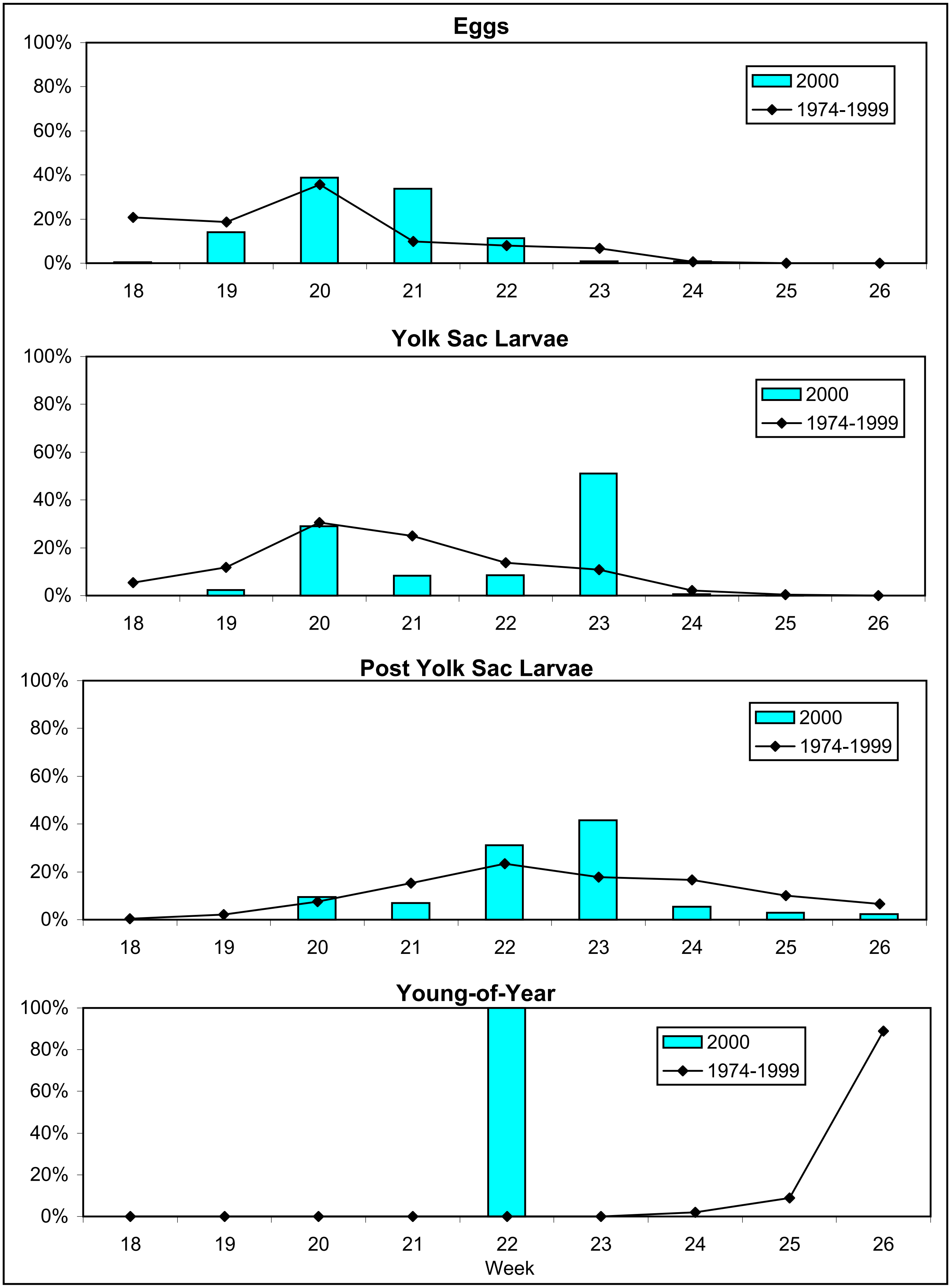

Figure 4-40. Temporal distribution indices for *Alosa* spp. collected during Long River surveys of the Hudson River estuary, 1974-2000.

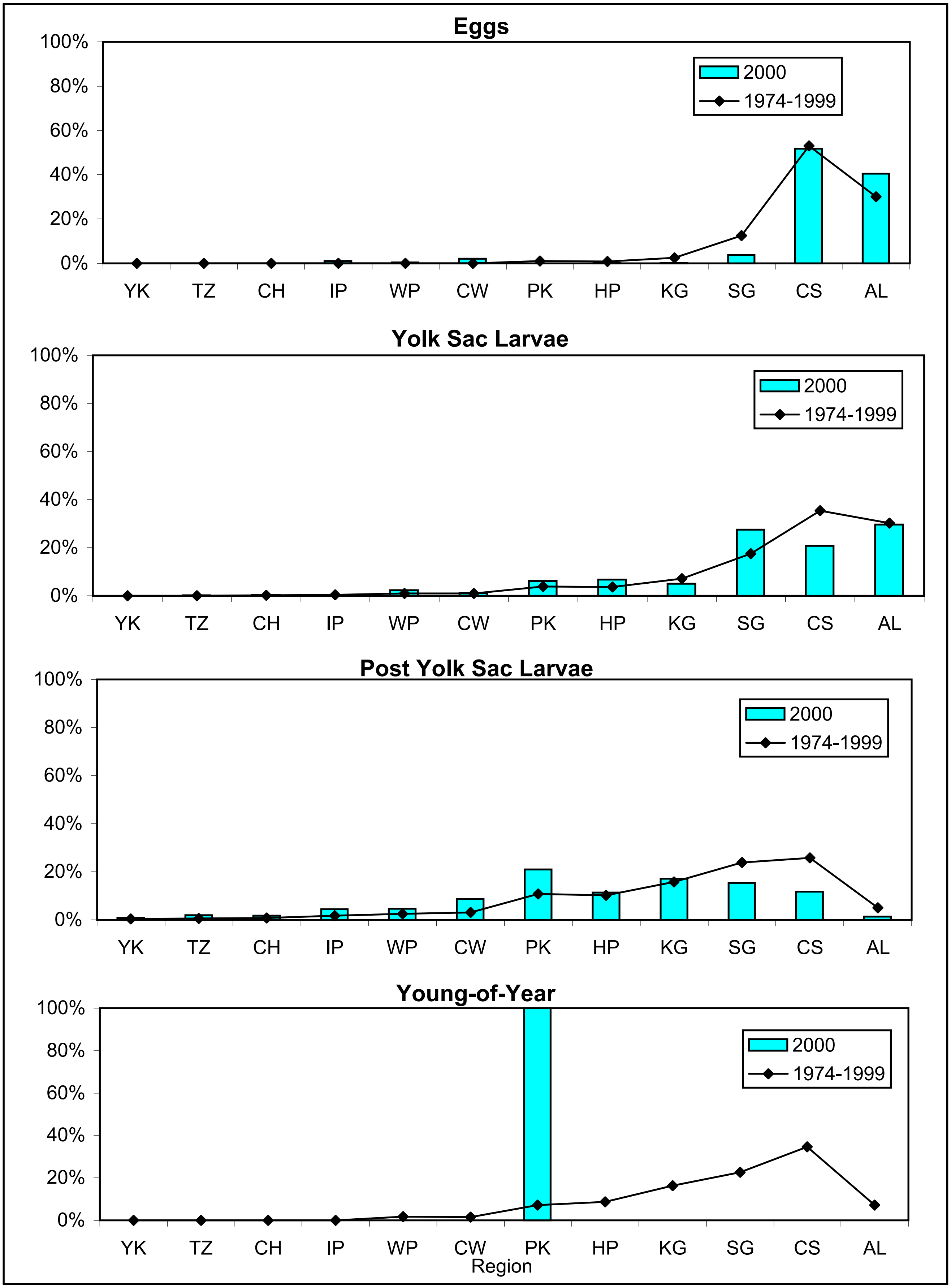

Figure 4-41. Geographic distribution indices for *Alosa* spp. collected during Long River surveys of the Hudson River estuary, 1974-2000.

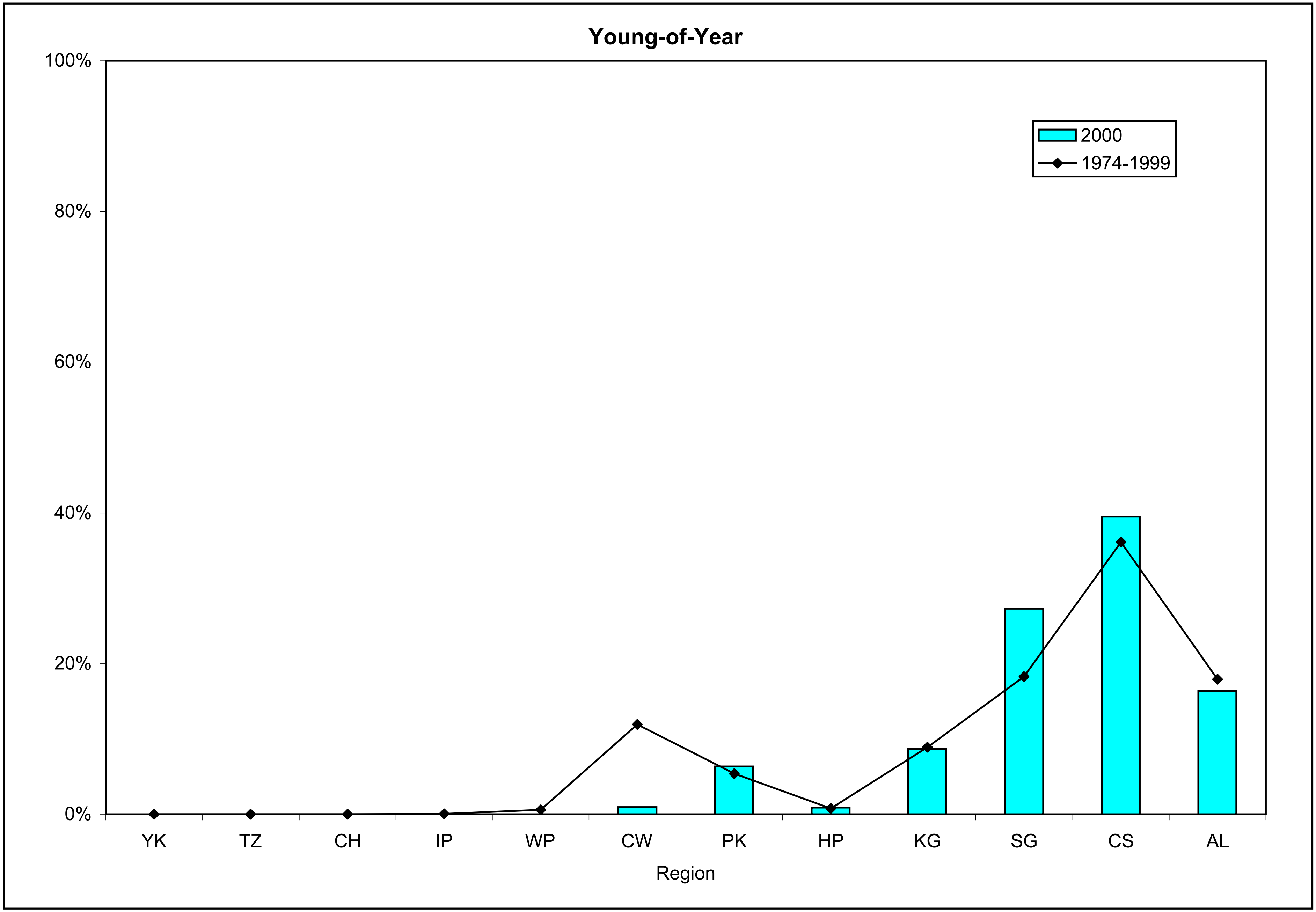

Figure 4-42. Geographic distribution indices for *Alosa* spp. collected during Beach Seine surveys of the Hudson River estuary, 1974-2000.

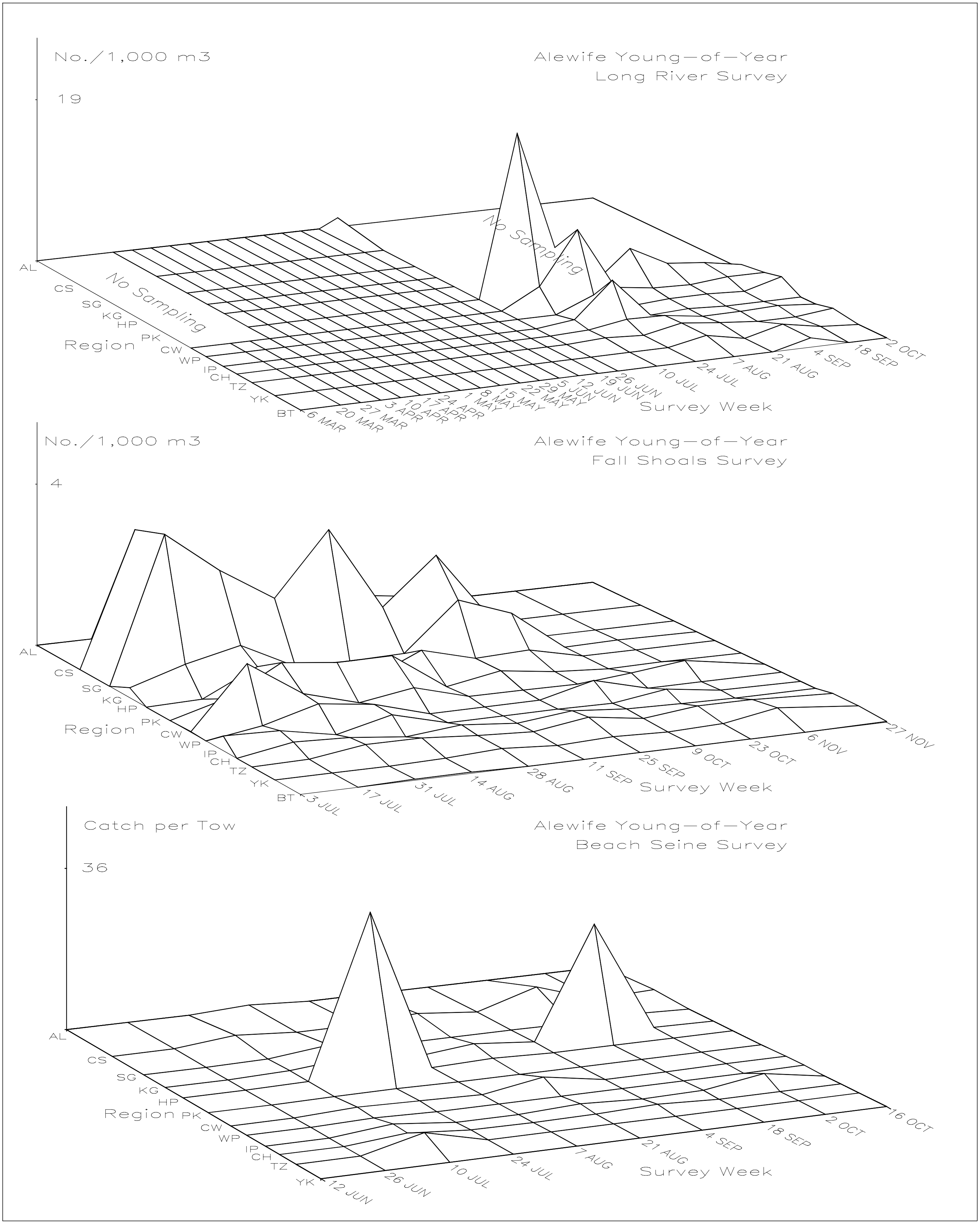

Figure 4-43. Spatiotemporal distribution of young-of-year alewife in the Hudson River estuary based on the 2000 Long River, Fall Shoals, and Beach Seine surveys.

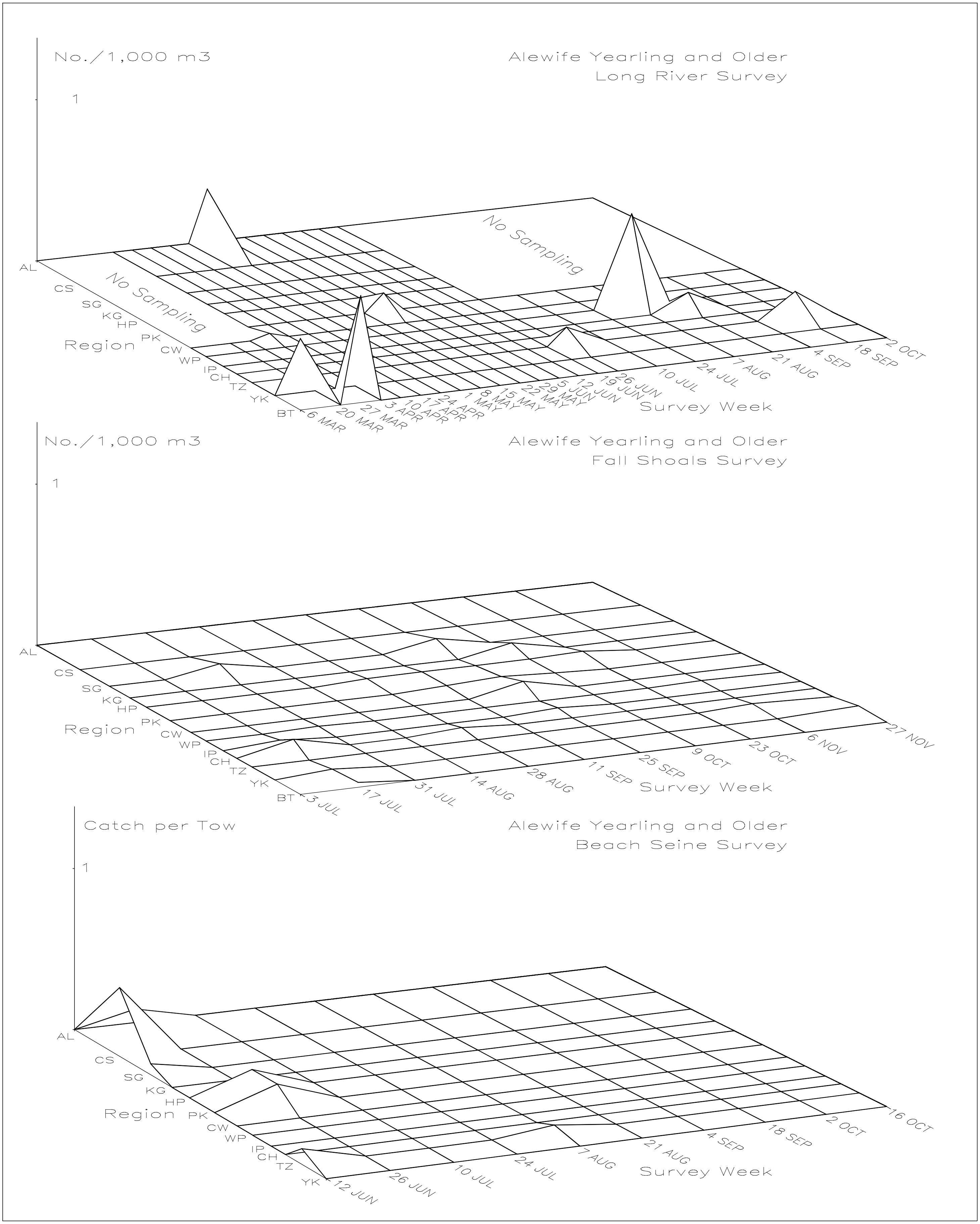

Figure 4–44. Spatiotemporal distribution of yearling and older alewife in the Hudson River estuary based on the 2000 Long River, Fall Shoals, and Beach Seine surveys.

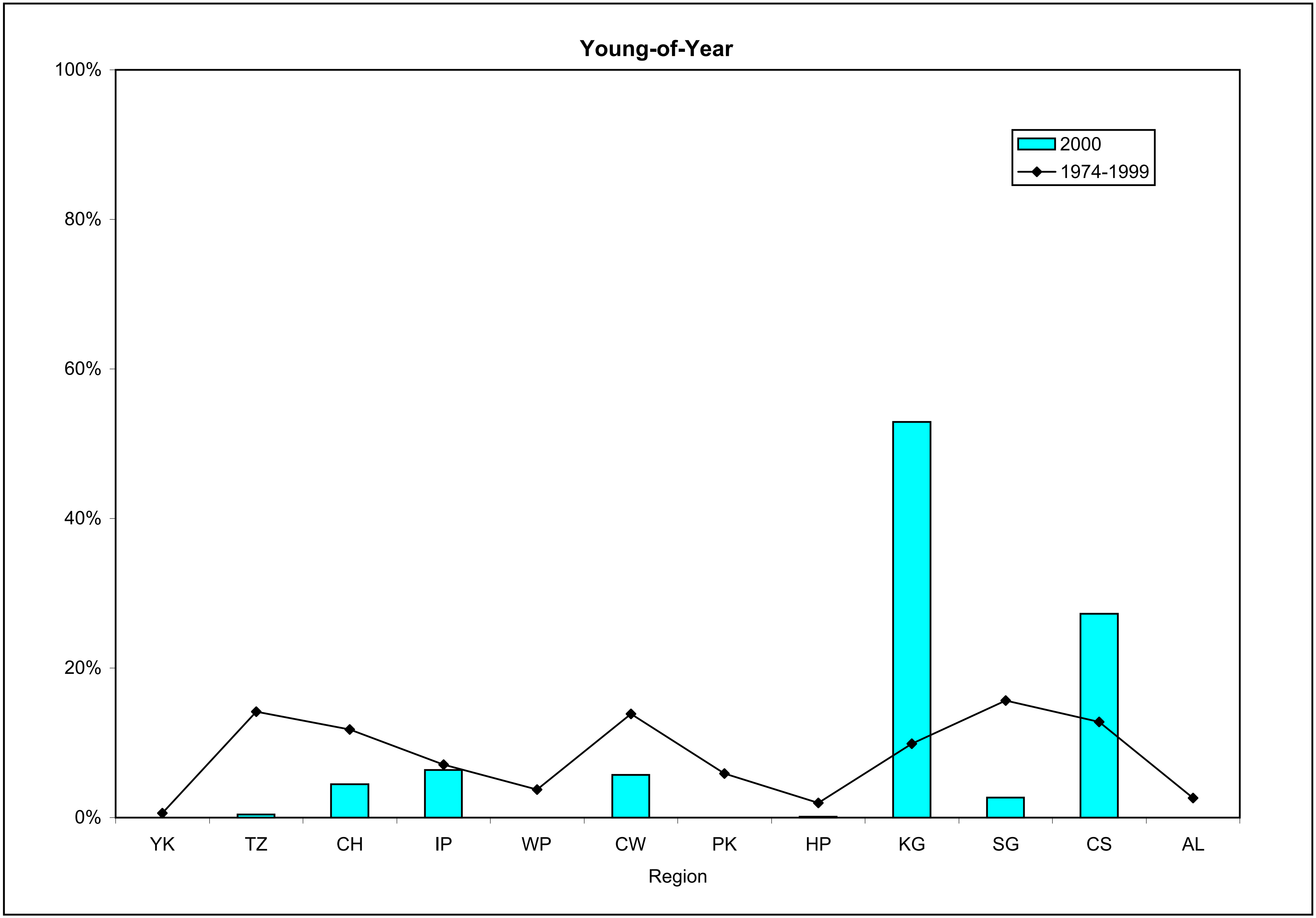

Figure 4-45. Geographic distribution indices for alewife collected during Beach Seine surveys of the Hudson River estuary, 1974-2000.

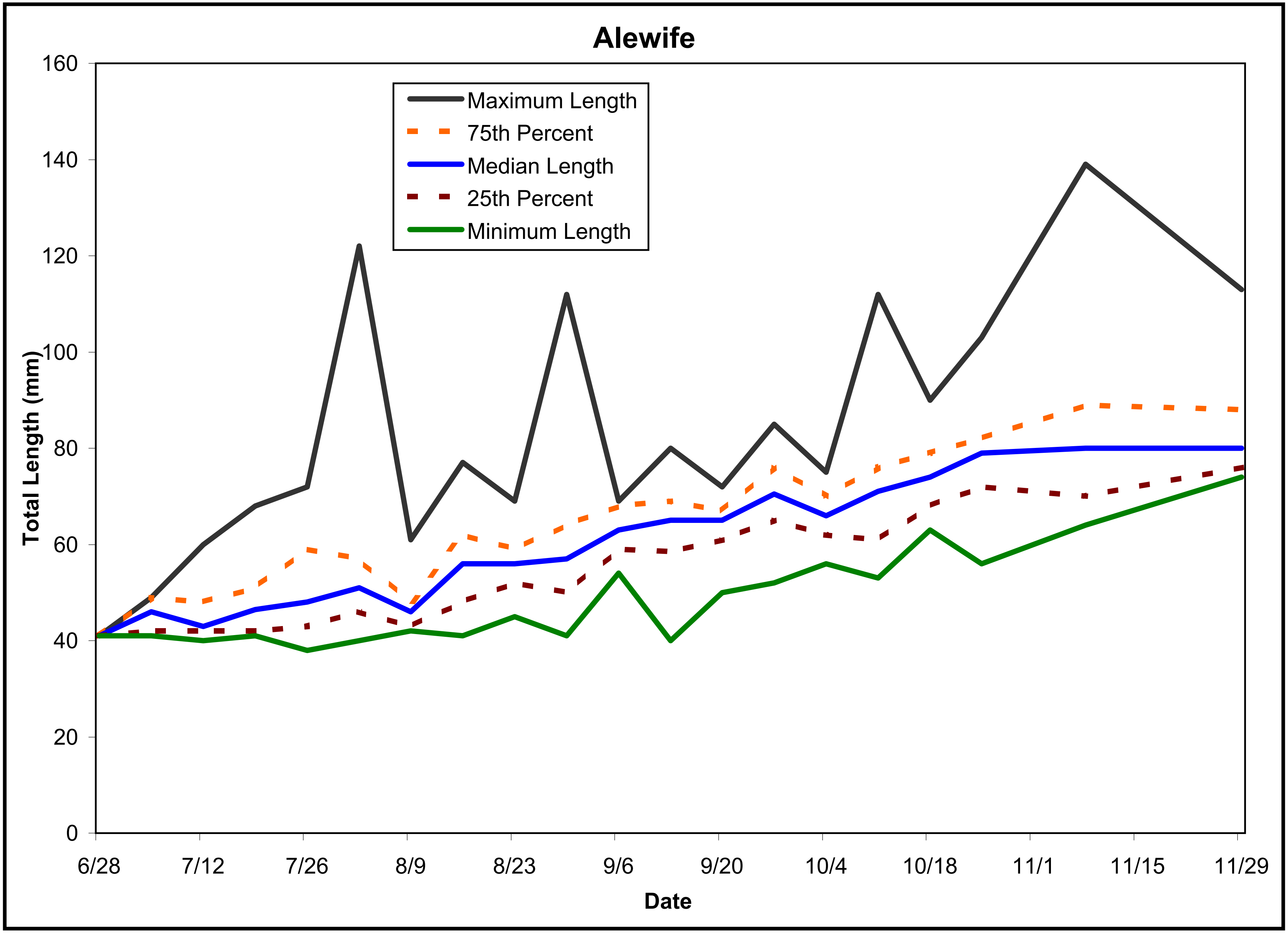

Figure 4-46. Weekly length statistics for young-of-year alewife in the Hudson River estuary, 2000.

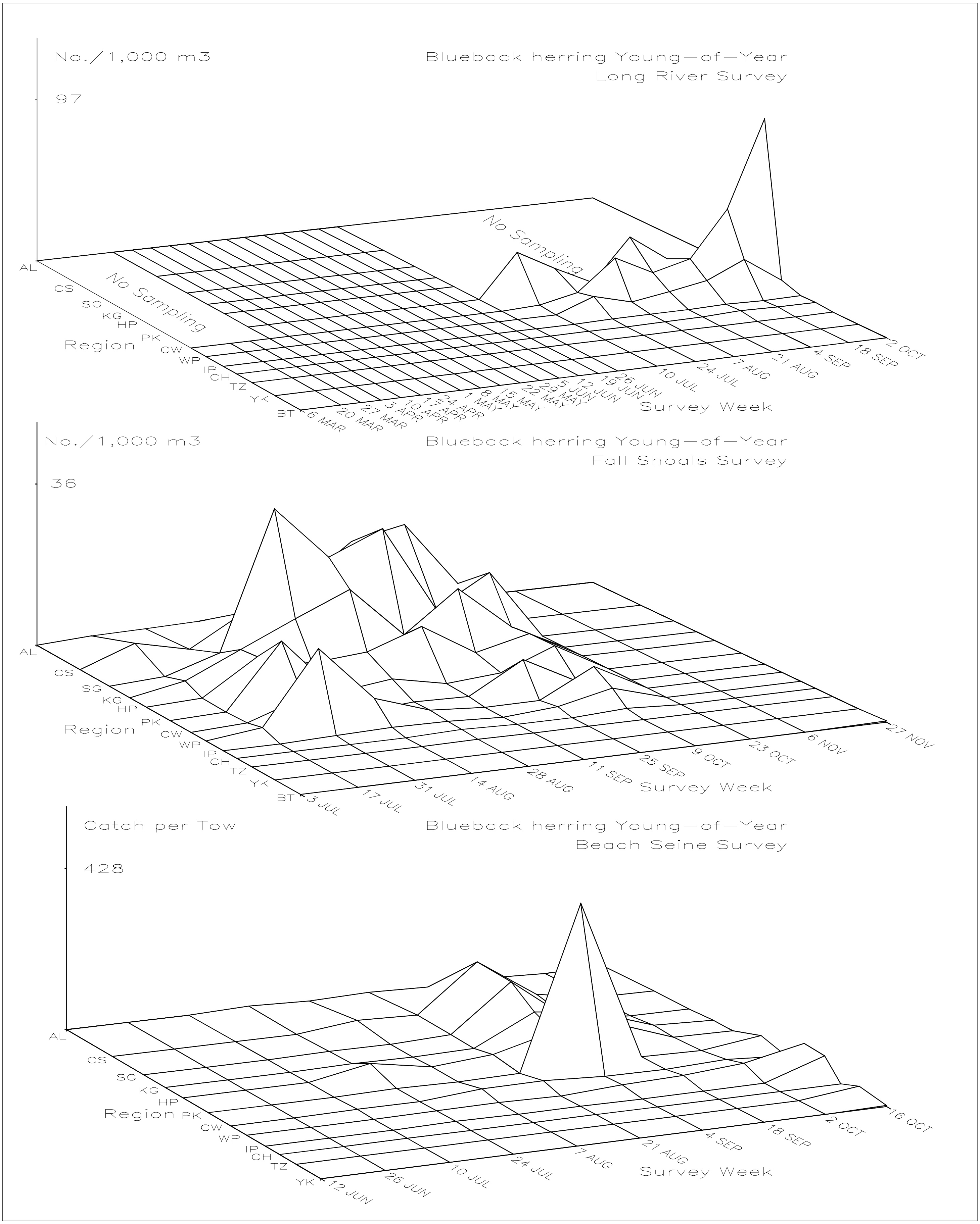

Figure 4-47. Spatiotemporal distribution of young-of-year blueback herring in the Hudson River estuary based on the 2000 Long River, Fall Shoals, and Beach Seine surveys.

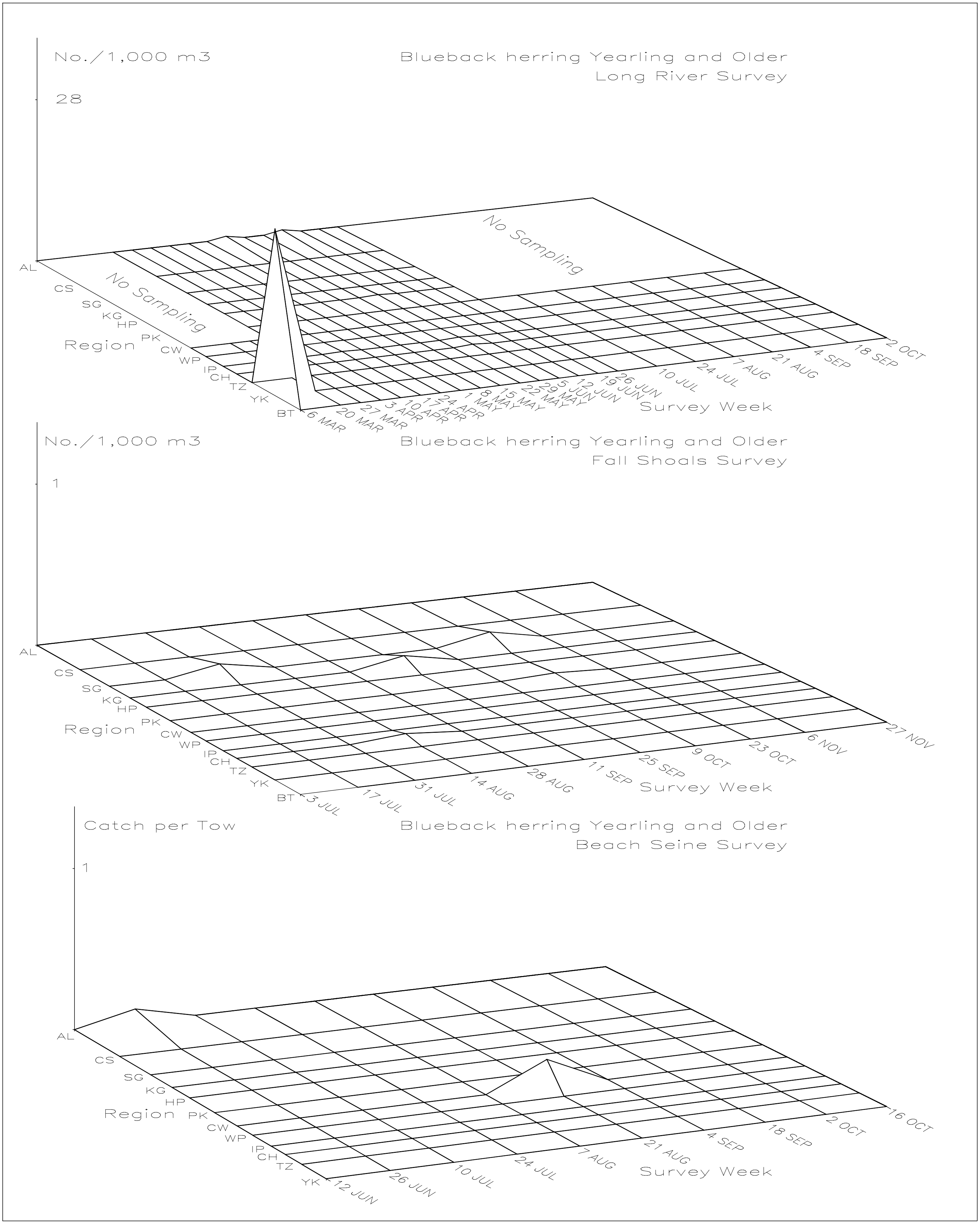

Figure 4–48. Spatiotemporal distribution of yearling and older blueback herring in the Hudson River estuary based on the 2000 Long River, Fall Shoals, and Beach Seine surveys.

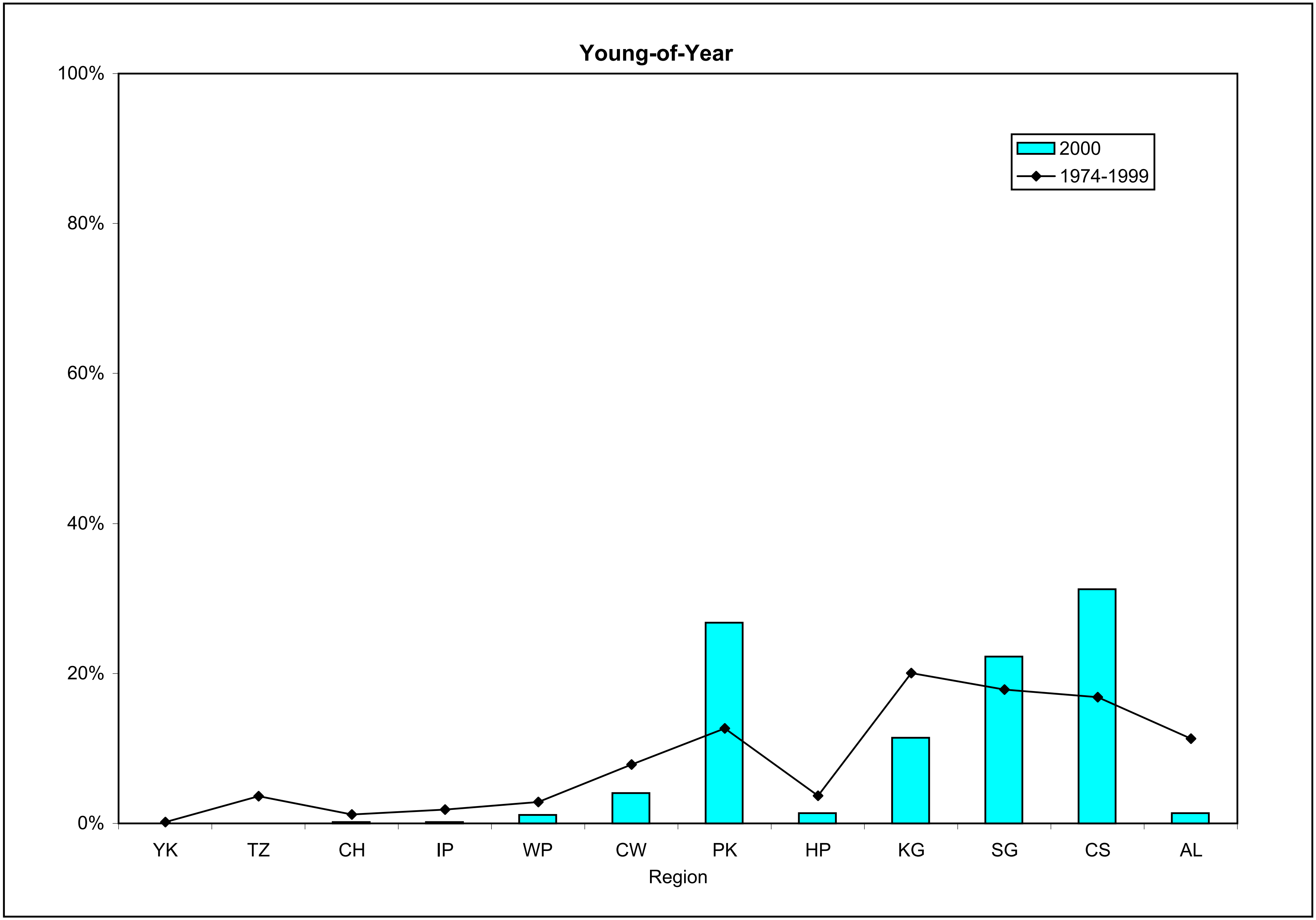

Figure 4-49. Geographic distribution indices for blueback herring collected during Beach Seine surveys of the Hudson River estuary, 1974-2000.

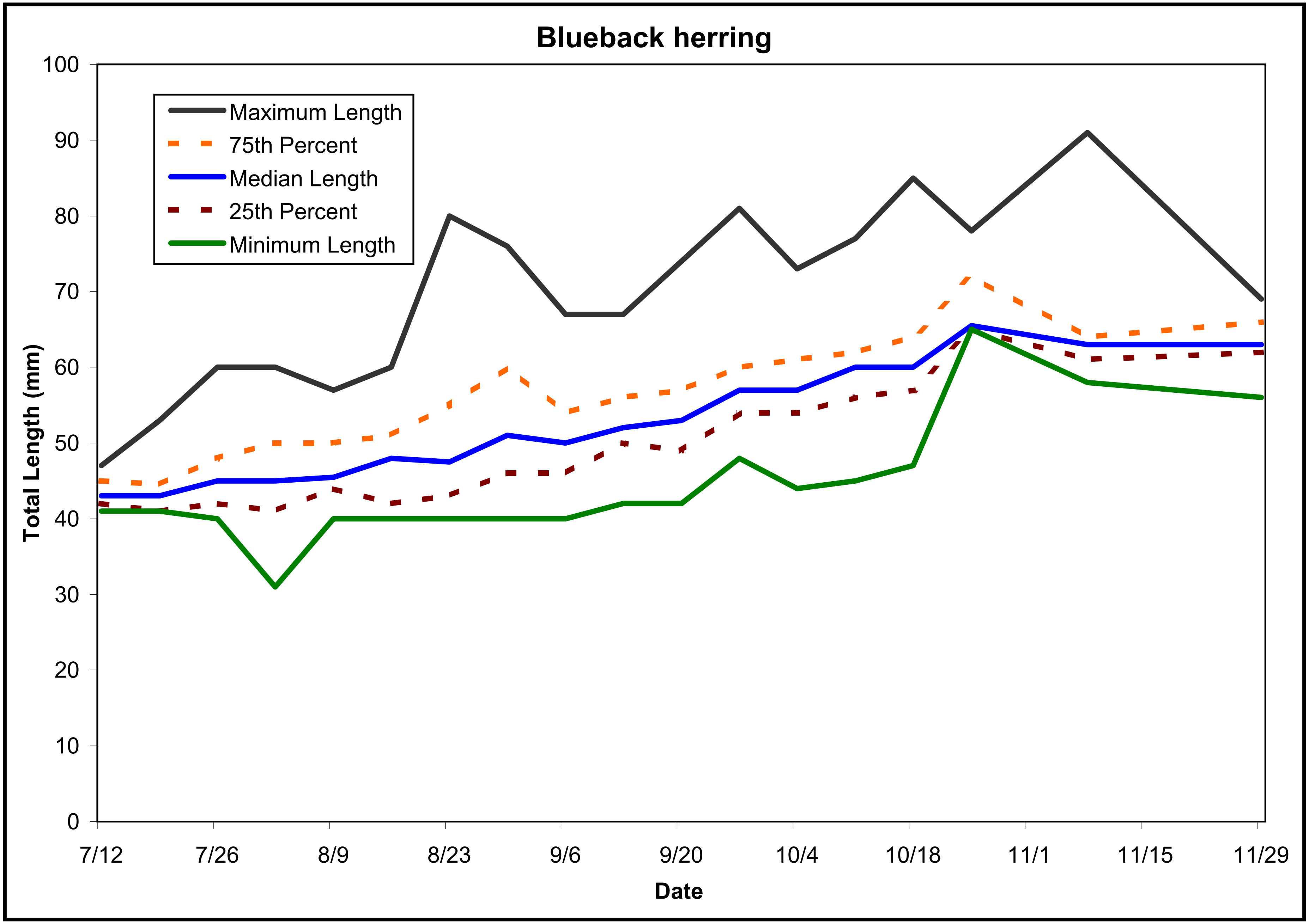

Figure 4-50. Weekly length statistics for young-of-year blueback herring in the Hudson River estuary, 2000.

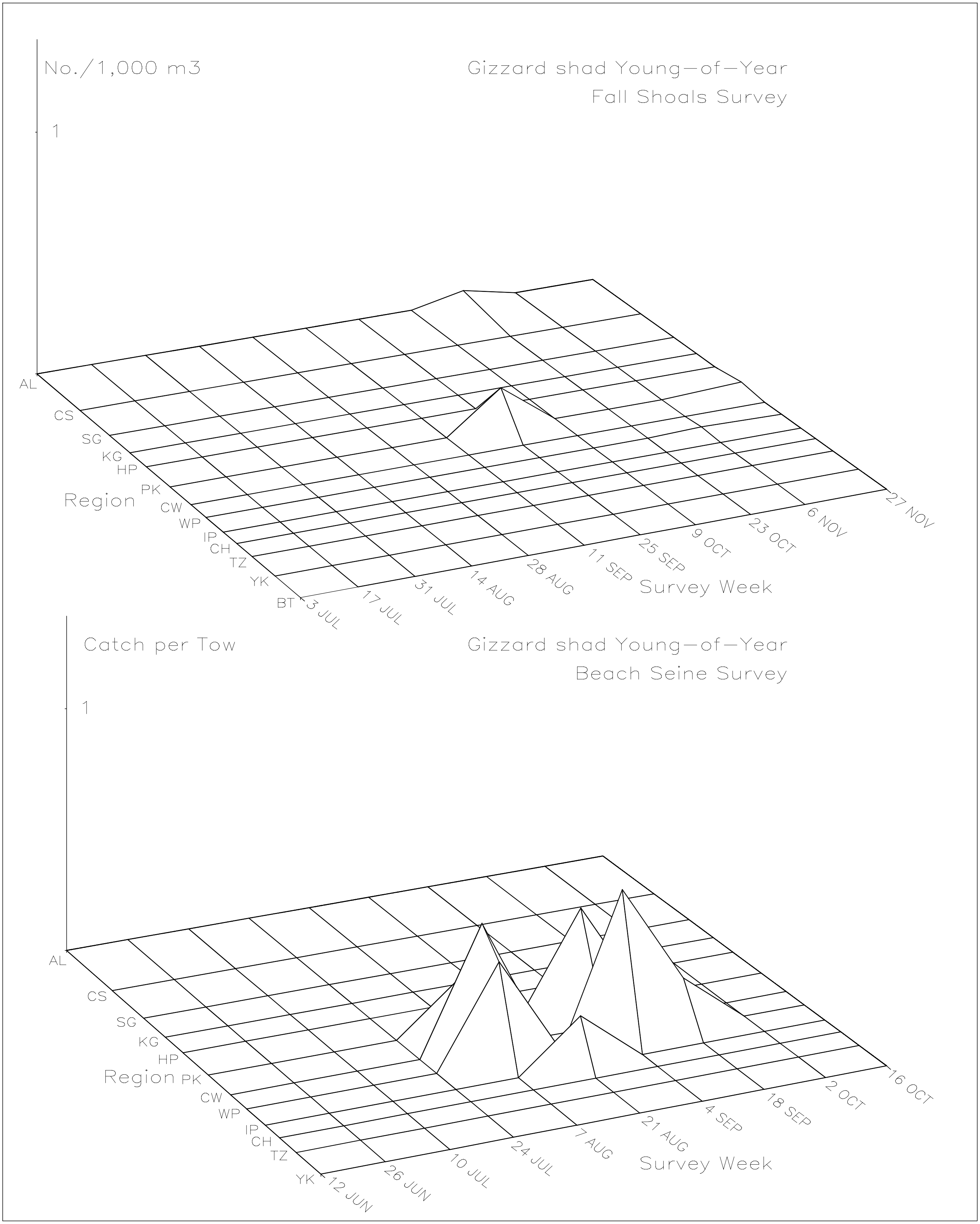

Figure 4–51. Spatiotemporal distribution of young–of–year gizzard shad in the Hudson River estuary based on the 2000 Fall Shoals and Beach Seine surveys.

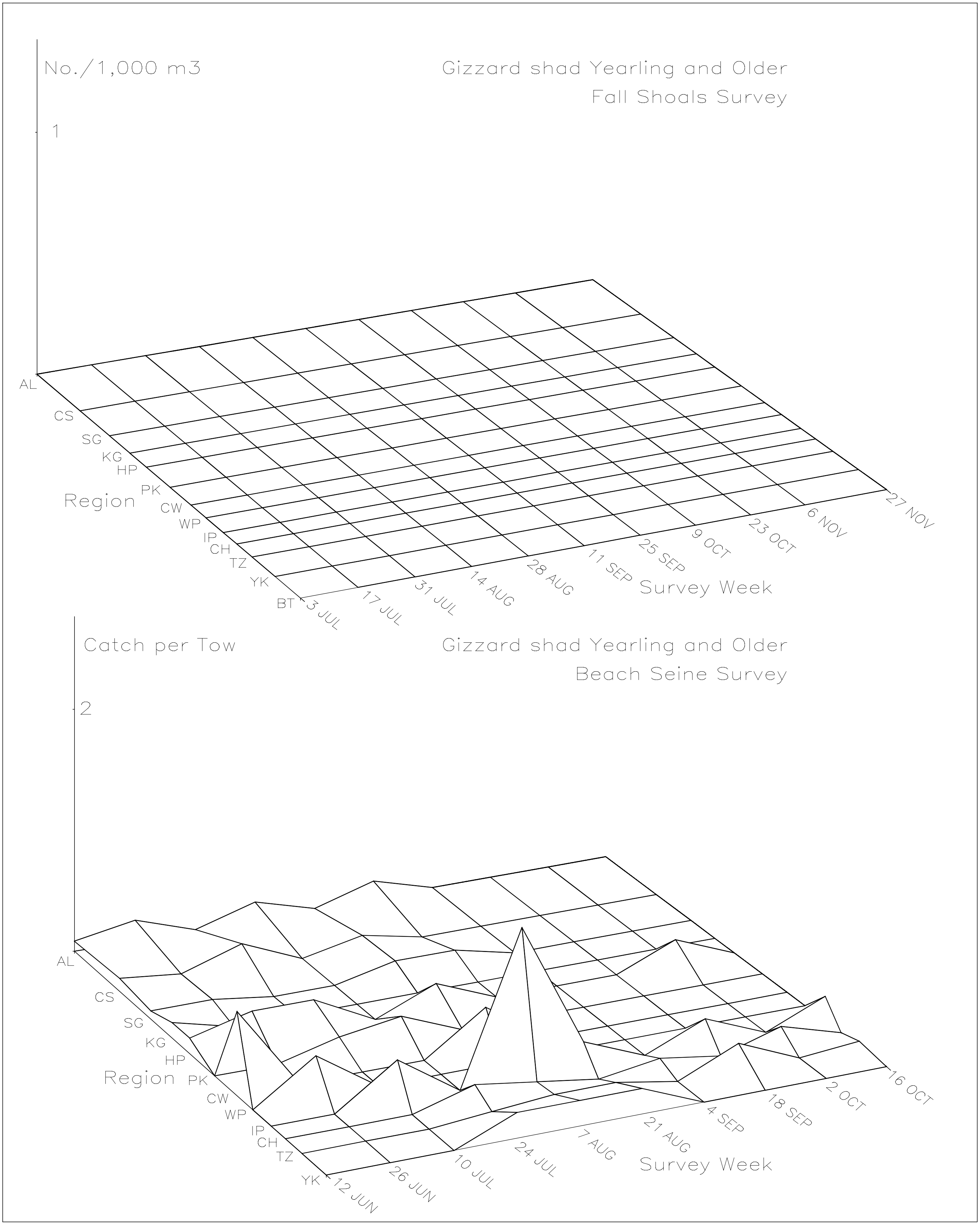

Figure 4–52. Spatiotemporal distribution of yearling and older gizzard shad in the Hudson River estuary based on the 2000 Fall Shoals and Beach Seine surveys.

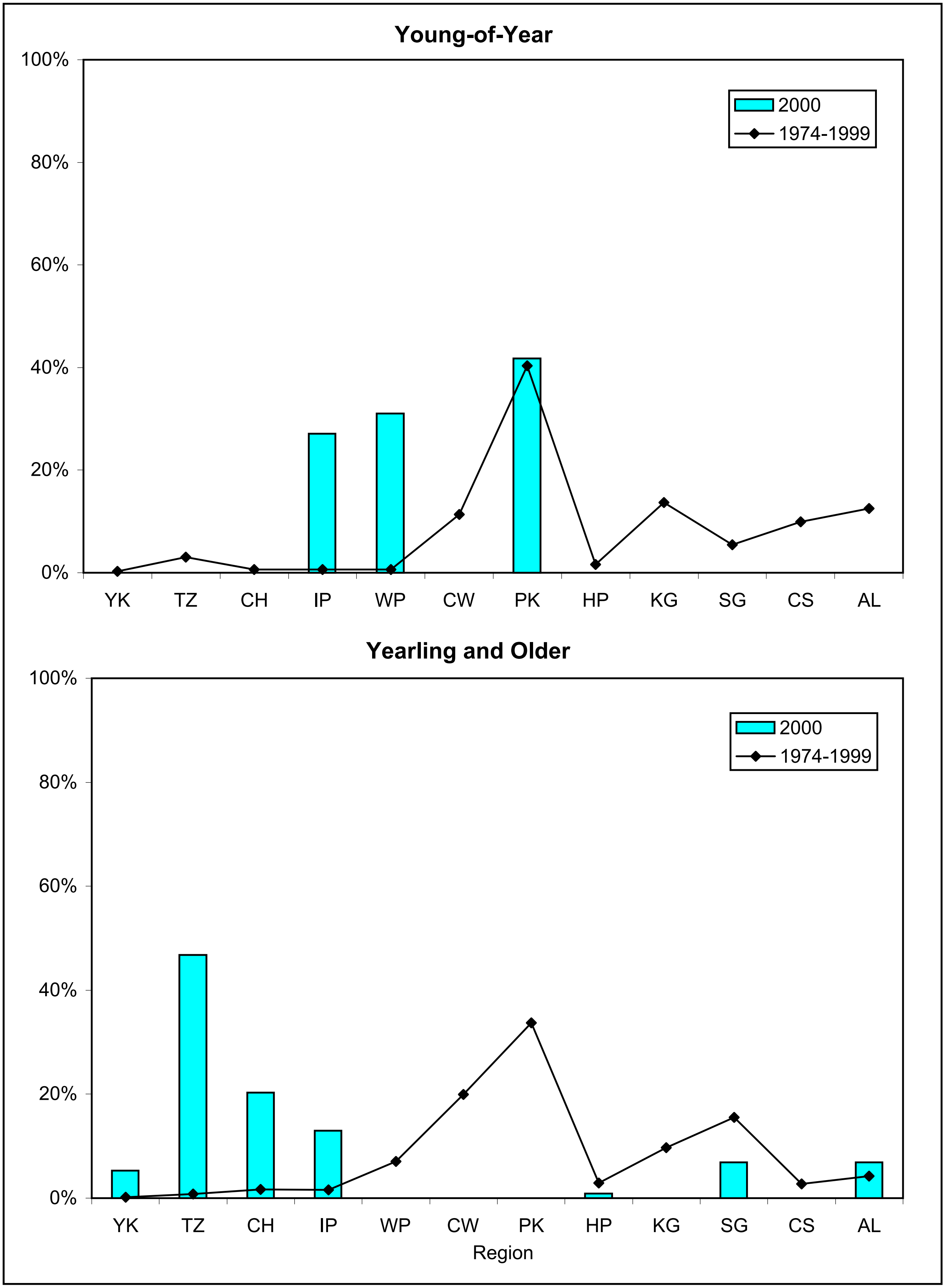

Figure 4-53. Geographic distribution indices for gizzard shad collected during Beach Seine surveys of the Hudson River estuary, 1974-2000.

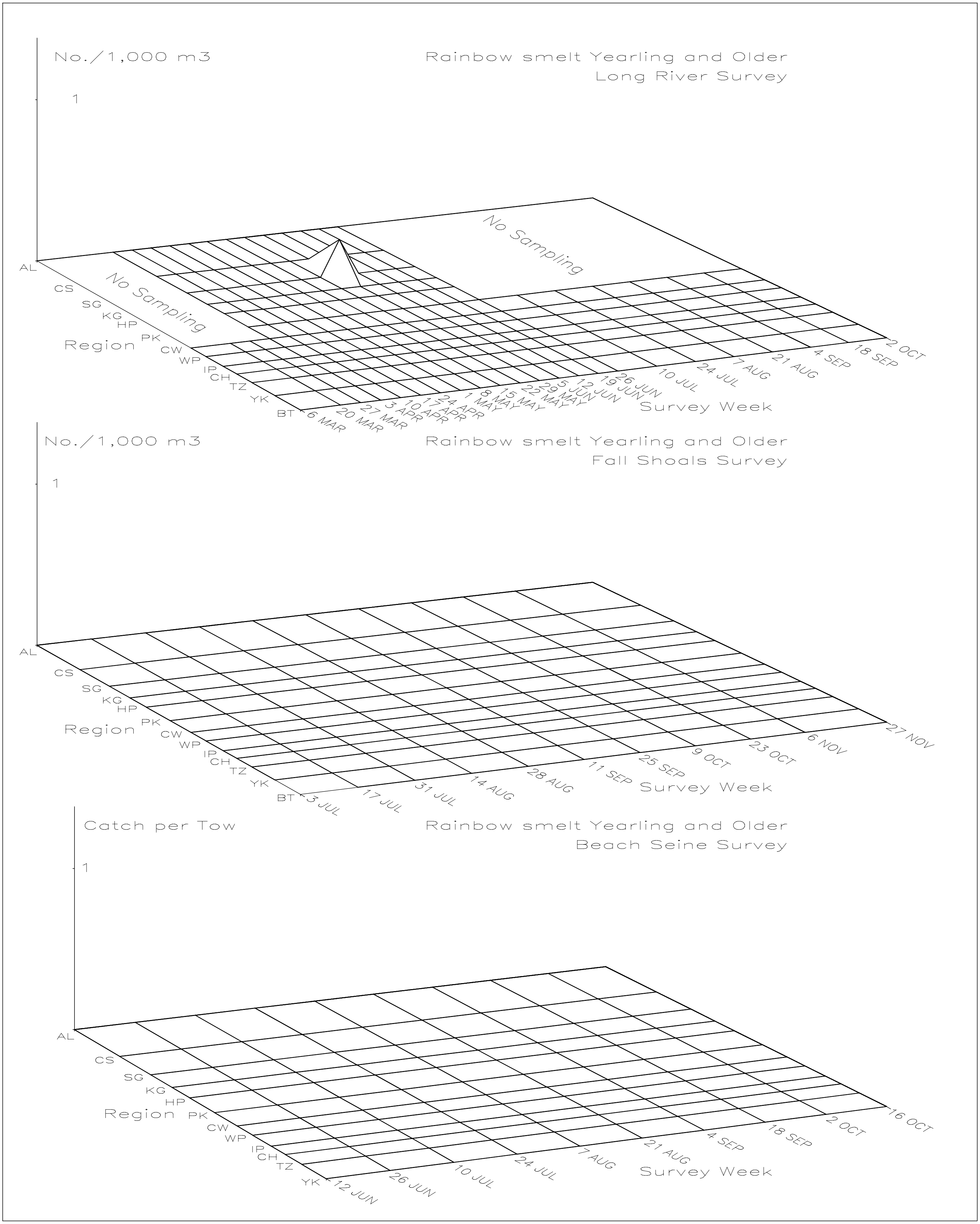

Figure 4–54. Spatiotemporal distribution of yearling and older rainbow smelt in the Hudson River estuary based on the 2000 Long River, Fall Shoals, and Beach Seine surveys.

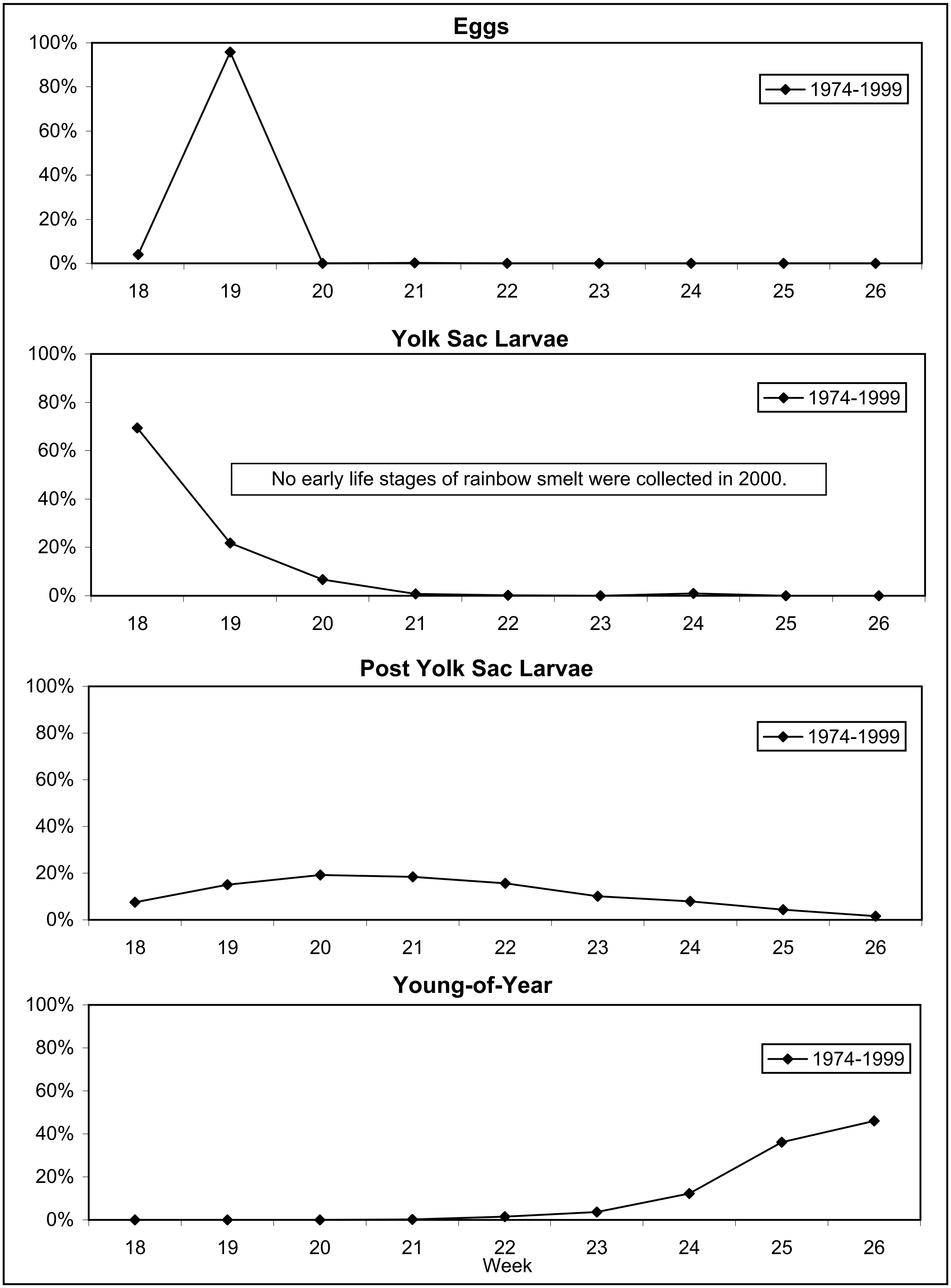

Figure 4-55. Temporal distribution indices for rainbow smelt collected during Long River surveys of the Hudson River estuary, 1974-2000.

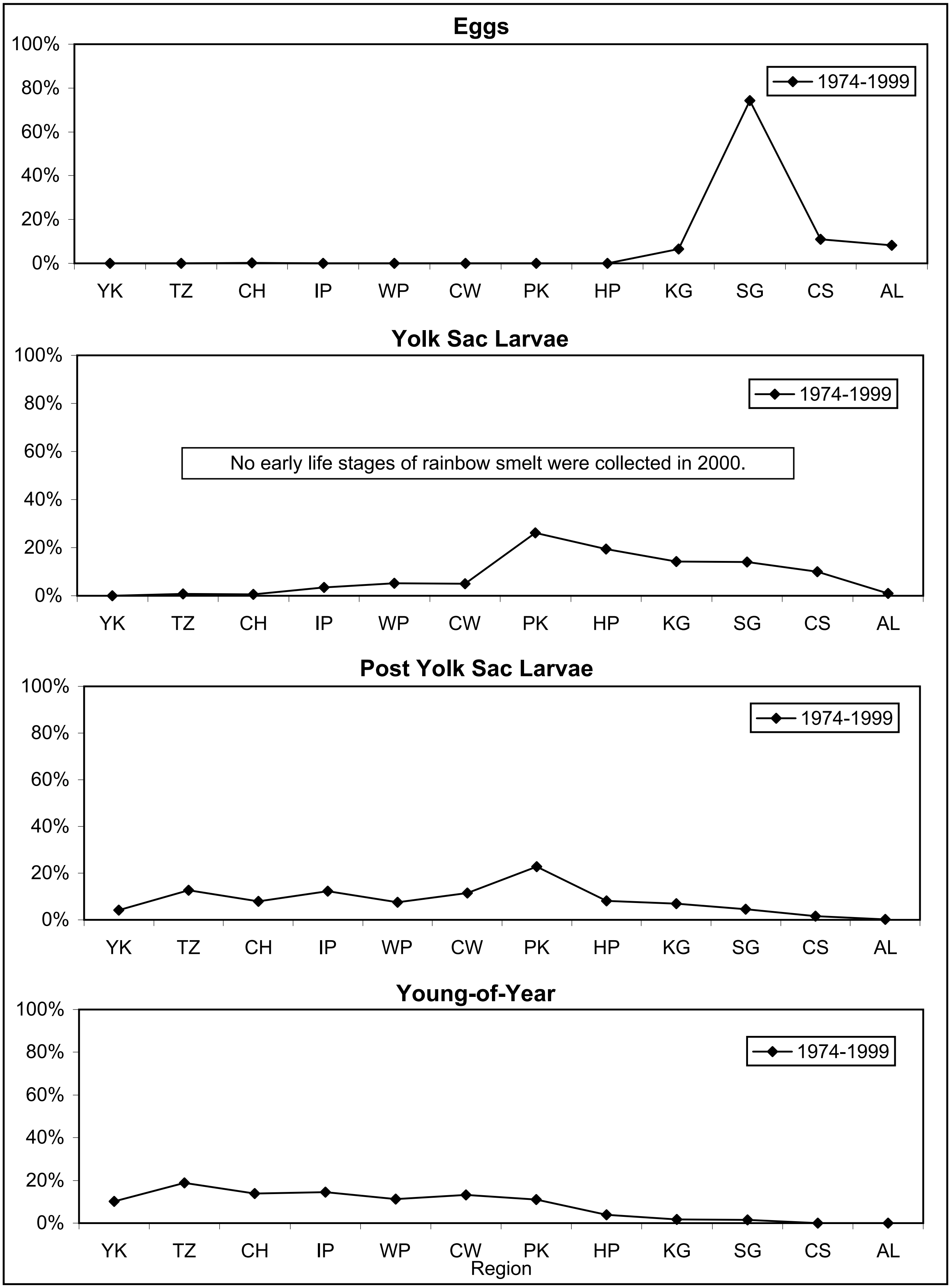

Figure 4-56. Geographic distribution indices for rainbow smelt collected during Long River surveys of the Hudson River estuary, 1974-2000.

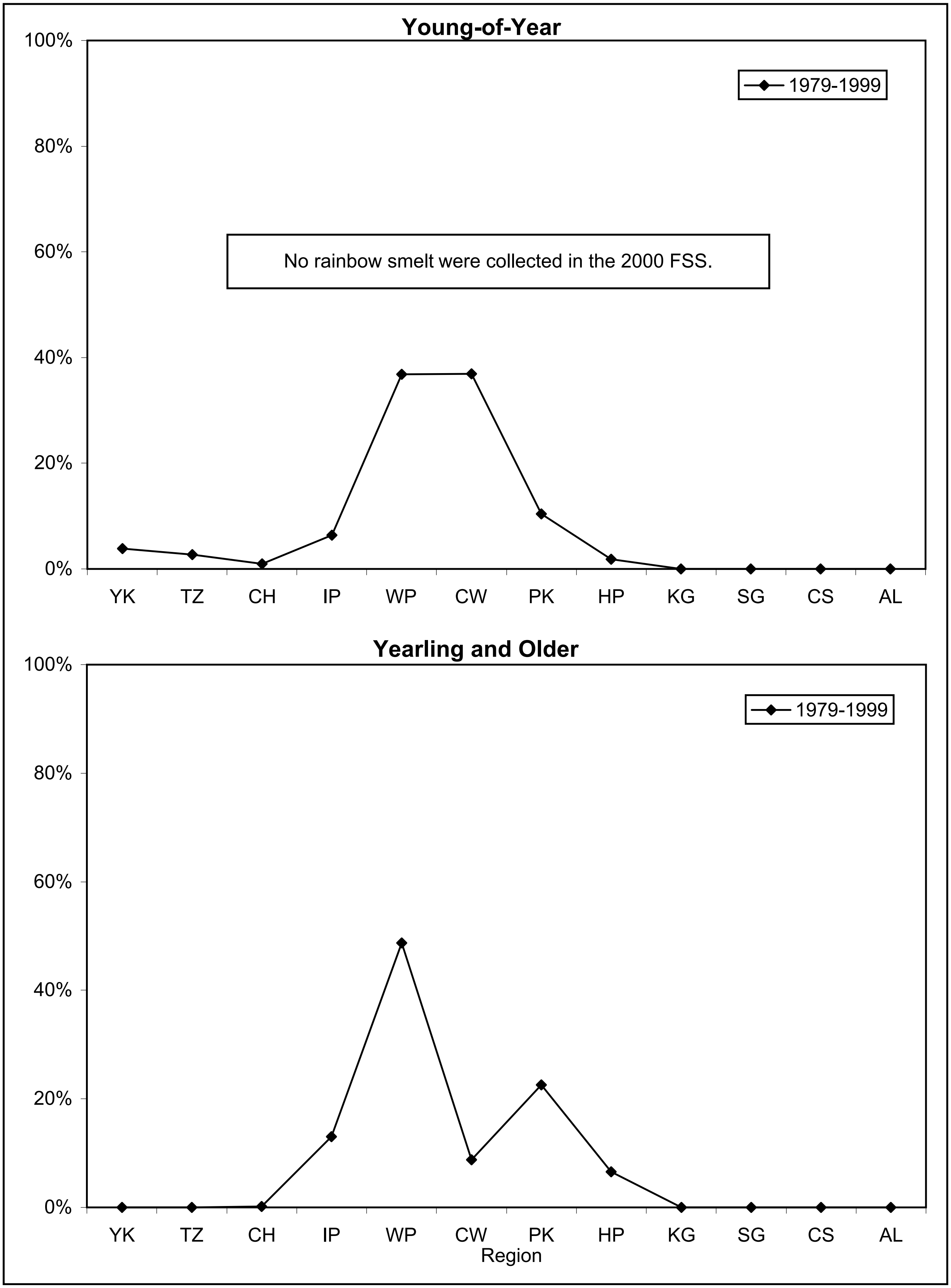

Figure 4-57. Geographic distribution indices for rainbow smelt collected during Fall Shoals surveys of the Hudson River estuary, 1979-2000.

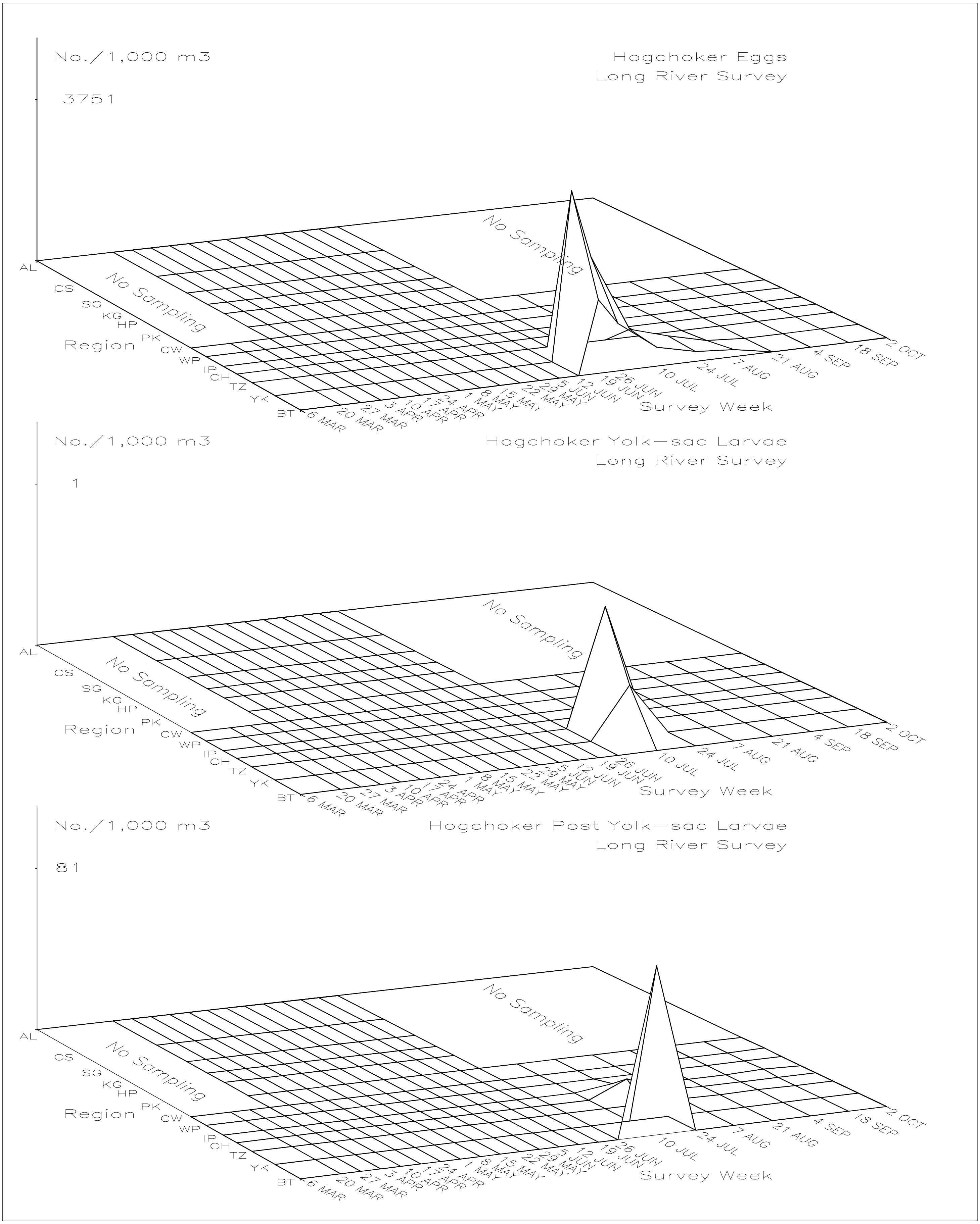

Figure 4-58. Spatiotemporal distribution of eggs, yolk-sac, and post yolk-sac larval hogchoker in the Hudson River estuary based on the 2000 Long River Survey.

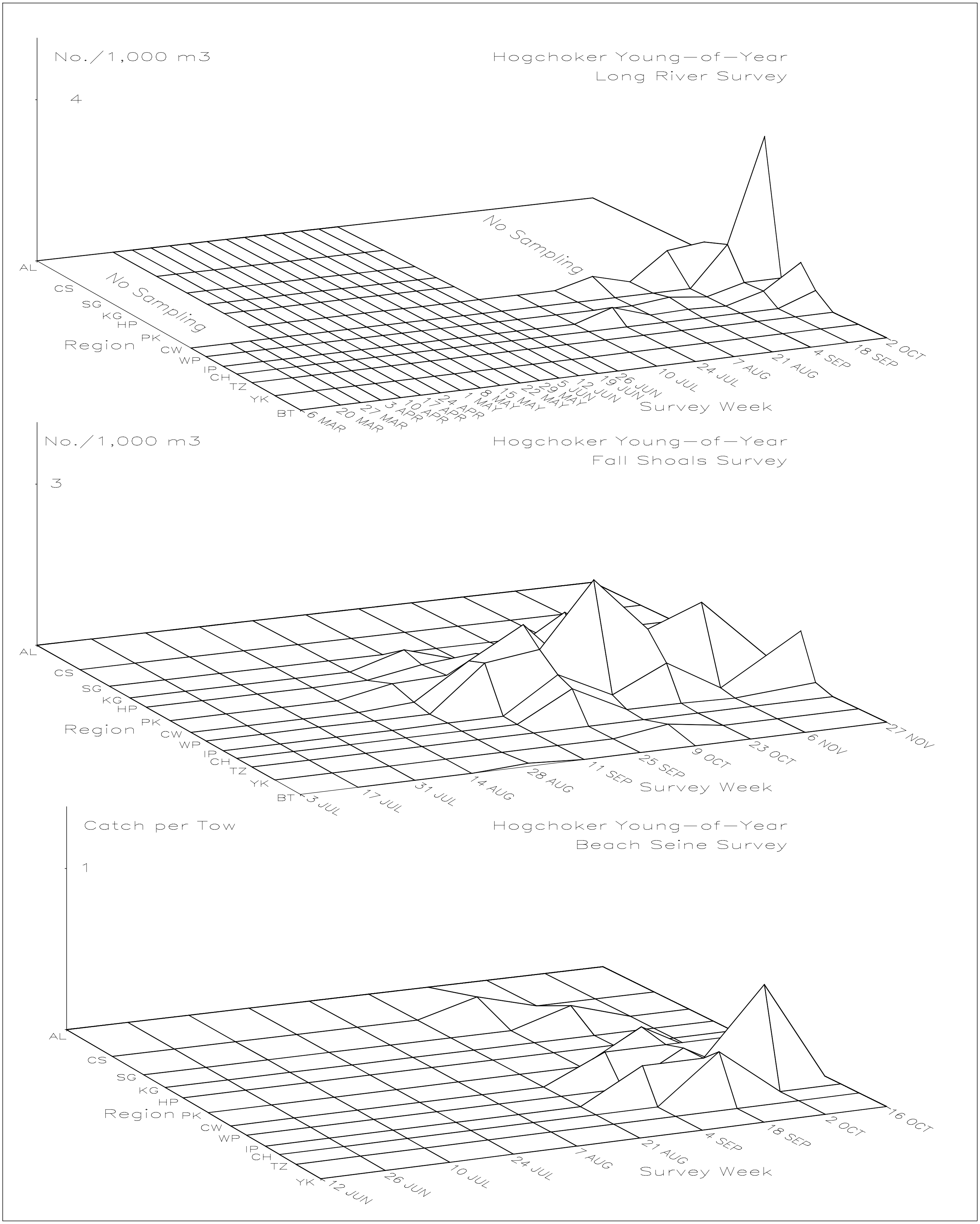

Figure 4-59. Spatiotemporal distribution of young-of-year hogchoker in the Hudson River estuary based on the 2000 Long River, Fall Shoals, and Beach Seine surveys.

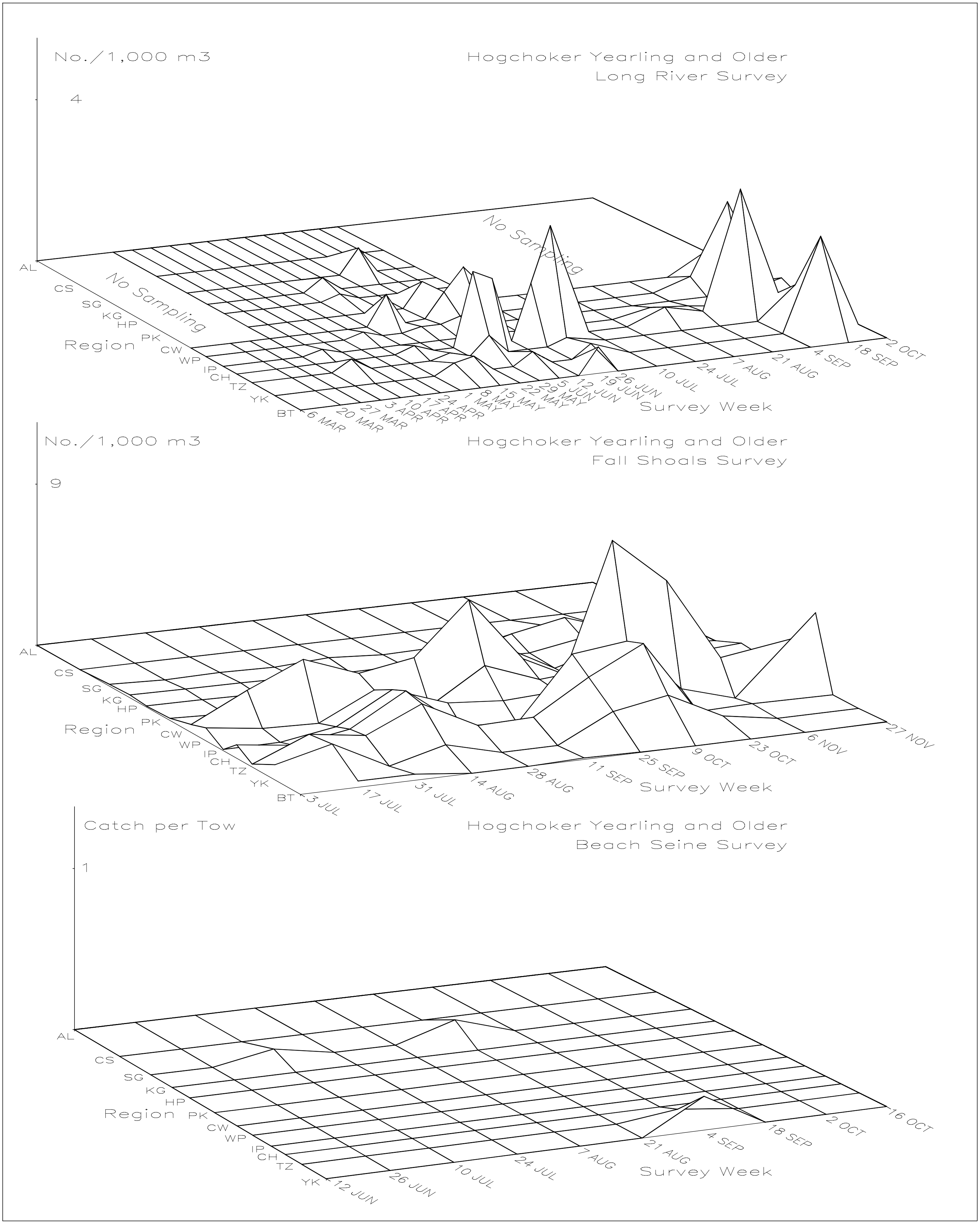

Figure 4-60. Spatiotemporal distribution of yearling and older hogchoker in the Hudson River estuary based on the 2000 Long River, Fall Shoals, and Beach Seine surveys.

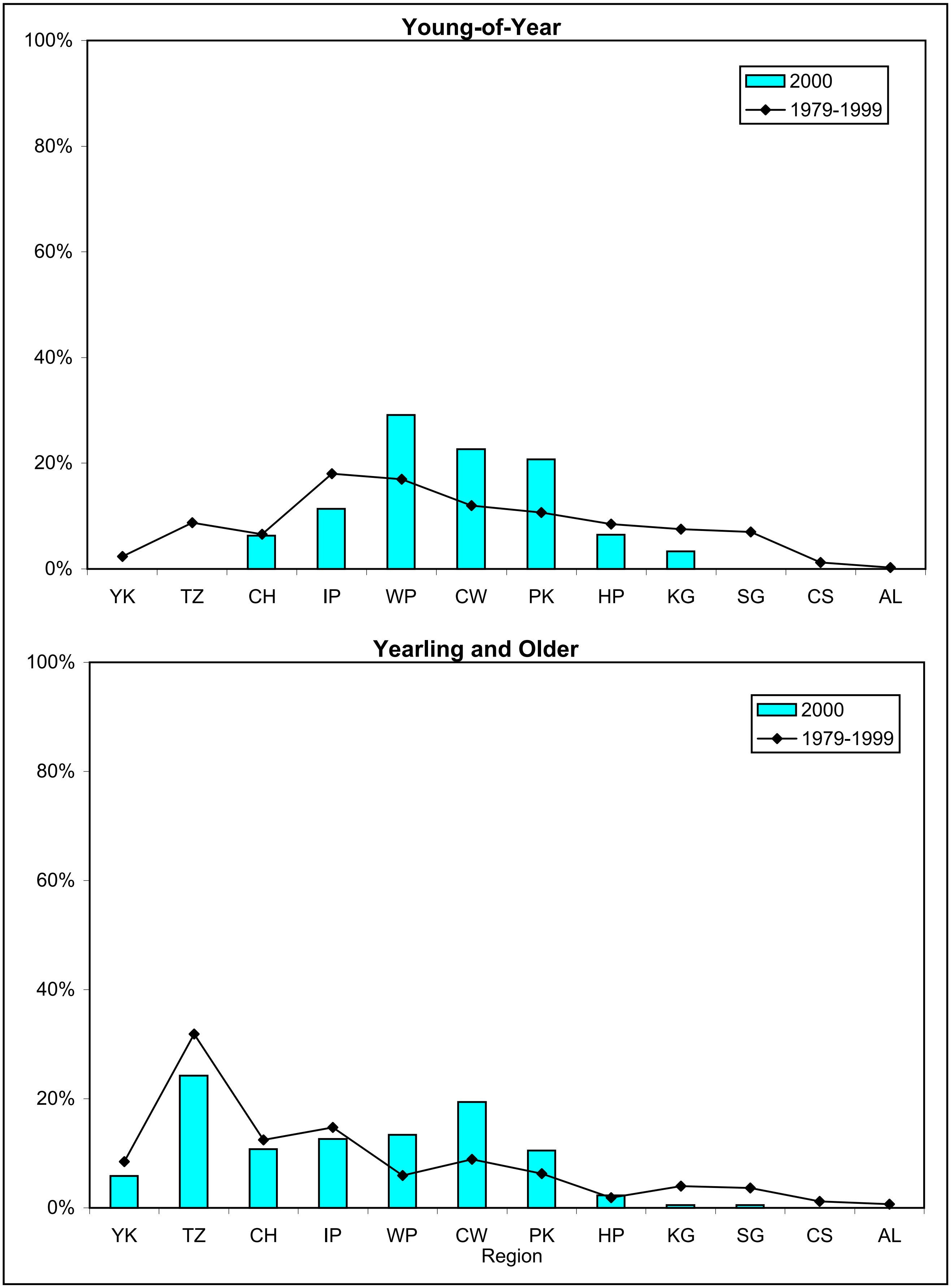

Figure 4-61. Geographic distribution indices for hogchoker collected during Fall Shoals surveys of the Hudson River estuary, 1979-2000.

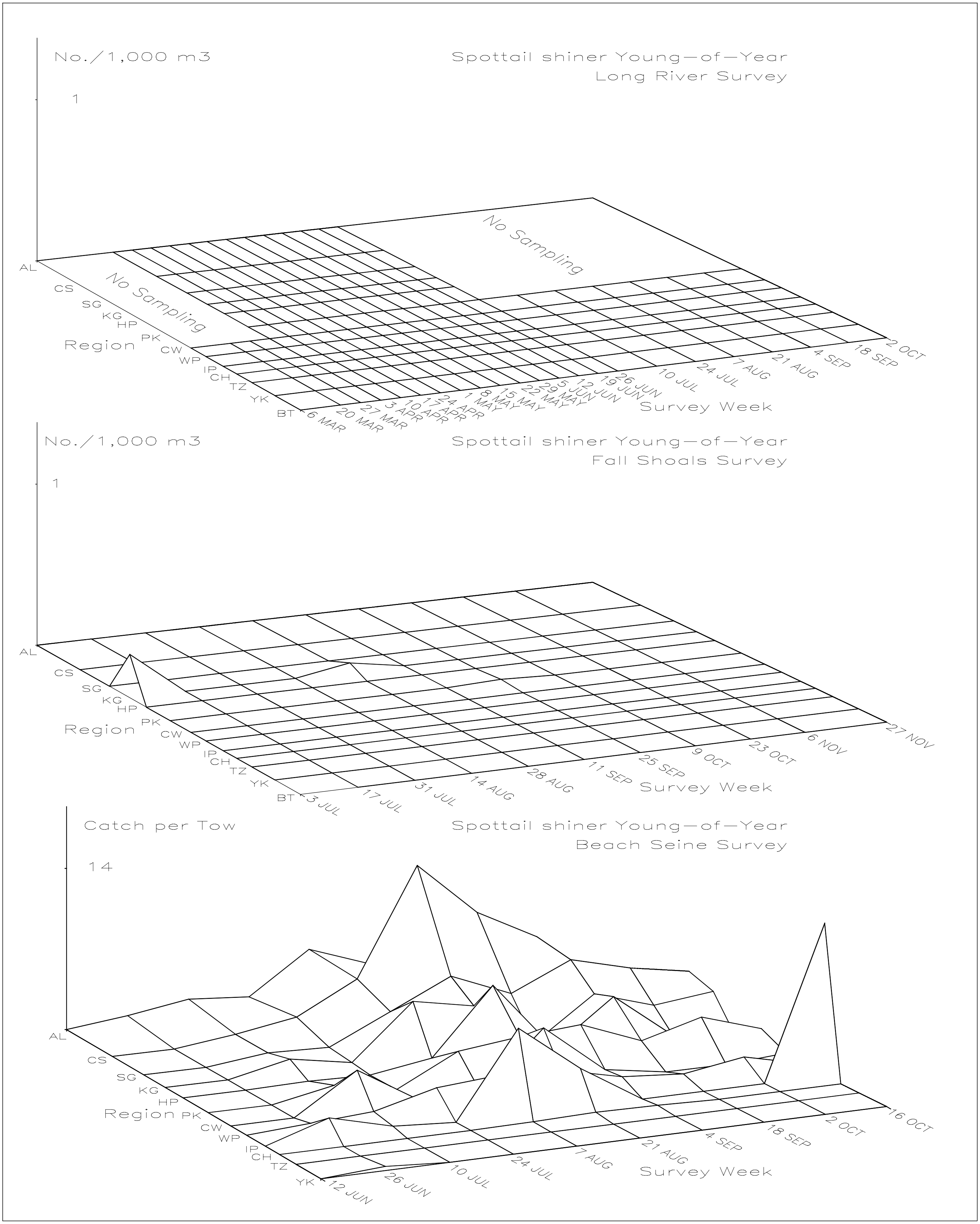

Figure 4–62. Spatiotemporal distribution of young–of–year spottail shiner in the Hudson River estuary based on the 2000 Long River, Fall Shoals, and Beach Seine surveys.

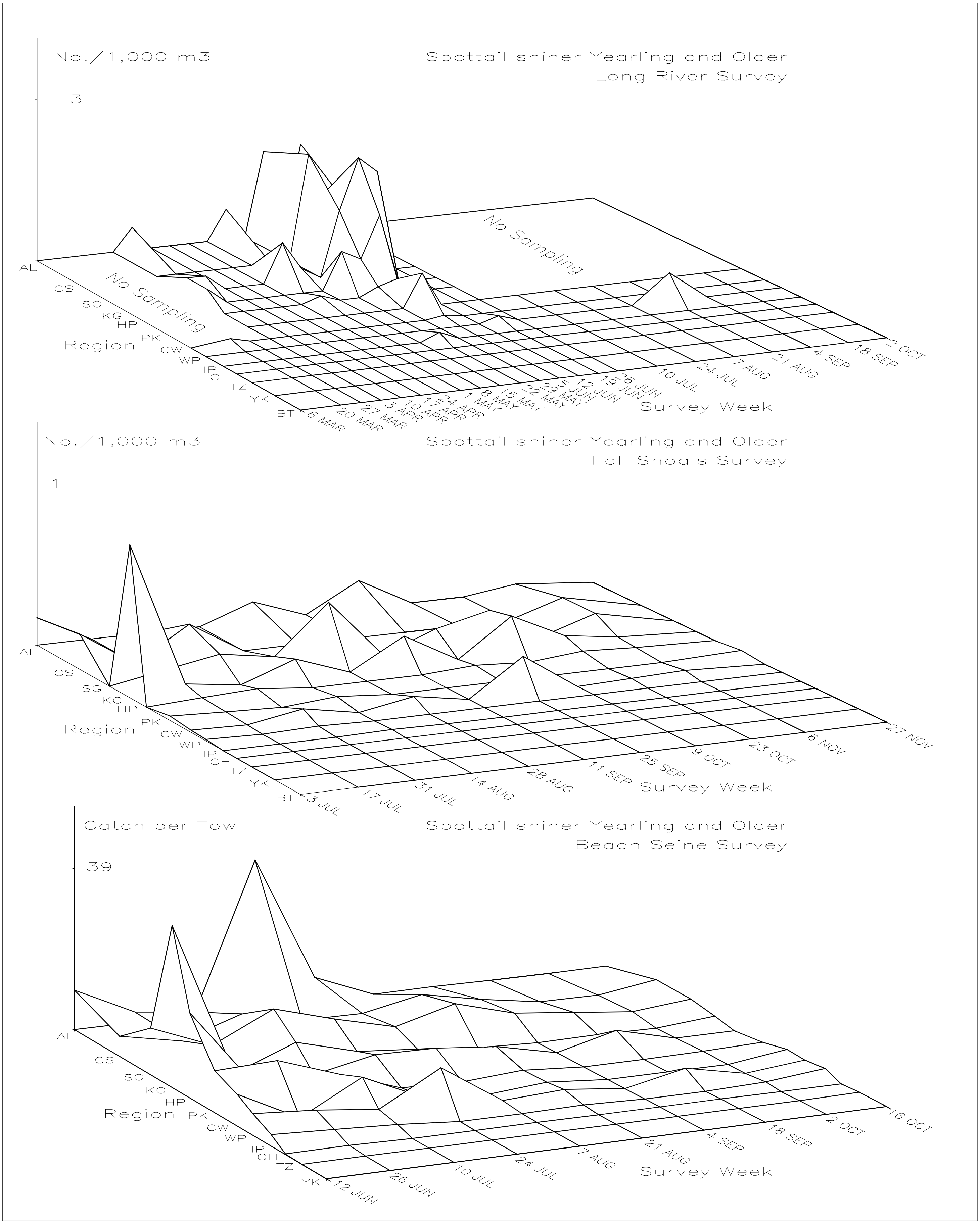

Figure 4-63. Spatiotemporal distribution of yearling and older spottail shiner in the Hudson River estuary based on the 2000 Long River, Fall Shoals, and Beach Seine surveys.

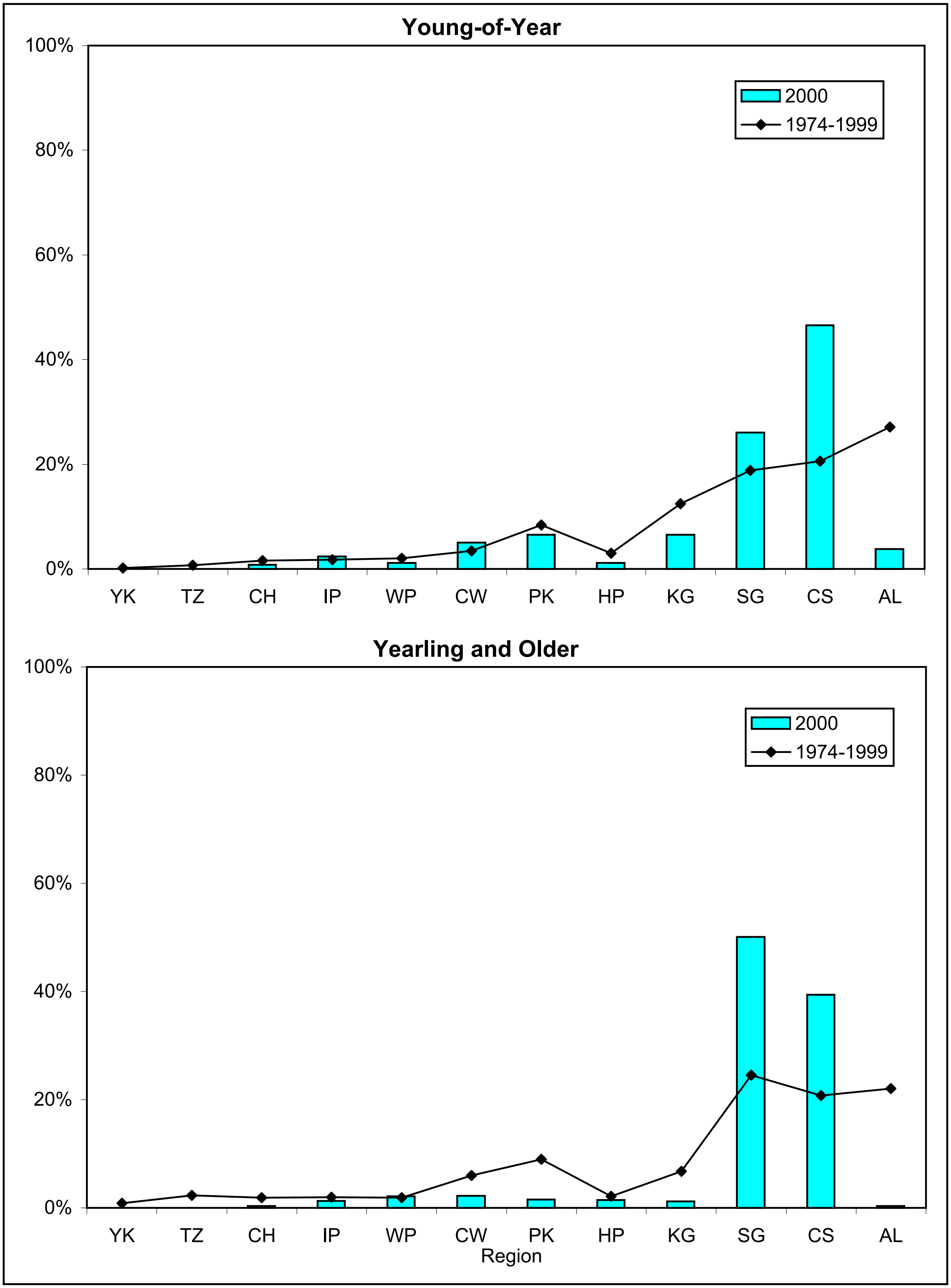

Figure 4-64. Geographic distribution indices for spottail shiner collected during Beach Seine surveys of the Hudson River estuary, 1974-2000.

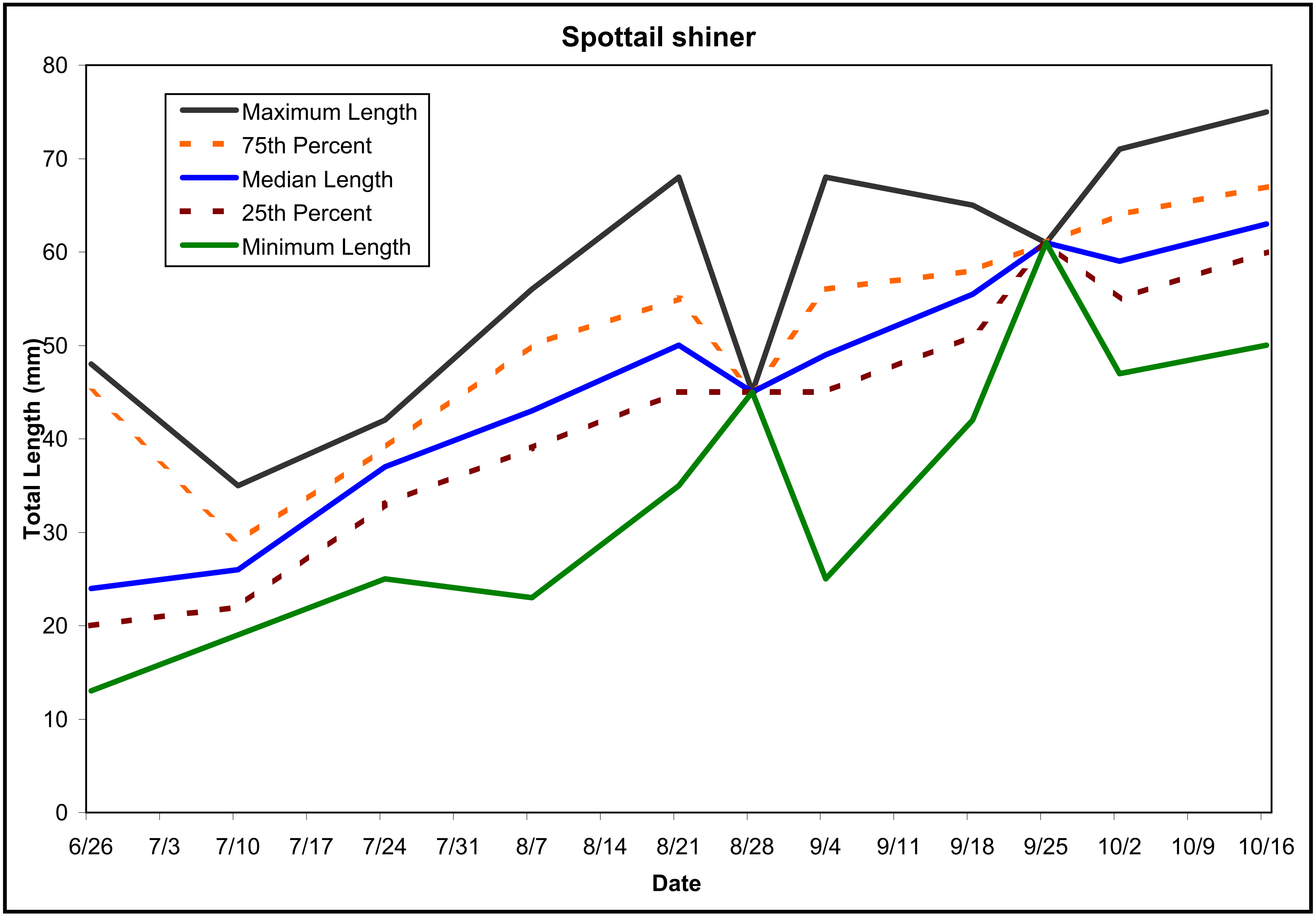

Figure 4-65. Weekly length statistics for young-of-year spottail shiner in the Hudson River estuary, 2000.

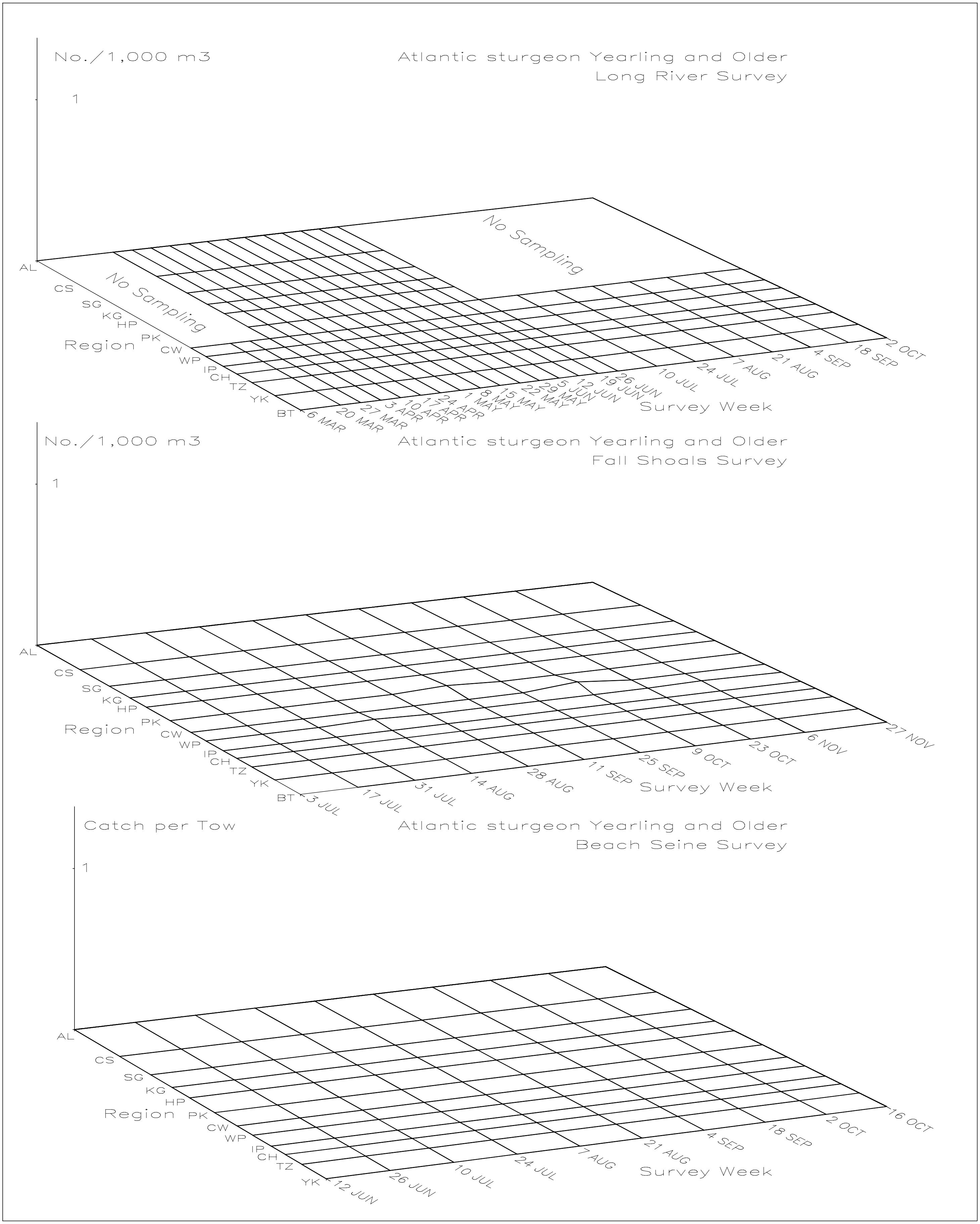

Figure 4–66. Spatiotemporal distribution of yearling and older Atlantic sturgeon in the Hudson River estuary based on the 2000 Long River, Fall Shoals, and Beach Seine surveys.

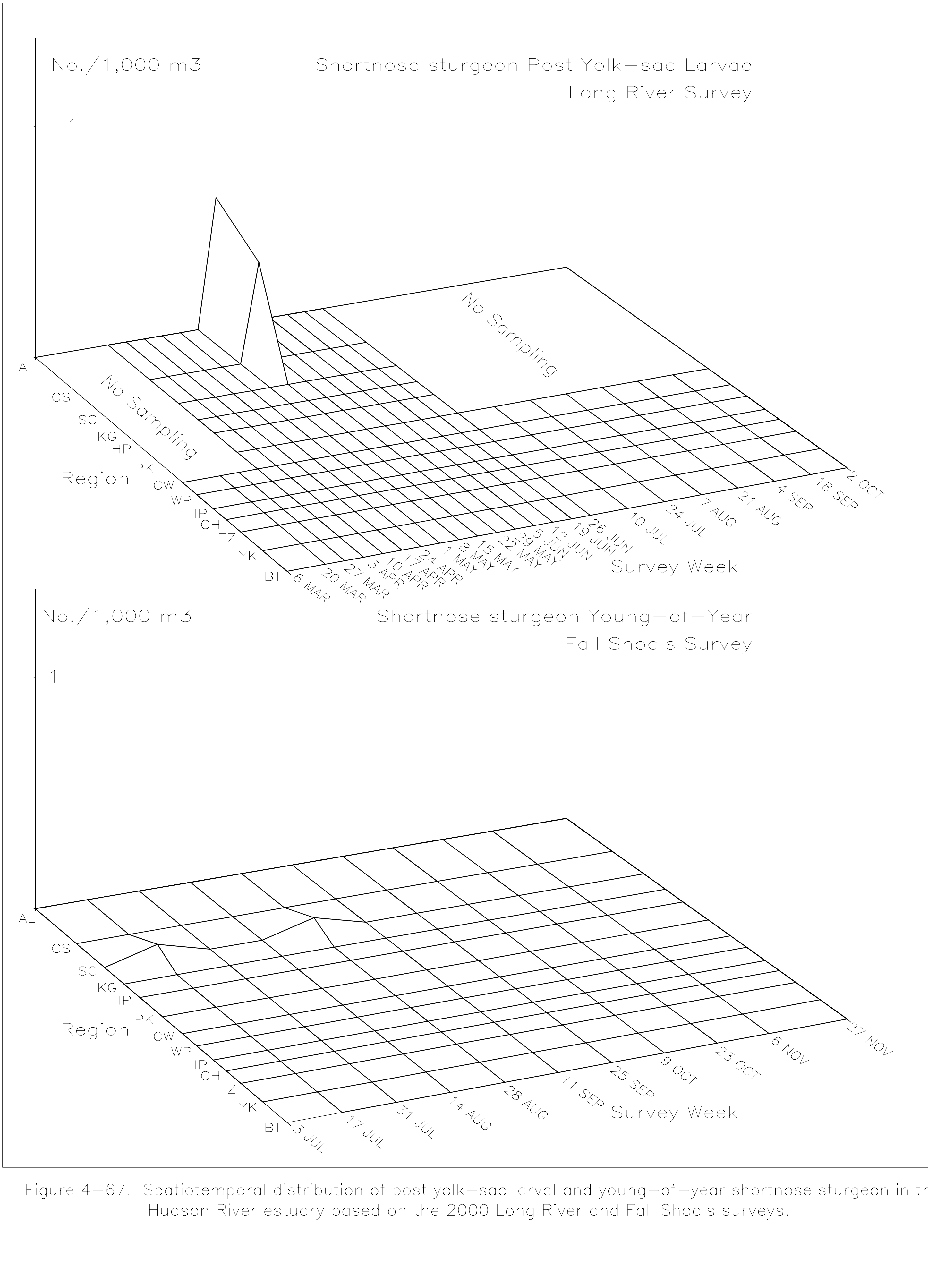

Figure 4-67. Spatiotemporal distribution of post yolk-sac larval and young-of-year shortnose sturgeon in the Hudson River estuary based on the 2000 Long River and Fall Shoals surveys.

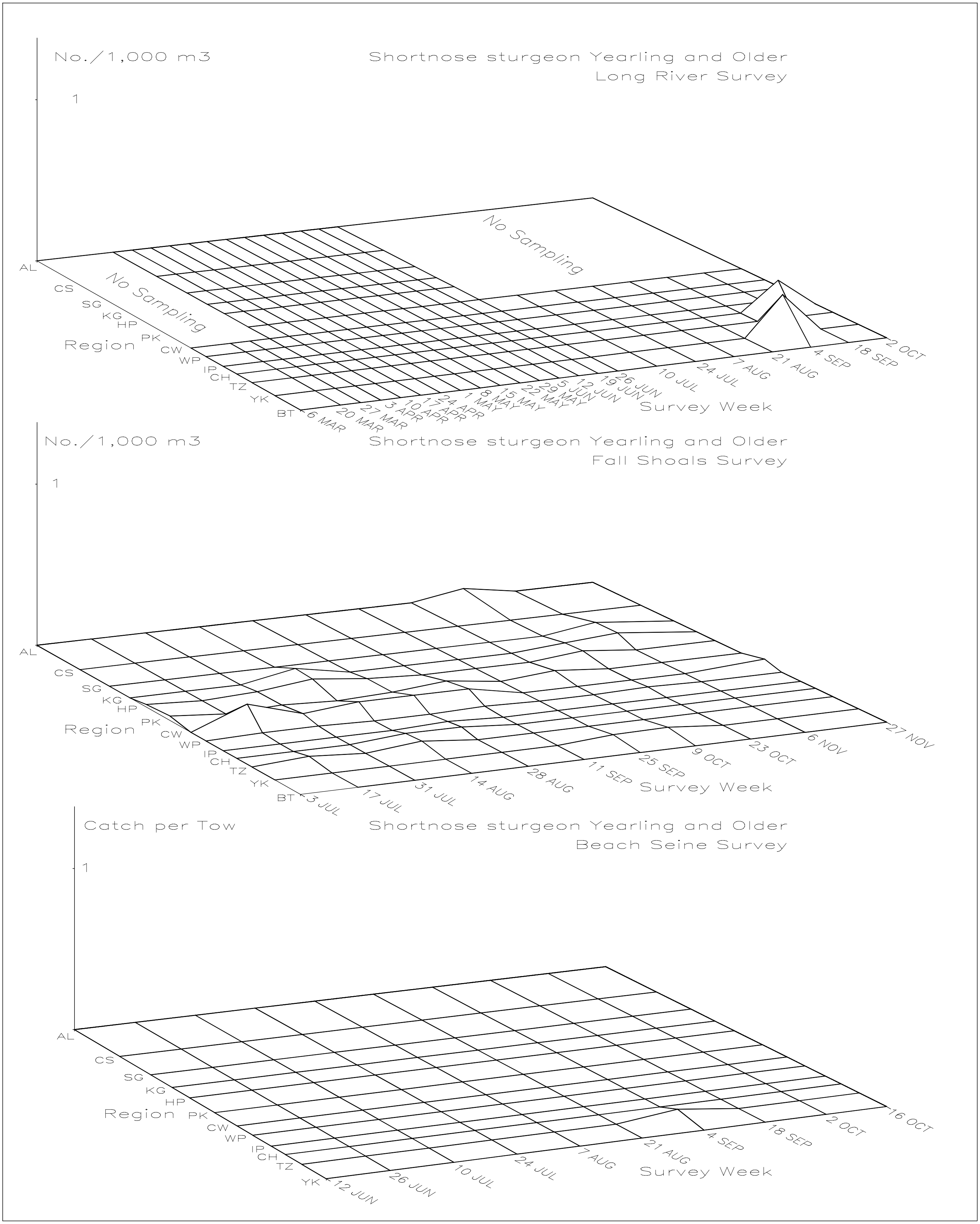

Figure 4-68. Spatiotemporal distribution of yearling and older shortnose sturgeon in the Hudson River estuary based on the 2000 Long River, Fall Shoals, and Beach Seine surveys.

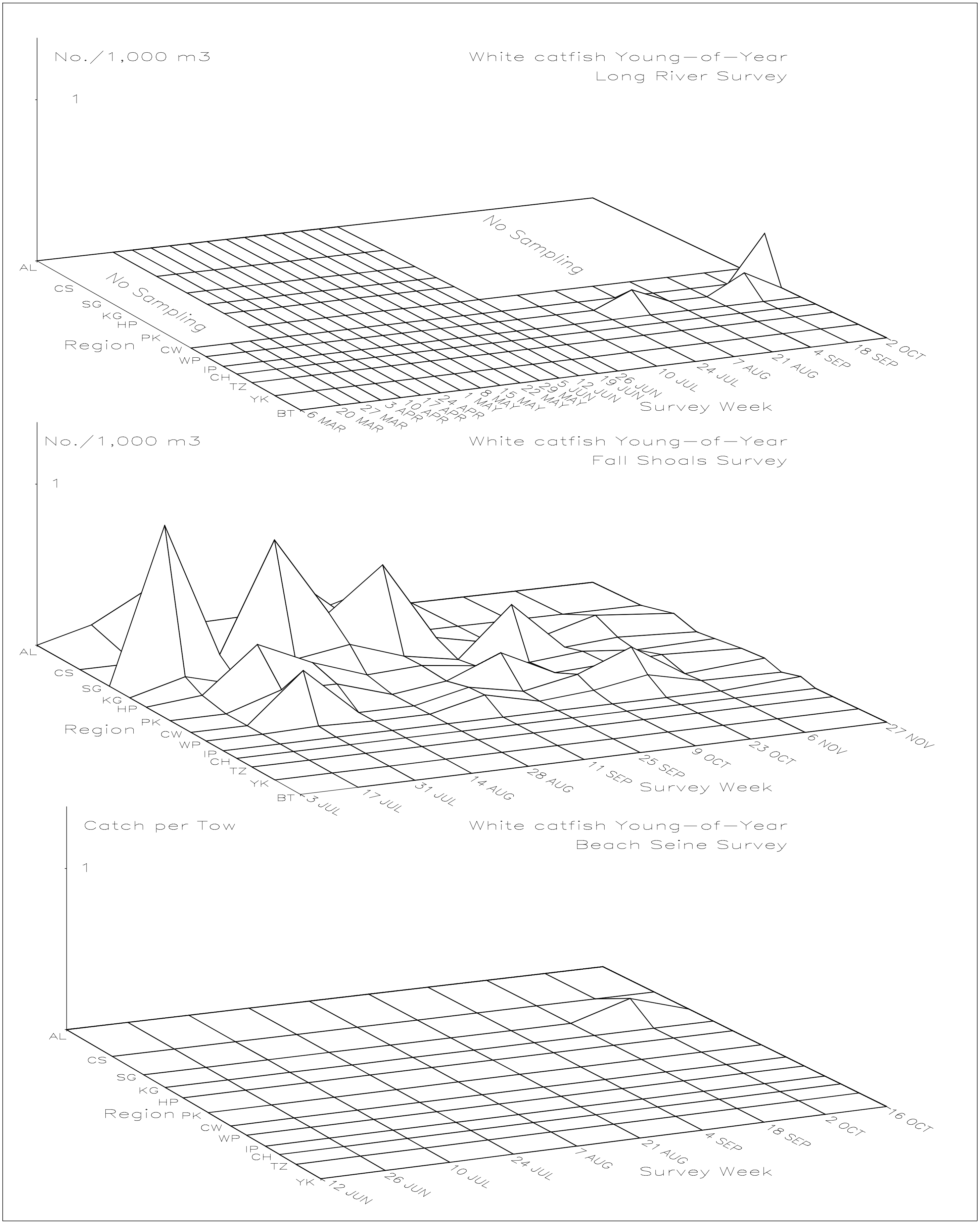

Figure 4-69. Spatiotemporal distribution of young-of-year white catfish in the Hudson River estuary based on the 2000 Long River, Fall Shoals, and Beach Seine surveys.

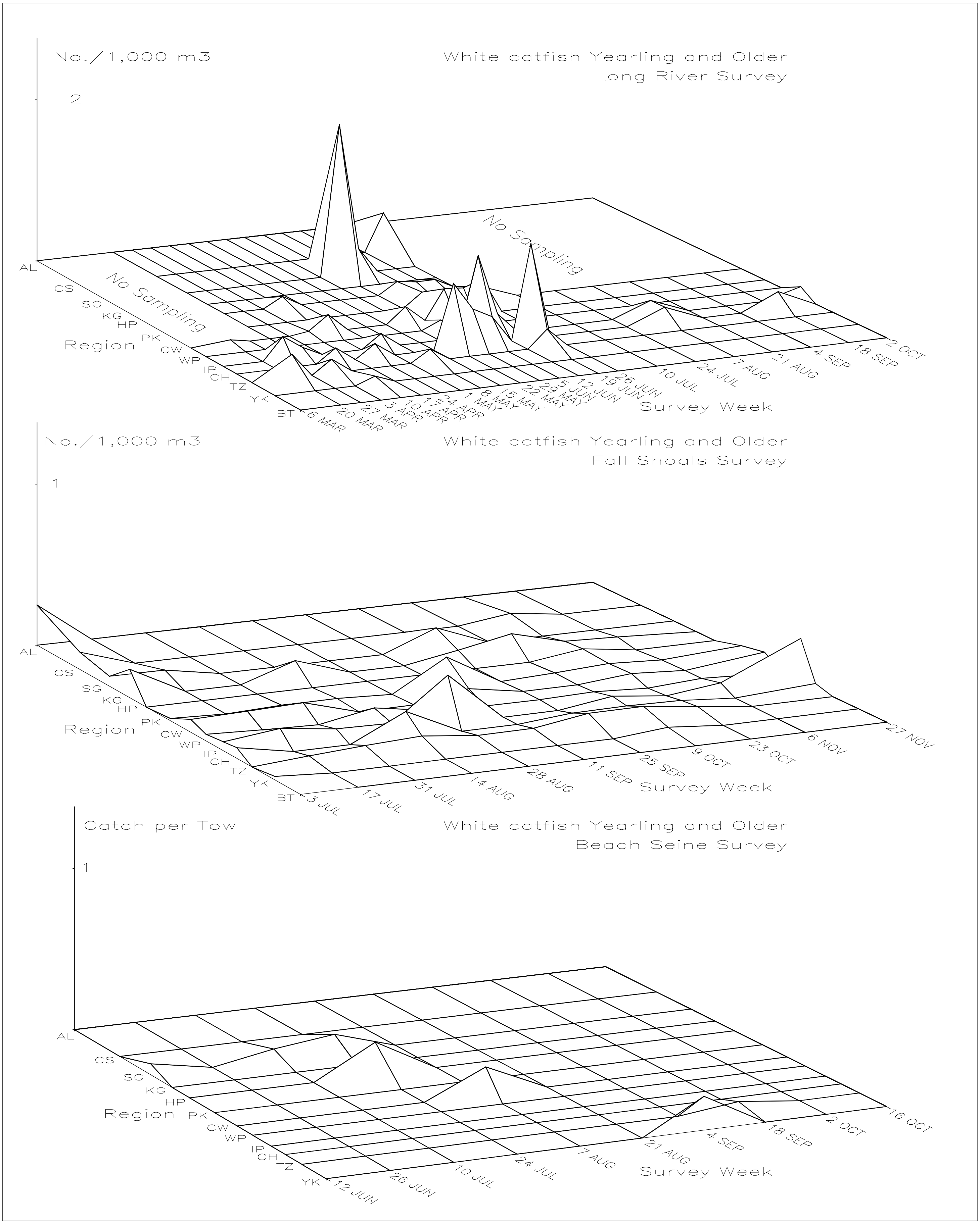

Figure 4–70. Spatiotemporal distribution of yearling and older white catfish in the Hudson River estuary based on the 2000 Long River, Fall Shoals, and Beach Seine surveys.

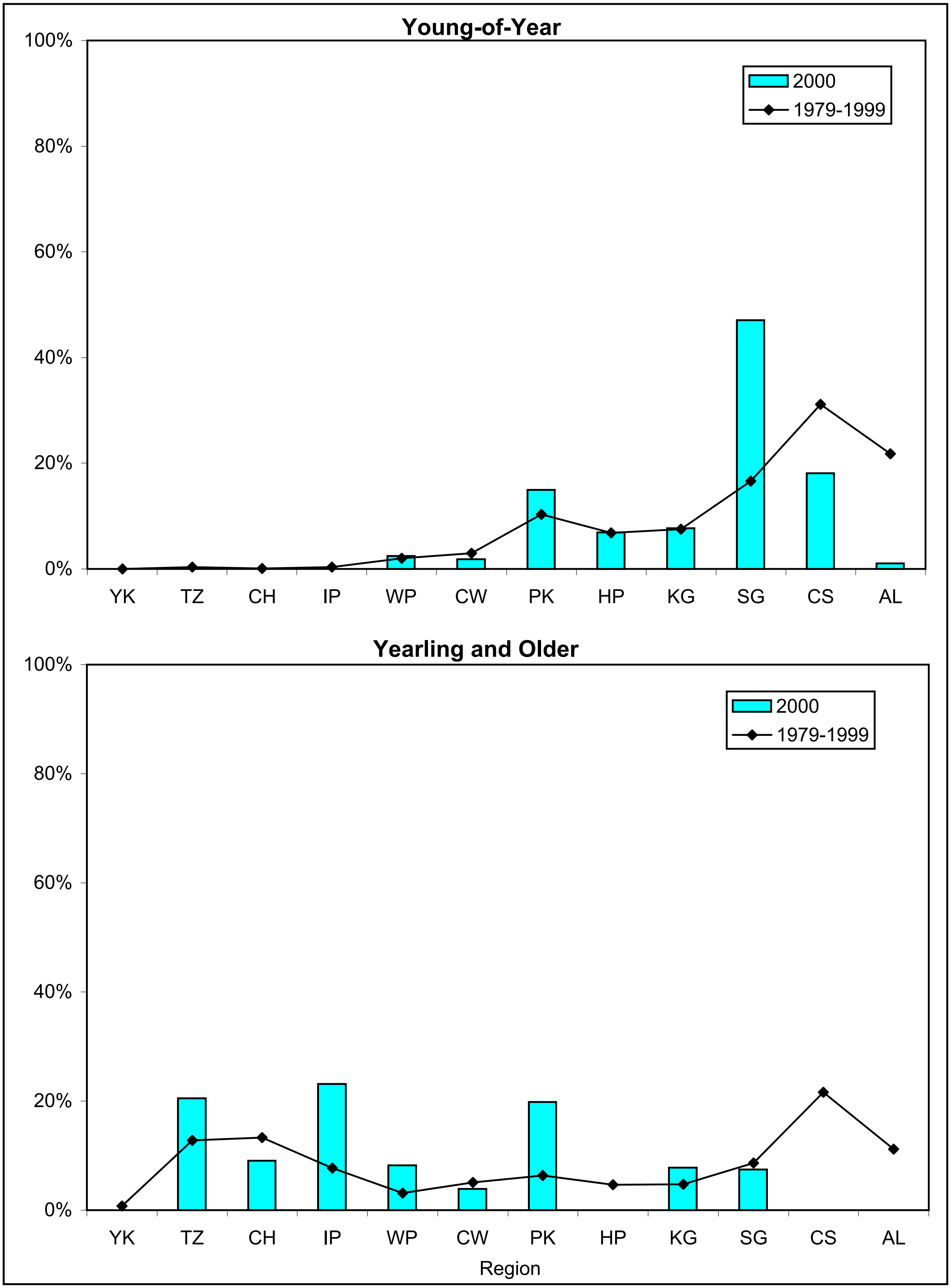

Figure 4-71. Geographic distribution indices for white catfish collected during Fall Shoals surveys of the Hudson River estuary, 1979-2000.

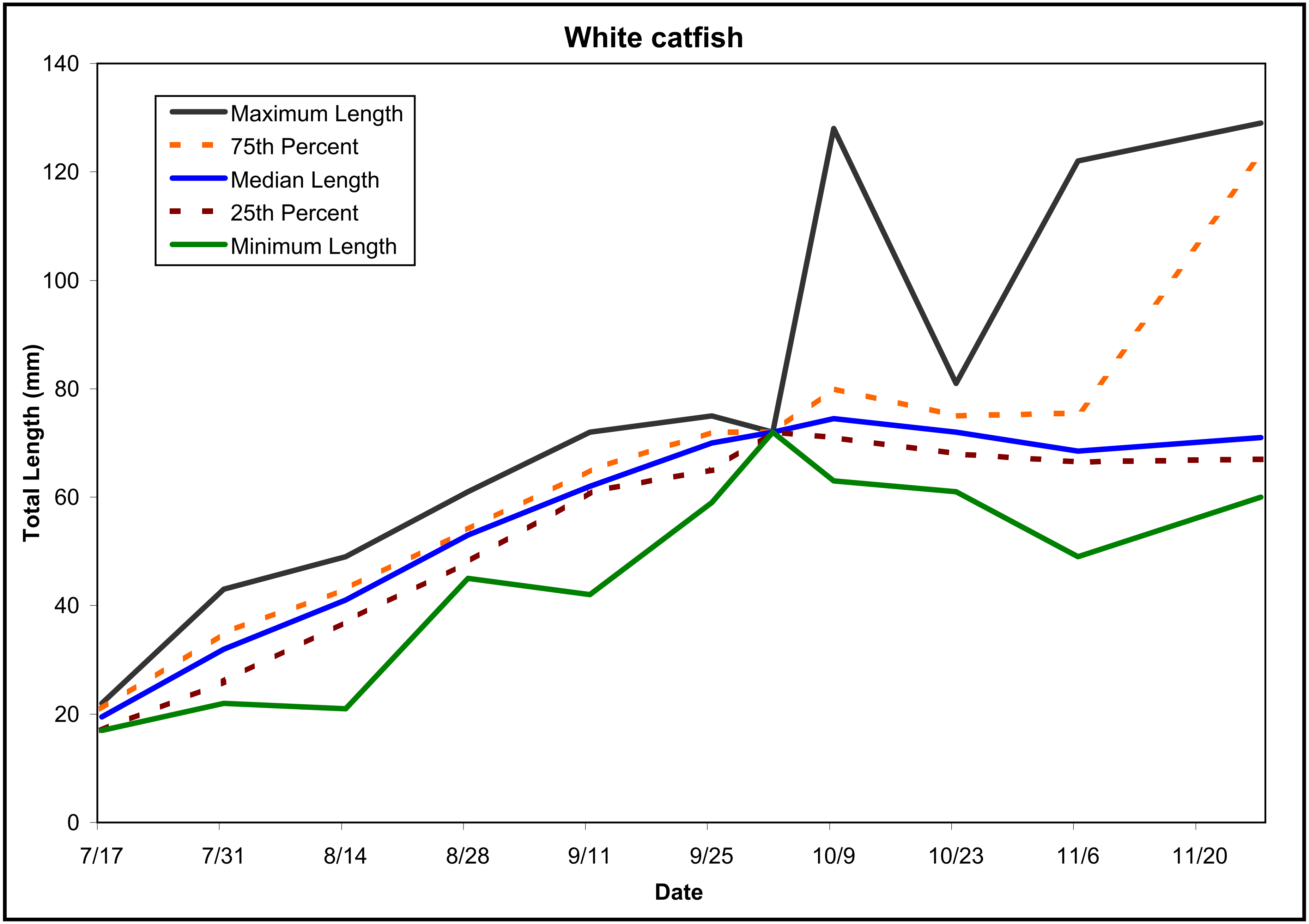

Figure 4-72. Weekly length statistics for young-of-year white catfish in the Hudson River estuary, 2000.

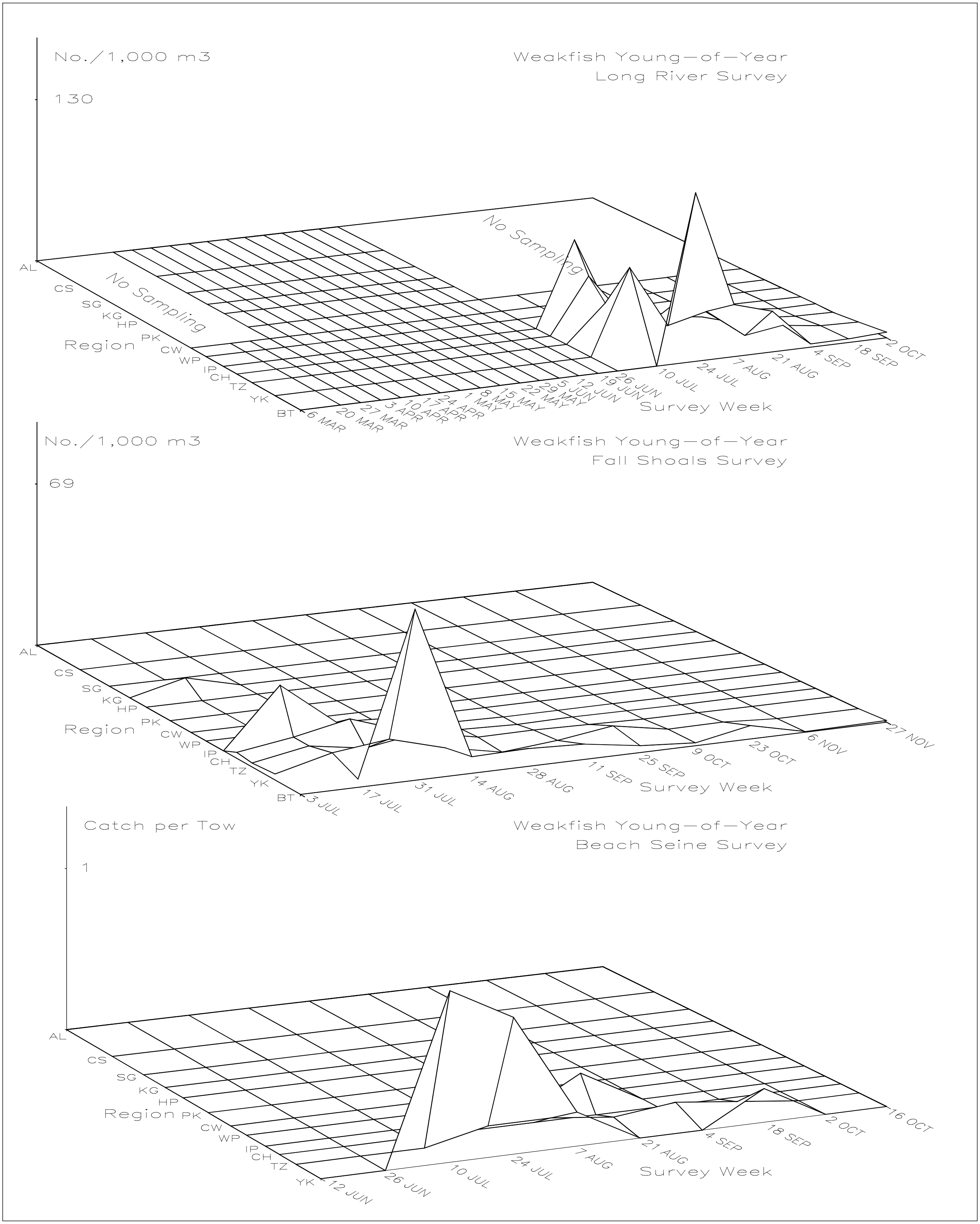

Figure 4-73. Spatiotemporal distribution of young-of-year weakfish in the Hudson River estuary based on the 2000 Long River, Fall Shoals, and Beach Seine surveys.

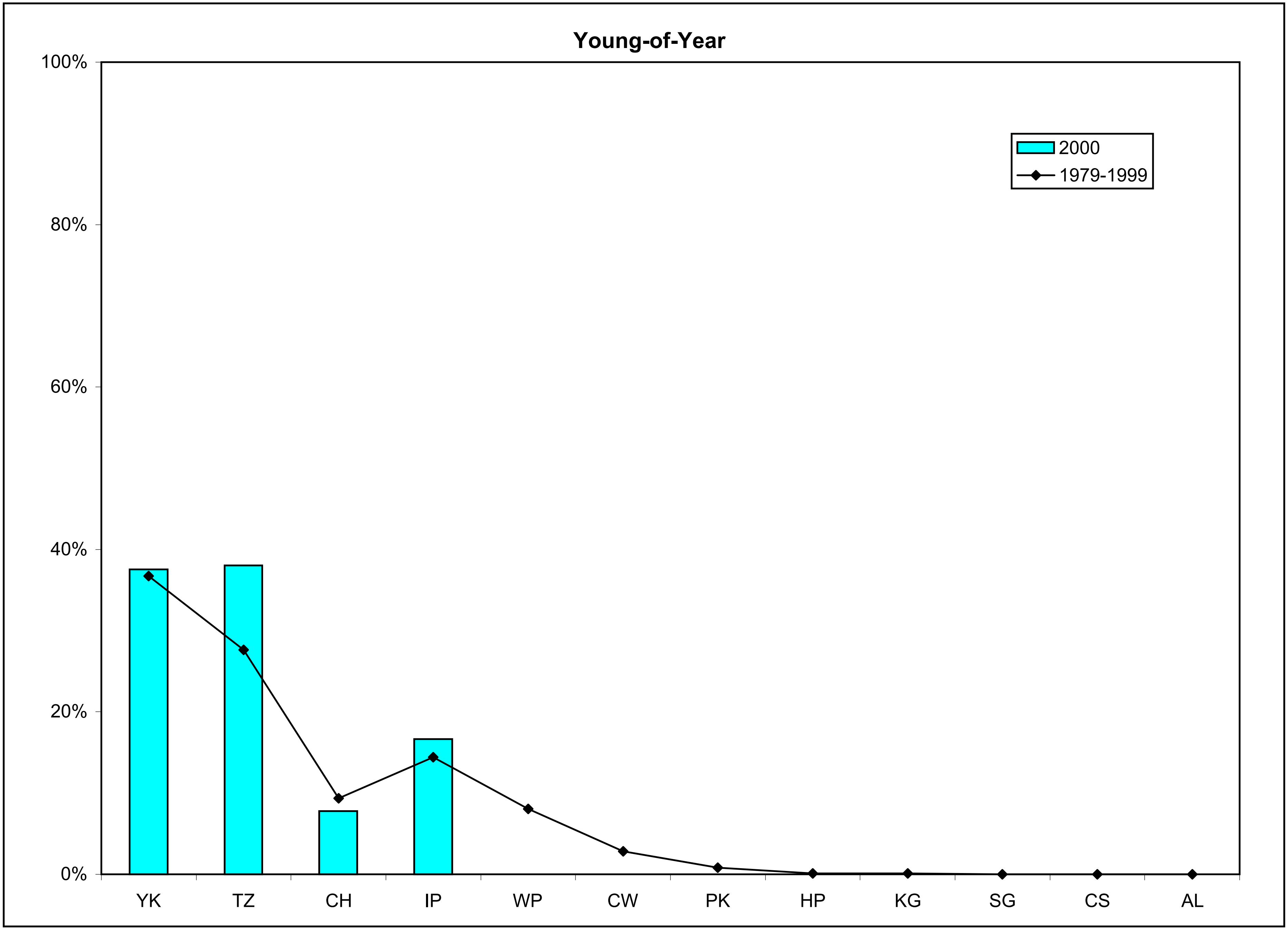

Figure 4-74. Geographic distribution indices for weakfish collected during Fall Shoals surveys of the Hudson River estuary, 1979-2000.

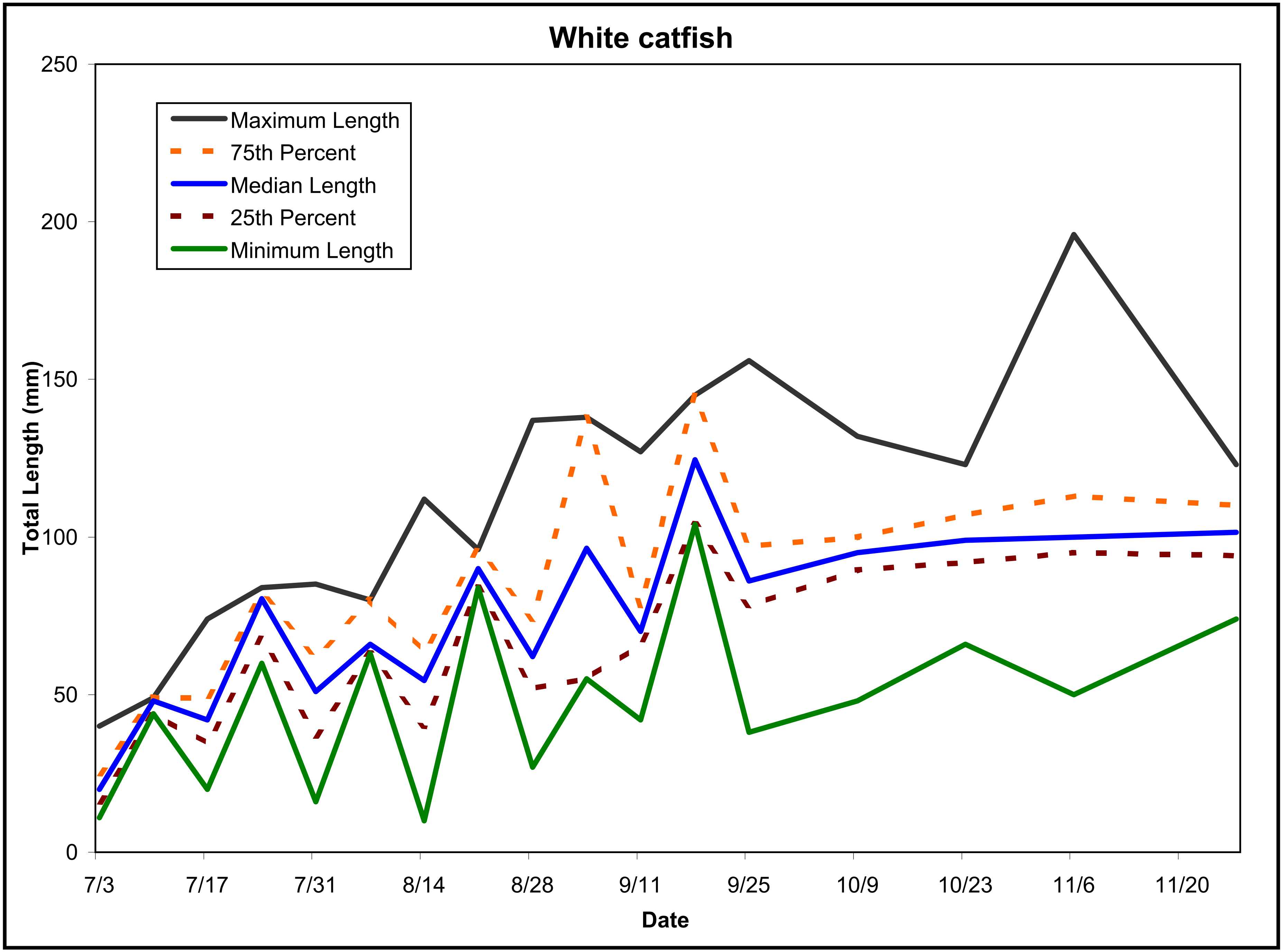

Figure 4-75. Weekly length statistics for young-of-year weakfish in the Hudson River estuary, 2000.

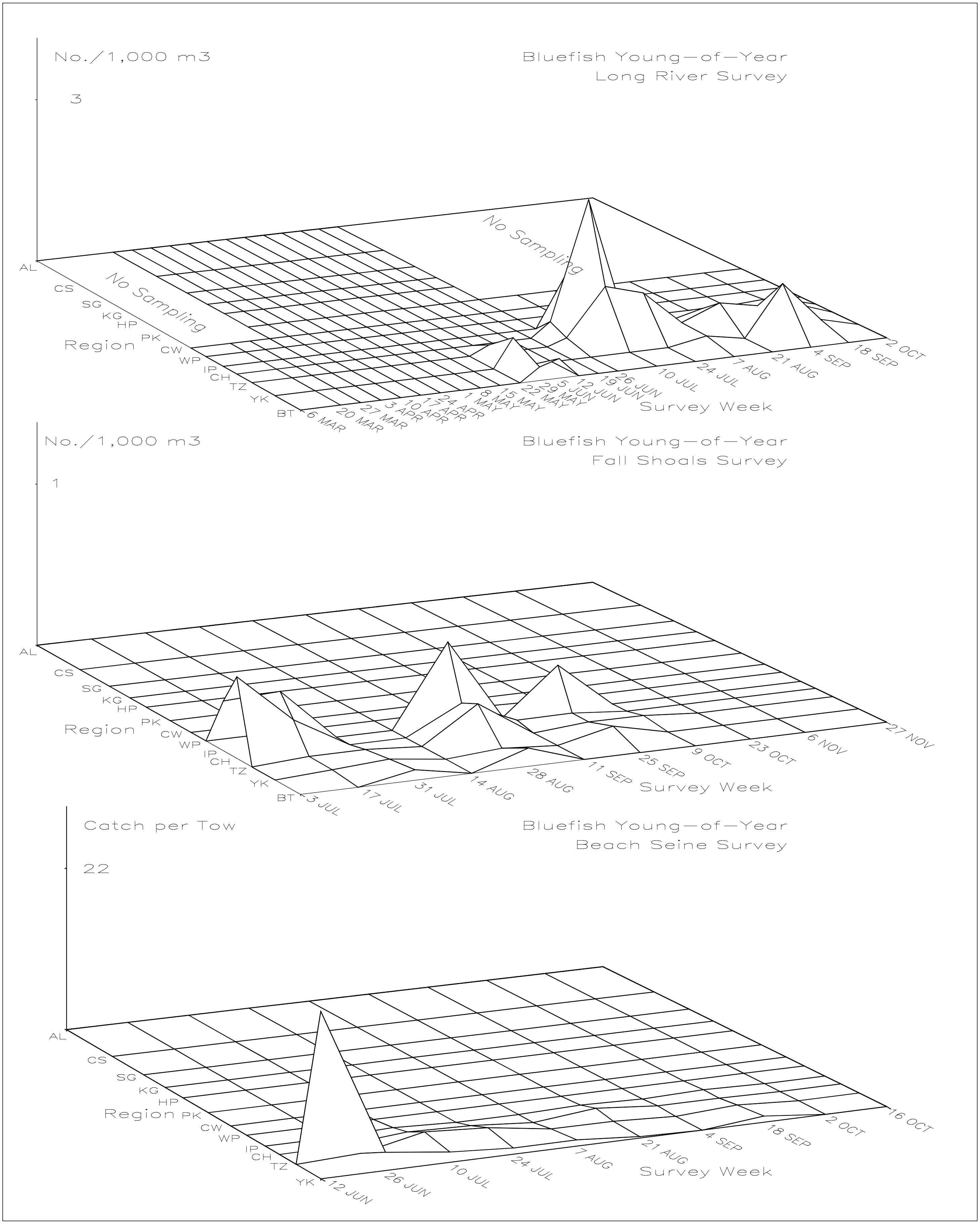

Figure 4–76. Spatiotemporal distribution of young–of–year bluefish in the Hudson River estuary based on the 2000 Long River, Fall Shoals, and Beach Seine surveys.

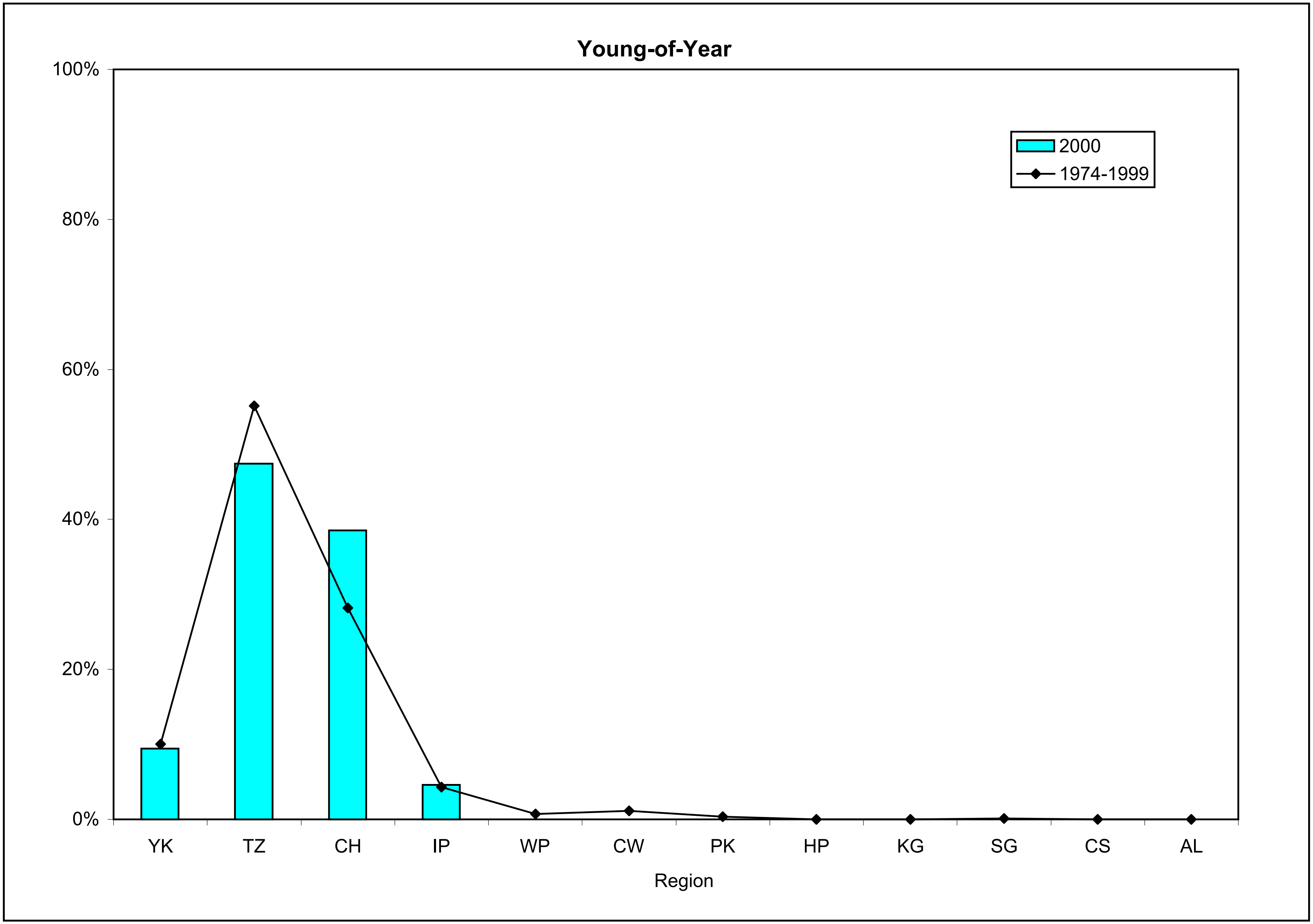

Figure 4-77. Geographic distribution indices for bluefish collected during Beach Seine surveys of the Hudson River estuary, 1974-2000.

TABLE 4-1 SPECIES COMPOSITION OF FISH COLLECTED DURING HUDSON RIVER STUDIES FROM 1974 TO 2000

Common Name	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Anadromous																											
Alewife	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
American shad	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Atlantic sturgeon	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Atlantic tomcod	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Blueback herring	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Hickory shad		X			X	X				X			X									X	X	X	X	X	
Rainbow smelt	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X			X	X	X
Sea lamprey	X	X				X	X	X			X				X		X							X	X		
Striped bass	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Total	8	9	7	7	8	9	8	8	7	8	8	7	8	7	8	7	8	7	7	7	7	8	7	8	9	8	7
Catadromous																											
American eel	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Total	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Estuarine																											
Atlantic silverside	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Banded killifish	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Fat sleeper													X													X	
Fourspine stickleback	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Hogchoker	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Inland silverside	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Lined seahorse															X		X	X				X		X	X	X	X
Mummichog	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Northern pipefish	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Shortnose sturgeon	X		X	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Threespine stickleback	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		X	X			X	
White catfish	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
White mullet	X	X	X	X	X	X	X		X	X	X	X	X			X	X	X		X				X			
White perch	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Total	12	11	12	12	11	12	12	11	12	12	12	12	13	11	12	12	13	13	11	12	10	12	11	12	11	13	11
Freshwater																											
Black bullhead				X				X			X	X															
Black crappie	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Blacknose dace	X	X	X	X	X	X	X					X		X	X									X			
Bluegill		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Bluntnose minnow	X	X	X	X	X	X	X														X		X		X	X	X
Bridle shiner	X		X						X																X		
Brook silverside																					X	X	X	X	X	X	X
Brook stickleback	X	X	X	X				X								X											
Brook trout				X	X													X									
Brown bullhead	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Brown trout			X	X	X	X	X	X				X					X	X	X		X	X					
Carp			X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Central mudminnow			X				X							X													

TABLE 4-1 (CONTINUED)

Common Name	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Chain pickerel	X	X	X	X	X	X	X	X	X		X					X			X			X	X	X	X	X	X
Channel catfish	X							X					X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Comely shiner	X						X													X							
Common shiner	X	X	X	X	X	X	X	X		X					X		X		X	X							
Creek chub		X	X	X	X	X	X			X		X						X		X		X	X	X	X	X	
Cutlips minnow	X	X	X	X	X	X									X	X											
Eastern mudminnow		X					X																				
Emerald shiner	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		X	X	X	X	X
Fallfish		X	X	X	X	X	X	X	X	X				X				X	X	X	X	X	X	X	X	X	
Fathead minnow	X	X	X	X	X	X	X					X	X			X					X		X			X	X
Freshwater drum																X			X	X	X	X	X	X	X	X	X
Gizzard shad	X	X	X	X	X	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Golden shiner	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Goldfish	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Grass pickerel	X				X												X										
Green sunfish		X		X			X								X												
Largemouth bass	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Logperch	X		X	X		X	X			X					X	X			X	X			X		X	X	
Longear sunfish																	X										
Longnose dace		X	X	X	X				X			X															
Margined madtom														X				X			X						
Mimic shiner	X																						X				
Northern hog sucker	X		X	X	X		X	X			X			X	X		X	X	X				X	X	X	X	X
Northern pike	X	X	X	X	X	X	X		X				X	X	X	X	X	X	X	X	X		X	X	X	X	X
Pugnose shiner																		X									
Pumpkinseed	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Rainbow trout						X																X					
Redbreast sunfish	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Redfin pickerel	X	X	X	X	X	X	X	X	X		X				X			X					X		X	X	X
Rock bass	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		X	X	X	X	X	X	X	X	X	X
Rosyface shiner	X																										
Satinfin shiner	X	X	X	X	X	X	X				X	X	X		X		X			X		X	X	X	X	X	
Shield darter							X																				
Silvery minnow	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Smallmouth bass	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Spotfin shiner	X	X	X	X	X	X	X	X			X	X	X	X	X					X	X	X	X	X	X	X	X
Spottail shiner	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Swallowtail shiner																			X						X	X	
Tessellated darter	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Tiger muskellunge																			X			X	X				
Trout perch	X	X	X	X	X	X					X																
Walleye			X	X	X	X				X	X			X		X		X	X	X	X		X	X	X		X
White bass				X																							
White crappie	X	X	X	X	X	X	X	X			X		X	X	X		X	X	X		X				X		
White sucker	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Yellow bullhead		X						X								X						X					
Yellow perch	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Total	37	36	40	42	38	36	38	30	23	23	27	26	24	28	30	28	26	30	31	29	30	29	35	30	35	33	29
Marine																											
American sandlance													X	X	X	X	X	X	X		X	X	X		X	X	X
Ammodytes sp.		X	X	X	X	X	X	X				X															

TABLE 4-1 (CONTINUED)

Common Name	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Atlantic cod							X							X	X												
Atlantic croaker			X	X		X						X	X	X		X	X		X	X	X	X	X	X	X	X	X
Atlantic cutlassfish																										X	
Atlantic herring		X	X		X	X			X				X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Atlantic mackerel															X			X	X				X	X	X	X	X
Atlantic menhaden	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Atlantic needlefish	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Bay anchovy	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Black seabass					X							X			X						X			X	X	X	
Blackcheek tonguefish																			X								
Bluefish	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Butterfish	X	X	X	X			X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Conger eel						X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Crevalle jack	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		X	X	X
Cunner									X	X	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X	X
Cusk																											X
Feather blenny																									X	X	X
Fourbeard rockling						X	X								X	X	X	X	X	X	X	X	X	X	X	X	X
Fourspot flounder	X						X	X			X	X	X		X	X	X				X			X		X	
Goosefish																		X	X								
Gray snapper							X					X	X	X				X									
Grubby													X		X	X	X	X	X	X	X	X	X	X	X	X	X
Gulf Stream flounder																								X	X	X	
Harvestfish																										X	
Hightail goby																	X									X	
Inshore lizardfish	X					X	X	X			X	X			X	X		X	X	X	X	X		X	X	X	X
Longhorn sculpin	X	X								X						X				X							
Lookdown	X	X	X	X		X	X	X				X	X	X	X	X	X				X			X	X	X	X
Moonfish			X										X	X		X			X		X				X	X	X
Naked goby	X		X								X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Northern kingfish	X	X	X	X	X	X	X	X	X	X	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X	X
Northern puffer		X		X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		X	X	X	X	X	X
Northern searobin			X		X		X	X	X		X		X	X	X	X	X	X		X	X	X	X	X	X	X	
Northern stargazer	X						X		X	X	X	X			X		X	X	X	X	X	X	X	X	X	X	X
Orangespotted filefish													X														
Oyster toadfish																			X			X	X		X	X	X
Permit																			X	X					X		X
Pinfish																						X					
Pollack		X																						X			
Radiated shanny																										X	
Red hake	X		X			X	X	X			X	X			X	X	X		X	X			X	X	X	X	X
Rock gunnel			X	X											X	X	X	X	X			X	X	X	X	X	X
Rough silverside		X	X	X	X	X	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Scup	X																					X					X
Seaboard goby		X	X				X								X			X	X	X		X		X	X	X	X
Sea raven							X																				
Sheepshead minnow								X																			
Silver hake	X	X		X									X		X	X	X	X					X	X		X	x

TABLE 4-1 (CONTINUED)

Common Name	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Silver perch	X					X					X	X	X		X			X	X	X	X	X	X	X	X	X	X
Smallmouth flounder						X	X		X		X	X			X		X	X	X	X	X	X	X	X	X	X	X
Spanish mackerel																	X	X		X	X						
Speckled worm eel					X		X				X			X	X								X				X
Spot	X	X	X	X			X		X	X		X	X	X	X		X	X	X	X	X		X		X	X	X
Spotfin butterflyfish									X			X										X					
Spotfin mojarra									X												X				X		
Spotted goatfish																				X							
Spotted hake							X			X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Striped anchovy		X				X			X			X							X	X	X	X	X	X	X	X	X
Striped cuskeel							X					X	X	X	X	X		X	X	X		X	X	X	X	X	X
Striped killifish			X																X								
Striped mullet	X		X	X		X	X	X	X	X	X	X	X	X	X			X				X					X
Striped burrfish													X														
Striped searobin		X			X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Summer flounder	X	X	X	X	X	X	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Tautog		X				X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Weakfish	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Windowpane	X	X		X		X	X	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Winter flounder	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Witch flounder																							X				
Yellowtail flounder	X																		X		X	X	X	X	X	X	X
Total	24	24	24	20	16	26	33	24	25	20	28	35	35	29	41	34	35	38	42	37	37	39	39	40	45	49	46
All Categories																											
Total	82	81	84	82	74	84	92	74	68	64	76	81	81	76	92	82	83	89	92	86	85	89	93	91	101	104	94

TABLE 4-2 SPECIES COMPOSITION OF FISH COLLECTED IN EACH OF THE HUDSON RIVER SURVEYS DURING 2000

Common Name	BSS	FSS	LRS
Anadromous			
Alewife	X	X	X
American shad	X	X	X
Atlantic sturgeon		X	
Atlantic tomcod	X	X	X
Blueback herring	X	X	X
Rainbow smelt			X
Striped bass	X	X	X
Total	5	6	6
Catadromous			
American eel	X	X	X
Total	1	1	1
Estuarine			
Atlantic silverside	X	X	X
Banded killifish	X		
Fourspine stickleback	X		
Hogchoker	X	X	X
Inland silverside	X		X
Lined sea horse			X
Mummichog	X		X
Northern pipefish	X	X	X
Shortnose sturgeon	X	X	X
White catfish	X	X	X
White perch	X	X	X
Total	10	6	9
Freshwater			
Black crappie	X		
Bluegill	X		X
Bluntnose minnow	X		
Brook silverside	X		
Brown bullhead	X	X	X
Carp	X	X	X
Chain pickerel	X		
Channel catfish	X	X	X
Emerald shiner	X	X	
Fathead minnow	X		
Freshwater drum	X	X	X
Gizzard shad	X	X	X
Golden shiner	X	X	X
Goldfish		X	
Largemouth bass	X		
Northern hog sucker	X		
Northern pike	X		
Pumpkinseed	X	X	
Redbreast sunfish	X	X	

(Continued)

TABLE 4-2 (CONTINUED)

Common Name	BSS	FSS	LRS
Freshwater (Continued)			
Redfin pickerel	X		
Rock bass	X		
Silvery minnow	X		
Smallmouth bass	X		X
Spotfin shiner	X		
Spottail shiner	X	X	X
Tesselated darter	X	X	X
Walleye	X		X
White sucker	X	X	X
Yellow perch	X		X
Total	28	13	13
Marine			
American sand lance			X
Atlantic croaker	X	X	X
Atlantic herring			X
Atlantic mackerel			X
Atlantic menhaden	X	X	X
Atlantic needlefish	X		
Bay anchovy	X	X	X
Bluefish	X	X	X
Butterfish		X	X
Conger eel		X	X
Crevalle jack	X		
Cunner			X
Cusk			X
Feather blenny			X
Fourbeard rockling			X
Grubby			X
Inshore lizardfish		X	X
Lookdown	X	X	
Moonfish		X	
Naked goby	X	X	X
Northern kingfish	X		
Northern puffer			X
Northern stargazer		X	
Oyster toadfish		X	X
Permit	X		
Red hake		X	X
Rock gunnel			X
Rough silverside		X	X
Scup		X	
Seaboard goby			X
Silver hake		X	
Silver perch	X		
Smallmouth flounder			X
Speckled worm eel			X
Spot	X	X	X
Spotted hake		X	X

(Continued)

TABLE 4-2 (CONTINUED)

Common Name	BSS	FSS	LRS
Marine (Continued)			
Striped anchovy	X		
Striped cuskeel		X	X
Striped mullet	X		
Striped searobin	X	X	X
Summer flounder	X	X	X
Tautog			X
Weakfish	X	X	X
Windowpane		X	X
Winter flounder	X	X	X
Yellowtail flounder			X
Total	18	24	34
Undetermined			
Alosa spp.	X	X	X
Atherinidae			X
Centrarchidae	X	X	X
Clupeidae			X
Cyprinidae			X
Gobiidae		X	X
Morone unidentified		X	X
Searobin spp.		X	
Unidentifiable			X
Total	2	5	8

TABLE 4-3 COLLECTIONS OF ATLANTIC STURGEON DURING THE 2000 HUDSON RIVER SURVEYS

Date		Survey	Region	River Mile	Gear	Number Collected	Total Length (mm)
7	July	FSS	West Point	47	3-m Beam Trawl	1	51
16	August	FSS	West Point	53	3-m Beam Trawl	1	720
13	September	FSS	Poughkeepsie	69	3-m Beam Trawl	1	230
12	October	FSS	Cornwall	59	3-m Beam Trawl	1	215
9	November	FSS	West Point	55	3-m Beam Trawl	1	283

TABLE 4-4 COLLECTIONS OF SHORTNOSE STURGEON DURING THE 2000 HUDSON RIVER SURVEYS

	Date	Survey	Region	River Mile	Gear	Number Collected	Total Length (mm)
15	May	LRS	Catskill	114	1-m Tucker Trawl	1	PYSL
15	May	LRS	Albany	136	1-m Epibenthic sled	1	PYSL
14	June	LRS	West Point	51	1-m Epibenthic sled	1	796
7	July	FSS	Hyde Park	83	3-m Beam Trawl	1	86
8	July	FSS	Poughkeepsie	68	3-m Beam Trawl	2	768,684
18	July	FSS	Tappan Zee	25	3-m Beam Trawl	1	715
19	July	FSS	West Point	55	3-m Beam Trawl	1	642
19	July	FSS	Saugerties	105	3-m Beam Trawl	1	87
20	July	FSS	Cornwall	56	3-m Beam Trawl	3	445,629,645
20	July	FSS	Cornwall	57	3-m Beam Trawl	1	738
2	August	FSS	Hyde Park	80	3-m Beam Trawl	1	688
3	August	FSS	West Point	55	3-m Beam Trawl	1	477
3	August	FSS	Cornwall	58	3-m Beam Trawl	1	770
3	August	FSS	Poughkeepsie	69	3-m Beam Trawl	1	419
15	August	FSS	Tappan Zee	31	3-m Beam Trawl	1	720
15	August	FSS	Croton-Haverstraw	34	3-m Beam Trawl	1	810
16	August	FSS	Hyde Park	77	3-m Beam Trawl	1	740
16	August	FSS	Hyde Park	78	3-m Beam Trawl	1	680
16	August	FSS	Hyde Park	85	3-m Beam Trawl	1	828
16	August	FSS	Kingston	93	3-m Beam Trawl	1	652
17	August	FSS	Cornwall	57	3-m Beam Trawl	1	750
17	August	FSS	Cornwall	58	3-m Beam Trawl	1	727
29	August	FSS	Croton-Haverstraw	36	3-m Beam Trawl	1	785
30	August	FSS	Indian Point	43	3-m Beam Trawl	1	780
30	August	FSS	Cornwall	57	3-m Beam Trawl	1	804
30	August	FSS	Poughkeepsie	69	3-m Beam Trawl	1	742
30	August	FSS	Hyde Park	77	3-m Beam Trawl	1	570
30	August	FSS	Saugerties	105	3-m Beam Trawl	1	-
31	August	FSS	Cornwall	59	3-m Beam Trawl	1	775
5	September	BSS	Tappan Zee	31	100' Beach Seine	1	-
6	September	LRS	Yonkers	16	1-m Epibenthic sled	1	603
13	September	FSS	West Point	55	3-m Beam Trawl	1	686
13	September	FSS	Poughkeepsie	72	3-m Beam Trawl	1	493
14	September	FSS	Cornwall	56	3-m Beam Trawl	2	633,799
14	September	FSS	Poughkeepsie	68	3-m Beam Trawl	2	424,548
21	September	LRS	Croton-Haverstraw	35	1-m Epibenthic sled	1	965
25	September	FSS	Yonkers	17	3-m Beam Trawl	1	670
11	October	FSS	Yonkers	18	3-m Beam Trawl	1	639
11	October	FSS	Poughkeepsie	65	3-m Beam Trawl	1	765
11	October	FSS	Poughkeepsie	70	3-m Beam Trawl	1	439
24	October	FSS	Albany	132	3-m Beam Trawl	1	222
25	October	FSS	West Point	55	3-m Beam Trawl	1	464
25	October	FSS	Hyde Park	80	3-m Beam Trawl	1	660
25	October	FSS	Hyde Park	81	3-m Beam Trawl	1	438
25	October	FSS	Kingston	87	3-m Beam Trawl	1	424
7	November	FSS	Saugerties	98	3-m Beam Trawl	1	237
7	November	FSS	Saugerties	103	3-m Beam Trawl	1	225
8	November	FSS	Kingston	88	3-m Beam Trawl	1	226
8	November	FSS	Kingston	89	3-m Beam Trawl	1	670
29	November	FSS	Cornwall	56	3-m Beam Trawl	2	-,223