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Demersal Fish and American Lobster Diets in the Lower Hudson - Raritan Estuary

U. S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
National Marine Fisheries Service
Northeast Region
Northeast Fisheries Science Center
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[a]Robins, C.R. (chair); Bailey, R.M.; Bond, C.E.; Brooker, J.R.; Lachner, E.A.; Lea, R.N.; Scott, W.B. 1991. Common and scientific names of fishes from the United States and Canada. 5th ed. *Amer. Fish. Soc. Spec. Publ.* 20; 183 p.

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[f]McEachran, J.D.; Dunn, K.A. 1998. Phylogenetic analysis of skates, a morphologically conservative clade of elasmobranchs (Chondrichthyes: Rajidae). *Copeia* 1998(2):271-290.

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Acronyms

DO = *dissolved oxygen*
ES = *empty stomachs*
FL = *fork length*
FO = mean percent *frequency* of *occurrence*
IRI = *index* of *relative importance*
TDW = mean percent contribution to *total* stomach content *dry weight*
TL = *total length*
TN = mean percent contribution to *total number* of individual items in the stomach
TV = mean percent contribution to *total* stomach content *volume*
TW = mean percent contribution to *total* stomach content *weight*
YOY = *young of* the *year*

ABSTRACT

Characterizing the demersal fish food web in the Hudson-Raritan Estuary is important for understanding specifically how this estuary is used by fishery resources. Knowledge of fish food webs and essential fish forage resources of the estuary can support habitat management decisions. Little is known about diets of the community of fish and the American lobster (*Homarus americanus*) that inhabit this estuary, although it is a major estuarine complex in the Northeast that continues to support fisheries. To gain insight into trophic and habitat functions in this estuary, the diets of the most abundant demersal fish species and the American lobster were examined. These predators were collected by trawl in various parts of the Hudson-Raritan Estuary over six seasons, July 1996 through November 1997.

The most widely preyed-upon taxa were crustaceans, such as: small or juvenile decapods (*e.g.*, sevenspine bay or sand shrimp (*Crangon septemspinosa),* hermit crabs (*Pagurus* spp.), juvenile Atlantic rock crabs (*Cancer irroratus*), lady crabs (*Ovalipes ocellatus)*, and mud crabs (Xanthidae)); the mysid *Neomysis americana*; and several amphipod species. Clam siphons, primarily from the northern quahog (*Mercenaria mercenaria*) and Atlantic surfclam (*Spisula solidissima*), were commonly preyed upon by winter flounder (*Pseudopleuronectes americanus*), as well as by scup (*Stenotomus chrysops*) and spot (*Leiostomus xanthurus*) during some seasons. The diets of common fish and the American lobster in the human-stressed Hudson-Raritan Estuary are similar to those in other, less-stressed estuaries in the Middle Atlantic Bight.

INTRODUCTION

The Lower Hudson-Raritan Estuary (hereafter, the Estuary), located at the mouths of the Hudson, Raritan, and Navesink-Shrewsbury Rivers (New Jersey - New York), is the polyhaline part of a major, urban, estuarine complex in the Northeast. The Estuary has supported diverse and productive commercial and recreational fisheries (MacKenzie 1992). Many of these fisheries are gone or operate at a reduced level because of low resource abundances, harvest regulations, and/or habitat degradation.

The Estuary has been characterized as one of the most human-altered on the East Coast (Wolfe *et al*. 1996). Although some sources of habitat alteration or degradation in the Estuary (*e.g.*, point-source discharges and marsh filling) are being largely controlled through regulation, other sources (*e.g.*, nonpoint-source discharges and toxic substance spills) continue with little effective control, and new activities have the potential for adverse effects (Palermo *et al.*1998). Despite these alterations, the Estuary is still used by a diversity of aquatic species (Wilk *et al.*1998).

To conserve and restore the Estuary's fishery resources, there is a need for community- or ecosystem-level information on the status and function of the Estuary's various habitats and associated species to provide advice for policy decisions on conflicting uses of the Estuary. Characterizing fish and American lobster diets in the Estuary is critical for understanding the value and habitat sources of various prey taxa in the estuarine food web. Knowledge of food webs and key predator-prey relationships is important for habitat-use policy development (Hartman and Brandt 1995).

Although broadscale trophodynamic studies have been conducted in many other Middle Atlantic Bight estuaries, *e.g.*, Long Island Sound (Richards 1963), central New Jersey (Festa 1979), Delaware Bay (de Sylva *et al.*1962), and Chesapeake Bay (Homer and Boynton 1978), as well as offshore in the New York Bight (*e.g.*, Sedberry 1983; Bowman *et al.*1987), the Hudson-Raritan Estuary has never had such an effort. Only the middle Hudson River part of the Estuary (near Indian Point, New York) has received attention for general dietary analysis (Gladden *et al.*1988), although there have been focused dietary analyses of a few species such as striped bass (*Morone saxatilus*) and juvenile bluefish (*Pomatomus saltatrix*). Also, Stehlik *et al.*(in preparation) examined the diets of several species of crabs within Raritan Bay, which complements the present study. Little else has been reported on the diets of the demersal fishery resource community of the Estuary, except for some brief incidental or anecdotal observations (Hall 1894; Merrill 1904; Breder 1922b; NJDEP 1975; Lynch *et al.*1977; Lawler, Matusky & Skelly Engineers 1980; Conover *et al.*1985).

To address this information deficiency, we report on the results of a seasonal study of the diets of common demersal fish species and the American lobster (*Homarus americanus*) collected in various parts of the Estuary. This study is roughly modeled on Festa's (1979) study for a shallow, south New Jersey estuary, and is intended to complement that effort, as well as the cursory dietary information in Able and Fahay (1998). These results are also compared to a comprehensive summary of most other dietary studies for the same predators in other Middle Atlantic Bight estuarine or coastal areas. A brief summary of the life history and habitat of major prey is also included because many of the habitat issues that managers have to deal with involve potential perturbations to the health and availability of common prey. This report is intended to be a ready source of trophic and habitat-use information for subtidal habitat management within this estuary.

METHODS

The strata and blocks (areas) that were sampled to collect fish and American lobster for stomach content analysis covered most of the Estuary (Figure 1), but were restricted to depths greater than 3.0 m because of survey vessel operational factors. The habitat characteristics of these strata are summarized in Table 1.

Six seasonal sampling periods were used to collect specimens for diet analysis: 1) July 8-12, 1996; 2) October 7-10, 1996; 3) January 27-30, 1997; 4) April 22-29, 1997; 5) August 18-28, 1997; and 6) November 17-20, 1997. In addition, a special collection of scup (*Stenotomus chrysops*) was made during June 9-11, 1997; data on scup from that collection are included in the August 18-28, 1997, sampling period. For each sampling period, approximately 40 blocks were randomly selected from about 200 possible blocks within the nine sampling strata.

Fish and American lobster samples were collected by a semiballoon otter trawl that had a 8.5-m headrope, 10.4-m footrope, 10.2-cm stretch-mesh nylon net, and a 3.5-cm stretch-mesh liner in the cod end. This trawl was towed for 15 min at ~3.7 km/hr (2 knots). Hydrographic data (*i.e.*, depth, salinity, temperature, and dissolved oxygen) were collected after each successful tow using a "Hydrolab Surveyor 4" multisensor. [Use of trade names is for information only, and does not represent endorsement by NMFS.] Details of the overall trawl survey are available in Wilk *et al.*(1998).

After the trawl was retrieved, the catch was sorted to species, weighed (g), and measured (0.1 cm). Then, up to about 10-15 specimens of each nonplanktivorous fish species were selected for analyses, as available. If available, additional samples were also collected for each apparent size class of a species. As feasible, the stomachs of large fish such as skates, dogfishes, and adult striped bass were examined in the field, or the eviscerated stomachs of such fish were placed individually in labeled plastic bags and quickly frozen. Small specimens were also bagged and frozen whole for later laboratory analysis.

To examine the diets in the field or laboratory, the contents of each stomach were carefully emptied onto a gridded petri dish. The total stomach bolus volume was visually estimated by a side-by-side comparison with a set of variable-diameter, volume-calibrated (cm^3) cylinders. The bolus was separated and examined (by dissecting microscope, if necessary), then the stomach items or prey were segregated into the lowest identifiable taxon, counted, and measured for length (if possible), and finally, the proportion of each prey taxon or other item to the total stomach volume was estimated visually using the petri dish grid. Items or prey were identified to the lowest level practical using numerous taxonomic references, *e.g.*, Bigelow and Schroeder (1953), Gosner (1973), and Weiss (1995). The findings of clam siphons in winter flounder (*Pseudopleuronectes americanus*) and a few other predators prompted the collection of whole specimens of larger bivalve mollusks which commonly occurred in the area in order to examine their siphons for characteristics that could identify the specific source of the siphons that were found in the stomachs. These characteristics were used to develop a rough guide to siphons to improve the level of prey species identification.

The young-of-the-year (YOY) stages of most fish species (either as predator or prey) examined in the analyses were identified mostly using Bigelow and Schroeder (1953), Fitz and Daiber (1963), and a prepublication draft of Able and Fahay (1998). The transition lengths at 50% maturity, used to segregate juvenile and adults of certain fish species as part of the diet analysis, were based on O'Brien *et al.* (1993).

A literature review of target predator diets in the coastal Middle Atlantic Bight, the area between Cape Cod and Cape Hatteras, was used to create summary tables of the diet of each predator for comparison with results of the present study. In these tables, prey were listed by their relative overall importance using several ranking metrics, as available from the document source: mean percent frequency of occurrence (FO), mean percent contribution to total stomach content volume (TV), mean percent contribution to total stomach content weight (TW), mean percent contribution to total stomach content dry weight (TDW), mean percent contribution to total number of individual items in the stomach (TN), and an index of relative importance (IRI; FO x TV, or, FO x TW). Those comparative data available as FO and TV are the same as those used in the present study. The two "fresh condition" variables of TV and TW are nearly equivalent (*i.e.*, 1 g of prey as "fresh" weight approximates 1 cm^3 of prey as "fresh" volume) for most prey such as crustaceans, polychaetes, fish, shell-less mollusk meat, etc., but not for heavy-shelled prey (*e.g.*, sand dollars and mollusks in the shell) consumed whole (Steimle *et al.*1994).

Our results for diets focus on dominant prey used by predators found in the Estuary. Dominant prey are generally defined as those contributing five or more percent to total stomach content volume, but prey of fishery management significance, such as juvenile fishery species, are also noted. The results are also presented in the order of predator sample abundance. For each predator, the results of this study are followed by the summary of the results of other studies for comparative purposes. Because of the relatively large number of predators considered in this predator-community-focused report, this strategy of reporting by predator sample abundance keeps relevant information together for each predator, and should be most convenient to users of this report. Summaries focused on common prey, with a brief review of their life history and habitat associations, are also presented.

RESULTS AND DISCUSSION

DIETS

Winter Flounder *(Pseudopleuronectes americanus)*

Hudson-Raritan Estuary Results

This species is a common, year-round inhabitant of the Estuary, and was collected in a range of sizes (6.1-45.0 cm total length (TL), mean of 20.0 cm) and strata, except in the central and coastal parts of Lower Bay, Stratum 3 (Figure 2). The 710 winter flounder which were examined ate 80 distinct, identifiable prey taxa, although only about 20 benthic invertebrates occurred at a relatively high FO. Endobenthic and epibenthic polychaetes (21+ species), amphipods (14+ species), and mollusks (10+ species) dominated the diet. This flounder also ate a range of food types, from plant detritus to algae to tunicates, including planktonic copepods (*e.g.*, *Pseudodiaptomus coronatus*), suprabenthic mysids and the amphipod *Gammarus lawrencianus*, as well as the epibenthic and endobenthic invertebrates. Typically, smaller species, earlier life stages, and/or fragments of larger benthic species were eaten. Some larger bivalve mollusks, *e.g.*, northern quahogs (*Mercenaria mercenaria*) and Atlantic surfclams (*Spisula solidissima*), were important in the diet, but only their siphons were nipped or torn off by this nearly toothless predator. The blue mussels (*Mytilus edulis*) that were found in the diet, *e.g.*, during April 1997 (Table 2a), were all spat less than 1 cm in length. The decapod crabs that were eaten – Atlantic rock crab (*Cancer irroratus*), blue crab (*Callinectes sapidus*), lady crab (*Ovalipes ocellatus*), and *Libinia* sp. – were all juveniles. A diversity of tube-dwelling amphipods were also eaten, especially *Ampelisca abdita*. Although several polychaete species were identified as being eaten, only the tube-dwelling *Asabellides oculata* and *Sabellaria vulgaris*, and the blood worm *Glycera* sp., were relatively common in the diet, *i.e.*, occurring in the top 20 prey ranked by FO (Table 2a). The percentage of empty stomachs that were found ranged from 2.9% in April 1997 to 42.2% in January 1997; this variable generally ranged between 6.7 and 16.9% for other sampling periods (Table 2a).

Unidentified organic matter (*i.e.*, detritus) ranked as the most frequently occurring diet item, followed by northern quahog siphons, *Ampelisca abdita*, Atlantic surfclam siphons, and unidentified polychaetes or their fragments (Table 2a). The TV of prey or prey type for all samples was again dominated by unidentified organic matter, Atlantic surfclam and northern quahog siphons, the mysid *Neomysis americanus* (hereafter, "*Neomysis*"), unidentified clam siphons, *A. abdita*, and unidentified polychaetes (Table 2a). Other prey individually represented a TV of less than 3%. As with FO, there was a high degree of intersample variability (Table 2a).

For most prey, there were only small seasonal variations in the degree of their use by winter flounder, but for some prey, there were obvious differences. For example, there was minimal use of clam siphons during January 1997 (Table 2a). At the same time, there was increased use of *Neomysis* and nemerteans. Seasonal predation peaks for other prey varied annually, *i.e.*, there was relatively high predation during one summer sampling, but not the other summer sampling, covered in this survey (*e.g.*, predation on juvenile Atlantic rock crabs and *Asabellides oculata*; see Table 2a).

Other prey or items found in winter flounder stomachs in lesser quantities were: green and red algae; anthozoans; nematodes; bryozoans; **gastropods** (juvenile *Crepidula* sp., *Lacuna vincta*, *Epitonium* sp., *Astyris lunata*, and *Nassarius trivittatus*); **bivalve mollusks** (*Solemya velum*, *Nucula* sp., *Mulinia lateralis*, *Tellina agilis*, softshell (*Mya arenaria*) siphons, and *Lyonsia hyalina*); **polychaetes** (*Phyllodoce* sp., *Eteone* sp., unidentified polynoids, *Nephtys* sp., *Nereis succinea*, *N. grayi*, *Nereis* sp., unidentified capitellids, *Asychis elongata*, *Clymenella torquata*, *Spiochaetopterus oculatus*, *Sabellaria vulgaris*, *Diopatra cuprea*, *Lumbrineris* sp., *Arabella iricolor*, *Pectinaria gouldii*, *Melinna cristata*, *Nicolea venustula*, and *Pherusa affinis*); **arachnids** (juvenile *Limulus polyphemus*); **copepods** (unidentified calanoids, harpacticoids, and cyclopoids, and the calanoid *Pseudodiaptomus coronatus*); **cumaceans** (*Diastylis* sp.); **tanaids** (unidentified); **isopods** (*Edotea triloba* and *Cyathura* sp.); **amphipods** (*Lembos websteri*, *Ericthonius* sp., *Gammarus* sp., *Jassa falcata*, *Hippomedon serratus*, *Orchomenella* sp., *Photis* sp., *Phoxocephalus holbolli*, *Stenothoe* sp., and *Parametopella* sp. (*cypris*?)); **mysids** (*Heteromysis formosa*); **decapod crustaceans** (*Pagurus* sp., *P. longicarpus*, xanthids (*Dyspanopeus*?), juvenile blue crabs, juvenile *Libinia* sp., and juvenile *Ovalipes ocellatus*); **echinoderms** (juvenile *Echinarachnius parma*); **tunicates** (*Molgula* sp.); and sand, shell hash, organic detritus, and manmade artifacts such as coal granules and synthetic fibers.

Winter flounder diet changed with size/growth. This shift in use of common prey was generally from small crustaceans (mysids and amphipods), polychaetes, and detritus by smaller fish, to more bivalve mollusk siphons by larger fish (Table 2b).

Winter flounder diet was examined for seasonal shifts in prey use as related to flounder size and maturity. Because of small sample sizes for each of the four size groups portrayed in Table 2b, the samples were pooled into two groups: juvenile (less than 20 cm TL; Table 2c) and adult (greater than or equal to 20 cm TL; Table 2d). In the summer-fall, juvenile winter flounder focused their feeding on northern quahog and Atlantic surfclam siphons, an amphipod (*i.e.*, *Ampelisca abdita* or *A. vadorum*), a tube-dwelling polychaete (*Sabellaria vulgaris*), and detritus, although *Neomysis* became important as prey in the winter (Table 2c). Other prey were relatively evenly used during most seasons or showed no seasonal pattern of use. For adults, the list of commonly eaten prey was condensed, with only four distinct prey being notable, and seasonal sample sizes were more irregular and often inadequate (Table 2d). Again, clam siphons were the dominant prey. The large bloodworm *Glycera* sp. and juvenile Atlantic rock crabs were the only other prey with any seasonal peaks.

Some studies of the winter flounder diet have shown that the diet closely reflects environmental conditions and prey availability in the areas in which the fish are collected (Frame 1974; MacPhee 1969). The winter flounder diet in this study also showed differences in prey use that varied among sampling strata, although sample sizes were small for some strata, particularly for the channel habitats, Strata 7-9 (Tables 2e,f). Some prey (*e.g.*, *Glycera* sp.) were eaten in similar proportion by juveniles and adults from the same strata areas of the Estuary. Other prey (*e.g.*, *Neomysis*, *Crangon septemspinosa* (hereafter, "*Crangon*"), and *Gammarus* sp.) were found in stomachs of juveniles or adults, but not both. The prey of juvenile winter flounder among different strata suggest no habitat-related patterns (Table 2e). There was no specific association of prey with channels (Strata 7-9), nor with the western or eastern areas, with the possible exception of the polychaetes *Glycera* sp. and *Sabellaria vulgaris* and northern quahog siphons in the western Strata 1-3, and Atlantic surfclam siphons in eastern Strata 4 and 6 (Table 2e). Predation by juveniles and adults on northern quahog siphons appears restricted to less-saline, western Strata 1-3 and 6, and predation on Atlantic surfclam siphons occurs in marine eastern Strata 4 and 5 and in channel Strata 7 and 8, as might be expected from the Atlantic surfclam's salinity preferences.

Comparisons with Other Diet Studies

Other winter flounder dietary studies in and near the Estuary, or within the coastal Middle Atlantic Bight, found a similar diet to that reported here, *i.e.*, opportunistic predation on benthic invertebrate macrofauna, especially polychaetes and amphipods, and on zooplankton by the smallest winter flounder sizes (Table 3). However, there was an unusually high degree of molluscan siphon nipping in this estuary compared to what has been reported elsewhere

(Tables 2 & 3; Lawler, Matusky & Skelly Engineers 1980; Stehlik and Meise 2000). A lesser degree of molluscan siphon nipping by winter flounder has been also reported in Canada (Medcoff and McPhail 1952), Cape Cod Bay (Gilbert and Suchow 1977), Long Island Sound (Carlson 1991), and near Woods Hole, Massachusetts (Frame 1974; Lux et al.1996), and in a few other studies (Table 3), however. It has been assumed that this siphon nipping is nonlethal to the mollusks, which can be fishery resources in their own right, and that the siphons regenerate (Irlandi and Mehlich 1996).

Windowpane *(Scophthalmus aquosus)*

Hudson-Raritan Estuary Results

Windowpane from YOY to adult (range of 2.5-35.0 cm TL, mean of 20.7 cm) are a year-round inhabitant of this estuary. Five hundred seventy windowpane were examined from all areas, although slightly greater quantities were available from the channels, especially in and near Raritan Channel, Stratum 9 (Figure 3). At least 37 prey taxa were identified in their diet. This prey spectrum included two mysid species, three or more decapod crustacean species, seven amphipod species, two or more copepod species, eight mollusk species, nine identifiable species of larval or juvenile fish, and some miscellaneous, nonprey items (green algae to coal fragments). This prey spectrum included a mix of benthic, suprabenthic, and pelagic species.

Despite the overall diversity of prey consumed, windowpane have a relatively focused diet. By FO for all samples, *Neomysis* was the dominant prey at 65.9% (range of 33.7-93.3%). It was followed in importance by *Crangon* at 31.7% (range of 23.6-53.0%) and the suprabenthic amphipod *Gammarus lawrencianus* at 9.5% (range of 0.8-39.0%). The other prey were eaten at a low FO (*i.e.*, less than 5%). The percentage of empty stomachs ranged from 2.0% in July 1996 to 33.7% in January 1997, and was between 10 and 24% in other sampling periods (Table 4a).

The TV paralleled the FO. *Neomysis* made up 57.1% of the overall diet by TV (range of 17.8-70.1%), with *Crangon* contributing 29% (range of 21.3-47.7%). Most other prey individually represented less than 0.1% of TV, although higher values occurred during some sampling periods (Table 4a).

Other prey or items found in windowpane stomachs in lesser quantities were: green algae; hydroids; nemerteans; **gastropods** (*Lacuna vincta*, juvenile *Crepidula* sp., *Nassarius trivittatus*, and *Astyris lunata)*; **bivalve mollusks** (*Mulinia lateralis*, *Nucula* sp., unidentified, and blue mussel spat); **cephalopods** (unidentified squid); **polychaetes** (unidentified); **copepods** (unidentified); **cumaceans** (unidentified); **amphipods** (*Corophium* sp., *Jassa falcata*, *Stenothoe* sp., *Hippomedon serratus*, and *Unciola* sp.); **mysids** (*Heteromysis formosa*); **decapod crustaceans** (*Pagurus longicarpus*, *Palaemonetes vulgaris*, and unidentified zoea); **fish** (unidentified juvenile flounder, unidentified juvenile fish, juvenile Atlantic menhaden (*Brevoortia tyrannus*), juvenile herring (*Alosa*), juvenile red hake (*Urophycis chuss*), juvenile cunner (*Tautogolabrus adspersus*), *Menidia* sp., juvenile Atlantic croaker (*Micropogonias undulatus*), and juvenile sand lance (*Ammodytes* sp.)); and sand and coal pebbles.

There was seasonal variability in the consumption of some prey (*e.g.*, the use of *Neomysis* peaked during the summer). The use of *Crangon* peaked in the winter-spring, although it was a major prey in July 1996 samples (Table 4a). *G. lawrencianus* was mostly consumed in the fall, especially in 1996, as was the red copepod *Pseudodiaptomus coronatus*.

There was a clear shift evident in prey use with windowpane growth (*e.g.*, from *Neomysis* as overwhelmingly dominant for windowpane less than 20.0 cm TL, to *Crangon* for windowpane at larger sizes, although *Neomysis* was dominant at all sizes (Table 4b). Small fish (*e.g.*, *Anchoa* sp.) also become more important for the larger-sized fish.

The results suggest some differences in prey use among strata and regions (Table 4c). *Neomysis* seems to be the basic prey in the Ambrose Channel to Verrazano Narrows area (Strata 6 and 7). *Crangon*, on the other hand, seems to be more often eaten in the central-western areas of the Estuary (*i.e.*, Strata 2, 3, 8, and 9). Other prey constituted an insignificant proportion (a TV of less than 10%) of the diet in most areas, except in Strata 4 and 5 (the marine shoals) where small or juvenile fish were eaten. Windowpane abundances were highest in channels (Figure 3) where *Neomysis* might be most abundant; see the "Forage Base" section for a discussion of the habitat of *Neomysis*.

Comparisons with Other Diet Studies

No previous focused studies of the diet of this species are known for this estuary, although Breder (1922b) commented that stomach contents of a few specimens that he examined "consisted of crustacean remains, probably schizopods [mysids]." In general, other studies of the diet of this species in the Middle Atlantic Bight found mysids (especially *Neomysis)*, *Crangon*, and "nekton" (*i.e.*, small fish and squid) to be primary prey (Table 5), but smaller-sized windowpane also ate copepods. For the continental shelf, Langton and Bowman (1981) reported 40-60% of the windowpane that they had examined had empty stomachs, but mysids and shrimp continued to dominate the diet offshore. The results of the present study are consistent with those of other studies and with Bigelow and Schroeder's (1953) general summary of the diet, except for the relatively high use of *G. lawrencianus* as prey in the present study.

Little Skate (*Raja erinacea*)

Hudson-Raritan Estuary Results

Little skate (mostly adults) were commonly found throughout this estuary during most seasons, except the summer (Figure 4; Wilk *et al.*1998). The stomachs of 332 little skate (range of 33.0-49.0 cm TL, mean of 43.2 cm) were examined. Over 50 prey taxa or items, which ranged from green algae to a variety of small fish, were identified in the little skate diet. These prey taxa included 11 decapod crustaceans, 6 amphipods, 5 polychaetes, 8 mollusks, 10 identifiable fish, and miscellaneous prey or items (Table 6).

The most frequently found prey, overall, was *Crangon* at an FO of 82.8% (range of 77.2-92.9%). This prey was followed by juvenile or small Atlantic rock crabs at an FO of 49.5% (range of 7.1-75.3%), which were often found in a soft-shell stage, then by *Neomysis* at an FO of 16.3% (range of 6.1-28.5%) and *Ovalipes ocellatus* at an FO of 10.9% (range of 1.2-36.4%). The remaining prey had overall FOs of less than 10% (Table 6), with few empty stomachs.

The TV parallels the FO, with *Crangon* having 29.6% (range of 20.3-90.1%) of the TV, Atlantic rock crabs having 18.6% (range of 4.7-38.1%), and other prey having less than 10%, with the exception of the October 1996 sampling period when *O. ocellatus* had 15.6% (Table 6). A number of juvenile blue crabs were also eaten (Table 6).

Other prey or items found in little skate stomachs in lesser quantities were: unidentified green algae; hydroids; nematodes; nemerteans; **gastropods** (*Lacuna vincta*, *Nassarius trivittatus*, and *Astyris lunata*); **bivalve mollusks** (blue mussels, *Mulinia lateralis*, northern quahog siphons, and unidentified); **polychaetes** (*Lumbrineris* sp., *Spiochaetopterus oculatus*, *Arabella iricolor*, *Pherusa affinis*, *Diopatra cuprea*, and unidentified); **copepods** (*Pseudodiaptomus coronatus*); **cumaceans** (unidentified); **isopods** (*Cirolana concharum*, and *Cyathura* sp.); **amphipods** (*Leptocheirus pinguis*, *Hippomedon serratus*, *Unciola* sp., *Ampelisca abdita*, and unidentified); **decapod crustaceans** (unidentified, xanthids, *Pagurus pollicaris*, *P. longicarpus*, *Palaemonetes vulgaris*, *Dichelopandalus leptocerus*, and *Axius serratus*); **stomatopods** (*Squilla empusa*); **fish** (*Raja* sp. egg case fragments, juvenile rock gunnel (*Pholis gunnellus*), juvenile windowpane, northern searobin (*Prionotus carolinus*), unidentified searobins, sand lance, smallmouth flounder (*Etropus microstomus*), goby (*Gobiosoma* sp.), northern pipefish (*Syngnathus fuscus*), juvenile red hake, juvenile winter flounder, and juvenile silver hake (*Merluccius bilinearis*)); and sand, wood fragments, and human artifacts such as coal granules, iron rust flakes, and plastic particles.

Although little skate tended to be most common in this estuary in the cooler months, and sample sizes are relatively small in the summer, there appears to be a possible predation emphasis on Atlantic rock crabs and *Neomysis* during the cooler months (Table 6).

Comparisons with Other Diet Studies

No previous studies of the diet of this species are known for this estuary. However, the diet of this species has been studied elsewhere, both on the Middle Atlantic Bight continental shelf, and within other bays and estuaries (Table 7). These studies also show that small crustaceans dominate the little skate diet; with skate less than 20.0 cm TL eating small crustaceans (*e.g.*, copepods, mysids, and amphipods such as *Unciola irrorata, Gammarus annulatus, Leptocheirus pinguis,* and *Monoculodes edwardsi*), and with larger skate eating more decapod crustaceans, especially *Crangon*, *Cancer* sp., *Dichelopandalus leptocerus*, and hermit crabs (*Pagurus* sp.). However, squid and small fish (*e.g.*, sand lance, butterfish (*Peprilus triacanthus*), “herring” (*Alosa* sp.?), searobins, juvenile flounder, and red hake) were also eaten (Table 7). The diet of little skate from the Estuary (Table 6) is consistent with these other study results, and with the general dietary summaries reported in Nichols and Breder (1927) and Bigelow and Schroeder (1953).

Scup (*Stenotomus chrysops*)

Hudson-Raritan Estuary Results

Scup, mostly juveniles, were found from spring through fall in the Estuary and were relatively widespread in distribution, although with a tendency to be collected more often in the northern areas (Figure 5). The stomachs of 254 scup (range of 8.0-24.0 cm FL, mean of 12.9 cm) were examined. At least 39 items or prey taxa were identified in their stomachs, including 8 polychaetes, 7 amphipods, 6 decapod crustaceans, 6 mollusks, 2 mysids, and other taxa (*e.g.*, hydroids). The majority of these prey were benthic, except for mysids and *Gammarus lawrencianus* (Table 8).

The dominant items in the diet by FO were unidentified organic matter at 35.8% (range of 21.3-46.1%), *Neomysis* at 32.3% (range of 17.3-50.0%), bivalve mollusk remains at 14.3% (range of 1.3-26.7%), *G. lawrencianus* at 16.8% (range of 0.0-48.3%), *Crangon* at 15.2% (range of 3.9-30.7%), unidentified polychaetes at 14.2% (range of 6.7-35.5%), and *Ampelisca abdita* at 10.1% (range of 0.0-18.0%) (Table 8).

The contribution of prey to the overall TV parallels that to the overall FO in the same order of contribution (Table 8). There were few empty stomachs.

Other prey or items found in scup stomachs in lesser quantities were: unidentified hydroids; unidentified nemerteans; **gastropods** (juvenile *Crepidula* sp., unidentified, and eggs); **bivalve mollusks** (*Tellina agilis* and *Nucula* sp.); **polychaetes** (*Paranaites speciosa*, *Asabellides oculata*, *Sabellaria vulgaris*, *Pectinaria gouldii*, *Phyllodoce* sp., *Pherusa affinis*, and *Nereis* sp.); **copepods** (*Pseudodiaptomus coronatus* and unidentified calanoid); **cirripeds** (*Balanus* sp.); **tanaids** (unidentified); **isopods** (*Cyathura* sp.); **amphipods** (unidentified, *Orchomenella* sp., *Photis* sp., caprellids, *Unciola* sp., and *Corophium* sp.); **mysids** (*Mysidopsis bigelowi*); **decapod crustaceans** (xanthid crabs, juvenile blue crabs, and unidentified); and **fish** (silversides (*Menidia* sp.) and unidentified).

There were few, notable, interannual or seasonal differences in the diet of this basically warm-season species, with the possible exception of predation on *G. lawrencianus* in 1996 that was not evident in 1997 (Table 8).

Comparisons with Other Diet Studies

Within this estuary, the only previous known data on the scup diet is from the unpublished, preliminary 1976 results of the senior author, who examined 13 juvenile fish from Strata 1, 3, and 4. He found that the mostly frequently consumed prey were: the polychaete *Asabellides oculata* and copepods in Sandy Hook Bay, polydorid polychaetes and the dwarf surfclam *Mulinia lateralis* off Staten Island, and copepods and blue mussel spat on Romer Shoal (Stratum 4).

Michelman (1988) found that the juvenile scup diet in Rhode Island varied seasonally, but was still generally focused on benthic invertebrates, such as polychaetes (*e.g.*, maldanids, *Nephtys* sp*., Nereis* sp*.,* and *Pherusa affinis*), small decapod crustaceans (*Pagurus* sp. and other crabs), *Neomysis*, amphipods (*Leptocheirus pinguis* and others), as well as mollusks, a burrowing anemone (*Ceriantheopsis americanus*), and fish eggs and larvae.

Most other studies found that scup less than 15 cm FL ate small invertebrates such as copepods, polychaetes, amphipods, decapod crustaceans (especially juvenile Atlantic rock crabs), and squid (Table 9); a number of qualitative or summary reports have found the same (Baird 1873; Peck 1896; Nichols and Breder 1927; Hildebrand and Schroeder 1928; Bigelow and Schroeder 1953; Allen *et al.*1978). Linton (1901) and Sedberry (1983) found that the diet of scup gradually shifted with growth or size from small pelagic crustaceans to a variety of benthic taxa. The results of the present study are basically consistent with these other results, and show a strong reliance on benthic macrofauna and detritus as prey.

Summer Flounder (*Paralichthys dentatus*)

Hudson-Raritan Estuary Results

This species was most commonly collected during the summer and throughout the Estuary, but especially along the New Jersey shore (Figure 6; Wilk *et al.*1998). The stomachs of 229 summer flounder (range of 13.8-69.0 cm TL, mean of 36.0 cm) were examined. Over 35 prey species or items were identified in their diet, including juvenile or small adults of 12 species of fish, 5 species of decapod crustaceans, *Neomysis*, and other taxa (Table 10).

Crangon with an FO of 49.5% (range of 34.4-78.0%) and *Neomysis* with an FO of 19.8% (range of 0.0-33.6%) were most frequently eaten. Unidentified fish were next with an FO of 13.2% (range of 0.0-14.0%), and juvenile *Ovalipes ocellatus* were prominent in the August 1997 stomach samples (Table 10).

The FO ranking was also followed by the TV ranking, with *Crangon* having a TV of 29.4%, and *Neomysis* having a TV of 11.4% (Table 10). The percentage of empty stomachs ranged from 10 to 50%, with the highest levels being found in the winter-spring period.

Other prey or items found in summer flounder stomachs in lesser quantities were: unidentified algae; hydroids; bryozoans; **gastropods** (*Crepidul*a sp. and *Nassarius trivittatus*); **bivalve mollusks** (blue mussel spat, *Mulinia lateralis*, *Ensis directus*, *Nucula* sp., and *Tellina agilis*); **polychaetes** (*Sabellaria vulgaris* and unidentified); **copepods** (unidentified calanoid); **isopods** (*Cyathura* sp.); **amphipods** (caprellids, *Gammarus lawrencianus*, and *Ampelisca abdita*); **decapod crustaceans** (juvenile blue crabs, *Pagurus longicarpus*, and unidentified); and **fish** (juvenile scup, cunner, rock gunnel, juvenile searobins, juvenile weakfish (*Cynoscion regalis*), *Menidia* sp., juvenile striped searobin (*Prionotus evolans*), juvenile black sea bass (*Centropristis striata*), northern pipefish, juvenile *Alosa* herring, and juvenile grubby (*Myoxocephalus aenaeus*)).

Summer flounder were mostly collected in the spring and summer (Table 10), so seasonal shift could not be examined. There were few notable dietary differences between 1996 and 1997, although in 1997 summer flounder made greater use of *O. ocellatus* and unidentifiable juvenile flounder as prey. Most (85%) of the summer flounder examined were 30 cm TL or more, and probably not YOY. Despite the small sample size for YOY summer flounder, their diet differed little from that of larger fish: *Crangon* and *Neomysis* dominated the diet, with small *Ovalipes* and fish being of notable importance (Table 10).

With the number of samples being few (*i.e.*, less than 30 samples per stratum), and with the distribution of samples among strata being small, the results of interstrata comparisons were inconclusive, although there was a suggestion that *Crangon* were eaten commonly everywhere except in the Romer Shoal and Ambrose Channel areas (Strata 4 and 7). *Neomysis* were mostly found in stomachs examined from deeper channels (Strata 8 and 9) and near the Verrazano Narrows (Stratum 6), but also within Sandy Hook Bay (Stratum 1). The latter observations perhaps reflected some recent feeding in the unsampled Sandy Hook and Earl Naval Channels, located between Strata 1, 2, and 4.

Comparisons with Other Diet Studies

No previous studies of the diet of this species are known for this estuary.

In general, YOY summer flounder prey upon small fish (*e.g.*, silversides, mummichog (*Fundulus heteroclitus*), bay anchovy (*Anchoa mitchilli*), and sticklebacks), and *Palaemonetes*, *Crangon*, and *Neomysis* shrimps (Table 11). The species is highly opportunistic, but its diet shifts ontogenetically, from small crustaceans at smaller sizes, to fish prey at larger sizes. The diet of the predominantly YOY and juvenile summer flounders examined in the Estuary, dominated by crustaceans and small fish (Table 10), is consistent with other studies (Table 11), and with the generalizations of Hildebrand and Schroeder (1928), Ginsberg (1952), and Bigelow and Schroeder (1953), which were often based on small or ambiguous sample sizes.

Red Hake (*Urophycis chuss*)

Hudson-Raritan Estuary Results

Red hake were commonly collected in channels and the deep area below the Verrazano Narrows (Gravesend Bay, Stratum 6; Figure 7) and during most seasons (Wilk *et al.*1998). The diet of 166 red hake (range of 4.3-39.0 cm TL, mean of 19.0 cm) was examined. These fish were primarily juveniles and were most frequently collected during cooler seasons. At least 33 prey species were identified in the diet, including 7 decapod crustaceans, 9 amphipods, *Neomysis*, 7 juvenile fishes, and other taxa from algae to mollusks. Most prey were benthic species.

Crangon with an FO of 77.6% (range of 56.3-100.0%), *Neomysis* with an FO of 31.7% (range of 0.0-48.4%), *Gammarus lawrencianus* with an FO of 20.9% (range of 0.0-100.0%), and unidentified organic detritus with an FO of 10.6% (range of 0.0-20.6%) dominated the diet.

Crangon dominated the diet's TV at 39.0% (range of 23.3-50.0%), followed again by *Neomysis* at 15.7% (range of 0.0-30.3%) (Table 12). The other prey were infrequently found in the stomachs, and few stomachs were found empty. The inadequate samples in 1996 and during warmer months (Table 12) prevent analysis of seasonal or interannual variation in the diet of this species.

Other prey or items found in red hake stomachs in lesser quantities were: green algae; hydroids; **bivalve mollusks** (*Nucula* sp., *Tellina agilis*, blue mussel spat, and unidentified); **polychaetes** (unidentified and *Pherusa affinis*); **copepods** (*Pseudodiaptomus coronatus* and unidentified calanoid); **isopods** (*Edotea triloba*); **amphipods** (*Phoxocephalus holbolli*, *Unciola* sp., *Ampelisca abdita*, *Corophium* sp., *Jassa falcata*, *Stenothoe* sp., *Hippomedon serratus*, and unidentified); **decapod crustaceans** (juvenile *Libinia* sp., *Pagurus longicarpus*, juvenile *Ovalipes ocellatus*, *Palaemonetes vulgaris*, and unidentified); **fish** (juvenile silver hake, juvenile red hake, smallmouth flounder, juvenile searobin, juvenile weakfish, juvenile cunner, unidentified juvenile flounder, and skate (*Raja* sp.) egg case fragments); and wood fragments.

Comparisons with Other Diet Studies

The diet of red hake from the Estuary (Tables 12) is consistent with other dietary studies for the species, with crustaceans being primary prey. The only previous, quantitative study of the diet of this species in Raritan Bay examined 45 subadults of this species in spring 1976 within Sandy Hook Bay and off Staten Island (Steimle, unpubl. data). That diet was dominated (*i.e.*, a TV of 92-100%) by *Crangon*. This result is consistent with Breder's (1922b) earlier comment that the few red hake that he looked at in Sandy Hook Bay in summer 1921 were "crammed full of large prawns"; these "prawns" were further defined as being *Crangon* in Nichols and Breder (1927).

In the nearby New York Bight apex (outside the mouth of the Estuary), over 1,000 red hake were examined and found to prey most commonly on *Crangon*, various polychaetes (mostly *Pherusa affinis* and *Nephtys incisa*), *Neomysis*, and benthic amphipods (Steimle 1985, 1994) (Table 13). Hildebrand and Schroeder (1928) observed that red hake that were caught off Sandy Hook had gorged on sand lance. In general, the summary of other studies (Table 13) and the treatise by Bigelow and Schroeder (1953) show that juvenile red hake eat a variety of small benthic and zooplanktonic invertebrates, but primarily crustaceans. Steiner *et al.*(1982) reported that juvenile red hake use shelter during the day (such as living sea scallops, *Placopecten magellanicus*) and leave this shelter to feed at night. As red hake grow, larger crustaceans such as decapods increase in importance in their diet, and some fish are also eaten (Table 13). Adult red hake were rarely collected within the Estuary (Wilk *et al.*1998).

Weakfish (*Cynoscion regalis*)

Hudson-Raritan Estuary Results

Weakfish were another summer-fall inhabitant of the Estuary and were collected mostly in or near channels, especially in Stratum 9, Raritan Channel (Figure 8). The stomachs of 197 weakfish (range of 7.5-54.0 cm TL, mean of 17.7 cm) were examined. Over 20 prey species or items were identified in the diet, but they were dominated by crustaceans and a few juvenile or small fish. *Crangon* and *Neomysis* were the most frequently eaten prey, with only *Gammarus lawrencianus* and digested fish (probably bay anchovy) being of any relative importance (Table 14). There do not appear to be any consistent interannual differences in the diet, although there were pulses of the consumption of *Neomysis*, bay anchovy, and juvenile silver hake in the diet during certain sampling periods (Table 14).

Other prey or items found in weakfish stomachs in lesser quantities were: unidentified hydroids; **gastropods** (*Nassarius trivittatus*); **polychaetes** (unidentified); **crustaceans** (unidentified); **copepods** (*Pseudodiaptomus* *coronatus*); **amphipods** (*Corophium sp.* and *Unciola* sp.); **decapod crustaceans** (*Dichelopandalus leptocerus*, juvenile *Ovalipes ocellatus*, juvenile Atlantic rock crabs, and juvenile blue crabs); **fish** (juvenile weakfish, juvenile Atlantic menhaden, butterfish, juvenile unidentified flounder, and juvenile windowpane); and human artifacts such as cellophane.

Comparisons with Other Diet Studies

The only previous information on the diet of this species known for this estuary are comments by Breder (1922b) that, when he examined a few adult weakfish from Sandy Hook Bay, he found that they had eaten fish such as Atlantic menhaden [juveniles?] , silver perch (*Bairdiella chyrsoura*), and anchovies, and squid and "prawns" [*Crangon*]. Another cursory diet examination by Lynch *et al.*(1977) of 25 juvenile fish from the Raritan River (western boundary of the Estuary) also noted that weakfish there also ate *Crangon* and fish. Within the upper Hudson River Estuary (above Manhattan Island), Gladden *et al.*(1988) reported that weakfish generally ate "fish and macroinvertebrates."

The summaries of the results of other weakfish studies (Table 15) and the generalized summary of Bigelow and Schroeder (1953) show that the diet of this species can vary substantially among estuaries. That is, it can be dominated by *Crangon* or small fish (especially bay anchovy and juvenile weakfish) in some estuaries, but by mysids (mostly *Neomysis*) or amphipods (*e.g.*, *Gammarus* sp.) in others. The earliest studies listed in Table 15 were less precise in defining prey, but the "shrimp," "prawns," or "mysids" that they noted are almost certainly *Crangon* and *Neomysis*, and suggest that there does not appear to be any substantial shift in dominant prey over the decades, at least in the past century. Other weakfish diet studies were not listed in Table 15 because of limitations or the general nature of their information, *e.g.*, Eigenmann (1902), Linton (1901), Tracy (1910), Nichols and Breder (1927), Hildebrand and Schroeder (1928), Lascara (1981), and Grecay (1990). The pattern of weakfish predation within the Estuary seems to be typical and focused on both *Crangon* and *Neomysis*, but small fish (*e.g.*, bay anchovy, butterfish, and weakfish) and *Gammarus* sp. amphipods are also important (Tables 14 and 15).

Spotted Hake (*Urophycis regia*)

Hudson-Raritan Estuary Results

Spotted hake of all size and age classes were collected commonly during the warmer months within the Estuary and mainly in channels, especially Raritan Channel (Stratum 9, Figure 9). The 162 spotted hake (range of 6.5-33.0 cm TL, mean of 18.3 cm) which were examined ate 30 prey taxa, ranging from hydroids to fish. The most frequently eaten prey were crustaceans (*i.e.*, *Crangon*, *Neomysis*, and *Gammarus lawrencianus*) and small fish (Table 16). The copepod *Pseudodiaptomus coronatus* was frequently eaten in half of the sampling periods. Few empty stomachs were found. *Crangon* dominated the overall stomach volumes with a TV of 45.7% (range of 31.3-60.9%) (Table 16).

Other prey or items found in spotted hake stomachs in lesser quantities were: unidentified nematodes; **bivalve mollusks** (unidentified, *Nucula* sp., blue mussel spat, and juvenile *Pitar morrhuanus*); **polychaetes** (unidentified, *Nereis* sp., and *Pherusa affinis*); **sipunculids** (unidentified); **crustaceans** (unidentified); **copepods** (unidentified); **amphipods** (unidentified, *Ampelisca abdita, Jassa falcata, Hippomedon serratus*, *Unciola* sp., and *Ericthonius* sp.); **decapod crustaceans** (juvenile Atlantic rock crabs, *Ovalipes oculata, Pagurus* sp., *Dichelopandalus leptocerus*, and *Palaemonetes* sp.); and **fish** (juvenile silver hake, juvenile red hake, juvenile searobins, and smallmouth flounder).

Comparisons with Other Diet Studies

No previous studies of the diet of this species are known for this estuary.

In general, other studies show that spotted hake usually eat larger epibenthic crustaceans and small fish (Table 17). Among the crustaceans eaten, *Crangon*, *Neomysis*, copepods, other decapod shrimp, and crabs were prominent in the diet of this species. The variety of fish identified in these other studies included bay anchovy and sand lance among others. This diet spectrum is consistent with Bigelow and Schroeder's (1953) review, the species' diet south of Cape Hatteras (Burr and Schwartz 1986), and with the results of the present study (Table 16).

Striped Searobin (*Prionotus evolans*)

Hudson-Raritan Estuary Results

Adults and juveniles of this species were collected mostly during the summer months, and in or near channels or within Sandy Hook Bay (Figure 10; Wilk *et al.*1998). The 153 samples of striped searobin (range of 4.5-47.2 cm TL, mean of 21.4 cm) which were examined ate 34 identifiable prey taxa, but most frequently preyed upon *Crangon, Neomysis*, and other crustaceans, and upon small or juvenile fish. Of interest was the relatively frequent occurrence of small, approximately 1-3 mm, coal granules or pebbles in their stomachs (Table 18). The TV was dominated (45.8%, range of 37.4-71.4%) by *Crangon* (Table 18). The diet was similar for 1996 and 1997 (Table 18).

Other prey or items found in striped searobin stomachs in lesser quantities were: unidentified hydroids; **gastropods** (unidentified, *Nassarius obsoletus*, and *N. trivittatus*); **bivalve mollusks** (*Nucula* sp., *Mulinia lateralis*, and *Ensis directus*); **cephalopod** (unidentified squid); **polychaetes** (unidentified); **crustaceans** (unidentified); **copepods** (unidentified and *Pseudodiaptomus coronatus*); **isopods** (*Edotea triloba*); **amphipods** (unidentified, *Corophium* sp., and *Unciola* sp.); **mysids** (*Heteromysis formosa*); **decapod crustaceans** (xanthid crabs and unidentified crab fragments); **fish** (smallmouth flounder, juvenile windowpane, juvenile anchovy, juvenile grubby, unidentified juvenile flounder, juvenile searobin, juvenile black sea bass, and juvenile stargazer (*Astroscopus* sp.)); and sand.

Comparisons with Other Diet Studies

There is only one other study of the diet of this species known for this estuary. Manderson *et al.* (1999) examined 35 stomachs of this species from shallow water in Sandy Hook Bay (near Stratum 1) and its Navesink River tributary, at its southern border. They reported an FO of 68% of YOY winter flounder in the searobin's diet, although *Crangon* and other crustaceans were the primary prey.

A summary of most other quantitative studies of the diet of this species from different areas shows that the diet was also based on crustaceans (*e.g.*, *Crangon*, *Neomysis*, copepods, amphipods, and juvenile crabs) and small or juvenile fish (*e.g.*, winter flounder, striped and northern searobins, scup, windowpane, bay anchovy, *Menidia*, northern pipefish, and probably others) as available (Table 19). Other, more generalized discussions of their diet, *e.g.*, Bigelow and Schroeder (1953), also note a broad spectrum of prey in the diet of this species, including crabs, amphipods, squid, bivalve mollusks, polychaetes, small fish (herring and winter flounder), and algae. In Richards *et al.*'s (1979) Long Island Sound study, they reported that the prey of age 1+ searobin varied with habitat type (*i.e.*, prey eaten on sandy bottoms were different from prey eaten on muddy bottoms). For example, on sandy bottoms, the razor clam (*Ensis directus*) was important. They also found that some predation showed no habitat-related differences (*e.g.*, on *Neomysis*, *Crangon*, and *Ovalipes ocellatus* and other crabs), and concluded that the diet of the adult striped searobin when at smaller sizes – although having a great deal of overlap with the sympatric but smaller northern searobin – tended to reduce competition for food by focusing on larger prey that were less specific in their habitat preferences. The results of the present study are consistent with the findings of other studies; although, again, one or more 2-5 mm diameter pebbles of coal or charcoal were observed in about 5% (range of 3-17%) of the stomachs (Table 18).

Northern Searobin (*Prionotus carolinus*)

Hudson-Raritan Estuary Results

This small species (range of 5.1-20.4 cm TL, mean of 15.1 cm) was collected mostly during the summer, and mainly in the eastern areas of the Estuary, *e.g.*, between Verrazano Narrows and Sandy Hook Bay (Figure 11; Wilk *et al.*1998). One hundred three northern searobin stomachs were examined, and over 20 prey taxa were identified, which were mostly crustaceans. The reoccurring prey group of *Crangon*, *Neomysis,* and *Gammarus lawrencianus* were most frequently found in the stomachs. The contribution of prey to TV parallels their contribution to FO, although juvenile Atlantic rock crabs were of added importance to the diet of the large, August 1997 collection sample (Table 20). Coal pebbles were also found in these stomachs, but only during one collection, and then at an FO of 25% for the 87 fish examined (Table 20).

Other prey or items found in northern searobin stomachs in lesser quantities were: **hydroids** (unidentified); **nematodes** (unidentified); **bivalve mollusks** (blue mussel spat); **polychaetes** (unidentified); **copepods** (*Pseudodiaptomus coronatus*); **isopods** (*Edotea triloba*); **amphipods** (*Corophium* sp., *Ampelisca abdita*, and *Leptocheirus pinguis*); **mysids** (*Heteromysis formosa*); **decapod crustaceans** (*Pagurus longicarpus*); **fish** (juvenile smallmouth flounder, juvenile striped searobin, and juvenile black sea bass); and unidentified organic matter.

Comparisons with Other Diet Studies

No previous studies of the diet of this species are known for this estuary.

Some results of other studies of the diet of this predator show that, like its sibling species, the striped searobin, the northern searobin also preys principally upon crustaceans, with *Crangon*, *Neomysis*, amphipods, and copepods being prominent in the diet, but fish are eaten to a lesser degree (Table 21). This dietary pattern was also reported by Hildebrand and Schroeder (1928) and Bigelow and Schroeder (1953). The smaller adult size of the northern searobin, compared to the striped searobin, is a logical explanation for the difference in the use of fish (although juvenile herring, winter flounder, weakfish, bay anchovy, and others are reported as prey), and perhaps for the slightly greater use of smaller macrofauna such as polychaetes and cumaceans. In Long Island Sound, Richards *et al.* (1979) reported on the diet of YOY and older northern searobins, and despite some ambiguity in their results, the YOY of this species appeared to prey principally upon *Neomysis* and copepods, based on numbers eaten. Larger fish were more focused on amphipods, isopods, and small decapod crustaceans as prey. Mann (1974) found that diet of this species varied with sediments and water depth. The summary of results (Table 21) also shows that the diet of northern searobin from this estuary (Table 20) is consistent with other studies (Table 21).

Striped Bass (*Morone saxatilus*)

Hudson-Raritan Estuary Results

Striped bass of small-to-medium size (range of 13.5-65.0 cm FL, mean of 33.2 cm) were generally only collected by trawl within the Estuary during the fall-winter, especially in western areas of the Estuary: Gravesend Bay (Stratum 6) and channels (Figure 12; Wilk *et al.*1998). The 81 striped bass which were examined ate a diversity of prey, with greater than 20 identifiable species. The diet was dominated by a variety of small or juvenile fish and crustaceans (Table 22). Many stomachs per collection (up to 100%) were empty. *Crangon* again led in the diet with an FO of 62.3% (range of 54.5-75.9%) and TV of 50.3% (range of 15.0-100.0%). All other prey occurred or contributed less than 5% to TV, except *Neomysis* (Table 22).

Other prey or items found in striped bass stomachs in lesser quantities were: **polychaetes** (*Nephtys* sp.); **isopods** (*Cirolana* sp.); **amphipods** (unidentified and *Gammarus lawrencianus*); **mysids** (*Heteromysis formosa*); **decapod crustaceans** (*Axius serratus*); **stomatopod** (*Squilla empusa*); **fish** (rock gunnel, juvenile searobin, juvenile unidentified flounder, juvenile conger eel (*Conger oceanicus*), juvenile *Urophycis* sp., northern pipefish, bay anchovy, striped anchovy (*Anchoa hepsetus*), juvenile winter flounder, and juvenile grubby).

Comparisons with Other Diet Studies

There are no data on the diet of striped bass from within this part of the overall Hudson-Raritan Estuary. However, Lawler, Matusky & Skelly Engineers (1980) and Gardinier and Hoff (1982) did report on the striped bass diet in the Hudson River, 50 km north of the Verrazano Narrows. There they found that juveniles, less than 20 cm FL, fed on a mix of freshwater and marine organisms, including *Gammarus* and other amphipods (*e.g.*, *Corophium, Leptocheirus*, and *Monoculodes*), insect larvae, copepods, isopods (*e.g.*, *Cyathura* sp.), polychaetes, small decapod crustaceans (*Crangon* and mud crabs), and some small fish. While larger individuals were almost totally piscivorous, preying on river herring, Atlantic tomcod (*Microgadus tomcod*), bay anchovy, white perch (*Morone americana*), and killifish, they occasionally ate small crustaceans. Gladden *et al.* (1988), possibly summarizing the same data, also reported the species ate "fish and macro invertebrates" in the same study area. Twenty-four, 7-39 cm FL striped bass were also collected in the Raritan River during April 1976 - March 1977, but all of their stomachs were found empty (Lynch *et al.* 1977).

In general, most dietary studies of this species found seasonal and regional variability in prey (Table 23) that often reflected differences in local environmental conditions (*e.g.*, salinity), in the size of the fish examined, and/or in the time of year (*e.g.*, Bigelow and Schroeder 1953). There is a clear and well documented ontological shift in predation focus from small crustaceans (*e.g.*, copepods, amphipods, and mysids) and small or juvenile fish for the youngest and smallest striped bass, to larger fish and crustaceans (*e.g.*, crabs and shrimp) for the older and larger striped bass. The smaller-sized striped bass examined in the present survey ate a mix of small crustaceans and fish (Table 22).

Clearnose Skate (*Raja eglanteria*)

Hudson-Raritan Estuary Results

Clearnose skate were collected in the sandier, eastern polyhaline areas within the Estuary, such as Lower Bay, Gravesend Bay, East Bank, Romer Shoal, Sandy Hook Bay, and Raritan Channel (Strata 1, 3-6, 9; Figure 13), and during the summer (Wilk *et al.*1998). The diet of the 71 clearnose skate which were examined (range of 49.0-86.0 cm TL, mean of 63.3 cm) included a diversity of crustaceans, fish, and other prey (Table 24). *Crangon*, juvenile or small Atlantic rock crabs and *Ovalipes ocellatus*, and fish were most frequently found in the stomachs and contributed most to overall stomach volumes (Table 24). No empty stomachs were found.

Other prey or items found in clearnose skate stomachs in lesser quantities were: unidentified algae; **mollusks** (unidentified); **amphipods** (unidentified); **mysids** (*Neomysis americana*); **decapod crustaceans** (*Pagurus longicarpus* and juvenile *Libinia* sp.); and **fish** (unidentified juvenile hake, juvenile striped searobin, juvenile black sea bass, rock gunnel, juvenile searobins, and gobies).

Comparisons with Other Diet Studies

No previous studies of the diet of this species are known for this estuary. In fact, information on the diet of this species in general is very weak, and only available from a few studies (Table 25). In Delaware Bay, Fitz and Daiber (1963) examined the diet of this species and found that it also most commonly ate *Crangon* (*i.e.*, an FO of 60%), *Ensis directus* (*i.e.*, an FO of 36%), mud crabs (*i.e.*, an FO of 20+%), and to a lesser degree, a variety of other small crustaceans, bivalve mollusks, and small fish such as weakfish and windowpane. Prey volume or weight contributions were not noted, but numerically, *Crangon* was still the dominant prey, and *Neomysis* was second in importance. Fritz and Daiber (1963) also noted that in the fall the skate ate more *Neomysis*, decapod crustaceans, and fish, but in the spring they focused more on *Crangon* and *Ensis*. Kimmel (1973) examined a small collection of juveniles (less than 44 cm TL) of this species at the mouth of Chesapeake Bay and found that *Crangon*, *Ensis*, and the mud shrimp *Upogebia affinis* volumetrically dominated stomach contents, but that a variety of epifaunal invertebrates (especially crustaceans) and small fish (searobins and hake) were also eaten. The diet described by the 1973 Kimmel paper is consistent with the prey that Hildebrand and Schroeder (1928) noted in the few clearnose skate that they examined from inside Chesapeake Bay. In the present study, the only prey that was found that have not been previously reported to be important in the diet were Atlantic rock crabs and *O. ocellatus* (Tables 24 and 25).

Bluefish (*Pomatomus saltatrix*)

Hudson-Raritan Estuary Results

Juvenile, YOY (range of 7.0-13.5 cm FL, mean of 8.9 cm) bluefish were collected in the summer-fall in the Estuary, and mostly in or near channels (Figure 14; Wilk *et al.*1998). The stomachs of 63 bluefish were examined; 62 of these were from one collection – August 1997. Fish, *Crangon,* and *Neomysis* dominated their diet (Table 26). The identifiable fish prey included mostly midwater forms: butterfish, silversides, anchovies, but also juvenile black sea bass.

The only other prey or items found in bluefish stomachs were unidentified algae and the polychaete *Nereis succinea*.

Comparisons with Other Diet Studies

Since only juvenile bluefish were collected and examined in this study, the following summary keeps that focus. Friedland *et al.*(1988) examined the diet of YOY bluefish in this estuary and reported that fish dominated the diet (by FO and TW) in Sandy Hook Bay (Stratum 1), especially bay anchovy, silversides, and killifish; however, *Crangon* were almost equally important, along with *Neomysis*. Breder (1922b) also notes that a small bluefish, also caught in Sandy Hook Bay, had a sand lance in its stomach. A limited study of the diet of bluefish in the Raritan River and adjacent western Raritan Bay found that juveniles (3-22.5 cm TL) collected by seine had eaten mummichog, bay anchovy, silversides, *Crangon*, *Palaemonetes* sp*.,* and unidentified fish, while larger bluefish (greater than 37 cm FL) collected by gill net had eaten Atlantic menhaden, spot (*Leiostomus xanthurus*), bay anchovy, and *Crangon* (Lynch *et al.*1977).

In the adjacent brackish Hudson River, YOY bluefish consumed a variety of fish during their summer residency, including juvenile striped bass, white perch, American shad (*Alosa sapidissima*), blueback herring (*A. aestivalis*), Atlantic tomcod, silversides, bay anchovy, and occasionally other species, as well as blue crabs (Juanes *et al.*1993; Buckel *et al.*1999) (Table 27).

In nearby southern Long Island, New York, and elsewhere in the coastal Middle Atlantic Bight, juvenile bluefish were reported to commonly eat small schooling fish such as silversides, bay anchovy, butterfish, killifishes, juvenile Atlantic menhaden, herring, and weakfish, as well as benthic fish such as winter flounder, spot, and Atlantic tomcod (Table 27; Greenley 1939; Tatham *et al.*1984). Small crustaceans, such as *Palaemonetes* sp., *Crangon,* and *Neomysis* also dominated the YOY or juvenile bluefish diet (Table 27). The diet of the relatively small sampling of juvenile bluefish examined in the present study (Table 26) show that Friedland *et al*.'s (1988) findings are probably representative of the species' diet within the Estuary, are typical for this life stage of the species (Table 27), and are consistent with previous dietary summaries (Baird 1873; Nichols and Breder 1927; Hildebrand and Schroeder 1928; Bigelow and Schroeder 1953; Richards 1976).

Winter Skate (*Raja ocellata*)

Hudson-Raritan Estuary Results

Adult winter skate were collected from all areas of the Estuary during the cooler seasons, but they were especially abundant in or near channels (Figure 15; Wilk *et al.*1998). The 57 winter skate (range of 36.0-77.0 cm TL, mean of 55.8 cm) which were examined ate a diverse diet of benthic invertebrates and fish. *Crangon* was also a major item in the diet, both in terms of FO and TV. Other crustaceans and a variety of small or juvenile fish (*e.g.*, Atlantic herring (*Clupea harengus*), sculpin, sand lance, and winter flounder) were also commonly consumed (Table 28).

Other prey or items found in winter skate stomachs in lesser quantities were: hydroids; **nematodes** (probably parasitic); **gastropods** (*Nassarius trivittatus*), **bivalve mollusks** (unidentified, *Mulinia lateralis*, and *Ensis directus*); **polychaetes** (unidentified); **mysids** (*Neomysis*); **decapod crustaceans** (unidentified crab fragments, *Pagurus longicarpus*, *Dichelopandalus leptocerus*, and juvenile blue crab); **stomatopods** (*Squilla empusa*); and **fish** (juvenile Atlantic herring, juvenile red hake, goby, unidentified juvenile sculpin, and smallmouth flounder).

Comparisons with Other Diet Studies

No previous studies of the diet of this species are known for this estuary.

Nichols and Breder (1927) and Bigelow and Schroeder (1953) noted the importance of Atlantic rock crabs and squid in the diet of this species in New England waters, and that this species also ate a variety of other benthic invertebrates (*e.g.*, polychaetes, amphipods, shrimp, and razor clams) and small fish, such as juvenile skates, eels, herrings, smelt, sand lance, mackerel, butterfish, cunner, sculpins, and silver and *Urophycis* hake. The few available quantitative studies, including the present study, are consistent with this overview (Table 29), except that the present study shows a higher use of flounder as prey (Table 28).

Black Sea Bass (*Centropristis striata*)

Hudson-Raritan Estuary Results

There was a significant recruitment of juvenile black sea bass into the Estuary in the summer-fall of 1997. (Juveniles were rarely collected in other survey years, and adults were seldom found within the Estuary.) These juveniles were widespread in occurrence with a slight tendency to be found in or near channels (Figure 16; Wilk *et al.*1998). The August 1997 survey collected 46 juveniles – 41 with nonempty stomachs (range of 2.9-29.0 cm TL, mean of 10.8 cm,), mostly at sites where colonies of redbeard sponge (*Microciona prolifera*) were collected. Various crustaceans dominated the diet, especially *Crangon*, *Neomysis,* and juvenile Atlantic rock crabs. The crustacean prey also included copepods, amphipods, isopods, and other small or juvenile decapods (Table 30). Several species of small or juvenile fish (*e.g.*, cunner, goby, Atlantic menhaden, and possibly anchovy) were also eaten, as were some other benthic invertebrate taxa.

Other prey or items found in their stomachs in lesser quantities were: **poriferans** (unidentified); **anthozoans** (unidentified); **nematodes** (unidentified); **gastropods** (juvenile *Crepidula* sp.); **bivalve mollusks** (*Ensis directus*); **polychaetes** (unidentified and *Asabellides oculata*); **copepods** (unidentified and *Pseudodiaptomus coronatus*); **isopods** (*Edotea triloba* and *Cirolana concharum*); **amphipods** (*Ericthonius* sp., *Stenothoe* sp., and caprellids); **decapod crustaceans** (juvenile *Ovalipes ocellatus* and *Pagurus* sp.); and **fish** (goby, juvenile cunner, and unidentified).

Comparisons with Other Diet Studies

No previous studies of the diet of this species are known for this estuary.

In other Middle Atlantic Bight estuaries, juvenile black sea bass prey principally upon small benthic crustaceans such as isopods, amphipods, small mud crabs, *Crangon,* mysids, and copepods, and upon small fish such as northern pipefish, anchovies, and silversides (Hildebrand and Schroeder 1928; Bigelow and Schroeder 1953; Richards 1963; Kimmel 1973; Allen *et al.*1978; Festa 1979; Orth and Heck 1980; Werme 1981). Kimmel (1973) noted that polychaetes (*e.g.*, *Nereis* sp. and *Glycera* sp.) can be important, too, and that the dominant prey shifted with fish growth (*i.e.*, from small crustaceans such as *Neomysis* and various amphipods, to decapod crabs and polychaetes).

Most of the black sea bass collected in the Estuary were YOY and older juveniles (Wilk *et al.*1998), but adults in other coastal areas have been reported to feed upon a variety of epifaunal and infaunal invertebrates, especially crustaceans, squid, and small fish (Bigelow and Schroeder 1953; Richards 1963; Mack and Bowman 1983; Steimle and Figley 1996). The diet of the juvenile black sea bass examined in the Estuary was dominated by small crustaceans (Table 30) and was similar to the diet of the species reported in other studies (Table 31).

Spot (*Leiostomus xanthurus*)

Hudson-Raritan Estuary Results

Spot are generally found in the Estuary in the summer-fall, and were especially common in or near the Raritan Channel (Stratum 9) and Sandy Hook Bay (Stratum 1, Figure 17) (Wilk *et al.*1998). Forty-seven spot (range of 12.8-18.5 cm FL, mean of 15.4 cm) were collected in fall-winter 1996. The tube-dwelling amphipod *Ampelisca abdita* dominated the identifiable prey, but *Crangon* and *Neomysis* were also prominent. Other benthic invertebrates, including the copepod *Pseudodiaptomus coronatus*, constituted the rest of the stomach contents, which also contained a notable amount of unidentifiable organic matter or detritus (Table 32).

Other prey or items found in spot stomachs in lesser quantities were: green algae; **bivalve mollusks** (unidentified spat); **polychaetes** (unidentified); and **amphipods** (*Corophium* sp., *Gammarus lawrencianus*, and unidentified).

Comparisons with Other Diet Studies

No previous studies of the diet of this species are known for this estuary.

In southern New Jersey, Festa (1979) found that YOY spot ate copepods and amphipods (*e.g.*, *Ampelisca* sp.), while larger juveniles also included a variety of polychaetes in the diet. Elsewhere, various studies show that YOY spot ate calanoid and harpacticoid copepods, a variety of other small crustaceans including larvae, and detritus; while larger juveniles (11-16 cm FL) ate more amphipods such as *Ampelisca macrocephala* (Table 33). Within Chesapeake

Bay, Hildebrand and Schroeder (1928) reported that the species ate “small and minute crustaceans and annelids, together with smaller amounts of small mollusks, fish and vegetable debris”. Smith *et al.*(1984) added that a wide diversity of plant material and benthic macrofauna was eaten. The diet of the spot examined from this estuary focused on small benthic organisms and detritus (Table 32), and is consistent with other dietary studies for the species (Table 33).

American Lobster (*Homarus americanus*)

Hudson-Raritan Estuary Results

A total of 47 American lobsters were collected during five seasons, mainly from Romer Shoal, Gravesend Bay, Chapel Hill, and Raritan Channel (Figure 18). The collections were a mix of juveniles and small adults (range of 2.8-9.9 cm carapace length, mean of 5.8 cm). The highly macerated state of the stomach contents, and the American lobster’s known tendency to eat calcareous shell fragments, make identification of all true prey tentative. Species or items that could be identified from the diverse, particulate material in the stomach were included in this analysis, however. The dominant items evident in the stomachs were fragments of decapod crustaceans, especially Atlantic rock crabs, *Pagurus* sp., and *Ovalipes ocellatus*. Other items that were found suggest a range of taxa being eaten (*i.e.*, hydroids to skate egg cases), as well as human artifacts such as coal pebbles, fragments of plastic and rubber, and synthetic fibers (Table 34).

Other prey or items found in American lobster stomachs in lesser quantities were: **gastropods** (*Crepidula fornicata*, *Nassarius trivittatus*, *Lacuna vincta*, *Turbonilla* sp., and *Euspira* operculums); **bivalve mollusks** (*Mulinia lateralis*); **polychaetes** (unidentified, *Nereis succinea*, and *Spiochaetopterus oculatus*); **arachnids** (juvenile *Limulus polyphemus*); **cirripeds** (*Balanus* sp.); **decapod crustaceans** (*P. longicarpus, O. ocellatus*, and juvenile *Callinectes* sp.); and **echinoderms** (*Arbacia punctulata*).

Comparisons with Other Diet Studies

No previous studies of the diet of this species are known for this estuary.

Steimle (1994) examined the diet of American lobster collected outside the mouth of this estuary. He reported that the diet varied among three collection sites that were variably influenced by sewage sludge disposal, and among bimonthly collections, although few American lobster were collected during winter. At the least-sludge-affected sites (probably being most appropriate for comparison with this estuary), the American lobsters were primarily eating Atlantic rock crabs, unidentified fish, the polychaete *Pherusa affinis*, and algae (Table 35). He also noted obvious human artifacts in the stomachs, especially animal hair and synthetic fibers.

In Long Island Sound, Weiss (1970) reported American lobsters also ate crustaceans, especially Atlantic rock crabs, mollusks such as *Lacuna vincta* and the blue mussel, and the polychaete *Nereis virens*. Other American lobster diet studies have been conducted outside the Middle Atlantic Bight area (*e.g.*, in the sub-boreal Gulf of Maine and for Canadian populations). The diet of small American lobsters collected in the Estuary in the present study (Table 34) is consistent with the few available studies summarized in Table 35, and with the more general comments of Herrick (1911).

Tautog (*Tautoga onitis*)

Hudson-Raritan Estuary Results

Fifty-one tautog (range of 8.4-58.0 cm TL, mean of 37.5 cm) were collected and examined, primarily during the warmer seasons and from Romer Shoal, East Bank, Gravesend Bay, and, to a lesser degree, nearby areas (Figure 19). A variety of decapod crustaceans and mollusks were the most frequently eaten prey, with Atlantic rock crabs, xanthid crabs (including *Dyspanopeus sayi*), and blue mussels being prominent in the diet (Table 36).

Other prey or items found in tautog stomachs in lesser quantities were: hydroids; **gastropods** (unidentified, *Crepidula* sp., and unidentified eggs); **bivalve mollusks** (*Anadara ovalis* and juvenile northern quahogs); **cirripeds** (*Balanus* sp.); **amphipods** (*Gammarus* sp. and *Ericthonius* sp.); **decapod crustaceans** (unidentified and juvenile *Libinia* sp.); and shell hash.

Comparisons with Other Diet Studies

No previous studies of the diet of this species are known for this estuary, although Duffy-Anderson and Able (1999) mention that the diet of juvenile tautog held in cages in New York harbor appears to be “harpacticoid copepods, mysids, and amphipods.”

Steimle and Shaheen (1999) summarized the diet of tautog, which has been resummarized in this report as Table 37. Dorf (1994) found that juveniles in Narragansett Bay, Rhode Island, ate various amphipods and copepods (mostly harpacticoids). Grover (1982) found a similar juvenile diet on the ocean side of Long Island, New York, as did Sogard (1992) in a southern New Jersey estuary. Nichols and Breder (1927) also noted seaweed in the diet of young tautog. The diet of older, 2-3 yr old juveniles was generally found to shift to mollusks, primarily blue mussels (Dorf 1994; Lankford *et al.*1995), but Festa (1979) reported mud crabs to be a primary item in the diet of larger juveniles in southern New Jersey.

Adult tautog are generally reported to prey primarily upon blue mussels, but also upon barnacles, crabs (*Pagurus* sp., Atlantic rock, and others), sand dollars (*Echinarachnius parma*), various amphipods, *Crangon* and other shrimp, American lobsters, scallops and other mollusks, and polychaetes (Hildebrand and Schroeder 1928; Bigelow and Schroeder 1953; Festa 1979; Steimle and Ogren 1982). Steimle (in review) found that besides blue mussels, the large anemone *Metridium senile* and razor clams (*Ensis directus*) can be important prey in Delaware Bay. The results of the present study (Table 36) reaffirm the importance of "shellfish," crustaceans, and mollusks, in the tautog diet.

Smooth Dogfish (*Mustelis canis*)

Hudson-Raritan Estuary Results

This relatively large (range of 55.0-111.0 cm TL, mean of 74.6 cm) visitor to the Estuary was collected in modest numbers (*i.e.*, 42 specimens) during the warm seasons of both survey years, and mostly from Romer Shoal, East Bank, Gravesend Bay, nearby eastern Lower Bay areas, and near the Raritan Channel (Figure 20). It primarily ate a variety of decapod crustaceans and mollusks, and an occasional fish. Among the decapod prey, *Crangon,* Atlantic rock crabs, and *Ovalipes ocellatus* were commonly eaten, and the most notable molluscan prey was the razor clam *Ensis directus* (Table 38).

Other prey or items found in smooth dogfish stomachs in lesser quantities were: **bivalve mollusks** (Atlantic surfclam); **cephalopods** (unidentified squid); **polychaetes** (unidentified and *Glycera* sp.); **decapod crustaceans** (*Pagurus pollicaris*, *Pagurus* sp., and *Libinia* sp.); **stomatopods** (*Squilla empusa*); and **fish** (juvenile Atlantic menhaden, northern pipefish, and lined seahorse (*Hippocampus erectus*)).

Comparisons with Other Diet Studies

No previous studies of the diet of this species are known for this estuary.

Rountree and Able (1996) examined the diet of YOY of this species in a southern New Jersey estuary and found small *Palaemonetes* sp. and *Crangon* shrimp as the dominant prey, followed by unidentified polychaetes and crabs, blue crabs, and a variety of other benthic invertebrates (especially crustaceans); very few fish were eaten (Table 39). These results were similar to an early study, near Atlantic City, New Jersey, by Breder (1921) who reported that various crabs, eel grass, detritus, and fish were the most common items in the stomachs of smooth dogfish less than 64 cm TL. Nichols and Breder (1927) noted a preference for eating young American lobster and blue crabs, as well as other crustaceans, fish, and a variety of benthic macrofauna. Bigelow and Schroeder (1953) also commented on the potential heavy predation of smooth dogfish on American lobsters in Buzzards Bay, Massachusetts, as well as predation on Atlantic menhaden and tautog. Festa (1979) examined 12 juvenile smooth dogfish from southern New Jersey and found that blue crabs dominated (*i.e.*, a TV of 91%) the diet, followed by "bay" [*Crangon*?] and *Palaemonetes* shrimp and juvenile weakfish. The present examination of the smooth dogfish diet in the Estuary (Table 38) shows that the species basically eats larger crustaceans and fish, which is consistent with the results of most other studies (Table 39).

Silver Hake (*Merluccius bilinearis*)

Hudson-Raritan Estuary Results

In general, silver hake were only collected as juveniles (range of 6.5-15.0 cm TL, mean of 10.1 cm) in the Estuary, and then primarily during the fall and in or near channels (Figure 21; Wilk *et al.*1998). Juvenile silver hake were not commonly available for examination except in November 1997 when 29 were collected. Crustaceans were the most common and important taxa in the diet, especially *Crangon*, *Neomysis*, *Gammarus lawrencianus*, and *Ampelisca abdita,* but small or juvenile fish were also eaten (*e.g.*, silver hake, Atlantic menhaden, and probably anchovies). Both benthic and midwater fauna were eaten (Table 40).

Other prey or items found in silver hake stomachs in lesser quantities were: **crustaceans** (unidentified); **cumaceans** (unidentified); **isopods** (*Edotea triloba*); **amphipods** (unidentified, *Jassa falcata*, *Hippomedon serratus*, and *Unciola* sp.); **decapod crustaceans** (*Palaemonetes* sp.); and **fish** (juvenile Atlantic menhaden).

Comparisons with Other Diet Studies

No previous studies of the diet of this species are known for this estuary.

Table 41 summarizes dietary studies for juvenile and older silver hake that could be relevant to the present study. Schaefer (1960) and Steimle (1985) examined stomachs of this species collected just outside this estuary, and found that mysids (mostly *Neomysis*), *Crangon*, small unidentifiable fish, and YOY silver hake were the most important prey for near adult and adult fish. Schaefer (1960) also examined adults caught by hook-and-line on a surf-zone fishing pier in Long Branch, New Jersey (20 km south of the mouth of the Estuary), and found a slightly different diet from that found offshore. Inshore, he found that silver hake ate amphipods, *Crangon*, YOY silver hake, and mysids, in that order of relative importance. Richards (1963) reported a similar diet in Long Island Sound. On the continental shelf, Sedberry (1983) and Bowman *et al.*(1987) found that juvenile (*i.e.*, less than or equal to 20 cm TL) silver hake ate various crustaceans, including euphausids and the hyperid amphipod *Parathemisto gaudichaudi*. Smaller, YOY silver hake (*i.e.*, less than 5 cm TL) ate benthic and pelagic amphipods; larger YOY (*i.e.*, between 5 and 10 cm TL) ate *Crangon* and *Dichelopandalus pinguis* [*leptocerus*?] shrimp, amphipods, small fish (sand lance and smaller silver hake), and squid. The juveniles collected in the Estuary during the present study ate a diet consistent with those studies noted in Table 41, with such studies as Jensen and Fritz (1960) and Vinogradov (1984), and with the generalizations of Bigelow and Schroeder (1953). Bowman *et al.* (1987) report that silver hake are mostly nocturnal feeders, and if so, mid-day collections might involve some loss of information by the digestion of softer prey. Few adult silver hake are collected in the Estuary (Wilk *et al.*1998).

Less Abundant Predators

The following predators were collected in lesser quantities and in more limited areas. Their diets are only briefly documented here, with identifiable prey being listed in order of their relative importance to overall stomach content volumes.

Fourspot Flounder (Paralichthys oblongus)

Forty-one examples of this predator were collected from several strata, and ranged between 6.7 and 33.0 cm TL (mean of 15.1 cm). *Crangon*, unidentified fish, *Neomysis*, and unidentified decapod crustacean zoeae were prominent in the diet.

Grubby (Myoxocephalus aenaeus)

Twenty-six specimens, ranging between 3.8 and 13.0 cm TL (mean of 7.9 cm), were collected mostly in the Lower Bay to East Bank area (Strata 3 and 5). They ate *Crangon*, *Neomysis*, juvenile Atlantic rock crabs, juvenile black sea bass, the tubiculous amphipod *Corophium* sp., the isopod *Cyathura* sp., caprellid amphipods, and the sand-tube worm *Sabellaria vulgaris*.

White Perch (Morone americana)

Twenty-one white perch were collected, mostly in western Raritan Channel (Stratum 9), and ranged between 16.0 and 27.7 cm TL (mean of 21.0 cm). These fish ate *Crangon*, unidentified small or juvenile fish, unidentified crustaceans, gobies (*Gobisoma* sp.), *Neomysis*, *Palaemonetes* sp., and *Gammarus* sp.

Northern Kingfish (Menticirrhus saxatilis)

Sixteen kingfish were collected, mostly in the Lower Bay to East Bank area (Strata 3 and 5), and ranged between 7.5 and 16.5 cm TL (mean of 10.9 cm). They ate *Crangon*, *Gammarus lawrencianus*, anchovies, unidentified polychaetes, unidentified crab, *Neomysis,* and *Pagurus* sp.

Smallmouth Flounder (Etropus microstomus)

Twelve specimens of this flounder were collected, mostly in the Lower Bay to East Bank area (Strata 3 and 5), and ranged between 11.3 and 15.0 cm TL (mean of 12.7 cm). These fish ate *Crangon*, *Pagurus longicarpus*, *Neomysis*, *Pagurus* sp., and *Gammarus lawrencianus*.

Spiny Dogfish (Squalus acanthias)

Twelve spiny dogfish were collected, mostly in the Romer Shoal and Ambrose Channel area (Strata 4 and 7), and ranged between 76.0 and 80.3 cm TL (mean of 77.4 cm). They ate unidentified fish, Atlantic rock crabs, juvenile ocean quahog, *Pagurus pollicaris*, *Ovalipes ocellatus*, and northern pipefish.

Atlantic Tomcod (Microgadus tomcod)

Eleven Atlantic tomcod were collected in the Gravesend and northern Lower Bay area (Strata 3 and 6), and ranged between 7.5 cm and 9.7 cm TL (mean of 8.7 cm). They ate *Crangon* and *Gammarus lawrencianus*.

Oyster Toadfish (Opsanus tau)

Ten toadfish were collected, mostly in Raritan Channel (Stratum 9), and ranged between 11.5 and 24.5 cm TL (mean of 16.1 cm). They ate *Crangon*, juvenile Atlantic rock crabs, *Pagurus longicarpus*, and unidentified fish.

Rock Gunnel (Pholis gunnellus)

Nine samples of this species were collected in the Lower Bay to East Bank area (Strata 3 and 5), and ranged between 5.2 and 12.3 cm TL (mean of 9.4 cm). They ate *Neomysis*, *Photis* sp., unidentified isopods, *Leptocheirus pinguis*, and unidentified copepods.

Cunner (Tautogolabrus adspersus)

Nine cunner were collected, mostly in the Sandy Hook Bay to East Bank area (Strata 4 and 5), and ranged between 3.2 and 12.2 cm TL (mean of 5.5 cm). Unidentified amphipods, harpacticoid copepods, *Gammarus lawrencianus*, *Neomysis*, *Corophium* sp., *Ampelisca abdita*, *Ericthonius* sp., unidentified foraminifera, and *Unciola* sp. were found in their stomachs.

Northern Puffer (Sphoeroides maculatus)

Eight puffer were collected in Sandy Hook Bay (Stratum 1), and ranged between 7.3 and 16.2 cm TL (mean of 10.0 cm). They ate the sand-tube worm *Sabellaria vulgaris*, Atlantic rock crabs, unidentified crabs, hydroids, *Pagurus longicarpus*, *Ampelisca abdita*, gastropod eggs, barnacles, algae, and wood fragments.

Atlantic Croaker (Micropogonias undulatus)

Four croaker were collected from Raritan Channel (Stratum 9), and ranged between 12.6 and 18.0 cm TL (mean of 15.6 cm). They ate *Crangon*, an unidentified clam, *Ampelisca abdita*, *Neomysis*, *Glycera* sp., and unidentified fish.

Longhorn Sculpin (Myoxocephalus octodecemspinosus)

Three specimens were collected from the East Bank-Ambrose Channel area (Strata 5 and 7), and ranged in length between 9.0 and 29.0 cm TL (mean of 22.2 cm). They ate sand lance, *Crangon*, unidentified fish, and juvenile Atlantic rock crabs.

Conger Eel (Conger oceanicus)

Three juvenile congers were collected (*i.e.*, shaken out of discarded beverage containers brought up in the trawl) in Gravesend Bay (Stratum 6), and ranged between 20.5 and 30.2 cm TL (mean of 24.6 cm). They ate *Pagurus longicarpus*, juvenile Atlantic rock crabs, *Crangon*, and mud (xanthid) crabs.

Overall Perspective on Diets

The predator collection discussed in the preceding text appears representative of what is typically found within the Estuary. Wilk *et al.*(1998) listed 17 of the 20 predators examined in this dietary study as being among the most commonly collected species within the Estuary. The other species that they found to be common were pelagic or "forage" species such as bay anchovy, herrings, butterfish, and longfin inshore squid (*Loligo pealeii*) which are discussed subsequently. Three predators that were examined in this study, but that were not listed as the most common in the trawl survey, were smooth dogfish, tautog, and American lobster. These species were examined either because of their fishery importance (tautog and American lobster) or because of their being among the largest apex predators found within the Estuary (smooth dogfish).

The species occurring in the Estuary in the 1990s appear to be persistent since 1970s, *i.e.*, the dominant species were consistent with those reported by Wilk and Silverman (1976). The fish community defined by Wilk *et al.*(1998) in this estuary is also similar, with a difference of only one or two dominant species, to that found in other larger Middle Atlantic Bight estuaries, *e.g.*, Narragansett Bay, Rhode Island (Oviatt and Nixon 1973), Long Island Sound (Richards 1963), and Delaware Bay (Grimes 1983). However, as prey availability may differ in those estuaries, the diets discussed above may not adequately represent the situation for other estuaries.

Examination of diets from trawl-collected fish can involve biases related to the collection method. Some prey that were fresh and readily identified in the stomachs can be an artifact of within-trawl predation. This potential bias exists in most diet data based on trawl-caught samples, and is likely to involve the use of larger or motile epibenthic prey such as small fish, *Crangon*, and crabs that accumulate within the trawl's cod-end, or that are disturbed by the trawl doors, warps, footrope, or tickler chain to expose them to rapid-response predation. These results are also subject to other potential biases or errors that are typical of the method. For example, differential rates of prey digestion and stomach evacuation can be a bias, especially for afternoon collections (assuming diurnal predators often feed heavily in the morning), although American lobsters and other predators such as red hake are thought to be primarily nocturnal feeders.

FORAGE BASE

Examination of the diets of common predators provides insight into the value of various estuarine prey and habitats to support fishery populations. Also, the conservation of the habitat of prey that can be essential to fishery resources is a requirement of the Magnuson-Stevens Fishery Conservation and Management Act (October 1996). Consequently, for those prey which were examined in this study and which were found to be eaten more commonly than others, a brief overview of their life histories and a discussion of their habitat use are presented to facilitate effective habitat management. The following section summarizes what is known of the life histories and habitat use of both the commonly eaten invertebrate prey as well as those fish that are less important to diets, but can be of interest to fishery management.

The prey that seem to be most widely used or to be eaten at the highest frequency or volume levels by one or more of the predators covered in the previous sections are summarized in Tables 42-44; Tables 42 and 43 list nonfish used as prey, and Table 44 lists fish used as prey. These prey are listed in order of their overall importance as prey within the Estuary, based on the ranking of their percent frequency of occurrence in the diet or percent contribution to total stomach content volume, relative to the predators examined in this study.

Dominant Invertebrate Prey and Their Life Histories and Habitats

Sevenspine Bay Shrimp (Crangon septemspinosa)

The epibenthic, sevenspine bay shrimp (or sand shrimp) ranked first in importance to overall diet volumes for most of the predators. It was the most common prey of little skate, juvenile summer flounder, juvenile red hake, weakfish, spotted hake, striped and northern searobins, juvenile striped bass, clearnose and winter skates, juvenile black sea bass, silver hake, and fourspot flounder (Tables 6, 10, 12, 14, 16, 18, 20, 24, 28, 30, and 40). Only winter flounder and tautog did not rely heavily on *Crangon* as prey, although it was occasionally eaten by both.

Crangon occurs on sandy to silty-sand sediments into which it can partially bury. It tolerates a wide range of salinity and temperatures, and occurs within estuaries and bays, offshore to about 90 m in depth, and from the sub-Arctic to Florida (Caracciolo and Steimle 1983). It is considered omnivorous, and will eat detritus, small invertebrates, and newly settled, postlarval fish such as flounder (Witting and Able 1993). It breeds throughout the warmer months, with prominent spring and weaker fall peaks known for some areas (Wehrtmann 1994). It can live for 2 yr and grow to about 7 cm TL.

Because *Crangon* is relatively motile and small, its abundance and distribution within the Estuary are not accurately known, although an unsuccessful effort was made to obtain such information (R. Reid, unpubl. data, National Marine Fisheries Serv., Highlands, NJ). It can avoid benthic grab samplers and pass through the mesh of standard trawls. Because of its importance to the diets of most fishery resources found in the Estuary, more should be known of its preferred habitats and sensitivity to human perturbation, including toxic chemical contaminant bioaccumulation. The species was also once found to be affected by "black spot disease," or chitinoclasia, within this estuary (Gopalan and Young 1975). The toxicity of chemically contaminated sediments in the Estuary to several crustacean species has been reported by Long *et al.*(1995), but tests were not conducted with *Crangon*, although tests on *Palaemonetes pugio*, a marsh dweller, were mentioned.

Neomysis americana

This mysid was generally second in overall importance, volumetrically, to diets. It was ranked first as prey for windowpane and second in overall importance to a variety of predators that focused upon *Crangon* as prey, except skates (Table 42). It was not found or identified in the diets of American lobster, tautog, and smooth dogfish in the size ranges examined in the present study.

Neomysis is a dominant component of the suprabenthic/planktonic community in most Middle Atlantic Bight estuarine ecosystems, but occurs widely along the Western Atlantic coast from Nova Scotia to the Caribbean Sea. Caracciolo and Steimle (1983) and Hargreaves (1995) report that it tolerates a wide range of salinities (*i.e.*, from marine to as low as 1‰) and temperatures (*i.e.*, from 0 to 25°C), and prefers to be over sandy sediment in depths less than 60 m. It occurs in swarms that are negatively phototaxic, and avoids strong light. It is omnivorous, eating mainly microalgae, zooplankton, and organic microdetritus. The abundance and distribution of *Neomysis* in the Estuary are unknown at present, but the species' photophobic nature suggests that deep channels and depressions in the Estuary with sandy sediments may be important daylight habitat, and when they may be most available as prey to demersal predators. As for *Crangon*, more needs to be known on *Neomysis*'s distribution, habitat use, and sensitivity to human perturbations in this estuary.

Gammarus lawrencianus

This semipelagic amphipod (also called "scud") ranked third in overall importance, being found in 68% of the diets examined. It was especially important as prey to windowpane, juvenile scup, juvenile red hake, juvenile weakfish, spotted hake, northern searobin, juvenile silver hake, and northern kingfish (Table 42).

G. lawrencianus was reported by Bousfield (1973) to occur on or over sandy or muddy areas of estuarine areas of Southern New England. Amphipods of the genus *Gammarus* typically move across the bottom on their sides, and their laterally compressed body allows them to move readily within cracks and spaces among algae and other objects. At summer breeding times, a species of *Gammarus* was observed swarming in the evening at the water surface within the Estuary (Grant 1984), suggesting a period of enhanced exposure to predation. Little is known of the relative abundance and distribution of *Gammarus* in this estuary, but the species' association with vegetation and other shelter, as well as its semipelagic habits, make it difficult to survey. Sage and Herman (1972), in a rare reference to the genus in this estuary, found that *G. fasciatus* was only common in Sandy Hook Bay (Stratum 1) during November.

Atlantic Rock Crab (Cancer irroratus)

Juvenile or small Atlantic rock crabs were eaten by 60% of the predators, being most important to larger species such as little skate, striped searobin, summer flounder, clearnose skate, winter skate, American lobster, tautog, smooth dogfish, and to some juveniles such as those of black sea bass (Table 42). This prey was usually eaten in its YOY stage during the summer-fall, but soft-shelled stages of larger crabs were also eaten at all seasons.

The postmegalop, juvenile stages of this crab generally appear as part of the benthic macrofauna in early summer (Steimle and Stone 1973), and this coincides with their appearance in the diets of juvenile fish using this estuary (*e.g.*, winter flounder, scup, summer flounder, and black sea bass; Tables 2, 8, 10, 30) and in the diets of other small predators such as northern searobin (Table 20). Larger juvenile and small adult Atlantic rock crabs are eaten by other predators during other seasons; these larger crabs appear to leave this estuary in summer, except in deeper channels (Wilk *et al.*1998). Studies of this crab suggest that, despite its common name, "rock crab," it is more commonly found on sand bottoms than on gravel and rock (*e.g.*, Jeffries 1966; Bigford 1979; Palma *et al.*1999). However, the use of rough bottom or rock habitats by motile invertebrates and fish is poorly known because of sampling problems and inadequate survey effort (Steimle and Zetlin 2000). Reilly and Saila (1978) used diver surveys and reported mussel beds as a preferred habitat for juvenile Atlantic rock crabs off Southern New England. Atlantic rock crabs were most commonly collected by trawl in and near channels and throughout the marine, eastern part of the Estuary (Figure 22).

Lady Crab (Ovalipes ocellatus)

The lady or calico crab is a warm-season (April-December) ecosystem component, being collected from all areas and strata (Figure 23), although it is reported to prefer sands (Stehlik *et al.*1991). Juveniles of this species were also most often found in diets. YOY seem to be available as prey in the summer and fall in this estuary, but larger (*i.e.*, 20-30 mm) crabs were collected in the spring too (L. Stehlik, pers. comm., National Marine Fisheries Serv., Highlands, NJ).

Right-Handed Hermit Crabs (Pagurus spp.)

Several species of hermit crabs (*Pagurus* spp.) were eaten by predators (*i.e.*, an overall FO of 64%), but these prey seemed only really important to American lobster and smallmouth flounder (Table 42). Usually only the distinct, distal ends of the legs and claws were identifiable in lobster stomachs. Two species were readily identified as prey, the small *P. longicarpus* and the larger *P. pollicaris*, the latter of which was rarely found as prey. Both species are considered omnivors/detritivors and are reported to be common on a wide range of habitats. *P. longicarpus* is found in shallow waters in the summer (including intertidal and lower salinity areas) from Canada to Texas, but migrates to deeper water and sandy bottoms as waters cool, where it often hibernates in pits that it digs (Rebach 1974). *P. pollicaris* tends to stay in deeper, more saline waters with sandy sediments.

Ampelisca abdita

This tube-dwelling amphipod was next in overall dietary importance, occurring in the diets of 56% of the predators examined. It was particularly important to the diets of winter flounder, windowpane, juvenile scup, juvenile weakfish, striped searobins, juvenile black sea bass, and juvenile silver hake (Table 42). Recent benthic surveys of this estuary (Cerrato *et al.*1989) found this species to be common throughout the year in silty areas such as Sandy Hook Bay (Stratum 1), in western areas of the Estuary (Strata 2 and 9), and in Gravesend Bay (Stratum 6). Considering this distribution, it is curious that Long *et al.*(1995) commented on tests of the toxicity of sediment from various locations within the Estuary to this species, and noted that, in the 1980s and early 1990s, western Raritan Bay silty sediments (western parts of Strata 2, 3, and 9) were found to be toxic, while sediments from sandy areas in the northeastern third of the Estuary (eastern part of Stratum 3, and Strata 4, 5, 7, and 8) were relatively low in toxicity. Wide variance in annual abundances have been reported for this species (Steimle and Caracciolo-Ward 1989).

Northern Quahog (Mercenaria mercenaria) and Atlantic Surfclam (Spisula solidissima) Siphons

This type of prey was important only to winter flounder, and was eaten infrequently by other predators (Table 42). Because winter flounder and these two clams are dominant and fishery important species within the Estuary, the clams are included in this discussion. Northern quahogs are generally found in the fine-sand, silty central, western, and southern areas of the Estuary (de Falco 1967; McCloy 1984; Cerrato *et al.*1989), basically in Strata 1-3 and 9, and in the deep silty area in Gravesend Bay (Stratum 6). Atlantic surfclams occur in the eastern, marine areas of the Estuary (Cerrato *et al.*1989), *i.e.*, Strata 4-7. Thus, either one or the other of these two species of larger clams is available throughout the Estuary for siphon predation by winter flounder. The use of siphons seems unrelated to the availability of polychaetes and amphipods as potential prey, based on the results of Steimle and Caracciolo-Ward (1989) and Cerrato *et al.*(1989), who show that these taxa were generally available, although at lesser biomass levels during the winter, and at quantities comparable to those in other estuaries (Steimle and Caracciolo-Ward 1989). Predation on clam tissue would appear not to have any energetic advantage, as clam tissue has one-half to one-third of the caloric food-energy value of polychaetes or crustaceans (Steimle and Terranova 1985), and tearing off a piece of relatively tough and muscular siphon must entail more effort than picking up unattached prey off the sediment surface. Thus, this focused use of siphons seems to be an enigma, although it could be related to a declining supply of benthos in the fall, as is typically found in many estuaries and coastal areas (Steimle 1985, 1990). Brief habitat summaries of other, less-used prey are presented in Table 43.

Habitat and Community Associations of Invertebrate Prey

Habitat Associations

The invertebrate prey discussed in the preceding section come from one of three general habitat-associated groups within the Estuary: endobenthic, epibenthic, and suprabenthic (semipelagic). The endobenthic (or infaunal) prey group includes organisms living within the sediment or in tubes upon the sediment surface, and consists primarily of mollusks (often only their siphons being eaten), polychaetes, and certain amphipods such as *Ampelisca abdita*, *Corophium* sp., and *Unciola* sp. (Table 42). This prey group generally uses sediment carbon (including bacteria and meiofauna) or surficial phytoplankton as food. This group is exploited as prey by a limited group of predators: winter flounder, scup, and spot (Table 42).

The epibenthic prey group consists of mostly motile species, especially small decapod crustaceans that move slowly across the sediment surface (*e.g.*, hermit, Atlantic rock, lady, and other crabs, and *Crangon*; Table 42). These prey tend to be omnivores, capable of using detritus as well as smaller organisms they encounter on the bottom, including larval fish (Witting and Able 1993). This group, especially *Crangon*, is exploited by the widest range of predators in this estuary.

The suprabenthic, or semipelagic, prey group consists primarily of *Neomysis*, seasonally augmented by gammarid amphipods such as *Gammarus annulatus* or *G. lawrencianus*, and by copepods that may be abundant near the bottom (*e.g.*, *Pseudodiaptomus coronatus*). These prey typically occur in swarms, and *Neomysis* can spend the daytime close to the bottom, but move up in the water column at night. They tend to be planktivors, although the gammarids may be capable of exploiting a wider range of small food items, including the scavenging of carrion.

The high use of crustaceans as prey in all three of these habitat-associated groups seems to be typical of food webs in many estuaries, and has apparently not been significantly altered for decades in the Estuary, *e.g.*, see Townes (1939). Townes (1939) also concludes that crustaceans are the most important prey of fish in New York coastal waters. He noted that "shrimp" (*Crangon* and *Palaemonetes*) and "opossum shrimp" (*Neomysis*) were the most important prey, but amphipods and other taxa were important, too.

Community Associations

Frame (1974), MacPhee (1969), and others have commented that the food of marine predators generally reflects the environmental conditions and habitats in which the predators live. Following is a brief review of where the aforementioned invertebrate prey can be expected to be found within the Estuary, based on available survey information. Because of logistic constraints, benthic invertebrate collections were not a feature of the 1996-97 survey. However, there have been several recent studies of the benthic community in the Estuary which have characterized the major community types and their distributions (Cerrato *et al.*1989; Steimle and Caracciolo-Ward 1989; Wilber *et al*., unpubl. data, National Ocean Serv., Charleston, SC).

Benthic organisms are known to exhibit wide variances in abundance, especially the smaller, short-lived species, but benthic communities, in general, are consistently associated with certain sediment characteristics and thus can be conservative over time, even if many community members fluctuate in abundance. Steimle and Caracciolo-Ward (1989) examined the information available on the Estuary's benthic community to the mid-1970s, Cerrato *et al.*(1989) examined the fauna in the mid-1980s, and Wilber *et al.*(unpubl. data, National Ocean Serv., Charleston, SC) examined the benthic fauna in the mid-1990s. All of these studies report both similarities and differences of major community types within the Estuary (as defined by dominant species), that are sediment and water depth related, for the most part.

Steimle and Caracciolo-Ward (1989) defined a silty sediment community numerically dominated by several species of polychaetes (*e.g.*, spionids, *Nephtys picta*, and *Sabellaria vulgaris*), mollusks (*e.g.*, *Mulinia lateralis*, *Acteon punctostratus*, *Tellina agilis*, and *Nassarius trivittatus*), and a few amphipods (*e.g.*, *Rhepoxynius epistomus*). Examination of biomass data identified: 1) *Nephtys incisa* as important in muddy areas (such as Strata 1-2 and 6); 2) *Glycera* sp., *Nassarius trivittatus*, and *Tellina agilis* as important in Lower Bay sands (Strata 3 and 4); 3) *Mulinia lateralis* as important in Sandy Hook Bay (Stratum 1); and 4) *Crangon*, *Pagurus* sp., and *Dyspanopeus sayi* as important in scattered areas. These authors noted that this community may have been stressed from a severe tropical storm (hurricane *Agnes*) that passed through the area during the previous year.

Cerrato *et al.* (1989) found a different mix of common species in the same areas reported by Steimle and Caracciolo-

Ward (1989). They noted dominant species and their general seasonal and spatial distributions; a majority of the benthic infaunal species that they found to be common in the mid-1980s were found to be numerically common prey items in the diets examined in the present study: *Ampelisca abdita*, *Asabellides oculata*, blue mussel spat, *Crepidula fornicata*, *Corophium tuberculatum*, northern quahogs, and Atlantic surfclams. This similarity of common infauna found by Cerrato *et al.*(1989) and common prey found in the present study suggests that the benthic community found in the mid-1980s persisted to the mid-1990 period of the diet survey. These benthic studies all reported that, overall, the benthic invertebrates within the Estuary were most abundant in a silty band that occurred: 1) from Sandy Hook Bay northwest to off Princes Bay, Staten Island (*i.e.*, basically Stratum 1 and the deeper areas of Strata 2 and 3); 2) adjacent to Raritan Channel (Stratum 9); and 3) in areas of Gravesend Bay (Stratum 6). The species which were most abundant in this band included those which were prey, such as *Ampelisca abdita*, *Asabellides oculata*, *C. tuberculatum,* and northern quahogs. Overall, benthic invertebrates were least abundant in the eastern, fine-to-medium sand habitats of Strata 4 and 5, and the eastern parts of Stratum 3; the species found to be most common in these areas were blue mussel spat and Atlantic surfclams, which are also prey species.

The most recent benthic survey of the Estuary, during October 1994 and June 1995 (Wilber *et al*., unpubl. data, National Ocean Serv., Charleston, SC), noted the distribution of several benthic species that were primary prey in the present study; but their survey did not sample the channels (Strata 7-9). Atlantic surfclams and northern quahogs, the siphons of which were a major prey type for winter flounder, were most commonly collected in two separate areas of the Estuary: Atlantic surfclams within sandy Strata 4 and 5 and the northeastern third of Stratum 3, and northern quahogs in the silty parts of Strata 1 and 2 and lower half of Stratum 3. Blue mussels, a less common prey of several species, were collected in scattered locations across the eastern, sandy half of the Estuary, including near banks, shoals, and former borrow pits, in Strata 3-6. Blue mussels were especially common in June 1995, suggesting a strong spring 1997 recruitment occurred. The amphipod *Ampelisca abdita* was collected widely within the Estuary during both sampling periods, but especially in the silty parts of Strata 1-3 and 6, and irregularly in Strata 4 and 5.

The results of the most recent benthic studies by Cerrato *et al.* (1989) and Wilber *et al.* (unpubl. data, National Ocean Serv., Charleston, SC) are consistent, and suggest that certain recent benthic prey communities have persisted in their relative abundance and distribution within the Estuary. Their results are most likely representative of the prey community that would be available during this 1996-97 diet study, especially of those species that are relatively long lived such as the clams. There were, however, also benthic invertebrates they defined as abundant that did not appear in the present study to be readily used as prey: the minute capitellid "thread" worms *Heteromastis filiformis* and *Mediomastus* spp.; the spionid polychaete *Streplospio benedicti*; and the small bivalve mollusks softshell, *Tellina agilis*, *Macoma baltica*, *Gemma gemma*, and *Mulinia lateralis*. Steimle *et al.*(1994) found that winter flounder collected outside the Estuary often, but not always, ate what was most available (*i.e.*, abundant and of a suitable size) in the benthic community.

Fish as Prey and Their Life Histories and Habitats

Fish are also eaten by a number of predators in the Estuary, especially by summer flounder, weakfish, spotted and silver hakes, striped bass, bluefish, and clearnose and winter skates (Tables 10, 14, 16, 22, 24, 26, 28, and 40). The bay anchovy seems to be a favorite prey for many predators, but a number of demersal or benthic fish species are eaten frequently, too. It seems few juvenile or small fish are relatively immune from predation. None of the piscivors seem to be obligatory and almost all rely on epibenthic invertebrate prey to a high extent. Below is a summary of the fish observed in their stomachs, and some brief notes on habitats known to be commonly used by this prey group.

Twenty-six species of fish were identified in the stomachs of the predators examined in this study; other fish remains could not be identified to the species level (Table 44). Fish, at some level of identification, occurred in the diets of all but three predators, these exceptions being winter flounder, spot, and tautog. No specific fish species was widely eaten by predators. The maximum FO of prey among predators was 28% for anchovy being eaten by smallmouth flounder. Most fish that were found in the stomachs were juveniles, but some were mixed sizes, including adults of such small species as rock gunnel, northern searobin, smallmouth flounder, goby, northern pipefish, and lined seahorse. Most fishes eaten by predators were demersal, except anchovies, Atlantic menhaden, Atlantic herring, *Alosa* herring, *Menidia* sp., juvenile weakfish, butterfish, and possibly juvenile silver hake. Most fishes found in the Estuary seem to be preyed upon by larger fish, except elasmobranchs (*i.e.*, skates and dogfish sharks), although fragments of skate egg cases (possibly empty) were found in some American lobster stomachs.

Following are some brief notes on the life history and habitat use of those fish most commonly eaten as prey, presented as a convenient reference for habitat managers involved in this estuary.

Searobins (Prionotus spp.)

All but the adults of the striped searobin were eaten by a number of predators, including incidences of cannibalism (Table 44). Able and Fahay (1998) reported that juveniles of both species prefer sandy sediments when they occur in estuaries during the late spring to fall, although northern searobin will move out of heated shallow waters to deeper, cooler water during mid-summer. Both species winter offshore.

Bay Anchovy (Anchoa mitchilli)

This is a common nektonic species and important prey for a variety of fish in this and other Middle Atlantic Bight estuaries (Houde and Zastrow 1991; Wilk *et al.*1998). It is a small, schooling species that feeds on zooplankton (including fish and decapod crustacean eggs and larvae), and tolerates a wide range of salinity and temperature, although its abundance and distribution within estuaries can vary annually (Houde and Zastrow 1991). It grows to about 9 cm TL, and can live for about 3 yr. Spawning begins at age 1 and occurs in the spring and summer. The eggs hatch in about 1 day, and the larvae and early juveniles are common in the summer/fall and can be an important prey for juvenile weakfish (*e.g.*, Richards (1963), Van Engle and Joseph (1968), and others (Table 44)) and many other predators found in the Estuary. Wilk *et al.*(1998) show that, within the Estuary, bay anchovy was most frequently collected by trawls in Strata 1-3 (near Staten Island), 6, and channel Strata 8 and 9 (Figure 24), but were not found in the winter within this estuary.

Silver Hake (Merluccius bilinearis)

Although juveniles are commonly found within the Estuary during the cooler months (Wilk *et al.*1998), all life stages of this species were reported rare within central New Jersey estuaries (Able and Fahay 1998). This species is usually considered nektonic, but Auster *et al.* (1997) reported that juveniles of this species occur at high densities in patches of amphipod tubes and other complex, structured benthic habitats found on the continental shelf.

Cunner (Tautogolabrus adspersus)

This small species is usually found year-round in marine parts of estuaries, and associated with structure such as shellfish and seagrass/algal beds, piers, pilings, bridge abutments, rock rip-rap, etc., although it can be less common in the winter (Able and Fahay 1998). In the trawl survey of Wilk *et al.* (1998), smaller sizes of cunner, which usually occur in stomachs, were usually collected when the trawl picked up some large debris (such as automobile tires), snagged on some object on the bottom, or caught a quantity of redbeard sponge. This reliance on shelter and rough bottom, which interferes with trawling, can explain why the species has been reported to be rare in previous trawl surveys of the Estuary (Berg and Levinton 1985). Its occurrence in the stomachs of open-bottom predators, such as summer flounder and skate (Table 44), suggests that cunner can be available away from, but probably near, shelter at times.

Silverside (Menidia sp.)

This common "baitfish" is usually found over shallow, sandy, nearshore areas, but was only identified in juvenile bluefish stomachs (Table 44). Conover and Murawski (1982) report that the species will move out of estuaries during the fall-winter in the northern part of its range.

Winter Flounder (Pseudopleuronectes americanus)

Although not normally considered a prey species, juvenile winter flounder were relatively common in skate diets in this estuary (Table 44), and Manderson *et al.*(1999) found that a limited sampling of adult striped searobins suggested that juvenile winter flounder were preyed upon in shallow water of Sandy Hook Bay (Stratum 1). Many of the unidentified small flounder remains found in the stomachs examined in the present study (Table 44) may also be this species, although both windowpane and smallmouth flounder are found in this size range. This is a well studied, estuarine-coastal species (Pereira *et al.*1999), and its life history and habitat uses need not be reiterated here.

Sand Lance (Ammodytes sp.)

Able and Fahay (1998) reported that this species is common in shallow marine waters where it occurs in schools that often dive and burrow into sands when threatened. Skates appear to be its primary predator within the Estuary (Table 44). Sand lance were rarely collected in the recent trawl surveys within the Estuary (*e.g.*, see Wilk *et al.*1998).

Butterfish (Peprilus triacanthus)

Able and Fahay (1998) summarized the life history and habitat use of this pelagic species which is found within estuaries during the summer, including the Hudson-Raritan (Wilk *et al.*1998). This species was collected from all survey strata, although collections were relatively scarce within Sandy Hook Bay (Stratum 1). Able and Fahay (1998) noted that this species is negatively phototaxic and stays near the bottom during the day, making it most accessible to demersal predators at that time. However, only the juveniles of bluefish and weakfish seem to eat it (Table 44).

Early juveniles have been reported to be associated with and to accompany jellyfish when they appear inshore during the summer (Bigelow and Schroeder 1953).

American Eel (Anguilla rostrata)

Juveniles (elvers and "whips") of this eel were found in the stomachs of skate and adult spotted hake (Table 44). Able and Fahay (1998) reported that the juvenile and other phases of this species are common in estuaries, especially the Hudson River, where they occur in a wide range of habitats, silty to sandy, structured to unstructured.

Overall Perspective on Forage Base

Overall, the fish that were eaten as prey in this estuary were not as important as crustaceans and some other invertebrates as food for the bulk of the fish found in the Estuary. However, fish were a common prey type for some predators, and at times could have a notable impact on the survival and recruitment of some estuarine-dependent species. Understanding this relationship and its potential is important in developing a better understanding of the role of the benthic environment in fishery resource production.

Information on the diets of common fish and American lobster collected in the stressed Hudson-Raritan Estuary shows that these diets were still similar to the diets of the same species in other larger, less-stressed Middle Atlantic Bight estuaries. This suggests that the Estuary still functions tropho-dynamically like other, less-stressed areas. The study results also suggest that the Estuary's benthic habitat and macrofauna community are important to support a sustainable, multispecies fishery (and other biological resources such as wintering, fish-eating ducks). Steimle and Caracciolo-Ward (1989) and recent surveys all suggest that the Estuary's benthic fauna seem to be relatively healthy compared with other major estuaries, and that most of its expected community structure is still intact, although long-term trend data are absent. There could still be a potential problem with contamination of benthic prey by toxic substances from the Estuary's sediments and water, and from biotransfer up the food web, as suggested by Long *et al.* (1995).

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Table 1. Habitat characteristics of strata sampled in the Hudson-Raritan Estuary, 1992-97. (See Figure 1 for boundaries and areas of each stratum.)

Stratum	Depths (m)[a]	Sediments[b]	Salinity Range (ppt)[a]	Dissolved Oxygen Range (mg/l)[a]	Temperature Range (°C)[a]	Currents[c]	Habitat Types/ Structure	Dominant Benthic Community Types[b]
1- Sandy Hook Bay	3.5-10.0 (avg. = 6.2); deepest to east and off Sandy Hook Point	>50% silt-clay, except nearshore. Moderate to high chemical (toxic metals and organics) contamination.	~15-27	2.0-13.0; avg. = 8.7	0.3-23.8; avg. = 11.1	~<0.6 knots; north-south	Protected. Gradual (<1%) slope, except abrupt shoals parallel to Sandy Hook. *Ulva,* other algae, redbeard sponge, and terrestrial plant debris common in fall.	Numerically abundant infauna, often including *Ampelisca abdita*, northern quahogs, softshells, and blue mussels.
2- Raritan Bay	3.3-14.0 (avg. = 6.6); deepest near Raritan Channel	>50% silt-clay in and west of Keyport Harbor and near Earle terminal channel; gravelly coarse sand to silty sand in between and in shallower areas. Moderate to high chemical contamination in silty areas.	~16-26; lowest to southwest	3.6-13.2; avg. = 8.9	0.0-24.8; avg. = 11.0	~<0.7 knots; east-west	Semiprotected. Flat, gradual (<1%) slope; the 3-m trawl depth limit excludes much of the wide shallow area off the New Jersey coast, especially to the west; Raritan Channel is along the north boundary.	Patchy abundance, lowest to west. *Ampelisca abdita* often common in deeper, siltier areas near Raritan Channel; patches of Atlantic surfclam, northern quahog, and softshell abundance.
3- Lower Bay	3.3-13.8 (avg. = 6.6); deepest in West Bank borrow pits and near channels	Sand, except mud in borrow pits and deepest areas near Raritan Channel and west of Old Orchard Shoal. Moderate chemical contamination in silty areas.	~16-29; lowest to west	5.1-13.8; avg. = 8.9	0.0-26.1; avg. = 11.1	~<0.7 knots, except near Chapel Hill Channel; east-west, but north-south near West Bank	Partially exposed. Gradual (<1%) slope, interrupted by borrow pits north and south of West Bank, bordered by channels south and east. Sponge patches in western areas.	Overall numerical abundance variable, lowest on flats off New Dorp Beach. *Ampelisca abdita*, other amphipods, bivalve mollusks, and polychaetes abundant in deeper, siltier areas along southern boundary.
4- Romer Shoal, Flynns Knoll, Swash Channel	3.5-9.0 (avg. = 7.0); deepest in Swash Channel.	Coarse to medium sand with shell. Low sediment chemical contamination.	~15-30	5.0-12.4; avg. = 8.8	0.9-23.7; avg. = 11.1	~0.4->2.5 knots, generally northwest-southeast and east-west	Exposed to the sea. Two shoals split by the Swash Channel, bordered by three channels. Blue mussel beds are common.	Overall abundance highest on Romer Shoal, <1000 ind./ m^2 elsewhere. Blue mussels and Atlantic surfclams common.
5- East Bank	4.0-22.0 (avg. = 7.5); deepest near Ambrose Channel and seaward of East Bank	Coarse to medium sand, and gravelly sand with shell near Breezy Point. Low chemical contamination.	~20-31	5.0-12.4; avg. = 8.8	0.6-23.0; avg. = 11.2	~0.2-2.0 knots, generally northwest-southeast	Exposed to the sea. Complex bathymetry including shoals and natural and dredged channels. Blue mussel beds are common.	Overall abundance highest near Breezy and Norton Points because of blue mussels. Atlantic surfclams common elsewhere.

6- Gravesend Bay, Narrows, West Bank	4.3-26.0 (below the Narrows); avg. = 10.1)	>50% silt near the Narrows and West Bank borrow pit; fine-medium sand to silty sand elsewhere. Low chemical contamination.	~19-29	5.0-12.0; avg. = 8.7	0.2-22.9; avg. = 11.2	~0.2-> 2.0 knots,north-south	Semiexposed. Seabed rapidly (>5%) slopes into main Hudson River mouth channel; West Bank shoal and several borrow pits to the west.	Overall abundance variable. *Ampelisca abdita* moderately common; blue mussels abundant near West Bank; polychaetes common in deeper, siltier areas.
7- Ambrose Channel (~600 m wide, ~7 km long)[d]	6.5-22.3 (avg. = 17.1); dredged to ~14 (45 ft)	Medium-coarse to gravelly sand. Low chemical contamination.	~21-31	5.0-11.7; avg. = 8.5	1.7-22.3; avg. = 10.7	~0.5->2.0 knots, within channel	Mechanically dredged to maintain authorized depth. Slopes increase at sides of channel. Accumulations of trash common in the western reach.	Overall abundance generally low, with spotty settlement of polychaete *Asabellides oculata.*
8- Chapel Hill Channel (~300 m wide, ~7 km long)[d]	6.6-15.2 (avg. = 10.3); dredged to ~9 (30 ft)	Variable sands. Low chemical contamination.	~20-30	5.9-11.6; avg. = 8.6	1.1-23.7; avg. = 11.4	~0.5-1.3 knots, east-west across channel	Mechanically dredged to maintain authorized depth. Slopes increase at sides of channel. Rocks are found in some places.	No data, but probably similar to Ambrose Channel.
9- Raritan Bay Channel (~265 m wide, ~16 km long)[d]	9.4-15.2 (avg. = 13.0); dredged to ~10.5 (35 ft)	Variable, silt-clay in west reach to mixed mud, gravelly sand, and sand in east reach. Moderate to high chemical contamination.	~20-29	5.0-12.0; avg. = 8.5	0.0-24.3; avg. = 10.9	~0.0-0.7 knots, within channel	Mechanically dredged to maintain authorized depth. Slopes increase at sides of channel.	Overall abundance low. *Ampelisca abdita* sometimes a dominant taxa.

[a] Channel characteristics are from National Ocean Service (1995).
[b] Sediment and benthic community descriptions are from the Cerrato *et al.*(1989) 1986-87 survey and Squibb *et al.*(1991).
[c] Current data from National Ocean Service (1994).

Table 2a. Summary of Hudson-Raritan Estuary winter flounder diet by sampling period during 1996-97, expressed as the percent frequency of occurrence of dominant prey or items (FO), and as the mean percent contribution of dominant prey or items to total stomach content volume (TV). (n = sample size; ES = percent of empty stomachs.)

	Sampling Period											
	Jul 96 (n = 89; ES = 6.7)		Oct 96 (n = 55; ES = 14.5)		Jan 97 (n = 135; ES = 42.2)		Apr 97 (n = 209; ES = 2.9)		Aug 97 (n = 83; ES = 16.9)		Nov 97 (n = 139; ES = 15.8)	
Prey	**FO**	**TV**	**FO**	**TV**	**FO**	**TV**	**FO**	**TV**	**FO**	**TV**	**FO**	**TV**
Unidentified organic matter	24.7	5.5	34.6	11.7	5.9	20.5	14.8	2.0	55.4	21.1	30.2	6.6
Northern quahog siphons	26.9	18.5	25.5	23.9	0.7	1.3	22.5	9.0	7.2	4.9	24.5	11.0
Ampelisca abdita	9.0	3.7	25.5	5.8	6.7	4.2	21.1	3.7	3.6	1.1	32.4	7.6
Atlantic surfclam siphons	11.2	2.6	25.5	9.0	0.0	0.0	45.9	31.3	2.4	1.1	22.3	21.5
Unidentified polychaetes	23.6	9.1	9.1	2.9	2.2	1.3	20.1	6.8	3.6	1.8	12.9	4.0
Neomysis americana	1.1	1.0	3.6	2.0	41.5	23.6	3.4	0.1	1.2	0.7	2.2	0.2
Unidentified clam siphons	2.2	0.9	1.8	0.3	0.7	1.3	11.5	6.9	18.1	12.7	1.4	1.7
Unciola sp.	0.0	0.0	20.0	5.8	7.4	6.8	0.5	<0.1	1.2	0.4	6.5	2.2
Blue mussel juveniles	2.2	1.4	3.6	0.6	0.0	0.0	7.3	10.5	0.0	0.0	0.0	0.0
Asabellides oculata	10.1	4.2	0.0	0.0	1.5	0.4	0.9	0.1	15.7	12.0	5.8	1.7
Corophium sp.	10.1	3.1	10.9	5.5	0.0	0.0	3.4	0.4	1.2	0.7	1.4	<0.1
Glycera sp.	14.6	11.7	1.8	1.7	0.0	0.0	3.4	1.0	2.4	6.7	2.9	2.5
Unidentified hydroids	2.2	2.1	0.0	0.0	0.0	0.0	11.9	5.1	8.4	7.8	2.9	0.9
Gammarus lawrencianus	6.7	4.5	5.5	2.6	5.9	6.3	1.0	0.3	0.0	0.0	3.6	1.2
Atlantic rock crab juveniles	19.1	10.5	0.0	0.0	0.0	0.0	1.4	1.5	1.2	3.3	1.4	0.3
Crangon septemspinosa	6.7	2.5	0.0	0.0	3.7	1.3	3.4	0.9	6.0	6.9	2.2	0.4
Nemerteans	9.0	3.9	0.0	0.0	1.5	19.8	7.7	3.7	0.0	0.0	0.0	0.0

Table 2b. Summary of Hudson-Raritan Estuary winter flounder diet by predator size group during 1996-97, expressed as the mean percent contribution of dominant prey or items to the total stomach content volume. (n = number of nonempty stomachs included.)

	Winter Flounder Size Group (cm TL)			
Prey	**6.0 - 9.9 (n = 44)**	**10.0 - 19.9 (n = 291)**	**20.0 - 29.9 (n = 158)**	**30.0 - 45.0 (n = 85)**
Neomysis americana	40.81	6.20	0.01	0.00
Detritus	14.47	11.80	3.40	1.70
Ampelisca vadorum	8.75	5.90	3.30	0.20
Unciola sp.	6.75	0.70	0.05	0.10
Unidentified polychaetes	5.34	5.85	3.70	1.40
Hydroids	5.34	2.32	1.90	3.50
Blue mussel spat	3.69	0.63	0.46	0.65
Northern quahog siphons	1.86	14.20	19.60	4.40
Atlantic surfclam siphons	1.80	8.10	32.30	69.50
Bivalve mollusk remains	0.85	3.01	0.74	12.50
Glycera sp.	0.00	5.26	4.32	1.00
Crangon septemspinosa	3.39	2.55	0.67	0.31
Ensis directus	0.00	0.27	5.10	0.02

Table 2c. Summary of Hudson-Raritan Estuary juvenile winter flounder (less than 20 cm TL) diet by sampling period during 1996-97, expressed as the mean percent contribution of dominant prey or items to total stomach content volume. (n = number of nonempty stomachs included.)

Prey	Sampling Period					
	Jul 96 (n = 63)	**Oct 96 (n = 39)**	**Jan 97 (n = 65)**	**Apr 97 (n = 65)**	**Aug 97 (n = 47)**	**Nov 97 (n = 56)**
Northern quahog siphons	10.50	23.77	0.01	7.68	3.59	22.15
Atlantic surfclam siphons	7.36	21.49	0.00	8.63	1.53	7.82
Ampelisca vadorum	3.98	11.20	4.28	7.03	0.93	8.62
Gammarus lawrencianus	7.42	1.68	13.06	0.00	0.00	0.65
Sabellaria vulgaris	3.34	3.20	0.39	0.00	19.52	0.00
Neomysis americana	0.11	0.00	62.47	5.80	0.00	0.17
Crangon septemspinosa	3.98	0.00	2.53	3.53	4.05	1.30
Unciola sp.	0.00	8.00	4.46	0.06	1.29	0.07
Detritus	6.64	17.68	2.96	5.14	26.10	22.15

Table 2d. Summary of Hudson-Raritan Estuary adult winter flounder (greater than or equal to 20 cm TL) diet by sampling period during 1996-97, expressed as the mean percent contribution of dominant prey or items to total stomach content volume. (n = number of nonempty stomachs included.)

Prey	Sampling Period					
	Jul 96 (n = 18)	**Oct 96 (n = 4)**	**Jan 97 (n = 7)**	**Apr 97 (n = 137)**	**Aug 97 (n = 16)**	**Nov 97 (n = 61)**
Northern quahog siphons	30.73	74.77	0.00	11.71	15.41	16.82
Atlantic surfclam siphons	2.74	0.00	0.00	49.95	0.00	47.79
Glycera sp.	20.25	0.00	0.00	2.42	37.25	0.65
Atlantic rock crab juveniles	10.93	0.00	0.00	3.55	1.28	0.11

Table 2e. Summary of Hudson-Raritan Estuary juvenile winter flounder (6.0 - 19.9 cm TL) diet by sampling stratum during 1996-97, expressed as mean percent contribution of dominant prey or items to total stomach content volume. (n = number of nonempty stomachs included.)

	Stratum								
Prey	**1 (n = 31)**	**2 (n = 46)**	**3 (n = 71)**	**4 (n = 51)**	**5 (n = 13)**	**6 (n = 70)**	**7 (n = 17)**	**8 (n = 18)**	**9 (n = 16)**
Glycera sp.	15.8	9.1	5.2	0.0	0.0	2.5	0.0	0.0	0.0
Sabellaria vulgaris	15.8	0.0	<1.0	<1.0	0.0	1.6	0.0	0.0	0.0
Pherusa affinis	0.0	0.0	7.8	1.8	0.0	1.1	6.2	0.0	0.0
Asabellides oculata	1.3	0.0	0.0	0.0	2.7	12.8	0.0	0.0	0.0
Ampelisca sp.	12.0	6.2	8.3	1.4	0.0	7.0	0.0	20.8	4.9
Gammarus sp.	<1.0	0.0	1.4	1.2	0.0	6.8	28.0	<1.0	0.0
Neomysis americana	0.0	2.2	13.3	20.5	51.1	4.1	3.5	20.0	18.8
Crangon septemspinosa	<1.0	0.0	4.0	5.1	9.8	2.9	0.0	0.0	0.0
Cancer sp. juveniles	0.0	0.0	<1.0	15.1	0.0	1.1	2.3	0.0	0.0
Northern quahog siphons	11.0	42.0	14.8	1.6	0.0	11.1	0.0	0.0	1.0
Atlantic surfclam siphons	0.0	7.2	2.0	20.7	0.0	10.5	2.4	7.9	0.0
Detritus	6.2	12.0	12.7	3.4	0.0	9.5	13.9	12.1	44.2

Table 2f. Summary of Hudson-Raritan Estuary adult winter flounder (20.0 - 45.0 cm TL) diet by sampling stratum during 1996-97, expressed as mean percent contribution of dominant prey or items to total stomach content volume. (n = number of nonempty stomachs included.)

	Stratum								
Prey	**1 (n = 29)**	**2 (n = 30)**	**3 (n = 45)**	**4 (n = 39)**	**5 (n = 48)**	**6 (n = 18)**	**7 (n = 18)**	**8 (n = 5)**	**9 (n = 11)**
Maldanopsis	20.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Glycera sp.	12.3	11.1	3.3	0.0	0.0	<1.0	17.5	0.0	0.0
Ampelisca sp.	6.9	14.5	1.0	0.0	0.0	<1.0	1.1	4.4	8.0
Cancer sp. juveniles	<1.0	0.0	4.0	<1.0	<1.0	20.8	1.3	0.0	0.0
Northern quahog siphons	14.5	31.6	47.1	0.0	<1.0	29.2	0.0	0.0	0.0
Atlantic surfclam siphons	6.0	6.8	16.3	77.3	78.8	1.3	42.1	11.8	0.0
Ensis directus	<1.0	1.1	0.0	13.4	0.0	0.0	0.0	0.0	0.0
Softshell siphons	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	50.3
Mulinia lateralis	<1.0	1.1	<1.0	0.0	0.0	<1.0	0.0	10.0	3.3
Detritus	2.0	4.9	3.5	0.0	<1.0	8.2	7.5	10.7	24.1

Table 3. Summary of other winter flounder diet studies for the coastal Middle Atlantic Bight. (Major prey taxa ranked in relative order of importance by: mean percent frequency of occurrence (FO), mean percent contribution to total stomach content volume (TV), mean percent contribution to total stomach content weight (TW), and mean percent contribution to total stomach content dry weight (TDW), as available from each source.)

Source	Study Area	Year(s) (month(s), season(s), and/or frequency)	No. Examined (size [TL cm]) or age range, mean size)	Primary Prey in Order of Importance by FO, IRI, TDW, TN, TV, and/or TW
Linton (1921)	Woods Hole, MA	1915-16 (May-Nov)	398 (2-22.5, ~8)	TV -- amphipods, copepods, ostracods, isopods, and "shrimp."
Tressler and Bere (1938)	Southern Long Island, NY	1938 (Jul-Aug)	120 (3-15)	FO -- copepods, amphipods, nematodes, ostracods, polychaetes, and isopods.
Smith (1950)	Block Island Sound, RI	1948-49 (seasonally)	Unknown	TW -- *Leptocheirus pinguis*, *Unciola irrorata*, and *Obelia* sp.
Richards (1963)	Long Island Sound - sandy site	1956-57 (monthly)	287 (4-17)	FO? -- nemertean, *Ampharete* sp., *L. pinguis*, *Neomysis, Nereis succinea*, and hydroids.
Richards (1963)	Long Island Sound - muddy site	1956-57 (monthly)	86 (8-16)	FO? -- *Nephtys incisa*, *L. pinguis*, and *Melinna cristata.*
de Sylva *et al.* (1962)	Delaware Bay shore	1958 (bimonthly)	95 (3-13)	FO? -- polychaetes, detritus, *Edotea* sp., and other isopods.
Pearcy (1962)	Long Island Sound (Mystic River, CT)	1958-59 (monthly)	359 (1-16)	TV (YOY) -- copepods to amphipods. TV (ages 1+) — amphipods to polychaetes.
Mulkana (1966)	Coastal Rhode Island ponds and rivers	1962 (Jul-Oct)	124 (3-8)	FO -- varies per estuary, mainly isopods (*Edotea* sp.), tanaids (*Leptochelia* sp.), polychaetes (*Nereis* sp. and spionids), and amphipods (*Ampelisca* sp. and *Lembos* sp.).
Lux *et al.* (1996)	Woods Hole, MA	Sep 1961 - Dec 1962 (weekly)	1,248 (12-42, mostly 22-38)	TW -- *Nereis* sp., *Glycera* sp., *Capitella* sp., *Macoma* sp., *Solemya* sp., softshell siphons, *Pagurus* sp., *Crangon*, and *Ampelisca* sp.
Frame (1974)	Buzzards Bay, MA	1968-69 (seasonally)	176 (ages 1+)	FO -- polychaetes, amphipods, and mollusks (*Nucula proxima*, *Tellina agilis*, and *Yoldia* sp.).
Steimle (1985)	New York Bight apex	1969-70 (summer)	196 (9-39, mostly 17-25)	FO -- *Pherusa affinis*, *Nephtys incisa*, amphipods, unidentified clam siphons, and isopods.
Festa (1979)	Little Egg Harbor, NJ	1972-77 (spring-fall)	97 (3-21) 45 (22-33)	TV -- *Palaemonetes* sp., polychaetes, clam siphons, and nemerteans. TV -- detritus, clam siphons, polychaetes, and *Ampelisca* sp.

Kurtz (1975)	Southern Long Island (NY) bays	Oct 1973 - Jun 1974	679 (13-28)	TW -- polychaetes (sabellids and terebellids), amphipods, and clam siphons.
Allen *et al.* (1978)	Hereford Inlet, NJ	1973-77 (biweekly/monthly)	106 (4-30)	FO -- polychaetes, amphipods, bivalve mollusks, *Crangon*, and isopods.
Steimle (unpubl. data)	Raritan Bay, NJ (Strata 1-4)	1976 (Mar-Jun)	84 (8-25)	FO -- *Asabellides oculata*, spionid polychaetes, hydroids, blue mussel spat, *Glycera* sp., and juvenile *Ensis directus*.
Homer and Boynton (1978)	Chesapeake Bay, MD	1977 (May-Jun)	168 (2-15)	TW -- *Scolecolepides viridis*, *Corophium lacustra*, softshells, *Macoma* sp., and *Nereis succinea.*
Lawler, Matusky & Skelly Engineers (1980)	Hudson River, NY	1979-80 (seasonally)	89 (mean = 170)	TV -- polychaetes and clam siphons.
Worobec (1984)	Charles Pond, RI	1979-80 (spring-summer)	181 (11-26)	TDW -- detritus, polychaetes, nematodes, and amphipods.
Conover *et al.* (1985)	Raritan Bay, NY	1982 (monthly)	409 (15-18)	TW -- *A. oculata*, *Gammarus* sp., algae, and other amphipods.
Steimle and Terranova (1991)	New York Bight apex	1982-85 (seasonally)	389 (mean = ~26)	FO -- *Ceriantheopsis americanus*, *Pherusa affinis*, *Lumbrineris* sp., and *Nephtys* sp.
Scarlett and Giust (1989)	Manasquan River, NJ	1984-86 (monthly)	273 (11-40, mean = ~25)	TV -- *Nereis succinea*, detritus, sand lance, clam siphons, hydroids, *Crangon*, and polychaetes.
Scarlett (1986, 1988)	Central New Jersey estuaries	1985-87 (winter-spring,	176 (12-37, means = 26-30) monthly)	TV -- *Nereis* sp., detritus, *Glycera* sp., other polychaetes, hydroids, *Cyathura* sp., and clam siphons.
Steimle *et al.* (1994)	New York Bight apex	1986-89 (monthly)	3,556 (18-30)	TV -- *P. affinis*, *Ceriantheopsis americanus*, *Nephtys incisa*, and *A. oculata.*
Bharadwaj (1988)	Narragansett Bay, RI	1987 (Nov)	266 (12-38)	FO -- *N. incisa*, *C. americanus*, *P. affinis*, and *Nereis* sp.
Carlson (1991)	New Haven Harbor, CT	Sep 1989 - Nov 1990	32 (10-15) 65 (16-20) 31 (21-25) 19 (26-29)	TW -- hydroids, crustaceans, and polychaetes. TW -- hydroids, snail feet, mysids, and polychaetes. TW -- *Streblospio* sp., hydroids, and *Ampelisca* sp. TW -- *Crangon*, *Ampelisca abdita*, and hydroids.
Timmons (1995)	Rehoboth Bay, DE	1994 (Aug)	36 (mean = 10)	TV -- polychaetes, detritus, and polychaete tubes.
Stehlik and Meise (2000)	Navesink River and Sandy Hook Bay, NJ	1996-98 (May, Jul, and Oct)	1,399 (1.0-45.0, mean = 10)	TV -- *Ampelisca* sp., softshell siphons, spionid and other polychaetes, copepods, mysids, and *Crangon*.

Table 4a. Summary of Hudson-Raritan Estuary windowpane diet by sampling period during 1996-97, expressed as the percent frequency of occurrence of dominant prey or items (FO), and as the mean percent contribution of dominant prey or items to total stomach content volume (TV). (n = sample size; ES = percent of empty stomachs.)

	Sampling Period											
	Jul 96 (n = 45; ES = 2.0)		**Oct 96 (n = 59; ES = 13.5)**		**Jan 97 (n = 98; ES = 33.7)**		**Apr 97 (n = 163; ES = 23.3)**		**Aug 97 (n = 127; ES = 11.8)**		**Nov 97 (n = 78; ES = 10.3)**	
Prey	**FO**	**TV**	**FO**	**TV**	**FO**	**TV**	**FO**	**TV**	**FO**	**TV**	**FO**	**TV**
Neomysis americana	93.3	57.1	81.4	39.0	33.7	19.7	42.9	31.6	85.0	70.1	60.3	17.8
Crangon	44.4	41.5	28.8	16.7	53.0	47.7	36.8	45.5	23.6	24.8	34.6	21.3
Gammarus lawrencianus	2.2	1.1	39.0	22.8	4.1	3.0	1.2	0.1	0.8	0.5	11.5	4.8
Unidentified organic matter	2.2	0.2	1.7	<0.1	0.0	0.0	15.3	1.9	2.4	1.6	5.1	1.1
Ampelisca abdita	0.0	0.0	3.4	2.9	1.0	0.9	3.7	1.6	0.8	0.1	9.0	7.1
Pseudodiaptomus coronatus	0.0	0.0	8.5	7.7	0.0	0.0	0.6	1.4	0.0	0.0	2.6	1.9
Unidentified juvenile fish	0.0	0.0	3.4	1.6	1.0	<0.1	1.2	2.5	0.0	0.0	10.3	3.7
Juvenile *Anchoa* sp.	0.0	0.0	0.0	0.0	0.0	0.0	2.5	5.0	0.0	0.0	12.8	7.9

Table 4b. Summary of Hudson-Raritan Estuary windowpane diet by predator size group during 1996-97, expressed as the percent frequency of occurrence of dominant prey or items (FO), and as the mean percent contribution of dominant prey or items to total stomach content volume (TV). (n = number of nonempty stomachs included.)

	Windowpane Size Group (cm TL)							
	<9.9 (n = 126)		**10.0 - 19.9 (n = 178)**		**20.0 - 29.9 (n = 229)**		**>30.0 (n = 24)**	
Prey	**FO**	**TV**	**FO**	**TV**	**FO**	**TV**	**FO**	**TV**
Neomysis americana	100.0	91.1	88.2	61.6	65.9	38.5	58.3	23.2
Crangon septemspinosa	7.7	4.9	35.4	23.6	54.6	51.0	66.7	56.3
Gammarus sp.	0.0	0.0	11.8	1.5	7.4	2.4	8.3	1.6
Anchoa sp.	0.0	0.0	5.6	12.3	1.3	1.4	4.2	8.7
Detritus	7.7	1.8	1.7	<1.0	12.7	<1.0	0.0	0.0

Table 4c. Summary of Hudson-Raritan Estuary windowpane diet by sampling stratum during 1996-97, expressed as mean percent contribution of dominant prey or items to total stomach content volume. (n = number of nonempty stomachs included.)

Prey	Stratum 1 (n = 23)	2 (n = 24)	3 (n = 34)	4 (n = 18)	5 (n = 33)	6 (n = 25)	7 (n = 24)	8 (n = 16)	9 (n = 32)
Neomysis	49.5	17.3	35.7	30.8	14.3	72.2	82.6	32.5	23.4
Crangon	44.4	77.7	52.8	21.2	36.2	26.1	6.1	64.6	76.5

Table 5. Summary of other windowpane diet studies for the coastal Middle Atlantic Bight. (Major prey taxa ranked in relative order of importance by: mean percent frequency of occurrence (FO), mean percent contribution to total stomach content volume (TV), and mean percent contribution to total stomach content weight (TW), as available from each source.)

Source	Study Area	Year(s) (month(s), season(s), and/or frequency)	No. Examined (size [TL cm]) or age range, mean size)	Primary Prey in Order of Importance by FO, IRI, TDW, TN, TV, and/or TW
Moore (1947)	Long Island - Block Island Sounds	1943-44 (monthly)	654 (18-34)	TV -- *Neomysis*, *Crangon*, chaetognaths, and larval fish (sand lance and silver hake).
Smith (1950)	Block Island Sound	1948-49 (seasonally)	Unknown, ~200	TW -- *Neomysis*, small fish, and squid.
Richards (1963)	Long Island Sound	1955-56 (seasonally)	Sand station - 49 (3-13) Mud station - 25 (3-13)	FO -- *Neomysis* and *Crangon*. FO -- *Neomysis*.
de Sylva *et al.* (1962)	Delaware Bay shore	1958-60 (Feb-Jul)	31 (5-17)	FO -- *Neomysis*, *Crangon*, and copepods.
Langton and Bowman (1981)	New Jersey - North Carolina	1969-72 (spring/fall)	163 (mean = 25)	TW -- *Neomysis*, pandalid shrimp, *Crangon*, and other decapod crustaceans.
Kimmel (1973)	Chesapeake Bay mouth	1971-72 (spring)	16 (7-17) 18 (19-24)	TV -- *Neomysis*, larval bay anchovy, and *Crangon*. TV -- *Neomysis*, *Crangon*, and bay anchovy.
Hickey (1975)	Eastern Long Island Sound	1972 (Apr-Dec)	120 (6-26)	TV -- *Neomysis*, *Crangon*, fish eggs, larvae, and "bait."

Festa (1979)	Little Egg Harbor, NJ	1972-77 (summer/fall)	4 (15-34)	TV -- *Crangon*, sand lance, *Neomysis*, and detritus. FO -- Detritus, *Neomysis*, and *Crangon.*
Allen *et al.* (1978)	Hereford Inlet, NJ	1973-77 (monthly)	60 (6-27)	FO -- Mysids, Crangon, amphipods, and decapod crab larvae.
Steimle and Terranova (1991)	New York Bight apex	1982-85 (seasonally)	131 (mean = ~27)	FO -- Mysids (*Neomysis* mostly), *Crangon*, and *Dichelopandalus leptocerus*.
Warkentine and Rachlin (1988)	New Jersey coast	Unreported	Unreported	FO -- *Neomysis.*
Carlson (1991)	New Haven Harbor, CT	Sep 1989 - Nov 1990 (monthly)	96 (11-34)	TW -- *Crangon*, bay anchovy, and naked goby (*Gobiosoma bosc*). FO -- *Crangon*, bay anchovy, goby, and *Neomysis.*

Table 6. Summary of Hudson-Raritan Estuary little skate diet by sampling period during 1996-97, expressed as the percent frequency of occurrence of dominant prey or items (FO), and as the mean percent contribution of dominant prey or items to total stomach content volume (TV). (n = sample size; ES = percent of empty stomachs.)

	Sampling Period											
	Jul 96 (n = 10; ES = 0)		Oct 96 (n = 33; ES = 0)		Jan 97 (n = 85; ES = 0)		Apr 97 (n = 116; ES = 0.8)		Aug 97 (n = 0; ES = N/A)		Nov 97 (n = 88; ES = 1.1)	
Prey	**FO**	**TV**	**FO**	**TV**	**FO**	**TV**	**FO**	**TV**	**FO**	**TV**	**FO**	**TV**
Crangon septemspinosa	92.9	90.1	81.7	29.9	85.9	36.2	87.9	31.2	-	-	77.2	20.3
Juvenile Atlantic rock crab	7.1	4.7	24.2	9.0	75.3	38.1	44.0	19.9	-	-	35.2	9.7
Juvenile *Ovalipes ocellatus*	7.1	1.4	36.4	15.6	1.2	0.2	1.7	0.7	-	-	25.0	6.4
Unidentified organic matter	14.3	2.6	24.2	7.3	2.4	0.5	3.4	1.0	-	-	6.8	1.1
Ensis directus	0.0	0.0	3.0	1.8	2.4	0.6	17.2	6.1	-	-	18.2	3.8
Neomysis americana	7.1	1.2	6.1	0.6	15.3	2.4	28.5	9.3	-	-	13.6	2.8
Unidentified juvenile flounder	0.0	0.0	6.1	1.9	3.5	0.7	0.9	0.6	-	-	13.6	5.4
Juvenile blue crab	0.0	0.0	0.0	0.0	0.0	0.0	4.3	1.4	-	-	28.4	8.8
Pagurus sp.	0.0	0.0	6.1	0.7	1.2	0.4	5.2	1.6	-	-	18.1	5.9
Atlantic surfclam	0.0	0.0	6.1	9.5	0.0	0.0	4.3	1.6	-	-	3.4	0.5
Gammarus lawrencianus	0.0	0.0	6.1	6.0	2.4	0.4	0.0	0.0	-	-	6.8	1.1

Table 7. Summary of other little skate diet studies for the coastal Middle Atlantic Bight. (Major prey taxa ranked in relative order of importance by: mean percent frequency of occurrence (FO), mean percent contribution to total stomach content volume (TV), mean percent contribution to total stomach content weight (TW), mean percent contribution to total number of individual items in the stomach (TN), and an index of relative importance (IRI), as available from each source.)

Source	Study Area	Year(s) (month(s), season(s), and/or frequency)	No. Examined (size [TL cm]) or age range, mean size)	Primary Prey in Order of Importance by FO, IRI, TDW, TN, TV, and/or TW
Linton (1901)	Woods Hole, MA	1899 (summer)	32 (unknown)	FO? -- "Hermit, rock, blue, and mud crabs, shrimp, amphipods, polychaetes, squid, clams, fish."
Field (1907)	Woods Hole, MA	1905 (summer)	516 (~30-60)	FO -- Crabs (rock, lady, mud, and hermit), *Crangon*, fish (sand lance, butterfish, herring, and bothid flounder), squid, *Nereis* sp., *Ensis directus*, and amphipods.

Smith (1950)	Block Island Sound	1948-49 (seasonally)	Unknown, ~200 (unknown)	TV -- *Leptocheirus pinguis*, Atlantic rock crab, *Crangon*, other crustaceans, polychaetes, mollusks, small fish, and squid.
Fitz and Daiber (1963)	Delaware Bay	1954-55 (seasonally)	185 (mean = 45)	FO -- *Crangon*, *Lepidonotus squamatus*, *E. directus*, *Nereis* sp., *Pagurus* sp., and fish (northern searobin and windowpane). TN -- *Crangon* and *E. directus*.
Richards *et al.* (1963)	Long Island Sound	1956-57 (seasonally)	3 (9-11)	FO -- Copepods, *Neomysis*, *Heteromysis formosa*, and *Crangon*.
Vinogradov (1984)	Georges Bank - Southern New England	1968-74 (unreported)	253 (unreported)	TW -- Crustaceans, polychaetes, and fish.
McEachlan *et al.* (1976)	Offshore	1969-70 (seasonally)	785 (mean = ~45-50)	IRI -- Decapod crustaceans (*Crangon*, etc.), amphipods (*Leptocheirus pinguis*, etc.), and polychaetes (*Eunice* sp. and *Nereis* sp.).
Bowman *et al.* (1987) ceans.	Southern New England	1973-76 (spring/fall)	168 (16-20)	TW -- *Crangon*, Atlantic rock crab, and other crusta-
Sedberry (1983) *serrata*,	New York Bight	1976-77 (seasonally)	1,050 (5-30, disc width)	TV -- Atlantic rock crab, *Unciola irroratus*, *Byblis* and juvenile red hake. IRI -- Amphipods and decapod crustaceans.
Carlson (1991)	New Haven Harbor, CT	Sep 1989 - Nov 1990	115 (31-57)	TW -- Atlantic rock crab, decapod crustacean fragments, *Ovalipes ocellatus*, fish, and *Crangon*. FO -- Atlantic rock crab, *Crangon*, *O. ocellatus*, and *Pagurus* sp.

Table 8. Summary of Hudson-Raritan Estuary scup diet by sampling period during 1996-97, expressed as the percent frequency of occurrence of dominant prey or items (FO), and as the mean percent contribution of dominant prey or items to total stomach content volume (TV). (n = sample size; ES = percent of empty stomachs.)

	Sampling Period											
	Jul 96 (n = 58; ES = 7.0)		Oct 96 (n = 45; ES = 4.0)		Jan 97 (n = 0; ES = N/A)		Apr 97 (n = 76; ES = 1.0)		Aug 97 (n = 75; ES = 1.0)		Nov 97 (n = 0; ES = N/A)	
Prey	FO	TV	FO	TV	FO	TV	FO	TV	FO	TV	FO	TV
Unidentified organic matter	36.2	14.7	37.8	8.9	-	-	46.1	14.8	21.3	3.4	-	-
Unidentified bivalve remains	22.4	11.2	8.9	7.3	-	-	1.3	0.4	26.7	8.0	-	-
Gammarus lawrencianus	48.3	20.8	17.8	10.4	-	-	0.0	0.0	0.0	0.0	-	-
Neomysis americana	50.0	24.4	42.2	13.5	-	-	19.8	9.2	17.3	2.8	-	-
Crangon septemspinosa	8.6	6.1	17.8	4.6	-	-	3.9	2.1	30.7	15.5	-	-
Ampelisca abdita	0.0	0.0	13.3	3.7	-	-	9.2	4.6	18.0	4.6	-	-
Unidentified polychaetes	6.9	4.1	6.7	2.8	-	-	35.5	15.2	9.3	2.2	-	-
Juvenile Atlantic rock crab	12.1	5.1	2.2	0.9	-	-	2.6	1.1	21.3	9.2	-	-
Juvenile blue mussel	1.7	0.5	2.2	0.3	-	-	31.6	10.2	1.3	0.2	-	-
Northern quahog siphons	1.7	1.5	13.3	7.0	-	-	0.0	0.0	17.3	9.8	-	-
Pagurus spp.	12.1	8.4	15.6	5.8	-	-	2.6	2.1	13.3	5.0	-	-
Ensis directus	1.7	1.0	0.0	0.0	-	-	1.3	7.4	13.3	8.8	-	-

Table 9. Summary of other scup diet studies for the coastal Middle Atlantic Bight. (Major prey taxa ranked in relative order of importance by: mean percent frequency of occurrence (FO), mean percent contribution to total stomach content volume (TV), mean percent contribution to total stomach content weight (TW),mean percent contribution to total stomach content dry weight (TDW), and an index of relative importance (IRI), as available from each source.)

Source	Study Area	Year(s) (month(s), season(s), and/or frequency)	No. Examined (size [TL cm]) or age range, mean size)	Primary Prey in Order of Importance by FO, IRI, TDW, TN, TV, and/or TW
Linton (1901)	Woods Hole, MA	1896-99 (summer)	51 ("YOY") 58 ("adults")	FO? -- Copepods and small crustaceans. FO? -- Small fish, squid, polychaetes, crabs, shrimp, amphipods, mollusks, and hydroids.
Richards (1963)	Long Island Sound - sand station	1956-57 (seasonally)	167 (2-15)	FO -- Polychaetes (*Ampharete* sp.), copepods (*Pseudodiaptomus coronatus*), and amphipods (*Photis* sp. and *Leptocheirus pinguis*).

Bowman *et al.* (1987)	Southern New England	1973-76 (spring/fall)	367 (<15)	TW -- Polychaetes, amphipods, decapod crustaceans (Atlantic rock crab), and squid.
Sedberry (1983)	New York Bight	1976-77 (seasonally)	138 (5-15)	IRI -- Amphipods (hyperids and gammarids) and polychaetes (*Potamilla reniforma* and *Glycera*)
			102 (15-30)	IRI -- Polychaetes, gammarid amphipods (*Ericthonius* sp.), and decapod crustaceans (Atlantic rock crab)
Steimle (unpubl. data)	Raritan Bay	1976 (Mar-Jun)	13 (YOY)	FO -- *Asabellides oculata*, copepods, polydorid polychaetes, *Mulinia lateralis*, blue mussel spat, and hydroids.
Michelman (1988)	Narragansett Bay, RI	1987 (seasonally)	66 (“juveniles”)	TDW -- Polychaetes (maldanids, *Nephtys incisa*, *Nereis* sp., and *Pherusa affinis*), *Pagurus* sp., *Neomysis*, amphipods (*L. pinguis*, etc.), mollusks, *Ceriantheopsis americanus*, and fish larvae.
Steimle *et al.* (unpubl. data)	Delaware Bay	1989-94 (May/Jun, Aug/Sep)	246 (9.0-28.0, mean = 14.2)	TV -- blue mussels, *Ensis directus*, unidentified mollusks, *Metridium senile*, *Dyspanopeus sayi*, *Neomysis*, Atlantic rock crab, and unidentified fish remains.

Table 10. Summary of Hudson-Raritan Estuary summer flounder diet by sampling period during 1996-97, expressed as the percent frequency of occurrence of dominant prey or items (FO), and as the mean percent contribution of dominant prey or items to total stomach content volume (TV). (n = sample size; ES = percent of empty stomachs.)

Prey	Sampling Period: Jul 96 (n = 50; ES = 10.0) FO	TV	Oct 96 (n = 8; ES = 25.0) FO	TV	Jan 97 (n = 5; ES = 40.0) FO	TV	Apr 97 (n = 38; ES = 50.0) FO	TV	Aug 97 (n = 128; ES = 25.0) FO	TV	Nov 97 (n = 0; ES = N/A) FO	TV
Crangon septemspinosa	78.0	44.0	75.0	41.2	60.0	89.3	36.8	31.4	34.4	12.2	-	-
Neomysis americana	30.0	19.6	0.0	0.0	20.0	10.7	5.3	3.1	33.6	11.5	-	-
Unidentified juvenile fish	14.0	9.1	12.5	21.0	0.0	0.0	13.2	10.9	12.5	4.3	-	-
Juvenile *Ovalipes ocellatus*	2.0	1.2	0.0	0.0	0.0	0.0	0.0	0.0	32.0	17.1	-	-
Unidentified organic matter	2.0	0.3	0.0	0.0	0.0	0.0	5.3	0.2	8.6	3.9	-	-
Unidentified juvenile flounder	0.0	0.0	0.0	0.0	0.0	0.0	7.9	24.0	2.3	1.7	-	-
Juvenile windowpane	4.0	9.5	0.0	0.0	0.0	0.0	0.0	0.0	1.5	6.5	-	-
Juvenile Atlantic rock crab	4.0	7.2	0.0	0.0	0.0	0.0	0.0	0.0	7.8	7.0	-	-

Table 11. Summary of other summer flounder diet studies for the coastal Middle Atlantic Bight. (Major prey taxa ranked in relative order of importance by: mean percent frequency of occurrence (FO), mean percent contribution to total stomach content volume (TV), and mean percent contribution to total stomach content weight (TW), as available from each source.)

Source	Study Area	Year(s) (month(s), season(s), and/or frequency)	No. Examined (size [TL cm]) or age range, mean size)	Primary Prey in Order of Importance by FO, IRI, TDW, TN, TV, and/or TW
Linton (1901)	Woods Hole, MA	Unknown	24 (unknown)	FO -- Squid and fish (*e.g.*, juvenile scup).
Poole (1964)	Great South Bay, NY	1958-59 (summer/fall)	1,210 (25-67, mostly 25-42)	TW -- *Crangon*, juvenile winter flounder, juvenile blue crabs, *Neomysis*, and northern pipefish. FO -- *Crangon*, *Neomysis*, and northern pipefish.
de Sylva *et al.* (1962)	Delaware Bay shore	1958 (bimonthly)	26 (5-21)	FO -- *Neomysis*, *Crangon*, *Menidia*, unidentified fish, and other crustaceans.
Langton and Bowman (1981)	New Jersey - North Carolina	1969-72 (spring/fall)	44 (mean = 38)	TW -- *Loligo* squid, juvenile silver hake and scup, and Atlantic rock crab.

Kimmel (1973)	Mouth of Chesapeake Bay	1971-72 (spring/summer)	35 (4-20) 36 (20-48)	TV -- *Neomysis* and goby. TV -- *Neomysis*, *Crangon*, and bay anchovy.
Festa (1979)	Little Egg Harbor, NJ	1972-77 (summer/fall)	25 (6-24) 13 (26-65)	TV -- Fish (anchovy), *Crangon*, *Palaemonetes* sp., and *Neomysis*. TV -- Fish (juvenile searobin and winter flounder, silver perch, anchovy), and juvenile blue crab.
Smith and Daiber (1977)	Delaware Bay	Unknown	131 (31-73)	TV -- Juvenile weakfish, *Crangon*, *Neomysis*, bay anchovy, squid, *Menidia*, herring, and *Pagurus* sp.
Allen *et al.* (1978)	Hereford Inlet, NJ	1973-77 (biweekly/monthly)	57 (1-55)	FO -- *Crangon*, mysids, and fish.
Homer and Boynton (1978)	Chesapeake Bay, MD	1977 (summer)	198 (5-27)	TW -- Juvenile weakfish and spot, bay anchovy, juvenile Atlantic menhaden, *Crangon*, amphipods, juvenile croaker, mollusks, *Menidia, Neomysis*, and nematodes.
Steimle and Terranova (1991)	New York Bight apex	1982-85 (seasonally)	20 (mean = ~30)	FO -- *Neomysis*, fish, and amphipods.
Scarlett and Giust (1989)	Manasquan River, NJ	1984-86 (monthly)	90 (19-44, mean = ~31)	TV -- Juvenile blue crab, *Crangon*, and fish (mummichog, sand lance, juvenile winter flounder, and unidentified species).
Rountree and Able (1992)	Little Egg Harbor, NJ	1987-90 (summer)	137 (17-31, mean = 23)	TW -- *Menidia*, mummichog, *Palaemonetes* sp., and *Crangon*. FO -- *Crangon*, *Menidia*, *Palaemonetes sp.,* and mummichog.
Steimle *et al.* (unpubl. data)	Delaware Bay	1989-94 (May/Jun and Aug/Sep)	43 (23.0-56.0, mean = 35.3)	TV -- *Neomysis* and unidentified fish and mollusk remains.
Timmons (1995)	Rehoboth Bay, DE	1994 (summer)	36 (8-25, mean = 13)	TV -- *Palaemonetes* sp., juvenile blue crab, other crabs and shrimp, and mysids.

Table 12. Summary of Hudson-Raritan Estuary red hake diet by sampling period during 1996-97, expressed as the percent frequency of occurrence of dominant prey or items (FO), and as the mean percent contribution of dominant prey or items to total stomach content volume (TV). (n = sample size; ES = percent of empty stomachs.)

Prey	Sampling Period											
	Jul 96 (n = 1; ES = 0)		Oct 96 (n = 0; ES = N/A)		Jan 97 (n = 62; ES = 5)		Apr 97 (n = 64; ES = 0)		Aug 97 (n = 7; ES = 14)		Nov 97 (n = 32; ES = 0)	
	FO	TV	FO	TV	FO	TV	FO	TV	FO	TV	FO	TV
Crangon septemspinosa	100.0	50.0	-	-	85.5	47.4	91.2	46.2	71.4	47.5	56.3	23.3
Gammarus lawrencianus	100.0	50.0	-	-	8.1	9.5	10.3	1.5	0.0	0.0	43.8	18.8
Neomysis americana	0.0	0.0	-	-	48.4	30.3	39.7	14.5	28.6	26.2	12.5	2.4
Unidentified organic matter	0.0	0.0	-	-	8.1	0.9	20.6	6.2	14.3	3.3	3.1	1.0
Juvenile Atlantic rock crab	0.0	0.0	-	-	1.6	1.0	7.3	1.1	0.0	0.0	6.3	2.8
Unidentified fish	0.0	0.0	-	-	0.0	0.0	1.5	3.3	0.0	0.0	12.5	3.7
Dichelopandalus leptocerus	0.0	0.0	-	-	0.0	0.0	0.0	0.0	14.3	23.0	0.0	0.0

Table 13. Summary of other red hake diet studies for the coastal Middle Atlantic Bight. (Major prey taxa ranked in relative order of importance by: mean percent frequency of occurrence (FO), mean percent contribution to total stomach content volume (TV), mean percent contribution to total stomach content weight (TW), mean percent contribution to total number of individual items in the stomach (TN), and an index of relative importance (IRI), as available from each source.)

Source	Study Area	Year(s) (month(s), season(s), and/or frequency)	No. Examined (size [TL cm]) or age range, mean size)	Primary Prey in Order of Importance by FO, IRI, TDW, TN, TV, and/or TW
Richards (1963)	Long Island Sound	1956-57 (seasonally)	Sand station - 21 (9-20)	FO -- Polychaetes (*Glycera* sp.), amphipods (*Ampelisca* sp. and *Leptocheirus pinguis*), *Neomysis*, *Heteromysis formosa*, and *Crangon.*
Steimle and Ogren (1982)	New York Bight	1966-67 (Jul-Aug)	31 (mostly 33-36)	TV -- *Crangon*, unidentified tunicate, Atlantic rock crab, unidentified fish, and *Nereis* sp.
Steimle (1985)	New York Bight	1968-70 (summer)	219 (mostly 17-25)	FO -- *Crangon*, polychaetes (*Pherusa affinis* and *Nephtys incisa*), *Neomysis*, and amphipods (*Unciola* sp. and *L. pinguis*).
Vinogradov (1984)	Southern New England	1968-74 (spring/fall?)	1,892 (unreported)	TW -- Sipunculids, unidentified fish, crabs, squid, “shrimp,” gammaridean amphipods, and bivalve mollusks.

Bowman *et al.* (1987)	Southern New England	1973-76 (spring/ fall)	"208" (<10)	TW -- Crustaceans (*Dichelopandalus leptocerus*), chaetognaths, amphipods, and decapod crustaceans.
			Part of above (10-20)	TW -- Crustaceans, amphipods (*Gammarus* sp.), decapod crustaceans (*Crangon*), and euphausids.
Steimle (unpubl. data)	Raritan Bay	1976 (Mar-Jun)	45 (Subadult)	FO -- *Crangon*.
Sedberry (1983)	New York Bight	1976-77 (seasonally)	716 (5-20)	IRI -- Amphipods (*Unciola irrorata*) and copepods.
			425 (25-50)	IRI -- Amphipods (*U. irrorata*), Atlantic rock crab, fish, and ocean scallops.
Luczkovich and Olla (1983)	Coastal New Jersey	1979-80 (1 yr, monthly)	130 (2-9)	FO -- Unidentified crustaceans, decapod crustaceans (*Crangon*), amphipods (*Unciola* sp., *L. pinguis*, *Monoculodes* sp., and *Ericthonius* sp.), calanoid copepods, and mysids.
Steimle and Terranova (1991)	New York Bight apex	1982-85 (seasonally)	144 (not noted)	FO -- *Crangon*, *P. affinis*, juvenile Atlantic rock crab, sand lance (*Ammodytes* sp.), and *D. leptocerus*.
Steimle (1994)	New York Bight apex	1986-89 (monthly)	1,047 (10-34, mostly >17)	FO -- *P. affinis*, *Crangon, D. leptocerus*, Atlantic rock crab, and *N. incisa*.
Rachlin and Warkentine (1988)	Central New Jersey	Unreported	133 (6-32, mostly subadults)	TN -- *Neomysis*, decapod crustaceans (*Crangon*), nematodes, copepods, amphipods, isopods, and fish.

Table 14. Summary of Hudson-Raritan Estuary weakfish diet by sampling period during 1996-97, expressed as the percent frequency of occurrence of dominant prey or items (FO), and as the mean percent contribution of dominant prey or items to total stomach content volume (TV). (n = sample size; ES = percent of empty stomachs.)

	Sampling Period											
	Jul 96 (n = 0; ES = N/A)		Oct 96 (n = 66; ES = 12)		Jan 97 (n = 0; ES = N/A)		Apr 97 (n = 0; ES = N/A)		Aug 97 (n = 117; ES = 3)		Nov 97 (n = 14; ES = 57)	
Prey	**FO**	**TV**	**FO**	**TV**	**FO**	**TV**	**FO**	**TV**	**FO**	**TV**	**FO**	**TV**
Crangon septemspinosa	-	-	63.6	20.5	-	-	-	-	54.7	30.0	14.3	23.9
Neomysis americana	-	-	31.8	3.3	-	-	-	-	81.3	26.7	14.3	4.5
Unidentified fish (*Anchoa*?)	-	-	24.2	3.8	-	-	-	-	21.4	12.5	7.1	15.9
Gammarus lawrencianus	-	-	27.3	4.3	-	-	-	-	0.9	0.9	14.3	11.4
Unidentified organic matter	-	-	10.6	0.5	-	-	-	-	1.7	0.9	7.1	1.1
Anchoa mitchilli	-	-	13.5	17.3	-	-	-	-	1.9	<0.1	0.0	0.0
Ampelisca abdita	-	-	0.0	0.0	-	-	-	-	1.7	<0.1	7.1	3.4
Juvenile silver hake	-	-	0.0	0.0	-	-	-	-	0.0	0.0	7.1	36.4

Table 15. Summary of other weakfish diet studies for the coastal Middle Atlantic Bight. (Major prey taxa ranked in relative order of importance by: mean percent frequency of occurrence (FO), mean percent contribution to total stomach content volume (TV), and mean percent contribution to total stomach content weight (TW), as available from each source.)

Source	Study Area	Year(s) (month(s), season(s), and/or frequency)	No. Examined (size [TL cm]) or age range, mean size)	Primary Prey in Order of Importance by FO, IRI, TDW, TN, TV, and/or TW
Welsh and Breder (1924)	Acushnet River, MA	1882 (Sep)	28 (7-11)	TV -- Fish (killifish and river herring) and “shrimp.”
Peck (1896)	Woods Hole, MA	1893 (summer)	570 (“older fish”)	FO -- Juvenile herring and bluefish, butterfish, herring, squid, crustaceans, and juvenile Atlantic menhaden.
Welsh and Breder (1924)	Cape May, NJ	1916 (Aug)	32 (3-8)	TV -- Mysids, “shrimp,” unidentified crustaceans, and juvenile herring.
		1919 (May)	30 (24-39)	TV -- Mysids, unidentified crustaceans, and “shrimp.”
Welsh and Breder (1924)	Cape Charles, VA	1916 (Sep)	45 (4-12)	TV -- Mysids, copepods, amphipods, and juvenile herring.
Breder (1922b)	Raritan Bay, NJ	1921 (summer)	? (33-51)	FO? -- Squid, shrimp, juvenile Atlantic menhaden, silver perch, and anchovy.
Tressler and Bere (1939)	Southern Long Island, NY	1938 (summer)	89 (4-11)	FO? -- *Crangon* and copepods.

Shuster (1959)	Delaware Bay	1952 (summer/fall)	205 (12-30)	FO -- *Neomysis*, unidentified fish, *Solen viridis*, and *Crangon*
Richards (1963)	Long Island Sound	1956-57 (seasonally)	Sand station - 23 (4-10)	FO? -- *Crangon*, *Upogebia* sp., juvenile bay anchovy, copepods, and *Ampelisca* sp.
			Mud station - 48 (4-8)	FO? -- *Crangon*, *Neomysis*, and copepods.
de Sylva *et al.* (1962)	Delaware Bay	1958-60 (summer/fall)	220 (2-15)	FO -- *Neomysis*, *Crangon*, decapod larvae, juvenile *Limulus polyphemus*, and unidentified juvenile fish.
Van Engle and Joseph (1968)	Chesapeake Bay, VA	1967 (summer)	268 ("juveniles")	TV -- Unidentified fish (mostly bay anchovy and naked goby), *Neomysis*, *Crangon*, copepods, and amphipods. FO -- *Neomysis*, fish, copepods, and amphipods.
Thomas (1971)	Delaware River	1969 (summer/fall)	494 (5-18)	FO -- *Neomysis*, *Gammarus* sp., unidentified fish , juvenile weakfish, detritus, and copepods.
			64 (>18)	FO -- Juvenile weakfish, unidentified fish, *Neomysis*, and *Gammarus* sp.
Kimmel (1973)	Mouth of Chesapeake Bay	1971-72 (spring/summer)	27 (2-28)	TV -- *Neomysis*, calanoid copepods, *Crangon*, and unidentified crustaceans.
Festa (1979)	Little Egg Harbor, NJ	1972-77 (summer/fall)	51 (<17)	TV -- *Neomysis*, fish (anchovy), *Crangon*, and *Ampelisca* sp. FO -- *Neomysis*, *Crangon*, fish, and *Ampelisca* sp.
Chao and Musick (1977)	York River, VA	1973 (summer)	36 (7-18)	FO -- Bay anchovy, *Neomysis,* and other fish.
Allen *et al.* (1978)	Hereford Inlet, NJ	1973-77 (biweekly/ monthly)	86 (3-22)	FO -- Mysids, *Crangon*, crab larvae, and unidentified fish.
Bason *et al.* (1975, 1976); Keirsey *et al.* (1977)	Chesapeake and Delaware Canal, DE	1974-76 (summer/fall)	1,119 (2-44, mostly < 10)	TV -- *Neomysis*, bay anchovy, *Crangon*, *Gammarus* sp., juvenile fish (Atlantic menhaden, weakfish, and croaker), polychaetes, and *Corophium* sp.
Homer and Boynton (1978)	Chesapeake Bay, MD	1977 (summer)	808 (3-19)	TW -- Bay anchovy, *Pseudodiaptomus coronatus*, juvenile weakfish, *Nereis succinea*, and other polychaetes.
Scarlett and Giust (1989)	Manasquan River, NJ	1984-86 (monthly)	45 (9-20)	TV -- *Crangon*, sand lance, detritus, *Neomysis*, unidentified fish, and naked goby.
Hartman and Brandt (1995)	Chesapeake Bay	1990-92 (bimonthly?)	564 (age 0)	TW -- Juvenile bay anchovy and other fish (*e.g.* juvenile croaker).
			353 (age 1)	TW -- Bay anchovy, juvenile Atlantic menhaden, spot, and other fish.
			54 (age 2+)	TW -- Spot, Atlantic menhaden, juvenile summer flounder, and bay anchovy.

Table 16. Summary of Hudson-Raritan Estuary spotted hake diet by sampling period during 1996-97, expressed as the percent frequency of occurrence of dominant prey or items (FO), and as the mean percent contribution of dominant prey or items to total stomach content volume (TV). (n = sample size; ES = percent of empty stomachs.)

	Sampling Period											
	Jul 96 (n = 44; ES = 0)		Oct 96 (n = 14; ES = 7)		Jan 97 (n = 1; ES = 0)		Apr 97 (n = 72; ES = 0)		Aug 97 (n = 3; ES = 33)		Nov 97 (n = 28; ES = 0)	
Prey	FO	TV	FO	TV	FO	TV	FO	TV	FO	TV	FO	TV
Crangon septemspinosa	95.5	60.9	85.7	42.4	100.0	33.3	76.4	47.1	66.7	38.9	89.3	31.3
Neomysis americana	15.9	5.9	14.3	4.1	100.0	33.3	33.3	8.9	100.0	40.7	7.1	0.3
Unidentified juvenile fish	0.0	0.0	7.1	13.5	0.0	0.0	5.6	5.0	33.3	20.4	50.0	17.2
Unidentified organic matter	6.8	0.4	0.0	0.0	0.0	0.0	13.9	5.4	0.0	0.0	3.6	<0.1
Gammarus lawrencianus	15.9	4.4	28.6	9.3	0.0	0.0	0.0	0.0	0.0	0.0	17.9	4.3
Pseudodiaptomus sp.	0.0	0.0	0.0	0.0	100.0	33.3	13.9	2.1	0.0	0.0	10.7	0.1
Unidentified juvenile flounder	2.3	0.5	0.0	0.0	0.0	0.0	1.4	4.1	0.0	0.0	17.9	4.2
Juvenile *Anguilla rostrata*	0.0	0.0	7.1	13.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Unidentified hydroids	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	17.9	9.5

Table 17. Summary of other spotted hake diet studies for the coastal Middle Atlantic Bight. (Major prey taxa ranked in relative order of importance by: mean percent frequency of occurrence (FO), mean percent contribution to total stomach content volume (TV), mean percent contribution to total stomach content weight (TW), and mean percent contribution to total number of individual items in the stomach (TN), as available from each source.)

Source	Study Area	Year(s) (month(s), season(s), and/or frequency)	No. Examined (size [TL cm]) or age range, mean size)	Primary Prey in Order of Importance by FO, IRI, TDW, TN, TV, and/or TW
Linton, quoted in Hildebrand and Schroeder (1928)	Woods Hole, MA?	Unknown	141 (unknown)	FO? -- "*Mysis*," shrimp, crabs, amphipods, isopods, fish, polychaetes, leeches, sponges, and hydroids.
Richards (1963)	Long Island Sound	1955-57 (monthly)	Sand station - 17 (6-20) Mud station - 16 (5-19)	FO -- *Leptocheirus pinguis*, *Crangon*, and sand lance. FO -- Sand lance, *Corophium* sp., and copepods (Temora sp.).
Barans (1969)	Chesapeake Bay	1966-68 (Mar-Jul)	600 (5-18)	FO -- *Crangon,* other shrimp, *Neomysis*, squid, polychaetes, and unidentified fish.
Kimmel (1973)	Mouth of Chesapeake Bay	1971-72 (spring)	44 (3-20)	TV -- *Neomysis*, *Crangon*, *Ampelisca* sp., other crustaceans, and bay anchovy.

Festa (1979)	Little Egg Harbor, NJ	1972-77 (spring/fall)	16 (5-19)	TV -- *Crangon*, *Palaemonetes* sp., and *Neomysis*. FO -- *Crangon* and *Neomysis*.
Bowman *et al.* (1987)	Southern New England	1973-76 (spring/fall)	244 (YOY)	TW -- Euphausids, *Crangon*, and *Dichelopandalus leptocerus*.
Rachlin and Warkentine (1987)	Coastal New York Bight	1973-74 (summer)	156 (5-21)	TN -- *Neomysis*, copepods (*Acartia* sp. and *Temora* sp.), *Crangon*, amphipods (*Gammarus* sp.), round herring (*Etrumeus teres*), and decapod crustacean larvae.
Allen *et al.* (1978)	Hereford Inlet, NJ	1973-77 (biweekly/ monthly)	101 (5-17)	FO -- *Crangon*, mysids, detritus, and copepods.
Sedberry (1983)	New York Bight shelf	1976-77 (seasonally)	129 (<20)	TV -- Atlantic rock crab, *D. leptocerus*, *Crangon*, unidentified hake, Gulf Stream flounder (*Citharichthys arctifrons*), and amphipods.
			68 (>20)	TV -- As above, plus squid and juvenile sea scallops.
Homer and Boynton (1978)	Chesapeake Bay, MD	1977 (spring)	19 (10-15)	TW -- *Crangon*, juvenile Atlantic menhaden, *Nereis succinea*, bay anchovy, and juvenile spot.

Table 18. Summary of Hudson-Raritan Estuary striped searobin diet by sampling period during 1996-97, expressed as the percent frequency of occurrence of dominant prey or items (FO), and as the mean percent contribution of dominant prey or items to total stomach content volume (TV). (n = sample size; ES = percent of empty stomachs.)

	Sampling Period											
	Jul 96 (n = 26; ES = 4)		Oct 96 (n = 39; ES = 11)		Jan 97 (n = 0; ES = N/A)		Apr 97 (n = 5; ES = 40)		Aug 97 (n = 81; ES = 5)		Nov 97 (n = 2; ES = 0)	
Prey	FO	TV	FO	TV	FO	TV	FO	TV	FO	TV	FO	TV
Crangon septemspinosa	96.2	56.2	74.4	42.3	-	-	60.0	71.1	75.3	37.4	50.0	71.4
Neomysis americana	23.1	12.8	25.6	9.5	-	-	0.0	0.0	37.0	10.2	0.0	0.0
Unidentified organic matter	0.0	0.0	15.4	8.6	-	-	0.0	0.0	6.2	0.7	0.0	0.0
Juvenile Atlantic rock crab	3.8	2.7	7.7	9.0	-	-	0.0	0.0	11.1	9.7	0.0	0.0
Coal pebbles	3.8	0.7	2.6	<0.1	-	-	0.0	0.0	4.9	1.6	0.0	0.0
Juvenile *Ovalipes ocellatus*	0.0	0.0	5.1	8.1	-	-	0.0	0.0	9.9	5.4	0.0	0.0
Unidentified juvenile fish	3.8	7.7	2.6	0.9	-	-	0.0	0.0	11.1	5.8	0.0	0.0
Juvenile striped searobin	0.0	0.0	0.0	0.0	-	-	0.0	0.0	7.4	8.8	0.0	0.0
Ampelisca abdita	7.7	1.3	0.0	0.0	-	-	0.0	0.0	2.4	0.1	0.0	0.0
Gammarus lawrencianus	3.8	0.7	15.4	7.4	-	-	0.0	0.0	0.0	0.0	0.0	0.0

Table 19. Summary of other striped searobin diet studies for the coastal Middle Atlantic Bight. (Major prey taxa ranked in relative order of importance by: mean percent frequency of occurrence (FO), mean percent contribution to total stomach content volume (TV), mean percent contribution to total stomach content weight (TW), and mean percent contribution to total number of individual items in the stomach (TN), as available from each source.)

Source	Study Area	Year(s) (month(s), season(s), and/or frequency)	No. Examined (size [TL cm]) or age range, mean size)	Primary Prey in Order of Importance by FO, IRI, TDW, TN, TV, and/or TW
Marshall (1946)	New Haven, CT	1942 (summer)	28 (YOY)	FO -- *Crangon* and unidentified fish.
Marshall (1946)	Woods Hole, MA	1943-44 (summer)	10 (3-6) 11 (18-30)	FO -- *Crangon*, copepods, and eggs. FO -- *Neomysis*, *Gammarus* sp., *Crangon*, and fish (northern searobin, unidentified flounder, and others).
Kimmel (1973)	Mouth of Chesapeake Bay	1971-72 (spring/summer)	7 (10-14)	TV -- *Neomysis* and *Crangon.*

Richards *et al.* (1979)	Long Island Sound, CT	1971-72 (spring/fall)	124 (4-14)	TN -- *Neomysis*, copepods (*Temora* sp. and *Labidocera* sp.), and *Crangon*.
		1976-77 (same)	57 (12-33)	TN -- *Crangon* and *Neomysis*.
Mann (1974)	Long Island Sound, NY	1973 (spring-fall)	533 (YOY) 390 (1-9)	TN -- *Neomysis* and *Crangon*. TN -- Crabs, *Crangon*, juvenile fish (scup, northern and striped searobins, windowpane, winter flounder, bay anchovy, *Menidia*, and northern pipefish), and *Neomysis*.
Carlson (1991)	New Haven Harbor, CT	1989-90 (monthly)	15 (32-39)	TW -- *Ovalipes ocellatus*, juvenile winter flounder, and juvenile Atlantic rock crab. FO -- *O. ocellatus*, Atlantic rock crab, and juvenile winter flounder.
Manderson *et al.* (1999)	Sandy Hook Bay, NJ	1998 (Jun-Oct)	77 (18-37, mean = 28)	TW -- *Crangon*, mysids (*Neomysis*), juvenile winter flounder, amphipods, and juvenile *O. ocellatus*. FO -- *Crangon*, mysids, juvenile winter flounder, amphipods, and *O. ocellatus*.

Table 20. Summary of Hudson-Raritan Estuary northern searobin diet by sampling period during 1996-97, expressed as the percent frequency of occurrence of dominant prey or items (FO), and as the mean percent contribution of dominant prey or items to total stomach content volume (TV). (n = sample size; ES = percent of empty stomachs.)

Prey	Sampling Period											
	Jul 96 (n = 0; ES = N/A)		Oct 96 (n = 2; ES = 0)		Jan 97 (n = 0; ES = N/A)		Apr 97 (n = 10; ES = 40)		Aug 97 (n = 87; ES = 5)		Nov 97 (n = 4; ES = 0)	
	FO	TV	FO	TV	FO	TV	FO	TV	FO	TV	FO	TV
Crangon septemspinosa	-	-	50.0	16.7	-	-	10.0	16.7	77.0	37.0	50.0	33.3
Neomysis americana	-	-	100.0	33.3	-	-	10.0	16.7	16.1	4.0	50.0	16.7
Gammarus lawrencianus	-	-	100.0	33.3	-	-	0.0	0.0	5.7	3.6	25.0	8.3
Unidentified crustaceans	-	-	0.0	0.0	-	-	30.0	25.0	1.1	0.1	0.0	0.0
Juvenile Atlantic rock crab	-	-	0.0	0.0	-	-	0.0	0.0	37.9	23.6	0.0	0.0
Unciola sp.	-	-	50.0	16.7	-	-	0.0	0.0	2.3	1.0	0.0	0.0
Juvenile *Ovalipes ocellatus*	-	-	0.0	0.0	-	-	0.0	0.0	9.2	6.2	0.0	0.0
Unidentified amphipods	-	-	0.0	0.0	-	-	0.0	0.0	2.3	0.5	25.0	8.3
Unidentified juvenile fish	-	-	0.0	0.0	-	-	0.0	0.0	4.6	1.6	25.0	25.0
Coal pebbles	-	-	0.0	0.0	-	-	0.0	0.0	24.1	6.8	0.0	0.0

Table 21. Summary of other northern searobin diet studies for the coastal Middle Atlantic Bight. (Major prey taxa ranked in relative order of importance by: mean percent frequency of occurrence (FO), mean percent contribution to total stomach content volume (TV), mean percent contribution to total stomach content weight (TW), and mean percent contribution to total number of individual items in the stomach (TN), as available from each source.)

Source	Study Area	Year(s) (month(s), season(s), and/or frequency)	No. Examined (size [TL cm]) or age range, mean size)	Primary Prey in Order of Importance by FO, IRI, TDW, TN, TV, and/or TW
Linton (1901)	Woods Hole, MA	1899-1900 (summer)	Unknown	FO? -- Herring, softshells, *Palaemonetes* sp., amphipods, squid, "clams," polychaetes, and juvenile winter flounder.
Marshall (1946)	Woods Hole , MA	1943 (summer)	42 (2-7)	FO -- Amphipods (*Gammarus locusta*), *Crangon,* copepods, and *Neomysis*.
			38 (>13)	FO -- *Crangon*, *G. locusta*, *Neomysis*, *Ampelisca* sp., and polychaetes.
Marshall (1946)	Block Island Sound	1943 (summer)	13 (>17)	FO -- *Ampelisca* sp., *G. locusta*, *Unciola irrorata*, *Cerapus tubularis*, and polychaetes.

Marshall (1946)	Montauk Point, NY	1943 (spring)	12 (18-25)	FO -- *Monoculodes edwardsi*, *Neomysis*, cumaceans, and *Crangon*.
Smith (1950)	Block Island Sound	1948-49 (seasonally)	Unknown	TV? -- *Leptocheirus pinguis*, *U. irrorata,* and *Crangon*.
Richards (1963)	Long Island Sound	1956-57 (seasonally)	Sand station - 103 (2-16)	FO? -- Copepods, amphipods, *Neomysis*, *Heteromysis formosa*, *Pagurus* sp., *Crangon*, bay anchovy, and *Cyathura* sp.
			Mud station - 23 (2-10)	FO? -- Copepods, amphipods (*Unciola* sp.), *Neomysis*, and cumaceans.
Kimmel (1973)	Mouth of Chesapeake Bay	1971-72 (spring-summer)	47 (2-12)	TV -- *Neomysis*, *Crangon*, and *A. macrocephala.*
Richards *et al.* (1979)	Long Island Sound	1971-73 (spring-fall)	120 (4-12)	TN -- *Neomysis*, copepods (*Acartia* sp., *Pseudodiaptomus coronatus*, and *Temora* sp.), and *Crangon*.
		1976-77	25 (10-30)	TN -- Amphipods, isopods, crabs, *Crangon*, and *Neomysis*.
Mann (1974)	Long Island Sound, NY	1973 (May-Dec)	419 (~10-29)	TN -- *Crangon,* crabs, bivalve mollusks (*Ensis directus*), amphipods (*Unciola* sp.), isopods, cumaceans, and copepods.
Allen *et al.* (1978)	Hereford Inlet, NJ	1973-77 (biweekly/ monthly)	107 (4-21)	FO -- Amphipods, *Crangon*, mysids, crabs, unidentified fish, polychaetes, crab larvae, and *Pagurus* sp.
Homer and Boynton (1978)	Chesapeake Bay, MD	1977 (May/Sep)	Unknown (~5-18)	TW -- Juvenile weakfish, *Nereis succinea*, amphipods, polychaetes, and anemones.

Table 22. Summary of Hudson-Raritan Estuary striped bass diet by sampling period during 1996-97, expressed as the percent frequency of occurrence of dominant prey or items (FO), and as the mean percent contribution of dominant prey or items to total stomach content volume (TV). (n = sample size; ES = percent of empty stomachs.)

Prey	Sampling Period											
	Jul 96 (n = 0; ES = N/A)		Oct 96 (n = 3; ES = 100)		Jan 97 (n = 24; ES = 37)		Apr 97 (n = 32; ES = 25)		Aug 97 (n = 0; ES = N/A)		Nov 97 (n = 22; ES = 9)	
	FO	**TV**	**FO**	**TV**	**FO**	**TV**	**FO**	**TV**	**FO**	**TV**	**FO**	**TV**
Crangon septemspinosa	-	-	0.0	0.0	58.3	100.0	75.9	36.9	-	-	54.5	15.0
Neomysis americana	-	-	0.0	0.0	0.0	0.0	31.0	16.6	-	-	4.5	<0.1
Unidentified fish remains	-	-	0.0	0.0	0.0	0.0	3.4	0.3	-	-	36.4	1.9
Smallmouth flounder	-	-	0.0	0.0	0.0	0.0	0.0	0.0	-	-	18.2	12.3
Palaemonetes sp.	-	-	0.0	0.0	0.0	0.0	0.0	0.0	-	-	13.6	5.1
Ampelisca abdita	-	-	0.0	0.0	0.0	0.0	17.2	6.6	-	-	0.0	0.0
Juvenile red hake	-	-	0.0	0.0	0.0	0.0	0.0	0.0	-	-	13.6	10.6
Unidentified goby	-	-	0.0	0.0	0.0	0.0	0.0	0.0	-	-	9.1	0.8
Juvenile silver hake	-	-	0.0	0.0	0.0	0.0	0.0	0.0	-	-	13.6	3.4
Juvenile *Ovalipes ocellatus*	-	-	0.0	0.0	0.0	0.0	0.0	0.0	-	-	13.6	4.2
Nassarius trivittatus	-	-	0.0	0.0	0.0	0.0	3.4	2.9	-	-	4.5	5.9
Northern searobin	-	-	0.0	0.0	0.0	0.0	3.4	2.4	-	-	4.5	5.9

Table 23. Summary of other striped bass diet studies for the coastal Middle Atlantic Bight. (Major prey taxa ranked in relative order of importance by: mean percent frequency of occurrence (FO), mean percent contribution to total stomach content volume (TV), mean percent contribution to total stomach content weight (TW), and mean percent contribution to total number of individual items in the stomach (TN), as available from each source.)

Source	Study Area	Year(s) (month(s), season(s), and/or frequency)	No. Examined (size [TL cm]) or age range, mean size)	Primary Prey in Order of Importance by FO, IRI, TDW, TN, TV, and/or TW
Curran and Reis (1937)	Lower Hudson River, NY	1936 (unknown)	Unknown ("small")	FO? -- *Gammarus fasciatus*, chironomids, and copepods.
Merriman (1941)	Connecticut coast	1936-37 (Apr-Nov)	550 ("juveniles")	FO? -- *Menidia* and juvenile Atlantic menhaden.
Hollis (1952)	Chesapeake Bay	1936-37 (seasonally)	1,736 (~14-74)	TN -- Bay anchovy, Atlantic menhaden, spot, croaker, herring, unidentified fish, cladocerans, isopods, *Crangon*, and *Palaemonetes* sp.
de Sylva *et al.* (1962)	Delaware Bay	1958-60 (Mar-Dec)	279 (4-31)	FO -- *Neomysis*, *Gammarus* sp., *Crangon*, *Palaemonetes* sp., other crustaceans, *Limulus polyphemus* eggs and larvae, and unidentified fish.

Schaefer (1970)	Southern Long Island surf zone	1964 (Apr-Nov)	61 (28-40)	TV -- Amphipods (*Gammarus* sp. and haustorids), *Neomysis*, Atlantic surfclam, and bay anchovy.
			183 (41-60)	TV -- Amphipods (*Gammarus* sp. and haustorids), bay anchovy, *Menidia*, and scup.
			123 (61-94)	TV -- Amphipods (*Gammarus* sp. and haustorids), red hake, *Ovalipes ocellatus*, scup, bay anchovy, juvenile tautog, northern puffer, and mullet.
Markle and Grant (1970)	York River, VA	1967 (Jul-Oct)	297 (3-15)	TV -- Fish (goby, *Menidia*, and shiners), *Palaemonetes* sp., Crangon, *Neomysis*, and polychaetes.
Festa (1979)	Little Egg Harbor, NJ	1972-77 (fall)	11 (43-58)	TV -- Sand lance, weakfish, unidentified fish, and *Crangon*. FO -- Sand lance, unidentified fish, and *Crangon*.
Gardinier and Hoff (1982)	Middle Hudson River Estuary	1974 (Apr-Nov)	546 (<15)	FO -- *Gammarus* sp., calanoid copepods, and juvenile fish (Atlantic tomcod).
			(15-28)	FO -- Fish (herring, Atlantic tomcod, bay anchovy, banded killifish, and mummichog).
		1976-77 (Apr-May)	380 (>20)	FO -- Fish (herring, bay anchovy, shiners, and killifish), detritus, and "invertebrates."
Boynton *et al.* (1981)	Potomac River, VA/MD	1976 (biweekly, Jun-Sep, higher salinity area)	703 (2.5-10)	TN -- Fish, mysids, and polychaetes.
Homer and Boynton (1978)	Chesapeake Bay, MD	1977 (spring)	19 (10-15)	TW -- *Crangon*, juvenile Atlantic menhaden, *Nereis succinea*, bay anchovy, and juvenile spot.
Lawler, Matusky & Skelly Engineers (1980)	Hudson River, NY	1979-80 (seasonally)	239 (mean = 18.50)	TV -- *Gammarus* sp., *Crangon*, *Paleomonetes* sp., and *Neomysis*.
Fay *et al.* (1982)	Hudson River	Unknown	(<7.5) (7.6-12.5) (13-20)	FO? -- *Gammarus* sp., calanoid copepods, and insect larva. FO? -- *Gammarus* sp. and calanoid copepods. FO? -- Atlantic tomcod.
Fay *et al.* (1982)	Delaware River	Unknown	(5-10)	FO? -- *Neomysis* and *Crangon*.
Fay *et al.* (1982)	Chesapeake Bay	Unknown	(7-15) (10-27)	FO? -- Naked goby and *Palaemonetes* sp. FO? -- Bay anchovy.
Hartman and Brandt (1995)	Chesapeake Bay	1990-92 (bimonthly)	(age 0) (age 1)	TW -- Juvenile Atlantic menhaden, spot, and other fish. TW -- "Invertebrates," Atlantic menhaden, bay anchovy, and *Gammarus* sp.
			(age 2)	TW -- Atlantic menhaden, spot, and other fish.

Table 24. Summary of Hudson-Raritan Estuary clearnose skate diet by sampling period during 1996-97, expressed as the percent frequency of occurrence of dominant prey or items (FO), and as the mean percent contribution of dominant prey or items to total stomach content volume (TV). (n = sample size; ES = percent of empty stomachs.)

	Sampling Period											
	Jul 96 (n = 27; ES = 0)		**Oct 96 (n = 13; ES = 0)**		**Jan 97 (n = 0; ES = N/A)**		**Apr 97 (n = 0; ES = N/A)**		**Aug 97 (n = 30; ES = 0)**		**Nov 97 (n = 1; ES = 0)**	
Prey	**FO**	**TV**	**FO**	**TV**	**FO**	**TV**	**FO**	**TV**	**FO**	**TV**	**FO**	**TV**
Crangon septemspinosa	78.8	25.1	61.5	29.2	-	-	-	-	36.7	15.1	100.0	33.3
Atlantic rock crab	60.6	37.2	7.7	1.9	-	-	-	-	73.4	25.7	0.0	0.0
Unidentified fish remains	9.1	2.3	46.2	17.7	-	-	-	-	20.0	10.1	100.0	33.3
Ovalipes ocellatus	6.1	2.5	15.4	9.8	-	-	-	-	13.3	7.6	100.0	33.3
Juvenile conger eel	0.0	0.0	15.4	11.3	-	-	-	-	0.0	0.0	0.0	0.0
Juvenile winter flounder	3.0	2.9	7.7	11.3	-	-	-	-	0.0	0.0	0.0	0.0
Unidentified juvenile flounder	0.0	0.0	0.0	0.0	-	-	-	-	23.3	13.3	0.0	0.0
Unidentified organic matter	6.1	1.7	23.1	6.8	-	-	-	-	3.3	<0.1	0.0	0.0
Xanthid crabs	12.1	6.4	0.0	0.0	-	-	-	-	6.7	2.2	0.0	0.0
Juvenile windowpane	6.1	4.7	0.0	0.0	-	-	-	-	3.3	1.7	0.0	0.0
Ensis directus	6.1	6.5	0.0	0.0	-	-	-	-	6.7	3.3	0.0	0.0

Table 25. Summary of other clearnose skate diet studies for the coastal Middle Atlantic Bight. (Major prey taxa ranked in relative order of importance by: mean percent frequency of occurrence (FO), and mean percent contribution to total stomach content volume (TV), as available from each source.)

Source	Study Area	Year(s) (month(s), season(s), and/or frequency)	No. Examined (size [TL cm]) or age range, mean size)	Primary Prey in Order of Importance by FO, IRI, TDW, TN, TV, and/or TW
Fitz and Daiber (1963)	Delaware Bay	1954-56 (seasonally)	363 (mean = 56)	FO -- *Crangon*, *Ensis directus*, xanthid crabs (*Dyspanopeus*), *Libinia dubia*, *Pagurus* sp., *Neomysis*, and fish (weakfish, windowpane, bay anchovy, and others).
Kimmel (1973)	Mouth of Chesapeake Bay	1971-72 (monthly)	28 (19-44)	TV -- *Crangon*, *E. directus*, *Solen* sp., *Upogebia* sp., *Neomysis*, and unidentified fish. FO — *Crangon*, *Neomysis*, unidentified fish, *Upogebia* sp., and *Neomysis*.
Steimle (unpubl. data)	Delaware Bay	1989-94 (May/Jun and Aug/Sep)	96 (28.0-78.0, mean = 58.0)	TV -- Atlantic rock crab, *E. directus*, unidentified fish and crustaceans, *Pagurus* sp., *Dyspanopeus sayi*, and *Crangon*.

Table 26. Summary of Hudson-Raritan Estuary bluefish diet by sampling period during 1996-97, expressed as the percent frequency of occurrence of dominant prey or items (FO), and as the mean percent contribution of dominant prey or items to total stomach content volume (TV). (n = sample size; ES = percent of empty stomachs.)

	Sampling Period											
	Jul 96 (n = 0; ES = N/A)		Oct 96 (n = 1; ES = 0)		Jan 97 (n = 0; ES = N/A)		Apr 97 (n = 0; ES = N/A)		Aug 97 (n = 62; ES = 0)		Nov 97 (n = 0; ES = N/A)	
Prey	**FO**	**TV**	**FO**	**TV**	**FO**	**TV**	**FO**	**TV**	**FO**	**TV**	**FO**	**TV**
Unidentified fish remains	-	-	0.0	0.0	-	-	-	-	41.9	41.4	-	-
Crangon septemspinosa	-	-	0.0	0.0	-	-	-	-	24.2	22.2	-	-
Neomysis americana	-	-	0.0	0.0	-	-	-	-	21.0	17.3	-	-
Unidentified organic matter	-	-	0.0	0.0	-	-	-	-	9.7	3.7	-	-
Juvenile butterfish	-	-	0.0	0.0	-	-	-	-	1.6	9.3	-	-
Anchoa sp.	-	-	100.0	100.0	-	-	-	-	1.6	1.9	-	-

Table 27. Summary of other bluefish diet studies for the coastal Middle Atlantic Bight. (Major prey taxa ranked in relative order of importance by: mean percent frequency of occurrence (FO), mean percent contribution to total stomach content volume (TV), and mean percent contribution to total stomach content weight (TW), as available from each source.)

Source	Study Area	Year(s) (month(s), season(s), and/or frequency)	No. Examined (size [TL cm]) or age range, mean size)	Primary Prey in Order of Importance by FO, IRI, TDW, TN, TV, and/or TW
Peck (1896)	Woods Hole, MA	1893 (Jul-Aug)	38 (?)	FO -- Atlantic menhaden, butterfish, herring, squid, and YOY fish.
Breder (1922a)	Atlantic City, NJ	1920 (Aug)	31 (14-21)	TV -- Butterfish, juvenile spot, unidentified fish, and plant material.
Grant (1962)	Indian River, DE	1956-58 (summer)	262 (3-24)	TV -- Mummichog, juvenile Atlantic menhaden, *Menidia*, bay anchovy, and unidentified fish. FO -- Unidentified fish, juvenile Atlantic menhaden, *Menidia*, mummichog, and polychaetes.
de Sylva *et al.* (1962)	Delaware Bay shore	1958-60 (summer)	152 (4-23)	FO -- Unidentified fish, *Menidia*, *Neomysis*, *Crangon*, herring, and bay anchovy.

Festa (1979)	Little Egg Harbor, NJ	1972-77 (summer/fall)	16 (6-10)	TV -- *Palaemonetes* sp., unidentified fish, *Nereis* sp., *Nephtys* sp., and *Menidia.* FO -- Unidentified fish, crab larvae, and *Nereis* sp.
			62 (11-20)	TV -- Unidentified fish, mummichog, *Menidia*, juvenile blue crab, and bay anchovy. FO -- Unidentified fish, *Crangon*, detritus, bay anchovy, *Menidia*, and *Neomysis.*
Allen *et al.* (1978)	Hereford Inlet, NJ	1973-77 (biweekly/ monthly)	301 (3-18)	FO -- Unidentified fish, *Crangon*, *Menidia*, crab larvae, juvenile spot, and shrimp larvae.
Bason *et al.* (1976)	Chesapeake and Delaware Canal, DE	1975 (spring-summer)	201 (5-33)	TV -- Bay anchovy, juvenile Atlantic menhaden, juvenile weakfish, unidentified fish, *Menidia*, and juvenile bluefish.
Lynch *et al.* (1977)	Raritan River and Bay	1976-77 (Apr-Mar)	10 (3-22)	FO? -- Mummichog, bay anchovy, *Menidia*, *Crangon*, *Palaemonetes* sp., and fish.
			39 (39+)	FO? -- Atlantic menhaden, spot, bay anchovy, and *Crangon*.
Friedland *et al.* (1988)	Sandy Hook Bay, NJ	1981-84 (spring-summer)	1,079 (9-18)	TW -- Bay anchovy, *Crangon*, *Menidia*, *Neomysis*, striped killifish, and *Palaemonetes* sp. FO -- *Crangon, Neomysis*, bay anchovy, *Menidia*, *Palaemonetes* sp., and striped killifish.
Scarlett and Giust (1989)	Manasquan River, NJ	1984-86 (summer)	211 (9-29, mean =~15)	TV -- Bay anchovy, *Menidia*, *Crangon*, unidentified fish, *Gammarus* sp., and juvenile weakfish.
Juanes *et al.* (1993)	Hudson River, NY	1989 (Jul-Oct)	374 (YOY)	TW -- Atlantic tomcod, unidentified fish, juvenile striped bass, juvenile bluefish, and bay anchovy.
Juanes and Conover (1994)	Great South Bay, NY	1989 (Jun-Jul)	256 (YOY)	TW (Jun) -- *Menidia*, “shrimp,” other fish, and bay anchovy. TW (Jul) -- bay anchovy, crustaceans, other fish, and *Menidia*.
Hartman and Brandt (1995)	Chesapeake Bay	1990-92 (bimonthly)	100 (age 0)	TW -- Bay anchovy, juvenile Atlantic menhaden, *Menidia*.
			132 (age 1)	TW -- Spot, juvenile Atlantic menhaden, and other fish.

Table 28. Summary of Hudson-Raritan Estuary winter skate diet by sampling period during 1996-97, expressed as the percent frequency of occurrence of dominant prey or items (FO), and as the mean percent contribution of dominant prey or items to total stomach content volume (TV). (n = sample size; ES = percent of empty stomachs.)

	Sampling Period											
	Jul 96 (n = 0; ES = N/A)		Oct 96 (n = 5; ES = 20)		Jan 97 (n = 19; ES = 0)		Apr 97 (n = 24; ES = 0)		Aug 97 (n = 0; ES = N/A)		Nov 97 (n = 9; ES = 0)	
Prey	**FO**	**TV**	**FO**	**TV**	**FO**	**TV**	**FO**	**TV**	**FO**	**TV**	**FO**	**TV**
Crangon septemspinosa	-	-	40.0	14.9	100.0	44.8	95.8	42.7	-	-	77.8	28.2
Unidentified fish remains	-	-	20.0	9.0	15.8	5.6	4.2	1.2	-	-	22.2	9.8
Unidentified flounder	-	-	20.0	7.5	5.3	1.1	8.3	5.0	-	-	11.1	3.3
Atlantic rock crab	-	-	40.0	11.9	36.8	25.0	8.3	2.7	-	-	0.0	0.0
Blue mussel	-	-	20.0	4.5	0.0	0.0	4.1	1.3	-	-	11.1	3.6
Juvenile winter flounder	-	-	0.0	0.0	10.5	4.5	4.1	1.3	-	-	33.3	14.9
Ovalipes ocellatus	-	-	40.0	16.4	0.0	0.0	8.3	3.8	-	-	11.1	3.9
Sand lance	-	-	60.0	19.4	0.0	0.0	0.0	0.0	-	-	33.3	12.8

Table 29. Summary of other winter skate diet studies for the coastal Middle Atlantic Bight. (Major prey taxa ranked in relative order of importance by: mean percent contribution to total stomach content weight (TW), and an index of relative importance (IRI), as available from each source.)

Source	**Study Area**	**Year(s) (month(s), season(s), and/or frequency)**	**No. Examined (size [TL cm]) or age range, mean size)**	**Primary Prey in Order of Importance by FO, IRI, TDW, TN, TV, and/or TW**
Smith (1950)	Block Island Sound	1848-49 (seasonally)	Unknown (?)	TW -- "Nekton" (fish and squid), *Leptocheirus pinguis*, and *Nephtys incisa.*
Vinogradov (1984)	Southern New England	1968-74 (various)	52 (unknown)	TW -- Crustaceans, polychaetes, and fish.
McEachlan *et al.* (1976)	Middle Atlantic Bight shelf	1969-70 (seasonally)	441 (mode = ~60)	IRI -- Amphipods (*L. pinguis*), polychaetes (*N. incisa*, *Nereis* sp., *Pectinaria gouldii*, and maldanids), fish (sand lance), and decapod crustaceans (*Crangon*).

Table 30. Summary of Hudson-Raritan Estuary black sea bass diet by sampling period during 1996-97, expressed as the percent frequency of occurrence of dominant prey or items (FO), and as the mean percent contribution of dominant prey or items to total stomach content volume (TV). (n = sample size; ES = percent of empty stomachs.)

	Sampling Period											
	Jul 96 (n = 1; ES = 0)		Oct 96 (n = 3; ES = 0)		Jan 97 (n = 0; ES = N/A)		Apr 97 (n = 3; ES = 33)		Aug 97 (n = 46; ES = 11)		Nov 97 (n = 2; ES = 0)	
Prey	**FO**	**TV**	**FO**	**TV**	**FO**	**TV**	**FO**	**TV**	**FO**	**TV**	**FO**	**TV**
Crangon septemspinosa	100.0	100.0	66.7	50.0	-	-	0.0	0.0	43.5	24.0	0.0	0.0
Neomysis americana	0.0	0.0	0.0	0.0	-	-	33.3	50.0	26.1	13.9	50.0	12.5
Juvenile Atlantic rock crab	0.0	0.0	33.3	2.9	-	-	0.0	0.0	17.4	16.8	0.0	0.0
Unidentified crustaceans	0.0	0.0	0.0	0.0	-	-	33.3	50.0	4.3	3.2	0.0	0.0
Corophium sp.	0.0	0.0	33.3	47.1	-	-	0.0	0.0	2.2	0.1	50.0	12.5
Xanthid crabs	0.0	0.0	0.0	0.0	-	-	0.0	0.0	8.7	10.3	0.0	0.0
Ampelisca abdita	0.0	0.0	0.0	0.0	-	-	0.0	0.0	15.2	1.0	0.0	0.0
Juvenile Atlantic menhaden	0.0	0.0	0.0	0.0	-	-	0.0	0.0	0.0	0.0	50.0	75.0
Unidentified organic matter	0.0	0.0	0.0	0.0	-	-	0.0	0.0	21.7	3.5	0.0	0.0

Table 31. Summary of other juvenile black sea bass diet studies for the coastal Middle Atlantic Bight. (Major prey taxa ranked in relative order of importance by: mean percent frequency of occurrence (FO), and mean percent contribution to total stomach content volume (TV), as available from each source.) [Note: there are other studies of the diet of black sea bass, but they were not included in this table because they were concerned with larger fish (*e.g.*, Steimle and Figley 1996), or because the size or life stage discussed was ambiguous, or because only a small sample (*e.g.*, less than 10 fish) was examined (*e.g.*, Steimle and Ogren 1982).]

Source	Study Area	Year(s) (month(s), season(s), and/or frequency)	No. Examined (size [TL cm]) or age range, mean size)	Primary Prey in Order of Importance by FO, IRI, TDW, TN, TV, and/or TW
Peck (1896)	Woods Hole, MA	1893 (Jul-Aug)	40 (unknown)	FO -- *Carcinus maenas*, *Ovalipes ocellatus*, amphipods, small fish (mostly sculpins), gastropods, American lobster, and *Pagurus* sp.
Richards (1963)	Long Island Sound - sand station	1956-58 (Sep-Oct)	28 (2-4)	FO? -- Caprellid amphipods, other amphipods (*Stenothoe* sp., *Corophium* sp., and *Ericthonius* sp.), hydroids, copepods, mysids, and *Pagurus* sp.
Kimmel (1973)	Mouth of Chesapeake Bay	1971-72 (spring/ summer)	48 (3-15)	TV -- *Neomysis*, unidentified polychaetes, xanthid (mud) crabs, and amphipods.

Allen *et al.* (1978)	Hereford Inlet, NJ	1973-77 (biweekly/ monthly)	201 (4-20)	FO -- Mysids, *Crangon*, detritus, amphipods, crabs, polychaetes, and unidentified fish.
Chee (1977)	Coastal Virginia	1975-76 (monthly)	26 (<15)	TV -- *Pagurus* sp., *O. ocellatus*, and Atlantic rock crab.
Festa (1979)	Little Egg Harbor, NJ	1976 (summer)	17 (6-21)	TV -- Mud crabs (*Neopanope* sp.), *O. ocellatus*, blue crab, *Palaemonetes* sp., and *Crangon*. FO -- Mud crabs, *Crangon*, isopod (*Idotea* sp.), amphipods (*Elasmopus* sp. and *Ampelisca* sp.), *Palaemonetes* sp., blue crab, and *Neomysis*.
Steimle (unpubl. data)	Delaware Bay	1989-94 (May/Jun and Aug/Sep)	185 (11.0-39.0, mean =24.0)	TV -- *Dyspanopeus sayi*, Atlantic rock crab, *Neomysis*, blue mussel, *Pagurus* sp., *Crangon*, and *Ensis directus*. FO -- *Neomysis*, Atlantic rock crab, *Dyspanopeus sayi*, blue mussel, and *Pagurus* sp.

Table 32. Summary of Hudson-Raritan Estuary spot diet by sampling period during 1996-97, expressed as the percent frequency of occurrence of dominant prey or items (FO), and as the mean percent contribution of dominant prey or items to total stomach content volume (TV). (n = sample size; ES = percent of empty stomachs.)

	Sampling Period											
	Jul 96 (n = 0; ES = N/A)		Oct 96 (n = 40; ES = 43)		Jan 97 (n = 6; ES = 83)		Apr 97 (n = 0; ES = N/A)		Aug 97 (n = 1; ES = 0)		Nov 97 (n = 0; ES = N/A)	
Prey	**FO**	**TV**	**FO**	**TV**	**FO**	**TV**	**FO**	**TV**	**FO**	**TV**	**FO**	**TV**
Ampelisca abdita	-	-	30.0	24.2	0.0	0.0	-	-	100.0	50.0	-	-
Unidentified organic matter	-	-	32.5	8.2	0.0	0.0	-	-	0.0	0.0	-	-
Neomysis americana	-	-	17.5	11.5	16.7	100.0	-	-	0.0	0.0	-	-
Crangon septemspinosa	-	-	20.0	11.5	0.0	0.0	-	-	0.0	0.0	-	-
Unidentified copepods	-	-	0.0	0.0	0.0	0.0	-	-	100.0	50.0	-	-
Pseudodiaptomus sp.	-	-	12.5	18.6	0.0	0.0	-	-	0.0	0.0	-	-

Table 33. Summary of other spot diet studies for the coastal Middle Atlantic Bight. (Major prey taxa ranked in relative order of importance by: mean percent frequency of occurrence (FO), mean percent contribution to total stomach content volume (TV), and mean percent contribution to total stomach content weight (TW), as available from each source.)

Source	**Study Area**	**Year(s) (month(s), season(s), and/or frequency)**	**No. Examined (size [TL cm]) or age range, mean size)**	**Primary Prey in Order of Importance by FO, IRI, TDW, TN, TV, and/or TW**
Van Engle and Joseph (1968)	York River, VA	Unknown	162 (juveniles)	TV -- Polychaetes, amphipods, clam siphons, and cumaceans. FO -- Harpacticoid copepods, *Gammarus* sp., nematodes, cumaceans, polychaetes, and *Neomysis*.
Thomas (1971)	Delaware River	1970 (Oct)	17 (unknown)	FO -- Copepods, *Gammarus* sp., *Monoculodes* sp., ostracods, detritus, and *Neomysis*.
Kimmel (1973)	Mouth of Chesapeake Bay	1971-72 (spring/summer)	13 (YOY, <10) 35 (10-16)	TV -- Detritus and harpacticoid and calanoid copepods. TV -- Detritus, *Ampelisca macrocephalus*, harpacticoid copepods, and *Nereis*.
Festa (1978)	Little Egg Harbor, NJ	1972-77 (summer/fall)	48 (3-10) 44 (11-19)	TV -- Copepods and *Ampelisca* sp. FO -- Copepods and amphipods. TV -- Polychaetes, amphipods, copepods, and *Neomysis*. FO -- Copepods, detritus, polychaetes, and *Ampelisca* sp.

Chao and Musick (1977)	York River, VA	1973 (summer)	77 (7-20)	FO -- *Pectinaria gouldii*, *Glycinde solitaria*, nematodes, *Neomysis*, *Nereis succinea*, clams, detritus, copepods, and cumaceans.
Allen *et al.* (1978)	Hereford Inlet, NJ	1973-77 (biweekly/ monthly)	722 (2-17)	FO -- Copepods, polychaetes, amphipods, detritus, isopods, and mysids.
Homer and Boynton (1978)	Chesapeake Bay, MD	1977 (May-Dec)	1,400 (~2-15)	TW -- *N. succinea*, *Scolecolepides viridis*, *Paraprionospio pinnata*, *Eteone* sp., juvenile *Macoma* sp., and softshells.
Scarlett and Giust (1989)	Manasquan River, NJ	1984-85 (summer)	8 (17-18)	TV -- Detritus, *Crangon*, *Neomysis*, and *Ampelisca* sp.
Pihl *et al.* (1992)	York River, VA	1989 (Jun-Sep)	649 (5-20)	TW -- Polychaetes (esp. *P. pinnata*), amphipods, and mysids.
Timmons (1995)	Indian River, DE	1994 (July)	20 (mean = 9)	TV -- Detritus, polychaetes, and mysids.

Table 34. Summary of Hudson-Raritan Estuary American lobster diet by sampling period during 1996-97, expressed as the percent frequency of occurrence of dominant prey or items (FO), and as the mean percent contribution of dominant prey or items to total stomach content volume (TV). (n = sample size; ES = percent of empty stomachs.)

	Sampling Period											
	Jul 96 (n = 0; ES = N/A)		Oct 96 (n = 6; ES = 0)		Jan 97 (n = 6; ES = 0)		Apr 97 (n = 10; ES = 0)		Aug 97 (n = 13; ES = 0)		Nov 97 (n = 12; ES = 0)	
Prey	**FO**	**TV**	**FO**	**TV**	**FO**	**TV**	**FO**	**TV**	**FO**	**TV**	**FO**	**TV**
Atlantic rock crab	-	-	0.0	0.0	67.7	16.7	50.0	14.9	42.1	18.4	41.6	18.3
Nucula sp.	-	-	0.0	0.0	50.0	15.2	30.0	13.0	30.8	7.0	16.7	0.4
Pagurus sp.	-	-	16.7	4.7	16.7	8.7	10.0	1.3	38.5	13.2	33.3	3.3
Human artifacts	-	-	16.7	4.8	16.7	3.6	20.0	1.9	0.0	0.0	16.7	0.4
Shell hash	-	-	50.0	23.8	16.7	3.6	10.0	0.6	15.4	4.4	0.0	0.0
Ovalipes ocellatus	-	-	50.0	23.8	0.0	0.0	0.0	0.0	0.0	0.0	8.3	1.7
Crangon septemspinosa	-	-	0.0	0.0	33.3	10.1	20.0	12.3	38.5	15.5	8.3	0.3
Unidentified hydroids	-	-	16.7	4.8	33.3	9.4	10.0	1.3	7.7	0.3	8.3	5.7
Sand	-	-	16.7	4.8	0.0	0.0	0.0	0.0	38.5	7.9	83.3	15.6
Unidentified organic matter	-	-	16.7	4.8	66.7	15.9	40.0	11.7	15.4	6.4	0.0	0.0
Unidentified crab fragments	-	-	0.0	0.0	16.7	3.6	40.0	11.7	7.7	0.9	8.3	0.1
Unidentified fish remains	-	-	0.0	0.0	16.7	5.8	20.0	7.8	23.1	6.7	0.0	0.0
Blue mussel	-	-	0.0	0.0	0.0	0.0	10.0	3.9	7.7	3.5	16.7	6.4
Skate egg case fragments	-	-	0.0	0.0	0.0	0.0	20.0	9.7	0.0	0.0	8.3	4.7
Hair and fibers	-	-	0.0	0.0	16.7	1.4	0.0	0.0	46.2	5.0	0.0	0.0
Xanthid crabs	-	-	0.0	0.0	0.0	0.0	0.0	0.0	7.7	3.5	66.7	10.2

Table 35. Summary of other American lobster diet studies for the coastal Middle Atlantic Bight. (Major prey taxa ranked in relative order of importance by mean percent frequency of occurrence (FO). Size is carapace length (CL), based on eye socket.)

Source	Study Area	Year(s) (month(s), season(s), and/or frequency)	No. Examined (size [TL cm]) or age range, mean size)	Primary Prey in Order of Importance by FO, IRI, TDW, TN, TV, and/or TW
Weiss (1970)	Eastern Long Island Sound	1967-69 (monthly)	557 (1.7-9.7, mean = 6.3)	FO -- Atlantic rock crab, unidentified fish, *Lacuna vincta*, *Nereis* sp., blue mussel, *Astyris* (*Mitrella*) *lunata*, and *Zostera marina*.
Steimle and Terranova (1991)	New York Bight apex	1982-85 (seasonally)	33 (not noted)	FO -- Atlantic rock crab, *Nucula*, *Ovalipes ocelatus*, *Pherusa affinis*, juvenile American lobster, fish, squid, and unidentified polychaetes.
Steimle (1994)	New York Bight apex	1986-89 (bimonthly)	935 (5-13.5)	FO -- Unidentified fish, Atlantic rock crab, *P. affinis*, *N. proxima*, and *Asterias* sp.
Steimle and Figley (unpubl. data)	Central New Jersey coast artificial reef	1996-97 (Jul-Sep)	99 (6.3-15.0, mean = 8.9)	FO -- Crab fragments (mostly Atlantic rock crab), *Euspira* sp. operculums, shell hash, skate egg case fragments, *Pagurus* sp., unidentified organic matter, *Mytilus* fragments, hydroids, sand, artifacts (*e.g.*, tire rubber particles), and *Asterias* sp.

Table 36. Summary of Hudson-Raritan Estuary tautog diet by sampling period during 1996-97, expressed as the percent frequency of occurrence of dominant prey or items (FO), and as the mean percent contribution of dominant prey or items to total stomach content volume (TV). (n = sample size; ES = percent of empty stomachs.)

	Sampling Period											
	Jul 96 (n = 16; ES = 0)		Oct 96 (n = 4; ES = 50)		Jan 97 (n = 1; ES = 0)		Apr 97 (n = 11; ES = 0)		Aug 97 (n = 13; ES = 0)		Nov 97 (n = 6; ES = 67)	
Prey	**FO**	**TV**	**FO**	**TV**	**FO**	**TV**	**FO**	**TV**	**FO**	**TV**	**FO**	**TV**
Atlantic rock crab	8.3	8.9	25.0	40.0	100.0	100.0	45.5	29.4	46.2	31.3	16.7	93.9
Xanthid crabs	25.0	12.5	25.0	20.0	0.0	0.0	36.4	19.1	15.4	5.1	0.0	0.0
Blue mussel	33.3	6.6	0.0	0.0	0.0	0.0	27.3	13.0	23.1	17.9	0.0	0.0
Pagurus sp.	0.0	0.0	25.0	40.0	0.0	0.0	0.0	0.0	7.7	2.8	0.0	0.0
Ensis directus	35.0	27.1	0.0	0.0	0.0	0.0	0.0	0.0	7.7	2.3	0.0	0.0
Ovalipes ocellatus	16.7	8.8	0.0	0.0	0.0	0.0	9.1	4.4	0.0	0.0	0.0	0.0
Crangon septemspinosa	8.3	8.9	0.0	0.0	0.0	0.0	9.1	2.2	0.0	0.0	0.0	0.0
Unidentified organic matter	0.0	0.0	0.0	0.0	0.0	0.0	9.1	<0.1	30.8	10.9	0.0	0.0
Juvenile blue crab	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	15.4	11.5	0.0	0.0

Table 37. Summary of other tautog diet studies for the coastal Middle Atlantic Bight. (Major prey taxa ranked in relative order of importance by: mean percent frequency of occurrence (FO), mean percent contribution to total stomach content volume (TV),mean percent contribution to total stomach content dry weight (TDW), and mean percent contribution to total number of individual items in the stomach (TN), as available from each source.)

Source	Study Area	Year(s) (month(s), season(s), and/or frequency)	No. Examined (size [TL cm]) or age range, mean size)	Primary Prey in Order of Importance by FO, IRI, TDW, TN, TV, and/or TW
Steimle and Ogren (1982)	New York Bight	1966-67 (Jul-Aug)	57 (23-29)	TV -- Atlantic rock crab, sand dollar (*Echinarachnius parma*), blue mussel, and hydroids.
Olla *et al.* (1974)	Great South Bay, NY	1971-72 (unreported)	25 (20-46, mean = 33)	TV -- “Mussels” and crustaceans (decapods and cirripeds).
Festa (1979)	Little Egg Harbor, NJ	1972-77 (summer/fall)	18 (6-16)	TV -- Isopods (*Idotea* sp.) and mud (xanthid) crabs. FO -- Amphipods, isopods, and nematodes.
			7 (20-32)	TV -- Mud crabs and *Ovalipes ocellatus*. FO -- Mud crabs.
Allen *et al.* (1978)	Hereford Inlet, NJ	1973-77 (biweekly/ monthly)	28 (4-44)	FO -- bivalve mollusks, amphipods, detritus, and polychaetes.

Grover (1982)	New York - southern Long Island	1978 (Aug-Nov)	36 (3-7)	TN -- Copepods and amphipods.
Sogard (1992)	Great Egg Harbor, NJ	1988-89 (summer)	63 (3-8)	FO -- Copepods, amphipods, other crustaceans, and ostracods.
Dorf (1994)	Narragansett Bay, RI	1990-92 (various)	82 (2.5-7)	TDW -- Amphipods, copepods, and shrimp *(Crangon* and *Palaemonetes* sp.). FO -- Copepods, amphipods, and flatworm.
			(7-10)	TDW -- Shrimp and crabs. FO -- Shrimp, flatworms, crabs, and detritus.
Lankford *et al.* (1995)	Delaware Bay	Unknown	Unknown (age 2+)	FO -- blue mussel.
Steimle *et al.* (in review)	Delaware Bay	1989-94 (May/Jun and Aug/Sep)	371 (11.0-58.0, mean = 32.0)	TV -- blue mussel, unidentified mollusks, *Metridium senile*, Atlantic rock crab, *Ensis directus*, *Pagurus* sp. FO -- blue mussel, unidentified crustaceans, unidentified mollusks, and *M. senile*.
Steimle and Figley (unpubl. data)	Central New Jersey artificial reef	1997 (May-Aug)	68 (30.6-68.0; mean = 37.9)	FO -- Hydroids, blue mussel spat, Atlantic rock crab, crab remains, caprellid amphipods, *P. longicarpus*, *Euspira* sp., *P. pollicaris*, and gammarid amphipods.

Table 38. Summary of Hudson-Raritan Estuary smooth dogfish diet by sampling period during 1996-97, expressed as the percent frequency of occurrence of dominant prey or items (FO), and as the mean percent contribution of dominant prey or items to total stomach content volume (TV). (n = sample size; ES = percent of empty stomachs.)

	Sampling Period											
	Jul 96 (n = 16; ES = 0)		Oct 96 (n = 9; ES = 0)		Jan 97 (n = 0; ES = N/A)		Apr 97 (n = 0; ES = N/A)		Aug 97 (n = 17; ES = 0)		Nov 97 (n = 0; ES = N/A)	
Prey	**FO**	**TV**	**FO**	**TV**	**FO**	**TV**	**FO**	**TV**	**FO**	**TV**	**FO**	**TV**
Atlantic rock crab	81.3	33.2	44.4	16.6	-	-	-	-	5.9	1.5	-	-
Ovalipes ocellatus	81.3	40.2	66.6	29.1	-	-	-	-	0.0	0.0	-	-
Crangon septemspinosa	18.8	4.5	11.1	3.8	-	-	-	-	47.1	13.6	-	-
Ensis directus	25.0	8.8	11.1	0.9	-	-	-	-	23.5	6.5	-	-
Unidentified clam fragments	6.2	8.8	44.4	13.3	-	-	-	-	41.2	14.5	-	-
Xanthid crabs	31.2	11.7	0.0	0.0	-	-	-	-	17.6	6.2	-	-
Unidentified organic matter	0.0	0.0	55.6	25.5	-	-	-	-	0.0	0.0	-	-
Unidentified fish remains	0.0	0.0	11.1	3.8	-	-	-	-	5.9	1.9	-	-
Unidentified crab remains	0.0	0.0	11.1	3.3	-	-	-	-	5.9	1.5	-	-

Table 39. Summary of other smooth dogfish diet studies for the coastal Middle Atlantic Bight. (Major prey taxa ranked in relative order of importance by: mean percent frequency of occurrence (FO), mean percent contribution to total stomach content volume (TV), and mean percent contribution to total stomach content weight (TW), as available from each source.)

Source	Study Area	Year(s) (month(s), season(s), and/or frequency)	No. Examined (size [TL cm]) or age range, mean size)	Primary Prey in Order of Importance by FO, IRI, TDW, TN, TV, and/or TW
Linton (1901)	Woods Hole, MA	~1895	16 (unknown)	FO -- Crabs (mud, Atlantic rock, and *Libinia* sp.), fish, squid, and polychaetes.
Field (1907)	Woods Hole, MA	1902-04 (summer)	388 (mean = ~100)	FO -- Atlantic rock crab, *Libinia* sp., American lobster, Atlantic menhaden, *Ovalipes ocellatus*, squid, *Nereis* sp., *Zostera marina*, and *Pagurus* sp.
Breder (1921)	Atlantic City, NJ	1920 (Aug)	102 (30-64)	FO -- Crabs, detritus, *Z. marina*, and fish.
Kimmel (1973)	Mouth of Chesapeake Bay	1971-72 (Dec-Sep)	6 (26-53)	TV -- *Upogebia* sp., *Ensis directus*, and *O. ocellatus*.

Festa (1979)	Little Egg Harbor, NJ	1972-77 (summer)	12 (39-56)	TV -- blue crab and juvenile weakfish. FO -- blue crab, *Palaemonetes* sp., and *Crangon.*
Rountree and Able (1996)	Little Egg Harbor, NJ	1988-90 (Apr-Nov)	85 (32-59)	TW -- blue crab, unidentified crabs, *Palaemonetes* sp., *Libinia* sp., *Crangon*, *O. ocellatus*, and polychaetes.
Steimle (unpubl. data)	Delaware Bay	1989-94 (May/Jun and Aug/Sep)	110 (39-115, mean = 71)	TV -- Atlantic rock crab, *Pagurus* sp., *E. directus*, and unidentified decapods. FO -- Atlantic rock crab, *Pagurus* sp., *E. directus*, and unidentified decapods.
Gelsleichter *et al.* (1999)	Mouth of Chesapeake Bay	1980-92	64 (46-126+, mode ~ 106-115)	TW -- Atlantic rock crab, blue crab, *O. ocellatus*, *E. directus*, and various fish. FO -- Atlantic rock crab, blue crab, *O. ocellatus*, *E. directus*, and various fish.

Table 40. Summary of Hudson-Raritan Estuary silver hake diet by sampling period during 1996-97, expressed as the percent frequency of occurrence of dominant prey or items (FO), and as the mean percent contribution of dominant prey or items to total stomach content volume (TV). (n = sample size; ES = percent of empty stomachs.)

Prey	Sampling Period: Jul 96 (n = 0; ES = N/A)		Oct 96 (n = 1; ES = 0)		Jan 97 (n = 6; ES = 0)		Apr 97 (n = 6; ES = 0)		Aug 97 (n = 0; ES = N/A)		Nov 97 (n = 29; ES = 7)	
	FO	TV	FO	TV	FO	TV	FO	TV	FO	TV	FO	TV
Crangon septemspinosa	-	-	100.0	100.0	100.0	94.9	66.7	32.6	-	-	24.1	11.8
Neomysis americana	-	-	0.0	0.0	16.7	5.1	50.0	15.2	-	-	37.9	16.1
Unidentified juvenile fish	-	-	0.0	0.0	0.0	0.0	50.0	28.3	-	-	31.0	14.9
Ampelisca abdita	-	-	0.0	0.0	0.0	0.0	16.7	10.9	-	-	31.0	11.2
Gammarus lawrencianus	-	-	0.0	0.0	0.0	0.0	16.7	10.9	-	-	31.0	12.4
Juvenile silver hake	-	-	0.0	0.0	0.0	0.0	0.0	0.0	-	-	3.4	5.6
Calanoid copepods	-	-	0.0	0.0	0.0	0.0	0.0	0.0	-	-	13.7	4.3
Unidentified organic matter	-	-	0.0	0.0	0.0	0.0	16.7	2.2	-	-	6.9	1.2

Table 41. Summary of other juvenile-or-older silver hake diet studies for the coastal Middle Atlantic Bight. (Major prey taxa ranked in relative order of importance by: mean percent frequency of occurrence (FO), mean percent contribution to total stomach content weight (TW), mean percent contribution to total stomach content dry weight (TDW), and an index of relative importance (IRI), as available from each source.)

Source	Study Area	Year(s) (month(s), season(s), and/or frequency)	No. Examined (size [TL cm]) or age range, mean size)	Primary Prey in Order of Importance by FO, IRI, TDW, TN, TV, and/or TW
Smith (1950)	Block Island Sound	1948-49 (seasonally)	Unknown	TW -- Nekton (fish and squid), *Crangon*, and *Leptocheirus pinguis*.
Richards (1963)	Long Island Sound	1956-57 (seasonally)	Sand station - 111 (7-21) Mud station - 165 (6-22)	FO -- *Neomysis*, *Crangon*, *L. pinguis*, and fish (bay anchovy, sand lance, and juvenile silver hake). FO -- Copepods, *Neomysis*, *L. pinguis*, *Crangon*, squid, and bay anchovy.
Schaefer (1960)	Long Branch, NJ, pier	1957-58 (Dec-Jan)	137 (~23-43)	FO -- Amphipods, fish, *Crangon*, blueback herring, *Menidia*, and mysids. TV -- Blueback herring, *Menidia*, juvenile silver hake, fish, and *Crangon*.

Schaefer (1960)	New York Bight apex	1958 (Feb-May)	201 (~23-43)	FO -- *Crangon*, juvenile silver hake, fish, and mysids. TV -- Juvenile silver hake, *Crangon*, *Loligo*, juvenile red hake, blueback herring, and fish.
Steimle (1985)	New York Bight apex	1968-70 (summer)	235 (7-40, mean = 27)	FO -- *Neomysis*, *Crangon*, and various fish.
Vinogradov (1984)	Southern New England	1968-74 (unreported)	3,233 (unreported)	TW -- Juvenile silver hake, Atlantic mackerel, red hake, and squid.
Bowman *et al.* (1987)	Southern New England	1973-76 (spring/fall)	580 (<10)	TW -- Crustaceans (*Crangon*, *Dichelopandalus leptocerus*, *Neomysis*, and amphipods) and fish (sand lance and juvenile silver hake).
			(11-20)	TW -- *Crangon*, *D. leptocerus*, euphausids, *Neomysis*, juvenile silver hake, and sand lance.
Sedberry (1983)	New York Bight shelf	1976-77 (seasonally)	334 (1-15)	IRI -- *Parathemisto gaudichaudi*, decapod crustaceans, and fish (juvenile red hake and sand lance).
			210 (15-25)	IRI -- Decapod crustaceans, fish, and *P. gaudichaudi*.
Steimle and Terranova (1991)	New York Bight apex	1982-85 (seasonally)	215 (not noted)	FO -- *Crangon*, mysids, fish, *D. leptocerus*, juvenile silver hake, and sand lance.
Steimle (unpubl. data)	New York Bight apex	1986-87 (monthly)	766 (9.0-26.2)	FO -- *Crangon*, *D. leptocerus*, mysids, fish, juvenile silver hake, and sand lance. TV -- *Crangon*, fish, *D. leptocerus*, decapod crustaceans, juvenile silver hake, and sand lance.

Table 42. Most commonly eaten invertebrate prey in the Hudson-Raritan Estuary by the 20 most common predators examined in this survey, in approximate order of their overall frequency of occurrence in the diets

Prey (common name)	**Primary Predators (also eaten by other predators)**
Crangon septemspinosa (sevenspine bay shrimp or sand shrimp)	Commonly eaten by all but winter flounder and tautog for which they are minor prey.
Neomysis americana (opossum shrimp)	Eaten by all but clearnose & winter skates, tautog, smooth dogfish, and American lobster.
Gammarus lawrencianus (scud amphipod)	Eaten by windowpane, scup, red, spotted & silver hakes, weakfish, northern searobin, and northern kingfish.
Cancer irroratus (Atlantic rock crab)	Mostly juveniles eaten by little, clearnose & winter skates, striped & northern searobin, black sea bass, tautog, smooth dogfish, grubby, American lobster, summer flounder, and red hake.
Ovalipes ocellatus (lady crab or calico crab)	Juveniles mostly eaten by little, winter & clearnose skates, summer flounder, smooth dogfish, spotted hake, striped searobin, and striped bass.
Pagurus spp**.**, *P. longicarpus* (right-handed hermit crabs, longwrist hermit)	Commonly eaten by little skate, American lobster, tautog, smooth dogfish, and smallmouth flounder.
Ampelisca abdita (four-eye amphipod)	Winter flounder, windowpane, scup, weakfish, striped searobin, black sea bass, spot, and silver hake commonly eat these.
Pseudodiaptomus coronatus (red copepod)	Commonly eaten by windowpane, spotted hake, and spot.
Mytilus edulis (blue mussel)	Adults eaten by winter skate and tautog; spat eaten by other predators.
Corophium tuberculatum (tube amphipod)	Weakfish and grubby eat them.
Unciola sp. (tube amphipod)	Eaten by winter flounder and northern searobin.
Dyspanopeus sayi (Say mud crab or xanthid crab)	Eaten mostly by tautog, black sea bass, and smooth dogfish.
Ensis directus (Atlantic jacknife or razor clam)	Siphons and whole clams eaten by little & clearnose skate, smooth dogfish, and tautog.

Callinectes sapidus (blue crab)	Minor use of juveniles by several predators.
Palaemonetes sp., mostly *P. vulgaris* (grass shrimps, marsh grass shrimp)	Found in striped bass and American lobster stomachs.
Dichelopandalus leptocerus (bristled longbeak shrimp or red-beaked shrimp)	Eaten by red hake, with minor use by several other predators.
Asabellides oculata (spaghetti worm)	Minor use only by several predators.
Pherusa affinis (green bristlehead tube worm)	Minor use only by several predators.
Mercenaria mercenaria (northern quahog or hard clam)	Only siphons eaten by winter flounder, and minor use by scup and little skate.
Spisula solidissima (Atlantic surfclam)	Only siphons eaten by winter flounder, and meats by smooth dogfish.
Glycera sp. (blood worm)	Minor use by winter flounder and smooth dogfish.

Table 43. Habitat associations of other, less commonly eaten invertebrate prey in the Hudson-Raritan Estuary, based primarily on Caracciolo and Steimle (1983). (Scientific and common names follow Turgeon *et al.* (1998) and Williams *et al.* (1989).)

Taxa (scientific name)	Habitat	Common Name and Comments
Algae (green, red, brown)	Attached and loose	*Ulva*-type fragments, branches usually found
Hydrozoans (unidentified spp.)	Hard surfaces	"Sea hair," incidentally eaten
Nemerteans (unidentified sp.)	Soft sediments, among mussels	Ribbon or "tapeworm"
Mollusca		
Gastropoda		
Crepidula fornicata	Hard surfaces, marine	Common Atlantic slippersnail, only juveniles usually eaten
Bivalvia		
Nucula sp.	Silty sediments	Nut clam, tiny
Mytilus edulis	Hard surfaces and open bottom	Blue mussel, spat often within hydroids
Mulinia lateralis	Fine-medium estuarine sands	Dwarf surfclam
Tellina agilis	Silty to medium marine sands	Northern dwarf-tellin
Ensis directus	Fine-coarse sands	Atlantic jacknife or razor clam, siphons or eaten whole
Mya arenaria	Soft mud-fine sands	Softshell, usually only siphons nipped
Cephalopoda		
Unidentified squid (*Loligo*?)	Nektonic	Fragments only found
Annelida		
Polychaeta		
Glycera sp.	Soft to medium sands	"Blood worms"
Nephtys sp.	Silty to fine sands	"Painted worms"
Nereis sp.	Silty to medium sands	"Clam worms," swarms to surface at times
Asabellides oculata	Silty sands	Rapid colonizer, "spaghetti worm"
Pherusa affinis	Marine silty sands to mud	Tube dweller
Arthropoda		
Crustacea		
Copepoda		
Pseudodiaptomus coronatus	Near bottom	Bright orange color
Isopoda		
Cyathura sp.	Less saline, silty areas	Tube dweller
Edotea sp.	Silty sediments	Common in detritus
Amphipoda		
Corophium tuberculatum	Silty sands	Tube dweller

Ericthonius sp.	Silty sands	Tube dweller
Unciola sp.	Various sands	Tube dweller
Decapoda		
Dichelopandalus leptocerus	Nektonic	Bristled longbeak or bristlebeak shrimp
Palaemonetes sp.	In and near salt marshes	Grass shrimp (mostly *P. vulgaris*, the marsh grass shrimp)
Callinectes sapidus	Estuarine, mud to sand, vegetation	Blue crab, eaten at smaller sizes
Xanthid crabs	Mud and shellfish beds	Mud crabs (mostly *Dyspanopeus sayi*, the Say mud crab)
Stomatopoda		
Squilla empusa	Burrows in sediments	Mantis shrimp

Table 44. Most commonly eaten fish prey in the Hudson-Raritan Estuary, in approximate order of their overall frequency of occurrence in diets

Prey	Prey Habitat (if definable)	Primary Predators (minor predation by others possible)
Unidentified fish (including scales, bones and otoliths)	Not definable	Windowpane, summer flounder, red, spotted & silver hakes, weakfish, northern searobin, striped bass, clearnose & winter skates, and smooth dogfish
Unidentified juvenile or small flounder	Not definable	Little & winter skates, summer flounder, red & spotted hakes
Unidentified juvenile searobins (*Prionotus* sp.)	Benthic genus, common in warmer months	Minor use of juveniles by little & clearnose skates, summer flounder, red & spotted hakes, striped searobin, and bluefish
Anchovy, *Anchoa* sp. (mostly bay anchovy)	Small, pelagic, schooling species, most common in warmer months	Windowpane, weakfish, northern kingfish; minor use by others
Smallmouth flounder	Small benthic species	Striped bass; minor use by others
Red hake	Benthic species, mostly found in the cooler months	Minor use of juveniles by several species
Goby (naked?), *Gobiosoma* sp.	Minute benthic species, usually associated with shelter, *e.g.*, sponges	Striped bass; minor use by skates
Juvenile silver hake	Semipelagic species, commonly found in cooler months	Weakfish, striped bass, larger silver hake; minor use by others
Juvenile black sea bass	Structure-oriented species, often collected in redbeard sponge patches, probably also found within rocky rip-rap	Minor use by several species
Juvenile Atlantic menhaden	Pelagic, schooling species, summer visitor	Minor use by several species
Juvenile windowpane	Resident species, found widespread throughout the Estuary	Adult red hake; minor use by other species
Juvenile cunner	Resident species usually found near structure	Summer flounder; minor use by skates and red hake
Silversides, *Menidia* sp.	Common, schooling species in shallow water during warmer months	Juvenile bluefish; minor use by others
Rock gunnel	Small, resident species, associated with structure	Minor use by little & clearnose skates, summer flounder, and striped bass
Northern pipefish	Small, semiresident species, often found in algal patches	Minor use by several species

Juvenile winter flounder	Resident species, most common in deeper, silty areas	Clearnose & winter skates; minor use by little skate
Juvenile striped searobin	Benthic, warm season visitor, usually trawled in deeper areas	Adult striped searobin; minor use by a few other species
Juvenile grubby	Small resident species	Minor use by several species
Sand lance, *Ammodytes* sp.	Sand-dwelling species, found in marine areas	Winter skate; minor use by windowpane and little skate
Juvenile weakfish	Semipelagic, summer resident	Minor use by summer flounder, red hake, and adult weakfish
Juvenile river herring, *Alosa* sp.	Schooling species, usually collected in cooler months	Minor use by windowpane and summer flounder
Northern searobin bass	Small, summer resident	Minor use of adults and juveniles by little skate and striped
Butterfish	Small, semipelagic schooling species common in warmer months	Weakfish and bluefish, only
Juvenile American eel	Prefers silty sediments	Clearnose skate and spotted hake
Unidentified juvenile hake, *Urophycis* sp.	Not definable	Striped bass; minor use by clearnose skate
Other juvenile or small fish infrequently preyed upon: Atlantic herring, Atlantic croaker, lined seahorse, scup, conger eel, and northern stargazer (*Astroscopus guttatus*)	Various	Winter skate, windowpane, smooth dogfish, summer flounder, striped bass, and striped searobin

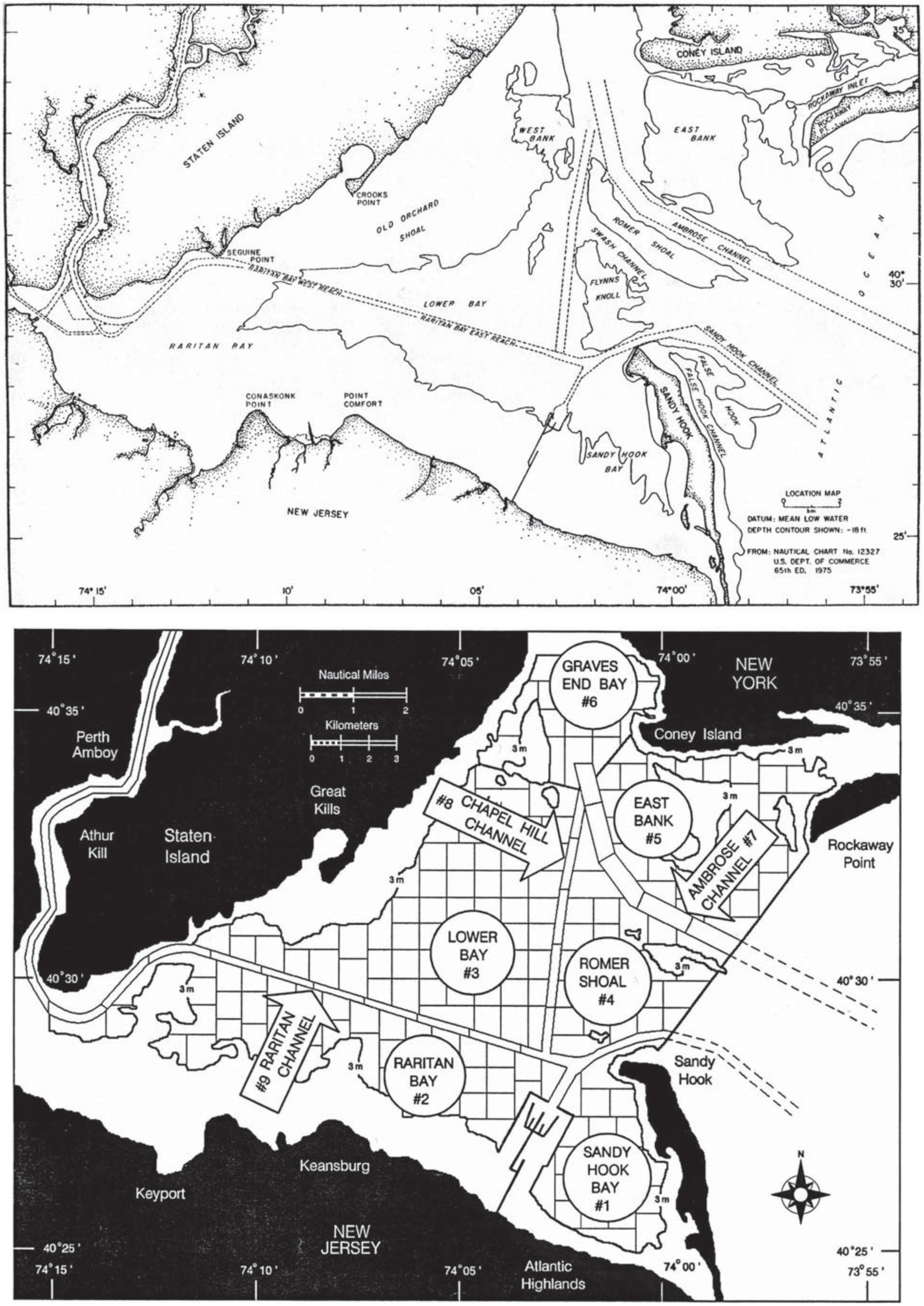

Figure 1. Upper Panel: Habitat features of the Hudson-Raritan Estuary. Lower Panel: Locations of sampling strata (#s 1-9) and blocks in the Hudson-Raritan Estuary.

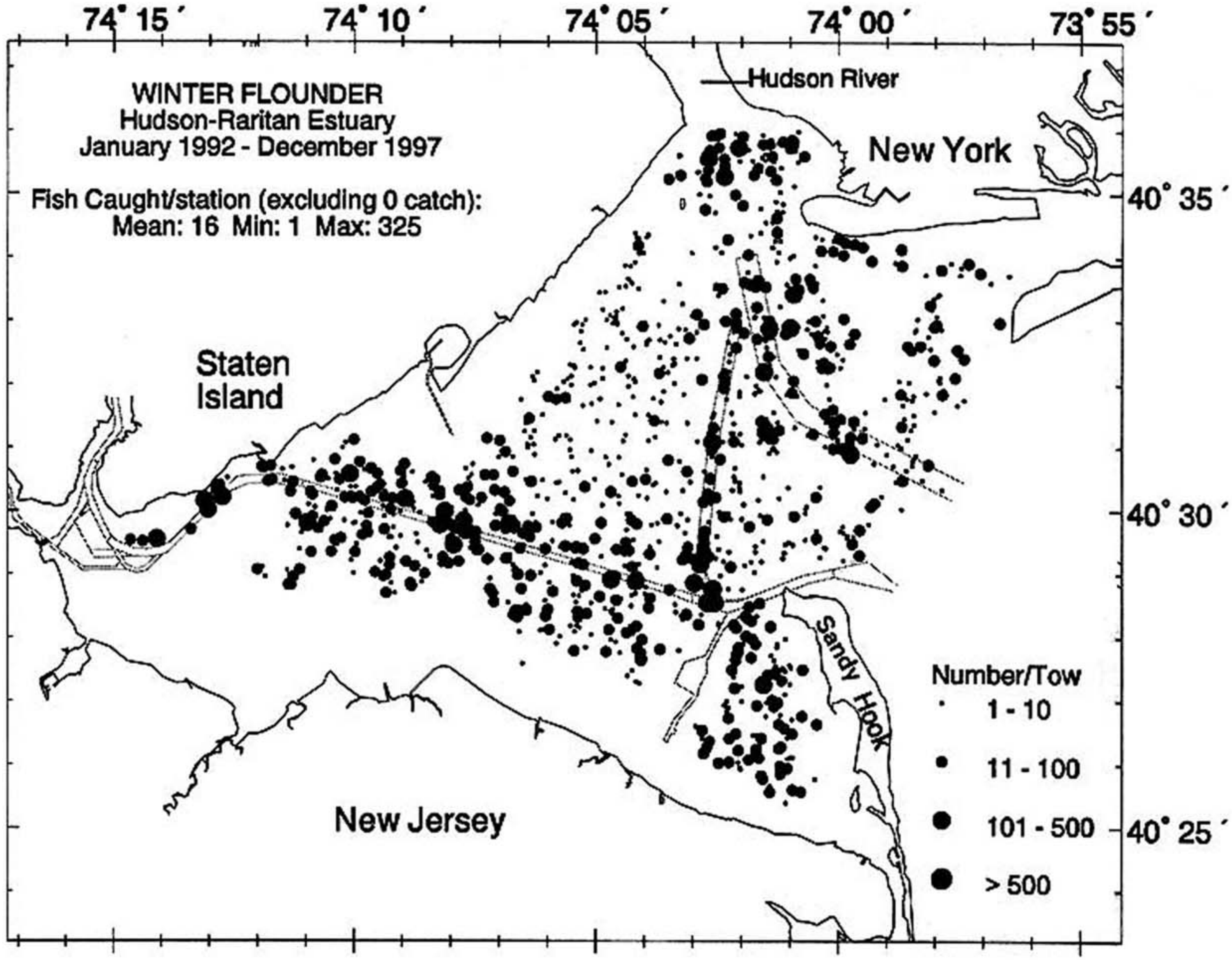

Figure 2. Winter flounder distribution and relative abundance in Hudson-Raritan Estuary, 1992-97 (Wilk et al. 1998).

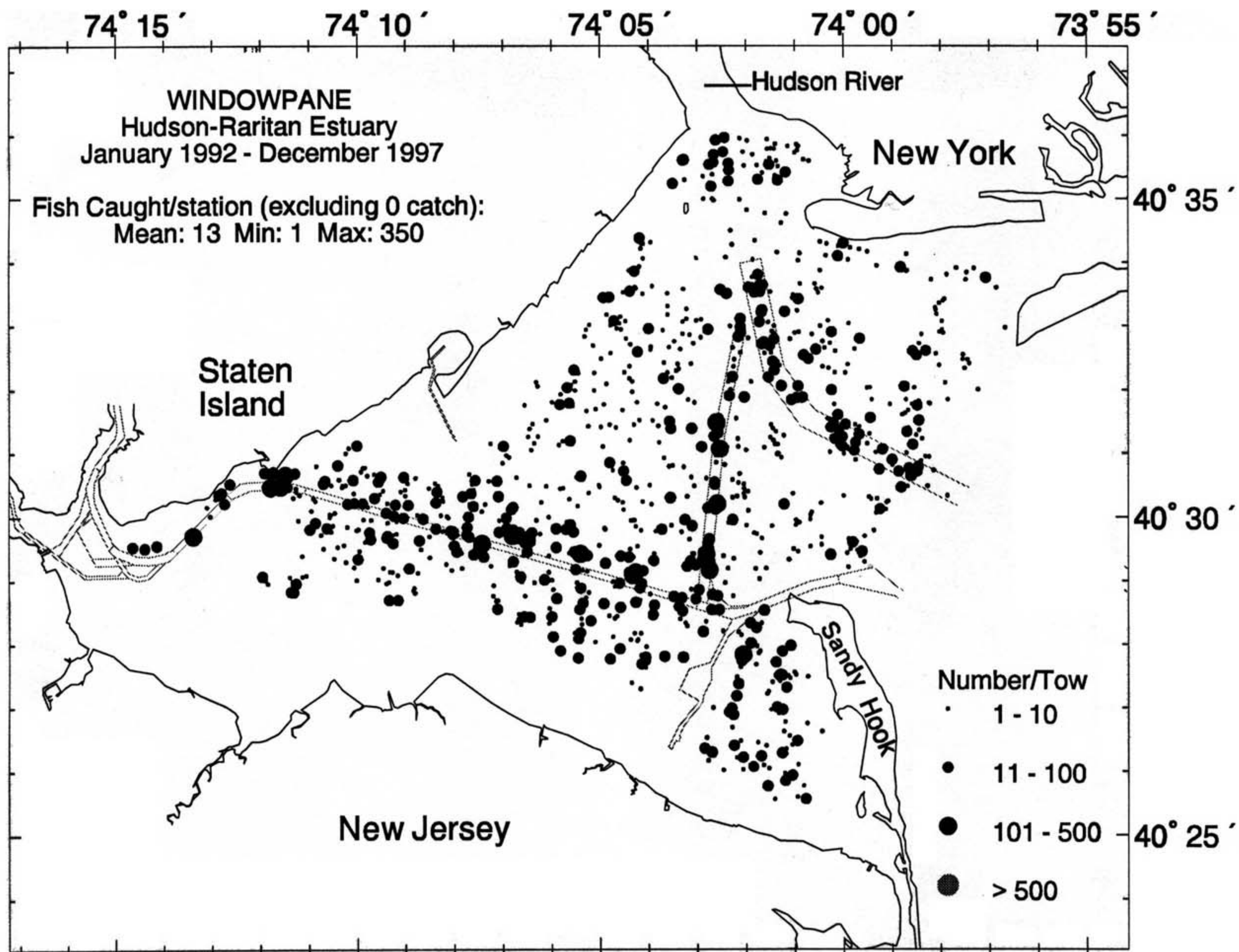

Figure 3. Windowpane distribution and relative abundance in Hudson-Raritan Estuary, 1992-97 (Wilk et al. 1998).

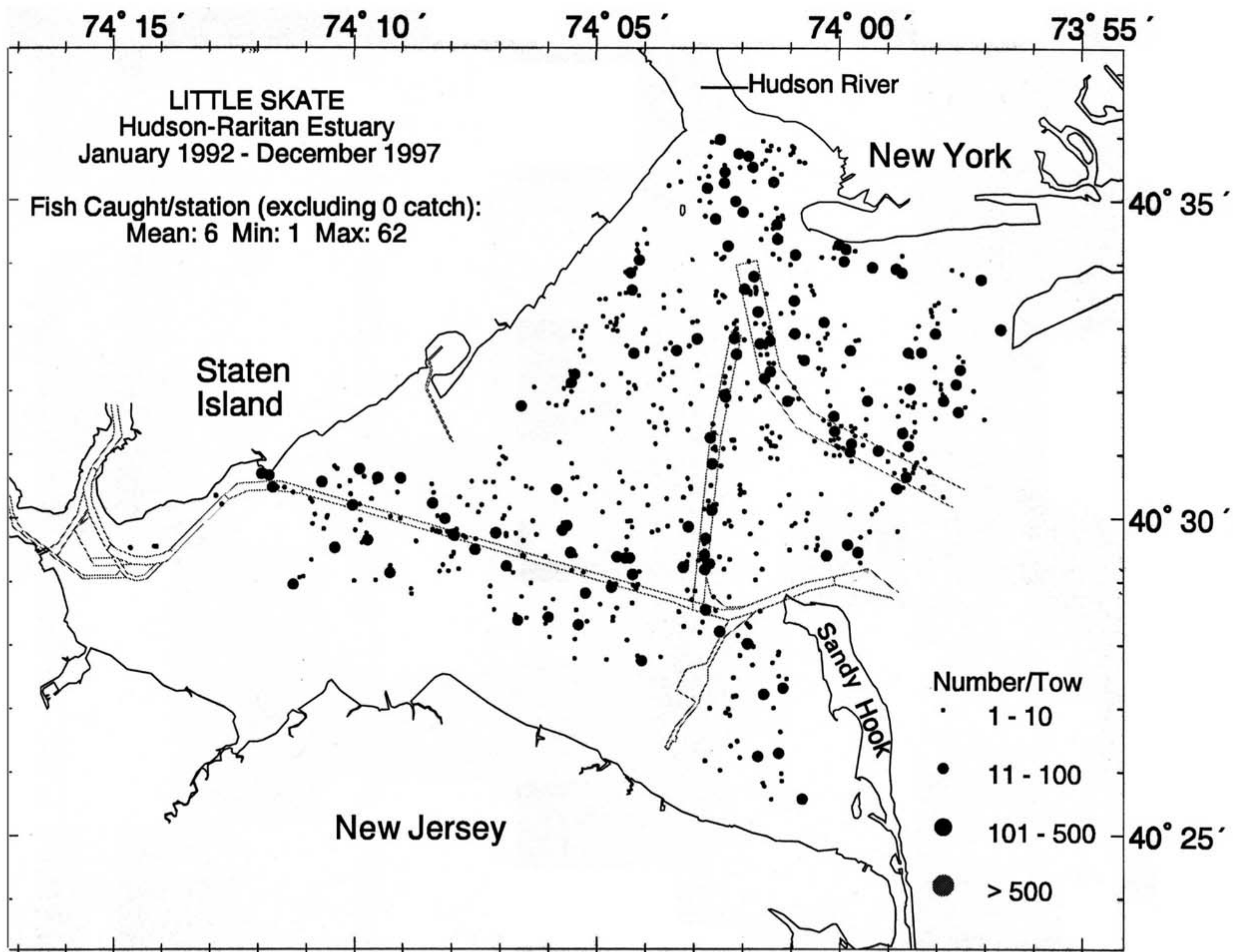

Figure 4. Little skate distribution and relative abundance in Hudson-Raritan Estuary, 1992-97 (Wilk et al. 1998).

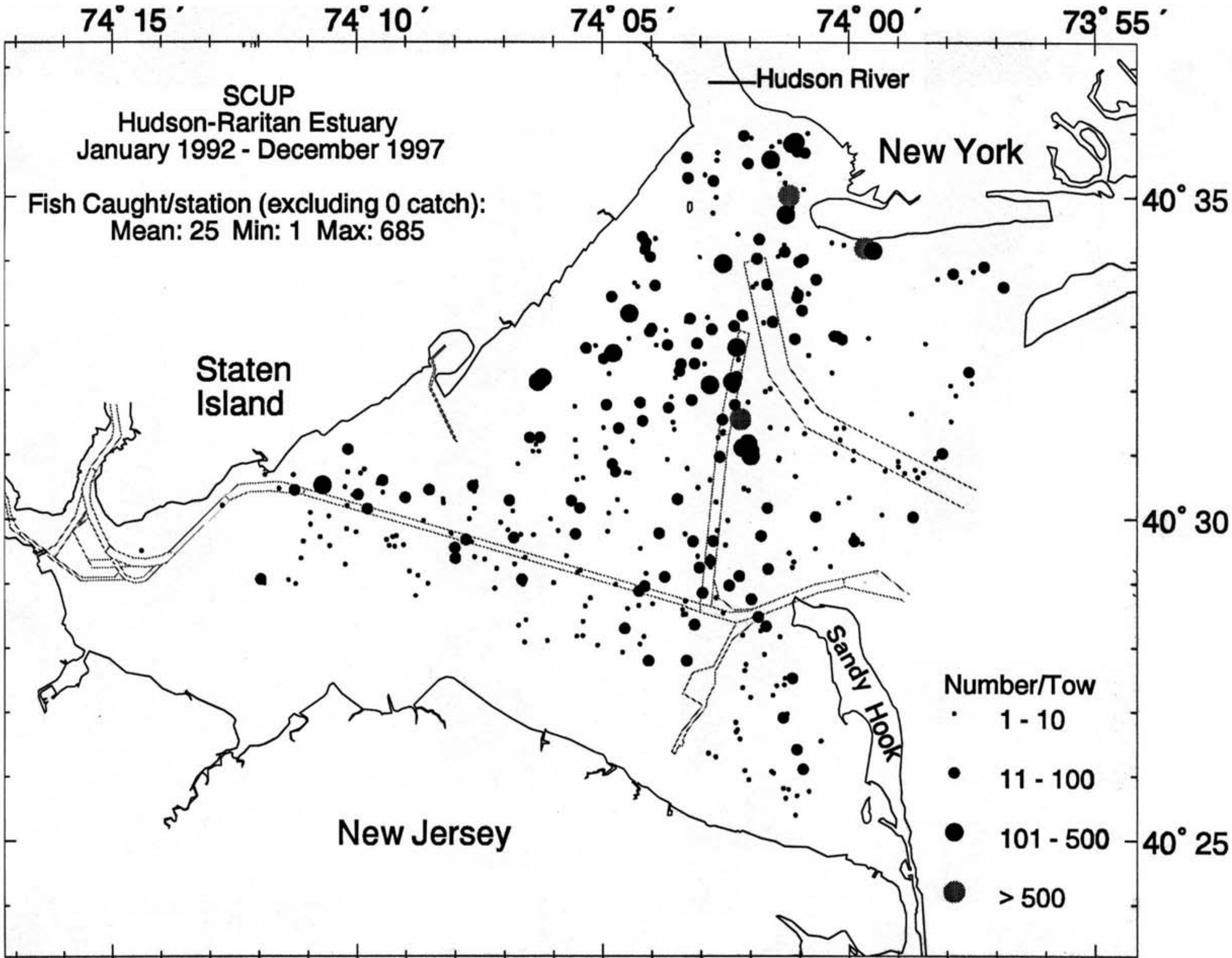

Figure 5. Scup distribution and relative abundance in Hudson-Raritan Estuary, 1992-97 (Wilk et al. 1998).

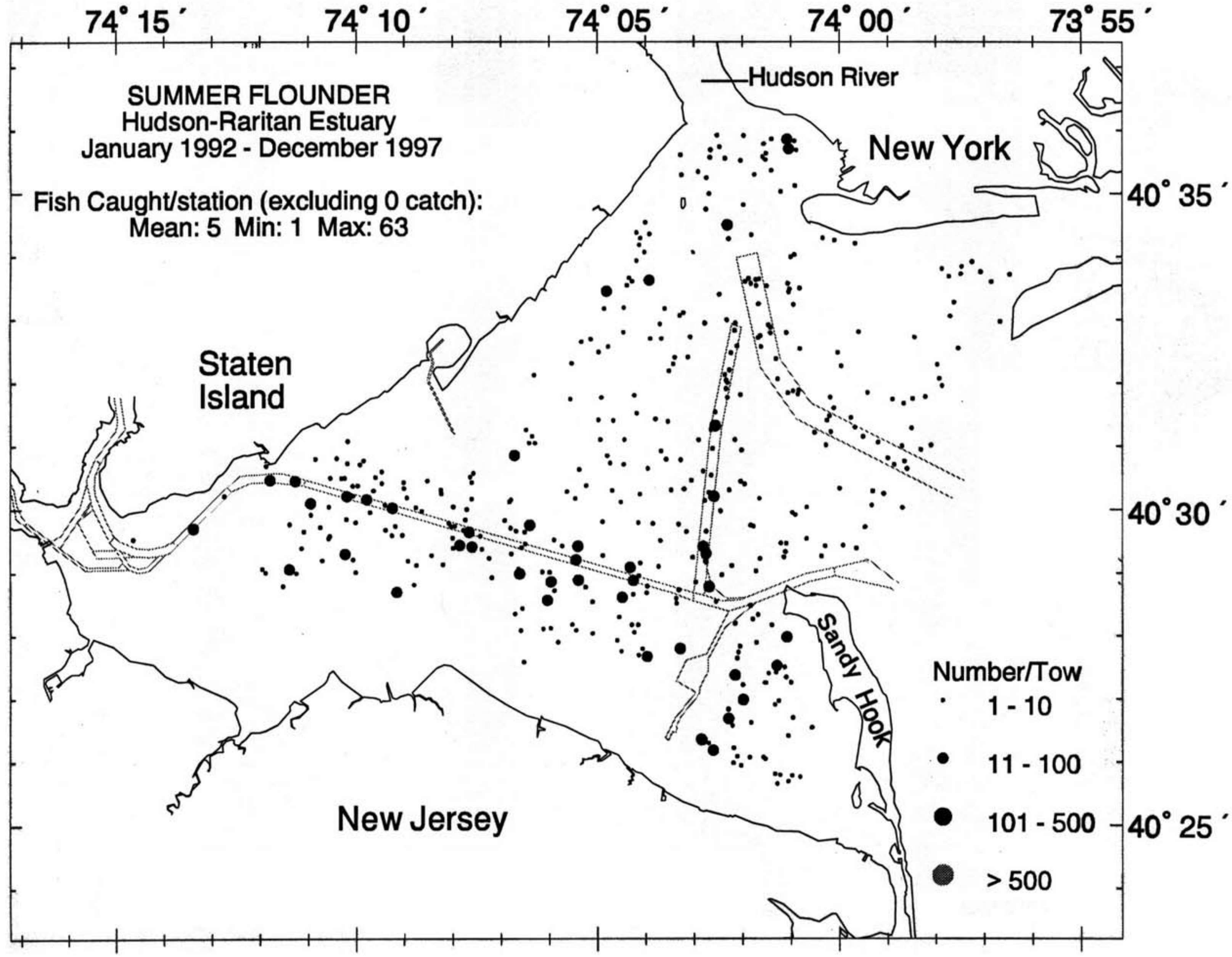

Figure 6. Summer flounder distribution and relative abundance in Hudson-Raritan Estuary, 1992-97 (Wilk et al. 1998).

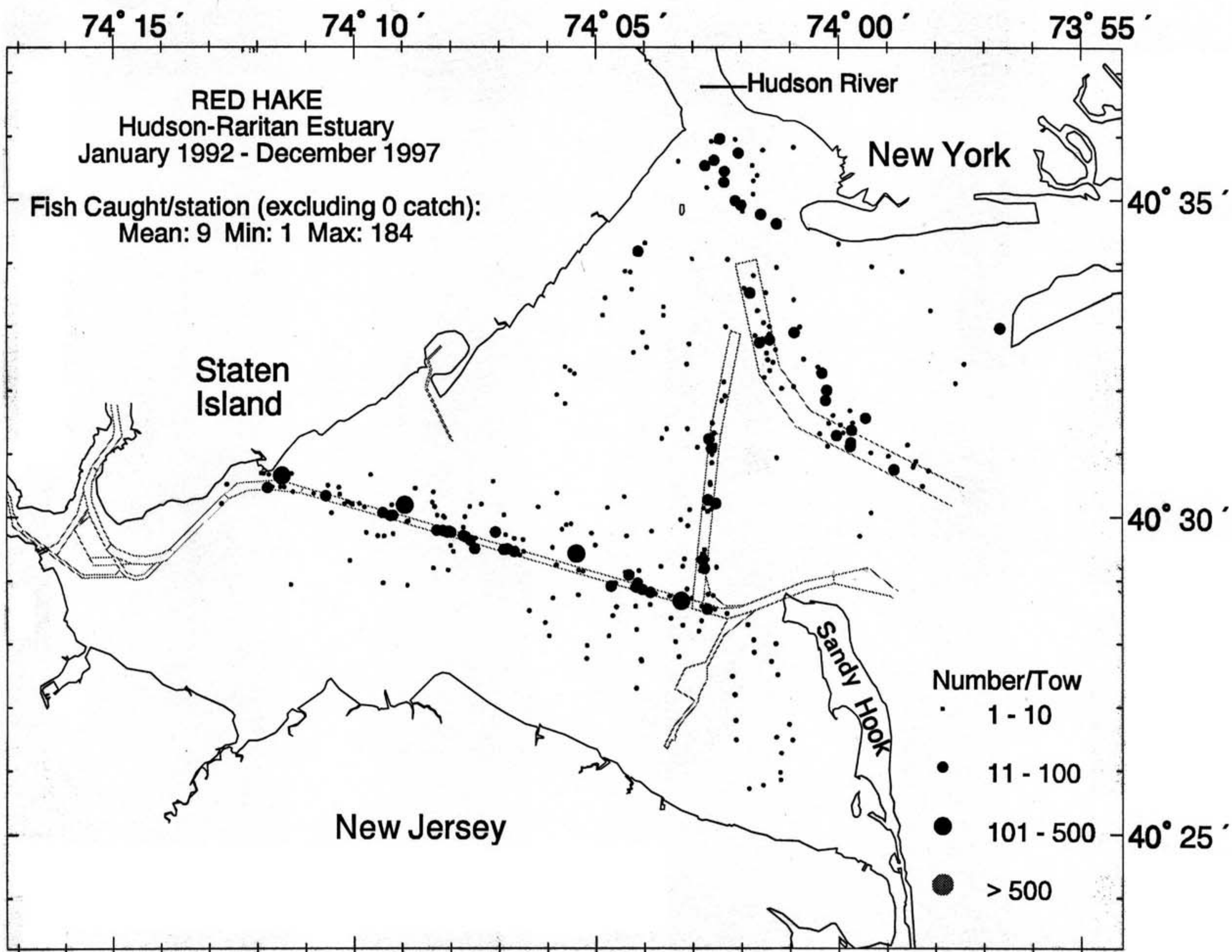

Figure 7. Red hake distribution and relative abundance in Hudson-Raritan Estuary, 1992-97 (Wilk et al. 1998).

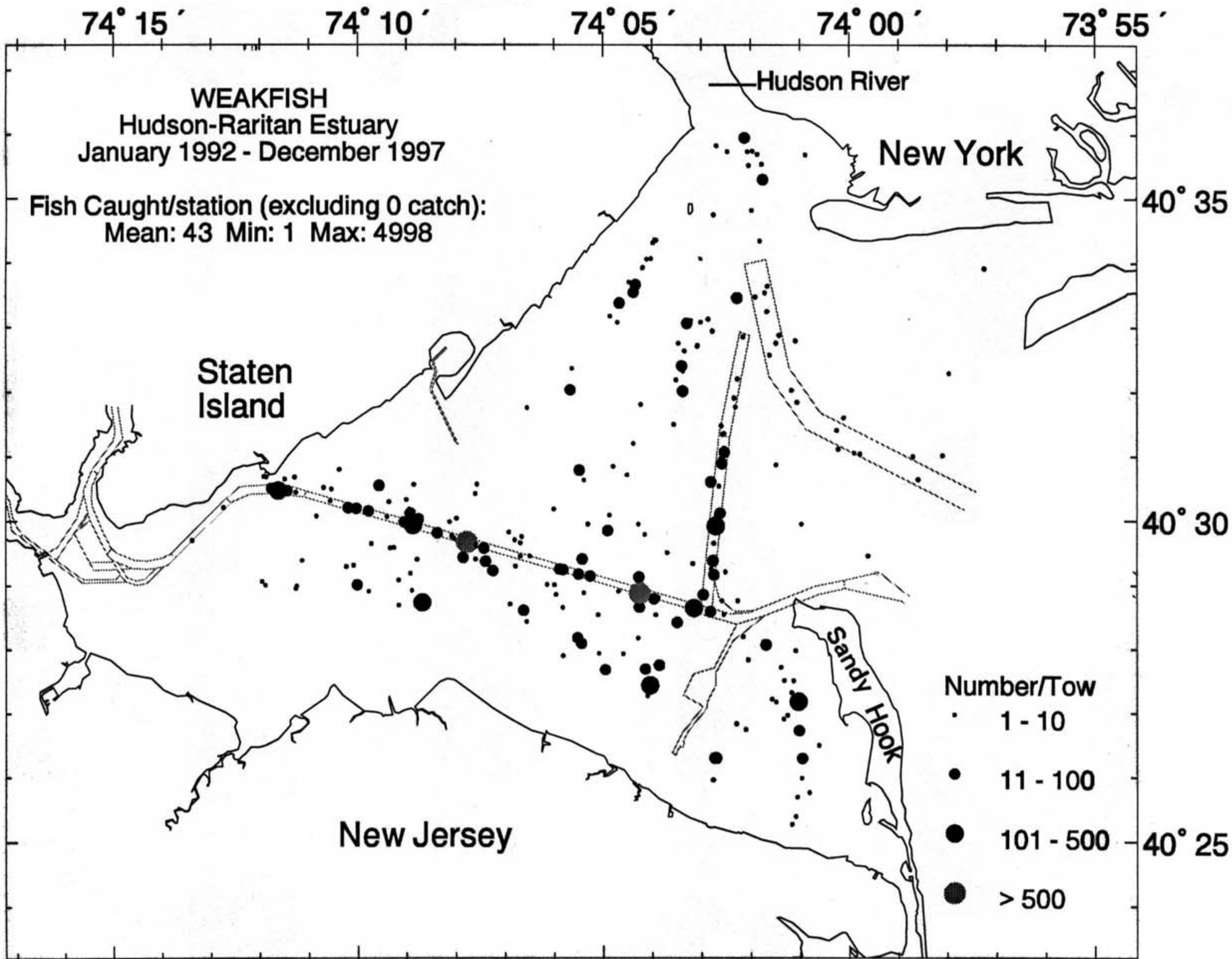

Figure 8. Weakfish distribution and relative abundance in Hudson-Raritan Estuary, 1992-97 (Wilk et al. 1998).

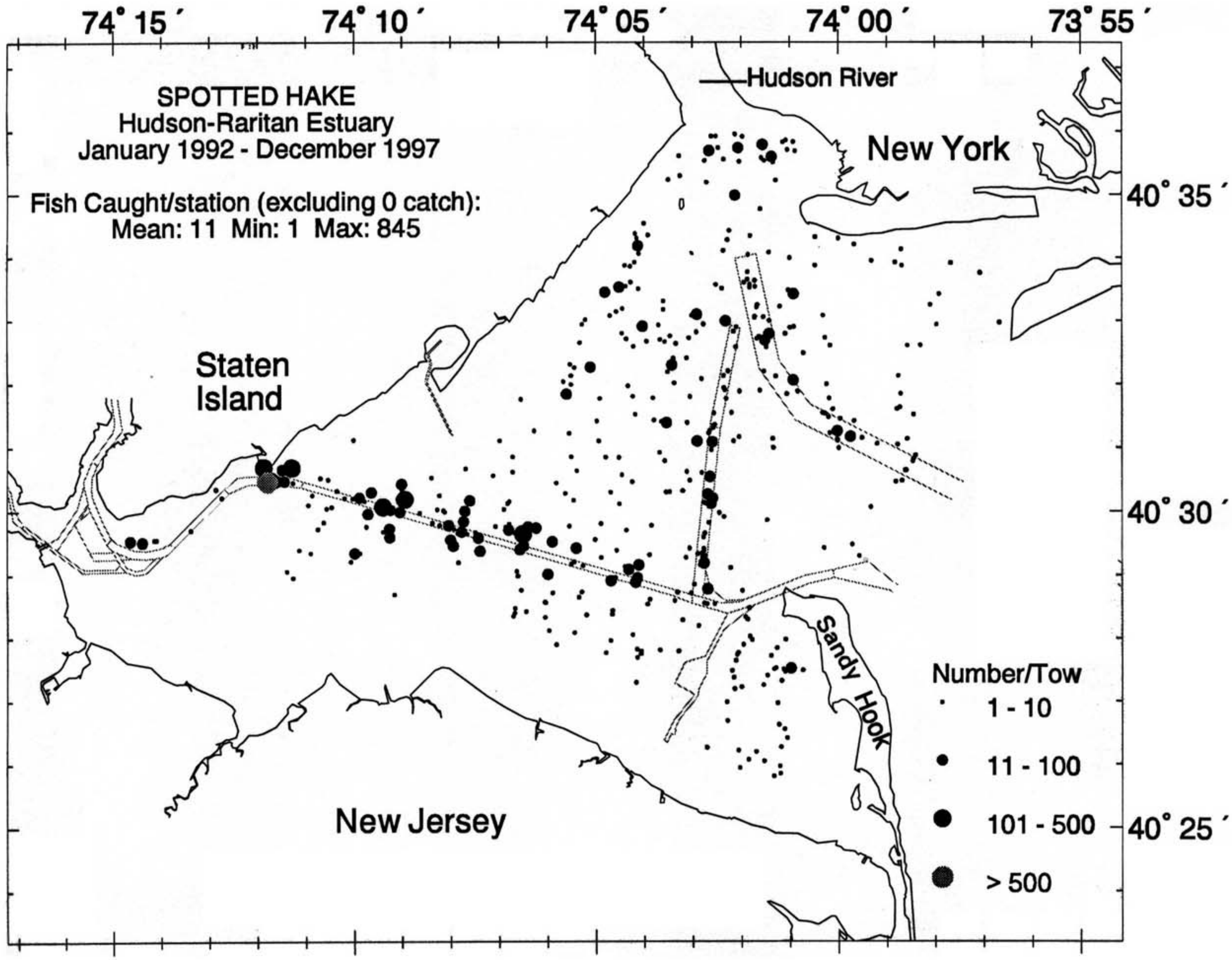

Figure 9. Spotted hake distribution and relative abundance in Hudson-Raritan Estuary, 1992-97 (Wilk et al. 1998).

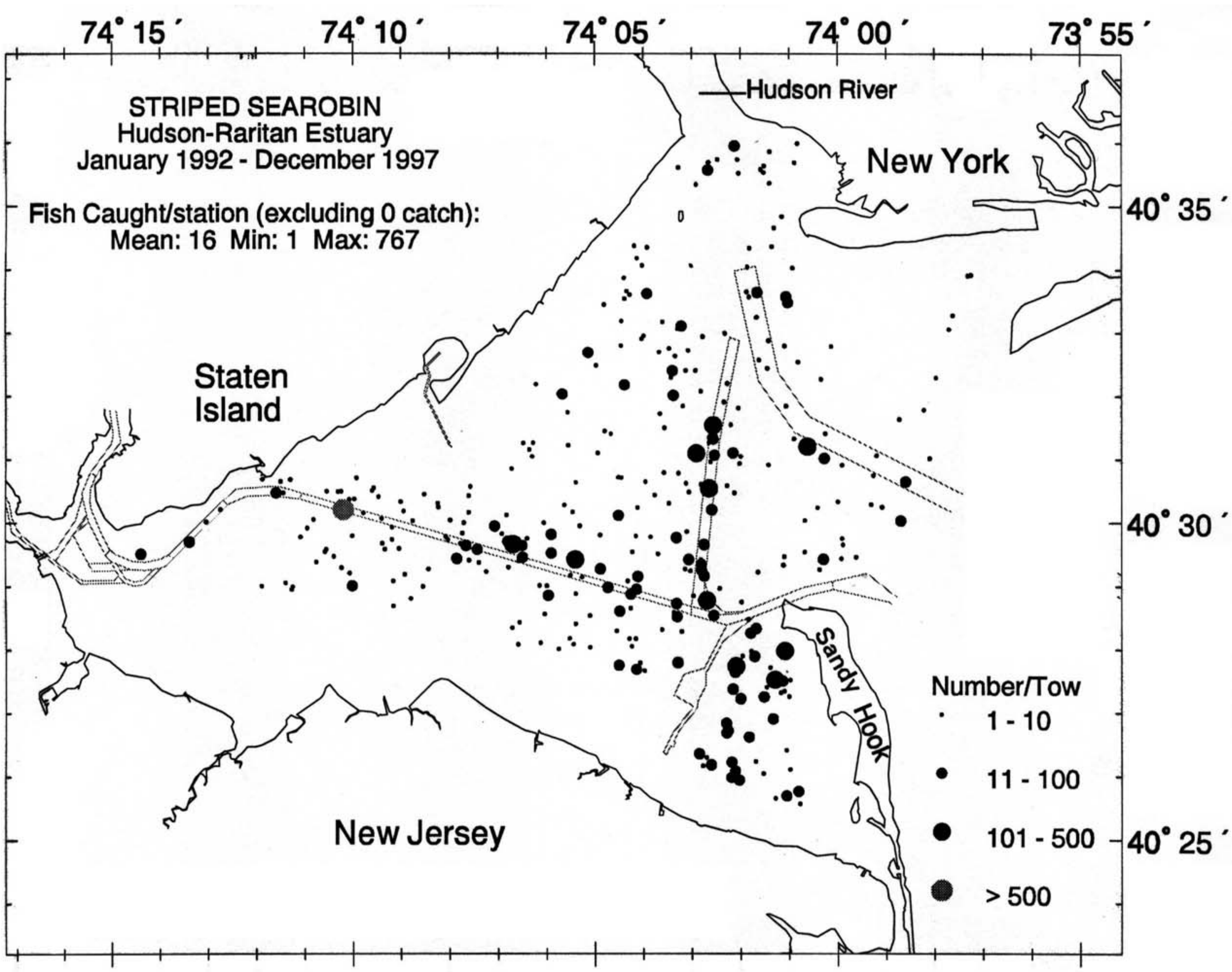

Figure 10. Striped searobin distribution and relative abundance in Hudson-Raritan Estuary, 1992-97 (Wilk et al. 1998).

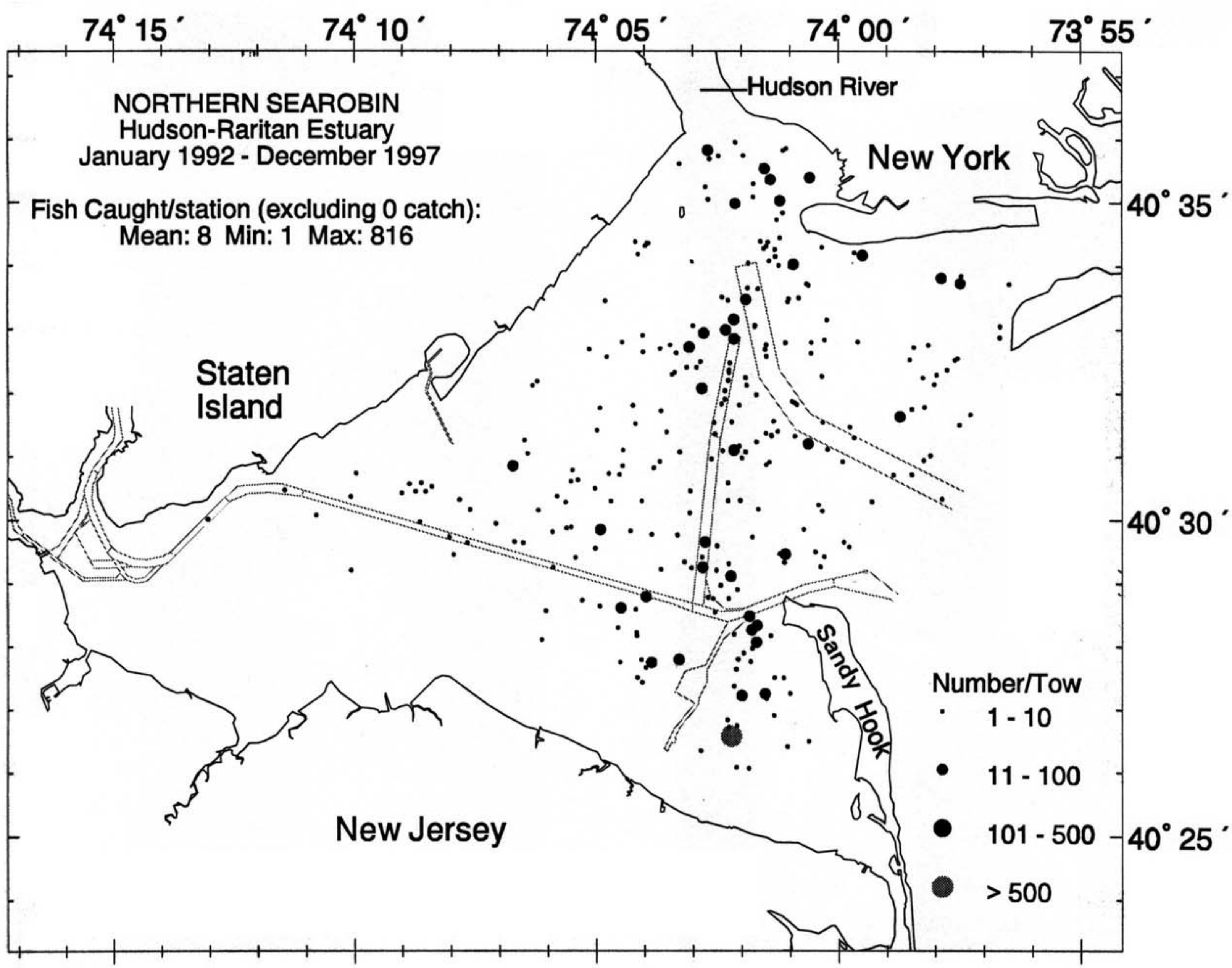

Figure 11. Northern searobin distribution and relative abundance in Hudson-Raritan Estuary, 1992-97 (Wilk et al. 1998).

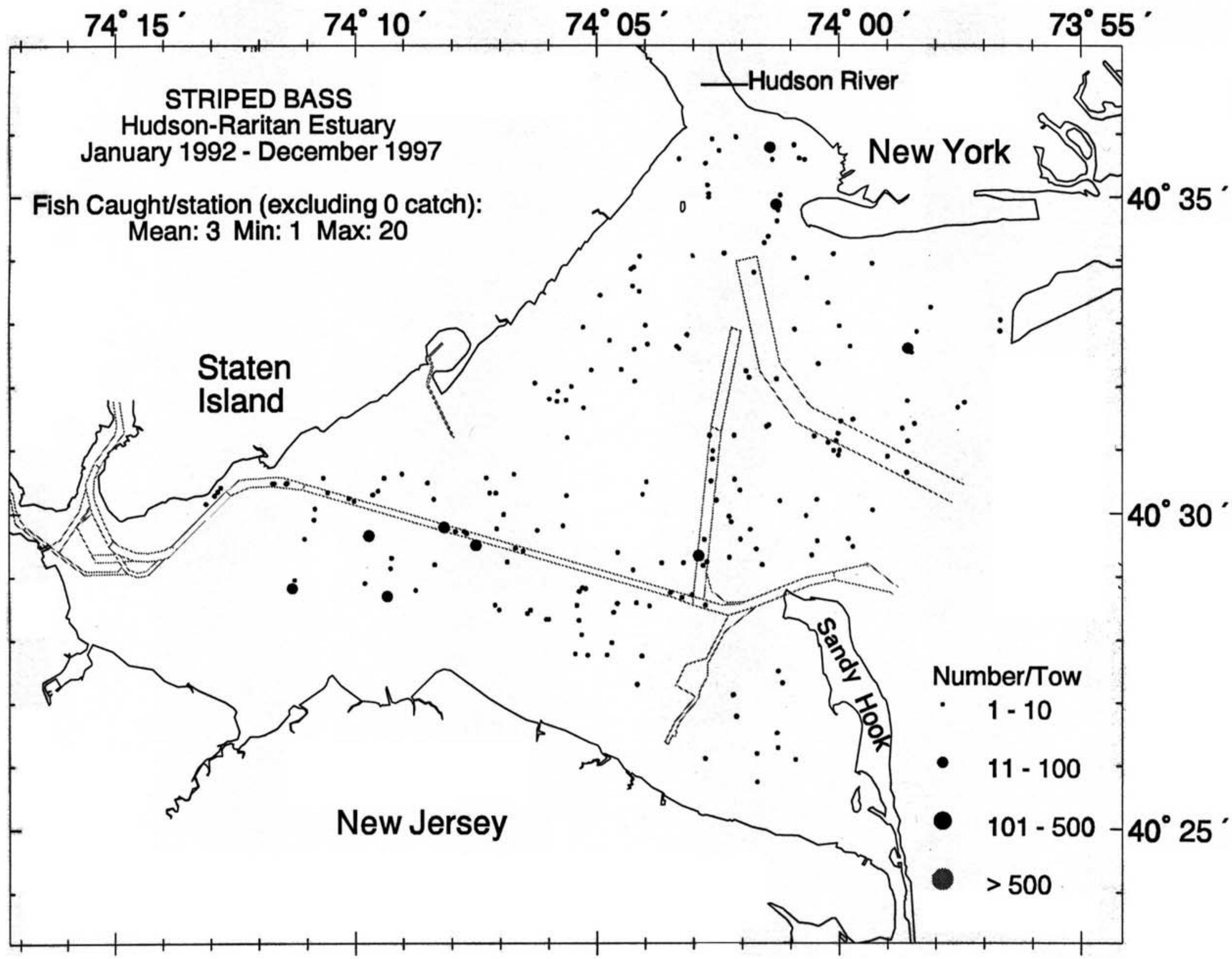

Figure 12. Striped bass distribution and relative abundance in Hudson-Raritan Estuary, 1992-97 (Wilk et al. 1998).

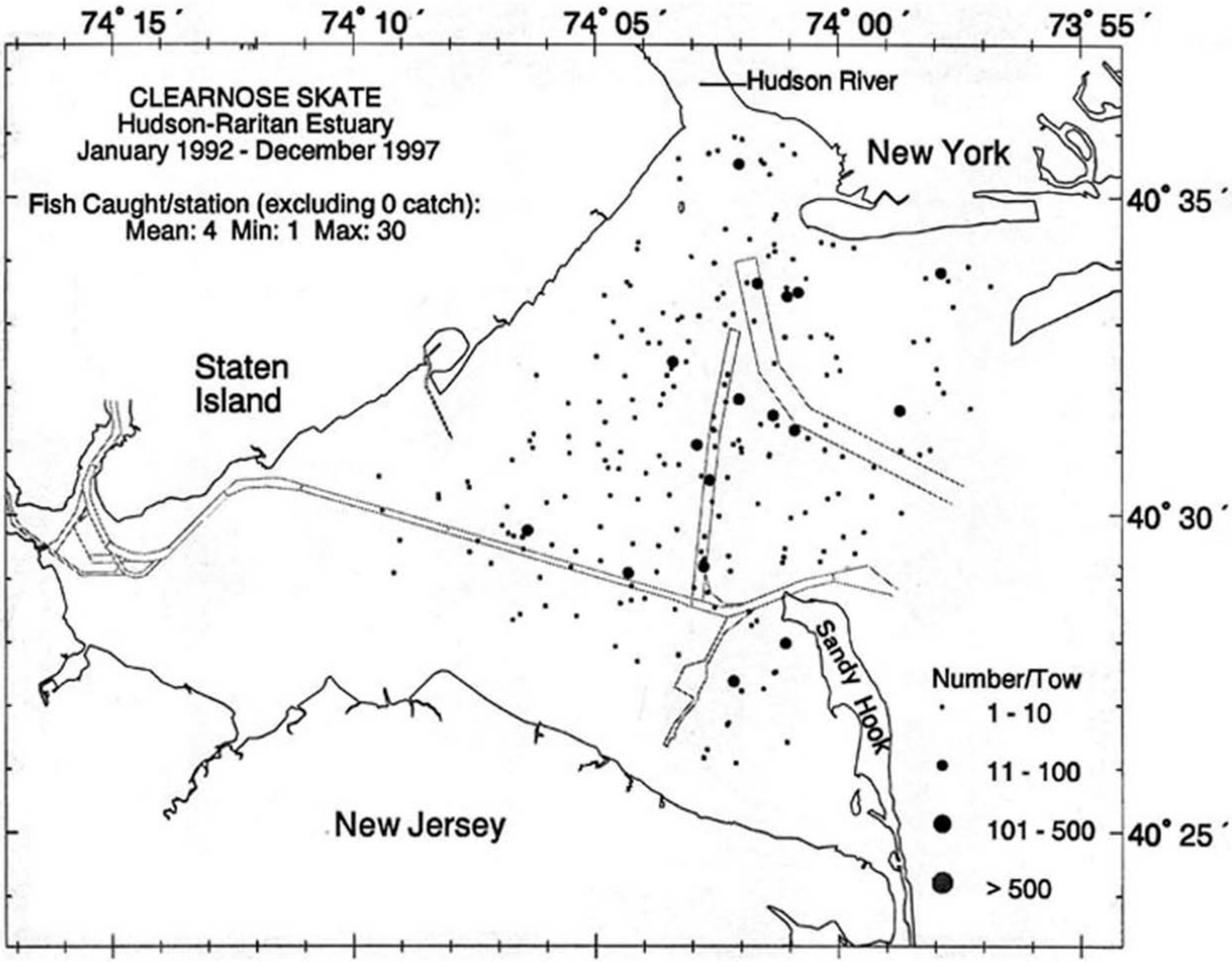

Figure 13. Clearnose skate distribution and relative abundance in Hudson-Raritan Estuary, 1992-97 (Wilk et al. 1998).

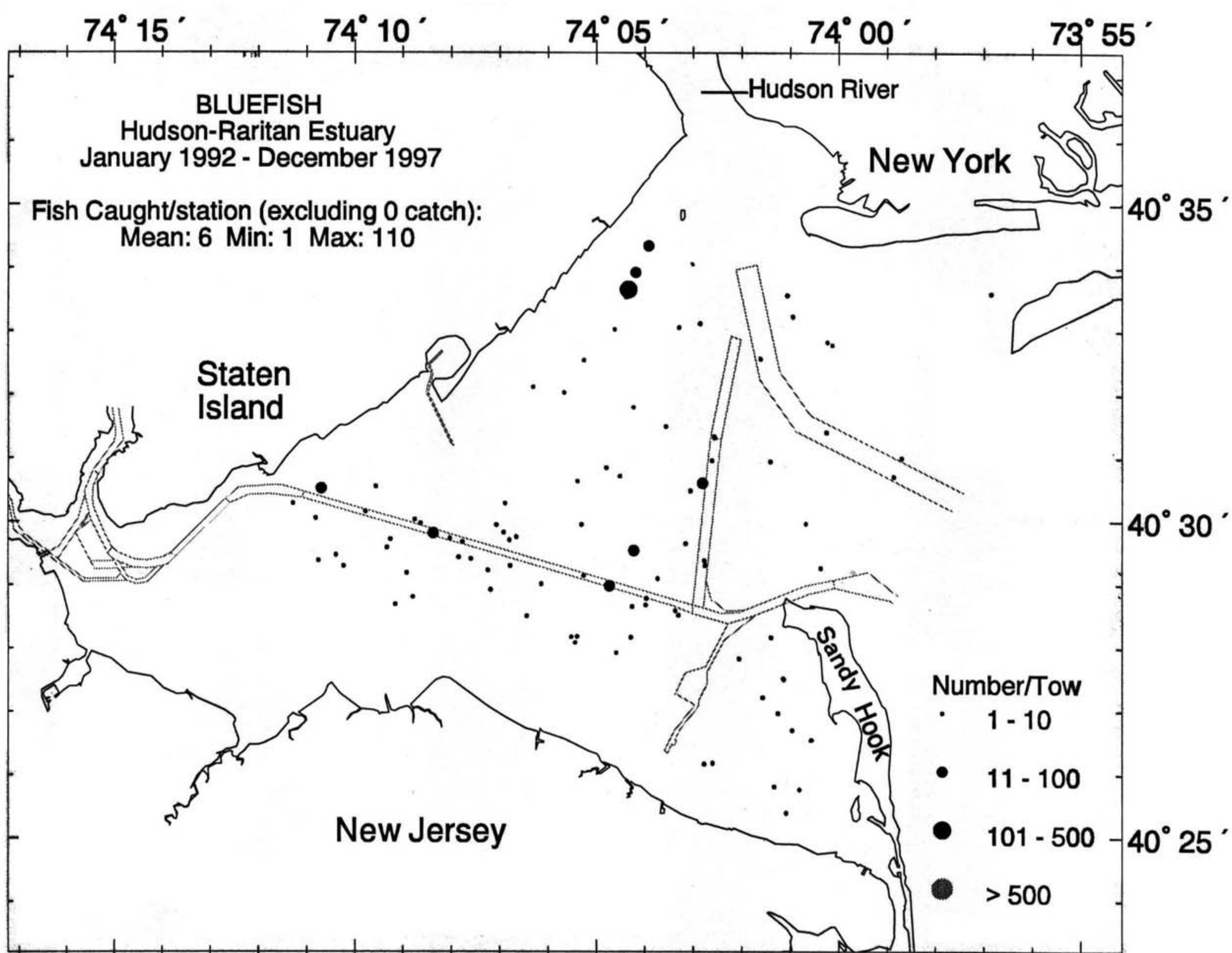

Figure 14. Bluefish distribution and relative abundance in Hudson-Raritan Estuary, 1992-97 (Wilk et al. 1998).

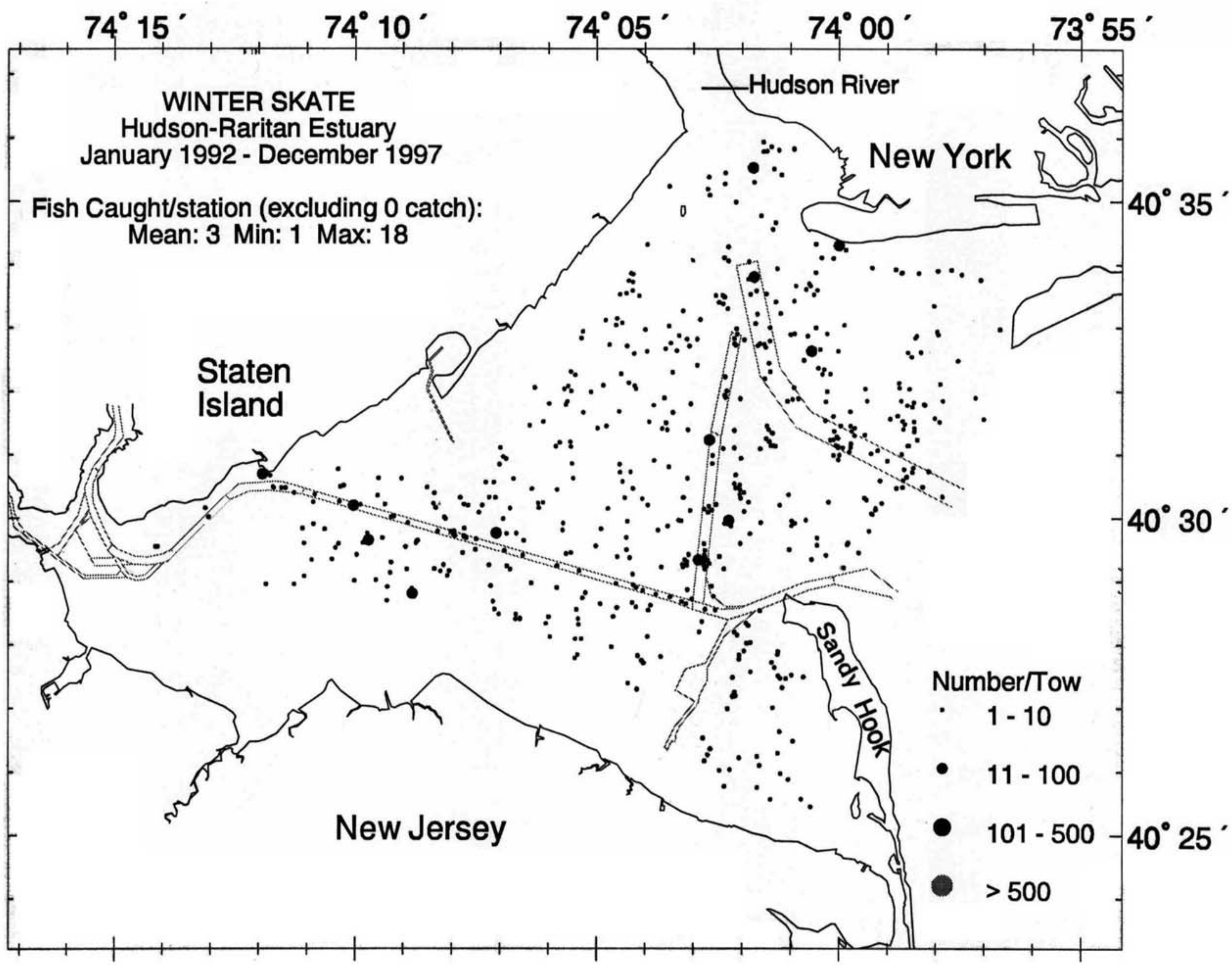

Figure 15. Winter skate distribution and relative abundance in Hudson-Raritan Estuary, 1992-97 (Wilk et al. 1998).

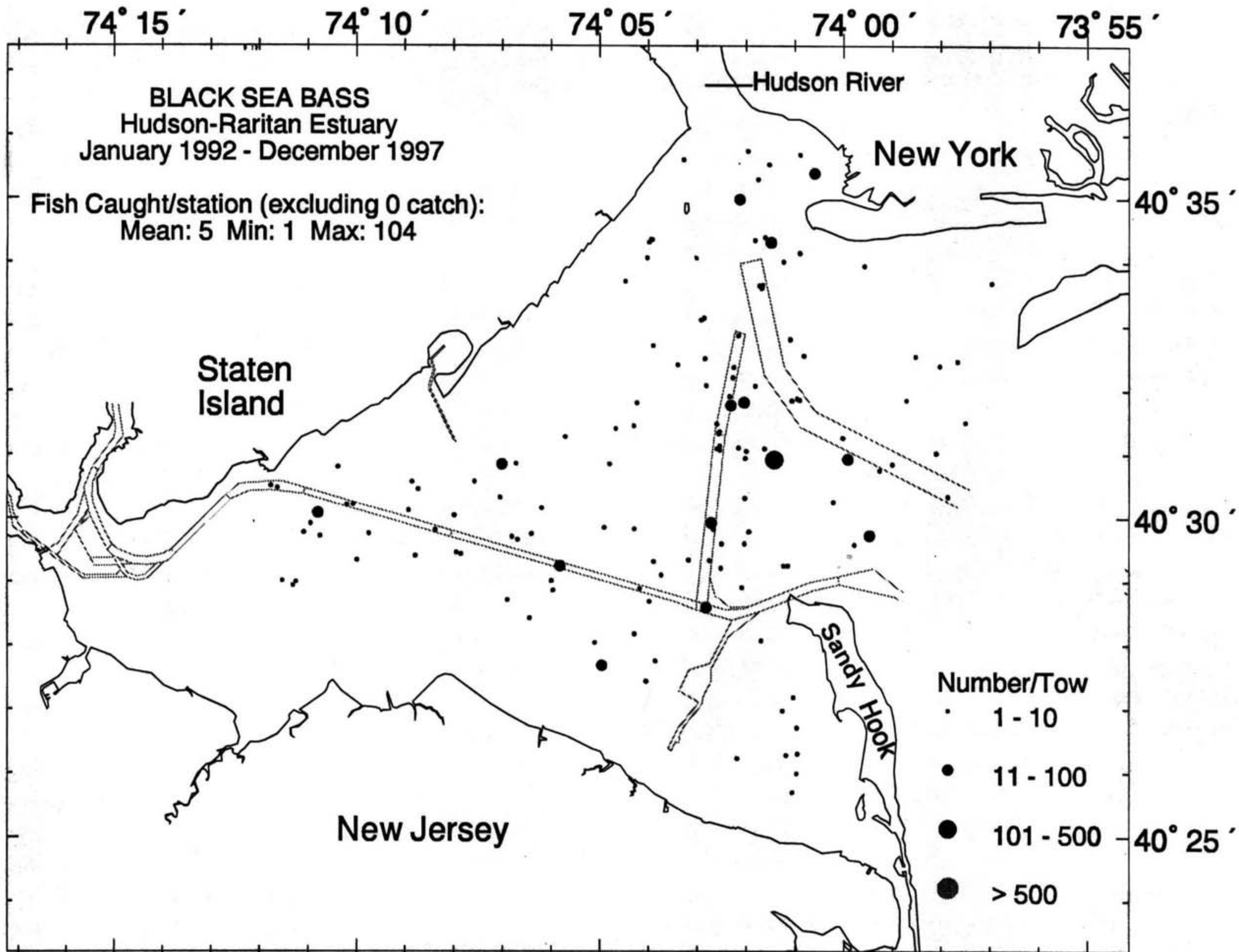

Figure 16. Black sea bass distribution and relative abundance in Hudson-Raritan Estuary, 1992-97 (Wilk et al. 1998).

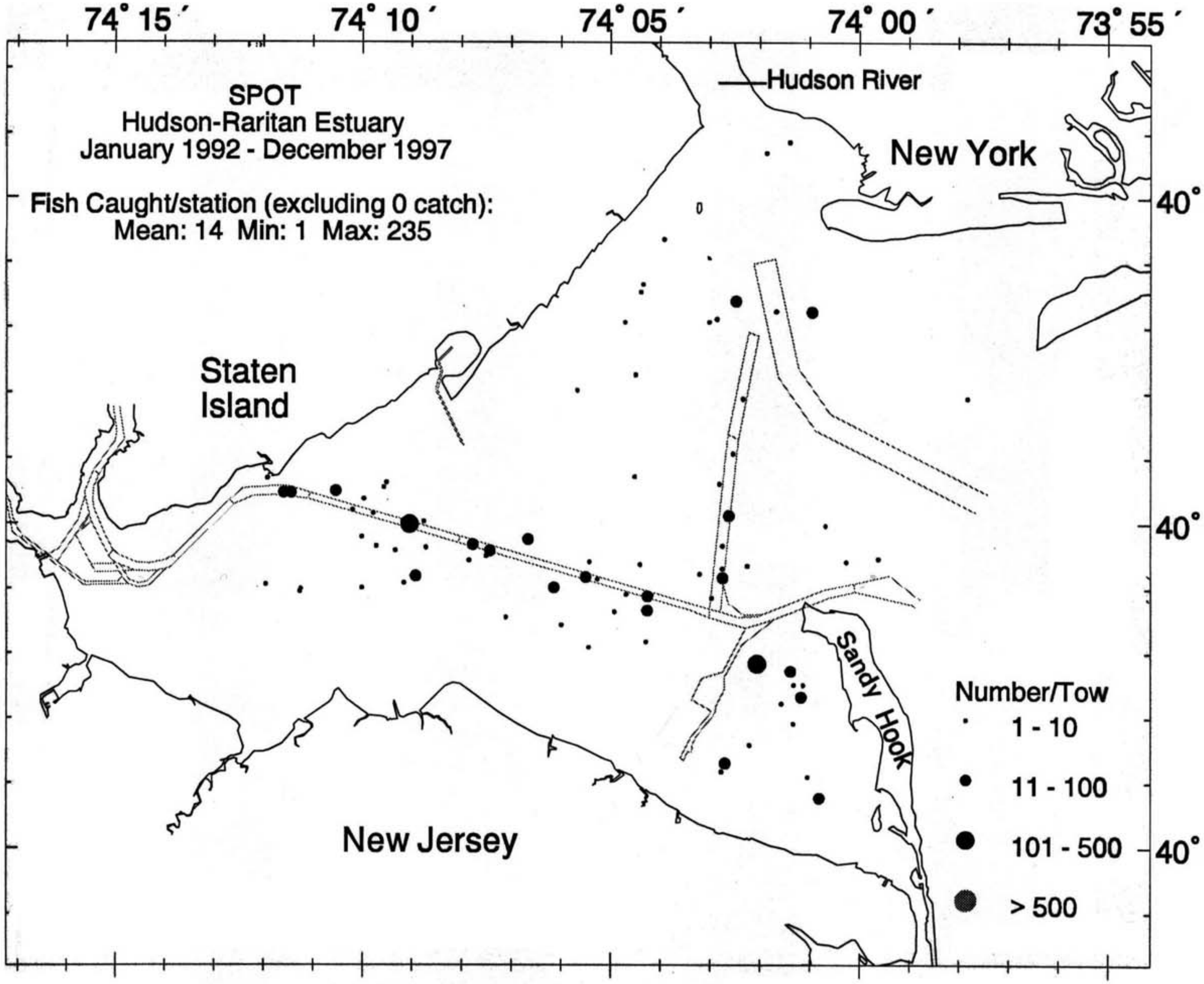

Figure 17. Spot distribution and relative abundance in Hudson-Raritan Estuary, 1992-97 (Wilk et al. 1998).

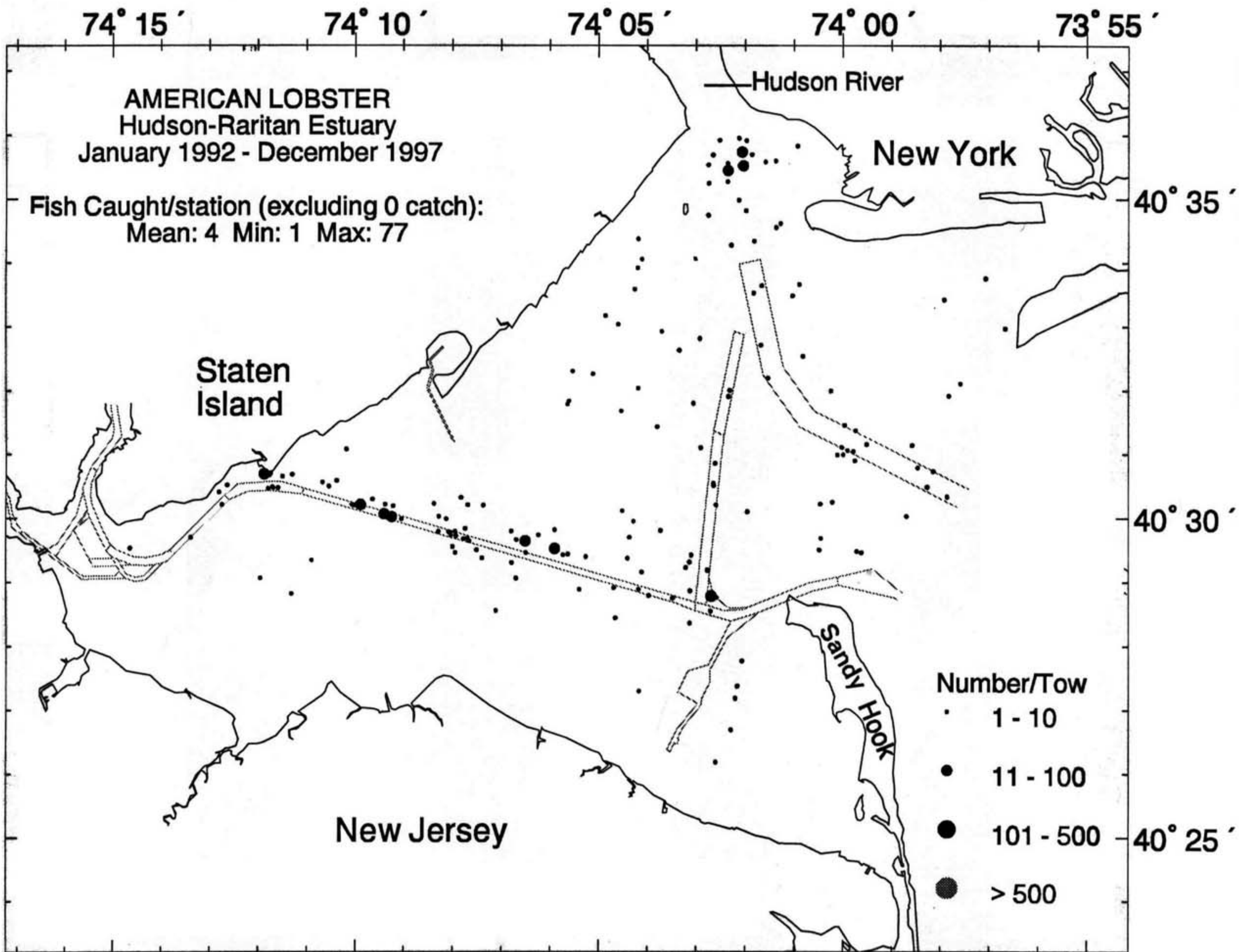

Figure 18. American lobster distribution and relative abundance in Hudson-Raritan Estuary, 1992-97 (Wilk et al. 1998).

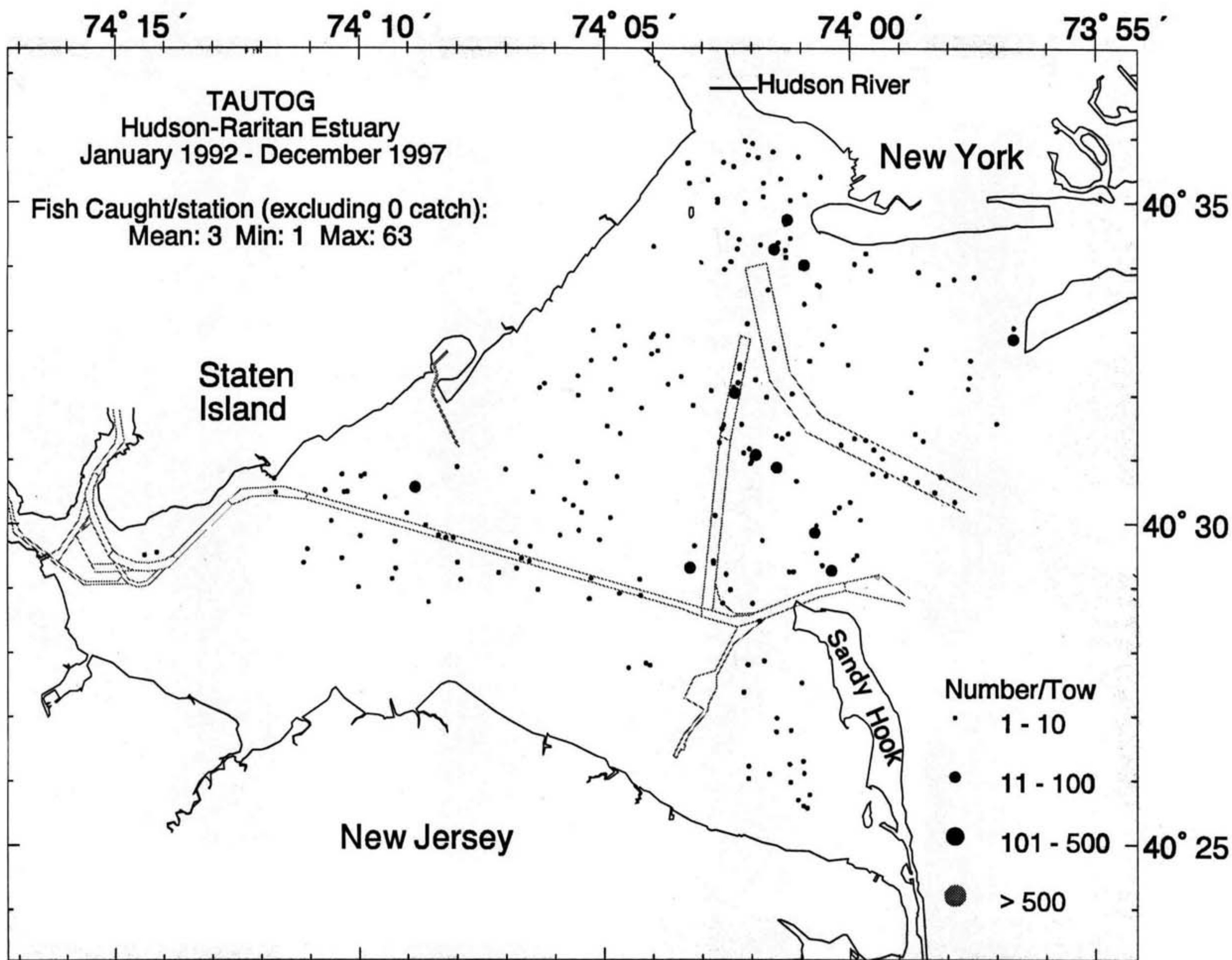

Figure 19. Tautog distribution and relative abundance in Hudson-Raritan Estuary, 1992-97 (Wilk et al. 1998).

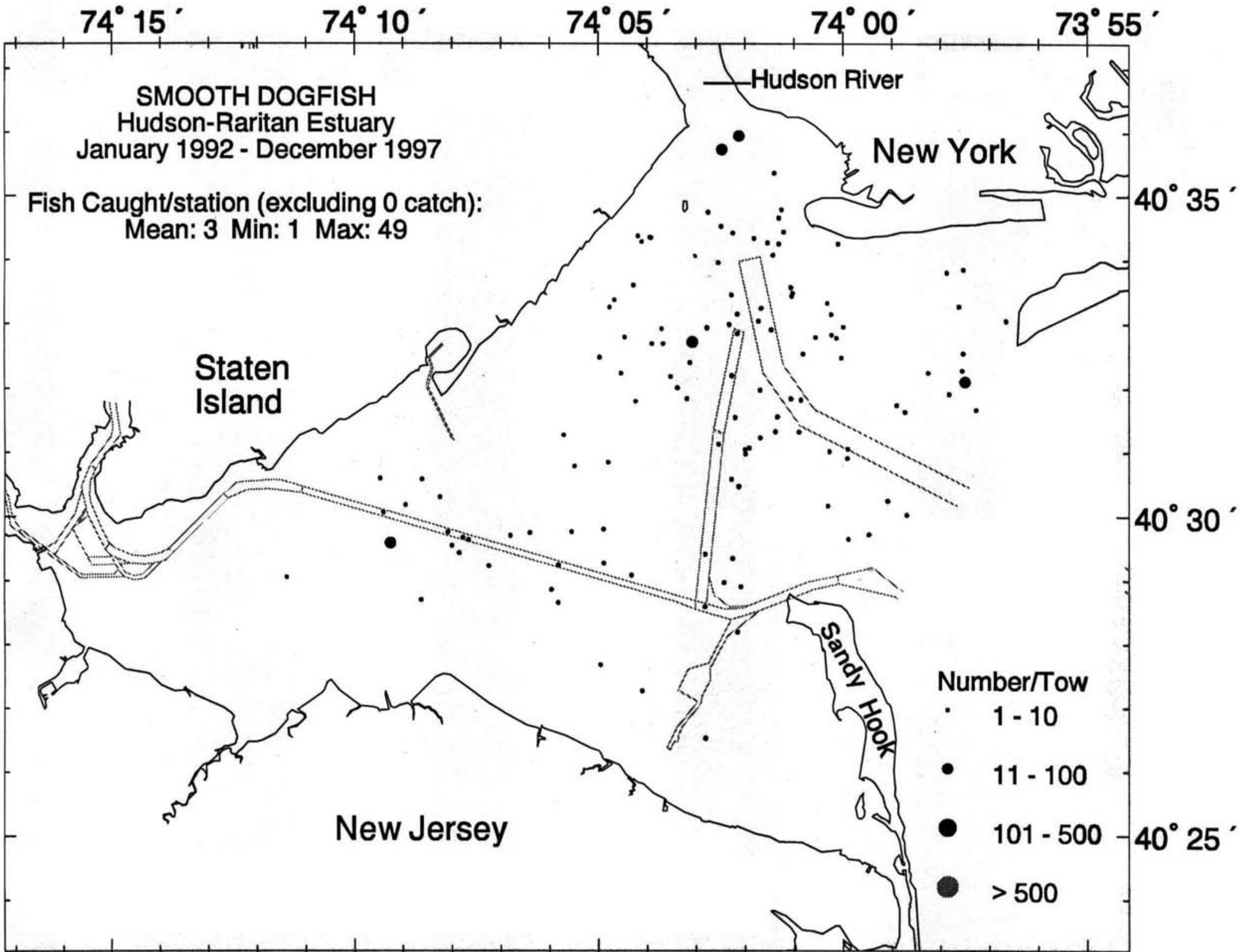

Figure 20. Smooth dogfish distribution and relative abundance in Hudson-Raritan Estuary, 1992-97 (Wilk et al. 1998).

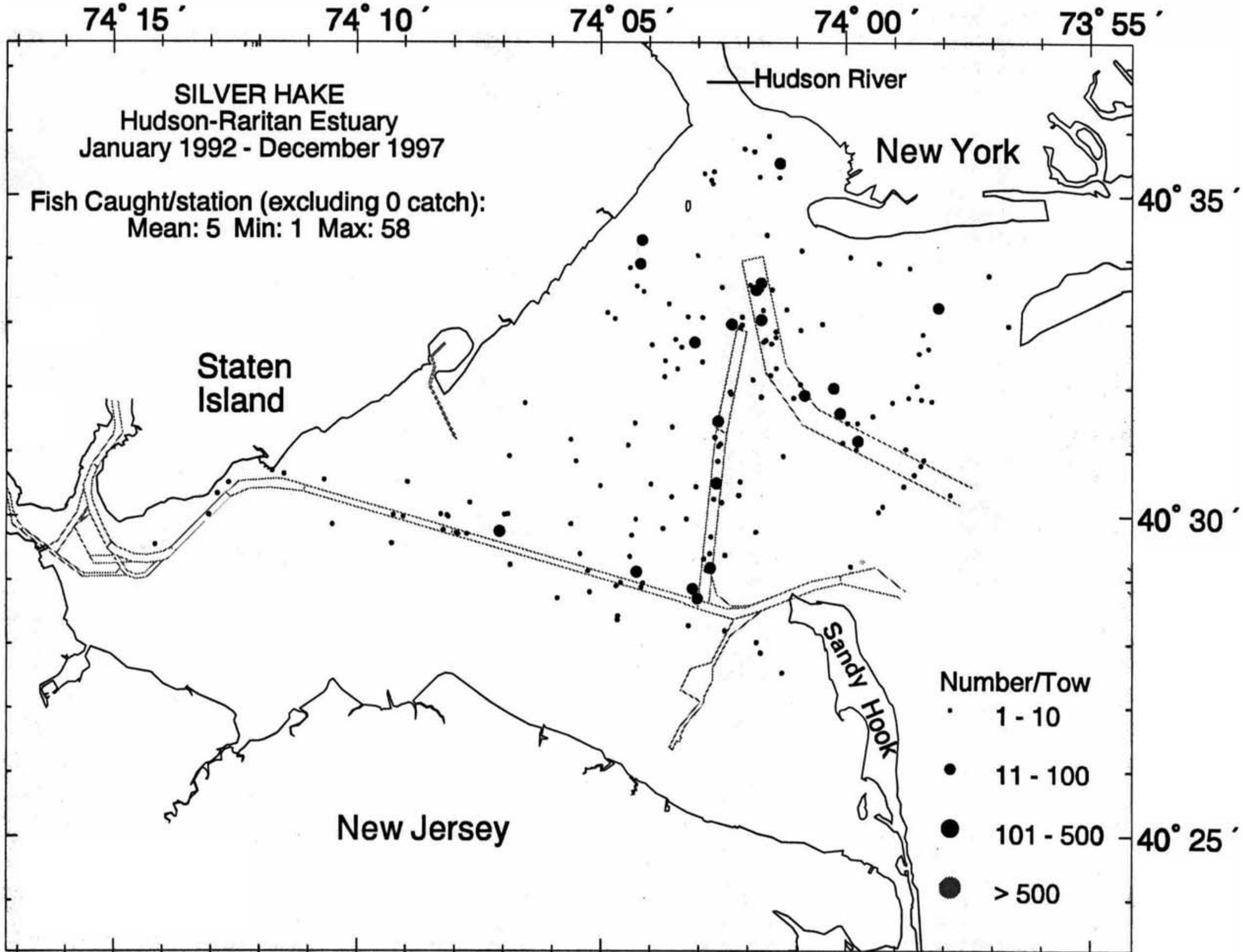

Figure 21. Silver hake distribution and relative abundance in Hudson-Raritan Estuary, 1992-97 (Wilk et al. 1998).

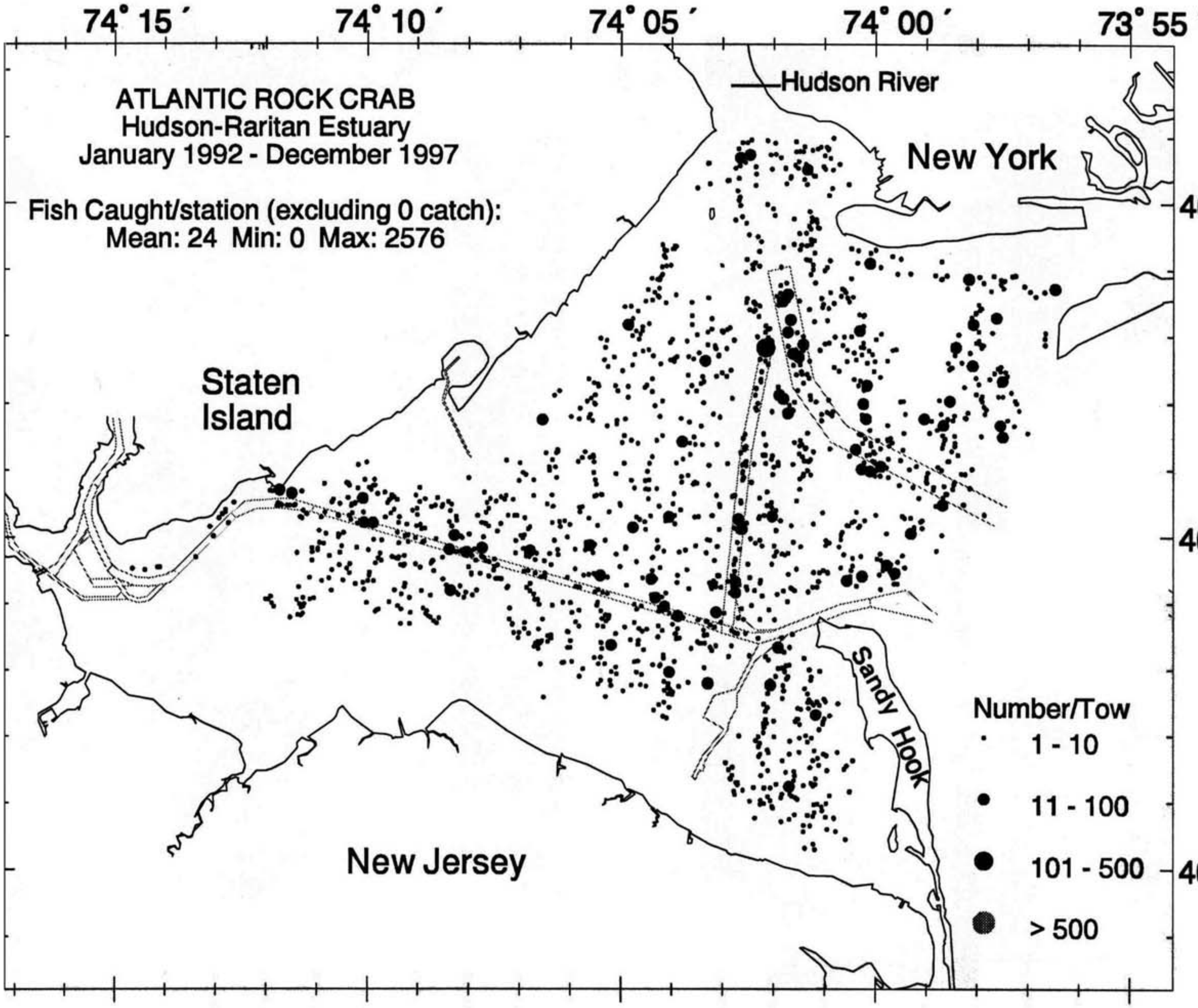

Figure 22. Atlantic rock crab distribution and relative abundance in Hudson-Raritan Estuary, 1992-97 (Wilk et al. 1998).

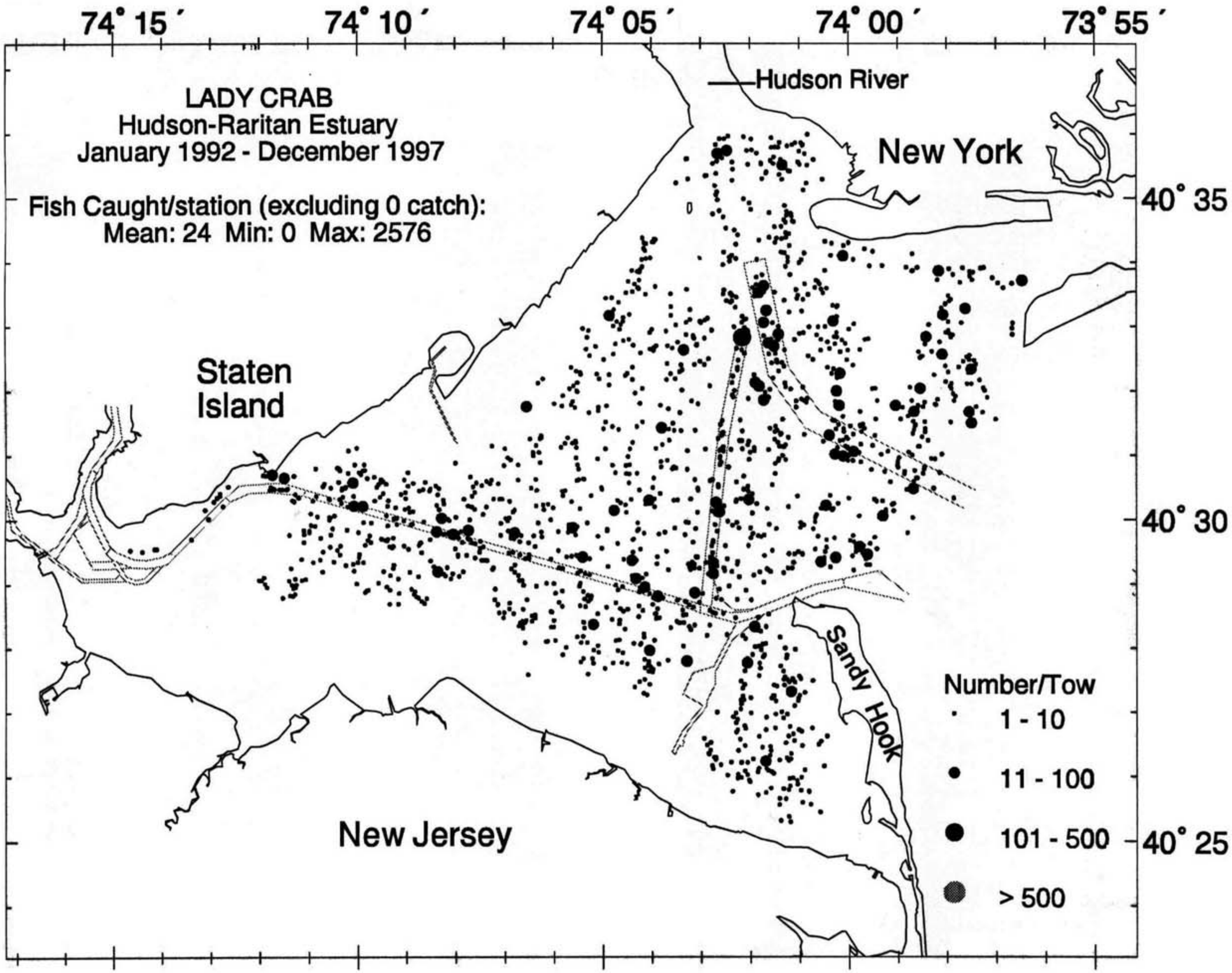

Figure 23. Lady crab distribution and relative abundance in Hudson-Raritan Estuary, 1992-97 (Wilk et al. 1998).

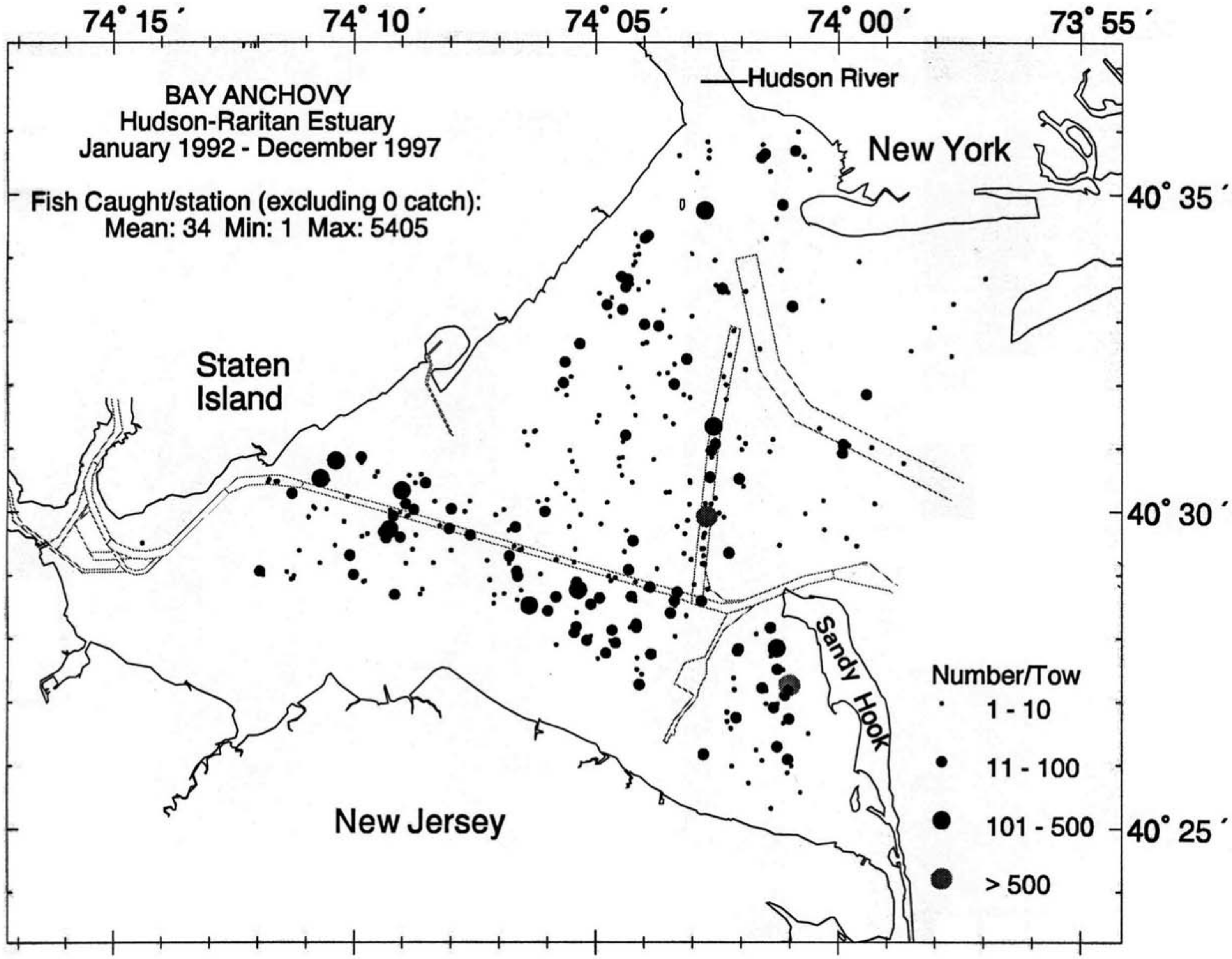

Figure 24. Bay anchovy distribution and relative abundance in Hudson-Raritan Estuary, 1992-97 (Wilk et al. 1998).

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Publications and Reports of the Northeast Fisheries Science Center

The mission of NOAA's National Marine Fisheries Service (NMFS) is "stewardship of living marine resources for the benefit of the nation through their science-based conservation and management and promotion of the health of their environment." As the research arm of the NMFS's Northeast Region, the Northeast Fisheries Science Center (NEFSC) supports the NMFS mission by "planning, developing, and managing multidisciplinary programs of basic and applied research to: 1) better understand the living marine resources (including marine mammals) of the Northwest Atlantic, and the environmental quality essential for their existence and continued productivity; and 2) describe and provide to management, industry, and the public, options for the utilization and conservation of living marine resources and maintenance of environmental quality which are consistent with national and regional goals and needs, and with international commitments." Results of NEFSC research are largely reported in primary scientific media (*e.g.*, anonymously-peer-reviewed scientific journals). However, to assist itself in providing data, information, and advice to its constituents, the NEFSC occasionally releases its results in its own media. Those media are in four categories:

NOAA Technical Memorandum NMFS-NE -- This series is issued irregularly. The series typically includes: data reports of long-term or large area studies; synthesis reports for major resources or habitats; annual reports of assessment or monitoring programs; documentary reports of oceanographic conditions or phenomena; manuals describing field and lab techniques; literature surveys of major resource or habitat topics; findings of task forces or working groups; summary reports of scientific or technical workshops; and indexed and/or annotated bibliographies. All issues receive internal scientific review and most issues receive technical and copy editing.

Northeast Fisheries Science Center Reference Document -- This series is issued irregularly. The series typically includes: data reports on field and lab observations or experiments; progress reports on continuing experiments, monitoring, and assessments; background papers for scientific or technical workshops; and simple bibliographies. Issues receive internal scientific review, but no technical or copy editing.

Fishermen's Report -- This information report is a quick-turnaround report on the distribution and relative abundance of commercial fisheries resources as derived from each of the NEFSC's periodic research vessel surveys of the Northeast's continental shelf. There is no scientific review, nor any technical or copy editing, of this report.

The Shark Tagger -- This newsletter is an annual summary of tagging and recapture data on large pelagic sharks as derived from the NMFS's Cooperative Shark Tagging Program; it also presents information on the biology (movement, growth, reproduction, etc.) of these sharks as subsequently derived from the tagging and recapture data. There is internal scientific review, but no technical or copy editing, of this newsletter.

OBTAINING A COPY: To obtain a copy of a *NOAA Technical Memorandum NMFS-NE* or a *Northeast Fisheries Science Center Reference Document*, or to subscribe to the *Fishermen's Report* or the *The Shark Tagger*, either contact the NEFSC Editorial Office (166 Water St., Woods Hole, MA 02543-1026; 508-495-2228) or consult the NEFSC webpage on "Publications and Reports" (*http://www.nefsc.nmfs.gov/nefsc/publications/*).

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