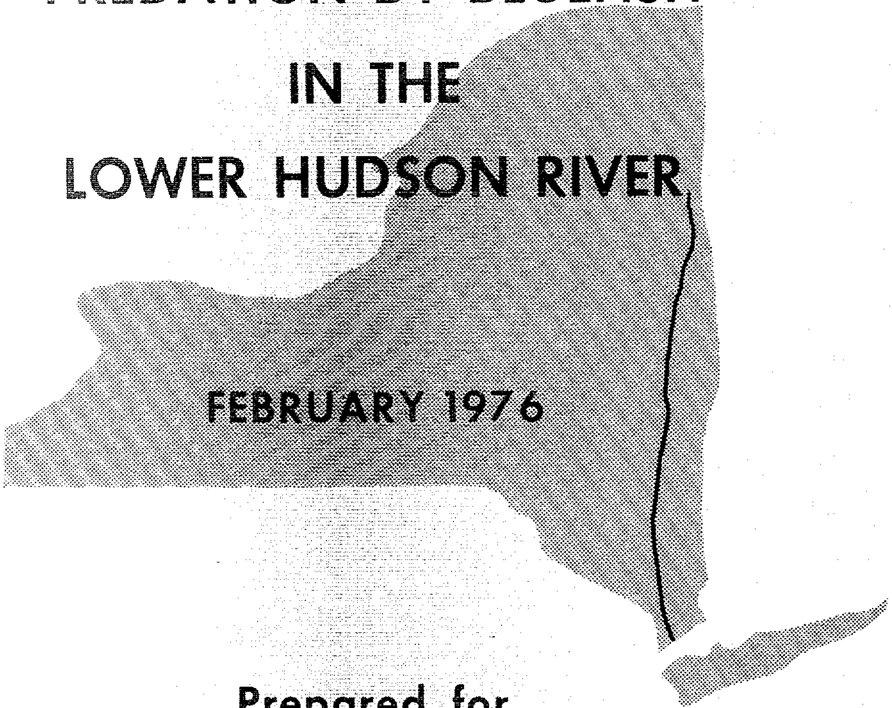
# PREDATION BY BLUEFISH IN THE LOWER HUDSON RIVER



FEBRUARY 1976

Prepared for

**CONSOLIDATED EDISON COMPANY OF NEW YORK, INC.**

4 Irving Place
New York, New York 10003

by

TEXAS INSTRUMENTS INCORPORATED
ECOLOGICAL SERVICES

P.O. Box 5621
Dallas, Texas 75222

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## SECTION I
## INTRODUCTION

The lower Hudson River Estuary is a spawning and nursery area for many commercial and sport species of anadromous and estuarine fish, including striped bass and white perch. During summer months, schools of young-of-the-year bluefish *(Pomatomus saltatrix)* enter the Hudson River and occupy a region determined by the northward incursion of saline water, primarily below river mile 65 (Texas Instruments, 1975a). The adults of this species are highly predacious and have been described as " ... perhaps the most ferocious and bloodthirsty fish in the sea ... " (Bigelow and Schroeder, 1953). Predation may be a serious limiting factor for species that are vulnerable to this source of mortality during some phase of their life cycle (Rounsefell and Everhart, 1953). Thus, Nikolsky (1963) stated that, "Predators are a significant cause of the decline in many species of fishes, and only in comparatively few (anchovies, herrings, etc.) does the main predatory mortality fall on the mature individuals of the population." The presence of the bluefish in the lower Hudson River led to the hypothesis that they may be an important source of predation of juvenile striped bass and white perch.

It is the purpose of this study to evaluate bluefish predation of striped bass and white perch as a source of natural mortality. Predation by bluefish is a potential source of natural density-dependent mortality. The impact of power-plant-induced mortality on the Hudson River striped bass and white perch populations is currently being investigated. Natural mortality must also be assessed to answer questions regarding power-plant impact.

The major objectives of this study were

- To assess the potential importance of bluefish as a predator upon young-of-the-year striped bass and white perch.

- To assess the potential importance of bluefish as a predator upon other species, including those utilizing the Hudson River as a nursery area, such as American shad.

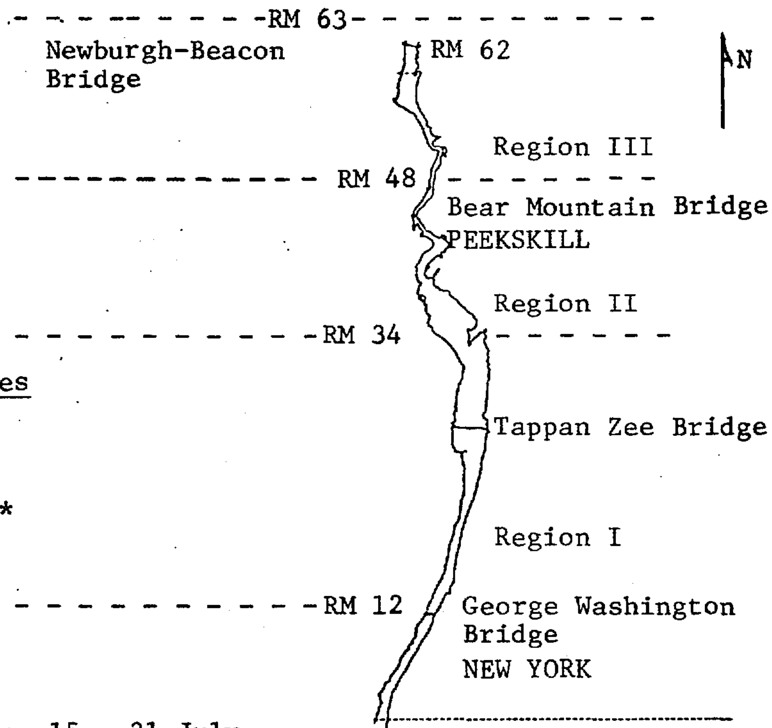
- To determine the spatial, temporal, and size-related predation patterns of bluefish in the Hudson River.

SECTION II

MATERIALS AND RESULTS

Bluefish were collected from beach-seine and bottom-trawl catches during June - September 1974. To minimize regurgitation of stomach contents, individuals were allowed to die of suffocation. Expired individuals were preserved in 10% formalin. The stomachs of all individuals larger than 100-mm total length were injected with 10% formalin to insure preservation of stomach contents.

Sampling was distributed both spatially and temporally. These spatial strata were defined as shown in Figure II-1.




| Region | River Miles |
|---|---|
| I | 12 - 34 |
| II | 35 - 48 |
| III | 49 - 63* |

* Only one sample: 15 - 31 July

Figure II-1. River Mile (RM) and River Region Demarcations of the Hudson River

Temporal strata consisted of biweekly sampling periods during July and August. Because of low abundance of bluefish during June and September, the biweekly samples were combined into monthly samples for data analysis.

In the laboratory, the total length of each individual was recorded. Stomachs were removed and any vertebrate contents identified to the lowest practical taxonomic level and enumerated; the presence of invertebrates was recorded. Ingested fish with intact heads were preserved for orbit-operculum measurements to estimate total lengths (see below).

Analysis of stomach contents was based on: (1) percent frequency of occurrence of invertebrates and fish in bluefish stomachs; (2) percent frequency of occurrence of invertebrates in bluefish stomachs; and (3) percent frequency by number of identifiable fish found in bluefish stomachs where:

$$\text{percent frequency of occurrence} = \frac{\text{number of fish stomachs containing food item j} \times 100}{\text{number of fish stomachs containing food}}$$

and

$$\text{percent frequency by number} = \frac{\text{number of fish stomachs containing food item j} \times 100}{\text{total number of food items encountered}}$$

The first two analyses show the relative role of vertebrates and invertebrates in the diets of young-of-the-year bluefish and the last provides more specific information on piscivorous feeding habits.

To estimate intact lengths and weights of ingested fish recovered from bluefish stomachs, reference young-of-the-year of available forage species were secured from various sampling efforts during the summer of 1974. A ratio between the total length and the measurement from the posterior margin of the orbit to the dorso-posterior margin of the operculum of the reference fish was developed. The orbit-operculum distance was delineated with fine-point dividers, which were used to score an acetate sheet. The acetate sheet bearing the scored distances was placed on an overhead microprojector with a magnification of 21.6X, and the distance between the projected score marks was measured to the nearest millimeter. Since the magnification did not affect the ratio, no conversion back to the original distance was necessary. A linear regression was generated using the formula:

$$y = a + bx$$

where

- x is the magnified orbit-operculum distance
- y is the total length
- a is the least squares estimation of the y intercept
- b is the corresponding estimate of the slope of the regression line

Atlantic tomcod was the only fish species recovered from stomachs in sufficient quantity to enable analysis of reconstructed lengths. Orbit-operculum measurements for all intact tomcod recovered from bluefish stomachs were substituted into the regression equation to estimate total length. Confidence intervals (95%) about these estimates were calculated according to Draper and Smith (1966). Reconstructed tomcod total lengths were plotted against the total lengths of bluefish which ate these individuals to determine the relation between prey and predator size. A regression line of the form:

$$L_b = a + b\,L_t$$

where

$L_b$ is the total length of the bluefish

$L_t$ is the reconstructed total length of the tomcod

a is the least squares estimate of the $L_b$ intercept of the regression line

b is the least squares estimate of the slope of the regression line

was calculated using the least squares approach, and the corresponding correlation coefficient (r) between bluefish lengths and reconstructed tomcod lengths was evaluated. The transformation

$$t = \frac{r}{\sqrt{(1 - r^2)/(n-2)}}$$

was then made, the Student's t distribution was used to test the significance of this correlation.

Of the 1627 bluefish stomachs examined, 577 (36%) contained food (Table II-1). In all, 381 fish were recovered from bluefish stomach contents. The dominant fish species present in bluefish stomachs was the bay anchovy, accounting for 43.1% of all identifiable fish recovered (Tables II-2 and II-3; Figure II-2). Six striped bass and two white perch were encountered accounting for 1.6% and 0.5% of all identifiable fish. Nineteen percent of all identifiable fish were clupeids with American shad composing 5.5%. Young-of-the-year tomcod totaled 12.4% of all identifiable fish.

During June, the bluefish diet consisted primarily of invertebrates, which were mainly copepods, dipterans, and cladocerans (Figure II-3). After June, fish became the dominant component of bluefish diets and continued to be throughout the summer of 1974. Invertebrates, represented predominantly by larger amphipods, isopods, and decapods, occurred occasionally thereafter. The changeover from an invertebrate to a piscivorous feeding mode occurred in both Regions I and II during July at a time when bluefish were ~ 70-90 mm in total length.

Table II-1

Summary of Results, Hudson River, New York, June-September 1974

| | Location* (Region) | No. Bluefish Examined | Mean Total Length (mm) | Standard Deviation of Length | No. Containing Food | No. Containing Invertebrates | Containing Fish | No. Containing Identifiable Fish |
|---|---|---|---|---|---|---|---|---|
| Jun | I | 66 | 64 | 14 | 17 | 9 | 8 | 3 |
| | II | 96 | 69 | 13 | 65 | 56 | 15 | 5 |
| 1-14 Jul | I | 88 | 93 | 15 | 26 | 7 | 21 | 10 |
| | II | 89 | 95 | 14 | 34 | 10 | 27 | 11 |
| 15-31 Jul | I | 97 | 109 | 17 | 33 | 9 | 24 | 12 |
| | II | 529 | 108 | 18 | 169 | 19 | 152 | 100 |
| | III | 77 | 102 | 11 | 42 | 0 | 42 | 28 |
| 1-14 Aug | I | 134 | 116 | 16 | 40 | 7 | 35 | 26 |
| | II | 269 | 127 | 17 | 77 | 4 | 74 | 48 |
| 15-31 Aug | I | 43 | 139 | 17 | 8 | 0 | 8 | 4 |
| | II | 93 | 141 | 24 | 44 | 2 | 42 | 27 |
| Sep | I | ← | | | No Sample | | | → |
| | II | 46 | 180 | 24 | 22 | 1 | 22 | 15 |
| Total | — | 1627 | — | — | 577 | 124 | 470 | 289 |

*I = RM 12-34, II = RM 35-48, III = RM 49-63

Table II-2

Common and Scientific Names of Fish Recovered from Bluefish Stomachs, RM 12-63, Hudson River, New York, June-September 1974

| Common Name | Scientific Name | Common Name | Scientific Name |
|---|---|---|---|
| Bay anchovy | *Anchoa mitchilli* | Striped bass (Y) | *Morone saxatilis* |
| Atlantic tomcod | *Microgadus tomcod* | American eel | *Anguilla rostrata* |
| Unidentified clupeid (Y)* | Clupeidae | Unidentified minnow | Cyprinidae |
| American shad (Y) | *Alosa sapidissima* | Blueback herring (Y) | *Alosa aestivalis* |
| Killifishes | Cyprinodontidae | Tessellated darter | *Etheostoma olmstedi* |
| Spottail shiner | *Notropis hudsonius* | White perch (Y) | *Morone americana* |
| Bluefish (Y) | *Pomatomus saltatrix* | Unidentified sunfishes (Y) | Centrarchidae |
| Goldfish (Y) | *Carassius auratus* | | |

*(Y) indicates young-of-the-year

## Table II-3

### Percent Frequency by Number of Identifiable Fish Remains Found in Bluefish Stomachs, RM 12-63, Hudson River, New York, June-September 1974

| | Location* (Region) | No. of Ident. Fish | Bay Anchovy | Atlantic Tomcod | Unident. Clupeid | Killifish | American Shad | Goldfish | Spottail Shiner | American Eel | Striped Bass | Bluefish | Unident. Minnow | Tessellated Darter | Blueback Herring | White Perch | Unident. Sunfish |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Jun | I | 4 | 50 | — | 50 | — | — | — | — | — | — | — | — | — | — | — | — |
| | II | 5 | 60 | — | 20 | — | — | — | — | — | — | 20 | — | — | — | — | — |
| 1-14 Jul | I | 10 | 70 | 10 | 20 | — | — | — | — | — | — | — | — | — | — | — | — |
| | II | 13 | 15.4 | — | 30.8 | — | 38.5 | — | 15.4 | — | — | — | — | — | — | — | — |
| 15-31 Jul | I | 12 | 91.7 | — | — | — | — | — | 8.3 | — | — | — | — | — | — | — | — |
| | II | 122 | 55.7 | 14.8 | 13.9 | — | 1.6 | — | 1.6 | 4.1 | 0.8 | 4.1 | 2.5 | 0.8 | — | — | — |
| | III | 44 | 2.3 | — | 25.0 | 2.3 | 18.2 | 29.5 | 6.8 | — | — | — | 2.3 | 6.8 | 6.8 | — | — |
| 1-14 Aug | I | 52 | 36.5 | — | 5.8 | 50.0 | 5.8 | — | — | — | 1.9 | — | — | — | — | — | — |
| | II | 60 | 51.7 | 20.0 | 8.3 | 5.0 | 1.7 | 1.7 | — | 1.7 | 1.7 | — | 3.3 | — | 1.7 | 3.3 | — |
| 15-31 Aug | I | 6 | 50.0 | 16.7 | — | — | — | — | — | — | 33.3 | — | — | — | — | — | — |
| | II | 32 | 31.3 | 28.1 | 6.3 | 9.4 | 3.1 | 6.3 | 3.1 | 3.1 | 3.1 | 3.1 | — | — | — | — | 3.1 |
| Sep | I | No Sample | | | | | | | | | | | | | | | |
| | II | 21 | 33.3 | 28.6 | — | 28.6 | 4.8 | — | 4.8 | — | — | — | — | — | — | — | — |
| Summary | — | 381 | 43.1 | 12.4 | 12.4 | 10.2 | 5.5 | 4.2 | 2.6 | 1.8 | 1.6 | 1.6 | 1.6 | 1.1 | 1.1 | 0.5 | 0.3 |

*I = RM 12-34, II = RM 35-48, III = RM 49-63

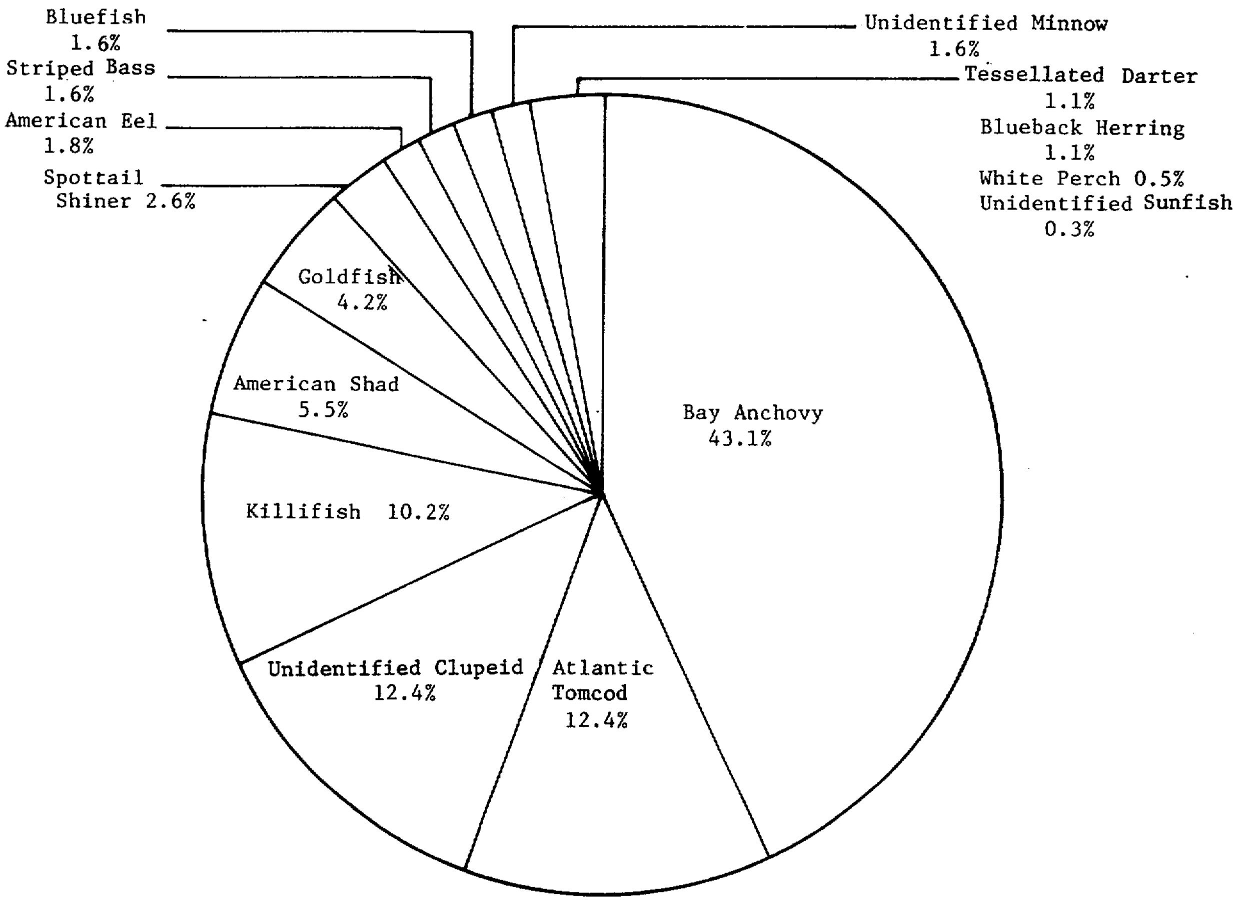



Figure II-2. Identifiable Fish Found in Bluefish Stomachs by Percent, RM 12-63, Hudson River, New York, June-September 1974

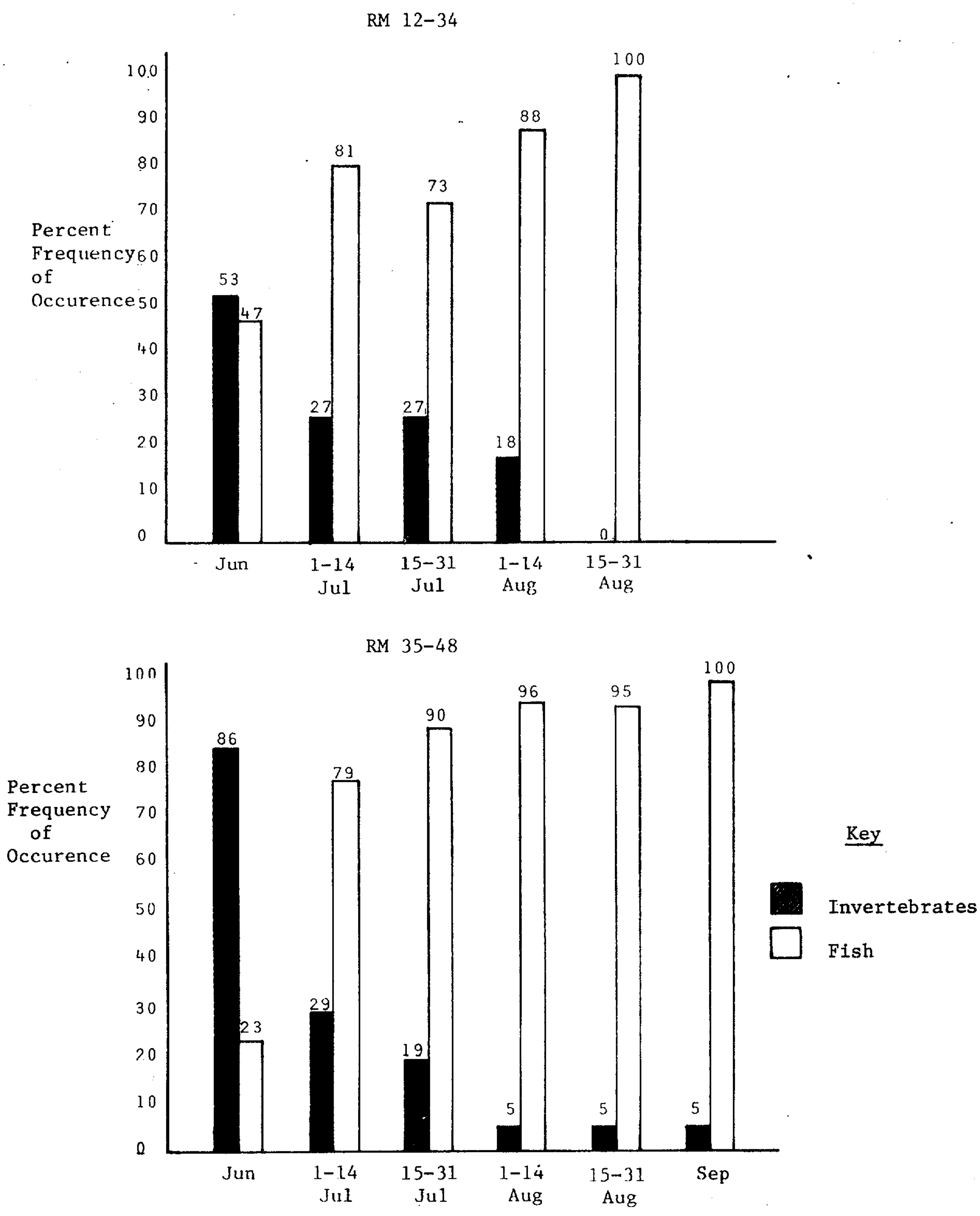



Figure II-3. Percent Frequency of Occurrence of Fish and Invertebrates in Bluefish Stomachs Containing Food, RM 12-34 and 35-48, Hudson River, New York, June-September 1974

Stomach examination showed that in both Regions I and II stomach contents and numbers of fish ingested through June until mid-July were similar (Appendix Figures A-1 and A-2). After mid-July, diversity and number of fish recovered from bluefish stomachs was greater in Region II (Appendix Figures A-3 through A-7). Temporally, both regions showed a gradual increase in the incidence of fish in bluefish stomachs until mid-August at which time numbers decreased.

The regression equation of orbit-operculum length versus total length of the reference Atlantic tomcod was $Y = 17.9341 + 0.2869X$ ($r = 0.9298$). Reconstructed total lengths of Atlantic tomcod with 95% confidence limits, and the total lengths of the bluefish that ate these fish are shown in Table II-4. The reconstructed total lengths of Atlantic tomcod are plotted against the total length of bluefish which ate the Atlantic tomcod (Figure II-4). The correlation coefficient ($r = 0.5998$) was significantly different from zero ($p = 0.052$).

Table II-4

Total Length (TL) of Bluefish and Estimated Total Length of Atlantic Tomcod Eaten by These Bluefish, RM 12-48, Hudson River, New York, 15 July-September 1974

| | Atlantic Tomcod | |
|---|---|---|
| Bluefish, TL (mm) | Reconstructed TL (mm) | 95% Confidence Interval |
| 118 | 75 | 75 ± 5.45 |
| 121 | 80 | 80 ± 5.48 |
| 137 | 67 | 67 ± 5.52 |
| 113 | 62 | 62 ± 5.65 |
| 146 | 81 | 81 ± 5.49 |
| 161 | 90 | 90 ± 5.70 |
| 134 | 57 | 57 ± 5.81 |
| 130 | 85 | 85 ± 5.57 |
| 152 | 72 | 72 ± 5.45 |
| 153 | 78 | 78 ± 5.46 |
| 186 | 86 | 86 ± 5.58 |
| Mean 141.0 | 75.7 | |
| Standard Deviation 21.5 | 10.4 | |

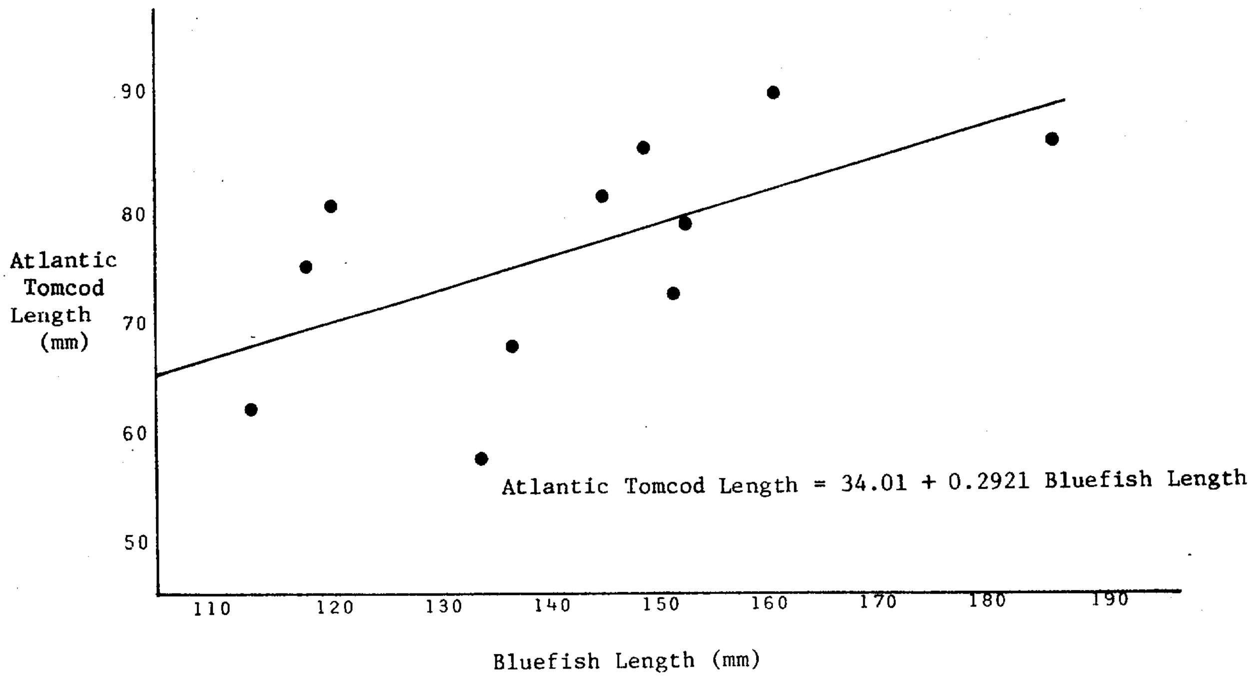



Figure II-4. Predator Length vs Prey Length, RM 12-48, Hudson River, New York, 15 July-September 1974

SECTION III

DISCUSSION

## A. PREDATION

Although unpublished results of a preliminary predatory study conducted in August 1973 by Texas Instruments indicated substantial predation by juvenile bluefish on striped bass, little corraborative data was collected during this study. During the preliminary predator study, contents of 33 young-of-the-year bluefish stomachs were examined. Of these fish, seven contained striped bass and two contained unidentified *Morone* sp. However, only six striped bass were recovered from 1627 bluefish stomachs examined during 1974. Despite the greater number of bluefish stomachs examined, in 1974 the incidence of striped bass was different from results indicated by the preliminary study.

The low percentages and numbers of striped bass and white perch found in bluefish stomachs indicate that these species played minor roles in the diets of bluefish in the lower Hudson River during 1974. It would be unwarranted on the basis of a single year's data to expand this conclusion as a general statement for other years. During 1973, when striped bass year-class strength was high, a substantial incidence of bluefish predation on striped bass was indicated by our preliminary study. Conversely during 1974, when striped bass year-class strength was low (Texas Instruments, 1975b), examination of a greater number of bluefish showed predation of striped bass to be inconsequential compared to the 1973 findings. These results suggest density-dependent predation which is further supported when catch-per-unit-area (CPUA) figures from 1973 and 1974 are compared. The CPUA figures during 1973 were 1.3 for bluefish and 26.9 for striped bass as compared to 5.9 and 7.3, respectively, during 1974. This indicates that there was a greater number of striped bass per bluefish during 1973 as compared to striped bass per bluefish during 1974.

Predation by bluefish may be a function of prey density rather than selective feeding. CPUA data show that those species which were numerous in bluefish stomachs, i.e., bay anchovies, American shad, and Atlantic tomcod were abundant in the lower Hudson River during 1974 (Texas Instruments, 1975b). In both Regions I and II, bluefish stomachs contained predominantly bay anchovy, clupeids, and Atlantic tomcod. Nonselective feeding is further indicated when the diversity of species encountered in the river is compared to the diversity of fish recovered from bluefish stomachs collected on a longitudinal basis. Based on catch-per-unit-effort data, an increase in total species collected as sampling progressed upriver was noted (Texas Instruments, 1975b). A corresponding increase in the number of forage fish species found ingested by bluefish also occurred as the collection site for bluefish proceeded upriver. A total of nine different fish species were found in bluefish stomachs from Region I and fifteen fish species were identified from Region II stomachs. When feeding, bluefish pursue virtually anything in their path (Bigelow and Schroeder, 1953; Young, 1962), and what they eat would seem to be a function of what they encounter. Raney (1952) noted a similar occurrence for striped bass which tended to feed on the most abundant prey.

## B. SIZE-RELATED PREDATION

A significant linear correlation ($p = 0.052$) was found when the reconstructed lengths of ingested tomcod were plotted against the lengths of bluefish that ate tomcod. This correlation indicates that the larger the bluefish, the larger the prey upon which they feed. A similar occurrence was also noted for the size of invertebrates consumed.

A general trend in size of food ingested and bluefish size was noted. During June, smaller invertebrates, copepods, dipterans, and cladocerans were the main food items found in bluefish stomachs. After June, fish constituted the main portion of the bluefish diet. Invertebrates encountered thereafter consisted mainly of the larger members of the orders Amphipoda, Isopoda, and Decapoda. This change in feeding occurred within 1 month and may be a function of growth of bluefish to a size at which available species of forage fish could be effectively used as prey. This same occurrence has been noted for many species of fish, specifically, striped bass which become almost totally piscivorous after attaining total lengths > 200 mm (Texas Instruments, 1973; 1974).

## C. STOMACH CONTENTS

The high incidence of empty bluefish stomachs and the food items consumed differed from studies conducted by other researchers. In a study by Grant (1962) working on the Indian River, Delaware, 80% (209 of 262) of the juvenile bluefish examined contained food, a much higher percentage than the 36% encountered in the present study. Spotte (1973) stated that bluefish are daytime feeders; therefore, the absence of nighttime samples should not have been a factor in the low incidence of food. Grant also found that polycheates and the oppossum shrimp *Neomysis americana* were the most commonly occurring invertebrates in the bluefish stomachs he examined. Although several species of polycheates and the oppossum shrimp are characteristically found in the regions from which bluefish were sampled, neither were found in the bluefish stomachs examined during 1974. Causal relationships for these differences cannot be explained on the basis of our data.

SECTION IV

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# APPENDIX

## IDENTIFIABLE FISH FOUND IN BLUEFISH STOMACHS BY PERCENT

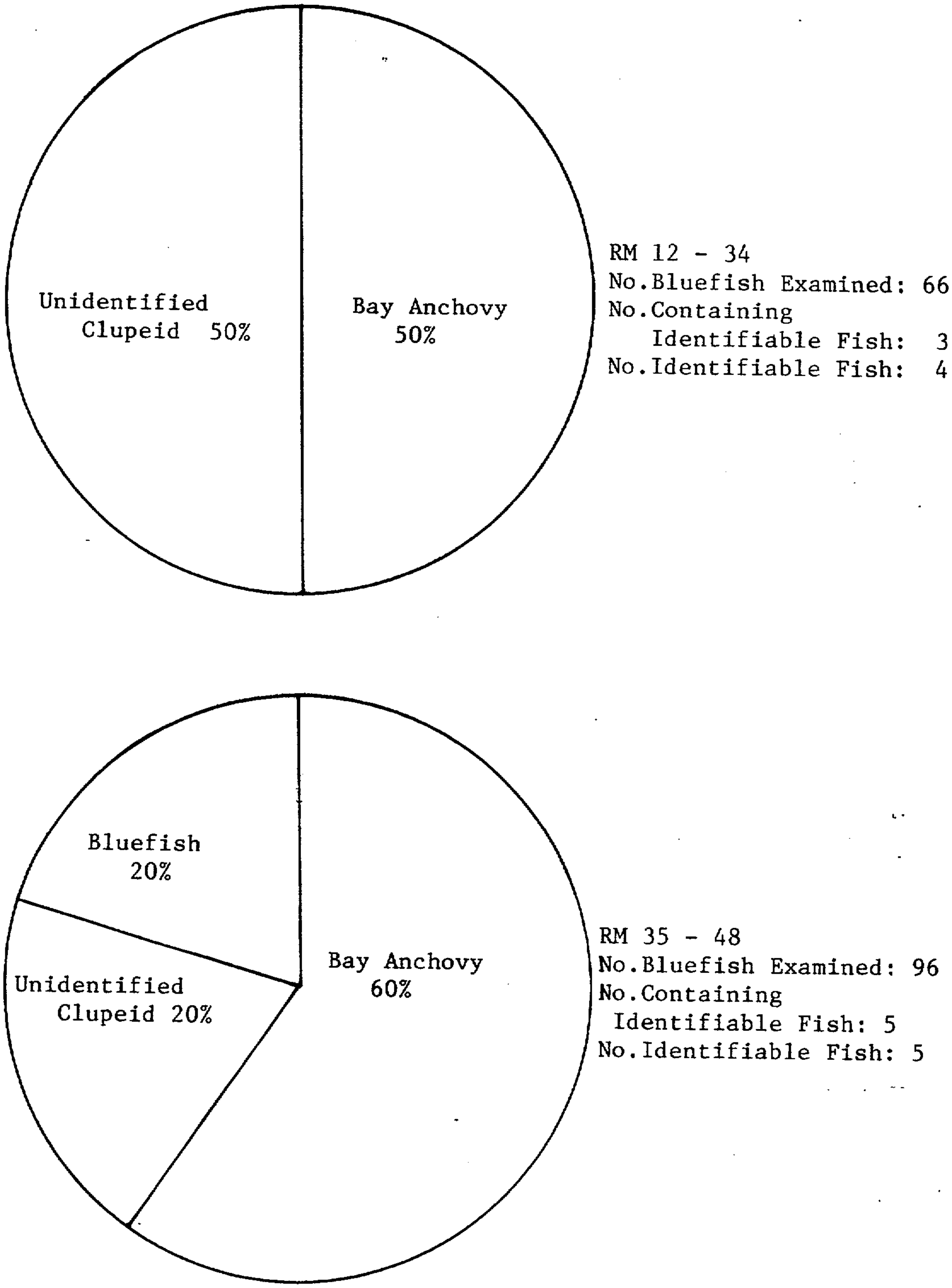



Figure A-1. Identifiable Fish Found in Bluefish Stomachs by Percent Number, Hudson River, New York, June 1974

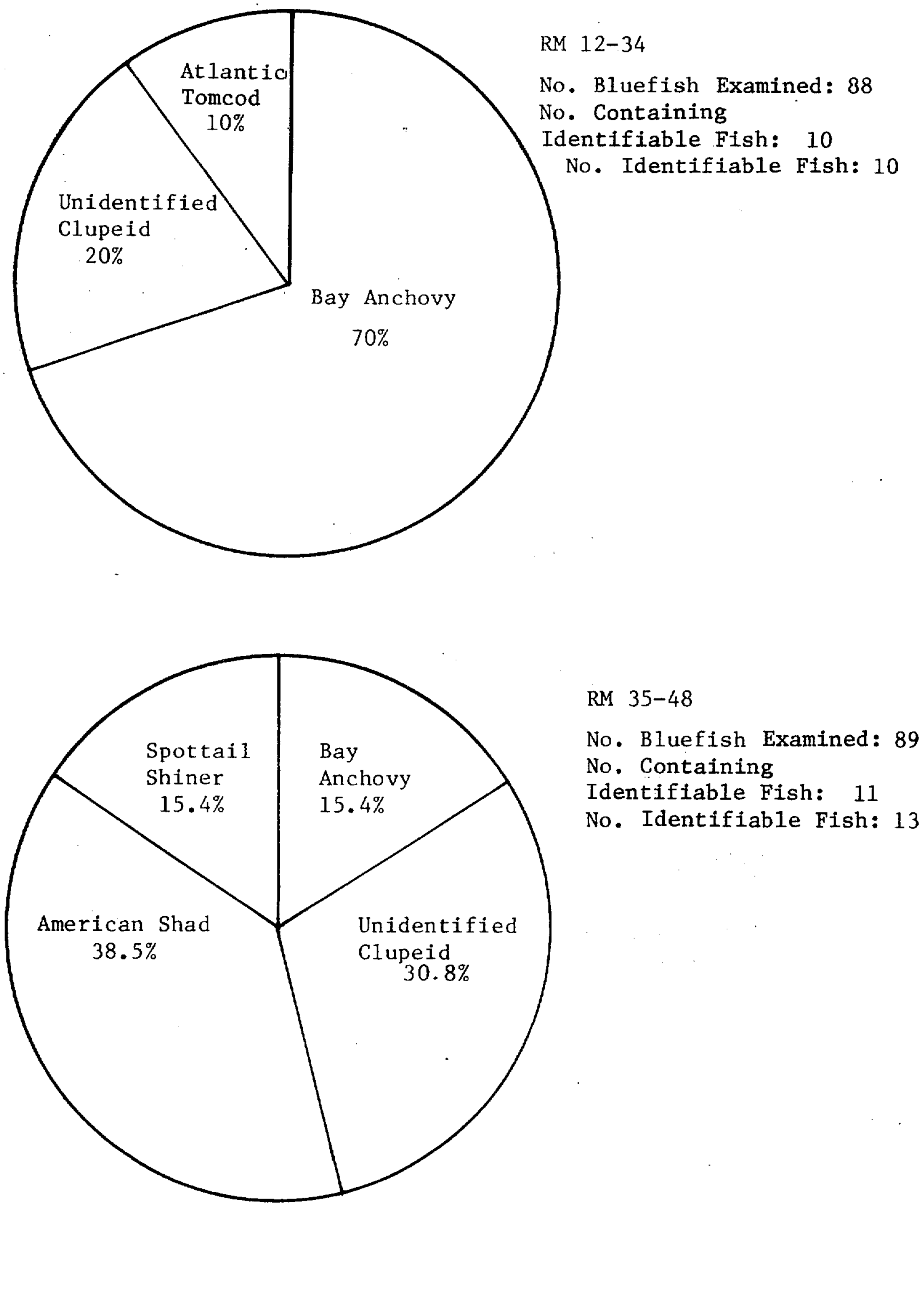
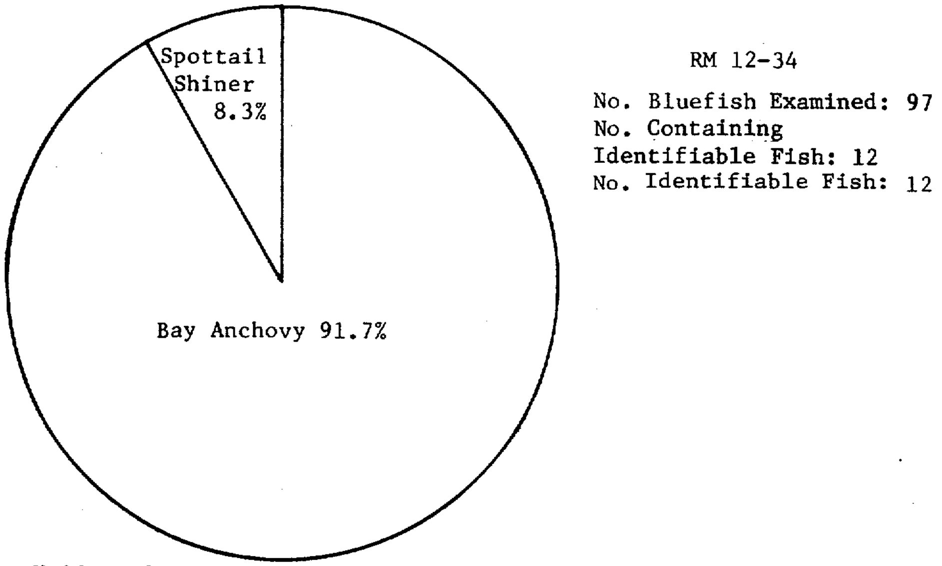



Figure A-2. Identifiable Fish Found in Bluefish Stomachs by Percent Number, Hudson River, New York, 1-14 July 1974



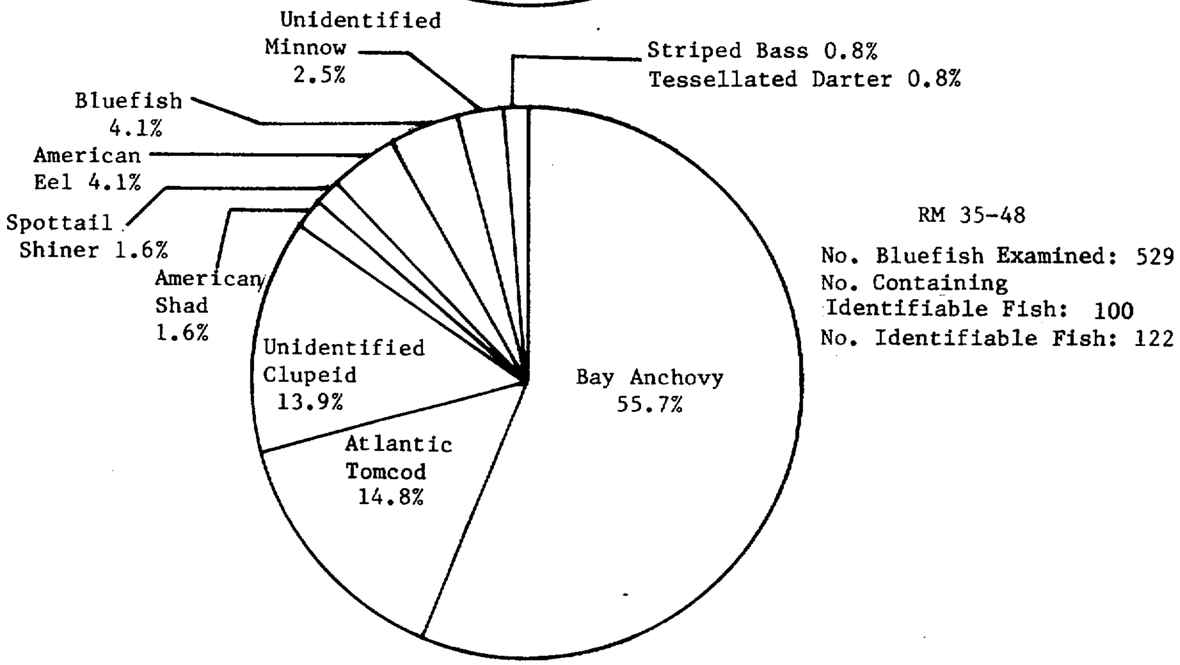




Figure A-3. Identifiable Fish Found in Bluefish Stomachs by Percent Number, RM 12-34 and 35-48, Hudson River, New York, 15-31 July

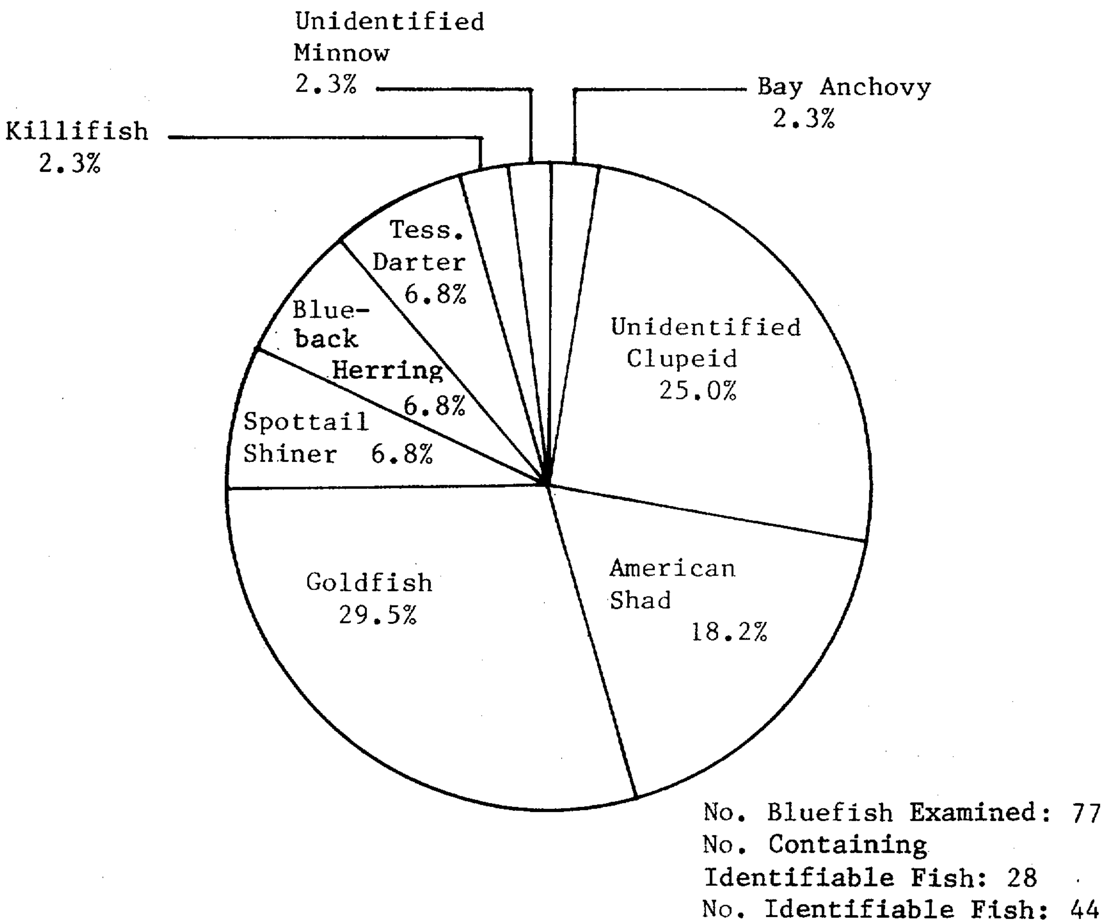



Figure A-4. Identifiable Fish Found in Bluefish Stomachs by Percent Number, RM 49-63, Hudson River, New York, 15-31 July 1974

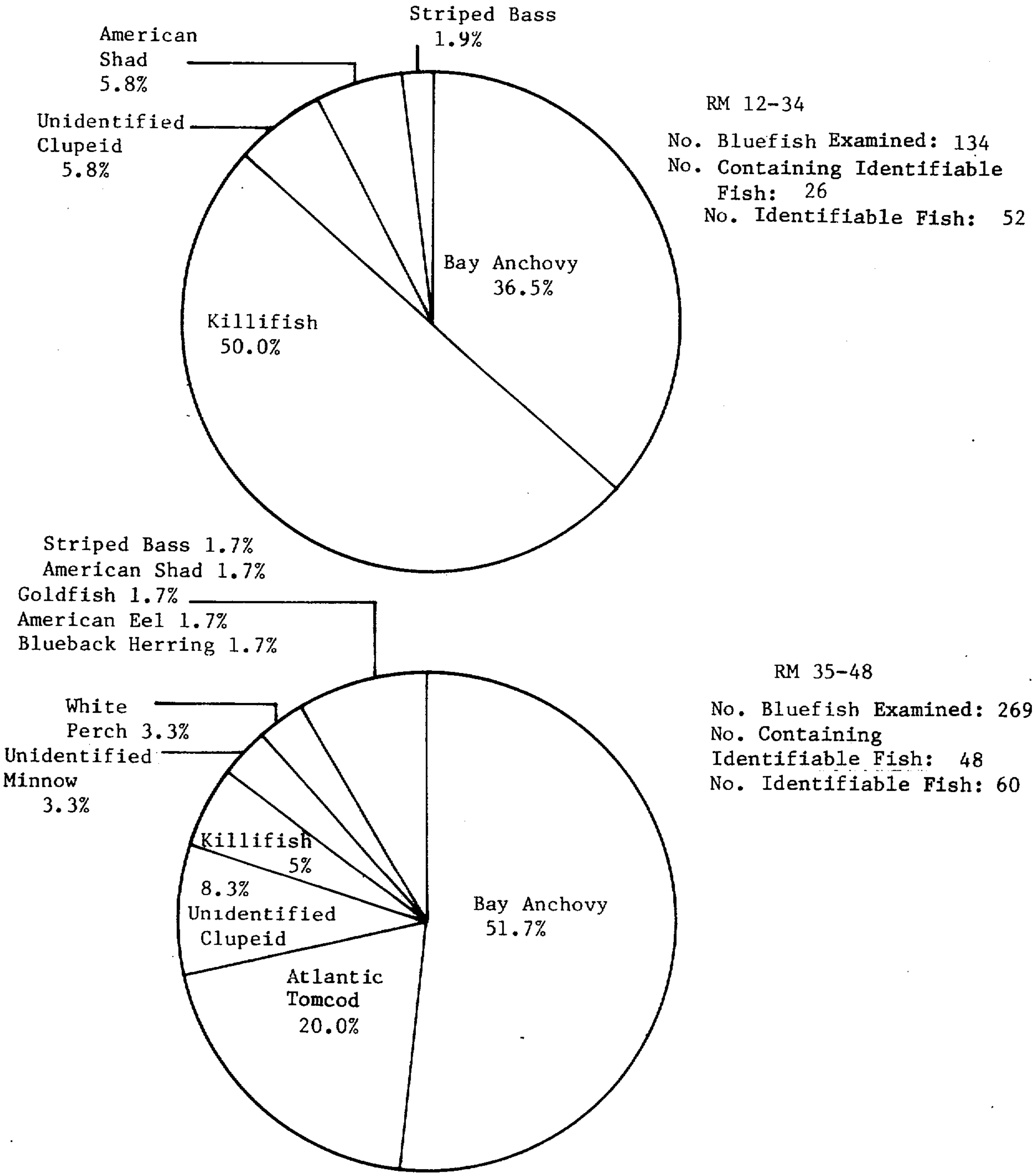



Figure A-5. Identifiable Fish Found in Bluefish Stomachs by Percent Number, Hudson River, New York, 1-14 August 1974

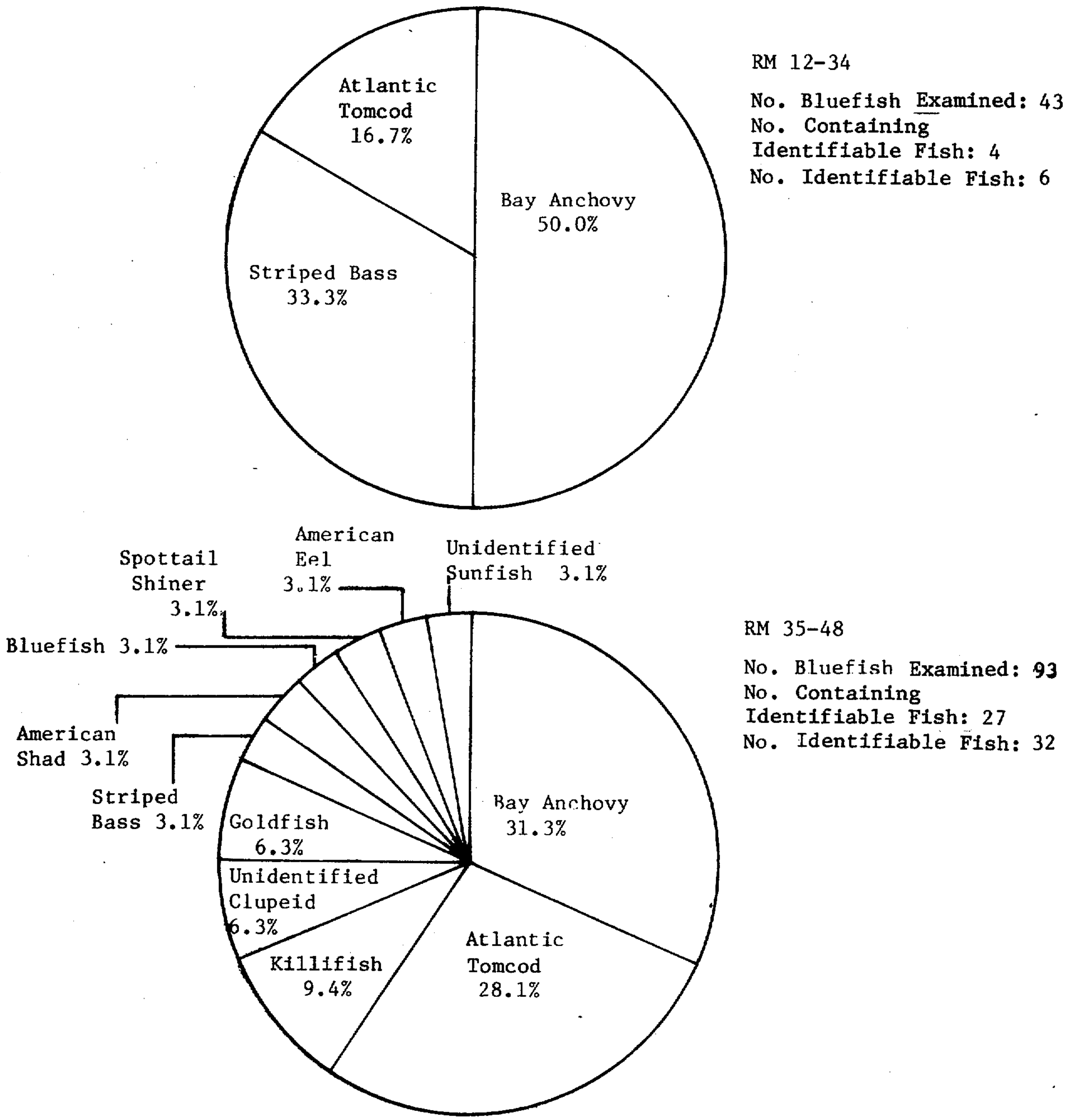



Figure A-6. Identifiable Fish Found in Bluefish Stomachs by Percent Number, Hudson River, New York, 15-31 August 1974

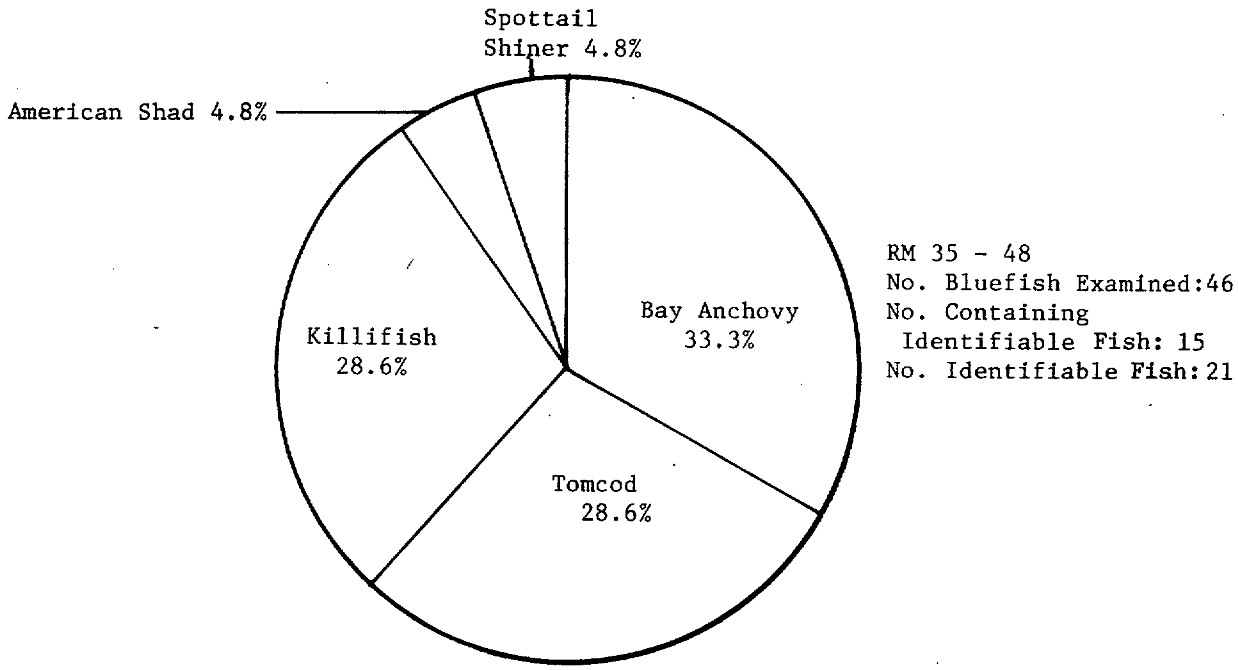



Figure A-7. Identifiable Fish Found in Bluefish Stomachs by Percent Number, Hudson River, New York, September 1974

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Predation by Bluefish in the Lower Hudson River

February, 1976

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