these tests were conducted during March–April when juvenile mackerels are rare in the coastal waters of South Carolina.

In 1986 we collected juvenile mackerels during July through October. Because of incomplete temporal sampling, we do not know if they were present earlier and later in the year in this region. Based on the occurrence of early larval stages, spawning of both mackerels in the South Atlantic Bight extends from May through at least September (Collins and Stender 1987). If growth rate estimates of ca. 3 mm/day for juveniles are correct (M. R. Collins, unpubl. data), king mackerel spawned in early May could be recruited into the bycatch of the shrimp fishery in June. Late-spawned fish from the previous year may also be present at this time. In South Carolina, the open season for commercial trawling for penaeid shrimps in state waters usually extends from June through December, which coincides with the presence of juvenile mackerels in the heavily fished nearshore waters. In addition, mackerels were much more abundant in tows made in depths $<9$ m, which includes the preferred shrimping areas, than in deeper waters. This may be due either to greater abundance in these depths or to greater catchability in response to the fact that the trawl nets fish a larger portion of the water column in shallower areas.

It is difficult to accurately estimate the bycatch of mackerels in the commercial shrimp fishery owing to lack of current, detailed information from throughout the region on number of vessels, effort expended, gears used, and areas fished. However, our catch rates suggest that the impact of tongue nets on mackerel stocks may be significant. As the current status of these stocks is such that strong restrictions have been imposed on both the recreational and commercial fisheries, it is unfortunate that the situation may be exacerbated by a potentially large bycatch of juvenile mackerels in the shrimp fishery. More information is needed on the ecology and behavior of young mackerels, and their vulnerability to various gears, in order to resolve this conflict.

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# STOMACH CONTENTS OF COMMERCIALLY CAUGHT HUDSON RIVER STRIPED BASS, *MORONE SAXATILIS*, 1973–75

The Hudson River estuary is a detritus-driven ecosystem. Only a few of the 100 or more reported fish species function as tertiary piscivores more typical of a grazing food chain. Of these few species, which include the American eel, *Anguilla rostrata*, and the summer-transient juvenile bluefish, *Pomatomus saltatrix*, striped bass, *Morone saxatilis*, are probably the most important in terms of biomass and commercial value. However, commercial fishing for the American eel and striped bass has been banned in the Hudson since 1976 because both species are contaminated with higher levels of toxic polychlorinated biphenyls (PCB's) than most other Hudson River fish species.

To date, only one published paper has touched upon the diet of prespawning Hudson River striped bass larger than 400 mm TL (Gardinier and Hoff 1982), and their results for fish of that size are based on less than 10 samples for which fish remains were identified to species or family level. The present paper describes the findings of stomach content analysis for 510 striped bass, most of which were prespawning adults larger than 400 mm TL (Fig. 1) collected during the spring months of 1973–75 by commercial gill nets in the Tappan Zee region of the Hudson River.

### Description of Sampling Area and Methods

The Tappan Zee gill-net fishery is located approximately 90 m south of the Tappan Zee Bridge at river km 43.5 (measured from the Manhattan Battery) in a relatively shallow section that is 4.5 km wide, a location through which many of the spawners move on the way to upstream spawning grounds. The staked gill nets were set perpendicularly to the north-south current in water depths of 2.4–9.8 m and spanned a distance of approximately 1.6 km out to the dredged channel on the east side of the river. Stretched mesh sizes were 11.4, 11.8, 12.1, 12.7, 13.3, and 14.0 cm. Water temperatures during the sampling period ranged from approximately 6° to 19.5°C, and the salinity was essentially that of freshwater, rarely rising above 300 mg/liter. Sampling dates included the following periods in each year: 28 March–9 May 1973, 8 April–20 May 1974, and 6 April–19 May 1975. Fish were collected from the nets at 8–12 h intervals, placed on ice, and taken directly to a laboratory for total length (TL) measurements and stomach content analysis. Prey items were identified with the aid of a binocular dissecting scope and frequency of occurrence was noted.

## Results

### Stomach Content Analysis

A summary table of stomach content data, pooled for the three years of analysis (Table 1), shows that adult, prespawning striped bass were highly piscivorous and that 89% of the stomachs containing identified food items contained fish and 21% contained invertebrate remains, primarily those of *Crangon* species. Clupeid species were the most prevalent fish, with blueback herring, *Alosa aestivalis*, predominating. Most of the clupeids were adult, prespawning herring, approximately 200 mm TL.

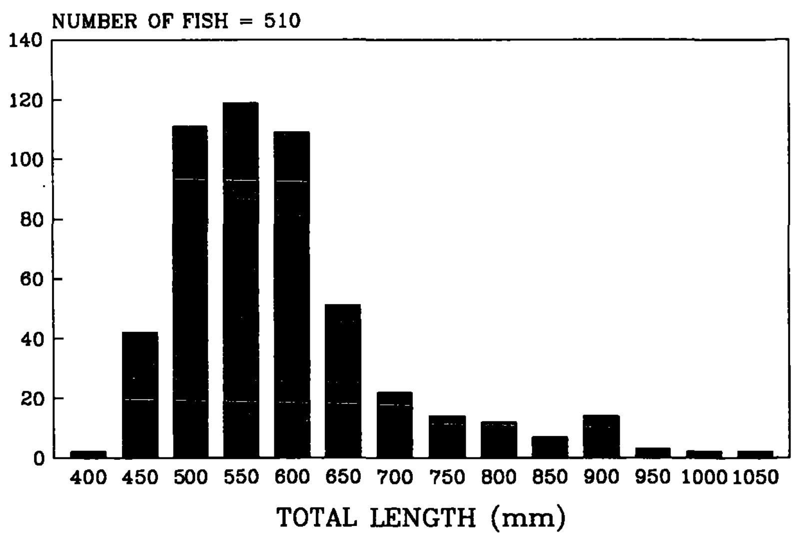


FIGURE 1.—Length distribution of Hudson River striped bass examined for stomach contents.

TABLE 1.—Stomach contents of adult prespawning striped bass collected by commercial gill net during spring 1973, 1974, and 1975.

| Food item | Number of stomachs in which item occurred | % Frequency of occurrence based on total stomachs analyzed ($n$ = 510) | % Frequency of occurrence based on number of stomachs containing identified food items ($n$ = 201) |
|---|---|---|---|
| Fish | 179 | 35.1 | 89.1 |
| Clupeidae | 73 | 14.3 | 36.3 |
| *Alosa pseudoharengus* | 13 | 2.5 | 6.5 |
| *Alosa aestivalis* | 29 | 5.7 | 14.4 |
| *Brevoortia tyrannus* | 3 | 0.6 | 1.5 |
| Clupeidae | 28 | 5.5 | 13.9 |
| *Morone* spp. | 9 | 1.8 | 4.5 |
| *Morone americana* | 6 | 1.2 | 3.0 |
| *Morone saxatilis*[1] | 1 | 0.2 | 0.5 |
| *Morone* spp. | 2 | 0.4 | 1.0 |
| Other fish | 29 | 5.7 | 14.4 |
| *Ammodytes americanus* | 14 | 2.7 | 7.0 |
| *Microgadus tomcod* | 7 | 1.4 | 3.5 |
| *Osmerus mordax* | 2 | 0.4 | 1.0 |
| *Syngnathus fuscus* | 2 | 0.4 | 1.0 |
| *Anchoa mitchilli* | 2 | 0.4 | 1.0 |
| *Ictalurus catus* | 1 | 0.2 | 0.5 |
| *Scomber scombrus* | 1 | 0.2 | 0.5 |
| Unidentified fish remains | 68 | 13.3 | 33.8 |
| Invertebrates | 43 | 8.4 | 21.4 |
| *Crangon* spp. | 38 | 7.5 | 18.9 |
| *Polychaeta* | 5 | 1.0 | 2.5 |
| Unidentified contents | 11 | 2.2 | Not applicable |
| Total stomachs analyzed | | | 510 |
| Number (percent) containing identified food items | | | 201 (39.4) |
| Number (percent) containing food material (identified and unidentified) | | | 212 (41.6) |
| Number (percent) empty | | | 296 (58.4) |

[1]Two yearling striped bass in female collected 15 April 1974.

The next most abundant fish prey species in the composite 1973–75 sample was the American sand lance, *Ammodytes americanus*. Sand lance were present in striped bass stomachs only during 1975, when the frequency of occurrence was about 11% (Fig. 2). Atlantic tomcod, *Microgadus tomcod*, were found in striped bass stomachs only during 1973 when the frequency of occurrence was about 20%, somewhat higher than the frequency of clupeid species for that year (Fig. 2). These fish were yearling, postspawning Atlantic tomcod averaging about 125 mm TL. The *Morone* species, white perch, *M. americana*, and striped bass, had a frequency of occurrence of 4.5% for the composite sample and were present in striped bass stomachs every year (Fig. 2).

## Discussion

Similar to findings in this study, Trent and Hassler (1966) found that blueback herring were predominant in the diet of adult, prespawning striped bass from the Roanoke River, NC, and Manooch (1973) found that herring ranked second after Atlantic menhaden, *Brevoortia tyrannus*, in the spring diet of adult striped bass from Albemarle Sound, NC. Data from Gardinier and Hoff (1982) do not indicate that blueback herring or clupeids were important in the diet of prespawning Hudson River striped bass collected during 1976 and 1977, but fish remains in bass stomachs were generally not identified to the family or species level in their study.

American sand lance are rarely found over muddy bottoms (Bigelow and Schroeder 1953; Leim and Scott 1966) or within estuaries (Massman 1960; Norcross et al. 1961), but they ranked second only to blueback herring in the diet of Hudson River striped bass. Sand lance were not reported from the Hudson River prior to 1975 when adults and larvae were relatively abundant in February–April ichthyoplankton collections south of the Tappan Zee Bridge (Dew and Hecht 1976). Data from the present study (Fig. 2) and from early spring ichthyoplankton sampling during 1976 (Dew, unpub. data), indicate that sand lance are not abundant every year in the Hudson, but it is probable that during some years adult sand lance serve as important alternate prey for prespawning striped bass.

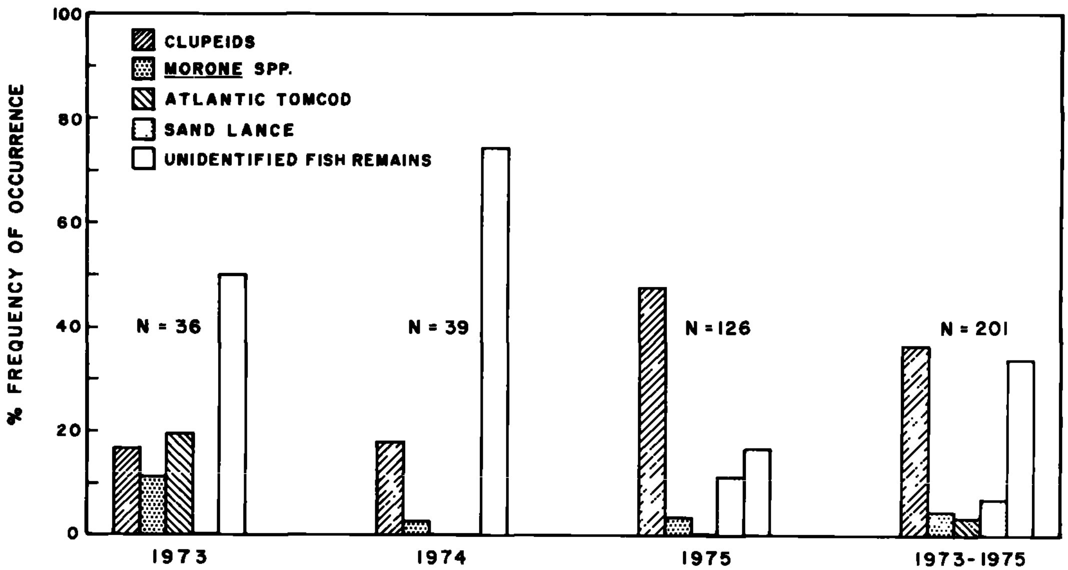


FIGURE 2.—Percent frequency of occurrence of fish prey categories based on number of stomachs containing identified food.

The fact that Atlantic tomcod were found only during 1973 may be due to a sampling artifact because 1973 was the only year in which March samples were taken, and all tomcod prey were found during March 1973. In March, gravid alewives, *Alosa pseudoharengus*, and blueback herring have not yet moved into the estuary and, prior to the arrival of these apparently preferred prey species, Atlantic tomcod may serve as an alternate forage fish. Thus the winter-spawning Atlantic tomcod may be a regular diet item at a time when alternate prey species are not available.

It is evident from Table 1 that there are several alternate fish prey for striped bass in the Hudson River (e.g., blueback herring, sand lance, alewife, Atlantic tomcod, white perch, and striped bass), and it is expected that striped bass predation upon these species would be of a compensatory nature. In a simple predator-prey situation where there are no alternate prey, predation is often depensatory (Neave 1953) because a population of predators would tend to seek out and consume a high proportion of small year classes and a lower proportion of strong year classes. In a more complex community where there are several species of prey, predation may be compensatory if predators change their feeding habits in response to the availability of food (Ivlev 1961; Forney 1971). That is, if several equally suitable prey species were available within a system, the predator species would tend to feed more heavily on the most abundant species, thus acting in a compensatory manner.

The ratio of white perch to striped bass in stomach samples identified to the species level is 6:1 (Table 1). This ratio is based on a small sample size, but it closely approximates the long-term average ratio of 5.9:1 for annual CPUE values for white perch and striped bass collected in several hundred bottom trawls from the Haverstraw Bay region (Milepoint 36) during 1971–77 (Lawler, Matusky and Skelly Engineers unpubl. data). In other words, yearling and older white perch and yearling striped bass may be equally attractive prey species, and their frequency of occurrence in adult striped bass stomachs may depend primarily upon the frequency of random encounters rather than active prey selection. If this were true, the frequency of cannibalism should be greatest during those years when the abundance of yearling striped bass relative to white perch (and other species) was greatest.

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## ACCUMULATION OF AGE PIGMENTS (LIPOFUSCIN) IN TWO COLD-WATER FISHES

In fisheries management, age structured models are the preferred method for meeting the key objectives of estimating optimal yields and determining the effect of fishing on stock structure (Gulland 1978). However, few species of commercial marine fishes exist in which age can be determined with certainty (Boehlert 1985). The concentration of age pigments (lipofuscin) (Ettershank 1984) in fish tissues (Agius and Agbede 1984) may be a measure of fish age that could be used to validate other ageing techniques and might also improve estimates of age of long-lived species where other techniques are difficult to apply.

Lipofuscin originates in biological membranes through lipid peroxidation (Tappel 1975). Lipofuscin accumulation has been documented for a wide variety of animals, from mammals to the bread-mold *Neurospora* (Ettershank et al. 1983 and references therein). The rate of accumulation has been shown to be constant during the lifetime of laboratory-raised mice (Reichel 1968; Miquel et al. 1978), dogs (Munnell and Getty 1968), fleshflies (Ettershank et al. 1983); man (Strehler et al. 1959); and also wild populations of mice (Dapson et al. 1980). On the other hand, the rate of lipofuscin accumulation has been shown to vary with level of activity and lifespan (Sohal and Donato 1978). It is expected that the rate in which lipofuscin accumulates with age in a natural population of fishes, or stock, with its free genetic interchange and likely common habitat, would be fairly uniform (but see Smith 1987). In addition, if measurements are made in nonmitotic and constantly metabolizing tissues such as brain or myocardium, the variation in concentration due to environmental effects is least likely.

In this paper we present the results of a preliminary study designed to assess the usefulness of extracted lipofuscin as a method of ageing fishes. Two species of cold-water fishes are included: the rainbow trout, *Salmo gairdneri*, reared in captivity, and of known age; and the Dover sole, *Microstomus pacificus*, a long-lived fish, in which age is not known with certainty. We present spectral characteristics of the extracted lipofuscin from several tissues and the change in concentration of lipofuscin with fish age.