Foraging Ecology of Bald Eagles on the Northern Chesapeake Bay
with an
Examination of Techniques Used in the Study of Bald Eagle Food Habits

by

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(ABSTRACT)

We monitored distribution and abundance of food resources and determined food habits of nonbreeding bald eagles (*Haliaeetus leucocephalus*) on the northern Chesapeake Bay, as a preliminary step toward examining food-base effects on bald eagle distribution and abundance. To correctly interpret our food habits results, we first examined biases of 2 commonly-used food habits techniques, pellet analysis and food remains collection, through feeding trials with 2 captive bald eagles. Eagles were fed a variety of food items found on the northern Bay. Egested pellet contents and frequency of remains were compared with actual diet. We also examined efficacy of direct observation by observing eagles in high-use foraging areas. We found pellet analysis accurately indicated the species of birds and mammals eaten, but overrepresented medium-sized mammals and underrepresented large carrion in percent occurrence results. Fish were poorly represented in pellets. Eagles rarely produced pellets after eating fish, suggesting that pellet egestion rate, defined as the number of pellets produced per eagle per night, can serve as an index to relative use of birds and mammals. Food remains collection was highly biased toward birds, medium-sized mammals, and large, bony fish. Direct observation was labor intensive and required close proximity of the observer for unbiased identification of food items. Observation may be the only means of documenting eagles′ use of small, soft-bodied fish.

We used direct observation, pellet analysis, and pellet formation rates to determine bald eagle food habits from December 1986 through April 1988. We monitored fish abundance by gillnetting and waterfowl abundance by aerial surveys over this same period. Fish and

waterfowl abundance varied reciprocally; waterfowl numbers peaked in winter and fish numbers peaked in spring and late summer. Bald eagles responded to differences in food abundance with diet shifts. Canada geese (*Branta canadensis*), mallard (*Anas platyrhynchos*), and white-tailed deer (*Odocoileus virginianus*) carrion were primary foods from November through February. Cold-stressed gizzard shad (*Dorosoma cepedianum*) were captured frequently by eagles below a hydroelectric dam on the Susquehanna River in November and December, and also were taken frequently throughout the study area during a winter when ice cover was extensive. Shad were not commonly available during a milder winter. From April through September, bald eagles fed on a variety of fish species, primarily gizzard shad, channel catfish (*Ictalurus punctatus*), Atlantic menhaden (*Brevoortia tyrannus*), white perch (*Morone americana*), American eel (*Anguilla rostrata*), and yellow perch (*Perca flavescens*). The 4 most commonly consumed fish species also were the most commonly gillnetted species. At least 25% of all fish taken were scavenged. Live fish were most abundant at the water's surface in shallow water. Bald eagles' use of live fish reflected this availability; water depth at live fish capture sites was less than at sites where fish of dead or unknown status were taken. Eagles foraged most intensively within 1 hour of sunrise. A second smaller peak in foraging activity was observed in early afternoon.

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INTRODUCTION

Coincident with the rise of public interest in nongame wildlife, research on raptor ecology and management has increased exponentially (Olendorff 1980:3). The bald eagle, because of its endangered status and symbolic appeal, has received a large proportion of this research effort (see Lincer et al. 1979). However, because these highly mobile birds are much easier to study when restricted by nesting activities, most of this research has focused on breeding birds. Additional emphasis on breeding eagles resulted from concern about DDT-induced reproductive failures. The recovery of reproductive rates since the DDT ban (Grier 1982) has made other aspects of bald eagle biology increasingly important to effective management. Characteristic of K-selected species, bald eagle populations are more sensitive to changes in survival rates than in reproductive rates (Young 1968, Grier 1980); yet little is known about factors affecting survival of immatures and nonbreeding adults. To improve our ability to manage this endangered species, researchers must begin to address the ecology of this portion of the population.

With these research needs in mind, the Virginia Tech Department of Fisheries and Wildlife Sciences, under contract to the U.S. Army Chemical Research, Development, and Engineering Center, began a study of bald eagles on the northern Chesapeake Bay in 1983. This study was designed to 1) determine the distribution and abundance of bald eagles on the northern Chesapeake Bay, and 2) determine the relative importance of environmental factors affecting this distribution. Eagle distribution and abundance on the study area were documented by aerial shoreline surveys, aerial telemetry of radio-tagged eagles, and counts in communal roosts. Environmental factors examined to date include human disturbance and development, food distribution and abundance, and vegetative and microclimatic characteristics of perches and roosts (Buehler, Ph.D. Thesis in progress, Virginia Tech). Breeding birds composed a small fraction of the eagle population using the northern Bay; therefore, results from this study apply primarily to the target population of immature and nonbreeding eagles.

In this thesis, I present research designed as a first step toward investigating how bald eagle distribution and abundance is influenced by food distribution and abundance, a factor often cited as primary in its effect on raptor numbers and distribution (Newton 1979:290). To adequately examine the effect of this important factor, we needed supporting information on local bald eagle foraging ecology. Primary information required was a determination of eagle food items, and measurement of their distribution in time and space. Thus, we conducted a food habits study and monitored abundance of major foods. As we began the food habits study, obvious biases prompted us to examine the reliability of common food habits techniques through feeding trials with captive eagles. Additionally, extensive observations of foraging eagles allowed us to explore some behavioral aspects of bald eagle foraging ecology.

Objectives for the research presented in this thesis, listed in order of treatment, were to

1. Examine biases of techniques commonly used to determine bald eagle food habits.

2. Describe seasonal and geographic variation in abundance of important food species on the northern Chesapeake Bay.

3. Determine food habits of northern Chesapeake bald eagles.

4. Investigate behavioral and physiological responses of bald eagles to periods of food scarcity.

STUDY AREA

We conducted our study on the northern Chesapeake Bay, from the Conowingo Dam on the Susquehanna River to the Bay Bridge at Annapolis. Included in the study area are portions of the Susquehanna, Northeast, Elk, Bohemia, Sassafras, Bush, Gunpowder, and Chester rivers and interlying lands. Although we studied eagle distribution and abundance over this entire area, for logistical reasons we limited our foraging ecology investigations to 8 foraging areas (Fig. 1) that were known from telemetry and aerial surveys to be intensively used by eagles (Buehler, Ph.D. Thesis in progress). These selected areas included the highest use sections of bay, river, and creek habitats on either side of the Bay (Foraging Areas 1 through 6). Also targeted for intensive study was the Susquehanna River below Conowingo Dam (Foraging Area 7), and Remington Farms Wildlife Management Demonstration Area and surrounding farmland (Foraging Area 8).

The waters of the northern Chesapeake Bay within the study area range from fresh to slightly brackish, with salinities of < 6 ppt in spring and approximately twice that in fall (Lippson 1973:6, Environmental Protection Agency 1982:11, Chesapeake Bay Living Resources Task Force 1987:12). The northern Bay is relatively shallow (most water is < 10 m in depth; Lippson 1973:5), and the bottom substratum is primarily clayey-silt (Lippson 1973:8). Due in part to intensive mixing of fresh and salt water, water in the study area is the most turbid on the Bay (Lippson 1973:8, Environmental Protection Agency 1982:13, Chesapeake Bay Living Resources Task Force 1987:12). Waters here support fresh and brackish-water species of plants and animals, and are important spawning and nursery grounds for anadromous and estuarine fish (Lippson 1973, Chesapeake Bay Living Resources Task Force 1987:12).

The eastern and western shores of the Chesapeake Bay within the study area offer a dramatic contrast in terrestrial habitats. The western shore (including portions of Baltimore and its suburbs) is highly urbanized, except for the 2 peninsulas of the Aberdeen Proving Ground (APG). This U.S. Army restricted area is predominately undeveloped and used primarily for weapons testing. Most eagles found on the western shore were on APG (Buehler, Ph.D. Thesis in progress, Virginia Tech). Extensive forests are interrupted by test ranges, which provide scattered field habitat. Because slopes are slight, forested wetlands and marshes are extensive. Gently sloping shorelines provide large areas of water less than 1 m in depth.

In contrast, the eastern shore of the study area is composed primarily of large farms and small communities. Agricultural fields are interspersed with numerous ponds and woodlots. The shoreline is characterized by steep bluffs, and water depths increase quickly from the shore.

Lying within a steeply-sloped, forested valley, the Susquehanna River below Conowingo Dam (Foraging Area 7) is a broad shallow river with numerous islands and a primarily boulder substratum. Flow regimes vary widely due to power generation demands, frequently transforming the Susquehanna from a rapidly running, overflowing river, to a riverbed of exposed boulders and isolated pools.

Remington Farms and surrounding area (Foraging Area 8) is an inland site used extensively by bald eagles during certain periods of the year. The 1300 ha Remington Farms Wildlife Demonstration Area, operated by Remington Arms and Ammunition Company, is composed of agricultural fields, large woodlots, and numerous ponds. Management activities are designed to maximize duck- and goose-hunting opportunities for visiting clientele and include grain plantings, water level manipulations, and stocking of pen-reared mallards. Similar management activities are conducted by landowners on surrounding farmlands. Waterfowl hunting in this area is excellent and is a principal winter land use.

CHAPTER 1: AN EXAMINATION OF BALD EAGLE FOOD HABITS TECHNIQUES

INTRODUCTION

Early studies of raptor food habits (Fisher 1893, May 1935, McAtee 1935, Imler and Kalmbach 1955) focused on the economic impact of raptor predation and relied primarily on stomach contents analysis (Hartley 1948). As conservation ethics have evolved and research objectives have changed from economic analysis to ecological understanding, raptor food habits techniques have shifted from stomach analysis to less destructive, indirect methods, primarily pellet analysis and food remains collection. Direct observation is often used to supplement these techniques. Information typically sought from raptor food habits studies includes a list of food items and some measure of their relative importance, usually in terms of frequency and percent occurrence. Results also may be reported in terms of biomass, calculated by multiplying frequency of an item by its average weight (Steenhof 1983). Caloric contributions also may then be calculated. However, the accuracy of percent occurrence results, upon which further calculations are based, varies with each technique, as well as each species and situation, due to differences in each raptor's physiology, behavior, habitat use, and diet preferences (Errington 1930, 1932; Glading et al. 1943; Marti 1987).

Bald eagle food habits have been studied extensively. In addition to early studies based on stomach contents (Fisher 1893, May 1935, McAtee 1935, Imler and Kalmbach 1955), many researchers have focused on the foods of breeding eagles by analyzing food remains collected at nests, either alone (Tate and Postupalsky 1965, Dunstan and Harper 1975, Sherrod et al. 1976, McEwan and Hirth 1980, Cline and Clark 1981, Cash et al. 1985) or in combination with pellet analysis (Murie 1940) or some level of direct observation (Retfalvi 1970, Henke 1973, Todd et al. 1982, Haywood and Ohmart 1986). Herrick (1924) and Ofelt (1975) based studies solely on direct observation of nesting eagles. A few studies have focused on nonbreeders, using analysis of pellets collected in communal roosts (Imler 1937, Platt 1976, Steenhof 1976) or of food remains collected under feeding perches (Wright 1953, Steenhof 1976).

Although many authors report the likelihood of biases in their results, only Todd et al. (1982) attempted to quantify these biases. They found underrepresentation of fish and overrepresentation of birds in food remains when compared with direct observation at nests; however, sample size was small ($n = 35$ items). In contrast, Retfalvi (1970) noted overrepresentation of fish in remains relative to his direct observations; however, sample sizes again were small ($n = 45$ items), and remains were not exclusively from the observation period. Haywood and Ohmart (1986) claimed minimal differences between their direct observation and food remains results; however, my Chi-square analysis of their data showed a statistically significant bias against fish, reptiles and amphibians, and in favor of birds and mammals ($\chi^2 = 33.7$, 3 df, $P < 0.005$). Collopy (1983) found no difference in diet determined through direct observation versus food remains and pellet collections at golden eagle (*Aquila chrysaetos*) nests.

To better interpret our food habits results, we examined biases and feasibility of using these 3 food habits techniques -- pellet analysis, food remains collection, and direct observation -- to determine percent occurrence of items in bald eagle diets. We examined these techniques through feeding trials with 2 captive bald eagles and by directly observing foraging eagles. Specific objectives were 1) to compare percent occurrence of food items determined through pellet analysis with the actual diet of captive eagles, 2) to examine the types and frequency of remains left from common food items and their persistence along the Chesapeake Bay shoreline over time, and 3) to determine the efficacy of direct observation by watching eagles in the most highly-used foraging areas on the northern Chesapeake Bay. Although this study was designed to examine the conditions and food species found in the northern Chesapeake Bay, results are broadly applicable to all studies of bald eagle food habits.

METHODS

We conducted feeding trials with 2 captive immature bald eagles housed in 3 x 3 x 3 m cages with pea-gravel flooring. Both eagles were permanently injured by collisions with powerlines. Both were hatched in 1986, and were recovered in early fall of 1986 on the Chesapeake Bay. Eagle 1 sustained neurological damage resulting in a drooping right wing. Eagle 2 received an amputation of the right wingtip including 3 primaries.

Feeding trials were conducted for the first 2 weeks of each month from June 1987 through July 1988. For the remainder of the month, eagles were fed *ad libitum* commercial bird-of-prey diet (see Chapter 2). During each day of the feeding trials, we fed each eagle one of a variety of naturally occurring food items found on the Chesapeake Bay. Most food items were presented to the eagles so that food was taken and eaten from a natural perch (tree branch) approximately 10 cm diameter. Larger birds and mammals were presented on the cage floor. At the time of feeding, all remains from the preceding day's food item were collected and described. Pellets, when produced, also were collected daily. A screen trough under feeding perches facilitated remains and pellet collection and ensured that food portions dropped were not retrieved and eaten.

Pellets were oven-dried and dissected manually. Feathers, hair, scales, and other persisent food parts were identified by comparison with reference collections. Hairs also were identified by shape, color, and medulla pattern (Mathiak 1938, Stains 1958, Moore et al. 1974). Each species identified within each pellet was recorded as 1 occurrence. These procedures were the same as those used to analyze pellets collected in communal roosts (see Chapter 2).

Fish species included in the feeding trials were chosen because of their abundance in the Chesapeake Bay (Lippson 1973) and their occurrence in a previous study on the foods of Chesapeake Bay nesting eagles (Cline and Clark 1981:20). These species were American eel, carp (*Cyprinus carpio*), catfish (*Ictalurus punctatus* and *I. nebulosus*), gizzard shad, Atlantic menhaden, and white perch. We distributed our sample of each species among three size classes: small (< 125g), medium (125 to 300g), and large (300 to 600g). Size classes were defined so each species fed to captive eagles was represented approximately equally among classes. Bird species also were divided into 3 size classes. Eleven mallards and 3 Canada geese composed the large size class; 8 rock doves, (*Columba livia*), 1 blue jay (*Cyanocitta cristata*), 1 mourning dove (*Zenaida macroura*), and 1 northern flicker (*Colaptes auratus*) composed the medium size class; and 8 house finches (*Carpodacus mexicanus*), 1 brown-headed cowbird (*Molothrus ater*), and 1 European starling (*Sturnus vulgaris*) composed the small size class. One whole and 18 partial white-tailed deer (*Odocoileus virginianus*) represented large mammals; 11 grey squirrels (*Sciurus carolinensis*), 1 eastern cottontail (*Sylvilagus floridanus*), and 1 Virginia opossum (*Didelphis virginianus*) represented medium mammals; and 10 white-footed mice (*Peromyscus leucopus*) represented small mammals. Fish fed to captive eagles were < 600 g so that complete consumption was possible. [Maintenance intake for bald eagles ranges from 5.5% to 10.7% of body weight per day (Stewart 1970, Stalmaster and Gessamen 1982) or 220 to 430 g per day for our 4-kg captive eagles. Maximum 1-day intake for a nestling bald eagle was 672 g, and an eagle deprived of food for 16 days consumed 924 g in its first post-fast meal (Stewart 1970)]. Large and small meals were alternated when possible to maintain hunger.

To determine our ability to recover remains over time, under circumstances similar to those under perches, food remains (excluding deer and geese, as these were deemed unlikely to be carried to a perch) were placed in 2x2 m plots on the Bay shoreline. Plots were placed approximately 5 m apart and marked with flagged stakes. Ground litter on these plots varied from bare soil to heavy leaf litter. After one month, we made a 3-min visual search of each plot, similar to that used in collecting remains under perches of free-ranging eagles, and recorded food species observed.

To determine efficacy of direct observation, we observed eagles in 8 high-use foraging areas (Fig. 1) from boat, car, and foot using 7 X 35 binoculars and 25-60X spotting scopes. Daylight hours were divided into 3 equal periods and observation effort was distributed among these morning, midday, and evening periods in a 2:1:1 ratio. We recorded strikes by eagles at the water's surface, pursuit of prey, and scavenging. Species of food item was identified when possible, either during flight or feeding, or by collecting food remains immediately after feeding.

RESULTS

Pellet Analysis

Diet composition as revealed by pellet analysis differed significantly from the actual diet of captive eagles ($\chi^2 = 281.37$, 2 df, $P < 0.001$; Table 1) because of low representation of fish. Only 12 of 213 (5.1%) fish fed to eagles were identified in egested pellets (Table 2); of these only 1 was recovered in a pellet composed entirely of fish (viz., large carp scales). The remaining 11 fish were identified as vertebrae, scales, or otoliths within pellets of hair and feathers and likely would not have been found without their combination with hair or feathers.

When considered without fish, the proportion of birds and mammals in pellets were similar to that in the actual diet ($\chi^2 = 0.018$, 1 df, $P < 0.90$). However, when results were divided into size classes, differences were statistically significant ($\chi^2 = 12.05$, 5 df, $0.05 > p > 0.01$; Table 3), primarily because eagles produced relatively few pellets after eating open deer carcasses and many pellets after eating medium-sized mammals.

Deer carcasses with exposed flesh resulted in pellets in 11 of 18 (61.1%) feedings. In the single instance in which an entire deer carcass was fed, 2 pellets were produced despite little ingestion of flesh. After 3 days, the captive eagle had eaten hair and produced pellets but had not broken the skin enough to obtain meat. Items in all other categories were fed whole and produced an average of >1 pellet per item (Tables 1 and 3). Only 5 of 59 (8.5%) birds and mammals that were fed whole to captive eagles were not detected in pellets. These items were 3 white-footed mice, 1 house finch, and 1 mallard.

Food Remains Collection

Fish, birds, and mammals were identified in remains at different rates ($\chi^2 = 14.64$, 2 df, $p < 0.001$; Table 4) with birds remains recorded more frequently than those of fish or mammals. Birds of all size classes were represented well in remains; only 1 house finch was undetected. Medium-sized mammals also were represented well, with remains identified in every instance; in contrast, small mammal remains were never recorded. The percent of fish with identifiable remains differed with size ($\chi^2 = 19.87$, 2 df, $P < 0.001$); larger fish occurred in remains at greater rates than smaller fish. Within the fish category, rates at which identifiable remains were left differed among species ($\chi^2 = 64.33$, 5 df, $P < 0.001$; Table 5). Catfish were left in remains at the highest rate; whereas, American eels were identified at the lowest rate.

Remains recovery after 1 month in shoreline plots differed among the 3 major food types ($\chi^2 = 23.90$, 2 df, $P < 0.001$; Table 4). Birds again were represented well, being recovered in all but 2 instances. Fish remains were recovered at the lowest rate with slightly more than one third of items recovered. Both fish size (χ^2 = 8.19, 2 df, P = 0.017; Table 4) and species (χ^2 = 19.55, 5 df, P = 0.002; Table 5) affected recovery rates. Remains from larger fish were recovered more frequently than those from smaller fish. Carp and catfish remains were recovered at higher rates than those of other fish species.

Direct Observation

In 951.9 hours of observation in the highest-use eagle foraging areas, we observed 1134.6 eagle-hours of activity (1 eagle hour equals 1 eagle observed for 1 hour). We observed 253 instances of eagles eating fish. Fish species was identified in 80 (31.6%) instances; of these 35 (43.8%) were identified from a distance and 45 (56.2%) were identified from food remains collected immediately after the eagle had finished eating. Thus fish species used by eagles were documented at a rate of 1 per 11.9 observation-hours and 1 per 14.4 eagle-hours. In addition, during this period, we identified 9 birds and 3 mammals eaten by eagles.

Direct observation was most efficient in morning. We observed successful foraging attempts at the rate of 1 per 3.01 observation-hours in the first third of the day, 1 per 4.66 observation-hours in the middle third, and 1 per 6.96 observation-hours in final third.

DISCUSSION

Pellet Analysis

Our results indicated that pellet analysis was not a good indicator of total bald eagle food habits because of under-representation of fish. This technique did, however, give a good qualitative picture of the bird and mammal component of the diet. Quantitative analysis of this component was biased by occurrence of items in >1 pellet and by absence of other items.

Multiple pellets from a single food item suggest that multiple egestions may be necessary to cleanse the stomach and crop of undigestible material from a single day's feeding. Over-representation of medium-sized mammals (up to 5 pellets/item) may reflect the difficulty of cleansing the stomach and crop of the short hair of squirrels. Evidence from our field collections (see Chapter 2) supports the conclusion that multiple pellets may be produced from a single day's feeding. In 1 collection from a single roost, 3 pellets contained a combination of sheep's wool, mallard drake head feathers, and feathers of a female red-winged blackbird (*Agelaius phoeniceus*). It is unlikely that 3 separate eagles had fed on this same combination of food items.

Duke et al. (1976) reported <1 pellet per "meal" for all falconiformes tested including the bald eagle; however, their "meal" consisted of a daily one-hour *ad libitum* feeding on house mice (*Mus musculus*). Because meals were identical, pellets could not be assigned to a particular meal. It seems likely therefore that each ingested mouse was represented in egested material but that each pellet contained material combined from >1 meal. In contrast, our feeding scheme, which ensured that bird and mammal food items were fed >1 day apart, allowed for documenting multiple pellets from the same food item.

Captive eagles occasionally produced multiple pellets during the same 24 hour period. We often were uncertain whether these represented separate egestions or multiple pellets of a single egestion. Evidence for multiple pellet egestion comes from pellets, collected from both free-ranging (pers. observ.) and captive eagles, which appeared to be separately formed but which were joined by small connections of hair or feather. After feeding on a mouse, one captive eagle egested a loose cluster of 16 distinct sub-pellets. For this study, egested material was recorded as 1 pellet when deemed to have been produced at one time and as separate pellets when we were uncertain. Similar judgements are required when collecting pellets in communal roosts.

Absence of bird or mammal items in pellets may occur when eagles avoid ingesting undigestible portions. Our results indicate, with large carrion such as white-tailed deer, eagles may feed on open carcasses without producing pellets, or, conversely, may produce pellets without obtaining much of a meal. Though Brooks (1929) believed that ducks observed being eaten by bald eagles were not detected in pellets due to their habit of plucking this prey, our captive eagles were unable to pluck or skin intact birds and mammals carefully enough to avoid ingesting feathers or hair.

Absence of bird or mammal items in pellets might also occur if eagles occasionally digest hair or feathers completely. As in our study, Glading et al. (1943) noted small mammals and birds occasionally were not represented in pellets collected during feeding trials with several species of falconiforms. Our results indicated that in most cases even small items were evident in pellets. Although it is possible that undetected items were completely digested, it seems as likely that some small pellets were overlooked in our collections.

The bald eagle's habit of roosting communally and egesting pellets in response to morning light (Duke et al. 1976) allows easy collection of eagle pellets at roost sites. Our results indicate that eagles feeding primarily on fish would rarely produce pellets and, conversely, eagles feeding primarily on birds or mammals would produce many pellets. This conclusion is supported by Shea's (1973) observation that eagles feeding entirely on salmon did not produce pellets. Therefore, I propose that the rate at which eagles egest pellets may be used as an index to the relative use of the bird and mammal dietary component. This pellet egestion rate (PER) can be estimated by dividing the number of pellets collected in a roost by the number of eagles using the roost. More specifically,

$$\text{PER} = \frac{\text{No. pellets collected over time t}}{\text{(Mean count of roosting eagles over time t)} \times \text{(No. nights in time t)}}$$

This index should approach 0 when birds and mammals are eaten rarely and be ≥1 when birds and mammals are eaten daily. We have obtained good results using this index on the northern Chesapeake Bay (see Chapter 2). Removal of brush and ground litter, or placing nylon netting under roost trees may be necessary to ensure complete collection of pellets.

Food Remains Collection

Differences in the likelihood of an item being left in remains and persistence of its remains over time can cause large biases in percent occurrence results. To illustrate the combined effect differences in remains deposition and 1-month recovery percentages (from Table 4) might have on a food habits study, I have applied the percent of items identified in remains and the percent of those remains recovered after 1 month on the shoreline to a hypothetical situation in which eagles were eating fish, birds, and small and medium-sized mammals with equal frequency (Fig. 2). Percent occurrence of remains collected 1 month after feeding are highly biased in favor of birds and greatly underestimate the use of fish and small mammals. These results agree with those of Todd et al. (1982) and confirm the biases suggested by other authors (Errington 1932, Sherrod et al. 1976, Cash et al. 1985). Lack of bias at golden eagle nests reported by Collopy (1983) may have been due to the predominance of medium-sized mammals and frequent collections at each nest.

Similar application of percentages from Table 5 to a hypothetical situation in which fish species are equally used results in strong biases toward carp and catfish, and underestimation of other species (Fig. 3). Frequent use of catfish (up to 56.3% of food items, McEwan and Hirth 1980) by bald eagles has been reported in many studies using food remains analysis (Dunstan and Harper 1975, McEwan and Hirth 1980, Cline and Clark 1981:20, Todd et al. 1982, Haywood and Ohmart 1986). Use of this benthic fish by surface-foraging eagles has been explained, in part, by susceptibility of catfish to aerial predation (Todd et al. 1982 and Haywood and Ohmart 1986 citing Swenson 1979). Our results suggest that some of the documented frequent use may be due to technique bias. Our field observations on the Chesapeake Bay support the existence of this bias: catfish composed 77 of 129 (59.7%) items collected under perches but were only 9 of 80 (11.3%) food items identified during direct observation of foraging eagles (see Chapter 2).

In addition to remains deposition and persistence, other factors may also introduce bias. Obviously, not all food items are carried to perches or nests (Dunstan and Harper 1975). Large items are eaten on the ground or on ice in winter; small items may be eaten during flight (Crehore 1974). During direct observations of foraging eagles, 76 of 265 (28.7%) food items were not taken to perches. These observations were made primarily in aquatic areas where food items were generally small fish. A greater percentage of items may not be taken to perches in terrestrial habitats where large carcasses are more abundant.

Unlike food remains of breeding eagles which are concentrated at nests, we found remains left by nonbreeders to be widely dispersed. Though many perches were used habitually for hunting and loafing, use of feeding perches was more variable. Possibly due to kleptoparasitism pressures, 61 of 189 (32.3) eagles carrying food to perches flew off of the shoreline and out of sight to feed. Southern (1964) noted similar behavior by successfully foraging eagles in Illinois.

Determining origin of remains is an additional problem encountered when using food remains to determine food habits of nonbreeders. On the northern Chesapeake, fish remains were common along all areas of shoreline as well as under perches. Shoreline scavengers such as red fox (*Vulpes vulpes*), raccoon (*Procyon lotor*) and crows (*Corvus brachyrynchus* and *C. ossifragus*) may have added remains of items pulled from the beach, as well as removed some eagle food remains. In addition, ospreys (*Pandion haliaetus*) were common on the study area over much of the year, and overlap in use of feeding perches was observed.

Direct Observation

Direct observation is generally regarded as the least biased though most labor intensive food habits technique (Marti 1987). Accuracy, however, depends on an observer's ability to document use of each food type with equal probability. For free-ranging eagles foraging in both terrestrial and aquatic habitats, this is not possible -- the probability of observing an eagle scavenging a deer carcass in the forest is less than that of observing an eagle capture a fish in open water. Even in open-water habitats where the probability of observing capture of each fish species should be nearly constant, we were unable to determine fish species in >33% of captures. Identified fish probably were not representative of unidentified fish. Distinctively shaped or colored fish (e.g., eel, carp, and catfish) were most easily identified during flight and feeding, and those most frequently left in remains (as discussed for food remains) were more likely to be identified by searching the feeding location.

Successful use of direct observation at nests (Herrick 1924, Ofelt 1975) is dependent on proximity of the observer to feeding. Attaining this proximity to free-ranging eagles may be difficult; McGarigal (1988) reported a stationary boater may affect eagle foraging as far as 800 m away. Greater success is possible where foraging is concentrated (Edwards 1988) and observations can be made from a stationary blind or car (Crehore 1974). Direct observation may be most efficient in morning; high levels of foraging activity in the morning have been reported by others (Grewe 1966, Servheen 1975, Stalmaster 1981, Steenhof 1983).

Despite its labor intensity, direct observation gives the best indication of relative use of fish species by bald eagles and may be the only means of documenting use of small, soft-bodied fish. In addition, observations can yield other important information on bald eagle foraging ecology such as foraging rates, habitat use, and inter- and intra-specific interactions.

SUMMARY AND CONCLUSIONS

Despite biases in commonly-used techniques, our present knowledge of bald eagle food habits and foraging ecology is good. The bald eagle's opportunistic foraging strategy; broad use of birds, mammals, and fish; and role as predator, scavenger and pirate are well documented. Increasingly, however, studies of bald eagle food habits are needed to provide specific information for local assessments of environmental impacts. Common questions asked are, "How important is this particular food item? What will be the effect on eagles of reducing this item's abundance?" Given the biases discussed here, drawing inferences from any 1 of these 3 techniques exclusively could result in erroneous answers.

Unfortunately, we have found no technique that will result in a complete list of bald eagle foods and unbiased estimates of their relative occurrence. Instead, a synthesis of information gathered using all available techniques, along with knowledge of their biases, is required. Additionally, new approaches such as our pellet formation rate index are needed.

Each of the 3 most commonly used techniques can add to our understanding of local bald eagle food habits. Although we found statistically significant differences between pellet analysis results and actual diet, this technique does indicate the range of bird and mammal species eaten and approximates their relative occurrence within the bird and mammal component of the diet. Pellet egestion rates can serve as an index of the total relative occurrence of birds and mammals. Collection of food remains may not reveal all eagle foods (e.g., small, soft-bodied fish and large carrion) and can give a highly biased picture of percent occurrence; bias can be minimized, however, with frequent collections. Dispersion of remains and determining the origin of remains, may present further difficulties when this technique is applied to nonbreeding eagles. Direct observation is necessary to assess biases in food remains results. Direct observation yields the best information on the relative occurrence of fish species and may be the only means of documenting use of small, soft-bodied fish. Although labor intensive, information gathered with this technique is essential for accurately determining food habits of bald eagles.

Our conclusions regarding bald eagle food habits techniques support Errington's (1930) early assertion: "No single method introduced is foolproof -- not even that of field observation ... We must use *all* of the most effective methods at our command, checking one against another, if our data are to be of the highest grade."

CHAPTER 2: FORAGING ECOLOGY OF BALD EAGLES ON THE NORTHERN CHESAPEAKE BAY

INTRODUCTION

The foraging ecology of bald eagles has been studied extensively. Bald eagles, like other members of the sea or fish eagle group (genus *Haliaeetus*), are primarily fish-eaters (Grossman and Hamlet 1964:323-329), and prefer fish over other foods when available (Wright 1953, Spencer 1976:87, Steenhof 1978:30). Fish eaten by bald eagles in winter often are dead, dying, or stranded in pools by fluctuating water levels (Fischer 1985, Spencer 1976, Steenhof 1978:27). Eagles wintering in the Pacific Northwest feed primarily on spawned-out salmon (Shea 1973, Servheen 1975, Stalmaster 1976). Gizzard shad is the fish most frequently eaten by wintering eagles throughout the midwest (see Spencer 1976 and Steenhof 1978 for reviews, Faanes 1976). Gizzard shad frequently die in large numbers in winter due to their sensitivity to cold stress (Bodola 1966, Gasaway 1970, Becker 1983:276, Williamson and Nelson 1985) and commonly are available below hydroelectric dams during late fall and winter and when ice melts in late winter (Spencer 1976, Steenhof 1978).

Collections of food remains and direct observations at nests indicated that fish were also the primary food of breeding eagles in Florida (Broley 1947, McEwan and Hirth 1980), interior Maine (Todd et al. 1982), Nova Scotia (Cash et al. 1985), Ohio (Herrick 1924), Louisiana (Dugoni 1980), Michigan (Tate and Postupalsky 1965), Minnesota (Dunstan and Harper 1975), Arizona (Haywood and Ohmart 1986), Alaska (Henke 1973, Ofelt 1975), and the Chesapeake Bay (Cline and Clark 1981:24). Benthic fish, especially catfish, were the most frequently recorded fish species in several of these studies (Broley 1947, Dunstan and Harper 1975, Dugoni 1980, McEwan and Hirth 1980, Cline and Clark 1981, Todd et al. 1982, Haywood and Ohmart 1986).

Although dead fish are taken when available, bald eagles are capable of capturing live fish. Unlike ospreys, which often dive for fish, bald eagles typically snatch fish from the water's surface. Therefore, to be available to a foraging eagle, a fish must be close to the water's surface; 20 cm probably is the maximum depth at which a fish is truly available. Steenhof (1976:98, 1978:27) suggested surface-feeding fish may be more susceptible to eagle predation than bottom-dwelling fish. In contrast, Swenson (1979) presented data indicating benthic fish are more vulnerable to osprey predation, possibly due to their downward visual focus and slow escape movements. This vulnerability hypothesis has been used to explain the frequent occurrence of catfish and other benthic species in bald eagle nests (Todd et al. 1982, Haywood and Ohmart 1986). Some authors suggest live fish may be most vulnerable to aerial predation in shallow water (Steenhof 1978:27). This effect has not been documented quantitatively, however.

When fish are not available, bald eagles readily take bird and mammal carrion. Although they have been observed to prey on live waterfowl (Bent 1937, Imler and Kalmbach 1955), wintering eagles most frequently feed on waterfowl carcasses, which are common near waterfowl concentrations and associated hunting (Spencer 1976, Steenhof 1978:30-31). Deer carrion also are frequently eaten (Spencer 1976, Steenhof 1978:31). Mammals, primarily jackrabbits (*Lepus* spp.), were the major food of bald eagles wintering away from large bodies of water in the interior western U.S. (Imler 1937, Edwards 1969:89, Platt 1976). Birds were the most frequently recorded items at eagle nests in coastal Maine (Todd et al. 1982) and the

Aleutians (Murie 1940). Duck and muskrat (*Ondatra zibethicus*) remains were common at nests on the Chesapeake Bay (Smith 1936, Cline and Clark 1981:20-22).

Bald eagles also demonstrate the ability to exploit locally abundant food resources; eagles fed predominately on sheep carrion in British Columbia (Hancock 1964), road-killed European hares (*Oryctolagus cuniculus*) on San Juan Island, Washington (Retfalvi 1970), and great blue herons (*Ardea herodius*) near a heron rookery in Nova Scotia (Cash et al. 1985). Although reptiles and amphibians are not frequently recorded in bald eagle food habits studies, remains of several turtle species were commonly found at Chesapeake Bay eagle nests (Cline and Clark 1981).

To date, researchers of bald eagle food habits have focused on eagles during nesting or at winter concentration areas. Only Wright (1953) attempted to describe eagle food habits over an entire year in one location. Although his quantitative data were limited primarily to summer, Wright concluded that nonbreeding eagles in New Brunswick primarily ate fish in summer, but shifted to a diet of birds and mammals in winter when fish were unavailable.

Knowledge of the relative availability of food items is essential to properly rate the importance of each item to the species being studied (Korschgen 1980). Few studies of bald eagle food habits have quantitatively assessed food abundance, however, possibly because of the variety of foods potentially used by eagles. Steenhof (1976) used overnight gillnet sets to assess relative fish species abundance at a bald eagle foraging area in South Dakota. Edwards (1988) used electroshocking to examine fish availability to ospreys in central Florida lakes.

In our study, determination of the distribution and abundance of bald eagle foods was essential to examine the effects of food on bald eagle distribution and abundance. Objectives for the research presented here were to 1) quantify the temporal and geographical distribution of fish and waterfowl on the northern Chesapeake Bay over the annual cycle, 2) determine temporal and geographical variation in bald eagle food habits on the northern Chesapeake Bay over the annual cycle, and 3) identify periods of food scarcity and any behavioral or physiological responses of bald eagles to food scarcity.

METHODS

Food Availability

From January through December 1987, we sampled live fish abundance and availability in Foraging Areas 1 through 6 (Fig. 1) using experimental, floating, monofilament gillnets (Nylon Net Co., Memphis, Tennessee). Gillnets were 60 m x 1.8 m (200 ft x 6 ft) and composed of five, 12-m (40 ft) panels of 25, 38, 51, 64, and 76 mm square mesh (1.0, 1.5, 2.0, 2.5, and 3.0 in). Mesh of 25 and 38 mm were constructed of 0.33 mm twine, and mesh of 51, 64, and 76 mm were constructed of 0.47 mm twine. The net bottom was bordered with #30 lead-core line. To sample fish abundance in shallow water, we constructed gillnets of 0.6 m depth that were otherwise identical to nets of 1.8-m depth. Hereafter, nets of 1.8 m depth will be referred to as deep-water nets and nets of 0.6 m depth will be referred to as shallow-water nets.

We sampled Foraging Areas 1 through 6 twice monthly, except in January, February, and March, when only one sample per month was taken (See Appendix B for sampling dates). Within each foraging area, a sample consisted of 2 deep- and 2 shallow-water nets placed randomly along the two 1-km shoreline sections that received the greatest use by bald eagles, as determined by aerial survey (Buehler, Ph.D. Thesis, in progress, Virginia Tech). Thus, each complete sample of the study area consisted of 24 sets: 2 deep- and 2 shallow-water sets in each of 6 foraging areas. All net sets for each sample were made within a 7-day period. Sample catch per unit effort (CPUE, number or weight of fish caught per hour), for each foraging area and net type, was calculated by combining catch and set-time for the 2 nets of the same type and then dividing total catch by total set-time.

Netting was conducted during daylight hours. Set duration was approximately 1 to 2 hours. We consistently sampled the Bay in morning, creeks in midday, and rivers in late afternoon. This sampling design confounded effects of time-of-day and habitat on catch rates, but was chosen because it allowed consistent comparisons of catch rate among months. We set nets perpendicular to the shoreline and anchored each end with Danforth anchors. Shallow-water nets were set as close as possible to shore at a randomly selected shoreline point. Deep-water nets were set in the first 1.8-m deep water encountered when traveling perpendicular from a randomly selected shoreline point. The smallest mesh size was set closest to shore. For each deep-water set, we measured water temperature at 0.6 m depth and water turbidity with a Secchi disk (Orth 1983).

For each fish caught, we recorded species, total length, and the mesh size in which it was caught. In addition, we indexed vertical distribution of fish caught in deep-water nets by recording the location of each fish as being in the top, middle, or bottom third of the net. Fish weights were estimated using regressions of total length to total weight. Regression equations were derived from measurements taken in this study or were obtained from the literature when our data were insufficient (Appendix A). Because all fish observed captured from the water by bald eagles during this study were estimated to be < 1 kg, fish > 1 kg were excluded from further analyses.

We monitored waterfowl distribution and abundance from November 1985 through May 1988 with monthly shoreline surveys in a Cessna 172. Surveys were flown between 0730 and 1100 at approximately 50 m altitude. The survey route included much of the study area shoreline (Fig. 4); Remington Farms and surrounding area (Foraging Area 8), an inland waterfowl concentration area, was added to the route in March 1987. Waterfowl observed during surveys were identified as ducks or geese, and their number estimated and location recorded. Because availability of waterfowl to bald eagles may be dependent on mortality and crippling due to hunting, we recorded location of waterfowl hunters during aerial surveys for the 1987-88 hunting season.

Food Use

We observed foraging eagles in 8 foraging areas (Fig. 1) from January 1987 through February 1988. Eagles were observed from boat, car, and foot, using 7 X 35 binoculars and 25-60X spotting scopes. We recorded total observation time and total time each eagle was observed. Often, > 1 eagle was observed at a time. Although we attempted to distribute observational effort equally among foraging areas, actual sampling intensity was dependent on eagle use of each area. Because we would proceed to a different foraging area if no eagles were observed in the initially chosen one, more time was spent observing areas with abundant eagles. Although we observed eagles during all daylight hours in all foraging areas, twice as much observation time was spent during the first third of the day, because morning peaks in bald eagle foraging activity have been previously reported (Grewe 1966, Servheen 1975, Stalmaster 1981, Steenhof 1983).

When we observed an eagle capture a food item, we attempted to identify the item from a distance. We estimated total length to the nearest 5 cm of captured fish by noting its size relative to that of the eagle. Weights of captured fish were estimated using estimated lengths in length-weight regressions (Appendix A). Weights of unidentified fish, for which length estimates were made, were calculated using the regression equation for gizzard shad. Captured fish without length estimates were assumed to have the weight of a 20 cm gizzard shad, because gizzard shad were the most frequently taken fish, and 20 cm was the median size. When possible, we collected and identified remains left after feeding. State of the food item (live, dead, or unknown) was determined through observation of dead fish floating prior to capture, movement of the prey item after capture, and/or examination of remains. For strikes at the water's surface, we recorded the distance (to the nearest 10 m) of the foraging strike from shore, and water depth (to the nearest 0.3m) at the strike location. Seasons were defined as Spring: 21 March to 20 June, Summer: 21 June to 22 September, Fall: 23 September to 21 December, and Winter: 22 December to 20 March.

During observations of foraging eagles, we recorded each eagle's activity (Altmann 1974). Activity was recorded to the nearest minute as either perching or flying. All intra- and inter-specific foraging interactions and their outcomes also were noted.

We collected pellets in all known communal roosts (Fig. 6) from December 1986 to June 1988. We facilitated collection by cutting brush and raking ground litter or by hanging nylon netting (1 cm x 1 cm mesh) under habitually used roost trees. Collected pellets were oven-dried and manually dissected. Feathers were washed and identified by comparison with museum specimens. Hairs were identified by shape, color, and medulla pattern (Mathiak 1938, Stains 1958, Moore et al. 1974). Occurrence of fish parts in pellets also was recorded. Each species identified within each pellet was recorded as 1 occurrence. All pellets were radiographed to determine presence of lead or steel shot.

From December 1986 through October 1987, we calculated pellet egestion rates for AA5 and Remington Farms Roosts (Fig. 6) by dividing the number of pellets found during each biweekly collection by the estimated number of eagle-nights spent in each roost since the previous collection. Eagle-nights were estimated by multiplying the mean of weekly counts of roosting eagles by the number of nights in the collection period. From November 1987 through June 1988, we limited pellet collections and eagle-night estimates to selected high-use roost trees in 3 communal roosts--AA5, Remington Farms, and Mosquito Creek (Fig. 6). By focusing on fewer roost trees, we improved the accuracy and efficiency of pellet egestion rate estimates.

We collected vertebrate remains under eagle perch trees on an opportunistic basis. Remains were collected during measurements of perch trees identified by locating radio-tagged eagles (Buehler, unpubl. data). Remains also were collected under perches used by feeding eagles during direct observation. Only items found above the high-tide line were included in analysis.

To document intrinsic cycles in bald eagle food requirements, we measured dry matter intake for 2 captive immature bald eagles (same as those described in Chapter 1). These eagles were housed outdoors in 3 x 3 x 3 m cages under ambient temperature and light regimes of Edgewood, Maryland (39 ° 25′ N, 76 ° 20′ W).

For 15 consecutive days each month, eagles were fed *ad libitum* (500 g wet wt./day) commercial bird-of-prey diet (Nebraska Brand, Lincoln, Nebraska). The first 5 days of *ad libitum* feeding were used to allow the eagles to adjust to the bird-of-prey diet and to recover from any food limitation that may have occurred during other feeding regimes used during the rest of the month (see Chapter 1). We measured intake of the bird-of-prey diet during the following 10 days. We oven-dried leftover food from these 10 days at 75 C for 72 hours or until dry weights stabilized. Percent dry matter of wet food was determined periodically by drying 100-g (wet weight) samples (n = 35). Daily dry matter intake was then determined by subtracting dry matter left from dry matter fed. Eagles were weighed before and after each *ad libitum* feeding period.

RESULTS

Food Availability

Fish

In 504 gillnet sets (252 deep-water, 252 shallow-water; mean set time = 1.32 hours, SE = 0.019, range = 0.77 - 3.55 hours), we caught 5539 fish of 16 species (Table 6). Of the 5305 fish caught that were less than 1 kg, 4 species -- menhaden, gizzard shad, white perch, and channel catfish -- composed over 95% of numbers and weight caught.

Number and weight of fish caught per hour peaked in spring and early fall and approached 0 in midwinter (Fig. 5). Increases in catch rate were noted during the first week in

April; declines occurred erratically in fall (October and November). Deep- and shallow-water catch rates were significantly correlated (Spearman's rank-order correlation, numbers: $R = 0.731$, $P < 0.001$; weight: $R = 0.698$, $P < 0.001$). Trends in catch rate followed that of water temperature except in mid-summer when a drop in catch coincided with peaking water temperatures (Fig. 6). Peak catch rates occurred at 25-28 C.

Mean catch rates for the period when fish were abundant (April - September) were higher on the west side of the Bay than on the east side (Table 7 and Figs. 7 and 8). Catch rates were higher in creeks and rivers than in the Bay (Table 7 and Figs. 9 and 10); however, effects due to habitat were confounded with time-of-day, because netting was always done in the Bay in morning, creeks in mid-day, and rivers in evening. Highest catch rates in both deep and shallow water were recorded in Romney Creek in mid-day; lowest rates were recorded in Eastern Shore Bay in morning (Fig. 11; Appendix C). Differences among locations were similar in deep and shallow water (Figs. 11 and 12). All areas experienced similar drops in catch from October through December, and catch rates were near 0 in all areas from January through March.

Trends in total catch are largely the result of changes in abundance of the 4 most common species (Figs. 13 and 14). Menhaden arrived relatively late to the northern Bay, not appearing in large numbers until May. Catch of this species declined sharply in mid-summer and peaked again in September before dropping dramatically in October. A second fall peak in November in deep water was primarily due to 1 sample taken in Romney Creek, though slight increases in menhaden catch were noted in other areas as well (Figs. 15 and 16). Menhaden > 20 cm in total length were rarely caught (Fig. 17), and although they were the most numerous species caught, they were second to gizzard shad in total weight netted (Table 6, Fig. 13).

Peak numbers of large gizzard shad were caught in April (Figs. 13 and 14). Gizzard shad catch rates declined in early summer and peaked again in late summer and early fall. Low numbers of gizzard shad were caught in winter months when few other species were found.

Gizzard shad were caught in a wide range of size classes, though predominately > 20 cm (Fig. 17).

An April peak in catch of white perch also was observed (Figs. 13 and 14). White perch were caught in April primarily in the Bush River and Romney Creek (Fig. 15), and were especially numerous in the shallow water of Romney Creek (Fig. 16). A second peak in June was due to catches in ES Bay and Stillpond/Churn Creek. A smaller peak in September also was noted. White perch caught on the study area were primarily < 20 cm (Fig. 17).

Catfish catch rates peaked in June (Fig. 13). This species was rarely caught in shallow water (Fig. 14). Channel catfish were caught in a wide range of sizes, but like gizzard shad, were predominately > 20 cm (Fig. 17).

Early spring spawning runs of large striped bass were observed, although striped bass catch throughout the year was small. Spot and bluefish were caught in summer only. Bluefish generally were young-of-the-year and associated with menhaden schools. Yellow perch, brown bullheads, golden shiners, white catfish, carp, largemouth bass, and sunfish were primarily associated with the freshwaters of creeks and upper rivers. Numbers of these species were likely greater in the upper sections of Bay tributaries that were not covered in our sampling.

Vertical distribution of fish caught in gillnets showed menhaden and gizzard shad had the greatest preference for the water's surface (&cui.^{2} = 654.27, 8 df, $P < 0.001$; Fig. 18). Channel catfish rarely were caught at the water's surface. Eighty-nine percent of catfish were caught near the net bottom. White perch also were associated strongly with the net bottom, though 8% were caught in the top stratum. Vertical distribution of fish differed with season ($\chi^2 = 25.75$, 6 df, $P < 0.001$; Fig. 19); surface fish were most common in summer and least common in winter.

Species composition of fish near the water's surface (Fig. 20) was different between shallow- and deep-water sets ($\chi^2 = 268.6$, 4 df, $P < 0.005$). Menhaden composed 67.4% of fish caught in deep-water nets but only 26.8% of fish caught in shallow-water nets. White perch and gizzard shad together formed 66.3% of shallow-water catch but only 30.6% of surface fish caught in deep water. Total catch within 0.6 m of the water's surface was significantly greater in shallow water than deep water (paired t-test: $t=3.65$, 125 df, $P = 0.0004$).

Waterfowl

Monthly aerial survey counts of waterfowl revealed waterfowl abundance on the northern Chesapeake was seasonal (Fig. 21), varying reciprocally with fish abundance (Pearson correlation coefficient: $R = -0.786$, $P = 0.002$; Fig. 22) Migrant Canada geese began arriving on the study area by October, peaked in number during fall and winter, and declined dramatically in number by March. Ducks, primarily mallards and lesser scaup (*Athya affinis*), but including a variety of dabblers and divers, generally arrived later and peaked at lower numbers than did geese. Goose numbers in winter 1987-88 peaked at less than half the 1986-87 peak. In contrast, duck counts were higher in 1987-88 than in previous years.

Waterfowl were most abundant on the east side of the Bay (Table 8, Fig. 23) presumably due to food associated with agricultural fields. Large numbers of lesser scaup were observed along the APG shoreline during winter 1987-88. These diving ducks were possibly attracted to the large areas of relatively shallow water on the west side of the Bay.

Waterfowl hunters seen during surveys in 1987-88 were distributed similarly to waterfowl (Fig. 24), with most hunting occurring on the east side of the Bay. Waterfowl hunting on APG was limited due to access restrictions. Waterfowl hunting generally occurred from November through January (see Appendix I for specific dates and bag limits).

Food Use

Direct Observation

Species use -- We observed bald eagles in 8 foraging areas (Fig. 1) for a total of 951.9 observation-hours, and 1134.6 eagle-hours. We observed 253 instances of eagles obtaining or eating fish. Eagles captured fish over open water on 232 occasions, scavenged fish from shorelines and floating ice on 18 occasions, and stole fish from other bird species on 3 occasions. The 232 successful forages over open water were the result of 342 strikes (67.9% success); 75 strikes (21.9%) were unsuccessful and 35 strikes (10.2%) were of unknown outcome. Of 253 successful fish captures, we identified fish species in 80 (31.6%) instances; 8 species were recorded (Tables 9 and 10). Status (live vs. dead) was determined in 93 (36.8%) instances (Table 11 and 12). Dead fish composed at least 24.5% of all fish taken and were 66.7% of fish with status determined.

Gizzard shad were the most commonly identified fish (Table 9). Bald eagles often fed on dead or moribund gizzard shad during winter 1987-88 particularly in APG Bay and in Romney Creek at ice out in late winter (Appendix D). Gizzard shad also were captured frequently on the Susquehanna River in late fall and early winter, when eagles and gulls concentrated below Conowingo Dam in response to available fish. Gizzard shad taken by eagles were recorded as dead more often than alive, but the majority were of unknown status (Table 12).

Catfish were taken spring through fall (Table 9), primarily in rivers (Table 10). They were taken predominately as carrion and never were documented as taken live (Table 12). Menhaden were taken primarily in spring and summer (Table 9) in a variety of habitats (Table 10). This species was recorded as taken live in greater proportion than any other species.

White and yellow perch were used primarily in the spring when these species spawn (Table 9). The majority of observations of these 2 species were made in the shallow water of upper Romney Creek (Table 10). Both of these species frequently were taken dead at this time (Table 12). Consumption of American eel was limited to late spring and summer; we commonly observed floating dead eels during that period. A single carp was observed captured on the Susquehanna River during winter 1987-88 (Table 9 and 10).

A 2-week period of intensive foraging activity was observed in October 1987, on a Remington Farms pond. Though only 1 gizzard shad was positively identified, other fish captured were thought to be live sunfish and largemouth bass. The importance of ponds as a source of fish in fall is unknown, but worthy of further investigation.

Observations involving bird and mammal food items include bald eagles scavenging Canada geese on 7 occasions, white-tailed deer on 3 occasions, and northern mallard on 1 occasion. An adult and immature eagle were flushed from a recently-killed lesser scaup near a large scaup flock on the APG shoreline; however, capture of this duck was not observed. Eagles often flushed waterfowl flocks with low flights, but active pursuit was rarely observed (5 instances) and predation was never observed. Other predation attempts observed included 2 unsuccessful pursuits of great blue herons (one of which resulted in the heron being struck and knocked to the water), and an unsuccessful attack by several eagles on a crippled ring-billed gull (*Larus delawarensis*). We also observed bald eagles stealing small food items from northern harriers (*Circus cyaneus*) on 2 occasions.

Incidental observations made during other field activities additionally included eagles taking a menhaden, a white perch, a American eel, a dead gizzard shad, and a dead striped bass. Eagles also were observed feeding on a road-killed black racer (*Coluber constrictor*), a road-killed Virginia opossum, and a recently-killed grey squirrel, Canada goose, and mallard.

Aquatic habitat use – Mean water depth at the location of live fish captures ($\overline{X} = 0.69$ m, $n = 10$) was less than that at locations where dead fish were taken ($\overline{X} = 1.60$ m, $n = 22$; t-test: $P = 0.008$). All fish confirmed live at capture were taken in water less than 1.2 m; depths at dead fish locations ranged from 0.3 m to 5 m (Fig. 25). Strike frequency declined with distance from shore (Fig. 26). In nonwinter months, > 75% of strikes occurred within 500 m of the shore in bay and river habitats, though distances ranged to 5000 m on the Bay. Five of 10 strikes > 1000 m from shore were made by eagles attracted by flocks of foraging gulls (*Larus* spp.). Strikes in creeks were distributed < 500 m due to the narrow width of creeks. In winter, use of central portions of the Bay was greater because floating ice provided widely distributed perching substrate.

Foraging methods -- Bald eagles initiated strikes at the water's surface from circling flights (n=169) more often than from perches (n = 121; $\chi^2 = 7.94$, 1 df, $P < 0.005$); however, strikes initiated from perches were successful more often than those made from flight (73.5% vs. 57.4%; $\chi^2 = 8.77$, 1 df, $P < 0.005$). Strikes were most frequent in the period directly preceding sunrise (Fig. 27); eagles commonly struck the water immediately upon arriving from roosting locations. A smaller peak in strike frequency in early afternoon also was recorded. Time of strikes ranged from 27 min before sunrise to 4 min before sunset.

Strikes initiated from foraging flights composed a greater proportion of total strikes within 1 hour of sunrise (74.4%) than during the remainder of the day (51.0%; $\chi^2 = 13.77$, 1 df, $P < 0.001$). Strikes made during the smaller peak in early afternoon were initiated from flight slightly more often than were strikes made during late morning and late afternoon ($\chi^2 = 2.73$, 1 df, $0.10 > P > 0.05$). Success rates ($\chi^2 = 1.74$, 1 df, $0.25 > P > 0.10$), kleptoparasitism rates ($\chi^2 = 0.04$, 1 df, $p > 0.75$), and proportion of fish taken live or dead ($\chi^2 = 1.24$, 1 df, $P > 0.25$) did not differ between the morning foraging peak and the remainder of the day.

Trends in fish use, kleptoparasitism, and activity -- Seasonal trends in rate of fish capture by eagles (g of fish caught per eagle hour) were correlated with gillnet catch rate (Pearson correlation coefficient: $R = 0.708$, $P = 0.01$), peaking from April through September and reaching minimum in winter (Fig. 28). Foraging rate recorded for August, however, was much less than in other months when fish were abundant (April through September). This decline may have been the result of summer movement of live fish to deeper, cooler waters; however, it was more pronounced and occurred later in summer than would be suggested by gillnet results. Foraging rate in January and February, 1988, was higher than that in January and

February, 1987, reflecting use of cold-stressed gizzard shad available in 1988. Foraging rates by area, from April through September, were not significantly correlated with corresponding gillnet catch rates ($P > 0.10$). Eagle density in each area (indexed by the ratio of eagle-hours to observation-hours), also was not significantly correlated with gillnet CPUEs ($P > 0.10$).

Trends in kleptoparasitism rates (percent of successful forages followed by pirating attempt by another eagle) were not obvious due to small sample sizes in some months (Fig. 29); however, early spring and fall peaks in this rate are possibly represented. Activity levels of eagles, in terms of the proportion of observed time spent in flight, peaked in spring, fall, and mid-winter, and reached lows in late winter, mid-summer, and late-fall (Fig. 30).

Pellet Analysis

Pellet composition -- Through analysis of 1089 bald eagle pellets collected in communal roosts between 1 December 1986 and 30 April 1988, we identified 1280 occurrences of birds and mammals representing 48 species (Table 13). Waterfowl, primarily Canada geese and mallards, and white-tailed deer were most frequently recorded. Other frequently encountered items were gulls, passerines, raccoons, muskrats, and rabbits (*Sylvilagus* spp.). Two occurrences of turtles (skull and claws) and 1 occurrence of blue crab (*Callinectes sapidus*; shell fragments) also were recorded.

Composition of pellets differed among communal roosts ($\chi^2 = 432.75$, 12 df, $P < 0.001$; Table 14), with pellets collected at Remington Farms Roost containing a greater proportion of waterfowl than those collected in APG roosts, which contained a greater proportion of mammals. Mosquito Creek Roost showed a higher occurrence of gulls than did other roosts. Pellet composition also differed between years ($\chi^2 = 78.09$, 5 df, $P < 0.001$; Table 13) with greater frequencies of deer and gulls and a lower frequency of waterfowl in 1987-88 versus 1986-87.

Pellet Egestion Rates -- Total pellet egestion rates peaked in March 1987 and January 1988 and fell to 0 during summer and early fall, indicating use of birds and mammals was primarily limited to the period November to April (Table 15). This rate was correlated with waterfowl survey counts (Pearson correlation coefficient, $R = 0.667$, $P = 0.008$; Fig. 31) and varied reciprocally with fish foraging rate ($R = -0.536$, $P = 0.048$; Fig. 32). Pellet egestion rates were much higher in Remington Farms Roost than in both AA5 and Mosquito Creek Roosts. Pellet egestion rates for Remington Farms Roost peaked in February in both years at slightly > 1 pellet per eagle-night.

Fish Occurrence in Pellets -- Fish were recorded in pellets in 183 instances (Table 16). Gizzard shad and carp were the most commonly identified species. Though pellet analysis does not accurately reflect the fish dietary component (see Chapter 1), the proportion of pellets containing fish parts varied reciprocally with pellet formation rate (Pearson correlation coefficient: $R = -0.619$, $P = 0.008$; Fig. 33), suggesting that this proportion might serve as another index to the relative use of fish (complementary to the pellet egestion rate index). This proportion was higher in 1987-88 than 1986-87, and higher for APG pellets over those from Remington Farms.

Lead and Steel Shot -- Radiographs of 1089 collected pellets revealed that 14 pellets (1.3%) contained lead shot and 9 pellets (0.8%) contained steel shot. Shot was found in 13 pellets containing remains of Canada geese, 8 containing remains of mallards, and 1 each containing remains of common merganser and common goldeneye. Remington Farms Roost was the source of 19 pellets containing shot, AA5 the source of 2, and 1 each came from Mosquito Creek and Andelot Farms.

Food Remains

Fish composed 94.5% (139 of 147) of vertebrate remains collected under eagle perch trees (Table 17). Catfish composed >50% of all items. In contrast, gizzard shad and menhaden were the most common items collected in fresh condition (judged to have been deposited within 1-2 weeks of collection).

Food Intake of Captive Eagles

Results from consumption trials were not conclusive (Fig. 34). Food consumption for Eagle 1 was relatively stable throughout the year, except for a decrease in August and an increase in April. Body weight also showed no clear trend except for a possible increase in fall. High variance in body weight was probably due to variable crop contents at the time of weighing.

Results from Eagle 2 were even less conclusive due to the condition of this bird. High consumption rates at the beginning of this trial appear to be the result of this eagle being underweight initially; consumption rates decreased as body weight increased. Body weight was highest from September to December, similar to Eagle 1, but fell dramatically from January through mid-March due to a foot infection and the stress of handling during treatment. After recovery, body weight rose in April with a large increase in food consumption, though it never reached pre-infection levels.

DISCUSSION

Food Availability

Fish

Fish abundance -- Gillnet sampling documented large seasonal differences in fish abundance. Spring and fall peaks and winter lows in fish numbers were similar to trends in catch recorded for trawl samples on the lower Bay (Markle 1976). Rising water temperatures in spring brought spawning activity and a return of anadromous fish to the Bay (cf. Lippson 1973). With declining water temperatures in fall, catch rates declined as anadromous fish returned to the ocean and resident fish sought the warmer, deeper waters of the lower Bay (.cf Hildebrand and Schroeder 1928:13, Lippson 1973). Because the northern Chesapeake is relatively shallow (Lippson 1973:5), fish exodus from these waters in fall is particularly pronounced. The mid-summer lull in catch rates also may have been due to water temperatures, as fish sought cooler temperatures in deeper waters. Markle (1976) suggested that declines in dissolved oxygen concentration, along with peaking water temperatures, resulted in midsummer declines in his catch. Hildebrand and Schroeder (1928:15) also noted midsummer declines in commercial fish catch on the Chesapeake Bay, particularly in the northern portion.

Although increases in catch rates were not recorded until 1 April, increases in fish abundance may have occurred slightly earlier. Commercial fishermen began catching spawning yellow perch in the upper Bush River in late February; eagles also were seen there at that time. Additionally, a concentration of eagles was observed foraging on white and yellow perch in upper Romney Creek in mid-March. Failure to detect this early influx with our mid-March gillnet sample (see Appendix B) may have been due to fish traveling in deep channels past our sampling locations before moving into the shallows of upper rivers and creeks. Alternatively, this early influx may have occurred between sampling dates. Yellow perch, which prefer fresh water, may reside primarily in upper tributaries all year (Lippson 1973:38), above our sampling locations (see Appendix H for discussion of potential biases in gillnet data).

Although Atlantic menhaden are ocean spawners, they are found in the Chesapeake Bay throughout the year, being especially common late May through November (Lippson 1973:28, Chesapeake Bay Living Resources Task Force 1987:38). This abundance in the northern Bay is due primarily to young menhaden, which seek low-salinity upper-estuaries during their first year (Wang and Kernehan 1979:89, Lippson 1973:28, Rogers and Van Den Avyle 1983, Chesapeake Bay Living Resources Task Force 1987:38). The size distribution of menhaden netted in our samples is indicative of yearlings (Rogers and Van Den Avyle 1983). Adult menhaden, which are tolerant to a wide range of salinities and temperatures (Rogers and Van Den Avyle 1983), are common in the lower Chesapeake Bay (Lippson 1973:28, Chesapeake Bay Living Resources Task Force 1987:38). Small numbers of menhaden winter in deeper waters of the Bay, but most juveniles and adults begin returning to the ocean in October as water temperatures decline (Lippson 1974:28, Wang and Kernehan 1979:89, Chesapeake Bay Living Resources Task Force 1987:38).

Trends in white perch catch were similar to those historically recorded for commercial catch, with a major peak in spring and a lesser peak in fall (Hildebrand and Schroeder 1928:245). Spring peaks likely were due to spawning activity because, white perch in the Chesapeake Bay spawn from late March to June in fresh to slightly brackish (<3.0 - 4.2 ppt), shallow water (Hildebrand and Schroeder 1928:245, Mansueti 1961, Lippson 1973:34, Wang and Kernehan 1979:165, Stanley and Danie 1983, Chesapeake Bay Living Resoures Task Force 1987:35). Water temperatures of 10-15 °C provide the primary spawning stimulus (Mansueti 1961, Morgan and Raison 1982, Stanley and Danie 1983). Despite their small size, spring netted white perch contained roe and milt. These fish become sexually mature at 100 mm (standard length; Lee et al. 1980:573). White perch tolerate a wide range of salinities and temperatures, and prefer areas with level bottoms of compact silt, sand, or clay (Stanley and

Danie 1983). They exhibit daily vertical migrations from deep water during the day to shallow water at night (Sheri and Power 1969, Stanley and Danie 1983). Though white perch in the Chesapeake Bay are year-round residents, both adults and juveniles migrate to water deeper than 10 m during winter (Lippson 1973:34, Stanley and Danie 1983, Chesapeake Bay Living Resources Task Force 1987:35). As few areas on the northern Bay reach this depth, this migration requires movement to shipping channels or the lower Bay.

Peak numbers of large gizzard shad also were caught in April, presumably due to spawning activity. Gizzard shad spawn from April through June at water temperatures > 17.5 C (Mansueti and Hardy 1967:77, Wang and Kernehan 1979:47, Lee et al. 1980) in waters usually less than 1.5 m deep (Williamson and Nelson 1985). General preferred temperature of gizzard shad is 23-24 C (Clark 1969). Possibly because they can tolerate a wide range of salinities (Mansueti and Hardy 1967:77, Wang and Kernehan 1979:47), gizzard shad were the most consistently netted fish species. In addition, gizzard shad were abundant in a wide range of size classes. Optimal conditions for gizzard shad are found in warm, fertile, shallow bodies of water with soft mud bottoms, high turbidity, and relatively few predators (Williamson and Nelson 1985) -- an apt description of much of the northern Bay. The gizzard shad's intolerance to cold stress, particularly as young-of-the-year, frequently results in large winter fish kills (Williamson and Nelson 1985).

Channel catfish are summer spawners (Wang and Kernehan 1979:104) with an optimal spawning temperature of 26.7 C (Becker 1983:713). Water temperatures on the study area reached this level in June and catfish catch rates peaked concurrently. Because channel catfish have a high preferred temperature (30 to 32 C, Becker 1983:713), midsummer catch of this species was not affected by warm water avoidance. The channel catfish's preference for deep-water holes and its nocturnal habits may have reduced our abundance index for this species. In winter, this species also seeks deep waters and may become semi-dormant (Becker 1983:716).

Though our fish sampling covered only Foraging Areas 1 through 6, fish also were available in the Susquehanna River and at Remington Farms. RMC Environmental Services has recorded more than 78 fish species below Conowingo Dam on the Susquehanna River (unpubl. data, RMC Environmental Services, Muddy Run Ecological Lab, Drumore, Pennsylvania). Gizzard shad was the most common species, comprising 33.5% of all fish caught electrofishing between 1982 and 1986. Dramatic increases in gizzard shad numbers were observed in the tailrace in November (Fig. 35) as lowering water temperatures made young-of-the-year shad susceptible to intake by generating turbines. Numerous ponds on the Eastern Shore, including many in the Remington Farms area, also provided fish for eagles. Common species probably found here are carp, sunfish, and largemouth bass.

Fish depth distribution -- Conclusions drawn from vertical distribution results are based on the assumption that fish caught within the top 0.6 m of the water's surface are more likely to be found within 20 cm of the water's surface than those caught at greater depths. Vertical distribution of fish caught in gillnets showed menhaden and gizzard shad to be the most common species near the water's surface. Menhaden are schooling, pelagic, filter-feeders, which are readily seen breaking the water's surface (Hildebrand and Schroeder 1928:103). Though feeding gizzard shad often are associated with silt bottoms (Hildebrand and Schroeder 1928:107, Bodola 1966), these filter-feeders also frequently travel in schools close to the water's surface (Bodola 1966, Mansueti and Hardy 1967:77, Becker 1983:276, Williamson and Nelson 1985).

In contrast, channel catfish, which are nocturnal bottom feeders that seek holes of deep water (Becker 1983:715), were rarely caught at the water's surface at either depth. Van Daele and Van Daele (1982) speculated that high proportions of brown bullheads in osprey food remains were a result of high availability of bullheads sunning at the water's surface. Todd et al. (1982) also observed bald eagles capturing brown bullheads at the water's surface. Although such sunning behavior might not be revealed by our gillnetting technique, in the absence of evidence to the contrary, I conclude that channel catfish rarely occur near the water's surface. Brown bullheads, which occupy shallower depths than do channel catfish (Becker 1973:703), may be more likely to be found at the water's surface. White perch also avoid surface waters during the day (Sheri and Power 1969); 71% of white perch were caught near the net bottom.

These results indicate that menhaden and gizzard shad are the species most frequently available to bald eagles as live fish. In contrast, live channel catfish and white perch, despite their overall abundance, probably were less frequently available, because of their preference for the water's bottom.

Dead fish -- Our efforts to document fish availability to bald eagles on the northern Chesapeake Bay focused on live fish. Direct observations, however, indicate that dead fish may have composed a significant proportion of fish eaten. In this study, we abandoned attempts to document dead fish availability because, for much of the time, dead fish were uncommon enough that large survey areas were required to reveal trends in abundance. This scarcity of dead fish held except for periodic fish kills occurring in summer 1987 and during winter 1987-88. Thus, dead fish availability appeared to be a boom or bust phenomenon.

Despite this appearance, dead fish may have been an important food source for bald eagles even during periods of apparent scarcity. Strong competition for dead fish among scavengers, such as gulls, great blue herons, and blue crabs, as well as bald eagles, may have caused dead fish to appear less abundant than they actually were. Prompt consumption of floating dead fish by aerial scavengers may have precluded measurement of this resource by our much less efficient surveying techniques. Documenting availability of dead fish, therefore, may only show periods of surplus.

Intensive surveys of dead fish made from May 1988 through April 1989 (DeLong, M.S. Thesis in progress, Virginia Tech) documented a spring and summer peak in dead fish numbers and an absence of dead fish in fall. These results, coupled with general observations made in 1988, suggest dead fish may be most available in spring due to spawning mortality, in summer due to heat stress, and in some winters due to cold stress.

Winter availability of dead fish was variable. DeLong recorded only 2 dead fish during the mild winter of 1988-89 when icing of the Bay was light. In contrast, dead gizzard shad were seen commonly during the more severe winter of 1987-88 when ice cover was extensive (D.

Buehler, D. DeLong,and A.K. DeLong, pers. comm.). The winter of 1986-87 was intermediate in severity relative to the other 2 years. Dead fish were again uncommon during this winter, and fish were rarely seen captured (20 of 22 fish listed for winter 1986-87 were taken in mid-March and can be considered a response to spring spawning; see Table 9). Dead fish availability in winter, therefore, appears to increase with winter severity.

DeLong's surveys also indicated species composition of dead fish may differ from that of live fish. In contrast to gillnet results, dead channel catfish were seen more often than other fish species, except for menhaden, which were subject to large periodic fish kills. This high relative abundance of dead catfish may be a better indication of its live relative abundance than are gillnet results, as gillnet sampling may have underestimated numbers of this fish due to its nocturnal habits and preference for deep holes. In general, Delong's data and personal observations suggest that common species of floating dead fish are the same as those commonly gillnetted, but also include American eels, not netted because of their body shape. Relative species abundance of floating dead fish may differ from that of live fish due to differential mortality rates and the propensity of each species to float when dead. Deep-water species, such as channel catfish and white perch, may not be frequently available to foraging eagles except as floating dead fish.

Birds and Mammals

Like fish, waterfowl numbers varied substantially with season; winter survey counts were 10-25 times higher than summer counts. Observed timing of waterfowl migration agreed with Lippson (1973:52); migrating Canada geese began arriving on the Chesapeake Bay by the end of September, and the spring return migration began near the first of March. Distribution of waterfowl also followed Lippson (1973:51,53). In contrast to fish, which were more abundant on the western shore, waterfowl were most abundant on the eastern shore, due primarily to waste corn in agricultural fields there.

Although our waterfowl monitoring focused on live birds, our observations of foraging eagles, radiograph results, and the abundance of waterfowl carrion in winter, lead me to conclude that bald eagles primarily obtained waterfowl by scavenging. Waterfowl carrion was undoubtably most abundant in areas of high waterfowl density and associated hunting, as hunter harvest and crippling loss account for 85-90% of mortality in Canada goose populations (Hindman 1989; see Appendix I for waterfowl hunting regulations on the study area). We were unable to directly survey waterfowl carcass distribution and abundance due to their dispersion and lack of consistent foot access to waterfowl areas during hunting seasons, though we commonly observed waterfowl carcasses on the ice, shorelines, and fields of the eastern shore.

Availability of mammal carrion also probably peaked in winter due to deer hunting and natural winter mortality; however, large mammal carrion also was too widely dispersed to be monitored effectively. White-tailed deer, abundant throughout nonurban areas on the northern Chesapeake, are present in especially high densities on APG where broken forests are extensive and hunting pressures are relatively low due to hunter access restrictions. These high densities appeared to result in high winter mortality; we observed starving deer, and carcasses were seen occasionally during project activities. Hunting-related mortality, as well as discarded entrails from field-dressed deer, also probably increased availability of deer to eagles. Raccoons also were abundant on APG, possibly due to the extensive marshes there. Raccoon carcasses were seen commonly during winter. Increases in numbers of other raptors during winter on the northern Bay also increased opportunities for kleptoparasitism, by which most small mammals and birds may have been obtained.

Use Versus Availability

Fish

Bald eagle use of food resources on the northern Chesapeake Bay generally reflected food abundance. Eagles fed almost exclusively on fish when fish were abundant, but shifted their diet to exploit abundant waterfowl and mammal carrion in winter when fish numbers were low. Their preference for fish however was indicated by frequent use of gizzard shad during winter 1987-88 when these fish became available amidst an abundance of waterfowl carrion. Eagles also used large numbers of gizzard shad when this fish became available below Conowingo Dam in late fall and early winter.

The bald eagle's use of fish also generally reflected fish species abundance -- the 4 fish species most frequently eaten by eagles were the same 4 species most commonly netted. A finer resolution comparison of fish species use versus availability (to examine preference among these highly used species) was complicated by several factors, including the large number of unidentified fish in direct observation results, the availability of dead fish, and species selectivity of gillnets (see Appendix H).

Relative abundance of fish species determined during direct observation probably is not an unbiased representation of unidentified fish. Identifying fish from a distance may have inflated relative occurrence of distinctively shaped fish such as American eels and, to a lesser extent, catfish. Identifying fish from remains probably resulted in the biases discussed in Chapter 1, i.e., over-representation of catfish and under-representation of menhaden, white perch, and small shad.

Unidentified small fish ($\leq$ 20 cm) composed 45.1% (78 of 173) of all unidentified fish. From size distributions determined through gillnet sampling, unidentified small fish probably were primarily menhaden, white perch, and small gizzard shad. Menhaden are particularly likely due to their large numbers and frequency at the water's surface. The large number of fish in this category during winter probably was dead and dying year-old gizzard shad as these were commonly observed among ice-flows on the Bay. Size distributions of gillnetted fish also indicate that unidentified large fish (15.0%, or 26 of 173 unidentified fish) probably were primarily gizzard shad and catfish, with gizzard shad more likely due to their greater abundance at the water's surface, and the biases toward identifying catfish. The remaining unidentified fish (39.9%, 69 of 173), for which no length estimates were made, were predominately from winter 1987-88. These fish were eaten by eagles on ice and were also likely gizzard shad because few other species were present at that time. Thus, identification of all fish during observations would likely have increased the relative occurrence of menhaden, gizzard shad, and possibly white perch, while decreasing the relative occurrence of catfish and American eel. Gizzard shad and menhaden, therefore, appear to be the most important fish species to northern Chesapeake eagles, though a wide variety of fish are used when fish are abundant. Gizzard shad may be particularly important due to their larger size (contributing a greater proportion to total biomass eaten), and their availability in fall and winter.

Although the number of fish with status (live versus dead) determined was small, status of fish species taken by eagles also reflects a response to availability. Menhaden and gizzard shad, caught at the water's surface relatively often, were taken live at greater frequencies than channel catfish and white perch, which were caught frequently near the net bottom. Neither of these latter 2 species were ever documented as taken live by eagles.

Dead fish appear to have been used most frequently in spring and winter, and live fish used most frequently in fall, in agreement with our assessment of dead fish abundance. Though status was not determined for a large proportion of observations, our data indicate that dead fish were a significant food source, composing at least 24.5% of fish eaten and possibly composing more than half of all fish taken. High success rates of eagles striking the water's surface (82% of strikes with known outcome) may also indicate frequent use of dead fish.

Catfish, despite identification biases in their favor and their abundance on the Bay, were not observed to be used more frequently than other common fish species, in contrast to other bald eagle food habits studies on the Chesapeake Bay (Cline and Clark 1981) and elsewhere (see Introduction of this chapter). This species' frequent use as carrion, their affinity for the water's bottom, and their disproportionate occurrence as floating dead fish (DeLong, thesis in progress) lead me to conclude that live channel catfish were rarely available to foraging eagles. Therefore, in our case, eagle use of catfish appears to be primarily dependent on floating dead fish and not on the susceptibility of live catfish to aerial predation (Swenson 1979, Haywood and Ohmart 1986).

Although carp also have been reported as an important food for breeding Chesapeake Bay eagles (Cline and Clark 1981), they did not often appear in our gillnetting or observational results. Carp scales did however occur with some frequency (45 of 183 fish) in eagle pellets, but the size of these scales indicated large individuals that likely were obtained by scavenging. These carp probably were obtained at inland ponds on both sides of the Bay where these fish were common (pers. obs.; J. Ondek, pers. commun.). In general, however, our data did not indicate frequent use of carp by northern Chesapeake eagles.

Despite general agreement between use and abundance of fish resources, we did not find significant correlation between foraging rates on fish and gillnet catch rates by foraging area. Foraging rate response to fish abundance may have been dampened by eagles shifting to a different location when foraging rates fell below some lower level. Conversely, eagles must also have an upper limit to foraging rate (our observations suggest a foraging rate of 50g / eagle-hour lies within this upper and lower limit; see Fig. 29). Insignificant correlation between eagle density and gillnet catch rates may indicate that fish availability in all (or most) areas over the period examined (April - September) was above the minimum required to provide for this foraging frequency. Additionally, my measures of fish use and abundance, and eagle abundance, may have lacked the precision or accuracy necessary to measure this relationship. Further analysis of the relationship of eagle distribution and abundance to that of food, will be done by Buehler (analysis in progress).

Birds and Mammals

Pellet contents also reflected eagle response to local food abundance. Large concentrations of waterfowl observed on the Eastern Shore during survey counts were mirrored in the contents of pellets collected at Remington Farms. In contrast, the Aberdeen peninsula, with more extensive forests and marshes but far fewer waterfowl than the eastern shore, was the source of pellets with a greater occurrence of deer, raccoon, and muskrat. The large proportion of gulls in Mosquito Creek pellets are presumably due to this roost's proximity to the Conowingo Dam on the Susquehanna River, which supported large concentrations of gulls during winter. Pellets from AA5 and Little Romney Creek Roosts also contained a larger proportion of passerines, primarily grackles and red-winged blackbirds, which were common in Aberdeen marshes.

Higher pellet egestion rates in the Remington Farms Roost also reflected the eagle's reliance on large concentrations of waterfowl in this area. Pellet egestion rates for Remington Farms peaked for both years at slightly > 1 pellet per eagle night. A pellet egestion rate of ≥ 1 pellets per eagle-night is indicative of eagles feeding on birds and mammals daily (Chapter 1). In contrast, pellet egestion rates in AA5 Roost peaked at 0.4 pellets per eagle-night in 1987-88, indicating a lower frequency of feeding on birds and mammals.

Occurrence of fish parts in pellets is presumably the result of eagles feeding on both fish and birds or mammals within a short period (i.e., 1-2 days; see Chapter 1). Thus, although fish may not often appear alone in pellet analysis, their occurrence within pellets of fur or feathers is an indication of their presence in the diet. The percentage of pellets containing fish parts in an area was inversely related to pellet egestion rate; lower egestion rates and higher fish percentages were found on APG, and higher egestion rates and lower fish percentages were recorded at Remington Farms.

Between-year differences in food abundance also were reflected in pellet contents. These differences can be partially attributed to differences in collection intensities for each roost -- greater pellet collections in Mosquito Creek and Little Romney Creek Roosts in the second winter resulted in higher representations of gulls and deer. Despite these effects, waterfowl appear to have been less important to bald eagles during the second year of our study and mammals concommitantly more important. Canada geese, used twice as frequently as mallards in winter 1986-87, appeared at the same frequency as mallards in winter 1987-88. This result corresponds with the relative abundance of geese and ducks observed during aerial surveys during these 2 winters. Decline in our goose count agrees with midwinter goose surveys conducted by the Maryland Department of Natural Resources which have recorded significant declines in Maryland goose populations since 1986 (Hindman 1989). Availability of large flocks of lesser scaup, located off the APG shoreline in winter 1987-88, were reflected in greater frequencies of this species in AA5 pellets that year.

Winter peaks and spring declines in pellet egestion rates were remarkably similar in magnitude between years despite using 2 different methods for calculating this rate. Because collecting pellets under a few selected trees is more efficient than collecting pellets over an entire roost, pellet egestion rates calculated for winter 1987-88 should be higher than those calculated for the preceding years, given equal bird and mammal use. Therefore, the equal rates actually observed may indicate greater use of birds and mammals during winter 1986-87. The greater percentage of pellets containing fish during winter 1987-88, in addition to direct observation results, agrees with this conclusion. The spring decline in pellet egestion rate lagged behind waterfowl survey counts, possibly indicating the continued use of carcasses and cripples left behind by migrating waterfowl.

Foraging Behavior

Foraging activity -- Bald eagles foraged most intensely within 1 hour of sunrise as indicated by strike frequency and the proportion of strikes initiated from foraging flights. Intense morning foraging activity also has been noted by others (Grewe 1966, Servheen 1975, Stalmaster 1981, Steenhof 1983). This activity may simply be stimulated by hunger after a night's fast; however, fish availability in early morning may be greater as well. Nocturnal or crepuscular fish, such as white perch and channel catfish, may be available in shallows at this time. Floating dead fish, which have accumulated over the night, also may be at daily peak abundance. Dead fish were taken in the morning at slightly higher proportions than during the remainder of the day; however, differences in proportions were not statistically significant.

After the morning peak in foraging, the proportion of strikes initiated from perches increased, as eagles apparently tended to respond to foraging opportunities as they arose rather than actively searching for prey. The small peak in strike frequency in early afternoon may indicate a second, less synchronized, pulse of foraging activity following digestion of the morning meal.

Use of aquatic foraging habitat -- High catch rates of surface fish in shallow-water gillnets and the relatively shallow water at sites of live fish captures suggest that shallow water is an important component of live fish availability to eagles. Fish in shallow water may be more vulnerable to predation because they are forced into proximity with the water's surface by the limited water column. Alternatively, eagles may be able to respond more quickly to live fish foraging opportunities in shallow water near the shoreline than in deeper water further from shore.

The decline in strike frequency with distance from shore probably reflects the eagle's dependence on the shoreline for perching substrate. Eagles also frequently followed the shoreline while in foraging or traveling flight. Depth of water at fish capture sites also reflected greater use of water near the shore; capture frequency declined with increasing depth for all status categories.

Seasonal Cycles and Food Scarcity

Abundance of fish and waterfowl varied reciprocally over the annual cycle. Periods of food scarcity, if occurring at all on the northern Chesapeake, would likely occur during periods of transition between fish and waterfowl sources, namely, in late February and March, and late October and early November. Overlap in fish and waterfowl abundance cycles, however, might supply sufficient food resources during these periods. Lack of a common food availability measure for the variety of foods used by eagles precludes accurate assessment of total food abundance. An additional factor important in assessing seasonal food scarcity is seasonal changes in eagle numbers, which vary widely on the northern Bay (Buehler, Ph.D. Thesis, in progress, Virginia Tech).

Simple activity budgets of eagles in foraging areas did not show effects of food transition periods. Trends in flight activity resembled trends in gillnet catch rates and fish foraging rates. This correspondence is likely due to our sampling design. Observed eagles were not chosen from the population at random, but were observed primarily in aquatic foraging areas; therefore, flight activity may simply have reflected levels of fish foraging activity, rather than total foraging activity.

Kleptoparasitism rates, however, do suggest some response to transition periods. Although sample sizes in some months are small, trends for this rate in months with ≥ 10 successful forages show an October peak. The March rate also was higher than mid-summer or mid-winter rates. Increases in kleptoparasitism during these periods may indicate an increase in competition resulting from food shortages.

The most adaptive response of highly-mobile birds to local food scarcity, however, may be to move. Thus, food scarcity might best be examined in relation to changes in eagle distribution and abundance. In continuing research on the northern Chesapeake, established distributional shifts by eagles may have been altered by experimental food supplementation in areas of hypothesized food limitation (DeLong, M.S. Thesis in progress, Virginia Tech). Buehler (analysis in progress) further examines distributional response of eagles to the seasonal and geographical distribution of food described here.

CONCLUSIONS AND MANAGEMENT IMPLICATIONS

Bald eagles are foraging opportunists capable of exploiting a variety of food sources as they become available. We have documented large seasonal and geographical variation in abundance of major bald eagle foods (fish and waterfowl) on the northern Chesapeake Bay. Eagle use of these foods reflected this variation in abundance. Bald eagles subsisted almost entirely on live and dead fish from April through September. From November through February, the eagle's diet consisted predominately of bird and mammal carrion, although this was supplemented by winter-killed gizzard shad in a severe winter. Eagles shifted between these 2 diets primarily in the transition months of March and October.

Management actions likely to affect the eagle food base include the reduction of waterfowl hunting seasons and bag limits due to declining waterfowl populations (Trost et al. 1986). Although these actions are designed to increase waterfowl populations in the long run, immediate impacts on eagle food abundance are possible, particularly in mild winters when natural mortality of birds, mammals, and fish is low. It is not known what level of decreased waterfowl populations and hunting pressure might impact eagles; however, even with decreased seasons and bag limits in 1987-88 (Appendix I), uneaten waterfowl carcasses were common in late February (D. DeLong, pers. commun.), indicating a food surplus at that time. Frequent use of waterfowl carrion in winter also indicates a potential for significant ingestion of lead shot.

Efforts to improve water quality and restore abundant and diverse fish stocks on the Chesapeake Bay will affect the fish portion of the eagle's food base. Impacts of these actions are uncertain. Decreasing eutrophication and siltation and increasing stocks of predatory fish, such as striped bass, may decrease numbers of the frequently eaten-gizzard shad and menhaden, but also may increase the availability of a variety of fish. Frequent use of dead fish by northern Chesapeake eagles also indicates potential for significant impacts from waterborne contaminants.

Our results also indicate that protection of aquatic foraging habitat for bald eagles should focus on areas of shallow water where fish may be most available. Controlling human disturbance in foraging areas is most crucial in the morning (50% of foraging strikes occurred within 2 hours of sunrise), however significant disturbance may occur at any time of day.

As local food scarcity will likely result in movement of eagles to areas of greater food abundance, only insufficient food resources over very large areas should result in obvious signs of food limitation such as starvation. This level of food limitation is unlikely given the low but expanding status of East Coast bald eagle populations (Wood et al., in press) and the variety of foods bald eagles utilize. No evidence of such critical food limitation was observed on the northern Chesapeake Bay; however, distribution of eagles may have been affected by food abundance (Buehler, analysis in progress).

Due to their ready acceptance of carrion, supplemental feeding of bald eagles may be effective in situations of local food scarcity, and has been used to affect eagle distribution (DeLong, M.S. Thesis in progress, Virginia Tech) and improve survival rates of immatures (McCollough 1986). This food-base management technique is labor intensive, however, and may result in undesirable dependence of wild birds on feeding stations (Archibald 1978). Because eagles are capable of shifting diets to exploit a wide variety of foods, maintaining an abundant and diverse fauna may be the best means of ensuring adequate long-term food resources for northern Chesapeake bald eagles.

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Tables

Table 1. Frequency (n) and percent occurrence (%) of food items in the actual diet of 2 captive bald eagles versus that determined by analysis of their egested pellets.[a]

Food Item	Actual Diet		Pellet Analysis		Pellet Frequency per Food Item
	n	%	n	%	
Fish	213	73.4	12	9.4	0.06
Birds	35	12.1	52	40.6	1.49
Mammals	42	14.5	64	50.0	1.52
Total	290	100.0	128	100.0	0.44

[a] Goodness-of-fit test: $\chi^2 = 281.37$, 2 df, $\underline{P} < 0.001$.

Table 2. Frequency (n) and percent occurrence (%) of fish species in the actual diet of 2 captive bald eagles versus that determined by analysis of their egested pellets.

Fish Species	Actual Diet n	Actual Diet %	Pellet Analysis n	Pellet Analysis %	Parts Detected
American Eel	32	15.0	0	0.0	
Carp	26	12.2	4	33.3	scales
Catfish	39	18.3	0	0.0	
Gizzard Shad	39	18.3	3	25.0	scales
Menhaden	36	16.9	1	8.3	scale
White Perch	41	19.3	2	16.7	otoliths, scale
Unidentified Fish			2	16.7	vertebrae
Total	213	100.0	12	100.0	

Table 3. Frequency (n) and percent occurrence (%) of birds and mammals in the actual diet of 2 captive bald eagles versus that determined by analysis of their egested pellets.[a]

Food Type	Actual Diet		Pellet Analysis		Pellet Frequency per Food Item
	n	%	n	%	
Large Birds	14	18.2	24	20.7	1.71
Medium Birds	11	14.3	18	15.5	1.64
Small Birds	10	13.0	10	8.6	1.00
Large Mammals	19	24.6	17	14.7	0.89
Medium Mammals	13	16.9	29	25.0	2.23
Small Mammals	10	13.0	18	15.5	1.80
Total	77	100.0	116	100.0	1.51

[a] Goodness-of-fit test: $\chi^2 = 12.05$, 5 df, $0.05 > \underline{P} > 0.01$.

Table 4. Percent of food items identified in remains after feeding by 2 captive eagles, and the percent of food remains recovered after 1 month in shoreline plots on the northern Chesapeake Bay.

	Remains Identification		Shoreline Recovery	
Food Item	No. Fed	Percent in Remains	No. Remains Placed in Plots	Percent Recovered
Fish	213	64.8	101	34.7
Large	53	84.9	30	56.7
Medium	72	69.4	36	27.8
Small	88	48.9	34	23.5
Birds	32	96.9	22	90.9
Large [a]	11	100.0	8	100.0
Medium	11	100.0	9	100.0
Small	10	90.0	5	60.0
Mammals	23	56.5	10	60.0
Large [a]				
Medium	13	100.0	10	60.0
Small	10	0.0	0	
Total	268	67.9	133	45.9

[a] Canada geese and white-tailed deer were omitted from this analysis as they were deemed unlikely to be carried to a perch.

Table 5. Percent of fish species identified in remains after feeding by 2 captive eagles, and the percent of these remains recovered after 1 month in shoreline plots on the northern Chesapeake Bay.

	Remains Identification		Shoreline Recovery	
Fish Species	No. Fed	Percent in Remains	No. Remains Placed in Plots	Percent Recovered
American Eel	32	15.6	2	0.0
Carp	26	73.1	12	83.3
Catfish	39	87.2	27	44.4
Gizzard Shad	39	66.7	16	18.8
Menhaden	36	61.1	21	19.1
White Perch	41	78.1	23	26.1
Total	213	64.8	101	35.0

Table 6. Total numbers and biomass of all fish and fish <1 kg caught in 504 gillnet sets on the northern Chesapeake Bay, January through December, 1987.

Species	Total catch		< 1 kg	
	n	kg	n	kg
Menhaden (*Brevoortia tyrannus*)	2260	152.3	2260	152.3
White perch (*Morone americana*)	1313	105.4	1313	105.4
Gizzard shad (*Dorosoma cepedianum*)	1269	663.1	1196	580.2
Channel catfish (*Ictalurus punctatus*)	375	241.3	289	115.5
Striped bass (*Morone saxatilis*)	87	113.6	38	18.7
Spot (*Leiostomus xanthurus*)	53	3.2	53	3.2
Bluefish (*Pomatomus saltatrix*)	39	11.1	35	6.6
Yellow perch (*Perca flavescens*)	30	2.5	30	2.5
Brown bullhead (*Ictalurus nebulosus*)	24	4.0	24	4.0
Blueback herring (*Alosa aestivalis*)	22	4.5	22	4.5
Golden shiner (*Notemigonus crysoleucas*)	21	1.2	21	1.2
White catfish (*Ictalurus catus*)	15	16.0	6	3.1
Carp (*Cyprinus carpio*)	13	32.5	1	0.1
Largemouth bass (*Micropterus salmoides*)	9	3.6	8	2.1
Hickory shad (*Alosa mediocris*)	6	1.8	6	1.8
Sunfish (*Lepomis* spp.)	6	1.8	6	1.8
Total	5539	1356.3	5305	1001.4

Table 7. Mean catch rates for deep- (1.8 m) and shallow-water (0.6 m) gillnets by bayside and habitat[a] on the northern Chesapeake Bay from April through September, 1987.

		Deep-water catch		Shallow-water catch	
Location	n	fish/hr	g/hr	fish/hr	g/hr
Bayside					
West	36	21.4[b]	3920[c]	5.1[b]	858[b]
East	36	16.0	3608	3.2	595
Habitat[a]					
Creek	24	27.3[d]	4913[d]	7.0[e]	1095[d]
River	24	20.6	4643	3.9	827
Bay	24	8.2	1737	1.6	257

[a] Effects of habitat and daytime on catch rates were confounded, because netting was consistently done in the Bay in morning, in creeks in mid-day, and in rivers in late afternoon.

[b] West-side catch was significantly greater than East-side catch; 2-way ANOVA, $P < 0.05$.

[c] West-side catch did not differ significantly from East-side catch; 2-way ANOVA, $P > 0.05$.

[d] Creek and River catch was significantly greater than Bay catch; 2-way ANOVA, $P < 0.05$.

[e] Differences in catch rate among habitats were not significantly different; 2-way ANOVA, $P > 0.05$.

Table 8. Total number (n) and density (n/km) of waterfowl, as determined by aerial shoreline surveys, on the northern Chesapeake Bay, October through March, 1986-87 and 1987-88.

	Eastern Shore		Western Shore		Susquehanna River	
Survey Date	n	n/km	n	n/km	n	n/km
1986-87						
Oct 18,19	5841	18.0	537	2.1	0	0.0
Nov 15,16	26125	80.7	1382	5.4	0	0.0
Dec 20,21	13637	42.1	790	3.1	25	0.8
Jan 24,25	10090	31.2	1890	7.3	380	12.0
Feb 14,16	11865	36.6	1065	4.1	75	2.4
Mar 14,15	2495	7.7	725	2.8	120	3.8
Total	70053	35.9 a[a]	6389	4.1 b	600	3.2 b
1987-88						
Oct 18,19	6060	17.2	190	0.7	110	3.5
Dec 6,7	9090	25.8	710	2.7	30	0.9
Dec 19,23	13649	38.8	5430	21.1	70	2.2
Jan 16,17	11560	32.8	525	2.0	250	7.9
Feb 27,28	11306	32.1	595	2.3	25	0.8
Mar 19,20	1120	3.2	0	0.0	0	0.0
Total	52785	25.0 a[b]	7450	4.8 b	485	2.6 b

[a] Kruskal-Wallis test (χ^2 approx.): $\chi^2 = 11.42$, 2 df, $P = 0.0033$.
Wilcoxon 2-sample test: East vs. West Shore, $W = 57.0$, $n = m = 6$, $P = 0.002$.
West Shore vs. Susquehanna, $W = 47.0$, $n = m = 6$, $P = 0.24$.

[b] Kruskal-Wallis test (χ^2 approx.): $\chi^2 = 8.99$, 2 df, $P = 0.0111$.
Wilcoxon 2-sample test: East vs. West Shore, $W = 55.0$, $n = m = 6$, $P = 0.008$.
West Shore vs. Susquehanna, $W = 39.5$, $n = m = 6$, $P = 0.88$.

Table 9. Seasonal frequency (n) and rate (no. / 100 eagle-hours) of fish capture by bald eagles on the northern Chesapeake Bay, January, 1987, through February, 1988.

Species	Winter 1986-87 (hr = 136.78)		Spring (hr = 135.23)		Summer (hr = 270.58)		Fall (hr = 259.83)		Winter 1987-88 (hr = 332.17)		Total (hr = 1134.59)	
	n	n/100 hr	n	n/100 hr	n	n/100 hr	n	n/100 hr	n	n/100 hr	n	n/100 hr
Gizzard shad	2	1.46	2	1.48	6	2.22	9	3.46	19	5.72	38	3.35
Catfish	0	0.00	3	2.22	5	1.85	1	0.38	0	0.00	9	0.79
Menhaden	0	0.00	5	3.70	3	1.11	1	0.38	0	0.00	9	0.79
White perch	4	2.92	4	2.96	1	0.37	0	0.00	0	0.00	9	0.79
American eel	0	0.00	2	1.48	5	1.85	0	0.00	0	0.00	7	0.62
Yellow perch	5	3.66	0	0.00	0	0.00	1	0.38	0	0.00	6	0.53
Carp	0	0.00	0	0.00	0	0.00	1	0.38	0	0.00	1	0.09
Striped bass	0	0.00	0	0.00	0	0.00	1	0.38	0	0.00	1	0.09
Total identified	11	8.04	16	11.83	20	7.39	14	5.39	19	5.72	80	7.05
Unidentified, ≤ 20cm	6	4.39	6	4.44	16	5.91	33	12.70	17	5.12	78	6.87
Unidentified, > 20cm	0	0.00	4	2.96	13	4.80	4	1.54	5	1.51	26	2.29
Unidentified, size unk.	5	3.66	3	2.22	10	3.70	12	4.62	39	11.74	69	6.08
Total, all fish	22	16.08	29	21.44	59	21.81	63	24.25	80	24.08	253	22.30

Table 10. Frequency (n) and rate (n / 100 eagle hours) of fish capture by bald eagles in 8 foraging areas on the northern Chesapeake Bay, January 1987 through February 1988.

	Foraging Areas (eagle-hours)																	
	APG Bay (191.27)		Bush R. (172.58)		Romney C. (254.25)		ES Bay (117.13)		Sass. R. (110.55)		Stillpond C. (30.28)		Susq. R. (139.33)		R. Farms (119.20)		Total (1134.59)	
Species	n	rate	n	rate	n	rate	n	rate	n	rate	n	rate	n	rate	n	rate	n	rate
Gizzard shad	8	4.18	3	1.74	11	4.33	1	0.85	3	2.71	1	3.30	10	7.18	1	0.84	38	3.35
Catfish	0	0.00	2	1.16	0	0.00	2	1.71	2	1.81	0	0.00	3	2.15	0	0.00	9	0.79
Menhaden	3	1.57	2	1.16	1	0.39	1	0.85	1	0.90	0	0.00	0	0.00	1	0.84	9	0.79
White perch	1	0.52	1	0.58	7	2.75	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	9	0.79
American eel	0	0.00	3	1.74	0	0.00	1	0.85	2	1.81	1	3.30	0	0.00	0	0.00	7	0.62
Yellow perch	0	0.00	1	0.58	5	1.97	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	6	0.53
Carp	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	1	0.72	0	0.00	1	0.09
Striped bass	1	0.52	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	1	0.09
Total identified	13	6.80	12	6.95	24	9.44	5	4.27	8	7.24	2	6.60	14	10.05	2	1.68	80	7.05
Unidentified, ≤ 20cm	8	4.18	3	1.74	16	6.29	7	6.00	4	3.62	3	9.91	21	15.07	16	13.42	78	6.87
Unidentified, > 20cm	6	3.14	2	1.16	5	1.97	3	2.56	6	5.43	0	0.00	4	2.87	0	0.00	26	2.29
Unidentified, size unk.	19	9.93	5	2.90	26	10.23	10	8.54	0	0.00	0	0.00	9	6.46	0	0.00	69	6.08
Total, all fish	46	24.05	22	12.75	71	27.93	25	21.34	18	16.28	5	16.51	48	34.45	18	15.10	253	22.30

Table 11. Status (live, dead, or unknown) by season of fish observed captured by bald eagles on the northern Chesapeake Bay, January 1987 through February 1988.

	Status							
	Live		Dead		Unknown		Total	
Season	n	%	n	%	n	%	n	%
Winter 1986-87	2	9.0	8	36.4	12	54.6	22	100.0
Spring	1	3.4	2	6.9	26	89.7	29	100.0
Summer	5	8.5	12	20.4	42	71.1	59	100.0
Fall	18	28.6	17	27.0	28	44.4	63	100.0
Winter 1987-88	5	6.2	23	28.8	52	65.0	80	100.0
Total	31	12.3	62	24.5	160	63.2	253	100.0

Table 12. Status (live, dead, or unknown) of fish species observed taken by bald eagles on the northern Chesapeake Bay, January 1987 through February 1988.

	Status							
	Live		Dead		Unknown		Total	
Species	n	%	n	%	n	%	n	%
Gizzard shad	5	13.1	8	21.0	25	65.9	38	100.0
Catfish	0	0.0	7	77.8	2	22.2	9	100.0
Menhaden	3	33.3	3	33.3	3	33.3	9	100.0
White perch	0	0.0	4	44.4	5	55.6	9	100.0
American eel	1	14.3	1	14.3	5	71.4	7	100.0
Yellow perch	1	16.7	3	50.0	2	33.3	6	100.0
Carp	0	0.0	0	0.0	1	100.0	1	100.0
Striped bass	0	0.0	1	100.0	0	0.0	1	100.0
Unidentified, ≤ 20cm	19	24.4	17	21.8	42	53.8	78	100.0
Unidentified, > 20cm	2	7.7	1	3.8	23	88.5	26	100.0
Unidentified, size unk.	0	0.0	17	24.6	52	75.4	69	100.0
Total	31	12.3	62	24.5	160	63.2	253	100.0

Table 13. Frequency (n) and percent occurrence (%) of bird and mammals found in bald eagle pellets collected on the northern Chesapeake Bay from Dec 1986 through May 1987 (no. of pellets = 518) and Jun 1987 through Apr 1988 (no. of pellets = 571).

	1986-87		1987-88		Total	
Food Item	n	%	n	%	n	%
Canada goose	264	41.9	135	20.7	399	31.1
Mallard	139	22.1	140	21.5	279	21.8
Scaup	4	0.6	31	4.8	35	2.7
Common merganser	5	0.8	24	3.7	29	2.2
Ruddy duck	14	2.2	0	0.0	14	1.1
American coot	0	0.0	5	0.8	5	0.4
Redhead	2	0.3	2	0.3	4	0.3
Common goldeneye	1	0.2	2	0.3	3	0.2
Northern pintail	2	0.3	0	0.0	2	0.2
Canvasback	0	0.0	2	0.3	2	0.2
Ring-necked duck	2	0.3	0	0.0	2	0.2
Bufflehead	0	0.0	2	0.3	2	0.2
Hooded merganser	0	0.0	2	0.3	2	0.2
Red-breasted merganser	1	0.2	1	0.2	2	0.2
Snow goose	1	0.2	0	0.0	1	0.1
American black duck	0	0.0	1	0.2	1	0.1
Wood duck	0	0.0	1	0.2	1	0.1
Unidentified *Anas*	1	0.2	10	1.5	11	0.8
Unidentified *Athya*	1	0.2	3	0.4	4	0.4
Unidentified Anseriforme	4	0.6	8	1.2	12	0.9
Total waterfowl	441	70.1	369	56.7	810	63.3
Herring gull	3	0.4	22	3.4	25	1.9
Ring-billed gull	6	1.0	17	2.6	23	1.8
Laughing gull	2	0.3	0	0.0	2	0.2
Unidentified gull	0	0.0	9	1.4	9	0.7
Total gulls	11	1.7	48	7.4	59	4.6
Common grackle	17	2.7	9	1.4	26	2.0
Red-winged blackbird	10	1.6	9	1.4	19	1.5
Brown-headed cowbird	3	0.4	0	0.0	3	0.2
American crow	0	0.0	2	0.3	2	0.2
Northern cardinal	1	0.2	1	0.2	2	0.2
European starling	2	0.3	0	0.0	2	0.2
Cape May warbler	1	0.2	0	0.0	1	0.1
Eastern meadowlark	0	0.0	1	0.2	1	0.1
Unidentified passerines	5	0.8	3	0.4	8	0.6
Total passerines	39	6.2	25	3.9	64	5.1
Rock dove	1	0.2	4	0.6	5	0.4
Unidentified grebe	2	0.3	0	0.0	2	0.2
Pied-billed grebe	0	0.0	1	0.2	1	0.1
Glossy ibis	0	0.0	1	0.2	1	0.1
Unidentified accipiter	0	0.0	1	0.2	1	0.1
Virginia rail	1	0.2	0	0.0	1	0.1
Northern flicker	1	0.2	0	0.0	1	0.1
Domestic chicken	0	0.0	1	0.2	1	0.1
Unidentified bird	5	0.8	6	0.9	11	0.8
Total other birds	11	1.9	13	2.1	24	2.0
Total birds	502	79.9	455	70.1	957	75.0

Table 13. (continued).

Food Item	1986-87		1987-88		Total	
	n	%	n	%	n	%
White-tailed deer	36	5.7	119	18.1	155	12.1
Raccoon	27	4.3	22	3.4	49	3.8
Muskrat	15	4.3	17	2.6	32	2.5
Rabbit	19	3.0	11	1.7	30	2.3
Vole	12	1.9	8	1.2	20	1.5
Domestic sheep	0	0.0	8	1.2	8	0.6
Red fox	4	0.6	4	0.6	8	0.6
Gray squirrel	4	0.6	2	0.3	6	0.4
Virginia opossum	1	0.2	3	0.4	4	0.3
Striped skunk	3	0.4	0	0.0	3	0.2
Peromyscus spp.	1	0.2	1	0.2	2	0.2
Bobcat	1	0.2	0	0.0	1	0.1
Domestic pig	1	0.2	0	0.0	1	0.1
Unidentified small rodent	3	0.4	0	0.0	3	0.2
Unidentified mammal	0	0.0	1	0.1	1	0.1
Total mammals (total)	127	20.1	196	29.9	323	25.0
Total, all taxa	629	100.0	651	100.0	1280	100.0

Table 14. Frequency (n) and percent occurrence (%) of birds and mammals identified in bald eagle pellets from 5 communal roosts on the northern Chesapeake Bay, Dec 1986 through May 1987 (no. of pellets = 518), and Jun 1987 - Apr 1988 (no. of pellets = 571).

	ROOST NAME													
	AA5		Mosquito Creek		L. Romney Creek		Andelot Farm		Remington Farms		Others		Total	
FOOD ITEM	n	%	n	%	n	%	n	%	n	%	n	%	n	%
1986-87														
Waterfowl	45	32	2	18			36	68	358	84			441	70
Gulls	3	2	4	37			1	2	3	1			11	2
Passerines	19	14	1	9			2	4	17	4			39	6
Other birds	5	4	1	9			1	2	4	1			11	2
Total birds	72	52	8	73			40	76	382	90			502	80
Whitetailed deer	23	16	0	0			6	12	7	1			36	6
Other mammals	45	32	3	27			6	12	37	9			91	14
Total mammals	68	48	3	27			12	24	44	10			127	20
Total	140	100	11	100			52	100	426	100			629	100
198788														
Waterfowl	56	47	38	40	8	12	11	52	248	74	8	62	369	57
Gulls	7	6	29	30	4	6	2	10	4	1	2	15	48	7
Passerines	11	9	5	5	0	0	1	5	8	2	0	0	25	4
Other birds	5	4	0	0	0	0	0	0	6	2	2	15	13	2
Total birds	79	66	72	75	12	18	14	67	266	79	12	92	455	70
Whitetailed deer	32	27	14	15	43	66	1	5	29	9	0	0	119	18
Other mammals	9	7	10	10	10	16	6	28	41	12	1	8	77	12
Total mammals	41	34	24	25	53	82	7	33	70	21	1	8	196	30
Total	120	100	96	100	65	100	21	100	336	100	13	100	651	100

Table 15. Pellet egestion rates (pellets/eagle night) of bald eagles in for 3 communal roosts on the northern Chesapeake Bay from December, 1986, through June, 1988.

Month	AA5 Roost	Remington Farms Roost	Mosquito Creek Roost	Total Total
Dec 1986	0.05 (21/434)	0.25 (54/217)		0.12 (75/651)
Jan 1987	0.03 (20/620)	0.28 (104/372)		0.13 (125/992)
Feb 1987	0.05 (27/504)	1.10 (92/84)		0.20 (118/588)
Mar 1987	0.11 (38/341)	0.80 (74/93)		0.26 (112/434)
Apr 1987	0.06 (12/210)	0.60 (18/30)		0.13 (30/240)
May 1987	0.00 (2/434)	0.00 (0/31)		0.00 (2/465)
Jun 1987	0.00 (2/480)	0.03 (1/30)		0.01 (3/510)
Jul 1987	0.00 (1/434)	0.00 (0/62)		0.00 (1/496)
Aug 1987	0.00 (1/310)	0.00 (0/124)		0.00 (1/434)
Sep 1987	0.01 (4/390)	0.00 (0/186)		0.01 (4/576)
Oct 1987	0.01 (2/155)	0.00 (0/155)		0.01 (2/310)
Nov 1987	0.29 (9/31)	0.36 (5/14)	0.00 (0/19)	0.22 (14/64)
Dec 1987	0.41 (21/51)	0.15 (42/282)	0.29 (24/83)	0.21 (87/416)
Jan 1988	0.15 (16/105)	0.74 (60/81)	0.19 (39/210)	0.29 (115/396)
Feb 1988	0.06 (10/169)	1.34 (39/29)	0.17 (17/98)	0.22 (66/296)
Mar 1988	0.27 (5/18)	0.15 (13/88)	0.14 (13/93)	0.16 (31/199)
Apr 1988	0.00 (0/73)	0.91 (10/11)	0.06 (5/90)	0.09 (15/174)
May 1988	0.02 (3/130)	0.00 (0/6)	0.00 (0/3)	0.02 (3/139)
Jun 1988	0.01 (1/97)	0.12 (1/8)	0.00 (0/60)	0.01 (2/165)

Table 16. Frequency (n) and percent occurrence (%) of fish found in bald eagle pellets collected on the northern Chesapeake Bay from Dec 1986 through May 1987 (no. of pellets = 518) and Jun 1987 through May 1988 (no. of pellets = 571).

Food Item	1986-87		1987-88		Total	
	n	%	n	%	n	%
Gizzard shad	10	18.2	48	37.5	58	31.7
Carp	14	25.5	31	24.2	45	24.6
Morone spp.	5	9.1	9	7.0	14	7.7
Catfish	1	1.8	0	0.0	1	0.0
Menhaden	1	1.8	0	0.0	1	0.0
Unidentified fish	24	43.6	40	31.3	64	35.0
Total	55	100.0	128	100.0	183	100.0

Table 17. Frequency (n) and percent occurrence (%) of vertebrate remains found beneath bald eagle perches on the northern Chesapeake Bay from Dec 1986 through Dec 1987. (Fresh items were those judged to have been deposited within 1-2 weeks of collection.)

	Total		Fresh	
Food Item	n	%	n	%
Catfish	78	53.0	1	9.1
Menhaden	19	12.9	3	27.3
White perch	18	12.2	1	9.1
Gizzard shad	17	11.5	4	36.3
Morone spp.	3	2.1	0	0.0
Yellow perch	2	1.4	0	0.0
Carp	1	0.7	0	0.0
Unidentified fish	1	0.7	0	0.0
Total fish	139	94.4	9	81.8
Mallard	2	1.4	1	9.1
Ring-billed gull	2	1.4	1	9.1
Unidentified bird	1	0.7	0	0.0
Muskrat	1	0.7	0	0.0
Raccoon (young)	1	0.7	0	0.0
Diamond-backed terrapin	1	0.7	0	0.0
Total	147	100.0	11	100.0

Figures

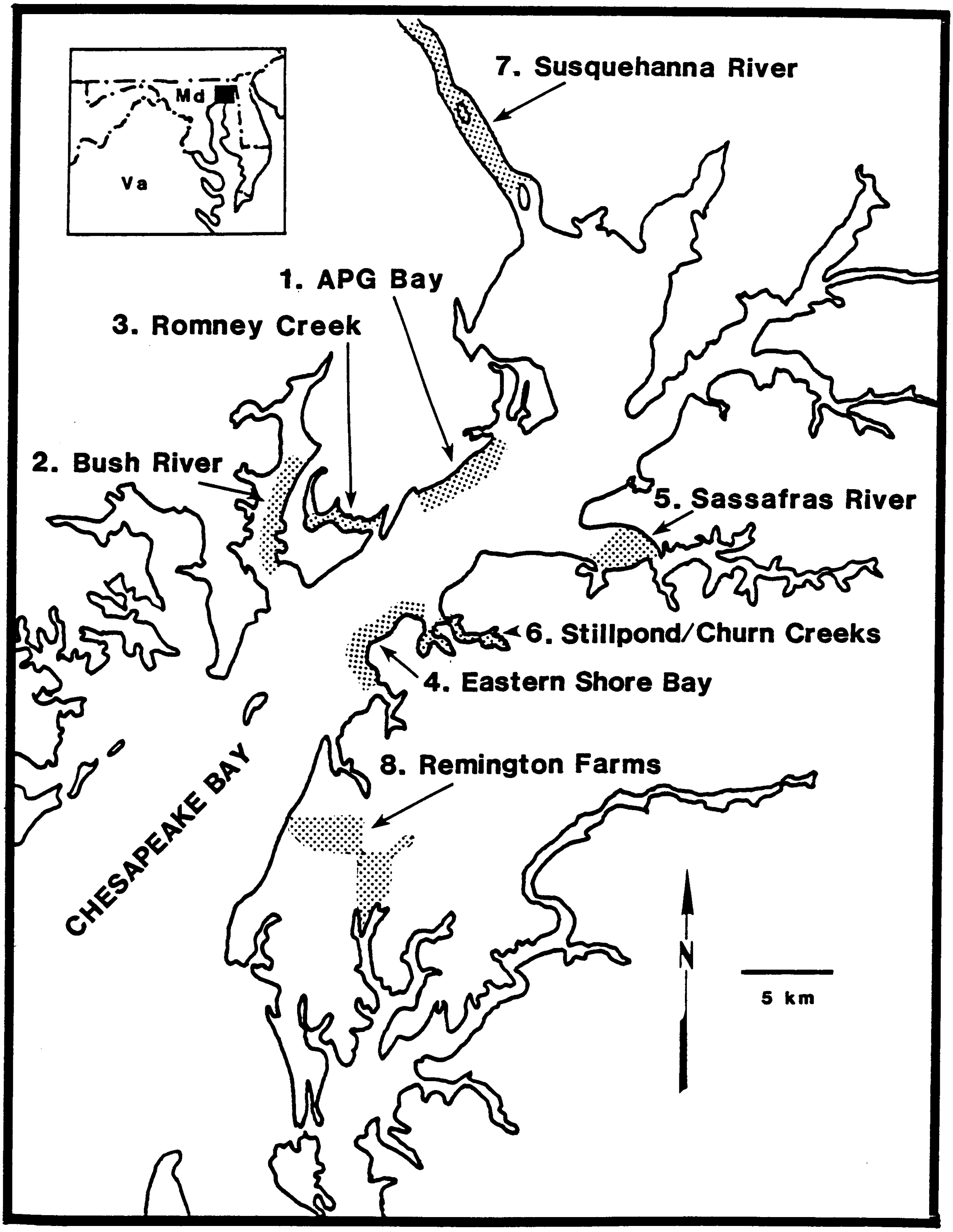


Figure 1. The northern Chesapeake Bay study area highlighting 8 intensively studied foraging areas.

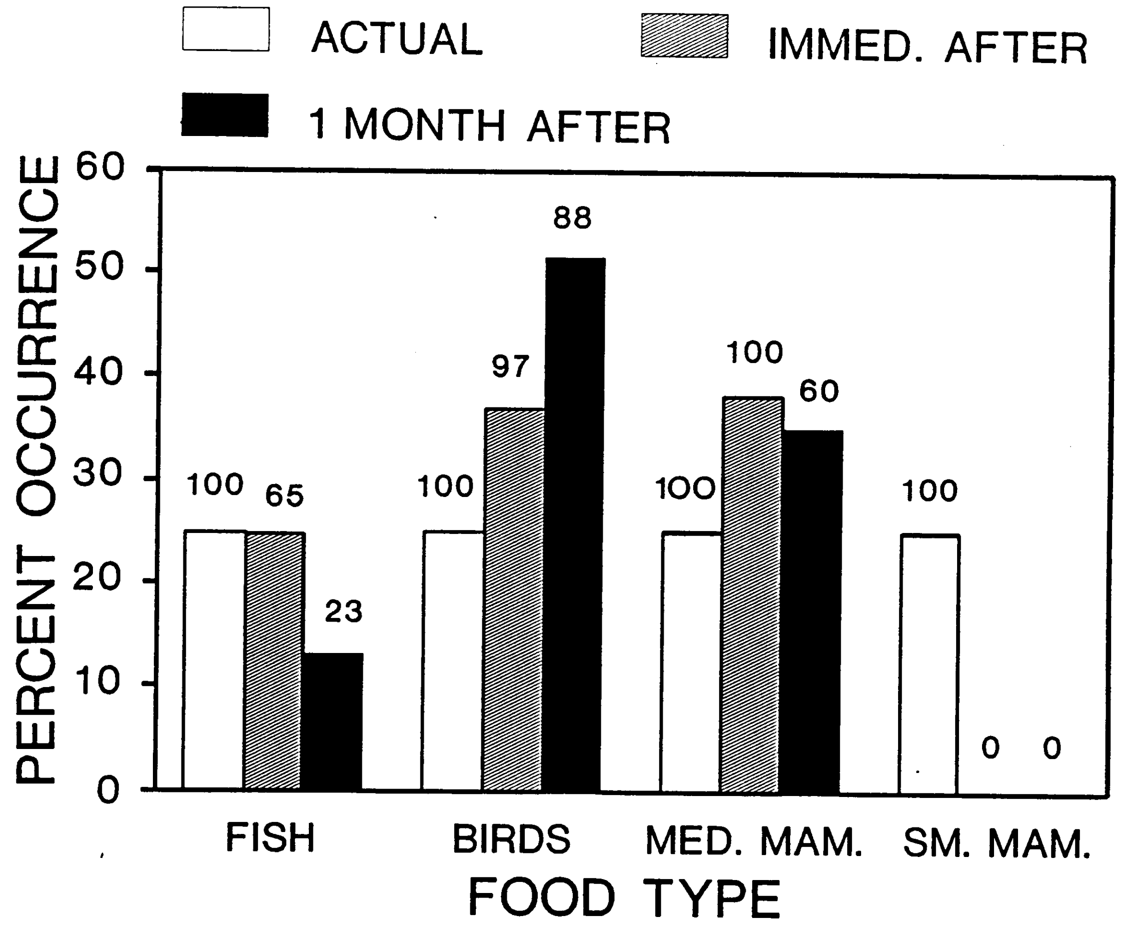


Figure 2. **Food remains results for an hypothetical situation in which bald eagles ate fish, birds, medium-sized mammals, and small mammals with equal frequency (viz., 100 each). Bars represent percent occurrence of food types in the actual diet, in remains collected immediately after feeding, and in remains collected 1 month after feeding. Numbers on top of bars indicate frequency of each food type at each step.**

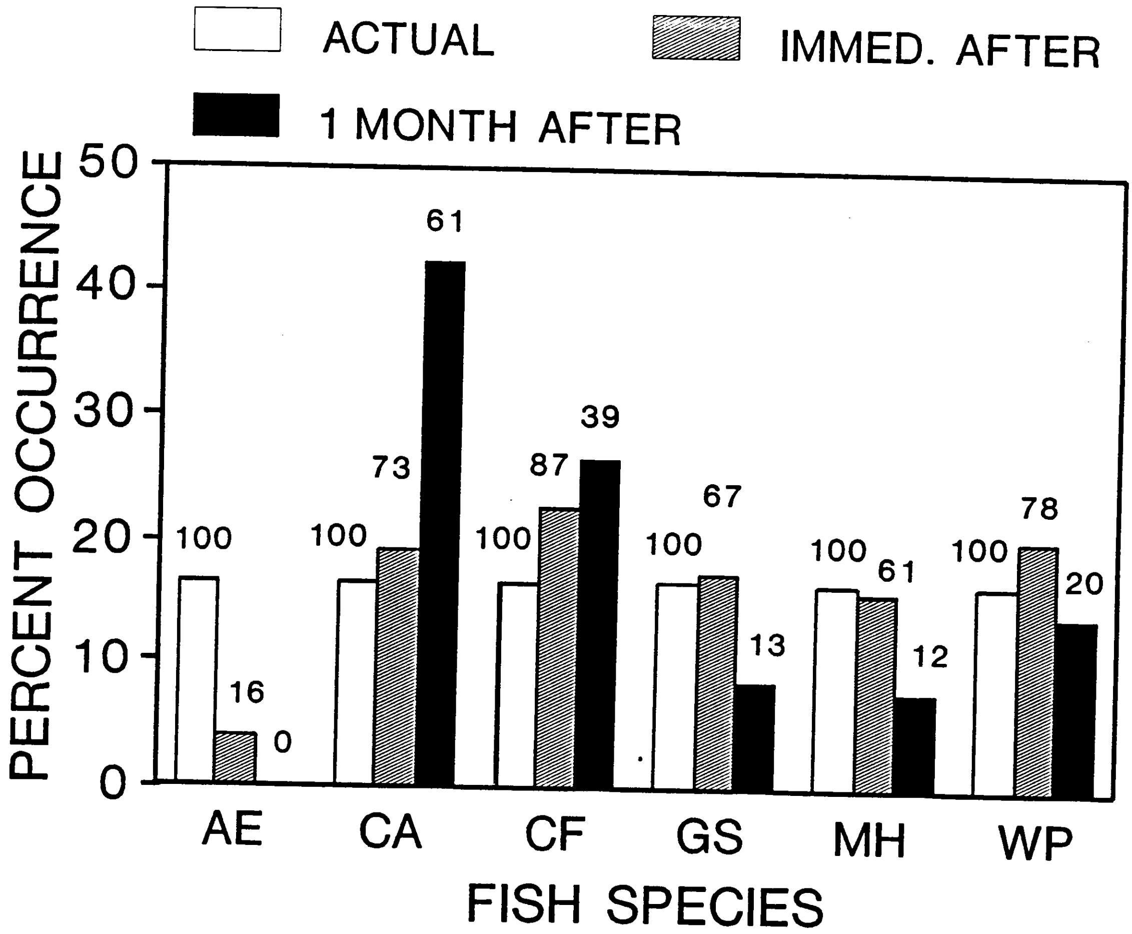


Figure 3. Food remains results for an hypothetical situation in which bald eagles ate all fish species with equal frequency (viz., 100 each). Bars represent percent occurrence of fish species in the actual diet, in remains collected immediately after feeding, and in remains collected 1 month after feeding. Numbers on top of bars indicate frequency of each food type at each step. AE = American eel, CA = carp, CF = catfish, GS = gizzard shad, MH = Atlantic menhaden, WP = white perch.

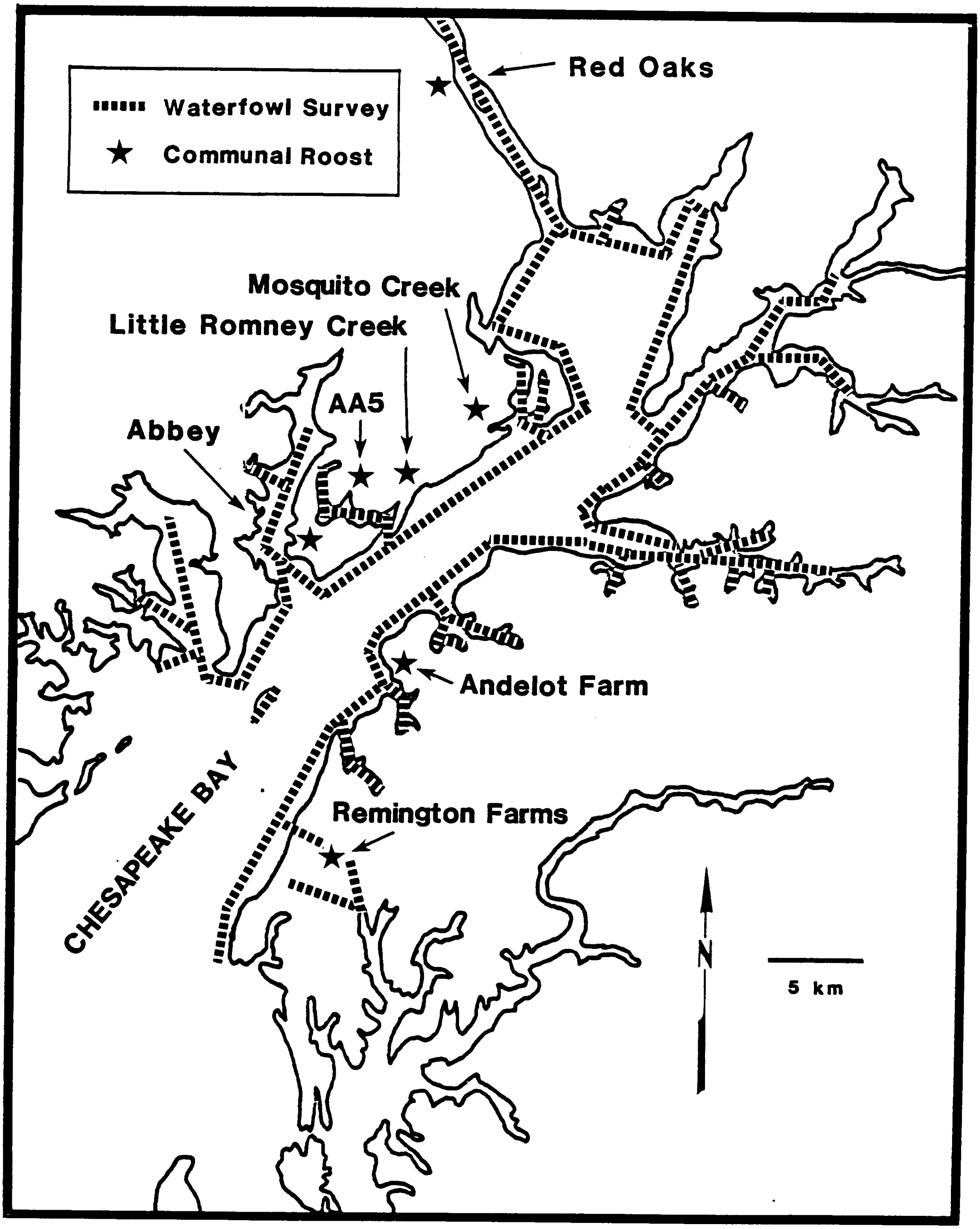
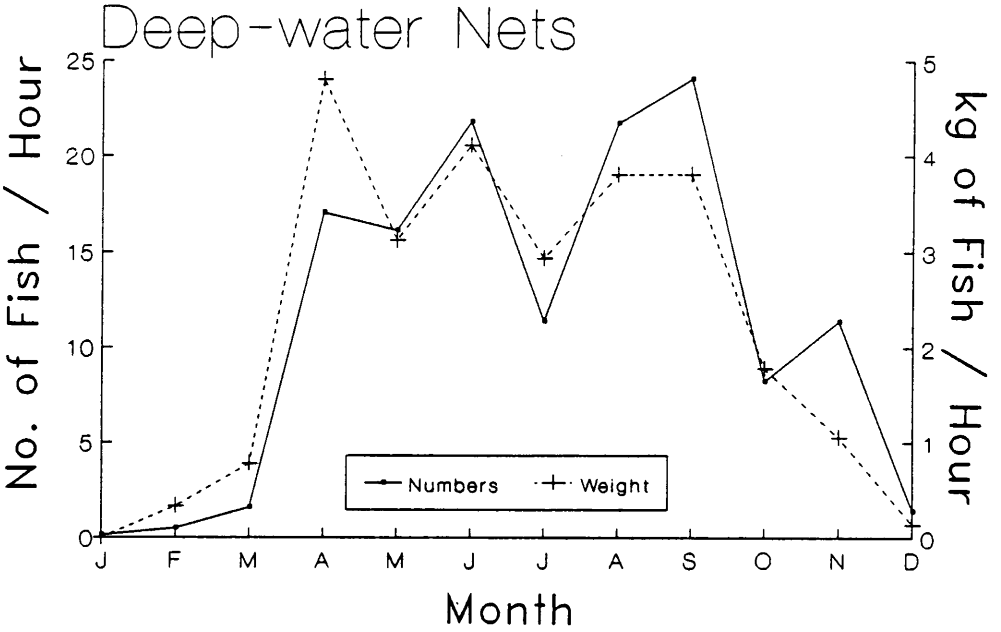


Figure 4. The northern Chesapeake Bay study area with waterfowl survey route and locations of communal roosts.



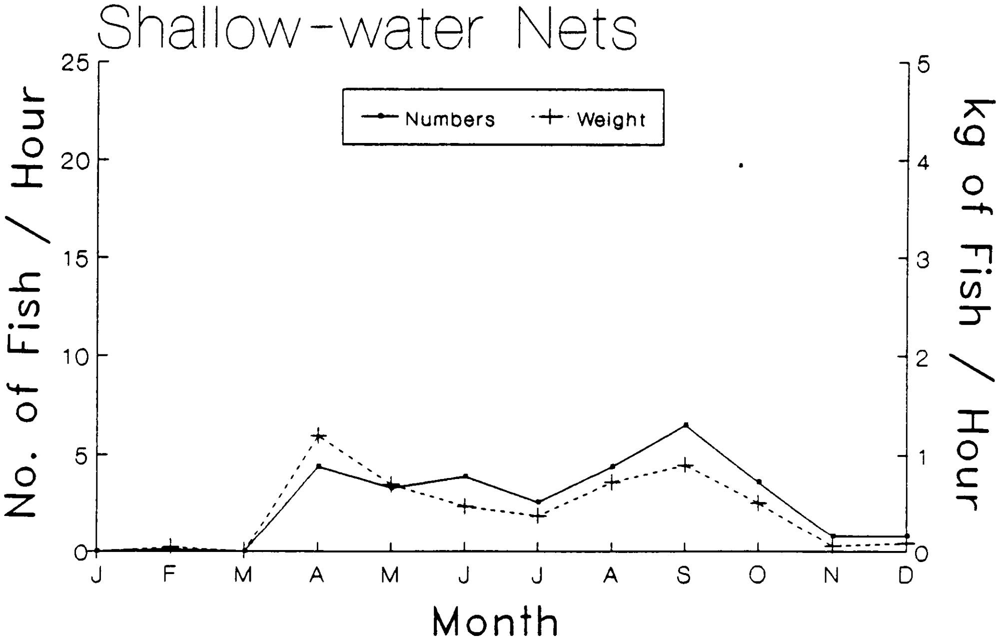


Figure 5. Mean catch rates of deep- (1.8 m) and shallow-water (0.6 m) gillnets set on the northern Chesapeake Bay, 1987.

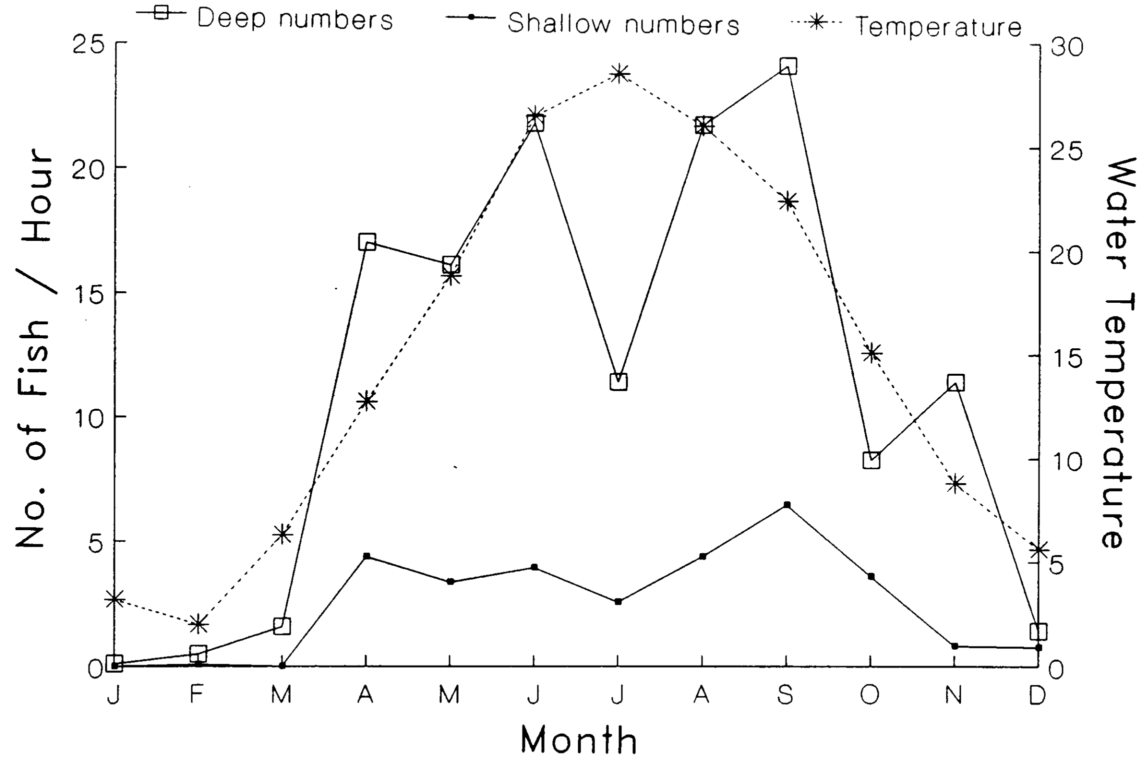


Figure 6. Mean catch rates for deep- (1.8 m) and shallow-water (0.6 m) gillnets and mean water temperatures (C) for the northern Chesapeake Bay, 1987.

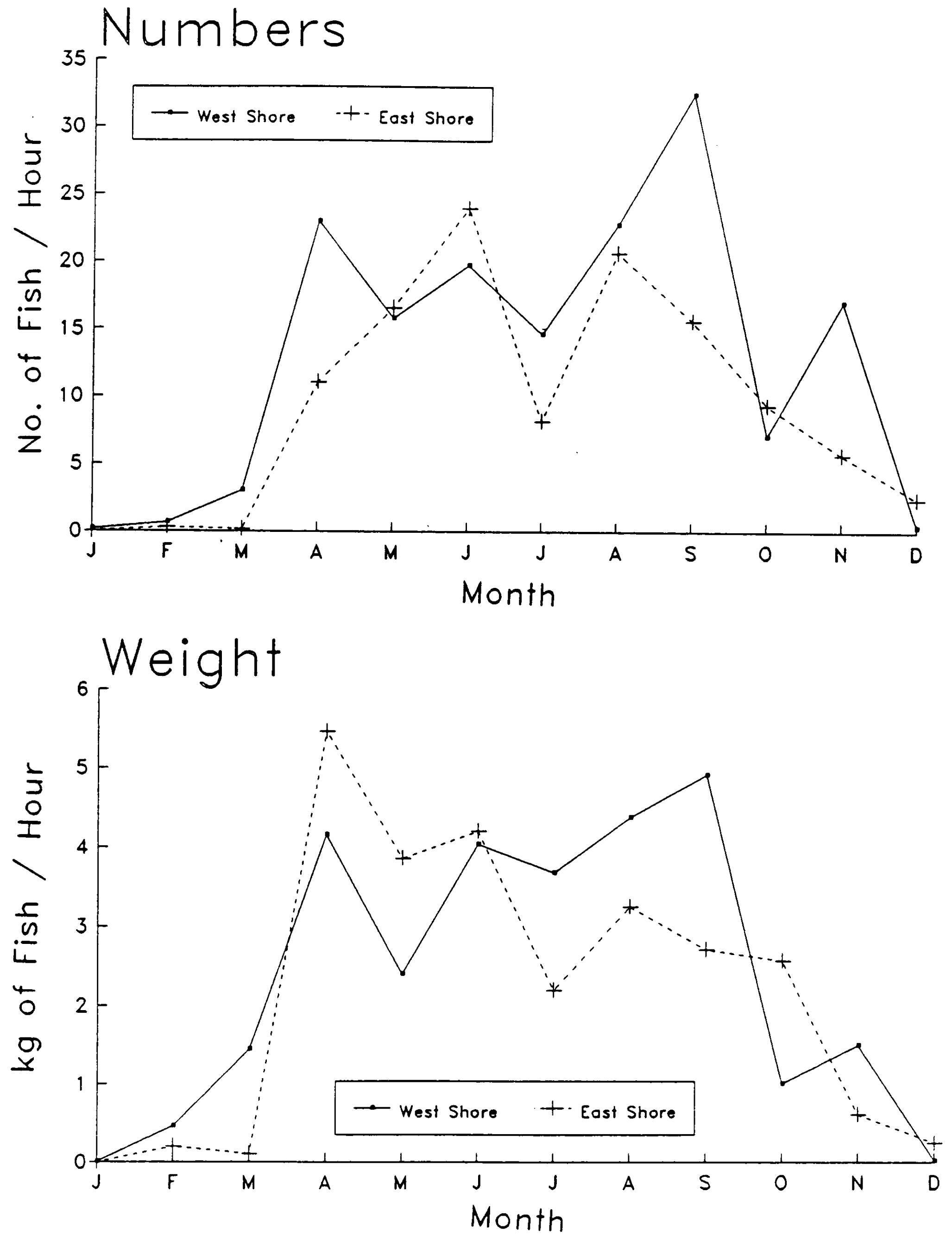


Figure 7. **Mean catch rates for deep-water (1.8 m) gillnets on the east and west side of the northern Chesapeake Bay, 1987.**

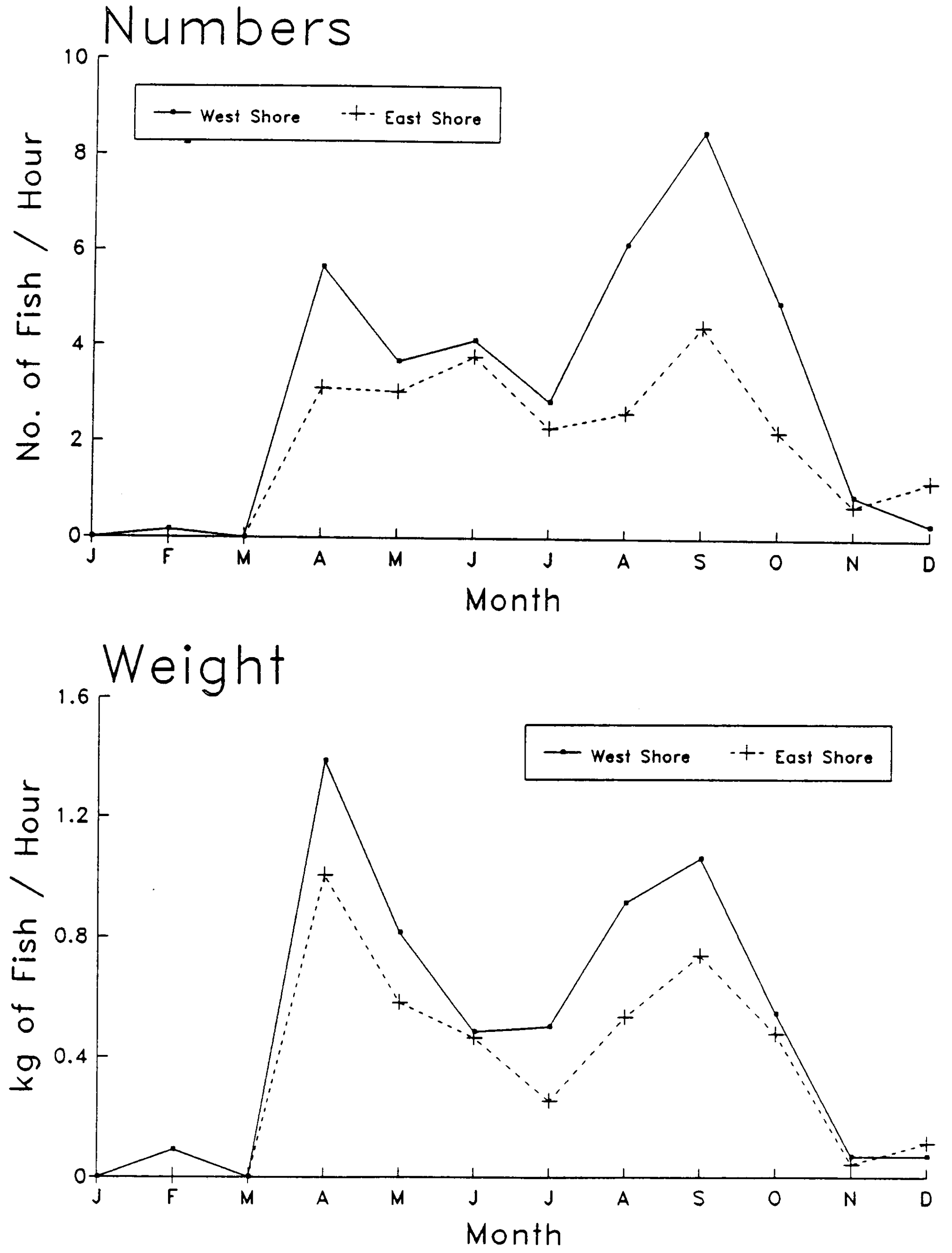


Figure 8. Mean catch rates for shallow-water (0.6 m) gillnets on the east and west side of the northern Chesapeake Bay, 1987.

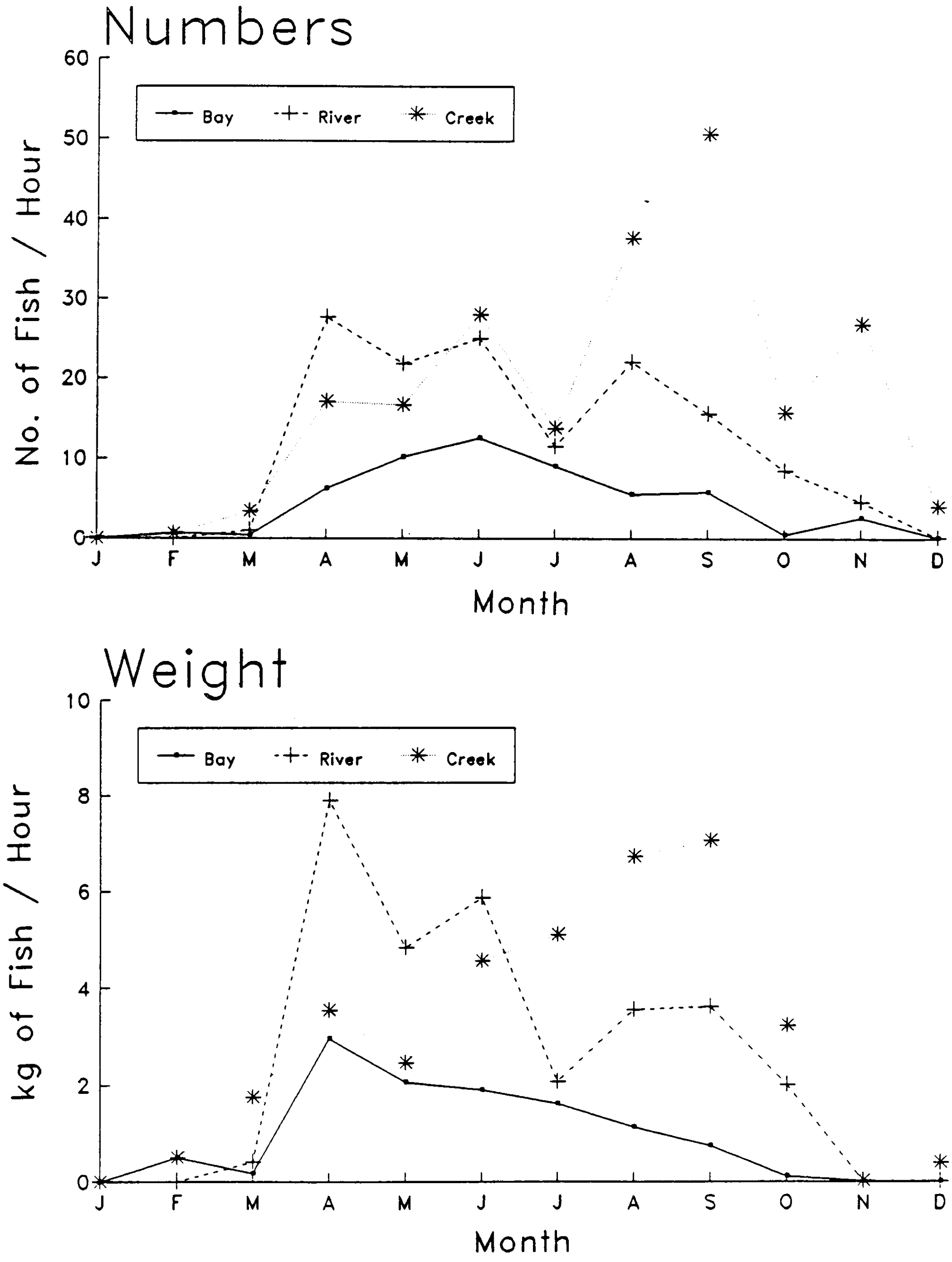


Figure 9. Mean catch rates for deep-water (1.8 m) gillnets in bay, river, and creek habitats on the northern Chesapeake Bay, 1987.

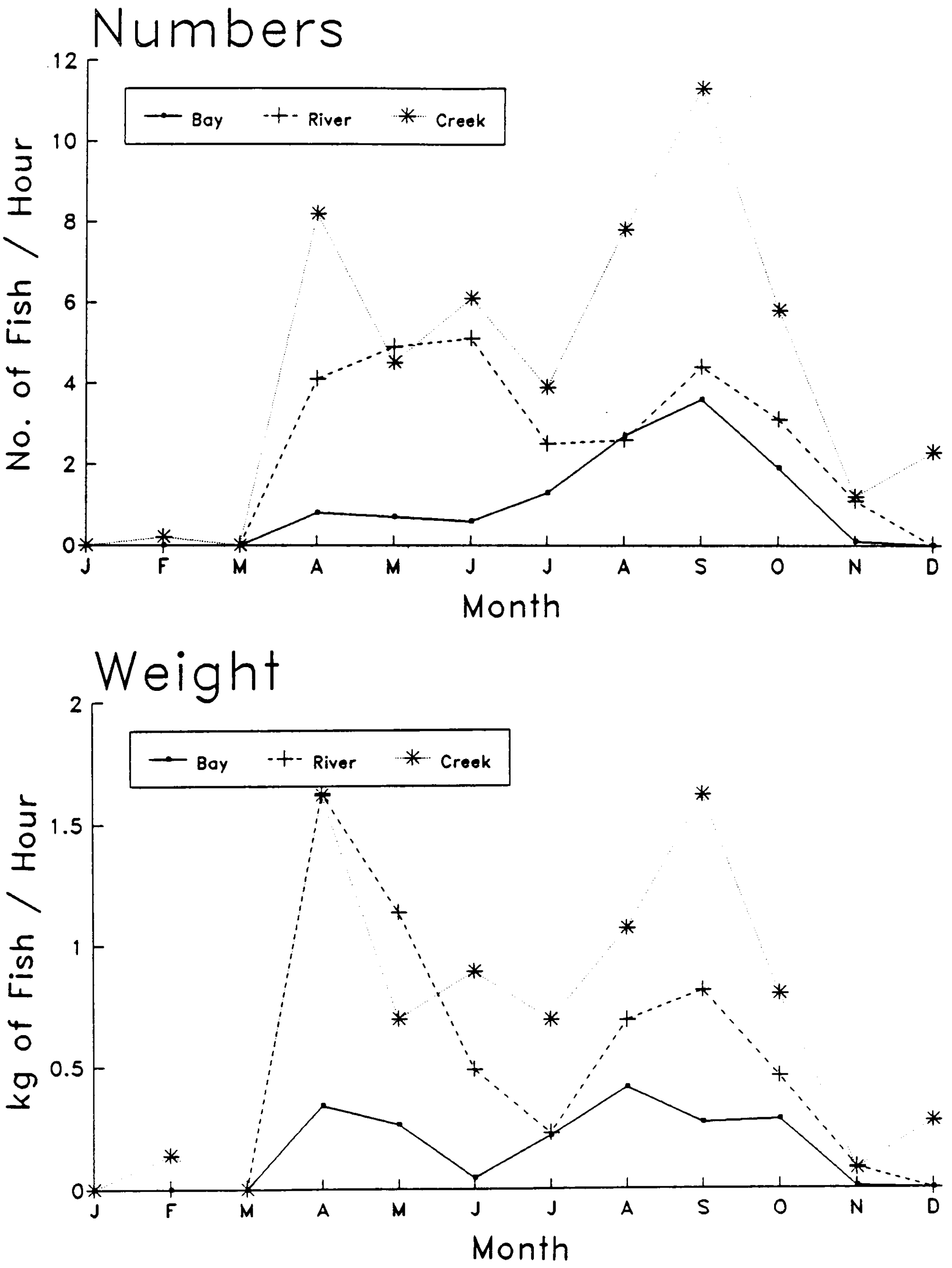


Figure 10. Mean catch rates for shallow-water (0.6 m) gillnets in bay, river, and creek habitats on the northern Chesapeake Bay, 1987.

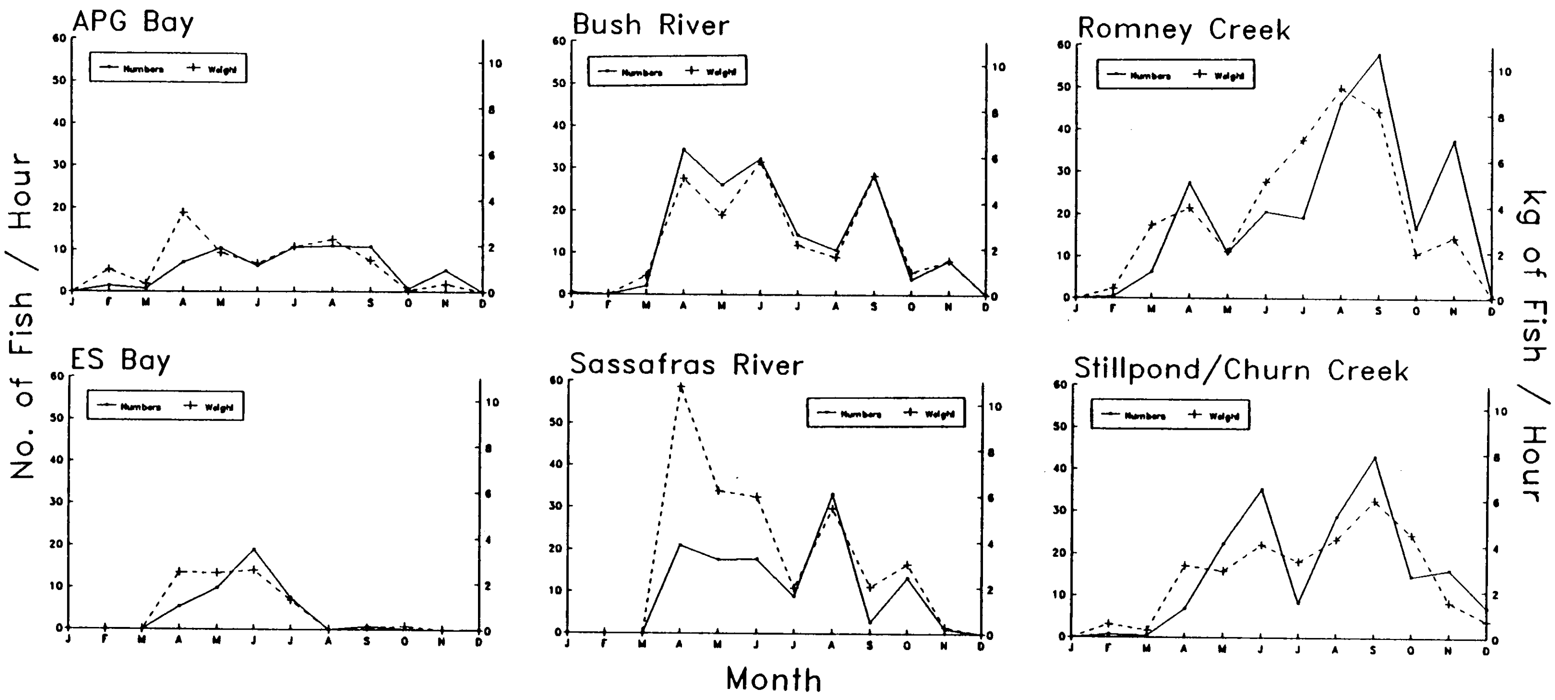


Figure 11. Mean catch rates (number and kg of fish caught per hour per net) for 1.8-m deep gillnets in 6 bald eagle foraging areas on the northern Chesapeake Bay, 1987.

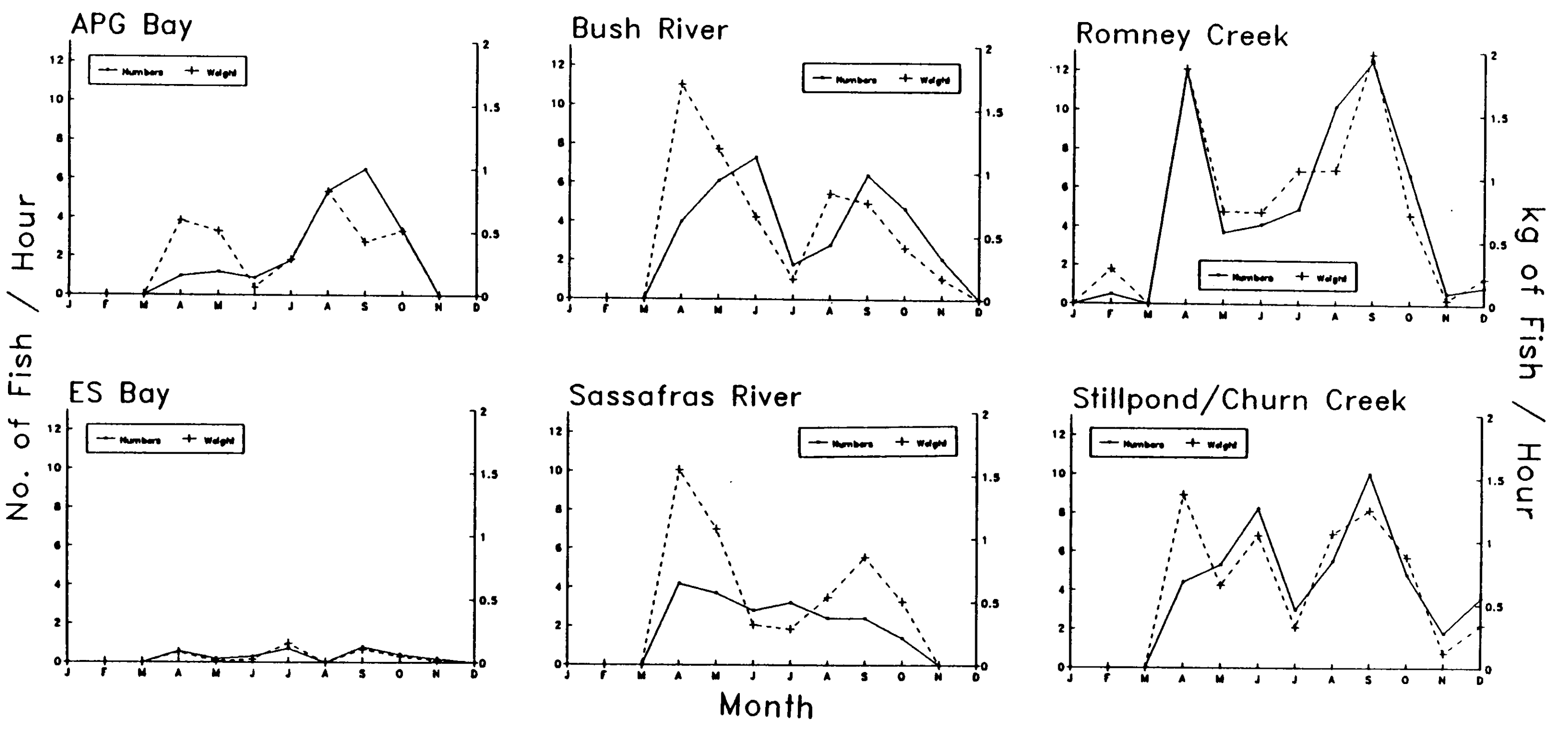


Figure 12. Mean catch rates (number and kg of fish caught per hour per net) for 0.6-m deep gillnets in 6 bald eagle foraging areas on the northern Chesapeake Bay, 1987.

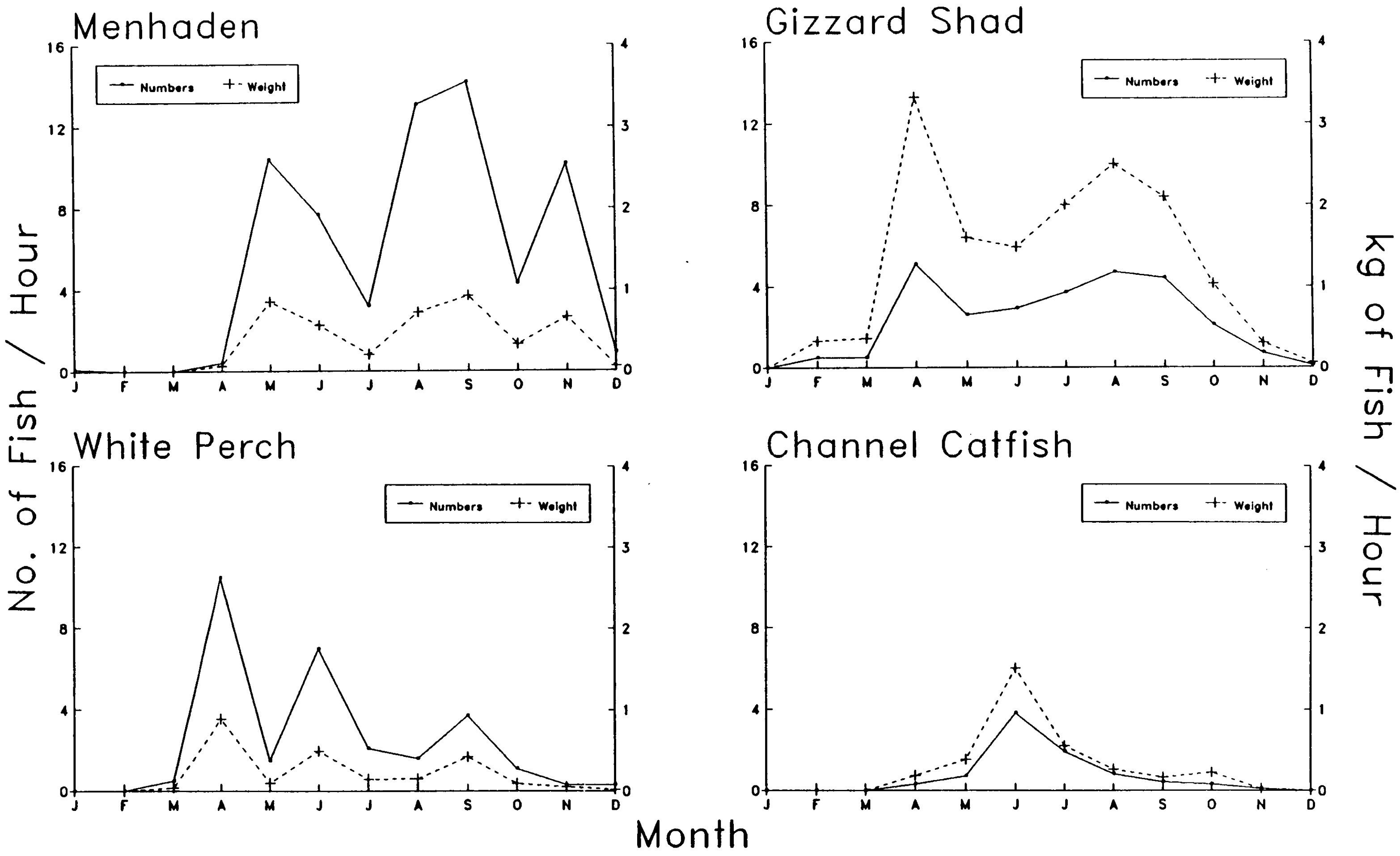


Figure 13. Mean catch rates (number and kg of fish caught per hour per net) of 1.8-m deep gillnets for 4 common species on the northern Chesapeake Bay, 1987.

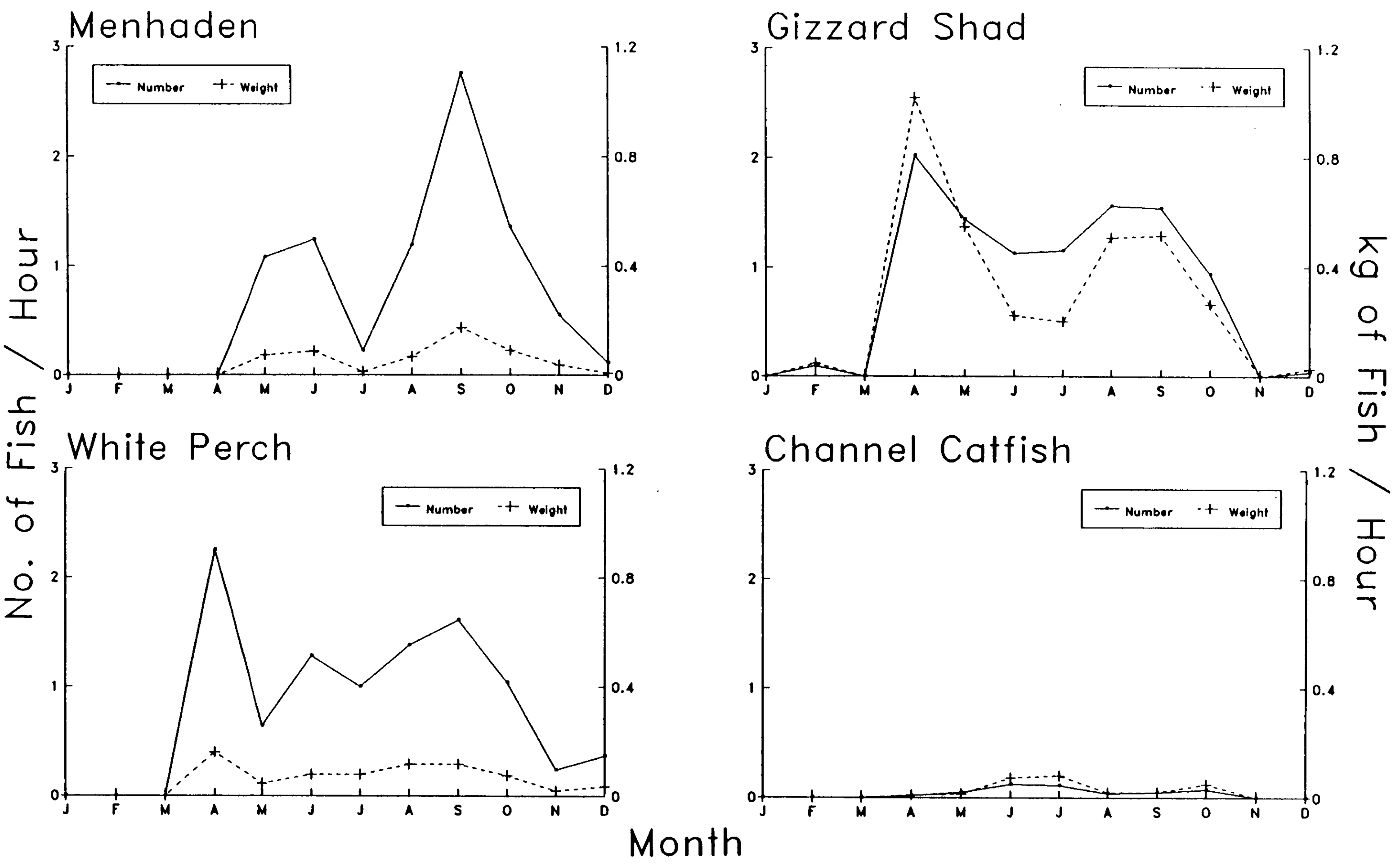


Figure 14. Mean catch rates (number and kg of fish caught per hour per net) of 0.6-m deep gillnets for 4 common species on the northern Chesapeake Bay, 1987.

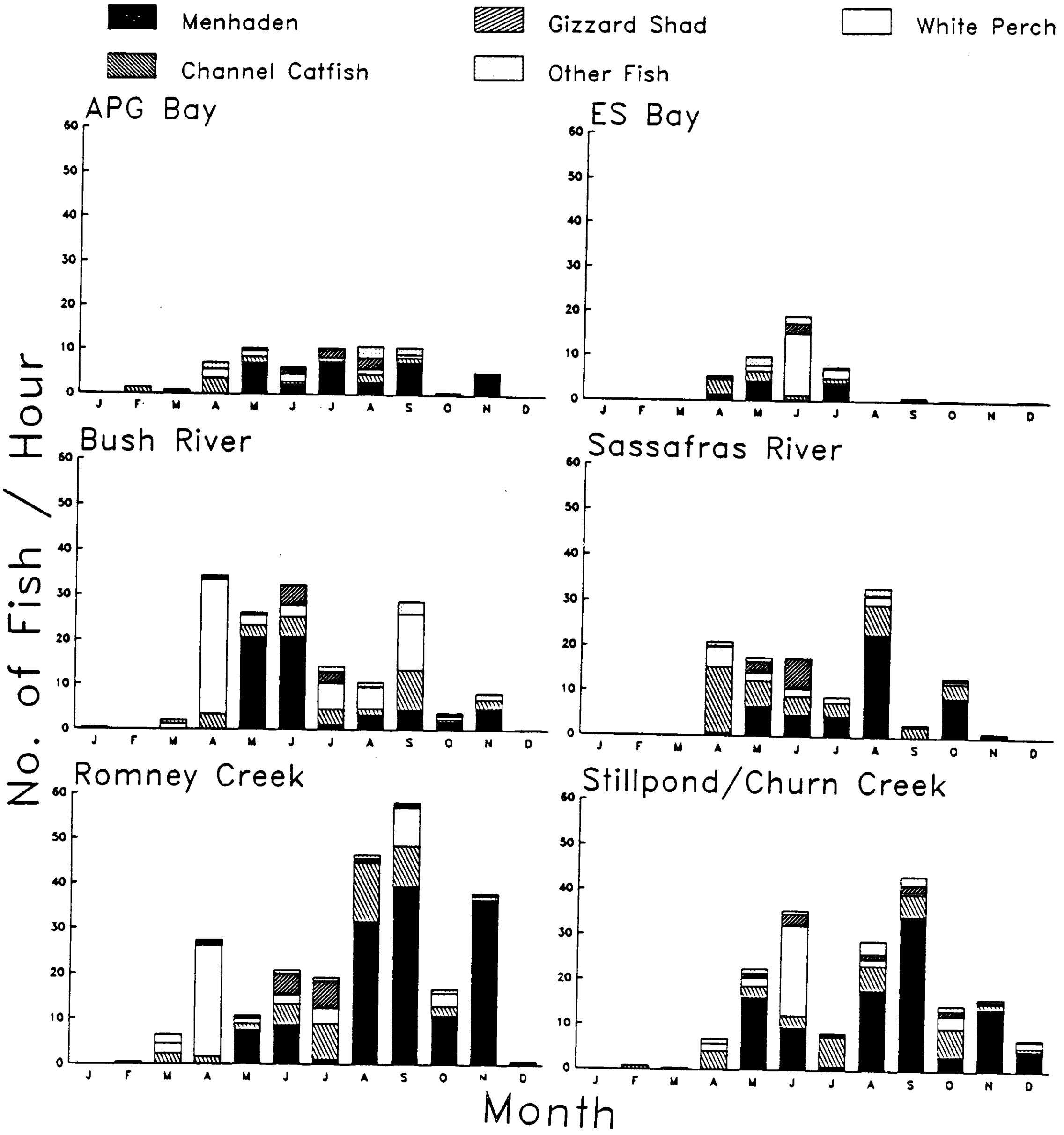


Figure 15. Fish species composition of deep-water (1.8 m) gillnet catch in 6 bald eagle foraging areas on the northern Chesapeake Bay, 1987.

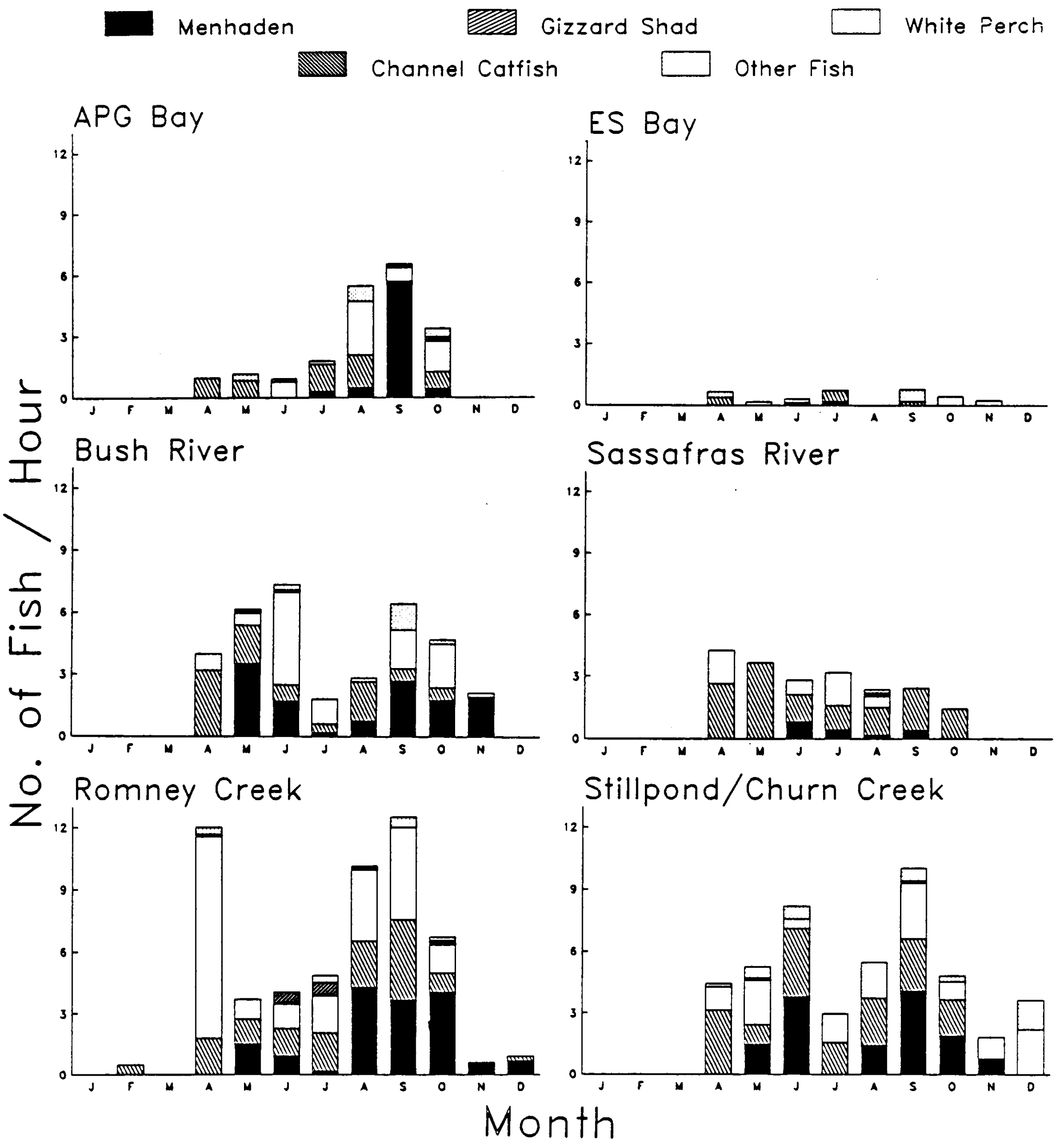


Figure 16. Fish species composition of shallow-water (0.6 m) gillnet catch in 6 bald eagle foraging areas on the northern Chesapeake Bay, 1987.

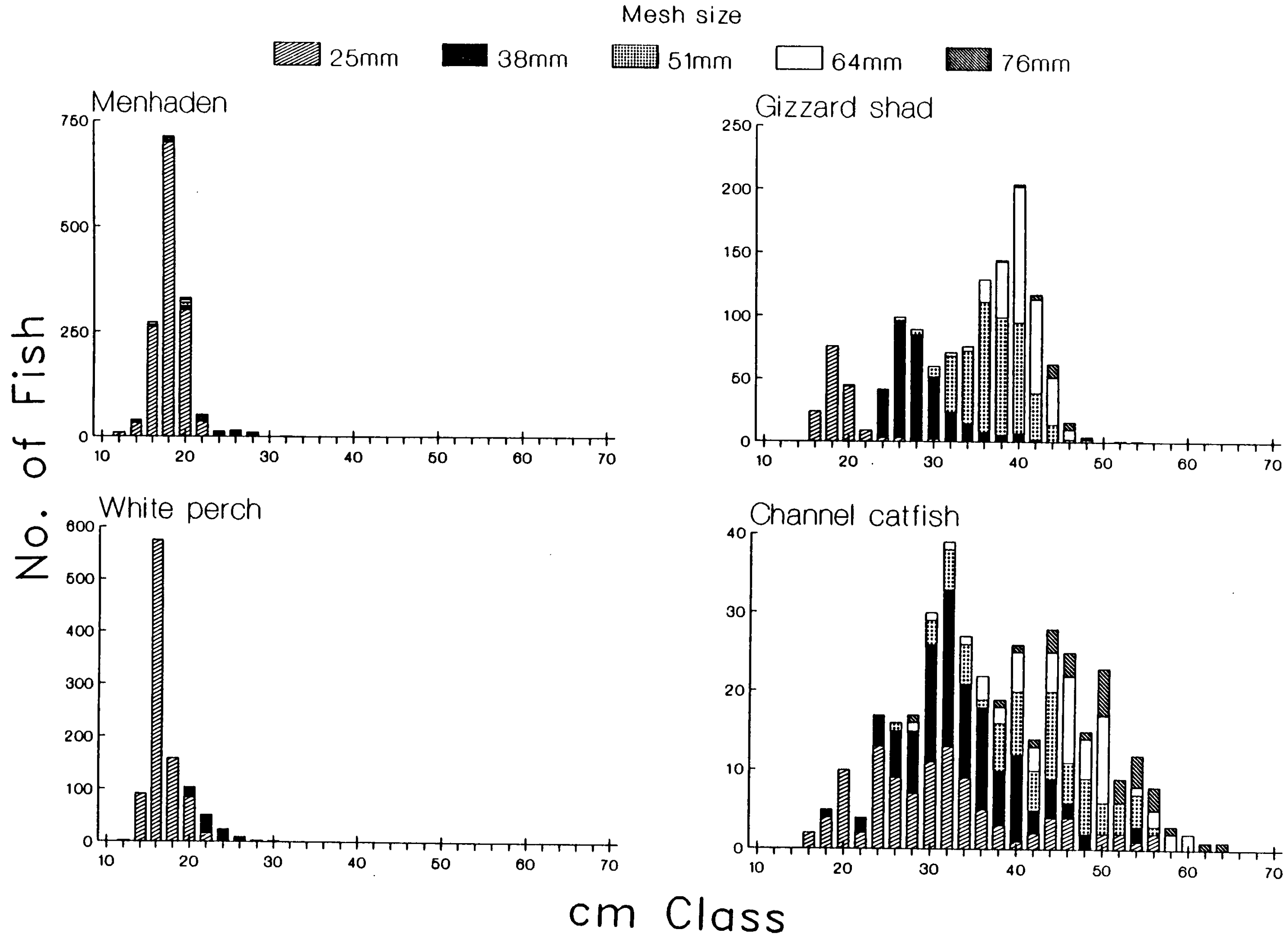


Figure 17. Size distribution (total length) by mesh size for 4 common fish species gillnetted on the northern Chesapeake Bay from January through December, 1987. Frequencies are totals for all nets set.

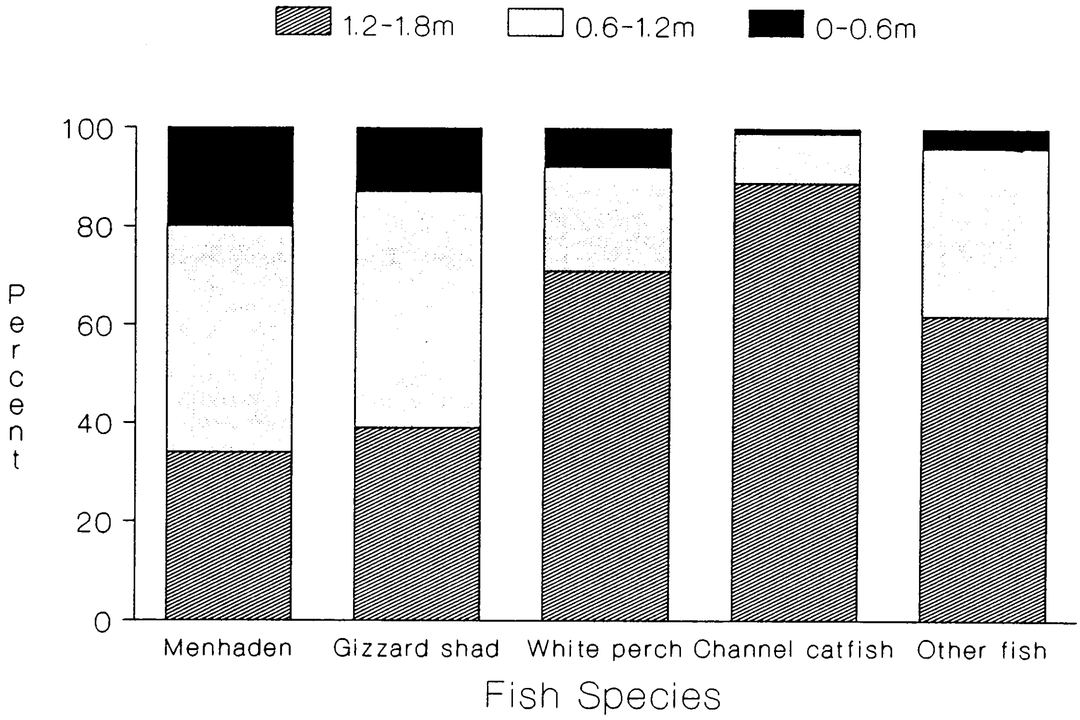


Figure 18. Distribution of 4 common fish species among the top (0 - 0.6 m), middle (0.6 - 1.2 m), and bottom (1.2 - 1.8 m) strata of deep-water (1.8 m) gillnets on the northern Chesapeake Bay from January through December, 1987 ($\chi^2 = 654.27$, 8 df, $P < 0.001$).

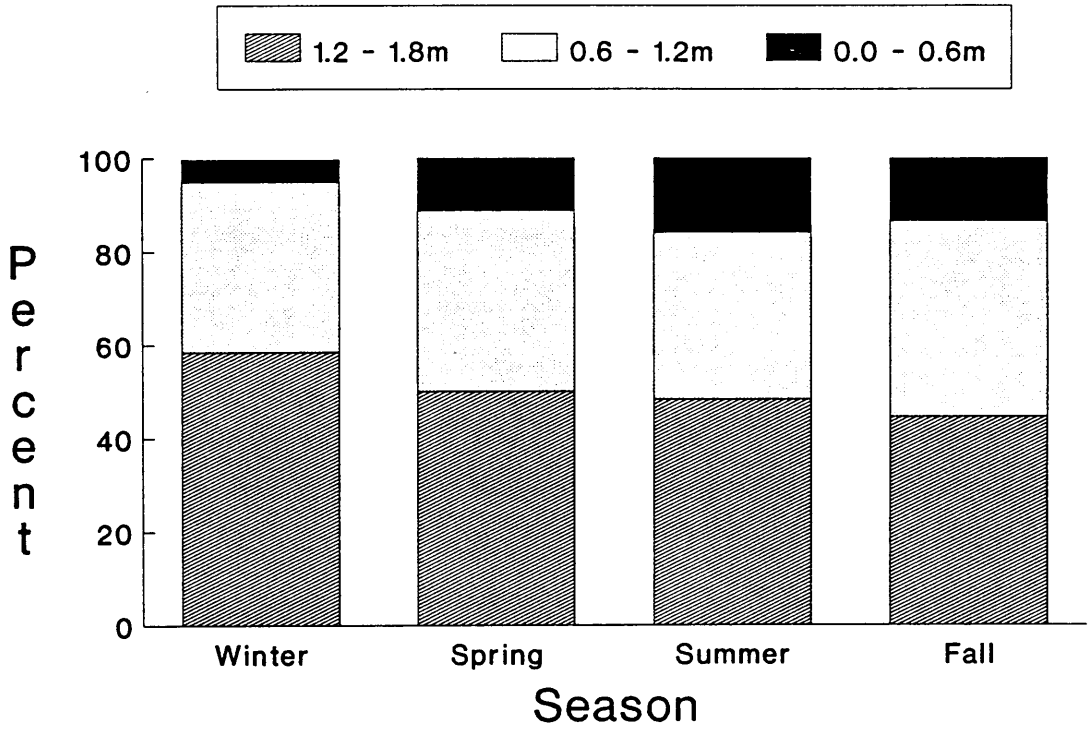


Figure 19. Distribution of fish among the top (0 - 0.6 m), middle (0.6 - 1.2 m), and bottom (1.2 - 1.8 m) strata of deep-water (1.8 m) gillnets by season on the northern Chesapeake Bay from January through December, 1987 ($\chi^2 = 25.75$, 6 df, $P < 0.001$).

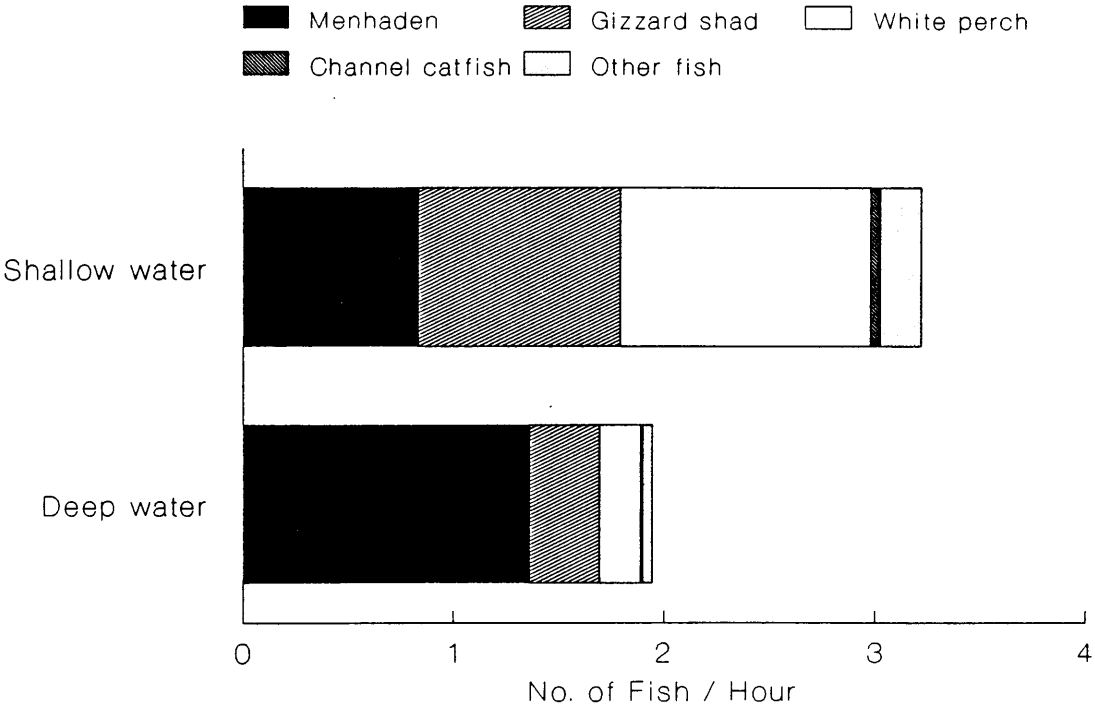


Figure 20. **Species composition and mean gillnet catch rates of fish caught within 0.6 m of the water's surface in deep (1.8 m) and shallow (0.6m) water on the northern Chesapeake Bay from January through December, 1987.**

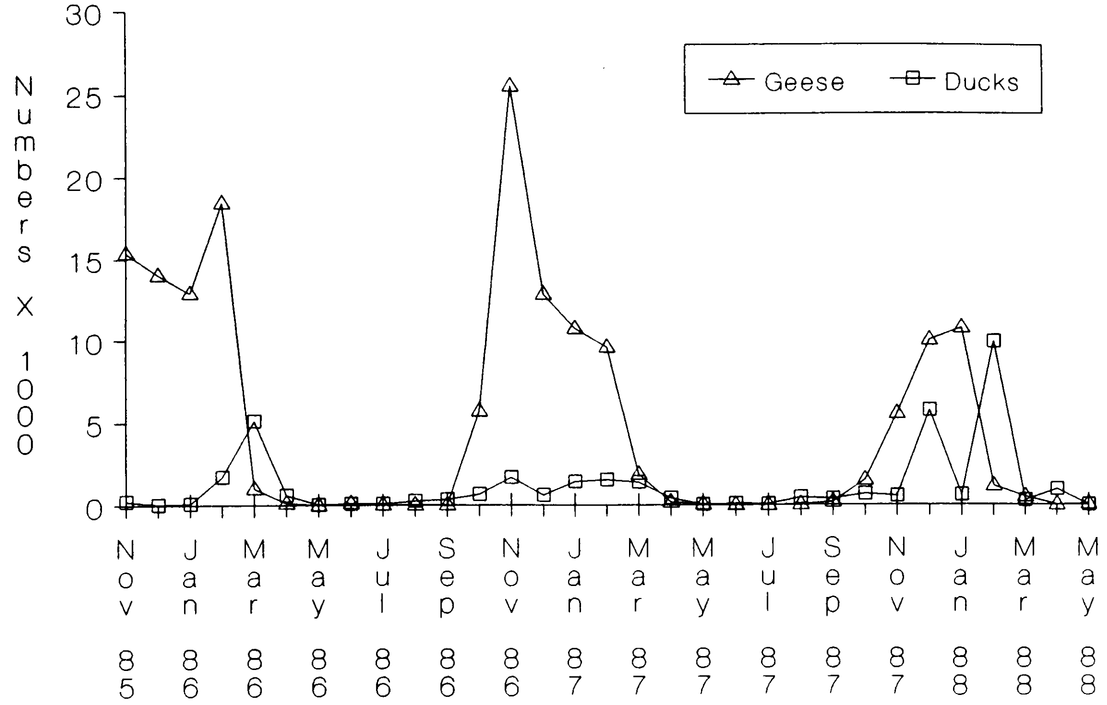


Figure 21. Aerial shoreline survey counts of ducks and geese on the northern Chesapeake Bay from November, 1985, though May, 1988.

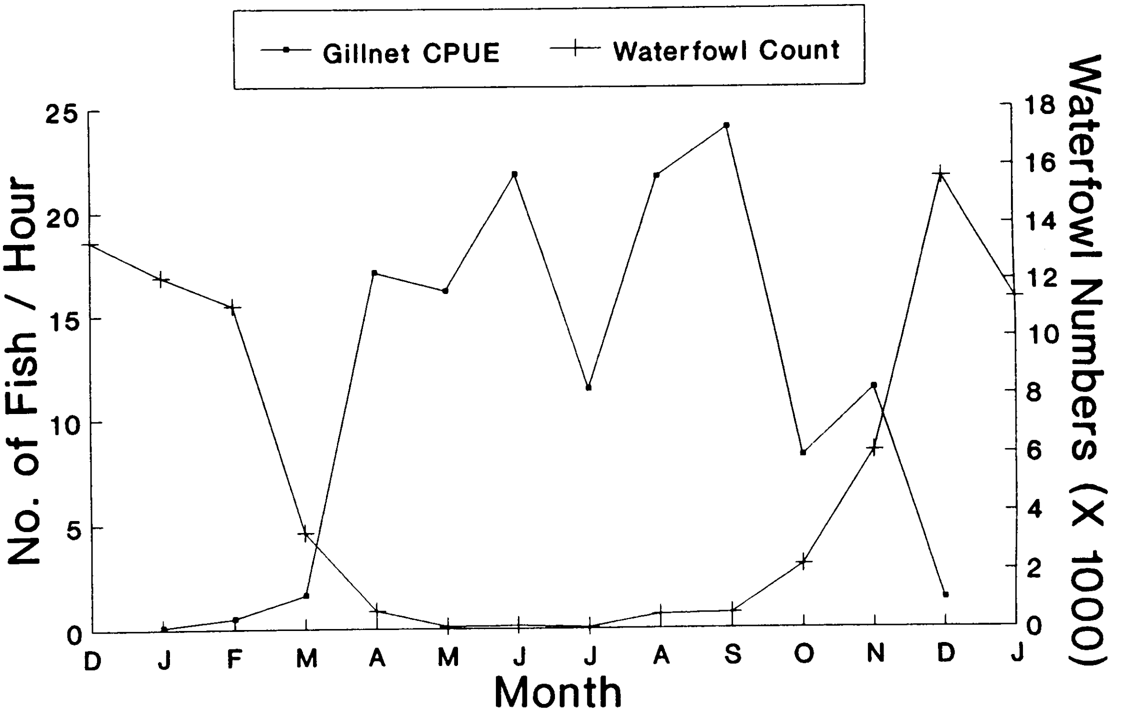


Figure 22. Deep-water (1.8 m) gillnet catch rate (CPUE) and aerial survey counts of waterfowl on the northern Chesapeake Bay from December, 1986, though January, 1988.

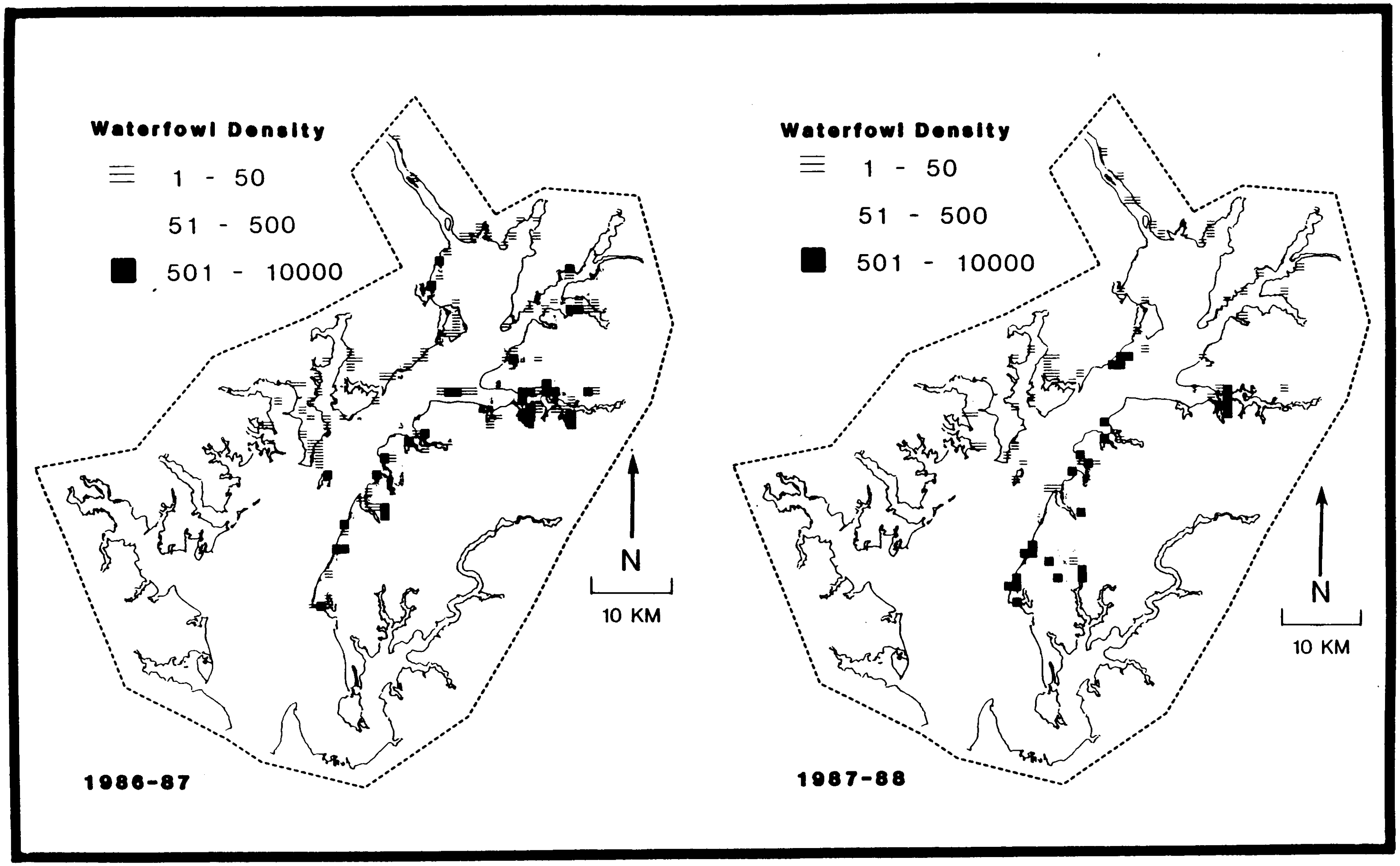
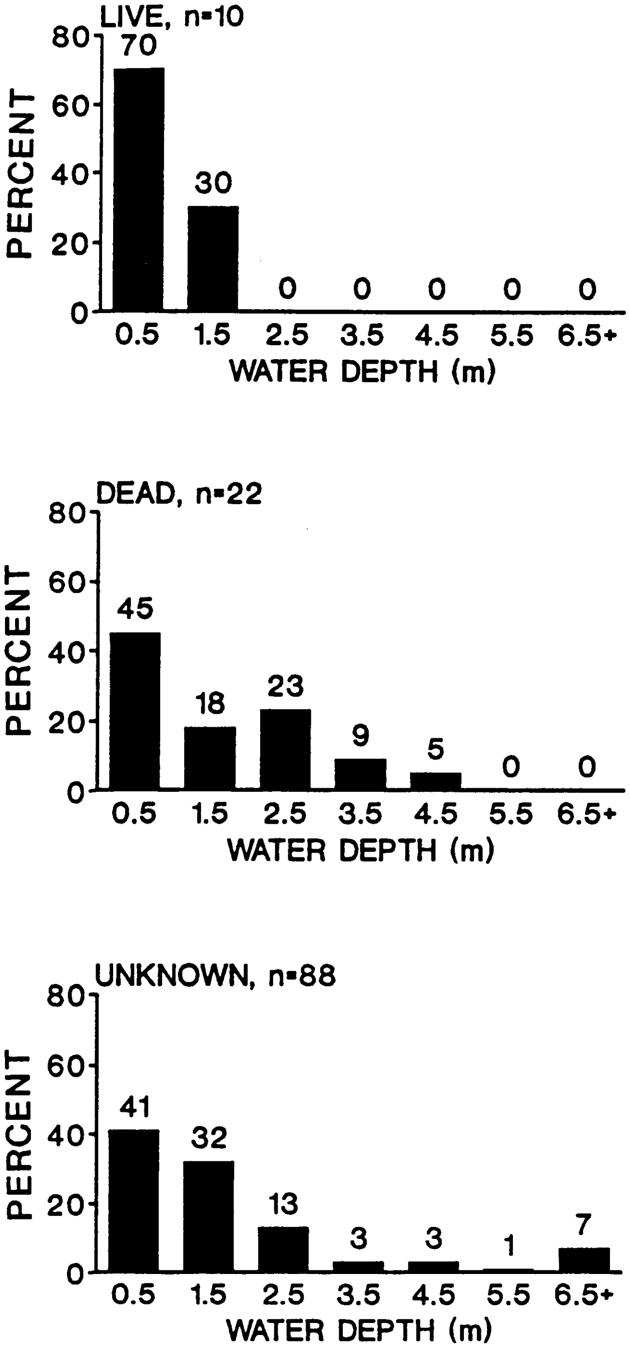


Figure 23. Waterfowl distribution determined from aerial shoreline surveys on the northern Chesapeake Bay from October through March, 1986-87 and 1987-88.

Figure 24. Location of waterfowl hunters seen during aerial shoreline surveys on the northern Chesapeake Bay from October through March, 1987-88.



LIVE, n=10

DEAD, n=22

UNKNOWN, n=88

Figure 25. Water depths (m) at locations of fish of live, dead, or unknown status captured by bald eagles on the northern Chesapeake Bay from January, 1987, through February, 1988. Numbers on top of bars indicate percentages of total within each status type.

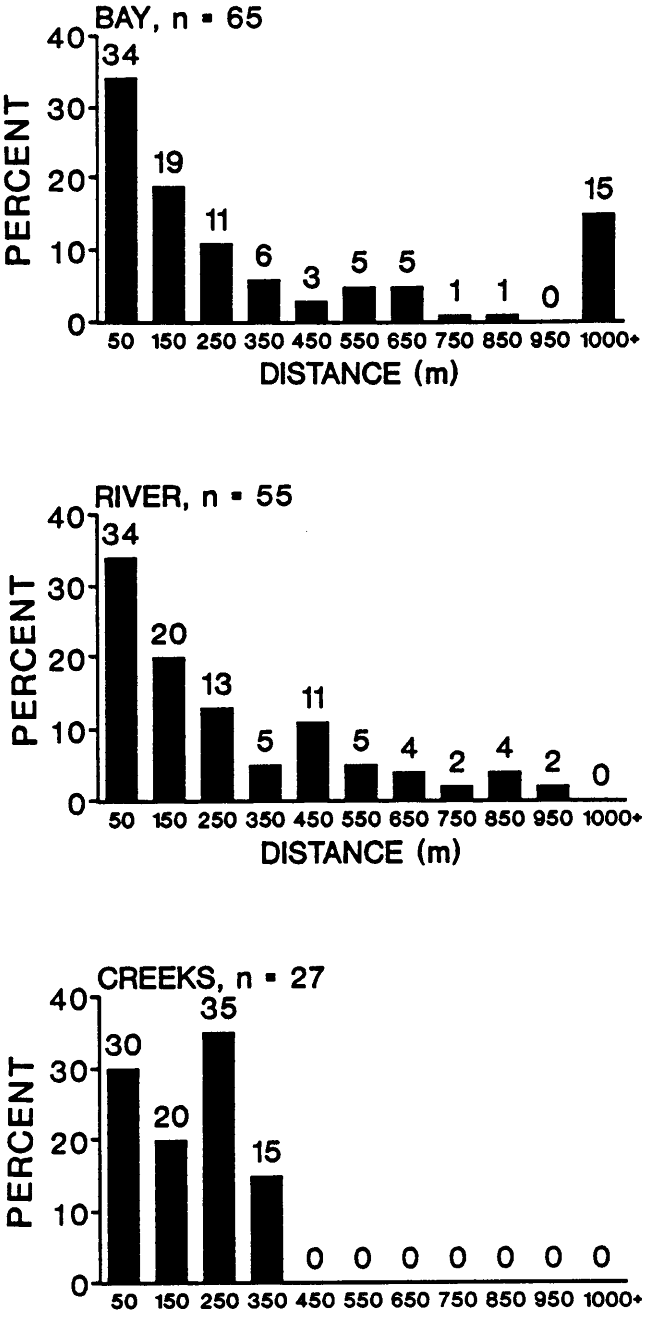


Figure 26. Distance from shore (m) of strikes at the water's surface made by bald eagles in bay, river, and creek habitats of the northern Chesapeake Bay from March through November, 1987. (Numbers on top of bars indicate frequencies).

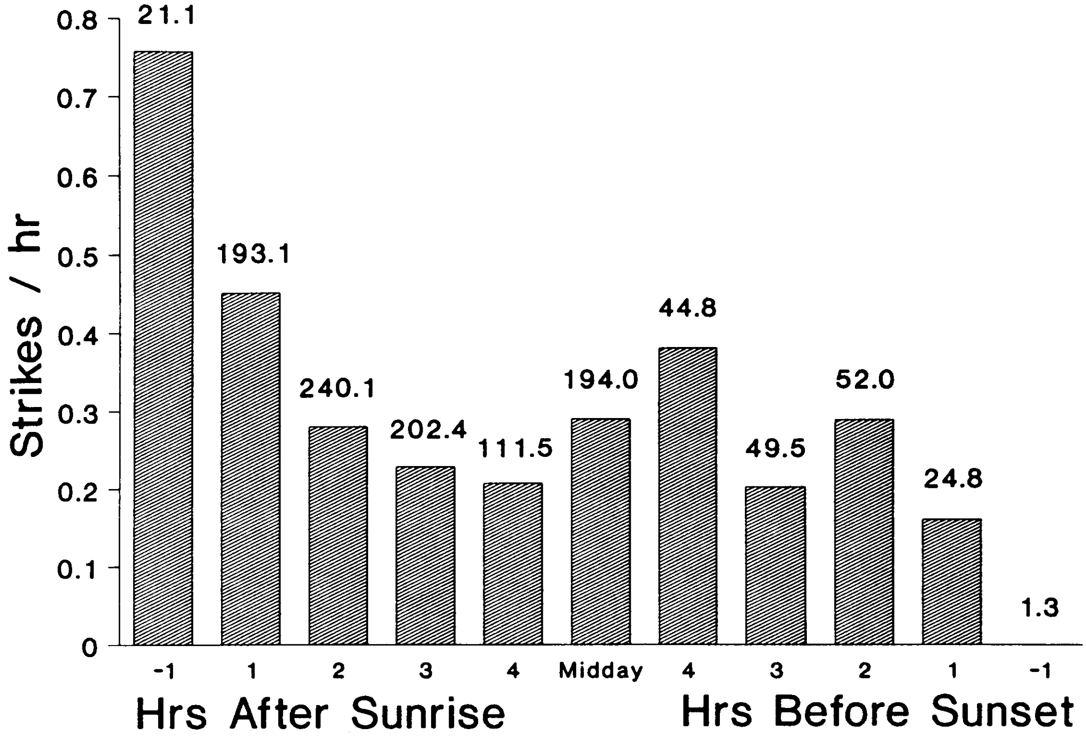


Figure 27. Distribution over daytime periods of strikes at the water's surface made by bald eagles on the northern Chesapeake Bay from March through November, 1987. Numbers on top of bars indicate total eagle-hours observed within each daytime period.

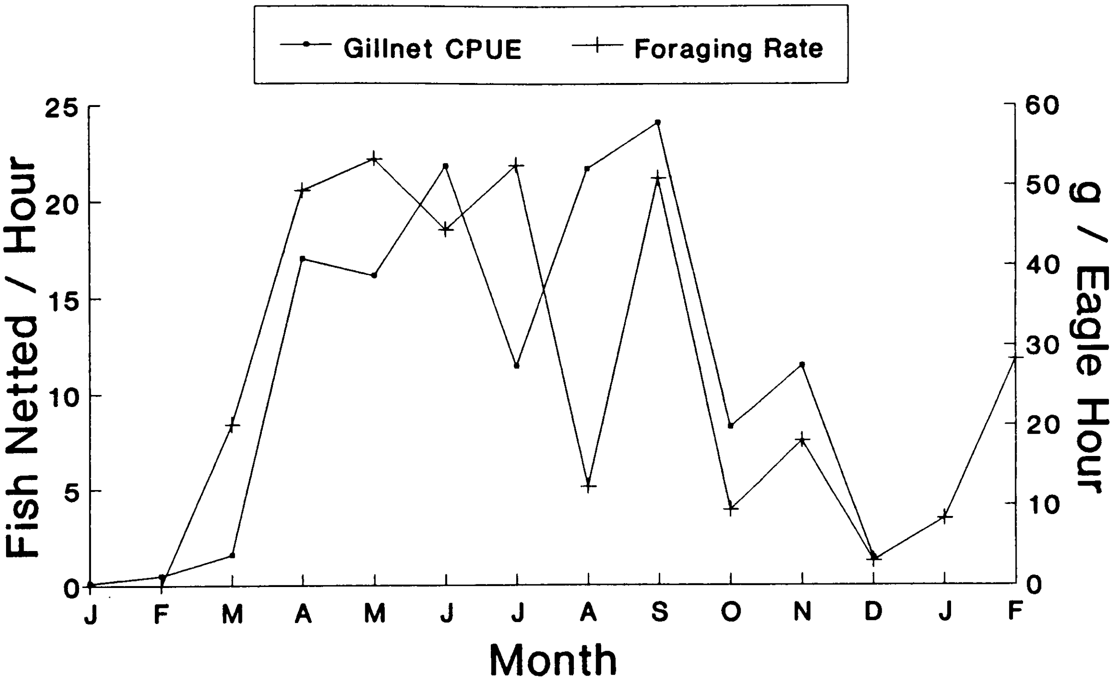


Figure 28. Deep-water (1.8m) gillnet catch rate (CPUE) and bald eagle foraging rate (g of fish caught / eagle-hour) for the northern Chesapeake Bay from January, 1987, through February, 1988.

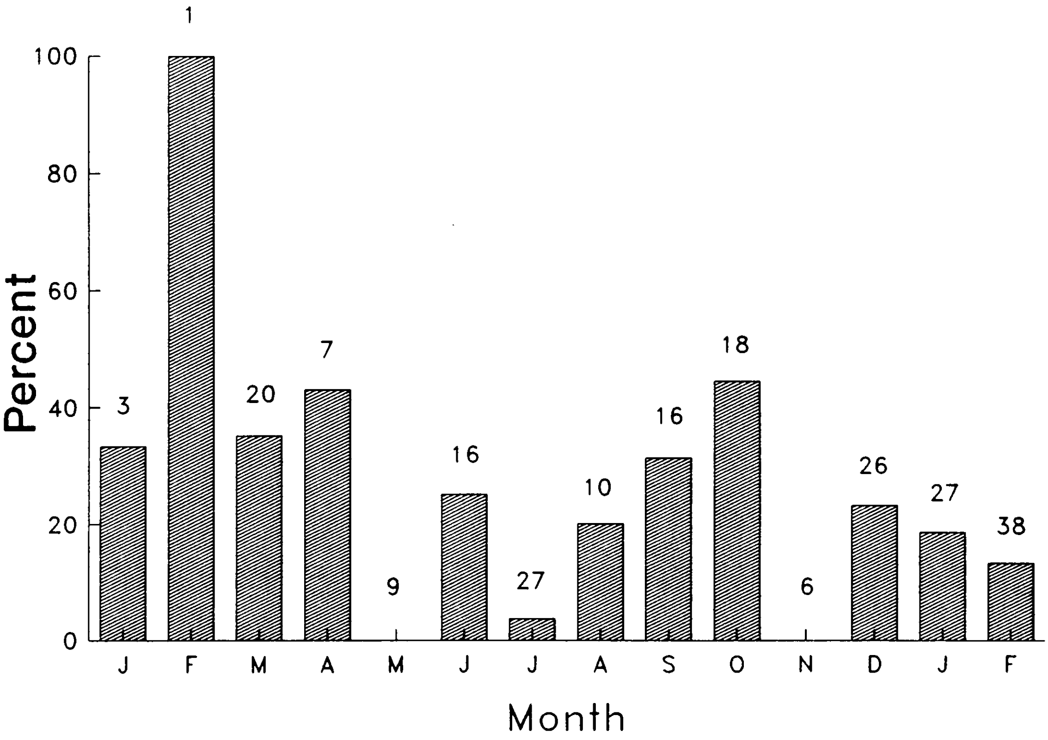


Figure 29. **Percent of successful bald eagle foraging attempts followed by an intra-specific kleptoparasitism attempt on the northern Chesapeake Bay from January, 1987, through February, 1988. Numbers on top of bars indicate the number of successful foraging attempts upon which percentages are based.**

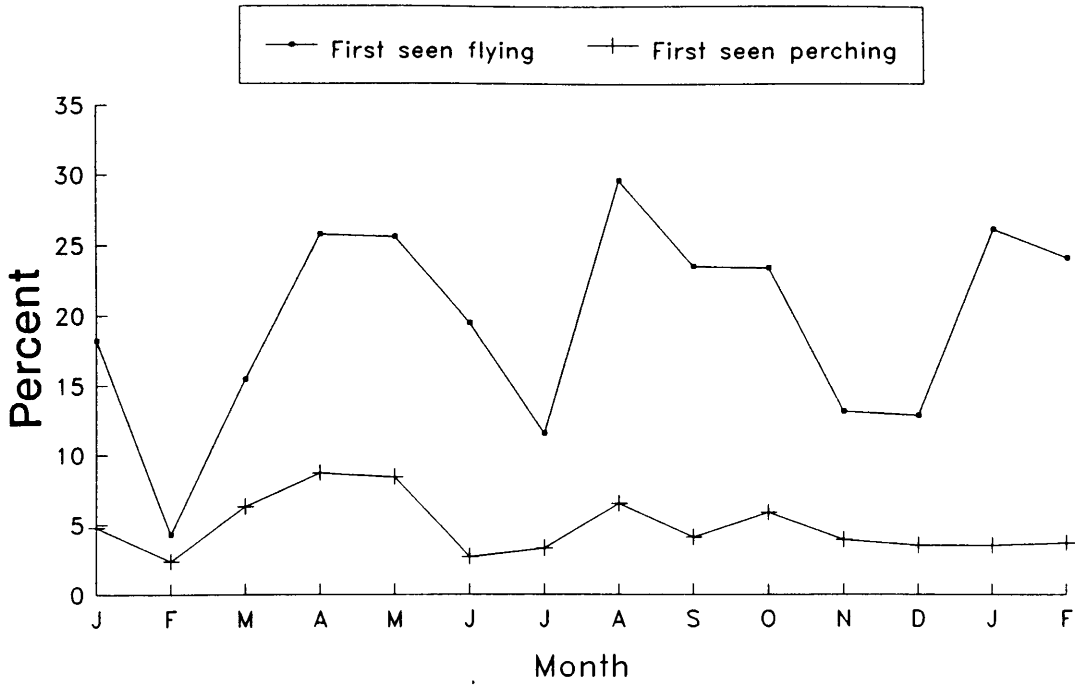


Figure 30. Percent of time spent in flight by eagles first seen flying and first seen perching on the northern Chesapeake Bay from January, 1987, through February, 1988.

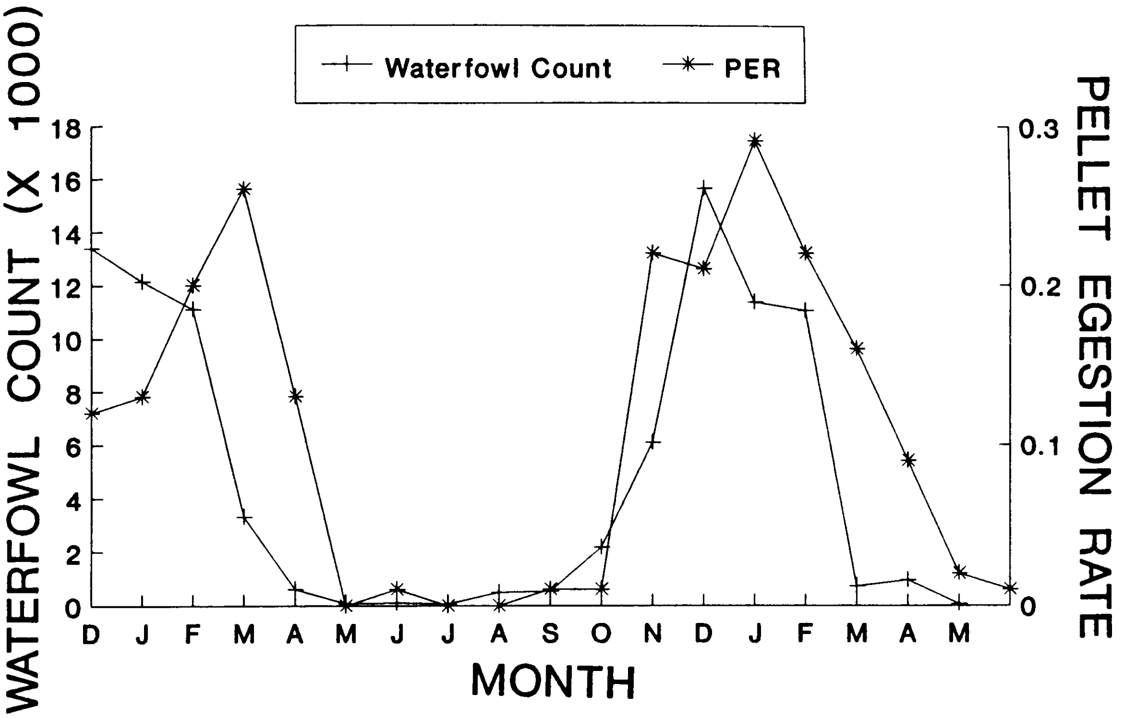


Figure 31. Aerial shoreline survey counts of waterfowl and pellet egestion rates (PER) of bald eagles on the northern Chesapeake Bay from December, 1986, through June, 1988.

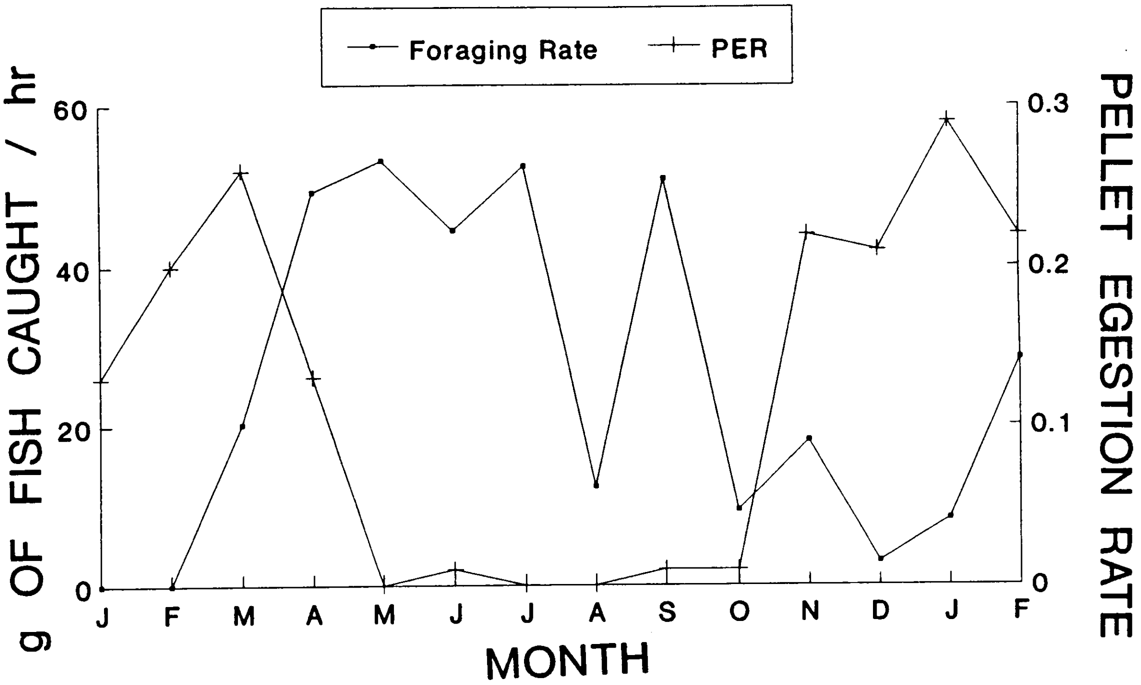


Figure 32. Pellet egestion rates (PER) and foraging rates (g of fish caught / hour) of bald eagles on the northern Chesapeake Bay from December, 1986, through June, 1988.

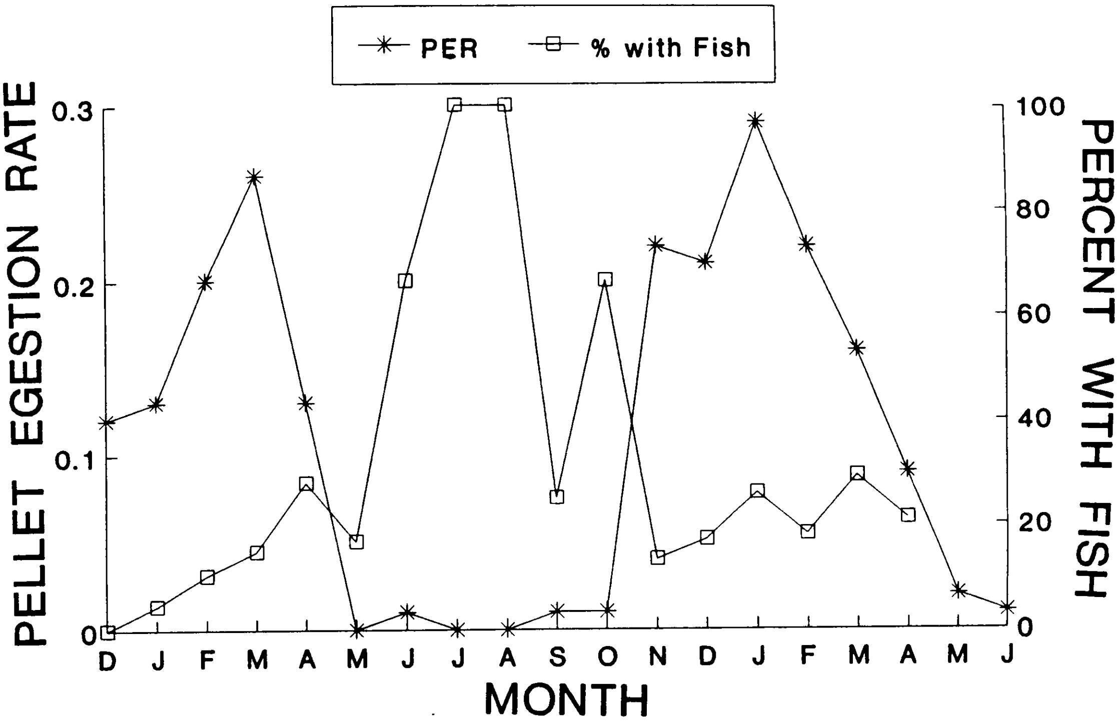
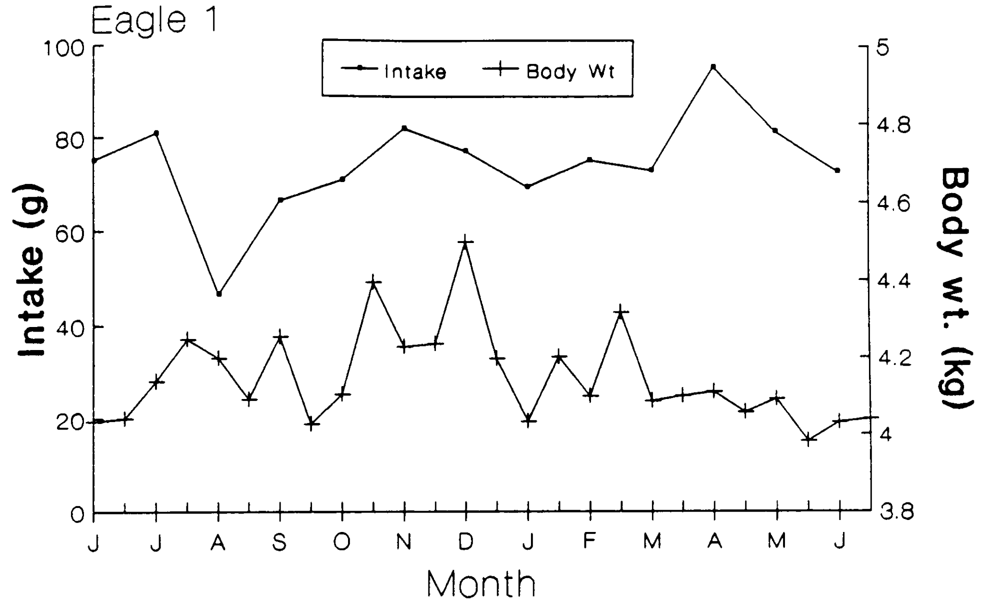


Figure 33. Pellet egestion rates (PER) of bald eagles and percent of eagle pellets containing fish parts on the northern Chesapeake Bay from December, 1986, through June, 1988.



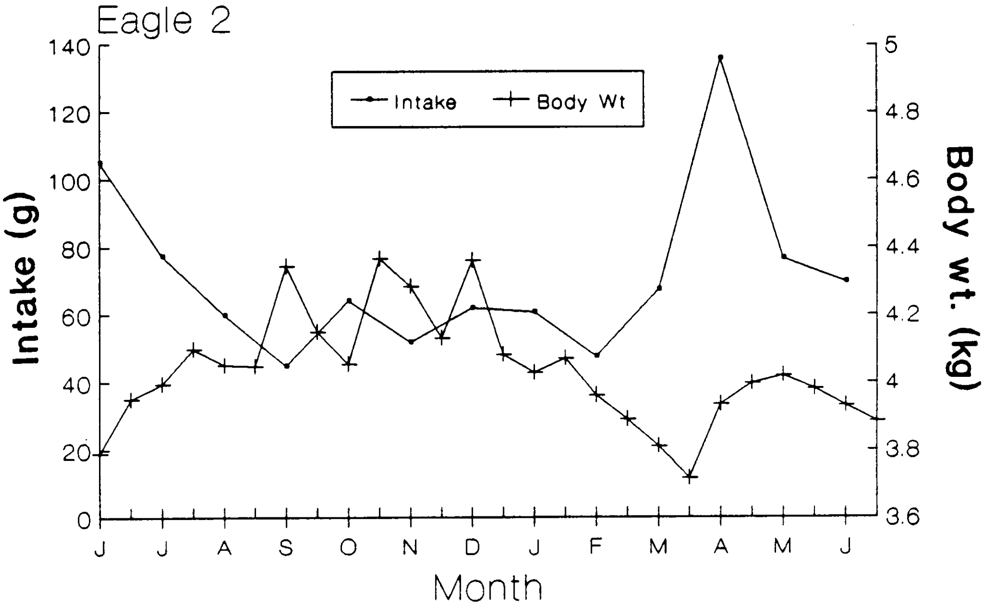


Figure 34. Dry weight intake of commercial bird-of-prey food and body weights of 2 captive immature bald eagles from June, 1987, through June, 1988.

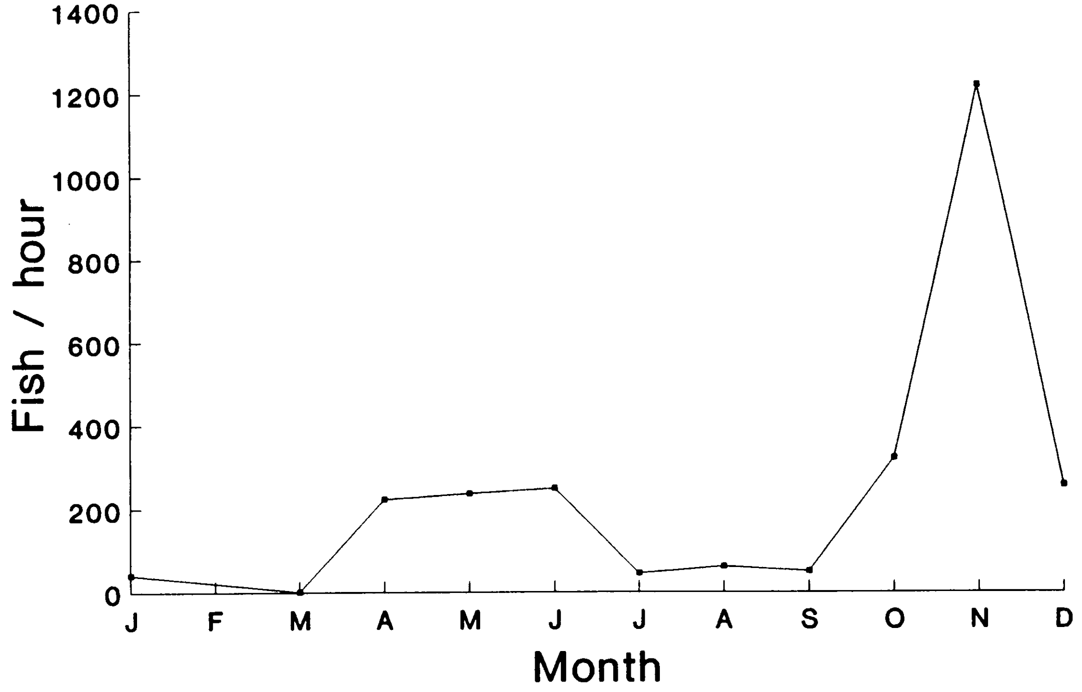


Figure 35. Mean electrofishing catch rates of gizzard shad in the tailrace below Conowingo Dam on the Susquehanna River, 1982 through 1986 (unpubl. data, RMC Environmental Services, Drumore, Pennsylvania).

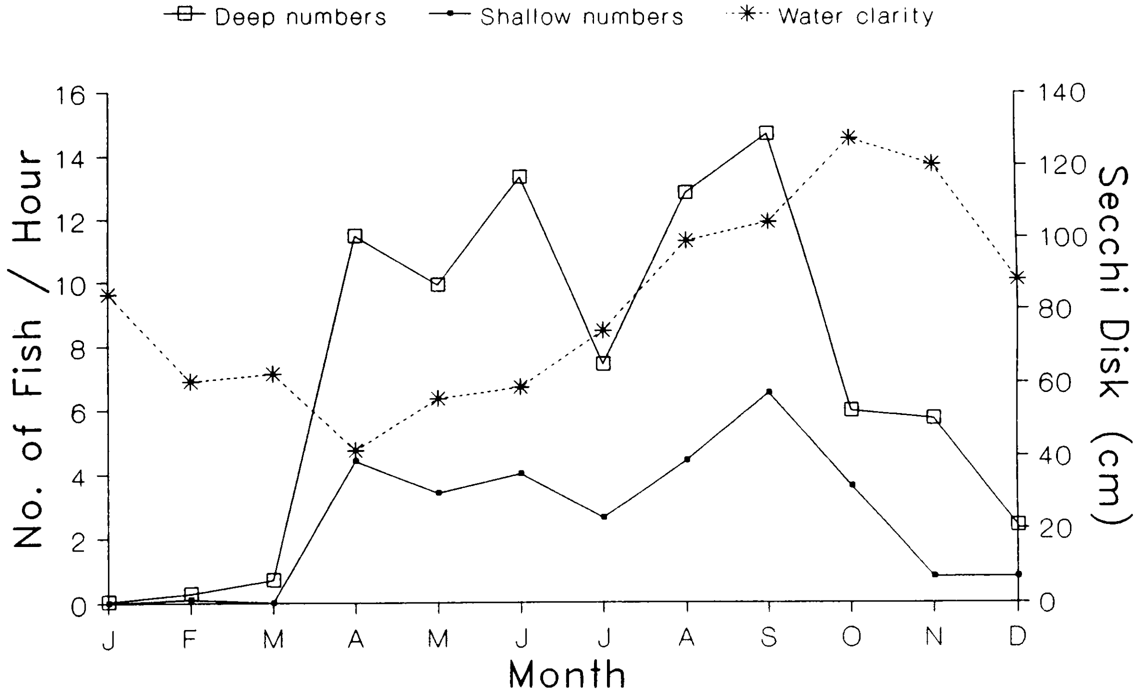


Figure 36. Mean catch rates for deep- (1.8 m) and shallow-water (0.6 m) gillnets and mean Secchi disk depth for the northern Chesapeake Bay, 1987.

Appendix A: Fish length X weight regressions

Species	Regression equation (length in mm, weight in g)	Source
Blueback herring (*Alosa aestivalis*)	$\log W = -4.702 + 2.904(\log TL)^1$	Messieh (1977) from Fay et al. (1983a)
Bluefish (*Pomatomus saltatrix*)	$\log W = -4.527 + 2.819(\log TL)$	this study, $r^2 = 0.953$ $n = 44$
Brown bullhead (*Ictalurus nebulosus*)	$\log W = -5.061 + 3.065(\log TL)$	Preigel (1966) from Carlander (1969)
Carp (*Cyprinus carpio*)	$\log W = -4.937 + 3.025(\log TL)$	Runnstrom (1955) from Carlander (1969)
Channel catfish (*Ictalurus punctatus*)	$\log W = -6.229 + 3.464(\log TL)$	this study, $r^2 = 0.986$ $n = 21$
Gizzard shad (*Dorosoma cepedianum*)	$\log W = -5.329 + 3.159(\log TL)$	this study, $r^2 = 0.992$ $n = 67$
Golden shiner (*Notemigonus crysoleucas*)	$\log W = -5.306 + 3.294\log(TL/1.26)$	Lewis (1950) from Carlander (1969)
Largemouth bass (*Micropterus salmoides*)	$\log W = -5.089 + 3.187\log(TL/1.08)$	Roseberry (1954) from Carlander (1977)
Menhaden (*Brevoortia tyrannus*)	$\log W = -4.941 + 2.989(\log TL)$	this study, $r^2 = 0.945$ $n = 46$
Pumpkinseed (Sunfish) (*Lepomis gibbosus*)	$\log W = -5.213 + 3.262(\log TL)$	Cooper et al. (1971) from Carlander (1977)
Spot (*Leiostomus xanthurus*)	$\log W = -4.344 + 2.769(\log TL)$	this study, $r^2 = 0.839$ $n = 16$
Striped bass (*Morone saxatilis*)	$\log(1000W) = -4.66 + 2.89\log(TL/10.8)$	Rogers et al. (1977) from Fay et al. (1983b)
White catfish (*Ictalurus catus*)	$\log TL = 1.979 + .1689(\log W)$	Schwartz and Jachowski (1965) from Carlander (1969)
White perch (*Morone americana*)	$\log W = -5.414 + 3.265(\log TL)$	this study, $r^2 = 0.977$ $n = 29$
Yellow perch (*Perca flavescens*)	$\log W = -5.455 + 3.237(\log TL)$	this study, $r^2 = 0.986$ $n = 5$

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[1] Also used to determine hickory shad (*Alosa mediocris*) weights.

Appendix B. **Gillnet sampling dates on the northern Chesapeake Bay, 1987.**

Sample number	Sample date	Area sampled
1	19 Jan	West Shore
	21 Jan	East Shore
2	8 Feb	West Shore
	12 Feb	West Shore
	12 Feb	East Shore
3	15 Mar	West Shore
	18 Mar	East Shore
	19 Mar	East Shore
4[1]	29 Mar	West Shore
	2 Apr	East Shore
	6 Apr	East Shore
5	12 Apr	West Shore
	14 Apr	East Shore
6	3 May	West Shore
	6 May	East Shore
7	17 May	West Shore
	21 May	East Shore
8[2]	31 May	West Shore
	1 Jun	West Shore
	2 Jun	East Shore
9	21 Jun	West Shore
	25 Jun	East Shore
10	5 Jul	West Shore
	7 Jul	East Shore
11	26 Jul	West shore
	29 Jul	East shore
12	12 Aug	East shore
	16 Aug	West shore
13	23 Aug	West Shore
	24 Aug	West Shore
	25 Aug	East Shore
14	7 Sep	West Shore
	8 Sep	East Shore
15	27 Sep	West Shore
	29 Sep	East Shore
16	11 Oct	West Shore
	15 Oct	East Shore
17	18 Oct	West Shore
	20 Oct	East Shore
18	8 Nov	West Shore
	13 Nov	East Shore
19	15 Nov	West Shore
	16 Nov	East Shore
20	6 Dec	West Shore
	7 Dec	East Shore
21	13 Dec	West Shore
	14 Dec	East Shore

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[1] Analyzed as an April sample.

[2] Analyzed as a June sample

Appendix C. Mean gillnet catch rates for 6 foraging areas (n = 12) on the northern Chesapeake Bay from April through September, 1987.[a]

	Deep-water catch		Shallow-water catch	
Foraging Area	n/hr[b]	g/hr[c]	n/hr[d]	g/hr[e]
Romney Creek	30.4 a	5887 a	7.9 a	1239 a
Stillpond/Churn Creek	24.1 a	3938 ab	6.1 ab	885 a
Bush River	24.4 a	3884 ab	4.8 abc	952 a
Sassafras River	16.8 ab	5401 a	3.1 bc	770 a
APG Bay	9.3 b	1988 bc	2.8 c	450 a
ES Bay	7.1 c	1486 c	0.4 d	64 b

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[a] All data, except g/hr in deep water were log transformed, prior to analysis. Significant differences between means within columns (Duncan's multiple range test; $P < 0.05$) are denoted by different letters. **Effects due to foraging area and time-of-day are confounded in these analyses; see text.**

[b] ANOVA, $F=7.33$, $df=5$, $p<0.0001$

[c] ANOVA, $F=4.96$, $df=5$, $p=0.0007$

[d] ANOVA, $F=9.89$, $df=5$, $p<0.0001$

[e] ANOVA, $F=8.47$, $df=5$, $p<0.0001$

Appendix D: Frequency and rate (no. / 100 eagle hours) of fish capture by Foraging Area and season on the northern Chesapeake Bay, January 1987 through February 1988 (for season totals, see Table 9).

	Winter 1986-87		Spring		Summer		Fall		Winter 1987-88		Total	
Species	n	n/100 hr	n	n/100 hr	n	n/100 hr	n	n/100 hr	n	n/100 hr	n	n/100 hr
APG BAY	(hr = 1.38)		(hr = 19.93)		(hr = 54.17)		(hr = 22.87)		(hr = 92.92)		(hr = 191.27)	
Gizzard shad	0	0.00	0	0.00	1	1.85	1	4.37	6	6.46	8	4.18
Catfish	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
Menhaden	0	0.00	1	5.02	0	0.00	2	8.75	0	0.00	3	1.57
White perch	0	0.00	1	5.02	0	0.00	0	0.00	0	0.00	1	5.02
American eel	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
Yellow perch	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
Carp	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
Striped bass	0	0.00	0	0.00	0	0.00	1	4.37	0	0.00	1	5.02
Total identified	0	0.00	2	10.04	1	1.85	4	17.49	6	6.46	13	6.80
Unidentified, ≤ 20cm	0	0.00	4	20.07	1	1.85	1	4.37	2	2.15	8	4.18
Unidentified, > 20cm	0	0.00	1	5.02	4	7.38	0	0.00	1	1.08	6	3.14
Unidentified, size unk.	0	0.00	0	0.00	2	3.69	2	8.75	15	16.14	19	9.93
Total, all fish	0	0.00	7	35.12	8	14.77	7	30.61	24	25.83	46	24.05
BUSH RIVER	(hr = 13.00)		(hr = 50.98)		(hr = 65.93)		(hr = 25.45)		(hr = 17.22)		(hr = 172.58)	
Gizzard shad	0	0.00	1	1.96	2	3.03	0	0.00	0	0.00	3	1.74
Catfish	0	0.00	1	1.96	1	1.52	0	0.00	0	0.00	2	1.16
Menhaden	0	0.00	2	3.92	0	0.00	0	0.00	0	0.00	2	1.16
White perch	0	0.00	0	0.00	1	1.52	0	0.00	0	0.00	1	0.58
American eel	0	0.00	2	3.92	1	1.52	0	0.00	0	0.00	3	1.74
Yellow perch	0	0.00	0	0.00	0	0.00	1	3.93	0	0.00	1	0.58
Carp	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
Striped bass	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
Total identified	0	0.00	6	11.77	5	7.58	1	3.93	0	0.00	12	6.95
Unidentified, ≤ 20cm	0	0.00	0	0.00	3	4.55	0	0.00	0	0.00	3	1.74
Unidentified, > 20cm	0	0.00	0	0.00	2	3.03	0	0.00	0	0.00	2	1.16
Unidentified, size unk.	0	0.00	2	3.92	3	4.55	0	0.00	0	0.00	5	2.90
Total, all fish	0	0.00	8	15.69	13	19.72	1	3.93	0	0.00	22	12.75

Appendix D. (continued):

	Winter 1986-87		Spring		Summer		Fall		Winter 1987-88		Total	
Species	n	n/100 hr	n	n/100 hr	n	n/100 hr	n	n/100 hr	n	n/100 hr	n	n/100 hr
SASSAFRAS RIVER	(hr = 6.42)		(hr = 1.00)		(hr = 57.93)		(hr = 31.02)		(hr = 14.18)		(hr = 110.55)	
Gizzard shad	0	0.00	0	0.00	3	5.18	0	0.00	0	0.00	3	2.71
Catfish	0	0.00	0	0.00	2	3.45	0	0.00	0	0.00	2	1.81
Menhaden	0	0.00	0	0.00	1	1.73	0	0.00	0	0.00	1	0.90
White perch	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
American eel	0	0.00	0	0.00	2	3.45	0	0.00	0	0.00	2	1.81
Yellow perch	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
Carp	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
Striped bass	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
Total identified	0	0.00	0	0.00	8	13.81	0	0.00	0	0.00	8	7.24
Unidentified, ≤ 20cm	0	0.00	1	100.00	1	1.73	1	3.22	1	7.05	4	3.62
Unidentified, > 20cm	0	0.00	0	0.00	3	5.18	3	9.67	0	0.00	6	5.43
Unidentified, size unk.	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
Total, all fish	0	0.00	1	100.00	12	20.71	4	12.89	1	7.05	18	16.28
STILLPOND/CHURN CREEK	(hr = 2.32)		(hr = 2.63)		(hr = 17.28)		(hr = 7.20)		(hr = 0.85)		(hr = 30.28)	
Gizzard shad	0	0.00	1	38.00	0	0.00	0	0.00	0	0.00	1	33.00
Catfish	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
Menhaden	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
White perch	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
American eel	0	0.00	0	0.00	1	5.79	0	0.00	0	0.00	1	3.30
Yellow perch	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
Carp	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
Striped bass	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
Total identified	0	0.00	1	38.00	1	5.79	0	0.00	0	0.00	2	6.60
Unidentified, ≤ 20cm	0	0.00	0	0.00	2	11.57	0	0.00	1	117.65	3	9.90
Unidentified, > 20cm	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
Unidentified, size unk.	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
Total, all fish	0	0.00	1	38.00	3	17.36	0	0.00	1	117.65	5	16.51

Appendix D. (continued):

Species	Winter 1986-87		Spring		Summer		Fall		Winter 1987-88		Total	
	n	n/100 hr	n	n/100 hr	n	n/100 hr	n	n/100 hr	n	n/100 hr	n	n/100 hr
ROMNEY CREEK	(hr = 65.93)		(hr = 46.07)		(hr = 29.12)		(hr = 20.68)		(hr = 92.45)		(hr = 254.25)	
Gizzard shad	1	1.52	0	0.00	0	0.00	0	0.00	10	10.82	11	4.33
Catfish	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
Menhaden	0	0.00	1	2.17	0	0.00	0	0.00	0	0.00	1	0.39
White perch	4	6.07	3	6.51	0	0.00	0	0.00	0	0.00	7	2.75
American eel	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
Yellow perch	5	7.58	0	0.00	0	0.00	0	0.00	0	0.00	5	1.97
Carp	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
Striped bass	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
Total identified	10	15.17	4	8.68	0	0.00	0	0.00	10	10.82	24	9.44
Unidentified, ≤ 20cm	5	7.58	1	2.17	1	3.43	1	4.84	8	8.65	16	6.29
Unidentified, > 20cm	0	0.00	3	6.51	0	0.00	0	0.00	2	2.16	5	1.97
Unidentified, size unk.	5	7.58	1	2.17	0	0.00	4	19.34	16	17.31	26	10.23
Total, all fish	20	30.34	9	19.54	1	3.43	5	24.18	36	38.94	71	27.93
ES BAY	(hr = 10.75)		(hr = 9.43)		(hr = 27.43)		(hr = 34.707)		(hr = 34.82)		(hr = 117.13)	
Gizzard shad	0	0.00	0	0.00	0	0.00	0	0.00	1	2.87	1	0.85
Catfish	0	0.00	1	10.60	1	3.65	0	0.00	0	0.00	2	1.71
Menhaden	0	0.00	1	10.60	0	0.00	0	0.00	0	0.00	1	0.85
White perch	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
American eel	0	0.00	0	0.00	1	3.65	0	0.00	0	0.00	1	0.85
Yellow perch	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
Carp	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
Striped bass	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
Total identified	0	0.00	2	21.20	2	7.29	0	0.00	1	2.87	5	4.27
Unidentified, ≤ 20cm	0	0.00	0	0.00	4	14.58	2	5.76	1	2.87	7	5.98
Unidentified, > 20cm	0	0.00	0	0.00	2	7.29	0	0.00	1	2.87	3	2.56
Unidentified, size unk.	0	0.00	0	0.00	2	7.29	3	8.65	5	14.36	10	8.54
Total, all fish	0	0.00	2	21.20	10	36.46	5	14.40	8	22.98	25	21.34

Appendix D. (continued):

	Winter 1986-87		Spring		Summer		Fall		Winter 1987-88		Total	
Species	n	n/100 hr	n	n/100 hr	n	n/100 hr	n	n/100 hr	n	n/100 hr	n	n/100 hr
SUSQUEHANNA RIVER	(hr = 36.67)		(hr = 5.18)		(hr = 13.40)		(hr = 56.73)		(hr = 27.35)		(hr = 139.33)	
Gizzard shad	1	2.73	0	0.00	0	0.00	7	12.34	2	7.31	10	7.18
Catfish	0	0.00	1	19.31	1	7.46	1	1.76	0	0.00	3	2.15
Menhaden	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
White perch	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
American eel	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
Yellow perch	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
Carp	0	0.00	0	0.00	0	0.00	1	1.76	0	0.00	1	0.72
Striped bass	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
Total identified	1	2.73	1	19.31	1	7.46	9	15.86	2	7.31	14	10.05
Unidentified, ≤ 20cm	1	2.73	0	0.00	4	29.85	13	22.92	3	10.97	21	15.07
Unidentified, > 20cm	0	0.00	0	0.00	2	14.93	1	1.76	1	3.66	4	2.87
Unidentified, size unk.	0	0.00	0	0.00	3	22.39	3	5.29	3	10.97	9	6.46
Total, all fish	2	5.45	1	19.31	10	74.63	26	45.83	9	32.91	48	34.45
REMINGTON FARMS	(hr = 0.32)		(hr = 0.00)		(hr = 5.32)		(hr = 61.18)		(hr = 52.38)		(hr = 119.2)	
Gizzard shad	0	0.00	0	0.00	0	0.00	1	1.63	0	0.00	1	0.84
Catfish	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
Menhaden	0	0.00	0	0.00	0	0.00	1	1.63	0	0.00	1	0.84
White perch	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
American eel	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
Yellow perch	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
Carp	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
Striped bass	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
Total identified	0	0.00	0	0.00	0	0.00	2	3.27	0	0.00	2	1.68
Unidentified, ≤ 20cm	0	0.00	0	0.00	0	0.00	15	24.52	1	1.91	16	13.42
Unidentified, > 20cm	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
Unidentified, size unk.	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
Total, all fish	0	0.00	0	0.00	0	0.00	17	27.79	1	1.91	18	15.10

Appendix E: Distribution of observation time and eagle hours among daytime periods and months for direct observation of foraging eagles on the northern Chesapeake Bay from January, 1987, through February, 1988.

	Month/Year														
Daytime Period	1/87	2/87	3/87	4/87	5/87	6/87	7/87	8/87	9/87	10/87	11/87	12/87	1/88	2/88	Total
Observation hours															
Before sunrise	0.6	0.3	0.7	0.2	1.2	2.3	4.6	3.2	1.2	4.5	1.7	6.0	12.4	2.5	41.4
1 hr after sunr.	6.6	4.0	7.6	4.4	9.9	10.0	16.0	13.2	10.7	12.7	8.0	17.6	29.3	10.2	160.2
2 hrs after sunr.	6.5	5.0	6.6	8.6	8.2	9.1	14.3	13.0	9.3	12.0	8.0	17.3	29.4	10.0	157.2
3 hrs after sunr.	4.6	4.3	4.7	4.4	5.6	6.3	12.2	11.4	7.4	10.5	6.2	14.8	21.2	7.1	120.8
4 hrs after sunr.	2.0	3.0	2.7	2.6	4.7	5.1	8.7	5.4	2.9	9.4	0.7	9.9	18.7	5.4	81.2
Midday	5.9	1.9	8.9	4.4	9.9	18.6	28.0	22.8	13.3	30.4	2.4	18.9	29.0	14.7	209.0
4 hrs before suns.	2.5	1.6	0.9	0.0	0.0	1.9	4.5	2.8	2.6	4.4	2.3	8.6	11.8	4.4	48.5
3 hrs before suns.	4.0	0.0	1.0	0.0	0.9	2.8	3.8	5.0	4.8	5.0	4.0	7.7	11.5	4.4	54.8
2 hrs before suns.	3.0	0.0	1.0	0.0	1.0	1.7	2.2	4.1	4.9	2.9	3.9	10.8	9.0	4.6	49.7
1 hr before suns.	0.2	1.0	1.0	0.0	0.6	1.0	1.0	2.8	1.5	0.2	2.3	5.9	7.2	2.3	26.9
After sunset	0.0	0.2	0.0	0.0	0.0	0.2	0.0	0.6	0.0	0.0	0.0	0.2	0.9	0.0	2.2
Total	35.9	21.6	35.1	24.6	42.0	59.2	95.4	84.2	58.6	91.9	39.5	117.8	180.4	65.8	951.9
Eagle hours															
Before sunrise	0.6	0.0	1.2	0.0	0.6	2.5	1.0	0.4	0.4	3.2	0.2	4.0	3.4	3.7	21.1
1 hr after sunr.	8.1	0.6	32.4	3.2	10.0	7.9	11.7	16.6	7.9	14.5	7.4	21.1	31.4	20.2	193.1
2 hrs after sunr.	7.2	6.3	33.4	10.3	8.0	10.4	21.1	25.1	10.0	15.4	11.1	27.6	35.1	19.1	240.1
3 hrs after sunr.	8.0	6.1	16.3	9.0	4.4	10.8	20.3	17.6	13.0	18.3	7.9	21.0	33.6	16.0	202.4
4 hrs after sunr.	1.4	3.4	7.6	2.6	2.9	3.3	12.6	8.6	4.4	13.2	0.8	10.9	27.2	12.4	111.5
Midday	7.5	3.7	12.3	3.4	3.4	18.8	22.8	10.5	13.2	32.9	0.4	19.0	22.1	24.0	194.0
4 hrs before suns.	2.8	5.8	0.6	0.0	0.0	2.4	2.7	1.2	2.7	4.9	0.9	11.4	5.0	4.4	44.8
3 hrs before suns.	4.0	0.0	1.0	0.0	0.2	2.7	5.2	3.4	4.6	4.6	4.7	6.7	10.1	2.4	49.5
2 hrs before suns.	3.1	0.0	1.8	0.0	0.1	1.2	3.4	4.2	4.8	3.8	4.2	12.6	11.8	1.0	52.0
1 hr before suns.	0.2	0.0	1.6	0.0	0.2	1.4	1.5	3.6	1.2	0.3	1.7	4.9	7.2	1.1	24.8
After sunset	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.4	0.0	0.0	0.0	0.2	0.5	0.0	1.3
Total	42.9	26.0	108.2	28.5	29.7	61.6	102.1	91.6	62.0	111.2	39.4	139.3	187.6	104.4	1134.6

Appendix F: Distribution of observation time and eagle hours among Foraging Areas and months for direct observation of foraging eagles on the northern Chesapeake Bay from January, 1987, through February, 1988.

	Month/Year														
Foraging Area	1/87	2/87	3/87	4/87	5/87	6/87	7/87	8/87	9/87	10/87	11/87	12/87	1/88	2/88	Total
Observation hours															
APG Bay	1.8	0.0	1.6	6.6	1.4	6.2	9.6	13.0	4.4	5.0	2.3	13.7	32.0	0.0	97.4
Bush River	4.3	2.8	15.0	2.0	8.2	24.3	20.1	11.5	9.1	9.0	6.3	13.0	5.4	3.4	134.4
Romney Creek	0.4	0.0	13.9	12.9	11.2	18.5	5.7	13.9	7.8	8.3	6.7	16.3	8.4	13.8	137.8
ES Bay	6.0	0.0	0.5	1.4	11.0	2.8	19.7	7.0	9.9	12.2	2.8	14.8	31.4	18.3	137.8
Sassafras River	5.4	0.0	0.0	0.0	2.8	2.5	20.4	11.7	11.6	10.7	5.8	10.6	9.7	0.0	91.2
Stillpond/Churn Cr.	5.4	0.0	2.0	1.6	3.3	4.9	19.9	7.8	1.5	2.6	9.6	11.0	8.2	9.5	87.3
Susquehanna River	12.6	18.6	2.2	0.0	4.0	0.0	0.0	19.4	10.7	15.8	5.9	14.2	19.8	10.2	133.5
Remington Farms	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0	3.5	28.3	0.0	24.3	65.6	10.5	132.3
Total	35.9	21.6	35.1	24.6	42.0	59.2	95.4	84.2	58.6	91.9	39.5	117.8	180.4	65.8	951.9
Eagle hours															
APG Bay	1.4	0.0	1.6	11.8	1.4	6.9	10.6	36.1	5.7	4.3	2.1	23.1	86.2	0.0	191.3
Bush River	9.0	4.0	31.5	1.3	2.4	29.2	31.5	11.6	9.3	7.7	8.1	15.7	6.5	4.6	172.6
Romney Creek	0.0	0.0	71.8	12.5	12.9	19.8	2.4	15.2	6.5	5.7	4.3	12.8	3.4	87.0	254.2
ES Bay	10.8	0.0	0.0	1.4	7.0	1.0	17.7	2.2	7.6	16.5	4.0	25.3	19.3	4.4	117.1
Sassafras River	6.4	0.0	0.0	0.0	1.0	1.0	31.0	14.1	22.0	9.8	9.3	12.4	3.6	0.0	110.6
Stillpond/Churn Cr.	0.3	0.0	2.0	1.6	1.0	3.7	8.9	4.7	0.0	0.4	5.0	1.8	0.6	0.2	30.3
Susquehanna River	15.0	21.7	1.2	0.0	4.0	0.0	0.0	7.8	5.6	21.0	6.5	29.3	21.9	5.5	139.3
Remington Farms	0.0	0.3	0.0	0.0	0.0	0.0	0.0	0.0	5.3	45.7	0.0	19.1	46.2	2.6	119.2
Total	42.9	26.0	108.2	28.5	29.7	61.6	102.1	91.6	62.0	111.2	39.4	139.3	187.6	104.4	1134.6

Appendix G: Pellet collections by month and roost on the northern Chesapeake Bay.

	Roost Name							
	AA5	Mosquito Creek	L. Romney Creek	Abbey	Andelot Farm	Remington Farms	Red Oaks	Total
Dec 1986	16	0	0	0	9	9	0	34
Jan 1987	22	0	0	0	27	131	0	180
Feb 1987	21	7	0	0	7	62	0	97
Mar 1987	42	1	0	0	1	109	0	153
Apr 1987	13	0	0	0	0	30	0	43
May 1987	6	0	0	0	0	0	0	6
Jun 1987	2	0	0	0	0	1	0	3
Jul 1987	1	0	0	0	0	0	0	1
Aug 1987	1	0	0	1	0	0	0	4
Sep 1987	4	0	0	0	0	0	0	4
Oct 1987	2	0	0	1	0	0	0	3
Nov 1987	0	0	0	0	1	14	0	15
Dec 1987	37	26	0	0	4	38	0	105
Jan 1988	15	31	0	0	0	16	9	71
Feb 1989	32	21	33	0	12	161	0	259
Mar 1989	24	14	33	0	0	23	0	94
Apr 1989	2	6	0	0	0	11	0	19
Total	240	106	66	2	61	605	9	1089

Appendix H: Biases and Selectivity of Gillnet Sampling

We chose gillnetting as our fish sampling technique because it is economical, requiring only a small boat and crew and low costs in materials and maintenance (Hamley 1975, Von Brant 1985). However due to its high selectivity, great care must be taken when interpreting gillnetting results. Since gillnets are passive gear (i.e., catch is dependent on fish swimming to the net), gillnet catch rate can act as a measure of fish activity as well as abundance. Catch rate is therefore affected by daily or seasonal periods of peak activity. Relative species abundance may be biased in favor of fast-swimming, active species which are more likely to contact the net than slow, sedentary species (Hammar and Filipsson 1985). Larger fish are more likely to be caught than smaller fish of the same species possibly because they are more active, thus introducing bias to length frequency data (Hamley 1975). Patterns of movement by each fish species may also affect relative abundance results. Placement of gillnets parallel or perpendicular to shore can affect relative catch of species which travel along the shore versus those which migrate from deep to shallow water (Hammar and Filipsson 1985).

Selectivity of different mesh sizes affects size distribution and species composition of fish caught (Hamley 1975, von Brant 1985). Selectivity due to mesh size can be reduced by using multiple mesh sizes, though defining optimal combinations can be difficult. Hammar and Filipsson (1985) recommended choosing mesh sizes so that standard deviations of each species lengths by mesh size overlap. They also observed that small changes in mesh size added new species to their catch.

Many other factors may add to gillnet selectivity. Fish behavior when encountering a gillnet and fish shape can affect relative species CPUE (Hamley 1975). Net characteristics such as the color, stretch, and flexibility of netting material, and the net's hanging coefficient (ratio of length of completed net to length of stretched netting used) also affect catch. Moreover, fish reaction to various netting materials can vary with fish species and age, and environmental conditions (Hamley 1975). Environmental conditions that can affect gillnet catch include water clarity, ambient light, and current. Low turbidity and high lighting serve to make gillnets more visible to fish thereby reducing catch. Nets stretched by strong currents catch less fish than nets in slack water as fish are less likely to attempt swimming through hard strands of a taut net. Catch by entangling is also reduced in a net stretched by water current.

Obviously, gillnet selectivity is a complex process affected by many factors and their interactions. Because of this complexity, we are unable to precisely determine to what extent this selectivity has affected our results. However because such affects are potentially significant, some discussion of these factors in relation to our results is warranted.

Though changes in fish activity may have affected observed changes in CPUE, no doubt exists that seasonal fish abundance varies dramatically on the Chesapeake Bay (Hildebrand and Schroeder 1928, Lippson 1973). Because increased fish activity, which was associated with rising temperatures and spawning, accompanied movement of fish into shallow water, effects of abundance and activity on CPUE are not separable. Increases in either abundance or fish activity should therefore increase general fish availability to bald eagles. Thus conclusions made regarding seasonal changes in live fish availability are probably not seriously biased by seasonal fish activity patterns. We examined water clarity because of its purported effect on gillnet efficiency (i.e, higher net visibility in clear water may allow net avoidence by fish, Hamley 1975). Though water clarity was negatively correlated with deep water catch rates (Spearman's rank-order correlation: $R = -0.459$, $P < 0.0001$), it was also related to other factors. Water clarity differed with season, reaching lows during the influx of fish in spring and peaking during the fish declines in fall (Fig. 36). Water clarity also differed between Bayside and among habitats (ANOVA: $P < 0.0001$); water was more turbid on the western shore than on the east, and more turbid in creeks and rivers than on the Bay (Duncan's multiple range test: $P < 0.05$). These differences precluded complete separation of water clarity effects from those of season or location. Water clarity and catch rates were no longer significantly correlated ($P > 0.05$) however when coefficients were calculated separately for each location using data from the period when fish are known to be abundant (April through September). Thus, I conclude that the effect of water clarity on gillnet efficiency was small relative to other factors affecting catch rates. Nevertheless, water turbidity may have been an important environmental factor affecting fish distribution and abundance, especially for filter feeders such as menhaden and gizzard shad.

I have found no studies that compare gillnet susceptability of common fish species found on the northern Chesapeake Bay, therefore effects of species selectivity on relative abundance results is unknown. Though some inaccuracies may exist in our relative abundance estimates for menhaden, gizzard shad, white perch, and channel catfish, our general observations and interactions with commercial fishermen support the conclusion that these four species are the most common on the northern Bay. For some species however, inaccuracies are greater. Channel catfish, because of their nocturnal habits and preference for deep holes, were probably underestimated relative to divrnal, pelagic fish. At an extreme, two species reportedly common on the northern Bay (Lippson 1973), American eel (*Anguilla rostrata*) and winter flounder (*Psuedopleuronectes americanus*), were never caught in gillnets due to their body shapes. Though eels were common enough on the study area to support commercial fishing, their habit of spending the day buried in mud or under logs and feeding nocturnally (Becker 1983) probably limited availability of live eels to foraging eagles. Winter flounder are present on the study area only during winter months making them potentially an important winter food for eagles; however, their bottom dwelling habits and preference for deep water may have limited the availability of this fish also. We never saw a winter flounder on the northern Bay during this study.

Examination of length distributions for each species (Fig. 17) reveals that fish sizes caught in each mesh size overlap considerably for both gizzard shad and channel catfish. Size selectivity for catfish is particularly low because catfish are often caught by entangling as well as gilling. Gizzard shad size selectivity is also relatively low because these fish often are caught at various locations on the body by wedging. Menhaden and white perch, two species caught primarily by gilling, were caught almost exclusively in the smallest mesh size. Though some size selection is probable, I feel the limited size distribution observed for these two species was largely dictated by the predominance of young-of-the-year fish in netted areas. In general, it is safe to conclude that gizzard shad and channel catfish are available to eagles in a wide range of sizes, but primarily greater than 20 cm. Menhaden and white perch are more available in size classes of 20 cm or less.

Appendix I: Maryland Waterfowl Hunting Regulations, 1986-89.

Year	Species	Location	Season dates	Bag limit
1986-87	Ducks	Statewide	Oct 10,11	4/day[1]
			Nov18-28	4/day[1]
			Dec 8-Jan 3	4/day[1]
	Canada geese	East shore	Nov 14-28	3/day
			Dec 8-Jan 31	3/day
		West shore	Nov 3-28	3/day
			Dec 8-Jan 20	3/day
1987-88	Ducks	Statewide	Oct 9,10	4/day[1]
			Nov 17-27	4/day[1]
			Dec 7-Jan 2	4/day[1]
	Canada geese	East shore	Nov 13-27	3/day
			Dec 7-Jan 30	3/day
		West shore	Nov 3-27	3/day
			Dec 7-Jan 20	3/day
1988-89	Ducks	Statewide	Oct 7,8	3/day[1]
			Nov 23-25	3/day[1]
			Dec 7-Jan 7	3/day[1]
	Canada geese	Statewide	Nov 11-25	1/day
			Dec 8-Jan 21	2/day

[1] with species restrictions