1-1-1973

Distribution of Pelagic Fishes in Sheepscot River-Back River Estuary, Wiscasset, Maine

C. W. Recksiek

James McCleave
University of Maine - Main, mccleave@maine.edu

Distribution of Pelagic Fishes in the Sheepscot River–Back River Estuary, Wiscasset, Maine

CONRAD W. RECKSIEK AND JAMES D. MCCLEAVE

Department of Zoology, University of Maine, Orono, Maine 04473

ABSTRACT

Fifteen species of pelagic fishes were collected in 156 gill net sets at eight locations in the Sheepscot River–Back River estuary, Wiscasset, Maine, June 1970 through December 1971. Highest catches occurred June through August. Only the rainbow smelt is a year-round resident. Differences in abundance in space and time are apparently related to temperature. During the summer, alewives, blueback herring, and Atlantic menhaden were most abundant in the relatively warm Back River estuary, while Atlantic herring, Atlantic mackerel, and spiny dogfish were most abundant in the more oceanic Sheepscot River estuary. Prolonged near-freezing temperatures apparently limit the time pelagic fishes spend in the estuary and limit the number of species which can inhabit it. It is hypothesized that the distribution of pelagic species which exhibited preferences for colder water, such as Atlantic herring, would be most affected by artificial warming of the surface waters of the Back River estuary, if a new atomic powered generating plant were allowed to discharge heated effluent directly into it.

INTRODUCTION

This study was designed to determine the relative seasonal abundance of pelagic fishes in the Sheepscot River–Back River estuary, Wiscasset, Maine, and to evaluate the effects of sampling location, temperature, and salinity on the occurrence of principal species. This investigation is part of an effort by several investigators to provide basic ecological information prior to the completion of a 855-megawatt atomic electric power plant.

Fish distribution studies from North American east coast inshore areas and estuaries have dealt with both pelagic and demersal components. Seasonal occurrence of fishes has been studied in a Georgia salt marsh (Dahlberg and Odum, 1970), in shore habitats near Beaufort, North Carolina (Tagatz and Dudley, 1961), on Virginia's eastern shore (Richards and Castagna, 1970), Chesapeake Bay and York and Pamunkey Rivers (Massmann, 1962), in the Delaware River estuary (de Sylva, Kalber, and Shuster, 1962), the surf waters of Long Island (Schaefer, 1967), the Mystic River estuary (Pearcy and Richards, 1962), near Woods Hole, Massachusetts (Lux and Nichy, 1971), in the Annisquam River–Gloucester Harbor (Massachusetts) coastal system (Jerome, Chesmore, and Anderson, 1969), and Passamaquoddy Bay (Tyler, 1971). Kinne (1964) stated that: "In the open ocean where salinities are rather constant, temperature usually represents the master factor controlling . . . distribution. In coastal areas and estuaries distribution depends increasingly on both factors, with varying degrees of dominance of either one." The effects of hydrographic conditions upon distribution of North Atlantic fishes have been treated extensively in a symposium (ICNAF, 1965). The influence of temperature on the distribution of fishes was discussed by Brett (1970). Hela and Laevastu (1962) summarized known temperature optima for several species. The relation of estuarine organisms to salinity is reviewed by Pearse and Gunter (1957) and Gunter (1961).

DESCRIPTION OF STUDY AREA

Stickney (1959) described the hydrography and geography of the Sheepscot River estuary and its relation to the Kennebec River estuary. The Back River estuary is separated from the Sheepscot River by Westport Island (Fig. 1). A narrow causeway connects the island and the mainland. The atomic power plant is located near sampling station G2 where Back River widens into Montsweag Bay. Except for a navigable channel from Hockomock Bay to the causeway and from near G3 into Montsweag Brook, Montsweag Bay is shallow and almost exposed at low tide.

The flood tide into Back River and Montsweag Bay flows south through the narrow

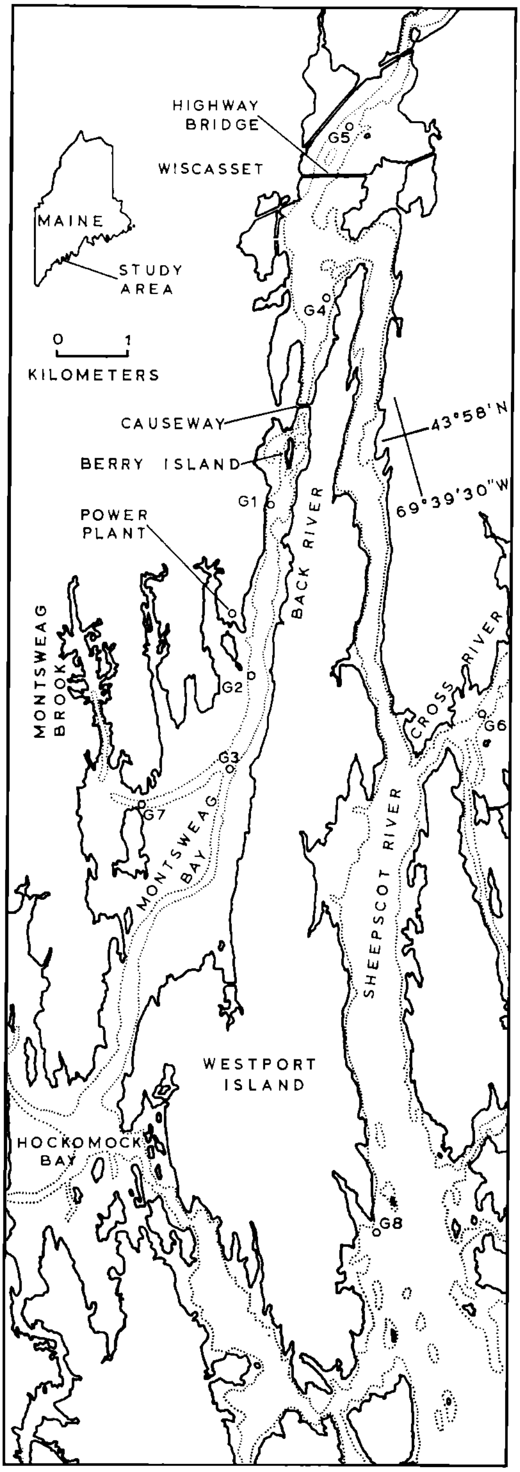


FIGURE 1.—The Sheepscot River–Back River estuary, Wiscasset, Maine, showing gillnetting stations G1 through G8. Contour depth = 3 m.

causeway opening and north through Hockomock Bay. Tidal currents from Berry Island (G1) to around G2 are sufficiently weak to permit seasonal icing over. At G3 strong tidal currents follow the channel. Near G4 tidal currents are mild. Local tidal currents, created by large eddies, are irregular and unpredictable. At G5 the currents are powerful and follow the channel. Near G6 in Cross River tidal current directions vary greatly with tidal stage.

MATERIALS AND METHODS

Sampling stations were selected near and at increasing distances from the power plant to determine the distribution of pelagic fish fauna; however station selection was influenced by tidal currents and weather considerations. Stations G1, G2, G3, and G7 are in the Back River estuary, and stations G4, G5, G6, and G8 are in the Sheepscot River estuary (Fig. 1).

Pelagic fish were sampled with cross-channel, anchored gill nets fished from a bow roller on a 5-m fiberglass skiff (Boston Whaler). The gill nets were of three monofilament nylon panels, each panel 2.4 m (8 ft) × 15.2 m (50 ft) with 5.1 cm (2 in), 1.3 cm (½ in), 2.5 cm (1 in) bar mesh. The sinking gill net was suspended so as to fish 1.9 m (6 ft) below the surface.

The efficiency of gill nets is reduced in strong currents and winter weather conditions prevented regular sampling in open areas. Thus south Montsweag Bay and the main channel of the lower Sheepscot River estuary were not sampled because of strong currents. Six stations (G1–G6) were sampled throughout the study. G8 was exposed to winter weather, and served only as a supplemental station during the summer of 1971. G7 was sampled the same summer.

Regular sampling was conducted from June 1970 to December 1971 during neap tides after full moon. During the summer, samples were collected fortnightly on the neap tides. Two consecutive nights (winter) or three consecutive nights (summer) were needed to fish all stations. The first station net was set at about 1500 EST and was retrieved at about 0700 EST the next morning. Remaining nets were set and retrieved as soon as possible thereafter. Sampling was suspended in Back River from January through March 1971 and in the Sheepscot River in January 1971 due to ice conditions.

A water sample was collected at a depth of 1.9 m at the beginning and conclusion of each set by means of a Meyer sampler. The two samples were mixed and the salinity determined by hydrometer. A continuous record of temperature was obtained from a thermograph suspended at a depth of 1.8 m.

The catches were fixed in 10% formalin for at least 10 days and preserved for study in 50% 2-propanol. Striped bass and spiny dogfish were studied fresh. The numbers and total weight of each species were recorded. The 1.3-cm and 2.5-cm mesh selected specific sizes of Atlantic herring, alewife, and blueback herring. These species were separated on the basis of size into two groups and the numbers and weights recorded.

Catches, expressed as both numbers and weights, of those species which were frequently encountered at G1, G2 and G4 were treated statistically. Catches at the other stations were not used for quanitative comparisons since tidal currents were believed to have decreased the efficiency of the gill nets. The experimental model was a two-factor randomized complete-block design. Analysis of variance was employed in testing the null hypotheses that the effects of sampling location (factor 1, 3 levels; G1, G2, G4), months (factor 2, 7 levels; June through December), interaction between months and sampling locations, and year (blocks, 2 levels; 1970, 1971) were nonsignificant. In summer, when two samples were collected per month, only those collected during the neap tides after full moon were used in this analysis. Duncan's new multiple-range test was used to test for significant differences among main effect levels when interaction was nonsignificant. When interaction was significant, as was the case only with numbers and weights of Atlantic menhaden, Duncan's test was performed separately for each sampling location to detect differences in time. Analyses of like design were conducted for summer data with catches during fortnightly neap tides in 1970 and 1971 (factor 2, 6 levels; June through August).

TABLE 1.—*Percentage composition by numbers and weights of the pelagic fish catches in Sheepscot River–Back River estuary, June 1970 through December 1971*

	Percent of total numbers of catch	Percent of total weight of catch
Alewife (*Alosa pseudoharengus*)	41.5	21.9
Blueback herring (*Alosa aestivalis*)	23.1	15.3
Atlantic herring (*Clupea harengus*)	21.9	3.1
Rainbow smelt (*Osmerus mordax*)	5.7	1.5
Atlantic menhaden (*Brevoortia tyrannus*)	3.6	16.4
Atlantic mackerel (*Scomber scombrus*)	2.0	3.4
Spiny dogfish (*Squalus acanthias*)	1.4	34.8
American shad (*Alosa sapidissima*)	0.4	0.6
Striped bass (*Morone saxatilis*)	0.2	2.7
Silver hake (*Merluccius bilinearis*) Butterfish (*Peprilus triacanthus*) Bluefish (*Pomatomus saltatrix*) Hickory shad (*Alosa mediocris*) Pollock (*Pollachius virens*) White perch (*Morone americana*)	0.2	0.3

RESULTS AND DISCUSSION

Fish Catches in Sheepscot and Back Rivers

This study yielded 9,840 individuals of 15 pelagic species in 156 gill net sets (Table 1).[1] Six species of demersal fishes, outside the scope of this study, were occasionally caught in gill nets.

Most of the common pelagic fish species of the Sheepscot River–Back River estuary were encountered May through November, with the largest catches occurring June through August (Fig. 2). With the exception of rainbow smelt and perhaps white perch, they leave the estuary during the winter months.

Differences between the Sheepscot River and Back River faunas were particularly striking during the summer (Fig. 2). Catches in the Back River estuary, in terms of both numbers and weights, were dominated by alewives and blueback herring. Atlantic menhaden contributed markedly to the weight of the catches. In the Sheepscot River estuary Atlantic herring were dominant numerically and spiny dogfish dominated by weight. At G6 in Cross River spiny dogfish even dominated numerically. Large catches of Atlantic mackerel at G8 in the lower Sheepscot River estuary in summer suggest that this fish may play an important role in the ecology of the lower estuary.

[1] A table of catch numbers and weights for all eight stations and all sampling periods is available from the junior author upon request.

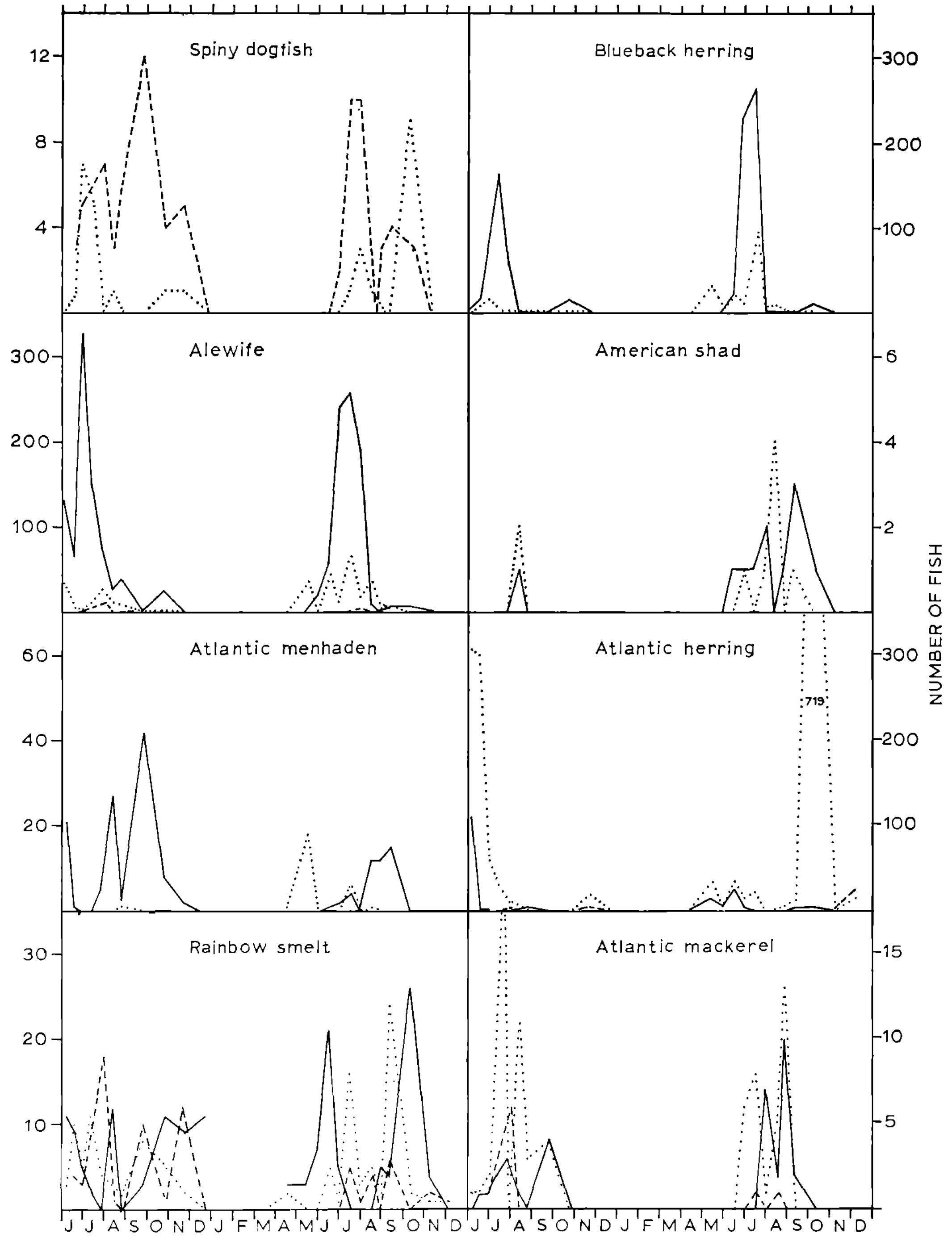


FIGURE 2.—Seasonal abundance of the major pelagic fish species at one station in Back River estuary (G2 ——), one in the Upper Sheepscot River estuary (G4 · · ·), and one in the lower Sheepscot River estuary (G6 – – –), June 1970 to December 1971.

The statistical analyses support the inference that the summertime pelagic fish fauna of the Back River estuary is distinct from that of the Sheepscot. Analyses of weights of fishes caught gave essentially the same results as those for numbers. For all species analyzed, with the exception of rainbow smelt, catches at the two stations, G1 and G2, in the Back River estuary were never significantly different from each other (Table 2). During the summer, significantly more alewives, blueback herring, and Atlantic menhaden were captured in Back River than at G4 in the Sheepscot River estuary. Significantly more spiny dogfish and Atlantic mackerel were collected at G4 in the Sheepscot than at the Back River estuary stations. Differences in the catch of Atlantic herring were not statistically significant, yet 75% of all Atlantic herring collected were from G4 in the Sheepscot River estuary.

Differences between species composition of fishes caught in the Back River and Sheepscot River estuaries became less distinct through the fall and during the spring. During this time Atlantic herring appeared more frequently at the Back River stations, and Atlantic menhaden were caught in the Sheepscot River estuary in the late spring.

For the species analyzed, differences in catches between 1970 and 1971, with the exception of American shad, were nonsignificant. Significantly more American shad were caught during 1971 than 1970.

The stations in the Sheepscot River estuary were more saline than those in the Back River estuary (Fig. 3). During the summer G8 in the lower Sheepscot and G6 in Cross River were the coldest, followed by G4 and G5 near Wiscasset, followed by stations in the Back River–Montsweag Bay area (Fig. 3). In the winter the temperature regime reversed, i.e., the Back River stations were coldest followed by G5 and G4 in turn followed by G6.

Role of Temperature and Salinity

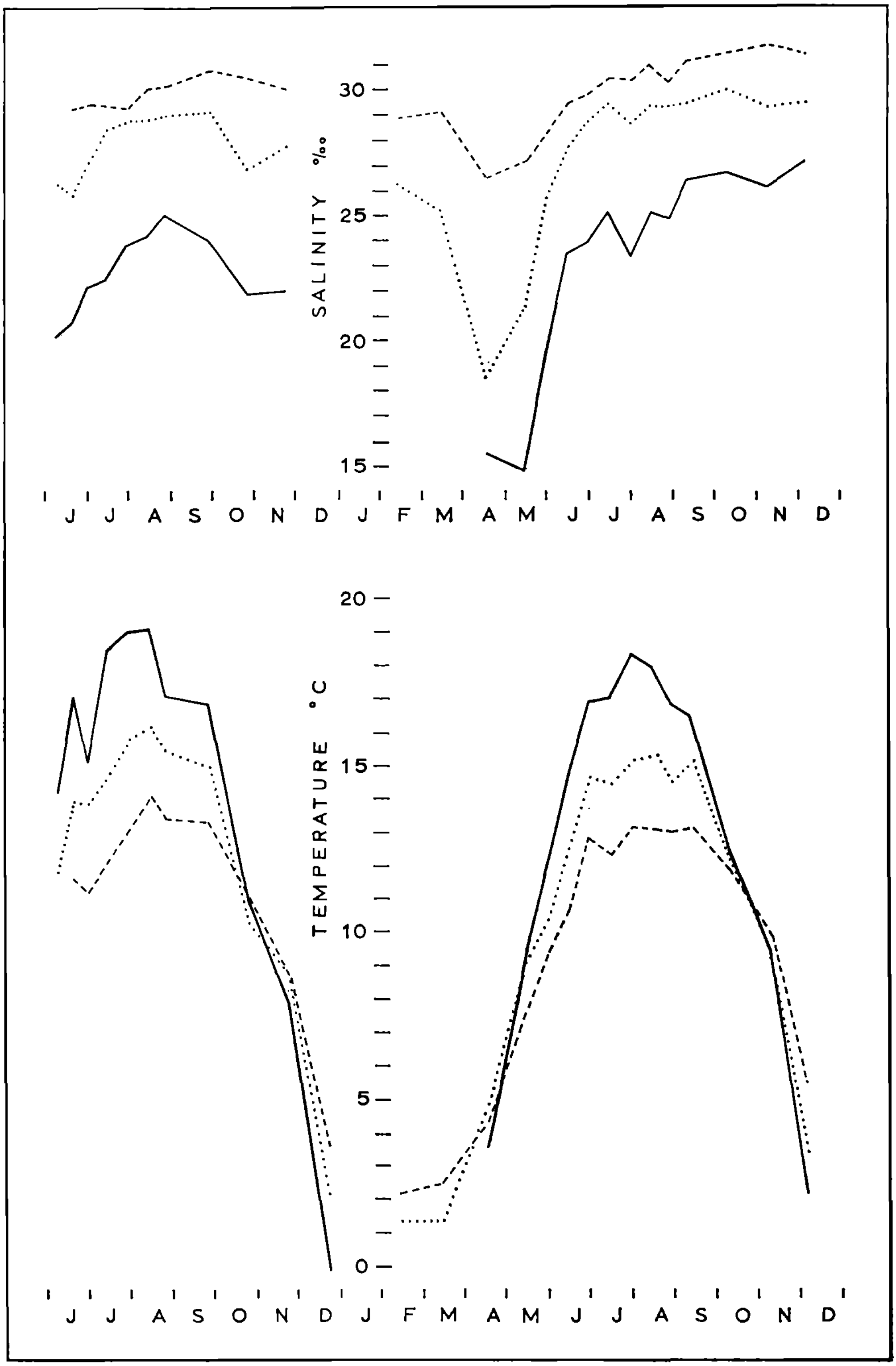
The effects of temperature on fish distribution have been emphasized (Hela and Laevastu, 1962; Kinne, 1964; de Sylva, 1969) often to the near exclusion of salinity. However, the latter may be a most important factor in distribution of estuarine organisms (Gunter, 1961), but it is often difficult to determine if the link between salinity and distribution is direct (Holliday, 1971). Some inferences can be drawn from our study on the roles of temperature and salinity on the abundance in time and space of several pelagic fishes in the estuary. The effects on fish distribution of artificially high temperatures, which would result from unrestricted power plant operation, can also be hypothesized for some of the dominant pelagic species.

TABLE 2.—*Significant differences in mean numbers of pelagic fish collected by gillnetting at stations G1, G2, and G4 in the Sheepscot River–Back River estuary, Wiscasset, Maine as determined by Duncan's new multiple-range test ($P < .05$). Data for 1970 and 1971 and for monthly sampling periods June through December, and fortnightly sampling periods June through August combined. Means not underscored by the same line are significantly different*

Species	Monthly			Fortnightly		
Spiny dogfish	G4	G1	G2	G4	G1	G2
Blueback herring	G2	G1	G4	G2	G1	G4
Alewife	G2	G1	G4	G2	G1	G4
American shad	G1	G2	G4	G1	G4	G2
Atlantic menhaden	Duncan's test not performed			G1	G2	G4
Atlantic herring	G4	G1	G2	G4	G2	G1
Rainbow smelt	G2	G4	G1	G4	G2	G1
Atlantic mackerel	G4	G1	G2	G4	G1	G2

About 99% of the spiny dogfish were collected at water temperatures between 8 C and 16 C. On a catch-per-net-set basis preferences for temperatures between 10 C and 14 C (Fig. 4) and salinities above 28‰ (Fig. 5) are evident. Jensen (1966) concluded from survey data that "dogfish in the Northwest Atlantic prefer bottom water between 7.2 C and 12.8 C." Leim and Scott (1966) stated that spiny dogfish do not appear until the temperature reaches 5.6 C and leave if it exceeds 15.6 C. Their virtual exclusion from surface waters of the Back River estuary suggests that these waters constitute a hostile environment throughout the year: too cold in winter, too warm in summer, and not saline enough in spring. In the lower Sheepscot River estuary where salinities are high throughout the year, dogfish are found only when temperatures exceed about 8 C.

Atlantic herring show a distinct preference for temperatures between 10 C and 16 C (Fig. 4). Since they were captured over a wide range of salinities (Fig. 5), temperature is apparently a more important factor influenc-


SALINITY ‰
30
25
20
15
J J A S O N D J F M A M J J A S O N D
TEMPERATURE °C
20
15
10
5
0
J J A S O N D J F M A M J J A S O N D

ing distribution. The scarcity of Atlantic herring in the Back River estuary during the summer implies that their distribution is practically limited to temperatures under 16 C. Exposure for 14 hr to temperatures above 23 C were lethal to yearling Atlantic herring acclimated to 15 C (Blaxter, 1960). Exposure for 48 hr to 21.2 C caused 50% mortality in Atlantic herring held at 8 C–11 C (Brawn, 1960). Stickney (1969), in a laboratory study of orientation of juvenile Atlantic herring to temperature and salinity, established a temperature preference of 12 C in fish acclimated to 15 C. Bērziņš (1949) found that most small Atlantic herring, in the Gulf of Riga, were caught between 8 C and 12 C. In this study Atlantic herring were relatively scarce at all stations during August, and those caught were most frequently in the cooler Sheepscot River estuary. Under natural conditions the Back River estuary during the warmer months is a marginal habitat for Atlantic herring. Any pronounced warming of the Back River estuary will likely exclude Atlantic herring from the area.

An optimum temperature range of 12 C to 14 C has been reported for Atlantic mackerel (Dannevig, 1955), and the highest temperature at which they commonly occur is 20 C (Bigelow and Schroeder, 1953). Although Atlantic mackerel were commonly caught at temperatures of 18 C to 20 C in this study, most were caught in the Sheepscot River estuary, not in Back River. This tendency would probably be strengthened during the warmer months should temperatures rise over 20 C. Sette (1950) concluded that water colder than 7 C or 8 C forms a temperature barrier to northward springtime advance of the Atlantic mackerel contingent which summers in the Gulf of Maine. Our observations substantiate this conclusion as we caught no mackerel at temperatures below 9 C.

Blueback herring, alewives, and American shad all showed a peak in catch-per-net-set at the highest temperatures sampled (18 C to 20 C) and they were not caught at low temperatures (Fig. 4). All three species were caught over a wide range of salinities (Fig. 5), but peak catches were in the 22‰ to 26‰ range. All three were more abundant in the Back River estuary than in the Sheepscot during the summer months, which suggests a preference for warmer water. Graham (1956) reported a tolerance limit (the water temperature extreme permitting 50% survival after 40 hours) of 23 C in yearling alewives acclimated to 9 C. Trembley (1960) found an upper tolerance limit range of 26.7 C to 32.2 C. Marcy, Jacobson, and Nankee (1972) recently reported field studies which suggest that the upper natural temperature limit of young shad, and probably blueback herring as well, may be about 30 C. Alewives, blueback herring, and shad were caught in about the same relative percentages over the same temperature intervals, and since over 90% were caught above 14 C and in the warmer (summer) Back River estuary, it is apparent that they should tolerate more artificial warming of the habitat than species more typical of the Sheepscot River estuary. Since no gill nets were set in water above 20 C, a definite preference range cannot be stipulated, yet 16 C to 20+ C seems reasonable.

Most Atlantic menhaden were caught in the Back River estuary during the summer suggesting a preference for warmer water (Fig. 4). Their distribution seems less influenced by salinity (Fig. 5). Reintjes (1960) stated that the movement of Atlantic menhaden north in spring and south in autumn along the Atlantic coast coincided with the seasonal shift of the 10 C isotherm. Only about 7% of the Atlantic menhaden in this study were caught below 10 C. Although they were caught over a wide range of temperatures (Fig. 4), there were peaks in abundance in August and September in the Back River estuary (Fig. 2). During July through September temperatures in Back River were consistently within the 15 C to 20 C preferred temperature range re-

←

FIGURE 3.—Average salinity and temperature during gillnetting at stations G1, G2, G3 (——), G4, G5 (· · ·), and G6 (– – –) in the Sheepscot River–Back River estuary, Wiscasset, Maine, June 1970 through December 1971. Stations significantly different (Duncan's new multiple-range test, $P < .05$) drawn with different symbol.

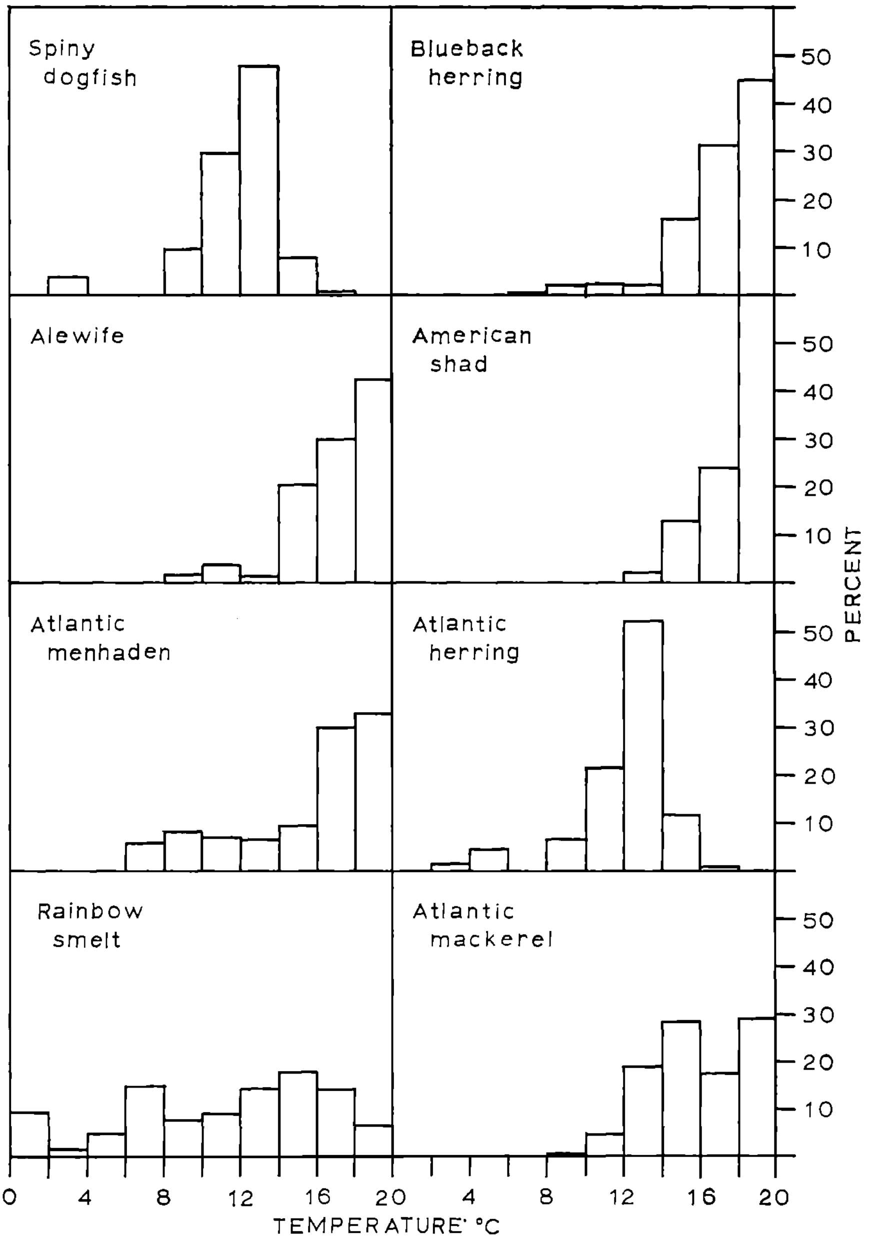


FIGURE 4.—Percentages of average catches (per gill net set) per 2 C temperature interval for the major pelagic fish species of the Sheepscot River–Back River estuary, June 1970 to December 1971. All stations and dates combined.

ported for menhaden by Goode (1879). A preference for 15 C to 20+ C water seems confirmed by this study, but since nets were not set at temperatures above 20 C, effects of artificially warmed water on the distribution of Atlantic menhaden are difficult to predict. It seems unlikely that moderate increases would alter their distribution in the estuary.

Rainbow smelt were collected in relatively small numbers over the widest temperature

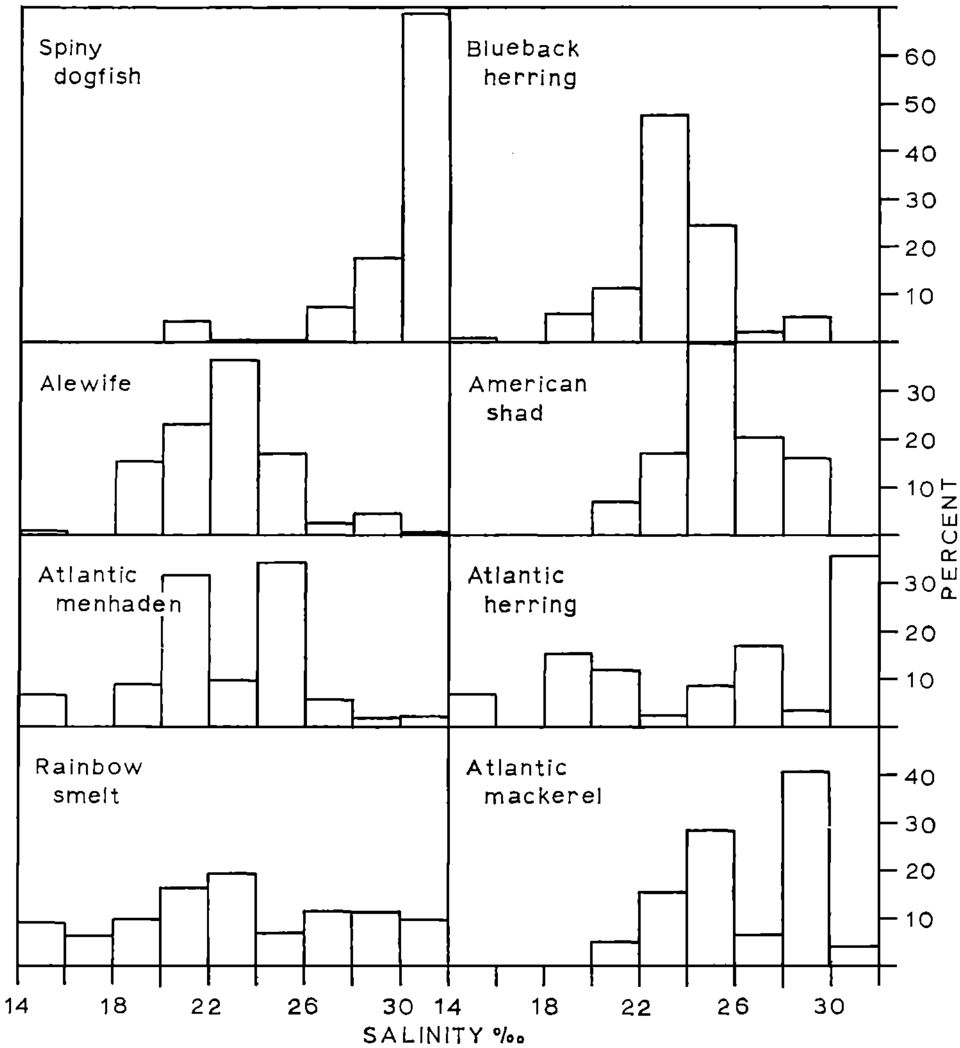


FIGURE 5.—Percentages of average catches (per gill net set) per 2‰ salinity interval for the major pelagic fish species of the Sheepscot River–Back River estuary, June 1970 to December 1971. All stations and dates combined.

range (0 C to 20 C, Fig. 4) and the widest salinity range (14‰ to 31‰, Fig. 5) in both the Sheepscot River and Back River estuaries. Since a tolerance limit of 21.5 C to 28.5 C depending on acclimation temperature has been reported by Huntsman and Sparks (1924), it seems unlikely that a moderate temperature increase will adversely affect smelt distribution in Back River.

For the other pelagic species, the outcome of any artificial warming cannot be predicted due to their scarcity in the gill net catches.

Comparison With Other Studies

Although direct comparisons of the results of this study with those of others are difficult due to dissimilarities of gear, some generalizations can be made. Tyler (1971) concluded from his trawling study of the fish community in a deep portion of Passamaquoddy Bay, New Brunswick, that "in temperate regions, inshore, deepwater fish communities are made up of regular, summer, and winter periodic components. There are also numerous occasional species. Spring and fall seasons are transitional with regard to fish fauna. Formation of temporal components is largely related to temperature regime, . . . At latitudes where there is relatively greater annual temperature fluctuation, there are proportionately more species in the temporal components and fewer in the regular component." The results of this study support Tyler's conclusions that formation of temporal components is largely related to temperature regime, and that with greater annual temperature fluctuation, more species are in the temporal component than in the regular component. The pelagic fish fauna in the Sheepscot River–Back River estuary, where annual temperature variation is greater than in nearby Passamaquoddy Bay, is wholly temporal with the exception of rainbow smelt (Fig. 2). In addition, there is no species, with the possible exception of Atlantic herring, which can be termed a "winter periodic." It would be more properly termed a "spring/fall periodic" in this estuary.

Norden (1966) and Fox and Mock (1968), in their studies of seasonal occurrence of fishes in two Louisiana bays, encountered annual temperature ranges of 29 C (6 C to 35 C) and 25 C (10 C to 35 C), respectively. These ranges are not much greater than the range in the Back River estuary (Fig. 3). Fox and Mock (1968) in Barataria Bay, found the number of fish and fish species to be lowest during winter and highest during summer. Norden's (1966) data from Vermilion Bay exhibited the same trend. He stated that "water temperature, rather than salinity, appears to exert a greater influence on the seasonal movements of fishes in and out of Vermilion Bay." Temporal components dominated the Louisiana pelagic fish faunas which were generally more diverse than those of the present study.

Richards and Castagna (1970), in a beach seine and trawl survey in inlet, mid-channel, inshore beach, and tidal creek habitats of Virginia's eastern shore, recorded temperatures from 4.0 C to 31.5 C. The temporal component dominated the pelagic fauna. Several pelagic species encountered could be properly termed winter periodics. Catches were heaviest during the summer months. They classified only one pelagic fish, the bay anchovy (*Anchoa mitchilli*) as a resident. Yet if a sampling scheme similar to the one in the present study had been used, more species may have qualified.

Evidently, prolonged near-freezing temperatures rather than yearly temperature range most severely limit the occupation of temperate estuaries by pelagic fish. Virtually all the pelagic fish leave the Sheepscot River–Back River estuary December through March. The number of species which are able to occupy the estuary is likewise affected.

ACKNOWLEDGMENTS

We thank Mrs. Shirley Recksiek who assisted in the field and helped complete the manuscript; and Dr. Hugh H. DeWitt and Messrs. Mason D. Bryant, Paul C. Jensen, William J. Hauser, Timothy E. Targett, and Stephen M. Fried for helpful suggestions and aid in the field. Research funds were provided by the Maine Yankee Atomic Power Company.

LITERATURE CITED

BĖRZIŅŠ, B. 1949. Über temperaturebedingte Tierwanderungen in der Ostsee. Oikos 1: 29–33. *Cited in* I. Hela and T. Laevastu, Fisheries hydrography. Fishing News (Books) Ltd., London. p. 27.

BIGELOW, H. B., AND W. C. SCHROEDER. 1953. Fishes of the Gulf of Maine. U.S. Fish Wildl. Serv., Fish. Bull. 53: 1–577.

BLAXTER, J. H. S. 1960. The effect of extremes of temperature on herring larvae. J. Mar. Biol. Ass. U.K. 39: 605–608. *Cited in* P. L. Altman and D. S. Dittmer (eds.), Environmental biology. Fed. Amer. Soc. Exp. Biol., Bethesda, Maryland. p. 73.

BRAWN, V. M. 1960. Temperature tolerance of unacclimated herring (*Clupea harengus* L.). J. Fish. Res. Bd. Canada 17: 721–723.

BRETT, J. R. 1970. Temperature. Animals. Fishes. Functional responses. 516–560 p. *In* O. Kinne (ed.), Marine ecology. Vol. 1, Part 1. John Wiley & Sons Ltd., London.

DAHLBERG, M. D., AND E. P. ODUM. 1970. Annual cycles of species occurrence, abundance, and diversity in Georgia estuarine fish populations. Amer. Midl. Natur. 83: 382–392.

DANNEVIG, A. 1955. Mackerel and sea temperature. Measurements—21 April to 15 May, 1952. Praktiske Fiskeforsøk, 1952. Arsber. Norges Fisk. 5: 64–67. *Cited in* I. Hela and T. Laevastu, Fisheries hydrography. Fishing News (Books) Ltd., London. p. 21.

FOX, L. S., AND W. R. MOCK, JR. 1968. Seasonal occurrence of fishes in two shore habitats in Barataria Bay, Louisiana. Proc. Louisiana Acad. Sci. 31: 43–53.

GOODE, G. B. 1879. The natural and economical history of the American menhaden. U.S. Comm. Fish and Fish., Pt. 5, Rep. Comm. 1877 (Appendage A): 1–529. *Cited in* J. W. Reintjes. 1969. Synopsis of biological data on the Atlantic menhaden, *Brevoortia tyrannus*. U.S. Fish Wildl. Serv., Food Agr. Organ. Fish. Synop. No. 42, Circ. 320. p. 5.

GRAHAM, J. J. 1956. Observations on the alewife, *Pomolobus pseudoharengus* (Wilson), in fresh water. Pub. Ontario Fish. Res. Lab., LXXIV, Univ. Toronto Biol. Ser. No. 62, 43 p. *Cited in* P. L. Altman and D. S. Dittmer (eds.), Environmental biology. Fed. Amer. Soc. Exp. Biol., Bethesda, Maryland. p. 78.

GUNTER, G. 1961. Some relations of estuarine organisms to salinity. Limnol. Oceanogr. 6: 182–190.

HELA, I., AND T. LAEVASTU. 1962. Fisheries hydrography. Fishing News (Books) Ltd., London. 119 p.

HOLLIDAY, F .G. T. 1971. Salinity. Animals. Fishes, p. 997–1083. *In* O. Kinne (ed.), Marine ecology. Vol. I. Part 2.

HUNTSMAN, A. G., AND M. I. SPARKS. 1924. Limiting factors for marine animals. 3. Relative resistance to high temperatures. Contr. Can. Biol. Fish., Nova Scotia, 2: 97–114. *Cited in* P. L. Altman and D. S. Dittmer (eds.), Environmental biology. Fed. Amer. Soc. Exp. Biol., Bethesda, Maryland. p. 77.

INTERNATIONAL COMMISSION FOR THE NORTHWEST ATLANTIC FISHERIES. 1965. ICNAF environmental symposium. Spec. Pub. No. 6. Headquart. Comm., Dartmouth, Nova Scotia, Canada. 914 p.

JENSEN, A. C. 1966. Life history of the spiny dogfish. U.S. Fish Wildl. Serv., Fish. Bull. 65: 527–579.

JEROME, W. C., JR., A. P. CHESMORE, AND C. O. ANDERSON, JR. 1969. A study of the marine resources of the Annisquam River–Gloucester Harbor coastal system. Monogr. Ser. No. 3. Massachusetts Div. Mar. Fish. 62 p.

KINNE, O. 1964. The effects of temperature and salinity on marine and brackish water animals. II. Salinity and temperature salinity combinations. Oceanogr. Mar. Biol. Ann. Rev. 2: 281–339.

LEIM, A. H., AND W. B. SCOTT. 1966. Fishes of the Atlantic Coast of Canada. Fish. Res. Bd. Canada, Bull. 155: 1–485.

LUX, F. E., AND F. E. NICHY. 1971. Number and lengths, by season, of fishes caught with an otter trawl near Woods Hole, Massachusetts, September 1961 to December 1962. U.S. Dep. Comm. Spec. Sci. Rep., Fish. 622: 1–15.

MARCY, B. C., JR., P. M. JACOBSON, AND R. L. NANKEE. 1972. Observations on the reactions of young American shad to a heated effluent. Trans. Amer. Fish. Soc. 101: 740–743.

MASSMANN, W. H. 1962. Water temperatures, salinities, and fishes collected during trawl surveys of Chesapeake Bay and York and Pamunkey Rivers 1956–1959. Virginia Inst. Mar. Sci. Spec. Sci. Rep. 27: 1–3.

NORDEN, C. R. 1966. The seasonal distribution of fishes in Vermilion Bay, Louisiana. Wisconsin Acad. Sci. Arts Letters 55: 119–137.

PEARCY, W. G., AND S. W. RICHARDS. 1962. Distribution and ecology of fishes of the Mystic River estuary, Connecticut. Ecology 43: 248–259.

PEARSE, A. S., AND G. GUNTER. 1957. Salinity, p. 129–157. *In* J. W. Hedgepeth (ed.), Treatise on marine ecology and paleoecology, Vol. 1. Ecology. Mem. Geol. Soc. America 67.

REINTJES, J. W. 1969. Synopsis of biological data on the Atlantic menhaden, *Brevoortia tyrannus*. U.S. Fish Wildl. Ser., Food Agr. Organ. Fish. Synop. No. 42, Circ. 320. 30 p.

RICHARDS, C. E., AND M. CASTAGNA. 1970. Marine fishes of Virginia's eastern shore (inlet and marsh, seaside waters). Chesapeake Sci. 11: 235–248.

SETTE, O. E. 1950. Biology of the Atlantic mackerel (*Scomber scombrus*) of North America. II. Migrations and habits. U.S. Fish Wildl. Serv., Fish. Bull. 51: 251–358.

SCHAEFER, R. H. 1967. Species composition, size and seasonal abundance of fish in the surf waters of Long Island. New York Fish Game J. 14: 1–46.

STICKNEY, A. P. 1959. Ecology of the Sheepscot River estuary. U.S. Fish Wildl. Serv. Spec. Sci. Rep., Fish. 309: 1–21.

———. 1969. Orientation of juvenile Atlantic herring (*Clupea harengus harengus* L.) to temperature and salinity. *In* Food Agr. Organ. Fish. Rep. 2: 323–342.

SYLVA, D. P. DE, F. A. KALBER, JR., AND C. N. SHUSTER, JR. 1962. Fishes and ecological conditions in the shore zone of the Delaware River estuary, with notes on other species collected in deeper water. Inf. Ser. Univ. Delaware, Publ. 5: 164 p.

TAGATZ, M. E., AND D. L. DUDLEY. 1961. Seasonal occurrence of marine fishes in four shore habitats near Beaufort, North Carolina, 1957–1960. U.S. Fish Wildl. Serv. Spec. Sci. Rep., Fish. 390: 1–19.

TREMBLEY, F. J. 1960. Research project on effects of condenser discharge water on aquatic life. Inst. Res., Lehigh Univ., Prog. Rep., 1956–1959. *Cited in* P. A. Krenkel and F. L. Parker (eds.), Biological aspects of thermal pollution. Vanderbilt Univ. Press, Nashville, Tennessee. p. 238.

TYLER, A. V. 1971. Periodic and resident components in communities of Atlantic fishes. J. Fish. Res. Bd. Canada 28: 935–946.