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LIMNOLOGY OF THE ANNAPOLIS RIVER AND ESTUARY II. FISH DISTRIBUTIONS IN THE ESTUARY, 1976 AND 1977

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Beach seine and otter trawl collections at numerous sites in the Annapolis Estuary during 1976 and 1977 produced 22 fish species. Five species were recorded only from the headpond and 3 from entirely freshwater sites, whereas the remaining species exhibited wide distributions encompassing all or most of the estuary. The wide distributions are apparently related to the highly stratified nature of the estuary which allows fish with preference for oligohaline conditions to occupy surface waters in the same stretch of the river inhabited by species preferring higher salinities. Seasonal variations in abundance and distribution are presented for the more abundant species: the alewife *(Alosa pseudoharengus)*, white perch *(Morone americana)*, Atlantic silverside *(Menidia menidia)*, 4-spine stickleback *(Apeltes quadracus)*, killifish *(Fundulus diaphanus)*, and mummichog *(F. heteroclitus)*.

Introduction

Despite the major role that estuarine and diadromous fishes play in the local economics of Nova Scotia, little information is available regarding the occurrence, distribution, and productivity of the species involved. In many parts of the world estuaries are rightly recognised as among the most productive of natural systems. Nourished by growth-facilitating nutrients derived from the watershed, and often considerably warmed by solar heating of intertidal mudflats, a clean estuary may represent a favorable combination of environmental conditions for those species able to tolerate or avoid variations in local salinity. On the other hand, excessive tidal amplitude, as in the Bay of Fundy, may completely nullify such advantages because of extreme turbidity and consequent restriction of phytoplankton growth, and transient patterns of sedimentation.

The Annapolis River Tidal Dam was constructed in 1960, reducing tidal range in the headpond to 1 m (Jessop 1976) compared with the range of 7 to 9 m in the Annapolis Basin itself. Fish passage is permitted through a permanently open 3 x 7 m fishway. The impoundment has resulted in extreme and relatively stable stratification in the estuary, but has also reduced markedly the high turbidity characteristic of the basin proper (Daborn et al. 1979). This combination of events has important implications for the resident migratory fishes of the area, particularly in view of the potential modification if the dam is converted for energy production by tidal power. The present study was initiated to provide a preliminary account of species composition and distribution within this presently stratified estuary.

Methods

Sampling was done primarily with a 15 m bag seine with mesh sizes of 0.6 cm in the bag and 1.3 cm on the wings. These mesh sizes select for juvenile and smaller species of fish. The seine was 2 m deep, but when drawn toward the shore was inclined to billow out under pressure and thus usually sampled only to a depth of 1.0 to 1.5 m.

During July and August 1976 a total of 62 seine collections was made at 43 sites between Annapolis Causeway (km 0) and Button Brook (km 29). These sites represented all locations in the estuary where presence of shelving beach or shallow

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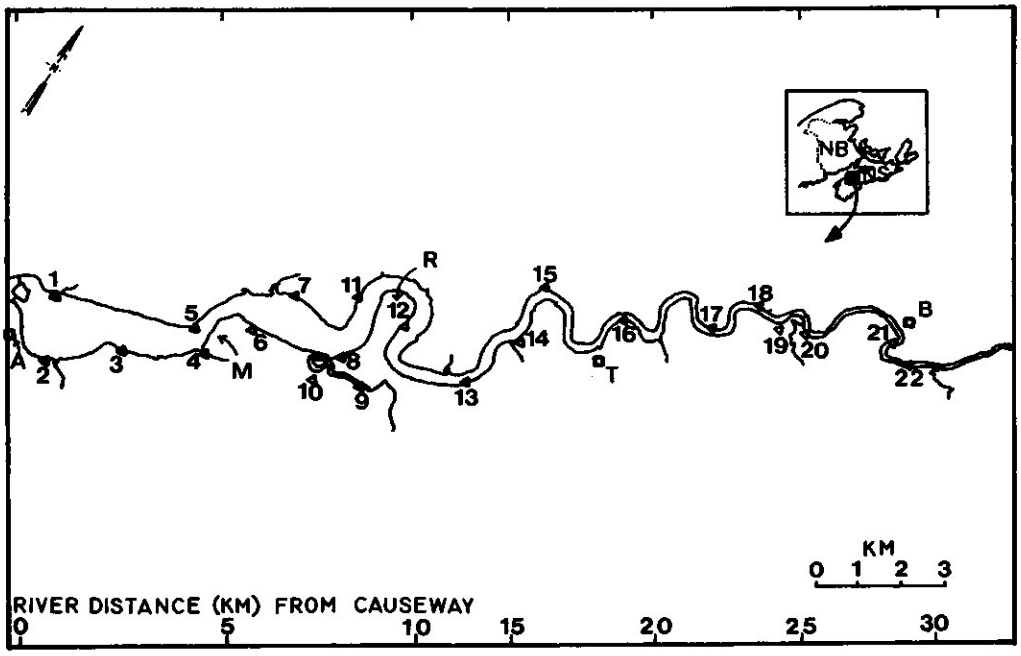

Fig 1 - The Annapolis Estuary. Inset: Maritime Provinces showing sample area. 1-22: sample station locations in 1977; A - Annapolis Royal; B - Bridgetown; M - Mochelle; R - Pré Rond; T - Tupperville.

ledges allowed the seine to be drawn to the shore close to the substrate, and thus with minimal loss of the catch. Elsewhere, slumping of river banks because of flood erosion has left almost perpendicular 2 to 5 m high banks and highly irregular substrate.

Sampling in 1977 was restricted to 22 sites (Fig 1) at intervals of 1 to 3 km from the causeway to Button Brook. From 26 May to 5 July, 11 of these sites (1, 4, 8, 9, 10, 12, 13, 15, 18, 20, 21) were sampled at intervals of 10 to 12 days. As young-of-the-year fish began to appear in samples during July, a further 10 sites were added to examine distributions more closely, and these sites were sampled at about the same intervals until 17 September. Eleven sites only were visited on 16 October. A total of 154 seine hauls was made. Captured fish were identified, counted, and released except for specimens of white perch and any fish for which identification was uncertain. These were fixed in 10% formalin and returned to the laboratory.

A site at Button Brook (No. 22, km 29) was occupied during the run of striped bass *(Morone saxatilis)* in May and June 1977. At this location a 75 m barrier net was stretched at an angle across the river and periodically used to sweep across the river in an attempt to capture striped bass. Fish collected were too numerous to count and details are not included with the seine collections described below. Information from this site regarding species occurrences, however, has been included.

Salinity and temperature were recorded with a S-C-T meter at 1 m intervals from the surface, at each sample site. Readings were made at a point about 35 m from shore, which corresponded to the maximum distance from shore sampled by the seine.

In this report, the position of each sample site (Fig 1) is identified in the text in terms of river distance (km) above the Annapolis Causeway.

Results

Species Composition

Most individuals recorded (Table I) were juveniles,except for the brook trout *(Salvelinus fontinalis),* killifish *(Fundulus diaphanus),* mummichog *(F. heteroclitus),* Atlantic silverside *(Menidia menidia),* and smelt *(Osmerus mordax).* Some juveniles could not be identified to species with complete confidence. Both the alewife *(Alosa pseudoharengus)* and shad *(A. sapidissima)* spawn in the Annapolis River, and although most of the *Alosa* spp juveniles recorded were undoubtedly alewives, some shad were probably present. Similarly, in 1976 the killifish and mummichog were not separated, although collections undoubtedly included both species.

Other species known to be present in the estuary, but not always identified with certainty in our collections, are the windowpane *(Scophthalmus aquosus)* and 3-spine stickleback *(Gasterosteus aculeatus).* Four little skate *(Raja erinacea)* were collected by otter trawl in 1976 (Williams 1977).

Species Distributions

The Annapolis is a highly stratified estuary, a consequence of construction of the Annapolis Causeway and the resultant restriction of tidal influences (Jessop 1976; Daborn et al. 1979). The highly stable stratification extends a considerable distance upstream. The exact location of the salt wedge tip varies according to river flow

Table I. Species collected by bag seine in the Annapolis estuary, 1976 and 1977.

Name	No. Collected 1976	No. Collected 1977	Range in 1977 Stations[1]	Range in 1977 km[2]
Alosa spp (alewife and shad)	7,147	9,134	1-21	0-28
Menidia menidia (Atlantic silverside)	1,496	11,783	1-17	0-22
Osmerus mordax (rainbow smelt)	3	200	1-16	0-18
Anguilla rostrata (eel)	121	421	1-21	0-28
Morone americana (white perch)	118	411	3-22	2-29
Morone saxatilis (striped bass)	1	2	1-22	0-29
Fundulus diaphanus (banded killifish)	(217)[3]	297	1-21	0-28
Fundulus heteroclitus (mummichog)		64	1-19	0-24
Catostomus commersonii (white sucker)	59	41	15 21	16-28
Semotilus atromaculatus (creek chub)	10	6	17-21	22-28
Apeltes quadracus (4-spine stickleback)[4]	835	952	1-21	0-28
Pungitius pungitius (9-spine stickleback)		33	1-21	0-28
Pseudopleuronectes americanus (winter flounder)[5]	31	60	1-21	0-28
Pollachius virens (pollock)	10			
Tautogolabrus adspersus (cunner)		9	1	0
Microgadus tomcod (tomcod)		3	1-5	0-5
Syngnathus fuscus (pipefish)	3	4	1-5	0-5
Salvelinus fontinalis (brook trout)		1	20	25
TOTALS	10,051	23,427		

1 Sample station numbers at which species collected in 1977
2 Range of river in km above causeway
3 Distinction between species of *Fundulus* not made in 1976
4 Records might include juveniles of 3-spine stickleback, *Gasterosteus aculeatus*
5 Records might include juveniles of the windowpane, *Scophthalmus aquosus.*

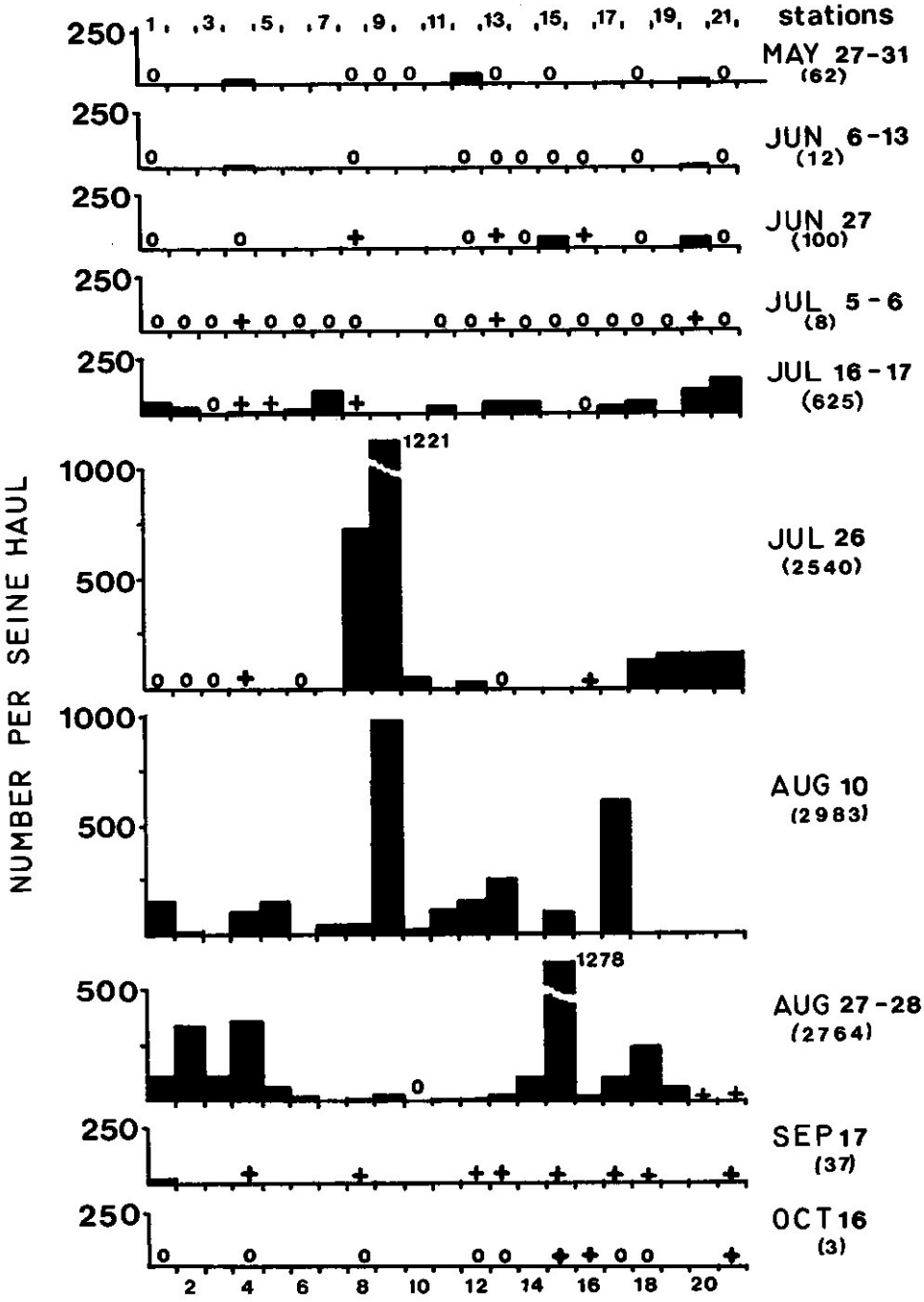

Fig 2 - Seine collections of alewife and shad (*Alosa* spp) in 1977.
o: sample taken but species not captured;
+: species present in low numbers;
( ): total numbers collected;
1-21: sample station numbers.

conditions and tidal phase, oscillating between Messenger Brook (km 22) and Bridgetown (km 28). Wind-induced turbulence is much diminished above Mochelle (km 5) where the river narrows abruptly and above which it meanders extensively. Thus the interface between fresh and salt water becomes progressively more acute upstream. Details of the physical structure of the river during 1976 are provided elsewhere (Daborn et al. 1979).

Of the 22 species recorded in the estuary in the 2 years, a few were only collected in the headpond region (sites 1-5). These include the tomcod, cunner, pollock, pipefish, and little skate (Table I). Winter flounder juveniles were captured up to Pré Rond East, about 10 km above the causeway. A 2 m deep bag seine is clearly a highly unsatisfactory sampling device for large, deep waters as in the headpond, and thus no comments can be made regarding the prevalence or distribution of these species. Three other species were collected only at the more upstream stations, where the salt wedge failed to penetrate or was represented by only a shallow layer on the bottom. These species were the creek chub, white sucker, and brook trout. All other species were recorded, or known to occur, throughout the sample areas, and thus exhibited completely over-lapping distributions.

Five species exhibited extensive migratory movement upstream during the sampling season. The catadromous eel was present throughout the estuary from May until September, but particularly large numbers of elvers were collected in early and mid-July (244 of 421 captured), suggesting an upstream movement of young entering the river from the sea. A decline in captures during September and October indicates that this species moves completely into freshwater in the autumn.

At the end of May and in early June, large numbers of alewives, white perch, a few shad, and striped bass were captured in the barrier net set up at Button Brook (km 29). Adult alewives and white perch were also caught in the bag seine at this time. All 4 species spawn in freshwater regions of the Annapolis River (>km 29), the striped bass just above the farthest extension of the salt wedge (Williams 1977) while the shad, white perch and alewives penetrate progressively farther upstream.

Both striped bass and shad lay pelagic eggs that float downstream and hatch in or near salt water. Few juvenile striped bass have been collected during this study, despite extensive sampling for them, but some of the unidentified *Alosa* spp juveniles captured by seine at lower stations during July (Fig 2) were probably larval shad. Details of spawning times for striped bass and shad are available elsewhere (Williams 1977). The alewives and white perch, on the other hand, spawn in June, laying demersal, slightly adhesive eggs that complete development in freshwater. Young-of-the-year alewives were first encountered on 16 July, primarily at the more upstream stations (>10 km), but subsequently were collected throughout the river. During July and August they were particularly abundant in samples near Evans Brook (km 8). By the autumn, few young alewives were captured at any sites, although individuals were caught throughout the river, and we presume that the majority had moved downstream into the headpond or beyond.

Young-of-the-year white perch were first encountered in mid-July, primarily at Gesner Brook (km 16), but also in shallow waters of the headpond (Fig 3). In late summer and autumn they were caught over much of the estuary and were still present in small numbers when the last samples were taken in mid-October. Examination of scales suggests that this population does not run out to sea and thus we presume that adults and young overwinter in the headpond or Annapolis Basin.

The remaining species can be considered to be true residents of the estuary. The 4-spine stickleback, for example, was captured at points over the whole estuary, although largest numbers were encountered along the headpond shoreline (Fig 4). Adults in spawning condition were caught on 6 June, and young-of-the-year first appeared in the 5 to 6 July samples. A similar pattern of distribution in space and time of breeding was observed for the 9-spine stickleback, but total catch of this species was small.

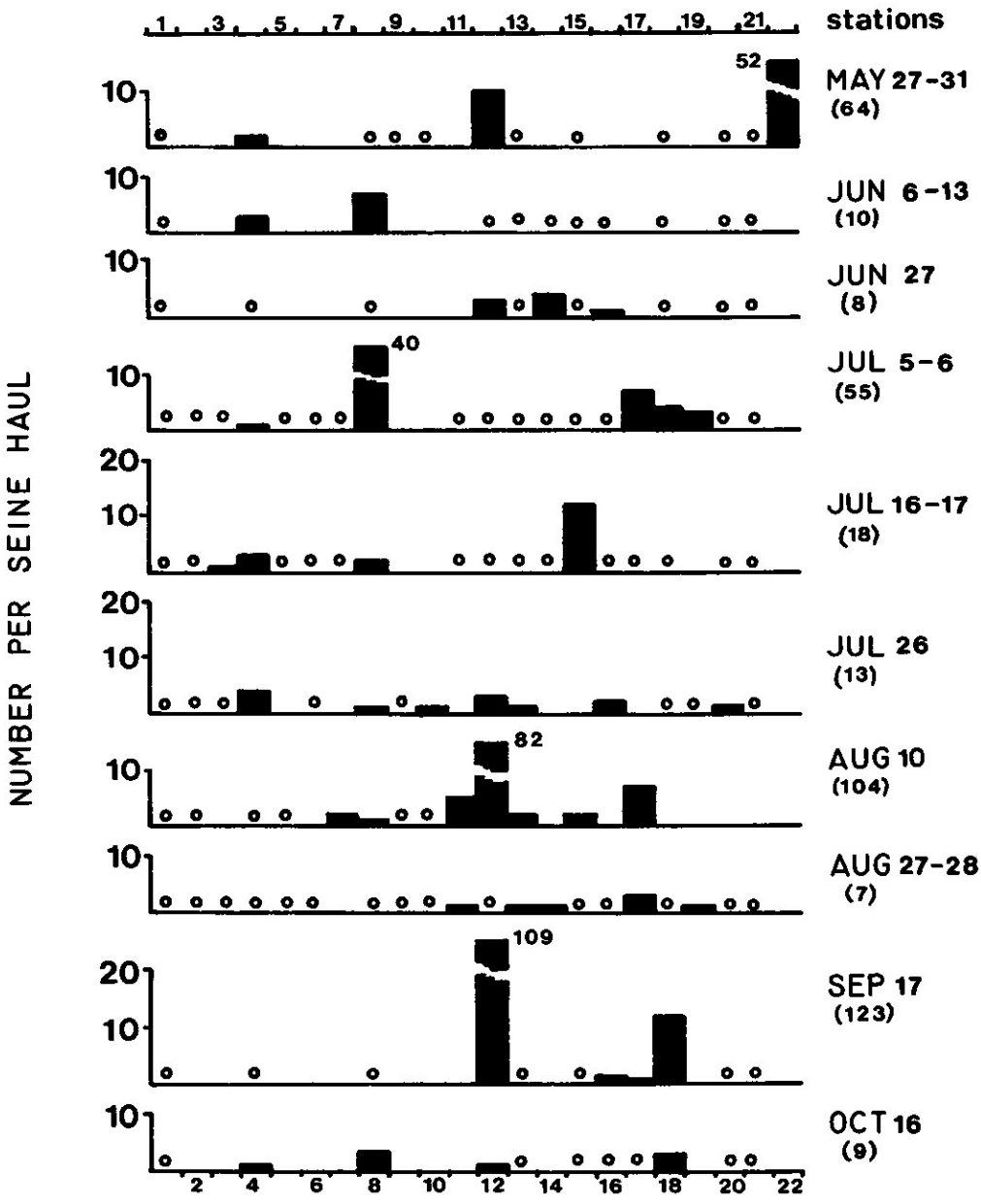

Fig 3 - Seine collections of white perch *(Morone americana)* in 1977. Symbols as Fig 2.

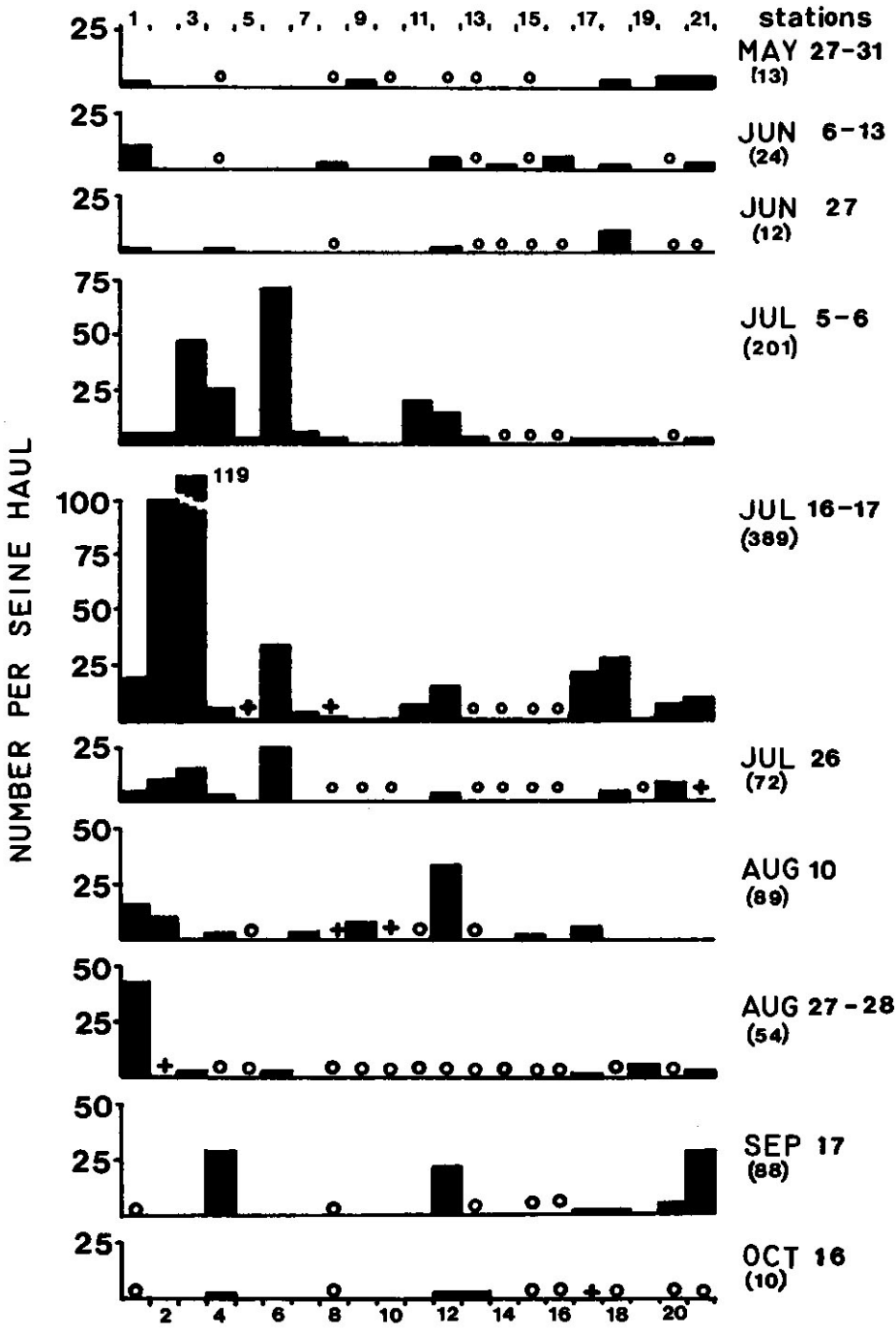

Fig 4 - Seine collections of 4-spine stickleback *(Apeltes quadracus)* in 1977. Symbols as Fig 2.

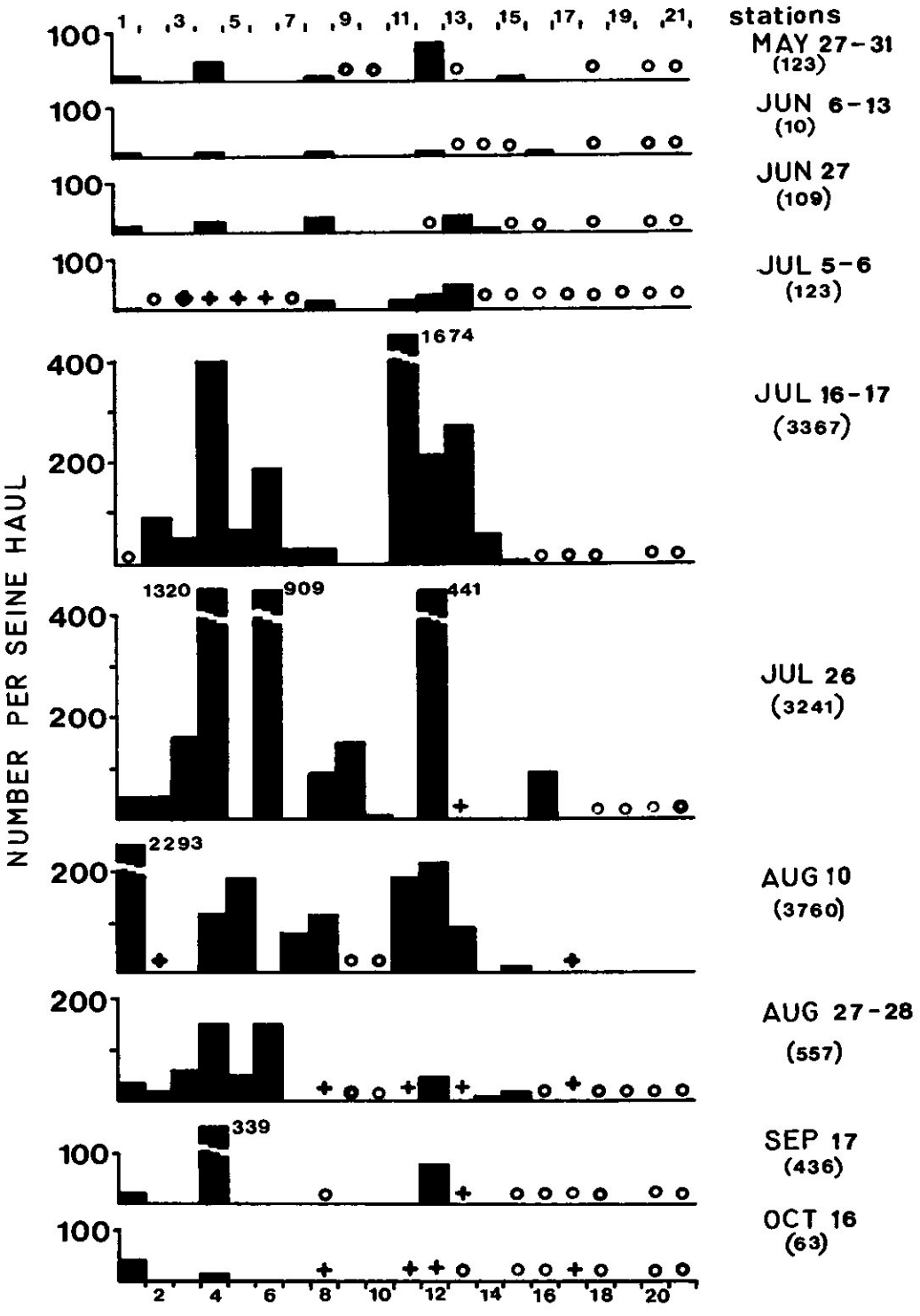

Fig 5 - Seine collections of Atlantic silversides *(Menidia menidia)* in 1977. Symbols as Fig 2.

One of the most important of resident species is undoubtedly the Atlantic silverside. As with the sticklebacks, it was encountered over much of the estuary (km 0-22), with young-of-the-year occurring in large numbers in the collections of July and August (Fig 5). In the October samples, the catch had diminished substantially, but a few silversides were caught as far upstream as Messenger Brook (km 22). Adults in spawning condition were seen on 22 June and the first young-of-the-year were caught on 5 July.

The 2 species of *Fundulus* were encountered together over most of the estuary (Fig 6), but young were particularly frequent in the middle estuary between Pré Rond (km 9) and Upper Granville (km 23). Both species breed about the end of June, and young first appeared in samples in mid-July.

Discussion

Inferences regarding the distribution of species in a large estuary, based upon collections with a 2 m deep bag seine are clearly hazardous. The Annapolis estuary is a difficult river to sample in any manner. Uneven bottom configuration resulting from river bank slumping and the presence of glacial erratic boulders precludes use of an otter trawl except in the headpond itself. There are few places in which the bottom shelves gradually, more often the banks are eroded to the perpendicular. Furthermore, much of the estuary is considerably deeper than the 1 to 1.5 m effectively sampled by our seine and thus escapement of more active fish is inevitable. Demersal fish cannot be effectively sampled except in very shallow upstream regions.

The vagaries of seining may well be the reason for great variation in numbers of a species captured at particular sites. Pré Rond (station 12) and Evans Brook (stations 8 and 9) which were particularly prolific sites, for example, may simply have been more suitable for operation of a bag seine. Alternatively, the large catches of alewives and silversides at various localities might merely reflect the chance enclosure of schools of these species. Where the greatest catches varied from one site to another on successive sampling dates, as with the alewife (Fig 2), we presume that sampling variability was primarily the result of close schooling behavior.

What remains most striking is the considerable range over which resident species, particularly, were encountered. Most truly estuarine species are euryhaline, compared with strictly freshwater or marine species, and thus might be expected to occupy a considerable stretch of the estuary. In well-mixed estuaries, however, there is usually a more-or-less distinct longitudinal succession of species reflecting the salinity gradient from the mouth of the estuary into the river (Cronin & Mansueti 1971; Perkins 1974). Indeed, salinity is one of the primary environmental factors influencing estuarine fish distributions (eg. McErlean et al. 1973; Hoff & Ibara 1977). In the Annapolis River, however, presence of the salt wedge > 20 km above the causeway allows species with high salinity preferences to occupy bottom waters over the range. Conversely, species preferring oligohaline waters can occupy surface waters over the same distance. At any given location, therefore, sampling to the full depth of the estuary should produce individuals representative of almost the whole estuarine ichthyofauna, rather than a limited subset of that fauna determined by salinity preferences as in well-mixed estuaries.

The present study is the first of its kind on the Annapolis River. It is interesting to note that sampling by both seine and otter trawl (Williams 1977) over 2 years produced a total of 22 species. Although a few might have been missed, particularly in the headpond, the Annapolis River ichthyofauna is clearly much less diverse than that of estuaries farther south. A similar study in a New England estuary, for example, recorded no less than 54 species (Hoff & Ibara 1977), whereas otter trawl sampling in Narragansett Bay collected 80 species (Jeffries & Johnson 1974).

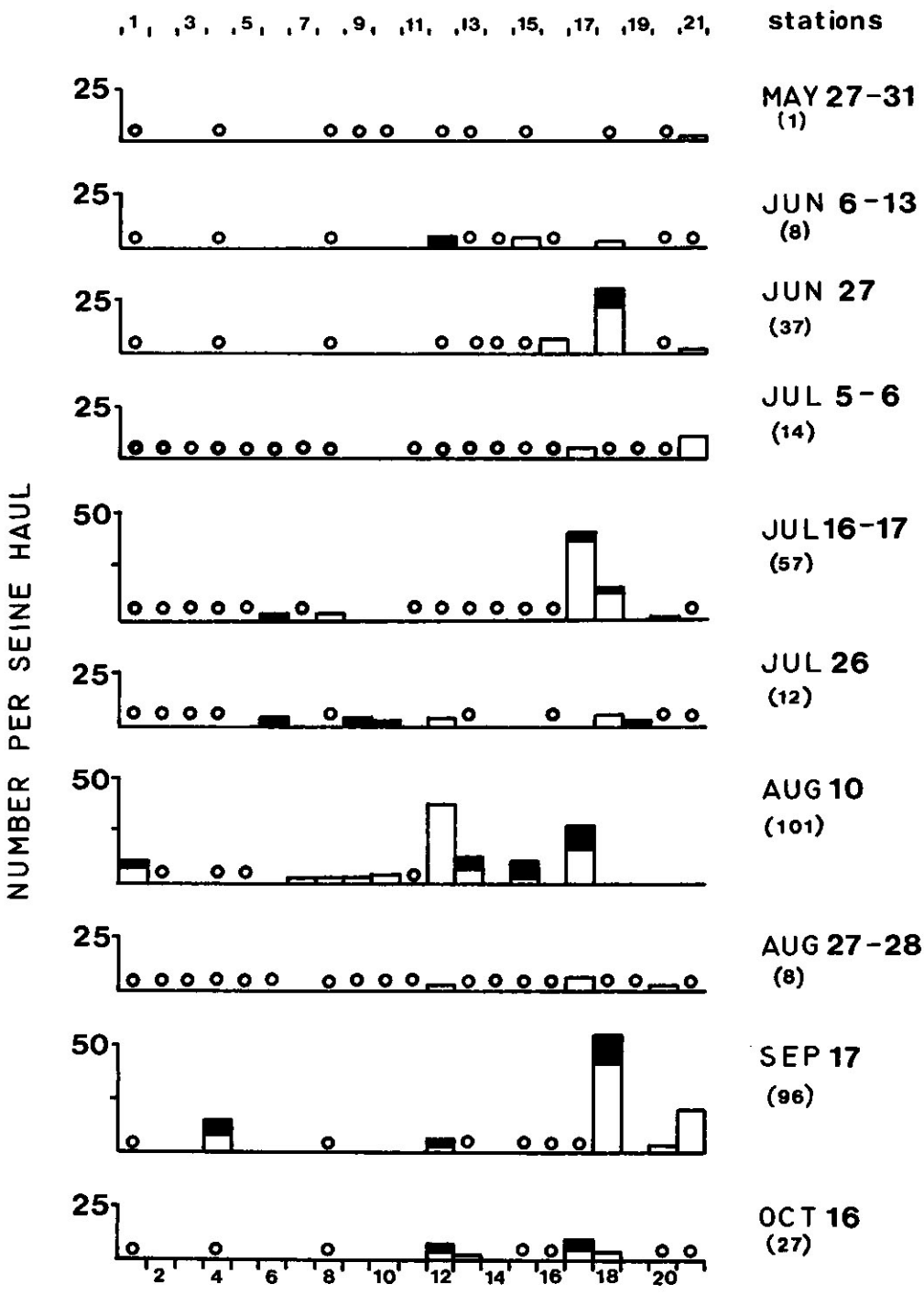

Fig 6 - Seine collections of banded killifish *(Fundulus diaphanus)* and mummichog *(F. heteroclitus)* in 1977. Open bars: killifish; closed bars: mummichog. Other symbols as Fig 2.

Impoundment of the Annapolis River to control tidal flooding of reclaimed land has resulted in formation of a large and apparently fairly productive stratified headpond. A more complete study of fish populations and productivity of the headpond is desirable and should be done before further modifications to the causeway are made.

Acknowledgments

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