1985 FIELD REPORT

Downstream Movements of Juvenile Alosids and Preliminary Studies of Juvenile Fish Mortality associated with the Annapolis Tidal Power Turbine

Kevin Stokesbury

Contribution No. 2, Acadia Centre for Estuarine Research,
Wolfville, Nova Scotia, BOP 1XO

Introduction

The following report presents results of a study of juvenile fish mortality conducted in the Annapolis River from 23 August to 30 October, 1985. The purpose of the 1985 field season was to determine which species were present in the headpond and the possible environmental cues which may cause their downstream migration. Attempts were also made to determine the fishes downstream route, optimal daily movement time and preliminary mortality estimates. Thus insight into how a large scale capture-tag-recapture mortality study may be conducted in the fall of 1986 will be gained. The following presents the results of this two-month field season as well as analysis and interpretation of those results.

Site Description

The first phase of study was conducted in the Annapolis River and Estuarine system. Four stations in the Annapolis River and Headpond were chosen with accessibility, substrate and previous fishing records as criteria (Daborn *et al.* 1984).

Station 1 was located approximately 50 m downstream from the Dunromin Campsite Wharf (Fig. 1). Station 1 was bounded on two sides by rock ridges and had a gravel substrate. The outward boundary was marked with a buoy at 1 1/2 m depth at low tide. At low tide the seine could be set in full with both ends just reaching shore.

Station 2 was directly across the headpond from Station 1 (Fig. 1). It had a mud substrate with *Spartina spp.* growing on its shore. The outward boundary was again marked at 1 1/2 m where the seine could be set in full at low tide. There was a small tributary just seaward of Station 2.

Station 3 was approximately 8 km upstream, at the mouth of Evans Brook (Fig. 1). The substrate was sand and as at Stations 1 and 2 the seine was just fully set at low tide.

An additional station (4) was sampled from 20 September onward. This station was located in the cove between Dunromin Campsite and the causeway and had a sand substrate.

The second phase of the study was conducted at the Annapolis turbine and fishway. Bottom nets (1,2) were placed approximately 250m below the turbine and two ichthyoplankton nets (3) were tied on the seaward boom below the generator. One net was placed in the old fishway (4) next to the sluice gate while an other was placed in the new fishway (5) next to the turbine (Fig. 1).

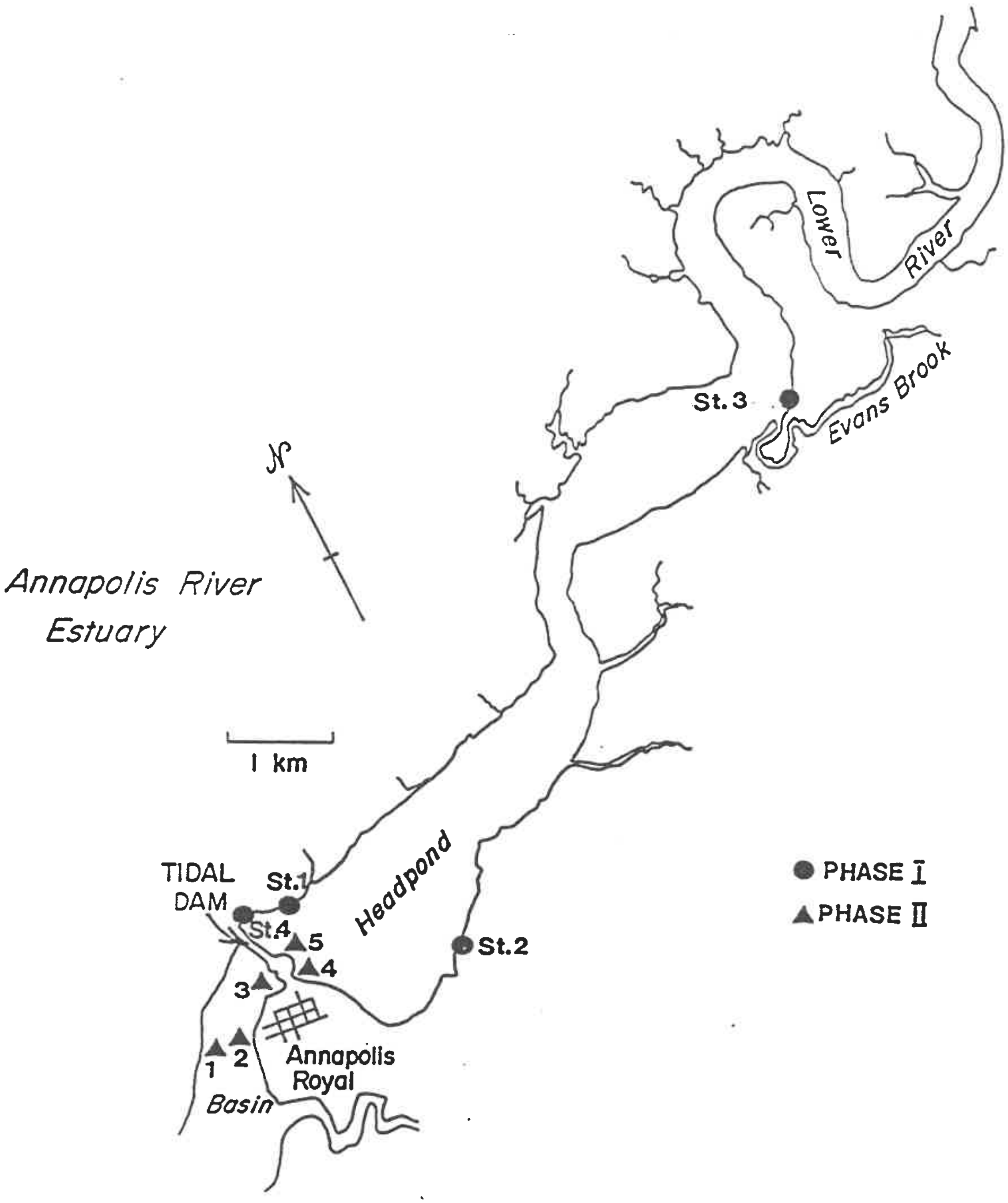


Fig. 1. Site Map

Methods

Phase I consisted of a total of 224 shore seines which were completed from the 27 August to the 19 October. These were fished at Stations 1-3 and at Stations 1-4 after 20 September.

All the seines were fished in the same manner. At low tide one person walked the seine around while the other person fed net out from shore. At high tide one person anchored one end of the seine while the other set the seine from the Zodiac. All seines were set so that the bag at the back of the seine was at 1 1/2 m depth at low tide. Then with each person taking a wing the net was walked in. Fish were sorted, identified to species, measured and released or preserved. All alosids were preserved as well as representatives from each species caught.

Phase II: between 25 September and 30 October fish movement was monitored through both fishways and the turbine. Four 1-metre diameter plankton nets and two 1-metre diameter bottom nets were used. The two bottom nets were hauled at low tide once a day from 25 September until 14 October; at this time they had to be removed due to severe decay of the net material.

One plankton net on a 1m wide neuston net frame without buoys, was set in each fishway. Preliminary trials showed that optimal fishing occurred at approximately 1-metre depth in each fishway; accordingly each net was sunk to that depth.

The other two nets were set on the seaward boom during generation. These nets had 1 m diameter circular frames and sampled in the top metre of water. A buoy was attached to the top of each frame to ensure constant sampling at this depth. On two occasions a net was sunk to the bottom to determine if catches were comparable throughout the water column, thus ensuring that the two nets were sampling representatively the fish population moving through the turbine. Nets were also rotated from the fishway to the turbine to ensure that neuston net frames sampled with the same efficiency as circular net frames.

The sites were given the following numbers: 3 and 3B were the nets set below the turbine while net 4 was set in the old fishway and net 5 was in the new fishway (Fig. 1). Nets 3 and 3B were set first just as generation began and were hauled just before generation stopped. All fish were then removed and the nets reversed on their frames; this reversal helped clean the nets and prevent plugging of the mesh. Net 3B had a two-litre dead water bucket while net 3 had the conventional plankton bucket.

Nets 4 and 5 were set after nets 3 and 3B; they were also hauled after 3 and 3B and their contents sorted. A photographic record was kept together with a recorded discription of the number of fish caught, the number of alosids and the amount of damage each sustained. The samples were then frozen or preserved in formalin except for 99 alosids which were sent fresh to the Fish Health Center at Fisheries and Oceans in Halifax. Autopsies were conducted on these fresh fish and later on the remaining frozen and preserved fish.

Fish were identified, measured and examined both internally and externally for damage. Autopsies took approximately two weeks to complete and the majority of them were completed at the Fish Health Center under the supervision of the biologist there.

Results

Seine Survey

Twenty-three species of fish were captured during the survey (Table 1).

At the beginning of Phase I seine collections were taken at 2-hour intervals for a 24-hour period to give an optimal fishing time estimate for a diurnal cycle. The results of these seines are shown on the optimal fishing time graphs for Stations 1 and 2 (Figs. 2,3).

It was found that *Menidia menidia* and sticklebacks (Gasterosteidae) occurred in high abundance earlier in the day than the majority of other species. Thus when their numbers are subtracted from the total fish catch the optimal fishing time became later in the evening by approximately two hours. The alosid catch for Stations 1 and 2, which consisted mainly of yearling alewives peaked in the late evening. Tidal phase does not appear to affect optimal fishing time.

On 17 September an extremely large number of alosids was collected at Station 3. Fig. 4 shows the seine times and the amount of each of the three alosid species that were sampled. The majority of these alosids were 1985 juveniles.

Mean catch per week and standard error (standard deviation divided by the square root of fishing effort) of alosids over the period 27 August to 19 October peaked in mid-september and early October (Fig. 5-7). The standard error is also shown. The catch was grouped weekly instead of daily because of the variability in catch-effort between days. Seine collections were made outside optimal fishing time as well as within to ensure that an accurate representation was being made; hence the variability. (For example: on one day ten seines were fished with two seines in optimal fishing time, and a total alosid catch of 5; the next day two seines were done both of which were in optimal fishing time and again the total alosid catch was 5.) All seine hauls are represented and therefore optimal fishing time is not taken into account.

Table 1:

#	Scientific Name	Common Name	Phase I	Phase II	Total
1	*Alosa sapidissima*	Shad	90	110	200
2	*Alosa pseudoharengus*	Alewife	326	274	600
3	*Alosa aestivalis*	Blueback herring	203	701	904
4	*Clupea harengus*	Atlantic herring	-	148	148
5	*Brevoortia tyrannus*	Menhaden	-	4	4
6	*Morone americanus*	White perch	277	-	277
7	*Morone saxatilis*	Striped bass	11	-	11
8	*Pseudopleuronectes americanus*	Winter Flounder	1069	-	1069
9	*Pollachius virens*	Pollock	41	-	41
10	*Anguilla rostrata*	American eel	445	26	471
11	*Osmerus mordax*	Rainbow smelt	599	102	701
12	*Microgadus tomcod*	Tomcod	106	-	106
13	*Menidia menidia*	Atlantic Silverside	8542	401	8943
14	*Raja erinacea*	Skate	5	-	5
15	*Scophthalmus aquosus*	Windowpane Flounder	5	6	11
16	*Ammodytes americanus*	Sandlance	4	1	5
17	*Gasterosteidae*	3, 4 and 9 spined stickleback	2833	16	2849
18	*Fundulus spp.*	Killifish and mummichog	296	1	297
19	*Syngnathus fuscus*	Pipefish	108	11	119
20	*Tautogolabrus adspersus*	Cunner	14	-	14
21	*Poronotus triacanthus*	Butterfish	-	8	8
22	*Petromyzon marinus*	Lamprey	-	12	12
23	*Pholis fasciata*	Blenny	-	1	1

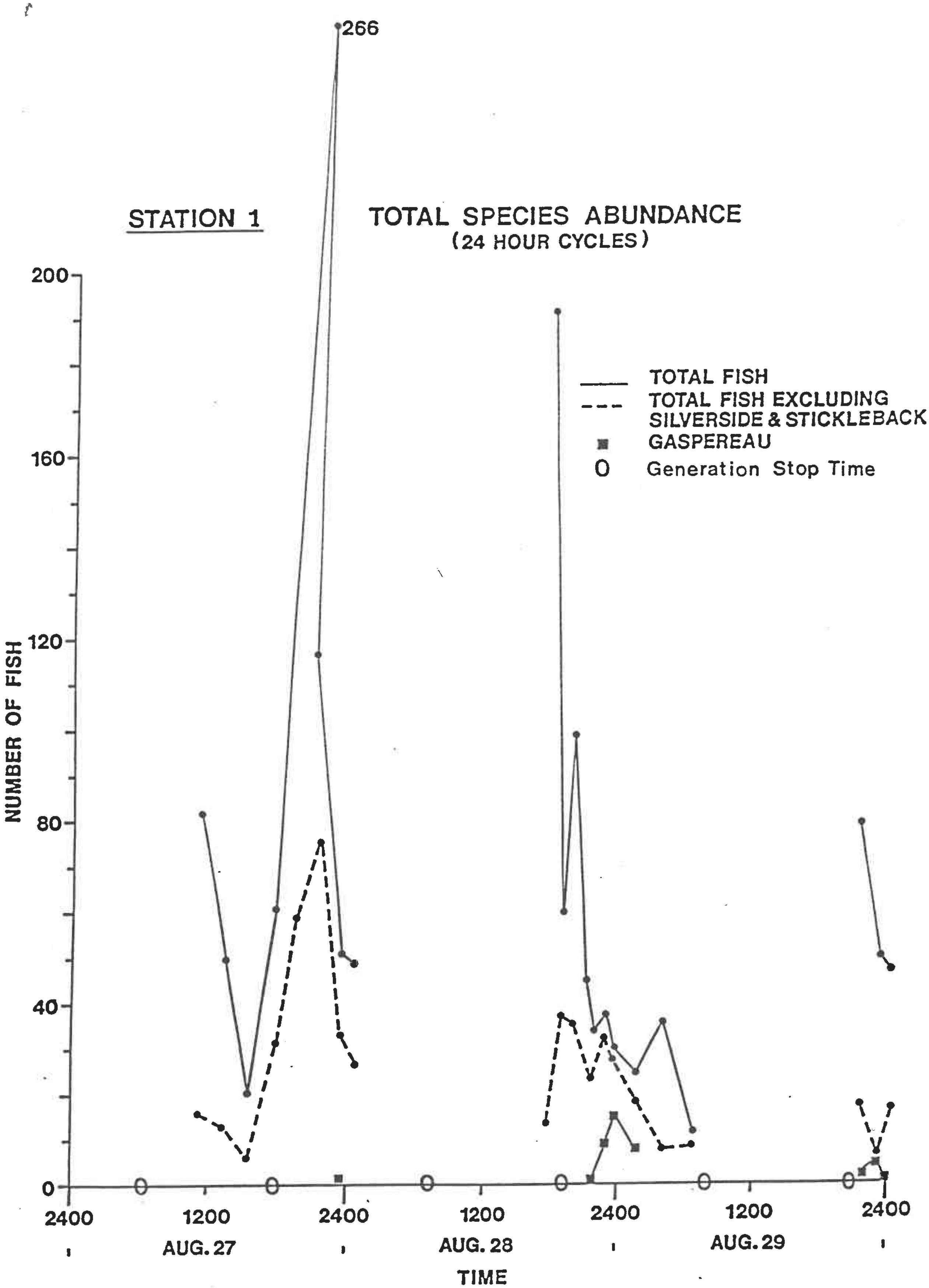

STATION 1
TOTAL SPECIES ABUNDANCE
(24 HOUR CYCLES)
266
200
160
120
80
40
0
NUMBER OF FISH
TOTAL FISH
TOTAL FISH EXCLUDING SILVERSIDE & STICKLEBACK
GASPEREAU
O Generation Stop Time
2400
1200
AUG. 27
2400
1200
AUG. 28
2400
1200
AUG. 29
2400
TIME

Fig. 2

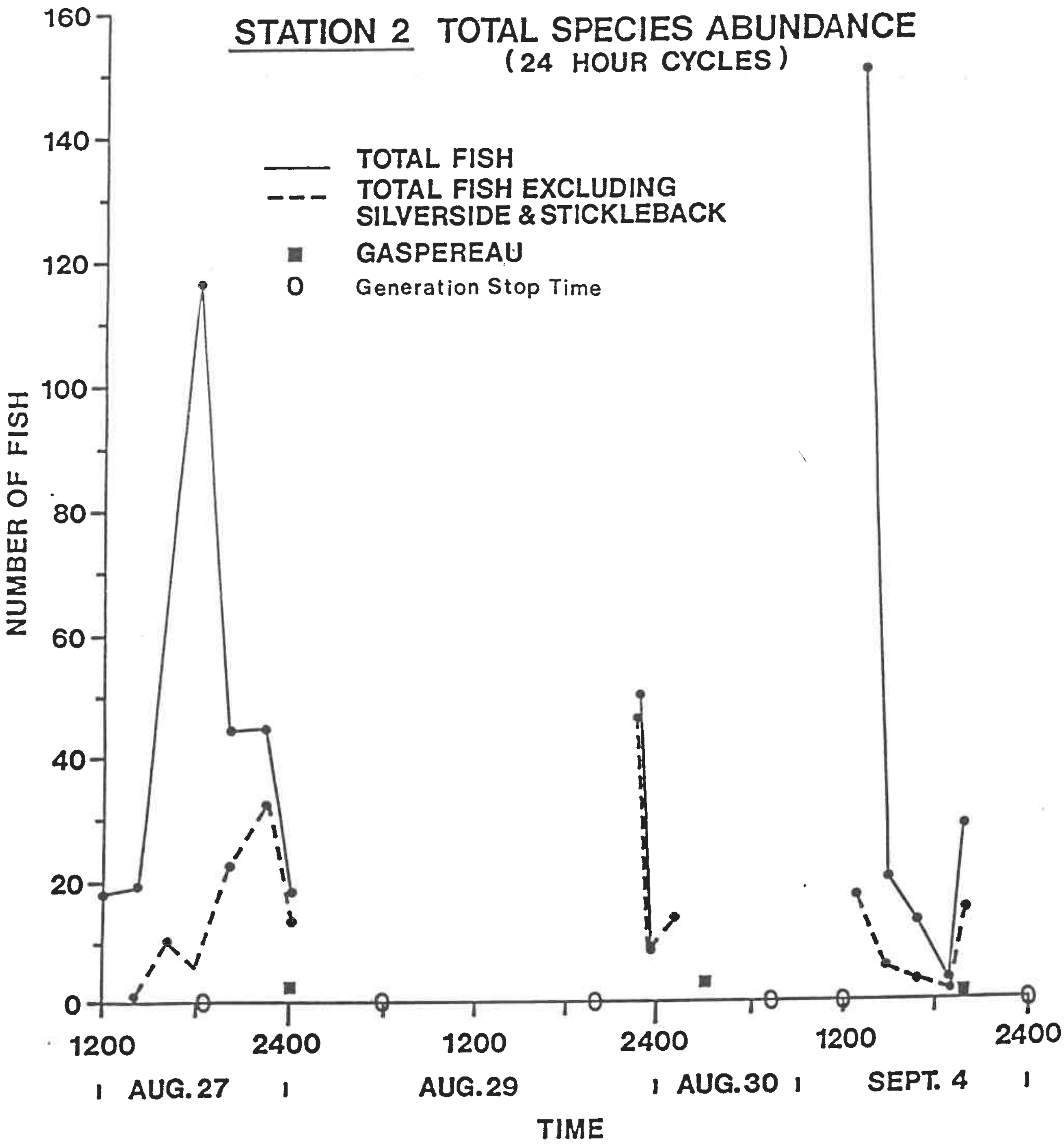
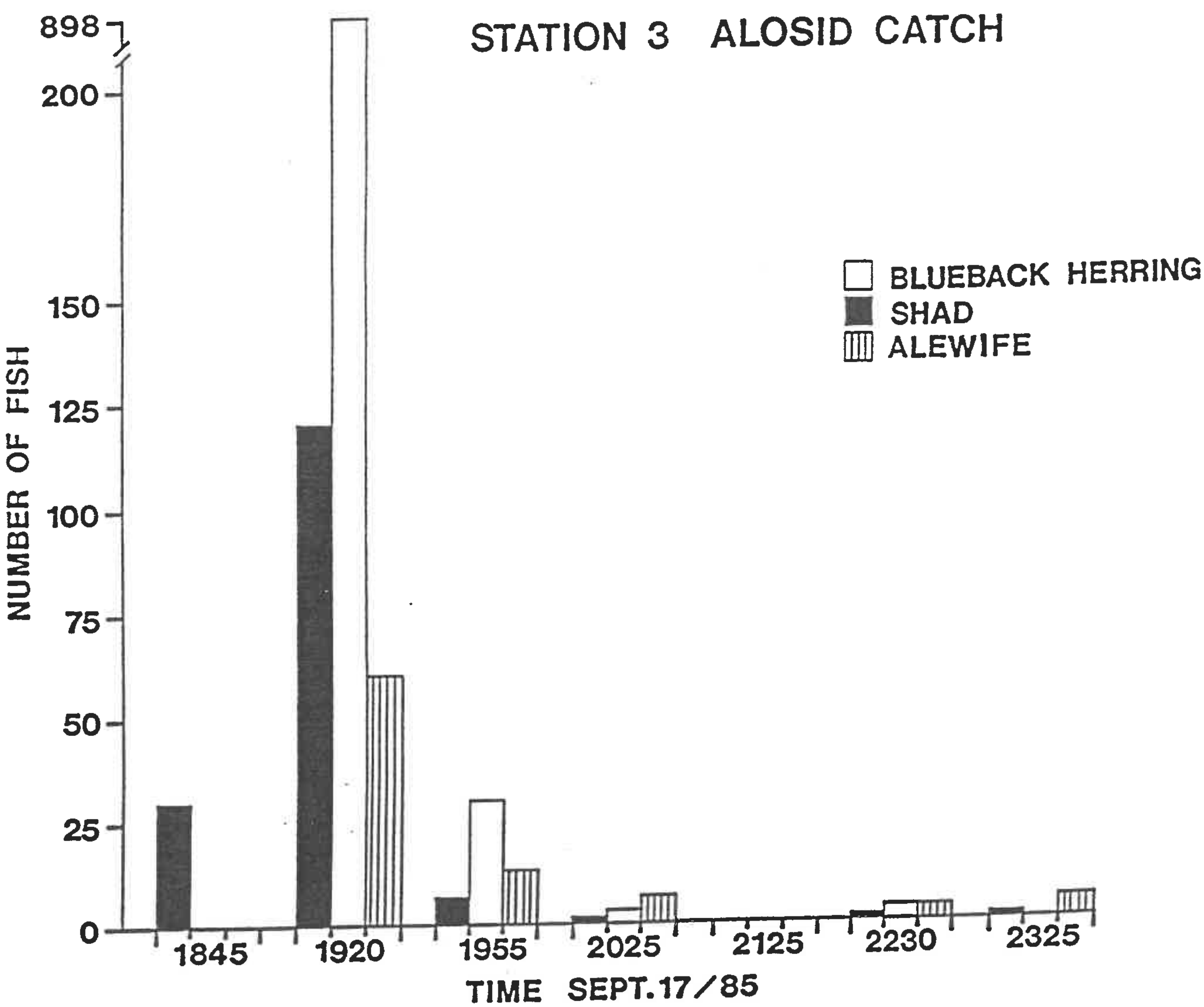

STATION 2 TOTAL SPECIES ABUNDANCE
(24 HOUR CYCLES)
TOTAL FISH
TOTAL FISH EXCLUDING SILVERSIDE & STICKLEBACK
GASPEREAU
Generation Stop Time
NUMBER OF FISH
0
20
40
60
80
100
120
140
160
1200
2400
1200
2400
1200
2400
AUG. 27
AUG. 29
AUG. 30
SEPT. 4
TIME

Fig. 3



STATION 3 ALOSID CATCH
BLUEBACK HERRING
SHAD
ALEWIFE
NUMBER OF FISH
898
200
150
125
100
75
50
25
0
1845
1920
1955
2025
2125
2230
2325
TIME SEPT.17/85

Fig.4

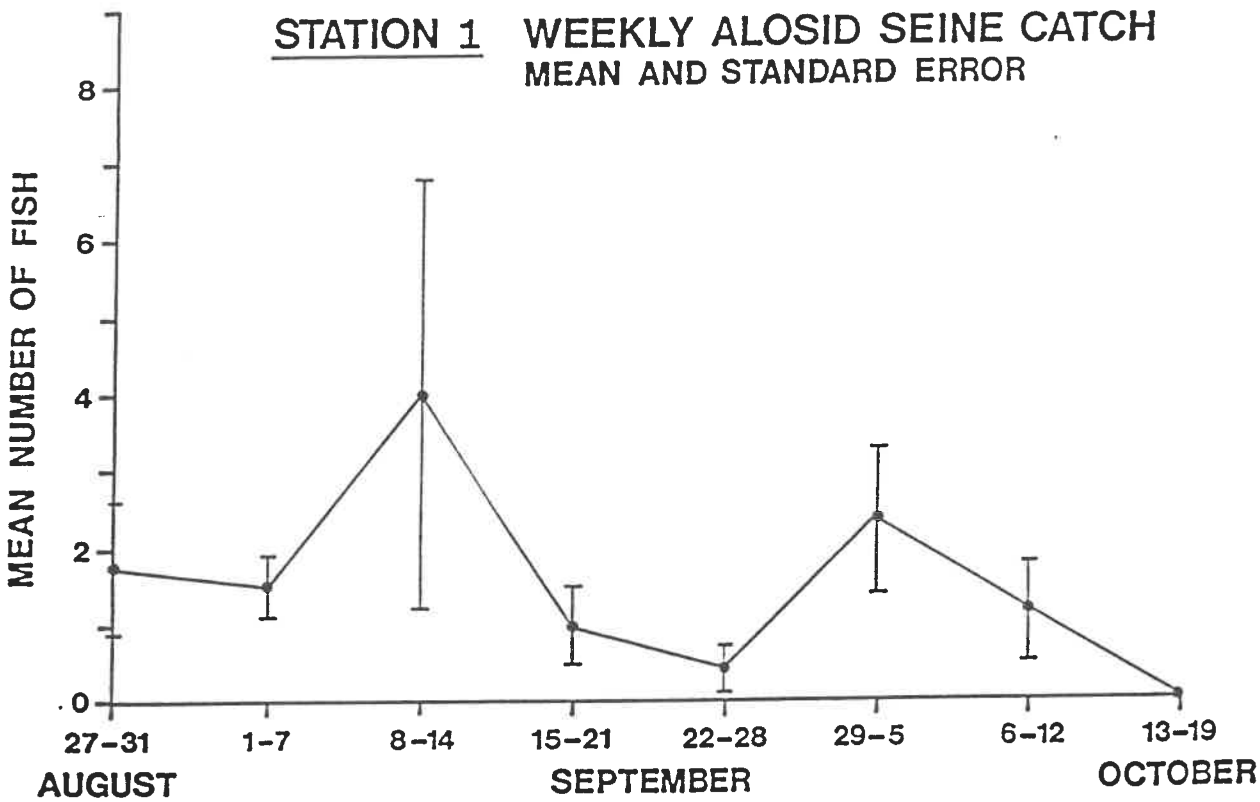

STATION 1 WEEKLY ALOSID SEINE CATCH
MEAN AND STANDARD ERROR
MEAN NUMBER OF FISH
0
2
4
6
8
27-31
1-7
8-14
15-21
22-28
29-5
6-12
13-19
AUGUST
SEPTEMBER
OCTOBER

Fig. 5

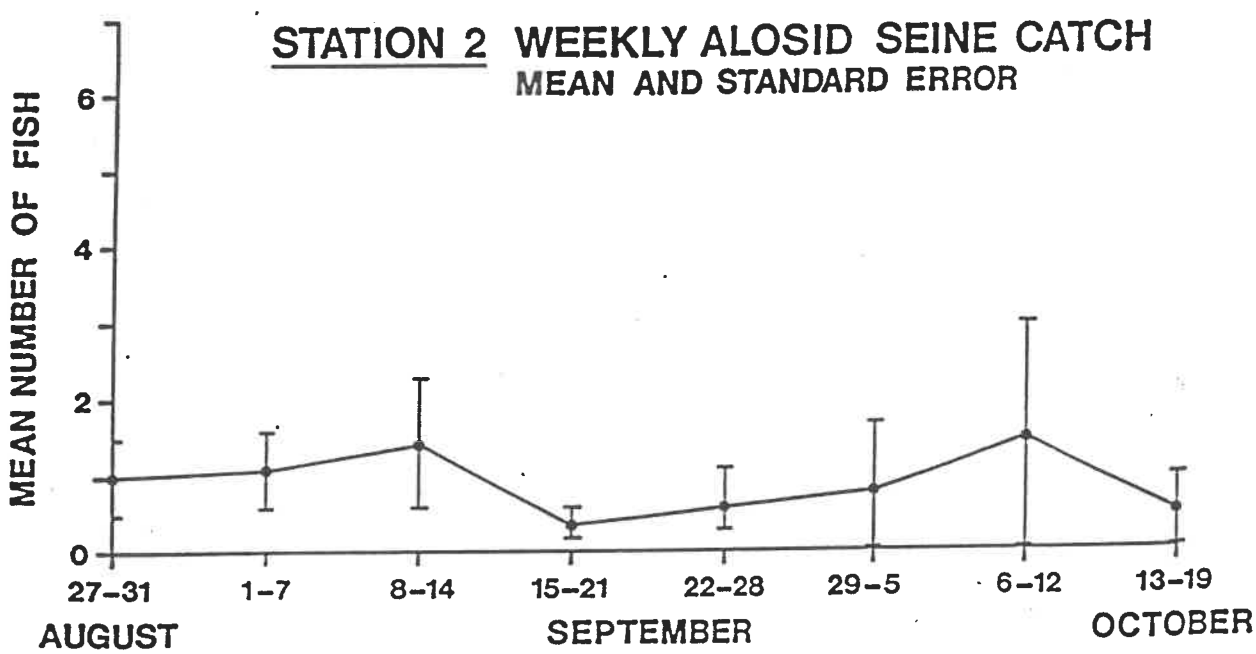
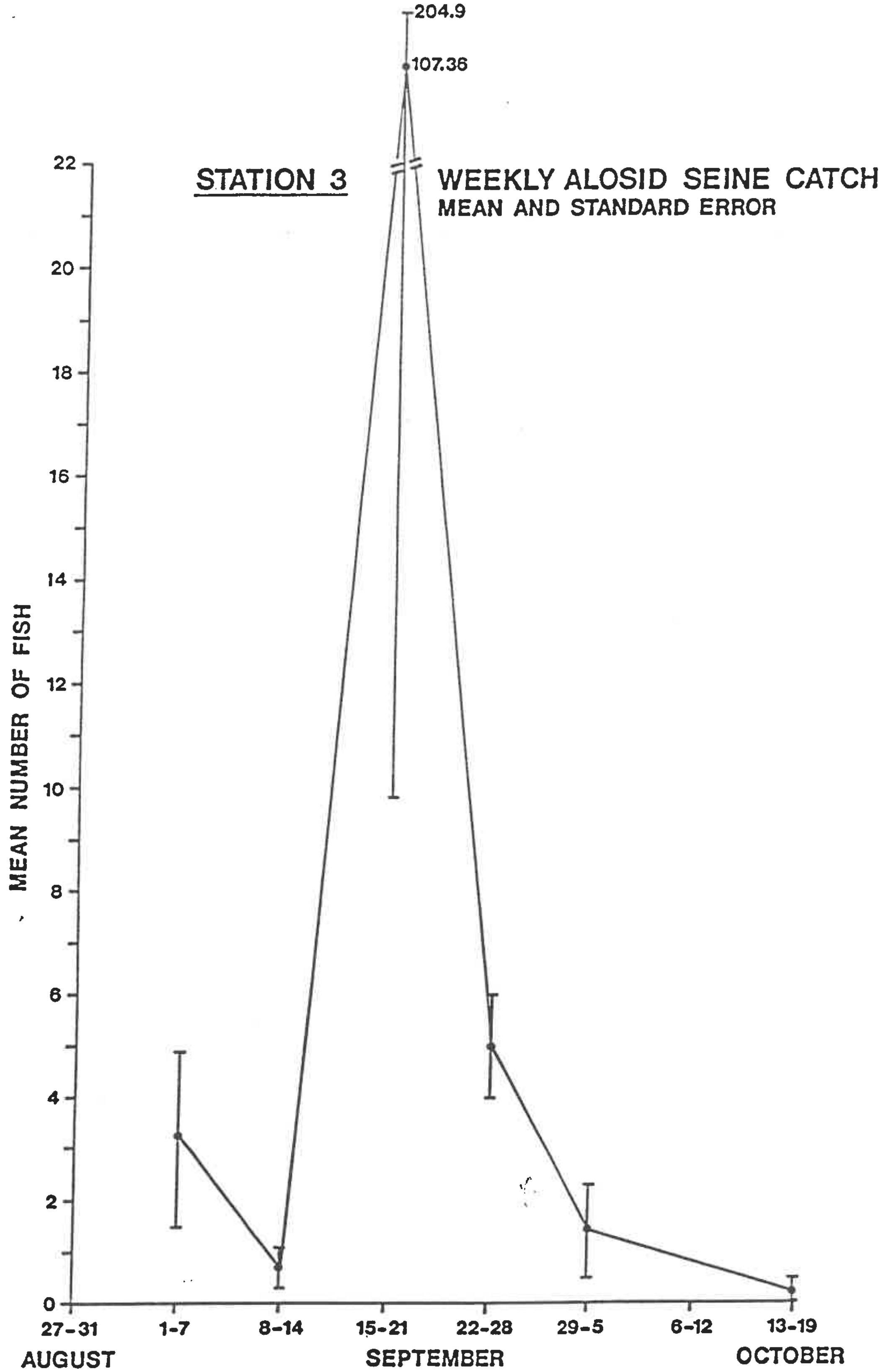

STATION 2 WEEKLY ALOSID SEINE CATCH
MEAN AND STANDARD ERROR
MEAN NUMBER OF FISH
0
2
4
6
27-31
1-7
8-14
15-21
22-28
29-5
6-12
13-19
AUGUST
SEPTEMBER
OCTOBER

Fig. 6



STATION 3
WEEKLY ALOSID SEINE CATCH
MEAN AND STANDARD ERROR
204.9
107.36
MEAN NUMBER OF FISH
0
2
4
6
8
10
12
14
16
18
20
22
27-31
1-7
8-14
15-21
22-28
29-5
6-12
13-19
AUGUST
SEPTEMBER
OCTOBER

Fig. 7

Lengths of the following fish species were recorded; Alosa sapidissima, Alosa pseudoharengus, Alosa aestivalis, Clupea harengus, Brevoortia tyrannus, Morone americana, Morone saxatilis, Pseudopleuronectes americanus, Pollachias virens and Osmerus mordax.

Length/frequency distribution for the alosids and Clupea harengus indicate that there was one year class of shad and two of alewife and herring in the estuary during fall (Fig.8-11). One histogram for each species is from the seine samples (except Clupea harengus which was not caught in the seine) while the other is from the turbine catches. Note that for shad and blueback herring the seine in which the majority were caught occurred on 17 September whereas the downstream run began on 16 October, thus giving a growth span of one month, in the Annapolis Lower River, upper headpond area.

The following table shows the mean length and standard deviation for the other species:

Table 2:

Species	Mean length (mm)	Standard Deviation
Morone americanus	185.1	(±) 62.1
Morone saxatilis	509.6	(±) 22.4
Pseudopleuronectes americanus	107.3	(±) 53.5
Pollachius virens	158.5	(±) 10.3
Osmerus mordax	123.4	(±) 22.6

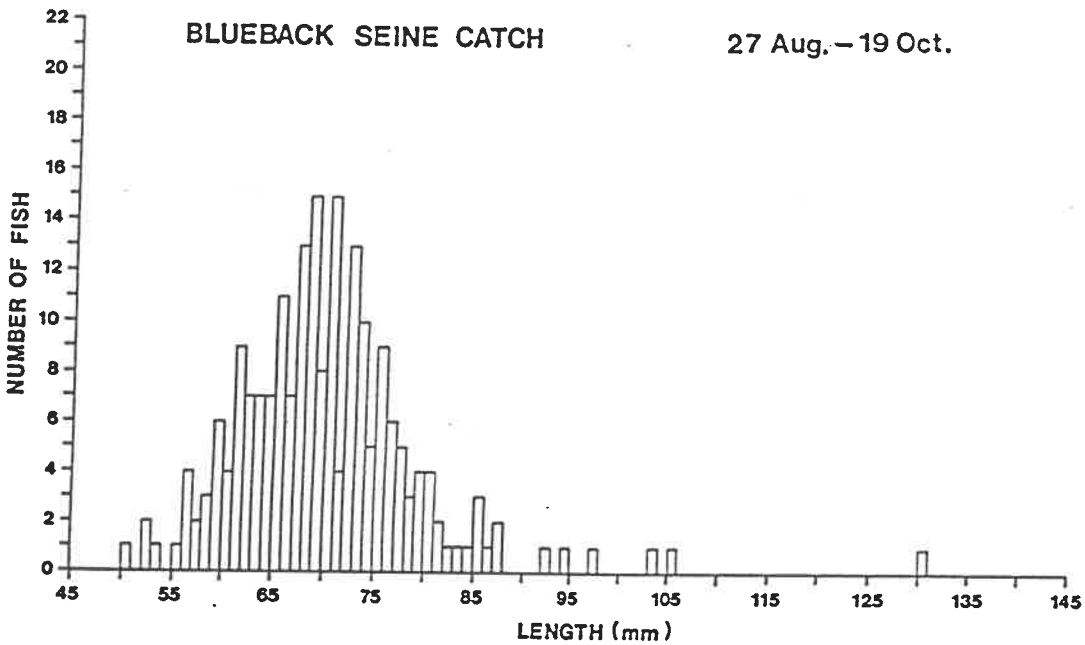
Though all three species of alosid juveniles were collected at Station 3, only one juvenile shad was collected at Station 2 and none were collected at Stations 1 and 4. Because of these intermittent catches, downstream migration could not be assessed using the seine collections.

Turbine Study

Downstream migration was monitored with the plankton nets used to monitor fish passage through the turbine. Fish catch from the turbine nets was plotted against the following physical conditions; river flow (recorded at Lawrencetown), salinity (at Station 1), water temperature (for Stations 1 and 3), precipitation (recorded at C.F.B. Greenwood) and lunar phase during September and October (Fig. 12).

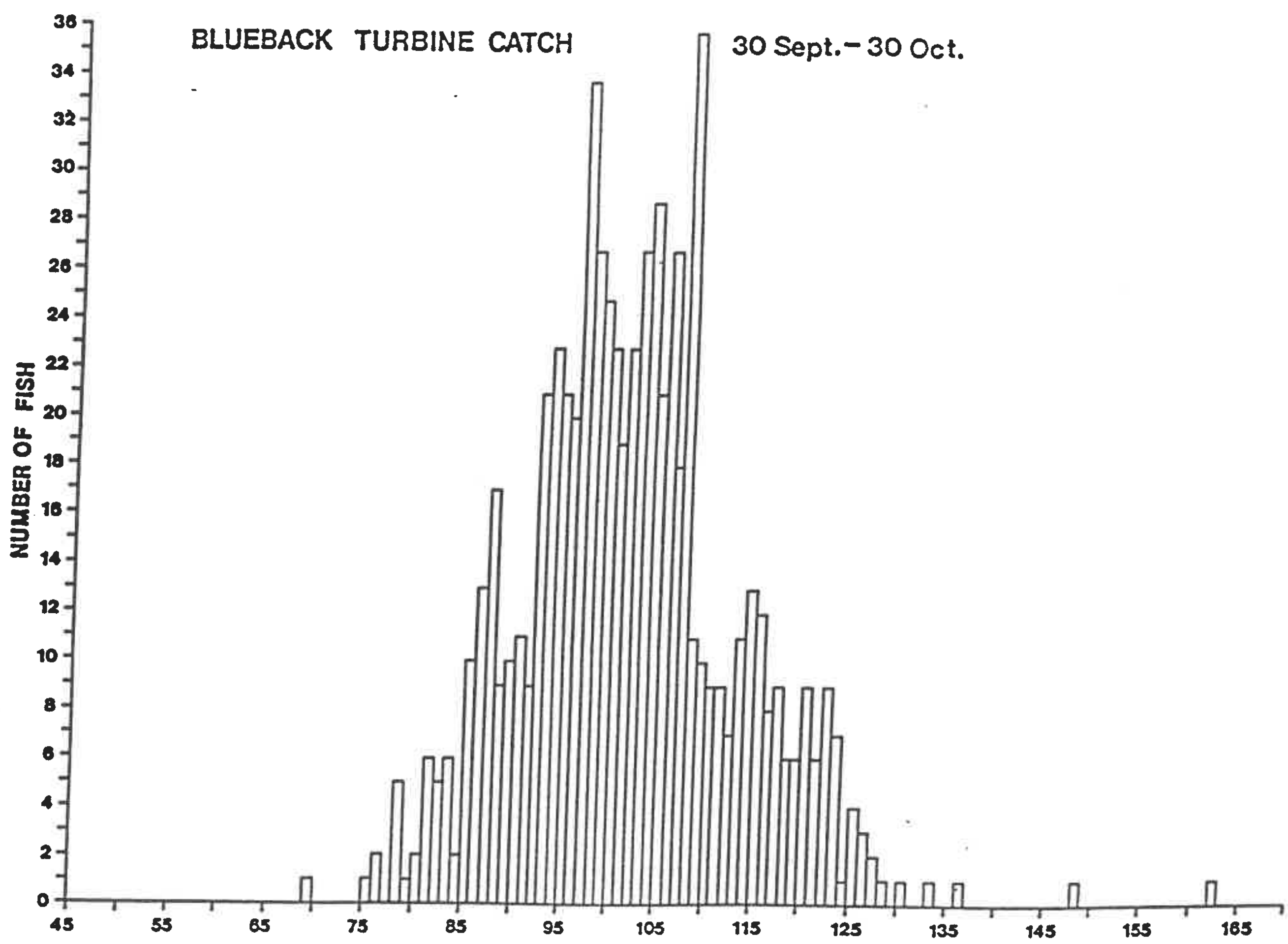
To determine the diurnal periodicity of downstream migration, day and night studies were also made. Large differences between day and night catches were apparent (Fig. 13). The daytime hours of 19 October were not fished.

a)



BLUEBACK SEINE CATCH
27 Aug. – 19 Oct.
NUMBER OF FISH
0
2
4
6
8
10
12
14
16
18
20
22
45
55
65
75
85
95
105
115
125
135
145
LENGTH (mm)

b)



BLUEBACK TURBINE CATCH
30 Sept. – 30 Oct.
NUMBER OF FISH
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30
32
34
36
45
55
65
75
85
95
105
115
125
135
145
155
165
LENGTH (mm)

Fig. 8

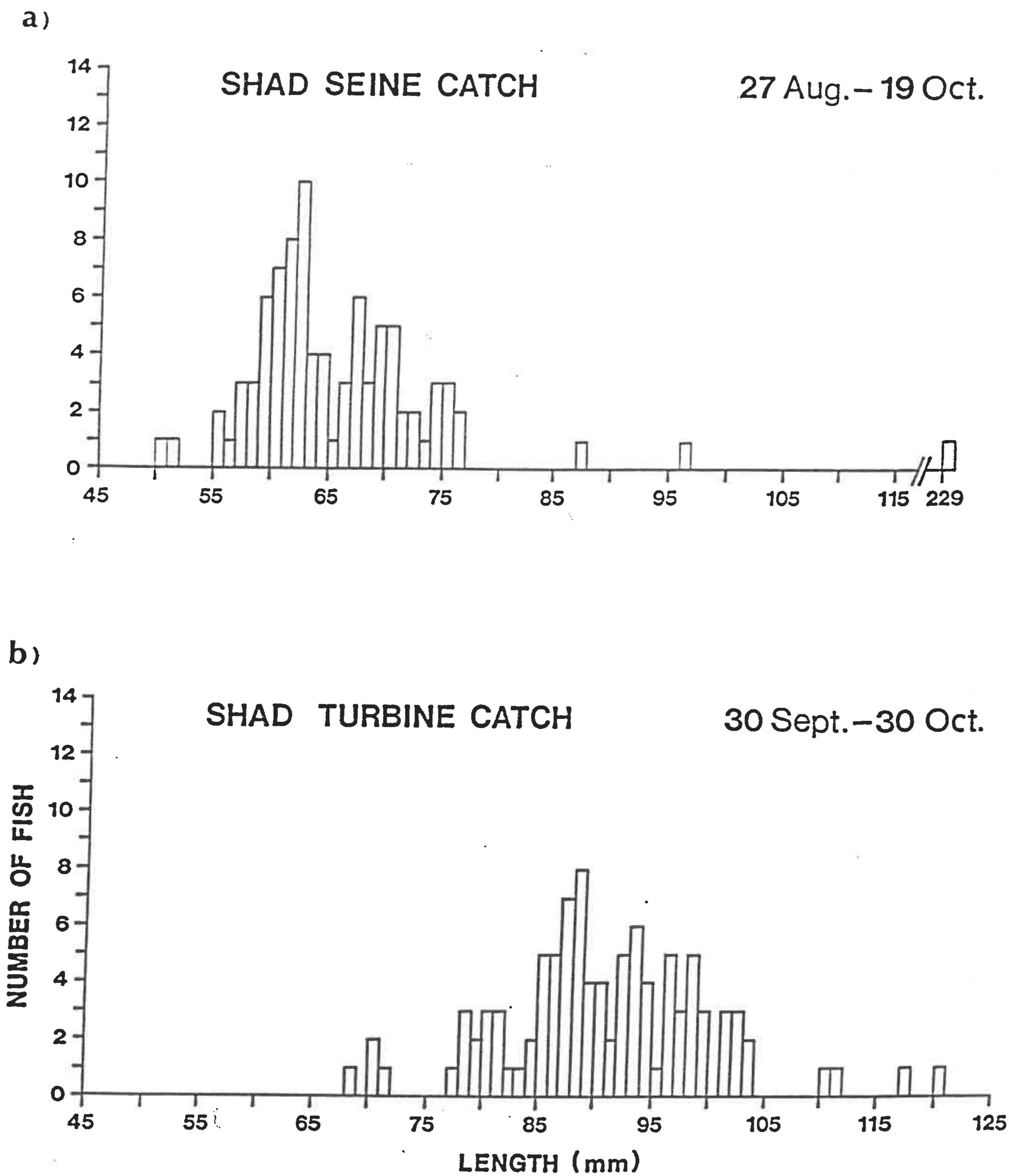
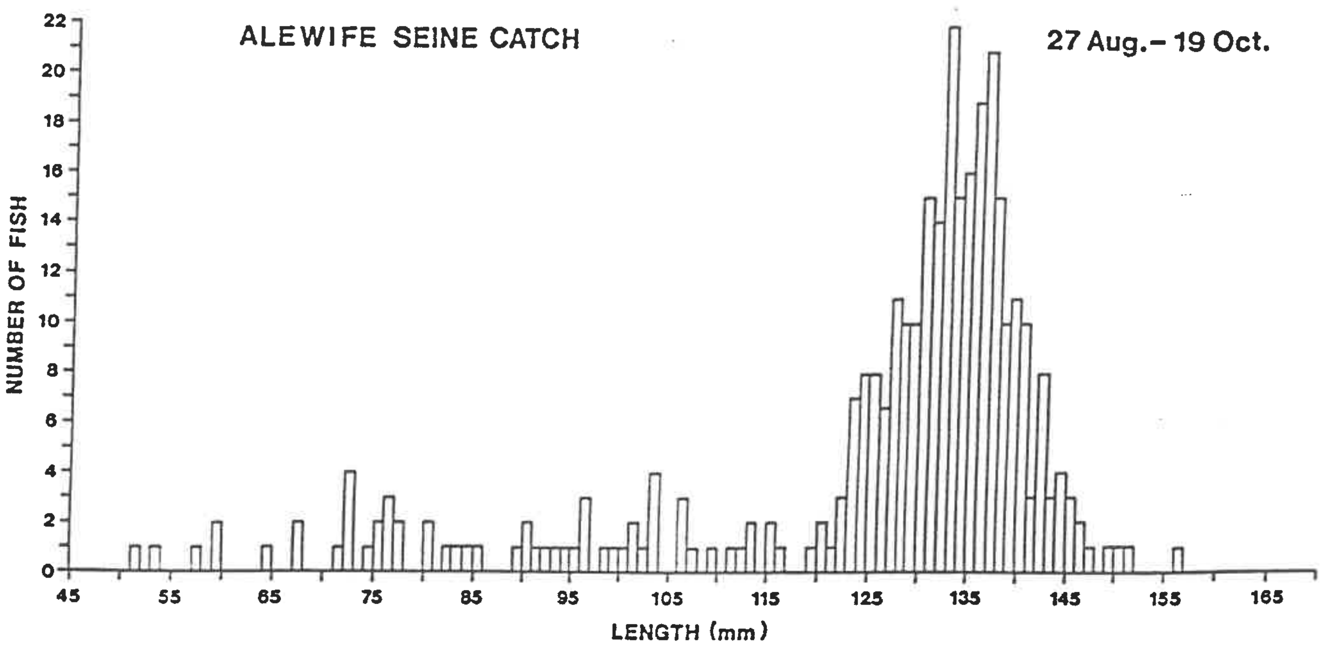

a)
SHAD SEINE CATCH
27 Aug.–19 Oct.
14
12
10
8
6
4
2
0
45
55
65
75
85
95
105
115
229
b)
SHAD TURBINE CATCH
30 Sept.–30 Oct.
NUMBER OF FISH
14
12
10
8
6
4
2
0
45
55
65
75
85
95
105
115
125
LENGTH (mm)

Fig. 9

a)


ALEWIFE SEINE CATCH
27 Aug.– 19 Oct.
NUMBER OF FISH
LENGTH (mm)
0
2
4
6
8
10
12
14
16
18
20
22
45
55
65
75
85
95
105
115
125
135
145
155
165

b)

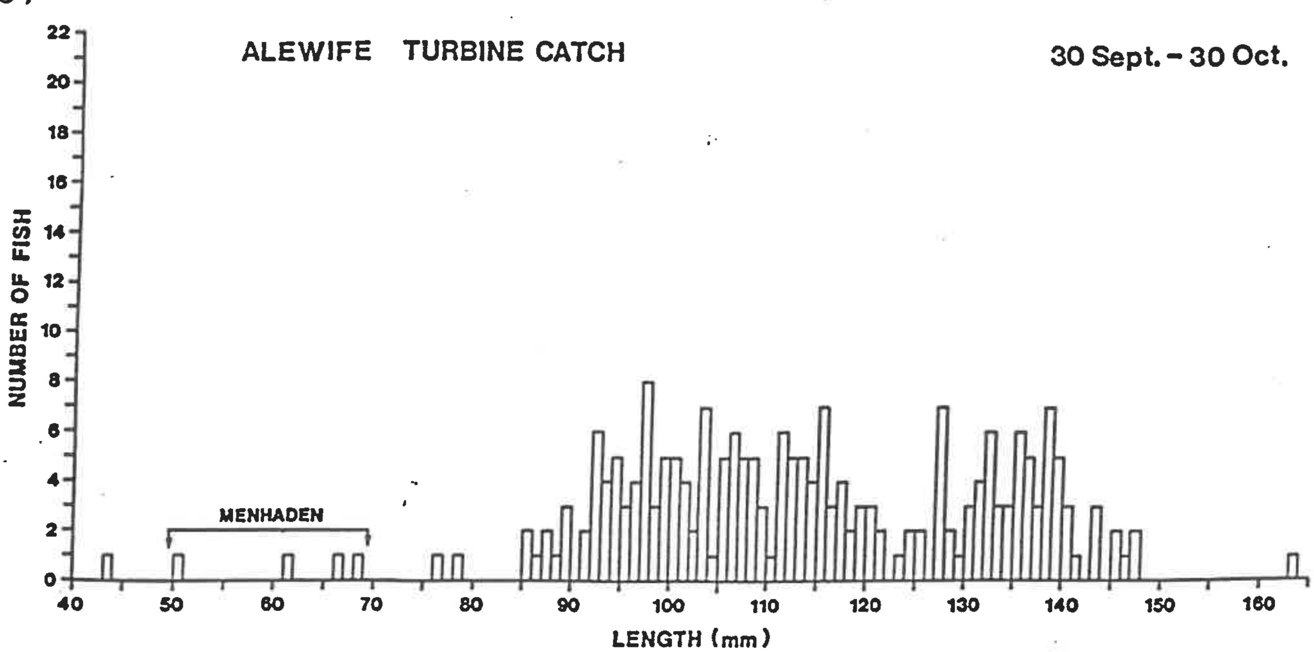

ALEWIFE TURBINE CATCH
30 Sept. – 30 Oct.
NUMBER OF FISH
MENHADEN
LENGTH (mm)
0
2
4
6
8
10
12
14
16
18
20
22
40
50
60
70
80
90
100
110
120
130
140
150
160

Fig. 10

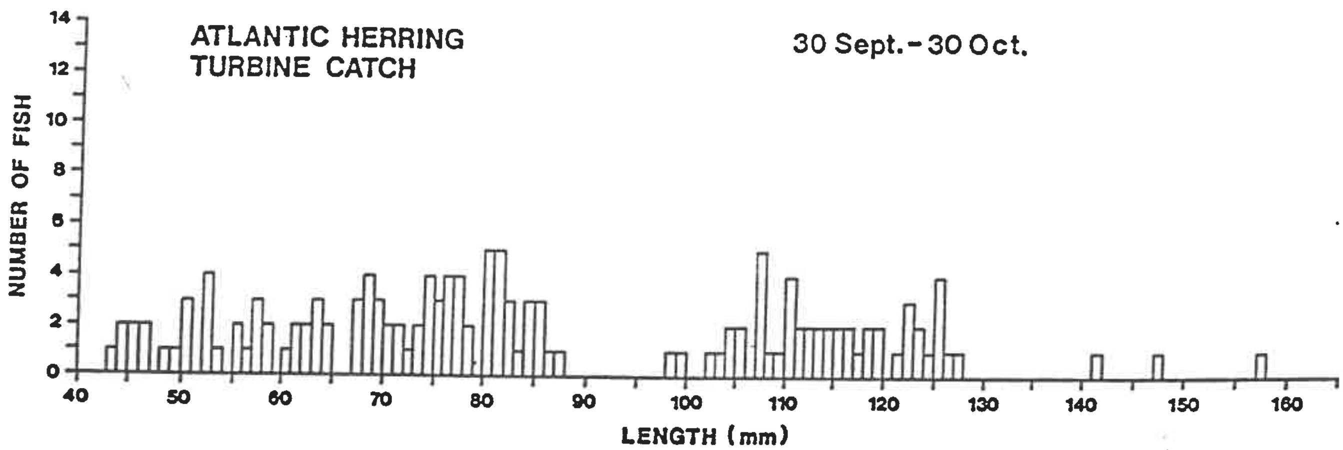
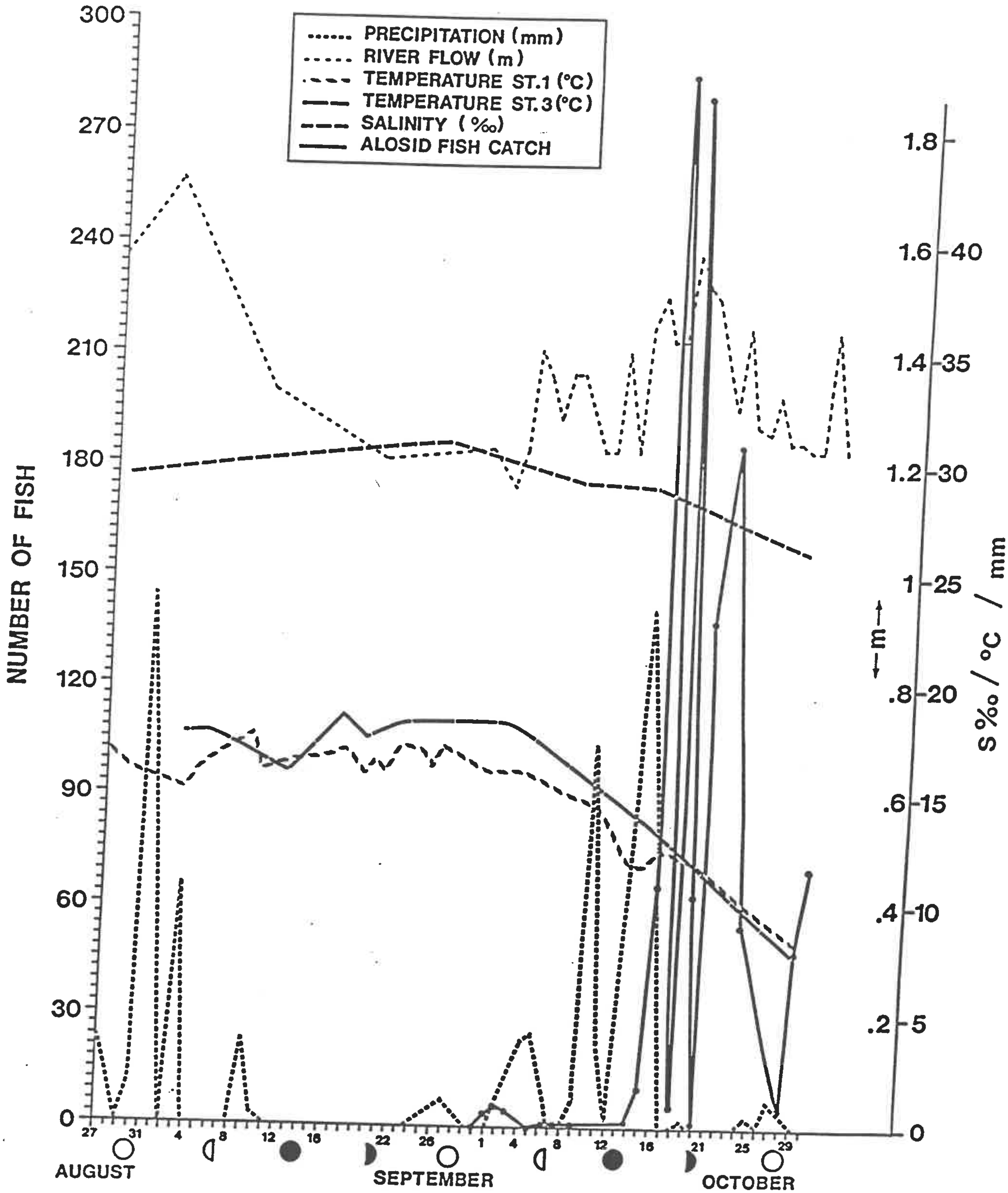

ATLANTIC HERRING
TURBINE CATCH
30 Sept. - 30 Oct.
NUMBER OF FISH
14
12
10
8
6
4
2
0
40
50
60
70
80
90
100
110
120
130
140
150
160
LENGTH (mm)

Fig. 11



PRECIPITATION (mm)
RIVER FLOW (m)
TEMPERATURE ST.1 (°C)
TEMPERATURE ST.3 (°C)
SALINITY (‰)
ALOSID FISH CATCH
NUMBER OF FISH
300
270
240
210
180
150
120
90
60
30
0
1.8
1.6
1.4
1.2
1
.8
.6
.4
.2
0
40
35
30
25
20
15
10
5
m
S‰ / °C / mm
27
31
4
8
12
16
22
26
1
4
8
12
16
21
25
29
AUGUST
SEPTEMBER
OCTOBER

Fig.12

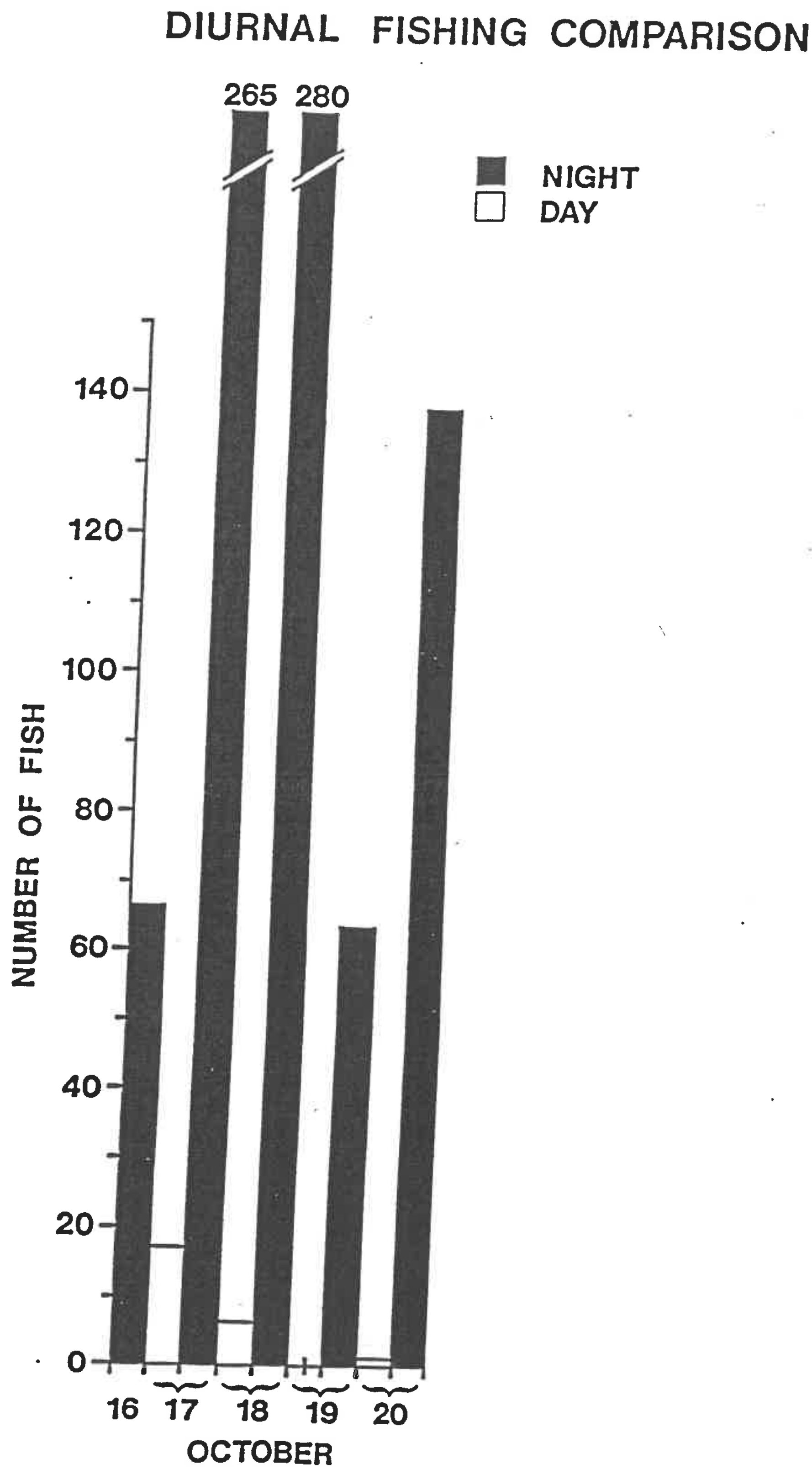

DIURNAL FISHING COMPARISON
265
280
NIGHT
DAY
NUMBER OF FISH
0
20
40
60
80
100
120
140
16
17
18
19
20
OCTOBER

Fig. 13

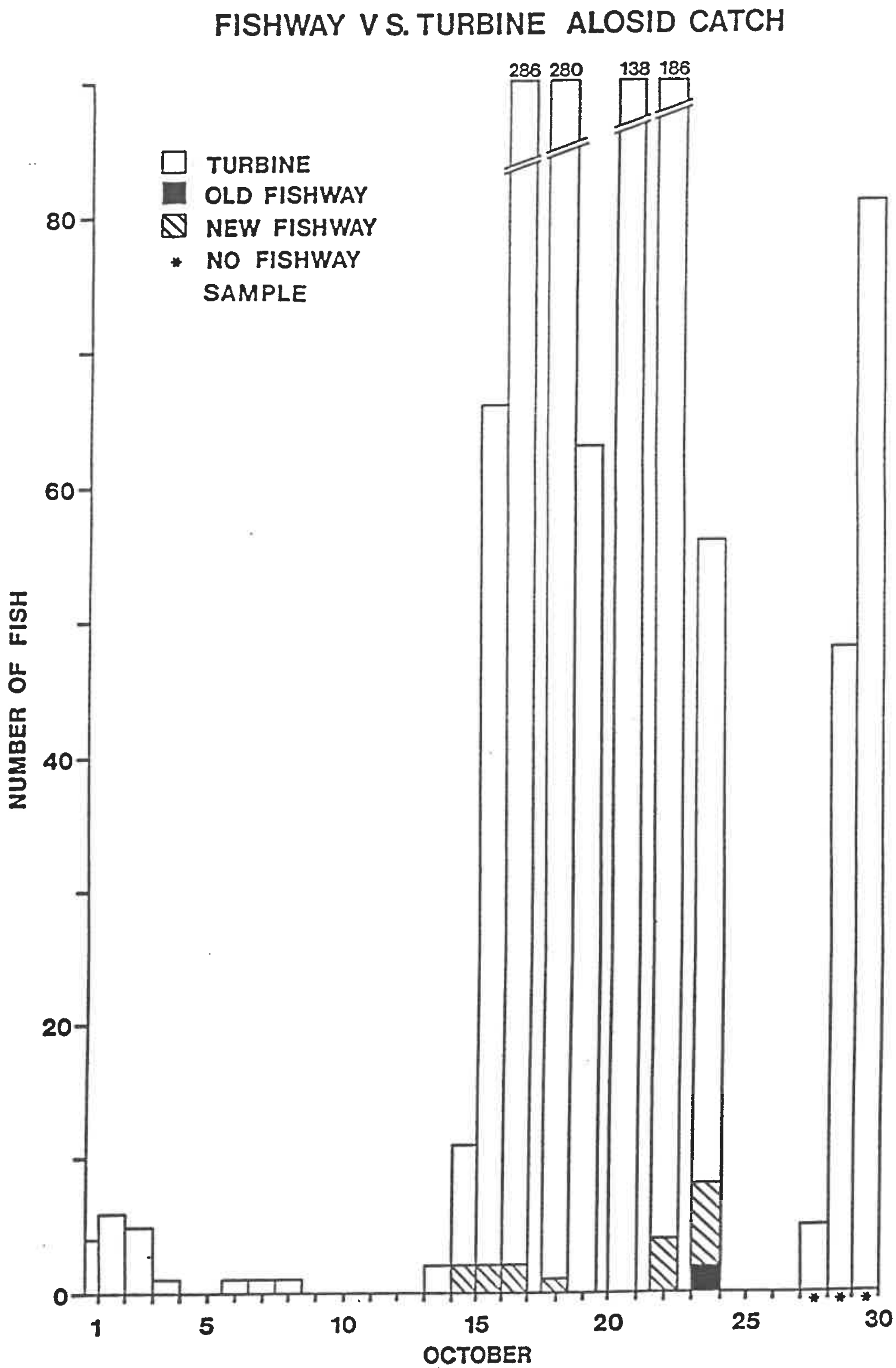

FISHWAY VS. TURBINE ALOSID CATCH
286
280
138
186
TURBINE
OLD FISHWAY
NEW FISHWAY
* NO FISHWAY SAMPLE
NUMBER OF FISH
0
20
40
60
80
1
5
10
15
20
25
30
OCTOBER

Fig.14

FISH CATCH DURING TURBINE GENERATION

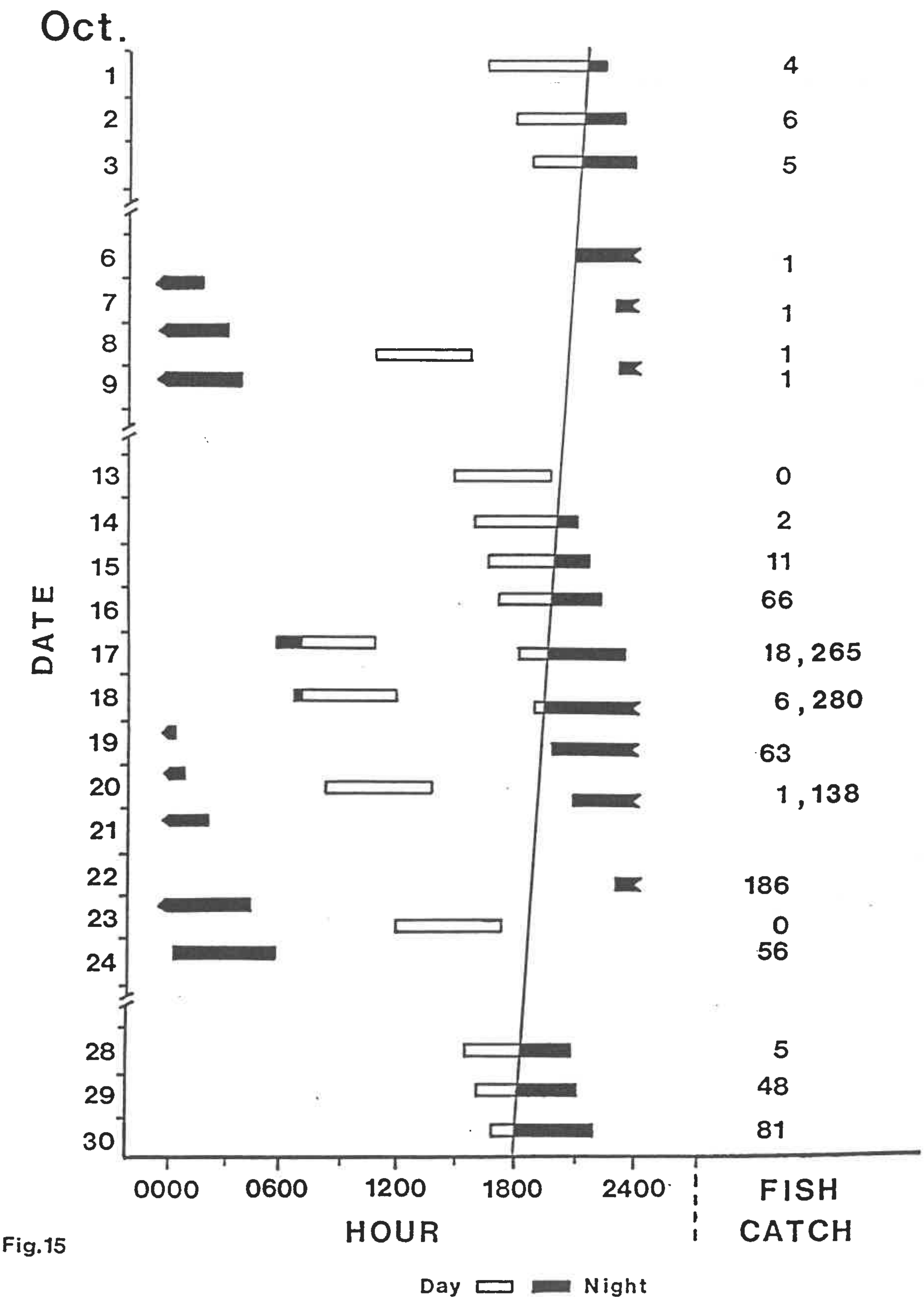


Fig.15

Nets were set in both fishways as well as downstream of the turbine (Fig. 14). Note that two nets were used to sample the turbine passage while only 1 net was set in each fishway. The nets downstream of the turbine together represnt a much smaller fration of the total cross-section area of the tailrace than does each single net in their respective fishway. Consequently, turbine fish passage is underrepresented, compared with fishway passage. By far the majority of alosids captured were taken in nets below the turbine. Collections were not made on the 5, 10, 11, 12, 25, 26 and 27 October. Nets were set in the fishways every time they were set behind the turbine except on the 28, 29 and 30 October. On these dates they were not fished due to damage in one case and the net sinking experiment on the other.

Fig. 15 shows generation time compared with turbine (3,3D) fish catch.

Examination of Fish

All alosids that were captured after passing through the turbine were collected. Observations were made immediately, then fish were preserved and autopsies performed later. Tables 3A and 3B show the results of these autopsies. Definitions for the pathological conditions observed may prove useful:

Red Eye - hemorrhaging in the eye, all cases had blood clearly visible in the eye, some so severe that the pupil could not be seen.

Blood on Operculum - blood distinctly visible on or following the arches of the peroperculum and suboperculum.

Blood in Pectoral Fins - blood distinctly visible in the rays on the pectoral fin near the base of the fin.

Skull Damage - bone damage to the head caused by direct contact with a solid object.

Decapitation - head is removed, not cut, always at the operculum cavity.

Body Cut in Half - distinct slicing of the body, usually only 1/2 of the body was found; however in a few cases the cut extended only halfway through the body.

Gas Bladder Damage (Pinhole and Burst) - small 1-2 mm diameter circular holes (termed pinholes) were found in some gas bladders. The gas bladder was considered burst when it was obvious that the membrane was completely ripped apart.

"Bruises" - these included damage anywhere on the fish except the skull,where the body made contact with a solid object. The bruises were not just areas of burst blood vessels but were scrapes, scratches and open cuts, they were not caused by

Table 3A:

Species	*Red Eye	*Blood on Operculum	*Blood in Pectoral Fin	Fresh & Frozen Fish Samples
Alosa sapidissima	51	12	3	81
% of n	63 %	14.8%	3.7%	
Alosa pseudoharengus	44	32	31	239
% of n	18.4%	13.4%	13 %	
Alosa aestivalis	225	116	170	626
% of n	35.9%	18.5%	27.2%	
Clupea harengus	41	10	7	83
% of n	49.4%	12 %	8.4%	
Total #	361	170	211	1029
Total % of n	35.1%	16.5%	20.5%	

* These symptoms could not be determined when samples were preserved in formalin; therefore, their number and percentage are taken only from fresh and frozen samples.

Table 3B:

Species	Skull Damage	Decapitated	Body cut in 1/2	Gas Bladder Damage: +No. of Fish with Gas Bladder Damage (N_g)	Gas Bladder Damage: *No. of Fish with Gas Bladder Damage without Red Eye (WR)	Bruises Include: Eye Bulging & Eye Burst	Total No. of Fish (n)
Alosa sapidissima	7	1	-	21	4	5	110
% of n	6.4%	0.91%	-	19.1 %	19 %	4.5%	
Alosa pseudoharengus	6	5	5	46	16	12	274
% of n	2.2%	1.8 %	1.8%	1.72%	34 %	4.4%	
Alosa aestivalis	24	6	8	131	66	34	701
% of n	3.4%	0.86%	1.1%	20 %	50.4%	4.9%	
Clupea harengus	6	1	4	38	4	2	148
% of n	3.8%	0.63%	2.5%	26.8 %	10.5%	1.3%	
Total #	43	13	17	236	90	53	1231
Total % of n	3.5%	1.1 %	1.4%	20.3 %	38.1%	4.3%	

+ When the gas bladder was damaged but it was not possible to tell for certain whether the damage was caused by the turbine or by the preservation process the fish was not included in the gas bladder column. The percentages were taken from the total 1163. It should be noted that many fish showed more than one symptom particularly red eye and gas bladder damage.

* These percentages were calculated using Gas Bladder damage as the total. Ex., $WR/N_g \times 100\%$.

pressure. These bruises were not always found to be fatal. Symptoms such as bulging eyes, missing eyes and burst eyes, which were probably caused by pressure are included in this category. Eyes which were bulging or burst also exhibited red eye.

Discussion

The optimal fishing time occurred between 1600 and 2300 for all fish and between 1800 and 2400 for fish excluding Menidia menidia and Gasterostidae (Fig. 1,2). It was observed that optimal fishing time varied with lunar phase by approximately one hour (On a full moon optimal fishing time occured one hour later then on a new moon). This suggests negative photosensitivity.

The large catch of alosid juveniles on 17 September occurred during optimal fishing time (Fig. 4). Samples were collected every 1/2 hour starting at 1845 and continuing to 2235 with a final seine at 2325. Sunset on the 17th occurred at 1900. The juveniles moved inshore and were jumping out of the water for approximately 1/2 hour. It is interesting to note that shad juveniles were recorded first, 30 minutes before the blueback herring and they were also the first to decline in number. The majority of juveniles caught at Station 3 were caught around sunset; 1900 ± 1 hour depending on cloud cover. Furthermore, the only juvenile caught in a seine in the headpond (at Station 2 on the 19 October) was captured at 1850. This coincides with O'Leary's obserations of the daily movement peak for American shad outward migration (O'Leary 1984).

A slight decline in weekly mean catch over the two month period can be noted. A large decline at Station 3 occurred following the large catch on the 17 September. However, because of variability in sampling effort, schooling of fish and inability to account for optimal fishing time, no patterns can be solidly defined. The graphs do give an idea of overall alosid catch and definitely show how variable these catches can be.

Lengths were recorded for the alosids and other species of commercial value, to provide length frequency estimates for these fish populations, or at least the inshore populations. A growth rate estimate can be made for both shad and blueback herring by comparing the fish caught on 17 September with those caught passing through the turbine from the 17 to the 29 October. There is approximately 30 mm difference between the length modes of the two shad catches, and 35 mm between the blueback herring catches. The only shad caught in a seine in the headpond had a length of 96 mm, on 19 September. This would seem to support the growth estimate. It is apparent that the shad caught in the turbine and the shad caught in the seines (with the exception of 1) were juveniles of 1985; this holds true for the majority of the blueback herring catch as well.

This is not the case for the alewives. The majority of alewives sampled were in fact one year olds (Fig. 10A). This is largely because these fish were caught regularly over the seining time period at Stations 1 and 2. There seems to be a large feeding population of alewives in the headpond. The alewife turbine catch histogram (Fig. 10B) shows a fairly constant size catch from 85 mm to 147 mm. There is no large peak as in the shad and blueback herring. Thus alewives may not have the large spawning population the other two species have. It may also be that alewife juveniles ran downstream before the 25 September.

The data suggest that there is a fairly regular movement of feeding one year old alewives from the headpond through the turbine and back in again through the sluice gates. Further work will have to be completed before this can be accurately assessed.

It is interesting that the Atlantic herring histogram (Fig. 11) is similar to the alewife histogram (Fig. 10). There are at least two year classes moving through the turbine in this case.

Also of interest is the presence of juvenile menhaden. Menhaden were caught during the summer when work was in progress on the adult mortality study (personal observation). The presence of these juveniles shows that there is a spawning population of menhaden, somewhere in Canadian waters.

The lengths for other abundant commercial fish were also recorded. There appears to be a very large population of juvenile winter flounder as well as a considerable population of rainbow smelt. Young pollock were also collected on a regular basis. Both adults and juvenile white perch were collected in fairly large numbers. All the striped bass caught were three years old. There is a very large population of striped bass present in the Annapolis system and a better idea of this population size can be obtained by studying the fishing log recorded at Dunromin Campsite. No young-of-the-year striped bass were collected.

It is evident from the seining and turbine data that although shore seines are useful in sampling the alosid juvenile populations upstream it is an inefficient means of sampling the downstream migration. The juveniles, once they begin their downstream migration, do not venture inshore. The turbine nets provide a much better representation of the downstream migration.

The downstream migration catch was plotted against five physical conditions (Fig. 12). River flow, salinity, water temperature and precipitation are all interrelated while lunar phase is independent. The largest rainfall was on the 15th and second largest on the 10th. Riverflow increased, temperature and salinity, both of which were already on the decrease, continued to do so, but more rapidly. No sampling occurred on the 9, 10, 11, 12 and 13 October, so that if there was a run of juveniles caused by the rain on the 10th it was not sampled. However after the large rainfall on the 15 October coincident with the new moon, the juvenile alosid run began. Whether one of these physical factors or the combination of all these factors together caused the downstream migration remains to be determined. The largest number of fish moved through in the first three days and by the 23rd the catch had declined to less than 100 per sample period. Although the graph only shows alosid migration, downstream migration of Anguilla rostrata (American eel) and Petromyzon marinus (Lamprey) also occurred.

The high peaks and sharp declines in the fish catch (Fig. 12) are due to diurnal fishing differences. These differences were clearly shown (Fig. 13). The data indicate that the majority of alosid juvenile fish movement through the turbine occurs during the night. This time period coincides with the optimal fish time found from the seines. Thus, this also may have interacted with the other conditions to result in the extremely high fish catches during the first five days of the run.

Downstream migration may peak during the generation cycle. During preliminary net kill controls only 4 alosids were caught in the last hour of generation on 17 September. Studies next field season will provide an answer.

Fishway catch was compared with turbine catch (Fig. 14). Less than 2% of the total alosid catch was collected in the fishways. The fishways appear to play a very minor role in juvenile fish passage. This assumes that all fish passing through the fishway survive, although the assumption may be invalid: at low tide the water passing through the new fishway drops approximately 2.5 m onto a flat rock. This could be fatal to juvenile fish. Mortality experiments on fish passing through the fishways will be conducted next field season.

Fish catch appears to be equal throughout the night time generation (Fig. 15). There may be a difference, but the run occured over only five days therefore it is hard to draw a solid conclusion.

A total of 1231 alosids were caught after they had passed through the turbine. Autopsies were performed on all of them (Table 3A and 3B). Of the alosids sampled 3.6% were known to have survived the passage and 23.9% were killed. Total mortality may be higher than 23.9%, however it is impossible at this point to seperate turbine from handling mortality. Controls to determine handling mortality, thus increasing the accuracy of the turbine mortality estimate will be preformed next field season. Hemorrhaging in the eye could not be considered a sign of certain death (though it may well be), because one alosid with one eye missing and hemorrhaging in the other was alive when the nets were hauled. It lived for approximately ten minutes. Bruises may not be fatal but they do inflict stress on the fish and will also increase its vulnerability to predators and infection, thus causing indirect mortality. As well, gas bladder damage may not cause immediate mortality but the fish will be immobilized and die soon after its gas bladder is destroyed. Fish survival trials on fish with these different symptoms will be completed next field season along with a large scale capture-tag-recapture study.

Pressure kill makes up a large percentage of juvenile mortality; whether this mortality figure will decrease with age, or varies between body morphs (example: spiny fish vs. soft rayed fish) remains to be seen. Usually one fish had more than one symptom - particularly red eye, blood on operculum and blood in pectoral fin rays. The majority of fish with gas bladder damage also had hemorrhaging in the eye. One fish caught in the new fishway had blood on its operculum, thus this symptom may only be the sign of a stressful death; in this case perhaps net kill. Further study into the causes and effects of these symptoms must be performed to determine a clear picture of mortality.

Mortality appeared to be greatest with the alosids and <u>Clupea harengus</u>. Rainbow smelt and Atlantic silversides both exhibited mortality due to passage through the turbine but in a less degree than the alosids. However, this is only an observation based on a relatively small number of fish and more detailed analysis may prove otherwise. The American eel and lamprey fared well through the turbine. Only two eels out of 26 were dead and their deaths may have been caused by suffocation in the net rather than by the turbine. Not only are further net kill experiments necessary for alosids but for all species that pass through the turbine. No striped bass, white perch or salmon juveniles were captured after passing through the turbine; thus no mortality estimates can be made. These species will be studied next field season.

Conclusion

The results from this field season give some insight into the fate of juvenile fish in the Annapolis Estuarine and River system. The alosid juvenile downstream migration began on the 16 October and the majority of fish had passed through the turbine within five days. The five physical conditions which may have caused the downstream run all occurred before the 16th with the largest rainfall occurring on the 15th and the new moon on the 14th. Whether one of the conditions or a combination of all these conditions caused the run remains to be seen. Hopefully the 1986 field season will provide more insight.

It is clear that the majority of fish in the seaward migration pass through the turbine with only a very small percentage passing through either fishway. The majority of fish also move at night. Of the total number of fish passing through the turbine 23.9% are estimated to be killed immediately; 3.6% were alive, 72.5% of the total mortality is still unknown. Many controls, as well as a large scale capture-tag-recapture study, need to be completed. This will give more accurate mortality estimates.

From the seining operation, it was observed that alosid juveniles may be negatively phototactic. Further work on this and other sensory studies are essential if a means to detour the fish paths from the turbine to the fishway is to be found. Work will be conducted in these areas as well, if possible, next field season.

REFERENCES

1 Grecco, Victor A. and Thomas F. Savory. 1984. Effects of Fluctuations in Hydrographic Conditions on Year - Class Strength of American Shad (Alosa sapidissma) in the Connecticut River. Can. J. Fish. Aquat. Sci. Vol. 41: 1216-1223.

2 Daborn, Graham R., John T. O'Neill and Robert R.G. Williams. 1979. Limnology of the Annapolis River and Estuary II. Fish Distribution in the Estuary, 1976 and 1977. Proc. N.S. Inst. Sci. Vol. 29: 173-183.

3 Leim, A.H. and W.B. Scott. 1966. Fishes of the Atlantic Coast of Canada. Bull. Fish. Res. Board Can., 155.

4 Loesch, Joseph G., William H. Kriete Jr. and Erig. J. Foell. 1982. Effects of Light Intensity on the Catchability of Juvenile Anadromous Alosa Species. Trans. Am. Fish. Soc. Vol. III: 41-44.

5 Melvin, G.D., M.J. Dadswell and J.D. Martin. 1985. Impact of Lowhead Hydroelectric Tidal Power Development on Fisheries I. A Pre-operation study of the Spawning Population of American Shad Alosa sapidissima (Pisces: Clupeida) in the Annapolis River, Nova Scotia, Canada. Canadian Technical Report of Fisheries and Aquatic Sciences No. 1340.

6 Moss, Sanford A., William C. Leggett and William A. Boyd. Recurrent Mass Mortality of the Blueback Herring, Alosa aestivalis, in the Lower Connecticut River. Connecticut River Ecological Study, pp. 227-234.

7 O'Leary, J.A. 1984. Characteristics of the downstream migration of juvenile American shad (Aalosa sapidissima) and blueback herring (Alosa aestivalis) in the Connecticut River. master's thesis. University of Massachusetts, Amherst, MA, USA.

8 Richkus, William A. 1975. The Response of Juvenile Alewives to Water Currents in an Experimental Chamber. Trans. Am. Fish. Soc. No. 3: 494-498.

9 Taylor, Ralph E. and Boyd Kynard. 1985. Mortality of Juvenile American Shad and Blueback Herring Rassed through a Low-Head. Kaplan Hydroelectric Turbine. Trans. Am. Fish. Soc. 114: 430-435.