Field Report 1986

Downstream Movements of Juvenile Alosids and Juvenile Fish Mortality Associated with the Annapolis Tidal Power Turbine

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Introduction

Following an initial study of the downstream movements and mortality of juvenile alosids associated with passage through the Annapolis Royal Tidal Power Turbine (Stokesbury 1985), an extensive investigation was carried out between August 1 and November 22, 1986. The objectives of this study were:

1. To monitor the downstream migration of juvenile alosids;
2. To monitor environmental cues that might trigger the migration;
3. To obtain population estimates by capture-mark-recapture techniques;
4. To determine the real causes and extent of turbine mortality.

Methods

The study had three components. In the first a total of 130 shore seines was completed between August 12 and November 3. All but 8 seines were fished at station 3 which is located at the mouth of Evans Brook in the upper portion of the Annapolis headpond (Fig. 1). Seines were fished in a manner similar to that used in 1985 (Stokesbury 1985).

Fishing experiments with a purse seine and a push net were also performed. The purse seine was approximately 166 m long and 6.5 m deep, with a 1.5 cm mesh. The push net had a 1 m by 1.5 m wide mouth with a 1 cm mesh, and was attached to an A frame that could be lowered in front of an 5.5 m Eastporter. Both techniques had only limited success in capturing juvenile alosids.

The second component was a monitoring study that began August 6 and continued to November 14. Nets 3 and 3B were set on the seaward boom below the tidal power plant during generation as in 1985 (Stokesbury 1985). From October 30 to November 14 two 1 m diameter ichthyoplankton nets were set in front of the turbine. These nets (HPN 1 and 2) were used to monitor fish movement into the turbine at varying depths in the intake water column as well as providing net controls for nets 3 and 3B. Torpedo flowmeters were placed in all nets.

The third component was an experimental marking operation. Fish were collected from shore seines at station 3. They were transported in a 1 m diam x 1 m deep circular holding pen on board an Eastporter to a similar holding pen anchored off the Dunromin Campsite.

Fish were marked and put in nets 3 and 3B as controls. The whaler used to service these nets was equipped with a third holding tank, and fish were transported from the holding pen to the whaler in a 10 gallon bucket. The fish were then marked using a fluorescent granular pigment (30-350 μm diameter). This pigment was sprayed onto the fish's scales using a low pressure spray gun connected to a SCUBA tank . Some of the fish were then placed back in the holding pen while the rest were put in one of the two nets. Holding pen survival, tagging survival and net survival were all recorded over different time intervals. This method of net control was very efficient and accurate, however the shore seine catches were too small to obtain a large control sample. Therefore HPN nets were set to increase the control sample size.

All fish were identified, measured and examined in the field and selected subsamples of each species were preserved in 10% formalin. Autopsies were performed on all fish obtained from the monitoring nets in the second component of the study.

A diving survey on November 8 covered the area below the turbine where personal observations had indicated that dead adult alosids and herring tend to collect.

Results and Discussion

The Annapolis alosid juvenile population was very small in 1986. Only 103 shad, 11 blueback herring and 7 alewives were collected during the 130 shore seines. This compares with 196 shad, 943 blueback herring and 113 alewives in 48 shore seines at station 3 during the 1985 study. The shad were 5 mm smaller on average than those of 1985 while the blueback herring were 10 mm smaller. However, the majority of shad and blueback herring were caught between August 10 and August 30 in 1986 compared to September 17 of 1985 which is when the majority of fish were collected that year. The alewives were in a similar size range to those of 1985 but so few were sampled that it is dificult to compare the years accurately.

During monitoring of fish passage 20 shad, 46 blueback herring, and 11 alewives were collected. In 1985 the mean length of shad caught at the turbine was 95 mm which is 30 mm larger than the mean length for 1986 (65 mm). The blueback herring turbine catch of 1985 had a mean of 105 mm which is 40 mm larger than the blueback herring catch of 1986 (also 65 mm). There was less than a 5 mm difference in length between shad and blueback collected at station 3 in August 1986 and those collected at the turbine in October 1986 whereas the difference between these two sample groups over the same period of time in 1985 was 30 mm.

This strongly suggests that September 1986 was an extremely poor growth period for fish compared with 1985. In 1985 there was little rainfall, river flow was low, and the majority of days had clear and sunny skies. During 1986, however, there was a large amount of rainfall, little sunshine and a major increase in river flow. Temperatures were comparable (15-19°C) during the first part of September for both years. In 1986, however, water temperature decreased from 18°C to 13°C by September 18, whereas the latter temperature was not reached until October 4 in 1985.

The lack of growth over the month of September in 1986 compared to that of 1985 suggests that these climatic conditions either had a direct effect on the fish themselves, or an indirect one on the fish through their prey. Natural mortality can be assumed to be higher as well, due to the fact that growth in juveniles is a reflection of fitness. Hoar (1953)suggested that alosids have to reach a minimum size before downstream migration can occur. This could be at least partially the cause for the lack of a 1986 alosid migration. However it is probably not the sole reason.

The 1986 turbine samples were plotted against physical conditions as they had been in 1985 (Fig 2 and 3). All alosids were collected on the quarter (1st and 3rd) or new moon phases. The largest catches usually followed rainfall, but the largest rainfall of the season occurred during a full moon and no alosids were collected. The largest catch occurred when the temperature decreased sharply from 15°C to 10°C. In 1986 riverflow did not appear to play a major role as a cue for migration, although it may have had an effect on growth. These data are comparable to other downstream migration studies on alosid populations of the Eastern United States (O'Leary and Kynard 1985).

It was not possible to do a capture-mark-recapture population estimate in 1986 because of the lack of fish. A population estimate was therefore obtained by using an equation that relates number of fish collected in the plankton nets to water volume sampled by the plankton nets and compares it proportionally to total water volume which passed through the turbine. Table 1.

Table 1. Population Estimates for species which passed through the turbine during 1985 and 1986.

Species	Population Estimate	
	1985	1986
Alosids	83554	5319
Atlantic herring	9964	87156
Menhaden	270	3299
American eel	1751	1451
Rainbow smelt (yearlings and adults)	6868	11988
Lamprey	808	366
Atlantic silverside	26998	6530

Catchability is considered random in this case due to the extremely turbulent conditions in the tailrace of the turbine where these nets were set. These conditions may have an even greater effect on the fish because downstream migration of alosids has been observed to be passive and therefore is influenced strongly by water current (O'Leary and Kynard 1985). It is not known if the migration is passive in the Annapolis population.

Fishing experiments during 1985 suggested that the majority of fish are in the top five nets of the tailrace where the nets were set. This is due to extreme boils which upwell just in front of the boom. In the bottom five meters there is approximately 8% of the number of fish that are in the top five meters. The population estimate was ajusted to take this fact into account.

Natural mortality is another potential source of error. However, due to the short period of time it takes the migration to pass through the turbine natural mortality is insignificant. These estimates only reflect the alosid population that has passed through the turbine on fishing days. It is assumed that if fish are passing through the turbine a constant proportion of them is captured in the nets.

The fishway estimates agree with the percent usage from last year. In 1985 it was estimated that 0.2% of the fish were passing through the fishway. Multiplying this by the 1985 population estimate gives an estimate of 288 which agrees with the fishway population estimate of 210.

Transport and holding pen mortality were investigated by holding fish for varying lengths of time between 1 hour and 141 hours. A total of 169 fish were held, of which 16 died, giving a mortality estimate of 9.5%.

Mortality resulting from marking procedures was found to be 0 over a 1-hour period. Controls for nets 1 and 2 had a set time of 1 hour. Longer controls were not performed due to the lack of fish. From the HPN nets (set in front of the turbine) it was found that the % mortality increased with time in the net.

No significant difference was found between the proportions of different kinds of damage for the two different control net sets. The following table shows HPN and net 1 and 2 control data:

Table 2. Autopsy Data for fish in Control Nets.

	Alive	Dead	No vis. D.	Eye D.	Skull D.	Bruises	Gas B.D.
HPN	68	37	96	6	2	1	-
%	64.8	35.2	91.4	5.7	1.9	1.0	
Net	30	13	35	2	-	3	3
%	69.8	30.2	81.4	4.7		7	7
Total	98	50	131	8	2	4	3
%	66.2	33.5	88.5	5.4	1.4	2.7	2.0

No vis. D. - no visible damage - no external or internal sign of damage.

Eye D. - eye damage - blood in the eye.

Skull D. - Damage to the skull; crushed bone.

Bruises - cuts to the body, or damaged muscle.

Gas B.D. - gas bladder damage - the gas bladder is either swollen or completely burst.

Three fish in the HPN nets that were alive showed damage, 2 with eye damage and one with Bruises. They died in the holding tank less than 10 minutes after collection. There was no visible damage on any fish found alive in control nets 1 and 2.

From the flow meters that were attached to all the ichthyoplankton nets, water distance (m), speed (cm/sec.), and volume (m^3) were all calculated using formulae found in General Oceanics Digital Flowmeter Manual (1983). Then using speed (cm/sec.), pressure difference (g/cm^2) was calculated for each net using standard equations (Zooplankton Sampling 1968 pp.31-32). The calculated pressure difference was as follows: Net 1, 0.4332 g/cm^2; Net 2, 0.456 g/cm^2; HPN1, 0.178 g/cm^2; and HPN2, 0.183 g/cm^2. However there was no significant difference between the proportions of different types of damage to fish in the HPN nets and those of Nets 1 and 2.

When the proportion of damage between autopsied fish of 1985 and those of 1986 was compared using a t-test no significant difference was found. Thus the two years can be combined to give a sample size of 1920.

There was a significant difference between fish with no visible damage and the actual number of fish found alive in the control nets. It can therefore be assumed that fish with no visible damage were killed in the net. This assumption excludes the possiblity of suffocation, shock and other mortalities which do not show physical damage but may occur as the fish passes through the turbine. Using this assumption, and multiplying the control percentages by the autopsy data, estimates of mortality associated with passage through the turbine can be made. Results are in Table 3.

Table 3. Actual Turbine Autopsy Data
(Total # fish - estimated net kill)

	Alive	Dead	Red Eye	Eye Missing	Skull D.	Shearing	Body cut
	875	1045	568	50	113	23	12
%	45.6	54.4	54.4	4.8	10.8	2.2	1.1

	Bruises	Gas Bladder D.
	268	258
%	25.6	32.9

Thus turbine mortality is estimated at 54.4% for juvenile alosids when they pass through the tidal power turbine during their downstream migration. This estimate excludes mortality not caused by discernible physical damage or by predation on weakened or disoriented fish that have otherwise successfully passed through the turbine.

This mortality estimate is similar to many hydroelectric plant mortality estimates. Taylor and Kynard (1985) found turbine mortality to be 62% on the Connecticut River and Smith (1960) found turbine mortality to be 52.9% on the Tusket River.

A crash in a year class population such as the one in 1986 is not uncommon with alosids. Mansfield and Jude (1986) state that, " the ability of alewife populations to recover from castrophic mortalities in 1 or 2 years suggest that early survival is flexible and an important mechanism of population recovery." They found mean survival from yolk-sac larvae to young of the year was 1% and daily mortality rate of juveniles was 2-5%.

In 1985 the Annapolis River downstream migration of juvenile alosids was estimated at approximately of 84000 fish. In 1986 the population suffered a crash and the population was estimated at 5000. The downstream migration of alosids appears to be triggered by climatic changes such as rainfall, decrease in water temperature, and lunar phase. Further study is required in order to determine what climatic condition is the critical factor and whether it changes from year to year. Turbine mortality on each of these downstream migrations was estimated at 54.4%.This does not include mortalities that do not cause visible damage such as shock and predation. The danger to the alosid population in the Annapolis River occurs when these conditions plus adult mortality are accumulated. If the estimated 54% mortality caused by passage through the turbine on the downstream run is added to natural mortalities of 99% for the stage from yolk sac to young-of-the-year, to daily losses of 2-5% and adult mortality during the spawning migration, predation, fishing, and occasional crashes of entire year classes (as happened in 1986), the result may be that the population's ability to rejuvenate itself is exceeded. The population does have means to compensate for some of these mortalities (Mansfield and Jude 1986). Some rates of natural mortality may be reduced considerably because they are density-dependent. This means that as the population decreases the natural mortality on that population also decreases. The population may thus have a chance to recover back to its original size. Predation rates on larvae and juveniles may be examples of density-dependent mortality.

Considered independently, turbine mortality is a serious but not necessarily disastrous problem; when combined with other forms of natural mortality acting on the population it may constitute a serious threat to the existence of the alosid population in the Annapolis River. To ensure that this does not occur, remodeling of the now inefficient fishways, and employment of methods to detour fish passage from the turbine mouth, should be examined in the near future.

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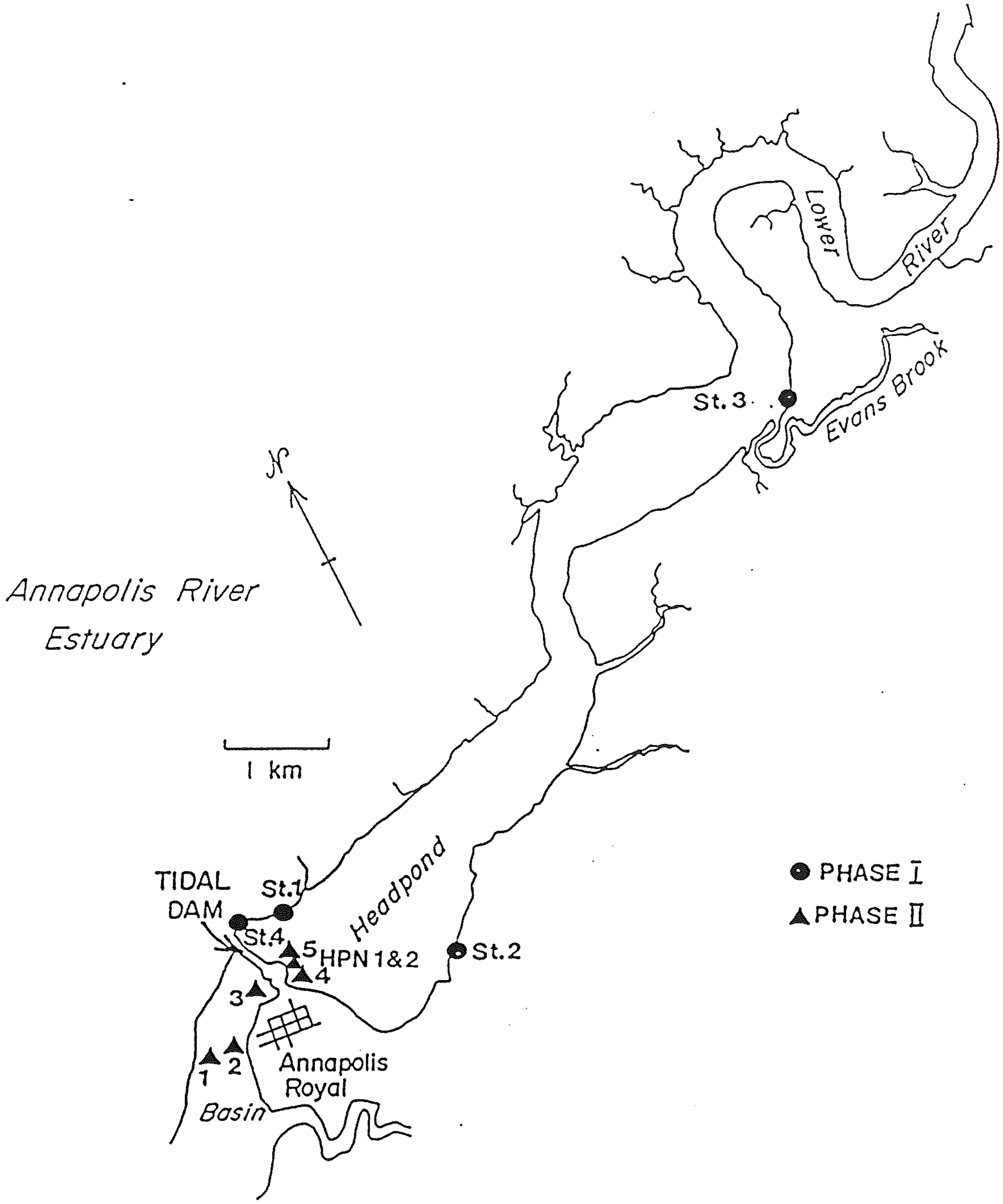

Fig. 1. Site Map Map of Annapolis River and Estuary

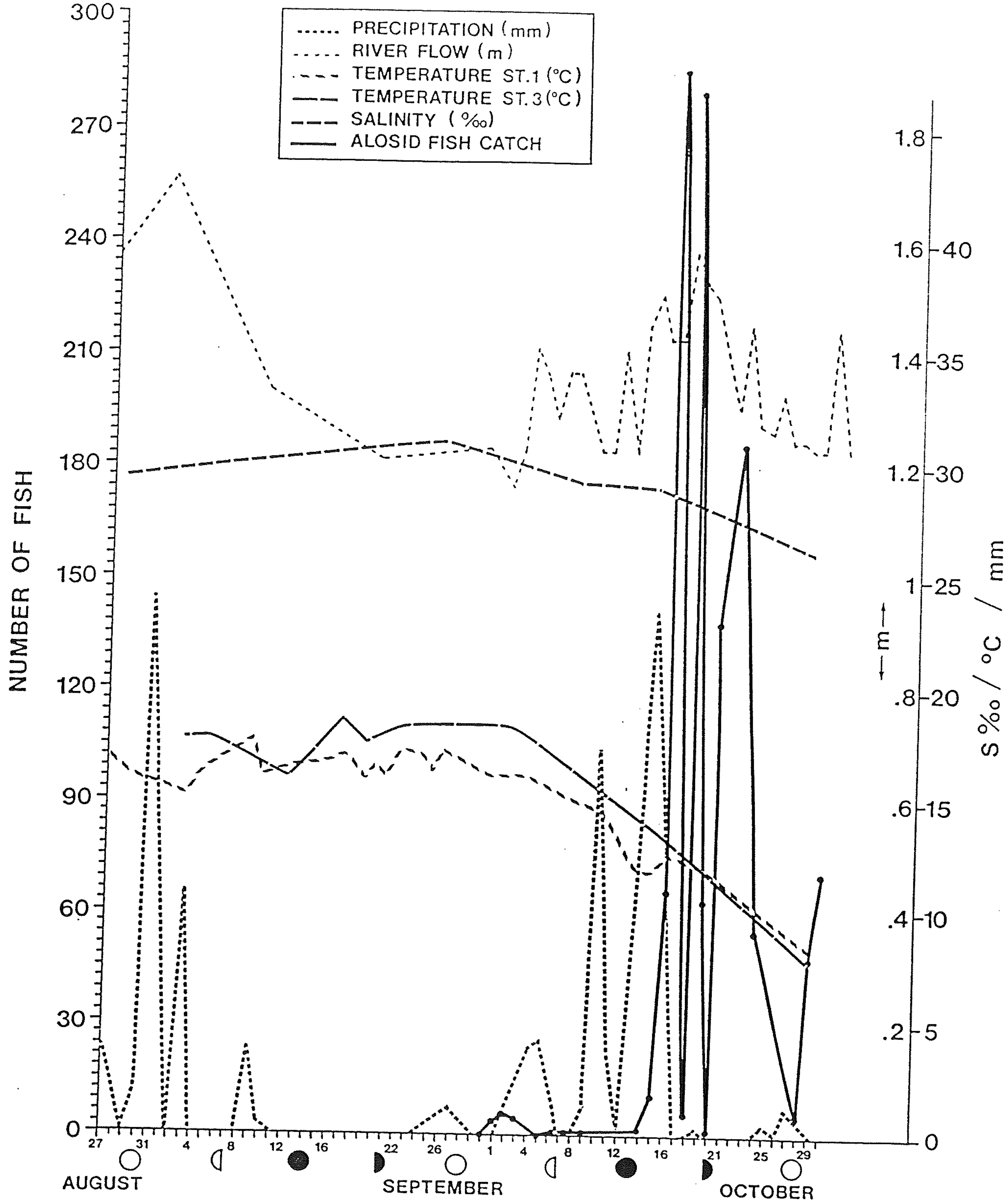

Fig. 2 Climatic Condition and Downstream Alosid Migration 1985

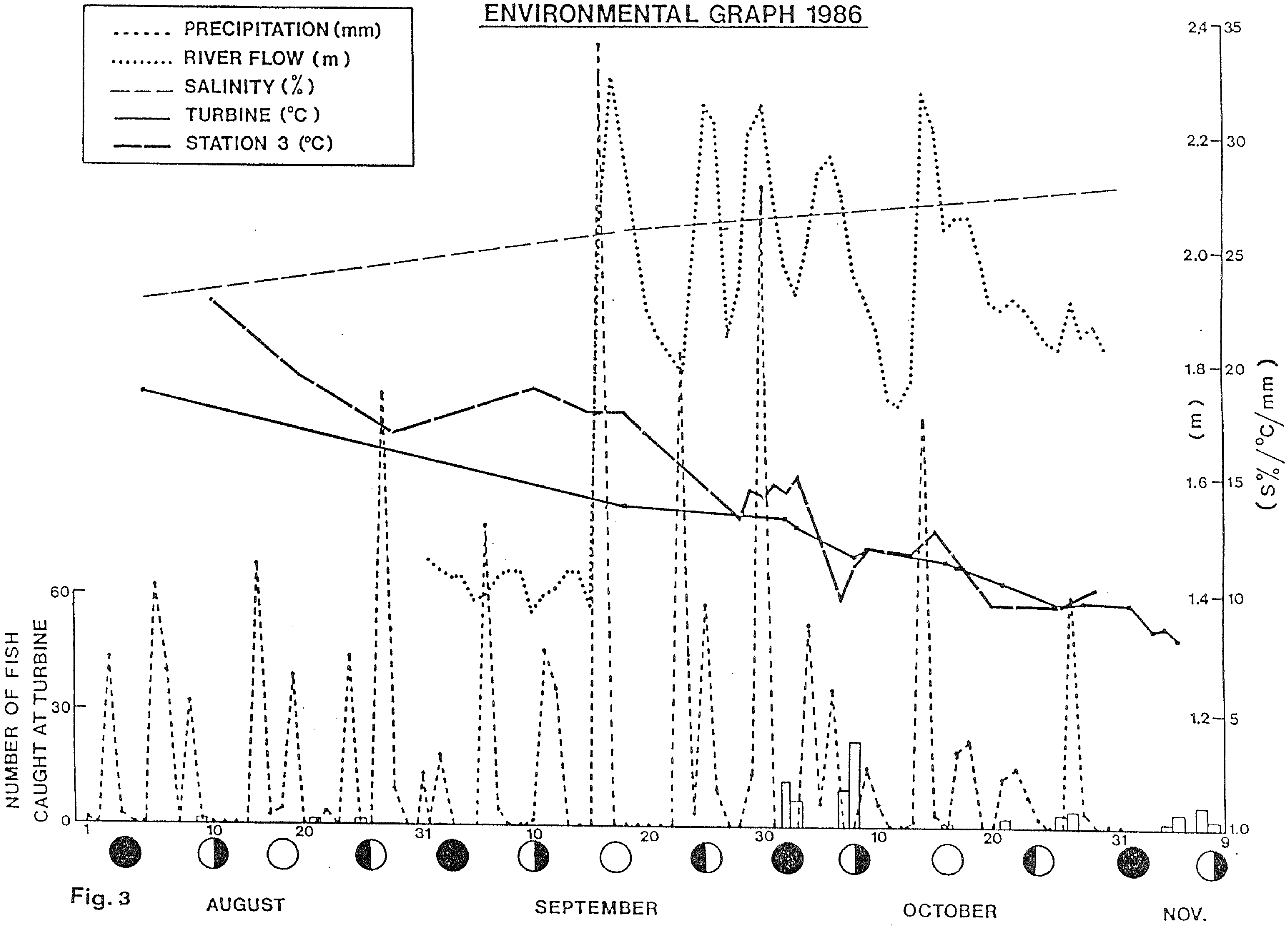

Fig. 3

Climatic Condition and Downstream Alosid Migration 1986