C.M.1968/M:9

Anadromous and Catadromous Fish Committee

Upstream movements of migratory salmonids in relation to river flows on the River Axe, Devon

by

A. Swain and A.S. Champion

(Salmon and Freshwater Fisheries Laboratory, Ministry of Agriculture, Fisheries and Food, London)

Introduction

For a number of years a counting fence has been in operation at the limit of tidal influence on the River Axe in Devon. This consists of a flat-topped underwater weir occupying sixty feet of river width. On this weir an apparatus of movable Wolf grilles is placed which captures descending fish and at the same time constitutes a barrier to upstream movement. At the end of this barrier is a corridor, with grilles on its river side, ending 25 feet upstream of the weir in a trap compound for ascending fish which gain access to it through re-entrant grilles with a vertical slit opening. The floor of the ascending fish trap is $2\frac{1}{2}$ feet below the weir top so that in dry weather flow conditions the entire flow of the river can be taken through the trap. The flows through the ascending fish trap, through the corridor grilles and over the weir can be regulated by various means; there is thus always an attracting flow passing down through the trap for ascending migrants, with a good depth of water even in the lowest of summer flows.

The annual runs of fish counted up through the trap vary from year to year and are between 250 and 500 for salmon and between 2,500 and 4,300 for sea-trout. The salmon run is mainly composed of 2 sea-winter fish and more than half of the sea-trout run consists of immature fish. The river flows vary from about 28 cusecs during a dry summer to around 2,700 cusecs with a mean average daily flow of 165 cusecs. The upstream trap is inspected at half hourly intervals and fish counted or marked, measured, sampled for scales and released upstream.

To date all studies of the factors affecting the upstream migration of salmonids have been complicated by the lack of detailed knowledge of the availability of fish in the lower reaches of the river or the extent of the

influence of fresh water in the sea. Thus the number of fish migrating upstream in response to a given stimulus cannot strictly be compared from one season to another or even in certain cases from day to day without certain assumptions being made about the number of fish in this catchment area. Neither the extent of this catchment area, which may vary with the wind and tide direction and also with the river flow, nor the availability of fish in the area is known for the River Axe so no attempt has been made here to treat the data mathematically. Instead a purely empirical approach has been made by plotting cumulatively the numbers of upstream migrants on the flow charts and noting where changes in the number per hour have occurred. In this way it has been possible to isolate some of the factors affecting upstream migration and to highlight seasonal variations in response where availability is not the limiting factor or where assumptions can reasonably be made about availability.

Discussion

Alabaster (personal communication) has shown that taken over the whole year flow and upstream migration of salmon in the River Axe may be considered as being distributed approximately log-normally; but that salmon generally select higher than average flows. If the data are examined on a monthly basis however, systematic deviations from log-normality are apparent especially in the summer months, when a significant number of fish migrate at relatively low flows. This is shown very clearly in the cumulative sum graphs for June and November, 1964, (Figure 1).

If the November curve is considered first it will be seen that the river was running at less than 105 cusecs for 610 hours; but that only 6 fish were passed through the trap during this time. In June the duration of these flows was similar but 39 fish were passed up showing clearly low water movements. If now the 140 cusec points are considered it will be seen that the numbers of fish for the two months in question are approximately equivalent and that the duration of flows is also of the same order. Further increase in the flow does

not lead to further increases in the rate of salmon migration expressed as number of fish counted per hour in November; the cusum graph remains strictly linear up to the maximum. In June however the rate increases steadily to the maximum flow (275 cusecs). This may be interpreted in two ways:- (a) availability of fish is much lower in June than in November thus depressing the upper part of the curve. (Low water movements as shown would also have the effect of lowering the availability of fish for high flows). (b) An increase in flow in November provides a greater stimulus than the same increase in June.

At this point some assumption must be made about availability. The upstream migration of salmon in the River Axe may be considered for the purpose of this study as composed of three separate "runs" ascending the river in spring, summer and autumn, the spring run ascending from March to the middle of July, the summer run (1 sea-winter fish) from the beginning of July until the beginning of December and the true autumn run (2 sea-winter fish) chiefly in October and November although some of these fish may enter the river as early as June. The peaks of these migrations appear to be in May or June, August and October or November respectively, thus the total availability of fish probably increases from virtually zero in January to a peak in July decreasing again in September with a further peak in October or November. Therefore June may be considered to have a lower availability of fish than November, thus explaining the shape of the upper part of the curve, particularly if the migration of about 50% of the June fish at flows below 105 cusecs is considered. If May is now assumed to have a smaller availability of fish than June, the following table shows that the fish are only responding to higher flows than in June. Applying the same line of reasoning to April still fewer fish are available but these select even higher flows, whilst in February and March fish movement is only recorded during very high flows. In July and August many fish migrate at flows less than 50 cusecs but as will be shown later a large response is possible to a small spate. Normally few fish migrate in September even if there is a spate, this adds support to our

assumption concerning availability. The runs of salmon in October and November (generally these are the months in which the biggest runs occur) appear to be related since if high flows occur in October large runs of fish are sometimes recorded to the detriment of the November and December runs. In 1964, however, the availability of fish in October apparently remained low because although high flows occurred few fish ascended until November and to a lesser extent December.

Monthly % availability of flows less than those shown, 1964.

	Flow (cusecs)				
	50	140	275	595	1,440
January		83	100		
February		71	88	98	100
March		33	66	83	95
April		19	97	100	
May		46	97	99	
June	22	90	99	100	
July	67	100			
August	72	100			
September	80	100			
October	76	97	99	100	
November	50	91	98	100	
December	19	72	86	93	97

No. of Salmon migrating at flows shown above

January		0	0		
February		0	0	4	4
March		0	0	3	3
April		1	9	20	
May		8	22	35	
June	3	48	67	71	
July	20	24			
August	14	27			
September	2	4	+ 5 at unknown flow (less than 140 cusecs)		
October	6	10	18		
November	2	39	91		
December	3	14	35	43	43

As this juncture it is necessary to comment in more detail on low water movements in the summer. Data for the time of passage of upstream migrants through the trap in June, 1967 has been utilised in compiling the graph (Figure 2) showing diurnal movement. During this period the flow did not rise above 105 cusecs and it is easily seen that most of the fish were passed up during the hours of darkness. It is also noteworthy that a significantly greater proportion migrated in the late evening than the early morning; this may be a temperature effect but it is considered to be more possibly due to the shadow cast over the river and particularly across the corridor leading to the trap by the high western bank of the river.

It has not been possible to isolate any one factor regulating these nightly movements, rather it is thought that certain combinations of temperature, tide and rainfall may be necessary to induce fish movement. Certainly a heavy rain shower with no concomitant increase in flow is frequently associated with an increase of fish movement the following night. High (Spring) tidal conditions also appear to promote upstream migration and on occasion an increase in the sea-trout run seems to be associated with rapidly falling barometric pressure; but any of the above changes does not necessarily guarantee nightly migration and these movements may be more closely linked to other nocturnal behaviour patterns. This aspect of fish movement is considered to be very important in spite of the lack of information regarding the causative factors, since in large rivers without obstructions or shallow water near their mouths a high proportion of the salmon, and possibly nearly all the sea-trout, may ascend far up towards the head-waters without the aid or attraction of a spate.

It has already been demonstrated that light intensity limits the movement of fish under low water conditions. If now three isolated floods are considered in detail (Figures 3, 4 and 5) it can be shown that the effect of the time of day in restricting fish movement decreases with increasing flow and with the time of year. In the period November 13th-18th 1964 for instance

there are no stepwise increases denoting diurnal variation in movements in the period following the first spate. In the graphs for July 1967 and August 1962 these are apparent for the sea-trout and in July 1967 for the salmon; also, during the spate on August 7th 1962 and July 23rd 1967 marked reductions in the rate of migration of both salmon and sea-trout occurred, in the period shortly before noon.

The problem of comparing spates is amply demonstrated again by considering the three small rises in November 1964. Salmon movement was initiated by the first freshet, quickly reached a maximum level and ceased after the river had returned to normal, a further small rise again initiated migration but at a considerably lower rate, on the third rise only two salmon were counted up. This effect can again be explained simply by a lower availability of salmon during the two later rises; but if the curve for large sea-trout is examined it will be seen that only the first rise was effective in promoting migration and that thereafter the fish ran at a fixed rate regardless of water conditions. Note also that small sea-trout do not respond to changes in flow throughout the November period, and that during both the summer spates, in July and August, a marked decrease in migration rate is noticeable during the run-off but that the rate increases again as the river falls to near its former level.

Large numbers of fish of either species have never been passed through the trap at very high flows. This statement requires some amplification since there is evidence that fish do run under these conditions; during very heavy spates the descending fish trap is sometimes lowered to avoid damage to the installation from too great an accumulation of trash on the structure; on these occasions, heavy escapements of fish can occur (in 1967, 90 fish were estimated from the subsequent kelt run to have passed through the trap during 28 hours in October when the trap was damaged) yet no heavy runs of fish have been recorded during the successful fishing of such spates. This could indicate that the trap for ascending fish is less efficient at very high flows, and the circumstances under which it becomes impossible to work the trap must be considered;

these are, a very high spate, rising very rapidly and bringing down a very large accumulation of weed and trash, such as occurs only after long dry periods in the summer and autumn when the fish are by assumption present in large numbers in the coastal area. Thus after the grilles of the descending fish trap are lowered, invariably before the peak of the spate when the fish have not yet started to run, a large escapement can occur. If, however, a very high spate is fished successfully, this is normally due to the fact that one or more smaller spates have already cleared most of the accumulated debris and, of course, most of the fish.

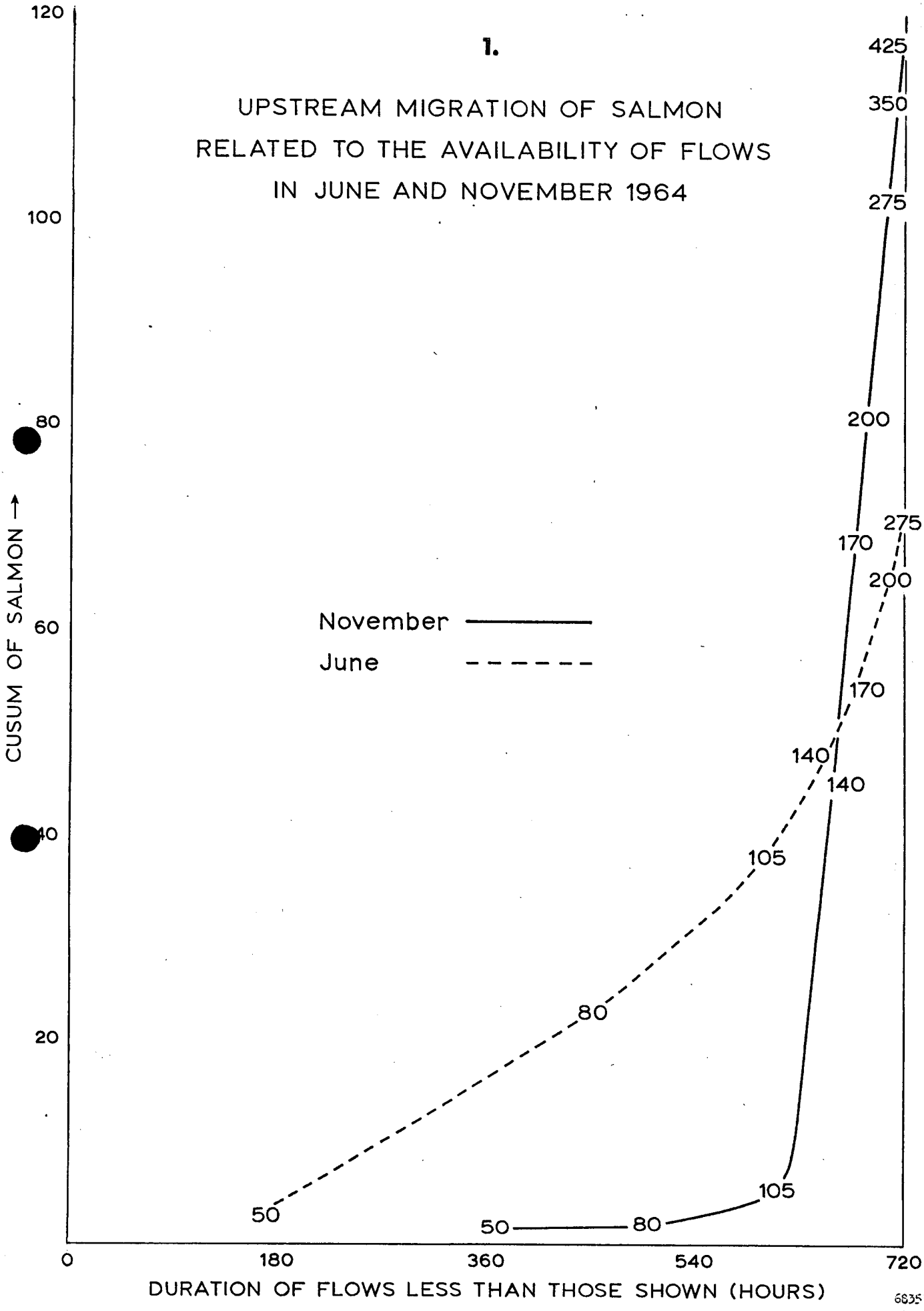
One common feature stands out from the cumulative curves in figures 3, 4 and 5, of both salmon and large sea-trout; namely, that whenever an increase occurs in the rate of migration (defined as the number of fish passing through the trap per hour) associated with extra water in the river, once the "run" has started the rate remains constant regardless of the flow until curtailed by daylight, shortage of fish or possibly weakening of the stimulus. It may be significant that the duration of the three salmon runs here considered is similar and that in view of this and the apparently constant migration rate once the run has started more attention should be paid to the possibility of a response to a change in dissolved substances in the water rather than a direct response to change in flow.

Conclusions

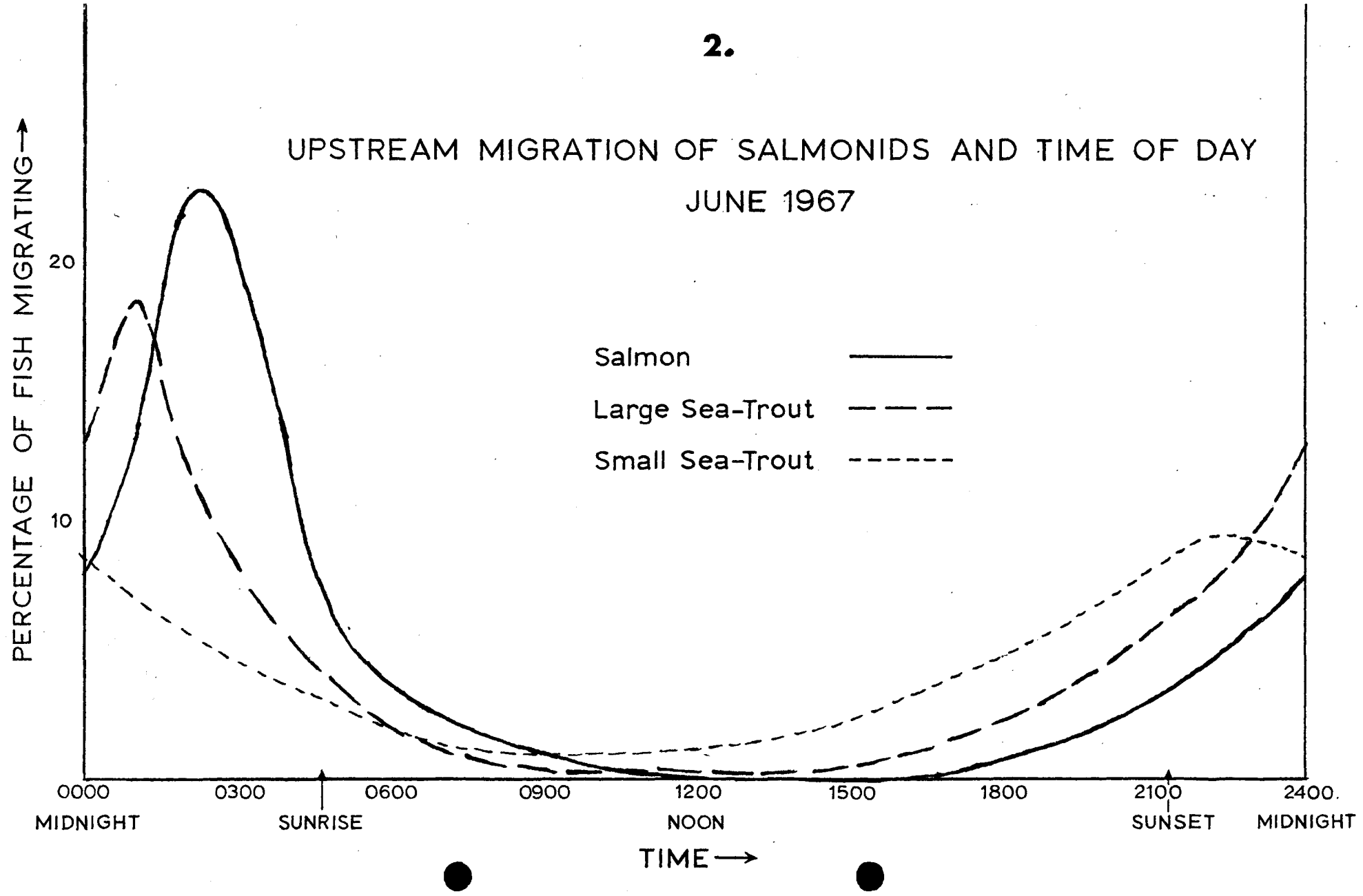
1. Appreciable numbers of salmon and large sea-trout migrate through the trap at flows less than 65% of the average daily flow; but these movements mainly occur at night during the summer months.
2. If the fish are available an increase in flow due to rainfall tends to initiate a "run" of fish.
3. Higher flows are necessary to initiate a run in the spring than later in the year but thereafter low or median flows are used by the fish and in the winter the high flows as well as the median flows are utilised.
4. Once the "run" has started in response to an increse in water flow the rate of migration, defined as the number of fish per hour passed through the trap, remains constant for up to two days regardless of changes in flow and, due to unknown factors, ceases before the river returns to its original flow.

1.

UPSTREAM MIGRATION OF SALMON RELATED TO THE AVAILABILITY OF FLOWS IN JUNE AND NOVEMBER 1964

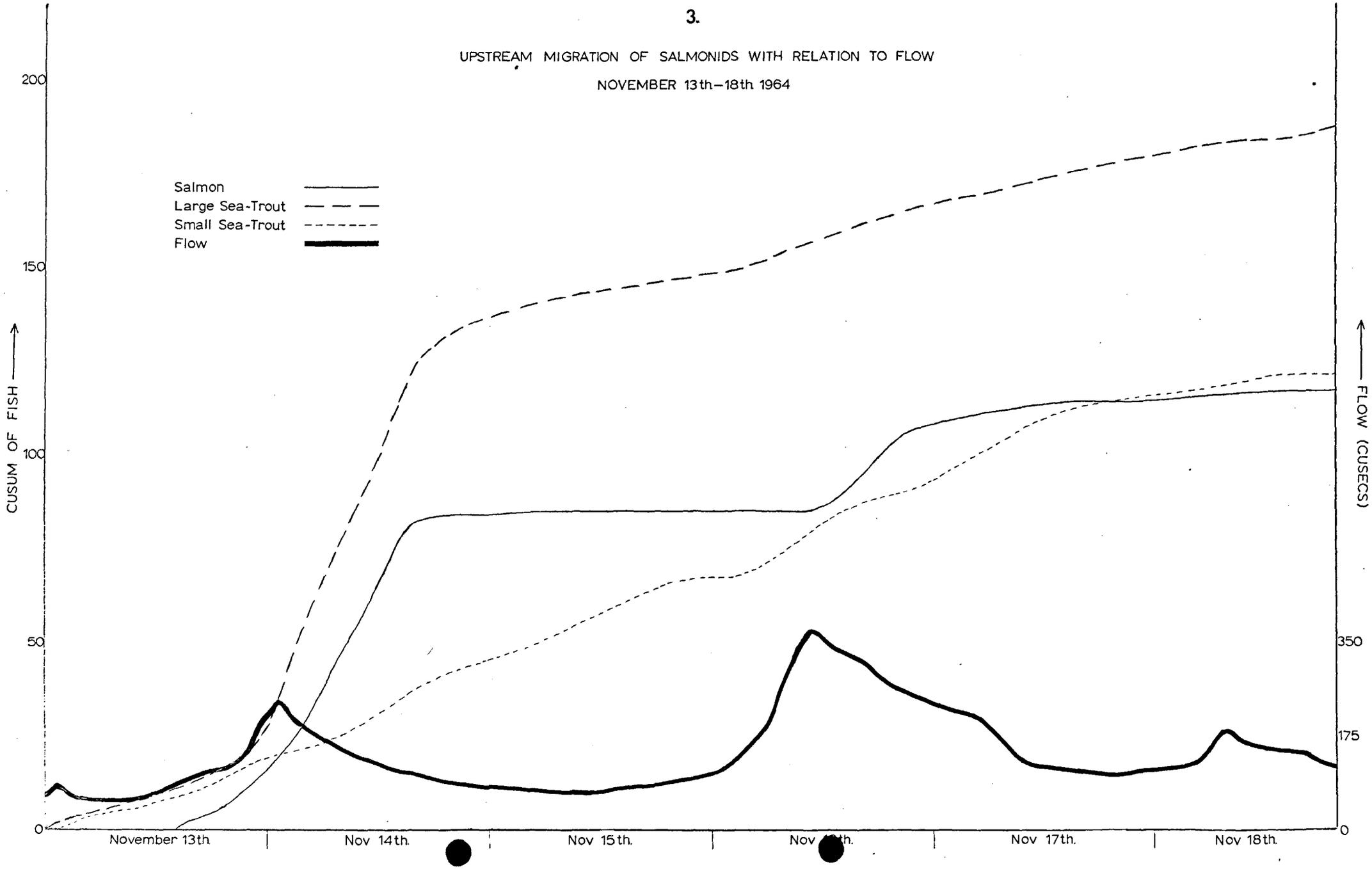


683514


UPSTREAM MIGRATION OF SALMONIDS AND TIME OF DAY
JUNE 1967
PERCENTAGE OF FISH MIGRATING→
20
10
Salmon
Large Sea-Trout
Small Sea-Trout
0000
MIDNIGHT
0300
SUNRISE
0600
0900
1200
NOON
1500
1800
2100
SUNSET
2400.
MIDNIGHT
TIME→

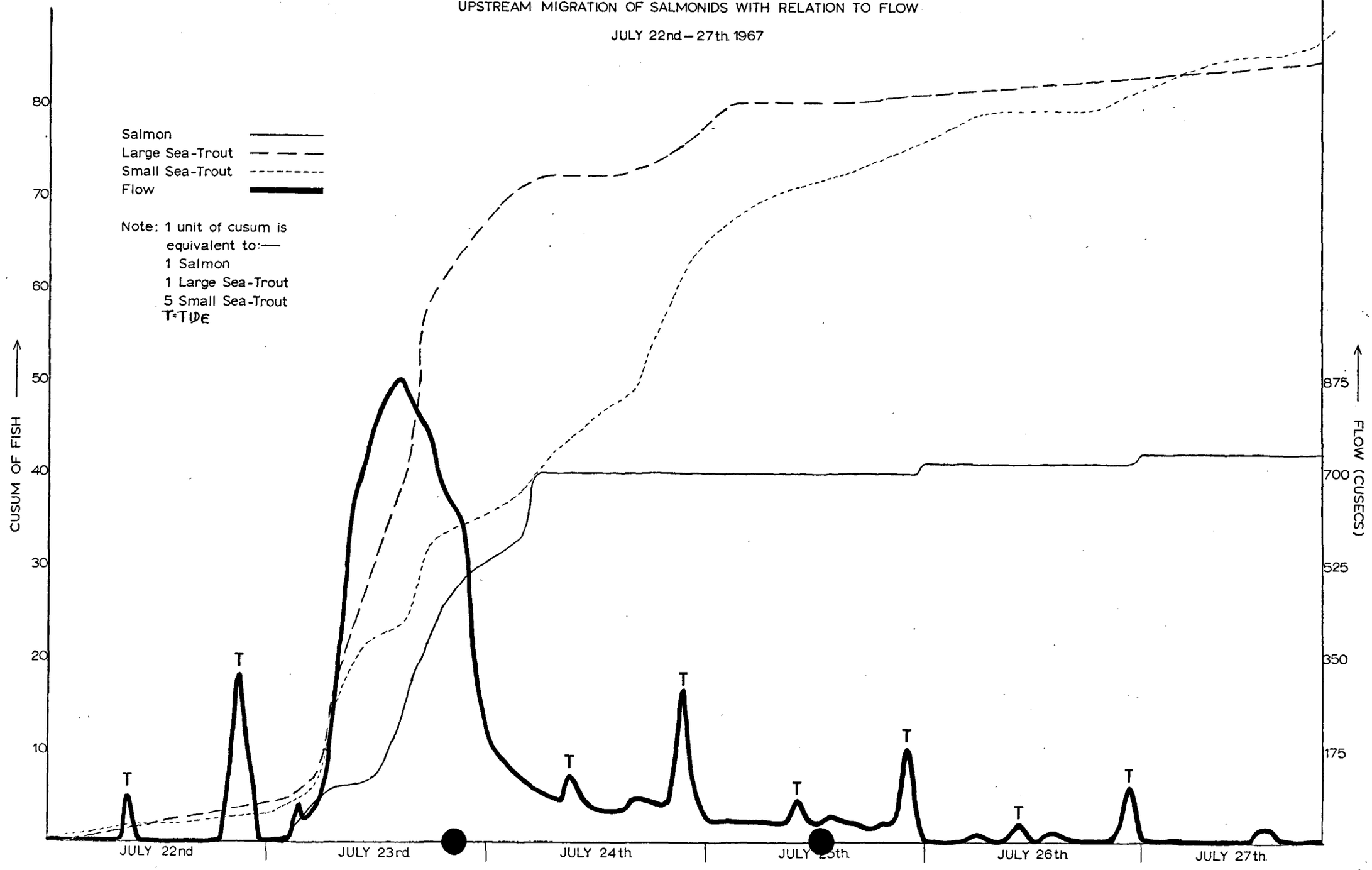
UPSTREAM MIGRATION OF SALMONIDS WITH RELATION TO FLOW

NOVEMBER 13th–18th 1964



UPSTREAM MIGRATION OF SALMONIDS WITH RELATION TO FLOW

JULY 22nd – 27th. 1967



UPSTREAM MIGRATION OF SALMONIDS WITH RELATION TO FLOW

AUGUST 5th—10th. 1962