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Shellfish and
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Summary

This account is a part of an assessment of the shrimp resources around Scotland. The fishery for brown shrimps /Crangon crangon (L.)/ from Annan on the Solway Firth is the only shrimp fishery in Scotland and employs six boats using beam trawls.

The biology of the brown shrimp in the Solway Firth is described. The sex ratio varies seasonally, males being most abundant in the autumn and almost absent in the late winter. Females become egg-bearing at a size of 8-9 mm carapace length. Egg laying commences in the late autumn and the proportion of berried females increases to a peak of some 80% in the spring, after which it decreases to zero in the early autumn. The mean size of males is smaller than that of females throughout the year.

The abundance of shrimps varies seasonally, showing two peaks, in the autumn and spring, with intervening periods of scarcity in the winter and late summer. These changes are reflected in the catch per unit effort of the commercial boats. Fishing ceases in the winter.

The gear used in the fishery is described, including an interesting development of the Dutch "double-decker" shrimp trawl. The lower cod-end has been dispensed with, leaving instead a hole through which fish and rubbish are allowed to escape.

Introduction

As part of an assessment of the shrimp resources of the waters around Scotland a study is being made of the only existing Scottish shrimp fishery, that for the brown shrimp based on Annan in the Solway Firth. The present paper sets out the preliminary data so far available.

Over the period 1963-1966 the average annual yield of the fishery was some 2475 cwt (125, 700 kg), valued at £12,300. Fishing occurs usually in the shallow upper reaches of the Solway Firth, in the Newbie-Southerness area, but also further west, in depths of 6-12 ft (1.8-3.7 m). Formerly (see Fullarton, 1899; Williams, Perkins & Hinde, 1965) the best area was off Newbie, but changes in the sand banks and channels have resulted in a movement of the shrimps, accompanied by a shift in emphasis from Annan to Silloth as the chief port. At present some 10-12 boats fish from Silloth. The boats, at present six in number at Annan, are 30-34 ft (9.1-10.4 m) long and draw only 3½-4 ft (1.1-1.2 m) owing to the shallowness of the water. The boats are powered by engines of 27-36 h.p., have a crew of one or two men, and each tows one beam trawl 18-20 ft (5.5-6.1 m) wide.

The net is towed for up to 1½ hours in each haul and the catch is then sieved to remove small shrimps, fish and rubbish (see p. 4). The retained shrimps are boiled on board the boat. On being landed, the shells are removed in "pickeries" and the meats sent to a factory for processing.

Material and Methods

During the period October 1962-December 1963, in the course of his studies in the Solway Firth, Dr E.J. Perkins (then of the United Kingdom Atomic Energy Authority) made trawl hauls at the five stations shown in Fig. 1. Wherever possible hauls were made monthly at each station, though there are some gaps in the records. The trawl used was an 18 ft beam trawl of courlene netting, 75 rows per yard throughout, except the cod-end, which was 80 rows per yard. Dr Perkins kindly made the shrimp catches available to the Marine Laboratory, where they formed the basis of a study of the biology and seasonal abundance of the shrimp. In addition, catch/effort data of the commercial landings of five boats were provided by Scottish Seafoods Ltd., Annan, and net and sieve selection have been studied by direct observations at sea on commercial boats.

Biology

A sample of approximately 100 shrimps was examined in detail from each station, and the seasonal cycle determined by combining all these. The carapace length (rear of eye socket to rear of cephalothorax) was measured to 0.1 mm and total length (tip of rostrum to tip of telson) to 1 mm accuracy. The relation between the two over the range of carapace lengths 5.0–17.1 mm is given by the equations

$$\text{Males} \quad T = 8.1 + 3.9\,C$$

$$\text{Females} \quad T = 6.1 + 3.9\,C$$

The sex of each individual was determined by an examination of the secondary sexual characters of the pleopods. It is possible to do this in individuals with a total length of 20 mm (C.L. = 3.5–4.0 mm) (Lloyd & Yonge, 1947; Meredith, 1952), and few or no specimens smaller than this were retained by the trawl. The results are presented in Fig. 2, which shows the size distribution (carapace length), sex-composition and proportion of berried (ovigerous) to non-berried females in each month).

The sex-ratio varied seasonally (Fig. 3). Males made up 68% of the catch in October 1962, but the proportion fell steadily to a minimum of 3% in March. Males particularly are unable to withstand low temperatures combined with low salinities (Lloyd and Yonge, 1947), and this minimum might be accounted for by a differential migration of males into deeper water, or by a lower activity or higher mortality in males than in females. The proportion of males began to increase later in the spring as the new brood entered the catches (Fig. 2) and rose to over 60% in October and December 1963.

Females appear to attain maturity (as shown by egg-bearing) at a size of 8–9 mm carapace length. Berried females were present in the catches at most times of the year (Fig. 2). Egg-laying commenced in the late autumn of 1962, and the proportion of females of carapace length $\geq$ 9 mm carrying eggs increased steadily throughout the winter to a peak of almost 80% in April 1963 (Fig. 4). It decreased during the spring and summer until no berried females were found in September and October. They reappeared in November 1963 and increased in December. Fig. 4 shows no sign of the two spawning periods per year found in *Crangon crangon* in the Bristol Channel and Severn estuary by Lloyd and Yonge (1947) and in the Welsh Dee estuary and Morecambe Bay by Meredith (1952).

The new brood of small shrimps, presumably arising from the eggs borne in the winter, appeared in the catches in the spring at a carapace length of 4-6 mm (Fig. 2). Males were smaller than females at all times of the year, and both were at their lowest mean size in the spring and summer after the influx of the new brood (Fig. 5). Few males were found with carapace length 10 mm or greater and the largest was 13.5 mm, while females 14 mm and over were common and the largest found was 17.5 mm (Fig. 2). Lloyd and Yonge (1947) found that during the first year of life, the growth rates of the two sexes are similar, though subsequently females grow more quickly. Meredith (1952) further suggested that there is a greater mortality of males and that females live at least a year longer. A further possible hypothesis is that there is a change of sex from male to female, though, like Meredith, I failed to find any evidence of this from examining either the gonads or the pleopods.

Seasonal abundance

The duration of trawl hauls at the five stations varied from 10 to 32 minutes, though most were of 15 minutes. The catches of shrimps were standardised as numbers taken per 15 minutes' fishing and subjected to statistical analysis by Mr W. B. Hall, to whom my thanks are due. The data were very variable, ranging from several blank hauls to catches of over 7000 shrimps. To offset this variability logarithms of the catches have been used. The data for September 1963 have been discarded as only one station was sampled. The seasonal data were averaged over the five sampling stations. Fig. 6 shows that there was a continuous drop in abundance from October 1962 to a minimum in February 1963. This was followed by an increase to a peak in July, a suggestion of a decrease in August, a further rise to a peak in October and then a decline. Analysis showed that the seasonal pattern was constant at the five stations, but there were significant differences in abundance ($P < 0.05$) among areas, shrimps being most abundant at Ellison Scar, falling to minima at Newbie and North Workington Bank (Fig. 7).

These seasonal differences in abundance are reflected in the catch of shrimps of commercial size (sieved) which are landed per unit of fishing effort by the Annan boats. These data (Fig. 8) are expressed as stones of shrimps landed per boat per day (1 stone = 6.35 kg). The data for 1964-1966 show even more clearly the two maxima (May-June and October-November) and two minima (winter and July-August) each year. As a result of scarcity of shrimps, coupled with adverse weather, fishing is usually abandoned during the winter months.

The winter minimum might be accounted for by an offshore migration such as was found in the Severn estuary by Lloyd & Yonge (1947), resulting from the susceptibility of the shrimps, especially males, to low salinities combined with low temperatures. Certainly the minimum bottom salinities at three of the stations, Newbie, Silloth and Ellison Scar, are sufficiently low (less than 16‰) to make this feasible (Perkins, Bailey & Williams, 1964). Alternatively it might be due to reduced activity of the shrimps or mortality induced by unfavourable conditions.

It seems most likely that the summer minimum results from the death of larger shrimps, such as was found by Meredith (1952), and the subsequent increase in numbers from the new brood growing to a size at which it enters the landings.

Nets and sieve-selection

Until recently all shrimp fishing from Annan has been by means of the traditional beam trawl, 18-20 ft (5.5-6.1 m) wide and some 24 ft (7.3 m) long, typically with a mesh 75 rows per yard (approx. 24 mm mesh) throughout, except the cod-end, which is 80 rows per yard (approx. 23 mm mesh).

There might be a blinder, or screen, inside the net about 7 ft (2.1 m) in front of the cod-end to catch the larger fish, chiefly plaice and dabs. The shrimps, together with smaller fish (young flatfish, gobies, Agonus, sprat etc.), shore crabs and rubbish such as leaves and twigs, pass into the cod-end. Most of the unwanted objects, which often constitute a large part of the contents, are removed by a shaking through a "crab riddle" with meshes of chicken wire 1½ x 1 in. (38 x 25 mm). The residue, almost entirely shrimps, with a few very small fish, is then shaken through a so-called "threepenny riddle", which has rectangular spaces ¼ in. (6 mm) wide and allows small, unwanted shrimps to escape. The selectivity of a "threepenny riddle" is shown in Table 1. The 50% selection point is at a carapace length of about 8.8 mm.

Recently the new Dutch net described by Boddeke (1965) has been tried at Annan. This has two cod-ends, one above the other, the part of the roof of the tunnel leading to the lower cod-end which forms the floor of the upper cod-end, being of large mesh (48 mm) so that shrimps, which jump off the bottom, can easily pass through into the upper cod-end, where they are retained by the small meshes. Fish are retained in the lower, large-mesh (75 mm) cod-end, and the smallest escape together with crabs and rubbish.

Mr G. Willacy, of Scottish Seafoods Ltd, Annan, adapted this net for the M.B. "Florence Elizabeth" but retained a small mesh (20 mm) for both upper and lower cod-ends in order to assess the quantities of shrimps which would be lost through a large-mesh lower cod-end: the roof of the lower cod-end being still of larger mesh (50 mm) in order to allow shrimps still to pass upwards. In April 1966 an observer from the Marine Laboratory watched the net in action and noted the quantities of shrimps in both cod-ends in five hauls of 1-1½ hours' duration. The results were as shown in Table 2. The catch in the upper cod-end was almost pure shrimps, but that in the lower cod-end was largely of fish, crabs, leaves and twigs, with shrimps scattered through them.

At first the small proportion of shrimps retained in the lower cod-end were sorted from the rubbish and kept. This was, however, laborious and it was decided to leave the lower cod-end open and allow its contents to escape. The time saved in sorting has made more time available for fishing. A later development has been to cut out the lower cod-end altogether, but to have a large-mesh (50 mm) blinder running obliquely backwards and downwards in the tunnel of the net, with a hole in the belly just in front of it to allow fish and other rubbish to escape (Fig. 9); the shrimps pass through the blinder into the fine-mesh (20 mm) cod-end.

While an observer was on board the "Florence Elizabeth" in October 1967 the escape hole was laced up to determine what would have escaped; this amounted to 22 kg of fish and other rubbish and only 0.3 kg of shrimps. The cod-end contained 75 kg of shrimps, which on sieving yielded 32 kg of marketable shrimps, and only 8.5 kg of small fish.

This indicates that few shrimps and much fish and other rubbish are lost through the escape hole. Indeed, so effective is the method that it has been found possible to dispense with the crab riddle. Most of the Annan boats are now using the modified net and the skippers say their daily catch of shrimps has increased.

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TABLE 1

Selection of shrimps by the "threepenny riddle"

Carapace length (mm)	No. retained by riddle	No. escaping through riddle	% retained
4	-	1	0.0
5	-	41	0.0
6	-	171	0.0
7	-	101	0.0
8	-	42	0.0
9	36	22	62.1
10	80	20	80.0
11	73	6	92.4
12	19	-	100.0
13	3	-	100.0
14	2	-	100.0
15	1	-	100.0

TABLE 2

Catch of shrimps in the upper and lower cod-ends of the Dutch-type modified trawl; M.B. "Florence Elizabeth", April 1966

Haul No.	1	2	3	4	5	Total
Wt of shrimps in upper cod-end (kg)	15.9	19.1	15.9	12.7	12.7	76.3
Wt of shrimps in lower cod-end (kg)	1.6	4.8	7.9	4.8	4.8	23.9
% of shrimps in upper cod-end	91	80	67	73	73	76

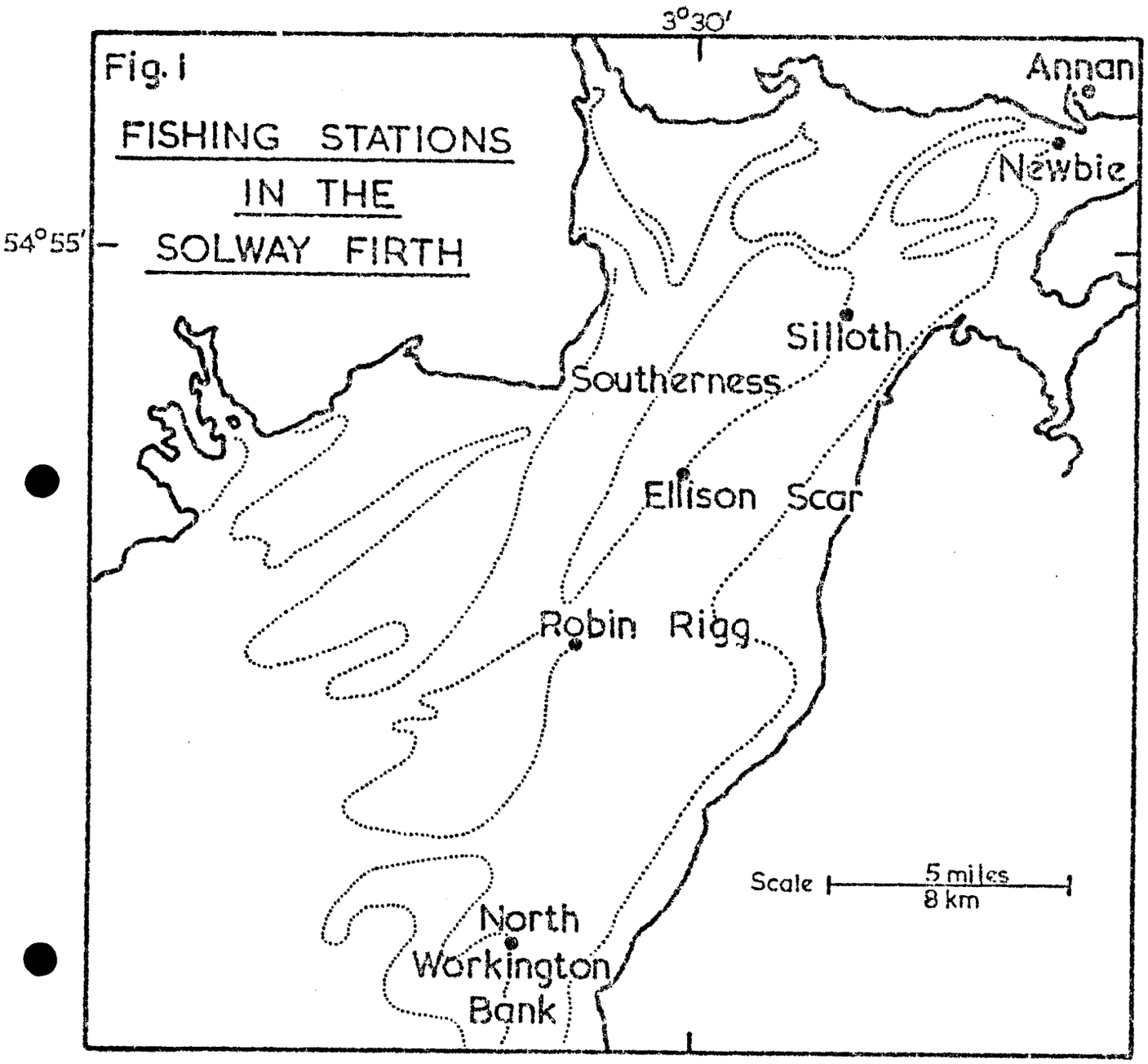
Fig. 1
FISHING STATIONS
IN THE
SOLWAY FIRTH
3°30'
54°55'
Annan
Newbie
Silloth
Southerness
Ellison Scar
Robin Rigg
North
Workington
Bank
Scale
5 miles
8 km

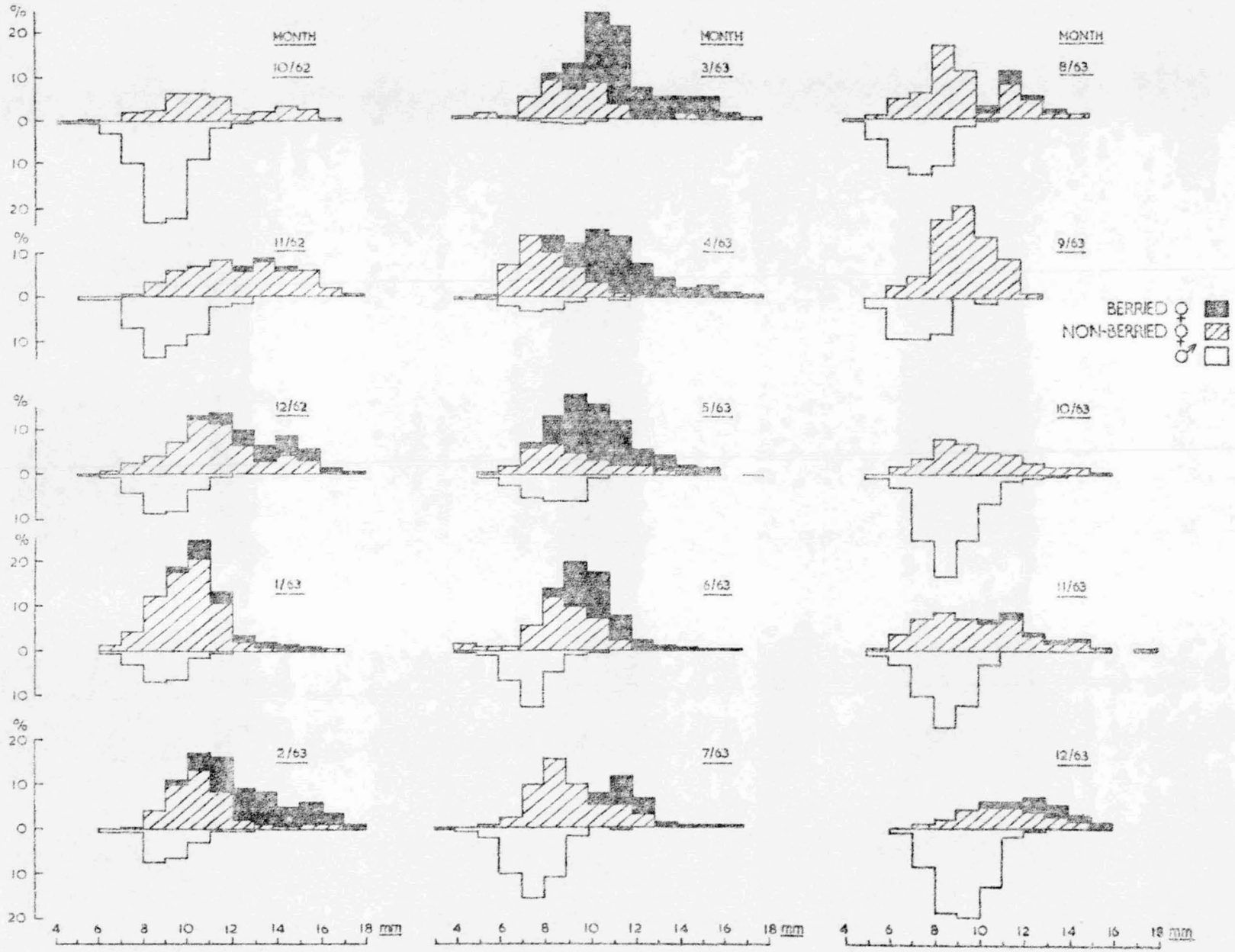

FIG. 2. LENGTH FREQUENCIES OF SHRIMPS IN MONTHLY SAMPLES (all areas combined)

Fig. 3 PERCENTAGE OF MALES IN TOTAL CATCH.

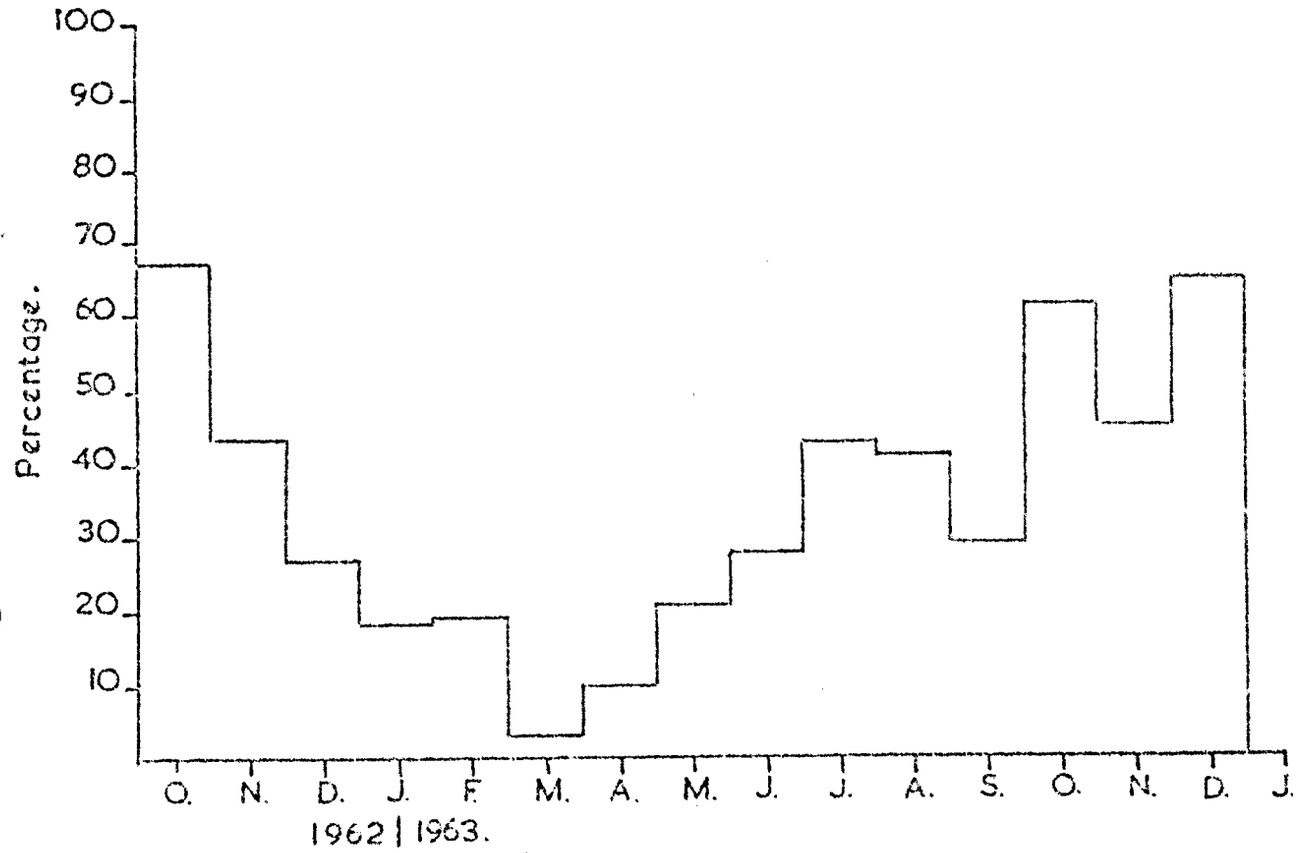

Fig.4. PERCENTAGE OF FEMALES ≥ 9mm CARAPACE LENGTH CARRYING EGGS.

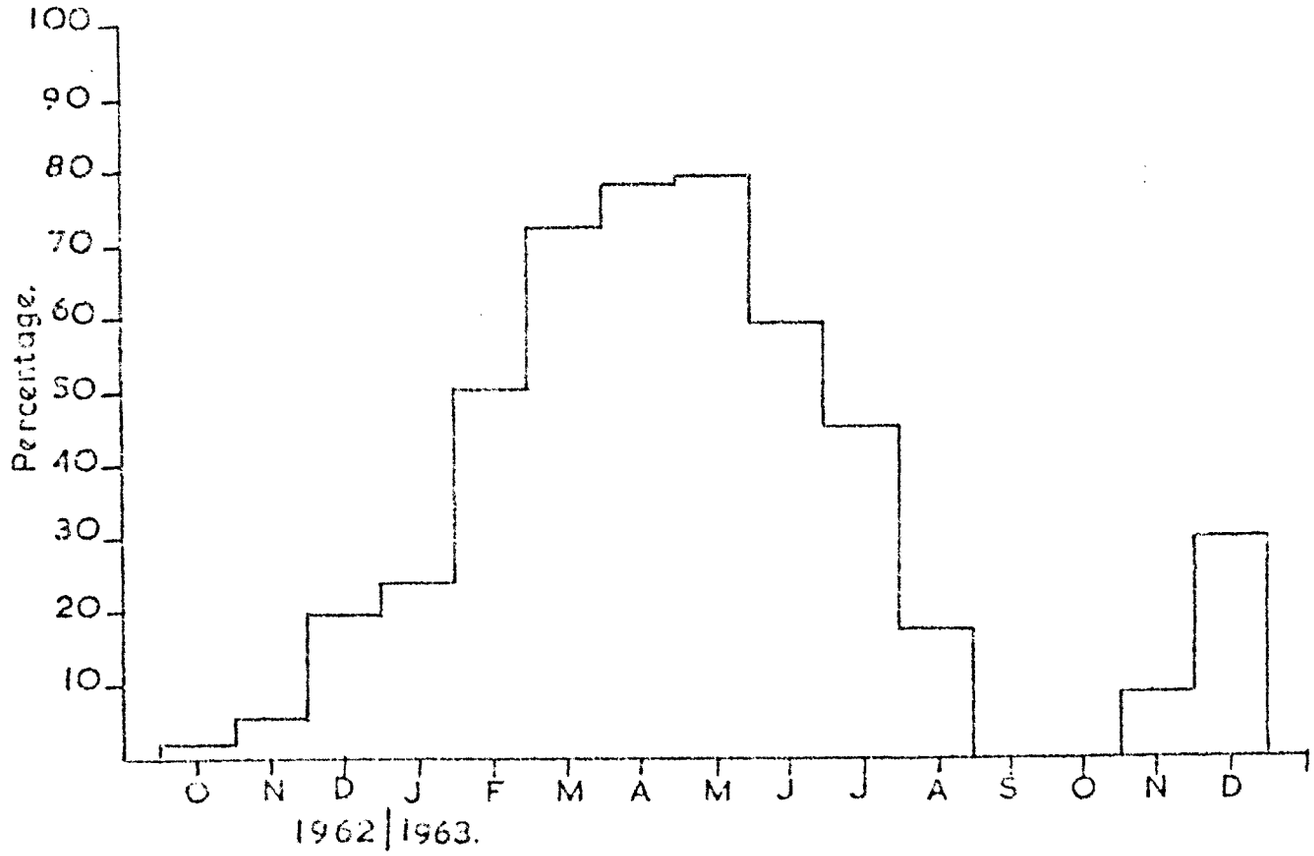

Fig.5. MEAN CARAPACE LENGTHS OF MALES AND FEMALES.

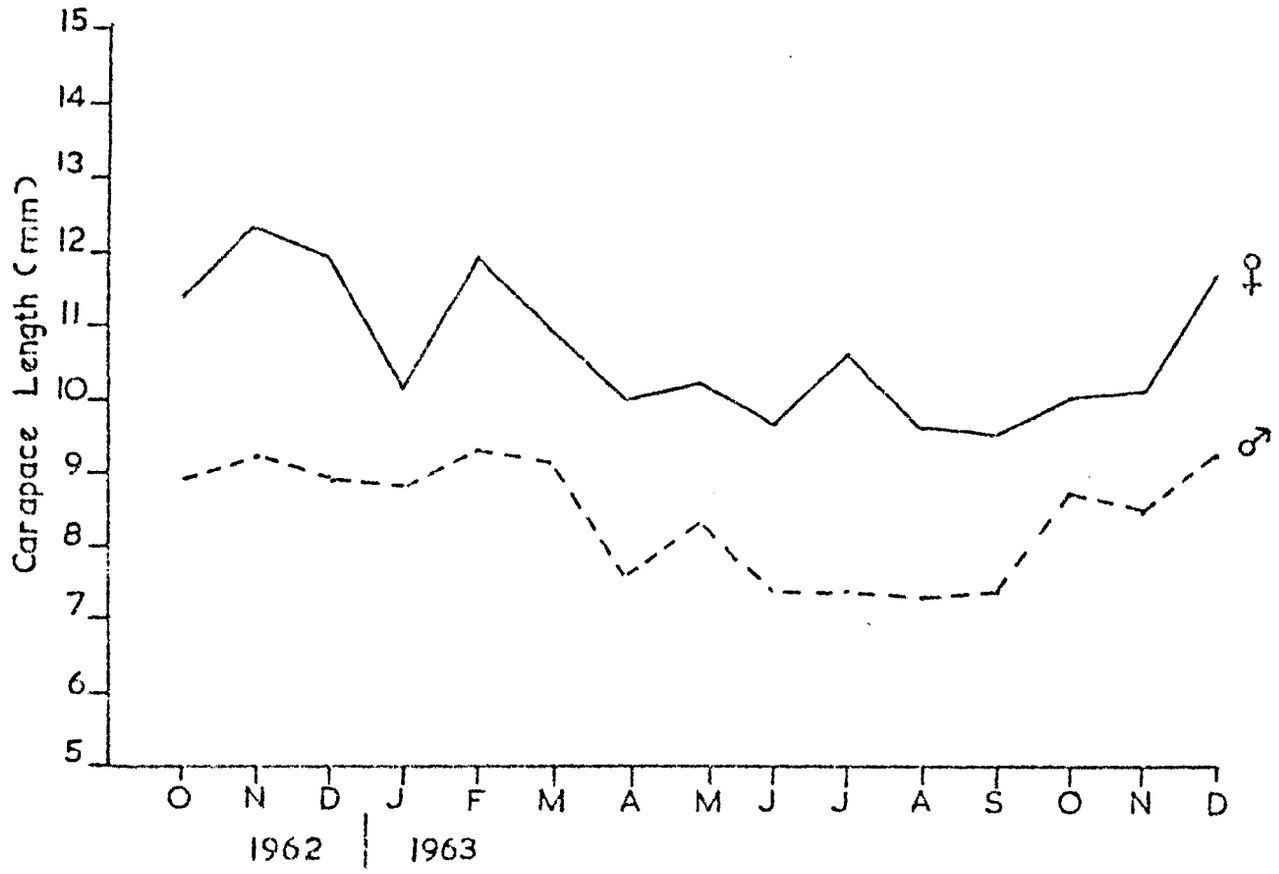

Fig. 6.

MEAN LOG CATCH PER 15 min HAUL
(ALL AREAS) BY MONTHS.

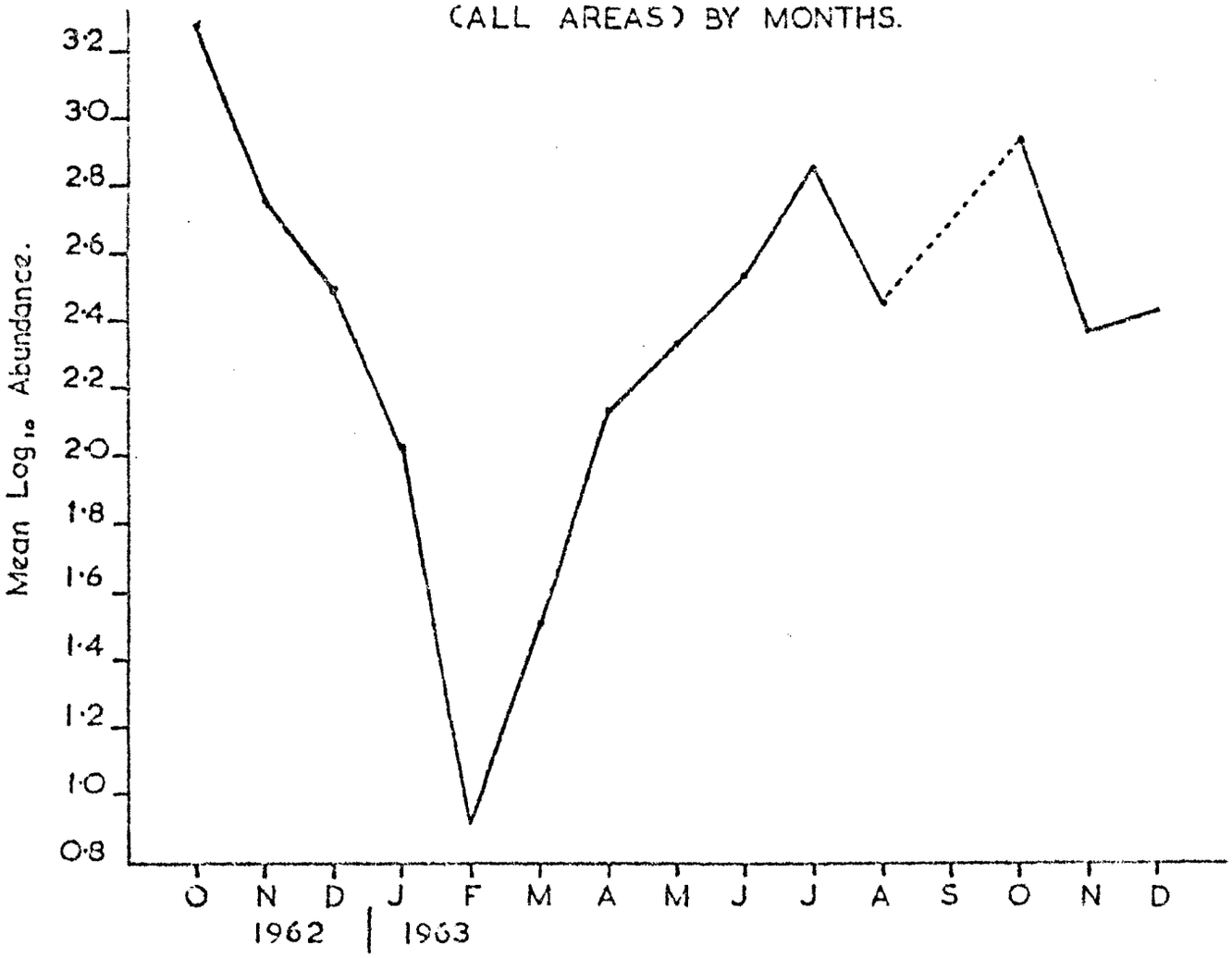

Fig. 7.

MEAN LOG. CATCH PER 15 min HAUL
BY AREA OCT. 1962 - OCT. 1963.

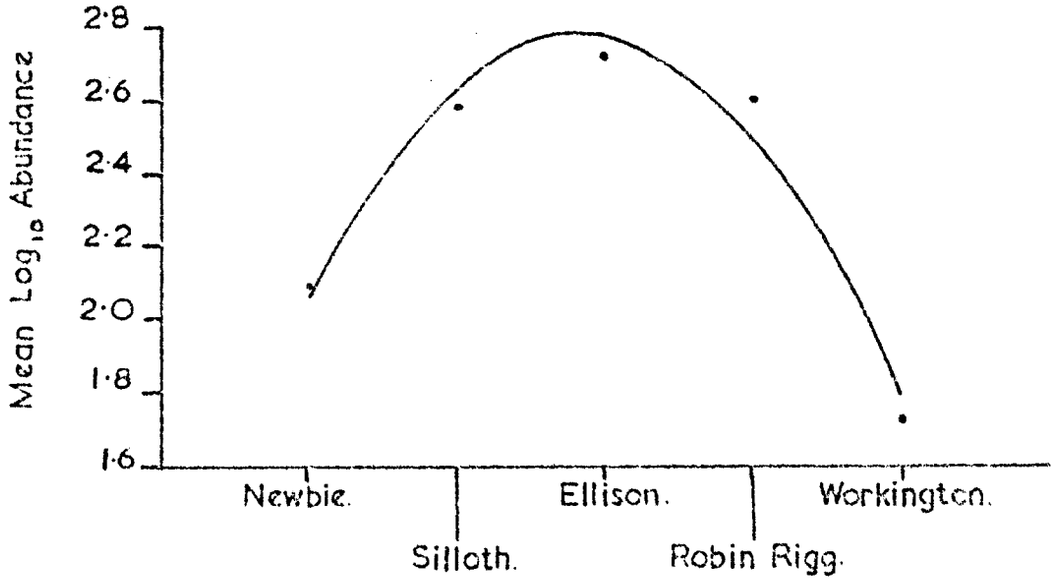

Fig. 8. MONTHLY CATCH EFFORT DATA OF COMMERCIAL BOATS LANDING AT ANNAN.

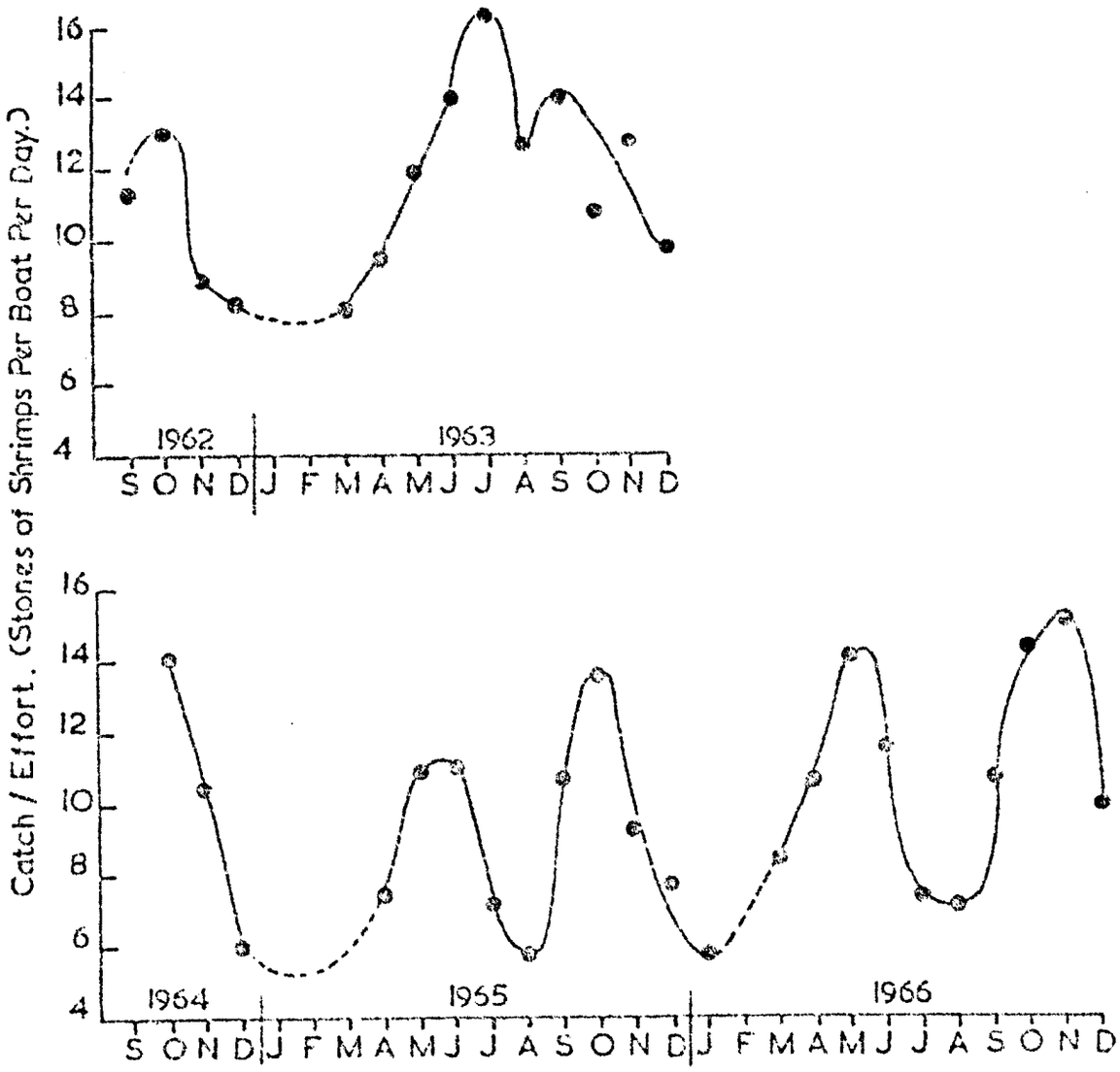

FIG. 9. ANNAN MODIFICATION OF DUTCH SHRIMP TRAWL DIAGRAMMATIC SECTION (see text)