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Duration of Maturity Stages in Spring Spawning Clyde Herring

by

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Introduction

Recent controversy about the allocation of pre-spawning concentrations of herring in the northern and central North Sea to their spawning communities has centred attention on the interpretation of maturity data. To interpret this with any confidence a time scale for translating maturity stages to the time of spawning is indispensable. At the meeting of the Working Group on Methods for North Sea herring held at Hamburg in April 1962 a paper on this subject by T.D.Iles considered this problem. This paper was received with considerable interest, although with some reservations by those workers present at this meeting and it was recommended that it should be presented to the wider forum of the Herring Committee in 1962. It was also recommended that other countries with suitable data bearing on this subject should also be invited to present it at this meeting.

To measure the duration of maturity stages with any confidence from the maturity composition of commercial catches demands that the stock sampled be a pure one, or if mixed that the individual fish can be allocated to their respective spawning groups; that the stock be fished throughout the maturation cycle and that the catches throughout this cycle should be representative of the maturity composition of the stock. These conditions are not met in the herring stocks fished by Scotland in the North Sea where the proportions of northern, central and southern North Sea spawners amongst the prespawning concentrations is at present unknown and the subject of much controversy. In the Firth of Clyde, however, there is a stock of fish which fulfills these conditions as closely as can be reasonably expected. This is a spring spawning stock which has been studied by Scottish workers with varying intensity over a considerable number of years and whose biology is fairly well known. (Wood 1960, Saville (in press)). It is true that the indigenous spring spawning stock is mixed at times with an autumn spawning component of unknown origin but this always forms a quite inconsiderable part of the total catch and autumn spawning fish can in any case be excluded by otolith characters. It is with this stock that the major part of this paper deals.

Methods.

The material available covers the period from 1930 to 1961. In the period from 1930-1959 sampling was rather irregular and the material available is not large enough to permit the treatment of individual year classes in each year of life. The data has accordingly been grouped into two periods, 1930-39 and 1949-61. In the pre-war period, when sampling was less intensive, the data has been considered on a monthly basis for fish of each age-group. Post-war it has been possible to treat on a fortnightly time scale. The split into pre- and post-war periods has been made because the change in time of first maturity which took place between these two periods could be expected to have had some influence on the maturation cycles (Saville, in press). Only females have been considered. Females with two, three and more than three winter rings on their scales are treated separately because of the spread of first recruitment to the spawning shoals over those age-groups in the pre-war period.

Fish have been categorised into maturity stages according to the Hjort classification. This is described in detail so that the scale can be compared and the stages equated with those of the Heinke scale used by Iles.

In general terms these stages correspond fairly closely with those of the Heinke scale. The main differences are the nondifferentation of maturing virgin fish from recovering spents and the absence of intermediate stages.

For each age-group and each period considered the percentage of the sampled fish in each maturity stage was calculated and plotted on a time scale.

Hjort Maturity Scale

Description

Stage	
I	Virgin individuals. Sexual organs small; breadth 2-3 mm; clear wine or amber coloured. No eggs visible to naked eye.
II	Maturing virgins or recovering spents. Diameter nearly 1 cm. Length slightly more than half length of body cavity. Eggs small, unyolked visible to naked eye.
III	Organs occupying about half of body cavity. Eggs yolked, amber coloured.
IV	Organs filling two-thirds of body cavity. No transparent eggs present.
V	Organs filling body cavity. Same, large, transparent eggs present.
VI	Spawning present or imminent. Most of eggs large and transparent.
VII	Spents - Organs blood-shot. Large residual eggs present.

The Maturation Cycle.

Spawning in the Clyde finishes in April and accordingly it is most convenient to consider the seasonal cycle of maturation as starting in that month. For two ringed fish the preponderance of fish in April, May and June are in stage 1. In July most of these pass into stage II and this remains the dominant stage for this age-group until November. In November many of these fish enter stage III and although fish in stage II are still caught in appreciable numbers until January, during November, December and January stage III is the dominant one. In two ringed fish stages IV and V never form a major constituent of the catches. Stage IV reaches its greatest representation in January and stage V in February or March but in these months fish in stage VI dominate the catches (Fig. 2). In the pre-war period the chief difference in the maturity composition for this age-group from that obtaining now was the greater prolongation of the dominance of immature fish into October. Thereafter the maturity composition of this group in the two periods were very similar (Fig. 1).

For three ringed fish in the post-war period stage II is the dominant one from May to August and is still represented in considerable numbers until October. Stage III first appears in the catches in August and dominates the maturity composition in the ensuing four months. Stage IV is to be found from September to February but is most prominent in December and January. Stage V as in the younger fish is never a dominant stage. Fish in stage V are taken from November to February with the highest representation in January and stage VI completely dominates the catches in February, March and April.(Fig. 4). Pre-war the maturity cycle differed principally in the much greater proportion of stage I herring in the catches in May, June and July and in the general tendency for the maturity composition to be less advanced at any given time in the season (Fig. 3).

For fish with four or more rings the pre-war and post-war pictures are very similar as would be expected in that the recruitment change would have little influence on older fish. Fish in stage II absolutely dominate the catches in the period May-August. In September stages II and III are of almost equal abundance and in October these two stages are still the only ones caught with stage III about three times more abundant than stage II. In November and December practically all this age-group are in stages III and IV with stage IV forming about two-thirds of the catch. By January stage V has begun to appear and continues to be caught through to March. In January stage V may form up to 50% of the catch, but in the later months the samples as in the younger fish are always dominated by spawners (Fig. 5 and 6).

Apart from the greater prevalence of stage I amongst the younger fish the maturity cycles for the three age-groups considered do not differ radically. There is a slight tendency for maturity to be more advanced at any given month in older fish than in younger ones but this is not marked enough to be given much significance.

The Duration of Maturity Stages.

From data of this nature there would appear to be two possible approaches to estimating the duration of stages in the maturation cycle. The first is by following the time intervals between modes in the occurrence of successive stages, the second is the technique used by Iles of measuring the area under the curve of the percentage

of each stage plotted against time. If the conditions which allow the duration of maturity stages to be measured at all by such data are complied with each seems equally applicable and they should give approximately the same result. Iles' technique has the advantage that it gives results which are at least apparently more accurate whereas by following modes the time intervals cannot be finer than those into which the material is grouped. This apparent advantage is probably largely fictitious; the inaccuracies inherent in grouped data are still present. In any case, for assessing to which spawning group fish in intermediate maturity stages belong, an accuracy of better than a fortnight is largely irrelevant. Both techniques have been applied to the present data.

From Figs. 1-6 the timing of the modes of the various stages for the three age-groups considered in the pre- and post-war periods age given in Table 1.

Table 1.

Period	Age-groups (rings)	Stages					
		I	II	III	IV	V	VI
1933-39	2	May-June	Sept.-Oct.	Nov.-Jan.	Jan.-Feb.	March	March
	3	May-June	Aug.-Sept.	Oct.	Jan.	Feb.	March
	4+	-	May-Aug.	Oct.	Jan.	Feb.	March-April
1949-61	2	May-June	Aug.-Oct.	II Nov.- I Jan.	II Jan.	II Feb.	II Feb.-IIMarch
	3	-	II May-I Aug.	I Sept.-II Dec.	I Jan.	II Jan.	II Feb.I Apr.
	4+	-	May-Aug.	I Sept.- I Dec.	II Dec.	I Feb.	II Feb.-I March

Then taking, for example, the length of time between the modes of stage I and stage II as being the duration of stage I one gets the estimates for the duration of the various stages in the age-groups and periods considered given in Table 2.

Table 2.

Period	Age-groups (rings)	Stages					
		I	II	III	IV	V	VI
1933-39	2	18 weeks	10 weeks	6 weeks	6 weeks	- weeks	?
	3	13 "	6 "	13 "	4 "	4 "	?
	4+	-	14 "	13 "	4 "	4 "	?
1949-61	2	14 weeks	13 weeks	5 weeks	4 weeks	2 weeks	?
	3	-	14 "	9 "	2 "	7 "	?
	4+	-	15 "	10 "	8 "	3 "	?

These figures are rather variable even between the same age-groups in the two periods. They are, however, sufficiently consistent to allow some conclusions to be drawn. The absence of stage I amongst 3 ringed fish in the post-war period is the result of the acceleration in maturity leading to full recruitment to the spawning shoals as three-year-olds in the post-war period. Spents never form other than a negligible proportion of the Clyde catches and accordingly no estimate can be made, on this basis of the duration of stage VI. It would appear from the data given in Table 2 that there is a general tendency for maturation to be an accelerating process, the stages being of progressively shorter duration as one ascends the maturity scale. Stage V appears to be the shortest scale even on this basis and an examination of the small part which this stage plays in the maturity composition (Figs. 1-6), would tend to suggest that its duration is probably over-estimated by this method.

The technique adopted by Iles has also been applied to the curves of Figs. 1-6. The area under each of the curves for each maturity stage has been measured and expressed as a fraction of the total area under all maturity stage curves of that age-group for that period. This is then taken as the fraction of the year spent in that stage of maturity.

Estimates of the duration of maturity stages prepared in this way are given in Table 3.

Period	Age-groups (rings)	Stages					
		I	II	III	IV	V	VI
1933-39	2	188	55	51	22	3	46
	3	43	129	69	58	1	66
	4	-	122	55	88	9	90
1949-61	2	108	131	57	21	2	46
	3	9	134	84	48	14	77
	4	-	146	90	56	35	38

These estimations do not differ radically from those derived from the progression of modes given in Table 2. They too point to a general tendency for a shortening of stage duration in successive stages up to stage VI. The length of stage VI derived by this method seems very long. This is probably partly due to the fact that at this time the fleet concentrate on spawning fish and as spents seem to move off the grounds immediately after spawning and are virtually unrepresented in the catches the representation of stage VI fish tends to be over-emphasised in the samples. However, extensive larval sampling over the spawning grounds has shown that the peak of hatching never occurs before the middle of March. As ripe fish are taken in greatest abundance in the second half of February this would suggest that stage VI normally lasts for several weeks.

The wide variation in the duration of stages I and II in the pre- and post-war periods amongst two ringers is undoubtedly due to the change which has occurred in the age of first maturity. It seems likely therefore that the post-war figures for 2 ringers better represent the duration of stages of fish which will spawn as three-year-olds. A feature of these results for which no explanation can yet be given is the apparent tendency for stages III-V to be passed through much more quickly in first time spawners than in older fish. The consistency of this in both periods suggests, however, that it has not simply resulted from an abbepation in sampling.

Discussion.

The only other data bearing directly on the duration of maturity stages in herring with which the figures deduced above can be compared are those given by Iles. The most directly comparable of the figures given by that author are those for N.Shields which are also for females and for three-year-old fish. They are thus directly comparable with those given here for Clyde 2 ringers apart from the fact that one set of data refers to an autumn or winter spawning race and the other to a spring spawning one. It is clear that in stages I, I-III and III, which are equivalent to stages I, II and III in the present data, the times given by Iles are considerably shorter than those deduced above. This may be a racial difference between the two spawning groups; both groups apparently start the maturation cycle about the same time and the spring spawning group have rather longer in which to complete the maturation process. It must be admitted, however, that in calculating the duration of stages I and I-III from his basic data Iles had to resort to a considerable amount of extrapolation which may account for some of the discrepancy in the duration of these stages between the two races. The differences between the estimates for stage III between the two spawning groups appears explicable only by a real difference in the maturation cycles. The duration of stage IV corresponds very closely between the two sets of data - assuming stage IV on the Hjort scale is equivalent to Iles' IV + IV-V.

The most striking and most important discrepancy between the two estimates of stage duration however is in stage V. The poor representation of this stage in all the present data must lead one to conclude that this stage in the Clyde herring is a very short one. Only in four ringed fish in the post-war period did the estimated duration exceed two weeks; and this set of data is the most suspect in that it is based on rather inadequate numbers of fish. Our knowledge of the biology of this stock and of the mode of operation of the fishery cannot suggest any bias which would result in such a gross under estimation of the proportion of this stage in the population as must have occurred if this was the stage in which the fish over wintered for two months or more as Iles suggests.

It must be remembered that the basis on which Iles deduces the duration of stage V for his North Shields fish is very different from that for other stages or that used in the present communication. In the Shields data all contact is lost with the stock fished after August when the fish most advanced in maturity are in stage IV-V. The duration of stage V is then estimated on the assumption that these fish subsequently spawn in the Channel in mid or late November (Burd 1958). Burd's relationship between N. Shields and E. Anglia is, however, based on fish of maturity stage less than IV in July, being subsequent Downs spawners whilst the fish of higher maturity he believes to be Banks fish. It appears, therefore, that on this evidence the N. Shields stock is a mixture of two spawning groups and this, if correct, is bound to throw some doubt on the reliability of maturity stage duration estimated from this stock. The basis for estimating the duration of stage V would appear even more dangerous. Burd's link between low maturity fish at Shields in July and August and the Downs spawning stock is based on a similarity in l_1 distributions and a correlation between abundance indices for the two fisheries which requires the introduction of external factors to explain some discrepant points. This does not seem sufficiently strong evidence of identity of these two stocks to deduce a length of stage V so very different from that deduced from more firmly based data. Iles points out the close relationship between the duration of maturity stages up to stage V in the N. Shields and Buchan areas and the similarity of the maturity composition of the stocks fished by the two fisheries in July. The stock of three-year-olds fished on the Buchan grounds in July is known to spawn predominantly in August and September. It would seem more rational to assume that the Shields fish also spawn in these months on the nearby spawning grounds at Whitby and on the Dogger.

The evidence used by Iles for a long stage V for winter and spring spawners is of a like nature. The link between the stage V fish on the Smalls ground in September and the spawning fish at Dunmore is not strong enough to draw far reaching conclusions regarding the duration of maturity stages from it. Similarly, the data for English inshore spawners is based on rather a small number of fish and data to support the contention that these fish do actually spawn between March and May are not given.

There are in the literature, however, two sets of data which do seem to supply a reasonably adequate basis for assessing maturity stage duration of spring-spawning herring and in particular for assessing the length of stage V in such fish. The first of these are the data on the Lusterfiord herring presented by Aasen (1952). This is in many respects the ideal data for the purpose as it was collected from a stock of herring isolated in a fiord and where any "strange" fish differed so radically in meristic and growth characteristics that they could be readily excluded. The stock was kept under observation throughout an entire cycle although it is admitted the samples tended to be rather small. From these data, on a fish stock spawning between March and May but principally in April, Aasen estimates the duration of stage IV + V as being about two months. Even assuming these two stages are of equal duration this would give one month for stage V. In fact Aasen infers, as we have found for Clyde herring, that maturation, at least from stage III to spawning is an accelerating process so it is probably considerably less than this.

The other set of data which is of some value in this connection is that provided by Naumov (1956) for Murmansk herring. This consists of the percentage maturity compositions during each month of the year for this spring spawning fish stock. The data are unfortunately not split by age or sex groups so that all that can be got is an indication of the mean lengths of stages for the population as a whole. The maturity scale used is that of Naumov (1939). This is a scale with only six stages from immature to spent individuals. The criteria used in discriminating between maturing stages are basically similar to those of the Hjort scale and it is possible to equate Naumov's stages with those of Hjort. The maturity composition data he gives here have been treated by the Iles technique to give the stage durations of Table 4.

Table 4.

Stage (Hjort)	I	II	III + IV	V	VI	VII
Duration (days)	55	175	53	29	24	29

It will be observed that in these data, as in that previously given for Clyde spring spawners and as can be also inferred from Aasen's data, fish spend a long time in stage II and thereafter successive stages are passed through in a progressively shorter time up to spawning. This also seems to be so for Iles' data for autumn spawning

fish in the north-western North Sea and in the Minch. It would then appear that in both autumn and spring spawning stocks where the spawning stock can be related with some confidence to the earlier maturity stages this pattern of maturation holds.

Abstract

Recent controversy regarding the allocation of pre-spawning herring in the northern and central North Sea to their spawning communities has focused attention on the duration of maturity stages. The Clyde herring stock is one in which these durations can be measured with some confidence because of its self-contained nature and because it is fished throughout the entire maturation cycle. The durations estimated suggest that fish spend a major part of the year in Stage II and that successive stages up to spawning are passed through in progressively shorter periods. This is in conflict with the findings of Iles who postulates a prolonged Stage V for winter and spring spawning herring. This conflict is discussed and supporting evidence for a short duration of Stage V is cited from other stocks.

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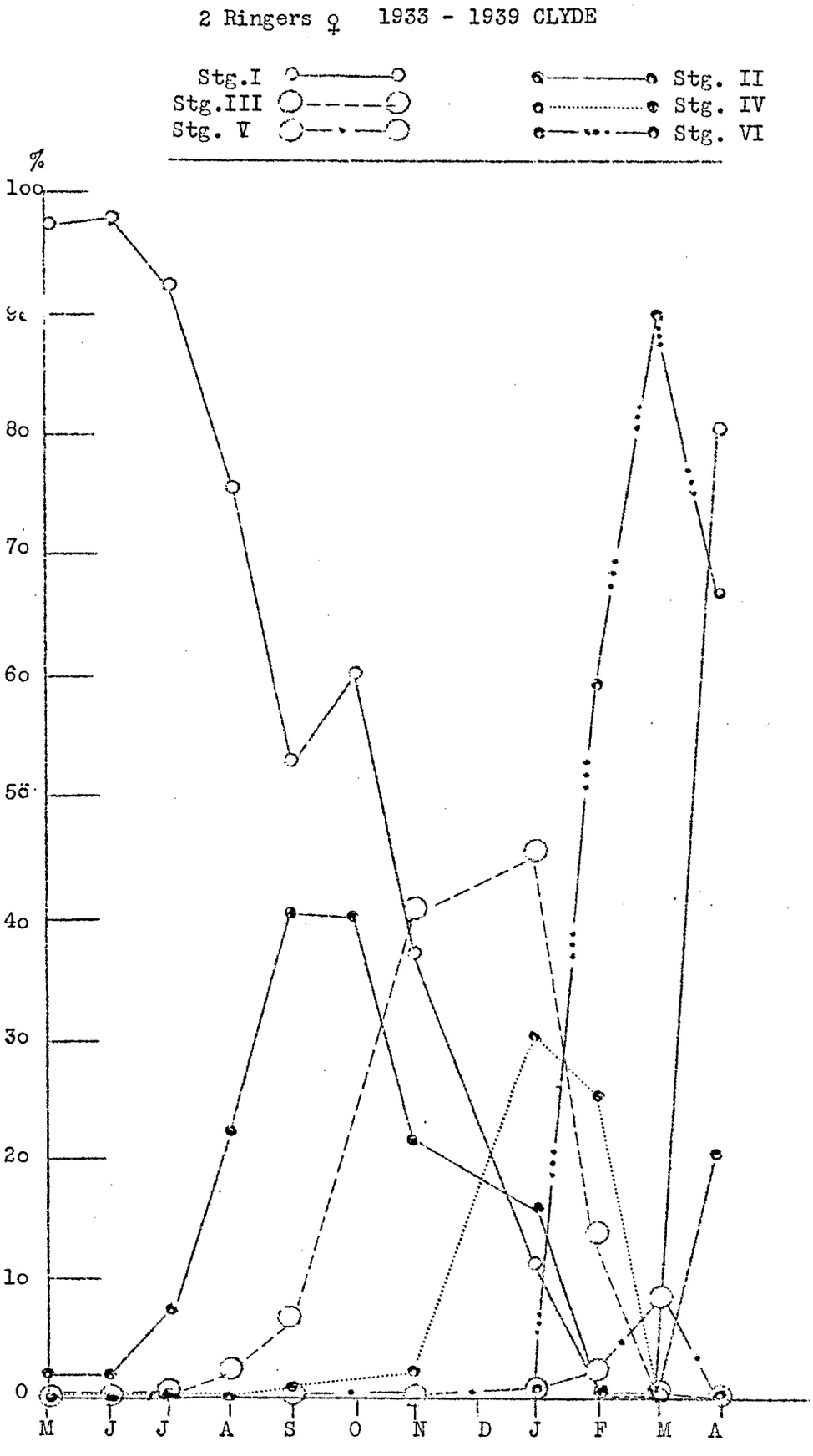

Figure 1. Percentage maturity composition of 2 ringed females 1933-39

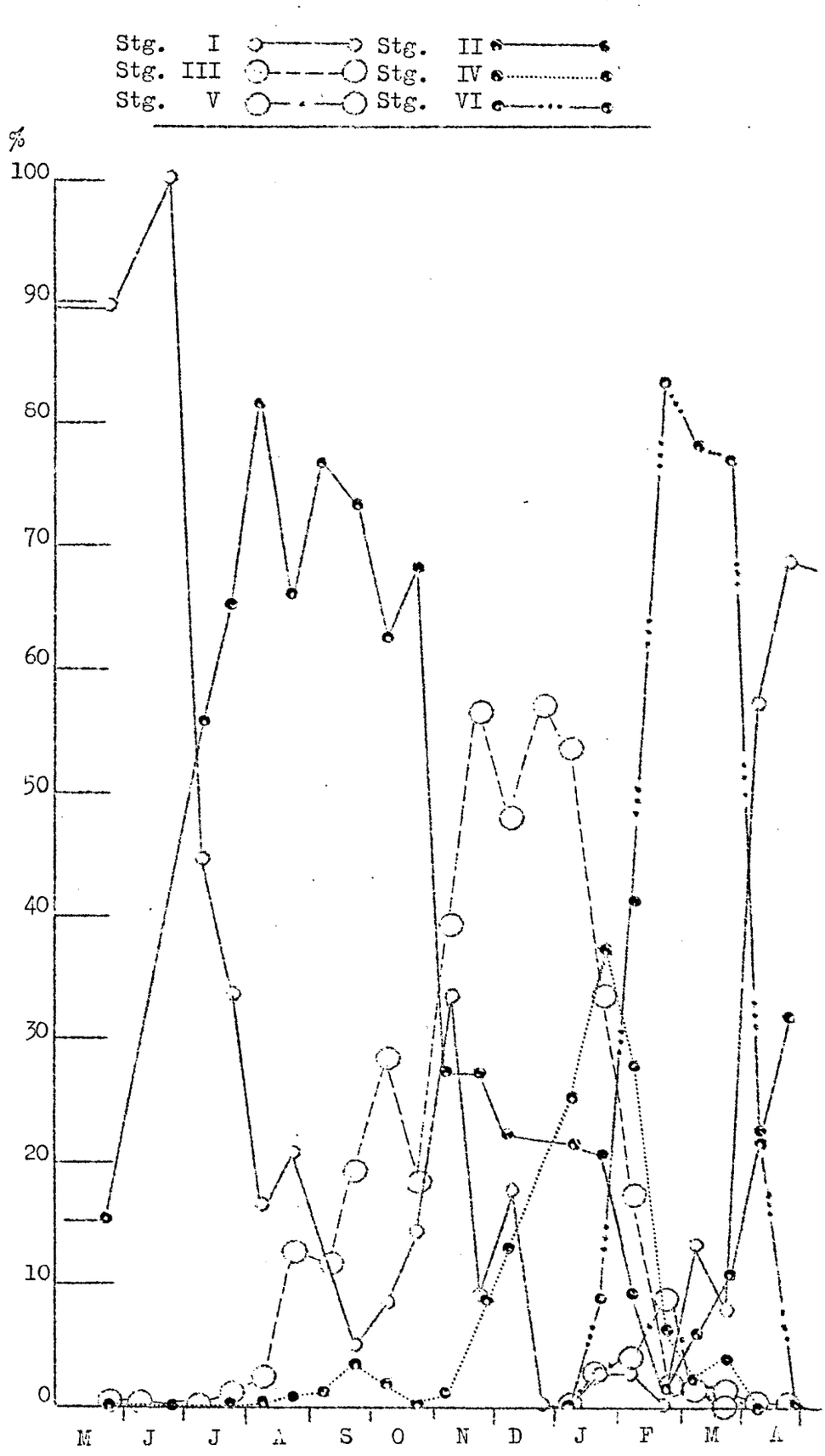

Figure 2. Percentage maturity composition of 2 ringed females 1949

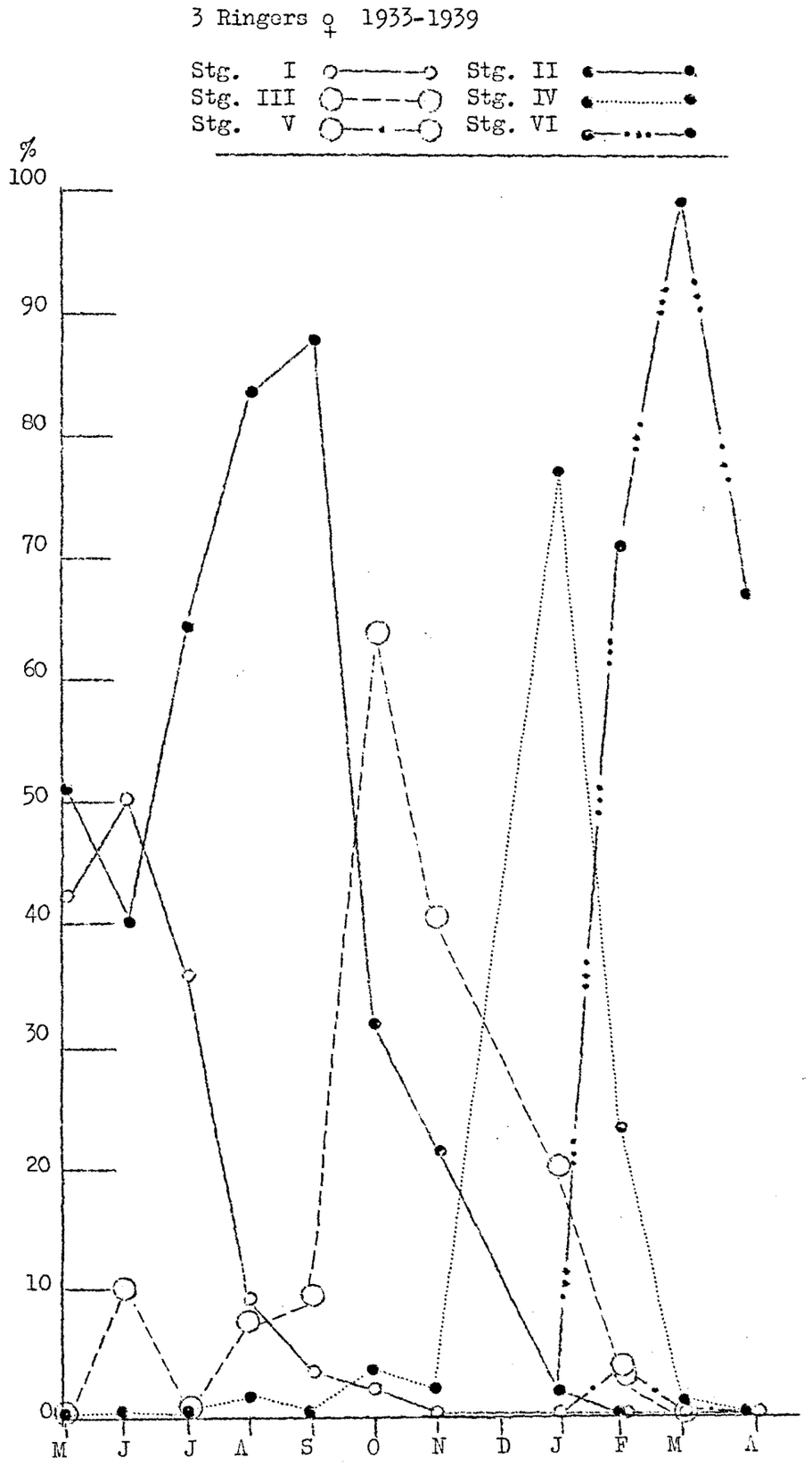

Figure 3. Percentage maturity composition of 3 ringed females 1933-1939

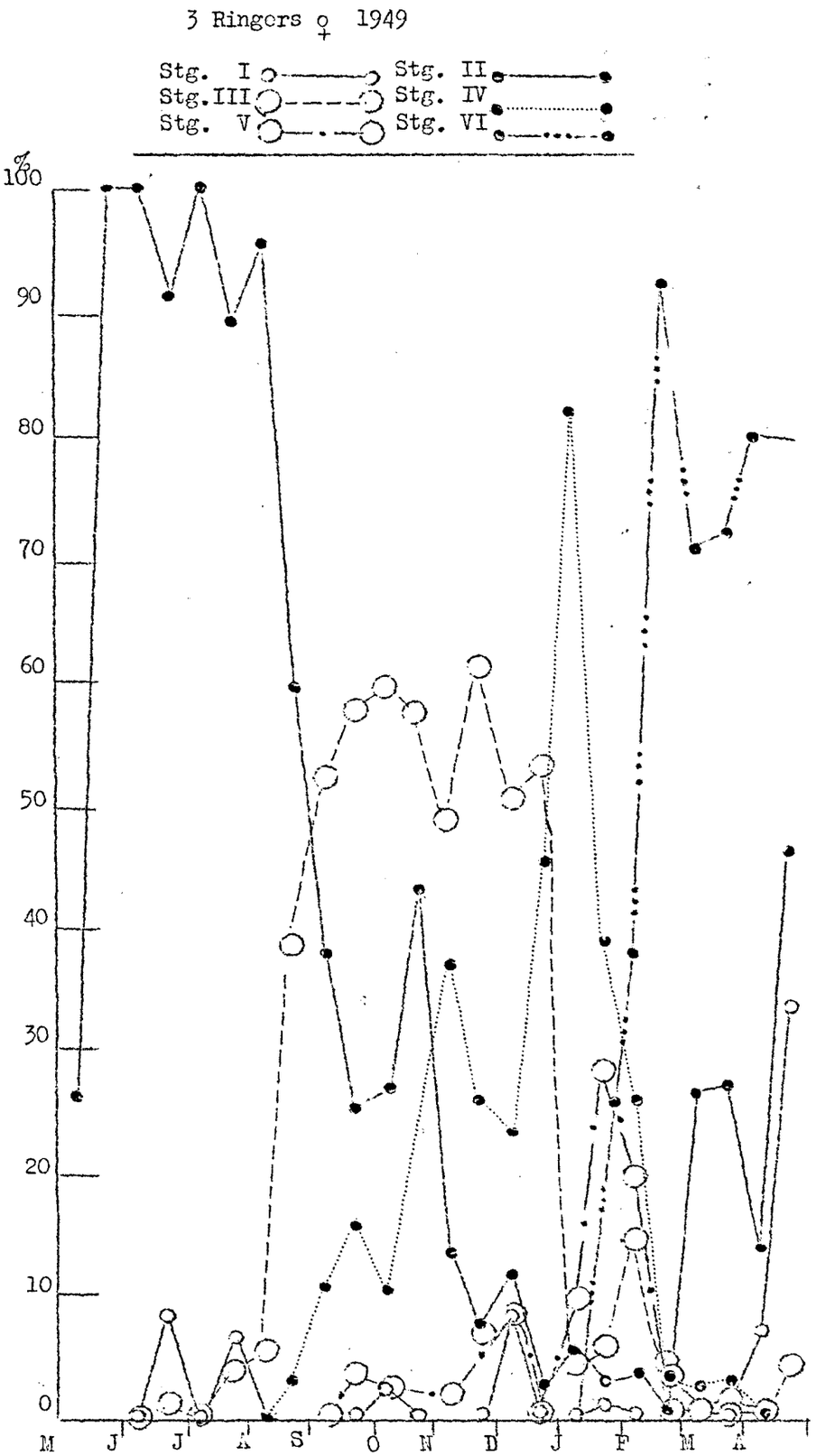

Figure 4. Percentage maturity composition of 3 ringed females 1949.

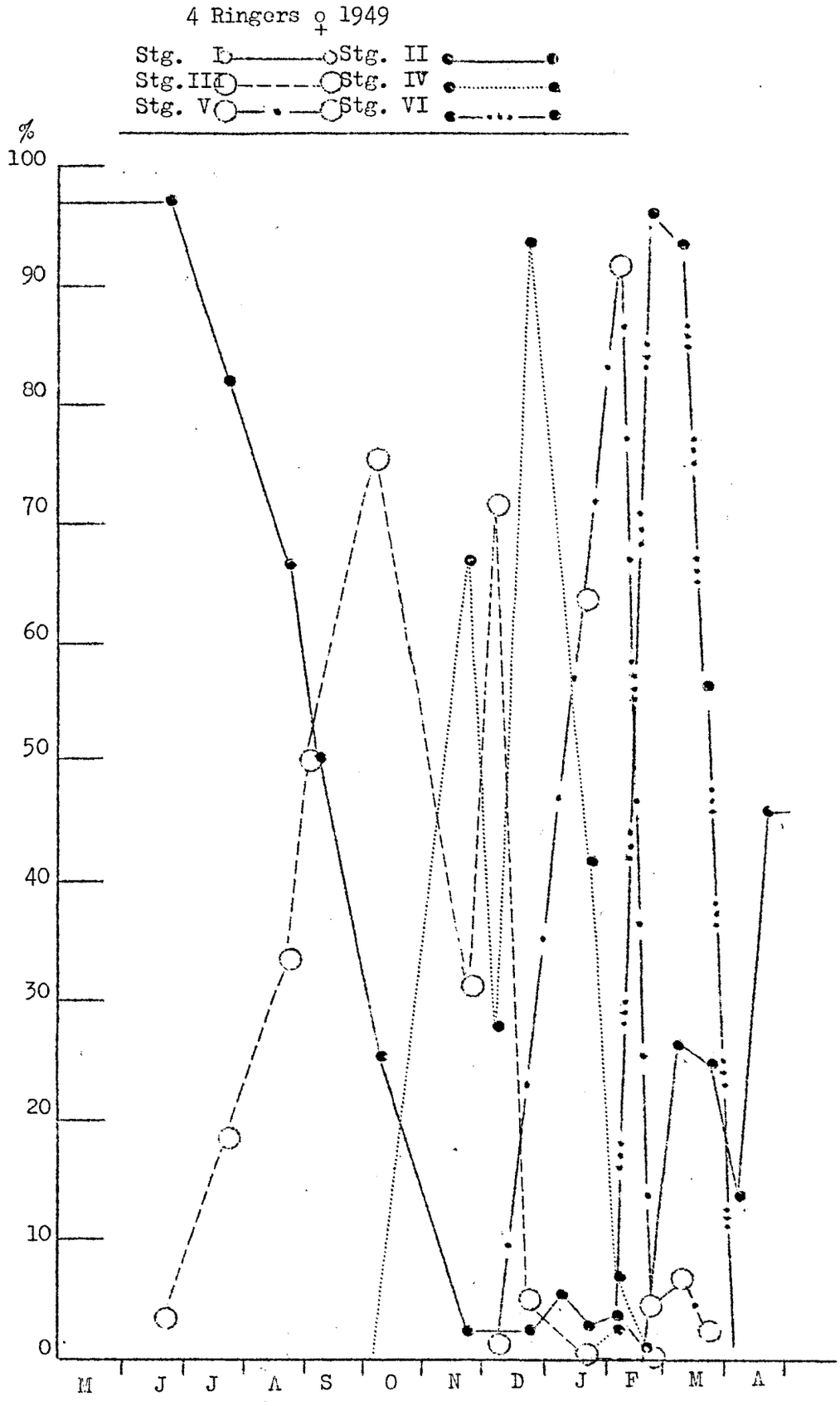

Figure 5. Percentage maturity Composition of 4 ringed females 1949

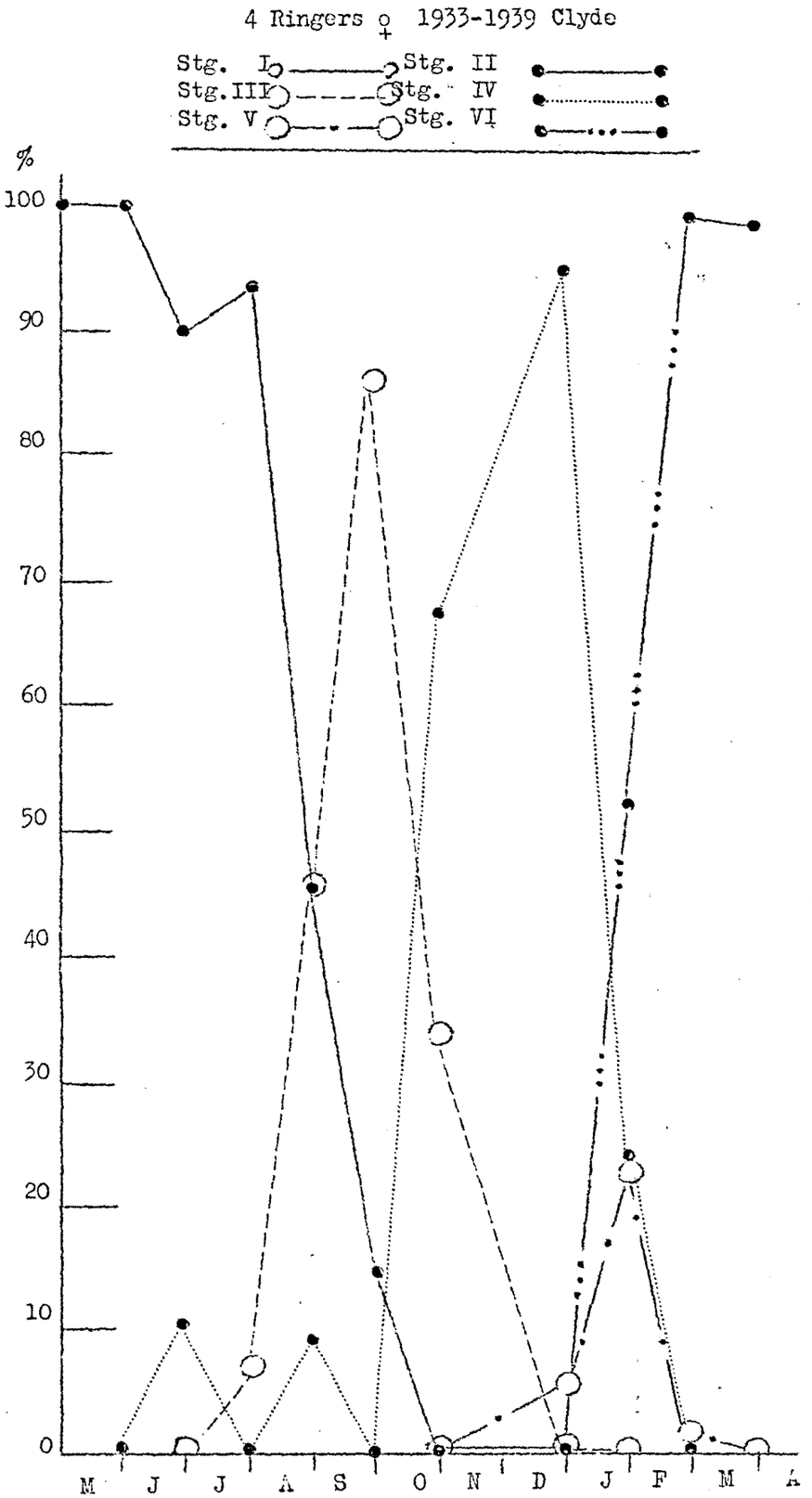

Figure 6. Percentage maturity composition of 4 ringed females 1933-39.