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ECOLOGICAL INVESTIGATIONS WITH THE CONTINUOUS PLANKTON RECORDER:

THE ZOOPLANKTON (OTHER THAN COPEPODA AND YOUNG FISH) IN THE SOUTHERN NORTH SEA, 1932-37

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INTRODUCTION.

THE object, plan and methods of the plankton recorder survey have been discussed in ' Bulletin ' No. 1 (Hardy, 1939). For the first five and a half years, 1932–37, the survey was confined to the southern part of the North Sea, and reports on the phytoplankton (Lucas, 1940) and the Copepoda (Rae and Fraser, 1941) have already been published. The following account deals with the rest of the zooplankton taken in that period, except for the fish eggs and larvae which are being treated together with those for 1938–39 in a report being prepared by Dr. Stubbings.

The present paper has been both delayed and curtailed by the absence of the authors in the services.

The first five and a half years was a trial period, the forerunner of the wider and more detailed survey begun in 1938. During this early phase, when the staff were also engaged on the plankton indicator work (see Hardy, *loc. cit.*) the identification of species was limited to certain important diatoms and Copepoda ; time only permitted the recording of other zooplankton under generic or group names. This is the most serious limitation to the present report ; the determination of groups dealt with is not carried further than the following categories : the *genera* Sagitta, Limacina, Clione, Evadne, Podon and Oikopleura, and the wider groups Echinoderm larvae, Lamellibranch larvae, Decapod larvae, Caprellid Amphipoda and Squilla larvae. Further, the distribution of the Mysidacea and Euphausiacea has not been dealt with because it has been shown that their marked vertical migration makes results from the recorder method difficult of interpretation for both groups. Unfortunate as these limitations are, it is nevertheless felt that this brief report, when taken with the details of the phytoplankton and Copepoda already published, will be of value in giving a general picture of the changing plankton community in these years, and also in providing some basis for comparison with the more detailed work carried out in the extended survey of the whole North Sea begun in 1938 (and which will be continued, it is hoped, after the war).

Reference should also be made to ' Bulletin ' No. 1 for the various changes which have been made in the recorder technique during the survey. A map of the recorder routes and a complete summary list of records giving particulars of dates, times, sea and weather conditions will be found in ' Bulletin ' No. 2 (Anon., 1939). All the records have been analysed for zooplankton except certain ones taken for phytoplankton only (indicated by " P " in this list).

Throughout the report the different routes will be referred to by the letters used in the summary list just mentioned : *i.e.* " C " for the Hull–Copenhagen, " B " for the Hull–Bremen, " E " for the London–Esbjerg, and " R " for the Hull–Rotterdam route.

Limitations of Sampling Methods.

For a general discussion of this matter and a section dealing with the catching power of the recorder the reader is again referred to 'Bulletin' No. 1.

Three important questions must be considered when interpreting the results shown by this method of taking continuous series of samples in straight lines across the sea at a uniform depth :

(1) What numerical differences along the lines are biologically significant, *i.e.* what differences are due to an actual uneven distribution of the plankton and what due simply to the errors inevitable in "linear" sampling at sea and sub-sampling in the laboratory.

(2) To what extent does the vertical migration of different animals interfere with an estimate of their spatial distribution ?

(3) Are the series of lines giving a representative picture of the changes which are going on over the whole area, or are there important events being missed between the lines of observation ?

The first of these has already been discussed at length by Rae and Fraser (1941, p. 178) when dealing with the Copepoda. After discussing two distinct sources of error due to random sampling, firstly by the machine in the sea and secondly in the process of laboratory estimation, they go on to say :

> "It will be seen that these [records] show a number of well-marked changes in concentration both in space and time, which are too large to be accounted for by any chance distribution, and further are shown by a number of successive but independent estimations. These are the major ecological variations that the survey was designed to reveal. Superimposed on these gross changes, there are, however, minor fluctuations which give the graph a wavy appearance. These may, of course, well be due to genuine minor patches or swarms only a mile or two in breadth, but it appears possible that they are artefacts produced by the errors entailed in the two random selections."

The same applies to the present work, but here the errors of sampling have less weight than in the Copepoda report, where the results were shown as graphs. Here the results are approximated to a series of figures and/or symbols which cut out the smaller and probably non-significant differences. Further, more emphasis in this report is placed on the broader seasonal changes than on the detailed spatial distributions of each month. In showing these seasonal changes year by year the average values for the whole of each line have been used, so that small errors due to random sampling should to a large extent cancel out. The random errors due to laboratory technique are referred to below under methods of estimation.

Regarding the second point, since the recorder is towed at a constant depth of 10 metres, it might be expected that more animals would tend to be taken at night than in daylight. Clearly no set of samples limited to one depth can give direct knowledge of vertical migration ; but it is important to consider whether this factor is producing an erroneous picture of the zooplankton distribution. To test this, the numbers of a given organism caught over a distance of 50 miles before sunset were compared with the numbers caught over 50 miles after sunset, and likewise before and after sunrise ; so large a distance was taken in order to minimize as far as possible the effects of irregular horizontal distribution. Since the average speed of the ships is about 10 knots the comparisons involve periods of five hours before and after sunset and sunrise, periods in which the major changes in vertical distribution may be expected to occur. Only the Mysidacea and Euphausiacea showed a marked correlation between their distribution and those parts of the line taken between sunset and sunrise ; for this reason, as mentioned in the introduction, all detailed consideration of their distribution is omitted from this paper. Of other forms, none showed any significant correlation by this admittedly indirect method. A discussion of the same problem will be found in Rae and Fraser's (1941) report on the Copepoda. These tentative results can in no way be taken as evidence against the occurrence of vertical migration, but it does seem clear, as Rae and Fraser found, that its effects are *masked* by the even greater fluctuations in spatial distribution. It is with these major distributional changes that this survey is concerned. The problem of vertical migration will be returned to in later reports.

The third question reveals an undoubted limitation to the value of results from these first five and a half years of the survey. The radiating lines became at their eastern ends so far apart that some events of importance may well have occurred between them, and passed unrecorded by our system. The E line begun in 1937, and the extended survey of 1938, with its new lines converging towards the east and intersecting the former lines, have gone far to overcome this defect. This early survey cannot present a complete picture, but it does for the first time attempt to show the kind of changes which are taking place in cross-sections through the plankton community month by month for a number of years over a considerable portion of the area. There are gaps in the picture which it is dangerous to attempt to fill by speculation based upon the too distant adjacent lines. Such a limitation to this pioneer period of the survey must be recognized.

Methods of Estimation.

All quantities of plankton have been calculated with reference to a water-tunnel aperture of $\frac{1}{2}$ in. square section on the experimental evidence (Hardy, *loc. cit.*, p. 43) that the volume of water passing through the recorder is proportional to the area of the aperture. The aperture was changed from $\frac{3}{4}$ in. square to $\frac{1}{2}$ in. square section in May, 1937, at the time when the silk/mileage ratio was increased to approximately 5 miles per section. This reduction of all quantities in reference to the smaller aperture has also been adopted in the other reports for this period, so that all the data will be comparable with the results of later surveys.

The larger zooplankton forms, *i.e.* Sagitta, Euphausians, Mysids, Amphipods and Decapod larvae have usually been counted with the naked eye, while the smaller forms, such as Echinoderm larvae, Lamellibranch larvae, Oikopleura, Cladocera and Limacina have been estimated by counts made with the traversing microscope (see Hardy, 1939, p. 32 for a description of this). Sagitta and Decapod larvae, when very small, have been estimated with the traversing microscope, while conversely the Limacina, when very large, have been counted with the naked eye. In the naked-eye counts all the organisms present on each division or 10-mile block of silk have been counted, while the numbers found in one microscope traverse on each division have been multiplied by a factor of 20 (*cf.* Rae and Fraser, 1941, p. 175), to give the totals present on each division of silk. This procedure alone was adopted during the earlier part of the survey when the ratio (*i.e.* the number of miles represented by each section of silk) was from 1·5 to 2·5 miles. In 1936, however, the rolls were cut up into 10-mile blocks, and one complete staggered traverse was then adopted in counting the total organisms on each block. Here the numbers counted in the traverse were multiplied by 20 times the number of sections per 10-mile block. Finally when the ratio was increased to 5 miles (approximately), one half traverse was made on each section and the factor changed to 20×2 (approximately).

The naked-eye counts of the larger and less numerous organisms should give within very narrow limits a true estimate of the numbers caught. Counts made by examining a sample of the plankton and then multiplying by a factor provide only small random variations from the true value for the catch unless the plankton is very unevenly spread on the gauze. While the zooplankton tended sometimes to be transversely displaced on the rolls, it was rarely clumped together in a way that would give anomalous results.

Form of Presentation.

The distribution of each form is shown in a series of charts in Plates CXXVI–CXLIX; for Limacina and Sagitta there is one for each month, but for some of the others there are only selections, those with little or no data being omitted for economy. Occasionally two or three months have been combined.

Graphs which were used in the earlier papers to record the fluctuating quantities on each line have not been adopted here. Each route has been divided into blocks of ten miles both as a convenient method for charting the results, and for more ready comparison with the data from the 1938–39 extended survey.

Two methods have been adopted for showing quantities. For the various larvae, Cladocera, Amphipoda and Oikopleura, symbols are used, each covering a certain range in numbers (*e.g.* scale in Plate CXLV). Those for each organism (apart from the Sagitta, Decapod larvae and Caprellidae) refer to the numbers present *per mile* per block, *i.e.* one tenth of the number estimated for each block. The Sagitta, Decapod larvae and Caprellidae, being on the whole less numerous, have been represented as *numbers per block*.

For Sagitta and Limacina both symbols and numbers have been used. Sagitta numbers refer to the nearest ten or hundred on each block. Limacina, although rarely occurring in high numbers in the southern area, has been plotted as numbers per mile per block so as to compare with those of 1938–39 for the whole North Sea. A scale of values for symbols or numbers is given on each series of charts. The date of each record is shown at its eastern end ; when it extended over more than one day the date is that on which the greater part was taken.

In summarizing the varying plankton through the months of each year histograms have been used, with the exception of a graph for Sagitta which, being present on the majority of the records, shows more continuity (Text-figs. 1–3). Each ordinate value represents the mean number of the organism per block over the sampled part of the standard route. Records with a mileage less than one half of the normal have not been shown except where a mean value, obtained artificially by dividing the total quantity by the number of blocks on the *whole* standard line (just as if it had been fully sampled), was higher than those for adjacent months. Such exceptional records have been indicated by open histograms.

Distribution of the Zooplankton.

It is not thought necessary to repeat in long description the details which are clearly shown on the charts. The plates themselves form the bulk of the report and give the most concise description of the distribution. The text will discuss and draw attention to only the more important features, particularly the seasonal and yearly differences which can be discerned throughout the period reviewed ; these changes in time are again mainly shown in graphical summary form in Text-figs. 1–3. The correlations between the fluctuations in distribution and the hydrological conditions will be discussed in a later ' Bulletin.'

Sagitta (Plates CXXVI–CXXXI).

Specific determination only became possible with the reorganization of the work in 1938. A subsequent report in preparation will show the relative distribution of the two species *S. elegans* and *S. setosa* within the area during 1938 and part of 1939. In the present account only the generic name Sagitta can be used.

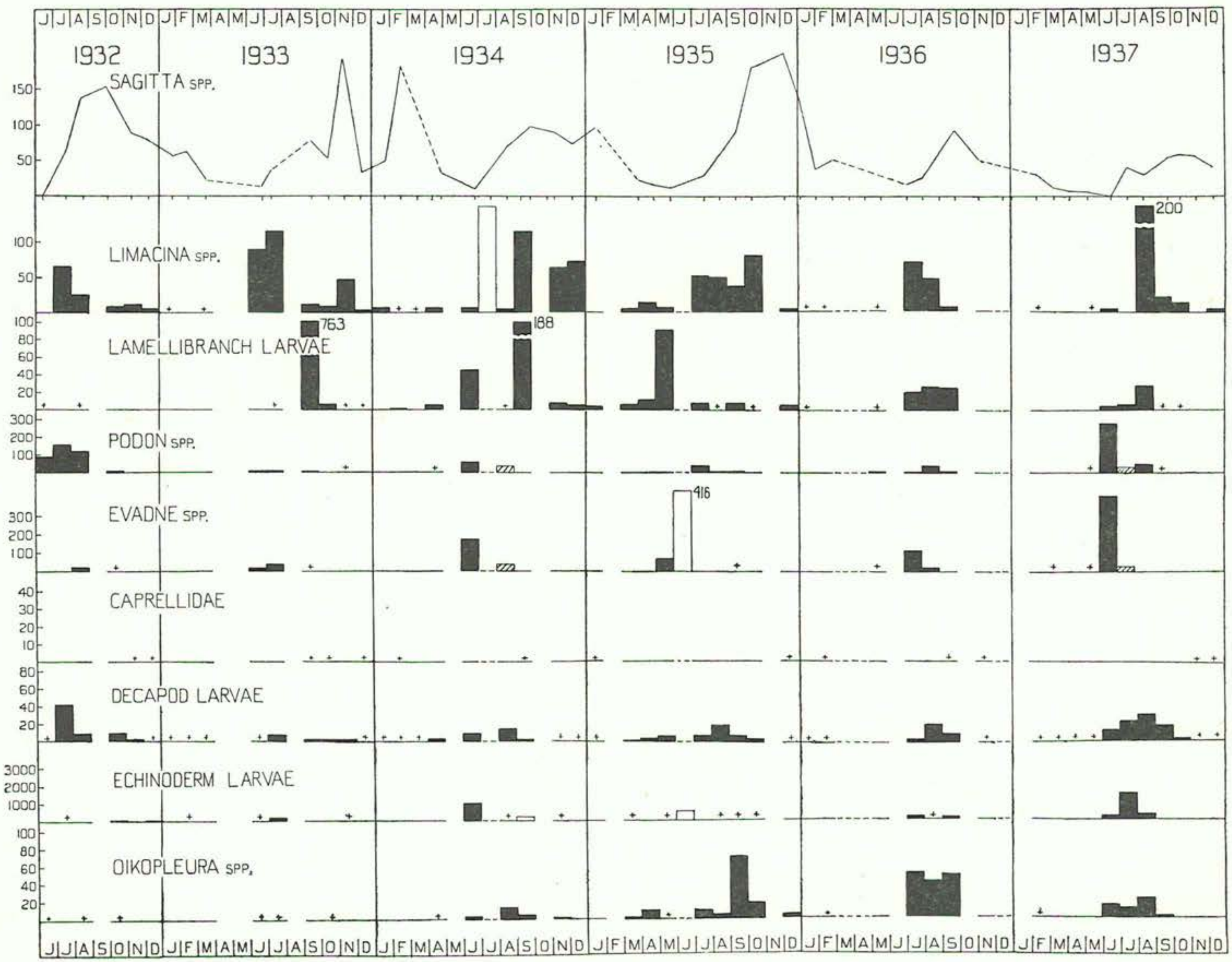
All the distribution data are shown in Plates CXXVI–CXXXI, the first of which explains the symbols in use, and the main seasonal changes from year to year for each line C, B and R are summarized in Text-figs. 1–3. The latter clearly show that Sagitta is taken in greatest numbers on the C line, in lesser numbers (except 1932) on the B line, and in only small numbers on the R line. The stock declines to a very low level on all lines in May and June. In July and August it increases again ; this first being noted on the C line, then on B. On the C line the numbers were high from 1932 to '35, and much lower in '36 and '37 ; on the B line 1932 showed the highest numbers, and '34 and '35 were poor years. Particularly noteworthy are the high numbers found along the whole of the C line in February, 1934 (Plate CXXVIII). Meanwhile Sagitta was almost uniformly scarce on the R line, but in August and September there were small increases here also, usually over the eastern half of the line, but sometimes, as in 1934, in the west as well. In August, 1937 (Plate CXXXI), this is also shown on the southern end of the new E line, the whole patch apparently shifting to the north-east in September. The general changes in distribution east and west may be studied on the plates ; sometimes the larger numbers are to the west, sometimes to the east and centre, although it is noteworthy that on the B line the numbers usually decrease towards the east.

From the data of the present survey it has been impossible to say to what extent the increase in each late summer is due to an " invasion " of fresh Sagitta into the area or to reproduction *in situ*. It is evident that young forms greatly increased about August ; this may be compared with the results of Russell (1933), and in particular with his finding that Sagitta is more abundant in the surface waters in the late summer months. There are, however, some signs of incursion from the north (see also the 1938–39 report to be published shortly), and it is likely that both factors play a part.

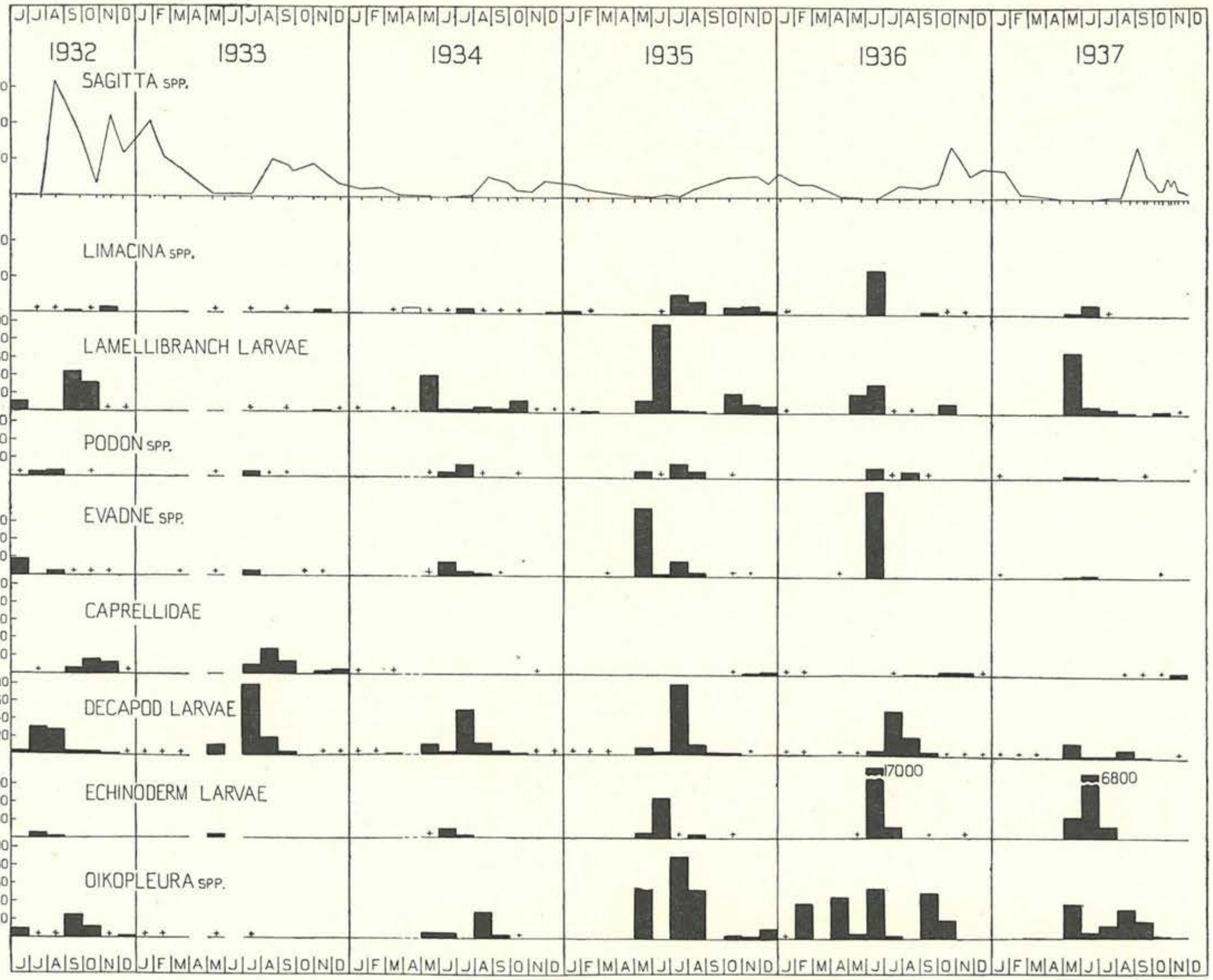
Limacina (Plates CXXXII–CXXXVII).

Although complete identification was not possible, the great majority, if not all, were *Limacina retroversa* Flemming. This species has its main distribution in the north-western North Sea, so it is not surprising that the denser patches were recorded on the northern line C. It was generally found in the largest numbers during the summer, appearing over or around the south-west or north-east ends of the Dogger Bank ; the former patches were the stronger in 1932 and '37, the latter in 1934 and '36. After September it was never recorded in quantity except in November, 1934, when a relatively dense patch was observed over the Dogger Bank. On the B line it was only twice taken in numbers exceeding 9 per mile per block, *i.e.* in June, '36 and '37, although in the later half of 1935 it was found regularly along the whole route. It was only recorded on the R line in August, September and November, 1934, April and July to November, 1935, February, 1936, and June and July, 1937, but always fewer than 9 per mile per block.

The relative numbers on the different routes in different years are summarized in Text-figs. 1–3. It should be noted that the maximum figures shown for the C line in August, 1937, are actually less than those for the *first* September record in 1934 (see Plate CXXXIV). Limacina was most extensively found in 1935, perhaps indicating a widespread northern influence, but until more evidence is forthcoming regarding the fluctuations in numbers from year to year, and as to whether local breeding takes place or not, it will be difficult to assess its significance as an indicator of northern influence.



TEXT-FIG. 1.—Graph and histograms showing the average number of the commoner zooplankton forms (other than Copepoda) per ten-mile block on the Copenhagen line for each month from June, 1932, to December, 1937. The dates of the records are denoted by small vertical strokes below the base line of the Sagitta graph; elsewhere the absence of a record in any month is shown by a gap in the base line. Records of less than half of the normal length have been discarded and denoted by broken base lines in the histograms (see text, however, for explanation of open histograms). The shaded histograms denote Cladocera spp. indet.



TEXT-FIG. 2.—Graph and histograms showing the average number of the commoner zooplankton forms (other than Copepoda) per ten-mile block on the Bremen line for each month from June, 1932, to December, 1937. For explanation of arrangement, see legend of Fig. 1.

Clione (Plates CXXXV and CXXXVI).

Owing to the forms taken being small and much compressed by the recorder it has not been possible to identify this pteropod with certainty, but it is probably *C. limacina* Phipps. Its occurrence was very limited, appearing only in January, 1935, and in January and February, 1936, on the C line. The significance of these observations is better discussed in the later report, together with the more extensive records over the whole North Sea in 1938 and '39.

Lamellibranch Larvae (Plates CXLV and CXLVI).

The plates show that the most important part of the area for larval production is where the C line crosses the Dogger Bank. This could be expected; it is well known from the work of Davis (1923, 1925) how rich the Dogger Bank is in Lamellibranchs. He showed that *Spisula subtruncata* (Da Costa) was the predominant species, with *Mactra stultorum* Linnaeus second, but much less abundant. The production on the B line is generally smaller, and on the R line very small indeed.

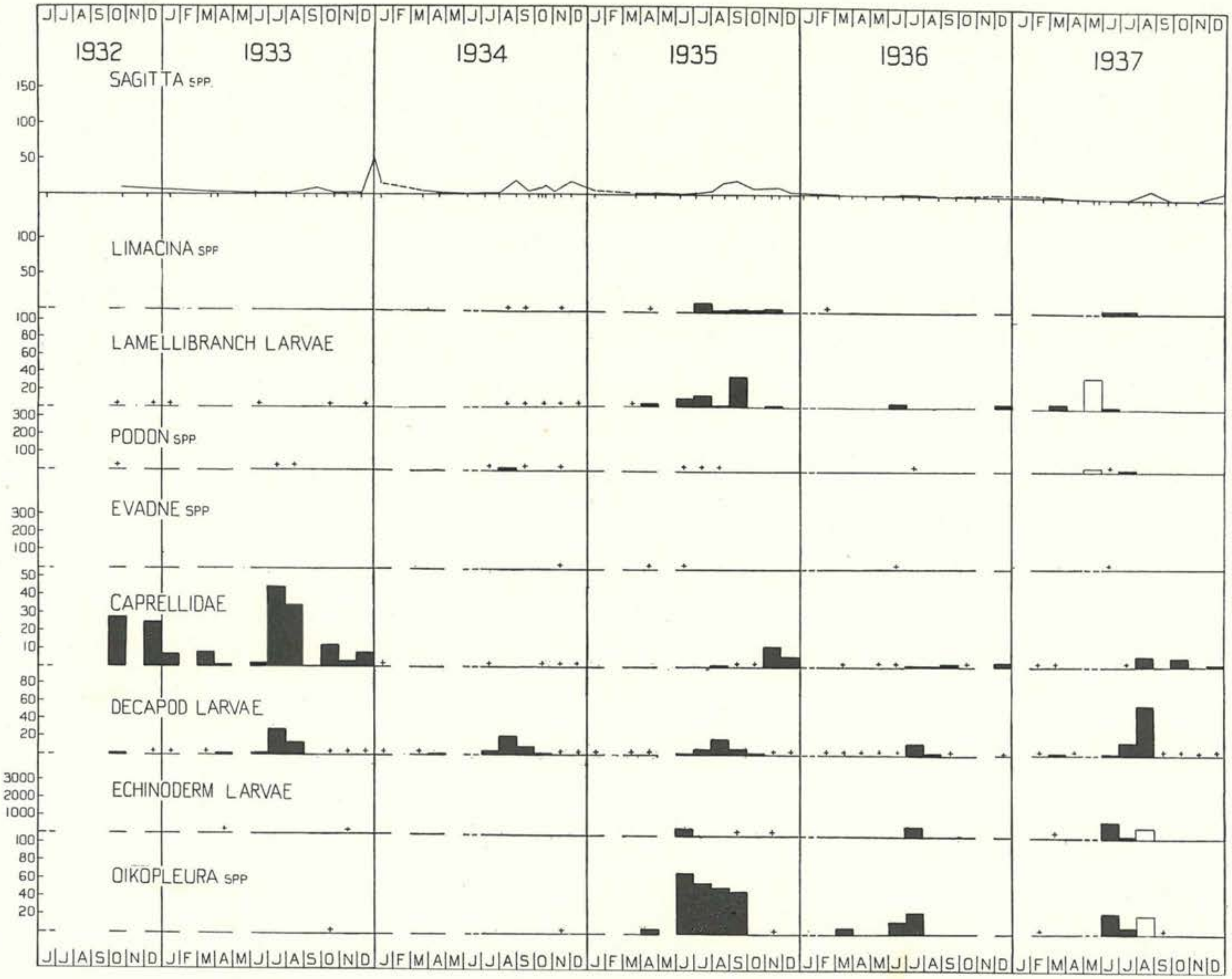
There is some evidence of two main productive periods in the year—May–June and September; but a comparison of the different years as seen in Text-figs. 1–3 will show how very irregular are the productions as recorded in our survey. The results for the C and B lines are brought together in Table I, where a capital letter **C** or **B** indicates when the average number exceeds 20 per block for the whole of one or other line; "–c" or "–b" indicates that no C or B record was obtained.

TABLE I.

	May.	June.	July.	August.	September.	October.
1932	–c, –b	. .	. .	. .	–c, **B**	**B**
1933	–c	–b	. .	–c	**C**	. .
1934	–c, **B**	**C**	–c	. .	**C**	–c
1935	**C**	–c, **B**	. .	. .	. .	**B**
1936	**B**	–c, **B**	**C**	**C**	**C**	–c
1937	**B**	. .	. .	**C**	. .	. .
	—	—	—	—	—	—
	4	3	1	2	4	2

At times such patches of larvae may have been missed in the space between the lines; more likely still, however, is it that some outbursts of larvae have been missed *in time* between one monthly record and the next. Davis (1925), writing of *Spisula subtruncata* (p. 24), says the length of the pelagic life of the larva is quite unknown, but suggests (p. 23) that a mean date of spawning may be "followed by a mean date of spat fall not many weeks or even days later."

Actually there is evidence in our survey that a period of high production may extend over at least a fortnight. The repeated C line in September, 1934 (Plate CXLV), gave a pattern of distribution on the 29th remarkably similar to that obtained



TEXT-FIG. 3.—Graph and histograms showing the average number of the commoner zooplankton forms (other than Copepoda) per ten-mile block on the Rotterdam line for each month from June, 1932, to December, 1937. For explanation of arrangement, see legend of Fig. 1.

on the 15th. It is clear that the recorder must be run more often if it is required to give a measure of the production of larval forms which have a planktonic life of less than a month. The value of these preliminary records lies, not in the actual information they provide, which is clearly inadequate, but in demonstrating how it might be possible in a general programme of fishery research to have a measure of the larval Lamellibranch production from year to year. The great importance of lamellibranchs as the food of plaice and other bottom-living fish is well recognized, and recorders on the C and new L line (Leith to Hamburg, begun in 1938), which cross the Dogger Bank in different directions, could be run at more frequent intervals, just as the B line has been run at weekly intervals for phytoplankton in the autumn. Davis indicates that the spawning season for *Spisula subtruncata* may extend from the beginning of June to the end of September.

Cladocera : Evadne and Podon (Plates CXLVII and CXLVIII).

The data for the two genera Evadne and Podon are charted separately except for three occasions (August, '34, and May and July, '37), when special conditions rendered identification uncertain. These doubtful cases are indicated by large stars on the Evadne charts, and the actual values of these undetermined Cladocera are shown on the Podon charts as squares. In Text-fig. 1 they are shown as cross-hatched histograms with those for both Podon and Evadne.

Evadne.—It is clear from both charts and histograms that Evadne was taken in highest numbers on the B and C routes, while it never reached significant proportions on the R route. It is an organism characterized by a relatively rapid appearance and disappearance. The high concentrations usually occur in May or June, or more rarely in July (*e.g.* 1936 C line). Numbers were comparatively low on both the C and B lines from 1932 to '34, but showing a gradual increase on the former. High numbers occur on both C and B in June, 1935 ; the C record is a short one, rather less than half the normal average, so the average figure cannot be compared with the averages for full records, but if the total value is averaged as if it constituted a complete record, a figure of 416 per block is obtained (shown as an open histogram in Text-fig. 1), which shows a great increase over 1934, and is nearly equal to the high figure for June, 1937, which is an average for a full record. In June, 1936, there was a very high concentration on the B line ; unfortunately there was no C record in this month. In 1937 the production on B was very low, whereas that on C in June was high.

Podon.—As with Evadne, the more important concentrations were taken on the C and B lines, but never reached such high numbers. There was no outstanding concentration on B, and only in 1932 and '37 (see Text-fig. 1) were moderately high numbers taken on C.

A comparison of the relative numbers of the two genera (Text-figs. 1, 2 and 3) gives a general correspondence for route B, but Evadne increased more in proportion to Podon in 1935 and '36. On route C Podon was abundant in 1932 when

Evadne was at a minimum, while conversely Evadne appeared in high numbers in 1935, when Podon was very scarce. As with the Lamellibranch larvae, the monthly records probably do not give a sufficiently detailed picture of the variations in the populations, since both genera show a pronounced swarming habit and occur over a relatively short period. It is clear, however, that the conditions governing the relative numbers of the two genera vary very considerably over the different areas.

Caprellid Amphipoda (Plates CXLI and CXLII).

Reference to the charts will show that the main concentrations were found over the eastern part of the area, particularly off the Dutch coast on the eastern ends of the B and R routes. The group, however, became widespread over the B route in the latter months of 1933, '36 and '37. Throughout there was a general tendency for them to appear on the C route later in the year than on the more southerly routes.

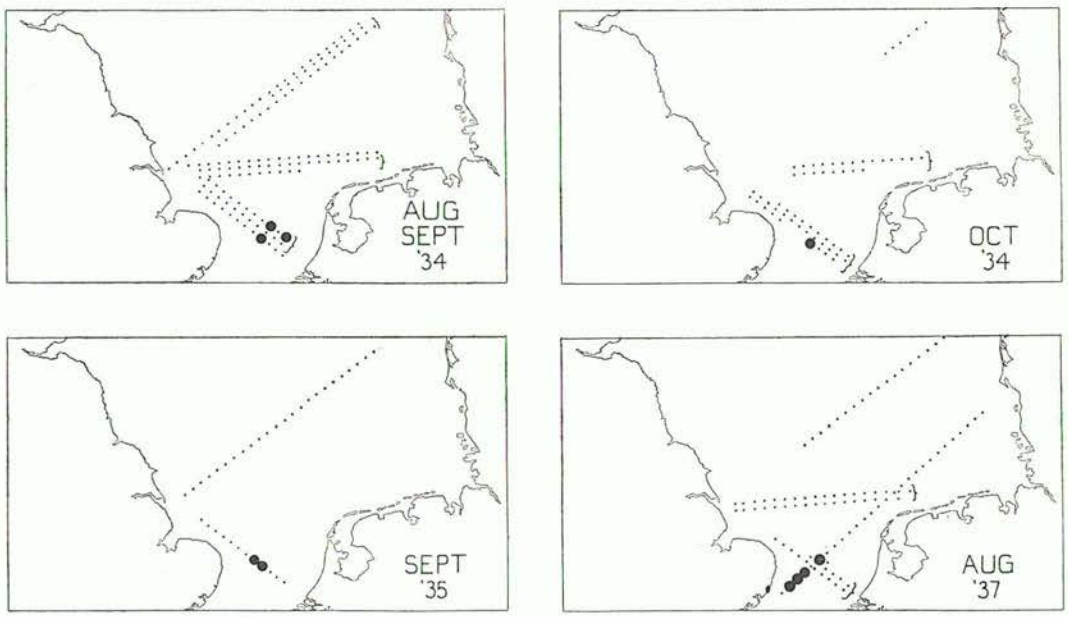
Text-figs. 1–3 show clearly a gradual reduction in numbers in a northerly direction, the densest populations being on the southerly R route and the most sparse on C. It will be seen that by far the highest numbers were taken on the B and R routes in 1932 and '33, while in marked contrast to this the averages were minimal in 1934 and quite low from 1935 to '37. The numbers on the C route were never sufficiently high to be plotted on the scale adopted for the histograms.

Regarding the tendency for the Caprellids to occur later in the year on the C route than on the others, there is some evidence to suggest a regular sequence in space and time for the appearance of the group. In the latter halves of 1933, '35, '36 and '37 they first appeared on the R route, then on the B route and finally on the C route, the region of the R route forming perhaps a nearby permanent reserve. As the Caprellids are generally considered to be tychopelagic forms, this northerly sequence may give important information regarding the changes in vertical water movements over the area as well as the possibility of " drift."

Decapod Larvae (Plates CXXXVIII–CXL).

The Decapod larvae were present over the southern North Sea during each month of the whole period. Generally speaking the main production begins in May, reaching a maximum in July or August, and starts to decline in September. It will be seen that production tends to be concentrated in well-defined areas. Thus the numbers are generally higher over the eastern part of the B line, the western part of the C line and, rather in contrast to other forms, the Humber end of the R line. The E line showed a large production in the Heligoland Bight region in July, 1937, suggesting that the higher numbers which are found on the eastern half of B may be part of an intense general production which is associated with the Heligoland Bight and neighbouring areas. Before and after this summer production, *i.e.* over the periods January to April and October to December, a rather sparse population of larvae is to be found.

If the annual variations shown in Text-figs. 1–3 are examined it will be seen that, while there is little evidence for a general trend of larval production over the whole area, certain trends are apparent on the different routes. On C and B there was a moderate production in July and August, 1932, while in July, 1933, maximum numbers were found. Savage (1937) found the herring to be eating Decapod larvae more in 1933 than in 1932 or '34. After a drop in numbers in 1934 the average for July, 1935, shows practically the same value as that obtained



Text-fig. 4.—Charts showing the occurrence of Alima larvae of Squilla spp. during the period 1932–37.

for 1933, while 1936 and '37 show a progressively decreasing production. The population on R was very small in 1932, but fairly numerous in 1933, thereafter gradually decreasing up to the end of 1936. In 1937, however, maximum numbers were taken in August. The trend for the C route is exactly opposite to that on the R route from 1932 to '36. Maximum quantities were taken in July, 1932, falling to a minimum in 1933, but from 1934 to '37 there occurred a progressive increase, the largest number for each of these years falling in August.

Stomatopod Larvae.

In the late summer or autumn, of three years out of six (1934, '35 and '37) the Alima larvae of Squilla (species undetermined) have been taken on the recorder lines always in the same region where the Channel opens into the Southern Bight.

The positions and months of the occurrences are shown in Text-fig. 4, where it will be seen that they were most persistently found in 1934, from August to October. Adult specimens of Squilla have very rarely been recorded for the North Sea, but two species, *S. mantis* (L.) and *S. desmaresti* Risso, are from time to time taken on the French and English coasts of the Channel, and Squilla larvae have been recorded as far north as the Dogger Bank. It seems likely that these larvae may be used as important indicators of water movements in this area when more is known of the spawning of the adults.

Echinoderm Larvae (Plate CXLIX).

The main centres of production were off the Dutch-German coast and the north-east border of the Dogger Bank (probably extending to the Danish coast as shown by the E and extended C lines in July, '37), whilst smaller numbers occurred over the western half of B. They appeared in notable abundance off the Dutch coast in July, 1935, '36 and '37, and over the Dogger Bank in June, July and September, '34, and July, '37.

Text-figs. 1–3 show that production on the B line was by far the most important, although numbers were very low until 1935, increasing further to very high figures in '36 and '37. Line R followed line B closely, but with much smaller numbers, there being practically no records until June, '35, to be followed by slight increases in '36 and '37. On the C route broods were poor except for the developments over the Dogger region in '34 and '37.

Oikopleura (Plates CXLIII–CXLIV).

It was not possible to identify the species concerned.[1] The charts show the whole distribution except for traces on the B line in November and December, 1932, January and February, '33, and October, '37, and larger quantities on the C and R lines in September, '35, the chart for which was omitted in error from Plate CXLIV, but is shown as a figure with the explanation of the Plates on p. 273.

The histograms of monthly averages for the three routes show a markedly similar trend over the period. Oikopleura was particularly sparse from 1932 to '34, only reaching values higher than 20 on the B route in September and August of 1932 and '34 respectively. Maximum numbers, however, occurred in 1935 in June on the R route, July on B, and September on C. In 1936, although there was a decrease in maximal numbers relative to 1935, the averages on the B and C routes were still comparatively high. On the former route in 1936 they were taken in irregular abundance on four occasions over the period February to September. By 1937 the averages on the B and C routes had fallen appreciably, while the R route showed values much the same as in 1936.

[1] Oikopleura usually suffered much damage on the silk and was often broken up. This condition has been somewhat improved by the device introduced at the end of 1937 (Hardy, 1939, p. 26), and it is hoped that specific identification may be made in later surveys.

This form was clearly most abundant over the B line. The extraordinary scarcity in 1933 recalls the fact that Savage (1937) found it to be scarcer in the herring food off Shields in that year.

Other Zooplankton Forms.

Apart from the Mysidacea and Euphausiacea, which have been omitted for the reasons already given (p. 258), a number of other forms were taken in small numbers and about which no useful distributional information can be given from the present survey; they include radiolarians, various medusae (badly damaged by the recorder), Hyperiid Amphipoda and Amphioxus larvae (taken over the Dogger Bank). These records may be used in later reports, when further data may add to their significance.

The General Community.

To conclude the account it may be well to outline the general ecological picture that can be gathered from the survey, particularly regarding those characters of distribution which the plankton recorder is specially designed to show by its continuity of action.

Apart from the copepods Paracalanus, Pseudocalanus, Temora and Acartia (see Rae and Fraser, 1941), Sagitta is the only zooplankton form which is nearly always present, and with them forms the basic predominant core of the animal community. Sagitta each year falls to a low ebb in May and June, but it is seldom completely absent from a record. While sparser in the south, it is widely spread throughout the region. Rarely does it form dense confined concentrations; a study of the charts will show that more often than not it is very evenly spread along the line of observation. Both distribution charts and time graphs (Text-figs. 1–3) show on the whole that populations rise and fall gradually; where lines have been repeated in the same month the distribution and quantities shown on consecutive runs are usually very similar (September, '33; September and October, '34; January, August and November, '35; February, '36; October and November, '37), and the few exceptions are mostly in August at the time of rapid increase (November, '32; August, '34; August, '36; and August, '37).

Next in usual presence are the decapod larvae, but more spasmodic in time and, as already described, occurring densely in definite areas. These areas are usually fairly wide in extent, and production may be heavy and remarkably even for long distances, particularly in July; as examples see the 90-mile stretch of uniform values at the north end of the E line in July, '37, and the long stretches of fairly even production on the B line in August, '32 (80 miles), July, '33 (140 miles), July, '34 (90 miles), July, '35 (110 miles), and July, '36 (110 miles).

Limacina is a summer and autumn form rarely occurring in the southern part of the area. It may be present in small numbers over long stretches at a time, but the higher numbers are usually more confined to definite patches of 40 miles or less.

The Cladocera come and go with a short burst of production, usually showing very dense concentrations of limited area. For Evadne (Plate CXLVII) see June, '32, July, '33, April, May, June and July, '35, June and July, '36, and for Podon (Plate CXLVIII), June, July and August, '32, June and July, '34, April and July, '35, June and August, '36. Evadne was more widespread in June, '34, and both genera showed an unusually wide distribution in June, '37.

Oikopleura is never taken in large numbers by the recorder; Text-figs. 1–3 show that it was much less abundant in the first three years of the survey than in the last three.

The patchy nature of the outbursts of Lamellibranch larvae has already been commented on (p. 264), while the Echinoderm larvae sometimes occur in great numbers over considerable stretches of the lines, *e.g.* June, '35, June, '36, June and July, '37.

The Caprellids, bottom-living forms coming up into the plankton, are sometimes widely spread as in August and September, '33, September and October, '36, and August to November, '37, or sometimes more confined in area as in 1933, '34 and '35.

Looking at the sequence of years (Text-figs. 1–3), one is struck by the general poverty of the plankton in 1933; this applied not only to the forms considered here. Rae and Fraser (1941) write of the Copepoda: "Although the successful preceding autumn crops were reflected in the early months of 1933 for some species, this was, on the whole, the leanest year of the survey."

Summary.

1. The report describes the main monthly changes in the distribution and abundance of the zooplankton, other than Copepoda and young fish (dealt with in separate reports), over the southern part of the North Sea from 1932 to 1937. The work is part of the survey carried out by continuous plankton recorders towed at a depth of 10 metres on regular steamship lines between England and the Continent.

2. The limitations to the sampling method are discussed, and it is shown to be unsuitable for recording Mysidacea and Euphausiacea on account of their marked diurnal variation due presumably to vertical migration; they are omitted from the report.

3. The changing distribution of Sagitta, Limacina, Clione, Lamellibranch larvae, Cladocera, Caprellid Amphipoda, Decapod larvae, Echinoderm larvae and Oikopleura are shown in a series of monthly charts while their seasonal fluctuations are compared in time-chart histograms.

4. The Alima larvae of Squilla are recorded on a few occasions in the regions where the Channel opens into the North Sea.

5. The distributional characteristics of the different forms, *i.e.* their tendencies to even or "patchy" production, are compared.

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EXPLANATION OF PLATES CXXVI TO CXLIX.

General Explanation.

Charts showing the distribution of the more important zooplankton organisms other than Copepoda and young fish as found by the plankton recorder survey of the southern North Sea from June, 1932, to December, 1937. The numerals and/or symbols denote the varying numbers *either* per 10-mile block *or* per mile per 10-mile block as is indicated together with the scale of symbols on the first plate for each group of organisms. When more than one record has been obtained in any month they have usually been shown " in parallel " (the earlier one above) and bracketed together; if more than two were obtained the additional ones may be shown below the chart, as, for example, September to November on Plate CXXXI. The day of the month on which each record (or the greater part of the record) was taken is shown enclosed in a circle opposite the eastern extremity of the line.

Plates CXXVI–CXXXI.

Charts showing the distribution of members of the genus Sagitta month by month from June, 1932, to December, 1937.

Plates CXXXII–CXXXVII.

Charts showing the distribution of the genus Limacina (largely, if not entirely *Limacina retroversa*) month by month from June, 1932, to December, 1937.

Occurrences of the Pteropod *Clione limacina* are shown by a special symbol.

PLATES CXXXVIII–CXL.

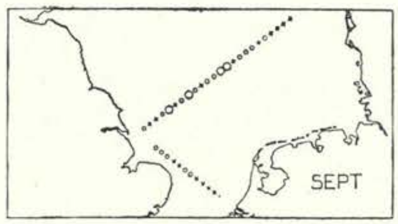
Charts showing the distribution of Decapod larvae month by month from June, 1932, to December, 1937.

PLATES CXLI, CXLII.

Charts showing the distribution of the Caprellid Amphipoda for just those months in which they were recorded from June, 1932, to December, 1937.

PLATES CXLIII, CXLIV.

Charts showing the distribution of Oikopleura in all those months in which they occur from June, 1932, to December, 1937, except for small traces referred to in the text (see page 269), and a chart for September, 1935, which was in error omitted from Plate CXLIV and is shown below.



PLATES CXLV, CXLVI.

Charts showing the distribution of the Lamellibranch larvae for those months in which they occur between June, 1932, and December, 1937.

PLATES CXLVII, CXLVIII.

Charts showing the distribution of the Cladocera (Evadne and Podon) in those months in which they occur in the period June, 1932, to December, 1937. On three occasions (August, 1934, and May and July, 1937) circumstances made the identification of the Cladocera doubtful. These records are shown by special symbols on the Podon charts on Plate CXLVIII, and the positions of these indetermined Cladocera are shown on the Evadne plate as large asterisks.

PLATE CXLIX.

Charts showing the distribution of the Echinoderm larvae for those months in which they occurred during the period June, 1932, to December, 1937.

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PLATE CXXVI

SAGITTA SPP. 1932

SCALE

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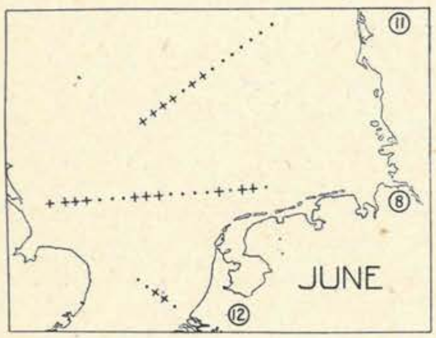
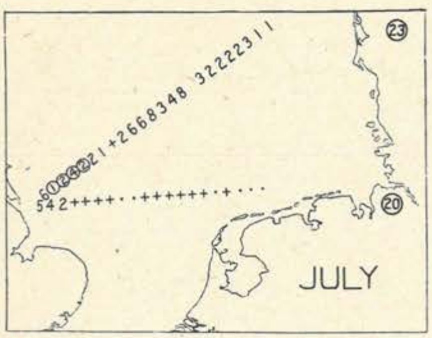
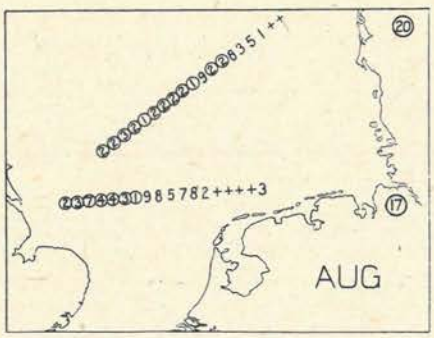
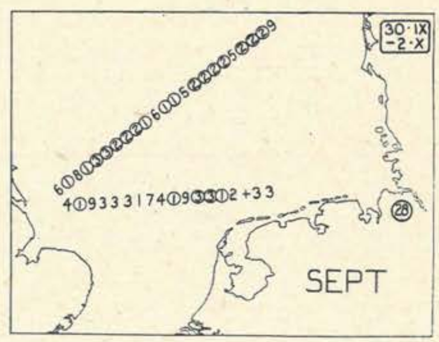
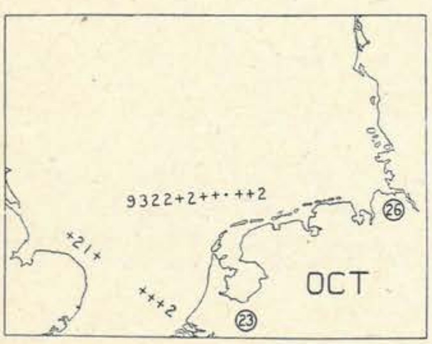
+ = 1-9		
1-9 = x 10		
①-⑨ = x 100		

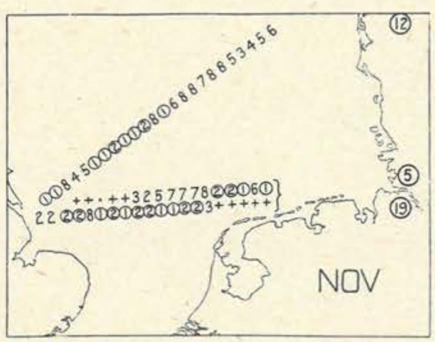












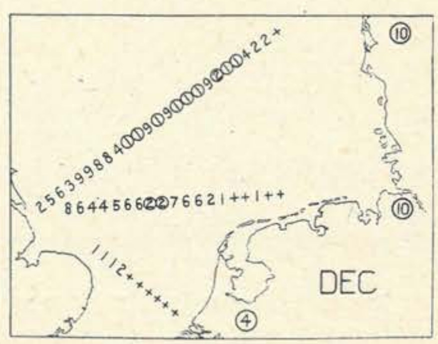


PLATE CXXVII

SAGITTA SPP. 1933

SCALE ON PLATE CXXVI

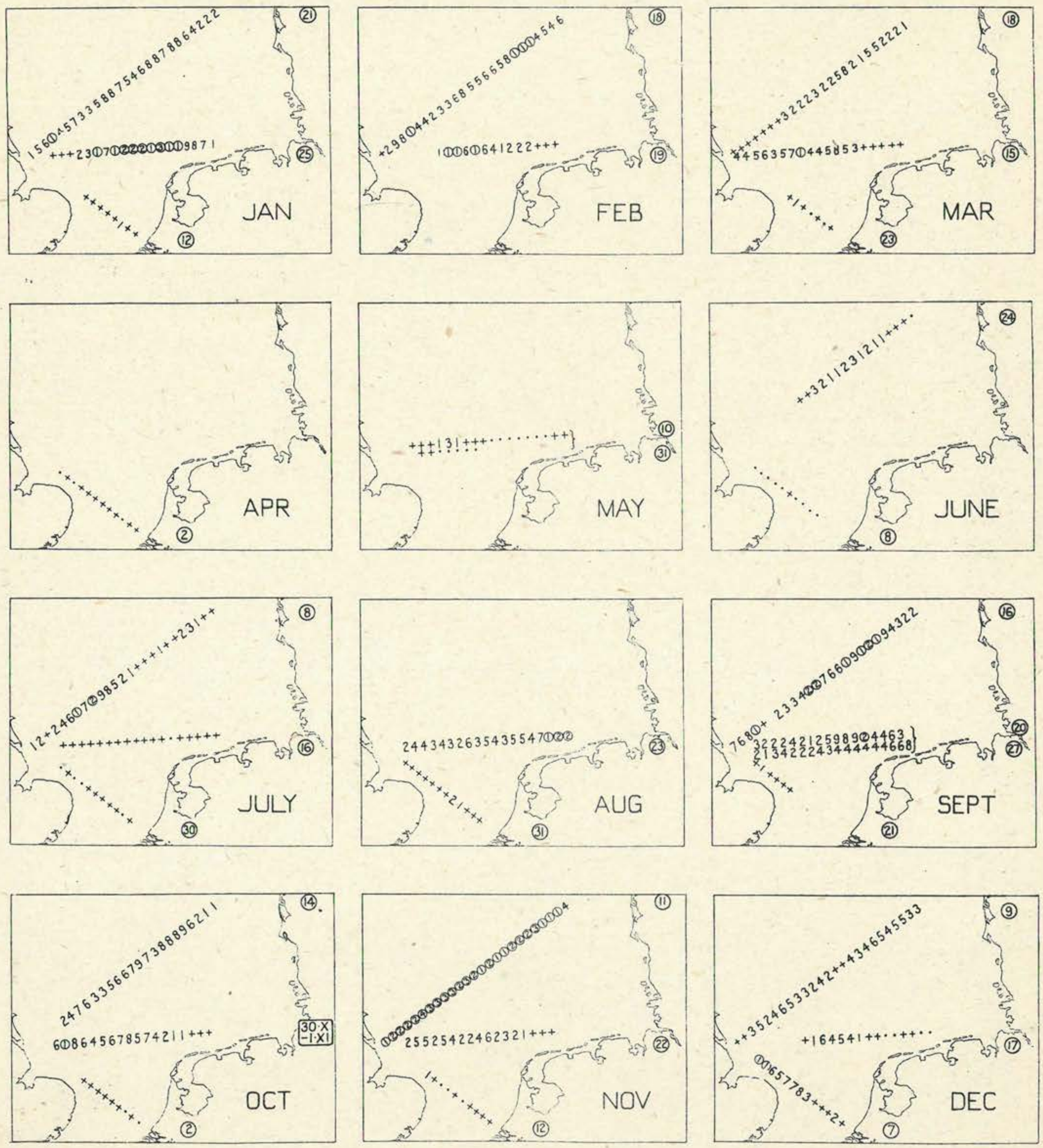


PLATE CXXVIII

SAGITTA SPP. 1934

SCALE ON PLATE CXXVI

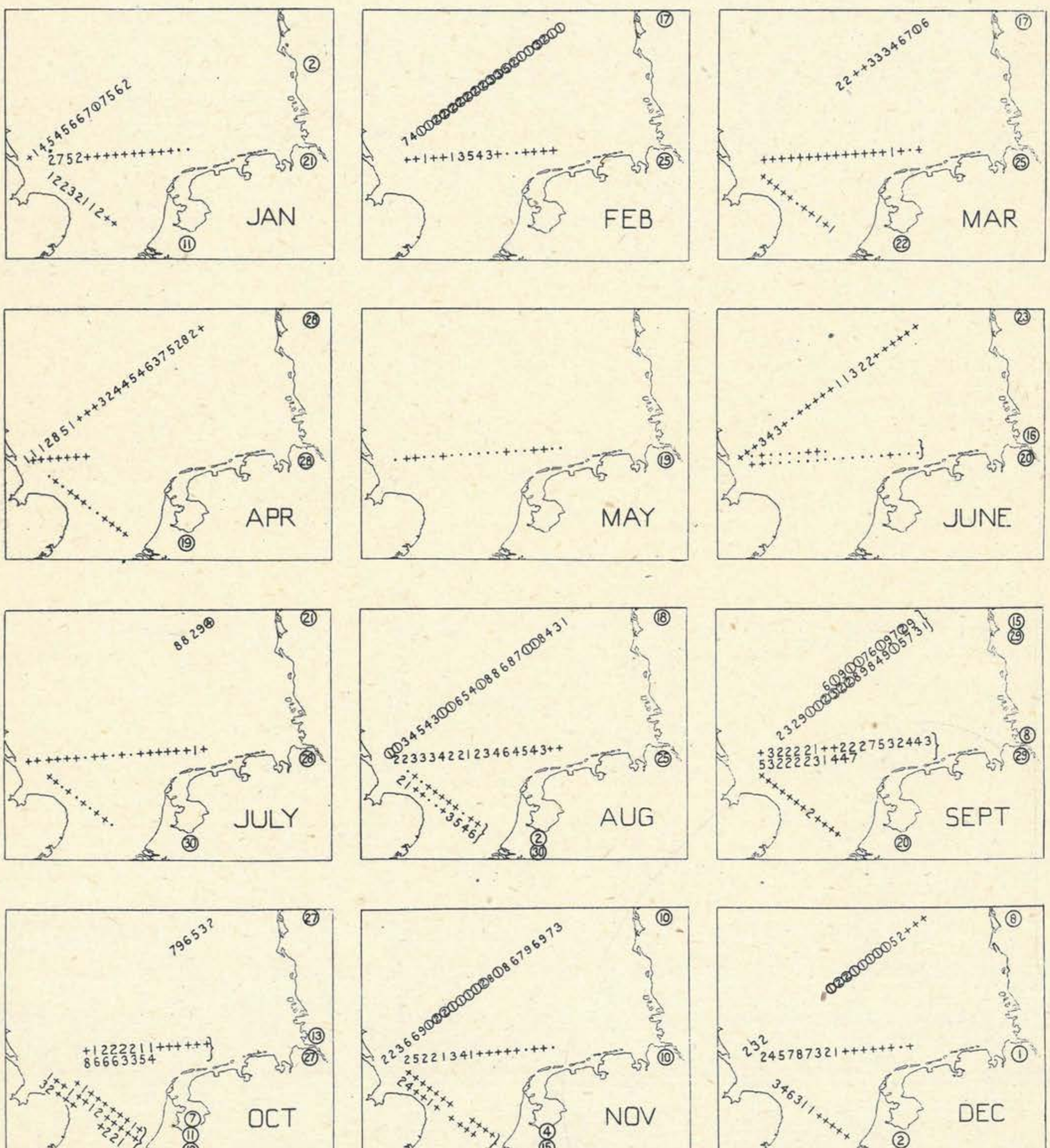


PLATE CXXIX

SAGITTA SPP. 1935

SCALE ON PLATE CXXVI

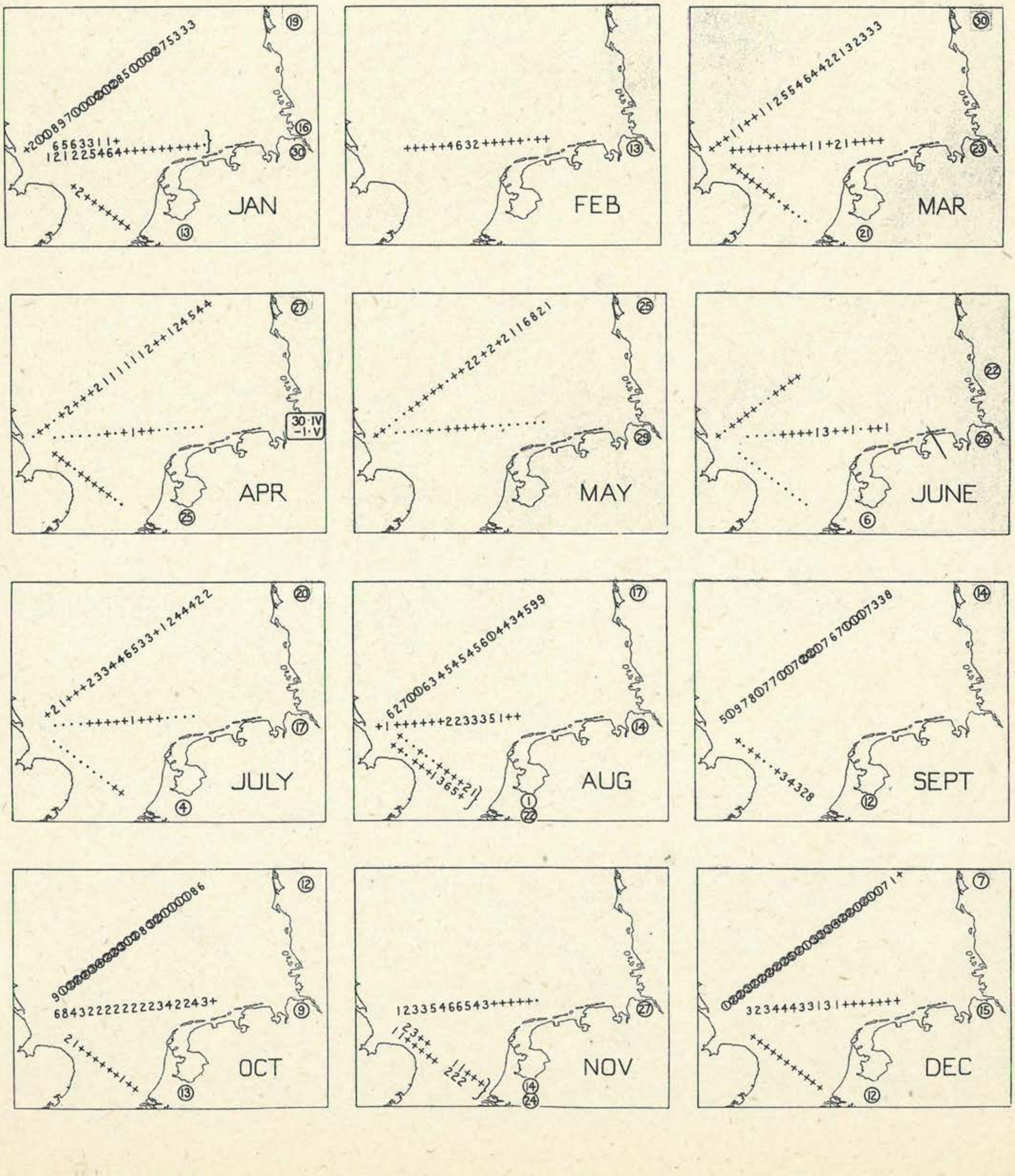


PLATE CXXX

SAGITTA SPP. 1936

SCALE ON PLATE CXXVI

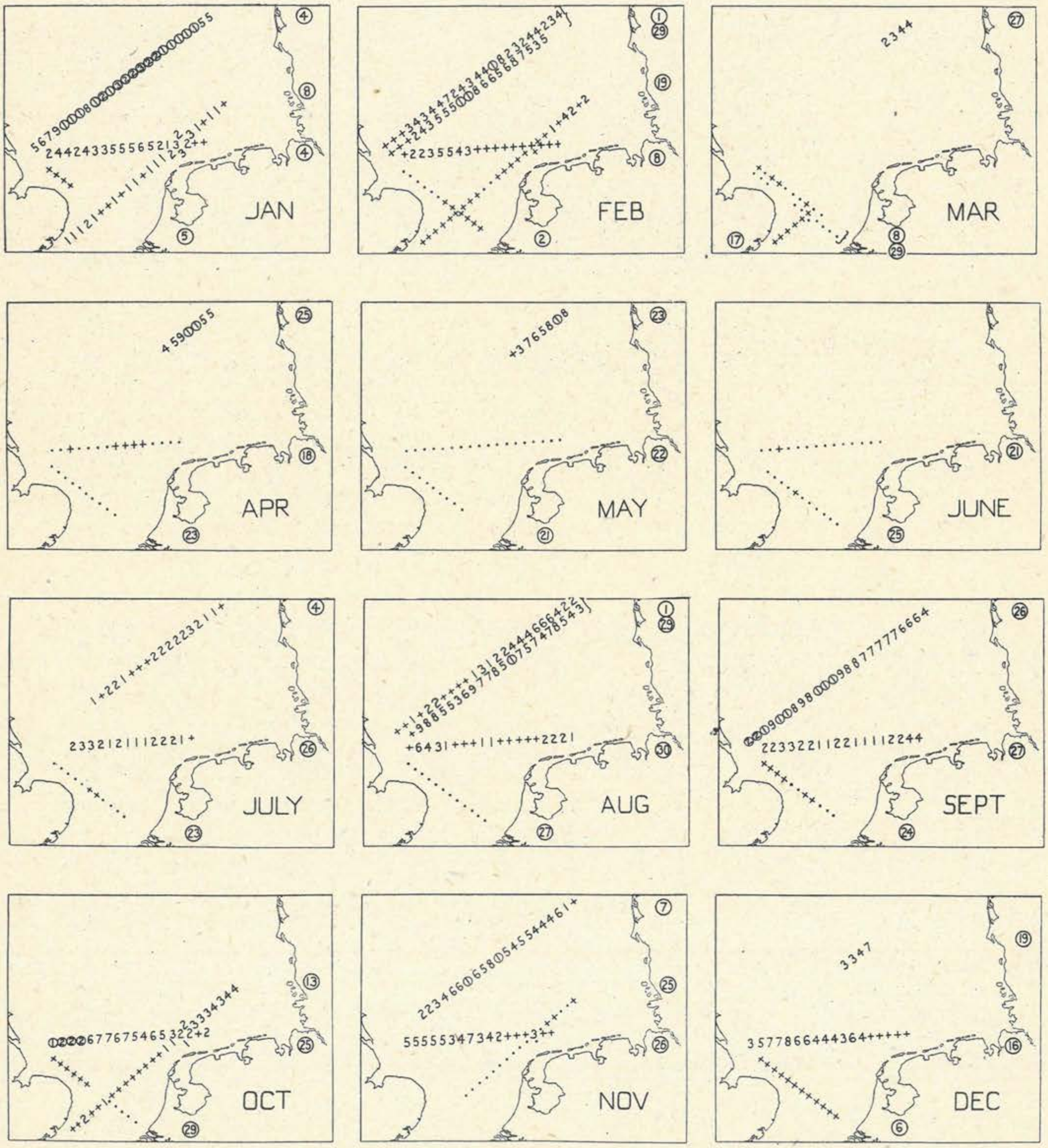


PLATE CXXXI

SAGITTA SPP. 1937

SCALE ON PLATE CXXVI

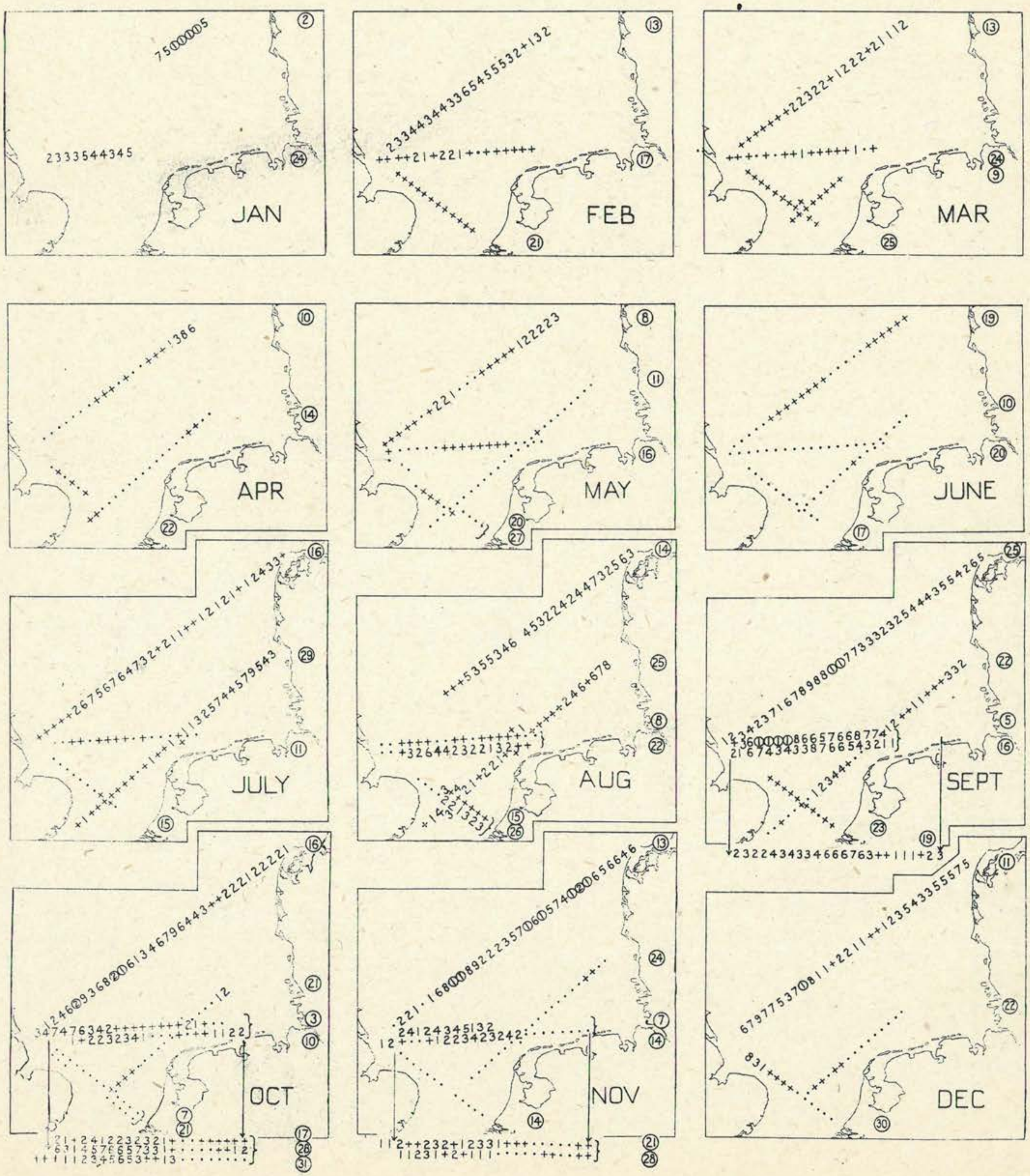


PLATE CXXXII

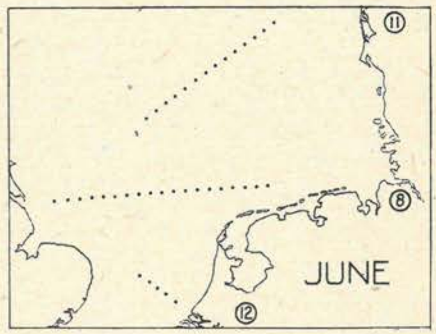
LIMACINA SPP. 1932

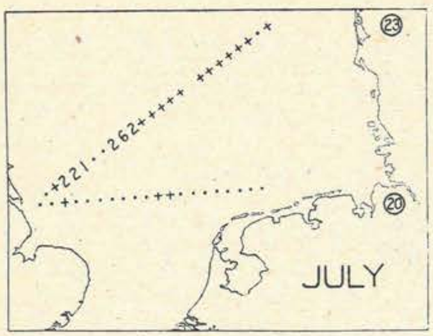
[ALSO *CLIONE LIMACINA*
IF RECORDED
SHOWN THUS ✝]

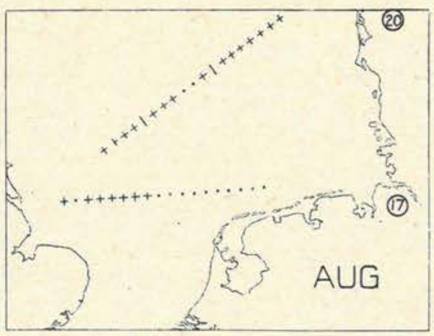
SCALE

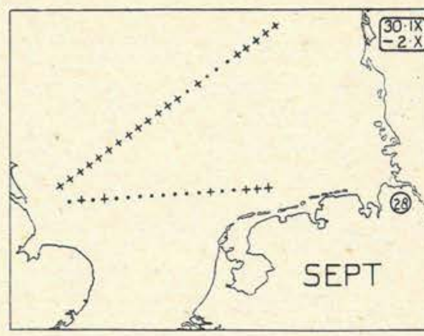
= 0
\+ = 1-9
1-9 = X 10
①-⑨ = X 100

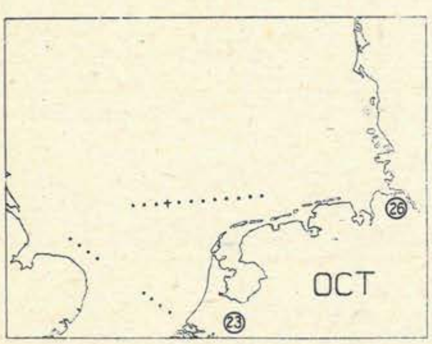
PER MILE
PER BLOCK

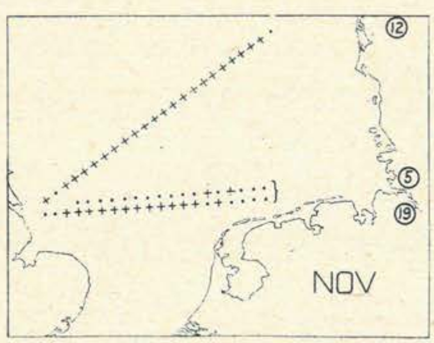












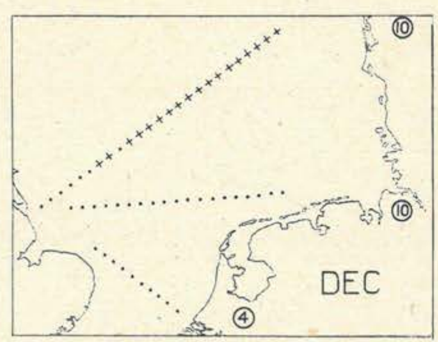
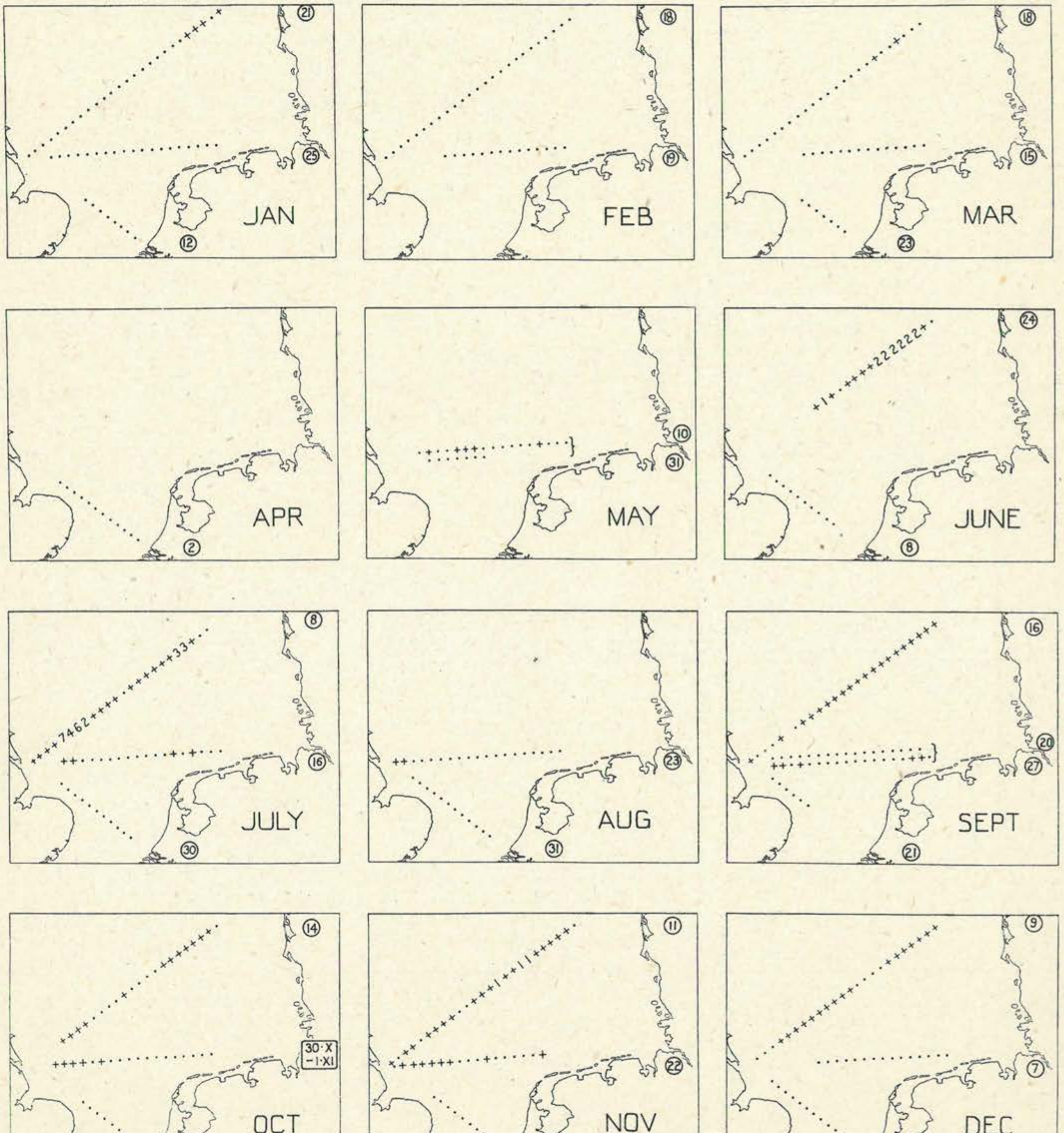


PLATE CXXXIII

LIMACINA SPP. 1933

SCALE ON PLATE CXXXII



LIMACINA SPP. 1934

SCALE ON PLATE CXXXII

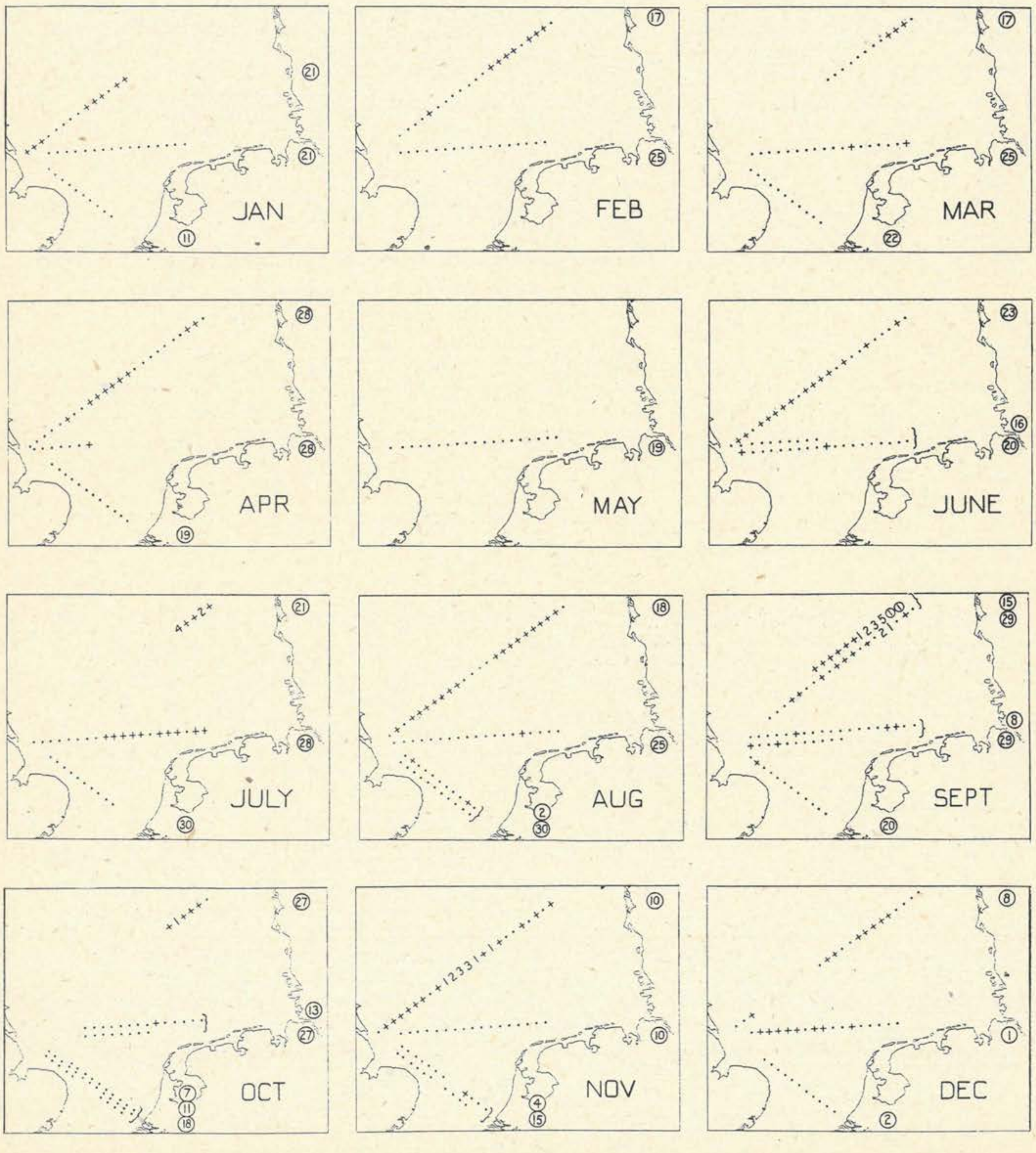


PLATE CXXXV

LIMACINA SPP. 1935

ALSO *CLIONE LIMACINA*: ✝

SCALE ON PLATE CXXXII

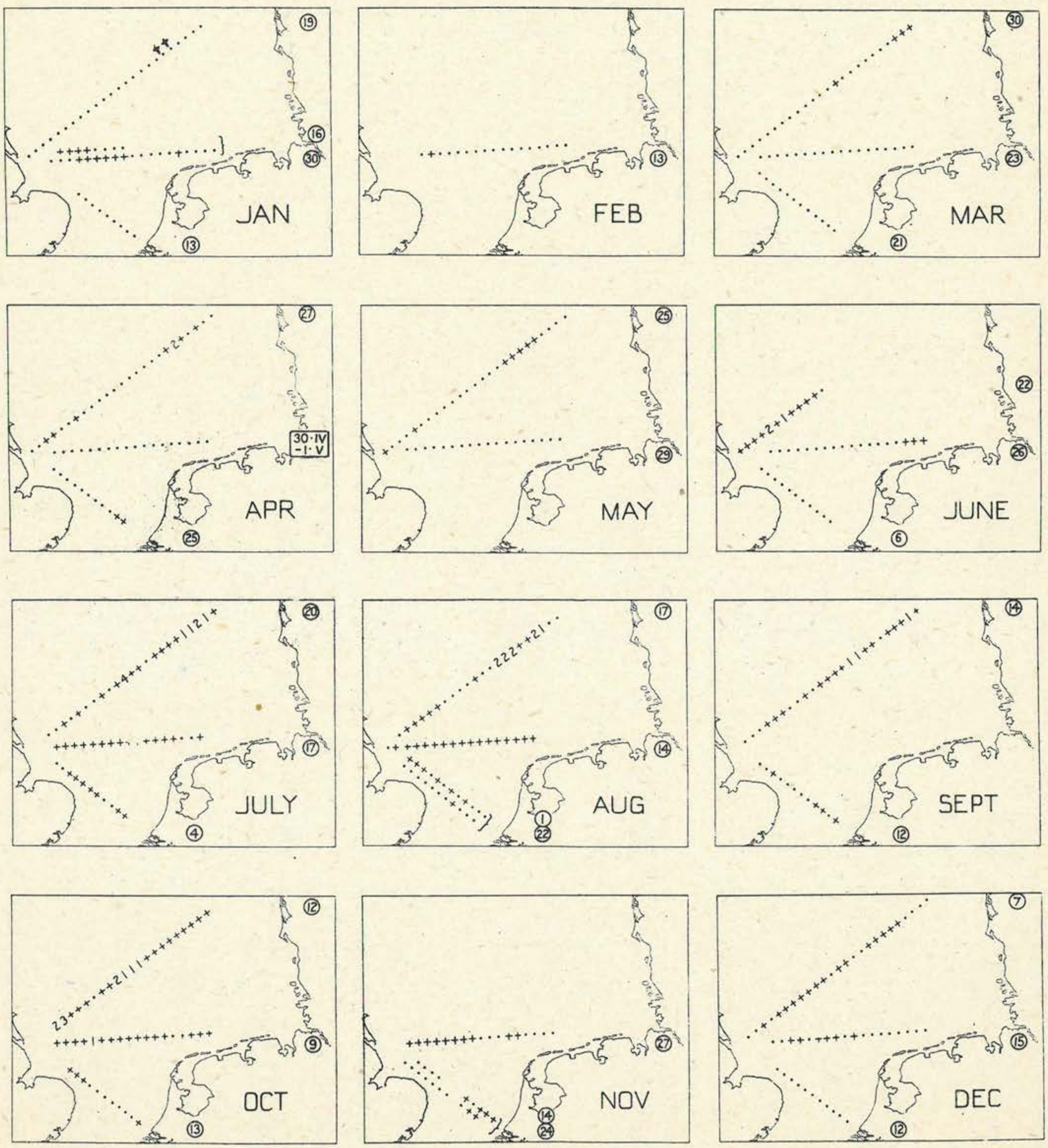


PLATE CXXXVI

LIMACINA SPP. 1936

ALSO *CLIONE LIMACINA*: ✝

SCALE ON PLATE CXXXII

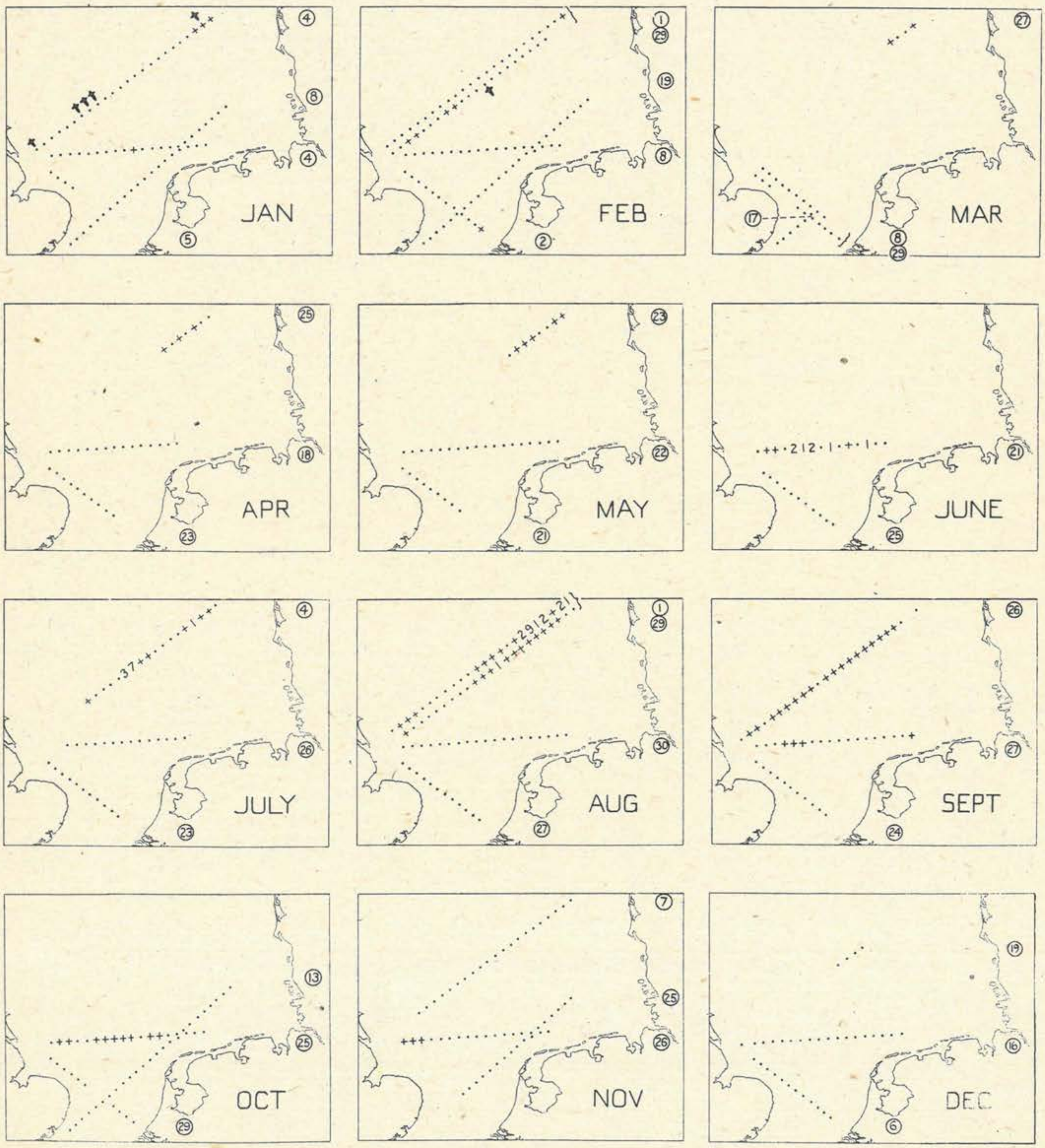


PLATE CXXXVII

LIMACINA SPP. 1937

SCALE ON PLATE CXXXII

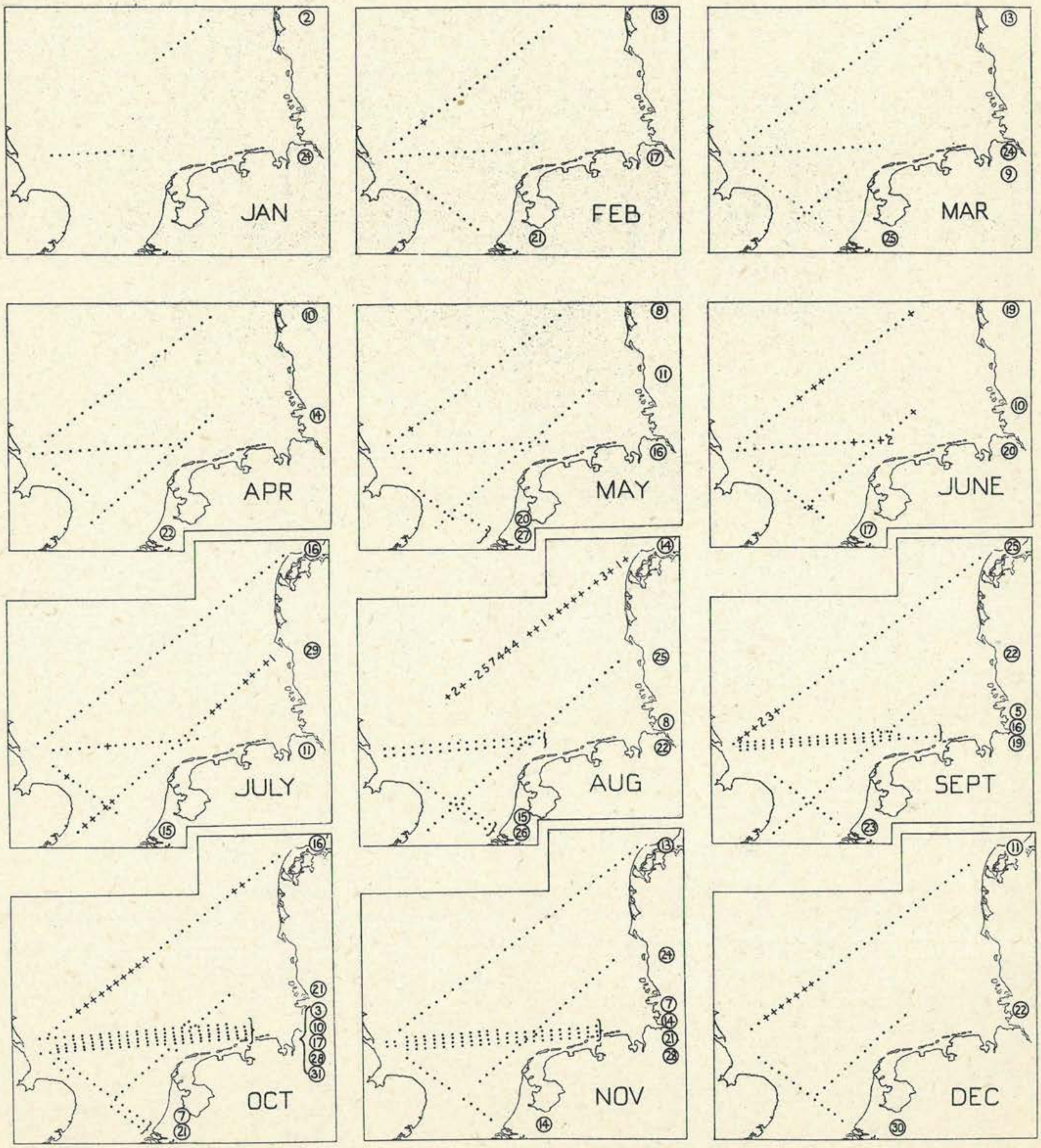


PLATE CXXXVIII

DECAPOD LARVAE

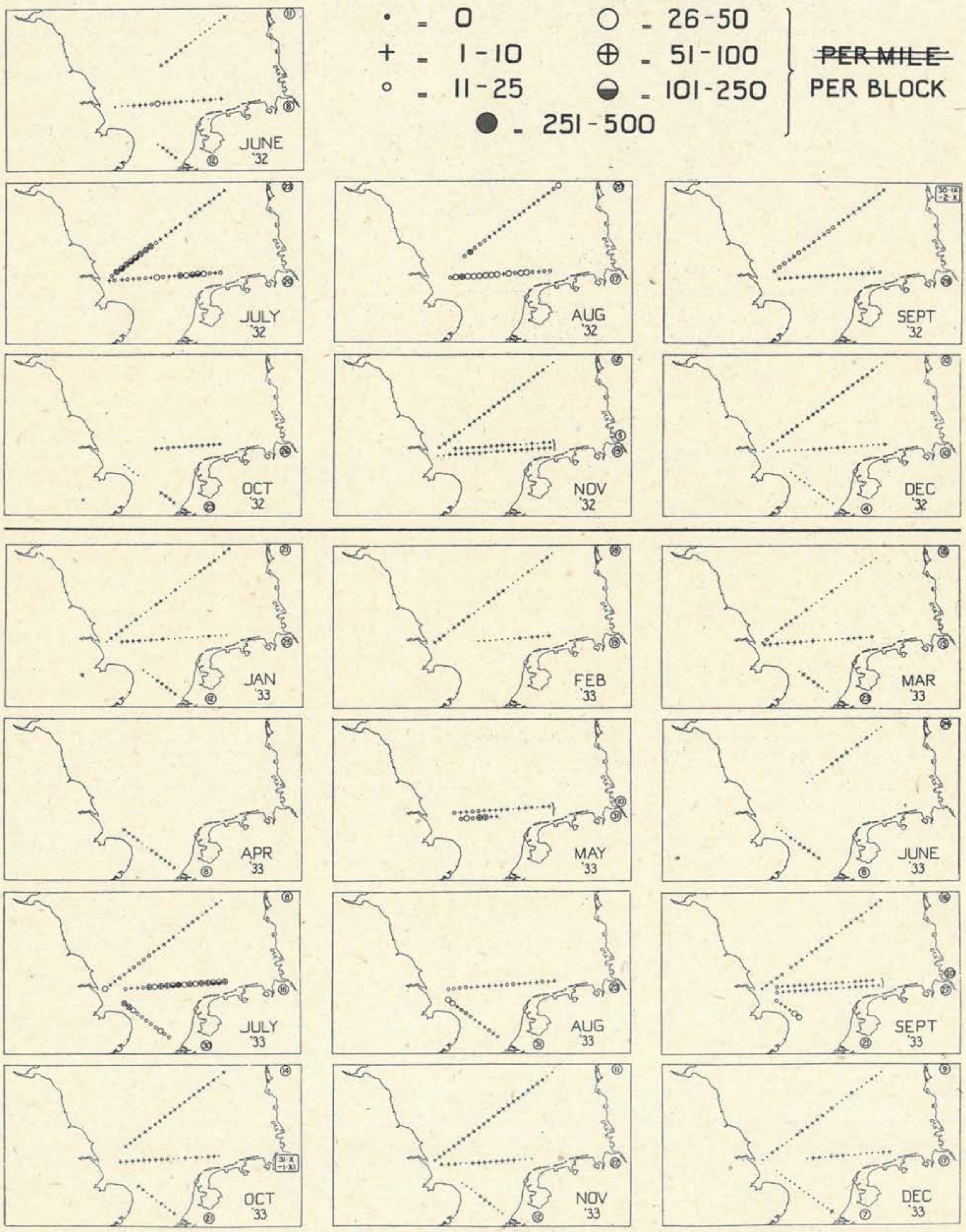


PLATE CXXXIX

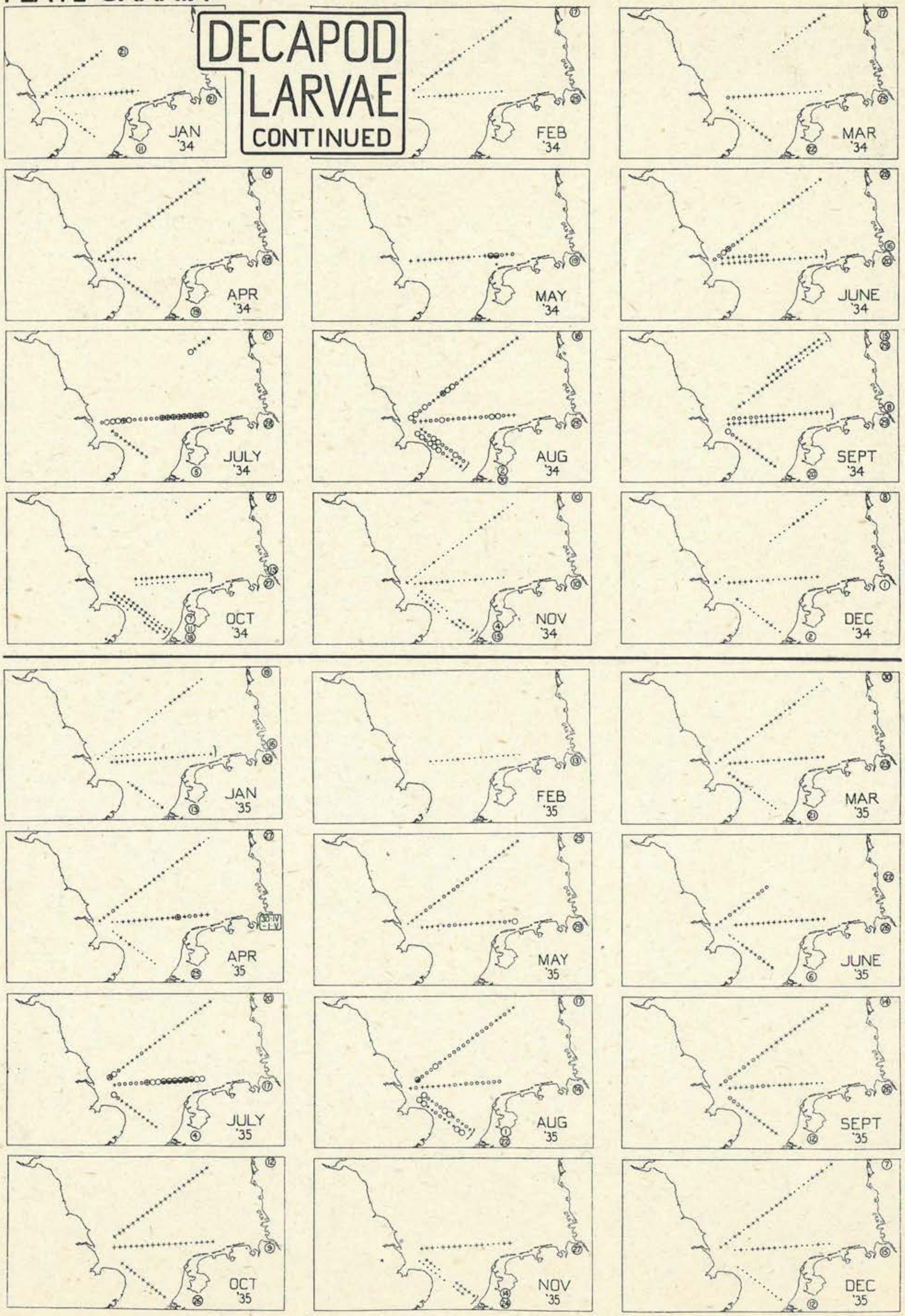


PLATE CXL

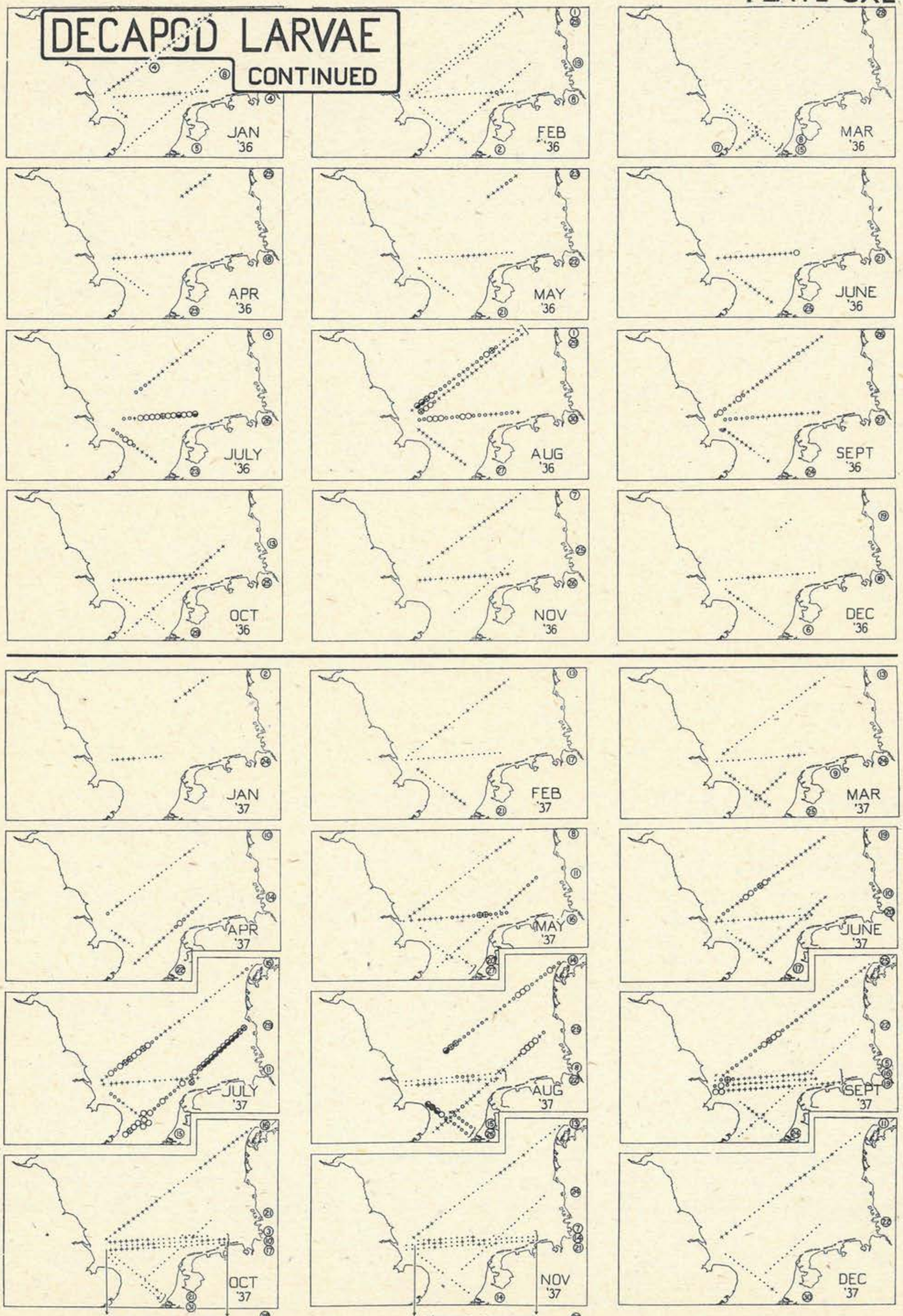

DECAPOD LARVAE
CONTINUED
JAN '36
FEB '36
MAR '36
APR '36
MAY '36
JUNE '36
JULY '36
AUG '36
SEPT '36
OCT '36
NOV '36
DEC '36
JAN '37
FEB '37
MAR '37
APR '37
MAY '37
JUNE '37
JULY '37
AUG '37
SEPT '37
OCT '37
NOV '37
DEC '37

PLATE CXLI

CAPRELLIDAE

SCALE

△ = 1 - 10 ◭ = 11-25 ▲ = 26-50 ▲ = > 50 } PER BLOCK

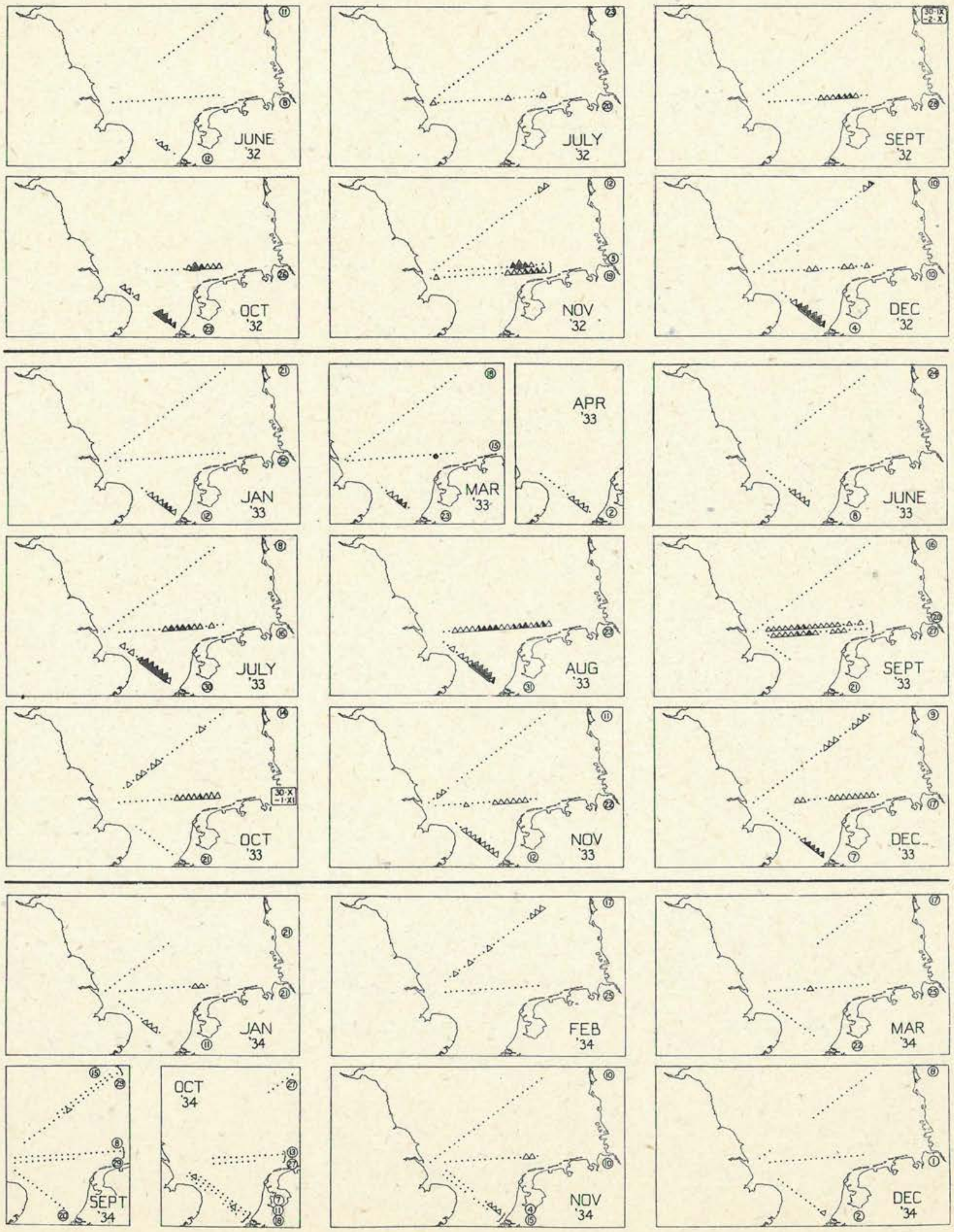


PLATE CXLII

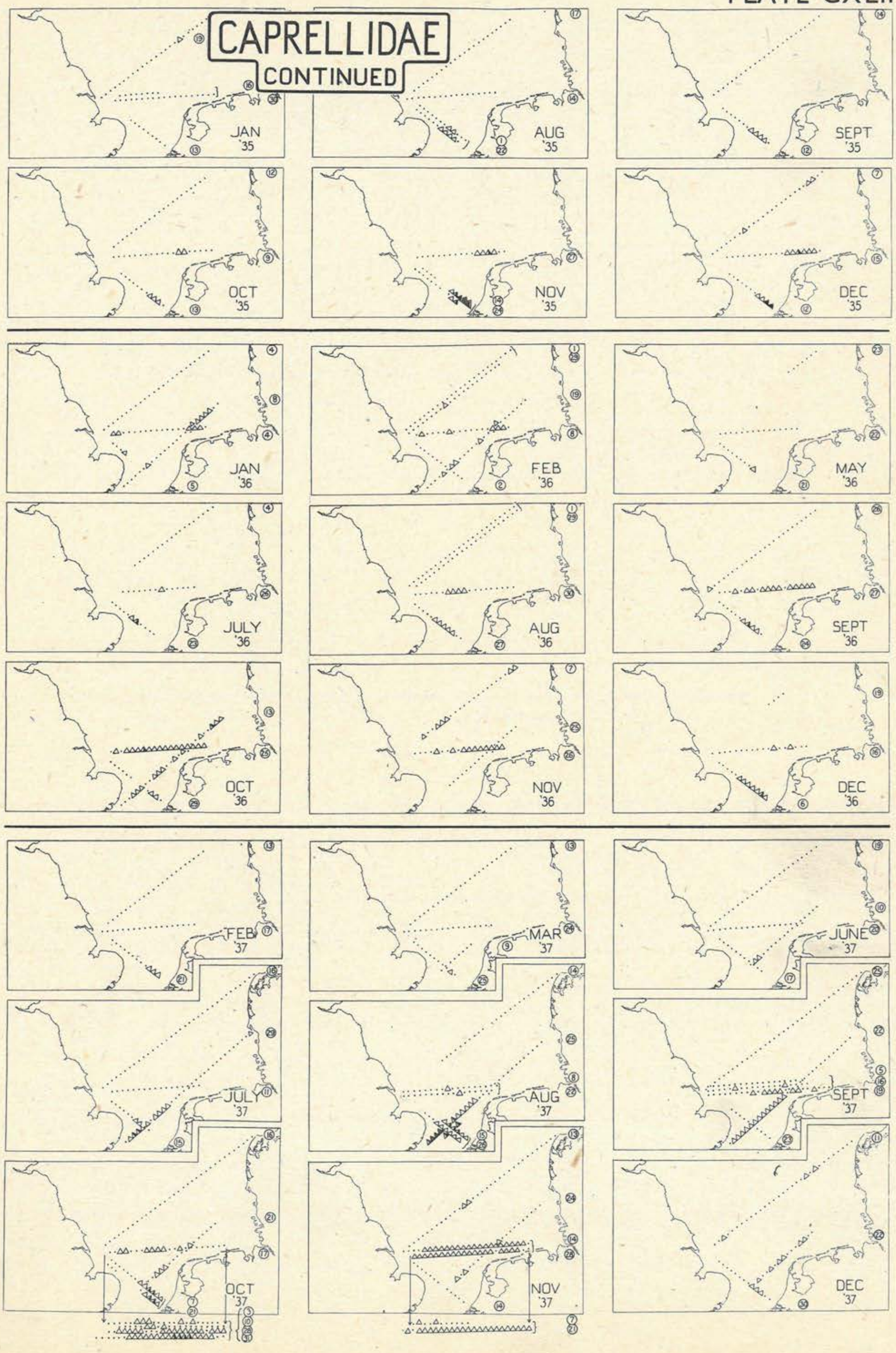

CAPRELLIDAE
CONTINUED
JAN '35
AUG '35
SEPT '35
OCT '35
NOV '35
DEC '35
JAN '36
FEB '36
MAY '36
JULY '36
AUG '36
SEPT '36
OCT '36
NOV '36
DEC '36
FEB '37
MAR '37
JUNE '37
JULY '37
AUG '37
SEPT '37
OCT '37
NOV '37
DEC '37

PLATE CXLIII

OIKOPLEURA SPP.

CONTINUED ON NEXT PLATE

SCALE

• -	0	PER MILE PER BLOCK
+ -	1-5	
∘ -	6-10	
○ -	11-25	

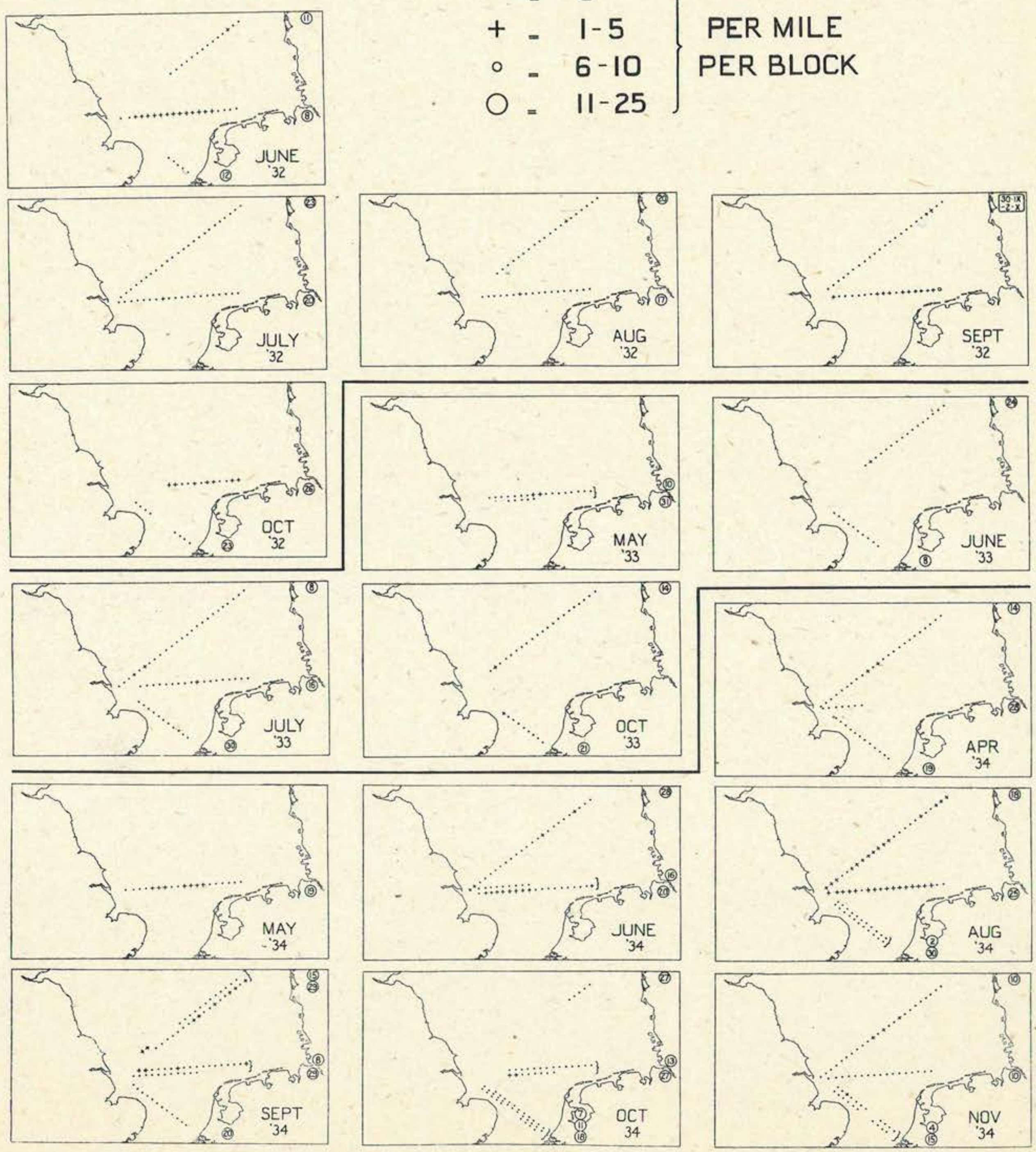


PLATE CXLIV

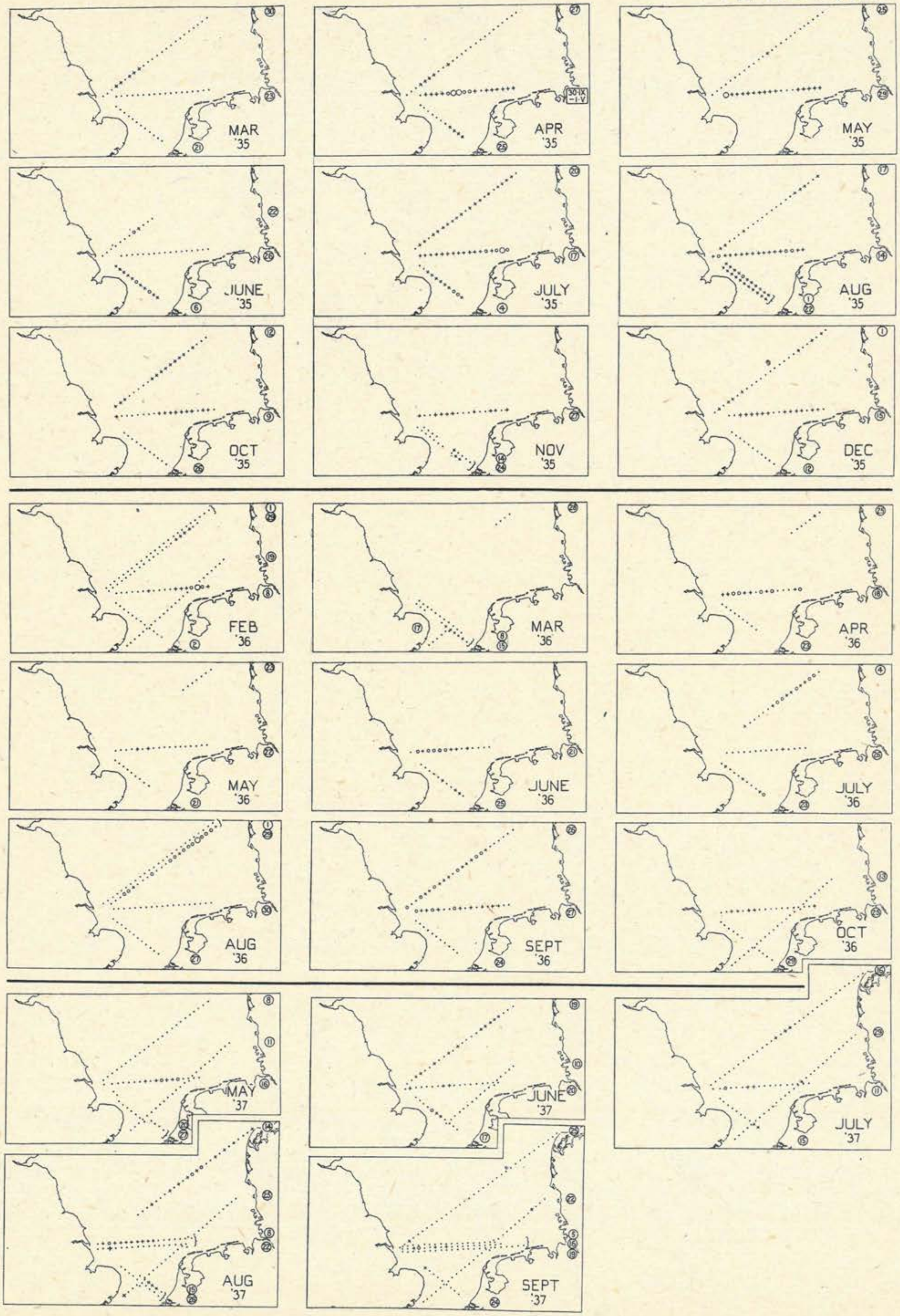

MAR '35
APR '35
MAY '35
JUNE '35
JULY '35
AUG '35
OCT '35
NOV '35
DEC '35
FEB '36
MAR '36
APR '36
MAY '36
JUNE '36
JULY '36
AUG '36
SEPT '36
OCT '36
MAY '37
JUNE '37
JULY '37
AUG '37
SEPT '37

PLATE CXLV

LAMELLIBRANCH LARVAE

SCALE

· – 0	○ – 26 - 50	PER MILE PER BLOCK
+ – 1 - 10	⊕ – 51 - 100	
∘ – 11 - 25	◒ – 101 - 250	

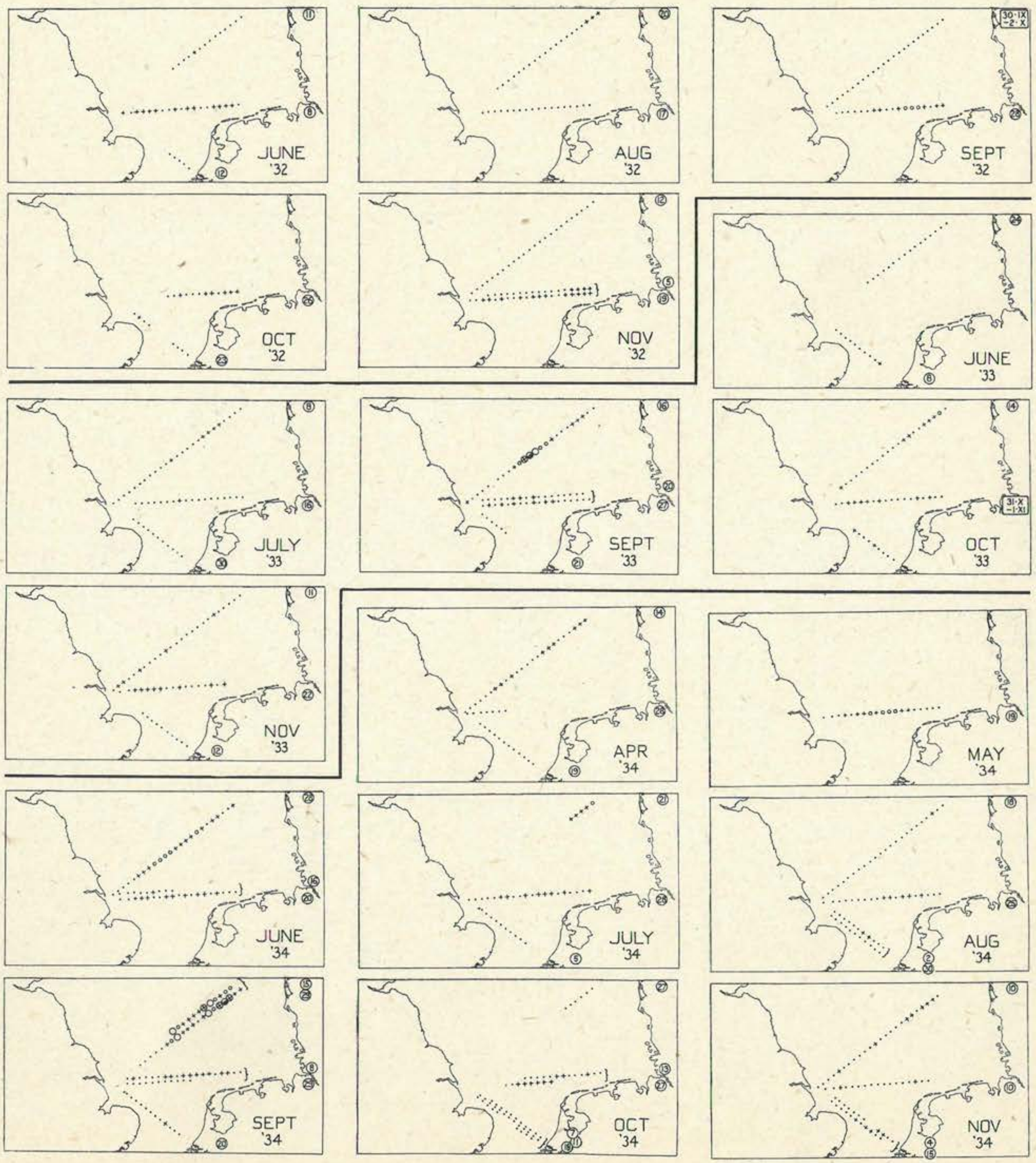


PLATE CXLVI

LAMELLIBRANCH LARVAE CONTINUED

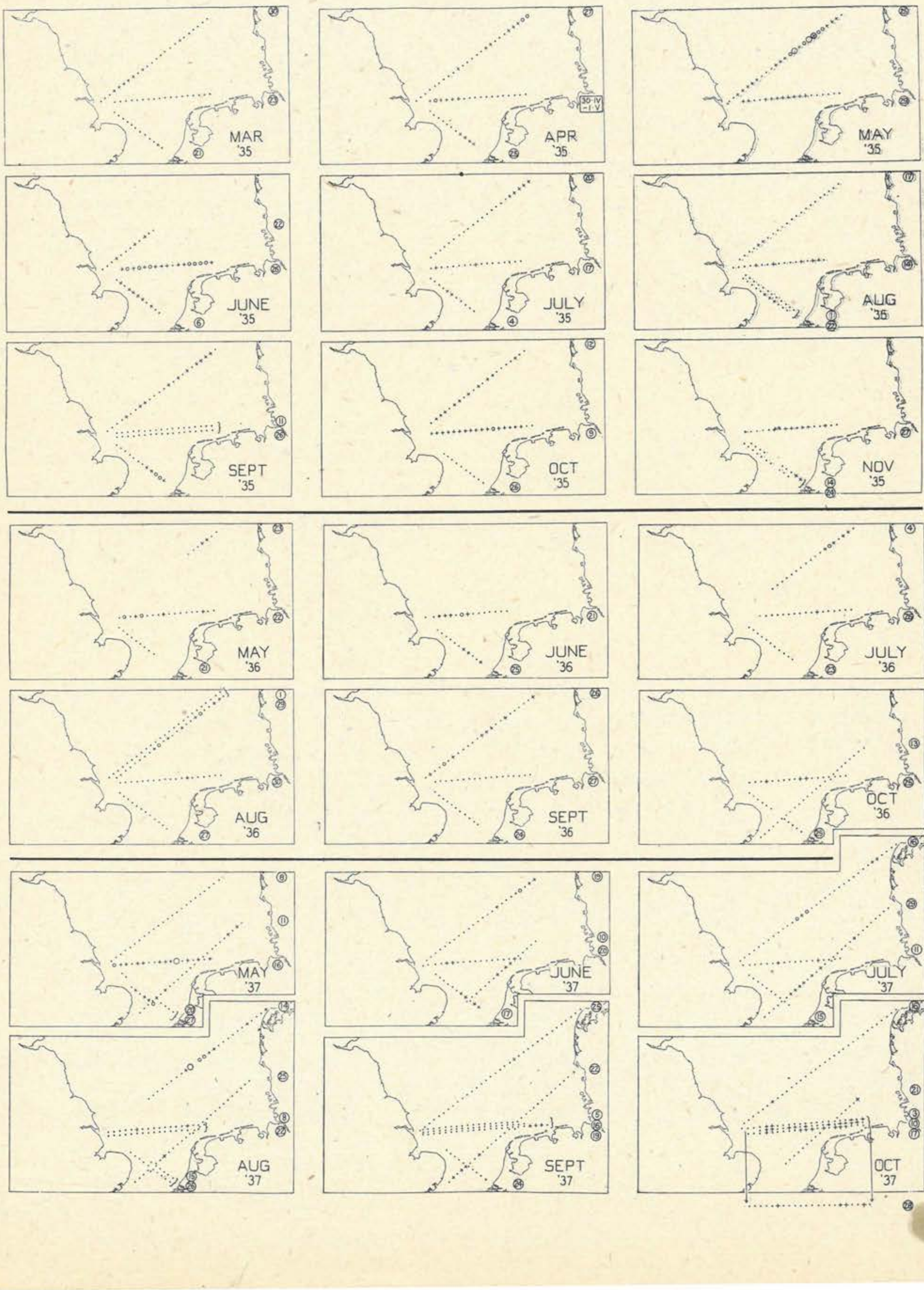
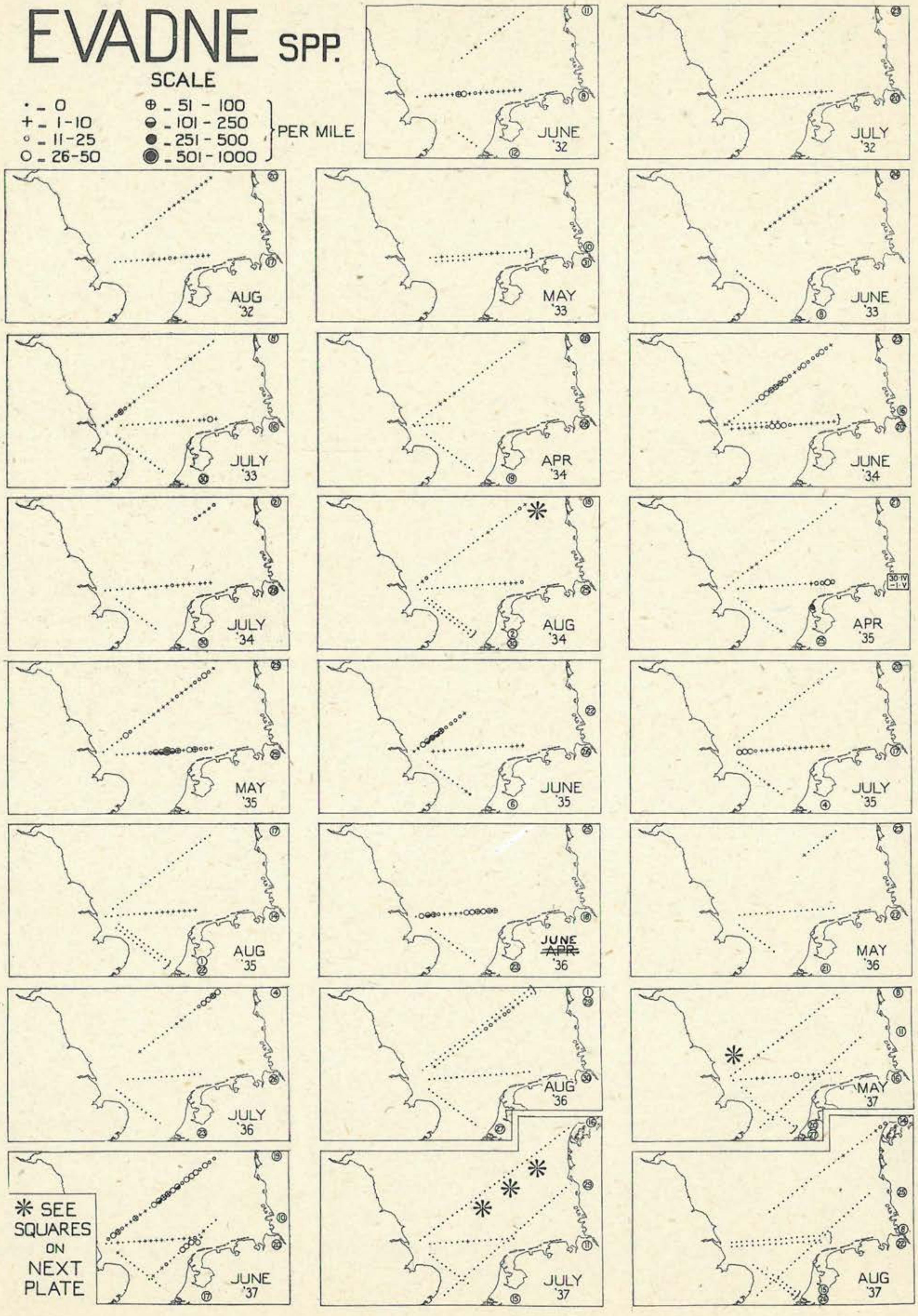


PLATE CXLVII

EVADNE SPP.

SCALE

· – 0
+ – 1-10
∘ – 11-25
○ – 26-50
⊕ – 51 - 100
⊖ – 101 - 250
● – 251 - 500
◉ – 501 - 1000
} PER MILE



PODON SPP.

SCALE AS FOR EVADNE EXCEPT THAT SQUARES DENOTE CLADOCERA INDET.

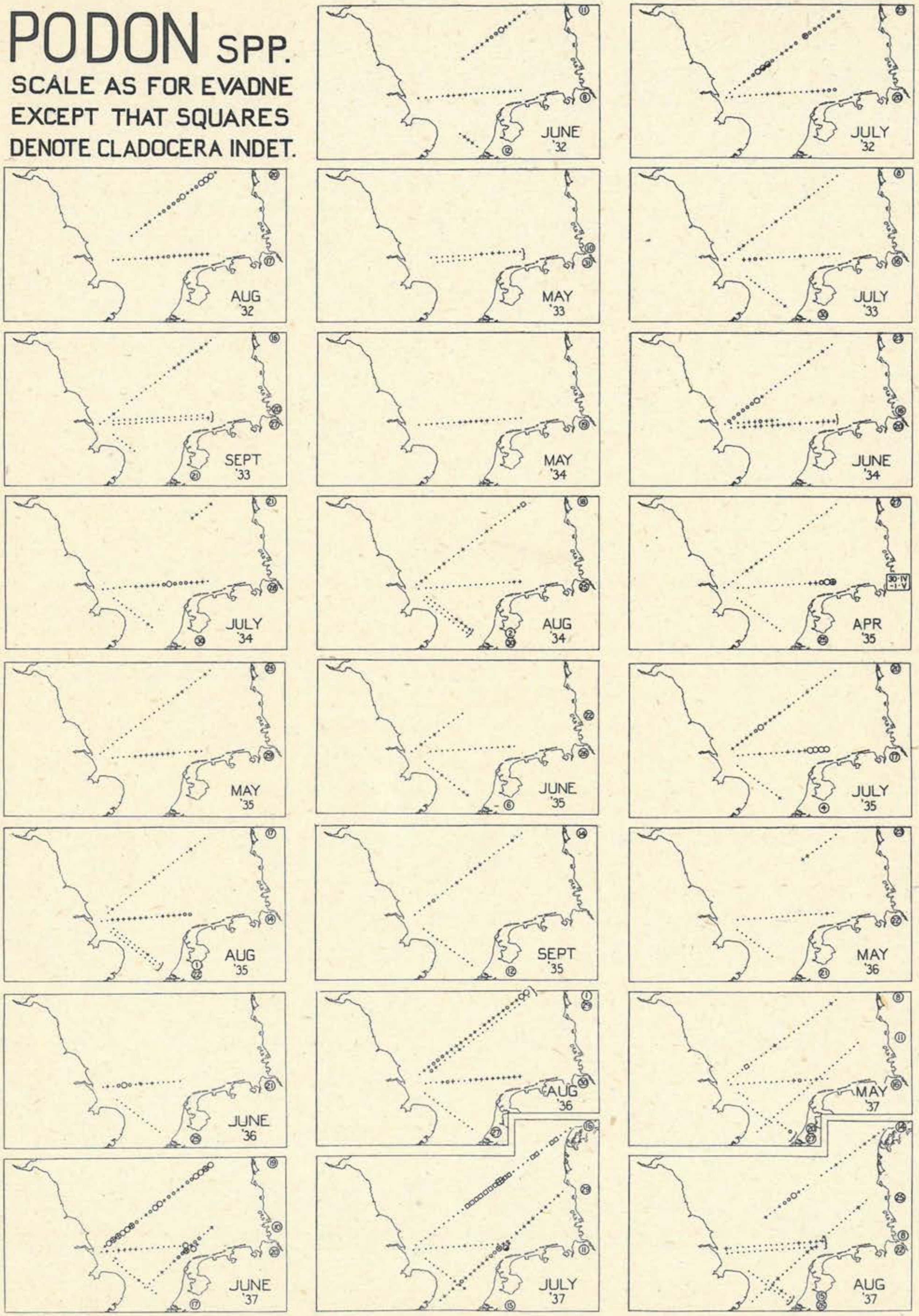


PLATE CXLIX

ECHINODERM LARVAE

+ - 1-25
○ - 26-50
○ - 51-100
⊕ - 101-250
⊖ - 251-500
● - 501-1500
● - >1500
} PER MILE