HERRING LARVAE SURVEYS IN THE NORTH SEA
AND ADJACENT WATERS IN 1975/76 AND 1976/77

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REPORT ON THE INTERNATIONAL SURVEYS OF HERRING LARVAE IN
THE NORTH SEA AND ADJACENT WATERS IN 1975/76 AND 1976/77

by

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Summary
Because of a systematic error in calculating the numbers of herring larvae per square metre surface, caught by one country, the results of the North Sea herring larval surveys in 1975/76 have had to be reappraised. These data, and those collected in 1976/77 are presented in this paper.

They suggest that larval production in 1975, in all areas except Buchan, was considerably less than in preceding years. In 1976 larval production remained at a generally low level, although there was some increase in estimated abundance in the Shetland/Orkney area.

Spawning stock sizes in the northwestern North Sea and in the Whitby/Dogger area, as estimated from a regression of larval abundance on spawning stock size, are 79 000 tons in 1975 and 87 000 tons in 1976 for these areas combined. These estimates are rather lower than those produced by the Herring Assessment Working Group for the Area South of 62°N from fisheries data.

Some factors which have a bearing on the planning of future surveys and on the utilisation of these data for the estimation of stock size are discussed.

Introduction
This report presents the results of the tenth international survey of herring larvae carried out in the North Sea and adjacent waters in 1976/77. It also includes a reappraisal of the data from the ninth survey, previously reported by Jacobsen & Hansen (1976).

These surveys were started in 1967 in order to monitor changes in the North Sea herring spawning stocks independently of fishery data. Results of the previous surveys have been reported by Saville (1970), Boštius & McKay (1970), Wood (1971), Zijlstra (1972), Schnack (1973), Saville & McKay (1974), Wood (1975) and Pommeranz (1977).

Material and methods
In 1975/76 five countries participated in these surveys. In 1976/77 seven countries took part; Norway, Poland and the German Democratic Republic participating for the first time in the ICES coordinated sampling programme. On all the ships sampling was carried out using a modified Gulf III plankton sampler towed in a double oblique haul. The water column was sampled from surface down to 5 metres or less above the bottom. The sampling technique has been described in detail by Saville (1970) and Anon (1977).

Following a recommendation by the Working Group on North Sea Herring Larval Surveys (Anon 1971), the area to be sampled is divided into four sub-areas.
The timing of the surveys, with details of the countries and research vessels involved, within these sub-areas are given in Tables 1 and 2 for 1975/76 and 1976/77. In these periods a total of 958 and 920 stations were sampled respectively. Although the input of effort was fairly similar in both years, the allocation of this effort to sub-areas was rather different. In 1975 the effort was fairly evenly distributed with three surveys being carried out in both the Whitby/Dogger and S Bight/Channel areas, four in the Shetland/Orkney area and two in the Buchan area. In 1976 there was considerable concentration of effort on the Whitby/Dogger area with six surveys, representing 50% of the total sampling effort, being carried out there. In the Shetland/Orkney, Buchan, and S Bight/Channel areas the number of surveys carried out was two, three, and one respectively. Although no area was over-sampled, the Shetland/Orkney area was very inadequately sampled and if the effort devoted to these surveys cannot be increased it should be allocated more appropriately.

For all areas except the S Bight/Channel the larvae have been grouped into three size ranges (<10 mm, 10-15 mm, and >15 mm long. For the Downs larvae, which hatch at a greater length, the size groups are <11 mm, 11-16 mm, >16 mm long. Abundance estimates were calculated in a similar manner to that of Schnack (1973) and Wood (1975): the abundance per square metre at each station being multiplied by the area appropriate to that station. In cases where a station was sampled more than once during a survey period, the greatest number of larvae caught was used in the calculations.

Results
1975/76 surveys - distribution
The results of the 1975/76 surveys have been reported by Jacobsen and Hansen (1976) but it was subsequently discovered that, due to an error in the computation of the catches from the stations sampled by the RV "Dana", the data given for these positions are under-estimated by a factor of 4. It has therefore been necessary to re-analyse these data to ensure that the results are comparable with those of other years. The results from the various surveys in 1975/76 are shown in Figures 1-17. These have been contoured at levels of 1, 25 and 100 larvae/m² surface to illustrate centres of abundance.

Shetland/Orkney
A total of four surveys was carried out in this area, but as the Scottish and English ones overlapped in time and sampled rather different areas, the data have been combined to give a more complete coverage (Figures 1 and 2). On the first survey, from 3-19 September, the major concentrations of recently hatched larvae (<10 mm long) were found to the north of the Orkney Islands. Larvae in the 10-15 mm length range were widely distributed over the surveyed area but at lower densities than the small larvae. On the second survey, 10-24 September, the main concentration of small larvae was located in the area west of the Orkney Islands (Figure 3). Larger larvae (10-15 mm long) were also most abundant in that area, although there was a wider spread of this age group to the north and east of the islands (Figure 4). On the third survey, 20-25 September, recently hatched larvae (<10 mm long) were largely confined to a small area off Clythness (Figure 5). Larvae in the 10-15 mm length range were generally distributed around the Orkney Islands with the major concentrations being to the west of the islands (Figure 6). Larvae >15 mm long, which had not been taken on the preceding surveys, were widely distributed over most of the surveyed area (Figure 7), but generally at low densities.

The timing of the surveys in this area overlapped quite considerably, but even so, there were variations in the distributions of the newly hatched larvae on these three surveys. It would appear that there was a gradual
progression of spawning from north to south, even in the short time period covered by the surveys.

**Buchan**

One complete and one partial survey of the Buchan area were carried out during September and early October 1975. During the first survey, 5-11 September, the whole survey area was sampled. Newly hatched larvae were found over a fairly wide area to the northeast of Aberdeen (Figure 8). Older larvae were found at low densities in a similar area (Figure 9). On the partial survey, 30 September - 2 October, very few larvae in the <10 mm and 10-15 mm length groups were caught but larvae >15 mm long were rather more abundant although densities were less than 5 per m² surface.

**Whitby/Dagger**

Three surveys of this area were carried out during September and October 1975. On the first survey, 15-23 September, newly hatched larvae (<10 mm long) were found in two patches, the major one stretching along the coast from the Tees north to the Farne Islands with a smaller patch being located off Whitby (Figure 10). Larvae in the 10-15 mm length range had a similar distribution except that for this size group the patch off Whitby was the larger one (Figure 11). No larvae >15 mm long were caught. On the second survey, 8-14 October, newly hatched larvae (<10 mm long) were largely confined to a patch off Flamborough Head (Figure 12). Larger larvae (10-15 mm and >15 mm long) were widely distributed along the coast from the Humber north to the Farne Islands (Figures 13 and 14) with the highest densities being recorded off Flamborough Head. On the third survey, newly hatched larvae were taken only in a small patch southeast of Flamborough Head (Figure 15). Older larvae (10-15 mm and >15 mm long) were chiefly confined to a more widespread patch north and east of Flamborough Head (Figures 16 and 17).

**S Bight/English Channel**

This area was surveyed three times during December 1975 and January 1976. On the first survey, 8-19 December, larvae in the <11 mm and 11-16 mm length groups were found at low densities (<10/m² surface) at a few stations in the northeastern part of the Bay of the Seine and off Dieppe. Larvae >16 mm long were located at very low densities (<1/m² surface) at only two stations in the northern part of the survey area. The second and third surveys covered overlapping time periods and have been treated as a single survey. Newly hatched larvae (<11 mm long) were recorded from a small, low density (<5/m² surface) patch west of Dieppe. Larvae in the 11-16 mm length range were located over a rather larger area north of Dieppe, but at low densities (<10/m² surface). Larvae >16 mm long were encountered at a few scattered stations in the Bay of the Seine and north of Dieppe.

**1976/77 surveys - distribution**

The results from the surveys carried out during 1976/77 are shown in Figures 18-41. These have been contoured at 1, 25 and 100 larvae/m² to show the centres of abundance.

**Shetland/Orkney**

During 1976/77 the Shetland/Orkney area was surveyed twice. On the first survey (4-11 September) recently hatched larvae (<10 mm long) were found over a wide area from Fair Isle north and west to Foula, at densities up to 397/m² surface (Figure 18). Larvae in the 10-15 mm length range were more generally distributed over much of the surveyed area. The maximum density of
32 larvae/m² surface was observed northwest of Westray (Figure 19). Larvae >5 mm long were found at a few widely dispersed stations at densities <5/m² surface. On the second survey (13–23 September) small larvae (<10 mm long) were found to the northeast of the Orkney Islands (Figure 20). The highest concentration in that area was 49 larvae/m² surface. Larvae in the 10–15 mm length range were generally distributed around the Orkney Islands at rather low densities (Figure 21). Larvae >15 mm long were sporadically distributed at low densities (<5/m² surface).

**Buchan**

The Buchan area was surveyed three times during September 1976. On the first survey (5–17 September) larvae were present only in small numbers, mostly in the size groups >10 mm long (Figures 22 and 23). The majority of the larvae were found east of Aberdeen. On the second survey (24–28 September) larvae were again only found in very low numbers (Figures 24 and 25), with the majority being in the 10–15 mm length range. The major concentrations were again found east of Aberdeen. The third survey in the Buchan area (Figure 26) was a wide ranging offshore one in which larvae, mostly >15 mm long, were taken at low densities (<2/m² surface).

**Whitby/Dogger**

This area was the most adequately surveyed with six surveys being carried out during September and October 1976. Two of these surveys, however, overlapped considerably in time (Table 2). On the first survey (3–14 September) newly hatched larvae (<10 mm long) were located over a fairly extensive area from Whitby north to the Farne Islands, with a maximum density of 90/m² surface being found off Blyth (Figure 27). Larvae in the 10–15 mm length range were located off Middlesbrough and Whitby but at generally very low densities (Figure 28).

On the second survey (14–24 September) newly hatched larvae were found in two large patches, one covering an area very similar to that of the previous survey and the other off Flamborough Head (Figure 29). The maximum density of larvae found on this survey was 61/m² surface, in the area off Flamborough Head. Older larvae (>10 mm long) were found over a wide area from the Tyne south to the Humber, with the major concentration (130/m² surface) being again found off Flamborough Head (Figures 30 and 31).

On the third survey (28 September – 10 October) newly hatched larvae (<10 mm long) were very scarce, and at only one station, off Flamborough Head, were densities as high as 5/m² surface observed. Larvae >10 mm long were again found over a wide area from the Tyne south to the Humber with the maximum density, 74/m² surface, off Flamborough Head (Figures 32 and 33). The fourth survey was a wide ranging offshore one covering the period 6–22 October. On this survey very few larvae were caught, almost all of which were greater than 15 mm long (Figure 34).

The last two surveys covered much the same time period, 19–25 October. Although the surveys located larvae in much the same area, off Scarborough (Figures 35–40), the densities found were rather different. That carried out by the Netherlands indicated that larvae were almost twice as numerous as the Norwegian data would suggest. This question is more fully discussed later.

**S Bight/English Channel**

This area was only sampled once, in January 1977 (Figure 41). On this survey larvae were very scarce with small numbers <11 mm long, being found in the Sandettie area. Older larvae were found at the eastern end of the Channel and in the Bay of the Seine.
Quantitative estimates

The major aim of these surveys is to monitor changes in larval production as a measure of spawning stock size. In Tables 3 and 4 the estimated abundances of the three size groups of herring larvae in each survey period are given for 1975/76 and 1976/77 respectively.

The results, as in previous years since these surveys began, suggest that in 1975 and in 1976 the larval production in the Shetland/Orkney area formed the major part of that for the North Sea population as a whole. Saville and McKay (1974) pointed out the problems in estimating total larval production from data of the type produced by these surveys and suggested that the best approach might be to obtain relative measures of spawning stock size by comparing estimates of larval abundance obtained from surveys carried out at similar times each year. It should be noted, however, that even to do this demands that there is little year to year variation in the timing of larval production within an area. From this type of comparison it would appear that the spawning stocks, in all areas except Buchan, in 1975 were considerably below the levels of the previous year.

The 1976 surveys produced a different picture with production in the Shetland/Orkney area showing some apparent recovery, at least in the earlier survey. In the Buchan area larval abundances were much lower than in 1975 and had indeed reverted to the very low levels observed in the late 1960s.

In the Whitby/Dogger area larval abundances were appreciably higher on the second survey in 1976 than on the comparable one in time in 1975, but on subsequent ones were very much lower. In the S Bight/Channel area larval abundances were maintained at the very low level of recent years. In the Report of the Working Group on North Sea Herring Larval Surveys (Anon 1977) regressions are given relating larval abundance in the northwestern North Sea, and in the central North Sea, to estimates derived from VPAs of the spawning stocks in these areas. From the larval abundances in Tables 3 and 4, and using these regression equations, the spawning stocks in these areas in 1975 and 1976 have been calculated as shown in the text table below.

<table>
<thead>
<tr>
<th>Year</th>
<th>Northwestern</th>
<th>Whitby/Dogger</th>
</tr>
</thead>
<tbody>
<tr>
<td>1975</td>
<td>56 000 tons</td>
<td>23 000 tons</td>
</tr>
<tr>
<td>1976</td>
<td>64 000 tons</td>
<td>23 000 tons</td>
</tr>
</tbody>
</table>

These estimates for the northwestern area are somewhat greater than those estimated from larval data in the Report of the Herring Assessment Working Group for the Area South of 62°N (Anon 1979), because of the re-estimation of larval abundance for 1975 mentioned in the Introduction and because at the time the Assessment Working Group met only part of the 1976 data for this area was available. The summation of these new estimates from the larval data is somewhat closer to the Assessment Working Group's estimate of spawning stock from VPA for the total North Sea, although they would still suggest that the latter estimate may be rather too high. It would seem inconceivable that the Downs spawning stock was of the order of 68 000 tons in 1976, as would be required to bring the two estimates into agreement.

Discussion

To use the data from these larval surveys to estimate either absolute or relative stock sizes in a more precise way it will be necessary to estimate either total production or total standing stock from a seasonal curve of larval...
abundance. The inability to do this with the present data is largely due to
the extent of the problem being tackled. Because herring in the North Sea
spawn over a wide area and an extended time period, to do so involves the
expenditure of a large amount of research vessel effort. To help optimise the
use of this effort, the North Sea has been divided into four sub-areas and
each area is surveyed as often as possible during the hatching period.

It has, however, been the case that surveys have attempted to cover the whole of
one area, e.g., Shetland/Orkney, and so have taken a long time to complete.
Spawning within these large areas is not, however, a single event but a series
of isolated events on individual spawning grounds. It might therefore be a
better approach to concentrate the available effort on restricted and more
frequently repeated surveys of known spawning sites over the period which is
critical to them. The production on the individual sites can be summed to
produce a total for the sub-area and the season.

At present not enough is known of the shape and timing of these hatching curves
for individual spawning sites. The 1975 surveys of the Orkney/Shetland area,
which covered only the period 3-25 September indicated at least three major
spawning sites, each of which was only apparent on one survey. To obtain
measures of either relative changes in spawning stock size or more absolute
estimates of stock size using the regressions would seem to demand some
assumptions about the shape of the curve of larval production during a season,
and about the constancy of its timing between seasons, irrespective of variations
in amplitude. This question has been discussed by Saville & McKay (1974) and by
Wood (1975). In particular the latter author produced some data which suggest
that within each of the discrete spawning areas in the Central North Sea the
larval production within a season might be defined by a normal curve and that,
within each spawning area, the timing of the modes of these curves did not differ
very radically.

As this is a question of considerable importance in the interpretation of the
data from these surveys, it has been re-examined, using the additional data
which have become available for the Central North Sea spawning grounds since
Wood's analysis.

In none of the other areas sampled are there sufficient observations even in
any one year, to make such an approach possible.

The data available, in substantial agreement with Wood's findings, suggest:
(a) that in the distinct spawning areas (Longstone, Whitby and Dowsing) in
the Central North Sea the larval production curve can, as a reasonable
first approximation, be fitted to a normal curve;
(b) that at least in most years the timing of the modes of these production
curves differs appreciably: with Longstone normally being earlier and
Whitby and Dowsing some weeks later;
(c) within a spawning area there can also be considerable variation in the
timing of the mode from year to year.

The latter point is the one on which there is some discrepancy between these
results and those reported by Wood (1975). In this investigation the
estimates of the abundance of larvae less than 10 mm long, for each survey,
in each of the years 1972-76 were fitted to a normal curve by a computer
program which also produced the basic parameters of the fitted curves. The
timing of peak production for the distinct spawning areas, as estimated by
this computer program, are given in the text table over the page.
These suggest a considerable variation in the timing of peak hatching of about a month, in the case of Longstone and Dowsing, and a rather smaller one of about 12 days in the case of Whitby. The same computer program also gives estimates of the standard deviation of the normal curves fitted to the data, which is a measure of the distribution of larval production about these modes. These are also given in the text table above. Apart from some markedly higher values, which are probably the results of the inadequacies of the input data in those years, they would suggest that practically all of the larval production within any one spawning site takes place within a period of 30-48 days and 90% of it within a period of 17-26 days. This type of data, if more firmly based, could have major repercussions on the planning of sampling in these surveys and on the precision with which spawning stock size can be estimated from the data produced by the larval surveys.

Inherent in the fitting of normal curves to these data is the assumption that all estimates are equally valid ones of standing stocks of larvae at the time sampling was carried out. A number of factors are likely to make this a dubious assumption:

(a) in some cases there are considerable variations in the intensity of, and distribution of, sampling within a spawning site between surveys;

(b) the surveys have been done by a number of countries whose sampling efficiency may differ, etc.

The latter point has previously been discussed in relation to these herring larval surveys, by McKay (1974) and Wood (1975), and their results pointed to differences between England, Netherlands and Scotland in the estimates of standing stocks of larvae when sampling in approximately the same area and time period. This problem is likely to have been increased in 1976 when three additional countries participated in the surveys. Unfortunately, the data available for that year are totally inadequate to estimate any differences in 'sampling efficiency' between the new participants and those of longer standing. The sampling by the German Democratic Republic in the Shetland area and by Poland in the Buchan and Central North Sea areas had no overlap in time with sampling in these areas by other participants. Norwegian and Dutch vessels surveyed the Whitby/Dagger area in 1976 in the period 19-25 October and the estimates of total larval standing stock from these two surveys differed by a factor of three.

This, however, does not necessarily mean that one of these countries was catching three times as many larvae as the other, under identical conditions, since the distribution of sampling in time and space between the surveys differed very significantly. As a result, the data are not suitable to do any precise test of whether these two countries were catching significantly different numbers of larvae when sampling under the same conditions. A rough test of this by taking catches per square metre, over all statistical squares sampled by the two

<table>
<thead>
<tr>
<th>Year</th>
<th>Longstone</th>
<th>Whitby</th>
<th>Dowsing</th>
</tr>
</thead>
<tbody>
<tr>
<td>1972</td>
<td>10 September (8.1)</td>
<td>5 October (5.0)</td>
<td>26 September (5.7)</td>
</tr>
<tr>
<td>1973</td>
<td>4 September (14.4)</td>
<td>6 October (12.8)</td>
<td>26 September (5.7)</td>
</tr>
<tr>
<td>1974</td>
<td>25 September (6.5)</td>
<td>25 September (5.8)</td>
<td>26 September (5.7)</td>
</tr>
<tr>
<td>1975</td>
<td>23 September (6.5)</td>
<td>1 October (8.1)</td>
<td>15 October (11.2)</td>
</tr>
<tr>
<td>1976</td>
<td>28 August (13.0)</td>
<td></td>
<td>18 September (7.0)</td>
</tr>
</tbody>
</table>
vessels within a maximum interval of four days, and applying an $X^2$ test to the
goodness of fit with the catches grouped into categories of 0, $\leq 1$ and $\geq 2$ per
square metre, suggested that the differences were not significant. However,
because of the variability of herring larval abundance over small area and time
differences, this is a very rough test and too much reliance should not be
placed on the results quoted above. In the light of previously reported
differences between countries and the number of new countries which have
recently joined these co-ordinated surveys, there is a pressing need for a
planned programme to measure the variability between participating countries in
the 'efficiency' with which they sample herring larvae.

In view of the major role which the North Sea herring larval surveys are likely
to play in assessment in the immediate future, when regulation of the fisheries
will make direct catch data unavailable or difficult to evaluate, it would seem
necessary to look more critically at the current sampling strategy, and the
utilisation for assessment, of the data collected. Key elements in this will be:

(a) a more critical examination of the data available on inter-ship differences
in catching larvae under comparable conditions;

(b) to use past data to try and establish key areas, and periods within these
areas, in which sampling effort should be concentrated;

(c) to look at methods of obtaining more accurate and precise estimates of
larval production and hence of spawning stock size.

It is hoped that the 1977 surveys will provide greater overlap in sampling
between vessels from different countries to allow (a) to be done; if not, it
may be advisable to mount experiments specifically for this purpose in 1978.
The planned programme for the surveys in 1977 should also result in a great
sampling intensity in each of the major spawning areas which will allow better
estimates of the variations with time in larval production within discrete
spawning areas. However, if these data are to be used for redesigning the survey
strategy for 1978, it will be essential that all countries analyse the material
collected in 1977 quickly, so that the results are available by early spring.

References

ICES C.M.1971/H:10 (mimeo).


herring larvae in the North Sea and adjacent waters in 1975/76.

Pommeranz, T., 1977. Report on the international survey of herring larvae in
the North Sea and adjacent waters in 1974/75. ICES Coop.Res.Rep.,
No.61:16-27.

Saville, A., 1970. Report on the international surveys of herring larvae in the

larvae in the North Sea and adjacent waters in 1972/73. ICES Coop.Res.Rep.,
No.41:1-39.


Table 1. Surveys carried out in 1975/76.

<table>
<thead>
<tr>
<th>Area</th>
<th>Period</th>
<th>Country</th>
<th>Vessel</th>
<th>Number of stations per survey</th>
<th>total</th>
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<tbody>
<tr>
<td>Shetland/Orkney</td>
<td>3-19 Sep 1975</td>
<td>Scotland</td>
<td>&quot;Clupea&quot;</td>
<td>87</td>
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<tr>
<td></td>
<td>6-13 Sep 1975</td>
<td>England</td>
<td>&quot;Corella&quot;</td>
<td>68</td>
<td></td>
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<tr>
<td></td>
<td>10-24 Sep 1975</td>
<td>Denmark</td>
<td>&quot;Dana&quot;</td>
<td>102</td>
<td></td>
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<tr>
<td></td>
<td>20-25 Sep 1975</td>
<td>Germany, F.R.</td>
<td>&quot;Anton Dohrn&quot;</td>
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<td>Scotland</td>
<td>&quot;Clupea&quot;</td>
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<td>15-23 Sep 1975</td>
<td>Netherlands</td>
<td>&quot;Tridens&quot;</td>
<td>104</td>
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<tr>
<td></td>
<td>8-14 Oct 1975</td>
<td>England</td>
<td>&quot;Corella&quot;</td>
<td>105</td>
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<td>21-29 Oct 1975</td>
<td>Netherlands</td>
<td>&quot;Tridens&quot;</td>
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<td>3-14 Sep 1976</td>
<td>England</td>
<td>&quot;Corella&quot;</td>
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<td>16-24 Sep 1976</td>
<td>Netherlands</td>
<td>&quot;Tridens&quot;</td>
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<td>28 Sep -</td>
<td>England</td>
<td>&quot;Corella&quot;</td>
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<td></td>
<td>10 Oct 1976</td>
<td>Poland</td>
<td>&quot;Birkut&quot;</td>
<td>15</td>
<td></td>
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<td></td>
<td>8-22 Oct 1976</td>
<td>Poland</td>
<td>&quot;Tridens&quot;</td>
<td>41</td>
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<td></td>
<td>18-23 Oct 1976</td>
<td>Netherlands</td>
<td>&quot;Havdron&quot;</td>
<td>98</td>
<td></td>
</tr>
<tr>
<td></td>
<td>3-7 Jan 1977</td>
<td>Netherlands</td>
<td>&quot;Tridens&quot;</td>
<td>65</td>
<td>65</td>
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Table 2. Surveys carried out in 1976/77.

<table>
<thead>
<tr>
<th>Area</th>
<th>Period</th>
<th>Country</th>
<th>Vessel</th>
<th>Number of stations per survey</th>
<th>total</th>
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</thead>
<tbody>
<tr>
<td>Shetland/Orkney</td>
<td>4-11 Sep 1976</td>
<td>Germany, F.R.</td>
<td>&quot;Anton Dohrn&quot;</td>
<td>91</td>
<td>179</td>
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<tr>
<td></td>
<td>6-17 Sep 1976</td>
<td>Scotland</td>
<td>&quot;Clupea&quot;</td>
<td>73</td>
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<td>&quot;Birkut&quot;</td>
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<td></td>
<td>3-14 Sep 1976</td>
<td>England</td>
<td>&quot;Corella&quot;</td>
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<tr>
<td></td>
<td>16-24 Sep 1976</td>
<td>Netherlands</td>
<td>&quot;Tridens&quot;</td>
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<td></td>
<td>28 Sep -</td>
<td>England</td>
<td>&quot;Corella&quot;</td>
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<td>538</td>
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<td>&quot;Birkut&quot;</td>
<td>41</td>
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<td></td>
<td>8-22 Oct 1976</td>
<td>Poland</td>
<td>&quot;Tridens&quot;</td>
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<td>18-23 Oct 1976</td>
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<td>&quot;Havdron&quot;</td>
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<td>3-7 Jan 1977</td>
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<td>&quot;Tridens&quot;</td>
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### Table 3. Estimated abundances of herring larvae on the various surveys of the North Sea and adjacent waters in 1975/76.

<table>
<thead>
<tr>
<th>Area</th>
<th>Period</th>
<th>Abundance of herring larvae x 10^-9</th>
</tr>
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<tr>
<td></td>
<td></td>
<td>&lt;10 mm</td>
</tr>
<tr>
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<td>455</td>
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<td></td>
<td>10-24 Sep 1975</td>
<td>116</td>
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<td></td>
<td>20-25 Sep 1975</td>
<td>66</td>
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<td></td>
<td>5-11 Sep 1975</td>
<td>231</td>
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<td></td>
<td>30 Sep - 2 Oct 1975</td>
<td>1</td>
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<td>Buchan</td>
<td>15-23 Sep 1975</td>
<td>91</td>
</tr>
<tr>
<td></td>
<td>8-14 Oct 1975</td>
<td>79</td>
</tr>
<tr>
<td></td>
<td>21-29 Oct 1975</td>
<td>8</td>
</tr>
<tr>
<td>Whitby/Dogger</td>
<td>3-7 Jan 1977</td>
<td>2</td>
</tr>
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</table>

### Table 4. Estimated abundances of herring larvae on the various surveys of the North Sea and adjacent waters in 1976/77.

<table>
<thead>
<tr>
<th>Area</th>
<th>Period</th>
<th>Abundance of herring larvae x 10^-9</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>&lt;10 mm</td>
</tr>
<tr>
<td>Shetland/Orkney</td>
<td>4-11 Sep 1976</td>
<td>732</td>
</tr>
<tr>
<td></td>
<td>13-23 Sep 1976</td>
<td>63</td>
</tr>
<tr>
<td>Buchan</td>
<td>6-17 Sep 1976</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>24-28 Sep 1976</td>
<td>1</td>
</tr>
<tr>
<td>Whitby/Dogger</td>
<td>3-14 Sep 1976</td>
<td>86</td>
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<tr>
<td></td>
<td>16-24 Sep 1976</td>
<td>137</td>
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<td>4</td>
</tr>
<tr>
<td>S Bight/English Channel</td>
<td>3-7 Jan 1977</td>
<td>2</td>
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Figure 1. Numbers of larvae <10 mm long below $1m^2$.
Shetland/Orkney area 3-19 September 1975.
Scottish and English surveys combined.
Figure 2. Numbers of larvae 10-15 mm long below lm². Shetland/Orkney area 3-19 September 1975. Scottish and English surveys combined.
Figure 3. Numbers of larvae <10 mm long below 1 m². Shetland/Orkney area 10-24 September 1975. Danish survey.
Figure 4. Numbers of larvae 10-15 mm long below 1 m². Shetland/Orkney area 10-24 September 1975. Danish survey.
Figure 5. Numbers of larvae <10 mm long below 1m². Shetland/Orkney area 20-25 September 1975. Federal Republic of Germany survey.
Figure 6. Numbers of larvae 10-15 mm long below 1m$^2$. Shetland/Orkney area 20-25 September 1975. Federal Republic of Germany survey.
Figure 7. Numbers of larvae >15 mm long below 1 m². Shetland/Orkney area 20-25 September 1975. Federal Republic of Germany survey.
Figure 8. Numbers of larvae <10 mm long below 1m$^2$.
Buchan area 5-11 September 1975.
Scottish survey.
Figure 9. Numbers of larvae 10-15 mm long below 1m². Buchan area 5-11 September 1975. Scottish survey.
Figure 10. Numbers of larvae <10 mm long below 1 m$^2$. Whitby/Dogger area 15-23 September 1975. Dutch survey.
Figure 11. Numbers of larvae 10-15 mm long below 1m². Whitby/Dogger area 15-23 September 1975. Dutch survey.
Figure 12. Numbers of larvae <10 mm long below \( \text{lm}^2 \).
Whitby/Dogger area 8-14 October 1975.
English survey.
Figure 13. Numbers of larvae 10-15 mm long below 1m$^2$. Whitby/Dogger area 8-14 October 1975. English survey.
Figure 14. Numbers of larvae >15 mm long below 1 m². Whitby/Dogger area 8-14 October 1975. English survey.
Figure 15. Numbers of larvae <10 mm long below lm². 
Whitby/Dogger area 21-29 October 1975. 
Dutch survey.
Figure 16. Numbers of larvae 10-15 mm long below 1m$^2$
Whitby/Dogger area 21-29 October 1975.
Dutch survey.
Figure 17. Numbers of larvae >15 mm long below 1m². Whitby/Dogger area 21-29 October 1975. Dutch survey.
Figure 18. Numbers of larvae <10 mm long below 1m². Shetland/Orkney area 4-11 September 1976. Federal Republic of Germany survey.
Figure 19. Numbers of larvae 10-15 mm long below 1m². Shetland/Orkney area 4-11 September 1976. Federal Republic of Germany survey.
Figure 20. Numbers of larvae <10 mm long below 1m². Shetland/Orkney area 13-23 September 1976. German Democratic Republic survey.
Figure 21. Numbers of larvae 10-15 mm long below 1m².
Shetland/Orkney area 13-23 September 1976.
German Democratic Republic survey.
Figure 22. Numbers of larvae 10-15 mm long below 1 m². Buchan area 6-17 September 1976. Scottish survey.
Figure 23. Numbers of larvae >15 mm long below 1m². Buchan area 6-17 September 1976. Scottish survey.
Figure 24. Numbers of larvae 10-15 mm long below 1m². Buchan area 24-28 September 1976. German Democratic Republic survey.
Figure 25. Numbers of larvae >15 mm long below 1 m$^2$. Buchan area 24-28 September 1976. German Democratic Republic survey.
Figure 26. Numbers of larvae >15 mm long below lm². Buchan area 27-29 September 1976. Polish survey.
Figure 27. Numbers of larvae <10 mm long below 1m². Whitby/Dogger area 3-14 September 1976. English survey.
Figure 28. Numbers of larvae 10-15 mm long below lm$^2$. Whitby/Dogger area 3-14 September 1976. English survey.
Figure 29. Numbers of larvae <10 mm long below 1 m$^2$. Whitby/Dogger area 16-24 September 1976. Dutch survey.
Figure 30. Numbers of larvae 10–15 mm long below 1m². Whithy/Dogger area 16–24 September 1976. Dutch survey.
Figure 31. Numbers of larvae >15 mm long below 1m². Whitby/Dogger area 16-24 September 1976. Dutch survey.
Figure 32. Numbers of larvae 10-15 mm long below 1 m².
Whitby/Dogger area 28 September - 10 October 1976.
English survey.
Figure 33. Numbers of larvae >15 mm long below 1 m². Whitby/Dogger area 28 September - 10 October 1976. English survey.
Figure 34. Numbers of larvae >15 mm long below 1m².
Whitby/Dogger area 8-22 October 1976.
Polish survey.
Figure 35. Numbers of larvae 10 mm long below 1m$^2$. Whitby/Dogger area 19-25 October 1976. Norwegian survey.
Figure 37. Numbers of larvae >15 mm long below 1 m$^2$. Whitby/Dogger area 19-25 October 1976. Norwegian survey.
Figure 38. Numbers of larvae <10 mm long below 1m$^2$. Whitby/Dogger area 18-23 October 1976. Dutch survey.
Figure 39. Numbers of larvae 10-15 mm long below 1m². Whitby/Dogger area 18-23 October 1976. Dutch survey.
Figure 40. Numbers of larvae >15 mm long below 1 m$^2$. Whitby/Dogger area 18-23 October 1976. Dutch survey.
Figure 41. Numbers of larvae <11 mm long below 1 m$^2$.  
S Bight/English Channel area  
3-7 January 1977.  
Dutch survey.
SPATIAL DISTRIBUTION OF HERRING LARVAE IN THE NORTH SEA IN 1976

by

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Sea Fisheries Institute, Al. Zjednoczenia 1,
81-345 Gdynia, Poland

Introduction


Material and methods

Ichthyoplankton including the herring larvae was collected during a cruise of the research vessel of the Fisheries Institute, "Birkut", from 27 September to 22 October 1976.

During this cruise, observations were made at 56 stations in the area embracing the regions: Aberdeen, Flamborough, and Little Pit.

Herring larvae were sampled by the methods established at the meeting of the ICES Working Group on North Sea Herring Larval Surveys in Lysekil, Sweden, held in May 1976 (Anon 1977). The plankton sampler of the "Gulf III" type with a conical inlet of 20.6 cm in diameter was used. The gear was shot at a speed of 50 m/min down to a maximum depth of 100 m, and at shallower stations to 5 m above the bottom. It was retrieved at a speed of 10 m/min. The speed of towing was 5 knots. The whole of the material was preserved in 4% formalin; the herring larvae were separated from other plankton components. Afterwards, they were measured with an accuracy of 0.5 mm and classified according to their body length, and the number under 1m² of sea surface.

Results

Herring larvae occurred in the above-mentioned area of the North Sea at only 17 stations. All the larvae were in the size category more than 15 mm (Table 1), apart from one of 14 mm length.

When comparing the quantitative distribution of larvae with temperatures, it can be noticed that larvae were most numerous in waters of temperatures about 12°C.

A similar pattern of distribution, i.e., occurrence of greater numbers of larvae in water of relatively high temperature in the range from 10 to 12°C was observed in previous years' investigations (Siudziński, 1974, 1975).

Discussion

Relative to the results of research carried out in previous years where an analysis was also carried out on the results of Polish surveys of the occurrence of herring larvae in the North Sea over the period 1963-1975, a decrease in the abundance of larvae was again observed in 1976 in the area investigated. However, the later start of the survey in 1976 does not allow a proper comparison of the 1976 results with those from previous years.
It was generally observed that in 1976 there was an exceptionally large decline in the abundance of herring larvae; the largest since 1971. The individuals caught, apart from one of 14 mm, were all over 15 mm long.

References


Ciszewski, P. Opracowanie w formie sprawozdawczej wyników badań nad ilością planktonu oraz występowaniem i rozmieszczeniem larw śledzia w Morzu Północnym w roku 1968. Morski Instytut Rybacki – Gdynia 1968 (Manuscript).


Szlachcikowska, L. Rozmieszczenie i sta ilościowy larw śledzia w Atlantyku Północnym w 1972 r.

Table 1. Number of larvae caught at different stations in the North Sea, 27 Sep - 22 Oct 1976.

<table>
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<th>Station No.</th>
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<th>Water filtered (m$^3$)</th>
<th>Herring larvae</th>
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<td></td>
<td></td>
<td></td>
<td>No. in catch</td>
</tr>
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<td>75</td>
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<tr>
<td>995</td>
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<td>82</td>
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<td>5</td>
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<td>1041</td>
<td>22 Oct 1976</td>
<td>39</td>
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</tr>
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THE DISTRIBUTION AND ABUNDANCE OF HERRING LARVAE TO THE WEST
OF SCOTLAND IN 1975 AND 1976

by

D W McKay

Marine Laboratory, Aberdeen, Scotland

Summary
This paper describes the results of the herring larval surveys carried out to the west of Scotland in the autumn of 1975 and 1976. These show that the abundance of herring larvae had declined from the levels observed in the early 1970s.

The results are discussed in relation to the changes in spawning stock size in Division VIa.

Introduction
This report gives the results of the sixth and seventh in a series of annual surveys of herring larvae to the west of Scotland. An initial survey in 1965 was followed by a regular series from 1971, resulting from a recommendation by the ICES North Sea Herring Assessment Working Group (Anon 1971). These surveys are intended to provide measures of the relative changes in herring spawning stock size which are independent of those estimated from commercial fishery data. The results of previous surveys have been reported by Wood (1971, 1973), Saville and McKay (1975, 1977).

Material and methods
During the autumn of 1975, two complete and two partial larval surveys of the spawning area of herring in Division VIa were carried out. During a similar period in 1976, two complete and one partial surveys were done. The timings of each survey are given in Tables 1 and 2 for 1975 and 1976 respectively. Samples were taken using a modified Gulf III sampler towed in a double oblique haul fishing the whole water column to within 5 metres of the sea bed. A more detailed description of the gear and sampling techniques is given by Saville (1970) and Anon (1976). During September and October of 1975 and 1976, a total of 414 and 376 stations were sampled respectively.

Abundance estimates were calculated in a similar manner to that of Schnack (1973). Each station value was multiplied by a sea surface area in square metres appropriate to that station, and the individual numbers were then summed for each survey and size group of larvae. This method gives results very similar to the density contouring and planimetering method of Saville and McKay (1974) used in earlier reports, but has the advantage of a considerable saving in the time needed to produce the estimates.

Results
1975 surveys
The results from the various surveys in 1975 are given in Figures 1-9. These have been contoured at the 1, 25 and 100 larvae/m² surface levels to illustrate the location and extent of larval concentrations. On the first complete survey (28 August – 15 September) <10 mm long larvae were found in several small
patches at densities between 50 and 250 larvae/m² surface. These patches of <10 mm larvae were found northwest of the Butt of Lewis, density up to 208 larvae/m² surface, southwest of the Flannan Isles, density up to 262 larvae/m² surface, west of North Uist, density up to 171 larvae/m² surface, west of Barra Head, density up to 121 larvae/m² surface, west of Tiree, density up to 54 larvae/m² surface, north of Malin Head, density up to 71 larvae/m² surface, and west of Aran Island, density up to 118 larvae/m² surface. The extent of the Aran Island patch was not completely defined as the density contours in this area were open to the west and the south. The total number of larvae <10 mm long was estimated to be 673 x 10⁹ (Table 3). Larvae in the 10-15 mm length range were largely confined to a patch west of the Outer Hebrides with a maximum density of 58 larvae/m² surface. No larvae >15 mm long were found on this survey.

On the second survey (10-13 September), sampling was restricted to the Cape Wrath/Butt of Lewis area (Figures 3 and 4). Larvae <10 mm were found in two distinct patches, to the north and east of Cape Wrath with a maximum density of 544 larvae/m² surface, and around the northern part of the Isle of Lewis with a maximum density of 493 larvae/m² surface. The extent of the Lewis patch was not adequately defined as the highest density was observed at the most westerly station. The total number of <10 mm long larvae in the surveyed area was estimated to be 1 161 x 10⁹. Larvae in the 10-15 mm length range had a similar distribution to those <10 mm long, but were generally present at lower densities. The total abundance of larvae in the 10-15 mm length range was estimated at 828 x 10⁹. Larvae >15 mm long were recorded at very low densities (<5 larvae/m² surface) at only two of the stations sampled.

On the second complete survey (29 September - 10 October), larvae <10 mm long were located in two main areas, to the west of the Outer Hebrides and to the north and west of Ireland. To the west of the Outer Hebrides, the major concentration of the smallest size category of larvae (Figure 5) was located west of North Uist with a maximum density of 343 larvae/m² surface. In the area north and west of Ireland, the major concentration, maximum density 413 larvae/m² surface, was an extensive patch of larvae off the Donegal coast. In this area, smaller patches of larvae were also found to the east of Malin Head, maximum density 130 larvae/m² surface and in Donegal Bay, maximum density 77 larvae/m² surface. The total number of larvae <10 mm long was estimated to be 1 490 x 10⁹ (Table 3). Larvae in the 10-15 mm length range (Figure 6) were widely distributed over the whole survey area at fairly low densities, with concentrations being found north of the Butt of Lewis, maximum density 187 larvae/m² surface, west of North Uist, maximum density 297 larvae/m² surface and off the Donegal coast, maximum density 92 larvae/m² surface. The total number of larvae in the 10-15 mm length range was estimated to be 883 x 10⁹ (Table 3). Larvae >15 mm long (Figure 7) were rather sporadically distributed over the whole survey area at very low densities, but were somewhat more abundant in the north than in the south. The estimated number of larvae >15 mm long was 57 x 10⁹ (Table 3).

The final survey (11-13 October) was restricted to the area to the west of the Outer Hebrides extending west to 8°W, and to a line of stations along the north coast of Scotland. Larvae <10 mm long were found to the west of North and South Uist with a maximum density of 297 larvae/m² surface (Figure 8), but the rather restricted nature of the survey made it impossible to delimit the western extent of the patch. Larvae in the 10-15 mm length range were found in similar areas but at lower densities, maximum density 155 larvae/m² surface (Figure 9). Larvae >15 mm long were encountered at very low densities mostly in the northern part of the survey area. Because of the restricted nature of this survey, estimates of larval abundance can only be regarded as lower limits. These are given in Table 3.
1976 surveys

The results from the various surveys in 1976 are given in Figures 10-16. These have been contoured at the 1, 25 and 100 larvae/m² surface levels to illustrate the location and extent of larval concentrations. On the first complete survey (8-24 September), <10 mm long larvae were largely confined to three small patches with maximum densities between 170 and 270 larvae/m² surface. These patches were located west of Handa Island, density up to 262 larvae/m² surface, west of South Uist, density up to 203 larvae/m² surface and north of Malin Head, density up to 177 larvae/m² surface. The total number of larvae <10 mm long was estimated to be 269 x 10⁹ (Table 4). Larvae in the 10-15 mm length range were found at low densities (<30/m² surface) over much of the North Minch and off the north coast of Scotland. Other patches of 10-15 mm long larvae were located to the west of the Outer Hebrides and off the northwest coast of Ireland. The total number of larvae in the 10-15 mm length range was estimated to be 114 x 10⁹ (Table 4). Larvae >15 mm long were confined to a small patch off the north coast of Scotland. The total abundance of >15 mm larvae was estimated to be 14 x 10⁹.

The second survey (25 and 26 September) was very restricted with sampling confined to the area west of the Outer Hebrides from Barra Head north to Harris (Figures 12 and 13). Larvae <10 mm long were found in two distinct patches, west of Barra with a maximum density of 340 larvae/m² surface and west of North Uist with a maximum density of 149 larvae/m² surface. The total number of larvae <10 mm long in the surveyed area was estimated to be 231 x 10⁹. Larvae in the 10-15 mm length range were found at low densities over much of the surveyed area with the peak density of 65 larvae/m² surface being located west of Benbecula. The total abundance of larvae in the 10-15 mm length range was estimated at 51 x 10⁹. Larvae >15 mm long were recorded at very low densities (<5 larvae/m² surface) at only two of the stations sampled.

On the third survey, the whole of the known spawning area of herring was sampled for a second time (Figures 14-16). Larvae <10 mm long were found over a wide area at rather low densities. In the northern part of the surveyed area, the major concentrations were located in the North Minch with a maximum density of 103 larvae/m² surface and west of Harris at a maximum density of 63 larvae/m² surface. In the southern part of the surveyed area, the major concentration of larvae was located in Donegal Bay, maximum density 145 larvae/m² surface with minor concentrations, maximum densities 46 and 57 larvae/m² surface respectively, being found north of Malin Head and Tory Island. The total abundance of larvae <10 mm long was estimated to be 261 x 10⁹ (Table 4). Larvae in the 10-15 mm length range had a distribution pattern that was very similar to that of the younger larvae. The estimated total abundance of larvae in the 10-15 mm length range was 607 x 10⁹ (Table 4). Larvae >15 mm long were sporadically distributed over the whole survey area at rather low densities, but were more abundant in the north than in the south. The estimated number of larvae >15 mm long was 60 x 10⁹ (Table 4).

Discussion

The main aim of these surveys is to produce a series of data which can be used to give estimates of annual variations in spawning stock size. Before such comparisons between years can be valid, it is necessary to group the estimates into comparable time periods and surveyed areas. As discussed by Saville and McKay (1974), it is desirable to split Division VIa into two areas, north and south of 56°30'W. The larval abundance data for the past and present surveys of Division VIa on this basis are given in Tables 5 and 6.

September surveys

The one complete survey carried out in September 1975 spanned two of the time periods previously used, i.e., 1-10 September and 11-25 September. However,
the timing of the survey was such that the area north of 56°30'N was sampled during the period 1-10 September and the area south of 56°30'N during the period 11-25 September. In addition to this complete survey, a partial one of the area north of 56°30'N was carried out during the period 10-13 September. For the area north of 56°30'N (Table 5), it would appear that the abundances of all size categories of larvae in the early part of September 1975 had declined by an order of magnitude from those observed in 1971 and 1972. In the latter part of September, the situation is less clear due to the restricted nature of the surveys in 1974 and 1975. However, examination of the larval distribution charts for the surveys carried out in the 11-25 September period during 1974 (McKay 1975b) and 1975 would indicate that larval densities were rather similar in both years, indicating that the total larval abundances for those areas surveyed in both years, were also rather similar.

In 1976, only one survey of the spawning area was carried out in September, and it covered the period 10-25 September. This survey indicated that for the area north of 56°30'N the larval abundances in 1976 were at least an order of magnitude lower than in 1975. It is difficult to be more specific as the comparable survey in 1975 was rather incomplete.

In the area south of 56°30'N (Table 6), it would appear that there has been a decline in larval production in the period covered by these surveys. The larval abundance in 1975 was about 75% of that in 1973, the last comparable survey, while that in 1976 was about 50% of the 1975 estimate. This decline, although marked, is however, much less than was observed in the more northern areas.

October surveys

During late September and early October, one complete survey was carried out in 1975 and this was followed by a restricted survey during mid-October. The survey from 29 September to 10 October indicated that there had been a marked decline in the abundance of herring larvae <10 mm long over the area as a whole with the decline being much more marked to the north of 56°30'N. During 1975, the abundance of <10 mm long larvae was 609 x 10^9, a decrease of 50% from the 1974 figure of 1.376 x 10^9 and a continuation of the decline in larval production since 1972. In the area south of 56°30'N, although the abundance of larvae <10 mm long was 20% lower than in 1974 (881 x 10^9 in 1975 compared with 1.013 x 10^9 in 1974), it remained considerably higher than those of 1972 or 1973, indicating that the increased importance of the area in terms of larval production was being maintained.

The restricted survey carried out in the northern area in the latter part of October gave larval abundances considerably less than in 1974. It should however be pointed out that the 1975 survey covered a much more restricted area than the 1974 one, and the apparent decline in larval abundance is probably largely due to this. The only other surveys carried out in this time period were those of Wood (1971 and 1973) in 1965 and 1971. These gave abundances of larvae <10 mm long which were less than those in 1975. The total abundances of larvae on the 1965 and 1971 surveys were higher than those on the 1975 survey, but this could be due to the increased area covered on the earlier surveys.

The one complete survey carried out in 1976 indicated that the larval abundance in the period 10-25 October had declined to about 20% of the 1974 estimates. This rate of decline applied equally to the areas north and south of 56°30'N.

Stock size estimates

Saville and McKay (1974b) and McKay (1975a and b) have attempted to estimate the size of the spawning stock of herring in Division VIa by comparing the abundance estimates for <10 mm long larvae in Division VIa with those of other stocks,
notably those in the central and northern North Sea, for which both larval abundance and stock size data are available. In the earlier reports, the stock and larval data used for the North Sea covered the periods 1957-60 and 1961-64 for the northern and central North Sea combined. In the Report of the Working Group on North Sea Herring Larval Surveys (Anon 1977), regressions of larval production on spawning stock size have been produced for the central North Sea for the period 1965-75, and these data are used to provide the comparative North Sea data. The relationship used was

\[ S_{VIa} = \frac{S_{N.S.} \times F_{N.S.} \times L_{VIa}}{F_{VIa} \times L_{N.S.}} \]

The fecundity data are those given by Saville and McKay (1974b).

The stock size estimates from larval surveys and from the most recent virtual population analysis (VPA) (Anon 1979) are given in Table 7. From this it is apparent that the estimates of spawning stock size from VPA and the larval abundance comparisons are in fairly good agreement for the period 1972-74. In 1965 and 1971, the larval abundance comparison underestimate the spawning stock size. In 1965 and 1971, the only larval abundance data available are from surveys carried out in late October, and it would appear from Tables 5 and 6 that the abundance of early larvae during this period is below the mean for the season as a whole. The situation in 1975 and 1976 is rather less clear as the surveys in both years seemed to cover the spawning period more adequately. It is however true that in 1976 only two complete surveys and one partial survey were carried out. The highest larval densities were observed on the partial survey but the very limited area covered during that survey inevitably resulted in a considerable underestimate of the actual abundance during that period. Any significant increase in the estimate of larval abundance during the period 26 September - 10 October would produce a similar increase in the seasonal mean larval abundance.

As has been previously mentioned, the distribution of sampling, in time, during the spawning period has not been the same in all the years in which surveys were attempted. These differences in coverage make the use of mean larval abundance estimates during a season, as a basis for stock size estimation, unreliable for the larval survey data at present available.

The Working Group on North Sea Herring Larval Surveys (Anon 1977) has shown that the abundance of <10 mm long larvae is related to the spawning stock size in the area, and this approach has been attempted for the larval abundance data available for Division VIa. Saville and McKay (this volume) have, however, demonstrated that the timing of hatching in sub-stocks of the central North Sea area is not constant from year to year. Examination of the data in Tables 6 and 7 would indicate that the timing of hatching in Division VIa is also subject to year to year variation. In an attempt to overcome these annual variations in hatching pattern, only years in which more than one survey was carried out have been used. The larval abundances used were the means of all the surveys carried out in that year. The data for larval abundance and stock size are compared in Table 8 and Figure 17. The regression of larval abundance on spawning stock size is

\[ y = 6.789 x -324 \]

This regression is not significant.

It would appear, therefore, that although there would appear to be some relationship between the larval abundance and the size of the parent stock, the relationship cannot be precisely defined until a longer series of comparable data is available.
References


Table 1. Surveys carried out in 1975.

<table>
<thead>
<tr>
<th>Country</th>
<th>Area</th>
<th>Period</th>
<th>No. of stations sampled</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scotland</td>
<td>55°N - 59°N</td>
<td>28 Aug-15 Sep</td>
<td>163</td>
</tr>
<tr>
<td>England</td>
<td>Cape Wrath/Butt of Lewis</td>
<td>10-13 Sep</td>
<td>38</td>
</tr>
<tr>
<td>Scotland</td>
<td>54°30'N - 59°N</td>
<td>29 Sep-10 Oct</td>
<td>175</td>
</tr>
<tr>
<td>Scotland</td>
<td>N of 57°N</td>
<td>11 Oct-13 Oct</td>
<td>38</td>
</tr>
</tbody>
</table>

Table 2. Surveys carried out in 1976.

<table>
<thead>
<tr>
<th>Country</th>
<th>Area</th>
<th>Period</th>
<th>No. of stations sampled</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scotland</td>
<td>54°25'N - 59°15'N</td>
<td>8-24 Sep</td>
<td>181</td>
</tr>
<tr>
<td>Scotland</td>
<td>56°55'N - 58°05'N</td>
<td>25-26 Sep</td>
<td>21</td>
</tr>
<tr>
<td>Scotland</td>
<td>54°25'N - 59°15'N</td>
<td>8-25 Oct</td>
<td>174</td>
</tr>
</tbody>
</table>

Table 3. Estimated abundances of herring larvae on the surveys of Division VIa in 1975 (Totals for N and S of 56°30'N given separately).

<table>
<thead>
<tr>
<th>Date</th>
<th>Survey area</th>
<th>Larval abundances x 10^-9</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>&lt;10 mm</td>
</tr>
<tr>
<td>28 Aug-15 Sep</td>
<td>N of 56°30'N</td>
<td>545</td>
</tr>
<tr>
<td></td>
<td>S of 56°30'N</td>
<td>128</td>
</tr>
<tr>
<td></td>
<td>Complete survey</td>
<td>673</td>
</tr>
<tr>
<td>10-13 Sep</td>
<td>Cape Wrath/Butt of Lewis</td>
<td>1161</td>
</tr>
<tr>
<td>29 Sep-10 Oct</td>
<td>N of 56°30'N</td>
<td>609</td>
</tr>
<tr>
<td></td>
<td>S of 56°30'N</td>
<td>881</td>
</tr>
<tr>
<td></td>
<td>Complete survey</td>
<td>1490</td>
</tr>
<tr>
<td>11-13 Oct</td>
<td>N of 56°30'N</td>
<td>421</td>
</tr>
</tbody>
</table>
Table 4. Estimated abundances of herring larvae on the various surveys of Division VIa in 1976 (Totals for N and S of 56°30'N given separately).

<table>
<thead>
<tr>
<th>Date</th>
<th>Survey area</th>
<th>Larval abundances x 10^-9</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>&lt;10 mm</td>
</tr>
<tr>
<td>8-24 Sep</td>
<td>N of 56°30'N</td>
<td>198</td>
</tr>
<tr>
<td>&quot;</td>
<td>S of 56°30'N</td>
<td>71</td>
</tr>
<tr>
<td>&quot;</td>
<td>Complete survey</td>
<td>269</td>
</tr>
<tr>
<td>25-26 Sep</td>
<td>56°55'N - 56°05'N</td>
<td>231</td>
</tr>
<tr>
<td>8-25 Oct</td>
<td>N of 56°30'N</td>
<td>145</td>
</tr>
<tr>
<td>&quot;</td>
<td>S of 56°30'N</td>
<td>117</td>
</tr>
<tr>
<td>&quot;</td>
<td>Complete survey</td>
<td>262</td>
</tr>
</tbody>
</table>


<table>
<thead>
<tr>
<th>Size group of larvae</th>
<th>Time period</th>
<th>Estimated abundance x 10^-9</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;10 mm</td>
<td>1-10 Sep</td>
<td>NS</td>
</tr>
<tr>
<td></td>
<td>11-25 Sep</td>
<td>NS</td>
</tr>
<tr>
<td></td>
<td>26 Sep - 10 Oct</td>
<td>NS</td>
</tr>
<tr>
<td></td>
<td>10-25 Oct</td>
<td>415</td>
</tr>
<tr>
<td>10-15 mm</td>
<td>1-10 Sep</td>
<td>NS</td>
</tr>
<tr>
<td></td>
<td>11-25 Sep</td>
<td>NS</td>
</tr>
<tr>
<td></td>
<td>26 Sep - 10 Oct</td>
<td>NS</td>
</tr>
<tr>
<td></td>
<td>10-25 Oct</td>
<td>ND</td>
</tr>
<tr>
<td>Total</td>
<td>1-10 Sep</td>
<td>NS</td>
</tr>
<tr>
<td></td>
<td>11-25 Sep</td>
<td>NS</td>
</tr>
<tr>
<td></td>
<td>26 Sep - 10 Oct</td>
<td>NS</td>
</tr>
<tr>
<td></td>
<td>10-25 Oct</td>
<td>1 330</td>
</tr>
</tbody>
</table>

NS = No survey
ND = No data given

1) Incomplete survey
2) Including yolk sac larvae

<table>
<thead>
<tr>
<th>Size group of larvae</th>
<th>Time period</th>
<th>Estimated abundance x 10⁻⁹</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;10 mm</td>
<td></td>
<td></td>
</tr>
<tr>
<td>11-25 Sep</td>
<td>NS</td>
<td>NS</td>
</tr>
<tr>
<td>26 Sep - 10 Oct</td>
<td>NS</td>
<td>NS</td>
</tr>
<tr>
<td>10-25 Oct</td>
<td>504</td>
<td>677</td>
</tr>
<tr>
<td>10-15 mm</td>
<td></td>
<td></td>
</tr>
<tr>
<td>11-25 Sep</td>
<td>NS</td>
<td>NS</td>
</tr>
<tr>
<td>26 Sep - 10 Oct</td>
<td>NS</td>
<td>NS</td>
</tr>
<tr>
<td>10-25 Oct</td>
<td>ND</td>
<td>ND</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td></td>
</tr>
<tr>
<td>11-25 Sep</td>
<td>NS</td>
<td>NS</td>
</tr>
<tr>
<td>26 Sep - 10 Oct</td>
<td>NS</td>
<td>NS</td>
</tr>
<tr>
<td>10-25 Oct</td>
<td>807</td>
<td>940</td>
</tr>
</tbody>
</table>

NS = No survey  ND = No data given

Table 7. Estimated spawning stock sizes in tons in Division VIa in 1965 and 1971-76 by comparison with the Central North Sea.

<table>
<thead>
<tr>
<th>Year</th>
<th>Estimated spawning stock size (tons x 10⁻³) by comparison with Central North Sea</th>
<th>VPA (Anon., 1977)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1965</td>
<td>139</td>
<td>220</td>
</tr>
<tr>
<td>1971</td>
<td>202</td>
<td>357</td>
</tr>
<tr>
<td>1972</td>
<td>780</td>
<td>549</td>
</tr>
<tr>
<td>1973</td>
<td>448</td>
<td>466</td>
</tr>
<tr>
<td>1974</td>
<td>359</td>
<td>305</td>
</tr>
<tr>
<td>1975</td>
<td>237</td>
<td>160</td>
</tr>
<tr>
<td>1976</td>
<td>58</td>
<td>161</td>
</tr>
</tbody>
</table>

Table 8. Mean larval abundance in Division VIa and spawning stock size from VPA during the period 1972-76.

<table>
<thead>
<tr>
<th>Year</th>
<th>Mean abundance of &lt;10 mm long larvae x 10⁻⁹</th>
<th>Spawning stock in tons x 10⁻³</th>
</tr>
</thead>
<tbody>
<tr>
<td>1972</td>
<td>3 830</td>
<td>549</td>
</tr>
<tr>
<td>1973</td>
<td>2 200</td>
<td>466</td>
</tr>
<tr>
<td>1974</td>
<td>1 942</td>
<td>305</td>
</tr>
<tr>
<td>1975</td>
<td>1 252</td>
<td>160</td>
</tr>
<tr>
<td>1976</td>
<td>285</td>
<td>161</td>
</tr>
</tbody>
</table>
Figure 1. Numbers of larvae < 10 mm long beneath 1 square metre surface, west of Scotland, 28 August - 15 September 1975.
Figure 2. Numbers of larvae 10-15 mm long beneath 1 square metre surface, west of Scotland, 28 August - 15 September 1975.
Figure 3. Numbers of larvae <10 mm long beneath 1 square metre surface, Cape Wrath/Butt of Lewis, 10-13 September 1975.
Figure 4. Numbers of larvae 10-15 mm long beneath 1 square metre surface, Cape Wrath/Butt of Lewis, 10-13 September 1975.
Figure 5. Numbers of larvae <10 mm long beneath 1 square metre surface, west of Scotland, 29 September - 10 October 1975.
Figure 6. Numbers of larvae 10-15 mm long beneath 1 square metre surface, west of Scotland, 29 September - 10 October 1975.
Figure 7. Numbers of larvae >15 mm long beneath 1 square metre surface, West of Scotland, 29 September - 10 October 1975.
Figure 8. Numbers of larvae <10 mm long beneath 1 square metre surface, Hebrides, 11-13 October 1975.
Figure 9. Numbers of larvae 10-15 mm long beneath 1 square metre surface, Hebrides, 11-13 October 1975.
Figure 10. Numbers of larvae <10 mm long beneath 1 square metre surface, west of Scotland, 8-24 September 1976.
Figure 11. Numbers of larvae 10-15 mm long beneath 1 square metre surface, west of Scotland, 8-24 September 1976.
Figure 12. Numbers of larvae <10 mm long beneath 1 square metre surface, Hebrides, 25-26 September 1976.
Figure 13. Numbers of larvae 10-15 mm long beneath 1 square metre surface, Hebrides, 25-26 September 1976.
Figure 14. Numbers of larvae <10 mm long beneath 1 square metre surface, west of Scotland, 8-25 October 1978.
Figure 15. Numbers of larvae 10–15 mm long beneath 1 square metre surface, west of Scotland, 6–25 October 1976.
Figure 17. Relationship between mean abundance of <10 mm larvae and estimated spawning stock size.