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Specific Seasonal Density Changes in Cod and Haddock Populations

G. C. TROUT

Fisheries Laboratory, Lowestoft

The term "catch per unit effort" has long been used as an index of fish stock density. Gulland (1955) has dealt fully with its usage and its limitations. Most commonly it has been valuable in comparing the changes occurring in a stock from year to year, in order, for example, to show a trend in a stock in successive years, or for comparison of the potential of different grounds or populations.

Russell (1922) noted variations in monthly catch per day but his data also showed that variations between grounds took place simultaneously. Hickling (1927) demonstrated a seasonal change in density for the hake and associated the summer maximum with its summer spawning period. The writer (1957) showed a seasonal change of density in the two main feeding regions of the western Barents Sea, on the Spitsbergen Shelf (Region IIb) and in the south-eastern Barents Sea (Region I). Daily variations in availability were also shown to occur at certain seasons for the Bear Island area (1960).

The present paper surveys data from several cod and haddock populations of the North Atlantic and implies that the different seasonal patterns in catch per unit effort for the two species reflect naturally occurring changes in density on the bottom, where the fish are vulnerable to bottom fishing gear, and that the changes occur as a result of significant biological and behavioural phenomena. Some of the implications of the observations are discussed briefly and incompletely and will be dealt with more fully elsewhere.

1. COD

Barents Sea The main features of the density curves from Regions I and IIb (Trout, 1957) were the presence of a summer maximum, reached in June, and a smaller but persistent winter maximum in December. In Figure 1 data for Region IIa, the Norwegian coast, have been added. This region is fished by U.K. trawlers in the months of January to April. Peak landings occur in February and March (Figure 2, black symbols). From May onwards landings fall away to very low levels which are, on the whole, the result of occasional hauls made on the coast by trawlers on passage to or from more distant grounds. Nevertheless, the catch per unit effort curve for IIa follows the general pattern of the other two areas where landings are heavy, i.e. with mid-summer and mid-winter maxima.

It will be observed that no "spawning peak" of catch per unit effort appears. This is a special feature of the Norwegian coast and is due to the fact that the spawning grounds of the "skrei" are in the fjords and sounds between the islands and are therefore not fished by the trawlers, which fish only the approach routes to the spawning grounds. Since, too, the cod spawn pelagically, at between 30 to 80 fathoms (ibid. 1957) and usually over deep water, they would probably not be vulnerable to a trawl fishery. The Coast data exhibit a spring minimum, comparable in timing to that of the immature cod fished in the regions I and IIb at the times when mature fish are spawning.

Other regions Cod data for other areas differ mainly in the level of catch per unit effort during the spawning period. The same general pattern of maxima in mid-summer and mid-winter is evident, but there is great variation in the contribution made by the spawning concentrations. For example, a spawning peak is just apparent in the U.K. trawler catch at Iceland, in the Portuguese catch on the Grand Banks, and in the Lowestoft North Sea trawler cod data (Figures 3, 4 and 5), whilst in the seiner catch from Grimsby and in the U.K. trawler catch at Faroe it is the dominant peak (Figures 6 and 8). Where data from catches of category "small" are available, only one peak occurs - in mid-summer. Only in one case - the North Shields steam trawler curve (Figure 9) - is the pattern apparently different. This is being investigated further.

2. HADDOCK

Western Barents Sea Catch per unit effort data from this area provide a pattern of density change contrasting markedly with that of the cod. Two maxima also occur but these are in spring and autumn, with minima during the summer and winter months when cod densities are maximal. The spring peak, contributed to by both adults and immatures, occurs at the spawning season.

Figure 10, based on data from the Spitsbergen Shelf (IIb) - an area of low landings - and from Region IIa - the Norwegian coast where the haddock spawn - shows a very similar pattern of density change (Region I - dotted curve - is referred to below).

Other areas United States trawler catches from ICNAF Sub-area 5 Z.- containing George's Bank - provide a seasonal curve (Figure 4) comparable to that of the Barents Sea haddock. A relatively much higher catch per unit occurs, however, during the summer months than in the western Barents Sea data.

Canadian data from ICNAF Sub-areas 3 N, 3 O and 3 P also exhibit spring and autumn peaks (Figure 4) but the latter is of only fractional importance. Scottish seiner data (Figure 11) show a distinct autumn peak which overshadows the springtime peak. Scottish trawl data (Figure 12) provide more balanced spring and autumn peaks and both curves are followed reasonably closely by data based on landings of category "small" - essentially the immature fish.

Haddock data from the remaining areas investigated depart from what is considered to be the basic seasonal pattern, and Figures 13, 14, 15 and 16 indicate only one maximum, in autumn. The most probable reason for this departure would appear to be incomplete exploitation of the stock, i.e. the species is only on the fringe of a particular port's traditional fishing area.

Discussion

The close similarity of the pattern of curve derived from catch per unit effort data from areas where cod and haddock populations are heavily exploited, suggests that the observed differences in annual rhythmic behaviour of the two species are real and could not be the result of selective fishing, i.e. the patterns reflect changes in the species' availability to the gears considered. Thus cod is the most important species caught by U.K. trawlers in the Barents Sea, both numerically and economically. Haddock is also important - though less numerous - because of a sharp price differential, and is therefore sought actively and specifically by the trawler fleets. Likewise, George's Bank haddock is heavily fished and as far as the American trawlers are concerned this species is the primary reason for the effort directed to the area. The haddock curves from these two very different regions of the North Atlantic are essentially similar, with spring and autumn peaks for adults and immatures. Outside the Barents Sea the cod shows characteristically summer and winter maxima for matures and immatures with a further spring spawning concentration and these curves are assumed to reflect the normal behaviours of the two species in relation to the sea bed. A number of interesting aspects both of biology and of exploitation follow from these observations.

Biology

(a) Spawning behaviour The cod spawns pelagically and, in the special case of the Barents Sea "skrei" stock, spawning usually takes place over deep water in the fjords and along the Norwegian coast. Only in shallower water regions does bottom gear provide a spring peak in catch per unit effort based on spawners. Immature haddock, on the other hand, contribute to the haddock spring peak. The implication is that all parts of the haddock population are on the bottom at this time of year, which includes the spawning period. Saetersdal (1952) was unable to determine the precise location of the Norwegian coast haddock spawning grounds. Trawlers take considerable quantities of mature haddock with gonads in a stage near to spawning. The presence of major concentrations of haddock in this deep water area - of around 200 fathoms depth - suggests that the haddock's spawning behaviour may differ radically from that of the cod and may in fact be benthic or at least bathypelagic. (A brief study of the European haddock literature has not provided evidence of its spawning behaviour).

(b) Feeding Zatsepin and Petrova (1939) and Brown and Cheng (1946) found ophiuroids and polychaetes to be the dominant food organism, i.e. benthic forms. There is increasing evidence that the haddock has, despite its apparent adaptation to bottom feeding, appreciable periods of pelagic life. For example, during pelagic trawl trials carried out from the ERNEST HOLT in July 1957, the only fish caught were large haddock of 80-90 cm which were feeding heavily on euphausiids. The net was fishing at a depth of 20-25 fathoms with the bottom at 70-90 fathoms. Saetersdal (personal communication) caught haddock on pelagic lines from the G.O. SARS in late summer in the south-eastern

Barents Sea, when Norwegian trawlers fishing alongside were catching only cod. Several photographs of pelagic shoals of haddock have been taken. Blacker (unpublished) photographed young haddock at c. 15 fathoms over the deep water of the Bear Island Channel during August 1956.

Whilst more observations by pelagic trawl are required before it can be certain that the pelagic habit is constant and widespread in the species during the summer months, such an assumption could explain the relative scarcity of haddock caught by trawl during this period and also account for the autumn peak. If the bulk of the population were pelagic in summer, then their return to the bottom would give rise to an increase in catch per unit effort and this is thought to be a more probable mechanism than the increase in density being the result of a spatial concentration in response to some external, or internal, "concentrating factor".

A summer pelagic phase at a limited depth range could provide an explanation for the atypical haddock curve for the south-eastern Barents Sea, Region I (Figure 10). There no two-peaked curve emerges but density increases gradually to mid-summer and then declines.

No quantitative data on the haddock's annual depth range are available unbiased by the search for cod, but if they become pelagic after the spawning season, their drift in the North Cape Current would take them from the deep Norwegian coast waters to the shallower depths of the south-eastern Barents Sea, where most of the water is less than 100 fathoms. A movement into such an area during the summer could increase their vulnerability to the trawl.

Curves from the regions IIa and IIb show that a very small proportion of the haddock population is available to the trawl during the summer months, whereas the shallower Barents Sea and George's Bank populations provide relatively good levels of catch. A portion of the haddock population appears to be on the bottom at all times, but the possible diurnal movement of this portion of the population requires investigation on the lines of Woodhead's plaice observation (Woodhead, 1960). If feeding takes place pelagically - and it is during this summer period that maximal growth occurs and otolith opaque material is laid down (Saetersdal, 1953) - it may be that a "resting and digesting" phase exists, as was assumed by the writer to explain the cod's behaviour on the Spitsbergen Shelf.

(c) Light The Barents Sea and George's Bank haddock inhabit regions with very different daylight regimes. The Barents Sea has a period of winter darkness, a period of increasing daylight alternating with darkness in spring and autumn, and nearly four months of daylight in summer. George's Bank has alternation of daylight and darkness during the whole year, with, of course, maximal light intensities during the summer. The fact that the annual rhythmic behaviour is strikingly similar in timing suggests that light itself may not be the factor directly responsible for initiating the pelagic phase and that an inherent, i.e. genetical, factor may be involved.

3. Exploitation

(a) Cod French, Spanish and Portuguese Grand Bank trawlers arrive on the ICNAF grounds in two main "waves" to fish primarily for cod. Data from the Portuguese catches (Figure 4) suggest that the timing of these traditional sorties not only misses the bulk of the spawning concentrations but permits only few ships to fish the summer maximum. In Figure 4 the point on the curve showing the maximum catch per unit effort for the month of June was based upon a mere 26 hours fishing. As cod is the main species sought by these countries, it seems possible that a change from their traditional pattern of fishing could be expected to improve total catch without increasing effort - a redeployment rather than an increase in effort - unless consideration of winter weather or economics preclude this.

(b) Haddock Although Canadian markets have a ready sale for haddock, the Canadian fishing effort fails to take advantage of the normally occurring higher autumn densities. In default of a full knowledge of the economics and species preference of the Canadian fishery, it appears that more detailed knowledge of the haddock's annual migrations could enable exploitation to be increased by taking advantage of the greater availability of the haddock in autumn.

Scottish seiners are small vessels and are unlikely to be able to reach the spawning grounds of their haddock stock and hence cannot take advantage of the spring spawning concentrations which, however, move into the seiners' range in the autumn and are obviously heavily exploited.

Summary

1. The use of unrefined catch per unit effort data from cod and haddock populations suggests that different patterns of seasonal behaviour occur for the two species.

2. Some biological and operational implications are discussed briefly.

[illegible]: [illegible] Schwankungen an Cod zu allen Jahreszeiten.

[illegible] Jahres[illegible], wenn nicht in den [illegible] der Fische [illegible]. [illegible] [illegible] Behauptung.

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Fig. 1. Cod
Barents Sea. U.K. trawlers
1949 – 57

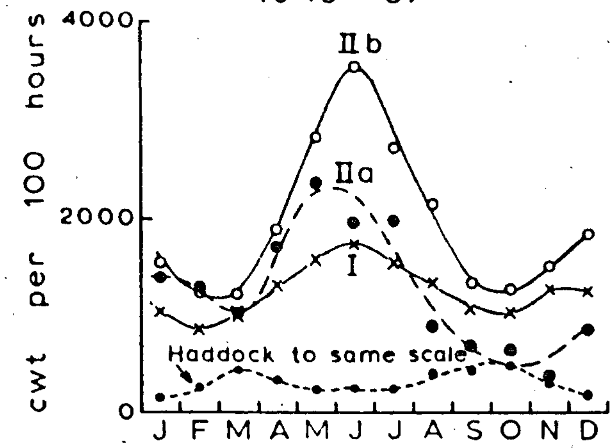

Fig. 2. Cod. Barents Sea. Mean monthly landings by areas 1949 – 57

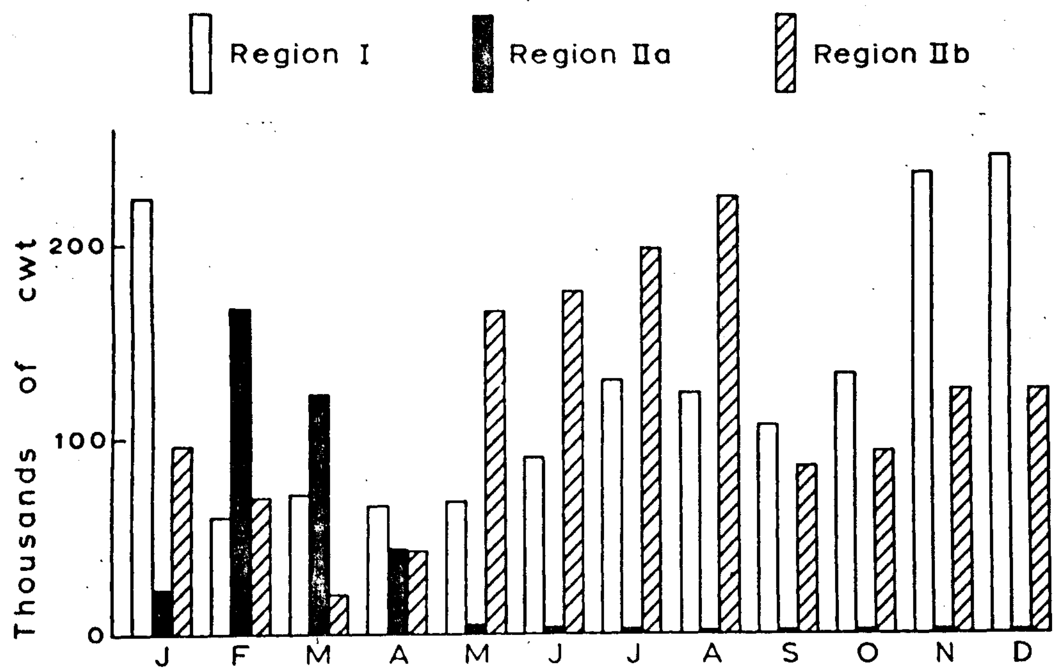

Fig. 3. Iceland
U.K. trawlers
1947-57

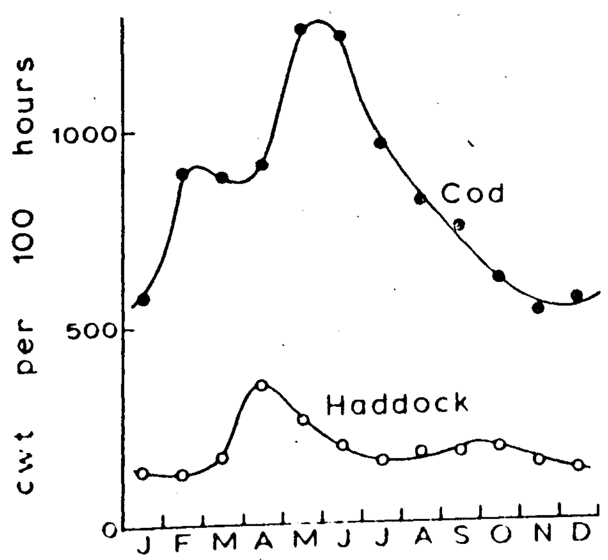

Fig. 4. 1955–58

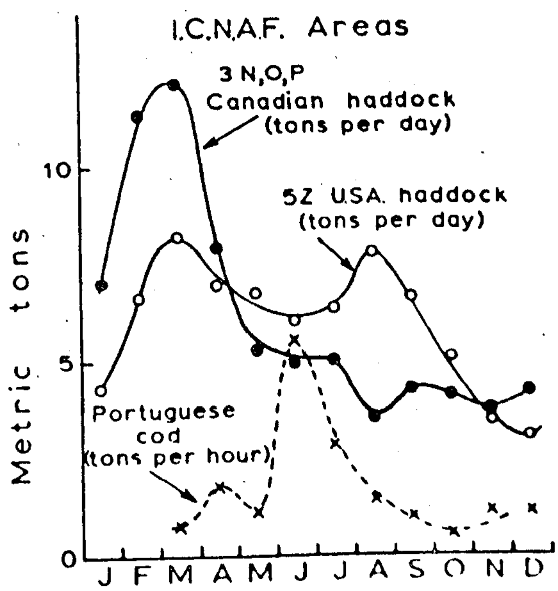

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Fig. 5. Cod
Lowestoft Motor trawl
1956-61 (1957 omitted)

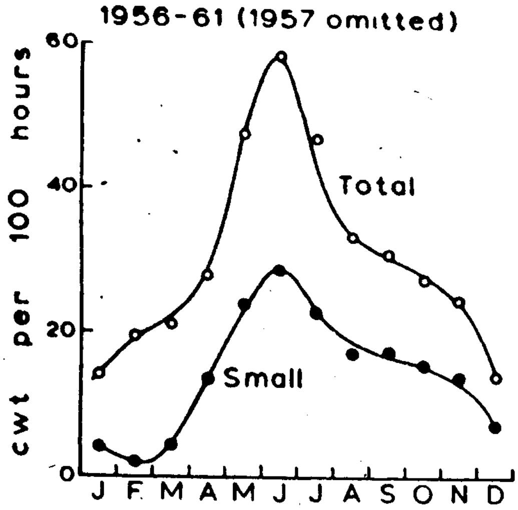

Fig. 6. Cod
Grimsby Seine
1956-61

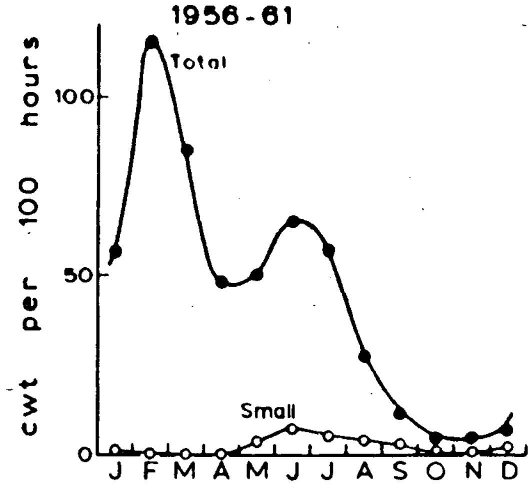

Fig. 7. Cod
North Shields Seine
1956-61

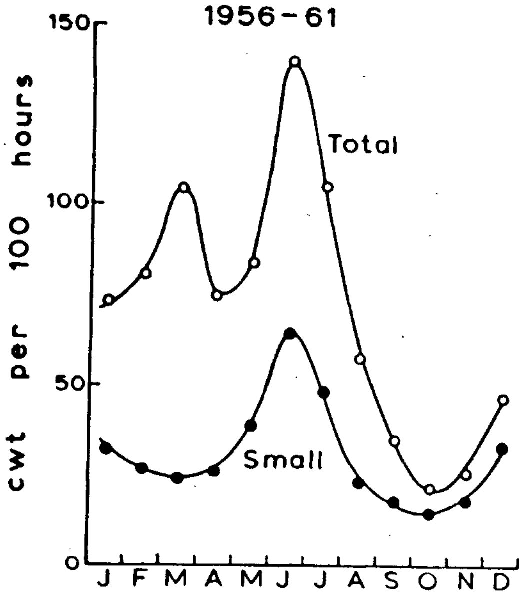

Fig. 8. Faroes U.K. trawlers
1947-57

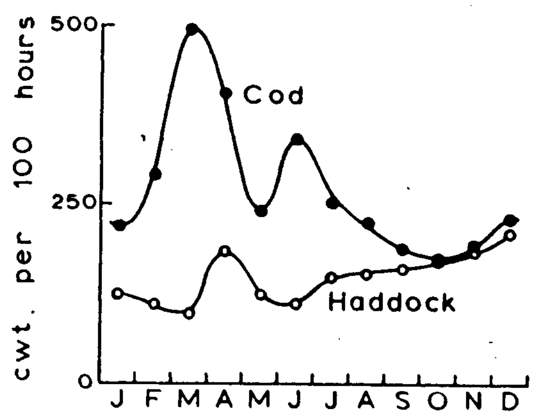

Fig. 9. Cod
North Shields Steam trawl
1956-61

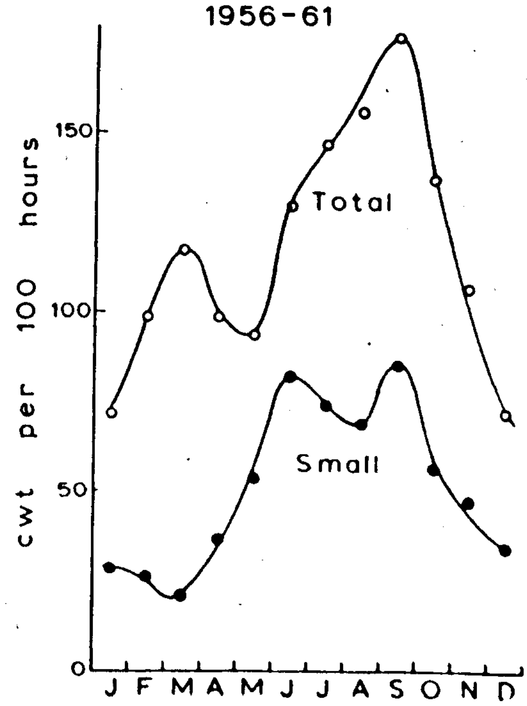

Fig. 10. Haddock
Barents Sea U.K. trawlers
1947-57

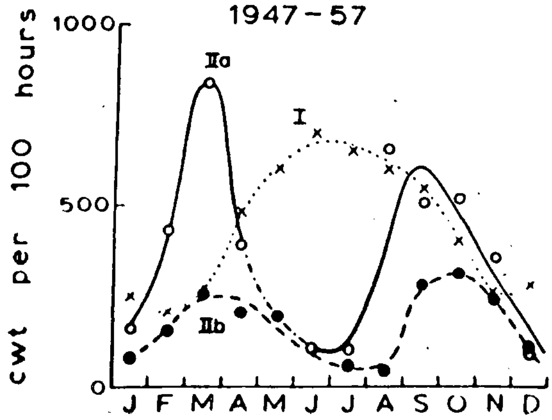

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Fig. 11. Haddock
Scotland Seine
1957–61

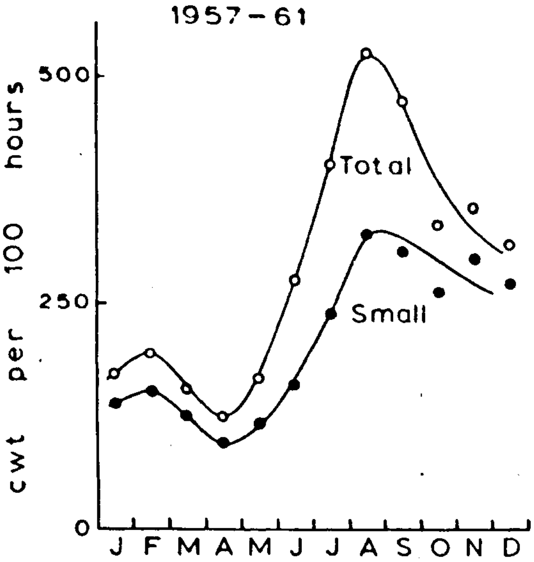


Fig. 12. Haddock. Scotland
1957–61

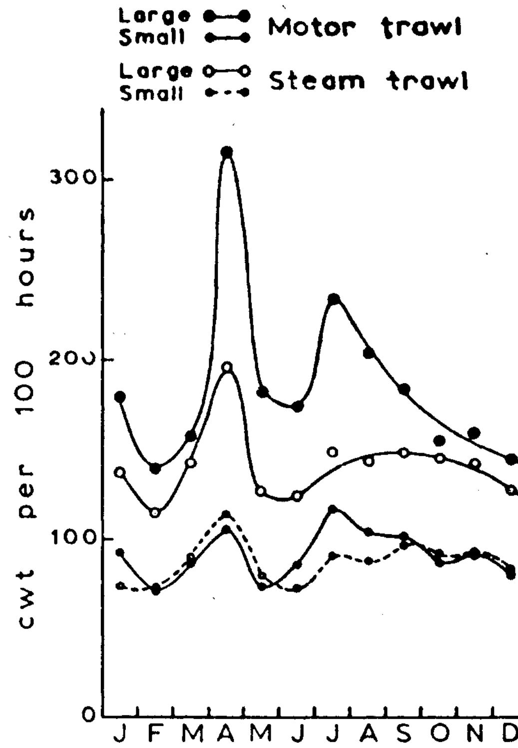


Fig. 13. Haddock
North Shields Steam trawl
1956–61

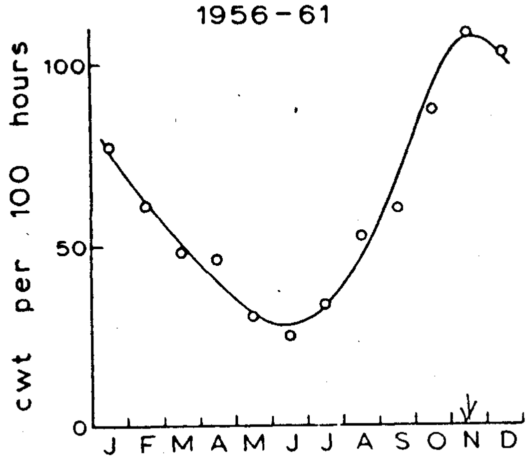


Fig. 14. Haddock
North Shields Seine
1956–61

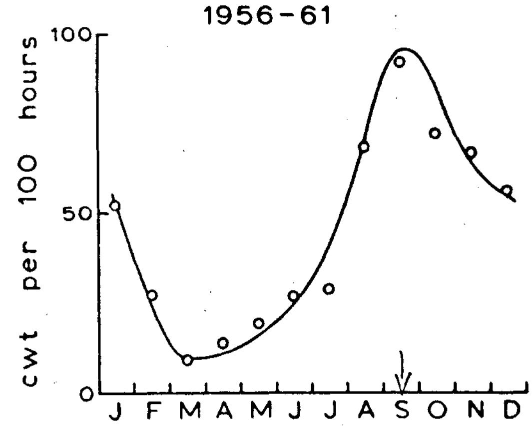


Fig. 15. Haddock
Grimsby Steam trawl
1956–61

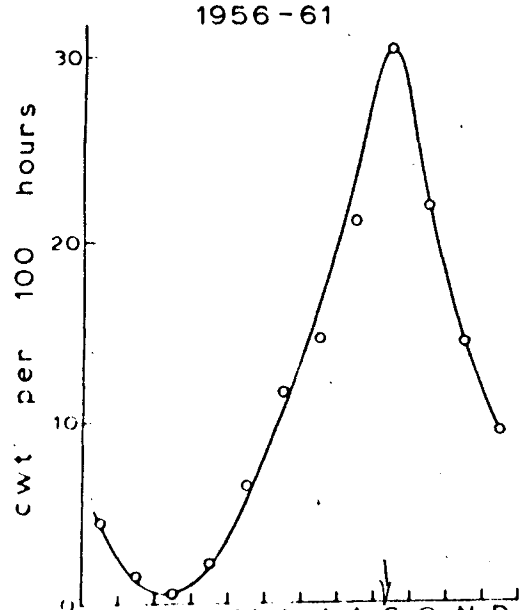
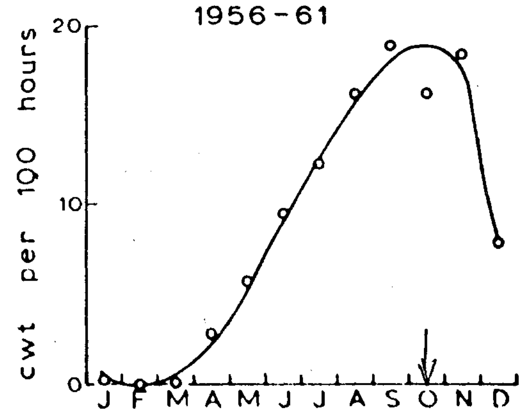


Fig. 16. Haddock
Lowestoft Motor trawl
1956–61



Sept/Nov.