PHD

The ecology of flounders, Platichthys flesus and other major fish species in the Severn Estuary and the Bristol Channel.

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Award date:
1977

Awarding institution:
University of Bath

THE ECOLOGY OF FLOUNDERS, *PLATICHTHYS FLESUS* AND OTHER MAJOR FISH SPECIES IN THE SEVERN ESTUARY AND THE BRISTOL CHANNEL

Submitted by

KARTAR SINGH BADSHA

For the Degree of

DOCTOR OF PHILOSOPHY

University of Bath

1977

TO MY FATHER

CONTENTS

ACKNOWLEDGEMENTS

I wish to express my gratitude to the C.E.G.B. and in particular the Staff and employees of the Power Stations at Oldbury, Berkeley and Hinkley Point for their invaluable co-operation and assistance.

I am also grateful to the Leverhulme Foundation, Rio Tinto Mines and the British Council for their financial support.

I owe my thanks to Professor M.W. Hardisty and to Dr. M. Sainsbury for their guidance and suggestions throughout the duration of this investigation and for their help and advice whilst preparing the manuscript.

I should also like to thank my past and present colleagues who have assisted with ideas and suggestions at various times during the study.

The various figures were photographed by Mr. C. Wilson and Mr. J. Philips and I am grateful to them.

Finally, my thanks are due to Miss J. Pitman for carrying out the difficult task of typing from my draft.

SUMMARY

1. Although flounders are present throughout the year in the estuary and the Bristol Channel, it was observed that sexually mature animals occurred in late summer/autumn and only in small numbers during the winter. Young animals (0+ and 1+), however, were present at all times but in varying numbers. The absence of sexually mature animals in late spring/early summer is occasioned by breeding factors, while in the case of the younger fish the variation in numbers is probably due to feeding migration. Sea snails and five bearded rocklings, on the other hand, are winter residents in the study area (except in the case of five bearded rocklings at Minehead), arriving in small numbers in autumn which build up to peak numbers by mid-winter, only to diminish by late winter/early spring. From year to year fish populations vary in this region, but the patterns of behaviour within species remains reasonably constant.

2. The age structure of the Severn fish population has been studied by otolith readings combined with length-frequency distributions and it was observed that the majority of the fish population in this area belong to the first and second year classes, indicating that this region is a nursery ground for a number of different species of fish.

3. Despite the fact that the Severn region is heavily industrialised, no disparity in growth in length and weight was observed for animals obtained from this region when compared with those from areas where little industrial activity exists and our results show rapid growth for young fish during their period of residency in the estuary and the Bristol Channel.

4. We note that there is generally a preponderance of females (in some cases, vary marked) over males in the three main species of teleosts investigated, but so far we can offer no explanation for this observation.

5. Flounders, sea snails and five bearded rocklings spawn from spring to early summer, but there is some evidence for species differences. Further, it is concluded that the rate of growth of the gonads is similar at all the sites within the estuary and the channel. Immediately prior to the onset of the spawning migration, the gonads of female sea snails, five bearded rocklings and flounders grew rapidly and eventually accounted for at least 10-13% of the total body weight, but the increase in weight of the testis was less dramatic and at the time of departure from the study area formed about 1.0-1.5% of the total body weight of the fish.

6. The spawning migratory pattern is the same for male and female flounders and five bearded rocklings, but in the case of sea snails there was a tendency for the males to leave for the spawning grounds a few weeks earlier than the females.

7. The utilisation of food organisms by teleosts has not always been closely correlated with the relative abundance of such organisms, but where many dietary organisms are present, food preferences may be observed. Thus, *Gammarus spp.* were found to be an important and relatively constant food organism for all the teleosts studied, except for mature flounders taken in the Barnstaple area, where the bivalve, *Macoma baltica* was found to be widely ingested. Despite the abundance of shrimps, *Crangon crangon*, throughout the year, there was an actual

decrease in the uptake of this decapod in all the three species investigated since 1973 in the Severn Estuary and the Bristol Channel.

8. Although there was variation in the percentage of nematode infestation from species to species, it was seen however, that in any one species the percentage of infection did not vary from site to site.

9. The rate of uptake of heavy metals in the vertebrate and invertebrate populations of the study area depend largely on such factors as salinity, water temperature, type of food uptake, and age, as well as differing from species to species. As a result of continuous monitoring a considerable amount of data has been collected concerning the uptake of zinc, lead and cadmium by fish and their prey. Concentrations of cadmium and lead in fish tissues are lower than in their food organisms. Thus, the ratios of concentrations in predator and prey varied from 1 : 25.0 for cadmium and 1 : 2-3 for lead. On the other hand, zinc concentrations in predator and prey are similar. Present studies suggest that while lead and zinc are to some extent present in high concentrations in the natural run off of the region, cadmium is an industrial by-product, since fish from the less industrialised areas contain much lower concentrations of this element compared with those from sampling sites closer to industrial activity.

PART 1

INTRODUCTION

1. INTRODUCTION

In the Severn Estuary and the Bristol Channel, Nickless *et al* (1972) reported high concentrations of heavy metals in the flora and the fauna and raised public concern in relation to the levels found. These studies were purely analytical in nature, and took no account of biological and ecological factors. Similar investigations by Butterworth *et al* (1972), and Pedan *et al* (1973) were subject to similar limitations but on the other hand, the work of Hardisty *et al* (1974a & b) commented specially upon the importance of considering ecological and environmental factors when assessing the effect of metal concentrations in living organisms in the ecosystem.

Indeed,any attempt to monitor possible changes in the ecology of a region pre-supposes the establishment of quantitative baseline data on populations, their inter-relationships and pattern of movement, related as far as possible to abiotic factors. In the case of the Severn Estuary, however, little detailed ecological work has been done, although historical records of the fisheries in the estuary can be traced back to medieval times. Even then,man's intervention with the natural ecology of the system was taking effect, for the construction of fish weirs of various types reduced the reproductive potential of some of the anadromous species and it is known that during the Industrial Revolution the building of permanent navigation weirs and dams caused serious damage to the stocks of salmon, lamprey and shad (Day, 1879, 1890).

The surveys carried out by Lloyd (1940), based upon figures from commercial catches, provided some useful conclusions on the species composition of the estuarine region and later formed part of a wider investigation into the biology and physico-chemical conditions of the estuary carried out in the Zoology Department of the University of Bristol and which resulted in several publications under the general title of 'Studies on the Biology of the Bristol Channel' (1947). In addition to surveys of the invertebrate and vertebrate fauna, detailed studies were carried out on the biology of the shrimp, *Crangon crangon* by Yonge and Lloyd (1947).

More recently, quantitative investigations have been made on the invertebrate fauna by Boyden and Little (1973). As a result it was concluded that, in contrast to the pattern displayed by rocky shore animals, the number of 'infaunal' species do not increase towards the mouth of the estuary, suggesting that the disappearance of a number of species might be attributable to sewage contamination. Investigations of Moore *et al* (1976) on the invertebrate population in the middle reaches of the Severn Estuary should be treated with caution as they not only contradict the findings of Yonge and Lloyd (1947), but also they do not agree with our own observations over the same period. This is possibly due to the small number of animals used by Moore.

Earlier work carried out by the present author (Kartar, 1974) on the flounder *(Platichthys flesus)*, sea snail *(Liparis liparis)* and sand goby *(Pomatoschistus minutus)* has demonstrated the feasibility of obtaining specimens of fish from power station intakes so that population studies could be made and the present study has been designed so as to co-ordinate these findings with a continuous monitoring of the rate of accumulation of zinc, lead and cadmium by key estuarine species. Furthermore, the feeding habits of these animals was determined so that a detailed knowledge of the food chains related to them could be worked out.

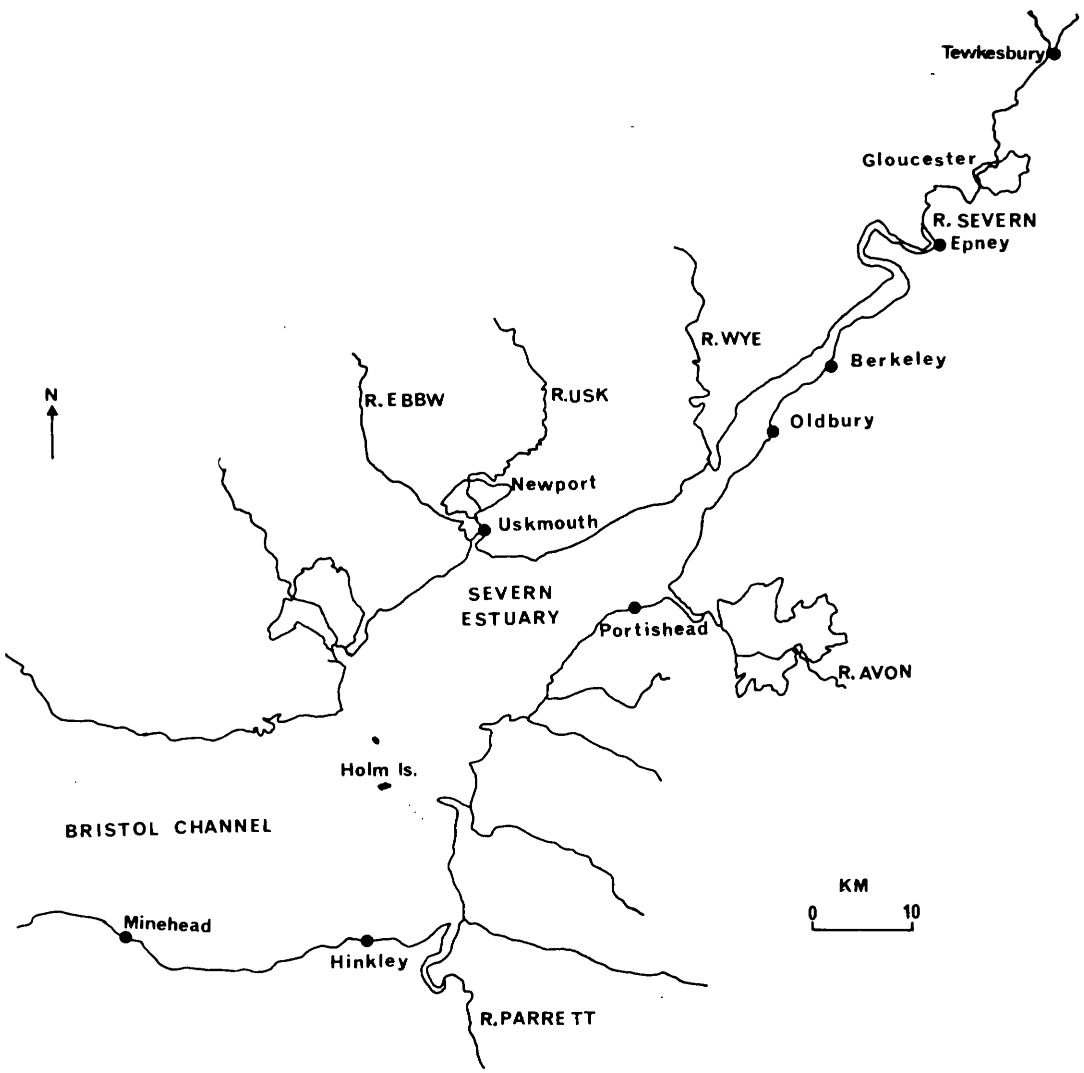
1.1. SAMPLING SITES

Figure 1 shows the relative geographical positions of Berkeley,Oldbury, Uskmouth and Hinkley Point Power Stations and the position of Minehead in relation to these stations. Berkeley and Oldbury Power Stations (8 km apart) are situated on the southern shore of the Severn Estuary, 42 km downstream from Gloucester. At this point the river is approximately 1.2 km wide (Plate 1) at high tide but very much less than this at low tide. To avoid fluctuations in the water levels at Oldbury, a large reservoir has been excavated out of the bed of the river in front of the station and it is from this reservoir that the cooling water for the reactor is drawn. Twice during each 24 hour cycle the reservoir is 'topped up' by the rising tide and it is during these times that 'new' marine animals are introduced.

BerkeleyPower Station is located 8 km upstream from Oldbury on the southern bank of the estuary in a region where salinity remains relatively constant between 10-25%, depending on the time of the year. Uskmouth Power Station, approximately ½ km upstream of the confluence of the River Usk with the Severn and experiences widely fluctuating salinity depending on the state of the tide and the season. Finally, Hinkley Point Power Station is on the edge of the Steart Flats at the mouth of the River Parret, taking its cooling water from the marine environment of Bridgewater Bay. Plates 2-7 show the mechanism involved in the intake of water from mid-channel to the filter screens at this site.

FIGURE 1

The relative positions of various sampling sites in the Severn Estuary and the Bristol Channel.


Tewkesbury
Gloucester
R. SEVERN
Epney
Berkeley
Oldbury
R. WYE
R. USK
R. EBBW
Newport
Uskmouth
SEVERN
ESTUARY
Portishead
R. AVON
Holm Is.
BRISTOL CHANNEL
Minehead
Hinkley
R. PARRETT
KM
0
10
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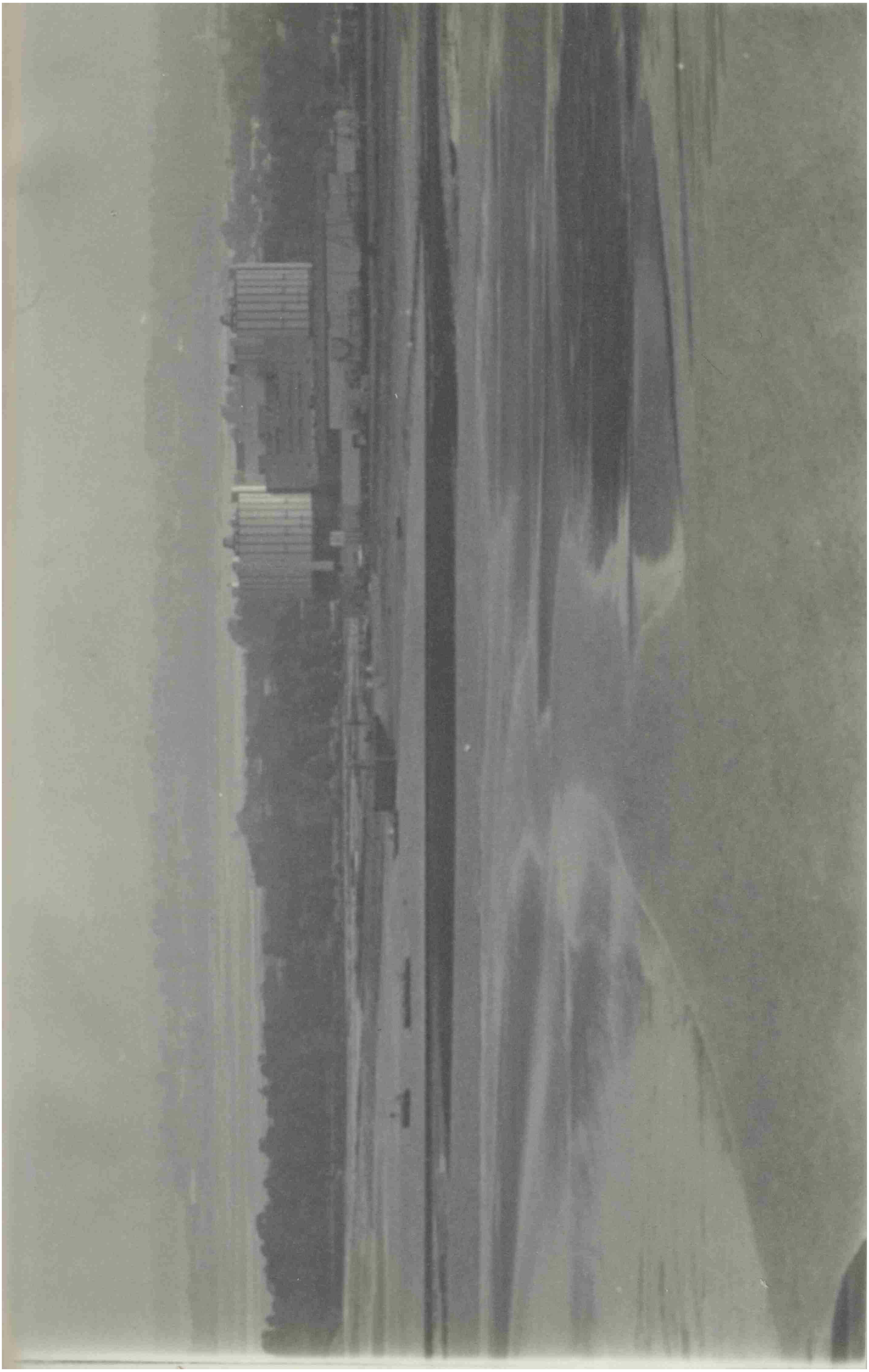

PLATE 1

Location of Oldbury Power Station.

PLATES 2 - 7

Screening mechanism of Hinkley Point Power Station.

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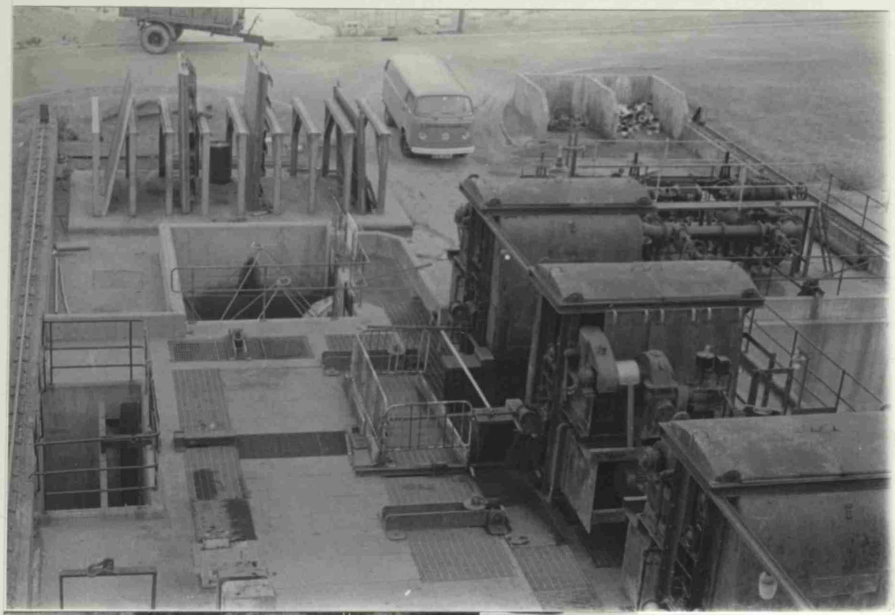

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1.2. SAMPLING AND SCREENING MECHANISMS

At Oldbury, the cooling water flows through a coarse mesh screen fixed to the centre of a 40 feet diameter revolving drum of 1 cm mesh size from where it passes to the pumping chamber. Troughs bolted to the inside surface of the drum collect any solid material and live fish, which are then washed by a water jet into a drain as the drum reaches the top of its cycle. The drum empties into the trash bins which have a circular mesh of about 1.5 cm diameter. There are four revolving drum screens feeding into four separate pumps, two of which are in operation at any one time, pumping 280 x 10^6 gallons of water a day with one trash drain serving all the screens. This divides to feed two filter baskets which can be connected or disconnected from the supply by a hand operated mechanism (Plates 8-12 illustrate the mechanism).

By regular weekly inspection over a protracted period, general trends in population and distribution of teleost species at the sampling site may be detected.

A selective bias against the smaller organisms might be expected to operate in relation to the size of the screen mesh, but in practice this has not been found to be a serious limitation since the presence of debris and vegetation in the surface on the screen tends to retain even the smallest fish and shrimps. This is borne out by the large numbers of very small bass, gobies and sea snails that have been recovered from the intake screens (Kartar, 1974). More serious attention was paid to the development of suitable sampling techniques, particularly to the timing, frequency and duration of the sampling periods. At Oldbury, the contents of trash bins are emptied

PLATES 8 - 12

Relative position of Oldbury Power Station and details of the screening mechanism.

8

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12

daily by the station staff and each sample is therefore representative of the fish intake over a 24 hour period. In the case of larger fish such as eels, flounders and lampreys, there has been no difficulty in ensuring that all the animals present are collected. Particularly in the Severn Estuary and the Bristol Channel, a more practical and economical method of sampling is difficult to visualise, especially with the abandonment of most of the commercial fishing.

Although there are differences in the intake and screening systems at the various power stations it is unlikely that these will affect the general validity of the sampling technique. Thus, at both Berkeley, Hinkley and Uskmouth the cooling water is taken from the middle of the river, while as described above, at Oldbury, it is drawn from a holding reservoir which is flooded by the tide. Fortunately, the close proximity of the two stations, Oldbury and Berkeley, allows us to determine the extent to which the position of the water inlet alters the apparent population as determined by the weekly catches and it will be observed in the sequel these effects are minimal.

At Minehead, where no power station complex is present, the majority of the animals used in this study were caught, using a fine mesh shrimp net tied to the mouth of a commercial trap built of stone, separating a tidally flushed pool from the sea (this is shown in Plates 13-15). Animals caught by this method were sampled only at the period of highest followed by lowest monthly tides. On average samples were obtained by this method twice a month.

The inlet water temperature for Oldbury-on-Severn is recorded daily and this is shown in Figure 2 together with the volume of fresh water flow at Gloucester. However, it was not possible to monitor temperature at other sites.

PLATES 13 - 15

The ancient fish weir (pre 14th century) at

Minehead in the Bristol Channel.

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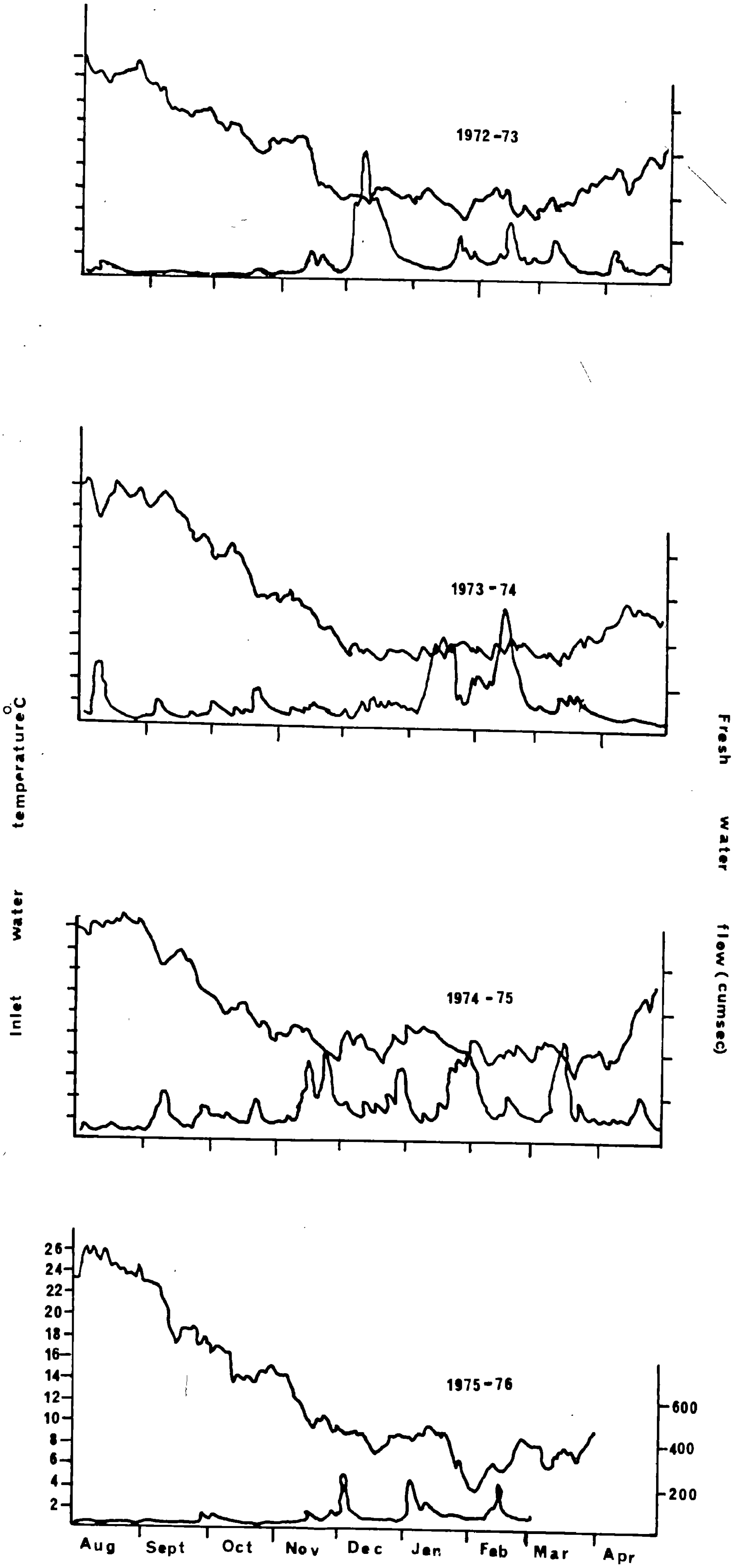
FIGURE 2

Daily inlet temperatures in the reservoir of Oldbury Power Station and the fresh water flow in the Severn Estuary at Gloucester.



1972-73
1973-74
1974-75
1975-76
Inlet water temperature °C
Fresh water flow (cumsec)
26
24
22
20
18
16
14
12
10
8
6
4
2
600
400
200
Aug
Sept
Oct
Nov
Dec
Jan
Feb
Mar
Apr

PART 2

MATERIALS AND METHODS

2. MATERIALS AND METHODS

Key species selected for the present study were flounders, *Platichthys flesus*; sea snails, *Liparis liparis*; five bearded rocklings, *Ciliata mustela*; sand gobies, *Pomatoschistus minutus*; and shrimps, *Crangon crangon*, all of which are present in abundance in the Severn Estuary and the Bristol Channel. With the exception of five bearded rocklings which were also obtained at Minehead, all the animals occurred in weekly collections from the trash bins of the Oldbury Nuclear Power Station and further monthly collections were made from Berkeley (1974), Uskmouth and Hinkley Point from 1975.

All the species obtained were weighed and measured to the nearest milligram and millimeter respectively. The lengths were used to construct length-frequency curves in order to ascertain growth rates during the period in the estuary and also to estimate the duration of life cycles. Otolith readings were used to check the age groups of the specimens studied (Kartar, 1974).

Estimations of fecundity were conducted for *Liparis liparis* and *Ciliata mustela* and after the gonads were weighed, the ovaries were preserved, using Gilson's fluid as a fixative, the composition of this medium being similar to that used by Simpson (1951), i.e:

60% alcohol (100 cm^3)

water (880 cm^3)

80% nitric acid (Analar grade) (15 cm^3)

glacial acetic acid (18 cm^3) and

mercuric chloride (20 g)

For sea snails, individual eggs were counted for all the animals but in the case of the five bearded rocklings,sub-sampling by weight was found to be ideal (the method used was similar to that described by McGregor, 1922).

After recording the biological parameters of all the fish, stomach analyses were conducted and individual food items were identified and weighed separately. These were then expressed as a percentage of the weight of total stomach content, also as a frequency of occurrence (expressed as a percentage of animals examined). Gonadosomic ratios were obtained by weighing the fresh gonads of fish and expressing them as a percentage of the total body weight (excluding the weight of the stomach contents).

Representative samples of animals were taken and analysed for zinc, lead and cadmium levels, where possible from all sites along the Severn Estuary and the Bristol Channel, on a regular basis (weekly at Oldbury).

Previous work on heavy metal concentrations (Kartar, 1974) showed that atomic absorption photometry is a suitable technqiue for analytical determination of zinc, lead and cadmium in fish tissues. However, constant checks were made to ensure the reliability of the method.

2.1. SAMPLE PREPARATION

The sample preparations were conducted in a similar manner to those discussed by Kartar (1974). Thus, individual animals were freeze-dried (Leybold-heraeus) for 48 hours, and approximately a g of dried tissue was accurately weighed, the sample digested in 2.5 cm^3 nitric acid and 6 cm^3 of perchloric acid (both of Aristar grade). The volume of nitric acid added depended on the tissues analysed. For example, tissues with high lipid content need 4 cm^3 of nitric acid to complete digestion. Two sets of blanks were treated in the same way. A standard solution, containing all three metals were digested the same way as the organic samples.

The Atomic Absorption Spectrophotometer (Plate 16) used in the present study allows the evaluation of zinc, lead and cadmium by well documented procedures. Thus, the test material, in solution is delivered into a spray chamber as a mist together with the fuel gas, acetylene, and ignited.

Pulse light from a hollow cathode lamp, emitting the spectrum of the element to be determined is passed through a flame and monochromator. The change in the intensity of the light at the selected wavelength which occurs when atoms of that particular element are introduced into the flame (Plate 17) is detected by the photomultiplier. The signal is isolated electronically and displayed on a meter or recorder as absorbance (i.e. I/I_o). It should be noted that the change in transmission of a flame is proportional to the number of atoms present.

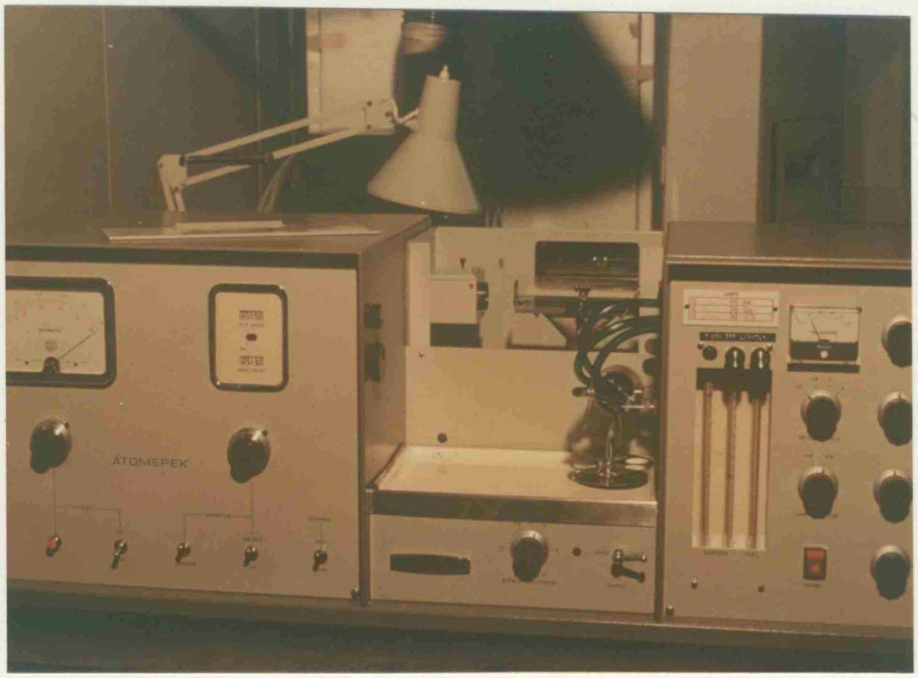
The following wavelengths and slit widths were used:

Element	*Wavelength*	*Slit width*
a) Zinc	213	50
b) Lead	216	76
c) Cadmium	288	45

Results were checked against analyses of standards. In addition, some duplicate analyses were conducted at the laboratories of the Varian Tetoran Ltd., London; and again, correlation with our results was good.

PLATES 16 - 17

The Hilger Watts Atomic Absorption Spectrophotometer.



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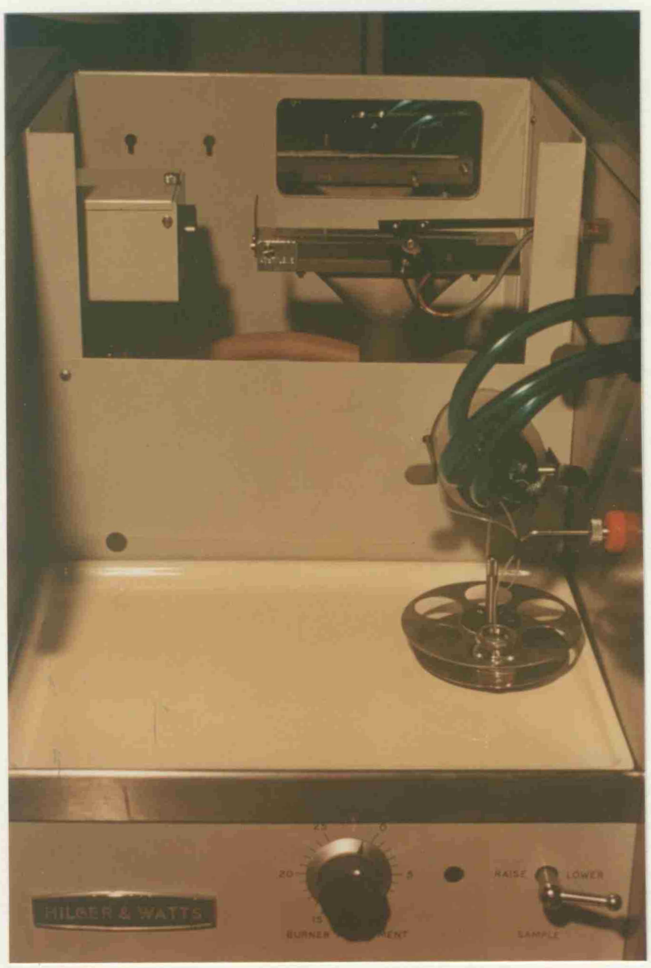

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PART 3

FLOUNDER, *PLATICHTHYS FLESUS*

3. FLOUNDER, *PLATICHTHYS FLESUS*

3.1. INTRODUCTION

It is not surprising that biological and ecological investigations of this teleost have been vigorously conducted by European workers, in view of its commercial importance. This is demonstrated by the yearly catch statistics of various European countries (Jensen, 1955-1959; Zemskaya, 1960) which, in the Baltic area alone totalled 10,000 tons (Wheeler, 1969). One major aspect of the life history of the flounder that has come to light as a result of several investigations (Cunningham, 1869; Redecke, 1907; Ehrebaum, 1908) at the turn of this century indicates that at all locations the fish tends to spend the late summer and winter in shallow and upper-reaches of estuaries returning to the open sea for a short period in spring to spawn. Initial findings of the author (1974) are in agreement with these studies. In general, it is commonly found in inshore waters within the 55 m line, but may well be rather local in its distribution within a specific area. Flounders are adapted to estuarine conditions and are most common in water of low salinity (Bregnballe, 1961). The ability to show such an adaptation to variable salinity involves biochemical and osmotic compensations at tne cellular level. Thus, it is known that flounders are able to regulate their body volume and plasma osmolarity (Buddenbrock, 1936; Fugelli, 1967) in a wide range of external concentrations. Therefore, it is not surprising to find flounders in freshwater, and it is said to be the only marine flat fish that besides adapting to conditions of low salinity, is able to penetrate and live for short periods in freshwater.

The migration and distribution of the flounder appears to be directly influenced by two major factors; but in addition there are a host of minor effects which exert an indirect influence. The requirements of spawning and the search for food constitute the two principal factors refered to above and both have been extensively studied and documented (Ehrenbaum, 1911; Hartley, 1940; Cieglewicz, 1947; Reiman, 1959; Kartar, 1974). The general picture that emerges from these researches indicates that flounders undertake spawning migrations from the shallow coastal waters to the deep sea in early spring and then return to the coastal water in the summer to feed and recuperate. There is, however, considerable variation in the commencement and termination of spawning periods from locality to locality and this indicates that factors such as temperature, food supply and probably light determine or at least influence the exact time at which the spawning migration commences. In the Goland and Faro regions, spawning starts in the latter part of April and continues until the beginning of June. Thus the pelagic larva of flounder can be observed in these regions of the Baltic as late as June (Hessle, 1930), while in the Belt Sea, it is known that flounders spawn from February till August, with peak activity during March, April and May (Heegaard, 1947). In contrast, the peak intensity of spawning in the Bornholm Deep is between March and April (Reiman, 1951-55) and in the Gulf of Finland between late May and early June. In Estonian waters the spawning activity is confined to the period April to June and in the region of Ventsplit-Leipaja between April and May (Kandler, 1935; Betesheva and Kulikova, 1953; Zemskaya, 1960). In Kiel Bay, (Kandler, 1960) found the pelagic eggs of flounders during February-April and pelagic larvae in March-May.

The study of the distribution and migratory behaviour of any marine animals involves tedious tagging procedures and considerable assistance from local fishermen. Despite these difficulties, this approach is often employed and the results of such investigations contribute important facts out of which a broad spectrum of events can be tentatively constructed. Two examples of such studies in the case of flounders are the investigations of Hartley (1940) and of Cieglewicz (1947). In a tagging experiment, Hartley marked 1,038 flounders and released them in the estuaries of the Tamar and Lynher Rivers in South Devon. Out of the total number, only 148 of the flounders released were recovered and when these were released for the second time only seven were recaptured. After the third release only one was subsequently caught. Although the poor yield of recapture did not allow specific conclusions to be drawn concerning the distribution of the adult fish, the general indication was that the majority of the flounders living in the lower reaches of the Tamar near Saltash tended to remain in one limited area during the winter months and that in spring there was an upstream movement of the small immature fish. Hartley suggested that flounders which had gone down to the sea to spawn frequently did not return to the same river but tended to move away. Unfortunately, there was not sufficient evidence of recovery from other areas to substantiate this conclusion, but it is recorded by Cieglewicz (1947) that flounders do undertake extensive long distant migration within the general area of origin. The tagging experiments of Cieglewicz were more successful and were more extensive than those of Hartley. Initially, 1,682 marked flounders were liberated in the Gulf of Gjdansk and a further group of some 200 in the Bornholm Basin. Of these 16 to 17% were recaptured and from the results, Cieglewicz concluded that the seasonal movement of the young immature flounders was offshore in the winter and inshore in the summer, thus confirming the view expressed by Hartley. The most important factor influencing the period of these movements was thought to be the abundance of food inshore and the corresponding scarcity of bottom fauna at the Gjdansk Deep. In addition to the spawning movement, Cieglewicz also noted that frequently during the summer, some adult flounders moved into the estuaries of the Baltic rivers, Vistula and Oder.

In a marine locality it is clear that among the various factors which influence the general growth and well-being of a fish such as the flounder, the quantity and quality of food is of paramount importance. Correspondingly, any environmental factors (pollutants, temperature, tides, etc.) that affect the growth and population of the bottom fauna, will also affect the nature and the density of flounder population. For example, in one particular region in the Russian Baltic (Ventsplit) it has been reported that the growth rate of the flounder was stunted by urban pollution (Shantunovskii, 1965). This highlights the serious difficulties that may arise when determining the age by length-frequency measurements. More problems arise when age measurement by the method of otolith counts is rendered unreliable for example. Hartley (1940) and the author (unpublished observation) find that the otolith rings of sea-caught flounders are less easily counted than those of the estuarine fish. It may be that the strain of spawning and the change from an estuarine to a marine environment so alters the metabolism of some fish that the regular laying down of summer and winter rings ceases or is at least interrupted.

Several authors have emphasised the variability of growth rate in the flounder. Cunningham (1896) found that a number of young flounders, kept in the laboratory at Plymouth and regularly but not very liberally fed, grew from a length of 1.25 cm in May 1890 to lengths varying between 5.0 and 19.0 cm by May 1891. Blegvad (1932) showed that there is a correlation between the growth rate of O-group fish and the temperature of the sea, the length of the fish increasing with an increase in temperature. He also found, that the growth is comparatively small in areas where young fish assemble in large numbers. Lubbert and Ehrenbaum (1936) also observed that the rate of growth varied with the density of the population. In the O-age group, Muss (1967) observed a linear growth rate from 12 to 46 mm in 49 days. This corresponds to, or is just below that noted by Bregnballe (1961) for flounders in Kysing Fjord in 1955 and 1956. Hartley has also noted that the growth of the fish slows down considerably in winter. This is to be expected since there is a marked period of fasting during winter months (Mulicki, 1947).

Females have been found to reach sexual maturity in their fourth year of life (Betesheva and Kulikeva, 1953; Kandler, 1935) but the males have been known to attain their sexual maturity at the age of three. The rate of growth of the male flounder is slower than that of the female, probably because of its earlier maturation and longer period of sexual activity (Hartley, 1940; Cieglewicz and Mulicki, 1938). More or less comprehensive data of the dietary intake of the flounder exists in the literature, recorded from almost all parts of the area of distribution. The early literature contains several general statements of flounder food preferences in their particular marine habitats (Todd, 1907, 1915; Regan, 1911; Markowski, 1933), but it seems that in general the principal diet consists of a number of marine species like polycheates, small fish, crustaceans and molluscs. An extensive investigation by Mulicki (1947) and studies by Blegvad (1916), Larsen (1936), Bregnballe (1961) and Muss (1967) have produced precise data in relation to the life history of the flounder. It is now generally agreed that worms and crustaceans constitute the main food of the bottom-living stages of the 0+ age groups. Thus, oligchaetes, small specimens of *Nereis diversicolor*, postomia of *Pygospio elegans*, *ostracods* and *harpacticoids* are eaten during the first month after the arrival in shallow water. Gradually *Corophia*, *gammarids*, small molluscs and bigger specimens of *Nereis diversicolor* become the important food items. Older flounders also feed on shrimps *(Crangon vulgaris)* and, in some cases, on gobies and sticklebacks. There is also a difference in diet between the sexes and Mulicki (1947) observed that as fish approached maturity, the female tended to consume more food than the male.

Among all age groups there are seasonal changes in the composition of food and intensity of feeding; dietary intake is most intense in summer but declines in winter, as previously mentioned. Bregnballe (1961) has investigated the stomach contents of 282 flounders from Kysing Fjord (Baltic) caught at different hours of the day and night, he showed that even in the same habitat there were diurinal variations in the diet. Fluctuating feeding activity probably accounts for earlier reports emphasising the growth rate variability in flounders (Cunningham, 1896; Blegvad, 1932; and Hartley, 1939). However, our earlier findings (1974) showed selectivity, rather than availability, as being the major factor in influencing the dietary habits of this species. Further studies showed (Bregnballe, 1961) that the fish feed greedily and continuously at temperatures between 19-20^{o}C, and this consequently results in rapid growth. Muss (1967) observed that under experimental conditions 0+ age group flounders (5-10 cm long, 1.3 - 13 gm) consumed an amount of food corresponding to about 30% of their body weight in order to grow 5-7%. These experimentally reared flounders were fed upon live *Nereis diversicolor* (dry matter content about 25%) at a maintained environmental temperature of 18^{o}C.

3.2. RESULTS

The present study was designed as a continuation of previous researches (Kartar, 1974) and includes information on the numbers of fish caught weekly, dietary habits, weight, length and growth characteristics, sexual maturity and age distribution of flounders from the Severn Estuary and the Bristol Channel (Oldbury, Berkeley, Hinkley Point and Barnstaple Bay). It was hoped that such information would lead to a clearer understanding of the life history of this species in this region (Plate 18).

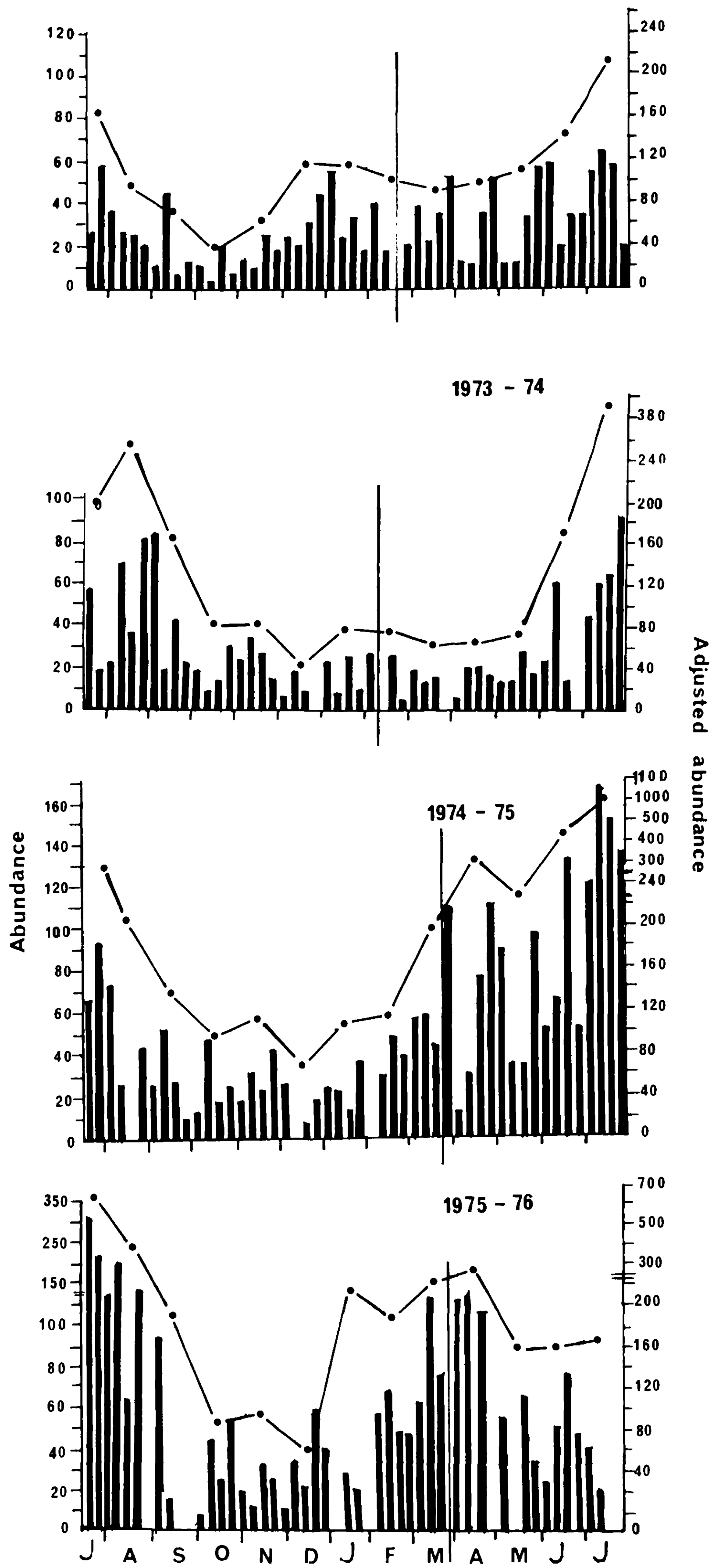
3.2.1. Seasonal and Annual Changes in Flounder Abundance at Oldbury

In order to study the migratory behaviour of this species, the weekly numbers caught during a twenty four hour collection period were recorded (1973-1976). These results show marked short term fluctuations in weekly samples (Figure 3). However, when the sample data were pooled at monthly intervals longer term trends in relative abundance can be recognised. Thus, it is observed that the flounder population reaches a maximum in summer, falling to a minimum by the

FIGURE 3

Seasonal and annual fluctuations in abundance of flounders, *Platichthys flesus* caught in a 24 h sampling period in the cooling water intakes of Oldbury Nuclear Power Station during 1972-1976. Superimposed vertical lines seen between February and March of each successive year indicate that a smolt gear is in operation in the intake screens.

Platichthys flesus



PLATES 18 - 20

The flounder, *Platichthys flesus*

Five Bearded Rockling, *Ciliata mustela*

and the Sea snail, *Liparis liparis*.

18

19

20

end of autumn and increasing again by late winter or early spring. An exception to this general pattern of bimodal distribution in seasonal abundance was seen in 1976 when maximum numbers were observed in mid-January to May. Two interesting but unexplained results have emerged from our studies of the flounder at Oldbury. First, during March-May 1975 and again in the same period the following year, maximum numbers of adult flounders were observed before the arrival of the newly hatched young. Secondly, annual numbers of flounders obtained from the cooling water intake screens over the 1972/76 period have significantly increased, as shown below:

1972 - 1973	1215
1973 - 1974	1435
1974 - 1975	2602
1975 - 1976	2979

Although there were substantial differences in temperature, rainfall and salinity over the period 1972/1976 (see Figure 2), no one factor can be invoked to explain these effects satisfactorily and correlate with the population changes, and it is likely that many variables need to be taken into account.

Since our present investigations show that animals at Oldbury-on-Severn are typical of the study area, it is reasonable to assume that the seasonal and annual migratory behaviour of flounders at other sites where no quantitative samples were obtainable, are to, some degree at least, similar to Oldbury. However, this may not apply to Barnstaple Bay, where only sexually mature animals were obtained in large numbers in summer and early autumn at a time when this species is known to spawn (Kartar, 1974), suggesting that this location is close to a breeding ground.

3.2.2. Length Frequency Curves and Age Distribution

i) Length Frequency Distribution

Limited investigations (Kartar, 1974) show that length-frequency curves can be used to ascertain the growth of newly hatched flounders. Thus, part of the present study was concerned with a more detailed analysis of new data to determine the ages of our specimens and to act as a check on otolith measurements.

The length-frequency distribution for the pooled data (1972/1976) shows a clear definition of the 0+ and 1+ classes with frequency modes at 4.5 cm and 12.5 cm (Figure 4). Further minor modes also occur at 18.0, 23.50, 27.0 and 32.0, which may represent the 2+, 3+, 4+ and 5+ age groups respectively.

As no significant differences in the seasonal length-frequency curves for individual years was observed, pooled data for the lengths of flounders caught during the study period (1973/1976) is presented in Figure 5 for Oldbury. It can be seen that the newly hatched animals caught in July are represented by a mode at approximately 37-57 mm, increasing by next July to approximately 97-117 mm.

Thus, the smallest animals (0+ year class) which first appear at the sampling site in May have a peak frequency at approximately 27-37 mm. However, by June this group of animals is represented by a peak of 37-57 mm. In the July/September period, a peak frequency occurs at 57-65 mm. Growth of the newly hatched animals appears to be stagnant in the next three months, October to December. In January, when large numbers of animals belonging to this group are caught, there is significant growth, represented by a mode at

FIGURE 4

Various age groups of flounders, *Platichthys flesus* ascertained from a length-frequency distribution of pooled data of animals caught at Oldbury from 1972-1976, with a smoothing average of 25 mm.

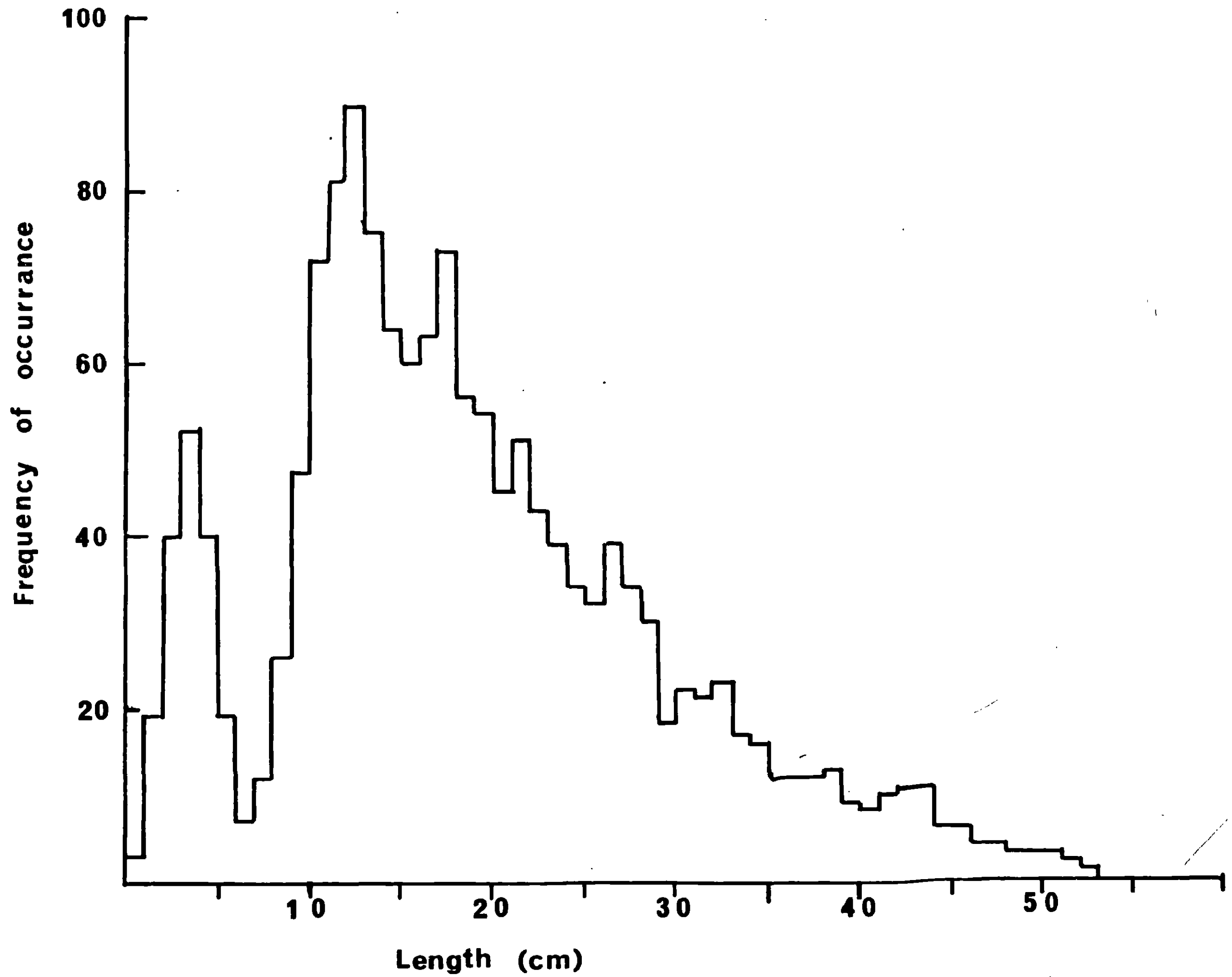
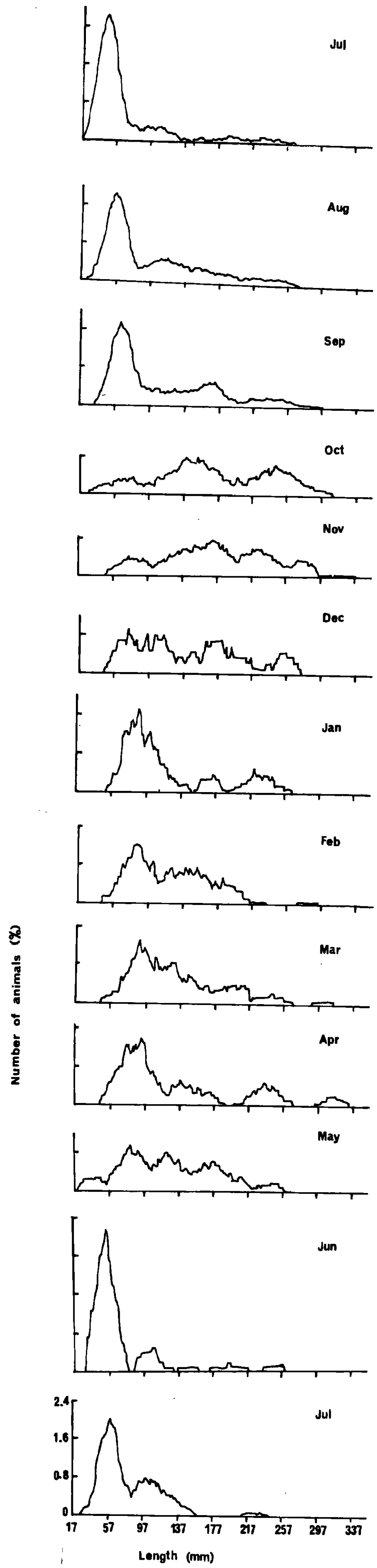

100
80
60
40
20
Frequency of occurrance
10
20
30
40
50
Length (cm)

FIGURE 5

Progression in growth of flounders, *Platichthys flesus* (as defined by length-frequency curves of pooled data of fish obtained between 1972-1976) observed at Oldbury Power Station, with a smoothing average of 25 mm.



Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Jul
Number of animals (%)
2.4
1.6
0.8
0
17
57
97
137
177
217
257
297
337
Length (mm)

approximately 77-97 mm. For reasons not understood, the growth of this group of animals remains relatively constant in the following months. However, by June this group is represented by a mode at 97-117 mm. It was not possible to identify any other groups of animals since the length-frequency curves are not resolved into discrete peaks due to overlapping (Kartar, 1974). Therefore, the present study confirms the view that, while the newly hatched animals belonging to the 0+ year class could easily be followed and characterised throughout the year, this method of ageing does not provide any distinctive pattern when applied to older fish.

The disappearance of the vast majority of the 0+ animals during the October/December period of each year supports the conclusion (Kartar, 1974) that the 0+ animals migrate further upstream and the author's observations indicate that a large number of fish are found in entirely freshwater streams adjoining the estuary in the winter.

Therefore, in order to age older flounders, otolith assessments (see Section *ii*, for ageing methods) were made on all the fish and these were found to be much more reliable and easily checked by the corresponding formation of annual growth rings in opercular bones. This method was, therefore applied throughout the study area to detect the spatial distribution of different age groups (Appendix 1-16).

ii) Age Distribution

In order to understand the distributional pattern of flounders of various age groups, at selected sites, animals were aged (by otolith reading) into the 0+,1+,2+ & 3 to 5+ groups each month and presented as a percentage of the total number of animals examined. Thus, in Figure 6 the frequency of occurrence of flounders belonging to

FIGURE 6

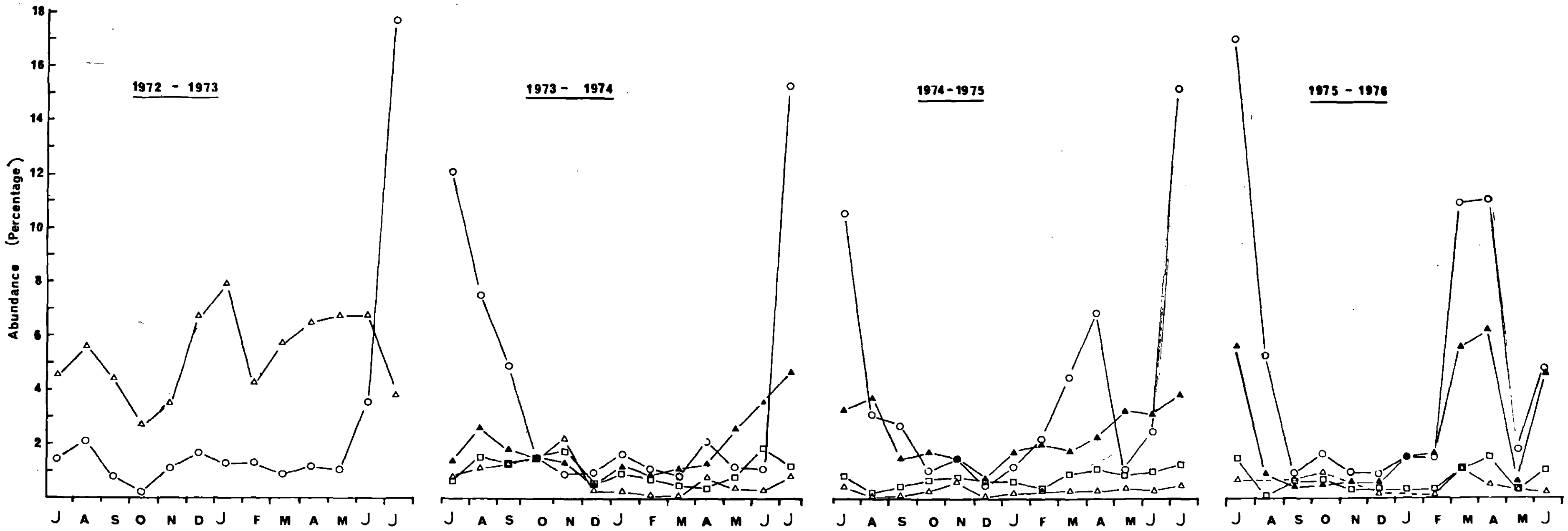
The abundance (as a percentage) of various age group flounders, *Platichthys flesus* caught at Oldbury in each successive year (1973-1976) studied.

△ = 0+

▲ = 1+

□ = 2+

○ = 3+ - 5+



Abundance (Percentage)
18
16
14
12
10
8
6
4
2
1972 - 1973
1973 - 1974
1974-1975
1975 - 1976
J A S O N D J F M A M J J
J A S O N D J F M A M J J
J A S O N D J F M A M J J
J A S O N D J F M A M J

the 0+, 1+, 2+ and 3 to 5+ groups are plotted for animals obtained at Oldbury. It can be seen that the seasonal fluctuation (see section 3.2.1) observed at Oldbury, is directly attributable to the arrival of the newly hatched 0+ animals which reaches a peak by July (17.5%). The above pattern occurred for each year except in 1976 when a very small percentage of animals of 0+ (4.9%) were observed. The implication of this change from the general picture is not readily understood, but the very high salinity and water temperature found during this rather exceptional summer may have played a major part.

As no continuous monitoring programme was possible for other localities, animals were obtained either in summer (Barnstaple Bay, Hinkley Point) or in winter (Berkeley). It is interesting to compare the summer results of the frequency of occurrence of specific age groups at the various sites. At Oldbury in summer, 0+ fish accounted for nearly 48% of the total fish caught in the cooling water intake screens of Oldbury Power Station (Figure 7), while at Hinkley Point only 12.5% of the total population belong to this age class and at Barnstaple Bay no 0+ fish were caught. The 1+ fish are totally absent from Barnstaple Bay but account for about 36% and 23% of the total catches at Oldbury and Hinkley Point respectively. When 2+, 3+, 4+, 5+ and over are considered, they are found to be present in relatively large proportions only at Barnstaple Bay and Hinkley Point (100% and 64.5% respectively) but in very small numbers at Oldbury (20%). To a large extent, these differences may be attributed to the selective effects of sampling technique. Thus, smaller fish probably tend to be taken in the power station intake screens, while the mesh size of the nets used to fish the flounder at Barnstaple Bay fail to catch the smaller animals. On the other hand, it is doubtful whether the differences between Oldbury and Hinkley Point can be attributed to the differential

FIGURE 7

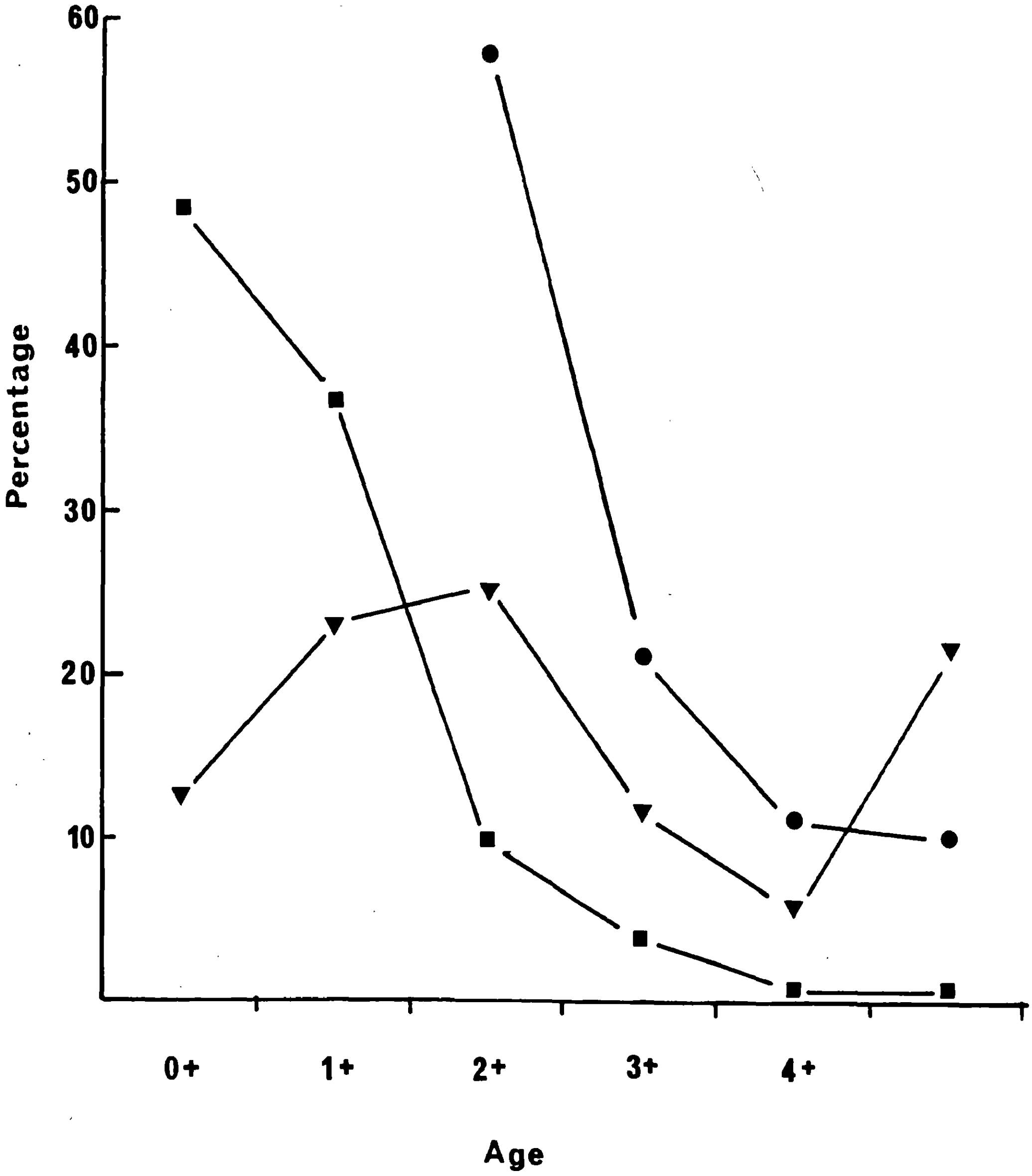
Frequency of abundance (as a percentage) of various age group flounders, *Platichthys flesus* obtained at

Oldbury (■)

Hinkley Point (▲) and

Barnstaple Bay (●)

in the summer season 1974.



60
50
40
30
20
10
Percentage
0+
1+
2+
3+
4+
Age

effects of the screening mechanism and so our results suggest that Hinkley is not a favoured habitat for the young of this species, and that the majority of this age class move into the estuary. In view of the close proximity of Oldbury and Berkeley (Figure 8) on the southern shores of the Severn, some 8 km apart, these differences must be due to screening procedures and the tidal conditions.

3.2.3. Logarithmic Relationship Between Length and Weight

Plotting log weight against log length over the entire range of weights and lengths (Figure 9), the regression line shows a clear inflexion at 9 cm (length) corresponding to the maximum length attained by the 0+ class in June. Beyond these lengths it is apparent that the closest fit to these data is a single line with a constant slope. For this reason, since the regression coefficient must be similar for all age groups beyond 0+ (or 9 cm) the weight/length data for the older age groups 1+ to 5+ have been pooled in each year. The corresponding calculated regression equations for these two groups for each year are as follows:

For the 0+ Class

1972/1973	(N = 435)	Log W = -2.346 + 3.344 Log L	r = 0.981
1973/1974	(N = 819)	Log W = -2.401 + 3.340 Log L	r = 0.991
1974/1975	(N = 1226)	Log W = -2.344 + 3.300 Log L	r = 0.902
1975/1976	(N = 1619)	Log W = -2.398 + 3.330 Log L	r = 0.981

while for the 1+ to 5+ age class, the equation was as follows:

1972/1973	(N = 780)	Log W = -1.939 + 2.918 Log L	r = 0.900
1973/1974	(N = 616)	Log W = -2.010 + 3.028 Log L	r = 0.989
1974/1975	(N = 1376)	Log W = -2.121 + 3.010 Log L	r = 0.991
1975/1976	(N = 1369)	Log W = -2.221 + 3.200 Log L	r = 0.987

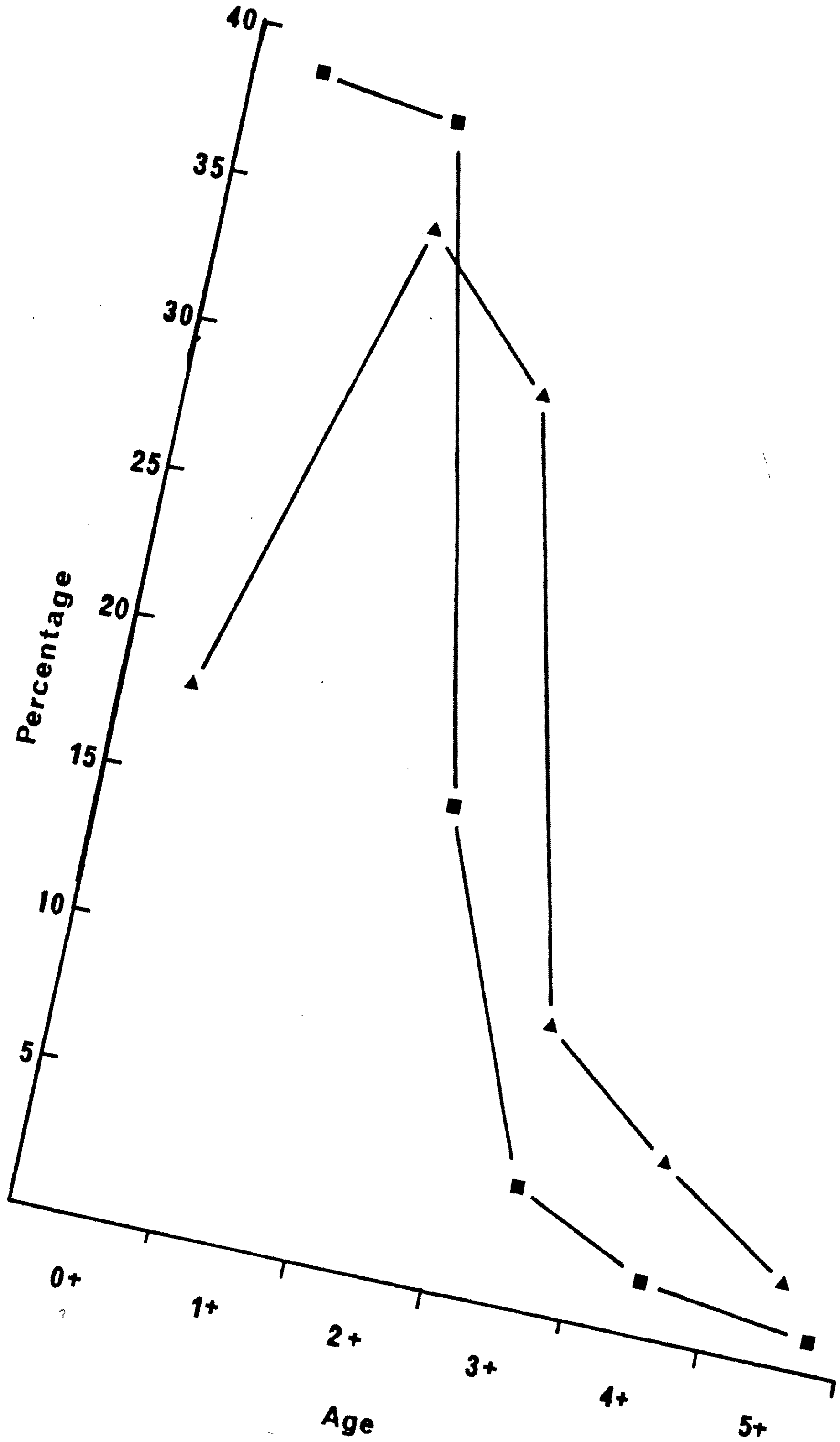
FIGURE 8

Abundance (as a percentage) of different age class flounders, *Platichthys flesus* at

Oldbury (■) and

Berkeley (▲)

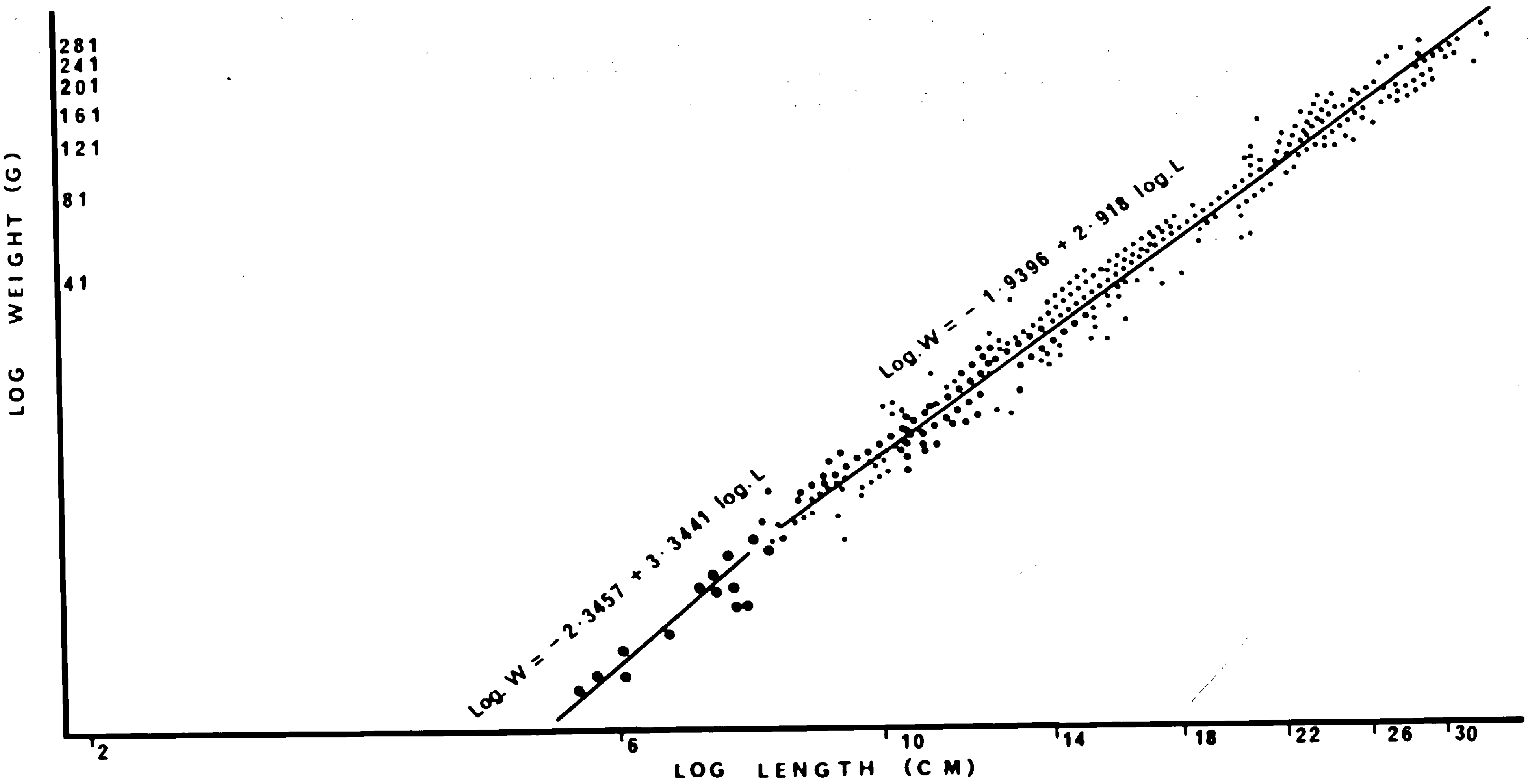
in the winter of 1974.



40
35
30
25
20
15
10
5
Percentage
0+
1+
2+
3+
4+
5+
Age

FIGURE 9

Logarithmic relationship between length and weight of flounders, *Platichthys flesus* caught at Oldbury Power Station.


281
241
201
161
121
81
41
LOG WEIGHT (G)
Log W = − 2·3457 + 3·3441 log L
Log W = − 1·9396 + 2·918 log L
2
6
10
14
18
22
26
30
LOG LENGTH (CM)

From these equations it will be noted that there are significant differences in the slope of the regression line for the 0+ age class compared with the older age groups. Thus, over the period 1972-1976 the value of the regression coefficient for the 0+ class varied only from 3.300 in 1974/1975 to 3.344 in 1972/1973. At the same time, the value for the combined 1+ to 5+ classes was been consistently smaller and showed a tendency to increase between 1972/1976 from 2.918 in 1972-1973 to 3.200 in 1975-1976. This could indicate increasingly favourable growth conditions over the period of study, but the higher regression coefficient for the 0+ class is a natural reflection of their rapid feeding and growth.

3.2.4. Growth in Length

i) *Annual Rates of Growth*

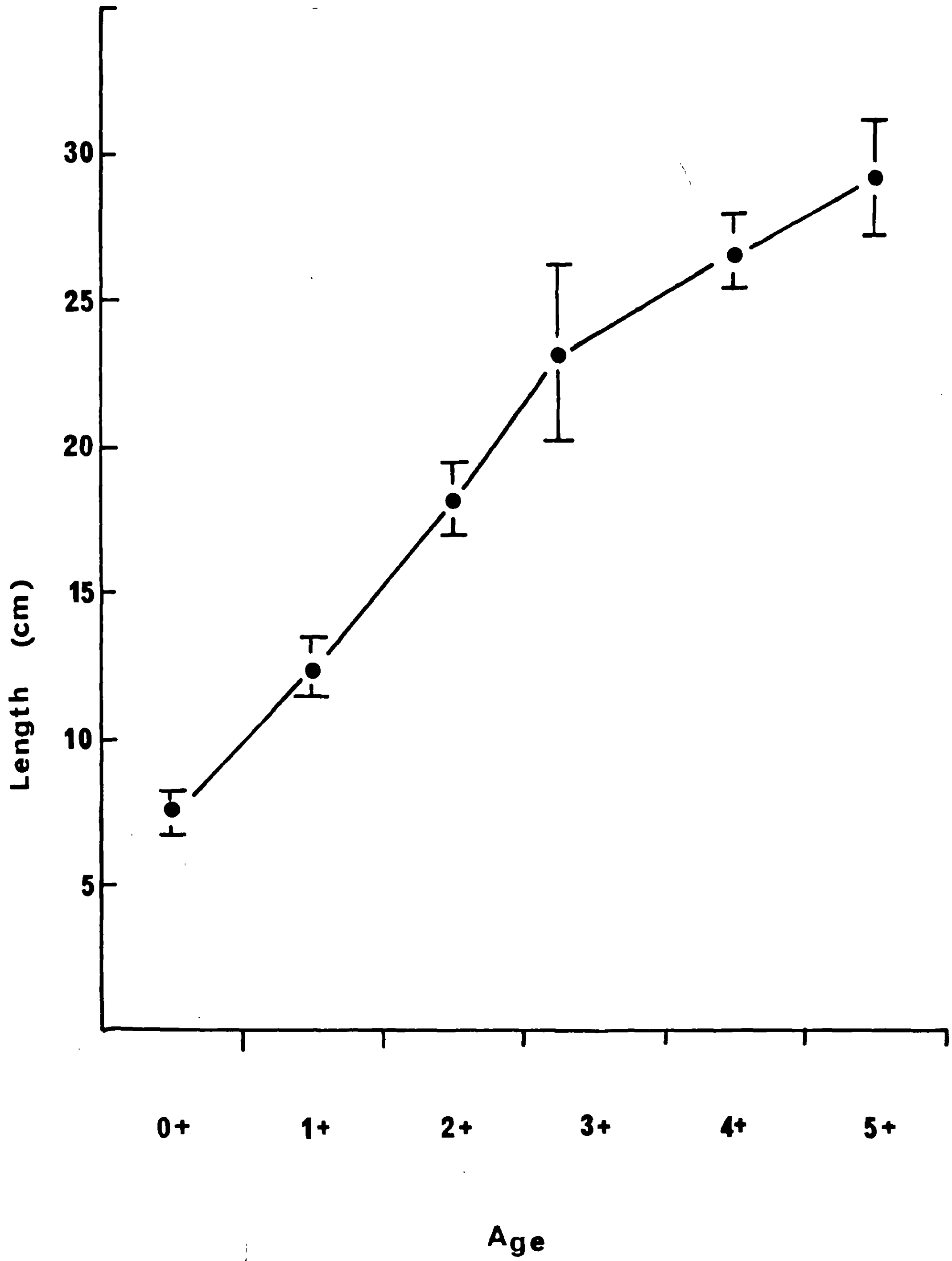
Taking June as the 'birthday' date for flounders, the mean lengths of various age groups (from otolith analyses) have been calculated for pooled data from December samples*. The growth curve (Figure 10) shows a fairly consistent rate of growth in length over the first three years and then indicates a distinct decrease for the 4+ and 5+ age groups.

---

*This was justified because the mean lengths at given ages have not differed significantly throughout this period (1973-1976).

FIGURE 10

Annual growth in length of various age class flounders, *Platichthys flesus* obtained in mid-winter (pooled data for four successive December months) caught at Oldbury Power Station. Also included is the ±95% confidence limit.


30
25
20
15
10
5
Length (cm)
0+
1+
2+
3+
4+
5+
Age

ii) Seasonal Growth in Length

The length of each age group as determined by otolith examination for monthly samples from Oldbury between 1973-1976 are summarised in Appendix 1-6. These trace the monthly growth in length of the individual age groups (0 - 5+), from the onset of their arrival in the Severn Estuary in the early summer.

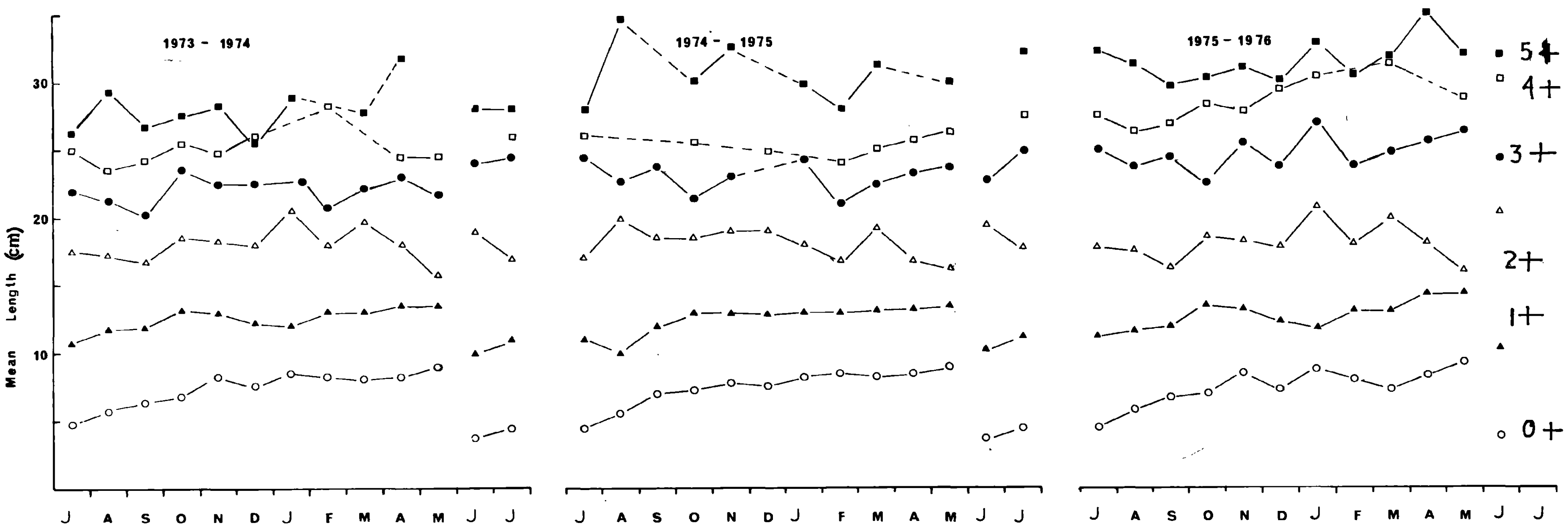
Thus, for the 0+ class which generally appear in abundance for the first time in June at a mean length of 3.90 cm, growth is rapid during the summer and early autumn and by November the mean length is about 7.5 - 8.5 cm; a pattern which is identical in each successive year. During winter and early spring, a slow growth rate is seen, the mean length increasing slightly from about 7.5 - 8.5 cm in November to 7.5 - 8.7 cm in March. These are some indications from the graph (Figure 11) of a renewal of growth in the late spring.

The pattern of growth in length is relatively similar in the 1+ age group, which are present in samples throughout the year although less numerous in the winter (see Section 3.2.3). In the late summer and autumn growth is relatively rapid; the length of the animals increasing from between 10.5 to 11.5 cm in July to about 13.0 - 13.5 cm by October. Thereafter in 1973/1974 and again in 1975/1976 there was an actual decrease in mean lengths during the period October to January. This was not apparent in 1974/1975 when the mean lengths remained almost constant throughout the winter. Since the average environmental conditions were similar in 1974-1975 and 1975-1976, it seems more likely that these annual differences may be due to changes in the migratory pattern of this age class.

In the older age groups it is difficult to detect any consistent pattern of seasonal growth. This may at least be partly

FIGURE 11

Seasonal variations in lengths of various age group flounders, *Platichthys flesus* encountered in the three successive years (1973-1976) at Oldbury-on-Severn.



Mean Length (cm)
30
20
10
1973 - 1974
1974 - 1975
1975 - 1976
J A S O N D J F M A M J J
J A S O N D J F M A M J J
J A S O N D J F M A M J J
5+
4+
3+
2+
1+
0+

due to the relatively small numbers involved, but additional factors may be the mobility of the flounder and their movements within the estuarine region.

iii) Growth at Different Localities

Comparing the annual growth curves for Oldbury and Berkeley (Figure 12), calculated from the mid-point of each age class (December) similar rates of growth in length can be observed throughout the 0+ to the 3+ age groups from both localities. After the 3+ year class, the growth in length for the 4+ and 5+ groups tend to slow down gradually at both sites (Appendix 7).

However, in an attempt to assess whether growth rates differ at other sites such as Hinkley Point or Barnstaple Bay, animals could only be obtained in summer and thus, comparisons were only possible for those months when samples were available and Figure 13 represents the mean lengths for age classes, calculated from the data for June/July. It is interesting to note that the 0+ class in June/July are somewhat larger at Hinkley, but there is no evidence that growth rates differ subsequently at this site. Similarly, at Barnstaple, the initial length of the 2+ class is distinctly greater than that at any of the other sites but this is not observed in subsequent age groups (Appendix 8).

FIGURE 12

The rate of growth in length of individual age class flounders, *Platichthys flesus* sampled in mid-winter of 1974 at

Oldbury (▲) and

Berkeley (■)

Also included is the ±95% confidence limit.

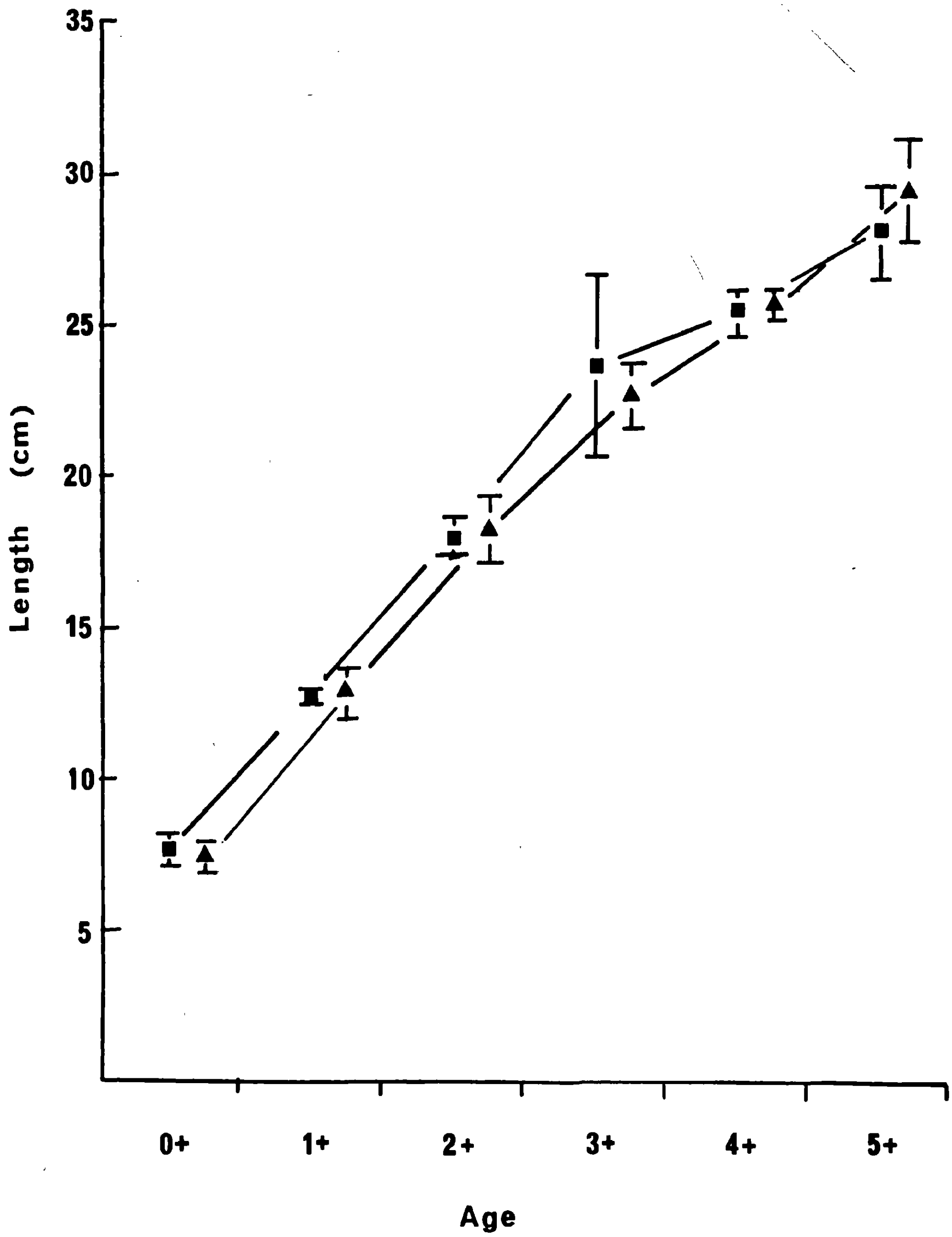

35
30
25
20
15
10
5
Length (cm)
0+
1+
2+
3+
4+
5+
Age

FIGURE 13

The comparison in the rate of growth in length of flounders, *Platichthys flesus* of different age classes obtained at

Oldbury (■)

Hinkley Point (▲) and

Barnstaple Bay (●)

in summer 1974. Also included is the ±95% confidence limit.

FIGURE 14

Annual growth in weight of various age group flounders, *Platichthys flesus* sampled at Oldbury Nuclear Power Station in December 1972.

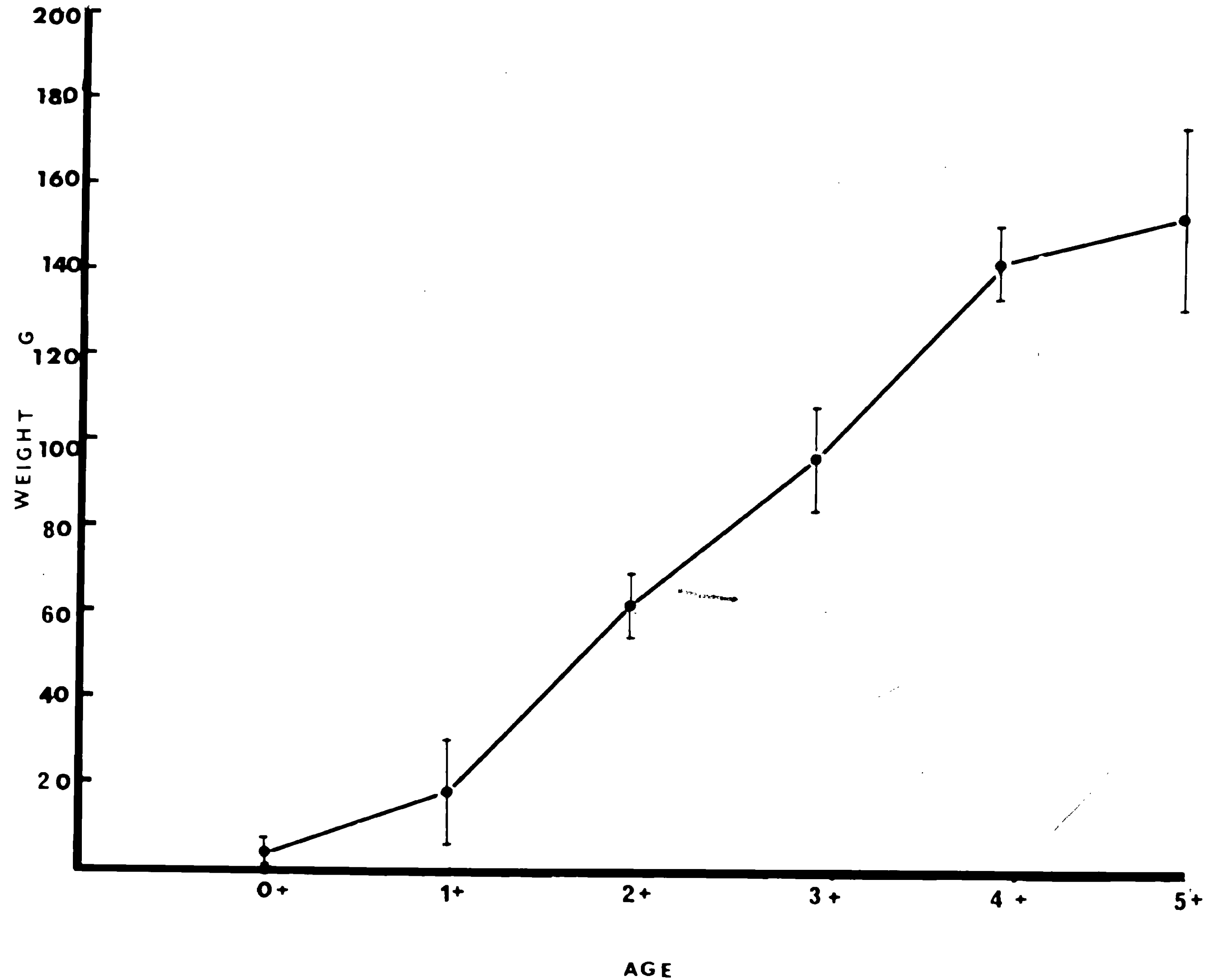
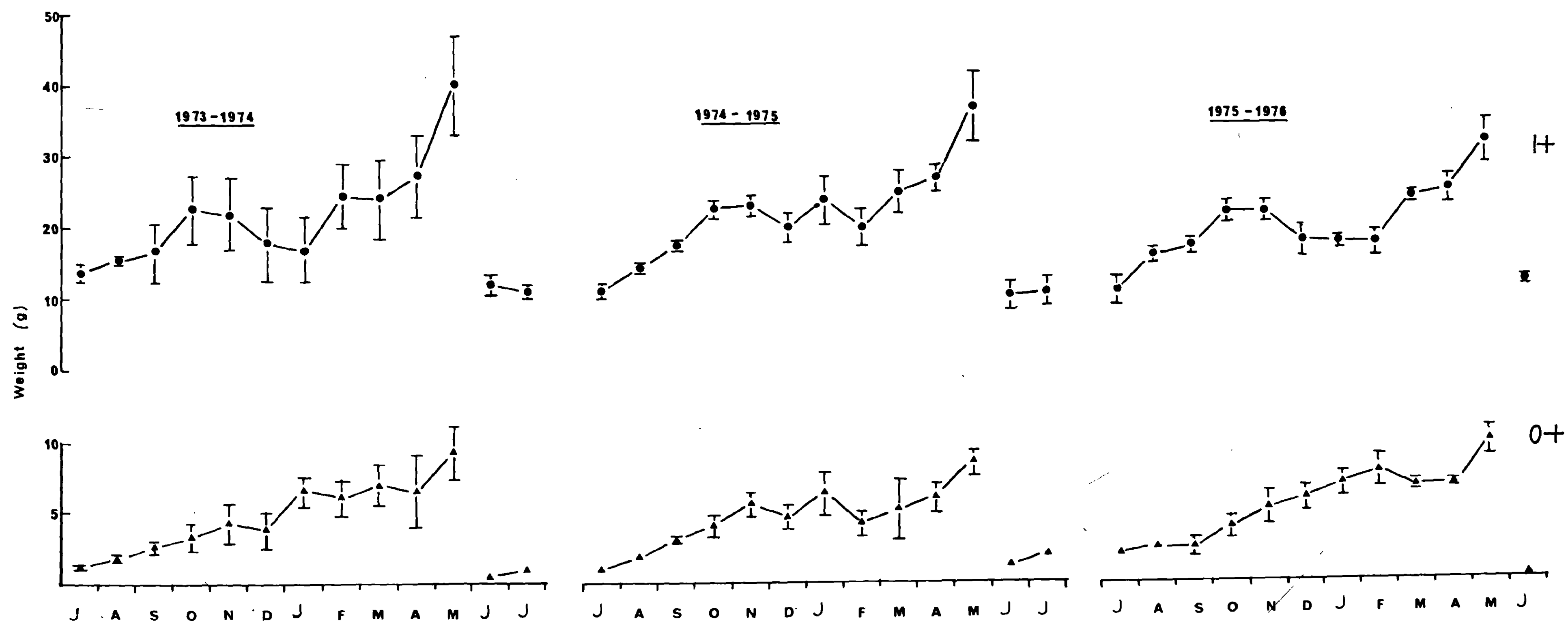

WEIGHT G
200
180
160
140
120
100
80
60
40
20
0+
1+
2+
3+
4+
5+
AGE

FIGURE 15

Seasonal growth in weight of the 0+ and 1+ age group flounders, *Platichthys flesus* caught in the cooling water intakes of Oldbury Power Station in each of the three years studied (1973-1976), with ±95% confidence limit.


1973-1974
1974 - 1975
1975 - 1976
Weight (g)
50
40
30
20
10
0
10
5
1+
0+
J A S O N D J F M A M J J
J A S O N D J F M A M J J
J A S O N D J F M A M J

3.2.5. Growth in Weight

i) Annual Growth Rates

Using the same method as for length, a growth curve for weight has been constructed for December samples in 1972/1973, when adequate numbers of the older age classes were available at Oldbury. During the first year the rate of growth in weight is relatively small, increasing from a mean weight of 4.8 g in the 0+ age class to 18.8 g in the following age group. Rapid weight increases are seen in the following years but in the oldest age group, growth in weight again falls off (Figure 14).

ii) Seasonal Growth in Weight

Because of inadequate numbers of older age groups, the mean values throughout the year show wide fluctuations and no significant trends can therefore be detected (Appendix 9-14).

In the 0+ class, however, where numbers in monthly samples are much larger, the pattern of growth in weight is biphasic. Thus, in Figure 15 0+ fish, when they are first caught in June, have a mean value of weight between 0.2 and 1.5 g. A rapid growth in weight is observed in summer and autumn and by November, the mean weights were between 4.5 - 5.5 g. The growth in weight slows down in winter and early spring, with mean weights increasing from 4.5 - 5.5 g in November to 6.0 - 7.0 g by March. There is strong indication of rapid growth in weight in late Spring/early summer (Figure 15)*.

---

*Bidmodal growth in weight of the 0+ flounders caught at the cooling water intake screens is noted in each of the years studied (1973-76).

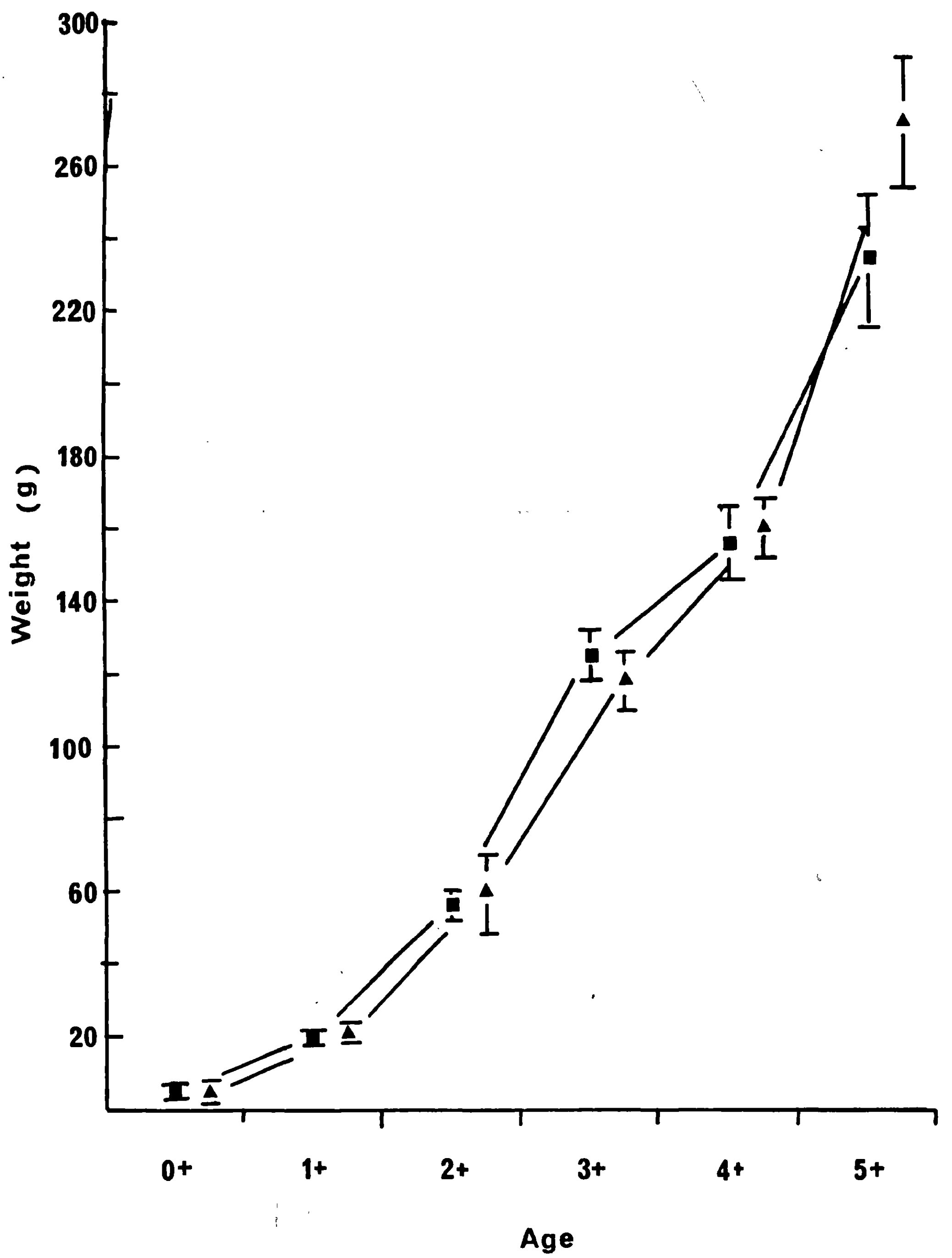
FIGURE 16

Growth in weight of flounders, *Platichthys flesus*

at Oldbury (■) and

Berkeley (▲)

in mid-winter 1974 with ±95% confidence limit.



300
260
220
180
140
100
60
20
Weight (g)
0+
1+
2+
3+
4+
5+
Age

FIGURE 17

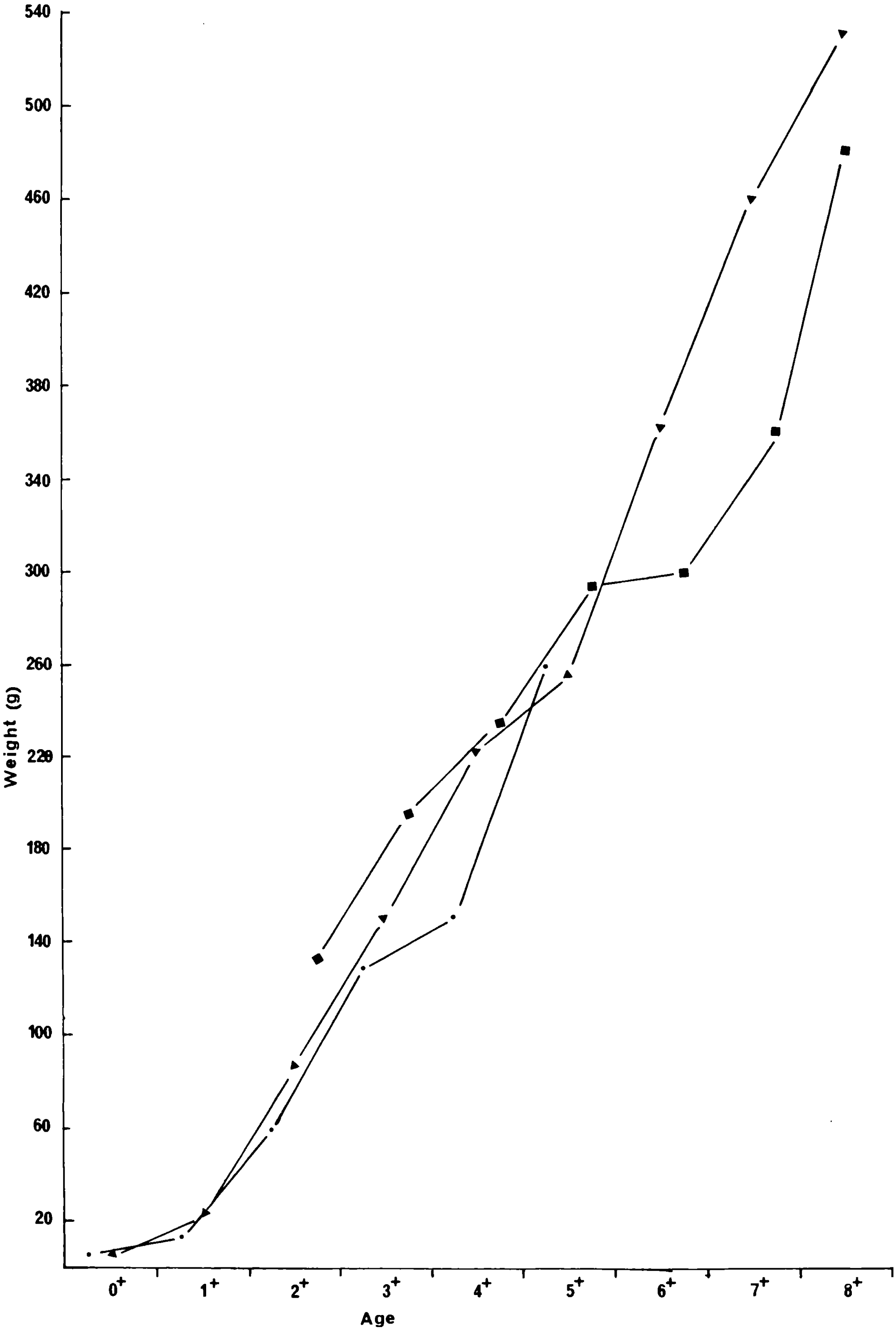
Growth in weight of flounders, *Platichthys flesus* sampled at

Oldbury (·)

Hinkley Point (▲) and

Barnstaple Bay (■)

in the summer of 1974.



540
500
460
420
380
340
300
260
220
180
140
100
60
20
Weight (g)
0+
1+
2+
3+
4+
5+
6+
7+
8+
Age

A similar pattern of growth in weight is seen for the 1+ animal. Thus, the weight increases in summer and early autumn remain relatively constant or in some years actually drops in winter/early spring, rising again in early summer (Figure 15). This pattern in growth in weight of flounders of 1+ is consistent for each of the successive years.

iii) Growth in Weight at Various Sites

Due to the close proximity of the two power stations, Oldbury and Berkeley, the data of all the fish (male and female combined) representing growth in weight at approximately halfway through each year of life, i.e. at mid-winter, shows no significant differences in growth in mean weight and this is borne out in Figure 16. Thus, the growth is gradual from 0+ to 1+ (from 5.0 to 20 g) but more rapid growth is seen for the other age classes (Appendix 15).

An identical pattern in growth in weight is seen for the summer animals obtained from Oldbury, Hinkley and Barnstaple Bay. Initial growth in mean weights from the 0+ (5.0 g at both localities, i.e. Oldbury and Hinkley) to the 1+ (12.0 g at Oldbury and 24.0 g at Hinkley) classes is gradual (Appendix 16). A steep rise in mean weights is observed in the 2+, 3+, 4+ and 5+ at these two sites. At Barnstaple Bay, 2+ animals were heavier than similar animals from Oldbury or from Hinkley (Figure 17).

3.2.6 Sex Ratio

In all the areas, females tend to predominate. Thus, excess of females is most pronounced in the 1+ and 2+ fish where the ratio of males to females varies from 1 : 2.0 and 1 : 2.5 respectively (Table 1)

TABLE 1

The ratio of males to females (♂ : ♀) in the various age group flounders, *Platichthys flesus* for pooled data obtained between 1972-1976 in the Severn Estuary and the Bristol Channel. (Also included are the numbers investigated).

AGE GROUP	OLDBURY ♂ : ♀	N	BERKELEY ♂ : ♀	N	HINKLEY POINT ♂ : ♀	N	BARNSTAPLE BAY ♂ : ♀	N
0+	1 : 1.00	(2559)	1 : 1.00	(46)	1 : 0.70	(20)	-	
1+	1 : 2.0	(1507)	1 : 2.5	(74)	1 : 1.80	(28)	-	
2+	1 : 1.5	(560)	1 : 2.0	(64)	1 : 1.60	(31)	1 : 2.30	(152)
3+	1 : 1.0	(211)	1 : 1.3	(21)	1 : 1.30	(14)	1 : 1.40	(120)
4+	1 : 1.2	(85)	1 : 1.5	(13)	1 : 1.30	(7)	1 : 1.30	(120)
5+	1 : 1.0	(83)	1 : 1.0	(6)	1 : 1.00	(10)	1 : 1.20	(120)
Above 5+	-		-		1 : 1.30	(16)	1 : 1.00	(120)

3.2.7. Dietary Habits

i) Seasonal Variation in Feeding Intensity

It appears that at Oldbury, the flounder population tends to feed more intensively during the summer and less so in winter. This is evident from Figure 18, where the percentage of empty guts is shown monthly from July to July for the three successive years, 1973-1976. In each season the maximum percentage of empty guts occurred in December when this was observed for about 80% of all the fish caught (of all ages), whereas in mid-summer the percentage was from 0-5% only. The summer figures are comparable with those for flounders at the same time at Barnstaple Bay where about 9% of empty guts were recorded in 1973 and 1974. At Hinkley, feeding apparently occurs more actively during the winter and the overall percentage of empty guts at this site in December was 21%.

ii) Variation in the Feeding of Flounders at Various Ages

Fish that are found with full guts in the winter at Oldbury belong mainly to the 0+, 1+ and to a much lesser extent, the 4+ and 5+ age groups (Figure 19). A much higher proportion of empty guts was recorded for the 2+ and the 3+ age groups (30% and 20% respectively) in winter. This situation for the older fish is similar to that described by Mulicki (1947) and Cieglewicz (1947) for Baltic flounders and may be related to the onset of the spawning activity.

FIGURE 18

Seasonal variations in occurrence of flounders, *Platichthys flesus* with empty guts (as a percentage) studied over three successive years (1973-1976) at Oldbury-on-Severn.

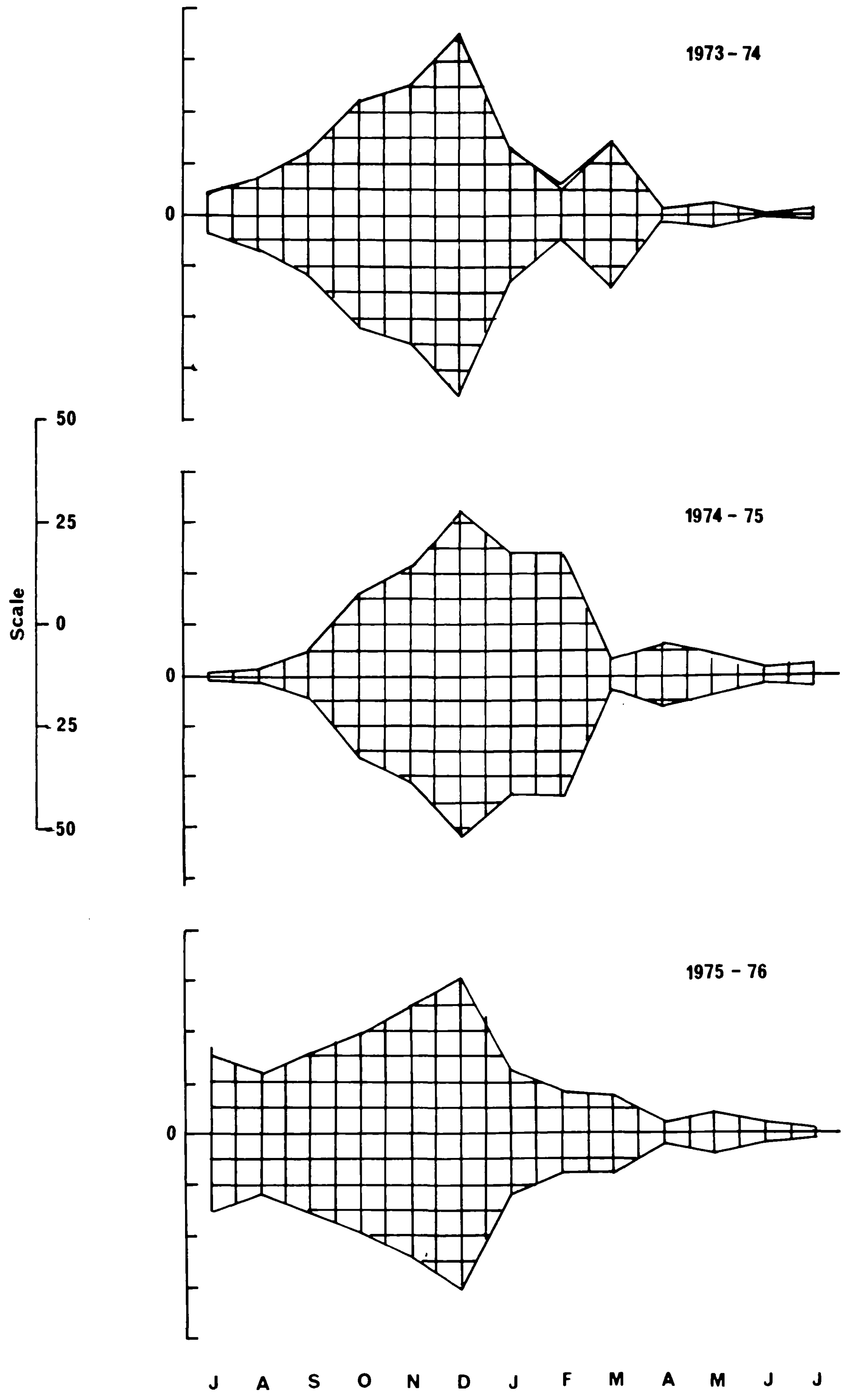
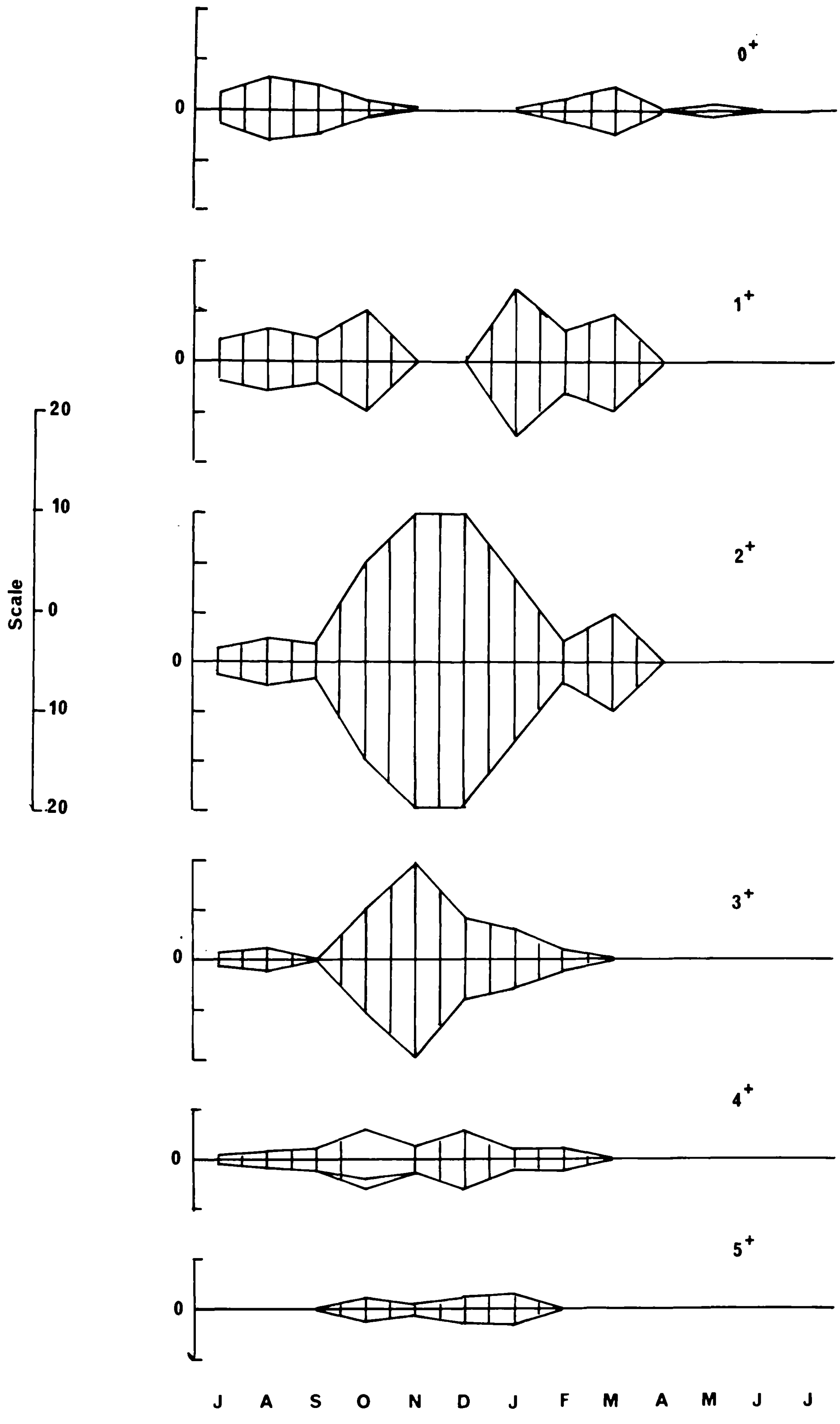

1973 - 74
1974 - 75
1975 - 76
Scale
50
25
0
- 25
-50
0
0
0
J
A
S
O
N
D
J
F
M
A
M
J
J

FIGURE 19

The intensity of feeding of various age class flounders, *Platichthys flesus* expressed as a percentage of empty guts sampled monthly at Oldbury.


0+
1+
2+
3+
4+
5+
0
Scale
20
10
0
10
20
J A S O N D J F M A M J J

iii) Organisms Found in the Gut of the Flounder

The organisms which have been identified in the gut of the flounders are listed in Table 2, which represents pooled data for the three seasons. In the estuary, the food taken by flounders is similar at Oldbury and nearby Berkeley where amphipods (*Gammarus spp*) were found in 55-59% of all guts examined. Similarly at both sites the next most important food item is *Neomysis* which accounts for 19-20% of the guts of all animals analysed. Other less important constituents are *Crangon crangon*, *Macoma baltica* and *Nereis diversicolor*, while at Oldbury, perhaps because of the presence of the reservoir, the sand goby (*Pomatoschistus minutus*) occurs, but only infrequently. Marked differences occur in the diet of the flounder in the Bristol Channel area in the more marine environments. Thus, both at Hinkley Point and in Barnstaple Bay, the major food constituent is the mollusc, *Macoma baltica* which occurs at a frequency of 48% and 84% respectively. *Crangon crangon* is also more often ingested at these sites.

iv) Seasonal and Annual Variation in Feeding Patterns

From Figure 20 the minimum utilisation of *Gammarus spp.* and *Neoymysis* at Oldbury which took place in November of 1973 can be seen. This period was marked by a corresponding drop in the abundance of these organisms at the sampling site (Moore *et al*, 1976). The drop in the intake of *Gammarus spp.* and *Neomysis* by flounders is inversely correlated with the increased consumption of *Macoma baltica* and *Crangon crangon*. Apart from the drop in utilisation of *Gammarus spp.* (Tables 3-5) in November, this organism remains fairly constant and at a higher level in the guts of flounders at Oldbury. Interestingly, *Crangon* is completely absent in the guts from December to March 1973/

FIGURE 20

Monthly and annual variations in the frequency of occurrence of principal food organisms in the guts of flounders, *Platichthys flesus* sampled at Oldbury Nuclear Power Station during 1973-1976, expressed as a percentage of the total number of animals examined with food items.

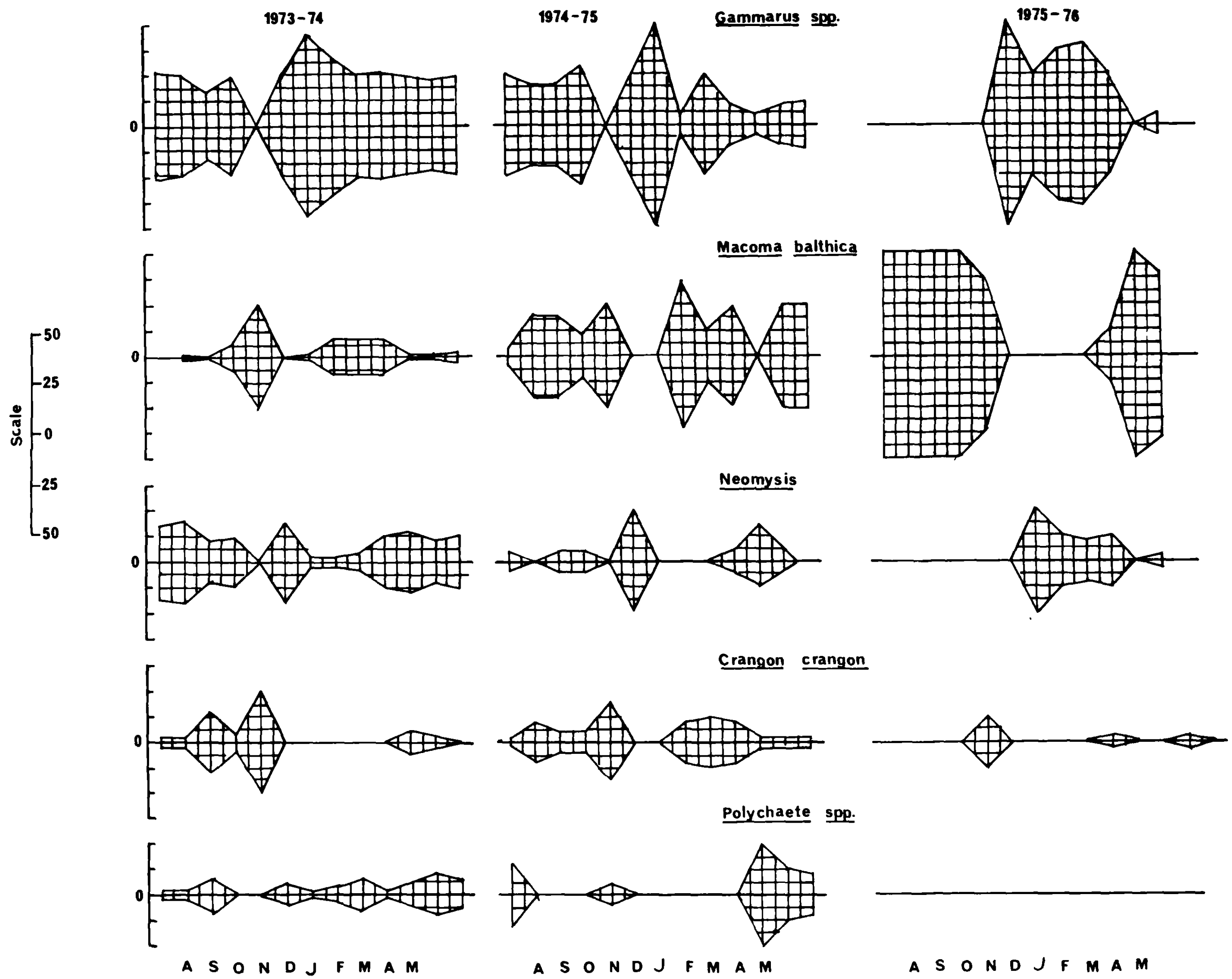

1973-74
1974-75
1975-76
Gammarus spp.
Macoma balthica
Neomysis
Crangon crangon
Polychaete spp.
Scale
50
25
0
25
50
0
A S O N D J F M A M
A S O N D J F M A M
A S O N D J F M A M

TABLE 2

List of food organisms found in the stomachs of flounders, *Platichthys flesus*, of all age classes and their relative importance, measured as guts with food items/guts examined.
N = Number examined.

FOOD ORGANISM		BERKELEY N = 221	OLDBURY N = 4675	HINKLEY POINT N = 126	BARNSTAPLE BAY N = 926
Annelida	*Neris diversicolor*	5.00	8.50	4.20	-
Mysidacea	*Neomysis*	20.00	19.90	2.80	-
Amphipoda	*Gammarus spp.*	55.00	59.20	31.10	3.60
Decopoda	*Crangon crangon*	10.00	7.20	14.20	12.40
Mollusca	*Macoma baltica*	10.00	4.30	47.70	84.00
Vertebrate	*Pomatoschistus gobius*	-	0.66	-	-
Miscellaneous	Fish Eggs	-	0.24	-	-

TABLE 3

Frequency of occurrence of major food organisms in 975 flounders, *Platichthys flesus*, caught during 1973-74 in the intake screens of Oldbury Power Station, expressed as a percentage of fish examined with identifiable organisms in the gut and stomach.

MONTH	*Polychaete spp.*	*Gammarus spp.*	*Neomysis*	*Macoma balthica*	*Crangon Vulgaris*	*P. minutus*	*Amathilla homair*	*Cumacean*	Fish Eggs
July	4.62	53.33	36.41	-	5.64	-	-	-	-
Aug	4.85	49.09	40.61	1.21	4.24	-	-	-	-
Sept	16.82	32.71	20.56	-	29.91	-	-	-	-
Oct	-	48.65	24.32	13.51	8.11	-	-	-	5.41
Nov	-	-	-	50.00	50.00	-	-	-	-
Dec	11.11	50.00	38.89	-	-	-	-	-	-
Jan	2.44	90.24	4.88	2.44	-	-	-	-	-
Feb	8.57	68.57	5.70	17.16	-	-	-	-	-
Mar	16.66	50.02	8.33	16.66	-	-	-	-	-
Apr	2.98	52.25	25.25	17.91	-	-	1.49	-	-
May	14.71	48.53	29.41	1.47	-	1.47	-	-	4.41
June	20.23	45.24	21.42	1.19	11.85	-	-	-	-
July	14.71	48.51	25.61	5.58	5.59	-	-	-	-

TABLE 4

Frequency of occurrence of major food organisms in 975 flounders, *Platichthys flesus*, caught during 1973-74 in the intake screens of Oldbury Power Station, expressed as a percentage of fish examined with identifiable organisms in the guts.

MONTH	*Polychaete spp.*	*Gammarus spp.*	*Neomysis*	*Macoma balthica*	*Crangon vulgaris*
July	30.0	50.0	10.0	7.5	2.5
August	-	40.01	-	40.09	19.0
September	-	40.08	10.0	39.00	10.02
October	-	59.00	10.02	20.80	10.18
November	10.0	-	-	50.29	39.71
December	-	50.19	49.81	-	-
January	-	100.00	-	-	-
February	-	9.01	-	70.09	20.0
March	-	50.02	-	25.16	29.82
April	-	20.80	10.0	48.20	21.00
May	50.0	10.0	35.41	-	4.49
June	25.00	20.00	-	50.0	5.00
July	20.00	24.48	-	50.0	5.42

TABLE 5

Frequency of occurrence of major food organisms in 2200 flounders, *Platichthys flesus*, caught during 1975-76 in the intake screens of Oldbury Power Station, expressed as a percentage of fish examined with identifiable organisms in the gut.

MONTH	*Gammarus spp.*	*Neomysis*	*Macoma balthica*	*Crangon vulgaris*
July	-	-	100.00	-
August	-	-	100.00	-
September	-	-	100.00	
October	-	-	100.00	-
November	-	-	75.0	25.0
December	100.00	-	-	-
January	50.00	50.50	-	-
February	75.00	25.00	-	-
March	80.00	20.00	-	-
April	50.00	25.00	20.0	5.0
May	-	-	100.0	-
June	10.0	5.0	80.0	5.0
July	-	-	-	-

1974 (Figure 20). The apparent decrease in the consumption of shrimps could be due to the higher proportion of small animals which were analysed at this time since the larger and older animals tend to move out of the area during the late winter and early spring.

In 1974/1975, the seasonal pattern of changing utilisation of *Gammarus spp.* and *Neomysis* one the one hand and *Macoma baltica* and *Crangon crangon* on the other, is similar to the preceding seasons (Figure 20). However, in this period shrimps remained a minor component of the diet until late winter and early spring when they were no longer consumed. This could be due to the higher salinity that developed during this season, since shrimps are known to prefer areas of low salinity.

By contrast, in 1975/76 seasonal fluctuations in feeding habits show a very different picture to that of either of the two earlier years. Thus, *Gammarus spp.* was not present in the guts from July to November and thereafter the trend was similar to that of previous years, rising in December to a maximum and decreasing throughout the spring. Similarly, *Neomysis* was absent from the guts throughout the summer and autumn and showed a maximum frequency in December. The most striking feature of this season was the predominance of *Macoma baltica,* which showed two distinct seasonal maxima; from July to October when it occurred in almost all the guts examined, but declining from October to December. None were found between December and April. This was followed by another period of intense utilisation of *Macoma baltica*, reaching a peak in May when the guts of all the animals examined were found to contain this bivalve.

Comparing the gut constituents over the period of study (1973-76) reveals some significant trends. Thus, *Macoma baltica* has consistently tended to increase in frequency. In the first season its maximum occurrence was 50% in November; in the following year the maximum frequency occurred in February (75%) and in 1975/1976 almost all the animals in summer and late spring had been feeding on this organism. 1974-1976 showed a very marked decrease in the intake of shrimps, and polychaetes were almost totally absent during this same period. The possibility that these changes in feeding habits may reflect changes in the relative abundance of these organisms, perhaps in response to changes in the salinity and water temperature,is discussed in a later section.

v) Dietary Preferences at Other Sites

Analyses conducted on the dietary habits of the flounder from the Bristol Channel (at Hinkley Point) are presented in Table 6 as a frequency of occurrence. *Macoma baltica* accounts for 31.1% of all the food organisms at this site in the guts examined. *Gammarus spp.* together with *Neomysis*, *Crangon crangon* and polychaete worms were less abundant

At Barnstaple Bay, near the spawning region, gut analyses for the two summers (Table 7) show that *Macoma baltica* becomes increasingly important (from 33.9% in 1973 to 87.6% in the following year). However, the most striking feature in the dietary investigations is the gradual decrease in the consumption of *Crangon* from 28.3% in the preceding year to only 3.0% in the summer of 1974. This diminution in the utilisation of the shrimp is thus a constant and conspicuous feature at all the sampling sites and for other major fish species that have been studied.

TABLE 6

Frequency of occurrence of major dietary organisms in flounders, *Platichthys flesus* obtained from the cooling water intake screens of Hinkley Point Power Station.

NO. INV.	SEASON	EMPTY	*Macoma balthica*	*Gammarus spp.*	*Neomysis*	*Polychaete worms*	*Crangon vulgaris*	UNIDENTIFIED
126	Winter '74	21.10	31.10	24.60	2.20	3.30	3.30	14.40

TABLE 7

Frequency of occurrence of major dietary organisms in flounders, *Platichthys flesus* obtained by trawling off Barnstaple Bay, expressed as a percentage of animals examined.

NO. INV.	SEASON	EMPTY	*Macoma balthica*	*Gammarus spp.*	*Neomysis*	*Polychaete worms*	*Crangon vulgaris*	UNIDENTIFIED
530	Summer '73	9.60	33.90	2.80	-	4.70	28.30	20.70
396	Summer '74	9.00	87.60	-	-	0.40	3.00	-

3.2.8. Incidence of Nematode Parasitism

In 1973/1974, 20% of the Oldbury flounders contained nematodes (Table 8). (No data is available for comparison from other localities).

In 1974/1975, the proportion of the infected fish was similar at Oldbury (21%) but 20% of the Berkeley population were also infected.

In 1975/1976, when animals were obtained from all the sites, the proportionsof infestation at Oldbury and Berkeley was relatively similar (18.99 and 22.00), but at Uskmouth, where sample numbers were smaller (50), only 2.0% showed infestation. In the Bristol Channel at Hinkley Point, 19% of the total catch were parasitised, while at Barnstaple Bay only 1.92% of the total catch were infected.

In order to assess if there is any size (of host) selectivity displayed by nematodes, the infected fish were aged (Table 9) and presented as a percentage of the total fish caught. Interestingly,the 0+ fish from the estuarine localities as well as at Hinkley did not carry this parasite. The infection in the rest of the animals in various age groups was uniform, with the exception of the 3+ animals where the incidence of parasites was relatively low. At Barnstaple Bay, nematode infestation occurred in the 2+ age group.

TABLE 8

Parasite infestation *(Nematode spp.)* in flounders, *Platichthys flesus*, of various age groups, expressed as a percentage of total pooled number investigated in the Severn Estuary and Bristol Channel during 1973-1976.

LOCALITY	1973 / 1974	1974 / 1975	1975 / 1976
Middle Reaches of Severn Estuary			
Oldbury	20.00	21.00	18.99
Berkeley	-	20.99	22.00
Uskmouth	-	-	1.99
Bristol Channel			
Hinkley Point	-	-	19.00
Barnstaple Bay	-	-	1.923

TABLE 9

Parasite infestation *(Nematode spp.)* in individual age class flounders, *Platichthys flesus*, expressed as a percentage of total pooled numbers investigated in the Severn Estuary and the Bristol Channel during 1973-76.

AGE GROUP	OLDBURY	BERKELEY	HINKLEY POINT	BARNSTAPLE BAY
0+	-	-	-	-
1+	10.281 (1507)	10.00 (74)	10.700 (28)	-
2+	7.610 (560)	8.961 (64)	9.700 (31)	1.923 (120)
3+	2.810 (211)	5.310 (21)	7.100 (14)	-
4+	10.00 (85)	8.00 (13)	14.300 (7)	-
5+	10.00 (83)	10.00 (6)	10.000 (10)	-
Above 5+	-	-	-	-

3.2.9. Developmental Abnormalities

Albinism and ambicoloration, common abnormalities in flatfish, are usual in flounders (Gudger, 1935) caught in European waters, from the White Sea to the Straits of Gibraltar and throughout the Mediterranean Sea and its subdivisions.

The Severn Region and the Bristol Channel was found to be no exception. A small proportion of the fish examined from all localities showed ambicoloration, or were sinistral (i.e. a departure from the normal condition with the eyes pointing to the left).

The percentage of ambicoloured fish is presented in Table 10 and those with sinistral feature in Table 11. No ambicoloured fish were found at Barnstaple Bay and in the areas (Berkeley, Oldbury and Hinkley) where these abnormalities were encountered, the fish belonged mainly to the 0+, 1+ and 2+ age groups and amounted to about 1% of the total catch. The incidence of ambicoloured fish of the 3+, 4+ and 5+ age classes was low (about 0.1 to 0.2% of the total numbers in each age group).

While, as stated previously, albinism in flatfish is common in European waters, no flatfish with this variation were found in the Severn Estuary and the Bristol Channel.

TABLE 10

Frequency of occurrence of various age group ambicolour flounders, *Platichthys flesus*, expressed as a percentage of total pooled data examined during 1972-76 in the Severn Estuary and Bristol Channel. (Also included are the numbers investigated).

AGE GROUP	OLDBURY	BERKELEY	HINKLEY POINT	BARNSTAPLE BAY
0+	0,99 (2559)	1,00 (40)	1,00 (20)	-
1+	1,00 (1507)	1,00 (74)	1,00 (28)	0.0 (152)
2+	0,99 (560)	0,98 (64)	0,99 (31)	- (120)
3+	0,10 (211)	0,00 (21)	0,10 (14)	- (120)
4+	0,20 (85)	0,10 (13)	0,00 (7)	- (120)
5+	0,10 (83)	0,10 (6)	0,00 (10)	- (120)
Above 5+	-	-	0,00 (16)	- (120)

TABLE 11

Frequency of occurrence of various age group flounders, *Platichthys flesus* with sinistral features, expressed as a percentage of total pooled data obtained during 1973-1976 in the Severn Estuary and the Bristol Channel.

AGE GROUP	OLDBURY	BERKELEY	HINKLEY POINT	BARNSTAPLE BAY
0+	10.00 (2559)	10.00 (40)	7.00 (20)	-
1+	9.99 (1507)	10.00 (74)	10.91 (28)	-
2+	10.00 (560)	11.20 (64)	9.70 (31)	11.50 (152)
3+	9.71 (211)	8.99 (21)	14.30 (14)	12.00 (120)
4+	10.00 (85)	9.99 (13)	14.30 (7)	10.80 (120)
5+	12.99 (83)	12.00 (6)	10.00 (10)	9.80 (120)
Above 5+	-	-	0.0 (16)	10.00 (120)

3.3. DISCUSSION

Present studies confirm our initial findings (Kartar, 1974) that flounders are present throughout the year in varying numbers in the Bristol Channel and the Severn Estuary. It is therefore, conceivable that the reason Lloyd (1941) found no flounders in this region throughout the year is probably due to the different sampling procedures used, as Lloyd was solely dependent on catches by local fishermen as a source of statistics for various fish species in the Severn Estuary.

From our results a bimodal pattern for the seasonal emigration and migration of flounders is suggested (see Figures 21 and 22). Flounders are caught at Oldbury in large numbers in the summer but these decline by late autumn and winter (the majority of these animals belonging to the 0+ group); when it is thought that the majority of the fish have moved further upstream. Circumstantial evidence for this is the observation during this period of 0+ animals in large numbers in the freshwater streams in the upper part of the estuary. In early spring, most of the animals caught at Oldbury and Berkeley belong to age classes older than 1+. These feed intensively before moving downstream to spawn. In 1975/76, however, sexually mature animals were found at these sites in which the mean gonadosomic ratio was 12% and mean oocyte diameter was 0.7 mm, similar to values observed at Barnstaple Bay, nearer to the spawning grounds. The first newly hatched fish are caught at Oldbury and Berkeley in May/June, although fish larvae of this species were found in the open sea throughout the late spring, summer and early autumn. Thus it seems that the extended spawning season in flounders from the Severn

FIGURE 21

Life cycle of mature flounders, *Platichthys flesus* in the Severn Estuary and The Bristol Channel.

LATE SPRING / EARLY SUMMER

Sexually mature and spent fish found.
(The larvae of flounders are found throughout the Spring, Summer and in small number in early Autumn).

LATE SUMMER / EARLY AUTUMN (OLDBURY)

64-66% of the total summer catch of key species at Oldbury are flounders, comprising spent and newly hatched fish. Intensive feeding occurs, majority of the animals disappear by late Autumn.

WINTER

Majority of the mature animals move away either upstream (more likely) or downstream during this period. Little feeding, if ever, occurs.

LATE WINTER / EARLY SPRING (OLDBURY)

Majority of the animals caught are mature animals, feeding intensively. Mean gonadosomic ratio account for about 8% (although in 1975/1976 mean gonadosomic ratio was 12% of the total body weight.

Estuary and the Bristol Channel is similar to that observed by Heegaard (1947) for the Belt Sea flounders.

In Figure 22 the disappearance of most of the 0+ and 1+ fish in winter suggest that they move elsewhere in the Severn Estuary to feed although the extent of these movements is not known, but in the Baltic Sea these age groups are known to have a feeding range of 40 miles (Mulicki, 1947).

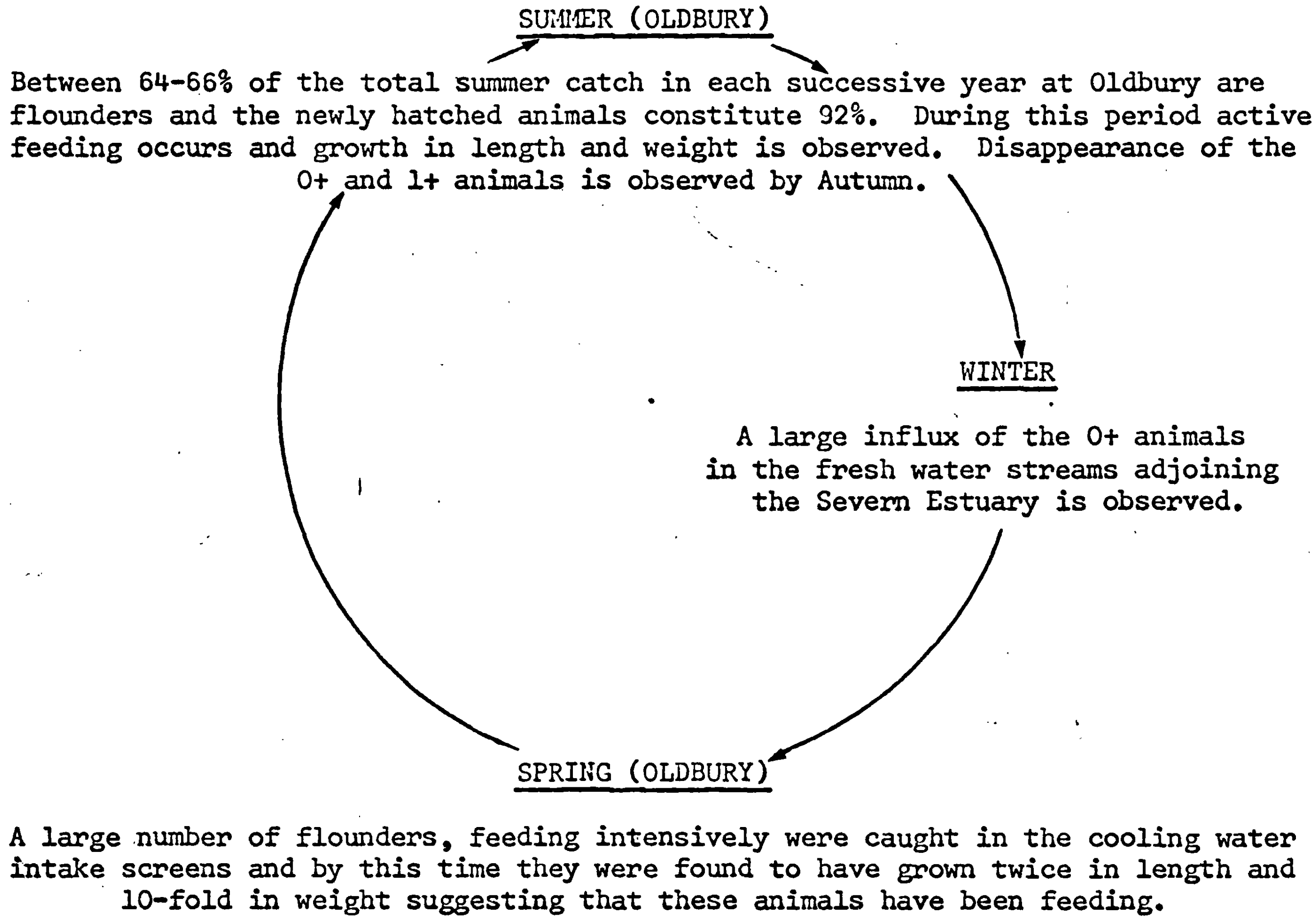
The high proportion of these age classes (making up 92% of the Severn flounder population) indicates the importance of the estuary as a nursery ground for the young flounders. The general variations in the numbers of mature flounders in the estuary is largely occasioned by the requirements of spawning, since food organisms (particularly crustaceans and small fish) are plentiful throughout the year. The migratory behaviour of the younger fish (0+ and 1+ animals), however, is not readily understood although changes in salinity, temperature etc. may play a part.

Present findings show that the most reliable method of ageing the flounder is by otolith counts, length-frequency distribution can only be used to ascertain the growth of the 0+ animals. Although, in the Baltic Sea, males attain sexual maturation earlier (3 years compared to 4 years for females) in the present study area there was no difference between the sexes. In contrast, to the Baltic flounders, the majority of flounders from the Severn estuary attained sexual maturity in their third year.

In flounders of all age groups except the 0+, there is slight but constant preponderance of females in the Severn region and the Bristol Channel. This excess of females is not confined to the flounders, but has also been observed in all the major marine and

FIGURE 22

Life cycle of the 0+ and 1+ flounders, *Platichthys flesus*, in the Severn Estuary and The Bristol Channel.



estuarine species studied over the period 1972-1976.

Studies on the feeding behaviour of this species indicate that selectivity rather than the availability of prey organisms is the more important factor. It is conceivable however, that environmental factors such as turbidity, and water temperature play an important part in the food selectivity of flounders, as suggested by Muus (1967) and the present author (1974). Muus found that the intensity of feeding is affected largely by changes in water temperature.

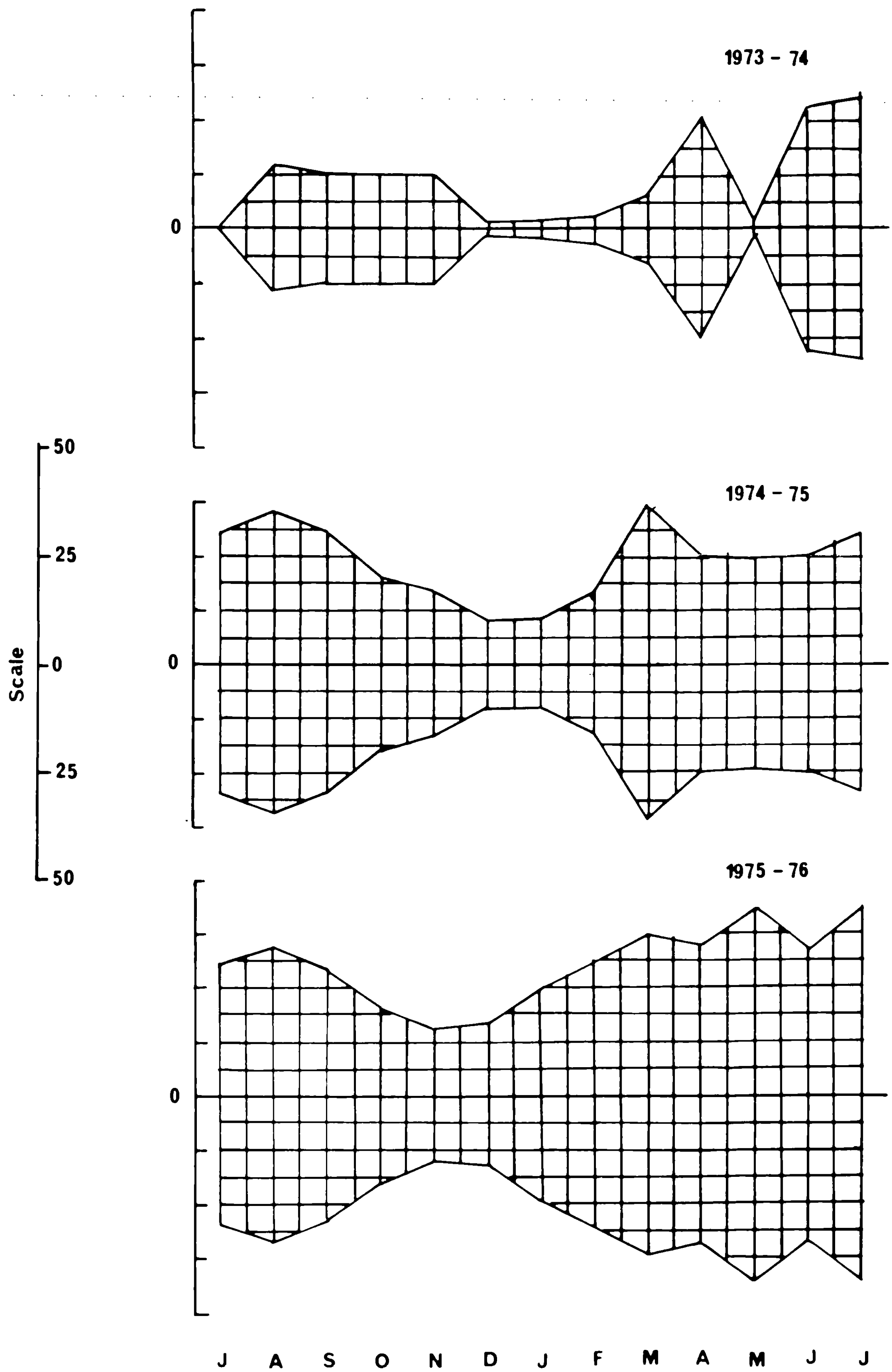
The juvenile fish were found to consume relatively greater quantities of food than the adults and fed throughout the year, although less intensively in the winter months. As reported by other workers (Cieglewicz, 1947; Mulicki, 1947; Kandler, 1960; Muus, 1967) in the adult fish, however, extensive feeding occurred in summer and early spring, but during the winter months food intake was greatly reduced. The present study confirms these conclusions.

The effect of water temperature on metabolism as reflected by the higher proportion of animals containing semi-digested food organisms in the gut in summer as compared with the winter months is illustrated in Figure 23. Thus, in 1973/74 the percentage of guts with half-digested food was 60% in the summer and 5% the winter. Additionally, there has been a steady and consistent increase over the years 1973/1976 in the proportion of animals containing semi-digested food from 5% in 1973 to 35% in 1976 in the winter months and in the summer months from 60% in 1974 to 85% by 1976. This may be the result of the trend towards higher water temperatures that has been evident during the same period (Figure 2).

The principal diet of the majority of the flounders in the

FIGURE 23

The seasonal and annual occurrence of flounders, *Platichthys flesus* with semi-digested food organisms at Oldbury during 1973-1976.


1973 - 74
0
1974 - 75
0
1975 - 76
0
Scale
50
25
0
25
50
J A S O N D J F M A M J J

Severn Estuary and the Bristol Channel consisted of *Gammarus spp.*, *Macoma baltica*, *Neomysis*, *Crangon crangon* and *Nereis diversicolor*, in order of importance. Thus, the diet is similar to that of the Baltic flounders, but while Mulicki (1947) found that in the Baltic there were distinct differences in the choice of principal food organisms between male and female flounders, in the present study no differences were noted. However, differences between various age groups were observed and this could be related to the size of the mouth of the predator relative to the size of the food organism.

At Oldbury (1973-1976) a distinct inverse relationship between the maximum uptake of *Gammarus spp.* and *Neomysis* on one hand and the minimum intake of *Macoma baltica* and *Crangon crangon* on the other hand was observed. Thus, minimum consumption in November of *Gammarus spp.* and *Neomysis* was marked by a corresponding increase in the uptake of *Macoma baltica* and shrimp. While *Gammarus spp.* remained relatively constant (except in November of 1973/74 and 1974/75), shrimps which were completely absent from the guts during December to March (1973/1974) were found to be a minor component of the diet in the following year.

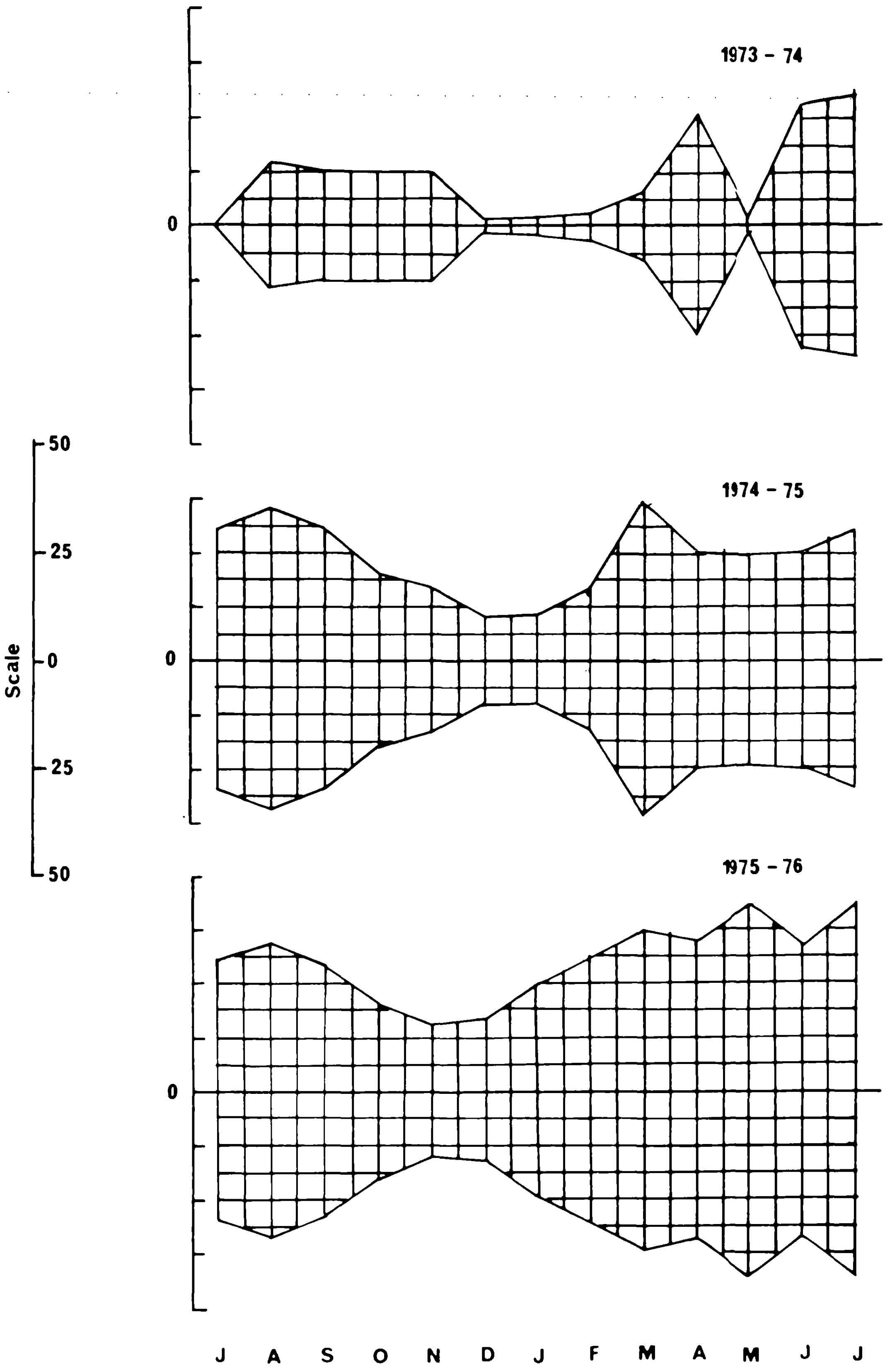
In 1975/1976 however, a different pattern of feeding emerged and this can, at least in part, be attributed to the change in the environmental factors. Thus, *Gammarus spp.* which were absent in the guts in summer and late autumn and rose to peak frequency in winter and decreased thereafter. *Macoma baltica* were present in all the guts examined in summer and late autumn but disappeared by winter, only to rise to a maxima by spring and summer.

One of the major conclusions that can be drawn from the present findings on the feeding habits of the flounder is, that contrary to expectation, the reservoir at Oldbury does not restrict the movement of flounders in their search for food and this is amply supported by the investigations of Moore *et al* (1976), whose studies showed the absence of the bivalve *Macoma baltica* in the fauna of the reservoir. However, as stated earlier (page 2) the findings of this author must be treated with great caution as they were based on small numbers. In addition Moore *et al* (1976b) did not find *Macoma baltica* in the gut of flounders at Oldbury but again this could be attributed to the very much smaller numbers of animals that were examined.

Striking differences have been noted in the choice of major food organisms by flounders from estuarine or marine environment. Thus, in the estuary, amphipods, mysids and decapods were the major food components. However, flounders from a totally marine environment tend to exhibit a distinct preference for the mollusc *Macoma baltica*. These differences probably indicate the spatial distribution density of *Macoma baltica* in these areas. A different situation however, exists in the case of the shrimp which is abundant throughout the year in the estuary and the Bristol Channel. In spite of its availability however, there has been a trend towards a decrease of this organism as a food item of flounders and other species, suggesting a major change in the feeding trend of fishes, perhaps due to the effects of physio- bio- environmental changes experienced in this region over the study period.

FIGURE 23

The seasonal and annual occurrence of flounders, *Platichthys flesus* with semi-digested food organisms at Oldbury during 1973-1976.


1973 - 74
0
1974 - 75
0
1975 - 76
0
Scale
50
25
0
25
50
J A S O N D J F M A M J J

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At Oldbury (1973-1976) a distinct inverse relationship between the maximum uptake of *Gammarus spp.* and *Neomysis* on one hand and the minimum intake of *Macoma baltica* and *Crangon crangon* on the other hand was observed. Thus, minimum consumption in November of *Gammarus spp.* and *Neomysis* was marked by a corresponding increase in the uptake of *Macoma baltica* and shrimp. While *Gammarus spp.* remained relatively constant (except in November of 1973/74 and 1974/75), shrimps which were completely absent from the guts during December to March (1973/1974) were found to be a minor component of the diet in the following year.

In 1975/1976 however, a different pattern of feeding emerged and this can, at least in part, be attributed to the change in the environmental factors. Thus, *Gammarus spp.* which were absent in the guts in summer and late autumn and rose to peak frequency in winter and decreased thereafter. *Macoma baltica* were present in all the guts examined in summer and late autumn but disappeared by winter, only to rise to a maxima by spring and summer.

One of the major conclusions that can be drawn from the present findings on the feeding habits of the flounder is, that contrary to expectation, the reservoir at Oldbury does not restrict the movement of flounders in their search for food and this is amply supported by the investigations of Moore *et al* (1976), whose studies showed the absence of the bivalve *Macoma baltica* in the fauna of the reservoir. However, as stated earlier (page 2) the findings of this author must be treated with great caution as they were based on small numbers. In addition Moore *et al* (1976b) did not find *Macoma baltica* in the gut of flounders at Oldbury but again this could be attributed to the very much smaller numbers of animals that were examined.

Striking differences have been noted in the choice of major food organisms by flounders from estuarine or marine environment. Thus, in the estuary, amphipods, mysids and decapods were the major food components. However, flounders from a totally marine environment tend to exhibit a distinct preference for the mollusc *Macoma baltica*. These differences probably indicate the spatial distribution density of *Macoma baltica* in these areas. A different situation however, exists in the case of the shrimp which is abundant throughout the year in the estuary and the Bristol Channel. In spite of its availability however, there has been a trend towards a decrease of this organism as a food item of flounders and other species, suggesting a major change in the feeding trend of fishes, perhaps due to the effects of physio- bio- environmental changes experienced in this region over the study period.

PART 4

SEA SNAILS, *LIPARIS LIPARIS*

4. SEA SNAILS, *LIPARIS LIPARIS* (Plate 19)

4.1. INTRODUCTION

Sea snails *(Liparis liparis)* are typical cold water forms, well represented in Arctic waters. The natural history of this teleost has not been seriously investigated, despite the fact that these organisms are common in shallow waters and are found in abundance during the winter months in most estuaries of Great Britain and Northwestern Europe.

For economic reasons alone, the sea snails certainly warrant a programme of study to elucidate their life cycle in a complex marine community, as they are recognised predators on shrimping grounds (Wheeler, 1969) but apart from the preliminary work of this author, little is known of their detailed biology. In his review of the fishes of the British Isles and Northwestern Europe, Wheeler states that the sea snails are generally found at depths of about 5 m, but in Northern latitudes they may occur as deep as 100 m. Breeding is said to take place between the months of December and February.

4.2. RESULTS

4.2.1. Seasonal and Annual Changes In Numbers

Within the study area the sea snail first appears in samples from Hinkley Point, Oldbury and Berkeley in August and even in one exceptional case as early as late July (at Hinkley). The main run however, does not usually begin until October and maximum numbers occur in December or January (Figure 24). Although the weekly samples show marked short term fluctuations, the adjusted monthly totals reveal a very distinct and sharply defined seasonal pattern. In 1973-1975 and again 1975-1976 the peak numbers occurred somewhat later than in previous years, perhaps as a result of exceptional environmental conditions (see page 5).

There have also been very marked annual differences in the numbers of sea snails taken at Oldbury (Figure 24). In 1975-1976 and in 1972-1973 the maximum sample numbers were 553 and 448 respectively, but in 1973-1974 this was reduced to only 148, while in 1974-1975 about 2,000 were obtained from a single sample in mid-January. Corresponding total numbers for these years are as follows:

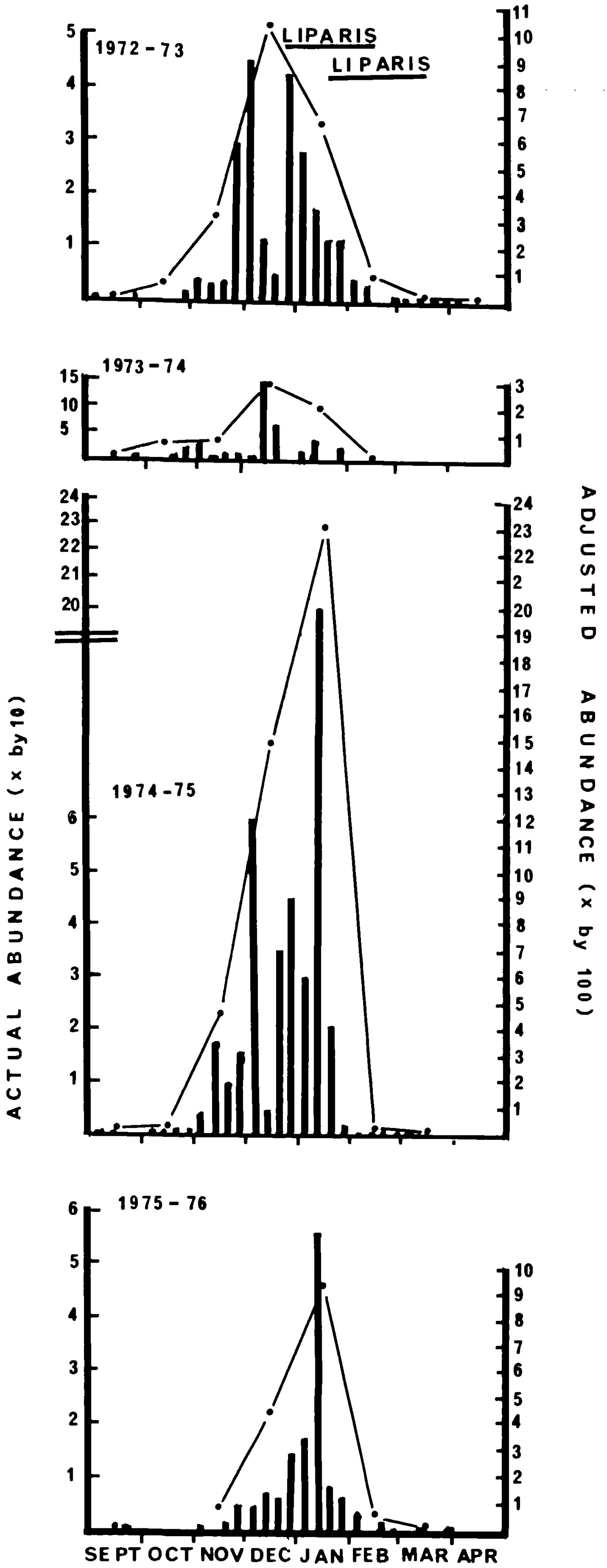
1972 - 1973	2268
1973 - 1974	396
1974 - 1975	4290
1975 - 1976	1240

Although there have been substantial differences in temperature, rainfall and salinity over this period, these factors can hardly be invoked to explain the marked differences in abundance in 1973-1974 and 1974-1975, since in both years the autumn and winter periods were characterised by raised salinities and lower than normal rainfall. It therefore seems more likely that these differences in relative abundance are due to natural fluctuations, although the alternation of years of high and low abundance could conceivably have some significance.

No quantitative samples are available for either Hinkley Point or Berkely, but the seasonal pattern at both these sites appear to be similar to those observed at Oldbury.

FIGURE 24

Seasonal and annual fluctuations in abundance of Sea snails, *Liparis liparis* caught in the cooling water intake screens over a 24 h sampling period at Oldbury during 1972-1976.



OLDBURY – ON – SEVERN

4.2.2. Length-Frequency Distribution

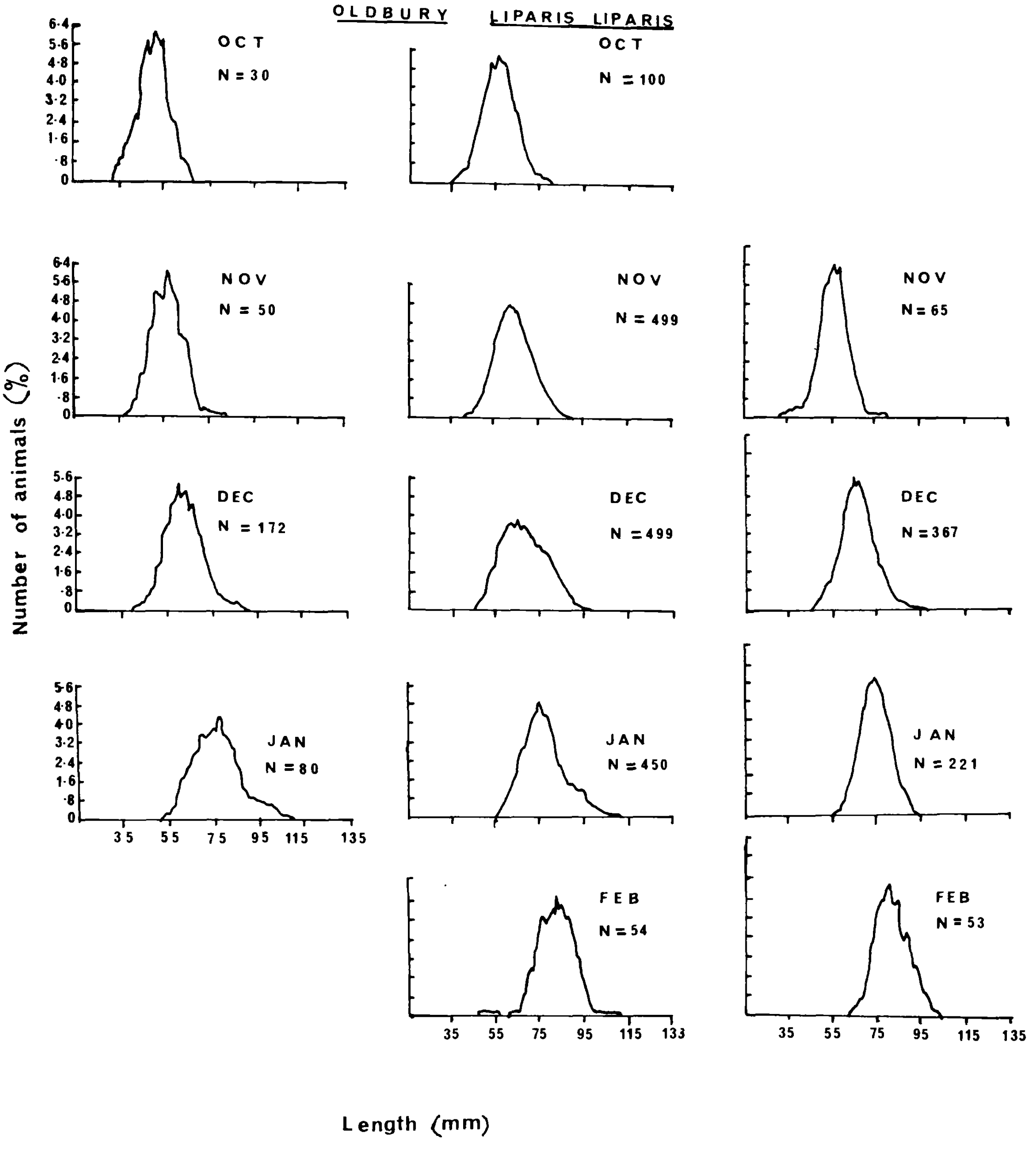
Length-frequency curves for animals caught at Oldbury, Berkeley, and Hinkley Point, during the period October-March, are presented in Figures 25-30. In general, sea snail distribution was unimodal in the study area.

Thus, in October when they first appear in appreciable numbers in the Severn Estuary, the majority of the animals show a frequency peak between 45-55 mm. This then progresses and in November, the peak is at 55-60 mm. No significant growth is seen in December, but by January the peak frequency occurred at 75-80 mm. This length-frequency distribution is typical of the region studied. While data, particularly for October-December is strongly indicative of homogeneous population (i.e. the animals belong to a single age group) a small but consistent number of animals is represented by a minor mode at 95-100 mm. This is seen more distinctly in the Berkeley and Hinkley length-frequency curves, suggesting the possibility of a further age group.

Length-frequency distributions for the Oldbury region, for the three years studied are shown in Figures 25-26. It can be seen that animals obtained in October show a mode at 45-55 mm, but, by January this peak frequency has advanced to 75-80 mm. To investigate whether there was any significant difference in the yearly length-frequency distributions, length-frequency curves for all the years studied at Oldbury were superimposed (Figure 26). From Figure 26 it can be seen that there was a very large correspondence in the distributions for different years. Similar patterns were seen at Berkeley (Figures 27-28). To investigate whether the screening mechanisms of the two Power Stations, Oldbury and Berkeley introduce a

FIGURE 25

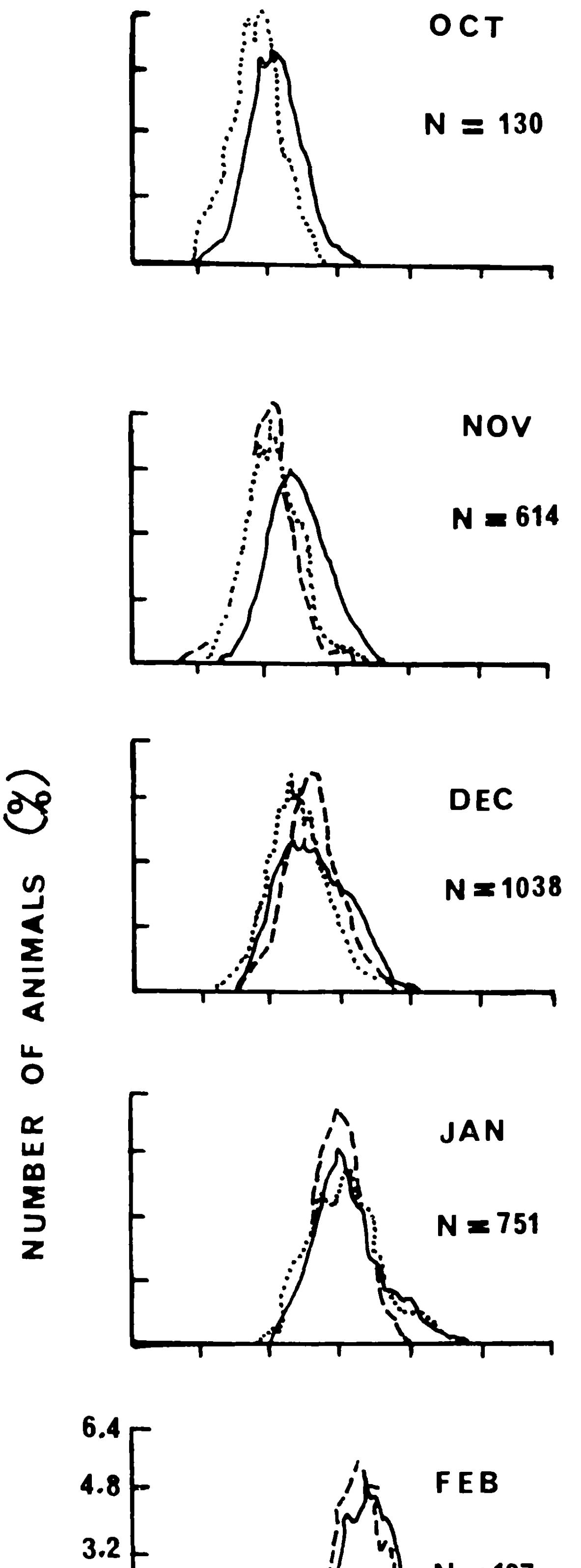
Length-frequency distribution of Sea snails, *Liparis liparis* obtained at Oldbury Power Station during 1973-1976, with a smoothing average of 9mm (N = number of animals).



OLDBURY
LIPARIS LIPARIS
OCT
N = 30
OCT
N = 100
NOV
N = 50
NOV
N = 499
NOV
N = 65
DEC
N = 172
DEC
N = 499
DEC
N = 367
JAN
N = 80
JAN
N = 450
JAN
N = 221
FEB
N = 54
FEB
N = 53
Number of animals (%)
Length (mm)

FIGURE 26

Superimposition of length-frequency of sea snails, *Liparis liparis* for the three years studied (1973-1976).



OCT
N = 130
NOV
N = 614
DEC
N = 1038
JAN
N = 751
FEB
N = 107
NUMBER OF ANIMALS (%)
6.4
4.8
3.2
1.6
0
35
55
75
95
115
135
LENGTH (mm)

FIGURE 27

Length-frequency distribution of sea snails, *Liparis liparis* caught at Berkeley Nuclear Power Station during the seasons of 1974-1976, with a smoothing average of 9 mm.

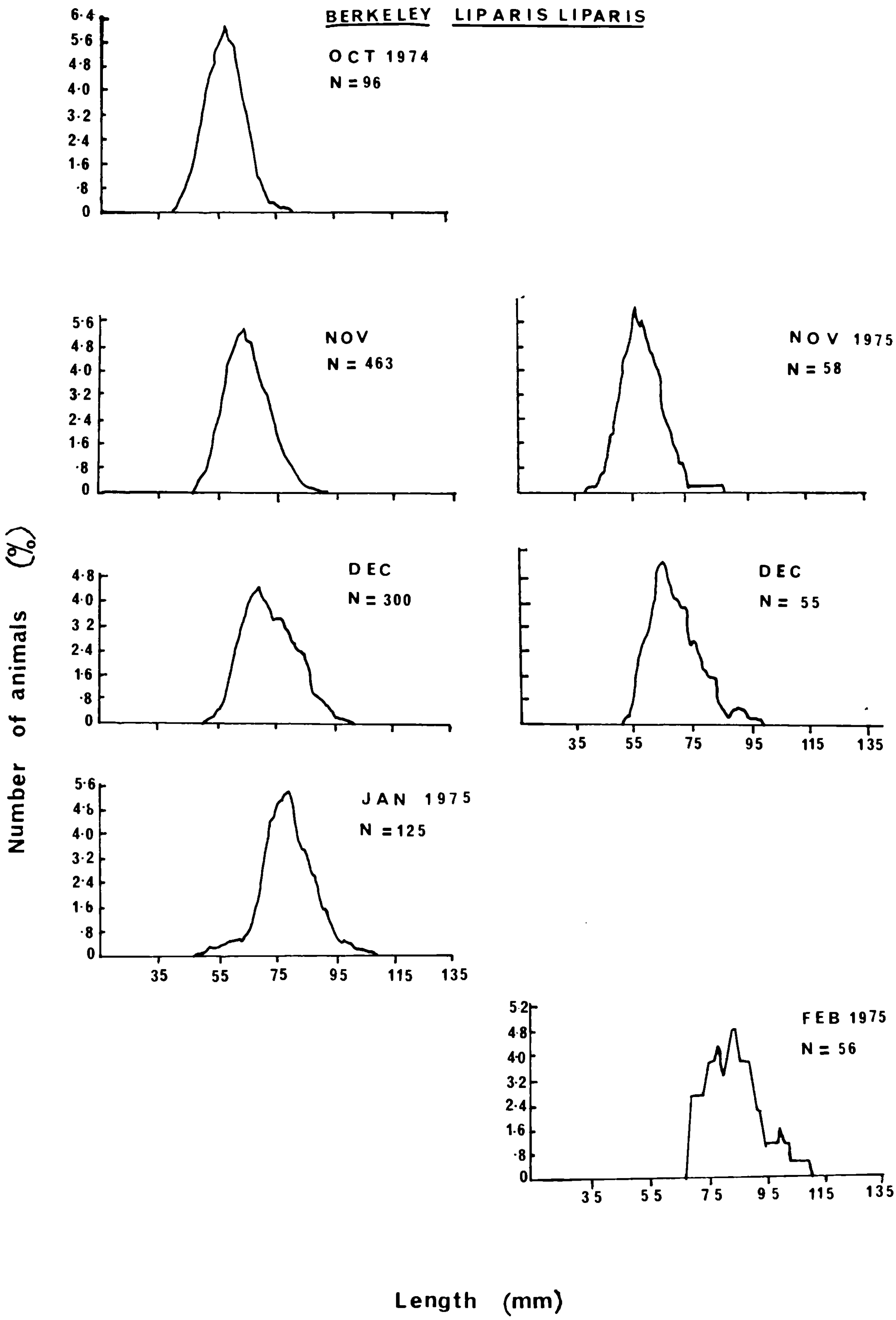

BERKELEY LIPARIS LIPARIS
OCT 1974
N = 96
NOV
N = 463
NOV 1975
N = 58
DEC
N = 300
DEC
N = 55
JAN 1975
N = 125
FEB 1975
N = 56
Number of animals (%)
Length (mm)
35 55 75 95 115 135

FIGURE 28

Superimposed length-frequency curves (1974-1976) for sea snails, *Liparis liparis* caught in the filter screens of Berkeley Power Station.

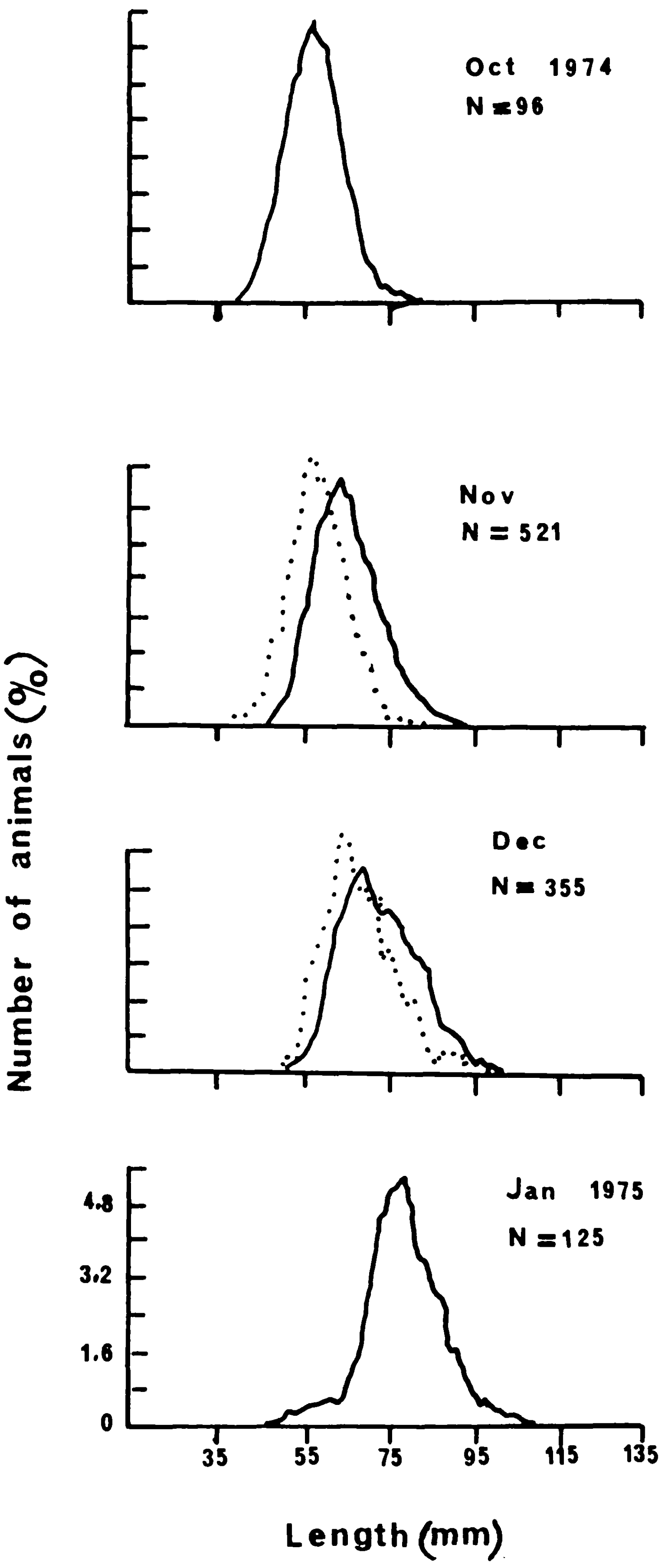
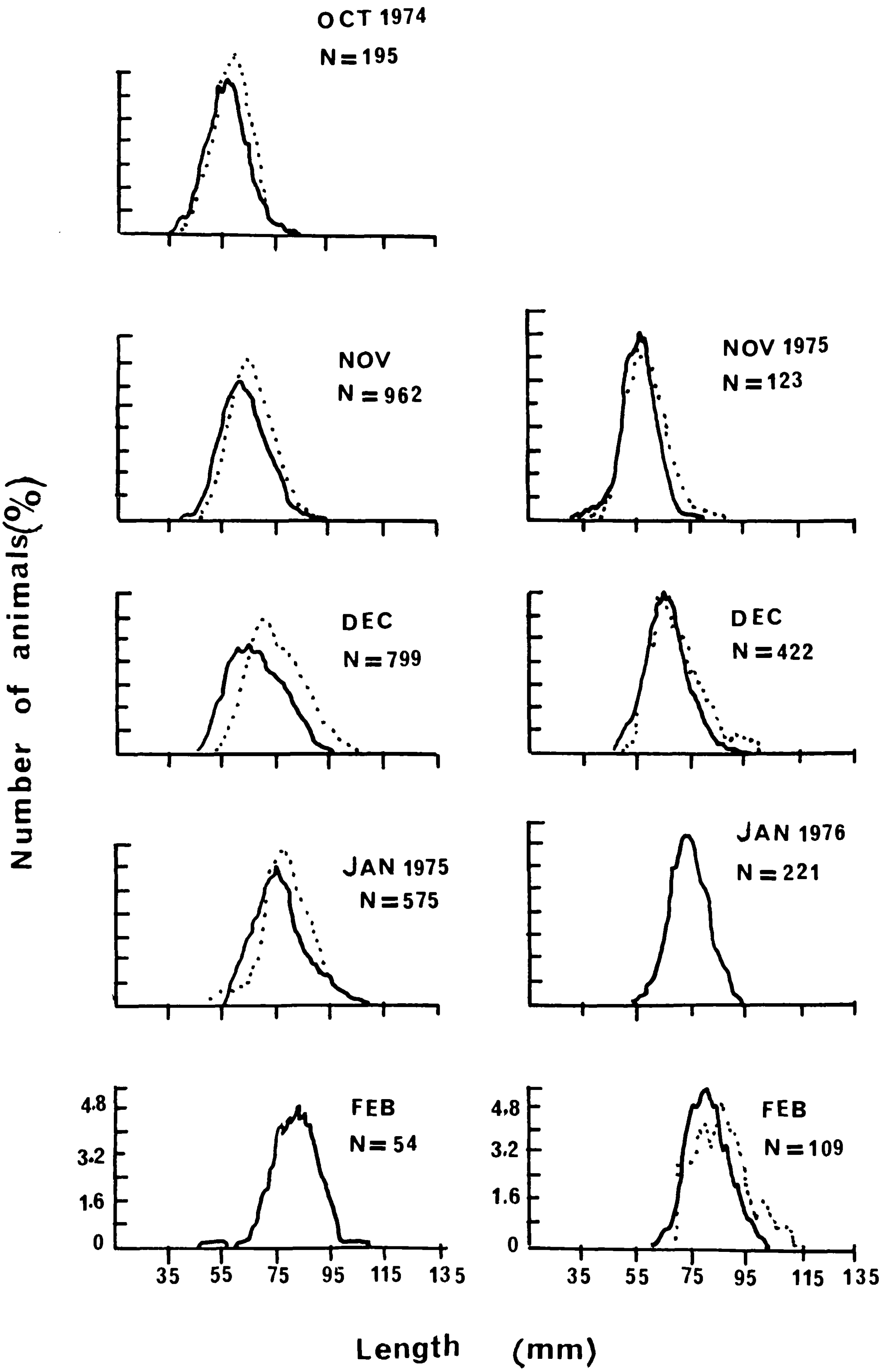

Oct 1974
N = 96
Nov
N = 521
Dec
N = 355
Jan 1975
N = 125
Number of animals (%)
4.8
3.2
1.6
0
35
55
75
95
115
135
Length (mm)

FIGURE 29

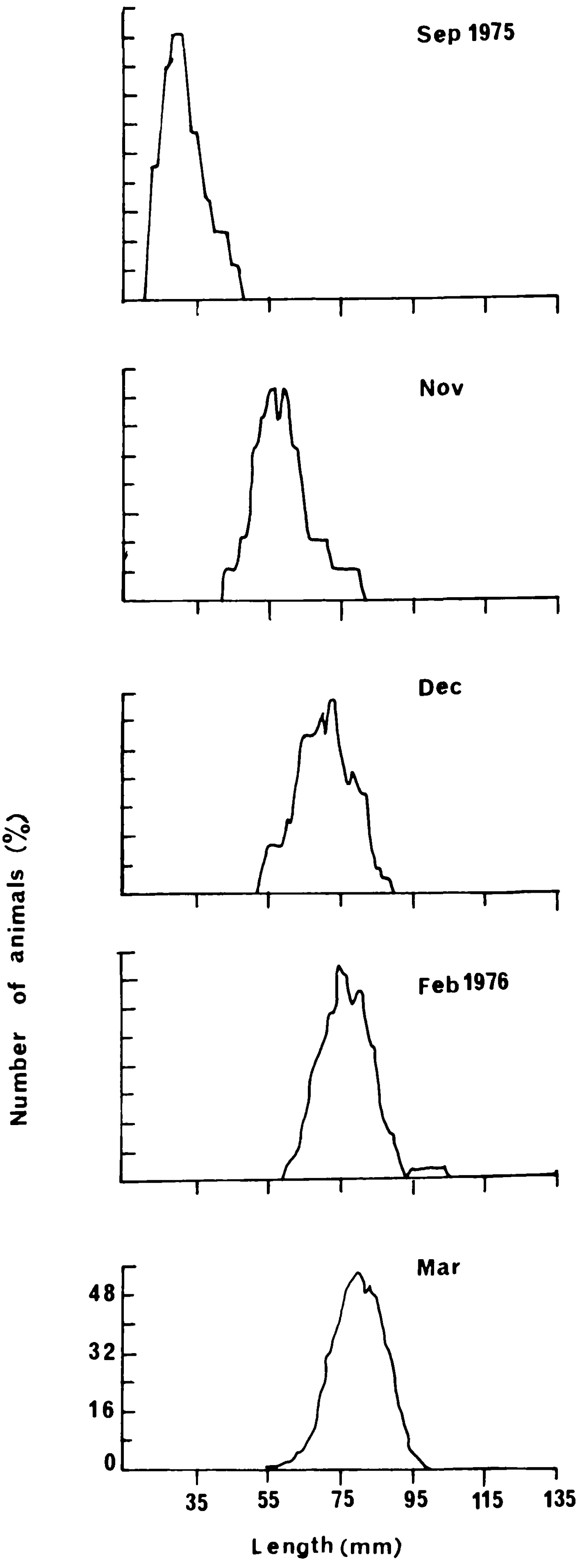
Superimposed length-frequency data obtained from Oldbury and Berkeley.



OCT 1974
N = 195
NOV
N = 962
NOV 1975
N = 123
DEC
N = 799
DEC
N = 422
JAN 1975
N = 575
JAN 1976
N = 221
FEB
N = 54
FEB
N = 109
4.8
3.2
1.6
0
35
55
75
95
115
135
Number of animals(%)
Length (mm)

FIGURE 30

Length-frequency distribution of se . snails, *Liparis liparis* caught in the intake screens of Hinkley Point Nuclear Power Station, with a smoothing average of 9 mm.


Sep 1975
Nov
Dec
Feb 1976
Mar
Number of animals (%)
48
32
16
0
35
55
75
95
115
135
Length (mm)

bias with regard to size or length, the results for 1974-1975 and 1975-1976 were superimposed (Figure 29). No evidence of sampling discrimination was observed.

At Hinkley Point, length-frequency curves show more distinct growth (Figure 30). In September, the mode occurs at 30-35 mm, and for the pooled data for October/November the mode has advanced to 55-60 mm. In December the peak frequency occurs at 70-75 mm. No significant growth is seen in the following months.

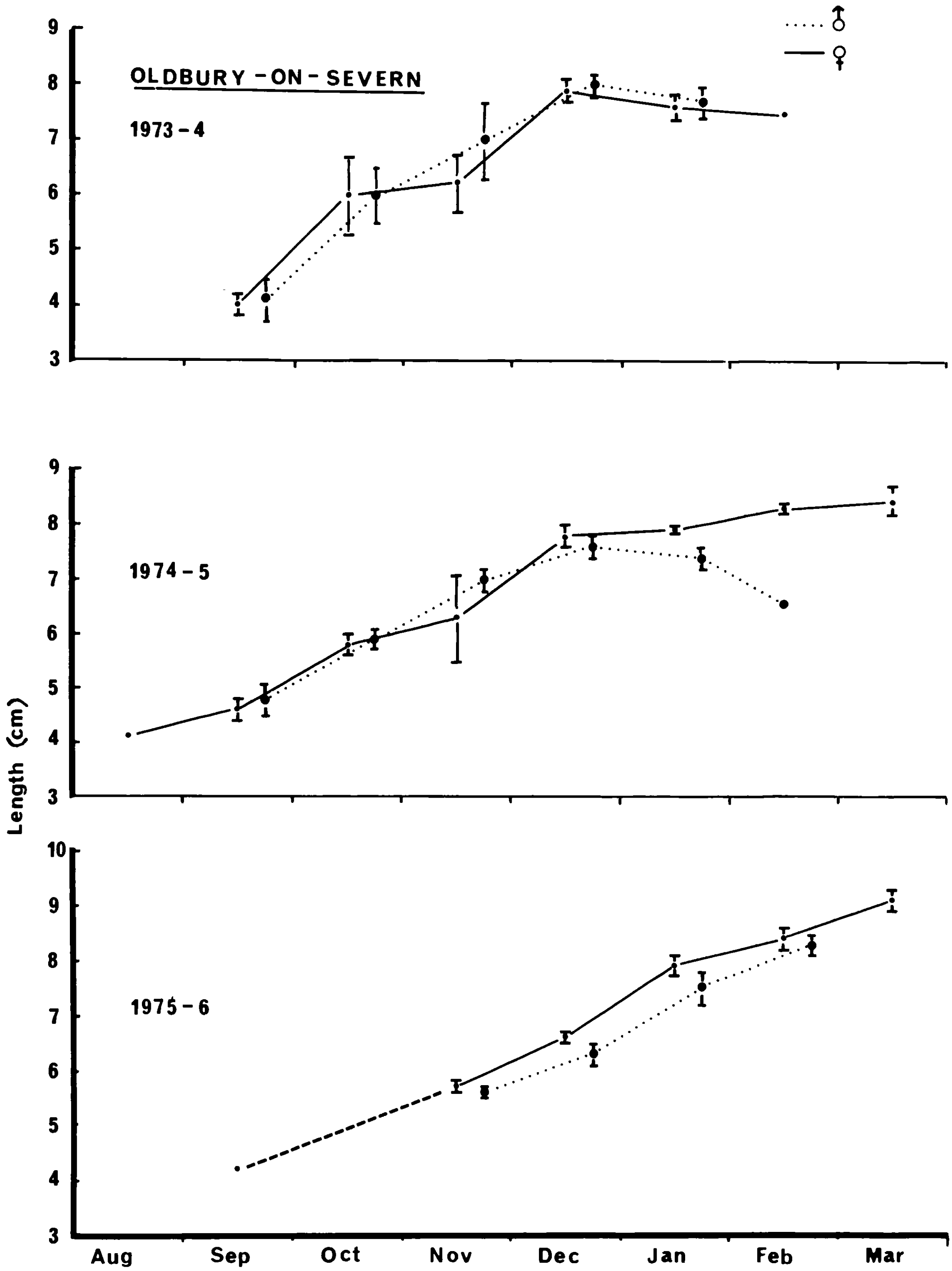
Thus it is clear from the present study that analysis of length-frequency distribution for sea snails indicates that the vast majority of the animals obtained from the intake screens in the middle reaches of the Severn Estuary and the Bristol Channel belong to a single age class and this is confirmed by otolith readings on animals belonging to this group.

4.2.3. Changes in Length and Weight

At Oldbury, the mean and modal lengths of the sea snails in monthly samples increases steadily throughout the autumn and early winter, and at this stage the two sexes do not show significant differences (Appendix 17-18). During this period the mean lengths are approximately doubled (Figure 31). In the season 1973-1974 maximum lengths were attained during December and the January samples showed no further increase but in 1974-1975 the mean lengths of the females continued to increase although at a lower rate between December and March; however, the lengths of the males showed an actual decline during this period; by 1975-1976 the pattern was somewhat different and both sexes continued to grow at a similar rate throughout the

FIGURE 31

Rate of growth in length of male and female sea snails, *Liparis liparis* during its peak abundance at Oldbury, with ±95% confidence limit.



OLDBURY - ON - SEVERN
1973 - 4
1974 - 5
1975 - 6
♂
♀
Length (cm)
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar

whole period of residency from early winter to early spring. For the restricted data obtained from Berkeley (Figure 32) the patterns of growth were generally similar to those observed at Oldbury, although the decline in length of the males in the late stages of the 1974-1975 season at Oldbury was not seen in animals from this location (Appendix 19-20).

It is interesting to note that the pattern of growth in length of this species, in the totally marine environment of Hinkley Point is similar to that at Oldbury (Appendix 21-22). Thus, in 1974 (February-May) no increase in length for either males or females was seen (Figure 33) but by contrast, in 1975-1976 there was a steady increase in length, in agreement with the findings at Oldbury and Berkeley and Uskmouth (Appendix 23).

Growth in weight at Oldbury is also very pronounced during the period in the estuary but was most marked in 1974-1975 and 1975-1976 when the females increased from a total mean value of about 1.0 g in September to 10.0 g in February 1975 and 10.8 g in March 1976 (Figure 34). In both these seasons, the rate of growth was particularly rapid in the winter months. In 1973-1974 growth in weight was much less marked than in the two following seasons; the mean weight of the females increasing only from 1.2 g in September to a maximum of 6.7 g in January. It is significant that the mean weight of the males in 1974-1975 was lower than that of the females from December onwards, from a maximum of 6.3 g in January to 4.1 g in February. In 1974-1976 the mean weight of the males was considerably below that of the females for every month for which data is available. For the Berkeley samples (Figure 35), the increase in weight of the females was similar to that of the Oldbury animals although the difference between the sexes was more apparent in the autumn samples.

FIGURE 32

Rate of growth in length of male and female sea snails, *Liparis liparis* at Berkeley with ±95% confidence limit.

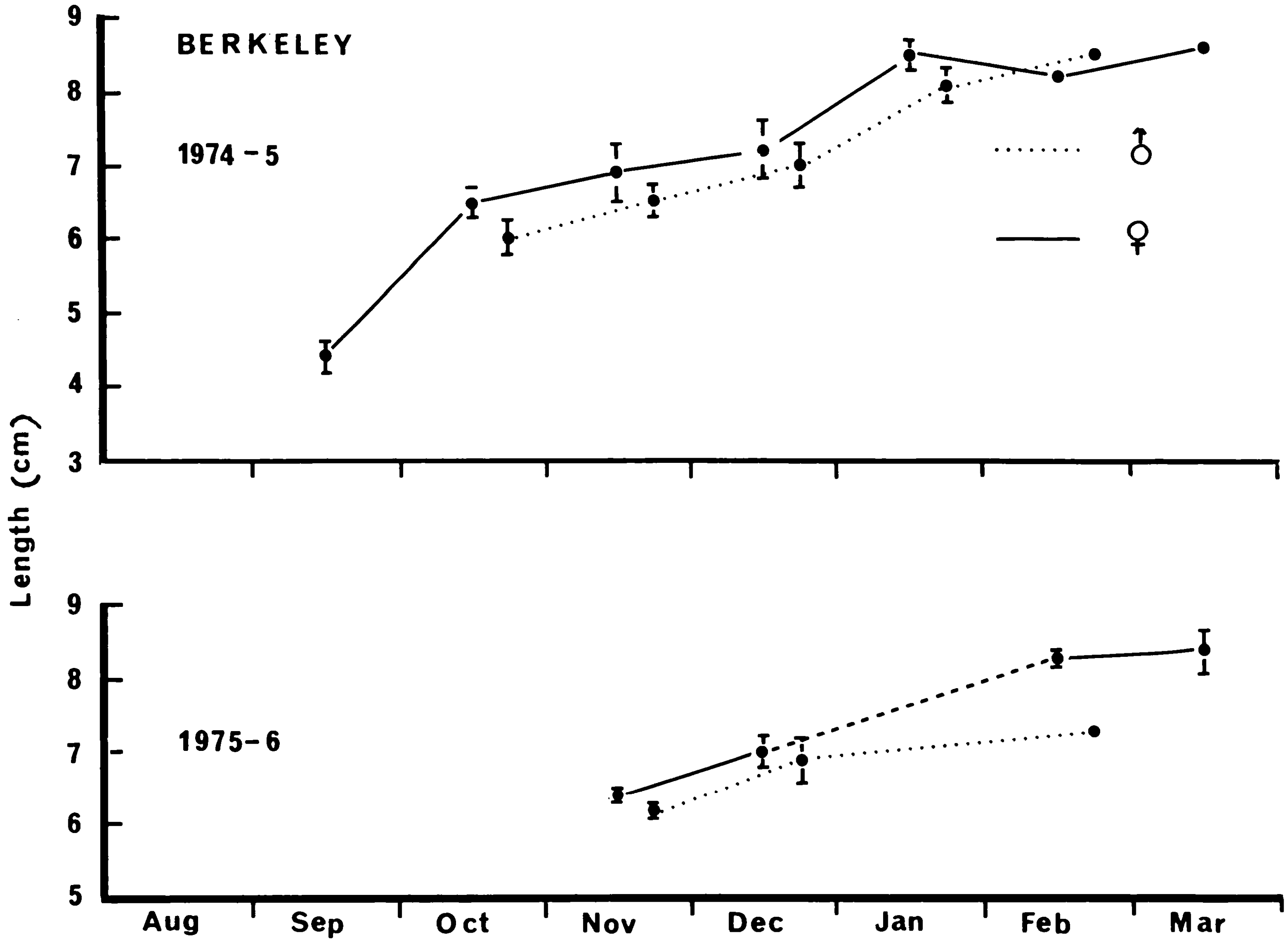

BERKELEY
1974 - 5
1975-6
♂
♀
Length (cm)
9
8
7
6
5
4
3
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar

FIGURE 33

Rate of growth in length of male and female sea snails, *Liparis liparis* at Hinkley Point with ±95% confidence limit.

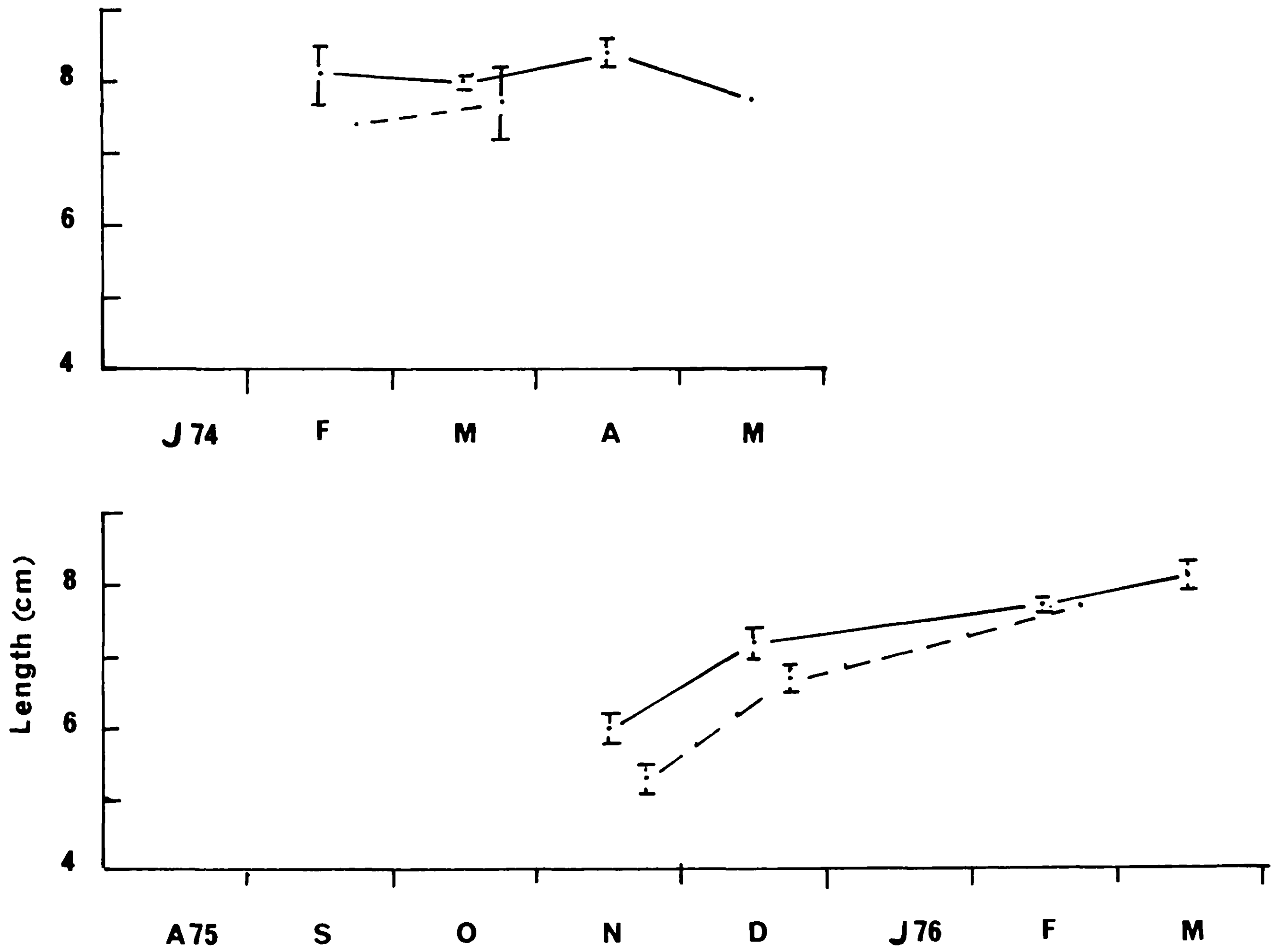
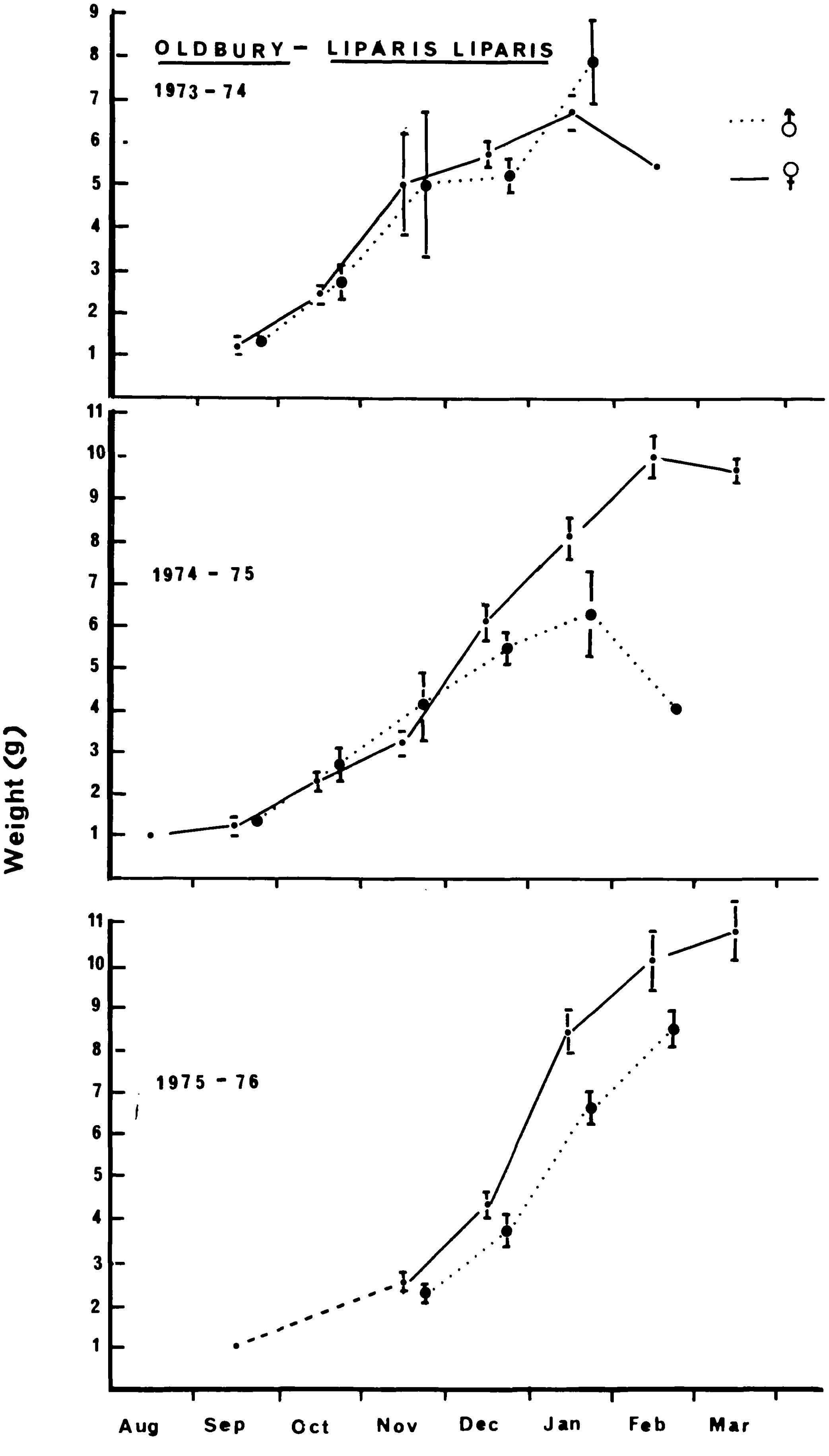

8
6
4
J 74
F
M
A
M
Length (cm)
8
6
4
A75
S
O
N
D
J76
F
M

FIGURE 34

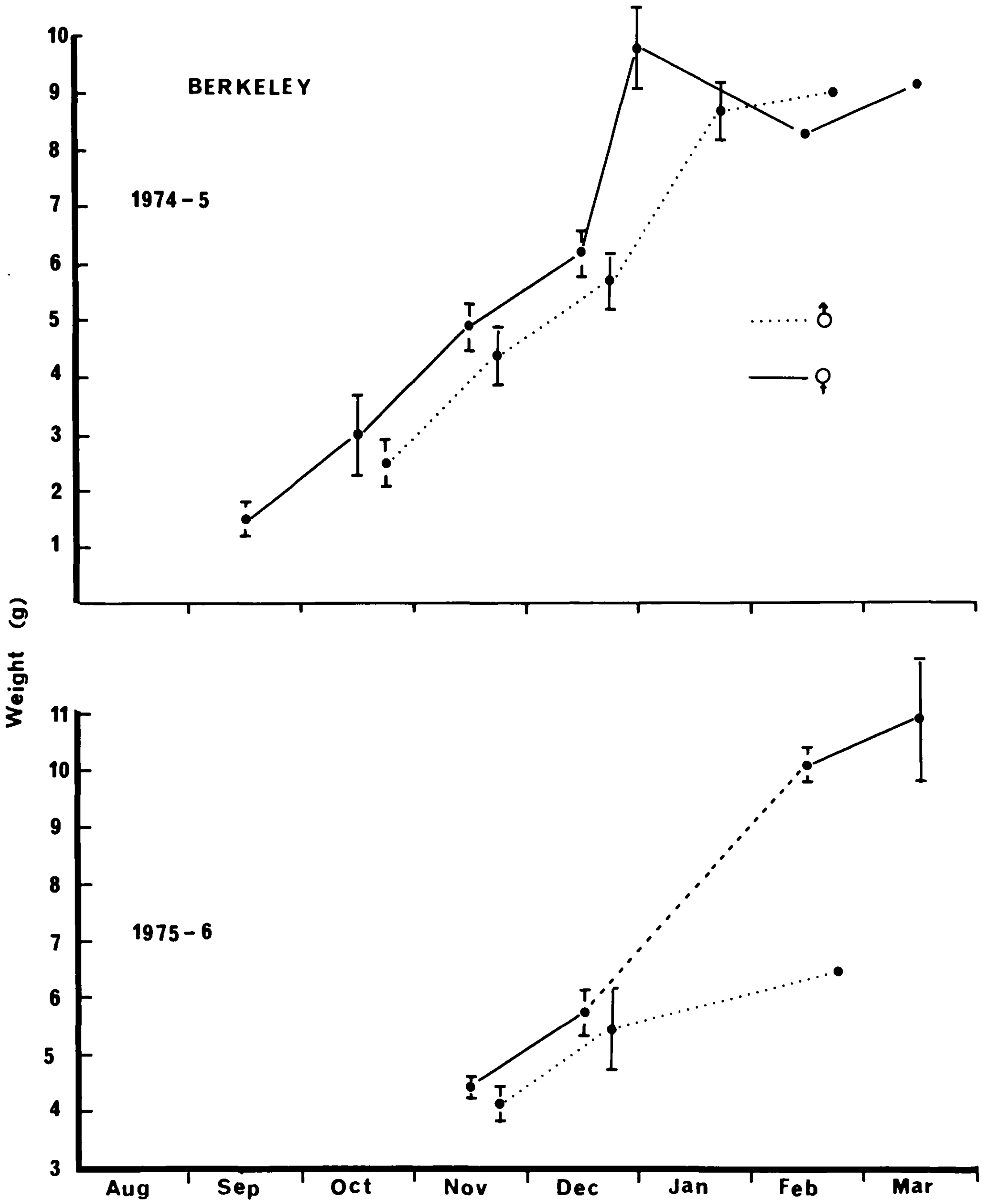
Growth in weight of male and female sea snails, *Liparis liparis* at Oldbury with ±95% confidence limit.



OLDBURY - LIPARIS LIPARIS
1973 - 74
1974 - 75
1975 - 76
♂
♀
Weight (g)
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar

FIGURE 35

Growth in weight of male and female sea snails, *Liparis liparis* at Berkeley with ±95% confidence limit.


BERKELEY
1974 - 5
1975 - 6
Weight (g)
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
♂
♀

At Hinkley Point the average weight of sea snails actually decreased steadily from 8.5 g in February 1974 to 5.8 g by April. As these animals were not spent, the significance of this drop is difficult to understand. During the 1975-1976 season the growth in weight of females was almost 3-fold; from 2.8 g in November to 8.0 g in March. On the other hand, the males increased from 2.0 g to 3.8 g between November 1975 and February 1976. Compared with the samples from Oldbury for the same period, growth in weight particularly for males, is very restricted at Hinkley.

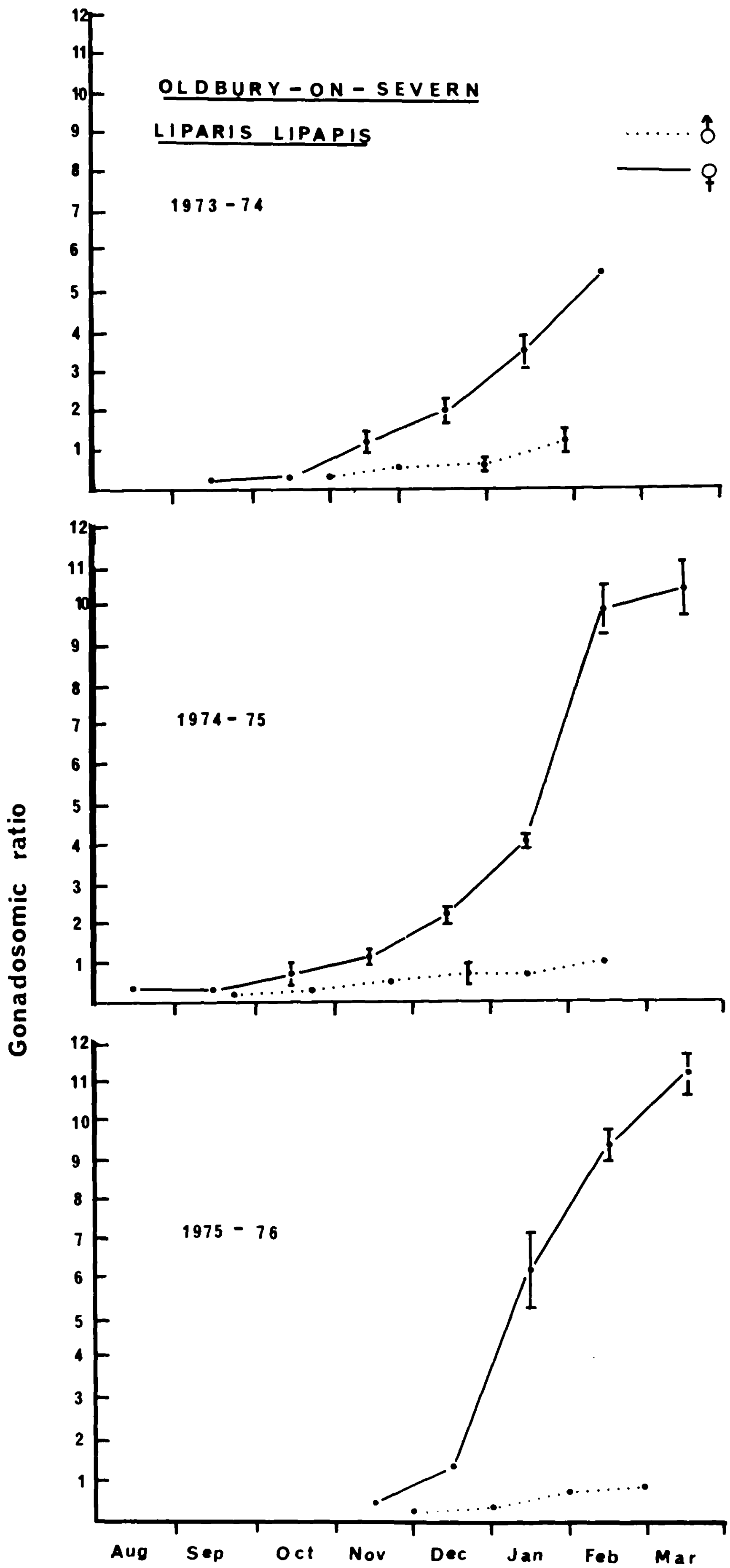
4.2.4. Reproduction

Comparisons between the wet weight of ovaries of sea snails captured in the cooling intakes in the middle reaches of the Severn (Berkeley, Oldbury and Uskmouth) and those found at Hinkley Point in the Bristol Channel, nearer to the spawning grounds show that little if any gonadal development occurs during the autumn (Figures 36-38). At this time, the ovaries of comparable sized fish from different sites are found to be similar in weight (Appendix 17-31). However, in December there is a small but sharp increase in the gonadosomic ratio in fish of similar size, regardless of the vicinity of the site.

A pooling of data shows that the gonadosomic ratio of a fish weighing 2 g is 1.3% while corresponding values for a 4 g fish is 1.5%. A sharp but similar increase in gonadosomic ratio occurs at all the localities in February. Thus, the gonadosomic ratio of a typical sea snail of 5 g was 6.0%, while that of a 10 g fish is 12.0%. Increases in gonadosomic ratio expressed in relationship to length, are almost identical to the pattern described above.

FIGURE 36

Gonadosomic ratio (as a percentage of the total body weight) of male and female sea snails, *Liparis liparis* at Oldbury with ±95% confidence limit.



OLDBURY - ON - SEVERN
LIPARIS LIPAPIS
♂
♀
1973 - 74
1974 - 75
1975 - 76
Gonadosomic ratio
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar

FIGURE 37

Gonadosomic ratio (as a percentage of the total body weight) of male and female sea snails, *Liparis liparis* at Berkeley with ±95% confidence limit.

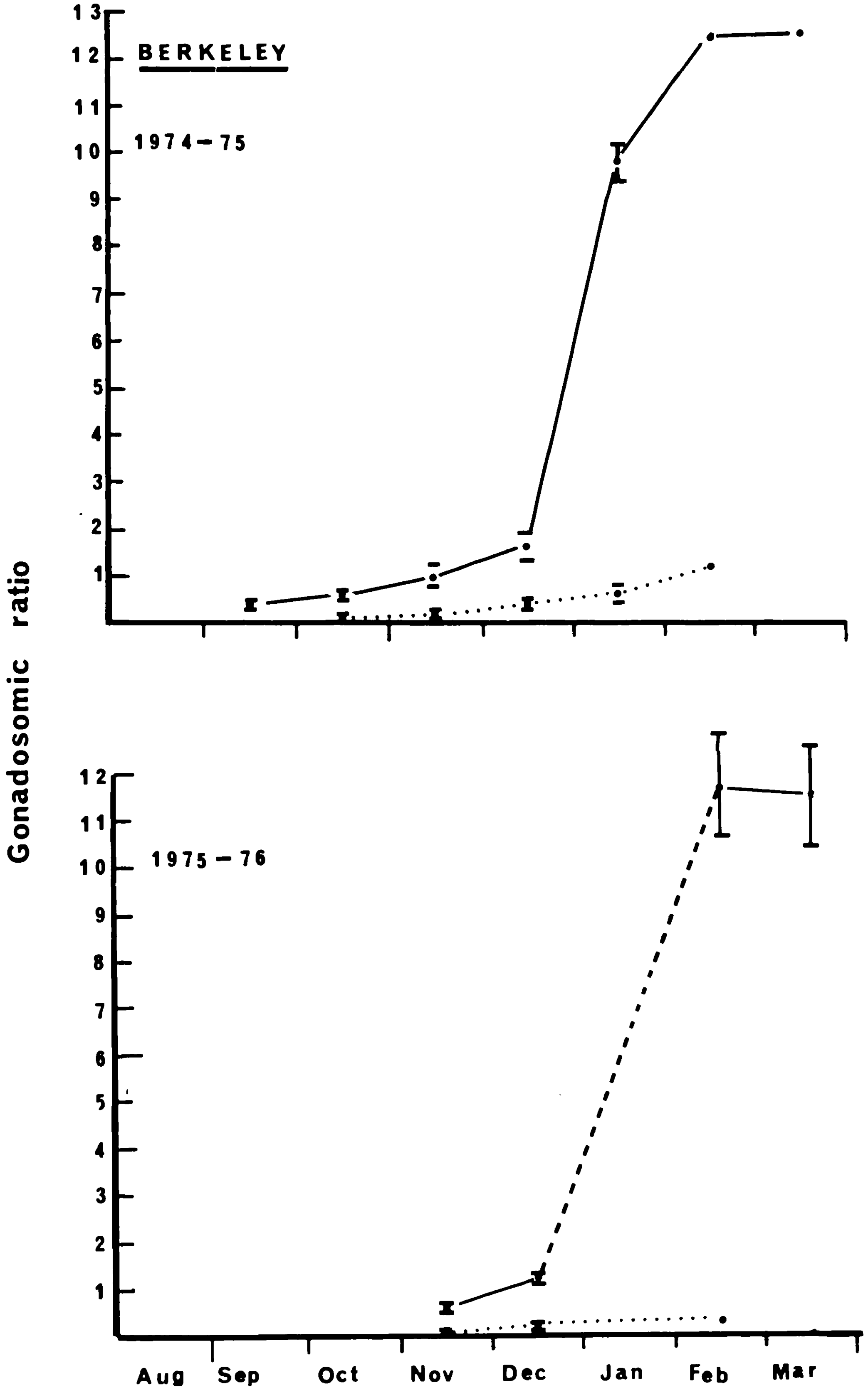
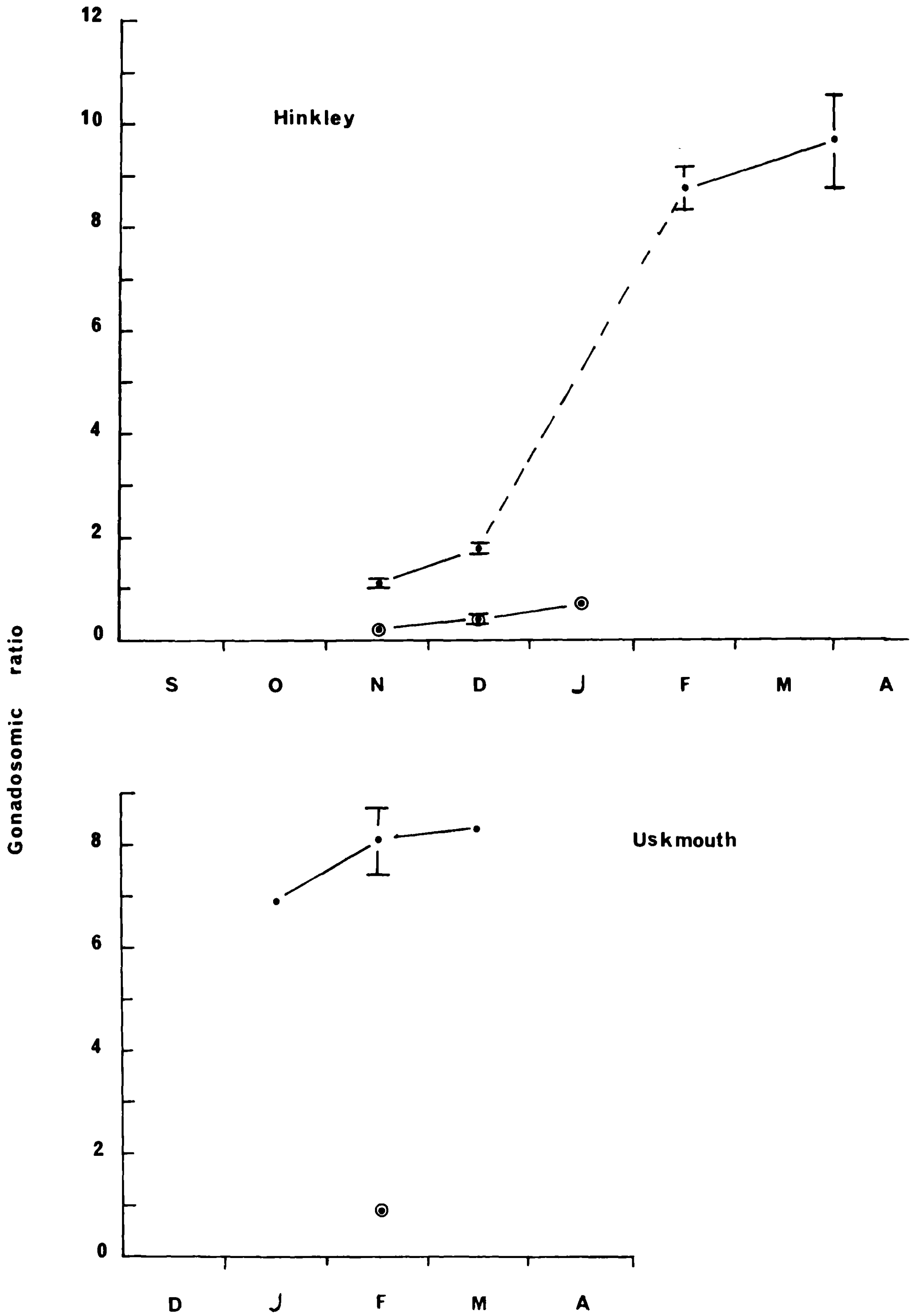

BERKELEY
1974 – 75
1975 – 76
Gonadosomic ratio
13
12
11
10
9
8
7
6
5
4
3
2
1
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar

FIGURE 38

Gonadosomic ratio (as a percentage of the total body weight) of male and female sea snails, *Liparis liparis* at Hinkley Point and Uskmouth with ±95% confidence limit.



Gonadosomic ratio
Hinkley
12
10
8
6
4
2
0
S
O
N
D
J
F
M
A
Uskmouth
8
6
4
2
0
D
J
F
M
A

The significance of slower gonadal growth in 1973-1974 at Oldbury is not known, but it is possible that salinity and temperature played a vital role in the gonadal maturation. It is not clear if this pattern of slow growth was uniform throughout the study period, as no data from other localities is available for comparison. However, as the present study has established that the population at Oldbury is fairly representative of the fish population in the Severn Estuary and the Bristol Channel region as a whole, it is reasonable to assume that slow gonadal growth was typical in 1973-1974.

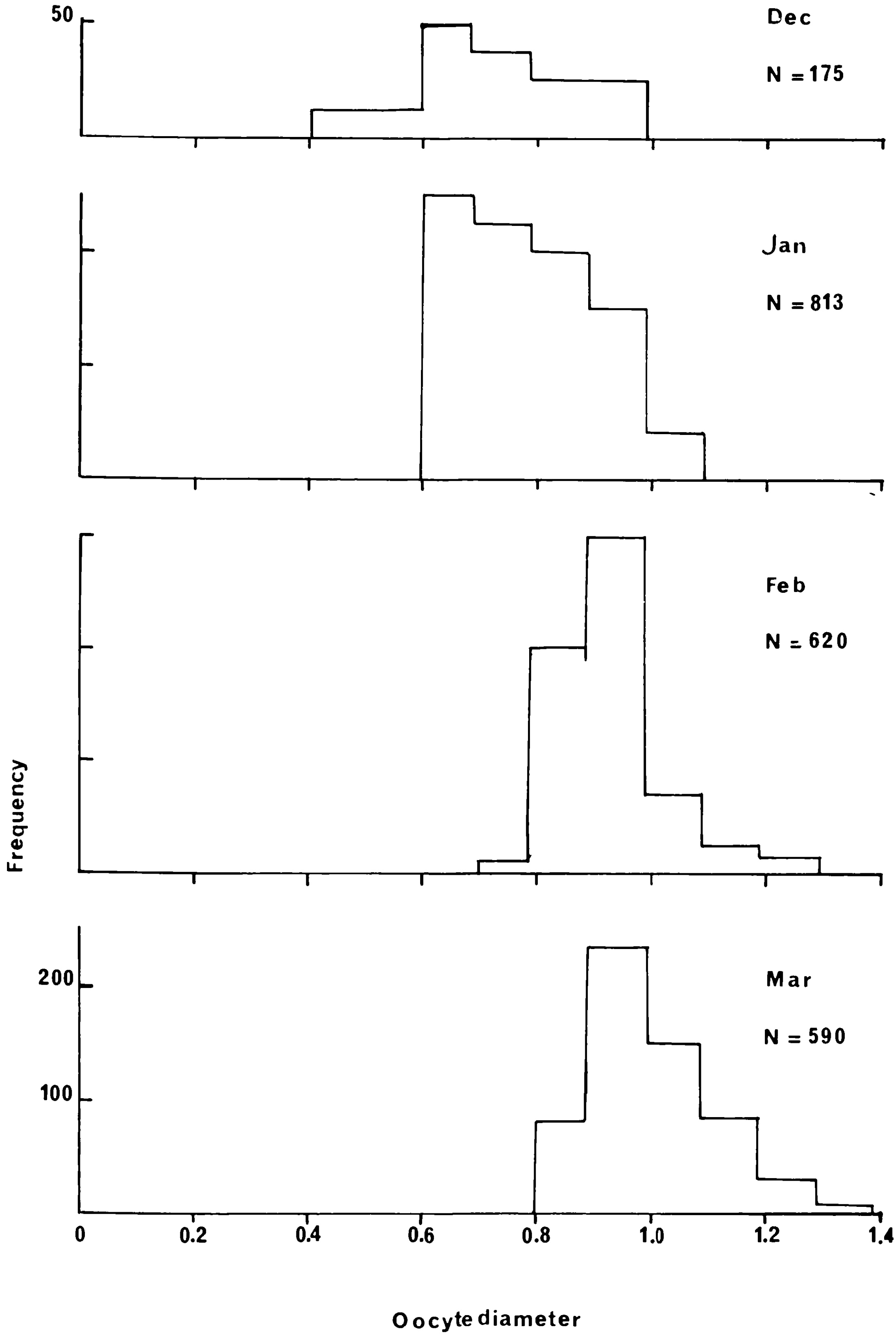
Gonadal development of male sea snails from all localities is estimated throughout the study period from increases in testis weight. The indications are that the weight of the testis shows a slower rate of growth than the ovary, in relationship to either length or weight and the gonadosomic value is similar.

For similar sized animals, fecundity varies from 400 - 520 oocytes. Fecundity also differed considerably among fish when expressed in terms of body weight. Thus, for a sea snail of 10 g oocyte numbers vary between 390 - 520.

Pooled oocyte diameters from Oldbury and Berkeley are shown in Figures 39 and 40 as histograms. Thus, Figures 39-40 show the histograms of oocyte diameter from different localities indicating the average sized oocyte to be 0.9 mm with a range from 0.4-1.2 mm and it is clear from this histogram that the great majority of oocytes fall within a comparatively narrow range of size, suggesting that the majority of sea snails spawn at approximately the same period.

FIGURE 39

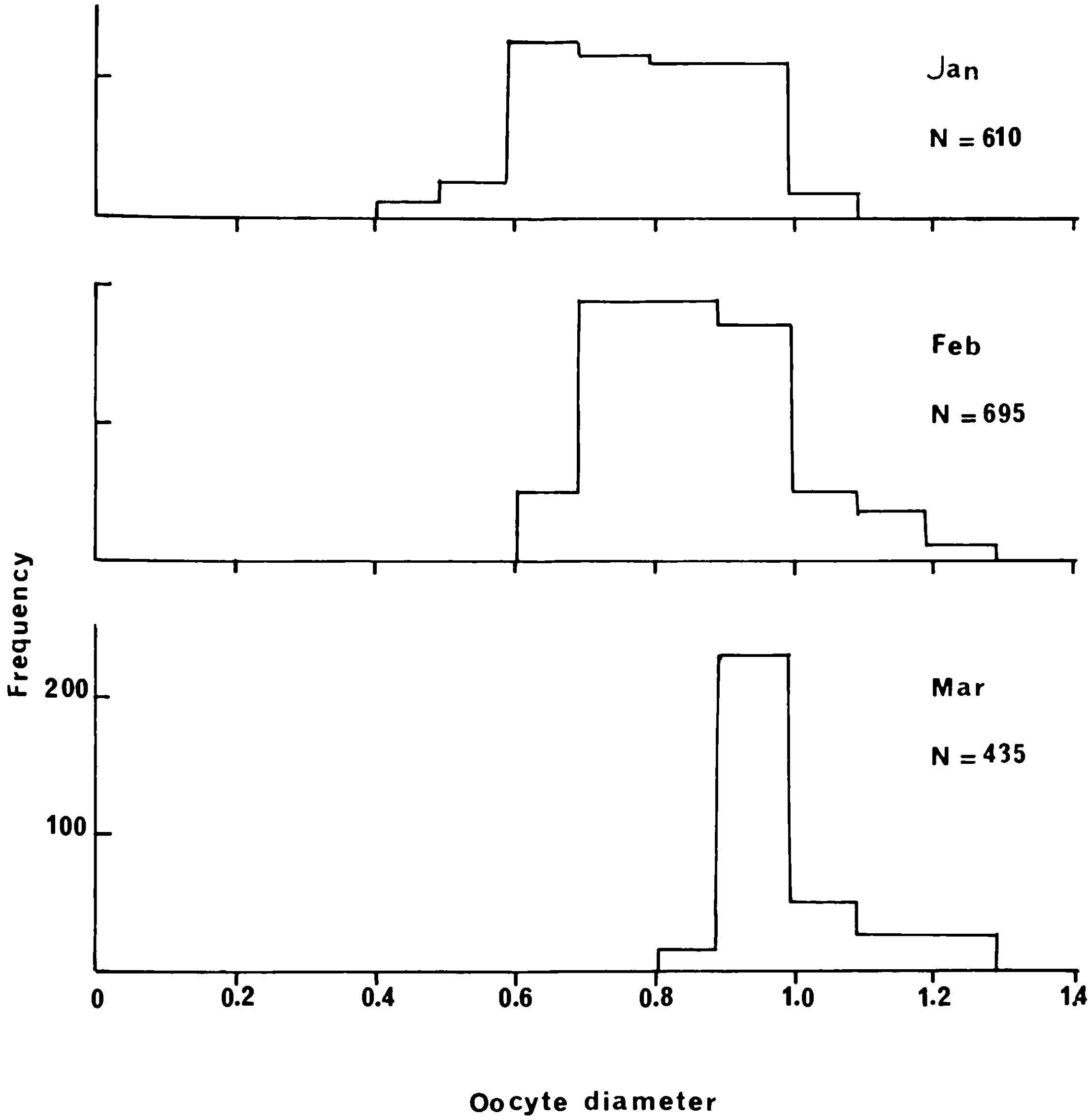
Frequency of occurrence of various oocytes (data pooled) for 1974-1976 in sea snails, *Liparis liparis* at Oldbury (N = number of animals examined).



50
Dec
N = 175
Jan
N = 813
Feb
N = 620
Frequency
200
100
Mar
N = 590
0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
Oocyte diameter

FIGURE 40

Frequency of occurrence of various sized oocytes (dated pooled) for 1974-1976 in sea snails, *Liparis liparis* at Berkeley (N = number of animals examined).


Jan
N = 610
Feb
N = 695
Mar
N = 435
Frequency
200
100
0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
Oocyte diameter

4.2.5. Sex Ratio

During 1975-1976, over the whole period in which sea snails are present at the various sampling sites, the sex ratio of male to female was 1 : 2.4 at Oldbury; 1 : 2.9 at Berkeley; and 1 : 5.9 at Hinkley Point. In the previous years, the corresponding ratio for Oldbury were 1 : 1.7 for 1973-1974; 1 : 2.9 for 1974-1975. At Berkeley the ratio was 1 : 1.9 in 1974-1975.

Nevertheless, there have been striking seasonal changes in sex ratios which are broadly similar in each of the three years at Oldbury (Table 12). Thus, at the time when the animals first appear in the estuary in the autumn (Figure 41), the ratio of male to female in pooled data for the three successive years (1973-1976) was 1 : 1.5 and remained at a similar value until December. In January and in subsequent months, the proportion of males decreased consistently and the ratio decreased from 1 : 4.1 in January to 1 : 11.4 in February and 1 : 18.0 in March. At Berkeley, the trends are very similar, the ratios remaining stable through the autumn at values almost identical with that at Oldbury but increasing in January to 1 : 3.3. Subsequent values although based on small numbers only, nevertheless show a tendency to decrease to a ratio of 1 : 16.0 in March. Numbers at Hinkley Point are very small but generally show an excess of females particularly in late winter and early spring.

The disappearance of the vast majority of males in January is probably due to their leaving the area earlier than the females on a downstream spawning migration. This is demonstrated by the fact that in January the absolute number of males in samples actually decreased by 23.3% in 1973-1974. In 1974-1975 the figure was 43.4%

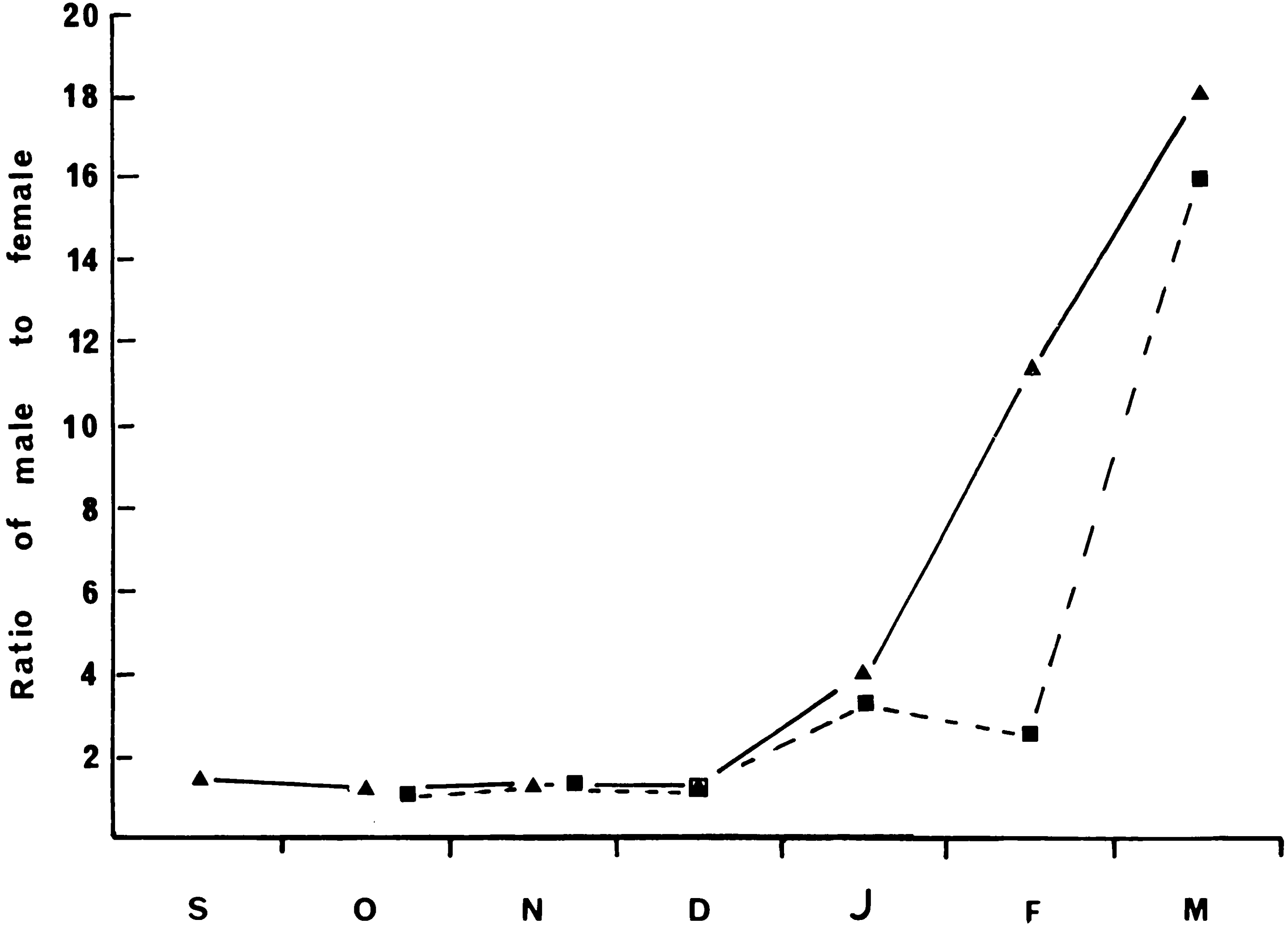
TABLE 12

The ratio of males to females in sea snails, *Liparis liparis*, shown monthly for data obtained between 1973-1976 in the Severn Estuary and the Bristol Channel. (Also included are the numbers examined).

MONTH/YEAR	OLDBURY			BERKELEY			HINKLEY POINT		
	Males	Females	Monthly Sex Ratio	Males	Females	Monthly Sex Ratio	Males	Females	Monthly Sex Ratio
1973–1974									
October	12	18	1 : 1.5						
November	22	28	1 : 1.3						
December	86	86	1 : 1.0						
January	20	60	1 : 3.0						
Annual Sex Ratio	140	192	1 : 1.40						
1974–1975									
August	0	1	0 : 1.00						
September	3	4	1 : 1.30	0	4	0 : 0.40			
October	15	15	1 : 1.00	39	43	1 : 1.10			
November	203	264	1 : 1.30	142	293	1 : 2.10			
December	691	761	1 : 1.10	254	356	1 : 1.40			
January	300	1200	1 : 4.00	60	200	1 : 3.30			
February	1	41	1 :41.00	1	1	1 : 1.00			
March	0	9	1 : 9.00	0	3	0 : 3.00			
Annual Sex Ratio	1213	2295	1 : 1.9	486	900	1 : 1.9			
1975–1976									
September	1	2	1 : 2.00						
October	0	0	0 : 0.00						
November	31	32	1 : 1.00	9	20	1 : 2.20	4	4	1 : 1.00
December	207	310	1 : 1.50	11	28	1 : 2.60	7	20	1 : 2.90
January	124	536	1 : 4.30						
February	6	39	1 : 6.50	1	3	1 : 3.00	1	32	1 : 3.20
March	1	9	1 : 9.00	1	13	1 :12.00	0	15	0 :15.00
Annual Sex Ratio	370	928	1 : 2.5	22	64	1 : 2.9	12	71	1 : 5.9

FIGURE 41

Ratio of male to female (♂:♀) from September to March at Oldbury (▲) and Berkeley (■) calculated from pooled data from 1973-1976.



Ratio of male to female
20
18
16
14
12
10
8
6
4
2
S
O
N
D
J
F
M

and 59.9% in 1975-76. At the same time in each year except 1973-1974, the number of females continued to increase during the same period. Thus, in 1974-1975 the females increased by 157.7%, while in 1975-1976 the increase was 172.9%.

4.2.6. Feeding Habits

i) Intensity of Feeding

In an attempt to demonstrate the intensity with which this species feeds in the Severn Estuary and the Bristol Channel, the total food content is presented as a percentage of the total body weight (Figure 42). These measurements show that the sea snail feeds continuously and intensively throughout the autumn and winter. Thus, when the first animals appear at Oldbury, the stomach contents accounted for 10% of the body weight, increasing to 25% in October and reaching a peak (34%) in January. A similar pattern was found in each successive season at Oldbury. At Berkeley and Hinkley Point, a similar trend was noted but only small numbers of stomachs were analysed (Figure 43).

In the winter months of 1975-1976 very high water temperatures were recorded and a large percentage of animals had empty stomachs (Figure 44). It is conceivable however, at this time (Figure 2) that the rate of metabolism increased substantially and the majority of the food organisms had already been digested.

The occurrence of a significant percentage of animals with stones, debris and polystyrene spherules (Kartar *et al*, 1976) suggests an indiscriminate mode of feeding. But the presence of debris of all kinds

FIGURE 42

Intensity of feeding of sea snails, *Liparis liparis* at Oldbury over the period studied (1973-1976).

● = the total percentage of food intake.

○ = the total percentage of *Gammarus spp.*

□ = the total percentage of *Crangon crangon*.

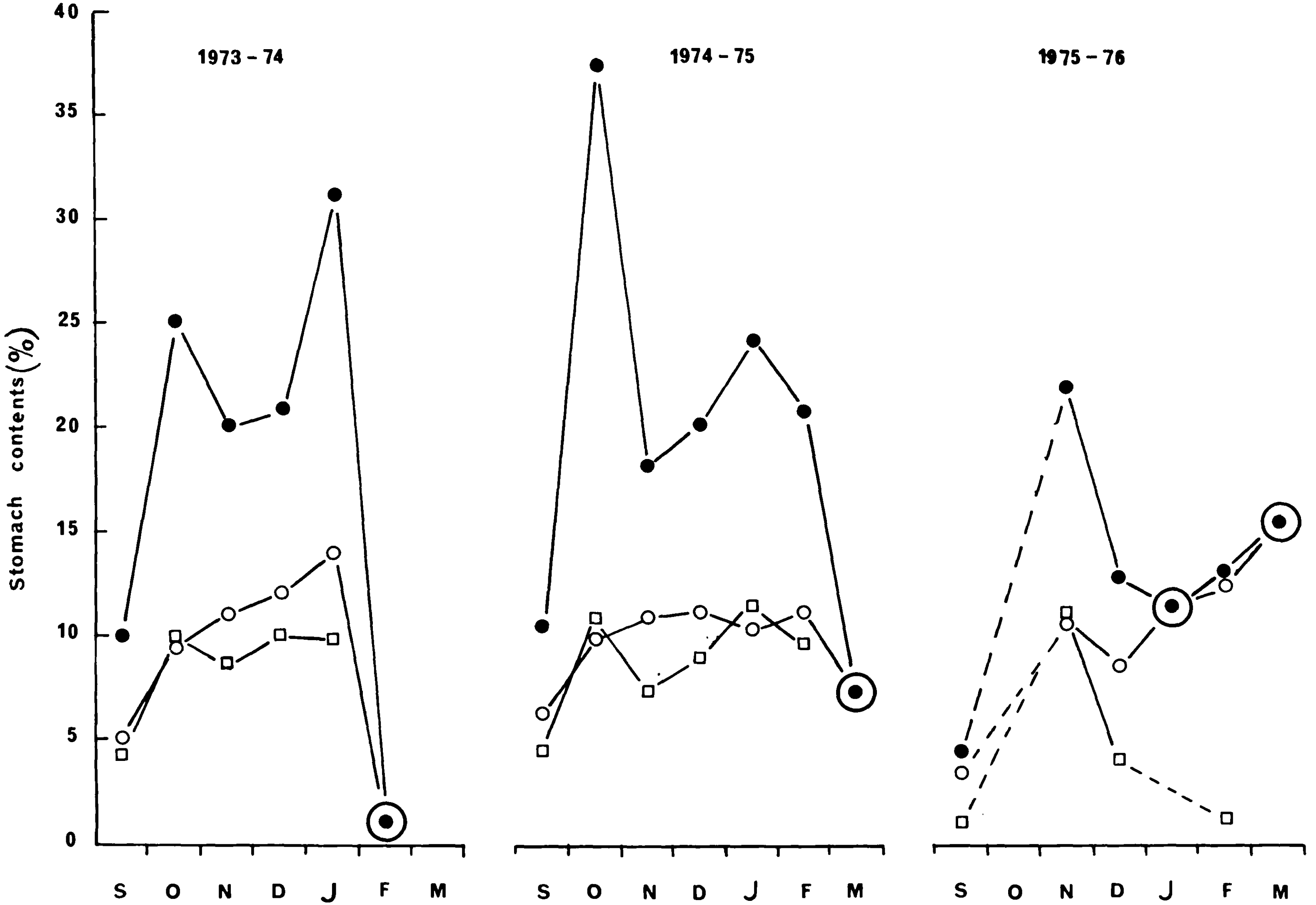

Stomach contents (%)
40
35
30
25
20
15
10
5
0
1973 - 74
1974 - 75
1975 - 76
S
O
N
D
J
F
M

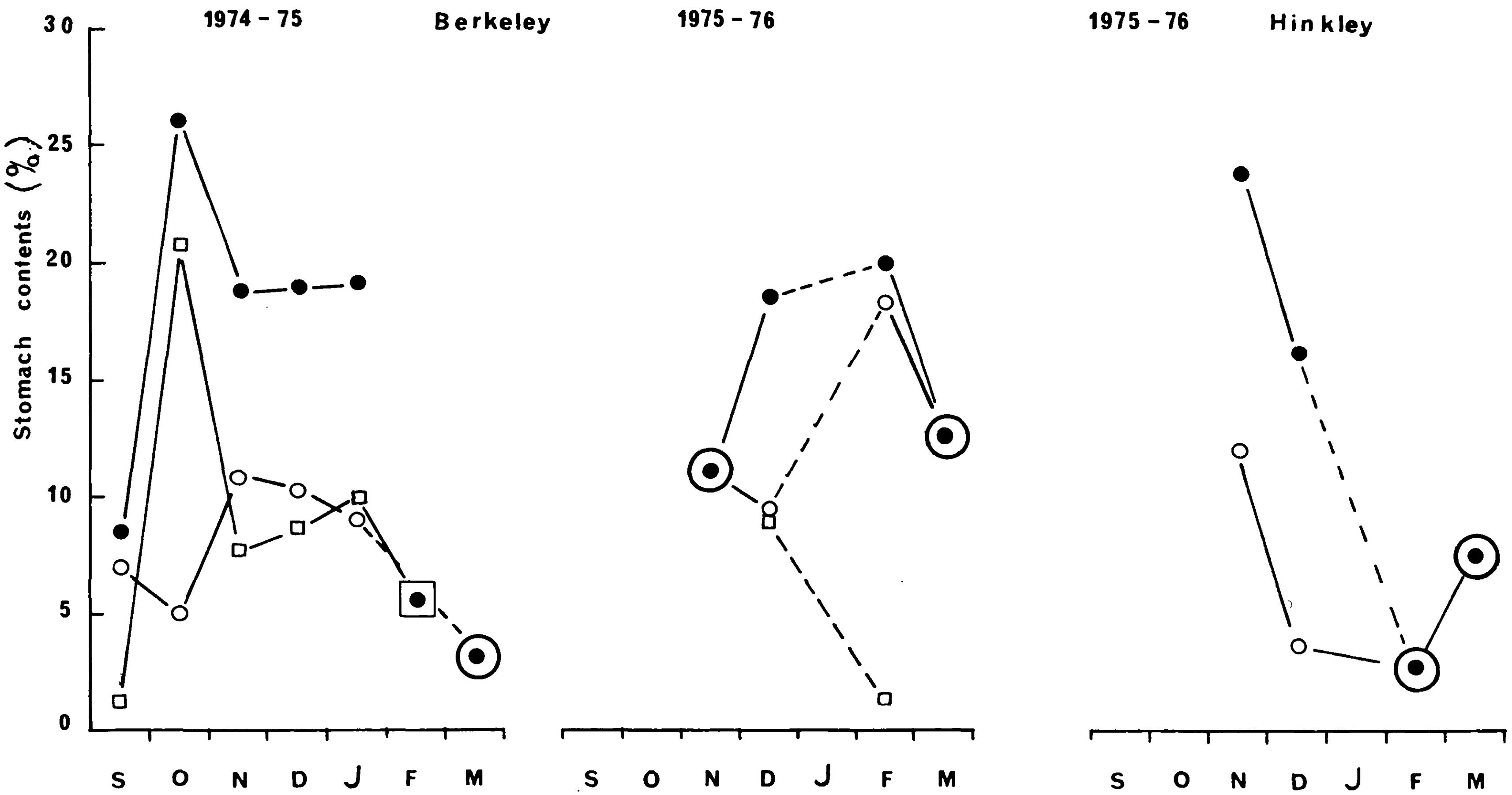
FIGURE 43

Intensity of feeding of sea snails, *Liparis liparis* at Berkeley (1974/1976) and Hinkley Point (1975/1976).

● = the total percentage of food intake.

○ = the total percentage of *Gammarus spp.*

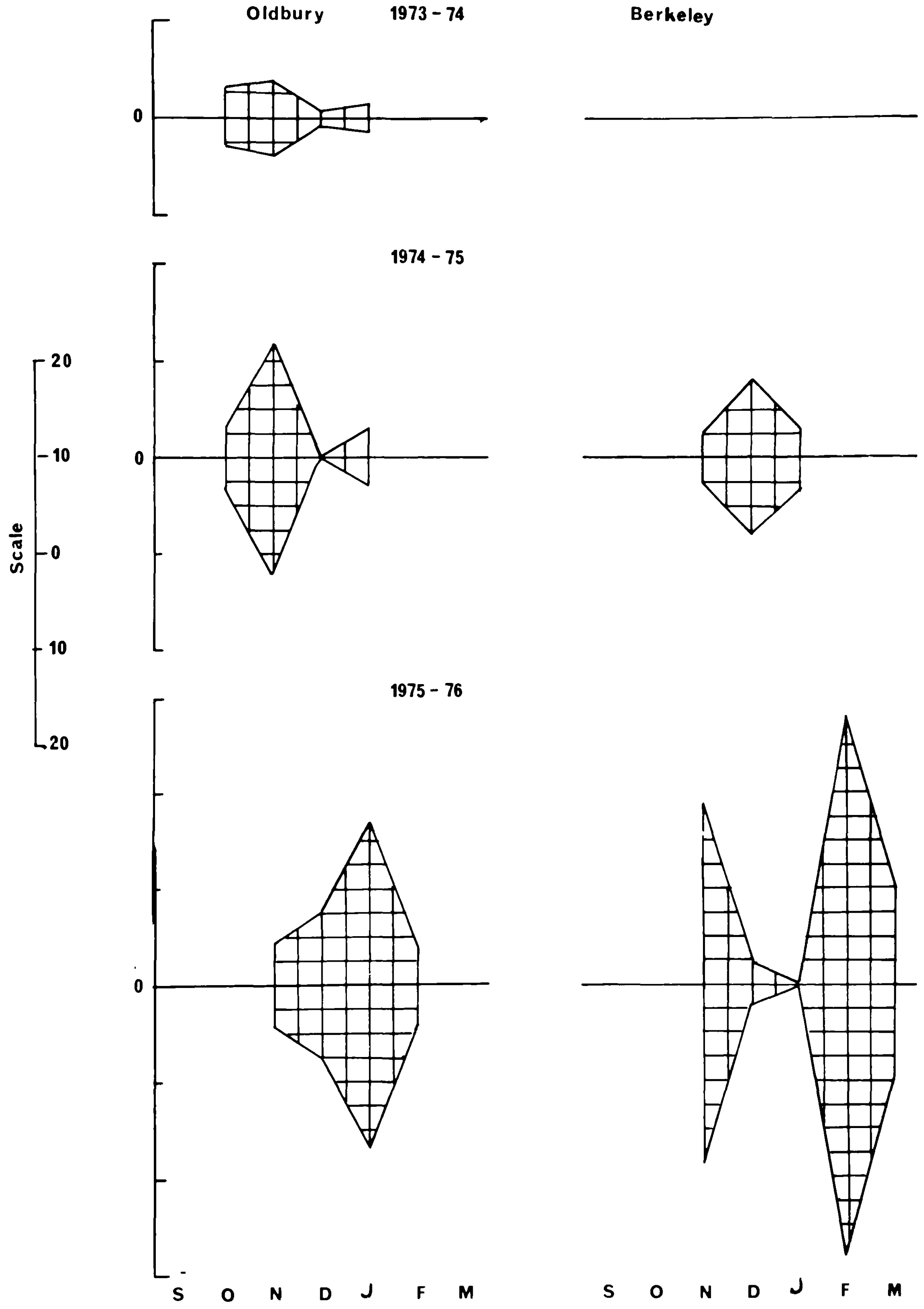
□ = the total percentage of *Crangon crangon.*



1974 - 75
Berkeley
1975 - 76
1975 - 76
Hinkley
Stomach contents (%)
30
25
20
15
10
5
0
S O N D J F M
S O N D J F M
S O N D J F M

FIGURE 44

Frequency of occurrence of sea snails, *Liparis liparis* with empty stomachs at Oldbury and Berkeley, expressed as a percentage of the total number of animals investigated.



Oldbury
1973 - 74
Berkeley
0
0
1974 - 75
0
Scale
20
10
0
10
20
1975 - 76
0
0
S O N D J F M
S O N D J F M

decreased from 5% in 1973 to 0.8% in December 1975 at Oldbury and this may be related to reduced rainfall and to the low amount of sediment present in the water. This trend of decrease of debris was evident at all the sites investigated.

ii) Dietary Organisms

In order to establish the major food organisms of sea snails, *Liparis liparis* in the Severn Estuary and the Bristol Channel, the stomach contents of over 6,960 animals were analysed. Thus, from Table 13 it can be seen that dietary preference of this species is directed mainly towards two major organisms, *Crangon crangon* and *Gammarus spp.* while *Pomatoschistus minutus*, *Neomysis* and *Idotea granulosa*, together with fish eggs, form minor food constituents.

Unlike *Ciliata mustela* (discussed later), Oldbury appears to be an ideal feeding ground for the sea snails and a large variety of food organisms have been found in their stomachs. However, just 8 km upstream at Berkeley, the principal food organisms were *Crangon crangon* and *Gammarus spp.* This is similar to the situation in the five bearded rockling, *Ciliata mustela* where only *Crangon crangon* and *Gammarus spp.* have been found in the stomachs. This confirms the author's previous view that the choice of food organisms at Berkeley is more limited than at Oldbury (may be as a consequence of the holding reservoir).

In the Bristol Channel, at Hinkley Point the major dietary component is *Gammarus spp.* (83.0%) with *Idotea granulosa*, *Neomysis* and *Crangon crangon* as minor food constituents. At Minehead where the number of sea snails samples was small (21) only *Gammarus spp.* were present in the stomachs (Figure 45).

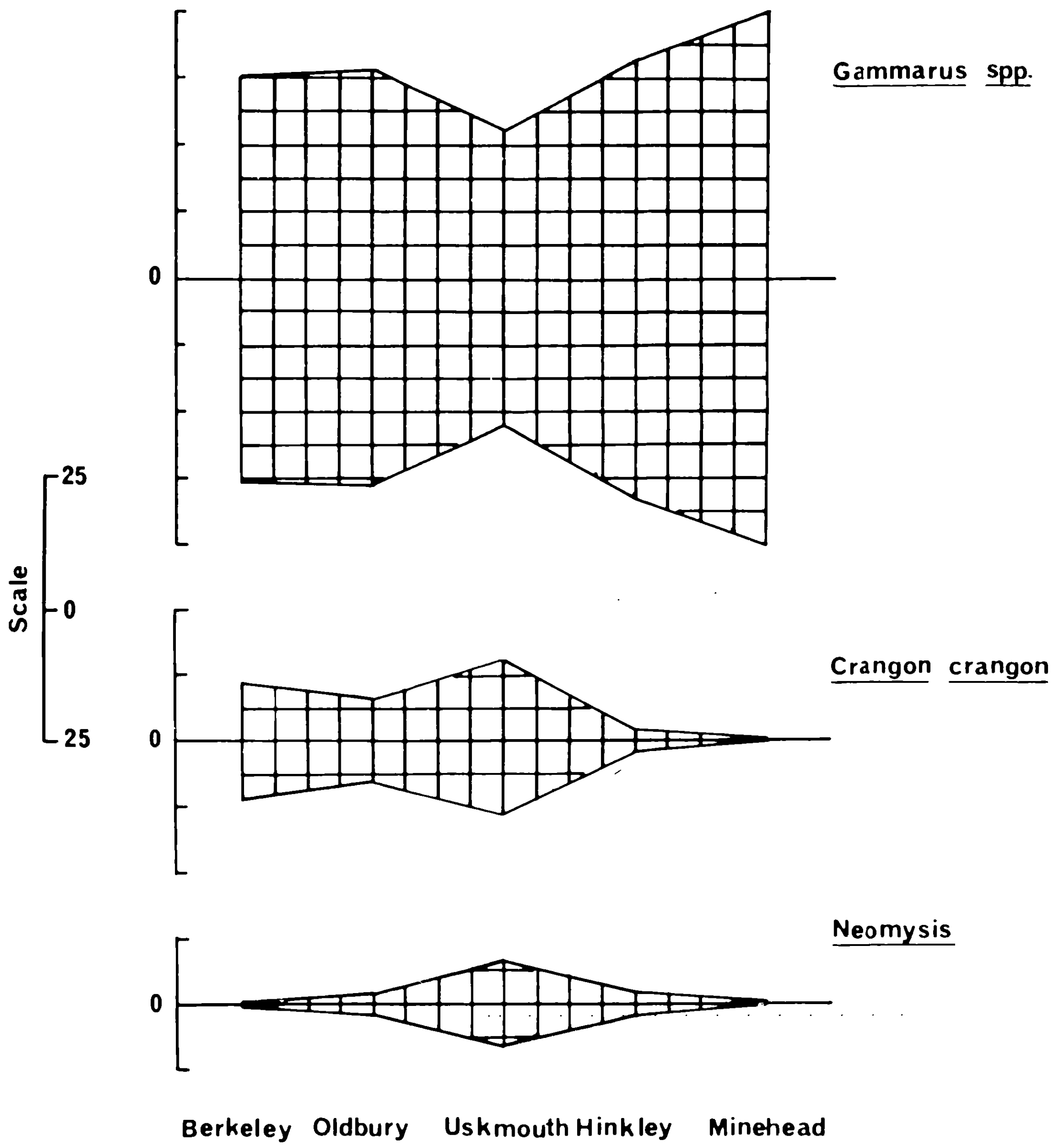
TABLE 13

The list of food organisms found in the stomachs of sea snails, *Liparis liparis*, and their relative importance measured as a percentage of stomachs/stomachs examined.

TAXONOMIC GROUP	INCLUDING SPECIES	% OF ORGANISMS IN THE STOMACH				
		OLDBURY	BERKELEY	USKMOUTH	HINKLEY	MINEHEAD
Isopoda	*Ideotea granulosa*	-	-	-	6.7	-
Mysidacea	*Neomysis*	3.5	-	16.67	3.33	-
Amphipoda	*Gammarus spp.*	78.59	78.19	55.55	83.34	100
Decopoda	*Crangon crangon*	16.96	23.81	27.78	3.33	-
Teleost	*Pomatoschistus minutus*	0.39	-	-	-	-
	Eggs (Fish	1.56	-	-	-	-
	Unidentified	-	-	-	3.33	-
NO. INVESTIGATED		5408	1436	14	83	21

FIGURE 45

Relative importance of dietary organisms in the stomachs of sea snails, *Liparis liparis* obtained at various sites in the Severn Estuary and the Bristol Channel, expressed as a percentage of the total number of animals with food organisms.


Gammarus spp.
Crangon crangon
Neomysis
Scale
25
0
25
0
0
0
Berkeley
Oldbury
Uskmouth
Hinkley
Minehead

iii) Seasonal and Annual Changes in Food Organisms

Whether the stomach contents (Tables 14 and 15) are expressed in terms of the weight of the total food organisms or as a frequency of occurrence (Figures 46 and 47 , the general picture at Oldbury is similar. In 1973/1974 the two major food organisms (i.e. *Crangon crangon* and *Gammarus spp.*) showed an inverse relationship; with the shrimps declining in importance in the diet in autumn, reaching minimum values by December. On the other hand, *Gammarus spp.* reach a maximum in December.

Comparing the three successive seasons, there has been an overall decrease in the importance of *Crangon crangon* in the diet, which in 1975/1976 represented only 8.6% by weight of stomach contents and occurred with a frequency of only about 6.7% in November. At the same time there is evidence that *gammarids* have become a more constant and significant feature of the diet in the last two seasons. *Neomysis*, which only represented a small proportion of the winter diet in 1973-1975, was not recorded at all in 1975/1976 at Oldbury.

iv) Dietary Constituents at Other Sites

Although at Berkeley the number of animals studied was less (1,500).than at Oldbury. Tables 16 and 17 show that either by frequency of occurrence or by a percentage of the total weight, *Crangon crangon* and *Gammarus spp.* are the only two major food components observed in 1974/1975 and 1975/1976 in the stomachs of the sea snails caught in the cooling water intakes. The overall pattern of decrease in *Crangon crangon* (Figures 48-49) is identical to Oldbury. Thus, the drop in the *Crangon crangon* level corresponds to an increase in the uptake of *gammarids*.

TABLE 14

Frequency of occurrence of major dietary organisms in each successive year (1973-76) in sea snails, *Liparis liparis*, obtained in the cooling water intake screens of Oldbury Power Station, expressed as a percentage of the total number of animals examined (Also included are the numbers investigated.

MONTH/YEAR	NO. INV.	*Crangon crangon*	*Gammarus spp.*	*Neomysis*	Debris	Eggs *P. minutus*
Sep 1973	2	50	-	-	50	-
Oct	30	79.2	20.8	-	-	1.6
Nov	50	52.6	42.5	3.3	-	-
Dec	170	13.6	82.3	2.1	-	-
Jan 1974	80	36.4	51.2	7.3	5.1	-
Feb	2	100	-	-	-	-
Sep 1974	7	5.3	94.7	-	-	-
Oct	30	27.3	50.0	6.8	-	15.9
Nov	400	37.3	51.0	3.9	7.8	-
Dec	1400	29.5	45.9	24.6	-	-
Jan	1400	15.4	79.0	4.0	1.6	-
Feb	42	13.7	86.3	-	-	-
Mar	9	17.8	82.2	-	-	-
Nov 1975	630	8.6	91.4	-	-	-
Dec	500	5.5	93.7	-	0.8	-
Jan 1976	600	-	100	-	-	-
Feb	46	2.8	97.2	-	-	-
Mar	10	-	100	-	-	-

TABLE 15

Relative importance of food organisms by weight in each successive year (1973-1976) in sea snails, *Liparis liparis*, obtained in the cooling water intake screens of Oldbury Power Station, expressed as a percentage of the total weight of food organisms in stomachs. (Also included are the numbers investigated).

MONTH /YEAR	NO. INV.	*Crangon crangon*	*Gammarus spp.*	*Neomysis*	Debris	Eggs *P. minutus*	Empty
Sep '73	2	50.0	-	-	50.0	-	-
Oct '73	30	54.9	41.9	-	-	-	3.2
Nov '73	50	25.5	52.9	15.7	-	2.0	3.9
Dec '73	170	5.5	91.7	2.2	-	-	0.6
Jan '74	80	30.3	62.1	6.1	3.0	-	1.5
Feb '74	2	100.0	-	-	-	-	-
Sep '74	7	8.3	91.70	-	-	-	-
Oct '74	30	16.7	60.0	6.7	-	13.3	3.3
Nov '74	400	31.0	47.6	2.4	7.1	-	11.9
Dec '74	1400	36.3	27.3	36.4	-	-	-
Jan '75	1400	10.0	81.3	2.9	2.9	-	2.9
Feb '75	42	15.6	84.4	-	-	-	-
Mar '75	9	11.1	88.9	-	-	-	-
Nov '75	500	6.7	88.9	-	-	-	4.4
Dec '75	500	4.8	86.3	-	1.5	-	7.6
Jan '76	600	-	83.3	-	-	-	16.7
Feb '76	46	3.6	92.8	-	-	-	3.6
Mar '76	10	-	100	-	-	-	-

TABLE 16

Frequency of occurrence of major dietary organisms in each successive year (1974-1976) in sea snails, *Liparis liparis*, obtained from the cooling water intake screens of Berkeley Power Station, expressed as a percentage of the total number of animals examined. (Also included are the numbers investigated).

MONTH/YEAR	NO. INV.	*Crangon crangon*	*Gammarus spp.*	Debris
Sep '74	4	40.0	60.0	-
Oct '74	82	70.0	30.0	-
Nov '74	400	40.4	59.6	-
Dec '74	600	38.3	61.7	-
Jan '75	260	7.9	92.1	-
Feb '75	2	100.0	-	-
Mar '75	3	-	100.0	-
Nov '75	29	13.5	86.5	-
Dec '75	39	12.7	87.3	-
Feb '76	4	7.1	92.9	-
Mar '76	13	-	98.5	1.5

TABLE 17

Relative importance of food organisms by weight in each successive year (1974-1976) in sea snails, *Liparis liparis*, obtained in the cooling water intake screens of Berkeley Power Station, expressed as a percentage of the total weight of stomach contents. (Also included are the numbers investigated.

MONTH /YEAR	NO. INV.	*Crangon crangon*	*Gammarus spp.*	Debris	Empty
Sep 74	4	50.0	50.0	-	-
Oct '74	82	56.3	47.5	-	-
Nov '74	400	38.1	59.5	-	2.4
Dec '74	600	50.0	41.7	-	8.3
Jan '75	260	10.5	86.5	-	3.0
Feb '75	2	100.0	-	-	-
Mar '75	3	-	100.0	-	-
Nov '75	29	18.2	63.6	-	18.2
Dec '75	39	10.9	86.9	-	2.2
Feb '76	4	14.3	57.1	-	28.6
Mar '76	13	-	80.2	9.9	9.9

FIGURE 46

Occurrence of major food organisms by weight in the stomachs of sea snails, *Liparis liparis* obtained from the intake screens of Oldbury Power Station during 1973-1976, expressed as a percentage of the total weight of the stomach contents.

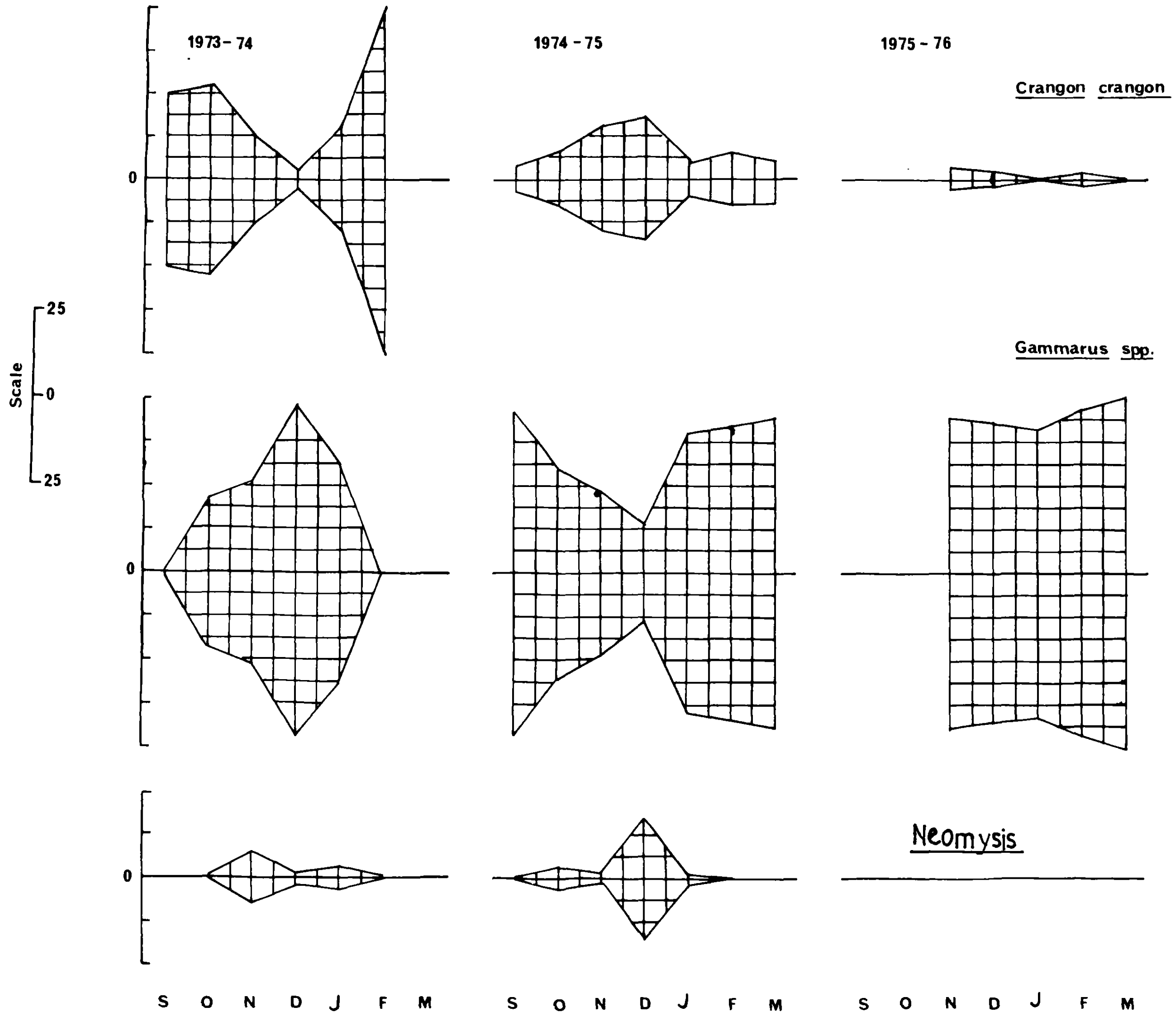
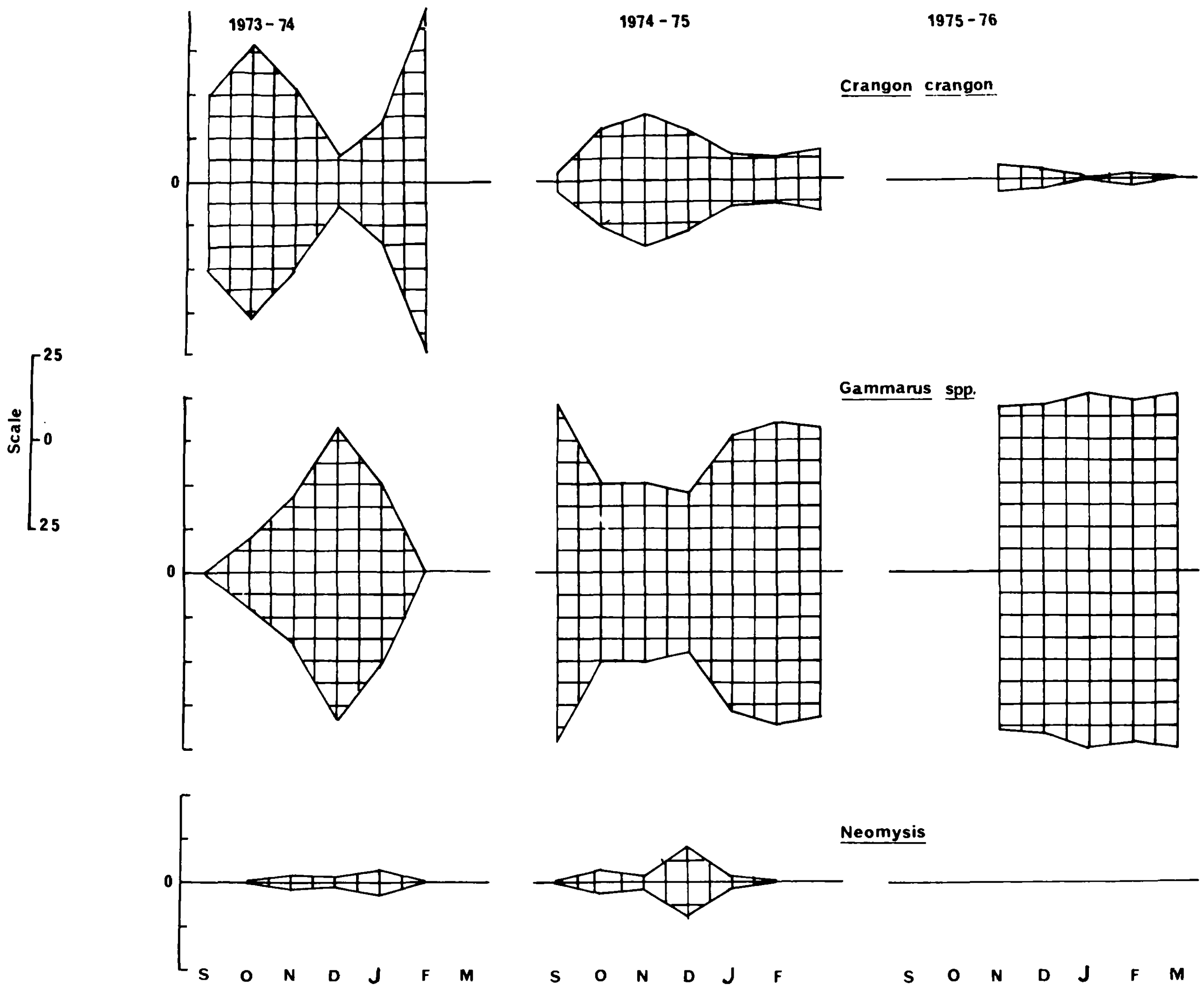

1973-74
1974-75
1975-76
Crangon crangon
Gammarus spp.
Neomysis
Scale
25
0
25
0
0
0
S O N D J F M
S O N D J F M
S O N D J F M

FIGURE 47

Frequency of occurrence of principal food organisms in the stomachs of sea snails, *Liparis liparis* obtained from Oldbury 1973-1976, expressed as a percentage of the total number of animals investigated.



Scale
25
0
25
1973 - 74
1974 - 75
1975 - 76
Crangon crangon
Gammarus spp.
Neomysis
0
0
0
S O N D J F M
S O N D J F
S O N D J F M

FIGURE 48

Occurrence of major food organisms by weight in the stomachs of sea snails, *Liparis liparis* obtained from the intake screens of Berkeley Power Station during 1974-1976, expressed as a percentage of the total weight of the stomach contents.

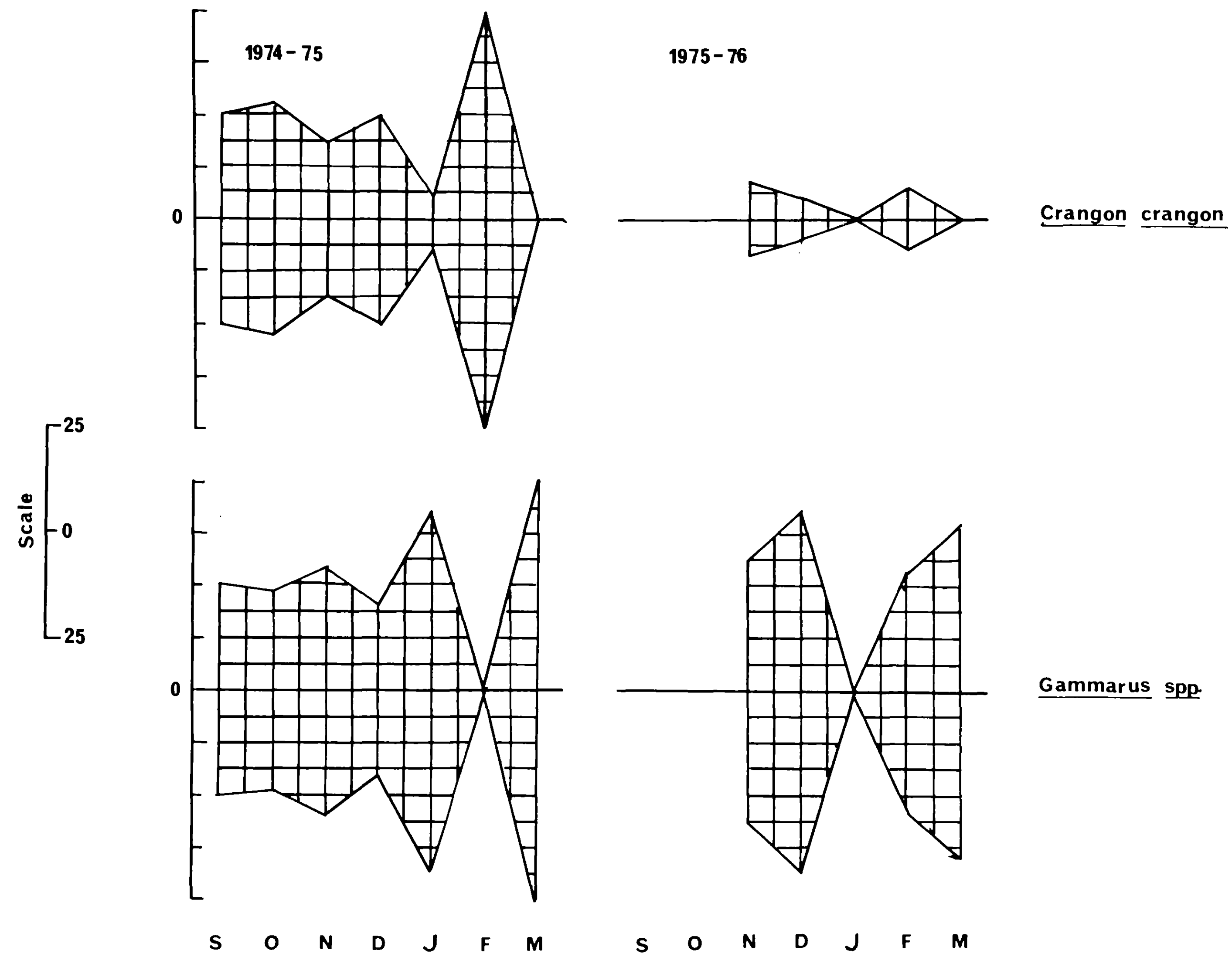
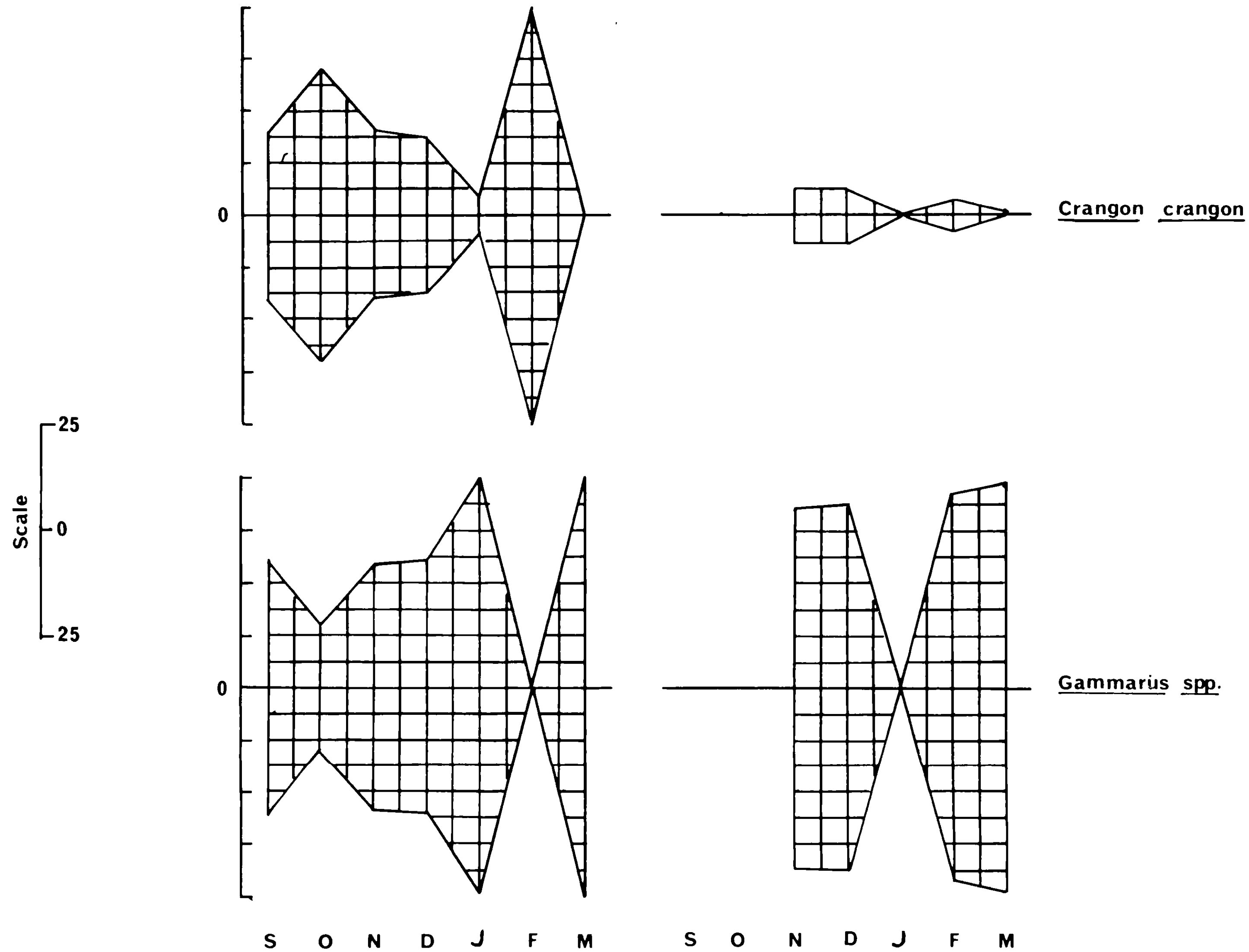

1974 - 75
1975 - 76
0
0
Scale
25
0
25
S O N D J F M
S O N D J F M
Crangon crangon
Gammarus spp.

FIGURE 49

Frequency of occurrence of principal food organisms in the stomachs of sea snails, *Liparis liparis* obtained at Berkeley during 1974-1976, expressed as a percentage of the total number of animals investigated.


Scale
25
0
25
0
0
S O N D J F M
S O N D J F M
Crangon crangon
Gammarus spp.

In order to obtain a more complete picture of the feeding behaviour of this species in the study area, dietary investigations were also conducted on animals obtained from Uskmouth, approximately ½ km upstream of the confluence of the River Usk with the Severn. This site experiences wide fluctuations in salinity, depending on the state of the tide and the season. The number of animals examined although small, (Tables 18-19) show a similar feeding pattern to those from Oldbury. Thus, 26.3% and 52.6% of the animals examined contained *Crangon crangon* and *Gammarus spp.* respectively (frequency of occurrence). There was no difference in the manner of feeding when these two major food constituents were presented as a percentage of the total weight of the stomach contents.

At Hinkley Point a large variety of food organisms were present in the stomachs, but *Gammarus spp.* (Tables 20 & 21) were the major food item either by the frequency of occurrence or by percentage of the total food weight, *Crangon crangon* and *Idotea granulosa* were the next most important prey species.

At Minehead, which is situated in an entirely marine environment, *Gammarus spp.* (Tables 18 & 19) also appeared to be the major food item by preference and frequency of occurrence in the early migrant sea snails (no data is available for fish caught later than August).

4.2.7 Parasite Infestation

At Oldbury, where the intake water is drawn from a holding reservoir built in front of the station, a greater number of animals were infested with nematodes in 1974/1975 (Table 22) than in the other years. The instance of parasite infestation at Berkeley was similar to Oldbury and a similar pattern was noted at the other sampling sites.

TABLE 18

Frequency of occurrence of major dietary organisms in sea snails, *Liparis liparis*, obtained from the intake screens of Uskmouth Power Station and from the fish weir at Minehead during 1975-76, expressed as a percentage of the total number of animals examined.

Locality	No. Inv.	*Crangon crangon*	*Gammarus* spp.	*Neomysis*	Debris	Empty
Uskmouth	14	26.3	52.6	15.8	5.3	-
Minehead	21	-	80.0	-	-	20.0

TABLE 19

Relative importance of food organisms by weight in sea snails, *Liparis liparis*, obtained from the intake screens of Uskmouth Power Station and from the fish weir at Minehead during 1975-1976, expressed as a percentage of the total weight of stomach contents. (Also included are the numbers investigated.

LOCALITY	NO. INV.	*Crangon crangon*	*Gammarus* spp.	*Neomysis*	Debris
Uskmouth	14	25.5	65.9	7.4	1.2
Minehead	21	-	100	-	-

TABLE 20

Frequency of occurrence of major dietary organisms in sea snails, *Liparis liparis*, obtained from the cooling water intake screens of Hinkley Point Power Station during 1975-76, expressed as a percentage of the total number of animals examined. (Also included are the numbers investigated).

MONTH /YEAR	NO. INV.	*Crangon crangon*	*Gammarus spp.*	*Neomysis*	*Idotea granulosa*	Unidentified	Debris	Empty
Nov '75	8	-	37.5	-	25.0	-	12.5	25.0
Dec '75	27	-	25.0	-	-	12.5	-	62.5
Feb '76	33	3.6	71.4	-	-	-	-	25.0
Mar '76		-	60.0	20.0	-	-	-	20.0

TABLE 21

Relative importance of food organisms by weight in sea snails, *Liparis liparis*, caught in the cooling water intake screens of Hinkley Point Power Station during 1975-76, expressed as a percentage of the total weight of food/stomach contents. (Also included are the numbers investigated).

MONTH /YEAR	NO. INV.	*Crangon crangon*	*Gammarus spp.*	*Neomysis*	*Idotea granulosa*	Unidentified	Debris	Empty
Nov '75	8	-	44.5	-	33.3	-	22.2	-
Dec '75	27	-	88.0	-	-	12.0	-	-
Feb '76	33	10.6	89.4	-	-	-	-	-
Mar '76	33	-	90.0	10.0	-	-	-	-

TABLE 22

Parasite infestation *(Nematode spp.)* in sea snails, *Liparis liparis*, caught at the various sampling sites along the Severn Estuary and the Bristol Channel, expressed as a percentage of the total number of animals obtained from 1973-1976.

LOCALITY	1973 / 1974	1974 / 1975	1975 / 1976
Middle Reaches of Severn Estuary			
Oldbury	2.2 - 5.7	2.3 - 15.4	2.2 - 6.7
Berkeley	-	2.5 - 15.0	2.3 - 7.0
Uskmouth	-	-	2.3 - 5.9
Bristol Channel			
Hinkley Point	-	-	3.6 - 12.5
Minehead	-	-	1.0 - 2.0

Thus it is reasonable to deduce that, as in the case of the flounder and the five bearded rockling, the reservoir does not influence the number of animals that contain nematodes.

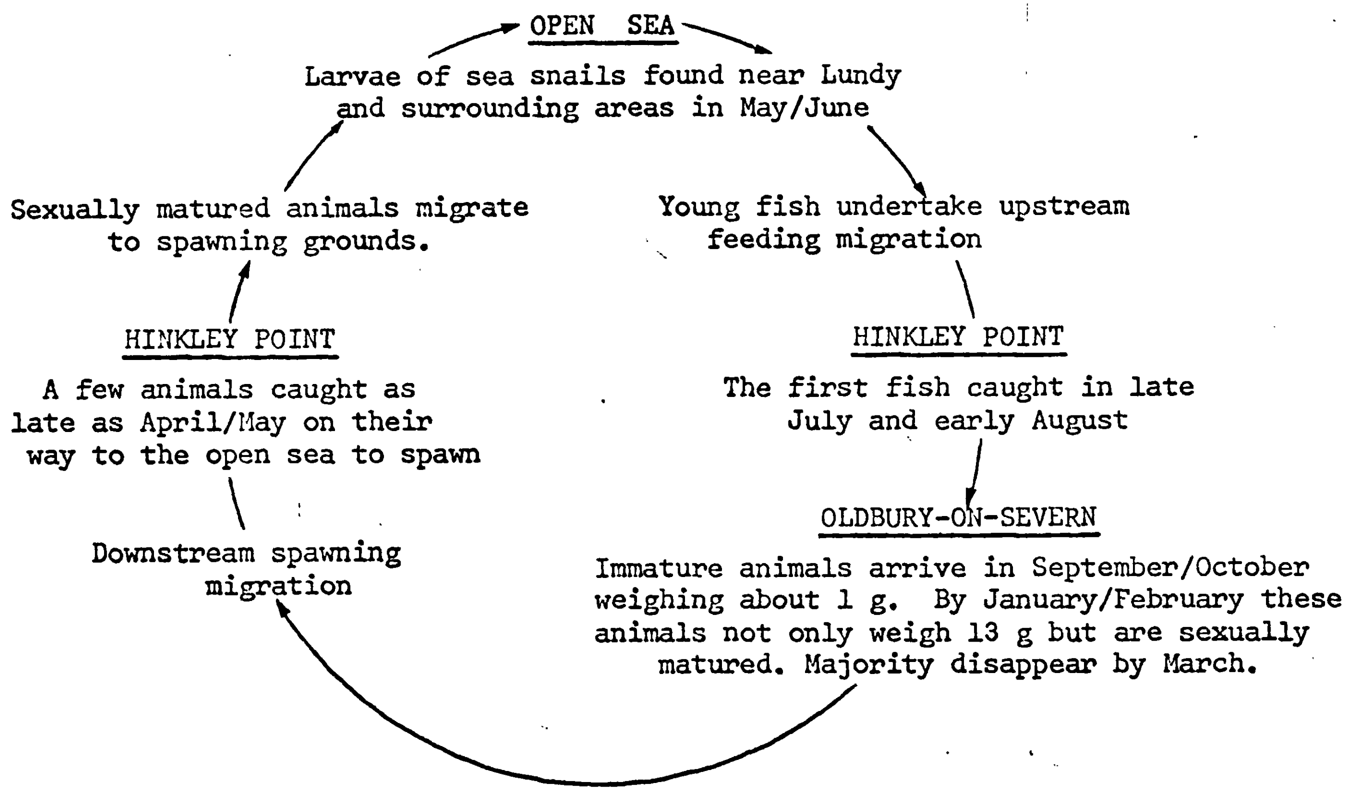
4.3. DISCUSSION

In an attempt to understand the ecology of the Severn Estuary and the Bristol Channel, one cannot ignore the importance of sea snails, *Liparis liparis* as they consitute at least 20% of the total fish population caught in the middle reaches of the Severn Estuary. The estuarine life history of this fish has not been previously studied. In particular there is a complete gap in our knowledge of its migratory behaviour, life span, dietary habits and the spawning period. It is commonly known that this species occurs in abundance during the winter period in estuaries of Great Britain and north-western Europe (Wheeler, 1969) but hardly anything else is known about its contribution to the marine community.

This species first makes its appearance in the Bristol Channel at Hinkley Point (Fig. 50) as early as July but at this time they are probably too small to be trapped in any significant numbers in the cooling water intake system of the power station. However, 70 miles upstream, some two to three months later, sea snails are large enough to be trapped in the filter screens, suggesting some feeding activity along the route from the channel to the estuary. The long upstream migration of the young fish into the estuary is also recognised in other species such as the whiting, sand gobies, five bearded rocklings, bass etc. at this locality and the main population of the upstream migrant sea snails begins to

FIGURE 50

Life cycle of Sea snails, *Liparis liparis* in the Severn Estuary and The Bristol Channel.



arrive in appreciable numbers in the estuary by late October and the majority of the population of a uniform size and weight were found in abundance during December. The assumption that the Severn area is a rich feeding ground is amply justified in the growth studies of this species. Sea snails grow phenomenally within a short period of time from a length of about 40 mm when they first arrive in October, to around 110 mm in the sexually mature fish in December/February. After February they disappear complètely from the estuary, presumably to spawn. These findings, however, conflict with those of Wheeler (1969) who defined the spawning period of this species as between December and February. Over the period of investigation (1972-1976) we found no evidence that the spawning migration commences before the end of January, nor have any spent fish been caught to substantiate Wheeler's findings. There is, however, ample indication from our sex ratio studies that males of this species undertake a downstream spawning migration much earlier than the females, sometime in late December, perhaps to select spawning grounds or to prepare 'nests' but we have no observations with which to substantiate this hypothesis. However, since the disappearance of the males has coincided with the attainment of minimum water temperature, the possibility cannot be excluded that this may be a factor in their migration.

The seasonal or annual abundance of this species in the Severn has not followed any consistent trend. In particular, the low numbers in the winter of 1973/1974 and 1976/1977 are difficult to explain. Although water temperatures and salinities have increased from 1972-1976 and dropped thereafter in 1976/1977, these changes do not correlate with the fluctuations in the sea snail numbers. During the two periods when small numbers of sea snails were caught, there is no evidence to suggest changes in the rate of water intake by the Power Station. Further, there is no evidence of a general reduction in the relative abundance of its chief food organisms, e.g. *Crangon crangon* or *Gammarus spp.* These variations in sea snail populations may be caused by some environmental factors as yet unknown or may represent natural fluctuations.

In the present study the length/frequency distributions suggest that the population in December consists mainly of 0+ year class and possibly a few 1+ fish. Earlier work (Kartar, 1974) using otolith analysis had suggested that in addition to the main 0+ class, a few specimens were present which may have represented 1+ and 2+ fish, but these would form only a very small proportion of the estuarine population and would not be apparent in the length/frequency histograms. Size differences between the sexes might also account for the wide dispersion of the length-frequency distributions.

Although the two stations, Oldbury and Berkeley, operate different screening mechanisms, superimposition and coincidence of the length-frequency curves suggest no discrimination relative to size or shape, despite the differences in the sampling procedures, thus confirming our earlier findings on flounders, that the fish population obtained from Oldbury Power Station is fairly representative of those in the Severn Estuary and the Bristol Channel.

From the growth characteristics it is evident that increase in length and weight (at all the sites investigated) is typical for this species in the estuary and the Channel despite the differences in the two environments. This view is further confirmed by the studies on the gonadosomic ratios of sea snails which indicate a similar but consistent rate of maturation in animals from the marine and estuarine environments, which, however, is more apparent in the females.

However, the significance of a slower gonadal growth (almost down by three-fold compared to other years) in 1973/1974 is not apparent and it is conceivable that biophysical changes in the environment might be responsible*.

The feeding habits of sea snails, like that of all the major estuarine and marine species studied, depend essentially upon selectivity by the fish rather than the availability of food organisms at each locality. It would appear that environmental conditions are less favourable at Berkeley, as the variety food organisms found in the stomachs were limited to two species.

Crangon crangon remains the prime food item at all sites in the Severn, but during the latter half of this research it was noted that *Gammarus spp.* became much more important. Whether this is because of selective preference or increasing abundance of gammarids is not clear. However, there is no evidence to suggest that the abundance of shrimps is in any way greater than other major species at a particular locality. Comparing all the years studied at Oldbury and Berkeley, it is clear that the number of fish consuming *Crangon crangon* actually decreased with a corresponding rise in the uptake of *Gammarus spp.* This anomaly is most perplexing, especially since *Crangon crangon* was abundantly available at these sites throughout.

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*One other factor that emerges from the present study is that slower gonadal growth experienced in 1973/74 sea-snail populations corresponds to low density of this species at the sampling sites.

As no data is available for other sites in 1974/1975, it is difficult to assess whether this behaviour is typical of the Severn Estuary and the Bristol Channel as a whole. This relationship between the utilisation of shrimps and gammarids has also been observed in other species studied, such as five bearded rocklings, flounders, etc.

In 1973/1974, a reciprocal relationship was noted between the frequency of occurrence of shrimps and that of gammarids. Thus, the occurrence of shrimps declined during the autumn reaching minimum values by December, while on the other hand, gammarids reached their peak frequency of occurrence in the stomachs of sea snails at Oldbury and Berkeley by December.

At the other sites investigated, ie. Uskmouth, similar feeding trends were observed to those of Oldbury and Berkeley, with *Gammarus spp.* and *Crangon crangon* as major food items, in order of importance. At Hinkley Point while *Gammarus spp.* remained the major food organism, shrimps and *Idotea granulosa* were the next most important species.

The presence of debris which is common in other species (Kartar, *et al* 1973, 1976) essentially reflects the habits of the fish and their somewhat indiscriminate feeding.

Like the majority of fish in the region, sea snails, *Liparis liparis* are infested by parasites. The degree of infestation by nematodes has been shown to be uniform over the whole area, but varies from one fish species to another.

PART 5

FIVE BEARDED ROCKLING, *CILIATA MUSTELA*

5. FIVE BEARDED ROCKLING, *CILIATA MUSTELA*

5.1. INTRODUCTION

Although the five bearded rockling, *Ciliata mustela* is found in abundance along the shores and in the estuaries of England and Northwest Europe, its life history has been largely ignored. Since *Ciliata mustela* is an important predator (see below) for economic reasons alone it deserves study, but apart from the preliminary work of Wheeler (1969), little is known of its detailed biology. The five bearded rockling is a small elongate fish belonging to the family Gadidae. Wheeler (1969) states that this fish is abundant between the tide marks in rocky shores and in sandy intertidal pools where there are rocks for protection. Larger individuals are to be found sublittorally in muddy, sandy or shell gravel grounds. In addition, Wheeler gives a brief description of diet, which is predominantly crustacean, and outlines the early life history. Coad (1973) also investigated the diet of *Ciliata mustela* and in his study of three species of littoral fishes caught in rock pools on the Gower Penninsular. His findings indicate that the five bearded rockling is predatory in habit; crustacea accounting for 75% of the diet. No variation in diet between large and small individuals was observed.

5.2. RESULTS

5.2.1 Seasonal Changes in Sample Frequency

In order to obtain information on the general movement of the five bearded rocklings near the sampling site at Oldbury, the numbers of *Ciliata mustela* (Plate 20) caught during a twenty-four weekly collection period were recorded. While there have been marked short-term fluctuations in number in the weekly samples (Fig. 51), longer term trends can nevertheless be recognised, especially when sample data are adjusted to monthly totals, taking into account the inlet flow standardised at a constant level of 280 x 10^6 gall/day.

Over the period of observation a seasonal pattern emerges. Thus, the fish first appear in August/September and increase in numbers by late autumn. In 1973/1974 numbers increased gradually, reaching a maximum in November, but during 1974/1975 and again in 1975/1976, the migrants approached the estuary earlier and reached peak numbers between October and December. Thereafter, numbers dropped rapidly and by March, no fish are caught in the power station screens. Exceptionally large numbers were recorded in 1974/1975. Their movement through the estuary is indicated by their appearance at Hinkley in July and at Oldbury or Berkeley in September. By March the majority of five bearded rocklings appear to move out of the Hinkley region, although individuals were collected from Uskmouth between October and January in 1975/1976.

At Minehead five bearded rocklings are found throughout the year although numbers are slightly reduced between May and September. Thus, in Fig. 52 it can be observed that fluctuations in numbers

FIGURE 51

Monthly fluctuations in abundance of five bearded rocklings, *Ciliata mustela* caught in the filter screens of Oldbury Power Station during 1973-1976.

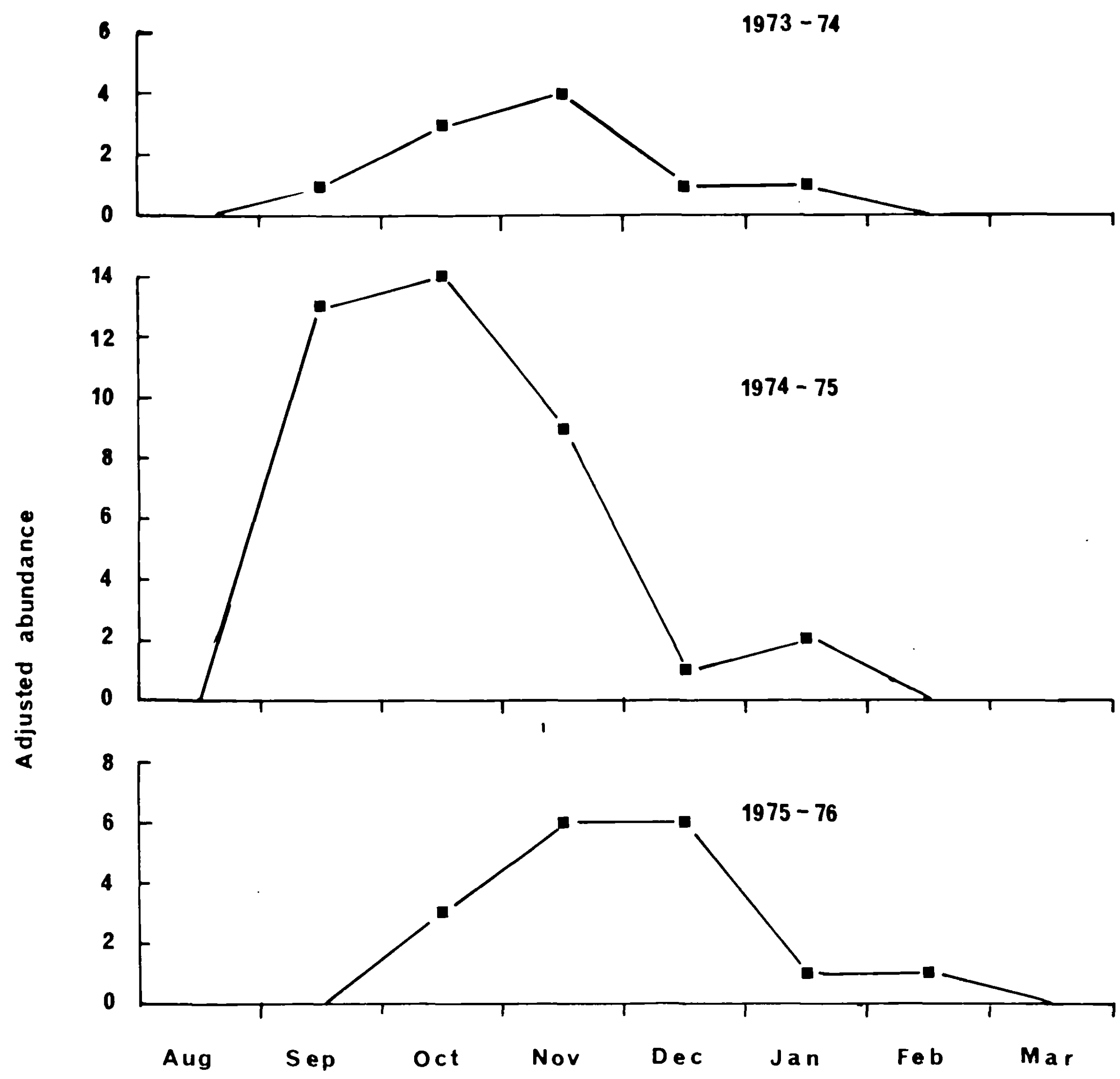
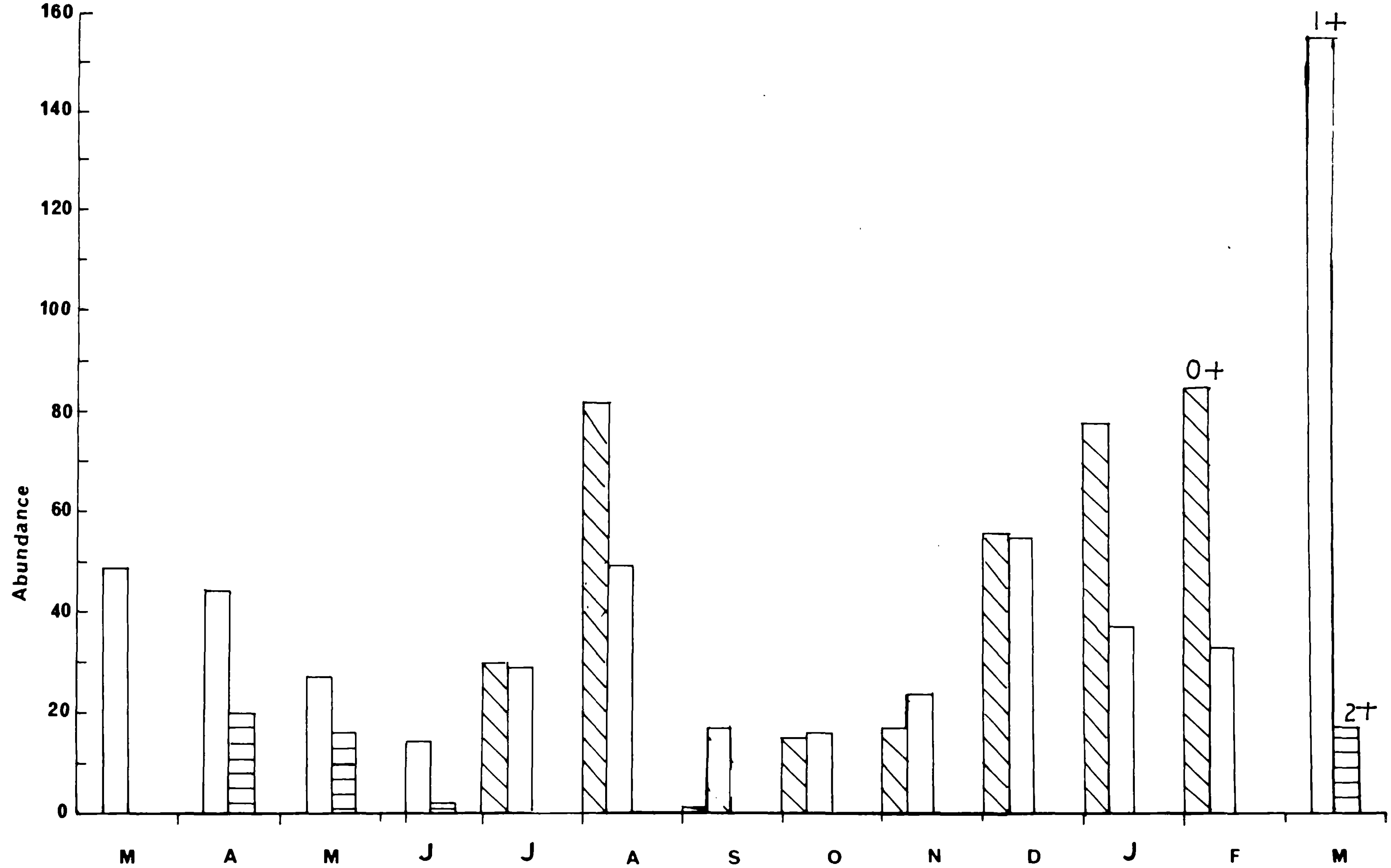

1973 - 74
1974 - 75
1975 - 76
Adjusted abundance
6
4
2
0
14
12
10
8
6
4
2
0
8
6
4
2
0
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar

FIGURE 52

Distribution of various age class five bearded rocklings, *Ciliata mustela* in monthly samples obtained from Minehead during 1975-1976.



160
140
120
100
80
60
40
20
0
Abundance
M
A
M
J
J
A
S
O
N
D
J
F
M
1+
0+
2+

at Minehead are entirely due to an inverse relationship between the two major age classes, the 0+ age class migrating into the area to feed and grow, whereas the 1+ group move away to spawn. The number of animals belonging to the 2+ group is too small to have any substantial effect on the total population at the sampling sites.

5.2.2. Age Structure

Due to the small numbers of animals obtained from Oldbury and Berkeley, it was not possible to identify age groups from length-frequency curves. Otolith analyses indicate the presence of only one dominant class at Oldbury, but at Minehead (Fig. 53) there appear to be at least two major age classes, the 0+ and 1+; the first year class (0+) appear in appreciable numbers in July and are represented by a mode of 72-92 mm. This increases to ∿130 mm by October and ∿150 mm in November. In July and more distinctly in October, a second mode appears in the length-frequency curves (probably representing the 1+ age class) of 192-212 mm but this group was not observed in the small numbers of animals collected in August. Although the length-frequency distribution data then becomes rather confused, there are a few animals probably belonging to the 2+ class, as indicated by a mode at 230 mm and this is substantiated by otolith counts. The results of otolith ageing are indicated in Fig. 53.

5.2.3. Growth in Length and Weight

Mean lengths for various age groups based on otolith readings, were calculated from measurements made between March 1975 and March 1976

FIGURE 53

Age determination of five bearded rocklings, *Ciliata mustela* using length-frequency distribution for animals caught at Minehead. Superimposed are the otolith findings for

0+ (- - -)

1+ (———) and

2+ (.....)

year classes.

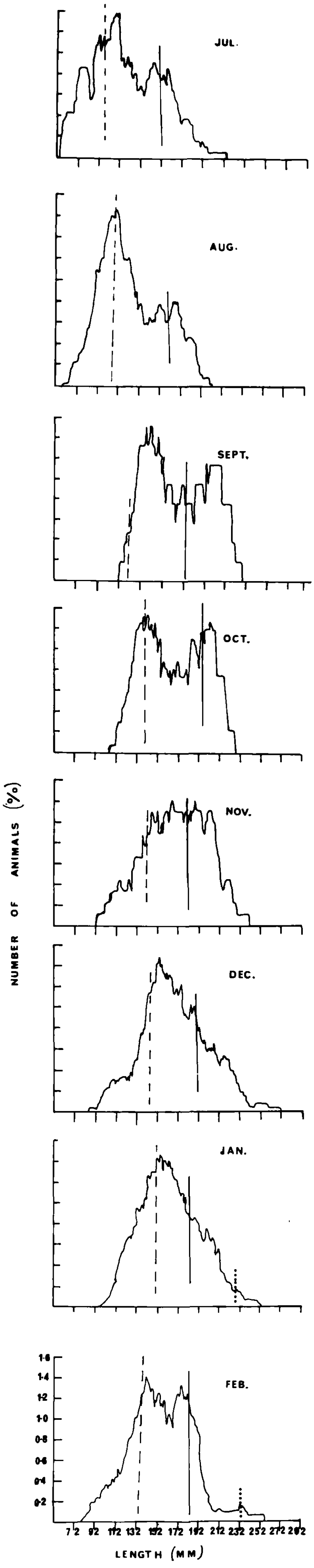
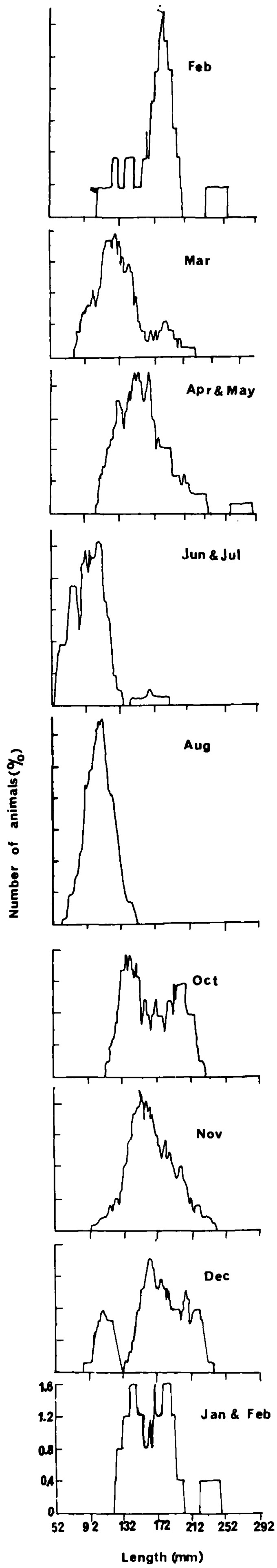

JUL.
AUG.
SEPT.
OCT.
NOV.
DEC.
JAN.
FEB.
NUMBER OF ANIMALS (%)
1·6
1·4
1·2
1·0
0·8
0·6
0·4
0·2
72
92
112
132
152
172
192
212
232
252
272
292
LENGTH (MM)

FIGURE 54

Length-frequency distribution of five bearded rocklings, *Ciliata mustela* at Hinkley Point.



Feb
Mar
Apr & May
Jun & Jul
Aug
Oct
Nov
Dec
Jan & Feb
Number of animals (%)
1.6
1.2
0.8
0.4
0
52
92
132
172
212
252
292
Length (mm)

for both sexes. These results are summarised in Figs. 55-56. Thus, it would appear that the oldest age group of animals disappear during the spawning season (after March). Initially, the populations at Minehead belong to the 1+ and 2+ age groups, but the number of older fish decline until none were caught in June. However, the July and August samples include the first representatives of the young of the year. The majority of the *Ciliata mustela* in autumn and early winter belong to the 0+ and 1+ year classes but the numbers caught were far too small to express this statistically.

In Figs. 57-58 a similar but much more rapid increase in weight is observed. Thus, female fish of a particular age group caught in March of 1975 weigh about 16 g but by the following March the weight had increased four-fold. An analogous growth pattern can also be observed for males of the same age class. For example, fish caught in March 1975 had trebled their original weight by March 1976.

5.2.4. Logarithmic Relationship Between Length and Weight

The relationship between wet weight (y in g) and total length (x in cm) for males and females of *Ciliata mustela* caught at Minehead in 1975/1976 can be expressed as:

Males $\quad \text{Log } y = -2.210 + 3.104 \text{ Log } x \quad r = 0.986$

Females $\quad \text{Log } y = -2.314 + 3.104 \text{ Log } x \quad r = 0.995$

while the relationship between length and weight for individuals caught in the estuary at Oldbury-on-Severn can be expressed as:

Males $\quad \text{Log } y = -2.544 + 2.431 \text{ Log } x \quad r = 0.971$

Females $\quad \text{Log } y = -2.900 + 2.000 \text{ Log } x \quad r = 0.871$

FIGURE 55

Growth in length of 0+ (•), 1+ (▲) and 2+ (■) age group male five bearded rocklings, *Ciliata mustela* caught at Minehead with ±95% confidence limit.

Male *Ciliata mustela*

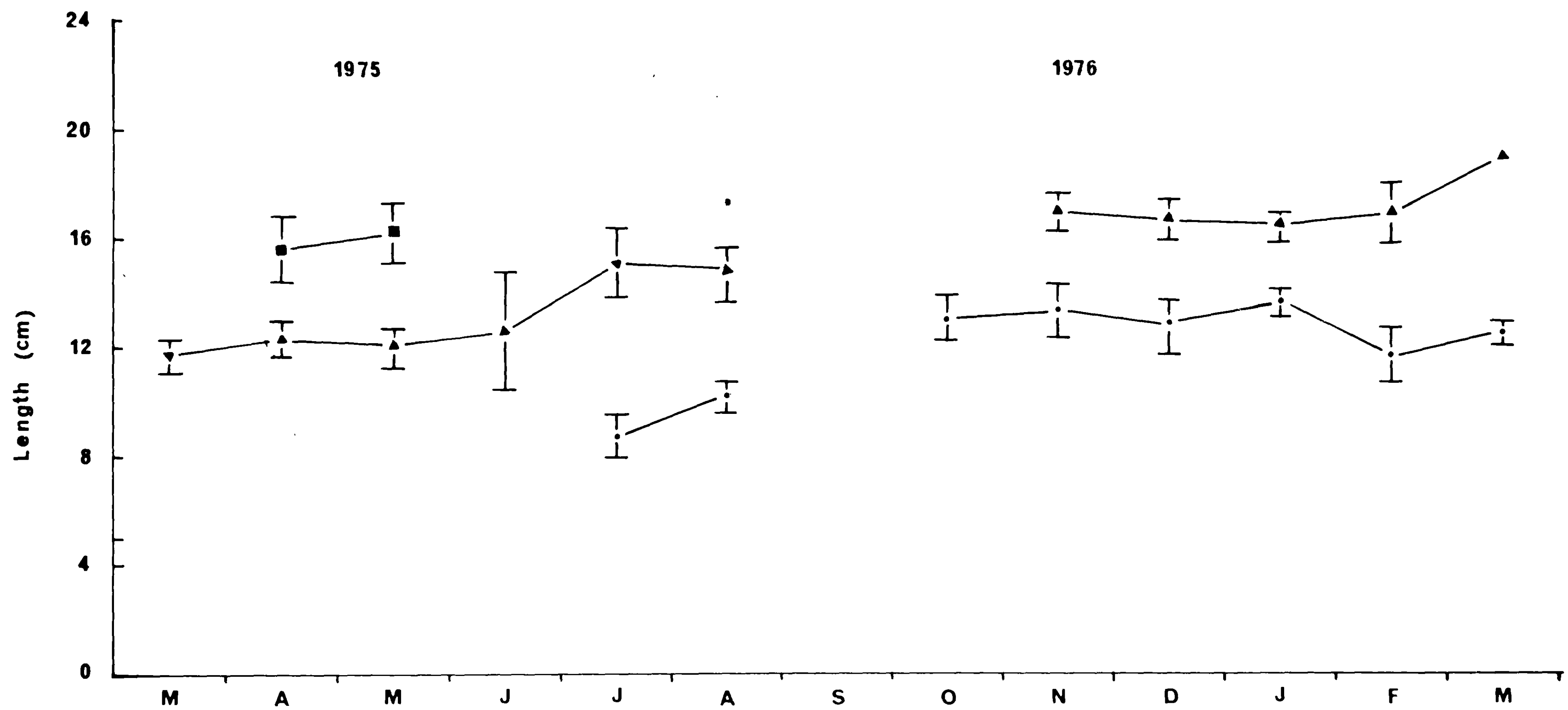


FIGURE 56

Growth in length of 0+ (•), 1+ (▲) and 2+ (■) age group female five bearded rocklings, *Ciliata mustela* caught at Minehead with ±95% confidence limit.

Female *Ciliata mustela*

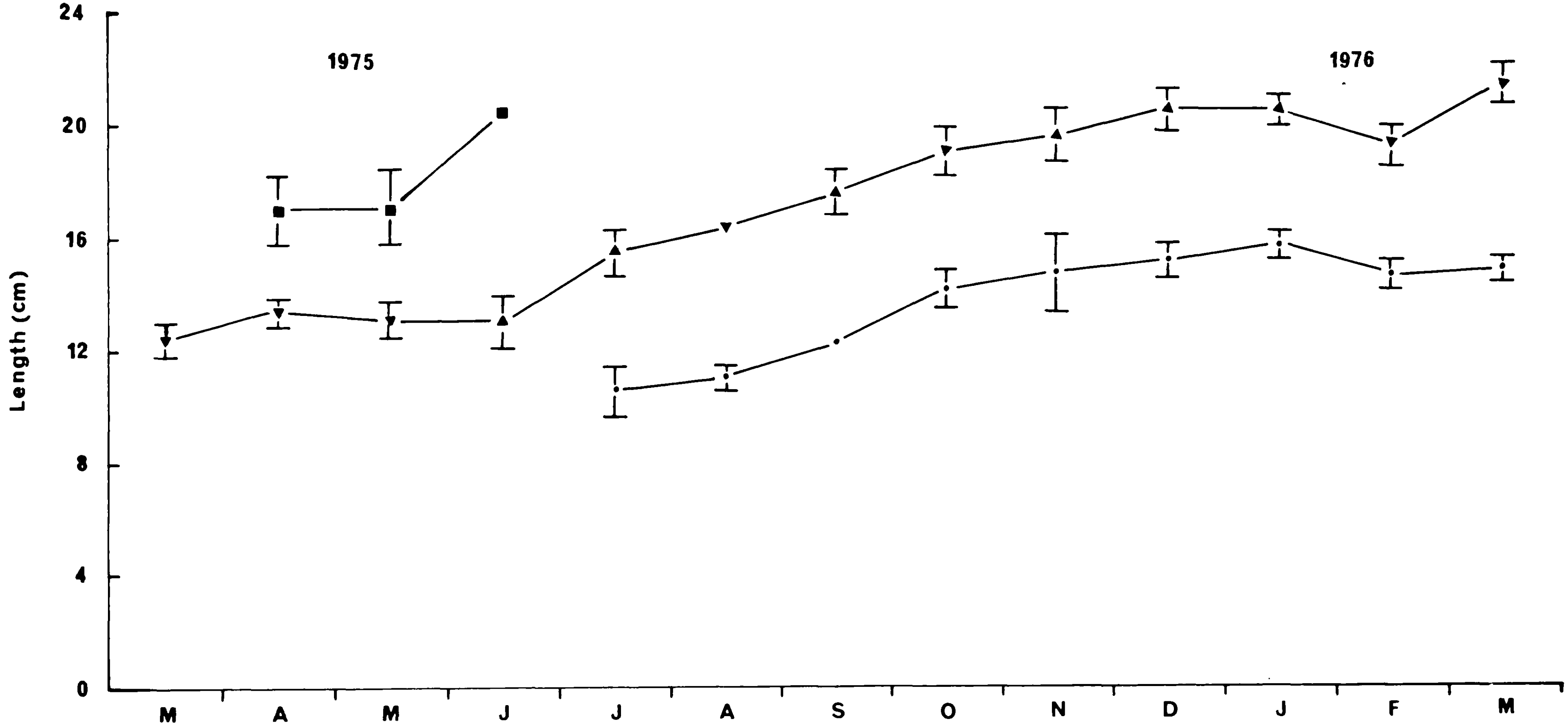
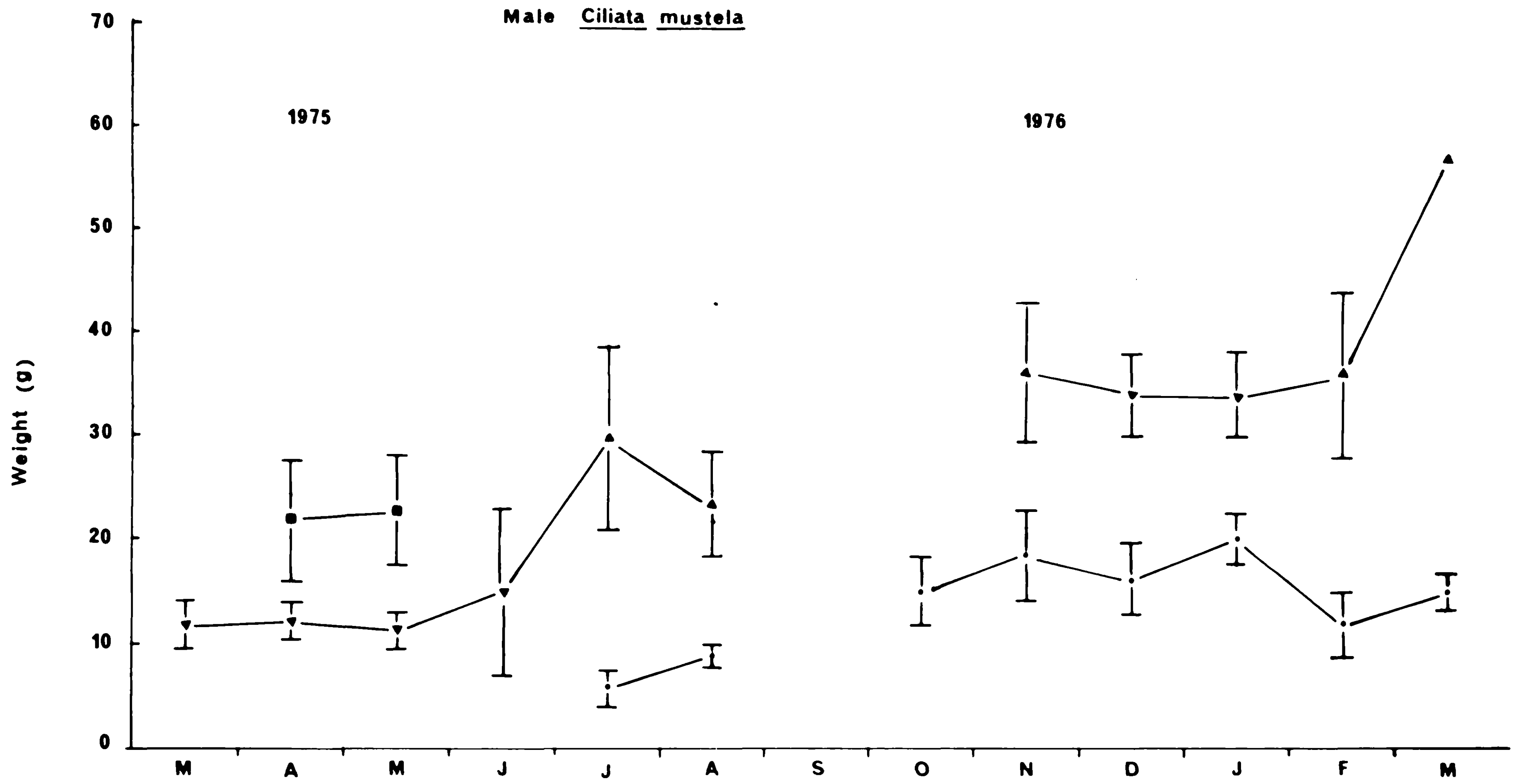


FIGURE 57

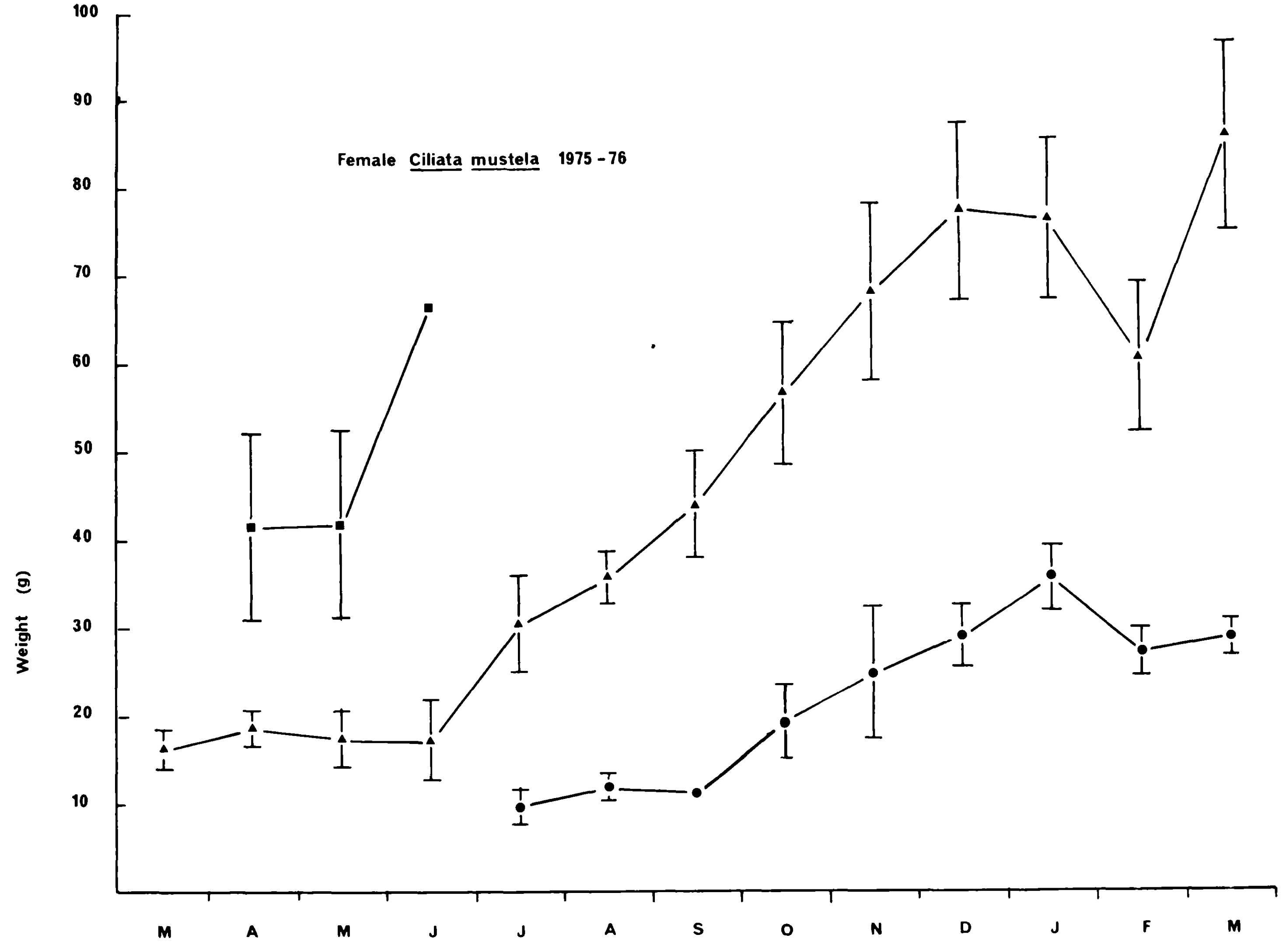
Growth in weight of 0+ (·), 1+ (▲) and 2+ (■) age group male five bearded rocklings, *Ciliata mustela* caught at Minehead with ±95% confidence limit.



Male Ciliata mustela
1975
1976
Weight (g)
70
60
50
40
30
20
10
0
M
A
M
J
J
A
S
O
N
D
J
F
M

FIGURE 58

Growth in weight of 0+ (·), 1+ (▲) and 2+ (■) age group female five bearded rocklings, *Ciliata mustela* caught at Minehead with ±95% confidence limit.



Female Ciliata mustela 1975 - 76
Weight (g)
100
90
80
70
60
50
40
30
20
10
M
A
M
J
J
A
S
O
N
D
J
F
M

From these equations it will be noted that there are significant differences in the regression lines for female fish at Minehead and Oldbury. Thus, over the study period the coefficient at the former site was to be 3.10 and at Oldbury 2.00; it seems therefore, that conditions at Minehead are more suited to rapid growth and development. Unfortunately, because of low numbers, regression coefficients were not calculated for fish from Bridgwater Bay, but there were indications that growth rates were intermediate between those of Minehead and Oldbury.

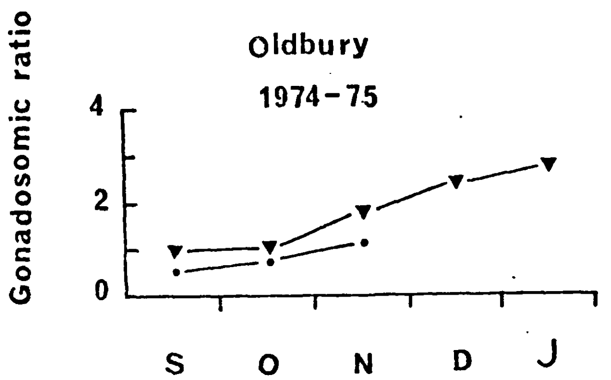
5.2.5. Gonadal Growth and Fecundity

Sexually mature *Ciliata mustela* belonging to the 0+, 1+ and 2+ year classes were recorded between January and May at all sample sites. The maximum numbers being caught in March. Gonadosomatic ratios (gonad weight expressed as a percentage of the total body weight excluding the stomach content weight) for Oldbury and Berkeley (Fig. 59) followed similar curves to those for animals trapped in the marine environment of Minehead (Fig. 60). For the majority of the animals in the Severn Region and the Bristol Channel, the gonads accounted for 10.5–12.3% of the total body weight and this indicates that the breeding period of this species is probably between March and June. Similar development trends for the testis of males at these two sites were also noted.

Fecundity of comparable sized five bearded rocklings varies considerably (Fig. 61). Thus, for animals caught at Minehead, measuring 14 cm in length, oocyte counts varied from 3,000 to 14,000. Similar variability also occurs in the ratio of oocyte number to body

FIGURE 59

Gonadosomic ratio (as a percentage of the total body weight) of male (•) and female (▲) five bearded rocklings, *Ciliata mustela* caught at Oldbury.



Ciliata mustela

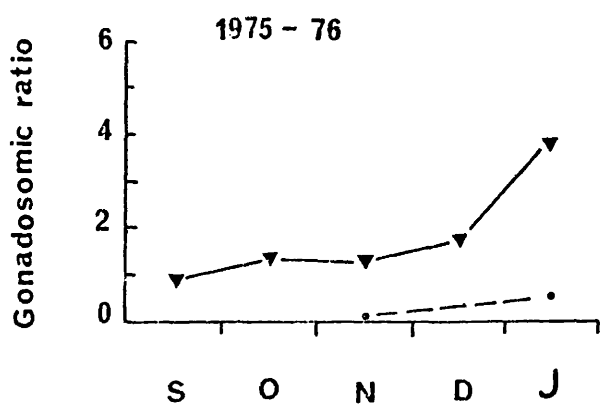


FIGURE 60

Gonadosomic ratio (as a percentage of the total body weight of male (•) and female (▲) five bearded rocklings, *Ciliata mustela* caught at Minehead.

Minehead

<u>*Ciliata mustela*</u>

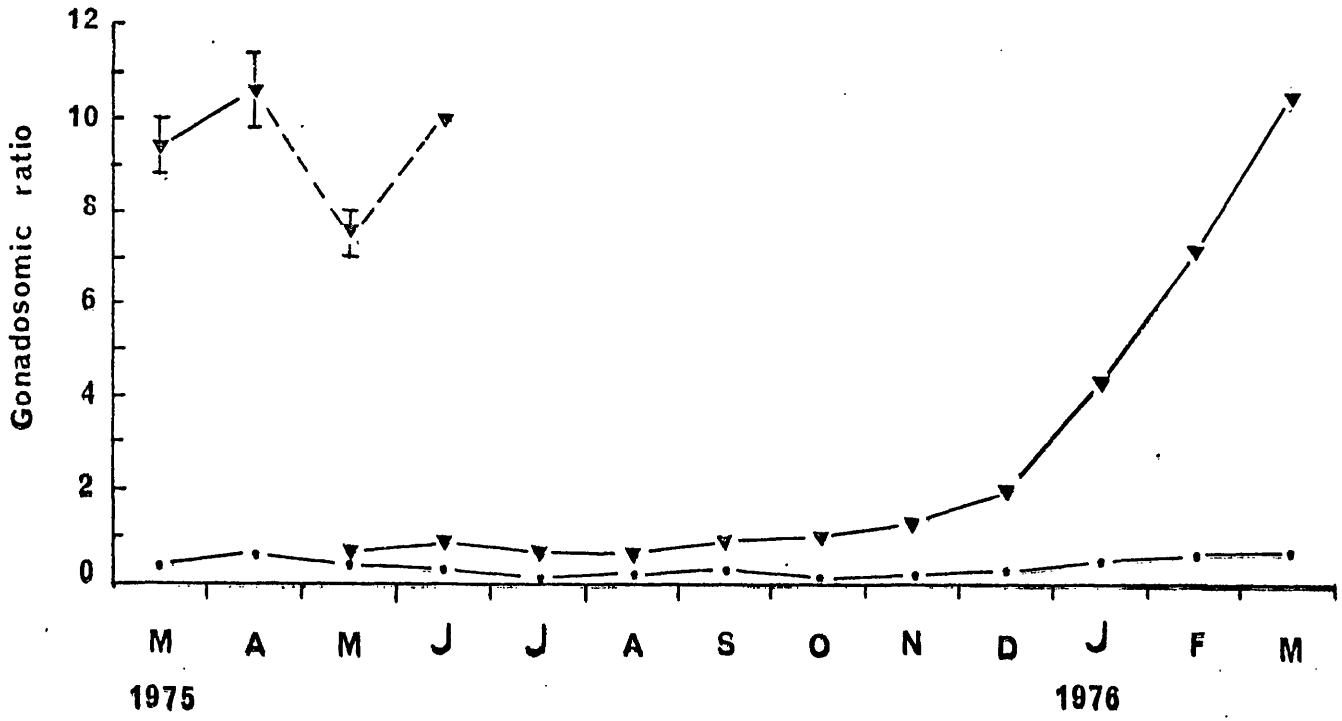
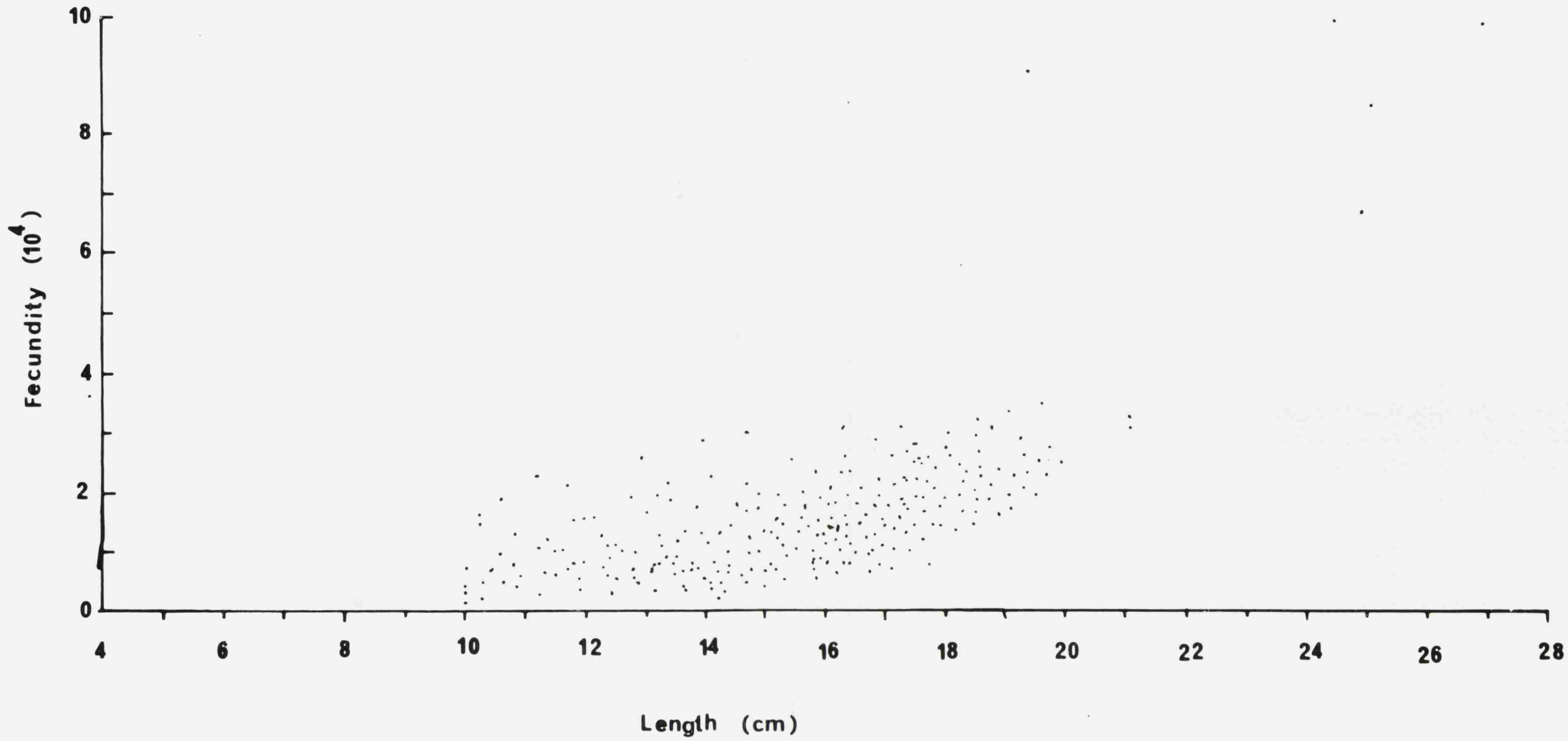


FIGURE 61

Relationship between length and fecundity of individual mature five bearded rocklings, *Ciliata mustela* caught at Minehead.


Fecundity (10^4)
0
2
4
6
8
10
4
6
8
10
12
14
16
18
20
22
24
26
28
Length (cm)

weight (Fig. 62). Thus, for animals (obtained at Minehead) weighing 50 g, oocyte numbers ranged from 800 - 3,200. Although fully mature females were not found at Oldbury or Berkeley, the majority contained immature oocytes in February and it was observed that the diameters (0.2 - 0.4 mm) of these fish were similar to those from fish taken at Minehead at the same time and in the same age group. The diameter of the majority of mature ova (Fig. 63) in all age groups was 0.70 mm and fecundity (ripe oocyte numbers) which was proportional to body length and weight can be expressed as:

$$F = -6.217 + 0.493 \text{ Log } L \qquad r = 0.781$$

$$F = -1.111 + 0.064 \text{ Log } W \qquad r = 0.810$$

where: F = Fecundity x 10^4

L = Length in cm

W = weight in g

R = Correlation coefficient.

5.2.6. Ratio of Males to Females (♂ : ♀)

Although the monthly ratios of males to females varied dramatically, the overall sex ratio for *Ciliata mustela* at Minehead was 1 male to 3.6 females. Values for Hinkley Point and Oldbury and Berkeley during the autumn were 1 : 3.66 and 1 : 4.79 respectively. This significant departure from the normal ratio of 1 : 1 is difficult to explain at this time.

FIGURE 62

Relationship between weight and fecundity of individual mature five bearded rocklings, *Ciliata mustela* caught at Minehead.

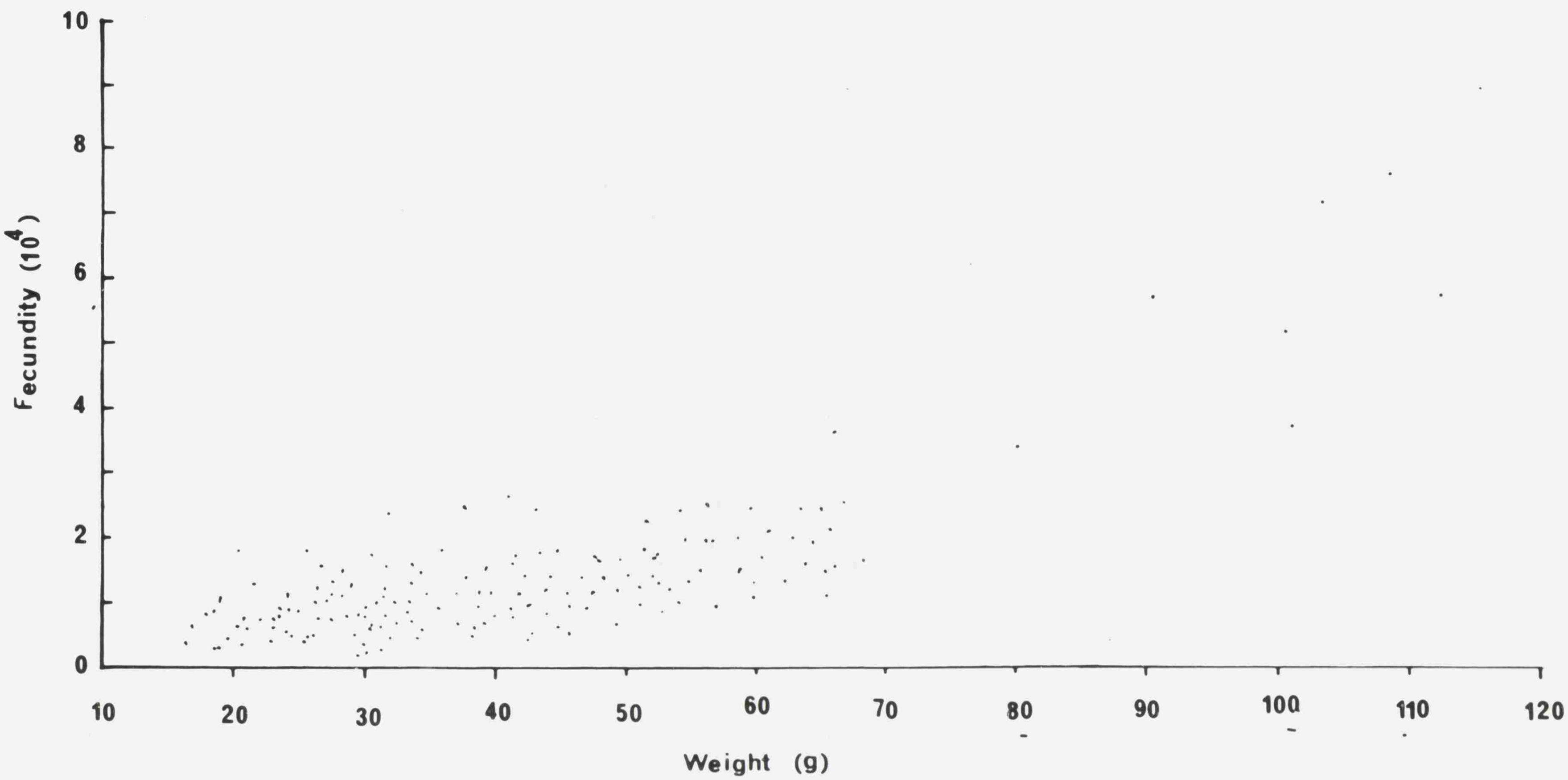
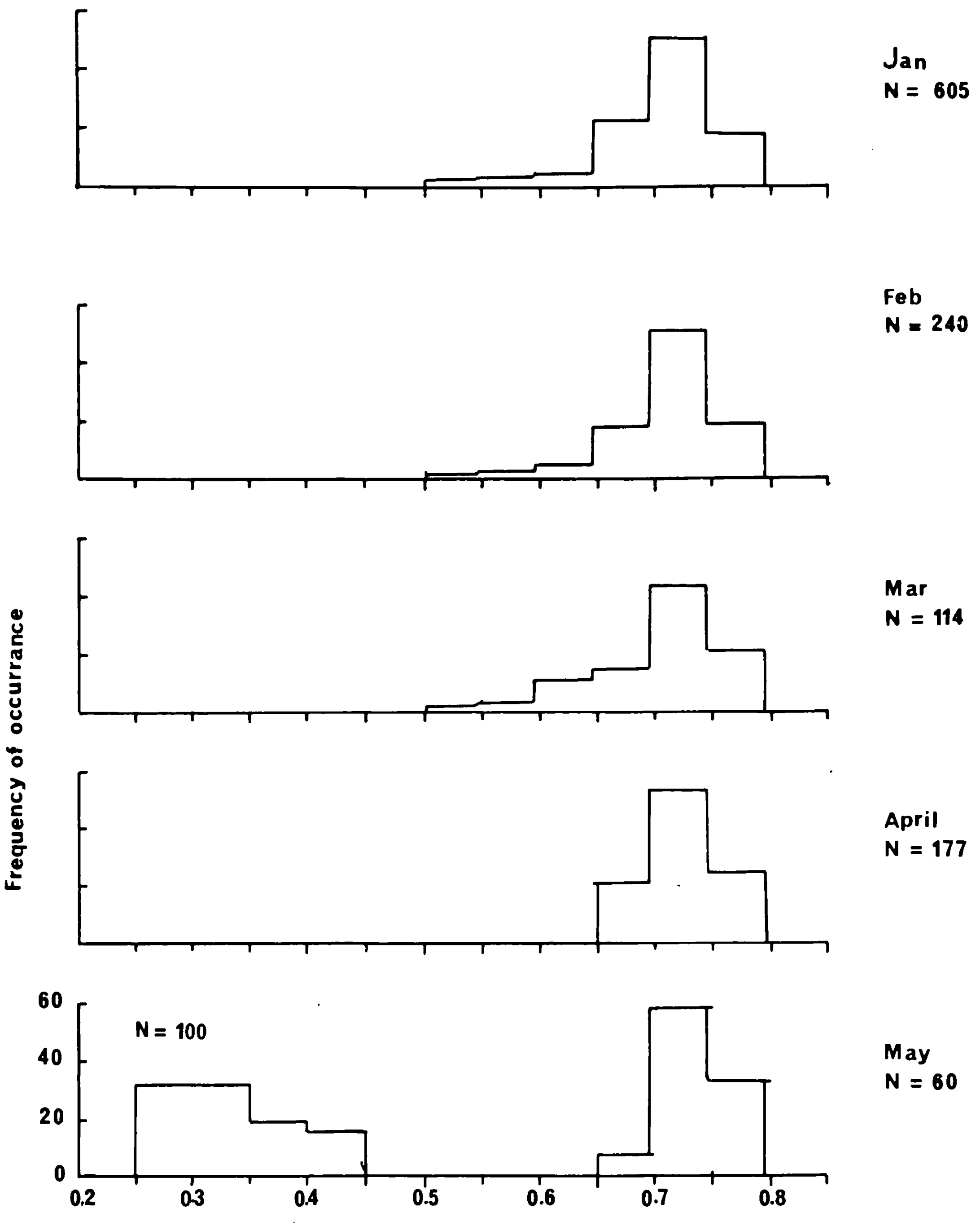

Fecundity (10^4)
10
8
6
4
2
0
10
20
30
40
50
60
70
80
90
100
110
120
Weight (g)

FIGURE 63

Frequency of occurrence of various sized oocytes in five bearded rocklings, *Ciliata mustela* caught between January-May at Minehead.


Jan
N = 605
Feb
N = 240
Mar
N = 114
April
N = 177
May
N = 60
N = 100
Frequency of occurrance
60
40
20
0
0.2
0.3
0.4
0.5
0.6
0.7
0.8

5.2.7. Feeding Habits

i) Intensity of Feeding

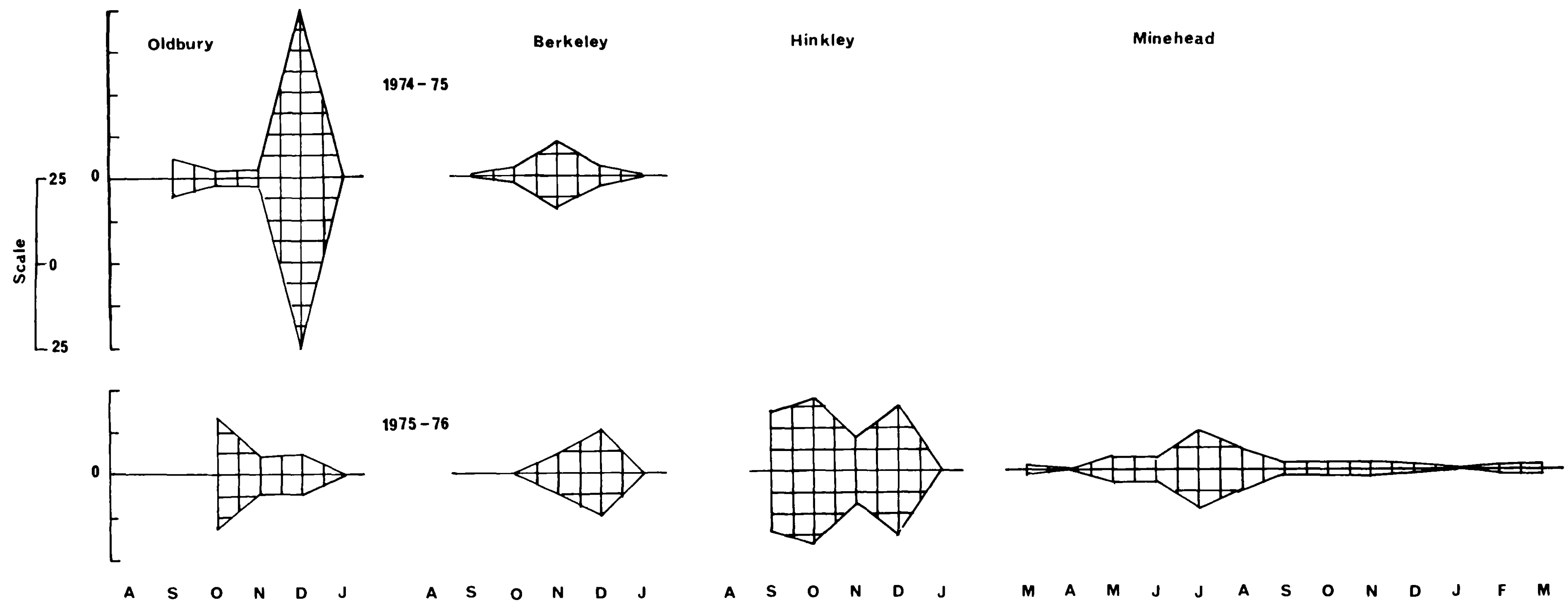
The intensity of feeding as reflected by the number of animals with empty stomachs at all sites can be seen in Fig. 64, where the numbers are expressed as a percentage of the total fish examined. Interestingly, it was found that Berkeley and Hinkley Point were the sites at which most 'non-feeding' animals were obtained. This is most perplexing, especially since both these areas and in particular, Hinkley Point, tend to support a large population of invertebrates, as evidenced by the amounts of such creatures eaten by other fish such as flounders, sea snails etc. and sampled at the same time.

ii) Variations in Feeding Organisms

The analyses of the stomach contents of *Ciliata mustela* has revealed some important aspects of its predatory habits during the period of residence in the Severn Estuary and the Bristol Channel. Although a wide variety of marine organisms have been found in the stomachs of *Ciliata mustela*, there is evidence that its diet is confined to a relatively few species. Further, there are significant variations in this choice, from locality to locality and in some areas even within its period of residence. Thus, it would appear that *Crangon crangon*, *Neomysis* and *Pomatoschistus minutus* become increasingly important as a source of food for five bearded rocklings as the season progresses within the estuary, whilst amphipods are an important but constant dietary constituent (Table 23). Fish at Minehead consume a wider variety of food species than those from the other sampling sites

FIGURE 64

Frequency of occurrence of five bearded rocklings, *Ciliata mustela* with empty stomachs at all the sites studied, expressed as a percentage of the total number of animals examined.



Oldbury
Berkeley
Hinkley
Minehead
1974 - 75
1975 - 76
Scale
25
0
25
0
0
A S O N D J
A S O N D J
A S O N D J
M A M J J A S O N D J F M

TABLE 23

List of food organisms found in the stomachs of five bearded rocklings, *Ciliata mustela* of all age classes and their relative importance measured as a percentage of the total stomachs examined.

TAXONOMIC GROUP	INCLUDING SPECIES	LOCATIONS AND NUMBERS INVESTIGATED				
		OLDBURY 159	BERKELEY 107	USKMOUTH 9	HINKLEY 249	MINEHEAD 841
Annelida	Sedentary Polychaetes	-	-	-	-	2.00
Isopoda	*Idotea granulosa*	3.90	-	-	15.50	2.76
	Unidentified Isopod	5.70	-	-	-	0.09
Mysidacea	*Neomysis*	15.40	-	10.50	-	0.34
Amphipoda	*Gammarus spp.*	30.80	46.10	15.70	31.00	48.22
Decopoda	*Crangon crangon*	42.30	53.90	36.70	33.80	13.53
	Leander serratus	-	-	-	5.20	8.28
	Carcinus maenas	-	-	21.30	15.50	16.64
	Eupagurus bernhardus	-	-	-	-	0.26
Gastropoda	*Littorina saxcatilis*	-	-	-	-	1.03
Cephalopoda	*Loligo forbesi*	-	-	-	-	0.09
Teleost	Eggs (*Leander serratus*)	-	-	-	-	0.34
	Unidentifiable	-	-	-	-	0.90
	Pomatoschistus minutus	1.9	-	15.8	-	5.52
	EMPTY	2	9	-	33	34

and it is interesting that while *Crangon crangon* forms about 32 to 53% of the dietary components at Oldbury, Berkeley, Uskmouth and Hinkley Point, this species is less frequently taken by *Ciliata mustela* at Minehead (13.53%). At Berkeley, the predatory behaviour of this species is almost entirely confined to the consumption of *Crangon crangon* and *Gammarus spp.*, possibly indicating that fewer 'food' species are present there compared with, for example, Minehead.

iii) Seasonal Fluctuation in Dietary Habits

From Table 24 where the results from Oldbury are summarised for two years, there are clear indications that during the 1974/1975 period, the principal food organisms of five bearded rocklings were shrimps *(Crangon crangon)* but in the 1975/1976 season this was replaced by *Gammarus spp.* This inverse relationship between uptake of *Gammarus spp.* and the decline in *Crangon crangon* is seen clearly in Fig. 65.

Continuous monitoring of the dietary preference of this teleost shows that there was a sharp increase in the percentage (by weight) of *Crangon crangon* consumed from 49.0% in September of 1974, to 91.6% by October 1975. This feeding pattern then changed, and the amount of shrimps consumed fell, being replaced by an increase in *Gammarus spp.* (Table 25). From Fig. 66, where for example, in January 1974 46.5% of the weight of the total food intake was attributed to shrimps, it may be seen that by January 1975, this value was only 29.2%. However, there is no reason to believe that there was any significant change in the density of shrimp population at this site during the study period, nor is there any correlation noted between the fluctuation of one organism with salinity or temperature.

TABLE 24

Frequency of occurrence of major dietary organisms in each successive year (1974-1976) in five bearded rocklings, *Ciliata mustela*, obtained in the cooling water intake screens of Oldbury Power Station, expressed as a percentage of the total number of animals examined. (Also included are the numbers investigated).

Month /Year	No. Inv.	*Crangon crangon*	*Gammarus* spp.	*P. minutus*	*Neomysis*	*Idotea granulosa*	Debris	Empty
Sep '74	39	35.2	17.7	-	29.4	-	5.9	11.8
Oct '74	35	40.0	25.0	-	-	-	-	3.5
Nov '74	10	55.6	33.3	-	-	-	5.6	5.5
Dec '74	1	-	-	-	-	-	-	100.0
Jan '75	4	42.9	28.6	-	14.2	14.3	-	-
Oct '75	20	34.0	33.0	-	-	-	-	33.0
Nov '75	20	55.6	11.1	11.1	-	-	11.1	11.1
Dec '75	20	29.4	35.3	-	11.8	5.8	5.9	11.8
Jan '76	10	40.0	60.0	-	-	-	-	-

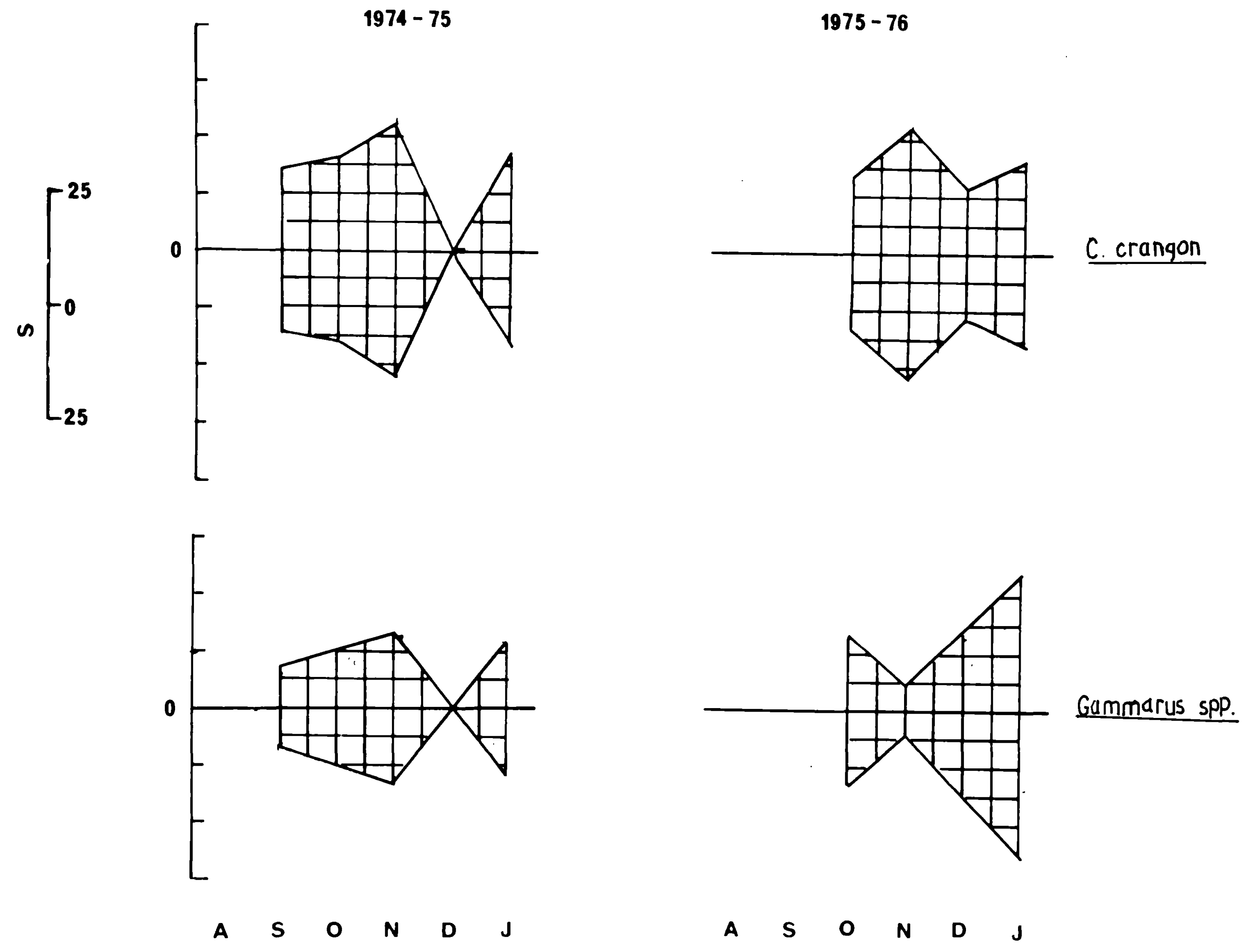
TABLE 25

Relative importance of major dietary organisms by weight in each successive year (1974-1976) in five bearded rocklings, *Ciliata mustela*, obtained in the cooling water intake screens of Oldbury Power Station, expressed as a percentage of the total weight of stomach contents. (Also included are the numbers investigated).

MONTH /YEAR	NO. INV.	*Crangon crangon*	*Gammarus spp.*	*P. minutus*	*Neomysis*	*Idotea granulosa*	Debris
Sep '74	39	49.0	18.9	-	30.2	-	1.9
Oct '74	35	82.0	18.0	-	-	-	-
Nov '74	10	89.0	9.8	-	-	-	1.2
Dec '74	1	-	-	-	-	-	-
Jan '75	4	36.3	29.2	-	17.3	17.3	-
Oct '75	20	91.6	8.4	-	-	-	-
Nov '75	20	84.4	9.4	4.6	-	-	1.6
Dec '75	20	25.7	65.4	-	6.7	1.5	0.7
Jan '76	10	53.5	46.5	-	-	-	-

FIGURE 65

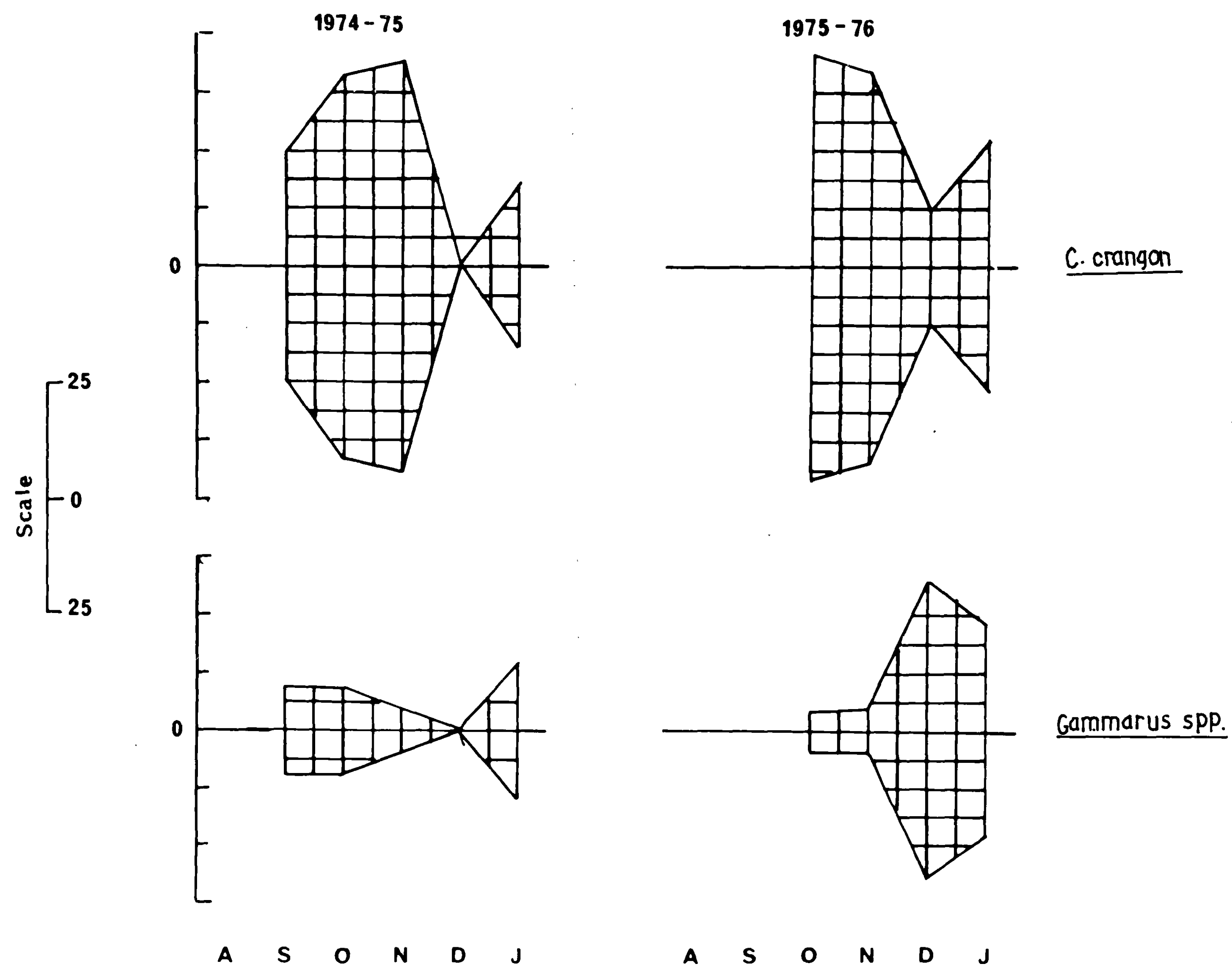
Frequency of occurrence of major dietary organisms in the stomachs of five bearded rocklings, *Ciliata mustela* caught at Oldbury during 1974-1976, expressed as a percentage of the total number of animals examined.



1974 - 75
1975 - 76
25
0
25
S
0
0
C. crangon
Gammarus spp.
A S O N D J
A S O N D J

FIGURE 66

Occurrence of major dietary organisms by weight in the stomachs of five bearded rocklings, *Ciliata mustela* caught at Oldbury during 1974-1976, expressed as a percentage of the total weight of stomach contents.


1974 - 75
1975 - 76
Scale
25
0
25
0
0
C. crangon
Gammarus spp.
A S O N D J
A S O N D J

There was a dramatic increase in the amount of debris in the stomachs of *Ciliata mustela* in 1974/1975 compared with 1975/1976, from an average of about 1.5% to 5.75%; this consisted of black stones, polystrene spherules, pieces of wood and vegetation, but no obvious relationship was found between the increase of this detritus and environmental factors, such as rainfall.

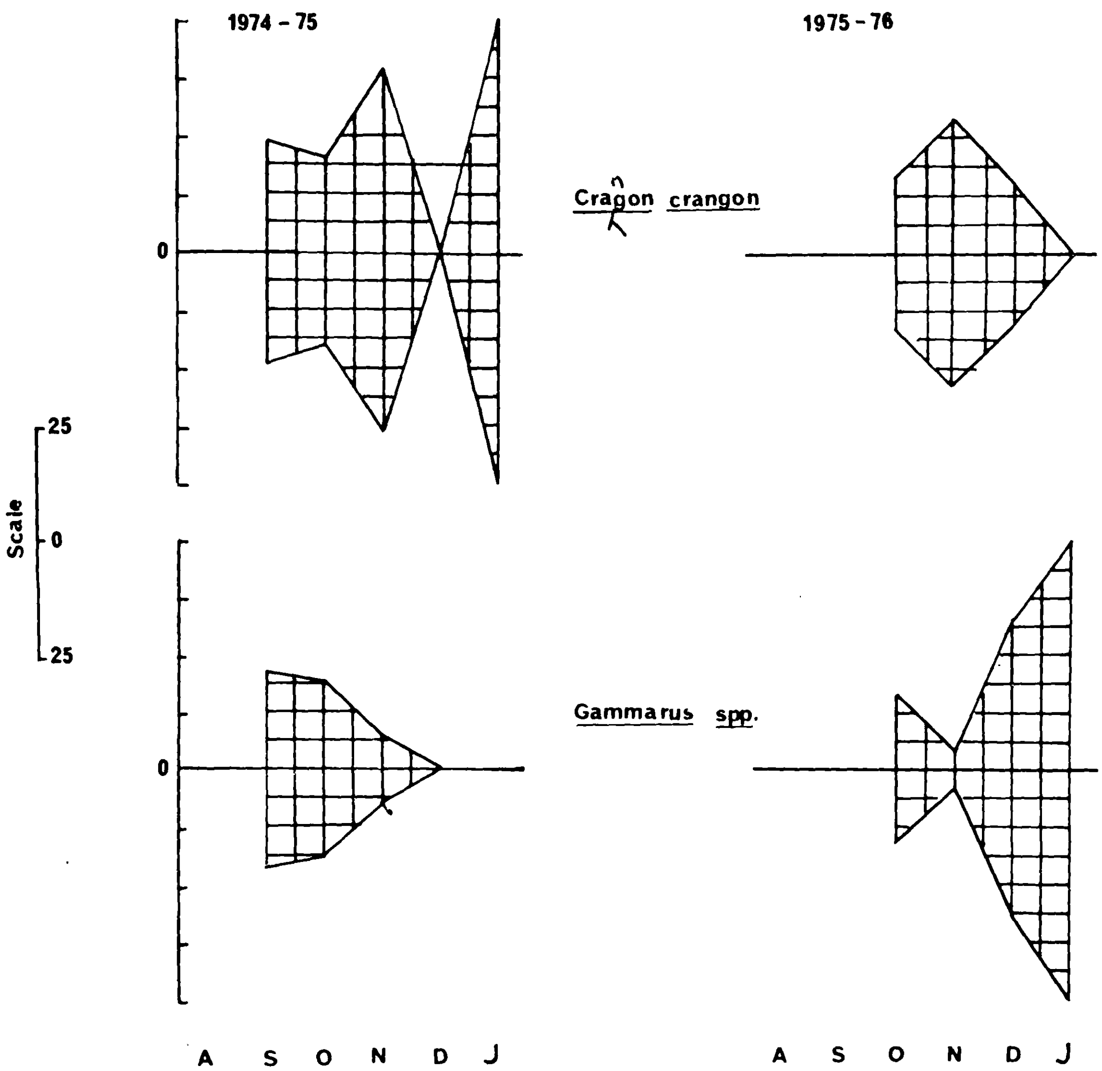
iv) Feeding Behaviour at Other Sites

Similar but more pronounced differences in the feeding trends were observed for samples collected from Berkeley (Table 26). Thus, Fig. 67 shows the utilisation of shrimp is paralleled by a sharp increase in the frequency of occurrence of *Gammarus spp.* This is clearly demonstrated especially when *Gammarus spp.* is presented as a percentage of the total weight of the stomach contents (Table 27). Fig. 68 (constructed from table from Table 27) for example, shows that in January of 1975, shrimps accounted for the total food intake but the following January, all the food consumed consisted of *Gammarus spp.* There was no obvious environmental factor which might account for this change and thus, reasons for it remain a mystery.

Samples from Uskmouth suggest that rocklings show less discrimination in feeding behaviour (Tables 28-29) either by frequency of occurrence or by percentage weight of the major food items (Fig. 69 a & b). Thus, for example, in November the fish fed on shrimps (25%), *Carcinus maenas* (25%), *Gammarus spp.* (12.5%), *Pomatoschistus minutus* (12.5%) and *Neomysis* (12.5%). Interestingly, despite the fact that this station is situated at the mouth of the River Usk, where the salinity is low, its environment is able to support a wider variety of marine organisms than at Oldbury, and crabs for example, are much more abundant.

FIGURE 67

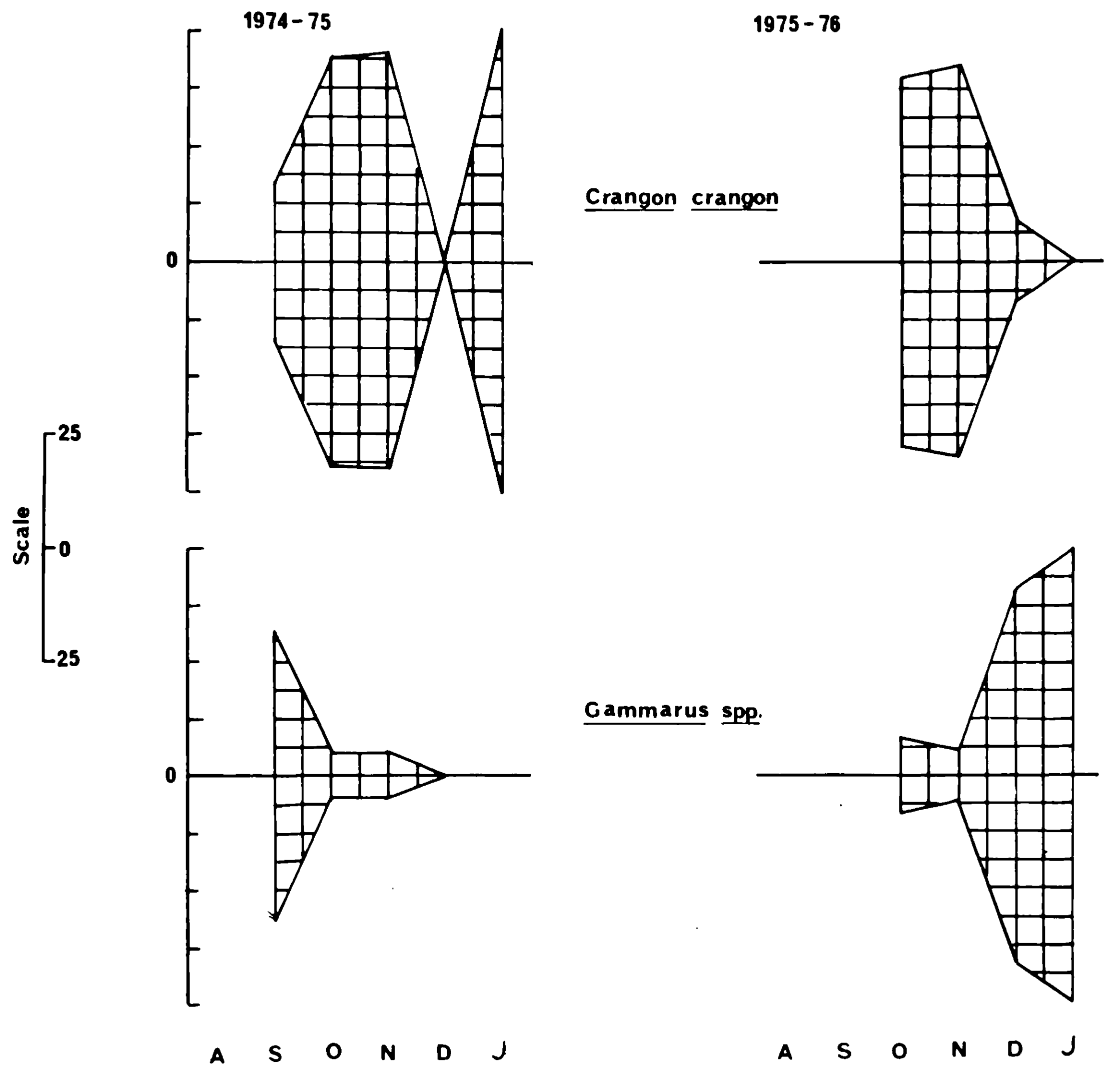
Frequency of occurrence of major dietary organisms in the stomachs of five bearded rocklings, *Ciliata mustela* caught at Berkeley during 1974-1976, expressed as a percentage of the total number of animals examined.



1974 - 75
1975 - 76
Cragon crangon
Gammarus spp.
Scale
25
0
25
0
0
A S O N D J
A S O N D J

FIGURE 68

Occurrence of major dietary organisms by weight in the stomachs of five bearded rocklings, *Ciliata mustela* caught at Berkeley during 1974-1976, expressed as a percentage of the total weight of stomach contents.

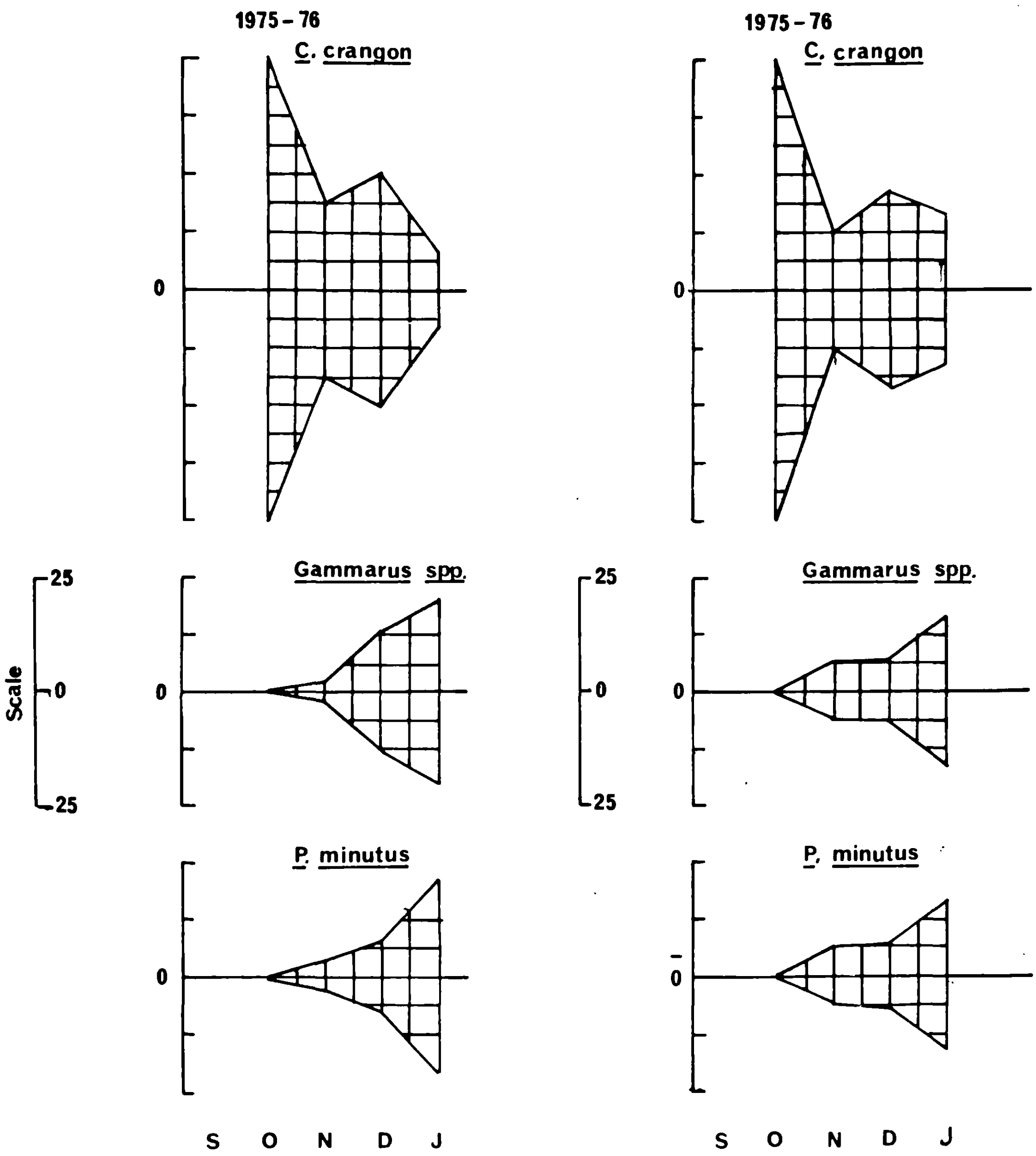


1974-75
1975-76
Crangon crangon
Gammarus spp.
0
0
Scale
25
0
25
A S O N D J
A S O N D J

FIGURE 69

(a) Frequency of occurrence of major dietary organisms in the stomachs of five bearded rocklings, *Ciliata mustela* caught at Uskmouth during 1975-1976, expressed as a percentage of the total number of animals examined.

(b) Occurrence of major dietary organisms by weight in the stomachs of five bearded rocklings, *Ciliata mustela* caught at Uskmouth during 1975-1976, expressed as a percentage of the total weight of stomach contents.



1975 - 76
C. crangon
1975 - 76
C. crangon
0
0
Gammarus spp.
Gammarus spp.
Scale
25
0
25
25
0
25
0
0
P. minutus
P. minutus
0
0
S O N D J
S O N D J

TABLE 26

Frequency of occurrence of major dietary organisms in each successive year (1974–1976) in five bearded rocklings, *Ciliata mustela*, obtained in the cooling water intake screens of Berkeley Power Station, expressed as a percentage of the total number of animals examined. (Also included are the numbers investigated.

MONTH /YEAR	NO. INV.	*Crangon crangon*	*Gammarus spp.*	Debris	Empty
Sep '74	38	48.0	42.9	3.6	3.4
Oct '74	14	40.0	38.0	2.0	20.0
Nov '74	4	78.0	15.0	2.0	6.6
Dec '74	-	-	-	-	-
Jan '75	1	100.0	-	-	-
Oct '75	10	33.3	33.3	11.1	11.1
Nov '75	27	58.3	8.4	8.3	25.6
Dec '75	6	33.3	66.7	-	-
Jan '76	7	-	100.0	-	-

TABLE 27

Relative importance of major dietary organisms by weight in each successive year (1974-1976) in five bearded rocklings, *Ciliata mustela*, obtained in the cooling water intake screens of Berkeley Power Station, expressed as a percentage of the total weight of stomach contents. (Also included are the numbers investigated).

MONTH/YEAR	NO. INV.	*Crangon crangon*	*Gammarus* spp.	Debris
Sep '74	38	34.4	64.5	1.1
Oct '74	14	89.0	10.2	0.8
Nov '74	4	89.5	10.0	0.5
Dec '74	-	-	-	-
Jan '75	1	100.0	-	-
Oct '75	10	80.6	16.7	2.7
Nov '75	27	86.8	11.8	1.4
Dec '75	6	16.7	83.0	0.3
Jan '76	7	-	100.0	-

TABLE 28

Frequency of occurrence of major dietary organisms in five bearded rocklings, *Ciliata mustela*, obtained in the cooling water intake screens of Uskmouth Power Station, expressed as a percentage of the total animals examined. (Also included are the numbers investigated).

MONTH /YEAR	NO. INV.	*Crangon crangon*	*Gammarus spp.*	*P. minutus*	*Carcinus maenas*	*Neomysis*	Debris	Empty
Oct '75	2	100.0	-	-	-	-	-	-
Nov '75	2	25.0	12.5	12.5	25.0	12.5	12.5	-
Dec '75	4	42.9	14.3	14.3	28.5	-	-	-
Jan '76	1	33.4	33.3	33.3	-	-	-	-

TABLE 29

Relative importance of major dietary organisms by weight of five bearded rocklings, *Ciliata mustela*, obtained in the cooling water intake screens of Uskmouth Power Station, expressed as a percentage of the total weight of stomach contents. (Also included are the numbers investigated).

MONTH /YEAR	NO. INV.	*Crangon crangon*	*Gammarus spp.*	*P. minutus*	*Carcinus maenas*	*Neomysis*	Debris	Empty
Oct '75	2	100.0	-	-	-	-	-	-
Nov '75	2	37.7	4.4	6.1	44.8	3.5	3.5	-
Dec '75	4	50.9	26.3	15.8	7.0	-	-	-
Jan '76	1	16.7	40.0	43.3	-	-	-	-

Five bearded rocklings from Hinkley Point show a greater diversity of food organisms in their stomachs than species taken from any site other than Minehead. Either by frequency of occurrence (Table 30, Fig. 70) or expressed as a percentage weight (Table 31, Fig. 71) *Crangon crangon* and *Gammarus spp.* occur in about the same proportions but other items such as *Idotea granulosa*, *Leander serratus*, and *Carcinus maenas*, make an important contribution to the total food intake.

The absence of *Pomatoschistus minutus* in the stomach of this species at this site is significant, though no explanation can be advanced at this stage for it, especially as they are locally quite numerous.

At Minehead (Table 32) the majority of the organisms consumed were *Crangon crangon*, *Gammarus spp.*, *Carcinus maenas*, *Leander serratus* and *Pomatoschistus minutus* in order of abundance (Fig. 72). A considerable number also fed on rough periwinkle *(Littorina sexatilus)*, *Isopod spp.*, hermit crabs *(Eupagurus bernhardus)* and eggs of *Leander serratus*, thus demonstrating a wide and possibly indiscriminate mode of feeding. Incidentally, there is no change in the preference of dietary organisms when presented as a percentage of the total weight of organisms found in the stomachs (Table 33, Fig. 73).

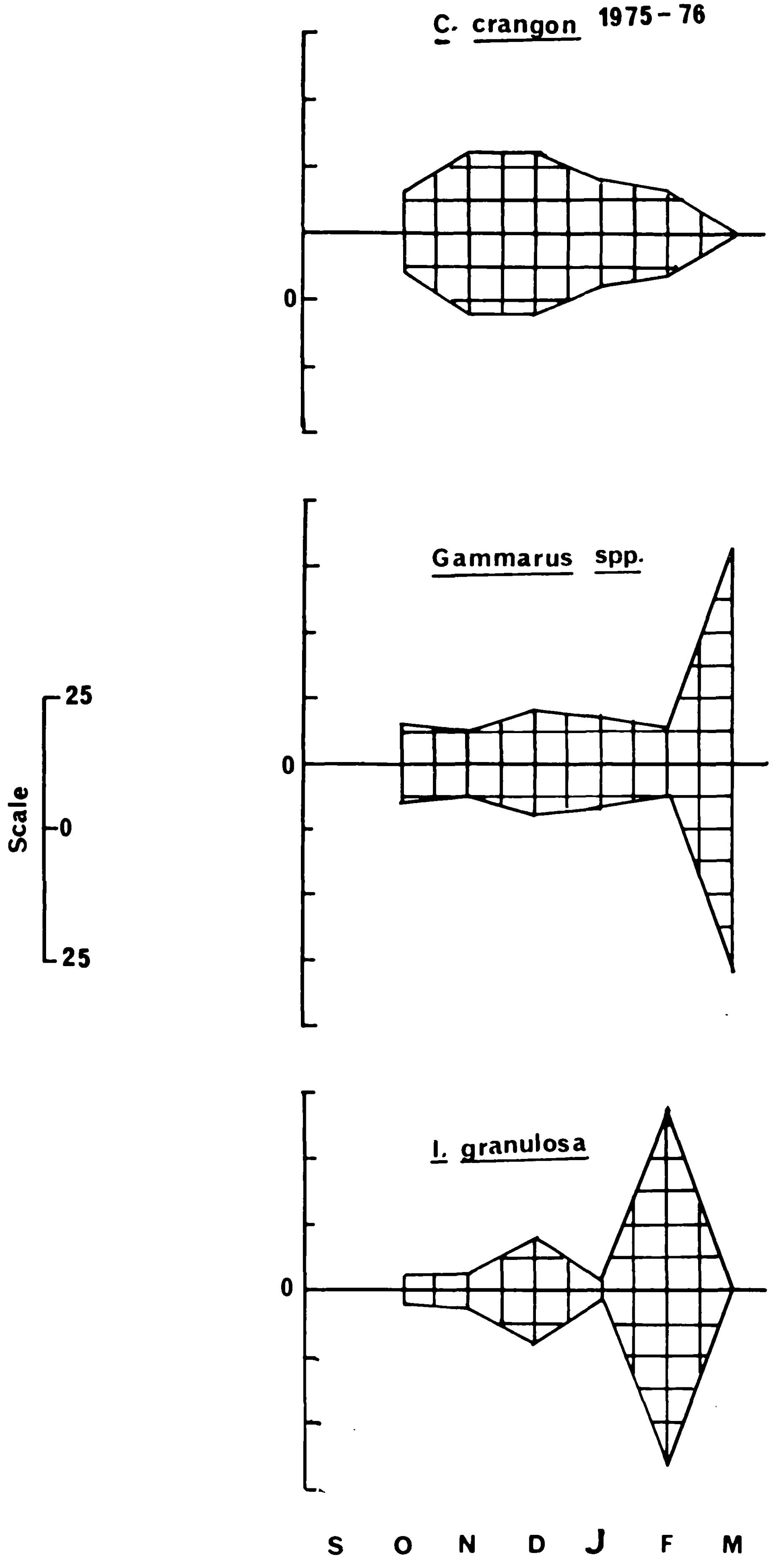
5.2.8. Parasitism

Two major but often conflicting views put forward by parasitologists are:

(a) the fish can harbour considerable numbers of most kinds of parasites without being adversely affected, although

FIGURE 70

Frequency of occurrence of major dietary organisms in the stomachs of five bearded rocklings, *Ciliata mustela* caught at Hinkley point during 1975/1976, expressed as a percentage of the total number of animals examined.



C. crangon 1975 - 76
0
Gammarus spp.
0
I. granulosa
0
Scale
25
0
25
S O N D J F M

FIGURE 71

Occurrence of major dietary organisms by weight in the stomachs of five bearded rocklings, *Ciliata mustela* caught at Hinkley Point during 1975-1976, expressed as a percentage of the total weight of stomach contents.

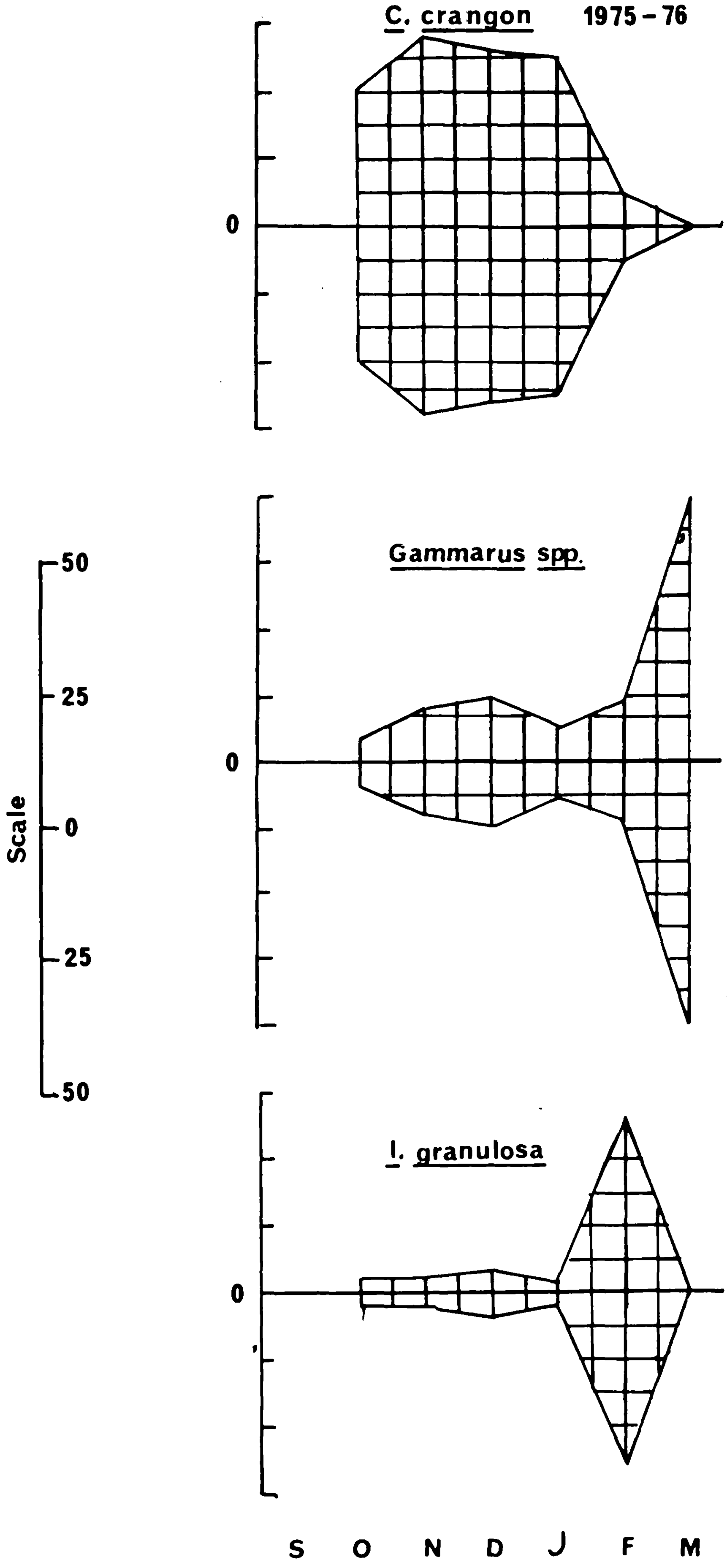
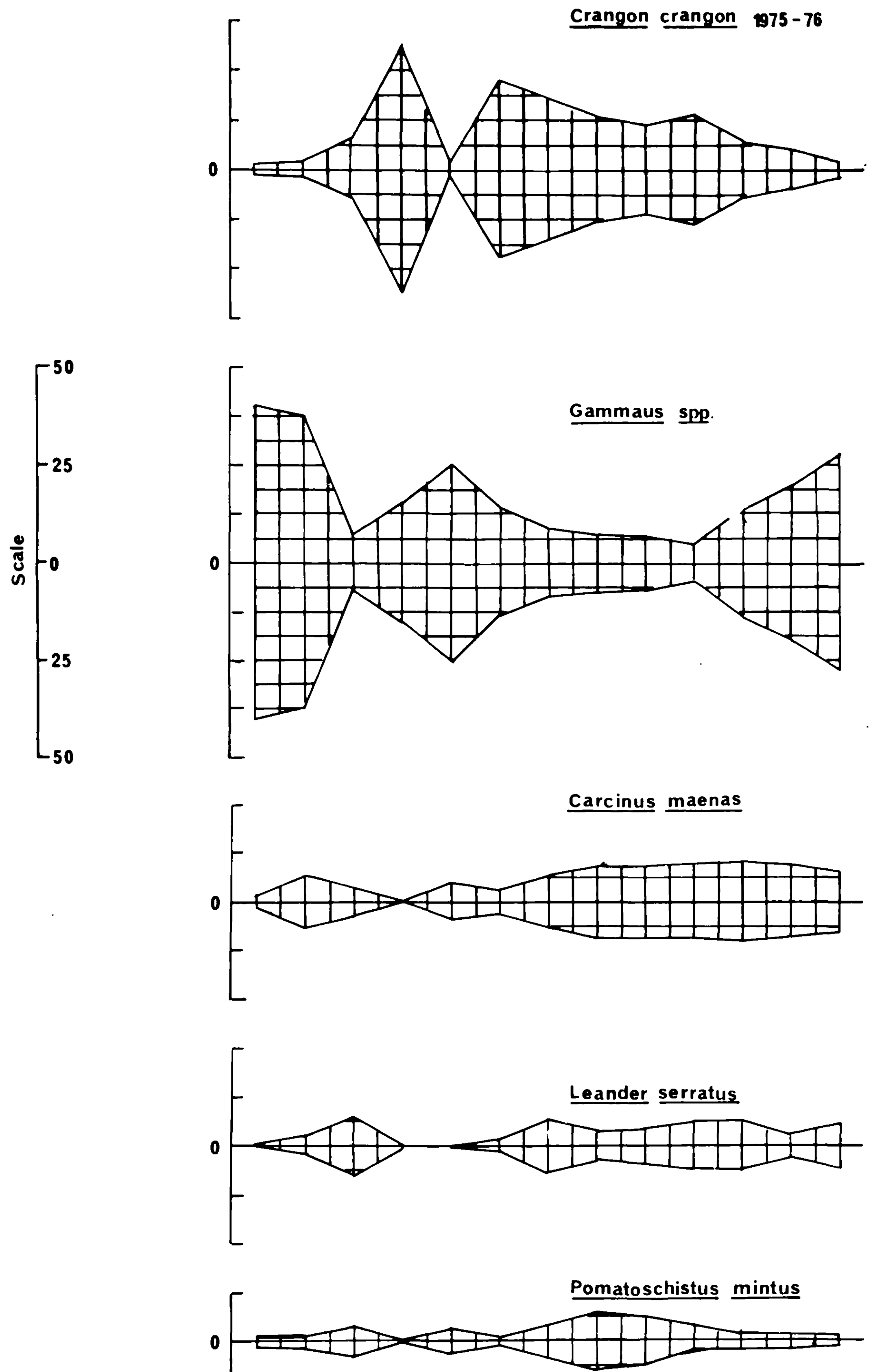

C. crangon 1975 - 76
Gammarus spp.
I. granulosa
Scale
50
25
0
25
50
0
S O N D J F M

FIGURE 72

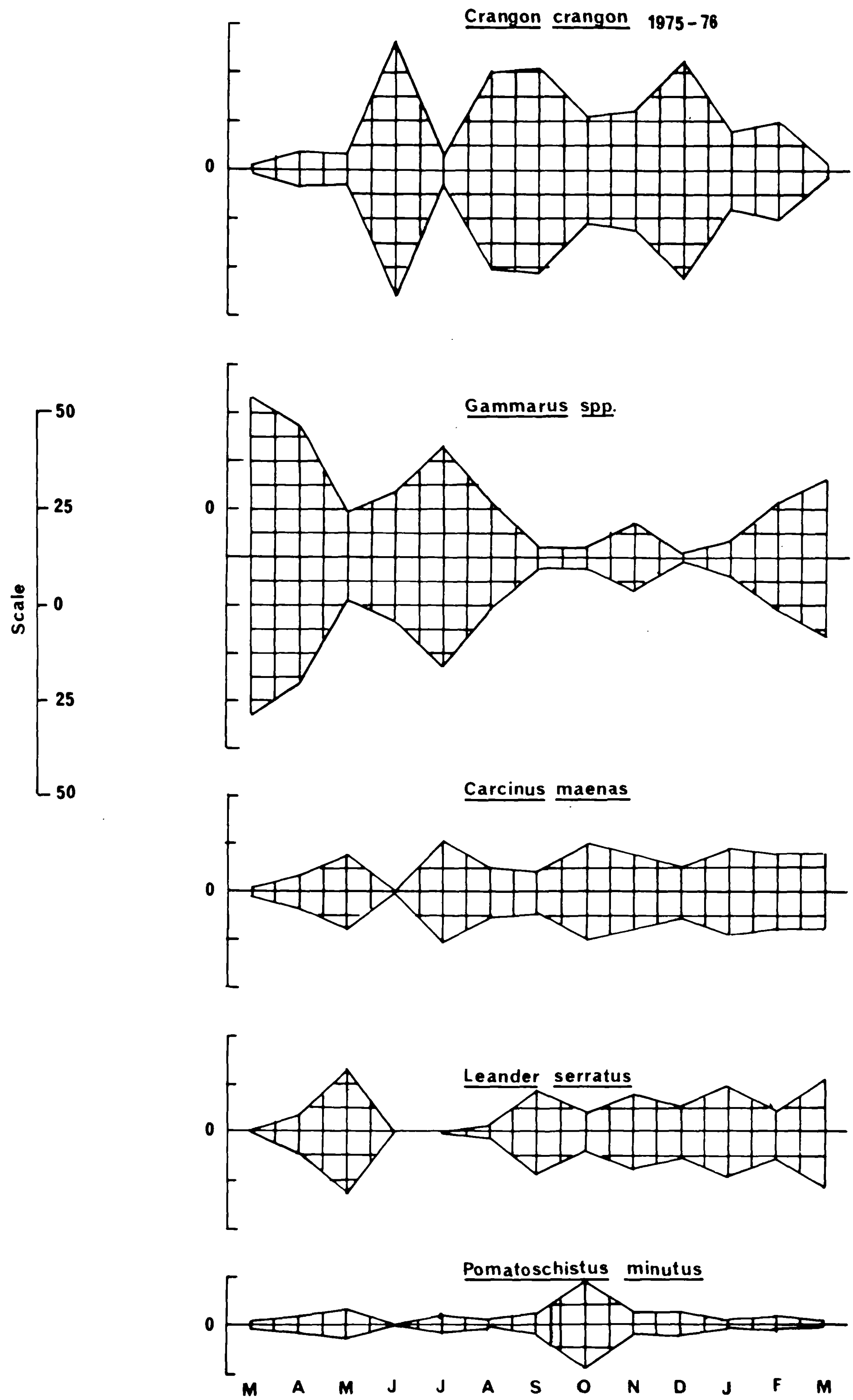
Frequency of occurrence of major dietary organisms in the stomachs of five bearded rocklings, *Ciliata mustela* caught at Minehead during 1975-1976, expressed as a percentage of the total number of animals examined.



Crangon crangon 1975-76
Gammaus spp.
Carcinus maenas
Leander serratus
Pomatoschistus mintus
Scale
50
25
0
25
50
0
M A M J J A S O N D J F M

FIGURE 73

Occurrence of major dietary organisms by weight in the stomachs of five bearded rocklings, *Ciliata mustela* caught at Minehead during 1975-1976, expressed as a percentage of the total weight of stomach contents.



Crangon crangon 1975-76
Gammarus spp.
Carcinus maenas
Leander serratus
Pomatoschistus minutus
Scale
50
25
0
25
50
0
M A M J J A S O N D J F M

TABLE 30

Frequency of occurrence of major dietary organisms in five bearded rocklings, *Ciliata mustela*, obtained from Hinkley Point Power Station, expressed as a percentage of the total number of animals examined. (Also included are the numbers investigated).

Month /Year	No. Inv.	*Crangon crangon*	*Gammarus spp.*	*Carcinus maenas*	*Leander serratus*	*Idotea granulosa*	Debris	Empty
Oct '75	16	15.8	15.8	-	15.8	5.3	10.5	36.8
Nov '75	15	31.3	12.5	-	-	6.3	6.2	43.7
Dec '75	31	30.0	20.0	10.0	-	20.0	-	20.0
Jan '76	45	20.0	17.1	22.9	-	2.9	-	37.1
Feb '76	5	16.7	16.7	-	-	66.6	-	-
Mar '76	5	-	80.0	-	-	-	20.0	-

TABLE 31

Relative importance of major dietary organisms by weight of five bearded rocklings, *Ciliata mustela*, obtained from Hinkley Point Power Station, expressed as a percentage of the total weight of the stomach contents. (Also included are the numbers investigated).

MONTH /YEAR	NO. INV.	*Crangon crangon*	*Gammarus spp.*	*Carcinas maenas*	*Leander serratus*	*Idotea granulosa*	Debris
Oct '75	16	50.4	8.3	-	31.5	3.0	6.8
Nov '75	15	72.3	20.5	-	-	5.4	1.8
Dec '75	31	65.2	24.4	0.7	-	9.6	-
Jan '76	45	62.1	13.4	19.8	-	4.7	-
Feb '76	5	12.8	22.1	-	-	65.1	-
Mar '76	3	-	99.5	-	-	-	0.5

TABLE 32

Frequency of occurrence of major dietary organisms of five bearded rocklings, *Ciliata mustela*, obtained from the fish weir at Minehead during 1975-1976, expressed as a percentage of the total number of animals examined. (Also included are the numbers investigated).

MONTH/ YEAR	NO. INV.	*Crangon vulgaris*	*Gammaris spp.*	*Neomysis*	Crabs	Prawns	*Gobies minutus*	*Idotea granulosa*	Hermit Crab	R Periwinkle	Squid	Prawn Eggs	*Polychaete* worms	Isopoda	Unidentified	Flora, Stones Debris etc.	Empty
Mar '75	49	2.0	80.0	-	2.0	-	2.0	2.0	-	-	-	-	6.0	-	-	4.0	2.0
Apr '75	67	4.4	75.7	-	13.3	4.4	2.2	-	-	-	-	-	-	-	-	-	-
May '75	68	15.4	15.4	-	7.7	15.4	7.7	30.7	-	-	-	-	-	-	-	-	7.7
Jun '75	16	62.5	31.3	-	-	-	-	-	-	-	-	-	-	-	-	-	6.2
Jul '75	31	3.2	51.7	3.2	9.7	-	6.4	3.2	-	-	-	-	-	-	-	-	22.6
Aug '75	52	45.4	27.3	-	6.5	2.6	1.3	3.9	-	-	-	1.3	-	-	-	-	11.7
Sep '75	17	35.6	17.9	-	14.3	14.3	7.1	3.6	-	-	-	-	-	-	-	3.6	3.6
Oct '75	12	26.8	13.4	-	19.2	7.7	15.4	-	-	-	-	-	-	-	7.7	3.9	3.9
Nov '75	25	22.8	14.6	-	18.8	8.3	12.5	4.2	-	-	-	-	-	-	-	14.6	4.2
Dec '75	73	27.8	8.6	-	19.0	12.0	8.6	-	-	1.7	-	-	-	-	8.6	12.0	1.7
Jan '76	127	13.9	27.8	-	20.8	12.5	4.2	1.4	-	-	-	-	9.7	-	0.7	9.0	-
Feb '76	147	10.1	40.4	1.5	19.7	6.6	4.5	2.0	1.5	5.0	0.5	-	-	-	-	6.6	1.0
Mar '76	157	4.6	55.7	-	16.3	11.7	2.5	2.1	-	0.4	-	-	-	1.7	0.4	3.3	1.3

TABLE 33

Relative importance of major dietary organisms by weight of five bearded rocklings, *Ciliata mustela* obtained from the fish weir at Minehead during 1975-76, expressed as a percentage of the total weight of the stomach contents. (Also included are the numbers investigated).

MONTH/ YEAR	NO. INV.	*Crangon crangon*	*Gammaris spp.*	*Neomysis*	Crabs	Prawns	*Gobius minutus*	*Idotea granulosa*	Hermit Crab	R. Periwinkle	Squids	Prawn Eggs	*Polychaete* Worms	Isopods	Unidentified	Flora, Stones, Debris etc
Mar '75	49	1.1	82.0	-	1.1	-	1.7	1.4	-	-	-	-	12.7	-	-	-
Apr '75	67	8.2	6.7	-	8.2	9.6	4.9	2.0	-	-	-	-	-	-	-	-
May '75	68	7.0	23.5	-	19.0	33.0	7.5	10.0	-	-	-	-	-	-	-	-
Jun '75	16	65.7	34.3	-	-	-	-	-	-	-	-	-	-	-	-	-
Jul '75	31	7.3	57.3	1.6	26.6	-	4.0	3.2	-	-	-	-	-	-	-	-
Aug '75	52	51.0	27.1	-	12.1	2.1	1.1	5.8	-	-	-	0.2	-	-	-	-
Sep '75	17	52.1	6.8	-	11.4	21.2	5.3	2.4	-	-	-	-	-	-	-	0.8
Oct '75	12	27.9	5.1	-	24.6	10.2	22.6	-	-	-	-	-	-	-	9.3	0.9
Nov '75	25	30.9	17.8	-	19.1	20.7	5.7	3.2	-	-	-	-	-	-	-	2.6
Dec '75	73	56.7	1.3	-	14.2	14.8	6.6	-	-	0.2	-	-	-	-	3.0	3.2
Jan '76	127	19.9	9.8	-	22.4	24.8	1.1	0.7	-	-	-	-	19.3	-	0.1	1.9
Feb '76	147	25.6	27.5	0.2	20.0	14.5	3.5	0.7	2.1	3.0	1.9	-	-	-	-	1.0
Mar '76	157	4.5	41.8	-	19.0	29.7	0.8	-	-	0.2	-	-	-	1.7	0.8	1.5

a parasite must obviously extract 'something' from its host and;

(b) the majority of parasites are not in the adult form but need to be transferred to a predator in order to complete their life cycle.

Thus in this case it may be to their advantage to weaken or kill the host fish (Thomas, 1964).

At Oldbury 50.0% of small numbers of animals investigated had Nematodes and in 1974/1975 and 1975/1976, the number of parasitised fish was reasonably constant (Table 34). The number of infected fish throughout the study area appeared to be similar to that of Oldbury, except that no parasitised fish were found at Uskmouth, but here the number of fish investigated was very small and this result may be misleading.

Another interesting feature was the occurrence of marks resembling those made by lampreys, thus from Table 35 it can be observed that at Oldbury and Berkeley in the 1975/76 season 0.9% of the total population had these marks, while at Hinkley and Minehead it was 1.1 and 1.5% respectively. An increased frequency of lamprey attack in the Bristol Channel compared to the Severn sites would be expected from the known habits of the River lamprey, *L. fluviatilis*. This species normally ceases to feed when it enters the estuary on its upstream spawning migration. However, latter study revealed that these marks were due to a parasitic amphipod which was found to be attached to the fish.

PLATES 21 - 23

Parasitic attack on Five Bearded Rocklings, *Ciliata mustela* at Minehead.

21

22

23

TABLE 34

Parasite infestation (*Nematode spp.*) in five bearded rocklings, *Ciliata mustela* caught at the various sampling sites along the Severn Estuary and the Bristol Channel, expressed as a percentage of the total number of animals obtained from 1974-1976.

LOCALITY	1973 / 1974	1974 / 1975	1975 / 1976
Middle Reaches of Severn Estuary			
Oldbury	50.00	1.90	2.00
Berkeley	-	2.10	2.01
Uskmouth	-	-	-
Bristol Channel			
Hinkley Point	-	2.20	2.40
Minehead	-	-	2.41

TABLE 35

Frequency of occurrence of five bearded rocklings, *Ciliata mustela* attacked by parasitic amphipod along the Severn Estuary and Bristol Channel, expressed as a percentage of the total number of animals examined during 1974-1976.

LOCALITY	1973 / 1974	1974 / 1975	1975 / 1976
Middle Reaches of Severn Estuary			
Oldbury	-	-	0.90
Berkeley	-	-	0.99
Uskmouth	-	-	-
Bristol Channel			
Hinkley Point	-	-	1.10
Minehead	-	-	1.50

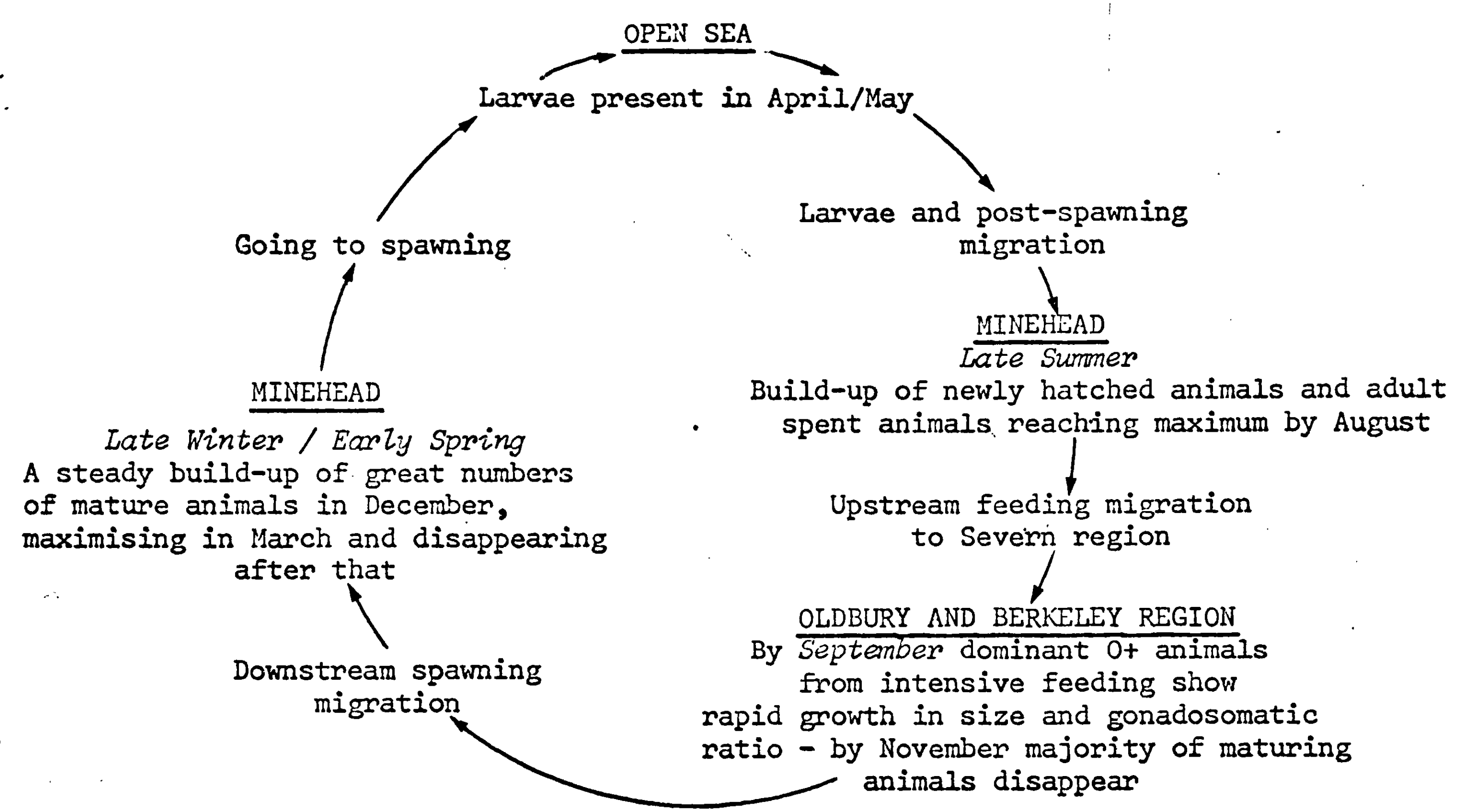
5.3. DISCUSSION

With the exception of Minehead, five bearded rocklings are winter residents in the study area and are found in abundance at Oldbury, Berkeley and Hinkley Point between the months of November and February. The larvae of this species is known to be present in the open sea (Collins : personal comm.) between late April and early May and it may be supposed that from the open sea, fish of two sizes or age groups migrate into the Bristol Channel. These would consist of the recently hatched fish and a small proportion of the adult population that has completed spawning. Support for this view is provided by analyses of the population at Minehead, a sampling point relatively near to the probable spawning grounds in the Bristol Channel. The presence of newly hatched animals and spent adults is detected as early as July, building up to maximum numbers by August. At this stage, only a small number of fish are present in the Oldbury region but by September there is a considerable increase in the 0+ age class and, to a lesser extent in the 1+ and 2+ year classes (Fig. 74).

During this period while numbers are increasing at Oldbury, there is an almost corresponding reduction in the numbers at Minehead. After extensive feeding and rapid growth, the majority of the fish disappear from the Oldbury region by November, presumably entering into a downstream spawning migration. These mature animals are then detected at Minehead in December, increasing to a maximum by March and then disappearing as they move to open sea to spawn. In these respects the migratory movements of this species are similar to those of other estuarine species, such as the flounder.

FIGURE 74

Life cycle of Five bearded rocklings, *Ciliata mustela*, in the Severn Estuary and The Bristol Channel.



Measurements of oocyte diameters provide clear evidence that the five bearded rocklings embark on a spawning migration of long duration, thus a wide variation in egg size is observed in the spawning population and this view is confirmed by the presence of larvae in the open sea from April to June.

Both otolith readings and length-frequency studies suggest that the population at Minehead (see life cycle diagram) falls into two or even three age categories. The two most important groups are the 0+ and 1+ year classes, accompanied by larger animals between 270-280 mm, adjudged to be at least two years of age and may be as old as six, as suggested by otolith analyses. Wheeler (1969), however, was unable to detect fish larger than 200 mm around the British coast, This could be due, at least in part, to his sampling techniques. There are differences in growth pattern between sexes. The males generally grow gradually during sexual maturation but the 1+ females grow slowly at first and then more rapidly. It appears that local variation in growth is common throughout the estuary and the channel and animals of the 2+ age class and older are rare, if not absent, in the upper reaches of the estuary. Another peculiar feature is that males generally occur in much smaller numbers than females, thus, over 72% of the fish at Oldbury, for example are females. The reason(s) for this fact are not yet known. It could be due to sex differences in life span, seasonal movements or physiological requirements. In fecundity the mature fish show a considerable variation; oocyte numbers do not exhibit any obvious correlation with local environmental conditions such as temperature, salinity, or 'rich feeding environment'.

The feeding habits of the rockling understandably reflect the total availability of acceptable food items in the estuary. The fact that the fish tends to be an indiscriminate feeder is evident from the presence in the stomach of debris, such as black stones, polystrene spherules (Kartar *et al*, 1976), wood and dead vegetation. At Oldbury and Berkeley, where conditions are slightly less conducive to supporting large varieties of food organisms, the fish depends largely on the readily available and abundantly occurring *Crangon crangon* and *Gammarus spp*. On the other hand at Minehead and Hinkley Point, which have a richer marine fauna, many other species are eaten.

PART 6

LITERATURE REVIEW – HEAVY METALS

6. LITERATURE REVIEW - HEAVY METALS

The vast majority of the literature on heavy metals in marine species relates to either toxicity, the presence of metals in the water or a statistical presentation of heavy metal data in marine organisms, but rarely a combination of all three. However, there is constant caution from well-documented observations that evaluation of toxic effects upon marine animals is meaningless unless several basic factors that influence the chemical or the physical form of the poison in the water or the biochemical reaction of the animal to them are taken into consideration. It is known that heavy metals such as copper, zinc, lead and cadmium are normally present in marine and estuarine environments, but additional quantities are inadvertently or deliberately introduced at certain times and since these metals are 'toxic' an important service is provided by analysts simply monitoring changes in levels and alerting ecologists to potential hazards. It is then up to the ecologists to define the toxicological parameters. Such a situation is described in a recent editorial (Marine Pollution Bulletin 4, 1973): "where that limit is, how close we are to it, whether or not as the limit is approached the ecosystem will show gradual deterioration or will suddenly deteriorate like the collapse of a house of cards are all unknown".

Thus, in order to understand some of these problems, a few workers (Krauskopf, 1965; Schutz and Turckian, 1965; Goldberg, 1957; Fukai and Huyuh-Ngoc, 1968) have investigated the course of events leading to teleost toxicity when high concentrations of heavy metals were introduced into the sea by rivers. Their results showed that besides the obvious effects of dilution, at least three other processes occur, namely precipitation, adsorption and absorption; significantly reducing the concentration of heavy metals in a marine environment. Krauskopf (1956) found for example, that normal sea water is far from saturated with heavy metals and since zinc, copper, cadmium, lead and silver sulphides in water are subsequently absorbed by bottom living organisms (Richards, 1965). Hahne and Kroontje (1973) reported that their investigations confirmed the above findings and suggested that both hydroxy and chloride complexes may contribute to the immobilisation of silver, zinc, cadmium and lead ions in the environment and further observed the importance of water of pH above 5, 7 and 8 in the hydrolysis of lead, zinc and cadmium salts respectively.

Bryan (1971) showed that absorption of metals from solution occurs at the surface of particular materials such as clay, phytoplanktonic organisms, hydrated ferric oxide and hydrated manganese dioxide, the last two being abundant in coastal waters. Studies by Krauskopf (1956) and Fukai and Huyuh-Ngoc (1968) indicated that zinc, copper and lead were readily absorbed by both hydrated ferric oxide and hydrated manganese dioxide.

The importance of distributional patterns of heavy metals in marine organisms led Preston and Jefferies (1969) to investigate the behaviour of radioactive wastes discharged into the sea and confirmed that metals which precipitated readily had a comparatively small area of distribution, whereas those metals which formed more soluble salts were dispersed further afield. Several workers (Jones, 1937; Henderson and Tarzwell, 1957; Cairns and Scheier, 1957; Lloyd and Herbert, 1962) found that many heavy metals have been shown to be more toxic in soft water than in hard water. Lloyd and Herbert (1962) in their studies on the effects of calcium carbonate on the lethal threshold concentrations of various metals, have shown that calcium ions in particular reduce the toxicity of heavy metals. The reason for this apparent protection by calcium ions has been suggested by Lloyd (1972) to be biochemical rather than the stimulation of a protective mucal film over the exterior of the animal, as was originally suggested by Jones (1937). Subsequently it has been found by Proctor and McGowan (1976) that magnesium also tends to show similar protective behaviour.

Several studies (Jones, 1937; Harvey, 1957; Parry, 1960; Shiray and Mori, 1958; Herbert and Wakeford, 1964; Westernhagen *et al*, 1975) show that one of the most important factors that influence the toxicity of most heavy metals to marine animals is salinity and it is now generally known that the harmful effects of most metallic poisons is considerably less in sea water than in fresh water and that a fish offers greatest resistance to heavy metals when the marine environment is isotonic with its blood (Jones, 1937; Herbert and Wakeford, 1964).

The action of an individual element is considerably affected by the addition of another. Thus, Bandt (1946) exposed trout and roach to mixtures of sulphates of some heavy metals in soft tap water and obtained the following results:

Zinc	+	Cadmium	=	additive toxicity effect
Zinc	+	Lead	=	synergistic effect
Zinc	+	Copper	=	strong synergistic effect, up to 5 times more toxic than the individual element.

Daudoroff (1952) obtained similar results, thus confirming Bandt's findings.

The consistency of response of a species of fish to toxic matter is also considerably influenced by factors relating to fish biochemistry, such as temperature of the environment, the age and the size of the teleost and the oxygen concentration of the water (Southgate, Pentelow and Bassindale, 1933; Well, 1935; Downing, 1954). Additionally each of these is related to the oxygen consumption rate of a particular species. The most obvious reaction of a fish to a lowered oxygen concentration is to increase the volume of water passing over the gills and thus increasing the amount of dissolved toxic material reaching the surface of the gill epithelium. Lloyd's (1961) investigations showed that is the site where the majority of the soluble toxic poisons are absorbed.

Extensive investigations in the past of the toxicity of zinc salts to aquatic animals, especially fish, have been conducted and most of these studies have been reviewed by Daudoroff and Katz (1953), Makee and Wolf (1963) and Skidmore (1964). Thus 300 ppm of zinc was found to be lethal to *Phonixus phonixus* (minnows) after 200 minutes in distilled water at a temperature of approximately 18^{o}C by Carpenter (1927) but Affect (1952) working on trout in a hatchery at a temperature between 8 and 12^{o}C reported that zinc concentrations as low as 0.13 ppm were sufficient to kill all the experimental animals within a day. Further experiments with *Scardinius erylbro-phthalmus* (Rudd) showed that this species has a 5 day Tlm (tolerance/limit/minutes) for zinc of 17 mg / litre (17,000 ppm) in hard water, about four times that of rainbow trout. Therefore, the resistance of aquatic animals to zinc poisoning varies at both the level of individual and of the species.

Lloyd (1960) found that the effect of the hardness of the water on zinc toxicity followed a general pattern, namely that zinc toxicity reduces considerably with increasing hardness, hence as the hardness increased from 10 ppm calcium carbonate to 320 ppm of calcium carbonate, the lethal concentration of zinc to trout increased from 0.2 ppm to nearly 4.0 ppm.

Although temperature has been found to influence the survival time of fish in toxic media, it does not affect the threshold concentration (Lloyd, 1960). This author observed that by decreasing the temperature from 22 to 12°C, the survival rate increased by a factor of 2.35*.

Westfall (1945) demonstrated that the effect of dissolved oxygen followed a general pattern, zinc being more toxic in water with low oxygen levels.

Lloyd (1960) and later Sprague *et al* (1965) calculated that over an exposure period of 1000 minutes, the concentration of zinc necessary to kill fish in a laboratory experiment was 14 times greater at an oxygen concentration of 8.9 ppm than it was at 3.8 ppm.

Edwards (1967) noted that the sensitivity of fish to heavy metals, particularly zinc, varied with size; the smallest fish of a given age generally being more resistant than the larger ones. His field data suggests that the fish population can "generally exist where (a) the sum of the threshold (48-h Tlm) of soluble poisons does

---

* In contrast to these findings, Cairns and Scheier (1957) in their studies with animals exposed to toxins over long periods observed little difference between the toxicity at 18 or 30°C in hard water. It is possible however, that the latter workers were using concentrations close to threshold levels, thereby not necessarily contradicting Lloyd's findings.

not exceed 0.3 to 0.4 ppm; (b) the dissolved oxygen concentration is about 50% of the air saturation value; and (c) the suspended solids concentration does not exceed 60 to 100 ppm."

The sequence of effects of cadmium poisoning on estuarine teleosts may vary dramatically, depending among other factors, on the quality and salinity of the water at the time of exposure (Pickering and Henderson, 1966; Gardener and Yevich, 1969). Shore *et al* (1975) and Westernhagen *et al* (1975) showed that besides the quality of the water and salinity levels, correlation between cadmium levels, glucose metabolism and salinity played a major part in cadmium toxicity. The toxicities of cadmium to the fresh water fathead minnow, *Pimephales promelas* exposed for 96 hours was 0.63 ppm in soft water and 73.5 ppm in hard water, with similar trends established for the green sunfish *Leponus ajanellus* (Pickering and Henderson, 1966).

Eisler (1971) found that the 96 hour Tlm for *Fundulus spp.* in sea water of 24% was 55 ppm for cadmium. These estimations are much higher than those of Powers (1917) and Ellis (1937). Schweiger (1957) quoted 4 ppm of cadmium as being lethal to rainbow trout in 7 days and 33 ppm of cadmium as being 'safe', while another report (Ministry of Technology, 1967) indicates that the 7 day Tlm for the same species was 0.4 ppm. In sea water, altered salinity, oxygen, pH and temperature were shown to change the sequence and the degree of occurrence of pathological changes in *Fundulus sp.* after exposure to 50 ppm of cadmium (Gardner and Yevich, 1969b). Investigations into the susceptibility of eggs of inshore spawning teleosts (*Clupea hatengus* and *Platichthys flesus*) showed that these eggs proved to be quite resistant to the toxic action of cadmium (Dethlefsen *et al*, 1975) and that there existed specific differences in the accumulation of cadmium from the sea water. Shuster and Pringle (1969) found that cadmium in excess of 100 ppm was lethal to oysters.

Several studies (Dilling *et al*, 1926; Carpenter, 1927) indicate that in general, factors that affect or change the toxicity of other metals discussed above, seem also to apply to lead. Lead salts are extremely insoluble in water and precipitate rapidly when added to either fresh or salt water, thus limiting lead distribution around the source. Investigations by Pickering and Henderson (1966) on the acute toxicity of lead found that 96 hour Tlm values in soft water for the fathead minnow and the goldfish were 7.48 and 31.5 ppm respectively, but were significantly lower than this for 24 hours. This, therefore, suggests that the mechanism of toxicity is different at high concentration and short exposure than at low concentration and long exposure.

As early as 1919 Carpenter (see Jones, 1964) first studied the relationship between pollution of a river with heavy metals and the resultant disappearance of aquatic animals. Subsequently, due to the recognition of the health hazard to humans of trace metals (Schroeder *et al*, 1967) and in the light of available information regarding the effect upon marine life, several detailed studies have been conducted periodically ever since, primarily to evaluate toxic metal accumulation in aquatic organisms. Depending on the metabolic effect of the individual elements and the species of aquatic life involved, Gustafson *et al* (1966) found that trace metals are either concentrated, maintained at constant values or are differentially eliminated at each of the various trophic levels. Fish generally accumulate trace metals from the environment via the food chain and therefore act as indicators of heavy metal pollution.

Lloyd (1961) and Skidmore (1964) reported that most of the absorbed heavy metals are subsequently lost if fish from heavily polluted areas are returned to a metal free environment. It is generally known that there are appreciable amounts of zinc in the tissues of all marine animals and according to analyses by Vinogradov (1953), there is usually much more zinc than cadmium present. Bodansky (1920) in his analyses of 14 common fishes, referred to species differences which indicated rather high values in spotted trout and flounders and extremely high values in the sea catfish. These differences in zinc concentrations are probably due to variations in feeding habits of individual marine species. Most of the zinc found in the fishes was concentrated in the liver, bone and the spleen of trout and flounders, whilst in the catfish the highest levels were found in the gills (Bodansky, 1922).

Samples collected from inshore waters along the Atlantic and the Gulf of Mexico by Chipman *et al* (1958) showed that oysters, clams and scallops contained large amounts of zinc. These figures were thousands of times greater than for the local sea water in which these animals live. Typical values reported were 391 to 3174 ppm (per gram of fresh tissues) in oysters from the coast of Galveston, on the Texas coast and at Mildford, Connecticut with corresponding values for the sea water at these sites being 0.008 to 0.018 ppm. Several American investigators have reported similarly high concentrations in oysters around the American coast (Cousen *et al*, 1932; MacFarren *et al*, 1962; Gallstoff, 1964; Pringle *et al*, 1968; Shuster and Pringle, 1969). Cadmium and lead levels found by these investigators are much lower than those of zinc, a typical range for cadmium being from 0.08 to 7.78 ppm and for lead 0.12 to 2.29 ppm (net oyster weight).

Several studies have recently appeared reporting heavy metal estimations in marine invertebrate and vertebrate populations in British estuaries and coastal waters. Mackay and Topping (1970) working on a number of marine animals collected from the Firth of Clyde concluded that the marine specimens from near the centre of the industrial area contained considerably higher levels of heavy metals than those from further downstream. Various heavy metals were also found in the guts of commercially valuable fish from that area. However, these findings indicate that gills are not the main source of entry of heavy metals. Hoss (1964) in a radiotracer study found that brine shrimps *(C. nauplii)* accumulated zinc 55 from water at a faster rate than did the flounder, and since the former animal constitutes an important item in the diet of the flounder, Hoss concluded that in the natural environment the amount of zinc passing through the food chain to the flounder would be greater than that obtained by direct uptake from the water. This concentration effect is confirmed by the data collected on food chain uptake by fresh water fish (Williams and Pickering, 1961; Ball and Hopper, 1963). The majority of the literature on the uptake of heavy metals by marine species appears to ignore to a large extent the ecological and environmental implications involved in the mechanism of uptake and retention of these metals. Hardisty *et al* (1974a) reported a correlation in the uptake of cadmium and the presence of *Crangon crangon* in the stomach of the host. Further observations indicate that animals in localities known to have rich zinc and lead deposits showed a greater retention trend. A more detailed studied of the uptake of heavy metals and possible biological parameters responsible for it are discussed by the author in his Masters thesis (1974).

Comparisons between marine and fresh water species show their heavy metal uptake to be greatest in the softer parts of the organisms. Thus in fish, the highest concentrations of heavy metals were generally found in the digestive organs and the gills and the lowest being in the muscles (Segar, 1970; Hardisty *et al*, 1974b).

Butterworth *et al* (1972) demonstrated that heavy metals are concentrated in living organisms within the littoral zones of the Severn Estuary and the south coast of the Bristol Channel (cf. Abdullah *et al*, 1972 for sea water results) reaching levels which they considered very high and probably constituting a hazard.

The Natural Environment Research Council and Bristol University in their Sabrina Project (Butterworth *et al*, 1972) found that metal concentrations were least in *Fucus* (producer) and greatest in *Thais* (secondary consumer). Other workers (Pedan *et al*, 1972) analysed limpets, *Patella vulgata* for heavy metals from eleven sites along the Somerset coast and came to similar conclusions to those of Butterworth *et al* (1972) and Nickless *et al* (1972). There appeared to be a gradient of cadmium concentrations rising to very high levels around Avonmouth. Further, the limpets collected from near the low tide mark contained more cadmium than individuals living at the high tide point. Higher concentrations of cadmium were found in larger limpets (36-43 mm shell diameter) but small limpets (20-26 mm shell diameter) showed surprisingly higher concentrations (approximately three times) than the larger limpets.

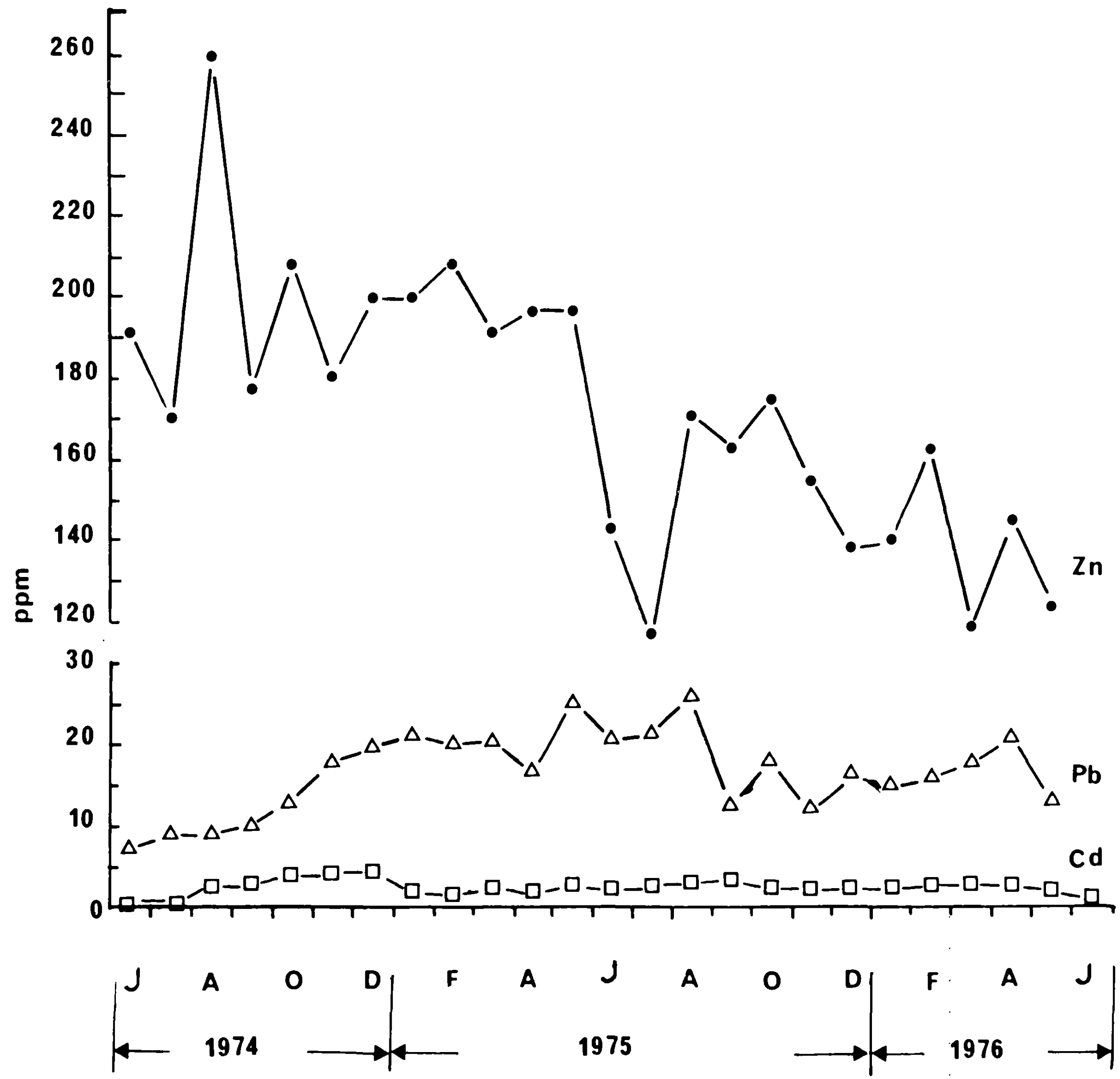
Several investigators have recently estimated heavy metal levels in sea water. Chipman *et al* (1954) found that zinc levels in sea water samples from inshore waters along the Atlantic coast of America and the Gulf of Mexico ranged from a trace to 24.6 ppm; the higher values were obtained for samples from areas known to receive metal contamination. Further, there was a seasonal difference in the zinc levels in the sea water, with lowest levels occurring during the winter months. Butterworth *et al* (1972) reported zinc concentrations as 10 ppm in the open sea and 52 ppm in the Severn Estuary with corresponding cadmium values of 0.1 ppm and 5.8 ppm respectively, both metals being most evident in the upper reaches of the estuary, near the industrial complex of Avonmouth. These results are supported by the extensive investigations of Abdullah *et al* (1972) who further suggested that the metals once released into the estuary tend to circulate within this region and are not easily removed into the deep sea. This is due to tidal effects within the Severn Estuary creating a pulsing effect. Both the natural metal run off, the industrial and domestic waste disposal in areas of limited circulation could lead to a considerable increase in the concentrations of these metals, far beyond that normally found in the open sea.

PART 7

RESULTS

FIGURE 75

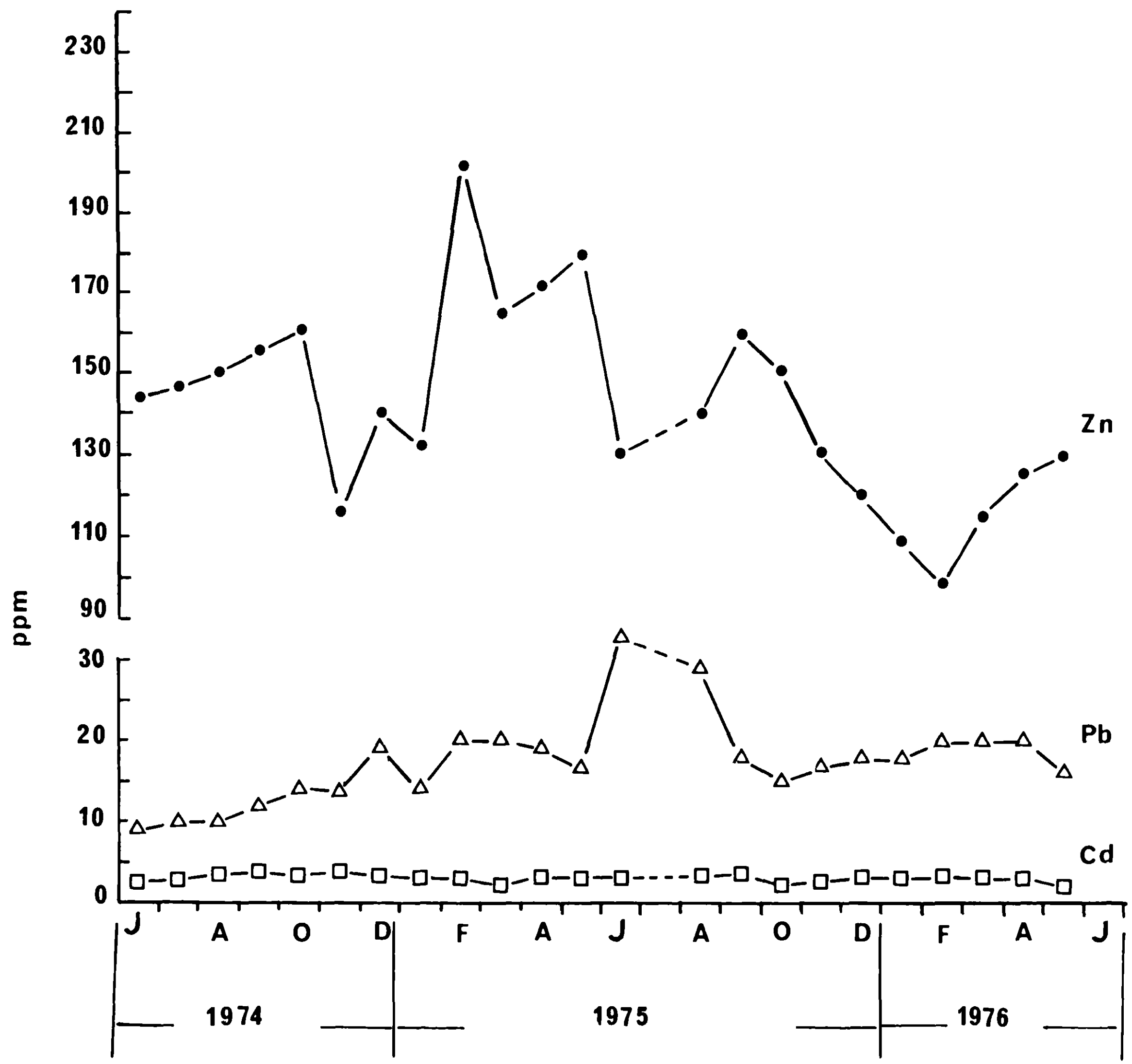
Mean zinc, lead and cadmium concentrations (ppm) in flounders, *Platichthys flesus* as it grows from 0+ to 1+ age class at Oldbury.



ppm
260
240
220
200
180
160
140
120
30
20
10
0
Zn
Pb
Cd
J A O D F A J A O D F A J
1974
1975
1976

FIGURE 76

Mean zinc, lead and cadmium concentrations (ppm) in flounders, *Platichthys flesus* as it grows from 1+ to 2+ age class at Oldbury.



ppm
230
210
190
170
150
130
110
90
30
20
10
0
Zn
Pb
Cd
J
A
O
D
F
A
J
A
O
D
F
A
J
1974
1975
1976

FIGURE 77

Mean zinc, lead and cadmium concentrations (ppm) in flounders, *Platichthys flesus* as it grows from 2+ to 3+ age class at Oldbury.

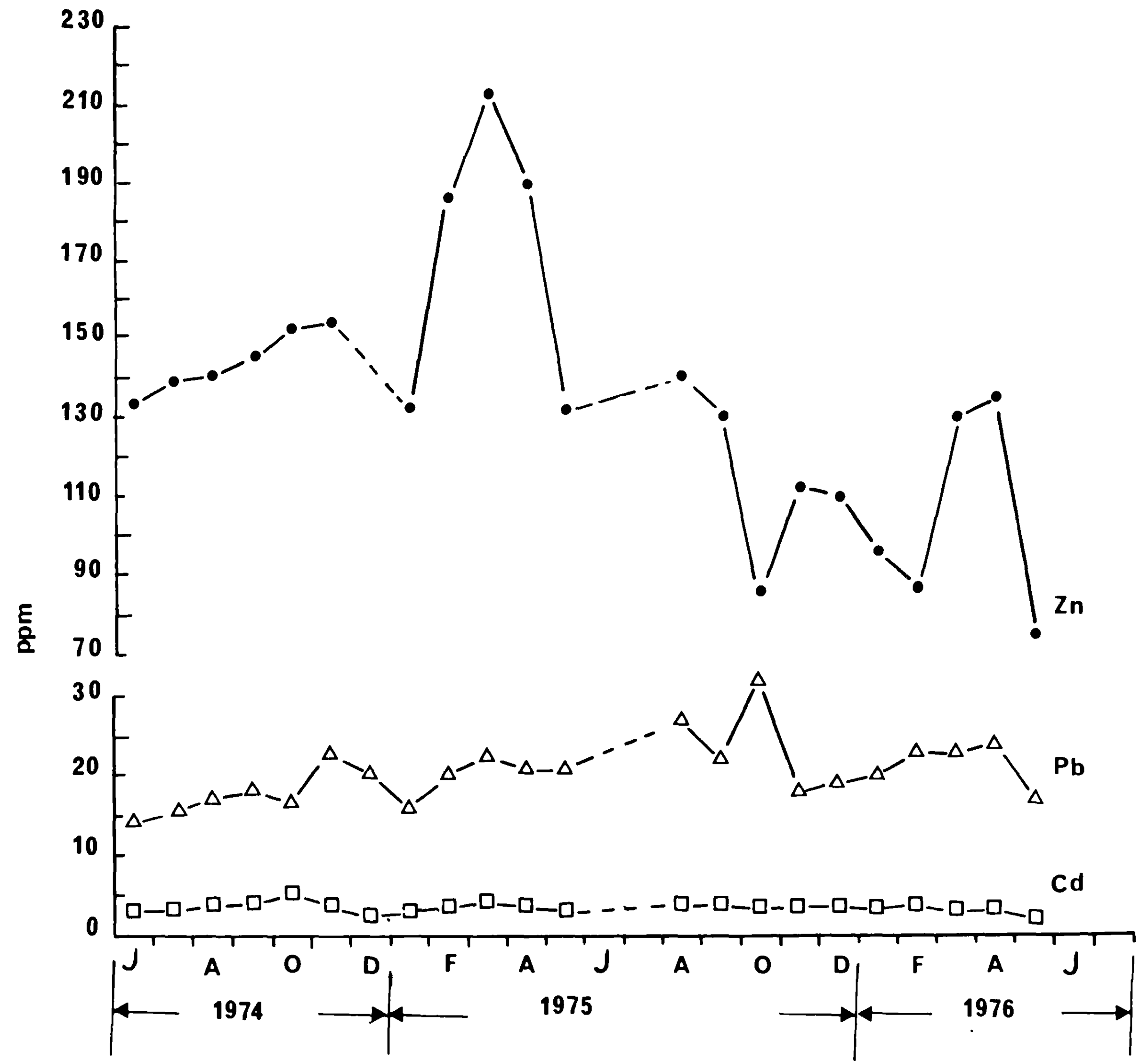

ppm
230
210
190
170
150
130
110
90
70
30
20
10
0
Zn
Pb
Cd
J
A
O
D
F
A
J
A
O
D
F
A
J
1974
1975
1976

FIGURE 78

Mean zinc, lead and cadmium concentrations (ppm) in flounders, *Platichthys flesus* as it grows from 3+ to 4+ age class at Oldbury.

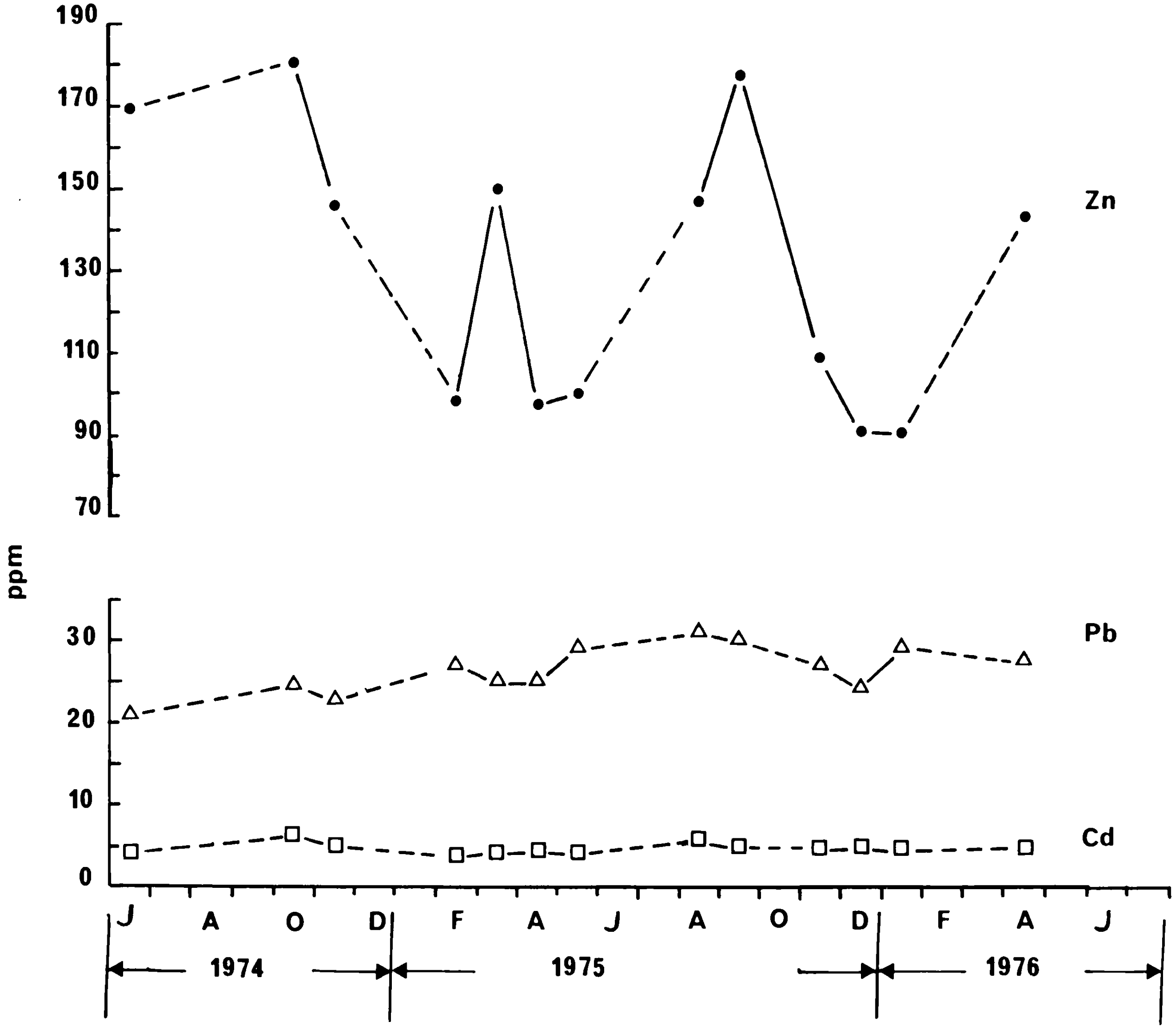

190
170
150
130
110
90
70
ppm
30
20
10
0
Zn
Pb
Cd
J
A
O
D
F
A
J
A
O
D
F
A
J
1974
1975
1976

FIGURE 79

Mean zinc, lead and cadmium concentrations (ppm) in flounders, *Platichthys flesus* as it grows from 4+ to 5+ age class at Oldbury.

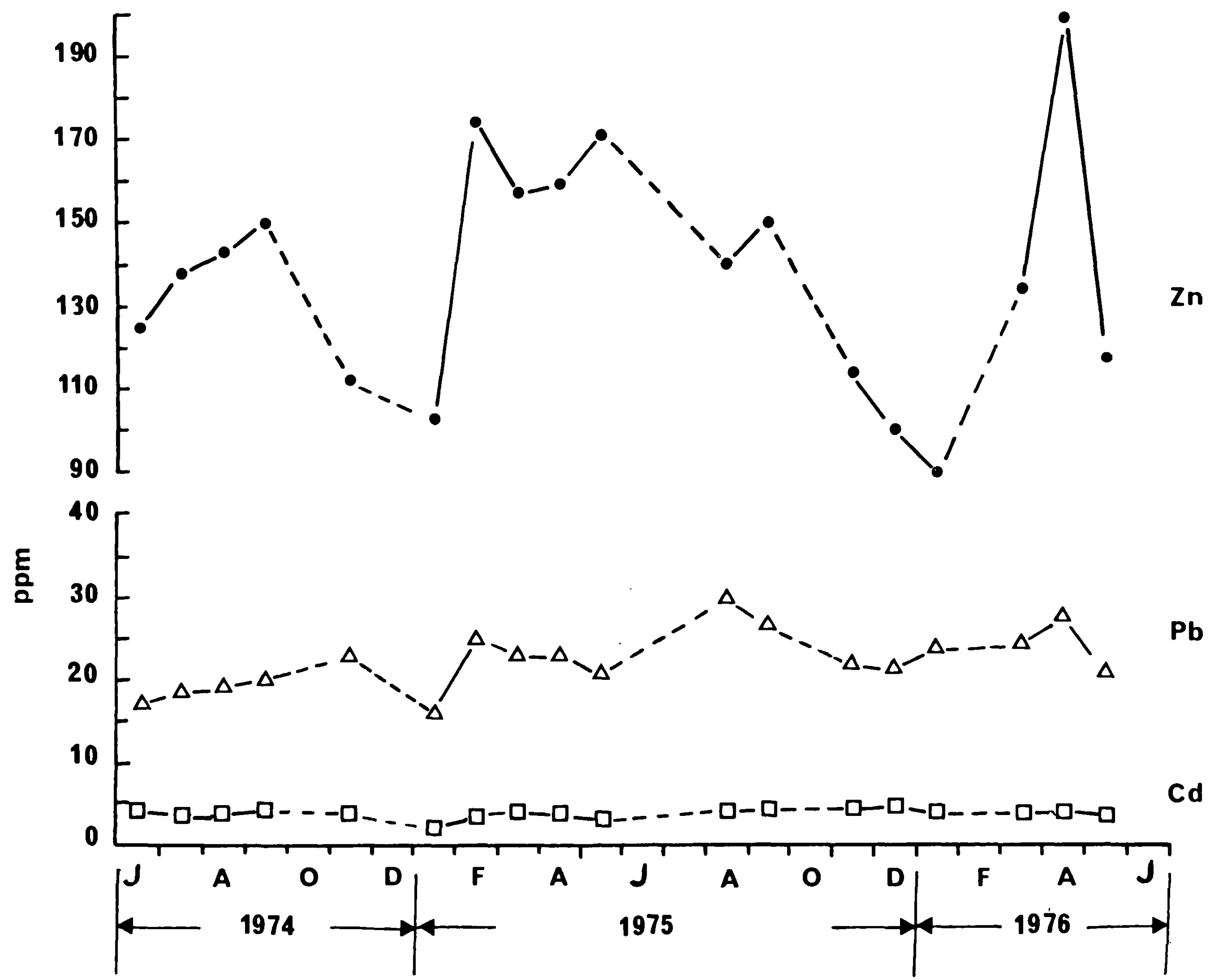

190
170
150
130
110
90
40
30
20
10
0
ppm
Zn
Pb
Cd
J
A
O
D
F
A
J
A
O
D
F
A
J
1974
1975
1976

FIGURE 80

Mean concentrations (ppm) of zinc in the 0+ and 1+ flounders, *Platichthys flesus* obtained from the cooling water intakes of Oldbury Power Station from 1972-1976.

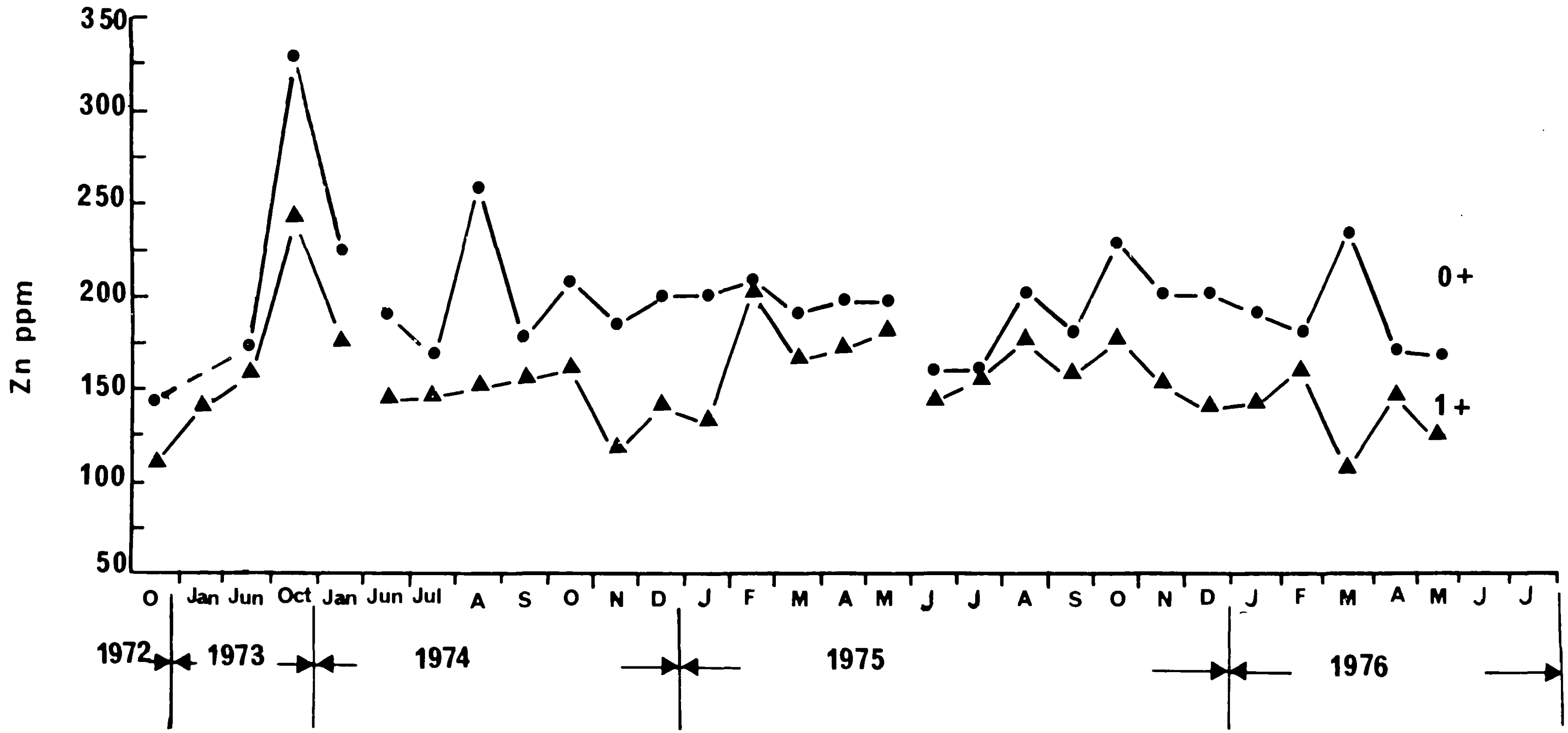
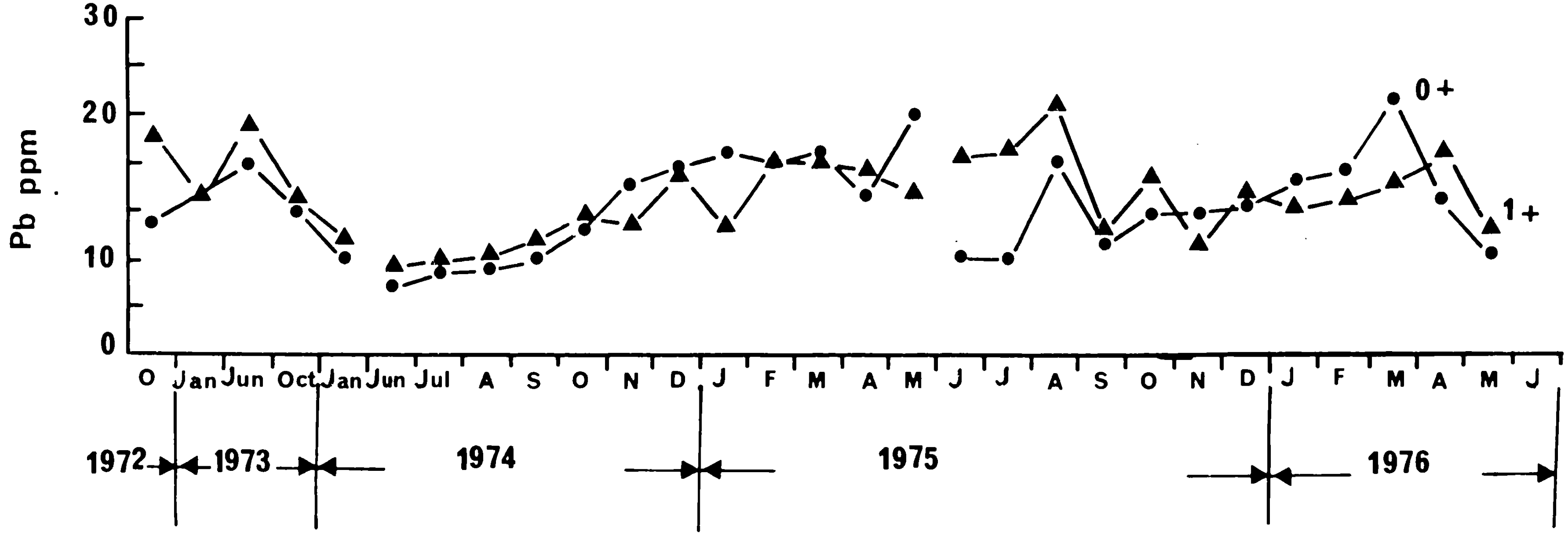

Zn ppm
350
300
250
200
150
100
50
0+
1+
O Jan Jun Oct Jan Jun Jul A S O N D J F M A M J J A S O N D J F M A M J J
1972
1973
1974
1975
1976

FIGURE 81

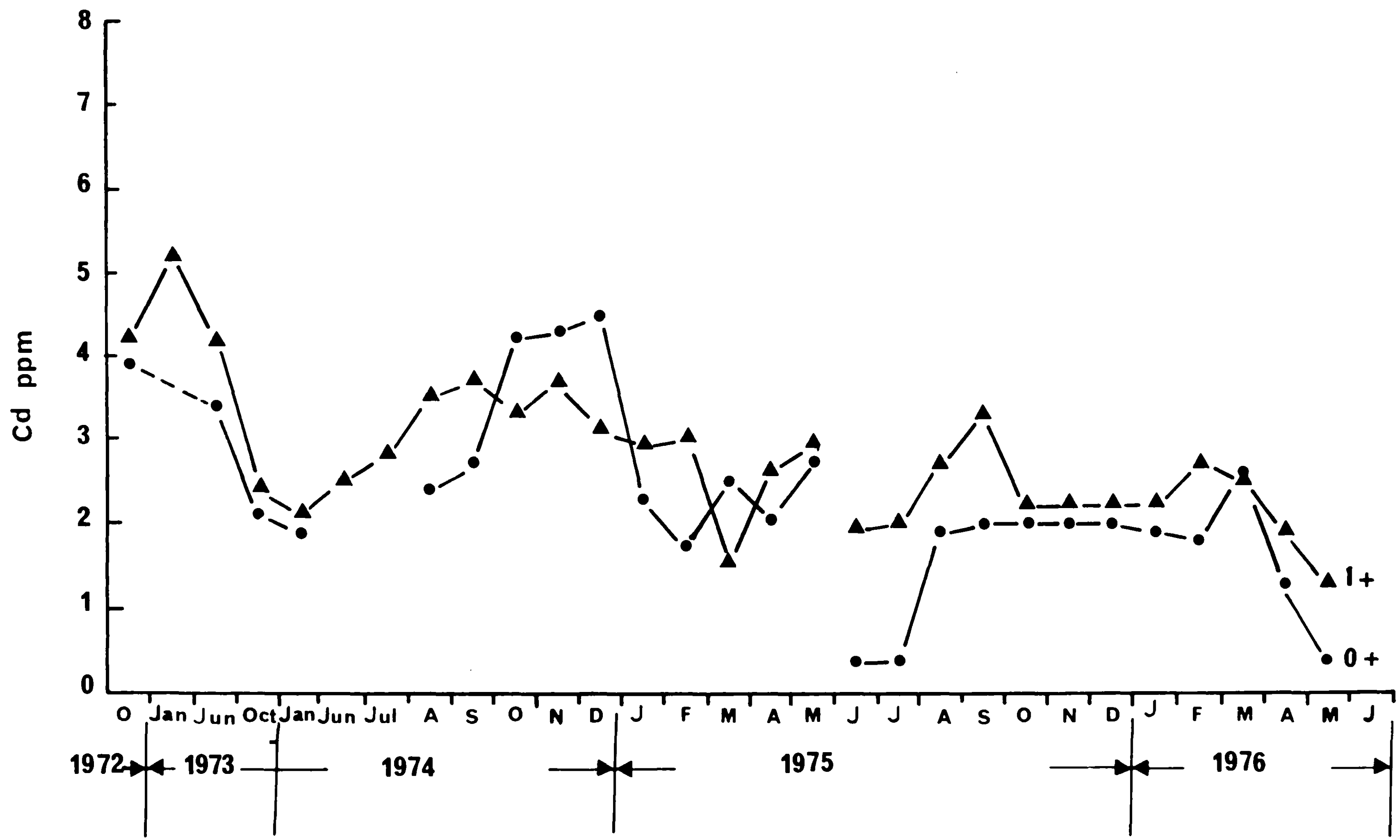
Mean concentrations (ppm) of lead in the 0+ and 1+ flounders, *Platichthys flesus* obtained from the cooling water intakes of Oldbury Power Station from 1972-1976.



Pb ppm
30
20
10
0
0+
1+
O Jan Jun Oct Jan Jun Jul A S O N D J F M A M J J A S O N D J F M A M J
1972
1973
1974
1975
1976

FIGURE 82

Mean concentrations (ppm) of cadmium in the 0+ and 1+ flounders, *Platichthys flesus* obtained from the cooling water intake screens of Oldbury Power Station from 1972-1976.



Cd ppm
0
1
2
3
4
5
6
7
8
O Jan Jun Oct Jan Jun Jul A S O N D J F M A M J J A S O N D J F M A M J
1972
1973
1974
1975
1976
1+
0+

levels ranging from about 7 ppm to 10 ppm for the first four months, rising fairly rapidly by mid-winter of the same year and remaining between 15 ppm and 25 ppm for the rest of the period. In the first two months (June and July 1974), cadmium was not detectable despite the analyses of over 200 animals but in August cadmium levels of about 2.5 ppm were recorded, these rose steadily to just under 5 ppm by December and then fell by January of the next year, (i.e. 1975) to around 2.5 ppm. Here the level remained more or less constant for the rest of the second year (1976).

By assuming that the effects of immigration and emigration are slight, a plot of zinc, lead and cadmium levels for one age class (gradually maturing) from 1+ in June 1974 to 2+ in May 1976 is shown in Fig. 76. The erratic nature of the zinc concentrations for example indicate that the above assumption may not be totally justified, but nevertheless it may be judged that zinc levels tend not to change greatly as flounders age, whereas lead slowly accumulates. Cadmium on the other hand remains more or less constant, perhaps slightly increasing. These trends still persist as the 2+ group matures (Figs. 77-79).

Fish in the 0+ and 1+ age range are growing quickly, thus their metal levels are particularly interesting,(Figs. 80-82) especially since the animals do not undertake a downstream spawning migration or any extensive feeding migration and are, thus more likely to be localised within the estuary for a greater part of their life.

With the exception of local monthly variations, zinc levels in both 0+ and 1+ age class animals do not significantly change from October 1972 to May 1976. But the animals of the 0+ class accumulate a marginally higher quantity of zinc than the 1+ age class. Lead tends to increase gradually but cadmium levels on the other hand, barring some monthly fluctuations, seem to show a just detectable fall from 1972 to 1976.

At the transition period from 1+ to 2+ age, the accumulation of lead in fish increases by a factor more than one and a half. The duration of this period of high lead accumulation is about four months.

Limited 1973/1974 summer results of flounders caught from Barnstaple Bay (Appendix 42) show the proportion of zinc present in all age groups from 2+ to 7+ are similar to those of Oldbury. Here, the younger fish contain more zinc and less lead than the older fish. The cadmium levels are much lower here than at Oldbury and a slight accumulatory evidence is noted as the fish grow from 2+ to 7+ year class as seen in Figs. 83-85.

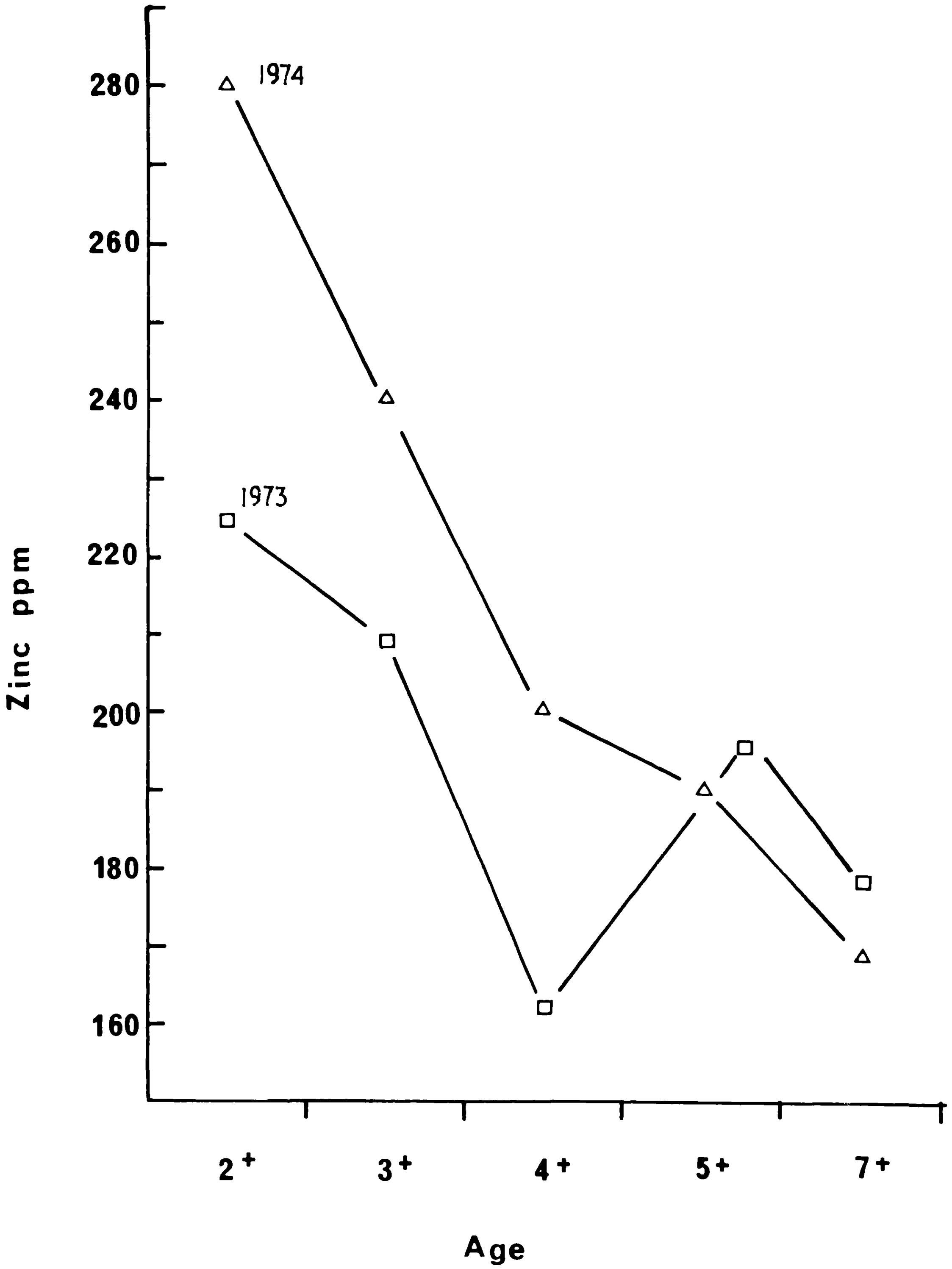
7.2. SEA SNAILS, *LIPARIS LIPARIS*

The three Power Stations at Berkeley, Oldbury and Hinkley Point are conveniently situated to serve as a constant source of sea snails, *Liparis liparis* which have been investigated for heavy metals. Sea snails are winter residents in the Severn Estuary (see biology, page 37) and are found in abundance at the above sites at this time. Samples from September until March were collected and analysed at Oldbury. These investigations were conducted for 1973/1974, 1974/1975, and 1975/1976 at Oldbury, at Berkeley for two winters 1974/1975 and 1975/1976 and at Hinkley Point for only one winter 1975/1976.

Thus, in order to assess more clearly the levels of zinc, lead and cadmium in the fish attempts were made to group them into age

FIGURE 83

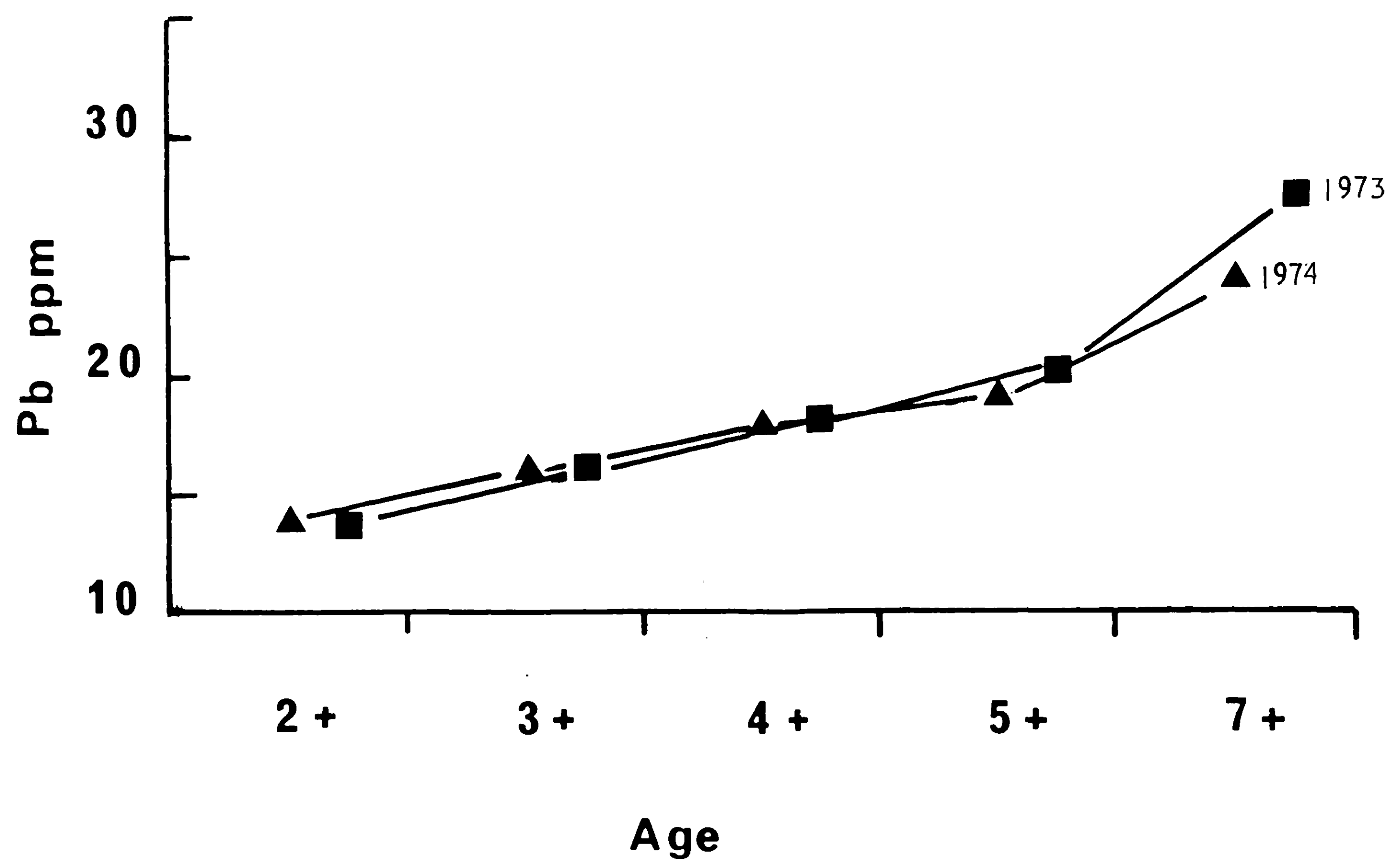
Zinc concentrations (ppm) in the various age group flounders, *Platichthys flesus* obtained from Barnstaple Bay in the summer of 1973 and 1974.



1974
1973
280
260
240
220
200
180
160
Zinc ppm
2 +
3 +
4 +
5 +
7 +
Age

FIGURE 84

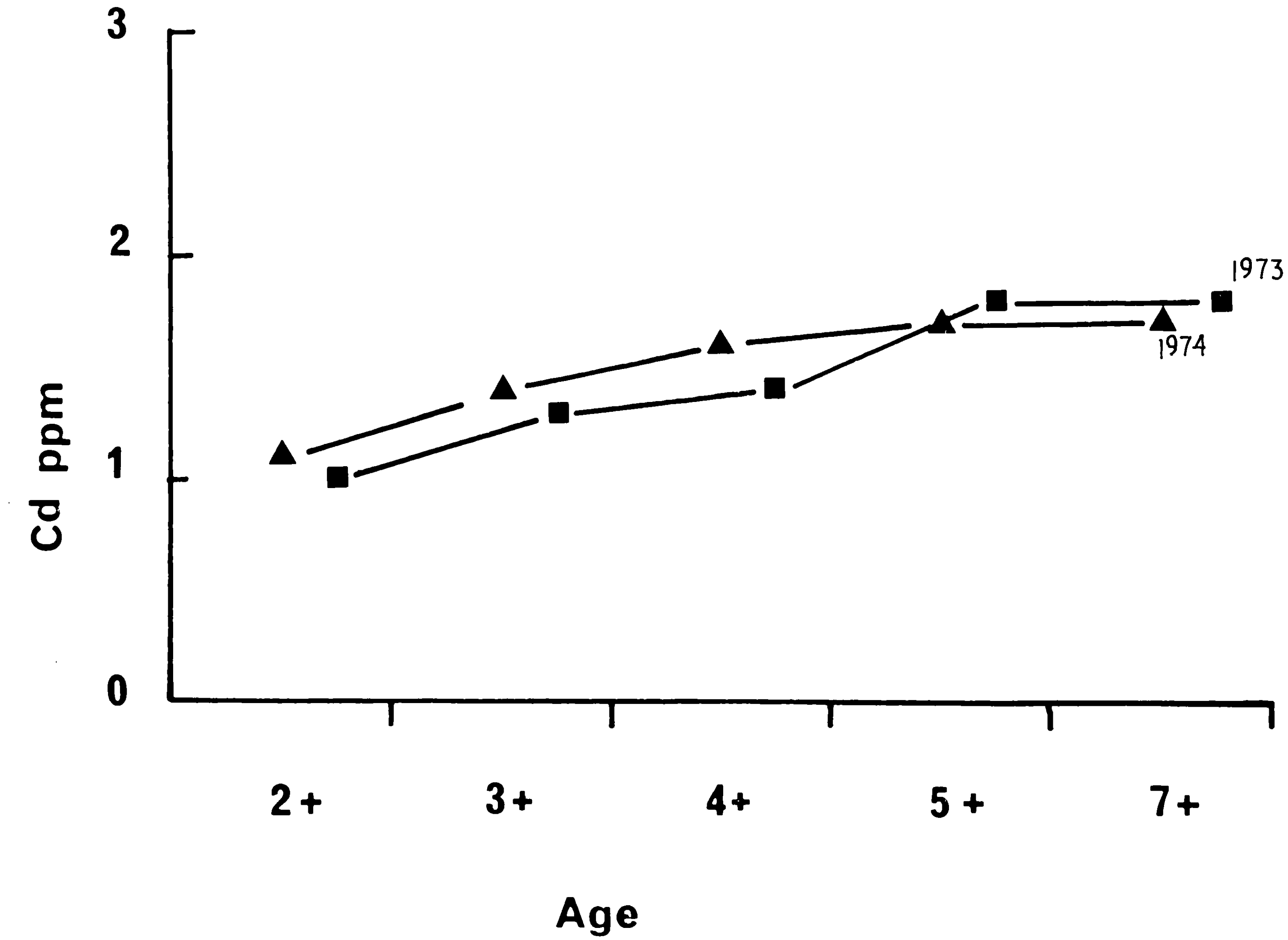
Lead concentrations (ppm) in the va:.ious age group flounders, *Platichthys flesus* obtained from Barnstaple Bay in the summer of 1973 and 1974.



Pb ppm
30
20
10
1973
1974
2 +
3 +
4 +
5 +
7 +
Age

FIGURE 85

Cadmium concentrations (ppm) in the various age group flounders, *Platichthys flesus* obtained from Barnstaple Bay in the summer of 1973 and 1974.



3
2
1
0
Cd ppm
1973
1974
2+
3+
4+
5+
7+
Age

classes and length-frequency criteria was satisfactory and this method was used to ascertain the ages of this species, thus, animals falling within the peak frequency were analysed for zinc, lead and cadmium concentrations. These results representing the monthly values for catches of several winters at each site are presented in Appendices 43-45.

Over three winters from 1973 to 1976, the samples from Oldbury (Fig. 86) show a considerable variation in the level of zinc and an overall gradual decrease in the concentration of this metal in the fish from 1973-1976.

At Berkeley where the study conducted covered only two winters (1974/1976) this drop in zinc level, especially in the 1975/1976 period is much more dramatic - more than 30% (Fig. 87). Strangely, the fish caught at Hinkley Point in the winter of 1975/1976 have higher zinc levels compared to Oldbury and Berkeley (Fig. 88).

On a seasonal basis results obtained from the three sites show some interesting features. Thus, at Oldbury 1973/1974 and 1974/1975 samples clearly indicate that zinc levels increased from October to a maximum in November/December, declining thereafter. A similar trend is noted for fish from Berkeley assessments in 1974/1975 (no results were obtained for both Berkeley and Hinkley Point in 1973/1974 for comparison).

The monthly lead estimations for both winters at Oldbury (Fig. 89) and 1974/1975 only for Berkeley (Fig. 90) show a steady increase from September to October, right up to the last samples taken in January (Berkeley) or March (Oldbury). The Hinkley figures for March are unusually high (Fig. 88). Lead levels at all three sites show a slight peak in December, but at Hinkley the September and

FIGURE 86

Zinc accumulation (ppm) in sea snails, *Liparis liparis* studied over three successive years (1973-1976) in animals obtained from the filter screens of Oldbury Power Station.

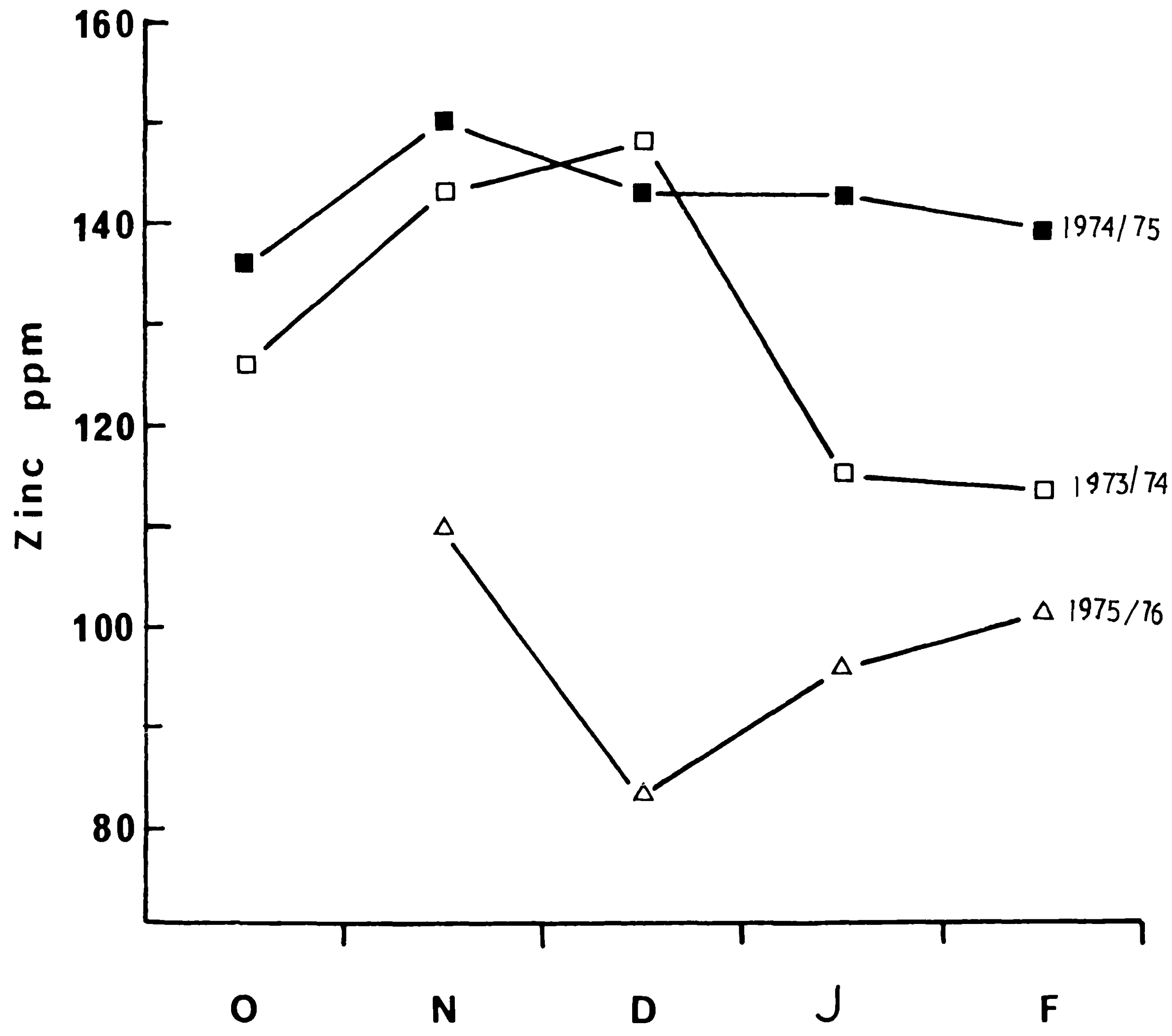

160
140
120
100
80
Zinc ppm
O
N
D
J
F
1974/75
1973/74
1975/76

FIGURE 87

Zinc accumulation (ppm) in sea snails, *Liparis liparis* studied over successive years (1974-1976) in animals obtained from the filter screens of Berkeley Power Station.

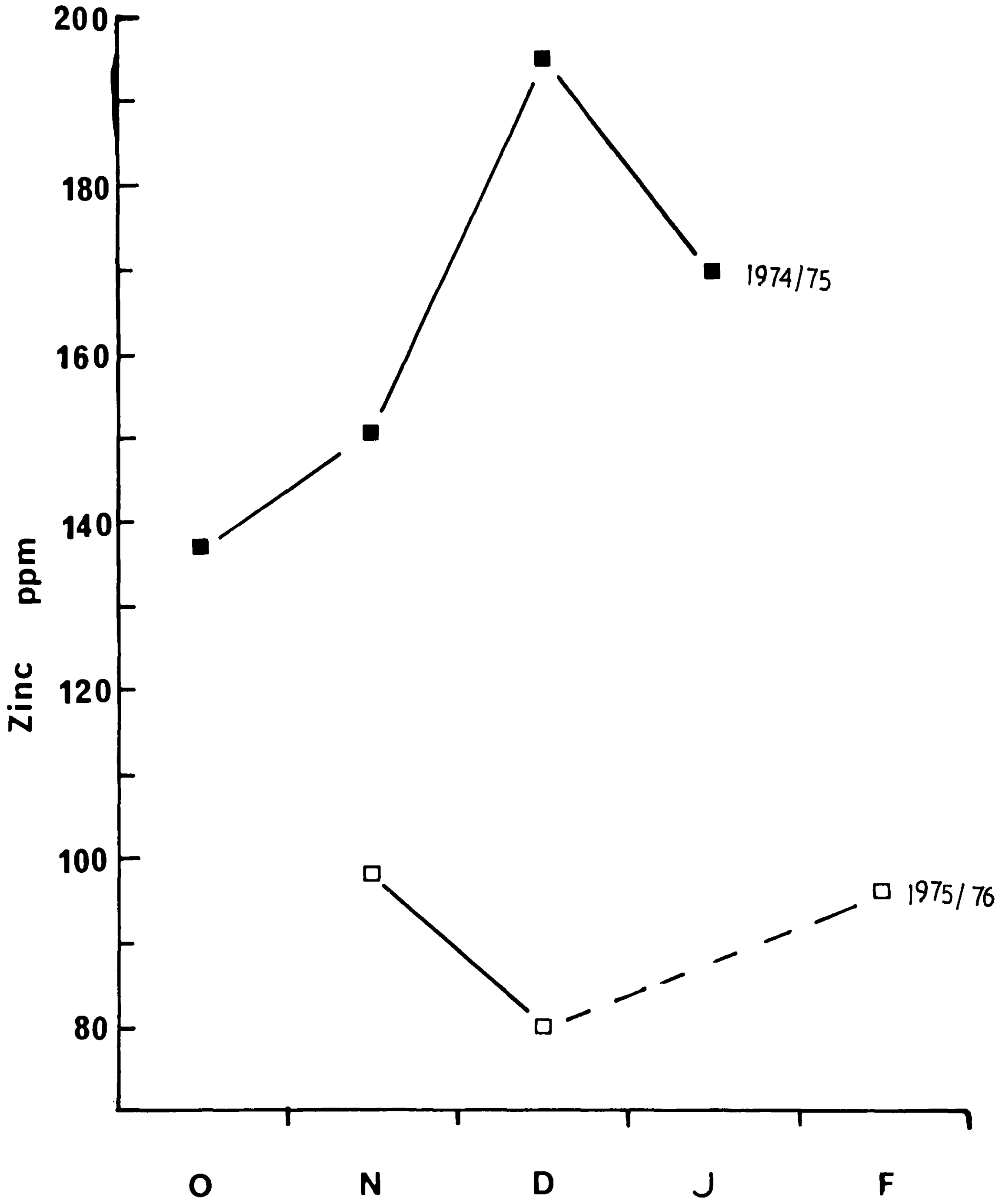
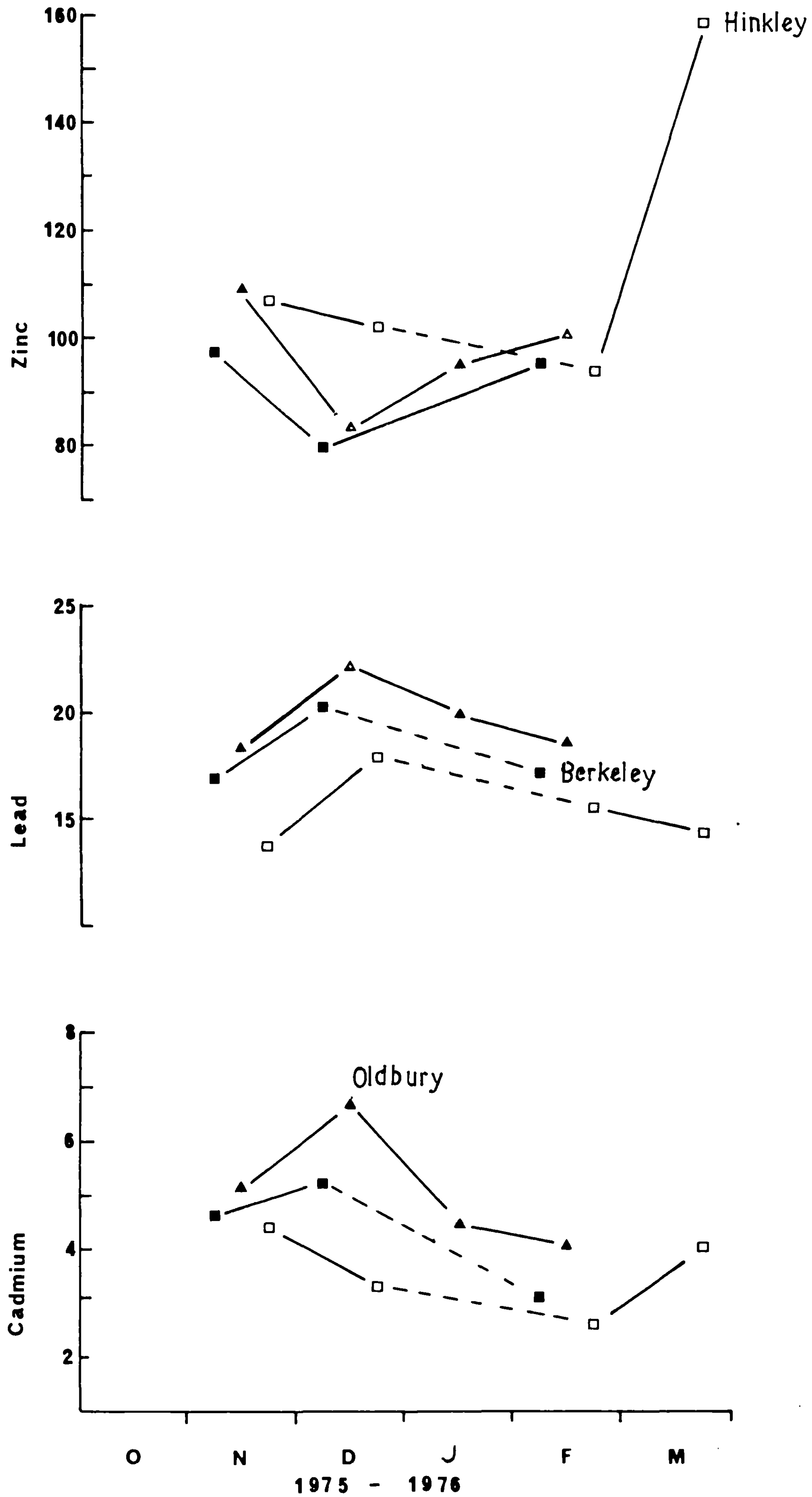

200
180
160
140
120
100
80
Zinc ppm
1974/75
1975/76
O
N
D
J
F

FIGURE 88

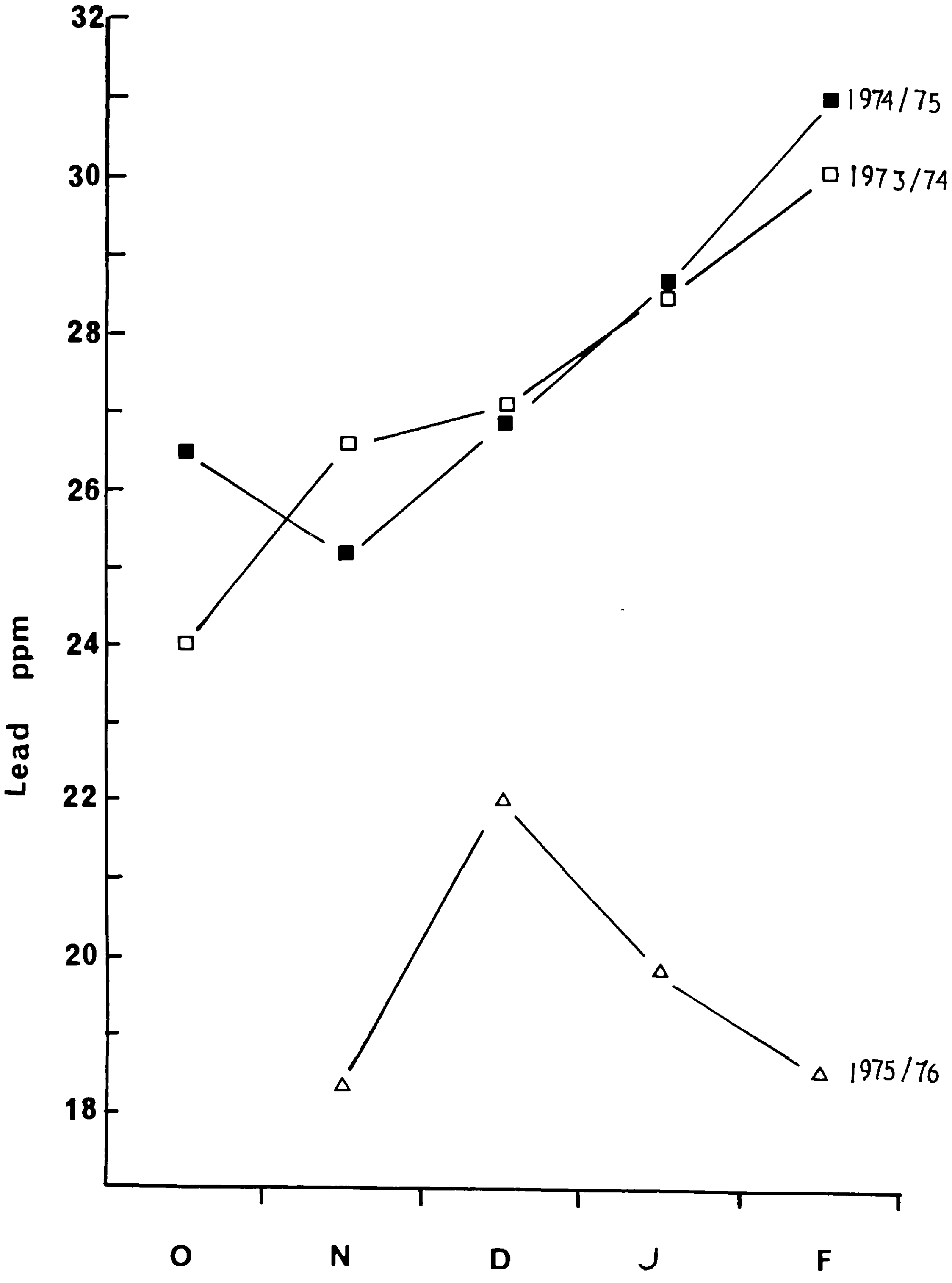
Concentrations of zinc, lead and cadmium (ppm) in the tissues of sea snails, *Liparis liparis* obtained from Oldbury, Berkeley and Hinkley Point during 1975-1976.



160
140
120
100
80
Zinc
Hinkley
25
20
15
Lead
Berkeley
8
6
4
2
Cadmium
Oldbury
O
N
D
J
F
M
1975 - 1976

FIGURE 89

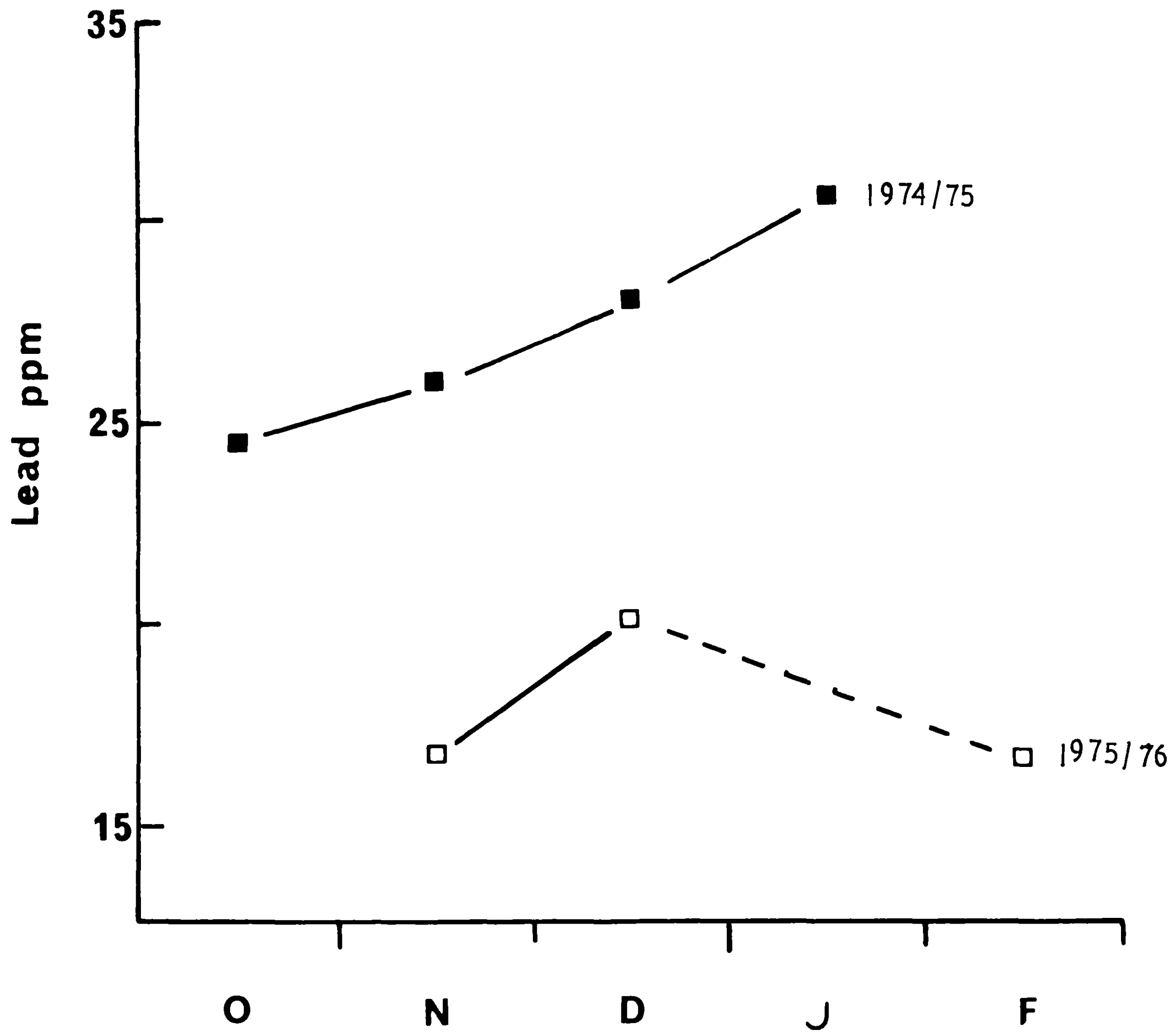
Lead accumulation (ppm) in sea snails, *Liparis liparis* studied over three successive years (1973-1976) in animals obtained from the filter screens of Oldbury Power Station.



Lead ppm
32
30
28
26
24
22
20
18
1974/75
1973/74
1975/76
O
N
D
J
F

FIGURE 90

Lead . accumulation (ppm) in sea snails, *Liparis liparis* studied over successive years (1974-1976) in animals obtained from the filter screens of Berkeley Power Station.


35
25
15
Lead ppm
1974/75
1975/76
O
N
D
J
F

November estimations are more than 5-fold less than that of any other month.

The values for cadmium in samples obtained from the three areas are expressed in Figs. 88, 91 and 92. Cadmium seems particularly accumulative and it is not surprising therefore, that for a particular season it is found in increasing amounts as the winter progresses. The 1973/1974 period cadmium values increased at Oldbury over two-fold from 4.6 ppm in October to 10.4 ppm in February, and in the following season, this increase is slightly less, from 5.1 ppm in October to 7.7 ppm in February and 8.9 ppm by March. These figures correlate well with those of Berkeley samples during the same period (October 4.6 ppm; January 7.1 ppm). Both at Oldbury and Berkeley, where at least results from two winters are available for comparison, the 1975/1976 samples show cadmium levels to peak in December. Samples taken from Hinkley Point show maximum values of cadmium in November (4.4 ppm) and again in March (4.0 ppm) and in February (2.6 ppm). The variation in the levels of cadmium within the 1975/1976 season was from 4.0 ppm to 6.6 ppm at Oldbury and 3.1 ppm to 5.1 ppm at Berkeley, indicating that the Oldbury samples were more contaminated than that of Berkeley or Hinkley. In contrast, Hinkley species were the least polluted.

The salient feature of these results if the significant reduction of these metals in the marine environment in 1975/1976, this drop in the levels could well be due to the steady increase in salinity levels (see Fig. 2). Several well documented studies indicate this as a real possibility (Jones, 1937; Harvey, 1957; Shiray and Mori, 1958; Perry, 1960; Wakeford, 1964; Westernhagen *et al*, 1975).

FIGURE 91

Cadmium accumulation (ppm) in sea snails, *Liparis liparis* studied over three successive years (1973-1976) in animals obtained from the filter screens of Oldbury Power Station.

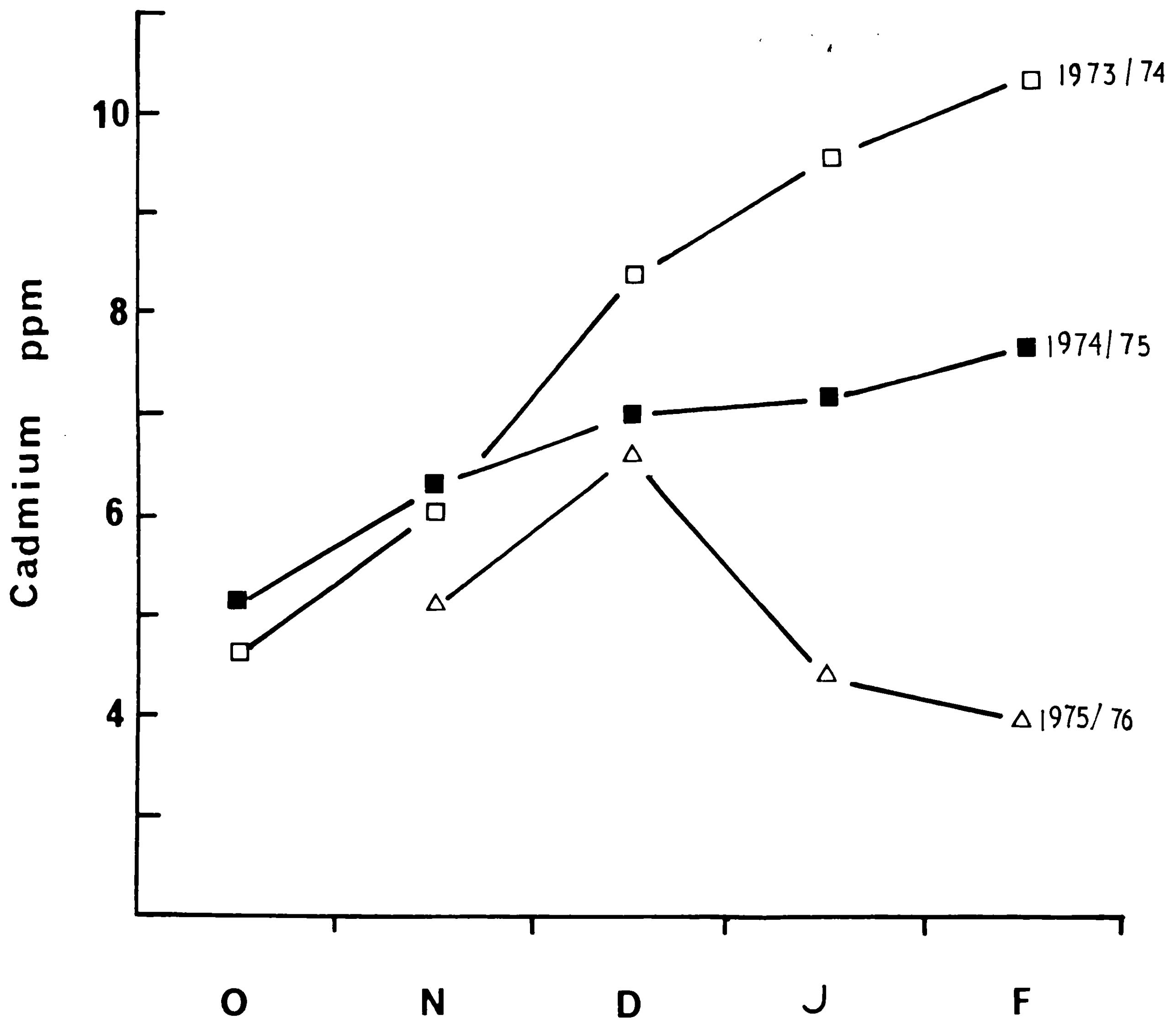
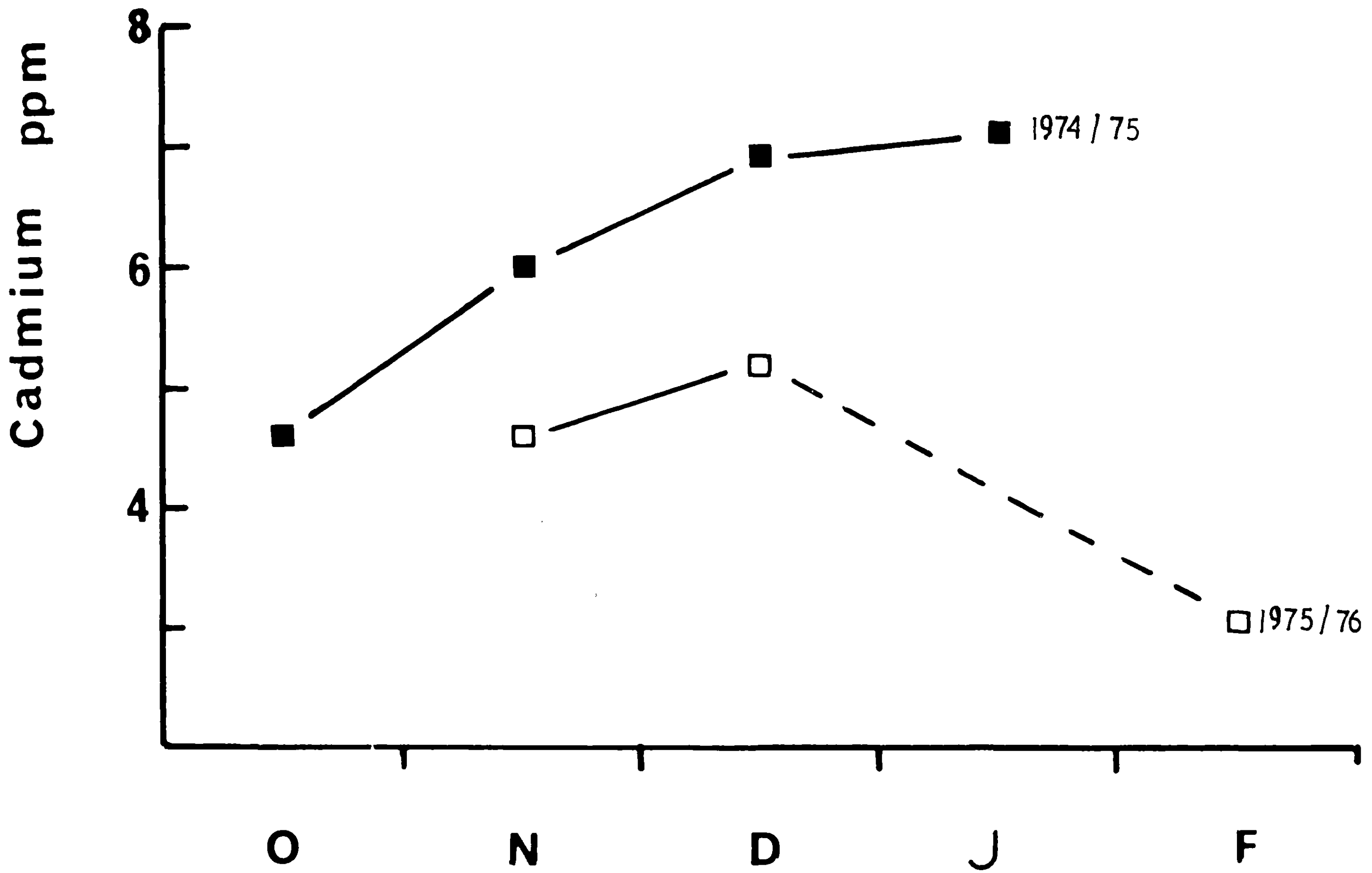

Cadmium ppm
10
8
6
4
1973 / 74
1974/ 75
1975/ 76
O
N
D
J
F

FIGURE 92

Cadmium accumulation (ppm) in sea snails, *Liparis liparis* studied over successive years (1974-1976) in animals obtained from the filter screens of Berkeley Power Station.


Cadmium ppm
8
6
4
1974 / 75
1975 / 76
O
N
D
J
F

7.3. FIVE BEARDED ROCKLING, *CILIATA MUSTELA*

Five Bearded Rocklings, like many other teleosts, i.e. sea snails, whitings, etc. are winter residents in the Severn Estuary. During this period (November-January) the rockling feed voraciously, increase in size rapidly and become sexually mature and by the end of January when it is ready to embark on a downstream spawning migration (see Biology page 50). Feeding extensively in an environment now known to be significantly polluted by heavy metals (Abdullah *et al*, 1972) during a vital maturation period, it provides ample justification for conducting a comprehensive investigation as to its capacity to accumulate such pollutants. As with most other species discussed in this thesis, these animals were obtained from a number of pre-selected sites namely: Oldbury, Berkeley, Minehead and Uskmouth; selected to provide information on a reasonable representation of the population within the Severn Estuary and the Bristol Channel (see Fig. 1).

In order to eliminate the variation due to age differences, fish of only the 1+ age class were assayed for zinc, cadmium and lead in this experiment, and unless otherwise stated each result is the mean value derived from the total number of fish in a monthly catch in any area.

The Oldbury and Berkeley samples were studied for two winter seasons (1974/75 and 1975/76), by analysing catches from October to January, when they may be caught in appreciable numbers at these sites (in the middle reaches of the Severn Estuary). These results are summarised in Appendices 46-47 respectively. The Minehead, Hinkley and Uskmouth results (from August 1975 to August 1976 at Minehead; from October 1975 to March 1976 at Hinkley and Uskmouth), are recorded in Appendices 48-50. From these tables are constructed a series of graphs to establish several relationships, namely: a) any variation in the levels of these heavy metals between two winters at Oldbury and Berkeley, and b) the nature of heavy metal accumulation/sampling intervals at each of these localities.

In Fig. 93 where the quantity of specific pollutants is presented against the corresponding month during which the samples were obtained from Oldbury and Berkeley, it is evident that zinc values are considerably lower for the 1975/1976 winter than the 1974/1975 winter. The difference between the two winters is almost of a factor of two. Another anomaly between these two periods is that while in the 1975/1976 season the concentration of zinc in the animals caught both at Oldbury and Berkeley were more or less similar, the 1974/1975 results show a marked difference between these two stations which are 8 kilometres apart. The Oldbury samples had concentrations of zinc 10-20 ppm lower than those of Berkeley for the same season. Furthermore, the concentration of this metal rose linearly from 60 ppm (Oldbury) and 68 (Berkeley) in September 1974 to 97 ppm and 108 ppm respectively by January 1975. In contrast the 1975/1976 analyses show that samples from both localities had levels of zinc generally around 60 ppm throughout the season. The accumulation of cadmium in the fish caught at Oldbury and Berkeley did not significantly differ but the monthly samples showed the levels to increase from about 3 ppm in September to just over 4 ppm by January. Interestingly, the fish caught in 1975/1976 from both these sites displayed a different pattern, thus from 2.2 ppm at Oldbury and 2.5 at Berkeley in October 1975, the concentrations increased to 3.0 ppm and 3.5 ppm respectively by November,

FIGURE 93

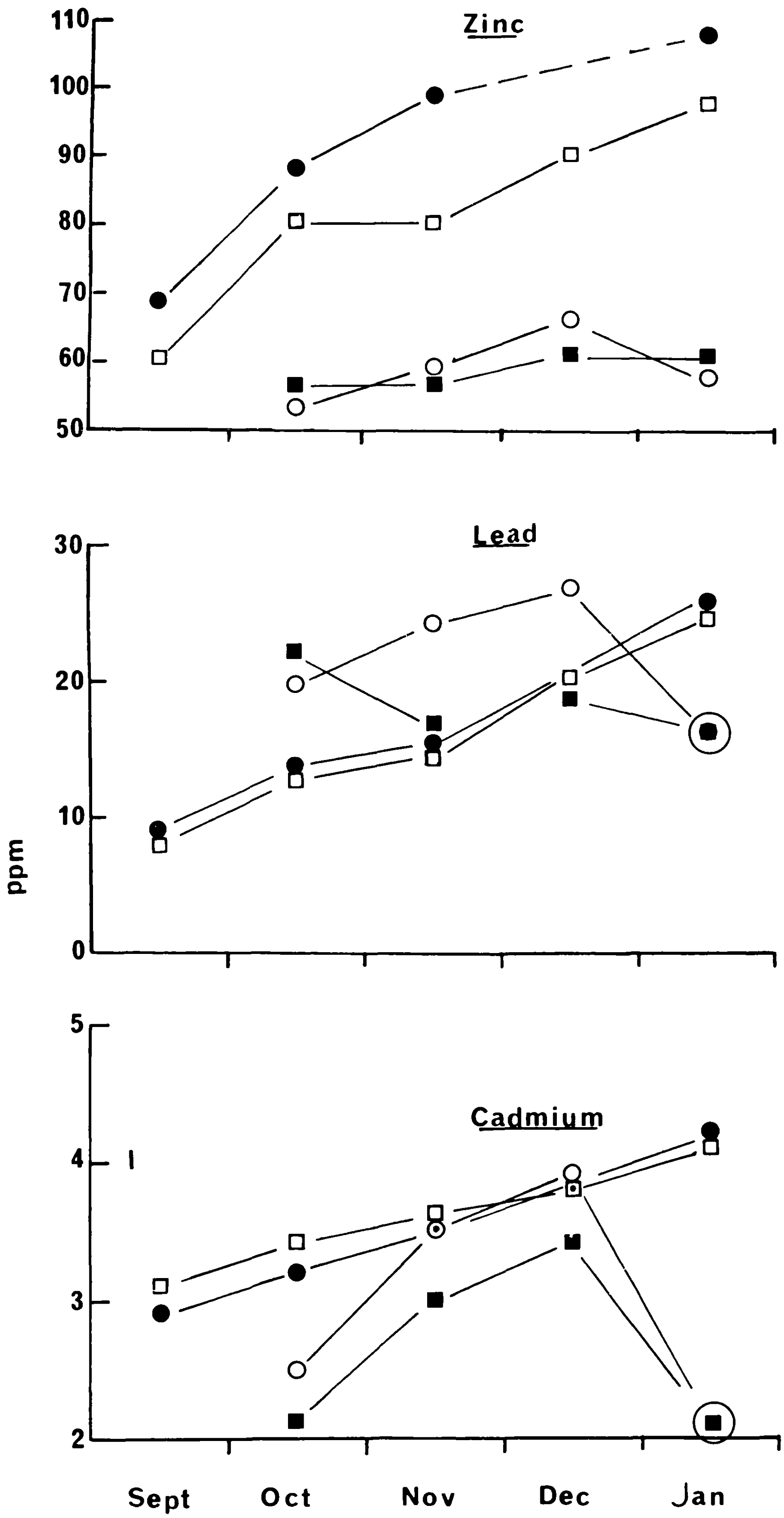
Accumulation of zinc, lead and cadmium (ppm) in the tissues of five bearded rocklings, *Ciliata mustela* obtained from:

Oldbury (□) 1974/1975

Oldbury (■) 1975/1976

Berkeley (●) 1974/1975

Berkeley (○) 1975/1976



Zinc
110
100
90
80
70
60
50
Lead
30
20
10
0
ppm
Cadmium
5
4
3
2
Sept
Oct
Nov
Dec
Jan

maximising at 3.4 and 3.0 ppm respectively by December. Afterwards the levels of cadmium in the animals from both the sites dropped rapidly to just over 2 ppm by January 1976. Generally cadmium levels in the Berkeley samples were somewhat higher than those of Oldbury.

There were no differences in the lead concentrations in fish from Oldbury and Berkeley, sampled in the winter of 1974/1975, but the levels gradually increased from just under 10 ppm in September to around 25 ppm by January 1975 in a linear fashion. On the other hand the 1975/1976 fish caught at Berkeley were shown to contain on average 20 ppm lead in October 1975, increasing to 27 ppm by December and then declining to about 16 ppm by January. At Oldbury the lead values averaged 22 ppm, in October declining to 16 ppm by November and then remained between 18-19 ppm for the rest of the winter.

The analysis of zinc, cadmium and lead from the catches of five collecting points, i.e. Oldbury, Berkeley, Uskmouth, Hinkley Point and Minehead for the season 1975/1976 are plotted against the sampling frequency (month) in Fig. 95. The reason for this presentation is to show the fluctuation in metal levels at various geographical locations (see General Introduction, Fig. 1) along the Severn Estuary and the Bristol Channel.

Of the first three collecting points, which are situated in the middle reaches of the estuary, Uskmouth (on the Welsh side), located nearer to an industrial complex, has considerably the highest concentrations of zinc, which increases from 70 ppm in October to 80 ppm by January. At Berkeley, the zinc is at a maximum (about 65 ppm) in December, falling in January to the level of 58 ppm. October samples from Hinkley Point contain a comparatively low concentration of zinc (36.5 ppm) but increase in subsequent monthly samples to 81.8 ppm by January, a rise of 224%. The levels in the Minehead samples also increase as the winter progresses; the variation between the October and January samples being about 10 ppm. After January the samples show much higher values but considerable individual variations (zinc concentrations ranging from 70 ppm to 91 ppm).

The samples from Berkeley, Uskmouth, Hinkley and Minehead show increasing lead concentrations from October to December (about 8 ppm increase) but decline to about the original levels of October by January. At Berkeley and Uskmouth levels of lead are higher by about 5 ppm throughout the winter period than elsewhere, except in January. At Oldbury the October samples have somewhat higher lead concentration (about 5 ppm) than the subsequent samples here which show values of lead comparable to those of Hinkley Point and Minehead.

The cadmium accumulation in fish from Oldbury and Uskmouth, and to a much larger extent in those of Berkeley, are seen to increase in each monthly catch, maximising in December then decreasing to the original levels in January. The results from samples taken at Oldbury and Uskmouth are almost identical with those of October, containing about 2 ppm, rising rapidly to about under 3.5 ppm in December and decreasing to about 2 ppm in January. In October animals were found to contain a marginally higher cadmium concentration of 2.5 ppm, rising to just under 4 ppm by December and then declining sharply to 2 ppm in January. In contrast, levels in the Hinkley and Minehead fish tend to remain more or less constant from October to January, the concentrations remaining between 1.3 to just over 2.0 ppm.

In summary therefore, catches from all the five sites show a tendency to accumulate large proportions of zinc as the winter

FIGURE 94

Relative concentrations of zinc, lead and cadmium (ppm) in the tissues of five bearded rocklings, *Ciliata mustela* obtained during 1975/1976 from:

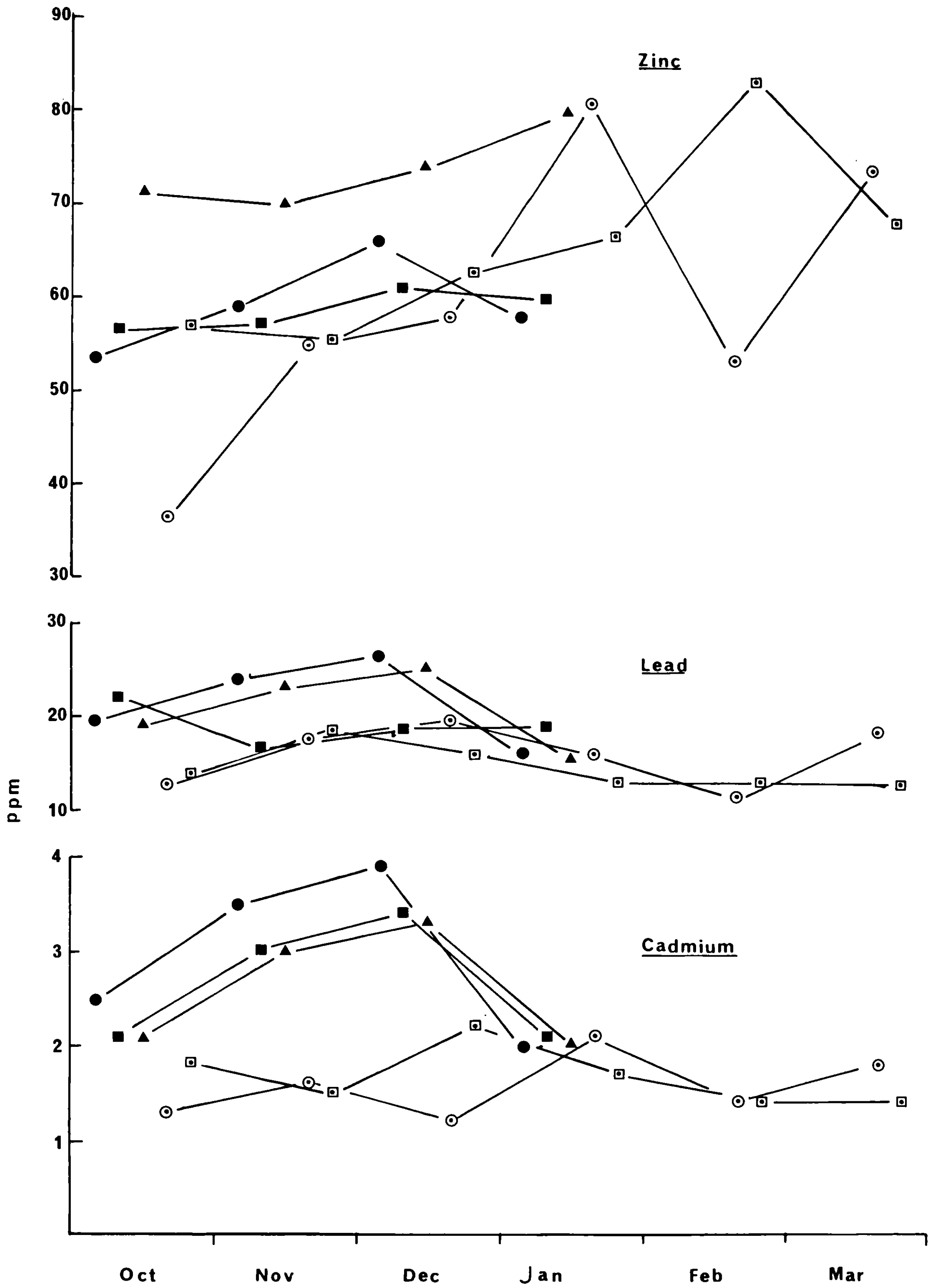
Berkeley (●)

Oldbury (■)

Uskmouth (▲)

Hinkley Point (⊙)

and Minehead (⊡).



Zinc
Lead
Cadmium
ppm
90
80
70
60
50
40
30
30
20
10
4
3
2
1
Oct
Nov
Dec
Jan
Feb
Mar

progresses; highest lead levels are mostly encountered in December.

In order to obtain some picture of the rate of concentration of zinc, cadmium and lead in the Severn Estuary and the Bristol Channel by five bearded rocklings, *Ciliata mustela*, it was necessary to express the metal levels as a percentage of the total metal levels found at these sites. Thus it is apparent that Berkeley, Oldbury and Uskmouth (Appendix 56) which are situated nearer to industrial complexes, contain higher percentages of all the three metals. On the other hand, fish from Hinkley and Minehead which are further down the channel, near the open sea, with no known major industrial activity in the vicinity, understandably have lower levels.

7.4. SHRIMP, *CRANGON CRANGON*

The part played by *Crangon crangon* in the marine environment is of much interest, since not only is it a major dietary component of numerous key estuarine fishes in the Severn Estuary and the Bristol Channel, but it is also an important vector of cadmium (Kartar, 1974) in contaminated waters. For these reasons studies were designed to examine some of the events involved in the accumulation of zinc, cadmium and lead by this species in the estuary.

The major part of this study encompasses a detailed investigation of the samples from Oldbury between 1972-1976 supplemented by some assessment of zinc, cadmium and lead uptake at Hinkley Point and Minehead from limited samples obtained in December 1975 (Fig. 95-97). The animals used in the present study belong to the 0+ & 1+ age classes

FIGURE 95

Accumulation of zinc (ppm) in the 0+ and 1+ age group shrimps, *Crangon crangon* caught in mid-winter (December) in the filter screens of Oldbury Power Station during 1972-1975.

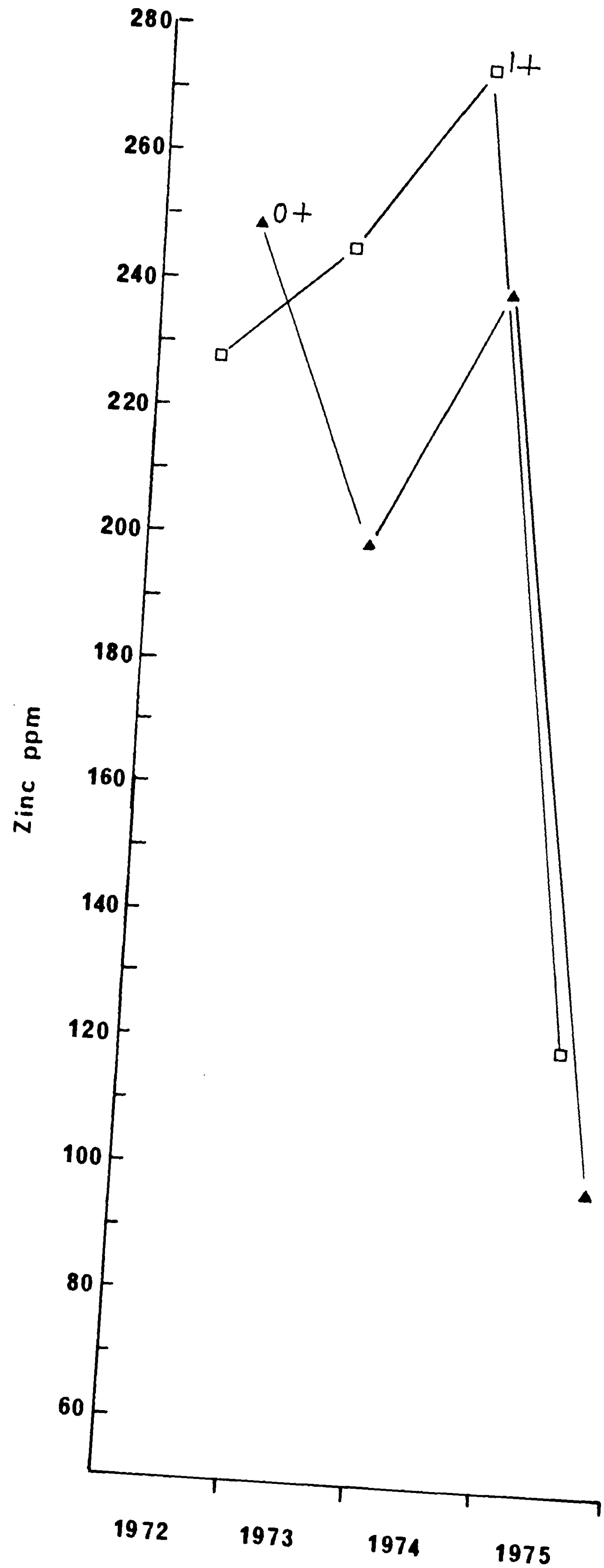

Zinc ppm
280
260
240
220
200
180
160
140
120
100
80
60
0+
1+
1972
1973
1974
1975

FIGURE 96

Accumulation of lead (ppm) in the 0+ and 1+ age group shrimps, *Crangon crangon* caught in mid-winter (December) in the filter screens of Oldbury Power Station during 1972-1975.

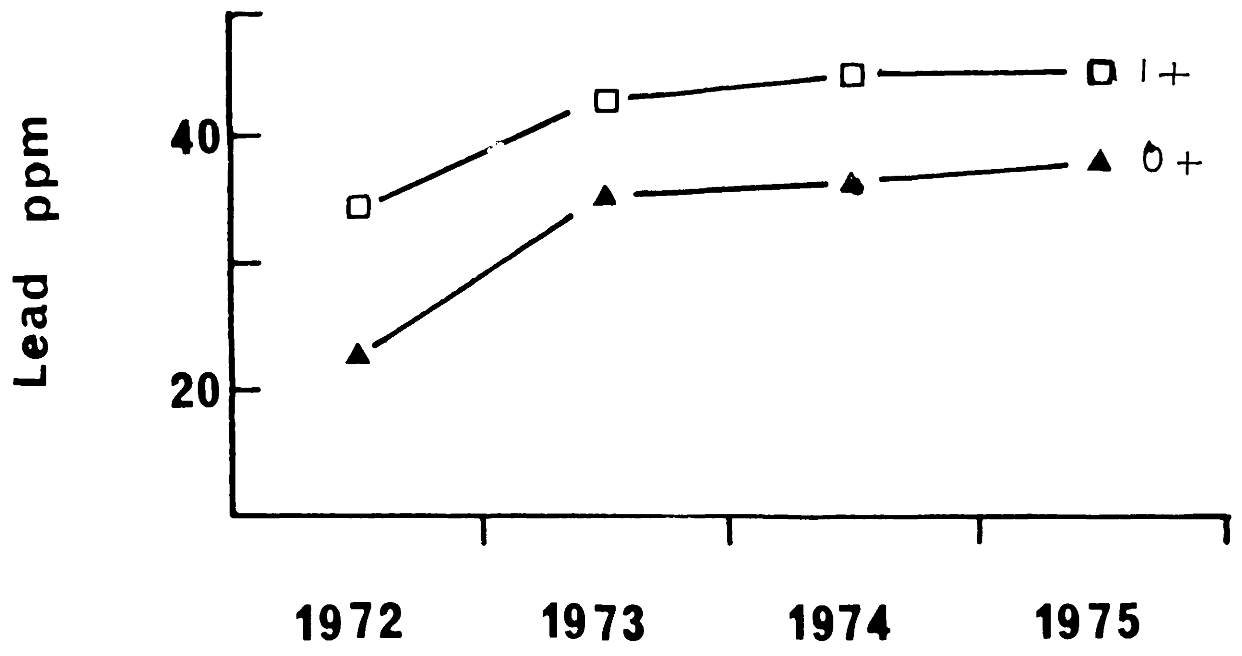
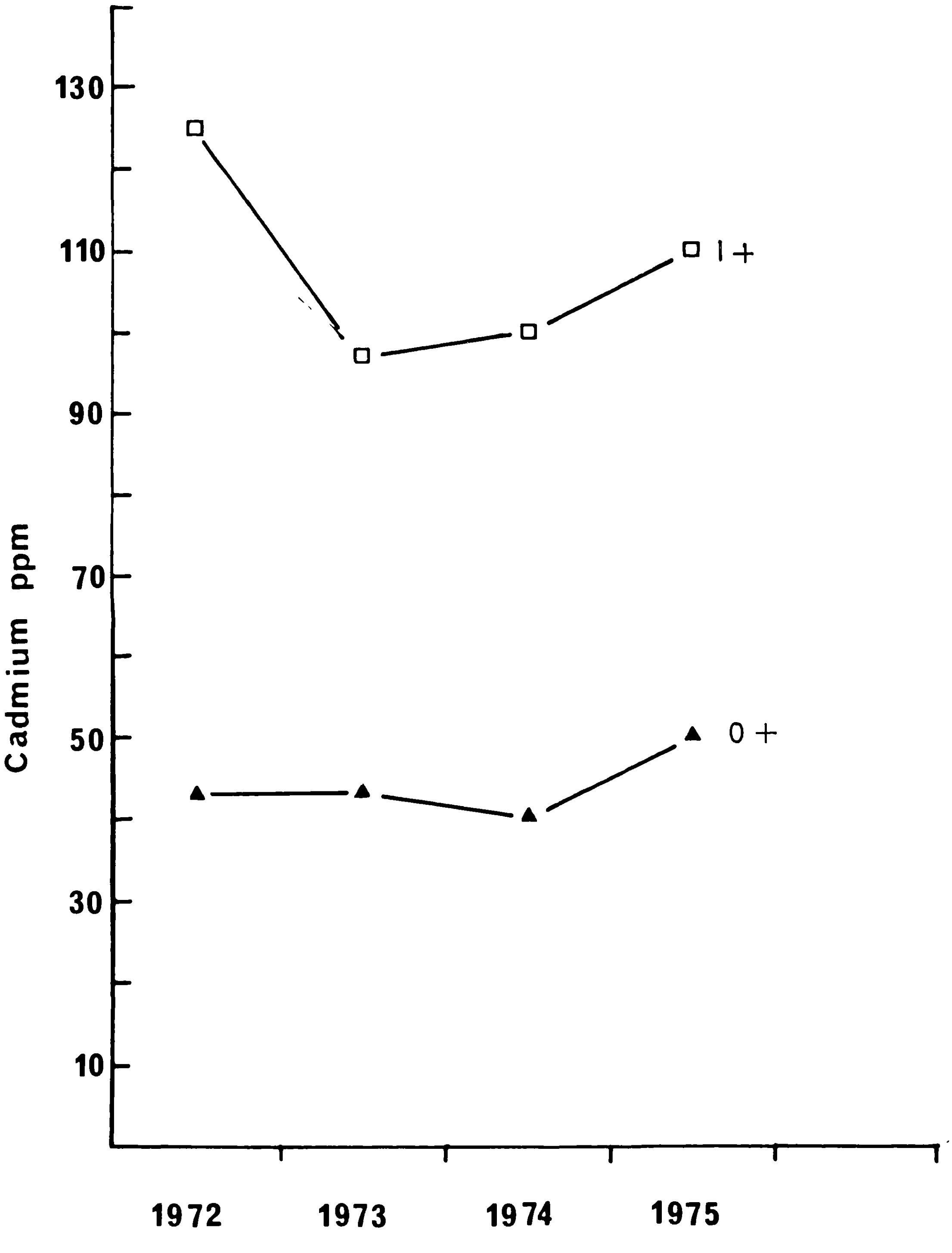

Lead ppm
40
20
1972
1973
1974
1975
I+
0+

FIGURE 97

Accumulation of cadmium (ppm) in the 0+ and 1+ age group shrimps, *Crangon crangon* caught in mid-winter (December) in the filter screens of Oldbury Power Station during 1972-1975.


Cadmium ppm
130
110
90
70
50
30
10
1972
1973
1974
1975
I +
0 +

(age was ascertained using a length-frequency distribution curve) when they were present in large numbers in December at these sites. Appendix 52 summarizes the estimations of heavy metals in *Crangon crangon* in the month of December for the years 1972-1976. It is important to emphasise the difference in the heavy metal levels between large (1+) and small (0+) animals; levels of cadmium and lead certainly bear this out, cadmium differences in particular are most pronounced. Interestingly high levels in the large animals do not necessarily correlate with high levels in the small animals. Thus, in 1972 a value of 125.30 of cadmium, the highest figure found, was present in large (1+ class) shrimps, yet the small animals contained only 43.30 ppm. On the other hand, 50.70 ppm was present in 1975 when the 1+ age class animals contained 120.8 ppm. In the case of lead this is not so, and the values for large and small shrimps follow one another, although the larger animals usually contain 16-30% more metal. Lead levels increased gradually from 1972 to 1975. The zinc concentrations in large animals increased from 228 ppm in 1972 to 275 ppm in 1974 but in 1975 the levels declined steeply to 120.00 ppm. This steep decrease is also apparent in the levels determined for the small animals. Here the amount of metal dropped from 249.00 ppm to 200 ppm in 1973, increased again to 240.00 ppm in 1974, and steeply decreased to 98.30 ppm in 1975. The amount of these metals in organisms from samples obtained at Hinkley Point and Minehead (Appendix 53) in December 1975 do not show any significant differences between the two sites but when these levels are compared with samples from Oldbury, an increase of 200.00 ppm is noted for zinc and lead but for cadmium the differences are much greater. At Oldbury, the 1+ animals contained 120.80 ppm of cadmium while at Hinkley Point and

Minehead the six individual analyses contained about 12.00 ppm cadmium, a difference of about 100%.

In Appendices 54-55 monthly figures for 1975/1976 are presented and Figs. 98-100 show the levels of zinc, lead and cadmium. The burden of zinc in larger animals gradually changes from 101.4 ppm in July 1975 to 88.5 ppm in November but rise again in December to a peak of 120.7 ppm dropping to 108.9 ppm in February and from then on the level rises again to 147.1 ppm in April to form a second peak which rapidly declines to 76.7 by June (1976). In small animals the zinc levels increase from 96.0 ppm in August 1975 to 131.6 ppm in September, drops steeply in October to 98.4 ppm then gradually rises to 105.9 ppm in January, declining subsequently to 75.5 ppm by June 1976.

As has already been stated, there is a pronounced difference in cadmium levels between the large and small animals, this is certainly quite obvious from the illustration shown in Fig. 100. Thus, in the larger organisms cadmium concentrations increase from 22.5 ppm in July 1975 to 120.8 ppm in December, dropping sharply to 15.4 ppm in June 1976. In the smaller animals this level starts at 16 ppm in August, increase to only 50.7 ppm in December and drops to 14.9 ppm by June. It is clear that this marked difference between the large and small animals is only apparent between the early autumn, winter and late spring, just before the mature shrimps undertake a downstream spawning migration. Lead levels between large and small animals also show some significant differences. In the large animals the levels rise from 24 ppm to a peak 53.9 ppm in November then drop by June to 16.7 ppm and in smaller animals the level peak to 62.1 ppm in September from 43.1 ppm in August then drop to the same levels that are observed in larger animals in January.

FIGURE 98

Seasonal variations in zinc concentrations (ppm) in the 0+ (▲) and 1+ (□) age class shrimps, *Crangon crangon* caught during a 24 h sampling period in the cooling water intake screens of Oldbury Power Station during 1975-1976.

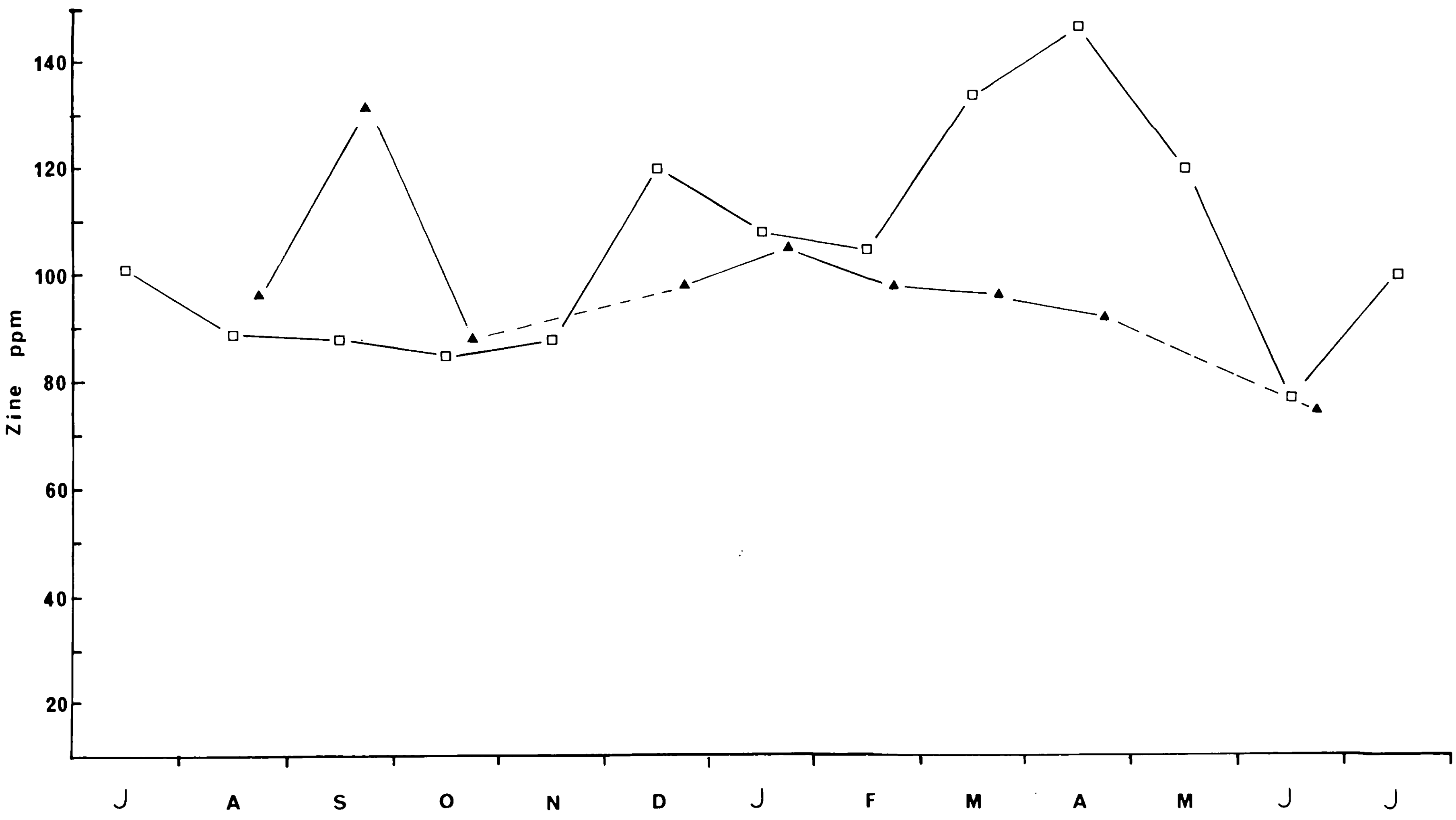

Zinc ppm
140
120
100
80
60
40
20
J A S O N D J F M A M J J

FIGURE 99

Seasonal variations in lead concentrations (ppm) in the 0+ (▲) and 1+ (□) age class shrimps, *Crangon crangon* caught during a 24 h sampling period in the cooling water intake screens of Oldbury Power Station during 1975-1976.

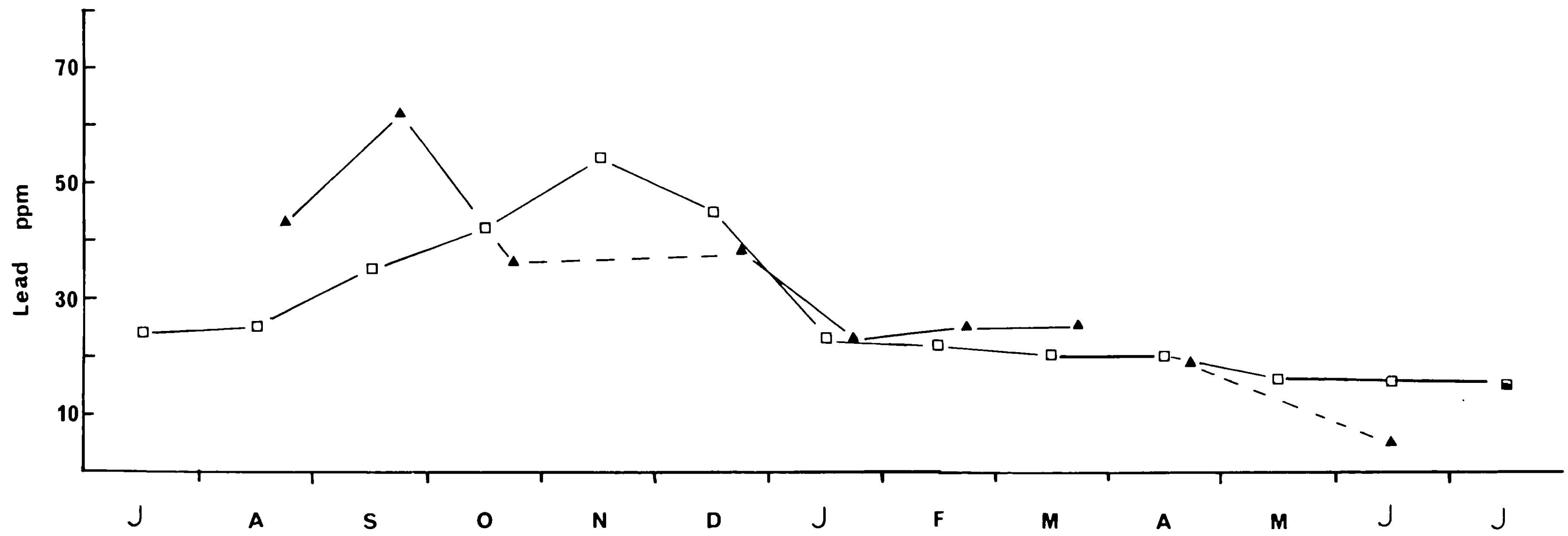
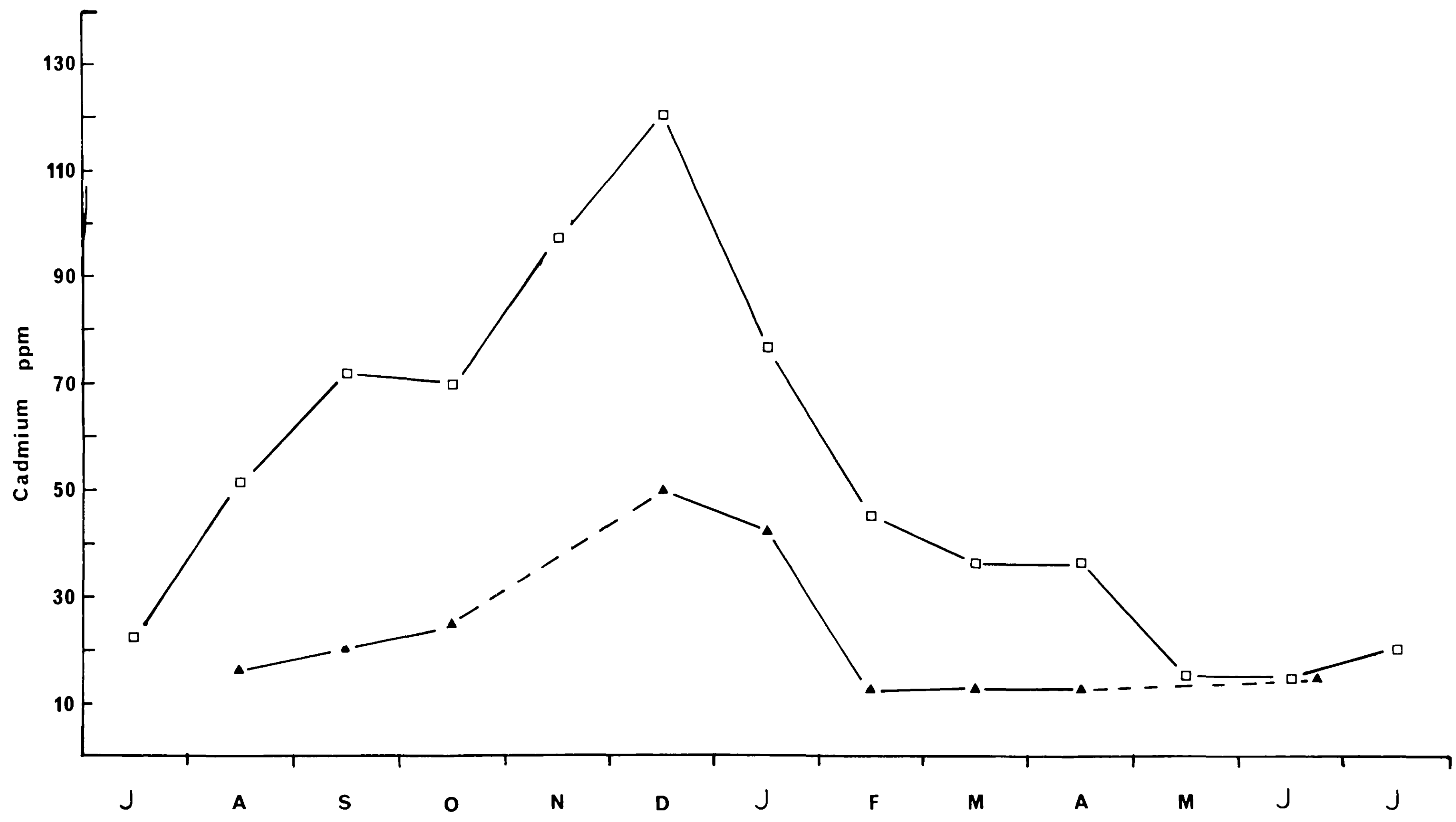

Lead ppm
70
50
30
10
J
A
S
O
N
D
J
F
M
A
M
J
J

FIGURE 100

Seasonal variation in cadmium concentrations (ppm) in the 0+ (▲) and 1+ (□) age class shrimps, *Crangon crangon* caught during a 24 h sampling period in the cooling water intake screens of Oldbury Power Station during 1975-1976.


Cadmium ppm
130
110
90
70
50
30
10
J
A
S
O
N
D
J
F
M
A
M
J
J


2 cms.

PLATE 24

Shrimp, *Crangon crangon* also known as *Crangon vulgaris*.

In general the results seem to indicate major differences in the levels of accumulation of lead and cadmium and to a lesser extent zinc, between the older and the younger shrimps. These differences are largest in autumn and early or late spring, just before the mature animals migrate to spawn.

From Table 36 it can be seen that the muscles contain very much less zinc, lead and cadmium at Oldbury and Milford Haven. Thus, taking the whole animals, muscles contain 31.8% of zinc, 22.1% lead and 15.7% cadmium at Oldbury, while at Milford Haven the percentage of zinc was similar to Oldbury, cadmium was slightly higher (23.1%), but lead levels were lower (19%) compared to Oldbury.

7.5. SAND GOBY, *POMATOSCHISTUS MINUTUS*

The aims of this research on the eco-biology of the sand goby at Oldbury-on-Severn were:

(i) the determination of the population density at this site;

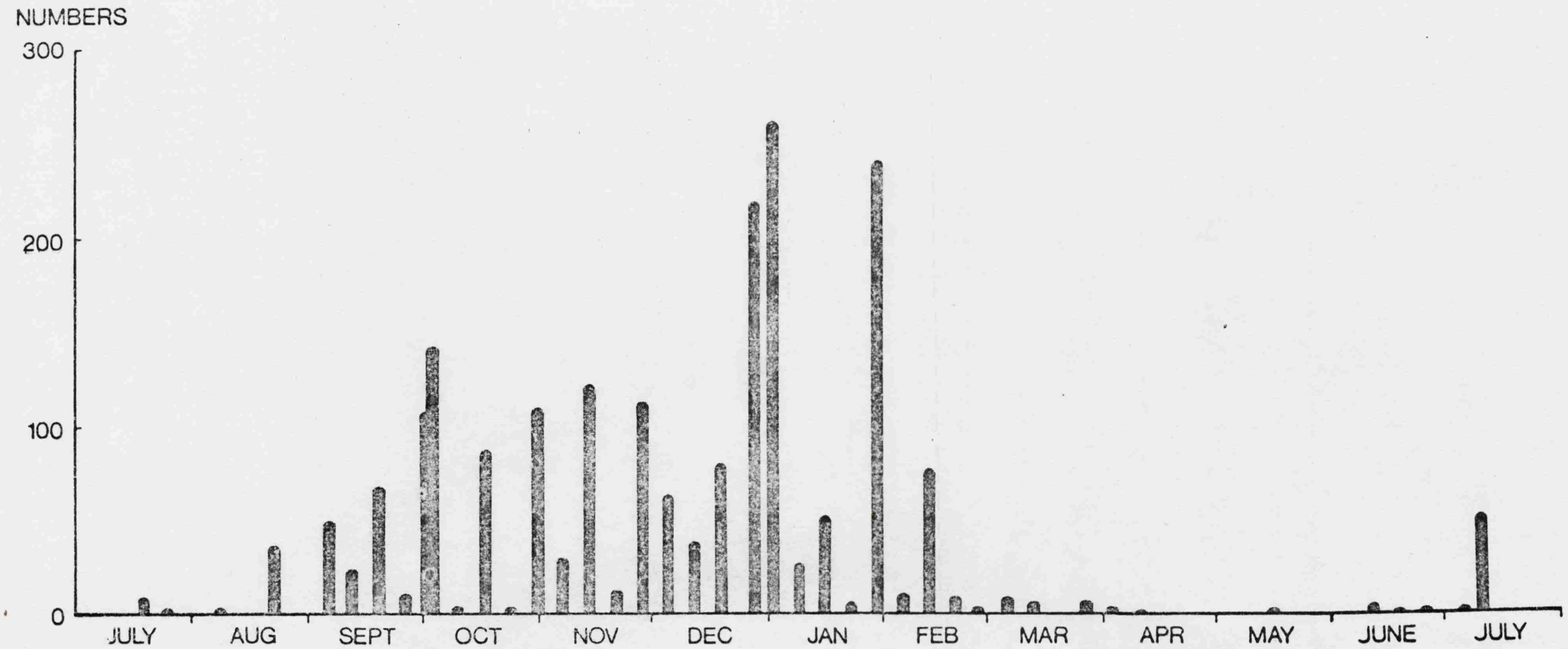
(ii) the study of the dietary habits through stomach analyses; and

(iii) the estimation of the levels of zinc, cadmium and lead in the tissues of gobies caught at regular intervals during 1972-1975.

The determination of the population density was achieved by counting the number of fish trapped in a 24 hour cycle by the screens at the cooling water intake of the power station and the monthly average plotted as in Fig. 101 (Kartar, 1974). This relatively straightforward procedure has given unexpectedly clear and easily reproducible results over the whole period of this research.

FIGURE 101

Seasonal fluctuation in numbers of sand gobies, *Pomatoschistus minutus* obtained over a 24 h sampling period in the cooling water intakes of Oldbury Nuclear Power Station.



Numbers of sand gobies (*Pomatoschistus minutus*) in weekly samples from Oldbury Power Station.

TABLE 36

Distribution of zinc, lead and cadmium (ppm) in various tissues of *Crangon crangon* obtained from Oldbury-on-Severn and Milford Haven. Also included are the number of individual analyses and ±95% confidence limit.

LOCALITY/TISSUE	ZINC	LEAD	CADMIUM
Oldbury-on-Severn			
Muscle Tissues	93.30 ± 1.50 (50)	16.20 ± 2.00 (50)	12.20 ± 0.80 (50)
Rest of Tissues	200.00 19.10 (50)	73.30 17.10 (50)	65.40 1.40 (50)
Milford Haven			
Muscle Tissues	65.40 1.70 (50)	15.30 1.80 (50)	1.80- 1.20 (50)
Rest of Tissues	131.40 2.00 (50)	65.30 25.00 (50)	6.00 1.00 (50)

In July the number of fish present in the estuary is comparatively small but dramatically increases to a peak by the end of December/January, thereafter declining again to a minimum level by late spring or early summer. This pattern is reasonably consistent over the three year study period from 1972 to 1975 (Kartar, 1974; Williams, 1976; Thurgood, 1976). In contrast to Lloyd's earlier findings (1940) at no time are sand gobies totally absent from this locality. Dietary habits at Oldbury of gobies depend largely on estuarine organisms which are abundant at this site, thus about 78% of the fish analysed contained *Neomysis* and *Gammarus spp.* in their stomachs. Some were observed to have the parasite, *Ligula intestinales* in their stomach cavity (Kartar, 1974).

The determination of zinc, cadmium and lead in the successive winter catches from 1972-1975, have produced entirely unexpected results (Appendix 56). The zinc levels (Fig. 102) in the 1973 and 1974 samples are more than two-fold greater than those of 1972 and 1975. Lead levels show a similar pattern (Fig. 103) but the yearly differences are much less pronounced. Cadmium concentrations (Fig. 104) in *Pomatoschistus minutus* are slightly more erratic, thus the levels found in 1972 are lower by a factor of more than one and a half that of 1973, but in 1974 samples contained increased cadmium levels, almost matching the 1972 results. Unpredictably the 1975 results show the least amount of metal to be present in the animals during the entire study period, amounting to a little over 1 ppm, a figure well under three times less than that of 1972.

The host parasite/zinc, lead and cadmium relationship is presented in Table 37.

FIGURE 102

Accumulation of zinc (ppm) in the tissues of the 1+ sand gobies, *Pomatoschistus minutus* obtained each December from 1972-1976 at Oldbury.

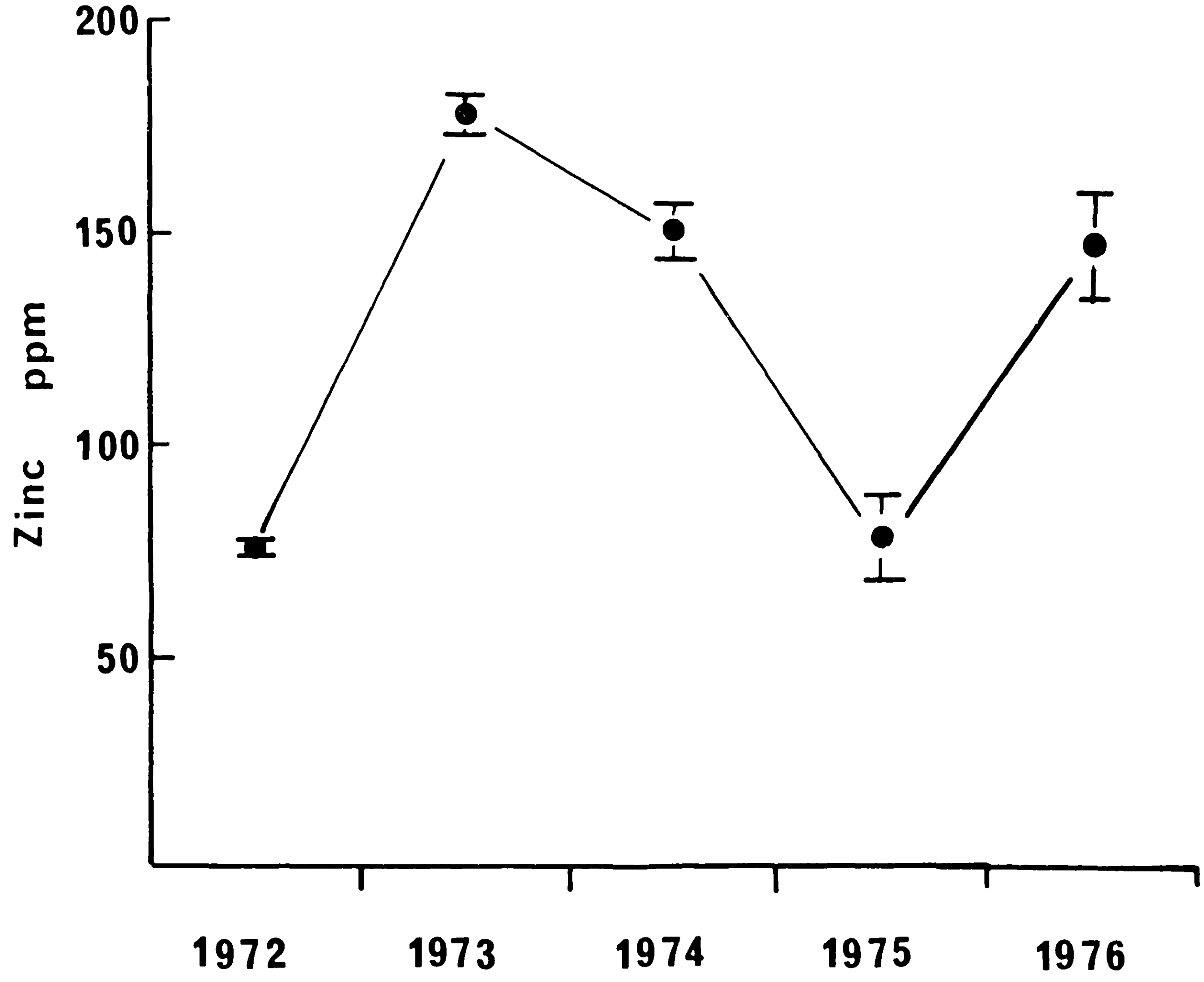

200
150
100
50
Zinc ppm
1972
1973
1974
1975
1976

FIGURE 103

Accumulation of lead (ppm) in the tissues of 1+ sand gobies, *Pomatoschistus minutus* obtained each December from 1972-1976 at Oldbury.

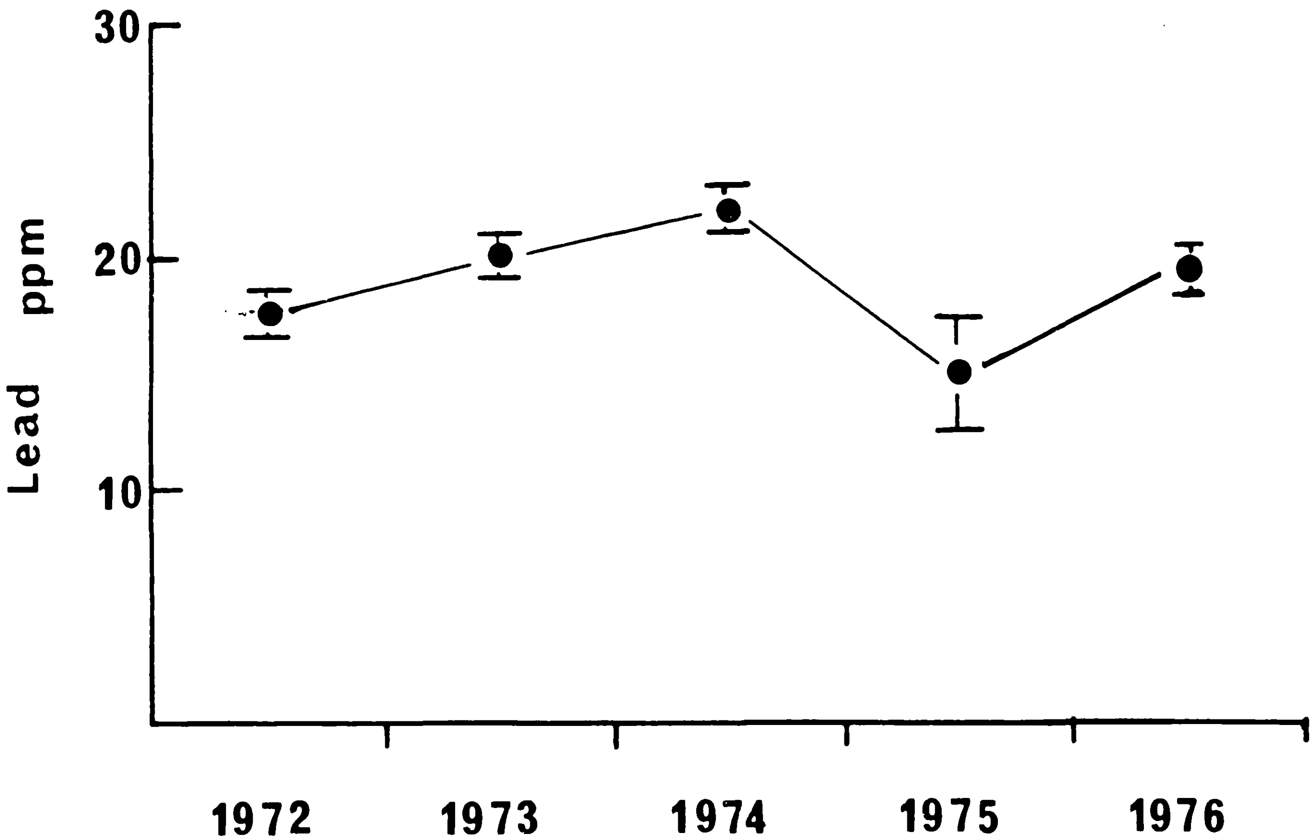
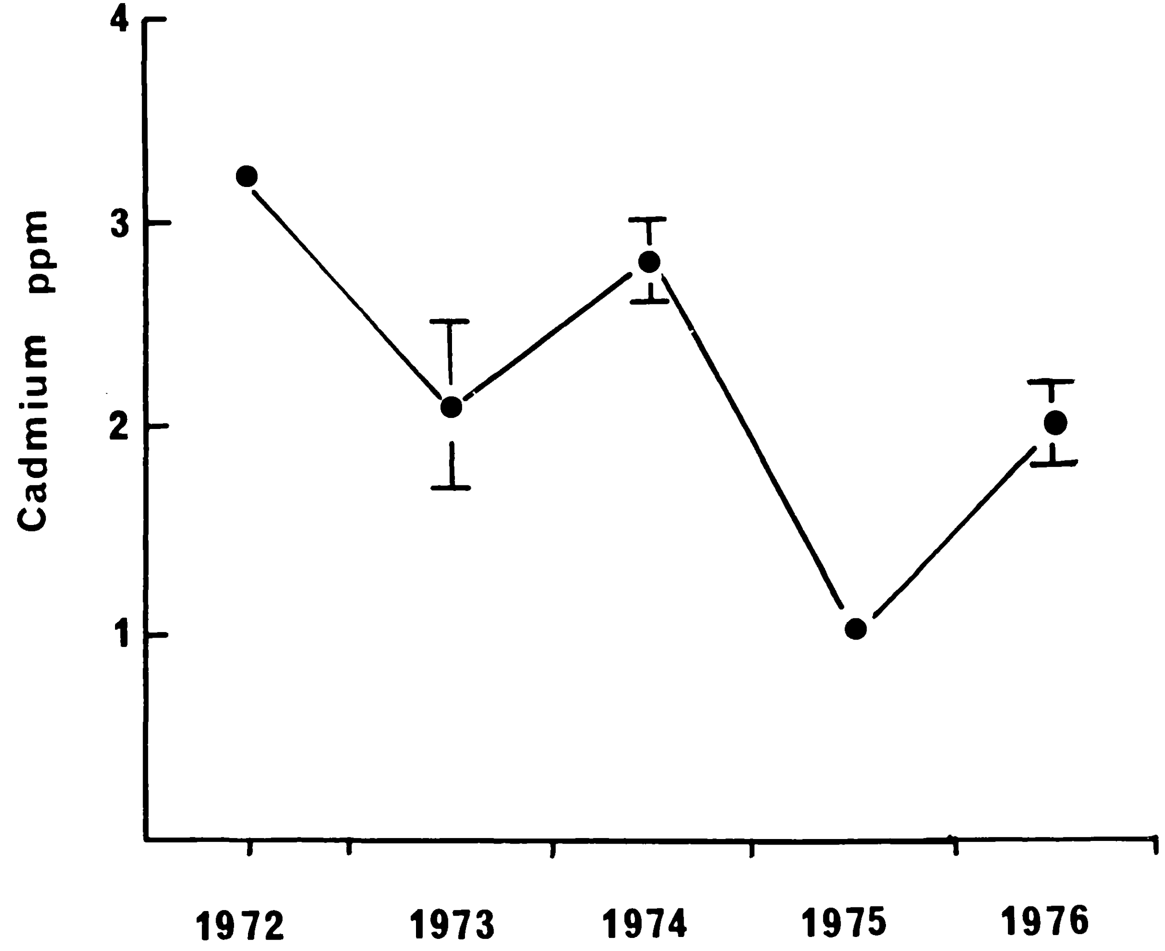

30
20
10
Lead ppm
1972
1973
1974
1975
1976

FIGURE 104

Accumulation of cadmium (ppm) in the tissues of 1+ sand gobies, *Pomatoschistus minutus* obtained each December from 1972-1976 at Oldbury.



Cadmium ppm
4
3
2
1
1972
1973
1974
1975
1976

TABLE 37

Concentrations (as a percentage) of zinc, lead and cadmium in the host, sand goby, *Pomatoschistus minutus* and its cestode parasite, *Ligula intestinalis*.

	ZINC	LEAD	CADMIUM
Sand goby	50.1	40.5	54.1
Ligula intestinalis	49.9	59.5	45.9

PART 8

DISCUSSION

8. DISCUSSION

Referring to the region under discussion in this dissertation Yonge (1937) remarked that "there is no region around the shores of Great Britain of greater intrinsic interest than the Bristol Channel and the estuary of the River Severn".

This statement is even more pertinent today than it was four decades ago, since the area is now much more heavily populated and industrialised, with the consequential growth in the problems of waste disposal. Additionally, with increasing demands for energy, the prospect of the construction of a Severn barrage is becoming a very real possibility. Before such a structure can be seriously considered however, much more effort must be undertaken to establish details of sedimentology and the effects that such a major disturbance would have upon the dilution of human and industrial wastes, which now enter the Severn through drainage.

Part of the latter study is obviously to establish baselines of 'pollution' as they currently exist, for without these, future predictions are meaningless; yet except for a few and often alarmist reports, very few carefully weighed ecological surveys have been conducted.

In an initial study (Kartar, MSc Thesis, University of Bath, 1974) an attempt was made to relate aspects of the general biology of key teleost species taken from the River Severn and the Bristol Channel to the levels of certain heavy metals, such as zinc, lead and cadmium, which are found in the tissues. It was soon realised however, just how complex a problem this represents, for not only do such species undertake extensive migrations either to spawn or to seek new feeding areas but their diet, which is of primary importance in the accumulation of metals, may change and the physical conditions of the estuary, water temperature, rainfall, salinity and the scale of waste disposal may vary from season to season, even from month to month.

An estuary is a meeting place for waters of very different chemical composition and properties. Here, sea water of high salinity mixes with river water of a lower salt content but often of lower pH. River water may be more concentrated with respect to plant nutrient elements derived from land drainage and also with transition metals, but the estuarine water contains much sediment and at the point where the sea and river waters mix, chemical reactions occur, greatly aided by the active sites on the suspended particulates. Often with heavy metals this means that a the point of physical mixing, they are occluded into the sediment or otherwise precipitated, so that their concentration in solution falls.

In the case of lead and zinc, considerable natural deposits occur and their presence in the waters of the area are to be expected. Cadmium on the other hand, is very much less abundant, and in this area its occurrence is due almost entirely to industrial pollution; much of the author's early work was intended to ascertain those biological vectors associated with the distribution of cadmium in the food chains.

In this dissertation, despite all the problems, outlined above, this study has been extended with the particular aim of determining the effects of zinc, lead and cadmium upon the rates of growth of key estuarine fish. Whilst at the same time continuing the monitoring of the accumulation of baseline data on metal in both prey and predators.

In an attempt to see if the metal levels have increased or decreased over the period studied, the 0+ and 1+ flounders which are present in the estuary throughout the year in varying numbers have been studied. Our results show that zinc, lead and cadmium levels have actually fallen. Thus, zinc levels have decreased by 39.3% and 41.9% in the 0+ and 1+ fish respectively since October 1973. Lead and cadmium levels which can be traced back to October 1972 show a drop of 28.6% (0+) and 56.5% (1) for lead and 89.7 (0+) and 39.1% (1+) for cadmium. It is interesting that there is a disparity in the results for the two age classes.

Further, as an illustration of how difficult it is to rationalise some of the heavy metal analyses, we have made a comparison of mean metal levels in three species obtained at the mid point of the seasons (December) in 1974 and 1975, this is shown in Table 38. Except for the 2+ age class flounders, all metal levels have decreased but not to the same extent.

An exception to the above pattern can be seen in Table 39, where November figures for five bearded rocklings and July levels for shrimps are compared (these months were selected since they correspond to the times of peak abundance in November for rocklings and July for shrimps). Here while no significant change can be observed for cadmium in five bearded rocklings except at Oldbury, lead levels in both the rocklings and shrimps have increased dramatically, especially in the region of the mid-estuary.

The problem of interpreting such results is quite typical and forms much of the sequel. Thus, attempts were made to correlate metal levels with salinity, water temperature and fresh water but no distinct relationship could be seen.

TABLE 38

Comparisons of mean concentrations of zinc, lead and cadmium (ppm) in the three major species, caught in the cooling water intake screens of the Power Stations during 1972-1976.

LOCATION/ SPECIES	AGE	MONTH/ YEAR	ZINC	LEAD	CADMIUM
OLDBURY					
Flounders	0+	Dec '74	200.0	19.5	4.5
"	0+	Dec '75	199.0	16.1	1.9
Overall drop	(as a percentage)		- 0.5%	- 57.8%	- 17.4%
Flounders	1+	Dec '74	140.0	19.0	3.1
"	1+	Dec '75	138.0	16.3	2.4
Overall drop	(as a percentage)		- 1.4%	- 14.2%	- 22.6%
Flounders	2+	Dec '74	99.2	20.0	3.6
"	2+	Dec '75	120.0	17.8	3.1
Overall drop/inc	(as a percentage)		+ 21.0%	- 11.0%	- 13.9%
Sea snails	-	Dec '73	148.4	27.1	8.4
"	-	Dec '74	143.3	26.9	7.0
"	-	Dec '75	83.6	22.0	6.6
Overall drop	(as a percentage)		- 43.7%	- 18.8%	- 21.4%
BERKELEY					
Sea snails	-	Dec '74	195.2	28.2	6.9
"	-	Dec '75	80.2	20.2	5.2
Overall drop	(as a percentage)		- 58.9%	- 28.4%	- 28.8%
Sand goby	1+	Dec '73	178.3	20.0	2.1
"	1+	Dec '76	148.9	19.8	2.0
Overall drop	(as a percentage)		- 16.5%	- 1.0%	- 5.0%

TABLE 39

Comparisons of mean concentrations of zinc, lead and cadmium (ppm) in Five bearded rocklings, *Ciliata mustela* and shrimps, *Crangon crangon* caught during 1972-1976.

LOCATION/ SPECIES	AGE	MONTH/ YEAR	ZINC	LEAD	CADMIUM
OLDBURY					
Five bearded rocklings	-	Nov '74	80.5	14.9	3.6
"	-	Nov '75	57.1	16.9	3.0
Overall drop/inc(as a percentage			- 29.1%	+ 13.4%	- 16.7%
BERKELEY					
Five bearded rocklings	-	Nov '74	99.0	15.0	3.5
"	-	Nov '75	59.1	24.3	3.5
Overall drop/inc(as a percentage			- 40.3%	+ 62.0%	0.0%
MINEHEAD					
Five bearded rocklings	-	Aug '75	45.0	12.0	1.8
	-	Aug '76	50.0	12.5	1.8
Overall drop/inc(as a percentage)			+ 11.1	+ 4.2	0.0%
MINEHEAD					
Shrimp	1+	Jul '75	101.4	24.0	22.5
"	1+	Jul '76	100.0	25.30	20.9
Overall drop/inc(as a percentage)			- 1.4%	+ 5.4%	- 7.1%
MINEHEAD					
Shrimp	1+	Jul '72	228.0	34.0	125.0
"	1+	Jul '76	120.0	54.0	120.8
Overall drop/inc(as a percentage)			- 47.4%	+ 58.8%	- 4.6%

It was further found that changes in the diet of the major species could not be satisfactorily correlated with metal levels, principally because it was not possible to obtain prey species in sufficient quantities for analyses. However, although no complete direct correlation was established between the metal levels in the shrimps and fish species, seasonal changes in cadmium levels in the shrimps are reflected in the levels found in their predator.

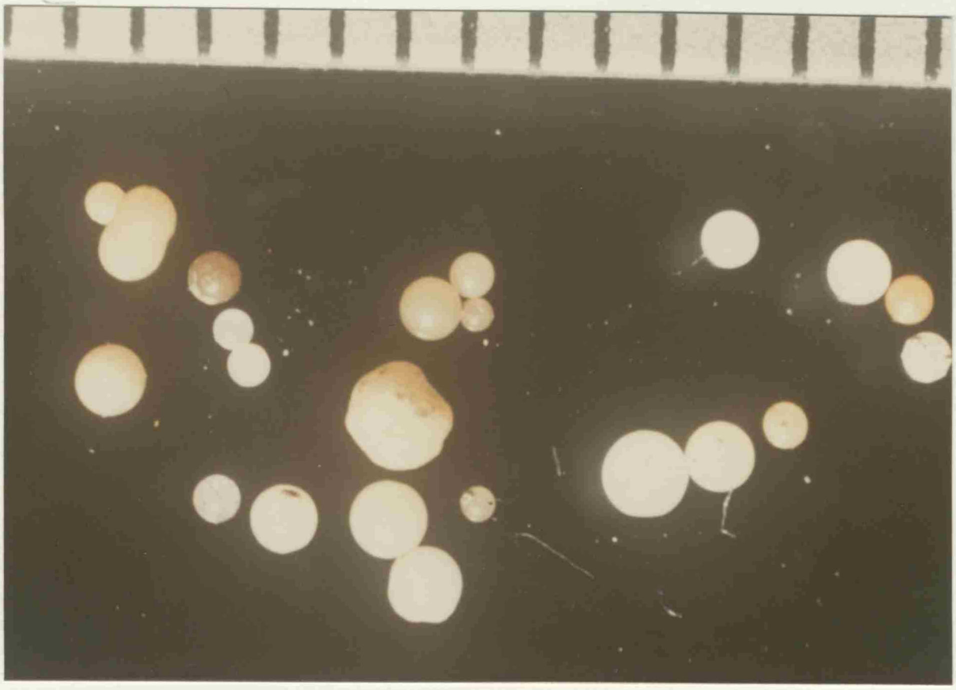
A possible implication of changes in ionic composition and osmoregulation due to increase in salinity, may well have a contributory effect on the uptake of metals and also the efficiency with which fish regulate the levels of zinc, lead and cadmium within their tissue.

Clearly there is a paucity of information both on the physiological state of the animals under investigation, as well as their range during spawning and feeding. In addition there is a lack of precise data on chemical changes in the estuarine water and on the contribution made by industrial effluent and natural run off. Thus, it is unlikely that any single factor could be evoked to explain the seasonal or annual fluctuations of zinc, lead and cadmium in the animal population.

Despite the evidence accumulated in the course of this study, the author is forced to conclude that much remains to be done in order to acquire even a basic knowledge of this complex ecosystem. At the same time it is hoped that the data which has been compiled will form a useful background in future work.

PLATES 26 - 27

Polystyrene spherules and plastic waste found in the stomachs of major key marine and estuarine species in the Severn Estuary and the Bristol Channel.



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PART 9

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10. REFERENCES

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PART 10

APPENDICES

APPENDIX 1

The mean length in cm of the 0+ age group flounders, *Platichthys flesus* caught in a 24 h sampling period in the cooling water intake screens of Oldbury Power Station during 1973-76. Also included are numbers investigated and ±95% confidence limit.

MONTH	1973 / 1974	1974 / 1975	1975 / 1976
July	4.90 ± 0.10 (185)	4.60 ± 0.10 (243)	4.50 ± 0.20 (347)
August	5.70 ± 0.09 (117)	5.60 ± 0.10 (73)	5.80 ± 0.20 (105)
September	6.40 ± 0.30 (77)	7.00 ± 0.20 (63)	6.80 ± 0.20 (18)
October	6.70 ± 0.80 (20)	7.20 ± 0.30 (24)	7.00 ± 0.50 (32)
November	8.20 ± 1.00 (13)	7.80 ± 1.100 (35)	8.50 ± 0.30 (17)
December	7.5 ± 0.80 (10)	7.5 ± 0.50 (12)	7.80 ± 0.80 (17)
January	8.40 ± 0.5 (27)	8.30 ± 0.70 (28)	8.30 ± 0.50 (30)
February	8.20 ± 0.50 (25)	7.60 ± 0.30 (51)	8.00 ± 0.80 (30)
March	8.00 ± 1.80 (19)	8.20 ± 1.100(104)	7.40 ± 1.00 (219)
April	8.30 ± 0.50 (50)	8.50 ± 1.00 (158)	8.20 ± 0.50 (220)
May	9.1 ± 0.50 (55)	9.00 ± 0.70, (26)	9.30 ± 0.80 (37)
June	3.90 ± 0.80 (8)	3.80 ± 0.20 (58)	3.90 ± 0.20 (6)
July	4.60 ± 0.10 (243)	4.50 ± 0.20 (347)	

APPENDIX 2

The mean length of the 1+ age group flounders, *Platichthys flesus*, caught in a 24 h sampling period in the cooling water intake screens of Oldbury Power Station during 1973-76. Also included are numbers investigated and ±95% confidence limits.

MONTH	1973 / 1974	1974 / 1975	1975 / 1976
July	10.80 ± 0.20 (29)	10.95 ± 0.30 (75)	11.50 ± 0.80 (111)
August	11.60 ± 0.20 (46)	10.00 ± 0.30 (85)	11.80 ± 0.50 (19)
September	11.9 ± 0.80 (26)	12.10 ± 0.20 (35)	12.00 ± 0.50 (8)
October	13.20 ± 0.60 (21)	13.10 ± 0.30 (40)	13.50 ± 0.20 (10)
November	13.00 ± 1.00 (23)	13.10 ± 0.20 (34)	13.20 ± 1.00 (11)
December	12.20 ± 1.20 (10)	12.70 ± 0.80 (15)	12.30 ± 1.30 (11)
January	11.90 ± 1.00 (17)	13.00 ± 0.70 (40)	11.80 ± 0.80 (30)
February	13.10 ± 0.90 (21)	13.00 ± 0.50 (45)	13.00 ± 1.00 (32)
March	13.00 ± 0.80 (20)	13.20 ± 0.50 (41)	13.00 ± 0.50 (111)
April	13.50 ± 0.80 (9)	13.20 ± 0.70 (52)	14.50 ± 0.80 (122)
May	15.80 ± 0.80 (13)	13.50 ± 0.50 (75)	14.40 ± 0.50 (12)
June	10.10 ± 0.60 (70)	10.20 ± 0.50 (95)	10.30 ± 0.80 (94)
July	10.95 ± 0.30 (75)	11.50 ± 0.80 (111)	

APPENDIX 3

The mean length in cm of the 2+ age group flounders, *Platichthys flesus*, caught in a 24 h sampling period in the cooling water intake screens of Oldbury Power Station during 1973-76. Also included are numbers investigated and ±95% confidence limit.

MONTH	1973 / 1974	1974 / 1975	1975 / 1976
July	17.50 ± 0.60 (11)	17.10 ± 0.30 (20)	17.80 ± 1.00 (29)
August	17.20 ± 0.40 (25)	19.80 ± 1.30 (6)	17.50 (2)
September	16.70 ± 0.60 (22)	18.40 ± 0.50 (11)	16.30 ± 0.50 (12)
October	18.50 ± 1.00 (24)	18.50 ± 0.30 (18)	18.50 ± 1.20 (12)
November	18.20 ± 0.80 (27)	18.70 ± 0.50 (19)	18.20 ± 1.00 (7)
December	18.00 ± 1.10 (9)	19.00 ± 1.40 (16)	17.90 ± 0.80 (7)
January	20.60 ± 1.70 (16)	17.80 ± 1.10 (15)	20.80 ± 1.00 (6)
February	17.90 ± 1.00 (11)	16.70 ± 0.70 (10)	28.90 ± 1.30 (6)
March	19.70 ± 1.70 (9)	18.90 ± 1.50 (21)	20.00 ± 1.30 (23)
April	18.00 ± 3.80 (7)	16.80 ± 2.00 (26)	18.00 ± 0.80 (29)
May	21.70 ± 1.50 (4)	16.30 ± 0.80 (21)	16.00 ± 0.80 (6)
June	18.80 ± 0.70 (30)	19.50 ± 0.80 (23)	20.20 ± 1.50 (20)
July	17.10 ± 0.30 (20)	17.80 ± 1.00 (29)	

APPENDIX 4

The mean length in cm of 3+ age group flounders, *Platichthys flesus*, caught in a 24 h sampling period in the cooling water intake screens of Oldbury Power Station during 1973-76. Also included are numbers investigated and ±95% confidence limit.

MONTH	1973 / 1974	1974 / 1975	1975 / 1976
July	22.10 ± 0.80 (10)	24.30 ± 0.60 (11)	25.00 ± 1.00 (7)
August	21.30 ± 1.00 (9)	22.60 ± 0.20 (3)	23.80 (1)
September	20.30 ± 2.00 (12)	23.70 ± 1.00 (4)	24.80 ± 0.90 (3)
October	23.50 ± 1.50 (11)	21.40 ± 1.10 (5)	22.50 ± 1.20 (9)
November	22.50 ± 1.10 (24)	23.00 ± 1.40 (8)	25.50 (2)
December	22.60 ± 3.90 (3)	Not Present	23.90 (2)
January	22.80 ± 1.00 (3)	24.80 ± 3.50 (3)	Not Present
February	20.8 (2)	21.00 ± 1.50 (3)	28.90 (1)
March	22.30 (2)	22.50 ± 0.50 (3)	24.90 ± 0.80 (13)
April	23.10 ± 1.20 (6)	23.20 ± 0.50 (4)	25.50 ± 0.80 (5)
May	24.60 (1)	23.80 ± 0.90 (6)	26.20 ± 0.50 (4)
June	24.10 ± 1.10 (6)	22.80 ± 0.90 (7)	24.30 (2)
July	24.30 ± 0.60 (11)	25.00 ± 1.00 (7)	Not Present

APPENDIX 5

The mean length in cm of 4+ age group flounders, *Platichthys flesus*, caught in a 24 h sampling period in the cooling water intake screens of Oldbury Power Station during 1973-76. Also included are numbers investigated and ±95% confidence limit.

MONTH	1973 / 1974	1974 / 1975	1975 / 1976
July	25.1 (2)	26.00 (1)	27.50 ± 2.00 (3)
August	23.40 ± 2.70 (7)	Not Present	Not Present
September	24.30 ± 2.50 (7)	Not Present	Not Present
October	25.50 ± 1.20 (10)	25.50 (1)	27.00 ± 1.90 (5)
November	24.90 ± 1.20 (5)	25.90 ± 1.70 (7)	Not Present
December	26.10 (2)	24.80 (1)	29.20 (2)
January	Not Present	Not Present	Not Present
February	28.20 (1)	24.00 (2)	Not Present
March	Not Present	25.00 (2)	31.20 ± 3.10 (10)
April	24.50 ± 2.00 (4)	25.70 ± 1.10 (4)	Not Present
May	Not Present	26.30 (2)	28.90 (2)
June	Not Present	Not Present	30.00 (2)
July	26.00 (1)	27.50 ± 2.00 (3)	Not Present

APPENDIX 6

The mean length in cm of 5+ age group flounders, *Platichthys flesus*, caught in a 24 h sampling period in the cooling water intake screens of Oldbury Power Station during 1973-76. Also included are numbers investigated and ±95% confidence limit.

MONTH	1973 / 1974	1974 / 1975	1975 / 1976
July	26.80 (1)	28.00 (1)	32.00 ± 4.10 (3)
August	29.10 ± 3.70 (4)	34.50 (2)	Not Present
September	26.80 ± 4.40 (5)	Not Present	29.90 ± 1.90 (5)
October	27.60 ± 5.90 (3)	30.00 (2)	30.30 ± 0.70 (5)
November	28.20 2.20 (7)	Not Present	Not Present
December	25.50 (1)	32.40 (1)	30.00 (2)
January	28.90 (2)	29.20 (2)	Not Present
February	Not Present	28.00 (2)	32.50 (2)
March	27.90 (2)	31.50 (2)	31.90 ± 1.20 (10)
April	31.80 ± 1.20 (3)	Not Present	35.00 ± 1.90 (4)
May	Not Present	30.00 (2)	32.00 (2)
June	Not Present	Not Present	32.00 (2)
July	28.00 (1)	32.00 ± 4.10 (3)	Not Present

APPENDIX 7

The mean length in cm of pooled data of various age group flounders, *Platichthys flesus*, caught in a 24 h sampling period in the cooling water intake screens during 1975-76. Also included are numbers investigated and ±95% confidence limit.

AGE GROUPS	OLDBURY	BERKELEY
0 +	7.5 ± 0.6 (213)	7.8 ± 0.6 (40)
1 +	12.9 ± 0.7 (209)	12.7 ± 0.3 (77)
2 +	18.3 ± 0.9 (89)	18.1 ± 0.5 (64)
3 +	22.7 ± 1.0 (23)	23.7 ± 3.0 (21)
4 +	25.6 ± 0.5 (13)	25.5 ± 0.7 (13)
5 +	29.5 ± 1.6 (6)	28.3 ± 1.5 (6)

APPENDIX 8

The mean lengths in cm of pooled data of flounders, *Platichthys flesus*, of various age groups caught during the summer of 1974 in the Severn Estuary and the Bristol Channel. Also included are the numbers investigated and ±95% confidence limit.

AGE GROUP	OLDBURY-ON-SEVERN	HINKLEY POINT	BARNSTAPLE BAY
0 +	5.8 ± 0.3 (437)	7.9 ± 0.4 (20)	Not Present
1 +	11.4 ± 1.0 (329)	12.7 ± 0.3 (28)	Not Present
2 +	19.5 ± 1.9 (187)	20.0 ± 0.5 (31)	22.4 ± 0.4 (152)
3 +	23.8 ± 2.0 (34)	24.6 ± 0.6 (14)	26.0 ± 0.4 (120)
4 +	25.9 ± 1.5 (5)	28.3 ± 0.5 (7)	28.5 ± 1.0 (120)
5 +	31.5 ± 2.0 (5)	30.6 ± 1.0 (10)	31.7 ± 1.3 (120)
6 +	Not Present	32.0 ± 0.5 (11)	32.1 ± 1.6 (120)

APPENDIX 9

The mean weight in g of 0+ age group flounders, *Platichthys flesus*, caught in a 24 h sampling period in the cooling water intake screens of Oldbury Power Station during 1973-76. Also included are the numbers examined and ±95% confidence limit.

MONTH	1973 / 1974	1974 / 1975	1975 / 1976
July	1.30 ± 0.10 (185)	0.97 ± 0.08 (243)	2.10 ± 0.20 (347)
August	1.90 ± 0.20 (117)	1.70 ± 0.10 (73)	2.30 ± 0.09 (105)
September	2.60 ± 0.50 (77)	3.10 ± 0.20 (63)	2.20 ± 0.50 (18)
October	3.20 ± 1.00 (20)	4.10 ± 0.70 (24)	3.90 ± 0.70 (32)
November	4.40 ± 1.40 (13)	5.50 ± 0.80 (35)	5.00 ± 0.90 (17)
December	3.90 ± 1.30 (10)	4.60 ± 0.70 (12)	5.90 ± 0.90 (17)
January	6.50 ± 1.10 (27)	6.20 ± 1.60 (28)	6.90 ± 0.80 (30)
February	6.00 ± 1.20 (25)	4.20 ± 0.70 (51)	7.50 ± 1.00 (30)
March	6.90 ± 1.40 (19)	5.00 ± 2.00 (104)	6.9 ± 0.30 (219)
April	6.50 ± 2.50 (50)	6.00 ± 1.10 (158)	6.90 ± 0.30 (220)
May	9.30 ± 1.70 (55)	8.50 ± 0.90 (26)	9.70 ± 1.10 (37)
June	0.50 ± 0.20 (8)	1.20 ± 0.10 (58)	0.20 ± 0.10 (6)
July	0.97 ± 0.08 (243)	2.10 ± 0.30 (347)	-

APPENDIX 10

The mean weight in g of 1+ age group flounders, *Platichthys flesus*, caught in a 24 h sampling period in the cooling water intake screens of Oldbury Power Station during 1973-76. Also included are numbers investigated and ±95% confidence limit.

MONTH	1973 / 1974	1974 / 1975	1975 / 1976
July	13.90 ± 1.30 (29)	11.30 ± 1.10 (75)	11.20 ± 0.90 (111)
August	15.50 ± 0.90 (46)	14.30 ± 0.90 (85)	16.00 ± 1.10 (19)
September	16.80 ± 3.50 (26)	17.20 ± 0.80 (35)	17.20 ± 0.90 (8)
October	22.60 ± 3.60 (21)	22.7 ± 1.43 (40)	22.00 ± 1.80 (10)
November	22.10 ± 4.80 (23)	23.00 ± 1.70 (34)	22.00 ± 1.80 (11)
December	17.90 ± 5.10 (10)	20.30 ± 4.00 (15)	18.10 ± 2.10 (11)
January	16.80 ± 5.00 (17)	24.00 ± 3.40 (40)	18.10 ± 1.00 (30)
February	24.60 ± 5.00 (21)	20.60 ± 2.70 (45)	18.10 ± 1.90 (32)
March	24.20 ± 4.60 (20)	25.00 ± 3.10 (41)	24.00 ± 0.90 (111)
April	27.40 ± 5.40 (9)	27.20 ± 1.90 (52)	25.00 ± 2.20 (122)
May	40.40 ± 7.30 (13)	32.10 ± 5.00 (75)	31.90 ± 3.10 (12)
June	12.10 ± 1.90 (70)	10.80 ± 2.20 (94)	12.00 ± 0.90 (94)
July	11.30 ± 1.10 (75)	11.20 ± 2.30 (111)	-

APPENDIX 11

The mean weight in g of 2+ age group flounders, *Platichthys flesus*, caught in a 24 h sampling period in the cooling water intake screens of Oldbury Power Station during 1973-76. Also included are the numbers investigated and ±95% confidence limit.

MONTH	1973 / 1974	1974 / 1975	1975 / 1976
July	53.60 ± 5.30 (11)	50.76 ± 2.84 (20)	48.30 ± 2.10 (29)
August	52.90 ± 5.40 (25)	83.40 ± 18.30 (6)	54.40 (2)
September	44.50 ± 7.10 (22)	61.40 ± 5.50 (11)	61.70 ± 7.60 (12)
October	62.30 ± 11.60 (24)	161.6 ± 3.80 (18)	62.60 ± 2.20 (12)
November	56.70 ± 8.80 (27)	65.20 ± 6.00 (19)	64.10 ± 1.90 (7)
December	61.90 ± 13.40 (9)	67.70 ± 14.40 (16)	68.00 ± 3.10 (7)
January	83.70 ± 24.90 (16)	50.00 ± 8.70 (15)	56.20 ± 4.10 (6)
February	58.90 ± 10.70 (11)	54.00 ± 7.90 (10)	90.30 ± 9.90 (6)
March	83.20 ± 20.60 (9)	60.00 ± 10.00 (21)	80.00 ± 11.70 (23)
April	59.00 ± 35.70 (7)	54.20 ± 3.90	70.00 ± 1.90 (29)
May	91.90 ± 20.80 (4)	44.20 ± 2.60 (21)	60.00 ± 1.10 (6)
June	60.20 ± 8.40 (30)	62.50 ± 9.80 (23)	53.50 ± 10.90 (20)
July	50.80 ± 28.40 (20)	48.30 ± 2.10 (29)	-

APPENDIX 12

The mean weight in g of 3+ age group flounders, *Platichthys flesus*, caught in a 24 h sampling period in the cooling water intake screens of Oldbury Power Station during 1973/76. Also included are the numbers investigated and ±95% confidence limit.

MONTH	1973 / 1974	1974 / 1975	1975 / 1976
July	111.00 ± 13.30 (10)	159.10 ± 12.70 (11)	156.70 ± 11.90 (7)
August	104.30 ± 17.20 (9)	103.30 ± 7.40 (3)	118.3 (1)
September	89.40 ± 24.00 (12)	117.60 ± 13.10 (4)	108.3 12.10 (3)
October	127.30 ± 19.80 (11)	116.80 ± 22.20 (5)	108.30 ± 17.90 (9)
November	109.00 ± 18.10 (24)	117.30 ± 30.70 (8)	110.00 (2)
December	126.30 ± 65.10 (3)	Not Present	112.80 (2)
January	89.20 ± 23.10 (3)	141.60 ± 36.60 (3)	Not Present
February	90.10 (2)	101.40 ± 40.40 (3)	90.30 (1)
March	106.90 (2)	107.90 ± 15.00 (3)	102.00 ± 9.70 (13)
April	109.70 ± 11.30 (6)	112.80 ± 20.00 (4)	110.00 ± 12.30 (5)
May	139.60 (1)	98.80 ± 10.00	94.30 ± 11.10 (4)
June	137.60 ± 22.60 (6)	140.00 ± 8.90 (7)	102.30 (2)
July	159.10 ± 12.70 (11)	156.70 ± 11.90 (7)	-

APPENDIX 13

The mean weight in g of 4+ age group flounders, *Platichthys flesus*, caught in a 24 h sampling period in the cooling water intake screens of Oldbury Power Station during 1973-76. Also included are the numbers investigated and ±95% confidence limit.

MONTH	1973 / 1974	1974 / 1975	1975 / 1976
July	166.70 (2)	203.3 (1)	220.9 (3)
August	116.0 ± 9.50 (7)	Not Present	Not Present
September	124.40 ± 46.6 (7)	Not Present	Not Present
October	173.20 ± 27.00 (10)	107.10 (1)	190.00 ± 81.70 (5)
November	134.50 ± 58.60 (5)	173.30 ± 74.90 (7)	Not Present
December	191.20 (2)	172.70 (1)	199.90 (2)
January	Not Present	Not Present	Not Present
February	270.3 (1)	142.00 (2)	Not Present
March	Not Present	202.20 (2)	230.00 ± 45.90 (10)
April	137.30 ± 16.60 (4)	190.80 ± 19.90 (4)	Not Present
May	Not Present	209.90 (2)	210.00 (2)
June	Not Present	Not Present	210.00 (2)
July	203.30 (1)	220.90 ± 21.80	-

APPENDIX 14

The mean weight in g of 5+ age group flounders, *Platichthys flesus*, caught in a 24 h sampling period in the cooling water intake screens, of Oldbury Power Station during 1973-76. Also included are the numbers investigated and ±95% confidence limit.

MONTH	1973 / 1974	1974 / 1975	1975 / 1976
July	157.20 (2)	130.00 (1)	240.00 ± 33.60 (3)
August	251.30 ± 10.10 (4)	400.50 (2)	Not Present
September	168.60 ± 82.00 (5)	Not Present	241.00 ± 11.50 (5)
October	182.50 ± 37.70 (3)	243.90 (2)	250.00 ± 8.90 (5)
November	234.90 64.80 (7)	Not Present	Not Present
December	93.50 (1)	433.40 (1)	210.00 (2)
January	194.50 (2)	274.40 (2)	Not Present
February	Not Present	203.90 (2)	249.90 (2)
March	190.40 (2)	206.20 (2)	260.00 (10)
April	254.70 (3)	Not Present	260.60 ± 41.00 (4)
May	Not Present	240.30 (2)	262.00 (2)
June	Not Present	Not Present	260.00 (2)
July	130.00 (1)	240.00 ± 33.60	-

APPENDIX 15

The mean weight in g of various age group flounders, *Platichthys flesus*, caught in the cooling water intake screens of Oldbury and Berkeley Power Stations during the winter of 1974. Also included are the numbers investigated and ±95 confidence limit.

AGE GROUPS	OLDBURY	BERKELEY
0+	4.6 ± 1.8 (213)	5.3 ± 0.9 (40)
1+	21.6 ± 3.1 (209	20.6 ± 1.6 (77)
2+	59.6 ± 10.1 (89)	56.7 ± 4.7 (64)
3+	118.3 ± 15.1 (23)	125.6 ± 14.0 (21)
4+	160.9 ± 16.6 (13)	156.2 ± 20.1 (13)
5+	272.3 ± 34.0 (6)	235.6 ± 36.2 (6)

APPENDIX 16

The mean weight in g of various age group flounders, *Platichthys flesus*, caught in the summer of 1974 at Oldbury, Hinkley Point and Barnstaple Bay. Also included are the numbers investigated and ±95% confidence limit.

AGE GROUP	OLDBURY-ON-SEVERN	HINKLEY POINT	BARNSTAPLE BAY
0+	5.3 ± 1.8 (437)	5.4 ± 0.8 (20)	Not Present
1+	13.0 ± 1.2 (329)	23.5 ± 1.6 (28)	Not Present
2+	58.9 ± 20.0 (187)	87.1 ± 6.7 (31)	132.8 ± 6.4 (152)
3+	128.9 ± 15.3 (34)	150.0 ± 10.3 (14)	196.8 ± 10.2 (120)
4+	151.0 ± 25.0 (5)	222.6 ± 26.3 (7)	234.2 ± 22.3 (120)
5+	259.0 ± 42.9 (5)	256.3 ± 25.7 (10)	294.0 ± 42.9 (120)
6+	Not Present	362.7 ± 33.9 (11)	330.9 ± 45.0 (120)

APPENDIX 17

The mean length (cm), weight (g) and gonadosomatic ratio (as a percentage of the body weight) of male sea snail, *Liparis liparis*, caught in a 24 h sampling period in the cooling water intake screens of Oldbury Nuclear Power Station during 1973-76. Also included are the numbers investigated and ±95% confidence limit.

MONTH/YEAR	NO. ANALYSD	LENGTH	WEIGHT	GONADOSOMATIC RATIO (%)
Sept '73	10	4.10 ± 0.40	1.30 ± 0.20	0.09 ± 0.00
Oct '73	12	6.00 ± 0.50	2.60 ± 0.40	0.09 ± 0.01
Nov '73	22	7.00 ± 0.70	5.00 ± 1.70	0.60 ± 0.05
Dec '73	86	8.00 ± 0.20	5.20 ± 0.40	0.60 ± 0.20
Jan '74	20	7.70 ± 0.30	7.90 ± 1.00	1.20 ± 0.20
Sept '74	3	4.80 ± 0.30	1.30 ± 0.10	0.20 ± 0.30
Oct '74	15	5.90 ± 0.20	2.70 ± 0.40	0.30 ± 0.50
Nov '74	203	7.00 ± 0.20	4.10 ± 0.80	0.50 ± 0.01
Dec '74	691	7.60 ± 0.20	5.50 ± 0.40	0.70 ± 0.20
Jan '75	300	7.40 ± 0.20	6.30 ± 1.00	0.70 ± 0.07
Feb '75	1	6.60 -	4.10 -	1.00 -
Oct '75	1	5.60 -	2.20 -	0.10 -
Nov '75	31	5.60 ± 0.10	2.20 ± 0.20	0.10 ± 0.01
Dec '75	207	6.30 ± 0.20	3.70 ± 0.40	0.20 ± 0.03
Jan '76	124	7.50 ± 0.30	6.60 ± 0.40	0.60 ± 0.50
Feb '76	6	8.30 ± 0.20	8.50 ± 0.40	0.70 ± 0.03
Mar '76	1	7.80 -	6.00 -	-

APPENDIX 18

The mean length (cm), weight (g) and gonadsomatic ratio (as a percentage of the body weight) of female sea snail, *Liparis liparis*, caught in a 24 h sampling period in the cooling water intake screens of Oldbury Power Station during 1973-76. Also included are the numbers investigated and ±95% confidence limit.

MONTH/YEAR	NO. ANALYSD	LENGTH	WEIGHT	GONADOSOMATIC RATIO (%)
Sept. '73	8	4.00 ± 0.20	1.20 ± 0.20	0.20 ± 0.01
Oct '73	18	6.00 ± 0.70	2.40 ± 0.20	0.30 ± 0.03
Nov '73	28	6.20 ± 0.50	5.00 ± 1.20	1.20 ± 0.20
Dec '73	86	7.90 ± 0.20	5.70 ± 0.30	2.00 ± 0.30
Jan '74	40	7.60 ± 0.20	6.70 ± 0.40	3.50 ± 0.40
Feb '74	2	7.50 -	5.40 -	5.50 -
Aug '74	1	4.10 -	1.00 -	0.30 -
Sept '74	4	4.60 ± 0.20	1.20 ± 0.20	0.30 ± 0.05
Oct '74	15	5.80 ± 0.20	2.30 ± 0.20	0.70 ± 0.30
Nov '74	264	6.30 ± 0.80	3.20 ± 0.30	1.10 ± 0.20
Dec '74	761	7.80 ± 0.20	6.10 ± 0.40	2.20 ± 0.30
Jan '75	1200	7.90 ± 0.01	8.10 ± 0.50	4.10 ± 0.20
Feb '75	41	8.30 ± 0.10	10.00 ± 0.50	10.00 ± 0.60
Mar '75	9	8.40 ± 0.20	9.70 ± 0.30	10.50 ± 0.70
Sept '75	2	4.20 -	1.00 -	Not Present
Oct '75	5	5.70 ± 0.10	2.50 ± 0.20	0.40 ± 0.05
Nov '75	32	5.70 ± 0.10	2.50 ± 0.20	0.40 ± 0.05
Dec '75	310	6.60 ± 0.10	4.30 ± 0.30	1.30 ± 0.06
Jan '76	536	7.90 ± 0.20	8.40 ± 0.50	6.20 ± 0.90
Feb '76	39	8.40 ± 0.20	10.10 ± 0.70	9.40 ± 0.40
Mar '76	9	9.10 ± 0.20	10.80 ± 0.70	11.20 ± 0.50

APPENDIX 19

The mean length (cm), weight (g) and gonadosomatic ratio (as a percentage of the body weight) of male sea snails, *Liparis liparis*, caught in the cooling water intake screens of Berkeley Power Station during 1974-76. Also included are the number investigated and ±95% confidence limit.

MONTH/YEAR	NO. ANALYSD	LENGTH	WEIGHT	GONADOSOMATIC RATIO (%)
Oct '74	39	6.00 ± 0.20	2.50 ± 0.40	0.10 ± 0.03
Nov '74	142	6.50 ± 0.20	4.40 ± 0.50	0.20 ± 0.01
Dec '74	254	7.00 ± 0.30	5.70 ± 0.50	0.40 ± 0.09
Jan '75	60	8.10 ± 0.20	8.70 ± 0.50	0.60 ± 0.20
Feb '75	1	8.50 -	9.00 -	1.20 -
Nov '75	9	6.20 ± 0.10	4.10 ± 0.30	0.10 ± 0.01
Dec '75	11	6.90 ± 0.30	5.40 ± 0.70	0.20 ± 0.02
Feb '76	1	7.30 -	6.40 -	0.30 -
Mar '76	1	8.40 -	7.70 -	Not Present

APPENDIX 20

The mean length (cm), weight (g) and gonadosomatic ratio (as a percentage of the body weight) of female sea snails, *Liparis liparis*, caught in the cooling water intake screens of Berkeley Power Station during 1974-76. Also included are the numbers investigated and ±95% confidence limit.

MONTH/YEAR	NO. ANALYSD	LENGTH	WEIGHT	GONADOSOMATIC RATIO (%)
Sept.'74	4	4.40 ± 0.20	1.50 ± 0.30	0.40 ± 0.04
Oct '74	43	6.50 ± 0.20	3.00 ± 0.70	0.60 ± 0.09
Nov '74	293	6.90 ± 0.40	4.90 ± 0.40	1.00 ± 0.20
Dec '74	356	7.20 ± 0.40	6.20 ± 0.40	2.60 ± 0.30
Jan '75	200	8.50 ± 0.20	9.80 ± 0.70	10.80 ± 0.40
Feb '75	1	8.20 -	8.30 -	13.50 -
Nov '75	20	6.40 ± 0.10	4.40 ± 0.20	0.60 ± 0.04
Dec '75	28	7.00 ± 0.20	5.70 ± 0.40	1.20 ± 0.05
Feb '76	5	8.30 ± 0.1	10.10 ± 0.3	11.70 ± 1.1
Mar '76	13	8.40 ± 0.30	10.90 ± 1.1	11.50 ± 1.1

APPENDIX 21

The mean length (cm), weight (g) and gonadosomatic ratio (as a percentage of the body weight) of male sea snail, *Liparis liparis*, caught in the cooling water intake screens of Hinkley Point Power Station during 1974-76. Also included are numbers investigated and ±95% confidence limit.

MONTH/YEAR	NO. ANALYSD	LENGTH	WEIGHT	GONADOSOMATIC RATIO (%)
Feb '74	2	7.40 -	4.60 -	1.00 -
Mar '74	10	7.70 ± 0.50	6.70 ± 0.70	1.90 ± 0.10
Nov '75	4	5.30 ± 0.20	2.00 ± 0.20	0.20 ± 0.00
Dec '75	7	6.70 ± 0.20	4.00 ± 0.60	0.40 ± 0.07
Feb '76	1	7.70 -	3.80 -	0.70 -

APPENDIX 22

The mean length (cm), weight (g) and gonadosomatic ratio (as a percentage of the body weight) of female sea snail, *Liparis liparis*, caught in the cooling water intake screens of Hinkley Point Power Station during 1974-76. Also included are numbers investigated and ±95% confidence limit.

MONTH/YEAR	NO. ANALYSD	LENGTH	WEIGHT	GONADOSOMATIC RATIO (%)
Feb '74	20	8.10 ± 0.40	8.50 ± 1.30	9.30 ± 1.20
Mar '74	25	8.00 ± 0.10	6.90 ± 0.20	11.10 ± 0.30
Apr '74	10	8.40 ± 0.20	5.80 ± 0.20	12.90 ± 0.99
May '74	2	7.80 -	7.60 -	7.40 -
Nov '75	4	6.00 ± 0.20	2.80 ± 0.30	1.10 ± 0.06
Dec '75	20	7.20 ± 0.20	5.50 ± 0.30	1.80 ± 0.10
Feb '76	32	7.70 ± 0.10	6.10 ± 0.30	8.80 ± 0.40
Mar '76	15	8.10 ± 0.20	8.00 ± 0.20	9.70 ± 0.90

APPENDIX 23

The mean length (cm), weight (g) and gonadosomatic ratio (as a percentage of the body weight) of female sea snail, *Liparis liparis*, caught in the cooling water intake screens of Uskmouth Power Station during 1975-76. Also included are the numbers investigated and ±95% confidence limit.

MONTH/YEAR	NO. ANALYSD	LENGTH	WEIGHT	GONADOSOMATIC RATIO (%)
Jan '76	2	9.30 -	11.40 -	6.90 -
Feb '76	10	7.80 ± 0.20	8.40 ± 0.80	8.10 ± 0.70
Mar '76	2	8.20 -	8.10 -	8.30 -

APPENDIX 24

Mean concentration of zinc in 0+ year class flounders, *Platichthys flesus*, caught in a 24 h sampling period in the cooling water intake screens of Oldbury Power Station during 1974-76, expressed as ppm. Also included are the number of individual analyses and ± S.E.

MONTH	1974 / 1975	1975 / 1976
June	191.70 ± 34.60 (20)	159.40 ± 1.00 (20)
July	170.40 ± 17.80 (20)	126.60 ± 2.10 (20)
August	259.00 ± 6.70 (20)	201.10 ± 2.40 (20)
September	177.50 ± 6.80 (20)	180.10 ± 3.10 (20)
October	208.50 ± 27.70 (20)	228.50 ± 2.00 (20)
November	180.20 ± 19.50 (20)	200.00 ± 1.90 (5)
December	200.00 ± 17.00 (20)	199.00 ± 2.80 (5)
January	200.00 ± 21.70 (20)	190.20 ± 5.10 (10)
February	208.30 ± 1.10 (20)	186.80 ± 2.40 (5)
March	191.20 ± 6.00 (20)	233.60 ±28.50 (10)
April	197.40 ± 5.80 (20)	171.10 ± 4.90 (10)
May	197.40 ± 2.10 (20)	168.60 ±12.10 (10)
June	159.40 ± 1.00 (20)	198.90 ±17.70 (4)

APPENDIX 25

Mean concentration of lead in 0+ year class flounders, *Platichthys flesus*, caught in a 24 h sampling period in the cooling water intake screens of Oldbury Power Station during 1974-76, expressed as ppm. Also included are the number of individual analyses and ± S.E.

MONTH	1974 / 1975	1975 / 1976
June	7.00 ± 0.70 (20)	10.00 ± 0.90 (20)
July	9.00 ± 1.50 (20)	15.00 ± 1.00 (20)
August	9.20 ± 1.00 (20)	20.00 ± 2.40 (20)
September	10.20 ± 2.10 (20)	11.70 ± 0.89 (20)
October	13.40 ± 4.10 (20)	14.70 ± 0.80 (20)
November	17.80 ± 1.10 (20)	14.70 ± 0.80 (5)
December	19.50 ± 2.100 (20)	16.10 ± 1.00 (5)
January	21.00 ± 4.80 (20)	18.30 ± 0.40 (10)
February	20.00 ± 0.20 (20)	19.40 ± 4.90 (5)
March	20.90 ± 0.90 (20)	26.50 ± 2.50 (10)
April	16.70 ± 1.10 (20)	16.00 ± 2.20 (10)
May	25.00 ± 2.00 (20)	10.50 ± 0.30 (10)
June	10.00 ± 0.90 (20)	10.00 ± 1.00 (4)

APPENDIX 26

Mean concentrations of cadmium in 0+ year class flounders, *Platichthys flesus*, caught in a 24 h sampling period in the cooling water intake screens of Oldbury Power Station during 1974-76, expressed as ppm. Also included are the number of individual analyses and ± S.E.

MONTH	1974 / 1975	1975 / 1976
June	Undetectable	0.40 ± 0.10 (20)
July	Undetectable	1.00 ± 0.10 (20)
August	2.40 ± 0.50 (20)	1.90 ± 0.10 (20)
September	2.70 ± 0.40 (20)	2.00 ± 0.00 (20)
October	4.20 ± 1.00 (20)	2.00 ± 0.00 (20)
November	4.30 ± 0.60 (20)	2.00 ± 0.00 (5)
December	4.50 ± 0.70 (20)	1.90 ± 0.00 (5)
January	2.30 ± 0.60 (20)	1.90 ± 0.00 (10)
February	1.70 ± 0.00 (20)	1.80 ± 0.00 (5)
March	2.50 ± 0.20 (20)	2.60 ± 0.20 (10)
April	2.00 ± 1.00 (20)	0.40 ± 0.00 (10)
May	2.70 ± 1.00 (20)	0.40 ± 0.00 (10)
June	0.40 ± 0.10 (20)	0.40 ± 0.00 (4)

APPENDIX 27

Mean concentration of zinc in 1+ year class flounders, *Platichthys flesus*, caught in a 24 h sampling period in the cooling water intake screens of Oldbury Power Station during 1974-76, expressed as ppm. Also included are the number of individual analyses and ± S.E.

MONTH	1974 / 1975	1975 / 1976
June	144.10 ± 0.30 (20)	142.90 ± 0.90 (10)
July	146.30 ± 3.20 (20)	116.90 ± 1.50 (10)
August	150.30 ± 2.20 (10)	171.80 ± 2.90 (10)
September	155.00 ± 1.70 (10)	162.80 ± 1.80 (10)
October	160.50 ± 3.00 (10)	175.30 ± 2.00 (10)
November	116.10 ± 3.60 (10)	150.00 ± 6.90 (10)
December	140.00 ± 4.50 (10)	138.00 ± 4.90 (5)
January	132.40 ± 8.10 (10)	140.50 ± 2.10 (10)
February	201.20 ± 2.90 (10)	163.10 ± 4.00 (5)
March	164.40 ± 2.50 (10)	109.40 ± 5.00 (10)
April	170.80 ± 6.10 (10)	145.20 ± 8.40 (10)
May	179.80 ± 1.80 (10)	125.30 ± 8.00 (10)
June	142.90 ± 0.90 (10)	140.90 ± 20.80 (10)

APPENDIX 28

Mean concentration of lead in 1+ year class flounders, *Platichthys flesus*, caught in a 24 h sampling period in the cooling water intake screens of Oldbury Power Station during 1974-76, expressed as ppm. Also included are the number of individual analyses and ± S.E.

MONTH	1974 / 1975	1975 / 1976
June	9.00 ± 0.70 (20)	20.50 ± 0.70 (10)
July	9.80 ± 0.70 (10)	21.30 ± 1.10 (10)
August	10.10 ± 0.70 (10)	25.90 ± 1.70 (10)
September	11.80 ± 0.90 (10)	12.90 ± 0.00 (10)
October	14.00 ± 0.40 (10)	18.30 ± 1.70 (10)
November	13.50 ± 1.10 (10)	12.30 ± 0.10 (5)
December	19.00 ± 0.90 (10)	16.30 ± 0.70 (5)
January	13.40 ± 1.70 (10)	15.20 ± 0.90 (10)
February	20.00 ± 0.10 (10)	16.10 ± 0.80 (5)
March	20.00 ± 0.70 (10)	17.60 ± 0.80 (10)
April	19.10 ± 0.80 (10)	21.10 ± 1.00 (10)
May	16.60 ± 0.70 (10)	13.10 ± 0.70 (10)
June	20.50 ± 0.70 (10)	10.00 ± 0.90 (10)

APPENDIX 29

Mean concentration of cadmium in 1+ year class flounders, *Platichthys flesus*, caught in a 24 h sampling period in the cooling water intake screens of Oldbury Power Station during 1974-76, expressed as ppm. Also included are the number of individual analyses and ± S.E.

MONTH	1974 / 1975	1975 / 1976
June	2.50 ± 0.20 (20)	2.40 ± 0.50 (10)
July	2.80 ± 0.10 (10)	2.50 ± 0.10 (10)
August	3.50 ± 0.20 (10)	2.70 ± 0.00 (10)
September	3.70 ± 0.10 (10)	3.30 ± 0.00 (10)
October	3.30 ± 0.10 (10)	2.40 ± 0.10 (10)
November	3.70 ± 0.00 (10)	2.40 ± 0.00 (5)
December	3.10 ± 0.10 (10)	2.40 ± 0.00 (5)
January	2.90 ± 0.10 (10)	2.40 ± 0.00 (10)
February	3.00 ± 0.00 (10)	2.70 ± 0.00 (5)
March	1.50 ± 0.20 (10)	2.50 ± 0.00 (10)
April	2.60 ± 0.00 (10)	1.90 ± 0.10 (10)
May	2.90 ± 0.10 (10)	1.30 ± 0.10 (10)
June	2.40 ± 0.50 (10)	2.50 ± 0.00 (10)

APPENDIX 30

Mean concentration of zinc in 2+ year class flounders, *Platichthys flesus*, caught in a 24 h sampling period in the cooling water intake screens of Oldbury Power Station during 1974-76, expressed as ppm. Also included are the number of individual analyses and ± S.E.

MONTH	1974 / 1975	1975 / 1976
June	133.70 ± 3.20 (10)	120.30 ± 1.00 (10)
July	138.70 ± 6.00 (5)	Not Present
August	140.10 ± 3.10 (10)	140.00 (2)
September	145.50 ± 1.10 (10)	159.10 ± 2.10 (10)
October	152.30 ± 1.70 (10)	150.20 ± 1.80 (10)
November	154.10 ± 3.20 (10)	130.00 ± 2.60 (5)
December	99.20 ± 1.80 (10)	120.00 ± 1.80 (5)
January	130.60 ± 3.90 (10)	109.00 ± 1.80 (5)
February	185.50 ± 2.10 (10)	99.00 ± 9.00 (5)
March	212.40 ± 3.10 (10)	115.00 ± 1.50 (10)
April	185.50 ± 3.90 (10)	125.50 ± 6.10 (10)
May	131.60 ± 3.20 (10)	130.00 ± 5.10 (5)
June	120.30 ± 1.00 (10)	135.70 ± 7.90 (10)

APPENDIX 31

Mean concentration of lead in 2+ year class flounders, *Platichthys flesus*, caught in a 24 h sampling period in the cooling water intake screens of Oldbury Power Station during 1974-76, expressed as ppm. Also included are the number of individual analyses and ± S.E.

MONTH	1974 / 1975	1975 / 1976
June	14.00 ± 1.00 (10)	32.50 ± 2.00 (10)
July	15.10 ± 0.30 (5)	Not Present
August	17.30 ± 0.90 (10)	28.70 (2)
September	18.00 ± 1.20 (10)	18.30 ± 0.80 (10)
October	16.60 ± 0.10 (10)	15.00 ± 0.00 (10)
November	22.80 ± 1.10 (10)	16.80 ± 0.70 (5)
December	20.00 ± 1.10 (10)	17.80 ± 0.10 (5)
January	15.90 ± 0.80 (10)	17.80 ± 2.00 (5)
February	20.00 ± 0.00 (10)	20.30 ± 3.10 (5)
March	25.00 ± 1.00 (10)	20.10 ± 1.20 (10)
April	20.80 ± 0.20 (10)	20.20 ± 0.00 (10)
May	20.80 ± 0.80 (10)	16.20 ± 0.90 (5)
June	32.50 ± 2.00 (10)	16.80 ± 0.90 (10)

APPENDIX 32

Mean concentration of cadmium in 2+ year class flounders, *Platichthys flesus*, caught in a 24 h sampling period in the cooling water intake screens of Oldbury Power Station during 1974-76, expressed as ppm. Also included are the number of individual analyses and ± S.E.

MONTH	1974 / 1975	1975 / 1976
June	2.70 ± 0.30 (10)	3.00 ± 0.20 (10)
July	3.10 ± 0.10 (5)	Not Present
August	3.70 ± 0.10 (10)	3.20 (2)
September	3.80 ± 0.30 (10)	3.50 ± 0.70 (10)
October	5.10 ± 0.70 (10)	2.30 ± 0.10 (10)
November	3.60 ± 0.10 (10)	2.50 ± 0.10 (5)
December	3.60 ± 0.10 (10)	3.10 ± 0.20 (5)
January	2.70 ± 0.30 (10)	3.00 ± 0.00 (5)
February	3.20 ± 0.00 (10)	3.30 ± 0.60 (5)
March	2.00 ± 0.30 (10)	2.70 ± 0.10 (10)
April	3.20 ± 0.00 (10)	2.10 ± 0.00 (10)
May	3.00 ± 0.00 (10)	1.300± 0.00 (5)
June	3.00 ± 0.20 (10)	3.00 ± 0.20 (10)

APPENDIX 33

Mean concentration of zinc in 3+ year class flounders, *Platichthys flesus*, caught in a 24 h sampling period in the cooling water intake screens of Oldbury Power Station during 1974-76, expressed as ppm. Also included are the number of individual analyses and ± S.E.

MONTH	1974 / 1975	1975 / 1976
June	125.50 ± 3.70 (5)	Not Present
July	138.10 ± 1.80 (5)	Not Present
August	143.30 ± 2.70 (3)	139.30 (1)
September	150.10 ± 1.70 (4)	130.30 ± 1.10 (5)
October	Not Present	76.70 (2)
November	112.50 ± 0.70 (8)	112.00 ± 0.90 (5)
December	Not Present	110.00 ± 2.10 (5)
January	102.90 ± 2.90 (3)	Not Present
February	174.50 ± 1.80 (3)	87.10 ± 1.60 (5)
March	157.10 ± 2.90 (5)	129.60 ± 1.50 (5)
April	159.60 ± 4.10 (5)	134.90 ±10.20 (5)
May	171.10 ± 2.00 (5)	75.30 ± 2.90 (5)
June	Not Detectable	99.30 ± 9.80 (5)

APPENDIX 34

Mean concentration of lead in 3+ year class flounders, *Platichthys flesus*, caught in a 24 h sampling period in the cooling water intake screens of Oldbury Power Station during 1974-76, expressed as ppm. Also included are the number of individual analyses and ± S.E.

MONTH	1974 / 1975	1975 / 1976
June	17.00 ± 1.50 (5)	Not Present
July	18.50 ± 0.40 (5)	Not Present
August	19.30 ± 0.20 (3)	28.00 (1)
September	20.10 ± 1.80 (4)	22.10 ± 0.10 (5)
October	Not Present	32.10 (2)
November	22.90 ± 1.20 (8)	18.10 ± 0.10 (5)
December	Not Present	19.10 ± 0.70 (5)
January	16.10 ± 0.80 (2)	Not Present
February	25.00 ± 0.30 (3)	23.00 ± 1.30 (5)
March	23.00 ± 0.20 (5)	23.10 ± 0.80 (5)
April	22.80 ± 1.20 (5)	24.10 ± 0.90 (5)
May	25.00 ± 0.30 (5)	17.20 ± 0.20 (5)
June	Not Present	20.00 ± 1.70 (5)

APPENDIX 35

Mean concentration of cadmium in 3+ year class flounders, *Platichthys flesus*, caught in a 24 h sampling period in the cooling water intake screens of Oldbury Power Station during 1974-76, expressed as ppm. Also included are the number of individual analyses and ± S.E.

MONTH	1974 / 1975	1975 / 1976
June	4.20 ± 0.10 (5)	Not Present
July	3.50 ± 0.20 (5)	Not Present
August	4.00 ± 0.30 (3)	3.90 (1)
September	4.30 ± 0.10 (4)	3.90 ± 0.20 (5)
October	Not Present	3.40 (2)
November	3.70 ± 0.30 (8)	3.50 ± 0.30 (5)
December	Not Present	3.50 ± 0.00 (5)
January	2.40 ± 0.20 (3)	Not Present
February	3.50 ± 0.00 (3)	3.60 ± 0.10 (5)
March	4.00 ± 0.20 (5)	3.00 ± 0.00 (5)
April	3.50 ± 0.00 (5)	3.10 ± 0.00 (5)
May	3.20 ± 0.00 (5)	1.90 ± 0.00 (5)
June	Not Present	3.50 ± 0.20 (5)

APPENDIX 36

Mean concentration of zinc in 4+ year class flounders, *Platichthys flesus*, caught in a 24 h sampling period in the cooling water intake screens of Oldbury Power Station during 1974-76, expressed as ppm. Also included are the number of individual analyses and ± S.E.

MONTH	1974 / 1975	1975 / 1976
June	168.90 ± 5.00 (5)	Not Present
July	Not Present	Not Present
August	Not Present	140.10 (2)
September	Not Present	150.00 ± 1.70 (5)
October	181.20 (2)	Not Present
November	146.00 ± 2.90 (5)	114.00 (2)
December	Not Present	100.00 (2)
January	Not Present	90.00 (2)
February	98.30 (2)	Not Present
March	150.80 (2)	134.70 ± 8.50 (5)
April	97.70 ± 3.90 (5)	200.00 ± 7.20 (4)
May	100.90 (2)	118.60 ± 1.60 (5)
June	Not Present	120.00 (2)

APPENDIX 37

Mean concentration of lead in 4+ year class flounders, *Platichthys flesus*, caught in a 24 h sampling period in the cooling water intake screens of Oldbury Power Station during 1974-76, expressed as ppm. Also included are the number of individual analyses and ± S.E.

MONTH	1974 / 1975	1975 / 1976
June	21.00 ± 0.20 (5)	Not Present
July	Not Present	Not Present
August	Not Present	30.30 (2)
September	Not Present	26.60 ± 0.00 (5)
October	24.60 (2)	Not Present
November	22.90 ± 2.50 (5)	22.30 (2)
December	Not Present	21.50 (2)
January	Not Present	24.00 (2)
February	27.00 (2)	Not Present
March	25.00 (2)	24.60 ± 0.00 (5)
April	25.00 (5)	27.90 ± 2.30 (4)
May	29.20 (2)	21.20 ± 1.10 (5)
June	Not Present	21.90 (2)

APPENDIX 38

Mean concentration of cadmium in 4+ year class flounders, *Platichthys flesus*, caught in a 24 h sampling period in the cooling water intake screens of Oldbury Power Station during 1974-76, expressed as ppm. Also included are the number of individual analyses and ± S.E.

MONTH	1974 / 1975	1975 / 1976
June	4.40 ± 0.00 (5)	Not Present
July	Not Present	Not Present
August	Not Present	4.30 (2)
September	Not Present	4.40 ± 0.10 (5)
October	6.40 (2)	Not Present
November	5.00 ± 0.90 (5)	4.40 (2)
December	Not Present	4.60 (2)
January	Not Present	3.80 (2)
February	3.80 (2)	Not Present
March	4.20 (2)	3.70 ± 0.00 (5)
April	3.80 ± 0.00 (5)	4.00 ± 0.10 (4)
May	4.00 (2)	3.00 ± 0.10 (5)
June	Not Present	3.50 (2)

APPENDIX 39

Mean concentration of zinc in 5+ year class flounders, *Platichthys flesus*, caught in a 24 h sampling period in the cooling water intake screens of Oldbury Power Station during 1974-76, expressed as ppm. Also included are the number of individual analyses and ± S.E.

MONTH	1974 / 1975	1975 / 1976
June	163.50 ± 3.10 (5)	Not Present
July	Not Present	Not Present
August	Not Present	147.90 (2)
September	Not Present	178.00 ± 1.20 (5)
October	Not Present	Not Present
November	Not Present	109.00 (2)
December	Not Present	90.80 (2)
January	87.70 (2)	80.90 ± 2.10 (5)
February	97.10 (2)	Not Present
March	204.40 (4)	Not Present
April	Not Present	143.30 ± 10.30 (5)
May	67.50 (2)	Not Present
June	Not Present	Not Present

APPENDIX 40

Mean concentration of lead in 5+ year class flounders, *Platichthys flesus*, caught in a 24 h sampling period in the cooling water intake screens of Oldbury Power Station during 1974-76, expressed as ppm. Also included are the number of individual analyses and ± S.E.

MONTH	1974 / 1975	1975 / 1976
June	23.00 ± 0.50 (5)	Not Present
July	Not Present	Not Present
August	Not Present	32.00 (2)
September	Not Present	30.00 ± 0.00 (5)
October	Not Present	Not Present
November	Not Present	27.00 (2)
December	Not Present	24.00 (2)
January	28.00 (2)	29.00 ± 1.80 (5)
February	97.10 (2)	Not Present
March	30.00 (2)	Not Present
April	Not Present	27.50 ± 1.40 (5)
May	30.00 (2)	Not Present
June	Not Present	Not Present

APPENDIX 41

Mean concentration of cadmium in 5+ year class flounders, *Platichthys flesus*, caught in a 24 h sampling period in the cooling water intake screens of Oldbury Power Station during 1974-76, expressed as ppm. Also included are the number of individual analyses and ± S.E.

MONTH	1974 / 1975	1975 / 1976
June	5.50 ±0.10 (5)	Not Present
July	Not Present	Not Present
August	Not Present	5.80 (2)
September	Not Present	5.00 ± 0.00 (5)
October	Not Present	Not Present
November	Not Present	4.80 (2)
December	Not Present	5.00 (2)
January	3.10 (2)	4.70 ± 0.20 (5)
February	4.00 (2)	Not Present
March	4.80 (2)	Not Present
April	Not Present	4.90 ± 0.10 (5)
May	5.40 (2)	Not Present
June	Not Present	Not Present

APPENDIX 42

Mean concentration of zinc, lead and cadmium in various age group flounders, *Platichthys flesus*, obtained in the summers of 1973 and 1974 at Barnstaple Bay, expressed as ppm. Also included are the numbers analysed and ± S.E.

AGE	ZINC	LEAD	CADMIUM
1973			
2+	224.5 ± 2.8 (20)	14.1 ± 1.2 (20)	1.1 ± 0.3 (20)
3+	209.4 ± 1.6 (20)	16.0 ± 1.2 (20)	1.4 ± 0.5 (20)
4+	162.4 ± 5.5 (20)	18.0 ± 0.7 (20)	1.6 ± 0.3 (20)
5+	195.2 ± 5.6 (20)	19.1 ± 1.2 (20)	1.7 ± 0.3 (20)
7+	178.1 ± 1.6 (20)	24.1 ± 0.4 (20)	1.7 ± 0.3 (20)
1974			
2+	280.0 ± 3.1 (20)	13.9 ± 1.0 (20)	1.0 ± 0.1 (20)
3+	240.1 ± 2.8 (20)	16.0 ± 0.7 (20)	1.3 ± 0.4 (20)
4+	200.0 ± 2.3 (20)	13.1 ± 0.9 (20)	1.4 ± 0.1 (20)
5+	190.3 ± 1.8 (20)	20.0 ± 0.0 (20)	1.8 ± 0.3 (20)
7+	168.9 ± 2.7 (20)	27.8 ± 2.6 (20)	1.8 ± 0.0 (20)

APPENDIX 43

Mean concentrations of zinc, lead and cadmium in sea snails, *Liparis liparis*, caught in the cooling water intake screens of Oldbury Power Station during 1973-76, expressed as ppm. Also included are the number of individual analyses and ± S.E.

METAL	MONTH	1973 / 1974	1974 / 1975	1975 / 1976
ZINC	Sep	Not Present	130.50 (2)	Not Present
	Oct	126.20 (2)	135.80 (2)	Not Present
	Nov	143.00 ± 6.90 (10)	150.00 ± 4.80 (10)	109.50 ± 5.30 (10)
	Dec	148.40 ± 8.70 (10)	143.30 ± 3.90 (10)	83.60 ± 2.6 (10)
	Jan	115.10 ± 0.60 (10)	143.10 ± 3.70 (10)	95.6 ± 4.2 (10)
	Feb	114.20 (2)	139.50 (2)	101.40 8.1 (10)
	Mar	Not Present	130.70 (2)	Not Present
LEAD	Sep	Not Present	29.70 (2)	Not Present
	Oct	24.00 (2)	26.5 (2)	Not Present
	Nov	26.60 ± 0.7 (10)	25.2 ± 1.5 (10)	18.3 ± 1.3 (10)
	Dec	27.1 ± 0.6 (10)	26.9 ± 1.8 (10)	22.00 ± 1.3 (10)
	Jan	28.5 ± 0.3 (10)	28.7 ± 0.7 (10)	19.8 ± 2.2 (10)
	Feb	30.1 (2)	31.0 (2)	18.5 1.9 (10)
	Mar	Not Present	31.8 (2)	Not Present
CADMIUM	Sep	Not Present	2.5 (2)	Not Present
	Oct	4.60 (2)	5.1 (2)	Not Present
	Nov	6.0 ± 0.4 (10)	6.3 ± 0.3 (10)	5.1 ± 0.4 (10)
	Dec	8.4 ± 0.9 (10)	7.0 ± 1.0 (10)	6.6 ± 0.7 (10)
	Jan	9.6 ± 0.3 (10)	7.2 ± 0.4 (10)	4.4 ± 0.3 (10)
	Feb	10.4 (2)	7.70 (2)	4.0 0.1 (10)
	Mar	Not Present	8.9 (2)	Not Present

APPENDIX 44

Mean concentrations of zinc, lead and cadmium in sea snails, *Liparis liparis*, caught in the cooling water intake screens of Berkeley Power Station during 1974-76, expressed as ppm. Also included are the number of individual analyses and ± S.E.

METAL	MONTH	1974 / 1975	1975 / 1976
ZINC	Oct	137.0 (2)	Not Present
	Nov	150.5 ± 2.9 (10)	97.8 ± 6.9 (10)
	Dec	195.2 ± 8.9 (10)	80.2 ± 3.0 (10)
	Jan	170.2 ± 6.3 (10)	Not Present
	Feb	Not Present	95.7 ± 9.9 (10)
LEAD	Oct	24.5 (2)	Not Present
	Nov	26.0 ± 1.8 (10)	16.8 ± 1.5 (10)
	Dec	28.2 ± 1.2 (10)	20.2 ± 1.0 (10)
	Jan	30.7 ± 1.9 (10)	Not Present
	Feb	Not Present	16.7 ± 0.6 (10)
CADMIUM	Oct	4.6 (2)	Not Present
	Nov	6.0 ± 0.1 (10)	4.6 ± 0.2 (10)
	Dec	6.9 ± 0.1 (10)	5.2 ± 0.1 (10)
	Jan	7.1 ± 0.2 (10)	Not Present
	Feb	Not Present	3.1 ± 0.2 (10)

APPENDIX 45

Mean concentrations of zinc, lead and cadmium in sea snails, *Liparis liparis*, caught in the cooling water intake screens of Hinkley Point Power Station during 1975-76, expressed as ppm. Also included are the number of individual analyses and ± S.E.

MONTH/YEAR	NO. ANALYSD	ZINC	LEAD	CADMIUM
Sep '75	10	120.50 ± 5.50	12.40 ± 0.30	2.40 ± 0.07
Nov '75	10	107.10 ± 5.10	13.60 ± 0.20	4.40 ± 0.50
Dec '75	10	102.10 ± 9.10	17.90 ± 2.00	3.30 ± 0.40
Feb '76	10	94.30 ± 2.20	15.50 ± 0.60	2.60 ± 0.10
Mar '76	10	159.70 ±15.20	14.40 ± 2.00	4.00 ± 0.30

APPENDIX 46

Mean concentrations of zinc, lead and cadmium in Five Bearded Rocklings, *Ciliata mustela*, obtained in the cooling water intake screens of Oldbury Power Station during 1974-76, expressed as ppm. Also included are the number of individual analyses and ± S.E.

METAL	MONTH	1974 / 1975	1975 / 1976
ZINC	Sep	60.8 ± 4.0 (4)	Not Present
	Oct	80.8 ± 2.8 (5)	56.6 ± 1.1 (3)
	Nov	80.5 ± 2.8 (5)	57.1 ± 4.7 (9)
	Dec	90.5 (1)	61.1 ± 2.8 (6)
	Jan	98.1 ± 4.0 (3)	60.0 ± 3.8 (10)
LEAD	Sep	8.1 ± 1.2 (4)	Not Present
	Oct	12.8 ± 0.8 (5)	22.0 ± 0.4 (3)
	Nov	14.9 ± 0.7 (5)	16.9 ± 0.4 (9)
	Dec	20.1 (1)	18.8 ± 0.3 (6)
	Jan	24.5 ± 1.0 (3)	19.0 (10)
CADMIUM	Sep	3.1 ± 0.8 (4)	Not Present
	Oct	3.4 ± 0.8 (5)	2.1 ± 0.3 (3)
	Nov	3.6 ± 0.6 (5)	3.0 ± 0.6 (9)
	Dec	3.8 (1)	3.4 ± 0.1 (6)
	Jan	4.2 ± 0.1 (3)	2.1 ± 0.1 (10)

APPENDIX 47

Mean concentrations of zinc, lead and cadmium in Five Bearded Rocklings, *Ciliata mustela*, obtained in the cooling water intake screens of Berkeley Power Station during 1974-76, expressed as ppm. Also included are the number of individual analyses and ± S.E.

METAL	MONTH	1974 / 1975		1975 / 1976	
ZINC	Sep	68.8 ± 4.5	(5)	Not Present	
	Oct	88.8 ± 3.1	(5)	53.5 ± 4.9	(4)
	Nov	99.0	(2)	59.1 ± 2.2	(9)
	Dec	Not Present		66.1 ± 4.0	(5)
	Jan	108.9	(1)	58.1 ± 3.2	(9)
LEAD	Sep	8.8 ± 1.4	(5)	Not Present	
	Oct	13.8 ± 1.1	(5)	19.6 ± 1.1	(4)
	Nov	15.0	(2)	24.3 ± 0.1	(9)
	Dec	Not Present		26.8 ± 0.1	(5)
	Jan	25.8	(1)	16.2 ± 0.7	(9)
CADMIUM	Sep	2.9 ± 0.8	(5)	Not Present	
	Oct	3.2	(5)	2.5	(4)
	Nov	3.5	(2)	3.5	(9)
	Dec	Not Present		3.9 ± 0.1	(5)
	Jan	2.0	(1)	2.0 ± 0.1	(9)

APPENDIX 48

Mean concentrations of zinc, lead and cadmium in Five Bearded Rockling, *Ciliata mustela*, obtained from the fish weir at Minehead during 1975-76 expressed as ppm. Also included are the number of individual analyses and ± S.E.

MONTH/YEAR	NO. ANALYSD	ZINC	LEAD	CADMIUM
Aug '75	10	45.0 ± 2.7	12.0 ± 1.0	1.8 ± 0.0
Sept '75	10	50.0 ± 4.7	13.0 ± 0.0	1.8 ± 0.0
Oct '75	10	57.0 ± 1.2	13.9 ± 0.0	1.8 ± 0.4
Nov '75	10	55.4 ± 2.6	18.6 ± 0.0	1.5 ± 0.0
Dec '75	10	62.8 ± 1.9	16.3 ± 0.0	2.2 ± 0.2
Jan '76	5	66.8 ± 5.0	13.1 ± 1.4	1.7 ± 0.1
Feb '76	10	83.4 ± 9.0	13.2 ± 1.8	1.4 ± 0.1
Mar '76	10	68.5 ± 3.6	12.7 ± 0.5	1.4 ± 0.1
Apr '76	10	91.0 ± 6.9	18.3 ± 2.4	2.1 ± 0.3
May '76	11	81.7 ± 2.4	11.5 ± 0.4	1.8 ± 0.1
June '76	11	75.3 ± 1.8	11.9 ± 0.9	1.8 ± 0.3
July '76	11	65.1 ± 1.2	10.9 ± 0.8	1.8 ± 0.1
Aug '76	11	50.0 ± 3.0	12.5 ± 1.2	1.8 ± 0.3

APPENDIX 49

Mean concentrations of zinc, lead and cadmium in Five Bearded Rockling, *Ciliata mustela*, obtained from the cooling water intake screens of Hinkley Point Power Station during 1975-76, expressed as ppm. Also included are the number of individual analyses and ± S.E.

MONTH/YEAR	NO. ANALYSD	ZINC	LEAD	CADMIUM
Oct '75	10	36.5 ± 0.9	11.9 ± 0.5	1.3 ± 0.2
Nov '75	10	55.1 ± 0.6	17.9 ± 0.0	1.6 ± 0.0
Dec '75	6	58.1 ± 2.4	19.7 ± 1.9	1.2 ± 0.0
Jan '76	5	81.1 ± 1.3	16.2 ± 0.8	2.1 ± 0.3
Feb '76	5	53.7 ± 5.2	11.7 ± 0.3	1.4 ± 0.1
Mar '76	5	69.0 ± 5.9	18.8 ± 1.0	1.8 ± 0.1

APPENDIX 50

Mean concentrations of zinc, lead and cadmium in Five Bearded Rockling, *Ciliata mustela*, obtained from the cooling water intake screens of Uskmouth Power Station during 1975-76, expressed as ppm. Also included are the number of individual analyses and ± S.E.

MONTH/YEAR	NO. ANALYSD	ZINC	LEAD	CADMIUM
Oct '75	2	71.3 -	19.0 -	2.1 -
Nov '75	2	70.2 -	23.0 -	3.0 -
Dec '75	4	74.2 ± 2.8	25.8 ± 1.0	3.3 ± 0.3
Jan '76	2	80.0 -	15.8 -	2.0 -

APPENDIX 51

Distribution (as percentage) of zinc, lead and cadmium in Five Bearded Rockling, *Ciliata mustela*, during 1975-76 from the various sites.

LOCALITY	ZINC	LEAD	CADMIUM
Berkeley	18.9	22.5	22.6
Uskmouth	23.8	21.8	22.5
Oldbury	18.9	22.7	22.9
Hinkley	18.7	17.0	16.4
Minehead	19.5	16.0	15.6

APPENDIX 52

Concentrations of zinc, lead and cadmium (ppm) in 0+ and 1+ year class shrimps, *Crangon crangon* caught in the intake screens of Oldbury Power Station since 1972. Also included are the number of individual analyses and ± S.E.

AGE GROUP	MONTH /YEAR	NO. ANAL.	ZINC	LEAD	CADMIUM
0+	Dec '72	6	249.50 ± 11.00	23.60 ± 1.40	43.30 ± 1.30
	Dec '73	6	199.00 ± 9.80	35.50 ± 1.70	43.00 ± 1.50
	Dec '74	6	240.00 ± 20.90	36.90 ± 2.90	40.00 ± 3.90
	Dec '75	6	98.30 ± 5.70	38.10 ± 0.20	50.70 ± 2.30
1+	Dec '72	12	228.00 ± 7.80	34.00 ± 3.60	125.30 ± 3.50
	Dec '73	12	246.00 ± 10.10	42.70 ± 2.90	97.00 ± 1.10
	Dec '74	12	275.00 ± 21.10	45.00 ± 2.10	100.00 ± 6.10
	Dec '75	12	120.70 ± 5.40	54.30 ± 3.70	120.80 ± 11.90

APPENDIX 53

Concentrations of zinc, lead and cadmium (ppm) found in individual analyses of shrimp, *Crangon crangon* obtained from Oldbury, Hinkley Point and Minehead during 1975. Also included are the ± S.E.

MONTH/ YEAR	NO. ANAL.	ZINC	LEAD	CADMIUM
Dec '75	12	120.70 ± 5.40	45.30 ± 3.70	120.80 ± 11.90
Dec '75	6	68.50 ± 1.20	22.50 ± 1.40	12.40 ± 0.80
Dec '75	6	67.90 ± 1.40	23.00 ± 1.50	12.00 ± 0.50

APPENDIX 54

Concentrations of zinc, lead and cadmium (ppm) in 0+ year class shrimp, *Crangon crangon* caught in the cooling water intake screens of the Oldbury Nuclear Power Station in the middle reaches of the Severn Estuary between July 1975 and July 1976. Also included are the number of individual analyses and ± S.E.

MONTH/ YEAR	NO. ANAL.	ZINC	LEAD	CADMIUM
Jul '75	-	Not Present	Not Present	Not Present
Aug '75	2	96.00	43.10	16.00
Sep '75	2	131.60	62.10	20.40
Oct '75	2	98.40	36.00	25.40
Nov '75	-	Not Present	Not Present	Not Present
Dec '75	6	98.30 ± 5.70	38.10 ± 0.20	50.70 ± 2.30
Jan '76	6	105.90 ± 6.40	23.10 ± 6.40	42.90 ± 4.40
Feb '76	6	98.60 ± 5.90	24.90 ± 4.30	12.70 ± 0.20
Mar '76	6	96.00 ± 11.50	24.90 ± 4.30	13.20 ± 1.70
Apr '76	6	92.50 ± 6.00	19.00 ± 1.80	13.20 ± 1.70
May '76	-	Not Present	Not Present	Not Present
Jun '76	6	75.70 ± 1.40	15.70 ± 0.90	14.90 ± 1.20
Jul '76	-	Not Present	Not Present	Not Present

APPENDIX 55

Concentrations of zinc, lead and cadmium (ppm) in 1+ year class shrimp, *Crangon crangon* caught in the cooling water intake screens of the Oldbury Nuclear Power Station in the middle reaches of the Severn Estuary between July 1975 and July 1976. Also included are the number of individual analyses and ± S.E.

MONTH/ YEAR	NO. ANAL.	ZINC	LEAD	CADMIUM
Jul '75	12	101.40 ± 2.60	24.00 ± 0.40	22.50 ± 1.70
Aug '75	12	89.00 ± 6.20	24.80 ± 1.30	51.50 ± 4.60
Sep '75	12	83.20 ± 2.80	34.80 ± 0.90	72.00 ± 2.70
Oct '75	12	85.60 ± 1.20	41.90 ± 2.10	70.00 ± 3.80
Nov '75	12	88.50 ± 1.50	53.90 ± 0.80	97.90 ± 4.10
Dec '75	12	120.70 ± 5.40	45.30 ±11.90	120.80 ±11.90
Jan '76	12	108.90 ± 3.90	23.20 ± 0.60	77.00 ± 1.20
Feb '76	12	105.40 ± 5.40	21.70 ± 1.50	45.80 ± 1.20
Mar '76	12	134.50 ± 5.90	20.40 ± 1.10	36.60 ± 4.10
Apr '76	12	147.10 ± 2.20	20.40 ± 1.10	36.60 ± 4.10
May '76	12	120.40 ± 1.90	16.20 ± 1.10	15.40 ± 0.30
Jun '76	12	76.70 ± 2.10	16.70 ± 0.10	15.40 ± 0.30
Jul '76	12	100.00 ± 3.60	25.30 ± 1.00	20.90 ± 2.00

APPENDIX 56

Fluctuation in the means of zinc, lead and cadmium (ppm) in sand gobies, *Pomatoschistus minutus* caught in mid-winter, when they are present in large numbers in the middles reaches of the Severn Estuary at Oldbury Nuclear Power Station, between 1972-1976. Also included are the number of individual analyses and ± **S.E.**

YEAR	NO. ANAL.	ZINC	LEAD	CADMIUM
1972	20	75.60 ± 1.50	17.60 ± 1.50	3.20 ± 0.00
1973	20	178.30 ± 4.30	20.00 ± 0.90	2.10 ± 0.40
1974	20	150.00 ± 5.80	22.00 ± 1.30	2.80 ± 0.20
1975	20	77.00 ± 10.90	14.90 ± 2.80	1.00 ± 0.00
1976	20	148.90 ± 3.70	19.80 ± 0.90	2.00 ± 0.20