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# ANALYSIS OF THE WHITING STOMACHS COLLECTED IN THE NORTH SEA DURING THE 1991 ICES STOMACH SAMPLING PROJECT

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## SUMMARY

Approximately 39,000 whiting stomachs were sampled during the 1991 ICES stomach sampling project. Generally, the overall picture of the food of the whiting is similar to the results of the 1981 stomach sampling exercise. The diet included a variety of prey types ranging from slow moving benthic animals to fast swimming fish species. Fish and crustacea together accounted for at least 60% by weight of the stomach contents of all size classes. Each whiting size class exploited a range of prey sizes with bigger fish eating an increasing proportion of larger prey. With increase in size, the proportion of fish prey in the diet increased. A step-wise change in the size composition of the prey associated with the switch from crustacea to fish, occurred around the 250 mm size group. As in 1981, a number of commercially important fish species, including sandeels and Norway pout, were major components of the diet. Cephalopod molluscs and Annelids were locally and seasonally important. There was a marked seasonal difference in the proportion of stomachs classified as empty. These stomachs were encountered most frequently in Quarter 1 when the percentage of empty stomachs recorded was considerably higher than the equivalent figure for 1981. In spite of this increase in the proportion of non-feeding fish, the mean stomach content weight of a fish of given weight was greater than in 1981. The average stomach weight (S,g) was related to live weight (W,g) as follows:

$$S = 0.009 \times W^{1.158}$$

Although the number of stomachs recorded as regurgitated or empty was independent of predator size class, area and quarter, it appeared to vary according to which research vessel collected the samples.

# 1. INTRODUCTION

In the North Sea, there is considerable predator-prey interaction between the various fish species and there is a recognised need to use management strategies which take this into consideration. Species interactions can be incorporated into routine stock assessment using Multispecies Virtual Population Analysis (MSVPA). However, this method requires a reliable quantitative estimate of the predation rate of fish on other fish, which can only be obtained from the analysis of stomach contents data.

In 1981, a major stomach sampling programme was carried out in the North Sea under the auspices of ICES. The intention of this programme was to provide data for use in MSVPA (Daan, 1989). MSVPA revealed large scale interactions both between and within the major exploited species, and predation mortality on the younger age groups was much higher than had previously been assumed.

Since 1981, major changes have occurred in the species composition of the North Sea stocks and predictions of catch levels based on stomach content data obtained in the early 1980's now require considerable extrapolation. It has, therefore, become increasingly important to know exactly how predation patterns have changed and the subsequent effect on MSVPA. Consequently the Multispecies Assessment Working Group recommended to ICES "that a full-scale stomach sampling programme should be repeated in 1991 in order to extend the basis for multispecies assessment" (Anon, 1988) and a resolution to this effect was adopted by ICES during the 1989 council meeting.

This paper summarises the results of the analysis of the whiting stomachs collected in the North Sea as part of this re-assessment.

# 2. METHODS

## 2.1 Stomach Sampling

Whiting stomachs were collected at sea in accordance with the detailed guidelines outlined in the Manual for the ICES North Sea Stomach Sampling Project (Anon, 1991). Samples were stratified by area (ICES statistical rectangle), season (quarterly period) and by predator size class. The objective was to maintain sampling levels at or above those achieved in 1981, with a target of at least 10 stomachs per size class, haul and quarter from whiting larger than 15 cm and five stomachs from each of the smaller size classes.

At sea, after fish with everted stomachs had been discarded and thus excluded from the sampling procedure, stomachs were classified as follows:

1. Feeding (valid) - stomach containing food, no evidence of regurgitation.
2. Regurgitated - showing evidence that all or part of the stomach contents had been lost.
3. Empty.
4. Stomach containing nothing but indigestible skeletal remains.

The gall bladder technique described by (Robb, 1992) was used to differentiate between empty and regurgitated stomachs. The numbers of stomachs in each category were recorded and those assigned to categories 1, 3 and 4 were either fixed in a 4% buffered

solution of formaldehyde or blast frozen for subsequent examination in the laboratory. Regurgitated stomachs were not retained for analysis, but the numbers of stomachs in this condition were used to calculate the proportion of feeding fish in the sample and the average stomach contents weight (see 2.3).

## 2.2 Analysis of Stomach Contents

The stomachs in each sample were analysed on a pooled basis. Prey items were identified to the lowest taxon possible and their weights and numbers were recorded. Although, it was sometimes difficult to measure prey accurately it was usually possible to estimate the size group to which they belonged. The prey size classes used are detailed in the project manual (Anon, 1991).

In the case of very small prey items, such as Copepods, the numbers of prey in each size class were estimated by dividing the total weight of the prey in each group by a previously determined mean weight at size. Prey items were assigned to one of the following states of digestion:

State 0: Intact prey
State 1: Partially digested prey
State 2: Skeletal material

Unidentified prey were assigned to known prey categories in proportion to the relative abundance of the identified species in the stomach contents. An analogous method was used to distribute prey of unknown size between the appropriate individual size classes.

## 2.3 Data Processing

The data were entered and processed using software developed at Ijmuiden by Professor Niels Daan.

The methods used to calculate the mean stomach content weights for a fish, in a sample, or for larger areas, were similar to that used in 1981 except that whereas the within-rectangle survey catch rates of whiting (number per hour fishing) were used as weighting factors to compensate for local differences in predator abundance in 1981, the square roots of the catch rates were used in 1991, as advocated by Daan (1983). Thus the mean stomach content weight of a fish of a given size class was calculated as follows:

### 2.3.1 Mean weight within a sample (= haul), WS

$$WS = W/F \times (F+R) / (F+R+E) \qquad 1$$

where WS = mean weight of stomach contents, W = total weight of food in the "valid" stomachs, F = number of "valid" stomachs + stomachs containing skeletal remains, R = number of regurgitated stomachs, E = number of empty stomachs.

### 2.3.2 Mean weight within a statistical rectangle, WR

$$WR = 1/h \sum_{i=1}^{h} WS_1 \qquad 2$$

where WR = arithmetic mean of sample means within the rectangle, h = number of hauls within the rectangle.

### 2.3.3 Mean weight within an area, WA

Rectangle means within an area (Roundfish Reporting Area or the Total North Sea) are weighted by the square roots of the catch rates of the appropriate predator size class.

$$WA = \frac{\sum_{i=1}^{r} WRi * Ci}{\sum_{i=1}^{r} Ci} \qquad 3$$

where r = number of rectangles within an area, C = square root of the catch rate within rectangle.

In this paper, results are presented in terms of fish size. However, in order to satisfy the requirements of the current MSVPA model, results based on the sizes of the predators and their prey have to be transformed into arrays based on the ages of the predators and their commercially important fish prey (Hislop *et al.*, 1991). The information on age composition etc needed to convert size-based data to age-based data came from the demersal trawl surveys which were the source of the majority of the stomach samples. An age-based summary of the diet of whiting in the North Sea in 1991 is given in Anon (1993).

## 3. RESULTS

### 3.1 Sampling Intensity

Figure 2 shows the numbers of stomachs examined at sea in each quarter in each rectangle. Table 1 gives the numbers of stomachs in each size class sampled in each quarter.

Good coverage of the North Sea was achieved in all four quarters. The total number of stomachs examined (*ca* 39,000) was more than double that sampled during the 1981 project (Hislop *et al.*, 1991); only in the first quarter were fewer stomachs sampled. However, a large proportion of the fish examined in 1991 belonged to the 150-250 mm size classes; the number of large whiting (>39 cm) was less than half that examined in 1981. Since there was an increase in the number of hours fishing spent on sample collection in 1991, the decrease in the abundance of large fish in the samples probably reflects a real difference in the size composition of the population between the two years.

### 3.2 The Incidence of Empty Stomachs

Overall, less than 50% of the stomachs examined at sea were classified as containing food. A further 37% were regurgitated and 16% were empty (Table 2). The incidence of stomachs without food seemed to vary with predator size class, area and quarter (Table 3). Generally, with the exception of Quarter 1, there was a tendency for the percentage of empty stomachs to decrease with size. There was also an apparent trend for the percentage of empty stomachs to be greater in the southern North Sea.

All the research vessels involved in the sampling recorded a large percentage of empty stomachs in Quarter 1. At other times of year, although there was no consistent seasonal pattern, the percentages of stomachs assigned to the "empty" and "regurgitated" categories appeared to vary according to which vessel had collected the samples. Thus *Scotia*, *Cirolana* and *Dana* usually recorded higher numbers of regurgitated than empty stomachs, whereas the opposite is true of *Tridens* and *Johan Hjort* (Table 4).

### 3.3 Average Weight of Food in the Stomach

The mean weight of the stomach contents of a whiting of each size class in each quarter, averaged over the whole North Sea, is given in Table 5. Fish with empty stomachs have been included in the calculation. The table also gives the total (live) weight of a whiting in each size class, derived from the estimated mean lengths (survey data) and quarterly weight/length relationships (Coull *et al.*, 1989). The average weight of food in the stomach increased exponentially with predator weight (Fig. 3). The data were converted to logarithms and the method of least squares used to calculate the relationship between stomach weight S(g) and live weight of the predator W(g):

$$S = 0.009 \times W^{1.158} \qquad 4$$

The equivalent equation for 1981, taken from Hislop *et al.* (1991) is:

$$S = 0.009 \times W^{1.057} \qquad 5$$

The estimated mean weights of the stomach contents of whiting of given body weights, in 1981 and 1991 are given in Table 6. There were appreciable between year differences in the mean stomach content weights. However analysis of variance indicated that the underlying relationships were not significantly different.

### 3.4 The Diet of Whiting of Different Sizes

Figure 4 gives a broad overview of the composition of the diet of each size class of whiting in each quarter of 1991, averaged over the whole North Sea.

The diet consisted mainly of crustacea and fish. In general, there was a higher proportion of fish prey in the diet of bigger whiting, and a corresponding decrease in the proportion of crustacea. The two most important "minor" prey groups were cephalopod molluscs and (most noticeably in Quarter 2) annelids.

A considerable proportion of the prey eaten by whiting consisted of commercially important species of fish. The relative importance of the individual species varied seasonally (Fig. 5). Sandeels and Norway pout were significant components of the diet at all times but the former were more important in Quarter 2, whereas Norway pout were the dominant fish prey in Quarter 4. The proportion of sandeels eaten tended to decrease with predator size, whilst the proportion of Norway pout in the diet increased with size. Whiting were present in the diet throughout the year, albeit in rather small quantities. Haddock were only prominent in Quarters 3 and 4 when the majority of the fish eaten were 0-group stages. Sprats occurred in whiting of many size classes in all seasons whereas herring occurred mainly in the stomachs of larger whiting, and were most noticeable in Quarter 3.

The relative contributions of the different prey groups to the diet also varied between areas, within quarters (Fig. 6). Thus annelids tended to form a larger proportion of the diet in areas 5, 6 and 7 than elsewhere. In Quarter 1, molluscs were important components of the diet of whiting, but only in areas 1 and 2.

Grouping the prey by major taxa is convenient, but it hides an important feature of the data, which is that different species are eaten by whiting in different parts of the North Sea. For example, haddock occurred mainly in the more northern areas and sprat and herring in the south. Similarly, a large proportion of the crustaceans eaten in the southern North Sea were Crangonids, whereas Euphausiacea were predominant in the northern areas.

### 3.5 Size Composition of the Diet

The median, the minima and maxima of the distributions of all prey and fish prey found in the stomachs of whiting of each size class, in each quarter are shown in Figures 7 and 8. The data are plotted on a logarithmic scale.

Generally, each whiting size class exploits a range of prey sizes, but there is a trend for bigger fish to eat an increasing proportion of larger prey. Similarly, for the fish prey a range of sizes are eaten, with a gradual increase in prey size with predator size.

The stepwise change in the size composition of the diet associated with the switch from crustacea to fish prey is most pronounced within the 250 mm size group.

## 4. SUMMARY AND DISCUSSION

The overall picture of the food of whiting in the North Sea in 1991 that has emerged from the present investigation is very similar to the results of the 1981 stomach sampling project (Hislop *et al.*, 1991). The diet of whiting included a wide spectrum of prey types, ranging from sedentary benthic animals to fast, free-swimming fish species. Fish and crustacea together accounted for at least 60% of the weight of the stomach contents of all size classes. Cephalopod molluscs and annelids were locally and seasonally important constituents of the diet. With increase in size, the proportion of fish prey in the diet increased, whereas the proportion of crustacea decreased. As in 1981, sandeels and Norway pout were important components of the diet.

There was a marked seasonal difference in the proportions of the whiting stomachs classified as empty in 1991. Empty stomachs were encountered far more frequently in Quarter 1 than at other times of year. This was also the case for the cod, haddock, saithe and mackerel sampled in 1991 (Anon, 1993). The percentage of empty whiting stomachs encountered during the first Quarter of 1991 was considerably higher than the equivalent figure for 1981. In the second, third and fourth Quarters, however, the percentages were similar to or lower than those in the same periods in 1981.

A comparison of equations 4 and 5 reveals that in spite of the high proportion of apparently non-feeding whiting in the first Quarter of 1991, the mean weight of the stomach contents of a whiting of given weight was greater than in 1981, when averaged over the whole year.

The estimated mean weight of the stomach contents (from which the quarterly rations required by MSVPA are estimated) is directly influenced by the relative proportions of feeding and non-feeding fish in the sample (Equation 1). It is therefore extremely important to distinguish correctly between fish with empty stomachs (non-feeders) and feeding fish which have regurgitated their stomach contents. Despite the availability of improved guidelines for classifying stomach at sea (Anon, 1991; Robb, 1992), it seems likely that some problems were encountered in 1991, because during the greater part of the year the percentages of whiting stomachs recorded as empty or regurgitated appear to vary according to the research vessel involved (Table 4). De Gee and Kikkert (1993) demonstrated that there were also significant between-ship differences in the classification of grey gurnard stomachs. Nevertheless, all countries recorded similar (high) percentages of empty stomachs in the first quarter, and there is no reason to suggest that the criteria used in Quarter 1 should differ from those used in the other quarters. This could indicate that the low values of mean stomach content weight estimated for Quarter 1 were not a consequence of the subjective judgement of the stomach sampler but were a real biological phenomenon. The problems of stomach classification and the subsequent effect on estimates of mean stomach content weight certainly requires a closer examination in the future.

## REFERENCES


Anonymous. 1988. Report of the Multispecies Assessment Working Group. ICES, Doc CM 1988/Assess:23.

Anonymous. 1991. ICES CM 1991/G:3. Manual for the ICES North Sea Stomach Sampling Project in 1991.

Anonymous. 1993. ICES Multispecies Assessment Working Group: Working paper submitted by the coordinators of the ICES Stomach Sampling Project in the North Sea in 1991.

Coull, K., Jermyn, A.S., Newton, A.W., Henderson, G. and Hall, W.B. 1989. Length/weight relationships for 88 species of fish encountered in the north east Atlantic. *Scot. Fish Rep. No. 43.*

Daan, N. 1983. Analysis of the cod samples collected during the 1981 stomach sampling project. ICES CM 1983/G:61.

Daan, N. (ed.). 1989. Data base report of the stomach sampling project in 1981. *ICES Coop. Res. Rep. 164*, 144pp.

De Gee, A. and Kikkert, A.H. 1993. Analysis of the grey gurnard samples collected during the 1991 International Stomach Sampling Project. ICES CM 1993/G:14.

Hislop, J.R.G., Robb, A.P., Bell, M.A. and Armstrong, D.W. 1991. The diet and food consumption of whiting (*Merlangius merlangus*) in the North Sea. *ICES J. Mar. Sci.*, **48**, 139-156.

Robb, A.P. 1992. Changes in the gall bladder of whiting (*Merlangius merlangus*) in relation to recent feeding history. *ICES J. Mar. Sci.*, **49**, 431-436.

TABLE 1: Number of stomachs sampled by predator size class, roundfish sampling area and quarter in 1991. Totals sampled during the 1981 exercise are shown in brackets

| Size class | 50 | 60 | 70 | 80 | 100 | 120 | 150 | 200 | 250 | 300 | 350 | 400 | Total | (1981) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Quarter 1** | | | | | | | | | | | | | | |
| Area 1 | | | | | 36 | 74 | 151 | 341 | 430 | 382 | 106 | 26 | 1546 | |
| Area 2 | | | | 2 | 30 | 254 | 337 | 281 | 226 | 89 | 15 | | 1234 | |
| Area 3 | | | | 19 | 120 | 261 | 256 | 248 | 240 | 80 | 17 | 1 | 1242 | |
| Area 4 | | | | | | 17 | 93 | 59 | 33 | 25 | 1 | | 228 | |
| Area 5 | | | | 9 | 9 | 37 | 49 | 38 | 37 | 22 | 6 | 1 | 208 | |
| Area 6 | | 1 | | 6 | 33 | 160 | 286 | 213 | 199 | 155 | 54 | 7 | 1114 | |
| Area 7 | | | | 13 | 64 | 88 | 169 | 104 | 97 | 36 | 6 | 2 | 579 | |
| Area 8 | | | | | | | | | | | | | | |
| Total | | 1 | | 49 | 292 | 891 | 1341 | 1284 | 1262 | 789 | 205 | 37 | 6151 | (7832) |
| **Quarter 2** | | | | | | | | | | | | | | |
| Area 1 | | | | | 1 | 4 | 130 | 496 | 1024 | 691 | 204 | 59 | 2618 | |
| Area 2 | | | | | 6 | 38 | 492 | 719 | 692 | 233 | 16 | 1 | 2197 | |
| Area 3 | | | | | | 31 | 187 | 392 | 357 | 158 | 8 | 1 | 1134 | |
| Area 4 | | | | | 3 | 14 | 190 | 207 | 261 | 153 | 16 | | 844 | |
| Area 5 | | | | | | 35 | 128 | 153 | 146 | 82 | 28 | 8 | 580 | |
| Area 6 | | | | | 71 | 237 | 773 | 842 | 774 | 359 | 50 | 9 | 3115 | |
| Area 7 | | | | | 11 | 136 | 248 | 201 | 168 | 66 | 9 | 3 | 842 | |
| Area 8 | | | | | | | | | | | | | | |
| Total | | | | | 92 | 495 | 2148 | 3010 | 3422 | 1742 | 331 | 81 | 11330 | (4211) |
| **Quarter 3** | | | | | | | | | | | | | | |
| Area 1 | 5 | 5 | 21 | 284 | 408 | 333 | 48 | 218 | 974 | 981 | 185 | 10 | 3472 | |
| Area 2 | 1 | 27 | 45 | 140 | 175 | 183 | 92 | 387 | 450 | 325 | 43 | 2 | 1870 | |
| Area 3 | | | 2 | 88 | 165 | 180 | 212 | 604 | 615 | 232 | 18 | 1 | 2117 | |
| Area 4 | | 10 | 15 | 23 | 13 | | 92 | 292 | 367 | 164 | 14 | 1 | 991 | |
| Area 5 | | | 10 | 13 | 1 | 3 | 66 | 150 | 136 | 65 | 35 | 3 | 482 | |
| Area 6 | 13 | 22 | 24 | 43 | 52 | 22 | 362 | 417 | 383 | 193 | 27 | 6 | 1564 | |
| Area 7 | | 24 | 30 | 77 | 69 | 33 | 189 | 319 | 159 | 124 | 22 | | 1046 | |
| Area 8 | | | | | | | | | | | | | | |
| Total | 19 | 88 | 147 | 668 | 883 | 754 | 1061 | 2387 | 3084 | 2084 | 344 | 23 | 11542 | (3727) |
| **Quarter 4** | | | | | | | | | | | | | | |
| Area 1 | 2 | | | 5 | 96 | 131 | 408 | 252 | 632 | 697 | 325 | 46 | 2594 | |
| Area 2 | | | | 12 | 83 | 140 | 319 | 239 | 256 | 199 | 35 | 1 | 1284 | |
| Area 3 | | | | 6 | 38 | 73 | 228 | 304 | 278 | 158 | 46 | | 1131 | |
| Area 4 | | 2 | 4 | 8 | 35 | 41 | 66 | 112 | 99 | 42 | | | 409 | |
| Area 5 | | | | 23 | 39 | 57 | 114 | 124 | 125 | 59 | 25 | | 566 | |
| Area 6 | | 4 | 12 | 38 | 205 | 160 | 475 | 743 | 646 | 406 | 112 | 17 | 2818 | |
| Area 7 | 1 | 3 | | 6 | 52 | 71 | 145 | 136 | 100 | 45 | 8 | 1 | 568 | |
| Area 8 | | | 3 | 48 | 101 | 136 | 249 | 211 | 205 | 81 | 13 | | 1047 | |
| Total | 3 | 9 | 19 | 146 | 649 | 809 | 2004 | 2121 | 2341 | 1687 | 564 | 65 | 10417 | (3447) |
| **Total year** | | | | | | | | | | | | | | |
| Area 1 | 7 | 5 | 21 | 289 | 541 | 542 | 737 | 1307 | 3060 | 2751 | 820 | 141 | 12030 | |
| Area 2 | 1 | 27 | 45 | 154 | 294 | 615 | 1240 | 1626 | 1624 | 846 | 109 | 4 | 6585 | |
| Area 3 | | | 2 | 113 | 323 | 545 | 883 | 1548 | 1490 | 628 | 89 | 3 | 5624 | |
| Area 4 | | 12 | 19 | 31 | 51 | 72 | 441 | 670 | 760 | 384 | 31 | 1 | 2472 | |
| Area 5 | | | 10 | 45 | 49 | 132 | 357 | 465 | 444 | 228 | 94 | 12 | 1836 | |
| Area 6 | 13 | 27 | 36 | 87 | 361 | 579 | 1896 | 2215 | 2002 | 1113 | 243 | 39 | 8611 | |
| Area 7 | 1 | 27 | 30 | 96 | 196 | 328 | 751 | 760 | 524 | 271 | 45 | 6 | 3035 | |
| Area 8 | | | 3 | 48 | 101 | 136 | 249 | 211 | 205 | 81 | 13 | | 1047 | |
| Total | 22 | 98 | 166 | 863 | 1916 | 2949 | 6554 | 8802 | 10109 | 6302 | 1444 | 206 | 39440 | (19217) |

TABLE 2: Numbers of whiting stomachs classified as empty, containing food or skeletal remains or showing evidence of regurgitation, in each area, in each quarter

| | No food | No reg | No empty | No skel | Total |
|---|---|---|---|---|---|
| **Quarter 1** | | | | | |
| Area 1 | 478 | 208 | 836 | 20 | 1542 |
| Area 2 | 431 | 276 | 522 | 4 | 1233 |
| Area 3 | 360 | 298 | 577 | 7 | 1242 |
| Area 4 | 54 | 54 | 120 | | 228 |
| Area 5 | 116 | 13 | 78 | | 207 |
| Area 6 | 556 | 58 | 477 | 21 | 1112 |
| Area 7 | 370 | 38 | 173 | | 581 |
| Total | 2365 | 945 | 2783 | 52 | 6145 |
| Percent | 38 | 15 | 45 | 1 | |
| **Quarter 2** | | | | | |
| Area 1 | 1310 | 1053 | 227 | 11 | 2601 |
| Area 2 | 1336 | 656 | 200 | 2 | 2194 |
| Area 3 | 593 | 485 | 53 | | 1131 |
| Area 4 | 494 | 230 | 114 | 1 | 839 |
| Area 5 | 343 | 132 | 105 | 1 | 581 |
| Area 6 | 1448 | 1156 | 505 | 1 | 3110 |
| Area 7 | 519 | 172 | 150 | | 841 |
| Total | 6043 | 3884 | 1354 | 16 | 11297 |
| Percent | 53 | 34 | 12 | + | |
| **Quarter 3** | | | | | |
| Area 1 | 1358 | 1689 | 419 | | 3466 |
| Area 2 | 963 | 700 | 208 | 1 | 1872 |
| Area 3 | 878 | 998 | 241 | | 2117 |
| Area 4 | 325 | 561 | 102 | | 988 |
| Area 5 | 170 | 254 | 55 | | 479 |
| Area 6 | 641 | 625 | 297 | | 1563 |
| Area 7 | 460 | 471 | 113 | 1 | 1045 |
| Total | 4795 | 5298 | 1435 | 2 | 11530 |
| Percent | 42 | 46 | 12 | + | |
| **Quarter 4** | | | | | |
| Area 1 | 1167 | 1335 | 68 | 22 | 2592 |
| Area 2 | 580 | 553 | 143 | 4 | 1280 |
| Area 3 | 360 | 716 | 49 | 8 | 1133 |
| Area 4 | 155 | 235 | 18 | | 408 |
| Area 5 | 228 | 286 | 53 | | 567 |
| Area 6 | 1734 | 844 | 239 | 1 | 2818 |
| Area 7 | 331 | 176 | 58 | | 565 |
| Area 8 | 615 | 236 | 191 | 3 | 1045 |
| Total | 5170 | 4381 | 819 | 38 | 10408 |
| Percent | 50 | 42 | 8 | + | |
| **Total Year** | | | | | |
| Area 1 | 4313 | 4285 | 1550 | 53 | 10201 |
| Area 2 | 3310 | 2185 | 1073 | 11 | 6579 |
| Area 3 | 2191 | 2497 | 920 | 15 | 5623 |
| Area 4 | 1028 | 1080 | 354 | 1 | 2463 |
| Area 5 | 857 | 685 | 291 | 1 | 1834 |
| Area 6 | 4379 | 2683 | 1518 | 23 | 8603 |
| Area 7 | 1680 | 857 | 494 | 1 | 3032 |
| Area 8 | 615 | 236 | 191 | 3 | 1045 |
| Total | 18373 | 14508 | 6391 | 108 | 39380 |
| Percent | 47 | 37 | 16 | + | |

TABLE 3: Percentage of empty stomachs by predator size class, area and quarter

| Size class | 50 | 60 | 70 | 80 | 100 | 120 | 150 | 200 | 250 | 300 | 350 | 400 | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Quarter 1** | | | | | | | | | | | | | |
| Area 1 | | | | | 13.9 | 13.5 | 33.1 | 61.9 | 60.0 | 60.5 | 60.4 | 34.6 | 54.2 |
| Area 2 | | | | 0.0 | 3.3 | 24.8 | 33.5 | 51.6 | 62.8 | 52.8 | 73.3 | | 42.3 |
| Area 3 | | | | 15.8 | 34.2 | 29.9 | 39.1 | 61.7 | 59.6 | 62.5 | 52.9 | 0.0 | 46.5 |
| Area 4 | | | | | | 64.7 | 41.9 | 57.6 | 51.5 | 76.0 | 0.0 | | 52.6 |
| Area 5 | | | | 22.2 | 33.3 | 54.1 | 40.8 | 34.2 | 43.2 | 13.6 | 16.7 | 0.0 | 37.5 |
| Area 6 | | 0.0 | | 16.7 | 12.1 | 41.9 | 40.2 | 46.9 | 53.3 | 40.6 | 38.9 | 43.9 | 43.1 |
| Area 7 | | | | 15.4 | 21.9 | 28.4 | 21.3 | 37.5 | 39.2 | 38.9 | 50.0 | 0.0 | 29.5 |
| Area 8 | | | | | | | | | | | | | |
| Total | | 0.0 | | 16.3 | 23.3 | 30.8 | 35.8 | 54.1 | 57.1 | 54.1 | 53.2 | 32.4 | 45.3 |
| **Quarter 2** | | | | | | | | | | | | | |
| Area 1 | | | | | 0.0 | 0.0 | 13.1 | 8.3 | 9.3 | 8.0 | 8.3 | 5.1 | 8.7 |
| Area 2 | | | | | 0.0 | 5.3 | 7.1 | 8.1 | 9.4 | 16.3 | 12.5 | 0.0 | 9.1 |
| Area 3 | | | | | | 0.0 | 5.9 | 3.3 | 4.8 | 6.3 | 25.0 | 100.0 | 4.8 |
| Area 4 | | | | | 0.0 | 7.1 | 13.2 | 20.3 | 11.1 | 9.8 | 18.8 | | 13.6 |
| Area 5 | | | | | | 14.3 | 16.4 | 19.1 | 20.6 | 18.3 | 7.1 | 50.0 | 18.3 |
| Area 6 | | | | | 11.3 | 25.7 | 16.2 | 15.0 | 15.4 | 16.2 | 14.0 | 22.2 | 16.2 |
| Area 7 | | | | | 18.2 | 10.3 | 17.3 | 20.4 | 24.4 | 15.2 | 0.0 | 0.0 | 17.9 |
| Area 8 | | | | | | | | | | | | | |
| Total | | | | | 10.9 | 16.8 | 12.9 | 11.6 | 11.6 | 11.5 | 9.9 | 12.4 | 12.0 |
| **Quarter 3** | | | | | | | | | | | | | |
| Area 1 | 0.0 | 0.0 | 9.5 | 31.3 | 10.1 | 2.7 | 16.7 | 10.6 | 10.3 | 11.5 | 17.3 | 20.0 | 12.1 |
| Area 2 | 0.0 | 0.0 | 0.0 | 2.1 | 6.3 | 5.5 | 17.4 | 14.2 | 12.9 | 15.4 | 11.6 | 0.0 | 11.1 |
| Area 3 | | | 0.0 | 0.0 | 4.9 | 4.4 | 12.7 | 12.6 | 11.4 | 19.8 | 33.3 | 0.0 | 11.4 |
| Area 4 | | 30.0 | 26.7 | 17.4 | 7.7 | | 4.4 | 10.3 | 9.5 | 13.4 | 7.1 | 0.0 | 10.5 |
| Area 5 | | | 20.0 | 0.0 | 100.0 | 33.3 | 16.7 | 8.0 | 7.4 | 18.5 | 17.1 | 66.7 | 11.8 |
| Area 6 | 69.2 | 50.0 | 20.8 | 4.7 | 36.5 | 18.2 | 17.7 | 19.7 | 14.9 | 22.8 | 7.4 | 0.0 | 19.1 |
| Area 7 | | 33.3 | 16.7 | 14.3 | 13.0 | 6.1 | 6.9 | 10.7 | 6.3 | 14.5 | 18.2 | 0.0 | 10.9 |
| Area 8 | | | | | | | | | | | | | |
| Total | 47.4 | 25.0 | 12.2 | 16.3 | 10.2 | 4.5 | 13.5 | 13.1 | 11.0 | 14.6 | 16.3 | 16.7 | 12.5 |
| **Quarter 4** | | | | | | | | | | | | | |
| Area 1 | 0.0 | | | 60.0 | 18.8 | 19.9 | 0.7 | 2.4 | 1.0 | 0.6 | 0.6 | 0.0 | 2.6 |
| Area 2 | | | | 0.0 | 13.3 | 14.3 | 5.6 | 14.2 | 10.9 | 13.1 | 17.1 | 0.0 | 11.1 |
| Area 3 | | | | 0.0 | 5.3 | 16.4 | 0.4 | 4.9 | 2.5 | 5.1 | 10.9 | | 4.4 |
| Area 4 | | 0.0 | 25.0 | 0.0 | 5.7 | 4.9 | 3.0 | 4.5 | 4.0 | 7.1 | | | 4.7 |
| Area 5 | | | | 17.4 | 20.5 | 22.8 | 4.4 | 3.2 | 12.0 | 6.8 | 0.0 | | 9.4 |
| Area 6 | | 25.0 | 25.0 | 10.5 | 18.1 | 10.6 | 4.8 | 6.3 | 7.9 | 10.6 | 11.6 | 10.0 | 8.5 |
| Area 7 | 0.0 | 0.0 | | 16.7 | 17.3 | 11.3 | 6.2 | 5.2 | 16.0 | 20.0 | 0.0 | 0.0 | 10.4 |
| Area 8 | | | 0.0 | 33.3 | 17.8 | 18.4 | 20.5 | 17.1 | 17.6 | 12.4 | 0.0 | | 18.3 |
| Total | 0.0 | 11.1 | 21.1 | 19.2 | 16.1 | 15.2 | 5.6 | 7.3 | 7.0 | 6.3 | 4.6 | 2.9 | 7.9 |
| **Total year** | | | | | | | | | | | | | |
| Area 1 | 0.0 | 0.0 | 9.5 | 31.8 | 11.8 | 8.3 | 10.6 | 21.5 | 15.0 | 14.7 | 14.0 | 9.9 | 15.2 |
| Area 2 | 0.0 | 0.0 | 0.0 | 1.9 | 7.8 | 15.5 | 14.7 | 17.9 | 18.0 | 19.0 | 22.0 | 0.0 | 16.3 |
| Area 3 | | | 0.0 | 2.7 | 15.8 | 18.0 | 15.7 | 16.6 | 15.9 | 18.2 | 24.7 | 33.3 | 16.4 |
| Area 4 | | 25.0 | 26.3 | 12.9 | 5.9 | 19.4 | 15.9 | 16.6 | 11.2 | 15.4 | 12.9 | 0.0 | 14.4 |
| Area 5 | | | 20.0 | 13.3 | 24.5 | 29.6 | 15.9 | 12.5 | 16.0 | 14.9 | 9.6 | 50.0 | 16.0 |
| Area 6 | 69.2 | 44.4 | 22.2 | 8.1 | 18.8 | 25.7 | 17.3 | 16.0 | 16.6 | 18.7 | 17.7 | 16.7 | 17.7 |
| Area 7 | 0.0 | 29.6 | 6.7 | 14.6 | 17.4 | 14.9 | 13.5 | 15.9 | 20.0 | 18.8 | 15.6 | 0.0 | 16.3 |
| Area 8 | | | 0.0 | 33.3 | 17.8 | 18.4 | 20.5 | 17.1 | 17.6 | 12.4 | 0.0 | | 18.3 |
| Total | 40.9 | 23.5 | 13.3 | 16.8 | 14.3 | 17.4 | 15.3 | 17.2 | 16.0 | 16.5 | 15.5 | 13.3 | 16.3 |

TABLE 4: Number and percentage by number of whiting stomachs classified as empty, containing food or skeletal remains, or showing evidence of regurgitation for each vessel in each quarter

| | No food | % food | No reg | % reg | No skel | % skel | No empty | % empty | Total |
|---|---|---|---|---|---|---|---|---|---|
| **Quarter 1** | | | | | | | | | |
| *Scotia* | 865 | 30.7 | 692 | 24.5 | 17 | 0.6 | 1248 | 44.2 | 2822 |
| *Tridens* | 367 | 41.3 | 51 | 5.7 | 5 | 0.6 | 465 | 52.4 | 888 |
| *Dana* | 215 | 36.8 | 83 | 14.2 | 6 | 1.0 | 280 | 48.0 | 584 |
| *Cirolana* | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 | 0 |
| *Isis* | 356 | 51.7 | 27 | 3.9 | 14 | 2.0 | 292 | 42.4 | 689 |
| *J Hjort* | 261 | 35.9 | 78 | 10.7 | 12 | 1.6 | 377 | 51.8 | 728 |
| *GO Sars* | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 | 0 |
| *IJM* | 12 | 44.4 | 2 | 7.4 | 1 | 3.7 | 12 | 44.5 | 27 |
| *H Mosby* | 9 | 36.0 | 0 | 0.0 | 0 | 0.0 | 16 | 64.0 | 25 |
| *W Herwig* | 10 | 58.8 | 0 | 0.0 | 0 | 0.0 | 7 | 41.2 | 17 |
| *Argos* | 267 | 71.8 | 16 | 4.3 | 0 | 0.0 | 89 | 23.9 | 372 |
| **Quarter 2** | | | | | | | | | |
| *Scotia* | 1358 | 48.8 | 1271 | 45.7 | 2 | 0.1 | 151 | 5.4 | 2782 |
| *Tridens* | 907 | 65.0 | 111 | 8.0 | 1 | 0.1 | 375 | 26.9 | 1394 |
| *Dana* | 311 | 48.4 | 187 | 29.1 | 5 | 0.8 | 120 | 18.7 | 643 |
| *Cirolana* | 1447 | 43.9 | 1644 | 49.9 | 8 | 0.2 | 198 | 6.0 | 3297 |
| *Isis* | 478 | 52.2 | 347 | 37.9 | 1 | 0.1 | 90 | 9.8 | 916 |
| *J Hjort* | 278 | 61.6 | 166 | 36.8 | 1 | 1.0 | 7 | 1.6 | 451 |
| *GO Sars* | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 | 0 |
| *IJM* | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 | 0 |
| *H Mosby* | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 | 0 |
| *W Herwig* | 1259 | 68.1 | 164 | 8.9 | 5 | 0.3 | 419 | 22.7 | 1847 |
| *Argos* | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 | 0 |
| **Quarter 3** | | | | | | | | | |
| *Scotia* | 1835 | 38.4 | 2365 | 49.4 | 1 | 0.0 | 584 | 12.2 | 4785 |
| *Tridens* | 670 | 55.9 | 216 | 18.0 | 1 | 0.1 | 311 | 26.0 | 1198 |
| *Dana* | 241 | 57.5 | 158 | 37.7 | 0 | 0.0 | 20 | 4.8 | 419 |
| *Cirolana* | 1483 | 35.5 | 2379 | 57.0 | 2 | 0.0 | 313 | 7.5 | 4177 |
| *Isis* | 299 | 49.2 | 134 | 22.0 | 1 | 0.2 | 174 | 28.6 | 608 |
| *J Hjort* | 129 | 80.6 | 26 | 16.3 | 0 | 0.0 | 5 | 3.1 | 160 |
| *GO Sars* | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 | 0 |
| *IJM* | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 | 0 |
| *H Mosby* | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 | 0 |
| *W Herwig* | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 | 0 |
| *Argos* | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 | 0 |
| **Quarter 4** | | | | | | | | | |
| *Scotia* | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 | 0 |
| *Tridens* | 1046 | 65.9 | 260 | 16.4 | 0 | 0.0 | 282 | 17.7 | 1588 |
| *Dana* | 807 | 48.9 | 601 | 36.4 | 11 | 0.7 | 231 | 14.0 | 1650 |
| *Cirolana* | 1563 | 36.5 | 2613 | 61.0 | 2 | 0.0 | 105 | 2.5 | 4283 |
| *Isis* | 739 | 75.5 | 154 | 15.7 | 0 | 0.0 | 86 | 8.8 | 979 |
| *J Hjort* | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 | 0 |
| *GO Sars* | 701 | 51.0 | 636 | 46.2 | 26 | 1.9 | 12 | 0.9 | 1375 |
| *IJM* | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 | 0 |
| *H Mosby* | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 | 0 |
| *W Herwig* | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 | 0 |
| *Argos* | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 | 0 |
| **Annual** | | | | | | | | | |
| *Scotia* | 4058 | 39.0 | 4328 | 41.7 | 20 | 0.2 | 1983 | 19.1 | 10389 |
| *Tridens* | 2990 | 59.0 | 638 | 12.6 | 7 | 0.1 | 1433 | 28.3 | 5068 |
| *Dana* | 1594 | 48.4 | 1029 | 31.2 | 22 | 0.7 | 651 | 19.7 | 3296 |
| *Cirolana* | 4493 | 38.2 | 6636 | 56.5 | 12 | 0.1 | 616 | 5.2 | 11757 |
| *Isis* | 1872 | 58.7 | 662 | 20.7 | 16 | 0.5 | 642 | 20.1 | 3192 |
| *J Hjort* | 668 | 50.0 | 270 | 20.1 | 12 | 0.9 | 389 | 29.0 | 1339 |
| *GO Sars* | 701 | 51.0 | 636 | 46.2 | 26 | 1.9 | 12 | 0.9 | 1375 |
| *IJM* | 12 | 44.4 | 2 | 7.4 | 1 | 3.7 | 12 | 44.5 | 27 |
| *H Mosby* | 9 | 36.0 | 0 | 0.0 | 0 | 0.0 | 16 | 64.0 | 25 |
| *W Herwig* | 1269 | 68.1 | 164 | 8.8 | 5 | 0.3 | 426 | 22.8 | 1864 |
| *Argos* | 267 | 71.8 | 16 | 4.3 | 0 | 0.0 | 89 | 23.9 | 372 |

TABLE 5: Total North Sea. Estimated mean length (L) cm, Live weight (W) g and Average stomach weight (S) g of whiting in each size class in each quarter

| Size class (mm) | Quarter 1 | | | Quarter 2 | | | Quarter 3 | | | Quarter 4 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | L | W | S | L | W | S | L | W | S | L | W | S |
| 50 | | | | | | | | | 0.01 | 5.50 | 2 | 0.06 |
| 60 | 6.50 | 2 | 0.01 | | | | 6.11 | 2 | 0.04 | 6.49 | 3 | 0.05 |
| 70 | | | | | | | 7.50 | 4 | 0.05 | 7.50 | 4 | 0.03 |
| 80 | 9.35 | 8 | 0.03 | | | | 9.05 | 7 | 0.13 | 9.23 | 8 | 0.07 |
| 100 | 11.33 | 14 | 0.13 | 11.42 | 13 | 0.31 | 10.88 | 12 | 0.33 | 11.17 | 13 | 0.19 |
| 120 | 13.72 | 24 | 0.20 | 14.16 | 25 | 0.26 | 12.86 | 19 | 0.63 | 13.49 | 23 | 0.29 |
| 150 | 16.98 | 44 | 0.47 | 17.55 | 46 | 0.77 | 18.68 | 58 | 0.70 | 17.04 | 46 | 1.01 |
| 200 | 23.17 | 111 | 0.83 | 22.48 | 95 | 1.55 | 22.11 | 95 | 1.42 | 23.36 | 118 | 1.67 |
| 250 | 26.87 | 172 | 1.27 | 26.87 | 162 | 2.80 | 27.15 | 174 | 2.99 | 26.76 | 176 | 3.54 |
| 300 | 31.62 | 278 | 2.33 | 31.59 | 260 | 5.66 | 31.59 | 272 | 5.92 | 31.69 | 289 | 5.32 |
| 350 | 36.62 | 432 | 3.43 | 36.64 | 402 | 8.71 | 36.76 | 424 | 8.79 | 36.81 | 449 | 5.81 |
| 400 | 42.13 | 647 | 8.53 | 42.03 | 602 | 12.02 | 41.64 | 613 | 16.19 | 42.74 | 696 | 10.52 |

TABLE 6: Comparison between the mean weight of stomach contents of whiting in 1981 ($S = .009 \times W^{1.057}$) and 1991 ($S = .009 \times W^{1.158}$)

| Fish weight (g) | Mean stomach weight (g) | |
|---|---|---|
| | 1981 | 1991 |
| 10 | 0.10 | 0.13 |
| 50 | 0.56 | 0.83 |
| 100 | 1.17 | 1.86 |
| 200 | 2.43 | 4.16 |
| 300 | 3.74 | 6.65 |
| 400 | 5.07 | 9.28 |
| 500 | 6.41 | 12.01 |
| 600 | 7.78 | 14.84 |
| 750 | 9.84 | 19.21 |
| 1000 | 13.34 | 26.81 |

Figure 1. Boundaries of I.C.E.S. Roundfish sampling areas.

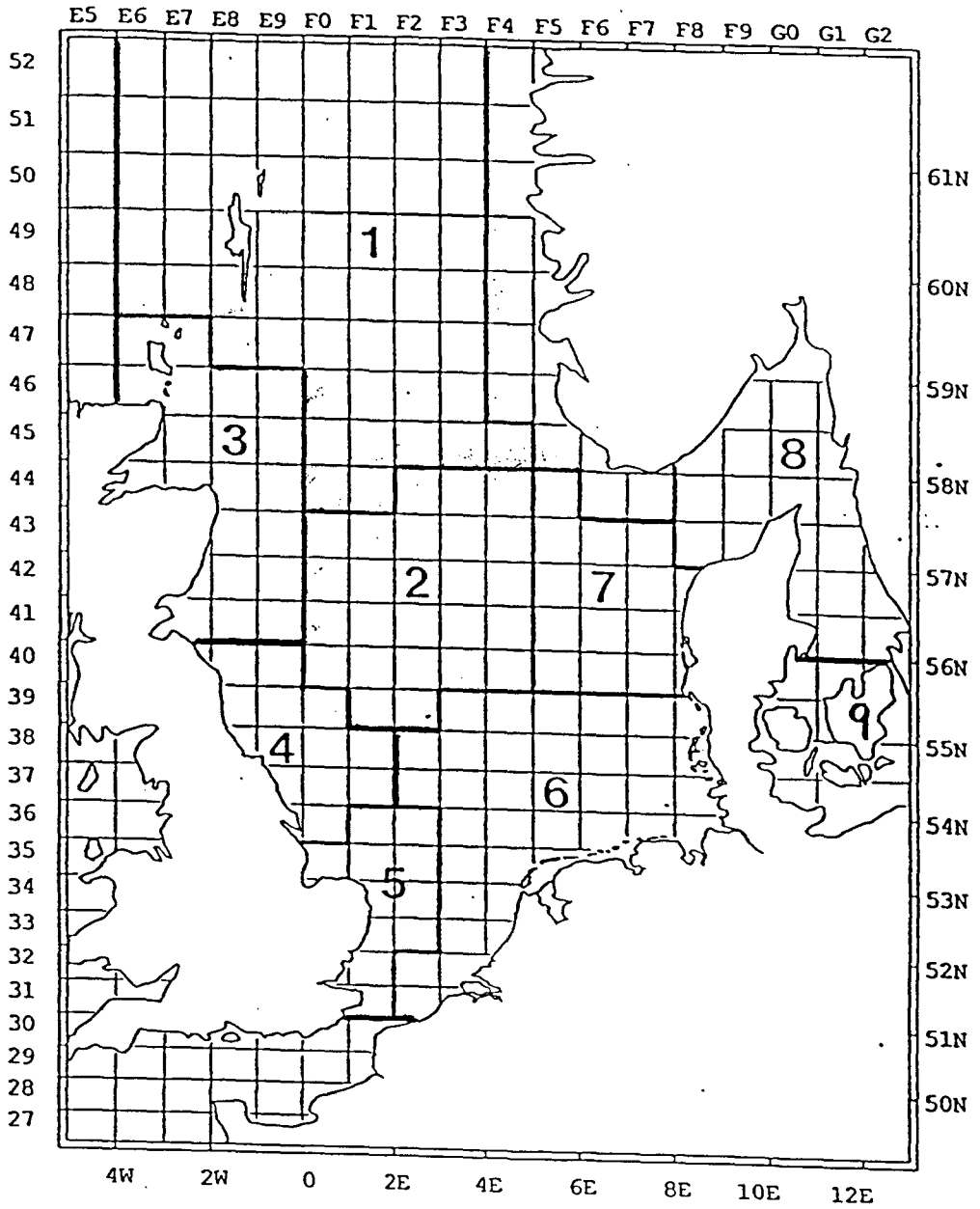
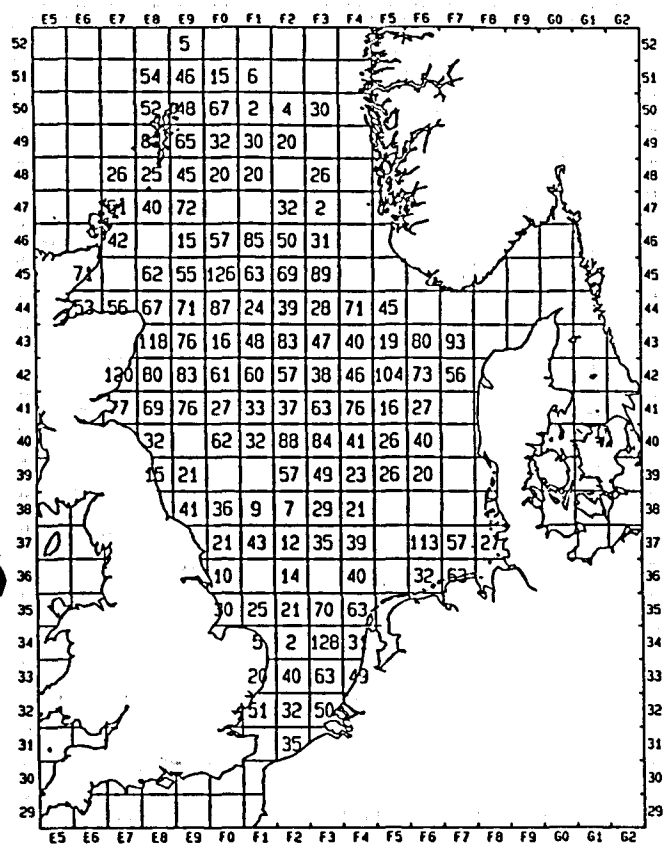
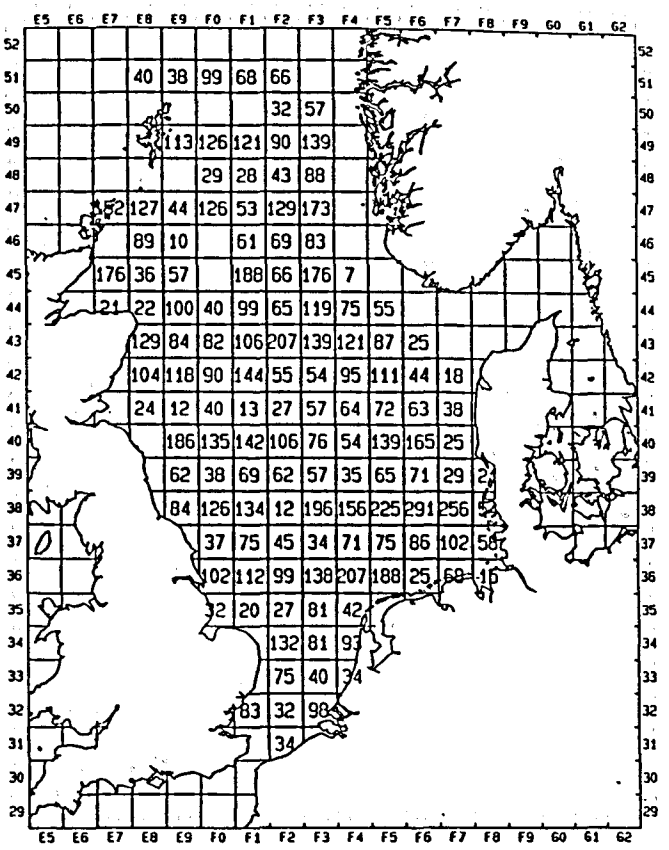


Figure 2. Number of whiting stomachs examined at sea in each quarter.

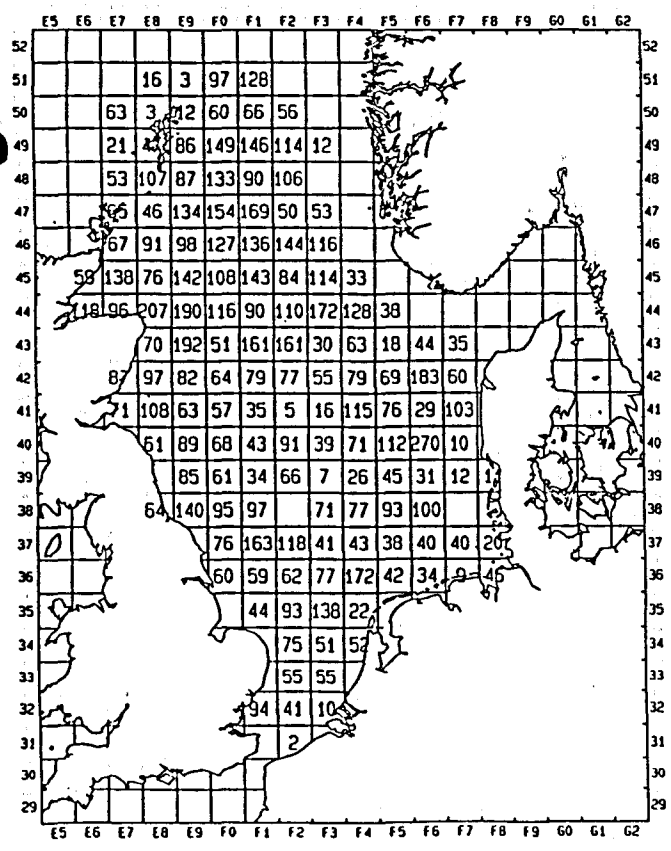
Quarter 1



Quarter 2



Quarter 3



Quarter 4

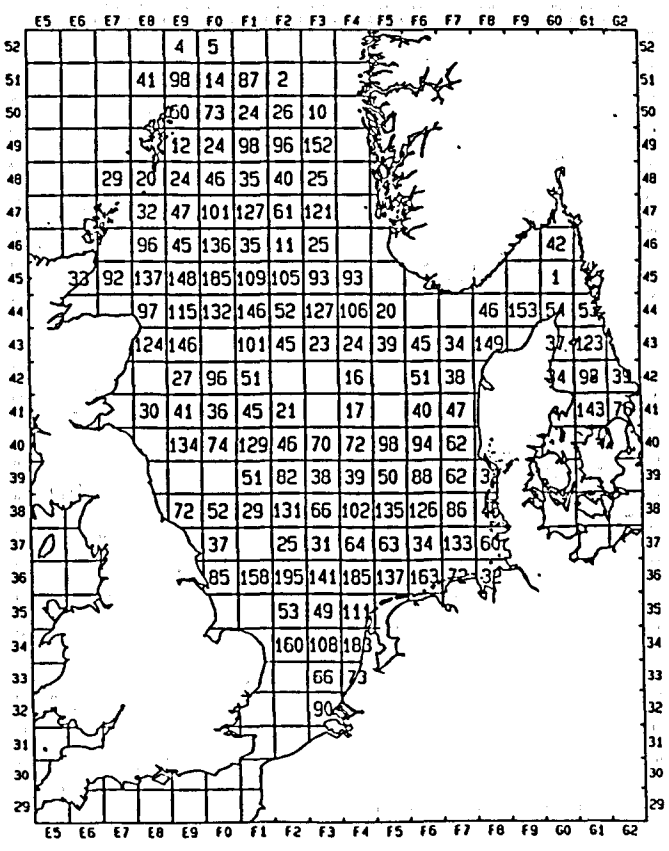


Figure 3.Relationship between Av.stom.wt./Pred.wt.

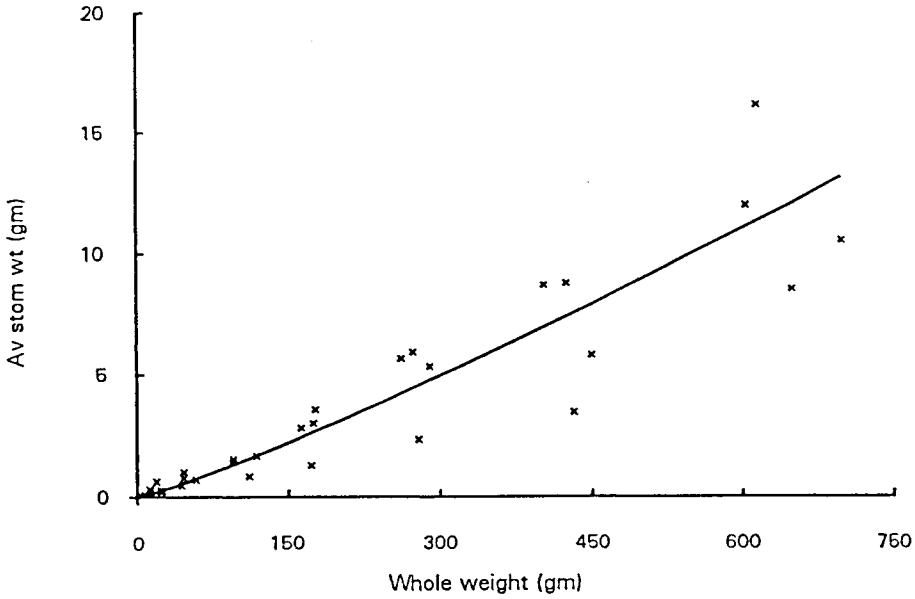


Figure 4. Percentage weight of major prey taxa in each predator size class and quarter

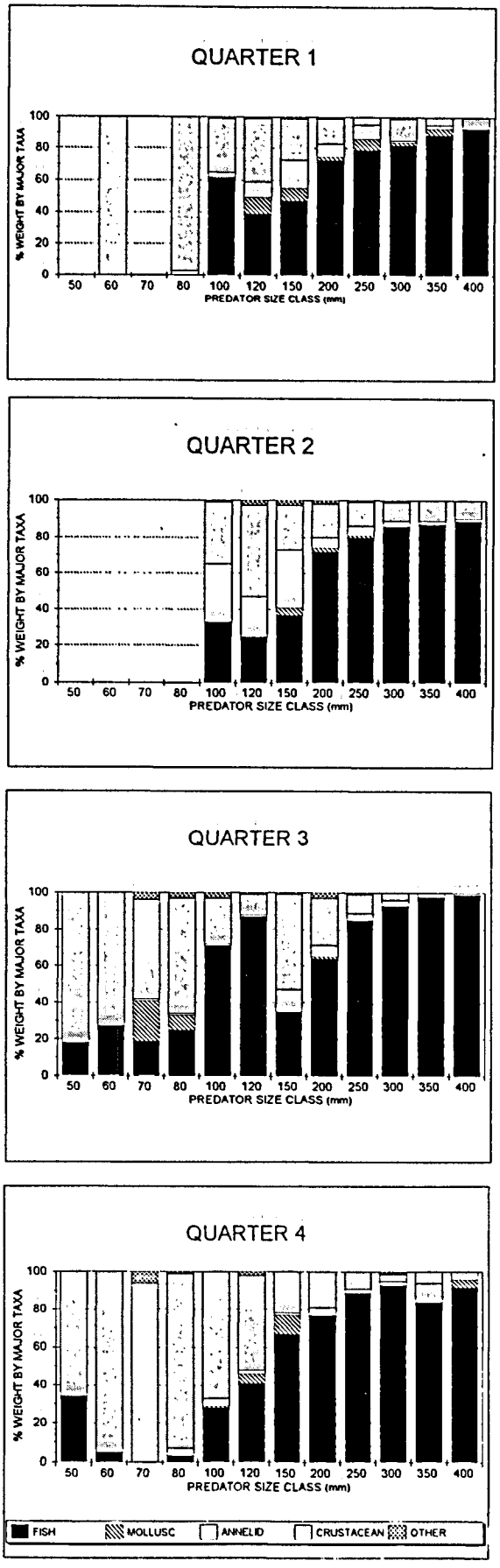


Figure 5. Percentage weight of commercial fish species per predator size class and quarter

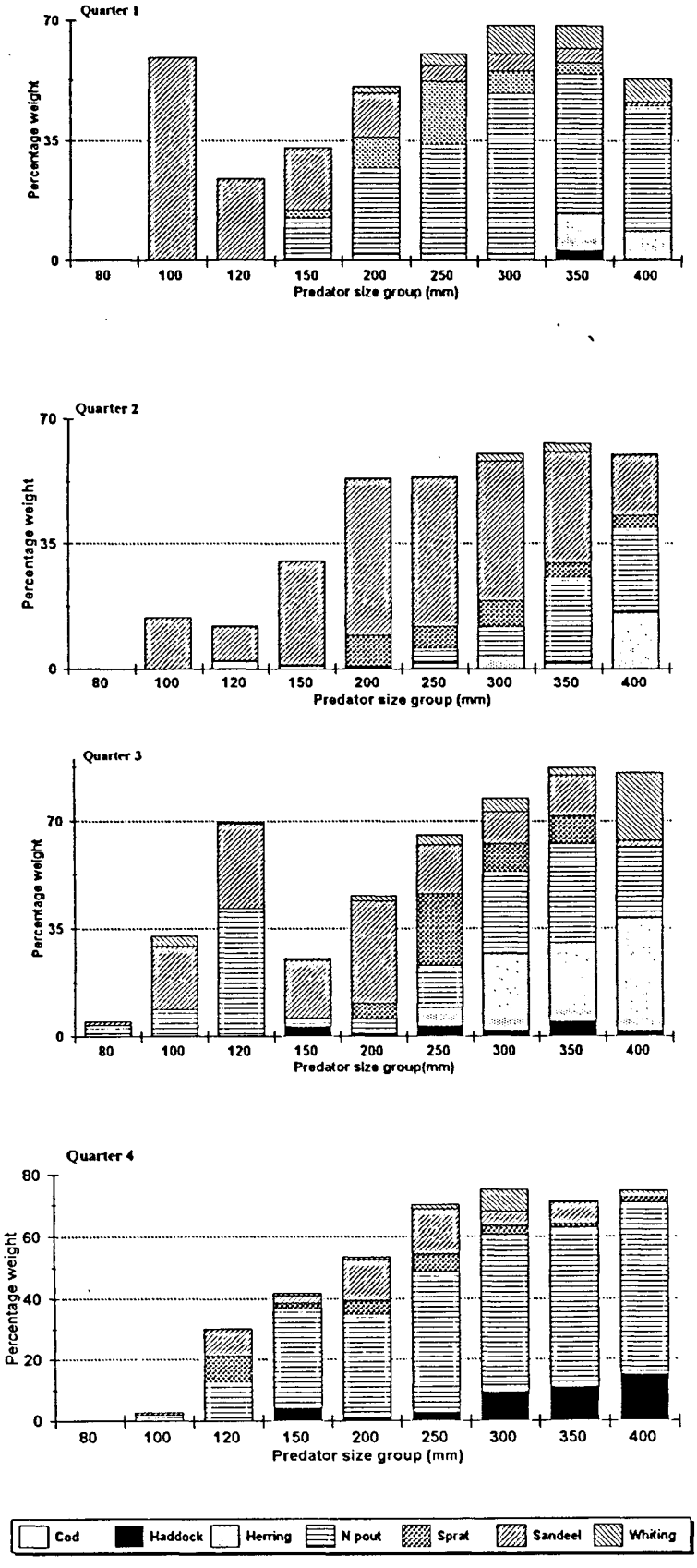


Figure 6. Percentage weight of the major prey taxa in each predator size class, quarter and area.

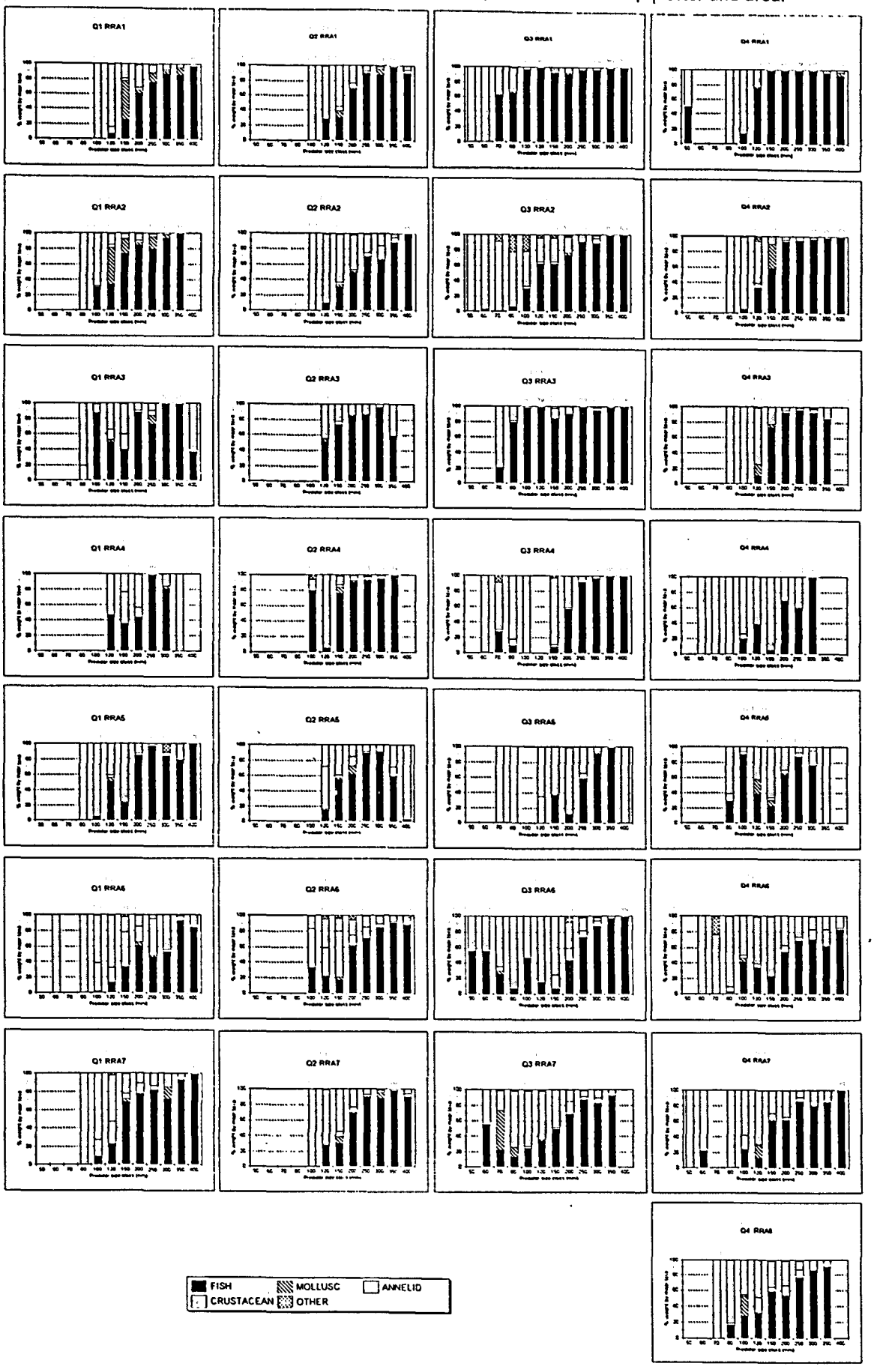
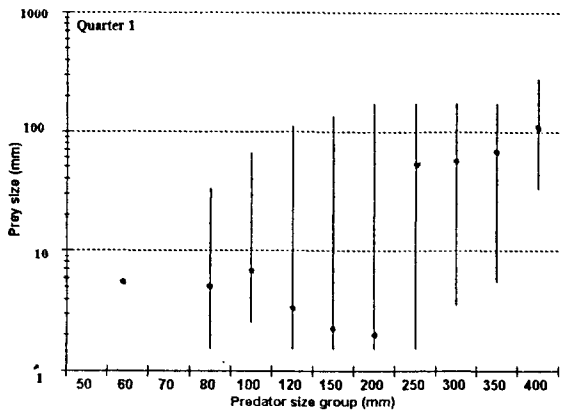
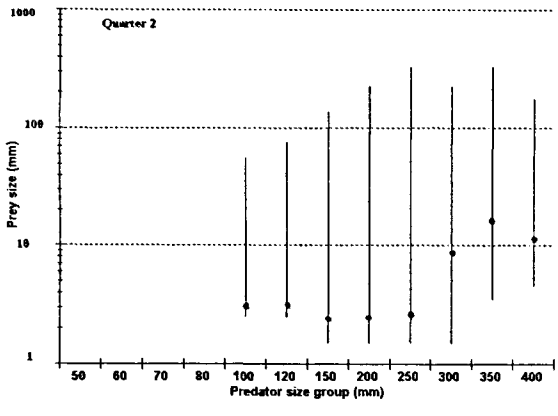
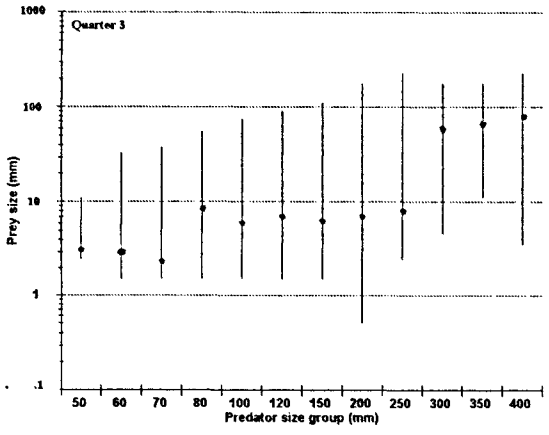


**Figure 7. Median,minimum and maximum ranges of all prey found in the stomachs of whiting of each size class in each quarter.**



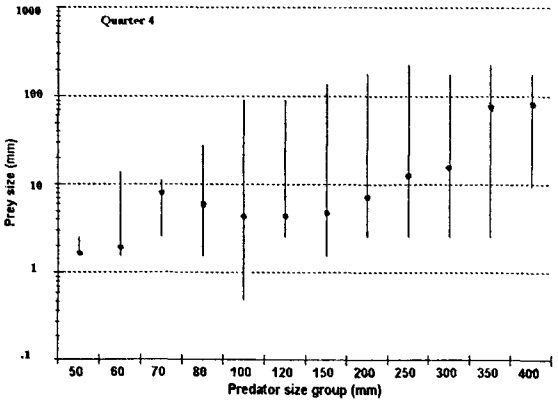



Figure 8. Median,minimum and maximum ranges of fish prey found in the stomachs of whiting of each size class in each quarter.