Importance of discarded blue whiting (Micromesistius poutassou) in the diet of lesser spotted dogfish (Scyliorhinus canicula) in the Cantabrian Sea

I. Olaso, F. Velasco, and N. Pérez

The blue whiting is the most important demersal species caught by the Spanish trawler fleet in the southern Bay of Biscay. Lesser spotted dogfish are not a commercial by-catch, and are discarded immediately after sorting. During 1994 the contents of 1094 dogfish stomachs were analysed. The results show that lesser spotted dogfish with a total length of >17 cm eat blue whiting throughout the year. The length range of blue whiting found in lesser spotted dogfish stomachs was similar to the length range discarded by the fishery. Blue whiting account for 20% of the stomach volume in lesser spotted dogfish 30–50 cm long. From the state of digestion of blue whiting prey, and the comparative analysis of the size distributions of blue whiting in lesser spotted dogfish stomachs and in the fishery, it appears that many of these blue whiting are discards, consumed when already dead or damaged. The impact of this supplementary food on lesser spotted dogfish abundance is discussed.

Key words: blue whiting, diet, discard, dogfish, scavenger.

Received 8 January 1997; accepted 8 May 1997.

Introduction

The Cantabrian Sea, to the north of Spain, corresponds to ICES Division VIIIc. In this Division there is a varied commercial fleet involving different gillnet, hook and trawl fisheries. The bottom-trawl fishery, which lands around 15 000 t of fresh fish annually, comprises vessels which use pair and single bottom trawls; it is a mixed fishery in which landings include hake, horse mackerel, and monkfish, but the main catch is blue whiting.

Several abundant species are discarded after capture, either because of their size or because of their low commercial value. Some of these individuals survive, while others die (Kaiser and Spencer, 1995), and they may provide an important food resource for scavengers (Kaiser and Spencer, 1994).

The records of Division VIIIc trawlers (single bottom-trawling vessels) from 1994 (Pérez et al., 1996) show that blue whiting have both the highest catch and discard rates, representing 33% of total weight and 22% of total discards. Lesser spotted dogfish are also commonly caught by the trawlers; the species has little commercial interest and, since it is a large fish, it is usually discarded at the beginning of sorting the catch. It is the second most important discarded species.

Bottom-trawl surveys series show that blue whiting is the most abundant fish in the area (Sánchez, 1993) and plays an important role in the diets of the Cantabrian fish community, according to Olaso and Velasco (personal communication). These authors studied the diet of 27 fish species which made up the trophic demersal structure in the area of study, and found that 19 of these species prey on blue whiting and eight of them are predators which actively feed on blue whiting, while the other 11 are opportunist feeders, probably preying on dying, dead or decomposing individuals.

Because the lesser spotted dogfish is the most commonly caught benthic shark in the area, we considered it to be of interest to study its particular ecological role. The aims of this study were to determine the proportion of the dogfish diet which comes from discards and to interpret the observed changes in the abundance of this species.
Material and methods

Discard sampling

The discard sampling programme (Pérez et al., 1996) was based on monthly random stratified sampling of single bottom sampling in Division VIIIc, from February to December 1994. Fourteen commercial trawlers made 301 hauls during 33 trips over the 109-day sampling period. The average duration of each commercial trip was 3 days, during which an average of 9.1 hauls was made, i.e. a daily average of 2.8 hauls. Catches and discard sampling of all taxa, including target species and low-interest or non-commercial species, were quantified. Data were standardised to 100 fishing hours (f.h.), with a mean of 5.3 f.h. per haul.

One observer went on each trip, collecting, by species, data on the quantities discarded and retained. Fish and decapod crustaceans were identified to the species level wherever possible, and non-commercial invertebrates usually to family or order. The total lengths of discarded blue whiting and lesser spotted dogfish, and blue whiting retained in the catch, were also measured to the nearest cm.

Stomach sampling and analysis

Lesser spotted dogfish stomachs were collected from each commercial haul, and during a bottom-trawl research survey conducted in October 1994. On the commercial vessels, hauls were made by day and by night, while on the bottom-trawl survey, all hauls were carried out by day. For each haul, stomachs were selected from 10 dogfish covering the length range. If there was any evidence of predation by dogfish during the haul, the predator was rejected and, whenever possible, another specimen of the same length was selected. Empty stomachs of dogfish with remains of food in the mouth were considered to have been regurgitated, but this was unusual (13 regurgitated stomachs in 1094 sampled predators).

Stomach contents were analysed on board both the commercial and research vessels. The volume (ml) of total prey groups in the stomach was measured using a trophometer, a calibrated instrument consisting of several different-sized half-cylinders built into a tray, so that they form horizontal cylindrical moulds (Olaso, 1990). The approximate percentage of the total volume made up by the individual identified prey categories was then determined, and the relationship between estimated volumes and actual weights of the stomach contents was derived from linear regression (a=0.932735, b=0.99324, r²=0.99); Bowman (1982) was the first to use this methodology. Prey were identified to the lowest possible taxon for decapod crustaceans, cephalopods and fish; other invertebrates were classified to higher taxonomic levels. For each prey type, the following data were quantified: the percentage of stomach volume, the state of digestion (1=intact prey; 2=partially-digested prey; 3=well-digested), and the number of individuals. Fish, decapod crustaceans and cephalopods were measured to the nearest mm. In the case of fish, when the state of the prey made determination of total length impossible, the otolith size was measured to the nearest mm, and the length was estimated from regressions of fish length on otolith length (Pereda and Villamor, 1991).

Data analysis

Fishing intensity and the analysis of catch data, discards and landings by species were reported by Pérez et al. (1996). The most representative data are shown in Table 1. In order to establish the minimum number of stomachs for each length group (minimum size of the sample) to obtain a reliable result, the accumulated number of prey types was plotted against the number of stomachs, in such a way as to consider an adequate number when the curve reaches its asymptote (Modde and Ross, 1983).

The relative importance of individual prey taxa was assessed with indices of volume (Hyslop, 1980). Total stomach fullness (%BW) and mean partial fullness index for prey i (PFI_i) were also calculated to permit comparison of quantities of prey in stomachs of dogfish of various sizes during different quarters of the year (Bowering and Lilly, 1992). The method used to calculate the mean partial fullness index of prey category i is:

<table>
<thead>
<tr>
<th>Species</th>
<th>Discard weight (tonnes)</th>
<th>Total (tonnes)</th>
<th>Discards % of total catch</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Blue whiting</td>
<td>1680</td>
<td>181</td>
<td>493</td>
</tr>
<tr>
<td>Dogfish</td>
<td>708</td>
<td>204</td>
<td>348</td>
</tr>
<tr>
<td>Other species</td>
<td>3423</td>
<td>1560</td>
<td>1735</td>
</tr>
<tr>
<td>Total</td>
<td>5811</td>
<td>1945</td>
<td>2576</td>
</tr>
</tbody>
</table>

Table 1. Summary of Spanish trawler fleet estimated discards and catches in weight in 1994 (Pérez et al., 1996).
where \( H \) is the number of hauls, \( F \) is the number of stomachs containing food, \( R \) is the number of regurgitated stomachs, \( E \) is the number of empty stomachs, \( V_{ij} \) is the volume of prey \( i \) in fish \( j \), and \( L_j \) is the length of fish \( j \).

The relationship between prey size and predator size was analysed by means of regressions analysis, and statistical analysis (chi-square) was used to analyse differences in empty stomach frequency.

Additional information from the fishery (Pérez et al., 1996) was used to compute catch rates (numbers per fishing hour per area) and length compositions, and these data were used to compare the blue whiting length distributions in the stomachs with those from landings and discards.

Results

Sampling intensity

Most of the fish sampled throughout the year were of similar size, except in the third quarter (Table 2). Plots of cumulative taxa vs. the number of stomachs examined (Fig. 1) indicate that sample sizes sufficient for description of prey type were obtained for all length groups, with the exception of the stomachs in the third quarter.

Dogfish diet

Lesser spotted dogfish consumed a wide variety of prey: 65 different taxa were found in the diet. Of these, 22 taxa were fish (Fig. 2). Crustaceans, almost all of which were decapods, were represented by 29 taxa. Small lesser spotted dogfish generally presented a small number of taxa, although, as shown in Figures 2 and 3, the taxa in all prey groups (crustaceans, fishes and other invertebrates) increased up to 50 cm. In the diet of larger-sized lesser spotted dogfish, crustaceans, other invertebrates and fishes diminished in species richness.

The diet of lesser spotted dogfish, in terms of percentage volume, comprised mostly decapod crustaceans and fish, the remaining being invertebrate groups, such as polychaetes and cephalopods (Table 3). Fish, of which blue whiting was the most important species, represented more than 50% of the percentage in volume. The diet of smaller-sized lesser spotted dogfish (14–30 cm) was 63% euphausiids and shrimps, and about 20% fish. As size increased, the consumption of crustaceans diminished slightly, while fish volume increased, reaching over 60% in dogfish of >50 cm in length.

Most of the potential prey groups found in the lesser spotted dogfish diet are also discarded by the trawl fleet, specifically, 21 of the 22 species of prey fish identified. The relative importance of the individual species varied seasonally. Figure 4 shows the most representative prey groups, separating the fish species which are important in discards and differentiating between other fish and undetermined fish, since the state of digestion did not usually permit their identification. The importance of the euphausiids was evident during the first months of the year for dogfish measuring less than 30 cm, and as the year progressed, other, mainly decapod, crustaceans tended to dominate. During the summer, the percentage of brachyuran crabs was more significant in medium and large-sized lesser spotted dogfish, although they fed on decapod crustaceans throughout the year.

Cephalopods appeared in the diet during the winter, and less so in autumn; other invertebrate groups were preyed on all year, but small dogfish did not prey on them in summer. Blue whiting were consumed by all length groups during autumn, but only lesser spotted dogfish of >30 cm preys on blue whiting throughout the year.

The incidence of empty stomachs and state of food digestion

As shown in Table 4, 86% of lesser spotted dogfish stomachs contained food. Taking into account the fact that dogfish from commercial vessels are caught in hauls of long duration, those coming from the fourth quarter were compared with those from the October research cruise. The emptiness percentage is clearly similar, because there are no significant differences between quarters and surveys (\( \chi^2 = 7.7306, p=0.102 \)), while there are significant differences between sizes classes (\( \chi^2 = 11.7389, p<0.01 \)).

The stomach contents were found in a highly digested state (Fig. 5). Comparing the distribution of the states of digestion between the autumn samples from commercial
vessels and the survey samples, no significant differences were found ($\chi^2 = 0.56927$, $p = 0.75$).

The stomach fullness index (BW) was 2.92. On transforming the length of blue whiting prey to live weight, it was found that it only made up 24% of stomach content weight. This low value was due to the highly digested state of the prey, and to the fact that, in many cases, only pieces had been eaten.

The importance of blue whiting in the diet of dogfish

From a length of 17 cm, lesser spotted dogfish preyed on blue whiting of 7–32 cm, although the regression line obtained for the relationship between the dogfish length and the length of blue whiting prey found in the stomachs is not representative, given the large variations.
in the data (Fig. 6). However, there is a statistical tendency for growth in prey size as predator size increases (Table 5).

The length distributions of blue whiting in discards, landings and as prey, for the whole of 1994, are shown in Figure 7. The length ranges of discarded blue whiting and blue whiting found as prey were similar (6–31 cm for blue whiting found in stomachs, and 7–39 cm for the discarded blue whiting), but we observed that the highest mode of the length composition of the blue whiting prey was 13 cm, while the modes of the discarded blue whiting were between 19 and 23 cm.

To determine the importance of blue whiting in the diet of lesser spotted dogfish throughout the year and at different sizes, we used the fullness index PFI. Figure 8 shows only four groups of taxa, since a large proportion of the fish were unidentified, although many of these were probably blue whiting, since the mean weight of a blue whiting is 10.47 ± 2.63 g, compared with 5.8 ± 0.026 g for other fish species, while the mean of the undetermined fish was 8.98 ± 0.067 g. Applying the Kruskal–Wallis test to the three groups gave significant differences ($\chi^2 = 22.7469$, $p > 0.01$), while applying the Mann–Whitney test to compare the mean volume of blue whiting prey and the mean volume of undetermined fish gave no significant differences ($U = 3850$, $W = 8431.0$, $z = -1.6376$, 2-tailed $p = 0.1015$). For this reason, we separated prey fish into three groups and allocated another to invertebrates. The total fullness index increased throughout the year, varying from 0.47 during the winter to 1.55 during autumn in the smallest specimens, with fish having very little importance during the first six months of the year, and only invertebrates forming the main food. From summer on, there was an increase in the fullness index due to the availability of blue whiting and undetermined fish. Lesser spotted dogfish of >30 cm consumed undetermined fish and blue whiting year round (although during the third quarter the only fish analysed were undetermined) and their total fullness index was similar throughout the year, between 0.41 and 0.43, except during the summer, when it was 0.21.

Figure 8 shows the seasonal length distributions of blue whiting discarded by the trawl fleet in 1994. The length range landed does not vary over the year, remaining above 16 cm. These data indicate that throughout the year the mean length of discarded blue whiting drops, for specimens greater than 20 cm in winter, which have a mode of around 22 cm, to specimens with a wider length range in the second half of the year, with a mode of around 15 cm. These changes in the length of discarded blue whiting are related to the results shown in Figure 9. In winter, the importance of blue whiting prey was not evident in smaller-sized lesser spotted dogfish, while in the spring they began to prey on undetermined fish. In summer and autumn the increase in small-sized discarded blue whiting coincided with the consumption of undetermined fish and blue whiting in small dogfish, while lesser spotted dogfish of greater size continued to prey on blue whiting.
Relationships between dogfish diet and material discarded in trawling

Lesser spotted dogfish prey on a wide range of megabenthic fauna (echinoderms, polychaetes, molluscs, sipunculids, tunicates, crustaceans), although decapod crustaceans and fish are their main food. This kind of general, opportunistic and scavenger feeding has been described by other authors (Lyle, 1979; Olaso and Rodríguez-Marin, 1995), but Kaiser and Spencer (1994) were the first to suggest that dogfish feed on damaged or dead animals from fishing operations or on other scavengers attracted to the trawled area.

On the basis of this information, the 1994 discard data of the Division VIIIc trawl fleet were analysed (Pérez et al., 1996), and it was observed that of 216 taxa caught (104 fish, 41 decapod crustaceans, 35 molluscs, and 36 of other groups of invertebrates), 150 taxa were discarded, each one representing, more than 90% of their total catch (52 fish, 35 decapod crustaceans, 27 molluscs, and 36 other groups of invertebrates). If we compare these results with the 65 taxa found in the dogfish diet (Table 3), we find that all the preyed fish and a large majority of the other phylum prey were discarded, with the exception of the groups of small size, such as non-decapod crustaceans. But many megabenthic species (Munida intermedia, Pagurus prideaux, Liocarcinus depurator, Solenocera membranacea, Rossia macrossoma and Sepia...
orbignyana) were abundant, although their abundance in the environment (Olaso, 1990; García-Castrillo and Olaso, 1995) should be taken into account, since they can be consumed alive. However, the presence in the lesser spotted dogfish diet of infaunal species (Alpheus glaber, Goneplax rhomboides, polychaetes), benthopelagic fish species with a high discard rate (M. poutassou, G. argenteus) or pelagic species that suffer from slipping (discard catches that are not taken on board, but released into the water, i.e. a part of the total catch.

Figure 4. Percentage volume of major prey taxa in each predator size class and quarter. ■ Winter; ● spring; □ summer; △ autumn.
which returns to the sea and may survive, Anon., 1991), such as E. encrasicholus, shows that they are likely to be discarded. The highest percentage in volume of anchovy occurs in the spring, which is when fishing for this species is at its most active, and so at this time discards and slipping take place.

As dogfish size increased, the number of prey taxa increased, the greatest variety being found in fish >30 cm. This may be the length at which discarded material becomes particularly beneficial, since small dogfish feed on a limited number of taxa (Fig. 3, Table 3), because their smaller mouth size restricts the consumption of large prey whole. The mean length of fish prey was 140.06 ± 11.04 mm (n=126), and that of crustaceans was 32.71 ± 2.85 mm (n=202). Nevertheless, we must consider that these small-sized prey (e.g. Goneplax rhomboides, Alpheus glaber and other shrimp) may

Table 4. Percentage of empty stomachs of dogfish, by length group and quarter in 1994.

<table>
<thead>
<tr>
<th>Size class</th>
<th>14–30 cm</th>
<th>30–50 cm</th>
<th>50–70 cm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quarter 1</td>
<td>10</td>
<td>13</td>
<td>19</td>
</tr>
<tr>
<td>Quarter 2</td>
<td>0</td>
<td>7</td>
<td>19</td>
</tr>
<tr>
<td>Quarter 3</td>
<td>0</td>
<td>0</td>
<td>15</td>
</tr>
<tr>
<td>Quarter 4</td>
<td>10</td>
<td>11</td>
<td>14</td>
</tr>
<tr>
<td>Cruise surv.</td>
<td>10</td>
<td>11</td>
<td>13</td>
</tr>
<tr>
<td>Total</td>
<td>8</td>
<td>11</td>
<td>14</td>
</tr>
</tbody>
</table>

Table 5. Analysis of variance of the regression.

<table>
<thead>
<tr>
<th></th>
<th>DF</th>
<th>Sum of squares</th>
<th>Mean square</th>
</tr>
</thead>
<tbody>
<tr>
<td>Regression</td>
<td>1</td>
<td>1.5688584</td>
<td>1.5688584</td>
</tr>
<tr>
<td>Residuals</td>
<td>83</td>
<td>7.9368303</td>
<td>0.0956245</td>
</tr>
</tbody>
</table>

F = 16.40645; Signif F = 0.0001.

Figure 5. Digestion states of lesser spotted dogfish stomach contents, by length range and quarters. ■ Winter; ■ spring; □ summer; □ autumn; ■ cruise.

Figure 6. Predator–prey relationships between lesser spotted dogfish and blue whiting. y=84.890 × exp(0.0125 × X); r²=0.1650; n=85 indiv.
remain available as food, since their availability may be
favoured by the effect of trawls on the sea bottom, as is
the case of the amphipod Ampelisca spinipes (Kaiser and
Spencer, 1994). The importance of fish prey increased
with dogfish size, but even though many of the fish prey
could not be identified, the majority would probably be
blue whiting.

Influence of the supply of blue whiting prey on
the feeding habits of lesser spotted dogfish

The high percentage of fish prey, in particular blue
whiting, consumed by the lesser spotted dogfish on the
northern coast of Spain contrasts with the small percent-
age of fish in this species’ diet in other Atlantic areas: 4%
(Lyle, 1979), 16% (Ellis et al., 1996). Bearing in mind
that the type and size of prey cause digestion to be faster
or slower, it is considered that invertebrates, which have
a lower energy value than fish, can be digested more
rapidly (Macpherson et al., 1989 point out that a fish
like the silvery pout takes twice as long to digest as a
natantian crustacean).

Feeding experiments carried out in the laboratory
using lesser spotted dogfish show that there is a close
relationship between the gastric evacuation rate and the
return of appetite, so that a single meal is evacuated 2–5
times more quickly than a double meal (Sims et al.,
1996). Studying the feeding habits of the lesser spotted
dogfish in areas in which its diet mainly comprises
invertebrates, Lyle (1979) considered the near absence
of empty stomachs and different states of digestion of
the prey to be due to the fact that these fish eat

Figure 7. Length distribution of blue whiting in lesser spotted dogfish stomachs, discarded and landed in 1994. In the sample
there were: 85 blue whiting prey, 6305 discarded blue whiting and 5178 landed blue whiting. — □— Discarded; — ○ — landed;
— ●— prey.

Figure 8. Seasonal variation in the length distribution of blue whiting discarded by the ICES Division VIIIc trawler fleet in 1994.
— ▲— Winter; · · · □— spring; — x x — summer; — ■— autumn.
intermittently throughout the day. However, in the lesser spotted dogfish studied for the present paper, although the percentage of empty stomachs was also low, there was a major component of fish prey in their diet, found in an advanced state of digestion. This would seem to indicate that the supply of discarded fish prey in the species’ diet, above all of blue whiting, modifies the energetic content of the food ingested, and lesser spotted dogfish may reach an overfed state.

These results indicate that, although fishing activity tends to have a negative impact on the majority of species, in this case, we find a certain benefit. Although the lesser spotted dogfish is indeed affected by fishing mortality, this effect is not as severe as it is for other species, since nearly all specimens caught are discarded, and their survival rate can be as high as 90% in half-hour hauls (Kaiser and Spencer, 1995); meanwhile, they take advantage of the food provided by discards and prey killed or damaged by fishing.

Acknowledgements
We would like to thank Antonio Punzón for his participation in lesser spotted dogfish stomach sampling,
References


