ICES C. M. 1995

CM 1995/J:27
Baltic Fish Committee

PRELIMINARY OBSERVATIONS OF SIZE AT SETTLING AND FOOD RESOURCE UTILIZATION OF JUVENILE (0-GROUP) BALTIC COD *(GADUS MORHUA* L.)

by

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Abstract

Juvenile Baltic cod were collected in the Bornholm Basin (28 September to 6 October 1994). A total of 381 cod were measured and their stomachs examined for prey composition. Juveniles less than 40 mm were observed to feed exclusively on pelagic food items such as copepods and cladocerans. At a length between 40 and 60 mm the juvenile cod began to consume benthic prey items such as mysids and amphipods, copepods however were still the dominant prey items consumed by this size group. Between 60 and 80 mm the dominant prey items were the mysids and amphipods with copepods now comprising a minor component of the diet. In the size range from 80 mm to 160 mm juvenile cod utilized a diet composed exclusively of benthic prey. An increase in prey diversity was also observed in these individuals with the importance of mysids in the diet reduced, while the occurrence of polychaetes, decapods and fish in the diet increased with increasing juvenile size. The occurrence of the amphipods was observed to remain more or less constant in the diet of juvenile cod from 60 mm to 160 mm in length. These results indicate that a major change in food preference started to occure at a fish length of 40 mm, with the main change taking place at approximately 60 mm, suggesting that juvenile Baltic cod make a transition to the benthic habitat at a length of about 60 mm.

Introduction

The importance of the earliest life stages in the determination of year class strength has been identified by a number of researchers (e. g. Cushin, 1972, Jones, 1973, Houde, 1987, Myers & Cadigan, 1993). They generally consider the egg/larval phase and the early juvenile stage as the critical life stages with the greatest impact on recruitment. Several authors however suspect that the period of transition from the pelagic to demersal stage and the condition during the first winter have a critical influence on the year class strength in haddock (e. g. Chase, 1955; Sissenwine, 1984). The determination of the year class strength of juvenile Baltic cod can be anticipated to be influenced accordingly as cod and haddock have a similar development (Bowman, 1981).

Previous studies conducted on larval fish indicate that groundfish species, such as cod, undergo a pelagic stage during which they feed predominantly on planktonic organisms (Last, 1978; Laurence, 1974; Robb, 1981; Robb & Hislop, 1980). During their first year of life juvenile cod switch to a demersal habitat feeding primarily on benthic prey. A number of researchers have over the years addressed the feeding habits of gadoids, with research focusing primarily on adults, larval and demersal juvenile stages. Only a few researches have examined feeding habits of the pelagic and settling stages (Pálsson, 1973; Bowman, 1981; Robb & Hislop, 1980; Robb, 1981; Mahon & Neilson, 1987).

During the settling period, the juvenile fish face major changes in food type, size and availability. Food availability is potentially a limiting factor at this particular time in the development of juvenile fishes. Cod is one of the commercially most important fish species in the Baltic Sea, with the importance of this life stage on the recruitment unknown. Results of research cruises performed in the Bornholm Basin have identified the nearshore benthic habitat as a possible key environment utilized by the pelagic and demersal stages of 0-group cod. In order to identify how these regions are utilized by settling stages and how they influence variations in the year class strength of Baltic cod (as outlined in the Baltic AIR research program AIR 2 1226) the goal of this research was to examine the food resources utilized by juvenile Baltic cod, with the main interest on the transition phase from pelagic to demersal life stage, and to determine at which length the fishes settle to the bottom.

Materials and Methods

Juvenile Baltic cod (0-group) were collected in the Bornholm Basin during the period 28/09/94 to 06/10/94. A total of 541 juvenile cod in the size range 0.7 mm to 160 mm were caught using pelagic (MIK, EXPO, EGYPT and pelagic GOV) and demersal (demersal GOV) trawls. The stations and sample sizes are shown in fig. 1.

After capture the fishes were immediately packed in plastic bags and stored in a -20 ^{0}C freezer. In the lab the fish were transferred to a -70 ^{0}C freezer. Upon thawing the standard length (accuracy 0.5 mm) of each fish was measured. The stomachs were removed and stored individually in a 4% solution of buffered formaldehyde.

Each individual stomach was drained on filter paper for approximately three minutes and then weighed[1]. Stomach contents were then removed and placed in a Petri dish with water. The stomach wall was washed, weighed, and the total stomach content weight calculated.

Food items were identified to the lowest possible taxonomical level, with abundance and wet weight[1] of the different taxonomical groups recorded per individual. Every food item was assigned a digestion degree ranging from 0 to 5 (0=fresh and 5=well digested remains). Wet weights[1] of all undigested food items were recorded. Weights of copepods and cladocerans were estimated using length/weight regressions described in Bretelen *et al.*, (1982) and Henroth (1985). Empty stomachs were recorded seperately.

Juvenile cod were grouped into 10 mm size classes, and prey type was identified by size class. All food species were assigned to either benthic or pelagic habitat according to the definition in Gosner (1971) and Mahon & Neilson (1987), and the relative abundance of pelagic/benthic food items in the stomach contents plotted against size class.

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[1]Weight=Formaldehyde wet weight

Results

Prey items utilized by juvenile Bàltic cod

The species consumed by the entire size range of 0-group cod was pooled and listed in table 1. in taxonomical order, together with the habitat designation defined by Gosner (1971) and Mahon & Neilson (1987).

Length at settling

In order to identify the length at which juvenile Baltic cod switch from the pelagic to demersal habitat the relative abundances of prey from pelagic and benthic habitat (see table 1.) were plotted against fish size. Bowman (1981) defined the threshold level of settling as the fish length (or age), at which more than 50% of the prey items consumed by numbers (or weight) are from a benthic source.

The difference between dominance by numbers and weight was small, with the exception of the largest size classes. In these size classes a limited sample size caused a single large, undigested prey item, such as a decapod or fish caused the relative abundance by weight to be slightly greater than the abundance by numbers. As the calculation of the exact wet weight of partly digested prey animals smaller than approximately 2 mm, such as copepods, cladocerans and juvenile mysids/amphipods was not considered reliable enough, the following results are based on the occurrence of food item numbers.

The plot of the relative abundance of benthic prey items consumed per size class of juvenile cod is shown in fig. 2. The relative abundance of the mysids was, although they belong to an intermediate habitat type, added to the abundance of the truly benthic species. Mysids stay near the bottom during the day and migrate up into the water column only at night time (Rudstam *et al.*, 1989). The individuals found in the stomachs of fishes caught after dark were in an advanced state of digestion in comparison with those in the stomachs of fishes caught during the day, indicating that they had not been eaten recently.

Utilizing Bowmans definition, the settling length of juvenile Baltic cod from this study was observed to occure at a length of approximately 60 mm. Utilizing the relative dominance of prey item weight on the other hand, the length at settling seems to be approximately 50 mm.

Food resources utilized before, during and after settling

For each size class the food items were recorded seperately as prey number per fish. In figure 3. the data of the size classes 0.7 mm to 40 mm, 40 mm to 60 mm, 60 mm to 80 mm and 80 mm to 130 mm were combined for simplicity sake.

Juvenile Baltic cod of standard length less than 40 mm exclusively preyed on pelagic food items such as copepods and cladocerans (see fig. 3. A). The most frequently consumed copepod species were *Pseudocalanus elongatus* and *Temora longicornis*, while the species *Acartia bifilosa*, *Centropages hammatus* and *Oithona similis* were consumed to a lesser extent. The most frequently consumed cladocerans were *Evadne nordmanni* and *Bosmina longispina maritima*, with *Podon* sp. being less important as a food item.

In the length interval from 40 to 60 mm juvenile cod began to increasingly prey on benthic organisms such as mysids and amphipods (see fig. 3. B). The main species consumed were *Mysis mixta*, *Neomysis vulgaris* and *Gammarus locusta* respectively. The copepods mentioned above were nevertheless still the most important food items in the juvenile cods diet.

In the interval between 60 and 80 mm the utilization of the copepods decreased quickly, while the importance of mysids and amphipods increased, suggesting a transition to the benthic habitat (see fig. 3. C).

From a size of 80 mm juvenile Baltic cod fed exclusively on demersal food items, with a marked increase in the diversity of prey items consumed by this size group. The diet was expanded to include decapods, cumaceans, isopods, molluscs, polychaetes and fishes (see fig. 3. D). Of the orders Decapoda, Cumacea and Isopoda only the species *Crangon vulgaris*, *Diastylis rathkei* and *Mesidotea entomon* respectively were consumed. The molluscs utilized by the demersal stages were mainly *Mytilus edulis* and a few *Hydrobia ulvae* and *Macoma* sp.. The only polychaet that could be identified with certainty was *Harmatoe* sp., (as they easily break into fragments while swallowed and are digested rapidly due to their soft body wall). Juvenile Baltic cod from 80 to 160 mm length were observed in this study to utilize only one fish species, this being *Pomatoschistus minutus*.

The importance of especially polychaetes, cumaceans and fishes increased with increasing fish size. Decapods were likewise only consumed by larger fish but were utilized by relatively few individuals. Molluscs were consumed to a minor extent by fishes in all size classes above 80 mm, comprising less than 5% of the total number of food animals per stomach and even less by weight. The isopod *Mesidotea entomon* cannot be assumed to be a prey item of any importance to juvenile Baltic cod, as only a few fishes had consumed a single individual of *Mesidotea*. The importance of the mysids *Mysis mixta* and *Neomysis vulgaris* in the diet of juvenile cod larger than 80 mm decreased gradually, while the occurrence of the amphipod *Gammarus locusta* stays more or less constant in juveniles larger than 60 mm.

Discussion

This paper provides preliminary observations of the food resources utilized by pelagic and demersal 0-group cod as well as their size at settling. In order to identify these periods it is necessary to assume that the food items found in the fish stomachs are indicative of the vertical distribution to make an estimate of the size at which they settle on the bottom. A factor that is likely to bias the results of this study is the limited sample size of the small size classes. Our results, however, correspond well with the observations from a survey on the northwest Atlantic cod published by Bowman (1981), where cod were found to prey on copepods during their pelagic life stage, switching to demersal habitat utilization upon settling at a size of approximately 90 mm fork length. Similar results were found to apply to cod in Icelandic waters by Pálsson (1973). Another study supporting our results has been published by Bailey (1975), who found that 0-group North Sea cod caught in midwater (from 12. to 29. August 1971) never were more than 70 mm long, whereas those caught on the sea bottom were larger.

The length at which juvenile Baltic cod settled can be determined to be approximately 60 mm. Baltic cod have a very prolonged spawning season, from March through to September/October, with the peak spawning in May/June (Bagge & Thurow, 1993), thus this settling length may not be applicable to all cohorts. Eggs and larvae spawned at other times of the season than those investigated in this study encounter different food availability, hydrographic regimes etc., which might lead to different settling sizes and growth rates.

Several studies have addressed the abruptness with which the transition from pelagic to demersal habitat utilization occures, with different results. Bowman (1981) found that the process of settling took place over a prolonged period of time in juvenile Atlantic cod. He observed pelagic juveniles of 30 mm fork length with small amounts of food of benthic origin in the stomach but still with pelagic species as primary food source (he does not, however, report whether food items from both pelagic and benthic origin occured in the same stomachs or in different fishes). However, in a study carried out by Mahon & Neilson (1987), juvenile Scotian Shelf haddock, which have a transition period similar to that of cod (Bowman, 1981), were found to switch from pelagic to benthic habitat utilization abruptly.

The results from this study seem to support a relatively abrupt transition for individual fish. All fishes smaller than 40 mm had only been feeding on pelagic prey, which corresponds with the results published by Robb (1981), who showed that pelagic juvenile North Sea cod were feeding exclusively on copepods. The fishes in the size intervall 40 to 60 mm were found to have consumed either copepods or mysids/amphipods, or both (in which case the mysids and amphipods, however, were so small that they could not be considered as definitely benthic).

Since some juvenile Baltic cod obviously start settling at a length of 40 mm and the majority at 60 mm, the duration of transition for the whole cohort obviously takes place within this length interval of 20 mm. Using the specific growth rates of 0.73 mm day^{-1} reported by Linkowski & Kowalewska-Pahlke (1993), Pálssons (1980) growth rate of 1.8% length day^{-1} and the ca. 2.0% length day^{-1} found by Brown *et al.* (1989), the duration of the transition period can be estimated to last between three and four weeks. Koeller *et al.* (1986) estimated the transition period for a cohort of Scotian Shelf haddock to be about 4 weeks, which corresponds well with the present results.

The analysis of the stomach contents shows that juvenile Baltic cod, before depending on the benthic organisms as food ressource, exclusively utilized pelagic prey items such as copepods and cladocerans. The diet of larger juveniles (after settling) consisted of mysids and amphipods and shifted gradually to larger prey such as polychaets, decapods and fish. Opposite to Pálsson (1980) who showed that newly settled cod in Icelandic waters fed on other juvenile gadids, the 0-group Baltic cod were not found to utilize other fishes than gobies (*Pomatoschistus minutus*) and to a far less extent than the cod investigated by Pálsson.

The stomach content anlysis carried out in this study showed, that the nearshore environments are important habitats for the development of juvenile Baltic cod. Mysids, amphipods, small fishes etc. are found abundantly in the shallow areas less than 40 m (Aschan, 1988), where they are not limited by oxygen deficiency, potentially providing the newly settled juveniles with sufficient food. Variations in the prey abundance could accordingly influence the settling success of 0-group Baltic cod and thereby the year class size of following years.

Acknowledgements

We would like to thank the Baltic AIR research program for the funding of this project and the Danish Institute for Fisheries and Marine Research for logistic support. Special thanks to Henrik Mosegaard and Kurt T. Jensen for useful advise, Kim N. Mouritsen, Mike St. John and Peter Grønkjær for critical comments on the manuscript, Anni H. Jensen for kind assistance in the lab and Uni V. Hansen for moral support.

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Table 1: Habitat utilized by prey of 0-group Baltic cod.
Habitat designations: P=pelagic; i=intermediate (pelagic during the night, benthic during the day); b=benthic.

Prey species		**Habitat**
Crustacea		
Copepoda	*Pseudocalanus minutus elongatus*	p
	Temora longicornis	p
	Acartia sp.	p
	Acartia bifilosa	p
	Centropages hammatus	p
	Oithona similis	p
Cladocera	*Evadne nordmanni*	p
	Bosmina longispina maritima	p
	Podon sp.	p
Mysidacea	*Mysis* sp.	i
	Mysis mixta	i
	Mysis flexuosa	i
	Neomysis vulgaris	i
Amphipoda	*Gammarus locusta*	b
	Gammarus sp.	b
Decapoda	*Crangon vulgaris*	b
Cumacea	*Diastylis rathkei*	b
Isopoda	*Mesidotea entomon*	b
Mollusca		
Bivalvia	*Mytilus edulis*	b
	Macoma sp.	b
Gastropoda	*Hydrobia ulvae*	b
Polychaeta	*Polychaeta* sp.	b
	Harmatoe sp.	b
Pisces	*Pomatoschistus minutus*	b

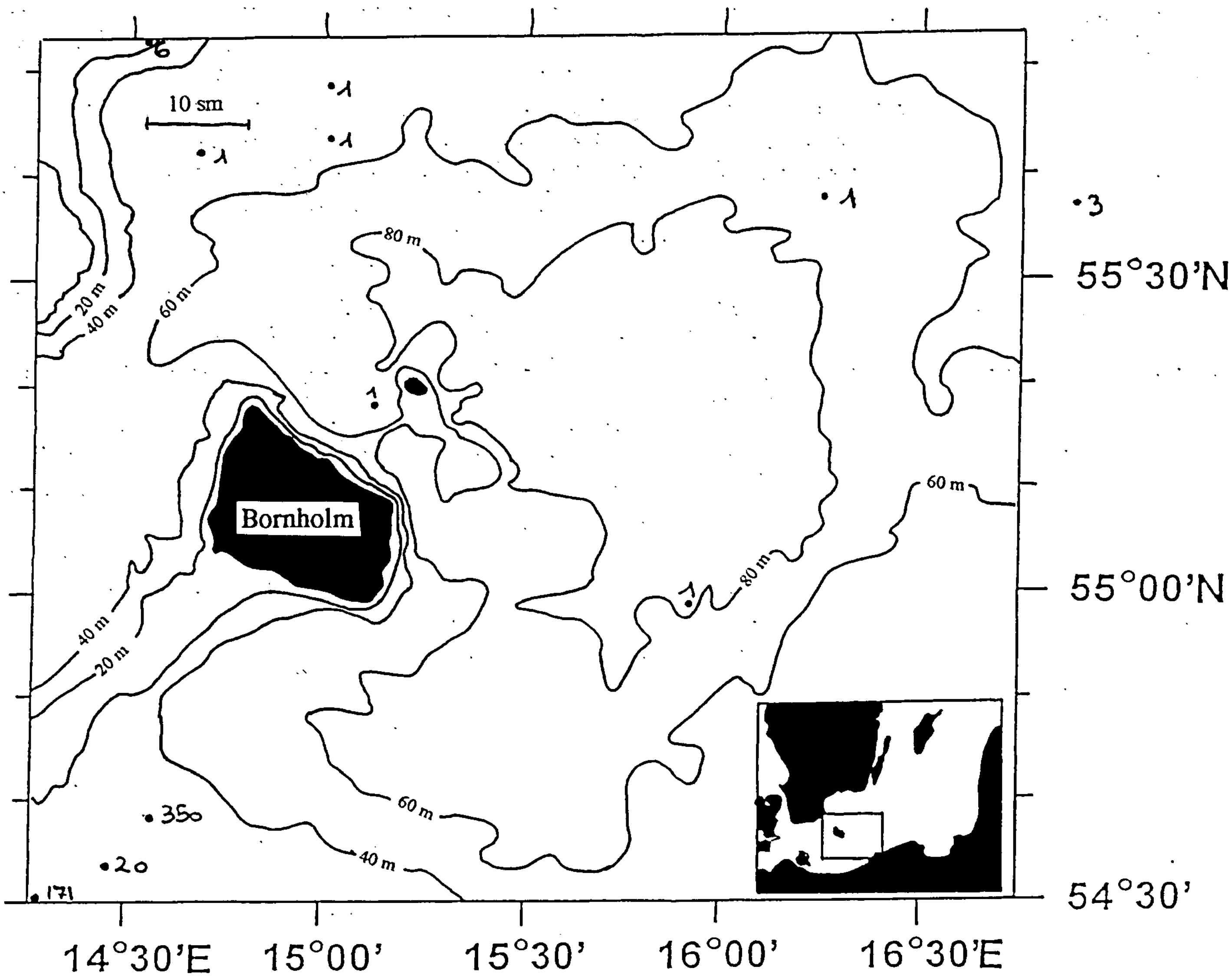

Figure 1.: Map of the stations sampled. Numbers next to the stations=sample size.

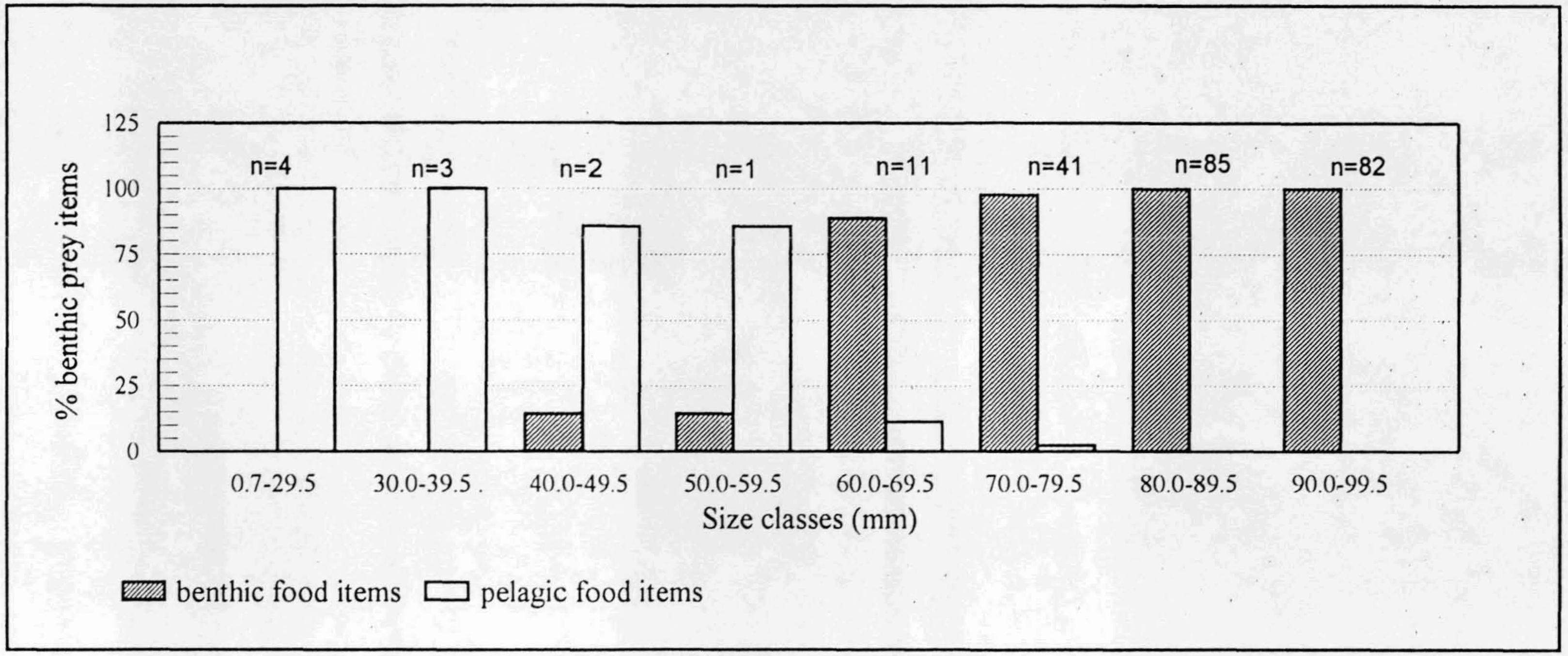

Figure 2.: Relative abundance of pelagic/benthic prey items by numbers in the stomachs of 0-group Baltic cod

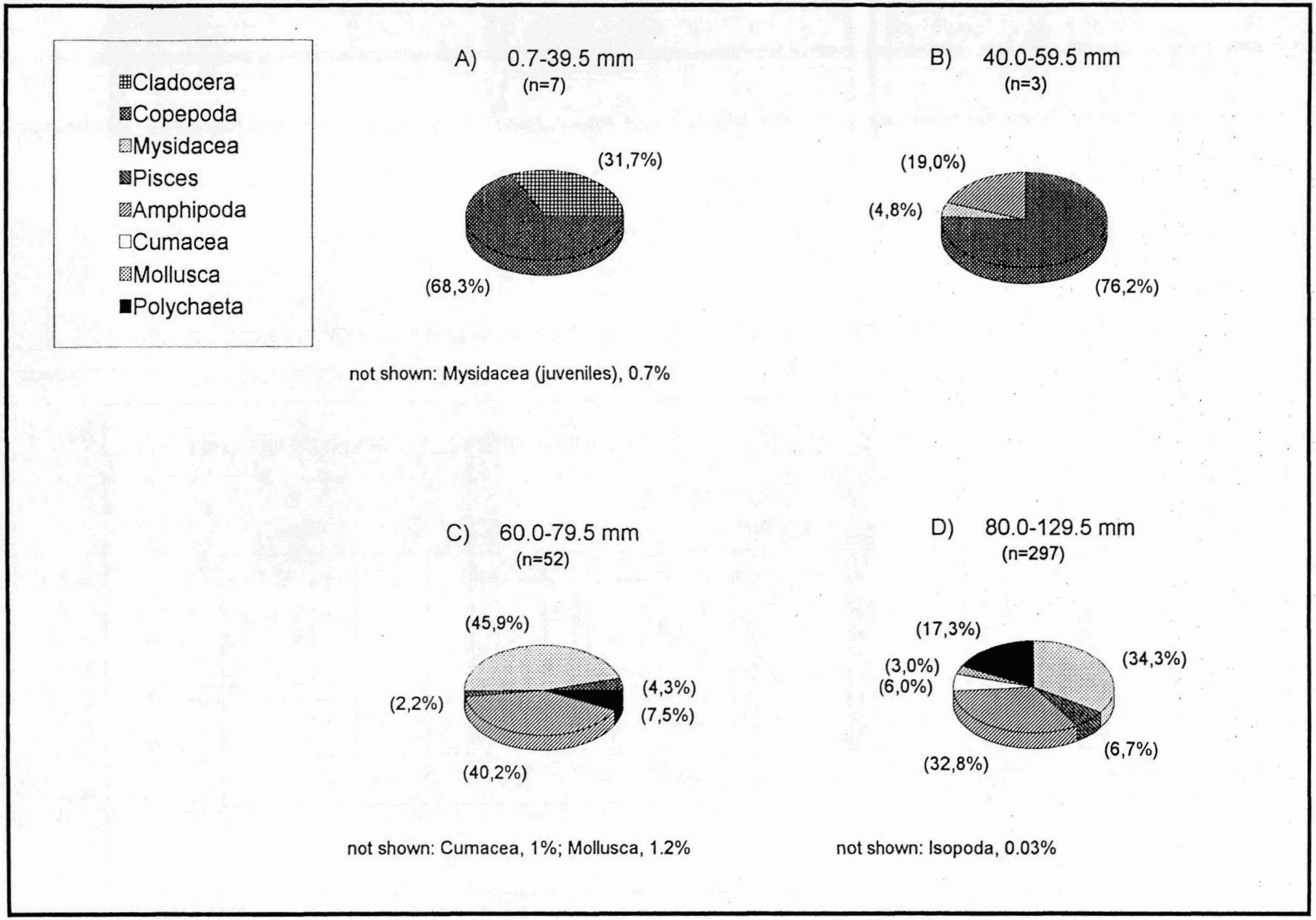

Figure 3.: Changes in Food resource utilization by Juvenile Baltic Cod in four size classes
Percent=Relative abundance of food items by numbers
Numbers in brakets= sample size