

Theme Session F

What plankton are fish really eating? Species and diets, availability and dependency

ICES CM 2006/F:01

Application of the Wisconsin bioenergetics model to Georges Bank and Gulf of Maine Atlantic cod populations

Ivan Mateo

Several authors state that foraging conditions and food web dynamics may be contributing to declines in Atlantic cod stocks. Therefore, it is essential to take a food web perspective to understand the complicated array of potential interactions affecting marine populations. The widely used Wisconsin bioenergetics model uses an energy-balance approach calculated on a daily time step, which allows for a fine-grained analysis of trophic interactions over various time scales. Bioenergetics modelling syntheses have been made for many important fishes within the Great Lakes. However, few have been developed for the US Northeastern Continental Shelf.

Growth performance of Georges Bank and Gulf of Maine Atlantic cod during the year 2004 was examined using bioenergetics modelling to synthesize information on their trophic dynamics. Growth efficiency, which incorporates daily growth and consumption rates, was used as a measure of growth performance. Overall growth performance for Atlantic cod was significantly lower at Georges Bank than in the Gulf of Maine. Monthly individual consumption demand and specific growth rates for Atlantic cod were significantly higher on Georges Bank than in the Gulf of Maine. Increasing water temperatures, which approached the upper limits of thermal tolerances for cod on Georges Bank, led to decreasing growth efficiencies for cod. Temperatures and energetic content of diets were less variable in the Gulf of Maine, which generated more consistent growth efficiencies.

Keywords: Bioenergetics, Atlantic cod, feeding ecology.

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ICES CM 2006/F:02

Perch and herring – different feeding strategies in early life history?

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The semi-enclosed NE part of the Gulf of Riga (Pärnu Bay) is a unique reproduction area for several marine and

freshwater fishes. The relatively limited area and timing of spawning causes the spatial and temporal overlap of the larval phase of many species.

However, herring, *Gobiidae*, and perch larvae dominate in larval communities. The study of feeding of perch and herring larvae was performed in May–July 2004 and 2005. Perch larvae started active external feeding at a length of 4 mm, i.e. clearly prior to complete utilization of the yolk sack (at app. 7 mm). The food consists mainly of different stages of copepod *Eurytemora affinis*, but includes also cladocerans and *Bivalvia* larvae. With increasing length, the share of copepod nauplii in the food decreases gradually and after yolk utilisation, the prey consists mostly of copepodids and adults.

The herring larvae also started to feed at the yolk-sac stage (at 6 mm), when the prey consisted mostly of copepod nauplii. The general trend of a decrease in small-sized food during larval growth was similar in both cases. However, the perch tend to switch to bigger (and more diverse) food items much earlier and faster – almost at 5 mm. Also, the average fullness of stomachs was essentially higher in perch (60% in perch vs. 30% in herring).

This may indicate that the feeding strategy of perch and herring larvae might be somewhat different: perch larvae tend to be more opportunistic with respect to prey while the prey composition for herring larvae largely depends on prey size, i.e. the adult feeding strategy seems to develop already in early life stages. The temporally shorter dependence on spatially patchy and highly versatile prey as copepod nauplii may provide perch larvae with an advantage in larval food competition.

Keywords: perch, Baltic herring, larvae, food composition, feeding strategy.

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ICES CM 2006/F:03

Food composition of herring larvae in the Vistula Lagoon (southern Baltic Sea): impact of hydrological factors and changes in zooplankton community structure

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The Vistula Lagoon plays a very important role as a spawning ground for herring (*Clupea harengus*) in the southern Baltic Sea.

First-feeding herring larvae depend on *Eurytemora affinis* nauplii and younger copepodites. Subsequently, within two or three weeks, *E. affinis* copepodites IV–V and adults become the main food for fast-growing larvae. During that time the mean biomass of food items is increasing rapidly. Then, during late spring, herring larvae start to feed on less favourable groups, e.g. rotifers, and the mean biomass of food items is decreasing – it is a consequence of considerable change in zooplankton composition, i.e. decrease of larger copepod species and increase of rotifer abundances.

Chesson's index was used to calculate the selectivity of larvae for their prey. In 1998 larvae at length class 10–14 mm strongly selected for all *E. affinis* copepodites stages and adults; at length class 15–19 mm selectivity shifted towards *E. affinis* copepodites IV–V and adults, and then at length 20–24 mm also *Diaphanosoma brachyurum* started to be positively chosen. The largest larvae (24–29 mm) selected for *D. brachyurum* and Cyclopoida copepodites IV–V and adults. The general selectivity pattern for 2004 was very similar, but *D. brachyurum* was selected by the largest class only.

This general pattern was additionally affected by year-dependent differences in temperature regimes and changes in zooplankton community structure. The impact of these differences and changes in the food composition of herring larvae is described and discussed.

Keywords: food composition, herring larvae, zooplankton, Vistula Lagoon, Baltic Sea.

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ICES CM 2006/F:04

Long-term dynamics of capelin feeding in the Barents Sea and factors determining it

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Long-term data on capelin feeding are used to study the dependence of capelin feeding on stock size and structure, distribution pattern and food supply in the cold

(1976–1982) and warm (2001–2004) periods. Special attention is paid to size- and age-related features of capelin feeding associated with food abundance and availability, duration of feeding, and food competition. It is shown that capelin prefer larger food objects which do not always dominate in plankton. It is concluded that capelin feed most efficiently (reaching up to 12–18% fatness) on the abundant, especially in warm years, food resources of the northern Barents Sea, including Arctic species of larger copepods (*Calanus glacialis*, *Calanus hyperboreus*) which are characterised by a high content of lipids.

Keywords: *Calanus glacialis*, *Calanus hyperboreus*, capelin, distribution, food supply, stock.

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ICES CM 2006/F:05

Zooplankton fatty acid composition in the Baltic Sea: spatial and interspecific variation

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Changes in salinity and proceeding eutrophication have caused major changes in the Baltic Sea ecosystem during the last three decades. The phytoplankton community structure has shifted from a diverse community towards a simpler one, and marine copepods have been replaced by species favouring lower salinity and a more eutrophic environment. Simultaneously, the weight-at-age of the Baltic herring has declined. To investigate the hypothesis that the growth of Baltic herring can be affected by the nutritional value of their food, we determined fatty acid (FA) composition of zooplankton species in the Gulf of Finland, Gulf of Bothnia, and the Baltic Proper in summer 2002. Four abundant zooplankton species (*Acartia bifilosa*, *Eurytemora affinis*, *Temora longicornis*, and *Bosmina longispina*) and three stations from the Baltic Proper were selected for more detailed analysis, and environmental variables, such as salinity, temperature, nutrients, chlorophyll *a*, and phytoplankton species composition, were used to explain variation between the species and areas. Within each station, there were no significant differences in the amounts of the most important FA's between the species. Instead, differences between the stations were significant, which implies that the FA composition of the zooplankton species is not fixed, but rather reflects the feeding history of each species. We therefore suggest that, while changes in the zooplankton community probably influence the growth of planktivores via the amount of ingested carbon, the changes in the lower trophic levels (phytoplankton and microzooplankton) influence the growth of Baltic planktivores by affecting the nutritional quality of their zooplankton food.

Keywords: Baltic Sea, zooplankton, fatty acid composition, food quality.

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ICES CM 2006/F:06

Feeding of 0-group herring *Clupea harengus* (Linné) in the Barents Sea

Irina Prokopchuk

0-group herring was sampled in the Barents Sea in August–September 2002–2005 during the 0-group survey and trawl acoustic survey of pelagic fish, as well as during the trawl acoustic survey of demersal fish in November–December 2003. The diet of 0-group herring was found to consist of 28 food organisms of 8 phyla. The most frequently occurring food of juvenile herring in August–September were Copepoda, Cladocera, larvae of Bivalvia and Cirripedia, while adult and larval euphausiids and *Calanus finmarchicus* were predominant by weight. In November–December, juvenile herring fed mainly on large euphausiids, pteropods, and *Metridia longa*, but the portion of euphausiids by weight was the greatest. A dependence of food composition on fish length was revealed. *C. finmarchicus* dominated in the diet of herring smaller than 60 mm, while fish larger than 60 mm consumed mainly euphausiids. The prevalence of certain food in the diet of herring, in particular of smaller fish, indicates that plankton species predominate in that period.

Keywords: Barents Sea, diet, 0-group herring, zooplankton.

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ICES CM 2006/F:07

Small-scale variability in fish diet and whether or not this reflects local patterns of prey availability

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Predation patterns in whiting, gurnard, haddock, mackerel, plaice and lesser-weeverfish have been studied at two small (20 × 33 km²) grids in the central North Sea differing in terms of the availability of sandeels and the intensity of sandeel fishing. Concurrent sampling of zooplankton, benthos, and sediments at the two sites means that it is possible to examine which ‘explanatory variables’ (e.g. predator size, benthos, zooplankton, sediment, depth, fishing, hydrography, etc.) are most impor-

tant in determining diet composition and whether or not diet reflects local patterns of prey availability. Diet differs markedly between the two sampling grids and there were also clear statistical differences in the diversity, species composition, and biomass of benthic invertebrate fauna and zooplankton, even though the sites were separated by only 28 km.

Keywords: Dogger Bank, sandeel, benthos, zooplankton, predation, prey availability.

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ICES CM 2006/F:08

What herring and sprat can eat in the Baltic Sea and what they should eat: species and diets, daily rations and food demands?

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The research of herring and sprat feeding in the Gdansk basin, carried out in 1992–2005, evidenced considerable changes in the food species composition of herring and sprat in the late 20th–early 21st centuries, resulting from a reorganization of the zooplankton community in the Baltic Sea ecosystem on the one hand, and high trophic plasticity of fish on the other hand. Under the existing conditions of Pseudocalanus deficiency, mysid reduction caused by water freshening and warming, and at retention of fish rations level, the increase of Acartia and the macro-zooplankton proportion was observed in herring diets, as well as an increase in the proportion of eggs, larvae, and juvenile fish, especially in the years of strong sprat year classes. The importance of *Cladocera* and *Temora* increased in sprat feeding. Estimates of individual diurnal rations for sprat and herring are presented, obtained with the exponential model of food digestion based on the results of 24-hour trawl stations. These ration estimates are compared to the food demands of fish, assessed using the equation of energy balance and taking into account available data on the energy density of different plankton species. In many cases bioenergetic estimates of food demands appeared much higher than diurnal rations estimated *in situ*, which may indicate a low food supply. Different scenarios of the optimal foraging are discussed with reference to the simulation of fish somatic growth.

Keywords: Baltic Sea, sprat, herring, plankton, diet, daily rations, food demands, somatic growth.

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ICES CM 2006/F:09

Influence of the small pelagic fish on the structure and functioning of the planktonic food web on the continental shelf of the Bay of Biscay

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Along the continental shelf of the Bay of Biscay, pico- and nanophytoplankton start to develop in spring right after the winter diatom bloom. Early in the season, the planktonic food web is therefore dominated by microbial organisms and the production is mainly production. The dissipation of carbon through respiration is high. The available amount of carbon to export towards superior trophic levels such as pelagic fish depends on the structure of the planktonic food web (number of links, quantity of carbon dissipated by heterotrophic respiration, etc.). The description of the food web functioning is therefore essential for a better comprehension of the links between the plankton and the superior trophic levels. On the continental shelf of the Bay of Biscay, small pelagic fish such as anchovy, sardines, or mackerels are zooplankton predators. The goal of this study is to understand the influence of the predation by small pelagic fish on the functioning of the planktonic food web (top-down control) as well as the effect of the dynamics of the planktonic food web on the nutrition of small pelagics (bottom-up control). To approach this question, we used data on plankton and small pelagics coming from the same oceanographic cruise (May 2001). A model of the planktonic food web at steady state had already been developed using the inverse analysis method. In this present study, the model is accommodated to account for predation by pelagic fish (anchovy, sprat, sardine, Atlantic horse mackerel, and Atlantic mackerel). The properties of the coupled plankton-fish model are analyzed.

Keywords: small pelagic fish, planktonic food web, Bay of Biscay, inverse analysis.

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ICES CM 2006/F:10

Feeding of Atlantic salmon (*Salmo salar* L.) post-smolts in the Northeast Atlantic

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Stomach samples from 1384 Atlantic salmon, collected from 1991 to 2003 in the Northeast Atlantic, were analysed to fill the gap between studies on post-smolt diet in fjords and coastal areas of the Northeast Atlantic and studies on the diet of pre-adults and adults in the Norwegian Sea. The post-smolts fed largely on 0-group fish. Blue whiting was an important prey only in the slope current transporting the larvae from the spawning areas west of the United Kingdom into the North and Norwe-

gian Seas. Sandeel and herring were important or present in the stomachs throughout most of the area studied. Unusually large quantities of 0-group herring in the Norwegian Sea in summer 2002 coincided with a high condition factor of post-smolts that year. The forage ratio of the post-smolts was positively related to the proportion of herring in the stomachs and the abundance of herring recruits. Despite these findings, the most productive period for Atlantic salmon on record, the 1970s, coincided with the collapse of the Norwegian spring-spawning herring, which raises the question as to whether herring is more important as a competitor than as a food source. Hyperiid amphipods were more important prey than krill, in contrast to the situation for other pelagic fish species.

Keywords: Atlantic salmon, diet, ecology, feeding preference, northeast Atlantic, wild salmon.

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ICES CM 2006/F:11

Evidence of niche segregation between mesopelagic fishes (*Myctophidae* and *Gonostomatidae*) and larval and juvenile Japanese anchovy from their gut contents and the diurnal vertical migration of prey zooplankton

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Food competition with mesopelagic fishes has been assumed to affect survival during early life stages of pelagic fish in Kuroshio-Oyashio Transition Zone (KOTZ) of the western North Pacific. Gut contents of dominant larval and juvenile fishes (Japanese anchovy *Engraulis japonicus* and 8 mesopelagic fish species) were analyzed from the samples caught by a frame trawl (MOHT, 5 m² opening, 1.59 mm square mesh size) in KOTZ in 2001 and 2002. Feeding habits were compared by the volumetric ratio and body width frequency of gut content items, and both of them were considerably different between anchovy and mesopelagic fishes. Larval and juvenile anchovy fed mainly on small copepods of mostly less than 0.4 mm in body width, but the gut contents of mesopelagic fishes had much greater size variations.

Differences in the vertical distribution of prey copepods were also analyzed between day and night. Small copepods (< 0.4 mm in body width) had similar vertical distribution patterns irrespective of the time of the day, while large copepods (> 0.4 mm) had considerably different patterns. The density of large copepods was 20-fold higher during night-time than during daytime in the 30-m surface layer. It was suggested that mesopelagic fishes migrate and forage in the surface layer during night-time, but possibly selectively feed on large mesopelagic zooplankton migrating at the surface layer concurrently. On the other hand, anchovy feed during daytime, but the density of large zooplankton was so low

during daytime that anchovy would not feed on them selectively at the surface layer.

Keywords: food competition, larvae, juvenile, Japanese anchovy, mesopelagic fish, feeding habit, prey size.

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ICES CM 2006/F:12

Feeding ecology of Atlantic mackerel (*Scomber scombrus*) in the Norwegian Sea: Diet, prey selection and possible food competition with herring (*Clupea harengus*) in different water masses

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Previous studies on Atlantic mackerel feeding during the migratory summer period are scarce. Here, we present detailed diet analyses and investigations of prey selection for Atlantic mackerel in relation to zooplankton distribution and hydrographical conditions in the Norwegian Sea during summer 2004. Stomachs of mackerel and herring were related to zooplankton samples and hydrographical data at 21 stations. Each station was assigned to one of the following water masses; 1) Coastal, 2) Atlantic, or 3) Arctic. The highest mackerel catches were taken in Arctic water masses, and these fish were significantly larger and older than mackerel from the other areas. Mackerel distributed in Atlantic water had the highest average condition factor, corresponding to a large zooplankton biomass in these water masses. A wide variety of prey organisms were found in the stomachs of mackerel in all water masses. According to dry weight *Limacina retroversa* was the principal prey of mackerel in Coastal and Atlantic water, whereas *Calanus finmarchicus* was important in all water masses. Mackerel showed a significant size-selective feeding behaviour and preferred large copepodite stages (IV–VI) of *C. finmarchicus*. Pronounced prey and size selection strongly suggest that mackerel performed particulate feeding. There was a clear difference in the diets of mackerel and herring, where *C. finmarchicus* and *L. retroversa* were the main prey of mackerel, while herring preferred euphausiids and amphipods, species that normally stay in deeper waters. Mackerel is less tolerant to lower temperatures than herring, and these physiological constraints could explain the pronounced differences in the diet.

Keywords: Atlantic mackerel, diet, prey selection, Norwegian Sea, *Limacina retroversa*, *Calanus finmarchicus*, inter-specific competition, Coastal water, Atlantic water, Arctic water.

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ICES CM 2006/F:13

Assessment of the diets of cod and whiting larvae in a frontal region close to the Norwegian trench: co-existence or competition?

Michael Shaw, Rabea Diekmann, Peter Bromley, David Righton and Steve Milligan

Frontal regions are important hydrographic features that enhance the primary and secondary productivity of the North Sea and cause the aggregation of planktonic organisms, including fish larvae. As part of the EU-LIFECO project, we analysed the zooplankton prey availability and stomach contents of over 200 0-group cod (*Gadus morhua*) and whiting (*Merlangius merlangius*) sampled in spring 2001 at stations inside and outside of a frontal region close to the Norwegian Trench. Whiting larvae appeared to feed on a more diverse subsample of the zooplankton community, whereas cod larvae appeared to preferentially select *Pseudocalanus* spp., even when these prey items were not the dominant component of the prey community. Our results show that whiting and cod are direct competitors for zooplanktonic prey. In addition, because they are more opportunistic, whiting larvae may be more robust to changes in the species composition of the prey community, and therefore out-compete cod larvae at times of low preferred prey abundance or under changing environmental conditions.

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ICES CM 2006/F:14

Do gadoids really prefer *Calanus*? The prey selection through metamorphosis in Irish Sea cod (*Gadus morhua*), haddock (*Melanogrammus aeglefinus*) and whiting (*Merlangius merlangus*)

William Ll. Rowlands, Mark Dickey-Collas, Audrey J. Geffen, and Richard D. M. Nash

Calanus is thought of as a preferred prey of gadoids in many seas. The Irish Sea is an area of known low *Calanus* and highly variable abundance. Diets of cod, haddock, and whiting were studied throughout development from the yolk-sac to juvenile stage. The study centred on changes in the diet through metamorphosis; a poorly studied development stage. Prey items in the stomach contents were analysed and compared to their natural abundances in the environment via an index of prey preference.

Cod, haddock, and whiting all selected nauplii at the onset of feeding (late yolk-sac stage), as expected, with little difference between species. As the larvae developed the prey preferences changed as small-sized copepods (especially Pseudo/Paracalanus) were selected. Cod and

whiting showed a similar transition of prey species preference. In both cases there was a clear preference for *Calanus* post-metamorphosis, above all other species of copepod. The diet composition in haddock differed to cod and whiting in that nauplii remained in the diet later into development and there was little preference for individual copepod species. It was concluded that Irish Sea cod and whiting were dependent on *Calanus* abundance in the Irish Sea, but haddock had a considerably different diet composition at a comparable developmental stage.

Keywords: gadoid; preference; prey; development; larvae.

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ICES CM 2006/F:15

Zooplankton-fish interactions in the Gulf of Finland, Baltic Sea: Results from the open sea cruises 2004–2005

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The pelagic ecosystem of the northern Baltic Sea has changed during the past few decades. Salinity has declined, eutrophication has proceeded, and populations and growth rates, as well as survival, of pelagic fish, such as herring, sprat and salmon have fluctuated. This has been suggested to have been caused both by changes in competition between clupeids, and by changes in food availability.

We conducted two open sea cruises in 2004 and 2005, studying the distribution, abundance and behaviour of plankton and fish in the Gulf of Finland, with some sampling also conducted on the easternmost Baltic Proper. Application of two vessels, RV “Aranda” and RV “Muikku”, ensured intensive sampling on several biological, chemical and physical variables. The fish abundance and distribution were determined with echosounding and trawling, and environmental factors and zooplankton species and abundances were sampled with traditional methods as well as continuously measuring devices.

Variance partitioning methods were used to analyze the interactions between fish abundance, plankton communities and environmental variables. Stomach contents of fish were analysed and compared with the ambient zooplankton composition. Also, distribution of cyanobacteria blooms was taken into account in the analysis of fish and zooplankton distribution.

The present study aims at relating trends in the feeding ecology of pelagic fish in the northern Baltic to the ambient food supply, i.e. composition and size of the zooplankton community.

Keywords: zooplankton, stomach analysis, selectivity, Baltic Sea, spatial distribution, Cyanobacteria.

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ICES CM 2006/F:16

Does gape matter: Prey size selection of cod (*Gadus morhua*), haddock (*Melanogrammus aeglefinus*) and whiting (*Merlangius merlangus*) larvae to juveniles

William Ll. Rowlands, Mark Dickey-Collas, Audrey J. Geffen, and Richard D. M. Nash

The size composition of the diets of cod, haddock, and whiting were studied throughout larval development to beyond metamorphosis. This provides valuable insight as very few previous studies have looked at the prey size selection in juvenile gadoids immediately post-metamorphosis.

As found by other investigators, cod, whiting, and haddock selected prey of a similar size at the onset of feeding (late yolk-sac stage). As development and growth progressed, haddock continued to select a small size of prey further into development compared to cod and whiting. However, haddock also took the largest prey size post-metamorphosis, which lead to the most rapid increase in prey size with development. The gape size and utilisation of gape size, pre-metamorphosis was similar between all three species. However, post-metamorphosis haddock utilised a far greater proportion of the gape potential to attain prey in comparison to cod and whiting.

This study shows that the difference in the prey size selection strategy of haddock compared to cod and whiting continues through metamorphosis and is maintained into the juvenile stage. This mechanism may reduce inter-specific competition for food between these closely related gadoid species in areas where they co-occur.

Keywords: gadoid; size; prey; development; larvae; selection.

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ICES CM 2006/F:17

Diet composition and feeding behaviour of Iberian sardine (*Sardina pilchardus*)

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Spatial and temporal variability in feeding intensity and diet composition of Iberian sardine was investigated through analysis of fish collected fortnightly during 2003 from the fishing ports of Peniche and Portimão (NW and S Portugal, respectively). Data on stomach content mass was used to investigate feeding intensity, diet composition was examined via microscopic examination of stomach contents, and the determination of dietary importance was assessed by calculation of the carbon content of ingested prey. In both areas sardine feeding intensity was highest during spring and second highest during winter.

Copepods (mainly *Euterpina*, *Oncaea*, *Centropages*, *Temora*, and *Acartia*) and fish eggs (especially at Portimão) contributed the bulk of dietary carbon. The higher relative occurrence of these species in stomach contents compared to the ambient food environment corroborates results from previous laboratory experiments that showed that sardine are able to feed selectively, preferentially ingesting fish eggs when fed cultured, mixed prey assemblages, and selecting copepods and decapod larvae when fed wild zooplankton assemblages. The numerical predominance of prey <200µm (particularly dinoflagellates and chain-diatoms) suggests that filter-feeding is the dominant feeding mode used by sardine in the wild. Laboratory experiments showed that sardine are able to filter-feed on nanoplankton as small as 4µm, and that filtration efficiency increases from 20% for prey of this size to close to maximum for prey >200µm. Temporal variability in remotely-sensed chlorophyll *a* appears to match temporal variability in the phytoplankton portion of sardine diet, indicating that satellite data could be used to proxy sardine dietary composition.

Keywords: *Sardina pilchardus*, feeding, phytoplankton, zooplankton.

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ICES CM 2006/F:18 – Withdrawn

ICES CM 2006/F:19 – Withdrawn

ICES CM 2006/F:20 – Poster

Observations on *Trachurus trachurus* diet and zooplankton community structure at two locations off the Portuguese coast

Maria Manuel Angélico, Marta Silva, Fátima Quintela, and Susana Garrido

During a campaign in February 2006, a series of observations aiming at describing the diet of *Trachurus trachurus* were carried out at two locations off southwest and southern Portugal. Sampling was undertaken, throughout the day, by bottom trawling and the fishes from a sub-sample were weighted, measured, and classified for maturation and fat content. The stomachs were extracted and preserved, frozen for analysis in the laboratory. Concurrently plankton samples were collected using Isaacs Kidd Midwater trawl, Bongo and WP2 nets; while characterization of the water column with respect to temperature and salinity was achieved by CTD profiling. Results on the zooplankton community structure are presented and the composition of prey items in the stomachs discussed in relation to ambient zooplankton availability.

Keywords: *Trachurus trachurus*, feeding, zooplankton, southwestern Iberia.

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ICES CM 2006/F:21 – Poster

Prey selection of early juvenile cod (*Gadus morhua* L.) in the Barents Sea

Kristin Helle

From 1977 through 1991 the Institute of Marine Research (IMR) conducted an annual early juvenile survey in June and July along the coast of northern Norway and in the western Barents Sea. The main purpose of these surveys was to generate an index of abundance for the early juvenile fish with particular emphasis on early juvenile cod (here defined as fish 2–3 months old). In 1989, zooplankton samples were also collected at 161 trawl stations during the period 2–23 July. These stomach and zooplankton samples were analyzed both quantitatively and qualitatively and various methods to estimate prey preferences were applied. Based on these analyses, it appears that early juvenile cod select the largest copepodite stages (IV and V) of *Calanus finmarchicus*. Capelin larvae were also found in the stomachs but no correlation between the abundance of capelin in the sea and in the stomachs was established.

Keywords: early juvenile cod, zooplankton, *Calanus finmarchicus*, prey selection.

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ICES CM 2006/F:22– Poster

Daily feeding patterns and feeding rates of copepod *Limnocalanus macrurus* in the Bothnian Sea (Baltic Sea)

Gunta Aispure

The large calanoid copepod *Limnocalanus macrurus* species inhabit deep big lakes and brackish water bodies. The copepod lives in the open and deepest parts of the Baltic Sea. Because of its comparatively large size the species is an important fish prey and plays a significant role in the Baltic Sea ecosystem. The present study was performed in October 2005 in the Bothnian Sea open station to ascertain *Limnocalanus macrurus* feeding rates – gut clearance rate coefficient, ingestion rate, daily ration – and daily vertical migrations related to reproduction and feeding intensity. *Limnocalanus macrurus* adult vertical migration behaviour in the autumn could be connected to reproduction as it coincides with the reproduction time of the monocyclic copepod and also with feeding characteristics. Sampling was done at the Bothnian Sea station at 125-m depth every 3 hours during the day and night above, inside, and below the thermocline layer. It was found that adults avoid migrating above the thermocline layer, notwithstanding that the temperature bound was at a profound depth – about 55–75 m. To derive information about *Limnocalanus macrurus* feeding ecology the aspects of feeding rates were examined.

Keywords: *Limnocalanus macrurus*, feeding.

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ICES CM 2006/F:23 – Poster

Interspecific feeding relationship between *Pomatoschistus microps* and *Pomatoschistus minutus*, two sympatric co-existing goby species from the Gulf of Gdańsk (Southern Baltic)

Ilona Złoch and Mariusz R. Sapota

The aim of the study was to estimate feeding strategy, prey importance, and food niche overlapping between the closely-related common and sand gobies.

The study was carried out in inshore waters of the Gulf of Gdańsk from summer 2001 to spring 2003. The samples were taken at two stations, Sopot and Chałupy, using hand trawl. The diet data were analyzed in terms of frequency of occurrence, quantity, and weight of prey in gobies stomachs. They were presented as “index of rela-

tive importance” (IRI) introduced by Pinkas *et al.* (1971) and expressed on a percent basis as mean values for all investigated time. Relationship between frequency of occurrence, quantity, and weight of prey were analyzed according to the Costello method (Costello, 1990) modified by Cortes (Cortes, 1997). Food niche overlapping was calculated from formulas given by Morisita (Horn, 1966), Renkonen (Hurlbert, 1978) and Horn (Krebs, 1989). Obtained results underwent cluster analysis.

Pomatoschistus microps feeding was more homogenous in terms of diversity of consumed preys than *Pomatoschistus minutus* feeding. In summer and autumn 2001, the diet of the sand and the common gobies seems to present a similar generalized feeding pattern of *Neomysis integer*, Amphipoda, none Copepoda eggs and Harpacticoida. In spring 2002 and summer 2002 the most important prey items for both gobies were *N. integer* and *B. pilosa*. In autumn 2001 the common goby specialized in none Copepoda eggs and in spring 2003 specialization towards Polychaeta and *N. integer* in terms of weight was observed for the sand goby.

The most important prey items for both gobies during the investigated time were *N. integer* and *B. pilosa*. The trophic niche significantly overlapped between gobies in autumn 2001, spring 2002, summer 2002, and spring 2003, which confirms a close similarity in feeding strategy for most of the investigated seasons. The examined gobies may be considered as generalists in their food choice with significant (>60%) overlaps during the investigation time.

Keywords: feeding habits, gobies, trophic niche overlap, Gulf of Gdańsk.

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ICES CM 2006/F:24 – Poster

Predation of mesopelagic fish in Faroese waters

Súni Lamhauge

Mesopelagic fish (lanternfish, pearlsides, and white baracudina) is not important as prey on the Faroese shelves and Faroe Bank. Only a few mesopelagic fish were found in stomachs of cod, haddock, and Greenland halibut (19 of 10.882 stomachs). Conversely, salmon and saithe feed on lanternfish of the Faroese shelf and of the Faroe Bank. In total 3949 salmon stomachs and 5386 saithe stomachs were analyzed in Faroese waters. Four percent of the analyzed saithe and 12% of the analyzed salmon had fed on lanternfish. The predators that had fed on lanternfish were caught on the shelf and on the Faroe Bank (86% of the saithe and 100% of the salmon). When the saithe was divided into areas, 10% had eaten lanternfish on the shelf and 2% had fed on lanternfish on the shelf and Faroe Bank.

White barracudina, which mainly occurs below 200-m depth was preyed upon by saithe (6.7%) and salmon (2.4%) on the shelf and Greenland halibut on the Faroe shelf (4%).

Pearlsides, which mainly occur in the epipelagic zone, were common prey for saithe on the shelf (2%) and Faroe Bank (1.8%) and for salmon on the shelf (12%).

Saithe that were caught relatively close to bottom fed on lanternfish more often and one saithe had eaten 27 lanternfish, while the cod that feed in the same area and depth as saithe preferred to feed on blue whiting.

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ICES CM 2006/F:25 – Poster

Ontogenetic dietary shift and feeding strategy of *Raja undulata* in the Portuguese continental shelf

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The understanding of trophic relationships is fundamental to characterize the ecosystem and propose adequate management actions. The increasing levels of landings of *Raja* spp. in mainland Portugal, makes it essential to improve the knowledge of this group of species, which are considered vulnerable to exploitation and which have an important role in the marine food webs. Stomach contents of *R. undulata* specimens caught in the Portuguese continental shelf were analysed. Identification of prey items was made to the lowest possible taxonomic level and dietary indexes were applied to quantify prey importance. Dietary ontogenetic shift was investigated using multivariate analysis. Availability of prey items in the same geographic area and time period was also investigated using data from research surveys. The smallest specimens were caught in estuaries and fed mainly on small crustaceans, particularly decapods, amphipods, and euphausiaceans. Larger individuals had a narrow diet spectrum, consuming mostly the decapod *Polydora henslowi*. Teleosts were not frequent and occurred in stomachs of specimens from all length ranges. Although most of the prey identified was benthic, mesopelagic organisms were also found, which indicates an active predatory capacity. Ontogenetic shift of *R. undulata* goes from generalised to specialised diet. In contrast to other Rajidae, the transition from a crustacean to a piscivorous diet is not evident, which suggests a well-defined ecological position of this species in coastal communities.

Keywords: diet, dietary ontogenetic shift, Portuguese continental shelf, *Raja undulata*.

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ICES CM 2006/F:26 – Poster

Variability in dominant prey types of larval and juvenile stage striped bass in strong and poor recruitment years

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Recruitment strength of anadromous striped bass (*Morone saxatilis*) in Chesapeake Bay varies >20-fold among years. Recent research has been directed at biophysical controls and biological constraints in the dynamic estuarine transition zone that affect survival and growth during the larval and juvenile stages. Diet analyses of larval and juvenile striped bass revealed differences in dominant prey between strong and poor recruitment years. The copepod *Eurytemora affinis* is important prey of larvae in most years, while the cladocerans *Bosmina longirostris* and *Daphnia* spp. are only important in strong recruitment years. Similarly, epibenthic amphipods are important prey of juveniles in most years, while the mysid shrimp *Neomysis americana* attains importance in poor recruitment years. Patterns and variability in diets are driven by weather and climate during the larval stage, especially precipitation and freshwater flow into the estuary which control plankton community structure and abundance. In the juvenile stage, abundance of striped bass and resulting density-dependent competition for preferred prey types affect diets and regulate growth. Recruitment of age-0 juvenile striped bass (approximately 150 days post-hatch) is positively correlated with freshwater flow and the abundance of cladocerans that serve as prey for larval-stage striped bass. And, environmental conditions associated with the strongest recruitment levels support enhanced production of prey for both larval and juvenile-stage striped bass. Striped bass is an important component of the Chesapeake Bay from ecological and economic perspectives. Results of this research are contributing to development of recruitment models and to ecosystem-level trophic modelling that account for variability in predator and prey dynamics in the Bay.

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