

## Theme Session T

### Death in the sea—Mortality in the zooplankton and early life stages of marine fish (estimates, processes, and outcomes)

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#### ICES CM 2009/T:01

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##### Improving confidence in copepod mortality estimates: choosing formulas and quantifying errors

W. C. Gentleman and P. Pepin

Estimates of copepod mortality rates from survey data are used to analyse trophic interactions, assess the importance of predation vs. advective losses, and specify model parameters. Accurate estimates are critical, and even small uncertainty in mortality can produce large uncertainty in predicted copepod population dynamics and production. The literature abounds with methods for calculating stage-dependent mortalities, each comprising a host of underlying assumptions that are not always evident. This makes it difficult to choose appropriate formulas or determine associated errors. Here, we provide researchers the means to improve confidence in their mortality estimates by conducting a quantitative analysis of different candidate formulas. We review the common vertical life table approach, and then explain its mathematical relationship with other steady-state equations. The effect of specific assumptions is quantified by comparison of mortality estimates for *Calanus finmarchicus* in the Northwest Atlantic using different estimation methods. An individual-based model of *C. finmarchicus* is then used to evaluate how these errors scale with those caused by violation of other assumptions (e.g. steady state). Finally, we make recommendations for types of field data that can be used to help reduce uncertainty in estimated mortality rates.

Keywords: mortality, vertical life table, IBM, copepods, *Calanus finmarchicus*.

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#### ICES CM 2009/T:02

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##### An evaluation of various models for the estimation of total mortality from length frequency distribution data confronted with seasonal variability in growth, recruitment, and mortality

Marc Hufnagl, Axel Temming, Volker Siegel, Ingrid Tulp, and Loes Bolle

Mortality determination in crustaceans and small fish is not always possible as a result of problems with age estimation. An alternative is length-based methods, but these are bound to specific basic assumptions and are only valid under non-seasonal conditions. In this study, the most commonly applied methods (Wetherall *et al.*, Powell, Beverton and Holt, Jones and Zalinge, Hoenig, Ssentongo and Larkin) as well as the seasonal and the non-seasonal length converted catch curve were critically evaluated with respect to their sensitivity against violation of the assumption of non-seasonality of growth, mortality, and recruitment. In addition we analysed the influence of variability in growth parameters between individuals. All methods were applied to artificially created length–frequency distributions of populations with seasonal variation in growth, recruitment, and mortality. The bias of the resulting  $\theta$  ( $Z/k$ ) and  $L_{\infty}$  from the input values was analysed. In general, all methods underestimated the real mortality and seasonality in recruitment particularly biased the results. The level of  $Z$  considerably influenced the results, whereas different  $L_{\infty}$  values only slightly altered the mortality estimates. In a species-specific approach, population-specific simulated length–frequency distributions of the brown shrimp (*Crangon crangon*) were created using available information on the seasonality of growth, recruitment, and mortality. The estimated bias from these simulations were used to interpret and correct mortality estimates based on field samples covering five decades.

Keywords: mortality, length-based methods, evaluation, Bertalanffy, maximum length.

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**ICES CM 2009/T:03**

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**Modelling rule-based behaviour: habitat selection and the growth–survival trade-off in larval cod**

T. Kristiansen, C. Jørgensen, R. G. Lough, F. Vikebø, and Ø. Fiksen

Environmental variation can cause significant fluctuations in the survival of larval fish and plankton. Understanding these fluctuations is critical for developing more accurate fishery models, which are needed for both scientific and socio-economic research. Growth, survival, and dispersal of marine planktonic larvae rely strongly on their behaviour. Larval fish change their vertical positioning because of strong vertical gradients in light, temperature, predation pressure, and prey availability. Here, we explore how various behavioural rules predict vertical distribution, growth, and survival of larval cod (*Gadus morhua*) in a numerical model. The rules determine the trade-offs between larval growth, feeding rate, and predation rate, including their dependence on gut fullness and body mass. We evaluated the survival through size classes for different rules and random behaviour and compared model predictions with observed larval distribution patterns. The rules predicted the correct average depth position with larval size, but failed to predict the timing of the observed vertical distribution pattern. However, model simulations revealed significant increases in survival for larval and juvenile cod with active behaviour compared with larvae with random behaviour. Behaviour was important across all sizes of fish, and this study illustrates the value of incorporating behaviour in biophysical models.

Keywords: behavioural heuristics, diel vertical migration, individual-based model, larval cod, trade-off.

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**ICES CM 2009/T:04**

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**Individual-based modelling of growth and survival of Atlantic cod and lesser sandeel larval and juvenile stages**

Zeren Gurkan, Asbjorn Christensen, and Henrik Mosegaard

The influences of prey/food availability and quality on the growth and survival of larval and early juvenile stages of Atlantic cod (*Gadus morhua*) and lesser sandeel (*Ammodytes marinus*) in the North Sea are studied using a generic individual-based model (IBM), where prey encounter and physiological processes are parameterized explicitly. Bioenergetic IBMs of larval and early juvenile cod and sandeel are formulated with particular emphasis on the responses to the local physical and feeding conditions, which are obtained from continuous plankton recorder (CPR) survey time-series data and hydrodynamic–biogeochemical models. IBMs are first analysed with typical environmental conditions to identify the survival windows and critical phases. They are then analysed with scenarios of climate change to assess the qualitative and quantitative differences in between in relation to: (i) the variations in spatiotemporal distribution and composition of the warm and cold water zooplankton; (ii) changes in physical conditions affecting feeding success and efficiency, and mortality from predation, caused by the changing meteorological forcing factors; (iii) direct and indirect effects of climate change that may shift fitness of alternative life-history strategies relative to each other, which may also lead to a regime shift in the ecosystem, constituting an optimal life-history analysis.

Keywords: individual-based model, bioenergetic, growth, survival, mortality, Atlantic cod, lesser sandeel, larva, juvenile, match/mismatch hypothesis, climate change.

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**ICES CM 2009/T:05**

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**Mortality of juvenile sandeel on the Faroe Shelf because of food limitation**

Kirstin Eliassen, Jákup Reinert, Eilif Gaard, Peter GrønkJær, and Jens Tang Christensen

On the Faroe Shelf, first-feeding larvae of sandeel (*Ammodytes marinus*) occur in late March and in April. Recruitment success of sandeel is, however, highly variable between years and here we investigate the recruitment success in relation to food availability. There are large interannual variations in the spring bloom onset and intensity on the Faroe Shelf, and this affects reproduction of zooplankton, and hence, feeding conditions and survival of early life stages of sandeel larvae. In the paper, we analyse data on phytoplankton, zooplankton, and stomach contents of sandeel larvae and juveniles, as well as time-series from sandeel 0-group surveys. The results confirm that survival of the early life stages of sandeel on the Faroe Shelf is highly dependent on the magnitude of the primary production, especially during the early spring bloom period. Sandeel is an important food source for higher trophic levels (e.g. seabirds, cod, and haddock). The established link between sandeel mortality and the spring bloom may therefore help to explain the previously found link between primary production and commercially important fish stocks on the Faroe Shelf.

Keywords: sandeel, Faroe plateau, mortality, phytoplankton, zooplankton, starvation

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**ICES CM 2009 /T:06**

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**Overwinter survival of larval herring in the northern North Sea can be related to food intake**

Susan Mærsk Lusseau, Emma M. C. Hatfield, Jens Rasmussen, Alejandro Gallego, and Mike R. Heath

The North Sea herring stock has experienced low recruitment since 2001 despite the presence of a large spawning-stock biomass. The primary cause is believed to be low survival of larvae in the overwintering period, although the underlying mechanisms are poorly understood. This study investigates feeding and parasite infection as potential causes for the poor survival. Herring larvae caught off the northeast of Scotland in February each year from 1995 to 2007 were dissected to identify and enumerate prey items and parasites in the alimentary tract. A biophysical model was used to simulate year-to-year changes in transport of herring larvae from known spawning grounds to the sampling area and used to quantify the relative contribution of advection and “true” mortality over the winter drift period. The prevalence of two parasite types explained a significant amount of the interannual variation in overwinter survival. Herring larvae infected with relatively benign tetraphyllidean parasites were found to have higher feeding success than larvae infected with digenean parasites. Digeneans are known to have a detrimental effect on herring larvae survival. Good feeding conditions, as indicated by a higher prevalence of tetraphyllideans, outweigh the detrimental effects of digeneans on survival. However, when feeding conditions are poor, incidence of digeneans further exacerbates the impact on survival. We conclude that variability in cumulative food intake over the lifespan up to February is a significant determinant of survival variability of herring larvae in the northern North Sea.

Keywords: herring larvae, overwinter survival, parasites, feeding incidence.

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**ICES CM 2009/T:07**

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**Live and let die—condition indices and starvation-induced mortality thresholds during the early life of marine fish**

Stefan Meyer, Helena M. Hauss, Philip Kanstinger, Myron A. Peck, and Josianne G. Støttrup

A number of techniques allow us to estimate the prevalence of starvation among individuals of early life stage marine fish in the wild. Highly sensitive nucleic acid and enzyme assays and image analysis of otolith microstructure are well documented and established methods. Recent

intercalibration studies between laboratory and field material have led to enhanced understanding of recruitment mechanisms. In this presentation we discuss the results of a suite of laboratory experiments calibrating otolith- (increment widths) and biochemical-based (nucleic acid ratios) condition proxies in larval stages of Baltic cod and sprat and larvae and juveniles of Atlantic herring that were reared under controlled laboratory conditions using different levels of abiotic (temperature, salinity, photoperiod) and biotic (prey levels) factors. Special emphasis is placed on quantifying temporal and interindividual variability in these condition proxies during starvation and comparing results obtained for larval and juvenile conspecifics. Threshold levels for irreversible starvation and rates of degradation can be approximated by means of biochemical condition indices and otolith increments. We provide an interspecific comparison to assess potential differences in prey requirements (leading to different life history strategies) and, thus, unsuitable habitats (those potentially leading to irreversible starvation and mortality) of early life stages of these three species.

Keywords: Baltic cod, Baltic sprat, North Sea herring, larvae and juveniles, starvation, condition, RNA/DNA ratio, otolith increments.

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### ICES CM 2009/T:08

#### **Modelling the sources of mortality for larval haddock on Georges Bank and their effects on behaviour**

Colleen M. Petrik, Rubao Ji, Cabell S. Davis, R. Gregory Lough, and Trond Kristiansen

Since Hjort postulated that year-class size is determined in the early life stage of fish, many studies have sought an understanding of the conditions that lead to high survival through the larval stage. Previous work has identified different sources of larval mortality through the match–mismatch, member–vagrant, ocean stability, downside of turbulence, washout, and predation hypotheses. Each of these hypotheses appears valid for larval stages of haddock (*Melanogrammus aeglefinus*). It is still unknown the degree to which each of these sources of mortality affects the survival of larval haddock on Georges Bank, and how their contributions change with climate variability. Interactions between feeding, growth, vertical behaviour, predation, and the oceanic environment of larval haddock on Georges Bank are quantitatively investigated here using individual-based models. Results are presented from experiments conducted with these models to identify the mechanisms that contribute to larval haddock mortality. In addition, the effects of starvation and predation mortality on the vertical swimming behaviour of larval haddock are discussed.

Keywords: Georges Bank, haddock, IBM, larval fish, mortality, vertical behaviour.

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### ICES CM 2009/T:09

#### **Cohort-specific mortality of black rockfish (*Sebastes cheni*) larvae and juveniles in the Seto Inland Sea: implications for conservation of seagrass and macroalgae habitats**

Jun Shoji, Hikari Kinoshita, Yasuhiro Kamimura, and Ken-Ichiro Mizuno

Black rockfish (*Sebastes inermis*) is a dominant component of fish fauna in vegetated habitats in temperate waters of Japan. Larval and juvenile rockfish immigrate to macroalgae (*Sargassum* spp.) beds in early March at a total length of 20 mm and then inhabit seagrass (*Zostera* spp.) beds through summer in the Seto Inland Sea. We tested the hypothesis that seasonal changes in the vegetation of coastal habitats affect mortality and production of the larval and juvenile rockfish and propose the importance of conservation of coastal habitats referring to the phenology of different types of vegetation (e.g. macroalgae and seagrass). Weekly physical and biological surveys were conducted from February to May 2008 in seagrass and macroalgae beds in central

Seto Inland Sea. Fish were collected with a dragnet (3-mm mesh) and were preserved in ethanol. Rockfish were divided into same hatch-date cohorts, each covering a 10-day extrusion period. Decrease in cohort-specific mortality rate with decrease in macroalgae biomass and results from mesocosm experiments suggested that vegetation acted as a predation refuge for rockfish larvae and juveniles. Mortality rates for fish <50 mm (macroalgae-dependent period: February–May) were higher than those for fish >50 mm (seagrass-dependent period: May–August). The macroalgae grow in winter and seagrass in summer in the temperate waters of Japan. Therefore, the coexistence of these two different types of vegetation within a small spatial scale can increase the accumulative survival rate of young-of-the-year rockfish from the post-immigration period (March) through summer in the Seto Inland Sea.

Keywords: rockfish, mortality, seagrass, macroalgae, conservation.

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### ICES CM 2009/T:10

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#### **Mortality schedules in the early life history phases of juvenile flatfish: European plaice (*Pleuronectes platessa*) as a case study**

Richard D. M. Nash and Audrey J. Geffen

The estimation of natural mortality in early life history stages of fish is difficult because the appropriate data are scarce. Many flatfish, and in particular, plaice (*Pleuronectes platessa*) have been extensively studied and much of the information and progress reported in a succession of international flatfish symposia. The study of mortality rates in the juvenile phase is made easier because the nursery grounds are inshore and generally less than 5 m deep. This contribution considers the factors affecting mortality rates from egg production through to the end of the nursery ground phase. The problems associated with estimating mortality rates, from experimental design to behavioural characteristics are highlighted. Examples include larvae residing close to the bottom in the latter stages of development, immigration in to nursery areas confounding losses through mortality, and emigration of larger individuals off nursery grounds in the latter part of an annual cycle. The shifts in mortality schedules and the causes through the early life history are investigated along with how they fit with concepts such as "nursery ground carrying capacity" etc. Finally, new and promising techniques for estimating mortality, understanding the processes, and areas where further study and/or understanding are needed are discussed.

Keywords: flatfish, plaice, mortality rates, early life history, egg, larvae, juveniles, pelagic, nursery grounds.

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### ICES CM 2009/T:11

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#### **The role of spatial processes in North Sea herring larval survival and recruitment**

Mark R. Payne, Asbjørn Christensen, Peter Munk, Richard D. M. Nash, and Mark Dickey-Collas

The North Sea autumn spawning herring stock consists of several substock components distributed along the east coast of Great Britain. In recent years, this stock, as a whole, has exhibited an unprecedented sequence of poor recruitment, despite simultaneously having a large adult population and historically low exploitation rates. The weak year classes arise as a consequence of poor survival through the larval overwintering period, between the end of the yolk-sack phase and metamorphosis. However, the mechanism responsible is, as yet, unclear. In this work, we reanalyse 25 years of extensive larval surveys through the use of an individual-based hydrographic advection model. We run the model in a backtracking mode to identify the most likely spatial and temporal origin of a particular larval observation, and then use this information to assign it to a component. By performing this exercise for every single larva observed in surveys performed both prior to and

after the overwinter period, it is possible to build up a picture of the annual larval survival rates of each component, and thereby identify any potential spatial differentiation in these processes. When combined with integrated information along the reconstructed drift trajectory (e.g. temperature, modelled plankton abundance), the patterns identified give us insight into the processes that drive both the survival of individuals from each component and the fundamental mechanisms causing the recent recruitment failure.

Keywords: North Sea herring, recruitment, individual-based modelling, survival.

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## ICES CM 2009/T:12

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### Size-dependent predation in piscivorous larval stages of three tuna species

P. Reglero, A. Urtizbera, Ø. Fiksen, I. A. Catalán, A. Pérez-Torres, and F. Alemany

The bluefin tuna (*Thunnus thynnus*) is a heavily fished temperate tuna that spawns in the Mediterranean Sea; the area off the Balearic Islands is a key spawning area. Other abundant tunas, including albacore (*Thunnus alalunga*) and the small bullet tuna (*Auxis rochei*) spawn in the same area. The three species temporally overlap during the summer spawning period of the adults. Because they are clearly piscivorous already at very early larval stages, we expect strong interactions both in terms of a direct predator–prey relationship and as competitors for food resources. In this study, we focus on understanding the size-dependent trophic interactions among the three species at the different developmental larval stages. First, we describe the environmental and biological scenarios where different size stages of the three species co-occur through the application of generalized additive model (GAM) analyses to field data collected during cruise surveys in 2004–2005. We then develop an individual-based model (IBM) to evaluate inter- and intraspecific predation rates considering size-structured prey and predator fields in the framework of piscivorous behaviour. The results demonstrate how predation mortality rates influence the spawning location of the three species.

Keywords: piscivorous, larvae, predation, tuna.

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## ICES CM 2009/T:13

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### Fate of reef fish larvae through ontogeny: advection or true mortality?

Claire B. Paris

The three-dimensional structure of *in situ* flow measured repeatedly for one month during two consecutive years in the coastal region of Barbados and synoptic sampling of larval cohorts of the bicolor damselfish was used to estimate larval transport within a small domain (15 km × 20 km × 100 m). Larval fluxes and observed declines in three-dimensional cohort densities were used to calculate age-specific instantaneous mortality rates throughout the entire pelagic duration. By tracking a total of 17 larval cohorts over station separations of 1 km × 2 km, we were able to separate advective losses from natural mortality rates, which were estimated at 0.38 d<sup>-1</sup> and 0.20 d<sup>-1</sup>, respectively. Both natural mortality rates and advective losses decreased with cohort age, the latter as a result of ontogenetic vertical migration. Differential retention rates in the near-field during the pelagic phase caused variations in age-specific survival rates of local settlers.

Keywords: larval fish, ontogeny, mortality, advection, *in situ* transport.

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**ICES CM 2009/T:14**

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**The successful and selective feeding of larval fish in the low-latitude open ocean: is starvation an insignificant source of mortality?**

Joel K. Llopiz and Robert K. Cowen

Historical interest in understanding the larval stage of high-latitude fish has provided extensive insight into feeding-related processes that can influence larval fish mortality. However, the feeding dynamics of larvae that occur in lower latitudes, especially those that primarily inhabit oceanic waters, is notably limited. From monthly sampling across the Straits of Florida (SOF) over two years, we acquired data on the feeding ecologies of 21 taxa of fish larvae in order to elucidate levels of feeding success, as well the degree to which this subset of the larval fish community relies upon specific zooplankton prey types. Larval taxa examined included billfish, tunas, mackerels, and seven families of coral reef fish. All but one taxon examined for gut contents (total  $n = 3138$ ) had feeding incidences near 100%. Additionally, gut evacuation was rapid and occurred in  $\sim 3$  h, indicating successful and frequent prey consumption. These observations, in conjunction with the fact that larvae withstand a nightly non-feeding period (10–14 h in low latitudes), point to the possibility that fish larvae in these waters experience low or even negligible levels of starvation mortality, although additional efforts specifically addressing this possibility are needed. Furthermore, diets of larvae were taxon-specific and often extremely narrow, illustrating very selective feeding among a high diversity of available zooplankton prey. Two notable characteristics of the diets of these larvae were high reliance upon appendicularians by several taxa and the prevalence of piscivory, which appears to be exhibited by over 30 species of scombroid larvae that occur in the SOF.

Keywords: fish larvae, zooplankton, feeding, diets, trophodynamics, starvation, mortality.

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**ICES CM 2009/T:15      Withdrawn**

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**ICES CM 2009/T:16**

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**Long-term seasonal and spatial patterns in mortality and survival of *Calanus finmarchicus* across the Atlantic Zone Monitoring Program region, Northwest Atlantic**

Stéphane Plourde, Pierre Pepin, and Erica Head

The Vertical Life Table method was used to estimate stage-specific daily mortality rates and survival from 1999 to 2006 for *Calanus finmarchicus* sampled in the Canadian Atlantic Zonal Monitoring Program (AZMP), which covers the Newfoundland Shelf (NLS), Gulf of St Lawrence (GLS), and Scotian Shelf (SS) regions. Stage-specific mortality rates and survival demonstrated significant regional and seasonal differences with the largest signal associated with variations in temperature. Density-dependent mortality, associated with the abundance of C6 females, was the predominant factor of mortality in the egg–C1 transition during the period of population growth in spring on the SS and in summer in the GSL and on the NLS. In autumn, mortality in egg–C1 was positively related to temperature and negatively related to phytoplankton biomass, with particularly high mortality rates occurring on the SS. The integration of our results into stage-specific recruitment rates from egg to C5 revealed that *C. finmarchicus* populations experience their greatest loss (mortality) during the egg–C1 transition. Loss during development to C1 was higher in the GSL than in other regions during the period of population growth, resulting in lower recruitment success in the GSL. In autumn, *C. finmarchicus* demonstrated low stage-specific daily recruitment rates on the SS at high temperatures and low phytoplankton biomass compared with those in the GSL and on the NLS. Our findings reinforce the necessity of describing regional and seasonal patterns in mortality and survival in order to understand factors controlling the population dynamics of *C. finmarchicus*.

Keywords: none.

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**ICES CM 2009/T:17      Poster**

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**Occurrence of *Ellobiopsis* spp. (Myzozoa) in copepods from the Russian waters of the South Baltic Sea**

Zhygalova Natalia, Semenova Anna, and Rodyuk Galina

The parasitic protists *Ellobiopsis* spp. (Myzozoa) occur in pelagic marine and freshwater copepods in various areas, including the Baltic Sea. Peculiarities of the distribution of these parasitic protozoa were researched for the purpose of revealing the probable influence of ellobiopsids on copepod populations in the Russian waters of the South Baltic Sea and Curonian Lagoon in 2007. In total, 278 zooplankton samples collected using a Juday net in the layer from 0 to 100 m (bottom) in the sea and 6-l Van-Dorn's bathometer in the Curonian Lagoon during February–October were investigated. It was found that copepods infected with *Ellobiopsis* spp. occurred in all areas during the entire study period. The maximum concentrations of infected copepods were observed in the sea and lagoon during the warm season, and the minimum concentrations were found during the cold season of the year. Copepods infected with *Ellobiopsis* spp. constituted the largest proportion in all populations of the species studied during the cold season and the lowest proportion during the warm season. The most abundant aggregations of infected copepods were recorded in the surface layer. The majority of infected copepods were alive. At the same time, the proportion of dead copepods with parasites was twice as high as those without parasites during the vegetation period, which is probably the result of the negative effect of these parasites on copepod vital capacity.

Keywords: Curonian Lagoon, *Ellobiopsis* spp., parasitic protists, South Baltic Sea, zooplankton.

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**ICES CM 2009/T:18      Poster**

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**Influence of cyanobacteria “blooming” on zooplankton in the Curonian Lagoon (the Baltic Sea)**

Anna Semenova, Sergey Aleksandrov, and Olga Dmitrieva

The Curonian Lagoon is the largest coastal lagoon of the Baltic Sea. Hydrobiological research (phytoplankton, primary production, chlorophyll) has been carried out every month from March to November during 2001–2008 at 12 stations. The impact of cyanobacteria “blooming” on zooplankton was investigated in the open area and coastal zone during 2007–2008. To estimate the proportion of dead specimens, zooplankton were painted with aniline blue dye. The Curonian Lagoon may be characterized as a hyper-eutrophic basin. Eutrophication affects all trophic levels, especially the development intensity of cyanobacteria, creating favourable conditions for “blooming” by toxic species (*Aphanizomenon flos-aquae*, *Microcystis aeruginosa*, *Planktothrix agardhii*). In 2001–2008 the primary production, chlorophyll concentration, and biomass of phytoplankton in summer were always at the level of “intensive blooming”, while during 2001, 2002, 2006, and 2008 it attained a “hyperblooming” state. The hyper-eutrophic conditions negatively affect the lagoon ecosystem, including zooplankton. Cladocerans are dominant in Curonian Lagoon; their biomass comprises on average 60–90% of the total zooplankton biomass. In the cyanobacteria “blooming” period the numbers of specimens with anomalies (tumours, etc.) and dead specimens increase. In summer the specimens with anomalies may constitute up to 90% of the total cladoceran abundance. During hyperblooming years, in particular during July–September 2008, the proportion of dead specimens (12–20%) of the total zooplankton biomass was 3–5 times higher than in the years when cyanobacteria development did not attain the hyperblooming state (2007).

The increase in the proportion of dead zooplankton specimens followed peaks of phytoplankton biomass and chlorophyll concentration with a delay of several weeks. The above considerations suggest the probable toxic impact of cyanobacteria on zooplankton in the Curonian Lagoon. It is possible that the increase of zooplankton mortality occurs either in the period of cyanobacteria decomposition, when toxins are released into the water, or during the accumulation of toxins consumed by the zooplankton with food.

Keywords: Curonian Lagoon, cyanobacteria blooming, eutrophication, zooplankton, mortality, toxic effect.

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## ICES CM 2009/T:19      Poster

### **Coupling a coastal three-dimensional hydrodynamic–biological model and an IBM to assess long-term effects of mesoscale variability on early life stages of European anchovy in the vicinity of the Gibraltar Strait**

I. A. Catalán, J. Solé, D. Macías, J. Ruiz, J. Tintoré, and B. Morales-Nin

Enrichment, production, retention, and dispersal of fish larvae are fundamental processes shaping essential fish habitats of pelagic species such as the European anchovy. Anchovy populations living in the vicinity of the Strait of Gibraltar dwell in coastal areas heavily influenced by the Atlantic Jet and with intense mesoscale variability. Historically, there has been a reduction in the anchovy population in the area, thought to be caused by the combination of human-induced pressure in an area of relatively localized spawning, together with changes in production processes. Having a localized nursery area is an advantage for conducting virtual experiments using individual-based models (IBMs) coupled to physical–biological models in an heuristic context. These exercises are rare in the Mediterranean but have proven useful in understanding processes governing fluctuations of early life stages of fish in numerous case studies worldwide. We present the first results of the coupling of a three-dimensional circulation model (ROMS, [www.myroms.org](http://www.myroms.org)) with an NPZD model to an IBM (through a modified version of Ichthyop, [www.eco-up.ird.fr/projects/ichthyop](http://www.eco-up.ird.fr/projects/ichthyop)) for the European anchovy that is being used to test the effect of variability in coastal physics and biology on the successful recruitment of the European anchovy.

Keywords: ROMS, NPZD, anchovy, larvae.

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## ICES CM 2009/T:20      Poster

### **Mortality and development during early life phases of Atlantic cod (*Gadus morhua*) in relation to paternity and water temperature**

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Water temperature is a key environmental factor influencing all processes in poikilothermic animals. Moreover, individual and family variation in the capacity to cope with water temperature variation may be pivotal to a population's adaptability to climate change. In the present study we focused on testing the effects of water temperature and family on egg mortality, hatching success, morphological development, and post-hatch performance. At the St Andrews Biological Station, gametes of one female and four male Atlantic cod (*Gadus morhua*) were crossed to produce four related families (half siblings). These four families were used to evaluate potential paternal contributions to early life characteristics at five temperatures (2, 4, 6, 8, and 10°C, respectively). Time until first day of hatch was inversely proportional to incubation temperature and ranged from 10 days post-fertilization (dpf) at 10°C to 26 dpf at 2°C. Duration of the hatching period was inversely related to temperature and sire effects were evident on the timing of hatch. Mean embryo mortality rate for the first 7 days post fertilization (families combined) was highest at 10°C and

mean hatching success was lowest at 10°C. Significant sire effects were exhibited for early mortality and hatching success. Highest variability among males for early mortality occurred at 4°C and for hatch rate at 6°C. Images of larvae on the first and fourth day post-hatch were recorded for morphological measurements and resistance to starvation was evaluated. Our results indicate that paternal effects can be instrumental in governing early life history responses to water temperature.

**Keywords:** cod, development, mortality, hatching success, egg, larva, paternity, temperature.

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