

Theme Session H

What do fish learn in schools? Life cycle diversity within populations: mechanisms and consequences

ICES CM 2009/H:01

Mechanisms and consequences of life cycle diversity of beaked redfish (*Sebastes mentella*)

Steve Cadrin, Matthias Bernreuther, Einar Hjörleifsson, Torild Johansen, Lisa Kerr, Kristjan Kristinsson, Stefano Mariani, Christophe Pampoulie, Jákup Reinert, Thorsteinn Sigurdsson, and Christoph Stranksy

Recent genetic research, supported by life-history information, indicates that there are three biological stocks of *S. mentella* in the Irminger Sea and adjacent waters: a “deep pelagic” stock (>500 m), a “shallow pelagic” stock (<500 m), and an “Icelandic Slope” stock. Throughout their range, *Sebastes* species are adapted to a diversity of ecological niches, with overlapping spatial distributions of different species that have little or no morphological differences. Divergence of behavioural groups into depth-defined adult habitats has led to reproductive isolation, adaptive radiation, and speciation of several *Sebastes* species. Congruent differences in fatty acid composition and parasites suggests that the three genetically distinct populations of *S. mentella* are adapted to disparate trophic habitats in pelagic waters (within and below the deep scattering layer), and in demersal habitats on the continental slope. Patterns of morphology are also consistent with adaptation to different habitats, because pelagic forms are more streamlined. Although genetic differences and evidence for reproductive isolation are clear, these populations appear to share common nursery habitats on the Greenlandic Shelf. Spatial overlap at early life stages and depth-defined adult populations present challenges for stock identification and fishery management. Effective resource monitoring, conservation, and fishery management require that the spatial definition of management units reflects biological stock structure. We describe a proposal for a redefinition of practical management units based on geographic proxies for biological stocks that minimize mixed-stock catches according to spatial patterns of the recent fishery.

Keywords: stock identification, redfish, *Sebastes mentella*.

Contact author: Steve Cadrin, NOAA/UMass CMER Program, School for Marine Science and Technology, 200 Mill Road, Fairhaven, MA 02719, USA [tel: +1 508 910 6358, e-mail: steven.cadrin@noaa.gov].

ICES CM 2009/H:02

Consequences of spatial structure and connectivity to productivity and persistence of local and regional populations

L.A. Kerr, S.X. Cadrin, and D.H. Secor

Understanding mechanisms of local and regional population persistence and the sustainability of productive fisheries is beneficial for effective fishery management. We describe a model framework to test hypotheses concerning the consequences of structure within populations and connectivity between populations to the productivity (spawning-stock biomass (SSB)), stability (variation in SSB), and resilience (time to rebuild SSB after disturbance) of the overall system (i.e. population or metapopulation). The generalized model is composed of linked age-structured models that incorporate the unique demographics and dynamics of population components, along with the degree and type of connectivity between them. We illustrate the flexibility of this framework with three case studies that examine consequences of: (i) spatial structure within an estuarine-dependent white perch population, (ii) different types and levels of connectivity between Atlantic herring populations, and (iii) spatial heterogeneity and connectivity within Northwest Atlantic cod populations. Relative abundance and degree of independent response to the environment of components were important determinants of system dynamics. Abundant, stable components and

asynchronous responses of components reduced variance within systems. Components with episodic productivity contributed disproportionately to resilience of systems. Increased connectivity between components increased synchrony of responses to environmental forcing, resulting in decreased productivity and stability of systems. Through simulations, this approach evaluates consequences of spatial structure and connectivity for persistence of populations and metapopulations and can be used to determine the appropriate spatial scale of management.

Keywords: population structure, connectivity, metapopulation, population persistence.

Contact author: Lisa A. Kerr, University of Massachusetts Dartmouth, School for Marine Science & Technology; PO 200 Mill Road, Suite 325 Fairhaven, MA 02719, USA [e-mail: lkerr@umassd.edu].

ICES CM 2009/H:03

Effects of source-sink dynamics on harvest policy performance for yellow perch in southern Lake Michigan

Michael J. Wilberg, Brian J. Irwin, Michael L. Jones, and James R. Bence

We used a spatially explicit stochastic simulation model to evaluate whether source-sink population dynamics would affect performance of alternative harvest policies for yellow perch (*Perca flavescens*) in southern Lake Michigan. The model contained four management areas in southern Lake Michigan representing each US state's waters. We parameterized the model such that all recruitment was produced by only one management area, considering each of the four areas to be the sole source in turn, and contrasted results with a base model where all areas produced recruits. We evaluated three types of harvest policies: constant- F , where fishing mortality was constant and two state-dependent policies where fishing mortality was constant above 40% and 70% of unfished spawning-stock biomass (B_0), and decreased to 0 at 0% B_0 . We used four performance statistics to evaluate policies: (i) average percentage of B_0 remaining, (ii) percentage of years with low spawning-stock biomass, (iii) average recreational harvest, and (iv) percentage of years with low recreational harvest. Performance of harvest policies differed predictably depending on which management area was the source because relative productivity of stock–recruitment relationships and growth patterns differed among source areas. Thus, if management areas on the western side of Lake Michigan were the source of most of the recruits, the fishery could support higher fishing mortality rates than if areas on the eastern side of the lake were sources. State-dependent harvest policies were less sensitive to assumptions about the source of recruits than were constant fishing mortality rate policies.

Keywords: *Perca flavescens*, stock–recruitment relationship, harvest control rules, density-dependent growth, metapopulation, spatial management.

Contact author: M. J. Wilberg, Chesapeake Biological Laboratory, University of Maryland Center for Environmental Science, PO Box 38, Solomons, MD 20688, USA [tel: +1 410 326 7273, fax: +1 410 326 7318, e-mail: wilberg@cbl.umces.edu].

ICES CM 2009/H:04

Fish escapement from fishing gears: the role of learning

Christopher Glass and Huseyin Ozbilgin

It has been long known that fish are capable of learning complex tasks. It has also been demonstrated that fish have good long-term memory retention, particularly when learning has been facilitated by response to aversive stimuli. For fish that encounter a fishing net, and that pass through the meshes of the netting, this could be considered a complex set of aversive stimuli and is likely to be a strong learning experience. For undersized fish in heavily fished areas, it is likely that fish encounter fishing nets on multiple occasions. If fish that have passed through the meshes of a fishing net are capable of escaping more easily on subsequent encounters, there may be important implications for the efficiency and selectivity of fishing gears in heavily fished populations. Here we report on the effect of learning on mesh escapement behaviour of haddock (*Melanogrammus aeglefinus*). Fish were trained using classical ethological conditioning techniques to race between

two alternately flashing light emitting diodes (LEDs) positioned at the ends of a 6-m-long experimental arena. Subsequently, the fish were presented, on a random basis, with netting barriers blocking their path. Fish quickly learned to race through the meshes, and once learned, the behaviour was demonstrated consistently. We present evidence that fish which encounter a trawl gear more than once may be capable of escaping more effectively on subsequent encounters and perhaps more importantly may help facilitate learned responses in naïve fish. We discuss these findings in relation to resilience of populations to varying fishing pressure.

Keywords: behaviour, learning, social facilitation.

Contact author: Christopher Glass, Northeast Consortium, University of New Hampshire, USA [tel:+1 603 862 0122, e-mail: chris.glass@unh.edu].

ICES CM 2009/H:05

Overwintering and the foraging predation risk trade-off

Mikael van Deurs, Asbjørn Christensen, Christina Frisk, and Henrik Mosegaard

The overwintering strategy is a common feature among fish from temperate to Arctic regions and yet the overwintering has never been studied in fish from the perspective of evolutionary ecology. In the present study our focus is the overwintering of sandeel (*Ammodytes* sp.) in relation to the conflicting concerns of foraging and avoiding predation. We construct an IBM model for sandeel that combines bioenergetics, environmental forcing, and overwintering behaviour. We then identify the timing of the overwintering that maximizes the net energy uptake divided by the probability of being eaten. Surprisingly enough, we find that the optimal timing is often independent of predation risk. We discuss the ecologically, evolutionary, and fishery-related consequences of this finding.

Keywords: adaptive behaviour, *Ammodytes* sp., fitness optimization, fishery-induced selection.

Contact author: Mikael van Deurs, National Institute of Aquatic Resources, Technical University of Denmark, Section for Population and Ecosystem Dynamics, Jægersborg Alle 1, Charlottenlund Castle, DK-2920 Charlottenlund, Denmark [e-mail: mvd@aqu.dtu.dk].

ICES CM 2009/H:06

Sexual selection, resource polymorphism and the evolution of partial migration: lessons from anadromous salmonids

Julian Dodson, Nadia Aubin-Horth, Véronique Thériault, and David Paez

Alternative life history tactics are common in fish and many cases involve resident and migratory lifestyles. The resident tactic may involve both sexes or be restricted to males. Disruptive selection favouring alternative tactics may arise from two different evolutionary mechanisms. On the one hand, alternative migratory tactics may be the result of sexual selection for alternative reproductive tactics that affect other aspects of life history, including resource exploitation. On the other hand, alternative migratory tactics may be caused by natural selection favouring divergence to exploit multiple niches which in turn affect reproductive tactics. Frequency-dependent selection plays a central role in maintaining alternative reproductive tactics and their associated migratory phenotypes. In cases where individuals exploit multiple niches, selection favours multiple phenotypes specialized for exploiting different niches and frequency-dependent selection is not expected to play a role. Based on anadromous salmonids, we provide evidence that these two mechanisms act differentially between males and females and may underlie the existence of two common gradients observed in partially anadromous salmonids: increasing residency with altitude or distance upstream, and increasing anadromy at higher latitudes. We also provide evidence that the step-like reaction norms that underlie alternative life history phenotypes are not consistent in time. Decisions to migrate based on growth rate are a function of age and may confound interpopulational and interspecific comparisons. Finally, the interplay between sexual selection for alternative reproductive tactics and natural selection for resource polymorphisms will determine

the degree of population genetic structure through its influence on reproductive isolation and gene flow.

Keywords: partial migration, frequency-dependant selection, resource polymorphism, population divergence.

Contact author : Julian Dodson, Département de biologie, Université Laval, Québec, Canada [tel: +1 418 656 3289, e-mail: julian.dodson@bio.ulaval.ca].

ICES CM 2009/H:07

Has cumulative habitat destruction and fragmentation caused systematic deviations from the expected interspecific occupancy–abundance relationship of Georges Bank fish?

Daniel E. Duplisea, Michael Frisk, and Verena Trenkel

Following on from previous work examining the occupancy–abundance (OA) relationships of Georges Bank fish, we focus on the temporal trends in the residual pattern on the expected community OA relationship. Previous work demonstrated that the OA slope tended to decrease over time whereas the quality of the relationship broke down. We further found that deviations from the expected OA were positive in the early part of the time-series (1960s) and negative in the latter part of the series (1990s onwards). We used various methods for transforming and fitting the OA relationship, including model-free smoother approaches, and this pattern persisted. It has been suggested in bird studies that changes in the way birds colonize and occupy habitats and, subsequently, time-trends in OA relationships are strongly affected by habitat destruction and fragmentation, which are relatively easily quantified in terrestrial environments. We do not have similar habitat information for Georges Bank but we suggest that changes in the OA relationships of fish may reflect similar phenomena.

Keywords: occupancy–abundance, habitat fragmentation, extirpation, population recovery.

Contact author: Daniel Duplisea: Fisheries and Oceans Canada, Institut Maurice-Lamontagne, 850 route de la Mer, Mont-Joli, QC, Canada G5H 3Z4 [tel: 1 418 775 0881, fax: 1 418 775 0740, e-mail: Daniel.Duplisea@dfo-mpo.gc.ca].

ICES CM 2009/H:08

The long-term autumn-spawning/winter-spawning component proportions in the Celtic Sea

C. Harma D. Brophy, and M. Clarke

The herring population to the south of Ireland in the Celtic Sea consists of autumn and winter spawners. These are assessed and managed together and are exploited by the same fleets. Long-term changes in key biological parameters have been documented by several authors. It was hypothesized that long-term variations in the spawning components could explain some of these trends. The aim of this study was to elucidate the relative abundance of autumn spawning and winter spawning per ICES division in the Celtic Sea (i.e. VIIj, VIIg, and VIIa South). Biological sampling data of catches (1958–present) were analysed. Catches were assigned to seasonal spawning components based on the stage of development of their gonads at the time of sampling. This allowed for classification of catches into autumn, winter or unknown spawning season. The results revealed that although in VIIj (western area) autumn spawners dominated specially during the 1990s period, whereas winter spawners appeared as a major component in VIIa South (the more eastern area), and VIIg (the middle area) had a mixture of these latter components. In addition the trends over time by ICES Division and spawning component were analysed. These results highlighted the long-term variability of spawning season in the different Celtic Sea areas, providing explanations about potential factors influencing the inherent biological parameters of the stocks, ensuring life cycle diversity over time.

Keywords: long-term dynamics, herring stocks, Celtic Sea, spawning season component, life cycle diversity.

Contact author: Clémentine Harma, Commercial Fisheries Research Group, Galway-Mayo Institute of Technology (GMIT), Dublin Road, Galway, Ireland [tel: +353 917 424 81, e-mail: clementineharma@aol.fr].

ICES CM 2009/H:09

Mechanisms that sustain life cycle closure in space and time

Pierre Petitgas and Dave Secor

Experience has demonstrated that the recovery of collapsed fish stocks takes place over long periods of time, and much longer than can be predicted by traditional fishery population models. It is here hypothesized that the collapse of a fish stock is associated with the disruption of biological mechanisms that sustain life cycle closure in space and time. Based on a review of case studies, we argue that stock collapses not only entail loss of biomass but key structural elements related to life cycle diversity (e.g. stock components, spawning units, contingents) that contribute to stability and resilience. A list of mechanisms is identified that are necessary to model how these structural elements can contribute to recovery of depleted populations. It is argued that models need to be spatially explicit and incorporate behavioural interactions among population components. Simulations are used to evaluate how behavioural mechanisms among population components influence stock recovery patterns.

Keywords: collapse, recovery, behaviour, life cycle diversity.

Contact author: Pierre Petitgas, IFREMER, Dept Ecologie et Modèles pour l'Halieutique, rue de l'île d'Yeu, BP21105 cedex3, 44311 Nantes, France [tel: +33 240 374163, fax: +33 240 374175, e-mail: pierre.petitgas@ifremer.fr].

ICES CM 2009/H:10

An update on Harden Jones' Migration Triangle

D. H. Secor

A first principal in fishery assessment is life cycle closure. In the seminal argument for life cycle closure, "Fish Migration", Harden Jones reviewed migration patterns of diverse species and found that they could be generalized as a simple triangular pattern between spawning, nursery, and adult habitats. Less well recognized was Harden Jones' critical articulation of ideas and controversies related to minority life cycle behaviours. Here, I provide updates on these "exceptions to the rule" for case study species including, (i) ecological traps due to maladaptive life cycles (European eel), (ii) parent stream theory (bluefin tuna), (iii) adoptive homing (Atlantic herring), and (iv) partial migration (Atlantic cod). I highlight some common approaches for addressing the consequence of minority behaviours as they relate to population and metapopulation stability and persistence.

Keywords: partial migration, natal homing, biodiversity, portfolio effect, storage effect.

Contact author: David H. Secor, University of Maryland Center for Environmental Science, Chesapeake Biological Laboratory, Solomons, MD 20688, USA [e-mail: secor@cbl.umces.edu].

ICES CM 2009/H:11

Establishment of new wintering areas in herring co-occur with peaks in recruit to spawner ratio

Geir Huse, Anders Fernö, and Jens Christian Holst

During late summer, Norwegian spring-spawning herring migrate to wintering areas, where they remain for about five months in dense aggregations. First-time spawning cohorts typically adopt the overwintering area of the spawning stock. However, during the last 50 years the stock has occupied seven discrete wintering grounds, spanning from high seas to narrow fjords, which reveals considerable plasticity in choice of wintering area. We here show that changes in herring wintering area take place when abundant recruit cohorts appear. The ratio in abundance between four year olds and five year and older herring is on average 14:1 in the years when changes in wintering area take place, compared with 0.3:1 in years without changes. The wintering areas vary greatly with regards to temperature and distance to the feeding and spawning grounds, features that affect energy expenditure heavily. The total migration distance of the stock has been quite

stable in the last 15 years, but in the preceding period the stock had a shorter total migration distance. Rather than being strictly optimized, the establishment of wintering areas seems to be governed by general school cohesion mechanisms with the transmission of learned migration routes disrupted if the first-time spawners are too numerous.

Keywords: herring, migration, wintering.

Contact author: Geir Huse, *Institute of Marine Research, Box 1870 Nordnes, N-5817 Bergen, Norway* [e-mail: geir.huse@imr.no].

ICES CM 2009/H:12

Blue travellers: basin-scale connectivity of bluefin tuna and blue marlin in the American Mediterranean

Jay R. Rooker, David H. Secor, R. David Wells, and Richard T. Kraus

Here, we report on the role of the Gulf of Mexico as an essential fish habitat for bluefin tuna and blue marlin, and examine the basin-scale population connectivity of these species. Data from several complementary approaches were used to characterize connectivity within and outside the basin at early life to adult stages. Catch data and transport models support the assertion that the Gulf of Mexico is a spawning habitat for bluefin tuna and blue marlin, and hot spots of productivity in the northern Gulf of Mexico represent essential spawning areas for both species. Until recently, the Gulf of Mexico was considered to be a “pit stop” for adult bluefin tuna and blue marlin; however, electronic tagging and otolith chemistry data indicate that the migratory pathways of both species are more complex than was thought and are linked to the Gulf of Mexico. For bluefin tuna, residency times of adults are limited and directed movements out of the Gulf of Mexico occur after spawning. A significant fraction of the population moves across the Atlantic, with a large proportion of the subadult bluefin tuna in the US Atlantic originating in eastern spawning grounds. Movement becomes more limited at the onset of maturity and natal homing is well developed. In contrast, movement of blue marlin out of the Gulf of Mexico is lower than that of bluefin tuna and retention within this basin is relatively high, with a large proportion of the blue marlin population overwintering in the region. Even though retention is high, movement within and outside the Gulf of Mexico occurs and basin-scale movements of both species are influenced by size/age and oceanographic conditions.

Keywords: bluefin tuna, blue marlin, population connectivity, movement.

Contact author: Jay R. Rooker, *Texas A&M University, Department of Marine Biology, 5007 Ave U, Galveston, Texas 77551, USA* [e-mail: rookerj@tamug.edu].

ICES CM 2009/H:13

Discrepancies between population genetic structure and adult migration patterns in cod (*Gadus morhua*) and whiting (*Merlangius merlangus*): evidence of entrainment?

Grégory Charrier

Whiting and cod are two closely related gadoids, sharing the same grounds in northern European waters as well as most of their life cycle features. Many studies have investigated the level of mixing of adults in both species for more than one century, using a wide spectrum of methods such as tagging experiments, parasitic tags, otolith analysis, meristics, and morphometrics. This large quantity of data is particularly valuable in evaluating the migration patterns of adults and detecting homing behaviour, but it does not allow us to draw any conclusions about the natal origins of the fish and thus to discriminate natal homing from entrainment. In the last decade, several studies have depicted the population genetics structure of cod and whiting in the Northeast Atlantic, providing useful information about the extent of gene flow between populations through the passive drift of eggs and larvae or the active migration of adults. Population genetic structure and adult migration patterns displayed substantial discrepancies, and the purpose of this talk is to review all these discrepancies reported in the literature for cod and whiting. The comparison of

gene flow and adult migration patterns in both species offers a very interesting opportunity to disentangle natal homing from entrainment.

Keywords: cod, whiting, *Gadus morhua*, *Merlangius merlangus*, genetic structure, migration, gene flow, natal homing, entrainment.

Contact author: Grégory Charrier, University of Göteborg, Department of Marine Ecology, Tjarnö Marine Biological Laboratory, Sweden [tel: +46 0526 686 32, e-mail: gregory.charrier@marecol.gu.se].

ICES CM2009/H:14

Could ecotype variation have stacked the deck for harvest selection in Newfoundland cod?

Graham D. Sherwood, Matthew J. S. Windle, Jonathan H. Grabowski, and George A. Rose

It is becoming increasingly evident that humans have a disproportionate capacity to alter natural populations of organisms not only in terms of abundance and distributional shifts, but also with respect to life history traits, leading to what has recently been called harvest selection and rapid evolution. Atlantic cod (*Gadus morhua*), in particular, have undergone major population declines in most parts of the North Atlantic and this collapse appears to have been preceded by an abrupt decrease in age at maturity for Newfoundland cod. Here, we provide evidence that this apparent directional selection may have been facilitated by previous adaptive divergence by cod to exploit different components of the foodweb (putative movement and feeding ecotypes) which in turn implicates other life history traits, including age at maturity and possibly vulnerability to offshore fishing. Through a coupled stable isotope and acoustic telemetry approach, we were able to resolve feeding and movement variants (benthic inshore residents vs. pelagic offshore migrants) in cod that differed in their use of a common spawning habitat (Placentia Bay, Newfoundland), interspawning (feeding) movements, and reproductive strategies. These results are consistent with life history (i.e. ecotype) variations demonstrated in other fish species and suggest that post-collapse changes in cod biology could be a function of changes in the relative frequency of ecotypes.

Keywords: Atlantic cod, life history, ecotype, resident, migrant, stable isotope, maturity, telemetry, Newfoundland.

Contact author: Graham D. Sherwood, Gulf of Maine Research Institute, 350 Commercial Street, Portland, ME 04101, USA [e-mail: gsherwood@gmri.org].

ICES CM 2009/H:15

Atlantic cod (*Gadus morhua*) alternate life history strategies in the Gulf of Maine

Jonathan Grabowski and Graham D. Sherwood

Atlantic cod are known to exist as different colour morphs (red vs. normal). The basis for the red colouration has been suggested to be genetic as well as a plastic response to local diets high in pigments and the habitats in which they reside. Here we present findings from Cashes Ledge, a shallow feature about 70 miles offshore in the Gulf of Maine, and coastal Maine demonstrating coexistence of the two colour morphs. Roughly equal proportions of both colour morphs were sampled by gillnet and hook and line from the centre of the Cashes Ledge closed area (closed to fishing) and ledges off the coast of Maine. We will present data demonstrating substantial differences between the morphology, diet, habitat use, and growth rate of the two colour morphs. Our findings support the hypothesis that colour morphs occupy distinct ecological niches: red cod appear to be more resident in shallow water kelp beds on ledges in the Gulf of Maine, whereas normal cod appear to be more transient and demonstrate weaker habitat associations. Our data suggest that red colour in cod is a consequence of a specific life history strategy associated with certain habitats (e.g. resident in kelp beds), is likely a fixed trait, and may be considered as a basis for future conservation strategies.

Keywords: cod, morphometrics, life cycle diversity, ecotypes.

Contact author: Jonathan H. Grabowski, Gulf of Maine Research Institute, 350 Commercial Street, Portland, ME 04101, USA [tel: +1 207 228 1628, e-mail: jgrabowski@gmri.org].

ICES CM 2009/H:16

Modelling and simulations of the migration of pelagic fish

A. Barbaro, B. Einarsson, B. Birnir, S. Sigurðsson, H. Valdimarsson, Ó. K. Pálsson, S. Sveinbjörnsson, and Þ. Sigurðsson

We applied an interacting particle model to the Icelandic capelin stock to reproduce the spawning migration route for three different years, successfully predicting the route for 2008. Using available temperature data and approximated currents, and without using artificial forcing terms or a homing instinct, our model was able to reproduce the observed migration routes from all three years. By means of a sensitivity analysis we identified oceanic temperature and the balance between the influence of interaction among particles and the particles' response to temperature as the control parameters most significant in determining the migration route. One significant contribution of this paper is the inclusion of orders of magnitude more particles than similar models, which affects the global behaviour of the model by propagating information about surrounding temperature through the school more efficiently. In order to maintain the same dynamics between different simulations, we argue a linear relationship between the time-step, radii of interactions, and the spatial resolution, and we argue that these scale as $N^{-1/2}$, where N is the number of particles.

Keywords: collective motion, fish migration, Icelandic capelin, interacting particle model, *Mallotus villosus*.

Contact author: B. Einarsson, University of Iceland [tel: +354 692 9493, fax: +354 525 4632, e-mail: baldvine@hi.is].

ICES CM 2009/H:17 Poster

Environmental factors affecting the daily catch levels of glass eels (*Anguilla japonica*) in the Geum River estuary, Korea

Sun-Do Hwang, Tae-Won Lee, and Il-Su Choi

The daily variation in glass eel catch was analysed in relation to environmental factors affecting the upstream migration. The glass eels were first caught in the Geum River estuary in early March 2003, when the water temperature exceeded 5°C. The catch rates revealed a peak in mid March, when the temperature reached 6–7°C. Few glass eels were caught when the temperature reached over 14–16°C in early May. Water temperature triggered the timing of the immigration of glass eels. The catch fluctuated with tidal cycle as the catch level was high during the new and full moon throughout the sampling period. As a result of a significance test using the generalized additive model (GAM), the glass eel catch was significantly related to tidal range ($p = 6.2^{-4}$), temperature ($p < 2.2^{-16}$), and salinity ($p = 4.2^{-2}$). To estimate minor effects such as salinity and windspeed on catch rate, we calculated the standardized residuals of catch rate. These did not show any correlations to the freshwater inflow and cloud cover but were increased 2–3 days after the decrease in salinity or after strong winds, indicating that these factors may additionally trigger the upstream migration of glass eels in the estuary.

Keywords: glass eel, *Anguilla japonica*, estuary, daily catch, environmental factor.

Contact author: Sun-Do Hwang, West Sea Fisheries Research Institute, National Fisheries Research and Development Institute (NFRDI), 707 Eulwang-dong Goong-gu Incheon, 400-420 South Korea [e-mail: sdhwang@nfrdi.go.kr].

ICES CM 2009/H:18

Phenotypic selectivity of fishing

Anna Kuparinen, Sakari Kuikka, and Juha Merilä

Behavioural and life history traits can affect fish vulnerability to a particular fishing gear. Consequently, fishing can shape the phenotype distributions and, potentially, induce evolutionary changes in fish life histories. Here, we focus on identifying traits under selection by commonly applied fishing gears. To relate phenotypic selectivity of a fishing gear to fisheries-induced changes in phenotypic distributions in fish populations, we sketch a mathematical link between gear selectivity curve and phenotypic mortality applicable to predict magnitude of phenotypic shifts expected under alternative fishing gears, gear combinations, and fishing intensities. The approach is illustrated by a simulation example tailored for the Baltic cod (*Gadus morhua*). From the point of view of “evolutionally sustainable” fisheries, our analyses suggest that large shifts in phenotypic distributions generated by fishing might at least partly be avoided by allocating fishing effort between gears with differing (or opposing) selection patterns.

Keywords: fishing, *Gadus morhua*, life history, phenotype, selection, selectivity, trait.

Contact author: Anna Kuparinen, Department of Biological and Environmental Sciences, PL 65, 00014 University of Helsinki, Finland [e-mail: anna.kuparinen@helsinki.fi].

ICES CM 2009/H:19 Poster

Morphological markers and the population structure of Icelandic cod

B.J. McAdam, T.B. Grabowski, and G. Marteinsdottir

Recent genetic studies of Atlantic cod (*Gadus morhua*) around Iceland demonstrate that what has traditionally been considered as a single stock demonstrates a diverse population structure. Behavioural studies of adult cod using data-storage tags have also demonstrated different classes of behaviour (coastal vs. frontal feeding) within geographic regions. These two aspects of diversity within the population are linked, as the frequency of the B allele at the *pantophysin* (*Pan I*) locus is greater in the fish that exhibit frontal feeding behaviour. We had an opportunity to photograph freshly caught adult cod from several spawning sites around Iceland in spring 2008. The same fish were genotyped at the *Pan I* locus. Several differences in shape were found between fish from different locations, and between different *Pan I* genotypes. Although it was not possible to directly observe the behaviour of the photographed fish, this evidence strongly suggests that Icelandic cod which behave differently also look different. Some of the morphological differences can be easily measured on fish in market condition, and may provide a means to estimate the proportion of each genotype and behavioural pattern in the catch. This work demonstrates that the diversity within the cod population around Iceland has consequences for morphology as well as genetics and behaviour. It further reinforces the view that diversity in behaviour maintains distinct subpopulations of cod. It also suggests that morphology may be a tool for assigning commercially caught fish to substocks.

Keywords: morphology, cod, *Gadus morhua*, population structure, behaviour, genetics.

Contact author: B. J. Adam, University of Iceland, Sturlugata 7, 101 Reykjavik, Iceland [e-mail: bruce@hi.is].

ICES CM 2009/H:20 Poster

Assessment of ovary condition of Antarctic toothfish (*Dissostichus mawsoni*; Nototheniidae) from the Ross Sea

Piyanova Svetlana, Andrey Petrov, and Nikolay Kokorin

The results of an analysis of ovary conditions in Antarctic toothfish (*Dissostichus mawsoni*) caught in December–February in the Ross Sea in 2005–2006 are presented. The study is a part of complex investigation of the life history of this fish species in different areas of the Antarctic. The Antarctic toothfish is the most valuable target species in Antarctica. Its reproductive potential is an important mechanism of population resilience for exploratory fisheries. The morphological parameters, weight, and indices of female gonads are described and histological criteria for the assessment of the ovary maturity stages and cytological parameters of oocytes and type of toothfish oogenesis are determined. The oocytes in the ovaries of analysed fish did not reach the maximum size;

consequently in the Ross Sea Antarctic toothfish were not mature enough for spawning during the investigation period.

Keywords: Antarctic toothfish, reproductive potential, maturity, oogenesis.

Contact author: S. V. Piyanova, Russian Federal Research Institute of Fisheries and Oceanography (VNIRO), 17 V. Krasnoselskaya, Moscow 107140, Russia [tel: +7 499 2649176, fax: +7 499 2649187, e-mail: pjanova@vniro.ru].

ICES CM 2009/H:21 Poster

Characteristics schools of Peruvian anchovy during the summer months 2003–2008

Salvador Peraltilla, Ramiro Castillo, Luis Vásquez, and Andrés Chipollini

During an acoustic assessment to estimate Peruvian anchovy numbers we obtained a high volume of information on shoals of anchovy and oceanographic information such as temperature, salinity, and oxygen. Summer evaluations cover much of the distribution of anchovy in the schools close to the coast because of the entry of warm water. This study considered the period between the years 2003 and 2008 and analysed 87 872 schools of anchovies that had been previously observed, identified, and classified using image-processing methods, composition catch, and other characteristics. Anchovy schools were analysed with regard to positional, morphometric, energy, environmental, and biological aspects. The results reveal that most anchovy shoals approach the coast in compact schools, with very high acoustic energy, very superficial, and preferably in the coastal cold waters (CCW) and also in the mix between the CCW and the subtropical superficial waters (SSW). The young anchovy in particular favour the mix between the CCW and the SSW, where there is a proliferation of organisms associated with the dynamics of water masses (convergence). This contributes to the juvenile and small anchovy having a greater chance of feeding.

Keywords: schools, Peruvian anchovy, acoustics, coastal cold waters, subtropical superficial waters, mixing waters.

Contact author: Salvador Peraltilla, IMARPE, Esquina Gamarra y Gral. Valle s/n Apartado 22, Callao, Lima, Perú [e-mail: speralt@imarpe.gob.pe].

ICES CM 2009/H:22 Poster

Inner fjords and shelf break canyons: spawning habitats for the southern hake (*Merluccius australis*) and hoki (*Macruronus magellanicus*) in the Chilean Patagonia

Leonardo R. Castro, Nicolas Alegría, Pamela Barrientos, Jorge Castillo, Mauricio Landaeta, Sergio Lillo, María I. Muñoz, Edwin Niklitscheck, A. Saavedra, and M. Sobarzo

The southern hake (*Merluccius australis*) and hoki (*Macruronus magellanicus*) are demersal species whose landings have been decreasing during recent years in Chile. They have been reported to reproduce in midwinter down to 200–600 m in three canyons between 43°S and 47°S off the Patagonian shelf. Ichthyoplankton studies carried out recently, however, have found large numbers of eggs at the shelf break and also in some Patagonian fjords and channels. In this study we report the horizontal and vertical distribution of eggs and larvae of both species in inshore and offshore Patagonian waters during winter and spring. Our results reveal a latitudinal range for eggs and larvae of both species wider than that previously reported for their adult spawning zones. Eggs and larvae of both species occurred in inshore and in offshore waters. Egg sizes also differed between areas. For both species an increase in larval length occurred from the inner fjords towards the outer (offshore) areas of the channels, suggesting seaward transport. Although surface hydrographic characteristics in inshore and offshore areas differed (inshore waters are colder, less saline, more stable, and contain smaller zooplankton than offshore waters), the deeper waters (>150 m deep) were more similar between areas. Because eggs of both species occur deep or along the water column in inshore waters, inshore spawning may be a secondary, smaller, reproductive habitat in some years. The relative importance of inshore spawning over the entire spawning season through the years, however, remains to be determined.

Keywords: alternative spawning habitats, hake, egg differences, Patagonia.

Contact author: Leonardo Castro, Laboratorio de Oceanografía Pesquera y Ecología Larval (LOPEL). Departamento de Oceanografía and Centro FONDAP-Copas. Universidad de Concepción. Concepción. Chile [e-mail: lecastro@udec.cl].

ICES CM 2009/H:23 Poster

Life history strategies and environmental variation in Atlantic salmon (*Salmo salar*)

Gloria Blanco, Agustín Fernández, Ian McCarthy, and José A. Sánchez,

Factors (environmental and genetics) that control life history variation in *Salmo salar* are not fully understood. Different studies indicate that the physiological state of an individual will determine whether the animal adopts an early maturing (MMP) or early migrant strategy (S1) the following year. The aims of this work were to analyse how the increase in water temperature influences life-history strategies in salmon during the first year of freshwater life. Eggs were obtained from adult salmon returning to spawn in the River Shin (58°06'N, Scotland). A sample (ShSc) of these eggs were reared in a Scottish hatchery and another (ShEñ) transferred to an Asturias hatchery (northern Spain, 43°15'N). Water temperature ranged from 2°C (winter) to 20°C (summer) in Scotland, and from 6°C to 22°C in Spain. Each fish was individually tagged and at the end of experiment, identified as smolts (S1), parr (P), or precocious mature male (PMM). No genetic differences were found between samples reared in these two different environmental conditions. However, at the end of experiment, in the ShSc sample, 50% of individuals are smolt whereas they represent 85% in the ShEñ sample. Differences in genetic variability (at six isozyme and nine microsatellite loci) were observed when the different groups of fish (P, S1, and MMP) were compared. These results reveal that an increase in the temperature of fresh and marine water caused by climate change can have direct consequences on genetic structure and polymorphism of natural populations, and can produce alterations that affect life history traits.

Keywords: climate changes, life history strategies, genetic variability.

Contact author: José A. Sánchez, Universidad de Oviedo, Laboratorio de Genética Acuicola, Julián Clavería s/n, 33071 Oviedo, Spain [e-mail: jafsp@uniovi.es].

ICES CM 2009/H:24 Poster

Persistent aggregation and retention of herring larvae in the Bay of Fundy

Michael Sinclair, Robert Stephenson, Michael Power, and Iain Suthers

It has been concluded from a qualitative evaluation of survey data that herring larvae are retained in relative close proximity to the spawning area off southwest Nova Scotia. In contrast, observations of herring larvae from some other locations have been interpreted as evidence for larval drift from spawning areas to juvenile nursing grounds. We have more quantitatively described the temporal changes in spatial distribution of herring larvae off southwest Nova Scotia and in the Bay of Fundy on the basis of over two decades (1975–1998) of annual survey data. Our analyses indicate that (i) the geographical centre of mass of larvae is relatively fixed during the first several months of the larvae stage, (ii) there is persistence of larvae as indicated by spatial overlap of size classes, and (iii) the pattern is consistent from year to year. Larval retention has been proposed as an important mechanism in the establishment and maintenance of herring subpopulation structure, and is of relevance as a comparison with relatively recent studies elsewhere of population connectivity at the larval stage. It is proposed that this approach should be applied to other herring larval datasets to facilitate a comparative analysis of drift, retention, and potential connectivity in diverse oceanographic settings.

Keywords: larval retention, herring larvae, population connectivity, population structure.

Contact author: Robert Stephenson, Fisheries and Oceans Canada, St Andrews Biological Station, 531 Brandy Cove Road, St Andrews, New Brunswick, Canada E5B 2L9 [tel: +1 506 529-5882, e-mail: Stephensonr@mar.dfo-mpo.gc.ca].