

Theme Session J

Comparative dynamics of populations in the Baltic Sea and Gulf of St Lawrence ecosystems

ICES CM 2008/J:01

Comparative dynamics of cod populations in the Baltic Sea, the Gulf of St Lawrence, and other areas

Keith Brander, Ghislain Chouinard, Irene Mantzouni, and Bob Mohn

Changes in productivity over time can be estimated using a moving-window analysis based on the equilibrium biomass and yield of an age-structured population. Productivity (as indexed by MSY) is affected by non-stationarity in growth, natural mortality, recruitment, maturation, and exploitation patterns. The influence of all of these is explored, where adequate time-series exist for them. The cod stock in the southern Gulf of St Lawrence has undergone three periods with very different levels of productivity since the 1950s as a result of changes in reproductive success, growth, and natural mortality. Productivity of the Baltic cod stocks has declined since the 1970s, mainly as a result of reduced reproductive success. Some of the changes in productivity in the Gulf of St Lawrence and the Baltic are probably caused by environmental factors, because cod in these areas experience extremes of their physiological tolerance (for temperature, salinity, and oxygen) during some part of their life history. Size-selective fishing and seals (preying on older fish) have affected growth and survival of cod in the Gulf of St Lawrence. Pelagic predators (on early life stages) have affected recruitment in both areas. This comparative analysis is extended to include all other major cod stocks in order to see whether they also undergo changes in productivity over time. For stocks in which productivity changes two questions arise: (i) can such changes be predicted, or at least monitored in a timely way and (ii) can management strategies robust to such changes be devised? The possible impact of climate on future productivity of cod stocks is also considered.

Keywords: cod, productivity, management, MSY, non-stationarity.

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ICES CM 2008/J:02

Is the change in distribution and abundance of blue whales related to the groundfish collapse in the northern Gulf of St Lawrence?

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The Gulf of St Lawrence is a summer feeding ground for the blue whale and other marine mammal species. Whale sightings in the northern part of the gulf show a decline in the number of blue whales (*Balaenoptera musculus*) since the early 1990s, whereas the number of humpback whales (*Megaptera novaeangliae*) has increased since then. Over the same period, the abundances of many Atlantic cod (*Gadus morhua*) and groundfish stocks in the Northwest Atlantic have declined to low levels because of overfishing. With this decrease in biomass, the ensuing predation pressure on small pelagic fish (capelin (*Mallotus villosus*) and Atlantic herring (*Clupea harengus*)) was quantitatively lower and could have led to an increase in pelagic fish abundance and geographical distribution throughout the Gulf of St Lawrence in the 1990s. Blue whales are specialists, feeding only on krill (zooplankton). Consequently, any increase in the capelin population, which mainly feed on zooplankton, would amplify potential competition with the blue whale for the same resource. However, the more opportunistic humpback whales, which target both zooplankton and fish, might be favoured by this pattern, thus explaining their increased abundance. All these findings support the assumption that a striking change in the ecosystem foodweb could explain the observed variations in the distribution and abundance of rorquals in this region.

Keywords: blue whale, groundfish collapse, capelin, predator-prey interactions, foodweb, ecosystem structure shift, Gulf of St Lawrence.

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ICES CM 2008/J:03

Long-term dynamics in eastern Baltic cod spawning time: from small-scale reversible changes to a recent drastic shift

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Significant changes occurred in the state of the eastern Baltic cod population at the end of the twentieth century which, among other effects, resulted in a shift in peak spawning time from spring to summer. We investigated long-term dynamics (1949 to present) of cod spawning time based on ichthyoplankton data for all three major Baltic spawning grounds (Bornholm Basin, Gdańsk Deep, Gotland Basin). Considerable quantities of cod eggs were recorded in March–April for the whole period 1949–1980. Peak spawning time, however, showed multiple, reversible changes from spring (March–April 1949–1955; 1971–1980) to summer (June–July 1956–1959; 1962–1970). These fluctuations occurred in all three spawning grounds. During this period, timing of spawning was correlated with the size of the reproductive volume (RV) in February–April, with a high RV being indicative of early spawning. In the mid-1990s, peak spawning time showed for the first time a drastic change to July–August. Stock structure (numbers-at-age) of the Baltic cod stock has been analysed back to 1949 and the relationship with spawning time investigated. One major consequence of shifts in spawning time could be changes in species composition and size-distribution of food items available for cod larvae. Seasonal changes in the abundance and size-distribution of the major food source for cod larvae (i.e. nauplii of *Pseudocalanus acuspes*) are presented for different spawning grounds. Indications for a possible effect of late spawning on the decrease in cod stock productivity are discussed.

Keywords: age structure, cod eggs, larval food item size distribution, spawning time dynamics.

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ICEM CM 2008/J:04

Ichthyoplanktonic community structure in the northwest Gulf of St Lawrence (Canada): past and present

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Biodiversity may play an important role in the stability and resilience of an ecosystem when facing environmental changes or anthropogenic impacts. In addition to the fishery-induced collapse of cod and redfish, the last two decades have been characterized by a cooling of water masses in the Gulf of St Lawrence. Historically the northwest of the Gulf was known to have a high fish-egg and larval productivity as a result of hydrodynamic features. To assess changes in the ichthyoplankton community, we compared data from samplings carried out in May in this region from 1985 to 1987 with data from May 2005 to 2007. Preliminary results suggest that the total fish egg and larval abundance were lower in the 2005–2007 period than during the late 1980s. Eggs from the H4B category that were the most abundant in the late 1980s are now replaced by *Hippoglossoides platessoides* eggs. CHW (that includes cod) eggs represented about 30% of the 1980s egg community but dropped to less than 10% today. Although *Ammodytes* spp. remains the dominant species, other species became more abundant (i.e. *Stichaeus punctatus*), whereas *Sebastes* spp. is no longer one of the top four dominant species. Other species also appeared recently in the community (i.e. *Reinhardtius hippoglossoides*, *Icelus* spp.). Our study provides much needed new information about the current biodiversity and productivity of the fish community in the Gulf of St Lawrence and insights into its changes as influenced by environmental fluctuations.

Keywords: ichthyoplankton, Gulf of St Lawrence, biodiversity, community change.

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ICES CM 2008/J:05

Environmental factors influencing macrobenthic biodiversity and bioturbation in the Estuary and Gulf of St Lawrence

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The abundance and diversity of organisms and the intensity of bioturbation are linked to habitat quality. Changes in environmental parameters near the seabed, such as a decrease in the oxygen concentration or an increase in the organic carbon loading, can have negative impacts on biological diversity and activity. Studies have shown that such changes are now taking place in the Estuary and Gulf of St Lawrence (EGSL). We photographed the seabed at 11 stations in the EGSL during the summers of 2006 and 2007 and analysed the images to identify surface manifestations (traces) of bioturbation and identify the macrobenthic organisms present. Twenty-one sediment cores were collected at four stations in the hypoxic zones of the Estuary in 2007 and incubated with luminophores to determine the reworking coefficient by organisms identified on the benthic images. The objectives of this study were (i) to determine the environmental factors influencing the macrobenthic biodiversity and the abundance and diversity of bioturbation traces in the EGSL, and (ii) to quantify bioturbation rates by individual organisms and by the benthic community. Preliminary results show

that both species predominance and bioturbation traces are different at oxic and hypoxic stations. The results and conclusions of this experiment are discussed.

Keywords: biodiversity, bioturbation, environmental factors, hypoxia, St Lawrence.

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ICES CM 2008/06

Disentangling variation in fish growth: evidence for size-selective fishing in southern Gulf of St Lawrence cod (*Gadus morhua*)

Anna B. Neuheimer, C. T. Taggart, and J. M. Hanson

Temperature, food consumption, and size-selective fishing are major factors that determine variation in fish size-at-age (growth), and their contributions to that variation must be disentangled to allow successful management strategies to be developed. Here we examine the various factors affecting size-at-age of Atlantic cod in the southern Gulf of St Lawrence, where a significant decline in size at ages 4+ has been observed over the past 30 years, a decline that is coincident with high fishing pressure and changing environmental conditions. We employ an integrated temperature metric (growing degree-days) and disentangle the effects of temperature, food consumption, and size-selective fishing on size-at-age among years and year classes over the three-decade period. We conclude that the declines are most parsimoniously explained by size-selective fishing, consistent with other studies using different methods, and coincident with another gadoid population in the North Atlantic (haddock, *Melanogrammus aeglefinus*). We further demonstrate that subtle changes in climate may have a large effect on fish size-at-age, although this is not easily predicted using the various extant fish-growth models.

Keywords: growth, size-at-age, growing degree-day, fishing mortality, Atlantic cod (*Gadus morhua*), haddock (*Melanogrammus aeglefinus*).

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ICES CM 2008/07

Hierarchical modelling of temperature and habitat effects on carrying capacity and maximum reproductive rate of North Atlantic cod in the Baltic Sea, Gulf of St Lawrence, and throughout the North Atlantic

Irene Mantzouni and Brian R. MacKenzie

Stock status evaluation and recovery policies in fishery management rely largely on reference points derived from single-stock spawner–recruit (SR) models, whose key biological parameters are maximum reproductive rate at low stock size (α) and habitat carrying capacity (CC). Recent studies, employing joint or meta-analytic methods, have provided evidence that these ecological parameters, or the factors controlling them, are sensitive to environmental effects. The issue is of critical importance given global ocean warming projections; better understanding of environmental impacts on key population parameters, and hence SR models will be needed. The objective of our study is to extend the commonly used Ricker and Beverton–Holt SR models to account for (i) dynamics and variability in all North Atlantic cod stocks, thus borrowing strength from each and (ii) possible ecosystem (temperature and habitat size) effects on the model parameters (α and CC). In order to model the variability in SR parameters across stocks and improve estimation accuracy, the models were developed employing hierarchical methods. These methods allow stock-specific estimates to be derived, borrowing strength from the full dataset and also the incorporation of stock-level models on the parameters. Two different and complementary hierarchical techniques were employed: mixed and Bayesian models. Results show a significant dome-shaped relationship of temperature on both cod CC and α in the North Atlantic, and that the impacts vary geographically. These patterns may have implications for ecosystem approaches to management of cod populations in the changing temperature situations expected in the twenty-first century.

Keywords: *Gadus morhua*, N. Atlantic, carrying capacity, maximum reproductive rate, temperature, hierarchical modeling, spawner–recruit relationships.

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ICES CM 2008/J:08

The Baltic Sea bio-manipulation experiment of the twentieth century: resolving relative impacts of human activities and climate on a cod population

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In this study we evaluate the impacts of climate and major human-induced changes in the Baltic ecosystem (i.e. increased fishing, eutrophication, and declines in abundances of marine mammal predators) on the dynamics of the eastern Baltic cod stock in the twentieth century. Major trends in recruitment throughout the century coincided with climatic variations, whereas the level of stock size under similar climatic conditions was largely determined by the compensatory and cumulative effects of different human manipulations. The record high cod stock in the late 1970s–early 1980s resulted from a combination of four major factors favouring the stock: favourable climate enhancing reproductive success, low marine mammal predation, high ecosystem productivity, and reduced fishing pressure. A similar combination did not occur earlier in the twentieth century. The cod stock was probably limited by low ecosystem productivity and high abundance of predators (i.e. marine mammals) in the 1920s–1940s and by high fishing pressure in the 1950s–1960s.

Keywords: cod, climate, human impacts, Baltic Sea.

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ICES CM 2008/J:09

Distribution pattern of cod and flounder in the Baltic Sea based on international coordinated trawl surveys

R. Oeberst

Since 2001 international coordinated trawl surveys have been carried out in the Baltic Sea in spring and autumn, replacing the former national surveys which were concentrated in spring. New standardized gear types (small and large version) were used instead of the former national gears. Furthermore, the surveys were realized within defined periods, and the planned stations were allocated in the area under investigations according to an agreed procedure, which was not the case for the national surveys. The total number of hauls increased from 195 in 2002 to about 300 since 2003 during the spring surveys, and from 91 stations in 2002 to about 200 since 2003 during the autumn surveys. The new method for allocating the hauls guaranteed a good coverage of the total distribution area of the main target species—cod. The catch per hour in units of the large standard gear by length intervals and age groups were used to study the distribution pattern of cod and flounder. The results showed that the distribution of cod larger than 20 cm was similar in all years and without strong variations in spring and autumn. The results suggest that the quality of stock indices can probably be improved by changing the use stratification of the Baltic Sea.

Keywords: Baltic Sea, distribution pattern of cod and flounder, stratification of the Baltic Sea.

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ICES CM 2008/J:10

Incorporating extrinsic drivers into the management of the Baltic cod, sprat, and herring stocks

Piotr Margonski, Sture Hansson, Maciej Tomczak, and Ryszard Grzebielec

Cod and sprat constitute much of the fish biomass and catches from the Baltic Sea. Both species reproduce in pelagic offshore areas and therefore, at least to a certain extent, are subjected to similar environmental conditions. The eastern Baltic cod stock is biologically distinct from the western Baltic one and is managed as a separate unit. Sprat is regarded as a single stock and is assessed and managed accordingly. In the Baltic proper, a number of local herring stocks can be distinguished on the basis of spawning area, otolith shape, maturation, or growth rate. These populations have been merged, however, into one “Central Baltic Stock” (CBH, SD 25-29+32) for assessment and management purposes. The only exception to this is the Gulf of Riga herring (GoRH), which has been assessed and managed separately. We have explored a wide range of possible drivers of recruitment (e.g. spawning–stock biomass, hydrography, climate, and food availability). Recruitment of both herring units appears to be influenced by slightly different factors. Spawning–stock biomass (SSB), winter Baltic Sea Index prior to spawning, and potentially also November–December sea surface temperature (SST) during winter after spawning were important to GoRH, whereas the best models for CBH included SSB and August SST. Recruitment of sprat appears to be influenced by July–August temperature, but is independent of the biomass of spawners (SSB) when SSB >200 000 t. Recruitment of eastern Baltic cod is significantly related to SSB, winter NAO index, and the reproductive volume in the Gotland Basin in May. In each case uncertainty analyses were provided, presenting different probabilities of

SSB required to maintain recruitment at the desired level (e.g. R_{lim}) under the changing environmental conditions. Models including extrinsic factors significantly improved our prediction abilities.

Keywords: cod, sprat, herring, Baltic Sea, stock management, extrinsic drivers.

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ICES CM 2008/J:11

Modelled impact of changing nutrient conditions on the Baltic Sea foodweb

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Although eutrophication is stated to be one of the most serious challenges to the environment of the Baltic Sea, the impacts of eutrophication on Baltic foodwebs are currently not fully understood. Here, we studied the ecosystem effects of changing nutrient (N and P) conditions with the Ecopath with Ecosim software (EwE). The entire Baltic Sea is now covered with spatial resolution (two-dimensional) and the impacts of currents, regional fishing effort, marine protected areas, and bottom hypoxia are specified. The foodweb model is based on Baltic Sea data from year 1996 and contains over 30 functional groups, including the most important commercial fish species, cod (*Gadus morhua*), herring (*Clupea harengus*), and sprat (*Sprattus sprattus*). The fish biomasses modelled here corresponded well with ICES multispecies virtual population analysis estimates (MSVPA) for Baltic fish stocks (1997–2006) and fishing pressure was detected as the most significant factor influencing the mortality of commercial fish. The induced nutrient changes were found to impact the whole foodweb. When both N and P concentrations were reduced by 5% and 10%, phytoplankton biomass was approximately halved and zooplankton reduced to one-quarter of the initial levels. [?Q1] Eventually, fish also suffered reductions in biomass, with the exception of cod, which experienced a slight biomass increase. A more detailed analysis reveals area-specific responses to nutrient changes and sensitivity to the proportion of nutrients recycled within the euphotic water layer.

Keywords: foodweb, Baltic Sea, nutrient reduction, Ecopath.

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ICES CM 2008/J:12

Seasonal dynamics in growth, energy storage and reproduction of cod (*Gadus morhua*) under different temperature and feeding conditions

Yvan Lambert, Francine Fortin, and Céline Audet

Changes in environmental conditions resulting in different distributions and timings of migration between overwintering, spawning, and feeding grounds can significantly alter the growth dynamic of cod. Modifications of the annual migration cycle leading to variations in temperature, food abundance, and availability inevitably influence the seasonal pattern of energy allocation of the fish. Possible consequences of these changes on the growth of cod were evaluated by measuring the effects of temperature and food rations on the seasonal dynamics of growth, energy storage, and reproduction. Three laboratory experiments of 10 weeks' duration each were conducted at different times of the year corresponding to different periods of the maturation cycle. Each experiment was carried out at two temperatures and with three food rations. Significant differences in food consumption, food conversion efficiency, and growth in length and mass between and within experiments indicated a different response of cod to temperature and food ration depending on the time of the year. Growth was positively correlated with temperature and food ration but both factors had less marked effects during the reproductive period. Different patterns of growth in length and mass and higher food conversion efficiency during the experiment corresponding to the initiation of maturation indicated that a decrease in food consumption during that period may have a major impact on accumulated energy reserves necessary for maintenance during winter and spawning. Environmental influences on migration behaviour may thus have important implications for the population dynamics of cod in both the northern Gulf of St Lawrence and the Baltic Sea.

Keywords: seasonal energy allocation, growth, temperature, food ration, *Gadus morhua*.

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ICES CM 2008/J:14

Applied predator–prey functional responses: grey seal (*Halichoerus grypus*) and Atlantic cod (*Gadus morhua*) interaction as a case study

Amanda L. Caskenette and Steve Crawford

In predator–prey population modelling, modellers often quantify the removal of the prey by the predator by using a functional response (FR). FR theory is well established in population ecology, but when it comes to applying a particular formulation to the complex real system at hand, it is not as straightforward. Modellers tend to lack of enough information to choose and parameterize FR confidently, which is problematic as models are sensitive to these details. The grey seal (*Halichoerus grypus*) and Atlantic cod (*Gadus morhua*) interaction in the southern Gulf of St Lawrence is an excellent example of a complex real system where the functional response is unknown. We used several different grey seal functional responses, based on ecological hypotheses, as inputs for a predation mortality component in an age-structured population model for Atlantic cod. The abundance estimates from these models were compared with the observed data to determine the most appropriate model or set of models.

Keywords: predator–prey, functional response, grey seal, Atlantic cod.

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ICES CM 2008/J:15

The impact of hypoxia on cod from the Baltic and the Estuary and Gulf of St Lawrence

Denis Chabot

Both the Baltic Sea and the Estuary and Gulf of St Lawrence (EGSL) are characterized by low dissolved oxygen (DO) levels in deep waters. When hydrographic conditions are favourable, salty and relatively oxygen-rich waters from the North Sea flow into the deep basins of the Baltic. Between such events, oxygen levels are progressively depleted. During the last few decades, the frequency of inflows has decreased and eutrophication has increased oxygen depletion. As a result, young cod have been displaced to shallower waters, whereas adult cod live in midwater, on top of the most hypoxic water. Diet has changed and cod rely less on benthic prey, although it is not clear if this has resulted in a reduced energy intake. The most deleterious effect of hypoxia has been frequent reproduction failure. Low salinity typical of the Baltic Sea causes negative buoyancy in cod eggs, which sink into the severely hypoxic deep waters and die. The deep waters of the EGSL are already mildly hypoxic (50–65% sat.) when they penetrate into this enclosed sea and DO levels deteriorate further as these waters progress towards the heads of the deep channels. Natural variability in the DO level of the waters entering the EGSL and also eutrophication have resulted in a drop from about 40 down to about 20% sat. in the estuary. Cod have suffered habitat loss as a result, but the main impact appears to be a slowing of growth caused by a reduction of the metabolic scope for growth.

Keywords: hypoxia, Atlantic cod, scope for growth, egg buoyancy.

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ICES CM 2008/J:17

The Baltic Sea large marine ecosystem: its structure and dynamics, human pressures and governance approaches

Jan Thulin

The Baltic Sea is a unique and potentially productive large marine ecosystem, which has been degraded over the last five decades or so by harmful and unsustainable human activities and practices. More than 200 rivers empty into it, covering a drainage or catchment area that is four times larger than the Sea itself. This area, which involves 14 countries including the nine riparian ones, is populated by close to 90 million people. The Baltic Sea is relatively young, only about 10 000 years old, and is a semi-enclosed brackish water area that is characterized by waters with a residence time of about 30 years and a relatively persistent vertical stratification with unpredictable renewal of its higher saline bottom water. Furthermore, it is characterized by a low diversity of plants and animal species. Besides the stress factors caused by its natural characteristics, the Baltic Sea is suffering from heavy eutrophication, overfishing, pollution, invasion of non-indigenous species, and climate change. Although the Baltic Sea is considered to be one of the most studied and assessed areas in the world, these mainly human-induced threats to its integrity have been hard to manage and to regulate. However, with the major political and socio-economic changes that have happened during the last decade, especially in the eastern part, cooperation, coordination, and management of the area seems to be improving. This presentation provides an overview of the Baltic Sea, its characteristics, its governance, and

its health problems and the recently developed action plans to cope with them, all as a background for a general comparison between the Baltic Sea and the Estuary and Gulf of St Lawrence ecosystem.

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ICES CM 2008/J:18

The Gulf of St Lawrence marine ecosystem: an overview of its structure and dynamics, human pressures, and governance approaches

Michel Gilbert, Réjean Dufour, and Patrick Ouellet

The Estuary and Gulf of St Lawrence (EGSL) is one of the largest and most productive estuarine/marine ecosystems in the world. With a drainage basin that includes the Great Lakes, the EGSL ecosystem receives more than half of the fresh-water inputs from the Atlantic Coast of North America, and is also strongly influenced by ocean and climate variability in the North Atlantic, of both Arctic (Labrador Current) and tropical (Gulf Stream) origin. As a result, the EGSL ecosystem exhibits large spatial and temporal variations in environmental conditions and oceanographic processes, which provide favourable conditions for highly diverse and productive biological communities, including large commercially important populations of marine invertebrates, fish, and marine mammals. However, the EGSL ecosystem is affected by a wide variety of environmental stresses that pose significant threats to its integrity and sustainable use of its resources. These stresses result from intense human activities and uses both within the system and in upstream highly industrialized areas, and include fisheries, hypoxia, invasive species, coastal eutrophication, chemical contamination, fresh-water run-off modulations, and disturbance. The EGSL was one of the first marine ecosystems in Canada to be recognized as a large ocean management area (LOMA) that required integrated management actions by the Government of Canada under the recently implemented Oceans Act to ensure the sustainable development of its human uses. This presentation will provide an overview of the EGSL ecosystem structure and functioning, human pressures, and recently developed governance approaches, as background information for addressing population dynamics within this area relative to the Baltic Sea ecosystem.

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ICES CM 2008/J:19

The Baltic Nest decision support system and the Baltic Nest Institute

Henrik Österblom

The Nest model is the result of the Mistra-founded research programme MARE (MARine Research on Eutrophication) for the Baltic Sea ecosystem, and contains a number of components describing, for example, the flow of nutrients from land to sea, internal nutrient dynamics, and atmospheric deposition. The model also covers fish stock and foodweb dynamics. It can be used both as a tool for scenarios on future development given trends in, for example, agriculture, and to calculate the effects of a range of different management options. Although the model has been completed and evaluated only recently, it has already been used in international political decision-making. In the process of developing the HELCOM Baltic Sea Action Plan, Nest was used to define the nutrient reductions needed in order to achieve politically agreed targets for water transparency (water quality). The model was also used to define a “fair” method of dividing this nutrient reduction between states. The Baltic Nest model has thus been found to be very useful for guiding negotiations on discharges and run-off of nutrients to the Baltic Sea. The Nest model shares many similarities with the model used for reducing air pollutants over Europe, although significant differences can also be found. It can be said that the nutrient reductions defined by Nest are analogous to the critical loads (of acidifying substances) defined by the air pollutants model. Both models have been effective tools to bridge science and policy. Nest does currently not have an effective way to calculate cost-efficient measures, however, nor to calculate social costs of inaction. These components, together with further developments of the fisheries and foodweb models components, as well as models for the inter-linkages between the foodweb and nutrient reduction components, will present substantial challenges for the Baltic Nest Institute in the near future.

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ICES CM 2008/J:20**Poster**

***In situ* determination of the impact of press and pulse disturbances on spatial variability of a St Lawrence rocky intertidal ecosystem assemblage**

A. Séguin and P. Archambault

Natural disturbance is an essential component of ecosystems, but with the increase of anthropogenic activities, ecosystems are often under increased stress. It is important to be able to identify efficiently a disturbed environment. The spatial variability of assemblages has often been used to detect potentially disturbed sites according to the Caswell and Cohen model. This model is based on the suggestion that there is more heterogeneity in disturbed sites than in control sites. However, this model has not been validated, perhaps because there are two types of disturbance (press and pulse) experienced by the ecosystem. A press disturbance is defined as one that continues through time, whereas a pulse disturbance occurs sporadically. These two types of disturbance induce different changes in assemblages. The aim of this study was to determine *in situ* the impact of press and pulse disturbance on a model benthic ecosystem (intertidal tide pools), and thus to increase the accuracy of the Caswell and Cohen's model. Tide pool ecosystems have been well studied and are recommended for testing ecological models. The experiment was conducted during the summer of 2008. Some tide pools were disturbed each day during the diurnal tide to simulate press disturbance, whereas others received disturbance five times during the experiment in order to simulate pulse disturbance. This study will help to identify general patterns of ecosystem responses to different types of disturbance and improve management and conservation approaches in disturbed sites.

Keywords: perturbation, press, pulse, assemblage, spatial variability, tide pool.

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