

Theme Session P

Ecological foodweb and network analysis: a tool for ecosystem-based management?

ICES CM 2009/P:01

Using foodweb scenarios to estimate fishery yields on Georges Bank

John Steele, Dian Gifford, and Jeremy Collie

Energy flow between, and competition within, trophic levels are principal processes prescribing community abundance and structure. Neither of these directly determines the potential fishery yield of particular stocks in the fish community, but together they can constrain the expected yields from individual species. An end-to-end budget for Georges Bank is used to determine the plankton and benthos production available for the three predator guilds (planktivores, benthivores, and piscivores) under a range of scenarios describing possible climatic changes and habitat disturbances. Species-abundance rankings and other measures of diversity set limits to the relative abundance of fish stocks, and generate measures of community response, without identifying the species. Together the requirements imposed by foodweb fluxes of plankton and benthos, and by patterns of relative abundance, provide constraints on the species that can be dominant within the fish community. These ecosystem-based constraints can be used to set limits to possible values for production under a range of possible management scenarios; these, in turn, can provide a basis for multispecies maximum sustainable yields (MSY). These general principles are illustrated by application to Georges Bank.

Keywords: foodweb, energy flux, MSY, fishery management.

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Qualitative foodweb modelling for predicting the joined directions of change of population and community indicators: identifying dominant pressures as a step towards an EAF

V. M. Trenkel and M-J. Rochet

Qualitative models for foodwebs resemble mass-balance models but instead of being parameterized, they only include the sign of the relationships. We constructed a range of simple foodweb models with varying harvesting strategies and predicted expected changes in the case of press perturbations imitating bottom-up (environment) or top-down (fishing) pressure changes. Single and multiple press perturbation experiments were carried out. The expected state changes correspond to increases or decreases in the abundance and/or life expectancy of species that are members of a given model group (node; e.g. top predators). Using population and community indicators derived from scientific trawl surveys in several European marine ecosystems, we empirically tested whether joined time-trends in abundance and length (proxy for age) indicators allowed the identification of the most likely pressure changes as predicted by model analyses. The confrontation of model predictions and data was carried out in a likelihood framework akin to model selection. At the functional group and community level, some consistency between the most likely causes identified and changes in pressures known from independent information was found. The results further suggested that there was some compensation between species within functional groups. Thus, qualitative modelling can provide the theoretical foundation for the integrated assessment of marine communities under multiple pressures. Combined time-trends in metrics then help to identify, among the known changing pressures, which are the most likely to be having an impact on various functional groups, and thus, which kind of action should be taken to mitigate these changes with an EAF.

Keywords: loop analysis, qualitative modelling, indicators, ecosystem approach to fishery management.

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Predator–prey overlap-induced Holling type III functional response in the North Sea fish assemblage

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Understanding the response of predator populations to varying prey fields is a prerequisite to evaluating the impact of fishery management strategies on foodweb stability and dynamics. Previous analyses on the large-scale feeding response of predator populations, however, have produced unrealistic results for the North Sea. The observed feeding response types (e.g. negative prey switching) would lead to the extinction of prey populations when these become scarce. We analysed the large-scale response of North Sea cod (*Gadus morhua*) and whiting (*Merlangius merlangus*) populations to varying prey fields using generalized additive models (GAMs) and taking changes in predator–prey overlap into account, in contrast to previous analyses. The composition of the prey field and changes in predator–prey overlap had significant effects on the diet composition in the final GAM, explaining 65.6% of the variance. The existence of a large-scale prey refuge at low prey abundances as proposed by the Holling type III functional response could be demonstrated from field data. The refuge was caused by active prey switching behaviour of the predators, and also by a passive change in the availability of prey as a result of changes in predator–prey overlap associated with changes in prey abundance. In addition, a rapid increase in relative stomach contents was observed if the prey populations passed the abundance threshold of the prey refuge leading to a predator pit. This study demonstrates that current ecosystem models can be significantly improved by taking into account changes in spatial predator–prey overlap.

Keywords: functional response, Holling type III, predator–prey overlap, prey refuge, predator pit.

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Ecological network analysis: indicators of foodweb changes in the Baltic Sea

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Long-term changes in the Baltic Sea ecosystems have been studied using a foodweb model based on the software Ecopath with Ecosim. Indices of ecosystem change were calculated using ecological network analysis. These indices were tested for decadal regime shifts using two different methods: sequential *t*-test analysis of regime shift (STARS) and chronological cluster analysis. The results indicate that at least one regime shift has occurred over the past 30 years. Our analysis further indicates that it is not only changes in physical drivers that cause regime shifts in the ecosystem, as regime shifts mostly occurred when anthropogenic stressors such as fishing were analysed in addition to large-scale environmental drivers.

Keywords: Baltic, foodweb, network analysis, regime shift, Ecosim.

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The trophic spectrum: a tool for assessing the effects of fishing on marine ecosystems at a global scale.

Melen Leclerc and Didier Gascuel

Among approaches developed for analysing the functioning of aquatic foodwebs, the EcoTroph model, proposed as an additional plug-in of the Ecopath with Ecosim software, provides users with a simplified and synthetic way to compare ecosystems and to assess the impact of fishing or other human disturbances. The model is based on a representation of the continuous distribution of the ecosystem biomass (or production, or consumption by predators, or catches) across trophic levels. This graphical representation is called the biomass (or production or consumption or catch) trophic spectrum. In this study we use the EcoTroph approach and the trophic spectrum representations to compare various ecosystems and to conduct a meta-analysis of the impact of fishing at the worldwide scale. This work is based on 57 published Ecopath models representing various marine ecosystems in terms of size, latitude, productivity, type of ecosystem, and exploitation. For each of them, biomass, production, consumption, and catch trophic spectra are built. Then, ecosystems are classified in distinct types of ecosystem functioning, according to their spectra characteristics. Several patterns of exploitation at the ecosystem scale are also defined and their impact on biomass and production trophic spectra is analysed through simulations using EcoTroph. As a result, we point out some key factors of ecosystems' resilience to fishing, which should be considered in an ecosystem-based management perspective.

Keywords: ecosystem, fishing, trophic spectrum.

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Decadal variability of the structure and functioning of the North Sea and Baltic Sea foodwebs—changes or replacements?

Jens Floeter and Christian Möllmann

North Sea and Baltic Sea foodwebs have both undergone substantial changes caused by a mixture of natural and anthropogenic forces, but both foodwebs differ substantially in their degree of complexity. By applying ecological network analysis we investigated whether the trophic groups or species that once were of key importance to the integrity of the higher levels of the ecological network (i.e. gadoids, clupeids, sandeels) have been replaced by others, or whether their decline in abundance has altered larger parts of the foodweb structure and functioning. A sensitivity analysis of the results towards the use of different sources of information (e.g. empirical vs. model data) was undertaken, taking also spatial heterogeneity aspects into account. Similarities and differences between the North Sea and the Baltic Sea foodweb responses are discussed in the light of their physical and human environments.

Keywords: North Sea, Baltic Sea, foodweb functioning.

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Reversing the match–mismatch relationship: the prey point of view

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Climate influences populations through a variety of processes. One mechanism that may be particularly important is the role of climate in disrupting unequally the phenology of the predator and prey in a food chain. The match–mismatch hypothesis, referring to the way in which the development and survival of a predator is affected by the synchrony with its prey, is used to describe climate effects on ecological patterns and processes in both terrestrial and marine systems. We expand on the match–mismatch hypothesis by considering the simple statement: “what is bad for the predator should be good for the prey”. In other words, we reversed the output of the match–mismatch hypothesis, so that the increase in asynchrony leads to better survival/recruitment for the prey. We tested this theoretical model using GAM models on marine time-series. We demonstrated that the effect of predators on prey in the top–down controlled ecosystems can be modified by the degree of asynchrony. We discuss this result in light of the increase of amplitude of year-to-year variations in phenology linked to climate change.

Keywords: reverse match–mismatch, phenology, recruitment, trophic interaction.

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Grazing pressure of mesozooplankton under anthropogenic impact in Ushuaia Bay, Argentina

Soledad Lorena Diodato, Mónica Susana Hoffmeyer, and Florencia Biancalana

Ushuaia Bay (on the north coast of the Beagle Channel, Argentina) is under threat of incipient ecological damage because of discharge of pollutants (sewage and industrial effluents, hydrocarbons, and urban wastes). As coastal zooplankton tolerate environmental stress and respond quickly to anthropogenic changes, they are excellent indicators of ecosystem health. Feeding is a key issue in the study of trophic interactions. The purpose of this work was to assess the grazing impact of mesozooplankton in two regions of Ushuaia Bay with different anthropogenic pressures: a polluted coastal station (CS) and unpolluted external station (ES), in summer. Grazing experiments were performed using mesozooplankton grazers and natural food <100 µm (phytoplankton and microzooplankton). Individual and community feeding rates were estimated for each food fraction after 24-h incubation using the particle removal method. Prey and grazers were qualitatively and quantitatively analysed, yielding results in terms of abundance and carbon. Differences in mesozooplankton composition between the stations were observed. The predominance of copepods such as *Oithona similis*, *Acartia tonsa*, and *Eurytemora americana*, and *Podon leuckarti* was recorded in CS. Nauplii and copepodids of herbivorous calanoids were dominant in ES. The different values obtained from feeding rates demonstrate the importance of the type and amount of food available, and of the concentration and diversity of grazers, and suggest the existence of two trophic subsystems: one associated with benthopelagic coupling maintained by *Macrocystis* prairies in the coastal zone and another more related to Beagle Channel plankton in cleaner waters on the outskirts of Ushuaia Bay.

Keywords: grazing, mesozooplankton, anthropogenic pressure, Ushuaia Bay.

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Foodweb models as tools for ecosystem-based management

Axel G. Rossberg

By synthesizing our understanding of foodweb topology, allometric scaling, population dynamics, and community evolution, the population–dynamical matching model (Rossberg *et al.*, *Ecology* 89: 567–580, 2008) reproduces the major known macroecological patterns relating body sizes,

abundances, species richness, trophic position, and foodweb structure. It therefore appears to be a credible tool for studying community dynamics. Here, applications of the model to issues of ecosystem-based fishery management are demonstrated. Specific questions addressed concern (i) the validity of single-stock fishery models; (ii) the effects of fishing pressure on species richness among fish and at lower trophic levels; (iii) the effects of fishing pressure on the community size structure (in particular the “proportion of large fish” EcoQO); (iv) time-scales of community recovery; and (v) characterizations of community intactness. Work supported by an Irish Beaufort Marine Research Award.

Keywords: none.

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Ecological marine network structure, functional roles and species identity—what matters most?

Andrea Belgrano, Christian Möllmann, and Ulrich Brose

On a global scale, marine ecosystems are currently being subjected to large-scale pressures, including over-harvesting, changing land–ocean interactions, spread of invasive species, and increasing effects of global climate change. This places at risk both marine biodiversity and the goods and services the oceans provide and sustain. Changes in the marine environment also affect these systems’ network structure, causing range shifts of some species, altered abundance of others, and potentially changed patterns of trophic interactions and energy flow. Species distributions may shift in ways that lead to major changes in their interactions with other species, leading to modifications in the structure and function within and between ecosystems. Understanding the relationship between species diversity and key ecological processes has become one of the most pressing and challenging themes in contemporary ecology. Previous studies have shown that there is not necessarily a simple linear relationship between biodiversity and ecosystem function, implying that every species is not equally important. Instead, some species may be characterized as drivers (by being able to compensate for the loss of other species) and others as passengers, suggesting that it is increasing functional diversity rather than species richness *per se* that facilitate ecosystem functioning. Here we will link the topological structure of a variety of marine ecosystems to species identity and their functional roles, which we believe are the threads that may provide some important insights into recent events of species loss and gain.

Keywords: network structure, species identity, functional roles, species loss, species gain.

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A mass-balance Ecopath model of Greek Ionian Sea (eastern Mediterranean): a preliminary approach

Dimitrios K. Moutopoulos, Simone Libralato, Cosimo Solidoro, and Konstantinos I. Stergiou

A trophic mass-balance Ecopath model has been developed to describe the foodweb structure of the coastal areas of the Greek Ionian Sea (eastern Mediterranean) during the 1990s, a period characterized by the modernization of Greek fishery vessels and decreasing trends in most commercially important species landings. Along Ionian Sea coasts (the second larger sea area of Greek waters) a variety of commercial fisheries operate, including trawlers, purse-seiners, beach-seiners, and artisanal boats. The present study attempts to assemble and summarize the existing information related to fisheries (reconstructed Greek marine fishery landings), biological (life-history parameters and diet composition) and operational (fishing effort) aspects. Functional groups include target and non-target fish species and invertebrate groups, as well as species

protected under specific conservation schemes such as dolphins and marine turtles. Sensitivity and uncertainty analyses on critical functional groups and parameters of the Ecopath model would enhance the representation of the ecosystem studied and set the baseline towards an ecosystem-based approach to fisheries in an ecologically important area.

Keywords: Ecopath, trophic level, foodwebs, ecosystem-based management.

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ICES CM 2009/P:13 Poster

Ecological foodweb and network analysis: a tool for ecosystem-based management

Mbiye Kalumbu Bienvenu

Description of the evolution of ecosystems is a challenge for many scientists. Several attempts have been made, mostly using compartments and flows, to describe the structure of ecosystems and holistic indicators or goal functions (GF) to describe the state and the trend of their evolution. Under a steady flow of energy from the environment, an ecosystem can increase the biomass by enlarging the number of individuals and/or their body weights until a certain steady state level. In this situation neither the structure (e.g. species composition) nor the pattern of flows linking its compartments varies and both biomass and flow reach an “optimal” level. Benefits compensate the costs of the ecosystem evolution. A question is: when can an ecosystem be considered to be in an optimal state and how does it reach this state? The answer to this question is also useful to solve the problems related to the concept of reference state as posed in the Water Framework Directive. In order to answer this question the characteristics of a suitable indicator are discussed and two state indicators are proposed, based on the assumption that the costs and benefits of the ecosystem growth have to be in balance. The first one, the benefit/cost indicator (BC), is a function of well-known state indicators that fully satisfies the properties required, but it is difficult to compute and complex to understand. Nevertheless, from the researcher’s point of view, this indicator gives interesting insights into system behaviour. The second, the supply demand balance (SDB), is an indicator based on two main assumptions: that an ecosystem can be represented by a network of compartments and flows, and that the metabolic rates scale across species approximately as the (3/4) power of mass. The SDB indicator summarizes the distance of an ecosystem from an optimal state in a single number. Under these assumptions the SDB indicator can be regarded as a measure of ecosystem state. It is easy to compute and simple to understand. SDB looks like a good indicator both for scientific and practical uses to understand where the ecosystem is going. Finally the applicability of SDB is investigated by computing its values for 33 tropic networks describing the foodwebs of different aquatic ecosystems.

Keywords: ecosystem indicator, goal function, thermodynamic indicator, trophic network, Ecopath.

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ICES CM 2009/P:14 Poster

Climate-induced alterations of dissolved organic carbon levels in the Baltic Sea pelagic system: implications for foodweb efficiency and fish production

Rickard Degerman and Robert Lefébure

Climate change predictions indicate increases in precipitation and consequently river run-off levels in the drainage area of the Baltic Sea, leading to a higher influx of terrestrial allochthonous dissolved organic carbon (ADOC). Elevated ambient ADOC loads have been shown to favour aquatic bacterial growth to such a degree that an uncoupling of bacterial production from primary production might result, yielding a net heterotrophic system. In addition, a shift towards bacterial dominance is predicted to lower the foodweb efficiency (FWE) of such systems, as the majority of the bio-available carbon would be channelled through the microbial foodweb, as opposed to

through the classic pathway of phytoplankton–mesozooplankton–fish. To model this potential effect of increased precipitation on the Baltic Sea ecosystem, an indoor mesocosm study was conducted in autumn 2008 with the aim of investigating differences in FWE and impacts on fish production. The three-spined stickleback (*Gasterosteus aculeatus*) was used as a model fish and placed as top predator in two contrasting foodwebs, one with a steady influx of ADOC in the form of glucose and one relying on an autochthonous supply. Preliminary results indicate a higher FWE and consequently a higher net fish growth in systems relying on autochthonous DOC. These results seem to be explained by alterations in the species composition of the phytoplankton community along with changes in zooplankton abundances. Moreover, the presence/absence of fish exerted a strong top–down control on the systems, with effects cascading down the entire food chain.

Keywords: climate change, Baltic Sea, DOC, foodweb efficiency, fish production.

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Long-term changes in the state of the coastal ecosystem in the Gulf of Finland

Jari-Pekka Pääkkönen, Ilppo Kajaste, Marjut Räsänen, and Katja Pellikka

This study reports investigations undertaken on the coastal zone of the Gulf of Finland. Intensive monitoring has been done since the late 1960s, collecting physical, chemical, and biological data for the sea area outside the city of Helsinki, Finland. The aim has been to examine the state of the coastal ecosystem and the interactions between the littoral and pelagic zones. Eutrophication (both internal and external) has been the main problem in the study area, as in the rest of the Gulf of Finland. We investigated the long-term dynamics (1968 to present) of phytoplankton and zooplankton populations, with the physical and chemical parameters in the sea area. Considerable changes in the composition of plankton species and nutrient loading (phosphorous and nitrogen) were observed over the period. The mass occurrence of blue-green algae decreased in the bay areas. In the pelagic zone, the number of diatoms has decreased. Both dinophyte and chrysophyte biomasses have increased during the period. Trends in phytoplankton biomass revealed no change in the open sea area, but have significantly decreased in the bay areas. The possible effect of changed human-induced nutrient loading on the coastal ecosystem and the eutrophication trend in the Gulf of Finland in general, is analysed. Indications of the possible effect of phytoplankton biomass changes on the composition of zooplankton are discussed.

Keywords: phytoplankton, zooplankton, coastal, biodiversity, Baltic Sea.

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