# Theme Session D
# Comparative Marine Ecosystem Structure and Function: Descriptors and Characteristics

**ICES CM 2007/D:01**

## Which forcing factors fit? Relative influence of climate and fishing on the dynamics of gadoids in marine ecosystems

S. Mackinson, G. Daskalov, H. Aranciba, F. Arreguin-Sanchez, and L. Shannon

Fishing mortality and primary production were used to drive the dynamics of gadoids and small pelagics in models of 4 contrasting ecosystems. Historical trends in the abundance were reconstructed by fitting model predictions to observations. The model fitting exercise derives values for otherwise unknown parameters specifying the relative contribution of top-down and bottom-up factors on trophic interactions. Using a step-wise fitting procedure, we investigate the relative contribution of top-down (fishing) and bottom-up (primary production forcing) in explaining the model fit to observed species dynamics and question if there is ecological meaning in the derived parameters.

Keywords: climate, fishing, ecosystem models, gadoids.

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**ICES CM 2007/D:02**

## Environmental forcing of life history strategies: Multi-trophic level response at ocean basin scales

R. Suryan., M. Frederiksen, S. Wanless, B. Wallace, V. Saba, and S. Hatch

Variation in life history traits of organisms is thought to reflect adaptations to environmental forcing occurring from bottom-up and top-down processes. Such variation occurs not only among, but also within species, indicating demographic plasticity in response to environmental conditions. Between North Atlantic and North Pacific Ocean basins, intra-specific variation in life history traits has been observed among trophic levels from zooplankton to sharks, seabirds, and sea turtles. In all cases examined, species in the Northeastern Pacific exhibited later maturation and lower fecundity, but greater annual survival, than conspecifics in the Atlantic. We hypothesize that this dichotomy results from frequency and amplitude shifts in resource availability over varying temporal spatial scales. Captive studies of fishes have shown that differences in growth and age of reproduction can indeed be a function of environmental control rather than genetic variation. Similar parallel occurrences also have been observed in adjacent seas; zooplankton and seabird species in cooler North Sea waters exhibit lower fecundity and greater annual survival than conspecifics in the Atlantic. Furthermore, a shift toward shorter reproductive intervals (resulting in greater annual fecundity) has been observed within a species in response to warming of an inland lake. These examples show system-wide adaptations in life history strategies resulting from environmental forcing and provide a framework for comparisons of ecosystem function among oceanic regions (or regimes) and may prove valuable in modeling ecosystem response to environmental change.

Keywords: basin scale processes, ecosystem function, life history strategies, population dynamics.

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**ICES CM 2007/D:03**

## Ecosystem state and trophic interactions of phytoplankton, micro- and mesozooplankton and planktivorous fish in the Gulf of Finland, Baltic Sea

Jari-Pekka Pääkkönen, H. Peltonen, J. Flinkman, M. Karjalainen, and Markku Viitasalo

The pelagic ecosystem of the northern Baltic Sea has changed during the past few decades. Salinity has declined, eutrophication has proceeded, and abundances of zooplankton and pelagic fish have fluctuated causing shifts between different ecosystem states. We conducted open sea cruises in 2004–06, studying the abundance of phytoplankton, micro- and mesozooplankton and planktivorous fish, in the Gulf of Finland, Baltic Sea, to reveal how their spatial distribution is determined by the environmental factors and food resources. Application of two vessels, R/V Aranda and R/V Muikku, ensured intensive sampling on several biological, chemical and physical variables. Zoo- and phytoplankton species and abundances were sampled

with traditional methods as well as continuously measuring devices. The planktivorous fish abundance and distribution were determined with echosounding and trawling and were related to plankton data. Multivariance analyses were conducted to provide an integrated view on the state of the ecosystem. Phytoplankton, zooplankton and fish abundance datasets were analyzed with principal component analysis, and with redundancy analysis to identify main explanatory variables from the nutrients and physical datasets. Relationships between trophic levels were analyzed from phytoplankton via microzooplankton to mesozooplankton, and further to planktivorous fish in the Gulf of Finland. The present study aims at revealing processes controlling pelagic ecosystem and their productivity in the Balic Sea, with low number of native species and simple ecosystem vulnerable to ecosystem changes.

Keywords: zooplankton, phytoplankton, Baltic Sea, trophic levels.

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**ICES CM 2007/D:04**

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### The Eastern Bering Sea shelf: a highly productive seasonally ice-covered sea

Franz J. Mueter and George L. Hunt, Jr.

The Eastern Bering Sea is characterized by its broad (> 500km), shallow (mean depth = 70m), and seasonally ice-covered shelf. The spatial extent of ice and the timing of ice retreat are driven by large-scale atmospheric forcing and vary considerably interannually. This variability affects the spatial distribution of fish and invertebrates, the timing of the spring bloom, and the flow of energy to upper trophic levels, including shifts between benthic and pelagic compartments. High productivity on the shelf (up to 200–250 gC m-2 y-1) is fueled by nutrient-rich waters originating in the deep Aleutian Basin and supports a large community of demersal and pelagic fish and shellfish, as well as large populations of seabirds and marine mammals. Fish biomass and commercial catches (> 1.3 million tons annually) are dominated by gadids, in particular walleye pollock (*Theragra chalcogramma*), and flatfishes (*Pleuronectidae*). Although the composition of the fish community has remained relatively stable for several decades, a large-scale community reorganization affecting all trophic levels followed a 1976/77 climate regime shift. Walleye pollock currently play a key role in the food web of the Eastern Bering Sea, with much of the primary production transferred to higher trophic levels through predation on larval and juvenile pollock. The Eastern Bering Sea occupies the transition between the sub-arctic and the Arctic, which makes the region particularly sensitive to climatic change. With recent warming, the region may be undergoing a transition from Arctic to sub-arctic conditions, including the emergence of newly dominant predators on commercially valuable species.

Keywords: Bering Sea, sea ice, productivity, fish community, warming

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**ICES CM 2007/D:05**

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### Comparative analysis of trophic webs of South New England and Northern Adriatic Sea

Fabio Pranovi and Jason Link

This work performs a comparative analysis between two ecosystems, the Northern Adriatic Sea (NAS) and South New England (SNE) ecosystems, to improve the knowledge about the driving and controlling processes in those marine ecosystems. The South New England ecosystem is a continental shelf ecosystem of the Western Atlantic with an average depth of 60 m, being relatively open and influenced by major current flow fields. The Northern Adriatic Sea represents a semi-enclosed basin, characterized by shallow water, average depth of about 20 m, with some environmental features more similar to the Atlantic than to the Mediterranean Sea. Both the ecosystems are characterized by high fishing pressure and a high biomass of benthic invertebrates. Our main emphasis was to compare the trophic flow structure by using steady-state models,. The basic structure of the food webs shows differences both in the number and definition of the functional groups described in the model. Fisheries, on the contrary, show similarities both in terms of catches and discard. Almost all statistics summarizing the structure and the dimension of flows show, as expected, values 3/4-times higher in the SNE than in the NAS ecosystem, but in terms of system maturity the Ascendency/Capacity index shows higher values for NAS than SNE. The functioning of the systems have also been compared by analyzing the relationships among different groups with mean trophic impact (MTI) and applying a related keystoneness index. The MTI and keystone index both demonstrate the importance of lower trophic levels, including benthos, that drive these ecosystems.

Keywords: trophic structure, EwE, MTI, keystoneness index, South New England, Northern Adriatic Sea.

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**ICES CM 2007/D:06**

## Comparison of 4 Northern Hemisphere regions: Physical oceanographic responses to recent climate variability

Ken Drinkwater, Cecilie Broms, Kevin Friedland, Jon Hare, George Hunt, Webjørn Melle, Franz Mueter, and Maureen Taylor

Recent changes in climate conditions in several regions of the globe raise concerns about ecosystem resilience and sustainability of ecosystem services. We examine oceanographic responses to these climate changes in four high latitude regions of the Northern Hemisphere, two in the Pacific (Bering Sea and Gulf of Alaska) and two in the Atlantic (Georges Bank/Gulf of Maine and the Barents/Norwegian Seas). Air temperature, heat fluxes and wind forcing over the four regions are examined. The effects of these on the oceanography of the regions are then determined, compared and contrasted, including changes in ocean temperatures, salinities, stratification, and circulation patterns. In addition, changes in seasonal sea ice cover are compared between the two regions where it occurs (Bering and Barents seas). Changes in temperature and salinity are examined as a function of latitude and compared to expected changes (increasing temperature and decreasing salinities in the north). The importance of advection in the four regions to explain the observed responses is discussed. This is a contribution from the Comparison of Marine Ecosystems of Norway and the US (MENU) project.

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**ICES CM 2007/D:07**

## Comparison of 4 Northern Hemisphere regions: Ecosystem responses to recent oceanographic variability

Franz Mueter, Cecilie Broms, Ken Drinkwater, Kevin Friedland, Jon Hare, George Hunt, Webjørn Melle, and Maureen Taylor

Ecosystem responses to oceanographic variability resulting from recent climate changes are compared and contrasted for four high latitude regions of the Northern Hemisphere, two in the Pacific (Bering Sea and Gulf of Alaska) and two in the Atlantic (Georges Bank/Gulf of Maine and the Barents/Norwegian Seas). Changes in nutrient content and its effect on phytoplankton biomass and production are compared among systems and recent trends towards smaller zooplankton in the Bering Sea and in the Georges Bank region are evaluated. In each of the regions, several fish species show a general poleward movement in response to the warming, as well as more complex, non-linear responses resulting from internal community dynamics and fishing. Observed changes in the abundance, individual growth and species composition of the fish communities are assessed in terms of environmental and fishing effects. Changes in marine mammals and seabirds in the four regions are documented. Comparisons between the different regions are made to identify and distinguish general responses from regionally unique responses. This is a contribution from the Comparison of Marine Ecosystems of Norway and the US (MENU) project.

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**ICES/CM 2007:D:08**

## Trophic structure of the Barents Sea fish community with the special reference to the cod stock recovery ability

Andrey V.Dolgov

The trophic structure of the Barents Sea fish community is considered based on the data of different species diets. Some trophic groups were revealed. Its composition, ratio of different trophic groups and its inter-annual dynamics are analyzed. Trophic structure of fish community of the Barents Sea and some other areas is compared too. Special attention is paid to the ability of cod stock recovery taking into account the trophic interrelations in fish communities from different North Atlantic seas. Analysis of trophic structure of the Barents Sea and other areas (North Sea, Western Greenland, Newfoundland-Labrador shelf) showed that only the Barents Sea cod ability to stock recovery cannot be restricted by trophic relations among fishes due to lack of other abundant predatory species and low competition level caused by spatial-temporal changes.

Keywords: Barents Sea cod, intrannual dynamics, low food competition, recovery ability, species diets, trophic groups.

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**ICES CM 2007/D:09**

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## A comparison of biological trends from four marine ecosystems: synchronies, differences, and commonalities

Jason S. Link, William Stockhausen, Georg Skaret, William Overholtz, Bernard A. Megrey, Harald Gjoesaeter, Sarah Gaichas, Are Dommasnes, Jannike Falk-Petersen, Kerim Aydin, Joseph Kane, Franz Mueter, Kevin Friedland, and Jon Hare

As part of the international MENU collaboration, major features of four marine ecosystems were analyzed based on a broad range of fisheries dependent and independent datasets, as well as a suite of oceanographic surveys. The ecosystems analyzed included the Gulf of Maine/Georges Bank in the Northwest Atlantic Ocean, the Norwegian/Barents Seas in the Northeast Atlantic Ocean, and the eastern Bering Sea and the Gulf of Alaska in the Northeast Pacific Ocean. We examined survey trends in major fish abundances, fishery catches, total system fish biomass, primary production- and zooplankton biomasses, mean length of the finfish community, and measures of various species diversity indices. We standardized each time series and examined trends and anomalies over time, using both qualitative and time series statistical methods. We compared dynamics of functionally analogous species from each of these four ecosystems. Major commonalities among ecosystems included a relatively stable amount of total fish biomass and the importance of large calanoid copepods, small pelagic fishes and gadids Many of the peaks in these components were synchronous across ecosystems. Major differences between ecosystems included gradients in the magnitude of total fish biomass, differences in primary production and lower trophic level production, commercial fish biomass, and timing of major biological events. This work demonstrates the value of comparative analysis across a wide range of marine ecosystems, suggestive of common features across all northern hemisphere ocean systems.

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**ICEM CM 2007/D:10**

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## A cross-ecosystem comparison of temporal variability in recruitment of functionally analogous fish stocks

Bernard A. Megrey, Jon Hare, Are Dommasnes, Harald Gjøsæter, William Stockhausen, William Overholtz, Sarah Gaichas, Georg Skaret, Jannike Falk-Petersen, Jason S. Link, and Kevin Friedland

As part of the international MENU collaboration, variability in temporal patterns of recruitment and spawning stock were compared among functionally analogous species from four marine ecosystems including the Gulf of Maine/Georges Bank, the Norwegian/Barents Seas, the eastern Bering Sea and the Gulf of Alaska. Variability was characterized by calculating coefficients of variation for each time series and by representing the time series as anomalies. Patterns of synchrony and asynchrony in recruitment and spawning stock indices were examined among and between ecosystems and related to observed patterns in biophysical properties (e.g. local trophodynamics, local hydrography and large scale climate indices) using a wide range of time series analyses, autocorrelation corrections, autoregressive processes, and multivariate cross-correlation analyses. Of all the commonalities, the relatively similar cross-ecosystem and within-species magnitude of variation was most notable. Of all the differences, the timing of high or low recruitment years across both species and ecosystems was most notable. However, many of the peaks in these indices of recruitment were synchronous across ecosystems for functionally analogous species. Yet the relationships (or lack thereof) between recruitment anomalies and key biophysical properties demonstrated that no one factor consistently caused large recruitment events. Our observations also suggested that there was no routine and common set of factors that influences recruitment; often multiple factors were of similar relative prominence. This work demonstrates that commonalities and synchronies in recruitment fluctuations can be found across geographically very distant ecosystems, but biophysical causes of the fluctuations are difficult to partition.

Keywords: Ecosystem, recruitment, trophodynamics, variation.

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**ICES CM 2007/D:11**

## A comparison of community and trophic structure in four marine ecosystems based on energy budgets and system metrics

Sarah Gaichas, Georg Skaret, Jannike Falk-Petersen, Jason S. Link, Wiliam Overholtz, Bernard A. Megrey, Harald Gjoesaeter, William Stockhausen, Are Dommasnes, and Kerim Aydin

As part of the international MENU collaboration, energy budget models for five marine ecosystems were compared to identify differences and similarities in trophic and community characteristics across ecosystems. We examined the Gulf of Maine and Georges Bank in the Northwest Atlantic Ocean, the combined Norwegian/Barents Seas in the Northeast Atlantic Ocean, and the eastern Bering Sea and the Gulf of Alaska in the Northeast Pacific Ocean. Comparable energy budgets were constructed for each ecosystem by aggregating information for similar species groups into consistent functional groups across all five ecosystems. Several ecosystem metrics (including functional group production, consumption, and biomass ratios, ABC curves, cumulative biomass, food web macrodescriptors, and network metrics) were examined across the ecosystems. The comparative approach clearly identified data gaps for each ecosystem, an important outcome of this work. Commonalities across the ecosystems included overall high primary production and energy flow at low trophic levels, high production and consumption by carnivorous zooplankton, and similar proportions of apex predator to lower trophic level biomass. Major differences included distinct biomass ratios of pelagic to demersal fish, ranging from highest in the Norwegian/Barents ecosystem to lowest in the Alaskan systems, and notable gradients in primary production per unit area, highest in the Alaskan and Georges Bank/Gulf of Maine ecosystems, and lowest in the Norwegian ecosystems. While comparing a disparate group of organisms across a wide range of marine ecosystems is challenging, this work demonstrates that standardized metrics both elucidate properties common to marine ecosystems and identify key distinctions for fishery management.

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**ICES CM 2007/D:12**

## The Gulf of Alaska continental shelf: physics, food webs, and fisheries

Sarah Gaichas, Bernard A. Megrey, and Franz Mueter

The Gulf of Alaska (GOA) continental shelf marine ecosystem is characterized by complexity and contradiction. It is a highly productive (300 gCm-2y-1) downwelling system. Circulation on the 300,000 km2 GOA continental shelf is driven by large scale ocean gyres, seasonally variable local winds, and freshwater runoff interacting with complex bathymetry. Mesoscale eddies form as a result of both bottom topography and the interaction of the parallel, westward flowing Alaska Stream and Alaska Coastal Current. GOA continental shelf physics is highly variable at local scales, and the time series of coastal SST and SLP do not display the obvious decadal shifts associated with the Pacific Decadal Oscillation (PDO) in the North Pacific. However, fish and marine mammal populations have changed dramatically over last 40 years, with some species shifts correlating well with the 1976–77 PDO shift. During the 1960's, fish biomass was dominated by a zooplanktivorous rockfish, Pacific ocean perch, which declined after heavy fishing in the mid-1960s. Intensive whaling during the mid-1960s removed another million metric tons of plankton-feeders. Lucrative GOA crab and shrimp fisheries collapsed in the 1980s, and groundfish catch increased. Groundfish biomass was dominated by walleye pollock (also a zooplankton feeder) in the 1980's, which subsequently declined as its predators, arrowtooth flounder, halibut, and Pacific cod, increased in total biomass. Pinniped populations declined over the same period. At present, the GOA food web appears dominated by piscivorous groundfish predators, many of which still feed on the forage species which apparently declined after the 1976–77 regime shift.

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**ICES CM 2007/D:13**

## The climate variations in the North Atlantic and North Pacific in 2000–2007 compared with the 2nd half of the XX century

Andrei S. Krovnin and George P. Moury

The analysis of the current climatic system state in the North Atlantic and North Pacific in 2000–2007 compared with the climatic conditions in 1950–1999 was conducted. It was obtained that in 2005–2006 there was a possible change in phase of the North Atlantic Oscillation from the positive to negative one. In the contrast to the 1950–1999, when the shift in climatic regimes was sharp (i.e. within one year), in the current

decade the transitional period of 3–4 years between shifting was observed. However, in winter 2007 there was a sharp intensification of zonal circulation over the North Atlantic. This resulted in warming of the surface layer in the ocean. In the North Pacific the 2000–2006 period was characterized by strengthening of meridional component of atmospheric circulation. But in 2007 the role of zonal atmospheric processes increased as it occurred over the North Atlantic. This might result in disturbance of the earlier revealed statistical relationships between climatic characteristics and biological parameters of the main commercial stocks in the both oceans.

Keywords: North Atlantic, North Pacific, climatic system state, regime shift, zonal and meridional atmospheric circulation, biological characteristics of the main fish stocks

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**ICES CM 2007/D:14**

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### Comparative analysis of Canadian Pacific North Coast and Strait of Georgia marine ecosystems

R. Ian Perry, William R. Crawford, and Alan F. Sinclair

We compare and contrast the structure, function, and ecosystem-based management issues for two of the major marine ecosystems of the Pacific coast of Canada: the North Coast of British Columbia; and the Strait of Georgia. We structure our analysis around four key questions: 1) what processes determine hydrographic properties; 2) what processes control the supply of nutrients; 3) who eats whom, and how are food-web interactions facilitated; and 4) what are the critical factors causing changes in these ecosystems? The North Coast is larger (76,000 versus 6,800 square kilometers), but both are strongly influenced by adjacent mountains that affect climate, rainfall, and circulation features. Both areas are also strongly influenced by freshwater, with this process dominating in the southern Strait of Georgia. Nutrient supply and food-web interactions in both regions are facilitated by "Bakun's Triad": enrichment (mixing and upwelling on the North coast; estuarine flow dynamics in the Strait of Georgia), retention (in both regions by topographic features), and by concentration (caused by interactions of the circulation with bathymetric and hydrographic features). The overall trophic structure of the North Coast appears to be robust to reduction or elimination of single components of the food web; it does not display a wasp-waist structure with a single constricting species, although pathways to individual top predators may be more limited. The North Coast ecosystem is more strongly connected to the adjacent deep ocean, including extensive migrations by fish, marine mammals, and seabirds. The Strait of Georgia and the deep ocean are less closely connected: deep-water properties in the Strait display a 1-year lag from the offshore, and the major biological connections are by salmon and herring. Analyses of productivity and fisheries yields suggest different time trends exist between these two regions. We conclude with an analysis of the critical factors driving changes, and the resilience or vulnerability of these ecosystems to these changes.

Keywords: ecosystem structure, ecosystem function, productivity, fisheries yields, food-webs, resilience, vulnerability.

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**ICES 2007/D:15**

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### Seals, cod and forage fish: a comparative exploration of variations in the theme of stock collapse and ecosystem change in NW Atlantic ecosystems

Alida Bundy, Sheila J.J. Heymans, Lyne Morissette, and Claude Savenkoff

The facts: four NW Atlantic ecosystems, three cod stock collapses fifteen years ago (plus one severely depleted), seals now top predator in all ecosystems, all had cod as a top predator before collapse, groundfish declines in all areas, forage base increased in most systems. No recovery in any system. Have these ecosystems fundamentally changed? Why? The challenge: compare and contrast these four ecosystems. The answer: using tropho-dynamic models, empirical data and a suite of ecosystem indicators, we explore how and why these systems have changed over time. At the ecosystem and community level, we see broad similarities between ecosystems. However, structurally and functionally these systems have shifted to an alternate state, with changes in predator structure, trophic structure and flow.

Key words: ecosystem structure, function, ecosystem indices.

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**ICES CM 2007/D:16**

### Do population and community metrics tell the same story about recent changes in Western Mediterranean fish communities?

Marie-Joëlle Rochet, Verena M. Trenkel, and Jacques A. Bertrand

This study presents a comparative study of human impacts on the length-structure of the fish community across North-Western Mediterranean ecosystems. We use survey data to examine trends in length-based metrics and their consistency within and among different levels of organisation (populations / communities), and to suggest interpretations of observed trend combinations. We start from a set of population processes potentially affected by human pressures: fishing will induce mortality especially in target species, whereas hydrological environment and eutrophication potentially affect recruitment and individual growth. How population changes will be reflected at the community level is expected to depend on community evenness. Based on these expectations, a tentative theory for predicting the joint response of a suite of population and community length-based metrics to potential changes in their environment is proposed. The trends in these metrics from survey data are then examined, focusing on the consistency with the above predictions. The potential causes suggested for the observed trends are then checked against independent evidence of environmental and human pressures on these communities.

The approach is applied to the MEDITS survey data, which cover a series of neighbouring fish communities undergoing various human pressures, including fishing, coastal pollution and eutrophication, and a possible change in temperature and hydrology over the last decade.

Keywords: community metrics; ecosystem approach to fisheries; fish community; length-based metrics; Mediterranean; survey data.

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**ICES CM 2007/ D:17**

### Classification schemes to facilitate inter-regional comparison of climate effects on marine fish populations Inter-regional comparison of climate effects on marine fish populations facilitated through classification of mechanisms or Inter-regional comparison of the response of marine fish populations to climate facilitated through classification of mechanisms or ….?

Geir Ottersen and N.C. Stenseth

Variations in climate strongly affect the structure and function of marine ecosystems, but a number of different mechanisms are at play and their relative importance varies between regions and with time. There are obvious semi-permanent regional differences in how marine populations respond to climate, but there may also be long-term trends either in climate itself or in the response pattern. Furthermore, in some cases single strong climate events may shift an ecosystem from one state to another (e.g., El Niño). To facilitate comparison between different large marine ecosystems we here give an overview of some of the manners in which one can classify how marine fish populations are affected by climate. Responses to climate fluctuations may be bottom-up, top-down or middle-out, immediate or temporally delayed, direct or via an intermediate population of predators, prey or competitors. Climate may invoke a linear or non-linear effect at the population or community level. Ecological effects of the NAO have been classified according to the four major classes: direct effects, indirect effects, integrated effects and translations. We explain these definitions, which also may be applied to other climate patterns and regions. By using classification schemes a more precise description of the particular properties of the various ecosystems may be possible. This approach enhances the possibility to compare between regions that may differ not only with regards to the relative importance of different climate factors for ecology, but also through dissimilarities in scientific tradition and terminology.

Keywords: climate, fish, population dynamics, comparative approach.

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**ICES CM 2007/D:18**

### Comparing pristine and depleted ecosystems : the Gulf of St. Lawrence, Canada vs. the Soerfjord, Norway. Effects of intense fisheries on marine ecosystems

Lyne Morissette, Torstein Pedersen, and Marianne Nilsen

The Soerfjord, Norway, and the Gulf of St. Lawrence, Canada are two sub-arctic ecosystems with similar trophic structure. However, in the Gulf of St. Lawrence, severe exploitation of groundfish stocks has lead to

important shifts in the trophic structure. In the Soerfjord, the situation is different: fishing pressure is much lighter. Our hypothesis is that overexploitation leads to changes in the trophic structure and severely alters the resilience of ecosystems. Based on the same modelling approach (*Ecopath with Ecosim*) the foodweb structure was compared, using different ecosystem indicators. Patterns of foodweb structure and trophodynamics were contrasted. The keystone species in both ecosystems is cod. In both ecosystems, forage fish are also important. Even after similar environmental changes in both ecosystems, and after a reduction of fishing pressure in the Gulf of St. Lawrence, there is no recovery of cod stocks in this ecosystem. In the Soerfjord, after different perturbations (but not from the fishery), the ecosystem seems to return to his equilibrium.

Keywords: Soerfjord, Gulf of St. Lawrence, Ecopath with Ecosim, Fisheries, Ecosystem approach, cod.

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**ICES CM 2007/D:19**

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## Fishing effects on fish species diversity in different environmental scenarios: a comparison of case-studies in Scottish, French and Italian waters

Catherine S. Longo, Marie-Joëlle Rochet, Francesco Colloca, Graham J. Pierce, Fabrizio Serena, and Simon P. R. Greenstreet

Maintaining species diversity has been recognised internationally as a priority for sustainable fisheries but an appropriate indicator of fish diversity trends resulting from fishing exploitation is still lacking. The way that fish assemblages respond to fishing exploitation in terms of diversity remains poorly understood – available studies show contradictory or inconclusive results.

Since many processes in marine communities, including fishing, are known to be size-based, we argue that an appropriate metric to detect fish species diversity changes should also be size-based.

With the same rationale underlying 'biomass size-spectra' (i.e. the distribution of biomass across body size categories) we analysed diversity size-spectra (the distribution of diversity measures such as species evenness across fish size) to detect the differential response of large versus small size classes to fishing disturbance. However, diversity changes result from the complex interaction of many factors. To understand how environmental drivers interact with the relationship between fishing disturbance and fish species diversity, we present a comparative study of demersal assemblages from heavily fished and less fished areas in each of 4 different systems: the North-western North Sea, the Celtic Sea, the Bay of Biscay and the Tyrrhenian Sea.

Our analyses show that fisheries induce different types of responses in large and small fish diversity. They also show that the type of response depends on local characteristics such as productivity regimes, degree of piscivory, and fishing strategies. Diversity changes were in large part predicted based on fishing effects on the trophic dynamics of the system.

Keywords: biodiversity; demersal fish; fisheries; trophic interactions; size-spectra; Tyrrhenian Sea; Celtic Sea; Biscay Bay; North Sea.

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**ICES CM 2007/D:20**

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## Variability of Large Marine Ecosystems in response to global climate change

K. Sherman, I. Belkin, and J. O'Reilly

Recent examination of LME time-series of sea surface temperature, chlorophyll and fish catch for emergent global patterns related to global climate change have been completed for the World's LMEs. The general pattern of loss in biomass yields of 13% since the peak period of global fisheries catches in 1994 was confirmed in the world's LMEs. Changes in trophic structure of fisheries were most pronounced along the western margins of the Pacific basin in the Gulf of Thailand and East China Sea LMEs, where catches are increasing with landings of small, low value species, indicative of fishing down the food chain. The SSTs in both LMEs showed increases since the 1980s. However, chlorophyll showed no significant trends, suggesting that excessive fishing effort was the likely driver of fisheries biomass changes. In contrast, the fisheries of LMEs subjected to large scale icemelt are increasing. In the East Bering Sea LME, temperature increased more than 1 degree since the regime shift of 1976–1977; biomass yields reached over 2 million tons in 2003, from less than 1 million tons in the early 1970s. The emergent chlorophyll pattern raises questions with regard to the interactions between the significant temperature increases and highly variable positive and negative chlorophyll anomalies, in contrast to previously published findings. The high

variability we observed is indicative of a decoupling between coastal waters and the open ocean. Close attention should be focused on the increasing importance of global warming on chlorophyll, primary production, and the goods and services of the world's LMEs, as our findings for the past 50 years show greatly accelerated rates of temperature increases during the past 2 decades, 2–3 times greater than in the previous 3 decades of our timeseries

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### Fronts in the World Ocean's Large Marine Ecosystems

Igor M. Belkin and Peter C. Cornillon

Oceanic fronts shape marine ecosystems; therefore front mapping and characterization is one of the most important aspects of physical oceanography. Here we report on the first effort to map and describe all major fronts in the World Ocean's Large Marine Ecosystems (LMEs). Apart from a geographical review, these fronts are classified according to their origin and physical mechanisms that maintain them. This first-ever zero-order pattern of the LME fronts is based on a unique global frontal data base assembled at the University of Rhode Island. Fronts were objectively derived with the Cayula-Cornillon edge detection algorithm from 12 years of twice-daily Pathfinder satellite SST 9-km resolution data. In addition to delineating LMEs, these frontal maps serve as guidance in using hydrographic data to explore subsurface thermohaline fronts, whose surface thermal signatures have been mapped from space. In our presentation we will discuss numerous diverse links between fronts and oceanic ecosystems, particularly the enhanced bio-productivity at fronts and fronts importance as most prolific fisheries grounds.

Keywords: Fronts; Large Marine Ecosystems; World Ocean; sea surface temperature.

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**ICES CM 2007/D:22**

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### Structure and function of three marine ecosystems in Korea: A comparative study

Chang Ik Zhang, Jae Bong Lee, Sun Kil Lee, and Bernard A. Megrey

Comparative analyses are a power way to evaluate similarities and differences in ecosystem structure and function. We identified key areas of differences and similarities in the structure and function of three marine ecosystems, that is, East/Japan Sea (EJS), Yellow Sea (YS) and East China Sea (ECS) in Korea. Common modeling approaches, such as Ecopath models to three marine ecosystems were applied with important commercial fisheries, and set of macrodescriptor metrics from systems ecology were used to examine large scale ecological characteristics for the three ecosystems. Macrodescriptor metrics were calculated with Ecopath diet matrices, which were provided by food web information in three marine ecosystems. The degree to which components of a system are affected by each other were measured by the number of interactions per component of a system (i.e. Connectivity) and by the proportion of all possible connections within a system that are realized (i.e. Connectance). Food web connectance showed that average number of trophic steps from primary producers to apex predators was longest in the EJS, and that trophic pathways were more linear in the YS. EJS and ECS had pelagic and benthic foodwebs, while YS mainly pelagic. Other macrodescriptor metrics, such as linked pathways starting from a group and returning to it, were described to compare ecological attributes for the three marine ecosystems.

Keywords: comparative analyses, ecosystem structure and function, Ecopath models, macrodescriptor, connectivity, connectance, ecological attributes.

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**ICES CM 2007/D:23**

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### Climate variability and the ecosystems of the Barents and Norwegian Seas

K. Drinkwater, W. Melle, and H. Loeng

The principal features of the marine ecosystems in the Barents and Norwegian seas and some of their responses to climate variations will be described. The physical oceanography is dominated by the influx of

warm, high salinity Atlantic waters from the south and cold, low salinity waters from the Arctic. Seasonal ice forms in the Barents Sea with maximum coverage typically in March. The total mean annual primary production rates are similar in the two regions (80-90 gC m-2) although in the Barents the production is higher in the Atlantic than in the ice-covered Arctic waters. The zooplankton is dominated by *Calanus species*, *C. finmarchicus* in the Atlantic waters of the Norwegian and Barents seas and *C. glacialis* in the Arctic waters of the Barents Sea. The fish species in the Norwegian Sea are mostly pelagics such as herring and blue whiting while in the Barents Sea there are both pelagics (capelin, herring, and polar cod) and demersals (cod and haddock). The latter two species spawn in the Norwegian Sea along the slope edge (haddock) or along the coast (cod) and drift into the Barents Sea. Marine mammals and seabirds, although comprising only a relatively small percentage of the biomass and production in the region, play an important role as consumers of zooplankton and small fish. While top down control by predators certainly is significant within the two regions, there is also ample evidence of bottom-up control. Distributional changes in several fish species, such as cod, herring and blue whiting, parallel shifts in the distribution of Atlantic and Arctic water masses. Evidence is also presented that increases in primary and secondary production associated with climate variability have led to increases in fish production, both through higher abundance and improved growth rates.

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**ICES CM 2007/D:24 Poster**

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## A light in murky waters: bivalve filtration facilitates growth of eelgrass in a eutrophied environment

Bradley J. Peterson, Charles C. Wall, and Christopher J. Gobler

Seagrass beds are important structural habitats in estuaries, and there may be mutual facilitation of growth and recruitment between seagrasses and suspension-feeding bivalves. In a series of mesocosm experiments lasting from 8 to 18 days, we tested the effect of various densities of three suspension feeding bivalves (*Mercenaria mercenaria*, *Crassostrea virginica*, *Mytilus edulis*) on the growth of eelgrass (*Zostera marina*) in a eutrophied environment. Eelgrass growth was measured by leaf area productivity, and varied from 3.18 ± 0.36 cm2 shoot-1 d-1 to 7.90 ± 2.12 cm2 shoot-1 d-1 (mean ± SD); leaf area productivity was always higher in the treatments with the highest density of bivalves compared to a control without bivalves. Experimental treatments with bivalves consistently had significantly lower chlorophyll a concentrations, and most bivalve treatments also showed substantial increases in light penetration. The data indicate that clearance of the water column and the subsequent increase in light penetration was the primary mechanism by which suspension-feeding bivalves facilitated the growth of eelgrass. This finding has important implications for the conservation of estuarine seagrass habitats and shellfish populations, specifically that healthy populations of suspension-feeding bivalves can serve as a control on estuarine eutrophication and can help restore degraded seagrass habitats.

Keywords: *Zostera marina*, *Crasostrea virginica*, *Mercenaria mercenaria*, *Mytilus edulis*, seagrass, eelgrass, eutrophication, bivalves, suspension feeders, mesocosms

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**ICES CM 2007/D:25 Poster**

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## Examining the relative significance of ocean climate forcing, fishing pressure, fish landings, and TACs on the status of commercial fish populations in the southern North Sea

A.J. Kenny and G.H. Engelhard

Results of an integrated assessment of the North Sea ecosystem using gridded data at the scale of ICES statistical rectangle between 1973 and 2004 revealed a striking correlation between changes in the abiotic state and fish landings for England and Scotland when measured at the scale of the North Sea. In order to better understand the significance of this relationship and to ascertain its possible underlying cause, additional data on fishing pressure (total hours trawled), fishery management quotas (TACs) and catch per unit effort data (CPUE) have been collated and integrated into the analyses at a range of different scales. The results provide some useful insights into the relative significance of climate, fishing and management (societal) pressures in relation to the status of commercial fish stocks and therefore on the choice of methods for managing their status.

Keywords: fishery management, TAC, North Sea, ecosystem, ocean climate.

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**ICES CM 2007/D:26 Poster**

### Estimation of fecundity in *Nephrops norvegicus* (L.) from the Irish Sea

N. McQuaid, R.P. Briggs, and D. Roberts

Potential fecundity (number of oöcytes in the mature ovary) and realised fecundity (number of eggs extruded and attached to the pleopods of females caught at the start of the incubation period) were estimated for females from the eastern and western Irish Sea grounds. Potential fecundity was found to differ significantly between eastern and western Irish Sea stocks, while realised fecundity did not differ between areas. Inter-year comparison of realised fecundity, and effective fecundity (the number of mature eggs on the pleopods of females at the end of the incubation period) in western Irish Sea stocks revealed no significant variation over time. Egg loss during the transition from oöcytes in the ovary to mature (stage D) eggs increased with female size, ranging from 40% at 25mm CL to 65% at 40mm CL. No relationship was found between egg diameter and/volume and female carapace length.

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**ICES CM2007/D:27**

### An orientation to the Gulf of Maine-Georges Bank ecosystem

Jason Link, Kevin Friedland, Jon Hare, William Overholtz, and Maureen Taylor

We provide an overview of major ecosystem components and processes for the Gulf of Maine-Georges Bank ecosystem. This descriptive analysis highlights the major biophysical features of the ecosystem and their dynamics over the past half- to full century. We examine a wide range of hydrographic, bathymetric, geological, chemical, and climate variables to characterize the physical features of this ecosystem. We then examine a wide range of primary producer, zooplankton, fish, marine mammal, aggregate biomass, community, trophodynamic, and network metrics to characterize the biological features of this ecosystem. Inter-annual variability in the physical environment has been clearly related to variability in the biota. Relationships among the biota are also reviewed, particularly the strong bottom-up processes that dominate energy fluxes in this ecosystem. Currently the system is more "horizontally" focused than "vertically" relative to 20-30 years ago. Despite having a wealth of databases relative to many other marine ecosystems, we also highlight those areas where we would like to improve our knowledge base. Finally, we briefly discuss the role that climate and resource harvesting will continue to play in this ecosystem.

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**ICES CM 2007/D:28 Poster**

### Characterizing the trophic environment of larval fishes in the low-latitude open ocean: Evolved niche separation and minimal starvation in tuna and billfish larvae

Joel K. Llopiz, Robert K. Cowen, and Elizabeth M. Crompton

The tropical and subtropical open ocean is larval habitat for a high diversity of fishes, including migratory species that utilize these waters as spawning habitat. Yet, the prey environment and trophic ecologies of larval fishes in low latitudes are substantially understudied despite their importance in understanding larval fish survival. Feeding data from six taxa of larval tunas and billfishes from the Straits of Florida indicate that starvation mortality is most likely negligible, contradicting the presumption that this unproductive environment should be nutritionally constraining. Prior to piscivory, larval billfishes fed almost exclusively upon either a single species of small copepod or cladoceran. For larval tunas, the likelihood of starvation or suboptimal feeding appeared to be reduced by the spatial distributions of the larvae in relation to their nearly exclusive prey, appendicularians. Overlap of all four genera of tuna larvae occurred where appendicularian abundance was greatest, yet only *Thunnus* spp. and *Katsuwonus pelamis* were present in regions of low appendicularian abundance. Additionally, these two taxa exhibited significantly different vertical distributions. All taxa underwent early ontogenetic shifts to piscivory, and are probably dependent upon the presence of fish larvae for optimal growth and survival. While these results highlight the evolved mechanisms that larval survival is optimized in these warm, oligotrophic waters, they also illustrate how different the planktonic trophic pathways are in such environments when compared to higher latitudes. Noteworthy is the lack of a role for large phytoplankton and evidence for complete reliance upon the microbial community via small crustaceans and appendicularians.

Keywords: larval fish, feeding, trophic ecology, essential fish habitat, spawning habitat, tunas, billfishes.

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**ICES CM 2007/D:29 Poster**

### Ecosystem of the Vistula Lagoon in the light of results obtained in mathematical modelling

Mariusz Zalewski, Zbigniew Witek, and Magdalena Wielgat-Rychert

Understanding of processes controlling the lagoon ecosystem functioning enables to provide reliable advice to managers. Our first attempts to build the 3D Vistula Lagoon ecosystem model started during the MANTRA-East project. Now, we wish to present results of the modified model. On that basis the significance of particular ecosystem processes and elements can be evaluated.

A working package of the DELF3D software was used as a tool to elaborate the biogeochemical model for the Vistula Lagoon. It aimed at primary production and nutrient cycling in water and sediments. Model calibrations were based on the in situ data gathered by various institutions carrying studies in the subjected region over the years 1998-2000.

The obtained modelling results, as well as problems occurring during the process of calculations, allowed to determine the importance of particular elements of the Vistula Lagoon ecosystem. Modelling made it possible to estimate seasonal variability in nutrient and chlorophyll concentrations, and primary production, with spatial distribution of these parameters being included. The authors determined factors responsible for primary production limitation, and among those factors light conditions and depletion of nutrients were found to be of utmost importance. Based on calculations it was also possible to estimate the impact of carbon, nitrogen, phosphorus and silicon loads reaching the Lagoon, and the impact of mineralization, denitrification, and nitrification processes on seasonal nutrient variability in the water column.

Keywords: Vistula Lagoon, biogeochemical model, nutrient loads, nutrient cycling, eutrophication.

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**ICES CM 2007/D:30 Poster**

### Structure and function of pelagic and benthic food webs at 3 ecohydrodynamically distinct sites in the North Sea

Suzanne Painting, R. Forster, N. Greenwood, O. Mikkelsen, R. Parker, L. Fernand, and P. Kershaw

A comparative approach has been adopted to study ecosystem structure and function at 3 hydrographically distinct sites in the North Sea (one southern and two central) over 2 seasonal cycles (Feb 2007 to Sept 2008). Preliminary results from 3 cruises (out of 10, ongoing), permanent *in situ* monitoring at the seabed and in surface waters, and satellite imagery clearly show temporal and spatial variability in oceanographic features, particle dynamics, and the structure of benthic and pelagic (from bacteria to zooplankton) communities. Through process-orientated studies of rates such as primary production, phytoplankton growth, bacterial growth, zooplankton grazing and nutrient recycling we aim to improve our understanding of the C and N flux through both benthic and pelagic food webs, and the coupling between them. By the end of the study in 2011, our overall objective is to determine the key ecosystem connections that are susceptible to change, due to changes in environmental conditions, or human impacts.

Keywords: food webs, benthic, pelagic, structure, function, North Sea.

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**ICES CM 2007/D:31**

### Food web structure at 3 contrasting sites in the North Sea

Benjamin Kürten, S. Painting, U. Strück, and N. Polunin

Carbon and nitrogen flows through benthic and pelagic food webs at 3 hydrodynamically distinct sites in the shelf waters of the North Sea (1 southern, 2 central, see poster by Painting et al) are being investigated over an annual cycle using δ13C and δ15N stable isotope techniques. Preliminary results of POM <62µm and different zooplankton species from a cruise in February 2007 indicate contrasting pelagic food web structures between the southern and central sites. During the winter conditions prior to the onset of spring phytoplankton blooms, zooplankton such as copepods and chaetognaths appear to have been feeding at higher trophic levels in the southern bight than in the central North Sea. Analyses of *Calanus* species, for example, indicate that the species dominant at the southern site (*C. helgolandicus*) was feeding on higher trophic levels than it's competitor, *C. finmarchicus*, particularly at the southern site. More detailed analyses of samples collected throughout the spring/summer growth season will contribute towards an improved understanding of temporal and spatial changes in food web structure.

Keywords: food webs, benthic, pelagic, stable isotopes, carbon, nitrogen, North Sea.

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**ICES CM 2007/D:32 Poster**

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### Satellite Climatology of SST and Chlorophyll Fronts in the Northeast U.S. Large Marine Ecosystem

Igor M. Belkin and John E. O'Reilly

Satellite data from several thermal and color sensors (AVHRR/NOAA, SeaWiFS and MODIS/Aqua) were processed with a newly developed algorithm to generate a climatology of SST and chlorophyll fronts in the Northeast U.S. Large Marine Ecosystem. Our approach is based on the Canny edge detection algorithm. The main novelty is image pre-processing with shape-preserving, scale-sensitive median filter applied selectively and iteratively until convergence. When applied to chlorophyll data, our approach emphasizes spatial patterns peculiar to this field, namely chlorophyll enhancement associated with thermohaline fronts, and small- and meso-scale chlorophyll blooms. These patterns are modeled as ridges and peaks; they need to be preserved and treated differently from SST fronts modeled as steps or ramps. The resulting climatology of front statistics (frequency/persistence, magnitude, and direction) is based on 20 years of SST and 9 years of chlorophyll data. In our presentation we will describe the main spatial patterns and temporal features, relationships between SST and chlorophyll fronts, and long-term trends of this climatology.

Keywords: Large Marine Systems; fronts; Mid-Atlantic Bight; Gulf of Maine; sea surface temperature; chlorophyll.

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**ICES CM 2007/D:33 Poster**

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### Propagation of Temperature-Salinity Anomalies along North America's Eastern Seaboard

Igor M. Belkin and John E. O'Reilly

Satellite and in situ data are used to study TS-anomalies and their propagation along North America's eastern seaboard. The Shelf-Slope Front appears as a main conduit for these anomalies which originate in the Arctic and propagate southward along the shelf break. For the first time, these anomalies are traced as far south as Cape Hatteras. Decadal-scale cold, fresh anomalies commonly referred to as the Great Salinity Anomalies (GSA) are observed off the U.S. Northeast in 1987-1988, 1996-1997 and 2005. The intervening warm, salty anomalies are less noticeable, except for a distinct warm anomaly in 2000. Thus, the Arctic forcing appears as a dominant factor that causes decadal-scale regime shifts in the Northwest Atlantic Ocean.

Keywords: Great Salinity Anomalies; fronts; shelf-slope front; shelf break; Mid-Atlantic Bight; temperature; salinity; chlorophyll.

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