S5.1 Scenarios for polar, mid-latitude, sub-tropical, and tropical environments and ecosystems

21 May, 09:15 (S5.1-4879) Plenary

The changing Northern Ocean

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It has long been argued that ocean climate change would occur first and fastest in the high-latitudes of the northern hemisphere; recent observations, reviewed here, now confirm this prediction to be true. Within the Arctic Ocean there have been pronounced changes in the properties and distribution of water masses derived from the Atlantic and Pacific Oceans, dramatic reductions in sea ice cover, and documented impacts on biota. However, our understanding of the full effects that a warming climate will have on subarctic and arctic seas remains fragmented - both regionally and among disciplines - and a panarctic perspective of these interconnected systems is urgently needed. In this talk I will attempt to (1) review the changes in the ocean and ice that have occurred in recent years; (2) discuss mechanisms of ice-ocean and physical-biological coupling; (3) present new observations of physical and biogeochemical structures in the three oceans surrounding northern North America; and (4) offer a conceptual model of climate change in subarctic and subarctic seas based on stratification typology and the ocean's hydrological cycle.

21 May, 10:35 (S5.1-4770) Invited

Impacts of climate change on Antarctic marine ecosystems

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Antarctic waters are expected to be particularly sensitive and vulnerable to climate change. Global warming will affect sea ice patterns and the survival of Antarctic krill and cold water plankton. Increased UV levels will also affect them. Ocean acidification has been predicted to be a more immediate threat to the plankton of the region causing the demise of species with calcium carbonate shells, e.g. pteropods. These events need to be considered together due to possible synergistic effects. Changes in plankton composition have been observed in the North Sea, Atlantic and North Pacific with flow on effects through the food web and linked to declines in fish stocks. A decline in krill abundance since the 1970s and associated increase in salps has been associated with the decrease in sea ice extent. The Southern Ocean Continuous Plankton Recorder Survey has also identified major changes in zooplankton composition in the sea ice zone (SIZ) around the year 2000 with smaller zooplankton now dominating instead of krill. Large blooms of *Emiliania huxleyi* are now extending southward well into the SIZ possibly due to ocean warming. In 2004/05 in waters north of the SIZ, pelagic foraminiferans exceeded 50% numerical abundance instead of the 2% long term average, replacing *Oithona* as the dominant species. The causes of the changes are still being investigated. However, such changes in food composition at the base of the food web and a shift downwards in the size of zooplankton prey could have a major impact on the survival of higher predators.

21 May, 11:00 (S5.1-4778) Invited

A scenario approach to forecast potential impacts of climate change on red king crabs in the eastern Bering Sea

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We developed scenario-based forecasts of potential impacts of climate change on three stocks (Bristol Bay, Pribilof Islands and Norton Sound) of red king crabs (*Paralithodes camtschaticus*) in the eastern Bering Sea (Alaska). Seven mechanisms responsible for crab population dynamics were identified: larval prey type, larval

prey timing, larval advection, juvenile predation and competition, benthic energy flow, ocean acidification, and commercial fisheries. Based on reasoned expert professional judgment, scenarios of the impacts of climate change on the biomass and commercial harvests for the years 2030 and 2050 were developed, driven by forecasts of anthropogenic and environmental conditions. Forecasts were developed largely from projections of key atmospheric and oceanographic variables from the Fourth Assessment Review by the Intergovernmental Panel on Climate Change. For each crab stock, three estimates of red king crab biomass – central, low, and high – were derived for each scenario year. Although results vary by area, global warming is generally expected to result in declines in all three stocks of red king crabs in the Bering Sea. Mechanisms operating to favour crab productivity include benefits of stock rebuilding plans and potential improved timing of red king crab larvae and their prey. These positive effects are likely to be overwhelmed by deleterious mechanisms including larval advection to unsuitable nursery habitats (Bristol Bay only), increased predation and food competition by expanding groundfish populations, and reduced energy flow to the benthic invertebrate prey species. Effects of ocean acidification on the growth and survival of king crab larvae are not likely by 2050.

21 May, 11:25 (S5.1-4631)

Predicting the effects of climatic change on the biodiversity of intertidal sessile fauna on coral reefs

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On coral reefs, sessile taxa occupying intertidal rubble habitats contribute significantly to the overall biodiversity and ecosystem function of coral reef ecosystems. The existing strong physical gradients in these intertidal habitats will be exacerbated under predicted climatic change, but it is unclear how communities will respond to these changes. We examined how biodiversity in these assemblages would be affected by one aspect of climatic change – increased storm intensity – through experimental manipulations of the disturbance regime on One Tree Reef in the southern Great Barrier Reef. We monitored colonisation of undisturbed (secured) and disturbed (unsecured), natural (coral) rubble plates over nine months. At the exposed sites disturbance resulted in 71% loss of species richness and 88% loss in total coverage low on the shore. Even at the sheltered location, there was significantly more species present when disturbance was removed. Some species that were absent on natural (unsecured) plates successfully colonised the undisturbed plates, indicating that disturbance was restricting their distribution As physical disturbance regimes increase due to more intense storms and wave action associated with global warming, we can expect to see a corresponding decrease in the diversity of these cryptic sessile assemblages. This could have implications for the future health and productivity of coral reef ecosystems, given the ecosystem services these organisms provide.

21 May, 11:40 (S5.1-4632)

Possible change in seaweed distribution in East Asia under a particular scenario of global warming

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Global warming effects on coastal marine ecosystems are already perceptible. Seaweed beds constitute highly valuable spawning, nursery and feeding grounds for numerous organisms in coastal waters. Hence, fisheries resources as well as biological diversity are dependent on the presence of these beds. Geographical distributions of seaweeds greatly depend on water temperatures in summer and winter because they are very sensitive to maximum and minimum water temperatures. As a result, it is expected that a water temperature increase will drastically influence the current distribution. In order to test this hypothesis, we referred to a scenario of global warming (A2) developed by Center for Climate System Research of the University of Tokyo. This simulation enables the prediction of water temperature in the Pacific Ocean and adjacent seas by 1 degree. Using simulated surface

water temperatures in February and August in 2050 and 2099, we examined changes in the spatial distribution of a specific seaweed species: *Sargassum horneri*. This species was selected because it is an important species forming seaweed beds and has a wide thermal tolerance. Results show that the southern limit of *S. horneri* distribution is expected to keep moving northward such that it may broadly disappear from Honshu Island, the Chinese coast and the Korean Peninsula by 2099. Since *S. horneri* forms drifting seaweeds in the East China Sea and that these floating habitats constitute a key nursery ground for yellowtail and jack mackerel spawning, *S. horneri* disappearance is expected to significantly damage not only fishes related to the plants but also pelagic ones.

21 May, 11:55 (S5.1-4959)

North Pacific Research Board and National Science Foundation partner to study biological processes on eastern Bering Sea shelf ecosystem and impacts of climate change

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The North Pacific Research Board (NPRB) and National Science Foundation (NSF) are partnering in a massive $50 million study of the eastern Bering Sea shelf ecosystem and how it may respond to climate change and loss of sea ice. It will include three field seasons in 2008-2010 and two years for analysis and reporting. Over 70 federal, state, and university scientists will be involved, hailing from Alaska, Washington, Oregon, British Columbia, and elsewhere in North America. NSF will study atmosphere and ocean physics and lower trophic levels, including physical and biological sampling near sea ice and the ocean floor, primary production, nutrients and stratification, and energy transfer through zooplankton. NPRB will emphasise forage fish, commercial fish species such as pollock, Pacific cod, and arrowtooth flounder; northern fur seals, walrus and whales; and common murres and blacklegged kittiwakes. Foraging patterns of birds and mammals will be studied within large prey aggregations near the Pribilof, Bogoslof, and St. Lawrence Islands. Federal matching funds from the National Oceanic and Atmospheric Administration, US Geological Survey, and US Fish and Wildlife Service will support trawl surveys, seabird telemetry, and studies of fur seal pups and persistence of foraging hotspots. Local and traditional knowledge will provide additional views on how the ecosystem functions. This study is certain to improve our understanding of biological processes that underpin the robust Bering Sea fisheries and our predictive capacity of those fish stocks as a result of an innovative, bio-physical ecosystem model that will tie programme components together.

21 May, 12:10 (S5.1-4819)

Getting hot and bothered about climate change impacts in Australian waters

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Marine ecosystems are extremely important economically and ecologically to Australia in terms of tourism, coastal defence, harvestable resources, and ecosystem services. Australian waters harbour a number of unique ecosystems which may be particularly vulnerable to climate change. We present findings of comprehensive reviews of observed and potential climate change impacts on Australian marine life, fisheries and aquaculture. Ocean acidification, alteration of storm regimes and warmer temperatures are expected to have the greatest impacts on tropical fauna increasing the frequency of coral reef bleaching and altering recruitment strength of important commercial species such as prawns. A strengthening of the East Australian Current is projected to drive intense warming of the Tasman Sea, challenging the persistence of cool-temperate fauna and flora. Climate change will impact the biological, economic and social aspects of many of Australia's valuable fisheries. Aquaculture industries have considerable adaptation potential via selective breeding, regulating the environment, and new species opportunities. Wild fisheries will see increased opportunity where tropical species move polewards, while for southern fisheries, reconciling non-climate threats with increasing temperature will require proactive

management. Climate change impacts are already being recorded in Australian waters and future changes are likely to be dramatic and have considerable socio-economic and ecological consequences, especially in 'hot spots' of climate change such as the Tasman Sea and the Great Barrier Reef. The reviews indicate that while we have a general understanding of the likely mechanisms of climate change impacts on a few species, we have limited knowledge at an ecosystem level.

21 May, 12:25 (S5.1-4841)

Long term changes in North Sea physics and phytoplankton from NORWECOM

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We explore the North Sea long term changes in circulation, hydrographic conditions and phytoplankton conditions in the period 1985-2007 from a simulation by the numerical model NORWECOM. The model is shown to reproduce the observed hydrographic conditions, inflows, heat content and phytoplankton distribution. A bipolar North Sea flow pattern is identified, with the northernmost pattern being regulated by large scale atmospheric forcing. For the last decade, mean annual heat content has been above the long term mean, and accumulated heat corresponds to an average temperature increase of roughly 0.5°C. The heat flow through the North Sea boundaries is explored and the seasonally variable main sources of heat identified. The model confirms a clear trend towards lower levels in the southern North Sea nutrients as a result of reduced anthropogenic loads. The interannual variability in primary production is controlled by the physics, and these mechanisms are investigated.

21 May, 12:40 (S5.1-4864)

Long-term environmental changes and the responses of the ecosystem in the northern South China Sea during 1976-2004

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Physical and chemical oceanographic data were obtained by seasonal monitoring along transect N, in the northern South China Sea (nSCS) during 1976-2004. The fluctuations of DIN (dissolved inorganic nitrogen), seawater temperature (SST and T_{av} - average temperature of the water column), N:P ratio and salinity (S_{av} and S_{200}—salinity at 200 m layer) exhibited an increasing trend, while those of T_{200}, DO, P, Si, Si:N and SSS exhibited a decreasing trend. The annual rates of DIN, DO, T and S revealed pronounced changes, and the climate trend coefficients Rxt, which was defined as the correlation coefficient between the time series of an environmental parameter and the nature number, were 0.38 to 0.89 and significant ($p \leq 0.01$ to 0.05). The results also show that marine ecosystems of the nSCS have obviously been influenced by the positive trends of both SST and DIN, and negative trends of both DO and P, e.g. before 1997 DIN concentration was very low and N:P ratios less than half of the Redfield ratio (16), indicating potential N limitation; while since 1998 all Si:P>22 and the N_{av}:P_{av} close to the Redfield ratio, indicating potential limitation of P and the limitation of N has mitigated. Ecological investigation shows that there were some improved responses of ecosystems to the long-term environmental changes, chlorophyll *a* concentration, primary production, phytoplankton abundance, benthic biomass, cephalopod catch and demersal trawl catch have increased. But phosphorus depletion in the upper water resulted in a succession of phytoplankton communities, i.e. the dominant species shifted from diatoms to dinoflagellates and cyanophytes. The signs of ecosystem response resulted from environmental changes, induced not only by climate changes, i.e. global climatic events, like ENSO, but also anthropogenic activities, which are discussed.

21 May, 12:55 (S5.1-4548)

Resilience of mangroves to indirect effects of climate change

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Climate change threatens the very survival of species and the integrity of ecosystems world-wide on which humans and generally all life on earth depends. Wetlands will suffer the most being a transitional ecotone between land and water bodies. Emerging scientific information indicates that the 1997/8 and last year's heavy rains in Kenya previously thought to have been caused by *El Niño* were a consequence of global climate change due to a phenomenon referred to as the Indian Ocean Dipole. During this event in 1997/8, there was elevation of sea surface temperature by 1°C which led to 50-80% coral reef death along the Kenyan coast due to bleaching. The impact of this phenomenon on mangroves, which are an important coastal resource has not been assessed. But preliminary data from Mwache Creek, Kenya indicates that there was extensive mangrove dieback in some areas due to massive sedimentation following severe erosion upstream. Land-use practices seem to be exacerbating soil erosion and sedimentation in this area. Such land-use practices observed include: shifting cultivation, overgrazing and poor tillage of land without any soil and water conservation measures whatsoever. As a result there is continuous loss of the top soil rich with nutrients leading to poor productivity which has significantly compromised the food security of the local people. Recovery of the impacted mangroves is limited and opportunistic species e.g. salt tolerant grasses and Sueda maritime are colonising the impacted sites, which has consequences on the livelihoods of the local people depending on the mangrove ecosystem for wood products, fisheries and even shoreline protection. Human intervention to restore the impacted mangroves and an integrated management of these mangroves with the contiguous terrestrial ecosystems will be necessary to mitigate the effects of climate change and safeguard the livelihoods of dependant communities.

21 May, 13:10 (S5.1-4919)

Predicting climate warming impact on marine fish communities from biogeography: example from tropical, subtropical and temperate case studies

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Species have adapted to the mean conditions encountered within their distribution area, including temperatures. Hence the temperature characteristics observed within the distribution area may indicate the thermal affinity and tolerance of the species. In a given ecosystem, the species adapted to warm waters should be favoured (increase of their biomass) by an increase of the sea temperatures, while the species adapted to cold waters should be unfavoured. However ecosystem responses to the common, large scale climatic forcing could vary in respective latitudinal regions due to regionally-specific environmental/ecological characteristics. These hypotheses were tested comparing the changes observed during the last decades in three fish communities of continental shelves regarding the temporal trend of sea surface temperatures of the three ecosystems, the biogeographic origin and the corresponding thermal affinity of the species from the communities. The three ecosystems chosen were a mid-latitude area, the Bay of Biscay (France), a sub-tropical up-welling area (South Morocco), and a tropical one, the Guyana shelf. Biomass data from scientific trawl surveys carried out in the three systems were used to assess the community changes. The results are discussed according to the diversity-stability hypotheses and the fishing pressure in these ecosystems as confounding factor.

21 May, 13:25 (S5.1-4952)

The ecosystem response of the Barents and Norwegian seas to future climate change with emphasis on the higher trophic levels

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Under future climate change, the Arctic is expected to undergo the largest changes in temperature. In the Barents Sea, ocean temperatures are predicted to increase between 2-8°C while farther south in the Norwegian Sea it is expected to be 1-3°C due to atmospheric warming and increased Atlantic Water inflow. In this presentation we use past observations and statistical relationships between ecological variables and climate along with the predicted future climate changes to develop future ecological scenarios. With the increased thermal heating, sea ice will disappear from the Barents Sea. Where this happens, the increase in light levels will lead to increased annual phytoplankton production. Arctic zooplankton biomass is expected to decrease and Atlantic zooplankton to increase as the Atlantic Water influence increases. In the Norwegian Sea plankton changes will be much reduced. At the higher trophic levels, higher recruitment levels and faster growth of species such as Atlantic cod, herring and capelin are expected in both seas, leading to increases in overall production and biomass. Distribution will spread northward including spawning sites for some species. Pelagic production will increase especially within the Norwegian Sea. Species such as blue whiting and mackerel will likely spread northward as well as into the Barents Sea. The effects of both fishing and species competition on the future changes in the major commercial species will be discussed. With an expected increase in the overall fish production increases in the abundance of marine mammals and seabirds are expected.

S5.1 Posters

Poster S5.1-4515

Climate changes and tourism: southeastern Anatolia region and southeastern Anatolia Project (GAP) in Turkey as a case study

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The Republic of Turkey has a special place in the Mediterranean Region from the respects of both its social-economic structure and its geo-politic and geo-strategic importance. It is also a model for the Middle East Countries by combining the traditional and modern life styles. The Southeastern Anatolia Project (Turkish: Güneydoğu Anadolu Projesi, GAP) is a multi-sector integrated regional development project based on the concept of sustainable development for the 9 million people living in the Southeastern Anatolia region of Turkey. GAP's basic aim is to eliminate regional development disparities by raising people's income level and living standards; and to contribute to such national development targets as social stability and economic growth by enhancing the productive and employment generating capacity of the rural sector. Climatic changes were observed in the region after the creation of artificial lakes for irrigation. The modified climate has started to cause changes in rural tourism in the region. It has also allowed for new types of flora to become established and created an environment for alternative types of tourism. In recent years, remarkable developments have been observed in eco-tourism and agro-tourism in the region and a general increase in the flow of tourists to the region has been observed. The main purpose of this study is to analyse the effects of climatic changes in the region. A brief introduction to the region and to the GAP Project will be given followed by an examination of the climatic structure of the region. Both the climatic features and tourism structure before and after the GAP Project will be included. In the third section, the results of climatic changes and new tourism alternatives will be analysed. Again, in this section, the existing tourism potential will be determined. This study will present a series of policies and strategies for differential tourism and tourism development after the climatic changes in this region

Poster S5.1-4845

Influence of climatic changes on density dynamics of boreal and subtropical bivalves larvae in plankton of Minonosok Bight (Possyet Bay, Japan/East Sea)

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The study was carried out in connection with global temperature changes, registered in the 20th century. The work was conducted in summer-autumn 2002-2004 in Minonosok Bight of the Possyet Bay, Japan/East Sea, 10-15 years after the last corresponding investigations. The influence of water temperature and salinity changes on the density dynamics of bivalve larvae in the plankton was studied. Features of the temporary distribution and dimensional structure of commercial bivalve larvae in the plankton of the Minonosok Bight in early 2000s were determined. Significant changes in terms of the pelagic period of larvae were revealed for *Mizuhopecten yessoensis, Mytilus trossulus, Chlamys farreri nipponensis* and *Crassostrea gigas* in comparison with available data obtained in the period from the mid-1970s to the early 1990s. These changes are explained by water temperature rise. It was established, that the degree of mollusk's reaction to a water temperature rise is connected with the thermopathy determined by biogeographic characteristics and ecological plasticity. A tendency towards an increase in the number of larvae of subtropical bivalves – *C. f. nipponensis* and *C. gigas* was marked.

Poster S5.1-4922

Effect of *El Niño* Southern Oscillation events on the distribution and abundance of phytoplankton in the northern South China Sea

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The distribution of physical and chemical parameters and their impact on phytoplankton abundance and primary production in the northern South China Sea were compared in two opposing situations: the *El Niño* Southern Oscillation (ENSO) event of 1998 and the non-ENSO period of 2004. During *El Niño* conditions (June-July 1998), lower cell abundance was recorded in the region of 18-22°N, 110-117°E. In August 2004, under the non-ENSO conditions, a well-established coastal upwelling produced an increase in the surface layer nutrient supply. This in turn caused an increase in phytoplankton populations at the surface layer, with chlorophyll concentrations >1.5 mg·m^{-3} and microalgae populations $>300\times10^3$ cell·dm^{-3} respectively. Integrated over 150 m, chlorophyll *a* concentrations were 4.2 times larger in 2004 than in 1998. A strong subsurface Chl *a* maximum which was dominated by photosynthetic picoplankton was found to contribute significantly to phytoplankton stocks and production year round, especially in shelf and open seas. The analysis of the spatial distribution of phytoplankton species shows how the community structure is related to the gradient of the nutrients from coastal region to the open sea.

S5.2 Adaptation and mitigation of impacts on the marine environment and ecosystems

23 May, 09:15 (S5.2-4978) Plenary

Managing for resilience in ocean ecosystems

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Climate change is likely to result in numerous changes – both those that can be anticipated as well as others that will come as surprises. Many changes may act synergistically, e.g. higher ocean temperatures and lower pH creating 'double jeopardy' for many species. The fast pace and interaction of multiple changes may prove unfavourable for many species. Moreover climate impacts co-occur with other changes (nutrient and chemical pollution, overfishing, habitat destruction, invasive species). At risk are a wealth of 'ecosystem services' such as the provision of seafood, protection of shores from storms, control of pests and pathogens, nutrient cycling, primary production, climate regulation, detoxification, opportunities for recreation and more. As the impacts of climate changes on ocean ecosystems become more obvious, society will seek strategies to maintain key ecosystem services. The complex nature of ocean ecosystems and the interactions across multiple changes argue for holistic approaches to adaptation. One strategy is to choose policies that accomplish one or both of these goals: (1) minimise stresses that can be reduced (e.g. pollution, overfishing, invasive species), and (2) maximise genetic, species and habitat diversity (e.g. create networks of no-take marine reserves). Strategies will likely shift away from achieving specific targets such as fishery catches and toward maintaining resilience within ecosystems. The knowledge systems needed to inform such management and policy decisions are not currently in place. These needs present new challenges and opportunities to the marine science and policy communities.

23 May, 10:35 (S5.2-4949) Invited

How can fisheries adapt to a changing ocean climate: beyond ecosystem-based fishery management

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Fishermen are masters of adaptation, but fishery management is not. In many cases, the policy and management strategies and tactics applied in developed fisheries around the world lag the changes in those fisheries by years. Fishermen adapt to changing conditions at sea on very short time-scales, changing regulations on an annual or multi-annual timeframe, and to market and business conditions on many different scales. But can fishermen and managers adapt to fundamental changes in ocean conditions, and do so without undermining sustainability of changing ocean ecosystems? This paper explores the adaptation strategies from a manager's perspective including changing the incentive structure in fisheries to support sustainability, altering the responsiveness of fishery management strategies as climate changes, and changing the perspective of fishery management working in isolation from other sectors of human activities in the marine environment. Taking an ecosystem-based approach to management across sectors of human activity is key to adaptation, but that ecosystem approach must be framed by the environmental changes that are driven by climate change.

23 May, 11:00 (S5.2-4710) Invited

Ecological and rapid evolutionary responses to climate change: implications for marine management

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An understanding of ecological and rapid evolutionary responses to climate change is critical to effective management and conservation of marine ecosystems given future change. Potential ecological and evolutionary responses to climate change include movement, acclimation, and genetic adaptation in phenology, life history

traits, and physiological tolerance. Adaptive responses are particularly relevant to species which exist at environmental extremes and the limits of their physiological tolerances, such as coral reefs and polar species. Theoretical explorations of ecological and evolutionary responses to climate change can inform conservation management prioritisation such as which types of locations to protect in marine reserves. To illustrate this potential, I will provide an overview of the general theory of rapid evolutionary responses to environmental change, which indicates the rate of change to which a species may adapt and the characteristics (e.g. genetic variance, selection strength) which influence that adaptive rate. Then I will apply this theory to case studies, such as the potential for coral reef ecological and evolutionary responses to the increase in thermal stress expected with climate change. Overall, theoretical predictions indicate the need to account for uncertainty and protect diversity in order to conserve marine ecosystems and their services in a changing climate.

23 May, 11:25 (S5.2-4924)

A global map of human impact on marine ecosystems

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The management and conservation of the world's oceans require synthesis of spatial data on the distribution and intensity of human activities and their overlap on marine ecosystems. We developed an ecosystem-specific, multi-scale spatial model to synthesize 17 global data sets of anthropogenic drivers of ecological change, including climate change, for 20 marine ecosystems, including coral reefs, seagrass beds, continental shelves, and the deep ocean. This approach stands out from past studies, which have focused largely on single activities or single ecosystems in isolation, and rarely at the global scale. Analyses indicate that no area is unaffected by human influence and that a large fraction is strongly affected by multiple drivers. The most heavily affected ocean regions include large areas of the North Sea, South and East China Seas, Caribbean Sea, east coast of North America, Mediterranean Sea, Red Sea, Persian Gulf, Bering Sea, and several regions in the western Pacific. Large areas of relatively little human impact remain, particularly near the poles, but as global warming melts polar ice these ecosystems may also become severely disrupted. Not surprisingly, anthropogenic drivers associated with global climate change are distributed widely and are an important component of global cumulative impacts, particularly for offshore ecosystems. This study provides critical information for evaluating where certain activities can continue with relatively little effect on the oceans, where other activities might need to be stopped or moved to less sensitive areas, and where the resilience of marine ecosystems to climate change impacts is likely to be weakest.

23 May, 11:40 (S5.2-4740)

Using regional ocean observing systems to develop adaptation tools to respond to climate change effects on the coastal environment

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The network of 11 regional coastal and ocean observing systems that cover the entire US coastline make up the major component of the Integrated Ocean Observing System (which is the US contribution to the Global Ocean Observing System). These regional systems, many of which are geographically larger than some global programmes, allow for acquisition of higher resolution data and development of models and forecasts critical to understanding the effects of climate change on coastal communities. They are developing as partnerships among federal, state, local, academic, and private entities in response to the needs of regional stakeholders, including resource managers and regulators, commercial and recreational fishermen, shippers, the oil and gas industry, and state and local planning agencies. Users at this scale have identified impacts of climate change on the coastal environment as one of their top priorities. Impacts already being observed are changes to weather patterns, winds, waves and currents, sea level, increased coastal storms and consequent inundation and erosion. These impacts, combined with increased development activities in the coastal zone, present increased challenges for those who use or manage the coastal environment. The regional observing systems being developed in the US in combination with the federal systems provide a unique opportunity to establish the sustained observations needed for climate change at higher resolution and create synergies in developing decision-making tools.

23 May, 11:55 (S5.2-4529)

Fishery management responses to climate change in the North Pacific

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In the North Pacific, warming trends, coupled with lack of sea ice, raise concerns about the population level and ecosystem impacts of climate change. However, scientists are only beginning to understand the potential feedback mechanisms that will affect everything from plankton populations to major fish species distributions. Fishery managers need to be in a position to prepare for and respond to changing fishing patterns and potential ecosystem impacts as better information unfolds. The North Pacific Fishery Management Council has jurisdiction over the Exclusive Economic Zone off Alaska, with primary responsibility for managing groundfish (e.g. pollock, cod, flatfish, etc.) harvested mainly by trawlers, hook and line, and pot fishermen, and shared management with the State of Alaska for crab and scallop fisheries. The Council is taking management actions in light of uncertainty about the ecosystem impacts of warming trends (and loss of sea ice) and potential expansion of fishing activities in the North Pacific. Extensive trawl area closures have been established to protect vulnerable crab habitats and to slow the northern expansion of the trawl fleet into newly ice free waters. Efforts are underway to close the Arctic Ocean to all commercial fishing until further research into its unique characteristics can be evaluated. A pilot Fishery Ecosystem Plan for the Aleutian Islands evaluates the region's physical, biological and cultural interactions with a view to informing management decisions. The Council is also developing additional measures to respond to varying distributions of fish and shellfish due to changing climate in the North Pacific.

23 May, 12:10 (S5.2-4853)

Building local solutions to manage the effects of global climate change on a marine ecosystem: a process guide for place-based resource managers

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The marine environment plays an important role in the amount of carbon dioxide (CO_2) that remains within the Earth's atmosphere, but has not received as much attention as the terrestrial environment when it comes to climate change discussions, programmes, and action plans. It is now apparent that the oceans have begun to reach

a state of saturation, no longer maintaining the "steady-state" carbon cycle that existed prior to the industrial revolution. The increasing amount of CO_2 present within the oceans and the atmosphere has a cascading effect on the marine environment. Potential physical effects of climate change within the marine environment, including ocean acidification, changes in upwelling and wind regimes, increasing global sea surface temperatures, and sea level rise, can lead to dramatic changes within marine and coastal ecosystems. Too often, resource managers feel overwhelmed by the addition of a new programme area of this magnitude. They may not feel they have the time, funding, or staff to take on a challenge as large as climate change and continue to not act as a result. This paper addresses three main areas of concern for marine resource managers: the potential effects of climate change on temperate marine environments, public perception of climate change, and the challenge of facilitating behavioural change. Using NOAA's Gulf of the Farallones National Marine Sanctuary as a case study, an easy-to-use process guide is provided, enabling resource managers to effectively incorporate climate change mitigation and adaptation strategies into their current operations.

23 May, 12:25 (S5.2-4594)

Managing local human impacts in marine systems under global climate change

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Elevated nutrients can have devastating and long lasting negative effects in marine systems. Current management of these impacts is based on contemporary environmental conditions, with no thought of future conditions that may be caused by climate change. However, forecasted changes, such as ocean acidification, are likely to combine with current impacts to enhance conditions where "weedy" species will dominate algal communities. For example, it is likely that the currently observed switches of reefs dominated by long lived species of algae to annual, weedy species will increase under climate change scenarios. We investigated the combined effects of elevated CO_2 and nutrient concentrations on coralline algae (perennial species which cover up to 80% of rocky reefs in southern Australia) and turf-forming algae (annual, weedy species). Both elevated CO_2 and nutrient concentrations had rapid negative effects on the photosynthetic activity and biomass of coralline algae, but a positive effect on turf-forming species. Importantly, the negative effects of CO_2 on coralline algae outweighed those of elevated nutrients. This result illustrates the importance of considering future environmental conditions in management of contemporary local impacts (e.g. nutrient discharge into coastal waters), as these global impacts may have large effects at local scales.

23 May, 12:40 (S5.2-4818)

Marine ecosystems: under resourced, overlooked and under threat?

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The IPCC 4th Assessment Report identified 28,586 significant biological changes consistent with recent climate change in terrestrial systems, but only 85 from marine and freshwater systems (<0.3%). We believe the dearth of documented biological changes in marine environments does not mean our oceans are immune to climate change, but rather is a misleading and dangerous artefact reflecting the distribution of global science funding, biases within the IPCC process, and historical realities in marine science research. We cannot use our more extensive knowledge of terrestrial biological climate impacts to fill our knowledge gap for marine environments because of fundamental differences in threats and responses between these systems. Historical realities in marine science and in the current IPCC process have also stymied inclusion of much of the marine climate impacts work. For example, the longest marine time series are generally from commercial fisheries and are a relatively untapped resource, although these suffer from aliasing with

heavy exploitation. The marine science community has also contributed to the problem through inadequate reporting of climate impacts. Emerging evidence suggests marine ecosystem responses to climate change may be faster than in terrestrial systems, despite slower ocean warming. A coherent vision is needed to focus marine biological climate impacts research, lobby for greater resources, and ensure broad uptake within the IPCC process. We describe focused research priorities that will help fill our current knowledge gap. This fundamental information is critical for developing integrated and adaptive management strategies to protect marine environments in the future.

23 May, 12:55 (S5.2-4549)

Adaptation of fishing communities in the Philippines to natural risks

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More than half a million small fishers in the Philippines have been availing of loans from Quedancor, the credit arm of the Department of Agriculture. The financing scheme has been quite successful with the repayment rate at 95%. However, the occurrence of natural calamities such as typhoons; as well as pests and diseases has affected the productivity of fisheries, thus, hindering fishers from paying and renewing their loans. Failure to access credit could disable them to continue venturing on fishing activities and could eventually jeopardise the welfare of their entire household. The inability of creditors to pay their loans and meet their obligations also impairs, to a large extent, the financial operation and viability of the lending institutions. This study analyses the natural risks and adaptation practices of these fishers. It recommends mitigation mechanisms to minimise the impact of natural calamities. Moreover, it suggests a bridge financing scheme that can be an effective and efficient instrument to enable fishers to carry on their livelihood activities and support their families' basic needs and slowly recover from their losses.

23 May, 14:30 (S5.2-4636)

Implications of changing sea surface temperature in the Bay of Bengal: livelihoods of coastal fisherfolks in jeopardy

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The sea surface temperature (SST) has been exhibiting a general increasing trend of about 0.45°C during the past four decades. Increases in SST during the monsoon period have been particularly high. Climate change has been believed to be predominantly responsible for such increases in SST. The marked increase in SST in 2007 caused a large accumulation of heat energy, forcing the formation of 12 'low pressures' to 'deep depressions', with a much higher frequency than normal. Consequently, the tidal activity on the surface becomes rough and turbulent. The coastal fisherfolk communities in Bangladesh represent the poorest of the poor, who can hardly earn a living from traditional fishing practices. A fishing trip generally lasts for about 15 days, including time for travelling to and from the fishing grounds in the Bay of Bengal. If the sea surface becomes rough, fishermen cannot continue fishing. The time intervals between two subsequent 'rough sea events' in 2007 were often short, which either forced coastal fishermen to stay out of action in anticipation of complete loss of investment or forced them to abandon incomplete fishing trips – the latter being economically draining. Because of too many incomplete fishing trips and scanty return from subsequent investments, coastal fisherfolk's livelihoods have been devastated. The increasing intensity of sea roughness along the Bay of Bengal and the loss of livelihoods of fisherfolks is attributed to a climate change induced increase in SST. The nation needs to devise plans to enhance resilience of these fisherfolks and facilitate towards reducing their overall vulnerability through planned adaptation.

23 May, 14:45 (S5.2-4530)

Marine Protected Areas as a tool for long-term monitoring of marine biota: separating climate from anthropogenic influences

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Randomly stratified underwater visual censuses and controlled angling were used to investigate the ichthyofauna at protected and exploited sites in and around the Goukamma Marine Protected Area (MPA). Roman (*Chrysoblephus laticeps*), the principal reef fish species targeted by the fishery, showed significantly higher densities within the protected parts of the study area (cpue: 4.3 fish per angler hour) as compared to the exploited area (cpue: 3.4 fish per angler hour). Furthermore, fishing pressure reduced age-at-maturity and sex change but increased the condition of roman. Sonar tagging experiments revealed a small home range of roman (1,000 m^2), however, females extended their home range during the spawning season (10,000 m^2). Using movement and life-history information, an individual based model showed the potential of roman populations to enhance adjacent fisheries through spill-over. A shore-based cpue assessment over eight years revealed high levels of natural variability of the reef fish community in a large MPA. Experiments during boat-based cpue and diving surveys identified the most suitable established and new survey methods for monitoring and a standardised sampling protocol to reduce bias and variability in the data. An overview of current long-term MPA monitoring projects in South Africa is presented.

23 May, 15:00 (S5.2-4754)

Functional indicators monitoring ecological status and vulnerabiliy of marine macroalgae to climate change

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Macroalgae are used as biological indicators of the ecological status as an expression of the quality of the structure and functioning of coastal ecosystems. They are good indicators because their sedentary condition integrates the effects of long term exposure of nutrient or climate variations. The biological indicators are usually based on composition, abundance and biomass of macrophytes. In this paper, an ecophysiological approach to determine both ecological status and vulnerability and adaptation capacity of marine macroalgae to climate change is presented. We discuss the usefulness of functional indicators as maximal quantum yield as *in vivo* Chl *a* fluorescence associated to Photosystem II as an indicator of physiological status, and stress indicators: heat shock proteins, proteases and reactive oxidative species (ROS). The interactive effects of factors of climate change (increased temperature) with increased UV-B radiation (due to ozone depletion) and nutrient availability (increased inorganic nitrogen) in macroalgae from southern Spain is presented. The integration of ecological and ecophysiological approaches will give the basis for the evaluation of ecological status and the prediction of the variations of the structure-function of aquatic ecosystems.

23 May, 15:15 (S5.2-4934)

Evaluation of climate change impacts and adaptation responses for marine activities: the CLIMAR project

Dries **Van den Eynde**[1], Renaat De Sutter[2], José Ozer[1], Stéphanie Ponsar[1], Katrien Van der Biest[3], Els Vanderperren[4], Toon Verwaest[3] and Annemie Volckaert[2]

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Based on the recommendations of the IPCC, Kyoto-Protocol and relevant strategic documents, scientific research is needed to assess the impact of climate change, specifically on the vulnerable marine ecosystem and its users. While preventive source measures such as reducing greenhouse gas emissions are necessary to tackle the problem

over the long term, adaptive measures are necessary to cope with the primary and secondary impacts of climate change in the North Sea. Furthermore, instruments are needed that can evaluate the adaptation measures on their sustainability, their impact on marine activities and their relationship with preventive measures and sectoral policies. In the project CLIMAR, the elaboration of an evaluation framework for adaptation scenarios/measures as a response to climate induced impacts for the total North Sea environment is established. Results are presented from the research and modelling activities, that are being carried out to differentiate the primary impacts of climate change from the natural evolution at the North Sea scale. These primary impacts include sea level rise, increased storminess, possible increased rainfall, erosion, temperature changes, salinity, etc. Further, first results are presented on the assessment of the secondary impacts of climate change, both on the ecological system of the North Sea as well as on social-economic activities (fisheries, transport and harbour, dredging, risk of flooding, wind energy, etc.). Two extensive case-studies (coastal flooding, fisheries sector) have high extrapolation potential towards the global North Sea environment. Adaptive measures are being formulated both for the ecosystem as well as for the other marine activities.

S5.2 Posters

Poster S5.2-4057

Hicacos penninsula, face to future changes.

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Varadero beach is located in the Hicacos Peninsula on the north coast of Matanzas province in Cuba. Varadero is one of the most important touristic places in Caribbean. It is approximately 20 km in length and 1-2 km in width and its height is between 5-10 m above sea level. The physio-geographic conditions in Varadero make it a place that is vulnerable to environmental change. Its geographic position, exposure to sea-level rise, floods, drought, changes in temperature, sunshine, winds, and hydrology, as well as its fragile ecosystems, are all aspects of its natural vulnerability to climate change. For the past decade, we have been studying the vulnerability of Varadero Beach to climate change, and evaluating future climate change scenarios, to determine the vulnerability and impacts. This work, involving physiographic and socio-economic diagnostics, focuses on climate variability, future climate change scenarios, vulnerabilities and impacts on tourism. We use these analyses to develop measures that will permit adaptation and future sustainability of this important region.

Poster S5.2-4921

Response and adaptation of salmon of the Pacific Northwest and the Columbia River region of the United States (Washington and Oregon) to climate change

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To determine how different life history types of salmon may respond to climate change, one needs descriptions of the present status of their freshwater and marine habitats as well as projections of the future status of these habitats. Basic information required includes: when and where salmon spawn in freshwater environments, when individuals migrate to the sea, where they live in the ocean, and when they return to their spawning habitats. IPCC AR4 climate models suggest that winter precipitation in the mountains on the west coast of North America will fall in the form of rainfall rather than snow. Highest river flows will be in winter (fed by rainfall) rather than in spring (if fed by snowmelt), thus spring-run salmon life history types which depend upon high river flows in spring may be selected against, whereas fall/winter runs may be positively selected. Significant changes may occur in the ocean habitats, especially in highly-productive coastal upwelling regions, however existing climate models have not resolved potential changes in marine productivity and marine ecosystem structure. Thus using first principles, we will develop a set of hypotheses of how salmon-specific marine habitats and ecosystems may change, focusing on effects of changes in the Pacific Decadal Oscillation, coastal upwelling, length of the upwelling season, source waters which feed the California Current, and marine food chain structure.