Annotated bibliography of climate change adaptation [resilience building] in the marine environment

(areas of economics, ecology, physiology, policy, community science etc)

Abel N, Gorddard R, Harman B, Leitch A, Langridge J, Ryan A and Heyenga S (2011). Sea level rise, coastal development and planned retreat: analytical framework, governance principles and an Australian case study. Environmental Science & Policy 14(3): 279-288.

Sea level rise is a major global issue for areas of coastal development. This article explores the concept of, and develops an analytical framework for planned retreat from the sea behind natural ecological defenses as an adaptation option to global sea level rising. The authors use South East Queensland, Australia as a case study and describe why the option of planned retreat in this area is diminishing as a viable management and adaptation option. The authors present five guiding principles for the implementation of planned retreat which could be adopted in coastal governance policies.
DOI: 10.1016/j.envsci.2010.12.002
http://www.sciencedirect.com/science/article/pii/S146290111000167X
KEYWORDS: adaptation; climate change; coastal development; ecological defense; governance; management; planned retreat; policy; sea level rise

Adger NW, Huq S, Brown K, Conway D and Hulme M (2003). Adaptation to climate change in the developing world. Progress in Development Studies 3(3): 179-195.

Resistance of social and ecological systems to extreme events is dependent on resilience. Social-ecological systems which are resilient to disasters typically incorporate mechanisms for dealing with and learning from change and unforseen events. This type of disaster management requires multi-level governance systems that can develop resilience measures within the system. Coastal use in terms of human settlement, resource use and global environment change emphasize the need for building resilience in coastal systems. Resilience of coastal ecosystems to recover following disturbance should not be anticipated, and socio-economic resilience must be understood and actively incorporated into management of these areas.
DOI: 10.1191/1464993403ps060oa
http://pubs.iied.org/pdfs/G00074.pdf
KEYWORDS: adaptation; climate change; environmental policy; uncertainty; vulnerability

Adger WN (2000). Social and ecological resilience: are they related? Progress in Human Geography 24(3): 347-364.

Social resilience (ability of groups to cope with stress exerted from social, political and environmental change) and ecological resilience (the ability of ecosystems to resist change in the face of perturbance) are clearly linked. This link appears strongest for social groups that rely on ecological and environmental resources for their livelihoods. However, it is unclear whether resilience in ecosystems transfers to resilience in communities; which is examined here in reference to a resource-dependent coastal community in Vietnam. The issues of resilience and vulnerability are likely to become more important in the development of resource management questions for the future.
DOI: 10.1191/030913200701540465
http://phg.sagepub.com/content/24/3/347.full.pdf+html

KEYWORDS: Resilience; social resilience; cultural geography; ecological resilience; human ecology; resource; dependency; sustainable development; southeast-Asia; resource; vulnerability; sustainability; environment; conservation; biodiversity; inequality; knowledge; security

Adger WN (2003). Social capital, collective action, and adaptation to climate change. Economic Geography 79(4): 387-404.

Society is faced with the challenge of how to best adapt to future climate change, and the ability to adapt is, in part, governed by the ability to act collectively. Collective action and social capital perspectives help to inform the nature of adaptive capacity and policy formation. The need to learn from past and present adaptation strategies will help to understand the way in which adaptation occurs as well as the limitations of change that are acting in these processes. Aspects of social capital are discussed for two examples: weather extremes in coastal SE Asia and community-based coastal management in the Caribbean. Both examples highlight the need to base resource management on building resilience to climate change, and illustrate how adaptation processes and collective action help adapt to climate change for the future.

DOI: 10.1111/j.1944-8287.2003.tb00220.x

KEYWORDS: Climate change; adaptive policy; social capital; vulnerability; adaptation; resilience; global climate; change; coastal management; economic development; environmental risk; vulnerability; management; framework; impacts; Vietnam; policy; institutions; perspective; government

Adger WN, Arnell NW and Tompkins EL (2005). Successful adaptation to climate change across scales. Global Environmental Change-Human and Policy Dimensions 15(2): 77-86.

Climate change impacts and responses are presently observed in physical and ecological systems. Adaptation to these impacts is increasingly being observed in both physical and ecological systems as well as in human adjustments to resource availability and risk at different spatial and societal scales. This paper reviews the nature of adaptation and the implications of different spatial scales for these processes. The authors argue that elements of effectiveness, efficiency, equity and legitimacy are important in judging success in terms of the sustainability of development pathways into an uncertain future.

DOI: 10.1016/j.gloenvcha.2004.12.005

http://research.fit.edu/sealevelriselibrary/documents/doc_mgr/422/UK_Successful_Adaptation_to_CC_-_Adger_et_al_2005.pdf

KEYWORDS: adaptation; vulnerability; scenarios; sustainability; decision making

Adger WN, Dessai S, Goulden M, Hulme M, Lorenzoni I, Nelson DR, Naess LO, Wolf J and Wreford A (2009). Are there social limits to adaptation to climate change? Climatic Change 93(3-4): 335-354.

While there is a recognised need to adapt to changing climatic conditions, there is an emerging discourse of limits to such adaptation. Limits are traditionally analysed as a set of immutable thresholds in biological, economic or technological parameters. This paper contends that limits to adaptation are endogenous to society and hence contingent on ethics, knowledge, attitudes to risk and culture. The authors conclude that the issues of values and ethics, risk, knowledge and culture construct societal limits to adaptation, but that these limits are mutable.

DOI: 10.1007/s10584-008-9520-z

http://research.fit.edu/sealevelriselibrary/documents/doc_mgr/338/Global_Social_Limits_to_CC_Adaptation_-_Adger_et_al._2008.pdf

KEYWORDS: adaptive capacity; change impacts; resilience; vulnerability; climate change

Adger WN, Hughes TP, Folke C, Carpenter SR and Rockstrom J (2005). Social-ecological resilience to coastal disasters. Science 309(5737): 1036-1039.

Resistance of social and ecological systems to extreme events is dependent on resilience. Social-ecological systems which are resilient to disasters typically incorporate mechanisms for dealing with and learning from change and unforseen events. This type of disaster management requires multi-level governance systems that can develop resilience measures within the system. Coastal use in terms of human settlement, resource use and global environment change emphasize the need for building resilience in coastal systems. Resilience of coastal ecosystems to recover following disturbance should not be anticipated, and socio-economic resilience must be understood and actively incorporated into management of these areas.

DOI: 10.1126/science.1112122

http://www.sciencemag.org/content/309/5737/1036.full.pdf

KEYWORDS: Resilience; adaptation; climate change; social; ecological; coral-reefs; vulnerability; hurricanes; management; resistance; capacity; tsunami; crisis

Adger WN, Paavola J and Huq S, Eds. (2006). Fairness in adaptation to climate change, MIT Press.

This book looks at the challenges of ensuring that policy responses to climate change do not place undue and unfair burdens on already vulnerable populations. Developing countries are more dependent on climate-sensitive livelihoods such as farming and fishing and hence are more vulnerable. It brings together scholars from political science, economics, law, human geography, and climate science to offer the first assessment of the social justice issues in adaptation to climate change.

http://mitpress.mit.edu/catalog/item/default.asp?ttype=2&tid=10860

KEYWORDS: adaptation; climate change; policy

Adger WN and Vincent K (2005). Uncertainty in adaptive capacity. Comptes Rendus Geoscience 337(4): 399-410.

The capacity to adapt is a critical element of the process of adaptation: it is the vector of resources that represent the asset base from which adaptation actions can be made. Adaptive capacity can in theory be identified and measured at various scales, from the individual to the nation. The assessment of uncertainty within such measures comes from the contested knowledge domain and theories surrounding the nature of the determinants of adaptive capacity and the human action of adaptation. The paper outlines the nature of uncertainty for the major elements of adaptive capacity and illustrates these issues with the example of a social vulnerability index for countries in Africa.

DOI: 10.1016/j.crte.2004.11.004

http://www.sciencedirect.com/science/article/pii/S163107130400330X

KEYWORDS: climate change; adaptive capacity; vulnerability; uncertainties

Agrawala S and Fankhauser S, Eds. (2008). Economic Aspects of Adaptation to Climate Change: Costs, Benefits and Policy Instruments.

This report provides a critical assessment of adaptation costs and benefits in key climate sensitive sectors, as well as at national and global levels. It moves the discussion beyond cost estimation

to the potential and limits of economic and policy instruments - including insurance and risk sharing, environmental markets and pricing, and public private partnerships - that can be used to motivate adaptation actions.
http://www.oecd.org/document/2/0,3343,en_2649_34361_40691458_1_1_1_1,00.html
KEYWORDS: adaptation; climate change; economic; policy

Allison EH, Perry AL, Badjeck MC, Adger WN, Brown K, Conway D, Halls AS, Pilling GM, Reynolds JD, Andrew NL and Dulvy NK (2009). Vulnerability of national economies to the impacts of climate change on fisheries. Fish and Fisheries 10(2): 173-196.

Based on several socio-economic indices, such as the relative importance of fisheries to national economies and diets, the societal adaptive capacity and the exposure to climate change, this study compares the vulnerability of the capture fisheries of 132 national economies to climate change impacts. Among the most vulnerable countries (mainly in Africa, South America and Asia), several countries were among the least developed, poorest and most dependent on fisheries. Despite uncertainties in the impacts of climate change on fisheries, this study indicates that developing countries have the greatest need for adaptation management procedures.
DOI:10.1111/j.1467-2979.2008.00310.x
http://onlinelibrary.wiley.com/doi/10.1111/j.1467-2979.2008.00310.x/abstract
KEYWORDS: climate change; vulnerability; impact; fisheries; poverty; adaptation; inequalities; society; policy; development

Allison G (2004). The influence of species diversity and stress intensity on community resistance and resilience. Ecological Monographs 74(1): 117-134.

Theory such as the insurance hypothesis suggests that higher biological diversity may diminish perturbation dynamics within a community. Rocky intertidal macroalgal community dynamics were examined using experimental heat stress following a 15 month diversity manipulation experiment. This simulated pulse event resulted in a gradient of thermal stress within plots and, consequently, different degrees of perturbation. Community resistance to the thermal stress was predicted by the pre-stress cover of dominant species, total algal cover, and standing biomass. Since higher diversity treatments had higher overall abundance, highest diversity treatments were the most harshly affected. Thermal stress was also reasonably non-selective, with species were reduced in approximately equivalent proportions. Community resilience was highly dependent on species initially present and degree of disturbance. In highly disturbed areas, initial recovery trajectory was similar in early successional stages, but differences arose later; appearing related to the composition of the surrounding regeneration pool. For treatments devoid of thermal stress, low-diversity plots (without fucoids) remained in states unlike the reference condition for most of the experimentally duration, however plots in high-diversity treatments returned to states similar to the reference rapidly. This work demonstrates that resilience (but not resistance) results are consistent with the insurance hypothesis and the overall influence of diversity on community dynamics is complex, depending on the characteristics of both the stress and characteristics of the species present.
DOI: 10.1890/02-0681
http://www.esajournals.org/doi/abs/10.1890/02-0681
KEYWORDS: disturbance; diversity manipulation; diversity-stability; macroalgae; Oregon; resilience; resistance; rocky intertidal community; thermal stress; temperature

Alongi DM (2008). Mangrove forests: Resilience, protection from tsunamis, and responses to global climate change. Estuarine Coastal and Shelf Science 76(1): 1-13.

This paper reviews mangrove resilience to large infrequent disturbance (tsunamis) and their role in coastal protection, as well as to climate change and the future of mangroves in light of these changes. Mangroves have shown considerable resilience over time scales corresponding with shoreline evolution. Evidence for this comes from soil accretion rates in mangroves which are currently keeping pace with mean sea-level rise; with further evidence for resilience coming from recovery patterns from natural disturbances which, combined with life history traits, suggest pioneer-phase characteristics. Physiological tolerances and competitive interactions produce stand composition and forest structure leading to a mosaic of interrupted succession sequences that occur in response to physical/chemical gradients and landform changes. In certain circumstances, mangroves may offer limited protection from tsunamis, with the magnitude of energy absorption depends on a number of variables including tree density, stem and root diameter, shore slope, bathymetry, spectral characteristics of incident waves, and tidal stage when entering the mangrove forest. Climate change may lead to losses of 10-15% of mangroves, but should be considered secondary to annual losses of 1-2% from deforestation. Mangrove resilience is strengthened by a number of factors including a large reservoir of below-ground nutrients, rapid rates of nutrient flux and microbial decomposition, complex and highly efficient biotic controls, self-design and redundancy of keystone species, and numerous feedbacks.
DOI: 10.1016/j.ecss.2007.08.024
http://www.sciencedirect.com/science/article/pii/S0272771407003915
KEYWORDS: climate change; disasters; disturbance; mangrove forest; resilience; tsunami; sea level rise

Alter SE, Simmonds MP and Brandon JR (2010). Forecasting the consequences of climate-driven shifts in human behavior on cetaceans. Marine Policy 34(5): 943-954.

While the greatest impact climate change is predicted to have on cetaceans is through habitat loss and prey availability, additional impacts may result from changes in human behaviour and economics that are brought about by climate change. These behavioural shifts may result in increases in shipping, exploration for resources (oil and gas) and fishing that result as a loss of Arctic sea ice will potentially exacerbate a range of influences on cetaceans, including acoustic disturbance, ship strikes and prey depletion. Tropical cetaceans may face increased hunting pressure off Asia, Latin America and Africa as other food resources become depleted. The potential consequences and risks faced by particular cetacean species are assessed here in the face of predicted climate-driven shifts in human behaviour. Policy recommendations are made here based on findings; including recommendation to incorporate information on cetacean populations into climate-adaptation decisions and that human-mediated impacts of climate change be included in cetacean conservation and management plans.
DOI: 10.1016/j.marpol.2010.01.026
http://www.sciencedirect.com/science/article/pii/S0308597X10000278
KEYWORDS: Climate change; cetaceans; economic activity; conservation; whales; dolphins; Arctic; IWC

Anderson L (2002). A bioeconomic analysis of marine reserves. Natural Resource Modelling 15: 311-334.

Follows Hannesson [1999] and Sanchirico and Wilen [2001] where effort is a function of profitability which is in part determined by the existence of reserves. The paper extends Hannesson's analysis by deriving sustainable catch and revenue curves which provide a more complete picture of

how marine reserves affect the proportion of the stock which is available for harvest and a comparison of the economic operation of the fleet under open access and marine reserves.
DOI: 10.1111/j.1939-7445.2002.tb00092.x
http://onlinelibrary.wiley.com/doi/10.1111/j.1939-7445.2002.tb00092.x/abstract
KEYWORDS: bioeconomic; sustainable catch; marine reserves; stock assessment

Andersson AJ and Mackenzie FT (2011). Technical comment on Kroeker et al. (2010) Meta-analysis reveals negative yet variable effects of ocean acidification on marine organisms. Ecology Letters, 13, 1419–1434. Ecology Letters: no-no.

Ocean acidification as a result of increasing atmospheric CO2 concentrations has attracted a wealth of interest over the impacts this may have on marine organisms and associated ecosystems. To date, experimental results have varied and sometimes contradicted each other, thus making it difficult to quantitatively synthesize research findings. This Technical Comment addresses the issue of calcification strategies of marine organisms and the need for categorizing different mineral groups used by calcifying organisms, which the authors believe should not be combined together into one group nor treated as the same category. The authors provide comment on the meta-analysis performed by Kroeker et al. (2010) and suggest further refinements for analyses evaluating the sensitivity and responsiveness of calcareous organisms to ocean acidification.
DOI: 10.1111/j.1461-0248.2011.01646.x
http://onlinelibrary.wiley.com/doi/10.1111/j.1461-0248.2011.01646.x/pdf
KEYWORDS: adaptation; CaCO3; calcification; CO2; climate change; meta-analysis; Mg-calcite; ocean acidification; solubility; technical comment

Anthony KRN, Maynard JA, Diaz-Pulido G, Mumby PJ, Marshall PA, Cao L and Hoegh-Guldberg OVE (2011). Ocean acidification and warming will lower coral reef resilience. Global Change Biology 17(5): 1798-1808.

The combined effect of CO2 and fishing pressure on herbivores, on the resilience of a simplified benthic reef community was modelled. Ecological resilience was defined as the capacity of the community to maintain and recover to coral-dominated states, and depended on the growth and mortality of simulated branching corals and macroalgae. Coral growth and survival were affected by acidification and warming through processes of calcification, coral bleaching, temperature-induced mortality, macroalgal mortality by grazing and macroalgal nutrient-dependent growth. The IPCC's fossil-fuel intensive A1FI predictions for sea surface temperature and CO2 concentrations for this century were used as inputs to the model. Results indicate that herbivore overfishing and nutrification result in increased vulnerability to higher CO2 concentrations and that above 450-500 ppm CO2, management of local-scale disturbances will be critical for reef ecosystems.
DOI: 10.1111/j.1365-2486.2010.02364.x
http://onlinelibrary.wiley.com/doi/10.1111/j.1365-2486.2010.02364.x/abstract;jsessionid=3E6A64D2129F51AAFCB3373ADA06567B.d02t03
KEYWORDS: global warming; ocean acidification; climate change; coral reefs; resilience; overfishing

Arroyo AM, Naim SM and Hidalgo JZ (2011). Vulnerability to climate change of marine and coastal fisheries in Mexico. Atmósfera 24(1): 103-123.

Biotic and abiotic factors impact on marine and coastal ecosystems, and this in turn impacts on human populations and their resulting interactions with the ecosystems. This article presents an

overview of the fishing activities adopted in marine and coastal environments in Mexico and discusses the potential implications of climate change on the ecosystems and human activities in the region. The authors examine the sustainability of marine ecosystem in light of current and future predictions of human fishing activities and changing climatic conditions, including sea surface temperature, sea level rise and precipitation patterns.
http://journals.unam.mx/index.php/atm/article/view/23805/0
KEYWORDS: circulation models; climate change; coastal lagoon; coral reef; current; fisheries; marine ecosystem; sea grass communities; sustainability

Arthur RI, Lorenzen K, Homekingkeo P, Sidavong K, Sengvilaikham B and Garaway CJ (2010). Assessing impacts of introduced aquaculture species on native fish communities: Nile tilapia and major carps in SE Asian freshwaters. Aquaculture 299: 81-88.

This study presents results from experiments carried out between 1999 and 2002 in wetland sites in 46 southern Lao PDR. The effect of the introduction and stocking of non-native species (Nile tilapia, mrigal, rohu and bighead carp) was estimated by comparing traits (eg fish biomass, native fish species richness, diversity indices, species composition, feeding guild composition) between sites where the non-native species were introduced and sites where these species were absent. Stocking of non-native species increased fish biomass by 180% in the observational study (sites where species were well established from earlier introductions) and by 49% in the experimental study (sites of recent non-native species stocking). Native fish biomass was not affected by stocking of the non-native species. Except for a moderately negative effect on Simpson diversity and equitability in the observational study, stocking of the non-native species did not significantly impact traits in the different sites. This mild-to-moderate impact on the native fish communities suggests that the introduction of these species to these sites would constitute a viable fisheries enhancement procedure.
DOI: 10.1016/j.aquaculture.2009.11.022
http://www.sciencedirect.com/science/article/pii/S0044848609009387
KEYWORDS: fisheries; enhancement; native species; species introduction; aquaculture; yield; risk

Badjeck MC, Allison EH, Halls AS and Dulvy NK (2010). Impacts of climate variability and change on fishery-based livelihoods. Marine Policy 34(3): 375-383.

Almost 1.5 billion consumers rely on fish oil for more than 20% of their dietary protein, provided by the 36 million fisherfolk that depend on fishing for their livelihood. There is escalating concern for food security and the livelihoods of these fisherfolk with increasing evidence of the impacts climate change on aquatic systems; however this area is somewhat neglected in climate adaptation policy. This paper synthesizes the pathways through which climate change and variability impact the livelihood of fisherfolk at household and community levels, exploring current and potential adaptation strategies, and assesses management and climate policies in relation to these. From this, responses to climate change should include approaches building the livelihood asset base while minimizing vulnerability to stressors; understanding of response mechanisms to climate change (to inform planned adaptation); recognition of climate-change driven opportunity; adaptive strategies with multi-sector perspectives and recognising the potential of fisheries contribution towards mitigation efforts.
DOI: 10.1016/j.marpol.2009.08.007
http://www.sciencedirect.com/science/article/pii/S0308597X09001237
KEYWORDS: Climate change; adaptation; fishery; climate adaptation policy; fisheries; livelihoods; climate variability

Baker AC (2001). Ecosystems - Reef corals bleach to survive change. Nature 411(6839): 765-766.

Coral bleaching involves the loss of symbiotic algae from reef-building invertebrates is a drastic and highly detrimental response to adverse environmental conditions. This work presents results from transplant experiments using varying combinations of coral host and algal symbiont, and supports an alternative understanding where bleaching offers a high-risk ecological opportunity for corals to free themselves of suboptimal algae and acquire new symbionts. This approach could be advantageous for reefs facing increasingly frequent and severe mass bleaching due to climate change.
DOI: doi:10.1038/35081151
http://www.nature.com/nature/journal/v411/n6839/full/411765a0.html
KEYWORDS: zooxanthellae; diversity; ecology; resilience; climate change; coral bleaching

Baker AC, Starger CJ, McClanahan TR and Glynn PW (2004). Corals' adaptive response to climate change. Nature 430(7001): 741-741.

Coral reefs may potentially be able to safeguard against extinction by changing to new symbionts. Long-term response of coral reefs to climate change depends on their reef-building symbioses to adapt or acclimatize to warmer temperatures, although as yet, there is no direct evidence that this response can occur. This paper demonstrates that corals containing unusual algal symbionts which are thermally tolerant are more abundant on coral reefs which have been affected severely by recent climate change impacts. This represents an adaptive shift in symbionts communities, making them more resistant to potential future increases in thermal stress.
DOI: doi:10.1038/430741a
http://www.nature.com/nature/journal/v430/n7001/full/430741a.html
KEYWORDS: reef corals; flexibility; hypothesis; mortality; diversity; patterns; ecology; climate change; adaptation

Balmford A, Gravestock P, Hockley N, McClean CJ and Roberts CM (2004). The worldwide costs of marine protected areas. Proceedings of the National Academy of Sciences of the United States of America 101(26): 9694-9697.

This paper provides an estimate of the costs of a global MPA network, based on a survey of the running costs of 83 MPAs worldwide. Annual running costs were higher in MPAs that were smaller, closer to coasts, and in high-cost, developed countries. Models extrapolating these findings suggest that a global MPA network conserving 20-30% of the world's seas might cost between $5 billion and $19 billion annually to run and would probably create one million jobs. However, there are potential private gains from improved fisheries and tourism and likely social gains from increasing the sustainability of fisheries and securing vital ecosystem services.
DOI: 10.1073/pnas.0403239101
http://www.pnas.org/content/101/26/9694.full
KEYWORDS: reserves; conservation; biodiversity; benefits; collapse; ecosystems; fisheries; Africa; region; Marine Protected Areas

Ban NC, Alidina HM and Ardron JA (2010). Cumulative impact mapping: Advances, relevance and limitations to marine management and conservation, using Canada's Pacific waters as a case study. Marine Policy 34(5): 876-886.

The cumulative impact of human activities on marine ecosystems is an important concept which

is rapidly developing as a valuable tool for the effective management of marine ecosystems. The more information that is acquired about the location and impacts of human activities on the ecosystems of concern could enable a reduction in the stressors that are acting on these systems. This article presents human activity data from a regional area in Canada's Pacific marine waters. The authors map and analyses the cumulative impacts of 38 human activities in the region and assess the effectiveness of pre-existing conservation regions. The authors were surprised to discover that most areas with conservation status actually contained higher impact levels as a result of human activities than surrounding regions, and discuss limitations that exist in cumulative impact mapping.
DOI: 10.1016/j.marpol.2010.01.010
http://www.sciencedirect.com/science/article/pii/S0308597X10000114
KEYWORDS: climate change; cumulative impact; management; marine ecosystem; region

Barange M, Cheung WWL, Merino G and Perry RI (2010). Modelling the potential impacts of climate change and human activities on the sustainability of marine resources. Current Opinion in Environmental Sustainability 2(5-6): 326-333.

The authors of this article call for the development of modelling frameworks that are capable of evaluating the transfer of climate signals from the atmosphere to marine environments, and the resulting impact this may have on both marine organisms and fisheries operations. This article discusses emerging models which attempt to address the above phenomenon, the associated challenges, and the significant advances which could be made in the management of marine ecosystems with the development of coupled modelling frameworks.
DOI: 10.1016/j.cosust.2010.10.002
http://www.sciencedirect.com/science/article/pii/S1877343510001089
KEYWORDS: climate signals; development; impacts; marine ecosystem; management; coupled modelling frameworks

Barnes DKA, Griffiths HJ and Kaiser S (2009). Geographic range shift responses to climate change by Antarctic benthos: where we should look. Marine Ecology-Progress Series 393: 13-26.

Several strategies exist for Southern Ocean species facing climate change (e.g. warming); including toleration, adaptation, migration or extinction. Evidence suggests that toleration and adaptation are often not possible due to slow generation turn-over. Avoiding extinction therefore relies on linear migration, moving into deeper waters, or both. Evidence of these types of range-shifts occurring exist along linear coastlines, however there are no continuous shelf/slope connections to Antarctica (which contains 3 major linear shelves). The greatest potential for thermally-driven range shifts is for the Kerguelen Plateau. Geographic range of several Southern Ocean invertebrate species was examined for areas where species limits coincided. Monitoring of these range shifts will provide information into the biodiversity response to climate change, and help to determine whether species are becoming tolerant or migrating to other areas.
DOI: 10.3354/meps08246
http://www.int-res.com/articles/meps2009/393/m393p013.pdf
KEYWORDS: Climate change; adaptation; Southern Ocean; range-shifts; biodiversity; continental shelf Southern Ocean; geographic limits; regional warming; South Georgia, Kerguelen

Barnett J (2001). Adapting to climate change in Pacific Island Countries: The problem of uncertainty. World Development 29(6): 977-993.

This paper highlights the inability of Pacific Island Countries to plan effectively for sea-level rise and climate change due to scientific uncertainty. Specific Pacific Island climate change and sea-level issues are discussed, exploring the limitations of the dominant approach to climate change induced vulnerability and adaptation. Scientific uncertainty creates problems for policies aimed at dealing with climate change and sea-level rise. The dominant approach to dealing with these requires impact anticipation; which the author argues is not a successful strategy, and should be replaced with enhancing resilience of entire island social-ecological systems in order to formulate goals aimed at adaptation policy making.
DOI: 10.1016/S0305-750X(01)00022-5
http://www.sciencedirect.com/science/article/pii/S0305750X01000225
KEYWORDS: Climate change; sea-level rise; resilience; social-ecological; adaptation; climate change; Pacific Islands; policy; resilience; uncertainty; vulnerability

Barrett RDH, Paccard A, Healy TM, Bergek S, Schulte PM, Schluter D and Rogers SM (2011). Rapid evolution of cold tolerance in stickleback. Proceedings of the Royal Society B: Biological Sciences 278: 233-238.

Increasing global temperatures as a result of climate change are predicted to impact on biological communities, although the way in which organisms and communities respond to these changes will vary and depend upon species adaptive evolution of temperature tolerance. This article reports research findings of the adaptive evolution of cold tolerance in stickleback fish populations. Freshwater sticklebacks were shown to tolerate lower minimum temperatures compared with marine sticklebacks, while marine sticklebacks demonstrated cold tolerance evolution over three generations when placed within a freshwater environment. The authors conclude that cold tolerance appears to be under strong selection and marine sticklebacks demonstrate sufficient genetic variation which should allow them to adapt to temperature changes over a relatively short timescale.
DOI: 10.1098/rspb.2010.0923
http://rspb.royalsocietypublishing.org/content/early/2010/07/29/rspb.2010.0923.full
KEYWORDS: adaptation; climate change; cold tolerance; evolution; phenotype; stickleback; temperature

Baskett ML, Gaines SD and Nisbet RM (2009). Symbiont diversity may help coral reefs survive moderate climate change. Ecological Applications 19(1): 3-17.

Climate change and its associated thermal stress-related impacts on coral reefs causing mass bleaching events represents one of the greatest anthropogenic threats faced by reefs. Although corals and their symbiont algae may have some ability to respond to thermal changes through genetic adaptation and changes in community composition, the rate at which climate change is occurring may be too rapid for corals to be able to respond. This study developed a model of coral and symbiont ecological dynamics and symbiont evolutionary dynamics to be able to test the potential for response. The results of modelling with no variation in thermal tolerance by symbionts suggest that reef collapse would occur within decades under multiple future climate change scenarios. Results with genetic or community variability in thermal tolerance predicted coral reef persistence into the next century, but this was dependent on lowering of greenhouse gas emissions. Greenhouse gas emissions will have a significant effect on the future of coral reefs, and accounting for biodiversity and biological dynamics is vital to being able to estimating the size of this effect.
DOI: 10.1890/08-0139.1
http://www.esajournals.org/doi/abs/10.1890/08-0139.1
KEYWORDS: adaptation; climate change; coral reefs; quantitative genetic model; zooxanthellae

Baskett ML, Nisbet RM, Kappel CV, Mumby PJ and Gaines SD (2010). Conservation management approaches to protecting the capacity for corals to respond to climate change: a theoretical comparison. Global Change Biology 16(4): 1229-1246.

Coral reefs are faced with a number of anthropogenic threats including bleaching from climate change related impacts. Protecting the capacity of corals to respond to increases in thermal stress may involve: promoting resistance and resilience of coral reefs and reducing anthropogenic impacts that are likely to decrease resistance and resilience. This work quantitatively compares potential priorities and current recommendations for protecting the response capacity of corals to climate change – with emphasis on the relevant dynamics, processes, and parameters in a size-structured model of coral and zooxanthellae ecological and evolutionary dynamics in relation to predicted future thermal stress. Modelled results incorporating varying initial conditions show that protecting diverse communities is essential for maintaining long-term coral cover, as is protecting communities comprised of higher abundances of thermally tolerant species. This work also suggests greater relative importance of reducing additional anthropogenic impacts that affect coral-macroalgal competition, early coral life history stages, and coral survivorship. Model results incorporating temperature trajectories from different locations, both with and without connectivity, show that protection of, and connectivity to, low-thermal-stress locations may also increase capacity for corals to be able to respond to climate change impacts.

DOI: 10.1111/j.1365-2486.2009.02062.x
http://onlinelibrary.wiley.com/doi/10.1111/j.1365-2486.2009.02062.x/abstract
KEYWORDS: coral bleaching; coral reefs; global climate change; quantitative; genetic model; size-structured matrix model; adaptation

Beisner BE, Haydon DT and Cuddington K (2003). Alternative stable states in ecology. Frontiers in Ecology and the Environment 1(7): 376-382.

Theory behind the idea of alternative stable states existing in communities has developed two perspectives into how a community may shift from one stable state to another. One idea assumes a constant environment with variables that shift (e.g. population density), and the other anticipates changes to underlying environmental 'drivers'. The alternative stable states theory is reviewed here, examining the two perspectives and incorporating the concepts of resilience and hysteresis as well as the role that stochasticity plays within each.

DOI: 10.1890/1540-9295(2003)001[0376:ASSIE]2.0.CO;2
http://www.esajournals.org/doi/abs/10.1890/1540-9295(2003)001%5B0376%3AASSIE%5D2.0.CO%3B2?journalCode=fron
KEYWORDS: Resilience; hysteresis; alternative stable states; thresholds; communities; ecosystems; stability; systems; lakes

Belkin IM (2009). Rapid warming of Large Marine Ecosystems. Progress In Oceanography 81(1-4): 207-213.

The sea-surface temperature (SST) trends of 63 Large Marine Ecosystems (LMEs) was investigated using the U.K. Meteorological Office Hadley Centre SST climatology from 1957 to 2006. The majority of LMEs have experienced an accelerated warming since the early 80s, with the exception of two upwelling areas, California and Humboldt currents, which have undergone a slight cooling. Three regions of particularly intense warming were detected: the Subarctic Gyre, the European Seas and the

East Asian Seas.
DOI: 10.1016/j.pocean.2009.04.011
http://www.sciencedirect.com/science/article/pii/S0079661109000317
KEYWORDS: Global warming; large marine ecosystems; subarctic gyre; European seas; East Asian seas

Bell JD, Purcell SW and Nash WJ (2008). Restoring small-scale fisheries for tropical sea cucumbers. Ocean & Coastal Management 51(8-9): 589-593.

This study discusses management procedures needed for the restoration of small-scale fisheries of tropical sea cucumbers, currently threatened by over-exploitation. A three-step procedure: 1. restocking no-take zones with hatchery-reared juveniles; 2. aggregating wild individuals in no-take zones; and 3. opening small farms to rear wild-caught sea cucumbers to the size above sexual maturity, is given and its socio-economic and ecological benefits are discussed.
DOI:10.1016/j.ocecoaman.2008.06.011
http://www.sciencedirect.com/science/article/pii/S0964569108000586
KEYWORDS: fisheries; over-exploitation; holothuria; management; restocking; conservation; sustainability; adaptation; mitigation

Bellwood DR, Hughes TP, Folke C and Nystrom M (2004). Confronting the coral reef crisis. Nature 429(6994): 827-833.

An urgent reassessment of current management practises is needed to address the worldwide decline in coral reefs – which is largely the result of overharvesting, pollution, disease and climate change. Such a large-scale crisis requires scaling-up of management efforts which are based primarily on increasing knowledge of the ecological processes that underlie coral reef resilience. To do this, the authors review the ecological roles of critical reef functional groups fundamental to understanding resilience and the avoidance of phase shifts to less desirable ecosystems. Biogeographic differences in species richness and composition of functional groups are identified, highlighting the vulnerability of Caribbean reef ecosystems. Implications arise for reef restoration, fisheries management, the implementation of marine protected areas and importance of biodiversity hotspots as conservation management tools. The authors highlight the critical lack of coral reef knowledge, and the need to focus on creating resilient coral reef ecosystems.
DOI: 10.1038/nature02691
http://www.nature.com/nature/journal/v429/n6994/abs/nature02691.html
KEYWORDS: Climate change; resilience; biodiversity; conservation; coral reefs; great-barrier-reef; Diadema-Antillarum philippi; long-term decline; biodiversity hotspots; phase-shifts; conservation priorities; genotypic; diversity; Caribbean corals; juvenile corals; eastern Pacific

Bengtsson J, Angelstam P, Elmqvist T, Emanuelsson U, Folke C, Ihse M, Moberg F and Nystrom M (2003). Reserves, resilience and dynamic landscapes. Ambio 32(6): 389-396.

Biodiversity conservation is essential for being able to maintain ecosystem resilience and ensure a sustainable flow of ecosystem goods and services. Existing reserves and parks are unlikely to be able to incorporate the long-term and large-scale dynamics that influence ecosystems, therefore conservation strategies need to be pro-active in incorporating the large areas of land that are managed for use by humans. Spatial resilience (ecological memory) is essential for ecosystems to be able to restructure following natural and human induced perturbance. Existing static reserves should be complemented with dynamic reserves that are part of ecosystem management, since long-term biodiversity

conservation requires an understanding the processes that allow species to persist in natural and human-dominated ecosystems.
DOI: 10.1579/0044-7447-32.6.389
http://www.bioone.org/doi/abs/10.1579/0044-7447-32.6.389?prevSearch=&cookieSet=1
KEYWORDS: Resilience; biodiversity; ecosystem management; reef-marine-park; coral-reefs; ecosystem management; infrequent; disturbances; ecological resilience; rain-forests; biodiversity; conservation; diversity; island

Berkes F, Colding J and Folke C, Eds. (2003). Navigating social–ecological systems: building resilience for complexity and change. Cambridge, UK., Cambridge University Press.

This book discusses sustainability in terms of developing new conceptual frameworks to better understand the dynamics between social and ecological systems. The underlying framework rests on complex systems theory, with emphasis of exploring ways to build social-ecological resilience (i.e. adaptive management) which will thereby increase the capacity for coping with complexity and change.
KEYWORDS: resilience; social-ecological; adaptive capacity

Bierwagen BG, Thomas R and Kane A (2008). Capacity of management plans for aquatic invasive species to integrate climate change. Conservation Biology 22(3): 568-574.

This paper examined available U.S. state aquatic invasive species (AIS) management plans to assess each program's capacity to adapt to climate-change effects. Most plans did not mention climate change specifically, but some did acknowledge climatic boundaries of species and ecosystem sensitivities to changing conditions. Activities associated with monitoring showed the highest capacity to include information on changing conditions, and future revisions to management plans are likely to be the easiest avenue through which to address climate-change effects on AIS management activities. The results show that programs have the capacity to incorporate information about climate-change effects and that the adaptive-management framework may be an appropriate approach.
DOI: 10.1111/j.1523-1739.2008.00954.x
http://www.ncbi.nlm.nih.gov/pubmed/18577086
KEYWORDS: adaptive capacity; adaptive management; aquatic invasive species; management plans; climate change; adaptive management

Blanchon P, Eisenhauer A, Fietzke J and Liebetrau V (2009). Rapid sea-level rise and reef back-stepping at the close of the last interglacial highstand. Nature 458: 881-886.

A complete reef-crest sequence and its U-series from the northeast Yucatan peninsula (Mexico) for the last interglacial sea-level highstand were analyzed. Reef development was affected by sea-level; reef-crest demise occurred at +3m and reef back-stepping occurred at +6m. Back-stepping appeared to be triggered 121 kyr ago by 2-3m jumps in sea-level caused by an episode of ice-sheet instability at the end of the last interglacial period.
DOI: 10.1038/Nature07933
http://www.nature.com/nature/journal/v458/n7240/full/nature07933.html
KEYWORDS: climate change; coral reef; isotope analysis; sea-level; interglacial

Bohensky E, Butler JRA, Costanza R, Bohnet I, Delisle A, Fabricius K, Gooch M, Kubiszewski I, Lukacs G,

Pert P and Wolanski E (2011). Future makers or future takers? A scenario analysis of climate change and the Great Barrier Reef. Global Environmental Change 21(3): 876-893.

Four scenarios designed to investigate how key uncertainties may influence climate change impacts on the Great Barrier Reef and adjacent catchments by 2100 are discussed. Results suggest the positive short-term outcome of regional mitigation procedures, but indicate their potential risks in the long-term due the existence of thresholds in the functioning of marine ecosystem. This study advocates for stronger regional management procedures, and the urgent need for action from decision-makers to maintain ecosystem services and the resulting human well-being.

DOI: 10.1016/j.gloenvcha.2011.03.009
http://www.sciencedirect.com/science/article/pii/S0959378011000367
KEYWORDS: climate change; great barrier reef; management procedures; scenario; regional management; human well-being; decision-making; stakeholders; mitigation; adaptation

Brander K (2010). Impacts of climate change on fisheries. Journal of Marine Systems 79(3-4): 389-402.

Evidence of the impacts of climate change on marine ecosystems is accumulating, but must be evaluated in the context of the "normal" climate cycles and variability which have caused fluctuations in fisheries. Recent studies of the effects of climate on primary production are reviewed and the consequences for fisheries production are evaluated through regional examples. Although our existing knowledge is in many respects incomplete it nevertheless provides an adequate basis for improved management of fisheries and of marine ecosystems and for adapting to climate change. In order to adapt to changing climate, future monitoring and research must be closely linked to responsive, flexible and reflexive management systems.

DOI: 10.1016/j.jmarsys.2008.12.015
KEYWORDS: climate change; climate impact; fish populations; fisheries management; marine ecosystems

Brander KM (2007). Global fish production and climate change. Proceedings of the National Academy of Sciences of the United States of America 104(50): 19709-19714.

This paper identifies a number of climate-related threats to both fisheries and aquaculture, but suggests low confidence in predictions of future fisheries production because of uncertainty over future global aquatic net primary production. There are strong interactions between the effects of fishing and the effects of climate because fishing reduces the age, size, and geographic diversity of populations and the biodiversity of marine ecosystems, making both more sensitive to additional stresses such as climate change. Reducing fishing mortality in the majority of fisheries, which are currently fully exploited or overexploited, is the principal feasible means of reducing the impacts of climate change.

DOI: 10.1073/pnas.0702059104
http://www.pnas.org/content/104/50/19709.abstract
KEYWORDS: fisheries; net primary production; aquaculture; climate; El Niño

Brierley AS and Kingsford MJ (2009). Impacts of climate change on marine organisms and ecosystems. Curr Biol 19(14): 602-614.

This paper reviews several physical processes affected by climate change and their effects on biological processes and ecosystems. Among others, global warming, ocean acidification, sea-level rise and altered ocean circulation will affect biological processes on diverse spatial and temporal scales, with negative implications for ecosystems services and human food security. The potential for adaptation of

organisms is discussed along with the variability of resistance and resilience of ecosystems, which in some cases may translate into ecosystem regime shifts. Mitigation procedures are explored, with an emphasis on the reduction of CO2 emissions.
DOI: 10.1016/j.cub.2009.05.046
http://www.ncbi.nlm.nih.gov/pubmed/19640499
KEYWORDS: climate change; ocean acidification; sea-level rise; global warming; oceanic circulation; regime shift; ecosystem services; mitigation; resilience

Brooks N, Adger WN and Kelly PM (2005). The determinants of vulnerability and adaptive capacity at the national level and the implications for adaptation. Global Environmental Change-Human and Policy Dimensions 15(2): 151-163.

This paper presents a set of indicators of vulnerability and capacity to adapt to climate variability, derived using a novel empirical analysis of data aggregated at the national level on a decadal timescale. The analysis is based on a conceptual framework in which risk is viewed in terms of outcome, and is a function of physically defined climate hazards and socially constructed vulnerability. The data are used to provide a robust assessment of vulnerability to climate-related mortality at the national level, and represent an entry point to more detailed explorations of vulnerability and adaptive capacity.
DOI: 10.1016/j.gloenvcha.2004.12.006
http://www.eldis.org/assets/Docs/55400.html
KEYWORDS: vulnerability; adaptive capacity; indicators; national-level; risk; mortality; governance; literacy; health; climate change

Brown CJ, Fulton EA, Hobday AJ, Matear RJ, Possingham HP, Bulman C, Christensen V, Forrest RE, Gehrke PC, Gribble NA, Griffiths SP, Lozano-Montes H, Martin JM, Metcalf S, Okey TA, Watson R and Richardson AJ (2010). Effects of climate-driven primary production change on marine food webs: implications for fisheries and conservation. Global Change Biology 16(4): 1194-1212.

The effects of changes in primary production on Australian ecosystems was simulated using Ecosim coupled to models of lower trophic levels. Results indicate that the expected increase in primary productivity will, on the whole, benefit ecosystem production, fisheries and threatened marine species. However, the inclusion of complex competition and predation sub-models resulted, in some cases, in the opposite response. Management procedures should therefore account for processes driving primary productivity, while future modelling studies should focus on predation and competition processes.
DOI: 10.1111/j.1365-2486.2009.02046.x
http://onlinelibrary.wiley.com/doi/10.1111/j.1365-2486.2009.02046.x/abstract
KEYWORDS: Climate change; primary production; fisheries; conservation; management procedures; predation; competition

Bruno JF, Sweatman H, Precht WF, Selig ER and Schutte VG (2009). Assessing evidence of phase shifts from coral to macroalgal dominance on coral reefs. Ecology 90(6): 1478-1484.

Using 3581 surveys of 1851 reefs from 1996 to 2006, the frequency, spatial extent, and degree of macroalgal dominance of coral reefs were analyzed. Results indicate an overall macroalgal dominance that is less intense than expected, contradicting previous studies. These results have implications for coral reef management procedures since these ecosystems appear to be more resistant to macroalgal blooms than assumed.
DOI: 10.1890/08-1781.1

http://www.ncbi.nlm.nih.gov/pubmed/19569362
KEYWORDS: Coral reefs; climate change; macroalgal dominance; resilience

Bunce M, Brown K and Rosendo S (2010). Policy misfits, climate change and cross-scale vulnerability in coastal Africa: how development projects undermine resilience. Environmental Science & Policy 13(6): 485-497.

East African coastal, social and ecological systems are subject to an array of environmental, social and economic changes. Recent work has stressed the link between human vulnerability in the world's poorest countries and the exposure to numerous stressors acting in combination with climate change, further intensifying their vulnerability. Mixed model empirical research explores local perceptions of recent changes at 4 coastal sites in eastern Africa. Climate and non-climate stressors are used and ranked according to livelihood. Specifically, two regional and international policy programs are perceived to have eroded resilience and intensified vulnerability – a river basin management and the development of a Marine Protected Area. This may represent an example of policy development failing to account for the cross-scale dynamic of change (a 'policy misfit'), interactions between numerous stressors or long-term climate change. This problem may be remedied by adaptive governance which builds on the adaptive capacity of those most vulnerable in society.
DOI: 10.1016/j.envsci.2010.06.003
http://www.sciencedirect.com/science/article/pii/S1462901110000663
KEYWORDS: resilience; climate change; stressor; vulnerability; adaptive governance; adaptive governance; development policy; Marine Protected Areas; river basins; Africa; adaptation

Byrne M, Soars N, Ho M, Wong E, McElroy D, Selvakumaraswamy P, Dworjanyn S and Davis A (2010). Fertilization in a suite of coastal marine invertebrates from SE Australia is robust to near-future ocean warming and acidification. Marine Biology 157(9): 2061-2069.

Fertilization in marine organisms may be negatively affected by climate change driven ocean acidification and hypercapnia; due to the narcotic effect these stressors have on sperm. Contrastingly, warmer less viscous may positively affect swimming speed of sperm, and thus ocean warming may enhance fertilization. To assess future vulnerability that ocean might have on fertilization success, the interactive effects of ocean warming and ocean acidification/hypercapnia on fertilization in intertidal and shallow subtidal echinoids, an asteroid and a mollusc species was examined. Eggs were fertilized in all combinations of three temperature and pH/PCO2 treatments and placed in projected near-future conditions for SE Australia. Fertilization was not significantly affected by warming or acidification, indicating that fertilization may be robust to temperature and pH/PCO2 fluctuations, reflecting possible adaptation to temperature and PH fluctuations that often characterise shallow coastal habitats. Climate change impacts should focus on vulnerable life history stages, such as embryo and larval stages which have long development times and may therefore be subject to temperature and pH impacts.
http://www.springerlink.com/content/b124760j48467523/
DOI: 10.1007/s00227-010-1474-9
KEYWORDS: Climate change; ocean acidification; hypercapnia; fertilization; adaptation; echinoid

Carter DW (2003). Protected areas in marine resource management: another look at the economics and research issues. Ocean & Coastal Management 46(5): 439-456.

This paper reviews the research to date that relates to the economics of MPAs. A special effort is made to examine the evidence on the benefits and costs of MPAs in terms of consumptive and

nonconsumptive marine resource interests. General observations are made regarding the net effects of MPAs on these two stakeholder categories. In general, the review finds that the empirical research on the economics of MPAs is limited and that there are several issues that might merit further investigation. The researchable topics are suggested as a way to better understand the socioeconomic impacts of MPAs and the potential response of stakeholders to proposed protected areas.
DOI: 10.1016/S0964-5691(03)00017-6
http://www.bren.ucsb.edu/academics/courses/595GG/Readings/Carter03.pdf
KEYWORDS: bioeconomic model; coral-reefs; reserves; marine protected areas

Chapin FS, Carpenter SR, Kofinas GP, Folke C, Abel N, Clark WC, Olsson P, Smith MS, Walker B, Young OR, Berkes F, Biggs R, Grove JM, Naylor RL, Pinkerton E, Steffen W and Swanson FJ (2010). Ecosystem stewardship: sustainability strategies for a rapidly changing planet. Trends in Ecology and Evolution 25: 241-249.

This review discusses the concept of ecosystem stewardship, which is described as an action-oriented framework that is proposed to address the social-ecological sustainability of a changing planet. In order to make optimal use of our current understanding of the implications of climate change, the authors discuss the development of strategies to compliment this knowledge, which include reducing the magnitude of known stresses, adopting proactive policies and avoidance of unsustainable socio-ecological traps. The authors posit that through ecological stewardship, social-ecological systems that have some form of adaptive capacity and resilience to climate change will be able to sustain ecosystem services.
DOI: 10.1016/j.tree.2009.10.008.
http://www.stockholmresilience.org/publications/artiklar/ecosystemstewardshipsustainabilitystrategiesforarapidlychangingplanet.5.7549e4d91267b3b9887800029022.html
KEYWORDS: adaptation; climate change; ecosystem; global warming; resource management; stresses

Chapin FS, Hoel M, Carpenter SR, Lubchenco J, Walker B, Callaghan TV, Folke C, Levin SA, Maler KG, Nilsson C, Barrett S, Berkes F, Crepin AS, Danell K, Rosswall T, Starrett D, Xepapadeas A and Zimov SA (2006). Building resilience and adaptation to manage Arctic change. Ambio 35(4): 198-202.

The Arctic system is important biologically (migrations of marine mammals and fish as well as birds), economically (petroleum and minerals) and ecologically (e.g. Polar Regions are the cooling systems for the planet); therefore developing management policy to enhance the resilience and adaptation ability of the Arctic system are fundamentally essential. Resilience is being able to sustain ecosystem attributes important to society despite change (such as global warming) and adaptation refers to the development of socio-ecological relationships that function effectively under new (i.e. changing) conditions. The Arctic represents a somewhat important ecosystem for being able to maintain near-natural ecological and social processes, and represents the opportunity to therefore better understand the dynamics of change and to apply these in areas which have had greater human modification.
http://pinnacle.allenpress.com/doi/pdf/10.1579/0044-7447(2006)35%5B198:BRAATM%5D2.0.CO%3B2
KEYWORDS: Resilience; adaptation; climate change; Arctic; vulnerability

Chapman RW, Mancia A, Beal M, Veloso A, Rathburn C, Blair A, Holland AF, Warr GW, Didinato GUY, Sokolova IM, Wirth EF, Duffy E and Sanger D (2011). The transcriptomic responses of the eastern oyster, Crassostrea virginica, to environmental conditions. Molecular Ecology 20(7): 1431-1449.

Understanding the mechanistic processes governing organism adaptations to environmental conditions is fundamental to predicting organism responses to environmental variation and change. This article explored changes in gene expression in the eastern oyster in response to oceanic physio-chemical conditions and contaminants. It was shown that temperature, pH, salinity and dissolved oxygen affected oyster physiology, with interactions between temperature and pH impacting gene expression. The authors successfully used transcript signatures to measure transcript responses to environmental conditions, and propose that important linkages between transcriptomics and physiological outcomes may provide an integrated approach for assessing the impacts of climate change on marine organisms.
DOI: 10.1111/j.1365-294X.2011.05018.x
http://onlinelibrary.wiley.com/doi/10.1111/j.1365-294X.2011.05018.x/abstract
KEYWORDS: adaptation; climate change; gene expression; environmental variation; marine mollusc; oyster; physiology; transcriptomics

Checkley DM, Jr., Dickson AG, Takahashi M, Radich JA, Eisenkolb N and Asch R (2009). Elevated CO2 enhances otolith growth in young fish. Science 324(5935): 1683.

Eggs and pre-feeding larvae of white sea bass (A. nobilis) were experimentally subjected to CO2-induced acidified conditions prior to the measurement of their sagittal otolith. While negative impacts of acidification on the growth of several other taxas have been reported and linked to reduced calcification, this study reports an enhancement of otolith growth in young white sea bass, partly due to the constancy of pH in the endolymph. This unexpected result highlights the need for a better understanding of the different effects of CO2 and pH on biomineralization processes in marine organisms.
DOI: 10.1126/science.1169806
http://www.ncbi.nlm.nih.gov/pubmed/19556502
KEYWORDS: acidification; calcification; fish; larval growth; pH; otolith; metabolism

Cheung WWL, Dunne J, Sarmiento JL and Pauly D (2011). Integrating ecophysiology and plankton dynamics into projected maximum fisheries catch potential under climate change in the Northeast Atlantic. ICES Journal of Marine Science: Journal du Conseil 68(6): 1008-1018.

Changes in ocean biogeochemistry and phytoplankton community structure are expected to affect marine invertebrate and fish population distributions and productivity. The authors report that this information has not been factored into previous global analyses which projected species distributional shifts and fisheries catch potential across the global oceanic systems by 2050 (contained within the Special Report on Emission Scenarios (SRES)). This article uses a dynamic biodimatic envelope model which aims to incorporate these factors into projections of species distributions and catch potentials within the Northeast Atlantic marine region. The authors discuss the implications of ocean acidification and reduced oxygen content on species growth performance, distributions and catch potentials, and the differences between the authors projections compared with previous projections.
DOI: 10.1093/icesjms/fsr012
http://oceanacidification.wordpress.com/2011/04/19/integrating-ecophysiology-and-plankton-dynamics-into-projected-maximum-fisheries-catch-potential-under-climate-change-in-the-northeast-atlantic/
KEYWORDS: biogeochemistry; climate change; distribution; fisheries catch potential; marine; Atlantic; ocean acidification; oxygen; range shift

Cheung WWL, Lam VWY, Sarmiento JL, Kearney K, Watson R and Pauly D (2009). Projecting global

marine biodiversity impacts under climate change scenarios. Fish and Fisheries 10(3): 235-251.

The global patterns of climate change impacts on marine biodiversity were investigated using a novel dynamic bioclimate envelope model, by projecting the 2050 distributional ranges of 1066 exploited fish and invertebrates. Results indicate that climate change may result in local species extinctions and species invasions, particularly intense in sub-polar regions. Such dramatic shifts in species composition will have severe impacts on ecosystem services.

DOI: 10.1111/j.1467-2979.2008.00315.x
http://onlinelibrary.wiley.com/doi/10.1111/j.1467-2979.2008.00315.x/abstract
KEYWORDS: climate change; biodiversity; model projections; species extinction; species invasion; ecosystem services

Cheung WWL, Lam VWY, Sarmiento JL, Kearney K, Watson R, Zeller D and Pauly D (2010). Large-scale redistribution of maximum fisheries catch potential in the global ocean under climate change. Global Change Biology 16(1): 24-35.

Climate change impacts on global food supplies have in recent focussed primarily on terrestrial sources, ignoring the large contribution that comes from marine capture fisheries; with global-scale projections of the impacts of climate change on these fisheries is lacking. This paper predicts the climate change impacts on global catch potential modelled for 2005-2055 for 1066 species of exploited marine fish and invertebrates. This illustrates the potential of large-scale redistribution of global catch potential, with major increases in high latitude regions and decreases in tropical regions. Additionally, catch potential is expected to decline in the southward margins of semi-enclosed seas and increase in poleward tips of continental shelf margins, particularly evident in the Pacific Ocean. It is predicted that under these climate change scenarios, the Exclusive Economic Zone (EEZ) regions with the greatest increase in catch potential include Norway, Greenland, Alaska and Russia (Asia). On the other hand, the EEZ regions with the greatest decrease in maximum catch potential are expected to include Indonesia, the United States (excluding Alaska and Hawaii), Chile and China. Further to this, many of the tropical regions that are likely to be impacted the most are already socio-economically vulnerable to these changes. These results indicate the need to design, develop and implement adaptation policy aimed at minimizing climate change impacts through fisheries.

DOI: 10.1111/j.1365-2486.2009.01995.x
http://www.seaaroundus.org/researcher/dpauly/PDF/2010/JournalArticles/LargeScaleRedistributionOfMaximumFisheriesCatchPotential.pdf
KEYWORDS: catch; climate change; fisheries; global; marine; redistribution; marine fishes; models; consequences; productivity; temperature; ecology; impact; growth; shifts; cod

Chircop A (2010). Regional cooperation in marine environmental protection in the South China Sea: a reflection on new directions for marine conservation. Ocean Development & International Law 41: 334-356.

This article outlines the need for action in marine environmental cooperation at both regional and global levels, amid recommendations from the Intergovernmental Panel on Climate Change (IPCC) Fourth Assessment. The article discusses the current situation within the South China Sea (SCS) region and the need for accelerated action to protect marine ecosystems in light of further proposed climate and ecological changes to the regions coastal marine ecosystems.

DOI: 10.1080/00908320.2010.499300
http://www.informaworld.com/smpp/content~content=a929816301~db=all
KEYWORDS: adaptation; climate change; coastal marine ecosystem; IPCC; management; marine

conservation; marine protected areas; South China Sea; region

Cinner JE, McClanahan TR, Graham NAJ, Pratchett MS, Wilson SK and Raina JB (2009). Gear-based fisheries management as a potential adaptive response to climate change and coral mortality. Journal of Applied Ecology 46(3): 724-732.

Managing fisheries across coral mortality events is expected to influence the persistence of species and reef recovery potential. The most common management recommendation has been to prohibit fishing using fisheries closures, but this response often has limited support from resource users. This study presents a way to help reduce the negative impacts of climate change and potentially increase resilience of marine ecosystems by managing fishing gear. Specific gears used by artisanal fishers differentially target fish functional groups. For instance, traps and spear guns targeted a high proportion of species highly susceptible to coral mortality and critical to coral reef resilience. Given that full fisheries closures are not always practical, selectively banning or restricting fishing gears is a potentially powerful tool for reducing the detrimental ecosystem effects of climate change disturbances.
DOI: 10.1111/j.1365-2664.2009.01648.x
http://www.ingentaconnect.com/content/bsc/jappl/2009/00000046/00000003/art00027
KEYWORDS: adaptive management; coral bleaching; climate change; herbivory; coral reef; artisanal fishery

Cochrane K, De Young C, Soto D and Bahri T (2009). Climate change implications for fisheries and aquaculture: overview of current scientific knowledge. FAO Fisheries and Aquaculture Technical Paper. No. 530. Rome**:** 212 pp.

This workshop report contains three papers reviewing different aspects of the current scientific knowledge of climate change impacts on fisheries and aquaculture. The first paper links the physical processes known to be impacted by climate change (e.g. stratification, circulation, sea level) to observed changes in ecosystem structure and fish production processes, in both marine and inland fisheries. In the last section, authors propose scenarios of anticipated responses of fish production to climate change in different regional marine ecosystems. The second paper focuses on capture fisheries and the expected impacts of climate change on these complex and dynamic social-ecological systems. This paper further explores the concepts of vulnerability and adaptive capacity of systems, their spatial and socio-economical heterogeneity, and the need for government intervention in the implementation of mitigation and adaptation procedures. The last paper reviews the potential impacts of climate change on aquaculture. After reviewing the current state and trends in aquaculture production, the authors examine the direct and indirect impacts of climate change on this sector. Finally, potential adaptation and mitigation procedures that could be implemented in this sector are addressed.
ISBN:978-92-5-106347-7
http://www.fao.org/docrep/012/i0994e/i0994e00.htm
KEYWORDS: Climate change; fisheries; aquaculture; marine; inland; impacts; adaptation; mitigation

Cochrane KL, Andrew NL and Parma AM (2011). Primary fisheries management: a minimum requirement for provision of sustainable human benefits in small-scale fisheries. Fish and Fisheries 12(3): 275-288.

This study discusses the benefits and limits of primary fisheries management, a term initially used in health care, where primary health care covers the basic needs of all. Although primary fisheries management may be beneficial for more fishermen, its low-cost implementation results in low benefits and high risk due to high uncertainties. On the other hand, tertiary management (higher costs, based on

power sharing and ecosystem approaches) is less uncertain and results in greater benefits and long term viability. Primary fisheries management is therefore seen as an emergency and temporary procedure, while tertiary management is a necessity for long term sustainability.
DOI:10.1111/j.1467-2979.2010.00392.x
http://onlinelibrary.wiley.com/doi/10.1111/j.1467-2979.2010.00392.x/abstract
KEYWORDS: fisheries; sustainability; small-scale; benefits; primary management

Coghlan A and Prideaux B (2009). Welcome to the Wet Tropics: the importance of weather in reef tourism resilience. Current Issues in Tourism 12(2): 89-104.

The effect of weather conditions on the reef experience of 1000 tourists in the Cairns/Port Douglas region was tested. Results suggest a strong negative impact of poor weather conditions on the level of satisfaction of tourists, due to the disruption of their activities (eg diving, seasickness...). This result indicates the importance of weather conditions on the reef tourism industry, an industry already vulnerable to climate change.
DOI: 10.1080/13683500802596367
http://www.tandfonline.com/doi/abs/10.1080/13683500802596367
KEYWORDS: climate change; reef; tourism; industry; weather

Coleman H, Foley M, Prahler E, Armsby M and Shillinger G (2011). Decision Guide: Selecting Support Tools for Marine Spatial Planning, The Woods Institute for the Environment [Center for Ocean Solutions].

This report presents the role that decision support tools can play in marine spatial planning. Inputting scientific and spatial information into decision making approaches is gaining momentum, whereby human activities in the marine environment are planned around maintaining ecosystem health, function and services. The report provides a framework for future planning processes, and uses a spatial component to add a regional-based focus, with the overarching goal to promote the efficient use of marine areas while reducing the impact this may have on marine ecosystems. In order to achieve these goals, spatially-explicit tools will be required by resource planners and managers to assist with the incorporation of data from a range of disciplines (i.e. ecological, economic, social systems), the assessment of management alternatives and the evaluation of management progress. The report is intended as a Decision Guide in order to assist resource managers and planners with the selection process of decision support tools for marine spatial planning relevant to their region.
http://ebmtoolsdatabase.org/sites/default/files/sources/cos_msp_guide_4lo.pdf
KEYWORDS: climate change; conflict; ecosystem-based management; impact; marine spatial planning; planning tool; regional; resource use

Coles SL and Brown BE (2003). Coral bleaching - Capacity for acclimatization and adaptation. Advances in Marine Biology. London, Academic Press Ltd. 46**:** 183-223.

Coral bleaching has occurred with increasing frequency in the past 20 years, particularly during periods of El Nino Southern Oscillation (ENSO). Studies indicate that bleaching results largely from increased sea water temperatures under high light conditions, which act to increase biochemical reaction rates associated with zooxanthellar photosynthesis, producing toxic forms of oxygen which inhibit cellular processes. Predictions of increasing ocean temperatures result from global warming, and suggest that annual temperature maxima levels within 30 years may cause frequent bleaching and widespread decline, yet these projections have not incorporated the variability which exists in bleaching

response. Information suggests that corals and their associated symbionts may be capable of acclimatization and selective adaptation to a degree. Potential mechanisms providing resistance and protection to elevated temperatures and light include inducible heat shock proteins that act to refold denatured cellular and structural proteins, production of oxidative enzymes which act to inactivate harmful oxygen radicals, fluorescent coral pigments that reflect and dissipate light energy, and phenotypic adaptations of zooxanthellae and adaptive shifts in their populations at increased temperatures. When considered in combination with experimental and observational evidence of coral recovery, these mechanisms suggest an undefined capacity to adapt to climate change impacts. Although there are limits to level of acclimatization, models will not be able to accurately predict coral reef destiny until there is a better understanding of coral-algal acclimatization and adaptation potential.
DOI: doi:10.1016/S0065-2881(03)46004-5
http://www.sciencedirect.com/science/article/pii/S0065288103460045
KEYWORDS: climate change; coral bleaching; Great Barrier Reef; El Niño; heat-shock-protein; Southern oscillation event; Scleractinian corals

Cooley SR and Doney SC (2009). Anticipating ocean acidification's economic consequences for commercial fisheries. Environmental Research Letters 4(2): 8.

Increasing anthropogenic CO2 emissions over the last two centuries have substantially increased ocean acidification, and currently, the global ocean absorbs about ~30% of the released anthropogenic CO2. Increasing dissolved CO2 and decreasing ocean pH, carbonate ion concentration and calcium carbonate mineral saturation on a worldwide scale. This acidification of surface waters and decrease in areas hospitable to calcium carbonate shells and skeletons may have severe impact for humans, the first of which being declining harvests and fishery revenues from decreases in shellfish, their predators and also their coral reef habitats. Using a US fishery example, economic projections for the next 50 years are modelled using atmospheric CO2 trajectories and laboratory-based studies of their effects, with focus on molluscs. In 2007 molluscs contributed $748 million (19%) of the US ex-vessel revenues. The impacts of ocean acidification on this fishery include substantial declines in revenue, job loss and indirect economic costs associated with marine habitat damage caused by acidification, which also alters resource availability and disrupts other ecosystem services. This paper reviews the implications for marine management strategies and proposes potential adaptation strategies designed to support fishery based communities which may already possess lower economic resilience.
DOI: 10.1088/1748-9326/4/2/024007
http://iopscience.iop.org/1748-9326/4/2/024007
KEYWORDS: Climate change; resilience; adaptation; ocean acidification; commercial fisheries; economic assessment; management implications

Cooley SR, Kite-Powell HL and Doney SC (2009). Ocean Acidification's Potential to Alter Global Marine Ecosystem Services. Oceanography 22(4): 172-181.

The causes and consequences of ocean acidification on ecosystem services are discussed. The projected negative economic impacts are expected to particularly occur in developing and coastal nations, which are the most dependent on ecosystem services. This study further reviews several published ecosystem services values, and, compairs global fisheries captures and seafood production to protein human requirements. Global trends suggest an increased vulnerability of low-latitude regions to ocean acidification and a consequently greater need for adaptive mitigation strategies.
http://www.tos.org/oceanography/archive/22-4_cooley.pdf
KEYWORDS: climate change; ocean acidification; ecosystem services; adaptation; mitigation; fisheries;

aquaculture

Cote IM and Darling ES (2010). Rethinking Ecosystem Resilience in the Face of Climate Change. Plos Biology 8(7): 5.

Ecosystem resilience is the capacity it has to maintain function and services in the face of disturbance, and the resistance in moving to an altered, less desirable state. This concept therefore incorporates two separate processes – the magnitude of the disturbance – and the recovery (speed of return to original state). Current management strategies seek to increase ecosystem resilience to global climate change, based on the premise that eliminating the drivers of change will increase the resilience to future disturbances and/or its ability to recover from these disturbances. Actually measuring resilience is difficult, but assessing changes in resilience is a fundamentally important management action since there is often a strong link between resilience and sustainability. Being able to actively increase the resilience of natural ecosystems may therefore have consequences for human welfare in the face of climate change. The authors argue that the expected increase in resilience of natural communities to climate change through reduction in local stressors may be incorrect, indicating that resilience-based management may result in increased vulnerability to the impacts of climate change; and corals reefs are used as a model to demonstrate this. Coral reefs are in decline worldwide, and face multiple stressors including climate change, fishing, eutrophication and sedimentation. Coral reef conservation management typically advocates marine reserves as spatial management options to increase resilience, but the authors discuss whether reserves really do meet this goal.
DOI: 10.1371/journal.pbio.1000438
http://www.plosbiology.org/article/info%3Adoi%2F10.1371%2Fjournal.pbio.1000438
KEYWORDS: Resilience; climate change; disturbance; coral reefs; marine protected areas; coral-reef crisis; alternative states; multiple; stressors; Caribbean reefs; phase-shifts; biodiversity; impacts; management

Cumming GS, Barnes G, Perz S, Schmink M, Sieving KE, Southworth J, Binford M, Holt RD, Stickler C and Van Holt T (2005). An exploratory framework for the empirical measurement of resilience. Ecosystems 8(8): 975-987.

Achieving long-term sustainability is highly dependent on understanding the dynamics of linked social and ecological systems. Resilience theory offers insight into how complex systems behave and highlights the significance of attributes such as diversity, ability to self-organize, system memory, hierarchical structure, feedbacks, and non-linear processes. This paper seeks to explore a framework for the operationalization of resilience for empirical studies; which has previously not been done. Resilience is likened to a system's ability to maintain its identity (key relationships and their continuity through space and time). Also fundamental to understanding the concepts of resilience and identity are innovation (sources may include diversity, migration, level of education and technological advances) and memory (e.g. Elderly people, seed banks, social and biological legacies that persist after disturbances, customs and taboos, laws, or formal archives and libraries). Surrogate measures of current resilience are developed based on assessment of potential for identity changes under specified perturbations and drivers when combined with a scenario-based approach to considering alternative futures. This approach provides insight into mechanisms behind change as well as to consequences of policy and management decisions.
DOI: 10.1007/s10021-005-0129-z

http://www.springerlink.com/content/p3374422353780v1/fulltext.pdf
KEYWORDS: Resilience; infrastructure; connectivity; networks; identity; social-ecological system; interdisciplinary; scenario

Curtin R and Prellezo R (2010). Understanding marine ecosystem based management: A literature review. Marine Policy 34(5): 821-830.

Ecosystem based management has recently been adopted and implemented across national and international organizations and governmental policy makers. This type of management takes into account the intricate nature and interconnectedness of ecosystem components and ecosystem services which are determined by the structures and functions thereof. This review addresses concepts of ecosystem based management, discusses its implementation across fisheries and marine systems and acknowledges that human activity can play a vital role in transforming ecosystem functioning.
DOI: 10.1016/j.marpol.2010.01.003
http://www.mendeley.com/research/understanding-marine-ecosystem-based-management-a-literature-review/
KEYWORDS: adaptive systems; climate change; ecology; ecosystem management; global warming; integrated management; socio-economy; zoning

Dale A and Armitage D (2011). Marine mammal co-management in Canada's Arctic: Knowledge co-production for learning and adaptive capacity. Marine Policy 35(4): 440-449.

This article discusses the emerging concept of, and challenges associated with knowledge co-production using a co-management case study in Nunavut, Canada. Knowledge co-production is proposed to assist scientists, managers, marine users and the broader community in sharing their expertise and knowledge across multiple aspects and uses of the marine environment, with the aim of learning and adapting within a co-management capacity for the management of regional marine ecosystem areas. The authors highlight how a greater understanding of knowledge co-production could assist with overcoming challenges that may arise within a co-management environment.
DOI: 10.1016/j.marpol.2010.10.019
http://www.sciencedirect.com/science/article/pii/S0308597X1000206X
KEYWORDS: adaptive capacity; challenges; co-management; community; environment; marine ecosystem; Canada; knowledge co-production; learning; science

Dambacher JM, Gaughan DJ, Rochet MJ, Rossignol PA and Trenkel VM (2009). Qualitative modelling and indicators of exploited ecosystems. Fish and Fisheries 10(3): 305-322.

Qualitative modelling was used to identify and interpret indicators of use in the implementation of ecosystem-based fishery management. Such an approach complements quantitative methods, which often suffer from the lack of observations. Models describing different ecosystems differently harvested were used and their sensitivities to perturbations tested. Community structure was identified as a major driver of dynamics. This approach permitted to cope for the lack of precise data and enabled the exploration of the socio-economic feedbacks controlling exploited systems.
DOI:10.1111/j.1467-2979.2008.00323.x
http://onlinelibrary.wiley.com/doi/10.1111/j.1467-2979.2008.00323.x/abstract
KEYWORDS: fisheries; management; ecosystem-based; model; exploitation; adaptation

De Silva SS and Doris S (2009). Climate change and aquaculture: potential impacts, adaptation and mitigation. Climate change implications for fisheries and aquaculture: overview of current scientific knowledge. FAO Fisheries and Aquaculture Technical Paper. K Cochrane, C De Young, D Soto and T Bahri. Rome, FAO. 530**:** 151-212.

This chapter reviews the potential impacts of climate change on aquaculture. After reviewing the current state and trends in aquaculture production, the authors inspect the direct and indirect impacts of climate change on this sector. Finally, potential adaptation and mitigation procedures that could be implemented in this sector are addressed.
ISBN:978-92-5-106347-7
ftp://ftp.fao.org/docrep/fao/012/i0994e/i0994e04.pdf
KEYWORDS: Climate change; fisheries; aquaculture; adaptation; mitigation

De'ath G, Lough JM and Fabricius KE (2009). Declining coral calcification on the Great Barrier Reef. Science 323: 116-119.

Skeletal records from 328 colonies of massive Porites corals from 69 reefs of the Great Barrier Reef (GBR) were analyzed to investigate trends in calcification. Results indicate a calcification decline by 14.2% since 1990, unprecedented in the last 400 years. The combined effect of increased temperature stress and reduced aragonite saturation state of seawater may be responsible for such a decline.
DOI: 10.1126/science.1165283
http://www.ncbi.nlm.nih.gov/pubmed/19119230
KEYWORDS: climate change; coral reef; calcification; great barrier reef; vulnerability

Della Patrona L, Beliaeff B and Pickering T (2011). Mitigation of sea level rise effects by addition of sediment to shrimp ponds. Aquaculture Environment Interactions 2(1): 27-38.

Shrimp ponds in New Caledonia are threatened by sea level rise due to their proximity to mangroves. This study presents a simple, low-cost and efficient procedure to mitigate the effects of sea level rise. Adding 15 cm of agricultural soil to the pond bottoms reduced the vulnerability to sea level rise and unexpectedly enhanced the yield of the shrimp ponds, through increased survival and food conversion ratio. Although the method requires improvements (e.g. the addition of soil negatively impacted meiofaunal colonization) it appears to be an effective and easily applicable solution for New Caledonian farmers.
DOI:10.3354/aei00028
http://www.int-res.com/abstracts/aei/v2/n1/p27-38/
KEYWORDS: aquaculture; sea level rise; mitigation; shrimp pond; strategy; yield; adaptation

Denman K, Christian JR, Steiner N, Portner H-O and Nojiri Y (2011). Potential impacts of future ocean acidification on marine ecosystems and fisheries: current knowledge and recommendations for future research. ICES Journal of Marine Science: Journal du Conseil 68(6): 1019-1029.

Ocean acidification has led to a reduction in the level of supersaturation of calcium carbonate in marine environments globally, while the potential pressure of carbon dioxide has increased. The authors present research findings of predicted changes in the ocean surface pH levels from the Canadian Earth System Model (CanESM-1) which demonstrate that CO2 is the major driving factor of ocean acidification when compared with other changes associated with climate change. The authors provide recommendations of a framework which considers the effects of multiple stressors derived from climate change on the thermal tolerance abilities of marine organisms.

DOI: 10.1093/icesjms/fsr074
http://icesjms.oxfordjournals.org/content/68/6/1019.full.pdf+html
KEYWORDS: adaptation; behavioural response; climate change; CO2; framework; ocean acidification; physiological response; projections; thermal tolerance

deYoung B, Barange M, Beaugrand G, Harris R, Perry RI, Scheffer M and Werner F (2008). Regime shifts in marine ecosystems: detection, prediction and management. Trends in Ecology & Evolution 23(7): 402-409.

Regime shifts are relatively sudden changes between contrasting, persistent states of a system, and the marine realm has exhibited surprisingly abrupt changes in form and function. There are three key drivers of regime shifts in oceans: abiotic processes, biotic processes and changes to structural habitat. These drivers can include both natural and anthropogenic components acting simultaneously, and whose influences are often difficult to separate. Being able to predict oceanic regime shifts and direct management accordingly depends on the shift characteristics in terms of drivers (anthropogenic and natural), scale (local to basin) and management action potential (adaptation to mitigation strategies). The conceptual framework presented enhances oceanic regime shift detection and prediction ability as well as to effectively manage these shifts. This framework uses three examples: the North Pacific, the North Sea and Caribbean coral reefs, and determines that the ability to effectively adapt or manage regime shifts depends upon their uniqueness and to understanding causes, linkages and observational capabilities.
DOI: 10.1016/j.tree.2008.03.008
http://www.cell.com/trends/ecology-evolution/abstract/S0169-5347(08)00166-3
KEYWORDS: long-term changes; cod Gadus morhua; North Pacific; climate; variability; coral-reef; fishery; management; German Bight; Atlantic; cod; ocean

Diaz-Pulido G, McCook LJ, Dove S, Berkelmans R, Roff G, Kline DI, Weeks S, Evans RD, Williamson DH and Hoegh-Guldberg O (2009). Doom and boom on a resilient reef: climate change, algal overgrowth and coral recovery. PLoS One 4(4): e5239.

The mechanisms of ecological recovery in inshore reefs of the Great Barrier Reef were investigated after the 2006 mass bleaching event. Observations show that an unprecedented bloom of seaweed occurred after the event, and that colonized corals recovered in less than a year and without involving the recruitment of new coral larvae. These results indicate the high resilience of some reefs through mechanisms of regeneration and out-competition of seaweed, providing new insights for reef ecosystem management.
DOI: 10.1371/journal.pone.0005239
http://www.ncbi.nlm.nih.gov/pubmed/19384423
KEYWORDS: climate change; coral reef; recovery; resilience; great barrier reef

Dixson DL, Munday PL and Jones GP (2010). Ocean acidification disrupts the innate ability of fish to detect predator olfactory cues. Ecology Letters 13(1): 68-75.

Ocean acidification is predicted to threaten marine biodiversity, but the direct processes which influence species persistence are not fully understood. The early life history stages of many marine species are particularly vulnerable to predators and the ability to detect predators can be critical for survival, yet it is no known whether increases in ocean acidification can impact on the detection of predators. This work demonstrates that Amphiprion percula (marine damselfish) larvae innately detect

predators by olfactory cues and that this ability remains through to larval settlement. Larvae that were reared in aquaria (i.e. not previously exposed to predators) were able to distinguish between olfactory cues of predators and non-predators. However, when eggs and larvae were exposed to conditions simulating ocean acidification (pH 7.8 and 1000ppm CO2), larvae at settlement stage became attracted to predators and were unable to distinguish between these and non-predators. Newly hatched A. percula larvae were not affected by CO2 exposure, retaining the ability to distinguish predators from non-predators. If this inability to distinguish predators translates to increases in mortality, consequences lie in the replenishment and sustainability of marine populations.
DOI: 10.1111/j.1461-0248.2009.01400.x
http://onlinelibrary.wiley.com/doi/10.1111/j.1461-0248.2009.01400.x/full
KEYWORDS: Amphiprion percula; innate behaviour; ocean acidification; olfactory cues; predator recognition; adaptation; coral reef fish

Done TJ (1999). Coral community adaptability to environmental change at the scales of regions, reefs and reef zones. American Zoologist 39(1): 66-79.

Predicted increases in temperature, sea-level, storms and atmospheric CO2 are likely to impact coral reef communities, as will increased frequency of extreme events. Decreased calcification rates caused by reduced aragonite saturation state of water may also increase the impact that severe weather events have on coral reefs. Additionally, increased frequency of extreme weather events that cause mass coral mortality are likely to more often set back coral reef communities to early successional stages or alternate states. Larger areas and longer the period of dominance of coral/coralline algae zones of reefs by non-calcifying stages will reduce the capacity of the reef to accrete the limestone bulk which is locked up in the large skeletal units of the late (old) successional stages. The flow-on effects for other reef biota such as reef fish are unpredictable, but a shifting steady-state mosaic null model may deliver a useful conceptual tool for baseline definition and tracking subsequent changes through time.
DOI: 10.1093/icb/39.1.66
http://icb.oxfordjournals.org/content/39/1/66.full.pdf+html
KEYWORDS: Great Barrier Reef; Acanthaster planci; stable states; phase shifts; disturbance; adaptation; climate change

Donelson JM, Munday PL, McCormick MI, Pankhurst NW and Pankhurst PM (2010). Effects of elevated water temperature and food availability on the reproductive performance of a coral reef fish. Marine Ecology Progress Series 401: 233-243.

The effect of temperature and food availability on the reproductive performance of the coral reef damselfish (A. polyacanthus) was experimentally tested on breeding pairs over a full breeding season. Reproductive output declined with increasing temperature and was null at the highest temperature (31.5°C, projected for 2100) and the lowest prey concentration. With increasing temperatures, individuals also grew slower and produced smaller eggs. The reduction of reproductive output was found to be a combination of reduced breeding rate and reduced spermatogenesis, suggesting the high vulnerability of this species to ocean warming.
DOI:10.3354/Meps08366
http://www.int-res.com/abstracts/meps/v401/p233-243/
KEYWORDS: warming; coral reef fish; reproduction; vulnerability

Donner SD, Skirving WJ, Little CM, Oppenheimer M and Hoegh-Guldberg O (2005). Global assessment of

coral bleaching and required rates of adaptation under climate change. Global Change Biology 11(12): 2251-2265.

Coral reefs appear highly vulnerable to climate change, with increasing water temperatures causing coral bleaching, which is the loss of colour due to breakdown of the symbiosis with the dinoflagellate Symbiodinium. Frequent or severe bleaching can have consequences such as reduced reproduction, growth, disease resistance and/or survivorship across large geographic scales. Global climate change could increase the frequency at which coral bleaching occurs, thereby threatening long-term coral reef viability. This paper conducts a global assessment of coral bleaching under climate change conditions by adapting NOAA Coral Reef Watch bleaching prediction method to the output of a low and high climate sensitivity general circulation model (GCM). This involves developing algorithms that predict mass coral bleaching with GCM-resolution sea surface temperatures for thousands of coral reefs; then using algorithms to determine coral bleaching frequency and the required thermal adaptation of corals under 2 emissions scenarios. Results indicated that coral bleaching could become an annual or biannual event in the next 30-50 years unless there is an increase of 0.2-1.0 degrees C in thermal tolerance per decade. The geographic variability required in thermal adaptation means that some regions may be particularly vulnerable to climate change impacts (e.g. Micronesia and western Polynesia). Monitoring and modelling advances will further refine the predictions for individual coral reefs, but without a concerted and accelerated effort to stabilize greenhouse gas emissions, the global prediction is unlikely to change.
DOI: 10.1111/j.1365-2486.2005.01073.x
http://onlinelibrary.wiley.com/doi/10.1111/j.1365-2486.2005.01073.x/pdf
KEYWORDS: adaptation; bleaching; climate change; coral reefs; general circulation; model; ocean warming; symbiosis; Great Barrier Reef; diversity; mortality; conservation; flexibility; thresholds; resilience; impacts; ecology; growth

Doria MD, Boyd E, Tompkins EL and Adger WN (2009). Using expert elicitation to define successful adaptation to climate change. Environmental Science & Policy 12(7): 810-819.

This paper develops definitions of adaptation and successful adaptation to climate change, with a view to evaluating adaptations. There is little consensus on the definition of adapting to climate change in existing debates or on the criteria by which adaptation actions can be deemed successful or sustainable. In this paper, a variant of the Delphi technique is used to elicit expert opinion on a definition of successful adaptation to climate change. According to the final definition, agreed by the Delphi panel, successful adaptation is any adjustment that reduces the risks associated with climate change, or vulnerability to climate change impacts, to a predetermined level, without compromising economic, social, and environmental sustainability.
DOI: 10.1016/j.envsci.2009.04.001
http://www.sciencedirect.com/science/article/pii/S1462901109000616
KEYWORDS: expert elicitation; successful adaptation; climate change; change impacts; policy

Duarte CM (2000). Marine biodiversity and ecosystem services: an elusive link. Journal of Experimental Marine Biology and Ecology 250(1-2): 117-131.

This work examines simple seagrass assemblages, which have limited species worldwide (i.e. ~50 species worldwide and <12 species in any one community) yet provide strong evidence for the existence of a strong positive link between species richness and ecosystem function. Ecosystem functions are, nevertheless, dependent on community composition, rather than number, for the functions are species-specific properties. Despite this, evidence shows that increasing species richness

should be linked to an increase in the functional repertoire that exists in the community, and will lead to more efficient use of resources and greater ecosystem function capacity and sustainability under disturbance. Functional variability of mixed-species seagrass assemblages is correlated to variability in species size, whereas species of similar size are inclined to exhibit similar functional capacities and, with this, greater functional redundancy. Positive interactions in seagrass communities dependent on the presence of engineering species in the community that facilitate the growth of other species, provides increasing expectation of enhanced functional performance of mixed communities. Multispecific communities also have a number of unrealised functional potentials which may be essential in ensuring the ecosystem function sustainability in the face of disturbance. This work shows that comparatively simple seagrass communities provide reasons to expect a strong positive relationship between species diversity and the functions and services that marine ecosystems provide to humans.
DOI: 10.1016/S0022-0981(00)00194-5
http://www.sciencedirect.com/science/article/pii/S0022098100001945
KEYWORDS: Seagrass; Marine ecosystems; Ecosystem services

Dupont S, Ortega-Martinez O and Thorndyke M (2010). Impact of near-future ocean acidification on echinoderms. Ecotoxicology 19: 449-462.

Oceanic warming and acidification are profounds affecting marine ecosystems, with calcification one of the focuses for understanding the impact of CO2-drivenclimate change on one of the key groups likely to be impacted: echinoderms. Echinoderms are often keystone ecosystem engineers. This paper reviews the impacts of ocean acidification on this group, revealing that they are a surprisingly robust group and that important differences in sensitivity to ocean acidification are found between populations and species. This work suggests that populations and species which are naturally exposed to varying pH conditions may be pre-adapted to future changes in ocean acidification. Although more data are still needed to fully understand and predict vulnerability to future conditions, this work suggests that near-future ocean acidification will negatively impact on this group with consequences likely at the ecosystem level.
DOI: 10.1007/s10646-010-0463-6
http://www.springerlink.com/content/2052510111052808/
KEYWORDS: Ocean acidification; climate change; echinoderm; CO2

Dwyer L, Edwards D, Mistilis N, Roman C and Scott N (2009). Destination and enterprise management for a tourism future. Tourism Management 30(1): 63-74.

Reviewing the outcome of a series of workshops joining a range of Australian tourism stakeholders, this study investigates how global change key drivers (economic, political, environmental, technological, demographic and social) may affect the global tourism industry by 2020. Adaptation strategies to develop sustainable tourism applicable by tourism operators are discussed.
DOI: 10.1016/j.tourman.2008.04.002
http://www.sciencedirect.com/science/article/pii/S0261517708000745
KEYWORDS: climate change; stakeholders; drivers of change; tourism; sustainability; adaptation

Edgar GJ, Moverley J, Barrett NS, Peters D and Reed C (1997). The conservation-related benefits of a systematic marine biological sampling programme: The Tasmanian reef bioregionalisation as a case study. Biological Conservation 79(2-3): 227-240.

In order to maximise the conservation value of sites within a proposed system of representative

MPAs around Tasmania, quantitative surveys of plants and animals were made around the Tasmanian coastline. Reef communities in the northern Bass Strait area were found to be distinctly different from those occurring further south, and are considered here to reflect a division between two biographical provinces. These two areas were each divisible into four biogeographical regions (bioregions). At least one marine reserve within each bioregion would be required within an integrated system of representative MPAs. In addition to the identification of appropriate MPA sites, this systematic sampling programme has generated baseline data which can assess the impact of MPAs after they have been declared and monitor the long-term effects of climate change.
DOI: 10.1016/S0006-3207(96)00095-X
http://www.sciencedirect.com/science/article/pii/S000632079600095X
KEYWORDS: marine; Tasmanian reef; biological sampling; marine protected areas; rocky reef

Eliason EJ, Clark TD, Hague MJ, Hanson LM, Gallagher ZS, Jeffries KM, Gale MK, Patterson DA, Hinch SG and Farrell AP (2011). Differences in Thermal Tolerance Among Sockeye Salmon Populations. Science 332(6025): 109-112.

Increased mortalities of adult sockeye salmon have been correlated with increased sea surface temperatures. The authors discuss the role and variability of cardiorespiratory physiology of salmon at population-based levels and relate this to historical climatic conditions that salmon encounter during migratory activities. Results from this investigation suggest that physiological adaptation by sockeye salmon can occur at very localised scales.
DOI: 10.1126/science.1199158
http://www.sciencemag.org/content/332/6025/109.full
KEYWORDS: adaptation; climate change; localised; migration; mortality; physiology; population; salmon; temperature; trout; variation

Elmqvist T, Folke C, Nystrom M, Peterson G, Bengtsson J, Walker B and Norberg J (2003). Response diversity, ecosystem change, and resilience. Frontiers in Ecology and the Environment 1(9): 488-494.

The production of ecosystem service and function are dependent on the resilience of desirable ecosystem states, of which biological diversity is thought to enhance. Response diversity – which is the array of responses to environmental change among species which contribute to the same function, is fundamental to a system's resilience. This is particularly important following change. Examples of response diversity across spatial and temporal scales are presented, demonstrating the adaptive capacity of this mechanism. It also highlights the need to incorporate the response diversity concept when developing planning and management and restoration strategies since it is likely to contribute significantly to ecosystem resilience against disturbance, mismanagement and degradation.
DOI: 10.1890/1540-9295(2003)001[0488:RDECAR]2.0.CO;2
http://www.esajournals.org/doi/abs/10.1890/1540-9295%282003%29001%5B0488%3ARDECAR%5D2.0.CO%3B2?journalCode=fron
KEYWORDS: coral-reef; species richness; seed dispersal; mass mortality; resource; use; biodiversity; scale; population; abundance; dynamics; resilience

FAO (2010). Report of the APFIC/FAO Regional Consultative Workshop "Securing sustainable small-scale fisheries: Bringing together responsible fisheries and social development". FAO Regional Office for Asia and the Pacific. Bangkok, Thailand, RAP Publication 2010/19. **19**.

This report summarizes findings and discussions from a workshop held in Thailand in October

2010 on securing sustainable small-scale fisheries. Key thematic areas were addressed to determine adequate governance practices, assistance needs and sustainable management procedures for small-scale fisheries. The rights of fishers were identified along with several key principles (e.g. transparency, gender equality) used to determine critical goals that must be attained to support and secure small-scale fisheries globally.
ISBN: 978-92-5-106724-6
http://www.fao.org/docrep/013/i1934e/i1934e00.pdf
KEYWORDS: fisheries; sustainability; climate change; communities; small-scale; management; policy; human rights; vulnerability

FAO (2010). The State of World Fisheries and Aquaculture. State of World Fisheries and Aquaculture. Rome, FAO Fisheries and Aquaculture Department: 197 pp.

This 2010 edition of the biannual report of the FAO Fisheries and Aquaculture Department provides a comprehensive overview of the state of world fisheries and aquaculture. The first part of the document reviews the trends in production, utilization and trade of world fisheries resources. The second part addresses selected issues in fisheries and aquaculture (e.g. biosecurity in aquaculture and transparency in the fisheries sector). The third part highlights special studies, including an overview of the implications of climate change for fisheries and aquaculture, a section on the ecosystem approach to fisheries, and, a review of the benefits of recent technological advancements in geographic information systems. The final section presents an outlook for the future of inland fisheries, a growing and socio-economically dynamic sector in great need of improved management.
ISBN: 9789251066751
http://www.fao.org/docrep/013/i1820e/i1820e00.htm
KEYWORDS: fisheries; aquaculture; policy; socio-economy; development; food security; exploitation; fish stocks; management; mitigation; poverty; climate change; biodiversity; conservation; adaptation; risk

Fazey I, Gamarra JGP, Fischer J, Reed MS, Stringer LC and Christie M (2010). Adaptation strategies for reducing vulnerability to future environmental change. Frontiers in Ecology and the Environment 8(8): 414-422.

Although management strategies focus on developing short-term capacities to cope with environmental change, they then inadvertently disregard the possibility that they may actually be increasing vulnerability to unanticipated future changes. With the aim of developing more effective long-term strategies to cope with change, this paper presents a conceptual framework of adaptation. The framework highlights the need to reduce the risk of further intensifying problems by ensuring that adaptation: addresses both human-induced and biophysical drivers of change; maintains a diversity of response options available for the future; and fosters human capacities which allow the uptake of those response options. Long-term adaptation relies also on emphasis on strategies that act to enhance human values, skills and behaviours that are conducive to sustainable activities.
DOI: 10.1890/080215
http://www.esajournals.org/doi/abs/10.1890/080215?journalCode=fron
KEYWORDS: climate-change; adaptive capacity; ecosystem services; resilience; management; systems; sustainability; flexibility; uncertainty; Australia; adaptation

Foley MM, Halpern BS, Micheli F, Armsby MH, Caldwell MR, Crain CM, Prahler E, Rohr N, Sivas D, Beck

MW, Carr MH, Crowder LB, Emmett Duffy J, Hacker SD, McLeod KL, Palumbi SR, Peterson CH, Regan HM, Ruckelshaus MH, Sandifer PA and Steneck RS (2010). Guiding ecological principles for marine spatial planning. Marine Policy 34(5): 955-966.

Despite recent and current efforts to govern and regulate human activities within marine ecosystems, and human use of marine resources, declining health of marine ecosystems is being recorded globally. The use of ecosystem-based marine spatial planning is one strategy which has been proposed to increase the sustainable use of marine environments by humans. This strategy examines the spatial distribution of ocean activities in order to better monitor and regulate patterns and areas of marine use, with the overarching aim of protecting ecosystem health and services and their continued sustained use. This article recommends four main ecological principles for guiding future ecosystem-based marine spatial planning activities, which include (i) maintaining and (ii) restoring a range of species, habitat and ecosystem-based properties; and accounting for (iii) context and (iv) uncertainty within these systems during the planning process.
DOI: 10.1016/j.marpol.2010.02.001
http://www.sciencedirect.com/science/article/pii/S0308597X10000436
KEYWORDS: climate change; ecology; ecological principles; ecosystem; human impact; framework; guide; marine spatial planning; policy; resources; sustainability

Folke C (2006). Resilience: The emergence of a perspective for social-ecological systems analyses. Global Environmental Change-Human and Policy Dimensions 16(3): 253-267.

This paper reviews the origin of the resilience perspective, providing a synopsis of its development in understanding the dynamics of social-ecological systems to date. The concept inspired social and environmental scientists to question the dominant stable equilibrium view. This approach emphasizes non-linear dynamics, thresholds, uncertainty and surprise, how phases of gradual change interplay with periods of rapid change and how these dynamics interact across both temporal and spatial scales. History of the resilience approach was dominated by empirical observations of ecosystem dynamics that were interpreted in mathematical models which then developed into adaptive management response. Currently efforts are being made to integrate the social component, with recent advances including understanding social processes including social learning memory, mental models and knowledge-system integration, visioning and scenario building, leadership, agents and actor groups, social networks, institutional and organizational inertia and change, adaptive capacity, transformability and systems of adaptive governance strategies which permit for the management of vital ecosystem services.
DOI: 10.1016/j.gloenvcha.2006.04.002
http://www.sciencedirect.com/science/article/pii/S0959378006000379
KEYWORDS: resilience; social-ecological systems; adaptive capacity; transformations; natural resource management; ecosystem management; climate change; regime shifts; stable states; coral-reefs; biodiversity; sustainability; vulnerability

Folke C, Carpenter S, Walker B, Scheffer M, Elmqvist T, Gunderson L and Holling CS (2004). Regime shifts, resilience, and biodiversity in ecosystem management. Annual Review of Ecology Evolution and Systematics 35: 557-581.

Resilience is the capacity of a system to absorb perturbance and to maintain structure, function and feedbacks mechanisms in the face of change. Regime-shifts, whereby human impact drives a system to a less desirable state, indicate a shift in ecosystem services and therefore, have consequences on humans. Human activities such as pollution, resource exploitation, land-use change, and climate impact

all reduce ecosystem resilience, and are resulting in more frequent regime shifts. These activities act to reduce resilience by removing response diversity, whole functional groups, whole trophic levels, or by impacting on ecosystems through pollution, emissions and climate change, which all alters the degree, frequency and duration of disturbance regimes. This paper reviews the evidence of regime shifts in relation to resilience of complex adaptive systems and the associated roles of biological diversity. It also emphasizes the need for adaptive management strategies that incorporate resilience into sustainability planning.
DOI: 10.1146/annurev.ecolsys.35.021103.105711
http://www.jstor.org/stable/pdfplus/30034127.pdf?acceptTC=true
KEYWORDS: alternate states; regime shifts; response diversity; complex adaptive; systems; ecosystem; services; alternative stable states; coral reefs; Baltic sea; species-diversity; phase-shifts; trophic cascades; climate change; shallow lakes; El-Nino; vegetation; resilience; biodiversity

Ford SE and Chintala MM (2006). Northward expansion of a marine parasite: Testing the role of temperature adaptation. Journal of Experimental Marine Biology and Ecology 339(2): 226-235.

In vitro and in vivo experiments were used to test whether the northward range expansion of the eastern oyster (Crassostrea virginica) parasite, Perkinsus marinus was associated with a low-temperature adapted strain of the parasite. In vitro proliferation of nine P. marinus isolates from three southern sites was measured at seven temperatures to determine whether between- and within-geographic location differences existed in proliferation rate, and whether these were linked to temperature. There was no evidence of low-temperature adaptation, but at the higher temperatures the southern isolates exhibited higher proliferation rates than their northern counterparts, suggesting potential high-temperature adaptation of strains that are routinely subjected to higher temperatures. There was significant within-location variation among isolates, but the data tended to group by geographic location, supporting the regional component of proliferation rate hypothesis of P. marinus isolates. These data support the hypothesis that resent warming in the north-eastern US is a likely contributing factor to P. marinus range extension.
DOI: doi:10.1016/j.jembe.2006.08.004
http://www.sciencedirect.com/science/article/pii/S0022098106004424
KEYWORDS: climate change; Crassostrea virginica; in vitro; in vivo; range extension; pathogen

Friedman K, Eriksson H, Tardy E and Pakoa K (2011). Management of sea cucumber stocks: patterns of vulnerability and recovery of sea cucumber stocks impacted by fishing. Fish and Fisheries 12(1): 75-93.

A time-series approach was used to investigate changes in sea cucumber populations in different Pacific Island countries (Samoa, Tonga, Palau, Fiji and Papua New Guinea), some of which have been subjected to a moratorium on exports for the last decade. Results indicate the negative impacts of artisanal fishing activities, and varying recovery rates after cessation of fishing. Some species did not show signs of recovery despite moratoriums, suggesting population dynamics constrained by the Allee effect. The authors suggest that current management strategies are ineffective and discuss new adaptive approaches that could be implemented.
DOI:10.1111/j.1467-2979.2010.00384.x
http://onlinelibrary.wiley.com/doi/10.1111/j.1467-2979.2010.00384.x/abstract
KEYWORDS: aquaculture; management; sea cucumber; vulnerability; recovery; fisheries; great barrier reef

Fuller T, Morton DP and Sarkar S (2008). Incorporating uncertainty about species' potential distributions under climate change into the selection of conservation areas with a case study from the Arctic Coastal Plain of Alaska. Biological Conservation 141(6): 1547-1559.

This article presents a conservation planning framework for decisions under uncertainty, which arise from climate change-driven distributional shifts in a species' range. The planning framework utilises a two-stage optimization model which (i) selects a nominal conservation area network followed by (ii) evaluation of its performance under climate scenarios. The authors focus on a case study of the Arctic Coastal Plain in Alaska for demonstration of their conservation framework.

DOI: 10.1016/j.biocon.2008.03.021

http://uts.cc.utexas.edu/~consbio/Cons/Fuller08AK.pdf

KEYWORDS: Arctic National Wildlife Refuge; biodiversity; climate change; conservation planning framework; management; model; reserve

Fussel HM (2009). An updated assessment of the risks from climate change based on research published since the IPCC Fourth Assessment Report. Climatic Change 97(3-4): 469-482.

This paper provides an updated assessment of the status of scientific knowledge of climate change to the Intergovernmental Panel on Climate Change (IPCC) Fourth Assessment Report (AR4), which was published in 2007. The current assessment is based a comprehensive review of the relevant scientific literature which has been published since the AR4 was released. Many of the risks that were first identified in the AR4 are now considered much greater, including sea-level rise, the amplification of global warming due to biological and geological carbon-cycle feedbacks, future committed warming due to a strong aerosol mask, increases in climate variability and risks to marine ecosystems from climate change and ocean acidification. Scientific debate still remains around a number of topics including changes in tropical cyclone activity. Additionally, greenhouse gas emissions have accelerated recently, and without targeted policy intervention, will continue to do so. This paper emphasizes the urgency for implementing mitigation policies as well as the development and implementation of comprehensive adaptation policies.

DOI: 10.1007/s10584-009-9648-5

http://www.springerlink.com/content/yj352w65g181016m/

KEYWORDS: sea-level rise; ice mass-loss; tropical cyclones; ocean acidification; AR4 simulations; CO2; temperature; intensity; Atlantic; system; climate change

Game ET, McDonald-Madden E, Puotinen ML and Possingham HP (2008). Should We Protect the Strong or the Weak? Risk, Resilience, and the Selection of Marine Protected Areas. Conservation Biology 22(6): 1619-1629.

It is thought that marine reserves recover faster than unprotected habitats when uncontrolled disturbance occurs; this paper defined the problem of deciding which habitat should be protected (those at greatest or lowest risk) mathematically for two alternate conservation objectives. This was followed by analytically solving this problem for both and determining the conditions under which different protection strategies was optimal. In the goal was to maximise the potential of having at least one healthy site, then the most effective strategy was to protect the site with the lowest risk. However, if the goal was to maximise the number of healthy sites, then the best approach was more complex. If protected areas were likely to spend high amounts of time in a degraded condition, then it was optimal to protect sites of low risk, but if most areas were largely healthy then it was better to protect sites that were at higher risk.

DOI: 10.1111/j.1523-1739.2008.01037.x

http://onlinelibrary.wiley.com/doi/10.1111/j.1523-1739.2008.01037.x/pdf
KEYWORDS: catastrophes; coral reefs; cyclones; habitat disturbance; marine reserves; reserve selection; climate change; Marine Protected Areas; resilience

Gardiner NM, Munday PL and Nilsson GE (2010). Counter-Gradient Variation in Respiratory Performance of Coral Reef Fishes at Elevated Temperatures. Plos One 5(10): 13.

Global warming is predicted to increase sea surface temperatures by 3°C within the next century. The effect of increasing temperatures on species' distribution and abundance includes range shifts, population collapses, local extinctions, and phase shifts, and the response of a species depends on how different populations are affected throughout its geographic range. This means that local adaptation to thermal gradients could result in populations within a species to respond to global warming differently. For aquatic animals, response to increased temperatures will depend on the ability to keep up with increased oxygen demand. Since populations at different latitudes experience different thermal environments, respiratory performance is likely to vary between populations. Geographic variation in respiratory performance was examined in tropical marine fishes by comparing thermal effects on resting and maximum rates of oxygen uptake in six species of reef fish from two locations on the Great Barrier Reef. Strong counter-gradient variation in aerobic scope was observed between locations in four species (from two families). High-latitude populations performed better than those from low-latitudes. Latitudinal variation was driven by ~80% higher maximum rate of oxygen uptake for populations from higher latitudes. These data suggest that compensatory mechanisms for populations in high-latitudes may enhance their performance at high temperatures, and that these populations will be less impacted by increasing ocean temperatures than low latitude populations.
DOI: 10.1371/journal.pone.0013299
http://www.plosone.org/article/info%3Adoi%2F10.1371%2Fjournal.pone.0013299
KEYWORDS: climate change; Great Barrier Reef; thermal tolerance; evolutionary significance; hypoxia tolerance; oxygen limitation; larval; marine fishes

Gerber LR, Wielgus J and Sala E (2007). A decision framework for the adaptive management of an exploited species with implications for marine reserves. Conservation Biology 21(6): 1594-1602.

There are no general criteria about when and where to establish new marine reserves, how to evaluate their efficacy, and how to conduct adaptive management to achieve conservation goals. This paper applies a decision-theory framework to optimally allocate conservation resources between improving data on population status and establishing a reserve for species conservation. The goal was to maximize reserve benefits given the constraints of a population growth rate that would permit sustainability of resources. The decision framework presented here may be used to identify the minimum number of years of data needed before a management decision about reserve establishment could be made that is reasonably likely to meet its management objectives.
DOI: 10.1111/j.1523-1739.2007.00824.x
http://onlinelibrary.wiley.com/doi/10.1111/j.1523-1739.2007.00824.x/full
KEYWORDS: adaptive management; decision theory; leopard grouper; marine reserve; Sea of Cortes; species monitoring; protected areas

Glynn PW (1993). Coral-Reef bleaching - Ecological Perspectives. Coral Reefs 12(1): 1-17.

Coral reef bleaching results from loss of symbiotic zooxanthellae and/or a reduction in

photosynthetic pigment concentrations that occur in zooxanthellae. Consequences of bleaching of reef-building scleractinian corals and hydrocorals are of particular concern, with data suggesting that scale, frequency and severity of recent bleaching disturbances are greater than ever before recorded. Stressors such as temperature, light, salinity, sedimentation, aerial exposure and pollutants often result in small scale bleaching, but there is not much definitive evidence for explaining large scale bleaching events in terms of potential climate change. This is mostly the result of lack of standardised methods for assessing bleaching and lack of continuous long-term baseline data. Efforts must be directed at understanding impacts of bleaching on current reef community along with long-term effects on competition, predation, symbioses, bio-erosion and substrate condition, which all have the ability to effect coral recruitment and recovery. Present evidence suggests that many corals will be unable to adapt to the rapid rates of ocean warming that are predicted for the near-future.
DOI: 10.1007/BF00303779
http://www.springerlink.com/content/k12w48311274206n/
KEYWORDS: coral bleaching; Great Barrier Reef; adaptation; El Niño; ultraviolet-radiation; community structure; Scleractinian corals

Gössling S, Hall CM and Scott D (2010). The Future of Tourism: Can Tourism Growth and Climate Policy be Reconciled ? A Mitigation Perspective. Tourism Recreation Research 35(2): 119-130.

The increase in tourism-induced greenhouse gas emissions caused by the global growth of tourism, and, the increasing need for mitigation procedures to maintain the sustainability of the tourism industry are two opposing processes discussed in this study. Current management procedures appear to be insufficient and radical changes in policies are needed to ensure a climatically sustainable global tourism.
http://www.mendeley.com/research/future-tourism-tourism-growth-climate-policy-reconciled-climate-change-mitigation-perspective/
KEYWORDS: climate change; tourism; sustainability; mitigation; greenhouse gas; industry; adaptation; management procedures

Grafton RQ (2010). Adaptation to climate change in marine capture fisheries. Marine Policy 34(3): 606-615.

Climate change is expected to have significant expected and unexpected effects on the marine environment, and management of capture fisheries must be able to adapt to change by providing policy options; by developing risk and vulnerability assessment and management into decision-making framework for adaptation; and by developing strategies for the predicted and non-predicted effects.This paper discusses the way in which management objectives and instruments influence system resilience and adaptation; outlines a decision-making process for assessment of vulnerability to climate change and adaptive-management responses; provides inter-temporal framework for assisting managers on when to adapt; presents a risk simulation approach outlining uncertainties of potential losses as a result of climate change and the benefits of adaptation; provides an explanation of how adaptation capacity can be strengthened by adaptive co-management; and presents a variety of potential 'win-win' management tools.
DOI: 10.1016/j.marpol.2009.11.011
http://www.sciencedirect.com/science/article/pii/S0308597X09001845
KEYWORDS: adaptation; climate change; fisheries; social-ecological systems; stock assessment; uncertainty; management; conservation; resilience; governance; resource; reserves; trends

Grafton RQ, Hilborn R, Ridgeway L, Squires D, Williams M, Garcia S, Groves T, Joseph J, Kelleher K, Kompas T, Libecap G, Lundin CG, Makino M, Matthiasson T, McLoughlin R, Parma A, Martin GS, Satia B, Schmidt CC, Tait M and Zhang LX (2008). Positioning fisheries in a changing world. Marine Policy 32(4): 630-634.

Marine capture fisheries face major and complex challenges: habitat degradation, poor economic returns, social hardships from depleted stocks, illegal fishing, and climate change. The key factors that prevent the transition to sustainable fisheries are information failures, transition costs, use and non-use conflicts and capacity constraints. Using the experiences of fisheries successes and failures it is argued only through better governance and institutional change that encompasses the public good of the oceans and societal values will fisheries be made sustainable.

DOI: 10.1016/j.marpol.2007.11.003
http://www.sciencedirect.com/science/article/pii/S0308597X07001327
KEYWORDS: governance; public and private benefits; fisheries; biodiversity; sustainability; future

Grafton RQ and Kompas T (2005). Uncertainty and the active adaptive management of marine reserves. Marine Policy 29(5): 471-479.

Unpredictable environmental fluctuations are a major problem in fisheries. To mitigate these uncertainties, reserves are advocated to help ensure population persistence, reduce population and harvest variance, provide a 'hedge' against management failures and increase resilience. Using recent insights from the modelling of marine reserves, this paper proposes a six-step process for establishing and adaptively managing reserves for fishery purposes.

DOI: 10.1016/j.marpol.2004.07.006
http://www.sciencedirect.com/science/article/pii/S0308597X04000880
KEYWORDS: marine reserves; uncertainty; adaptive management; protected areas; fisheries management

Grafton RQ, Kompas T and Ha PV (2006). The economic payoffs from marine reserves: Resource rents in a stochastic environment. The Economic Record 82(259): 469-480.

This paper analysed the economic payoffs from marine reserves using a stochastic optimal control model, with a jump-diffusion process. The results show that even if the reserve and harvested populations face the same negative shocks, harvesting is optimal, the population is persistent and there is no uncertainty over current stock size, a reserve can increase resource rents. Using fishery data it is shown that the payoffs from a reserve, and also optimum reserve size, increase the larger is the magnitude of the negative shock, the greater its frequency and the larger its relative impact on the harvested population.

DOI: 10.1111/j.1475-4932.2006.00360.x
http://onlinelibrary.wiley.com/doi/10.1111/j.1475-4932.2006.00360.x/abstract
KEYWORDS: bioeconomic model; protected areas; stochastic model; marine reserve; fisheries; management; ecosystems

Grafton RQ, Kompas T and Lindenmayer D (2005). Marine reserves with ecological uncertainty. Bulletin of Mathematical Biology 67(5): 957-971.

To help manage the fluctuations inherent in fish populations scientists have argued for both an ecosystem approach to management and the greater use of marine reserves. Using a stochastic optimal

control model with two forms of ecological uncertainty this paper demonstrates that reserves create a resilience effect that allows for the population to recover faster. The tradeoff of a larger reserve is a reduced harvest in the absence of a negative shock such that a reserve will never encompass the entire population if the goal is to maximize the economic returns from harvesting, and fishing is profitable. Overall, the results show that, in many cases, there is no tradeoff between the economic payoff of fishers and ecological benefits when a reserve is established at equal to, or less than, its optimum size.
DOI: 10.1016/j.bulm.2004.11.006
http://www.springerlink.com/content/7128wq2p78625444/
KEYWORDS: fisheries management; marine reserve; metapopulation; dynamics; stocks; model

Grafton RQ, Kompas T and Schneider V (2005). The bioeconomics of marine reserves: A selected review with policy implications. Journal of Bioeconomics 7: 161-178.

The paper 'bridges the divide' between the biological and economic literature on marine reserves. It provides a selected review of the traditional use of reserves, the early reserve literature, the potential benefits of reserves, spillovers from reserves to harvested areas and bioeconomic models of marine reserves. The bioeconomics literature is examined from the perspectives of deterministic models, spatial economic models and models that include uncertainty and stochasticity. Insights from the review are used to provide management implications in terms of reserve design, stakeholder cooperation and process, reserve-fishery transfers, traditional management controls, and ecosystem approaches to managing fisheries.
DOI: 10.1007/s10818-005-6885-1
http://www.springerlink.com/content/y1x4q13683888584/
KEYWORDS: reserve spill-overs; deterministic; stochasticity; spatial models; fisheries management

Graham NAJ, McClanahan TR, MacNeil MA, Wilson SK, Polunin NVC, Jennings S, Chabanet P, Clark S, Spalding MD, Letourneur Y, Bigot L, Galzin R, Ohman MC, Garpe KC, Edwards AJ and Sheppard CRC (2008). Climate Warming, Marine Protected Areas and the Ocean-Scale Integrity of Coral Reef Ecosystems. Plos One 3(8): 9.

Coral reefs are one of the ecosystems that are highly vulnerable to climate variability and change. Increasing sea surface temperatures associated with global warming have caused widespread coral bleaching due to their restricted thermal tolerance capabilities. Despite documentation of this widespread loss in coral cover across spatial and temporal scales, little is known on the effects on fish. This work assesses the importance of local management in conserving coral reefs in the context of climate change. This work assesses the impacts of the mass bleaching event that occurred in 1998 affecting coral cover, reef structural complexity and reef fishes from 7 countries, 66 sites and 26 degrees of latitude in the Indian Ocean. Bayesian meta-analysis showed that changes in the size structure, diversity and trophic composition of reef fish communities have all followed this decline in corals. Ocean scale integrity has been lost, however effects were showed spatial variation at multiple scales, suggesting impacts and vulnerability are affected by geography, but not the management regime. Existing no-take marine protected areas continued to support high fish biomass, but they did not appear to have a positive effect on the ecosystem response to the large scale disturbance of coral decline. Future conservation and management efforts need to identify and subsequently protect regional refugia, and develop resilience-building policy and framework into management options for climate change.
DOI: 10.1371/journal.pone.0003039
http://www.plosone.org/article/info%3Adoi%2F10.1371%2Fjournal.pone.0003039

KEYWORDS: climate change; coral reefs; Marine Protected Areas; resilience; thermal tolerance

Gruber N (2011). Warming up, turning sour, losing breath: ocean biogeochemistry under global change. Philosophical Transactions of the Royal Society A 369(1943): 1980-1996.

Increasing temperature, ocean acidification and ocean deoxygenation are predicted to significantly alter ocean function and ecosystem dynamics over the coming decades and centuries, including aspects of physical, chemical and biological processes. This article discusses the impacts of warming, acidification, and deoxygenation at regional and global scales and likely mitigation strategies for reducing the rate at which these factors are occurring globally.
DOI: 10.1098/rsta.2011.0003
http://rsta.royalsocietypublishing.org/content/369/1943/1980
KEYWORDS: climate change; deoxygentation; global warming; ocean acidification; ocean biogeochemistry; temperature

Gunderson LH and Pritchard Jr. LE (2002). Resilience and the behaviour of large-scale systems. Washington DC, Island Press.

Resilience is the ability of a system to return to its natural state following disturbance, and has been the subject of much concern amongst the scientific community of recent. The work of C.S. Holling in the 1970s was one of the first to look at regime shifts following disturbance and the role of resilience in rate at which the disturbed system could return to its natural (or pre-disturbed) state. This paper examines resilience and change theories, offering understanding of how ecological resilience and human adaptability properties interact in complex and regional-scale systems. Concepts of resilience and stability in large-scale ecosystems are addressed in terms of theoretical concepts, along with the empirical application of those concepts. Practical implications of new theoretical approaches are discussed in terms of sustaining systems in light of human impacts. Key properties of complex adaptive systems contributing to resilience are reviewed, and include multiple equilibria, complexity, self-organization at multiple scales and order. This book also uses case studies to explore the biophysical dimensions of resilience in different ecosystems, and presents information on the relationship between recovery times and resilience for perturbed systems.
KEYWORDS: resilience; complex adaptive systems; regional scale

Haapkyla J, Melbourne-Thomas J, Flavell M and Willis BL (2010). Spatiotemporal patterns of coral disease prevalence on Heron Island, Great Barrier Reef, Australia. Coral Reefs 29(4): 1035-1045.

Little information exists on the factors driving coral disease dynamics on the Great Barrier Reef. This work investigates temporal patterns in coral disease and potential drivers of this around Heron Island. Surveys between 2007 and 2009 identified six diseases: brown band syndrome (BrB), growth anomalies (GA), ulcerative white spots (UWS), white syndrome (WS), skeletal eroding band disease (SEB) and black band disease (BBD); with lowest disease occurrence in Nov 2007 and highest in August 2008. Evidence of seasonality was detected for two diseases: BrB and UW, with this being the first recording of higher BrB in winter. The dominance of Gas and SEB was not seasonal, although incidence of GA increased throughout the study duration. WS was slightly higher in summer, but overall prevalence was relatively low.
Sites with high abundance of staghorn Acropora and Montipora had greatest disease. These data emphasize the correlations between coral disease prevalence, seasonally varying environmental parameters and coral community composition, yet highlight for more work in these areas.

DOI: 10.1007/s00338-010-0660-z
http://www.springerlink.com/content/b300236124w6h871/
KEYWORDS: coral disease; Indo-Pacific; seasonality; sea surface temperature; brown band syndrome; growth anomalies; climate change; resilience

Halford A, Cheal AJ, Ryan D and Williams DM (2004). Resilience to large-scale disturbance in coral and fish assemblages on the Great Barrier Reef. Ecology 85(7): 1892-1905.

Recognition of the complexity variability (spatial and temporal) of species abundance and diversity in many populations has shifted focus to the importance of heterogeneity, stochasticity, and disturbance for structuring and persistence of communities. Coral reef communities have high species diversity in a spatially heterogeneous environment, display stochastic variability (spatial and temporal) in community structure, and are also subject to significant disturbances. Coral and fish assemblages were monitored on fixed sites over 80km of the Great Barrier Reef (GBR) for 14 years. The data revealed large-scale resilience and predictable recovery of these species assemblages. Live coral cover decreased from >80% to <10% in some north-eastern reefs during 1987-89, which was potentially the result of storm damage. This allowed comparison of fish and benthic communities prior to the disturbance and throughout the time of disturbance. Hard coral cover increased at a slow rate from 1992-94, but accelerated in growth rate and was the same as pre-disturbance by 1998. The community was dominated by tabulate Acropora corals, which have rapid growth and competitive dominance, and allowed this quick response. Species richness within the fish families Acanthuridae, Chaetodontidae, Scaridae, and Pomacentridae emulated the patterns observed of hard corals, except that one family (Pomacentridae) had not fully recovered by 1998. Overall, 88% of fish species decreased in abundance post disturbance, but subsequently increased to pre-disturbance levels except for two species. These data suggest that habitat may play an important role in modifying fish assemblages, with both coral and fish assemblages demonstrating resilience to large-scale natural disturbance.
DOI: 10.1890/03-4017
http://www.esajournals.org/doi/pdf/10.1890/03-4017
KEYWORDS: coral assemblage; disturbance; Great Barrier Reef; large scale; recovery; reef fish; assemblage; resilience; Acanthaster planci; tropical cyclone; catastrophic predation; herbivorous fishes; temporal patterns; habitat structure; communities; dynamics; recruitment

Hallegraeff GM (2010). Ocean Climate Change, Phytoplankton Community Responses, and Harmful Algal Blooms: A Formidable Predictive Challenge Journal of Phycology 46(2): 220-235.

The impact of harmful algal blooms (HAB) are difficult to predict, but information can be gathered from a variety of sources, including fossil records of dinoflagellate cysts, long-term monitoring programs (e.g. Continuous Plankton Recorder surveys) and short-term phytoplankton community responses in the face of El Nino Southern Oscillation (ENSO) and North Atlantic Oscillation (NAO) events. A number of factors can result in contradictory species or strain-specific responses; including increasing temperature, surface stratification, changing ocean currents, nutrient upwelling variability, elevated CO2, ocean acidification, and increased storm events and precipitation causing changes in run-off. Additional to these, complex interactions exist, which can rarely be accurately simulated under laboratory conditions. Expected outcomes may include poleward range-extension of warm-water species; species-specific abundance changes and seasonal windows for HABs; some phytoplankton experiencing earlier peak production times; and secondary effects for food webs. Some harmful algal species may proliferate under disturbed conditions, but others may diminish in presently disturbed areas. This paper highlights the limitations in our understanding of marine ecosystem

responses to multifactorial physicochemical climate drivers and emphasizes the lack of knowledge regarding genetic and phenotypic adaptation ability of marine microalgae to accelerating climate change. This work stresses that lack of preparedness of human society in the face of increasing algal biotoxin problems, and calls for increased vigilance in areas that are currently poorly monitored. Phytoplankton community changes can also provide early warning systems for climate-driven perturbances.
DOI: 10.1111/j.1529-8817.2010.00815.x
http://onlinelibrary.wiley.com/doi/10.1111/j.1529-8817.2010.00815.x/full
KEYWORDS: adaptation; algal blooms; climate change; continuous plankton recorder; ENSO; NAO; ocean acidification; range expansion; North-Atlantic oscillation; plankton recorder survey; dinoflagellate; cysts; atmospheric CO2; red tides; Gymnodinium catenatum; positive feedback; marine plankton; El Niño

Halsnaes K and Traerup S (2009). Development and Climate Change: A Mainstreaming Approach for Assessing Economic, Social, and Environmental Impacts of Adaptation Measures. Environmental Management 43(5): 765-778.

The paper introduces the so-called climate change mainstreaming approach, where vulnerability and adaptation measures are assessed in the context of general development policy objectives. The approach is based on the application of a limited set of indicators. These indicators are selected as representatives of focal development policy objectives, and a stepwise approach for addressing climate change impacts, development linkages, and the economic, social and environmental dimensions related to vulnerability and adaptation are introduced. The conclusions of the paper confirm that climate risks can be reduced at relatively low costs, but the uncertainty is still remaining about some of the wider development impacts of implementing climate change adaptation measures.
DOI: 10.1007/s00267-009-9273-0
http://www.springerlink.com/content/y3x0212l15286h70/
KEYWORDS: climate change; mainstreaming; sustainable development

Hansen L, Biringer J and Hoffman J, Eds. (2003). Buying Time: A User's Manual for Building Resistance and Resilience to Climate Change in Natural Systems. Washington, DC, WWF.

Awareness has been elevated regarding invasive species, environmental contaminants, altered hydrology, and habitat fragmentation, all impacting on ecosystems, and further to this conservation practitioners must now address climate change as a major ecosystem threat. The aim of this manual is to provide support for natural resource and protected area managers as they begin to contemplate how to respond to climate change. This study demonstrates a clear fingerprint of climate change. Parmesan and Yohe (2003) analysed data from over 1700 species to demonstrate that climate change has already altered range boundaries and phenology. Root et al. (2003) showed that 80% of the 143 studies they used demonstrated trait characteristics conferring climate change predictions. Examples are provided showing specific climate-driven ecosystem responses.
http://www.worldwildlife.org/climate/Publications/WWFBinaryitem4922.pdf
KEYWORDS: climate change; resilience; resistance; IPCC

Harley CDG, Hughes AR, Hultgren KM, Miner BG, Sorte CJB, Thornber CS, Rodriguez LF, Tomanek L and Williams SL (2006). The impacts of climate change in coastal marine systems (vol 9, pg 228, 2006). Ecology Letters 9(4): 500-500.

Human-induced climate change has significant implications for marine ecosystems as well as the

economic and social systems that depend on them. Temperate is linked to individual performance, and much clime-related research has centred on potential distribution and abundance shifts which are driven directly by temperature. Recent work suggests that the abiotic changes and biological responses will be substantially more complex than first anticipated, for example, with changes in chemistry likely to be more important for performance and survival in many organisms than temperature. Ocean circulation, driving larval transport, is also predicted to change, which will have important effects on population dynamics. Other climatic impacts on leverage species may result in community-level changes, and combined climatic and human-induced impacts such as fishing pressure may intensify climate-induced changes. Conservation and management efforts will require enhancement of predictive frameworks, and direction of future research should include identifying key demographic transitions that act to influence population dynamics, predict community-level impacts of dominant species, involve adaptation ability, and understand the appropriate time scales in which systems will be able to respond
DOI: 10.1111/j.1461-0248.2005.00871.x
http://onlinelibrary.wiley.com/doi/10.1111/j.1461-0248.2005.00871.x/pdf
KEYWORDS: climate change; coastal marine; adaptation; community-level; human impacts

Harvell CD, Mitchell CE, Ward JR, Altizer S, Dobson AP, Ostfeld RS and Samuel MD (2002). Ecology - Climate warming and disease risks for terrestrial and marine biota. Science 296(5576): 2158-2162.

Extinction or rapid decline in population numbers can be the result of infectious diseases. Many pathogens are susceptible to temperature, rainfall and humidity, and can create synergisms that could potentially affect biodiversity. Increases in global warming can amplify pathogen development and survival rates, spread of disease and susceptibility of pathogen hosts. Global warming is predicted to increase frequency or severity of disease impacts for host-parasite systems; however some pathogens may decline with increasing temperatures, and releasing hosts from disease. Climatic events such as El Nino Southern Oscillation (ENSO) have influenced pathogens including coral disease and oyster pathogens. To improve effective epidemic predictions in wild populations, we need to be able to separate both independent and interactive effects of various climate drivers on disease impact.
DOI: 10.1126/science.1063699
http://www.sciencemag.org/content/296/5576/2158.full.pdf
KEYWORDS: amphibian population declines; emerging infectious-diseases; vector-borne diseases; Phytophthora cinnamomi; Perkinsus-marinus; mass-mortality; Culex quinquefasciatus; Haemonchus contortus; climate change

Hasselmann K, Latif M, Hooss G, Azar C, Edenhofer O, Jaeger CC, Johannessen OM, Kemfert C, Welp M and Wokaun A (2003). The challenge of long-term climate change. Science 302(5652): 1923-1925.

Climate policy needs to address the multi-decadal to centennial time scale of climate change. Although the realization of short-term targets is an important first step, to be effective climate policies need to be conceived as long-term programs that will achieve a gradual transition to an essentially emission-free economy on the time scale of a century. This requires a considerably broader spectrum of policy measures than the primarily market-based instruments invoked for shorter term mitigation policies. A successful climate policy must consist of a dual approach focusing on both short-term targets and long-term goals.
DOI: 10.1126/science.1090858
http://www.sciencemag.org/content/302/5652/1923.full.pdf
KEYWORDS: climate change; policy; fossil-fuel CO2; model; stewardship; economics

Havenhand JN, Buttler FR, Thorndyke MC and Williamson JE (2008). Near-future levels of ocean acidification reduce fertilization success in a sea urchin. Curr Biol 18(15): 651-652.

Gametes and larvae of the sea urchin H. erythrogramma were subjected to CO2-induced acidification (pH reduced by 0.4, ca 1000 ppm CO2, the upper limit of predictions for 2100) in tanks. Sperm swimming speed, motility and hence, fertilization success were significantly reduced in acidified water. These findings suggest that ocean acidification may drastically impact taxa with calcareous larval skeletons in the near future, putting entire populations, species or ecosystems at risk.
DOI:10.1016/j.cub.2008.06.015
http://www.ncbi.nlm.nih.gov/pubmed/18682203
KEYWORDS: ocean acidification, fertilization, urchin, calcification; gametes; fertility

Hawkins SJ, Sugden HE, Mieszkowska N, Moore PJ, Poloczanska E, Leaper R, Herbert RJH, Genner MJ, Moschella PS, Thompson RC, Jenkins SR, Southward AJ and Burrows MT (2009). Consequences of climate-driven biodiversity changes for ecosystem functioning of North European rocky shores. Marine Ecology-Progress Series 396: 245-259.

This paper reviews the response of intertidal biodiversity from rocky shores in the British Isles to global climate change, using long-term data sets. There is evidence suggesting that warming around the British Isles has resulted in the highest sea surface temperatures ever recorded in this region. Poleward movement on rocky shores is distinctive and dependent on life history characteristics, dispersal ability and habitat requirements. Southern (warm water) species have been recorded advancing more than northern (cold water) species have been retreating. Models predicting likely species assemblage composition have been developed based on future environmental scenarios. Here qualitative and quantitative forecasts investigate the functional consequences of changes in the identity, abundance and species richness of grazing gastropods as well as foundation species (e.g. barnacles and canopy-forming algae). The authors predict that the balance of primary producers and secondary consumers may change along wave exposure gradients that match changes occurring with latitude, which will alter the export and import of primary production. Increases in grazer and sessile invertebrate diversity will potentially be accompanied by a reduction in primary production by large canopy-forming algae, which are discussed here in relation to biodiversity and ecosystem functioning.
DOI: 10.3354/meps08378
http://www.int-res.com/abstracts/meps/v396/p245-259/
KEYWORDS: climate change; intertidal; range shifts; biodiversity; ecosystem functioning; Northeast Atlantic

Hemming NG (2009). Isotopes Illuminate Chemical Change: Boron Isotope pH Proxy. Chemical Evolution II: From the Origins of Life to Modern Society. AS Series, American Chemical Society. 1025**:** 157-177.

This book chapter discusses methods relating to the indirect acquisition of climatic information that is otherwise directly unavailable. Using boron isotopes as a proxy for estimating ancient ocean pH may assist in our understanding of natural variations in atmospheric CO2 concentrations, given present knowledge on the relationship between atmosphere and surface ocean. This chapter discusses the important value of CO2 and temperature proxies for predictions of future climatic shifts.
DOI: 10.1021/bk-2009-1025.ch009
http://pubs.acs.org/doi/abs/10.1021/bk-2009-1025.ch009
KEYWORDS: boron; climate change; CO2; methodology; ocean; proxy; temperature

Hennige SJ, Smith DJ, Walsh SJ, McGinley MP, Warner ME and Suggett DJ (2010). Acclimation and adaptation of scleractinian coral communities along environmental gradients within an Indonesian reef system. Journal of Experimental Marine Biology and Ecology 391(1-2): 143-152.

Multiple sites along a gradient of light, temperature, and turbidity within the Wakatobi Marine National Park, South East Sulawesi, Indonesia, were selected to include 'optimal', intermediate and marginal sites in terms of survival threshold limits of corals. Across this gradient, coral communities ranged from diverse, mixed growth form assemblages to specialised, massive growth form dominated. Only one species of massive (Goniastrea aspera) was identified at most marginal and optimal sites, but branching species (Acropora formosa and Porites cylindrical) were only recorded at optimal sites. The Symbiodinium community changed along the gradient, from different clades on optimal (in branching and massive species) and marginal reefs (in massive species). Massive coral species exhibited variability in both respiration and photosynthesis, suggesting the inability to consider all corals equal across environments. Information on present-day marginal environments is important for understanding reef biodiversity, function, and accretion in terms of future climate change impacts.
DOI: 10.1016/j.jembe.2010.06.019
http://www.opwall.com/Library/Opwall%20library%20pdfs/Journal%20publications/hennige%20acclimation.pdf
KEYWORDS: acclimation; adaptation; environmental gradients; marginal reefs; massive corals; Symbiodinium; Great Barrier Reef; shade-adapted colonies; Pocillopora damicornis; Stylophora pistillatal; Goniastrea aspera; climate change; South Africa; ultraviolet radiation; symbiotic algae

Hobday AJ, Dowdney J, Bulman C, Sporcic M, Fuller M and Ling S (2007). Ecological Risk Assessment for the Effects of Fishing: Southern Bluefin Tuna Purse Seine Fishery. Report for the Australian Fisheries Management Authority. Canberra, CSIRO**:** 110 pp.

The ERAEF method (Ecological Risk Assessment for Effect of Fishing, developed in a research program sponsored by CMAR and AFMA) is applied to assess the ecological impacts of the Southern Bluefin Tuna Purse Seine Fishery. This method follows a hierarchical framework to assess fishing impacts on five ecological components (target species; by-product and by-catch species; threatened, endangered and protected species; habitats; and ecological communities), using four analytical steps designed to sequentially eliminate fishing hazards of lesser importance. This cost-efficient prioritization enables the implementation of appropriate management strategies targeted at high-risk components. This document contains the three first steps of the process, namely, scoping, expert judgment-based level 1 analysis and empirically-based Level 2 analysis.
http://www.environment.gov.au/coasts/fisheries/commonwealth/southern-bluefin-tuna/pubs/sbt-attachmentb-fishery-report.pdf
KEYWORDS: fisheries; Southern Bluefin tuna; risk assessment; management; strategy

Hobday AJ, Mapstone B, Connolly R, Hughes T, Marshall P, McDonald J and Waschka M (2009). Enhancing Species Adaptation to Climate Change. Marine Climate Change in Australia; Impacts and Adaptation Responses.

Climate change is one of a number of pressures impacting on the marine environment, and also includes coastal development, fishing, tourism, pollution and increase in terrestrial pollutants. Climate change will intensify the effects of these pressures, and management and governance practises will need to be adjusted to incorporate these effects. Response to climate change impacts comprises two platforms – mitigation of impact and adaptation. This report card presents some adaptation options for

the natural marine environment with focus on assisting species to being able to cope with climate change.
http://www.oceanclimatechange.org.au/content/images/uploads/Adaptation_to_climate_change.pdf
KEYWORDS: climate change; management; adaptation; mitigation

Hobday AJ, Smith ADM, Stobutzki IC, Bulman C, Daley R, Dambacher JM, Deng RA, Dowdney J, Fuller M, Furlani D, Griffiths SP, Johnson D, Kenyon R, Knuckey IA, Ling SD, Pitcher R, Sainsbury KJ, Sporcic M, Smith T, Turnbull C, Walker TI, Wayte SE, Webb H, Williams A, Wise BS and Zhou S (2011). Ecological risk assessment for the effects of fishing. Fisheries Research 108(2-3): 372-384.

The ERAEF (Ecological Risk Assessment for the Effects of Fishing) framework is a tool used to assist in the implementation of ecosystem-based fisheries management, which has been applied to 30 fisheries in Australia and elsewhere. This method follows a hierarchical framework, passing through different analytical steps designed to sequentially eliminate fishing hazards of lesser importance, while maximizing the use of available data. This cost-efficient prioritization enables the implementation of appropriate management strategies targeted on high-risk species.
DOI:10.1016/j.fishres.2011.01.013
http://www.sciencedirect.com/science/article/pii/S0165783611000324
KEYWORDS: fisheries; Australia; ecological risk assessment; management; sustainability; adaptation

Hoegh-Guldberg O (1999). Climate change, coral bleaching and the future of the world's coral reefs. Marine and Freshwater Research 50(8): 839-866.

In many tropical regions, ocean temperatures have increased by almost 1˚C in the past century, and continue to increase at 1-2˚C per century. Coral bleaching occurs when their thermal tolerance is surpassed. Elevated sea temperatures have occurred concurrently to mass coral bleaching events over the past 20 years and have resulted in significant global loss of coral. This work considers the biochemical, physiological and ecological perspectives of coral bleaching; as well as analyses outputs from three models of climate change simulating sea temperature change and how bleaching frequency and intensity will change over the next century. Results indicate that reef-building thermal tolerances are expected to be exceeded annually over the coming decades, with events as severe as the 1998 bleaching likely to become common within 20 years. Information indicates that coral adaptive capacity may already be exceeded, and that adaptation will not be able to match the rate of climate change, resulting in loss and degradation of coral reefs on a global scale.
DOI: 1323-1650/99/080839
http://www.reef.edu.au/climate/Hoegh-Guldberg%201999.pdf
KEYWORDS: global climate change; zooxanthellae; temperature; photoinhibition; coral bleaching; adaptation; acclimation

Hoegh-Guldberg O (2004). Coral reefs in a century of rapid environmental change. Symbiosis 37(1-3): 1-31.

Characteristic symbioses of coral reefs have been used to explain their structure, biodiversity and existence, with complex inter-relationships between hosts, habitats and symbionts belie combined nutrient and community dynamics that create this ‘something from nothing’ circumstance. The reverse side of these dynamics is a close dependency between species, which can result in non-linear relationships as conditions change. There is more focus on these responses in light of increasing anthropogenic influences. Both Caribbean and Indo-Pacific corals are now in severe decline which has

resulted in substantial reorganisation of how coral reefs function. Mass coral bleaching has been brought about by rapid climate change, and has increased since the 1970s; with mass bleaching events triggered by small increases in water temperature, often during ENSO events. Loss of coral has flow-on effects for other species, much of which is yet not fully known. Research must focus on understanding the extent of thermal tolerances of corals and their symbionts if bleaching and disease are linked; how coral loss will affect other species; and how coral loss will affect the people that depend on them.
http://espace.library.uq.edu.au/view/UQ:73713
KEYWORDS: symbiosis; coral reefs; dinoflagellate; climate change

Hoegh-Guldberg O and Bruno JF (2010). The Impact of Climate Change on the World's Marine Ecosystems. Science 328(5985): 1523-1528.

Understanding of how marine ecosystems are being affected by human-induced climate change is fairly limited. Recent studies have predicted ocean systems being driven towards conditions not witnessed for millions of years, with substantial risks to fundamental and irreversibly ecological transformations a potential outcome. Current climate impacts of anthropogenic origin include decreased ocean productivity, altered food web dynamics, decreases in abundance of habitat-forming species, changing distributions and greater disease occurrence. Although there is still considerable uncertainty about spatial and temporal aspects, it is clear that climate change will fundamentally alter marine systems, and will create vast challenges for societies globally, but particularly in developing countries.
DOI: 10.1126/science.1189930
http://www.sciencemag.org/content/328/5985/1523.abstract
KEYWORDS: ocean acidification; hydrogen-sulfide; southern-ocean; ice-sheet; temperature; CO2; resilience; eruptions; responses; anoxia; climate change

Hoegh-Guldberg O, Mumby PJ, Hooten AJ, Steneck RS, Greenfield P, Gomez E, Harvell CD, Sale PF, Edwards AJ, Caldeira K, Knowlton N, Eakin CM, Iglesias-Prieto R, Muthiga N, Bradbury RH, Dubi A and Hatziolos ME (2007). Coral reefs under rapid climate change and ocean acidification. Science 318(5857): 1737-1742.

By the years 2050-2100, atmospheric CO2 concentration is predicted to exceed 500 parts per million and global temperatures to rise by 2 degrees C. Predicted conditions suggest that climate change and global warming will include carbonate accretion resulting in further decline in coral reefs. This is likely to decrease diversity of reef communities and the failure to maintain carbonate reef structures. Additionally, climate change intensifies stresses from declines in water quality and exploitation of key species, which heightens the risk of functional collapse. This paper reviews future scenarios for coral reefs, predicting serious effects for fisheries, tourism, coastal protection and human, implying the need to scale-up management decisions on global emissions to reduce the loss of further coral reefs.
DOI: 10.1126/science.1152509
http://www.sciencemag.org/content/318/5857/1737.full.pdf
KEYWORDS: atmospheric co2; glacial cycles; marine; dynamics; ecology; disturbances; recruitment; thresholds; resilience; intensity; climate change; ocean acidification; coral reefs

Hofman GE, Barry JP, Edmunds PJ, Gates RD, Hutchins DA, Klinger T and Sewell MA (2011). The effect of ocean acidification on calcifying organisms in marine ecosystems: an organism-to-ecosystem perspective. . Annual Review of Ecology, Evolution, and Systematics 41: 127-147.

This review addresses the impacts of anthropogenic-driven ocean acidification on marine organisms spanning diverse marine ecosystems across the globe. The authors focus on reviewing literature concerned with the implications of ocean acidification on marine taxonomic groups that precipitate calcium carbonate from the ocean (i.e. calcification). The authors highlight that research needs to be expanded on the impacts of ocean acidification on fertilization, early life-history stages and interactions with synergistic stressors, in order to grasp the long-term implications of ocean acidification.
DOI: 10.1146/annurev.ecolsys.110308.120227
http://www.annualreviews.org/doi/pdf/10.1146/annurev.ecolsys.110308.120227
KEYWORDS: acclimation; adaptation; calcification; climate change; CO2; diversity; marine ecosystem; ocean acidification; review; stressors

Holling CS (1973). Resilience and Stability of Ecological Systems. Annual Review of Ecology and Systematics 4: 1-23.

This paper deals with the theory of resilience and stability of ecological systems, providing some real-life examples to illustrate and a synthesis of findings. This work explores theoretical and empirical ecology in terms of traditional analysis pathways and shows the tendency to emphasize the importance of quantitative rather than qualitative analysis. The author surmises that traditional views of natural systems may therefore be less a meaningful reality than a perceptual convenience. This paper further explores resilience and stability as well as the interplay between the two, and discusses how this may manifest in ecological systems.
http://www.jstor.org/stable/2096802
KEYWORDS: resilience; stability

Hollowed AB, Barange M, Ito S, Kim S, Loeng H and Peck MA (2011). Effects of climate change on fish and fisheries: forecasting impacts, assessing ecosystem responses, and evaluating management strategies Preface. Ices Journal of Marine Science 68(6): 984-985.

This document is the preface of a scientific report from the PICES/ICES/FAO international symposium held in April 2010 in Sendai, Japan. This report covers a wide range of scientific, social and economic themes, and constitutes an assessment of the current knowledge of the impacts of climate change on fisheries.
DOI:10.1093/icesjms/fsr085
http://icesjms.oxfordjournals.org/content/68/6/984
KEYWORDS: fisheries; climate change; ecosystem response; management strategies

Hughes TP, Baird AH, Bellwood DR, Card M, Connolly SR, Folke C, Grosberg R, Hoegh-Guldberg O, Jackson JBC, Kleypas J, Lough JM, Marshall P, Nystrom M, Palumbi SR, Pandolfi JM, Rosen B and Roughgarden J (2003). Climate change, human impacts, and the resilience of coral reefs. Science 301(5635): 929-933.

Coral reefs are in a state of serious decline at the global scale due to increasing human disturbance on these ecosystems. The increase in carbon dioxide and temperature predicted for the next 50 years will by far surpass the conditions in which coral reefs have flourished in the past half-million years. This paper reviews the current knowledge of status of current reefs, including human threats now and in the future, giving rise to new directions for research which will support effective management of these resources. It is expected that reefs will change rather than disappear, with species

already exhibiting greater tolerance to climate change and bleaching. Reef resilience strategies need to be developed and implemented along with policy decisions aimed at reducing the rate of global warming.
DOI: 10.1126/science.1085046
http://www.sciencemag.org/content/301/5635/929.abstract
KEYWORDS: Great Barrier Reef; marine reserves; biodiversity; ecosystems; evolution; future; perspectives; disturbance; mortality; diversity; coral reefs; climate change; policy; CO2

Hughes TP, Bellwood DR, Folke C, Steneck RS and Wilson J (2005). New paradigms for supporting the resilience of marine ecosystems. Trends in Ecology & Evolution 20(7): 380-386.

Declines in marine environments are primarily a result of human impacts including over-harvesting, pollution and the direct and impacts effects of climate change. In light of this, resource managers and researcher are placing more importance on trying to understand and moderate the impact of humans on the marine environment. Communication barriers that have always existed between marine ecologists, fisheries biologists, social scientists and economists are starting to be resolved in light of increasing awareness that humans are having on marine ecosystems, an increased focus on spatial and temporal scales and assessment and importance of the role that diversity plays in the sustainability of ecosystem goods and services. This paper draws attention to the emergence of a complex systems approach for sustaining and rebuilding marine ecosystems by linking ecological resilience to government, economics and society.
DOI: 10.1016/j.tree.2005.03.022
http://www.cell.com/trends/ecology-evolution/abstract/S0169-5347(05)00084-4
KEYWORDS: kelp forest ecosystems; regime shifts; coral reefs; North-Atlantic; fishery management; climate change; Pacific Ocean; human impacts; biodiversity; conservation; resilience ;diversity

Hughes TP, Graham NAJ, Jackson JBC, Mumby PJ and Steneck RS (2010). Rising to the challenge of sustaining coral reef resilience. Trends in Ecology & Evolution 11: 633-42.

Coral reefs are important economic, social and environmental assets and are in serious decline worldwide. Phase-shifts between species assemblages have become more frequent in reefs and other systems as a result of increasing human impacts. Science, monitoring and assessments of coral reefs have primarily focussed on providing detailed descriptions of reef decline, yet continue to neglect the underlying processes causing degradation. A more effective pathway is to harness new theoretical insights and empirical information on why some reefs degrade yet others do not. Information which allows avoidance of undesirable phase shifts and the ability to reverse them if they do occur is integral and important in directing scientific approach, governance structures and reef management.
DOI: 10.1016/j.tree.2010.07.011
http://www.ncbi.nlm.nih.gov/pubmed/20800316
KEYWORDS: phase shift; coral reefs; human impacts; coral decline; management

Hughes TP, Rodrigues MJ, Bellwood DR, Ceccarelli D, Hoegh-Guldberg O, McCook L, Moltschaniwskyj N, Pratchett MS, Steneck RS and Willis B (2007). Phase shifts, herbivory, and the resilience of coral reefs to climate change. Current Biology 17(4): 360-365.

A number of coral reefs have undergone phase sifts to less desirable states due to a combination of human-induced disturbances, including overfishing, decreasing water quality and direct and indirect climate change impacts. This study manipulated the density of large herbivorous fishes on

the Great Barrier Reef (GBR) to examine their influence on the resilience of coral reef assemblages following large scale coral-bleaching that occurred in 1998 (the largest coral-bleaching event on record). The experiment was conducted in a no-take marine reserve where coral abundance and diversity had been significantly reduced by the coral bleaching event. In control areas with abundant fishes, algal abundance remained low, but coral cover almost doubles during a 3 year period, mostly because of recruitment of species that had been locally extinct. Contrastingly, exclusion of large herbivores caused a significant increase in macroalgae, which suppressed coral fecundity, recruitment and survival. These data highlight the management of fish stocks in preventing ecosystem phase shifts and managing reef resilience. Local stewardship of fishing effort is an achievable goal for reef conservation which may also provide some insurance against large-scale disturbances which are impractical to manage.
DOI: 10.1016/j.cub.2006.12.049
http://www.adelaide.edu.au/efn/publications/Hughes%20et%20al.%20Curr%20Biol%202007.pdf
KEYWORDS: ecosystems; recovery; decline; climate change; phase shift; Great Barrier Reef; resilience; fishing communities

Jennings S and Brander K (2010). Predicting the effects of climate change on marine communities and the consequences for fisheries. Journal of Marine Systems 79(3-4): 418-426.

A modelling approach is used to predict the effects of climate change on the structure and function of marine communities. This model focuses on the size-structure of communities and does not require information about the dynamics of the component populations. According to the authors, size-structure may be predicted by combining metabolic scaling, predator-prey interactions and energy transfer in food webs, to predictions of primary production. This approach has weaknesses (since taxas are not explicitly represented, the model does not discriminate fishable from non-fishable species) but provides valid 'null' outputs used as baseline results for model comparisons and evaluations.
DOI:10.1016/j.jmarsys.2008.12.016
http://www.sciencedirect.com/science/article/pii/S0924796309000955
KEYWORDS: fisheries; climate change; marine communities; metabolism; size; primary production

Ji RB, Edwards M, Mackas DL, Runge JA and Thomas AC (2010). Marine plankton phenology and life history in a changing climate: current research and future directions. Journal of Plankton Research 32(10): 1355-1368.

In situ and satellite data from biological time series data has revealed significant phonological variability in marine phytoplankton. The impact which climate change has on the range of this variability is important, and this paper summarises recent work on phytoplankton and zooplankton phenology. This work then suggests 4 ways in which to better direct phytoplankton phenology shifts: examination of the primary mode of predicted future changes (e.g. fixed vs. evolutionary adaptation of timing); broader understanding of phenology at species and community levels; including advancing statistical metrics for indexing timing and trophic synchrony; and improved deliberation of spatio-temporal scales and the Lagrangian nature of plankton assemblages in being able to separate temporal and spatial changes.
DOI: 10.1093/plankt/fbq062
http://plankt.oxfordjournals.org/content/early/2010/06/06/plankt.fbq062.abstract
KEYWORDS: plankton; phenology; life history; climate change; North-Atlantic ocean; spring phytoplankton bloom; krill; Euphausia superba; Calanus finmarchicus; Antarctic krill; interannual variations; population biology; Pseudocalanus sp

Johnson JE and Welch DJ (2010). Marine Fisheries Management in a Changing Climate: A Review of Vulnerability and Future Options. Reviews in Fisheries Science 18(1): 106-124.

Coastal and oceanic fish are a rich source of essential fatty acids, vitamins and minerals, and capture fisheries supply this source of protein at a global scale. Fisheries also support economies and social structures in many nations, but are under serious decline, with increasing threat coming from the effects of climate change. Climate change will exert a number of pressures on fisheries, including increasing sea surface temperatures, ocean acidification, sea level rise, increasing storm intensity, altered ocean circulation and rainfall patterns. These impacts will affect target fisheries species through a range of direct and indirect mechanisms. Fish stock sensitivity will determine impact on life cycle, distribution, community structure, productivity, connectivity, performance, recruitment, invasive species and the access to marine resources by fishers. Many fisheries are currently already experiencing a number of these changes. This paper assesses the vulnerability of marine fisheries to climate change using a vulnerability framework which includes examination of factors that will influence vulnerability (e.g. adaptive capacity). This information is essential for being able to provide direction to research and to be able to effectively review current fisheries management and develop management aimed at securing future sustainability.

DOI: 10.1080/10641260903434557
http://www.informaworld.com/smpp/content~content=a918752429~db=all~jumptype=rss
KEYWORDS: vulnerability; adaptation; climate change; marine ecosystems; fisheries; Great Barrier Reef; coral-reefs; Northeast Atlantic; trophic cascades; population-dynamics; ocean acidification; larval dispersal; community

Jones GP, McCormick MI, Srinivasan M and Eagle JV (2004). Coral decline threatens fish biodiversity in marine reserves. Proceedings of the National Academy of Sciences of the United States of America 101(21): 8251-8253.

Marine reserves can protect fish from exploitation, but do they protect fish biodiversity in degrading environments? This paper suggests that a devastating decline in coral cover caused a parallel decline in fish biodiversity, both in marine reserves and in areas open to fishing. Over 75% of reef fish species declined in abundance, and 50% declined to less than half of their original numbers. In conclusion, fish biodiversity may be threatened wherever permanent reef degradation occurs and warn that marine reserves will not always be sufficient to ensure their survival.

DOI: 10.1073/pnas.0401277101
http://www.pnas.org/content/101/21/8251.abstract
KEYWORDS: Great Barrier Reef; protected areas; conservation; degradation; communities; recruitment; coral decline

Jones RJ (2008). Coral bleaching, bleaching-induced mortality, and the adaptive significance of the bleaching response. Marine Biology 154(1): 65-80.

Although coral bleaching events are often linked with coral mortality, it is not fully understood when this occurs in the timeline of individual bleaching events. Knowing the chronology of bleaching mortality occurs is central for understanding molecular mechanisms and adaptive significance of the response; known as the Adaptive Bleaching Hypothesis. In a study of coral bleaching on the Great Barrier Reef, data show that bleaching of three species (Acropora latistella, A. subulata and Turbinaria mesenterina) was an acute and rapid response which occurred within days of a peak temperature event which exceeded previously known thresholds. Full and partial bleaching was observed in the Acropora spp. whilst the T. mesenterina colonies typically paled changing to a light brown colour. Algal densities in

bleached corals were 10-30% of normally pigmented corals and for this, bleaching was clearly a sudden, isolated, stress event (i.e. not an extreme low-point in the seasonal fluctuation of symbiotic algae density). Bleached corals were associated with increased levels of partial and whole-colony mortality, but mortality was limited to only the two Acropora spp. Significantly, most mortality was recorded 1 - 2 weeks after bleaching was first observed, and for A. latistella as little as 1 week after bleaching was first noted, suggesting that for this species and event, bleaching and mortality were directly linked – implying a pathological phenomenon at work. This work highlights a problem in the adaptive bleaching hypothesis, where mortality can occur in a bleaching event before any chance for successive recombination of the host-symbiont unit. In order to further evaluate the significance of bleaching as a potentially adaptive mechanism, bleaching-induced and -related mortality need to be fully understood.
DOI: 10.1007/s00227-007-0900-0
http://www.springerlink.com/content/9j48141j525193g8/
KEYWORDS: coral bleaching; climate change; adaptation; Adaptive Bleaching Hypothesis; Great Barrier Reef; seasonal fluctuations; Scleractinian corals; thermal tolerance; water temperature; French Polynesia

Jones RN (2001). An environmental risk assessment/management framework for climate change impact assessments. Natural Hazards 23(2-3): 197-230.

This work evaluates an environmental risk assessment/management framework which assesses climate change impacts on individual exposure units that have been identified as vulnerable. The framework is intended to manage systematic uncertainties which accompany the proliferation of climate change scenarios through biophysical and socio-economic climate impacts. Risk analysis methods which comply with the IPCC are set within a larger framework. This involves stakeholders in the identification, assessment as well as the implementation of adaptation measures. Extensive involvement of stakeholders and scientifically-based risk analysis occurs within a flexible structure broadly set within social decision-making. Risk analysis links important climatic variables (projected ranges of climate change) with impact thresholds (as identified by researchers and stakeholders). This step is followed by assessment of the conditional probabilities of exceeding these thresholds. The window of adaptation is defined as the time between the identification of acceptable risk level and its exceedance (of a critical threshold). Risk is treated by adapting to anticipated changes and the mitigation of climate change, both acting to reduce the likelihood of critical thresholds being exceeded. This framework is then discussed in terms of its ability to address the requirements of the United Nations Framework Convention for Climate Change.
DOI: 10.1023/A:1011148019213
http://www.springerlink.com/content/k778787311482411/fulltext.pdf
KEYWORDS: climate impacts; risk assessment; climate change; risk management; integrated assessment; water-resources; uncertainty; indicators

Kalikoski DC and Allison EH (2010). Learning and Adaptation: The Role of Fisheries Comanagement in Building Resilient Social–Ecological Systems. Adaptive Capacity and Environmental Governance, Springer Series on Environmental Management. D Armitage and R Plummer, Springer**:** 69-88.

The focus of this work is to examine how robust self-organisations can be formed in fisheries co-management systems, which have been increasingly advocated as a solution for small-scale fisheries crisis. A number of government, NGO, international and donor organisations have been catalysing projects for implementing comanagement of fisheries. Support of comanagement recognises that sustainable and resilient fisheries management is not possible without the combined support of fishers

and government. However, if comanagement becomes too conventional, it risks being viewed as straightforward and states may then desolve rights and responsibilities of resource conservation and livelihood improvement. The hazard here is the proliferation of widespread ill-conceived comanagement systems which do not account for core values, fail and are then faced with backlashes regarding participatory approaches to management.
DOI: DOI 10.1007/978-3-642-12194-4_4
KEYWORDS: fisheries; co-management; resilience; management; conservation; social-ecological

Kelly RP, Foley MM, Fisher WS, Feely RA, Halpern BS, Waldbusser GG and Caldwell MR (2011). Mitigating Local Causes of Ocean Acidification with Existing Laws. Science 332(6033): 1036-1037.

Ocean acidification is occurring on a global scale as a result of increasing levels of an atmospheric stressor, atmospheric CO2, which is correlated with increasing CO2 concentrations in the ocean. Ocean acidification can also occur at more localized scales and these areas are often referred to as acidification 'hot spots'. These can be caused by a range of non-atmospheric stressors including non-uniform changes in circulation and biological processes, precipitation runoff, and/or a range of anthropogenic influences such as pollutants, soil erosion and freshwater inputs. These impacts can be magnified in the presence of other environmental stressors including temperature increases, overfishing and habitat modification. This article outlines policy options which could be implemented at the local and state government level, as opposed to federal and international levels, in order to reduce local and regional 'hot spot' ocean acidification areas. Policy recommendations are based on US policies currently implemented and include the control of emissions, runoff and land-use patterns (through zoning and permitting).
DOI: 10.1126/science.1203815
http://www.sciencemag.org/content/332/6033/1036.summary
KEYWORDS: acidification hot spots; climate change; CO2; conservation; ocean acidification; global; policy; pH; regional; stressor

King JR and McFarlane GA (2006). A framework for incorporating climate regime shifts into the management of marine resources. Fisheries Management and Ecology 13(2): 93-102.

This work discusses the ability to use an ecosystem-based management approach to include knowledge of climate regime influences on ecosystem productivity to be able to manage fishery resources. This requires the development of a rational framework that can be constructed using current stock assessment and management activities: ecosystem assessment, risk analyses, adaptive management and reference points. This work forms such a framework and uses two Population Simulations to demonstrate the benefits and tradeoffs of variable regime-specific harvest rates. The framework assumes that detection can occur soon after a regime shift has happened, which means that decisions do not need to be parallel to regime shifts, but can be deferred by an appropriate period of time that is related to a species' life history, i.e. age of maturity or recruitment. Fisheries scientists should deliver harvest recommendations which reflect an array of risk levels to the stock under different productivity assumptions. Coupling ecosystem assessment with ecosystem-based management will permit managers to choose appropriate regime-specific harvest rates.
DOI: 10.1111/j.1365-2400.2006.00480.x
http://onlinelibrary.wiley.com/doi/10.1111/j.1365-2400.2006.00480.x/abstract
KEYWORDS: ecosystem assessment; ecosystem-based management; regime shifts; adaptive management

Kirby RR, Beaugrand G and Lindley JA (2009). Synergistic Effects of Climate and Fishing in a Marine Ecosystem. Ecosystems 12(4): 548-561.

This paper reports that climate change and overfishing are likely to be responsible for a rapid restructuring of a highly productive marine ecosystem. Analysis of a long-term, spatially extensive biological (plankton and cod) and physical (sea surface temperature) dataset suggests that synchronous changes in cod numbers and sea temperature have established an extensive trophic cascade favouring lower trophic level groups over economic fisheries. This modified North Sea ecology may provide a clear indication of the synergistic consequences of coincident climate change and overfishing. The extent of the ecosystem restructuring that has occurred in the North Sea suggests that it is unlikely to reverse current climate and human-induced effects through ecosystem resource management in the short term. This implies that fisheries management policies will have to be fully integrated with the ecological consequences of climate change to prevent a similar collapse in an exploited marine ecosystem elsewhere.

DOI: 10.1007/s10021-009-9241-9
http://www.springerlink.com/content/k728373270681u57/
KEYWORDS: climate change; cod; fisheries management; plankton; temperature; trophic cascade; overfishing

Klein CJ, Ban NC, Halpern BS, Beger M, Game ET, Grantham H, Green A, Klein T, Kininmonth S, Treml E, Wilson K and Possingham HP (2010). Prioritizing Land and Sea Conservation Investments to Protect Coral Reefs. . PLoS ONE 5(8): e12431.

Conservation efforts to protect and preserve marine coral reef ecosystems have been effective in some instances, and have been shown to increase the resilience of coral reefs to atmospheric stressors including warming water and ocean acidification. As conservation efforts and resources are often limited at both regional and global scales, there is a need to efficiently prioritize conservation-based efforts in order to sustain coral reef ecosystems. This article addresses the issue by developing the first explicit method for priority-based conservation actions and locations, and looks at cost-effectively reducing the impacts of both land- and sea-derived threats to coral reef ecosystems. The authors apply their methodologies to the Coral Triangle, a high conservation priority area.

DOI:10.1371/journal.pone.0012431
http://cmap.msi.ucsb.edu/publications/klein_etal_2010_plosone
KEYWORDS: climate change; conservation; coral reefs; Coral Triangle; ecosystem; global warming; management; marine conservation priorities; ocean acidification

Knowlton N (2001). The future of coral reefs. Proceedings of the National Academy of Sciences of the United States of America 98(10): 5419-5425.

Anthropogenic influences have profoundly changes coral reef ecosystems, with flow-on effects expected to continue for the foreseeable future. Although reefs are exposed to many of the processes that also impact other ecosystems, they hold distinct features that warrant mention. These include that many dominant reef-building corals spawn into the water column as are thus vulnerable to Allee effects including potential extinction linked with chronic reproductive failure; those more resistant to habitat degradation are the smaller, shorter-lived ones with limited larval dispersal; small increases in ocean temperature can cause changes in coral symbiont communities as well as coral death; that human activities increase near reefs (e.g. fishing and nutrient input), favouring rapid growing competitors and explosions if predator populations; combinations of stress appear to be linked with threshold responses;

and the fossil record suggests corals are more likely to suffer extinctions than some of the groups that acquaint with them.
DOI: 10.1073/pnas.091092998
http://www.pnas.org/content/98/10/5419.full
KEYWORDS: coral reefs; climate change; coral bleaching; resistance; phase-shifts; evolutionary history; environmental change

Knowlton N and Jackson JBC (2008). Shifting baselines, local impacts, and global change on coral reefs. Plos Biology 6(2): 215-220.

This work highlights the need for baseline data in understanding how a system functioned prior to disturbance – which is essential if management is focussed on introducing strategies that attempt to return it to its natural state. This work outlines the major questions for local management of coral reefs in the face of climate change. These include identifying the extent that overfishing and eutrophication increase coral reef vulnerability to bleaching, disease, and acidification; determining the physiological or ecological mechanisms if local protection decreases coral their vulnerability to climate change; assessing whether protection from overfishing and eutrophication increases coral recruitment rate, growth and reproduction, which are crucial to recovery following disturbance; and identifying thresholds in abundance and composition of marine consumers below which corals will decline or fail to recover from.
DOI: 10.1371/journal.pbio.0060054
http://www.plosbiology.org/article/info:doi/10.1371/journal.pbio.0060054
KEYWORDS: Marine Protected Areas; multiple stable states; climate change; trophic; cascades; phase-shifts; ecosystems; management; conservation; biodiversity; resilience

Kordzadze AA and Demetrashvili DI (2011). About coupled regional modelling system: The Black Sea-atmosphere. Journal of Environmental Protection and Ecology 12(1): 317-326.

Globally, the past decade has seen an adaptation of human activity to significantly modified climatic conditions. While there is a general consensus within the scientific community that the earth is experiencing rising global temperatures, there remain localized and regional areas which appear to be cooling. This article focuses on one such region, the Black Sea, which plays an important role in the formation of regional weather and climatic conditions. The authors present methodology for the development of a regional modelling system and apply this to the Black Sea atmosphere, with the aim of providing more detailed and accurate predictions for climatic conditions in the region.
KEYWORDS: atmosphere; climate change; coupled model; Black Sea atmosphere; global warming; hydro-thermodynamic equations; model; numerical solutions

Kroeker KJ, Kordas RL, Crim RN and Singh GG (2010). Meta-analysis reveals negative yet variable effects of ocean acidification on marine organisms. Ecology Letters 13(11): 1419-1434.

Ocean acidification, resulting from rising atmospheric CO2 concentrations which alter seawater carbonate chemistry and pH levels, is expected to increase with increasing CO2 emissions. Marine organisms are often sensitive to changes in carbonate chemistry, while their responses can vary broadly for a variety of reasons. This article discusses the results from a meta-analysis that the authors have run on the biological responses of a range of taxa to ocean acidification. Findings suggest that generally, calcifying organisms experienced larger negative responses than non-calcifying organisms, and there was taxonomically-derived variation in the sensitivities of different developmental stages to ocean

acidification. [But see Technical Comment by Andersson and Mackenzie (2011) for further interpretation of these findings.]
DOI: 10.1111/j.1461-0248.2010.01518.x
http://onlinelibrary.wiley.com/doi/10.1111/j.1461-0248.2010.01518.x/pdf
KEYWORDS: adaptation; calcification; climate change; CO2; ecosystem responses; growth; meta-analysis; ocean acidification; pH; photosynthesis; reproduction

Lane MB and Robinson CJ (2009). Institutional complexity and environmental management: the challenge of integration and the promise of large-scale collaboration. Australasian Journal of Environmental Management 16(1): 16-24.

Recent collaborative efforts addressing water quality issues in Queensland's Great Barrier Reef region are discussed to better understand the challenges inherent to integration procedures. The evaluation of the current efforts indicates the value of 'scaling-up' collaborations in integration procedures, and the importance of a clearly defined management context in the establishment of such collaborative partnerships.
http://search.informit.com.au/documentSummary;dn=708568352029860;res=IELHSS
KEYWORDS: climate change; environmental management; integration; collaboration; mitigation; adaptation

Last PR, White WT, Gledhill DC, Hobday AJ, Brown R, Edgar GJ and Pecl G (2011). Long-term shifts in abundance and distribution of a temperate fish fauna: a response to climate change and fishing practices. Global Ecology and Biogeography 20: 58-72.

South-eastern Australia is a well-known climate change hotspot, but the impact on temporal on and temporal responses of the biota in relation to change are not as well understood – but appear to involve both climate and non-climate influences as well as human impacts. This work examines major temporal and distributional shifts that have occurred in fish fauna, with cautious attribution of potential causal factors.
DOI: 10.1111/j.1466-8238.2010.00575.x
http://onlinelibrary.wiley.com/doi/10.1111/j.1466-8238.2010.00575.x/pdf
KEYWORDS: Climate change; fishing; south-eastern Australia; spatial shift; Tasmania; temperate fishes; temporal shift

Lavitra T, Fohy N, Gestin P-G, Rasolofonirina R and Eeckhaut I (2010). Effect of water temperature on the survival and growth of endobenthic Holothuria scabra (Echinodermata: Holothuroidea) juveniles reared in outdoor ponds. SPC Beche-de-mer Information Bulletin. I Eeckhaut. Mons, Belgium**:** 25-28.

The growth and survival of Holoturia scabra juveniles were measured in two pond configurations: with and without a greenhouse system (plastic sheath stretched on a frame) placed over the pond during the winter season. While mortality remained unchanged, growth was significantly higher in the 'heated' ponds (0.254 vs 0.095 g/d). The authors recommend the use of such greenhouse system in Holoturia mariculture during winter, in addition to a shading system during summer (the benefits of which are demonstrated in a previous study).
http://www.spc.int/DigitalLibrary/Doc/FAME/InfoBull/BDM/30/BDM30_25_Lavitra.pdf
KEYWORDS: Aquaculture; Holoturia; temperature; growth; survival; yield; adaptation

Lawler JJ (2009). Climate Change Adaptation Strategies for Resource Management and Conservation Planning. Annals of the New York Academy of Sciences 1162: 79-98.

Climate change has altered ecosystems globally, with links to changes in physiology, phenology, species distributions, interspecific interactions and disturbance regimes. Predicted changes with are for more dramatic shifts, which presents challenges to resource management and conservation planning. New approaches must be implemented to account for this uncertainty, and this paper reviews a number of adaptation management strategies. Most approaches are based on general principles, and others specify tools that managers may already have in place. New strategies are adopting more agile management perspectives, which are needed to act on the changes that are occurring over a range of spatial and temporal scales. Focus will need to be placed on potential future ecosystem services and active adaptive management that is based on future impact scenarios will need to become commonplace management strategies. Triage may also need to become a management option. A better understanding of species that are likely to be most affected by climate change is still required, including avenues for preserving and enhancing the evolutionary capacity of species and how to implement adaptive management in new systems. Particularly important is identifying situations and systems where adaption strategies have worked and how they can be further applied.
DOI: 10.1111/j.1749-6632.2009.04147.x
http://onlinelibrary.wiley.com/doi/10.1111/j.1749-6632.2009.04147.x/pdf
KEYWORDS: adaptation; adaptive management; climate change; conservation planning; management; scenario planning; range shifts; habitat fragmentation; adaptive management

Lehodey P and Maury O (2010). CLimate Impacts on Oceanic TOp Predators (CLIOTOP): Introduction to the Special Issue of the CLIOTOP International Symposium, La Paz, Mexico, 3-7 December 2007 Preface. Progress In Oceanography 86(1-2): 1-7.

This document is the introduction to the special issue from the international workshop 'CLimate Impacts on Oceanic TOp Predators' held in December 2007 in La Paz, Mexico. After a brief history of CLIOTOP meetings, the different themes addressed in the special issue are summarized. The first section discusses research on early life history of top predators such as billfish and tuna, with the effect of mesoscale processes, temperature and transports investigated for different species and systems. The second section sheds light on the physiology, behavior and distribution of top predators through tagging and laboratory experiments. The third section reviews trophic pathways and prey-predator relationships, using stomach content analysis, stable isotope analysis or modelling experiments. The fourth section focuses on management strategies and their socio-economic implications, and is followed by a section on the importance of mesoscale oceanic processes. The final section addresses several aspects of the effects of climate change and variability on top predators.
DOI:10.1016/j.pocean.2010.05.001
http://www.sciencedirect.com/science/article/pii/S0079661110000832
KEYWORDS: climate change; top predators; tuna; early life history; physiology; behavior; distribution; trophic pathways; prey-predator; management strategies; mesoscale processes; climate variability

Leslie HM, Schluter M, Cudney-Bueno R and Levin SA (2009). Modeling responses of coupled social-ecological systems of the Gulf of California to anthropogenic and natural perturbations. Ecological Research 24(3): 505-519.

This paper investigates the impacts of multiple economic sectors on the marine ecosystem and dependent human community in the Gulf of California with an ecological-economic model. It focuses

on the spotted rose snapper, an economically important species targeted concurrently by the nearshore artisanal fleet, the sportfishing fleet, and by the industrial shrimp fleet as bycatch. The results suggest that vital components of coupled systems may well respond differently to climate variability or other perturbations, and that management strategies should be developed with this in mind.
DOI: 10.1007/s11284-009-0603-8
http://www.springerlink.com/content/43v7888543026127/
KEYWORDS: trade-offs; marine ecosystem services; social-ecological system; ecosystem-base; management; modelling; ecological-economics; fisheries

Levin PS, Fogarty MJ, Murawski SA and Fluharty D (2009). Integrated Ecosystem Assessments: Developing the Scientific Basis for Ecosystem-Based Management of the Ocean. PLoS Biol 7(1): e1000014.

Ecosystem-based management aims to devise management strategies that deal with entire ecosystems rather than the individual components that ecosystems are comprised of, and take into account interactions among ecosystem components and management sectors, the impacts of ocean-use sectors and also considers humans as part of the ecosystem. The authors identify that the implementation of ecosystem-based management remains a significant hurdle in marine ecosystems, and propose integrated ecosystem assessments (IEAs) as a framework to assist ecosystem-based management decisions across multiple scales and sectors.
DOI: 10.1371/journal.pbio.1000014
http://www.plosbiology.org/article/info:doi/10.1371/journal.pbio.1000014
KEYWORDS: adaptation; ecosystem-based management; human impact; integrated ecosystem assessments; management; marine; services

Levin SA and Lubchenco J (2008). Resilience, robustness, and marine ecosystem-based management. Bioscience 58(1): 27-32.

Anthropogenic exploitation of marine resources threatens the robustness and resilience of marine ecosystems, despite the reliance of humans on these systems for important services. Marine ecosystems are complex adaptive systems. They are composed of individual agents interacting with others and integrating a range of scales from individual behaviours to whole system dynamics. Even small changes within these systems can magnify through non-linear interactions and result in regime shifts and ecosystem collapse. The balance among heterogeneity, modularity, and redundancy, tightening feedback loops is needed to maintain the adaptive capacity of the system and also to provide incentives for stewardship. Management is challenged with increasing incentives to individuals and tightening reward loops in ways that will increase the resilience of these systems for the future.
DOI: 10.1641/B580107
http://caliber.ucpress.net/doi/pdf/10.1641/B580107
KEYWORDS: complex adaptive systems; scale; resilience; robustness; ecosystem; management; food webs; biodiversity; sustainability; services

Ling SD, Johnson CR, Frusher SD and Ridgway KR (2009). Overfishing reduces resilience of kelp beds to climate-driven catastrophic phase shift. Proceedings of the National Academy of Sciences of the United States of America 106(52): 22341-22345.

Climate change and overfishing are two of the greatest impacts affecting marine ecosystems. Coastal waters are warming in eastern Tasmania at four times the average global ocean warming rate,

driving the range-extension of the ecologically-important long-spined sea urchin (Centrostephanus rodgersii). This sea urchin has commenced catastrophic overgrazing of kelp beds in Tasmania, leading to significant biodiversity loss and loss of rocky reef ecosystem services. Coincident with this overgrazing is increased fishing of its predators, including the spiny lobster (Jasus edwardsii). Experimental manipulation within and outside Marine Protected Areas demonstrate that removal of large predators has reduced ecosystem resilience against the climate-driven expansion of the sea urchin; increasing the risk of catastrophic shift to urchin barrens. This demonstrates that interaction between multiple anthropogenic stressors can intensify nonlinear responses to climate change, limiting their adaptive capacities. This work emphasizes the need for management to focus on reducing the risk of catastrophic phase shifts.
DOI: 10.1073/pnas.0907529106
http://www.pnas.org/content/early/2009/12/11/0907529106.abstract
KEYWORDS: climate change; overgrazing; sea urchin; temperate reefs; trophic interactions;; Centrostephanus rodgersii; shallow subtidal reefs; range; biodiversity; survival; density

Ling SD, Johnson CR, Ridgway K, Hobday AJ and Haddon M (2009). Climate-driven range extension of a sea urchin: inferring future trends by analysis of recent population dynamics. Global Change Biology 15(3): 719-731.

The climate-driven geographical extension of the sea urchin C. rodgersii is investigated by combining abundance observations with a growth model designed to estimate the age of individuals. A strong pattern of decreasing age with increasing latitude on the eastern coast of Tasmania confirms the suggested poleward shift of sea urchin related to the Eastern Australian Current (EAC). The predicted intensification of the EAC is expected to result in an increased poleward expansion of this species of sea urchin in the future, with severe repercussions for benthic communities.
DOI:10.1111/j.1365-2486.2008.01734.x
http://onlinelibrary.wiley.com/doi/10.1111/j.1365-2486.2008.01734.x/abstract
KEYWORDS: climate change; east australian current; larval growth; larval dispersal; thermal tolerance; benthic communities

Lo-Yat A, Simpson SD, Meekan M, Lecchini D, Martinez E and Galzin R (2011). Extreme climatic events reduce ocean productivity and larval supply in a tropical reef ecosystem. Global Change Biology 17(4): 1695-1702.

Trends in remote sensing data of sea surface temperature (SST) anomalies, surface current flows and chlorophyll-a concentrations were compared to observed patterns of larval fish supply in the Rangiroa Atoll (French Polynesia) from 1996 to 2000. This period was characterized by an intense El Niño event (+3.5°C SST anomaly, decreased surface current towards the reef, low chlorophyll concentrations and -51% in larval supply) between two periods of La Niña conditions (-2.0°C SST anomaly, strong surface currents, +150% chlorophyll concentration and +249% larval supply). These trends are driven by the ENSO cycle and suggest a potential negative impact of global warming on reef ecosystems.
DOI: 10.1111/j.1365-2486.2010.02355.x
http://onlinelibrary.wiley.com/doi/10.1111/j.1365-2486.2010.02355.x/abstract;jsessionid=063F250CFA23110232228AD715F6DE76.d01t04
KEYWORDS: climate change; global warming; coral reef; larval fish; El Nino; ENSO

MacNeil MA, Graham NAJ, Cinner JE, Dulvy NK, Loring PA, Jennings S, Polunin NVC, Fisk AT and

McClanahan TR (2010). Transitional states in marine fisheries: adapting to predicted global change. Philosophical Transactions of the Royal Society B: Biological Sciences 365(1558): 3753-3763.

This review discusses the predicted impacts that global climatic shifts will have on the production and structure of marine fisheries. The authors discuss the fact that species distributional and community compositional shifts are already being observed in some marine ecosystems, and use case studies from the Indian Ocean, North Sea and Bering Sea to examine the direct and indirect effects that climate change is having on production and biodiversity in these systems. The authors predict that global warming will lead to habitat loss in tropical reef fisheries, thus creating yield and species losses; the dominance of warm water species in temperate fisheries; and the invasion of southern species into Arctic marine ecosystems leading to increased diversity and yield in Arctic fisheries. Society responses to such changes will depend on their capacity to adapt to a changing environment.
DOI: 10.1098/rstb.2010.0289
http://rstb.royalsocietypublishing.org/content/365/1558/3753.abstract
KEYWORDS: adaptation; climate change; community composition; distribution; fisheries; global warming; review

Marshall DJ and McQuaid CD (2011). Warming reduces metabolic rate in marine snails: adaptation to fluctuating high temperatures challenges the metabolic theory of ecology. Proceedings of the Royal Society B: Biological Sciences 278(1703): 281-288.

This article tests applications of, and controversies surrounding theoretical aspects of the metabolic theory of ecology (MTE), which proposes a universal relationship between body mass, temperature and an organisms metabolic rate. The authors examined thermal scaling of metabolic rate in a marine gastropod which inhabits a rocky-shore environment and experiences fluctuating high temperatures when emerged. The authors found that in contrast to the theoretical predictions, metabolic rate of the marine gastropod was often negatively correlated with temperature, and this relationship was driven by aspects of temperature range, degree of metabolic depression and shell dynamics. The gastropod demonstrated a reduced metabolic rate in response to increasing temperatures, which would be expected to improve the conservation of energy in a high temperature environment, a result which challenges previous theoretical predictions.
DOI: 10.1098/rspb.2010.1414
http://rspb.royalsocietypublishing.org/content/early/2010/08/03/rspb.2010.1414
KEYWORDS: adaptation; climate change; ecology; gastropod; metabolic rate; temperature; thermal scaling

Marshall DJ, McQuaid CD and Williams GA (2010). Non-climatic thermal adaptation: implications for species' responses to climate warming. Biology Letters 6(5): 669-673.

Ectothermic organisms have the ability to physiologically and behaviourally adapt to biotic and abiotic factors, such that they may be able to buffer the effects of increasing global temperatures. This article highlights the need for increased research efforts into the adaptive ability of marine ectothermic organisms to heat sources, including non-climatic (solar, geothermal) and climatic (air or sea surface temperature) varieties, in order to tease apart the effects of climatically relevant and non-climate heat sources. The authors demonstrate that a marine intertidal snail showed thermal resistance adaptation to solar heating, and conclude that non-climatic thermal adaptation is likely to occur widely across ectothermic organisms which may enable species to tolerate climatic rises in air temperature.
DOI: 10.1098/rsbl.2010.0233
http://rsbl.royalsocietypublishing.org/content/6/5/669.short

KEYWORDS: adaptation; climate change; ectotherm; gastropod; radiation; response; sea surface temperature; solar heat; thermal adaptation; temperature

Maynard JA, Marshall PA, Johnson JE and Harman S (2010). Building resilience into practical conservation: identifying local management responses to global climate change in the southern Great Barrier Reef. Coral Reefs 29(2): 381-391.

The greatest long-term threat on coral reefs is climate change, despite mitigation efforts. Focus must therefore turn to promoting the natural resilience of reefs. This work develops a framework for assessing resilience, with testing applied to target management responses to climate change on the Great Barrier Reef (GBR).This generates a resilience score for a site based on differentially weighted indicators that are either thought to, or known to, confer resilience. Once scores are summed, sites within a region are ranked in terms of relative resilience (to other sites) and extent to which resilience can be influenced by management response. This framework was applied to 31 sites in the southern region of the GBR, which has a history of known disturbance and recovery regimes. Both resilience and management influence potential varied among sites, which informs on site selection as being important for the staged implementation of reliance management. This framework informs management of operational means for resilience management, as well as being easy to teach and implement management response to climate change for local communities and stakeholders.
DOI: 10.1007/s00338-010-0603-8
http://www.springerlink.com/content/b441632345777x07/fulltext.pdf
KEYWORDS: climate change; coral reefs; environmental management; Great Barrier Reef; resilience Caribbean coral-reefs; social-ecological systems; phase shifts; connectivity; communities; diversity; mortality; herbivory

McClanahan TR, Cinner JE, Maina J, Graham NAJ, Daw TM, Stead SM, Wamukota A, Brown K, Ateweberhan M, Venus V and Polunin NVC (2008). Conservation action in a changing climate. Conservation Letters 1(2): 53-59.

Changes in temperature, weather patterns and extreme events brought on by climate change pose challenges to effective conservation of ecosystems. Addressing these challenges will require practical conservation actions that are informed by site-specific understanding of susceptibility to climate change. It will also identify the capacity of societies to cope with and adapt to climate change. Depending on the environmental susceptibility and social adaptive capacity of a location, the appropriate actions will require a mix of the following strategies: large-scale ecosystem protection, active transformation and adaption of social-ecological systems; capacity-building of communities to cope with change; and government assistance focused on distancing communities from dependence on natural resources. Analytical framework examines conservation actions in five west Indian Ocean countries – each differing in climate-driven coral disturbance and adaptive capacity. Current conservation strategies are found to not reflect adaptive capacity, indicating lack of preparedness for climate change. The authors direct vision for conservation policy which considers the ability of adaptive capacity to cope with the complexities of climate change as being better that only relying on singular emphasis on governmental; control and the formation of no-take areas.
DOI: 10.1111/j.1755-263X.2008.00008.x
http://onlinelibrary.wiley.com/doi/10.1111/j.1755-263X.2008.00008_1.x/pdf
KEYWORDS: Adaptive capacity; social-ecological systems; socioeconomic; marine; conservation; climate change; environmental susceptibility; coral reefs; bleaching; global change

McCook LJ, Almany GR, Berumen ML, Day JC, Green AL, Jones GP, Leis JM, Planes S, Russ GR, Sale PF and Thorrold SR (2009). Management under uncertainty: guide-lines for incorporating connectivity into the protection of coral reefs. Coral Reefs 28(2): 353-366.

Protecting ecological connectivity within and among reefs is critical to resilience. This article provides a set of practical guidelines that can be applied to protect connectivity. These 'rules of thumb' are based on current knowledge and expert opinion, and on the philosophy that it is better to act with incomplete knowledge than to wait for detailed understanding that may come too late. The guidelines include: (1) allow margins of error in extent and nature of protection as insurance against unforeseen or incompletely understood threats or critical processes; (2) spread risks among areas; (3) aim for networks of MPAs; (4) protect entire biological units where possible; (5) provide for connectivity at a wide range of dispersal distances; and (6) use a portfolio of approaches, including but not limited to MPAs. Three case studies illustrating the application of these principles to coral reef management are described.
DOI: 10.1007/s00338-008-0463-7
http://www.springerlink.com/content/j7584gq847263222/
KEYWORDS: ecological connectivity; reef management; margin of error; resilience; risk spreading; Great Barrier Reef

McIlgorm A, Hanna S, Knapp G, Le Floc'H P, Millerd F and Pan M (2010). How will climate change alter fishery governance[glottal stop] Insights from seven international case studies. Marine Policy 34(1): 170-177.

The impacts of climate change on marine ecosystem productivity and community structure is expected to impact heavily on marine fisheries. This article examines the implications of climate change on the governance of fisheries across multiple international fisheries in low, mid and high latitude regions including eastern Australia. The authors caution that fishery governance needs to address the uncertainty arising from climate change, and in those areas where fishery governance is less developed the fisheries will be less adaptable to the impacts of climate change.
DOI: 10.1016/j.marpol.2009.06.004
http://www.sciencedirect.com/science/article/pii/S0308597X0900092X
KEYWORDS: adaptation; climate change; fisheries; fishery governance; impacts; international; marine; Pacific Ocean

McLeod E, Salm R, Green A and Almany J (2009). Designing marine protected area networks to address the impacts of climate change. Frontiers in Ecology and the Environment 7(7): 362-370.

Design principles for Marine Protected Area (MPAs) networks which deal with social, economic and biological criteria are well studied in scientific literature. Climate change poses a significant new threat to marine systems, but few studies have focussed on designing MPAs to be resilient to this threat. This paper compiles information on MPA network design and provides specific recommendations for resilience-building into these networks. Direction is given on aspects such as size, spacing, shape, risk spreading, critical areas, connectivity and maintaining ecosystem function. It is hoped that this information will help MPA planners and managers design MPA networks that are more robust to climate change.
DOI: 10.1890/070211
http://www.esajournals.org/doi/abs/10.1890/070211
KEYWORDS: Great Barrier Reef; coral reefs; ecological criteria; propagule; dispersal; reserves;

populations; resilience; conservation; ecosystems; management; Marine Protected Areas; climate change

McLeod E and Salm RV, Eds. (2006). Managing Mangroves for Resilience to Climate Change. Gland, Switzerland, International Union for the Conservation of Nature.

This work provides some areas for consideration that are aimed at conservation practitioners as they are designing conservation strategies for mangroves. This builds upon the concept of resilience as developed by West and Salm (2003) to address coral bleaching. This work defines resilience and then reviews previous work to outline strategies in helping managers identifying reef areas that are resistant to bleaching and areas where maximum recovery following disturbance is likely, recommending these be incorporated into marine protected areas. Although this work dealt with coral reefs, the ideas are transferable to mangrove systems and sea-level rise. Despite these principles being developed specifically to address coral reefs and increases in sea temperature, similar ideas of resilience can be applied to mangroves and sea-level rise. Building resilience into mangrove conservation plans necessitates an understanding of the way in which mangroves will respond to climate changes, identifying which factors help them survive these changes, and, consequently which mangroves are most likely to then survive these changes. This work provides an overview of mangrove ecosystems, discussing the benefits to people, and identifies both the human and global threats that compromise mangrove ecosystems. This impacts of climate change on mangroves are discussed and tools and strategies that enhance mangrove resilience are further outlined.

KEYWORDS: resilience; climate change; mangrove; conservation; management; sea level rise

Melbourne-Thomas J, Johnson CR, Alino PM, Geronimo RC, Villanoy CL and Gurney GG (2011). A multi-scale biophysical model to inform regional management of coral reefs in the western Philippines and South China Sea. Environmental Modelling & Software 26(1): 66-82.

Global coral health and function is in decline as a result of anthropogenic-induced stress, with the rate of this decline set to accelerate further. Regional-scale mitigation is essential since reef systems are highly connected across regions by ocean transport of larval stages and pollutants. Models are useful tools for dealing with the inherently complex coral reef systems and can inform management for reef management. Spatially explicit biophysical models are developed for a general coral reef system, combining dynamics from local to regional scales, and integrating larval connectivity patterns that are derived from larval dispersal models. This model is validates for coral reefs in the Philippines region of the South China Sea, where the authors demonstrate the usefulness of the model as a decision support tool. This is done by presenting two regional-scale scenario projections that relate to management issues in this region: marine reserve design and fish stock recovery; and synergistic effects between bleaching and reduced water quality. This work emphasizes the importance of incorporating multiple stressors to reef health and patterns of larval connectivity in regional-scale management decisions.
DOI: 10.1016/j.envsoft.2010.03.033
http://www.sciencedirect.com/science/article/pii/S1364815210000927
KEYWORDS: corset; coral reef; regional scale; decision support; ecosystem model; management; connectivity; Philippines; South China Sea; climate change

Mertz O, Halsnaes K, Olesen JE and Rasmussen K (2009). Adaptation to Climate Change in Developing Countries. Environmental Management 43(5): 743-752.

Adaptation to climate change is given increasing international attention as the confidence in

climate change projections is getting higher. This article provides a status of climate change adaptation in developing countries. An overview of observed and projected climate change is given, and recent literature on impacts, vulnerability, and adaptation are reviewed, including the emerging focus on mainstreaming of climate change and adaptation in development plans and programs. It concludes that although many useful steps have been taken in the direction of ensuring adequate adaptation in developing countries, much work still remains to fully understand the drivers of past adaptation efforts, the need for future adaptation, and how to mainstream climate into general development policies.
DOI: 10.1007/s00267-008-9259-3
http://www.springerlink.com/content/f3162k37t61305rt/
KEYWORDS: adaptation; Africa; Asia; climate change; climate impacts; climate; projections; developing countries; development policy; Latin America; mainstreaming; small island states; vulnerability

Miller K, Charles A, Barange M, Brander K, Gallucci VF, Gasalla MA, Khan A, Munro G, Murtugudde R, Ommer RE and Perry RI (2010). Climate change, uncertainty, and resilient fisheries: Institutional responses through integrative science. Progress in Oceanography 87(1-4): 338-346.

This work explores the significance of attention on resilience and adaptive capacity goals found in the governance of uncertain fishery systems, including climate change. Climate change intermingles with fishery systems, which adds to the uncertainty that already exists in these systems. This highlights the need for robust and adaptive management approaches in order to enhance ecosystem resilience. This work focuses on placing more importance on integrative science methods and process to support institutional responses, broader planning perspectives and the development of adequate strategies that act to build resilience. Synergies between institutional change and integrative silence can enable the development of effective fisheries policy strategies. Integrative science provides an avenue for examining policy options in respect to their robustness against uncertainty (e.g. climate change regime shifts) and also allow better understanding of behavioural assessments of fish, humans and institutions. Understanding these aspects facilitates the move toward implementing integrative science for improved fishery governance. This work explores how the development of more effective fishery approaches can be facilitated by the synergies between institutional change and integrative science.
DOI: 10.1016/j.pocean.2010.09.014
http://www.sciencedirect.com/science/article/pii/S0079661110001266
KEYWORDS: climate change; resilience; fisheries; adaptive management; management

Miller KA (2000). Pacific Salmon fisheries: Climate, information and adaptation in a conflict-ridden context. Climatic Change 45(1): 37-61.

Pacific salmon are anadromous fish that cross state and international boundaries in their oceanic migrations. The rocky history of attempts by the United States and Canada to cooperatively manage their respective salmon harvests suggests that such shared resources may present difficult challenges for effective adaptation to climate change. Adaptation is difficult when a resource is exploited by multiple competing users who possess incomplete information. If, in addition, their incentives to cooperate are disrupted by the impacts of the climatic variation, dysfunctional breakdowns in management rather than efficient adaptation may ensue. Institutional factors will determine the extent to which the management of such resources can adapt effectively to climate variability or long-term climate change.
DOI: 10.1023/A:1005684815698
http://www.springerlink.com/content/q43052461317260v/
KEYWORDS: North Pacific; variability; oscillation; impacts; treaty; climate change; management;

adaptation

Moore SE and Huntington HP (2008). Arctic marine mammals and climate change: Impacts and resilience. Ecological Applications 18(2): S157-S165.

Evolutionary selection has refined life history of seven Arctic species (including cetaceans, pinnipeds and the polar bear) to spatial and temporal fields influenced by seasonal extremes and variability if sea ice, temperature and day length – which are characteristic of the Arctic. Arctic climate changes occurring in recent times may test the adaptive capacity of these species. Along with this, nine other species (including cetaceans and pinnipeds) which seasonally occupy the Arctic and subarctic may extend habitat ranges into more northern latitudes (including staying there longer), competing with other Arctic species. An understanding of the impacts that future climate change will have on all of these species will be determined by the role of sea ice as a platform, a marine ecosystem function and a barrier (to both humans and non-ice adapted species). This work categorizes the climate-driven impacts for ice-obligate species relying on platforms, ice-associated species that are adapted to these ecosystems and seasonal migratory species where ice can act as a barrier. A resilience assessment is speculative since it can be based on any number of scenarios involving trophic cascades and human disturbance. Resilience scenarios are provided for three ice-related species categories that are relative to four regions defined by projected sea-ice reductions by 2050 and extant shelf oceanography. The resilience scenarios presented have implications for marine mammal survival in relation to sea ice, ice-associated species finding suitable feeding opportunities within sea-ice refugia and benefiting from foraging in new areas (previously covered by ice) and that competition with migratory species infiltrating Arctic regions may increase. This work thus offers a framework for scientific investigation of the impacts of climate change as well as highlighting the need for responsible resource management.
DOI: 10.1890/06-0571.1
http://www.esajournals.org/doi/pdf/10.1890/06-0571.1
KEYWORDS: Arctic; climate change; impacts; marine mammals; resilience; sea ice; sea-ice cover; traditional knowledge; ecosystem; cetacean

Morton SR, Hoegh-Guldberg O, Lindenmayer DB, Olson MH, Hughes L, McCulloch MT, McIntyre S, Nix HA, Prober SM, Saunders DA, Andersen AN, Burgman MA, Lefroy EC, Lonsdale WM, Lowe I, McMichael AJ, Parslow JS, Steffen W, Williams JE and Woinarski JCZ (2009). The big ecological questions inhibiting effective environmental management in Australia. Austral Ecology 34(1): 1-9.

Increasingly, managers and policy-makers will be called on to use the present state of scientific knowledge to supply reasonable inferences for action based on imperfect knowledge. Hence, one challenge is to use existing ecological knowledge more effectively; a second is to tackle the critical unanswered ecological questions. This paper identifies areas of environmental management that are profoundly hindered by an inability of science to answer basic questions, in contrast to those areas where knowledge is not the major barrier to policy development and management. Of the 22 big questions identified herein, more than half are directly related to climate change. The paper goes onto the say that there is enough information already available to develop effective policy and management to address several significant ecological issues, and that ecologists will increasingly be engaging a wide range of other disciplines to help identify pathways towards a sustainable future.
DOI: 10.1111/j.1442-9993.2008.01938.x
http://www.landscapelogic.org.au/publications/Refereed_journal_papers/Morton_et_al_Austral_Ecology.pdf
KEYWORDS: Australian ecology; environmental management; knowledge gaps; climate change; plant

invasions; biodiversity; ecosystems

Moser SC and Ekstrom JA (2010). A framework to diagnose barriers to climate change adaptation. Proc Natl Acad Sci U S A 107(51): 22026-22031.

A three-step framework designed to identify barriers to the process of adaptation to climate change is presented. Each step is designed to understand the causes, consequences and solution to factors limiting the adaptation process in social-ecological systems. This framework provides answers at all levels of decision-making regarding climate change adaptation procedures.
DOI: 10.1073/pnas.1007887107
http://www.pnas.org/content/107/51/22026
KEYWORDS: climate change; adaptation; decision-making; social-ecological system

Mumby PJ, Edwards AJ, Arias-Gonzalez JE, Lindeman KC, Blackwell PG, Gall A, Gorczynska MI, Harborne AR, Pescod CL, Renken H, Wabnitz CCC and Llewellyn G (2004). Mangroves enhance the biomass of coral reef fish communities in the Caribbean. Nature 427(6974): 533-536.

Mangrove forests represent one of the world's most threatened tropical ecosystems with global losses exceeding 35%. Juvenile coral reef fish often inhabit mangrove forests, but the significance of these nurseries to reef fish population dynamics has not yet been quantified. This work demonstrates that mangroves are important as an intermediate fish nursery habitat which may increase survival. Caribbean mangroves influence fish community structure on neighbouring reefs. Additionally, biomass of a number of commercially important species significantly increases when adult habitat is connected to mangrove forests. Present rates of mangrove deforestation are expected to have severe deleterious effects om ecosystem function, fisheries productivity and resilience of reefs, which suggests strongly that conservation efforts should aim to protect connected corridors of mangroves, seagrass beds and coral reefs.
DOI: 10.1038/nature02286
http://www.nature.com/nature/journal/v427/n6974/abs/nature02286.html
KEYWORDS: seagrass beds; habitats; resilience; biomass; biodiversity

Mumby PJ, Elliott IA, Eakin CM, Skirving W, Paris CB, Edwards HJ, Enríquez S, Iglesias-Prieto R, Cherubin LM and Stevens JR (2011). Reserve design for uncertain responses of coral reefs to climate change. Ecology Letters 14(2): 132-140.

Coral bleaching events have been attributed to increasing sea temperatures and these events are predicted to increase in their frequency as global sea temperatures continue to rise. Marine reserves have been shown to reduce biological stress in some situations, although reserves are unable to protect coral reefs from physical stress. The authors propose that reserve placement be concentrated in areas of low physical stress, in an attempt to minimize overall stress in the system and maximize resilience. They map proxies of varying levels of thermal stress and provide predictions of coral reef responses to thermal stressor level, and relate this to spatial predictions of larval connectivity within the Bahamas coral reef system. This information may enable the development of coral reef reserve regions which are spatially connected through species' dispersal patterns, thus creating a marine reserve network. Both the phenotypic and genetic adaptation capacity of corals are expected to play a critical role in influencing reserve design.
DOI: 10.1111/j.1461-0248.2010.01562.x
http://onlinelibrary.wiley.com/doi/10.1111/j.1461-0248.2010.01562.x/abstract

KEYWORDS: acclimation; adaptation; adaptive management; climate change; connectivity; coral reef; marine reserve; ocean acidification; temperature

Mumby PJ, Harborne AR, Williams J, Kappel CV, Brumbaugh DR, Micheli F, Holmes KE, Dahlgren CP, Paris CB and Blackwell PG (2007). Trophic cascade facilitates coral recruitment in a marine reserve. Proceedings of the National Academy of Sciences of the United States of America 104(20): 8362-8367.

Decreases in fishing pressure and weak predator-prey interactions that occur within marine reserves can produce trophic cascades which increase the number of grazing fishes and subsequently reduce the coverage of macroalgae on coral reefs. This work reveals that the impacts of marine reserves ranges outside trophic cascades and increases coral recruitment. Increased fish grazing in a Bahamian reef system was driven by reduced fishing pressure and was negatively correlated with macroalgal cover, resulting in a 2-fold increase in the density of coral recruits. Alternative hypotheses that may generate a false correlation between grazing and coral recruitment were tested and rejected. Grazing seems to influence the density and community structure of coral recruits, however no influence was found on the overall size-frequency distribution, community structure, or cover of corals. The absence of pattern in the adult coral community is thought to be symptomatic of the influence of a recent disturbance event that hides the recovery trajectories of individual reefs. Marine reserves can facilitate the recovery of corals following disturbance events and may help sustain biodiversity dependent on a complex three-dimensional coral habitat.
DOI: 10.1073/pnas.0702602104
http://www.pnas.org/content/104/20/8362.full
KEYWORDS: biodiversity; coral reef; grazing; predation; resilience; marine reserves; trophic cascade; fishing

Mumby PJ and Hastings A (2008). The impact of ecosystem connectivity on coral reef resilience. Journal of Applied Ecology 45(3): 854-862.

Ontogenetic dispersal has been recorded in a number of ecosystems, but full ecological is yet to be fully understood. Modelling of ontogenetic reef fish dispersal consequences between Caribbean mangroves and adjacent reefs allowed quantification of broader implications of ecosystem connectivity for ecosystem function and ecosystem resilience to climate-induced disturbance. Empirical data was used to calculate mangrove-driven enhancement of parrotfish grazing on two reef habitats, with the consequence of increased grazing then investigated using spatial simulation of reef dynamics in shallow and mid-shelf reefs. Although the greatest increase in grazing was in shallow reefs, it was found to have insignificant consequences for coral population dynamics. Contrastingly, weak increases in grazing on deeper reefs had important consequences; reefs close to mangroves experienced recovery under intense extreme weather events due unlike those without connectivity. Reefs exhibit multiple stable equilibria and mangrove enhancement of grazing in mid-shelf systems overlaps with a zone of system instability. Therefore, small increases in grazing moved the reef beyond a bifurcation point; greatly enhancing resilience. Large increases in shallow reef grazing had little consequence since the grazing levels concerned were over twice that needed to exceed the corresponding bifurcation point for this particular habitat. This work shows that ontogenetic mechanisms of ecosystem connectivity involving parrotfish may increase coral populations recovery potential from climate-induced changes of disturbance.
DOI: 10.1111/j.1365-2664.2008.01459.x
http://onlinelibrary.wiley.com/doi/10.1111/j.1365-2664.2008.01459.x/pdf

KEYWORDS: resilience; grazing; mangroves; model; ontogenetic; climate change

Munday PL, Crawley NE and Nilsson GE (2009). Interacting effects of elevated temperature and ocean acidification on the aerobic performance of coral reef fishes. Marine Ecology Progress Series 388: 235-242.

The effect of pH and temperature on the respiration of two coral reef fish (O. doedeleini and O. cyanosoma) was measured experimentally. The aerobic scope of these fish was reduced at higher temperatures and low pH (pH 7.8, equivalent to 1000 ppm CO2), with a minimum reached in warm (32°C) and acidified conditions. Mortality increased with temperature and 33°C was determined to be close to the thermal limit of these species. Acidification significantly increased the mortality of O. doederleini. These results suggest that these species are vulnerable to the projected global warming and ocean acidification.

DOI:10.3354/Meps08137
http://www.int-res.com/abstracts/meps/v388/p235-242/
KEYWORDS: global warming; reef fish; acidification; metabolism; aerobic scope; great barrier reef

Munday PL, Dixson DL, Donelson JM, Jones GP, Pratchett MS, Devitsina GV and Doving KB (2009). Ocean acidification impairs olfactory discrimination and homing ability of a marine fish. Proc Natl Acad Sci U S A 106(6): 1848-52.

The effect of CO2-induced acidification on the ability of larval clownfish to detect olfactory cues, a crucial process during settlement, was tested. The ability of larvae was modified under the pH conditions predicted to occur in 2100 (pH 7.8) and completely disrupted at pH 7.6. Such a loss of homing ability may have dramatic effects on clownfish populations in an acidified ocean.

DOI:10.1073/pnas.0809996106
http://www.ncbi.nlm.nih.gov/pubmed/19188596
KEYWORDS: acidification; coral reef fish; olfaction; population connectivity; larval settlement

Munday PL, Donelson JM, Dixson DL and Endo GG (2009). Effects of ocean acidification on the early life history of a tropical marine fish. Proc Biol Sci 276(1671): 3275-83.

The effect of CO2-induced acidification on eggs and larvae of the orange clownfish (A. percula) was tested experimentally in tanks. Acidification did not significantly impact embryonic duration, egg survival and size at hatching, but unexpectedly enhanced individual growth. These results suggest that future ocean acidification might not negatively impact the early life stages of this fish.

DOI:10.1098/rspb.2009.0784
http://www.ncbi.nlm.nih.gov/pubmed/19556256
KEYWORDS: ocean acidification; coral reef fish; clownfish; larval growth

Munday PL, Jones GP, Pratchett MS and Williams AJ (2008). Climate change and the future for coral reef fishes. Fish and Fisheries 9(3): 261-285.

Coral reef fisheries will be impacted by climate change through effects on individual performance, trophic linkages, recruitment dynamics, population connectivity and a range of other ecosystem processes. Immediate impacts will include diversity loss and changes in fish community composition due to coral bleaching, which suffer rapid population declines in relation to coral loss. Additionally, many other species will undergo long-term declines as a result of loss of settlement habitat

and erosion of habitat structural complexity. Ocean warming will influence the physiological performance of coral reef fishes, particularly during their early life stages. Despite small temperature increases potentially favouring larval development, this may be counteracted by negative effects on adult reproduction. The variability which already exists in recruitment will be further exacerbated, making optimal harvest strategies difficult to determine and populations more susceptible to overfishing. A number of species could undergo range shifts, with implications for increasing extinction-risk of species with small ranges near reef margins. A number of critical gaps exist in knowledge pertaining to climate change impacts on marine tropical fishes, with predictions often based on temperate examples. Improved predictions of ocean current and primary productivity will change are required to more accurately forecast how reef fish population dynamics and connectivity will change in light of climate-driven impacts. Additionally, this work highlights the need to pay more attention to adaptation to climate change, including information on species with characteristics that are conducive to acclimation or local adaptation and perhaps will be resilient to change.
DOI: 10.1111/j.1467-2979.2008.00281.x
http://onlinelibrary.wiley.com/doi/10.1111/j.1467-2979.2008.00281.x/full
KEYWORDS: climate change; adaptation; community structure; global warming; habitat; coral reefs; population dynamics; range shifts; Great Barrier Reef; El Niño southern-oscillation; larval duration; phase-shifts; life-history; habitat specialization; evolutionary responses; Plectropomus leopardus

Munday PL, Leis JM, Lough JM, Paris CB, Kingsford MJ, Berumen ML and Lambrechts J (2009). Climate change and coral reef connectivity. Coral Reefs 28(2): 379-395.

This review assesses and predicts the impacts that rapid climate change will have on population connectivity in coral reef ecosystems, using fishes as a model group. Increased ocean temperatures are expected to accelerate larval development, potentially leading to reduced pelagic durations and earlier reef-seeking behaviour. Depending on the spatial arrangement of reefs, the expectation would be a reduction in dispersal distances and the spatial scale of connectivity. Changes to the spatial and temporal scales of connectivity have implications for the management of coral reef ecosystems, especially the design and placement of MPAs. The size and spacing of protected areas may need to be strategically adjusted if reserve networks are to retain their efficacy in the future.
DOI: 10.1007/s00338-008-0461-9
http://www.springerlink.com/content/r7101j726524g567/
KEYWORDS: climate change; population connectivity; global warming; larval; dispersal; habitat fragmentation; marine protected areas

Neuheimer AB, Thresher RE, Lyle JM and Semmens JM (2011). Tolerance limit for fish growth exceeded by warming waters. Nature Climate Change.

Increasing global temperatures are predicted to affect the reactive, growth and metabolic rates of ectotherms (cold-blooded animals) such that slight increases in temperature are likely to benefit growth rates, but large temperature increases may become deleterious to growth. This paper provides evidence consistent with this prediction for a marine fish in the southwest Pacific Ocean, an area that is one of the fastest warming in the Southern Hemisphere ocean. The authors analyzed long-term changes in the growth rate of banded morwong from the Tasman Sea and compared these changes to temperature trends across the species distribution. An increased growth rate with increasing temperature was observed for the cooler water Australian populations, but a decreased growth rate with increasing temperatures was observed in the warmer water New Zealand populations. Data demonstrates that increasing water temperatures has exceeded the point where warming is beneficial

to growth, and suggest mechanisms for range contraction as a result of this temperature increase. The authors propose that populations living at the warm-edge of their distribution, temperatures that exceed the growth rate benefit may have important repercussions for the population's recruitment success and productivity.
DOI: 10.1038/NCLIMATE1084
http://www.nature.com/nclimate/journal/v1/n2/full/nclimate1084.html
KEYWORDS: climate change; global warming; ecosystems; cascades; dispersal; impacts; otolith; population dynamics; range shifts; resilience; Tasman Sea; temperature

Newton K, Cote IM, Pilling GM, Jennings S and Dulvy NK (2007). Current and future sustainability of island coral reef fisheries. Current Biology 17(7): 655-658.

One of the primary threats to coral reef diversity, structure, function and resilience is overexploitation. Although coral reef fisheries are generally considered unsustainable, there is little known of the scale of this impact, including which reefs are overfished. Ecological footprints and a review of exploitation status lead to reporting of widespread unsustainability for island coral reef fisheries. Over half of the 49 countries included are unsustainably exploiting their fisheries, with estimated current landings an estimated 64% higher than can be sustained. Consequently the area of coral reef which is appropriated by these fisheries exceeds the available effective area by 75000km2. The extreme imbalance between current and sustainable catches implies the urgent need for management methods to reduce social and economic dependence on these fisheries if they are able to prevent their collapse.
DOI: 10.1016/j.cub.2007.02.054
http://www.sciencedirect.com/science/article/pii/S0960982207010639
KEYWORDS: ecosystems; catch; cascades; impacts; coral reefs; fisheries; sustainability; resilience; overfishing

Nilsson GE, Crawley N, Lunde IG and Munday PL (2009). Elevated temperature reduces the respiratory scope of coral reef fishes. Global Change Biology 15(6): 1405-1412.

The aerobic scope (capacity to perform aerobically, which controls thermal tolerance), was measured on five common coral reef fish species at different temperatures. The aerobic scope (calculated as a percent of increase between resting and maximum oxygen consumption) was reduced for all species with increasing temperatures, with different intensities according to the species. These different thermal tolerances among species suggest that ocean warming might cause significant changes of reef community structure in the future, to the benefit of thermally tolerant species.
DOI:10.1111/j.1365-2486.2008.01767.x
http://onlinelibrary.wiley.com/doi/10.1111/j.1365-2486.2008.01767.x/abstract
KEYWORDS: ecosystem; reef; fish; warming; temperature; aerobic scope; tolerance; community structure

Norberg J, Wilson JR, Walker B and Ostrom E (2008). Diversity and resilience of social-ecological systems. Complexity theory for a sustainable future. CG Norberg J. New York, Columbia University Press**:** 46-79.

This book chapter discusses the notion that diversity is an essential component for sustainable functioning of both biological and social systems, demonstrating fundamentally significant reasons as to

the importance of diversity. The authors discuss adaptive capacity for coping with change over time, and review the importance of understanding and being able to maintain diversity for the purpose of creating sustainable social-ecological systems.
KEYWORDS: social-ecological; diversity; resilience

Norgaard RB (2010). Ecosystem services: From eye-opening metaphor to complexity blinder. Ecological Economics 69(6): 1219-1227.

Development of the ecological system services approach has enabled the exploration and communication of a framework which determines the relationship between humans, the global economy and nature. The scientific assessment of ecosystem change has stemmed from this framework, along with the development of theoretical and empirical documentation of the nature and value of ecosystem services. This scientific framework seeks an innovative approach to reduce environmental degradation in developing countries, the design and implementation of environmental management programs, and curbing excessive energy and material consumption by wealthy nations. This article discusses the challenges faced by continued economic growth and posits that the ecosystem services approach can be a part of a larger solution, but cautions that ecological, economic and political complexities will present additional challenges to the solutions sought.
DOI: 10.1016/j.ecolecon.2009.11.009
http://www.sciencedirect.com/science/article/pii/S0921800909004583
KEYWORDS: assessment; climate change; development; economic growth; ecosystem services; environmental management; framework; general equilibrium analysis; sustainability; governance

Norström AV, Nyström M, Lokrantz J and Folke C (2009). Alternative states on coral reefs: beyond coral–macroalgal phase shifts. Marine Ecology Progress Series 376: 295-306.

An overview of alternative states observed in coral reefs is presented and discussed to clarify the current debate on coral reef phase shifts. Phase shifts result from coral mass mortality events induced by pulse disturbances, and may lead to a stable state due to positive feedback mechanisms. Several phase shifts are discussed, complementing the commonly reported coral–macroalgae shift. Management procedures could benefit from a better understanding of the drivers and controls of phase shifts in coral reefs.
DOI: 10.3354/meps07815
http://www.int-res.com/abstracts/meps/v376/p295-306/
KEYWORDS: coral reef; phase shift; climate change; reef management

Nunn PD (2009). Responding to the challenges of climate change in the Pacific Islands: management and technological imperatives. Climate Research 40(2-3): 211-231.

Despite being faced with similar impacts of climate change, Pacific Island nations face further challenges in relation to their small size, remoteness and archipelagic character. Climate change solutions for Pacific Islands are often uncritically imposed from elsewhere and have proven unsuited both environmentally and culturally. Pacific Island-specific climate change solutions should acknowledge their distinctive environmental characteristics including insularity, their topographic and geological diversity, and also the raw materials which are available to support adaptation. Policy makers must understand and incorporate cultural influences as well as the ways in which climate change adaptation can be sustained. The effectiveness of top-down (donor funder policy) rather than bottom-up involvement (e.g. community-level decision-makers) is questionable, with emphasis on Pacific Island

governments to take ownership of the climate change adaptation process, with external assistance only if necessary. Inundation and salinization of economically critical lowland and coral reef degradation should be incorporated into management objectives, rather than primarily focussing only on sea level rise.
DOI: 10.3354/cr00806
http://www.int-res.com/articles/cr_oa/c040p211.pdf
KEYWORDS: climate change; Pacific Islands; environmental management; technology; adaptation; sea-level rise; adaptation; governance; community

Nystrom M and Folke C (2001). Spatial resilience of coral reefs. Ecosystems 4(5): 406-417.

Human impacts alter the natural disturbance regimes experienced by coral reef ecosystems, as well as introducing new stressors and modifying background conditions of these reefs. Ecosystem resilience is the capacity of complex systems comprising multiple stable states to absorb disturbance, to be able to consequently reorganise and to adapt to change. These relate to the ability of coral reefs to be able to cope with human impacts. This work focuses on spatial resilience, i.e. the dynamic capacity of a reef matrix to reorganize and maintain ecosystem function after disturbance, highlighting the relationship between disturbance and ecosystem resilience. Identification of spatial sources of resilience in dynamic seascapes is the first step in this study, followed by exemplification and discussion of the relation between 'ecological memory' (biological legacies, mobile link species, and support areas) and functional diversity in terms of seascape ecosystem resilience. Conservation of coral reefs is enhanced by managing for ecosystem resilience, which also aids in providing sustainability of ecosystem services which are vital for humans.
DOI: 10.1007/s10021-001-0019-y
http://www.springerlink.com/content/bt8f2ggwhnjqu09l/fulltext.pdf
KEYWORDS: coral reefs; disturbance; resilience; spatial resilience; ecological; memory; mobile links; management; Great Barrier Reef; phase shifts; disturbance; community structure; mass mortality; recruitment; biodiversity

Nystrom M, Folke C and Moberg F (2000). Coral reef disturbance and resilience in a human-dominated environment. Trends in Ecology & Evolution 15(10): 413-417.

Human-driven alters the natural disturbance regimes of coral reefs by changing pulse events into persistent disturbance or chronic stress, or by introducing, removing or supressing disturbance. Human impacts are also changing the capacity of reefs to cope with stress, which then further intensifies the effects of altered disturbance regimes. There are substantial implications for the changes for reef-associated human activities including fishing and tourism, which are discussed here.
DOI: 10.1016/S0169-5347(00)01948-0
http://www.sciencedirect.com/science/article/pii/S0169534700019480
KEYWORDS: phase shifts; management; ecosystems; diversity; scale; communities; adaptation; thresholds; coral reefs; resilience; human impact

Nystrom M, Graham NAJ, Lokrantz J and Norstrom AV (2008). Capturing the cornerstones of coral reef resilience: linking theory to practice. Coral Reefs 27(4): 795-809.

Phase shifts refer to unexpected and dramatic changes in community composition, as can occur in coral reef ecosystems; with significant consequences for ecosystem services on which humans

depend. Ecosystem resilience is thought to confer insurance against unexpected responses in the face of climate change, and has become important in the development of coral reef management strategies. The ambiguity of the term resilience presents a number of problems, with concern regarding its practical applicability of major focus. Operationalizing theory to be able to observe resilience is therefore an important assignment, requiring empirical assessments of resilience. Biodiversity, spatial heterogeneity, and connectivity have been proposed as key foundations of resilience since they may provide insurance against ecological uncertainty. This paper provides a synopsis of the divergent uses of the concept of resilience as well as proposing empirical indicators of the key foundations of this concept. Indicators include functional group approaches, ratios of good and bad colonizers of space, measurements of spatial heterogeneity, and estimates of possible space availability against grazing capacity. The crux of these operational indicators of resilience is to use them as predictive tools to identify vulnerability that may lead to unexpected phase shifts before the disturbance occurs.
DOI: 10.1007/s00338-008-0426-z
http://www.springerlink.com/content/y736137635618158/
KEYWORDS: diversity; functional groups; management; phase shifts; coral reefs; resilience

Obura DO (2005). Resilience and climate change: lessons from coral reefs and bleaching in the Western Indian Ocean. Estuarine Coastal and Shelf Science 63(3): 353-372.

This paper presents evidence for the West Indian Ocean supporting recent hypotheses on coral reef vulnerability to thermal stress that have been termed 'resistance and resilience to bleaching'. The author argues for more explicit terminology, and identified three concepts which affect coral-zooxanthellae holobiont and reef vulnerability to thermal stress previously termed 'resistance to bleaching'. These are: ‘thermal protection’ which has been used where some reefs are protected from thermal conditions including bleaching; ‘thermal resistance’ has referred to when individual corals bleach differently to the same thermal stress; and ‘thermal tolerance’ where individual corals experience differing levels of mortality when subjected to the same thermal stress. The term ‘resilience to bleaching’ is a particular case of ecological resistance, where coral recovery following large-scale bleaching may vary according to ecological and other processes. Thermal resistance and tolerance have genetic basis and may interact with environmental protection properties that result in phenotypic variation in coral bleaching. Human threats and varying levels of management may alter these aspects in respect to resilience, and appropriate management needs to link science and management when dealing with these larger-scale impacts of climate change.
DOI: 10.1016/j.ecss.2004.11.010
http://www.sciencedirect.com/science/article/pii/S0272771404003191
KEYWORDS: coral bleaching; thermal stress; spatial resilience; climate change; protection; resistance; tolerance; Western Indian Ocean; Great Barrier Reef; resilience

Obura DO and Grimsditch G (2009). Coral Reefs, Climate Change and Resilience - An Agenda for Action from the IUCN World Conservation Congress in Barcelona, Spain.**:** 1-48.

This report is derived from workshop proceedings held at the IUCN Conservation Congress in October 2008, and highlights new themes and priorities for action regarding resilience-based management of coral reefs and other marine organisms. This report covers aspects of assessing reef resilience; drivers, indicators and monitoring of resilience; and enhancing resilience-based management.
http://cmsdata.iucn.org/downloads/resilience_barcelona.pdf
KEYWORDS: adaptive management; climate change; coral bleaching; coral reefs; management; policy; resilience; science

Obura DOaG, G. (2009). Resilience Assessment of coral reefs – Assessment protocol for coral reefs, focusing on coral bleaching and thermal stress. . Gland, Switzerland**:** 1-71.

Climate change is now recognized as one of the most significant threats to coral reefs globally. This report discusses coral reefs, their role in terms of resources and services, and reef resilience to climate change - which is likely to be determined by the rate and extent of climate change, the ability of reefs to cope with change, additional anthropogenic stressors and management actions taken.
http://cmsdata.iucn.org/downloads/resilience_assessment_final.pdf
KEYWORDS: climate change; coral reefs; coral bleaching; management; resource; thermal stress

OECD (2010). The Economics of Adapting Fisheries to Climate Change. OECD Publishing, Paris, France.

This book summarises results from a workshop on the Economics of Adapting Fisheries to Climate Change held in June 2010 in Busan, Korea. This document discusses policy and economic aspects of fisheries adaptations to climate change. A range of adaptation strategies to be applied by policy makers are discussed, including ecosystem protection, the strengthening of the global governance system, an attention to the increased demand for sustainably-caugh seafood, and, a particular emphasis on aquaculture management.
DOI: 10.1787/9789264090415-en
http://www.oecd-ilibrary.org/agriculture-and-food/the-economics-of-adapting-fisheries-to-climate-change_9789264090415-en
KEYWORDS: climate change; fisheries; adaptation; policy; governance; sustainability; ecosystem protection; economy

Olsson P, Folke C and Berkes F (2004). Adaptive comanagement for building resilience in social-ecological systems. Environmental Management 34(1): 75-90.

Ecosystems are complex adaptive systems that necessitate flexible control that includes the ability to respond to environmental feedback. This study shows the development of adaptive comanagement systems, demonstrating how local groups self-organize, learn, and actively adapt to and shape change with social networks that bond institutions and organizations across levels and scales and that make information flow possible. This comanagement development occurred through a sequence of responses to environmental events that broadened the scope of local management; going from a particular issue or resource to a broad set of issues relating to ecosystem processes across a range of scales and from individual actors, to group of actors to multiple-actor processes. The results indicate that the institutional and organizational landscapes should be approached carefully as should the ecological in order to clarify factors that contribute to the resilience of social-ecological systems. This includes: vision, leadership, and trust; permitting legislation that generates social space for ecosystem management; finances for responding to environmental change and for corrective action; capacity for monitoring as well as responding to environmental feedback; information flow via social networks; the combination of a variety of sources of information and knowledge; and sense-making and arenas of collaborative learning for ecosystem management. This work suggests that the self-organizing process of adaptive comanagement development, facilitated by rules and incentives of higher levels, has the potential to develop advantageous stability domains of a region and make social-ecological systems more robust to change.
DOI: 10.1007/s00267-003-0101-7
http://www.springerlink.com/content/mlg2g9dphj4b1a20/

KEYWORDS: adaptive management; co-management; social-ecological systems; resilience; self-organization; ecosystem management

Olsson P, Folke C and Hughes TP (2008). Navigating the transition to ecosystem-based management of the Great Barrier Reef, Australia. Proceedings of the National Academy of Sciences of the United States of America 105(28): 9489-9494.

The strategies and decisions which facilitate ecosystem-based management are analysed using the recent governance changes of the Great Barrier Reef (GBR) Marine Park as a case study. The flexibility of the GBR Marine Park Authority was crucial for initiating the transition to ecosystem-based management among the various individuals, organisations and institutions involved. This management agency was also crucial in the subsequent transformation of the governance regime by providing effective leadership through the process. The strategies incorporate here included internal reorganisation and management innovation, which were important in coordinating the research community, increasing public awareness, involving a range of stakeholders and manoeuvring the political system for support at critical times. The increased pressure on the GBR helped to trigger the sense of urgency required to address these challenges, and the focus of governance shifted to stewardship of large-scale seascapes over protection of individual reefs. This study demonstrates how new forms of management and governance can be influenced significantly by stewardship, and is crucial for adaptive comanagement of complex marine ecosystems.
DOI: 10.1073/pnas.0706905105
http://www.ncbi.nlm.nih.gov/pmc/articles/PMC2474521/pdf/zpq9489.pdf
KEYWORDS: adaptive governance; ecosystem services; transformation; social-ecological systems; adaptive governance; marine ecosystems; ocean governance; conservation; sustainability; ecosystem-based management; Great Barrier Reef; stewardship; biodiversity; climate change

Pantzartzi C, Drosopoulou E, Yiangou M, Drozdov I, Tsoka S, Ouzounis CA and Scouras ZG (2010). Promoter Complexity and Tissue-Specific Expression of Stress Response Components in <italic>Mytilus galloprovincialis</italic>, a Sessile Marine Invertebrate Species. PLoS Comput Biol 6(7): e1000847.

Stress tolerance mechanisms of sessile organisms can offer important insights into responses and adaptations to a range of environmental stressors. This article examines heat shock response in a sessile marine invertebrate within the Mytilus genus using comparative genomics and network inference. Results indicate that the heat shock response in Mytilus is regulated by a complex upstream region of Mytilus Hsp90 gene, a key stress response gene, and suggest future research directions for the investigation of a biosensor system using the heat shock process.
DOI: 10.1371/journal.pcbi.1000847
http://www.ploscompbiol.org/article/info%3Adoi%2F10.1371%2Fjournal.pcbi.1000847
KEYWORDS: adaptation; climate change; environment; marine; molluscs; sessile; stress tolerance

Parker LM, Ross PM and O'Connor WA (2009). The effect of ocean acidification and temperature on the fertilization and embryonic development of the Sydney rock oyster Saccostrea glomerata (Gould 1850). Global Change Biology 15(9): 2123-2136.

The fertilization and embryonic development of Sydney rock oysters (S. glomerata) were measured under different temperatures (18, 22, 26 and 30°C) and CO2 concentrations (375, 600, 750 and 1000 ppm) in tank experiments. The optimum temperature for fertilization and embryonic development was determined to be at 26°C, with higher temperatures causing reductions in both

processes. The synergistic effect of elevated temperatures and CO2 concentrations caused reduced fertilization and growth, abnormal development and increased mortality. These results suggest severe implications for both the aquaculture industry and ecosystem structure in a warmer, higher CO2 ocean.
DOI: 10.1111/j.1365-2486.2009.01895.x
http://onlinelibrary.wiley.com/doi/10.1111/j.1365-2486.2009.01895.x/full
KEYWORDS: ocean acidification; temperature; oyster; embryonic development; fertilization; calcification

Parkinson RW (2009). Adapting to Rising Sea Level: A Florida Perspective. Sustainability 2009: The Next Horizon. GL Nelson and I Hronszky. Melville, Amer Inst Physics. **1157:** 19-25.

Florida's coastal and marine ecosystems are being impacted by global climate change and associated sea level rise; which will erode beaches, cause saltwater intrusion into water supplies, inundate coastal marshes and make coastal property more susceptible to erosion and flooding. The threat of sea-level rise and climate-driven extreme weather events requires planning management and resources to reduce risks to humans. Researchers must direct effort to assessing coastal vulnerability for short-term management, model future change and develop sustainable plans for long-term planning and management. Additionally, this information must then be efficiently conveyed to appropriate planners, managers and officials to accurately drive informed decision-making. Adaptation, coastal management and planning documents must be revised in light of climate-driven impacts.
DOI: 10.1063/1.3208022
http://research.fit.edu/sealevelriselibrary/documents/doc_mgr/449/Florida_SLR_Adaptation_-_Parkinson_2009.pdf
KEYWORDS: climate change; sea-level rise; Florida; vulnerability; management; adaptation

Parmesan C and Yohe G (2003). A globally coherent fingerprint of climate change impacts across natural systems. Nature 421(6918): 37-42.

Non-climatic influences can complicate accurate attribution of biological trends to climate change, since these also dominate local, short-term biological changes. Analyses which examine systematic trends across diverse species and geographic ranges are likely to detect any underlying signals from climate change, yet debates within the Intergovernmental Panel on Climate Change (IPCC) expose that there are multiple definitions for the term 'systematic trend'. This paper explores these different definitions, and applies various analyses to over 1700 species showing how recent biological trends reflect climate change predictions. Global meta-analysis revealed significant poleward range shifts averaging 6.1 km per decade as well as significant mean advancement of spring events by 2.3 days per decade. This work defined a diagnostic fingerprint of temporal and spatial 'sign-switching' responses predicted by climate trends, and for which was found for 279 species, indicating that climate change is already affecting living systems.
DOI: 10.1038/nature01286
http://www.nature.com/nature/journal/v421/n6918/abs/nature01286.html
KEYWORDS: climate change; predictions; biological trends; British butterflies; phenology; responses; temperature; abundance; IPCC

Patarnello T, Verde C, di Prisco G, Bargelloni L and Zane L (2011). How will fish that evolved at constant sub-zero temperatures cope with global warming? Notothenioids as a case study. BioEssays 33(4): 260-268.

Species that have evolved to live in narrow ranges of cold temperatures (i.e. stenothermal

Antarctic marine fauna) are thought to have limited abilities to respond to global warming events. The impact of climate change is likely to depend upon the rate of temperature changes and species' adaptive abilities. This article focuses on the taxonomic group Notothenioidei which dominates Antarctic fish. While they possess unique phenotypic modifications for adaptation to cold Antarctic conditions, this has come at the price of genomic losses or gene amplifications which are thought to be irreversible. This feature, coupled with proposed shallow genetic diversity and distinct genetic structure of the taxa, leads the authors to conclude that Antarctic fish may have a limited potential to adapt to the impacts of rising global temperatures, although more research is required into the phenotypic plasticity of these species.
DOI: 10.1002/bies.201000124
http://onlinelibrary.wiley.com/doi/10.1002/bies.201000124/full
KEYWORDS: adaptation; Antarctic; climate change; evolution; fish; genetic diversity; global warming; notothenioids; temperature

Peck LS, Morley SA and Clark MS (2010). Poor acclimation capacities in Antarctic marine ectotherms. Marine Biology 157(9): 2051-2059.

Response to temperature can include a number of mechanisms employed by animals, including physiological flexibility (e.g. acclimation), adaptation, or migration; with the major mechanism used by marine groups thought to be acclimation. Six species of Antarctic invertebrate were subjected to acclimation experiments for 60 days at 3°C. Only one species (Marseniopsis mollis) increased its acute upper limit to acclimate; and analysis of oxygen consumption by the sea urchin Sterechinus neumayeri and the amphipod Paraceradocus gibber revealed that their metabolic rates were also not compensated over the trial period. The results thus show that 5 out of 6 species did not acclimate to temperatures 3°C above annual averages (i.e. 1-2°C above maximum summer temperatures). This work suggests that Antarctic marine species have low abilities to adjust to increased environmental temperatures.
DOI: 10.1007/s00227-010-1473-x
http://www.springerlink.com/content/34684858ll351425/
KEYWORDS: thermal tolerance; climate change; Laternula elliptica; Pagothenia borchgrevinki; elevated temperatures; Notothenioid fishes; warm acclimation; oxygen; adaptation; acclimation

Pecl G, Frusher S, Gardner C, Haward M, Hobday A, Jennings S, Nursey-Bray M, Punt A, Revill H and van Putten I (2009). The east coast Tasmanian rock lobster fishery – vulnerability to climate change impacts and adaptation response options. Report to the Department of Climate Change, Australia.
: 8.

Climate change is predicted to have major impacts on the rock lobster (Jasus edwardsii) industry in Tasmania via declines in biomass – occurring initially in the north, but also then in the south. Simultaneously the range-extending sea urchin (Centrostephanus rodgersii) will continue to increase in Tasmanian waters. Several measures will assist the adaptation of the rock lobster fishery to adapt to changing conditions; including improved catch modelling, long-term monitoring programs, better risk assessment and effective education and communication with stakeholders.
KEYWORDS: climate change; fishery management; rock lobster; sea urchin; adaptation

Perkol-Finkel S and Airoldi L (2010). Loss and Recovery Potential of Marine Habitats: An Experimental Study of Factors Maintaining Resilience in Subtidal Algal Forests at the Adriatic Sea. Plos One 5(5): 11.

Prediction of and then reduction of natural habitat is a major challenge in science, conservation and management. Hypotheses regarding triggers for decline and recovery potential were tested in

subtidal canopy-forming algae (Genus Cystoseira). A combination of historical, quantitative and in situ data and observations of natural recruitment patterns revealed the trigger of recent declines in north Adriatic Sea algal forests were increasing cumulative impacts of natural and human-driven habitat instability as well as extreme weather events. Experiments on clearing and transplantation revealed that at such degraded levels, increased substratum stability would be essential, although still not sufficient to recover the loss, and that removal of the new dominant space occupiers would also be necessary. Lack of nearby adult canopy did not appear to restrict the recovery potential. Sudden habitat loss can be facilitated by long-term biotic and abiotic conditions which act to erode ecosystem resilience. This work further demonstrates that restoring environmental conditions (if possible) may still not be efficient to allow full ecosystem recovery, and that management of incremental habitat changes and attributes facilitating recovery can help mitigate the loss of complex marine habitats.
DOI: 10.1371/journal.pone.0010791
http://www.ncbi.nlm.nih.gov/pmc/articles/PMC2875393/
KEYWORDS: disturbance; Cystoseira barbata; climate change; kelp forests; ecology; ecosystems; community; canopy-forming; algae; human impact; resilience

Perry RI and Ommer RE (2010). Introduction: Coping with global change in marine social-ecological systems. Marine Policy 34(4): 739-741.

The human social components of marine social-ecological systems are often considered separate to their biophysical components, and by diverse scientific disciplines. An international symposium on Coping with global change in marine social-ecological systems was held in attempt to bridge these gaps as well as to explore the conceptual, comparative and governance issues concerning marine social-ecological systems. This paper introduces this topic, briefly describing the nine papers that arose from it (making up a special issue of Marine Policy). Progress is being made towards the study of marine social and ecological systems as combined systems, but that a number of challenges remain including incorporation of multi-stakeholder involvement, long-term perspectives and developing flexible livelihoods and governance strategies.
DOI: 10.1016/j.marpol.2010.01.025
http://www.sciencedirect.com/science/article/pii/S0308597X10000266
KEYWORDS: Social-ecological systems; global change; fishing communities; ecosystems; vulnerability; climate change

Perry RI, Ommer RE, Barange M and Werner F (2010). The challenge of adapting marine social–ecological systems to the additional stress of climate change. Current Opinion in Environmental Sustainability 2: 356-363.

Maintaining the healthy marine social-ecological systems which allow desirable ecosystem services to be sustained is a broad goal of marine policy. These systems are stressed by environmental factors as well as globalisation, and climate change is an additional stressor. Human social systems have strategies for coping with variability within normal ranges of experience, but these capacities are not distributed evenly across the globe. This paper addresses the supplementary impacts that climate change places on social-ecological systems that focus on fishing. Management must seek to enhance the adaptive capacities of these systems in the light of uncertainty and change, with specific challenges involving addressing non-climate related stressors such as fishing, and how this can interact with climate change. Recognising changes, enhancing communication with stakeholders, and developing flexible institutions that can adjust rapidly to new circumstances are all important components of integrating observing and modelling systems for the full social-ecological system.

DOI: 10.1016/j.cosust.2010.10.004
http://www.sciencedirect.com/science/article/pii/S1877343510001107
KEYWORDS: climate change; policy; management; fishing communities; social-ecological; stakeholders

Pistevos JCA, Calosi P, Widdicombe S and Bishop JDD (2011). Will variation among genetic individuals influence species responses to global climate change? Oikos 120(5): 675-689.

Increasing sea surface temperatures and ocean acidification are predicted to have a significant impact on the health and function of marine organisms globally. This article investigates the potential influence of individual genetic variation within a species on population- and species-level responses to variable and changing oceanic conditions. A microcosm system was used to examine the effects of temperature and CO2 on colony growth rate, reproductive investment and sex ratio across populations of a bryozoan species. Reduced growth rates and increased reproductive investments were recorded with decreasing pH and increasing temperature treatments, while an increase in the male sex ratio was observed with decreasing pH levels. The authors conclude that levels of individual genetic variation within a species may enable future adaptation to changes in climatic conditions including pH and temperature levels.
DOI: 10.1111/j.1600-0706.2010.19470.x
http://onlinelibrary.wiley.com/doi/10.1111/j.1600-0706.2010.19470.x/abstract;jsessionid=91170E2CC70571D7B3D67E637547520A.d03t01
KEYWORDS: bryozoan; climate change; CO2; genetic variation; global warming; growth rate; ocean acidification; pH; reproductive investment; sea surface temperature

Pitcher TJ (2001). Fisheries managed to rebuild ecosystems? Reconstructing the past to salvage the future. Ecological Applications 11(2): 601-617.

This paper provides the case for adopting ecosystem rebuilding as the goal of fisheries management, which may represent the only real hope for future fisheries existence and the essential ecosystem services they allow. Archaeological, historical, and recent evidence are reviewed, and the ecological effects of overfishing on aquatic ecosystems are examined. Fish with life histories and spatial behaviour that is unfavourable to harvesting are selectively removed, both within and among species. Keystone species loss and the replacement of high-value, demersal resources with pelagic, rapid-turnover, low-value species, acts to shift the nature of ecosystems, which is seen by accelerating local extinctions worldwide declines in trophic levels. Harvest limits that appear safe by single species evaluation can bring about ecosystem changes that are difficult to correct. Motivated by a progression of modern human harvest technologies, three ratchet-like processes have resulted in episodes of depletion. The processes are: "Odum's ratchet" which is ecological in nature, comprising depletion and local extinction; "Ludwig's ratchet," which is economic in nature, and is a positive feedback loop between increased catching power and sequential depletion, driven by the need to pay back borrowed money; and "Pauly's ratchet" which is cognitive, shifting the baseline of what each generation regards as primal abundance and diversity. Here, a rebuilding policy goal is distinguished from sustaining current catches and biomass, since the baseline can refer to present misery. Present policies can therefore unintentionally foreclose potential options for the generation of food, wealth, and services from ocean resources. The author also outlines a novel methodology, termed "Back to the Future," that can put into practice a goal of ecosystem rebuilding, before discussing two practical management measures, which parallel recent developments in terrestrial reconstruction ecology, the implementation of no-take marine reserves, and the reintroduction of high-value species that were previously endemic.
http://www.seaturtle.org/PDF/Pitcher_2001_EcolApp.pdf

KEYWORDS: biodiversity; ecosystem rebuilding; fisheries management and sustainability; fisheries policy; mass-balance models; restoration ecology; marine reserves

Pitt NR, Poloczanska ES and Hobday AJ (2010). Climate-driven range changes in Tasmanian intertidal fauna. Marine and Freshwater Research 61(9): 963-970.

Global warming in south-eastern Australia over the past 50 years has exceeded the global average, resulting in several subtidal species exhibiting poleward range expansion. This work provides first evidence of similar patterns in intertidal invertebrates, with 55% of species examined detected further south than recorded in the 1950s. The average minimum movement of southern ranges was 116km, which represents movement of 29 km per decade (for warming of 0.22 degrees C per decade). Barnacles and gastropods exhibited the greatest range extensions, with one species of barnacle (Austromegabalanus nigrescens) not recorded during the 1950s, but now being quite common along the east coast. Distances moved were not related to qualitative dispersal potential index. This work predicts the local extinction of some north-eastern species in the future.
DOI: 10.1071/MF09225
http://www.publish.csiro.au/?act=view_file&file_id=MF09225.pdf
KEYWORDS: climate change; distribution change; latitudinal range; poleward movement; English channel; biodiversity; extension; responses; dynamics; impacts; range expansion; dispersal

Pittock AB (1999). Coral reefs and environmental change: Adaptation to what? American Zoologist 39(1): 10-29.

Concern of climate change and sea-level rise is discussed in context of past changes, detailing best estimates of future changes, with explanation of methods and uncertainties. Climate change related stressors to coral reefs include sea-level rise, temperature, human disturbance, salinity, pollution, ocean currents, ENSO and extreme weather events. These stressors may be further be intensified by reduced calcification rates in corals due to changes in ocean chemistry. This study highlights the need for assessments of adaptation in terms of risk and probability, and management options should include autonomous and planned adaptations.
DOI: 10.1093/icb/39.1.10
http://icb.oxfordjournals.org/content/39/1/10.abstract
KEYWORDS: climate change; El Niño southern oscillation; adaptation; management

Planque B, Fromentin JM, Cury P, Drinkwater KF, Jennings S, Perry RI and Kifani S (2010). How does fishing alter marine populations and ecosystems sensitivity to climate? Journal of Marine Systems 79(3-4): 403-417.

The alteration of marine ecosystem structure by exploitation and its effects on the ecosystem's response to climate variability are discussed. The selectivity of fisheries (e.g. fisheries targeting large-old fish, a given species or a sub-population unit) appears as a major destabilizing factor causing the reduction of ecosystem resilience to perturbations. This study highlights the importance of diversity in resilience processes, and suggests a need for more attention to ecosystem structure and functioning in management procedures.
DOI: 10.1016/j.jmarsys.2008.12.018
http://www.sciencedirect.com/science/article/pii/S0924796309000943
KEYWORDS: fisheries; conservation; biodiversity; resilience; adaptation; ecosystem structure; climate variability; overfishing

Pörtner HO (2010). Oxygen- and capacity-limitation of thermal tolerance: a matrix for integrating climate-related stressor effects in marine ecosystems Journal of Experimental Biology 213(6): 881-893.

Investigations into the thermal tolerance of marine ectotherms have provided an important indicator of the effects of rising temperatures on species abundances in marine environments. This article discusses the relevance, but lack of physiological studies in marine organisms in response to climate-induced environmental changes. The author reviews aspects of oxygen- and capacity-limited thermal tolerance, acclimatization capacities and CO2 tolerance in marine organisms and the effects this has on ecosystem-level processes within the marine environment.

DOI: 10.1242/jeb.037523

http://jeb.biologists.org/content/213/6/881.abstract

KEYWORDS: climate change; global warming; marine ecosystem; ocean acidification; oxygen; stressors; thermal tolerance

Pörtner HO and Peck MA (2010). Climate change effects on fishes and fisheries: towards a cause-and-effect understanding. Journal of Fish Biology 77(8): 1745-1779.

Direct and indirect effects of climate change are predicted to affect individual organisms across all life-history stages right through to species, populations, communities and functioning ecosystems. The authors propose that the implications of climate change on populations of marine fish will be observed across four interlinked biological levels – at the organism level there will be observed physiological changes; at the individual level there will be observed behavioural changes; at the population level there will be observed changes in survival, growth and reproductive output; and at the ecosystem level there will be observed changes in productivity and interactions. These predicted changes are expected to impact global fisheries and their associated economies.

DOI: 10.1111/j.1097-8649.2010.02783.x

http://www.mendeley.com/research/climate-change-effects-on-fishes-and-fisheries-towards-a-causeandeffect-understanding/

KEYWORDS: climate change; ecophysiology; fisheries; modelling; thermal tolerance

Pratchett MS, Wilson SK, Graham NAJ, Munday PL, Jones GP and Polunin NVC (2009). Coral bleaching and consequences for motile reef organisms: past, present and uncertain future effects. Coral Bleaching. Patterns, causes and consequences. MJH Van Oppen and JM Lough. Berlin, Springer. 205**:** 139-158.

This book chapter reviews the consequences of coral bleaching on motile reef organisms, by sequentially assessing the effects in the short-term (up to 3 years), medium-term (3-10 years) and long-term (> 10 years). In the short term, the mortality of fish and motile invertebrates is expected to increase due to the loss of food and shelter. In the medium-term, coral erosion and reef collapse are expected to amplify this phenomenon, resulting in shifts in species composition. The long-term effects are expected to severely impact fisheries, indicating the need for improved management procedures.

DOI:10.1007/978-3-540-69775-6_9

http://www.springerlink.com/content/w027010hn767k860/

KEYWORDS: fisheries; coral reef; bleaching; species composition; management; mitigation

Proffitt C and Travis S (2010). Red Mangrove Seedling Survival, Growth, and Reproduction: Effects of

Environment and Maternal Genotype. Estuaries and Coasts 33(4): 890-901.

Phenotypic plasticity and genetically differentiated responses are used by plants in response to environmental stress, which can have flow-on effects for population dynamics and species-specific interactions. This article examines the response of a marine foundation plant species, the red mangrove, to environmental stressors by investigating the variation among plant genotype and the genotype by environment effect at varying intertidal treatments. The factors that explained survival and growth of mangroves were maternal genotype, elevation and a genotype by elevation interaction. The authors conclude that mangrove seedlings of different maternal genotypes can perform differently under different environmental conditions, potentially showing adaptation to local differences or differences in plasticity among genotypes.

DOI: 10.1007/s12237-010-9265-6
http://www.springerlink.com/content/5318604xgg01368r/
KEYWORDS: adaptation; climate; environment; genotype; mangrove; phenotypic variation; seedling; stressor

Reed TE, Martinek G and Quinn TP (2010). Lake-specific variation in growth, migration timing and survival of juvenile sockeye salmon Oncorhynchus nerka: separating environmental from genetic influences. Journal of Fish Biology 77(3): 692-705.

Pacific salmon display strong intraspecific variation, which is predicted to occur as a result of reproductive isolation when populations travel back to natal spawning sites, with local adaptation to specific breeding and rearing habits existing. This article examined the site-specific environmental impacts on sockeye salmon juvenile migration timing, individual size and survival rates. The authors looked at a range of environmental impacts including temperature differences and found that juvenile salmon that were raised at sites with higher temperatures and greater productivity were larger and had a greater survival probability in marine environments than those individuals raised in cooler, less productive sites. Environmental factors including temperature played an important role in the life-history variation in sockeye salmon, and in governing their survival rate in marine environments.

DOI: 10.1111/j.1095-8649.2010.02711.x
http://onlinelibrary.wiley.com/doi/10.1111/j.1095-8649.2010.02711.x/full
KEYWORDS: climate; genetics; environment; migration; plasticity; salmon; survival; temperature

Reilly J and Schimmelpfennig D (2000). Irreversibility, uncertainty, and learning: Portraits of adaptation to long-term climate change. Climatic Change 45(1): 253-278.

The usefulness of adaptation strategies to changing climate depends on the characteristics of the system that must adapt. This paper identifies a set of fundamental characteristics of natural systems and social systems that help to make underlying assumptions in climate change adaptation studies explicit. It concludes that if empirical research is to resolve questions of adaptability, more careful specification of the exact measure of impact and far richer models of the process of adaptation, able to test implicit assumptions in much of the existing empirical research, are needed.

DOI: 10.1023/A:1005669807945
http://www.springerlink.com/content/t76622511466kwk2/
KEYWORDS: adaptation; agriculture; impact; timber

Reusch TBH, Ehlers A, Hammerli A and Worm B (2005). Ecosystem recovery after climatic extremes enhanced by genotypic diversity. Proceedings of the National Academy of Sciences of the United States

of America 102(8): 2826-2831.

Current-day climate change is characterised by increasing mean temperature and climate variability. Central to this idea lies understanding the way in which populations and communities cope with such extreme climatic conditions, and central to this is that species diversity can affect ecosystem function and resilience. Genotypic diversity can substitute the role of species diversity for species-poor ecosystems and thereby present a safeguard against extreme climatic events. Genotypic diversity of the seagrass Zostera marina was increased, enhancing biomass production, density and faunal abundance despite near-lethal water temperatures. Genotypic complementarity explained net biodiversity effects, with positive effects on invertebrate fauna suggesting genetic diversity has second-order effects which reach high trophic levels. This work emphasizes the need to maintain both genetic and species diversity to better enhance ecosystem resilience.

DOI: 10.1073/pnas.0500008102

http://www.pnas.org/content/102/8/2826.abstract

KEYWORDS: global change; ecosystem functioning; ecological resilience; seagrass; eelgrass Zostera marina; rocky intertidal community; genetic diversity; biodiversity; productivity; variability; climate change

Richards JG (2011). Physiological, behavioral and biochemical adaptations of intertidal fishes to hypoxia. Journal of Experimental Biology 214(2): 191-199.

Limited research attention has focused on the adaptive value of fish responses to hypoxia, across physiological, behavioural, biochemical and molecular level responses. This article provides a review of the use of phylogenetically corrected comparative methods which can be used to investigate the physiological and behavioural adaptations of organisms to hypoxia. The focal organisms consist of marine fishes from the family Cottidae (the sculpins) and the authors discuss their varitation in hypoxia tolerance, which is largely driven by gill surface area and the binding ability of red blood cells. The authors posit that the degree of metabolic rate suppression and the quality of stored energy is strongly selected for in hypoxia-tolerant fish.

DOI: 10.1242/jeb.047951

http://jeb.biologists.org/content/214/2/191.abstract

KEYWORDS: adaptations; behaviour; biochemical adaptation; Cottidae; fish; hypoxia; intertidal; physiology

Riebesell U, Kortzinger A and Oschlies A (2009). Sensitivities of marine carbon fluxes to ocean change. Proceedings of the National Academy of Sciences of the United States of America 106(49): 20602-20609.

The oceans play a vital role in the storage and transport of heat and the exchange of water and climate-relevant gases with the atmosphere. The oceans heat capacity is far greater than that of the atmosphere, and contains far more reactive carbon. Physical, chemical and biological processes of the ocean act to drive climatic variability on a range of scales. This work assesses the response of the seawater carbonate system and the ocean's physical and biological carbon pumps in ocean warming, acidification and carbonation, highlighting that many responses have feedback potential to the climate system. Accurate prediction of future climate change will depend on understanding these processes and their susceptibility to global change.

DOI: 10.1073/pnas.0813291106

http://www.pnas.org/content/106/49/20602.abstracT

KEYWORDS: climate change; marine carbon cycle; ocean acidification; ocean warming; dissolved organic-carbon; atmospheric CO2; phytoplankton growth; calcium-carbonate; partial-pressure; cycle

feedbacks

Rijnsdorp AD, Peck MA, Engelhard GH, Mollmann C and Pinnegar JK (2009). Resolving the effect of climate change on fish populations. Ices Journal of Marine Science 66(7): 1570-1583.

A framework is developed for studying climate change on fish populations that is based on first principles of physiology, ecology and available observations. Oceanographic and ecologically relevant environmental variables relevant to fish and likely to be affected by climate change are reviewed here. Hypotheses are derived from differences in response expected from different species groups. Data on north-Atlantic fish species are reviewed in relation to different biogeographic affinities, habitats and body size which lend support to hypothesized shifts in abundance and distribution as a result of global warming. Pelagic fish species show changes in migration patterns that correlate with climate-driven changes in zooplankton productivity. Lusitanian species have recently increased, particularly in northern limits, but Boreal species have decreased at the southern limits of their distribution while increasing at the northern ranges. The mechanisms behind this are uncertain but evidence suggest climate-driven changes in recruitment success may be an important factor.
DOI: 10.1093/icesjms/fsp056
http://icesjms.oxfordjournals.org/content/66/7/1570.abstract
KEYWORDS: climate change; eco-physiology; ecosystem; fish; population dynamics; individual-based models; marine ecosystems; trophic cascades; regime shifts

Rockstrom J, Steffen W, Noone K, Persson A, Chapin FS, Lambin EF, Lenton TM, Scheffer M, Folke C, Schellnhuber HJ, Nykvist B, de Wit CA, Hughes T, van der Leeuw S, Rodhe H, Sorlin S, Snyder PK, Costanza R, Svedin U, Falkenmark M, Karlberg L, Corell RW, Fabry VJ, Hansen J, Walker B, Liverman D, Richardson K, Crutzen P and Foley JA (2009). A safe operating space for humanity. Nature 461(7263): 472-475.

The stability of the Earth's ecosystem was relatively stable throughout the Holocene, but humans have since become dominant drivers in global environmental change; threatening this stability and having potentially catastrophic consequences. This work highlights a new approach for defining preconditions for human development, emphasizes that crossing certain biophysical thresholds could have disastrous consequences for humanity and reveals that three of nine interlinked planetary boundaries (i.e. the safe operating space for humanity with respect to the Earth system; associated with the planet's biophysical subsystems or processes) have already been overstepped.
DOI: 10.1038/461472a
http://www.nature.com/nature/journal/v461/n7263/full/461472a.html
KEYWORDS: social-ecological systems; human impact; biodiversity; climate; perspective; resilience; consequences; ecosystems; phosphorus; shifts

Roessig JM, Woodley CM, Cech JJ and Hansen LJ (2004). Effects of global climate change on marine and estuarine fishes and fisheries. Reviews in Fish Biology and Fisheries 14(2): 251-275.

Climate change is and will continue to influence marine and estuarine fish and fisheries on a global scale. Data shows effects that include increases in oxygen consumption for fishes, changes in foraging and migration in polar seas, and fish community changes in bleached reefs. Predictions of future conditions foreshadow additional impacts on fish distribution and abundance that are a result of relatively small changes in temperature. Changes in distribution and abundance of fish communities will have flow-on effects for humans who rely on harvest of these stocks, including coastal-based harvesters

(subsuistence, commercial and recreational).
Additionally, marine protected area boundaries, low-lying island countries that depend on coastal economies, and disease incidence are also affected by relatively small increases in temperature and sea level. There is increasing need to research the physiology and ecology of marine and estuarine fishes.
DOI: 10.1007/s11160-004-6749-0
http://www.springerlink.com/content/v25138090n302030/
KEYWORDS: climate change; fisheries; global climate change; adaptation; temperature; sea level rise

Rowan R (2004). Coral bleaching - Thermal adaptation in reef coral symbionts. Nature 430(7001): 742-742.

Increasing ocean temperatures cause coral bleaching due to loss of their symbiotic algae. These symbioses need to adapt to global warming if they are to survive. This work demonstrates that some corals have adapted to higher temperatures, partly by hosting specific Symbiodinium (symbiotic algae); and if other corals can follow this, they may be able to adapt to warmer temperatures easier. Throughout Guam, Pocillopora corals associate with at least two Symbiodinium taxa, with one appearing more temperature-tolerant. This work tested whether this was able by comparing photosynthetic response of the taxa. Observed differences observed are regarded as intrinsic symbiont adaptations which appear to contribute significantly to whole-coral physiology. These observations indicate that symbiosis recombination may be a possible mechanism through which corals adapt, in part, to global climate change.
DOI: 10.1038/430742a
http://www.nature.com/nature/journal/v430/n7001/full/430742a.html
KEYWORDS: climate change; coral bleaching; photoinhibition; photosynthesis; adaptation

Sales RFM (2009). Vulnerability and adaptation of coastal communities to climate variability and sea-level rise: Their implications for integrated coastal management in Cavite City, Philippines. Ocean & Coastal Management 52(7): 395-404.

Adopting a participatory research approach, the study examines the vulnerability of socioeconomic groups among the coastal population in Cavite City, Philippines, their current adaptation strategies and their adaptive capacity to cope with the impacts of climate variability and extremes and sea-level rise. Under a future scenario of a 1 m accelerated sea-level rise (ASLR), the study also looks into its potential effects on these urban coastal communities and ecosystems. In the context of poverty reduction and sustainable development, this study suggests a local framework for integrating adaptation strategies and actions into integrated coastal management (ICM) planning. It also recommends appropriate policy and institutional reform, capacity building and improved knowledge management towards increasing the resilience and adaptive capacity of these coastal communities to current and future climate risks.
DOI: 10.1016/j.ocecoaman.2009.04.007
http://www.sciencedirect.com/science/article/pii/S0964569109000246
KEYWORDS: climate change; sea-level rise; socioeconomic; adaptation strategy; policy; management

Salvadeo CJ, Lluch-Belda D, Gómez-Gallardo A, Urbán-Ramírez J and MacLeod CD (2010). Climate change and a poleward shift in the distribution of the Pacific white-sided dolphin in the northeastern Pacific. Endangered Species Research 11: 13-19.

Isotherms are shifting poleward as a result of climate-driven oceanic warming, which may cause

shifts in species range limits that are found in specific thermal ranges. A decline in the Pacific white-sided dolphin (Lagenorhynchus obliquidens) has occurred in the southwest Gulf of California (GOC) believed to be due to long-term changes in the local climate. Current knowledge is summarised and analysed in relations to Pacific white-sided dolphins in the GOC and sea surface temperature variability at regional scales.
DOI: 10.3354/esr00252
http://www.int-res.com/articles/esr2010/11/n011p013.pdf
KEYWORDS: climate change; pole-ward; marine mammals; California; distribution change

Sanford E and Kelly MW (2011). Local Adaptation in Marine Invertebrates. Annual Review of Marine Science 3(1): 509-535.

Until recently, local adaptation in the marine environment has received little attention, particularly in comparison to processes and documentation of local adaptation in terrestrial and freshwater environments. Local adaptation in marine environments has traditionally been viewed as rare, being limited to few species that have low dispersal potential. This article highlights a range of recent experimental studies which demonstrate that adaptive differentiation is occurring in many marine invertebrate species in response to selection which is imposed by strong environmental gradients. These findings offer important insights into adaptive divergence among populations occurring over a range of spatial scales, and knowledge can be inputted into management strategies for conserving marine ecosystems.
DOI: 10.1146/annurev-marine-120709-142756
http://www.annualreviews.org/doi/abs/10.1146/annurev-marine-120709-142756
KEYWORDS: adaptive differentiation; conservation; dispersal rates; environmental gradient; invertebrate; local adaptation; marine ecosystem; selection

Scheffer M, Carpenter S, Foley JA, Folke C and Walker B (2001). Catastrophic shifts in ecosystems. Nature 413(6856): 591-596.

Gradual climatic change, nutrient loading, habitat fragmentation and exploitation are experienced by all ecosystems, but nature typically responds to these small changes in a smooth manner. Studies on a variety of ecosystems indicate that smooth change can be interrupted by abrupt and drastic changes to a contrasting state. Recent work shows that loss of ecosystem resilience can provide the basis for a switch to an alternative state, and this work suggests focus on maintaining ecosystem resilience for sustainable management.
DOI: 10.1038/35098000
http://www.nature.com/nature/journal/v413/n6856/abs/413591a0.html
KEYWORDS: multiple stable states; grazing systems; phase-shifts; dynamics; climate; management; resilience; climate change

Smith LD, Gilmour JP and Heyward AJ (2008). Resilience of coral communities on an isolated system of reefs following catastrophic mass-bleaching. Coral Reefs 27(1): 197-205.

Climate change is expected to result in sea-water temperature increases, potentially causing more frequent and severe episodes of coral bleaching. This study assessed the impact of increased water temperatures at an isolated system of reefs by quantifying the benthic community changes over almost 10 years. Mass-coral bleaching which occurred in 1998 dramatically changed the reef community

structure, including a > 80% relative decrease in the cover of hard and soft corals and a twofold increase in the cover of algae (not including macroalgae). The scale of the impact varied among sites according to their initial cover and community structure, which appeared largely due to the differing susceptibilities of the dominant groups of hard corals. Successive increase in cover of these groups varied according to their life history traits, such as reproduction mode and growth rate. Furthermore, the increase in cover was correlated with the degree of the impact at different sites, signifying that recovery was driven by processes acting at local scales. Six years post bleaching, the hard corals had returned to approximately 40% of their pre-bleaching cover, but there was little change in the cover of soft corals, and the structure of most hard coral communities remained different to that prior to the bleaching event. This work offers insights into the degree to which coral communities are resilient to catastrophic disturbances, when they are isolated from other reef systems and yet not exposed to some of the stressors that affect many reefs worldwide.
DOI: 10.1007/s00338-007-0311-1
http://www.springerlink.com/content/260580034763w573/
KEYWORDS: coral bleaching; climate change; resilience; disturbance; Great Barrier Reef

Smith SV and Buddemeier RW (1992). Global Change and Coral Reef Ecosystems. Annual Review of Ecology and Systematics 23: 89-118.

This paper reviews coral reef ecosystem response to global change. Coral reefs are unique in that communities are supported by biogenic geologic structures of their own creation, providing a dimension of interaction between community and environment that is not present in most other ecosystems. This paper focuses mainly on the nature and directions of current or reliably anticipated environmental change-warming and sea level rise rather than the onset of an ice age, increases rather than decreases in ultraviolet light, etc. This work also centres on expected changes within the next century, instead of longer-term or less predictable effects. This assessment shares with most reef-oriented research an inherent bias for negative effects and stresses. Although future reef communities may spread to and flourish at sites not presently classified as coral reefs, direct observations or specific predictions of such occurrences are, and seem likely to remain, limited.
http://www.jstor.org/stable/2097283
KEYWORDS: global change; climate change; coral reefs;

Somero GN (2010). The physiology of climate change: how potentials for acclimatization and genetic adaptation will determine 'winners' and 'losers'. Journal of Experimental Biology 213(6): 912-920.

Through determination of which species live close to their upper thermal tolerance limits, which physiological systems set these limits and how species acclimatization capacities differ, physiological studies are able to help predict the impacts of climate change. Molecular-level studies contribute to this analysis by revealing how much change in sequence is required to adapt proteins to warmer temperatures. This provides insight into the rate of adaptive evolution. Congeneric invertebrates from thermally stressed rocky intertidal habitats have indicated that warm-adapted congeners are most susceptible to local extinction. This is due to acute upper thermal limits lying near current thermal maxima and their ability to acclimate is limited. Cardiac function collapse may underlie acute and long-term thermal limits, with heat-related death offset by in-migration of genetically warm-adapted conspecifics. Lesions in genomes of stenotherms are more challenged by adaptation such as in Antarctic marine ectotherms which have lost the ability to cope with increasing temperatures, which may not be able to cope with climate change impacts.
DOI: 10.1242/jeb.037473

http://jeb.biologists.org/cgi/content/abstract/213/6/912
KEYWORDS: acclimation; acclimatization; adaptation; biogeography; climate change; extinction; genome; global warming; intertidal zone; thermal adaptation; thermal tolerance limits; heat-shock proteins

Sorte CJB, Williams SL and Carlton JT (2010). Marine range shifts and species introductions: comparative spread rates and community impacts. Global Ecology and Biogeography 19(3): 303-316.

Global climate change has, and will continue to; shift species ranges, yet few studies have addressed the rates and consequences of these shifts in marine ecosystems. Considering there are ecological similarities between shifting and introduced species, this work examined how understanding range shifts may be informed by the (more-established) study of introduced species. Spread rates and impacts on recipient communities for 129 marine species experiencing range shifts were determined by meta-analysis. These data revealed that 75% of these range shifts were poleward, spread rates were lower than for introduced species, shifting species spread significantly faster in marine systems compared to terrestrial, and direction of community effects were mostly negative and magnitude similar between shifting and introduced species, although data were limited in this comparison.
DOI: 10.1111/j.1466-8238.2009.00519.x
http://onlinelibrary.wiley.com/doi/10.1111/j.1466-8238.2009.00519.x/abstract
KEYWORDS: Climate change; exotic species; introduced species; invasion; invasion; impacts; invasive; marine systems; non-indigenous species; range shift; spread rate; biodiversity

Sotka EE and Thacker RW (2005). Do some corals like it hot? Trends in Ecology & Evolution 20(2): 59-62.

Worldwide increases in ocean temperatures threaten resilience of coral reef ecosystems. Increases in temperature can cause coral bleaching which causes corals to lose their photosynthetic microalgal symbionts. There is evidence that proposes some corals may be able to resist future thermal stress by associating with particular genotypes, but these genotypes may provide less energy for growth when thermal stress are reduced. Resilience of coral reefs depends on whether phenotypic and genotypic changes in coral-algal associations can match predicted increases in thermal stress, as well as continuing efforts to lessen human impacts.
DOI: 10.1016/j.tree.2004.11.015
http://www.cell.com/trends/ecology-evolution/abstract/S0169-5347(04)00345-3
KEYWORDS: adaptive bleaching hypothesis; climate change; reef ecosystems; algal symbionts; susceptibility; resilience

Soto CG (2001). The potential impacts of global climate change on marine protected areas. Reviews in Fish Biology and Fisheries 11(3): 181-195.

There is a notable lack of literature relating to the potential impacts of global climate change on marine protected areas. This paper reviews literature on protected areas, conservation biology, marine ecology, oceanography and climate change – looking at differences between marine and terrestrial environments, and discussing framework and classification systems used in design of protected areas. Important oceanic processes and their links to the food chain are also reviewed. Species abundance and distribution are predicted to change in the face of climate change, potentially compromising their goal in protecting biodiversity. Further interdisciplinary research and linked models, more protected areas and research sites for investigating fishing effects, a temporally responsive approach to siting new management strategies and large-scale management are needed to properly address competing ocean

use issues such as climate change and pollution.
DOI: 10.1023/A:1020364409616
http://www.springerlink.com/content/xm6h8825695451q3/
KEYWORDS: climate change; global warming; Marine Protected Areas; planning; regime shift; species distribution; biodiversity; California current; conservation; ecosystems

Spence BC and Hall JD (2010). Spatiotemporal patterns in migration timing of coho salmon (Oncorhynchus kisutch) smolts in North America. Canadian Journal of Fisheries and Aquatic Sciences 67(8): 1316-1334.

The migration of juvenile salmon from freshwater to marine environments is thought to be an adaptation to increase survival rates during this period of life transition. This article examined the peak timing, duration and variation in timing of salmon migrations between the Californian and Alaskan regions. The authors discovered a strong latitudinal gradient in migration patterns and identified three major population groupings which correlated with major coastal marine locations in the northern Pacific Ocean. Salmon demonstrated adaptation to differences in timing and predictability in favourable conditions within the marine regions that they enter.
DOI: 10.1139/F10-060
http://www.nrcresearchpress.com/doi/abs/10.1139/F10-060
KEYWORDS: adaptation; climate change; marine environment; migration; North America; Pacific Ocean; salmon

Steele JH (1998). Regime shifts in marine ecosystems. Ecological Applications 8(1): S33-S36.

Marine time scales are responsive to decadal scale physical environment alterations, implying difficulty in defining baseline states for these systems. Furthermore, regime shifts in fish communities can result in major economic consequences, but without representing ecological disasters. Natural and anthropogenic causes driving climatic changes at decadal scales are likely to either produce or enhance regime shifts, with different challenges for management in different sectors. Coastal zones require integration of land and sea management while open oceans are essential for climate prediction and therefore eventual management. Additionally, our use of resources between these two systems – continental shelf seas – requires the ability to be able to distinguish between human and natural cases of long-term change.
http://www.jstor.org/stable/2641361
KEYWORDS: ecological fungibility; fisheries; management; regime shifts; sustainability; decadal scale

Steele JH (2004). Regime shifts in the ocean: reconciling observations and theory. Progress in Oceanography 60(2-4): 135-141.

This paper reviews issues discussed at the Villefranche Workshop in 2003. The term ‘regime’ shift’ was first restricted to spatial or temporal links between climatic indices and population abundance. Evidence for physical-biological relations has allowed a better understanding of the decadal scale variability in marine ecosystems, although it is still difficult to define the trophic pathways that produce the correspondence between climatic indices and population abundance. Comparisons between oceanic systems subject to a variety of perturbations or stress are needed to identify the causal connections. Overfishing in different marine regimes was the primary focus of this Workshop, since the consequences of these large-scale community structure changes provide valuable case studies. This work considered aspects such as the associated benefits of maximising ecosystem resilience, and

discussed the consequences of these.
DOI: 10.1016/j.pocean.2004.02.004
http://www.sciencedirect.com/science/article/pii/S0079661104000242
KEYWORDS: regime shifts; resilience; alternative stable states; climate change; stable states; fish stocks

Steneck RS, Graham MH, Bourque BJ, Corbett D, Erlandson JM, Estes JA and Tegner MJ (2002). Kelp forest ecosystems: biodiversity, stability, resilience and future. Environmental Conservation 29(4): 436-459.

This paper reviews global kelp forests, with respect to the various aspects of their decline. Case studies are included primarily from southern California, the Aleutian Islands and the western North Atlantic. Global distribution is constrained by latitude, nutrients, temperature and other macrophytes; with threats coming from overgrazing by sea urchins which are often caused by overfishing and local extinction of urchin primary predators, and can lead to widespread kelp deforestation. Sea urchin harvesting has lead to kelp forests returning in some areas, but these systems are still devoid of apex predators, which can change community dynamics. Although climate change does impact on kelp forest ecosystems, overfishing of key predators appears to be the largest manageable threat to these ecosystems. Management direction should be on reduction of fishing impacts along with restoration of functionally important species populations within these ecosystems.
DOI: 10.1017/s0376892902000322
http://journals.cambridge.org/action/displayAbstract?fromPage=online&aid=142451
KEYWORDS: apex predators; biodiversity; herbivory; human interactions; kelp; trophic cascades; sea-urchins; giant-kelp; community structure; macroalgal assemblages; biodiversity; stability; resilience

Stern NH, Ed. (2007). The Economics of Climate Change: the Stern Review, Cambridge University Press.

This review of the economic effects of climate change was carried out by Sir Nicholas Stern, Head of the Government Economic Service and former World Bank Chief Economist. The first half focuses on the impacts and risks arising from uncontrolled climate change, and on the costs and opportunities associated with action to tackle it, and the second half of the examines the national and international policy challenges of moving to a low-carbon global economy.
http://www.cambridge.org/gb/knowledge/isbn/item1164284/?site_locale=en_GB
KEYWORDS:

Stuart-Smith RD, Barrett NS, Stevenson DG and Edgar GJ (2009). Stability in temperate reef communities over a decadal time scale despite concurrent ocean warming. Global Change Biology 16(1): 122-134.

Few empirical data on community-level response to global warming are available for temperate reefs despite escalating concerns for potential climate-driven impacts on marine ecosystems. Decadal and regional changes in temperate subtidal reefs are described for Tasmanian rocky reefs; in an area which has undergone considerable warming and is considered a 'hotspot' for future oceanic warming. Plant and animal communities were censused from 136 rocky reef communities in 1992-1995 and again in 2006-07. Reef communities appeared relatively stable, with multivariate and univariate metrics of biotic communities revealing few changes with time, although some species may exhibit responses symptomatic of ocean warming including fish species only detected in recent surveys (indicative of range expansion) and species with warmer-water affinities appearing to extend distributions further south. Change in species abundances were statistically significant and not related to biological affinities, possessing lower to mid-range abundances rather than being common – with implications for

monitoring and management. This work suggests a time of relative stability following a more abrupt change and proposes that community responses to ocean warming may follow non-linear, step-like trajectories.
DOI: 10.1111/j.1365-2486.2009.01955.x
http://onlinelibrary.wiley.com/doi/10.1111/j.1365-2486.2009.01955.x/full
KEYWORDS: climate change; biodiversity; decadal scale; rocky reef; stability; species-level response; range expansion

Talmage SC and Gobler CJ (2009). The effects of elevated carbon dioxide concentrations on the metamorphosis, size, and survival of larval hard clams (Mercenaria mercenaria), bay scallops (Argopecten irradians), and Eastern oysters (Crassostrea virginica). Limnology and Oceanography 54(6): 2072-2080.

Three species (M. mercenaria, A. irradians, and C. virginica) of shellfish were maintained in tanks with the CO2 concentration predicted to be reached by the end of the century (66 Pa CO2, the current being 39 Pa CO2). Reduced growth and delayed development were observed in all species, while survival was differently affected among species. The survival of M. mercenaria and A. irradians was reduced by more than 50% under 66 Pa CO2, while C. virginica had to be exposed to 152 Pa CO2 (expected by 2250) to undergo a similar survival reduction. The impact of acidification on the larval stages of these shellfish species raise concerns about the future of the industries and ecosystems depending on them.
DOI:10.4319/lo.2009.54.6.2072
http://www.aslo.org/lo/toc/vol_54/issue_6/2072.html
KEYWORDS: ocean acidification; shellfish; larval growth; survival; development; clams; scallops; oysters; industry; aquaculture; ecosystem

Thrush SF, Hewitt JE, Dayton PK, Coco G, Lohrer AM, Norkko A, Norkko J and Chiantore M (2009). Forecasting the limits of resilience: integrating empirical research with theory. Proceedings of the Royal Society B-Biological Sciences 276(1671): 3209-3217.

There is little work focusing on the resilience that provides resistance against ecosystem regime shifts to undesirable states. Increased variance may help predict a regime shift, but this type of modelling requires long-term data sets and knowledge of functional links between key processes. Although field-based research exists for understanding resilience, experimental studies are lagging behind theory, management and policy requirements. Ecological resilience needs understanding in terms of community dynamics and the potential for shifts in environmental force to break the feedbacks that maintain resilience. Theory and empirical data are combines to understand potential thresholds in resilience, and therefore the potential for regime shifts. Predictive information is more useful for management to implement ecosystem-based approaches.
DOI: 10.1098/rspb.2009.0661
http://rspb.royalsocietypublishing.org/content/276/1671/3209.full.pdf+html
KEYWORDS: regime shift; resilience; intrinsic dynamics; coastal ecosystems; regime shifts; marine ecosystems; ecological-systems; community structure; habitat loss; biodiversity; disturbance; diversity

Tirado MC, Clarke R, Jaykus LA, McQuatters-Gollop A and Frank JM (2010). Climate change and food safety: A review. Food Research International 43(7): 1745-1765.

This article provides a review on the proposed impacts of climate change on food contamination and global food safety issues across multiple stages of the food chain. The authors identify adaptation

strategies that need to be adopted, and future research directions which aim to address global climate change-induced food safety issues.
DOI: 10.1016/j.foodres.2010.07.003
http://www.sciencedirect.com/science/article/pii/S0963996910002231
KEYWORDS: adaptation; climate change; contamination; food safety; fisheries; industry; monitoring; risk assessment; surveillance

Tobey J, Rubinoff P, Robadue D, Ricci G, Volk R, Furlow J and Anderson G (2010). Practicing Coastal Adaptation to Climate Change: Lessons from Integrated Coastal Management. Coastal Management 38(3): 317 - 335.

Coastal ecosystems are under increasing threats from the impacts of climate change and other anthropogenic activities. Developing nations are expected to experience greater impacts on their coastal ecosystems than developed nations, as the challenges faced in adapting to climate change will be significantly greater for developing nations that must also combat issues associated with population growth, inadequate infrastructure and declining natural resources. This article provides an overview of the challenges faced by the world's coastal regions in light of current and predicted climate change scenarios, and discusses best practices for coastal adaptation processes and challenges which may arise.
DOI: 10.1080/08920753.2010.483169
http://www.informaworld.com/smpp/content~content=a922680468~db=all~jumptype=rss
KEYWORDS: adaptation; climate change; coastal adaptation; climate divide; developed and developing nations; global warming; management

Tol RSJ (2009). The Economic Effects of Climate Change. Journal of Economic Perspectives 23(2): 29-51.

This study reviews the current knowledge of the economic costs of climate change, based on the 14 published estimates of welfare impact (%GDP) as a function of global warming. Results indicate an initial increase in welfare with increasing temperature, followed by a decreasing, and eventually negative trend, when the temperature increase reaches +2°C. Furthermore, although welfare loss may appear moderated on a global scale, the impacts are expected to be more pronounced in poor countries. The need for more estimates of the costs of climate change to improve policy management procedures is discussed.
http://www.aeaweb.org/articles.php?doi=10.1257/jep.23.2.29
KEYWORDS: climate change; costs; welfare; global warming; carbon tax; economic development

Tompkins EL and Adger WN (2004). Does adaptive management of natural resources enhance resilience to climate change? Ecology and Society 9(2): 14.

Insights from adaptive and community-based management suggest that resilience-building of human and ecological systems is important in coping with climate-driven change and uncertain risks. These emerging insights have implications for policy and strategy directed at responding to climate change. Perspectives on collective action for natural resource management are reviewed in terms of being able to understand climate response capacity. Social learning in relation to acceptance of strategies that build social and ecological resilience is fundamentally important. Societies and communities that depend on natural resources need to enhance capacity to adapt to climate change impacts. This is illustrated using a case study in Trinidad and Tobago and demonstrates community-based adaptive management by building networks important for coping with extreme

events and retaining ecosystem resilience.
http://www.ecologyandsociety.org/vol9/iss2/art10
KEYWORDS: resilience; collective action; coral reefs; vulnerability; community; sustainability; conservation; impacts; policy; adaptive management; adaptation; climate change

Tompkins EL and Adger WN (2005). Defining response capacity to enhance climate change policy. Environmental Science & Policy 8(6): 562-571.

Climate change adaptation and mitigation decisions made by governments are usually taken in different policy domains. At the individual level however, adaptation and mitigation activities are undertaken together as part of the management of risk and resources. This paper proposes that a useful starting point to develop a national climate policy is to understand what societal response might mean in practice. The authors argue that the ability to respond to climate change is both enabled and constrained by social and technological conditions. The ability of society to respond to climate change and the need for technological change for both decarbonisation and for dealing with surprise in general, are central to concepts of sustainable development.
DOI: 10.1016/j.envsci.2005.06.012
http://www.sciencedirect.com/science/article/pii/S146290110500105X
KEYWORDS: adaptation; mitigation; climate change policy; risk; technology; social; change; response capacity

Trebilco R, Halpern BS, Flemming JM, Field C, Blanchard W and Worm B (2011). Mapping species richness and human impact drivers to inform global pelagic conservation prioritisation. Biological Conservation 144(5): 1758-1766.

The prioritization of conservation efforts across the world's marine areas has gained momentum over the past decade, with areas of coastal ecosystems receiving substantial assessment and conservation prioritizations, while areas of open ocean have received limited development in conservation strategies in comparison. This article examines relationships between pelagic biodiversity, fishing pressure and increases in sea surface temperature in tropical to temperate ocean regions in order to identify the top 50 hotspot areas for species richness and the two impact drivers. Results demonstrate that the impact drivers correlate with high species richness; greater fishing pressure positively correlates with species richness in several regions across the Indian and Pacific Oceans, and species richness is higher in areas which have experienced minimal changes in sea surface temperature. The authors conclude that regional-based conservation efforts which aim to protect areas of high species diversity may be possible with minimal effects to fishing effort in these areas.
DOI: 10.1016/j.biocon.2011.02.024
http://sd.ddns.us/science/article/pii/S0006320711000942
KEYWORDS: billfish; climate change; conservation; fisheries; hotspots; management; marine; pelagic; sea surface temperature; tuna

Tribbia J and Moser SC (2008). More than information: what coastal managers need to plan for climate change. Environmental Science & Policy 11(4): 315-328.

Climate change and sea-level rise (SLR) increasingly threaten the world's coastlines, managers will need to plan and implement adaptation measures to cope with these impacts in order to continue to protect the economic, social, and environmental security of the state and of local communities. This paper explores the information needs of California coastal managers as they begin confronting the

growing risks from climate change. This study can be placed in the broader context of how science can best support policy-makers and resource managers as they begin to plan and prepare for adaptation to climate change. It illustrates the strong need for boundary organizations to serve various intermediary functions between science and practice, especially in the context of adaptation to global climate change impacts.
DOI: 10.1016/j.envsci.2008.01.003
http://www.sciencedirect.com/science/article/pii/S1462901108000130
KEYWORDS: climate change; sea-level rise; coastal impacts; coastal zone; management; information needs; boundary organization

Troadec JP (2000). Adaptation opportunities to climate variability and change in the exploitation and utilisation of marine living resources. Environmental Monitoring and Assessment 61(1): 101-112.

Since fisheries, aquaculture and other uses of marine renewable resources and environment contribute little to climate change, they have restricted means to mitigate the impacts of climate change, highlighting the importance of adaptation. Adaptation strategies should target enhancing resilience of marine renewable resources and their uses as well as the current capacity to respond to unexpected events. Two complementary strategies for adaptation exist; adjusting conventional management systems to resource scarcity; and reduction of current resource constraint by aquaculture development and better utilization of fishery and aquaculture harvests. In light of this work, climate change acts to enhance exiting priorities of environment and fisheries management and aquaculture development.
DOI: 10.1023/A:1006322303247
KEYWORDS: climate change; fisheries; resilience; adaptation; management

Turner RA, Cakacaka A, Graham NAJ, Polunin NVC, Pratchett MS, Stead SM and Wilson SK (2007). Declining reliance on marine resources in remote South Pacific societies: ecological versus socio-economic drivers. Coral Reefs 26(4): 997-1008.

Detrimental effects of degraded coral reef ecosystems on goods and services which humans rely are expected to have significant socio-economic impacts, particularly on isolated tropical islands which rely heavily on these reefs. This work investigates socio-economic changes, particularly in fresh fish consumption and fishing activities, related to environmental degradation at 5 fishing grounds in Fiji. Interviews with fishers and senior household members showed that the importance of fishing was low compared to other professions, and consumption of fresh fish had declined over the past decade. Reduced fishing and choice of fresh fish is loosely attributable to an amplified need to derive income as well as novel income-generating prospects. A potential consequence of reduced reliance on marine resources includes limited awareness of current climate-induced environmental degradation including coral bleaching and outbreaks of coral-feeding crown-of-thorns starfish. Low reliance on marine resources might grant greater flexibility to adapt to future ecological change in the marine environment. Changes in fish consumption and exploitation of resources appear connected to socio-economic features rather than a consequence of recent environmental degradation. Increased knowledge of the dynamics behind change in marine resource use is essential for understanding society response to ecological and socio-economic change, as well as for identifying opportunities for adaptive sustainable ecosystem management.
DOI: 10.1007/s00338-007-0238-6
http://www.springerlink.com/content/y4610q408326414q/
KEYWORDS: Fiji; fishing practices; coral reefs; social-ecological systems; socio-economic drivers;

environmental change; adaptation; management

Valsson T and Ulfarsson GF (2009). Adaptation and Change with Global Warming Emerging Spatial World Structure and Transportation Impacts. Transportation Research Record(2139): 117-124.

This paper discusses economic activity and habitation in relation to the new spatial structure of the Earth and the impacts that human-induced polar ice retreat present for resource development and shipping routes. The greatest impact on global marine transportation arises as all-year shipping develops in the Arctic, eventually leading to most transportation between the North Atlantic and the North Pacific passing through the Arctic Ocean. This has consequences for transportation, security, and natural resource use. It also holds geopolitical significance, since it provides alternative routes to Panama or Suez Canal shipping.
DOI: 10.3141/2139-14
http://pubsindex.trb.org/view.aspx?id=880897
KEYWORDS: climate change; spatial structure; human impact; marine transport; polar ice retreat

Veron JE, Hoegh-Guldberg O, Lenton TM, Lough JM, Obura DO, Pearce-Kelly P, Sheppard CR, Spalding M, Stafford-Smith MG and Rogers AD (2009). The coral reef crisis: the critical importance of <350 ppm CO2. Mar Pollut Bull 58(10): 1428-1436.

The causes and consequences of global coral bleaching are reviewed. Mass bleaching events related to El Nino phases, CO2-induced acidification, water quality decrease and severe weather events are among the main causes identified. The consequences for reef ecosystems are expected to be dramatic, with a reduced biodiversity, negative impacts on early stages of organisms using coral reefs as nursery grounds, and a domino effect expected to impact other marine ecosystems. The authors suggest that anthropogenic CO2 may be responsible for the Earth's sixth mass extinction.
DOI: 10.1016/j.marpolbul.2009.09.009
http://www.ncbi.nlm.nih.gov/pubmed/19782832
KEYWORDS: coral reef; climate change; bleaching; Acidification; El Nino; mass extinction; biodiversity loss; domino effect

Walker B, Holling CS, Carpenter SR and Kinzig A (2004). Resilience, adaptability and transformability in social-ecological systems. Ecology and Society 9(2): 9.

The concept of ecosystem resilience has received much interest since Holling's (1973) work; however there is still confusion over interpretation over what is actually meant by the term resilience. There are 3 related attributes thought to determine future trajectories of social-ecological systems (SES): resilience, adaptability and transformability. Resilience is the capacity of a system to absorb disturbance and reorganise in the face of change, and has 4 components (latitude, resistance, precariousness and panarchy). Adaptability describes the capacity of actors within a system to influence its resilience. Transformability relates to a systems capacity to create a fundamentally new system when the existing one becomes weak due to ecological, economic or social structure influences. Interpretation of SES dynamics in this fashion has implications for sustainability science including focus on resilience analysis, adaptive resource management and adaptive governance.
http://www.ecologyandsociety.org/vol9/iss2/art5/
KEYWORDS: resilience; social-ecological; adaptation; transformability; disturbance; management

Walker PJ and Mohan CV (2009). Viral disease emergence in shrimp aquaculture: origins, impact and the effectiveness of health management strategies. Reviews in Aquaculture 1(2): 125-154.

This paper reviews the causes and consequences of viral disease in global shrimp aquaculture. Inadequate management in this industry (e.g. lack of mitigation, species displacements from their natural environment, over-population of tanks, individuals subjected to water quality and temperature stresses) has resulted in the increased virulence of existing infections and the emergence of new pathogens, putting at risk the livelihood of poor shrimp farming communities in Asia. This study further reviews pre-existing disease management strategies, discusses their effectiveness, and indicates potential improvements facilitated by recent technological advancements (eg anti-virals, infrastructure and development strategies). The authors conclude by discussing the need for a change of attitude from all stakeholders, from farmers to policy makers. The application of adequate management strategies will come to a cost and will require willingness from all stakeholders, but will result in increased profits and long term environmental sustainability in the shrimp aquaculture.
DOI:10.1111/j.1753-5131.2009.01007.x
http://onlinelibrary.wiley.com/doi/10.1111/j.1753-5131.2009.01007.x/pdf
KEYWORDS: aquaculture; industry; viral disease; adaptation; mitigation; management; shrimp; stakeholders; policy

Wang MY, Overland JE and Bond NA (2010). Climate projections for selected large marine ecosystems. Journal of Marine Systems 79(3-4): 258-266.

The ability of 23 coupled atmosphere-ocean general circulation models to reproduce observations of variables relevant to selected large marine ecosystems was evaluated, along with the predictions from a subset of selected models for the 21st century under the A1B IPCC emission scenario. About half of the models were found able to reproduce large-scale variations of the historical observations, while the remainder were characterized by a high degree of uncertainty. Results suggest the need for focused studies on several uncertain geographical regions, and increased global modeling efforts in the future.
DOI: 10.1016/j.jmarsys.2008.11.028
http://www.sciencedirect.com/science/article/pii/S0924796309000839
KEYWORDS: model validation; IPCC; model uncertainty; climate change; GCM; model prediction

Watson SA, Southgate PC, Tyler PA and Peck LS (2009). Early Larval Development of the Sydney Rock Oyster Saccostrea Glomerata under near-Future Predictions of CO2-Driven Ocean Acidification. Journal of Shellfish Research 28(3): 431-437.

The larval growth and survival of the Sydney rock oyster (Saccostrea glomerata) were measured in tanks under different pH conditions. CO2 was added to seawater at different concentrations resulting in three pH conditions: 8.1 (control), 7.6 and 7.8 (range predicted in the surface ocean by 2100). Compared to the control experiment, the growth (ca -8% at pH 7.6) and especially the survival (-72% at pH 7.6) of S. glomerata larvae were reduced under lower pH conditions. Acidified conditions resulted in developmental abnormalities and increased shell dissolution (compared to the control experiment, 90% less shells remained from dead larvae at pH 7.6). These results indicate that the Sydney rock oyster industry, with $34.5 million in annual sales, is expected to be severely impacted by 2100.
DOI:10.2983/035.028.0302
http://www.bioone.org/doi/abs/10.2983/035.028.0302
KEYWORDS: ocean acidification; climate change; oyster; larval growth; larval survival; industry; calcification; dissolution; tolerance

Webster M, Forest C, Reilly J, Babiker M, Kicklighter D, Mayer M, Prinn R, Sarofim M, Sokolov A, Stone P and Wang C (2003). Uncertainty analysis of climate change and policy response. Climatic Change 61(3): 295-320.

To aid climate policy decisions, accurate quantitative descriptions of the uncertainty in climate outcomes under various possible policies are needed. This paper applies an earth systems model to describe the uncertainty in climate projections under two different policy scenarios. The results show that in the absence of greenhouse gas emissions restrictions, there is a one in forty chance that global mean surface temperature change will exceed 4.9°C by the year 2100. A policy case with aggressive emissions reductions over time lowers the temperature change to a one in forty chance of exceeding 3.2°C, thus reducing but not eliminating the chance of substantial warming.
DOI: 10.1023/B:CLIM.0000004564.09961.9f
http://web.mit.edu/globalchange/www/MITJPSPGC_Rpt95.pdf
KEYWORDS: sea-level rise; model; sensitivity; projections; emissions; climate change; policy

Welladsen HM, Southgate PC and Heimann K (2010). The effects of exposure to near-future levels of ocean acidification on shell characteristics of Pinctada fucata (Bivalvia: Pteriidae). Molluscan Research 30(3): 125-130.

Adult pearl oysters (P. fucata) were subjected to acidified water (pH 7.6) in tanks for 28 days. Compared to individuals kept in control tanks (pH 8.1), the shell of individuals were ca 25% weaker, suggesting that the shells' structural integrity was compromised by dissolution. The sensitivity of pearl oyster shells to such small reduction in pH indicates the potentially devastating impacts of ocean acidification on pearl aquaculture by the end of 2100.
ISSN: 1323-5818
http://www.mapress.com/mr/content/v30/2010f/n3p130.pdf
KEYWORDS: Pearl oyster; climate change; acidification; calcification; pearl industry; vulnerability

Wernberg T, Russell BD, Moore PJ, Ling SD, Smale DA, Campbell A, Coleman MA, Steinberg PD, Kendrick GA and Connell SD (2011). Impacts of climate change in a global hotspot for temperate marine biodiversity and ocean warming. . Journal of Experimental Marine Biology and Ecology 400: 7-16.

Temperate Australia has been identified as a global hotspot for marine biodiversity, while ocean warming in this region has exceeded the global average warming rate. This review presents the observed impacts of climate stressors (i.e. temperature, trophodynamics, ocean acidification, storm patterns, rainfall, run-off, nutrients, desease) and non-climate stressors (i.e. fishing and harvesting, introduced species) on Australian subtidal temperate coasts and likely system responses to these impacts. The review presents data on range contractions, range extensions and reduced recruitment on some key marine species in temperate Australia. While there appears to be less observed climate-induced change on other coastlines around Australia, the authors posit that this is likely due to a lack of data rather than a lack of change. Recent experiments suggest that the impacts of both climate and non-climate stressors will lower the resilience of temperate marine communities to stresses including storms, diseases and introduces species, and the authors highlight the importance of management approaches at local and regional-scale levels in an attempt to increase the resilience of temperate marine communities to climate stressors.
DOI: 10.1016/j.jembe.2011.02.021
http://oceanacidification.wordpress.com/2011/03/14/impacts-of-climate-change-in-a-global-hotspot-fo

r-temperate-marine-biodiversity-and-ocean-warming/
KEYWORDS: climate change; community ecology; global warming; macroalgae; management; multiple stressors; phase shift; range contraction; range extension

Whiteley NM, Rastrick SPS, Lunt DH and Rock J (2011). Latitudinal variations in the physiology of marine gammarid amphipods. Journal of Experimental Marine Biology and Ecology 400(1-2): 70-77.

The latitudinal distribution patterns of species in coastal marine environments are often driven by temperature-related factors. The physiological and biochemical adaptations of ectothermic species to latitudinal temperature change have been shown to influence their distribution patterns. This study investigated the physiological capabilities of amphipod distributions along a natural thermal gradient in the Atlantic and Arctic Oceans. Temperature-adaptive responses of metabolic rates and muscle contractibility were examined across molecular and whole animal levels. Results demonstrated species-specific physiological variation as a function of latitude, providing important information on each species' ability for physiological adaptation in order to maintain function in response to global temperature increases.
DOI: 10.1016/j.jembe.2011.02.027
http://www.sciencedirect.com/science/article/pii/S002209811100075X
KEYWORDS: adaptations; amphipod; biochemical; climate change; coastal environment; distribution; latitude; marine; physiology; variation

Wielgus J, Sala E and Gerber LR (2008). Assessing the ecological and economic benefits of a no-take marine reserve. Ecological Economics 67(1): 32-40.

The management of marine resources is often impeded by a lack of models to integrate ecological and economic information on exploited populations. This paper used available biological and economic data for an overexploited population of the leopard grouper to study if closing parts of the population to fishing would allow sustainable use and maximum economic benefits. The results suggest that fishing should be closed in all spawning areas and in at least 50% of the adjacent areas. High non-consumptive benefits would be achieved with large closures because the abundance of the leopard groupers would increase. An adaptive management scheme could provide a way to incorporate newly available information into management decisions for the no-take reserve.
DOI: 10.1016/j.ecolecon.2008.04.019
http://www.sciencedirect.com/science/article/pii/S0921800908002073
KEYWORDS: adaptive management; bioeconomics; fisheries; groupers; gulf of California; marine protected areas; marine reserves; modeling

Wilkinson C and Brodie J (2011). Catchment Management and Coral Reef Conservation: a practical guide for coastal resource managers to reduce damage from catchment areas based on best practice case studies. Global Coral Reef Monitoring Network and Reef and Rainforest Research Centre. Townsville, Australia.

This book reviews and discusses management procedures for coral reefs and coastal ecosystems, with a focus on the problem of catchment areas neighboring zones under management. Catchment areas are locations channeling freshwater of terrestrial and atmospheric origin and are characterized by their inputs of sediments and nutrients to a given ecosystem. The increase in anthropogenic sediments, nutrients, pollutants and freshwater inputs are threatening coastal ecosystems. This book highlights the need for better management procedures of catchment areas,

through 11 specific recommendations to managers based on the analysis of 33 case studies.
ISBN 0 642 322228 7
http://www.reefbase.org/resource_center/publication/main.aspx?refid=77359&referrer=GCRMN
KEYWORDS: climate change; coastal ecosystem; reef ecosystem; catchment area; management procedures

Willis KJ, Bennett KD, Bhagwat SA and Birks HJB (2010). 4° C and beyond: what did this mean for biodiversity in the past? Systematics and Biodiversity 8(1): 3-9.

This article focuses on time intervals in the fossil records when CO2 concentrations were as high as 1200 ppmv, temperatures in mid to high latitudes increased more than 4 degrees C within 60 years and se levels were 3 m higher than present. For these time intervals, studies examining past biotic responses are presented demonstrating the scale and impact of the extent and rate of such climate change on biodiversity. Despite causal mechanisms responsible for these changes in climate being different (i.e. natural processes as opposed to anthropogenic), the rates and extent of climate change are comparable to those predicted for the future and consequently potentially relevant to understanding future responses. Evidence reveals rapid community turnover, migrations, development of novel ecosystems and thresholds from one stable ecosystem state to another, however there is little evidence for broad-scale extinctions due to climate warming. Recommendations for future climate-change integrated conservation strategies are presented here.
DOI: 10.1080/14772000903495833
http://biblioteca.universia.net/html_bura/ficha/params/id/52412857.html
KEYWORDS: biodiversity; climate warming; community turnover; conservation; fossil records; historical records; increasing CO2; migration; persistence; thresholds; resilience; climate change

Wilson SK, Adjeroud M, Bellwood DR, Berumen ML, Booth D, Bozec YM, Chabanet P, Cheal A, Cinner J, Depczynski M, Feary DA, Gagliano M, Graham NAJ, Halford AR, Halpern BS, Harborne AR, Hoey AS, Holbrook SJ, Jones GP, Kulbiki M, Letourneur Y, De Loma TL, McClanahan T, McCormick MI, Meekan MG, Mumby PJ, Munday PL, Ohman MC, Pratchett MS, Riegl B, Sano M, Schmitt RJ and Syms C (2010). Crucial knowledge gaps in current understanding of climate change impacts on coral reef fishes. Journal of Experimental Biology 213(6): 894-900.

Expert opinion identified critical gaps in understanding climate change impacts on coral reef fishes. Relevant scientists were asked to propose 5 questions that, if addressed, would improve understanding of climate change on reef fishes. Thirty three scientists provided 155 questions, with 32 of these scoring questions in terms of: (i) identifying a gap in knowledge, (ii) achievability, (iii) applicability to a broad spectrum of species and reef habitats, and (iv) priority. Forty-two percent of questions were linked to habitat associations and community dynamics of fish, reflecting the recognized effects and concern involving climate-induced coral loss and habitat degradation. Other questions concerned fish demographics, physiology, behaviour and management, all of which could be affected by climate change. Irrespective of their expertise and background, scientists scored questions from diverse topics similarly, suggesting limited prejudice and identified the need for increased interdisciplinary and collaborative research. Presented here are the 53 highest-scoring unique questions. The highest scoring questions are presented and should act as a guide for directing future research, providing a foundation for better evaluation and management of climate change impacts on coral reefs and associated fish communities.
DOI: 10.1242/jeb.037895
http://jeb.biologists.org/cgi/content/abstract/213/6/894

KEYWORDS: ecosystem management; fisheries; coral reef ecology; physiology; behaviour; conservation; global warming; ocean acidification; coral bleaching; climate change; adaptation

Woerdman E, Ed. (2004). The institutional economics of market-based climate policy, Elsevier.

The objective of this book is to analyse the institutional barriers to implementing market-based climate policy, as well as to provide some opportunities to overcome them. The approach is that of institutional economics, with special emphasis on political transaction costs and path dependence.
http://books.google.com.au/books?id=oZ7xeYMft-wC&printsec=frontcover&dq=The+institutional+economics+of+market-based+climate+policy+-+woerdman&source=bl&ots=FstQbb4e6n&sig=veeVV4lMvuMaop18w3K5bnBXXV0&hl=en&ei=5k8ITZv_B8OxrAf_qMTVDg&sa=X&oi=book_result&ct=result&resnum=1&ved=0CBUQ6AEwAA#v=onepage&q&f=false
KEYWORDS: policy; economics; climate

Wooldridge S, Done T, Berkelmans R, Jones R and Marshall P (2005). Precursors for resilience in coral communities in a warming climate: a belief network approach. Marine Ecology-Progress Series 295: 157-169.

This work investigates the benefit of successful management interventions on coral reefs during the climate change associated warming that is predicted to occur in the near future. A prototype decision-support tool, called 'ReefState' was developed to aid this task. This tool integrates management intervention outcomes within a 'belief network' of linked variables that describe future warming, coral damage and recovery. The central Great Barrier Reef, Australia, is used as a case study, with worst case scenarios predicting that reefs will become devoid of coral cover and associated biodiversity by 2050. Under lower rates of warming, the persistence of hard coral dominated reefs beyond 2050 will still rely on the ability of corals to adapt thermal tolerance and management that produces local condition constraining excessive algal biomass during inter-disturbance intervals. Local-scale management of ecological factors will be of critical importance in shaping the future trajectories of coral reef ecosystems, despite global warming impacts.
http://www3.aims.gov.au/source/research/climate-change/pdf/wooldridge-etal-2005.pdf
KEYWORDS: belief network; decision support; uncertainty; coral bleaching; adaptation; resilience; community composition; Great Barrier Reef

Zardi G, Nicastro K, McQuaid C, Hancke L and Helmuth B (2011). The combination of selection and dispersal helps explain genetic structure in intertidal mussels. Oecologia 165(4): 947-958.

Barriers to dispersal and environmental gradients can result in observed patterns of genetic differentiation among adjoining coastal populations. In order to explain the phylogeographic structure of the intertidal mussel Perna perna, which consist of two distinct genetic lineages in South Africa, this study used regional oceanographic data and lineage-specific responses of mussels to environmental conditions to examine gene flow and local selection processes within the two populations. It was discovered that mussels from the eastern lineage were more tolerant to sand accumulation and increased temperatures compared with mussels from the western lineage. This is most likely attributed to naturally higher body temperatures experienced by mussels from the eastern lineage, whereby physiological tolerances may explain the exclusion of western lineage mussels from the east coast of South Africa.
DOI: 10.1007/s00442-010-1788-9
http://www.springerlink.com/content/1316l126593x2v20/

KEYWORDS: adaptation; biogeographic region; climate change; dispersal; evolutionary divergence; gene flow; macro-ecology; mussels; ocean dynamics; physiology; South Africa; tolerance