Marine Science Review 156

Ecosystems and Habitats

SeaWeb
Leading Voices for a Healthy Ocean

In this review:

A. Recent articles with no abstract available
B. Recent publications available online
C. Recent articles with abstracts

A. Recent articles with no abstract available

Crabbe, M.J.C. and Smith, D.J. **Sediment impacts on growth rates of *Acropora* and *Porites* corals from fringing reefs of Sulawesi, Indonesia.** *Coral Reefs* 24(3): 437-441, 2005.

Donovan, S.K. **The fossil record of *Diadema* in the Caribbean.** *Coral Reefs* 24(4): 603-605, 2005.

Ritson-Williams, R., Paul, V.J., and Bonito, V. **Marine benthic cyanobacteria overgrow coral reef organisms.** *Coral Reefs* 24(4): 629, 2005.

Marris, E. **The vanishing coast.** *Nature* 438(7070): 908-909, 2005.

B. Recent publications available online

UNEP-WCMC. 2006. **In the Front Line: Shoreline Protection and other Ecosystem Services from Mangroves and Coral Reefs.** UNEP-WCMC, Cambridge, UK 33pp.

Available at: http://www.unep.org/pdf/infrontline_06.pdf

Notes: The aim of this publication is to help decision makers and policy makers around the world understand the importance of coastal habitats to humans, using coral reefs and mangroves as an example. It looks at the role of these ecosystems in protecting the coast, and takes into account new studies of this complex topic triggered by the tsunami and tropical storms. The publication also addresses the huge range of other benefits provided by these ecosystems and the role that they can play in coastal development and in restoring and maintaining the livelihoods of those who have suffered from extreme events, whether natural or induced by human activity.

C. Recent articles with abstracts

Jefferies, R.L., Jano, A.P., and Abraham, K.F. **A biotic agent promotes large-scale catastrophic change in the coastal marshes of Hudson Bay.** *Journal of Ecology* 94(1): 234-242, 2006.

Notes: 1 Herbivores may initiate small changes to plant-soil systems that trigger positive feedbacks leading to rapid catastrophic shifts in vegetative states, including irreversible changes in soil properties. In the coastal marshes of Hudson and James bays, foraging by increasing numbers of lesser snow geese (*Chen caerulescens caerulescens* A.O.U.) has led to loss of vegetation, and exposure and partial erosion of sediment. 2 Multi-temporal analysis of LANDSAT data has been carried out to detect vegetation change from 1973 to 1999 or later at nine sites in the coastal marshes of these bays where staging and/or breeding geese are present annually. 3 Images were co-registered, and for each image NDVI (Normalized Differential

Vegetation Index) channels were generated. For each location, pairwise normalized differences were calculated between these NDVI images for each successive period defined by the imagery acquisition dates. The resulting secondary NDVI difference images expressed changes in NDVI values for each time interval and yielded three well-defined classes: water, vegetation decline and no detectable change in vegetation. 4 At the nine widely separated study sites, the intertidal saltmarsh (an ecological sere) has been lost (to a total of 35 000 ha) and an alternative stable state (exposed sediment) established. Similar changes have occurred elsewhere along the 2000-km coastline where the geese breed or stage. 5 Re-vegetation of these coastal marshes will take decades because of near-irreversible changes in soil properties that require erosion and re-deposition of unconsolidated sediment before large-scale plant colonization can occur, and because large numbers of geese continue to forage annually producing this dramatic top-down effect.

Rinkevich, B. **What do we know about Eilat (Red Sea) reef degradation? A critical examination of the published literature.** *Journal of Experimental Marine Biology and Ecology* 327(2): 183-200, 2005.

Notes: During the last four decades, the coral reef at Eilat, northern Red Sea, has undergone major changes. Increasing impacts from human activities, coupled with those from natural disasters, have set off its current poor state. Here, I critically overview the salient features for Eilat's reef degradation published since the 1960s. Although this reef is one of the most intensively studied small coral reef worldwide, the literature elucidates that the available results are exceedingly fragmented, offering only scanty knowledge for the causes and pathways of the reef deterioration. During the years, 1975-2000, scarcely any reef evaluation had been done and the reef at Eilat was not well characterized to establish baseline data for future evaluations and for analyzing the trends. Even the follow up studies on the extreme low tide episode (occurred during 1970) are limited and localized, and cannot be used as a model case in calibrating Eilat reef status. Natural forces affecting the reef at Eilat are understood only vaguely, and coral assemblages/recruitments, even between neighboring sites, vary markedly in any studied biological-ecological parameter. The importance of the complex networks of interactions between algae, their grazers and corals for structuring coral assemblages, were overlooked, and massive algal growths were mistakenly attributed to anthropogenic impacts alone. Whereas, no long-term study can provide much indication for future prospects, at present, the tourist industry is probably the major cause for reef decline. Surprisingly, the literature further unveils at some sites various ecological properties, such as species diversity and densities of coral species and colonies, similarly to the values recorded decades ago and reveals that the paucity of information has led to conclusions unsubstantiated by robust sets of experiments. At this stage, therefore, decisive conclusions pertaining to the causes and pathways of Eilat reef degradation cannot be reached. Four future prospectuses are outlined, including the need for implementation of active restoration measures.

Silliman, B.R., van de Koppel, J., Bertness, M.D., Stanton, L.E., and Mendelssohn, I.A. **Drought, snails, and large-scale die-off of southern U.S. salt marshes.** *Science* 310(5755): 1803-1806, 2005.

Notes: Salt marshes in the southeastern United States have recently experienced massive die-off, one of many examples of widespread degradation in marine and coastal ecosystems. Although intense drought is thought to be the primary cause of this die-off, we found snail grazing to be a major contributing factor. Survey of marsh die-off areas in three states revealed high-density fronts of snails on dieoff edges at 11 of 12 sites. Exclusion experiments demonstrated that snails actively converted marshes to exposed mudflats. Salt addition and comparative field studies suggest that drought-induced stress and grazers acted synergistically and to varying degrees to cause initial plant death. After these disturbances, snail fronts formed on die-off edges and subsequently propagated through healthy marsh, leading to cascading vegetation loss. These results, combined with model analyses, reveal strong interactions between increasing climatic stress and grazer pressure, both potentially related to human environmental impacts, which amplify the likelihood and intensity of runaway collapse in these coastal systems.

Ranasinghe, R. and Turner, I.L. **Shoreline response to submerged structures: A review.** *Coastal Engineering* 53(1): 65-79, 2006.

Notes: Submerged coastal structures are widely perceived to be capable of providing beach protection, without the adverse impacts (including loss of beach amenity and aesthetic considerations) often associated with more conventional structures such as revetments and groynes. In addition, there is growing interest in the concept that the layout and cross-section of submerged coastal protection structures can be optimised to also enhance local surfing conditions. However, as submerged structures have only rarely been adopted for beach protection, the shoreline response to these structures is not well

understood at present. Therefore, this review of the available published literature was undertaken with the aim of investigating the environmental and structural parameters governing shoreline response to submerged structures, gleaned from the results of field, laboratory and numerical studies undertaken to date. The review reveals that, contrary to expectations, a majority of the submerged structures constructed to date have resulted in shoreline erosion in their lee. Furthermore, the key environmental and structural parameters governing the mode (i.e. erosion or accretion) and the magnitude (i.e. size of salient) of shoreline response to submerged structures are yet to be identified. Although submerged coastal structures offer the potential for low aesthetic impact incorporating multi-function design, until the response of the adjacent shoreline to submerged structures is better resolved, their use is likely to remain relatively limited.

All, J.D. **Colorado river floods, droughts, and shrimp fishing in the upper Gulf of California, Mexico.** *Environmental Management* 37(1): 111-125, 2006.

Notes: Accurate procedures that measure hydrologic variability would have great value for evaluating ecosystem impacts of upstream water use in the Colorado River Basin. Many local extractive income-based stakeholders rely directly or indirectly on ecosystem health and are adversely affected when the river does not flow. This study focuses on the impact of little or no Colorado River flow on the Mexican shrimp industry. Although there have been complaints that U.S. diversions of Colorado River flow have greatly impaired the shrimp fishery, this research demonstrates that freshwater rarely reaches the Gulf even during times of flooding, and that other factors such as overfishing may influence the instability of shrimp populations. Advanced very-high-resolution radiometer (AVHRR) satellite imagery was used to assess water volumes diverted away from the channel of the Colorado River and ultimately the Gulf of California during flooding periods. Analysis of data demonstrated that little freshwater actually reaches the Gulf even during floods because of its diversion into a large dry lake bed basin known as Laguna Salada. Fuller use of the Colorado River throughout its entire course to the sea is possible and could benefit a large cohort of users without catastrophic habitat destruction in delta ecosystems. Reconstruction of a natural earthen berm, as proposed by Ducks Unlimited, would maximize the use of floodwaters for ecosystem benefits. These findings have profound implications for local economic activities dependent on hydrologic resources in the Colorado River Delta and Upper Gulf.

Hobbs, R.J., Arico, S., Aronson, J., Baron, J.S., Bridgewater, P., Cramer, V.A., Epstein, P.R., Ewel, J.J., Klink, C.A., Lugo, A.E., Norton, D., Ojima, D., Richardson, D.M., Sanderson, E.W., Valladares, F., Vila, M., Zamora, R., and Zobel, M. **Novel ecosystems: theoretical and management aspects of the new ecological world order.** *Global Ecology and Biogeography* 15(1): 1-7, 2006.

Notes: We explore the issues relevant to those types of ecosystems containing new combinations of species that arise through human action, environmental change, and the impacts of the deliberate and inadvertent introduction of species from other regions. Novel ecosystems (also termed 'emerging ecosystems') result when species occur in combinations and relative abundances that have not occurred previously within a given biome. Key characteristics are novelty, in the form of new species combinations and the potential for changes in ecosystem functioning, and human agency, in that these ecosystems are the result of deliberate or inadvertent human action. As more of the Earth becomes transformed by human actions, novel ecosystems increase in importance, but are relatively little studied. Either the degradation or invasion of native or 'wild' ecosystems or the abandonment of intensively managed systems can result in the formation of these novel systems. Important considerations are whether these new systems are persistent and what values they may have. It is likely that it may be very difficult or costly to return such systems to their previous state, and hence consideration needs to be given to developing appropriate management goals and approaches

---

Wulff, J.L. **Rapid diversity and abundance decline in a Caribbean coral reef sponge community.** *Biological Conservation* 127(2): 167-176, 2006.

Notes: Sponges are abundant and diverse on coral reefs, and play key functional roles; but virtually nothing is known of their dynamics. This is the first report of coral reef sponge community dynamics documented by a series of censuses in which volume and species of every individual were recorded. At the start of the 14 year study, there were 1395 sponge individuals, representing 39 species in nine orders, and a total sponge volume of 33,721 cm^3 in the censused area of a shallow Caribbean reef in San Blas, Panama. The most striking results of the 5 censuses were steady disappearance of species (51.3%) throughout

the study period, and a steep drop in total sponge volume (42.6%). Species in keratose orders and with massive growth forms were lost disproportionately. Sponge losses could not be attributed to predators, physical disturbance (including a hurricane), extreme episodes of other abiotic factors, or disproportionately great loss of rare species due to random fluctuations. Disease may have played a role. High loss rates documented at this and nearby sites could be a local phenomenon, but scattered reports of disease and mass mortality of sponges from other sites suggest these data may reflect region-wide losses. Monitoring programs designed for corals and mobile unitary organisms can miss changes in sponges because very high sponge species diversity, facile fragmentation and fusion, and quick and complete disappearance of dead sponges, impedes perception of changes if there are no prior censuses. Whether or not sponge declines are extensive will remain unknown until repeat censuses have been accomplished at additional sites. Sponges can increase water clarity, bind live corals to the reef frame, and facilitate reef regeneration, suggesting that loss of sponges could accelerate declines of coral reefs.

Kelmo, F., Attrill, M.J., and Jones, M.B. **Mass mortality of coral reef ascidians following the 1997/1998 El Nino event.** *Hydrobiologia* 555: 231-240, 2006.

Notes: In April/May each year from 1995 to 2000, ascidians were sampled randomly with 35 1m² quadrats from three different reef habitats (intertidal reef tops, coastal reef walls and shallow-bank reefs) at four replicate localities (Praia do Forte, Itacimirim, Guarajuba and Abai) in northern Bahia (Brazil). As the sampling period included the 1997/1998 El Nino event, the most severe on record, for the first time these results allow a quantitative assessment of the impact of this major environmental stressor on the biodiversity of associated coral reef ascidians. Across all reef habitats, 22 ascidian species were recorded from three different orders (Aplousobranchia, Phlebobranchia and Stolidobranchia). After El Nino, all species showed significantly altered densities (ANOVA, $F=602.90$, $p < 0.0001$); many species were absent from the reefs within 2 years of the El Nino period, but densities of *Lissoclinum perforatum* (all reefs) and *Echinoclinum verrilli* (subtidal reefs) increased significantly from 1998 onwards. Univariate and multivariate analyses confirmed that significant changes in assemblage composition had occurred. BIOENV analysis identified turbidity, mean temperature and cloud cover as the main factors best explaining these assemblage changes. Our results suggest that although the 1997/1998 El Nino had a differential effect on the species contributing to the ascidian assemblage of Brazilian coral reefs, most species disappeared and those remaining are likely to enhance reef degradation through their bioeroding activities.

Thibaut, T., Pinedo, S., Torras, X., and Ballesteros, E. **Long-term decline of the populations of Fucales (*Cystoseira* spp. and *Sargassum* spp.) in the Alberes coast (France, northwestern Mediterranean).** *Marine Pollution Bulletin* 50(12): 1472-1489, 2005.

Notes: Only five of fourteen species of Fucales reported at the end of the XIXth century are currently present in the Alberes Coast (France, NW Mediterranean). According to historical data there has been a steady decrease of all the populations since the 1940s. Seven taxa now extinct (*Cystoseira crinita*, *Cystoseira barbata*, *Cystoseira foeniculacea* f. *tenuiramosa*, *Cystoseira spinosa*, *Cystoseira spinosa* var. *compressa*, *Sargassum hornschuchii* and *Sargassum vulgare*) were considered frequent and some of them were the dominant and engineering species in several phytobenthic assemblages. Moreover, only one of the five species left, shows no signs of regression (*Cystoseira compressa*), two are considered as rare (*Cystoseira caespitosa*, *Cystoseira zosteroides*), and one is very rare (*Cystoseira elegans*). *Cystoseira mediterranea*, a species that was reported to make a continuous belt along the shores of the Alberes coast, has almost disappeared from some areas. Overgrazing by sea urchins, outcompetition by mussels, habitat destruction, scientific research sampling and, probably, human trampling and chemical pollution are to be blamed for the decline of populations thriving in shallow waters. Deep-water species have been affected by an increase in water turbidity and, probably, chemical pollution and direct plant destruction attributed to net fishing. If degradation of the environmental conditions continues, the remaining *Cystoseira* species will face a most unwelcome prospect. Even after the removal of the causes that led to its die-off, natural restoration of extinct species seems not to be possible because the decline has also affected populations from nearby areas and zygotes are unable to disperse over long distances. Urgent management actions have to be designed in order to improve the current situation of the populations of Fucales in the Alberes coast.

Leao, Z.M.A.N. and Kikuchi, R.K.P. **A relic coral fauna threatened by global changes and human activities, Eastern Brazil.** *Marine Pollution Bulletin* 51(5-7): 599-611, 2005.

Notes: Coral species composition of drilled cores from emergent bank reefs, and coral cover of the surface of old and living reefs located along the coast of the state of Bahia, Eastern Brazil, revealed that there is a marked change in the occurrence of the major building coral species in different time intervals of the reef structure, as well as in the living surface of reefs located in two different geographical sites. Holocene core sections from two reef areas (12 degrees 40'S-38º00'W and 18 degrees 00'S-39º00'W) have as major reef builders, on its topmost core interval (3 to 4 ky old), the endemic coral *Mussismilia braziliensis* Verrill, 1868, which also dominate on the 2.5-3.5 ky old surfaces of truncated reef tops. At the base of the cores (the 2 m lower interval, older than 4 ky BP), another endemic coral *Mussismilia harttii* Verrill, 1868 is the dominant reef component. The relative abundance of *M. braziliensis* on the living surfaces of shallow reefs from both areas, shows that in the southern area, it is up to 98% on reefs located 60 km off the coast, in depths between 3 and 4 m, but do not exceed 1.3% on the surface of the northern reefs located 1-2 km off the coast in depths 4-5 m. The Holocene falling sea level that occurred along the coast of Brazil since 5.1 ky BP, causes an increasing runoff into the area of coastal reefs. This phenomenon may have affected the nearshore reef building fauna, replacing a more susceptive coral fauna with one better adapted to low light levels and higher sediment influx. The high turbidity associated with early Holocene shelf flooding, should also be responsible for the absence of *M. braziliensis* during the initial stages of reef buildup in Brazil. At the present time, the rapidly increasing human pressure, due to changes in land uses of the coastal zone (increasing sedimentation rate, nutrification of coastal waters, industrial pollution) and underwater practices, such as overfishing and an intense tourism, is aggravating the recovery capacity of this already naturally threatened coral community. If this situation coupled with increasing sea surface temperature persists, modern coral reef growth, in Brazil cannot be maintained and the major reef building coral species of the reefs in Bahia, a remnant endemic coral fauna will very soon appear in the list of endangered species.

Sheaves, M. **Nature and consequences of biological connectivity in mangrove systems.** *Marine Ecology Progress Series* 302: 293-305, 2005.

Notes: Mangroves are important nursery and feeding areas for fish. Their rich invertebrate faunas render them productive feeding areas, while their shallow waters and structural complexity provide sanctuary habitats at a variety of scales. However, in most parts of the world mangroves are available to fish for only part of the time because they are alternately inundated and exposed by the high-tide/low-tide cycle. As a result, few fish can use mangroves exclusively but must migrate in and out of the mangroves with the tide, occupying alternative habitats when mangroves are unavailable. These movements connect the mangroves and the alternative habitats to form an 'interconnected habitat mosaic'. Living in a habitat mosaic puts limits on the patterns of life possible in mangrove systems, complicates trophic structures, and creates the need for tactics and strategies to meet the challenges imposed by movement among components of the mosaic. Moreover, this biological connectivity means that understandings of trophic relationships, life-history strategies, predation and mortality, and patterns of distribution and abundance must be set in a spatially and temporally variable context. Despite the obvious consequences and importance of biological connectivity in mangrove ecosystems, it has often not been given appropriate consideration in the development of theories and paradigms.

Dorenbosch, M., Grol, M.G.G., Christianen, M.J.A., Nagelkerken, I., and van der Velde, G. **Indo-Pacific seagrass beds and mangroves contribute to fish density coral and diversity on adjacent reefs.** *Marine Ecology Progress Series* 302: 63-76, 2005.

Notes: There is a long-standing debate whether mangrove and seagrass habitats in the Indo-Pacific region function as nurseries for coral reef fishes. We studied the use of all major shallow-water habitat types by juvenile coral reef fish using visual census surveys at 4 islands along the Tanzanian coast (East Africa) and at the island of Grande Comoros (Comoros archipelago). We investigated the value of mangroves, seagrass beds, coral reefs, macroalgae and intertidal flats as a juvenile habitat for fish by studying density distribution patterns of juveniles and adults of 76 reef fish species in these habitats. We assessed (1) which part of the reef fish-community used mangrove-seagrass habitats as juvenile or adult habitats, (2) whether adult fish densities and diversity on adjacent reefs were related to the presence of these shallow habitats, and (3) whether adults of species that use these habitats when juvenile were less abundant on coral reefs situated far away from these juvenile habitats. Sea-grass beds and coral reefs were the most important juvenile fish habitats. Ontogenetic migrations between seagrass beds and reef habitats possibly occur, since several species showed their highest juvenile densities on seagrass beds, whereas adults showed their highest densities on reefs adjacent to these seagrass beds. The presence of areas with seagrass beds positively influenced adult densities of many reef fish species on adjacent coral reefs. Of the 36 fish species whose

juveniles were observed in seagrass beds along the Tanzanian coast, 32 species were absent from or showed low densities on coral reefs of the island of Grande Comoros (lacking seagrass beds or mangroves). On reefs far from seagrass beds and mangroves along the Tanzanian coast, 25 of these 36 species were absent or showed low densities in comparison with reefs adjacent to these habitats.

Kemp, W.M., Boynton, W.R., Adolf, J.E., Boesch, D.F., Boicourt, W.C., Brush, G., Cornwell, J.C., Fisher, T.R., Glibert, P.M., Hagy, J.D., Harding, L.W., Houde, E.D., Kimmel, D.G., Miller, W.D., Newell, R.I.E., Roman, M.R., Smith, E.M., and Stevenson, J.C. **Eutrophication of Chesapeake Bay: historical trends and ecological interactions.** *Marine Ecology Progress Series* 303: 1-29, 2005.

Notes: This review provides an integrated synthesis with timelines and evaluations of ecological responses to eutrophication in Chesapeake Bay, the largest estuary in the USA. Analyses of dated sediment cores reveal initial evidence of organic enrichment in similar to 200 yr old strata, while signs of increased phytoplankton and decreased water clarity first appeared similar to 100 yr ago. Severe, recurring deep-water hypoxia and loss of diverse submersed vascular plants were first evident in the 1950s and 1960s, respectively. The degradation of these benthic habitats has contributed to declines in benthic macro-infauna in deep mesohaline regions of the Bay and blue crabs in shallow polyhaline areas. In contrast, copepods, which are heavily consumed in pelagic food chains, are relatively unaffected by nutrient-induced changes in phytoplankton. Intense mortality associated with fisheries and disease have caused a dramatic decline in eastern oyster stocks and associated Bay water filtration, which may have exacerbated eutrophication effects on phytoplankton and water clarity. Extensive tidal marshes, which have served as effective nutrient buffers along the Bay margins, are now being lost with rising sea level. Although the Bay's overall fisheries production has probably not been affected by eutrophication, decreases in the relative contribution of demersal fish and in the efficiency with which primary production is transferred to harvest suggest fundamental shifts in trophic and habitat structures. Bay ecosystem responses to changes in nutrient loading are complicated by non-linear feedback mechanisms, including particle trapping and binding by benthic plants that increase water clarity, and by oxygen effects on benthic nutrient recycling efficiency. Observations in Bay tributaries undergoing recent reductions in nutrient input indicate relatively rapid recovery of some ecosystem functions but lags in the response of others.

Edmunds, P.J. **The effect of sub-lethal increases in temperature on the growth and population trajectories of three scleractinian corals on the southern Great Barrier Reef.** *Oecologia* 146(3): 350-364, 2005.

Notes: To date, coral death has been the most conspicuous outcome of warming tropical seas, but as temperatures stabilize at higher values, the consequences for the corals remaining will be mediated by their demographic responses to the sub-lethal effects of temperature. To gain insight into the nature of these responses, here I develop a model to test the effect of increased temperature on populations of three pocilloporid corals at One Tree Island, near the southern extreme of the Great Barrier Reef (GBR). Using *Seriatopora hystrix*, *S. caliendrum* and *Pocillopora damicornis* as study species, the effects of temperature on growth were determined empirically, and the dynamics of their populations determined under natural temperatures over a 6-month period between 1999 and 2000 [defined as the study year (SY)]. The two data sets were combined in a demographic test of the possibility that the thermal regime projected for the southern GBR in the next 55-83 years -- warmer by 3º C than the study year (the SY + 3 regime), which is equivalent to 1.4º C warmer than the recent warm year of 1998 -- would alter coral population trajectories through the effects on coral growth alone; the analyses first were completed by species, then by family after pooling among species. Laboratory experiments showed that growth rates (i.e., calcification) varied significantly among species and temperatures, and displayed curvilinear thermal responses with growth maxima at ~27.1º C. Based on these temperature-growth responses, the SY + 3 regime is projected to: (1) increase annualized growth rates of all taxa by 24-39%, and defer the timing of peak growth from the summer to the autumn and spring, (2) alter the intrinsic rate of population growth (l) for *S. hystrix* (l decreases 26%) and *S. caliendrum* (l increases 5%), but not for *P. damicornis*, and (3) have a minor effect on l (a 0.3% increase) for the Pocilloporidae, largely because l varies more among species than it does between temperatures. Ten-year population projections suggest that the effects of a sub-lethal increase in temperature (i.e., the SY + 3 regime) are relatively small compared to the interspecific differences in population dynamics, but nevertheless will alter the population size and increase the relative abundance of large colonies at the expense of smaller colonies for all three species, as well as the Pocilloporidae. These effects may play an important role in determining the nuances of coral population structure as seawater warms, and their significance may intensity if the coral species pool is depleted of thermally sensitive species by bleaching.

Varpe, O., Fiksen, O., and Slotte, A. **Meta-ecosystems and biological energy transport from ocean to coast: the ecological importance of herring migration.** *Oecologia* 146(3): 443-451, 2005.

Notes: Ecosystems are not closed, but receive resource subsidies from other ecosystems. Energy, material and organisms are moved between systems by physical vectors, but migrating animals also transport resources between systems. We report on large scale energy transport from ocean to coast by a migrating fish population, the Norwegian spring-spawning (NSS) herring *Clupea harengus*. We observe a rapid body mass increase during parts of the annual, oceanic feeding migration and we use a bioenergetics model to quantify energy consumption. The model predicts strong seasonal variation in food consumption with a marked peak in late May to July. The copepod *Calanus finmarchicus* is the most important prey and 23 x 10(6) tonnes (wet weight) of *C. finmarchicus* is consumed annually. The annual consumption-biomass ratio is 5.2. During the feeding migration 17% of consumed energy is converted to body mass. The biomass transported to the coast and left as reproductive output is estimated from gonad weight and is about 1.3 x 10(6) tonnes for the current population. This transport is to our knowledge the world's largest flux of energy caused by a single population. We demonstrate marked temporal variation in transport during the last century and discuss the effects of NSS herring in the ocean, as a major consumer, and at the coast, where eggs and larvae are important for coastal predators. In particular, we suggest that the rapid decline of lobster *Homarus gammarus* landings in Western Norway during the 1960s was related to the collapse of NSS herring. We also discuss spatial variation in energy transport caused by changed migration patterns. Both climate and fisheries probably triggered historical changes in the migration patterns of NSS herring. New migration routes emerge at the level of individuals, which in turn determines where resources are gathered and delivered, and therefore, how meta-ecosystems function.

Reisewitz, S.E., Estes, J.A., and Simenstad, C.A. **Indirect food web interactions: sea otters and kelp forest fishes in the Aleutian archipelago.** *Oecologia* 146(4): 623-631, 2006.

Notes: Although trophic cascades -- the effect of apex predators on progressively lower trophic level species through top-down forcing -- have been demonstrated in diverse ecosystems, the broader potential influences of trophic cascades on other species and ecosystem processes are not well studied. We used the overexploitation, recovery and subsequent collapse of sea otter (*Enhydra lutris*) populations in the Aleutian archipelago to explore if and how the abundance and diet of kelp forest fishes are influenced by a trophic cascade linking sea otters with sea urchins and fleshy macroalgae. We measured the abundance of sea urchins (biomass density), kelp (numerical density) and fish (catch per unit effort) at four islands in the mid-1980s (when otters were abundant at two of the islands and rare at the two others) and in 2000 (after otters had become rare at all four islands). Our fish studies focused on rock greenling (*Hexagrammos lagocephalus*), the numerically dominant species in this region. In the mid-1980s, the two islands with high-density otter populations supported dense kelp forests, relatively few urchins, and abundant rock greenling whereas the opposite pattern (abundant urchins, sparse kelp forests, and relatively few rock greenling) occurred at islands where otters were rare. In 2000, the abundances of urchins, kelp and greenling were grossly unchanged at islands where otters were initially rare but had shifted to the characteristic pattern of otter-free systems at islands where otters were initially abundant. Significant changes in greenling diet occurred between the mid-1980s and 2000 although the reasons for these changes were difficult to assess because of strong island-specific effects. Whereas urchin-dominated communities supported more diverse fish assemblages than kelp-dominated communities, this was not a simple effect of the otter-induced trophic cascade because all islands supported more diverse fish assemblages in 2000 than in the mid-1980s.

Davis, S.M., Childers, D.L., Lorenz, J.J., Wanless, H.R., and Hopkins, T.E. **A conceptual model of ecological interactions in the mangrove estuaries of the Florida Everglades.** *Wetlands* 25(4): 832-842, 2005.

Notes: A brackish water ecotone of coastal bays and lakes, mangrove forests, salt marshes, tidal creeks, and upland hammocks separates Florida Bay, Biscayne Bay, and the Gulf of Mexico from the freshwater Everglades. The Everglades mangrove estuaries are characterized by salinity gradients that vary spatially with topography and vary seasonally and inter-annually with rainfall, tide, and freshwater flow from the Everglades. Because of their location at the lower end of the Everglades drainage basin, Everglades mangrove estuaries have been affected by upstream water management practices that have altered the freshwater heads and flows and that affect salinity gradients. Additionally, interannual variation in precipitation patterns, particularly those caused to El Nino events, control freshwater inputs and salinity dynamics in these estuaries. Two major external drivers on this system are water management activities and global climate change. These drivers lead to two major ecosystem stressors: reduced freshwater flow volume and duration, and sea-level rise. Major ecological attributes include mangrove forest production, soil accretion, and resilience; coastal lake submerged aquatic vegetation; resident mangrove fish populations; wood stork (*Mycteria americana*) and roseate spoonbill (*Platelea ajaja*) nesting colonies; and estuarine crocodilian

populations. Causal linkages between stressors and attributes include coastal transgression, hydroperiods, salinity gradients, and the "white zone" freshwater/estuarine interface. The functional estuary and its ecological attributes, as influenced by sea level and freshwater flow, must be viewed as spatially dynamic, with a possible near-term balancing of transgression but ultimately a long-term continuation of inland movement. Regardless of the spatio-temporal timing of this transgression, a salinity gradient supportive of ecologically functional Everglades mangrove estuaries will be required to maintain the integrity of the South Florida ecosystem.

Rudnick, D.T., Ortner, P.B., Browder, J.A., and Davis, S.M. **A conceptual ecological model of Florida Bay.** *Wetlands* 25(4): 870-883, 2005.

Notes: Florida Bay is a large and shallow estuary that is linked to the Everglades watershed and is a target of the Greater Everglades ecosystem restoration effort. The conceptual ecological model presented here is a qualitative and minimal depiction of those ecosystem components and linkages that are considered essential for understanding historic changes in the bay ecosystem, the role of human activities as drivers of these changes, and how restoration efforts are likely to affect the ecosystem in the future. The conceptual model serves as a guide for monitoring and research within an adaptive management framework. Historic changes in Florida Bay that are of primary concern are the occurrence of seagrass mass mortality and subsequent phytoplankton blooms in the 1980s and 1990s. These changes are hypothesized to have been caused by long-term changes in the salinity regime of the bay that were driven by water management. However, historic ecological changes also may have been influenced by other human activities, including occlusion of passes between the Florida Keys and increased nutrient loading. The key to Florida Bay restoration is hypothesized to be seagrass community restoration. This community is the central ecosystem element, providing habitat for upper trophic level species and strongly influencing productivity patterns, sediment resuspension, light penetration, nutrient availability, and phytoplankton dynamics. An expectation of Everglades restoration is that changing patterns of freshwater flow toward more natural patterns will drive Florida Bay's structure and function toward its pre-drainage condition. However, considerable uncertainty exists regarding the indirect effects of changing freshwater flow, particularly with regard to the potential for changing the export of dissolved organic matter from the Everglades and the fate and effects of this nutrient source. Adaptive management of Florida Bay, as an integral part of Everglades restoration, requires an integrated program of monitoring, research to decrease uncertainties, and development of quantitative models (especially hydrodynamic and water quality) to synthesize data, develop and test hypotheses, and improve predictive capabilities. Understanding and quantitatively predicting changes in the nature of watershed-estuarine linkages is the highest priority scientific need for Florida Bay restoration.

Sime, P. **St. Lucie Estuary and Indian River Lagoon conceptual ecological model.** *Wetlands* 25(4): 898-907, 2005.

Notes: The St. Lucie Estuary is one of the largest brackish water bodies on the east coast of Florida, USA and a major tributary to southern Indian River Lagoon. The Indian River Lagoon is a biogeographic transition zone, rich in habitats and species, with the greatest species diversity of any estuary in North America. Habitats and species diversity in the lagoon system are believed to be affected by the decline in water and sediment quality. The health of the system is being affected by water management and land-use development in this rapidly growing area of South Florida. These affects are expressed through the six major stressors identified in this conceptual ecological model. The model diagram and its associated text describe the effects of these stressors on the key ecological attributes of the system and are a way to describe both the well-known linkages and pathways between these stressors and the detrimental impacts they have on the ecology of the system. This model also provides a means to describe some of the uncertainties and associated research that will be needed to fine tune our understanding of some of the more complicated ecological interactions and interdependencies in order to carry out effectively the goals and objectives of Everglades restoration in this system and adaptively manage the restoration into the future.

Barnes, T. **Caloosahatchee Estuary conceptual ecological model.** *Wetlands* 25(4): 884-897, 2005.

Notes: The Caloosahatchee Estuary is a large estuarine ecosystem, located on Florida's lower west coast, that supports a productive and diverse floral and faunal community. Major modifications to the hydrology of the Caloosahatchee watershed through water management, including water releases from Lake Okeechobee into the Caloosahatchee River, along with land-use transformations, increased development, and dredging for navigation, have resulted in alterations within the estuary. Changes in estuarine salinity, flows, and nutrient inputs, along with physical alterations to the estuary as a result of these

stressors, can affect estuarine fishes and manatees, as well as benthic communities including several species of bivalves, such as oysters, scallops, and clams. Additionally, the submerged aquatic vegetation and mangrove shoreline habitat are affected through a variety of processes associated with these changes. As a result, these estuarine attributes can be used as indicators of restoration success.

Ogden, J.C., Davis, S.M., Barnes, T.K., Jacobs, K.J., and Gentile, J.H. **Total System Conceptual Ecological Model.** *Wetlands* 25(4): 955-979, 2005.

Notes: The total South Florida ecosystem encompasses all natural areas that were once interconnected and embedded within the vast Everglades basin that originally extended from coast to coast and from the upper Kissimmee basin headwaters to Florida Bay, Biscayne Bay, the Gulf of Mexico, and Caloosahatchee and Indian River Lagoon estuaries. Restoration of this system will be successful once defining characteristics of the pre-altered system are recovered. Defining characteristics of the ecosystem are 1) abundant large vertebrates and aquatic prey bases, 2) animals with large spatial requirements, 3) healthy, dynamically sustainable estuaries, 4) oligotrophic freshwater wetlands, and 5) complex landscape mosaics and interactions. These defining characteristics have been altered by three external drivers that create stressors on the system: water management, land-use management and development, and climate change and sea-level rise. Stressors on the South Florida ecosystem include loss of spatial extent; loss of connectivity; altered geomorphology and topography; altered volume, timing, and distribution of regional hydropatterns; input of nutrients; altered fire patterns; and introduction and spread of exotic plants and animals. The Total System Conceptual Ecological Model links stressors to changes in the defining characteristics through major working hypotheses of cause- and-effect relationships. The linkages (ecological effects) relate to hydroperiod and depth patterns, sheet flow, salinity gradients, nutrient status and dynamics, fire patterns, habitat availability, and marsh aquatic fauna prey bases. For each defining characteristic, key ecological indicators are identified to collectively track the decline and restoration of the ecosystem.

Rohmann, S.O., Hayes, J.J., Newhall, R.C., Monaco, M.E., and Grigg, R.W. **The area of potential shallow-water tropical and subtropical coral ecosystems in the United States.** *Coral Reefs* 24(3): 370-383, 2005.

Notes: Geographic information system-based analysis was used to derive comprehensive, consistent estimates of the potential area of broadly defined, shallow-water, tropical and subtropical coral ecosystems within the territorial sea and exclusive economic zone of the United States. A coral ecosystem is composed of habitats including unconsolidated sediment, mangrove, hermatypic coral, colonized hardbottom, and submerged vegetation, and major structural zones like reef crest, lagoon, and fore reef. This broad definition reflects the importance of both reef and non-reef habitats and structural zones in the function of these ecosystems. Nautical charts, published by the National Oceanic and Atmospheric Administration's Office of the Coast Survey, provide a consistent source of 10-fathom (~18 m) and 100-fathom (~183 m) depth curve information. The 10-fathom or 100-fathom depth curves are used as surrogates for the potential distribution and extent of shallow-water coral ecosystems in tropical and subtropical U.S. waters. An estimated 36,813 sq·km area has been identified where coral ecosystems can potentially be found in waters less than 10 fathoms (18 m) deep. In addition, an estimated 143,059 sq·km area has been identified where coral ecosystems potentially can be found in U.S. waters at depths down to 100 fathoms (183 m). Results also indicate that previous studies underestimated the extent of potential coral ecosystems for some locations in U.S. tropical and subtropical waters by as much as 100% and that the regional distribution of coral ecosystems has been incorrectly reported.

Pratchett, M.S. **Dynamics of an outbreak population of *Acanthaster planci* at Lizard Island, northern Great Barrier Reef (1995-1999).** *Coral Reefs* 24(3): 453-462, 2005.

Notes: Despite their significant influence on coral reef ecosystems, causes of population outbreaks of crown-of-thorns starfish (*Acanthaster planci* L.) are still poorly understood. Essentially, outbreaks of *A. planci* could arise from either (1) a single mass recruitment event or (2) the progressive accumulation of starfish from multiple cohorts. This study explored fine-scale variation in the size, distribution, and abundance of *A. planci*, during an outbreak at Lizard Island in the northern Great Barrier Reef, to assess the mechanism by which the outbreak occurred. Densities of *A. planci* around Lizard Island increased very gradually from October 1994 until December 1996, then remained at around 1.0 starfish per 200 m^2 until June 1998. The population of *A. planci* comprised individuals ranging in size from 11-cm to 62-cm diameter, representing individuals from multiple (at least four) different cohorts. These data suggest that the outbreak of *A. planci* at Lizard Island resulted from a

prolonged build-up in starfish numbers through multiple successive recruitment events. This study shows that outbreaks of *A. planci* may arise independently of any sudden or substantial increase in rates of recruitment, such that any factor(s) responsible for the initial onset of outbreaks are likely to be very subtle and difficult to detect.

Bak, R.P., Nieuwland, G., and Meesters, E.H. **Coral reef crisis in deep and shallow reefs: 30 years of constancy and change in reefs of Curacao and Bonaire.** *Coral Reefs* 24(3): 475-479, 2005.

Notes: Coral reefs are thought to be in worldwide decline but available data are practically limited to reefs shallower than 25 m. Zooxanthellate coral communities in deep reefs (30-40 m) are relatively unstudied. Our question is: what is happening in deep reefs in terms of coral cover and coral mortality? We compare changes in species composition, coral mortality, and coral cover at Caribbean (Curacao and Bonaire) deep (30-40 m) and shallow reefs (10-20 m) using long-term (1973-2002) data from permanent photo quadrats. About 20 zooxanthellate coral species are common in the deep-reef communities, dominated by *Agaricia* sp., with coral cover up to 60%. In contrast with shallow reefs, there is no decrease in coral cover or number of coral colonies in deep reefs over the last 30 years. In deep reefs, non-agaricid species are decreasing but agaricid domination will be interrupted by natural catastrophic mortality such as deep coral bleaching and storms. Temperature is a vastly fluctuating variable in the deep-reef environment with extremely low temperatures possibly related to deep-reef bleaching.

Barton, A.D. and Casey, K.S. **Climatological context for large-scale coral bleaching.** *Coral Reefs* 24(4): 536-554, 2005.

Notes: Large-scale coral bleaching was first observed in 1979 and has occurred throughout virtually all of the tropics since that time. Severe bleaching may result in the loss of live coral and in a decline of the integrity of the impacted coral reef ecosystem. Despite the extensive scientific research and increased public awareness of coral bleaching, uncertainties remain about the past and future of large-scale coral bleaching. In order to reduce these uncertainties and place large-scale coral bleaching in the longer-term climatological context, specific criteria and methods for using historical sea surface temperature (SST) data to examine coral bleaching-related thermal conditions are proposed by analyzing three, 132 year SST reconstructions: ERSST, HadISST1, and GISST2.3b. These methodologies are applied to case studies at Discovery Bay, Jamaica (77.27ºW, 18.45ºN), Sombrero Reef, Florida, USA (81.11ºW, 24.63ºN), Academy Bay, Galapagos, Ecuador (90.31ºW, 0.74ºS), Pearl and Hermes Reef, Northwest Hawaiian Islands, USA (175.83ºW, 28.25ºN), Davies Reef, Australia (147.68ºE, 18.83ºS), and North Male Atoll, Maldives (73.35ºE, 4.70ºN). The results of this study show that (1) The historical SST data provide a useful long-term record of thermal conditions in reef ecosystems, giving important insight into the thermal history of coral reefs and (2) While coral bleaching and anomalously warm SSTs have occurred over much of the world in recent decades, case studies in the Caribbean, Northwest Hawaiian Islands, and parts of other regions such as the Great Barrier Reef exhibited SST conditions and cumulative thermal stress prior to 1979 that were comparable to those conditions observed during the strong, frequent coral bleaching events since 1979. This climatological context and knowledge of past environmental conditions in reef ecosystems may foster a better understanding of how coral reefs will respond in future, ocean warming scenarios.

Paul, V.J., Thacker, R.W., Banks, K., and Golubic, S. **Benthic cyanobacterial bloom impacts the reefs of South Florida (Broward County, USA).** *Coral Reefs* 24(4): 693-697, 2005.

Notes: Benthic cyanobacteria of the genus *Lyngbya* can form prominent mats and blooms in tropical and subtropical coral reef and seagrass habitats worldwide. A *Lyngbya* bloom on the reef tract offshore of Broward County, Florida, was first noted in 2002, and although it is seasonally variable in its distribution and abundance, it has persisted and spread over the past 3 years. In this study, the most abundant species of *Lyngbya* found in the blooms have been identified and compared to other species of *Lyngbya* by morphological and molecular methods. The most common species of *Lyngbya* is consistent with the properties of *Lyngbya confervoides* C. Agardh. The 16S ribosomal DNA sequence shares 88-92% identity with other known *Lyngbya* sequences, suggesting that this bloom consists primarily of a new, previously unsequenced species of *Lyngbya*. The second most common *Lyngbya* in the bloom is consistent with *Lyngbya polychroa*. This persistent bloom is a concern because it smothers octocorals and other invertebrates and negatively impacts these southeastern Florida reefs.