Marine spatial planning (MSP): A first step to ecosystem-based management (EBM) in the Wider Caribbean

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Abstract: The rapid decline of coastal ecosystems of the Wider Caribbean is entering its fifth decade. Some of the best science documenting this decline and its causes has been done by the laboratories of the Association of Marine Laboratories of the Caribbean (AMLC). Alarmed at the trends, Caribbean conservation pioneers established marine protected areas (MPAs) which spread throughout the region. Unfortunately, many have little or no protection and are now known to be too small to be effective in sustaining coastal ecosystems. Marine spatial planning (MSP) holds much promise to encompass the large geographic scales of the ecological processes and human impacts that influence coastal ecosystems and adjacent lands. The AMLC, through the scientific expertise and the national political connections of its member institutions, is well-positioned to help implement a pilot project. MSP a first step in ecosystem-based management and has had considerable success elsewhere. It holds our best chance of sustaining human use and conserving the coral reefs and associated ecosystems. Rev. Biol. Trop. 58 (Suppl. 3): 71-79. Epub 2010 October 01.

Key words: Wider Caribbean, marine protected areas, marine spatial planning, ecosystem-based management, coral reefs.

The Alarming Recent History of the Marine Ecosystems of the Wider Caribbean: The decline of Caribbean coral reefs and associated coastal ecosystems including seagrasses and mangroves has been in progress for at least several hundred years, pacing the explosion of the human population which began in the late 19th and early 20th centuries (Jackson *et al*. 2001, Pandolfi *et al*. 2003, Pandolfi *et al*. 2005). The recent period of rapid decline began approximately 4 to 5 decades ago coincident with the start of my career in Panama and St. Croix. Then, if someone had told me that these relatively luxuriant coral reefs would be as damaged and diminished as they are today in only 40 years, I would have thought that they were completely crazy. Yet this is exactly what happened and we now recognize this decline is not confined to the Caribbean but is global in extent.

Arguably the earliest and the best science documenting the decline of reefs and associated ecosystems and seeking its causes have been done in the Caribbean region. This is perhaps not surprising as the 35 nations and territories of the wider Caribbean region have long supported field stations and coastal laboratories for national academic programs or fisheries management. These facilities were usually established in relatively undisturbed locations with excellent field access and provided a baseline against which future changes were measured. The Association of Island Marine Laboratories of the Caribbean (later AMLC) was established in 1958 to facilitate communication and exchange of data, technology and people (Goodbody 1993). Researchers at these laboratories, aided by colleagues from around the world, began to document and monitor the status and trends of coastal ecosystems (Bone *et al*. 2001, CARICOMP 2001, Linton & Fisher 2004).

Others investigated the causes of the decline and achieved the earliest understanding of, for example, the coral-algal balance on reefs (Hughes 1994), the importance of herbivores (Hughes *et al*. 1999, Kuffner *et al*. 2006, Ogden & Lobel 1978), the impact of fishing (Jackson *et al*. 2001), top-down predator control (Mumby *et al*. 2007), the role of nutrients (Szmant 2002), coral diseases (Harvell *et al*. 2004), field and physiological studies of coral bleaching (Brown 1997) and most recently ocean acidification (Albright *et al*. 2008). Caribbean scientists have examined the connection with land (Rogers 1990), the inter-connectivity with other coastal ecosystems including seagrass beds and mangroves (Nagelkerken 2009, Ogden 1997) and connectivity by pelagic larvae (Cowen 2000). These studies and many others have been done in the context of a thorough understanding of the geological history of the Caribbean reefs (Adey 1977), the growth of reefs through the Pleistocene and Holocene (Hubbard *et al*. 2005) and the origin and evolution of Caribbean corals (Knowlton & Budd 2001).

The firm conclusion is that the decline of coastal ecosystems in the Caribbean has been a result of multiple stresses the most important of which are anthropogenic in origin and include poor land-use practices, runoff and pollution, over-fishing and climate change.

Marine Protected Areas (MPAs): Supported by long-term observations, monitoring and assessment and the long experience of local people in particular coastal areas, the pioneers of marine conservation, notably Tom van't Hof originally of Caribbean Research and Management of Biodiversity (CARMABI) in Curacao, implemented early MPAs and communicated widely their design and political considerations. Starting from small beginnings, MPAs expanded across the region as the Great Barrier Reef Marine Park became the icon of tropical marine management (Kelleher *et al*. 1995). A relatively recent compendium of MPAs for the Lesser Antilles and Central Caribbean, including Belize and the Turks and Caicos lists 75 functional MPAs (Geoghegan *et al*. 2001). However, many of these are still so-called "paper parks" which are no more than boundary lines on a chart and have little protection or management.

Early studies of a class of MPAs called "no-take marine reserves", prohibiting all extractive use, documented the relatively rapid response of demersal fishes to fishing prohibition. In most cases, no-take reserves developed more and bigger fishes in approximately three to five years (Halpern 2003). The rapidity and consistency of this response all over the world was seductive to scientists and managers alike. However, longer term studies of corals for example, have shown that declines continue through a failure of recruitment under no-take protection, at least at a relatively small geographic scale (S.R. Smith pers. comm.). At a larger scale, Mumby & Harborne (2010) demonstrated in a survey of 10 sites inside and outside of Exuma Cays Land and Sea Park in the Bahamas (enforced since 1986) significantly greater coral cover inside the Park. Perhaps it is not unexpected that fish, corals and other major groups will react differently to no-take protection, related to the ecological processes, such as recruitment and herbivory, that drive their dynamics.

It is clear that so far the efforts to protect coastal ecosystems from human disturbances have been at best ineffective and that implementation of small marine protected areas, even no-take marine reserves, has not been sufficient (Allison *et al*. 1998). Networks of MPAs, such as "Islands in the Stream" proposed in 2009 in the Gulf of Mexico by NOAA Marine Sanctuaries, have been sketched out as one response to the geographic scale problem. The U.S. through the NOAA Marine Protected Area Center (2009) recently announced a national network of MPAs made up of 225 federal, state and territorial sites, but the work of making this network truly representative of the nation's marine biodiversity, production and cultural heritage has just begun. As scientists and members of the complex international society of the Wider Caribbean with a stake in its future, we are failing and in danger of being accused of "*fiddling while Rome burns*".

MARINE SPATIAL PLANNING

Underlying Rationale: More comprehensive ocean governance is needed that encompasses the geographic scales of marine biodiversity, human impacts and of the ecological processes that sustain coral reefs and associated ecosystems. There is abundant scientific evidence that the wider Caribbean functions as a large marine ecosystem (LME, Sherman *et al*. 2005) and plans for regional management inspired by the CARICOMP network of marine laboratories have been developed (Rivera-Monroy *et al*. 2004). The ocean currents of the Wider Caribbean connect ecosystems over large areas through the planktonic transport of larvae of many organisms (Cowen *et al*. 2000, Baums *et al*. 2006). While the patterns vary with reproductive strategy and timing, transport of larvae increases the resilience of populations through recruitment following disturbances. In addition to being linked over long distances by larvae, the key ecosystems of the Caribbean, coral reefs, seagrasses and mangroves are physically, chemically and biologically connected (Nagelkerken 2009).

There are other striking examples of connectivity in the Wider Caribbean LME. In 1983, the long-spined, black sea urchin *Diadema antillarum* began to die near the Caribbean end of the Panama Canal. Relentlessly over only one year, almost all the *Diadema* in the Caribbean, Florida, the Bahamas and Bermuda died. This mass mortality, attributed to a species-specific pathogen, was unprecedented in its geographic extent and the severity of its impact (Lessios *et al*. 1984). As predicted by earlier research, the net result was that the removal of this key grazer caused a bloom of fleshy benthic algae on Caribbean coral reefs which over-grew and killed corals (Hughes *et al*. 1999, Miller *et al*. 2003).

Spreading more slowly but with similar devastation was White Band Disease (WBD) of the acroporid corals first described in 1974 by Gladfelter (1982) as moving in a front along a luxuriant *Acropora palmata* reef in St. Croix. WBD was subsequently implicated in the virtual extirpation of *Acropora palmata* and *A. cervicornis* in the Caribbean over the next decade. In 2004 the Caribbean acroporids were declared endangered under the U.S. Endangered Species Act (ESA). As required under ESA, the Recovery Plan for these species is nearing completion (National Marine Fisheries Service, in press).

Another example of the ecological coherence of the Caribbean LME is the annual incursion of the plume of discharge of the Orinoco River from Venezuela across the Caribbean Sea (Muller-Karger *et al*. 1989). Major discharges of the Orinoco cause obvious changes in the color and smell of the sea as far as Puerto Rico and the Virgin Islands and perhaps farther and have been implicated in occasional fish kills presumably due to blooms of toxic algal species. In a similar way, short-term discharges of major rivers after storms exert a dramatic impact over large regions. This was seen along the coasts of Honduras, Guatemala and Belize following Hurricane Mitch in 1998 (Sheng *et al*. 2007).

These examples provide a strong rationale for planning and management of larger areas of the ocean including adjacent land masses than the current patchwork of MPAs.

How is an region selected for MSP?: While the wider Caribbean is a functioning LME, its large size and political complexity suggest that smaller sub-regions may be better suited for a pilot program in MSP. Unlike terrestrial or freshwater systems, marine ecoregions are not easily compartmentalized and represent a continuum of overlapping, interdependent ecosystems. However, in several recent schemes, the Caribbean has been subdivided into a number ecoregions (Spaulding *et al*. 2007) and these can be used as focal points for discussion and potential selection for MSP.

It is critical that this be an inclusive process integrating the people and political entities in the region. Thus, practical and political considerations may trump more scientific criteria in site selection. The key is to select regions where planning and implementation efforts have a reasonable chance of success.

MSP begins with assessment and assembly of existing spatial biophysical data and information in GIS formats including, for example, key resources, benthic habitats, biological diversity, oceanography, bathymetry and sediments. Human uses are also mapped including shipping lanes, pipelines and cables, minerals leases, protected areas, fishing zones and aquaculture sites to name a few. The sources of this information include publications, databases and local and traditional knowledge. The public meetings and outreach required to collect the latter play an important part in building a political constituency for this inclusive process. The GIS overlays show areas where information is abundant and areas where there are significant information gaps. Continually updated maps from spatially organized databases allow assessments of changes and provide parameters for models to help predict the future under different scenarios of management and environmental change. The importance of maps in engaging the stakeholders, illuminating complex use problems and suggesting solutions cannot be over-emphasized (Carollo *et al*. 2009).

MSP is an idea whose time has come. It originated during the planning effort that established the Great Barrier Reef Marine Park in 1972 and continues today with the 2004 revised zoning plan (Day *et al*. 2005). It has been used in Europe, notably in the extensively exploited North Sea, and in various locations in Asia to balance economic and environmental objectives. Recently, a step-by step guide to MSP has been published which presents clearly and with many examples its importance and how to do it (Ehler & Douvere 2009). This exemplary work shows that while the tools and approaches of MSP can be outlined, each location is unique in terms of engagement of the stakeholders and the local and national political apparatus.

Where has MSP been used in the Caribbean?: There are several regional ocean governance projects in the Caribbean which serve as examples. The Meso-American Barrier Reef System (MBRS) project used a spatial planning approach to define biophysical characteristics, human uses and potential conservation management measures within a four-country region of the western Caribbean (Kramer & Kramer 2002). The planning process was inclusive and thorough, but the political complexity of the region and sovereignty issues has hampered implementation of internationally coordinated ecosystem-based management and governance.

At a larger scale, the Caribbean Large Marine Ecosystem (CLME) Project based at the Secretariat of the Intergovernmental Oceanographic Commission for the Caribbean (IOCARIBE) in Cartagena, Colombia is a multilevel governance network linking regional inter-governmental initiatives together with the Caribbean Sea Initiative of the Association of Caribbean States. While the project to date has concentrated on organization, conceptual designs and political considerations to approach comprehensive governance of the Caribbean LME, it will use MSP to define management concerns and identify use areas to implement governance (Fanning *et al*. 2007, Mahon *et al*. in press).

The Puerto Rico-Virgin Islands shelf (including the British Virgin Islands) encompasses one of the most heavily visited touristic regions and forms an attractive region for a pilot project in MSP. The economic value of the marine ecosystems of this ecoregion is huge and this facilitates buy-in by government and the public. Both Puerto Rico and the Virgin Islands have strong, active research teams who could be engaged with sufficient funding.

THE GOAL OF MSP

***"We must use the ocean, but we can't afford to use it up"*:** This phrase coined by author and conservationist Carl Safina captures the ultimate goal of MSP as a first step in EBM in response to the relentless decline of ocean resources and the looming crisis of governance. Similar to land-use planning, MSP concentrates on places of importance to human societies and provides a mapping and analysis framework for visualizing the finite nature of resources and the need for governance, principally through zoning, of human enterprises on the ocean (Crowder *et al*. 2006). Young *et al*. (2007) outline four principles to help implement governance (EBM): (1) Create governance arrangements that minimize mismatches between biophysical systems and socioeconomic activities; (2) Develop procedures that recognize multiple-uses of ocean areas and can mediate conflicts; (3) Insure that all interested parties have a voice in decision-making in MSP and governance from the beginning and (4) Design governance to monitor results of management policies and to change them as necessary as understanding of the dynamics of the place advances.

MSP and EBM will bring planning and order to human activities and other concerns, such as conservation, to the ocean. In most countries the ocean is a commons, governed by sector, if at all, by local and national agencies with overlapping and conflicting legal mandates (Crowder *et al*. 2006). Recently, many nations are beginning to seek a way to govern that will accommodate an ecosystem approach. In the U.S., the Interagency Ocean Policy Task Force (2009) was charged by Executive Order to develop a framework for marine spatial planning which may lead to significant ocean policy developments in the next few years.

In the U.S., there is also developing interest in the public trust doctrine, currently applied only in state waters (shoreline to 3 nm), which mandates that ocean resources be managed in the best interests of the citizens. Extension of the public trust doctrine to the Exclusive Economic Zone (EEZ, 3nm to 200nm) will gather ocean assets under the same administration and help to answer a compelling question: "For whom should our country's oceans be managed and for what purpose?" (Turnipseed *et al*. 2009).

AN OPPORTUNITY FOR THE AMLC

The AMLC is ideally positioned to draw upon its scientific strengths and political connections to influence the development of MSP and governance at large geographic scales. I support the AMLC's current plans to host a workshop in 2010, consisting of the member laboratory directors and key invitees, including principals from existing regional marine governance programs in the Caribbean, to discuss how the AMLC might contribute to existing programs with scientific information and data and monitoring for adaptive management. The output of this meeting could be a proposal to a private foundation or other funding sources to implement a collaborative pilot MSP program.

An opportunity is for the member laboratories of the AMLC to engage more directly with their national governments to advocate for regional ocean governance. Every year we scientists gather at scientific meetings and talk to each other about the dismal and declining state of Caribbean ecosystems. Similarly, but with a very different tone, ministers of tourism of numerous Caribbean nations gather in a nice hotel on a beach and tell each other how exciting new tourism developments are having a positive impact on their respective economies. With some help from inside the Caribbean tourism establishment, the AMLC could field a team of experts to attend a regional tourism meeting and tell the real story of the Caribbean of the last 50 years and what the science says about what must be done to halt and possibly reverse the decline. This would align AMLC with an economically influential group with access to the highest levels of national governments. Pangea World has taken this approach in the tropical Pacific, using tourism and its impact on the economy to foster government conservation and sustainability planning in Panama and Fiji (AAAS 2006).

CONCLUSION

The marine resources of the Wider Caribbean are in rapid decline and there is little evidence that the MPA programs that we have developed to halt or reverse the decline are working. The growth of the human population, doubling since 1965, has driven increasingly environmentally risky and damaging development decisions all over the region. The AMLC, as one of the oldest and most influential scientific associations in the Caribbean has an opportunity, if not an obligation, to collaborate with nascent programs in MSP, EBM and regional ocean governance with appropriate scientific information and counsel. As scientists we have been too long talking to the choir and our message has not resonated at the higher political levels of government. The actions proposed herein may be in time to reverse the decline of coastal ecosystems but certainly have the benefit of raising the profile of the central economic importance of healthy marine ecosystems. This will engage the public and increase their understanding of what must be done live sustainably with ocean resources in this first century of the Anthropocene.

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RESUMEN

La rápida disminución de los ecosistemas costeros del Mar Caribe está entrando en su quinta década. Algunos de los mejores aportes científicos que documentan este descenso y sus causas han sido realizados por los laboratorios de la Asociación de Laboratorios Marinos del Caribe (ALMC). Alarmados por las tendencias, los pioneros de la conservación del Caribe establecieron áreas marinas protegidas (MPAs) que se extendieron por toda la región. Desafortunadamente, muchas de estas áreas tienen poca o ninguna protección y ahora se conoce que son demasiado pequeñas para ser efectivas en el mantenimiento de los ecosistemas costeros. La planificación espacial marina (MSP) es promisoria para englobar las grandes escalas geográficas de los procesos ecológicos y los impactos humanos que influyen en los ecosistemas costeros y las tierras adyacentes. La ALMC, a través de los conocimientos científicos y las conexiones políticas nacionales de los miembros de sus instituciones, está bien posicionada para ayudar a implementar un proyecto piloto. MSP es un primer paso en el manejo de ecosistemas y ha tenido un éxito considerable en otros lugares. La misma nos ofrece la mejor posibilidad del manejo de uso humano sustentable y la conservación de los arrecifes coralinos y ecosistemas asociados.

Palabras clave: Mar Caribe, áreas marinas protegidas, planificación espacial marina, manejo de ecosistemas, arrecifes coralinos.

REFERENCES

AAAS (News and Notes). 2006. Ayalas' passion for knowledge shines at AAAS event. Science 312: 542.

Adey, W.H. 1977. Shallow water Holocene bioherms of the Caribbean Sea and West Indies. Proc. 3rd Int. Coral Reef Symp. 2: 21-24.

Albright, R., B. Mason & C. Langdon. 2008. Effect of aragonite saturation state on settlement and post-settlement growth of *Porites astreoides* larvae. Coral Reefs 27: 485-490.

Allison, G.W., J. Lubchenco & M.H. Carr. 1998. Marine reserves are necessary but not sufficient for marine conservation. Ecol. Appl. 8: S79-S92.

Baums, I.B., M.W. Miller & M.E. Hellberg. 2006. Geographic variation in clonal structure of a reef-building Caribbean coral, *Acropora palmata*. Ecol. Monogr. 76: 503-519.

Bone, D., A Croquer, E. Klein, D. Perez, F. Losada, A. Martin, C. Bastidas, M. Rada, L. Galindo & P. Penchaszadeh. 2001. Programa CARICOMP: Monitoreo a largo plaza de los ecosistemas marinos del Parque Nacional Morrocoy, Venezuela. Intersciencia 26: 457-462.

Brown, B.E. 1997. Coral bleaching: causes and consequences. Coral Reefs 16: 129-138.

Caribbean Large Marine Ecosystem Project. 2010 (Downloaded: August 11, 2010, www.cavehill.uwi.edu/cermes/clmeInfo.html).

CARICOMP. 2001. The Caribbean Coastal Marine Productivity Program (CARICOMP). Bull. Mar. Sci. 69: 819-829.

Carollo, C., D.J. Reed, J.C. Ogden & D. Palandro. 2009. The importance of data discovery and management in advancing ecosystem-based management. Mar. Pol. 33: 651-653.

Cowen, R.K., M. Kamazima, M. Lwiza, S. Sponaugle, C.B. Paris & D.B. Olson. 2000. Connectivity of marine populations: open or closed? *Science* 287: 857-859**.**

Crowder, L.B., G. Osherenko, O.R. Young, S. Airame, E.A. Norse, N. Baron, J.C. Day, F. Douvere, C.N. Ehler, B.S. Halpern, S.J. Langdon, K.L. McLeod, J.C. Ogden, R.E. Peach, A.A. Rosenberg & J.A. Wilson. 2006. Resolving mismatches in U.S. ocean governance. Science 313: 617-618.

Day, J., L. Fernandez & B. Jago. 2005. Planning for the future of the Great Barrier Reef. Queensland Plan. 45: 12-14.

Ehler, C. & F. Douvere. 2009. Marine Spatial Planning: A Step-by-Step Approach Toward Ecosystem-Based Management. Intergovernmental Oceanographic Commission and Man and the Biosphere Program. IOC Manual and Guides No. 53, ICAM Dossier No. 6. Paris, UNESCO.

Fanning, L., R. Mahon, P. McConney, J. Angulo, F. Burrows, B. Chakallal, D. Gil, M. Haughton, S. Heileman, S. Martinez, L'ouverture Ostine, A. Oviedo, S. Parsons, T. Phillips, C.S. Arroyo, B. Simmons & C. Toro. 2007. A large marine ecosystem governance framework. Mar. Pol. 31: 434-443.

Geoghegan, T., A.H. Smith & K. Thatcher. 2001. Characterization of Marine Protected Areas: An Analysis of Ecological, Organizational and Socio-Economic Factors. CANARI Technical Report #287: 140 p.

Gladfelter, W.B. 1982. White-band disease in *Acropora palmata*: Implications for the structure and growth of shallow reefs. Bull. Mar. Sci. 32: 639-643.

Goodbody, I. 1993. The Association of Island Marine Laboratories of the Caribbean - a historical perspective. Rev. Biol. Trop. 41: 1-15.

Halpern, B.S. 2003. The impact of marine reserves: Do reserves work and does reserve size matter? Ecol. Appl. 13: 117-137.

Harvell, D., R. Aronson, N. Baron, J. Connell, A. Dobson, S. Ellner, L. Gerber, K. Kim, A. Kuris, H. McCallum, K. Lafferty, B. McKay, J. Porter, M. Pascual, G. Smith, K. Sutherland & J. Ward. 2004. The rising tide of ocean diseases: unsolved problems and research priorities. Front. Ecol. Environ. 2: 375-382.

Hubbard, D.K., H. Zankl, I. Van Heerden & I.P. Gill. 2005. Holocene reef development along the northeastern St. Croix shelf, Buck Island, U.S. Virgin Islands. *J. Sed. Res*. 75: 97-11.

Hughes, T.P. 1994. Catastrophes, phase shifts, and large-scale degradation of a Caribbean coral reef. Science 265: 1547-1551.

Hughes, T., A.M. Szmant, R. Steneck, R. Carpenter & S. Miller. 1999. Algal blooms on coral reefs: What are the causes? Limnol. Oceanogr. 44: 1583-1586.

Interagency Ocean Policy Task Force. 2009. Interim Framework for Effective Coastal and Marine Spatial Planning. White House Council on Environmental Quality, Washington, D.C., USA.

Jackson, J.B.C., M.X. Kirby, W.H. Berger, K.A. Bjorndal, L.W. Botsford, B.J. Bourque, R.H. Bradbury, R. Cooke, J. Erlandson, J.A. Estes, T.P. Hughes, S. Kidwell, C.B. Lange, H.S. Lenihan, J.M. Pandolfi, C.H. Peterson, R.S. Steneck, M.J. Tegner & R.R. Warner. 2001. Historical overfishing and the recent collapse of coastal ecosystems. Science 293: 629-638.

Kelleher, G., C. Bleakley & S. Wells. 1995. A Global Representative System of Marine Protected Areas. Volume II: Wider Caribbean, West Africa and South Atlantic. Great Barrier Reef Marine Park Authority, The World Bank and IUCN.

Knowlton, N. & A.F. Budd. 2001. Recognizing coral species past and present, p. 97-119. *In* J.B.C. Jackson, S. Lidgard & F.K. McKinney (eds.). Evolutionary Patterns: Growth, Form and Tempo in the Fossil Record. Univ. of Chicago, Chicago, Illinois, USA.

Kramer, P.A. & P.R. Kramer. 2002. Ecoregional Conservation Planning for the Mesoamerican Caribbean Reef (MACR). World Wildlife Fund, Washington, D.C., USA.

Kuffner, I.B., L.J. Walters, M.A. Becerro, V.J. Paul, R. Ritson-Williams & K.S. Beach. 2006. Inhibition of coral recruitment by macroalgae and cyanobacteria. Mar. Ecol. Prog. Ser. 323: 107-117.

Lessios, H.A., D. Robertson, D. Ross & J.D. Cubit. 1984. Spread of *Diadema* mass mortality through the Caribbean. Science 226: 335-337.

Linton, D. & T. Fisher (eds.). 2004. CARICOMP: Caribbean Coastal Marine Productivity Program, 1993-2003. CARICOMP, Kingston, Jamaica.

Mahon, R., L. Fanning, P. McConney & C. Toro. In press. Governance for Caribbean living marine resources: seeking a path. Proc. Gulf & Carib. Fish. Inst. 60.

Marine Spatial Planning (UNESCO). 2009. (Downloaded: Date, 2009, www.unesco-ioc-marinesp.be/).

Miller, R.J., A.J. Adams, N.B. Ogden, J.C. Ogden & J.P. Ebersole. 2003. *Diadema antillarum* 17 years after mass mortality: Is recovery beginning on St. Croix? Coral Reefs 22: 181-187.

Muller-Karger, F.E., C.R. McCain, T.R. Fisher, W.E. Esaias & R. Varela. 1989. Pigment distribution in the Caribbean Sea: Observations from space. Progr. Oceanogr. 23: 23-64.

Mumby, P.J. & A.R. Harborne. 2010. Marine reserves enhance the recovery of corals on Caribbean reefs. PLoS ONE 5(1): e8657. doi:10.1371/journal.pone.0008657.

Mumby, P.J., A.R. Harborne, J. Williams, C.V. Kappel, D.R. Brumbaugh, F. Micheli, K.E. Holmes, C.P. Dahlgren, C.B. Paris & P.G. Blackwell. 2007. Trophic cascade facilitates coral recruitment in a marine reserve. Proc. Nat. Acad. Sci. (USA) 104: 8362-8367.

Nagelkerken, I. (ed.). 2009. Ecological Connectivity among Tropical Coastal Ecosystems. Springer, Berlin, Germany.

National Marine Fisheries Service. In press. Recovery Plan for Elkhorn *(Acropora palmata)* and Staghorn *(A. cervicornis)* Corals. Prepared by the *Acropora* Recovery Team for the National Marine Fisheries Service, Silver Spring, Maryland, USA.

NOAA Marine Protected Area Center. 2009. (Downloaded: Date, 2009, www.mpa.gov/).

NOAA Marine Sanctuaries. 2009. (Downloaded: Date, 2009, www.sanctuaries.noaa.gov/about/pdfs/se_gom.pdf).

Ogden, J.C. 1997. Ecosystem interactions in the tropical coastal seascape, p 288-297. *In* C. Birkeland (ed.). Life and Death of Coral Reefs, Chapman and Hall, New York, USA.

Ogden, J.C. & P.S. Lobel. 1978. The role of herbivorous fishes and urchins in coral reef communities. Environ. Biol. Fish. 3: 49-63.

Pandolfi, J.M., R.H. Bradbury, E. Sala, T.P. Hughes, K.A. Bjorndal, R.G. Cooke, D.H. McArdle, L. McClenachan, M.J.H. Newman, G. Paredes, R.R. Warner & J.B.C. Jackson. 2003. Global trajectories of the long-term decline of coral reefs ecosystems. Science 301: 955-958.

Pandolfi, J.M., J.B.C. Jackson, N. Baron, R.H. Bradbury, H.M. Guzman, T.P. Hughes, C.V. Kappel, F. Micheli, J.C. Ogden, H.P. Possingham & E. Sala. 2005. Are US coral reefs on the slippery slope to slime? Science 307: 1725-1726.

Pangea World. 2010. (Downloaded: August 11, 2010, www.pangeaworld.com/home.htm).

Rivera-Montoy, V.H., R.R. Twilley, D. Bone, D.L. Childers, C. Coronado-Molina, I.C. Feller, J. Herrera-Silveira, R. Jaffe, E. Mancera, E. Rejmankova, J.E. Salisbury & E. Weil. 2004. A conceptual framework to develop long-term ecological research and management objectives in the Wider Caribbean region. Bioscience 54: 843-856.

Rogers, C. 1990. Responses of coral reefs and reef organisms to sedimentation. Mar. Ecol. Prog. Ser. 62: 185-202.

Sheng, J., L. Wang, S. Andréfouët, C. Hu, B.G. Hatcher, F.E. Muller-Karger, B. Kjerfve, W.D. Heyman & B. Yang. 2007. Upper ocean response of the Mesoamerican Barrier Reef System to Hurricane Mitch and coastal freshwater inputs: A study using Sea-viewing Wide Field-of-view Sensor (SeaWiFS) ocean color data and a nested-grid ocean circulation model. J. Geophys. Res. 112, C07016, doi:10.1029/2006JC003900.

Sherman, K., M. Sissenwine, V. Christensen, A. Duda, G. Hempel, C. Ibe, S. Levin, D. Lluch-Belda, G. Matishov, J. McGlade, M. O'Toole, S. Seitzinger, R. Serra, H.R. Skjoldal, Q. Tang, J. Thulin, V. Vandeweerd & K. Zwanenburg. 2005. A global movement toward an ecosystem approach to management of marine resources. Mar. Ecol. Prog. Ser. 300: 275-279.

Spaulding, M.D., H.E. Fox, G.R. Allen, N. Davidson, Z.A. Ferdana, M. Finlayson, B.S. Halpern, M.A. Jorge, A. Lombana, S.A. Lourie, K.D. Martin, E. McManus, J. Molnar, C.A. Recchia & J. Robertson. 2007. Marine ecoregions of the world: A bioregionalization of coastal and shelf areas. Bioscience 57: 573-583.

Szmant, A.M. 2002. Nutrient enrichment on coral reefs: is it a major cause of coral reef decline? Estuaries 25: 743-766.

Turnipseed, M., L.B. Crowder, R.D. Sagarin & S.E. Roady. 2009. Legal bedrock for rebuilding America's ocean ecosystems. Science 234: 183-184.

Young, O.R., G. Osherenko, J.Ekstrom, L.B. Crowder, J. Ogden, J.A. Wilson, J.C. Day, F. Douvere, C.N. Ehler, K. McLeod & R. Peach. 2007. Solving the crisis in ocean governance: Place-based management of marine ecosystems. Environment 49: 20-32.