

Biological Criteria for Protection of U.S. Coral Reefs

P. Bradley^{1*}, W. Davis², W. Fisher³, H. Bell⁴, V. Chan⁵, C. LoBue⁶, W. Wiltse⁷

¹ U.S. EPA Office of Research and Development, National Health and Environmental Effects Research Laboratory, Atlantic Ecology Division, Key West, FL

² U.S. EPA, Office of Environmental Information, Environmental Analysis Division, Ft. Meade, MD

³ U.S. EPA, Office of Research and Development, National Health and Environmental Effects Research Laboratory, Gulf Ecology Division, Gulf Breeze, Florida

⁴ U.S. EPA, Office of Water, Office of Science and Technology, Washington, DC

⁵ U.S. EPA, Office of Research and Development, Office of Science Policy, Washington, DC

⁶ U.S. EPA, Region 2, Division of Environmental Planning and Protection, New York, NY

⁷ U.S. EPA, Region 9, Honolulu, HI

Coral reef ecosystems are threatened by natural stressors, human activities, and natural stressors exacerbated by human activities. Under the U.S. Clean Water Act, States and Territories may guard against anthropogenic threats by adopting water quality standards based on biological, physical, and chemical criteria. The condition of biological communities is a more dependable water quality standard than are physical and chemical attributes because living organisms are responsive to effects of low-level, chronic, cumulative, interacting point- and non-point source pollution. The President's Ocean Action Plan directed the U.S. Environmental Protection Agency (EPA) to develop biological assessment methods and tools for evaluating the health of coral reefs so that States and Territories could more easily establish biological water quality standards, including descriptions for designated waterbody uses and biological criteria (biocriteria). Biocriteria are qualitative or quantitative thresholds of biological condition necessary to sustain the designated uses. Rigorous biological assessments are needed to identify metrics that reflect biological characteristics and are responsive to a gradient of human disturbance, and to generate defensible long-term monitoring programs. Implementation of biocriteria for freshwater ecosystems has forged a process that can be adopted for coral reefs. EPA is fostering development of coral reef biocriteria through research, evaluation, and collaboration.

Key Words: bioassessment, biocriteria, Clean Water Act, coral reefs, U.S. EPA

Coral reef ecosystems are declining worldwide, threatened by a variety of human activities including polluted runoff from agriculture and land-use practices, over-fishing, ship groundings, coastal development and climate change, as well as by natural stressors such as tropical storms, bleaching and disease (Knowlton and Jackson 2008). Concern over the existing and impending threat of climate change on coral reef communities has been expressed (Richardson and Poloczanska 2008), but local anthropogenic sources also contribute directly to reef decline and can exacerbate climate change impacts (Mora 2008). Local managers have little control over climate change, but regional policies and local decisions for waterbody activities and watershed land use could substantially reduce anthropogenic stresses.

In the United States and its dependent territories there are a variety of management approaches and opportunities for reducing anthropogenic stresses to coral reefs. The National Oceanic and Atmospheric Administration (NOAA), the National Park Service

(NPS) and U.S. Fish and Wildlife Service (FWS) function as natural resource custodians for coral reefs and commonly establish Marine Protected Areas (MPAs) to protect habitat from physical damage and to restrict fishing (e.g., no-take zones). MPAs can be reserved by federal, state, territorial, tribal, or local laws or regulations; federal MPAs have been established by NPS, FWS, and NOAA (National Marine Fisheries Service, National Estuarine Research Reserve System, and National Marine Sanctuary Program). MPAs restrict human activities in particular areas in order to promote non-consumptive and non-destructive uses of natural and cultural resources, such as coral reefs. Even outside coral reef MPAs, responsible fishery management may be promoted through fishing restrictions and habitat protection. Managers may employ additional tools, such as mooring buoys and informational programs to protect reefs from physical damage and pollution.

Recently, natural resource managers have initiated programs to support coral reef resilience, or potential for recovery from climate change events (e.g., Keller 2008). Some resilience goals include:

- Assurance that resilient species and habitats are well-represented and replicated throughout the coral reef ecosystem, and in particular, inside protected areas
- Protection of critical areas, such as fish spawning aggregations and nursery habitats
- Preservation of connectivity among reefs and their associated habitats.

Finally, the U.S. Environmental Protection Agency (EPA), under aegis of the Clean Water Act (CWA), is authorized to protect coral reefs and coastal zones from sediment, nutrients, contaminants or microorganisms introduced into water bodies from human activity. This protection can be achieved through a variety of programs to reduce sewage effluent, industrial contaminant releases, agricultural pesticides, nutrient applications, and riverbed stability. However, the full weight of the CWA has not been directly applied in coral reef protection. The CWA creates the opportunity for States, Tribes, and Territories to implement enforceable water quality standards based explicitly on the biological condition of coral reef communities.

U.S. Clean Water Act

The Clean Water Act (CWA) is the primary federal law governing water pollution control in the United States. The objective of the CWA is to restore and maintain the chemical, physical and biological integrity of the Nation's waters. There are several regulatory vehicles in the CWA to curb pollution, and these indirectly protect coral reefs. For example, the CWA provides controls for point (Section 402) and nonpoint (Section 319) pollution sources, and a strong foundation for attainment of aquatic life uses (Section 303). However, there is even greater potential to protect coral reefs by focusing designated uses and water quality standards explicitly on coral reef conditions.

The CWA requires that States, Tribes, and Territories define chemical, physical and biological expectations for water resources (i.e., water quality standards), monitor conditions regularly, and report whether those expectations are being met. Water quality standards include 1) designated uses, which reflect goals for the water body, 2) numeric and narrative criteria to achieve the designated uses, and 3) antidegradation policies to prevent deterioration of high-quality waters (Karr and Yoder 2004).

States and Territories establish designated uses based on the physical, chemical, and biological characteristics of the water body, its geographical

setting, and at their discretion scenic qualities and economic values as well. Waterbodies can be protected for public water supply, for protection and propagation of fish, shellfish, and wildlife, and for recreational, agricultural, industrial, and navigational purposes. Designated uses can also be written to specifically protect coral reef ecosystems by further defining the desired biological attributes. This is particularly compelling for those jurisdictions with generic designated uses.

For example, some jurisdictions may have simply adopted water classes for designated uses: *Class A* waters might cover many of the generic uses described above (i.e., navigation, agriculture, drinking water, aquatic life protection) and would be considered higher quality waters in need of more stringent criteria than *Class B* and *Class C* waters. More specific language could be added to these legally binding narratives to characterize the biological goals for coral reef ecosystems. This could include the need to maintain the structure and function of coral reefs similar to the natural community or a condition similar to minimally impaired reference sites. Designated uses for coral reef protection could include specific goals, such as '*protection of reef fish spawning aggregations*', or '*protection of coral taxa richness and community structure*'. While revision of designated uses can be a time-consuming process, it is well worth the benefits to coral reef protection. The Biological Condition Gradient (BCG), as described by Davies and Jackson (2006) can be applied to the development of designated uses for coral reefs. Physical, chemical and biological criteria establish thresholds, qualitative or quantitative, to benchmark the desired water quality necessary to support the designated uses. Biological criteria (biocriteria) are perhaps the most relevant to coral reefs, not only because they integrate multiple cumulative stressors, but also because biological measurements resonate with managers and stakeholders. Biocriteria, codified under CWA Section 304a, represent the agreed upon condition, attributes and services that society seeks to maintain. Biocriteria specific to coral reef condition are a necessity if valued reef attributes are incorporated into designated uses.

Biocriteria and several other aspects of the CWA rely on biological assessments (bioassessments), which directly measure the condition of one or more taxonomic assemblages (e.g., corals, fish) and the chemical and physical attributes that support those assemblages. Since the community of plants and animals reflect the underlying health of the waterbody in which they live, assessments of species richness, species composition, population size, and trophic

composition of resident biota are the most direct measures of biological integrity (Karr 1991).

To implement quantitative (numeric) biocriteria, States and Territories must determine the biological conditions that sustain the designated uses, select measurements that reflect the relevant biological conditions (e.g., range, variability and responsiveness to human disturbance), and establish a defensible long-term monitoring program (Jameson et al. 2001). Coral reef biologists have a strong history of bioassessments and monitoring, and have developed biological indicators that might ultimately serve as biocriteria metrics, including:

- live coral coverage
- proportion of species tolerant to stressors of concern (e.g. pH, nutrients, temperature, sediments, metals, pathogens, etc.)
- number of species (taxa richness)
- proportion of exotics
- prevalence of disease
- percent recent mortality
- coral recruitment

Waterbody Attainment or Impairment

The CWA provides several different regulatory vehicles to curb pollution and thereby protect coral reefs. Section 305(b) of the Clean Water Act requires each State to prepare a biennial report on the quality of its waters. A 305(b) report describes the extent to which waterbodies support their designated uses. The report also identifies the pollutants or stressors causing impairment of designated uses and the sources of these stressors (e.g., wastewater treatment plants, agriculture, or industrial plants). EPA transmits the individual 305(b) reports to Congress along with a summary report on the Nation's water quality prepared using the 305(b) information. A well-prepared, scientifically sound 305(b) report can be beneficial to coral reef managers in these ways:

- The 305(b) report is a public information tool documenting State/Tribal/Territorial actions to protect waterbodies; it increases the visibility of the water quality programs.
- The report can call attention to special issues such as loss of critical fish spawning aggregation areas or coral reef habitat.
- The process offers an opportunity for State/Territorial technical staff to coordinate assessments and data management for shared waters.

Section 303(d) of the Clean Water Act requires each State and territory to periodically prepare and submit a list of specific waterbodies that currently violate or have the potential to violate water quality standards, including designated uses and numeric or

narrative biocriteria. These lists must prioritize the waterbodies for development of Total Maximum Daily Loads (TMDLs). TMDLs identify the maximum amount of a pollutant that a waterbody can receive and still safely meet water quality standards, and allocate that amount among various sources (e.g., nutrient loads could be allocated between agriculture and sewage systems).

Comprehensive Strategy to Address Impaired Waters

It is a clear benefit of a biocriteria program that each monitoring cycle automatically triggers a regulatory decision (e.g., 303(d) listing requires priority rankings and development of TMDLs). Potential regulatory actions that managers can implement include:

- Increase the scope of National Pollutant Discharge Elimination System (NPDES) permits to incorporate bioassessments and biological thresholds
- Establish marina pumpout facilities and no discharge zones
- Implement new permit requirements (i.e., require that commercial and recreational boaters hold pollution discharge permits covering deck and hull cleaning, fueling, trash management, and graywater discharges)
- Require dischargers to evaluate wastewater reuse and recycle options or install more advanced technology

There are also non-regulatory, Best Management Practices that managers can choose to implement, such as:

- Agricultural (runoff control, grass/riparian buffers, manure management, conservation tillage, etc.)
- Urban and residential (upgrade sewer and water infrastructure, xeriscaping, pesticide management, riparian buffers, etc.)

Coral reef protection calls for integrated, collaborative management. Clear, shared objectives and improved coordination of programs are a necessity. States and Territories can adopt a watershed approach to managing coral reefs, where community officials, industries, environmental groups, and citizens throughout the watershed basin jointly identify the problems and develop priorities and actions to address them. By effectively managing watersheds, we can protect both the health of coral reefs and the people who depend on them. The CWA regulatory vehicles, including biocriteria, provide watershed-based management options to protect coral reef ecosystems that complement existing natural resource management.

EPA's Biocriteria Outreach

While the responsibility for establishing water quality standards lies with the States and Territories, EPA is providing support to define conservation and management needs, refine designated uses, develop bioassessment procedures and monitoring strategies, establish reference conditions and biological thresholds, differentiate anthropogenic from natural causes of change, and identify causes of adverse effects.

Over the last 20 years, EPA has developed a body of work to support implementation of biocriteria protective of freshwater and estuarine ecosystems (e.g., EPA 1996, 1998, 2000). Ongoing research (<http://epa.gov/bioindicators/coral/>) will help develop comparable opportunities for coral reefs.

Current Efforts of States and Territories

The U.S. Coral Reef Task Force has identified the need for local action to reduce key threats to coral reefs and called for the development of Local Action Strategies (LAS) in each of the seven states and territories that possess significant coral reef resources. While no LAS specifically addresses biocriteria, each is focused on improving water quality and coral reef condition through better understanding of the links between land-based pollution and coral reef health; improving compliance and enforcement of laws, rules, and regulations related to construction and land development permits; and implementation of best management practices to reduce pollution from agricultural and residential areas. Specific biocriteria-related activities of the States and Territories include:

American Samoa and the Commonwealth of the Northern Mariana Islands (CNMI): New narrative biocriteria have been proposed that include coral species richness (Houk et al. 2005). CNMI received an EPA Wetlands Program Development Grant to support the development of numeric biological criteria for coral reefs, and American Samoa is in the process of evaluating four measures as potential coral biocriteria: 1) coral diversity per unit area, 2) total coral diversity, 3) coral community evenness, and 4) a benthic substrate ratio.

Florida: An established quality assurance process is in place to ensure that data for Clean Water Act purposes are properly and consistently collected. Florida's Department of Environmental Protection has begun to identify and evaluate protocols that could be applied as biocriteria, beginning with EPA's Stony Coral Rapid Bioassessment Protocol (Fisher 2007).

Hawai'i: EPA is funding a wetlands grant to devise biocriteria based on the Hawai'i Coral Reef Assessment and Monitoring Program (Jokiel et al. 2004).

US Virgin Islands (USVI): Designated uses are being revised to include more specific biological attributes, and EPA is assisting USVI's Department of Planning and Natural Resources to design an integrated monitoring program to assess coral reef condition (Fisher et al. 2008).

Summary and Conclusions

Thus several US jurisdictions now recognize that the CWA provides a suite of powerful regulatory tools that can be applied to protect coral reefs. The process to establish a biocriteria program has been vetted in both freshwater and estuarine programs, and can also be applied to coral reefs. Coral reef biologists have knowledge and expertise, as well as a strong history of monitoring and assessment. They have also developed biological indicators that could ultimately serve as biocriteria metrics for supporting assessment of coral condition relative to the set standards, and for implementing regulatory or non-regulatory corrective action. Development of biocriteria is not easy, but many of the tools are available. With strong collaborative effort, we can successfully develop and apply biocriteria to protect U.S. coral reefs.

The development and implementation of coral reef biocriteria can also be incorporated into Water Quality and Coral Reef Programs outside the US and its territories. For example, the Coral-based Indicators of Changes in Water Quality on Nearshore Coral Reefs of the Great Barrier Reef (Cooper and Fabricius 2007) may be candidates for biocriteria to determine if Australian and New Zealand waters meet their beneficial use "Maintain health of aquatic ecosystems". In addition, the Healthy Mesoamerican Reef System Initiative has developed a suite of ecological indicators for coral reef ecosystems that may serve as biocriteria for Mexico, Belize, Guatemala, Honduras, Nicaragua and El Salvador (McField and Kramer 2006).

Acknowledgements

This paper is contribution number AED-08-086, of the U.S. EPA National Environmental Health and Environmental Effects Research Laboratory's Atlantic Ecology Division. The research described in this paper has been funded wholly or in part by the U.S. EPA under Department of Commerce contract number 50-CMAA900065 with Perot Systems Government Services, Inc., and contract number EP-C-06-033 with Great Lakes Environmental Center. It has been subjected to Agency review and approved for publication. Mention of trade names or commercial products does not constitute endorsement or recommendation for use.

References

- Cooper, T and K Fabricius (2007) Coral-based Indicators of Changes in Water Quality on Nearshore Coral Reefs of the Great Barrier Reef. Australian Institute of Marine Science
- Davies SP, Jackson SK (2006) The Biological Condition Gradient: A Descriptive Model for Interpreting Change in Aquatic Ecosystems. *Ecol App*:16(4):1251–1266
- EPA (U.S. Environmental Protection Agency) (1996) Biological Criteria Technical Guidance for Streams and Small Rivers. Revised Edition. EPA/822/B-96/001. U.S. Environmental Protection Agency, Office of Water, Washington, DC
- EPA (U.S. Environmental Protection Agency) (1998) Lake and reservoir bioassessment and biocriteria – Technical guidance document EPA 841-B-98-007. U.S. Environmental Protection Agency, Office of Water, Washington, DC
- EPA (U.S. Environmental Protection Agency) (2000) Estuarine and Coastal Marine Waters: Bioassessment and Biocriteria Technical Guidance. EPA 822-B-00-024. U.S. Environmental Protection Agency, Office of Water, Washington, DC
- Fisher, WS (2007). Stony Coral Rapid Bioassessment Protocol. U.S. Environmental Protection Agency EPA/600/R-06/167, Office of Research and Development, Washington DC
- Fisher WS, Fore LS, Hutchins A, Quarles RL, Campbell JG, LoBue C, Davis WS (2008). Evaluation of stony coral indicators for coral reef management. *Mar Pollut Bull* doi:10.1016/j.marpolbul.2008.07.002
- Houk P, Didonato G, Iguel J, van Woesik R. (2005). Assessing the effects of non-point source pollution on American Samoa's coral reef communities. *Env Monit Assess* 107:11-27
- Jameson SC, Erdmann MV, Karr JR, Gibson JR, Potts KW (2001) Charting a course toward diagnostic monitoring: a continuing review of coral reef attributes and a research strategy for creating coral reef indexes of biotic integrity. *Bull Mar Sci* 69:701-744
- Jokiel PL, Brown EK, Friedlander A, Ku'u'lei Rodgers S, Smith WR (2004) Hawai'i coral reef assessment and monitoring program: spatial patterns and temporal dynamics in reef coral communities. *Pac Sci* 58(2):159-174
- Karr JR (1991) Biological integrity: a long-neglected aspect of water resource management. *Ecol Appl* 1: 66-84
- Karr JR, CO Yoder (2004) Biological assessment and criteria improve total maximum daily load decision making. *J. Environ. Engineer* 130:594-604
- Keller BD (2008) Marine Protected Areas. Preliminary review of adaptation options for climate-sensitive ecosystems and resources. A Report by the U.S. Climate Change Science Program and the Subcommittee on Global Change Research. [Julius SH, West JM (eds). U.S. Environmental Protection Agency, Washington, DC, USA, pp 8-1 to 8-95 <http://www.climatechange.gov/Library/sap/sap4-4/final-report/>
- Knowlton N, Jackson JBC (2008) Shifting baselines, local impacts, and global change on coral reefs. *PLoS Biol* 6(2):e54 doi:10.1371/journal.pbio.0060054
- McField, MD and PR Kramer (2006) The Healthy Mesoamerican Reef Ecosystem Initiative: a conceptual framework for evaluating reef ecosystem health. Proceedings of 10th International Coral Reef Symposium, Okinawa, Japan. June 28- July 2, 2004. pp 1118-1123
- Mora C (2008) A clear human footprint in the coral reefs of the Caribbean. *Proc Roy Soc B* 275:767-773
- Richardson AJ, Poloczanska ES (2008) Under-resourced and under threat. *Science* 320:1294-1295.