Review comments for "Coral Reef Biological Criteria: Using the Clean Water Act to Protect a National Treasure".
5/24/2010

Reference conditions

Overall, I believe this report makes sufficient reference to the limitations of reference conditions in Chapter 7 and their strengths and weaknesses in Table 7.1. Although I personally don't agree that reference conditions are needed to develop biocriteria (Rodgers 2010) this report does a great job in detailing steps and explaining concepts for biocriteria development. The case studies and examples aid in understanding the rationale.

The development of biocriteria in this report relies heavily on reference conditions for comparison. However, the use of reference sites to provide thresholds can be flawed (Rodgers 2005). This document clearly addresses spatial and temporal variability in Chapter 7. In many areas there is high spatial and temporal variability that cannot be encompassed by a single reference site or a small number of reference sites. The reference concept can be defective in some regions largely because it can not embrace the diversity of unimpacted reef communities. Because of this high variability there is limited power in detecting disturbance. It prevents discrimination on a fine scale.

The use of historical data in developing reference sites creates the issue of shifting baselines. This is addressed in the section on temporal variability. However, if different baselines from different time periods are used as reference conditions this creates an inaccurate representation of overall conditions.

Another major underlying problem is that selection of a reference site is highly subjective, even by experts as stated in Table 7.1. There is seldom agreement by any two investigators. Also, since no two reefs are exactly alike reference site selection can be subjective, biased and inaccurate. When reference conditions are derived through modeling and estimations this can also be subjective.

It is difficult to distinguish the degree of impairment. Comparisons can appear to be a reasonable approach if only a single parameter such as coral cover is being compared. For example, a reef with high coral cover is usually taken as a reference for comparison to an impacted reef with low coral cover but the comparison begins to break down as more measured parameters are added to the analysis. We begin to see that the two reefs are quite different in other fundamental respects.

Although useful in other environments such as freshwater streams and wetlands, the reference site paradigm does not appear to be highly applicable in some coral reef environments. Knowing the value and limitations of reference sites, classification, and potential metrics is important to developing reef indicators.

Classification

The heterogeneity of reefs makes habitat classification a critical step in biocriteria development. The value of separation by habitat type and ecoregions in Chapter 7 to reduce variability is extremely relevant and was addressed clearly. Geographic classification groups similar characteristics that are not dominated by human disturbance. This helps separate natural from anthropogenic impacts. However, in coral reef environments many marine organisms are stratified by wave energy and depth. The significance of depth in explaining coral cover is analogous to stratification of vegetation by elevation, the most apparent environmental gradient in terrestrial ecology. The phenomenon of coral cover increasing with increasing depth is partially a function of decreasing wave energy. This study supports Peter Glynn's research (1976) conducted in the eastern Pacific suggesting that physical factors like depth and wave regimes control shallow environments, while biological factors are the forcing function in deeper waters. Corals have been reported to stratify by depth and waves in Hawai'i, with wave energy reported as the most dominant forcing function structuring coral communities (Grigg 1983). Thus, further classification may be appropriate.

Climate Change

The climate change variability section is critical and the inclusion of the consequences of ignoring this global impact is a vital addition. In Table 8.1 the response to the stressor global climate change is coral bleaching, loss of *Acropora* spp. Although the major coral in many regions they are not dominant in other areas such as in the Hawaiian Islands where *Pocillopora* spp. show the strongest response to temperature increases. This table also includes ocean acidification as a stressor. A missing response that will be critical to the survival of corals reefs is the impact to calcareous coralline algae (Kuffner et. al 2008). The list in Table 8.1 is only a partial list of responses. Global stressors will affect all coral life stages and those of many other marine organisms. Managing the entire watershed as included in the report will indeed be important at many locations.

Appendix 6 Ocean Acidification is an important inclusion if water quality standards are amplified to include no observable change in pH for marine coastal waters. However, Appendix 6 states the following: *"Generally the oceans are well buffered, meaning that they resist changes in pH. This occurs because hydrogen ions, the concentration of which determines pH, react with carbonate to form bicarbonate. This removes hydrogen ions from the water and diminishes any change in pH. Unfortunately, it also removes carbonate ions that are needed by corals and marine organisms to construct calcium carbonate skeletons and shells. By 2100, it is expected that there will be 30-50% less carbonate available for calcification. This will likely affect growth and survival of corals, mussels, oysters, snails, sea urchins, and microscopic plants and animals that use calcium carbonate to build shells and tests."*

Bicarbonate not carbonate is the most abundant form of dissolved inorganic carbon in the oceans and is the principal form taken up by corals and utilized by zooxanthellae for photosynthesis (Al-Moghrabi et al. 1996; Gorian et al. 1996; Moya et al. 2008). Bicarbonate will be even more abundant in future acidic waters and will not be the limiting factor in decreases in coral growth. Although coral growth will decline in the future (Jokiel et.al 2008, and many others) decreases in carbonate ions is not the explanation.

Works cited

Al-Moghrabi S, Goiran C, Allemand D, Speziale N, Jaubert J (1996) Inorganic carbon uptake for photosynthesis by the symbiotic coral-dinoflagellate association. 2. Mechanisms for bicarbonate uptake. J Exper Mar Biol Ecol 199:227–248.

Glynn P.W. 1976. Some physical and biological determinants of coral community structure in the eastern Pacific. *Ecological Monographs* 46:431-456.

Grigg, R. W. 1983. Community structure, succession and development of coral reefs in Hawai‘i. *Marine Ecology Progress Series* 11: 1-14.

Goiran C, Almoghrabi S, Allemand D, Jaubert J (1996) Inorganic carbon uptake for photosynthesis by the symbiotic coral/dinoflagellate association. 1. Photosynthetic performances of symbionts and dependence on sea water bicarbonate. J Exp Mar Biol Ecol 199:207–225

Jokiel, Paul L., Ku‘ulei S. Rodgers, Ilsa B. Kuffner, Andreas J. Andersson, Evelyn F. Cox, Fred T. Mackenzie. 2008. Ocean acidification and calcifying reef organisms: a mesocosm investigation. Coral Reefs. 27:473-483

Kuffner, Ilsa B., Andreas J. Andersson, Paul L. Jokiel, Ku‘ulei S. Rodgers, and Fred T. Mackenzie (2008) Decreased abundance of crustose coralline algae due to ocean acidification. Nature Geoscience 1: 114-117

Moya A, Tambutte S, Bertucci A, Tambutte E, Lotto S, Vullo D, Supuran CT, Allemand D, Zoccola D (2008) Carbonic anhydrase in the scleractinian coral *Stylophora pistillata*: characterization, location and role in biomineralization. J Biol Chem 283(37):25475 – 2548

Rodgers, K. S. Evaluation of Nearshore Coral Reef Condition and Identification of Indicators in the Main Hawaiian Islands. 2005. PhD Dissertation. University of Hawai’i, Dept. of Geography. Honolulu, Hawai’i. Pp.203.

Rodgers, K.S., Jokiel, P.L., Bird, C.E., Brown, E.K. 2010. Quantifying the Condition of Hawaiian Coral Reefs. Aquatic Conserv: Mar. Freshw. Ecosyst. 20:93-105.