# CHAPTER 7: CONCLUSIONS

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This report is comprised of a suite of studies investigating fish fauna, benthic communities, nutrient levels, and chemical contaminants in the marine environment adjacent to the former land-use zones around Vieques. The main finding was that overall, there was little difference in marine resources, nutrients, or chemical contaminants around Vieques offshore of the various former land-use zones. This finding was somewhat surprising given the conflicting hypotheses that, 1) U.S. Naval activities could negatively impact adjacent marine ecosystems through mechanisms such as chemical contamination or errant bombing practice, 2) civilian activities could negatively impact adjacent marine ecosystems through mechanisms such as nutrient discharge or overfishing, and 3) much of the land formerly owned by the U.S. Navy was undeveloped and may have been a positive influence on adjacent marine environments by the lack of widespread anthropogenic development activities that are documented to affect coral ecosystems. Although some differences were found in the biota among sampling strata and some elevated contamination and nutrient levels were documented at specific sites around the island, the results of this study do not support any of the hypotheses of land-use history as a major factor structuring the marine environment of Vieques. Nor does it appear to be the case that the marine resources around Vieques are particularly depressed or elevated relative to those of other nearby islands. Instead, the biota, nutrients, and chemical contaminant levels around Vieques generally match those for other coral reef ecosystems in the Puerto Rico and U.S. Virgin Islands region and are likely to have been shaped primarily by regional-scale processes rather than local factors.

By design, components of the studies in this assessment shared many sampling sites, sampling periods, strata, and methods with those used to monitor nearby islands. Results can therefore be easily combined and compared for more integrated analyses. We intentionally did not examine all variables from all studies simultaneously for correlations. Doing so would have yielded a high chance of spurious or random correlations due to the large number of variables involved. Instead, in this chapter we highlight some key observations, point out findings that merit further assessment, and discuss examples where results were integrated across multiple chapters in the report.

The Live Impact Area (LIA) was used for decades as a bombing training range. Why were long term effects of this activity not readily seen in the marine environment during scuba surveys? To better understand this, it is important to recall that the scope of inference for most of this study was the entire marine ecosystem around Vieques. Sampling design was based on randomly placed survey points within several large strata, one of which consisted of waters offshore of the LIA. As such, sampling was not intentionally directed toward specific features such as impact craters (although the random design did result in sediments being sampled from some suspected impact craters). Acute and severe physical impacts from events such as bomb detonation are unquestionable, however, assessment of such specific events was not the objective of the present study. That we found no detectable effects on fish or habitat in scuba surveys, for example, should not be taken as evidence of no impact from

Image 7.1 Unexploded ordnance adjacent to a patch of hardbottom.

bombing activities. Instead it is merely likely that the impacts from bombing were more concentrated in areas closer to shore or nearer the land-based bombing targets and that our randomly placed surveys simply did not encounter them. Other research has directly sought impact craters to quantify such damage (Rogers et al. 1978; DON 1980; Macintyre et al. 1983; DON 1986; Porter 2000; Barton and Porter 2004). Additional sampling could ultimately detect such effects and strata could be added to force sampling into suspected areas. As more time passes since Naval activities ceased in 2003, coral and other benthic cover will continue to regrow, hurricanes will continue to rearrange and create more rubble, and bombing effects will further blend into the natural condition of Vieques' other reefs.

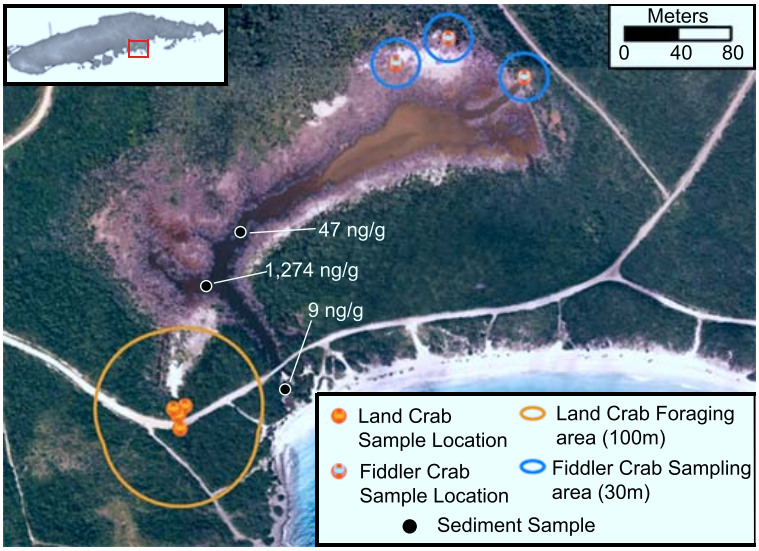


Figure 7.1. DDT levels in sediment samples collected inshore from Playa la Chiva. Crab sample locations from NOAA and Ridolfi (2006) are also displayed.

As part of this project, 78 sediment samples were analyzed for chemical contaminants, including 15 energetics and energetic-related compounds. The presence of energetics could not be confirmed in any of the sediment samples analyzed. A number of possibilities can be suggested for these findings. As noted, the bombing that occurred on Vieques was focused on land-based and nearshore targets. It is likely that many of the sites sampled for sediments and corals in this study were not in an area where ordnance had detonated. Four sites sampled, however, appeared to be in bomb craters and also yielded no confirmed detections of energetics. The detonation of ordnance containing compounds like RDX, HMX and TNT has been reported to result in only small (parts per thousand to parts per million) amounts of these materials remaining at the site of detonation (Hewitt et al. 2003; Walsh et al. 2005). This is in contrast to the higher reported concentrations of energetics found adjacent to at least one unexploded piece of ordnance in Vieques (Barton and Porter 2004). Finally, it is also likely that environmental degradation of any energetics present, even in what appeared to be bomb craters, has occurred since 2003. It is important to note that this study was focused on the sediments and corals of the marine and wetland environments of Vieques. A number of other studies including ATSDR (2003) and CH2M HILL (2002) have assessed the presence of energetics (and other contaminants) in both the terrestrial environment and selected biota (fish, ATSDR 2003; land crabs, NOAA and Ridolfi 2006). Additional sampling using both targeted and randomized strategies to examine particular features (e.g., only four bomb craters were sampled in the present study), key habitats, biota, and the ecological connections among them is warranted to further characterize the presence of energetics around Vieques.

While chemical contaminants were generally below known levels of concern, there were a few exceptions. The most noteworthy being the very high level of DDT observed in the inland lagoon north of Playa la Chiva (Blue Beach). The high levels of parent compound (DDT) and relatively low proportion of degradation products (DDE) found in sediments may indicate that an old spill or application of DDT persists in the area due to environmental conditions that are not conducive to degradation. Of greater concern, it is also possible that given the extremely high parent compound values, there may be a source of non-degraded DDT still leaking from a container. Both the overall extent and the maximum concentration of contamination in this area are unknown. Only three samples were taken in this salt pond and these were within 250 meters of each other (Figure 7.1). Only the central sample had the highly elevated DDT levels. Additional sampling in and around this area is needed to determine the extent and concentration of contaminated soils and possibly identify the source of the contaminant. While separated from the marine waters off Playa la Chiva at the time of sampling by a low sand berm, this salt pond presumably has a periodic connection with and is flushed into the reef ecosystem to the south. It is important to note that the high DDT concentrations seen here were measured in sediments. Land crabs and fiddler crabs were sampled from nearby forests in 2005 (NOAA and Ridolfi 2006) although the suspected foraging range of the specific crab samples did not overlap with the sediment sample with high DDT. While DDT/DDE was detected in crab tissues, concentrations were below levels known to cause adverse health effects in children and adults (ATSDR 2006). Biota such as consumable fish and crabs should be sampled more thoroughly in the area to identify pathways of trophic transfer and determine the potential for human health effects.

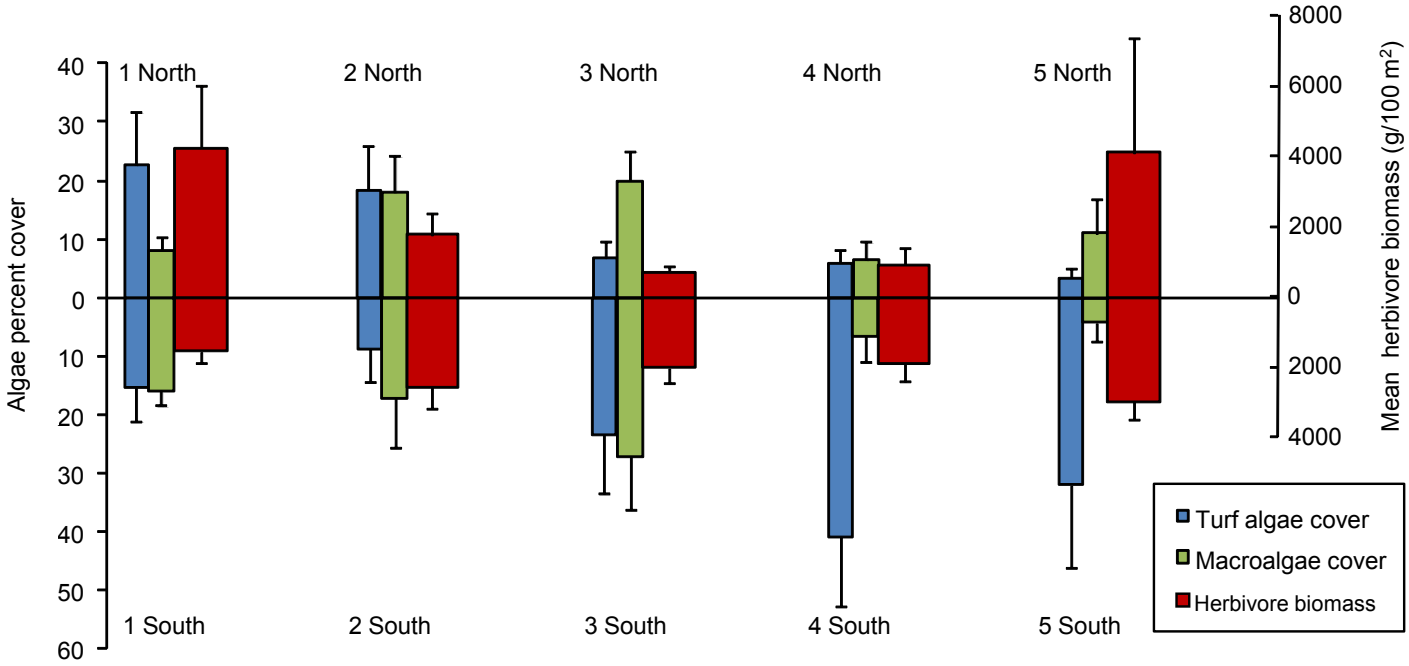


Figure 7.2. Mean (±SE) percent turf and macroalgal cover, and herbivore biomass across strata.

Like most of the Caribbean, algae was the dominant cover type encountered on scuba surveys of Vieques reefs although percent cover varied considerably among strata. Macroalgae had higher cover in the central and western strata (Figure 7.2). This observation was consistent with the hypothesis that anthropogenic sources of nutrients from the civilian area may have caused the higher algal concentrations in the central strata and those down current in the strata to the west. Cover of turf algae also differed among strata with highest values in the northwest and southeast strata (Figure 7.2). The nutrient levels observed in this study, however, did not have a pattern consistent with that of algal coverage (turf or macro-algae or both combined) and showed no evidence of an anthropogenic or land based source of pollution. The recent pattern of algal dominance on Caribbean reefs is thought to be due to the combined effects of massive die-offs of the dominant coral species through disease and bleaching, nutrient enrichment, and primarily, the severe depression of algal grazers such as urchins and herbivorous fish through disease and overfishing (Lapointe 1997; Littler and Littler 2007; Sotka and Hay 2009). Biomass of herbivorous fish was indeed inversely related to macroalgal cover on the north shore of Vieques. This observation is consistent with the hypothesis that heavy grazing controls algal cover, however, this same pattern was not evident on the south shore of Vieques. The interesting patterns in algal cover observed among strata around Vieques may be due primarily to factors other than herbivore grazing or nutrient enrichment such as simple habitat differences.

Fish communities of Vieques were similar in composition and biomass to those seen elsewhere in the US Caribbean. One exception was for overall snapper biomass and density on hard bottom, especially along the south shore of Vieques (Figure 3.31). Values there were more than twice as high as on similar habitats in Parguera, Puerto Rico, an area for which comparable data is available (Figure 3.45). The south shore of Vieques has an abundance of juvenile fish habitat for snappers in the form of bays, lagoons, seagrass meadows, and mangroves. It is possible that adult or juvenile habitat, or both, are higher quality around Vieques than Parguera and therefore they support higher snapper densities. This pattern is not consistent among other fish families and community measures (e.g., species richness or diversity) and may be due to random aspects of recruitment success. The causes of different snapper abundance in these two locales are worthy of further investigation.

Recent attention has been given to the potential for establishment of a marine protected area (MPA) in Vieques (Shvilani 2007; H.R. 5864 2008). Further, the findings of the current and other recent studies (e.g., Kendall and Eschelbach 2006) coupled with the recent conversion of large portions of Vieques land into a National Wildlife Refuge represent a potential opportunity for marine conservation. Marine resources are in similar condition to those elsewhere in the region and do not appear especially degraded or impacted by either Naval or civilian use. Much of Vieques' land is now preserved and will be allowed to return to a natural state which will greatly limit many of the negative impacts to coral reef ecosystems that are associated with watershed development. The bioluminescent bay, which was designated the Reserva Natural Bahia Puerto Mosquito as part of the

Puerto Rico Coastal Zone Management Program (PRCZMP) in 1989, is a rare ecological treasure that was targeted for further protection in proposed congressional legislation (H.R. 5864 2008). Additionally, the Compania de Parques Nacionales operates Sun Bay to the east, and currently the Fish and Wildlife Service controls land-based access to the eastern coastal areas. In a recent community study, stakeholder groups expressed a variety of opinions on the establishment of an MPA in Vieques, but many agreed that protection of the marine environment needed to be improved (Shivlani 2007). There are additional attributes that suggest an MPA would be locally beneficial to Vieques and Puerto Rico. Vieques has a full diversity of representative marine habitats in close proximity to each other from mangrove lined bays to shelf edge coral reefs. This density of ecosystem features can be more efficiently encompassed at Vieques relative to conserving target habitats that are more widely spread out elsewhere in Puerto Rico. In addition, the prevailing currents in this region place Vieques upstream relative to the rest of Puerto Rico for much of the year. Although much research remains on the topic, healthy fish and larval production in a Vieques MPA may be exported to and benefit other parts of Puerto Rico more than an MPA positioned farther downstream. Collectively, these features make local coral reef ecosystems, marine zoning, and MPA planning a valuable opportunity for conservation, ecotourism, and fisheries management for Vieques and Puerto Rico.

A wide diversity of additional ecological connections and management alternatives could be investigated by combining the data collected for this report with data from previously existing studies summarized in Part I of this series (Bauer et al. 2008) and other types of information entirely such as socioeconomic surveys (Shivlani 2007). Further investigation of Vieques' marine ecosystems using the data in this series of reports is encouraged. Data for this and our other nearby studies in the region are available at no cost and can be querried and downloaded on the internet. For more information please visit the site:

http://ccma.nos.noaa.gov/ecosystems/coralreef/vieques.html

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