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Brian K. Walker
Nova Southeastern University, walkerb@nova.edu

David S. Gilliam
Nova Southeastern University, gilliam@nova.edu

Richard E. Dodge
Nova Southeastern University, dodge@nova.edu

Joanna Walczak
Florida Department of Environmental Protection

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Dredging and shipping impacts on southeast Florida coral reefs

Brian K. Walker[1], David S. Gilliam[1], Richard E. Dodge[1], Joanna Walczak[2]

[1] National Coral Reef Institute, Nova Southeastern University, Dania Beach, FL, USA
[2] Florida Department of Environmental Protection, Miami, FL, USA
Corresponding author: walkerb@nova.edu

Abstract. Many coastal regions have experienced extensive population growth during the last century. Commonly, this growth has led to port development and expansion as well as increased vessel activity which can have detrimental effects on coral reef ecosystems. In southeast Florida, three major ports built in the late 1920's along 112 km of coastline occur in close proximity to a shallow coral reef ecosystem. Recent habitat mapping data were analyzed in GIS to quantify the type and area of coral reef habitats impacted by port and shipping activities. Impact areas were adjusted by impact severity: 100% of dredge and burial areas, 75% of grounding and anchoring areas, and 15% of areas in present anchorage. Estimates of recent local stony coral density and cover data were used to quantify affected corals and live cover. After adjusting for impact severity, 312.5 hectares (ha) of impacted coral reef habitats were identified. Burial by dredge material accounted for 175.8 ha. Dredging of port inlet channels accounted for 84.5 ha of reef removal. And 47.6 ha were impacted from a large ship anchorage. Although the full extent of all ship groundings and anchor drags associated with the ports is unknown, the measured extents of these events totaled 6 ha. Based on the adjusted impact areas, over 8.1million corals covering over 11.7 ha of live cover were impacted. Burial impacts were the greatest. The planned expansion of two of the ports would remove an additional approximate 9.95 ha of coral reef habitat. Ongoing marine spatial planning efforts are evaluating the placement of large ship anchorages in an effort reduce future impacts from ship anchoring. However, increasing populations and shipping needs will likely continue to be prioritized over protection of these valuable natural resources.

Key words: Benthic habitat map, vessel, grounding, anchor, burial.

Introduction

Many coastal regions have experienced extensive population growth during the last century. This growth has included infrastructure to facilitate the transit of large ocean-going vessels. Maritime shipping is essential to the global economy and is a critical element in the global freight transport system (Corbett et al. 2010). In response to globalization, maritime shipping has rapidly increased in the last century from 30,000 total vessels in 1900 to 90,000 (Corbett et al. 2010) and is expected is continue. Along with freight, the cruise ship industry has increased significantly over the years (Véronneau and Roy 2009). Increases in vessel demands have led to coincident port development.

Port development and increased vessel activity can have detrimental effects to associated benthic communities, especially on coral reefs where the hard framework may take thousands of years to form. Port development may require blasting and/or dredging through nearby sensitive coral reef habitat to facilitate vessel access. It may also include burial of areas to place spoil or build infrastructure. These types of impacts can have irreversible effects.

Increased vessel activity, among other things (e.g. pollution, turbidity), can lead to greater grounding and anchoring incidences. Previous ship groundings have destroyed local reef communities worldwide by scraping, pulverizing, and/or burying the biota (Hudson and Diaz 1988; Precht et al. 2001; Jaap et al. 2006; Precht and Robbart 2006; Lirman et al. 2010). Ship anchoring can have similar effects not only from the anchor itself, but from movements of the chain (Smith 1988; Allen 1992; Rogers and Garrison 2001). Grounding and anchoring events can permanently modify the landscape of the area and may degrade the surrounding communities if appropriate restoration techniques are not implemented (e.g., rubble removal, securing loose substrate) (Jaap et al. 2006).

Effects of port development and increased shipping activities on coral reef systems are prevalent in southeast Florida. Coincident with global increases in shipping, three southeast Florida (SE FL) deep-water ports, Port of Miami (PoM), Port Everglades (PE), and Port of Palm Beach (PoPB), have grown substantially. Every year an increasing number of ships (especially cruise and freight) visit the region (Port Everglades Department 2010). Although their

economic contribution is immense [e.g. Port Everglades contributed an estimated $13.9 billion in economic value to the State of Florida (Martin Associates 2010)], increased ship traffic has also increased the risk of associated impacts to sensitive marine habitats.

SE FL contains an extensive high latitude (25.5° – 27.25°) reef system, extending approximately 170 kilometers (km) through Miami-Dade, Broward, Palm Beach, and Martin counties (Walker et al. 2008b; Walker 2012) (Fig. 1). Approximately 255 km² of coral reef habitat have been mapped consisting of a diverse coral reef community of scleractinian corals, gorgonians, sponges, algae, and reef fish. Three reef lines separated by sand deposits run approximately parallel to the shore in water depths ranging from 5 – 30 meters (m) and a series of ridges and colonized pavement exist on the shoreward side of the reefs in approximately 2 to 5 m depth.

Historically (late 1920's), large areas of coral reef habitats were impacted by dredging and burial to develop the three major ports that occur along 112 km of coastline (PoM, PE, and PoPB). More recently, shipping activity has also impacted coral reef habitats by anchoring and grounding incidences due to the close proximity and design of large-vessel anchorages (Fig. 1). At PoM and PE, large ships are brought to anchor in waters adjacent to, or directly on, coral reef and hardbottom habitats. This practice has led to a number of vessel groundings and anchor impacts, causing damage to natural resources and ships.

The cumulative extent of port development and shipping-related coral reef impacts associated with these three ports has never been previously documented, yet the amounts are thought to be substantial. Habitat mapping data are now available (Walker 2012) that can be used to estimate the extent of coral reef habitats impacted by these activities. Here we analyze bathymetry, habitat mapping data, grounding assessment data, and large vessel anchorages to estimate the cumulative extent of coral reef impacts from port dredging and burial as well as from related ship groundings and anchor damage on the SE FL reef system. Based on development plans, we estimate future injury extents. We provide recommendations to help reduce future impacts.

Material and Methods

Impacts were categorized into five main types: dredging, burial, anchoring, grounding, and in-present-anchorage (Figs. 2 & 3). Dredging impacts were estimated by visually analyzing lidar bathymetry and existing benthic habitat data in GIS. The present entrance channel to each port was evaluated to identify dredging impacted coral reefs. In areas where reef habitat was present on both the north and south side and appeared to be previously impacted by dredging (sharp edges, striated surfaces), polygons were drawn with straight lines to connect the north and south habitats. Planar area of each polygon was calculated in GIS and totaled.

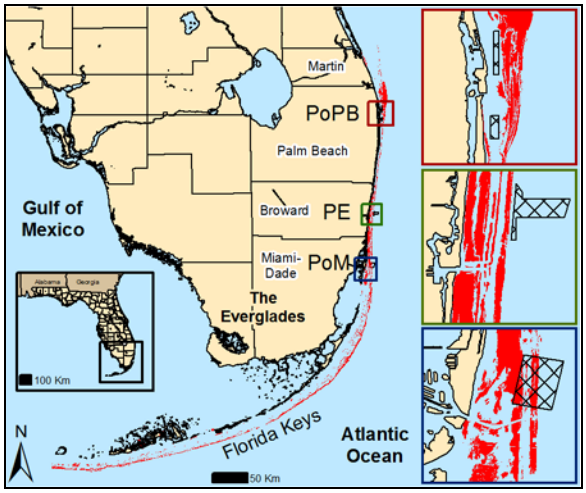

Figure 1: A map of south Florida illustrating the coral reef habitats (red) and the large vessel anchorages associated with each port (black hashed). Port of Palm Beach (PoPB) is outlined in red, Port Everglades (PE) is outlined in green, and Port of Miami (PoM) is outlined in blue.

Coral reef habitat burial area was estimated by visual interpretation of the lidar bathymetry with *in situ* confirmation. Burial occurred either from the dumping of dredged material onto reef or by construction of submerged breakwaters or artificial reefs near the channel to dissipate wave energy. Areas where piled material on previously continuous reef habitats was evident were delineated. These areas were confirmed by divers to be piles of unconsolidated materials ranging in size from pebbles to 1-2 m diameter boulders (Walker et al. 2006).

In situ known grounding and anchoring data were obtained from the Florida Department of Environmental Protection's Coral Reef Conservation Program (FDEP CRCP). FDEP keeps an active record on the locations and measured amount of vessel impacts in southeast Florida.

In-present-anchorage impacts were determined by evaluating the large vessel anchorages associated with each port to determine the amount of mapped coral reef habitat inside.

Effects within impact types were not considered equally, thus impact areas were adjusted according to an estimated impact severity. Dredging and burial areas, where the habitat was removed or buried, were considered a total loss of habitat (100% impacted). *In situ* measured grounding and anchoring areas were estimated at 75% impacted because these assessments included some areas that were not entirely impacted.

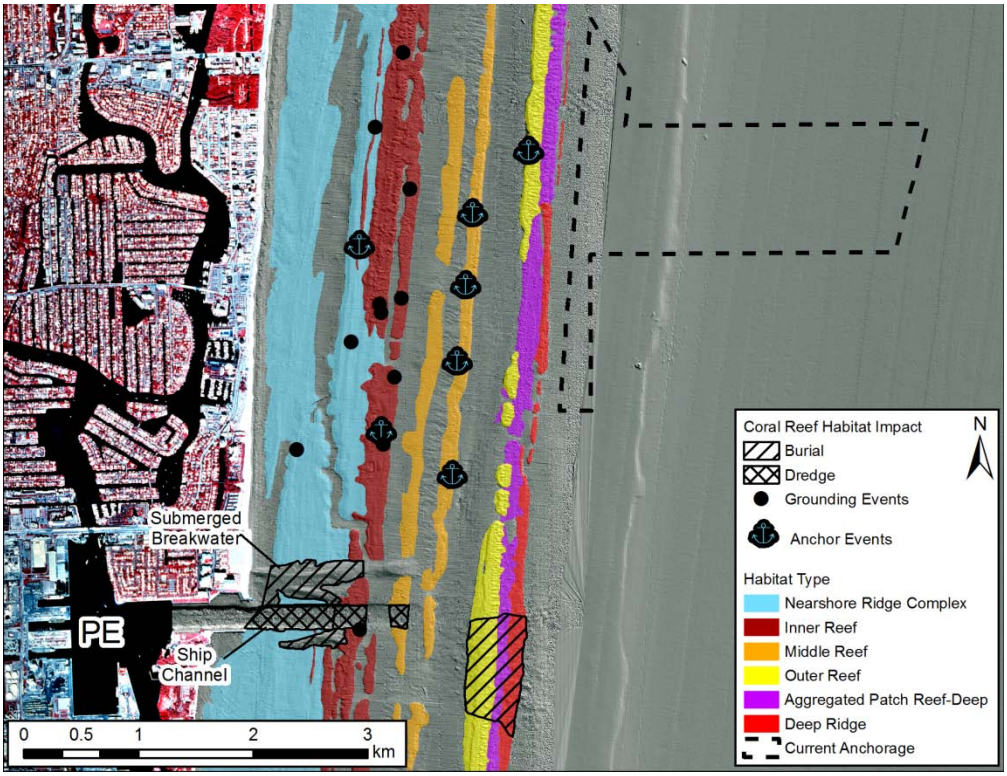

Figure 2: Map of Port Everglades dredging and shipping-related direct impacts to coral reef habitats. Grounding and anchoring points show the locations of known events present in the Florida Department of Environmental Protection's Coral Reef Conservation Program (FDEP CRCP) database.

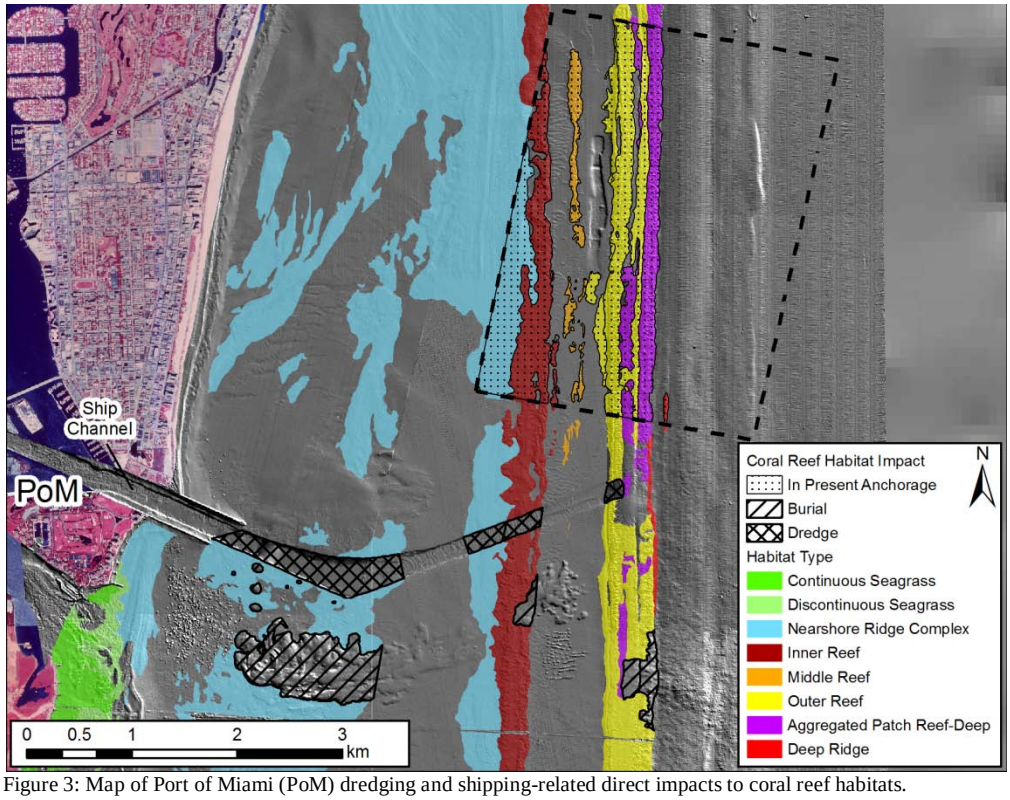

Figure 3: Map of Port of Miami (PoM) dredging and shipping-related direct impacts to coral reef habitats.

Estimating impacts for habitats in the present anchorage were challenging because of a lack of information on the anchorage's use, the severity of each incident, and the cumulative impact. A conservative estimate of 15% of the total area of habitat in the present anchorage was considered entirely impacted.

Scleractinian coral impacts were estimated per impact type by multiplying the adjusted impact area by local density and cover estimates. Coral density and cover varies in SE FL with habitat and latitude (Walker 2012), but mean density (colonies >2 cm diameter) and cover are approx. 2.6 m^{-2} (26,000 per ha) and 3.75% respectively (Gilliam et al. 2010).

Results

Table 1 shows the results of the GIS spatial analysis of benthic habitats by impact type. Over 584 hectares (ha) of coral reef habitats were identified as having impact. Adjusting for impact severity (impact %) within these areas reduced this amount to 312.5 ha. The largest reef impacts came from burial by dredge material, which totaled 175.8 ha. An estimated 84.5 ha of reef were dredged to create and maintain the port channels. And 47.6 ha of the 317.5 ha of coral reef habitats currently located within the PoM ship anchorage were considered entirely impacted.

	Impact Type	Total Imp. Area (ha)	Impact %	Adjusted Impact Area	Est. Impacted No. of Corals	Est. Impacted Live Cover (ha)
Benthic Habitat Analysis	Previously Dredged	84.5	100%	84.5	2,196,920	3.17
	Previously Buried	175.8	100%	175.8	4,569,635	6.59
	In Present Anchorage	317.5	15%	47.6	1,238,352	1.79
FL DEP Data	Grounding Incidences	6.0	75%	4.5	116,805	0.17
	Anchor Incidences	0.2	75%	0.16	4,261	0.01
	Total	584.0	-	312.5	8,125,973	11.72

Table 1: The total impact area, impact percentage, adjusted impact area, estimated number of impacted corals, and area of impacted live cover by impact type.

The estimated total number of impacted corals and the area of lost live coral cover by port and vessel activities were substantial. Based on the adjusted impact areas, over 8.1 million (M) corals covering over 11.7 ha of live cover were impacted. Burial impacts were the greatest destroying over 4.5M corals comprising 6.59 ha of live cover.

Adjusted impacted areas were not proportional throughout the region. 65.1% of the adjusted impacted area was associated with PoM (Fig. 4). This was mainly from three impact types: buried (30.4%), dredged (19.5%), and in-present-anchorage (15.2%). Total impacted area associated with PE was estimated to be 32.1%; the majority coming from three types: buried (23.1%), dredged (7.6%), and groundings (1.4%). PoPB had 2.8% of the total impact area, which was nearly all associated with buried habitat.

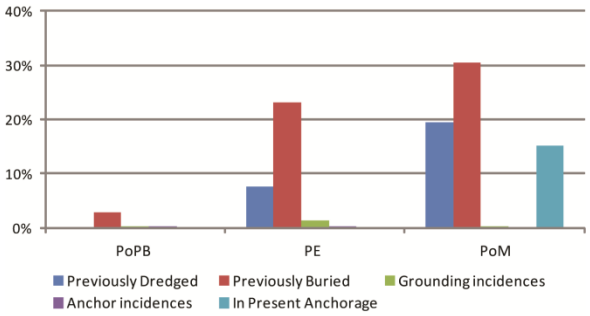

Figure 4: Percent of total adjusted impacted area by port (PoM = Port of Miami, PE = Port Everglades, and PoPB = Port of Palm Beach) and impact type.

Although the full extent of all ship anchoring and groundings are unknown, the measured extents totaled approximately 6 ha according to the FDEP CRCP database. Until recently, SE FL ship grounding data were not compiled. In 2006, FDEP CRCP started actively logging grounding and anchoring occurrences, locations, and impact extents where possible and set up a hotline for reporting events. Their database contained 14 reef anchoring and 21 ship groundings from state records and reports. The impact extent of many of these incidences remains unknown, but three groundings comprised 74% of the recorded injury: the M/V Federal Pescadores (2004) with 2.3 ha, the M/V Eastwind (2004) with 1.1 ha, and the M/V Morania (1979) with 0.99 ha.

Discussion

Port dredging and shipping associated impacts to coral reef habitats in SE FL are substantial. Much of the impacts (83.3%) came from dredging and burial associated with the creation of the ports in the late 1920's. These activities impacted 260.3 ha of habitat containing nearly 6.8 M corals greater than 2 cm dia with 9.7 ha live cover. This occurred in a time that promoted development before the economic and ecological value of coral reefs was understood. Although these values are better known today, it is still a small consideration when evaluating the feasibility of port expansion. Presently, all three ports are planning expansion in the near future to accommodate the next class of supertankers. In a spatial analysis of the planned port expansions with respect to mapped habitats, PoM is planning to dredge an additional 1.3 ha of coral reef and PE is planning to remove an additional 8 ha (Walker et al. 2008a).

It bears noting here that impact estimates based on recent density and cover data which have been affected by numerous local, regional, and global stressors likely underestimate the coral impacts. Stony coral populations have dramatically decreased in the last 50 years. Their sizes and densities were likely higher when the burial and dredging impacts occurred.

The effects of short- and long-term anchoring impacts in the present PoM anchorage are currently unknown. The anchorage has been frequently visited since the 1960s, it averages three ships anchoring per day, and the most used portion is comprised of ~55% coral reef habitat. The largest area of impacted habitats came from those present in the current anchorage at PoM; however the nature of these impacts were not as severe as burial and dredging. Adjusting for the severity of impact conservatively estimated that 47.6 ha were totally impacted. The actual number may be much higher depending on the severity and extent of cumulative anchoring impacts. Following a detailed study of the SE FL anchorages (Walker 2010), marine spatial planning (MSP) efforts are underway by a group of local, state, and federal agencies, port personnel, and stakeholders to modify the current anchorage configurations and avoid these continuing reef impacts. Several proposals are being considered in this process. If a configuration is chosen without coral reef habitat present, almost 318 ha of reef will be conserved from future anchorage activity and allowed the potential to recover.

Most of the grounding and anchoring incidences were associated with the PE large-vessel anchorage (Fig. 2). Its original design brought ships to anchor unnecessarily close to coral reef habitats and did not allow much time for evasive action in the event of an emergency before the ship was aground. This practice led to a number of vessel groundings and anchor impacts on these reefs, causing damage to natural resources and ships. A MSP effort similar to PoM was conducted and modifications were implemented in 2008. There have been no groundings associated with the PE anchorage since that time.

Globally, coral reefs are impacted by numerous large-scale factors like climate change and runoff that take many years, strong political will, and millions of dollars to correct. In contrast from these large-scale factors, most impacts from shipping activities are avoidable by employing best management practices in locales where shipping is in close proximity to coral reef habitats. In SE FL, reconfiguring the present PoM anchorage would reduce shipping related impacts on a large portion of the impacted area. Furthermore avoiding impacts on planned port expansion projects could keep another 9.95 ha from being destroyed. Ultimately, it will be up to the public to weigh the economic benefits with coral reef health; however, previous trends have favored development over conservation.

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References

Allen WH (1992) Increased dangers to Caribbean marine ecosystems: Cruise ship anchors and intensified tourism threaten reefs. Bioscience 42:330-335

Corbett JJ, Winebrake J, Endresen Ø, Eide M, Dalsøren S, Isaksen IS, Sørgård E (2010) International Maritime Shipping:The Impact of Globalisationon Activity Levels. In: OECD (ed) Globalisation, Transport and the Environment, pp55-79

Gilliam D, Dodge R, Spieler R, Jordan L, Goergen E (2010) Marine biological monitoring in Broward County, Florida: Year 9 Annual Report. Prepared for the BC Board of County Commissioners, BC Natural Resources Planning and Management Division 105

Hudson JH, Diaz R (1988) Damage survey and restoration of M/V Wellwood grounding site, Molasses Reef, Key Largo National Marine Sanctuary, Florida. . SIXTH INTERNATIONAL CORAL REEF SYMPOSIUM 2: CONTRIBUTED PAPERS (MINI SYMPOSIUM 1 TO 10/14):231-236

Jaap W, Hudson J, Dodge R, Gilliam D, Shaul R (2006) Coral reef restoration with case studies from Florida. In: Cote I, Reynolds J (eds) Coral Reef Conservation. University of Cambridge Press, Cambridge, United Kingdom, pp478-514

Lirman D, Gracias N, Gintert B, Gleason A, Deangelo G, Dick M, Martinez E, Reid R (2010) Damage and recovery assessment of vessel grounding injuries oncoral reef habitats by use of georeferenced landscape video mosaics. Limnology and Oceanography: Methods 8:88-97

Martin Associates (2010) The local and regional economic impacts of Port Everglades: Fiscal Year 2009. Prepared for Broward County's Port Everglades Department, Lancaster, PA

Port Everglades Department (2010) Fiscal Year 2009 Commerce Report: Buoyed by Sustainability. Broward County, Fort Lauderdale, FL 64

Precht WE, Robbart M (2006) Coral reef restoration: The rehabilitation of an ecosystem under siege. In: Precht WE (ed) Coral reef restoration handbook. CRC Press, pp1-24

Precht WF, Aronson RB, Swanson DW (2001) Improving scientific decision-making in the restoration of ship-grounding sites on coral reefs. Bull Mar Sci 69:1001-1012

Rogers CS, Garrison VH (2001) Ten years after the crime: Lasting effects of damage from a cruise ship anchor on a coral reef in St. John, U.S. Virgin Islands. Bull Mar Sci 69:793-803

Smith SH (1988) Cruise Ships: A Serious Threat to Coral Reefs and Associated Organisms. Ocean & Shoreline Management 11:231-248

Véronneau S, Roy J (2009) Global service supply chains: An empirical study of current practices and challenges of a cruise line corporation. Tourism Management 30:128-139

Walker BK (2012) Spatial Analyses of Benthic Habitats to Define Coral Reef Ecosystem Regions and Potential Biogeographic Boundaries along a Latitudinal Gradient. PLoS ONE 7:e30466

Walker BK (2010) A Study to Minimize or Eliminate Hard Bottom and Reef Impacts from Anchoring Activities in Designated Anchorages at the Ports of Miami and Palm Beach. Florida DEP report #RM083, Miami Beach, FL 59

Walker B, Dodge R, Gilliam D (2006) Coral Reef Burial in Southeast Florida. Global Challenges Facing Oceanography and Limnology, American Society of Limnology and Oceanography

Walker B, Dodge R, Gilliam D (2008a) LIDAR-derived Benthic Habitat maps enable the Quantification of Potential Dredging Impacts to Coral Reef Ecosystems. ACES: A Conference on Ecosystem Services 2008: Using Science for Decision Makingin Dynamic Systems

Walker BK, Riegl B, Dodge RE (2008b) Mapping coral reef habitats in southeast Florida using a combined technique approach. J Coast Res 24:1138-1150