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Capacity-building paper

Identifying management challenges and implementation shortcomings of a new fishing refuge: Akumal reef, Mexico

Ana L. Molina-Hernández[a], Joaquín R. Garza-Pérez[a,b,*], Adán Aranda-Fragoso[a,b]

[a] Programa de Investigación Espacial en Ambientes Costeros y Marinos (PIESACOM), Unidad Multidisciplinaria de Docencia e Investigación Sisal, Universidad Nacional Autónoma de México, Puerto de Abrigo S/N, Sisal, Hunucmá, Yucatán, C.P. 97355, Mexico
[b] Laboratorio Nacional de Resiliencia Costera (LANRESC), Mexico

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ABSTRACT

No-take marine reserves (fish refuges -FR-in Mexico) eliminate fishing pressure for long periods in delimited areas, promoting fish reproduction and recruitment, recovery of fish community abundance and biomass, augment resistance and resilience in coral reef-associated marine ecosystems, and support local fishing-based economies. A FR was implemented on Akumal reef in 2015 limiting fishing for six years with the specific aim of increasing the biomass of commercial and sport-recreational interest fish species. However, no previous reference data were considered to establish an ecological baseline to quantify progress towards this aim, or to implement any other policy necessary to ensure compliance with this objective. To fill this gap, Akumal FR's current level of potential success was assessed (relating reef fish community characteristics and habitat components characteristics). FR's potential success was quantified as low due to the absence of 50% of listed commercial-sport fish species, critical biomass values for recorded species on the list, and generally low reef fish abundance and biomass values. In addition, current habitat condition is critical because of coral-algal phase shift, changes in coral community structure, and loss of reef structure and the associated reef's refuge function for fish species. Considering the performance of existing no-take marine reserves, Akumal low FR's potential success implies that a much longer no-take period (than the established six years), will be necessary to allow reef fish populations to recover biomass and attain functional levels within the ecosystem that could support on-going fishing impact. Based on this, a number of recommendations were established in order to strengthen the management provisions to allow the reef to attain a better condition, including an extension of the no-take period, enforcement of non-extractive uses, and simultaneous implementation of coastal management strategies.

1. Introduction

Forty percent of fish species worldwide are distributed in coastal zones on continental shelves above 200 m depth and are mainly associated with coral reefs (Helfman et al., 2009). This species group is one of the most diverse vertebrate assemblages and is extremely valuable in ecosystem functioning and as a commercial resource (Moberg and Folke, 1999; Cesar et al., 2003). Reef fish species have many functions that favor reef resistance and resilience to natural and anthropogenic impacts, including transferring energy through trophic levels and habitats, limiting growth in different trophic groups by predation, influencing succession patterns in benthic communities by mediating competition for space, contributing to natural erosion and removing and replacing sediment (Szmant-Froelich, 1983; Munday et al., 2008; Clark et al., 2009; Green and Bellwood, 2009; Pratchett et al., 2012). Their capture generates substantial income; the 3741-ton average annual capture in the Mexican Caribbean accounts for 0.2% of national gross domestic product (GDP) (Cesar et al., 2003; INEGI, 2011; CONAPESCA, 2012).

Of clear ecological and economic importance, reef fish and their habitats are threatened by alterations caused by factors associated with growing human populations in coastal zones. Principal among these is fishing, but others include environmental modifications and habitat loss in synergy with global climate changes that are leading to critical conditions for ecosystems and fisheries (Roberts, 1995a; Moberg and Folke, 1999; Munday et al., 2008; Wilson et al., 2010).

Reef habitat transformation and loss in the Caribbean are associated with a series of factors: disappearance of coral structures; decrease in topographical complexity and rugosity; diminishing live coral cover and coral colony numbers; changes in dominance from primary reef-

* Corresponding author. Programa de Investigación Espacial en Ambientes Costeros y Marinos (PIESACOM), Unidad Multidisciplinaria de Docencia e Investigación Sisal, Universidad Nacional Autónoma de México, Puerto de Abrigo S/N, Sisal, Hunucmá, Yucatán, C.P. 97355, Mexico.
E-mail address: rgarza@ciencias.unam.mx (J.R. Garza-Pérez).

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building species to non-reef-building species; and overall changes in benthic group composition and dominance, mainly due to increases in macroalgae cover. All these factors imply declines in or loss of reef functions as a substrate, refuge and food source (Mumby et al., 2007; Alvarez-Filip et al., 2009, 2011; 2013; Jackson et al., 2014).

Fishing directly unbalances fish populations, causing, among other effects, earlier maturity with progressively smaller-sized adults. It also diminishes the number of trophic levels in the fish community, primarily due to loss of large predators such as sharks, barracudas and groupers. Size, abundance and biomass of some fish species are consequently used as indicators of fishing impact (Pauly et al., 1998; Graham et al., 2005; Wilson et al., 2010; Garcia et al., 2012). How habitat transformation and fishing affect a fish community will depend on different species' degree of association or dependence on habitat, as well as fishing target species and fishing intensity (Wilson et al., 2008, 2010; Alvarez-Filip et al., 2015).

Management strategies have been implemented in the Mexican Caribbean, and many other reef zones around the world, using legal tools to promote ichthyofauna conservation and maintain local fisheries. Among these tools are the spatial limitation, temporal restriction (such as closed seasons during specific life cycle stages), catch limits, and protection of critical habitat (e.g. Natural Protected Areas, No-Take Marine Reserves, etc.) (Pitcher and Hart, 1982; Russ and Alcala, 2003).

Several successful cases have shown no-take marine reserves to be effective in protecting coral reefs in the Caribbean: Saba Marine Park, Glover's Reef, Belize; Jardines de la Reina, Cuba; Exuma Cays, Bahamas; and Dry Tortugas, USA. After five to fifteen years of protection from fishing, increases have been reported in the abundance, biomass and diversity of fish, crustacean, mollusk and other species, and positive effects observed along reserve boundaries (Roberts, 1995b; Roberts et al., 2001; Lubchenco et al., 2008; Ault et al., 2013). In response, no-take marine reserves (legally termed *zonas de refugio pesquero*, or fish refuge zones – FR-) have become increasingly popular in Mexico since 2010.

The success of a FR depends on the details of its management provisions, compliance with these, and environmental and ecological factors. Provisions include the type of restrictions established, inspection and monitoring guidelines, protection time period, the proximity of other protected areas, actor participation, etc. (Pollnac et al., 2001; Jupiter and Egli, 2011; McClanahan and Graham, 2015). However, fish community variability as well as the FR recovery capacity, aside of management provisions, are influenced by three main factors: 1) habitat structure, including benthic organisms cover, depth, rugosity and nearness of reproduction and nursery areas (e.g. seagrass beds and mangrove); 2) ecological processes such as competition for food and refuge, predation and disease; and 3) stochastic processes such as recruitment and natural disturbances (Roberts, 2000; Nagelkerken et al., 2002; Sale, 2002; Mumby et al., 2004; De Raedemaecker et al., 2010).

Local NGOs in Northern Quintana Roo México (Centro Ecológico Akumal – CEA, and Alianza Kanan Kay) worked with reef users (Cooperativa de Pesca Tulum – SCPPPT, legal grantee of the fishing concession in Akumal) to propose an area of 9.88 km^2 of Akumal reef as a FR; which was decreed on 2015 (DOF, 2015). based on their concerns about observed declines in reef fish community abundance and biomass; specifically, critical biomass values ($\approx 500\ g/100\ m^{-2}$) for key commercial species, and general decreases in reef fish abundance (Figueroa and Penié, 2013; Kramer et al., 2015; SAGARPA, 2015). Akumal FR was created to meet three main objectives: 1) conserve 21 species of commercial and recreational-sport interest; 2) recover biomass levels for these species, particularly the grouper *Epinephelus striatus*; and 3) increase overall fish biomass inside the FR and adjacent areas (SAGARPA, 2015).

The specific guidelines of Akumal FR were established, and are currently regulated, by the interested parties (i.e. CEA, SCPPPT, SAGARPA). They are partially described in the technical-support study for FR implementation, the official federal declaration of the FR, and the refuge management plan (SCPPPT, 2014a; b; SAGARPA, 2015):

a) A six-year partial-seasonal fishing restriction was established for commercial or food fish species, and the capture of any flora and fauna inside FR boundaries.
b) Catch-and-release sport fishing is permitted
c) The only species excluded from any regulations is the invasive lion fish *Pterois volitans*.
d) No zonation of the protected area was designated, including no core zones.
e) Inspection and enforcement of compliance are carried out by the SAGARPA via the CONAPESCA and the Ministry of the Navy, while reef condition monitoring throughout the six years is to be done monthly by CEA and every four months by SCPPPT members.

In the context of the FR's conditions to achieve success, it lacks both a prior characterization of the reef fish community, as well as an assessment of the refuge function of the habitat; which would have enabled estimation of the FR's potential success and established a baseline condition with which to evaluate effectiveness. As part of an effort to provide support to the FR management decision making process, the main objective of this study was to establish the FR's current potential success, understood as its capacity to effectively meet its original management objectives based on the condition of reef fish and benthic communities.

2. Materials and methods

2.1. Study area

Akumal reef is on the east coast of the Yucatan Peninsula, in the state of Quintana Roo, Mexico (Fig. 1). Part of the Mesoamerican Reef System, it exhibits a typical fringing reef zonation. Seagrass beds, sand and bare limestone bedrock constitutes the reef lagoon extending from the shore to coral patches nearer the reef crest. The reef crest is dominated by *Acropora palmata* colonies in different states of conservation. The reef front and slope have a clearly defined ridge and channel system with greater coral, octocoral and sponge cover as depth increases up to 25 m (Jordan, 1978; Garza-Pérez, 2004). In the 1970s and 80s, scleractinian corals dominated (> 40%) benthic cover, algae covered no more than 20% of the substrate and coral and fish communities were highly diverse (Gutiérrez et al., 1995; Figueroa and Penié, 2013). From 2000 to 2016, the coastal zone area modified by urban/tourism development has risen 200% from 6.48 to 18.75 km^2.

2.2. Assessing current level of potential success

Five steps were used when assessing Akumal FR's potential success: 1) Fish community structure: Characterized in terms of specific richness; abundance and biomass of species, families and functional groups; and the sizes of key commercial and key herbivore fish species. 2) Benthic Habitat: Characterized in terms of benthic cover, coral community, rugosity and depth. 3) Reef Condition: Indicators were used to establish a score of the FR reef condition using the Simplified Integrated Reef Health Index -SIRHI- (Kramer et al. 2015) adjusted for reefs in the Mesoamerican Reef System. 4) Refuge Function: The relationship between fish and benthic communities was explored using multivariate analysis, to establish species associations to habitat components; and the area of fish critical habitats (seagrass and mangrove) was measured from satellite imagery. Finally, 5) A synoptic information tool for managers: Predictive maps were generated to identify zones that currently have the highest and lowest biomasses of key commercial and key herbivore fish species.