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Assessing the vulnerability of demersal elasmobranchs to a data-poor shrimp trawl fishery in Costa Rica, Eastern Tropical Pacific

Tayler M. Clarke[a,b,*,1], Mario Espinoza[b,c], Raquel Romero Chaves[b], Ingo S. Wehrtmann[b,c]

[a] *Programa de Posgrado en Gestión Integrada de Áreas Costeras Tropicales (GIACT), Centro de Investigación en Ciencias del Mar y Limnología (CIMAR), Universidad de Costa Rica, 11501–2060 San José, Costa Rica*

[b] *Unidad de Investigación Pesquera y Acuicultura (UNIP), Centro de Investigación en Ciencias del Mar y Limnología (CIMAR), Universidad de Costa Rica, 11501–2060 San José, Costa Rica*

[c] *Escuela de Biología, Universidad de Costa Rica, 11501–2060 San José, Costa Rica*

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ABSTRACT

The impact of shrimp trawl fisheries on slow-growing demersal sharks, skates and rays has been widely documented. Yet, a lack of catch records and biological information has hindered improvements in elasmobranch bycatch management, particularly in tropical regions. When information is scarce, data–poor methods can be valuable tools to guide the management and conservation of vulnerable marine taxa. Here we combined an Ecological Risk Assessment commonly used in data-deficient fisheries (Productivity Susceptibility Analysis or PSA) with a spatial analysis (Hotspot Analysis) to (i) identify which elasmobranch species are most vulnerable to the Costa Rican shrimp trawl fishery, and (ii) locate areas and seasons with high concentrations of vulnerable elasmobranchs. According to the results of our PSA, the scalloped hammerhead (*Sphyrna lewini*), prickly shark (*Echinorhinus cookei*), and long–tail stingray (*Hypanus longus*) were the most vulnerable species, while the least vulnerable species were small batoids of the Urotrygonidae family. We identified large information gaps, namely demographic parameter estimates and long–term bycatch trends. Spatial aggregations of vulnerable elasmobranchs occurred near highly productive estuaries and coastal habitats, especially at depths of 50–100 m. Based on our findings, PSA and Hotspot analyses can be powerful tools to identify spatial areas where trawl fishing grounds overlap with the habitat of vulnerable bycatch species, and thus can be used to design spatial trawling closures that protect species at risk. We therefore conclude that our methodological approach may aid in the implementation of ecosystem–based fisheries management in data–poor situations.

1. Introduction

Concern over widespread declines in elasmobranch populations has placed this group in the conservation spotlight (Dulvy et al., 2008, 2014; Simpfendorfer et al., 2011; Davidson et al., 2016; Davidson and Dulvy, 2017). A recent global assessment estimated that 25% of the world's sharks, skates and chimaeras are threatened with extinction (Dulvy et al., 2014). Although overfishing has been identified as the main driver of elasmobranch population declines, additional threats include habitat degradation, pollution, invasive species, and climate change (Polidoro et al., 2012; Bornatowski et al., 2014; Dulvy et al., 2014). Moreover, Davidson et al. (2016) found that declines in shark catches are correlated with large coastal human populations, large shark export volumes, high endemic diversity, and small continental shelves. Despite initiatives to reverse declining trends, only a quarter of the documented recoveries were a consequence of improved management, while the remaining 75% were a consequence of predatory or competitive releases (Ward-Paige et al., 2012; Davidson et al., 2016).

Management efforts to improve the sustainability of shark fisheries in the tropics are hindered by a lack of biological information and species–specific landing statistics (Bornatowski et al., 2014). Moreover, a large proportion of elasmobranch catches are discarded at sea, making it even more difficult to assess and manage the impact of some fisheries on elasmobranch populations (Stobutzki et al., 2002; Shepherd and Myers, 2005; Oliver et al., 2015; Clarke et al., 2016; Herrera-Valdivia et al., 2016; Navia and Mejía-Falla, 2016). Tropical bottom trawl fisheries discard a high diversity of elasmobranchs. Batoids (skates and rays) in particular, tend to be highly susceptible to bottom trawl fisheries due to their relatively large body size and low mobility (Stobutzki et al., 2002; Shepherd and Myers, 2005; Oliver et al., 2015;

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[*] Corresponding author.
E-mail address: t.clarke@oceans.ubc.ca (T.M. Clarke).

[1] Present address: Changing Ocean Research Unit, Institute for the Oceans and Fisheries, The University of British Columbia, 242–2202 Main Mall Vancouver, B.C., Canada V6T 1Z4.

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Clarke et al., 2016; Herrera-Valdivia et al., 2016; Navia and Mejía-Falla, 2016).

Shrimp trawl impacts on elasmobranch populations in the Eastern Tropical Pacific have been documented for Colombia (Navia and Mejía-Falla, 2016) and the Gulf of California (Herrera-Valdivia et al., 2016). However, bycatch records for most bottom trawl fisheries in the Eastern Tropical Pacific do not exist (Oliver et al., 2015), so fishing impacts on elasmobranch assemblages remain largely unknown. Concern over the environmental impacts of bottom trawl fisheries has spurred different initiatives: while Ecuador has prohibited bottom trawling in general (Alava et al., 2015), Costa Rica will only allow its bottom trawl fishery to continue past 2017 if it can be managed sustainably (MARVIVA, 2016).

In Costa Rica, shrimp trawl fishing grounds overlap with the habitat of 25 demersal elasmobranch species (Clarke et al., 2016). The vulnerability of these elasmobranchs is unknown and there are no management strategies to ensure the sustainability of their populations. In fisheries where elasmobranch bycatch is not recorded, data–poor methods can guide management and conservation priorities. Here, we used the best available scientific information to propose management measures for elasmobranch bycatch in the Costa Rican shrimp trawl fishery. Specifically, we used a Productivity Susceptibility Analysis (PSA, a semi-quantitative Ecological Risk Assessment commonly used in data-deficient fisheries) combined with a spatial Hotspot Analysis to identify (i) which elasmobranch species are most vulnerable to the Costa Rican shrimp trawl fishery, (ii) the location and seasonal variation in spatial clustering of vulnerable elasmobranchs. These analyses can be used to identify species with similar vulnerability levels, prioritize research needs, design spatio-temporal fishing closures, and provide qualitative management advice (Patrick et al., 2010; Hobday et al., 2011; Gallagher et al., 2012).

2. Methods

2.1. Study area

The Costa Rican Pacific coastline extends over 1254 km and is highly irregular (Wehrtmann and Cortés, 2009; Fig. 1). The main fishing port is in Puntarenas (central Pacific), with secondary ports in Playas del Coco (north Pacific), Golfito and Quepos (south Pacific). The Costa Rican commercial shrimp trawl fishery operates exclusively along the Pacific coast between 3.5 m and 1000 m deep (Wehrtmann and Nielsen-Muñoz, 2009; Arana et al., 2013). The fleet is comprised of approximately 27 Florida–type vessels with an average length of 21.8 m, each towing two nets (MARVIVA, 2016). In recent years, vessels have shifted their effort towards shallow water teleosts due to the depletion of shrimp stocks (Fargier et al., 2014; Herrera et al., 2016). Turtle exclusion devices are mandatory but not regularly used, resulting in four embargos from the State Department of the United States since 1999 (609 Law 101–162). Other forms of bycatch reduction devices are not employed.

2.2. Productivity and susceptibility analysis (PSA)

We assessed the relative vulnerability of 25 elasmobranch bycatch species to the Costa Rican shrimp trawl fishery. In the absence of historic elasmobranch catch records, we applied a Productivity Susceptibility Analysis (PSA) based on short–term scientific survey data (2008–2012) (Espinoza et al., 2012, 2013, 2015; Clarke et al., 2014, 2016; Sandoval-Herrera et al., 2016; Chabot et al., 2015), published scientific literature and FishBase (Froese and Pauly, 2017) (Supplement 1). PSAs estimate the relative vulnerability of a species to an anthropogenic threat by combining information on biological productivity and susceptibility (Patrick et al., 2010).

Productivity was estimated based on life history traits proposed by Hobday et al. (2011), and described in Table 1. The correlation between these life history traits and productivity has been well established for elasmobranchs (Dulvy et al., 2000; Denney et al., 2002; Shepherd and Myers, 2005; Dulvy et al., 2008; Hutchings et al., 2012). In general, species with large maximum sizes, late maturity, low fecundity, slow growth rates, and high trophic levels have low intrinsic population growth rates and are consequently less resilient to high fishing mortality (Dulvy et al., 2000; Denney et al., 2002; Shepherd and Myers, 2005; Dulvy et al., 2008; García et al., 2008; Hutchings et al., 2012). In

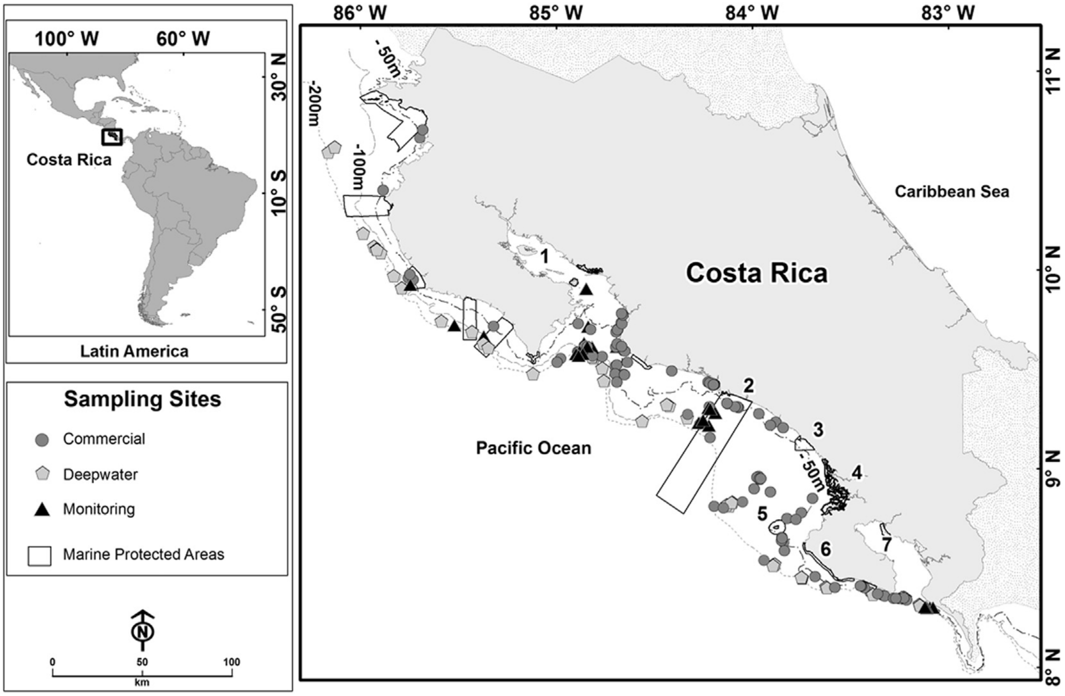

Fig. 1. Sampling sites along the Pacific coast of Costa Rica, 2008–2012. Polygons indicate marine protected areas. (1) Golfo de Nicoya; (2) Manuel Antonio; (3) Marino Ballena; (4) Térraba–Sierpe; (5) Isla del Caño (6) Corcovado; (7) Golfo Dulce.