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Reproductive ecology of demersal elasmobranchs from a data-deficient fishery, Pacific of Costa Rica, Central America

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ABSTRACT

The elasmobranch bycatch associated with the Costa Rican deepwater shrimp fishery is mainly comprised of four species: *Raja velezi*, *Mustelus henlei*, *Zapteryx xyster* and *Torpedo peruana*. In data-deficient fisheries such as this one, knowledge of the reproductive ecology of a species may serve as a valuable management tool to determine its vulnerability and apply precautionary measures to ensure its long-term conservation. This study examined the reproductive ecology of *R. velezi*, *M. henlei*, *Z. xyster* and *T. peruana* based on data collected during demersal trawling along the Pacific coast of Costa Rica, Central America. A total of 290 trawls was analyzed at depths of 18–350 m (March 2010–August 2012). While *R. velezi*, *M. henlei* and *Z. xyster* matured at similar sizes (range: 37–60 cm TL), *T. peruana* matured at a larger size (70 cm TL in females). The four elasmobranch species exhibited strong sex and size segregation patterns, which were mainly influenced by depth. Adults were more common at depths >50 m, whereas neonates and gravid females were more abundant in shallow estuarine waters (<50 m). Moreover, large aggregations of immature *R. velezi* and *M. henlei* occurred near coastal wetlands, bays and estuaries of the central Pacific region. These results suggest that shallow estuarine habitats may be important for early life stages of demersal elasmobranchs caught in the Costa Rican trawling fishery. However, our knowledge of critical habitats for elasmobranch along the entire Pacific of Costa Rica is still limited, and thus future studies are needed to identify and understand the role of these habitats in the early life-history of sharks, skates and rays.

1. Introduction

Elasmobranchs have a wide range of reproductive strategies, but most species are characterized by a slow growth, large sizes at maturity and low fecundities (Stevens et al., 2000). Slow growing life history traits can lead to low intrinsic population growth rates, making some elasmobranch species particularly vulnerable to overexploitation (Hoenig and Gruber, 1990; King and McFarlane, 2003; Dulvy et al., 2014). For example, several studies have reported that large elasmobranch species tend to have a low reproductive output, and thus are more susceptible to overfishing (Stevens et al., 2000; Dulvy et al., 2014). Conversely, small species with short reproductive cycles and high fecundities (e.g. *Rhizoprionodon taylori*) are known to withstand high fishing pressures (Simpfendorfer, 1999; Harry et al., 2011).

Sex and size segregation in elasmobranch species have been well documented (Springer, 1967; Mollet, 2002; Escobar-Sánchez et al., 2006). For example, neonates and juveniles are typically found in shallow, coastal habitats, whereas adults are more common in offshore waters (Heupel et al., 2007; Pereyra et al., 2008; Knip et al., 2010; Wearmouth and Sims, 2010; Jacoby et al., 2011). Gravid females are also known to move inshore during parturition (Heupel et al., 2007; Pereyra et al., 2008). Segregation patterns displayed by some elasmobranchs can result in the removal of a larger proportion of a specific life-stage (e.g. neonates or gravid females), which may influence the size and structure of the population (Wearmouth

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and Sims, 2008; Noriega et al., 2011). Additionally, the formation of permanent or seasonal aggregations can increase an elasmobranch population's vulnerability to overexploitation (Wearmouth and Sims, 2008; Mucientes et al., 2009; Jacoby et al., 2011), especially when there is a high overlap between aggregation sites and fishing grounds (Jacoby et al., 2011).

Elasmobranchs are a common component of the bycatch in tropical bottom trawling fisheries (Stobutzki et al., 2002; Walker, 2005). However, species-specific catch records are often not available (Casey and Myers, 1998; Stevens et al., 2000). Therefore, long-term catch trends cannot be used to properly identify species with declining populations. In this type of data-deficient situations, information on the reproductive ecology of elasmobranch species has been recognized as a valuable data source to assess a fishery's impact on vulnerable species (Walker, 2005; García et al., 2012). While basic information on elasmobranch bycatch, such as distribution and species composition has been described for trawl fisheries in Mexico (López-Martínez et al., 2010), Costa Rica (Clarke et al., 2011) and Colombia (Puentes et al., 2007; Mejía-Falla and Navia, 2011), the reproductive ecology of most species remains to be studied, particularly in the Central American region. This lack of basic biological information of elasmobranch bycatch has limited the implementation of effective management and conservation strategies in the Eastern Tropical Pacific (ETP) (Wehrtmann and Nielsen-Muñoz, 2009; Espinoza et al., 2012, 2013; Trujillo et al., 2012).

Bycatch of the Costa Rican shrimp trawl fishery includes six species of sharks and 19 species of skates and rays, which accounts for over 35% of the elasmobranch diversity reported for this region (Bussing and López, 2009; Clarke et al., 2011). *Raja velezi*, *Mustelus henlei*, *Zapteryx xyster* and *Torpedo peruana* are the most abundant species associated with this fishery (Espinoza et al., 2012, 2013; Clarke et al., 2011). These species occur exclusively in the ETP, have wide depth distribution ranges (approx. 18–300 m), and are often caught by both shallow and deepwater shrimp fisheries (Allen and Robertson, 1994; Mejía-Falla and Navia, 2011). The size at maturity and fecundity of *M. henlei* has been previously reported in Baja California (Mexico) and California (USA) (Pérez-Jiménez and Sosa-Nishisaki, 2008); however, reproductive information for most demersal elasmobranch species along the Central American region is still lacking. In this study, we estimated the size at maturity and sex-size segregation patterns of *R. velezi*, *M. henlei*, *Z. xyster* and *T. peruana* in the Pacific coast of Costa Rica.

2. Material and methods

2.1. Study area

Costa Rica is located in Central America, and is characterized by well-defined rainy (June–November) and dry seasons (December–April), which drastically influence the amount of sediment, nutrients and water that flow into the ocean (see Wehrtmann and Cortés, 2009). The highly irregular Pacific coastline allows the formation of productive wetlands, the largest of which are located in the Golfo de Papagayo, Golfo de Nicoya, Humedal Nacional Térraba-Sierpe, and Golfo Dulce, a tropical fjord (Wehrtmann and Cortés, 2009). The central Pacific is delimited and heavily influenced by two large estuarine systems: the Golfo de Nicoya and the Térraba-Sierpe (see Wehrtmann and Cortés, 2009). Fishing effort is concentrated in the central Pacific region due to its proximity to Puntarenas, the main fishing port used by the entire fleet (Álvarez and Ross-Salazar, 2009). Furthermore, 42 of the 47 vessels that comprised the fleet in 2009 fished exclusively in the central Pacific (Álvarez and Ross-Salazar, 2009).

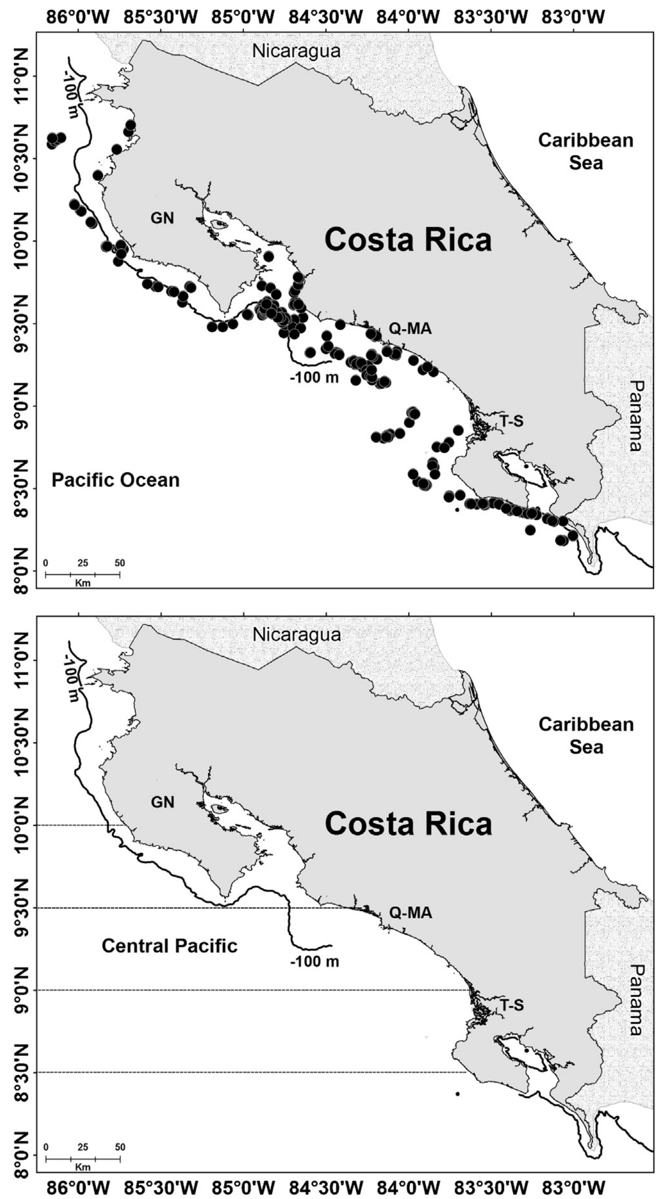

Fig. 1. Map of the geographic areas and trawling locations (black circles) along the Pacific coast of Costa Rica, Central America (March 2010–August 2012). GN: Golfo de Nicoya; Q-MA: Quepos-Manuel Antonio; T-S: Térraba-Sierpe.

2.2. Sampling methods

Sampling was conducted on-board commercial shrimp trawlers operating at depths between 18 and 350 m (Fig. 1). Each vessel was 22.5 m long, powered by a 270 HP engine, and equipped with two standard epibenthic nets (20.5 m long, 5.35 m × 0.85 m mouth opening, 30 mm mesh-size in the cod-end, and 44 mm mesh-size in the webbing of the rest of the trawl net). Monthly fishery independent and dependent surveys were carried out between March 2010 and August 2012 (Fig. 1). A detailed description of sampling effort across regions and depths is presented in Table 1. Date, time, depth, and fishing location (latitude/longitude) were recorded for each trawl. All elasmobranchs were identified, measured and sexed on-board (Bussing and López, 1993; Allen and Robertson, 1994; Compagno et al., 2005). The following measurements were taken: total length (TL, mm, tip of the snout to posterior tip of the tail, with the tail flexed down; Francis, 2006), total body mass (TBM, g) and