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Decline or stability of obligate freshwater elasmobranchs following high fishing pressure

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ABSTRACT

Despite elasmobranchs are a predominantly marine taxon, several species of sharks and rays are regularly found in fresh water. Although there is ample evidence of declining elasmobranch populations around the world, this evidence comes exclusively from marine and euryhaline species; the ecology and conservation status of obligate freshwater elasmobranchs is far from being understood. River stingrays (Potamotrygoninae, 32 species) live exclusively in South American rivers and represent the overwhelming majority of freshwater elasmobranch diversity. Here, we present evidence of a decline in the abundance of river stingrays in the middle and lower Paraná River, an extensive wetland mosaic of approximately 35,000 km^2. By taking advantage of a stingray-manipulation procedure widespread among South American fishermen, we were able to estimate spatial differences in relative fishing pressure and found that the observed decline is related to fishing pressure. The highest fishing effort and lowest relative abundance occurred in areas where fisheries operate on the river floodplain. The lowest fishing effort and highest relative abundances occurred in areas where fisheries operate in the main channel. The only species with a stable trend was *Potamotrygon motoro*. This evidence confirms the long-presumed vulnerability of obligate freshwater elasmobranchs and suggests that some species, *e.g. P. motoro*, can be exploited sustainably. Our results also indicate that negative effects on freshwater elasmobranchs can be minimized by adjusting fishing grounds.

1. Introduction

In recent years, the evidence that shark and ray populations around the world are declining has been growing (Baum et al., 2003; Ferretti et al., 2008; Field et al., 2009; Dulvy et al., 2014). In most cases, these declines are the result of overexploitation. Overfishing is the most important threat to marine elasmobranchs, because they have naturally low intrinsic population growth rates (Field et al., 2009), therefore even moderate levels of fishing effort may be enough to negatively affect a population of a given elasmobranch species (Myers and Worm, 2005). All of this evidence comes from marine species, and very little information on the status of freshwater elasmobranchs is available.

Sharks and rays live mostly in marine environments, but approximately 60 species (5%) of elasmobranchs occur in freshwater environments. Some species, termed euryhaline elasmobranchs, are marine species that have the physiological ability to enter, survive for extended periods, and even reproduce in freshwater environments. Obligate freshwater elasmobranchs, on the other hand, are species that complete their entire life cycle in fresh water and cannot survive in sea water (Lucifora et al., 2015). Most of the world's obligate freshwater

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elasmobranch diversity is contained in a single clade, the subfamily Potamotrygoninae, which is endemic to tropical and subtropical rivers and wetlands of South America, east of the Andes. This lineage is unique among extant elasmobranchs in that it radiated exclusively in fresh water from a marine ancestor (Rosa et al., 2010; Lucifora et al., 2015).

Freshwater elasmobranchs are thought to be highly susceptible to human threats, but no evidence on actual population trends has ever been presented. Obligate freshwater elasmobranchs combine the high intrinsic vulnerability to anthropogenic threats typical of marine elasmobranchs with living in a small habitat (as compared to the ocean) that is highly impacted by growing human populations (Compagno and Cook, 1995; Rosa et al., 2010; Dulvy et al., 2014; Lucifora et al., 2015). This makes obligate freshwater elasmobranchs vulnerable to both habitat degradation and, similar to their marine relatives, overfishing (Compagno and Cook, 1995; Rosa et al., 2010; Dulvy et al., 2014; Lucifora et al., 2015). Furthermore, while distant populations of euryhaline elasmobranchs can be linked by individuals dispersing through marine environments (Li et al., 2015), populations of obligate freshwater elasmobranchs are more limited in their dispersal possibilities (Compagno and Cook, 1995). Despite this presumed susceptibility of obligate freshwater elasmobranchs to anthropogenic threats, little scientific knowledge is available on their biology and ecology as to allow for a sound assessment of their actual conservation status (Compagno and Cook, 1995; Rosa et al., 2010; Dulvy et al., 2014; Lucifora et al., 2015). As a result, 54.5% of all obligate freshwater elasmobranchs are categorized as Data Deficient by the International Union for Conservation of Nature and Natural Resources (IUCN) (Dulvy et al., 2014).

The Paraná River, within the Río de la Plata basin, is a major river in South America, second in length only to the Amazon. It runs for almost 4000 km in a general north-south direction through Brazil, Paraguay and Argentina (Bonetto, 1986). After receiving the Paraguay River, where its middle reach begins, the Paraná forms a large, complex floodplain composed of secondary channels, islands, bars, shallow lakes and swamps (Paira and Drago, 2007) (Fig. 1). This floodplain expands laterally and forms an extensive delta in its lower reach (Bonetto, 1986) (Fig. 1). Together, the middle and lower reaches of the Paraná River comprise a subtropical wetland mosaic of approximately 35,000 km^2, that ends in the Río de la Plata, between Argentina and Uruguay (Bonetto, 1986; Paira and Drago, 2007).

Six species of river stingrays of the genus *Potamotrygon* occur in the middle and lower Paraná River: *P. amandae*, *P. brachyura*, *P. falkneri*, *P. histrix*, *P. motoro*, and *P. schuhmacheri* (Rosa et al., 2010; da Silva and de Carvalho, 2011; Loboda and de Carvalho, 2013; Lucifora et al., 2016). Five of these species are categorized as Data Deficient by the IUCN (Charvet-Almeida and de Almeida, 2004; Drioli and Chiaramonte, 2005; de Araújo, 2009; Charvet-Almeida et al., 2009; Soto et al., 2009), and *P. amandae* has not been assessed. Some of these species are of particular conservation concern because they have traits that correlate positively with high extinction risk, such as endemicity, large body size and rarity (Pimm and Jenkins, 2010; Dulvy et al., 2014). Four species (*P. amandae*, *P. brachyura*, *P. histrix* and *P. schuhmacheri*) are endemic to the Río de la Plata basin (Rosa et al., 2010; Loboda and de Carvalho, 2013; Lucifora et al., 2016). *P. brachyura* attains a very large body size, reportedly exceeding 200 kg (Lucifora et al., 2016), and *P. schuhmacheri* is one of the rarest elasmobranch species (either freshwater or marine), since it is known from less than 5 specimens (Rosa et al., 2010).

Stingray tail mutilation is an extended practice along the Paraná River (*e.g.* Castex, 1963; Garrone Neto, 2010), as well as in many other South American rivers (*e.g.* Rincon, 2006; Duncan et al., 2010; Oddone et al., 2012; Gama and Rosa, 2013; Rincon et al., 2013). When fishermen catch a river stingray, it is very common that they cut off its tail just anterior to the sting (Rosa et al., 2010). This practice has the objective of eliminating the possibility of being stung by the stingray,

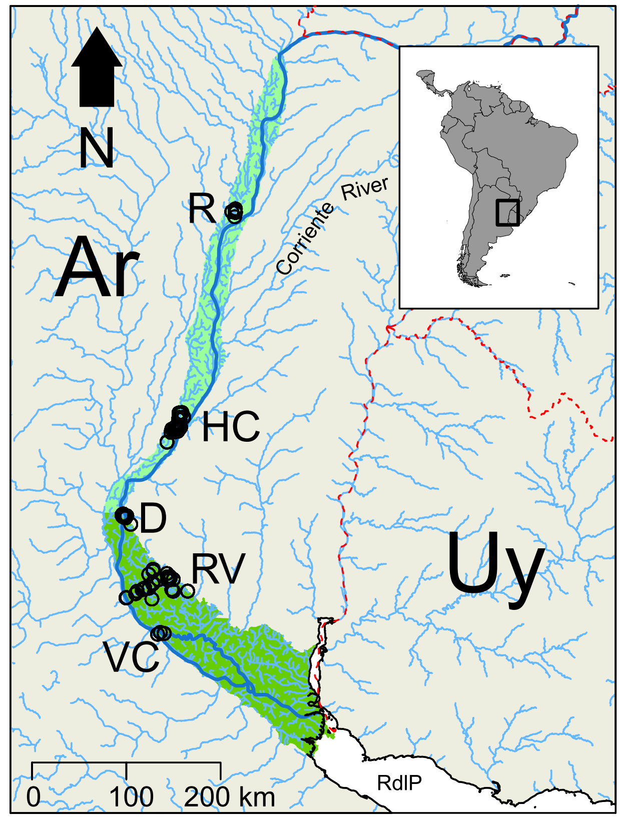

Fig. 1. Map of the middle and lower Paraná River, showing study area and sampling localities. Places where samples were taken (empty circles) are grouped in locations identified with capital letters (R: Reconquista, HC: Helvecia/Cayastá, D: Diamante, RV: Rosario/Victoria, VC: Villa Constitución). The middle Paraná River floodplain is shaded in light green, and the lower Paraná River floodplain and delta is shaded in bright green. The main channel of the Paraná River is shown in bold blue. The inset shows the location of the study area in South America. Ar: Argentina; Uy: Uruguay; RdlP: Río de la Plata. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

ensuring a safe manipulation of the catch. Many stingrays that are returned to the water after having their tail cut survive since, in some areas, it is common to catch stingrays with cut, healed tails (Rosa et al., 2010). It has been shown that, in a tributary of the Tocantins River (Brazil), tailless stingrays are far more common around fishing villages than in river reaches far away from human settlements (Rincon, 2006). Therefore, the incidence of tailless stingrays in a given area can be taken as a proxy for fishing pressure.

Here, we present the first formal assessment of abundance trends for obligate freshwater elasmobranchs and evaluate the relationship between the observed trend and fishing pressure by utilising a manipulation technique (*i.e.* tail mutilation) that is widespread among South American fishermen.

2. Materials and methods

2.1. Sampling

Samples came from a standardised sampling program conducted by the project "*Evaluación Biológica y Pesquera de Especies de Interés Deportivo y Comercial en el Río Paraná, Argentina*" (Biological and Fishery Assessment of Recreational and Commercial Species of the Paraná River, Argentina). This program samples regularly at different sites along the middle and lower Paraná River (Fig. 1) using, at each site, batteries of gillnets and trammel nets of different mesh sizes to catch a representative sample of species and sizes. Gillnet batteries consisted of 25-m long pannels with mesh sizes of 30, 40, 50, 60, 70, 80,