



A Synthesis of the Ecology, Human-Related Threats and Conservation Perspectives for the Endangered Franciscana Dolphin

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The franciscana is endemic to subtropical coastal waters of Brazil, Uruguay, and Argentina, and is the only living species of the family Pontoporiidae. It is regarded as the most endangered cetacean in the western South Atlantic. Five management units are recognized (Franciscana Management Areas, FMAs – sensu Secchi et al., 2003a), with abundance estimates ranging from a few hundred to around 15,000 dolphins. Low reproductive potential and short life span make this species highly susceptible to current non-natural removal rates. Bycatch in gillnet fisheries occurs in high levels since the 1960s in Uruguay and 1980s in Brazil and Argentina. Although other threats exist, such as habitat degradation that includes physical (noise) and chemical pollution, depletion of fish stocks and climate change, incidental mortality in gillnets is currently the greatest threat to franciscanas. Fishing-related mortality ranges from approximately 100, in FMA I, to more than 1,000 in FMA III, and exceed from near two (in FMA IV) to more than five times (in FMA III) the maximum allowed sustainable mortality rate, based on potential biological removal (PBR) approach. These numbers indicate that the species is unlikely to cope with the current levels of bycatch and that urgent and extreme reduction on fishing practice and effort are required to avoid collapse of the franciscana and to lower its risk of extinction. Current mortality levels and projected declines resulted in the listing of the franciscana as “Vulnerable” in the IUCN Red List. Recent fisheries regulations were implemented in areas with extensive bycatch in Brazil and were expected to improve the species’ conservation status. There is evidence, however, that this regulation is insufficient to reduce fishing-related mortality to sustainable levels due to either or both lack of compliance and inadequate regulation strategies. Here we provide a comprehensive review on the franciscana ecology and threats and discuss perspectives for its conservation.

Keywords: *Pontoporia blainvillei*, cetaceans, western South Atlantic, fisheries, bycatch, habitat degradation, pollution

INTRODUCTION

The franciscana or La Plata River dolphin, *Pontoporia blainvillei* (Figure 1), is perhaps the most endangered cetacean in the Western South Atlantic (Secchi, 2010). Its life history traits, including low reproductive and survival rates, and short life span, makes it vulnerable to high levels of non-natural mortality (e.g., Danilewicz et al., 2002; Secchi et al., 2003b; Secchi, 2010). The genus *Pontoporia* belongs to the so-called river dolphins, lineage that diverged well before the radiation of delphinids, with adaptation to fluvial habitats might have insured their survival against environmental changes in the marine ecosystem or the emergence and dominance of delphinids (Cassens et al., 2000). It has been hypothesized that the ancestral of *Pontoporia* occupied the Paraná basin and reinvaded the marine coastal waters to north and south of the La Plata River mouth (Cozzuol, 1985; Hamilton et al., 2001). This recent ecological reversal was followed by ecologically specialized adaptations that allowed the species to benefit from a productive environment for reproduction, growth and survival demands, and to cope with competitive pressures of the dominant delphinids and predation by sharks and killer whales inhabiting the inner continental shelf of the eastern South America. This adaptation, that allowed franciscana to reach demographic balance of reproduction and mortality, however, is insufficient to respond to non-natural mortality due to the ever increasing impacts from human activities (Secchi, 2006; Cáceres et al., 2020). Franciscana's restricted distribution to coastal waters makes it vulnerable to a variety of impacts from coastal development (Danilewicz et al., 2009, 2010; Secchi, 2010; Amaral et al., 2018). Habitat degradation such as chemical and physical pollution (noise) and overfishing have affected the species. Nevertheless, the large spatial overlap between the distribution the species and extensive fishing activities has led to high and unsustainable levels of incidental mortality, especially in gillnets, and is currently the greatest danger to franciscanas (e.g., Secchi, 2010).

Here we present a comprehensive review on the ecology of franciscana and the main impacts that have led it to be the most endangered species in the Western South Atlantic. We also showed that the current levels of bycatch in fisheries are unsustainable and discuss the conservation perspectives to increase the species long-term chances of survival.

FRANCISCANA ECOLOGY

Distribution and Movements

The franciscana is endemic to the western South Atlantic Ocean, ranging from Itaúnas (18°25'S – 30°42'W), southeastern Brazil (Siciliano, 1994), to Golfo Nuevo (42°35'S - 64°48'W), in the Argentinian Patagonia (Crespo et al., 1998; Figure 2). Franciscanas are predominantly coastal, occupying waters beyond the surf zone and out to the 30 or 50 m isobaths (Secchi et al., 1997; Crespo et al., 2010; Danilewicz et al., 2010; Botta et al., 2015). No size, age or sex-related differences in habitat use patterns in relation to depth have been observed in southern Brazil (Danilewicz et al., 2009). Occasional occurrences

were recorded in estuaries of Brazil (e.g., Santos et al., 2009), and the species is rather common in the Uruguayan portion of the La Plata River estuary (Praderi, 1986), in the Negro River estuary, Argentina (Failla et al., 2012) and resident in the estuary of Babitonga Bay, Brazil (Cremer and Simões-Lopes, 2005; Sartori et al., 2017). The species is not distributed continuously throughout its range. Siciliano et al. (2002) first reported the existence of two areas in its northern range where franciscanas are extremely rare or absent. These areas were reassessed by Amaral et al. (2018) and reshaped as Gap I, from Santa Cruz (19°57'S), in the state of Espírito Santo, to Barra de Itabapoana (21°18'S), in the state of Rio de Janeiro, Brazil; and Gap II, from Armação dos Búzios (22°44'S) to Piraquara de Dentro (22°59'S), in the state of Rio de Janeiro, Brazil (Figure 2). The extension of the gaps was reduced and the narrowing of the continental shelf, water transparency and lower water temperature, due to local upwelling, seem to be among the reasons for these hiatuses (Siciliano et al., 2002; Amaral et al., 2018). It is suspected that variation in anthropogenic pressures, population demography, and prey availability, among other ecological factors, might influence the extension of the hiatus over time, creating small expansions and retractions on franciscana distribution (Danilewicz et al., 2012). Nevertheless, current genetic information suggests that reproductive isolation is very likely (Cunha et al., 2014).

Franciscanas do not migrate and probably occupy small spatial ranges (Basso et al., 2020). Travels of up to 70–100 km alongside the coast have been documented for a few satellite-tagged individuals off Argentina, although most animals performed much more restricted movements (Wells et al., 2013). In Babitonga Bay, Brazil, the movements of satellite-tagged individuals were very limited, remaining in a very small portion of the bay (Cremer et al., 2013), and home range was smaller in the summer than in the winter season (Cremer et al., 2018b). The species inshore-offshore movements were related to tidal state, and the individuals follow the flow of the current in Bahía Anegada, Argentina (Bordino et al., 1999; Bordino, 2002) and in Babitonga Bay, Brazil (Paitach et al., 2017).

Population Structure/Management Units

Genetics, morphology, distribution, and populational parameters were used by Secchi et al. (2003a) to propose four provisional management units (Franciscana Management Areas, or FMAs), with the following areas of occurrence: FMA I – coastal waters of Espírito Santo and Rio de Janeiro States, Brazil; FMA II – São Paulo, Paraná and Santa Catarina States, Brazil; FMA III – coastal waters of Rio Grande do Sul State, southern Brazil, and Uruguay; and FMA IV – coastal waters of Buenos Aires and Rio Negro Provinces (with occasional records as far south as Chubut), in Argentina. Since then, new genetic and morphological information have indicated the probable subpopulation structure throughout the species range (Lázaro et al., 2004; Mendez et al., 2008, 2010; Vêras, 2011; Barbato et al., 2012; Costa-Urrutia et al., 2012; Negri et al., 2012; Cunha et al., 2014; Gariboldi et al., 2015, 2016; Ott et al., 2015), leading to the proposition of new subdivisions within each FMA (Cunha et al., 2014). Nevertheless, since (i) the degree of differentiation within the FMAs was highly



FIGURE 1 | Group of franciscanas including two adults (longer beaks), two likely juveniles (shorter beaks) and a newborn calf.

variable, (ii) evidence were founded only on mitochondrial DNA data, and (iii) there is presently no agreement on threshold levels of gene flow, the proposed management units should be accepted, latest refinements in franciscana subpopulation structure were restricted only to locations where the greatest levels of genetic difference were observed (Anonymous, 2015). Accordingly, FMA I was considered an Evolutionarily Significant Unit and was split into two distinct management units (FMA Ia and FMA Ib, Cunha et al., 2014). The other important change was the displacement of the boundary between FMA II and FMA III, moved about 250 km northward, at the central coast of Santa Catarina State (Cunha et al., 2014; Ott et al., 2015). It is not meant to apply new management dogmas to these units, rather, it is strongly recommended that limits and sub-structuring of these FMAs be constantly reassessed as new data become available.

Morphological and molecular data support the existence of distinctive franciscana populations. Evidence of population structuring was first demonstrated through multivariate analysis of morphometric data, which revealed the existence of two geographical forms: a smaller one in the northern part of the species' range (north of 27°S) and a larger form in the coastal waters of southern Brazil, Uruguay, and Argentina (south of 32°S) (Pinedo, 1991, 1995). Body length of individuals from São Paulo (23°30'S-25°30'S) and Rio de Janeiro (21°35'S-22°25'S) states, Brazil, were significantly different, with animals from Rio de Janeiro being larger (Ramos et al., 2002). Similar growth patterns were observed in cranial dimensions (Ramos et al., 2002) as well as for other body metrics (Barbato et al., 2012). These results indicated that metric differences in body and skull

variables were not clinal. Analyses of the highly variable d-loop region of mitochondrial DNA (mtDNA) provided molecular-based support to the existence of these two geographic forms (Secchi et al., 1998). Subsequent studies compared the mtDNA of franciscanas from Uruguay and Argentina with those published by Secchi et al. (1998) and found support for the existence of a large southern population (including animals from Rio Grande do Sul State in Brazil, Uruguay and Argentina), that is markedly distinct from animals inhabiting the waters of Rio de Janeiro State, in Brazil (Ott, 2002; Lázaro et al., 2004). Moreover, fixed genetic differences between the populations were observed, implying essentially no effective genetic exchange (Secchi et al., 1998; Ott, 2002; Lázaro et al., 2004). A pairwise analysis of haplotype distances showed increasing differentiation in the haplotype frequencies with increasing geographic gap, following an isolation-by-distance configuration (Lázaro et al., 2004). These authors and Ott (2002) also suggested that haplotypic frequencies of samples from Claromecó (in Argentina) were significantly different from the remaining southern population. The data presented by Mendez et al. (2008), however, do not fit this model. Rather, they propose that ecological forces can be more important than geographic distance in defining population structuring by regulating gene flow. Franciscanas from Claromecó are more similar to those from coastal marine areas, including those from Uruguay, than to those from the estuarine area of Samborombón Bay, northern Argentina. A similar pattern was observed in the Uruguayan coast (Costa-Urrutia et al., 2012). The authors noticed that, among several sampled areas including marine and estuarine coasts, the most



genetically distinct individuals were those collected in the La Plata estuary, regardless of the geographic distance. This suggests that a fine-scale structuring occurs in areas with higher influence of the La Plata River estuary in both Argentina and Uruguay. These areas are shallow, relatively enclosed, and have high abundances of estuary-dependent prey, which make them a suitable habitat for calving. In fact, telemetry studies have

demonstrated that individuals from Samborombón Bay have a very restricted movement range of about 20 km (Bordino and Wells, 2005). Furthermore, Rodríguez et al. (2002) found that individuals from this area prey upon different species when compared to those from the coastal oceanic environments. If part of the population has evolved and is mostly adapted to occupy an estuarial niche, intra-specific competition for

resources is minimized, representing an advantage for the species as a whole.

Abundance

Abundance estimation for the franciscana has long been both a research priority and a major scientific challenge (Secchi et al., 2001; Danilewicz et al., 2010). Because the species' small size, elusive behavior, avoidance of engine boats, and cryptic color pattern, it is very rarely sighted in the wild, especially during onboard surveys. Although aerial surveys have been agreed to be the best platform to assess franciscana's abundance, boat surveys may be useful in small inner water areas (Bordino et al., 1999; Crespo et al., 2002; Cremer and Simões-Lopes, 2008). Nevertheless, as discussed by Danilewicz et al. (2010), the lack of appropriate correction factors for visibility biases (mainly availability bias, i.e., the proportion of time a group is available for detection), have been a major caveat and precluded reliable abundance estimates. Recent experiments applying alternative methodologies (use of helicopters and simultaneous boat/aerial surveys) have been carried out (e.g., Sucunza et al., 2018) and produced significant advances on computing correction factors for the species' abundance estimations. Currently, no range-wide abundance estimation for franciscana is available. Estimates have been obtained either for a portion or the entire individual FMAs, through aerial surveys carried out by experienced researchers.

In FMA I, Danilewicz et al. (2012) conducted aerial surveys in Espírito Santo State (FMA Ia) and Rio de Janeiro, Brazil (FMA Ib) in 2011. In that study, no sighting was recorded during on-effort time in FMA Ia, despite relatively large survey work, suggesting that abundance of franciscana in FMA Ia is very small, a hypothesis further supported by Cunha et al. (2014), who identified a very low genetic diversity of that population. Further aerial surveys (2018–2019) estimated an abundance of 893 individuals for this area (CV = 0.30) and nearly 2,000 individuals in FMA Ib (CV = 0.46) (Sucunza, 2020), indicating that these are the two smallest populations among all FMAs.

Franciscana abundance in FMA II was estimated at 6,800 animals (CV = 0.26) (Sucunza et al., 2020) in 2008–2009. This value might be slightly underestimated as a few flights occurred when weather conditions were not ideal. Estimates are also available for Babitonga Bay, in Santa Catarina State, Brazil, where an isolated population of franciscanas occurs (Cremer et al., 2012). Boat-based and aerial line-transect surveys estimated, respectively, 50 individuals in the early 2000s (CV = 0.29, Cremer and Simões-Lopes, 2008) and 55 animals in 2011 (Zerbini et al., 2011), which suggests that this population is stable over a 10-year period.

Surveys in FMA III have been conducted only within the Brazilian portion (RS State). The first estimate was computed from aerial surveys conducted over a small region in 1996 (435 km²; 1.5% of its presumed distribution up to the 50 m isobath) (Secchi et al., 2001). Density corrected for availability bias was estimated at 0.66 individuals/km² (CV = 0.34), and an extrapolated abundance of nearly 42,000 individuals (CV = 0.34) was assumed to the range of the entire population (Secchi et al., 2001). Later, Danilewicz et al. (2010) conducted an aerial survey

covering an area from the shoreline to as far as 13 nm (43% of its presumed distribution) and estimated 6,800 individuals (CV = 0.32) in 2004. Surveys to estimate franciscana abundance in Uruguay are a research priority for this FMA.

In FMA IV, a population of nearly 15,000 individuals (CV = 0.42) was estimated from aerial surveys carried out in Argentina, during 2003–2004 (Crespo et al., 2010). This estimate was not corrected for perception bias and density estimated for offshore areas (depths greater than 30 m) was not extrapolated to non-surveyed areas, and it is possible that this estimate is downward biased.

Trophic Ecology

Franciscana is an intermediate trophic-level predator and is likely to play an important role in the food web of coastal subtropical western South Atlantic Ocean.

Franciscanas seem to be opportunistic feeders, eating the most abundant prey in the area. Seasonal fluctuations in diet match patterns of temporal variation in the abundance of the main prey species, and decadal changes in the dolphin's diet seem to coincide with declines in fish stock abundance (Basso et al., 2020). Franciscanas feed predominantly upon several species of fish (e.g., Sciaenidae, Engraulidae, Gadidae, Batrachoididae, Trichiuridae, and Carangidae families), but also mollusks and crustaceans with important variation in prey relative contribution among FMAs (Brownell, 1989; Di Benedetto and Ramos, 2001; Rodríguez et al., 2002; Danilewicz et al., 2002; Cremer et al., 2012; Lopes, 2012; Troina et al., 2016; Henning et al., 2017; Rupil et al., 2019; Campos et al., 2020), totaling around 80 prey species. Prey items are typically smaller than 80 mm in length (Danilewicz et al., 2002). In spite of regional variation, teleosts of the Sciaenidae family (bottom-dweller croakers) are the predominant fish prey and small squids are the main mollusk prey (Di Benedetto and Ramos, 2001; Rodríguez et al., 2002; Danilewicz et al., 2002; Cremer et al., 2012; Henning et al., 2017; Campos et al., 2020). Lactation period seems to range from 6 to 9 months depending on the region and the duration of exclusive milk intake may last a few months until the transition to a mixed diet of milk (Kasuya and Brownell, 1979; Di Benedetto and Ramos, 2001; Rosas and Monteiro-Filho, 2002; Rodríguez et al., 2002; Denuncio et al., 2013; Panebianco et al., 2016). The first solid food items are slow-moving prey such as very small fish and shrimps (e.g., Danilewicz et al., 2002; Rodríguez et al., 2002; Denuncio et al., 2013). Information regarding daily food requirements for wild franciscanas is lacking.

The known predators of franciscanas include killer whales (*Orcinus orca*) and some other top marine predators, including broadnose sevengill (*Notorynchus cepedianus*), hammerhead (*Sphyrna* spp.), sand tiger (*Eugomphodus taurus*), tiger (*Galeocerdo cuvieri*), and requiem (*Carcharhinus* sp.) sharks (Praderi, 1985; Ott and Danilewicz, 1996; Santos and Netto, 2005). There is little overlap in diet with other coastal cetaceans such as bottlenose dolphins (*Tursiops* spp.), and Guiana dolphins (*Sotalia guianensis*) (Hardt et al., 2013; Secchi et al., 2016; Cremer et al., 2018b). On the other hand, feeding competition is likely with some predatory

fish such as the cutlass fish (*Trichiurus lepturus*) (Bittar and Di Benedetto, 2009). In some areas, the franciscana's main prey items are also bycatch of trawling fisheries (Machado et al., 2020).

Reproduction

The franciscana has among the shortest reproductive life cycles of all cetaceans (Danilewicz, 2003). The species can be classified as birth-pulse and birth-flow breeder, depending on the region. Reproduction is markedly seasonal in the southern range, with births occurring in a “pulse” in the austral spring and summer, from October to February (Brownell, 1984; Rosas and Monteiro-Filho, 2002; Danilewicz, 2003; Cremer et al., 2013; Panebianco et al., 2016). In the northernmost part of the species range (FMA I), reproductive seasonality does not seem to occur and births “flow” year-round (Di Benedetto and Ramos, 2001). Although lack of reproductive seasonality was also proposed for franciscanas collected in São Paulo State (Silva et al., 2020) evidence is not strong as the size of the fetuses reported indicate that births are likely to occur during austral spring and summer.

Age and length at attainment of sexual maturity also varies among FMAs (Table 1). Sexual maturity for both males and females is reached at between 2 and 5 years of age. Spatial variation in the mean length at sexual maturity is due to the marked inter-population differences in body size. In the northern range of the species distribution (FMA I and II) franciscana males and females attain sexual maturity between and 3 years of age and total lengths spanning from 112 to 132 cm (Ramos et al., 2000; Di Benedetto and Ramos, 2001; Silva et al., 2020). Annual pregnancy rate was estimated to be 0.36, with an interbirth interval of 2.8 years (Silva et al., 2020). In the southern range (FMA III and IV), franciscanas reach sexual maturity at the age of 3–4 years and length varying from about 126–131 cm in males and from 133 to 140 cm in females (Kasuya and Brownell, 1979; Danilewicz et al., 2000; Danilewicz, 2003; Panebianco et al., 2012, 2016). The annual pregnancy rate was estimated to be 0.65, which is correspondent to an average birth interval of 1.5 years. This implies that within the population, half of the females reproduce yearly and the other half biannually (Danilewicz et al., 2000; Danilewicz, 2003).

The gestation period does not vary much geographically, with estimates of between 10.2 and 11.2 months (Kasuya and Brownell, 1979; Harrison et al., 1981; Di Benedetto and Ramos, 2001; Rosas and Monteiro-Filho, 2002; Danilewicz, 2003; Panebianco et al., 2016). Neonatal length and weight were estimated at slightly over 70 cm and 6 kg in the southern range. In parts of the northern range, the newborn calves are about 10 cm smaller and 1–2 kg lighter. Weaned calves are near 1 m long and weigh about 15 kg (Rosas and Monteiro-Filho, 2002; Danilewicz, 2003). Females do not show any evidence of reproductive senescence (Kasuya and Brownell, 1979; Rosas and Monteiro-Filho, 2002; Danilewicz, 2003; Panebianco et al., 2016; Silva et al., 2020). Considering the age of first reproduction, life span, and calving intervals, a female franciscana might produce from four to eight offspring in her lifetime (Danilewicz, 2003), although investment in reproduction seems to vary geographically.

Age and Growth

The franciscana's life span seems to be around 20 years. The oldest aged franciscana was a 21-year old female and the maximum observed age for males was 17 years (Botta et al., 2010). The age frequency distribution of incidentally caught and washed ashore animals suggests that only a fraction of the population lives more than 12 years, irrespective of their geographic location (Kasuya and Brownell, 1979; Pinedo, 1994; Pinedo and Hohn, 2000; Di Benedetto and Ramos, 2001; Secchi et al., 2003b). This indicates that franciscana has one of the shortest life spans among all cetaceans. Mean asymptotic length for franciscanas from Rio de Janeiro State, Brazil (FMA I), is 117.1 cm for males and 144.7 cm for females (Ramos et al., 2000). For specimens from São Paulo and Paraná states, Brazil (FMA II), mean asymptotic length ranges from 113.3 to 117.3 cm for males and 128.9 to 136.2 cm for females (Barreto and Rosas, 2006; Conversani et al., 2020). In FMA III, individuals from Rio Grande do Sul State, Brazil, present mean asymptotic length ranging from 129.8 to 130.6 cm for males and 146.3 to 152.6 cm for females (Barreto and Rosas, 2006; Botta et al., 2010). For specimens from Uruguay, the asymptotic length is 133.3 cm for males and 153.0 cm for females (Kasuya and Brownell, 1979). In Argentina (FMA IV) the mean asymptotic length is 135.8 cm for males and 150.5 cm for females (Botta et al., 2010). It is worthwhile to note that franciscana variation in size is not clinal as one would expect (Table 1). Franciscanas are larger in their southern range (Rio Grande do Sul State, Brazil; Uruguay and Argentina – FMAs III and IV) followed by animals from the northern range (Rio de Janeiro and Espírito Santo States, Brazil – FMA I) and are smaller in the middle of its range (São Paulo, Paraná and Santa Catarina States, Brazil – FMA II). Body weight also follows the same geographic pattern (e.g., Rosas, 2000; Botta et al., 2006).

Reversed sexual size dimorphism (RSSD) occurs in franciscana (Kasuya and Brownell, 1979; Pinedo, 1995; Higa et al., 2002; Ramos et al., 2002). Females are larger than males in both the total body length as well as weight (Brownell, 1989; Rosas, 2000; Botta et al., 2006). Larger females might represent an evolutionary advantage for small species by allowing gestation and birth of larger, even slightly, calves. Larger calves potentially have a higher likelihood of survival due to several factors including a relatively lower metabolic rate and a lower surface/volume ratio, which reduces heat loss. Predation of larger calves might also be less likely. In fact, most of the odontocetes presenting RSSD are the smaller species in the group (Danilewicz et al., 2004). In general, these species produce relatively larger calves at birth than the other species within the taxonomic group (e.g., Ralls, 1976).

Behavior

The franciscana exhibits a reduced repertoire of surfacing behavior and a small portion of the body is exposed during immersion (Bordino et al., 1999; Cremer and Simões-Lopes, 2005; Cremer et al., 2018b). Group size is small (Figure 1), ranging from one to 13 individuals (Bordino et al., 1999; Cremer and Simões-Lopes, 2005; Cremer and Simões-Lopes, 2008), but solitary individuals are uncommon. Nevertheless, in

some occasions many groups may form large aggregations of up to 50 dolphins sharing a relatively small area. Association patterns were investigated through the deployment of satellite-linked tags on franciscanas in Bahía San Blas, Argentina, showing that female–male pairing occurs for extended periods, suggesting that they form reproductive pairs (Wells et al., 2013), considering that these animals were not genetically related (Mendez et al., 2010). This authors also suggest that the groups form functional social units. Considering further the reversed sexed length dimorphism and the absence of secondary sexual characteristics, it is hypothesized that franciscanas have a single-male breeding system (serial monogamy) with guarding strategy to increase mating chances (Danilewicz et al., 2004; Costa-Urrutia et al., 2012; Panebianco et al., 2012; Wells et al., 2013), which is unusual in cetaceans. This is coincident with some evidence that males do not disperse from their social units (Costa-Urrutia et al., 2012). An alternative but not exclusionary hypothesis is that adult males might help provide parental care. This behavior could increase the offspring's chances of survival. Epimeletic behaviors were recorded in Uruguay and Brazil for franciscana dolphins and were associated to parental care after their neonates being incidentally killed in gillnets (Pilleri, 1971; Cremer et al., 2006).

Bioacoustics

Franciscanas produce pulsed and tonal sounds. Pulsed sounds, as the clicks, are produced in a narrow band high frequency (NBHF) (Melcón et al., 2012), similar to dolphins of the genus *Cephalorhynchus*, which could be related to either predation avoidance behavior (Morisaka and Connor, 2007) or a consequence of the small size of the animals, hence their sound-producing structures. Tellechea et al. (2017) recorded high and low-frequency click trains in the La Plata River estuary, in Uruguay. Click trains with mean frequency of 130 kHz and bandwidth of 20 kHz were recorded for an adult franciscana held in captivity (Von Fersen et al., 1997). Wild neonate produces clicks in frequencies ranging between 37 and 160 kHz (Melcón et al., 2016). Whistles were recently recorded for the species. Their frequencies varied between 0.7 and 23.4 kHz for free ranging individuals and between 8.6 and 94.6 kHz for individuals handled during capture/tagging/release procedures. These sounds were more complex, indicating that they were related to a stressful situation and/or to parental care (Cremer et al., 2017). Tellechea et al. (2017) suggest that franciscana echolocates only sparingly because it takes advantage of passive listening to find the sound-producing preys. The echolocation system has an early but continuing postnatal maturation (Frainer et al., 2015). Neonates are acoustically active at 1-week-old and can produce broad band clicks, including burst pulses, that could be important in the mother-calf communication (Tellechea and Norbis, 2014).

FRANCISCANA THREATS

Incidental Mortality in Fishing Nets

Mortality due to bycatch in gillnets is the greatest threat to the franciscana. There is no indication of direct exploitation

of the species. Reports of incidental mortality in the shark gillnet fisheries of Punta del Diablo, Uruguay, date back to the early 1940s (Van Erp, 1969). Although gillnetting in southern Brazil began around this time (Haimovici, 1997), gillnet sets for bottom-dwelling fish were only recognized as a major threat to the franciscana in the 1980s (Pinedo, 1994). Bycatch has since been reported from the main fishing communities along most of the species' range (e.g., Corcuera, 1994; Moreno et al., 1997; Praderi, 1997; Secchi et al., 1997, 2003b; Di Benedetto et al., 1998; Bertozzi and Zerbin, 2002; Rosas et al., 2002; Franco-Trecu et al., 2009; Frizzera et al., 2012; Marcondes et al., 2018). Estimates of incidental capture totaled at least 2,900 animals per year in all management units combined in the early 2000s (e.g., Ott et al., 2002; Secchi et al., 2003b), but these figures are probably underestimated to an unknown extent, primarily due to: (1) the occurrence of catches in other non-monitored categories of fisheries (e.g., active gillnetting, Secchi et al., 1997; trawling, Szephegyi et al., 2015); (2) lack of data on the number of fishers and fishing effort carried out with gillnets (3) limited number of communities where landings are monitored; (4) under-reporting of incidental catches by fishers; and (5) dolphins captured may drop off the net during retrieval (Secchi et al., 2003b). For example, in southern Brazil alone, annual fishing-related mortality can exceed this value (e.g., Prado et al., 2013). Bycatch for each of the FMAs has been estimated from different approaches. A beach monitoring project in FMA Ia recorded an average of 5.9 carcasses/year in the period of 2011/2017, ranging from one to 14 franciscana' carcasses recorded each year (Marcondes et al., 2018). In just 1 month, in 2006, four franciscanas were incidentally caught in the artisanal fishery from Doce River community, Espírito Santo State, Brazil (Frizzera et al., 2012). For the FMA Ia and Ib together bycatch estimated can be > 110/year, based on interviews with fishers (Di Benedetto, 2003; Freitas-Netto and Barbosa, 2003). In FMA II, most complete estimates of mortality also came from near-daily beach carried out from 2016 to 2018. These surveys recorded 1,628 carcasses that represent a mean of 543 individuals/year. Despite the fact that many animals were in advanced state of decomposition, data indicated that most of them died because of incidental capture in fishing nets (Cremer et al., 2018a). Since most carcasses do not wash ashore (see Prado et al., 2013), these mortalities estimated from beach surveys are probably highly underestimated. Bycatch estimates in FMA III and IV have been obtained through monitoring of the fishing fleet. Annual bycatch is higher in FMA III, with estimates of 1,300 animals/year (Ott et al., 2002; Secchi et al., 2003b, 2004) and much higher in some years (Prado et al., 2013, 2016). In FMA IV the annual bycatch was estimated in 350–800 individuals/year (Bordino and Albareda, 2004; Cappozzo et al., 2007; Negri et al., 2012). These annual mortality estimates suggest that bycatch levels are unsustainable (Secchi, 2006; Danilewicz et al., 2009, 2012; Crespo et al., 2010; Zerbin et al., 2011; Prado et al., 2013, 2016) and are fragmenting functional social units, as suggested by some authors (Mendez et al., 2010; Costa-Urrutia et al., 2012). Although franciscana is legally protected in Brazil, Uruguay and Argentina (e.g., Arias et al., 2002; Instituto Chico Mendes de Conservação da Biodiversidade

(ICMBio), 2011; Soutullo et al., 2013), regulations addressing the management of gillnet fisheries that propose restrictions with potential to minimize bycatch of franciscana are limited to Brazil (Brasil, 2012). Their effectiveness, however, seems limited either because of lack of enforcement and compliance or due to their limited spatial scope (see section “Conservation Perspectives” below).

Habitat Degradation

Ingestion of Debris

Ingestion of plastic debris by cetaceans for long time has been a global concern (e.g., Laist, 1997). Analyses of stomach contents have shown that franciscana is also susceptible to the ingestion of many sorts of debris including discarded fishing gear (Basso, 1997; Bastida et al., 2000; Danilewicz et al., 2002; Denuncio et al., 2011). For instance, in Rio Grande do Sul State, southern Brazil, stomach contents of franciscanas ($n = 36$) contained pieces of nylon net (17% of the stomachs), cellophane, and plastic fragments (6%) (Basso, 1997). The rate of debris ingestion by franciscanas varies spatially with higher values observed in northern Argentina, where cellophane, fishing debris, and plastic were found in 45, 32, and 16% of the stomachs, respectively (Bastida et al., 2000). According to these authors, fishing-related debris were more often found in stomachs of specimens collected along the shore of the La Plata River estuary while, in contrast, cellophane debris were more abundant (100% greater) in animals stranded on the marine coast. In the northern range (FMA I), plastic debris were found in nearly 15% of the stomach contents of franciscana (Di Benedetto and Awabdi, 2013). Regardless of the fact the ingestion may occur directly or indirectly through the prey, the effects of such debris ingestion on the health status of individual franciscanas have not been determined, and the population-level implications are uncertain, but should not be ignored.

Chemical Pollution

There is no evidence that coastal oil spills have affected franciscanas. On the other hand, trace elements, organobrominated compounds and organochlorines compounds have been documented in the tissues of this species along its distribution range. O’Shea et al. (1980) were the first to analyze the concentration of organochlorine in franciscanas incidentally killed in fisheries off Uruguay. Much later, the presence of these pollutants in tissues of franciscanas were investigated in Argentina (e.g., Borrell et al., 1995, 1997) and Brazil (Castello et al., 2000). Comparatively, the concentrations of DDTs in Brazil and Argentina were lower than in Uruguay. A wide range of organochlorine residues has been discovered in the blubber of franciscanas from the Brazilian coastal waters (Kajiwara et al., 2004; Lailson-Brito et al., 2011). In contrast to the lower residue levels of CHLs, HCB, HCHs, and heptachlor epoxide, the concentrations of DDT’s and PCB’s are surprisingly, the highest compared to those of north Atlantic dolphins, possibly reflecting high levels of industrialization or poor ecological enforcement in Brazil (Kajiwara et al., 2004).

With regard to trace elements, Seixas et al. (2008) found that the concentrations of selenium (Se), total mercury (Hg),

and organic mercury (OrgHg) were higher in the livers and kidneys of franciscanas from Rio Grande do Sul State than Rio de Janeiro State, Brazil. For both areas, the values were of the same order of magnitude as those reported in earlier studies with the same species from Brazil (Lailson-Brito et al., 2002; Kunito et al., 2004; Seixas et al., 2007) and Argentina (Marcovecchio et al., 1994; Gerpe et al., 2002; Denuncio et al., 2017; Romero et al., 2017). Franciscana livers showed higher concentrations of mercury, zinc, and copper relative to concentrations in other organs, whereas their highest cadmium concentrations were mostly found in kidneys (Marcovecchio et al., 1990; Gerpe et al., 2002; Lailson-Brito et al., 2002; Kajiwara et al., 2004; Seixas et al., 2008). The concentrations of these trace elements seem to be positively correlated with age (e.g., Seixas et al., 2008). For example, mercury is an exogenous and harmful metal (no benefit at any concentration), which accumulates in the tissues of higher food web organisms (such as marine mammals) as they grow (Caurant et al., 1994; Feroci et al., 2005; Polizzi et al., 2014; Baptista et al., 2016; Kehrig et al., 2016; Romero et al., 2016). Conversely, selenium is acknowledged as an essential element for metabolic activity of aquatic mammals, performing as a protective agent against the toxicity of exogenous metals such as mercury and silver (Feroci et al., 2005; Baptista et al., 2016). Recently, Ti concentrations and metalloprotein detoxification in livers of franciscanas dolphins from southeastern Brazil were assessed (Monteiro et al., 2020).

In general, the observed trace elements concentrations are considered low by the authors when compared to those found in delphinids. However, it is important to highlight that the franciscana is smaller than the majority of delphinids, weighting nearly half the weight of an adult Guiana dolphin (*Sotalia guianensis*), another coastal species. Therefore, the contamination does not become less relevant because of the observed concentrations, since the doses may be very similar to those of delphinids. It is possible that the adverse effects also occur in the franciscana. Likewise, the synergic effects of the pollutants reported for the species must be taken in consideration. Other emergent contaminants, such as pyrethroid insecticides and sunscreen agents, also represent a potential threat that should be evaluated (e.g., Alonso et al., 2015).

A wide set of contaminants was already reported in franciscana’s tissues’ along its distribution. In particular, the concentrations found in populations under the influence of La Plata river, Argentina and in southeastern Brazil. Due to its coastal habits, franciscana will always be highly exposed to elevated concentrations of contaminants. In fact, recent data shows that even those contaminants banned for decades can still be found in its tissues. This could be related to the remobilization of contaminated sediments (i.e., dragging), inappropriate storage of old stocks of these pollutants, or even their cycle in the biotic compartment. In this context, it is important to highlight the PCBs concentrations in franciscanas from the southeastern region in Brazil, which is an important immunosuppressor. Additionally, the input and incorporation of emerging contaminants of unknown effects to mammals is also of concern. Hence, franciscanas are exposed to a cocktail of substances that are, mostly, immunosuppressors and/or present

deleterious effects over the reproductive process. Then, it is possible for those contaminants to be exerting pressure over this species, altering reproductive cycles and increasing its susceptibility to pathogens.

The most concerning impact by chemical pollution on franciscanas is much likely being experienced by the small population (<700) that inhabits the FMA Ia. This isolated population of franciscanas, was impacted and is under direct and indirect effects of the iron ore tailing due to Fundão dam collapse, in Minas Gerais state, Brazil, that reached the outfall of Doce river. This has been considered the most catastrophic environmental disaster in Brazil (Garcia et al., 2017) and it produced an unprecedented pollution load and habitat modification in coastal waters off FMA Ia. In this sense, long-term monitoring is required to assess the status of this population.

Coastal Development

Harbors represent a big threat for coastal habitats as they bring together many impacts related to dredging, noise pollution and chemical pollution that can affect directly and indirectly the franciscanas (Pinheiro et al., 2019; Marcondes et al., 2020). Franciscanas do not approach to harbors, and in Babitonga Bay, Brazil, they represent a loss of habitat (Cremer et al., 2018b). The development of harbor activities is growing fast on the south and southeast coast of Brazil, at least from Santa Catarina State to Espírito Santo State, Brazil (considering the area of franciscana distribution). In Espírito Santo state, where is located the smallest franciscana population (FMA Ia), 14 new harbors were proposed, which represent one harbor complex for every 20 km of coastline (Pinheiro et al., 2019). Along with that, this same area was recently contaminated with around 62 million tons of Fe-enriched tailings through the Doce River, in an episode that became known as the “Mariana disaster,” which is likely to have significant impact on franciscana and its ecosystem (e.g., Frainer et al., 2016; Hatje et al., 2017).

Depletion of Fish Stocks

Historical catch records of commercial fishes have demonstrated a decline in yearly landings of the sciaenids *Micropogonias furnieri* and *Macrondon ancylodon* in southern Brazil (Haimovici, 1997; Haimovici, 1998). This is consistent with a reduction in the occurrence of these two species in franciscana’s diet (Basso and Secchi, 2000; Secchi et al., 2003b). *Micropogonias furnieri* has been heavily exploited by gillnet and trawl fisheries for more than three decades (Reis, 1992; Haimovici, 1998) and a drastic decrease in the density of juveniles in coastal waters has been observed (Ruffino and Castello, 1992). During that same period, *M. ancylodon* and *M. furnieri* decreased drastically from 41 to 7%, and from 27.5 to 4% in the frequency of occurrence, respectively, in the diet of franciscana (Secchi et al., 2003b). Haimovici (1998) showed that stocks of these sciaenid species have been greatly exploited and are currently at very low levels in the region. On the other hand, frequency of occurrence of cutlassfish *Trichiurus lepturus* and the sciaenid *Umbrina canosai* in the diet of the franciscana increased from about 5 and 3% in the late 1970s, to about 39 and 20% in the mid 1990s, respectively. *Trichiurus*

lepturus, together with *Cynoscion guatucupa*, represents 47% of the total estimated bony fish biomass in this region (Haimovici et al., 1996). Both species have only experienced moderate fishing pressure (Haimovici, 1997, 1998). While *C. guatucupa* has always been the most important prey for franciscana, *T. lepturus* has had only a little importance in the franciscana’s diet in the past. However, now it is the second most important prey for the species in this region. These values suggest that changes in the franciscana diet are related to the reduced availability of certain prey species due to their over-exploitation. Although the effects of this major dietary change on the franciscana are unknown, the sharing prey with extensive fisheries may affect the trophic dynamics and have negative energetic implications for the species in some areas (e.g., Machado et al., 2020).

ASSESSMENT AND CONSERVATION PERSPECTIVES

Potential Biological Removal (PBR) for Franciscana

The PBR is defined as the maximum number of animals that may be removed from the population by non-natural causes, while allowing it to reach or maintain its optimum sustainable level (Wade, 1998). The sustainability of the estimated annual bycatch of franciscana was assessed through the PBR approach for each FMA, as follow:

$$PBR = N_{min} \cdot (R_{max}/2) \cdot R_f$$

Where N_{min} is the 20th percentile of a log-normal distribution based on the estimated abundance of franciscanas (N); R_{max} is the maximum net productivity level; and R_f is a recovery factor. N_{min} is used instead of N to account for imprecision in the abundance estimates. The R_{max} values used in the PBR analysis of up to 4% is considered reasonable for small cetaceans impacted by fisheries (Wade, 1998). The recommended R_f values varied from 0.1 for populations considered endangered by the IUCN (Hilton-Taylor, 2000), or poorly studied, up to 1.0 for populations considered of low risk and well-studied. Since franciscana is currently classified as “Vulnerable” by the IUCN (Zerbini et al., 2017), is declining, with some populations with much higher risk of collapse than others (Secchi and Wang, 2002; Secchi and Fletcher, 2004; Secchi, 2006), and there are uncertainties in mortality estimates, a R_f of 0.1 was used.

Fishing-related mortality ranges from approximately 100, in FMA I, to more than 1,000 in FMA III, and exceed from near two in FMA IV to more than fivefold in FMA III the maximum allowed sustainable mortality rate base on potential biological removal (PBR) approach (Table 2). These numbers reveal that species cannot sustain the current levels of bycatch and that urgent and extreme restrictions on fishing practice and effort are necessary to avoid collapse of franciscana and to reduce its risk of extinction.

Although the PBR approach has a clear advantage that management actions linked to direct human-related kills no longer rely on detecting negative population trend, but on simply

TABLE 1 | Spatial differences in age at attainment of sexual maturity (AASM), body length at attainment of sexual maturity (LASM), modeled asymptotic length (MAL), annual pregnancy rate (APR), and maximum observed age (MOA) of female franciscanas among FMAs (sensu Secchi et al., 2003a).

Franciscana Management Areas	AASM (years)	LASM (cm)	MAL (cm)	APR	MOA (years)
FMA I	3.0	130	144.7	N/A	9
FMA II	2.7	128.5	128.9	0.36	16
FMA III	3.7	139	152.6	0.65	21
FMA IV	4.0	133	150.5	N/A	14

Since there is slight variation within FMAs values are based on most up to date estimates. N/A, not available.

TABLE 2 | Franciscana abundance estimate (N) and coefficient of variation (CV), minimum abundance (N_{min}), maximum net reproductive rate (R_{max}), recovery factor (R_f), approximate annual bycatch and maximum sustainable bycatch valued based on the potential biological removal approach (PBR, sensu Wade, 1998), for each Franciscana Management Area (FMA – sensu Secchi et al., 2003a).

FMA	N	CV abundance	N_{min}	R_{max}	R_f	PBR	Annual bycatch
FMA Ia	893	0.3	697	0.4	0.1	14	
FMA Ib	2,000	0.46	1,383	0.4	0.1	28	ca. 100
FMA II	6,827	0.26	5,504	0.4	0.1	110	ca. 500
FMA III (*)	15,814	0.32	12,158	0.4	0.1	243	> 1,000
FMA IV	14,175	0.42	10,096	0.4	0.1	202	500–800

All absolute values were rounded to the nearest integer. (*) It was assumed that the estimates provided by Danilewicz et al. (2010) for approximately 43% of the distribution area can be extrapolated to the whole FMA III.

detecting a mortality level that would cause depletion (Wade, 1998), it does not capture population-specific differences in life history traits, described here, that shape population dynamics and its potential to respond to impact (e.g., Secchi and Fletcher, 2004; Secchi, 2006; Cáceres et al., 2020). Viability analyses using population-specific estimates of abundance, fisheries-related incidental mortality and vital rates suggested that levels of bycatch were not sustainable and that projected probability of decline was high for all FMAs in a time frame of 25 years (Secchi and Fletcher, 2004; Secchi, 2006), which is coherent with the PBR values of this present study. Projected declines resulted in the listing of franciscana as “Vulnerable” in the IUCN Red List (Zerbini et al., 2017).

Conservation Perspectives

Even though franciscana is legally protected in Brazil, Uruguay and Argentina (Arias et al., 2002; Weiskel et al., 2002; Instituto Chico Mendes de Conservação da Biodiversidade (ICMBio), 2011; Soutullo et al., 2013), threats to the species are far from being mitigated. Although other potential sources of non-natural mortality, as described in this present study, also affect the franciscanas in a difficult way to scale, the greatest threat to the species is incidental capture in gillnets (Secchi, 2010). Some efforts have been made to evaluate the effectiveness of methods for reducing bycatch. Pingers were tested in Argentina in a small-scale fishery and a highly significant reduction in bycatch was demonstrated (Bordino et al., 2002), but a dinner bell effect was observed with the attraction of southern sea lions (*Otaria flavescens*), which depredated the catch hence, discouraging the continuity of that study. Later, with the advancement of new pingers, experiments carried out in Argentina with Dolphin Pinger 70 kHz of Future Oceans (Bordino, 2018), and in Brazil with Banana Pinger

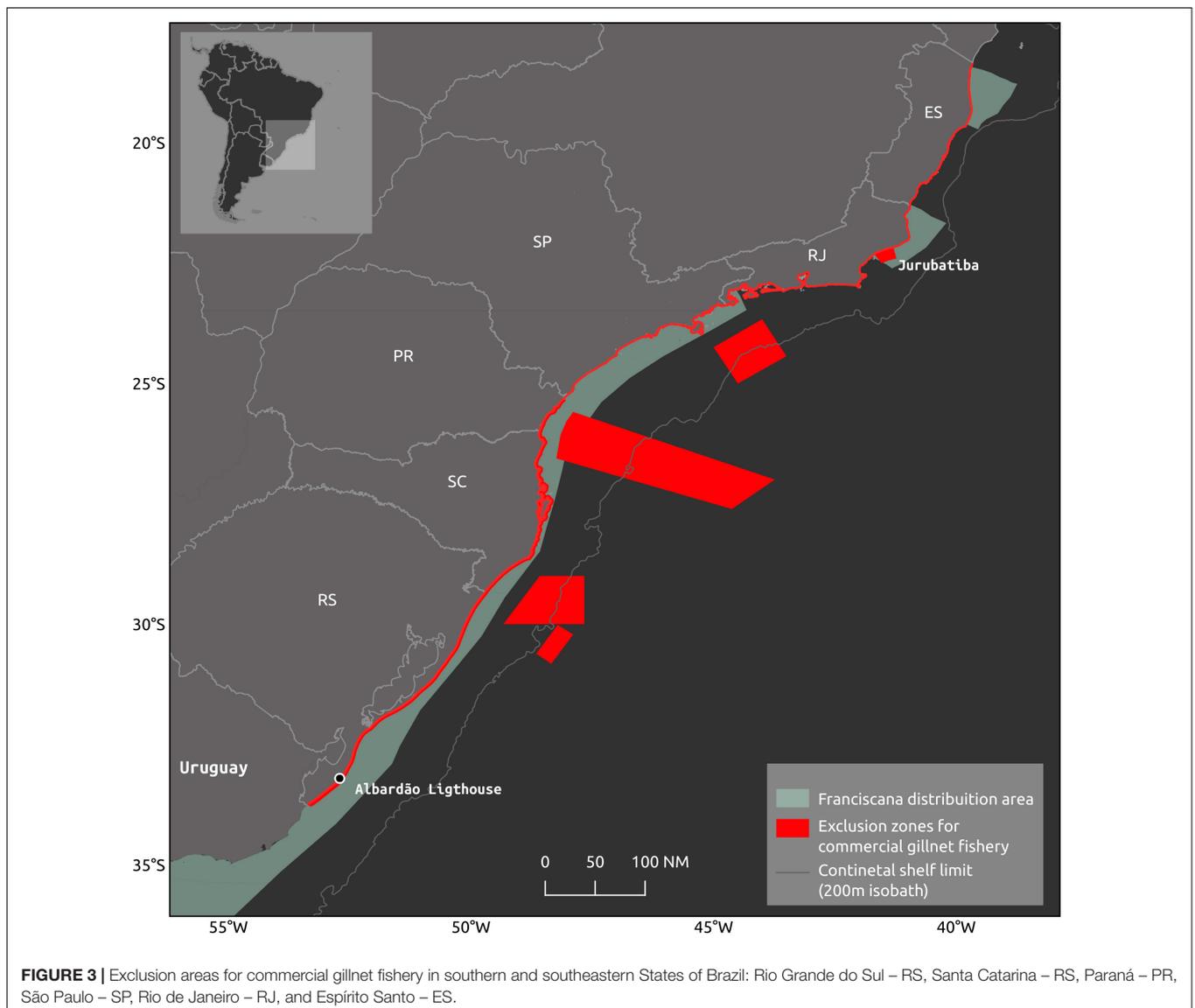
of Fishtek Marine (Paitach et al., 2018), demonstrated the potential of “seal safe” devices for franciscanas deterrence. Despite the experiments showed a significant displacement of the franciscanas from the vicinity of the ensounded area (Bordino, 2018; Paitach et al., 2018), both studies were focused on the behavior response to a single pinger, and questions remain regarding the long-term effectiveness of the pingers in a real fishing situation, arranged in an array of many pingers along a gillnet. Understanding the behavior of franciscanas in the vicinity of the nets, with and without pingers, is crucial for designing technological alternatives for bycatch mitigation. Acoustically reflective gillnets, in turn, were not efficient in reducing bycatch (Bordino et al., 2013). Berninsone et al. (2020) investigated the potential of switching gillnets to bottom longlines to reduce franciscana bycatch rates in a small-scale artisanal fishery in Argentina. They concluded that the use of bottom longlines result in significant mitigation of current bycatch of franciscana dolphins, but it requires the acceptance and compliance of the fishers before implementation (e.g., Brownell et al., 2019).

In Brazil, where most of the franciscana bycatch occurs, gillnet fishery had been carried out unregulated for several decades. The number of boats, the dimension of the nets and the duration of the fishing trips increased with no rules. Despite the frequent and significant mortality of several endangered species, such as cetaceans, sea turtles, birds and sharks, as well as the decline of some target species, no enforcement could take place. Lack of regulation markedly increased fishing effort and the catch of the already depleted stocks. One of the most affected species is the franciscana. In 2012, a joint Interministerial Regulation of the Ministry of Environment and Ministry of Fisheries and Aquaculture (hereafter referred to as INI12/2012) was published aiming at regulating gillnet fisheries in southern and southeastern

Brazil, between the States of Rio Grande do Sul to Espírito Santo, distribution limits of franciscana in the country (Brasil, 2012).

Although less conservative in several aspects than the recommendations in the Brazilian Action Plan for the Conservation of the Franciscana (Instituto Chico Mendes de Conservação da Biodiversidade (ICMBio), 2011), several rules of this INI 12/2012 establish limits on the gillnet fishing effort (Brasil, 2012). Maximum allowed gillnet length was reduced and varied according to boat size. If the boat length is modified, the net length will follow the smaller previous category. Gillnet fishing permits were halted. New boats are not allowed to have gillnet fishing permits and boats operating with a different gear cannot change to gillnetting. No gillnet fishing is allowed between 15 May and 15 June, except for the artisanal fishery. A mosaic no-fishing areas for gillnets with different levels of restriction were established along the entire region regulated by INI12/2012 (Figure 3): (i) no powered boat can fish within the

first nautical mile (ii) only rowing boats can operate within the first nautical mile but with nets no longer than 1000 m; (iii) no powered boat can operate within the 5 nm between the southern border of Brazil (with Uruguay) to Albardão lighthouse (located approximately 120 km further to the north); (iv) to the north of Albardão lighthouse, no gillnetting is allowed for commercial gillnetting within 4 nm up to the northern limit of Rio Grande do Sul state and within 3 nm from this point to the remaining area concerned in this Regulation; (v) no gillnetting is allowed within the 15 nm off the Jurubatiba National Park, in Rio de Janeiro state. All boats longer than 15 m are obligated to carry and turn on Virtual Monitoring System (VMS) when at sea so their fishing location can be monitored. Fishing license will be lost in case of infraction to the Regulation. These rules were set to be implemented in areas with extensive bycatch in Brazil and were expected to improve the species' conservation status. However, they were never effectively implemented, either due



to the lack of awareness in small fishing communities, or the lack of enforcement. Furthermore, some rules proposed in the INI 12/2012, such as the functioning of steering committees and the implementation of on-board observer programs, under the responsibility of the Federal Government, have yet to be established. While lack of enforcement persists, no assessment regarding the effectiveness of the regulation can be made. Evidence, however, indicates that the level of franciscana's fishing-related mortality in Brazil remains high, in the order of several hundreds to a few thousands, which is not different from the numbers observed in years that preceded the regulations (e.g., Prado et al., 2013, 2016; Cremer et al., 2018a). Moreover, a recent case study showed that even with full compliance, the current fishing regulations cannot reduce franciscana bycatch to sustainable levels in southern Brazil (Prado et al., 2021). Therefore, these regulations are proved insufficient to reduce fishing-related mortality to sustainable levels due to either or both lack of enforcement and, hence, compliance, and insufficient reduction in fishing effort.

Recently, franciscana and other six threatened small cetaceans, according to the IUCN Red List of Threatened Species, were assessed by worldwide experts to determine the extent to which *ex situ* management could, together with strengthen *in situ* conservation efforts, increase likelihood of success (Taylor et al., 2020). It was stressed that the species is relatively abundant in much of its range and there is still the potential for successful *in situ* conservation and long-term viability of franciscanas in the wild, hence that it is currently not a high-priority candidate for *ex situ* management (Secchi et al., 2020). If *ex situ* management is considered in the future, improved knowledge is necessary about the requirements for successful handling and maintenance of animals under human care and preparation for their subsequent release (Secchi et al., 2020). It was further recommended that a capture/tag/release program for franciscanas in Brazil and Argentina should be expanded and include biological data gathering in support of rehabilitation/release of live by-caught and stranded franciscanas and to inform the possible future development of an action plan using the One Plan approach (*sensu* Byers et al., 2013; Taylor et al., 2020).

Meanwhile, an immediate and significant bycatch reduction, as a result of a drastic decrease of the total fishing effort, and habitat restoration is, perhaps, the only short-term options for reducing the risk of franciscana's collapse (e.g., Prado et al., 2021). These authors identified two bycatch hotspots areas in Rio Grande do Sul state coast (part of FMA III), south of Brazil, and recommended that they should be designated as no-fishing zones for gillnets. One of the recommended gillnet no-take area is off the Albardão region, a strong candidate to become a marine protected area as it represents an important feeding and breeding ground for endangered loggerhead sea turtle and elasmobranchs, respectively (Vooren and Klippel, 2005; Monteiro et al., 2016). Prado et al. (2021) also recommended that total fishing effort outside these areas should drop considerably. These sort of management options are extremely unpopular among fishers (e.g., Murray et al., 2000; Brownell et al., 2019), especially if the closure areas encompass significant proportions of their fishing grounds, which is the case in the study of

Prado et al. (2021). In fact, any action with higher likelihood of effectiveness will, necessarily, result in lowering absolute fishing effort or changing location of main fishing grounds, which, in turn, may have negative socio-economic impact. Although the implementation of the exclusion zones for gillnetting and limiting fishing effort as recommended by Prado et al. (2021) will strongly distress the *status quo*, they followed international guidelines (e.g., International Whaling Commission (IWC), 2016; Food and Agriculture Organization (FAO), 2021) and were founded on robust scientific evidence and on a clearly defined management goal to reduce risk of collapse of franciscana's population in southern Brazil. It is worthwhile noting, however, that reducing fishing effort will be beneficial for franciscana, and also for the economic viability of the fishery, especially if fisheries agency is focused on long-term outcomes by aligning economic and conservation objectives. Therefore, key stakeholders need to work together and to build participative multi-fisheries management and other ecosystem-based conservation strategies in order to increase the chances of franciscana long-term survival while maintaining sustainable fishing activities that are relevant to some communities that are socioeconomically vulnerable.

In that sense, extensive overfishing (e.g., Haimovici and Cardoso, 2017; Cardoso et al., 2018; Instituto Chico Mendes de Conservação da Biodiversidade (ICMBio), 2018) and prolonged ineptitude of federal fisheries agency toward a proper management impelled local fishers in Rio Grande do Sul State to lead a movement that ended in the sanction of the Sustainable Fisheries State Policy Act in 2018 (RS State Law 15,223/2018). This Law banned all bottom trawling up to 12 miles from the State's ca. 570 km of marine coast. Scientific evidence indicated that the ban would have ecosystem benefits, by reducing impact on endangered species and facilitating the recovery of fish stocks, which in turn may promote continued revenues for small-scale and industrial fisheries (Cardoso et al., 2018, 2021). According to these authors, the establishment of the trawl exclusion zones would promote habitat restoration and a rapid increase in the biomass of important sciaenid species for gillnet fisheries including white croaker, striped weakfish, king fish (*Macrodon atricauda*) and Argentine croaker (*Umbrina canosai*). Although trawl fisheries do not represent a direct threat to franciscana, they are responsible for a high bycatch of juvenile sciaenids that are both important prey of franciscana and potential recruits for the gillnet fishery. If biomass of sciaenid fishes increases, it is expected that gillnet fishery can have higher yield with lower fishing effort.

The trawl fishery ban and the regulation of gillnetting represent important advances regarding fisheries management in Brazil. If fully complied and improved as recommended by Prado et al. (2021), in the case of gillnet fishery, these regulations can enhance the conservation status of franciscana and several other endangered coastal species as well as promote the recovery of some fish stocks and their habitats. Franciscana mortality data in recent decades allow us to infer that the species probably was once the most abundant small cetacean in coastal waters off the western South Atlantic, and certainly played, and might still play, an important role in the trophic web of this ecosystem. The evidence presented the present study shows that this situation is

certainly the result of increasing human pressure on the coastal zone, with the depletion of its natural resources and very high and unsustainable fishing effort, that leads to an unsustainable fishing-related mortality. Franciscana is the most endangered small cetacean in the entire western South Atlantic and the only living member of the family Pontoporiidae. Losing the franciscana represents the loss of a unique evolutionary lineage that survived to several changes on the planet, but that could become extinct in a few decades.

AUTHOR CONTRIBUTIONS

ES conceived this study. All authors wrote the first draft, revised, and approved the submitted version.

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