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Human-wildlife conflict between Neotropic cormorant and artisanal fisheries induces dubious management policies in southern Brazil

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ABSTRACT

Human-wildlife conflicts pose significant challenges, requiring nuanced solutions rooted in ecological understanding and community engagement. In this sense, this opinion essay explores the first documented South American conflict scenario between Neotropic cormorants (*Nannopterum brasilianum*) and artisanal fisheries, located on Laguna Estuarine System, southern Brazil. Local reports converge on the information that, after 2015, Neotropic cormorants began to establish a reproductive colony on a non-breeders dormitory located at Noca Lagoon, near the estuary mouth. The colony's consistent presence over the years and intense feeding activity, along with possible recruitment of cormorants, may lead to the perspective of increased population and nuances among fishermen. These concerns include vegetation suppression dealt by guano deposition, food competition, property damage, and fishery resources depletion. Despite no evidence of cormorant population increase and due the fact that fishing is an important regional activity, there was a response from local lawmakers to address this issue (Municipal Ordinary Law number 2.154/2020). The law imposes the harmful status to the native bird species and permit measures to "clean" harmful populations from properties. In addition, this law lacks control guidelines to cormorant populations, threating the local biodiversity and exacerbating the emerging human-wildlife conflict. To address these challenges, holistic and interdisciplinary approaches that understand cormorant behaviors and its interaction with fisheries activity are needed. From the knowledge bridge built from lawmakers, stakeholders, scientists, and fishermen, it is possible to foster dialogue and adopt a conceptual framework to mitigate conflict outputs and promote harmonious coexistence between wildlife and human activities.

Keywords: Ecological conflict, Environmental policy, Estuarine ecosystem, *Nannopterum brasilianum*, Southern Brazil

INTRODUCTION

Human–wildlife conflicts (HWC) may be defined as interactions between humans and wildlife with adverse outcomes for both sides (Nyhus, 2016). HWCs are associated with real threats (Treves and Karanth, 2003) and/or with

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an unreal perception that wildlife threatens humans activities and livelihood (Peterson et al., 2010). Unresolved HWC can be considered "intractable" when human interested actors (e.g., aquiculture, fisheries, social communities, and lawmakers) have different perspectives (Marzano, Carss and Cheyne, 2013), lack of basic scientific information, and poor legal instruments (Ottoni et al., 2021) regarding the conflict issues and solutions. These "intractable" conflicts need a broader overview (participation of different actors) and interdisciplinary approaches (transboundary scientific and jurisdictional disciplines) to generate multiple knowledge and new resolutions (König et al., 2020; Carss, 2022).

As a consequence of human invasion in natural areas and habitats loss (Powers and Jetz, 2019), there is a high spatial overlap between wildlife and humans, increasing HWC worldwide (König et al., 2020). Furthermore, HWCs can be amplified by climate changes (Nyhus, 2016; Abrahms et al., 2023). In Brazil, HWCs have been intensified and diversified for the past two decades (Marchini and Crawshaw, 2015), involving depredation of livestock (Balbuena-Serrano et al., 2021), attack on humans (Campos Neto, Garrone Neto and Haddad, 2011), fishing gear damage (Cook et al., 2022), traffic collisions (Da Silva, De Menezes and Santos, 2022), damage to agriculture (De Carvalho et al., 2019), exotic species expansion (Pelicice et al., 2014), and erroneous law creation that threats biological diversity and ecosystem services (Ottoni et al., 2021). These HWCs involve a wide range of species with different conservation status, from endangered species such as Jaguar (*Panthera onca*) (Campos Neto, Garrone Neto and Haddad, 2011) and Black caiman (*Melanosuchus niger*) (Cook et al., 2022), to least concerned species, as White-eyed parakeet (*Psittacara leucophthalmus*) (De Carvalho et al., 2019) and Capybara (*Hydrochoerus hydrochaeris*) (Da Silva, De Menezes and Santos, 2022).

As the global HWCs, the ones in Brazil need representation from social, scientific, and political actors working to propose and implement interdisciplinary ways of solving management and decision-making for human-wildlife coexistence (Marchini and Crawshaw, 2015). In this context, the present opinion essay aims to highlight the first documented HWC between fisheries and an abundant colonial bird species in Brazilian waters, the Neotropic cormorant (*Nannopterum brasilianum*). In this study, we contextualized the global problem with an illustrative local conflict between cormorants and local stakeholders (i.e. aquaculture producers and artisanal fishers) in the Laguna Estuarine System (LES), southern coast of Santa Catarina State, Brazil. With a holistic approach, we explore the context of this HWC, assessing the management action (i.e., municipal law) created to handle the conflict, which is not science-based and is in mismatch with the Brazilian Federal Constitution, while also suggesting a conceptual model to frame this cormorant-fisheries conflict for the first time in Brazil.

Cormorant-fisheries conflicts overview

Cormorants (Aves: Phalacrocoracidae) comprises a group of 40 piscivorous bird species with a worldwide distribution, occurring mainly near marine and freshwater environments (Kennedy and Spencer, 2014). Their significant predatory roles (Doucette et al., 2011), colonial breeding strategy (Quintana et al., 2002; Kalmbach and Becker, 2005), and guano deposition (Kolb et al., 2015) enhances the perception that these birds negatively impact human activities (Östman et al., 2013). This interaction between cormorant and fisheries/aquaculture is an issue of global concern (Marzano et al., 2013). North Hemisphere countries have a long history of localized and widespread cormorants-fisheries conflicts that led to a series of management strategies, policy debates, and creation of laws. Most of these created international laws allow lethal actions and propose hunting seasons, as well as protective measures against harmful species (see Table 1 for more details) (Keith, 1995; Taylor et al., 2011; Van Eerden et al., 2012; Marzano et al., 2013; Carss, 2022; Dorr et al., 2022; Ludwig et al., 2023). As an example, in Sweden, Kolb et al. (2015) highlighted the significant impact of cormorants nesting colonies on soil chemistry, microbial communities, and soil fauna in island ecosystems. Wires (2015) extensively analyzed

the long-standing conflicts related to cormorants in the Northern Hemisphere, investigating legal and policy issues that have led to condemnations of cormorant populations in Canada and the United States, including the measurement of population impacts and management strategies. In South America, few studies regard specific points of the Neotropic cormorants interaction with fisheries and aquacultures. For instance, in the Los Olivitos estuary in Venezuela, a negligible impact on fisheries was found by balancing several cormorants' ecological function values, such as harvested food by cormorants, fish school indication, and guano contribution to fish biomass (Gil-Weir et al., 2011). Another documented interaction between Neotropic cormorants and commercial fishponds occurred in the Highland Lakes of Ecuador, where an increase in the cormorant population negatively impacted pond owners as the cormorants preyed on fish stocks (Guevara et al., 2011). As an example, to mitigate such negative interactions, non-lethal actions employed by Colombian fish producers to reduce economic losses caused by birds, including Neotropic cormorants, involve the use of noise-making devices such as guns, fireworks, and cannons, as well as human patrols and the installation of netting around ponds (Bechard and Marquez-Reyes, 2003). In Brazil, there are no documented conflict between cormorants and fisheries, but their inexistence may be explained by the use of other means of publication, such as social media and newspapers, rather scientific literature (Bell et al., 2012). Lack of documented scientific knowledge can lead to economically biased conflict solutions (Carneiro and da Silva Rosa, 2011) or the creation of erroneous laws and policies that can either threat biodiversity (Ottoni et al., 2021) or legally endorse actions against living beings, such as cormorants (Wires, 2015; Dorr et al., 2022). In Brazil, challenges in using evidence-based knowledge in policymaking include not fully using scientific evidence, political interference, ignoring conflicting data (specially within agriculture and biodiversity conservation), institutional barriers, and resistance to making structural changes, which hinders evidence-based decision-making (Donadelli, 2020).

Neotropic cormorants distribution in Brazil

Neotropic cormorants (*Nannopterum brasilianum*) forage on shallow waters by pursuit diving its preys; it also exhibits a generalist and opportunistic behavior, consuming mainly juvenile fishes and crustaceans (Branco, 2002; Barquete et al., 2008a; Oliveira et al., 2019; Pomárico et al., 2020). Their plasticity in resource use allows them to tolerate changes in prey availability and change prey preferences accordingly (Barquete et al., 2008a). The species reproductive colony is conspicuous, with hundreds of animals located near aquatic ecosystem (Sick et al., 1997). Reproductive colonies of the species are documented in the United States (Hanson et al., 2010), Central Chile (Kalmbach and Becker, 2005), and Argentina (Quintana et al., 2002), with a few studies in Brazil that indicate punctual cormorants colonies in Santa Catarina State (Azevedo, 1995), Pantanal region (Da Silva et al., 2000), and Rio de Janeiro coast (Alves et al., 2011).

The literature indicate that the species have seasonal migrations between foraging and breeding sites; however, in Brazil, there is only a few studies that focus on temporal abundance fluctuations, which may indicate species migration patterns (Branco, 2002; Barquete et al., 2008b; Silva et al., 2014). For instance, an abundance fluctuation was observed in Lagoa dos Patos, located in the South region of Brazil, by Barquete et al. (2008b), suggesting that cormorants either migrate in autumn-winter to breeding colonies northwards to Pantanal or southwards to Santa Fé and Paraná River basin in Argentina, the latter area corroborating a local study (Olrog, 1975). Abundance fluctuations were also observed in Saco da Fazenda estuary, Santa Catarina, and northern part of Amazon basin, State of Amapá (Branco, 2002; Silva et al., 2014), without reproductive colony observed nearby both areas. In the Guanabara Bay ecosystem, in Rio de Janeiro, cormorant populations exhibited abundance fluctuation; however, with an opposite trend, with the highest peaks occurring during autumn-winter and decreasing during summer-spring (Da Silva et al., 2018). These ecological aspects, as well as their predatory

behavior and gaps of migration patterns, not only raise ecological questions about this abundant and widespread cormorant, but also exacerbate potential conflicts with fisheries and aquiculture activities, which may compete for the same resources, as an example of Laguna cormorant population conflict with its artisanal fisheries and aquaculture.

The Laguna city conflict: estuary, cormorants and artisanal fisheries

The Laguna Estuarine System is located in the Brazilian southern coast, State of Santa Catarina. The estuary holds three interconnected elliptical lagoons spread parallel to the coast, with a choked connection to the sea (Figure 1), an average depth of two meters, a total area of 184 km², and a strong hydrological influence from the Tubarão River basin (Netto and Pereira, 2009; Barletta et al., 2017). The climate is classified as "Cfa," which consists of a Temperate region with a hot summer and no dry season (Peel et al., 2007; Beck et al., 2018). LES contains two temperate and tropical intertidal zones, respectively, marshes and mangroves, with the latter on its austral distribution limits (Cohen et al., 2020). These vegetation types and LES estuary dynamics, such as tide regimes and Tubarão river fresh water discharge, provide different feeding habitats, nursery grounds, and refuge for the fresh water, marine, and estuarine fauna (Netto and Pereira, 2009; Frischknecht et al., 2023), as well as habitat for cormorants to establish colonies and night roosts along the estuary (Figure 1). As consequence of these ecological features, LES contains important fishing activities (Sunye et al., 2014; Piazza et al., 2021), which provides historical, economic, social, and cultural values to artisanal fishermen in the region (Barletta et al., 2017; Rodrigues-Filho et al., 2023).

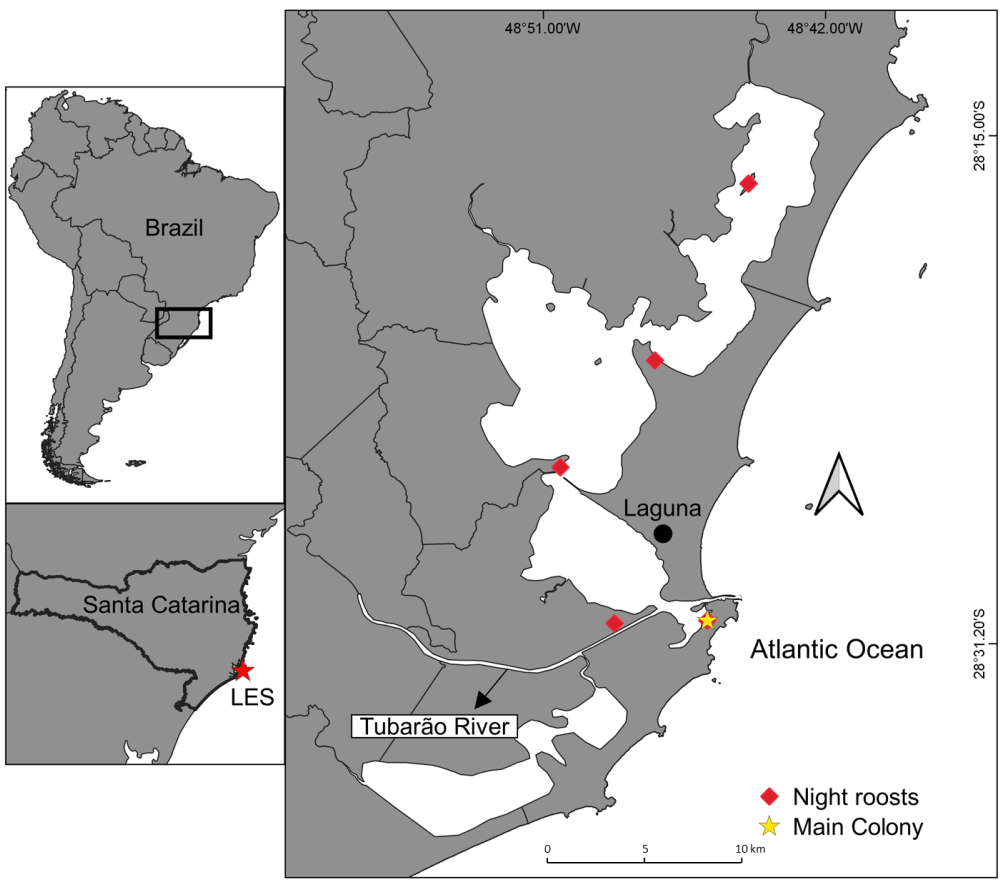

Figure 1. Location map of Laguna Estuarine System, highlighting *Nannopterum brasilianum* night roosts distribution along the estuary, the main breeding colony location, and Tubarão River mouth.

The conflict between fishermen and cormorants in LES can date back in 1760 (Ulysséa, 2005), when fishery was considered exclusively the main economic activity in Laguna city, the major city in LES's adjacencies. In that occasion, the municipal chamber imposed several strategies to avoid stocks depletions, as implementing larger fishing net meshes, prohibiting estuary mouth fishing, and obliging the population to turn in cormorant heads to authorities, with strict penalties for no adherence. The latter imposition was intended to "protect the local fisheries from the voracious seabirds" (Ulysséa, 2005).

Despite its historical nature, concerns persist among the fishing community regarding the "voracious" behavior of cormorants, which relates to their feeding strategies. Thus, local reports indicate an increase in cormorant populations around 2015, probably marked by migrating cormorants using the estuarine areas and the establishment of new colonies throughout the estuary adjacencies. These colonies intensify guano deposition on land, suppressing vegetation at roosting sites (Figure 2), while feeding activities of cormorants draw attention from observers and artisanal fisheries with conspicuous flocks.

Figure 2. *Nannopterum brasilianum* nest density and vegetation suppression dealt by guano deposition on the main breeding colony at Laguna Estuarine System, southern coast of Santa Catarina, Brazil.

Although the ecological aspects of this local conflict have not yet been fully explored, with further investigation still pending, the conflict permeates various outcomes of HWC, including resource competition, livestock depletion, habitat degradation, property damage, and income loss (Abrahms et al., 2023). For instance, cormorants feeding behaviors and daily consumption (Barquete et al., 2008a; Gil-Weir et al., 2011) underlies a perception of species voracity. Prey preferences (Barquete et al., 2008a; Branco et al., 2009) creates a perspective of food resource competition with LES artisanal fisheries and fish stock depletion by consuming locally targeted species, including White croakers, *Micropogonias furnieri*; Catfishes, *Genidens* spp.; Mullets, *Mugil liza*; and pink-shrimps *Farfantepenaeus* spp. (Sunye et al., 2014; Piazza et al., 2021). Moreover, the local community living near the colonies complains about the smell and vegetation suppression caused by toxic loads of nutrients as a result of intensified guano deposition beneath nests and perching sites. It is important to highlight that guano deposition in coastal ecosystems is considered a support ecosystem service (Green and Elmberg, 2014; Costanza et al., 2017; Rodrigues-Filho et al., 2023) that assists soil formation and primary production by incorporating

carbon, nitrogen, and phosphorus to biomass and inflicting a bottom-up cascade effect (Gagnon et al., 2013).

LES are fully explored by artisanal fisheries, which use 11 different types of fishery methods (Barletta et al., 2017), mainly by the usage of passive fishing gear, such as fyke nets, crab traps, and gillnet (Sunye et al., 2014; Biehl et al., 2019). These artisanal and subsistence fishermen claim economic losses when cormorants reach their bait or destruct their gear to access the captured resource. Meanwhile, shrimp farmers are also affected by cormorant predation at artificial ponds, as all invested time and capital in the whole process of production is lost when cormorants consume their grown shrimp. Actions to avoid/reduce cormorants on fish pounds are already employed among fish/shrimp producers worldwide (Lemmens et al., 2016; Russell et al., 2022). Shrimp farmers from the Laguna Estuarine System mitigate the predation effects of cormorants by the use of nylon nests above the artificial ponds.

Brazilian law limitations and Human-Wildlife conflict escalation

Brazil's legal framework is complex, with the Federal Constitution at the top of the normative hierarchy, along with its constitutional amendments. Meanwhile, at the bottom of this hierarchy are Primary Norms, consisting of legislative mechanisms that regulate and enforce the basic rights and guarantees ensured by the Federal Constitution. In this sense, according to the principle of the hierarchy of norms (Article 59), these primary norms (i.e., Ordinary and Complementary laws) must comply with the Federal Constitution. However, an Ordinary Law passed by a simple majority at the municipal level may not be regulated by higher authorities unless it is challenged (questioned) or indicted for irregularities.

In the city of Laguna, as a response to the apparent abundance increase and raised concerns about cormorant impacts on the estuary and artisanal fishery production, the municipal chamber implemented the Ordinary Law number 2.154 in 2020 (Table 1) to handle with this HWC. Despite the lack of scientific basis regarding *N. brasilianum*, the bird species was declared harmful and synanthropic, alongside Capybaras (*H. hydrochaeris*), which are associated with human fatalities due to the Brazilian Spotted Fever (Labruna, 2013). This ordinary law, driven by community concerns, did not present explicit management actions or guidelines for *N. brasilianum*. Instead, it broadly permitted "citizens, public authorities, and property owners to adopt necessary measures to keep properties clean and free from harmful synanthropic fauna, without harming nature" (Ordinary law 2.154/2020, Article 5). The municipal law, without evidence, claimed a population increase in cormorants and justified control actions by stating that the increase was "a result of extinction or lack of cormorant predators." It also argued that "cormorants cause a significant decrease in marine fauna in the Laguna Estuarine System," that "cormorant guano, being acidic, affects the environment by damaging roots, leaves, and soil," and that "the species is out of control since it occupies urban areas." This first documented act serves as an example of how Brazilian environmental lawmakers may neglect scientific knowledge while prioritizing local economic interests (Carneiro and da Silva Rosa, 2011).

Subsequently, in 2021, an autonomous public agency, the Laguna Foundation for Environmental Conservation (FLAMA) sent an Internal Notification number 76 in 2021 to the Brazilian Institute for the Environment and Renewable Natural Resources (IBAMA), a centralized executive environmental public agency. The document issued "a possible overpopulation of *Nannopterum brasilianum* in Laguna" and informed the responsible institutions about Laguna's "cormorant population boom" and "its potential impacts on native vegetation, shrimp farms, and artisanal fisheries," while also raising important ecological questions about this abundance being atypical, seasonal, or having historical precedent. This internal notification (76/2021) is a technical document made by FLAMA, in which the lack of scientific knowledge into the matter is recognized. Furthermore, it underscores the need for comprehensive ecological research to better understand the

dynamics of the cormorant population surge and its potential impacts on the local ecosystem. Additionally, it emphasizes the importance of considering historical data and ecological factors in assessing the situation, thereby highlighting the complexity of managing HWCs effectively. By advocating for comprehensive ecological research and the consideration of historical data, this notification represents a pivotal step towards effectively managing HWCs in the LES.

An escalation of this HWC came in May 2022, with a documented illegal hunting of 300 active nests and the killing of at least 75 cormorants by unknown agents (Figure 3). This case was identified during research surveys on a smaller colony located near aquiculture activities inside Laguna territory limits and filed into the Environmental Military Police of Laguna city. To clarify this act as illegal hunting, the Brazilian environmental law (Normative Instruction number 141/2006, IBAMA) states that it is only permitted to manage harmful and synanthropic species with approval and explicit authorization from the responsible government institution. According to the fourth article/first paragraph of this normative instruction, only invertebrates with epidemiologic interests, harmful arthropods, domestic animals, chiropters, and exotic species are allowed to be managed without authorization from government institutions. Cormorants, however, are native species and do not fit within these taxa and there is no evidence of harmful influence into economical or environmental matters to classify/impose these birds as harmful.

Figure 3. Footage of illegal hunting of cormorants in Laguna Estuarine System, in May 2022. (a, d, and e) cormorant corpses near nests, (b) Box of .22LR ammunition, and (c) Empty bullet casing.

Future focus for mitigation of conflicts related to neotropic cormorants

Neotropic cormorants are considered a species of "Least Concern (LC)" in the International Union for Conservation of Nature (IUCN) red list, with a population increase trend in its distribution range (BirdLife International 2018) considered abundant and wide distributed across Brazilian territory (Silva et al., 2000, 2014; Branco, 2002; Barquete et al., 2008b; Alves et al., 2011). Their predatory roles as piscivorous birds (Barquete et al., 2008a; Pomárico et al., 2020; Harding and Mesler, 2022) and breeding capability (Quintana et al., 2002; Kalmbach and Becker, 2005) make the species a potential competitor with Brazilian fisheries, similarly to how the Great cormorant *Phalacrocorax*

carbo is in Europe and North America (Östman et al., 2013; Aguado-Giménez et al., 2018; Ovegård et al., 2021).

Artisanal fisheries of LES targets mostly crustaceans and fishes within the estuary and coastal waters (Barletta et al., 2017; Piazza et al., 2021). Meanwhile, cormorants predominantly prey on juvenile fishes and invertebrates (Barquete et al., 2008a; Branco et al., 2009; Pomárico et al., 2020; Harding and Mesler, 2022), which can compose the diet of small fishermen as a subsistence source. However, these juvenile fishes and invertebrates are mostly found in noncommercial sizes, some being non-targeted species typically captured as bycatch (Sunye et al., 2014; Barletta et al., 2017). Thus, discarded carcasses are important food source for seabirds and may influence cormorant distribution along the estuary, as fisherman in LES tend to clear and screen their catches at docks and not at fishing sites (Branco, 2001; Barbieri, 2010). In a finer scale, cormorants may compete with smaller fisherman for juvenile food type, eat fishermen bait, and also destroy the fishing apparatus on the process, as reported by many artisanal fishermen at LES. Beyond these scenarios of competition and economic loss done by cormorants, their predatory impacts on aquatic community is a complex subject to be evaluated (Ovegård et al., 2021).

The HWC in LES is a complex socioecological situation since it involves multiple stakeholder groups (policymakers, managers, scientists, fishermen, and aquaculture producers) with various perspectives and a species with a major predatory role. Neotropic cormorants also interact directly and indirectly with several other species in this estuarine ecosystem. In the bigger picture, multidisciplinary research is needed (Treves and Karanth, 2003) in the LES, with a focus on the trophic ecology of cormorants, as well as on the ecosystem functioning, to understand how species interact and the consequences of HWC. Moreover, there is a demand to integrate ecological, socioeconomic, and socioecological research, transforming HWC in a sustainable coexistence (König et al., 2020). This task may be achieved by adopting and adapting the conceptual framework of König et al. (2020). Following the framework, the first step could be to (1) create a working group that promotes discussion between various actors. This group would aim to generate information by different approaches (scientific and fishing data); propose ways to mitigate Neotropic cormorants economic damages; generate data to advise law creation and management actions at the municipal level, respecting higher hierarchies and the Federal Constitution; and secure the protection of biodiversity and associated ecosystem functions/services of LES.

Another important topic for this framework would be to (2) quantify and assess damage done by Neotropic cormorants into fishing apparatus or producers' properties. Damage to fishponds and shrimp producers can be estimated with direct observations of foraging birds on site. The implementation of measures to mitigate this economic loss can also be developed with the aid of stakeholder. For instance, overhead nylon lines used to avoid bird accessibility to ponds and artificial tanks are commonly used in LES by shrimp producers but may be ineffective as these lines may not prevent cormorants from landing on water (Moerbeek et al., 1987). Another important damage assessment is the measurement of daily biomass consumed by Neotropic cormorants via regurgitated pellets (Barquete et al., 2008a; Pomárico et al., 2020) and stomach content (Barrett et al., 2007). This assessment, particularly when compared to the species targeted by LES fisheries, can offer valuable insights into the extent of this HWC (Gil-Weir et al., 2011; König et al., 2020).

The most complex approach would be to (3) understand the interdisciplinary processes that ecologically shape all three conflict components (Cormorants, fish assembly, and fisheries). For instance, while it is relatively easy to assess cormorants' diet, their impact on fish assembly and distribution is a complex subject, as bird predation is only one aspect among others, such as abiotic variables fluctuations and density-dependent processes (Carss et al., 2012; Ovegård et al., 2021). Environmental variables play a crucial role in shaping the spatial patterns of fish populations within estuaries, with factors such as salinity, temperature, turbidity, and habitat structure influencing the presence and abundance of different species (Whitfield, 2021). To investigate

the relationships between estuarine conditions and fish community data, researchers may employ gillnetting, trawl, or seine netting to capture and identify fish species across different habitats (França et al., 2012). Integrating ecological data with remote sensing techniques, geographic information systems (GIS), and assessments of anthropogenic impacts (i.e., pollutant discharges and habitat loss) can allow the development of ecological models at temporal and spatial scales (Bruno et al., 2013; Frischknecht et al., 2023). These models can then be linked to data on cormorant diet and fishery production in the LES and be used as long-term tools for conservation and decision making. Finally, climate changes and extreme events must also be considered in these robust ecological models as the main cause of amplification of HWCs by impacting species biological processes, such as growth and migrating patterns, while also affecting local economic interests (Abrahms et al., 2023).

Table 1. Summary of laws and policies related to cormorant management and protection. Document access and link to official government internet pages.

Document access and link to official government internet pages.				
International law and policies	Main resolves and guidelines	Regulating Organ	Implementation date/status	Link to access
United States Code of Federal Regulations: 50 CFR 21.123	Establishes a new special double-crested cormorant permit to lethally take cormorants to alleviate damage and conflicts associated with aquaculture and fishery resources.	U.S. Fish and Wildlife Service	December 2020 / Operative	https://www.ecfr.gov/current/title-50/chapter-I/subchapter-B/part-21/subpart-D/section-21.123
Environmental Registry of Ontario, Canada ERO 013-4124	Proposal to establish a hunting season for double-crested cormorants in Ontario, Canada.	Environmental Registry of Ontario	July 2020 / Operative	https://ero.ontario.ca/notice/013-4124
European birds directive	Despite the protection of wild birds and their habitats, derogations from its protective measures can be made at certain species that cause damage to crops, livestock, fauna, or represent a threat to public health	European Parliament	November 2009 / Operative	http://data.europa.eu/eli/dir/2009/147/oj
Brazilian law and policies	Main resolves and guidelines	Regulating Organ	Implementation date/ status	Link to access
Ordinary law no. 2154	Declares Capybara and Neotropic cormorant as harmful and synanthropic species within the municipality of Laguna.	Laguna Municipal chamber	June 2020 / Operative	https://leismunicipais.com.br/a/sc/l/laguna/lei-ordinaria/2020/216/2154/lei-ordinaria-n-2154-2020-declara-a-capivara-hydrochoerus-hydrochaeris-e-o-bigua-phalacrocorax-brasilianus-como-animais-pertencentes-a-fauna-sinantropica-nociva-no-ambito-do-municipio-de-laguna-e-da-outras-providencias
Normative Instruction no. 141	Regulates the control and environmental management of harmful and synanthropic species	IBAMA	December 2006 / Operative	https://www.ibama.gov.br/component/legislacao/?view=legislacao&legislacao=112966
Internal Notification° 76	Information about a possible overpopulation of Neotropic cormorants in Laguna	FLAMA	August 2021 / Analyzed	https://laguna.sc.gov.br/fundacao-lagunense-do-meio-ambiente/ Attachment*

Currently, in 2023, FLAMA services are slowly being dismantled by Laguna Municipal chamber and, as a result, data and other information are difficult to access on their website. We are attaching the Internal Notification number 76/2020, downloaded in 2021.

The last framework topic would be to (4) manage options for the coexistence between cormorants and fisheries. Shoot wildlife and use physical barriers may be ineffective and unsustainable actions for coexistence to both sides. In this context, increasing people's tolerance to wildlife might be a complementary approach to the resolution of this HWC (Marchini and Crawshaw, 2015). Educative programs and workshops could focus on promoting sustainable coexistence, as greater ecological knowledge within communities and fishermen can lead to positive attitudes and reduce negative conflict outcomes (Kuentzel et al., 2012). Thus, scientific evidence must be brought to public with balanced approaches between species conservation and economic sustainable use to avoid attrition and polarized perspectives. Meanwhile, necessary management actions and policy making must be straightened, such as evidence-based manage controls of cormorant populations (controlled nest knock down or egg removal) and creation of laws regarding the conservation of biodiversity, not only aiming for economic interests. Engaging local community and stakeholders can aid increase public perception and recognition about cormorants-fisheries conflict nature, while also bridging the gap between decision makers and ecological issues (Carss, 2022; Vieite et al., 2022).

CONCLUSION

Human-wildlife conflicts between Neotropic cormorants and humans, despite being expected, still lack research in South America. In this study, we presented the first documented conflict in the Laguna Estuarine System, Brazil, highlighting the complex issue arising from insufficient scientific data on cormorant biology and fisheries of LES. This scientific gap between an abundant piscivorous species and an important sustainable activity generates the perception of a "strange" and "voracious" species that "competes" with artisanal fisheries and "depletes" their natural resources. Moreover, the Brazilian environment legislation, although powerful, still enforces dubious and impartial laws, mostly focusing on economic interests, rather than on a balanced conservation. By adopting holistic and interdisciplinary approaches and an adapted conceptual framework, as described here, to mitigate and solve this conflict (creation of a working group; damage assessment; ecological understatement by interdisciplinary data; and solutions to coexistence and tolerance), bridges can be built between Laguna lawmakers, science, and artisanal fishermen to a better coexistence, reducing negative outcomes from this ecological conflict.

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AUTHOR CONTRIBUTIONS

V.R.A.P.: Conceptualization; Investigation; Writing – Original draft; Writing – Review & Editing.

J.L.R.F: Supervision; Conceptualization; Resources; Writing – Original Draft; Writing – Review & Editing.

J.S.A.: Investigation; Writing – Original Draft; Writing – Review & Editing.

J.O.B.: Supervision; Resources; Project Administration; Writing – Review & Editing.

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