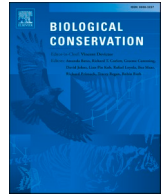


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Perspective



## Research priorities for the conservation of chondrichthyans in Latin America

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## ABSTRACT

Latin American countries have a high diversity of sharks, rays, and chimaeras, yet many species are at high risk of extinction due to numerous threats. The conservation of chondrichthyans is key to achieving healthy and productive aquatic ecosystems, and countries in Latin America are increasingly recognizing the need for aligning conservation strategies across jurisdictions with similar ecological and socioeconomic challenges. Reflecting on the current state of knowledge and providing consensus expert opinion on research priorities are critical steps to ensure sound management and conservation strategies for chondrichthyans. The present study is a multinational collaboration by leading researchers in Latin America to identify the top-ten research priorities for the conservation of chondrichthyans within this region. Our results were highlighted from a total of 20 broader relevant topics including taxonomy and biology, ecological function, climate change and other stressors, contribution to local economies, and international collaboration. This constitutes the first comprehensive academic perspective on research priorities for chondrichthyans in Latin America which considers the varied perceptions and perspectives related to the management of sharks, rays, and chimaeras across the region and beyond. The main conservation implications highlighted by our study relate to the urgent need to implement, evaluate and/or improve management regulations based on scientific evidence and interdisciplinary research, especially in areas with little progress on the subject and/or where species threatened by extinction are distributed.

## 1. Introduction

Latin America is a highly diverse region both culturally and ecologically, though there are important shared histories and ecosystems across its nations. The combination of different climates in a significant latitudinal gradient, bathymetry, oceanographic conditions, and biodiversity creates diverse and unique aquatic environments that play a critical role in resource use, management, and conservation (Salas et al., 2007; Carrillo-Briceño et al., 2018). The region's aquatic biodiversity is also evident in its chondrichthyan species richness (Last et al., 2016; Weigmann, 2016), with over 400 known species from both marine and freshwater environments (Rosa and Gadig, 2014; Last et al., 2016; Weigmann, 2016; Carrillo-Briceño et al., 2018; Ehemann et al., 2018, 2019; Espinoza et al., 2018; Vooren and Oddone, 2019). These species have cultural, ecological, social, and economic relevance given their role in ecosystems functioning and as key resources for fisheries, tourism, science, and other activities specific to each country (Vannuccini, 1999; Awruch et al., 2019; Galván-Magaña et al., 2019; Villafaña et al., 2019; Cisneros-Montemayor et al., 2013, 2020).

During the last decades, we have witnessed an increase in the number of chondrichthyan studies undertaken in Latin American countries, as reflected by the surge of scientific publications produced in the region (Awruch et al., 2019). Other advances on chondrichthyan conservation are related to the creation and expansion of marine protected areas at insular locations such as the Galapagos Islands (Ecuador; Hearn et al., 2016; Salinas-de-León et al., 2016), Cocos Island (Costa Rica; Friedlander et al., 2012), Malpelo Island (Colombia; Bessudo et al., 2021), and Revillagigedo Archipelago (Mexico; Aldana-Moreno et al., 2020, Becerril-García et al., 2020, Klimley et al., 2022), among others. However, there are still deficiencies in scientific research, management, and conservation of this taxonomic group, with some populations being overexploited to the brink of extinction (Bonfil, 1997; Stevens et al., 2000; Vooren and Klippel, 2005; Dulvy et al., 2014, 2021; Barreto et al., 2017; Steinke et al., 2017; Bonfil et al. 2018; Larson et al., 2021; Pacoureau et al., 2021). The recovery of these populations not only depends on effective management and conservation policy based on accurate scientific evidence but also on addressing and recognizing relevant social and political perspectives (Tambutti and Gómez, 2020).

In this context, and to address the needs for relevant data highlighted by the United Nations Decade of Ocean Science for Sustainable Development (2021–2030), the aim of the present perspective is to identify key research questions and topics crucial to improving sustainable management and conservation of chondrichthyans in Latin America.

## 2. Materials and methods

This study followed a protocol similar to that of Parsons et al. (2015) and Hays et al. (2016) in soliciting the opinions of experts, particularly from specialists in Latin American chondrichthyan populations. Between 2020 and 2021, specialists were contacted based on their publication records, past or current projects, and colleagues' recommendations. Each author was asked to answer a survey and provide research topics that would improve the knowledge of chondrichthyans in the region. Questions were formulated according to the criteria suggested by Parsons et al. (2015), in which the proposed questions: 1) could have affected, due to a lack of answers, chondrichthyan conservation efforts in Latin America; 2) would significantly benefit the conservation of chondrichthyans if answered; 3) cannot be answered with "yes", "no" or "it depends"; 4) could be answered if there were adequate funding and research inputs; and 5) could be answered by life or social sciences. Contributions were compiled and grouped into 20 research topics. The authors were asked to rank their top ten research topics via an online questionnaire and to prioritize research questions within each topic using a Likert scale where 1 represented "low priority" and 5 "high priority". The highest priority question of each topic was selected based on the average of the responses. Expert information related to the activity sector (e.g., Academia, Government, NGO), countries where they have worked, years of experience working with chondrichthyans in the region, and perception regarding advances in chondrichthyan conservation were also noted. The top ten topics that emerged from the expert elicitation, along with their associated highest priority questions, were further discussed and reviewed by all authors.

### 3. Results and discussion

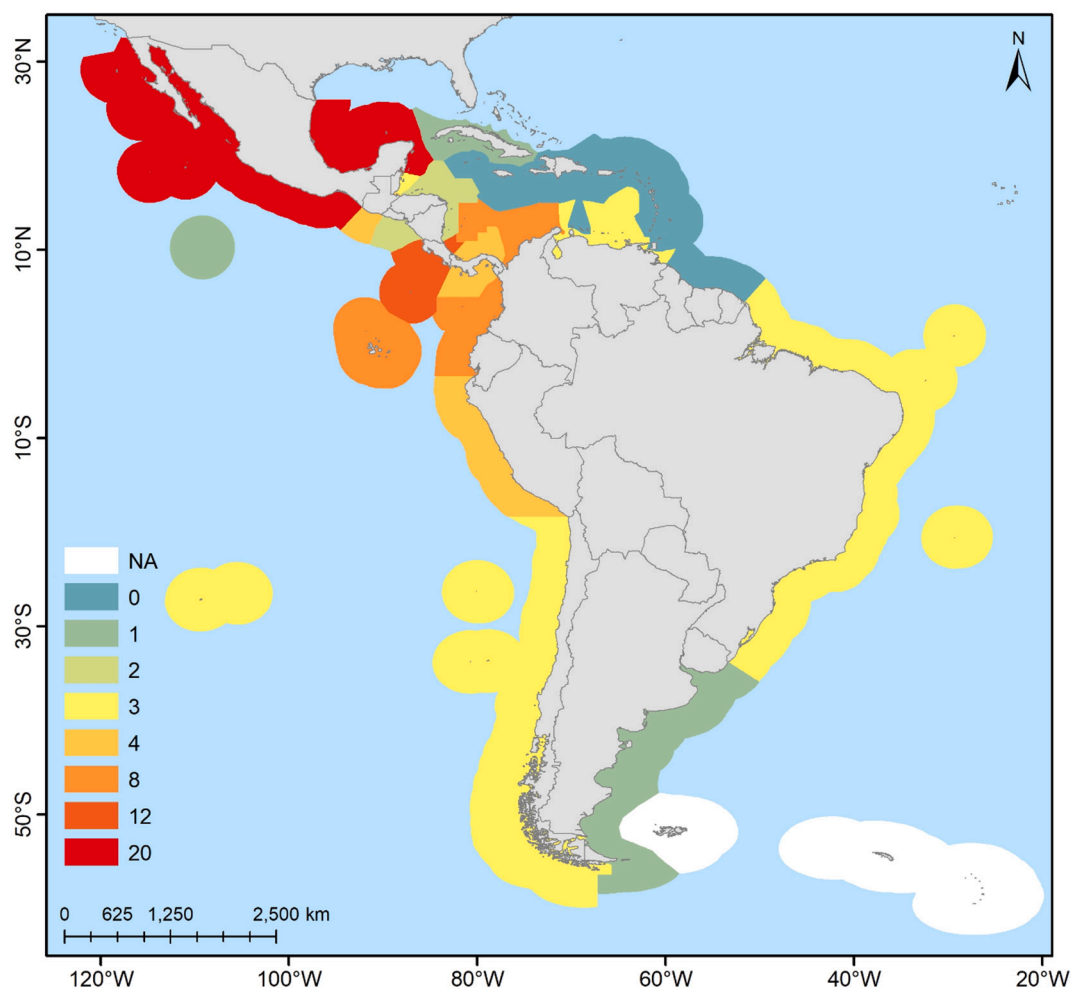
#### 3.1. Overview

The online questionnaire was answered by 32 specialists, affiliated primarily with academia (63%), non-governmental organizations (41%), or both (9%); with one respondent as a governmental specialist (3%). Sixty-six percent of the respondents were men ( $n = 21$ ) and 34% were women ( $n = 11$ ). The majority of chondrichthyan experts had more than 10 years of experience working in Latin America (69%), while 25% had between 5 and 10 years (25%), and a minority had less than five years (6%). Most specialists reported research experience throughout Latin America, highlighting researchers from Mexico and Central America, Colombia, Ecuador, Peru, Venezuela, Chile, Brazil, and Argentina (Fig. 1). According to personal perspectives in their country of work, most of the respondents indicated that scientific research on chondrichthyans had shown medium (56%) or little progress (34%) under a global context, with a lack of financial support being the main limitation for conducting research activities (72%). In contrast, a lack of governmental interest was identified as the main factor affecting chondrichthyan management and conservation (53%), for which it was considered that little (41%) or medium (44%) progress has occurred. The section below discusses the top ten research topics with their respective scientific questions, which were identified according to the specialists' votes (Fig. 2). All topics and questions generated by the specialists are provided in Table S1, reflecting a first approach to the

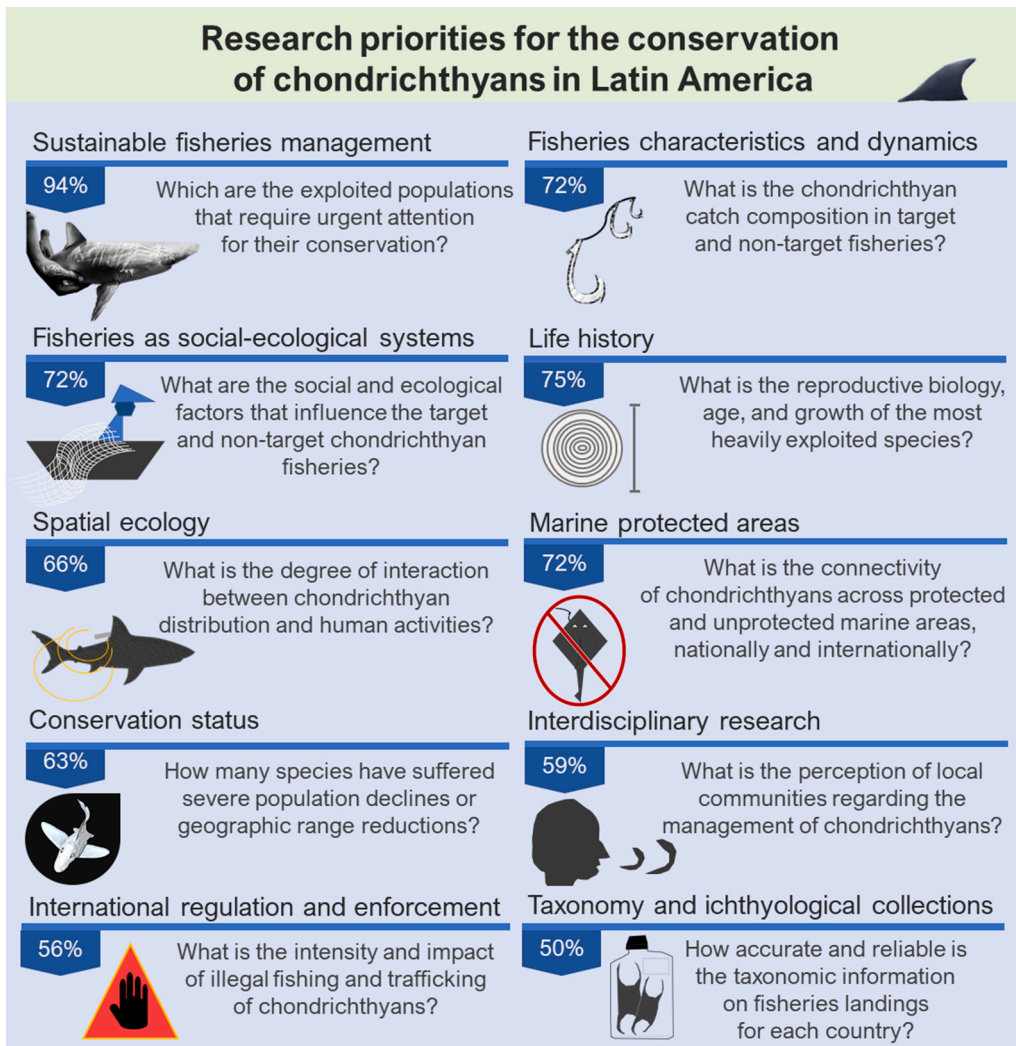
major concerns regarding scientific research, management, and conservation in Latin America.

#### 3.2. Sustainable fisheries management. Which exploited populations require urgent attention to ensure conservation?

Several chondrichthyan populations are overexploited or collapsed, primarily due to increasing fishing effort and bycatch, which resulted in a substantial decrease in abundance either regionally or globally (Stevens et al., 2000; Barreto et al., 2017; Dulvy et al., 2021; Larson et al., 2021; Pacoureaux et al., 2021). In this context, sustainable fisheries management is critical for the long-term conservation of commercially exploited chondrichthyans (Roberson et al., 2020). Identifying the populations most vulnerable to overfishing is relevant for their conservation, as rigorous assessments are required to update current fisheries legislation (Dulvy et al., 2021). Evaluation of chondrichthyan stocks must be coordinated in regions that share migratory species to ensure proper management of catches and conservation actions (Bonfil, 1997; Queiroz et al., 2019; Bonaccorso et al., 2021; Klimley et al., 2022). Understanding the factors contributing to the success or failure of fishery policies currently existing in some countries can provide the information needed to assess the feasibility of implementing similar regulations elsewhere. Throughout Latin America, future management actions would benefit from engaging the participation of different sectors (fishers, scientists, entrepreneurs, local stakeholders, etc.) to ensure the community's needs within the One Health framework.



**Fig. 1.** Geopolitical map of Latin America and research areas studied by the surveyed specialists ( $n = 32$ ). Colour legend shows the number of researchers interviewed per area. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)



**Fig. 2.** Synopsis of the top ten research topics and questions formulated by 32 experts in Latin American chondrichthyan. Percentages represent the proportion of experts who voted for each research topic.

**3.3. Fisheries characteristics and dynamics.** *What is the chondrichthyan catch composition (species, size, sex, and maturity stages) in target and non-target fisheries?*

Chondrichthyan populations are exploited by both target and non-target fisheries, which are heterogeneous given the multiple fishing gears used in coastal and oceanic Latin American waters (Bonaccorso et al., 2021). Understanding the fisheries characteristics and seasonal dynamics is essential to assessing their potential impacts on chondrichthyan populations (Galvan-Magaña et al., 1989; Bonfil, 1997; Stevens et al., 2000; Queiroz et al., 2019). Developing cost-effective approaches for assessing chondrichthyan population trends is crucial given the high rate at which some species are declining (Field et al., 2009; Queiroz et al., 2019). Therefore, monitoring fisheries dynamics (e.g., independent surveys, governmental observers, Global Fishing Watch, and vessel tracking systems), species-specific landing statistics, and biological parameters (e.g., length, weight, sexual maturity, fecundity, seasonality, etc.) in coastal and offshore sites is key to assessing population trends over time (Oliver et al., 2015). In this regard, the identification of any systemic weaknesses in catch reporting mechanisms is a priority. Current deficiencies include inconsistent and incomplete records of captured species (e.g., common names that would be different per region or comprise many species), a lack of incentives for self-reporting, and scarcity of trained personnel in some fishing locations.

**3.4. Fisheries as social-ecological systems.** *What are the social and ecological factors that influence target and non-target chondrichthyan fisheries?*

Fisheries are complex systems in which multiple social and ecological factors interact. Therefore, holistic methodological frameworks are required for their study, such as the one proposed by Ostrom (2009), in which fisheries are considered social-ecological systems. During the assessment of fisheries' performance, indicators should be considered based not only on the biology of the exploited species, but also on other relevant ecological and social indicators (Gutierrez et al., 2011; Adiga et al., 2015). This will contribute to the implementation, evaluation, and constant improvement of fishing regulations in each country, which must consider the needs, opportunities, and possible impacts on the communities involved. These impacts should focus on relevant issues of human well-being, including employment, education, and health. One of the main challenges faced by Latin American governments is evaluating and understanding the consumption of chondrichthyan meat, which currently represents an essential source of protein in many human communities, but also a health risk that needs to be comprehensively assessed (Dent and Clarke, 2015; Barreto et al., 2017; Rangel et al., 2021). The potential risks associated with consuming these species (e.g., those known to bioaccumulate toxic substances), especially of those not yet assessed, could significantly affect human health and ecosystem



resilience (Carrillo-Briceño et al., 2018; Tiktak et al., 2020; Consales and Marsili, 2021). Attention should thus be given to include research and risk assessment relevant to all social settings to avoid further impacts in marginalized communities (Cisneros-Montemayor et al., 2018).

### 3.5. Life history. What are the reproductive biology, age, and growth patterns of the most heavily exploited species?

Information regarding demographic parameters such as reproduction, age, growth, and population structure is essential for a practical and effective management approach (Cooke et al., 2018). In Latin America, data on sexual maturity and fecundity have been reported for some chondrichthyan species. However, this information is largely lacking for most species or is restricted to specific countries (Bonfil, 1997; Ramírez-Amaro et al., 2013; Awruch et al., 2019; Vooren and Oddone, 2019). Furthermore, there are major gaps in age and growth parameters, critical to defining population viability modelling (Cooke et al., 2018). The development of research plans coordinated among academia, NGOs, and fisheries authorities can facilitate the systematic acquisition of samples and biological data as long as sufficient funding is granted. Investment in these projects would generate crucial knowledge for population characterization, threat identification, and ultimately resource protection (Field et al., 2009; Barreto et al., 2017; Espinoza et al., 2018; Dulvy et al., 2021). Moreover, attention should be given to the ontogenetic and sexual differences present in some species, as well as to the genetic connectivity that may hide existing patterns among the distribution of exploited stocks (Hoyos-Padilla et al., 2014; Hearn et al., 2016; Weigmann, 2016; Queiroz et al., 2019).

### 3.6. Spatial ecology. What is the degree of interaction between chondrichthyan distribution and human activities in Latin America?

Understanding how chondrichthyans interact with their environment is essential to determine the effect of biotic and abiotic factors on their populations. Investigating the spatial ecology (e.g., movement patterns, residency, and habitat use) of chondrichthyan species has direct application to spatial management and conservation (Bonfil, 1997; Hussey et al., 2015; Richert et al., 2015; Queiroz et al., 2019; Klimley et al., 2022). Furthermore, the study of key habitats for feeding or reproduction (e.g., aggregation sites, nursery areas) is critical for effective conservation plans in coastal and oceanic regions (Klimley and Nelson, 1984; Klimley, 1987; Klimley and Butler, 1988; Richert et al., 2015; Hoyos-Padilla et al., 2016; Estupiñán-Montaño et al., 2021a). Evaluating the interaction between the distribution of chondrichthyans and human activities such as fishing, deep-sea mining, agriculture runoff, marine tourism, and coastal development is of particular importance since these represent potential threats to the survival and habitat use of chondrichthyans (Queiroz et al., 2019; Consales and Marsili, 2021; Pacoureaux et al., 2021; Klimley et al., 2022).

### 3.7. Marine protected areas. What is the degree of connectivity of chondrichthyans across protected and unprotected marine areas, nationally and internationally?

The designation of marine protected areas (MPAs) has proven to be fundamental in conserving threatened taxa, including chondrichthyans (Knip et al., 2012; Salinas-de-León et al., 2016; Sala and Giakoumi, 2018; Klimley et al., 2022). MPAs play an essential role in the feeding, development, reproduction, sheltering and management of chondrichthyans (Hearn et al., 2010, 2016; Bessudo et al., 2012; Ketchum et al., 2013, 2014; Nalesso et al., 2019; Aldana-Moreno et al., 2020; González-González et al., 2021), by regulating fishing and promoting conservation through non-extractive use (Cisneros-Montemayor et al., 2020; Klimley et al., 2022). However, MPAs cannot effectively fulfil their role if they are not accompanied by enforced regulations related to fishing dynamics and local or regional interests (economic, social, and

ecological; Bonfil, 1999; Sala and Giakoumi, 2018). Assuming that there is adequate support to prevent interactions with unregulated fisheries or other threats, the success of MPAs will depend on the knowledge of population's distributions and species' life-history traits (Queiroz et al., 2019; Bonaccorso et al., 2021). In addition, spatial ecology studies should contribute to MPA performance evaluation and inform interested parties on potential needs for MPA increase or alteration (Bonfil, 1999; Friedlander et al., 2012; Sala and Giakoumi, 2018; Becerril-García et al., 2020; Birkmanis et al., 2020; Estupiñán-Montaño et al., 2021a; Klimley et al., 2022).

### 3.8. Conservation status. How many species have experienced severe population declines or geographic range reductions?

Due to a paucity of available information, several chondrichthyan species found in Latin America do not have their conservation status accurately assessed (Kyne et al., 2012; Larson et al., 2021). These data deficiencies hamper the evaluation of population trends, traits, and distribution changes, hence affecting conservation actions (Dulvy et al., 2014; Cooke et al., 2018). Given the current situation, acquiring sufficient data to conduct regional assessments of chondrichthyan populations is urgently needed (Kyne et al., 2012; Pacoureaux et al., 2021). This would improve the regulation of frequently captured endangered species (e.g., hammerhead sharks, *Sphyrna* spp.) and promote the monitoring of threatened taxa (Dulvy et al., 2021; Rangel et al., 2021). Specifically, there is a critical need to evaluate possible reductions and other changes in the distribution of the most affected species, such as sawfishes (Pristiformes), guitarfishes (Rhinoipristiformes), and saw sharks (Pristiophoriformes), which have historically suffered serious losses along the tropical and subtropical coasts (Vooren and Klippel, 2005; Bonfil et al., 2018; Valerio-Vargas and Espinoza, 2019; López-Angarita et al., 2021). Of equal importance is the implementation of other methods such as ecological risk assessments, which in the case of poorly studied species, can incorporate knowledge gaps and are useful to understand vulnerability to a specific threat (Gallagher et al., 2012; Clarke et al., 2017). Such actions could prevent the disappearance of species and the subsequent impacts on regional marine biodiversity (Dulvy et al., 2014; Carrillo-Briceño et al., 2018).

### 3.9. Interdisciplinary research. What is the perception of local communities regarding the management of chondrichthyans?

The oceanographical characterization of chondrichthyan habitats, in chemical, physical, and biological terms, is essential to understand their ecology (Klimley and Butler, 1988; Klimley, 1993; Jorgensen et al., 2009, 2016; Richert et al., 2015). Along with life sciences (biology, anatomy, physiology, genetics, etc.), social sciences are crucial to understand and address the social and economic context necessary for effective chondrichthyan management and conservation (Cisneros-Montemayor et al., 2013; Friedrich et al., 2014; Mason et al., 2020). Thus, managers and scientists will need to include knowledge generated by both social sciences and communities in their recommendations and initiatives to achieve sustainable management goals (Friedrich et al., 2014; Rangel et al., 2021). This is particularly important given the limited enforcement capacity of most fisheries management and conservation agencies across Latin America, and the increasing push for integration of these agencies' mandates with broader marine and sustainable development approaches (Cisneros-Montemayor et al., 2021; Tambutti and Gómez, 2020).

### 3.10. International regulation and enforcement. What is the intensity and impact of illegal fishing and trafficking of chondrichthyans?

Chondrichthyan species, as well as their fins, meat, jaws, gills, skin, and internal organs, are legally and illegally traded for consumption or ornamental purposes (Vannuccini, 1999; Araújo et al., 2004; Rosa et al.,

2010; Dent and Clarke, 2015; Barreto et al., 2017; Steinke et al., 2017; Rangel et al., 2021). Consequently, the labelling and traceability of marketed chondrichthyan products are fundamental for effective conservation (Steinke et al., 2017; Pavitt, 2021; Rangel et al., 2021). Strengthening mechanisms for surveillance, traceability, and prosecution of illegal fishing activities are essential to conserving marine biodiversity in Latin America, especially in oceanic areas with greater vulnerability to these transgressions (Araújo et al., 2004; Bonaccorso et al., 2021). Changes in diversity and abundance of chondrichthyans can have significant implications on the balance of ecosystems and human populations relying on a healthy environment (Stevens et al., 2000; Field et al., 2009; Queiroz et al., 2019). Under this context, management authorities must seriously consider the illegal fishing of chondrichthyans and its contribution to their decline in aquatic ecosystems (Pacoureau et al., 2021).

### 3.11. Taxonomy and ichthyological collections. How accurate and reliable is the taxonomic information on fisheries landings for each country, especially for taxa with identification issues?

Taxonomy is the first step to any research, management, and/or conservation initiatives (Weigmann, 2016; Ehemann et al., 2019). However, the continuous discovery of new species, changes in taxonomy, nomenclature, systematic, and phylogeny, prompted by the application of genetic techniques, mean that an updated list of species and their distribution is sorely needed in each country (Ehemann et al., 2018, 2019, 2021; Espinoza et al., 2018). Like other regions, Latin American countries have historically shown deficiencies regarding accurate identification and taxonomic certainty of their chondrichthyans and their distribution (Kyne et al., 2012; Last et al., 2016). This greatly affects proper conservation and management and must be solved promptly. A first step could involve the revision and update of stored and classified chondrichthyan specimens, including holotypes and other type specimens (paratypes, syntypes, etc.). Another critical step would be generating taxonomical baselines in countries where chondrichthyans have not or have scarcely been studied (Carrillo-Briceño et al., 2018). Given the ecological and biological differences among chondrichthyans, strengthening taxonomic identification for fishing landings is essential for effective management and conservation (Ehemann et al., 2018, 2019; Espinoza et al., 2018).

### 3.12. Additional research priorities

In addition to the top ten conservation priorities presented here, the survey identified 10 other topics discussed during the writing of this manuscript along with their respective questions (Table S1). Additional topics included the impact of *Wildlife tourism* (identification of the species and localities involved, societal benefits for local communities, impacts of tourism on wild populations) and the relevance of estimating chondrichthyans' *Economic value* (assessment of the monetary value and ecological relevance of non-charismatic species, administration of economic benefits, contribution to local economies). Elasmobranch tourism is a profitable activity that could be considered sustainable under specific scenarios. However, there are concerns related to the impact that such activities may have on chondrichthyan populations in Latin America (and elsewhere), as well as deficiencies in resource management and meaningful involvement of local fishing communities (Cisneros-Montemayor et al., 2020). The estimation of economic value has been a valuable tool for supporting conservation and sustainable use of several terrestrial and aquatic species (Turpie et al., 2003; Cisneros-Montemayor et al., 2013). A better understanding of current and potential economic value from shark and ray ecotourism in Latin America could provide alternative perspectives on the ecosystem and the social, cultural, and commercial benefits of chondrichthyan species (Cisneros-Montemayor et al., 2013, 2020).

The relevance of *Trophic ecology* research (identifying ecological

roles, interactions between chondrichthyans and their prey, changes in diet over space and time) was also emphasized. Quantifying trophic levels and defining functional roles in Latin America aquatic ecosystems is relevant given that many species have experienced substantial population declines (Galvan-Magaña et al., 1989; Galván-Magaña et al., 2019; Richert et al., 2015; Pacoureau et al., 2021; Dulvy et al., 2021). While stomach content analyses provide detailed descriptions of recent prey consumption, biochemical studies through stable isotope and fatty acid profiles from multiple tissues (e.g., blood, dermis, muscle, cartilage) can integrate short and long-term dietary information (Galván-Magaña et al., 2019; Estupiñán-Montaño et al., 2019, 2021b). Combining such methods can effectively quantify a species diet patterns, its trophic level, and nutritional needs, as well as movements between isotopically distinct habitats (Espinoza et al., 2015).

The importance of describing the past natural history of chondrichthyans in terms of *Biogeography and palaeontology* (description of paleo-characteristics of chondrichthyan ecosystems, composition of extinct species assemblages, influence on the historical and current distribution of chondrichthyans) was mentioned as well. Furthermore, it can provide key information related to the environment in which extinct chondrichthyans lived and perished (Guinot et al., 2013; Carrillo-Briceño et al., 2018; Villafaña et al., 2019).

Additional concerns were related to understudied aquatic environments such as *Deep-sea ecosystems* (identification of hotspots for chondrichthyan biodiversity, vulnerability assessments, ecological role assessment) and *Freshwater ecosystems* (specific protected areas, effect of commercial trade, and identification of other anthropogenic and environmental threats; Rosa et al., 2010, Last et al., 2016). Recent studies have shown that the deep ocean floor can have a high biological diversity of chondrichthyans, which play an essential role in maintaining deep-sea ecosystems (Finucci et al., 2018; Friedlander et al., 2019; Becerril-García et al., 2020). Freshwater ecosystems in Central and South American continental waters provide habitats for at least 37 endemic species of Neotropical freshwater stingrays (Potamotrygoninae; Rosa et al., 2010, Last et al., 2016, Kyne and Lucifora, 2022). These species contribute significantly to chondrichthyan biodiversity and constitute a repository of ecologically and evolutionary information. However, some species are at high risk of extinction due to unregulated ornamental trade, specimen poaching and the impacts of human activities on their habitats, such as deforestation, mining, and pollution (Charvet-Almeida, 2006; Last et al., 2016).

Of particular interest was the mention of *Climate change* (effects on physiology, ecology, and distribution, as well as the impact on economic activities) along with *Pollution and other stressors* (identification of key stressors and most concerning sources, investigation of sensitivity and resilience, description of toxicity and its mechanisms). We expect that either in ecological, economical, or societal terms, climate change will pose important challenges for the conservation of chondrichthyans, where international coordination will be essential to assess and respond to potential impacts in Latin America (Chin et al., 2010; Birkmanis et al., 2020). For instance, a changing environment can have significant effects on the distribution, feeding, and reproduction of chondrichthyans which could affect their relationship with human populations (Rosa et al., 2014; Birkmanis et al., 2020). In addition, pressure from various stressors such as organic and inorganic pollution, acidification, and habitat degradation can decrease fitness and increase stress and vulnerability to population collapse (Field et al., 2009, Rosa et al., 2014; Consales and Marsili, 2021). It is notable that climate change was not one of the top-ranked research priorities for chondrichthyan conservation in Latin America in this study. This is likely reflective of the many fundamental information and management capacity gaps in the region, as discussed above, and more specific focus on climate change effects will hopefully emerge as these pressing gaps are addressed.

The specialists also recognized the need for *International collaboration* in conservation efforts (identifying stocks to be managed in regional partnerships, designation of regional strategies and initiatives).

Furthermore, given the socioeconomic and ecological implications of chondrichthyan diversity loss, suitable regional population assessment and concerted conservation regulations should be a priority for countries sharing species distribution (Oliver et al., 2015; Weigmann, 2016; Awruch et al., 2019; Queiroz et al., 2019).

Finally, specialists identified that the appropriate use and study of *Chondrichthyan*s in captivity (new research opportunities, application of results to wild populations, social perception, and creation of species awareness) could benefit our general understanding of these species. For instance, the maintenance of chondrichthyan in captivity has favoured scientific research, environmental education, and the economy of some localities worldwide (Grassmann et al., 2017). Furthermore, studies in captivity have allowed fundamental advances in the biology of chondrichthyan (Rasmussen and Murru, 1992; Chapman et al., 2007), in addition to changing the public's perception of these "misunderstood" species (Grassmann et al., 2017).

#### 4. Relevance of interdisciplinary research

We believe the research priorities established above revolve around interdisciplinary research. Maintaining interdisciplinary connections is key to preserving the dynamic balance between management and science-based conservation, including further integration of the social and life sciences. The synergistic union and constant feedback between responsible stakeholders from each sector may favour environmental sustainability as well as human well-being. However, factors such as pollution and climate change can hinder management actions and therefore, species conservation (Fig. 3).

#### 5. Geographical bias and ethics considerations

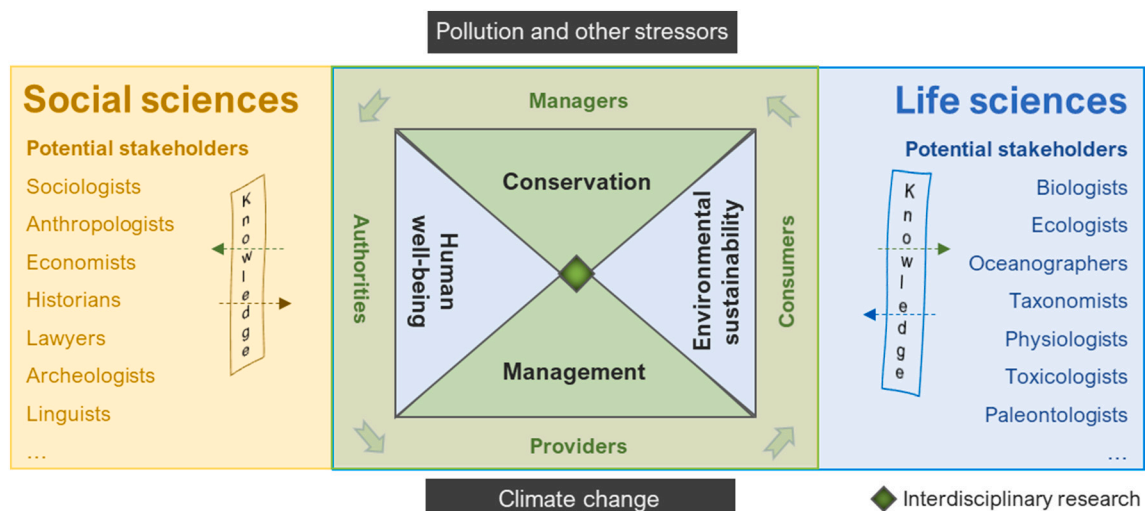
Due to the scarcity of chondrichthyan studies in some parts of Latin America, we recognize the geographic bias inherent to the perspective offered here. In the coming years, we hope to see more specialists from the Caribbean, Antilles, European territories, and other countries throughout Central and South America, as well as greater inclusion of Indigenous people and underrepresented minorities in science. Ethical, equitable, and professional collaborations across countries could benefit

chondrichthyan research in poorly studied areas but need to avoid historical issues such as scientific neocolonialism and parachute science (Barreto et al., 2017; Awruch et al., 2019; Malpica-Cruz et al., 2021). Coordinated and inclusive chondrichthyan research will strengthen shared goals, universal knowledge, and management regulations.

#### 6. Conclusions

This initiative identified ten research top priorities for the conservation of chondrichthyan in Latin America. We understand that chondrichthyan conservation needs in Latin America are vast, diverse, dynamic, and complex. Therefore, we do not claim that these ten research top priorities are absolute or definitive, but rather provide a starting point for discussion and encourage feedback and communication between all researchers and sectors committed to strengthening the conservation of these species. This academic exercise constitutes a first approach to providing urgently needed information to managers, conservationists, legislators, and other researchers. Further studies, discussions, initiatives, scientific reviews, and research are required and highly encouraged, as we all (consumers, fishers, scientists, and managers) depend on and should be committed to ecosystem health, biodiversity, and equitable management of resources.

Latin America is a region with shared historical roots among its inhabitants, where culture, economy, and natural resources maintain a close relationship. As such, the success of chondrichthyan research and conservation programs will largely depend on the degree of international and interdisciplinary collaboration between Latin American countries and the active participation of the fishing industry, government authorities, scientists, tour operators, and non-governmental organizations (Barreto et al., 2017; Queiroz et al., 2019; Mason et al., 2020). New funding opportunities, international collaboration in both research and regulations, as well as the implementation of multi-disciplinary investigations will foster significant advances in the coming decades. In this context, the research questions highlighted here constitute the first concerted effort to improve the conservation of chondrichthyan in the region, by promoting lines of research identified as critical by experts and the creation of an urgently needed Latin America research network structure.



**Fig. 3.** Theoretical diagram on the relevance of interdisciplinary research in the conservation and management of chondrichthyan. The fusion of the life sciences (blue rectangle) with the social sciences (yellow rectangle) results in a cycle of appropriate actions for conservation and management, environmental sustainability, and human well-being (green rectangle). The keystone that supports the diagram is interdisciplinary research (green diamond), which provides stability between management and conservation, as well as environmental sustainability and human well-being. Both Life and Social sciences play critical roles in this fusion, imparting the system with knowledge and contributing to its homeostasis. Arrows within the knowledge square represents the feedback needed for such homeostasis. The balance of the system could be affected by independent factors such as pollution and other stressors, as well as climate change (black rectangles). Examples of responsible stakeholders can be provided in each area, including specialists, authorities, managers, providers, and consumers. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)



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## Declaration of competing interest

Authors state that they do not have any competing interests to disclose.

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