Shark and ray research in India has low relevance to their conservation

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Highlights

1. Relevance and applicability of chondrichthyan research in India for the conservation of these species were low.
2. Research efforts were biased towards charismatic species like the whale shark, and towards the states in south India.
3. Paucity of research on socio-economic and management aspects, with little change over time.
4. Existing research might be more applicable to an ecosystem approach to fisheries management, rather than the conventional single species paradigm.
5. Need for more applied and directed research on chondrichthyans, with an explicit conservation focus.

Abstract

With global biodiversity currently facing unprecedented losses, it is critical that resources are allocated and used effectively to mitigate these threats, especially in resource-limited tropical countries of the global south. Chondrichthyans (sharks, rays and chimaeras) are particularly threatened by overexploitation, with India being amongst the top fishing nations for these species and a priority region for their conservation. We conducted a scoping review of chondrichthyan literature in India to assess the relevance of this research to the conservation of these threatened species. Between March and April 2021, we searched for peer reviewed and grey literature across national and international databases and found 482 chondrichthyan

publications. While the number of publications exponentially increased with time, the literature is dominated by short-term fisheries studies, biological records and observations, with less than 10% of studies addressing socio-economic and management themes. Research was biased towards specific states, particularly Tamil Nadu and Kerala, and towards charismatic species like the whale shark, leading to under-representation of potentially important regions and taxa. Overall, our study found low relevance and applicability of India's research literature to chondrichthyan conservation. There is a need for more directed and applied research explicitly aimed at informing conservation. We highlight specific data gaps, such as the need for improved understanding of the socio-economic aspects of chondrichthyan fisheries, species risk assessments at the regional level, data on critical habitats, and the evaluation of existing policies. Addressing these gaps can help ensure that effort is allocated to the regions, species and topics that need it the most, for improved conservation outcomes.

Keywords: Chondrichthyans; Elasmobranchs; Gap analysis; Fisheries management; Policy; Scoping review

1 Introduction

Biodiversity is deteriorating at an alarming rate worldwide (Díaz et al., 2019). In order to conserve nature and its vital contributions to people, there is a need for research that combines novel and rigorous science with conservation-relevant questions (Cook et al., 2013). While conservation research has significantly increased in recent decades, this may not necessarily translate to policy and practice (Milner-Gulland et al., 2012; Williams et al., 2020). Biodiversity and conservation research has been found to make few direct contributions to real world conservation outcomes (Pullin et al., 2004; Williams et al., 2020). This has been especially documented in the Global South; despite having some of the most biodiverse areas and largest human populations, research in these regions seldom meets the needs of conservation practice (Gossa et al., 2015; Meijaard & Sheil, 2007; Sheil, 2002). With a view to promoting evidence-based conservation, there is a need to review existing research and if necessary, revise and re-focus future research efforts for conservation. Review and synthesis of literature has been valuable in identifying key data gaps, formulating research questions, guiding decision-making for policy, and forming the basis of horizon scans for future conservation issues, amongst other things (Haddaway et al., 2015; Muenchow et al., 2018; Wintle et al., 2020).

Sharks, rays and chimaeras, collectively called chondrichthyans, provide valuable contributions to people, through direct economic benefits from the fisheries and tourism industries, as important food sources in many parts of the world, and by playing critical ecological roles in aquatic ecosystems (Ferretti et al., 2010; Gallagher & Hammerschlag, 2011; WWF, 2021). However, chondrichthyans are one of the most threatened groups in the world, with over a third of all known species currently threatened with extinction due to overfishing and other anthropogenic activities (IUCN, 2021). This situation is even more critical in the Arabian Sea region, where over half the chondrichthyan species have been assessed as Threatened on the IUCN Red List (Jabado et al., 2018). Bordering the Arabian Sea and the Bay of Bengal, India has a high diversity of chondrichthyans in its waters (at least 155 species, Akhilesh et al., 2014), and hosts one of the largest chondrichthyan fisheries globally (Dent & Clarke, 2015). Fisheries in India are also poorly regulated, making it one of the highest priority countries for the conservation of sharks and rays in the world (Dulvy et al., 2017).

An extensive body of literature exists on the biology of chondrichthyans in India. Taxonomic and species descriptions of sharks and rays from Indian waters began in the 18th century, and a systematic fisheries database was started as early as 1947 (Jabado et al., 2018). Chondrichthyan research and conservation also appears to be receiving increasing interest and investment in recent years (BOBP, 2015). However, existing research may not be translating to action, as there has been little improvement in fisheries management on the ground and limited formulation of policies (Karnad et al., 2014; Karnad et al., 2019). India currently has few policies and regulations for the conservation of chondrichthyans and management of their fisheries, particularly in comparison to other Asian countries (Karnad, 2018). The policies that exist include the protection of 10 species under the Wildlife (Protection) Act (WLPA) in 2001, and the prohibition of shark fin exports in 2015 (Kizhakudan et al., 2015). These policies may not be entirely driven by scientific information; for instance, most of the 10 species protected under the WLPA are very rarely caught in fisheries, and a few of these species do not actually occur in Indian waters (Akhilesh et al., 2014; Tyabji et al., 2020). While poorly framed policies can be attributed to multiple factors, having a body of scientific research that addresses policy-relevant questions to draw on can aid in improving policy making.

When it comes to fisheries management, the conventional single-species management paradigm is largely followed in India on ground (Mohamed & Malayilethu, 2013). This

approach has been critiqued for working on species in isolation, thereby neglecting ecosystem interactions as well as human interactions and societal objectives (NOAA, 2021); furthermore, it relies on data-intensive stock assessments which may be limited in the Indian context. The Ecosystem Approach to Fisheries Management (EAFM) is a newer and more holistic form of fisheries management that combines concepts of conserving biodiversity and ecosystems with those of fisheries management, food security and livelihoods (Staples & Funge-Smith., 2009). Although an ecosystem-based approach has been advocated in India's marine fisheries policy, it has not yet been implemented (Mohamed, 2013; Mohamed & Malayilethu, 2013). Understanding the availability and quality of existing data can support the updating and implementation of these management approaches.

These points highlight a need to review chondrichthyan research in India to understand the applicability of research to date, and inform future research and conservation efforts. Therefore, we conducted a comprehensive scoping review of chondrichthyan research in India, with the larger aim of assessing the relevance of this research to conservation of these threatened species. We looked at the distribution and biases of chondrichthyan literature across research topics, taxa and locations. We assessed the availability of data and whether it could potentially contribute to different fisheries management frameworks. Specific research questions, and the rationale behind them, can be found in Table 1. Through this review, we identified the main research gaps and priorities that future efforts need to address in order to guide policy more effectively.

2 Methods

We conducted a scoping review of scientific and grey literature on chondrichthyans in India. Structured searches were first carried out using specific search terms (Table 2) for the abstract, title or keywords only, in order to only include literature primarily focused on chondrichthyans. Searches were conducted in English only, as most scientific literature in India is in English, and carried out on Google Scholar as well as a number of global and Indian databases (Table 2). Following this, supplementary searches were conducted by reviewing the reference lists of the literature from the structured searches to compile a comprehensive list of published and grey literature. The latter included reports, theses, newsletters, bulletins and other unpublished work; media articles were excluded from this study, however. All searches were conducted in March and April 2021.

1 Table 1: The main research questions that were addressed in this scoping review, hypotheses for each, and the rationale behind them.

Research Question	**Hypotheses**	**Rationale**
What are the main themes of chondrichthyan research in India?	Research will be dominated by fisheries landings and biology.	This trend was reported in the draft National Plan of Action for Sharks (NPOA; BOBP, 2015).
How is chondrichthyan research distributed across the different regions in India?	Research will be skewed towards regions of high chondrichthyan fisheries landings.	India has 9 coastal states (i.e. provinces) and 4 coastal Union territories; chondrichthyan research efforts will likely be distributed across these regions based on where fisheries for these species occur.
Which taxa have research efforts focused on?	Research will be dominated by charismatic species.	Globally, chondrichthyan research is biased towards charismatic species (Ducatez, 2019).
To what extent can the available data contribute to different management frameworks?	Overall applicability of research towards management frameworks will be low, but research will be more applicable to a single species management approach than EAFM	As the single species approach is largely followed in India, we expected that existing data will be more applicable to this approach than EAFM.
To what extent does existing literature provide recommendations for chondrichthyan management?	Few publications will provide explicit recommendations for chondrichthyan management.	Few policies and conservation measures for chondrichthyans exist in India, hence we expected a low proportion of publications providing management and policy recommendations.
How have the above listed characteristics of chondrichthyan research changed over time?	Chondrichthyan research increasing over time; Research themes like socio-economics will be gaining prominence; Proportion of conservation-relevant research increasing with time.	Globally, chondrichthyans are receiving increasing research attention, and conservation science is becoming more holistic (Booth et al., 2019).

Table 2: Search terms, databases, and exclusion criteria for the literature review.

Search Terms[1]		
(india OR gujarat OR maharashtra OR goa OR karnataka OR kerala OR tamil OR andhra OR orissa OR odisha OR "west bengal" OR lakshadweep OR andaman*)	AND	(*shark* OR stingray* OR whipray* OR elasmobranch* OR chondrichth* OR guitarfish* OR wedgefish* OR dogfish* OR skate* OR batoid* OR "sting ray*" OR wobbegong* OR hammerhead* OR bonnethead* OR carcharhin* OR dasyati* OR mobul* OR manta OR isurus OR alopi* OR sphyrn* OR sawfish* OR gymnur* OR chimaer*)
Search Databases		
Global databases Google Scholar, Web of Science, Scopus and ProQuest		Indian databases and repositories Central Marine Fisheries Research Institute (CMFRI), Central Institute for Fisheries Technology (CIFT), National Institute of Oceanography (NIO), Centre for Marine Living Resources & Ecology (CMLRE), Zoological Society of India (ZSI) and Shodhganga
Screening Criteria		
The following types of publications were excluded: – Paleontological publications and fossil records – Parasitology publications – Studies conducted outside India – Studies not related to chondrichthyans – IUCN red list pages – Media articles		

[1] – The Asterix * at the start and/or end of a search word is a wildcard of undetermined length, and guaranteed that all potentially relevant publications were considered

Findings from the first ten pages of results in Google Scholar and all findings from the other databases were screened for inclusion in the review. We adapted the flowchart from Haddaway et al. (2017) to organise the screening process (Figure A.1). The title and abstract of each publication were read, and those meeting the criteria for exclusion were recorded and removed from the review (Table 2). Duplicates, which refers specifically to the same publication appearing in multiple databases, were also recorded and excluded.

After screening, all included publications were downloaded and randomly divided amongst the 3 reviewers. Each publication was read in full text and reviewed. Metadata such as study locations, study taxa, affiliations of authors and publication type (grey or peer reviewed) were extracted and stored. We then coded each publication for its main research themes, coding up to three themes per publication. Research themes were Biology, Ecology, Records, Taxonomy/Phylogeny, Fisheries, Socio-economic, Management/Policy and Other (Table A.1). Publications were also coded for whether they provided explicit policy and/or management recommendations, and whether they contained data that could potentially contribute to the conventional single species fisheries management and to EAFM. The coding protocol and definitions can be found in Supplementary Table A.1.

To test for reliability in coding amongst the 3 reviewers, the lead reviewer (TG) independently reviewed and coded 10% of the publications (16, selected at random) assigned to the second reviewer. The Cohen's Kappa test was then conducted for 5 variables coded by the two different reviewers. This process was repeated for the third reviewer. The test produces a coefficient that measures the agreement between two reviewers, with a score of 1 representing complete agreement. Any discrepancies found after the test were discussed and the process for coding was refined accordingly to maximise inter-reviewer consistency.

The coded data was analysed to calculate the number and proportion of chondrichthyan publications in each research theme, study state (i.e. province) and taxonomic group. We also assessed the proportion of literature that was potentially relevant to policy for and management of these species. Finally, we looked at trends in chondrichthyan literature with time. The publication year was categorised into 4 time periods: before 1991, 1991-2000, 2001-2010 and 2011-2020, in order to assess decadal trends. We used chi-squared tests to assess temporal changes in themes within the chondrichthyan literature, taxonomic group under study, and a publication's relevance to policy and management. All data analyses were conducted on RStudio version 1.3.1093 (R Core Team, 2014; RStudio Team, 2015), while regional distribution of publications was mapped using QGIS version 3.16.3 (QGIS, 2021).

To identify gaps in chondrichthyan literature and provide recommendations, we drew upon global and regional literature (e.g. Dulvy et al., 2017; Jabado et al., 2018) as well as the draft NPOA for sharks in India (BOBP, 2015). We also took insights from shark and ray research and conservation in other developing, fisheries-dependent countries.

3 Results:

3.1 Overview of chondrichthyan literature in India

Our searches produced a total of 1385 publications; a large number of these were duplicates or met the exclusion criteria and were screened out, resulting in 482 publications for review (Supplementary Figure A.1; Table A.2). The Cohen's Kappa test gave an average score of 0.8, ranging from 0.59 to 1 for the different pairwise comparisons across variables and reviewers, representing a fair level of reliability amongst reviewers. Most discrepancies were found in coding of the research themes; these were discussed and resolved wherever possible.

For most of the reviewed studies, lead authors were from governmental institutes (79%, n=385) such as the Central Marine Fisheries Research Institute (CMFRI), which is a research institute under the Indian Council of Agricultural Research. The number of journal articles were marginally less than the grey literature (47% and 51%, respectively); most were open access and easily available. The vast majority of publications contained some primary data (89%, n=431).

There was an overall increase in the number of publications on chondrichthyans with time (Figure 1). Nearly half of all chondrichthyan studies (46%, n=219) were published in the most recent decade (2011-2020, excluding publications from 2021). This was considerably higher than the previous decade (2001-2010), with only 90 publications (19%). Fewer studies were published between 1991 to 2000 (16%, n=74). Before 1991, we found a total of 88 studies on chondrichthyans (19%), with the earliest publication dating back to 1945. There was also a significant increase in the proportion of peer-reviewed publications with time, particularly from 2011 onwards ($\chi^2 = 72.10$, df = 3, p-value < 0.001; Figure 1).

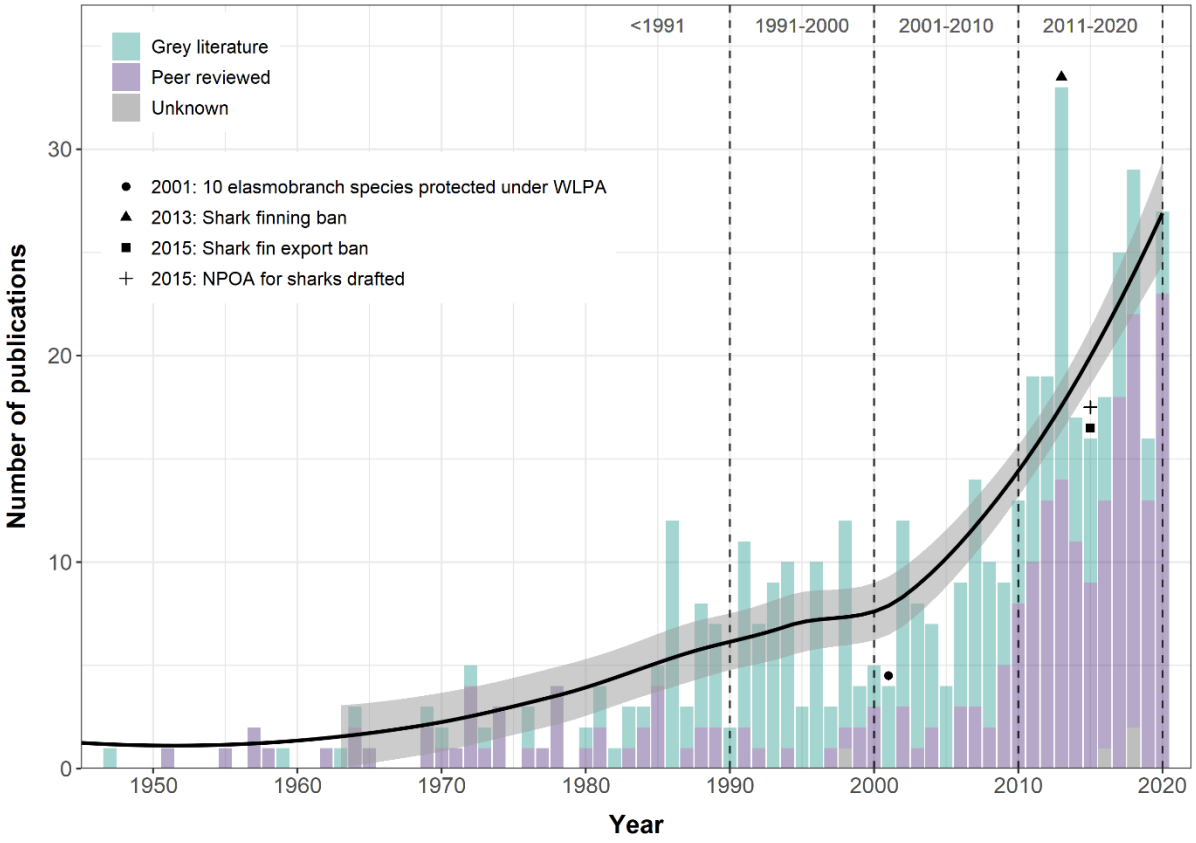


Figure 1: Number of publications over time, with proportions of grey (purple bars) and peer-reviewed (green bars) literature. The black line is the trend line of a linear model with the standard error in grey shading. The points represent key events for elasmobranch policy and conservation in India. WLPA: Wildlife (Protection) Act, 1972. NPOA: National Plan of Action.

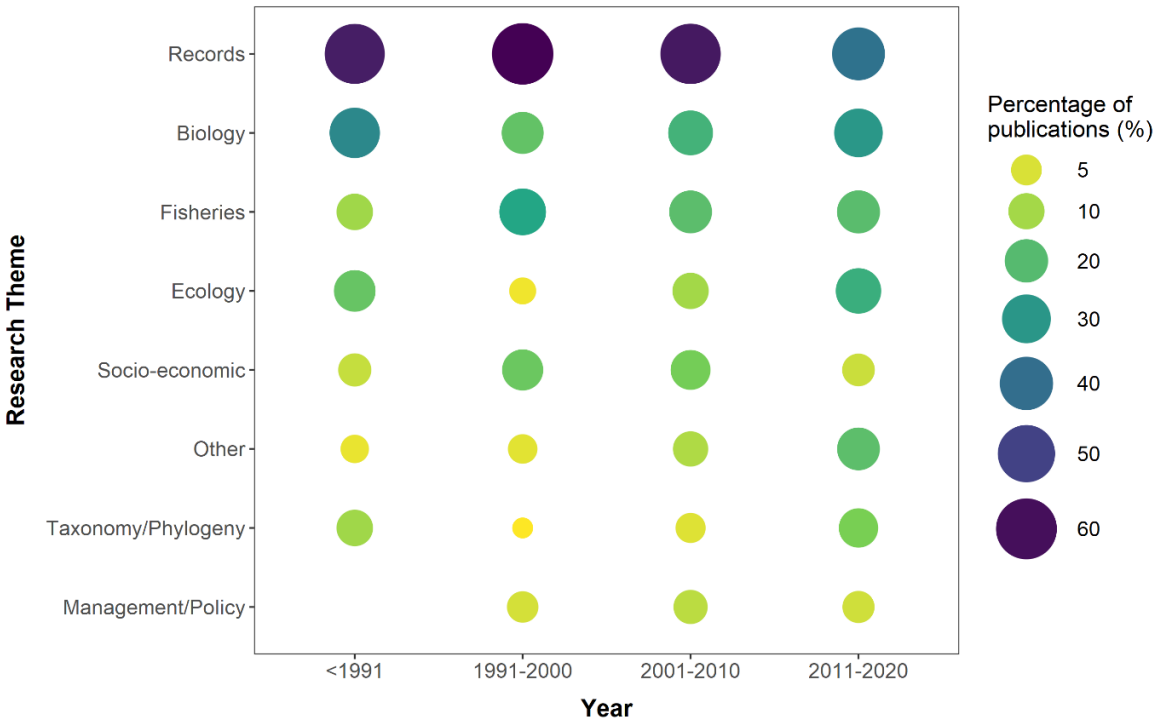
3.2 Research themes

The main theme of research on chondrichthyans in India was found to be Records (n=232, 48% of all publications), which are publications focusing on single observations or events (e.g. observations of morphological deformities in certain specimens, records of usually high landings, strandings of whale sharks, etc.). This was followed by research focusing on Biology (n=127, 26%), and Fisheries (n=87, 18%). A few publications (6% of total) covered both Fisheries and Biology in combination, which generally consisted of research using landings surveys to assess species composition, fisheries characteristics, size, sex and other biological parameters of chondrichthyans. Contrary to *a priori* expectations, themes like Socio-economic and Taxonomy/Phylogeny were poorly covered, with less than 10% of publications on each. Socio-economic research included studies focused on the processing, utilisation, marketing and trade of shark and ray products. Very few publications (n=24, 5% of total) were in the theme of Management/Policy. The bulk of the research in this theme

composed of non-detriment finding (NDF) reports, which assess whether international trade of a species will be detrimental to its survival in order to inform policy under the UN Convention on International Trade in Endangered Species (CITES; e.g. Kizhakudan et al., 2019; Zacharia et al., 2017), and documents related to the development of the draft National Plan of Action for Sharks (NPOA; BOBP, 2015; Kizhakudan et al., 2015; Zacharia & Vivekanandan, 2013). Other Management/Policy themed publications included literature on conservation campaigns and policy evaluations for the whale shark (*Rhincodon typus;* e.g. Premjothi et al., 2016a; Matwal et al., 2014).

Research themes were not equally distributed across the decades (<1991, 1991-2000 2001-2010 and 2011-2020), based on a chi squared test (χ^2 = 82.07, df = 21, p-value < 0.001). The themes of Records and Socio-economic appeared to decrease in proportion over time, especially between 2011 to 2020, despite an overall increase in number (Figure 2). By contrast, the proportion of publications on Management/Policy, Ecology and Taxonomy/Phylogeny appeared to increase across the decades (Figure 2). The proportion of Fisheries-themed publications increased in the 1990s but showed little change after that; Biology was also nearly constant in proportion across the time periods. On the whole, research themes have become more diverse with time, as seen by increasing proportions of the 'Other' category, which comprises themes like Ecotoxicology, Biochemistry, Checklists and Field guides (Figure 2).

As there were a large number of publications that were only of the theme Records, with no other theme (n=187, 39%), these may be masking broader trends in chondrichthyan literature and were hence excluded from further analyses, unless specified otherwise.



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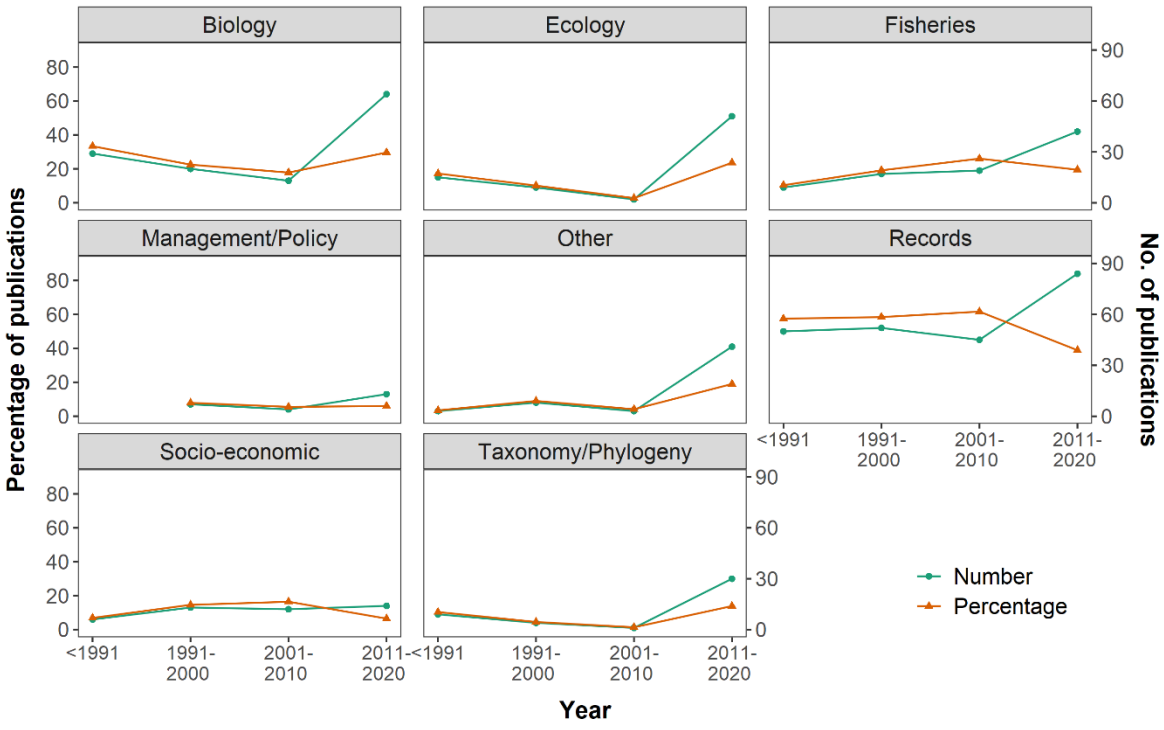

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3 Figure 2: Main research themes of reviewed literature per time period (before 1991, 1991-2000, 2001-
4 2010 and 2011-2020). Publications with more than one research theme are counted in each relevant
5 theme. Top: Size and colour of the symbols represent the percentage of publications in each theme;
6 larger and purple-coloured dots signify a higher percentage of that theme. Bottom: Total number of
7 publications (green lines with circles, right axis) and percentage of the total (orange lines with
8 triangles, left axis) for each research theme.

3.3 Research locations

The location of the data collection for chondrichthyan research was not equally distributed across the Indian maritime states (Figure 3). Excluding Records-only publications, Tamil Nadu, on the south-east coast of India, had the largest number of chondrichthyan publications (22%, n=65). This was closely followed by Kerala, on the south-west coast (20%, n=58; Figure 3). Research in both these states were dominated by the theme of Biology, followed by Ecology for Tamil Nadu and Fisheries for Kerala. Management/Policy was the least studied theme, with only 2 studies in each state.

The states of Goa (on the west coast) and West Bengal (on the north-east coast) were poorly studied, with only 6 and 7 chondrichthyan publications respectively. There was no research on the Management/Policy theme in these states. On the whole, less chondrichthyan research was conducted on the east coast than the west (Figure 3). Excluding Tamil Nadu, there were only 25 studies (9% of all publications excluding Records only) related to the remaining 3 east coast states combined. Excluding Kerala, the remaining west coast states were collectively represented in more than a quarter of chondrichthyan publications (27%, n=78).

These publication trends represented a mismatch between research efforts and chondrichthyan landings across India's coastline. States like Gujarat and Andhra Pradesh had proportionally less research despite having high landings, whereas research efforts in Kerala and Maharashtra were higher in proportion to the chondrichthyan landings in these states (CMFRI, 2019; Figure 3).

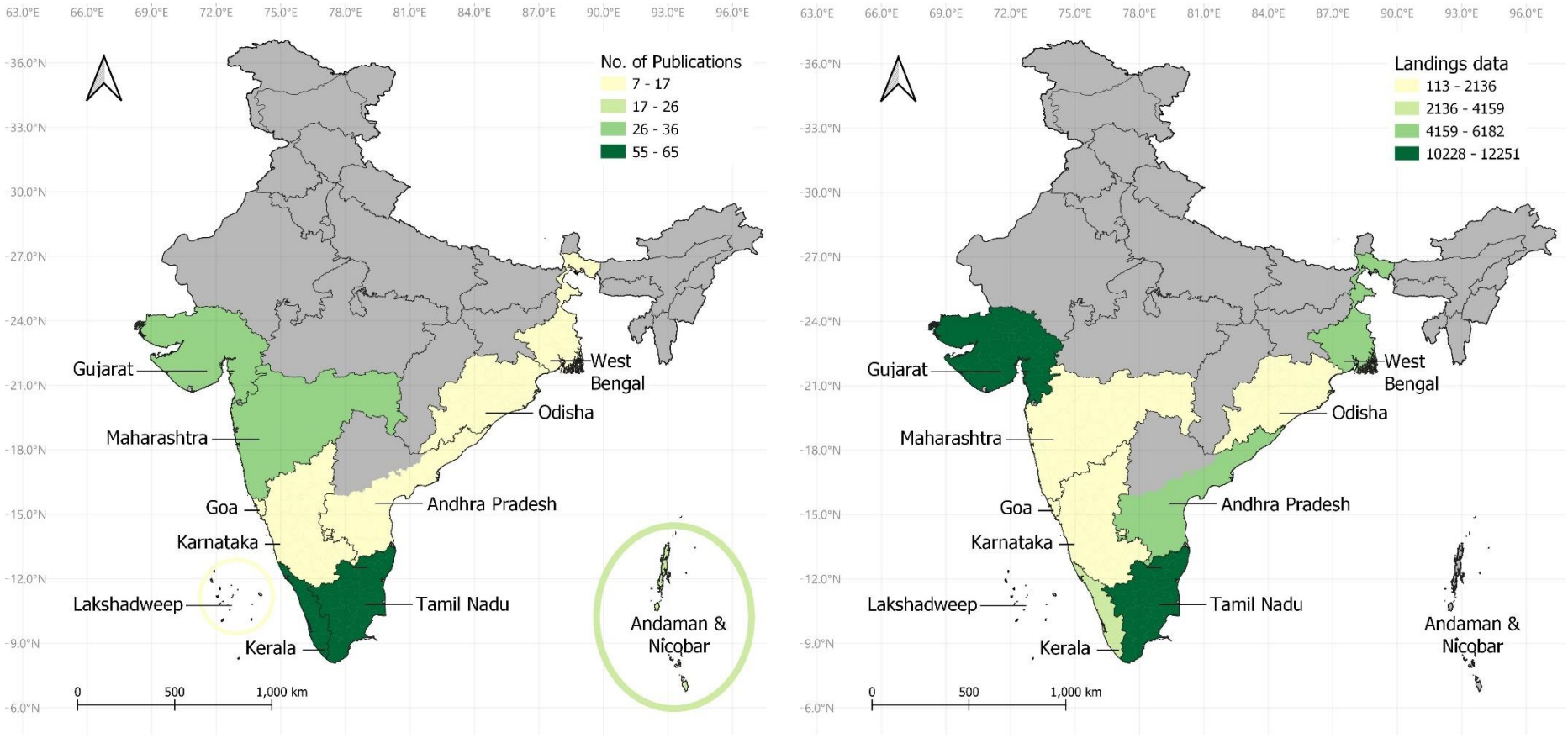

Figure 3: Total number of publications reporting research conducted in each coastal state (left; excluding publications that are Records only) and the total chondrichthyan landings per state in 2019 (right; CMFRI, 2019). No recent landings data for chondrichthyans were available for the Andaman and Nicobar Islands and Lakshadweep. Dark green colour indicates a higher number of publications at that state, and higher chondrichthyan landings, whereas light yellow indicates fewer publications and lower landings. Non-coastal states are marked in grey.

3.4 Researched taxa

Sharks (infraclass Selachii) were the main focus of research, represented in 79% of all publications (n=379). Rays (infraclass Batoidea) were studied in 32% of publications (n=156), while less than 3% of publications looked at chimaeras (class Holocephali, n=12). Note that these groups are not mutually exclusive, and there are a number of publications that studied both sharks and rays (n=71). The whale shark (*Rhincodon typus*) was the most studied chondrichthyan species, with over 22% of all reviewed publications (including Records) focusing solely on this species (n=106). Other commonly researched taxa were mantas and devil rays (*Mobula sp.*), spadenose shark (*Scoliodon laticaudus*), requiem sharks (*Carcharhinus sp.*) and bramble shark (*Echinorhinus brucus*). Most of the literature studied sharks and rays at the species level (87%, n=416), with very few looking at them at the genus level or above.

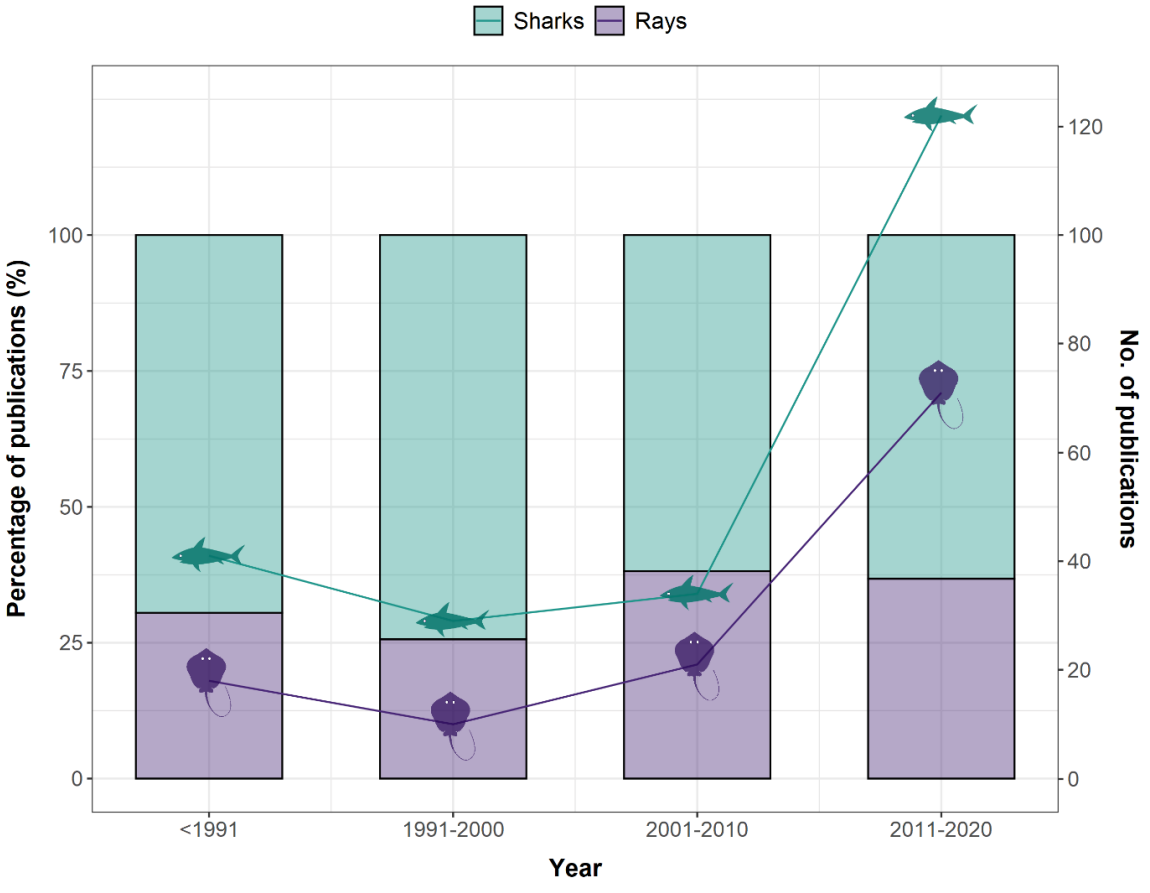

Figure 4: Number (right axis, line graph) and percentage (left axis, bars) of publications on each taxa (sharks, green and rays, purple) across the time periods. The data represented here excludes publications that are Records only. Publications studying both sharks and rays (n=71) are split and considered individual counts.

Nearly half of the shark literature was Records (48%, n=183), followed by Biology (26%, n=97). For rays, research was more evenly distributed across the different themes, with Records, Biology and Fisheries being the most common (33%, 32% and 26% respectively). Research on the theme Management/Policy was low for both sharks and rays (6% and 5% respectively). Although the number and proportion of ray-focused research increased over time, this increase was not significant (Figure 4, $\chi^2 = 2.54$, df = 3, p-value = 0.47).

3.5 Relevance of research for policy and management

Overall, the existing literature appeared to have low relevance and applicability in guiding policy and management for chondrichthyans. Only 12% of the reviewed publications (n=34) provided explicit policy and/or management recommendations for chondrichthyans and their fisheries. About 40% of the publications (n=110) contained data that could in principle contribute to a single-species management approach to chondrichthyan fisheries, while more than half contained data relevant to an Ecosystem Approach to Fisheries Management (EAFM; 56%, n=154). This was excluding publications that are just Records (n=187), as only 2 of these publications (1% of all Records) contained data that could contribute to single-species management and EAFM respectively, and none had any policy recommendations. On inclusion of research that only concerned Records, the proportion of publications relevant to policy and management decreased markedly.

The relative proportion of publications (excluding those that are only Records) with policy recommendations significantly increased with time ($\chi^2 = 9.01$, df = 3, p-value = 0.029). A similar trend was found for the proportion of publications with data relevant to EAFM ($\chi^2 = 9.64$, df = 3, p-value = 0.022), with significantly higher proportions of relevant publications in recent years. However, no significant change was observed for publications relevant to a single-species management approach with time ($\chi^2 = 3.56$, df = 3, p-value = 0.314; Figure 5).

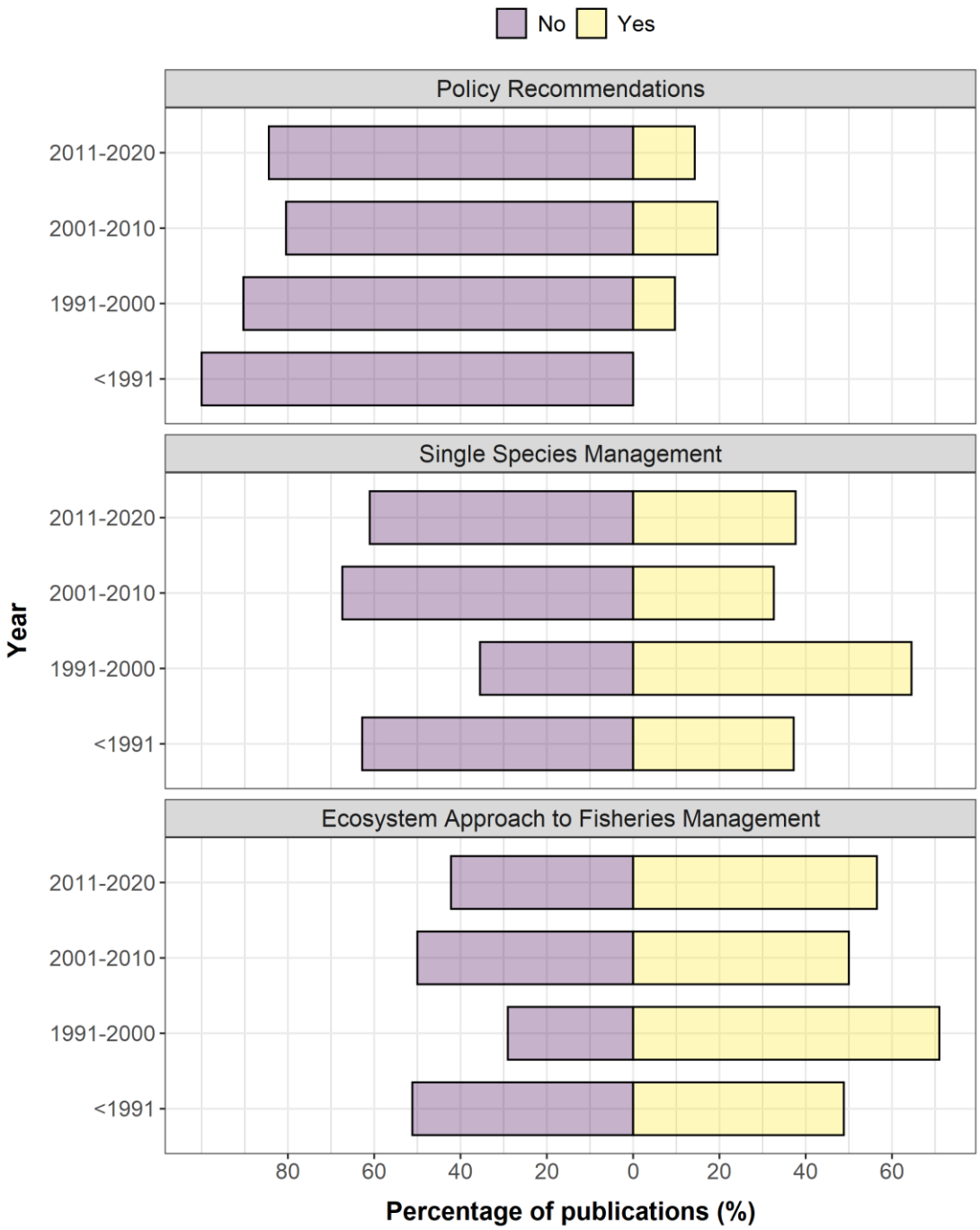

Figure 5: Relevance of publications to policy and/or management per decade (before 1991, 1991-2000, 2001-2010, and 2011-2020). Top: Number of publications that discussed the policy implications of their findings and provided policy/management recommendations; Centre: Number of publications with data that would be relevant to a single-species management approach; Bottom: Number of publications with data that would be relevant to an ecosystem approach to fisheries management (EAFM). The data represented here excludes publications that are Records only.

4 Discussion:

This study shows that the research on chondrichthyans in India has significantly increased over time, and has especially grown in the last decade. In support of our hypotheses (Table 1), we found biases in research efforts towards certain states (provinces), taxonomic groups and topics. However, against our expectations, we found that chondrichthyan research remains strongly dominated by Records, with a paucity of literature on the socio-economic and management aspects. Overall, chondrichthyan research had little relevance for on-ground management or conservation policy-making. Although the field of conservation science has rapidly grown in India over the past few decades, particularly for terrestrial species (Bawa et al., 2021; Mishra et al., 2021; Thanuskodi & Venkatalakshmi, 2010), our findings highlight the need for improved conservation research for threatened marine species like sharks and rays.

4.1 Biases in chondrichthyan research

The dominance of Tamil Nadu and Kerala as sites for chondrichthyan research is likely to be due to the presence of governmental research institutes in these states (for example, CMFRI and CMLRE both have their headquarters in the Kerala, with major research centres in the Tamil Nadu), resulting in a large body of fisheries and marine research. Furthermore, Tamil Nadu is amongst the states with the highest level of chondrichthyan fishing (CMFRI, 2019), while Kerala is known to have a culturally high consumption of seafood, including sharks and rays (Salim, 2020). Research in other parts of the country remains patchy and scattered, particularly along the east coast, despite states like Andhra Pradesh and West Bengal having fairly high chondrichthyan landings and significant levels of local consumption (CMFRI, 2019; Karnad et al., unpublished). Geographical bias in research efforts is not a new occurrence in conservation and biodiversity research, and has been noted for various different taxa and topics by global-scale reviews (e.g. Mas et al., 2021; Wraith et al., 2020) as well as within particular regions (e.g. Jamieson et al., 2019; Pitman et al., 2011; Suryawanshi et al., 2019). Bias in research locations can compromise conservation efforts through the neglect or under-representation of important biodiverse regions, and the development of conservation measures at a national scale that are inappropriate for the local or regional context (Marco et al., 2017; Muenchow et al., 2018; Teixido et al., 2020). Given the high cultural, socio-economic and political diversity across India, drivers of fisheries, utilisation and values of chondrichthyans are likely to vary with region (e.g. Jaini et al., 2018). Hence, this

geographical research bias may be masking true patterns in chondrichthyan status, fisheries and trade, leading to poor decision making in conservation and management.

We found a similar bias in the taxonomic group under study, with research skewed towards sharks, and dominated by the whale shark (*R. typus*). Conservation science has long been plagued with a strong bias towards charismatic species, with non-charismatic yet ecologically important groups often overlooked in terms of research, policy and conservation (Donaldson et al., 2017). While the rationale is that charismatic species may serve as umbrella or flagship species for biodiversity conservation, this is not always the case (Zacharias & Roff, 2001; Wang et al., 2021). Extensive research and campaigns about the whale shark in India, combined with policy interventions, have led to the apparently successful conservation of this species (Bloch et al., 2019). However, it remains unclear whether this has led to positive outcomes for other chondrichthyan species. Rays are under-represented in Indian chondrichthyan literature, despite being more species-rich, widespread and threatened than sharks (Last et al., 2016). Rays also form a greater contribution to fisheries in India (59.5% of the total landed chondrichthyans in 2019; CMFRI, 2019) and are important for local food and livelihoods. Similarly, chimaeras are very poorly studied, which may be attributed to their deep-sea habitat and relative rarity in fisheries catch (Holt et al., 2013). Research efforts need to diversify and include a wider range of species, as a 'one size fits all' approach to chondrichthyan conservation will likely be unsuccessful given their high ecological and biological diversity (Dulvy et al., 2017).

4.2 Management of chondrichthyan fisheries

Fisheries management has been undergoing a paradigm shift worldwide from single species to an ecosystem approach (Townsend et al., 2019). While there have been advances in developing ecosystem approaches in India, its on-ground implementation is hindered by a multitude of operational challenges (Mohamed & Malayilethu, 2013). Our findings show that there is limited published information on chondrichthyan stock status and other parameters that are required for conventional management; this may be true for other commercially exploited species in India as well. Furthermore, contrary to *a priori* expectations, we found that the existing chondrichthyan literature might potentially contribute more to EAFM than single species management. While this result was surprising, EAFM is a broad and holistic framework that can integrate different types of data from various sources (Staples & Funge-Smith., 2009). Hence, we highlight the need to develop a feasible and locally appropriate framework for implementation of EAFM in India (Vijayakumaran, 2014).

4.3 Relevance of research for conservation

Overall, applied chondrichthyan research in India was limited, evidenced by the small number of publications in the Management/Policy theme, and equally few publications providing explicit recommendations for chondrichthyan conservation. A similarly small proportion of publications could contribute directly to fisheries management. Furthermore, although research is becoming increasingly diverse with time, it remains dominated by Records. While records have some value in understanding long-term trends, identifying shifting baselines and enabling the analysis of historical changes in socio-economic values (Baum & Myers, 2004; Monsarrat et al., 2019), we found that they have little direct relevance in guiding conservation and management of fisheries. The dominance of Records in the literature indicates that most published studies in our sample were largely incidental or opportunistic, with little directed and dedicated research on sharks and rays.

In the Asian tropics, conservation research priorities are often driven by the sources of funding, which are frequently external; this is further challenged by the social and economic priorities of governments, limited resource capacity, and conflict between development and conservation objectives (McNeely et al., 2009; Sheil, 2002). Conservation research in India has largely focused on terrestrial biodiversity, with significant attention given to charismatic land species such as the tiger and elephant; marine biodiversity has been relatively overlooked (Kuppasamy et al., 2013). Chondrichthyans are exceptionally challenging as they are both a threatened marine species group in need of conservation as well as a commercially valuable group that is regularly fished (Gupta et al., 2020a). As our findings show, most chondrichthyan research in India has been conducted by organisations under the Ministry of Agriculture and the Ministry of Fisheries, Animal Husbandry and Dairying of the Government of India, where these species are viewed through a fisheries resource lens. Very little research is conducted by the agencies under the Ministry of Environment, Forest and Climate Change, whose mandate is focused on wildlife and environmental conservation. Hence, chondrichthyan research tends to be production-oriented rather than conservation-oriented. This is not an issue confined to India; as a result, fish species are often neglected in wildlife conservation legislation globally (Vincent et al., 2014; Wyatt et al., 2021). There is a need for a pluralistic approach for sharks and rays, encompassing their different aspects and complexities in order to produce research relevant to conservation as well as fisheries management (Booth et al., 2019).

4.4 Key gaps and recommendations

We identified a number of critical gaps in chondrichthyan knowledge in India, that need to be addressed in order to make their conservation more effective. While there have been significant advances in documenting and describing the chondrichthyan species present in Indian waters, there is a need to assess the status of these populations, through species stock assessments or risk assessments (BOBP, 2015). Risk assessments will aid in identification of priority species and fisheries for conservation and management in India (Dulvy et al., 2017; Jabado et al., 2018). For instance, an adapted productivity-sensitivity analysis was conducted in Indonesia to identify at-risk shark and ray species; priority sites for conservation were also identified (Booth et al., 2018). Similar assessments would be highly valuable in India.

We also highlight a paucity of knowledge about critical habitats of sharks and rays. These species are known to use specific sites for spawning and nurseries, as well as for feeding, making them highly vulnerable to fisheries and other activities occurring at these areas (Heupel et al., 2007; Martins et al., 2018). Few studies in India have looked at the spatial ecology of chondrichthyans, with very few attempting to identify and characterise their critical habitats (c.f. Chembian, 2010; Kumari & Raman, 2010; Premjothi et al., 2016b; Gupta et al., 2020b). Knowledge of habitat use and aggregation sites can aid in the formulation of nuanced, area-based conservation measures (Barnett et al., 2019). Conventional methods for research on habitat use can be resource-intensive and may be a challenge for the Indian context. However, fisher knowledge (i.e. Local Ecological Knowledge and Traditional Ecological Knowledge) can be a crucial source of information in resource and data-limited situations. Fisher knowledge has been used to gain insights on shark and ray habitats in regions in Bangladesh (Haque et al., 2021), Mexico (Cuevas-Gómez et al., 2020) and Fiji (Rasalato et al., 2010), and could be used to address similar data gaps in India.

There is also a need for deeper understanding of the human dimensions of chondrichthyan fisheries, as they form complex social ecological systems with important contributions to livelihoods and food security (Karnad et al., 2019). Chondrichthyan research needs to be inter- and multidisciplinary to address all elements of this system and guide holistic management. Social sciences are becoming increasingly mainstreamed into conservation science in general (Bennett et al., 2017), as well as into chondrichthyan research (Booth et al., 2019; Simpfendorfer et al., 2011). Social science can be used to understand attitudes, perceptions and values of sharks and rays and their use by local communities, in order to

design appropriate and inclusive conservation strategies (Glaus et al., 2018; Mason et al., 2020; Sabbagh & Hickey, 2020; Skubel et al., 2019). Against our expectations, we found alarmingly few publications on socio-economic themes in India, with no increase over time. With a large population of fisher folk (4.9 million; Department of Fisheries, 2020) and evidence of substantial local chondrichthyan consumption in the country (Karnad et al., 2019), understanding the socio-economic drivers of chondrichthyan fishing is a priority for India.

Finally, we propose that evaluation of existing policies and regulations for chondrichthyans in India is urgently needed. With the exception of the whale shark (e.g. Bloch et al., 2019), we did not find any policy evaluations that assessed their effectiveness for conservation of these species, which can be a hindrance to decision-making. It is essential that policies for sharks and rays in India are evaluated and strengthened based on scientific evidence. For instance, Collins et al. (2020) and MacKeracher et al. (2020) assessed effectiveness of and compliance with shark fishing bans in Sri Lanka and Myanmar respectively, to provide strong recommendations for improved outcomes. Similarly, Booth et al., (2020) developed a framework to evaluate the impact of regulations on manta ray trade in Indonesia. These approaches could be applied in the Indian context.

4.5 Limitations of this study

While every effort was made to ensure that we accessed and reviewed the entire set of chondrichthyan literature in India, such as using a comprehensive set of search terms and searching across numerous international and national databases, we acknowledge that we may have missed some relevant publications, particularly grey literature. Searching through a greater number of national databases, such as repositories of fisheries institutions, and in different regional languages, may yield more results. In person searches of research institute archives and libraries would no doubt have yielded some reports, theses and older journal articles that have not been digitised. However, as our main objective was to assess the conservation relevance of existing literature, publications that are not easily available online are unlikely to guide conservation policy-making. Lastly, we note that our assessments of the conservation relevance of chondrichthyan literature were based on the potential or hypothetical contributions to on-the-ground conservation or conservation policy. Assessing the actual real-world contribution made by each publication would be a significant challenge.

5 Conclusion

There is a substantial body of research for sharks and rays in India, increasing rapidly with time, which is a very positive sign for a data-limited region and taxonomic group. However, research on this group in India need to be refocussed towards producing data and evidence that can better support practical conservation and policy-making. Future research needs to focus on regional species risk assessments and knowledge of critical habitats to identify vulnerable species and areas for conservation. Understanding the socio-economic drivers and aspects of chondrichthyan fisheries must also be a priority, as it can be vital to developing successful management measures. Lastly, there is a need to review and improve existing policies for chondrichthyan fisheries and conservation. While implementation of conservation measures will remain a challenge in India due to limited capacity, political will, and other factors, strengthening the research and evidence base will help in developing science-based solutions to the challenges facing chondrichthyans. Our findings can help shape these future research efforts.

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Competing Interests

The authors declare no competing interests

References

Akhilesh, K. V., Bineesh, K. K., Gopalakrishnan, A., Jena, J. K., Basheer, V. S., & Pillai, N. G. K. (2014). Checklist of Chondrichthyans in Indian waters. *J. Mar. Biol. Ass. India,* 56 (1), 109-120.

Anderson, S. C., Elsen, P. R., Hughes, B. B., Tonietto, R. K., Bletz, M. C., Gill, D. A., Holgerson, M. A., Kuebbing, S. E., McDonough MacKenzie, C., Meek, M. H., & Veríssimo, D. (2021). Trends in ecology and conservation over eight decades. *Frontiers in Ecology and the Environment*, 19(5), 274–282. https://doi.org/10.1002/fee.2320

Barnett, A., McAllister, J. D., Semmens, J., Abrantes, K., Sheaves, M., & Awruch, C. (2019). Identification of essential habitats: Including chimaeras into current shark protected areas. *Aquatic Conservation: Marine and Freshwater Ecosystems*, 29(6), 865–880. https://doi.org/10.1002/aqc.3087

Baum, J. K., & Myers, R. A. (2004). Shifting baselines and the decline of pelagic sharks in the Gulf of Mexico. *Ecology Letters*, 7(2), 135–145. https://doi.org/10.1111/j.1461-0248.2003.00564.x

Bawa, K. S., Sengupta, A., Chavan, V., Chellam, R., Ganesan, R., Krishnaswamy, J., Mathur, V. B., Nawn, N., Olsson, S. B., Pandit, N., Quader, S., Rajagopal, P., Ramakrishnan, U., Ravikanth, G., Sankaran, M., Shankar, D., Seidler, R., Shaanker, R. U., & Vanak, A. T. (2021). Securing biodiversity, securing our future: A national Mission on biodiversity and human well-being for India. *Biological Conservation*, 253(August 2020), 108867. https://doi.org/10.1016/j.biocon.2020.108867

Bennett, N. J., Roth, R., Klain, S. C., Chan, K., Christie, P., Clark, D. A., Cullman, G., Curran, D., Durbin, T. J., Epstein, G., Greenberg, A., Nelson, M. P., Sandlos, J., Stedman, R., Teel, T. L., Thomas, R., Veríssimo, D., & Wyborn, C. (2017). Conservation social science: Understanding and integrating human dimensions to improve conservation. *Biological Conservation*, 205, 93–108. https://doi.org/10.1016/j.biocon.2016.10.006

Bloch, F., Premjothi, P. V. R., Matwal, M., Joshi, D., Goutham, S., Kumar, P., Choudhury, B. C., Kaul, R., Menon, V., & John, S. (2019). Communities and corporates for conservation: A decade of conservation effort to save whale shark. Success story from Gujarat, India. https://doi.org/10.5339/qproc.2016.iwsc4.8

BOBLME (2015) National Plan of Action for conservation and management of shark fisheries in India. BOBLME-2015-Ecology-65. https://www.boblme.org/documentRepository/BOBLME-2015-Ecology-65.pdf

Booth, H., H., Muttaqin, E., Simeon, B., Ichsan, M., Siregar, U., Yulianto, I., & Kassem, K. (2018). Shark and ray conservation and management in Indonesia: Status and strategic priorities 2018-2023. May 2020.

Booth, H., Mardhiah, U., Siregar, H., Hunter, J., Giyanto, Putra, M. I. H., Marlow, J., Cahyana, A., Boysandi, Demoor, A. Y. L., Lewis, S., Adhiasto, D., Adrianto, L., &

Yulianto, I. (2020). An integrated approach to tackling wildlife crime: impact and lessons learned from the world's largest targeted manta ray fishery. *Conservation Science and Practice*, October, 1–18. https://doi.org/10.1111/csp2.314

Booth, H., Squires, D., & Milner-Gulland, E. J. (2019). The neglected complexities of shark fisheries, and priorities for holistic risk- based management. *Ocean & Coastal Management*, July, 104994. https://doi.org/10.1016/j.ocecoaman.2019.104994

Chembian, A. J. (2010). Description of spawning ground and egg capsules of the batoid Raja miraletus Linnaeus, 1758 in the Wadge Bank, along the south-west coast of India. *Indian J Fish*, *57*(1), 13-6.

CMFRI. (2019). Annual Report 2018-19. Central Marine Fisheries Research Institute, Kochi. 320p

Collins, C., Letessier, T. B., Broderick, A., Wijesundara, I., & Nuno, A. (2020). Using perceptions to examine human responses to blanket bans: The case of the thresher shark landing-ban in Sri Lanka. *Marine Policy*, *121*, 104198. https://doi.org/10.1016/j.marpol.2020.104198

Cook, C. N., Mascia, M. B., Schwartz, M. W., Possingham, H. P., & Fuller, R. A. (2013). Achieving conservation science that bridges the knowledge–action boundary. *Conservation Biology*, *27*(4), 669-678. https://doi.org/10.1111/cobi.12050

Cuevas-Gómez, G. A., Pérez-Jiménez, J. C., Méndez-Loeza, I., Carrera-Fernández, M., & Castillo-Géniz, J. L. (2020). Identification of a nursery area for the critically endangered hammerhead shark (Sphyrna lewini) amid intense fisheries in the southern Gulf of Mexico. *Journal of Fish Biology*, 97(4), 1087–1096. https://doi.org/10.1111/jfb.14471

Dent, F., & Clarke, S. (2015). State of the global market for shark products. In FAO technical paper 590. http://www.fao.org/docrep/field/003/ab825f/AB825F00.htm#TOC%5Cnhttp://www.fao.org/3/a-i4795e.pdf

Department of Fisheries (2020). Handbook on Fisheries Statistics, 2020. Compiled by the Fisheries Statistics Division, Department of Fisheries, Ministry of Fisheries, Animal Husbandry & Dairying, Government of India.

Díaz, S., Settele, J., Brondízio, E. S., Ngo, H. T., Guèze, M., Agard, J., ... & Zayas, C. (2019). Summary for policymakers of the global assessment report on biodiversity and ecosystem services of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services. *Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services*.

Donaldson, M. R., Burnett, N. J., Braun, D. C., Suski, C. D., Hinch, S. G., Cooke, S. J., & Kerr, J. T. (2017). Taxonomic bias and international biodiversity conservation research. *Facets*, 1(1), 105–113. https://doi.org/10.1139/facets-2016-0011

Ducatez, S. (2019). Which sharks attract research? Analyses of the distribution of research effort in sharks reveal significant non-random knowledge biases. *Reviews in Fish Biology and Fisheries*, 29(2), 355–367. https://doi.org/10.1007/s11160-019-09556-0

Dulvy, N. K., Simpfendorfer, C. A., Davidson, L. N. K., Fordham, S. V., Bräutigam, A., Sant, G., & Welch, D. J. (2017). Challenges and priorities in shark and ray Conservation. *Current Biology*, 27(11), R565–R572. https://doi.org/10.1016/j.cub.2017.04.038

Ferretti, F., Worm, B., Britten, G. L., Heithaus, M. R., and Lotze, H. K. (2010). Patterns and ecosystem consequences of shark declines in the ocean. Ecol. Lett. 13, 1055–1071. doi: 10.1111/j.1461-0248.2010.01489.x

Gallagher, A. J., and Hammerschlag, N. (2011). Global shark currency: the distribution, frequency, and economic value of shark ecotourism. *Curr. Issues Tour*. 14, 797–812. doi: 10.1080/13683500.2011.585227

Glaus, K. B. J., Adrian-kalchhauser, I., Piovano, S., Appleyard, S. A., Brunnschweiler, J. M., & Rico, C. (2018). Fishing for profit or food? Socio-economic drivers and fishers' attitudes towards sharks in Fiji. *Marine Policy*, December, 1–9. https://doi.org/10.1016/j.marpol.2018.11.037

Gossa, C., Fisher, M., & Milner-Gulland, E. J. (2015). The research-implementation gap: How practitioners and researchers from developing countries perceive the role of peer-reviewed literature in conservation science. *Oryx*, 49(1), 80–87. https://doi.org/10.1017/S0030605313001634

Gupta, T., Booth, H., Arlidge, W., Rao, C., Manoharakrishnan, M., Namboothri, N., Shanker, K., & Milner-Gulland, E. J. (2020a). Mitigation of elasmobranch bycatch in trawlers: A case study in Indian fisheries. *Frontiers in Marine Science*, 7(July), 571. https://doi.org/10.3389/FMARS.2020.00571

Gupta, T., Warde, K., Rao, C., Manoharakrishnan, M., and Shanker, K. (2020b). Potential nursery grounds of endangered elasmobranchs around Sindhudurg. Technical Report submitted to the Mangrove Foundation, Forest Department of Maharashtra, India.

Haddaway, N. R., Woodcock, P., Macura, B., & Collins, A. (2015). Making literature reviews more reliable through application of lessons from systematic reviews. *Conservation Biology*, 29(6), 1596–1605. https://doi.org/10.1111/cobi.12541

Haddaway, N. R., Macura, B., Whaley, P., & Pullin, A. S. (2018). ROSES Reporting standards for Systematic Evidence Syntheses: pro forma, flow-diagram and descriptive summary of the plan and conduct of environmental systematic reviews and systematic maps. *Environmental Evidence*, *7*(1), 1-8. https://doi.org/10.1186/s13750-018-0121-7

Haque, A. B., Washim, M., Gloria, N., Costa, D., Robert, A., Hossain, N., Nanjiba, R., Jahedul, S., & Ahsan, N. (2021). Socio-ecological approach on the fishing and trade of rhino rays (Elasmobranchii: Rhinopristiformes) for their biological conservation in the Bay of Bengal, Bangladesh. *Ocean and Coastal Management*, 210(August 2020), 105690. https://doi.org/10.1016/j.ocecoaman.2021.105690

Heupel, M. R., Kanno, S., Martins, A. P., & Simpfendorfer, C. A. (2018). Advances in understanding the roles and benefits of nursery areas for elasmobranch populations. *Marine and Freshwater Research, 70*(7), 897-907. https://doi.org/10.1071/MF18081

Hilborn, R., Walters, C. J., & Ludwig, D. (1995). Sustainable exploitation of renewable resources. *Annual Review of Ecology and Systematics*, *26*(1), 45-67.

Holt, R. E., Foggo, A., Neat, F. C., & Howell, K. L. (2013). Distribution patterns and sexual segregation in chimaeras: implications for conservation and management. *ICES Journal of Marine Science*, *70*(6), 1198-1205. https://doi.org/10.1093/icesjms/fst058

IUCN. (2021). The IUCN Red List of Threatened Species. Version 2021-1. https://www.iucnredlist.org. Downloaded on 20th July 2021.

Jabado, R. W., Kyne, P. M., Pollom, R. A., Ebert, D. A., Simpfendorfer, C. A., Ralph, G. M., Al Dhaheri, S. S., Akhilesh, K. V, Ali, K., Ali, M. H., Al Mamari, T. M. S., Bineesh, K. K., Elhassan, I. S., Fernando, D., Grandcourt, E. M., Moazzam Khan, M., Moore, A. B. M., Owfi, F., Robinson, D. P., … Dulvy, N. K. (2018). Troubled waters: threats and extinction risk of the sharks, rays, and chimaeras of the Arabian Sea and adjacent waters. *Fish and Fisheries*, March, 1–20. https://doi.org/10.1111/faf.12311

Jaini, M., Advani, S., Shanker, K., Oommen, M. A., & Namboothri, N. (2018). History, culture, infrastructure and export markets shape fisheries and reef accessibility in India's contrasting oceanic islands. *Environmental Conservation, 45*(1), 41-48. doi:10.1017/S037689291700042X

Jamieson, M. A., Carper, A. L., Wilson, C. J., Scott, V. L., & Gibbs, J. (2019). Geographic biases in bee research limits understanding of species distribution and response to anthropogenic disturbance. *Frontiers in Ecology and Evolution*, 7(JUN), 1–8. https://doi.org/10.3389/fevo.2019.00194

Karnad, D., Gangal, M., & Karanth, K. K. (2014). Perceptions matter: how fishermen's perceptions affect trends of sustainability in Indian fisheries. *Oryx*, 48(2), 218-227. doi:10.1017/S0030605312001251

Karnad, D. (2018). Conservation amidst shifting sands in India's marine fisheries. In: Srinivasan and Velho (eds) Conservation from the Margins, Orient Blackswan, pp 276.

Karnad, D., Sutaria, D., & Jabado, R. W. (2019). Local drivers of declining shark fisheries in India. *Ambio*. https://doi.org/10.1007/s13280-019-01203-z

Kizhakudan, S. J., Zacharia, P. U., Thomas, S., Vivekanandan, E., & Menon, M. (2015). Guidance on National Plan of Action for Sharks in India (p. 104). http://eprints.cmfri.org.in/10403/1/NPOA_SHARKS.pdf

Kizhakudan, S. J., Zacharia, P. U., Thomas, S., Najmudeen, T. M., Akhilesh, K. V., Muktha, M., ... & Wilson, L. (2019). Marine Fisheries Policy Series No. 14; India Non-

Detriment Finding (NDF) for thresher sharks, *Alopias spp*., in the Indian Ocean. *Marine Fisheries Policy Series*, (14), 1-60.

Kumari, B., & Raman, M. (2010). Whale shark habitat assessments in the northeastern Arabian Sea using satellite remote sensing. *International Journal of Remote Sensing*, *31*(2), 379-389.

Kuppusamy, S., Johnson, J.A., Pande, A. (2013) Research gaps in coastal and marine conservation in India. In Coastal and Marine Protected Areas in India: Challenges and Way Forward; Sivakumar, K., (Ed.); Wildlife Institute of India: Dehradun, India, pp. 230–241.

Last, P., Naylor, G., Séret, B., White, W., de Carvalho, M., & Stehmann, M. (Eds.). (2016). *Rays of the World*. CSIRO publishing.

MacKeracher, T., Mizrahi, M. I., Bergseth, B., Maung, K. M. C., Khine, Z. L., Phyu, E. T., ... & Diedrich, A. (2021). Understanding non-compliance in small-scale fisheries: shark fishing in myanmar's Myeik archipelago. *Ambio*, *50*(3), 572-585. https://doi.org/10.1007/s13280-020-01400-1

Marco, M. Di, Chapman, S., Althor, G., Kearney, S., & Watson, J. E. M. (2017). Changing trends and persisting biases in three decades of conservation science. *Global Ecology and Conservation*, 10, 32–42. https://doi.org/10.1016/j.gecco.2017.01.008

Martins, A. P. B., Heupel, M. R., Chin, A., & Simpfendorfer, C. A. (2018). Batoid nurseries: Definition, use and importance. *Marine Ecology Progress Series*, 595, 253–267. https://doi.org/10.3354/meps12545

Mas, M., Flaquer, C., Rebelo, H., & López-Baucells, A. (2021). Bats and wetlands: synthesising gaps in current knowledge and future opportunities for conservation. *Mammal Review*, 51, 369–384. https://doi.org/10.1111/mam.12243

Mason, J. G., Alfaro-Shigueto, J., Mangel, J. C., Crowder, L. B., & Ardoin, N. M. (2020). Fishers' solutions for hammerhead shark conservation in Peru. *Biological Conservation*, 243(January), 108460. https://doi.org/10.1016/j.biocon.2020.108460

McNeely, J. A., Kapoor-Vijay, P., Zhi, L., Olsvig-Whittaker, L., Sheikh, K. M., & Smith, A. T. (2009). Conservation biology in Asia: The major policy challenges. *Conservation Biology*, 23(4), 805–810. https://doi.org/10.1111/J.1523-1739.2009.01284.X

Meijaard, E., & Sheil, D. (2007). Is wildlife research useful for wildlife conservation in the tropics? A review for Borneo with global implications. *Biodiversity and Conservation*, 16(11), 3053–3065. https://doi.org/10.1007/s10531-007-9161-y

Milner-Gulland, E. J., Barlow, J., Cadotte, M. W., Hulme, P. E., Kerby, G., & Whittingham, M. J. (2012). Ensuring applied ecology has impact. *Journal of Applied Ecology*, 49(1), 1–5. https://doi.org/10.1111/j.1365-2664.2011.02102.x

Mishra, M., Sudarsan, D., Santos, C. A. G., Mishra, S. K., Kar, D., Baral, K., & Pattnaik, N. (2021). An overview of research on natural resources and indigenous communities: a bibliometric analysis based on Scopus database (1979–2020). *Environmental Monitoring and Assessment* 2021 193:2, 193(2), 1–17. https://doi.org/10.1007/S10661-020-08793-2

Mohamed, K. S., & Malayilethu, Vinod. (2013). Towards an ecosystem approach to fisheries management in India - case study of the Ashtamudi Lake yellow-foot clam fishery. In: Regional Symposium on Ecosystem Approaches to Marine Fisheries & Biodiversity, October 27-30, 2013, Kochi.

Mohamed, K. S. (2013). Ecosystem approach to marine fisheries management. In: ICAR funded Short Course on "ICT -oriented Strategic Extension for Responsible Fisheries Management, 05-25 November, 2013, Kochi.

Monsarrat, S., Novellie, P., Rushworth, I., & Kerley, G. (2019). Shifted distribution baselines: Neglecting long-term biodiversity records risks overlooking potentially suitable habitat for conservation management. *Philosophical Transactions of the Royal Society B: Biological Sciences*, 374(1788). https://doi.org/10.1098/rstb.2019.0215

Muenchow, J., Dieker, P., Kluge, J., Kessler, M., & von Wehrden, H. (2018). A review of ecological gradient research in the Tropics: identifying research gaps, future directions, and conservation priorities. *Biodiversity and Conservation*, 27(2), 273–285. https://doi.org/10.1007/s10531-017-1465-y

NOAA. (2021). *Understanding Ecosystem-Based Fisheries Management*. https://www.fisheries.noaa.gov/insight/understanding-ecosystem-based-fisheries-management. Retrieved on 20th July 2021.

Pitman, N. C. A., Widmer, J., Jenkins, C. N., Stocks, G., Seales, L., Paniagua, F., & Bruna, E. M. (2011). Volume and geographical distribution of ecological research in the Andes and the Amazon, 1995-2008. *Tropical Conservation Science*, 4(1), 64–81. https://doi.org/10.1177/194008291100400107

Premjothi, P. V. R., Choudury, B. C., Kaul, R., Subburaman, S., Matwal, M., Joshi, D., ... & Menon, V. (2016a). An assessment of the past and present distribution status of the whale shark (Rhincodon typus) along the west coast of India. In *The 4th International Whale Shark Conference* (Vol. 2016, No. 2, p. 43). Hamad bin Khalifa University Press (HBKU Press).

Premjothi, P. V. R., Goutham, S., Subburaman, S., Bloch, F., Bhattacharya, T., Choudhury, B. C., ... & Menon, V. (2016b). New records of neonatal whale sharks (Rhincodon typus) from the Arabian Sea and discovery of a possible natal ground on the Gujarat coast, India. In *The 4th International Whale Shark Conference* (Vol. 2016, No. 2, p. 44). Hamad bin Khalifa University Press (HBKU Press).

Pullin, A. S., Knight, T. M., Stone, D. A., & Charman, K. (2004). Do conservation managers use scientific evidence to support their decision-making? *Biological Conservation*, 119(2), 245–252. https://doi.org/10.1016/j.biocon.2003.11.007

QGIS.org, 2021. QGIS Geographic Information System. QGIS Association. http://www.qgis.org

R Core Team (2014). R: A Language and Environment for Statistical Computing. Vienna: R Foundation for Statistical Computing.

Rasalato, E., Maginnity, V., & Brunnschweiler, J. M. (2010). Using local ecological knowledge to identify shark river habitats in Fiji (South Pacific). *Environmental Conservation*, 37(1), 90–97. https://doi.org/10.1017/S0376892910000317

RStudio Team (2015). RStudio: Integrated Development for R. Boston, MA: RStudio, Inc.

Sabbagh, S. M., & Hickey, G. M. (2020). Social factors affecting sustainable shark conservation and management in Belize. *Sustainability*, 12(1), 1–19. https://doi.org/10.3390/SU12010040

Salim, S. S. (2020). Demand pattern and willingness to pay for high value fish consumption: Case study from selected coastal cities in Kerala, South India. *Indian Journal of Fisheries*, 67(3), 135–143. https://doi.org/10.21077/ijf.2020.67.3.70635-15

Sheil, D. (2002). Why doesn't biodiversity monitoring support conservation priorities in the tropics? *Unasylva*, 53(209), 50–54.

Simpfendorfer, C. A., Heupel, M. R., White, W. T., & Dulvy, N. K. (2011). The importance of research and public opinion to conservation management of sharks and rays: A synthesis. *Marine and Freshwater Research*, 62(6), 518–527. https://doi.org/10.1071/MF11086

Skubel, R. A., Shriver-Rice, M., & Maranto, G. M. (2019). Introducing relational values as a tool for shark conservation, science, and management. *Frontiers in Marine Science*, 6(53). https://doi.org/10.3389/fmars.2019.00053

Staples, D. & Funge-Smith, S. (2009) Ecosystem approach to fisheries and aquaculture: Implementing the FAO Code of Conduct for Responsible Fisheries. FAO Regional Office for Asia and the Pacific, Bangkok, Thailand. RAP Publication 2009/11, 48pp.

Stevens, J. D., Bonfil, R., Dulvy, N. K., & Walker, P. A. (2000). The effects of fishing on sharks, rays, and chimaeras (chondrichthyans), and the implications for marine ecosystems. *ICES Journal of Marine Science*, 57(3), 476–494. https://doi.org/10.1006/jmsc.2000.0724

Suryawanshi, K. R., Khanyari, M., Sharma, K., Lkhagvajav, P., & Mishra, C. (2019). Sampling bias in snow leopard population estimation studies. *Population Ecology*, 61(3), 268–276. https://doi.org/10.1002/1438-390X.1027

Sutherland, W. J., Taylor, N. G., MacFarlane, D., Amano, T., Christie, A. P., Dicks, L. V., Lemasson, A. J., Littlewood, N. A., Martin, P. A., Ockendon, N., Petrovan, S. O., Robertson, R. J., Rocha, R., Shackelford, G. E., Smith, R. K., Tyler, E. H. M., & Wordley, C. F. R. (2019). Building a tool to overcome barriers in research-implementation spaces: The conservation evidence database. *Biological Conservation*, 238(August), 108199. https://doi.org/10.1016/j.biocon.2019.108199

Teixido, A. L., Gonçalves, S. R. A., Fernández-Arellano, G. J., Dáttilo, W., Izzo, T. J., Layme, V. M. G., Moreira, L. F. B., & Quintanilla, L. G. (2020). Major biases and

knowledge gaps on fragmentation research in Brazil: Implications for conservation. *Biological Conservation*, 251(July), 108749. https://doi.org/10.1016/j.biocon.2020.108749

Thanuskodi, S., & Venkatalakshmi, V. (2010). The growth and development of research on ecology in India: a bibliometric study. *Library Philosophy and practice*, 1.

Townsend, H., Harvey, C. J., deReynier, Y., Davis, D., Zador, S. G., Gaichas, S., Weijerman, M., Hazen, E. L., & Kaplan, I. C. (2019). Progress on implementing Ecosystem-Based Fisheries Management in the United States through the use of ecosystem models and analysis. *Frontiers in Marine Science*, 0, 641. https://doi.org/10.3389/FMARS.2019.00641

Tyabji, Z., Wagh, T., Patankar, V., Jabado, R. W., & Sutaria, D. (2020). Catch composition and life history characteristics of sharks and rays (Elasmobranchii) landed in the Andaman and Nicobar Islands, India. *PloS one*, 15(10), e0231069. https://doi.org/10.1371/journal.pone.0231069

Vijayakumaran, K. (2014). Are we ready for Ecosystem Approach to Fisheries Management. In: International Training Programme on Ecosystem Approach to Fisheries Management, 11 August 2014, Chennai.

Vincent, A. C. J., Sadovy de Mitcheson, Y. J., Fowler, S. L., & Lieberman, S. (2014). The role of CITES in the conservation of marine fishes subject to international trade. *Fish and Fisheries*, 15(4), 563–592. https://doi.org/10.1111/faf.12035

Wang, F., Winkler, J., Vina, A., McShea, W. J., Li, S., Connor, T., ... & Liu, J. (2021). The hidden risk of using umbrella species as conservation surrogates: A spatio-temporal approach. *Biological Conservation*, *253*, 108913. https://doi.org/10.1016/j.biocon.2020.108913

Williams, D. R., Balmford, A., & Wilcove, D. S. (2020). The past and future role of conservation science in saving biodiversity. *Conservation Letters*, 13(4), 1–7. https://doi.org/10.1111/conl.12720

Wintle, B. C., Kennicutt II, M. C., & Sutherland, W. J. (2020). Scanning horizons in research, policy and practice. *Conservation research, policy and practice*, *1*, 29-47.

Wraith, J., Norman, P., & Pickering, C. (2020). Orchid conservation and research: An analysis of gaps and priorities for globally Red Listed species. *Ambio*, 49(10), 1601–1611. https://doi.org/10.1007/s13280-019-01306-7

WWF. (2021). The shark and ray meat network. A deep dive into a global affair.

Wyatt, T., Friedman, K., & Hutchinson, A. (2021). Are Fish Wild? *Liverpool Law Review*, July. https://doi.org/10.1007/s10991-021-09285-0

Zacharia, P. U., & Vivekanandan, E. (2013). Shark fishery and conservation in Indian waters: need for a National Plan of Action. In: Regional Symposium on Ecosystem Approaches to Marine Fisheries & Biodiversity, October 27-30, 2013, Kochi.

Zacharia P.U., Shoba Joe Kizhakudan, Sujitha Thomas, P.P. Manojkumar, Rekha J. Nair, T.M. Najmudeen, G.B. Purushottama, M. Muktha, Swathipriyanka Sen Dash, K.V. Akhilesh & L. Remya. (2017). Non-Detriment Findings (NDF) for the export of Shark and Ray species listed in Appendix II of the CITES and harvested from Indian waters. Marine Fisheries Policy Series No. 6, Central Marine Fisheries Research Institute, Kochi, India, 240 pp.

Zacharias, M. A., & Roff, J. C. (2001). Use of focal species in marine conservation and management: a review and critique. *Aquatic Conservation: Marine and Freshwater Ecosystems*, *11*(1), 59-76.