Sharks and rays in troubled waters

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DOI:
10.33612/diss.986573116

Publication date:
2024

Chapter 10

Opportunities and challenges in value chain analysis for sustainable management of sharks and rays

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Published in Marine Policy (2024)

Abstract

Studies on elasmobranch trade have often focused on a single commodity: shark fins. Such a narrow focus can result in an incomplete understanding of the socio-cultural importance of sharks, limiting discussion on the range and efficacy of potential management interventions. Assessments must be performed across the value chain from fisher to retail vendor to better conserve vulnerable elasmobranch species, offering a broader view of capture, use, and trade. Here, we collate insights from shark value chain assessments conducted in eight countries (Mexico, Peru, Guinea-Bissau, India, Bangladesh, Sri Lanka, Indonesia and Fiji) spanning five continents. Approaches and processes implemented in a shark value chain analysis (VCA) were reviewed to understand: (1) better approaches and tools and (2) to collate shared experiences. Our results demonstrate that VCAs broaden the outlook of fishery and trade assessments when capturing a more comprehensive range of economic and socio-cultural aspects (e.g., livelihoods, cultural use of commodities) of trade in all shark commodities. Time invested in various components of assessments produced different outcomes, with considerable returns from stakeholder selection, survey design, and assessor/stakeholder relationship building. Contrastingly, results demonstrated that efforts in communication with stakeholder groups and policymakers could be further streamlined to focus on key results using a variety of communication formats. Outcomes from this study offer guidance to those embarking on shark VCAs, facilitating improving the assessment process and outcomes.

Introduction

Many sharks and rays (hereafter referred to as 'sharks') targeted or inadvertently captured in fisheries have slow life history traits, such as late maturity and low fecundity, that make them vulnerable to overexploitation and their populations slow to recover (Castillo-Géniz *et al.* 1998; Dulvy *et al.* 2021). Due to stressors such as overfishing and habitat degradation, approximately one-third of all Chondrichthyan species (i.e., sharks, rays and chimeras) are currently threatened with extinction (Dulvy *et al.* 2021). With many sharks caught as bycatch, their outlook is uncertain due to challenges preventing their effective conservation (Juan-Jordá *et al.* 2022; Sherman *et al.* 2023). Recognition of the important ecological (e.g., Heupel *et al.* 2014, Bird *et al.* 2018) and socio-cultural system roles (e.g., Leeney and Poncelet, 2015) of sharks has led to a strengthening in their management and conservation. Management measures are either implemented at an international, national or regional level (Techera and Klein, 2011; FAO, 1999). However, the cross-border movements of sharks (Veríssimo *et al.* 2017; Nosal *et al.* 2021), and their fisheries and trade, can complicate management approaches, emphasizing the need for fishery and trade controls over various spatial scales and across jurisdictional boundaries (Friedman *et al.* 2018). Issues concerning the (mis)identification and mislabeling of shark species further complicate the management of trade and fisheries of these species (Hasan *et al.* 2023).

Multi-lateral environmental agreements like the Convention on International Trade in Endangered Species of Wild Fauna and Flora, also known as CITES, can contribute to shark conservation (https://cites.org/eng). Species listed on Appendix II of the convention come under provisions by a country to ensure both legality and sustainability of trade in that species and its commodities. Global efforts to strengthen governance have focused on shark fin due to its importance in driving exploitation and trade, stemming from its high value (Shiffman and Hueter, 2017). Focusing exclusively on this perspective of shark use fails to incorporate and manage other drivers of use and trade, such as the importance of other commodities like shark meat. Some information on other commodities such as meat (Bornatowski *et al.* 2018, Karnad *et al.* 2020, WWF, 2021), liver/squalene (Hasan *et al.* 2017), and skin (Dent and Clarke, 2015) exist, but background and time-series information remains limited. Additionally, the challenging task of identifying shark commodities other than fins in trade complicates efforts to improve sustainability (Hasan *et al.* 2023). For example, shark fins are an easily recognizable commodity, although identifying fins at the species level remains an ongoing challenge. Other shark commodities like meat are often destined for local or regional markets (Dent and Clarke, 2015) and are less easily discernable across shark species and from other fish. To address these issues, sharks of the Carcharhinidae family were all listed under CITES to ease implementation (CITES, 2022).

Once a species is CITES listed, parties are bound to deliver on the convention's provisions, yet many face challenges in implementing conservation strategies due to the limited availability of resources and capacity (Parker *et al.* 2012, Adenle *et al.* 2015). In response, some authorities have instituted retention or trade bans despite such bans being associated with potential increases in non-compliance across existing markets (Friedman *et al.* 2018).

Traditionally, investment in fisheries management predominantly focuses on understanding the population status of a species to guide levels of exploitation (e.g., with monitoring of catches and stock assessments to determine a measure of maximum sustainable yield, see Methot and Wetzel, 2013; Hilborn, 2020). Although stock assessments provide indicators and measures of the status of resource populations (Kleiber *et al.* 2009, Punt *et al.* 1998), translating this information into practical and effective management solutions consistent with the importance of sharks for people and the environment remains an ongoing challenge (Castellanos-Galindo *et al.* 2021). In addition, shark declines are often related to trade in shark-derived commodities (Pacoureau *et al.* 2021), highlighting the need to address knowledge gaps surrounding the entire value chain (VC) of use and trade in sharks. Recently, studies have suggested more holistic approaches to understanding the entire value chain of shark fisheries, aiming to disincentivize the unsustainable use of sharks (e.g., Booth *et al.* 2019; Haque *et al.* 2021). These approaches have been proposed to design and deliver a combination of locally appropriate management actions rooted in sustainability and inclusiveness (e.g., the inclusion of local community members and their needs in the process),

Gaining insights into the primary considerations underlying how sharks are fished, used, and sold offers broader opportunities for leverage points involved in adaptive management (Garcia *et al.* 2003, Staples and Funge-Smith, 2009). These types of insights are sought through value chain analysis (VCA) approaches (e.g., see Hellin and Meijer, 2006). In a VCA, researchers aim to map the socio-economic and ecological aspects of the full range of activities in a fishery, from the moment of commodity acquisition to disposal after use by the final consumer. This information identifies opportunities for improved or new policies for the adaptive management of sharks.

The social importance of sharks needs to be considered when designing policy changes, as a large variety of stakeholders depend on sharks due to the breadth of shark-derived commodities traded and the tourism sector relying on sharks.

In this study, we aim to identify crucial steps in conducting shark VCAs and provide important lessons learned by researchers experienced in conducting shark VCAs. To assist those designing and conducting shark VCAs, assessment programs currently active across five continents were reviewed to:

(1) document better approaches and tools, and

(2) collate shared experiences and current understanding.

The results of this study highlight how socio-cultural and economic aspects of shark fishery and trade management are included in shark VCAs. Importantly, recommendations are provided for researchers considering the added value, including which approach to take in running assessments to support the adaptive management of shark value chains.

Methods

Development of Guidance for Shark VCAs

To assist in VCAs focused specifically on sharks, the Food and Agriculture Organization of the United Nations (FAO) is developing generic shark and ray VCA guidance in close cooperation with managers and researchers. The guidance is aimed at fishery managers to support their efforts to assess the current state, management and sustainability of shark value chains. To date, the development of the guidance has been informed by ongoing work of the FAO under the Shark International Plan of Action (IPOA) umbrella (FAO, 1999) and expert meetings (ICAR, 2019) to assist country planning and implementation of shark VCAs. FAO's draft guidance describes five essential 'steps' of the VCA process, each describing respective 'tasks' to undertake in delivering a shark VCA (Table 10.1).

Data collection

Researcher teams from eight countries involved in shark VCAs were requested to participate in this study to share experiences and recommendations. Researchers were selected based on the workshop by the FAO and the Central Marine Fisheries Research Institute of India (CMFRI; Kochi, India 2019) or based on authorship of academic publications on shark value chains.

Lead researchers of participating teams were asked to collaborate in the study by:

(1) completing a semi-structured interview to describe their shark VCA process and experiences;

(2) sharing their shark VCA surveys and outputs (e.g., survey questionnaires, reports, draft manuscripts) for review; and

(3) taking part in a structured questionnaire to quantify the effort invested in relation to outputs and outcomes achieved in different VCA activities and tools.

Table 10.1 Overview of the steps and tasks for shark value chain assessments as described in the (draft) guidance by the Food and Agriculture Organization of the United Nations (FAO). Discussed during an expert workshop in Kochi (India) in 2019 (ICAR, 2019).

Step	Task
1. Establishment of a Monitoring, Evaluation and Reporting Process.	1.1. Identifying and documenting value(s) and objective(s) of the assessment.
	1.2. Searching out available information.
	1.3. Considering key stakeholders and key stakeholder groups.
	1.4. Preliminary value chain mapping and selection.
2. Designing a Survey.	2.1. Determine what will be measured.
	2.2. Decide on the form of the survey.
3. Deploying a Survey	3.1. Logistical planning of survey deployment.
	3.2. Survey deployment.
4. Management and Use of Data	4.1. Formatting and consolidating data.
	4.2. Data processing and analysis.
5. Communication and Adaptive Management	5.1. Identifying an adaptive management framework.
	5.2. Monitoring implementation and response of adaptive management.

The work of all participating teams covered a total of 94 ports and trade sites across Mexico, Peru, Guinea-Bissau, India, Sri Lanka, Bangladesh, Indonesia, and Fiji (Figure

10.1). Together, these countries are responsible for 33.1% (2010-2021) of production and 9.8% in exports (2019-2021) of elasmobranch commodities. However, production varies significantly amongst countries. For example, Guinea-Bissau is only responsible for 0.001%, and Indonesia has a 15.6% share in global reported production (FAO, 2023).

Semi-structured interviews

Semi-structured interviews, comprising 14 open-ended questions (Appendix 10.1), were conducted to understand approaches and tools used in shark VCAs and to identify lessons learned during their analysis. Participants were asked to describe their VCA process from planning and delivery to outputs, outcomes and communication (i.e., following the guidance steps and tasks described in Table 10.1). Participating researchers were also asked about their main objectives in conducting a VCA to determine if the primary objective of the VCA was: i) improving the population status of sharks (referred to as 'Resource'), ii) improving the livelihoods of fishery participants (referred to as 'Fisher'), or iii) measuring the impact(s) and effectiveness of management interventions by the relevant fisheries authority (referred to as 'Management'). In addition, for each step of their shark VCA, researchers were asked to report on the 'better' and 'poor' practices they had identified during the implementation of the shark VCA. These recommendations are defined as what was effective in terms of effort allocation and generated outcomes for adaptive management ('better practices') and examples of what was less effective or required adaptation during the process ('poor practices'). All recommendations were included in this study but were condensed and merged when multiple researchers referred to similar experiences.

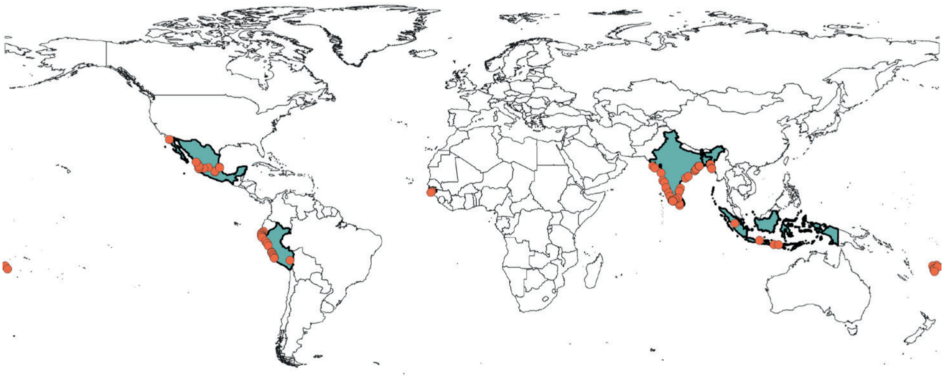

Figure 10.1 The global distribution of landing sites and ports where shark value chain assessments included in this study were conducted. Red points indicate single ports or landing sites where sampling was conducted, and countries of sampling studies are colored in blue (Fiji, Mexico, Peru, Guinea-Bissau, India, Sri Lanka, Bangladesh and Indonesia).

Questionnaire and output reviews

Researchers were asked to share questionnaires used in their respective shark VCA, and any (draft) outputs and outcomes resulting from their assessment (e.g., reports, manuscripts) were also shared. For each study, the VCA questionnaires were reviewed to determine and quantify the lines of inquiry with regard to further understanding the research focus along the three objectives stated earlier (resource, fisher or management focus) and the scale and breadth of the assessment (fisher, mid-chain, end-seller, exporter, consumer). Any reports (including manuscripts and final draft reports) describing the outcomes of VCAs were also reviewed to supplement the formerly described inquiry.

Table 10.2 The description of topics included in the value chain assessments.

	Topic	Description
←Social-Ecological System Continuum→	Diversity of species impacted	Species specific information before processing.
	Quantity of extraction	The number of kilograms or liters of a certain commodity.
	Fishing locations/habitats impacted	Description of fishing areas and marine habitats impacted by fisheries.
	Compliance and Environmental law	Knowledge, compliance, and description of environmental laws and regulations.
	Fisher demographics	Personal and demographic information (e.g., age, residence, family in the business).
	Fisher experience (temporal)	Questions describing the experience of the interviewee (e.g., years in fisheries/trading, job specification).
	Fishing effort	Information describing (a change in) fishing effort (e.g., soak times, fishing days) exerted on marine species within the respective study area.
	Traditional/Cultural links	Traditional and cultural use of shark commodities or fisheries.
	Livelihoods	Income, costs, and importance of fisheries to the livelihood.
	Gear and boats	The description of used gear and boats (e.g., specifics on boats, mesh size, crew size).
	Preservation and waste	
	Processing	Processing of sharks and rays.
	Commodity pricing	Prices of sharks and rays or related commodities.
	Trade logistics	The route along which commodities and traded or transported.

Shark VCA questionnaires were analyzed by classifying each question into topics along the social-ecological continuum (e.g., livelihoods, traditions, demographics, habitats impacted, commodity processing and prices) (Table 10.2). The proportion of each of these topics was calculated (i.e., the number of questions on a specific topic as the proportion of the total number of questions of the survey used), which was used as a proxy for the line of questioning used for each shark VCA concerning the main objective of the assessment (e.g., 'resource', 'fisher' or 'management' focus) or target-link of the value chain (e.g., fisher, mid-chain, seller). The differences in survey design were tested for significance using a Chi-squared test.

Structured survey

Based on the semi-structured interviews and review of VCA outputs, participants were asked to contribute through a structured survey comprising six closed and five open-ended questions. Researchers were asked to rank the steps and tasks of their shark VCA in terms of effort allocation (i.e., time and resources) and delivery in terms of insights gained or outcomes generated (protocol provided in supplementary material). In addition, the survey also included questions on how shark VCAs compared to or complemented traditional fishery assessments that were more focused on the status of shark stocks.

To allow participants to consider the inputs of others in the study before settling on their final responses, participant researchers were able to anonymously review all other responses after completion of the survey and adapt their responses before final submission (as per the Delphi method, see Hemming *et al.* 2018).

Researchers were asked to rank the steps and tasks of the shark VCA process (see Table 10.1) on an ordinal scale. For the steps, this was on a scale from 1 (most effort and/or most valuable outcomes) to 5 (least effort and/or least valuable outputs), and for the ranking of tasks within each step, this was on a scale from 1 (most effort and/or most valuable outputs) to 12 (least effort and/or least valuable outputs). Scoring of invested effort and generated outcomes of the structured survey were used to calculate rank indices for each step and task. A ranking index (RI) was calculated by taking the effort ranking (R_{effort}) minus the output ranking ($R_{outcome}$), divided by the number of available ranking positions (R_{max}; R_{max} = 5 for steps and 12 for tasks). For the draft FAO guidance 'steps' (n = 5), the RI ranges from -0.80 to 0.80, with -0.8 indicating the minimum efficiency (i.e., high effort and low generated outcome), 0.0 indicating a relatively balanced efficiency (i.e., no difference between invested effort and generated outcomes), and 0.8 indicated the maximum efficiency (i.e., a low invested effort led to high generated outcomes). For in-step tasks (draft FAO guidance 'tasks', n = 12), the RI ranges from -0.9 (low efficiency) to 0.9 (high efficiency). A one-sample Wilcoxon signed-rank test was used to determine if ranking indices differed significantly from zero. To determine if ranking indices differed among the three assessment focus groups, a non-parametric Kruskal-Wallis analysis of variance was used in combination with Dunn's post-hoc test.

Ethics statement

All participants were informed about the outline and intention of the study prior to data collection. Informed consent was given by all teams participating, and all were allowed to change their contribution to this study at any time. All participants approved the publication of their contribution as described in this manuscript.

Results

Shark VCA focus and objectives

The eight participating studies ranged from local, national and regional assessments of shark VCAs (Table 10.3). The common objective of all assessments was to elucidate information on the nature and extent of the shark fishery and trade, how this historically evolved, and the level of compliance with regulations. Two of the eight studies included assessments focused predominantly on the 'resource' (population trends and status), three on 'fishers' (the role and livelihood of the fishing community), and three on 'management' (assessments focused primarily on evaluating regulations while mapping trade). Five out of eight assessments included the primary links in the value chain (fisher, mid-chain and end-seller), and three assessments included additional links like exporters and consumers (Table 10.3).

Table 10.3 Overview of the shark value chain assessments analyzed as part of this study, including the scale (local, regional, national or international), the primary focus of the assessment (resource, fisher or management authority), links assessed in the VCA, and the main objective of each assessment.

			Links assessed					
Country	**Scale**	**Primary focus**	**Fisher**	**Mid-Chain**	**End-Seller**	**Exporter**	**Consumer**	**Main objective**
Peru	National	Fisher	•	•	•	•		Describe current and retrospective trade of non-fin shark and ray commodities within Peru.
Guinea Bissau	Local	Resource	•					Reconstruction of shark and ray fisheries and landings over the past decades, including reconstruction of population trends.
Sri Lanka	Regional	Fisher	•	•	•	•		Determine socio-economic drivers for shark fishing according to shark commodity and ascertain social reliance.
Bangladesh	National	Resource	•	•				Determine the baseline in landing data of sharks and rays in coastal fisheries and map national and international trade routes.
India	National	Management authority	•	•	•		•	Supplement stock assessments with information on the trade in shark and ray species.
Indonesia	National	Management authority	•	•	•		•	Map the trade of non-fin shark commodities and determine how these commodities are used within Indonesia.
Fiji	National	Fisher	•	•				Describe the characteristics of the fishery, determine if sharks are targeted or a bycatch species, describe how sharks are utilized and how they contribute to food security.
Mexico	National	Management authority	•	•	•			Determine how the market for shark commodities work with a focus on domestic shark meat market and the international market for other shark commodities.

Measuring effectiveness and efficiency across effort investment and outcomes of VCAs

Considering the multi-step process of establishing and implementing a VCA, the cross-study overview presented here showed that effort allocation and outcome returns were highest for investment in the survey questionnaire design step. This indicates that investing more effort in survey design leads to the most valuable outcome of the five-step assessment process (Figure 10.2A). Examining what could be learned across the various steps individually highlights specific learnings that can inform new assessments (Figure 10.2).

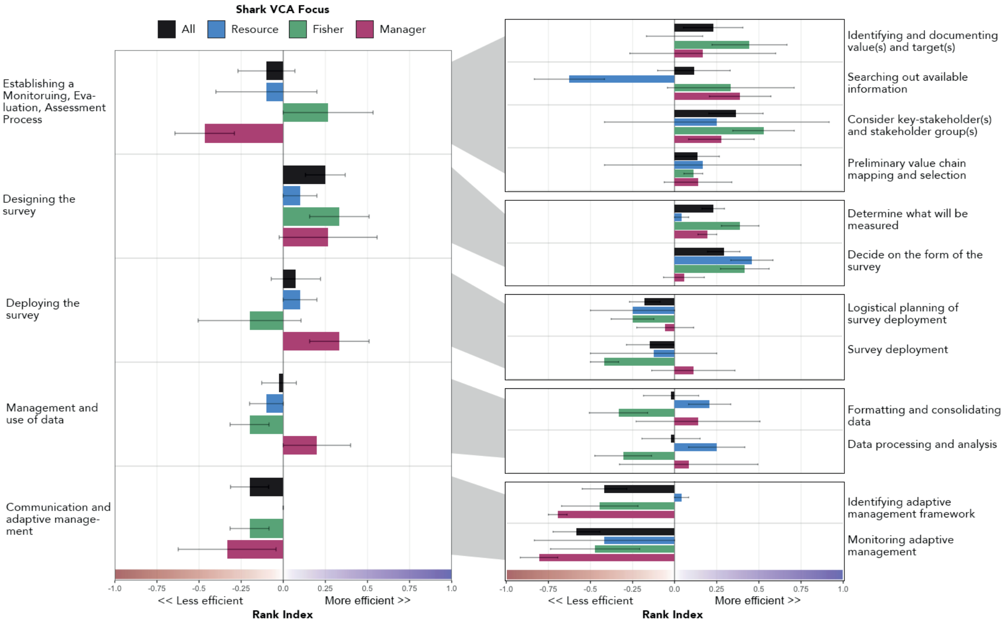

Figure 10.2 The mean ranking indices for each step (left) and associated tasks (right) as described in the FAO guidance for shark VCAs. Participants were asked to rank the steps and tasks of a VCA based on (1) effort and resources spent and (2) how these steps and tasks contributed to the valuable outcomes of their assessment. A negative ranking index indicates that the effort invested did not lead to more generated outputs (less efficient), an index of zero indicates that effort investment and generated outcomes are balanced, and a positive ranking index indicates that the effort invested led to more valuable outputs (more efficient). Error bars indicate the standard error of the mean, colors indicate the focus of the assessment (black = all assessments, blue = resource focused, green = fisher focused, red = management authority focused), and asterisks indicate significance.

Establishing a Monitoring, Evaluation and Reporting Process

The first step of a shark VCA is identifying and documenting the value(s) and objective(s) of the assessment, as well as searching for information and considering key stakeholders and stakeholder groups (i.e., establishing a monitoring, evaluation and reporting process). This initial step showed a lower ranking index when compared to other steps (RI = -0.10 ± 0.17; mean ± std. error), indicating that most researchers felt they invested more resources and time in this than necessary for the generated outputs (Figure 10.2A). However, when researchers were asked to rank the different tasks belonging to this step, these tasks were thought to contribute towards valuable outcomes of the overall assessment. Identifying key stakeholders was thought to be the most important of the tasks during this preparation step (RI = 0.36 ± 0.16, see Figure 10.2B). Searching for available information was also thought to be important but had the lowest ranking index (RI = 0.11 ± 0.22) of all four tasks in this step.

Designing a survey

The mean ranking index was highest for the second step of a shark VCA, the survey design step, but did not significantly differ from other steps (RI = 0.25 ± 0.12; X^2 = 33.1, d.f. = 11, p = 0.09, see Figure 10.2A). The ranking indices for the tasks within this step show the benefit of investing more effort in determining what will be measured (RI = 0.23 ± 0.07; V = 28, p = 0.02) and the correct format of the survey (RI = 0.29 ± 0.01; V = 33.5, p = 0.04, see Figure 10.2B).

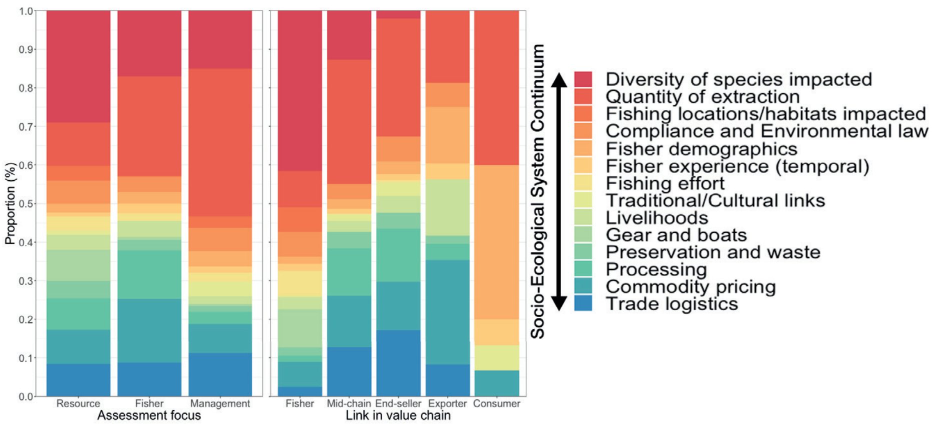

Figure 10.3 Reported relative importance of different topics along the continuum of social-ecological systems within value chain assessment questionnaires, considering the focus of the assessment (left) or the target links that comprise elements of the value chain (right).

The survey design did not markedly differ between assessments focused on resource use, fisher or management authority, or between surveys conducted within different links in the value chain (Figure 10.3). Generally, more information on species and commodity quantities was collected in fisher and mid-chain surveys. In contrast, the focus turned to processing and preservation of commodities in surveys with sellers and exporters. Also, researchers suggested that they spent less effort collecting biological data (e.g., species composition, length) when moving down the value chain (i.e., from fisher to consumer). In mid-chain surveys, the effort spent collecting commodity data (e.g., processing, commodity quantities, pricing and trade routes) increased to determine the flow of commodities and related economic measures. The collection of socio-cultural information (e.g., livelihoods, traditions, and demographics) also increased when moving up the value chain to allow researchers to determine the cultural and traditional motivation behind use and trade.

Deploying a survey

The investment versus return on survey deployment step was relatively balanced (RI = 0.01 ± 0.15; Figure 10.2), meaning that researchers indicated that the effort spent on this step aligned with the generated outcomes for the assessment. Contrastingly, both associated tasks show a negative ranking index, indicating that relatively more time and resources were invested in the logistical planning of survey deployment (RI = -0.18 ± 0.09) and the deployment itself (RI = -0.15 ± 0.14) concerning the contribution of these steps to the most valuable outcomes of the assessment.

Management and use of data

Participants highlighted that resource and time use should be better balanced, with the need for investment in the management and use of data (RI = -0.03 ± 0.10; Figure 10.2), as consolidating data (RI = -0.02 ± 0.16) and the processing data (RI = -0.02 ± 0.17) showed a balanced ranking index.

Communication and adaptive management

The last step of the shark VCA, the communication of findings and use of knowledge for adaptive management had the lowest ranking index of all steps (RI = -0.20 ± 0.11; Figure 10.2), indicating that efforts spent on this step contributed the least to generating valuable outcomes of their assessment relatively to other steps. Researchers indicated that the effort invested into identifying the management framework (RI = -0.42 ± 0.13) and monitoring adaptive management (RI = -0.58 ± 0.14) did not result in more desired outputs from the assessment compared to other tasks. These two tasks also significantly differed from the tasks with a positive ranking index (task 1-6; $H = 33.06$, $p > 0.001$).

Recommendations for shark VCA steps based on real-world experiences

Establishing a monitoring, evaluation and reporting process

All research teams indicated that investment in stakeholder selection and trust-building between surveyors and those surveyed (stakeholder groups and local communities) is crucial to the success of VCAs. Stakeholders should be selected based on preliminary research, during workshops, meetings, capacity-building activities and by involving local community members in the assessment design and deployment step of any planned survey (Table 10.4). During this process, researchers indicated that the objectives of the survey should be clearly communicated and that complex descriptions, jargon and long meetings should be discouraged. Appropriate community or region-specific messaging tools could be identified during preliminary research. In addition, shark VCA resources should be allocated based on the anticipated sample sizes and extent of study areas/regions to match investment across the preparation and delivery of a survey. Finally, researchers considered it important to identify sociocultural events that could potentially influence the success of fishery and/or trade surveys during preliminary research (e.g., active fishing times, fishery ban periods, and national holidays).

Designing a survey

Researchers recommended consulting and involving statistical experts in the design stages of the survey to ensure results will be suitable for anticipated statistical assessment (Table 10.4). This ensures that the outcomes generated are suitable for analyses against researchers' VCA objectives.

Prior to survey design, during preliminary research, researchers should identify possible 'units' used by fishery value chain participants, which are also well recognized across the focal fishery, trade, and use communities. Adopting such units allows better catch, length and volume measurement standardization across surveys. Although open and non-structured questions allow fishers, traders and community members to share more information and could be used to infer more understanding of issues like non-compliance, this type of question can negatively impact survey length. Researchers undertaking shark VCAs in large regions or different study areas should design flexible surveys that allow variations in fishery, trade and cultures to be collated and compared.

Deploying a survey

Most researchers indicated the importance of involving potential enumerators in the shark VCA process well before the deployment of surveys (Table 10.4). This allows researchers to train enumerators and standardize survey delivery, with enumerators having a clear understanding of the evolution of a survey. Involving enumerators with local insights enables researchers to more effectively reach and communicate with stakeholders, taking into account appropriate socio-cultural context and possibly gaining greater access to communities and information that may have been restricted to 'outsiders' or that are found to be isolated from mainstream knowledge. However, when involving local enumerators, researchers should ensure that they are free from conflicts of interest and can take a neutral position during the delivery of VCA information collection processes.

Spatially, sampling efforts should not be limited to landing sites and ports during survey deployment. Sampling design should also consider inland parts of the value chain and isolated markets and trade components.

Management and use of data

Researchers in this study involved local enumerators in processing collected data and asked them to collect additional field notes (Table 10.4). These field notes describe additional survey information, like the presence of specific traders or fishers at auctions, price changes, and events impacting prices, demand or supply of commodities. These field notes were valuable in confirming and explaining the results from the VCA.

Communication and adaptive management

Researchers highlighted the importance of visualizing outcomes for management authorities, policymakers, and local communities through methods such as flowcharts and graphical abstracts (Table 10.4), thus making results more accessible. This could include visual representations of trade routes, source and on-sale locations of commodity processing as well as aggregation areas, and commodity flow diagrams.

To strengthen long-term relations with stakeholders, scheduling reoccurring meetings with managers, policymakers, and local communities was thought to increase the delivery of key VCA outcomes, ensuring that outcomes were fed back to fishing communities and traders.

Table 10.4 Examples of better (left) and poor (right) practices reported by shark value chain assessment proponents. Responses are context-driven and based on the experience of the shark VCAs conducted in their own socio-cultural setting.

Establishing a Monitoring, Evaluation and Reporting Process	
Better practice	**Poor practice**
• Formulate goals and objectives into understandable jargon. • Use preliminary research to identify stakeholders and governance regimes. • Organize capacity-strengthening activities within local communities to improve inter-stakeholder relations. • Collaborate with experts to consolidate preliminary research. • Plan assessments considering cultural events and traditions.	• Allocate resources evenly over study areas without statistical analyses and sample size calculation. • Do not use long meetings and descriptions to convey study objectives. Determine the appropriate method for communicating with stakeholders.
Designing a Survey	
Better practice	**Poor practice**
• Ensure the outputs of questions are suitable for statistical analyses. • Include open or non-structured questions to ask about non-compliance and other problems stakeholders face. • Make surveys flexible and adaptable to changes in fisheries, trade, and culture between regions. • Use time references that are easy to recall (e.g., ‘now’ and ‘when fishing started’ rather than set dates).	• Prevent using different units between surveys. Standardize given answers such as catch quantities and prices. • Do not use complex survey tools (e.g., tablets) that limit the collection of unstructured data. It can also negatively impact data collection if stakeholders or enumerators are unfamiliar with tools. • Including many questions with potential overlapping responses increases the survey length. However, overlapping questions can also be used to confirm given responses, warranting their use in specific cases.
Deploying a Survey	
Better practice	**Poor practice**
• Potential (local) enumerators from local communities should be involved early in the process to facilitate training and delivery of the survey. • Respect the time of the interviewee and be flexible about pausing or discontinuing interviews. • Actively build networks within local communities to gain access to critical information (e.g., silent auctions, new stakeholders). • Follow the appropriate hierarchy to access information or interviewees. • Monitor additional activities (e.g., product transport) to confirm results and contextualize the VC.	• Familiarize with local socio-cultural aspects influencing data collection (e.g., illiteracy). This negatively impacts the quality and amount of collected information, and impacts stakeholder relations. • Do not limit study resources and effort to landing sites; doing so will cause the rest of the value chain to be overlooked (e.g., inland markets). • Going to landing sites or markets without local community members can limit data collection or interpretation of essential details.

Management and Use of Data	
Better practice	**Poor practice**
• Collect additional field notes to cover any additional information not covered in the structured survey, including observations to confirm survey outcomes.	• *None specified.*
Communication and Adaptive Management	
Better practice	**Poor practice**
• Visualize spatial and temporal information for managers, such as trade routes and hubs. • Include the perspectives and needs of local communities in the communication of outcomes. • Have reoccurring meetings with local communities and decision-makers to maintain communication and delivery of outcomes. • Published results should be accessible to local communities while also providing utility to local and national managers. • Communicate outcomes of non-compliance with (international) regulations with the national authority.	• Prevent sending a report to decision-makers without a visual summary. • Do not communicate outcomes to decision-makers before consulting with local stakeholders. • Formulate outcomes and recommendations for adaptive management in a constructive manner, e.g., prevent accusing or sensitive language. • Always ensure interviewee anonymity when communicating outcomes.

Discussion

This study sought to identify the most common approaches of research teams to VCAs for adaptive management of shark fisheries. The goal was to gain advice on refining VCAs when considering trade-offs between limited capacity and resources to optimize returns for management use. Our results showed that shark VCAs offer a holistic view of complex shark fisheries and trade in shark commodities, the importance of which is also highlighted by previous studies (e.g., Booth *et al.* 2019). Researchers contributing to this study indicated that those conducting shark VCAs in the future should invest the most effort and resources into (1) the selection process of key stakeholders, (2) building and maintaining trustworthy relations among stakeholders and researchers, and (3) adequate design of surveys prior to deployment (Figure 10.4). These three components were found to be the most beneficial in generating valuable insights for the adaptive management of sharks (e.g., improved communication and relations with stakeholders and collection of accurate information on trade and fisheries).

Our results indicate that organizing capacity-building and training activities during the early stages of the shark VCA process is essential, as it increases the volume and accuracy of data collected while also providing contextual information (Figure 10.4). Capacity-building activities include involving key stakeholders early in the process by organizing reoccurring stakeholder meetings, which has been identified as an important success factor in other VC studies (Dubay *et al.* 2010, Pradhan *et al.* 2022). Reoccurring events promote mutual understanding and trust but also aid in developing short- and long-term objectives. During these interactions, it was important to consider cultural norms, traditions, and hierarchical structure (Lückmann and Färber 2016). Diversity within the fisheries sector should also be considered (Ngwenya *et al.* 2012) and was also recommended by researchers participating in this study. For example, women constitute half of the workforce in global fisheries (World Bank, 2012). Neglecting their perceptions and perspectives could negatively impact the representation of shark VCA outcomes and hamper future decision-making.

After a broad range of stakeholders have been identified, our results show the importance of including these stakeholders early in the process of shark VCA survey design and deployment (Figure 10.4). Early involvement ensures that all aspects of the complex social-ecological system being examined are considered, with the capture of additional information, identification of differences in nomenclature, appropriate survey timing and accuracy of local ecological knowledge.

Including open-ended questions in surveys can be beneficial as they allow stakeholders to have direct conversations while also providing information not covered by a structured survey design. The information gained from these open-ended questions may offer insights into pain points linked to adaptive management and non-compliance to current governance regimes (Neuert *et al.* 2021). Also, including open questions in shark VCA surveys generated new lines of inquiry not known during the design phase (e.g., trade routes, new commodities, trading areas).

Another important aspect of survey design is addressing differences in common species nomenclature and units (e.g., commodity traded per kilogram, bucket) (Figure 10.4). For example, Leeney and Poncelet (2015) concluded that within the Bijagós Archipelago (Guinea-Bissau), approximately 66 different names for sawfish (Pristidae) are used. Within the same archipelago, sharks and fish are traded using either buckets or estimated kilograms (Leurs, personal observation). Using locally accepted paradigms that are cross-referenced to scientific measures improves the interpretation and accuracy of locally collected information and ensures that the assessment is flexible towards sociocultural differences, enabling better comparison within and between study areas (McCarter and Gavin 2014, Bernos *et al.* 2021).

Although globally, shark populations have declined over the past decades (Stevens *et al.* 2000; Dulvy *et al.* 2021), historical information on local populations is often lacking (Begossi 2010, Beaudreau and Levin 2014). Measuring temporal changes in species catch or catch compositions based on fishers' local ecological knowledge may be one of the only avenues to understand historical changes. However, it can be complicated due to shifting baselines (Pauly 1995, Sáenz-Arroyo *et al.* 2005). Not only this, but accurately recalling retrospective catch information from specific periods can be challenging for stakeholders (Beaudreau and Levin 2014, Early-Capistrán *et al.* 2020). Experienced fishers can provide valuable insights into historical changes in shark populations (Almojil, 2021). One method is asking stakeholders about catches and trades with decade-long increments. Another method to increase the accuracy of this temporal local ecological knowledge is to ask stakeholders about specific moments in time (e.g., when one started fishing and the current situation; Figure 10.4).

To ensure the accuracy of local knowledge collected, the timing and spatial extent of survey deployment need to be considered (Figure 10.4). Events such as traditional festivities can cause a rise in demand for shark commodities while seasons have differing fishing efforts. For example, the dish 'bacalao' in Mexico is traditionally consumed during Christmas and Easter, and the traditional cod is often substituted with shark meat (Lambarri *et al.* 2015). Shark curry is also consumed during local festivities on the western coast of Sumatra in Indonesia (Muttaqin *et al.* 2019). Considering these events and their influence on commodity demand is crucial in understanding VCs. Similarly, the spatial extent of trade should be considered and often requires a flexible survey deployment strategy, especially when new locations of interest are identified during the preliminary research phase or survey deployment. For example, shark products processed in coastal areas of India are transported inland near the northeastern Himalayan plateau to be traded within regional markets (Kizhakudan, personal communication). A VCA primarily focused on coastal areas would fail to cover this important facet of trade. Participatory mapping can also be incorporated into the survey design, allowing important trading and fishing sites to be mapped (Thiault *et al.* 2017). Exercises such as these can reduce uncertainty caused by inconsistency in area names across communities while also preventing difficulties experienced by stakeholders in describing areas of interest on a map.

Feeding back VCA outcomes to local stakeholders is essential for the design and implementation of successful management. Before communicating any outcomes for adaptive management purposes, researchers should identify if the adaptive management framework is passive (i.e., the management strategy is solely taking the influence of intervention on resources into account) or active (i.e., the management strategy anticipates the impact of intervention on learning as well as the resource being managed; Williams, 2011). Given the complexity of shark VCAs, researchers should distill their messaging to critical themes and identify appropriate communication tools to transmit assessment outcomes. Our study highlights the importance of local stakeholder involvement to facilitate effective communication. In addition, outcomes from shark VCAs should be communicated in a way that is accessible to local stakeholders (e.g., limited use of scientific jargon, using the correct local language or dialect, and using data visualization tools). Multiple researchers indicated that reoccurring meetings enabled stakeholders to be closely involved in the process, stimulating information uptake and positively impacting the mutual relationship between researchers and stakeholders.

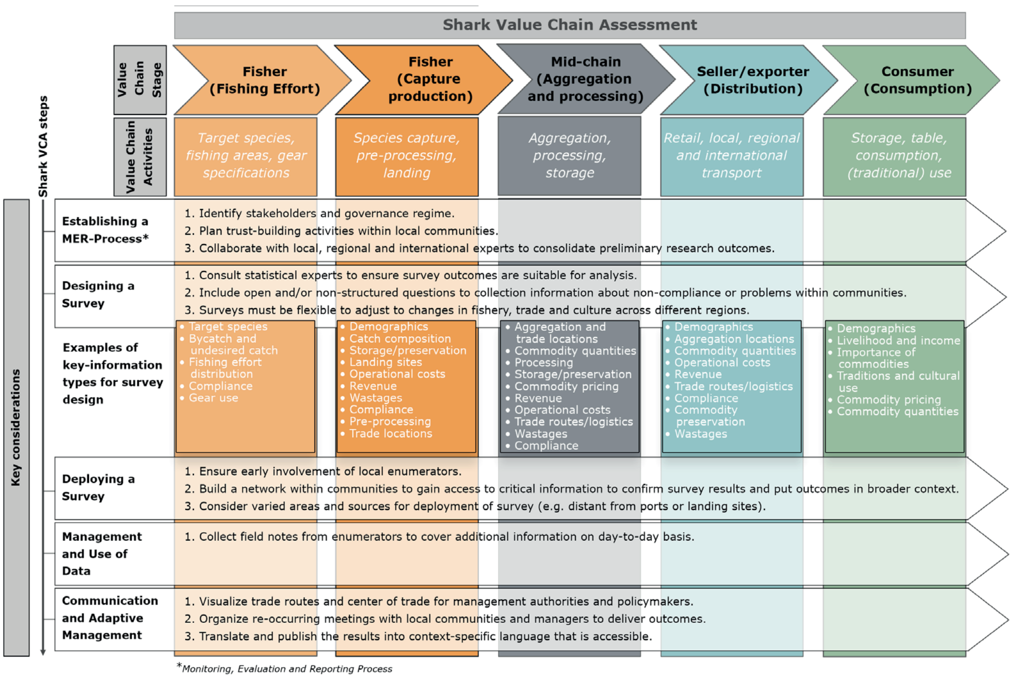

Figure 10.4 Summary of the most important study outcomes. The collection of key information differs among value chain links (i.e., fishers, mid-chains, end-sellers, consumers). The holistic value chain approach covers all three pillars of sustainability in comparison to traditional fishery assessments, which focus on environmental aspects. Key considerations are given for each step in a shark VCA, including key information to include in the survey design. Adapted from Kruijssen *et al.* (2020).

Fisheries are complex social-ecological systems in which the ecology of species is intertwined with the socio-cultural and economic aspects of the fishery, including trade in fishery commodities (Booth *et al.* 2019). Retrieving a management-relevant assessment of fishery VCs requires a paradigm shift in how stakeholders and social-environmental systems are included in surveys. The move to include a clearer view of the social-ecological system expands the assessment to be more akin to the ecosystem approach to fisheries (FAO, 2003) rather than a traditional stock-centered assessment (Figure 10.4). Compared to these conventional stock assessments, perspectives informed by VCA cover a broader array of socio-economic elements that are often drivers of the fishery (Rosales *et al.* 2017). This broadening of perspectives provides vital information on the reasons for fishing and trade, how commodities are processed, bought and sold, where wastages and commodity preservation occur, and information on traditions and cultural aspects that influence commodity acquisition, all of which are opportunities for management interventions (Figure 10.4) (Rosales *et al.* 2017, Booth *et al.* 2019, Kruijssen *et al.* 2020).

Conclusion

Shark fisheries and associated value chains are complex, involving interactions between socio-cultural, economic and ecological systems. These aspects need to be recognized for policy and management development to have the best chance of being effective. This study outlines lessons learned by shark VCA researchers, and we describe the 'better' (what to do) and 'poor' (what not to do) practices in shark VCAs conducted by research groups from five continents. Shark VCAs could provide a holistic approach to the adaptive management of shark populations. Most importantly, shark VCA assessments offered insights into the other causes of (over)exploited stocks (e.g., the underlying socio-economic system of shark fisheries), in addition to assessing the relative status and resilience of the fishery. Recommendations presented here can assist managers, researchers, and stakeholders in streamlining the collection of essential information for adaptive management of shark fishery and trade across fishery VCs, ultimately conserving shark populations more effectively.

Acknowledgments

This work was supported by the FAO regular program, the Japanese Government ("Biodiversity mainstreaming for sustainable fisheries", part of GCP/GLO/173/JPN), collaboration and investment by the CITES Secretariat as well as a UN to UN project funded by the European Union (EP/INT/334/UEP, "CITES-FAO Collaboration to Strengthen the Capacity of Developing Countries to Ensure the Sustainability, Legality and Traceability of International Trade in CITES-listed Species, with a Focus on Commercially-Exploited Aquatic Species").