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Sharks and rays of the Samoan archipelago: a review of their biological diversity, social and cultural values, and conservation status

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ABSTRACT

Context. Data on chondrichthyan (sharks, rays, and chimaeras) populations is largely lacking for many countries and territories in the Indo-Pacific. **Aims.** This study aims to provide a desktop review and information synthesis of the biodiversity, threats, and conservation of chondrichthyans in the Samoan archipelago (Samoa and American Samoa), focusing on their interactions with fisheries and exploring their social, cultural, and economic values. **Methods.** This study uses various literature sources, citizen science, and in-country engagement to assemble a review of current available information on chondrichthyans. **Key results.** A total of 67 chondrichthyans were documented to be present or potentially present in Samoa and American Samoa, consisting of 23 ray species and 44 shark species. Thirty-six of these species were listed in Threatened categories on the International Union for the Conservation of Nature Red List of Threatened Species. A biological productivity analysis conducted for species with sufficient information indicated that the silvertip shark (*Carcharhinus albimarginatus*), silky shark (*Carcharhinus falciformis*), bull shark (*Carcharhinus* leucas), oceanic whitetip (*Carcharhinus longimanus*), and whitetip reef shark (*Triaenodon obesus*) had the highest relative productivities. **Conclusions.** Both Samoa and American Samoa have relatively diverse shark and ray communities with management plans in place to protect chondrichthyans. These include participation in Western and Central Pacific Fisheries Commission initiatives, spatial protections, and community-based management programs. **Implications.** Current management approaches have the potential to provide significant protection to sharks and rays, however, their effectiveness may be hindered by a lack of proper enforcement, or compliance at the national and community levels.

Keywords: biodiversity, citizen science, conservation, fisheries, Indo-Pacific, management, productivity analysis, shark sanctuary.

Introduction

There are approximately 1250 species of Chondrichthyes (sharks, rays and chimaeras, hereafter 'sharks') found throughout the world (Dulvy *et al*. 2017). Sharks occupy a range of trophic niches and are integral components of many marine ecosystems (Jacoby *et al*. 2012). In addition to their ecological value, sharks also hold important social, economic, and cultural values to human populations (McDavitt 2005; Cisneros-Montemayor *et al*. 2013; Mustika *et al*. 2020). Globally, shark populations are declining primarily due to fishing pressure, habitat loss, climate change, and pollution (Dulvy *et al*. 2021). Sharks generally have life history traits such as late maturity, slow growth, and low fecundity, which make them vulnerable to overexploitation (Cortes 2002; Myers and Worm 2005). It is estimated that 37.5% of sharks are currently threatened with extinction on the International Union for the Conservation of Nature (IUCN) Red List of Threatened Species (Dulvy *et al*. 2021). The continual exploitation of sharks in fisheries, and a lack of scientific identification of landed species in commercial and small-scale fisheries, particularly in the Global South, pose critical challenges to shark conservation (Bornatowski *et al*. 2014). The ongoing population declines of sharks risk biodiversity loss, deterioration of the ecosystems they inhabit, and may impact the human livelihoods that depend on them, highlighting the need for conservation and management strategies to ensure long-term sustainability (Simpfendorfer and Dulvy 2017; Mackeracher *et al.* 2019; Jorgensen *et al.* 2022).

Our knowledge of shark populations in the Indo-Pacific is incomplete, and data is lacking for many countries and territories (Juncker *et al.* 2006; Hari *et al.* 2021). For example, recent research has led to the discovery of new species, and the rediscovery of species thought to be locally extinct in remote nations of the Indo-Pacific (White *et al.* 2015, 2017). Furthermore, many species lack thorough population assessments, and factors effecting species are only broadly identified (e.g. Grant *et al.* 2022). For example, while fisheries are the most prominent threat to sharks, a major constraint is that fisheries catch data and landing statistics are often unreliable (Gillett and Lightfoot 2001; Pauly and Zeller 2014), and limited enforcement of existing fishing regulations hinders the effectiveness of management and conservation efforts (Lack and Meere 1994; Espinoza *et al.* 2018). The Indo-Pacific has been identified by Dulvy *et al.* (2014) as one of three major areas where biodiversity of shark and ray populations are seriously threatened. For example, in the Arabian Sea 50.9% of shark species are assessed as threatened (Critically Endangered, Endangered, or Vulnerable) and 17.6% as Near Threatened (Jabado *et al.* 2018), and in south-east Asia, 59% of assessed species are threatened with extinction (Clark-Shen *et al.* 2023).

Coastal fisheries throughout the tropics have been reported to be capturing sharks in large numbers as both target or bycatch, although this remains poorly quantified (Temple *et al.* 2018). Annually, Indonesia has the highest reported landings of elasmobranchs globally (110.737 MT) (Okes and Sant 2019). Other factors that are poorly understood include the effects of riverine and coastal development, land clearing for agriculture, and pollution (Dulvy *et al.* 2021; Mather *et al.* 2024). It is likely that these factors, are also contributing to ongoing declines of shark populations, and reducing the extent and quality of available habitat. An issue across the Indo-Pacific is that nations are often under resourced, lack capacity, and may have more pertinent political, welfare, and economic challenges (MacKeracher *et al.* 2021). In order to assist nations in their conservation management of shark populations, there is a need for a baseline understanding of biodiversity, threats, cultural values, and management, to identify knowledge gaps and facilitate development of conservation initiatives.

The Samoan archipelago is situated within Polynesia in the Central Pacific, approximately 804 km north-east of Fiji. The archipelago (13–17°S, 171–173°W) has a total land area of 3135 km^2. The western group of islands consists of two large islands, Upolu and Savai'I, and the smaller islands of Apolima, Manono, Fanuatapu, Namua, Nu'utele, Nu'ulua and Nu'usafe'e (Meleisea and Meleisea 1987; Passfield *et al.* 2001). The eastern group consists of seven islands, Tutuila, Aunu'u, Ta'ū, Olosega, Ofu in the Manu'a group and Rose Islands and Swains islands (Meleisea and Meleisea 1987). Politically, the archipelago is divided into 'American Samoa', a United States territory, which consists of the eastern group of islands, and 'Samoa' an independent nation, which consists of the western group of islands (Stice and McCoy 1968). Samoa has a population of 206,179 people while American Samoa has a population of 55,197 people (2022) (Central Intelligence Agency 2022). Due to its proximity to other Pacific Island countries, Samoa has the smallest Exclusive Economic Zone (EEZ) in the Pacific, covering 131,535 km^2 (Pernetta 1990; SeaAroundUs 2022). American Samoa's US territorial EEZ covers a total of 404,367 km^2 (SeaAroundUs 2022). The islands of the archipelago are situated along the crest of a submarine ridge that ranges over 482 km from Savai'i to Rose Atoll (Stice and McCoy 1968). Due to the steep gradients of its islands, shallow coastal habitats are restricted, although support a high diversity of Indo-Pacific corals, fishes, and invertebrates (Craig *et al.* 2005) that many local people rely on for their livelihoods (Skelton *et al.* 2003). For example, a national household fisheries survey conducted in 2000 found that Samoa has 11,700 fishers (18% of these identified as female), living in 8377 fishing households (Passfield *et al.* 2001). Both small-scale subsistence and commercial fishing are undertaken in Samoa and American Samoa and the following methods rod and reel, handline, freediving, gill netting and gleaning are used (Hill 1978; Wass 1980; Ponwith 1991; Craig *et al.* 1993). Vessels used by fishermen include small traditional catamaran-style vessels fishing boats (alias) to larger commercial vessels (Clark and Brown 2004). Subsistence fishing is undertaken by village communities in shallow lagoon waters adjacent to their land, while commercial fishing occurs in deeper waters off the coast (Food and Agriculture Organization (FAO) 2018).

Despite the high reliance on marine resources, relatively little is known about the region's chondrichthyan diversity, ongoing threats, how threats are managed, and how chondrichthyans are used and valued by Samoan people. To address these knowledge gaps, this study aims to review the biodiversity, conservation status, and threats to sharks in the Samoan archipelago, provide an overview of the fisheries in the area and their interactions within fisheries, and present a synthesis of the available information on their social, cultural, and economic values to the people of Samoa and American Samoa. This review is extended by conducting a preliminary assessment of relative risk of the species occurring in fisheries based on their life history traits (Pardo and Dulvy 2022). This work forms part of the Shark-Search Indo-Pacific program, a larger initiative currently underway in the Indo-Pacific that aims to provide a knowledge synthesis regarding the diversity and use, and condition of sharks and rays for every country in the region.

Materials and methods

Compilation of species list

The study applies a standard methodological approach that has been developed and peer reviewed for the wider

Shark-Search Indo-Pacific program (see Hylton *et al.* 2017; Hari *et al.* 2021). Following these standard protocols, the primary taxonomic information sources consulted were Sharks of the World (Ebert *et al.* 2021) and Rays of the World (Last *et al.* 2016). These references together with other published literature, focusing primarily on local and regional literature was used to compile a list of chondrichthyan species that may be present in Samoan waters, along with their distributions, habitat, biology, and life history traits. Searches of scientific and grey literature were performed using Google Scholar and Web of Science using the search terms: 'Samoa'; 'American Samoa'; 'shark'; 'ray'; 'Chondrichthyes'; 'management'; 'fishing'; 'shark sanctuary'; and 'culture'. In cases where taxonomy of species differed between sources, the most updated taxonomy as listed in the taxonomic databases Fishbase and World Register of Marine Species were used (Froese and Pauly 2022; Horton *et al.* 2022). Citizen science was also explored through social media accounts of local dive shops (who were engaged and informed of our research), where images of shark and ray species were extracted and identified accordingly. The confidence of each species' occurrence in Samoa and American Samoa was qualitatively assessed and assigned based on specific criteria outlined by Hari *et al.* (2021) (Table 1). The six confidence levels were as follows: (1) unlikely; (2) plausible; (3) requires verification; (4) confirmed and verified; (5) provisionally confirmed (pending taxonomic clarification); and (6) unknown – taxonomy unclear.

Data collected for the study included a range of information on each of the species listed. For each species, this included records of occurrences, life history traits, threats, current conservation measures, as well as general information on fisheries in Samoa and America Samoa. To provide an indication of the level of conservation concern for each species, the level of global extinction risk for each species was collated from the IUCN Red List, and listed together with a species' inclusion as a species of concern in the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) and the Convention on the Conservation of Migratory Species of Wild Animals (CMS). Finally, information on conservation concerns and fishery specific management was collated from the Western and Central Pacific Fisheries Commission (WCPFC), and where available, local government policy documents.

Current conservation and management plans and actions surrounding sharks and rays were then examined to identify the major pressures and mitigation efforts for sharks and rays in Samoa and American Samoa. This predominantly focused on fisheries and the existing fisheries management approaches. Additional resources consulted to draw these conclusions were taken from annual fisheries logbook data and bycatch statistics, National Oceanic and Atmospheric Administration (NOAA) and Food and Agriculture Organisation (FAO) reports, legislative documents regarding Samoa and American Samoa's management of fisheries and marine resources, and any scientific literature available.

Productivity analysis

To identify the relative vulnerability of the different shark and ray species in Samoan waters, a biological productivity analysis was completed for each species that had sufficient published life history information (see Stobutzki *et al.* 2001). Due to limits on data availability a full productivity and susceptibility analysis (PSA) that would otherwise include assessing a species' susceptibility to fishing mortality, was not completed. Although a full PSA would be beneficial, it

Table 1. Description of confidence categories used to classify elasmobranch species found in Samoa and American Samoa following Hari *et al.* (2021).

Confidence category	Description
Unlikely	Occurrence record limited to a single *independent* source; AND occurrence is *outside* the species' expected range OR environmental envelope; AND/OR occurrence *contradicts* biogeographic patterns; AND/OR species is easy to misidentify; AND/OR species absent from other records and observations from that country where it would otherwise be expected.
Plausible	Occurrence records limited to generic taxonomic sources; AND occurrence is within the species' expected range and/or environmental envelope.
Requires verification	Occurrence recorded in published official documents such as fisheries reports or peer-reviewed literature specific to the country; AND/OR the *country is specifically listed* in descriptions of the species' range by generic taxonomic sources, AND occurrence is *within* the species expected range and/or environmental envelope, AND species misidentification is *unlikely*.
Confirmed and verified	Species occurrence evident from museum specimen; OR photographs; OR taxonomic or genetic material; OR recorded in a taxonomic database; AND verified by a chondrichthyan expert or taxonomist; AND/OR species' occurrence evident in a published peer-reviewed paper, checklist, or guide book *specific to the country* AND the source *includes taxonomists as authors*.
Provisionally confirmed (pending taxonomic clarification)	Species occurrence confirmed and verified; however, taxonomic issues (for example, a newly described species photographed in an area out of its apparent range) mean that the species needs further attention in that location to resolve taxonomic issues to confirm species, separate cryptic species, or remove invalid species.
Unknown – taxonomy unclear	Taxonomic changes have rendered previous records unusable; e.g. the original species recorded is no longer recognised, or was part of a species complex that has since been resolved; e.g. *Squalus species A*; or newly identified species within the species complex call into question historical records. As such, the actual specie(s) recorded in these records are not known; OR a specimen or photo of a specimen that cannot be separated to species due to taxonomic issues; e.g. look-alike species.

would require data on life history traits for more species and to quantify susceptibility, would require detailed information on fishing effort and catch rates, as well as catch fate and post release survival (Walker 2005). Unfortunately, these data are not yet available for shark and rays in Samoan waters.

Meanwhile, the biological productivity component of the PSA provides a preliminary assessment of the relative vulnerability of species occurring in the Samoan archipelago based on their biological characteristics, an approach that has been employed for numerous shark and rays species (Dulvy *et al.* 2014; Pardo and Dulvy 2022). Five female life history traits used in the analysis included maximum size, size at maturity, age at maturity, longevity, and fecundity per year (Stobutzki *et al.* 2001). Each species was also assigned a trophic level based on their diet according to specific criteria (Table 2). Analysis for sharks (Selcahii) and rays (Batodeia) were completed separately and only species that had information for all five traits were included in the analysis.

Where a range of values were observed for a life history trait, the average of these values was used. For example, Sharks of the World describes female blacktip sharks (*Carcharhinus limbatus*) as maturing between 120 and 190 cm total length (TL) (Ebert *et al.* 2021), while the IUCN Red List provides a range of 145–207 cm TL (International Union for Conservation of Nature 2021). Therefore, size at maturity was determined to range from 120 to 207 cm TL, with an average length of 163.5 cm TL. Where values differed drastically between sources, the value from the most recent publication were used. If multiple size ranges were given according to size of populations in geographic locations, the size of the population closest to the Samoan archipelago was used.

Following collation of life history data, a productivity category of 1, 2, or 3 was assigned to each life history trait, where a productivity category value of 1 refers to the most productive (lowest risk), and 3 refers to least productive (highest risk) (Hari *et al.* 2021). Categories were assigned according to the value of each species trait against the range of values for that trait among all other species in the analysis. For example, maximum sizes of the shark species being analysed was 102.0–1097.0 cm TL, which results in a range of 762.5 cm. This range was then equally divided into three 'bins' representing low (small-bodied), moderate (medium-bodied), and high (large-bodied). Therefore, species with maximum sizes of 102.0–433.7 cm TL were assigned a rank of 1, species maximum sizes between 433.8 and 765.5 cm TL were assigned a rank of 2, and species between 765.6 and 1097 cm TL were assigned a rank of 3. This biological productivity analysis was intended to be broad in nature, and compatible to the information available across a range of species to achieve a larger sample size for relative comparisons.

Profiling fisheries

To understand the context of how marine resources including sharks and rays are being affected by human activities, the fisheries of Samoa and American Samoa were profiled by conducting a literature a search using Google Scholar and Web Of Science with the following search terms: 'Samoa'; 'American Samoa'; 'fishery'; 'commercial'; 'small-scale'; and 'subsistence'. Results were presented by fishery sector including subsistence and commercial fisheries.

Results

Species diversity and biological productivity

A total of 67 species were documented for Samoa and American Samoa (Table 3). This consisted of 23 rays and 44 sharks, no chimaeras were reported. For Samoa, four species were classed as 'confirmed and verified', 38 as 'requires verification' and 25 as 'plausible'. For American Samoa, only 1 species was 'confirmed and verified', 42 were classed as 'requires verification' and 25 as 'plausible'. Species identified included mainly those associated with two habitat categories; approximately 40% of ray species are found in continental shelf/slope habitats and a further 40% are found in inshore habitats, while more than half of the shark species (28 individual species) are found on continental shelf/slope habitats. The checklist available as Supplementary material to this paper, includes information and sources on species occurrence, taxonomy, habitat and conservation threats for each species.

According to the IUCN Red List, most species found in Samoa and American Samoa have globally declining population trends. Four species are listed as Critically Endangered, including the giant guitarfish (*Rhynchobatus djiddensis*),

Table 2. Description of trophic level categories used to classify shark and ray species found in Samoa and American Samoa.

Trophic level	Description (as applied to fully grown adults)
3 – Top predator	Diet includes mammals, turtles, sharks and rays, and/or higher order fish or invertebrates. Exist within one level of the top tier of the food web. Adults rarely eaten by other sharks. Examples include the white shark, tiger shark, great hammerhead, sevengill shark, oceanic whitetip shark, mako shark.
2 – Meso predator (high level)	Diet includes teleost fishes, small sharks and rays, and/or invertebrates. Prey are within two levels of primary producers. Adults sometimes eaten by other sharks. Examples include the silvertip shark, grey reef shark, giant shovelnose ray, blacktip reef shark, common blacktip shark.
1 – Meso predator (low level)	Diet includes plankton, and low order consumers such as herbivores and/or first order predators such as invertivores, and invertebrates. Prey are within one level of primary producers in the food web. Adults often eaten by other sharks and rays. Examples include milk shark, cowtail stingray, mangrove whipray, epaulette shark, banded maskrays, spot tail shark, creek whaler.

Table 3. Shark and ray species confirmed (in bold) or predicted to occur in Samoa and American Samoa, with global conservation listings.

Common Name	Family	Genus	Species	Confidence Samoa	Confidence American Samoa	IUCN	CITES	CMS	WCPFC
Pelagic thresher	Alopiidae	*Alopias*	*pelagicus*	Requires verification	Requires verification	EN	Appendix II	Appendix II	Key species
Bigeye thresher	Alopiidae	*Alopias*	*superciliosus*	Requires verification	Requires verification	VU	Appendix II	Appendix II	Key species
Thresher shark	Alopiidae	*Alopias*	*vulpinus*	Requires verification	Requires verification	VU	Appendix II	Appendix II	Key species
Alis' velvet Skate	Arhynchobatidae	*Notoraja*	*alisae*	Plausible	Plausible	LC	NA	NA	
Fiji Velvet skate	Arhynchobatidae	*Notoraja*	*fijiensis*	Plausible	Plausible	LC	NA	NA	
Strange skate	Arhynchobatidae	*Notoraja*	*inusitata*	Plausible	Plausible	LC	NA	NA	
Longlobe velvet skate	Arhynchobatidae	*Notoraja*	*longiventralis*	Plausible	Plausible	LC	NA	NA	
Silvertip shark	Carcharhinidae	*Carcharhinus*	*albimarginatus*	Requires verification	Requires verification	VU	Appendix II	NA	
Bignose shark	Carcharhinidae	*Carcharhinus*	*altimus*	Plausible	Plausible	NT	Appendix II	NA	
Grey reef shark	Carcharhinidae	*Carcharhinus*	*amblyrhynchos*	**Confirmed and verified**	Requires verification	EN	Appendix II	NA	
Silky shark	Carcharhinidae	*Carcharhinus*	*falciformis*	Requires verification	Requires verification	VU	Appendix II	Appendix II	Key species
Bull shark	Carcharhinidae	*Carcharhinus*	*leucas*	Requires verification	Requires verification	VU	Appendix II	NA	
Blacktip shark	Carcharhinidae	*Carcharhinus*	*limbatus*	Requires verification	Requires verification	VU	Appendix II	NA	
Oceanic whitetip shark	Carcharhinidae	*Carcharhinus*	*longimanus*	Requires verification	Requires verification	CR	Appendix II	NA	Key species
Blacktip reef shark	Carcharhinidae	*Carcharhinus*	*melanopterus*	**Confirmed and verified**	Requires verification	VU	Appendix II	NA	
Galapagos shark	Carcharhinidae	*Carcharhinus*	*galapagensis*	Requires verification	Requires verification	LC	Appendix II	NA	
Tiger shark	Carcharhinidae	*Galeocerdo*	*cuvier*	Requires verification	Requires verification	NT	Appendix II	NA	
Sicklefin lemon shark	Carcharhinidae	*Negaprion*	*acutidens*	Requires verification	Requires verification	EN	Appendix II	NA	
Blue shark	Carcharhinidae	*Prionace*	*glauca*	Requires verification	Requires verification	NT	Appendix II	Appendix II	Key species
Whitetip reef shark	Carcharhinidae	*Triaenodon*	*obesus*	Requires verification	**Confirmed and verified**	VU	Appendix II	NA	
Smallfin gulper shark	Centrophoridae	*Centrophorus*	*moluccensis*	Plausible	Plausible	VU	NA	NA	
Longsnout dogfish	Centrophoridae	*Deania*	*quadrispinosa*	Plausible	Plausible	VU	NA	NA	
Basking shark	Cetorhinidae	*Cetorhinus*	*maximus*	Requires verification	Requires verification	EN	Appendix II	Appendix I and II	
Pygmy shark	Dalatiidae	*Euprotomicrus*	*bispinatus*	Requires verification	Requires verification	LC	NA	NA	
Cookiecutter shark	Dalatiidae	*Isistius*	*brasiliensis*	Requires verification	Requires verification	LC	NA	NA	
Blue spotted stingray/Kuhl's Maskray	Dasyatidae	*Neotrygon*	*kuhlii*	Requires verification	Requires verification	DD	NA	NA	
Coral sea maskray	Dasyatidae	*Neotrygon cf.*	*trigonoides*	Requires verification	Plausible	LC	NA	NA	
Broad cowtail ray	Dasyatidae	*Pastinachus*	*ater*	Plausible	Plausible	VU	NA	NA	
Pink Whipray	Dasyatidae	*Pateobatis*	*fai*	**Confirmed and verified**	Requires verification	VU	NA	NA	
Pelagic Stingray	Dasyatidae	*Pteroplatytrygon*	*violacea*	Requires verification	Requires verification	LC	NA	NA	

(*Continued on next page*)

Table 3. (*Continued*).

Common Name	Family	Genus	Species	Confidence Samoa	Confidence American Samoa	IUCN	CITES	CMS	WCPFC
Blotched fantail ray	Dasyatidae	*Taeniurops*	*meyeni*	Plausible	Plausible	VU	NA	NA	
Porcupine whipray	Dasyatidae	*Urogymnus*	*asperrimus*	Plausible	Plausible	VU	NA	NA	
Mangrove whipray	Dasyatidae	*Urogymnus*	*granulatus*	Plausible	Plausible	VU	NA	NA	
Tailspot lanternfish	Etmopteridae	*Etmopterus*	*caudistigmus*	Plausible	Plausible	LC	NA	NA	
Pink lanternshark	Etmopteridae	*Etmopterus*	*dianthus*	Plausible	Plausible	LC	NA	NA	
Blackbelly lanternshark	Etmopteridae	*Etmopterus*	*lucifer*	Plausible	Plausible	LC	NA	NA	
False lanternshark	Etmopteridae	*Etopyerus*	*pseudosqualiolus*	Plausible	Plausible		NA	NA	
Tawny nurse shark	Ginglymostomatidae	*Nebrius*	*ferrugineus*	Requires verification	Requires verification	VU	NA	NA	
Sharpnose sevengill shark	Hexanchidae	*Heptranchias*	*perlo*	Plausible	Plausible	NT	NA	NA	
Bluntnose sixgill shark	Hexanchidae	*Hexanchus*	*griseus*	Requires verification	Requires verification	NT	NA	NA	
Bigete sixgill shark	Hexanchidae	*Hexanchus*	*nakamurai*	Plausible	Plausible	NT	NA	NA	
Sixgill stingray	Hexatrygonidae	*Hexatrygon*	*bickelli*	Plausible	Plausible	LC	NA	NA	
White shark	Lamnidae	*Carcharodon*	*carcharias*	Requires verification	Requires verification	VU	Appendix II	Appendix I and II	
Shortfin mako shark	Lamnidae	*Isurus*	*oxyrinchus*	Requires verification	Requires verification	EN	Appendix II	Appendix II	Key species
Logfin mako shark	Lamnidae	*Isurus*	*paucus*	Requires verification	Requires verification	EN	Appendix II	Appendix II	Key species
Megamouth shark	Megachasmidae	*Megachasma*	*pelagios*	Requires verification	Requires verification	LC	NA	NA	
Reef Manta Ray	Mobulidae	*Mobula*	*alfredi*	Requires verification	Requires verification	VU	NA	NA	Key species
Giant Manta Ray	Mobulidae	*Mobula*	*birostris*	Requires verification	Requires verification	EN	Appendix II	NA	Key species
Shortfin devilray	Mobulidae	*Mobula*	*kuhlii*	Requires verification	Requires verification	EN	Appendix II	Appendix I and II	
Giant devilray	Mobulidae	*Mobula*	*mobular*	Requires verification	Requires verification	EN	Appendix II	Appendix I and II	Key species
Chilean devilray	Mobulidae	*Mobula*	*tarapacana*	Requires verification	Requires verification	EN	Appendix II	Appendix I and II	
Bentfin devilray	Mobulidae	*Mobula*	*thurstoni*	Requires verification	Requires verification	EN	Appendix II	Appendix I and II	Key species
Ocellated Eagle Ray	Myliobatidae	*Aetobatus*	*ocellatus*	**Confirmed and verified**	Requires verification	VU	NA	NA	
Bigeye sandtiger	odontaspididae	*Odontaspis*	*noronhai*	Plausible	Plausible	LC	NA	NA	
Giant stingaree	Plesiobatidae	*Plesiobatis*	*daviesi*	Plausible	Plausible	LC	NA	NA	
Crocodile shark	Pseudocarchariidae	*Pseudocarcharias*	*kamoharai*	Requires verification	Requires verification	LC	NA	NA	
Whale shark	Rhincodontidae	*Rhincodon*	*typus*	Requires verification	Requires verification	EN	Appendix II	Appendix I and II	Key species
Giant guitarfish/ Whitespotted wedgefish	Rhinidae	*Rhynchobatus*	*djiddensis*	Requires verification	Requires verification	CR	Appendix II	NA	
Velvet dogfish	Somniosidae	*Zameus*	*squamulosus*	Requires verification	Requires verification	LC	NA	NA	NA

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Table 3. (*Continued*).

Common Name	Family	Genus	Species	Confidence Samoa	Confidence American Samoa	IUCN	CITES	CMS	WCPFC
Scalloped hammerhead	Sphyrnidae	*Sphyrna*	*lewini*	Requires verification	Requires verification	CR	Appendix II	Appendix II	Key species
Great hammerhead	Sphyrnidae	*Sphyrna*	*mokarran*	Requires verification	Requires verification	CR	Appendix II	Appendix II	Key species
Smooth hammerhead	Sphyrnidae	*Sphyrna*	*zygaena*	Requires verification	Requires verification	VU	NA	Appendix II	Key species
Southern mandarin dogfish	Squalidae	*Cirrhigaleus*	*australis*	Plausible	Plausible	DD	NA	NA	
Bighead spurdog	Squalidae	*Squalus*	*bucephalus*	Plausible	Plausible	DD	NA	NA	
Blacktailed spurdog	Squalidae	*Squalus*	*melanurus*	Plausible	Plausible	DD	NA	NA	
Zebra shark	Stegostomatidae	*Stegostoma*	*tigrinum*	Requires verification	Requires verification	NT	NA	NA	
New Caledonian stingaree	Urolophidae	*Urolophus*	*neocaledoniensis*	Plausible	Plausible	LC	NA	NA	

CR, Critically Endangered; EN, Endangered; VU, Vulnerable; NT, Near Threatened; LC, Least Concern; DD, Data Deficient.

oceanic whitetip shark (*Carcharhinus longimanus*), scalloped hammerhead (*Sphyrna lewini*) and great hammerhead (*Sphyrna mokarran*). A total of 12 species are listed as 'Endangered', 20 as 'Vulnerable', seven as 'Near Threatened', while 19 species were listed as 'Least Concern'. The remaining species, the Coral Sea maskray (*Neotrygon* cf. *trigonoides*), the velvet dogfish (*Zameus squamulosus*), and the crocodile shark (*Pseudocarcharias kamoharai*) were listed as 'Data Deficient' (International Union for Conservation of Nature 2021). Twenty-six species are listed on at least one of CITES, CMS, or the WCPFC key species list (Table 3). A total of nine species can be found across all three conservation and management instruments, these include the: (1) giant devilray (*Mobula mobular*); (2) bentfin devilray (*Mobula thurstoni*); (3) shortfin mako shark (*Isurus oxyrinchus*); (4) scalloped hammerhead; (5) bigeye thresher (*Alopias superciliosus*); (6) pelagic thresher (*Alopias pelagicus*); (7) whale shark (*Rhincodon typus*); (8) great hammerhead (*Sphyrna mokarran*); and (9) thresher shark (*Alopias vulpinus*).

Twenty-two of the 44 shark species had sufficient life history information to be included in the productivity analysis (Table 4). Five species equally ranked the highest in their productivity, reflected with the lowest risk score of 1.43, these species include: the silvertip shark (*C. albimarginatus*), silky shark (*C. falciformis*), bull shark (*C. leucas*), oceanic whitetip (*C. longimanus*), and whitetip reef shark (*Triaenodon obesus*). The white shark (*Carcharodon carcharias*) and basking shark (*Cetorhinus maximus*) had the lowest productivity with a score of 2.14. Only four species of rays were able to be included in the analysis due to a lack of available life history information for all other ray species (Table 5). The giant devil ray (*M. mobular*) had the highest productivity score of 1.43 while the reef manta ray (*Mobula alfredi*) held the lowest productivity score of 2.29.

Fishing activities and behaviours in the Samoan archipelago

Small-scale and commercial fishing are important occupations in both Samoa and American Samoa (Food and Agriculture Organization (FAO) 2018), with both men and women involved in fishing activities (Titii *et al*. 2014). In 1980, approximately 7860 Samoans were employed through fishery-based work; this increased to 12,500 in 2000 before decreasing to 530 in 2015 (Food and Agriculture Organization (FAO) 2018). Fishing contributes to the culture of Samoan communities. For example, in American Samoa, skipjack tuna (locally referred to as 'atu') is seen as a nutritionally and traditionally valued species that is distributed among the community according to ceremonial traditions (Western Pacific Regional Fishery Council 2010).

Samoa

Subsistence fishing is undertaken by village communities in shallow lagoon waters adjacent to their land (Food and Agriculture Organization (FAO) 2018). Annual catch for coastal subsistence fisheries in 2014 was estimated at 5000 tonnes, which was equivalent to the coastal commercial catch for the same year (Gillett 2016; Food and Agriculture Organization (FAO) 2018). Catch from these fisheries is mainly for local consumption; however, some may be exported to family members in Apia (Food and Agriculture Organization (FAO) 2018). The act of giving fish, termed 'faasoso', is an important social dynamic within cultural traditions of Samoa (Food and Agriculture Organization (FAO) 2018).

Samoa's commercial longline fishery started in the 1990s (Clark and Brown 2004; Food and Agriculture Organization (FAO) 2018), beginning with small catamaran-style vessels (called 'alia') of sizes 12.5 m or less (Clark and Brown 2004). Catches of the commercial fishing fleet have grown into a major export earner for Samoa. In 2014, the gross domestic product (GDP) generated from commercial fisheries accounted for 3.5% of the nation's total GDP (Gillett 2016). In 2012, the approximated total finfish catch was 9066 tonnes with an estimated value of 89 million Samoan Tala (WST) (US$~33 million) (Titii *et al.* 2014). The commercial longline fishery primarily targets tuna species, with South Pacific albacore tuna (*Thunnus alalunga*) making up 70% of the catch over the past decade, averaging 2230 tonnes total catch annually between 2008 and 2012 (Food and Agriculture Organization (FAO) 2018). Outstanding catch is a mixture of non-tuna species such as black and blue marlin and swordfish (Food and Agriculture Organization (FAO) 2018). In 2021, South Pacific albacore remained the main catch (62% by weight), followed by yellowfin tuna (*Thunnus albacares* 26% by weight) and bigeye tuna (*Thunnus obesus* 4% by weight) (Ministry of Agriculture and Fisheries 2022). Most albacore tuna catch (60–80%) catch is exported frozen locally, to Pago Pago for canning, while bigeye and yellowfin tuna are exported to higher value markets in Japan and the US (Clark and Brown 2004).

The size of the domestic commercial longline fishing fleet has declined, being as large as 53 vessels (Fisheries Division 2016) to a fleet of 25 vessels in 2021. In 2015, a new fish processing plant was established in Samoa and foreign fishing vessels were granted licences to fish in Samoa's EEZ As of 2021, eight foreign flagged longline vessels were fishing in Samoa's EEZ; four from Vanuatu and four from the Cook Islands (Ministry of Agriculture and Fisheries 2022). In spite of new licences being granted, the overall size of the tuna fleet in 2021 has decreased by half compared to 2015, with the decrease partly attributed to the impacts of the global COVID-19 pandemic (Ministry of Agriculture and Fisheries 2022). While effort has reduced, tuna fishing remains an important part of Samoa's economic activity with 4.5 million hooks deployed in 2021, landing 1027 mt of tuna (Ministry of Agriculture and Fisheries 2022).

American Samoa

In American Samoa, small-scale fisheries consist of shoreline subsistence, pelagic artisanal fisheries, shoreline subsistence fisheries and coral reef fisheries (Craig *et al.* 1993; Western Pacific Regional Fishery Council 2010). In the shoreline subsistence fishery, reef flats and shallow waters adjacent to villages are harvested for fish and shellfish species using methods such as rod and reel, handline, freediving, gill netting and gleaning (Hill 1978; Wass 1980; Ponwith 1991; Craig *et al.* 1993). In 1991, subsistence catches on Tutuila Island totalled at 200 tonnes, with majority of catch retained for consumption (Ponwith 1991). Artisanal fisheries in American Samoa are generally based around trolling for pelagic fishes in surface waters or vertical handlining for demersal fish species (Aitaoto *et al.* 1991). Coral reef fishes and invertebrates are also harvested in the country's coral reef small-scale fisheries, using an array of gear such as hook and line, spear gun, and gillnet (Dalzell 1996; Western Pacific Regional Fishery Council 2010).

American Samoa also has a commercial tuna fishery, which is a limited entry pelagic longline fishery in the US EEZ around American Samoa (NOAA 2021). In 2019, there were nine active vessels in the fishery participating in 200 trips during the year (NOAA *et al.* 2020), while during 2020, there were 11 active vessels but only 95 trips in the year (NOAA and NMFS 2022). This can be attributed to the impact of COVID-19 on the fishery. American Samoa is also a homeport to a fleet of large commercial vessels who fish beyond their EEZ, and deliver tuna to the canneries on Tutuila Island (Craig *et al.* 1993). Fifty percent of these vessels use purse seine nets as their predominant gear type, and skipjack tuna accounted for most of the deliveries (Craig *et al.* 1993). As in Samoa, albacore tuna are also the predominant catch for the fishery. In 2019, total tuna catch was 8011 tonnes, albacore comprised 72% of this catch, followed by skipjack at 14%, yellowfin at 11.7% and bigeye and bluefin with <3% (NOAA *et al.* 2020). Other fish species caught in the fishery include various species of billfish (blue marlin, stiped marlin, shortbill spearfish) and species such as mahimahi, moonfish, wahoo, oilfish and pomfret (NOAA *et al.* 2020). In 2020, following the impacts of COVID-19, total tuna catch decreased to 51,150 tonnes, with albacore comprising 60% of the catch (NOAA and NMFS 2022).

Fisheries interactions with sharks and rays

Interactions between fisheries and sharks and rays are better documented in the American Samoa commercial fisheries, which have publicly available logbook reports, while shark and ray interactions in Samoa's commercial fishery are much less understood. A report by the United States Office of the Federal Register (2015) indicates the following shark species to be of potential harvested coral reef taxa in the American Samoa coral reef fishery; grey reef shark (*Carcharhinus amblyrhynchos*), silvertip shark, Galapagos shark (*Carcharhinus galapagensis*), blacktip reef shark (*Carcharhinus melanopterus*) and the whitetip reef shark (*T. obesus*). An array of shark and ray species are caught as

Table 4. Productivity analysis for shark species in Samoa and American Samoa.

Scientific name	Common name	Average age at maturity	Average max age	Fecundity	Average max size	Average size at maturity	Reproductive strategy	Trophic level	Total productivity
Alopias pelagicus	Pelagic thresher shark	1	1	1	1	1	3	3	1.57
Alopias superciliosus	Bigeye thresher shark	1	1	1	2	1	3	3	1.71
Alopias vulpinus	Thresher shark	1	1	1	2	2	3	3	1.86
Carcharhinus amblyrhynchos	Grey reef shark	1	1	1	1	1	3	2	1.42
Carcharodon carcharias	White shark	3	2	1	2	1	3	3	2.14
Carcharhinus falciformis	Silky shark	1	1	1	1	1	3	3	1.57
Carcharhinus galapagensis	Galapagos shark	1	1	1	1	1	3	2	1.43
Carcharhinus leucas	Bull shark	1	1	1	1	1	3	3	1.57
Carcharhinus limbatus	Blacktip shark	1	1	1	1	1	3	2	1.43
Carcharhinus longimanus	Oceanic whitetip shark	2	1	1	1	1	3	3	1.71
Carcharhinus melanopterus	Blacktip reef shark	1	1	1	1	1	3	2	1.43
Centrophorus moluccensis	Smallfin gulper shark	2	2	1	1	1	3	2	1.71
Cetorhinus maximus	Basking shark	2	2	1	3	3	3	1	2.14
Deania quadrispinosa	Longsnout dogfish	2	2	1	1	1	3	2	1.71
Galeocerdo cuvier	Tiger shark	1	1	2	2	1	3	3	1.86
Heptranchias perlo	Sharpnose sevengill shark	3	3	1	1	1	3	2	2
Isurus oxyrinchus	Shortfin mako shark	2	1	1	2	1	3	3	1.86
Prionace glauca	Blue shark	1	1	1	1	1	3	3	1.57
Sphyrna mokarran	Great hammerhead shark	1	2	2	2	1	3	3	2
Sphyrna zygaena	Scalloped hammerhead shark	1	2	2	1	1	3	3	1.87
Stegostoma tigrinum	Zebra shark	1	1	3	1	1	3	1	1.57
Triaenodon obesus	Whitetip reef shark	1	1	1	1	1	3	2	1.43

Table 5. Productivity analysis for ray species in Samoa and American Samoa.

Scientific name	Common name	Average age at maturity	Average max age	Fecundity	Average max size	Average size at maturity	Reproductive strategy	Trophic level	Total productivity
Aetobatus ocellatus	Ocellated eagle ray	1	1	3	1	1	3	2	1.71
Mobula alfredi	Reef manta ray	3	3	1	2	3	3	1	2.28
Mobula birostris	Giant manta ray	1	3	1	3	3	3	1	2.14
Mobula mobular	Giant devil ray	1	1	1	2	1	3	1	1.43

bycatch each year in the American Samoa longline tuna fishery. The American Samoa Longline Limited-entry Fishery Annual Report for 2019 indicates the capture of 3207 individual sharks. These interactions are incidental, and only eight of these individuals were reported to be retained and the remainder released (NOAA *et al.* 2020). The blue shark (*Prionace glauca*) accounted for 51% catch, silky shark represented 28% of catch, followed by the oceanic white tip with 12% and mako and thresher species each representing 4% of the total catch (NOAA *et al.* 2020). Of the eight individuals retained, seven were thresher sharks and one a mako shark (NOAA *et al.* 2020).

In 2020, COVID-19 affected the deployment of observers onboard fishing trips due to government regulations (McCracken and Cooper 2022). As a result, only one observed trip occurred in 2020 and thus, observer data over the years 2012–2019 were used to estimate the 2020 bycatch estimates (McCracken and Cooper 2022). Total estimated bycatch for sharks was 5125 tonnes, with the majority of bycatch represented by species in the family Carcharinidae (McCracken and Cooper 2022). Blue sharks accounted for 58% of total catch, silky sharks 24%, oceanic white tips 9% and shortfin mako sharks accounted for 4.5% (McCracken and Cooper 2022). The remainder of catch comprised of bigeye and pelagic threshers, Galapagos sharks, longfin and shortfin mako, crocodile sharks, velvet dogfish and smooth and scalloped hammerheads (McCracken and Cooper 2022). Total estimated catch for ray species was 8416 tonnes, with the Pelagic stingray (*Pteroplatytrygon violacea*) accounting for 99% of the total ray catch (McCracken and Cooper 2022). Other bycatch species include the giant manta ray (*Mobula birostris*) and giant devil ray (McCracken and Cooper 2022). Giant manta rays, however, are not common bycatch species with three reported catches in 2010 and none in the following consecutive years. According to annual reports of logbooks, majority of shark and ray bycatch are released (NOAA *et al.* 2020; NOAA and NMFS 2022), however, no information on post release mortality for this fishery exists.

Meanwhile, there is very little information available to indicate any commercial capture (targeted or incidental) of sharks and rays in Samoa. Sharks are caught within the WCPFC jurisdiction (see section 'Shark and ray management') and annual reports may include data on shark by-catch. Samoa's annual report to the WCPFC reports only 27 individual oceanic whitetip sharks being captured in 2021 and 0.03 mt of mako shark (Ministry of Agriculture and Fisheries 2022). Aggregate catch data from 2017 to 2021 report very few sharks in the dataset, with 0.2 mt of hammerheads reported in 2020 and 1.0 mt of thresher shark reported in 2017; otherwise, there was no reported catch of blue sharks, hammerhead sharks, silky sharks, and thresher sharks over the 5-year period (Ministry of Agriculture and Fisheries 2022).

Shark and ray management

Both Samoa and American Samoa have management in place to protect their marine resources. In 1974, Samoa was the first Pacific Island country to establish a national marine reserve, the Palolo Deep National Marine Reserve (Skelton *et al.* 2003) and in 2018 created a national shark sanctuary. Marine protected areas have also been established in American Samoa at the federal and local government levels, and also by some communities (Montgomery *et al.* 2019). Both Samoa and American Samoa are signatories to tCITES, CMS, and members of the FAO.

Samoa

In 2018, Samoa became the eighth Pacific Island country to declare the waters of its EEZ a 'shark sanctuary' (SPREP 2018). Declaration of the sanctuary placed a ban on all commercial fishing, sale, and trade of shark and ray species in the country's waters (SPREP 2018). Samoa also has fisheries management regulations to conserve sharks, such as those under *Samoa's Marine Wildlife Protection Regulations 2009* (Ministry of Natural Resources and Environment 2009). Further, Samoa's tuna fisheries are managed on a regional scale through the WCPFC conservation and management measures for sharks (2019) (WCPFC 2019) and the Samoa tuna and management and development plan (2011–2015) (STMDP) (Ministry of Agriculture and Fisheries Division 2011), respectively. WCPFC regulations require all vessels to land sharks with their fins naturally attached to the carcass (WCPFC 2019). Furthermore, longline fisheries are not permitted to use or carry wire traces, branch lines or shark lines and a strict ban on the retention of any oceanic whitetip, silky shark and whale shark is in place (WCPFC 2019). The STMDP's regulations regarding sharks supersedes the WCPFC regulations regarding the prohibition of wire traces, shark lines and the ban on retention of oceanic whitetips and silky sharks (Ministry of Agriculture and Fisheries Division 2011). However, the plan also acknowledges that retaining carcasses places a burden on small vessels and that fishers likely incur a loss of income from decreased sales of sharks (Ministry of Agriculture and Fisheries Division 2011). Thus, Samoa has exercised their Sovereign Rights and in accordance with the WCPFC conservation and management measures for sharks, developed alternative arrangements (Ministry of Agriculture and Fisheries Division 2011). These arrangements are that all vessels are permitted to take a maximum of five sharks per trip, class A (vessels <40 ft) and B vessels (vessels between 40 and 50 ft) are not required to retain carcasses on board, however, fins must be stored in separate bags to display how many sharks are being represented (Ministry of Agriculture and Fisheries Division 2011).

Samoa's small-scale fisheries are managed through Community-based Fisheries Management Programs, where participating villages develop their own strategy to manage their marine resources and environment (Food and Agriculture Organization (FAO) 2018). These programs were initiated in 1995 with assistance from the Australian Agency for International Development and as of 2018, 98 villages have been working with the Samoa's fisheries division to engage in fisheries development and marine conservation (Food and Agriculture Organization (FAO) 2018). Seventy-three active fish reserves have been established thus far, and the districts of Safata and Aleipata, are under a marine protected area program overseen by the Ministry of Natural Resources and Environment (Food and Agriculture Organization (FAO) 2018). However, currently, the influence of these reserves on conserving shark populations and regulating fishing efforts is largely unknown.

American Samoa

American Samoa has a national marine sanctuary which consists of six protected areas, spanning 35,175 km^2 of coral reef, offshore, and open ocean habitats (National Oceanic and Atmospheric Administration 2022). The sanctuary has regulations that prohibits the gathering of coral or invertebrate species and prohibits the use of explosives and drift nets; however, no current sanctuary regulations exist to directly prohibit the take of sharks or rays from sanctuary waters (National Oceanic and Atmospheric Administration 2022). Alongside these sanctuaries, the territory has introduced a ban on all shark fishing and possession and trade of shark fins and body parts within the territory and its waters (PEW Charitable Trusts 2012). These changes were made to fishing regulations by the Department of Marine and Wildlife Resources in 2012 (PEW Charitable Trusts 2012). Further fisheries regulations include commercial vessels having to carry an observer onboard when instructed to do so by the Regional Administrator (United States Office of the Federal Register 2015).

Social and cultural values of sharks and rays

Little information was retrieved from Google Scholar or Web of Science about the social and cultural values of sharks and rays in Samoa. Jones (2020) writes about the Samoan folktale of a woman and child navigating a famine by casting their fate to the sea. Jumping into the ocean, they transformed into a shark and turtle, and upon re-emerging on another island, they were welcomed and fed by the island Chief. To show their gratitude, they vow to live in the sea and return when needed. Leaving a song for the Samoans to sing when they wish to call back the turtle and the shark.

Apart from this story, further accounts of the social and cultural values of sharks and rays in the Samoan archipelago were not evident in published or grey literature. While this likely exists, it was not retrieved using our search terms and sources.

Discussion

Biodiversity, conservation concerns and values

This review presents a synthesis of available literature on the diversity of sharks and rays found in the Samoan archipelago, and their conservation status, threats, and a summary of current management. The number of shark and ray species recorded for Samoan waters ($n = 67$) is relatively high compared to previous information synthesis from the Pacific, with 56 species identified from Palau (Hari *et al.* 2021) and 50 species identified form the Solomon Islands (Hylton *et al.* 2017). The cause of this is not clear given that Samoa is more distant from the Indo-Pacific centre of biodiversity than the Solomon Islands, and consist of a collection of islands and reefs within a vast ocean area similar to Palau. While this potential anomaly could result from the general lack of information on shark and ray diversity in the region, it also highlights the potential for further research to document and explain chondrichthyan biogeographic patters across the Pacific.

The lack of available data required information to be collated from a wide range of sources including primary and grey literature, government reports, fishery status reports, and IUCN Red List assessments. Species reference books (e.g. 'Sharks of the World' Ebert *et al.* 2021) and peer-reviewed scientific literature accounted for majority of species reports. However, grey literature and unpublished data were also important sources in compiling the species list. The scarcity of extensive, region-specific species-level data in the Samoan archipelago means that this synthesis is not definitive and should be treated as a preliminary review with potential for further research. Nevertheless, this synthesis does provide a reference point of the present understanding from which to build upon moving forward. The possibility of more sharks and rays being present in Samoa and American Samoa is high, given the lack of current knowledge and research in the region.

Meanwhile, conservation concerns regarding the sharks and rays of Samoa appears to be relatively high, with 35 of the 67 species potentially found in these waters listed as threatened on the IUCN Red List. Furthermore, nine species in Samoan waters were listed across CITES Appendix II, the CMS, and the WCPFC 'key species' list. This overlap between listings on independent measures for species occurring in the Samoan archipelago suggests that Samoa and American Samoa can play important roles in the efficacy of these conservation measures. For example, seven of these species have been recorded as bycatch in American Samoa tuna fisheries (NOAA *et al.* 2020; McCracken and Cooper 2022). A key outstanding knowledge gap is to gain an understanding of the post-release survival in fisheries within the Samoan archipelago, as currently the impact of fisheries between these nations remains poorly understood. It should also be noted that the conservation status of each species should be treated as a preliminary account, as understanding the nation specific risks and conservation status will require species-by-species risk assessments. The current IUCN Red List assessments used for each species are based on global population trends, and therefore do not necessarily reflect the local and regional situation. For example, the blue shark has a global conservation assessment of 'Near Threatened'; however, given the high levels of bycatch of the species in American Samoa's tuna fishery and no records of post-release survival, there is potential for this assessment to vary on at the local stock level. What these global conservation status and conservation agreements indicate, is that there are several species that are vulnerable to fisheries in the Samoan archipelago, and efforts will be needed to ensure their interactions with fisheries are sustainable, to assist in stabilising global declines (Pacoureau *et al.* 2021).

The conservative nature of the confidence criteria for species occurrence validation meant that even if certain species are likely to occur in Samoan waters, their occurrence could not be verified without explicit taxonomic certainty. For example, species such as the smooth and scalloped hammerhead are reported in American Samoa fisheries bycatch accounts and have been confirmed to be found in waters of bordering countries (Ebert *et al.* 2021). Given their large migratory range (Gallagher and Klimley 2018; Santos and Coelho 2018), it is very plausible that these species occur in Samoan waters also. However, with the possibility of misidentification between the two species, no explicit reference of their occurrence in species reference books, and no photographic evidence of their occurrence in Samoa, these species still require validation. Taxonomic uncertainty also limits the number of species that can be considered confirmed and verified. For example, photographic evidence of a *Neotrygon* species was obtained (Fig. 1*a*); however, it was not possible to confirm its identification due to the lack of certainty around the ranges of each of these newly classified Neotrygon species (W. White, pers. comm.). Therefore, this record could be a range extension of the Coral Sea maskray (*Neotrygon trigonoides*) or an undescribed *Neotrygon* spp. That may be restricted to Samoa and/or the Central Pacific, but further taxonomic work is needed. No chimaeras were reported, hinting to a possible absence of chimaera species in the region or (more likely) the lack of research around these species. Further, given the geographical location of the Samoan archipelago the likelihood of more deepwater species is highly plausible, however, with large knowledge gaps surrounding deepwater environments this remains unconfirmed. Overall, the high number of species requiring validation in Samoa underlines the lack of shark and ray orientated research in this nation.

Social media posts from local dive shop were useful for obtaining photographic evidence and validating species occurrences in the region (Fig. 1). For example, one source of published literature of the occurrence of the grey reef shark in Samoan waters exists (Wass 1984), this occurrence was then able to be 'confirmed and verified' through a photograph of a grey reef shark located on a local dive company's social media page with geo-referenced tags indicating it was photographed in Samoa (Fig. 1*b*). This aspect of data verification highlights the importance of citizen science in data poor scenarios. The value of citizen science is increasingly being recognised within chondrichthyan biodiversity and conservation research (Bargnesi *et al.* 2020) particularly in discerning species distributions in data poor areas (Grant *et al.* 2022) or for species that are highly threatened and rare (McDavitt and Kyne 2020). Furthermore, citizen science may to help overcome difficulties that can arise when trying to obtain reliable catch statistics for small-scale fisheries as catch is often directly consumed or sold in unmonitored local markets (Levine and Sauafea-Le'au 2013). Samoa and American Samoa are no exception and data on shark and ray captures in small-scale sectors are extremely limited, highlighting the importance for further research into uses and value of implicit species in small-scale fisheries in this region. Unfortunately, very few photographs were sourced from the Samoan islands compared to other locations such as Palau (Hari *et al.* 2021), and the Solomon Islands (Hylton *et al.* 2017), restricting the application of this method in the present study. Samoa is not a major diving destination and paired with the impacts of COVID-19 to the tourism industry (Australian Government Department of Foreign Affairs and Trade 2020), underwater photographs from Samoan dive operations were scarce.

There was very little information available about the social, cultural, and economic values of sharks and rays in

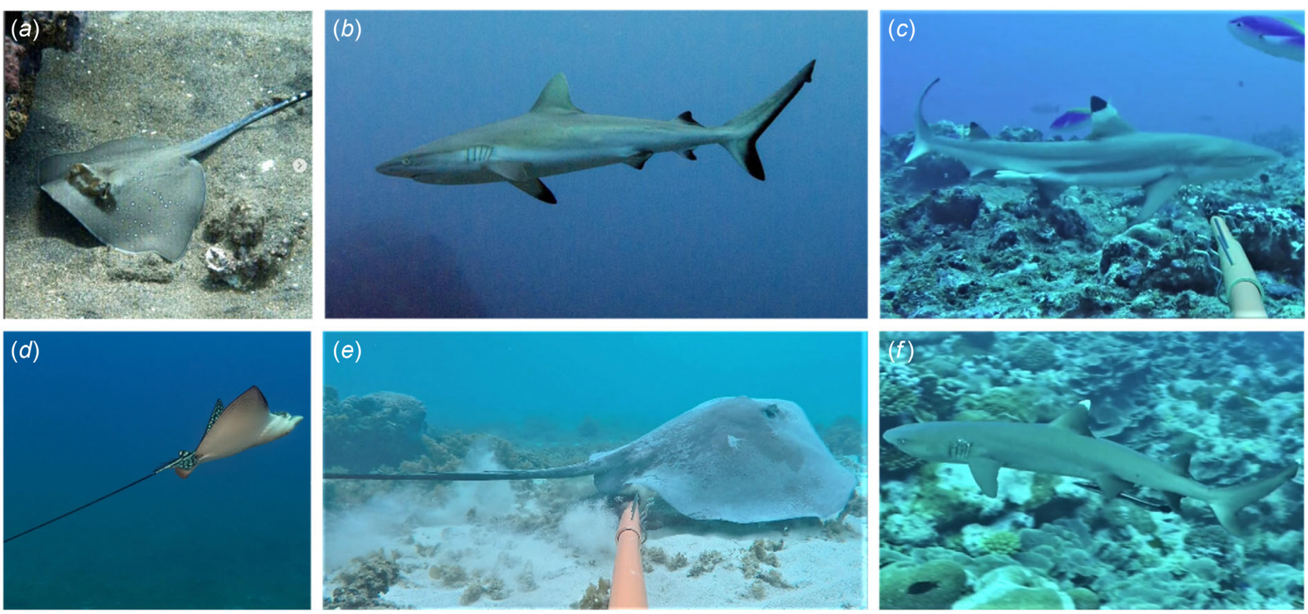

Fig. 1. Photographs used in the verification process of species on the checklist: (*a*) Coral Sea maskray (*Neotrygon* cf. *trigonoides*) (photo credit: AquaSamoa Dive Centre); (*b*) Grey reef shark (*Carcharhinidae amblyrhynchos*) (photo credit: Samoa Dive and Snorkel Centre); (*c*) Blacktip reef shark (*Carcharhinidae melanopterus*) (photo credit: Global Fin Print); (*d*) Ocellated eagle ray (*Aetobatus ocellatus*) (photo credit: AquaSamoa Dive Centre); (*e*) Pink whipray (*Pateobatis fai*) (photo credit: Global Fin Print); and (*f*) Whitetip reef shark (*Triaenodon obesus*) (photo credit: Dr. John Costello).

the Samoan archipelago. This is perhaps not surprising. Much of the literature concerning shark and ray values focuses on the economic values of shark tourism (e.g. Vianna *et al.* 2012) and Samoa is not a major dive destination. Meanwhile, as evident here, there are also very little data on the catch and landings of sharks and rays in Samoa, let alone the economic value of these landings. It can also be very difficult to retrieve accounts of cultural values. Much of this knowledge may be in the form of traditional knowledge that is not recorded, may be sensitive, challenging, and potentially inappropriate to digitise and make available (e.g. Forsyth 2012). Traditional and cultural knowledge is also being lost which may make it unavailable for this study (Fernández-Llamazares *et al.* 2021). Nevertheless, we assume that cultural values relating to sharks and rays do exist across the Samoan archipelago and recommend that culturally appropriate research is initiated to explore what knowledge and cultural information may still exist, and the appropriate way to preserve it for future Samoan peoples to use as they see fit.

Management and conservation

Increasing human population size paired with limited economic resources and opportunities is a challenge that many Pacific Island countries are faced with in securing sustainable livelihood options for their populations (Western Pacific Regional Fishery Council 2010). Fish and fishing have historically been important elements of island nations, and fisheries hold strong economic, social, and cultural importance (Food and Agriculture Organization (FAO) 2018). Approximately 500 species are caught in the Samoan small-scale fisheries sector (Zann and Mulipola 1995), with the most critical groups being: octopus, giant clams, sea cucumbers, gastropods, crab, and finfish species such as surgeonfish, grouper, mullet, and rabbitfish (Food and Agriculture Organization (FAO) 2018). The importance of fish and fishing is particularly true for Samoa and American Samoa because fisheries have an important role in food security and is one of the largest export commodities (Food and Agriculture Organization (FAO) 2018). This highlights the need for adequate conservation and management strategies to ensure long-term sustainability of marine resources.

Shark sanctuaries have attracted much attention globally as a positive step towards multispecies shark conservation action (Techera 2019). However, many shark sanctuaries may not consider the biology and movement patterns of the species they intend to protect, may lack the legal frameworks to make them enforceable, and compliance levels are often unclear (Techera 2019; Chin *et al.* 2023). This is no different in Samoa, with the establishment of the shark sanctuary in 2018, as currently there are no existing laws to enforce the sanctuary. There is also a discrepancy in regulations between the ban of commercial shark fishing in the shark sanctuary (the entire EEZ) and Samoa's Tuna Management Plan that permits the commercial catch of sharks. Samoa's declaration of shark sanctuary demonstrates promising intent, but requires greater enforcement and clarity to achieve its intended, operational effectiveness (Techera 2019). Meanwhile, American Samoa's enforced ban on all shark fishing activities can be seen as a progressive step in shark conservation. However, the social and economic consequences of a firmly governed and enforced ban on shark fishing for communities who may rely on sharks for their livelihoods creates challenges that require careful consideration in developing shark management approaches (Mizrahi *et al.* 2019; Booth *et al.* 2020). Developing, low-income countries, especially those who rely heavily on marine resources for protein and income, often do not have the capacity to adapt to 'top-down' legislation (Dunne *et al.* 2014; Jaiteh *et al.* 2016). Conservation measures developed without consideration of the livelihoods of local communities can result in non-compliance, generating a negative feedback loop, which will ultimately see the conservation goals of the shark fishing ban fail (Mizrahi *et al.* 2019; Haque *et al.* 2022). Trade-offs between biodiversity benefits and costs to livelihoods must therefore be considered when dealing with the impacts of shark fishing bans in developing nations such as Samoa, with prominent small-scale fisheries sectors (Mizrahi *et al.* 2019). Increased opportunities for alternative incomes or other methods of conservation such as development of alternative fisheries may need to be considered in circumstances where communities are negatively affected by prohibitions on shark fishing (e.g. Mizrahi *et al.* 2019). Community-based management, such as the processes already employed in Samoa, have been demonstrated to bridge the gap between resource use and sustainability by initiating collaboration between various stakeholders, to ultimately improve resource use and socio-economic conditions in local communities (Dey and Kanagaratnam 2007). The integration of shark and ray conservation into these management approaches with consideration and mitigation of the potential impacts to local communities may be a possible way forward in biodiversity conservation that does not undermine local livelihood opportunities or impede negatively on traditional practices.

Samoa's main form of shark and ray protection resides in specific fisheries provisions that restrict commercial fisheries impacts on local shark populations. Commercial fishing regulations imposed by WCPFC and Samoa's own tuna management plan, and marine wildlife protection regulations, directly protect threatened shark species such as the silky shark and oceanic whitetip, and discourage the practice of finning sharks at sea. These fisheries restrictions have the potential to contribute significantly to shark conservation, however, their success relies heavily on Samoa's capacity to implement and enforce these regulations (Techera 2019). If enforced, fishery regulations are likely to protect pelagic species that interact regularly with fisheries. However, it is less clear how these management initiatives effect the various deep-sea and inshore species that are noted as being present or having the potential to be present in Samoan waters in the current study. Fisheries regulations may not directly affect these species as they do not commonly interact with these regulated fisheries that mainly target teleost species in the upper pelagic zone. There is a need for information of the fisheries risk posed to both inshore and deep-sea species by commercial fishing activities. For deep-sea species in particular, greater information availability on diversity and threats would help safeguard this vulnerable group from future expansions of fishing effort into deep waters (Finucci *et al.* 2021). Furthermore, the presence of regular onboard observers, such as in American Samoa's observer program, or other means for independent validation of catch reports, would be a positive step to assessing efficacy of these measures, while simultaneously increasing the amount of reliable catch data (Tolotti *et al.* 2015). This need is highlighted by the lack of sharks reported in catch data in Samoa's longline fishery. While 4.5 million hooks were deployed in 2021, catch reports of no sharks and rays strongly contradicts the records from adjacent American Samoa, indicating that there may be issues in catch reporting. It is likely that sharks are incidentally caught, as observed in longline fisheries in American Samoa and elsewhere throughout the tropical Pacific (e.g. Schaefer *et al.* 2019).

Conclusion

Our current understanding of sharks and their threats, management and uses and values to local people in the Samoan archipelago is generally poor. Research on potential ecological and biogeographical drivers is lacking and significant knowledge gaps exist in current taxonomic validation of species present in the region. Only 26 of the 67 shark and ray species had sufficient life history data to perform a productivity analysis on and only 5 of the 67 total species were able to be 'confirmed and verified' for their presence in the region. This highlights the need for further research to be conducted on shark and ray populations in the Samoan archipelago, to better inform population assessments. The implementation of citizen science programs and further systematic research in both countries has the potential to fill these knowledge gaps.

Samoa and American Samoa have made significant efforts in managing and conserving their shark and ray populations. Samoa has implemented a shark sanctuary, and American Samoa has placed a ban on all shark fishing and fin trade. Along with this, fisheries regulations targeting shark finning in both country's commercial tuna fisheries are in place. These regulations have the potential to provide significant protection to sharks and rays. Moving forward, a better understanding on the efficacy of these policies is needed. A good understanding of fisheries catch and landings underpins sustainable management and development of conservation measures. However, it appears that catch documentation is presently poor in Samoa. Priority should also be assigned towards understanding the interactions between small-scale and artisanal fisheries and shark and rays to understand the full scope of the impacts of fisheries on shark and ray populations in the Samoan archipelago. Lastly, the importance of sharks and rays to the culture and livelihoods of the citizens of Samoa and American Samoa must be further explored, and acknowledged during the development and implementation of new and existing legislation, as biodiversity protection should not come at an unreasonable cost to the cultural heritage and livelihoods of resource dependent communities. Active involvement of local people and fishers during stakeholder engagements and increased opportunities for alternative incomes should be encouraged.

Supplementary material

Supplementary material is available online.

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