**Sharks and Rays of The Samoan Archipelago: a review of their biological diversity, social and cultural values, and conservation status**

ABSTRACT

Data on Chondrichthyes populations is largely lacking for many countries and territories in the Indo-Pacific. This report aims to assemble a desktop review on the biodiversity, conservation overview and threats to Chondrichthyes in the Samoan archipelago. Focusing on their interactions within fisheries and their social, cultural, and economic values. A total of 67 Chondrichthyes were documented to be present or potentially present in Samoa and American Samoa, consisting of 23 ray species and 44 shark species. Twenty of these species were listed by the IUCN as ‘vulnerable’, 12 as ‘endangered’ and four as critically endangered. A biological productivity analysis demonstrated that of the species with sufficient information to be assessed, five species ranked the highest in their productivity, these include: the grey reef (*Carcharhinus amblyrhynchos*), galapagos shark (*Carcharhinus galapagensis*), blacktip shark (*Carcharhinus limbatus*), blacktip reef shark (*Carcharhinus melanopterus*) and whitetip reef shark (*Triaenodon obesus*). Meanwhile the white shark (*Carcharodon carcharias*) and basking shark (*Cetorhinus maximus*) had the lowest productivity. Both Samoa and American Samoa have management plans in place to protect sharks and rays. These range from large shark sanctuaries to fishery management plans and community-based management programs. This study uses multiple information sources including the use of citizen science and in-country engagement to assemble a review of current available information on Samoan Chondrichthyes.

Key words: biodiversity, citizen science, fisheries, management, conservation, shark sanctuary, productivity analysis, Indo-Pacific

1. INTRODUCTION

More than 1,250 species of Chondrichthyes (sharks, rays and chimeras) are found throughout the world’s waters (Dulvy et al., 2017). Chondrichthyes are amongst the oldest vertebrate fauna still extant on Earth (Giovos et al., 2021), persisting for at least 420 million years (Dulvy et al., 2017). Sharks hold unique value as integral components of marine ecosystems, acting as top predators and demonstrating high species diversity and complex social structures (Jacoby et al., 2012). On top of their ecological value, Chondrichthyes also hold important social, economic, and cultural values (Cisneros-Montemayor et al., 2013; McDavitt, 2005; Mustika et al., 2020). Certain life history traits of sharks and rays such as late maturity, slow growth and low fecundity make them vulnerable to overexploitation (Cortes, 2002; Myers & Worm, 2005). Globally, Chondrichthyes populations are experiencing declines due to increased fishing pressure, pollution, by catch, habitat loss, and climate change (Dulvy et al., 2021). It is estimated by Dulvy et al. (2021) that globally, over one-third of chondrichthyans are threatened with extinction. These ongoing population declines cause uncertainty over the future of global shark and ray populations, highlighting the need for urgent and effective conservation and management strategies (Mackeracher et al., 2019).

Chondrichthyan populations in the Indo-Pacific are not well studied and data on shark and ray populations is lacking for many of these countries and territories (Juncker et al., 2006). New research has led to the discovery of new species of Chondrichthyes and the rediscovery of species thought to be locally extinct in Indo-Pacific waters (White et al., 2015), however, the majority of Chondrichthyes populations still lack thorough assessments. Fisheries catch data and landing statistics are poor and often unreliable (Gillett & Lightfoot, 2001; Pauly & Zeller, 2014), and limited enforcement of existing fishing regulations hinders any current management and conservation efforts along with impeding the development of further fishing and conservation policies (Espinoza et al., 2018; Lack & Meere, 1994). 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. Coastal fisheries throughout the tropics have been reported to be capturing sharks in large numbers as bycatch and targeted catch (Temple et al., 2018). Annually, Indonesia has the highest reported landings of elasmobranchs globally (>100, 000 tonnes) (Blaber et al., 2009; Lack & Sant, 2012). The impacts of small-scale shark fisheries on shark populations are likely significant (Glaus et al., 2019). In combination with overfishing, habitat loss stemming from development, aquaculture operations, human intrusions, and invasive species, they contribute to the further decline of Chondrichthyes populations (Dulvy et al., 2021).

The Samoan archipelago is situated approximately 3540 kilometres southwest of Hawaii and 804 kilometres northeast of Fiji (Jordan, 1905; Stice & McCoy Jr, 1968). The archipelago has a total land area of 3135 square kilometres and is located between latitudes 13-17 degrees South and longitudes 171- 173 degrees West (Skelton et al., 2003). 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 & 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 & Meleisea, 1987). Politically, the archipelago is divided into ‘American Samoa’, a US territory which consists of the eastern group of islands and ‘Samoa’ an independent nation, which consists of the Western group of islands (Stice & McCoy Jr, 1968). Samoa has a population of 206 179 people whilst American Samoa has a population of 55 197 people (2022) (Central Intelligence Agency, 2022). Due to its proximity to other Pacific Island countries, Samao has the smallest Exclusive Economic Zone (EEZ) in the Pacific, covering a mere 131, 535 square kilometres (Sea Around Us; Pernetta, 1990). Whilst American Samoa’s U.S territorial EEZ covers a total of 404, 367 square kilometres (Sea Around Us, 2022).

The islands of the archipelago are situated along the crest of a submarine ridge which ranges over 482 kilometres from Savai'i to Rose Atoll (Stice & McCoy Jr, 1968). Due to the steep gradients of its islands, habitats around the land are restricted and consist predominantly of fringing coral reefs and offshore banks (Craig et al., 2005). The reefs of the archipelago support a high diversity of Indo-Pacific corals, fishes, and invertebrate (Craig et al., 2005). Samoans rely heavily on these reefs and offshore ecosystems for their livelihoods (Skelton et al., 2003). A national household fisheries survey conducted in 2000 demonstrated that Samoa has 11,700 fishers, living in 8,377 fishing households, with 18% of these fishers being female (Passfield et al., 2001). Fish is a major source of health and nutrition for Samoans, especially to the population living on the coastal fringe (Passfield et al., 2001). Total seafood consumption for the country was estimated by Passfield et al. (2001) to be 9,971 tonnes. On top of its nutritional value, fishing activities play a particularly important role in the economy of the islands (Passfield et al., 2001). In the year 2000, Samoa exported approximately 4500 metric tonnes of fish amounting to ST $45 million (Watt & Moala, 2001) which is equivalent to approximately 60-70% of the total value of exports for the country (Passfield et al., 2001). Pairing fishery exports together with household consumption, the gross value of Samoa’s marine resources is estimated to be approximately ST $100 million (USD $27 million) per year (Passfield et al., 2001).

Both Samoa and American Samoa have management plans 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). Marine protected areas have also been established in American Samoa at the federal, local and community levels (Montgomery et al., 2019). Certain regulations are in place which also specifically aid in the protection of Chondrichthyes, a major one being Samoa’s decision to declare the waters of its EEZ a ‘shark sanctuary’ (Techera, 2019) prohibiting the commercial fishing and export of shark products (Ward-Paige, 2017). Furthermore, fisheries management regulations are instilled to conserve sharks, such as those under Samoa’s Marine Wildlife Protection Regulations (2009). Both Samoa and American Samoa (as a U.S territory) are also participants in the Convention of International Trade in Endangered Species of Wild Fauna and Flora (CITES), Convention on the Conservation of Migratory Species of Wild Animals (CMS) and The Food and Agriculture Organisation. Despite these measures, lack of general knowledge of shark species present in the waters of the archipelago and absence of proper enforcement still leaves room for improvement for the conservation of sharks and rays in the Archipelago.

This report aims to assemble a desktop review on the biodiversity, conservation status and threats to Chondrichthyes in the Samoan archipelago. Focusing on their interactions within fisheries and their social, cultural, and economic values to the Samoan population.

1. MATERIALS AND METHODS
   1. **Species List**

Data collected for the study included a range of information on each of the species listed. For each species this included records on occurrences, life history traits, risks and threats, current conservation measures and an overview of fishing activities occurring in Samoan and American Samoan waters relative to the species mentioned. The primary 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 to Samoa, were used to compile a list of Chondrichthyan species which may be present in Samoan waters, along with their distributions, habitat, biology, and life history traits. Searches of scientific and grey literature were performed on *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 (WoRMS)* were used (Froese & Pauly, 2022; Horton et al., 2022). Collaboration with in-country partners to obtain up to date information was also crucial to the rigorousness of the checklist. Furthermore, the use of citizen science was a crucial tool in the verification of species. Social media accounts of local dive shops were examined, and 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 this information and specific criteria (Table 1). The 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.

**Table 1.** Description of confidence categories used to classify elasmobranch species found in Samoa and American Samoa.

|  |  |
| --- | --- |
| **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[[1]](#footnote-1); 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 envelop, 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 an 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 recognized, 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 |

Each species’ current extinction risk and conservation concerns were deduced from current global species assessments including current Red List assessments and population trends from the International Union for Conservation of Nature (IUCN), and from species listings in conservation conventions such as the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES), the Convention on the Conservation of Migratory Species of Wild Animals (CMS), and in any conservation management measure or policy by the Western and Central Pacific Fisheries Commission (WCPFC).

* 1. **Productivity Analysis**

To identify the relatively vulnerable species to establish priorities for research, management, and conservation, (Furlong-Estrada et al., 2017), a biological productivity analysis was completed for each species that had sufficient published life history information. Five traits used in the analysis included maximum size, size at maturity, age at maturity, longevity and fecundity per year (Furlong-Estrada et al., 2017). Each species was also assigned a trophic level based on their diet according to specific criteria (Table 2). Analysis for sharks and rays were completed separately and only the female traits were used in the analysis. Only species that had information for all five traits were included in the analysis.

**Table 2.** Description of trophic level categories used to classify elasmobranch 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. |

Firstly, 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 120-190cm total length (TL) (Ebert et al., 2021), whilst the IUCN Red List provides a range of 145-207cm TL (IUCN, 2021). Therefore, size at maturity was determined to range from 120-207cm TL, with an average length of 163.5cm 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 Samoa was used.

Following this, a productivity category of 1, 2 or 3 was assigned to each life history trait, where a productivity category of 1 refers to the most productive (lowest risk) and 3 refers to least productive (highest risk). Categories were assigned according to the value of each species trait against the range of values for that trait amongst all other species in the analysis. For example, the range for maximum size of the shark species being analysed was 102-1097cm TL, which results in a range of 762.5 years. Therefore, species with maximum sizes of 102-433.7cm TL were assigned a rank of 1, species maximum sizes between 433.8-765.5cm TL were assigned a rank of 2 and species between 765.6 and 1097cm TL were assigned a rank of 3.

Current conservation and management plans and actions surrounding elasmobranchs were then examined to identify the major pressures facing Samoa’s sharks and rays. This predominantly focused on fishery pressures and the existing management approaches which exist to address these threats. 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 regarding the issues.

1. RESULTS
   1. **Species diversity and risk analysis**

A total of 67 Chondrichthyes were documented for Samoa and American Samoa (Table 3.), consisting of 23 rays and 44 sharks, no chimeras were reported. Of these, for Samoa, four were classed as ‘confirmed and verified’, 38 as ‘requires verification’ and 25 as ‘plausible’. For American Samoa, only one species was ‘confirmed and verified’, 42 were classed as ‘requires verification’ and 25 as ‘plausible’. Species ranged from various types of habitat categories, with approximately 40% of ray species found in continental shelf/slope habitats and a further 40% found in inshore habitats. While more than half of the shark species (28 individual species) are found on continental shelf/slope habitats.

**Table 3.** Elasmobranch species confirmed 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** |
| Bigeye thresher | *Alopiidae* | *Alopias* | *superciliosus* | Requires verification | | Requires verification | VU | Appendix II | Appendix II | Key species |
| Pelagic thresher | *Alopiidae* | *Alopias* | *pelagicus* | Requires verification | | Requires verification | EN | 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 | NA | NA |  |
| Grey reef shark | *Carcharhinidae* | *Carcharhinus* | *amblyrhynchos* | **Confirmed and verified** | | Requires verification | EN | NA | NA |  |
| Silky shark | *Carcharhinidae* | *Carcharhinus* | *falciformis* | Requires verification | | Requires verification | VU | NA | Appendix II | Key species |
| Galapagos shark | *Carcharhinidae* | *Carcharhinus* | *galapagensis* | Requires verification | | Requires verification | LC | NA | NA |  |
| Bull shark | *Carcharhinidae* | *Carcharhinus* | *leucas* | Requires verification | | Requires verification | VU | NA | NA |  |
| Blacktip shark | *Carcharhinidae* | *Carcharhinus* | *limbatus* | Requires verification | | Requires verification | VU | NA | NA |  |
| Oceanic whitetip shark | *Carcharhinidae* | *Carcharhinus* | *longimanus* | Requires verification | | Requires verification | CR | NA | NA | Key species |
| Blacktip reef shark | *Carcharhinidae* | *Carcharhinus* | *melanopterus* | **Confirmed and verified** | | Requires verification | VU | NA | NA |  |
| Tiger shark | *Carcharhinidae* | *Galeocerdo* | *cuvier* | Requires verification | | Requires verification | NT | NA | NA |  |
| Sicklefin lemon shark | *Carcharhinidae* | *Negaprion* | *acutidens* | Requires verification | | Requires verification | EN | NA | NA |  |
| Blue shark | *Carcharhinidae* | *Prionace* | *glauca* | Requires verification | | Requires verification | NT | NA | Appendix II | Key species |
| Whitetip reef shark | *Carcharhinidae* | *Triaenodon* | *obesus* | Requires verification | | **Confirmed and verified** | VU | NA | NA |  |
| Bignose shark | *Carcharhinidae* | *Carcharhinus* | *altimus* | Plausible | | Plausible | NT | NA | 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 & 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 |  |
| 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 |  |
| 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 |  |
| 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 |  |
| Blackbelly lanternshark | *Etmopteridae* | *Etmopterus* | *lucifer* | Plausible | | Plausible | LC | NA | NA |  |
| Tailspot lanternfish | *Etmopteridae* | *Etmopterus* | *caudistigmus* | Plausible | | Plausible | LC | NA | NA |  |
| False lanternshark | *Etmopteridae* | *Etopyerus* | *pseudosqualiolus* | Plausible | | Plausible |  | NA | NA |  |
| Pink lanternshark | *Etmopteridae* | *Etmopterus* | *dianthus* | Plausible | | Plausible | LC | NA | NA |  |
| Tawny nurse shark | *Ginglymostomatidae* | *Nebrius* | *ferrugineus* | Requires verification | | Requires verification | VU | NA | NA |  |
| Bluntnose sixgill shark | *Hexanchidae* | *Hexanchus* | *griseus* | Requires verification | | Requires verification | NT | NA | NA |  |
| Sharpnose sevengill shark | *Hexanchidae* | *Heptranchias* | *perlo* | Plausible | | Plausible | NT | NA | NA |  |
| Bigete sixgill shark | *Hexanchidae* | *Hexanchus* | *nakamurai* | Plausible | | Plausible | NT | NA | NA |  |
| Sixgill stingray | *Hexatrygonidae* | *Hexatrygon* | *bickelli* | Plausible | | Plausible | LC | NA | NA |  |
| 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 |
| White shark | *Lamnidae* | *Carcharodon* | *carcharias* | Requires verification | | Requires verification | VU | Appendix II | Appendix I & II |  |
| 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 |
| Giant Devilray | *Mobulidae* | *Mobula* | *mobular* | Requires verification | | Requires verification | EN | Appendix II | Appendix I & II | Key species |
| Shortfin devilray | *Mobulidae* | *Mobula* | *kuhlii* | Requires verification | | Requires verification | EN | Appendix II | Appendix I & II |  |
| Bentfin devilray | *Mobulidae* | *Mobula* | *thurstoni* | Requires verification | | Requires verification | EN | Appendix II | Appendix I & II | Key species |
| Chilean devilray | *Mobulidae* | *Mobula* | *tarapacana* | Requires verification | | Requires verification | EN | Appendix II | Appendix I & II |  |
| 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 & 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 |
| Scalloped hammerhead | *Sphyrnidae* | *Sphyrna* | *lewini* | 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 |
| Great hammerhead | *Sphyrnidae* | *Sphyrna* | *mokarran* | Requires verification | | Requires verification | CR | Appendix II | 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 |  |

The IUCN Red list provides a globally accepted conservation assessment for individual species. Nineteen species were listed as of ‘least concern’, seven as ‘near threatened’, and 20 as ‘vulnerable’. Twelve species of sharks and rays were listed as ‘endangered’ and four species were listed as critically endangered, including the giant guitarfish (*Rhynchobatus djiddensis*), oceanic whitetip shark (*Carcharhinus longimanus*), scalloped hammerhead (*Sphyrna lewini*) and great hammerhead (*Sphyrna mokarran*). The remaining four species were listed as ‘data deficient’. All species in the endangered and critically endangered category also have decreasing population trends. In total, 43 species are recorded to have decreasing population trends and 20 have unknown population trends. Whilst only the Coral Sea maskray (*Neotrygon trigonoides*), the velvet dogfish (*Zameus squamulosus*), and the crocodile shark (*Pseudocarcharias kamoharai*) have stable and increasing population trends, respectively (IUCN, 2021).

Several species are listed on global multilateral environmental agreements such as the CITES and CMS conventions, and on regional level conservation through listings in the WCPFC key species list. 20 species are listed on at least one of these forms of environmental agreements (Table 3). A total of nine species can be found on all three management instruments, these include: the giant devilray (*Mobula mobular*), bentfin devilray (*Mobula thurstoni*), shortfin mako shark (*Isurus oxyrinchus*), scalloped hammerhead (*Sphyrna lewini*), bigeye thresher (*Alopias superciliosus*), pelagic thresher (*Alopias pelagicus*), whale shark (*Rhincodon typus*), great hammerhead (*Sphyrna mokarran*) and thresher shark (*Alopias vulpinus*).

**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** |
| *Stegostoma tigrinum* | Zebra shark | 1 | 1 | 3 | 1 | 1 | 3 | 1 | **1.57** |
| *Isurus oxyrinchus* | Shortfin mako shark | 2 | 1 | 1 | 2 | 1 | 3 | 3 | **1.86** |
| *Carcharhinus amblyrhynchos* | Grey reef shark | 1 | 1 | 1 | 1 | 1 | 3 | 2 | **1.42** |
| *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** |
| *Galeocerdo cuvier* | Tiger shark | 1 | 1 | 2 | 2 | 1 | 3 | 3 | **1.86** |
| *Prionace glauca* | Blue shark | 1 | 1 | 1 | 1 | 1 | 3 | 3 | **1.57** |
| *Triaenodon obesus* | Whitetip reef shark | 1 | 1 | 1 | 1 | 1 | 3 | 2 | **1.43** |
| *Sphyrna zygaena* | Scalloped hammerhead shark | 1 | 2 | 2 | 1 | 1 | 3 | 3 | **1.87** |
| *Alopias superciliosus* | Bigeye thresher shark | 1 | 1 | 1 | 2 | 1 | 3 | 3 | **1.71** |
| *Alopias pelagicus* | Pelagic thresher shark | 1 | 1 | 1 | 1 | 1 | 3 | 3 | **1.57** |
| *Sphyrna mokarran* | Great hammerhead shark | 1 | 2 | 2 | 2 | 1 | 3 | 3 | **2** |
| *Cetorhinus maximus* | Basking shark | 2 | 2 | 1 | 3 | 3 | 3 | 1 | **2.14** |
| *Alopias vulpinus* | Thresher shark | 1 | 1 | 1 | 2 | 2 | 3 | 3 | **1.86** |
| *Carcharodon carcharias* | White shark | 3 | 2 | 1 | 2 | 1 | 3 | 3 | **2.14** |
| *Heptranchias perlo* | Sharpnose sevengill shark | 3 | 3 | 1 | 1 | 1 | 3 | 2 | **2** |
| *Centrophorus moluccensis* | Smallfin gulper shark | 2 | 2 | 1 | 1 | 1 | 3 | 2 | **1.71** |
| *Deania quadrispinosa* | Longsnout dogfish | 2 | 2 | 1 | 1 | 1 | 3 | 2 | **1.71** |

**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** |
| *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** |
| *Aetobatus ocellatus* | Ocellated eagle ray | 1 | 1 | 3 | 1 | 1 | 3 | 2 | **1.71** |

Twenty-two of the 44 shark species had adequate information on their life history traits 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 grey reef (*Carcharhinus amblyrhynchos*), galapagos shark (*Carcharhinus galapagensis*), blacktip shark (*Carcharhinus limbatus*), blacktip reef shark (*Carcharhinus melanopterus*) and whitetip reef shark (*Triaenodon obesus*). The white shark (*Carcharodon carcharias*) and basking shark (*Cetorhinus maximus*) had the lowest productivity with scores of 2.14. Only four species of rays were able to be included in the analysis based on lack of available life history information for all other species (Table 5.). The giant devil ray (*Mobula mobular*) had the highest productivity score of 1.43 while the reef manta ray (*Mobula alfredi*) held the lowest productivity score of 2.29. These scores are based on global assessments, presenting the general inherent biological risks of each species.

* 1. **Fishing Activities and Behaviours in the Samoan Archipelago**

Subsistence and commercial fishing are important occupations in both Samoa and American Samoa (FAO, 2018), with both men and women involved in fishing activities (Ulusapeti Titii, 2014). In 1980 approximately 7,860 Samoans were employed through fishery-based work, this increased to 12,500 in 2000 and decreased again to 530 in 2015 (FAO, 2018). Fishing also continues to contribute to the cultural integrity and social structure of Samoan communities. For example, in American Samoa, skipjack tuna, locally referred to as ‘atu’ is seen as a nutritionally and culturally important species and when caught, the fish is distributed among the community according to ceremonial traditions (Western Pacific Regional Fishery Management Council, 2009).

* + 1. **Samoa**

Coastal subsistence fishing is undertaken by villagers in shallow lagoon waters adjacent to their land (FAO, 2018). Annual catch for coastal subsistence fisheries in 2014 was 5000 tonnes which was equivalent to the coastal commercial catch (FAO, 2018; Gillett, 2016). Catch from these fisheries is mainly consumed in households of villages near where they are caught, however, some may be exported to family members in Apia (FAO, 2018). The act of giving fish ‘faasoso’ is an important cultural tradition in Samoa (FAO, 2018). A study conducted by Zann (1992) stated that approximately 500 species are used in the Samoan small-scale fisheries, with the most critical groups being: octopus, giant clams, sea cucumbers, gastropods, crab and finfish such as surgeonfish, grouper, mullet, carangids and rabbitfish (FAO, 2018).

The nation’s commercial longline fishery started in the 1990s (Clark & Brown, 2004; FAO, 2018), beginning with small catamarans (alias) of sizes 12.5 meters or less (Clark & Brown, 2004). As of 2014, according to the fisheries division of Samoa, there were no reported foreign catches or vessels in Samoa’s EEZ (Gillett, 2016). Catches of the commercial fishing fleet is 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 9,066 tonnes with an estimated value of WST 89 million (Ulusapeti Titii, 2014). As of 2015, the size of the commercial longline fishing fleet was 53, inclusive of all vessel classes (Fisheries Division, 2016).

The commercial longline fishery primarily targets tuna species, with albacore tuna making up 70% of the catch over the past decade, averaging 2230 tonnes total catch annually between 2008-2012 (FAO, 2018). Yellowfin tuna comprises 11% of remaining catch, and bigeye and skipjack tuna 3% each (FAO, 2018). Outstanding catch is a mixture of non-tuna species such as black and blue marlin and swordfish (FAO, 2018). Most albacore tuna catch (60-80%) catch is exported frozen locally, to Pago Pago for canning, whilst bigeye and yellowfin tuna are exported to higher value markets in Japan and the US (Clark & Brown, 2004).

* + 1. **American Samoa**

In American Samoa small-scale fisheries consist of coral reef fisheries, shoreline subsistence fisheries and offshore and pelagic artisanal fisheries (Craig et al., 1993; Western Pacific Regional Fishery Management Council, 2009). 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 (Craig et al., 1993; Hill, 1978; Ponwith, 1991; Wass, 1980). In 1991, subsistence catch 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 bottomfish (Aitaoto et al., 1991). Coral reef fishes and invertebrates are also harvested by locals in the country’s coral reef subsistence fishery, using an array of gear such as hook and line, spear gun, and gillnet (Dalzell, 1996; Western Pacific Regional Fishery Management Council, 2009).

Similar to Samoa, American Samoa also has a commercial tuna fishery, this is a limited entry pelagic longline fishery in the U.S. 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), whilst during 2020, there were 11 active vessels but only 95 trips in the year (NOAA, 2022). This can be attributed to COVID-19’s impact on the fishery. American Samoa is also a homeport to a fleet of large commercial vessels who fish beyond their EEZ, whom 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 8,011 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 51150 tonnes, with Albacore comprising 60% of the catch (NOAA, 2022).

* 1. **Fisheries Interactions with Sharks and Rays**

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 (*Carcharhinus albimarginatus*), galapagos shark (*Carcharhinus galapagensis*), blacktip reef shark (*Carcharhinus melanopterus*) and the whitetip reef shark (*Triaenodon obesus*) (United States Office of the Federal Register 2015). Interactions between fisheries and elasmobranchs however, are better documented in the commercial fisheries. There is however, a significant lack of available data for Samoan fisheries. Conversely, American Samoa has publicly available logbook reports. An array of elasmobranch species are caught as 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 3,207 individual sharks in the fishery with eight of these individuals kept and the remainder released (NOAA et al., 2020). The blue shark (*Prionace glauca*) accounted for 51% catch, silky shark (*Carcharhinus falciformis*) 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 kept after capture, seven were thresher shark species and the remainder mako shark species (NOAA et al., 2020). In 2020, COVID-19 affected the deployment of observers onboard fishing trips due to government regulations (McCracken & Cooper, 2022). As a result, only one observed trip occurred in 2020 and thus, observer data over the years 2012−2020 were used to derive the 2020 bycatch estimates (McCracken & Cooper, 2022). Total estimated bycatch for sharks was 5,125 tonnes, with the majority of bycatch represented by the family Carcharinidae (McCracken & 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 & 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 & Cooper, 2022) (McCracken & Cooper, 2022). Total estimated catch for ray species was 8416 tonnes, with the Pelagic stingray (*Pteroplatytrygon violacea*) accounting for 99% of the total catch (McCracken & Cooper, 2022). Other bycatch species include the giant manta ray (*Mobula birostris*) and giant devil ray (*Mobula mobular*) (McCracken & 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 log books, majority of shark and ray bycatch are released (NOAA et al., 2020; NOAA, 2022), however, no information on post release mortality exists.

* 1. **Shark and Ray Management** 
     1. **Samoa**

Even with Samoa’s EEZ being the smallest of the Pacific Island countries, the nation has still successfully established one of the largest offshore fisheries in the region (Clark & Brown, 2004). Samoa’s tuna fishery is 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 backstops 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 loss of income from decreased sales of sharks is also likely (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. Additionally, the weight of fins on board any vessels must not exceed 5% of total carcass weight (Ministry of Agriculture and Fisheries Division, 2011). Furthermore, the Samoa Marine Wildlife Protection Regulations (2009) (Ministry of Natural Resources and Environment, 2009) state that it is an offence to, commercially fish for sharks, take a shark without intending to consume it or use it for any proper purpose, land fins without the associated carcass and take sharks as fisheries bycatch (Ministry of Agriculture and Fisheries Division, 2011).

Samoa’s small-scale fisheries are managed through Community-based Fisheries Management Programs (CBFMP) where participating villages develop their own strategy to manage their marine resources and environment (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 country’s fisheries division to engage in fisheries development and marine conservation (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 (FAO, 2018).

* + 1. **American Samoa**

American Samoa has a national marine sanctuary which consists of six protected areas, spanning 13,581 square miles of coral reef, offshore and open ocean habitats (U.S. Department of Commerce et al., 2012). The sanctuary has regulations which 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 (U.S. Department of Commerce et al., 2012). Irrespective of the sanctuary, the territory has taken a large step in placing a ban on all shark fishing and possession and trade of shark fins and body parts within the territory and its waters (PEW, 2012). These changes were made to fishing regulations by the Department of Marine and Wildlife Resources in 2012 (PEW, 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 Register, 2015).

1. DISCUSSION
   1. **Species List**

This review presents a synthesis on species of Elasmobranchs found in the Samoan archipelago, their diversity, conservation status, threats and a summary of current management actions related to sharks and rays in the region.

**A picture containing fish, different, shark, same

Description automatically generatedFigure 1.** Photographs used in the verification process of species on the checklist (a) Coral Sea maskray (*Neotrygon cf. trigonoides*) (b) Grey reef shark (*Carcharhinidae amblyrhynchos*) (c) Blacktip reef shark (*Carcharhinidae melanopterus*) (d) Ocellated eagle ray (*Aetobatus ocellatus*) (e) Pink whipray (*Pateobatis fai*) (f) Whitetip reef shark (*Triaenodon obesus*)

Due to the lack of available data, multiple sources were used to gather information for this synthesis. Species reference books 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 identification data in the Samoan archipelago infers that this synthesis is not definitive and should be treated as a preliminary review with potential for further research. The possibility for more elasmobranchs to be present in Samoa and American Samoa is high, given the lack of current knowledge and research of species in the region. The conservation status of each species should also be treated as a preliminary account as understanding the specific risk and conservation status requires a species-by-species risk assessment specifically for the Samoan archipelago. The IUCN assessments used for each species were based on global estimates and therefore may not accurately reflect the species local conservation status. For example, the blue shark (*Prionace glauca*) has a global conservation assessment of ‘near threated’ 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 a local level. Likewise, CITES and CMS listings are a result of global assessments, given this, species listings on these global agreements along with global red list assessments should currently be taken as the most available indicators of at-risk species. A total of 35 of the 67 species potentially found in Samoa and American Samoa are listed as being threatened by the ICUN, with nine of these species listed on both CITES and CMS measures and on WCPFC key species list. This evident overlap between listings on independent measures suggests there should be serious conservation focus for these species. Of these species, seven have been recorded as bycatch in American Samoan tuna fisheries (McCracken & Cooper, 2022; NOAA et al., 2020), indicating opting for concern over the species’ population status. However, without post-release survival statistics and no accurate understanding of local population dynamics, their overall risk in Samoa remains unknown.

The conservative nature of the confidence criteria 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 & Klimley, 2018; Santos & Coelho, 2018) it is very plausible that these species occur in Samoan waters 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 remain requiring validation. Furthermore, a taxonomic expert was also contacted to verify certain species. For example, photographic evidence of a *Neotrygon* species was obtained (Figure 1 a), however taxonomic expertise could not confirm its identification due to the lack of certainty around the ranges of each of these newly classified Neotrygon species. Therefore, it has the potential to be *Neotrygon trigonoides* or a new *Neotrygon* species distinct to Samoa, and thus remains as requiring verification.

Social media posts from local dive shop were used as a means of obtaining photographic evidence for the presence of certain species in the region (Figure 1). For example, one source of published literature of the occurrence of the grey reef shark (*Carcharhinus amblyrhynchos*) 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 tags indicating it was photographed in Samoa (Figure 1b). This aspect of data verification highlights the importance of citizen science in data poor scenarios. Numerous studies such as that by Bargnesi et al. (2020) comment on the success of citizen science at contributing data to shark research particularly in regional distributions and abundance of populations. Nevertheless, 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). 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. The increased utilisation of citizen science in understudied regions such as Samoa can benefit the overall understanding and documentation of elasmobranch populations in the region.

* 1. **Management and Conservation**

Increasing human population size paired with limited economic resources is a challenge that many Pacific Island countries are faced with (Western Pacific Regional Fishery Management Council, 2009). Fish and fishing have always been important elements of island nations holding strong economic and social and cultural importance, and this is particularly true for Samoa and American Samoa where fish is a large part of the Samoan diet and one of the country’s largest exports (FAO, 2018).

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 all shark and ray species in the country’s waters (SPREP, 2018). Whilst shark sanctuaries have attracted much attention globally, with many considering them to be a positive step towards widespread shark conservation action, many shark sanctuaries lack the legal frameworks to make them enforceable (Techera, 2019). This is no different in Samoa, with no existing laws to enforce the regulations of the sanctuary. Thus, Samoa’s shark sanctuary is promising but without proper enforcement, may lack operational effectiveness (Techera, 2019). This is evident in the contradiction in regulations between the ban of commercial shark fishing in the shark sanctuary (the entire EEZ) and Samoa’s Tuna Management Plan which permits the commercial catch of sharks. In contrast, American Samoa’s ban on all shark fishing activities can be seen as a progressive step in shark conservation. However, the socio-economic consequences of a firmly governed and enforced ban on shark fishing for the local resource dependent communities who may rely on sharks for their livelihoods must be considered (Booth et al., 2020; Mizrahi et al., 2019). 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 these blanket ‘top-down’ legislations (Dunne et al., 2014; Jaiteh et al., 2016). As resource use of sharks are completely restricted, it is evident that this will come at a cost to local communities (Mizrahi et al., 2019). The absence of consideration to the livelihoods of local communities has the potential to result in non-compliance, generating a negative feedback loop which will ultimately see the conservation goals of the shark fishing ban fail (Haque et al., 2022; Mizrahi et al., 2019). 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 and on their small scale fisheries in particular (Mizrahi et al., 2019). Livelihood development and increased opportunities for alternative incomes or other methods of conservation such as fisheries development may need to be implemented in circumstances where communities are negatively affected by prohibitions on shark fishing (Mizrahi et al., 2019). Community based management, such as the processes already employed in Samoa, have been demonstrated to bridge the gap between supply and demand issues by initiating collaboration between various stakeholders, to ultimately improve resource use and socioeconomic conditions in local communities (Dey & 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 doesn’t jeopardise local livelihoods.

Samoa’s main form of protection for sharks resides in specific fisheries provisions which restrict commercial fisheries impacts on local shark populations. 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 white tip, 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). The presence of onboard observers, such as in American Samoa’s observer program, would be a step to assessing compliancy while simultaneously increasing the amount of reliable catch data (Tolotti et al., 2015). If enforced, fishery regulations are likely to protect pelagic species who interact regularly with fisheries, however, various deep sea and inshore species were noted as being present or having the potential to be present in Samoan waters. Fisheries regulations may not directly affect these species as they are not commonly interacted with within fisheries, which at face would also reduce the risks these species face. Further action and research is required to ensure the protection of these species. Furthermore, difficulties arise when trying to obtain reliable catch statistics for small scale fisheries as they typically tend to involve multiple species and fishing methods and distribution of catch is not normally documented (Levine & Sauafea-Le'au, 2013). Samoa and American Samoa are no exception and data on elasmobranch captures are largely absent, highlighting the importance for further research into the impacts of small-scale fisheries on shark and ray populations.

1. CONCLUSION

This study provides an insight into the species of sharks and rays present in Samoa and American Samoa, an overview of their conservation and the dynamics surrounding their management and social, cultural, and economic importance. This review sheds a light on the importance of these factors and provides a foundation for further research to better understand species occurrences and their regional conservation status. The implementation of citizen science programs and further systematic research in both countries has the potential to achieve this. Samoa and American Samoa have made significant efforts in managing and conserving their shark and ray populations with the implementation of a shark sanctuary in Samoa and a ban on all shark fishing and fin trade in American Samoa along with fisheries regulations targeting shark finning in both country’s commercial tuna fisheries. These regulations have the potential to provide significant protection to sharks and rays however, their effectiveness relies heavily on proper enforcement. Shark catch data is extremely valuable for research and conservation measures however, catches are poorly documented in Samoa. The implementation of an observer program in Samoa’s commercial fisheries would aid in the enforcement of regulations and improve reliability of catch data. Furthermore, priority should 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 elasmobranch 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 acknowledged during the development and implementation of new and existing legislation, as biodiversity protection should not come at an unreasonable cost to the livelihoods of resource dependent communities. Active involvement of local people and fishermen during stakeholder engagements and increased opportunities for alternative incomes should be considered.

REFERENCES

Aitaoto, F., Ponwith, B., & Craig, P. (1991). Fisheries catch statistics for American Sa moa, 1990. *Department of Marine and Wildlife Resources American Samoa, BioI. Rep. Ser*, *21*, 40.

Bargnesi, F., Lucrezi, S., & Ferretti, F. (2020). Opportunities from citizen science for shark conservation, with a focus on the Mediterranean Sea. *The European Zoological Journal*, *87*(1), 20-34. https://doi.org/10.1080/24750263.2019.1709574

Blaber, S. J. M., Dichmont, C. M., White, W., Buckworth, R., Sadiyah, L., Iskandar, B., Nurhakim, S., Pillans, R., Andamari, R., Dharmadi, & Fahmi. (2009). Elasmobranchs in southern Indonesian fisheries: the fisheries, the status of the stocks and management options. *Reviews in Fish Biology and Fisheries*, *19*(3), 367-391. https://doi.org/10.1007/s11160-009-9110-9

Booth, H., Squires, D., & Milner‐Gulland, E. J. (2020). The mitigation hierarchy for sharks: A risk‐based framework for reconciling trade‐offs between shark conservation and fisheries objectives. *Fish and Fisheries*, *21*(2), 269-289.

Central Intelligence Agency, (2022). The World Factbook – Samoa. Retrieved 02/07/2022 from <https://www.cia.gov/the-world-factbook/countries/samoa/>

Cisneros-Montemayor, A. M., Barnes-Mauthe, M., Al-Abdulrazzak, D., Navarro-Holm, E., & Sumaila, U. R. (2013). Global economic value of shark ecotourism: implications for conservation. *Oryx*, *47*(3), 381-388. https://doi.org/10.1017/s0030605312001718

Clark, L., & Brown, C. (2004). *GEF SAP II Project: National Project Preparation Reports - Samoa*. T. G. E. Facility.

Cortes, E. (2002). Incorporating Uncertainty into Demographic Modeling: Application to Shark Populations and Their Conservation. *Conservation Biology*, *16*(4), 1048-1062. https://doi.org/10.1046/j.1523-1739.2002.00423.x

Craig, P., DiDonato, G., Fenner, D., & Hawkins, C. (2005). The state of coral reef ecosystems of American Samoa. *The state of coral reef ecosystems of the United States and Pacific freely associated states*, 312-337.

Craig, P., Ponwith, B., Aitaoto, F., & Hamm, D. (1993). The Commercial, Subsistence, and Recreational Fisheries. *Marine Fisheries Review*, *55*(2), 109.

Dalzell, P. (1996). Catch rates, selectivity and yields of reef fishing. In *Reef fisheries* (pp. 161-192). Springer.

Dey, M. M., & Kanagaratnam, U. (2007). Community based management of small scale fisheries in Asia: Bridging the gap between fish supply and demand.

Dulvy, N. K., Fowler, S. L., Musick, J. A., Cavanagh, R. D., Kyne, P. M., Harrison, L. R., Carlson, J. K., Davidson, L. N., Fordham, S. V., Francis, M. P., Pollock, C. M., Simpfendorfer, C. A., Burgess, G. H., Carpenter, K. E., Compagno, L. J., Ebert, D. A., Gibson, C., Heupel, M. R., Livingstone, S. R., . . . White, W. T. (2014). Extinction risk and conservation of the world’s sharks and rays. *eLife*, *3*. https://doi.org/10.7554/elife.00590

Dulvy, N. K., Pacoureau, N., Rigby, C. L., Pollom, R. A., Jabado, R. W., Ebert, D. A., Finucci, B., Pollock, C. M., Cheok, J., & Derrick, D. H. (2021). Overfishing drives over one-third of all sharks and rays toward a global extinction crisis. *Current Biology*, *31*(21), 4773-4787. e4778.

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

Dunne, R. P., Polunin, N. V. C., Sand, P. H., & Johnson, M. L. (2014). The Creation of the Chagos Marine Protected Area. A Fisheries Perspective. In *Advances in Marine Biology* (Vol. 69, pp. 79-127). https://doi.org/10.1016/B978-0-12-800214-8.00003-7

Ebert, D. A., Dando, M., & Fowler, S. (2021). *Sharks of the World: A complete guide*. Princeton University Press.

Espinoza, M., Díaz, E., Angulo, A., Hernández, S., & Clarke, T. M. (2018). Chondrichthyan Diversity, Conservation Status, and Management Challenges in Costa Rica [Review]. *Frontiers in Marine Science*, *5*. https://doi.org/10.3389/fmars.2018.00085

Fisheries Division. (2016). Samoa Annual Report to the Western and Central Pacific Fisheries Commission. Fisheries Division, Ministry of Agriculture and Fisheries, Apia, Samoa. .

Food and Agriculture Organisarion (FAO). (2018). *Fishery and Aquaculture Country Profiles - Samoa* (Fishery and Aquaculture Country Profiles, Issue.

Froese, R., & Pauly, D. (2022). FishBase. World Wide Web electronic publication. www.fishbase.org. .

Furlong-Estrada, E., Galván-Magaña, F., & Tovar-Ávila, J. (2017). Use of the productivity and susceptibility analysis and a rapid management-risk assessment to evaluate the vulnerability of sharks caught off the west coast of Baja California Sur, Mexico. *Fisheries Research*, *194*, 197-208.

Gallagher, A. J., & Klimley, A. P. (2018). The biology and conservation status of the large hammerhead shark complex: the great, scalloped, and smooth hammerheads. *Reviews in Fish Biology and Fisheries*, *28*(4), 777-794. https://doi.org/10.1007/s11160-018-9530-5

Gillett, R. (2016). *Fisheries in the economies of Pacific Island countries and territories*. https://fame1.spc.int/component/content/article/237-benefish-study-2016?lang=en

Gillett, R., & Lightfoot, C. (2001). The contribution of fisheries to the economies of Pacific Island countries.

Giovos, I., Barash, A., Barone, M., Barría, C., Borme, D., Brigaudeau, C., Charitou, A., Brito, C., Currie, J., Dornhege, M., Endrizzi, L., Forsberg, K., Jung, A., Kleitou, P., Macdiarmid, A., Moutopoulos, D. K., Nakagun, S., Neves, J., Nunes, F. L. D., . . . Mazzoldi, C. (2021). Understanding the public attitude towards sharks for improving their conservation. *Marine Policy*, *134*, 104811. https://doi.org/10.1016/j.marpol.2021.104811

Glaus, K. B. J., Adrian-Kalchhauser, I., Piovano, S., Appleyard, S. A., Brunnschweiler, J. M., & Rico, C. (2019). Fishing for profit or food? Socio-economic drivers and fishers’ attitudes towards sharks in Fiji. *Marine Policy*, *100*, 249-257. https://doi.org/10.1016/j.marpol.2018.11.037

Haque, A. B., Cavanagh, R. D., & Spaet, J. L. (2022). Fishers' tales—Impact of artisanal fisheries on threatened sharks and rays in the Bay of Bengal, Bangladesh. *Conservation Science and Practice*, e12704.

Hari, K., Jaiteh, V., Chin, A., & Lymbery, A. (2021). The sharks and rays of Palau: biological diversity, status, and social and cultural dimensions. *Pacific Conservation Biology*.

Hill, H. B. (1978). The use of nearshore marine life as a food resource by American Samoans.

Horton, T., Kroh, A., Ahyong, S., Bailly, N., Bieler, R., Boyko, C. B., Brandão, S. N., Gofas, S., Hooper, J. N. A., Hernandez, F., Mees, J., Molodtsova, T. N., Paulay, G., Bouirig, K., Decock, W., Dekeyzer, S., Vandepitte, L., Vanhoorne, B., Adlard, R., . . . Zullini, A. (2022). *World Register of Marine Species (WoRMS)* https://www.marinespecies.org

Hylton, S., White, W., & Chin, A. (2017). The sharks and rays of the Solomon Islands: a synthesis of their biological diversity, values and conservation status. *Pacific Conservation Biology*, *23*(4), 324-334.

IUCN. (2021). The IUCN Red List of Threatened Species. Version 2021-3. https://www.iucnredlist.org.

Jacoby, D. M. P., Croft, D. P., & Sims, D. W. (2012). Social behaviour in sharks and rays: analysis, patterns and implications for conservation. *Fish and Fisheries*, *13*(4), 399-417. https://doi.org/10.1111/j.1467-2979.2011.00436.x

Jaiteh, V. F., Lindfield, S. J., Mangubhai, S., Warren, C., Fitzpatrick, B., & Loneragan, N. R. (2016). Higher Abundance of Marine Predators and Changes in Fishers' Behavior Following Spatial Protection within the World's Biggest Shark Fishery [Original Research]. *Frontiers in Marine Science*, *3*. https://doi.org/10.3389/fmars.2016.00043

Jordan, D. S., Seale, Alvin. (1905). *The fishes of Samoa* (Vol. 25). Washington Government Print Office.

Juncker, M., Robert, M., & Clua, E. (2006). Coastal shark fisheries in the Pacific: a brief overview of current knowledge. *Coral Reef Initiatives for the Pacific, SPC, Noumea, New Caledonia*.

Lack, M., & Sant, G. (2012). An Overview of Shark Utilisation in the Coral Triangle Region (PDF, 550 KB.

Lack, P. M., & Meere, F. (1994). Pacific Islands Regional Plan of Action for Sharks: Guidance for Pacific Island Countries and Territories on the Conservation and Management of Sharks. Accessed online at http://www. ffa. int/sharks 37.

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

Levine, A., & Sauafea-Le'au, F. (2013). Traditional Knowledge, Use, and Management of Living Marine Resources in American Samoa: Documenting Changes over Time through Interviews with Elder Fishers1. *Pacific Science*, *67*(3), 395-407.

Mackeracher, T., Diedrich, A., & Simpfendorfer, C. A. (2019). Sharks, rays and marine protected areas: A critical evaluation of current perspectives. *Fish and Fisheries*, *20*(2), 255-267. https://doi.org/10.1111/faf.12337

Ministry of Agriculture and Fisheries Division. (2011). Samoa Tuna Management and Development Plan 2011-2015.

McCracken, M., & Cooper, B. (2022). *Estimated Bycatch with Seabirds, Sea Turtles, Bony Fish, Sharks, and Rays in teh 2020 Permitted American Longline Fishery* (PIFSC data report; DR-22-001, Issue.

McDavitt, M. T. (2005). The cultural significance of sharks and rays in Aboriginal societies across Australia’s top end. *Marine Education Society of Australasia, Canberra, viewed*, *13*(09), 2011.

Meleisea, M., & Meleisea, P. S. (1987). *Lagaga: A Short History of Western Samoa*. University of the South Pacific. https://books.google.com.au/books?id=Gt\_RrCAkctwC

Ministry of Natural Resources and Environment. (2009). Marine Wildlife Protection Regulations. Samoa.

Mizrahi, M. i., Duce, S., Pressey, R. L., Simpfendorfer, C. A., Weeks, R., & Diedrich, A. (2019). Global opportunities and challenges for Shark Large Marine Protected Areas. *Biological Conservation*, *234*, 107-115. https://doi.org/https://doi.org/10.1016/j.biocon.2019.03.026

Montgomery, A. D., Fenner, D., Kosaki, R. K., Pyle, R. L., Wagner, D., & Toonen, R. J. (2019). American Samoa. In *Mesophotic coral ecosystems* (pp. 387-407). Springer.

Mustika, P. L. K., Ichsan, M., & Booth, H. (2020). The economic value of shark and ray tourism in Indonesia and its role in delivering conservation outcomes. *Frontiers in Marine Science*, 261.

Myers, R. A., & Worm, B. (2005). Extinction, survival or recovery of large predatory fishes. *Philosophical Transactions of the Royal Society B: Biological Sciences*, *360*(1453), 13-20. https://doi.org/10.1098/rstb.2004.1573

NOAA. (2021, 21/07/2021). *American Samoa Longline Fishery - MMPA List of Fisheries*. NOAA. Retrieved 20/05/2022 from https://www.fisheries.noaa.gov/national/marine-mammal-protection/american-samoa-longline-fishery-mmpa-list-fisheries

NOAA, National Marine Fisheries Service, Pacific Islands Fisheries Science Centre (U.S.), Fisheries Research and Monitoring Division. (2020). *The American Samoa Longline Limited-entry Fishery Annual Report 1 January-31 December 2019* (PIFSC working paper ; DR-20-019, Issue.

NOAA, National Marine Fisheries Service, Pacific Islands Fisheries Science Centre (U.S.), Fisheries Research and Monitoring Division. (2022). *The American Samoa Longline Limited-entry Fishery Annual Report 1 January-31 December 2020*.

Passfield, K., Mulipola, A., & King, M. (2001). Profile of village fisheries in Samoa. *Project milestone*, *17*.

Pauly, D., & Zeller, D. (2014). Accurate catches and the sustainability of coral reef fisheries. *Current Opinion in Environmental Sustainability*, *7*, 44-51.

Pernetta, J. C. (1990). Projected climate change and sea level rise: a relative impact rating for the countries in the Pacific Basin. *Implications of expected climate changes in the South Pacific Region: and overview. UNEP Regional Seas Report*.

PEW. (2012). *American Samoa Ends Shark Fin Trade, Shark Fishing in Coastal Waters*. https://www.pewtrusts.org/en/research-and-analysis/articles/2012/11/15/american-samoa-ends-shark-fin-trade-shark-fishing-in-coastal-waters#:~:text=American%20Samoa%2C%20a%20U.S.%20territory,other%20shark%20parts%2C%20is%20prohibited.

Ponwith, B. (1991). The shoreline fishery of American Samoa: a 12-year comparison. *Department of Marine and Wildlife Resources Biological Report Series*(22).

United States Office of the Federal Register. (2015). *Code of Federal Regulations: 2000*. U.S. General Services Administration, National Archives and Records Service, Office of the Federal Register. https://books.google.com.au/books?id=xN9DiHyRIIAC

Santos, C. C., & Coelho, R. (2018). Migrations and habitat use of the smooth hammerhead shark (Sphyrna zygaena) in the Atlantic Ocean. *PLoS ONE*, *13*(6), e0198664. https://doi.org/10.1371/journal.pone.0198664

Sea Around Us. (2022). *Catches by Taxon in the waters of American Samoa*. https://www.seaaroundus.org/data/#/eez/16?chart=catch-chart&dimension=taxon&measure=tonnage&limit=10

Skelton, P. A., Bell, L. J., Mulipola, A., & Trevor, A. (2003). The status of coral reefs and marine resources of Samoa. In M. Kulbicki (Ed.), *Les récifs coralliens du Pacifique : état et suivi, ressources et gestion = Coral reefs in the Pacific : status and monitoring : resources and management* (pp. 219-247). IRD ; ICRI. https://www.documentation.ird.fr/hor/fdi:010032220

Secretariat of the Pacific Regional Environmemt Programme (SPREP). (2018). *Samoa Establishes A Sanctuary For Sharks And Rays In Its National Waters*. https://www.sprep.org/news/samoa-establishes-sanctuary-sharks-and-rays-its-national-waters

Stice, G. D., & McCoy Jr, F. W. (1968). The geology of the Manu'a Islands, Samoa.

Techera, E. (2019). Legal Approaches to Shark Conservation and Management across the Indo-Pacific Small Island States. *Transnational Environmental Law*, *8*(3), 547-574. https://doi.org/10.1017/s2047102519000050

Temple, A. J., Kiszka, J. J., Stead, S. M., Wambiji, N., Brito, A., Poonian, C. N., Amir, O. A., Jiddawi, N., Fennessy, S. T., & Pérez-Jorge, S. (2018). Marine megafauna interactions with small-scale fisheries in the southwestern Indian Ocean: a review of status and challenges for research and management. *Reviews in Fish Biology and Fisheries*, *28*(1), 89-115.

Tolotti, M. T., Filmalter, J. D., Bach, P., Travassos, P., Seret, B., & Dagorn, L. (2015). Banning is not enough: The complexities of oceanic shark management by tuna regional fisheries management organizations. *Global Ecology and Conservation*, *4*, 1-7.

Australian Government Department of Foreign Affairs and Trade. (2020). Samoa COVID-19 Development Response Plan.

U.S. Department of Commerce, U., National Oceanic and Atmospheric Administration, N., & Office of National Marine Sanctuaries, O. (2012). Fagatele Bay National Marine Sanctuary Final Management

Plan / Final Environmental Impact Statement. Silver Spring, MD. .

Ulusapeti Titii, M. S., Joyce Ah-Leong. (2014). *Samoa socioeconomic fisheries survey report: 2012–2013*.

Ward-Paige, C. A. (2017). A global overview of shark sanctuary regulations and their impact on shark fisheries. *Marine Policy*, *82*, 87-97.

Wass, R. C. (1980). *The shoreline fishery of American Samoa--past and present*.

Wass, R. C. (1984). *An Annotated Checklist of the Fishes of Samoa* (NOAA technical reports, Issue. U. D. o. Commerce.

Watt, P., & Moala, S. (2001). Estimate of rejection in the Samoa tuna fishery, 2000. *Report prepared under the AusAID supported fisheries project. GRM International, Apia*.

Western and Central Pacific Fisheries Commision (WCPFC) (2019). *Conservation and Management Measures for Sharks*.

White, W. T., Appleyard, S. A., Sabub, B., Kyne, P. M., Harris, M., Lis, R., Baje, L., Usu, T., Smart, J. J., Corrigan, S., Yang, L., & Naylor, G. J. P. (2015). Rediscovery of the Threatened River Sharks, Glyphis garricki and G. glyphis, in Papua New Guinea. *PLoS ONE*, *10*(10), e0140075. https://doi.org/https://dx.doi.org/10.1371/journal.pone.0140075

Western Pacific Regional Fishery Management Council. (2009). *Fishery Ecosystem Plan for*

*the American Samoa Archipelago*.

Zann, L. (1992). The inshore resources of Upolu, Western Samoa. Field Report No. 2, FAO/UNDP Project SAM/89/002. Apia, Western Samoa.

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