Status of Frigate tuna (*Auxis thazard*) and Kawakawa (*Euthynnus affinis*) fishery in the Maldives

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Abstract

Pole-and-line tuna fishery in the Maldives date back to the 19th century CE. The significance of this fishery in the culture and livelihood of Maldivians in the past and present contributes greatly towards its continued success and sustainability. Of the five tuna species commonly caught in the tuna fishery, neritic tuna species, kawakawa (*Euthynnus affinis*) and frigate tuna (A*uxis thazard*) form a minor component, contributing to about 1 % of all tuna landings in the Maldives. Throughout history, pole-and-line, handline and trolling gear have been used to catch neritic tunas. Prior to the mechanization of the fishing fleet in the 1970s, the majority of the frigate tuna catch was landed by pole-and-line vessels and kawakawa by trolling vessels. Nominal catch of frigate tuna and kawakawa has fluctuated significantly throughout the years, with catches declining since 2010 and stabilizing since 2015. In 2021, 62 tons of frigate tuna and 15 tons of kawakawa were landed. The distribution of these two species in the Maldives waters has been reported to vary based on oceanographic conditions such as oscillating monsoon currents. Neritic tunas are not favored by the dominant commercial tuna processors and exporters. A survey among the small-scale processors suggests that neritic tunas caught in the pole-and-line fishery are sold to the processors who make value added products. The study also informed that neritic species fetch a lower value compared to tropical tunas, skipjack and yellowfin. This paper reviews the status of frigate tuna and kawakawa fishery and fish processing operations in the Maldives.

1. Introduction

Pole-and-line tuna fishery in the Maldives date back to the 19th century CE, its cultural significance in the past and present contributing greatly towards its continued success and sustainability. Exploiting neritic tuna species, kawakawa (*Euthynnus affinis*) and frigate tuna (A*uxis thazard*) is a minor component in the tuna fishery. However, these two species play a significant role in the diet and livelihood of locals. They are mainly harvested by pole-and-line fishing vessels to be sold to local small-scale processors to make varieties of products or for their own consumption.

Of the six species of neritic tunas managed by IOTC, Maldives tuna fishery catches two species, frigate and kawakawa. The two species contribute about 1 % of all tuna landings in the Maldives (Ahusan et al., 2022). Oceanic species such as skipjack and yellowfin tuna are the most commonly harvested species in the fishery, its dominance increased with the mechanization of fishing fleet during the 1970s. This also led to a decline in troll fishery which contributed a substantial proportion of the national catch of neritic species, subsequently lowering its economic importance (Ahusan and Adam., 2011a; Ahusan and Adam., 2011b).

2. Data

The Ministry of Fisheries, Marine Resources, and Agriculture (MoFMRA) collected and compiled the historical catch and tuna catch and effort data used in this paper. A desktop survey targeting small-scale fish processors throughout the country was also conducted to have a better understanding of neritic tuna fisheries along with fish processors' perception of aspects such as species seasonal variability and to understand the process of deriving value-added products from tuna.

The Maldives' first systematic catch data collection system for tuna fisheries was established in 1959 when the Maldives' government required reporting of tuna catch from the islands in three categories of fish (large skipjack; small skipjack and yellowfin; frigate and kawakawa). The system was further expanded with the inclusion of catch data of other species, such as reef fish and sharks, in the early 1970s (Anderson., 1986). With the introduction of logbooks for tuna fisheries in 2010, fishery catch and effort data reporting from the pole-and-line and handline fisheries improved substantially. The fisheries data is collected by the Fisheries Management Section (FMS) of the MoFMRA. Additionally, samplers collect tuna length frequency data at two key landing sites. This data is collected, compiled and reported to the IOTC by the Maldives Marine Research Institute (MMRI).

3. Fishery Status

3.1. Catch trend

The Maldives tuna fishery landings peaked in 2006, at around 167,000 t, before declining by 53% by 2010. Catches have since been recovering, with approximately 143,531 t caught in 2021 (Figure 1) (Ahusan et al., 2022). The nominal catch of frigate tuna and kawakawa has fluctuated significantly throughout the years, with catches declining since 2010 and stabilizing since 2015. The reported catch of frigate tuna peaked in 1973 and 1996 (Figure 2). As for Kawakawa, the reported catch reached a peak in the year 1996 (Figure 3).

Despite shifting catch rates, compared to skipjack tuna and yellowfin tuna, frigate tuna and kawakawa's contribution to annual tuna landings in the Maldives has remained low (Figure 1). According to the nominal catch data, the contribution of frigate tuna and kawakawa to the total tuna caught in 2021 is less than 1%. The highest proportion of frigate tuna to total tuna landings was recorded in 1973, which was 20% (Anderson et al). On the other hand, 3.65% of total tuna landings in 2010 was comprised of kawakawa, which is the highest contribution of kawakawa to total tuna landings since 1984 (Ahusan and Shiham., 2011a).

The recent catches of frigate tuna and kawakawa have been substantially lower than in the past, and this trend can be attributed to factors such as market preference for tropical tuna over neritic species. Tropical tuna species such as skipjack tuna and yellowfin tuna are preferred by large fish processing companies to make products such as canned tuna. The demand for frigate tuna and kawakawa might also be low in the local market due to its small size and Maldivian's preference towards skipjack tuna in their diet, leading to a probable decline in the purchase of these two species by small-scale fish processing parties as well (Ahusan & Adam., 2011b). It has also been suggested that most of the pole-and-line fleet in the northern atolls, where neritic catches have been higher in the past, has shifted to handline yellowfin tuna fishery (Ahusan et al., 2022).

According to Anderson (1993), the abundance of frigate tuna and kawakawa also depend on latitudinal variations in the Maldives. In the north, both these species are more abundant compared to the southern atolls (Anderson and Hafiz., 1985). This may be due to the significant gradient in oceanographic conditions along the chain of atolls such as varying strength of the monsoons, water current, and levels of dissolved oxygen (Anderson., 1993). Available data shows that frigate tuna and kawakawa were predominantly caught in the northern atolls. This observation could be coupled with a variety of socioeconomic and environmental factors including, (1) the operation of smaller vessels in the north that predominantly fish at Anchored Fish Aggregating Devices (AFADs) compared to modern vessels in the south, (2) the availability of markets such as small-scale processors, and (3) higher abundance or catchability of neritic species in the north than in southern atolls in the country (Ahusan and Adam., 2011a; Ahusan and Adam., 2015).

Traditionally, data such as catch by species and effort (number of days fished) used to be reported by respective island offices where the fishing vessels are registered (home port). The data was then aggregated and reported to the MoFMRA where it was processed and published. This system of reporting was changed following the introduction of logbooks for tuna fisheries to address reporting requirements and obligations, as well as other challenges that existed in the data reporting system at the time (Ahusan., 2014).

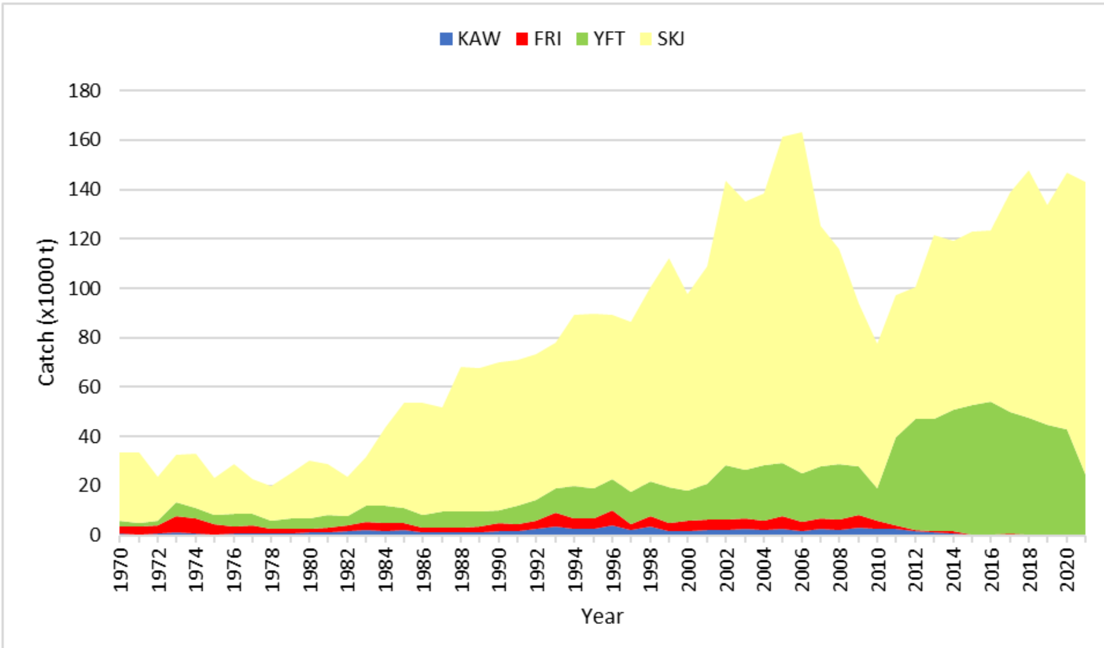

Figure 1: Trends in nominal catches (t) of SKI (Yellow), YFT (Green), FRI (Red) and KAW (Blue) from 1970 to 2021 in Maldives.

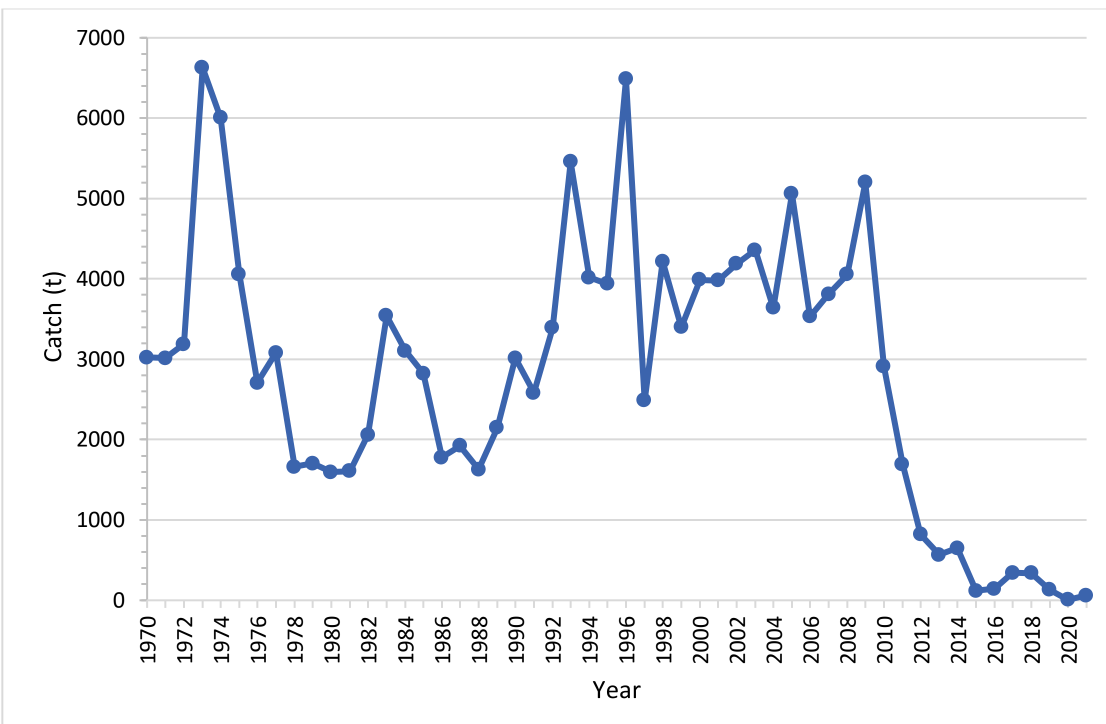

Figure 2: Trend in nominal catch (t) of frigate tuna from 1970 to 2021 in Maldives.

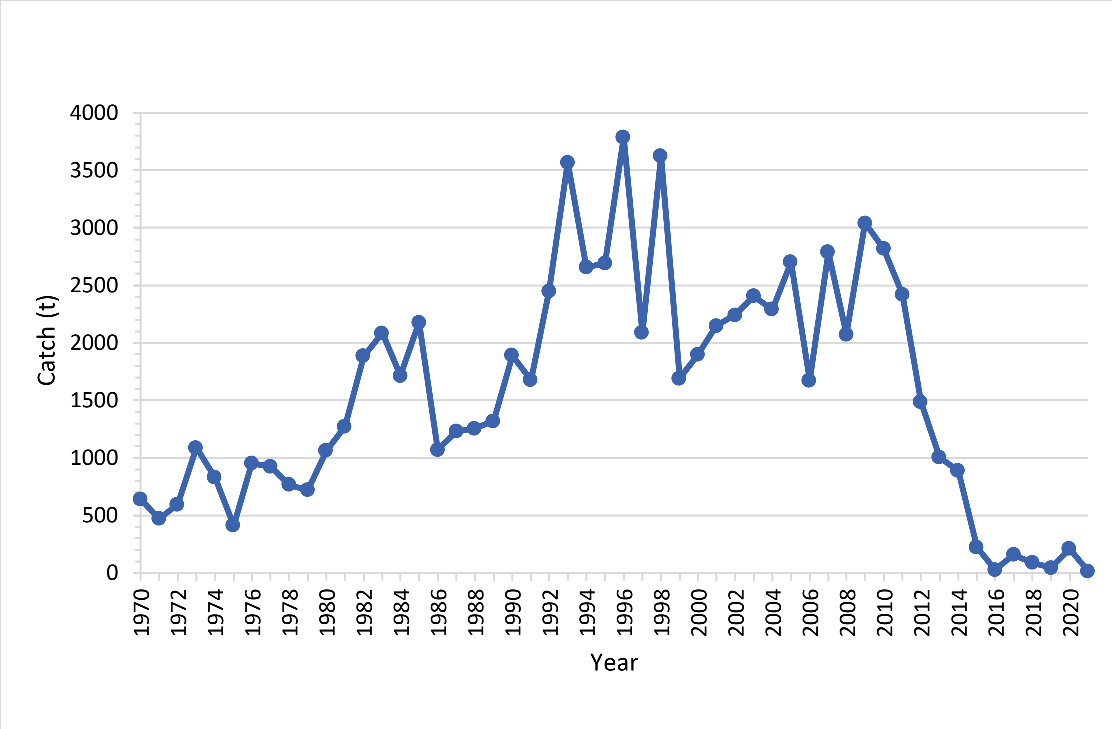

Figure 3: Trend in nominal catch (t) of kawakawa from 1970 to 2021 in Maldives.

3.2. Catch by gear

In the past, two types of fishing vessels using single fishing gear were found in the Maldives. The *vadhu dhoni* (trolling vessels) in which trolling gear is used and *masdhoni* (pole-and-line vessel) exploit fish with pole-and-line. As a result, until 1989, the fishery data collection system did not identify the gear used. Consequently, in previous literature, the terms *vadhu dhoni* and *masdhoni* were used interchangeably for trolling and pole-and-line gear, respectively (Ahusan., 2016).

Frigate tuna and Kawakawa are exploited in the Maldives using pole-and-line (PL), handline (HL) and trolling (TR) gear. In the past, neritic tuna used to be a significant component of pole-and-line tuna catches. Nevertheless, because neritic tunas are of low economic value and not purchased by large-scale processors, exclusively targeting neritic tuna by commercial pole-and-line vessels is uncommon. However, pole-and-line persists to be the primary gear for catching frigate tuna and kawakawa.

During the past five years, an average of 86% of the total reported frigate tuna catch was caught by the pole-and-line gear, followed by trolling with 10%. Throughout the years, pole-and-line has been the most common gear used to exploit frigate tuna (Figure 4). This was due to the fact that, unlike kawakawa, frigate tuna was rarely caught by the large trolling fleet that was present prior to the mechanization of fishing fleet (Ahusan., 2016). Trolling vessels contributed 10% of total frigate tuna catch reported between 1970 and 1997 (Anderson, Waheed, and Adam., 1998).

Concurrently, the average contribution of pole-and-line gear to reported catches in the past five years of kawakawa was 72 %, followed by 23% by handline (Figure 5). The decline in catch by trolling since 2012 and handline from 2013 could be owing to the decline in effort due to various socio-economic reasons. Compared to frigate tuna, average reported catch during the past five years indicates handline has been more commonly used to catch kawakawa than trolling gear. This increased contribution is due to the declined effort of troll fishing and hence reduced catch. This could also be coupled with improved reporting of handline effort and its associated catch (Ahusan., 2016).

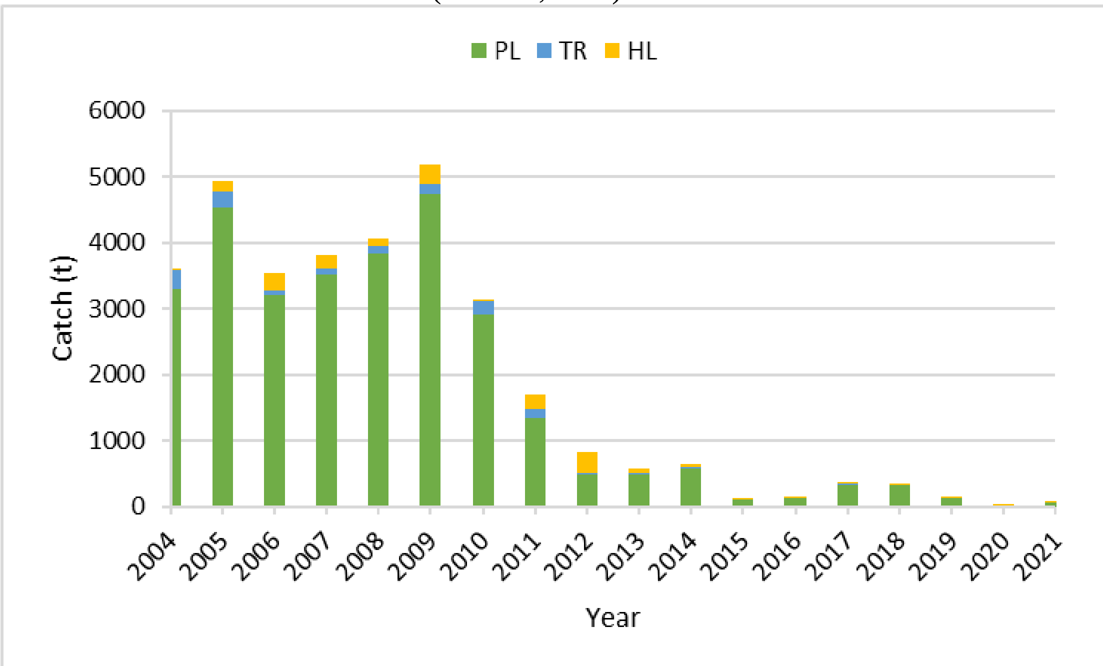

Figure 4: Reported catch of Frigate tuna (t) by gear type, from 2004 to 2021.

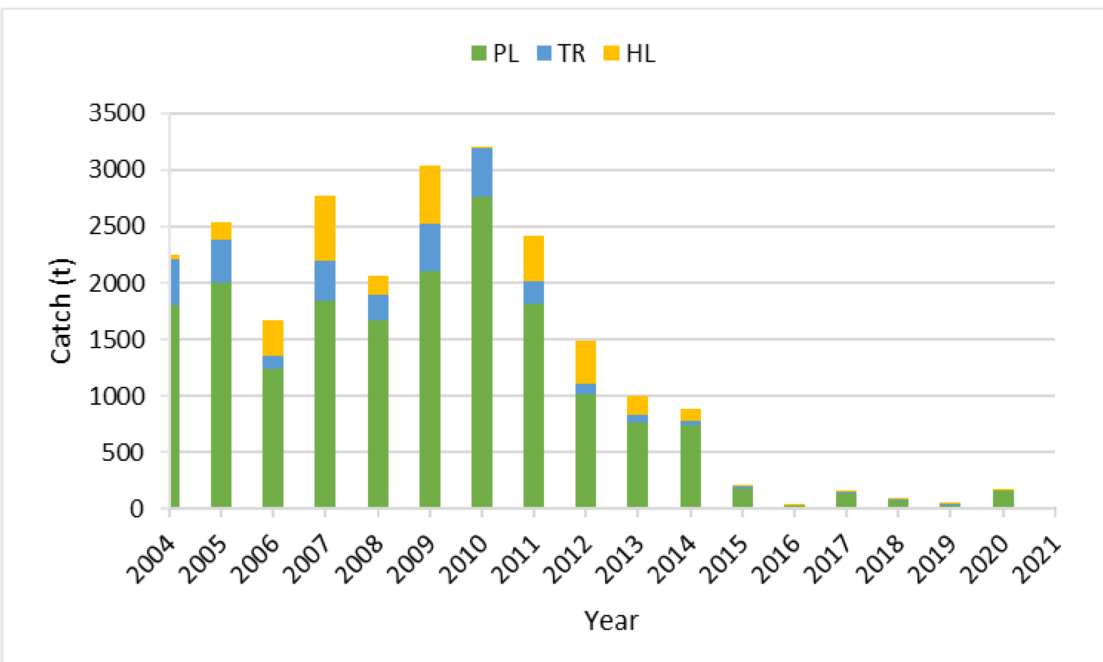

Figure 5: Reported catch of Kawakawa (t) by gear type, from 2004 to 2021.

3.3. Fishing effort

The Maldivian tuna fishery is seeing a slow decline in effort in terms of the number of days fished (Figure 6). During the past five years (2017-2021), the average combined fishing effort is 64% less compared to the average combined fishing effort between the years 2012 and 2016. This decrease in the effort could be attributed to the cumulative effect of a decrease in tuna catch and increase in fuel prices and other costs involved in the fishery. The fishing effort by type of fishing gear can be observed in Figure 7 from the year 2004 to 2021.

Pole-and-line gear contributes most to the fishing effort, followed by handline and trolling. Pole-and-line and handline fishery mainly target skipjack tuna and yellowfin tuna, respectively, which are both positioned in the export market as high value species. The general trend shows that handline effort is larger compared to trolling. By using trolling gear, catches are low compared to pole-and-line and handline hence there is not an incentive to go for trolling for commercial purposes. Trolling was prominent in the olden days, as the vessels were smaller, and sail powered and did not have the capacity to venture out. The reason for the observed trend may also be attributed to improved catch reporting rates in handline yellowfin tuna fishery, coupled with more fishers turning to handline yellowfin tuna fishery in hopes of a better income (Ahusan., 2016).

Small-scale trolling in atoll lagoons and coastal areas target frigate tuna and kawakawa as well. Due to improved socioeconomic changes, the main trolling fleet died in the late 1980s. The traditional sailing pole-and-line fleet began to be mechanized in 1974-75. By 1982, mechanized vessels had landed the vast majority of tuna catch. From 1974 to 1993, the number of mechanized pole-and-line vessels increased steadily. The trolling fleet increased its fishing activity during the transition to a mechanized pole-and-line fleet from 1975 to 1978 (Anderson et al., 1996). However, mechanized pole-and-line vessels have dominated the fishery since then, while trolling vessels have been marginalized. This is because modern vessels have the capacity to venture longer distances with an increase in efficiency (Ahusan and Adam., 2011b).

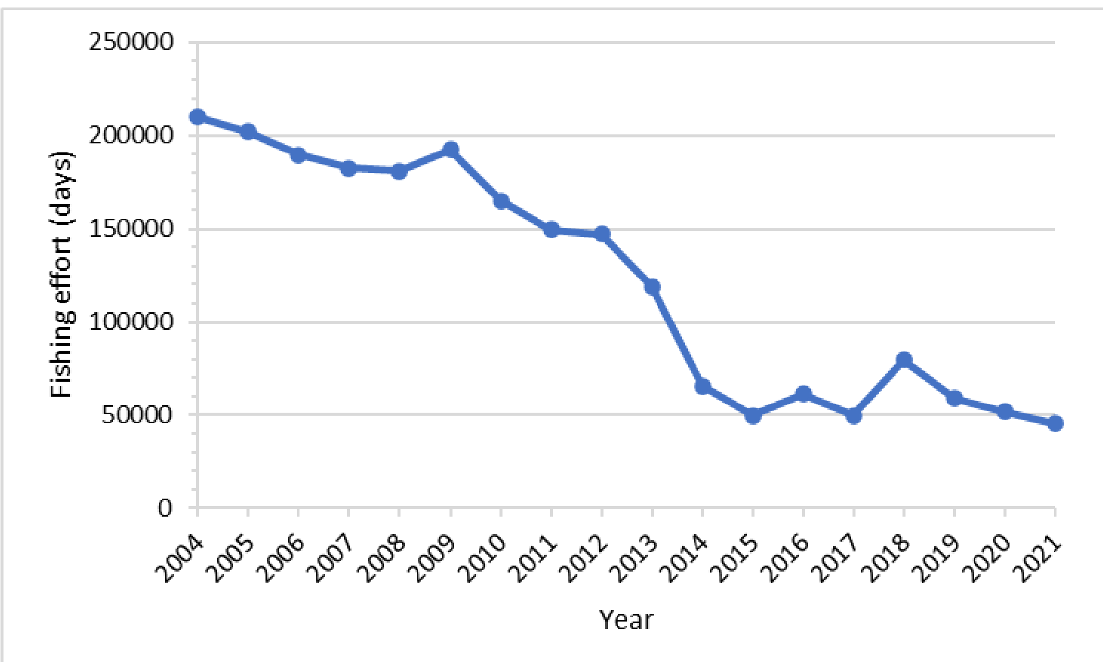

Figure 6: Fishing effort (number of fishing days) for mechanized vessels, 2004-2021.

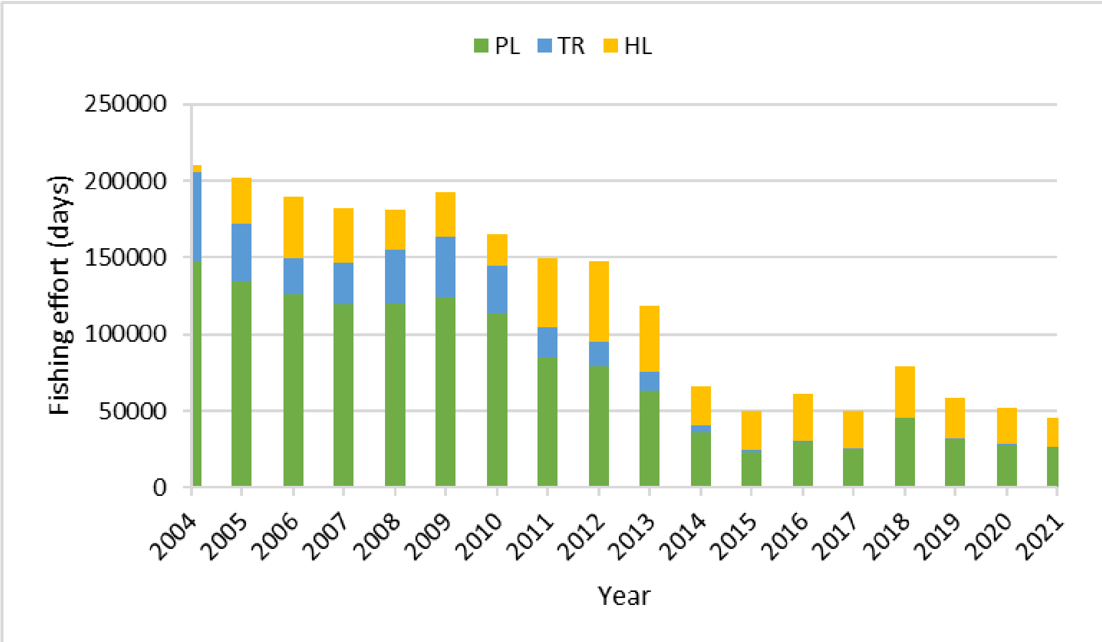

Figure 7: Fishing effort (number of fishing days) by gear, 2004-2021.

4. Seasonal variations and movement

In the Maldives, frigate tuna has shown seasonal distribution. Based on catch rates, frigate tuna has been suggested to show east-west migration within the atolls, in phase with the oscillating monsoon currents (Anderson, Waheed and Nadheeh., 1998). No such observations were made for Kawakawa and the only observed changes to catch rates were attributed to changing fishing patterns based on monsoonal currents. In addition, Anderson (1998) reported that frigate tuna is more abundant in the west during northeast monsoon and in the east during the southwest monsoon. Further studies are required to understand the movement patterns of tuna species found in the Indian Ocean.

Previous studies have reported changes in neritic tuna catch can be influenced by oceanographic changes, particularly those associated with El Niño Southern Oscillation (ENSO) events (Anderson., 1993; Anderson., 1987; Rochepeau and Hafiz., 1990). The catch recorded during the El Niño year of 1973 was relatively high for both frigate tuna and kawakawa and in 1977 for kawakawa (Anderson., 1993). According to Anderson, Waheed and Scholz (1998), during the El Niño years between 1970 to 1997, catch rates by *masdhonis* (pole-and-line) and *vadhu dhoani* (trolling vessels) were 60% and 11% higher, respectively. Moreover, Anderson, Waheed and Nadheeh (1998) reported peak catch rates by pole-and-line vessels during the El Niño years of 1972-73, 1983 and 1993. Similarly, 1998 also showed a peak in reported catch of frigate tuna landings with 3600 t, which is 74% higher compared to 1997 (Ahusan., 2016).

5. Stock relationships and status

Neritic tuna is generally found throughout the Indian Ocean and contributes a significant proportion to the national catches of some coastal states. Despite this, the efforts towards understanding the stock structure of neritic species have been low compared to tropical tuna. The IOTC Working Party on Neritic Tunas assesses the status of the neritic tuna stocks in the Indian Ocean. Stock assessments, however, rely on data limited stock assessment methods and indicators because only limited qualitative and quantitative data is available on these species. The Indian Ocean frigate tuna was assessed to be unknown (IOTC-WPNT12., 2022). The limitations in fishery data which is crucial for stock assessment was highlighted as a considerable concern in the 12th working party on neritic tunas (WPNT12). According to the stock assessment that was carried out in 2020 by the IOTC, based on the available data, the Kawakawa stock was classified as not overfished and not subjected to overfishing. However, the report highlighted that if annual catches for kawakawa continue to rise, it may further increase the fishing pressure on the stock (IOTC-WPNT12., 2022).

The population structure of Kawakawa along with two other neritic species, longtail tuna and Spanish mackerel was carried out as part of a 3-year collaborative project by CSIRO with AZTI Techalia (Spain), IRD (France) and CFR (Indonesia) in 2017. Funded by the European Union and consortium partners, this study carried out genetic analysis of new and archived tissue samples along with microchemical analysis of otoliths. The results reported strong evidence of genetic partitioning for longtail tuna and Spanish mackerel, and three genetic groups were identified within the sampling locations in the northern and eastern parts of their Indian Ocean. The level of genetic differentiation in these two species was not evident for Kawakawa. There is evidence of genetic structure between locations north and south of the equator but not as distinctive as longtail tuna and Spanish mackerel (Davies et al., 2020).

To date, no studies have been conducted to understand the stock structure of kawakawa and frigate tuna in the Maldives. Even though both species can be caught offshore, they appear to be more abundant in the coastal areas, closer to the atolls (Ahusan., 2016). In the early 1990s, a 12-month exploratory offshore fishing survey was conducted off the east coast of Maldives (Anderson, Waheed and Scholz., 1998). Based on the limited number of specimens (4 specimens), the study reported that kawakawa found in the Maldives may be considered as a single unit of stock. Concurrently, mixing of frigate tuna stocks with Sri Lankan stocks was reported by the same study, suggesting that this species may belong to an Indian Ocean or central Indian Ocean stock. Nonetheless, based on the small number of individuals caught offshore and the distribution of larvae, the authors speculated that Maldivian frigate tuna may be considered a separate 'sub-stock' for some purposes. Ahusan (2016) suggested that based on the information recorded in the logbooks about the locations where neritic catches occur implies that kawakawa and frigate tuna in Maldives waters are mixed and form a part of the Indian Ocean or central Indian Ocean stock.

6. Fish Processing

A variety of tuna products are exported from the Maldives, with skipjack and yellowfin tuna dominating the export market. The majority of the kawakawa and frigate tuna landings are sold to the small-scale processors on local islands to make value-added products which are usually sold to local markets. A desktop survey was conducted as part of this paper, to understand the local small-scale fish processing operations, demand for neritic tuna and its products.

Frigate tuna and Kawakawa are generally used to make a traditional dish of salty fish paste called *Rihaakuru*, by slowly boiling the tuna. They are also smoked and dried to be consumed by the locals and exported to neighboring international markets. Generally, fish processors carry out their operations on a smaller scale in their households or by leasing land to build their processing plants. They buy tuna landed from pole-and-line vessels and sometimes from trolling vessels on rare occasions. On average, they buy 1.5 Tonnes of tuna on every purchase and survey findings showed that they make an average of 11 purchases each month. The most frequently bought species are skipjack tuna followed by yellowfin tuna, frigate tuna and kawakawa. However, the majority of the processors highlighted that they buy smaller skipjack and yellowfin tuna remaining on the fishing vessels when they return to the islands after selling to larger fish processing companies. Hence, they purchase frigate tuna and kawakawa which are available and sold at a lower price compared to tropical tuna. Moreover, it is rare to purchase only one species from a fisher if other species are available. On some islands, frigate tuna and kawakawa is preferred to make *Rihaakuru*. Some fish processors also noted that they purchase neritic tuna due to its small size making it ideal for cooking, drying and smoking. The small size also makes it easier to maintain good fish handling practices.

Smoked frigate tuna and kawakawa have a lower landing price compared to skipjack and yellowfin tuna. However, when dried, the price of the product is the same and more often all the species are sold together.

In some atolls or islands, there is a preference for *Rihaakuru* made from frigate tuna. However, the majority of the small-scale processors who took part in the survey make *Rihaakuru* by cooking all the tuna species together. Hence, the price of *Rihaakuru* differs slightly in some atolls, based on the raw materials used.

7. Research

Frigate tuna and kawakawa have received little attention due to lower contributions to the annual catch and low value in the market. The tuna sampling sites are the primary tuna landing sites in the Maldives and very few neritic tunas are landed at the sampling sites as the landing sites do not purchase frigate tuna and kawakawa.

Future research will be focused on contributing to reach the IOTC research goals necessary to develop stock status indicators for neritic tuna in the Indian Ocean. Studies assessing the biological parameters including sex ratio, length-at-maturity, fecundity, weight-length relationships, and spawning season will be developed and carried out. Moreover, focus will also be given to understand the socio-economic aspects of neritic tuna on Maldivian fishers and stakeholders in understanding the significance of neritic species on the livelihood, its contribution to food security and nutrition.

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