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Some warning signs detected in coastal pelagic fisheries of the west coast of Sri Lanka: Declining trend of *Amblygaster sirm* suggesting the need for immediate management initiatives

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Abstract Coastal fisheries, mainly characterized by small pelagic species, are significant on the west coast of Sri Lanka in terms of livelihood and food security. However, currently, the fishery has faced numerous challenges, particularly with the stock depletion allied with poor management practices. The present study was carried out using the time series data of 2001–2020 on the west coast of Sri Lanka representing four fisheries districts - Kalutara, Colombo, Negombo, and Chilaw - to explore the present status and the tendency of the fishery towards management considerations. The analysis was based on the outboard engine fiber-reinforced plastic boats (OFRP) with small meshed gillnets, which are the main boat gear combination that exists in the fishery. The recent five-year landings within the study period indicated that the highest average catch rates resulted in the onset of the southwest monsoon and extended until the end of the northeast monsoon. The catch rates of fishery exhibited greater inter-annual fluctuations during a two-decade period, with an average of 66.7 ± 17.3 kg per trip from 2011 to 2020. Over the past two decades, the Mean Trophic Level (MTL) of the coastal fish landings ranged from 3.13 to 3.62 and showed a declining trend with the forecast of 3.38 for 2022-2026. Moreover, the catch rates and the relative contribution of *Amblygaster sirm*, one of the main target species in the country, showed a declining trend over the past two decades while indicating the need for immediate management initiatives.

Keywords: Catch rate, Stocks, Trophic, Chlorophyll, Monsoon

INTRODUCTION

Coastal fisheries, particularly small pelagic, play extremely important ecological roles in marine ecosystems and contribute to global food security, the economy (Peck *et al.* 2021), and nutrition (Isaacs 2016) of the local communities, with no exception for Sri Lanka. Being a low-middle-income nation (World Bank 2022) surrounded by the Indian Ocean, Sri Lanka's per capita fish consumption was estimated to be 31.4 kg per year in 2016 (FAO 2019). Fish and fish products are estimated to comprise approximately 55% of total animal protein intake per capita (FAO 2018). Therefore, fish is considered the most important source of animal protein in the Sri Lankan diet. Small pelagic fish are popular among Sri Lankans due to their affordable price and availability most of the time. This reveals that keeping sustainably managed small pelagic fish stocks will contribute to ensuring a healthy population in the country (Hasini *et al.* 2019).

Among the different regions in the country, the west coast, represented by four fisheries districts, Chilaw, Negombo, Colombo, and Kalutara of Sri Lanka, provides the highest contribution to the small pelagic fishery (Bandaranayake *et al.* 2022). This has been confirmed by the Dr. Fridtjof Nansen survey conducted in 2018 in Sri Lanka coastal waters, where small pelagic biomass accounted for 21,000 tonnes; out of this, more than 18,000 tonnes has been from the west coast of Sri Lanka (Krakstad *et al.* 2018). Regarding the fishing effort, approximately 17% of the Outboard engine Fiber-Reinforced Plastic (OFRP) boats of Sri Lanka are operated within the area (Ministry of Fisheries 2022).

The fishers engaged in the small pelagic fishery are mostly artisanal fishers who operate

OFRP vessels and motorized or non-motorized traditional crafts. At present, the coastal pelagic fishery is mainly practiced by OFRP boats (Dissanayake 2005; Haputhantri *et al.* 2008; Wijayaratne 2001) with a range of mesh sizes (Bandaranayake *et al.* 2022). However, this fishery is greatly influenced by the two monsoons; South West and North East (Wijayaratne & Maldeniya 2003). There are around sixty small pelagic marine fish species under different families dominated by Clupeidae (De Bruin *et al.* 1994; Karunasinghe *et al.* 2000). Of these, the spotted sardinella (*Amblygatster sirm*) is one of the key targeted species in small-scale artisanal fisheries (Jayasinghe *et al.* 2019; Bandaranayake *et al.* 2022).

There is much evidence for the unsustainable utilization of coastal pelagic fishery resources (Haputhantri *et al*. 2008), in particular, the use of smaller mesh sizes (Jayasinghe *et al.* 2018, 2019) and the prevailing open-access nature (Wijayaratne 2001) which leads to altering the structure of marine food web (Razzaghi *et al.* 2016). The poor management of small-scale fisheries in many coastal countries is a result of a set of factors: poverty, lack of alternative employment, inappropriate incentives, and weak governance (Gréboval 2002). Sri Lanka's coastal fishery prevailing on the west coast is also experiencing the same (Bandaranayake *et al.* 2022) despite the century-old history of fisheries management (Joseph 2013). Understanding the immediate management needs on the west coast, discussions are ongoing for establishing a management plan for the small pelagic fishery on the west coast of Sri Lanka (Bandaranayake *et al.* 2022). The present study was carried out to understand the current status of the coastal fishery of the west coast of Sri Lanka and thereby to consider management responses.

MATERIALS AND METHODS

The study was conducted based on time series data of four fisheries districts in Sri Lanka: Chilaw, Negombo, Colombo, and Kalutara, which geographically cover the western coastal stretch of the country (Figure 1.)

The catch and effort data of small pelagic and other coastal species from 2001 to 2020 (20 years) was obtained from the Small Pelagic Database of the National Aquatic Resources Research and Development Agency (NARA), Sri Lanka. However, 2021 and 2022 were excluded from the analysis as the fishery was highly impacted due to the temporary fishing ban for the X-press Pearl incident, and the Covid-19 pandemic situation followed by the fuel crisis. The boats operated in the fishery were representatively sampled based on a stratified random sampling method by the NARA enumerators at the fish landing sites. Accordingly, the information relevant to the landed catch by species/ species groups was recorded against the sampled boat with other relevant information: vessel type, gear type used, gear-specific information such as mesh size and the number of net pieces used, gear operated depth, true fishing time and total fishing time.

Fig 1: Study area; Chilaw, Negombo, Colombo and Kalutara Fisheries Districts on the west coast of Sri Lanka. 10 NM buffer is given by dotted lines.

The species composition of coastal fish landings and Catch per Unit effort (CPUE) of

Amblygaster sirm; the key target fishery species in a small meshed gillnet, was specifically analyzed to understand the present status of the fishery. The mesh sizes that contributed more than 50% of the total *A. sirm* catch were considered the target mesh sizes of *A. sirm* for analysis purposes.

The average fish catch of OFRP boats was considered to estimate the CPUE in terms of catch in kg per OFRP boat per trip. Seasonal CPUE means were constructed from the catch data collected in December–January–February (DJF) for the North-East monsoon, March-April (MA) for 1st Intermonsoon, May-June–July–August-September (MJJAS) for South-West monsoon and October–November (ON) for 2nd Intermonsoon. The mean CPUE corresponding to each monsoon was computed. Monthly Chlorophyll-a data from multi-satellite observation were obtained from Copernicus-GlobColour product OCEANCOLOUR_GLO_BGC_L4_MY_009_104 (Maritorena *et al.* 2010) produced by E.U. Copernicus Marine Service Information (https://doi.org/10.48670/moi-00281). The Chloraphyll-a concentration in the study area was calculated in terms of mean Chloraphyll-a extracted from the valid pixels (excluding cloud cover).

Mean Trophic Level (MTL) is calculated from a combination of coastal fisheries landings and diet composition data of the landed fish species. MTL was calculated following the method described by Pauly and Palomares (2005) using 65 fish species recorded in coastal pelagic fisheries on the west coast of Sri Lanka. Fishing areas with low trophic species were demarcated following Christensen *et al.* (2003), with a reference level of MTL 3.75. In this study, trophic level estimates for 65 species, based on their diet composition, were found in FishBase (www.fishbase.org) (Table 1). MTL for 2022-2026 was forecasted using the ARIMA (0,1,1) model in the forecast package (Hyndman *et al*. 2022) in R 4.0.3 (R Core Team 2020).

Table 1: Trophic Levels of fish species in the coastal fish landings in Sri Lanka

Family	Species	English name	Trophic Level
Aridae	*Arius* sp.	Cat fish	3.5
Balistidae	*Canthidermis maculata*	Trigger fish	3.5
Belonidae	*Strongylura* sp.	Needle fish	4.2
Stromateidae	*Pampus* sp.	Pomfrets	3.3
Caesionidae	*Pterocaesio* sp.	Fusilier	3.4
Carangidae	*Caranx* sp.	Trevallies	4.2
	Decapterus russelli	Indian Scad	3.7
	Megalaspis cordyla	Torpedo Scad	3.9
	Selar crumenophthalmus	Big eye scad	3.8
	Selaroides leptolepis	Yellow stripe scad	3.8
Chanidae	*Chanos chanos*	Milk fish	2.4
Clupeidae	*Amblygaster clupeoides*	Smooth belly sardinella	3.1
	Amblygaster sirm	Golden spotted sardinella	2.89
	Dussumieria acuta	Rainbow sardine	3.4
	Escualosa thoracata	White sardine	3.2
	Herklotsichthys quadrimaculatus	Blue stripe herring	3.6
	Hilsa kelee	Kelee shad	2.5
	Sardinela longiceps	Indian Oil Sardine	2.4
	Sardinella albella	White sardinella	2.6
	Sardinella gibbosa	Goldstripe sardinella	2.9
	Sardinella sindensis	Sind sardinella	2.9

	Chirocentrus dorab	Dorab wolf herring	4.4
Engraulidae	*Stolephorus indicus*	Indian anchovy	3.6
	Thryssa baelama	Baelama anchovy	2.9
	Thryssa setirostris	Longjaw thryssa	3.3
Pristigasteriadae	*Pellona ditchela*	Indian pellona	4.0
	Opisthopterus tardoore	Tardoore	3.4
Coryphaenidae	*Coryphaena* sp.	Common dolphin fish/Dorado	4.4
Exocoetidae	*Hirundichthys* sp.	Flying fish	3.0
Fistularidae	*Fistularia* sp.	Blue spotted cornet fish	4.3
Hemiramphidae	*Hemirhamphus* spp.	Halfbeak	3.4
Istiophoridae	*Istiophorus platypterus*	Indo Pacific sailfish	4.5
Lactarriade	*LactariusLactarius*	False trevally	4.2
Leognathidae	*Gazza minuta*	Tooth pony	4.2
	Leiognathus spp.	Pony fishes	3.0
	Secutor sp.	Pugnose pony fish	2.8
Mugilidae	*Mugil* sp.	Mullets	2.5
Mullidae	*Mulloidichthys* sp.	Yellowfin/Yellow stripe Goat fish	3.8
Cynoglossidae	*Paraplagusia bilineata*	Double linetonguesole	3.5
Polynemidae	*Polynemus* sp.	Threadfins	3.9
Rachycentridae	*Rachycentron canadum*	Cobia	4.0
Scianidae	*Otolithes ruber*	Croakers	3.6
Scombridae	*Auxis rochei*	Bullet tuna	4.4
	Auxis thazard	Frigate tuna	4.4
	Euthynnus affinis	Kawakawa	4.5
	Katsuwonus pelamis	Skipjack tuna	4.4
	Rastrelliger kanagurta	Indian mackerel	3.2
	Sarda orientalis	Bonito	4.2
	Scomberomorus spp.	Mackerel	4.5
Sciaenidae	*Nibea* sp.	Croaker	4.0
Nemipteridae	*Nemipterus bipunctatus*	Threadfin breams	3.9
Scombridae	*Thunnus albacares*	Yellowfin tuna	4.4
Siganidae	*Siganus* spp.	Rabit fish/spinefoot	2.8
Sillaginidae	*Sillago whitings*	Sillago	3.3
Sphyranidae	*Sphyraena Jello*	Barracuda	4.5
	Sphyraena obtusata	Obtuse barracuda	4.5
	Sphyraena sp.	Barracuda	4.5
Terapontidae	*Therapon* sp.	Terapon perches	3.6
Trichuridae	*Lepturachanthus savala*	Hairtail	4.3
Carcharhindae	*Carcharinus* sp.	Sharks	4.5
		Rays	3.1
Sepidae	*Sepia* sp.	Cuttle fish	3.39
Loliginidae	*Loligo* spp.	Squids	3.39
Portunidae	*Portunus* sp.	Crabs	3.0
Palinuridae	*Panulirus* sp.	Lobsters	3.57

RESULTS

Small meshed gill net is the key gear operated and the fish catch was dominated by Clupeids, which included Spotted sardinella (*Amblygaster sirm)*, Goldstripe sardinella (*Sardinella gibbosa*), Indian oil sardine (*Sardinella longiceps*) and White sardinella (*Sardinella albella*). The other species mainly included Scads (*Decapterus russelli* and *Selar crumenophthalmus*), queen fish (*Scomberoides commersonianus*), travellies (*Caranx* sp), and Sprats (*Stoleophorus* sp and *Thryssa* sp).

A remarkable decline in the relative contribution of spotted sardinella in the small meshed gillnet fishery was observed over the past two decades (Figure 2). The contribution of spotted sardinella has dropped dramatically from 47% in 2001-2005, to 51% in 2006-2010, to 37% in 2011-2015, and 34% in 2015-2020. Moreover, it was observed that the average CPUE of the spotted sardinella during 2016-2020 showed a 25% drop in comparison to the 2001-2010 period (Figure 3).

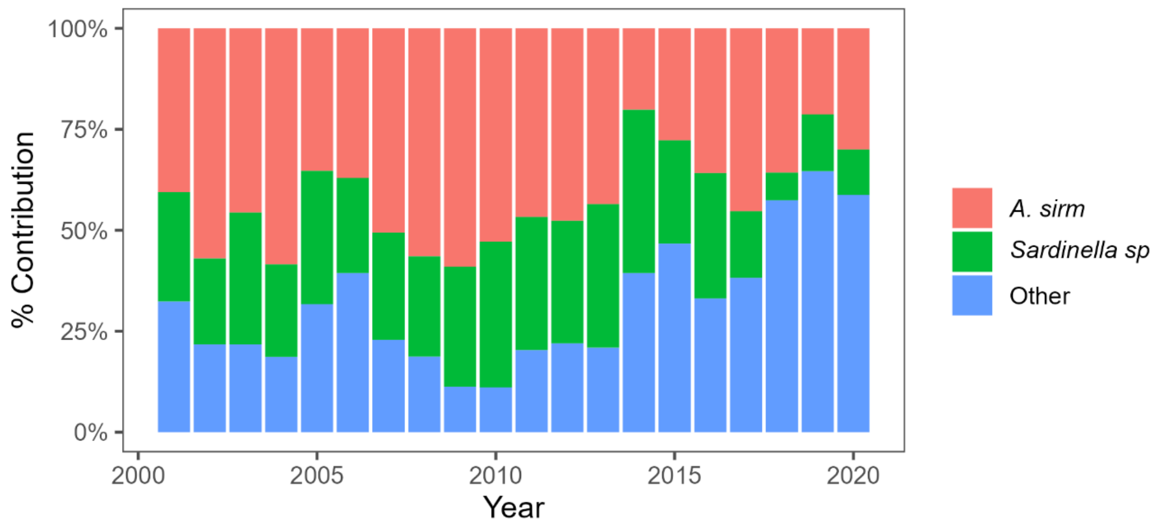

Fig 2: Species composition of key small pelagic fish landings; *Amblygaster sirm; Sardinella species* and others in small meshed gillnet fishery on the west coast of Sri Lanka: 2001 – 2020.

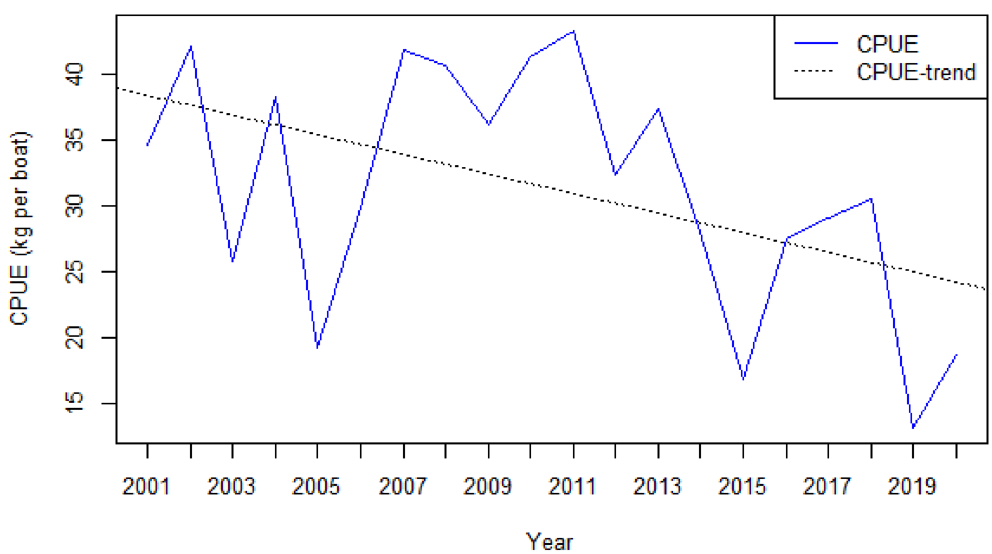

Fig 3: Annual variation in mean CPUE of spotted sardinella target fishery on the west coast, Sri Lanka: 2001- 2020

The average CPUE of the small pelagic fishery increased from the onset of the southwest monsoon until the end of the northeast monsoon with an average of 85.18± 2.25 kg per boat. The lowest average CPUE of 44.7± 3.8 kg per boat was recorded during 1st intermonsoon period from March to April (Figure 4).

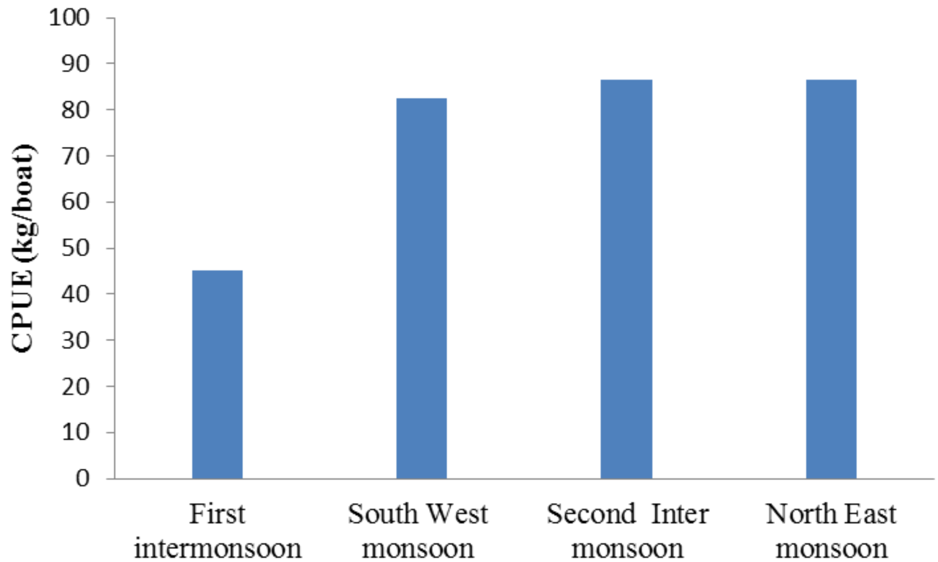

Fig 4: Average catch rates observed in different monsoon periods 2016-2020

The average CPUE per boat per trip during the recent decade was 66.7 ± 17.3kg, but there were greater inter-annual variations (Figure 5). However, an extraordinary increase in CPUE was observed in 2017, followed by a continuous decline in subsequent years. Furthermore, higher catch rates could be observed with a one-year time lag period of Chlorophyll peaks (Figure 5).

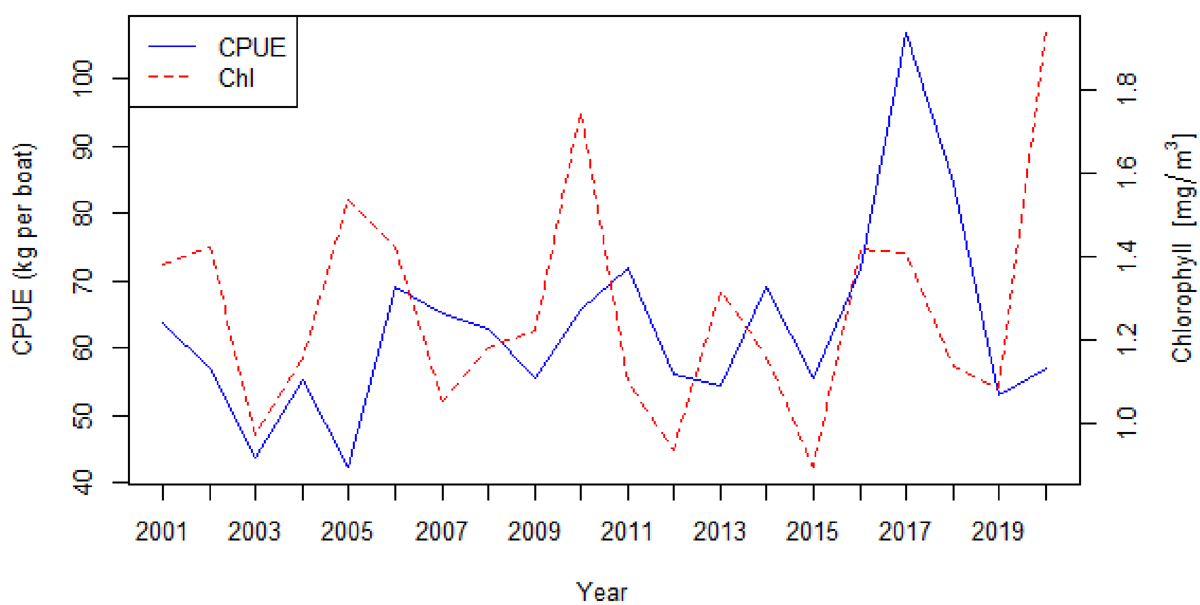

Fig 5: Fluctuation of annual average catch rate per OFRP boat operated with small mesh gillnets with respect to the average Chlorophyll concentration.

The MTL of the coastal fish landings ranged between 3.13 and 3.62 over the past two decades, with the lowest record in 2014. However, MTL of coastal fish landings on the west coast showed a declining trend over the past twenty years, while the forecast for the 2022 to 2026 period is 3.38 (Figure 6).

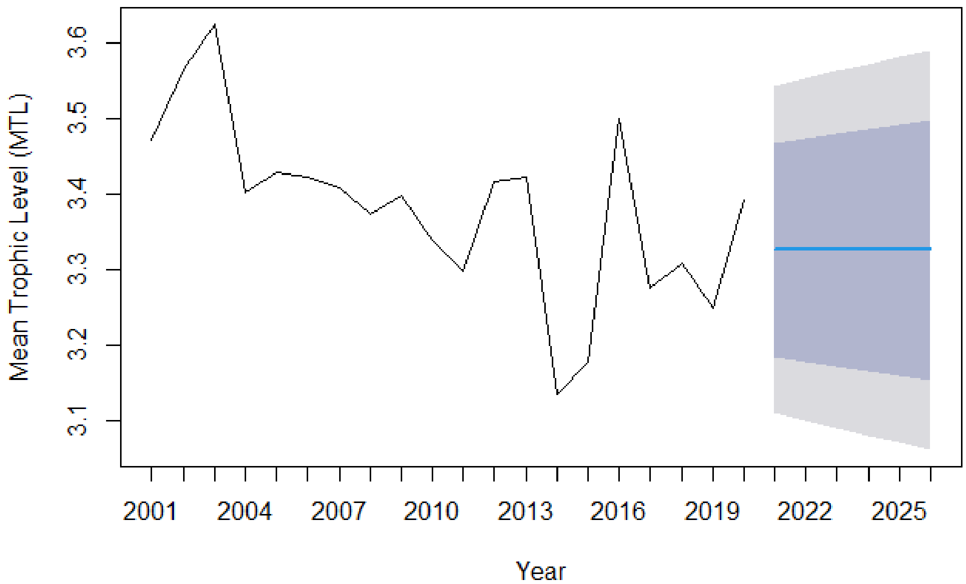

Fig 6: Variations of MTL over the past 20 year period (2001-2020) in coastal fishery on the west coast of Sri Lanka with Forecasted MTL for 2022 to 2026 (Summary results for the fitted ARIMA model ma1 = -0.6673, SE = 0.1614). Forecast is presented in a blue line, with the 80% prediction interval as a purple-shaded area, and the 95% prediction interval as a grey-shaded area.

DISCUSSION

The present study reveals the current status of the coastal pelagic fishery on the west coast of Sri Lanka with some warning signals and clues for the stocks. Managing coastal marine fisheries is a real challenge for many countries (Salas *et al.* 2007), with no exception in Sri Lanka. The coastal fisheries in Sri Lanka, which included small pelagic fishery, reached its Maximum Sustainable Yield (MSY) of 165,235 tons by 1992 (Wijayaratne 2001) and has been continuously exceeding the threshold (except 2005, a year after the Indian Ocean tsunami in 2004) (Ministry of Fisheries 2022).

This study provides evidence for greater fluctuations in the coastal pelagic catch rates on the west coast in terms of intra-annual variations influenced by the southwest monsoon and the inter-annual fluctuations which are greatly associated with Chlorophyll concentration (Punya *et al.* 2021). The inter-annual fluctuations in the coastal pelagic catch rates could be obvious with the variations of oceanographic conditions such as Sea Surface Temperature (SST) and Net Primary Production (NPP) (Dalpadado *et al.* 2021). An extraordinary catch increase in 2017 probably resulted in the unprecedented surface chlorophyll blooms ever recorded during the late boreal summer and fall of 2016 (Thushara & Vinayachandran 2020; Khan *et al.* 2021). Supporting the statement provided by Haputhantri *et al.* 2008 on time lag responses of small pelagic fish populations to extreme events, the possible peaks of catch rates in the present study further revealed that there is nearly one-year time lag after recording chlorophyll peaks.

During the present study, a declining trend of the MTL was observed and could be explained by the concept of “fishing through marine foodweb” by Pauly *et al.* (1998). A similar trend has been detected in commercial fish landings in many regions of the world, such as India (Bhathal & Pauly2008), Europe (Jayasinghe *et al.* 2015, 2017), and Madagascar (Gough *et al.* 2022). This could be due to multiple reasons; however, high fishing pressure exerted towards economically important higher trophic level species in the marine food web (Pauly & Watson 2005) followed by climate change impacts could primarily be attributed (Brander 2010). For the present analysis, 65 species of fish belonging to trophic levels ranging from 2.4 to 4.5 were used. Hence, the findings are reasonable as considered various marine species belonging to a wide range of trophic levels with various food habits (Pauly *et al.* 1998). Christensen *et al.* (2003) stated that the MTL< 3.75 throughout the years depicted the fish communities characterized by dominance of low trophic level species. Therefore, it can be suggested that due to heavy fishing efforts, the fisheries on the west coast of Sri Lanka are in a threatened status.

Jayasinghe *et. al.* (2019) addressed the possible threats to the small pelagic fishery, particularly for *A. sirm* in Sri Lanka waters. The presence of higher percentages of immature *A. sirm* in commercial catches due to the use of small meshed gillnets has been identified as a major threat to the sustainability of herring fishery. The *A. sirm* stock on the west coast of Sri Lanka is currently at the optimal resource utilization or unsustainable status with an estimated MSY of around 30,000t (Haputhantri & Sharma 2021). The present study indicated an alarming signal for the *A. sirm* stock on the west coast of Sri Lanka, with a downward trend in terms of relative contribution to the total catch and decreased catch rates. Lawrence and Fernandes (2021) have reported that increased and prolonged fishing pressure toward the key species could be a reason for shifting the non-target species in pelagic ecosystems. In addition, species changes in the commercial landing could seriously impact the ecosystem structure and socio-economic status of the coastal communities (McIntyre 2002). In the change of species compositions in pelagic fisheries, strict management measures are needed to regain the previously dominated species (Lawrence & Fernandes, 2021). Therefore, immediate precautionary management measures, such as mesh size regulations, and temporary closures, are recommended for implementation to improve the stock status. The collapse of Norwegian spring spawning herring stock is an ideal example as the stock increased its abundance due to good recruitment, reaching high levels in the late 1950s and then decreasing and collapsing in the late 1960s (Nakken 2008). Understanding the danger to the small pelagic fishery, the Government of Sri Lanka established a project (Lanka-Norway bilateral project: Grant Number 15113-39) with the Government of Norway to manage the fishery holistically. Under this project, the port sampling system in the country is being upgraded (IMR 2023), and acoustic surveys for small pelagics are introduced (Jayasinghe *et al.* 2020). Most importantly, a fishery management plan for small pelagic on the west coast of Sri Lanka is being formulated to ensure the sustainable utilization of coastal fishery resources on the west coast of Sri Lanka. Since ecological interactions are vital in considering the stock status and preparing the management plans (Lawrence & Fernandes 2021), the present findings could be attributed. Moreover, the knowledge of the coastal fishery resources in the concerned region is important as this region was severely affected by the X-press Pearl ship fire incident in 2021 (Partow *et al.* 2021), and anticipated short-term to long-term impacts on the food web. (Rubesinghe *et al.* 2022).

In conclusion, the current status of coastal pelagic fishery resources dominated by small pelagic species on the west coast of Sri Lanka depicts the essentiality of intense monitoring and the introduction of immediate management measures to restore the resources, including *A. sirm* stocks.

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