Status of shrimp trawl fisheries in the seas off Kalpitiya and Mannar on the Northwestern coastal waters of Sri Lanka

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Abstract

A study was carried out to find out variations of Catch Per Unit Effort (CPUE) and total shrimp production in Kalpitiya and Mannar trawl fisheries. Monthly catch and effort data were collected from January to December 2021, and monthly average CPUE (shrimp weight per fishing trip) and monthly total shrimp production were estimated. Generally, 23, 11 ton trawlers and 180, 3.5 ton boats were operated in Kalpitiya and Mannar respectively without any closer seasons. Being opposite to Kalpitiya (06 fishing days per trip per week), in Mannar, fishing was conducted in the night (03 single fishing days per week). *Penaeus semisulcatus* was the most abundant targeted shrimp species and pony fishes were dominant in the by-catch. The CPUE (kg of shrimps 06 days trip^{-1} boat^{-1}) of Kalpitiya fishery ranged from 94 kg (in February) to 189.7 kg (in August). Also, the estimated annual total shrimp production in Kalpitiya was 142 tons which mostly comprised medium sized (30 – 49 g) shrimps. CPUE (kg of shrimps 01day trip^{-1} boat^{-1}) of Mannar exhibited the lowest (12.2 kg) in October and the highest (38.7 kg) in February and an annual total shrimp production of 415 tonnes mainly with small sized (13 – 29 g) shrimps. In addition, higher mean CPUE of Kalpitiya was recorded during the Southwest monsoon season (around 48% of total annual shrimp production) while, for Mannar it was coincided with the Northeast season (about 30% of total production). However, statistical analysis revealed that in the Mannar shrimp fishery only, there is a significant difference (P< 0.05) in mean CPUE between four monsoonal seasons. Net income per trawl trip was LKR 180,000 and 15,000 while operational costs were LKR 140,000 and 9,000 in Kalpitiya and Mannar respectively.

Keywords. Fisheries, monsoon, shrimp, sustainability, trawling.

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Introduction

Shrimp fishery provides greatest contribution in Sri Lankan fisheries sector via aquaculture production as well as wild capture (Jayasinghe *et al*., 2019). Bottom trawling is widely used to capture the wild shrimp around the world and in Sri Lanka too, trawling is widely practiced especially in the Northwest and Northern coastal sites (Wijesundara and Amunugama, 2017). In early days, Sri Lankan fishermen were engaged in trawling in some offshore trawling grounds that included Wadge Bank, Pedro Bank, Palk Bay and Gulf of Mannar. However, after signing the maritime agreements in 1974 and 1976, Sri Lanka faced the restrictions and challenges to access these fishing grounds (Kularatne, 2019). As a considerable portion of the continental shelf around Sri Lanka has rocky bottoms, shrimp trawling is restricted to muddy areas (Jayawardane and Dayaratne, 1998).

In 2017, bottom trawling was banned in Sri Lanka through an amendment made to the Fisheries and Aquatic Resources Act of 1996. Although there are alternative fishing gears and methods that may be economically viable in certain situations, capturing of benthic target species such as penaeid shrimps would pose challenges without some form of bottom trawling (Suuronen *et al*., 2012). Due to the lack of efficient fishing gear for wild shrimp harvesting in Sri Lanka, trawling is still continued within the demarcated fishing grounds, concerning the socioeconomic aspects of fishers. Trawl fisheries are consequently confined to limited areas in the West coast; North of Colombo (Hendala), North of Negombo, Portugal Bay off Kalpitiya, Mannar off Pesalei and Jaffna peninsula by ensured with the absence of eco-sensitive habitats (NARA, 2019).

The trawling activities conducted in particular regions almost throughout the year are expected to cause heavy resource exploitation in an unsustainable manner. Hence, proper scientific management is much needed to ensure the sustainability of fishery resources in defined coastal waters. In the present study, a survey was conducted in Kalpitiya and Mannar to assess seasonal variation of the shrimp trawl fisheries using Catch Per Unit Effort (CPUE) and total production. Also, based on the biological sampling of the landings, monsoonal changes in length frequency, weight frequency, sex and maturity stage of major shrimp species exploited were investigated.

Materials and Methods

The study was carried out from January to December 2021. About 14.9 km^2 and 427.9 km^2 of fishing ground area were permitted for the trawling activities in Kalpitiya and Mannar respectively (Fig 1). In the present study, samplings were conducted at the landing sites and shrimp landing huts in Kalpitiya and Mannar/ Pesalei. Throughout the year, monthly visits were conducted to each study site to collect catch data from the active trawls. Subsequently, shrimp and major bycatch species composition from trawl catches were identified using standard identification guides (De Bruin *et al*., 1995; Dore, 2012). Additionally, detailed information regarding vessel operation, gear type, and fishing periods were gathered by interviewing fishermen. Furthermore, the logbook was utilized to gather catch and effort data from trawl fishers in each region.

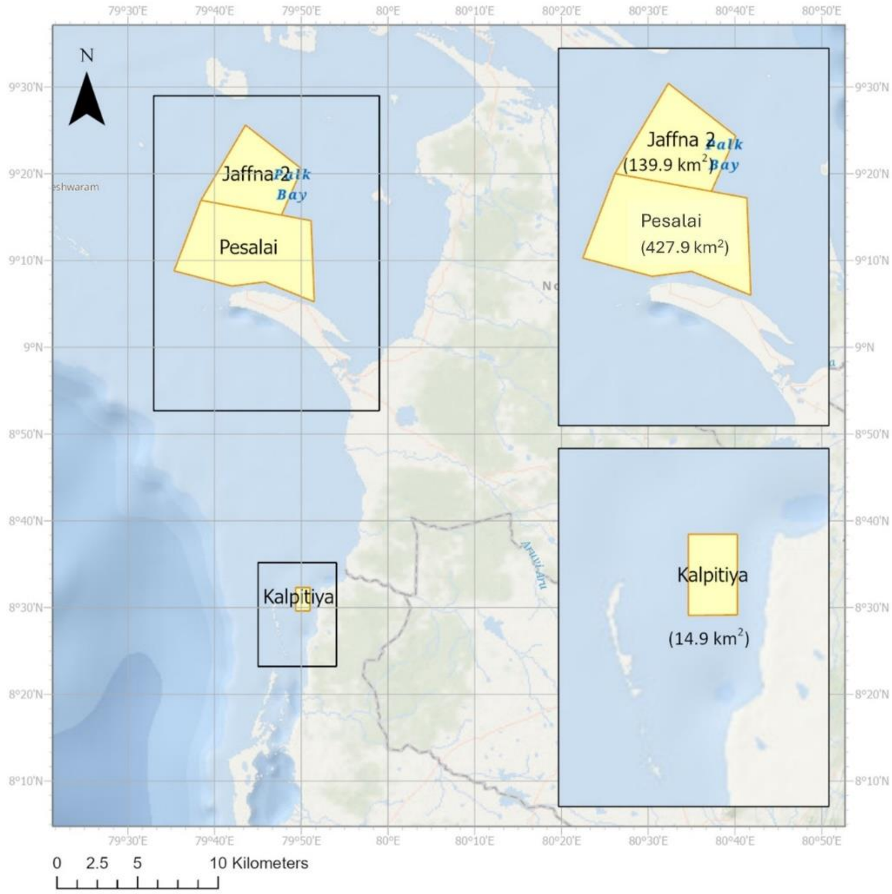

Fig. 1. Shrimp trawl fishing grounds in Mannar (Peaslai) and Kalpitiya

Catch and effort (CPUE) data collection and analyses:

Data collections were conducted on a monthly basis, and the logbook's monthly fishing trips and catch data were collected and standardized. All the relevant data sets were digitalized and estimates were made for CPUE and total shrimp production for each month at each site, considering different size categories (Large-L, Medium-M, Small-S, and Very small-VS). CPUE was expressed as kilograms of shrimp caught per boat per fishing trip. Monthly total shrimp production (P) was estimated as follows:

$P = CPUE \times N \times T$

where N is the mean number of fishing crafts operated per trip and T is the mean number of fishing trips per month.

Monthly variations of CPUE and total catch of shrimp were assessed separately for Kalpitiya and Mannar. To investigate the influence of monsoonal patterns on shrimp landings, CPUE data were grouped into four monsoonal phases i.e., Northeast monsoon (December-February), First inter-monsoon (March-April), Southwest monsoon (May-September) and Second inter-monsoon (October-November).

CPUE of four monsoonal phases were statistically investigated and to better satisfy the assumptions of normality required for the one-way analysis of variance, log-normal distribution data converted into normal distribution data *(Ln (CPUE+1))* as prescribed by Gulland (1983). Subsequently one-way ANOVA was carried out in order to reveal whether the mean values in different seasons are significantly different ($\alpha = 0.05$) using Minitab® 21.2 statistical software. In presence of significant difference, post-hoc test (Tukey test) also carried out for pair-wise comparison of monsoonal phases.

Biological sample collection and analyses:

The shrimps were categorized into four size groups by fishermen for sorting: large size (L) for specimens above 50 g, medium size (M) for specimens weighing between 30 g and 49 g, small size (S) for specimens weighing between 13 g and 29 g, and very small size (VS) for specimens weighing between 08 g and 12 g. As these size categorizations allowed for assessing the quantity of shrimp populations overall, regardless of specific species.

On each sampling day at each site, a standardized amount of (2 kg) pre-sorted shrimp was extracted from the trawl catch. These sub-samples were assumed to represent the composition and distribution of trawling sites during the study period. All samples were properly labelled, kept in styrofoam boxes with ice and transported to the NARA laboratory at Kalpitiya Regional Research Center for further analyses. From these samples, total length, carapace length, individual weight, sex and maturation level were examined for each specimen. Seasonal variations of length frequency and sex distribution were also investigated.

Results and Discussion

Catch and effort information

The demarcated trawling ground in Kalpitiya is 14.9 km^2 in extent at the site of Portugal Bay. There are 23 registered 11ton trawlers with 95 HP inboard engines. On average, 20 boats are engaged in fishing in a day. The number of fishing trips per month is not consistent and as such, the actual number of trawler fishing trips was verified through harbour records. Bottom trawl nets with typical size (body mesh size: 3.8 cm, cod-end mesh size: 2.5 cm and mouth width: 9.4 m) are used by all trawler boats. Trawl fishing in Kalpitiya is a year-round activity without any off-season. The number of fishing days per trip is generally about 06 days (Monday to Saturday) with four fishing trips per month. About 16 number of hauls are carried out by single boat per trip and the trawling process strictly restricted to daytime only.

For Mannar trawl fishery, the designated area is approximately 428 km^2 in the vicinity of Palk Bay and Gulf of Mannar. About 180 number of 3.5ton trawler boats with 30 HP inboard engines are operated from the landing site of Pesalei. Bottom trawl nets with typical size (body mesh size: 3.8 cm, cod-end mesh size: 2.5 cm and mouth width: 3.6 m) are used by all trawler boats. Fishing is conducted on a single-day basis and average number of boats operated per day is 150. There are three fishing trips (Monday, Wednesday and Saturday) per week and about 12 fishing days per month. In Mannar too, trawling is a year-round activity. Unlike Kalpitiya trawl fishery, the trawling activity in Mannar is performed during night-time.

In both trawl fishing grounds of Kalpitiya and Mannar, *Penaeus semisulcatus* (green tiger shrimp) is the major target shrimp species. Other shrimp species that contribute to the landings are *Penaeus merguiensis* (banana shrimp), *Penaeus indicus* (Indian white shrimp) and *Metapenaeus moyebi* (moyebi shrimp). *M. moyebi* has relatively less commercial value, while prices of other species both in export and local markets are based on different size categories. *Leiognathus* sp. (pony fish), ranks as the primary bycatch species in both locations followed by *Gerres abbreviates* (Deep-bodied mojarra), *Selaroides leptolepis* (yellowstripe scad), *Portunus pelagicus* (blue swimming crab) and *Sepia* sp. (cuttlefish) also documented as bycatch, making a noteworthy contribution to the total catch.

By referring to catch composition, the average shrimp caught contribution to total trawl catch is about 30% and 45% in Kalpitiya and Mannar respectively. In Kalpitiya, *P. semisulcatus* accounts for ca. 80% of the total shrimp production and ca. 25% of the total trawl catch, meantime *Leiognathus* sp constitutes ca.70% of bycatch and ca.50% of total trawl catch. In Mannar, *P. semisulcatus* responsible for a sole contribution of ca. 88% to the total shrimp production and ca. 40% of total trawl catch. Simultaneously, *Leiognathus* sp comprises ca. 57% of bycatch and ca. 32% of total trawl catch.

Catch per unit effort (CPUE) and total shrimp production

Kalpitiya trawl fishery:

The CPUE of Kalpitiya trawl fishery ranged between 94 kg. boat^{-1}trip^{-1} and 189 kg. boat^{-1}trip^{-1} throughout the study period. The lowest CPUE was recorded in the February period (94 kg. boat^{-1}trip^{-1}) and the highest was in August (189.7 kg. boat^{-1}trip^{-1}). The results show there was a gradual rise in CPUE from February to May and a gradual decline from August to December having a distinct decline during the period of June to July (Fig. 2).

The highest value of CPUE representing small-sized/ juvenile shrimps mostly observed during April possibly representing the recruitment season of shrimp to particular trawl ground. However, during June – October, small-sized shrimp catch was very low. Also, when compared to other sizes, catch of medium-sized (30g - 49g) shrimp dominated throughout the year.

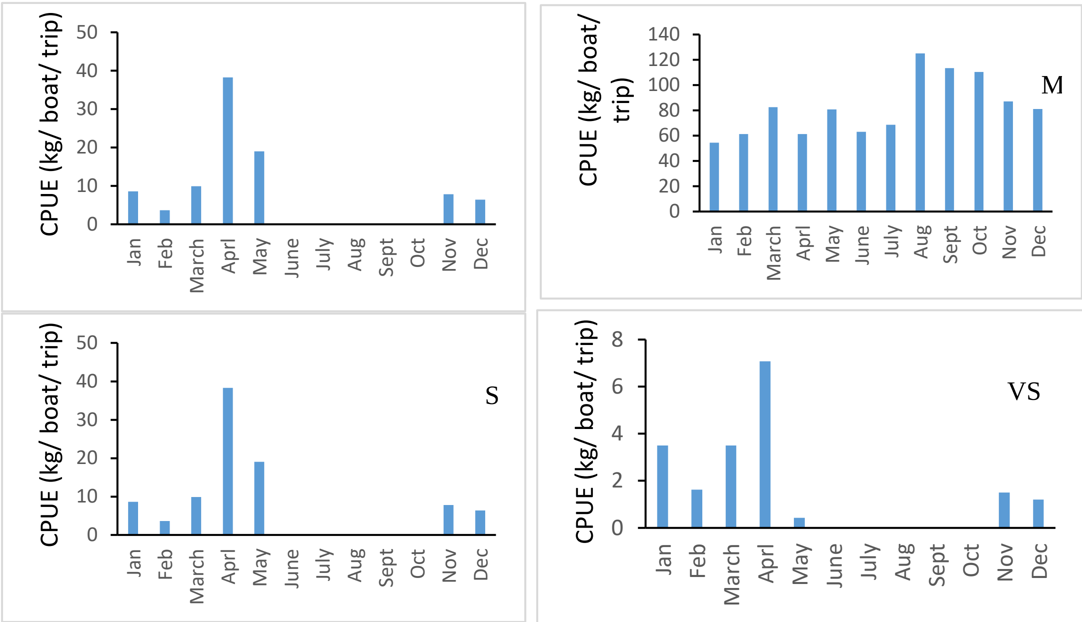

Fig. 2. Monthly variation of CPUE for different sized shrimp caught in Kalpitiya. L: Large size; M: Medium size; S: Small size; VS: Very small size

The total shrimp production of Kalpitiya trawl fishery in 2021 was estimated at 142 tonnes. Monthly total shrimp production (Fig. 3) indicates that the highest shrimp production occurred from August to November, having a contribution of about 47% of the annual shrimp production. In comparison, in the period between January and July, shrimp production was the lowest in Kalpitiya.

Variations in mean CPUE of 4 categories of shrimp in the trawl landings in Kalpitiya (Fig. 4) during four seasons indicate that medium-sized shrimp dominated during all four seasons followed by large-sized shrimps. The pattern of variation of mean CPUE of medium-sized and large-sized shrimp was similar registering the peak values during the southwest monsoon period and second inter-monsoonal period. The mean CPUE of small and very small shrimp was much lower in all four seasons. As the CPUE of small-sized shrimp was the highest during the north-east monsoonal period, this season might represent recruitment of shrimp to the fishing area.

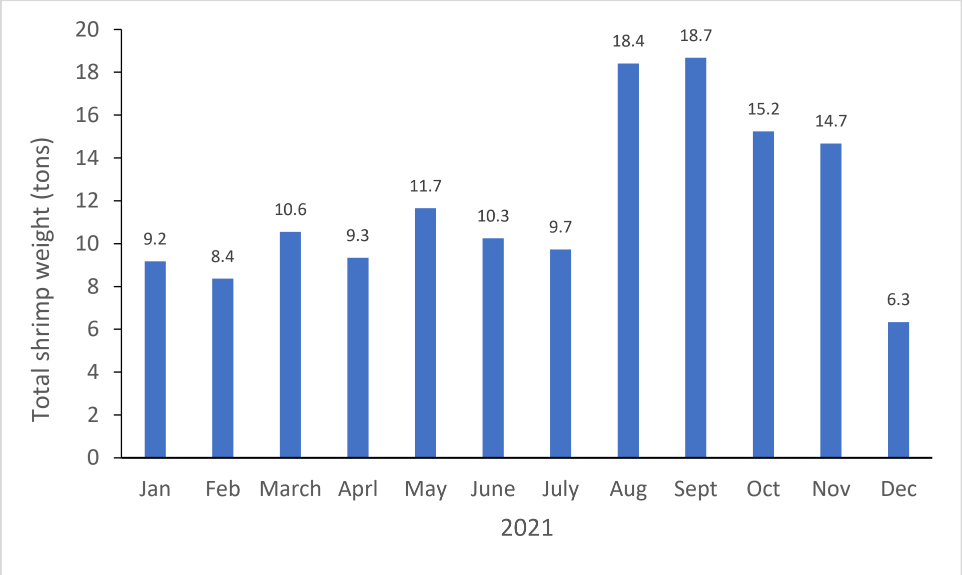

Fig. 3. Total monthly shrimp production in Kalpitiya trawl fishery in year 2021

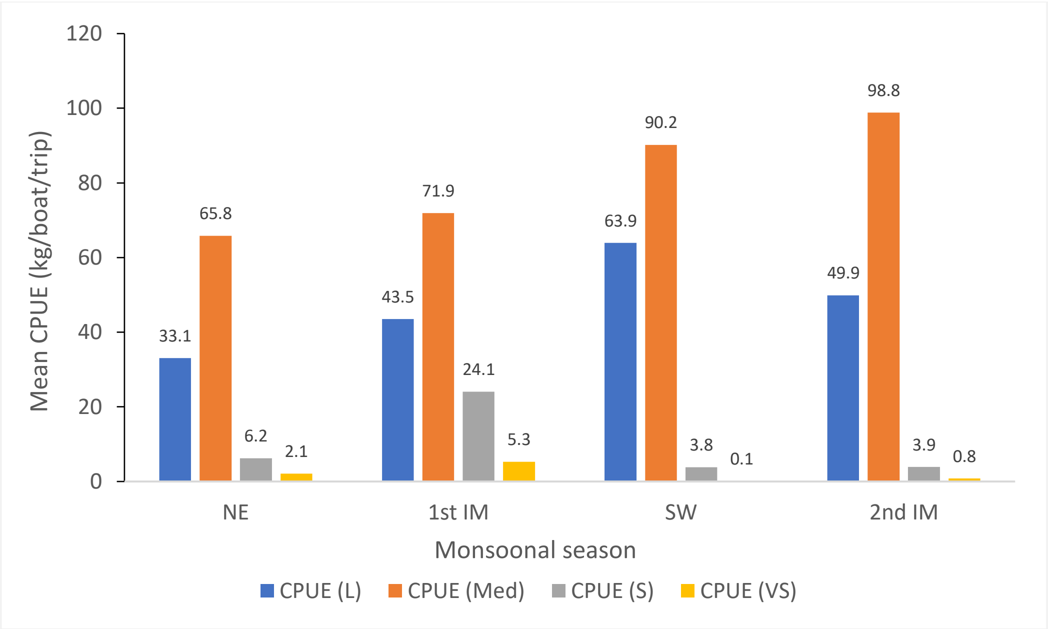

Fig. 4. Seasonal variation of mean CPUE represent Kalpitiya shrimp production in 2021. NE: North-east monsoon; 1st IM: First inter-monsoon; SW: South-west monsoon; 2nd IM: Second inter-monsoon

Statistical analysis on CPUE reveals, that no significant differences ($P > 0.05$) exhibited in overall shrimp production among four monsoonal phases irrespective to size variations. In concern of four size classes, small-sized and very small sized shrimps only show significant differences ($P < 0.01$) among four monsoons. Post-hoc analyses (Tukey pairwise comparison test between monsoons) reveals the significance of shrimp catch among different monsoonal phases (Fig. 5). For small-sized shrimps, differences exist between northeast–southwest and 1st inter-monsoon – southwest, while for VS sized shrimps, differences are observed among northeast–southwest, northeast – 2nd inter-monsoon, 1st inter-monsoon – southwest, and 1st inter-monsoon – 2nd inter-monsoon.

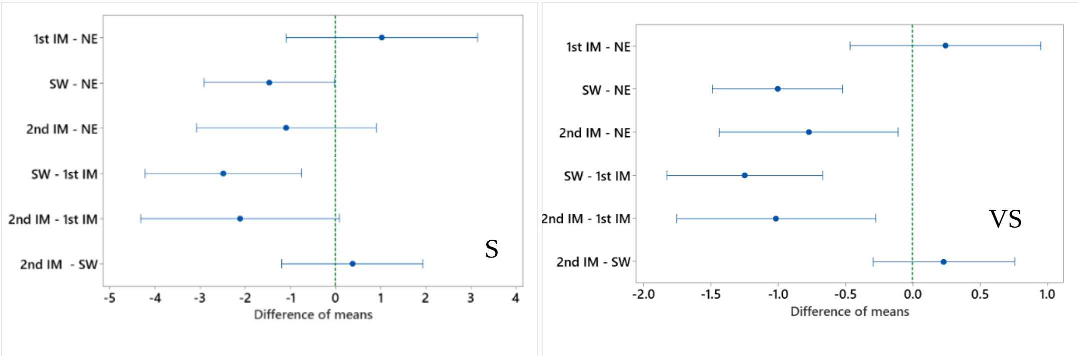

Fig. 5. Interval plots of Tukey simultaneous test (at individual confidential level of 95%) for differences of the means of CPUE represents Kalpitiya with pairwise monsoonal phases (S: Small sized shrimp; VS: Very small sized shrimp). An interval does not intercept the zero-reference line of mean difference (green dotted line), the corresponding means are significantly different. NE: North-east monsoon; 1st IM: First inter-monsoon; SW: South-west monsoon; 2nd IM: Second inter-monsoon

Mannar trawl fishery:

The CPUE of Mannar trawl fishery ranged between 12 kg boat^{-1} trip^{-1} and 38 kg boat^{-1} trip^{-1} throughout the study period. The lowest CPUE was recorded in the October period (12.2 kg boat^{-1} trip^{-1}) and the highest was in February (38.7 kg boat^{-1} trip^{-1}). The results show there was a firm rise in CPUE from January to February and a gradual decline from March to May, having a distinct decline during the period of June to October. The highest value of CPUE represents small and very small-sized/juvenile shrimps mostly observed during January to February, possibly representing the recruitment season of shrimp to particular trawl ground. However, from June to October, small and very small-sized shrimp catch was very low. In contrast, the CPUE of large-sized shrimp shows a gradual rise from March to June and has a distinct peak up to the period of September. Also, when compared to other sizes, the catch of small-sized (13 g – 29 g) shrimp dominated throughout the year (Fig. 6). The total shrimp production of Mannar trawl fishery in 2021 was estimated at 415 tonnes. Monthly total shrimp production (Fig. 7) indicates that the highest shrimp production occurred from January to April, having a contribution of about 42% of the annual shrimp production. In comparison, the period between July to October, shrimp production was the lowest in Mannar.

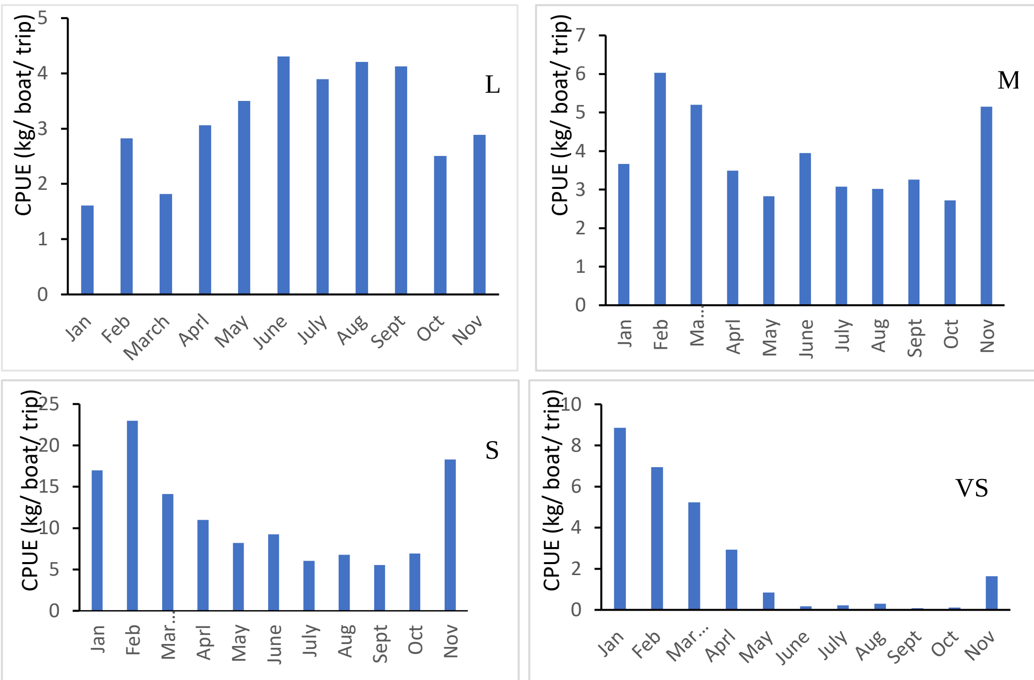

Fig. 6. Monthly variation of CPUE for different sized shrimp caught in Mannar. L: Large; M: Medium: S: Small; VS: Very small

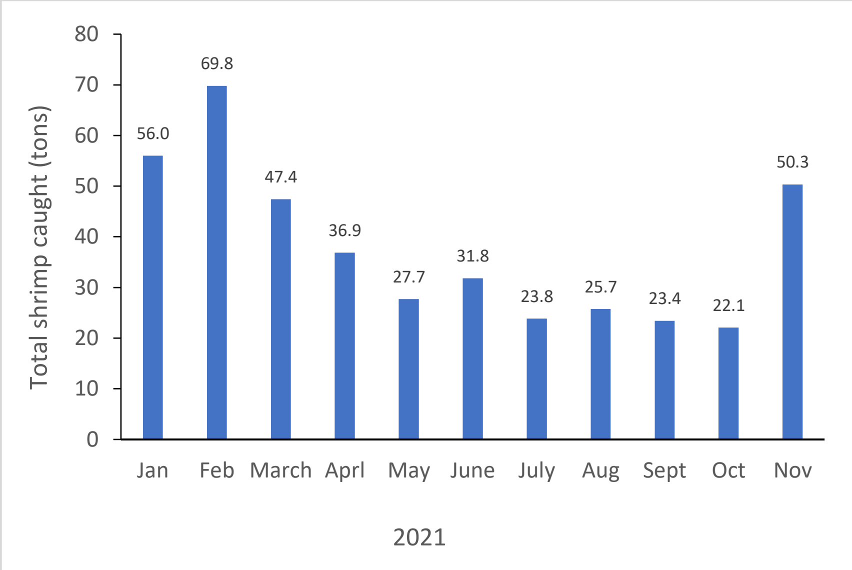

Fig. 7. Total monthly shrimp production in Mannar trawl fishery in 2021

Variations in the mean CPUE of 4 categories of shrimp in the trawl landings in Mannar (Fig. 8) during four seasons indicate that small-sized shrimp dominated during all four seasons followed by medium-sized shrimps. The pattern of variation of mean CPUE of small-sized and medium-sized shrimp was similar registering the peak values during the Northeast monsoon period. Moreover, small-sized shrimp, solely represent about 57% of caught shrimp in the Northeast season. The mean CPUE of large-sized shrimp was much lower in all four seasons. As the CPUE of small and very small-sized shrimp was highest during the Northeast monsoonal period, this season might represent the recruitment of shrimp to the fishing area.

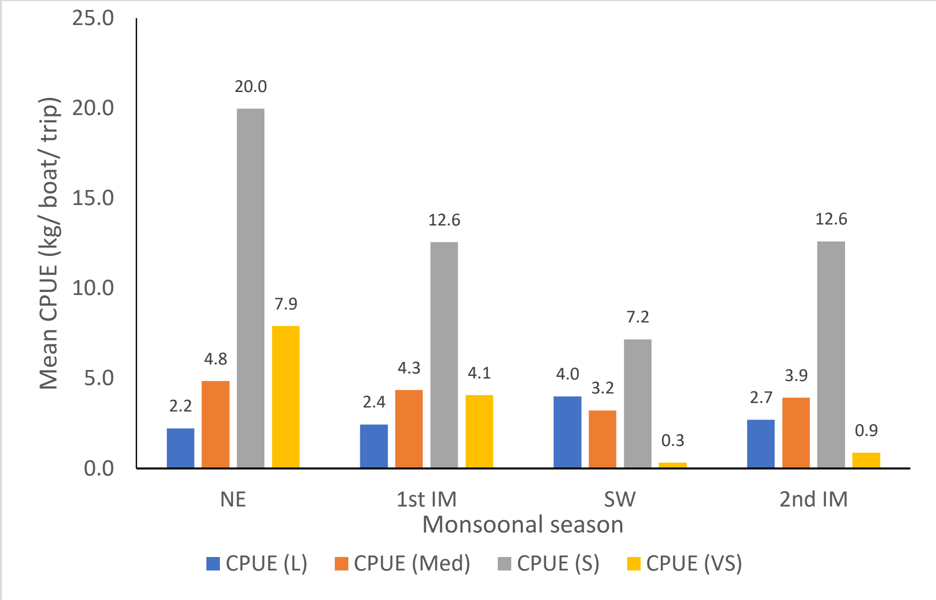

Fig. 8. Seasonal variation of mean CPUE represents Mannar shrimp production in 2021. NE: North-east monsoon; 1st IM: First inter-monsoon; SW: South-west monsoon; 2nd IM: Second inter-monsoon

Statistical analysis on CPUE reveals that a significant difference ($P < 0.01$) exists in overall shrimp production among four monsoonal phases irrespective of size variations. In concern of size categories, all four sizes show significant differences (large: $P < 0.05$; medium, small and very small: $P < 0.01$) among the four monsoons. Tukey pairwise comparison test reveals the specific significance of shrimp caught in between different monsoonal phases. For all four sizes, differences exist between northeast–southwest and 1st inter-monsoon – southwest. Moreover, small and very small-sized categories expressed the mean difference between northeast – 1st inter-monsoon, northeast – 2nd inter-monsoon, 1st inter-monsoon – 2nd inter-monsoon phases also (Fig. 9).

Seasonal size variation of main target shrimp species

In both Kalpitiya and Mannar trawl fisheries, *Penaeus semisulcatus* was the most targeted and abundant shrimp species. Seasonal variation of length classes of *P. semisulcatus* in the two fishing areas was investigated. In Kalpitiya, trawl fishery, size class of 14 -16cm (total length) was abundant in the landings during the northeast and 1st inter-monsoonal period (Fig. 10). Throughout the southwest and 2nd inter-monsoonal period, 12 to 14 cm sized shrimp were prominently caught, meanwhile, 16 to18 cm sized shrimp were also high (above 20%) all around the four seasons. Largest sized (18 to 20 cm) shrimp were caught only during 1st inter-monsoon and southwest monsoon periods.

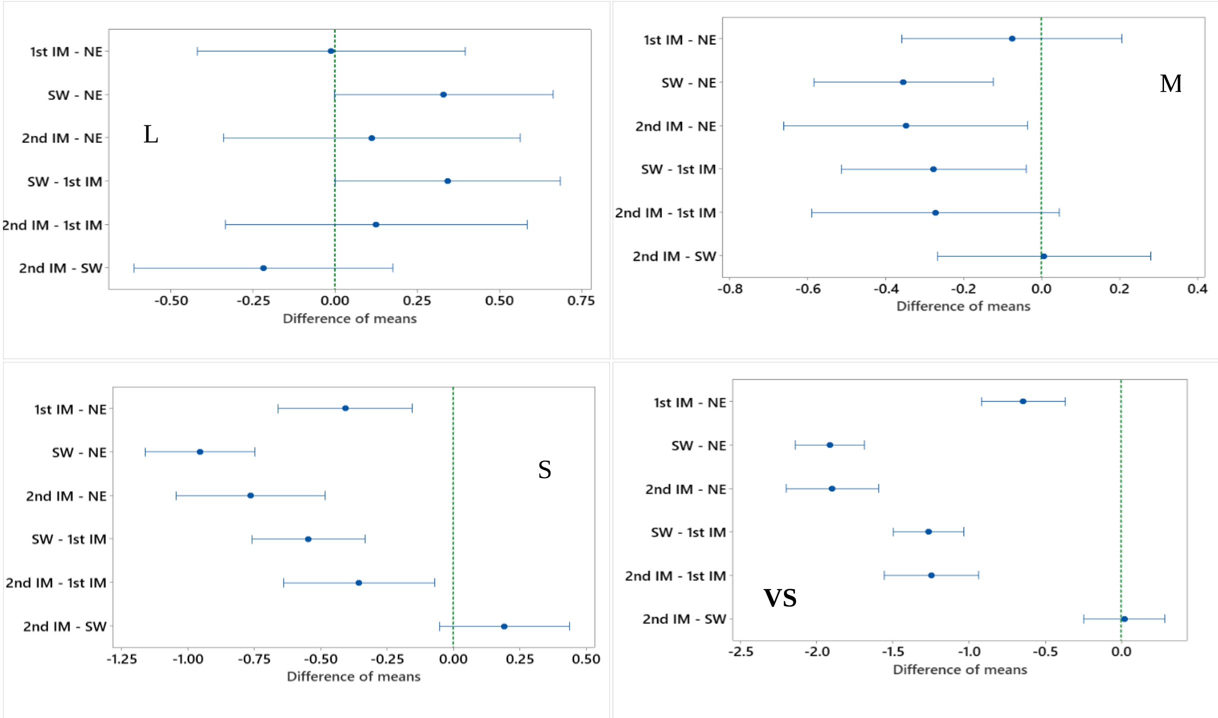

Fig. 9. Interval plots of Tukey simultaneous test (at the individual confidential level of 95%) for differences of the means of CPUE represents Mannar with pairwise monsoonal phases (L: Large sized shrimp; M: Medium-sized shrimp; S: Small- sized shrimp; VS: Very small sized shrimp). An interval does not intercept the zero-reference line of mean difference (green dotted line), the corresponding means are significantly different. NE: North-east monsoon; 1st IM: First inter-monsoon; SW: South-west monsoon; 2nd IM: Second inter-monsoon

In Mannar trawl fishery, 12 to 14 cm sized *P. semisulcatus* were caught throughout the year representing above 35 % of total landings in all four monsoonal phases (Fig. 11).

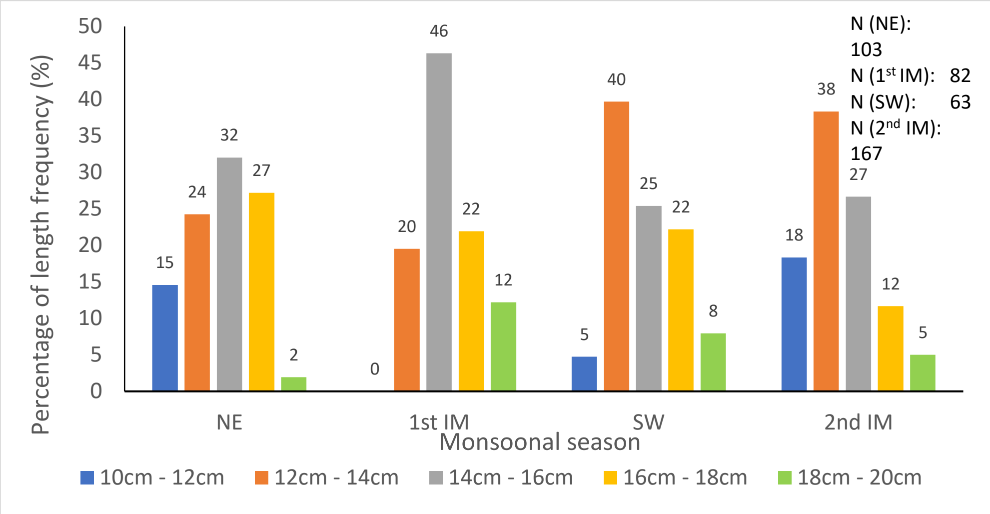

Fig. 10. Seasonal variation of length frequency for *P. semisulcatus* (Kalpitiya)

Length classes of 10 to 12 cm and 14 to 16 cm also contributed to reasonable percentage (mostly above 20%) of shrimp caught throughout the year. Smallest-sized (8 to 10 cm) *P. semisulcatus* were caught only during the northeast monsoonal period perhaps reflecting their recruitment season to the fishing ground.

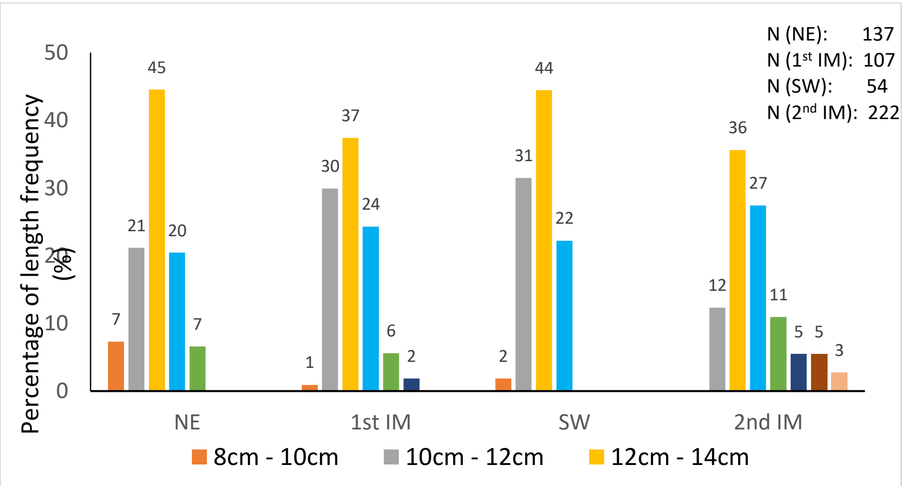

Fig. 11. Seasonal variation of length frequency for *P. semisulcatus* (Mannar)

Seasonal variation in the sex ratio of P. semisulcatus

The sex composition of *P. semisulcatus* in both trawl grounds did not show any prominent changes between different monsoonal phases, but there was a contrasting difference in the sex ratio between the two sites (Fig. 12). In Kalpitiya, female shrimp dominance was evident whereas in Mannar, male shrimps were dominant throughout the year except 1st inter-monsoonal phase. Further studies are needed to understand these site-specific variations of sex ratio.

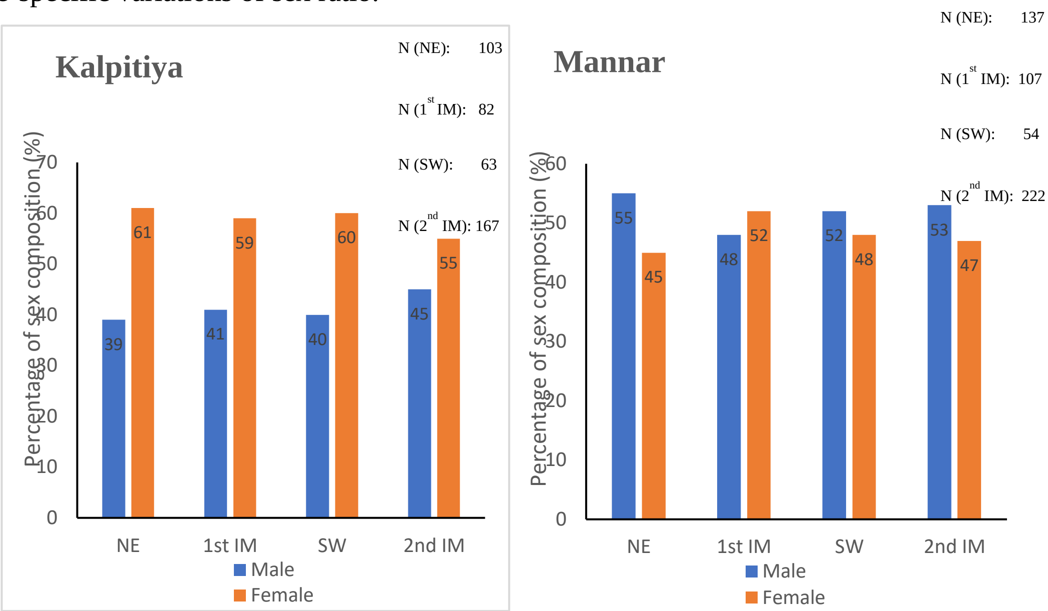

Fig. 12. Seasonal variation of sex composition for *P. semisulcatus* (Kalpitiya & Mannar)

Effect of monsoonal wind patterns on shrimp production

Shrimp catch rates of trawl fisheries were reported to be considerably influenced by monsoonal wind patterns and wind velocity (Jayawardane *et al.*, 2004). The seasonal wind pattern of the northwest coast off Kalpitiya coincides with the southwest monsoonal phase (May to October) and during this period, the average wind velocity is also high. From the present study, it is evident that in Kalpitiya, shrimp catch was the highest during the period of the Southwest monsoonal phase, registering around 48% of total annual shrimp production during this season. In addition, a peak value of mean CPUE (about 155 kg boat^{-1}trip^{-1}) also was recorded during the Southwest monsoon. Lower total monthly shrimp production and relatively lower mean CPUE (about 107 kg boat^{-1}trip^{-1}) of shrimp caught in Kalpitiya were observed during the period of the Northeast phase when there was low wind with calm sea.

In contrast, on the Northern coast off the Gulf of Mannar during the Northeast monsoonal period (December to February), the average wind velocity was also relatively high. Shrimp catch rates in the Mannar trawl fishery were higher (about 30% of total production) during the northeast monsoon. Furthermore, the highest mean CPUE (about 35 kg $boat^{-1}trip^{-1}$) was also recorded during the Northeast monsoon. Lower total monthly shrimp production and lower mean CPUE (about 15 kg $boat^{-1}trip^{-1}$) were noted during the period of the Southwest monsoonal season having low wind and calm sea off Mannar. Similar studies conducted earlier in west coast trawl grounds also evidently prove that the high shrimp catch recorded within the period of high average wind velocity over the west coast (Southwest monsoon) and relatively low shrimp catches were observed during the northeast and the inter-monsoon periods with calm seas (Haputhantri and Jayawardena, 2006). Further, the earlier study was conducted during 2008/2009 in Kalpitiya trawl fishery by NARA (Sanders and Jayasinghe 2009) reported that total annual shrimp production was about 109 tons and *P. semisulcatus* was by far the most abundant shrimp species. Accordingly, the present annual shrimp production in Kalpitiya area (142 tons in 2021) was around 30% increase over the past decade.

Fishery management generally encompasses technical measures concerning gear and operations, spatial controls, impact quotas, and fishing effort controls. The effectiveness and feasibility of these measures, whether implemented individually or in combination. It also varies based on fishery characteristics, management capabilities, environmental impacts, food security, income, and employment (McConnaughey *et al*., 2020).

Addressing trawling concerns becomes much more manageable through the adoption of current technical gear and management practices, such as altering gear design and implementing spatial controls. For instance, the reduction of bycatch and discards in trawl fisheries in Europe, North America, and Australia can be attributed to improved gear selectivity and decreased fishing effort, as noted by Kennelly and Broadhurst in 2021. Additionally, a significant change in Southeast Asia involves the increased utilization of all species in trawl fisheries such as for local markets and aquaculture feed, ultimately resulting in a decline in discarding (Suuronen *et al*., 2020). If stakeholders and regulatory bodies adopt these measures and eliminate the rush to fish, it seems that bottom trawling could have a lesser environmental impact. This is important, as these alternatives might replace trawl-caught fish in the event of a trawling ban.

Acknowledgments

The authors would like to thank the trawl fishers, shrimp collectors, and sellers in Kalpitiya and Mannar. Financial support provided by the National Aquatic Resources Research and Development Agency (NARA) is greatly acknowledged. The staff of the NARA's Kalpitiya Regional Research Centre helped in many ways with this research. The critical comments of two reviewers helped to improve the scientific contents of the manuscript.

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