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Gillnetting for small indigenous cyprinids in a Sri Lankan reservoir where culture-based fisheries are practiced

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Abstract In Sri Lankan reservoirs, small, indigenous fish species (SIS) are abundant and can be differentially exploited using small mesh (15-38 mm stretched mesh sizes) gillnets without any detrimental effects on the cichlid fisheries. However, in the recent past a paradigm shift in the reservoir fisheries of Sri Lanka is observed from total dependence on exotic cichlids to exploitation of exotic carps, stocked in reservoirs for the development of culture-based fisheries (CBF). As fingerlings of Chinese and Indian major carps and common carp are regularly stocked in reservoirs for the development of CBF, it is essential to investigate the potential impact of the use of small mesh gillnets to catch SIS on stocked fish fingerlings on CBF. In the present study, small mesh gillnets were used to exploit SIS during September 2011 to March 2013 when carp fingerlings were stocked in Chandrika wewa, Sri Lanka. The results revealed that no carp fingerlings (except 2 specimens of Indian carp species) were caught in any of the fishing trials with small mesh gillnets. As juvenile fish and stocked fish fingerlings occur in shallow littoral areas of reservoir, and as small mesh gillnets are laid at the depths ≥ 1.5 m, there is a habitat segregation of these two categories of fish. It is therefore possible to introduce a subsidiary fishery with small mesh gillnets to exploit SIS, which can co-exist with CBF in reservoirs of Sri Lanka.

Keywords: reservoir fisheries; small indigenous species; Cyprinidae; Cichlidae; culture-based fisheries

INTRODUCTION

Inland fish and fisheries are crucial for many socially, economically and nutritionally vulnerable groups of people around the world because of their vital role in providing an important source of animal protein and essential micronutrients for local communities, especially in the developing world and ensuring global food security (Yong et al. 2014; Funge-Smith and Bennett 2019). In the tropical belt, reservoirs make a significant contribution to inland fish production (Fernando and Holčik 1991; Welcomme 2001). However, reservoir fish production in many counties of Asia is dependent on a few species so that utilization of spectrum of biological production in reservoir ecosystems is often not fully realized (Pet et al. 1996; Amarasinghe and De Silva 2015). Occurrence of small indigenous fish species (SIS) in inland waters of many tropical countries are reported (De Silva and Sirisena 1987, 1989; Ahmed et al. 2001; Amarasinghe et al. 2016; Kolding et al. 2019). Nevertheless, many of these fishery resources remain unexploited or underexploited and this may be due to, among other reasons, the fisheries management strategies currently in place targeting the exotic fish species which contribute most to commercial fisheries production by regulating mesh sizes of gillnets (Amarasinghe and De Silva 2015).

Previous studies in Sri Lankan reservoirs have shown that SIS could be differentially exploited using gillnets of stretched mesh sizes, 15 mm to 38 mm without adverse effects on the fishery based on larger fish species such as exotic cichlid species (i.e., *Oreochromis mossambicus* and *O. niloticus*), which account for over 70% of the landings (Amarasinghe 1985, 1990; De Silva and Sirisena 1989; Pet and Piet 1993). Such differential exploitation of SIS and commercially important fish species is possible since individuals of the latter group exhibit depth preference, juveniles occupying shallow littoral areas while adults inhabit deeper areas of the reservoir. In deeper areas of reservoirs (≥1.5 m depth), gillnet selection curves of effective mesh sizes for the two groups of fish do not overlap (Ajith Kumara et al. 2009a). In Sri Lankan reservoirs, abundant SIS are reported to be *Amblypharyngodon melettinus*, *Dawkinsia singhala*, *Puntius chola* and *P. dorsalis* (De Silva and Sirisena 1987; Amarasinghe 1990; Pet and Piet 1993; Ajith Kumara et al. 2009b). SIS are recognized as a group of fish rich in minerals and vitamin A, having high potential for contributing to improved food and nutrition security, income and livelihoods of the people of South and Southeast Asia (Roos et al, 2007; Thilsted 2012; Fielder et al. 2016). Amarasinghe et al. (2016) recommended introducing a subsidiary small-mesh gillnet fishery for exploiting SIS in Sri Lankan reservoirs to enhance inland fisheries production in the country.

Culture-based fisheries (CBF) development in the multitude of reservoirs is a recent trend in the Sri Lankan inland fishery (Wijenayake et al. 2005; Amarasinghe and Nguyen 2009; Amarasinghe and Wijenayake 2015; Pushpalatha and Chandrasoma 2010). In CBF, hatchery-reared fingerlings are released to reservoirs for subsequent capture after a reasonable growth period. As shape characteristics of stocked fish fingerlings are more or less similar to those of SIS, particularly *A. melettinus*, one can argue that the use of small-mesh gillnets for exploiting SIS may pose a potential risk of stocked fingerlings being caught jeopardizing CBF efforts. Depending on the hypothesis that juvenile stages of fish occupy littoral zones and adults move to deeper areas of reservoirs, and that exploitation of SIS using small mesh gillnets would not make stocked fingerlings vulnerable for getting caught, the present study was carried out to find the answer to the question if there would be any adverse impact on the CBF development strategies if a subsidiary small-mesh gillnet fishery is introduced to exploit SIS. Experimental fishing with small-mesh gillnets was carried out in a reservoir for the purpose, during the period of stocking of fingerlings of Indian major carps for CBF production, and this paper aims at providing answer to the research question mentioned above.

MATERIALS AND METHODS

The present study was carried out in Chandrika wewa (area: 439 ha; Location: 6° 19' N; 80° 51' E; Figure 1), an irrigation reservoir Sri Lanka.

This reservoir was selected due to the reasons that it is a medium-sized perennial reservoir with a fishing community of manageable size operating only 12 fishing boats, that fishers were cooperative for conducting experimental fishing, and that National Aquaculture Development Authority of Sri Lanka (NAQDA) has chosen this reservoir for stocking fish fingerlings for CBF development. Based on the information about annual fish stocking plan of NAQDA, the present study was conducted from September 2011 to March 2013, coinciding the duration of stocking of carp fingerlings in Chandrika wewa.

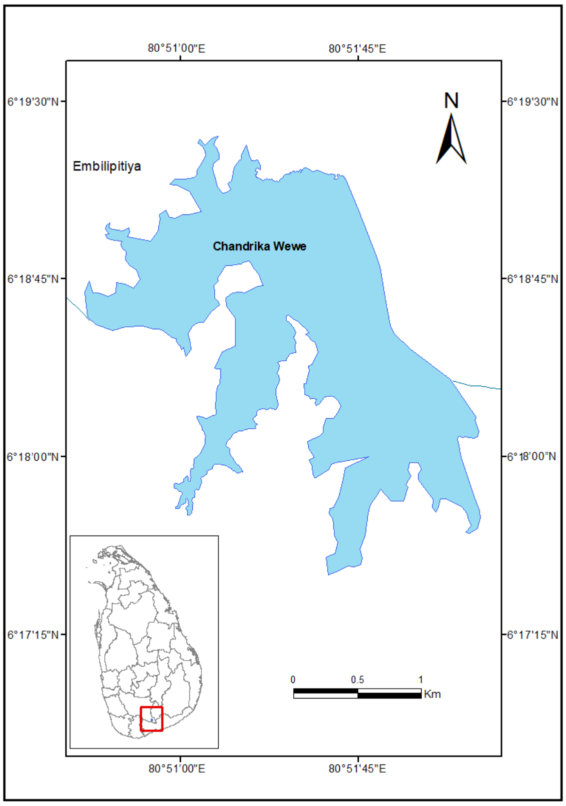

Figure 1 Map of Chandrika wewa.

Authors approached office bearers of the fishermen's society and based on their advice, two reliable fishermen, who were willing to record daily catches of small-mesh gillnets, were chosen to get assistance for experimental gillnet fishing. Gillnet pieces of 7 different mesh sizes were used for two experimental fishing trial periods; during September 2011 to May 2012 (Trial period I) and during June 2012 to March

2013 (Trial period II). During the two trial periods, two different heights of gillnets were used while keeping other dimensions and filament characteristics unchanged. The details of dimensions and filament characteristics, and calendar of experimental fishing trials during Trial periods I and II are given in Table 1.

Table 1 Dimensions and filament characteristics of experimental gillnets

Characteristics	Net code						
	GN1	GN2	GN3	GN4	GN5	GN6	GN7
Trial period I (from September 2011 to May 2012)							
Mesh size (stretched) (mm)	10	12	15	19	25	32	38
Hanging ratio*	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Filament thickness	2 ply	2 ply	2 ply	2 ply	2 ply	2 ply	2 ply
Height of net (m)							
Trial period I	3.8	4.6	4.8	5.5	6.9	7.3	8.2
Trial period II	-	-	-	2.7	3.4	2.3	5.5
Length of net (m)							
Trial period I	23.8	25.6	28.3	16.5	17.4	23.8	26.5
Trial period II	-	-	-	16.5	17.4	23.8	26.5
Trial date (fishing occasion)	Number of fishing trials						
15-16 Sep 2011 (I)	2	4	-	-	-	-	-
28-30 Sep 2011 (II)	1	10	9	-	-	-	-
19-21 Oct 2011 (III)	3	10	7	-	-	-	-
2-4 Nov 2011 (IV)	-	9	9	-	-	-	-
16-17 Feb 2012 (V)	3	3	3	3	3	3	3
21-23 Mar 2012 (VI)	-	3	3	3	3	3	3
25 Apr 2012 (VII)	-	1	1	1	1	1	1
16 May 2012 (VIII)	-	-	-	1	1	1	1
19-20 Jun 2012 (IX)	-	-	-	2	2	2	2
28 Feb-01 Mar 2013 (X)	-	-	-	-	-	6	8

* Hanging ratio = ratio of hung length to stretched length (Sparre and Venema 1996)

The two fishermen who were selected for seeking assistance for experimental fishing were given one gillnet piece each of the 7 mesh sizes. The fishermen were requested to catch fish on mutually convenient dates when the first author (D.A.A.) could visit and supervise fishing activities. During the study period, there were 10 experimental fishing occasions, and on these fishing occasions 135 experimental fishing trials were carried out using gillnets of 7 mesh sizes (Table 1). Fishermen have laid gillnets in the deeper areas (≥ 1.5 m depth) of the reservoir in the late afternoon and recovered nets with gilled/entangled fishes on the following morning. As the lowest height of gillnet (10 mm mesh gillnet during trial period II; Table 1) was 1.9 m, fishermen were compelled to set their gillnets at least at the reservoir depth of 2 m. The fishermen were provided with log-sheets to record mesh-wise and species group-wise catches. As an incentive, the two fishermen who were engaged in experimental fishing were requested to sell their catches enabling them to supplement their fisheries income.

The following information was obtained from NAQDA.

1. Stocking size of fingerlings;
2. Species-wise stocked numbers from January 2011 to December 2014;
3. Monthly species-wise fish production from January 2011 to December 2014

The monthly catches of SIS in experimental gillnets were determined from the data recorded in the fishermen's log-sheets for the trial periods I and II separately. Analysis of gillnet catches of SIS for each trial period separately was necessary due to the differences in dimensions of gillnets (i.e., depth of net) of each mesh size between the trial seasons. Monthly mesh-wise and species group-wise catch data were expressed as kg per month and were plotted to compare with commercial fisheries landings. For this purpose, monthly species group-wise stocking data and monthly species group-wise fish production data obtained from the NAQDA database were also used to prepare histograms. The commercial gillnet mesh sizes in the fishery of Chandrika wewa ranged from 6.9 cm to 35.6 cm, and the different mesh gillnets are used by fishermen targeting various fish species in the fish community (Table 2). Fishermen lay their nets late in the afternoon and recover following day morning. The fishing depth of commercial gillnetting is > 3m.

Table 2 Mesh sizes of commercial gillnets in the fishery of Chandrika wewa and species targeted by each mesh size.

Gillnet mesh size (cm)	Target species
6.9	*Oreochromis mossambicus*
7.6	*O. niloticus*
8.4	
8.9	
10.2	*O. mossambicus, O. niloticus,*
11.4	*Cirrhinus mrigala, Cyprinus carpio, Labeo rohita*
12.7	*Cirrhinus mrigala, Cyprinus carpio, Labeo rohita*
14.0	
15.2	
19.0	*Catla catla*
21.6	
25.4	
35.6	

RESULTS

List of fish species caught in the experimental gillnets during the study period and the mean body length (and range) of each species are given in Table 3.

Table 3 List of fish species caught in the experimental gillnets during the study period and the mean body lengths (and ranges) of each species caught in small mesh gillnets. Abb. – Abbreviations as given in Figure 3.

Species	Abb.	Mean length (TL in cm)	Length range (TL in cm)
Amblypharyngodon melettinus	Am	6.0	3.0-9.0
Cirrihinus mrigala (2 specimens)	Cm	15.3	14.5-16.0
Dawkinsia singhala	Ds	10.8	7.5-14.5
*Glossogobius giuris**	Gg	7.4	3.0-35.0
Hyporhamphus quoyi (=gaimardi)	Hg	9.9	6.5-13.0
*Labeo dussumieri**	Ld	17.0	13.0-22.0
Mystus keletius	Mk	12.1	9.0-14.0
Puntius chola	Pc	11.5	7.0-17.5
*Puntius dorsalis**	Pd	10.9	10.0-12.5
Rasbora daniconius	Rd	6.5	4.5-9.5
Others*	Ot		
Etroplus suratensis		8.1	7.0-10.5
Garra ceylonensis		19.0	18.0-20.0
Heteropneustes fossilis		14.1	12.5-14.5
Ompok bimaculatus (1 specimen)		20.0	-
Systomus sarana		20.9(TL)	19.5-22.0

* caught in 25-38 mm mesh gillnets during Trial II

Of these, *A. melettinus* was the most dominant species. The size range of fish fingerlings stocked was 5-7 cm, which was presumably vulnerable to 15-18 mm mesh gillnets. The gillnets of 12 mm mesh size were not recommended because previous studies (Amarasinghe 1985) indicated that immature individuals of *A. melettinus* were caught in this mesh size. Interestingly however, none of the stocked fish fingerlings, except in one occasion when two specimens of fingerlings of *Cirrihinus mrigala* was caught in a 19 mm mesh gillnet in May 2012, were caught experimental gillnets. Stocked species, and species caught in the commercial landings are given in Table 4.

Table 4 List of species stocked in Chandrika wewa during the study period (Source: NAQDA) and species caught in the commercial gillnets

Species stocked
Exotic carps
Catla catla
Cirrhinus mrigala
Cyprinus carpio
Ctenopharyngodon idella
Labeo rohita
Cichlids
Oreochromis niloticus
Others
Labeo dussumieri
Macrobrachium rosenbergii
Species caught from naturally recruited populations
Channa striata
Etroplus suratensis
Glossogobius giuris
Ompok bimaculatus
Systomus sarana

Mesh-wise experimental gillnet catches of major SIS in Chandrika wewa during the study period (Figure 2) indicate that there are species-specific mesh sizes for different SIS and that for the most abundant SIS, *A. melettinus*, the effective gillnet mesh sizes are 15 mm and 19 mm. Species composition of SIS caught in the 10 fishing occasions (Figure 3) indicates that except in one fishing occasion (8th fishing occasion in May 2012) when 2 specimens of *C. mrigala* were caught, none of the stocked fingerlings was caught in small-mesh gillnets.

Number of fishes of three categories stocked in different months from January 2011 to December 2014 (Figure 4(A)) coincided the experimental gillnet fishing trials for SIS in Chandrika wewa. Monthly fish production of three categories of fishes (Figure 4(B)) indicates that stocking of fish fingerlings had a significant positive impact on CBF harvest. It must be noted that as stocking of fish fingerlings had been carried out during preceding years, such stocking has also influenced species composition of the landings.

DISCUSSION

Since early 1980s, several studies have been reported providing scientific evidence that subsidiary gillnet fishery for SIS, which can co-exist with the tilapia gillnet fishery would be feasible in major reservoirs of Sri Lanka (Amarasinghe 1985, 1990; De Silva and Sirisena 1987, 1989; Pet and Piet 1993; Ajith Kumara et al. 2009a). Exploitation of SIS in reservoirs of Sri Lanka does not take place, which may be due to, among other reasons, current gillnet mesh regulations (≥8.5 cm stretched mesh size) prevent the use of gillnets of smaller mesh sizes (Amarasinghe and De Silva 2015). Despite these regulatory constraints for exploiting SIS, in some reservoirs of Sri Lanka, fishermen are engaged in small mesh gillnet fisheries to exploit SIS, providing supplementary income for fishing communities (Amarasinghe et al. 2009, 2016). Furthermore, in terms of trophic interactions in reservoir fish communities, exploitation of SIS is shown to be advantageous to enhance existing commercial-scale fisheries mainly dependent on exotic cichlids, through reduction of competition for food resources (Pet et al. 1996; Amarasinghe et al. 2014).

Present study has shown that in Chandrika wewa, exploitation of SIS and stocking of carp fingerlings for CBF development can be accomplished simultaneously because stocked fingerlings are not vulnerable to be getting caught in small mesh (15-38 mm stretched mesh size) gillnets. As regular stocking of fingerlings of exotic carps for CBF development in reservoirs is a recent development in Sri Lanka, these findings are crucial for introducing small mesh gillnet fisheries along with stocking of fish fingerlings. As juvenile stages of fish species in lentic ecosystems such as lakes and reservoirs are known to occur in littoral zones (Levin et al. 2004; Říha et al. 2015), depth preference of juvenile carp species stocked in the reservoir occur in the littoral zone. As such, small mesh gillnets laid in deeper areas (≥ 1.5 m depth) of the reservoir to catch SIS do not impact carp fingerlings stocked in the reservoir. Amarasinghe et al. (2016) also demonstrated that small-mesh (15–52 mm stretched mesh) gillnets can be used to exploit SIS in the deeper, pelagic areas of Sri Lankan reservoirs, without impacting on the recruitment of cichlids and without a potential danger of 'growth overfishing' of cichlid stocks. Present study therefore confirms the hypothesis that exploitation of SIS using small mesh gillnets would not make stocked fingerlings vulnerable for getting caught.

Amarasinghe et al. (2002) have demonstrated that SIS in Sri Lankan reservoirs have high production per biomass (P/B) ratios compared to those which are exploited by the commercial reservoir fisheries. The species having high P/B ratios (i.e., high turnover rates) are known to be able to withstand heavy fishing pressure. As such, SIS in reservoirs can be expected to support productive fisheries as suggested by Amarasinghe et al. (2002).

Regulatory restrictions hampering exploitation of hitherto unexploited SIS fishery resources are not unique to Sri Lanka. Such situations are also reported to exist in reservoirs of Indian sub-continent (Kumar 2010; Sugunan 2010). There is also ample evidence that SIS occur in high abundance in reservoirs in several Asian countries (Ahmed et al. 2001; Jutagate et al. 2003; Roos et al. 2007) and Ethiopian lakes in Africa (Vijverberg et al. 2012). Also, regular stocking of fish fingerlings for CBF development is not uncommon in the Asian region (Kartamihardja 2015; Saphakdy et al. 2009; Nguyen et al. 2005; Srun and De Silva 2015). As such, findings of the present study have a regional applicability. In conclusion, it is reiterated that introduction of a subsidiary fishery for SIS in reservoirs in Sri Lanka is desirable to enhance inland fisheries production. There are legal provisions to issue licenses to identifiable group of fishermen under the Fisheries and Aquatic Resources (Amendment) Act No. 35 of 2013 (Anon. 2013).

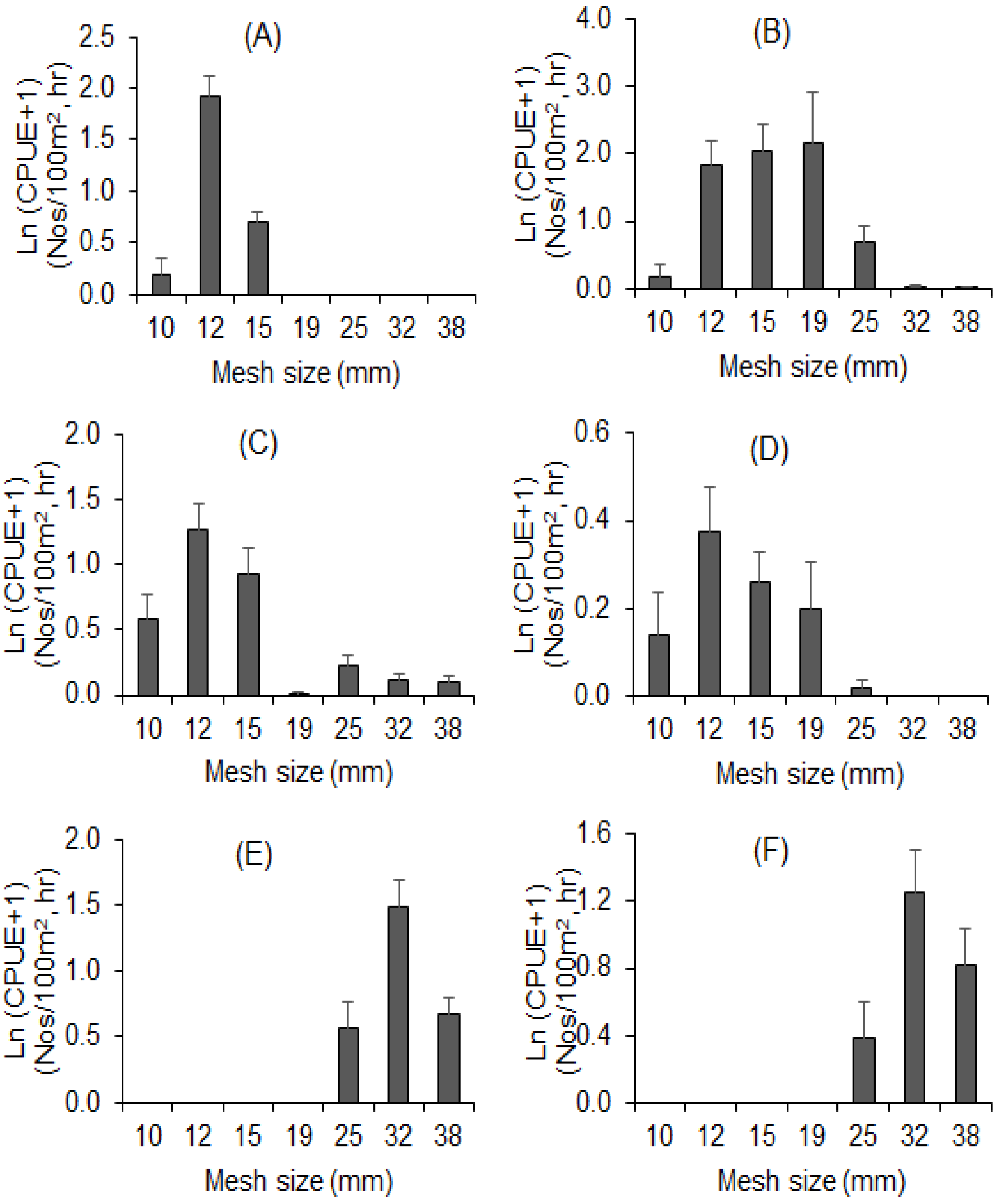

Figure 2 Relative abundance of major SIS caught in different mesh gillnets during the study period, showing effectiveness of various mesh sizes for catching individual SIS in Chandrika wewa. (A) *H. gaimardi*; (B) *A. melettinus*; (C) *Glossogobius giuris*; (D) *Rasbora daniconius*; (E) *Dawkinsia singhala*

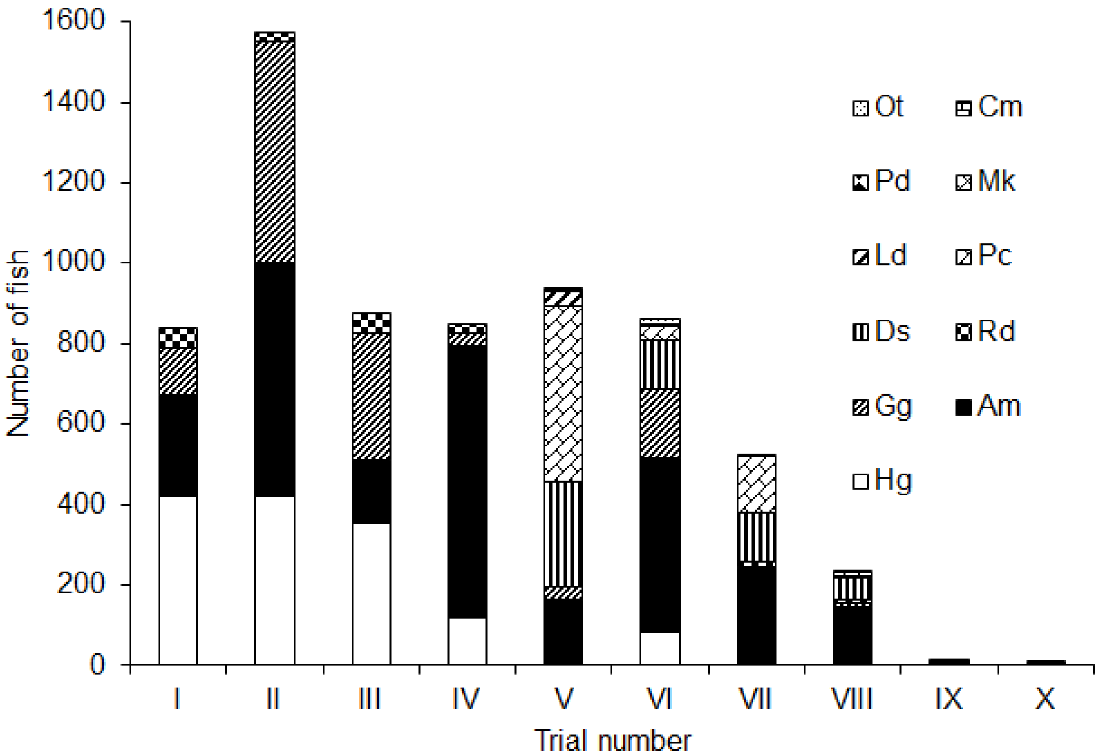

Figure 3 Species composition of SIS caught in small-mesh experimental gillnets during 10 fishing occasions. Fishing occasions are as given in Table 1. Abbreviations of species names are as given in Table 2. Note: In the 8th fishing occasion, only 2 specimens of stocked *C. mrigala* were caught.

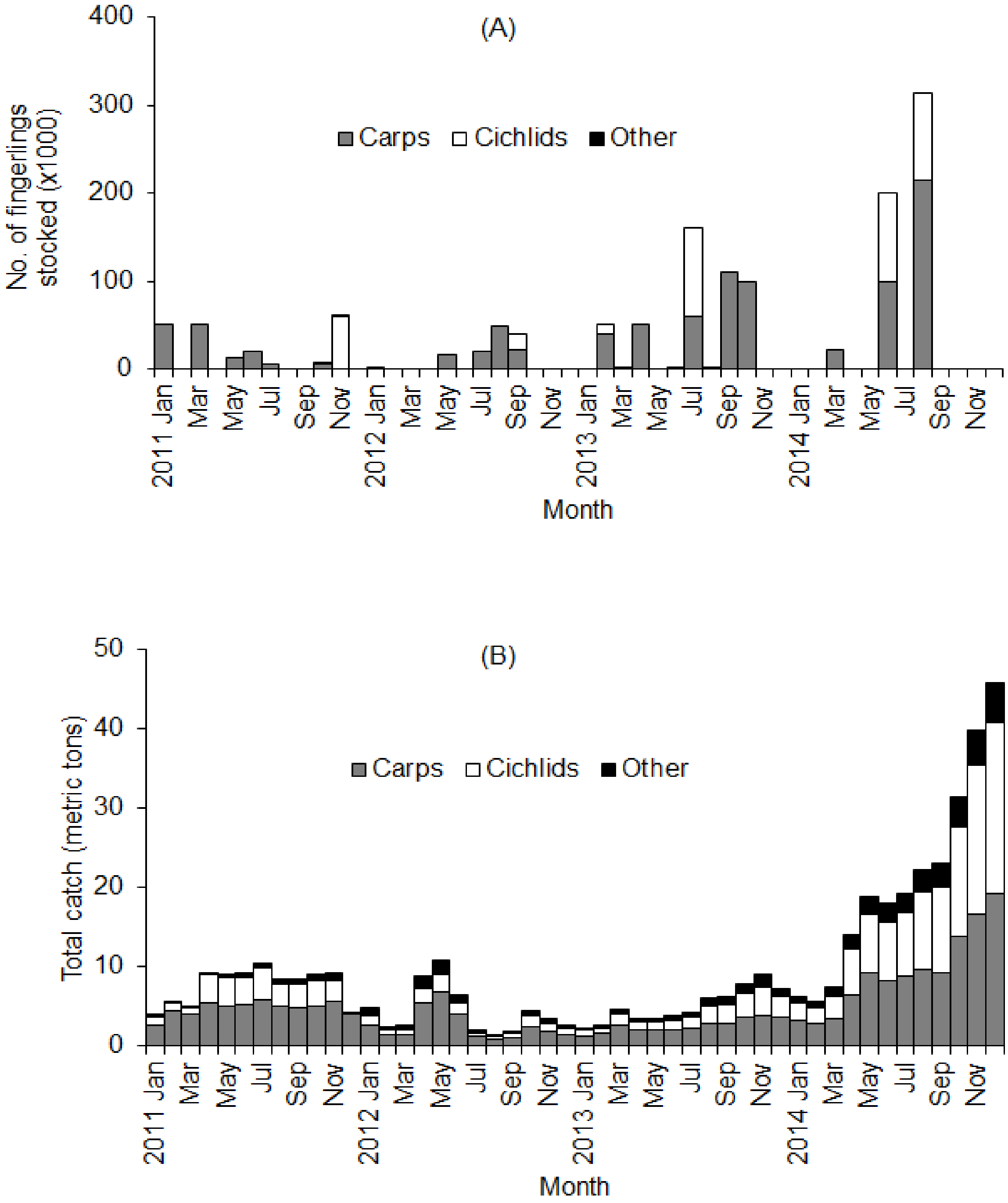

Figure 4 Fish species stocked and total landings during January 2011 – December 2014 in Chandrika wewa. List of three categories of species stocked and those which were caught in commercial fisheries are given in Table 3 (Source of data: NAQDA)

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