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Role of giant freshwater prawn (*Macrobrachium rosenbergii*) in livelihoods of the rural fishers of Northern Province of Sri Lanka

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Abstract
The overall objective of this study was to assess to what extent *Macrobrachium rosenbergii* culture in reservoir is sustainable and whether it has the potential to provide a livelihood option for reservoir fishers. Fisheries and socio-economic data collection were conducted from 2016 January to 2018 December in five perennial reservoirs in the Northern Province of Sri Lanka. Results revealed that culture-based fisheries and the introduction of *M. rosenbergii* in the five selected reservoirs have achieved considerable success and resulted in significant increases in fish production, income of fishers, availability of fresh fish for the rural communities and livelihood opportunities for fishing families. Socio-economic factors such as, age, fisheries experience, fish catch of the previous day, market value, household status and livelihood diversification influenced reservoir fishing. Low rainfall, strong wind, high temperature, over-growth of aquatic plants and algal blooms wildlife attacks and theft of fishing gear were identified as key stressors.

Keywords: *Macrobrachium rosenbergii*, reservoir fisheries, socio-economics, Northern Province, livelihoods, stressors

1. Introduction

Sri Lankan reservoirs are primarily used for irrigation and/or generation of hydroelectricity and secondarily for inland fisheries, livestock rearing, and household water needs. Culture based fisheries (CBF) in reservoirs are artisanal, extensive, low cost, highly seasonal and ecologically friendly aquaculture practice, which contributes to livelihood opportunities, food security as well as fulfilment of nutritional requirement of rural communities [1]. Introduction and stocking of desirable/ potential fish species in reservoirs as CBF is done for various purposes such as, enhancement of fisheries, restoration, pollution mitigation and initiation of new fisheries to increase species diversity and to increase fish yield in the reservoirs [2]. The National Aquaculture Development Authority (NAQDA) of Sri Lanka along with the public and private stakeholders have conducted continuous stocking of exotic fish species and native giant freshwater prawn (*Macrobrachium rosenbergii)* in selected reservoirs. At present there are 137 freshwater fish species in Sri Lanka, which consists of 53 endemics, 23 estuarine and 24 exotic species [3]. *M. rosenbergii* is one of the most economically important freshwater prawn species due to its taste and premium market value, which makes it as one of the fittest species for extensive culture [4]. *M. rosenbergii* is not naturally found in the reservoirs in the Northern Province of Sri Lanka due to the absence of perennial rivers in the Northern Province. As stocking is the only way to develop culture based fisheries of *M. rosenbergii* in the reservoirs in the Northern Province of Sri Lanka, NAQDA has introduced it in selected perennial and seasonal reservoirs. Culture based fisheries in the reservoirs in Sri Lanka was restricted due to limited amount of seed production with 65.91 million *M. rosenbergii* seeds and 88.5 million seeds of exotic tilapia and carps in 2019 [5].

Over 2,000 fishing families in the Northern Province of Sri Lanka depend on the reservoir fisheries for their livelihood. However, CBF in the reservoirs in the Northern Province has been expanded only recently. In present study, GFWP was introduced in a significant quantity in all five selected reservoirs in the Northern Province. As CBF mostly target on exotic fish species, details on native fish species, socioeconomic status of fishers and climatic and non-climatic stressors of reservoir fisheries and its impacts on the social and economic wellbeing of reservoir fishing communities are lacking, which may cause major challenge to the stakeholders who are involved in the implementation process of CBF in reservoirs. Therefore, the overall objective of this study was to assess to what extent *M. rosenbergii* culture in reservoir is sustainable and whether it has the potential to provide a livelihood option for reservoir fishers.

The specific objectives of the study are: to evaluate and compare the current status of captive and culture-based fisheries in the five selected perennial reservoirs in the Northern Province of Sri Lanka, to evaluate the role of FWP culture in fisher's livelihoods in Northern Sri Lanka and to investigate on conflicts, threats and stressors to reservoir fisheries and the impacts of reservoir fisheries on socio-economics characteristics of rural fishers. Even though many authors have discussed facts and significance of CBF in the reservoirs in Sri Lanka, none of the earlier studies were done in these selected reservoirs in the Northern Province and this study is the first of its kind on the reservoir fisheries in the Northern Province of Sri Lanka.

2. Materials and Methods

2.1 Study area

The study was conducted in five perennial reservoirs in the Northern Province of Sri Lanka, which are Vavunikulam (R1), Muthayankattu (R2), Puthumurippu (R3), Kalmadu (R4) and Muhathankulam (R5) (Figure 1). Vavunikulam (1275 ha) and Muthayankattu (1255 ha) perennial reservoirs were categorized as larger reservoirs (>1000 ha) and Puthumurippu (151 ha), Kalmadu (74 ha) and Muhathankulam (211 ha) were categorized as small reservoirs (<1000 ha) for comparison purposes based on water surface area at full supply level. These reservoirs were selected based on PL stocking were significant, FWP production was concentrated and one landing site per reservoir. Fishers attached to the selected reservoirs were members of respective fisheries societies that allowed them to get the fishing permit. Fishers are registered under particular society for getting permits for fisheries and the number of registered fishers of Vavunikulam, Muthayankattu, Puthumurippu, Kalmadu and Muhathankulam were 84, 90, 21, 21, and 65 respectively.

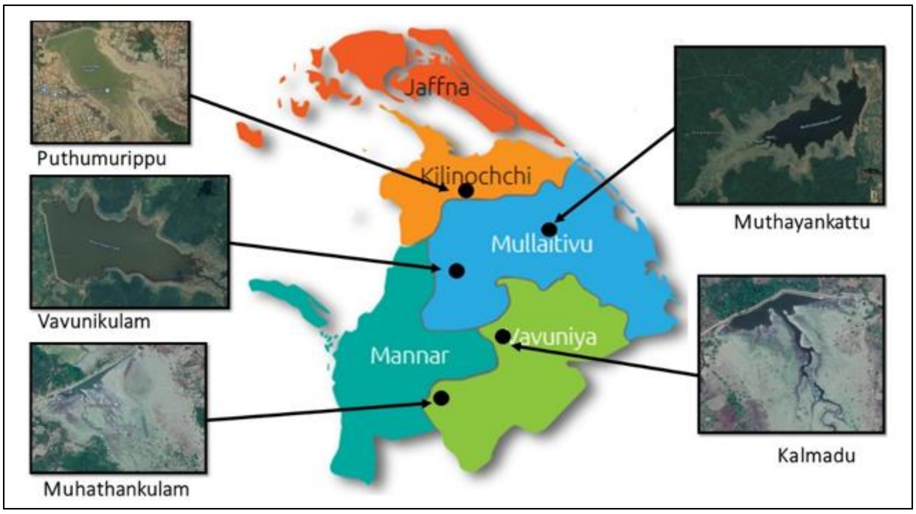

Fig 1: Locations of selected reservoirs

2.2 Fisheries data collection

Fish and prawns were sampled from 2016 January to 2018 December by gillnets. All the gillnets were laid covering almost all parts of the reservoirs by the local fishers in the evening between 4 p.m. and 6 p.m. Some fishers stayed at the reservoirs and some went back home and returned next day morning, depending on the season. All the laid nets were collected next day between 6 a.m. and 9 a.m. All the fish and prawn species were sorted, identified to species level according to Pethiyagoda, (1991) [6] and counted species wise. Total numbers of each species and individual numbers was recorded for each month. Data related to catch (kg), effort (number of active fishermen), cost and revenues of *M. rosenbergii* fisheries were collected biweekly at the fish landing site and stocking time and number of post larvae (PL) stocked data was collected from NAQDA. Monthly rainfall and water level data was collected from Department of Irrigation.

2.3 Socio-economic data collection

A combination of participatory, qualitative, and quantitative data collection methods was used for wide & in-depth analysis. Focus Group Discussions (FGD) were conducted in selected topics such as fish and prawn harvesting and its diversity in catch, PL/fry stocking, marketing and price fluctuation during seasons and climatic and non-climatic stressors in reservoir fisheries to selected five reservoir fisher communities. A total of 30 FGD sessions (6 sessions in each 5 reservoirs) were conducted mostly at landing sites and fisher society buildings in particular reservoir. A total of 45 key informants were interviewed, including District NAQDA directors and field officers, fisher society leaders, prawn collectors at landing sites, prawn and fish traders, transporters and relevant non-governmental organization (NGO) officers. A questionnaire was developed to measure the socio-economic status and climatic and non-climatic stressors of fishers and fishery resources, together with threats and conflicts of the study area. Climatic and non-climatic key stressors were identified based on the literature review, field observations at reservoir landing sites, fish markets and households with relevance and applicability to perennial reservoir fisheries [7]. These indicators were divided into two groups in order to determine fisher's and their community characteristics and to determine the threats and conflicts that affect fisher's in selected reservoirs. To measure the conditions at community and household level, a total of seven indicators were used. Those seven indicators were; sex, age, fishing experience, education level, household income from fishing, livelihood assets and household nutrition [8]. Information on other livelihood activities fishers got involved besides fishing were also collected. To determine the threats and conflicts that affected fishers, two indicators were used; namely, factors that disrupted fishing and conflicts experienced by fishers. 190 questionnaires were collected from randomly selected fishing families from fisher's registration number of the five perennial reservoirs.

2.4 Data analysis
Relative abundance (RA) of each species was calculated as, RA = (a_i / A) * 100%, where a_i is the number of individuals caught in the i^{th} species and A is the total number of individuals. Catch and effort data were used to calculate catch per unit effort (CPUE ± SD) in kg/day/fisher and fishing effort (FE, fishers/km^2) for each reservoir separately. The statistical significance of CPUE, FE and yield between reservoirs were compared using analysis of variance (ANOVA) In the event of significance, Tukey simultaneous confidence interval test was used to determine which means were significantly different at a 0.05 level of probability. Data from FGD and questionnaire were coded and entered into Microsoft Excel 2016 for analysis using Minitab17 statistical software to produce descriptive statistics. To test the significant difference between reservoir household characteristics and livelihood assets with regard to indicators used in the study, the chi-square test for association (χ^2) were used. Kruskal-Wallis test was used to determine the relationships among income from fishing and household diet data that were continuous but not normally distributed. Chi-square test for association was used for categorical data, such as sex, age group, fishing experience, educational level, livelihood assets, events that disrupted fishing and conflicts with other reservoir users.

3. Results and Discussion
3.1 Fish and Prawns species composition and fisheries in selected reservoirs
Totally 122,374 individuals belonging to 27 finfish species and 2 freshwater prawn species were quantified and identified (Table 1). Higher number of fish species were observed in the R2 (26) and R1 (23) major perennial reservoirs, followed by small reservoirs R5 (22), R4 (21) and R3 (14). In terms of average catch, Relative abundance (figure 2) of exotic species was high in the large reservoirs (60%); R1 (65%) and R2 (55%), followed by small reservoirs (32.8%); R3 (39%), R5 (30.4%) and R4 (29.1%). However, Relative abundance of native fish in the catch was high in the small reservoirs (59.4%); R5 (66.7%), R4 (62.2%) and R3 (47.3%) than large reservoirs (37.9%); R1 (32.8%) and R2 (43%). Even though the selected five reservoirs from the Northern Province did not have much development in culture based fisheries due to the civil disturbances, *O. niloticus* was the dominant species in the catch throughout the year.

Table 1: Relative abundance of species in the five perennial reservoirs

Species	R1	R2	R3	R4	R5
Catla catla	0.43	0.98	7.3	2.4	2.67
Labeo rohita	0.35	1.28	2.91	6.57	2.1
Cirrhinus mrigala	0.18	0	1.5	0	1.48
Cyprinus carpio	0.4	0.62	1.26	1.46	1.3
Hypophthalmichthys molitrix	0	0.2	0	0.52	0
Oreochromis mossambicus	0.44	2.23	0.8	4.67	3.9
Oreochromis niloticus	63.19	49.66	25.11	13.5	18.94
Macrobrachium rosenbergii	2.23	2.08	13.85	6.66	2.93
Native species (marketable)	14.16	16.77	9.3	28.2	23.1
Native species (Non-marketable)	18.62	26.18	37.97	34.03	43.58
Number of species	23	26	14	21	22

R1: Vavunikulam; R2: Muthayankattu; R3: Puthumurippu; R4: Kalmadu; R5: Muhathankulam

M. rosenbergii had relatively higher farm-gate price, between Rs. 500-1200, depending on body weight, gender, and quality while native species such as, *Etroplus suratensis, Channa striata* had the same price as tilapia with a price of Rs. 200/kg. Exotic carp species, Anguilla species *(A. bicolor, A. mamarota, A. bengalensis), Labeo dussumieri, Anabas testudineus, Ompok "bimaculatus"* had comparatively lower price (Rs. 120/kg) and the price was depended on the body weight. However, non-marketable native species, such as *A. melettinus***,** *M. gulia, M. zeylanicus, P. dorsalis, S. timbiri, H. limbatus* became discards. In the smaller reservoirs, (R3 [38%], R4 [34%] and R5 [44%]) non-marketable fish species were the most abundant and they contributed to more than one third of the total catch.

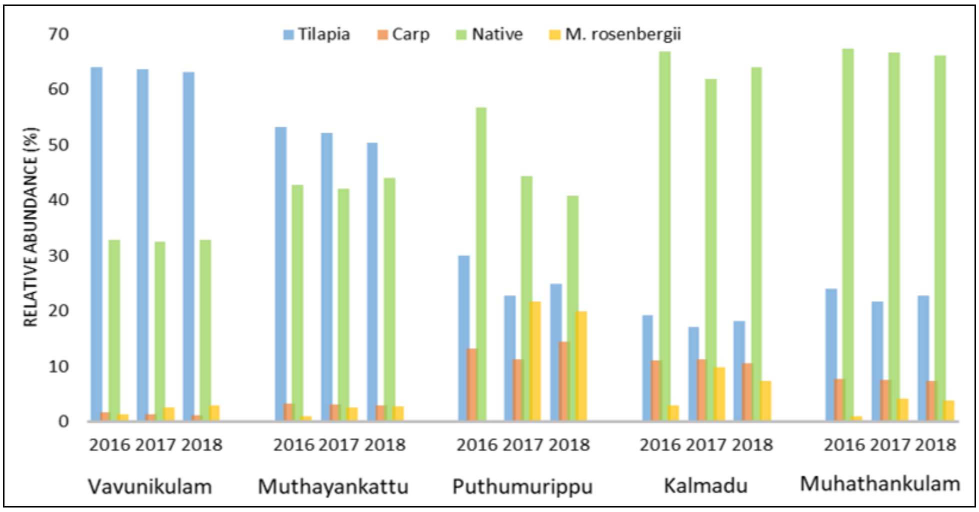

Fig 2: Relative abundance of fish species at the selected reservoirs between 2016-2018

Variation in the fish yield, FE, CPUE, *M. rosenbergii* (GFWP) production in the selected five reservoirs were computed and compared among the reservoirs (Table 2). Yield and CPUE were higher in the larger reservoirs (486.3 kg/day and 12.4 kg/day/fisher, respectively) than the smaller reservoirs 60.4 kg/day and 5.2 kg/day/fisher, respectively) (p<0.05), while fishing effort is higher in the smaller reservoirs (9.8 fishers/km^2) than the larger reservoirs (3 fishers/km^2). The mean weight of tilapia, male and female GFWP were also higher in the large reservoirs (490g, 395g and 165g) than the small reservoirs (240g, 280g and 95g). The weight range (min – max) of GFWP in R21-R5 was 155g - 680g, 170g – 700g, 115g – 635g, 70g – 560g and 65g – 520g, respectively. Though the Relative abundance of GFWP was higher in the smaller reservoirs (7.8%) than the larger reservoirs (2.2%), average production of GFWP was higher in the larger reservoirs (5,560 kg/year) than the smaller reservoirs (1,604 kg/year).

Table 2: Variation in the fish yield, fishing effort (FE), catch per unit effort (CPUE) and *M. rosenbergii* (FWP) production in the five selected reservoirs from January 2017 to June 2018

Parameter	Vavunikulam	Muthayankattu	Puthumurippu	Kalmadu	Muhathankulam
Yield (kg/day)	597.3 ± 324^a	375.2 ± 228.1^b	38.1 ± 13.1^c	55.3 ± 36.2^c	87.7 ± 52.4^c
FE (Fishers/km^2)	3.3 ± 0.8^a	2.7±0.7^a	4.6±1.8^a	12.6 ± 8.6^b	12.1 ± 1.9^b
CPUE (kg/day/fisher)	13.9 ± 5.4^a	10.9 ± 4.4^a	5.8 ± 1.6^b	6.3 ± 2.7^b	3.4 ± 1.7^b
FWP (kg/day)	16.5 ± 10.2^a	8.6 ± 6.2^{a,b}	7.6 ± 4.9$^{a, b}$	5.1 ± 10.3^b	7.4 ± 7.0^{a,b}

Note: Values in same raw bearing different letters are significantly different (ANOVA, p < 0.05).

Fishers were allowed to use passive gear, gillnets with a minimum mesh size of 88.9 mm. The type of gear used to target species and fishing methods could have influenced the fish yield and species composition of the reservoirs in the present study. In larger reservoirs of R1 and R2 58% and 49% of fishers respectively targeted for both exotic tilapia and carp species and *M. rosenbergii* together, while 37% and 44%, respectively targeted only for tilapia. In the smaller reservoirs, except for R3, majority of the fishers (R4 - 62%, R5 - 71%) targeted for both exotic and *M. rosenbergii*, while 63% of fishers from R3 targeted for *M. rosenbergii* only. An important reason for this significant contribution of *M. rosenbergii* to the harvest in these reservoirs is also partly because of the modification in fishing gear technique. Adult *M. rosenbergii* is a bottom dweller and it has fast backward movement when it touches or senses strange objects [4]. Therefore, to increase the catching efficiency of *M. rosenbergii*, the fishers modified their gear by adding more sinkers with a few floats to reach the bottom and to reduce stretch. As this modification of gear may lower the catch of surface and column dwelling fish species such as catla, rohu and tilapia, fishers from small reservoirs highly prefer this fishing practice than fishers from larger reservoirs. Hence, the targeting of *M. rosenbergii* and modification of gear could have contributed to lower species diversity in the reservoirs as found in the present study as the catch of species like minor cyprinids, which are smaller in size, was not significant.

3.2 Livelihood assets and characteristics of fisher households in the selected reservoirs

Table 3 shows the difference in household characteristics among the fisher households of the five selected reservoirs in terms of sex of the participant in the survey, age group, fishing experience, education level, income from fishing, livelihood assets and household nutrition. Survey respondents were mostly male with 93%, 93%, 94%, 90% and 96% of respondents of R1, R2, R3, R4 and R5, respectively. Components of Sustainable Livelihoods Framework (SLF); livelihood assets (human, financial, social, physical and natural) and livelihood outcomes (food security and income) (Scoones, 1988) [9] were assessed in this section. Human assets represent skills, experience and knowledge of fishers, level of interest in fishing and ability to work on extreme conditions and health status of fisher enable fishers to pursue their diverse livelihood strategies. Most fishers attended up to secondary school level except for R4 (64% in R1, 77% in R2, 89% in R3, and 47% in R5). Among the fishers of Kalmadu reservoir majority (86%) of them attended only up to primary school level. Factors such as, age, experience of the fisher in fisheries, fish catch of the previous day, market value of the fish, financial status of the fisher household and livelihood diversification affected the choice of fishing and also the quantity of fish catch. *M. rosenbergii* was mostly targeted (93%) by younger fishers of 20-40 years while, 98% of older fishers above 60 years mainly chose tilapia and carp species. Fishers between the age of 40-60 years have almost equal choice (48%). Experienced fishers, who have 10 or more years of fishing experience, still chose to harvest tilapia (74%) while less experienced fishers, who have less than 10 years of fishing experience, highly targeted for *M. rosenbergii* (84%). Older fishers consider catching of *M. rosenbergii* as new fishery, which is risky for them, and themselves as experienced in catching tilapia and carps compared to *M. rosenbergii.*

Table 3: Household characteristics in Vavunikulam (R1), Muthayankattu (R2), Puthumurippu (R3), Kalmadu (R4) and Muhathankulam (R5) reservoirs

Variables	R1 (n = 64)	R2 (n = 58)	R3 (n = 19)	R4 (n = 21)	R5 (n = 28)	Total (n = 190)
Sex						
Male	59 (92 %)	54 (93 %)	18 (94 %)	19 (90 %)	27 (96 %)	177 (93 %)
Female	5 (8 %)	4 (7 %)	1 (6 %)	2 (10 %)	1 (4 %)	13 (7 %)
Age group (years)***						
0-20	0 (0 %)	0 (0 %)	0 (0 %)	0 (0 %)	0 (0 %)	0 (0 %)
20-40	37 (58 %)	33 (57 %)	16 (85 %)	14 (67 %)	13 (46 %)	107(56 %)
40-60	25 (39 %)	22 (38 %)	2 (10 %)	7 (33 %)	12 (43 %)	72 (38 %)
>60	2 (3 %)	3 (5 %)	1 (5 %)	0 (0 %)	3 (11 %)	11 (6 %)
Fishing experience (years) ***						

<10	25 (39 %)	27 (47 %)	16 (85 %)	8 (38 %)	12 (43 %)	88 (46 %)
11-30	31 (48 %)	26 (45 %)	2 (10 %)	9 (43 %)	12 (43 %)	80 (42 %)
>30	8 (13 %)	5 (8 %)	1 (5 %)	4 (19 %)	4 (14 %)	22 (12 %)
Education level (maximum)***						
Pre-school	0 (0 %)	1 (2 %)	0 (0 %)	2 (10 %)	4 (14 %)	7 (4 %)
Grade 1-5	23 (36 %)	12 (21 %)	2 (11 %)	18 (86 %)	11 (39 %)	64 (34 %)
G.C.E. O/L	41 (64 %)	45 (77 %)	17 (89 %)	1 (4 %)	13 (47 %)	119 (62 %)
G.C.E. A/L	0 (0 %)	0 (0 %)	0 (0 %)	0 (0 %)	0 (0 %)	0 (0 %)
Diploma/ Degree	0 (0 %)	0 (0 %)	0 (0 %)	0 (0 %)	0 (0 %)	0 (0 %)
Income from fishing in 2016 (Rs./ month) ***	34922 ± 4033	33190 ± 4282	15789 ± 2123	21857 ± 2535	24964 ± 2950	
Income from fishing in 2018 (Rs./ month)	45468 ± 6246	42350 ± 5812	43783 ± 3944	36938 ± 4073	39793 ± 4912	
Livelihood assets						
Boats**	60 (94 %)	52 (90 %)	18 (95 %)	21 (100 %)	28 (100 %)	179 (94 %)
Fishing gear	64(100 %)	58(100 %)	19(100 %)	21 (100 %)	28 (100 %)	190 (100 %)
Fishing permit	64(100 %)	58(100 %)	19(100 %)	21 (100 %)	28 (100 %)	190 (100 %)
Paddy land***	12 (19 %)	11(19 %)	4 (21 %)	12 (57 %)	14 (50 %)	53 (28 %)
Crop**	37 (58 %)	26 (45 %)	11 (58 %)	15 (71 %)	17 (61 %)	106 (56 %)
Cattle***	49 (77 %)	16 (28 %)	4 (21 %)	15 (71 %)	10 (36 %)	91 (48 %)
Goat***	15 (23 %)	7 (12 %)	2 (11 %)	9 (43 %)	8 (29 %)	41 (22 %)
Chicken***	24 (38 %)	20 (34 %)	14 (74 %)	17 (81 %)	15 (54 %)	90 (47 %)
Pig***	0 (0 %)	4 (7 %)	0 (0 %)	0 (0 %)	5 (18 %)	9 (5 %)
Motorbike***	29 (45 %)	35 (60 %)	12 (63 %)	13 (62 %)	23 (82 %)	112 (59 %)
Van/truck	2 (3 %)	1 (2 %)	0 (0 %)	0 (0 %)	0 (0 %)	3 (2 %)
Weekly food consumption						
Fish*	5.17	5.22	5.16	4.48	4.82	5.13
Meat*	1.17	1.22	0.84	1.52	1.18	1.19
Vegetables*	4.45	4.57	5.11	6.24	5.9	4.93

Significant levels *** $P < 0.001$, ** $P < 0.01$, * $P < 0.05$

Quantity of catch and fish species from the previous day highly influenced (87%) the choice of location for fishing for next day in the reservoir by the fishers. If fishers got a large amount of catch on the previous day, 56% of fishers chose to go to the same location as previous day for fishing, while 31% of fishers chose different locations for fishing. Fishers who had low income and who had fishing as the sole livelihood chose to catch tilapia and carps over high priced *M. rosenbergii* while, fishers who were mostly income secure and had alternative income sources chose to take the risk and invest in the catching of *M. rosenbergii*. Catching of *M. rosenbergii* would require few adjustments in the fishing practices as *M. rosenbergii* is a bottom dweller and males show territorial behavior unlike the grouping behavior seen in tilapia and carps. Therefore, gillnets have to reach the bottom of the reservoir and due to the territorial behavior it may result in zero catch. Furthermore, gear damage is highly likely in the catching of *M. rosenbergii* due to the presence of tree stumps at the bottom. In this study, after the introduction of *M. rosenbergii* into the reservoirs damage to the gear increased significantly (93%) due its application at the bottom of the reservoir because of the presence of decaying tree stumps and also due to wildlife attacks by crocodile and tortoise (see Table 4). A gear can be used only for a month. Therefore, the maintenance cost was increased after the introduction of *M. rosenbergii*. However, it still provided high revenue as the cost of a gillnet can be recovered by selling 2 kg of GFWP.

Fishers in selected reservoirs were found in involving variety of livelihood diversification other than fishing for income generation and household needs. Results shows that majority of fishers (>55%) involved in agriculture activities other than fishing, while reservoir based activities was rare among fishers. Wage & business activities comparatively higher in smaller reservoirs (63%) than larger reservoirs (43%). Kalmadu fishers were more involved in the cultivation of paddy (57%) and crops (71%) during the wet season and livestock rearing (cattle - 71%, goat - 43%, chicken - 81%, and pig - 18%) throughout the year. Majority of the fishers in all the reservoirs were involved in home gardening (56%) for their consumption at their households which fulfilled the dietary and economic needs and they also shared the harvest with their neighbors. Livestock farming except chicken were limited to R2, R3 and R5. Vegetables were produced mainly for their home consumption and they exchanged their excesses with their neighbors. Egg and meat were obtained from chicken, while goat was mainly grown to obtain mutton. In addition to fish, the fishermen who had livestock and poultry obtained more animal protein through the consumption of meat and egg. Mainly indigenous cattle species are found in this area and the milk production is around 1.5 liters/cow/day. According to the survey, the fishermen who were growing a wide range of crops including legumes, and rearing livestock such as cattle, goats and chickens were reared to fulfill the dietary and economic needs of the respondents. Majority of the households consumed caught fish five to six days a week on average, while meat was eaten once or twice a week. Consumption of native fish species is significantly higher in smaller reservoirs (87%) than larger reservoirs (25%). Small native fish species such as, minor cyprinids which are consumed with head, bones and internal organs, can be rich source of essential vitamins and minerals [10].

3.2.1 Financial assets: are savings, credits and debts needed to achieve livelihood goals. In 2016, Vavunikulam fishers had the highest mean income with a mean of Rs. 34,922 per person per month and fishers from Puthumurippu had the lowest mean income with Rs. 15,789 per person per month. It was observed that mean income per month from fishing is significantly higher in the larger reservoirs than the smaller reservoirs. However, after the introduction of *M. rosenbergii*, due to the catchable size of *M. rosenbergii* (average male >250g and female >150g) in large quantity the income of the fishers from fishing increased continuously from 2017 onwards. The mean income of fishers was increased by 30.2%, 27.6%, 177.3%, 69%, 59.4% respectively in R1, R2, R3, R4 and R5 in 2018. Vavunikulam fishers had the highest mean income from fishing (Rs. 45,468) while Kalmadu fishers had the lowest mean income (Rs. 36,938) and the difference in mean income between smaller reservoirs and larger reservoirs was not significant. Borrowing and lending of money for various necessities of day to day life was a common practice in the fisher households in all the five selected reservoirs. In 2016, about 94% of them had borrowed money from microfinance companies; 62 (97%) in R1, 58 (100%) in R2, 14 (74%) in R3, 20 (95%) in R4 and 25 (89%) in R5. After the introduction of *M. rosenbergii*, borrowing by the fishers from financial institutions increased up to 100% in 2018 in all 5 reservoirs due to their interest in investing on physical assets such as, motor bikes, renovation of house and agriculture, whereas, earlier they borrowed money for survival and for climate risk aversion.

3.2.2 Physical assets: are the infrastructures (quality of road, electricity, water supply, market, housing and roofing material, sanitary and health facilities) and tools and goods (gear, canoes, transportation facilities) required to support livelihoods. Fishermen in all the selected reservoirs used traditional fishing gear; major gear being gillnets and a few used hooks and line as well. Fishing gear was either purchased locally from fish/prawn traders on loans or from Provincial Council of Northern Province as a subsidy or by getting a loan from micro-finance companies and a few purchased from nearby cities. Gillnets were owned by all of the respondents (100%), while few respondents in all the reservoirs 8 (12.5%) respondents in R1, 12 (21%) respondents in R2, 02 (11%) respondents in R3, 4 (19%) respondents in R4 and 07 (25%) respondents in R5) used hooks and line mostly during low water level conditions mainly for targeting freshwater eels (*Anguilla* species). 94% of respondents owned canoes. Types of materials used for the construction of houses are important indicators of the socio-economic status of the households. Majority (67%) of the houses were made of brick walls with a cemented floor and with tile or concrete roofs and constructed with the assistance from housing loans. Less than 10% of the respondent households lived in wooden or clay houses with roofs made of palm leaves or coconut leaves and were considered as poor. Fishers from small reservoirs (18%) had higher percentage of wooden or clay house than fishers from large reservoirs (4%). Toilet facilities were lacking in many households. 42% of the interviewed households did not possess proper latrines, where fisher households catching on larger reservoirs had higher percentage (54%) than those fisher households catching on smaller reservoirs (35%). On average, 24 % of the respondent households depended on the reservoir for drinking water, which is higher in fishers from smaller reservoirs (46%) than larger reservoirs (12%). Overall, the study found that fishers were suffered with lack of physical assets such as hospital and road.

3.2.3 Social assets: are social resources (fisher societies, institutions, supporting environment at household and neighborhood, and social status) is a key component in sustainable livelihood practices. Reservoir fishing practices were regulated by both particular inland fisheries society and NAQDA and all the fishers (100%) owned a fishing permit, which was mandatory for fishing. In FWP fisheries, traders and NGOs also significantly contributed in development of culture based fisheries by stocking PLs in larger quantities and market facilitation. Survey reveals that the relationship between fishers and other stakeholders were healthy. Also, conflicts among fishers and other reservoir users and the adverse social environments such as theft of gear were also reported, but was not significant (section 3.3). Natural assets such as fish and prawns PL/fry/fingerlings are vital for developing culture based fisheries in reservoirs, which provides sustainable livelihood opportunities to fishers and also improves species diversity (section 3.1) in reservoirs. GFWP culture in reservoirs was fully depended on stocking of PLs due to inability to breed at reservoirs.

3.3 Threats and conflicts of fishers in the selected reservoirs

Findings from the evaluation of threats and conflicts experienced by fishers and how they differ between the five reservoir fisher groups are summarized in table 4 under the two indictors; *viz.*, events that disrupt fishing and conflicts with other reservoir users.

Table 5: Threats and conflicts experienced by fishers in Vavunikulam (R1), Muthayankattu (R2), Puthumurippu (R3), Kalmadu (R4) and Muhathankulam (R5) reservoirs

Indicators and variables	R1 (n=64)	R2 (n=58)	R3 (n=19)	R4 (n=21)	R5 (n=28)	Total (n=190)
Threats to fishing*						
Low water levels	41 (64%)	31 (53%)	5 (26%)	9 (43%)	12 (43%)	98 (52%)
Winds	64 (100%)	58 (100%)	19 (100%)	20 (95%)	24 (86%)	185 (97%)
Wildlife attacks	61 (95%)	58 (100%)	11 (58%)	14 (67%)	24 (86%)	168 (88%)
Conflicts with other reservoir users***						
Hook and rod fishery	15 (23%)	18 (31%)	0 (0%)	9 (43%)	10 (36%)	52 (27%)
Farm organization	8 (13%)	3 (5%)	0 (0%)	9 (43%)	14 (50%)	34 (18%)
Seasonal fishers	28 (44%)	25 (43%)	0 (0%)	9 (43%)	12 (43%)	74 (39%)
Tourism	2 (3%)	0 (0%)	0 (0%)	2 (10%)	0 (0%)	4 (2%)
Others	12 (19%)	17 (29%)	0 (0%)	4 (19%)	7 (25%)	40 (21%)

Significance levels at *** $P < 0.001$, ** $P < 0.01$, * $P < 0.05$

Results revealed that most of the respondents were affected by low water levels, where fishers at R1 (64%) were mostly affected with low water levels, while R3 (26%) fishers were the least affected. While the low water level enables them to catch Tilapia species, Carp species and *M. rosenbergii* in larger quantity, it also leads to discarding of large quantity of native fish species caught. Therefore, low water level is beneficial to highly seasonal fishers in economic terms by increasing income while it is harmful to the reservoir ecosystem and threatens the existence of native species and full time fishers. Vulnerability of fishing households highly influenced by seasonal patterns which control fishing activities. As majority of the perennial reservoirs of Sri Lanka are located in the dry zone, each year drought condition of 4-5 months (June-October) significantly affects the water level fluctuations in those reservoirs. During the rainy season from November to March with an average monthly rainfall of 164.3 mm, the water level in these reservoirs reaches up to almost to the full supply level. However, due to the high volume of water required for paddy cultivation from December to May and the drought season from June to July with an average monthly rainfall of 26.5 mm the water level decreases rapidly in these reservoirs. Amarasinghe and De Silva (2015) [11] also reported that water level fluctuations have significant impact on the fish yield in the Sri Lankan reservoirs. Higher percentage of fishers was threatened by winds (97%) and wildlife attacks (88%) where crocodile and tortoises damage the nets and fish which caught in the nets. All the respondents of Muthayankattu reservoir were affected by both winds and wildlife attacks. During the strong wind period the fishers (25%) abandon fishing between 1-3 months and take up part time jobs to manage their daily household expenses. Fishers from larger reservoirs experienced comparatively higher threats from low water level (59%), winds (100%) and wildlife attacks (98%) than fishers from smaller reservoirs (38%, 92%, and 72%, respectively).

Fishers also experienced conflicts with the other users of the reservoir such as, rod and hooks fishers, farm organizations, seasonal fishers and tourists. However, all these threats were of low significance in all the reservoirs. Fishers of Puthumurippu reservoir had zero conflicts with other users of the reservoir. Overall, fisher respondents from smaller reservoirs experienced comparatively higher conflicts with rod and hook fishers (28%), farm organization (34%) and tourists (9%) than fishers from larger reservoirs (27%, 9%, and 2%, respectively). However, seasonal fishers had higher conflicts with fisher respondents from larger reservoir (43%) than fisher respondents from smaller reservoirs (31%). Some fishers, mostly the seasonal fishers, were more active only during the low water level periods in the reservoirs and they tried to harvest as much as possible by resorting to some illegal fishing practices such as, hitting the water and chasing the fish, using small mesh size nets, using monofilament nets. This situation was reported highly in the smaller reservoirs (65%) of R4 and R5 and relatively less in the larger reservoirs (20%) of R2 and R1 and none in the R3 small reservoir. Also, the local fishers had fights mainly with the villagers, who lived nearby the reservoir area and used rod and hooks during low water level, because they were fishing without paying a tax and without having any contribution to fish stocking in the reservoirs.

Low rainfall, strong wind and high temperature were identified as key climatic stressors in reservoir fisheries. Increase in fishing cost, limited fish fry and/or fingerlings, post-harvest facilities, market fluctuations, strict implementation of rules and regulations, over-growth of aquatic plants and algal blooms, increasing wildlife attacks and theft of fishing gear were identified as key non-climatic stressors among the fishers in the five selected reservoirs. During strong winds fishers cannot go alone for fishing due to difficulties for paddling the canoe. Therefore, usually two or three fishers fish together in a canoe and divide the total harvest among themselves. They try to avoid distant areas from landing sites, which results in having higher fishing pressure in close areas and have led to conflicts with other fishers in setting the gear. Gear also drifts with winds and may get stuck with tree stumps, which caused damage to gear and also led to poor harvest. NAQDA along with society leaders confiscated and burned monofilament nets, which were banned though they were the only long-lasting nets available to the fishers. Fishers argued that they could not afford to buy the recommended nets and those nets that are legal were not readily available on the local market. As fishing was their only source of livelihood, confiscating their nets denied them of their very livelihood. Fishers expected the government to help them acquire the recommended multifilament nets as subsidies. Vegetation and algal blooms were more frequent now in the selected reservoirs than in the past. They occurred mostly on the surface and also at the bottom of the reservoir, and often clogged fishing nets. Fishers also mentioned a few other stressors such as, unhygienic drinking water, poor sanitation, lack of working capital, weak fishers' association, flooding and lack of alternative livelihoods or income sources. Changes in food availability and food affordability due to decreased catches and low income during certain periods, may increase the risk of malnutrition in fisher families as they are highly dependent on fish as a source of protein. Private or public insurance/ loan schemes may support fishers to avoid livelihood disruption arising from limited access to credit and loans to support, especially during those periods [12]. Education and skill development support are required for the fishers to make broader choices such as, on how to diversify their livelihoods, involving in multiple income generating activities, and developing sustainable fishing techniques by considering fish behavior, market knowledge and choice of fish species.

3.4 Women involvement

Generally, women used to involve in fisheries during low water levels and their participation mainly involved in separating fish from the net and cleaning the gear. However, after the introduction of *M. rosenbergii*, involvement of women in reservoir fisheries significantly increased (Vavunikulam (47%), Muthayankattu (60%), Puthumurippu (26%), Kalmadu (52%) and Muhathankulam (21%)). It was observed that involvement of women in reservoir fisheries was higher in the larger reservoirs (86%) than the smaller reservoirs (47%). This was due to the quality requirement for selling the caught *M. rosenbergii*. If damage to the head or claw happens it affects either the weight or the quality of the prawn and hence resulting in lower price. Therefore, to ensure the quality of the harvest, women are being employed to remove the prawn carefully from the gear. Introduction of *M. rosenbergii* has improved the social status of women and also has provided equal opportunities for participation in fisheries and has strengthened their social stability.

4. Conclusion

CBF and the introduction of *M. rosenbergii* in the five selected reservoirs have achieved considerable success and resulted in significant increases in fish production and income of fishers and availability of fresh fish for rural communities and livelihood opportunities for fishing families. Before the introduction of *M. rosenbergii*, income from fishing was significantly higher in the larger reservoirs. These values indicated that the fisheries and fishing practices were better in the larger reservoirs than the smaller reservoirs. However, after the introduction of *M. rosenbergii*, income increased rapidly where income difference was not significant among the reservoir groups. Also, it significantly increased the involvement of women in reservoir fisheries and has provided them equal opportunities for participation in fisheries and strengthened their social stability. Other benefits include increased fish consumption at the household level and household food and income security. Also, this leads to less engagement in part time employment via migration to neighboring areas and it resulted in better family bonding. Furthermore, from the additional income from *M. rosenbergii*, the fishers were able to invest on personal assets and other livelihoods. Socio-economic factors such as, age, experience of the fisher in fisheries, fish catch of previous day, market value of fish, the financial status of the fisher household and livelihood diversification affected the fishing choice of the fisher and also quantity of the fish catch. Low rainfall, strong wind and high temperature were identified as key climatic stressors in reservoir fisheries while increase in fishing cost, limited fish fry and/or fingerlings, post-harvest facilities, market fluctuations, strict implementation of rules and regulations, over-growth of aquatic plants and algal blooms, increasing wildlife attacks and theft of fishing gear were identified as key non-climatic stressors among the fishers in the five selected reservoirs.

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