2.2 The culture-based fishery of giant freshwater prawn in Sri Lankan perennial reservoirs: evaluation of past stocking and production data

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Abstract

The present study has been articulated as a system approach to sustainably develop the high valued giant freshwater prawn (FWP) CBF in Sri Lankan perennial reservoirs. The approach comprised of (a) appraising past stocking practices; (b) assessing reservoir capacity and CBF performance with multiple strategic scientific studies; (c) investigating possible measures to increase the production and recapture; (d) identifying the market driving factors; and (e) understanding the constraints in the management of a socioecological system. Based on the scientific evidence, recommendations for better approaches for future FWP CBF have been suggested.

Keywords: *culture-based fishery, giant freshwater prawn, reservoir*

Introduction

In Sri Lanka, CBF of FWP *(M. rosenbergii*) is at the early stage of development. The National Aquaculture Development Authority of Sri Lanka (NAQDA) initiated the CBF of FWP in seasonal reservoirs in 2001 (Wijenayake et al. 2005; Amarasinghe and Wijenayake 2015), later extended to perennial reservoirs by 2011 (Chandrasoma et al. 2015; Chandrasoma and Pushpalatha, 2018). Several recent studies identify that among all freshwater species, as FWP is high valued with solely exceptional export demand that has a potential to support the economic development of rural fisher communities (Asoka et al. 2015; Pushpalatha et al. 2017; Pushpalatha et al. 2020), the monetary return is high even under a low recapture scenario. In the present analysis, we attempted to identify the knowledge gap for better performance of CBF of FWP that hinders the optimisation of production in Sri Lankan perennial reservoirs. This analysis is aimed at achieving sustainable and better harvesting of FWP to enhance income of reservoir fisher communities. For this purpose, the present study was equipped with a system approach:

a. to evaluate the stock and recapture returns based on the data gleaned from NAQDA (2008 to 2019)

b. to study the performance of FWP under the controlled stocking trials (2 cycles) in relation to biological productivity of the water bodies and identify those characteristics that will improve the effectiveness of the recapture strategy of FWP in Sri Lankan reservoirs

c. to examine the most effective method of capture with regard to catch rate and quality of product to provide recommendations on the most appropriate gear type for FWP

d. to map the value chain of GFP and address the related socioeconomic and livelihood features of the fishery.

Materials and methods

Information about reservoir extent, stocking and CBF harvest data from 2009 to 2019 was obtained from NAQDA. Further, the reservoirs were geo-positioned and spatial-temporal investigation was accompanied for the 769 reservoirs (Figure 2.2.1). Stocking densities (SD) of tilapia, carps and FWP were determined as numbers ha^{-1}, yr^{-1} and CBF yields for each species category as kg ha^{-1} yr^{-1} in individual reservoirs for each year separately.

Further, data from an empirical study with different stocking strategies and stocking densities (as detailed in Table 2.2.1) across 48 reservoirs (Figure 2.2.2), selected using a 'purposive sampling method' (Palys 2008) were also analysed. Through a reconnaissance survey conducted in the Fisheries Committees of the selected reservoirs, information about the nature harvesting and management strategies of CBF were gathered.

Along the 48 reservoirs, sampling was conducted at bi-monthly intervals to determine selected limnological features such as Secchi-depth, conductivity, pH, temperature, dissolved oxygen and chlorophyll-a using standard methods (APHA 2012). Information on fish harvests were gleaned from data log sheets of fisheries societies. Attempts were made to evaluate the most effective method of capture and assess product quality in relation to gear type and time of capture of GFP reservoirs.

All market actors involved in the market chain of the FWP were examined and their roles and inter-relationships within the selected reservoirs were determined through the questionnaire survey, considering both local consumption and export market. The value chain was examined to identify constraints and opportunities, possible market-based solutions and interventions. A need assessment was conducted considering several other key factors, including access to basic production inputs, risk coping mechanisms, relationships among value chain participants, policies and strategies, standards and branding mechanisms, 'kickstarting' of domestic markets, promotion of potential alliances with fair-trade chains, and product differentiation to create niche markets.

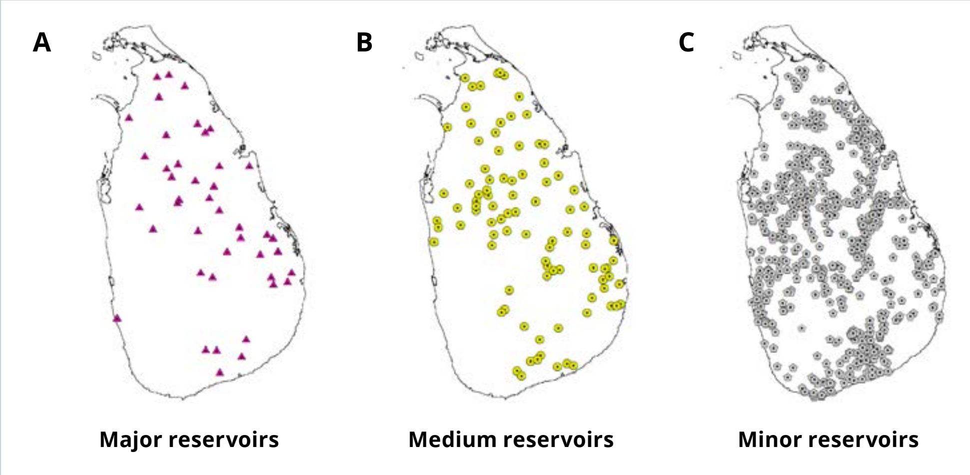

Figure 2.2.1: Distribution of perennial reservoirs in Sri Lanka where CBF was practised (according to the NAQDA database, 2009–2019)

(a) Major reservoirs (>800 ha reservoir extent), (b) Medium reservoirs (800–200 ha reservoir extent) and (c) Minor reservoirs (<200 ha reservoir extent).

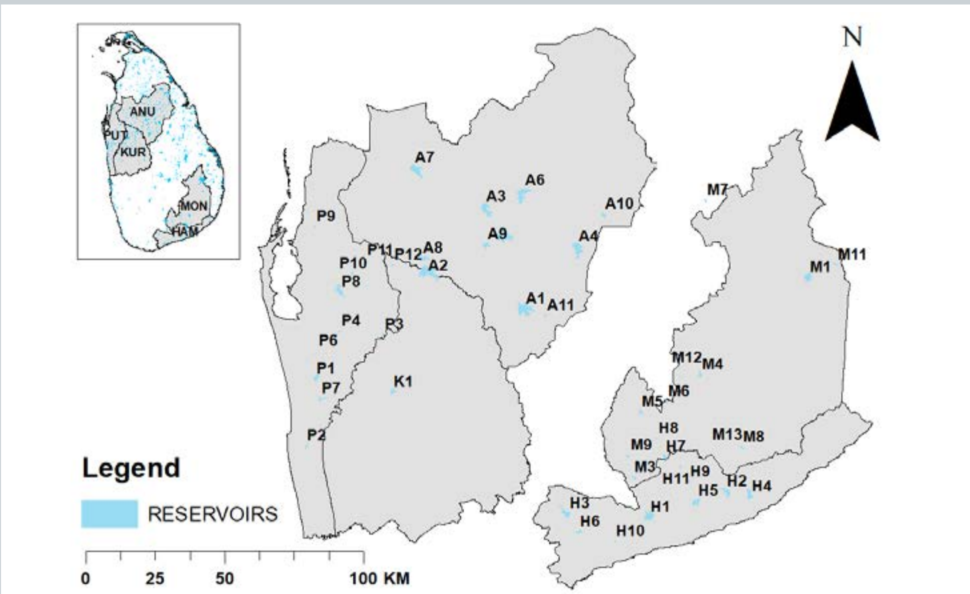

Figure 2.2.2: Selected 48 reservoirs for the current empirical study on GFP CBF

Note: For the detail of the code given in the map refer to Table 2.2.1. Selected reservoirs are located in 5 different districts: Anuradhapura (ANU), Puttalam (PUT), Kurunegala (KUR), Monaragala (MON) and Hambantota (HAM).

Table 2.2.1: Important details of selected 48 reservoirs for the empirical study

No.	RCode	District	Type	Reservoir name	Area (ha)	Stocking density (number of PL per ha)	Stocked PLs (number of PL)	Stocking strategy
1.	A1	Anuradha-pura	Major	Kala Wewa	1,440	1,200	1,728,000	NIGHT
2.	A10	Anuradha-pura	Medium	Kiwlekada	200	2,000	400,000	NIGHT
3.	A11	Anuradha-pura	Minor	Mahaalagamu-wa	80	5,000	400,000	MINOR
4.	A2	Anuradha-pura	Major	Rajanganaya	1,619	1,500	2,428,500	DAY
5.	A3	Anuradha-pura	Major	Nuwara wewa	1,197	800	957,600	NIGHT
6.	A4	Anuradha-pura	Major	Hurulu wewa	1,619	1,800	2,914,200	NIGHT
7.	A5	Anuradha-pura	Major	Nachchaduwa	1,781	1,000	1,781,000	DAY
8.	A6	Anuradha-pura	Major	Mahakanadar-awa	1,457	2,000	2,914,000	NIGHT
9.	A7	Anuradha-pura	Major	Maha wilach-chiya	971	800	776,800	NIGHT
10.	A8	Anuradha-pura	Medium	Angamuwa	445	800	356,000	NIGHT
11.	A9	Anuradha-pura	Medium	Thuruwila	280	2,500	700,000	DAY
12.	H1	Hamban-tota	Major	Ridiyagama	871	2,300	2,003,300	DAY
13.	H10	Hamban-tota	Minor	Kattakaduwa maha wewa	80	1,800	144,000	DAY
14.	H11	Hamban-tota	Minor	Maha Aluthgam ara	70	2,200	154,000	DAY
15.	H2	Hamban-tota	Medium	Weerawila Wewa	567	2,100	1,190,700	DAY
16.	H3	Hamban-tota	Medium	Muruthawela	516	1,800	928,800	DAY
17.	H4	Hamban-tota	Medium	Yoda Wewa	486	1,700	826,200	DAY
18.	H5	Hamban-tota	Medium	Badagiriya	381	2,100	800,100	DAY
19.	H6	Hamban-tota	Medium	Udukiriwila	263	1,700	447,100	DAY
20.	H7	Hamban-tota	Minor	Mahagalwewa	140	1,800	252,000	DAY

No.	RCode	District	Type	Reservoir name	Area (ha)	Stocking density (number of PL per ha)	Stocked PLs (number of PL)	Stocking strategy
21.	H8	Hamban-tota	Minor	Maha wewa	80	3,200	256,000	DAY
22.	H9	Hamban-tota	Minor	Pahala Andara	80	2,500	200,000	DAY
23.	K1	Kurunegala	Medium	Magalla wewa	263	1,000	263,000	DAY
24.	M1	Monaragala	Medium	Muthukandiya	560	1,900	1,064,000	DAY
25.	M10	Monaragala	Minor	Alugalge wewa	70	1,100	77,000	DAY
26.	M11	Monaragala	Minor	Sugaladevi wewa	50	1,000	50,000	DAY
27.	M12	Monaragala	Minor	Buduruwagala	125	1,600	200,000	DAY
28.	M13	Monaragala	Minor	Gestupana wewa	80	2,000	160,000	DAY
29.	M2	Monaragala	Medium	Kiribban wewa	375	1,800	675,000	DAY
30.	M3	Monaragala	Medium	Urusita wewa	262	1,600	419,200	DAY
31.	M4	Monaragala	Medium	Handapanagala	226	1,500	339,000	DAY
32.	M5	Monaragala	Medium	Hambegamuwa	210	1,400	294,000	DAY
33.	M6	Monaragala	Minor	Balaharuwa wewa	150	2,000	300,000	DAY
34.	M7	Monaragala	Minor	Demodara wewa	100	1,500	150,000	DAY
35.	M8	Monaragala	Minor	Milegama	80	1,500	120,000	DAY
36.	M9	Monaragala	Minor	Habaralu wewa	80	1,250	100,000	DAY
37.	P1	Puttalam	Medium	Devalahandiya	257	2,200	565,400	DAY
38.	P10	Puttalam	Minor	Pahariya	72	1,000	72,000	DAY
39.	P11	Puttalam	Minor	Saliyawewa	85	3,000	255,000	NIGHT
40.	P12	Puttalam	Minor	Thanguswewa	50	1,800	90,000	DAY
41.	P2	Puttalam	Medium	Karavitagaraya	256	2,000	512,000	NIGHT
42.	P2	Puttalam	Minor	Kottukachchiya	70	2,000	140,000	NIGHT
43.	P3	Puttalam	Medium	Mahauswewa	212	2,500	530,000	NIGHT
44.	P4	Puttalam	Minor	Kachchimaduwa	65	800	52,000	NIGHT
45.	P6	Puttalam	Minor	Viluka wewa	65	1,500	97,500	NIGHT
46.	P7	Puttalam	Medium	Vijayakatupotha	243	3,000	729,000	NIGHT
47.	P8	Puttalam	Medium	Tabbowa	607	1,500	910,500	NIGHT
48.	P9	Puttalam	Minor	EluwankulaMma	65	1,500	97,500	DAY

Notes:

- RCode is the code of reservoir name code.
- Type is given according to the NAQDA's reservoir classification (based on irrigation categories): Minor (<200 ha), Medium (<800 ha) and Major (>800 ha).
- Stocking strategy: DAY stocking is conducted in daylight (7 am to 6 pm) and NIGHT stocking is conducted in dark (7 pm to 3 am); twilight was systematically avoided.

Results

CBF efforts of NAQDA (2009 to 2019)

According to the NAQDA database, from 2009 to 2019, the average number of reservoirs where CBF was practised was 769 (0.1–7,793 ha), comprising 43 major, 90 medium and 636 minor reservoirs (Figure 2.2.1). The CBF catches were dominated by tilapia (257,046±12,876 kg) accounting for more than 70% of the annual total catch, whereas FWP was considerably low as 5,534±634 kg. Significant annual, seasonal and monthly variations were observed (p=0.000) in trends of both stocking and catch. More specifically, the seasonal variation of FWP production, which is the most noteworthy finding, indicated higher production during both south-west and north-east monsoons registering FWP yield greater than 5 kg ha^{-1} (Figure 2.2.3). Stocking of FWP was significantly low during dry months of pre-south-west monsoonal season especially in May (Figure 2.2.4).

The comprehensive recapture analysis (Figure 2.2.5) implied the following scenarios in CBF extension:

a. lack of CBF extension (i.e. absence of CBF in reservoirs that lacked extension)

b. no reported stocking but with catches (i.e. inland capture fisheries or unreported previous stocking)

c. stocked but no catches (i.e. unreliability of stocking and harvesting data or extension failures)

d. information of stocking and catches (i.e. reliable information on CBF).

The examination on the correlation between consecutive production with previous stocking shown in Figure 2.2.6 suggests that lack of robustness due to combined effects of multiple ad hoc stocking practice.

Reservoir limnology and stocking trials

According to the findings depicted in Figure 2.2.7, Figure 2.2.8 and Figure 2.2.9 the CBF performance, apart from reservoir categorisation as major, medium and minor, multiple factors influencing CBF are evident. This warrants a new classification of reservoirs for future planning of CBF. Results of the analysis indicated that the optimum SD of post larvae (PL) of FWP was 1,000 PL ha^{-1} in major reservoirs; 1,500 PL ha^{-1} in medium reservoirs, and 2,000 PL ha^{-1} in minor reservoirs. Further, the study suggests that stocking at night is efficient – after 8 pm and before 4 am, even without artificial light to prevent predation by small cyprinids and juveniles of other predatory fishes such as snakeheads and even tilapia. Further, avoiding shallower reservoir coves to stock PLs is important for the same reason.

Catch efficiencies of FWP

Both pond and field trials of traps showed that FWP had a higher affinity to traps that are green in colour with comfortable entrance aperture, but the sizes of prawns that were caught were less than 150 g. This size was appreciably lower than the mean weight of an individual caught to gillnets (>250 g) in Sri Lankan reservoirs. The catch dynamics of the FWP showed that female catches peaked in December and January near the outlets while males were in middle and near inlets of a reservoir (Figure 2.2.10 Stratum 1).

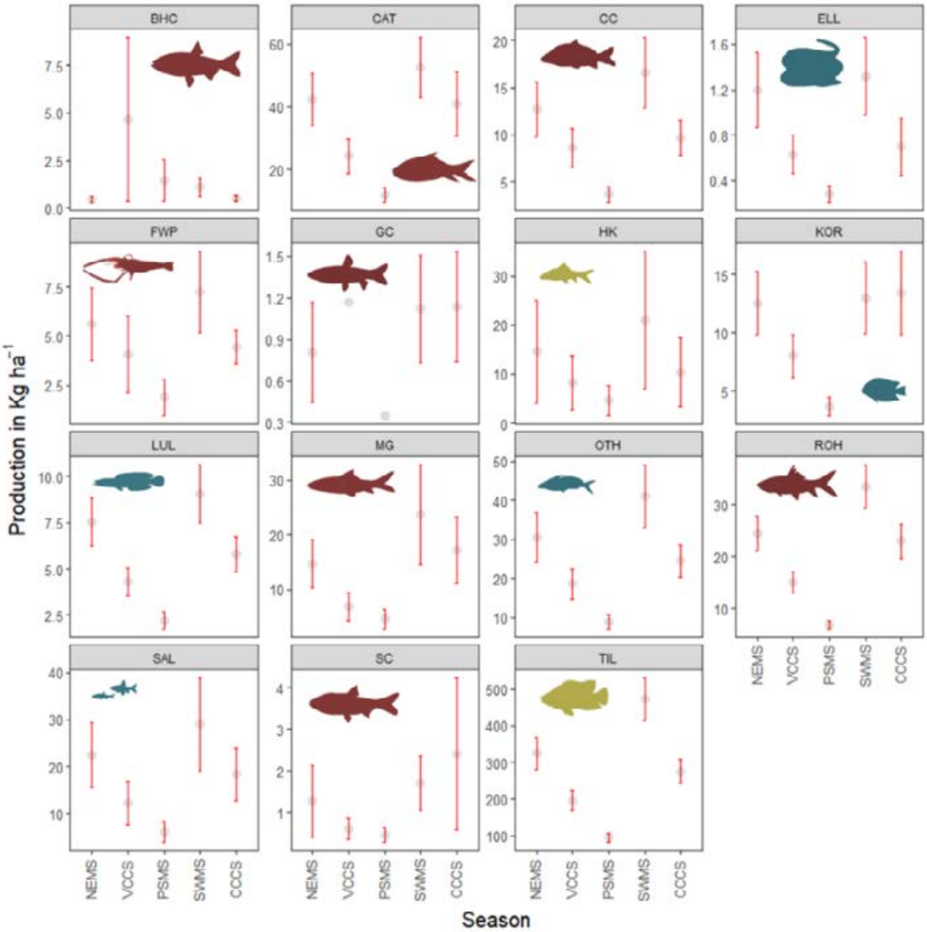

Figure 2.2.3: Plot of mean and standard error for seasonal production (kg ha^{-1}) in perennial reservoirs during 2011–2019 according to NAQDA species categories

Notes: Mean and standard error are indicated respectively by grey point and red stretched line. Seasons are: (a) the vernal convergence – convectional season (VCCS); March to April (b) the pre-south-west monsoonal season (PSMS); May (c) the south-west monsoonal season (SWMS); June to September (d) the convergence – convectional – cyclonic season (CCCS); October to November (e) the north-east monsoonal season (NEMS); December to February.

Species group: BHC – Big head Carp; CAT – Catla; CC – Common Carp; ELL – Eel; FWP – Giant freshwater prawn; GC – Grass Carp; HK – Lankan Labeo; KOR – Pearl spot; LUL – Snakehead; MG – Mrigal; OTH – Indigenous Catfishes and Perch; ROH – Rohu; SAL – Indigenous minor Cyprinides; SC – Silver Carp; TIL – Tilapia.

Colours given to fishes depicts fishery category as reported by NAQDA: Green – Capture fishery; Yellow – Enhanced fishery; Red – Culture-based fishery.

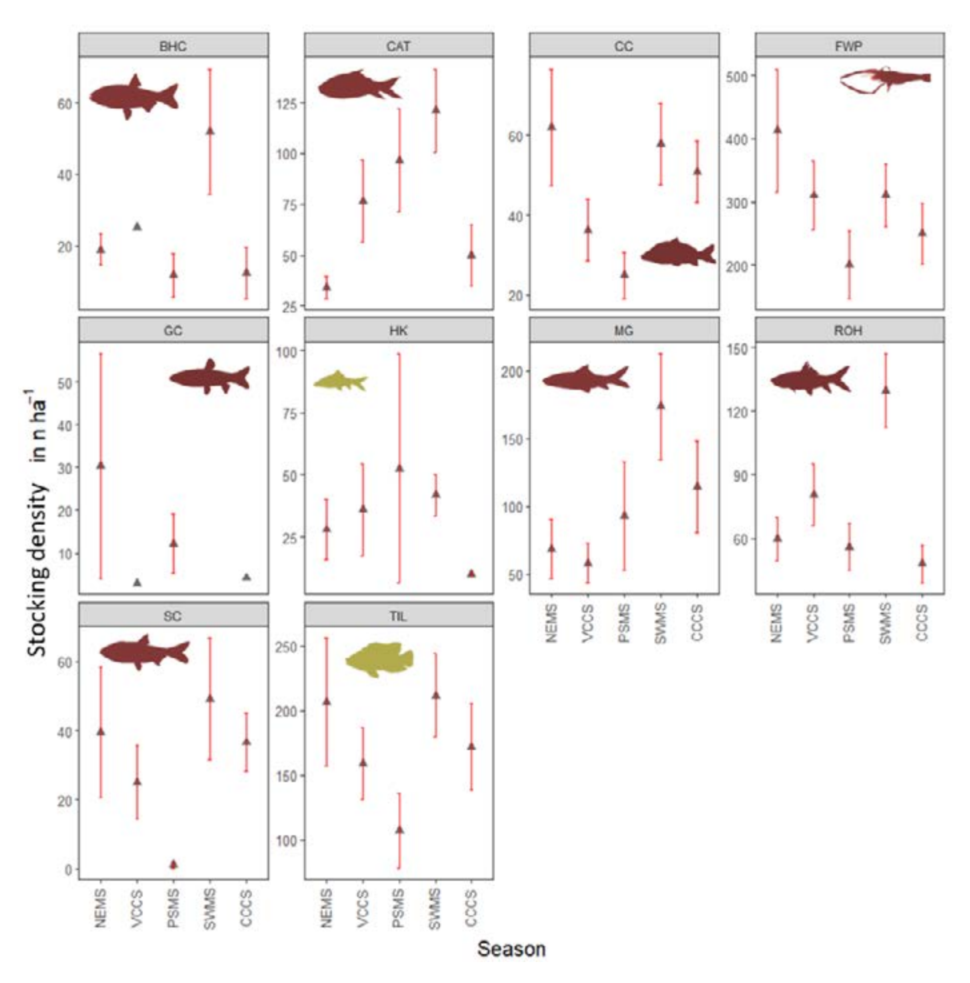

Figure 2.2.4: Plot of mean and standard error for seasonal stocking density (n ha^{-1}) in perennial reservoirs during 2011–2018/9 according to NAQDA species categories

Notes: Mean and standard error are indicated respectively by black triangle and red stretched line. Seasons are: (a) the vernal convergence – convectional season (VCCS); March to April (b) the pre-south-west monsoonal season (PSMS); May (c) the south-west monsoonal season (SWMS); June to September (d) the convergence – convectional – cyclonic season (CCCS); October to November (e) the north-east monsoonal season (NEMS); December to February.

Species group: BHC – Big head Carp; CAT – Catla; CC – Common Carp; ELL – Eel; FWP – Giant freshwater prawn; GC – Grass Carp; HK – Lankan Labeo; KOR – Pearl spot; LUL – Snakehead; MG – Mrigal; OTH – Indigenous Catfishes and Perch; ROH – Rohu; SAL – Indigenous minor Cyprinides; SC – Silver Carp; TIL – Tilapia.

Colours given to fishes depicts fishery category as reported by NAQDA: Yellow – Enhanced fishery; Red – Culture-based fishery.

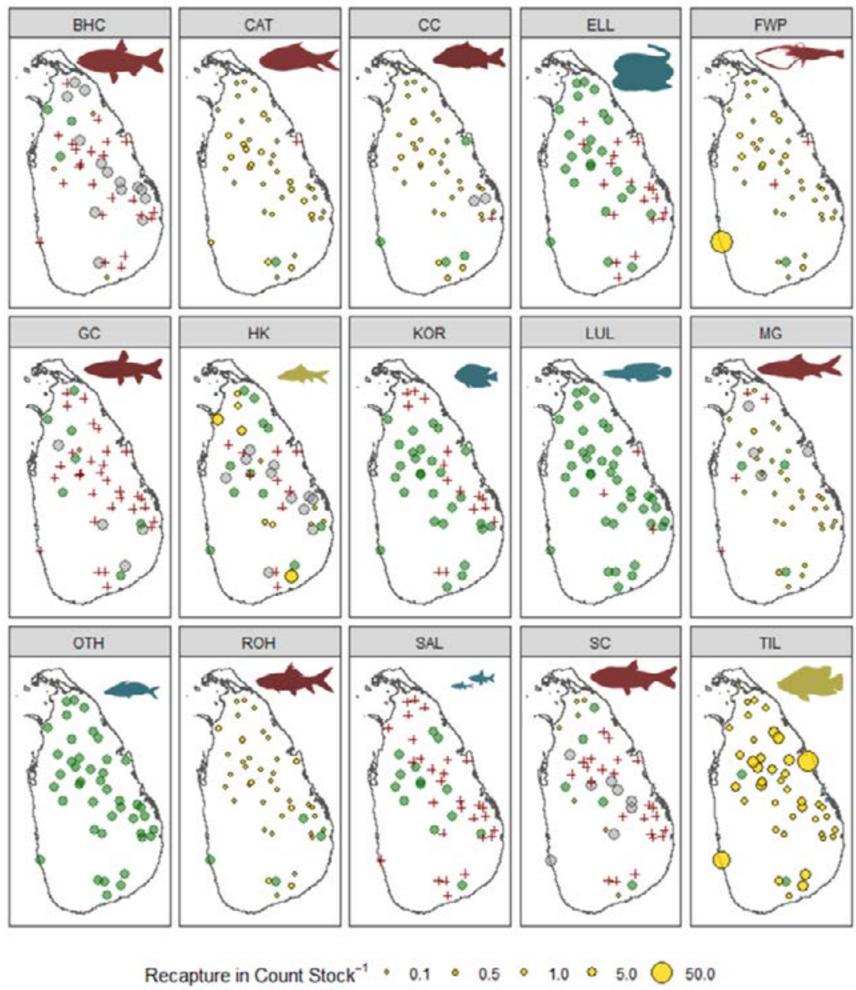

Figure 2.2.5: Thematic explanation of species or group specific reservoir fisheries status across all major perennial reservoirs of Sri Lanka, according to the NAQDA data (2011–2018/9)

Notes: Reservoirs with: (a) no stocking and catches, annotated by red '+', absence of fishery or reservoirs that lacked extension; (b) no stocking but with catches, interpreted by green points, inland capture fisheries or stocked prior to time of concern or possibly unreported stocking); (c) stocked but no catches, construed by grey points, stocking or extension failures; (d) information of stocking and catches, marked by graduated yellow points.

Species group: BHC – Big head Carp; CAT – Catla; CC – Common Carp; ELL – Eel; FWP – Giant freshwater prawn; GC – Grass Carp; HK – Lankan Labeo; KOR – Pearl spot; LUL – Snakehead; MG – Mrigal; OTH – Indigenous Catfishes and Perch; ROH – Rohu; SAL – Indigenous minor Cyprinides; SC – Silver Carp; TIL – Tilapia.

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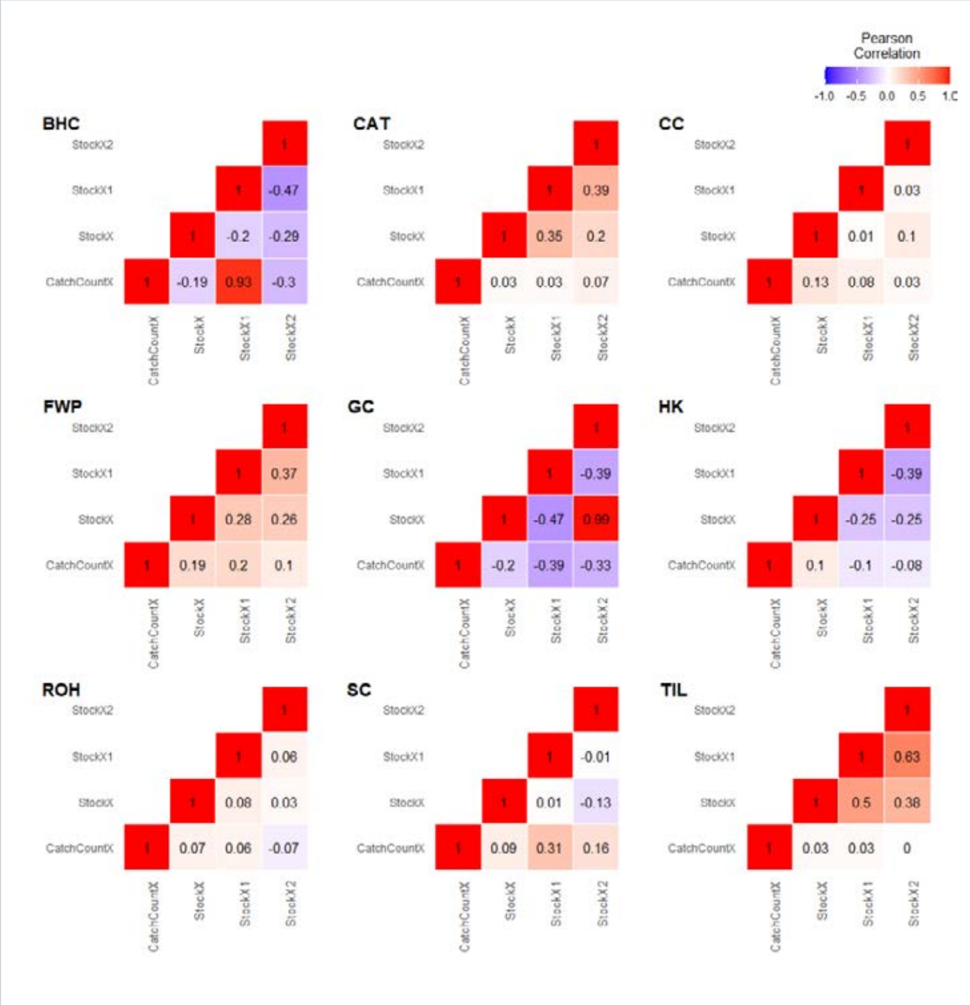

Figure 2.2.6: Pearson's Correlation between stocking and catch-converted counts (values given in intersections of 2 variables) in major perennial reservoirs during 2011–2019 according to NAQDA species categories

Note: CatchcountX is referred to catch-converted counts of year X, similarly, StockX is referred to stocking at year x. Meanwhile, StockX1 refers to stocking at year x-1 (Previous year) and StockX2 refers to stocking at the year x-2 (the year before the previous).

Species group: BHC – Bighead Carp; CAT – Catla; CC – Common Carp; FWP – Giant freshwater prawn; GC – Grass Carp; HK – Sri Lankan Labeo; ROH – Rohu; SC – Silver Carp; TIL – Tilapia. The shaded cells indicate significant correlations.

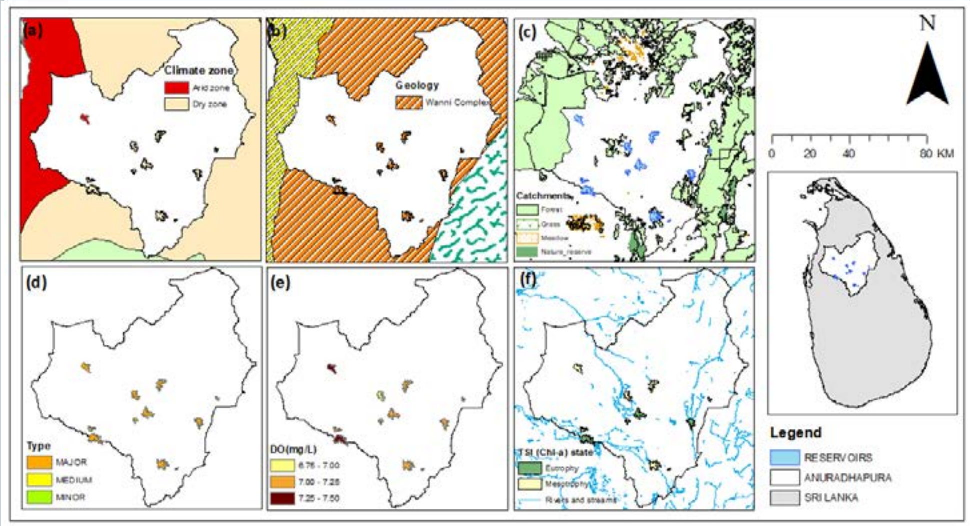

Figure 2.2.7: Maps of explanatory analysis developed for Anuradhapura district

Note: Characterisation of (a) climate zones and (b) base soil structure that a reservoir falls in; (c) Characterisation of catchments and land use; (d) Types of reservoirs; (e) Characterisation dissolved oxygen reported in the study; (f) Characterisation TSI (Chl-a) values of the study with cannels and streams.

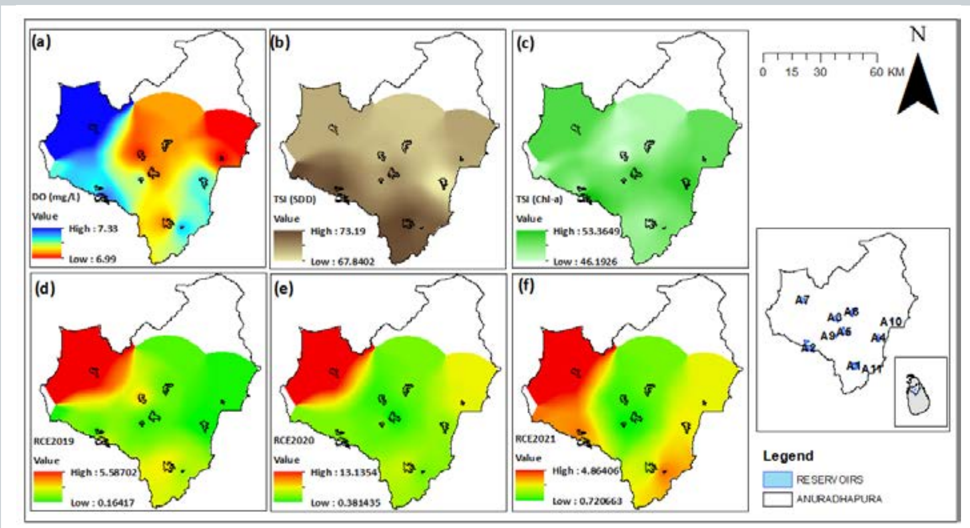

Figure 2.2.8: Maps produced in singular static density weighting analysis (DYA) for Anuradhapura district

Note: Selected environmental parameters: (a) Dissolved Oxygen; (b) TSI (SDD); (c) TSI (Chl-a); and annual recapture rates: (d) RCE 2019; (e) RCE 2020; (f) RCE 2021. RCE – Recapture efficiency of FWP.

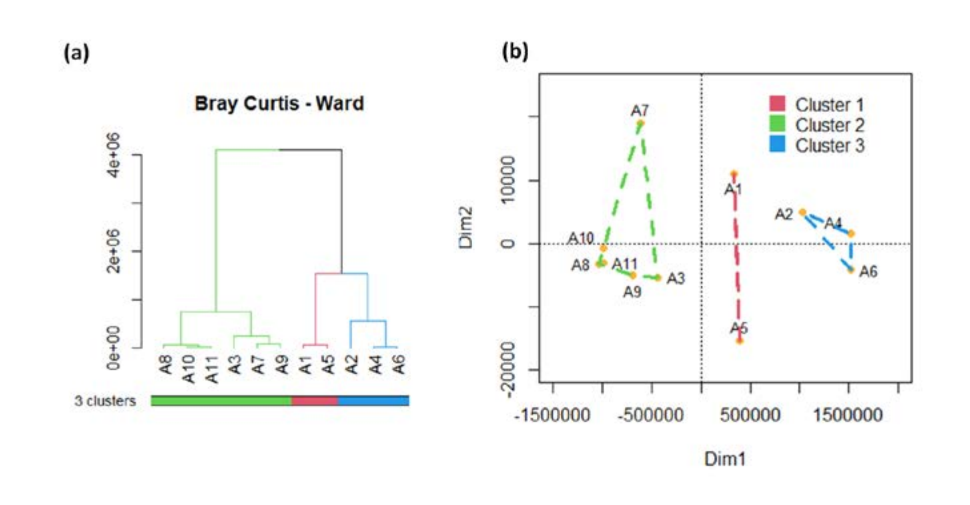

Figure 2.2.9: Results of cluster analysis and PCoA of 11 reservoirs in Anuradhapura district

Note: (a) Dendogram of clusters and (b) position of reservoirs in a multidimensional space (PCoA).

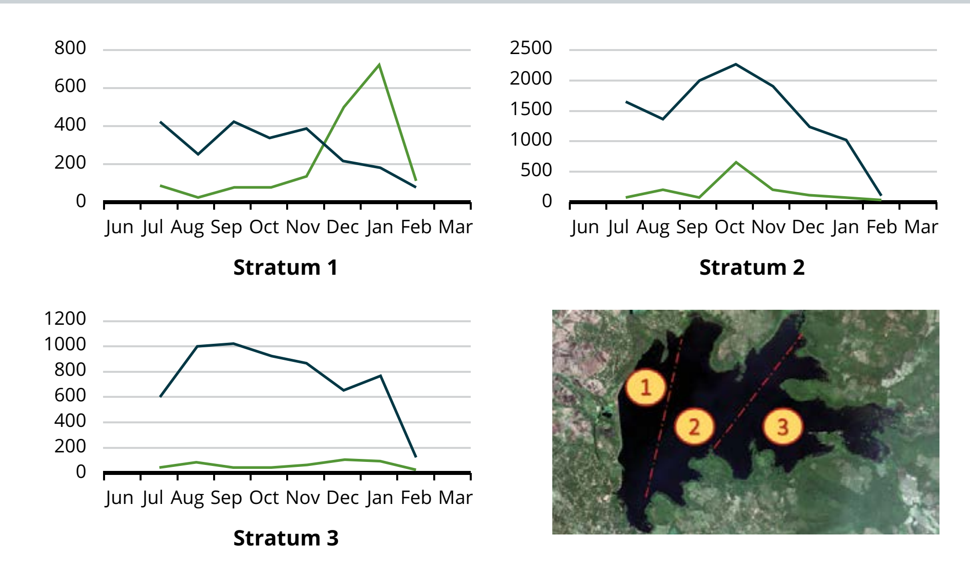

Figure 2.2.10: Catch dynamic of FWP observed in Huruluwewa

X axis – Months and Y axis – Catch in kg.

Market chain, socioeconomic and interventions

The market-chain analysis suggests that there is disparity in profit sharing across the market-chain actors, having greater benefits for middlemen and exporters at the current market scenario (Table 2.2.2). Although increases bring about significantly increased exports, the sustainability of FWP CBF is questionable due to prevailing disparity of benefit sharing among the stakeholders (Table 2.2.3), which might be a point of concern in the policymaking process. Possible approaches such as public–private interventions to bear the cost of stocking of FWP PLs should be considered with their potential pros and cons.

Table 2.2.2: FWP price variations across the market chain (price in USD per kg)

Product and size categories of GFP		Reservoir or fisher price	Farm-gate or middleman price	Sri Lankan export price	Thailand retail selling price
FM and OC	130 g up	3.00	6.17	23.55	<26
FM and OC	150 g up	3.00	6.17	23.80	26
FM, OC and BC	200 g up	3.70	6.17	24.71	35
FM, OC, OBC and BC	250 g up	3.70	9.25	25.99	38
BC and OBC	300 g up	5.55	9.25	27.34	45
BC and OBC	350 g up	5.55	9.25	26.76	>45
OBC	400 g up	6.00	11.00	28.81	>45

Note: USD1 = LKR324 (2023); USD1 = THB35 (2023); FM: Female; OC: Orange Claw; BC: Blue Claw; OBC: Old-Blue Claw.

Table 2.2.3: Identified influential political, economic, social and technical (PEST) factors on CBF practices

Political	Economic	Social	Technical
Increased attraction of stakeholders. (***) Increased competition for accepting managerial positions in FO. (**) The incapability of FO in management. (**) Influences of regional and state political authorities. (*) Lack of control measures over illegal fishing. (****)	Comparatively higher price for GFP. (*) More market attraction (increased vendors and middlemen). (***) Individual tie-ups with a middleman for the loan. (****) Increased trade deals with export companies. (**)	Grievances regarding managerial disagreements. (**) Conflicts with illegal fishers and buyers. (**) Increased participation of women in fishing. (*)	Poor financial handling in FO. (**) Unavailability of a specific gear for GFP fishing. (**) Lack of sound mechanism to control illegal fishing. (**) Lack of knowledge on stocking strategies and planning. (**)

Notes: Star marks depict the outcome of SWOT analysis over identified PEST factors:
(*)=Strengths, (**)=Weaknesses, (***)=Opportunities and (****)=Threats.
FO: Farmers' organisations; GFP: Giant Freshwater Prawn.

Discussion

From this study, the suggested stocking densities can be implemented with night-time stocking. Further, from this analysis it is evident that spatial variations in FWP harvest are influenced by limnological characteristics such as dissolved oxygen (DO), trophic state indices, which should be taken into account for CBF planning rather than considering reservoir categorisation based on the reservoir size.

Although not attempted in the present analysis, it is apparent that seasonal availability of PLs of FWP from the hatcheries is greatly influenced by captive breeding success. Monsoonal rainfall patterns, low habitat temperature and quality of broodstock appear to affect hatchery performance of FWP. As such, hatchery inefficiencies should be studied further. The aspects that need further studies include:

a. a prolonged hatching period of >60 days causing heavy mortality may be due to frequent precipitation that lowered the environment temperature

b. the high performance in hatcheries could be achieved if source water has water salinity >50 ppt, not the lagoon water

c. lack of probiotic use in state hatcheries but the private hatchery causes larval mortality

d. molecular biological screening of broodstock to ensure better genetic quality.

Conclusion

This study has addressed several knowledge gaps that should be addressed in developing FWP CBF in Sri Lanka. We believe that strengthening the CBF extension mechanism together with capacity building through provision of science-based training to the extension staff is necessary for sustainable development of GFP CBF in Sri Lankan reservoirs. It is also recommended that future studies should focus on climate resilient development activities of CBF.

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