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Small research and development activity

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prepared by	Clive Jones, James Cook University
co-authors/ contributors/ collaborators	Prof. Upali Amarasinghe Prof. Sena De Silva Dr Dileepa de Croos S. Digamadulla Dr Asanka Jayasinghe G.A.T.K. Yomal K.H.M.A. Deepananda
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Acronyms and abbreviations

ACIAR	Australian Centre for International Agricultural Research
CBF	Culture-Based Fishery
FAO	Food and Agriculture Organization of the United Nations
GFP	Giant Freshwater Prawn *Macrobrachium rosenbergii*
JCU	James Cook University
NAQDA	National Aquaculture Development Agency of Sri Lanka
PL	Post larvae - refers to post-larval giant freshwater prawns
SRA	Small Research Activity - refers to current project FIS/2017/002 Development of a culture based fishery for giant freshwater prawn in Sri Lankan reservoirs

1 Acknowledgments

Professors Upali Amarasinghe and Sena De Silva provided coordination of the project activities and their efforts in leading the team in Sri Lanka are gratefully acknowledged. Doctors Dileepa de Croos and Asanka Jayasinghe from Wayamba and Ruhuna Universities respectively, led the teams from each of these Universities, ensuring the project objectives were met. Their contribution is greatly appreciated. Thank you to NAQDA, spearheaded by the Chairman and the Director General, for their central role in delivering the project and especially to Dr J.M. Asoka and Mahanama Gunasena for their individual efforts. Associate researchers Prof Udith Jayasinghe Mudalige (Wayamba) Dr Hiranya Kelum Wijenayake (Wayamba) and Dr Ashoka Deepananda (Ruhuna) made valuable contributions, that are gratefully acknowledged. The two research assistants (S. Digamadulla from Wayamba University and G.A.T.K. Yomal from Ruhuna University) contributed significantly to data collection and analysis. We also acknowledge fishers of the 48 reservoirs studied for their cooperation during this research activity.

2 Executive summary

This small research activity has provided important information concerning the status of the Sri Lankan giant freshwater prawn culture based fishery and the efficacy of current management practices, revealing significant knowledge gaps that must be addressed to achieve effective management and optimised production and outcomes for the reservoir communities.

Culture-based fisheries (CBF) for finfish species have provided social and economic benefits to rural communities in Sri Lanka for several decades, and access to much needed dietary protein for the people. The recent addition of giant freshwater prawns (GFP) (*Macrobrachium rosenbergii*) to CBF in many reservoirs has provided even greater economic and social benefit, as the prawns are of high value and are destined for Colombo restaurants and export.

The SRA has provided important opportunity to develop an effective network among fisheries communities through the respective fisheries societies and researchers to gather data and initiate preliminary research activities to more fully understand the fishery dynamics of GFP in reservoirs and the knowledge gaps that should be addressed to achieve effective management of GFP fisheries to optimise benefits to rural Sri Lankan communities.

It was clear from examination of historical stocking and fishery production data for GFP that there was very little, if any, science-based decision making involved in the stocking procedures and that yields of GFP from across the country were highly variable. It was also evident that this variation could neither be adequately explained by the stocking procedures nor by the physical attributes of the reservoirs. Although some relationships between GFP yields and reservoir morphometric features were evident, a more comprehensive and deeper investigation would be necessary to determine the relationships between stocking and yield, that can then be applied to improved management practices. It was also apparent that GFP dynamics cannot be evaluated in isolation and the dynamics of stocked finfish species have to be an integral component to obtain a complete understanding.

Preliminary indications from the stocking/yield model development are that fish yields bear a relationship to the reservoir morphometric features such as reservoir size and catchment features such as the extent of forest cover. The preliminary analyses also indicate that the fishery yields are impacted by micro-climatic regimes and further research will lead to the development of models that will account for this and enable authorities to fine tune stocking strategies to optimise fish yields and economic gains.

Some key limnological parameters, including total nitrate and phosphate concentrations and chlorophyll “a” were examined, but data are too limited to reveal relationships of these variables with fish yield etc. The large project will enable these and additional variables to be more thoroughly examined through multiple regression models and/or multivariate statistical approaches that will determine if such relationships exist, and how reservoir water quality management might be more effectively managed.

Examination of current *Macrobrachium* fishing methods has been performed, revealing that a significant proportion of prawns caught by gill nets are damaged by the net rendering them lower value. A range of crustacean traps, used for commercial and recreational purposes in Australia, were supplied to Sri Lanka for testing with *Macrobrachium*.

Assessment of conventional recreational fishing traps for capturing GFP have demonstrated that trapping results in higher quality (less damaged) product, than that achieved using the current method with gillnets. These results suggest that innovation in trap design and method of deployment, activities planned for the large project, may achieve even greater advances in catch rate and product quality.

Preliminary examination of the supply chain for reservoir produced GFP and finfish has shown that the finfish are all sold and consumed locally, in communities adjacent to the reservoirs, while the GFP are supplied to wholesalers in Colombo, using local collecting agents, for high-end restaurants there, or for export. A complete inclusive assessment of the value chain, through to consumers in export countries, and exploration of expanded markets both locally and internationally, will be performed in the large project.

Preliminary findings indicate that CBF activities have generated significant secondary employment and income generating opportunities for women from the community who play a role in catering to the fishers who return with their catches after a night's fishing. This aspect has not been previously studied nor documented, and warrants more detailed investigation to assess the inputs from such activities to the economy and wellbeing of the rural households and communities, and the importance of gender overall, in CBF activities.

The fishers of individual reservoirs are organised into 'Reservoir Fishery Societies', legal, government-recognised entities. It is clear from meetings with fishers at selected reservoirs, the significant level of economic and social benefit of the reservoir culture based fishery in Sri Lanka. Finfish production provides significant benefit to local food security, the bulk of the daily catch being purchased and consumed by surrounding communities, and small proportion marketed in coastal townships. Freshwater prawn production in contrast, while comparatively small in volume, is highly valuable (10x price per kg of finfish) and sales are primarily to wholesalers for export. Income from prawns is a significant stimulus to the local economy.

There are many aspects of prawn production from stocking through to marketing that are poorly understood, and that will benefit from further research enabled by the planned multi-disciplinary project. The science capacity of the three agencies involved is strong, and there will be limited need for outside expertise. This SRA has provided important preliminary and foundational data, and established an effective and coordinated team, that will enable a follow-on, large project to be initiated quickly and with momentum to maximise outcomes.

3 Introduction

This project was a small research activity (SRA) implemented in response to a recommendation from an ACIAR scoping study conducted in July 2016, to evaluate re-engagement in agricultural research for development partnership in Sri Lanka. It further recommended a long term view to establish a multidisciplinary project in aquaculture for freshwater prawns, including a socio-economic component, focused on communities in the Northern Province. A full proposal for the proposed multidisciplinary project has been submitted to ACIAR.

The SRA was contracted to JCU in September 2017 and began activities on 1st October 2017. Sub-contracts and financial arrangements took some time to finalise and payments of project funds to the three Sri Lankan agencies were made in January 2018. Research activities in Sri Lanka began in February 2018. Due to the delayed start, a no-cost extension was requested and approved to extend the end date to 30 September 2019.

The project sought to collate existing reservoir fisheries data to generate preliminary models of stocking and yield of giant freshwater prawns (GFP), *Macrobrachium rosenbergii,* and to use these for subsequent stocking strategies to test their efficacy and to seek improved production. The models have been generated and are informing current stocking. The results from those more current stockings, in terms of yields will not be known within the life of the project, but can be measured in the follow-on large project if approved.

The project conducted research on aspects of the current stock and recapture strategy of GFP in reservoirs in the north, eastern and south eastern regions of Sri Lanka with a view to improving the overall yields and fisher family/ community incomes that will contribute to the long term sustainability of the practice. A key aspect of the research of the SRA was to identify knowledge and capacity gaps that may be addressed through the larger and longer term research project that has now been submitted to ACIAR.

The project comprised four activities.

Activity 1: Mathematical / statistical evaluation of the stock and recapture returns of GFP based on the past stocking practices (data provided by NAQDA, supplemented with the data from Divron Bioventures Ltd.) in relation to stocking density, geographical location, reservoir size, catchment and productivity features of the water bodies and determine the most practical and statistically robust relationships between variables that will provide the basis for the stocking strategies to be optimised.

Activity 2: Controlled stocking trials (two cycles) of GFP in selected districts in northern, eastern and south eastern regions of the island. In each district 12 reservoirs (4 small, 4 medium and 4 large[*]) will be selected using purposive sampling method.

Data will be gathered on the growth rate, sex ratios, rate of recapture, overall yield etc. in relation to reservoir morphometry and limnological aspects related to biological productivity of the water bodies, and analyses performed to identify those characteristics that will improve the effectiveness of the stock/ recapture strategy of GFP in Sri Lankan reservoirs.

Activity 3: Conduct a survey on the catch of GFP in relation to time of day, method of capture, gear (including experimental gear such as new trap designs), and size of reservoir (in a total of 12 reservoirs, conducted over at least five samplings in each, distributed in time and space). From the data gathered, evaluate the most effective method of capture in regard to catch rate and quality of product to provide

[*] *a classification used for Sri Lankan reservoirs based on reservoir surface area at full supply level (FSL)*

recommendations on the most appropriate gear type for capture of GFP in Sri Lankan reservoirs.

Activity 4: Study the value chain in relation to the GFP production in the three different types of reservoirs (i.e. small, medium, large). Study the related socio-economic features of the fishery, including gender roles at each stage of the chain, the public-private partnership, and as independent fisheries. Analyses these data to determine the most effective and efficient market chain modes that would facilitate long term sustainability and equity of the fishery.

This report is structured in accordance with the four research activities, with a full report presented for each separately.

4 Activity 1. Evaluation of historical stocking and recapture data of giant freshwater prawns

4.1 Abstract

The giant freshwater prawn (GFP) fishery in Sri Lankan reservoirs is an impending and promising source of prompt endowment of fisherfolk's livelihood through emphasized marginal profitability in comprehensive culture based fishery (CBF) practices. Though CBF practices are well-developed in Sri Lanka for finfish species, GFP is at a preliminary stage of development with spared stocking and lag phased extension initiatives. Inland fishery data of GFP; stocking number (PL counts) (2009 to 2017) and harvest data (kg) (from 2011 to 2017) were collected from NAQDA. Geographical statistical analysis was performed using ArcMap 10.3 spatial analysis software. Basic digitized map layers of Sri Lanka were collected from Surveyor General's Department, Sri Lanka. Regression models (linear and polynomial (quadratic and cubic)) and surface analysis using Weighted Least Square (WLS) was studied for the stocking and production data with consideration of perennial reservoir types: Major (> 800 ha), medium (800 to 100 ha) and minor (< 100 ha). According to the data from 2009 to 2017, Sri Lankan reservoirs have attained production of 5.205 ± 12.320 kg ha^{-1} yr^{-1}, from a mean stocking density of 699.1 ± 1124.1 PLs ha^{-1} yr^{-1}. The relationship between stocking density and production is stochastic, possibly resulting from the extemporaneous nature of CBF practices in the past. The monetary biomass gain from the medium-sized reservoirs (9.85 ± 26.28 kg PL^{-1} ha^{-1} yr^{-1}) is significantly higher than that of the major reservoirs (0.0760 ± 0.4197 PL^{-1} ha^{-1} yr^{-1}) and minor (0.01134 ± 0.01747 PL^{-1} ha^{-1} yr^{-1}) reservoirs ($p=0.000$). Unit production is low in medium reservoirs with higher surface area though the stocking density is high and production increases with declining surface area. Results implied that medium reservoirs are the most appropriate for GFP CBF, and the northern region of the country shows compellingly high potential. An extension framework with a scientific approach for stocking and recapture has the potential to improve yields and facilitate empowerment of fisher livelihood of GFP fishery in Sri Lankan reservoirs.

Keywords: Culture based fishery, Reservoirs, *Macrobrachium rosenbergii*

4.2 Introduction

Freshwater resources of Sri Lanka provide an inimitable environment for enormous inland fishery production potential based largely on the tropical climate and natural primary productivity of the many reservoirs (Cooke *et al*., 2016; De Silva, 2016; Jayasinghe *et al*. 2005). As an agricultural populace, Sri Lanka has depended on the reservoirs initially for irrigation and hydropower, and more recently for the development of inland fisheries. Culture-based fishery (CBF) is a development strategy adopted by many developing nations in Asia and around the world, to harness the natural biological productivity of water bodies with provisions of social benefits to rural communities (Welcomme and Bartley, 1998; Quiros, 1998; De Silva, 2001; Jayasinghe *et al*., 2005; De Silva, 2016). CBF represents a paradigm of ecosystem-based aquaculture which is non-consumptive of water (Amarasinghe and Nguyen, 2010). CBF in Sri Lanka is well developed in a multitude of reservoirs, and over the last two decades the fishery has enhanced the inland fish production through a co-management strategy (Pushpalatha, 2000; De Silva, 2003; Pushpalatha *et al*., 2015). Sri Lanka is endowed with more than 12,000 reservoirs (Fig. 4.1). According to hydrological regimes, they are broadly classified into perennial and seasonal reservoirs. The perennial reservoirs of the country have three categories based on their size; minor (< 200 ha), medium (200-800 ha) and major (>800 ha).

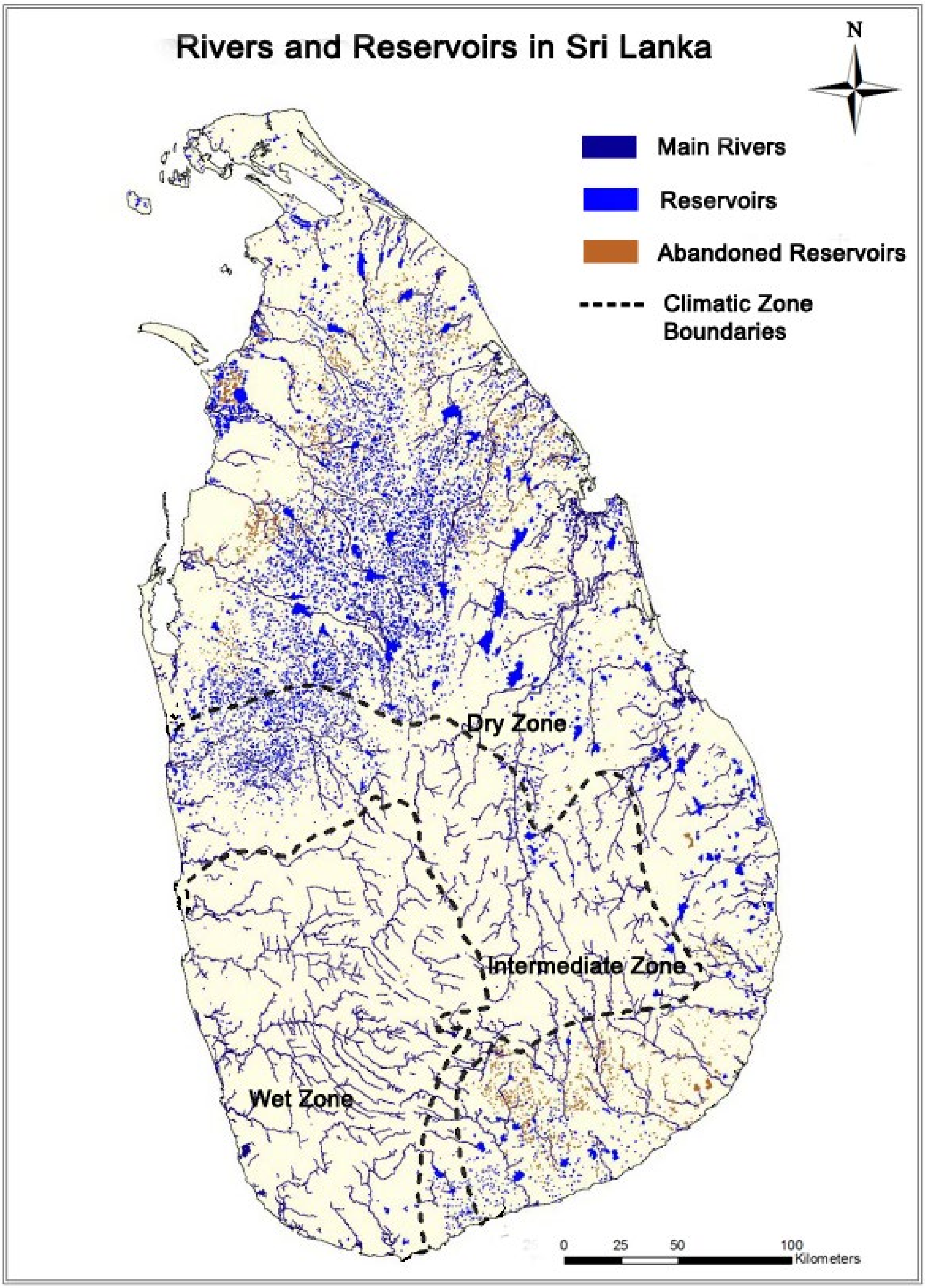

Figure 4.1. Distribution of reservoirs in Sri Lanka (Source: Jayasinghe and Amarasinghe, 2018).

Sri Lanka represents a good example of research and development efforts on CBF (Amarasinghe and Nguyen, 2010; Amarasinghe and Wijenayake, 2015), that over the last decade have resulted in an increase in food fish supplies, particularly among rural populations. The Sri Lankan inland fishery, principally the reservoir fishery, is one of the best recognized in the world and has been commendably self-nourishing over the years (Amarasinghe and De Silva, 1999; Jayasinghe et al., 2005), contributing approximately

12-15% of the Islands' total fish production. Two strategies were implemented in recent years to encourage further development of existing CBF in Sri Lanka (Chandrasoma et al., 2015; Pushpalatha and Chandrasoma, 2010), and exploitation of minor cyprinid fish resources in reservoirs, with an expectation of annual yield of over 20,000 t/yr (Amarasinghe et al., 2016).

Giant freshwater prawn (GFP), *Macrobrachium rosenbergii* (de Man, 1879), is one of the most widely cultured crustacean species in the world owing to its fast growth rate, ability to grow in a wide range of salinity, high consumer acceptance, and high market value (Smith et al., 1980; Sahu et al., 2012). The GFP fishery is currently one of the most important sectors of the national economy of Sri Lanka. GFP contributed around 0.6% to the total annual freshwater fish production of the country during 2010-2014 (Chandrasoma et al., 2015). GFP is an indigenous species found in both lacustrine and, more predominantly, in lotic aquifers. The existing freshwater prawn fishery of Sri Lanka is based on a CBF approach using the giant freshwater prawn, *M. rosenbergii*; initiated as a stocking program by the National Aquaculture Development Authority (NAQDA) of Sri Lanka, commencing in 2008, as a follow-up to the pilot study conducted by Wijenayake et al. (2005) in the period of 2002 to 2004.

Generally, the fisheries sector has attracted considerable attention because of its huge export potential. Unfortunately, the potential for freshwater prawn export has been negatively impacted by poor fishery statistics that have been intermittent, incomplete and in many cases inaccurate. In addition, the freshwater prawn fisheries of Sri Lanka, have been faced with numerous challenges including poor hatchery production technology, socio-economic and environmental issues and inadequate biological information. This study was therefore prepared to more accurately assess the present status of the freshwater prawn fishery in Sri Lanka with regard to existing resources, current exploitation levels, production and the development and management systems in the country. Further, the study evaluated the unexploited potential of the freshwater prawn fishery in Sri Lanka and its future prospects, while highlighting key areas that require urgent extensive research in order to provide a solid base for the sustainable development of this important fishery.

4.3 Materials and Methods

NAQDA is the authorised Sri Lankan governmental agency responsible for collecting and storing inland fishery data under the Ministry of Fisheries and Aquatic Resources (MFAR). Stocking (PL counts from 2009 to 2017) and harvest (kg) (from 2011 to 2017) data of GFP were gathered from NAQDA. Basic digitised maps of Sri Lanka were collected from Surveyor General's Department, Sri Lanka.

4.3.1 GIS analysis and map generation

Geographical statistical analysis of production and stocking data were performed using ArcMap 10.3 spatial analysis software. Hence, the collected data does not meet the statistical assumptions of more advanced interpolation methods. Comparison of Monetary Biomass Gain (MBG) (kg PL^{-1} ha^{-1} yr^{-1}) of all three reservoir types was achieved using the Interpolate Distance Weighted average (IDW) method. This method does not make explicit assumptions about the statistical properties of the input data, and is well-suited for use with very large input datasets.

4.3.2 Statistical data analysis

Descriptive analysis was conducted on production and stocking data. Furthermore, covariance and correlation tests were carried out for both raw and transformed data (Amarasinghe et al., 2002) to study the relationships within. Regression models (linear and polynomial (quadratic and cubic)) and surface analysis using Weighted Least Square

(WLS) was applied for the stocking and production data with consideration of reservoir types.

4.4 Results and Discussion

4.4.1 Stock enhancement of GFP CBF

Application of GIS and Remote Sensing techniques for planning and managing fisheries and aquaculture are still at the initial phase in Sri Lanka. The first application of GIS in world aquaculture occurred in the late 1980's (Kapetsky et al., 1990; Kapetsky, 1989), while in Sri Lanka was introduced in the 1990's for reservoir fish yield prediction (De Silva et al., 2001) and planning CBF in small village reservoirs (De Silva et al., 2005). Sri Lanka has shown an immense development of CBF enhancement through regular stocking from continuous GFP PL production. Previous stocking of GFP in 2004 piloted under the Aquatic Resource Development and Quality Improvement Project (ARDQIP), was an initiative of GFP CBF in Sri Lanka, led by a Participatory Rapid Appraisal (PRA) to motivate the relevant fishing communities (Pushpalatha and Chandrasoma, 2010).

In early projects, GFP fingerlings were imported, but subsequently, hatchery technology was introduced and the first government run hatchery at Pamabala started functioning with a production capacity of 20 million PLs per production cycle. A new hatchery building in Pambala was constructed in 2016 and the capacity is expected to reach 10 x 10^6 PL, and finally to 20 x 10^6 PL/ year. A second hatchery was established in Kahadamodera in 2008, with a capacity of post larvae (PL) production of around 20 x 10^6, and a subsequent target was to increase up to 40 x 10^6 PL per year. Up to 2018, two hatcheries were in operation with a potential of PL production of 40 x 10^6 per year. In 2019, a third government hatchery at Kallarawa in Trincomalee was established, with an additional capacity production of 20 x 10^6 PL per year. With the commissioning of the third hatchery building and when the full pace of operation is reached, total annual GFP PL production capacity will increase to about 80 x 10^6.

According to data from 2009 to 2017, GFP stocking in Sri Lankan reservoirs had a mean stocking density of 699.1 ± 1124.1 PLs ha^{-1} yr^{-1}, followed, since 2018 with a higher mean stocking density of 9,120.4 PLs ha^{-1} yr^{-1}. Significant increases in stocking number occurred ($p=0.000$) from year to year from 2009 to 2017, with 321.9 ± 1,114.8 PLs ha^{-1} yr^{-1} mean stocking density in 2009, increasing to a figure of 2,053 ± 4,436 PLs ha^{-1} yr^{-1} in 2017. This was made possible through increasing productivity of the original hatchery and the establishment of second hatchery at Kahandamodara with capacity of 40 million PL production in 2015.

During the period of 2009 to 2010, the country was subjected to post-war reclamation and repossession. Consequently, many of the reservoir systems were subject to malfunctioning infrastructure and low importance, which inturn resulted in less demand for GFP seed and stocking. Subsequently, a more consistent stocking program has been executed nationwide for the past five years. The stocking density for the northern reservoirs was dramatically increased from less than 500 PLs ha^{-1} yr^{-1} in earlier years, to above 1,000 PLs ha^{-1} yr^{-1} in 2015 (Fig 4.2). Progressive renovations of northeast reservoirs and infrastructure developments since late 2015 have enhanced the value of CBF and enabled livelihood benefits for the reconciled and rehabilitated residents. In the southern districts of Matara, Hambantota and Monaragala, relatively high stocking density above 2,000 PLs ha^{-1} yr^{-1}, has been applied due in part to the close proximity of the Kahandamodara hatchery.

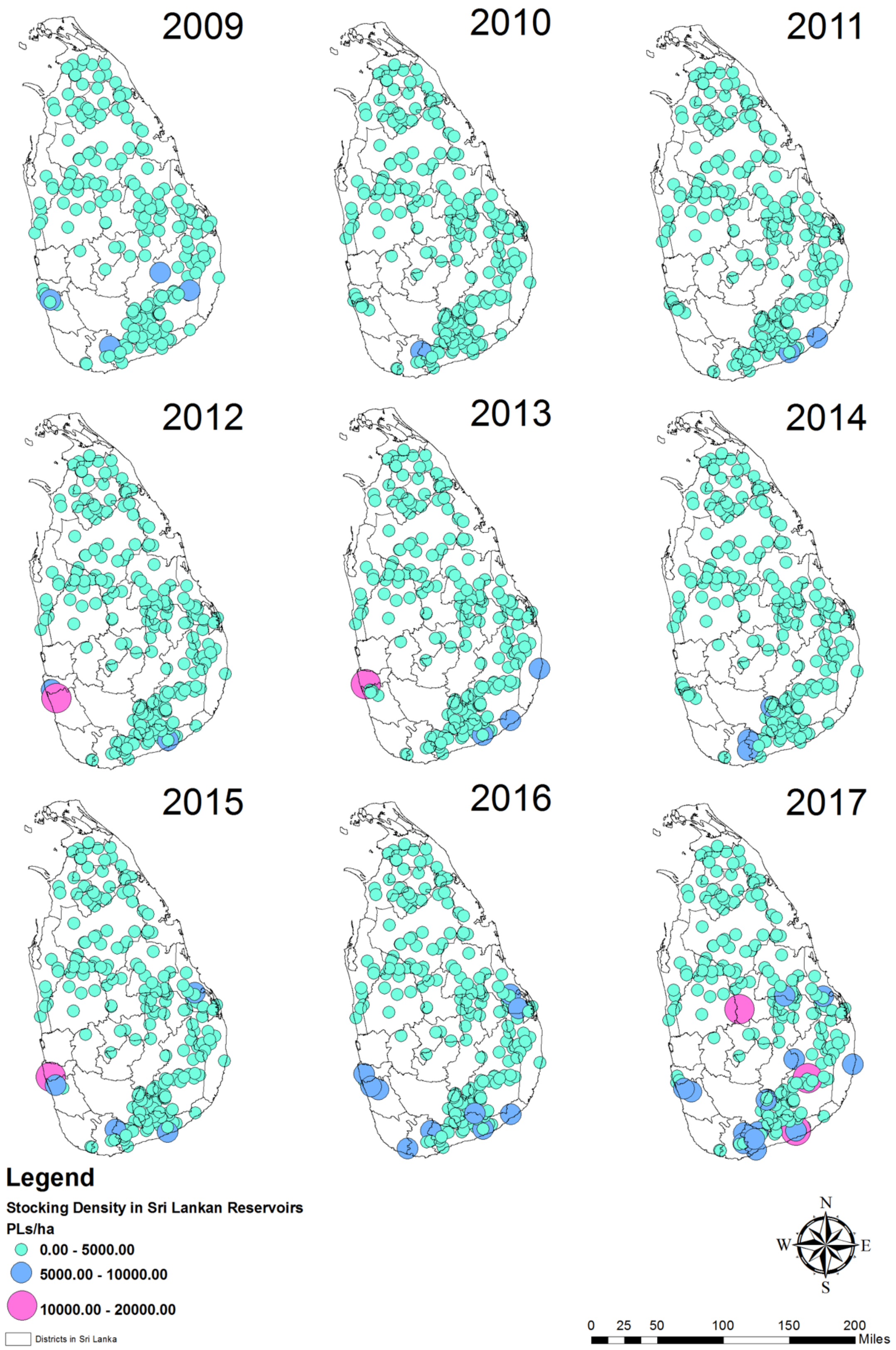

Figure 4.2. Stocking pattern of GFP PLs from 2009 to 2017; (Maps were generated for stocking densities (PLs ha^{-1}).

4.4.2 Underestimated production; Consequences of subsidiary fishery

GIS based yield prediction models will be useful for reservoir fishery management in the tropics with a high degree of reliability and confidence (Amarasinghe, *et al.*, 2002). The documented GFP harvests (kg ha^{-1} yr^{-1}) in Sri Lankan reservoirs from 2011 to 2017 seem to be similar, but in 2012 the production at 12.55 ± 61.03 kg ha^{-1} yr^{-1} was significantly higher (p=0.003), than in all other years for which it ranged from 3.494 ± 9.792 kg ha^{-1} yr^{-1} (in 2013) to 5.055 ± 11.859 kg ha^{-1} yr^{-1} (in 2014). To date, the mean production of GFP in Sri Lankan reservoirs is 5.205 ± 12.320 kg ha^{-1} yr^{-1}, the highest individual reservoir yield of 151.116 1g ha^{-1} yr^{-1}.

Interpolated maps in Figures 4.2 and 4.3 provide contradictory perception in relation to the deployed stocking density and recovered harvest. The predominant pattern was relatively trivial GFP production, regardless of stocking density. Yield trends suggest that northern and southern districts had comparatively highly production than other districts, consistent production of 10 – 30 kg ha^{-1} yr^{-1} over the years. Higher yields, above 50 kg ha^{-1} yr^{-1} was apparent in Polonnaruwa (2011- 2013), Monaragala (2012 and 2014), Hambantota (2014-2016) and Vavuiya/Mullativu (2012 and 2016).

GFP are not a fast self-replenishing species in wild populations. They do not breed in freshwaters so that wild populations that are found in some reservoirs are essentially those which are drawn from the associated rivers. Culture-based fishery of GFP is fully dependent on regular stocking. It is evident from the data examined, that increasing the stocking rate does not necessarily result in a concurrent increase in yield. Figure 4.3 shows that the GFP yield is primarily a modest 10 to 30 kg ha^{-1} yr^{-1}.

According to Lorenzen (1998 a, b), this is to be expected as the yield will be determined by the carrying capacity of the water body, and excess stocking might result in decreased growth and/or increased mortality, and no appreciable increase in yield. Similarly, the yield is also influenced by the preferred size of capture and/or the mesh selectivity of the gear, especially in those water bodies that retain relatively large amounts of water through the year. Furthermore, the intrinsic characteristics of the reservoirs defined with respect to their climatic zone, catchment and drainage specifications, topographical and geometric factors and biological provision for establishment of GFP populations, are all likely to influence the yields of GFP.

4.4.3 Chasing the peak with an ad hoc stocking and extension

There is a scarcity of studies on the dynamics of GFP culture-based fisheries, with more effort generally applied to aquaculture aspects (i.e. hatchery) than on the population interaction aspects within the reservoirs. A generalized interpretation of the interactions amongst some of the factors influencing the population dynamics of culture-based fisheries was provided by Lorenzen (1998 a, b). The interrelationships amongst stocking density and production of GFP are shown respectively in Figures 4.4, 4.5 and 4.6.

In accordance with the covariance and correlation analyses applied, there was no significant relationship identified between stocking density, production and area, suggesting a stochastic nature. The highly variable productivity among reservoirs at similar stocking density, may be due to the influence of varying environmental parameters and inherent characteristics of the reservoirs. Further detailed research is necessary to examine such factors in relation to GFP production. Studying such interactions will likely be highly beneficial in determining the CFB management strategy for each reservoir (De Silva, 2003).

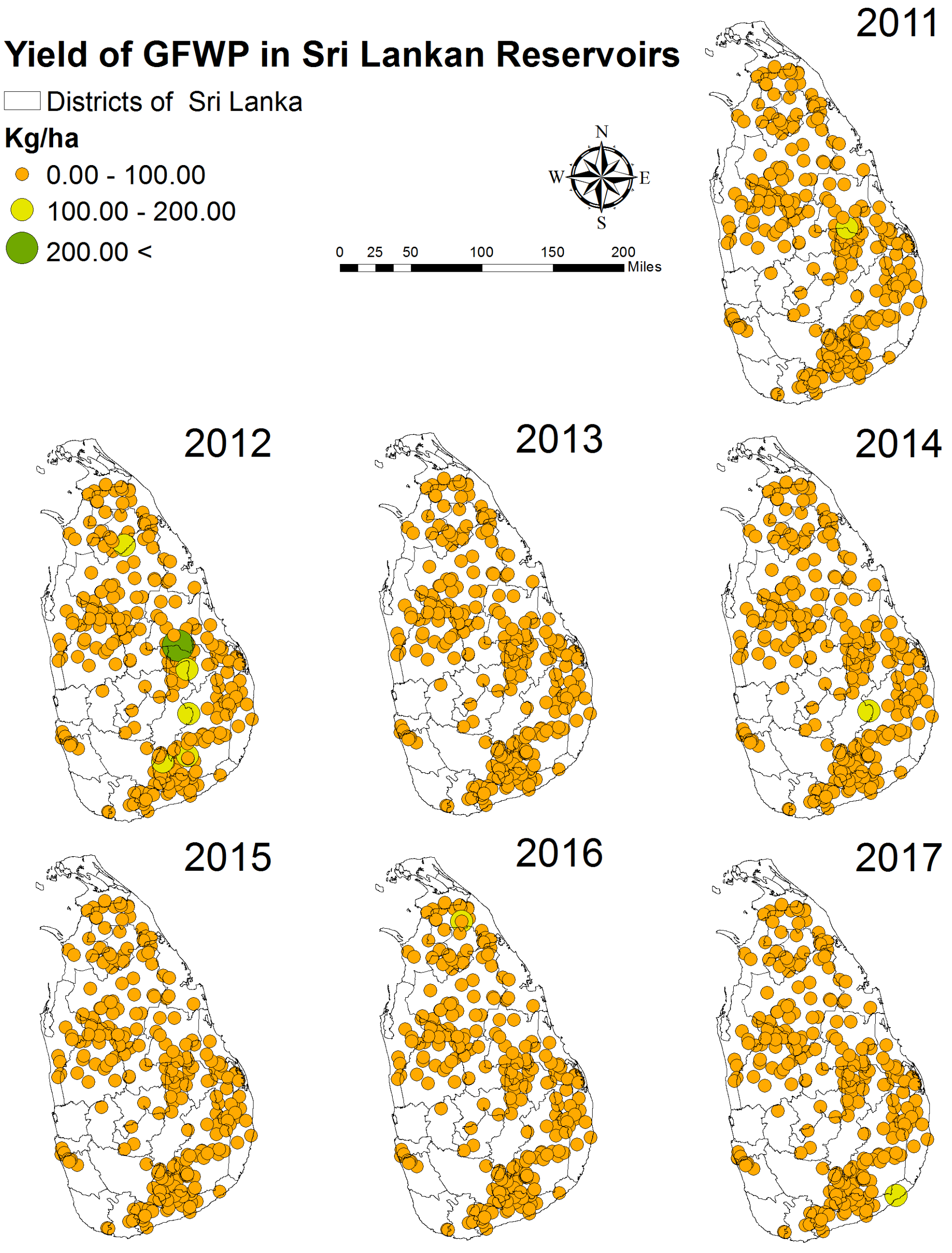

Figure 4.3. GFP production from 2011 to 2017. (Production is given in kg ha^{-1})

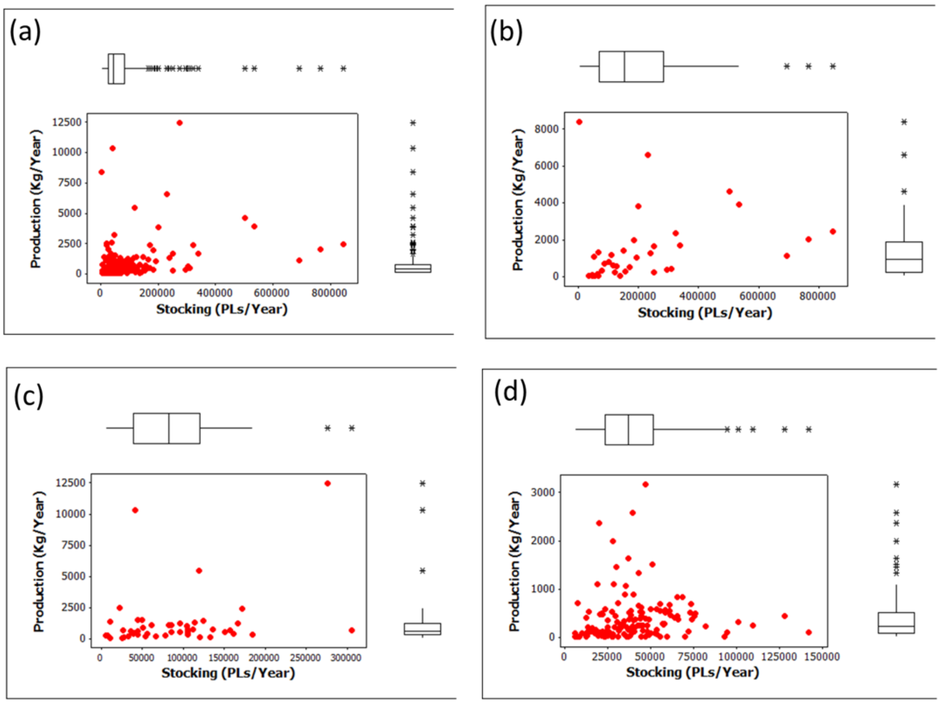

Figure 4.4. Stochastic nature between stocking and reservoir production: (a) All types of reservoirs, (b) Major reservoirs, (c) Medium reservoirs and (d) Minor reservoirs.

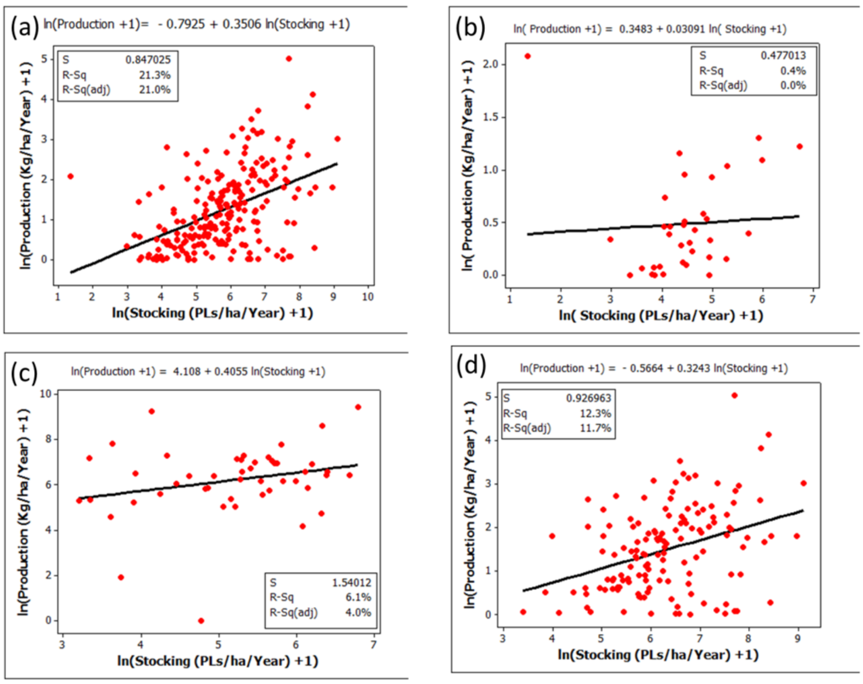

Figure 4.5. Relationship between stocking and reservoir production: (a) All types of reservoirs, (b) Major reservoirs, (c) Medium reservoirs and (d) Minor reservoirs.

Statistics in Table 4.1 and Fig. 4.5 reveal some inconsistencies in relationships between stocking density and production. Lack of fit is mainly caused by the high variability of production in relation to stocking density that makes interpretation difficult. Clearly, there has been no science-based approach to calculating appropriate stocking density for each reservoir and the stocking numbers applied appear to have been derived from past yield records and/or based on demand from the Community Based Organizations (CBOs).

Table 4.1. Relationships and probability levels between GFP production (kg ha^{-1} yr^{-1}) and stocking density (PLs ha^{-1} yr^{-1}).

Variables	Reservoir	Relationship	R%	P value
Linear -Production vs Stocking density	All	P = 2.91 + 0.00328 * S	8.60	0.0000
Linear -Production vs Stocking density	Major	P = 0.589 + 0.00208 * S	3.10	0.1540
Linear -Production vs Stocking density	Medium	P = 312 + 3.62 * S	8.30	0.0280
Linear -Production vs Stocking density	Minor	P = 4.07 + 0.00284 * S	5.90	0.0020
Linear - ln(Production +1) vs ln(Stocking +1)	All	ln(P+1) = 0.793 + 0.351 * ln(S+1)	21.00	0.0000
Linear - ln(Production +1) vs ln(Stocking +1)	Major	ln(P+1) = 0.348 + 0.0309 * ln(S+1)	0.00	0.7240
Linear - ln(Production +1) vs ln(Stocking +1)	Medium	ln(P+1) = 4.11 + 0.405 * ln(S+1)	4.00	0.9400
Linear - ln(Production +1) vs ln(Stocking +1)	Minor	ln(P+1) = 0.566 + 0.324* ln(S+1)	11.70	0.0000
Quadratic - ln(Production +1) vs ln(Stocking +1)	All	ln(P+1) = 0.3285 - 0.0582* ln(S+1)+ 0.03552* ln(S+1)^2	22.10	0.0000
Quadratic - ln(Production +1) vs ln(Stocking +1)	Major	ln(P+1) = 3.537 - 1.568* ln(S+1) + 0.1901* ln(S+1)^2	51.90	0.0290
Quadratic - ln(Production +1) vs ln(Stocking +1)	Medium	ln(P+1) = 8.877 - 1.592* ln(S+1) + 0.2011* ln(S+1)^2	7.60	0.0870
Quadratic - ln(Production +1) vs ln(Stocking +1)	Minor	ln(P+1) = 1.295 + 0.5590* ln(S+1) - 0.01838* ln(S+1)^2	11.10	0.0000

4.4.4 Choosing the potential; the early call

Monetary biomass gain (MBG) is an indirect measure of the economic gain from CBF. High variation of MBG was observed for medium reservoirs (Fig. 4.6). Despite the haphazard GFP stocking protocols and extension practices, MBG of the medium reservoir

(9.85 ± 26.28 kg PL^{-1} ha^{-1} yr^{-1}) is significantly higher than for the major (0.0760 ± 0.4197 kg PL^{-1} ha^{-1} yr^{-1}) and minor (0.01134 ± 0.01747 kg PL^{-1} ha^{-1} yr^{-1}) reservoirs (p=0.000).

With the exception of several medium reservoirs, most reservoirs displayed a homogenous MBG range of 0 to 1.0 kg PL^{-1} ha^{-1} yr^{-1} (Pushpalatha et al., 2010). Most of the southern, eastern, north central and northwest regions of the country have low MBG with a range of 0 to 10 kg PL^{-1} ha^{-1} yr^{-1} (Pushpalatha et al, 2015). Reservoirs with higher MBG were clustered to northern and central parts of the country.

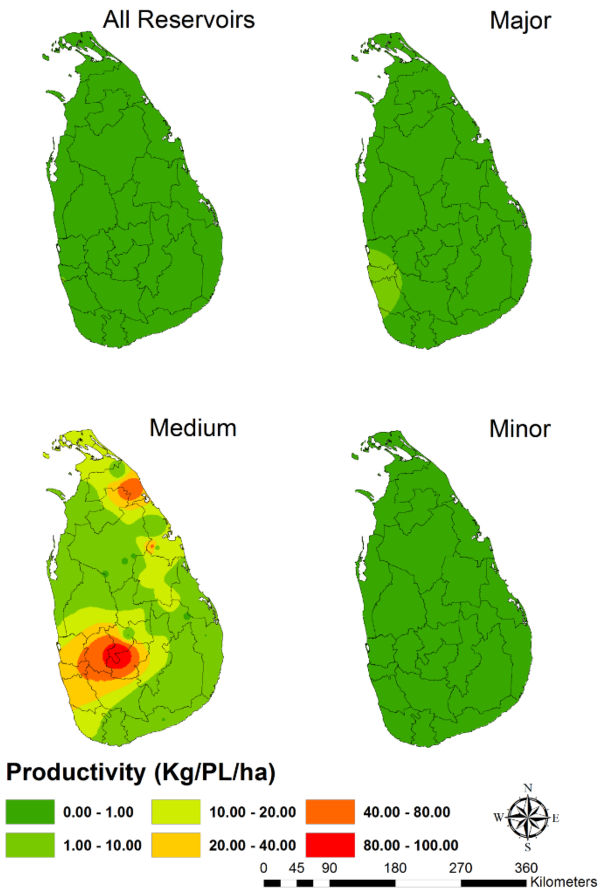

Figure 4.6. Potential of production with respect to the stocking density: Map is generated for the value of GFP fishery productivity or monetary biomass gain (kg PL^{-1} ha^{-1} yr^{-1}); (a) Major reservoirs (b) Medium reservoirs and (c) Minor reservoirs.

4.4.5 Necessity for a change in approach; stocking and harvesting

In the major reservoirs, where the stocking density is high, production is low (Fig. 4.7 (b)), which may be attributable to decreased catchability of GFP due to (1) large mesh size (8.5 cm) of nets used, (2) decreased accessibility to the specific niche of GFP, (3) loss of stock at reservoir out-takes where water is harvested for irrigation, (4) losses from predation and (5) upstream or downstream migration. Potential for the above mentioned losses is comparatively less in minor and medium reservoirs. In particular, the specific niche of the GFP is more accessible within the smaller area. The present recapture rate of GFP averages 9.4%, which is considered satisfactory compared to the recapture rates reported by Jutagate and Rattanchai (2010) which is less than 5% in reservoirs of Thailand. The highest recapture reported was around 10% from a freshwater wetland in Nakhon Sawan province (Rithcharung and Srichareondham, 1998).

For effective decision making on stocking and harvesting strategy, more data are required on the relationship between reservoir size, yield and stocking density. In both major and medium reservoirs production per unit area declined as the surface area increased, even though stocking density was increased/ high (Fig. 4.7 b). On the other hand, at low stocking densities, production per unit area followed a relatively consistent pattern for both groups of reservoirs, irrespective of the surface area.

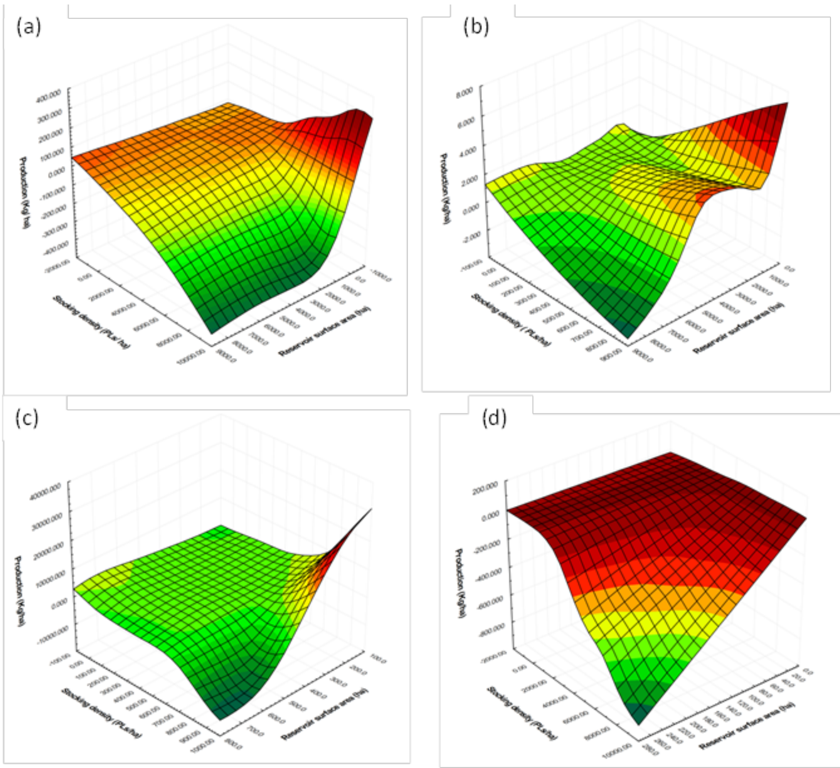

Figure 4.7. Surface plot of Weighted Unit production (kg ha^{-1}) on Unit Stocking (PLs ha^{-1}) with concern to reservoir surface area (ha); (a) All reservoirs (b) Major (c) Medium and (d) Minor.

4.5 Conclusions and Recommendations

At present the Sri Lankan government strategy for GFP is to focus on enhancing production capacity of existing hatcheries, establishment of new hatcheries and increasing stocking in perennial reservoirs. Despite the great potential for GFP culture in Sri Lankan reservoirs, its development has been *ad hoc*. Stocking strategies are not science based and harvesting of GFP is not targeted. Very little is known on the market chain and respective socio-economic aspects. GFP for CBF development should be considered through a holistic approach where the recovery rate is a cumulative function of the stocking protocol. A scientific approach to stocking and recapture will improve yields, increase incomes of rural families and ensure sustainability in the long term.

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5 Activity 2. Controlled stocking trials of giant freshwater prawns to inform new stocking strategies

5.1 Abstract

Culture Based Fisheries (CBF) of Giant Freshwater Prawn (GFP), *Macrobrachium rosenbergii*, were started in 2008 in Sri Lankan reservoirs for generating substantial income for the fishing communities. The present study analysed the influence of the trophic state of the reservoirs on the production of GFP. Forty-eight reservoirs, 24 from Hambanthota and Monaragala districts, and 24 from Anuradhapura, Puttalam and Kurunegala districts were selected for this analysis. Sampling was done monthly from March 2018 to March 2019 to measure water temperature, pH, conductivity, dissolved oxygen (DO), Secchi disk depth (SDD) and chlorophyll-a content. Capture data of GFP were collected from the fishermen and the yield was calculated for each reservoir. Carlson's Trophic State Index (TSI) was calculated to evaluate the trophic state of each reservoir based on the SDD and chlorophyll-a. The reservoir morphometry data, shoreline length, reservoir area at full supply level and extent of the littoral zone were measured and included in the analyses. Catch data were collected with the aid of village fishers' organizations. Results suggested that the limnological condition in reservoirs between northern and southern regions have remarkable differences. Principal Component Analysis (PCA) based on limnological data ordinated northern and southern reservoirs into two separate clusters. Out of measured water quality parameters conductivity, pH and chlorophyll-a might be important to discuss about variations in GFP yield. However, there were no significant correlations between total GFP yield (kg ha^{-1} yr^{-1}) and measured water quality parameters. All reservoirs examined were eutrophic, and of those, 74.47% were in the hyper-eutrophic status according to the trophic classification based on SDD (TSI SDD). However, according to the trophic classification based on the chlorophyll-a (TSI Chl-a) content, 42.56% were eutrophic. As TSI SDD was greater than TSI Chl-a, this suggests relative abundance of non-algal particulate matter and possibly colour dominated underwater light attenuation. There was a positive trend between TSI Chl-a and the yield of GFP in reservoirs with catch data available, although not significant. Measured morphometric characteristics, organic matter content of the sediment and Shannon-Weiner index, calculated on basis of macrobenthos diversity within the littoral area, showed non-significant trends with GFP yield in a selected sub-sample of reservoirs. It was recommended to carry out further research covering a wider geographical area and increasing sample size, to more thoroughly examine these variables. It was also evident from this research that efforts should be made to improve the efficiency of PL production at NAQDA, to determine or develop the best fishing gear to catch GFP efficiently, to look for suitable tagging / marking techniques to identify a particular GFP stock and to conduct a more detailed study on reservoir food web and finfish diversity and biomass.

5.2 Introduction

Aquaculture is now playing a crucial role in Sri Lanka contributing 81,870 tonnes, jointly with inland fisheries, to the total fish production of 531,310 tonnes for the country (NARA, 2017). Though the marine fish production has been rather stagnant through recent years, the inland fisheries sector has grown due to on-going efforts of the stake holders and the abundance of aquatic resources with potential for development. Culture Based Fisheries (CBF) is one of the development strategies in the inland fisheries sector that can meet the demand for the cheap animal protein in rural areas (De Silva, 1988). Initially, CBF mainly focused on exotic species such as Indian carp, Chinese carp and Tilapia (Thayaparan, 1982). With a view to improve the income generated by CBF, the National Aquaculture

Development Authority (NAQDA) commenced a program to culture Giant Freshwater Prawn (GFP) *Macrobrachium rosenbergii* in selected reservoirs in the dry zone since 2008. However, the implementation of the program has been somewhat ad-hoc, such that further development of effective strategies will be necessary to maximize the profit and benefits.

In spite of being a high value product with high export potential, currently there is a huge gap between the high stocking density of GFP and yield captured. Owing to the ad-hoc stocking strategy there is high variability in the yields and fisher incomes among reservoirs, impairing further improvements in reservoir fishery for GFP. This is mainly due to lack of a scientific approach for the overall production of GFP. Since its commencement, NAQDA has continuously stocked GFP in dry zone reservoirs in an ad-hoc manner without any scientific basis. The only basis for these stockings is that more stocking will return more yield. In addition, due to high export value and market price of GFP, farmer organizations/ fishing communities associated with those reservoirs demand even more stocking.

This study is a part of the collaborative research project with a view to addressing some of the existing issues regarding culture-based fisheries of GFP in Sri Lankan reservoirs. There was no previously published literature on influence of limnological parameters on the yield of GFP cultured in reservoirs of Sri Lanka. However, previous research on CBF suggest that a similar kind of limnological perspective is necessary for the development of CBF of GFP (Jayasinghe et al., 2005b, Wijenayake et al., 2005, Jayasinghe et al., 2005a, Jayasinghe et al., 2005b, Jayasinghe et al., 2006).

Therefore, this study was carried out mainly to analyse whether there is any relationship between the limnological parameters, reservoir morphometry and macrobenthos diversity with the overall production of GFP cultured in some selected reservoirs. This study is of high significance since this is the very first attempt to work on the influence of limnological parameters on the yield of GFP. It is of utmost importance to understand the factors affecting the yield, to determine optimal stocking practices that generate optimal yields.

5.3 Materials and Methods

For this study, forty-eight reservoirs from five districts i.e. 24 from Hambanthota and Monaragala districts, representing southern part of the country, and 24 from Anuradhapura, Puttalam and Kurunegala districts representing northern part of the country, were selected. Since the stocking of reservoirs with GFP was supported by the NAQDA, the original annual stocking program of NAQDA was not altered for this study. Sampling sites were selected from the reservoir list of NAQDA. Under permission from NAQDA, a private company called Divron Bioventures was also stocking GFP in some reservoirs. To avoid any conflict of interest, this study selected reservoirs without the involvement of Divron Bioventures. The limnological survey was planned to start in early 2018, however, due to the previous year drought, especially in northern part, many reservoirs were completely dry and the research team had to wait until the reservoirs started to fill with the onset of rains. Sampling was started in March 2018, with 47 reservoirs as per the Table 5.1.

Table 5.1. List of reservoirs studied with their geographical coordinates.

Reservoir	Code	Area (ha)	GPS Coordinates	
			N	E
Kalawewa	A1	1440	8° 0'38.77"	80°33'16.69"
Rajaganaya	A2	1619	8° 8'6.19"	80°14'24.09"
Nuwarawewa	A3	1197	8°20'26.58"	80°25'37.52"
Huruluwewa	A4	1619	8°12'52.04"	80°43'39.67"
Nachchaduwa	A5	1781	8°14'57.61"	80°28'55.37"
Mahakanadarawa	A6	1457	8°23'42.65"	80°33'7.84”
Mahawilachchiya	A7	971	8°28'5.04"	80°11'46.78"
Angamuwa	A8	445	8°10'27.49"	80°13'17.35"
Thuruwila	A9	280	8°13'11.35"	80°25'54.78"
Manankatiya	A10	276	8°12'32.00"	80°39'41.90"
Rideeyagama	H1	871	6° 12'15.17”	80 59'3.64”
Weerawila Wewa	H2	567	6° 17'13.30”	81 13'57.39”
Muruthawela	H3	516	6° 12'54.85 “	80 43'27.13”
Yoda Wewa	H4	486	6° 16'14.46”	81 18'51.85”
Bandagiriya	H5	381	6° 15'19.40”	81 8'20.14”
Udukiriwala	H6	263	6° 9'20.52”	80 45'28.05”
Mahagal Wewa	H7	140	6°23'54.00”	81° 2'2.64"
Maha Wewa	H8	80	6°27'29.93"	81° 0'40.03"
Pahala Andara Wewa	H9	80	6° 19'7.43”	81 6'46.82”
Kattakaduw	H10	80	6° 7'30.35”	80 52'27.10”
Maha Aluthgama Ara	H11	70	6 21'51.57”	81 5'8.49”
Magallewewa	K1	263	7°44'31.69"	80° 7'38.82"
Muthukandiya	M1	560	6° 58'46.58”	81 30'07.66”
Kiriibban Wewa	M2	375	6° 22'33.46”	80 58'13.66”
Urusita Wewa	M3	262	6°19'55.17"	80°55'59.56"
Handapangala	M4	226	6° 39'56.88"	81 9'07.00”
Hambegamuwa	M5	210	6° 32'33.69”	80 57'19.19”
Balaharuwa Wewa	M6	150	6° 34'25.40”	81 23'7.56”
Demodara Wewa	M7	100	7 13'41.99”	81 10'6.77”
Milegama	M8	80	6°25'44.79”	81°17'4.44"
Habaralu Wewa	M9	80	6 24'10.23”	80 55'9.67”
Alugalge Wewa	M10	70	6°39'34.01”	81° 5'18.95"
Sugaladevi Wewa	M11	50	7 1'15.77”	81 35'28.14"

Reservoir	Code	Area (ha)	GPS Coordinates	
			N	E
Buduruwagala Wewa	M12	145	6°41'15.59"	81° 5'6.03"
Gestupana Wewa	M13	80	6°26'13.67”	81°16'24.54"
Devalahandiya	P1	257	7°47'10.04”	79°52'36.61”
Karavitagaraya	P2	256	7°34'6.25”	79°50'39.75”
Mahauswewa	P3	212	7°55'37.36”	80° 5'47.61"
Kachichimaduwa	P4	65	7°56'25.37"	79°57'29.27"
Kotukachchiya	P5	70	7°55'39.29"	79°56'40.39"
Viluka	P6	65	7°52'30.80"	79°53'4.16"
Vijayakatupotha	P7	243	7°43'11.52"	79°53'36.83"
Thabbowa	P8	607	8° 4'0.34”	79°57'23.48"
Eluwankulama	P9	65	8°16'37.08"	79°52'37.63"
Pahariya	P10	72	8° 7'31.67"	79°59'46.04"
Saliyawewa	P11	85	8°10'6.55"	80° 5'38.89"
Thangusewa	P12	50	8° 9'11.93"	80° 7'40.10"

5.3.1 Stocking of GFP

In the stocking plan of NAQDA, reservoirs are conventionally categorized as small or minor (< 200 ha), medium (200-800 ha) and large or major (> 800 ha). For this study, reservoirs were selected in a size continuum ranging from 50 to 1781 ha. The annual stocking plan from NAQDA was modified slightly for our research to have a range of stocking densities in reservoirs of various size, as per the Table 5.2 below.

However, GFP PL production at NAQDA was not sufficient to stock all reservoirs at once during the early months of the project. Therefore, the stocking was protracted throughout the year 2018 and into 2019, and the second cycle of stocking is still on-going. Tables 5.3 and 5.4 show the stocking data. For some reservoirs, the fishery community overruled the specified stocking number, and they stocked excess amounts of PL expecting higher returns. Tables 5.3 and 5.4 also show the amount stocked and the average size of the PL.

Table 5.2: Stocking plan of the ACIAR project and NAQDA for Hambanthota and Monaragala districts

District	Culture System	Name of Reservoir	Area	No.of PL decided by NAQDA	NAQDA stocking density	ACIAR stocking density	ACIAR PL need
Hambantota	Major	Ridiyagama	871	2,000,000	2,296	2300	2,003,300
Hambantota	Medium	Weerawila Wewa	567	1,000,000	1,764	2100	1,190,700
Monaragala	Medium	Muthukandiya	560	200,000	357	1900	1,064,000
Hambantota	Medium	Muruthawela	516	950,000	1,841	1800	928,800
Hambantota	Medium	Yoda Wewa	486	800,000	1,646	1700	826,200
Hambantota	Medium	Badagiriya	381	800,000	2,100	2100	800,100
Monaragala	Medium	Kiribban wewa	375	150,000	400	1800	675,000

District	Culture System	Name of Reservoir	Area	No.of PL decided by NAQDA	NAQDA stocking density	ACIAR stocking density	ACIAR PL need
Hambantota	Medium	Udukiriwila	263	400,000	1,521	1700	447,100
Monaragala	Medium	Urusita wewa	262	200,000	763	1600	419,200
Monaragala	Medium	Handapanagala	226	150,000	664	1500	339,000
Monaragala	Medium	Hambegamuwa	210	300,000	1,429	1400	294,000
Monaragala	Minor	Balaharuwa wewa	150	100,000	667	2000	300,000
Hambantota	Minor	Mahagalwewa	140	250,000	1,786	1800	252,000
Monaragala	Minor	Buduruwagala wewa	125	50,000	400	1600	200,000
Monaragala	Minor	Demodara wewa	100	50,000	500	1500	150,000
Hambantota	Minor	Maha wewa	80	250,000	3,125	3200	256,000
Hambantota	Minor	Pahala Andara	80	200,000	2,500	2500	200,000
Monaragala	Minor	Gestupana wewa	80	150,000	1,875	2000	160,000
Hambantota	Minor	Kattakaduwa maha wewa	80	150,000	1,875	1800	144,000
Monaragala	Minor	Milegama	80	100,000	1,250	1500	120,000
Monaragala	Minor	Habaralu wewa	80	100,000	1,250	1250	100,000
Hambantota	Minor	Maha Aluthgam ara	70	150,000	2,143	2200	154,000
Monaragala	Minor	Alugalge wewa	70	65,000	929	1100	77,000
Monaragala	Minor	Sugaladevi wewa	50	50,000	1,000	1000	50,000

Table 5.3: Stocking in Hambantota District

Index	Name of Reservoir	ACIAR PL need	PL stocked	excess stocked	Completion of stocking (Month)	Mean wet weight of stocked PL (mg)	Mean Total Length of stocked PL (mm)
1	Ridiyagama	2,003,300	2,003,300	0	Jun-18	16.1	7.3
2	Bandagiriya	800,100	1,200,100	400,000	Jun-18	15.7	6.4
3	Muruthawela	928,800	928,800	0	Jun-18	15.8	6.7
4	Udukirivila	447,100	447,100	0	Jun-18	15.5	6.2
5	Weeravila	1,190,700	1,190,700	0	Jun-18	15.8	6.5
6	Yoda wewa	826,200	826,200	0	Jun-18	13.8	5.2
7	Kattakaduwa maha wewa	144,000	300,000	156,000	Jul-18	14.2	5.6
8	Maha aluthgamara	154,000	250,000	96,000	Aug-18	15.1	6.1
9	Maha wewa	256,000	256,000	0	Jun-18	15.5	6.3
10	Mahagal wewa	252,000	252,000	0	Jun-18	15.5	6.6
11	Pahala Andara wewa	200,000	400,000	200,000	Aug-18	15.3	6.2
	TOTAL	**7,202,200**	**8,054,200**	**852,000**			

Table 5.4: Stocking in Monaragala District

Index	Name of Reservoir	ACIAR PL need	PL stocked	excess stocked	Completion of stocking (Month)	Mean weight of stocked PL (mg)	Mean Total Length of stocked PL (mm)
1	Muthukandiya	294,000	294,000	0	Dec-18	17.2	7.6
2	Urusita Wewa	339,000	339,000	0	Oct-18	14.8	5.8
3	Demodara Wewa	675,000	675,000	0	Dec-18	17.1	7.2
4	Alugalge Wewa	1,064,000	1,064,000	0	Nov-18	16.6	6.9
5	Kiriibban Wewa	419,200	419,200	0	Nov-18	16.2	6.9
6	Hadapanagala	77,000	77,000	0	Oct-18	15.5	6.6
7	Hambegamuwa	300,000	300,000	0	Oct-18	15.5	6.4
8	Balaharuwa wewa	200,000	200,000	0	Oct-18	15.5	6.2
9	Buduruwagala Wewa	150,000	150,000	0	Oct-18	15.4	6.3
10	Gestupana Wewa	160,000	160,000	0	Oct-18	15.1	6.1
11	Habaralu Wewa	100,000	100,000	0	Oct-18	14.6	5.4
12	Sugaladevi Wewa	120,000	120,000	0	Dec-18	17.4	7.1
13	Milegama	50,000	50,000	0	Oct-18	14.5	5.9
	TOTAL	**3,778,200**	**3,778,200**	0			

5.3.2 Limnological data collection

Limnological data collected comprised; water temperature, pH, dissolved oxygen (DO), conductivity, Secchi disk depth (SDD), chlorophyll-a content and sediment organic matter content. These were collected monthly from March 2018 to March 2019 period. Water temperature, pH, DO and conductivity were measured *in situ* from five randomly selected sites in each reservoir using a multiparameter water quality meter (HANNA, USA: model HI 98194). SDD was measured using a standard black and white 20cm diameter Secchi disk. For chlorophyll-a analysis, a known volume of water was filtered through GF/C filters (1.2 µm; 47 mm Ø), and the filters were stored in acid free, lightproof vials in ice to be taken to the laboratories (Carlson and Simpson, 1996). In the laboratory, filter papers were macerated in 90% acetone and the absorption values of the acetone extraction were measured at 750 nm and 664 nm before acidification and at 750 nm and 665 nm after acidification (Carlson and Simpson, 1996).

Sediment samples were collected at each site, operating a Peterson grab from the boat. Samples were placed in polythene bags and stored in ice, then taken back to the laboratory for organic matter content analysis. Organic matter content was analysed by the method given by (Boyd, 1995). Macrobenthic fauna were separated from sediment samples and preserved in plastic vials containing 70% ethanol for further analysis. Preserved samples were later identified using standard keys for benthos identification.

For the reservoir morphometry, shoreline length, reservoir area at full supply level and extent of the littoral zone were measured. Twenty different GPS locations on the shoreline around each reservoir were recorded and reservoir areas were mapped using GARMIN GPS Etrex-10. Shoreline length of each reservoir was measured using this map. Littoral extent of each reservoir was considered by assuming photic zone boundary was at the 15 feet depth contour, and by measuring the distance from that benchmark to shoreline. Ten different locations were considered around the reservoir to mark GPS position at the shore and directly adjacent at the depth of 4.6m (15ft) to calculate the distance between two positions. That distance and the depth of 4.6m was used to calculate the diagonal length over the bottom as littoral extent by using the Pythagorean Theorem. A mean value of littoral extent was taken from ten different locations around the reservoir.

5.3.3 GFP catch data

Catch data was collected with the aid of village fishers' organizations. Daily and monthly total catch of GFP was recorded by the fishers' organizations, and that data was used for this study. In addition, length and weight of some specimens caught by the fishers were measured during the visits for limnological sampling. Those specimens were brought back to the laboratory in ice to assess different morphometric characters and gut contents.

5.3.4 Data analysis

Past version 3, Primer- E version 7 and Microsoft Excel 2016 were used for the calculations and statistical analyses. Principal Component Analysis (PCA) was carried out for the main limnological parameters i.e. temperature, pH, DO, conductivity, SDD, and chlorophyll-a to see underlying patterns of distribution (Clarke and Warwick, 1994). Pearson correlation was tested between water quality parameters and the yield.

Shoreline development and ratio of shoreline length and area were calculated. Shoreline development (D_L), a standard limnological parameter of reservoir morphometry is a measurement of length of the shoreline relative to the perimeter of a circle with an area similar to that of the lake. D_L at full supply level was calculated for each reservoir using $D_L = L/2 \sqrt{(0.001\pi A)}$ where L is shoreline length in km, and A is reservoir area in ha at full supply level (Wetzel, 2001). Ratio of shoreline length and area (R_{LA}) was calculated as $R_{LA} = L/A$ (Jayasinghe et al., 2006). Shoreline development and Ratio of shoreline length and area were calculated at the full supply level since there can be changes in the shoreline length with decreasing water levels. Pearson correlation was tested between reservoir morphometry parameters and the yield.

Trophic state of each reservoir was evaluated based on the Trophic State Index (TSI) developed by Carlson (1977) using Secchi disk depth and the chlorophyll-a content. TSI were calculated using following equations.

$$\text{TSI (SDD)} = 60 - 14.41 \ln \text{SDD (meters)} \quad (1)$$

$$\text{TSI (Chl-a)} = 9.81 \ln \text{chlorophyll-a (mg/m3)} + 30.6 \quad (2)$$

Pearson correlation was tested between TSI and the yield.

Shannon Weiner index (H index) was calculated to determine the macrobenthos diversity, and ordination techniques were used to see underlying patterns of sample distribution.

5.4 Results and Discussion

Average values of limnological parameters during the study period are given in Table 5.5 and Figures 5.1 to 5.6. The results show that northern reservoirs had higher water temperatures while southern reservoirs had relatively lower values (Figure 5.1). As a result of that, DO of southern reservoirs was relatively higher (Figure 5.2). Conductivity of northern reservoirs was relatively higher while southern reservoirs displayed high variability (Figure 5.3).

Table 5.5. Mean value (±SE) of the measured limnological parameters for each study reservoir T- water temperature (°C); DO- dissolved oxygen (mg/L); Cond- Conductivity (µS/cm); SDD- Secchi disc depth (cm); Chl-a- chlorophyll-a (µg/L)

Code	T	DO	Cond.	pH	SDD	Chl-a
A1	30.91±0.78	7.04±0.07	481.13±40.66	7.14±0.02	0.40±0.01	5.59±1.53
A2	30.08±0.59	7.30±0.09	658.70±81.48	7.25±0.10	0.46±0.02	10.28±2.17
A3	30.65±0.63	7.00±0.06	438.26±29.72	7.18±0.02	0.53±0.02	4.90±0.76
A4	30.62±0.93	7.21±0.05	471.93±23.82	7.09±0.01	0.58±0.03	7.61±0.79
A5	29.49±0.76	7.03±0.09	498.19±15.18	6.95±0.06	0.47±0.04	7.59±1.02
A6	30.13±0.70	7.06±0.08	535.52±17.19	6.81±0.06	0.54±0.04	5.57±1.31
A7	28.50±0.41	7.33±0.07	509.82±18.15	7.34±0.04	0.51±0.01	7.14±1.48
A8	28.15±0.26	7.20±0.05	567.12±37.21	7.36±0.03	0.40±0.01	5.33±0.95
A9	27.99±0.22	7.17±0.08	607.43±51.08	7.27±0.01	0.50±0.01	6.63±1.00
A10	29.68±0.47	6.99±0.06	451.21±38.63	7.28±0.02	0.50±0.01	6.79±0.81
H1	28.63±0.23	10.73±0.31	488±39.21	7.47±0.09	0.37±0.02	10.95±0.10
H2	29.06±0.25	9.73±0.20	472.17±9.62	8.13±0.13	0.38±0.02	13.31±0.13
H3	28.33±0.18	10.58±0.45	193.67±15.00	8.16±0.11	0.50±0.01	8.06±0.12
H4	28.55±0.18	10.15±0.22	640.98±8.73	7.87±0.08	0.40±0.02	13.30±0.13
H5	28.57±0.14	10.34±0.24	571.68±22.37	7.70±0.09	0.33±0.01	34.05±0.35
H6	28.39±0.13	10.47±0.43	252.68±10.56	8.39±0.09	0.34±0.01	8.14±0.04
H7	28.60±0.17	10.52±0.27	364.25±14.84	8.04±0.08	0.35±0.01	8.55±0.19
H8	28.48±0.09	10.82±0.36	365.25±10.96	7.96±0.06	0.41±0.02	11.02±0.25
H9	28.58±0.09	11.33±0.53	473.85±20.65	8.15±0.09	0.58±0.01	8.93±0.19
H10	28.38±0.09	8.42±0.33	320.05±10.85	7.85±0.06	0.52±0.02	10.33±0.09
H11	28.12±0.11	11.03±0.23	56.35±9.17	7.67±0.07	0.43±0.02	11.08±0.30
K1	30.06±0.42	7.17±0.05	506.30±30.65	7.27±0.19	0.57±0.01	6.28±1.29
M1	28.23±0.06	10.36±0.23	197.15±16.15	7.79±0.04	0.40±0.03	7.66±0.83
M2	28.12±0.05	9.17±0.07	89.58±9.91	7.72±0.04	0.40±0.02	6.26±0.60
M3	28.44±0.10	9.80±0.12	189.00±11.88	7.70±0.07	0.41±0.02	6.34±0.54
M4	28.62±0.06	9.71±0.22	329.48±10.62	7.83±0.06	0.40±0.01	4.87±0.42
M5	28.58±0.07	9.18±0.14	423.25±22.51	7.88±0.02	0.48±0.02	4.68±0.60
M6	28.63±0.06	9.58±0.25	298.75±29.96	7.79±0.04	0.52±0.01	3.84±0.22
M7	28.49±0.07	9.83±0.13	238.79±19.81	7.88±0.02	0.36±0.02	8.63±0.37

Code	T	DO	Cond.	pH	SDD	Chl-a
M8	27.52±0.07	9.54±0.20	288.04±11.42	8.33±0.06	0.43±0.01	5.68±0.60
M9	28.51±0.08	9.93±0.15	105.02±7.56	8.00±0.07	0.38±0.02	4.95±0.24
M10	28.43±0.09	9.88±0.12	250.07±11.57	7.84±0.03	0.37±0.01	5.87±0.31
M11	28.11±0.11	9.76±0.13	279.90±14.08	7.87±0.03	0.48±0.01	3.71±0.18
M12	28.18±0.09	9.81±0.16	347.32±21.77	7.91±0.05	0.34±0.01	8.09±0.10
M13	26.76±0.13	10.09±0.14	250.13±18.27	8.47±0.06	0.46±0.01	3.50±0.12
P1	31.19±0.73	6.88±0.13	597.16±65.30	7.45±0.06	0.39±0.02	5.74±0.8
P2	30.35±0.78	6.81±0.13	597.51±60.88	7.22±0.03	0.41±0.02	8.26±1.05
P3	30.96±0.97	7.25±0.21	536.03±55.86	7.43±0.13	0.46±0.03	8.76±0.69
P4	29.88±0.61	6.57±0.21	515.62±49.00	6.84±0.11	0.51±0.04	6.98±0.87
P5	29.55±0.41	7.00±0.16	508.10±41.04	7.30±0.09	0.46±0.02	5.19±1.07
P6	29.13±0.75	7.10±0.08	491.71±38.32	7.21±0.08	0.48±0.02	9.87±0.94
P7	29.84±0.61	7.28±0.08	467.36±34.12	7.07±0.09	0.48±0.02	7.19±2.01
P8	29.68±0.85	7.25±0.05	468.37±16.12	7.56±0.08	0.47±0.02	5.27±1.48
P9	29.18±0.36	7.10±0.13	456.65±30.38	7.46±0.05	0.40±0.01	7.33±0.56
P10	28.97±0.64	7.21±0.16	428.08±25.78	7.05±0.02	0.43±0.02	5.97±0.88
P11	29.72±0.68	7.19±0.08	462.92±25.10	7.07±0.02	0.50±0.01	5.53±0.72
P12	29.98±0.74	6.83±0.17	494.07±27.08	7.08±0.01	0.33±0.02	6.49±0.73

pH was also relatively higher in southern reservoirs (Figure 5.4). There was no clear difference in SDD among northern and southern reservoirs as displayed in Figure 5.5. In the same way, chlorophyll-a did not vary significantly between the two regions with the exception of one outlier (Figure 5.6). Overall, the results suggest that the limnological conditions in reservoirs between northern and southern regions have remarkable differences that might affect the GFP production.

Water quality parameter values were normalized by ln(X+1) transformation, and subjected to a Principal Component Analysis (PCA) to see underlying patterns in the ordination plot of all reservoirs in five districts together. The results of PCA are given in the Table 5.6 and Figure 5.7. First two principal components explained a cumulative variance of 83.1% and with third component it was 98.9%.

Table 5.6. Results of the PCA. *Eigenvalues*

PC	Eigenvalues	%Variation	Cum.%Variation
1	0.385	59.5	59.5
2	0.153	23.6	83.1
3	0.103	15.9	98.9
4	0.00454	0.7	99.6
5	0.00192	0.3	99.9

Table 5.7. Results of the PCA. *Eigenvectors.* (Coefficients in the linear combinations of variables making up PC's)

Variable	PC1	PC2	PC3	PC4	PC5
T	-0.034	0.021	-0.020	0.077	0.028
pH	0.501	-0.596	0.570	0.262	-0.012
DO	0.197	-0.212	0.038	-0.952	-0.026
Cond	-0.840	-0.366	0.393	-0.078	0.009
SDD	-0.018	0.040	0.027	0.018	-0.998
Chl-a	-0.051	-0.681	-0.720	0.113	-0.044

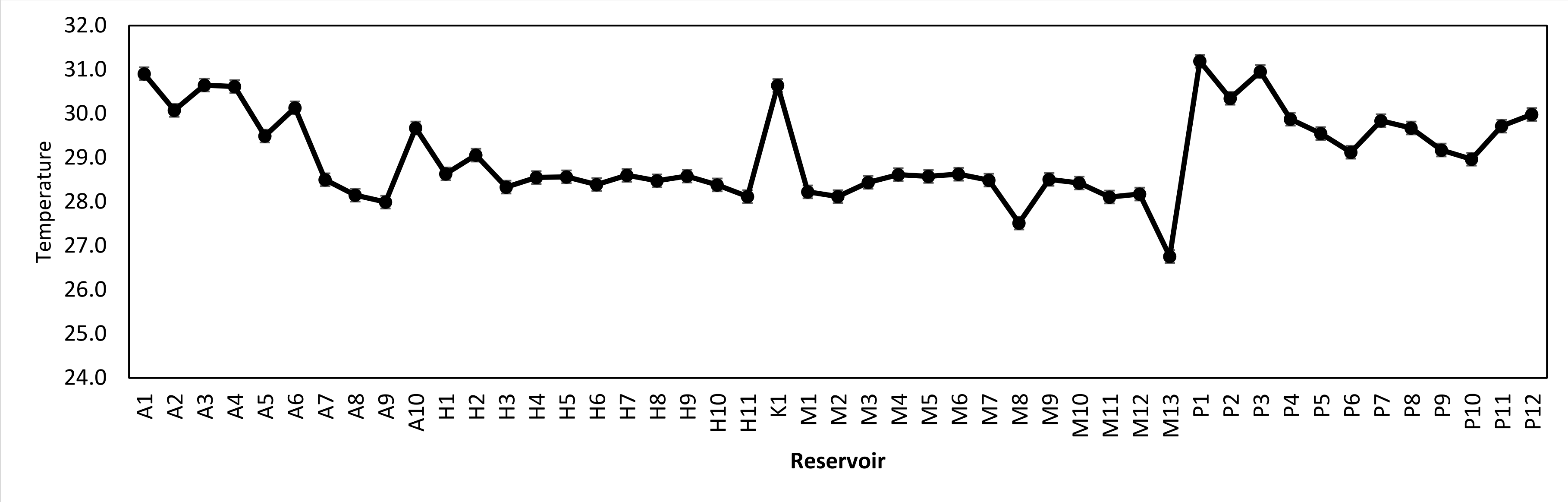

Figure 5.1. Variations of water temperature (T in °C) in 47 reservoirs. Error bars denote the standard errors of mean.

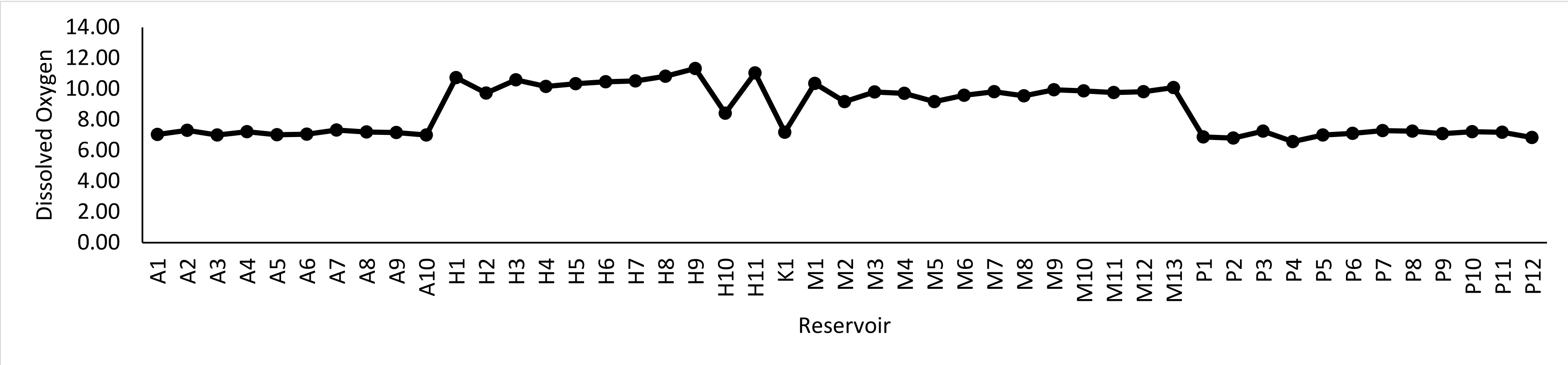

Figure 5.2. Variations of Dissolved Oxygen (DO in mg L–1) in 47 reservoirs. Error bars denote the standard errors of mean.

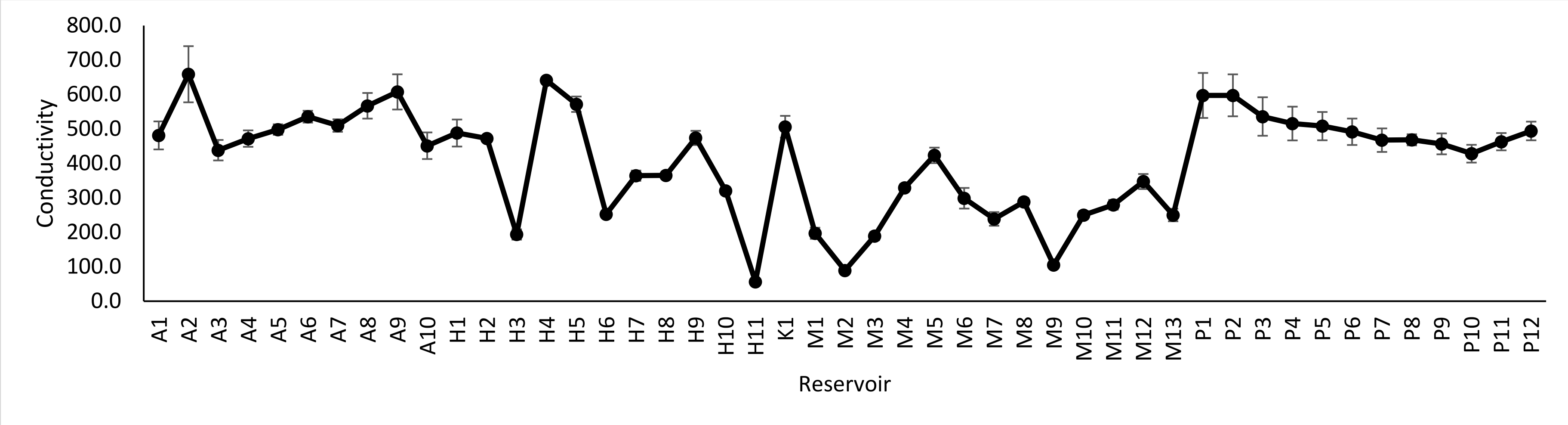

Figure 5.3. Variations of Conductivity (Con. in μS cm–1) in 47 reservoirs. Error bars denote the standard errors of mean.

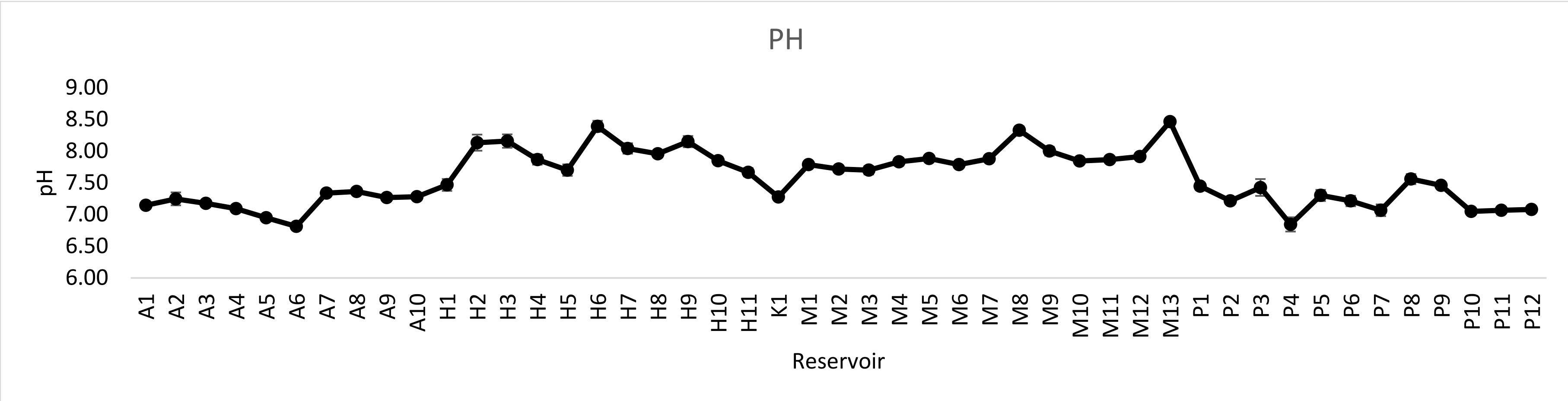

Figure 5.4. Variations of pH in 47 reservoirs. Error bars denote the standard errors of mean.

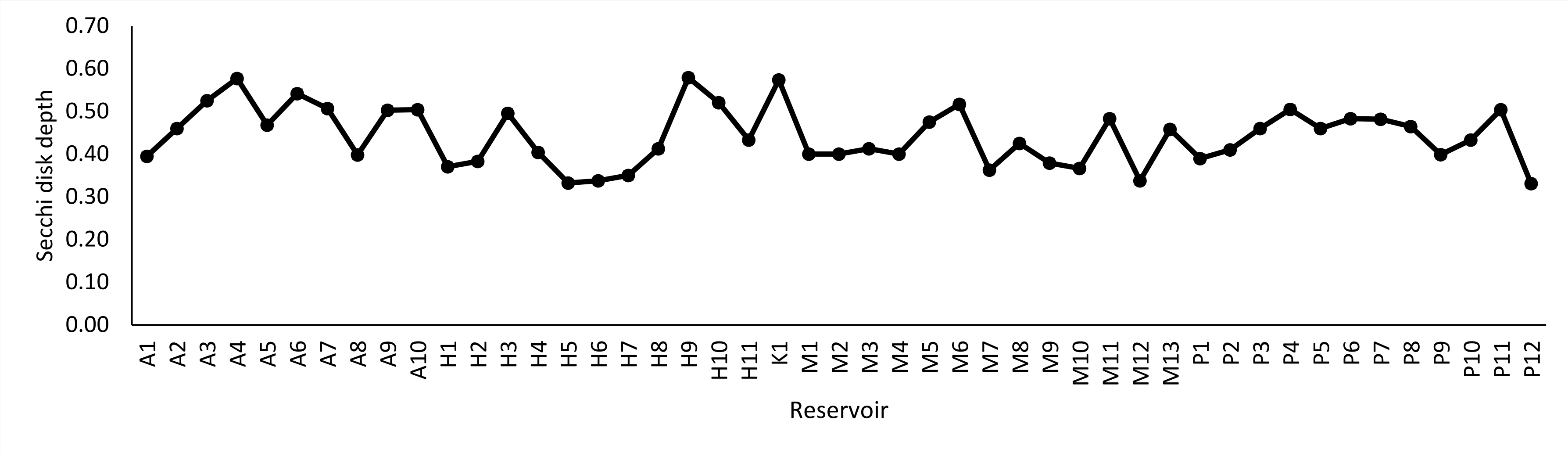

Figure 5.5. Variations of Secchi Disk Depth (SDD in m) in 47 reservoirs. Error bars denote the standard errors of mean.

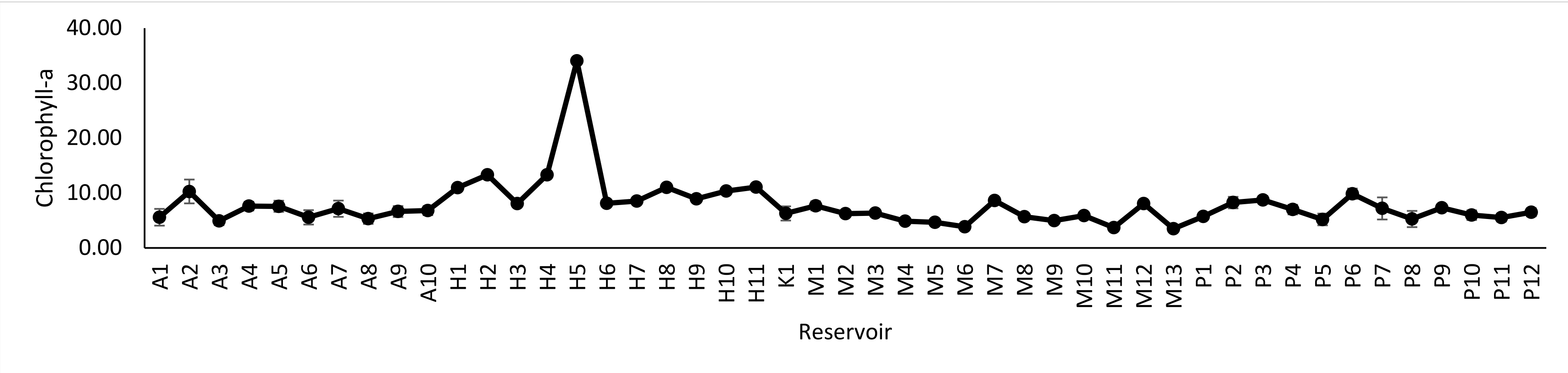

Figure 5.6. Variations of Chlorophyll-a (Chl-a in μg/L) in 47 reservoirs. Error bars denote the standard errors of mean.

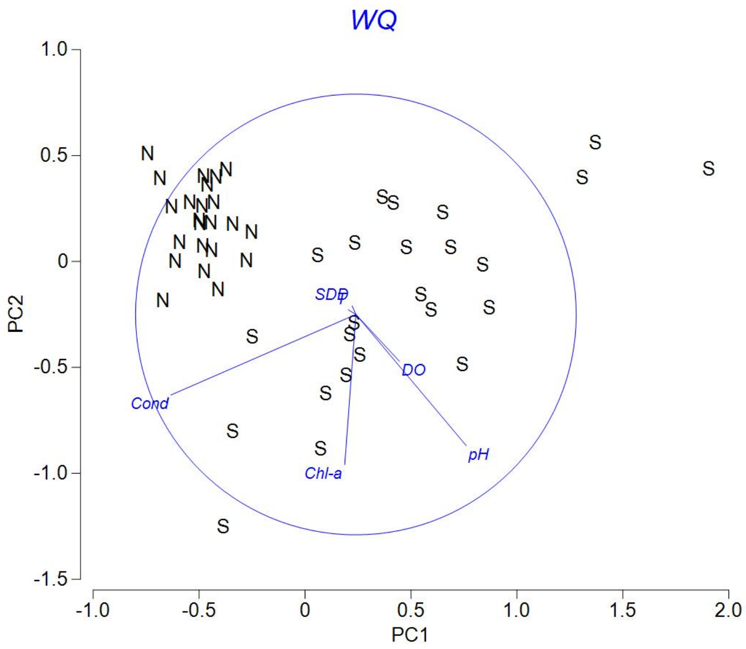

Figure 5.7. PCA plot of water quality (WQ). N and S stands for northern and southern reservoirs respectively

The PCA plot (Figure 5.7) clearly shows that northern and southern reservoirs are limnologically different. In the plot, northern reservoirs were clustered together with greatest influence of higher conductivity and lower pH values. Southern reservoirs were scattered in the opposite side depending on the influences by higher pH, and higher or lower conductivity or cholorophyll-a. Therefore, out of the measured water quality parameters, conductivity, pH and chlorophyll-a appear to be important for further investigations of variations in GFP yield for those reservoirs. However, there were no significant correlations between total GFP catch (kg ha^{-1} yr^{-1}) and measured water quality parameters (Table 5.7). Since the total catch was an aggregate from gill net bycatch, it was not truly representing the total harvest of the reservoirs. It is likely that with the development of specific gear to catch GFP, a clearer picture of limnological effects on yield may be revealed.

Table 5.7: Calculated Correlation values for each limnological parameter with the yield of three districts. P values are given at 95% confidence interval

Parameter	Correlation with the yield (r value)	(p value)
Temperature	0.147	0.20
DO	0.018	0.56
Conductivity	0.229	0.55
pH	-0.079	0.94
Secchi Disk Depth	0.038	0.86
Chlorophyll-a	0.288	0.83

Table 5.8: Calculated TSI±SE based on SDD and Chl-a of studied reservoirs.

Code	TSI (SDD)	Trophic State	TSI (Chl-a)	Trophic State
A1	73.17±0.13	Hypereutrophy	47.09±2.74	Mesotrophy
A2	71.14±0.29	Hypereutrophy	53.24±2.10	Eutrophy
A3	69.16±0.21	Eutrophy with algal scums	46.07±1.53	Mesotrophy
A4	67.91±0.39	Eutrophy with algal scums	50.46±1.02	Eutrophy
A5	71.12±0.55	Hypereutrophy	50.39±1.32	Eutrophy
A6	68.92±0.54	Eutrophy with algal scums	47.17±2.35	Mesotrophy
A7	69.63±0.13	Eutrophy with algal scums	49.67±2.05	Mesotrophy
A8	73.07±0.14	Hypereutrophy	46.85±1.75	Mesotrophy
A9	69.75±0.15	Eutrophy with algal scums	49.04±1.48	Mesotrophy
A10	69.71±0.12	Eutrophy with algal scums	49.31±2.04	Mesotrophy
H1	74.46±0.67	Hypereutrophy	54.07±0.09	Eutrophy
H2	73.96±0.62	Hypereutrophy	55.99±0.09	Eutrophy
H3	70.14±0.28	Hypereutrophy	51.06±0.5	Eutrophy
H4	73.18±0.57	Hypereutrophy	55.98±0.10	Eutrophy
H5	75.91±0.35	Hypereutrophy	65.20±0.10	Eutrophy with algal scums
H6	75.76±0.52	Hypereutrophy	51.16±0.05	Eutrophy
H7	75.23±0.51	Hypereutrophy	51.64±0.07	Eutrophy
H8	72.88±0.56	Hypereutrophy	54.12±0.22	Eutrophy
H9	67.91±0.33	Eutrophy with algal scums	52.06±0.21	Eutrophy
H10	69.47±0.45	Eutrophy with algal scums	53.51±0.08	Eutrophy
H11	72.20±0.64	Hypereutrophy	54.16±0.25	Eutrophy
K1	67.89±0.21	Eutrophy with algal scums	48.41±2.04	Mesotrophy
M1	73.67±1.16	Hypereutrophy	48.33±1.58	Mesotrophy
M2	73.36±0.66	Hypereutrophy	47.80±1.09	Mesotrophy
M3	72.95±0.71	Hypereutrophy	48.11±0.79	Mesotrophy
M4	73.24±0.32	Hypereutrophy	45.84±0.72	Mesotrophy
M5	70.89±0.69	Hypereutrophy	44.32±1.15	Mesotrophy
M6	69.57±0.37	Eutrophy with algal scums	43.26±0.64	Mesotrophy
M7	74.78±0.65	Hypereutrophy	51.44±0.52	Eutrophy
M8	72.39±0.39	Hypereutrophy	46.94±0.98	Mesotrophy
M9	74.12±0.62	Hypereutrophy	46.06±0.46	Mesotrophy
M10	74.51±0.38	Hypereutrophy	47.74±0.49	Mesotrophy

Code	TSI (SDD)	Trophic State	TSI (Chl-a)	Trophic State
M11	70.52±0.35	Hypereutrophy	43.06±0.59	Mesotrophy
M12	75.51±0.38	Hypereutrophy	51.15±0.14	Eutrophy
M13	71.30±0.39	Hypereutrophy	42.97±0.36	Mesotrophy
P1	73.46±0.25	Hypereutrophy	47.74±0.14	Mesotrophy
P2	61.70±0.32	Eutrophy with algal scums	51.23±1.24	Eutrophy
P3	71.27±0.43	Hypereutrophy	51.85±0.78	Eutrophy
P4	70.06±0.57	Hypereutrophy	49.58±1.23	Mesotrophy
P5	71.10±0.27	Hypereutrophy	46.53±2.04	Mesotrophy
P6	70.44±0.32	Hypereutrophy	53.01±0.93	Eutrophy
P7	70.43±0.28	Hypereutrophy	49.55±2.81	Mesotrophy
P8	71.00±0.33	Hypereutrophy	46.49±2.82	Mesotrophy
P9	73.05±0.17	Hypereutrophy	50.11±0.75	Eutrophy
P10	72.03±0.32	Hypereutrophy	48.01±1.44	Mesotrophy
P11	69.71±0.11	Eutrophy with algal scums	47.29±1.28	Mesotrophy
P12	75.78±0.22	Hypereutrophy	48.88±1.11	Mesotrophy

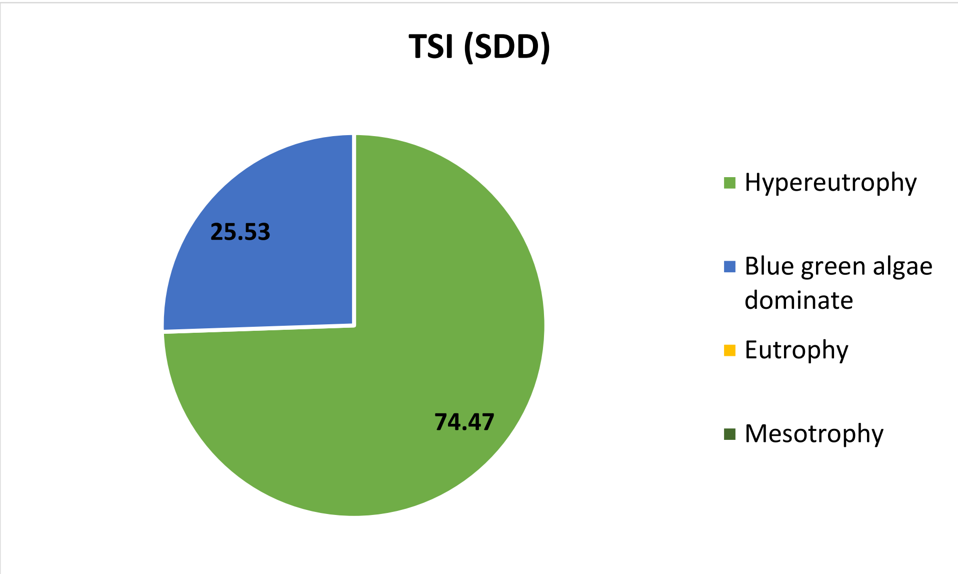

Figure 5.8. Percentages of trophic state types on the basis of SDD

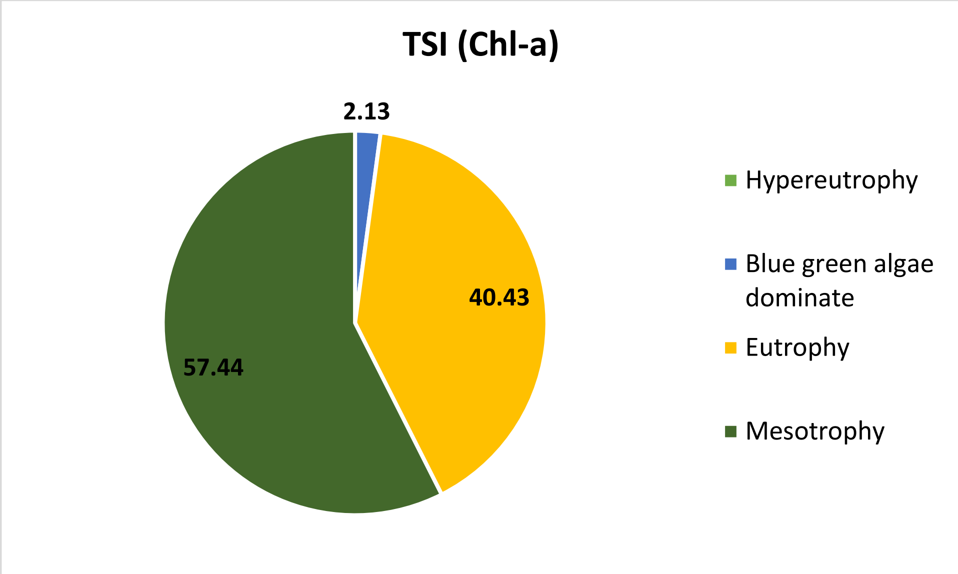

Figure 5.9. Percentages of trophic state types on the basis of Chl-a

Since the nutrient state of reservoirs influences fish yields, the sampled reservoirs were trophically categorized (Table 5.8). All reservoirs sampled were eutrophic, and of those, 74.47% were in the hyper-eutrophic state according to the trophic classification based on SDD (TSI SDD) (Figure 5.8). However, according to the trophic classification based on the chlorophyll-a (TSI Chl-a) content, 42.56% were eutrophic (Figure 5.9), and the majority were mesotrophic. As TSI SDD was greater than TSI Chl-a, this suggests relative abundance of non-algal particulate matter and possibly colour dominated underwater light attenuation. (Carlson, 1977, Carlson and Simpson, 1996) as in the case of non-perennial reservoirs of Sri Lanka (Jayasinghe et al., 2005b).

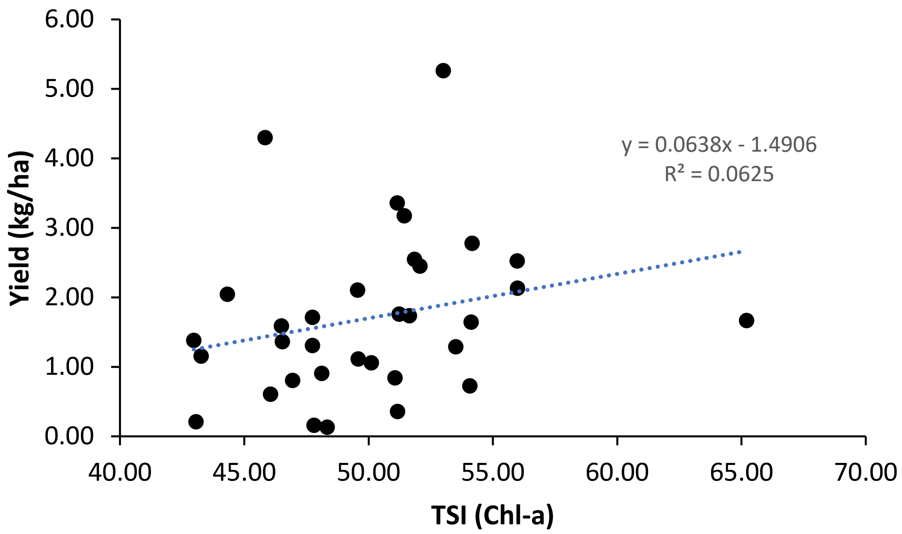

Figure 5.10: Variation of yield with TSI (Chl-a) of reservoirs in 3 districts Hambanthota, Monaragala and Puttalam.

There was a positive trend between TSI Chl-a and the yield of GFP in reservoirs with catch data available, although the relationship was not significant. With the development of specific gear to catch GFP, and with more catch data from more reservoirs any relationship may be more evident.

Table 5.9: Selected morphometric characteristics measured for 24 reservoirs

Code	Area (ha)	Littoral Extent (m)	Shoreline Length (km)	D_L	R_{LA} (km/ha)
H1	871	19.42	20.74	0.20	0.02
H2	567	17.30	17.47	0.21	0.03
H3	516	16.50	24.12	0.30	0.05
H4	486	13.61	15.32	0.20	0.03
H5	381	14.21	12.76	0.18	0.03
H6	263	9.70	12.02	0.21	0.05
H7	140	12.31	8.55	0.20	0.06
H8	80	14.34	3.92	0.12	0.05
H9	80	11.74	4.58	0.14	0.06
H10	80	11.10	3.67	0.12	0.05
H11	70	9.66	4.93	0.17	0.07
M1	560	15.30	21.75	0.26	0.04
M2	375	12.48	15.55	0.23	0.04
M3	262	10.14	9.30	0.16	0.04
M4	226	9.98	8.73	0.16	0.04
M5	210	18.11	11.42	0.22	0.05
M6	150	15.97	3.68	0.08	0.02
M7	100	15.40	4.45	0.13	0.04
M8	80	8.95	3.22	0.10	0.04
M9	80	7.57	6.54	0.21	0.08
M10	70	8.87	4.63	0.16	0.07
M11	50	6.69	7.18	0.29	0.14
M12	145	7.52	4.27	0.10	0.03
M13	80	16.31	3.15	0.10	0.04

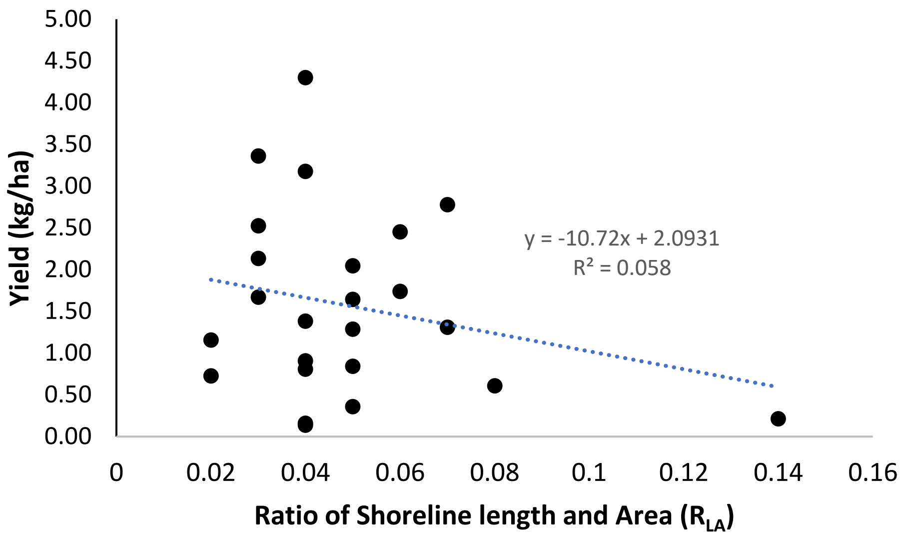

Figure 5.11: Variation of yield with ratio of shoreline length (R_{LA}) of 24 reservoirs in Hambanthota and Monaragala districts

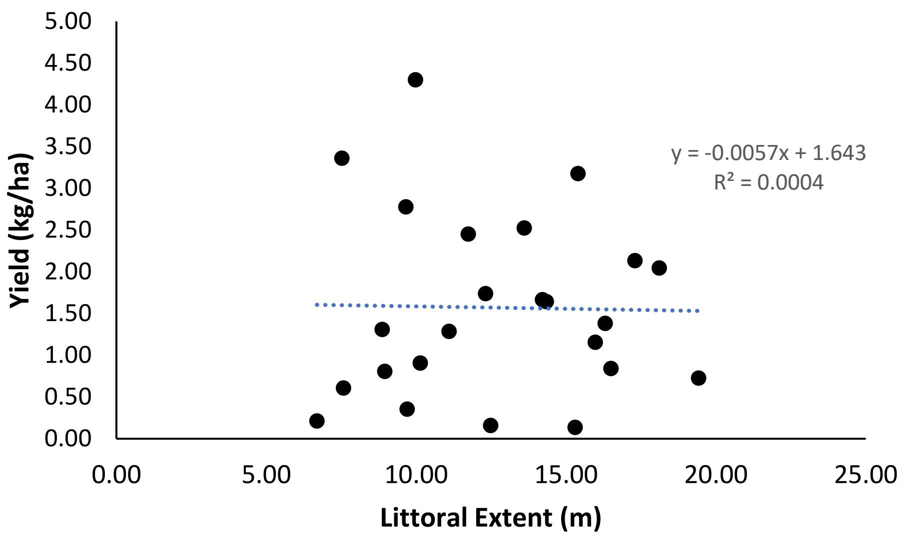

Figure 5.12: Variation of yield with littoral extent of 24 reservoirs in Hambanthota and Monaragala districts

Measured reservoir morphometric characteristics (Table 5.9) also showed non-significant trends with GFP yield in the selected 24 reservoirs (Figures 5.11 and 5.12). In the same way, organic matter content of the sediment and Shannon-Weiner index calculated based on the macrobenthos diversity within the littoral area showed non-significant trends with GFP yield in selected 24 reservoirs (Figures 5.13 and 5.14).

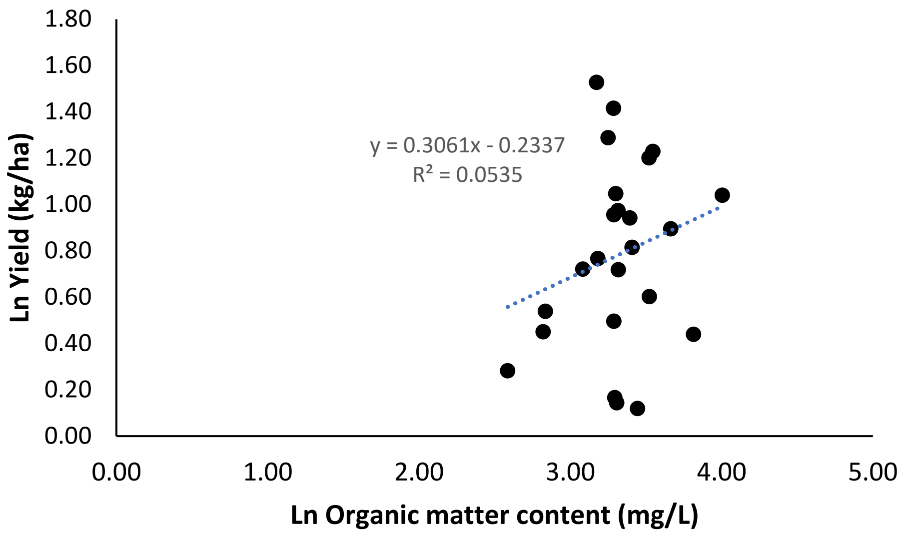

Figure 5.13: Variation of yield with organic matter content in the littoral area of 24 reservoirs in Hambanthota and Monaragala districts

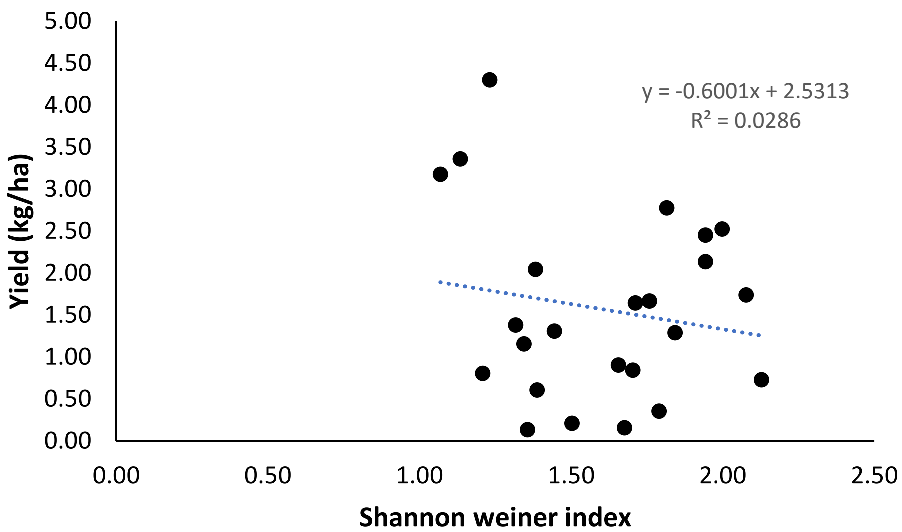

Figure 5.14: Variation of GFP yield with Shannon-Weiner index calculated based on the macrobenthos diversity within the littoral area of reservoirs in Hambanthota and Monaragala districts.

5.5 Conclusions and Recommendations

It is evident from this preliminary investigation that the limnological condition in reservoirs between northern and southern regions have remarkable differences that might affect the GFP and other finfish production. Therefore, further research is needed covering a wider geographical area. Increasing the sample size is also important in terms of both the number of reservoirs and the number of sampling cycles or both. A significant constraint of this brief study was the lag effect of stocking and subsequent production of GFP. It is likely that the GFP require more than 12 months to reach a harvestable size. Research over a longer time frame will be necessary to fully determine the effects of stocking practices on subsequent yield. Further to this, is the complicating factor of protracted stocking of PLs. Ideally, for research purposes, all study reservoirs would be stocked at once. A method for tagging PLs to enable each stocked cohort to be followed through time would be a useful research tool.

Since the total catch of GFP was an aggregate of gillnet bycatch, it was not truly representing the total GFP population of the reservoirs. Therefore, it is important to find or develop a specific gear that targets GFP efficiently.

Reservoir morphometry, sediment organic matter and littoral macrobenthos diversity are variables worthy of further investigation in relation to GFP catch. In addition to examining more variables, the research must also increase sample size to enable meaningful relationships to be revealed. To achieve this, there are logistical and labour issues involved in covering a wider geographical area, with the reservoirs sometimes hundreds of kilometres apart. More research assistants will need to be involved to cover duties over disparate areas. As Sri Lankan CBF involves several finfish species in addition to GFP, the macrobenthos are potentially food items of many species. As such, examination of reservoir food webs must necessarily include the finfish. Gathering of such holistic information will be necessary for effective management of culture-based fisheries of GFP in reservoirs of Sri Lanka.

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6 Activity 3. Evaluation of giant freshwater prawn fishing techniques and equipment

6.1 Abstract

Giant Freshwater Prawn (GFP) is a high valued culture based fishery (CBF) product for Sri Lanka, with immense export potential, commanding a high price, and providing high margin revenue for the fishers. However, to the date the GFP fishery in Sri Lanka has generated low yields and low retrieval rate in comparison with other CBF fish species, due to higher early mortality and ineffective harvesting techniques. To assess alternative harvesting techniques for GFP, three standard crustacean traps were trialled (opera-house trap, crab-pot and bait trap). The experiment included treatments with and without bait and deployed during the day (8.00 am to 4.00 pm) or night (5.00 pm to 7.00 am) in a 0.5ha pond at the Wayamba University of Sri Lanka from October to December 2018. Tilapia, GFP and Barbs were present in the pond. The bait trap was highly selective to barbs due to its small (2.5cm) opening and the crab pot failed to trap any species. GFP was most successfully captured in the baited opera-house trap deployed at night, with a mean biomass of 88.7 ± 20.3 g, carapace length of 6.7 ± 0.5 cm and a retrieval rate of 33.33%. Further studies in reservoirs and using additional trap designs will be necessary to more fully assess optimal fishing techniques for the Sri Lankan GFP fishery.

Keywords: Reservoirs, Culture based fishery, *Macrobrachium rosenbergii*, Opera-house trap

Introduction

Sri Lanka has a vast network of freshwater ecosystems including more than 12,000 reservoirs and around 30 rivers and streams. These ecosystems comprise two basic types; (i) natural and manmade closed water bodies, including irrigation reservoirs, where culture-based fisheries (CBF) have developed, and (ii) natural and manmade open water bodies such as rivers, and flood plains which are subject to traditional capture based fisheries. Inland fish production in Sri Lanka is primarily sourced from culture based fisheries, which are essentially confined to man-made-reservoirs (Amarasinghe and Wijenayake, 2015), contributing around 93% of the total inland fisheries and aquaculture production of the country (MFAR, fisheries statistics). The giant freshwater prawn (GFP) (*Macrobrachium rosenbergii*), is a highly valued component of Sri Lankan CBF with strong export potential for international markets (Tidwell *et al*., 2005).

Although the potential of CBF for GFP in Sri Lanka's reservoirs is high, as a bycatch of finfish harvesting, the full potential is not being realised. Currently under the legal provisions of the Fisheries and Aquatic Resources Act (FAR Act, 1996) fishing gear is restricted to gillnets with a mesh size of above 8.5 cm as part of the management of CBF. Such gillnets are aimed at targeting the finfish species including Tilapia, Indian and Chinese major carps. Other fishing gear, such as dragnets, seine nets, monofilament gillnets and trammel nets are prohibited in inland waters, and their use is categorised as illegal. GFP are captured by the gillnets, although there is a high incidence of damage to the prawns, rendering them of lower value. It is assumed by fishers that GFP could be caught more effectively and with less damage, if there was a specific gear used to target the prawns.

Traps are rarely used in the Sri Lankan CBF for capture of GFP and the practice is limited to just a few fishermen in some districts, and use is seasonal. This is likely due to fishers' inexperience with GFP and lack of exposure to trap types that might be used. Despite the trend in CBF practices to stock giant freshwater prawn (*Macrobrachium rosenbergii*) in view of its high market value, the recapture rates are relatively low (Jutagate and

Rattanachai 2010; Sripatrprasite and Lin 2003; Jindapun and Sungkapaitoon 2006; Chandrasoma et al. 2015). Traps are used in other Southeast Asian countries such as Thailand, Cambodia and Vietnam for harvesting of GFP, so there is precedent and technology that can be applied in Sri Lanka to increase the GFP capture. This paper investigates alternative fishing gear for application to GFP fishery in Sri Lanka.

6.2 Materials and Methods

The study was carried out between October 2018 and December 2018 at Makandura premises, Wayamba University of Sri Lanka. Three types of fishing gear were assessed in the study, representing readily available recreational fishing traps from Australia, known to catch crustaceans, including crabs and crayfish. These included the Opera-house trap (OH), so-called because of its shape that mimics the Sydney Opera House, a circular Crabpot (CP) generally used for catching swimmer crabs (Portunidae) and a rectangular, collapsible bait trap (BT) (Figure 6.1). The experiment was conducted in an earthen research pond (0.5 ha), which had previously been stocked with GFP and tilapia. The research pond is known to also support a population of Barbs, *Puntius* species. Four of each trap were deployed under two levels of two treatments, baited (roasted coconut) and non-baited and at two different times; day (8.00 am to 4.00 pm) and night (5.00 pm to 7.00 am). Cluster analysis was applied to the catch data.

6.3 Results and Discussion

Both the Opera-house and bait traps were successful in capturing GFP, tilapia and Barbs (Figure 6.2). The crab pot was not effective, catching none of these species. The highest catch of GFP was achieved in the baited Opera-house trap deployed at night; with a mean biomass of 88.7 ± 20.3 g and carapace length of 6.7 ± 0.5 cm and a retrieval rate of 33.33%.

The bait trap was highly selective to barbs due to its smaller opening (25 mm) in comparison with the other traps, and the crab pot was considered unsuitable for GFP as it failed to catch any prawns. Standard length data for captured fish are presented in Table 6.1.

Cluster analysis revealed that baited traps were more effective than non-baited (Tables 6.2 and 6.3, Figure 6.3). With respect to the time of deployment, fishing at night was more effective for GFP. This result is supported by behavioural data which reveal that adult prawns are active at night (Ling and Merican, 1961; Nakamura, 1975), and inactive during the day (John, 1957; Karplus and Harpaz, 1990).

In contrast juvenile prawns exhibit nocturnal swimming activity, probably to take advantage of pelagic food resources, whereas during the day they settle on the bottom and crawl (Scudder et al., 1981). The diet of prawn larvae is principally zooplankton (mainly small crustaceans), very small worms, and the larval stages of other crustaceans (New and Singholka, 1985). Both post larval and adult *M. rosenbergii* are omnivorous, eating algae, aquatic plants, molluscs, aquatic insects, worms and other crustaceans (John, 1957; Ling, 1969).

Figure 6.1. Three traps trialled for capture of giant freshwater prawns. Bait trap (BT, top left), Crab Pot (CP, top right) and Opera House Trap (OH, bottom left).

Table 6.1. Descriptive statistics of Fish catches

	Mean (mm)	SE of Mean (mm)	Min (mm)	Max (mm)
Tilapia-D	52.97	5.94	18.53	117.64
Tilapia-N	74.73	2.28	51.26	131.66
Tilapia-NB	40.87	7.85	18.53	117.64
Tilapia-B	74.73	2.28	51.26	131.66
Barbs-NB	19.34	0.25	17.07	21.59
Barbs-B	27.72	0.45	22.27	32.49
Barbs-D	25.89	0.33	19.54	32.15
Barbs-N	27.55	0.71	22.88	32.93

D - Deployed in the day, N - Deployed at night, B - Baited, NB - Not baited

Figure 6.2. Traps with catches and measuring morphometrics. (a) Non-baited Opera house trap, (b) Non-baited Bait trap, (c) Baited Opera house trap, (d) measuring the standard length of Barb and (e) Tilapia, and (f) measuring the carapace length of GFP.

Table 6.2. Coefficients of clusters.

Cluster	Tilapia	Barbs	GFP
1	-0.2376	-0.5325	-0.2886
2	-0.3639	1.5521	-0.2886
3	2.993	-0.3956	3.1754

Table 6.3. Cluster components of k-mean clustering.

Cluster 1	Cluster 2	Cluster 3
BT-NB-N	OH-NB-D	OH-B-N
BT-B-D	CP-NB-D	
BT-B-N	BT-NB-D	
	OH-NB-N	

Cluster 1	Cluster 2	Cluster 3
	CP-NB-N	
	OH-B-D	
	CP-B-D	

BT- Bait trap, OH- Opera house trap, CP- Crab pot

B- Baited, NB- Not baited

N- Deployed at night, D- Deployed in day

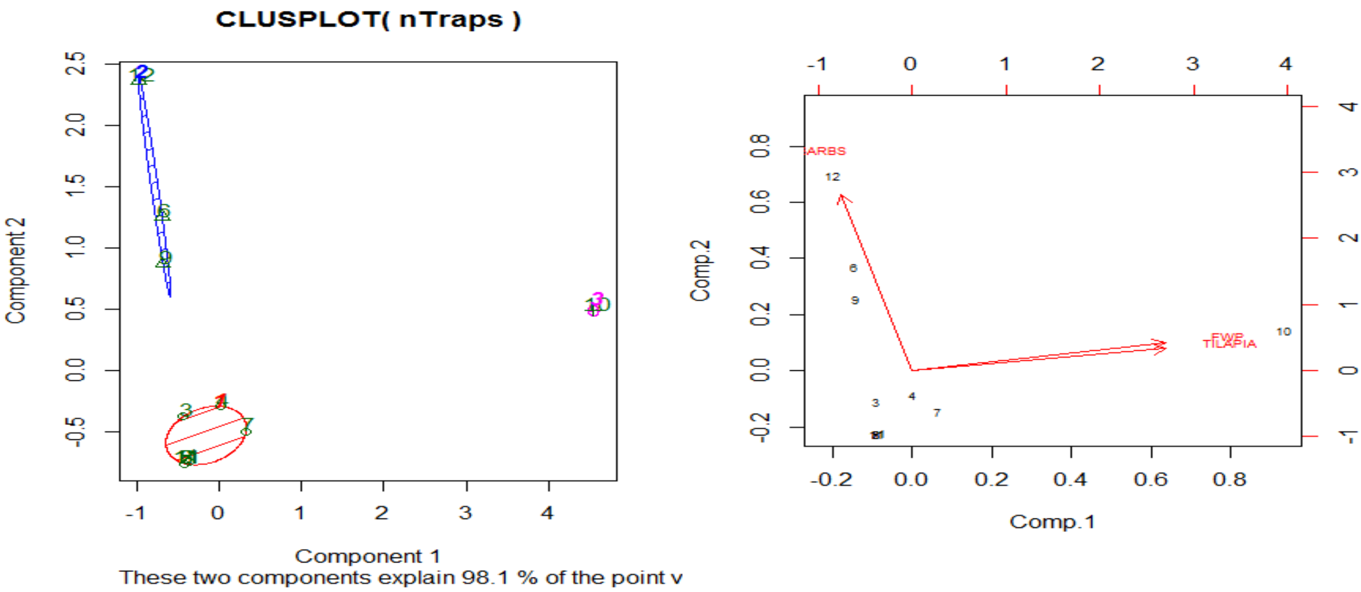

Figure 6.3. Cluster plot of trap experiment

Although the traditional fishing method using gillnets is relatively inefficient for the capture of GFP, it is size selective, permitting juveniles to escape thus preventing over-exploitation of the fishery. In the development of traps that target GFP, consideration must be given to such size selectivity, in accordance with minimum acceptable market size.

In the north-western province of Sri Lanka, there is some use of traditional wicker traps (*karaka* and *kamana*) but their effectiveness for catching GFP is unknown. In Thailand harpooning is practiced for GFP fishing, which is selective for large sized prawns, but will negatively affect the selling price due to the damage caused.

To date, GFP production within culture-based fisheries generally experience low yields and low retrieval rates, which have dampened enthusiasm for GFP in comparison to other CBF fish species (De Silva, 2016; Jutagate and Kwangkhang, 2015). The initial CBF experience with GFP in Sri Lanka was unsuccessful with a contribution of only 0.7% of fish harvest (Wijenayake *et al*., 2005; Pushpalatha and Chandrasoma, 2010). However, consecutive findings of Pushpalatha *et al.* in 2015 (0.3%) and in 2017 (ranges from 0.6 to 1.8) revealed an increase of recapture of GFP in Sri Lankan reservoirs. More recently, a study by Rajeevan *et al.* (2017) reported a comparatively higher recapture rate of 2.48% in the reservoir gillnet fishery in Sri Lanka.

A recapture rate (proportion of prawns caught relative to the number stocked as PL's) of less than 3% is far less than required to achieve sustainability, given the relatively high cost to produce the prawn PL's in government hatcheries. An acceptable recapture rate would be 5 to 10%, which is likely only achievable with development of specific fishing gear and techniques that target the GFP.

Current practice, in which prawns are captured in the gillnets – designed for capture of finfish, results in low catch and damaged prawns. The gillnet is also not suitable to set to the ground in deeper water or where there is submersed vegetation, trees and logs. Such areas may support higher concentrations of prawns that would support greater catch if fishing gear suited to that environment were available. Traps are likely to meet this need.

So there is clear need for new gear and fishing technique that are economically viable, non-destructive and sustainable. Studies in reservoirs under prevailing natural conditions will be needed in future research of traps for the Sri Lankan GFP fishery.

6.4 Conclusions and Recommendations

Information available on *M. rosenbergii* culture-based fisheries in Sri Lanka suggests that the fishery has achieved considerable success, especially in terms of economic benefits, even though the recapture rate is low compared to stocked fish species. Despite considerable success in CBF development based on *M. rosenbergii*, there is a lack of information on appropriate gear to increase the catchability. The experiment performed revealed some promising results in catching undamaged *M. rosenbergii* using the Opera-house trap. More comprehensive studies are necessary to examine different trap designs, baits and trap deployment within the reservoir environment to achieve optimal catch of prawns within a proper legal approach and that ensures the sustainability of the GFP fishery.

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7 Activity 4. Socio-economic study of the giant freshwater prawn CBF value chain

7.1 Abstract

Political, economic, social and technical issues all influence the development of GFP marketing in a developing country like Sri Lanka and there is a need for these to be taken into account in fostering and planning appropriate market development. Fish marketing chains in South Asia, especially in Sri Lanka, involve a number of intermediaries between fishers and consumers, which often increase the market margin for intermediaries but not for the fishers. The current study was conducted to examine means to improve the socioeconomic conditions of poor fishers by increasing income from their available water resources through the promotion of improved and sustainable freshwater prawn CBF practices. Roles and inter-relationships of political, economic, social and technical factors in the value chain of GFP within selected reservoirs was analysed using integrated PEST-SWOT analysis. Preliminary screening was done using cluster analysis. The livelihoods of fishers depending on the GFP is primarily driven by political and economic wellbeing and influences, which are intrinsic and extrinsic. It is easier to manage and implement the legal enforcements with fisherwomen than fishermen. The relationship of revenue with stocking cost and recapture rate is explained as: $Revenue = -70363E^5 + 3.7124E^7\ (Recapture\ rate) + 3.0465(Stocking\ Cost)$. Further, more detailed studies are needed to fully examine the complex market strategies deployed in the Sri Lankan GFP supply chain.

7.2 Introduction

Culture based fisheries (CBF) of giant freshwater prawn (GFP) offer promise to improve human livelihoods and maintain a steady rise in contributions to GDP, in Sri Lanka. Within the overall agriculture-based economy of the country, the contribution of fish production holds good promise for creating jobs, earning foreign currency and supplying protein. A large number of people, many of whom live below the poverty line, find employment in the domestic fish marketing chain in the form of farmers, collectors, processors, traders, intermediaries, day labourers and transporters. The giant freshwater prawn (*Macrobrachium rosenbergii*), is a highly valued product for international markets (Tidwell *et al*., 2005). In Sri Lanka over recent years, GFP have been produced as post-larvae in government operated hatcheries and then released into many of the country's freshwater reservoirs as part of a culture-based fishery management strategy. Almost all prawns harvested from the reservoirs are exported, particularly to the United States, Japan, Australia and Europe. The quantity of prawn exports remains rather obscure because export statistics often do not distinguish between prawns and shrimp. Although tiger shrimp (*Penaeus monodon*) is the major export species, freshwater prawns account for about 8 to 10% of the export volume, and this proportion is expected to rise with the increasing expansion of GFP CBF into more reservoirs in different parts of Sri Lanka.

Fish supply chains in South Asia, especially in Sri Lanka, involve a number of intermediaries between fishers and consumers, increasing the market margin for intermediaries but not for the fishers. Globally, marketing of fish is quite difficult because of limited and/or congested market infrastructure and facilities (FAO, 2012). Poor infrastructure and scarcity of credit are two main (but not limited to) reasons for the presence of a number of these intermediaries. With the improvement of infrastructure and better availability of credit in South Asia and especially in Sri Lanka, it is now necessary to find an alternative or shorter supply chain to provide improved benefits to the fishers and make the prawn marketing system more sustainable.

So far little attention has been applied to critical examination of the supply chain of the aquaculture/fisheries products in Sri Lanka. Issues for possible technological and/or institutional intervention must be addressed so add value to the supply chain and the products to improve the livelihoods of fishers.

The overall goal of this project was to improve the socioeconomic conditions of target groups of poor male and female fishers by raising income from their available water resources through the promotion of improved and sustainable freshwater prawn CBF practices.

7.3 Materials and Methods

The study was carried out between August 2018 and July 2019 on the supply chain of freshwater prawns from selected reservoirs. Three methods of data collection were used: semi-structured interviews, Focus Group Discussions (FGDs), and Large Group Discussions (LGDs). A total of 190 (10 for each reservoir) face-to-face semi structured interviews (composed of closed and open-ended questions) were conducted with fishers to gather in-depth information regarding strength, weakness, opportunity and threats (SWOT) of political, economic, social and technical factors (PEST) in the prawn supply chain system, which will be used in integrated PEST-SWOT analysis. The specific objective of this activity was to analyse the prawn supply chain before and after the implementation of ACIAR project activities.

For these interviews, in each reservoir, fishers, collectors, dealers and company agents were included. A list of topics and possible questions for the participants were developed before the start of the FGDs/LGDs to ensure some structure and direction in the discussions. More emphasis was given to clarifying issues that seemed unclear from the semi-structured interviews. FGDs/LGDs also served as the means to triangulate the data obtained from the semi-structured interviews.

The collected data were transformed in the Rickter's scale with respect to the SWOT nature; transformed in to PEST wellbeing data, data were analysed using cluster analysis (complete and average), which provides efficient information in multivariate condition. A specific hypothetical bioeconomic model is being built for the benefit of fisherfolks dependent of GFP fishery; the assessment will include local consumption of GFP and external markets.

7.4 Results and Discussion

7.4.1 PEST in Sri Lankan reservoirs

Political, economic, social and technical (PEST) are all issues influence the development of the GFP supply chain and need to be considered in seeking to identify improvements. For example, even if biological, technological and environmental conditions are favourable for the development of the GFP supply chain, it may fail if social and economic factors are unfavourable. The development of the GFP supply chain calls for a holistic approach accounting for all of the factors indicated in Figure 7.1.

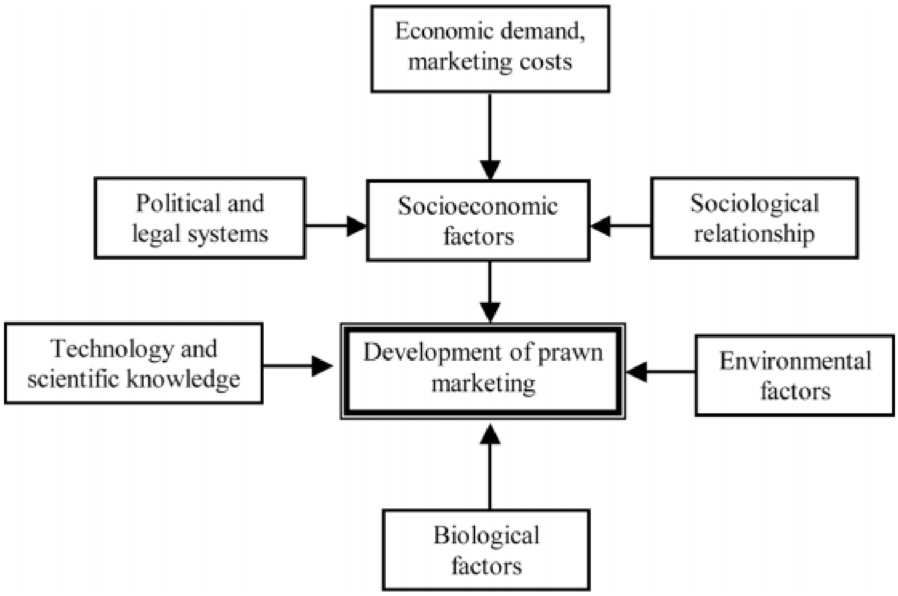

Figure 7.1. Factors influencing the development of the GFP supply chain in Sri Lanka

7.4.2 Influences of political factors in GFP CBF in Sri Lanka

In Sri Lankan reservoirs, influences of political factors are a common phenomenon. The GFP fishery has benefited from several political interventions, including; (a) central government of Sri Lanka and provincial governments providing free boats and nets as subsidies to encourage communities to become involved in inland fisheries, which provides a major cost reduction in fishing operation, (b) GFP post larvae are supplied from government operated hatcheries at no cost, for stocking to the reservoirs, in an annual schedule across the island, and (c) a legal framework has been established to identify and prevent illegal reservoir fishery activities, implemented by government extension officers. This exposes the reservoir fisheries to political influences that may bias allocation and distribution of the government subsidies, potentially negatively impacting some individual reservoirs or personnel, and therefore negatively affecting development of GFP CBF.

7.4.3 Influences of economic factors in GFP CBF in Sri Lanka

Most of the fishery societies that operate at individual reservoirs are under poor management, due to lack of long standing management structure and strategy, and poor financial management and funding arrangements. Their dependency on government subsidies and NGO (Non-Government Organisation) aid is high. A limited number of reservoirs have implemented co-management strategies to a good standard, having an effective operational management system for decision making and controlling the society activities, and financially backing themselves through the allocation of a proportion of revenue from daily catches landed. Such self-replenishing economy has led to a sustainable fisher community and even piqued the interest of politicians and government to emulate the experience elsewhere.

7.4.4 Influences of social factors in GFP CBF in Sri Lanka

Most inland fishers of Sri Lanka are involved in multiple occupations for their livelihood. Fishing is generally a part-time activity, as necessitated in drought conditions when fishing is not possible, and the need for more income to account for day to day living expenses.

Typically, a fisher sets nets through the evening, returning home for some sleep, and then goes to the reservoir in the early morning to retrieve the nets, collect the catch and sell to the vendors. Afterwards, through the day they are involved in other labouring activities, cattle raising and farming. Inland fishers of Sri Lankan reservoirs nowadays consist of both those originally employed in coastal fisheries who have resettled near the reservoir, and rural villagers and farmers who have learned to fish by experience over the past three decades since CBF was introduced. The actual fishers have traditionally been mostly men, with women more likely to be involved in pre-harvest (Harper et al., 2013; Weeratunge et al., 2010) and post-harvest (Bennett, 2005) activities. The women have been proactive in forming fisher-women societies, as a sub-group within the broader fishery society of the reservoir.

Fishers generally have a poor education background, having mostly dropped out of school by grade 9 and not achieved the general certificate of education (GCE) ordinary level. This has implications for the monitoring, control and surveillance of CBF, with onus on the government extension officers. The attitude of the fishers varies from others in the community and they are highly susceptible to involvement in illegal, anti-social activities and political violence.

Sri Lankan reservoirs are common pool property which comes under the regime of a restricted area, where multiple stakeholders share the interests and benefits. Farmers rely on the reservoir for irrigation, fishers for fishing and villagers for household uses. Management of Sri Lankan reservoirs is at risk due to disputes regarding the water resources particularly when water becomes limited in the dry season. Even government has problems in resolving issues due to the unreliability of the rainfall.

7.4.5 Influences of technical factors in GFP CBF in Sri Lanka

Fishing is a purely technical activity advantaged by experience, and characterised by some exclusivity as the knowledge of fishing is carried by heredity through generations of fisher families. With the implementation of CBF in Sri Lanka, there has been an expansion of fishing as a livelihood, but the dissemination of necessary technical and scientific knowledge of fishing and fisheries, and implementation of legal enforcements has been difficult due to the low education level and attitude of those most likely to be engaged. There is a significant behavioural difference observed between the two types of fishers; the experienced fishers who have migrated from coastal locations, and local farmers who have converted to fishing. Generally, the converted farmer fishers show more interest in learning as evidenced by their predominance at workshops and technical training programmes conducted by NAQDA (National Aquaculture Development Authority of Sri Lanka).

7.4.6 PEST-SWOT analysis

The livelihoods of fishers depending on the GFP is primarily driven by political and economic wellbeing and influences, which are both intrinsic and extrinsic (Figure 7.2). The issue of GFP post larvae (PL), boats and nets being provided at no cost by central and provincial governments, plays a major role in GFP CBF development. The selection of reservoirs to be subject to CBF may be influenced by political issues. Reservoirs which have established effective fishery societies, are financially sustainable and sound in membership, intrinsically adhere to political status quo. Figure 7.2 shows the significance of the interrelationship between political and economic wellbeing of the fishery society in Sri Lanka, and less so for the technical.

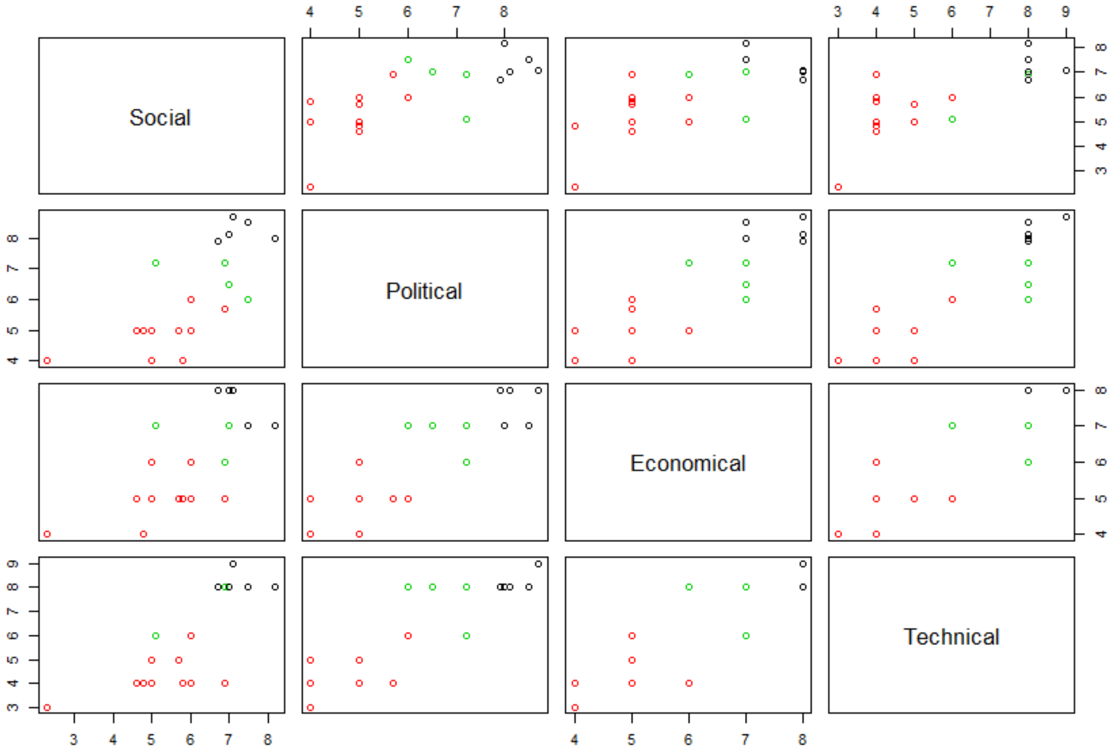

Figure 7.1. Correlation plot of PEST factors; (black- Cluster 1, green – cluster 2 and red- cluster 3)

According to the cluster analysis, both average and complete clustering produced three homologous clusters (Table 7.1). The reservoirs included into the first cluster have good PEST wellbeing and have potential for future development of GFP CBF (Table 7.2).

Table 7.1. Cluster components of k-mean clustering.

Cluster 1	Cluster 2	Cluster 3
Vijayakatupotha	Karavitagaraya	Devalahandiya
Kalawewa	Kachichimaduwa	Mahauswewa
Rajaganaya	Kottukachchiya	Tabbowa
Nuwarawewa	Viluka	Angamuwa
Thuruwila	Eluwankulama	
	Pahariya	
	Saliyawewa	
	Thanguswewa	
	Mahawilachchiya	
	Magallewewa	

Reservoirs that fall in to cluster 3 are comparatively poor in gross PEST wellbeing status (Table 7.2). The social wellbeing score of all selected reservoirs, was comparatively lower than political, economic and technical scores, attributable to grievances within the fisher folk and among the other stakeholders of the reservoir such as agrarian society and villagers depend on the reservoir for irrigation, which leads to poor management, and results in poaching, illegal fishing and social conflicts etc.

Table 7.2. Coefficients of clusters

Cluster	Political	Economical	Social	Technical
1	0.894	0.8919	0.67925	0.9444
2	-0.7437	-0.718	-0.3782	-0.7777
3	-1.3526	-1.5654	-2.7094	-1.5

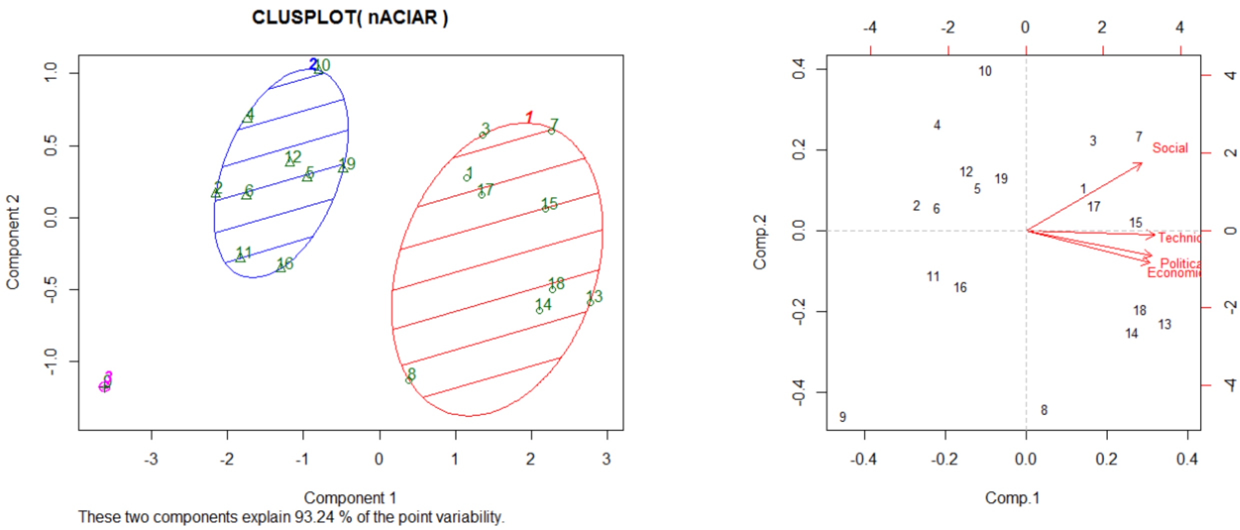

Figure 7.2. Cluster plot of PEST analysis

Participation of women in GFP fishery: special case Tabbowa reservoir

Fishing activities, particularly in the primary sector, is traditionally still seen as a male domain (Choo et al, 2008; Frocklin et al., 2013; Williams, 2008). In fact, women, including those who catch fish for a living and wives of fishermen who directly or indirectly relate to her husband's activities, have important roles and make significant contributions to the fisheries sector. The important role of women in the fisheries sector is evidenced by the findings in number of studies (Harper et al., 2013; Weeratunge et al., 2010).

Figure 7.3. Contribution of women in GFP CBF at Tabbowa reservoir in Sri Lanka. a)

women fishers b) GFP catch made by fisherwomen (3 canoes- 6 fisherwomen).

There has been an increase in the number of women involved in the fisheries sector throughout Asia. Harper et al. (2013) noted that about 33% of the workforce in the field of rural aquaculture in China is women, while they represent about 42% and 80% in Indonesia and Vietnam. FAO data in 2014 also showed that 19% of all people who are directly involved in the fishery primary sector activities such as fishing and aquaculture are women. However, in the secondary sector of fisheries, especially in small-scale fisheries, almost half of the workforce is women (FAO, 2016). Fisherwomen are predominantly engaged in pre-harvest (Harper et al., 2013; Weeratunge et al., 2010) and post-harvest (Bennett, 2005) activities.

Fisherwomen at Tabbowa reservoir fish seasonally, when the catch availability is high. Fisherwomen return 15 to 30% of the total catch, which is significant in that they represent only 15 to 20% of fishing effort relative to the men. It is generally easier to manage and implement the legal enforcements to the fisherwomen.

Even though women appear to have an important role in the fisheries sector and have potential, they still face a number of constraints that can reduce their access to fisheries resources and assets. For instance, they are often low-paid or unpaid with unofficial status (FAO, 2016). Limitations on the roles for women in the fishing value chain impacts on their incomes, and most of them are still poor. This poverty then brings consequences on the survival of not only women but also families. According to Weeratunge et al. (2010), gender disparities affect the livelihoods of women and the entire household and community. This is a barrier to access to financial resources and policy support for these women.

Moreover, since fishing is regarded as an activity with a high level of uncertainty, fisherwomen can also be impacted by the uncertainty. As argued by Anna (2012) fisherwomen face insecurity and risks in conducting their roles, not only in terms of environmental risks but also competition in fishery markets. These problems show that fisherwomen’s significant roles have not correlated fully to their life improvement. Hence, there is a need to transform their significant roles to economic empowerment. For that reason, improving women’s incomes, educational levels, access to information and ability to participate in decision-making processes may enhance the capabilities of the entire household and of society in general (Weeratunge et al., 2010) as well as women’s empowerment.

7.5 Market chain analysis of GFP in Sri Lankan reservoirs

This study seeks to broadly understand freshwater prawn supply and marketing systems, the development of which has been shown to lead to poverty reduction. In spite of prawn marketing constraints and poor socioeconomic conditions, most of the fishers and traders have improved their status through prawn supply activities. In the Sri Lankan context, the GFP supply chain and value determination is a monopsony, with generally only one buyer. The harvested GFP are primarily targeting the export market and secondarily the local hotels with foreign tourists, and local consumption of GFP is negligible.

In Sri Lankan reservoirs, the GFP catches are collected and sorted by a single collector generally a person recruited from the export company. Although the insulated packing box and packing ice are issued by the Company dealer (Com) for free, both the fishers and the collectors experience a labour cost. In some reservoirs there are intermediary dealers, but this is uncommon. Typically, the company representative visits all nearby reservoirs, collects the GFP packed boxes and delivers them to the exporting company.

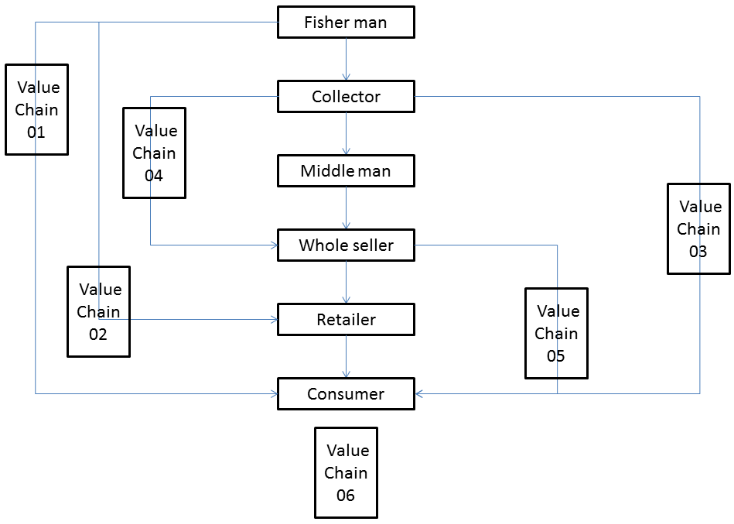

Figure 7.4. Hypothetical Value Chains available in a Reservoir.

Table 7.3. Coefficients of clusters

Cluster	Price/Kg	Market Chains' efficacy	Production	Revenue
1	-0.04878	-0.7668	0.5706	0.4309
2	-0.5637	-0.0146	-0.8614	-0.9003
3	1.0635	0.7404	0.9798	1.1897

Table 7.3, depicts the situation before the ACIAR project began, showing that reservoirs in the cluster 3 have a comparatively healthy value chain as result of multiple factors such as fetching higher price than other reservoirs, having multiple market chains, having good production and the total revenue is comparatively high. Moreover, most of the reservoirs in the cluster 3 are located in the Puttalam district. Though reservoirs in the cluster 1 are having considerable production the revenue is low due to the lower price given.

Table 7.4. Cluster components of k-mean clustering.

Cluster 1	Cluster 2	Cluster 3
Devalahandiya	Vijayakatupotha	Karavitagaraya
Mahauswewa	Eluwankulama	Kachichimaduwa
Tabbowa	Kalawewa	Kottukachchiya
Pahariya		Viluka
Rajaganaya		Saliyawewa
Nuwarawewa		Thanguswewa
Angamuwa		Mahawilachchiya
Thuruwila		Magallewewa

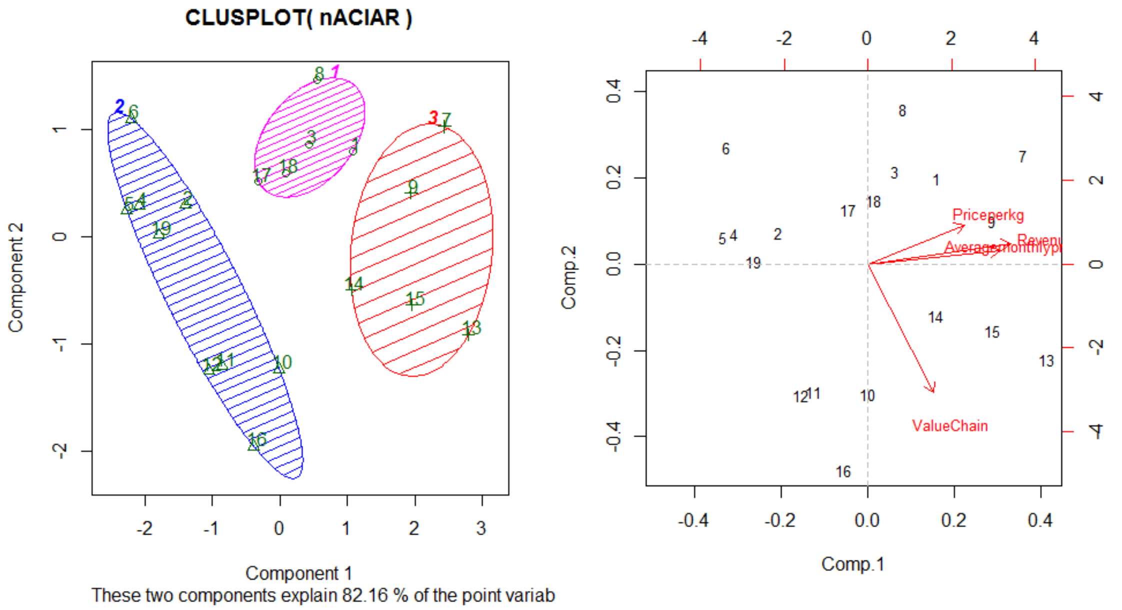

Figure 7.5. Cluster plot of Value chain efficacy

According to the data collected from February 2019 to July 2019, fishers were paid LKR 600 to LKR 1100 per kilogram of GFP (each greater than 300g), irrespective of sex differentiation. Collectors sell a GFP at a price of LKR 1000 to LKR 2000 (Blue Clawed Male LKR 2000, Orange Clawed Male and Female LKR 1600, De-shelled and undersized GFP- LKR 1000). Meanwhile the dealers are paid LKR 2000 to LKR 3000 per kilogram.

As a beneficiary of free stocking conducted from August to December 2018, the fishers from 9 reservoirs have earned mean total revenue of LKR 2,413,734 ± 641,610 for the period February to July 2019. The highest revenue was recorded from Tabbowa reservoir (LKR 4,328,034), where 910,500 GFP PLs were stocked at a stocking density of 1500 PLs ha^{-1}, representing a recapture rate of 1.62%. If the PLs are costed at LKR 2.00/PL to all reservoirs, the mean total marginal profit is LKR 1,606,200 ± 456,208.00.

Through the supply chain the total revenue and marginal profit shared as;

Collectors: mean total revenue of LKR 1,481,863 ± 414,727 and marginal profit of LKR 1,333,677 ± 373,254 (where 10% of the revenue is taken as the marketing cost)

Middleman: mean total revenue of LKR 595,512 ± 543,600 and marginal profit of LKR 178,653 ± 163,080 (where 70% of the revenue is considered for the marketing cost),

Export company dealer: mean total revenue of LKR 1,468,719 ± 463,187 and marginal profit of LKR 440,616 ± 138,956 (where 70% of the revenue is considered for the marketing cost).

The linear relationship of revenue with stocking cost and recapture rate can be explained by the following equation:

$$Revenue = -70363E^{5} + 3.7124E^{7}\ (Recapture\ rate) + 3.0465(Stocking\ Cost).$$

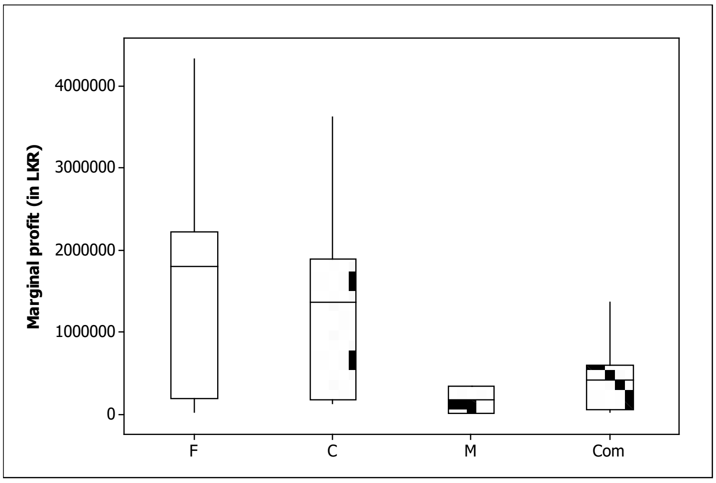

Figure 7.6. Comparison of marginal profit across the market chain of fishermen (F), collectors (C), middleman (M) and company agents (Com).

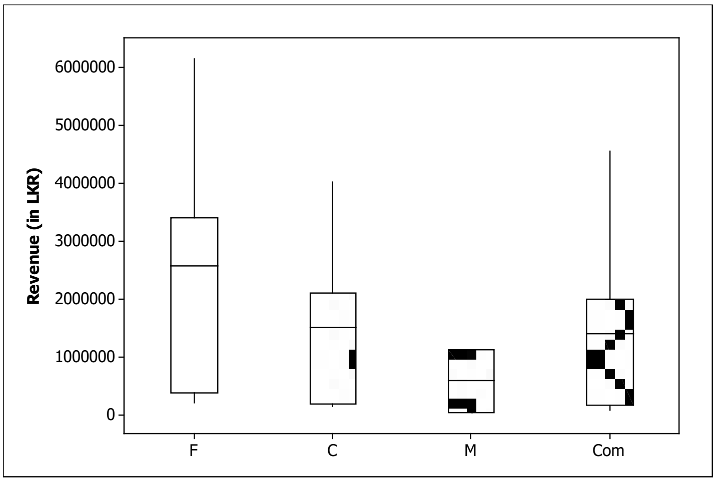

Figure 7.7. Comparison of revenue across the market chain of fishermen (F), collectors (C), middleman (M) and company agents (Com).

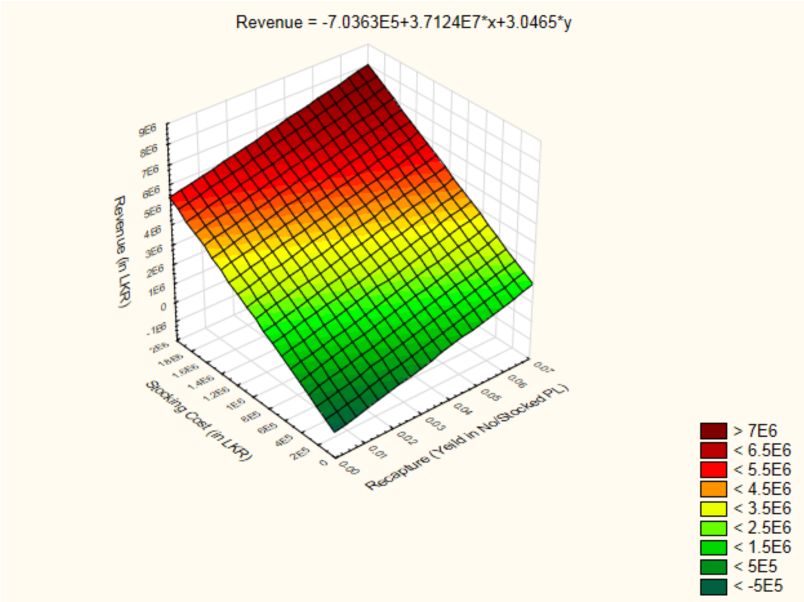

Figure 7.8. Trend of revenue with the stocking cost and recapture rate

7.6 Conclusions and Recommendations

Though the fishery is delineated by political and social issues, there is huge potential for GFP CBF in the Sri Lankan reservoirs. Improvements of market infrastructure, prawn transport, handling, preservation and shipment facilities are essential to enable supply of a quality product. Training of prawn market operators in areas of prawn preservation, handling, icing and curing would improve the quality of prawns. It is also necessary to ensure sufficient supplies of ice in prawn farming areas and hence a better quality product. In addition, institutional and organizational support, government support and credit facilities are needed to maintain sustainable prawn marketing systems.

7.7 References

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8 Conclusions and recommendations

8.1 Conclusions

The nature of culture based fisheries, where seed stock are produced through conventional aquaculture hatchery practices, and then released to reservoirs to establish and enhance a fishery, necessarily involves a considerable time lag, for stocked fish and prawns to grow and reach acceptable market size. Consequently, in the time available within a small research activity, in this case 18 months, it is only possible to make preliminary investigations concerning stocking strategies and their impact. Nevertheless, this SRA has generated considerable data on aspects of reservoir limnology, stocking and harvest practices, and social and economic aspects of the supply chain that will serve as a benchmark for comparative purposes, as further research occurs. It is clear that culture based fishery practices have made a significant contribution to the social, economic and environmental well-being of Sri Lankan rural communities, particularly those most impoverished in the north and east. The addition of giant freshwater prawns to CBF has had the most significant impact, although it is equally clear that the full potential value is yet to be realised. This study provides a solid foundation for longer term research and the testing of interventions that can increase CBF yields of GFP and provide optimal benefits to the people and communities involved.

8.2 Recommendations

The research has generated useful data on all aspects of CBF in relation to giant freshwater prawns and identified knowledge gaps that should be addressed to achieve an outcome of increased CBF productivity and efficiency, and enhanced and expanded benefits to reservoir communities throughout Sri Lanka. It is recommended that a proposed follow-on, large project be supported by ACIAR to enable such research to be performed and to generate a return on the investment made to date.

9 Publications

9.1 List of publications produced by project

Digamadulla, D.S., Asoka, J.M., Chandraratne, P.N. and de Croos, M.D.S.T. (2019). Culture based fisheries of giant freshwater prawn in Sri Lankan reservoirs: An overview. Proceedings of the Scientific Sessions of Symposium on Sustainable Inland Fisheries and Aquaculture for Food Security and Nutrition, 30-31 May 2019, National Inland Fisheries and Aquaculture Training Institute, Vijithapura, Kala wewa, Sri Lanka. Book of Abstracts, 31 p.

Digamadulla, D.S., Wijenayake, W.M.H.K., Asoka, J.M. and de Croos, M.D.S.T. (2019). Preliminary investigations on the feasibility of traps used for giant freshwater prawn in culture based fisheries. Proceedings of the Scientific Sessions of Symposium on Sustainable Inland Fisheries and Aquaculture for Food Security and Nutrition, 30-31 May 2019, National Inland Fisheries and Aquaculture Training Institute, Vijithapura, Kala wewa, Sri Lanka. Book of Abstracts, 34 p.

Yomal, G.A.T.K., Jayasinghe, U.A.D., Deepananda, K.H.M.A. and Amarasinghe, U.S. (2019). Influence of trophic state on culture based fisheries yield of giant freshwater prawn, *Macrobrachium rosenbergii* (de Man, 1879) in reservoirs of Sri Lanka. Proceedings of the 25th Anniversary Scientific Sessions of the Sri Lanka Association for Fisheries and Aquatic Resources, 19th August 2019, Faculty of Fisheries and Marine Science & Technology, University of Ruhuna, Matara, Sri Lanka. Book of Abstracts, 32 p.