2.1 Analysing the agrarian reservoir environment to optimise culture-based fisheries in Sri Lanka

Asanka D Jayasinghe
Department of Limnology and Water Technology, Faculty of Fisheries and Marine Sciences & Technology, University of Ruhuna, Sri Lanka

Abstract

Compared to the long agrarian history of Sri Lanka, inland fisheries in agrarian reservoirs are a recent development based mainly on introductions of exotic species. The aim of this short review is to analyse published information on agrarian reservoir environment and its suitability for fisheries production. In global scale, total fisheries production keeps rising due to both marine and inland aquaculture inputs, and a similar trend can be found in Sri Lanka as well. The development of culture-based fisheries (CBF) in agrarian reservoirs was not efficient at first, due to lack of knowledge on the limnological properties of the reservoirs. Since then, several scientists have formulated relationships between fish yield and the reservoir nutrient levels and other factors deciding primary production. Lately, indigenous riverine giant freshwater prawns (GFP) were introduced to the reservoir systems as a culturable species to diversify the catch and boost the income of rural fishing communities. Despite the continued stocking, the catch of GFP in return was not comparable. As a solution, proper scientific investigations on harvesting techniques, assessment of existing biomass, GFP distribution in microhabitats and their interactions with the agrarian reservoir environment and co-existing species, were subject to research.

Keywords: *culture-based fisheries, limnology, nutrient dynamics, giant freshwater prawn*

Introduction

Agrarian reservoirs are an intrinsic part of the hydraulic civilisation that ruled throughout more than 2500 years of written history of Sri Lanka (Brohier 1934; Brohier 1937; Shand 2002). It has resulted in more than 30,000 reservoirs and anicuts throughout the island especially in the dry zone (DAS 2000). It has been estimated to have about 3 ha of reservoir area for every km^2 of the island, probably the highest density of reservoirs in the world (De Silva 1988; Piet 1996). In the global context, major objectives of reservoir constructions are hydroelectric power generation or irrigation and agriculture or both. Nevertheless, there may be secondary objectives such as flood protection, aesthetic value, religious reasons and fishing purposes (De Silva et al. 1991). In Sri Lanka, the vast majority of the reservoirs are meant for paddy cultivation since ancient times. Compared to the long agrarian history of Sri Lanka, inland fisheries development as a sector started in the last century with time-to-time introduction of exotic species suitable for lacustrine environment into those agrarian reservoirs.

Though there are some significant differences between reservoirs and natural lakes, after the initial filling period, a dammed reservoir behaves just like a natural lake (Straskraba 1998). Therefore, despite their origin, man-made lakes (= reservoirs) also synchronise well with nature as time goes on. Hence, apart from the major reasons for which the reservoirs are built such as agriculture, irrigation, hydroelectric power generation, they are important as freshwater habitats from an ecological point of view and as sources of cheap protein supply from fisheries. Owe to this comparatively shorter fisheries history, still there are information gaps regarding the suitability of the dry zone reservoir environment for achieving optimum fisheries production to contribute to the country's economy significantly. The aim of this short review is to analyse published information on agrarian reservoir environment relating it to the associated fisheries production and find the way forward with the current research.

Significance of inland fisheries

Significance of inland fisheries is well demonstrated in global fisheries statistics compiled by the Food and Agriculture Organization (FAO) of the United Nations (Figure 2.1.1). According to FAO (2024) the total fish production in the world has increased from 20 million tonnes in the 1950s to 185 million tonnes in 2022. But the traditional majority of marine capture inputs has decreased its rate of increase and levelled off by the 1980s. The total production keeps rising thanks to the inputs from aquaculture both marine and inland. Of that aquaculture production, more than 26% comes from the non-fed aquaculture under which culture-based fisheries (CBF) are considered.

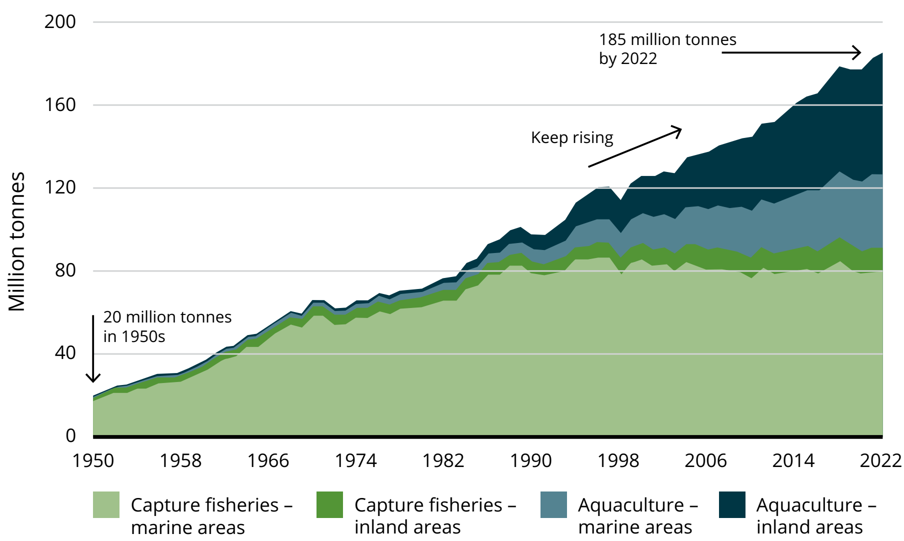

Figure 2.1.1: Historical trends in global fisheries production (FAO 2024)

Similar trends can be found in Sri Lanka as well (Figure 2.1.2) where inland fisheries contributed less than 10% of the total fish production in the 1970s and increased up to 20% by the 1980s (Silva et al. 2006). This boost occurred with the introduction of exotic tilapia into the reservoirs of Sri Lanka. However, cultural influences always took place deciding the existence of inland fisheries and the production declined without government support to the sector. The situation was rectified later, thereafter inland fisheries gained momentum again as shown in Figure 2.1.3. Before losing government support the total inland fisheries had reached about 40,000 t/year. Though it dropped without government support, now it has passed the 80,000 t/year limit.

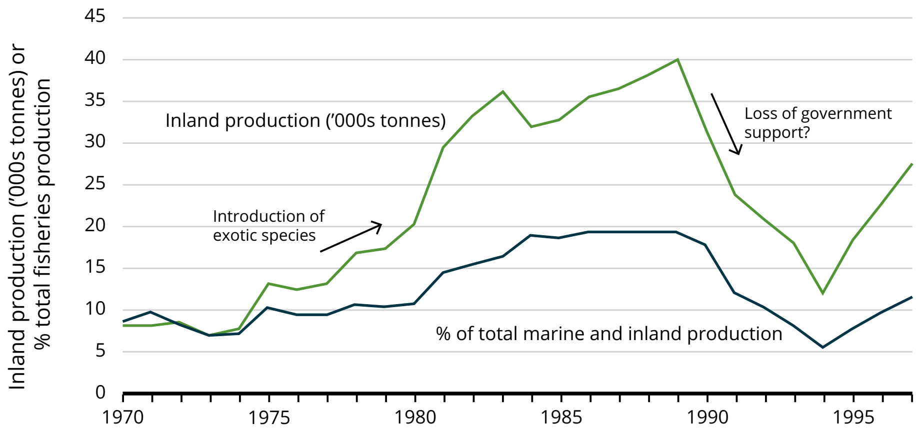

Figure 2.1.2: Inland fish production trends in Sri Lanka in 20th century (Silva et al. 2006)

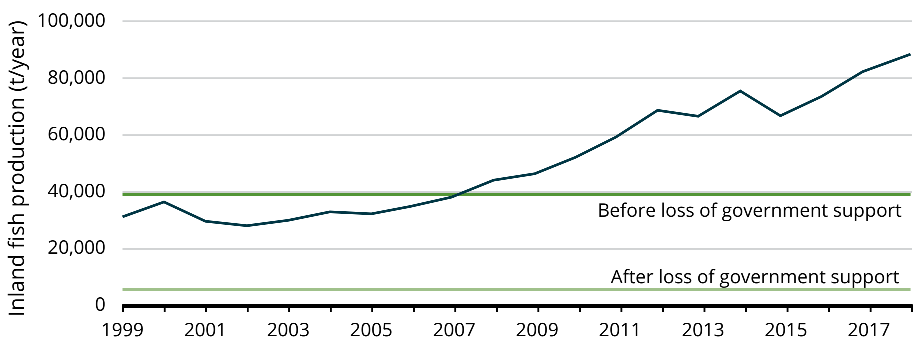

Figure 2.1.3: Recent trends in inland fish production based on the data of Ministry of Fisheries (MOF) (2019)

Culture-based fisheries in agrarian reservoirs

During the colonial period, paddy culture was neglected by the British rulers, so were the agrarian reservoirs. An economic value was induced to fish during the 1890s with the introduction of *Salmo trutta* and *Oncorhynchus mykiss* to hill country streams to develop sport fishing for British people (De Silva 1988). Subsequently, Chinese and Indian carps and tilapine species were introduced to lacustrine water bodies in order to develop commercial fisheries. Though fish production is on average higher in rivers than in lakes in other parts of the world (Randall et al. 1995), there is no riverine commercial fishery in Sri Lanka possibly due to rapid water flow, lack of extensive flood plains and low species richness (De Silva 1988). Indigenous species found in reservoirs are the same smaller riverine species spread through ephemeral water courses during rainy seasons. Introduction of exotic species filled the niches in reservoir environments supporting the development of inland fisheries. However, there is no evidence whether the authorities considered environmental aspects of agrarian reservoirs when carrying out those exotic fish introductions.

Culture-based fishing strategy is a hybrid of capture fishing and aquaculture. Here the farm-produced seed are released to a water body, which is beyond the control of fishermen and are recaptured upon reaching a desirable size. CBF can also be included under the fisheries enhancement strategy by definition, where there is human intervention in the life cycle of fish species (Lorenzen et al. 2001). The efficiency of harvesting in CBF is largely dependent on the size and depth of the culture system. Since it has been proven that the fish yield is inversely proportionate to the surface area of a water body (Amarasinghe 1998; De Silva 2003), smaller reservoirs are better for inland fisheries enhancement.

Mendis (1965) pointed out first the suitability of non-perennial reservoirs of Sri Lanka for CBF enhancement. With that, there were infrequent instances of stocking and harvesting of tilapias in village reservoirs (Indrasena 1965). However, after the recommendations of FAO experts (Rosenthal 1979; Oglesby 1981), the fisheries authorities in Sri Lanka tried to formalise the development of CBF in non-perennial reservoirs since the early 1980s (Thayaparan 1982; Chandrasoma and Kumarasiri 1986). It was observed that through proper management of seasonal reservoirs, a yield over 1,000 kg ha^{-1} yr^{-1} could be easily obtained (Thayaparan 1982; Chandrasoma and Kumarasiri 1986). However, this program did not sustain after the 1980s. De Silva (1988) predicted such an occurrence and indicated that one of the primary reasons for failure would be the inappropriate selection of water bodies due to lack of knowledge on their limnological properties.

Limnological aspects for fisheries in agrarian reservoirs

It is evident that the management of lakes or reservoirs can be facilitated through investigation of their limnology (Dillon and Rigler 1974; Carlson 1977). Some have reported on the limnological characteristics of small water bodies in relation to CBF where such fisheries management practices occur, for example, oxbow lakes in Bangladesh (Hasan et al. 2001; Hasan and Middendorp 1998) and farmer-managed small reservoirs in Vietnam (Nguyen et al. 2001). During fish introductions, main physicochemical parameters of the water should be at a status similar to the place of fish origin and therefore should not be limiting for the survival of those exotic species (Li and Xu 1995; Sugunan 1995). Therefore, CBF in Sri Lanka, which is relying on exotic species, should pay attention to the prevailing limnological conditions in the reservoirs for achieving better results.

In non-perennial reservoirs of Sri Lanka, some limnological measurements have been made as a routine, parallel to the data collection of CBF yield, without attempting to investigate the underlying relationships between fish yield and limnology (Thayaparan 1982; Chandrasoma and Kumarasiri, 1986). Gradually this trend was changed by the Sri Lankan scientists who understood the importance of studying limnological parameters of reservoirs in relation to the expected fisheries output (Amarasinghe et al. 1983; Amarasinghe and Upasena 1985; Amarasinghe 1998; Nissanka et al. 2000).

Figure 2.1.4 shows such important relationships derived for perennial reservoirs by taking 11 reservoirs as a sample. Relationship of chlorophyll-a content (Chl-a) is considered here with several independent variables, i.e. dissolved and total phosphorus; CA = catchment area; MEIa = morphoedaphic index based on alkalinity (MEIa = alkalinity in mgL^{-1}/ mean depth in m); MEIc = morphoedaphic index based on conductivity (MEIc = conductivity in μScm^{-1} / mean depth in m); RC = reservoir capacity in km^3 and RA = reservoir area. Since chlorophyll-a is directly related to the primary production of the water body these relationships can be considered as proxies for fish production (Nissanka et al. 2000).

In a country with thousands of reservoirs scattered over a vast area, to get a generalised picture on limnological conditions, it is always better to select a larger sample size. Jayasinghe et al. (2005a) selected 45 seasonal reservoirs randomly from 5 administrative districts and studied variations in 13 limnological parameters. When samples were ordinated in a Principal Component Analysis (PCA) based on their limnological conditions, chlorophyll-a showed a high variability across the dataset (Figure 2.1.5). Conductivity was not a limiting factor for those reservoirs as all of those were bearing higher values. Trophic status of the studied reservoirs was analysed following trophic state indices (TSI) described by Carlson (1977) and Carlson and Simpson (1996). In oligotrophic water bodies TSI calculated using Secchi disk depth (SDD), total phosphorus (TP) and cholorophyll-a (Chl-a) should be more or less similar. When TSI (Chl-a) is well below the other 2 indices, there is no comparable algae production in the water although there is higher turbidity and higher TP contents. That means water is turbid not because of algae but because of mud. Results showed that the non-perennial reservoirs of Sri Lanka were turbid with non-algal particulates and/or colour (Figure 2.1.6). As a result, fishery managers must rely more on chlorophyll values when estimating the productivity of those small waterbodies rather than using much easier tool like SDD (Jayasinghe et al. 2005b).

Morphometric parameters of reservoirs, catchment characteristics and land-use patterns also give clues regarding respective productivity levels of the reservoirs, which can be attributed to the fisheries production. De Silva et al. (2001) explained that the ratio of Forest Cover plus Shrub-Land to Reservoir Capacity had significant relationships with the fish yield. Similarly, the ratio of Forest Cover plus shrub-land to Reservoir Area was significant with the fish yield. For non-perennial reservoirs smaller in size, Jayasinghe et al. (2006) demonstrated that instead of conventional morphometric parameter

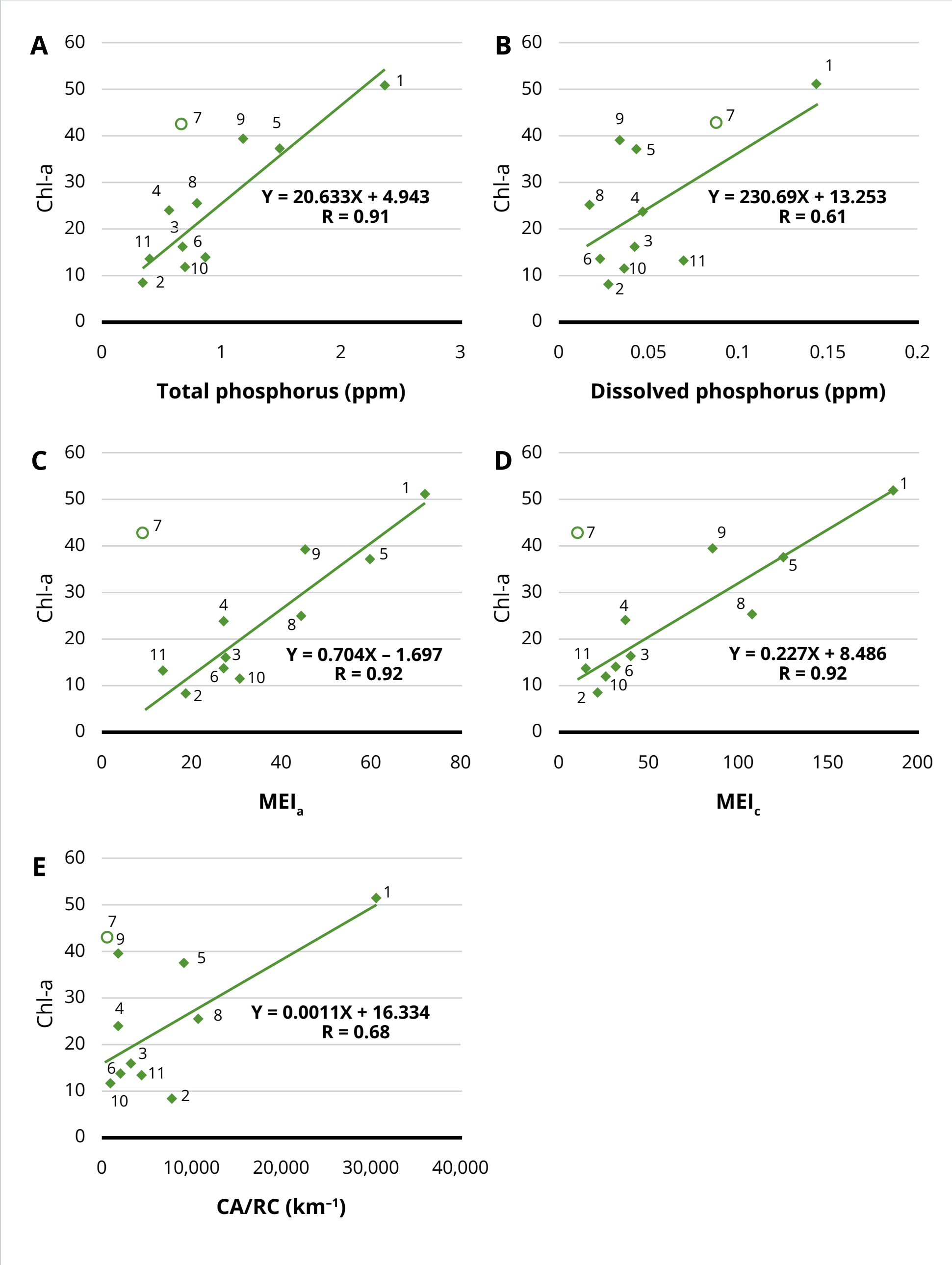

Figure 2.1.4: Relationship of chlorophyll-a content (Chl-a) with total and dissolved phosphorus; MEIa = morphoedaphic index based on alkalinity; MEIc = morphoedaphic index based on conductivity; and ratio between CA = catchment area and RC = reservoir capacity (Nissanka et al. 2000)

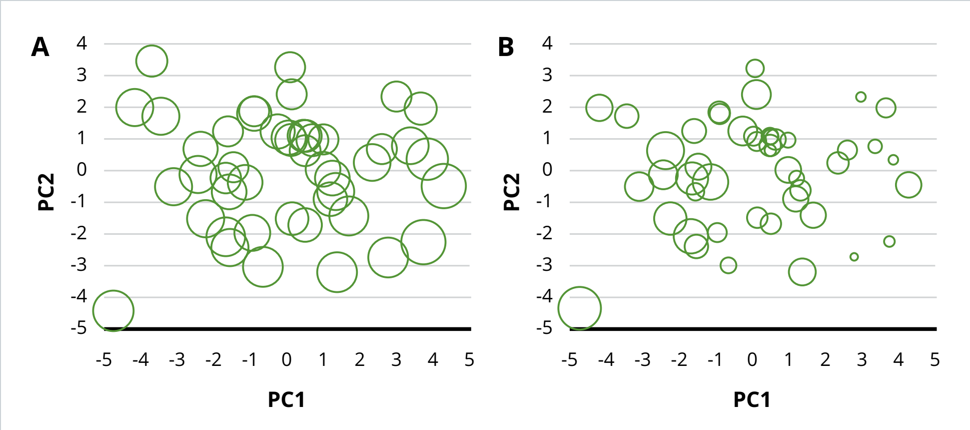

Figure 2.1.5: Bubble scale showing variations of (a) conductivity (b) chlorophyll-a among 45 seasonal reservoirs. Chlorophyll-a is showing a high variability across the dataset (Jayasinghe et al. 2005a)

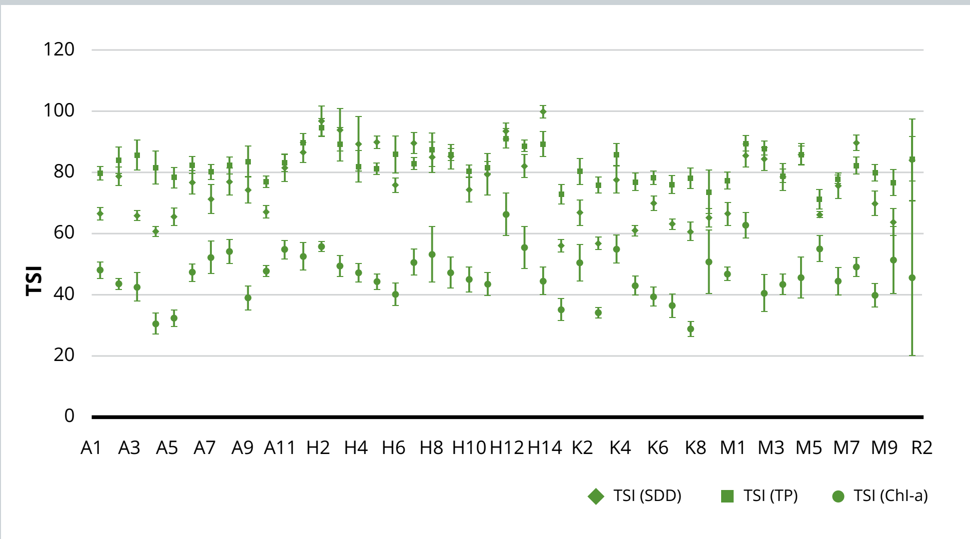

Figure 2.1.6: TSI measured using SDD, TP and Chl-a for 45 seasonal reservoirs. A, H, K, M and R depict the districts, Anuradhapura, Hambantota, Kurunegala, Monaragala and Ratnapura, respectively (Jayasinghe et al. 2005b)

‘shoreline development’ in limnology, using shoreline to area ratio would be meaningful to relate with fish production. Figure 2.1.7 shows how shoreline to area ratio correlates with the chlorophyll-a content in the reservoir. Shoreline development of non-perennial reservoirs are smaller probably because those are built in a semicircular manner with a linear earthen bund on one side to hold water to capacity and having dendritic margins only on the opposite side of the bund. On the other hand, non-perennial reservoirs in Sri Lanka have mean depths ranging from 1 to 4 m, and also basins with a gradual slope. This converts the whole reservoir a littoral zone promoting higher fish production.

Livestock farming is another significant human activity influencing the reservoir productivity. Most of the rural farming communities possess cattle and buffaloes for dairy production as well as in support of their day-to-day agricultural activities. All village livestock is grazing within the catchment of the village reservoir and contribute a large amount of nitrogen and phosphorus through their fecal matter (Jayasinghe and Amarasinghe 2007). It has been estimated that approximately 70% of phosphorus in feed concentrates of cattle is exported to land in excreta. Nevertheless, when inundated, the nutrient release rate from dung is normally higher than that of submerged vegetation (Nash and Halliwell

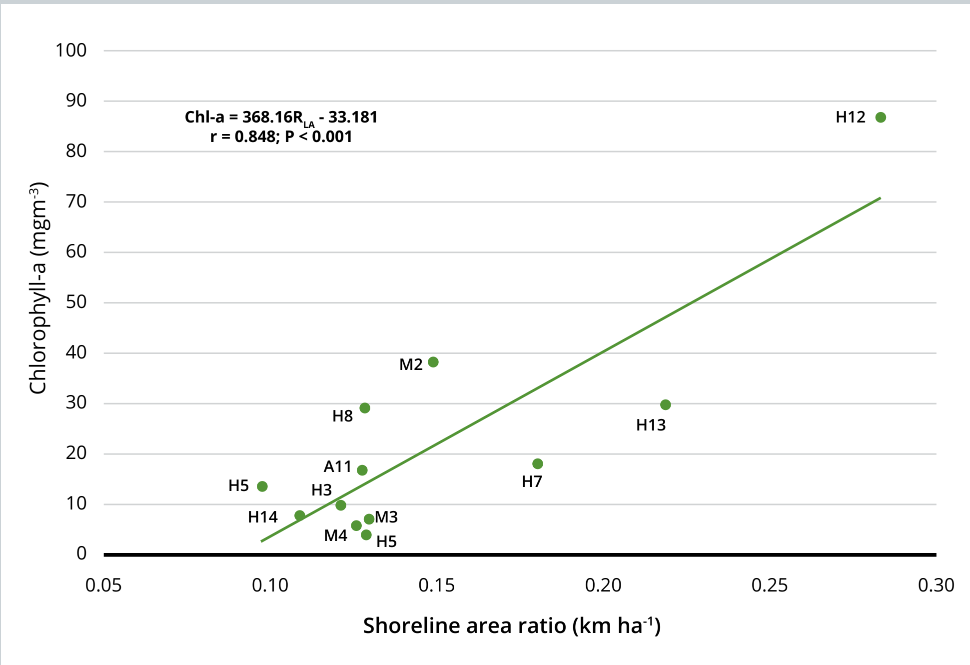

Figure 2.1.7: Relationship of shoreline to area ratio (km ha-1) to surface Chl-a content (mgm^{-3}) in 12 reservoirs examined (Jayasinghe et al. 2006)

2000; Bravo et al. 2003). Jayasinghe et al. (2016) estimated the total average cattle/buffalo-borne organic matter content in a model reservoir as 0.323 kg/buffalo. Jayasinghe et al. (2018) further clarified the relationships between the cattle/buffalo density and the nutrient and productivity parameters in the reservoir, thereby the fish yield as shown in Figure 2.1.8.

Recent trends in CBF and way forward

It has been several decades since CBF started to play a major role in fish production in Sri Lanka. It has relied mainly on exotic tilapia, Chinese carps and Indian carps until the indigenous riverine GFP was introduced to the reservoir systems as a culturable species to diversify the

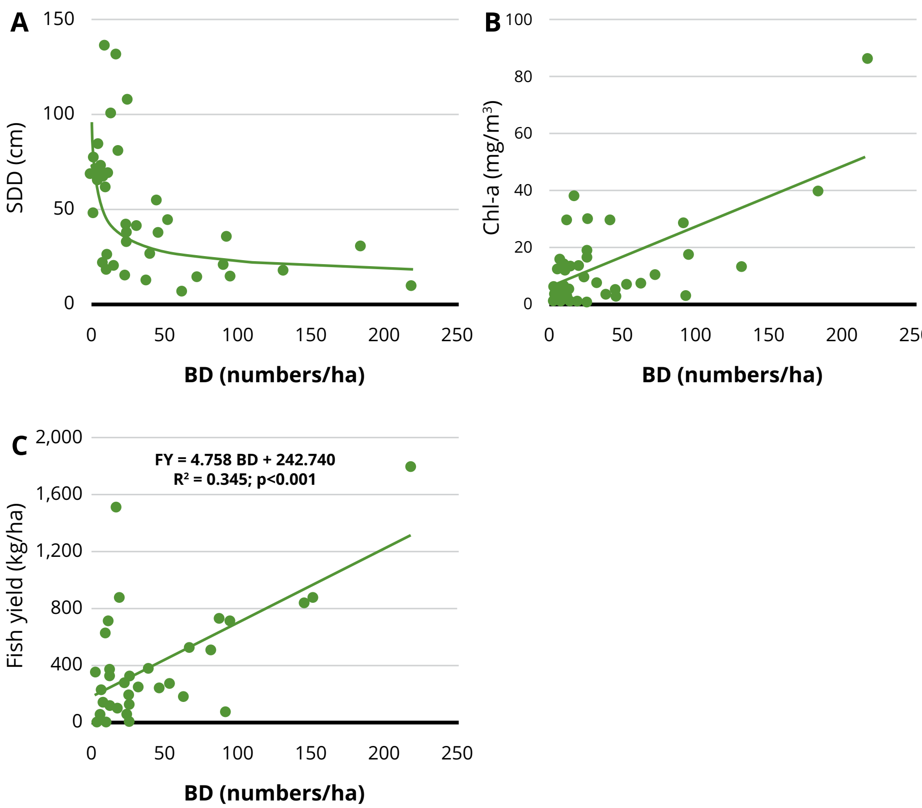

Figure 2.1.8: Correlations between the cattle/buffalo density (BD) in the reservoir catchment and (a) SDD; (b) Chl-a content; (c) total annual fish yield in seasonal reservoirs investigated by Jayasinghe et al. (2018)

catch and boost the income of rural fishing communities. Trials of introducing GFP to seasonal reservoirs were carried out since the start of this millennium (Wijenayake et al. 2005), although hatchery techniques to produce sufficient numbers of post larvae of GFP was not robust until 2007. According to Chandrasoma and Pushpalatha (2018), during the 2009 to 2015 period, over 12 million post larvae of GFP per year on average have been stocked into all 3 size categories of reservoirs: major perennials, medium perennials and minor perennials. Since then, this stocking continues to date despite lower GFP catches in return for higher inputs. As a solution, proper scientific investigations on harvesting techniques, assessment of existing biomass, GFP distribution in microhabitats and their interactions with the agrarian reservoir environment and co-existing species were essential. ACIAR funded these investigations, preliminary investigation was completed (Yomal et al. 2019, Yomal et al. 2020, Jones et al. 2021) and past stocking and harvesting data were analysed (Digamadulla et al. 2023). Detailed investigations on the agrarian reservoir environment and its effect on GFP and other CBF species are being conducted to date.

Status of the current research on agrarian reservoir environment and optimising CBF yield is being described in other chapters in this report. As recommended by Jones et al. (2021) further investigations of reservoir morphometry, sediment organic matter and other limnological factors are being conducted. In addition, the distribution of GFP, other exotic fish used in CBF and co-existing indigenous species in different microhabitats of the reservoir is being analysed (Mithila et al. 2023). The feeding interactions of all those economically important co-existing species are being analysed using stable isotopic evidence rather than depending on the conventional gut content analyses (Silva et al. 2023). This novel technique gives evidence on long-term assimilation of different food types instead of something like taking a snapshot of the last meal through the gut content analyses. Also, it allows us to imagine predator–prey relationships occurring underwater, which are not easily visible, and to construct the agrarian reservoir food web giving an emphasis on CBF. Another important aspect is to think about food safety when utilising fish or GFP from CBF in agrarian reservoirs under the circumstance of heavy usage of agrochemicals in these environments. Initially, it was attempted to investigate the influence of potential heavy metal accumulation in a few reservoirs stocked with GFP (Lakchani et al. 2019). Then the experiments were expanded to pollution and pesticide residues in agrarian reservoirs in addition to heavy metals. Under that research, a review on methodologies used in analysing microplastics in freshwater environments has been already published (Lakchani et al. 2025) while the results of the other analyses are on the way.

Conclusion

Total fisheries production in Sri Lanka keeps rising due to both marine and inland aquaculture inputs, in which CBF play a major role. The efficiency of harvesting in CBF is largely dependent on the size and depth of the culture system. Chlorophyll-a content of the reservoir and its relation to alkalinity and conductivity along with reservoir capacity and area are important in determining fish production in perennial reservoirs. Non-perennial reservoirs are turbid with non-algal particulates and/or colour, therefore, have to rely on chlorophyll values when estimating the productivity rather than using much easier tools like SDD. The whole reservoir acts as a littoral zone promoting higher fish production in non-perennial reservoirs. Shoreline to area ratio and cattle/buffalo densities in the catchment also correlate with the chlorophyll-a content in the reservoirs. Catches of recently introduced GFP were not comparable with continued stocking; therefore, proper scientific investigations have been initiated on harvesting techniques, assessment of existing biomass, distribution in microhabitats and their interactions with the agrarian reservoir environment and co-existing species.

References

Amarasinghe US (1998) 'Reservoir fisheries management in Sri Lanka: Achievements, mistakes and lessons for future', *International Review of Hydrobiology,* 83:523–530.

Amarasinghe US, Costa HH and Wijeyaratne MJS (1983) 'Limnology and fish production potential of some reservoirs in Anuradhapura district, Sri Lanka', *Journal of Inland Fisheries (Sri Lanka),* 2:14–29.

Amarasinghe US and Upasena T (1985) 'Morphometry of a man-made lake in Sri Lanka: a factor influencing recruitment to cichlid fishery', *Journal of the National Aquatic Resources Agency,* 32:121–129.

Bravo D, Sauvant D, Bogaert C and Meschy F (2003) 'III quantitative aspects of phosphorus excretion in ruminants', *Reproduction Nutrition Development,* 43:285–300.

Brohier RL (1934) *Ancient irrigation works in Ceylon* Colombo, Ceylon Government Press.

Brohier RL (1937) *Ancient irrigation works in Ceylon* Colombo, Ceylon Government Press.

Carlson RE (1977) 'Trophic state index for lakes', *Limnology and Oceanography,* 22:361–369.

Carlson RE and Simpson J (1996) *A coordinator's guide to volunteer lake monitoring methods,* Medison, Wisconsin, North American Lake Management Society.

Chandrasoma J and Kumarasiri WSAAL (1986) 'Observations on polyculture of fish in seasonal tanks in Ratnapura and Moneragala districts in Sri Lanka', *Journal of Inland Fisheries (Sri Lanka)* 3:49–55.

Chandrasoma J and Pushpalatha KBC (2018) 'Fisheries enhancements in inland waters in Sri Lanka with special reference to culture based fisheries: current status and impacts', *Sri Lanka Journal of Aquatic Sciences,* 23:49–65.

DAS (2000) *Data book for village irrigation schemes of Sri Lanka,* Colombo, Department of Agrarian Services.

De Silva SS (1988) *Reservoirs of Sri Lanka and their fisheries,* Rome, FAO.

De Silva SS (2003) 'Culture-based fisheries: an underutilised opportunity in aquaculture development', *Aquaculture,* 221:221–243.

De Silva SS, Amarasinghe US, Nissanka C, Wijesooriya WADD and Fernando MJJ (2001) 'Use of geographical information systems as a tool for predicting fish yield in tropical reservoirs: case study on Sri Lankan reservoirs', *Fisheries Management and Ecology,* 8:47–60.

De Silva SS, Zhitang Y and Lin-Hu X (1991) 'A brief review of the status and practices of the reservoir fishery in mainland China', *Aquaculture and Fisheries Management,* 22:73–84.

Digamadulla DS, Asoka JM, Jones C, Jayasinghe-Mudalige UK, Wijenayake WMHK, Amarasinghe US and De Croos MDST (2023) 'Appraisal of culture-based fisheries of giant freshwater prawn (Macrobrachium rosenbergii, De Man, 1879) in reservoirs of Sri Lanka', *Aquaculture, Fish and Fisheries,* 3:81–95.

Dillon PJ and Rigler FH (1974) 'Phosphorus-chlorophyll relationship in lakes', *Limnology and Oceanography,* 19:767–773.

FAO (2024) *The State of World Fisheries and Aquaculture 2024 – Blue Transformation in action,* Rome, Food and Agriculture Organization of the United Nations.

Hasan MR and Middendorp HAJ (1998) 'Optimising stocking density of carp fingerlings through modelling of the carp yield in relation to average water transparency in enhanced fisheries in semi-closed water bodies in western Bangladesh', *Food and Agriculture Organization of the United Nations Fisheries Technical Paper,* FAO, 374:159–168.

Hasan MR, Mondal MAW, Miah MI and Kibria MG (2001) 'Water quality study of some selected Oxbow Lakes with special emphasis on chlorophyll-a' in Silva SSD (ed) *Reservoir and culture-based fisheries: biology and management*, Australian Centre for International Agricultural Research, Canberra.

Indrasena HHA (1965) 'The development of freshwater fisheries in Ceylon- Proceedings of the symposium on the Development of Ceylon's Fisheries', *Bulletin of Fisheries Research Station, Ceylon* 17:287–289.

Jayasinghe A and Amarasinghe U (2007) 'Buffaloes in favour of culture-based fisheries in Sri Lanka', *Aquaculture Asia,* NACA, Bangkok.

Jayasinghe AD, Arachchige AJ, Silva SSD and Amarasinghe US (2018) 'Cattle and water buffalo densities wading into small village reservoirs of Sri Lanka impact on yields on the culture-based fisheries thereof', *Sri Lanka Journal of Aquatic Sciences,* 23:67–75.

Jayasinghe U, Gunawardhana C, Maithreepala R, Amarasinghe U and De Silva S (2016) 'Quantification of the cattle/buffalo-borne organic content in non-perennial reservoirs utilized for culture-based fisheries in Sri Lanka', *7th World Fisheries Congress (WFC),* BEXCO, Busan, Korea.

Jayasinghe UAD, Amarasinghe US and De Silva SS (2005a) 'Limnology and culture-based fisheries in non-perennial reservoirs in Sri Lanka', *Lakes & Reservoirs Research and Management,* 10:157–166.

Jayasinghe UAD, Amarasinghe US and De Silva SS (2006) 'Culture-based fisheries in non-perennial reservoirs of Sri Lanka: influence of reservoir morphometry and stocking density on yield', *Fisheries Management and Ecology,* 13:157–164.

Jayasinghe UAD, Amarasinghe US and Silva SSD (2005b) 'Trophic Classification of Non-Perennial Reservoirs Utilized for the Development of Culture-Based Fisheries, Sri Lanka', *International Review of Hydrobiology,* 90:209–222.

Jones C, Amarasinghe U, Silva SD, Croos DD, Digamadulla S, Jayasinghe A, Yomal GATK and Deepananda KHMA (2021) *Assessing production of giant freshwater prawns in reservoirs in Sri Lanka*, Canberra, Australia.

Lakchani DT, Jayasinghe A, Maithreepala RA, Ulrich U and Collard F (2025) 'Microplastics in freshwater sediment in the Indo-Sri Lankan region: a review of methodologies', *Microplastics and Nanoplastics,* 5:16.

Lakchani EGDT, Jayasinghe UAD and Sanjaya HLK (2019) 'Potential Heavy Metal Pollution and their Accumulation within Macrobrachium rosenbergii Cultured in Dry Zone Reservoirs, Sri Lanka', *25th Annual Scientific Sessions of the Sri Lanka Association for Fisheries and Aquatic Resources (SLAFAR),* Sri Lanka Association for Fisheries and Aquatic Resources (SLAFAR).

Li S and Xu S (1995) *Culture and capture of fish in Chinese reservoirs*, Ottawa & Southbound Sdu Bhd, International Development Research Centre, Penang.

Lorenzen K, Amarasinghe US, Bartley DM, Bell JD, Bilio M, De Silva SS, Garaway CJ, Hartman, WD, Kapetsky JM, Laleye P, Moreau J, Sugunan VV and Swar DB (2001) 'Strategic review of enhancements and culture-based fisheries' in Subasinghe RP, Phillips MJ, Hough C, McGladdery SE and Arthur JR (eds) *Aquaculture in the Third Millenium, Technical Proceedings of the Conference on Aquaculture in the Third Millenium, Bangkok, Thailand,* NACA and FAO, Rome.

Mendis AS (1965) 'A preliminary survey of 21 Ceylon lakes, 2: Limnology and fish production potential', *Bulletin of Fisheries Research Station, Ceylon,* 16:7–16.

Mithila D, Jayasinghe A, Deepananda KHMA, Wijenayke WMHK and Silva SSU (2023) 'Investigating the distribution of giant freshwater prawns (*Macrobachium rosenbergii*) stocked in reservoirs of Sri Lanka with varying bottom characteristics: A comparison with indigenous knowledge', *Giant Prawn 2023,* , Thailand Asian Institute of Technology, Pathumthani.

MOF (2019) *Fisheries Statistics 2019*, Colombo, Sri Lanka.

Nash D and Halliwell D (2000) 'Tracing phosphorus transferred from grazing land to water', *Water Research,* 34:1975–1985.

Nguyen SH, Bui AT, Le LT, Nguyen TTT and De Silva SS (2001) 'The culture-based fisheries in small, farmer-managed reservoirs in two provinces of northern Vietnam: an evaluation based on three production cycles', *Aquaculture Research,* 32:975–990.

Nissanka C, Amarasinghe US and Silva SD (2000) 'Yield predictive models for Sri Lankan reservoir fisheries', *Fisheries Management and Ecology,* 7:425–436.

Oglesby RT (1981) *Inland fisheries of Sri Lanka and their management, Interim report to FAO for the project TCP/SRL/8804 – Development of fisheries in the man-made lakes and reservoirs*, FAO, Rome.

Piet GJ (1996) *On the ecology of a tropical fish community,* MC Escher/Cordon Art, Baarn, Holland.

Randall RG, Minns CK and Kelso JRM (1995) 'Fish production in freshwaters: Are rivers more productive than lakes?', *Canadian Journal of Fisheries and Aquatic Sciences,* 52:631–643.

Rosenthal H (1979) *Preliminary report and recommendations on reservoir and tank stocking activities in inland fisheries in Sri Lanka, Project TCP/SRL/8804 – Development of fisheries in the man-made lakes and reservoirs.*

Shand R (2002) *Irrigation and agriculture in Sri Lanka,* Colombo, Institute of Policy Studies.

Silva SS, Amarasinghe US, Jayasinghe A, Wijeyanayake K, Nguyen TTT, Sim SY, Nguyen SH and Murray F (2006) *Better-practice approaches for culture-based fisheries development in Asia,* ACIAR, Canberra.

Silva SS, Jayasinghe A, Deepananda KHMA, Jones C and Perera SADM (2023) 'Natural food of riverine *Macrobrachium rosenbergii* after stocking in reservoirs of Sri Lanka', *Giant Prawn 2023,* Asian Institute of Technology, Pathumthani, Thailand.

Straskraba M (1998) 'Limnological differences between deep valley reservoirs and deep lakes', *International Review of Hydrobiology Special issue,* 83:1–12.

Sugunan VV (1995) *Reservoir fisheries of India,* FAO, Rome.

Thayaparan K (1982) 'The role of seasonal tanks in the development of freshwater fisheries in Sri Lanka', *Journal of Inland Fisheries (Sri Lanka),* 1:133–167.

Wijenayake WMHK, Jayasinghe UAD, Amarasinghe US, Athula JA, Pushpalatha KBC and De Silva SS (2005) 'Culture-based fisheries in non-perennial reservoirs in Sri Lanka: production and relative performance of stocked species', *Fisheries Management and Ecology,* 12:249–258.

Yomal GATK, Jayasinghe UAD, Deepananda KHMA and Amarasinghe US (2019) 'Influence of Trophic State on Culture Based Fisheries yield of Giant Freshwater Prawn Macrobachium rosenbergii (de Man, 1879) in Reservoirs of Sri Lanka', *25th Annual Scientific Sessions of Sri Lanka Association for Fisheries and Aquatic Resources,* Sri Lanka Association for Fisheries and Aquatic Resources.

Yomal GATK, Jayasinghe UAD, Deepananda KHMA and Amarasinghe US (2020) 'Relationship between reservoir morphometry and the culture-based fisheries yield of giant freshwater prawn in selected reservoirs of Sri Lanka', *7th Ruhuna International Science & Technology Conference,* University of Ruhuna, Matara, Sri Lanka.