6.2 Potential to estimate relative fish biomass in reservoirs using a commercially available hydro-acoustic fish finder

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Abstract

This study evaluates the potential of the Fish Smart Sonar Deeper CHIRP +2 for estimating relative fish biomass in reservoirs. Data were collected from 5 Sri Lankan reservoirs between 19 March and 1 April 2024: Kiriibban wewa, Handapanagala, Hakwatuna Oya, Maha Wilachchiya and Mahakanadarawa. Hydro-acoustic data were recorded in down-imaging mode using a 7° beam at 675 kHz, wirelessly connected to its official mobile app (Fish Deeper – Fishing App). Fish count, their size categories, swimming depth (ft) and depth at target location (ft) were manually extracted by observing the recorded survey in mobile and web applications. Statistical analyses revealed significant differences in mean fish swimming depths across reservoirs (ANOVA: $p<0.001$), with larger fish occupying deeper waters compared to smaller fish. In Kiriibban Wewa, swimming depth of all fish size categories showed strong correlations with the depth at target locations ($R^2 = 0.94–0.96$). The number of fish living in each reservoir was estimated from the number of fish targets counted on the hydro-acoustic survey transects of corresponding reservoir. The findings suggest that the Fish Smart Sonar Deeper CHIRP+2 is a potential cost-effective tool for hydro-acoustic surveys subject to further research testing accuracy of the estimates.

Keywords: *hydro-acoustics, fish biomass estimation, sonar, agrarian reservoirs, Sri Lanka*

Introduction

Fish biomass is a crucial factor in aquaculture and fisheries management, enabling fishery managers to make effective decisions. Regular biomass assessments are essential for optimising feeding, controlling stocking and determining the optimal harvest time. In natural systems, directly measuring total biomass and species composition is not feasible. There are traditional methods based on manual sampling for biomass estimation, which are extremely time consuming, laborious, inaccurate and invasive towards the fish (Li et al. 2020). Over the past 3 decades, significant research and development efforts have advanced the use of sound waves for fish biomass estimation. This technology is known as hydro-acoustics and it provides a more efficient and non-invasive alternative to traditional biomass estimation methods (Ramírez-Coronel et al. 2024).

Hydro-acoustic fish biomass estimation is a non-invasive technique which uses sound waves to estimate fish biomass by emitting acoustic signals and analysing the reflected sound (echo) from the target (fish). These signals are used to determine the size, density, and distribution of fish populations (Simmonds and MacLennan 2005). Acoustic methods are useful tools in scientific research to calculate the size of fish stocks and to set catch limits for each species. Acoustics is advanced enough to locate targets of interest, interpret the signal strength to determine whether they are individuals or groups of organisms and calculate the shape and density of the aggregates (Romero et al. 2015). The same method aids in mapping depth profiles of the water body relating fish distribution to their habitats.

Scientific echosounders are employed for the acoustic fish biomass estimation, which have more advanced technology to identify fish, its size and measure their biomass using advance calculations. Furthermore, echosounders are invariably associated with hydro-acoustic data post-processing software to compute the mean density of fish and extract quantifiable descriptors on fish schools. Inexpensive and portable fish finders used in recreational and commercial fisheries share the same principles used in advanced scientific echosounders yet are more affordable and widely accessible. These devices are pre-calibrated, hence do not allow advance alterations to get accurate measurements on fish density and biomass like scientific echosounders do. Algorithms used in those devices to identify the fish or other targets are not usually exposed in their user manuals due to trade competition. In addition, fish finders lack advanced technical software for post-processing of data, which tends to be a drawback for scientific purposes. Despite those disadvantages, fish finders can be used to get a general idea on presence and absence of fish due to the prohibitive cost of scientific echosounders. Nevertheless, fish finders allow determination of fish density, if there is a way to measure the target strength (TS) of the individual fish located by those devices (McInnes et al. 2015).

Fish biomass estimation in Sri Lankan inland reservoirs is important due to several reasons, such as managing fisheries, conservation of aquatic ecosystems, and ensuring sustainable use of aquatic resources. Sri Lanka has been estimated to have more than 30,000 reservoirs and anicuts throughout the island especially in the dry zone (DAS 2000). After identifying the suitability of those reservoirs for inland fisheries development (Mendis

1965; Oglesby 1981; Rosenthal 1979), continuous fish stocking has been carried out in some reservoirs (Amarasinghe 1998; De Silva 2003; Chandrasoma and Pushpalatha 2018), and the current existing fish biomass is unknown. The aim of the present study is to assess the feasibility of using a commercially available hydro-acoustic fish finder as a tool for monitoring fish populations in reservoirs. No previous research has been recorded on using fish finders or echosounders in Sri Lankan inland reservoirs, therefore, this attempt would be an innovative approach to introduce a robust, non-invasive and affordable tool for managing inland fisheries in a developing country like Sri Lanka.

Materials and methods

Study area

The present study was conducted using a data set recorded during a bathymetric survey using a hydro-acoustic fish finder in 5 reservoirs. Selected 5 reservoirs were Mahawilachchiya, Mahakanadarawa and Hakwatuna Oya reservoir from North Western province and Handapanagala and Kiriibban wewa from Southern province (Figure 6.2.1). All the reservoirs were at their full supply level when the survey was carried out. The spatial distribution of reservoirs is shown in Figure 6.2.1 along with their Global Positioning System (GPS) location and other relevant information in Table 6.2.1.

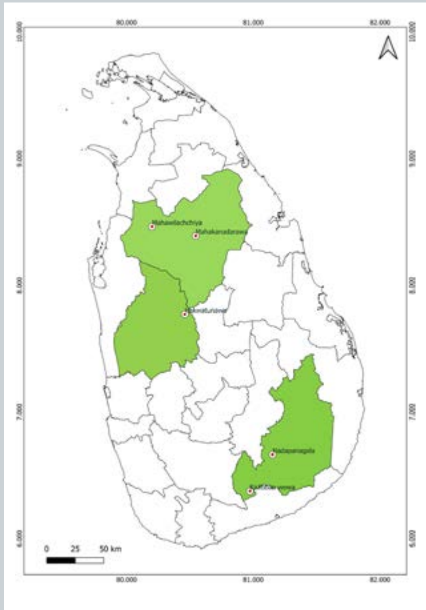

Figure 6.2.1 Distribution of reservoirs selected for the study across the country in Anuradhapura, Monaragala and Kurunegala districts

Table 6.2.1: GPS coordinates and the size of the studied reservoirs

Code	District	Name	Size	Surface area (ha)	Latitude	Longitude
Mo2	Monaragala	Handapanagala	Medium	264.0	6.665547	81.15166
Mo3	Monaragala	Kiribban wewa	Medium	324.0	6.375799	80.97003
Ku1	Kurunegala	Hakwatuna oya	Medium	362.2	7.772887	80.46125
A2	Anuradhapura	Mahawilachchiya	Major	1,188.6	8.466018	80.19969
A3	Anuradhapura	Mahakanadarawa	Major	1,287.1	8.387917	80.54395

Sampling design

The hydro-acoustic depth survey was conducted during the daytime from 19 March to 1 April 2024. Sonar data collection was performed using the Fish Smart Sonar Deeper CHIRP+2 (Deeper, Lithuania, EU). This device was equipped with 3 CHIRP (Compressed High-Intensity Radar Pulse) frequency modes: Narrow CHIRP at 675 kHz (cone angle: 7°), Medium CHIRP at 240 kHz (cone angle: 20°), and Wide CHIRP at 100 kHz (cone angle: 47°). Additionally, it integrated various GPS technologies within a compact, portable floating ball measuring 67 mm in diameter (Figure 6.2.2). Though the device has been designed as a castable sonar, it was adapted for boat-mounted use, allowing it to be dragged along the water surface during data collection. Traditional canoes were used to navigate along predetermined paths, covering both lacustrine and intermediate regions of each reservoir. The fish finder was connected via Wi-Fi to an Android mobile phone using the Fish Deeper application. The application categorised fish into 3 size groups: small, medium and large, but the specific length range in cm for each size group has not been mentioned in user manuals. Therefore, laboratory analyses were performed for fish size category identification by using known fish targets of different sizes in a cement pond of 45x15x3 ft. All sonar readings, along with reservoir depth measurements, were recorded directly into the mobile application and later, utilised for the analysis.

Data collection

Deeper Smart Sonar CHIRP+2 fish finder, which emits 15 pulses per second, was dragged along systematically designed transects at a constant boat speed of approximately 2.5 km/h to record fish distributions. Figure 6.2.3 shows the observed transect in each reservoir. While drifting, the fish finder continuously recorded hydro-acoustic data in down imaging mode in real time. The surveys were carried out in the daytime between 8 am and 5 pm. Of the 3 beams (7°, 20° and 47°), the 7° beam was utilised to detect

Figure 6.2.2: Fish Smart Sonar Deeper CHIRP+2

fish targets since the narrow beams give clearer acoustic images. The Deeper sonar was fully charged before deployment, and a stable Wi-Fi connection between the sonar and the mobile device was ensured throughout the survey. During the survey, at random locations, dissolved oxygen (DO) and chlorophyll-a content were measured using a multipara water quality meter (YSI ProDSS) to get an idea about the surrounding environment.

Post-processing of acoustic data

The Fish Deeper application displayed fish location using fish icons, categorising them into 3 size groups: small, medium and large. It also indicated the swimming depth of the fish along with the overall reservoir depth. Fish count data were extracted manually along with the corresponding swimming depth by observing the sonar recording in the mobile application and web portal (**https://maps.fishdeeper.com/en-us**). Scatter plots and analysis of variance (ANOVA) were used to identify the spatial distribution of fish and its significance according to their relative size categories. QGIS and Google Earth pro were used to create spatial maps. All the analyses were done in RStudio (version RStudio 2024.12.0+46) and Microsoft Excel.

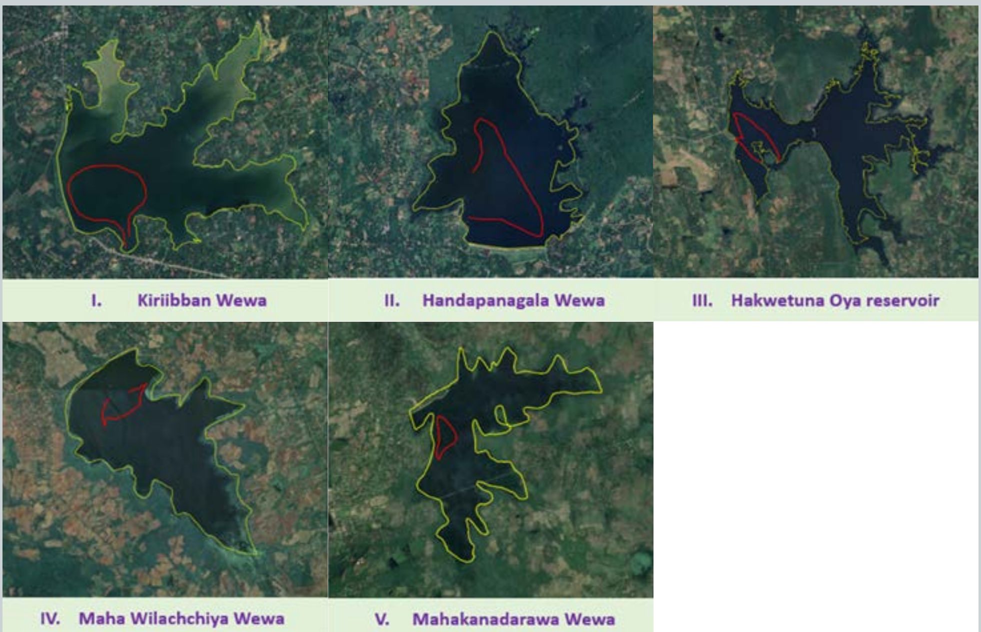

Figure 6.2.3: Maps of reservoirs showing the transect (in red) of acoustic survey used for this analysis

Results

Table 6.2.2 shows the maximum recorded depths of the selected reservoirs by the sonar device. Maha Wilachchiya and Mahakanadarawa are shallower compared to the other reservoirs, which have over 35 ft of maximum depth.

Table 6.2.2: Maximum depths recorded by the sonar device in the reservoirs

Reservoir name	Maximum depth (ft)
Kiriibban wewa	39
Handapanagala	37
Mahawilachchiya	24
Mahakanadarawa	27
Hakwatuna Oya	35

According to the boxplots shown in Figure 6.2.4, average fish swimming depth varied significantly among reservoirs ($p<0.001$). Hakwatuna Oya was recorded with the highest average fish swimming depth.

Kiriibban wewa was the second highest when the average is considered; however, fish seemed clustered at 2 depth layers in the reservoir, making a bimodal skewed distribution in the plot. Significantly, lowest average fish swimming depth was observed in Maha Wilachchiya.

When the fish target sizes as identified by the fish finder are separated, the resulted distribution is shown in Figure 6.2.5. Large fish have a significantly higher average swimming depth when compared to both the medium and small categories ($p<0.001$). Swimming depths of medium- and small-sized fish targets are not different from each other. To clarify more, swimming depths of fish targets were separated based on both target size and the reservoir, and the distributions were arranged according to the increasing order of swimming depths in Figure 6.2.6. It showed that Hakwatuna Oya had the highest average values for fish swimming depths for all 3 size categories of

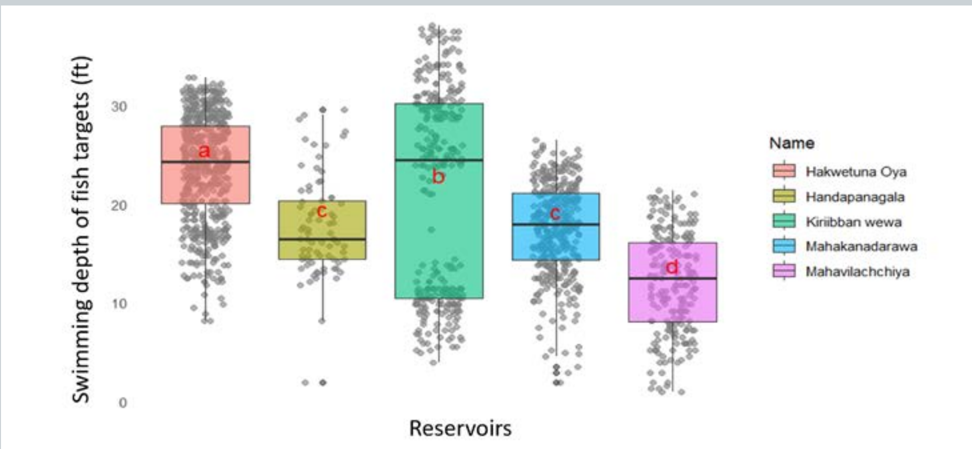

Figure 6.2.4: Box plots showing the data distribution of swimming depths of fish targets captured by the fish finder in 5 reservoirs

Note: Simple letters 'a, b, c, d' depict the significant differences between average swimming depth values for reservoirs based on Tukey's test.

fishes. In general, large fishes tend to have higher values of swimming depth in their respective reservoirs.

When reservoirs are considered separately, Kiriibban wewa shows a strong positive correlation between swimming depth of fish targets and the reservoir depth at the target location (Figure 6.2.7). There are correlations for all 3 size groups. That means, regardless of the body size, fish tend to swim in the deeper layers of that particular location. But in other reservoirs studied, there were no such correlations, and larger fish targets tend to cluster in deeper layers.

Table 6.2.3 shows the measurements of DO and chlorophyll-a content collected at random locations in the reservoirs. Here the depth measurements were recorded from the values shown in the water quality meter. At some locations, high chlorophyll-a values were observed even beyond the depths of 20 ft, but relatively DO values were low.

To estimate the number of fish in the reservoirs, observed hydro-acoustic transect was used. Since this is an average estimate, average fish swimming depth was considered as the observed plain. From the tan value of the half of the acoustic beam angle (i.e. 3.5°), half of the width of the transect could be calculated. By multiplying that value with 2 and the length of the transect, the area of the observed transect was estimated. When the number of fish targets observed is divided by the observed transect area, and multiplied with the reservoir area, the total number of fish targets that can be expected from the whole reservoir can be estimated (Table 6.2.4).

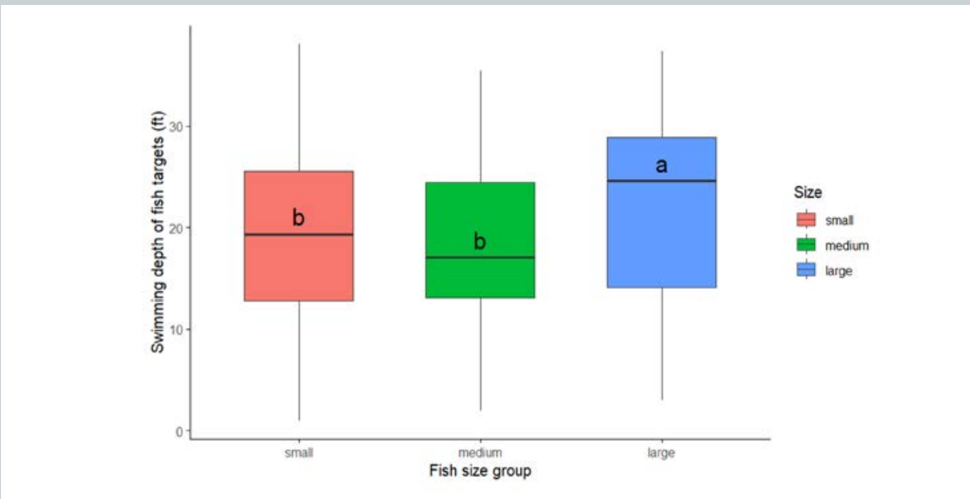

Figure 6.2.5: Box plots showing data distribution of swimming depths of fish targets captured by the fish finder, grouped according to the fish target size

Note: Simple letters 'a' and 'b' depict the significant differences between swimming depths of different fish size categories, based on Tukey's test.

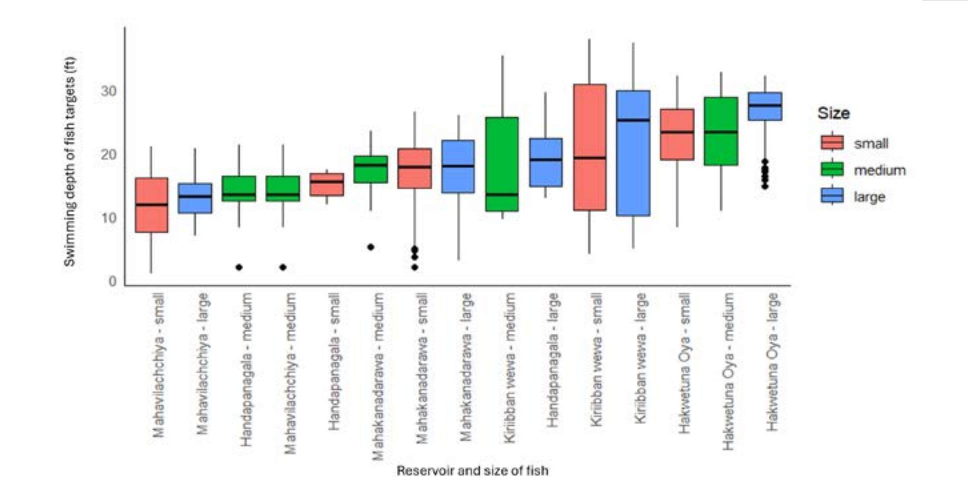

Figure 6.2.6: Box plots showing data distribution of swimming depths of fish targets captured by the fish finder, grouped according to the reservoir and the size of fish

Note: Box plots are arranged from the smallest to biggest values of average swimming depth.

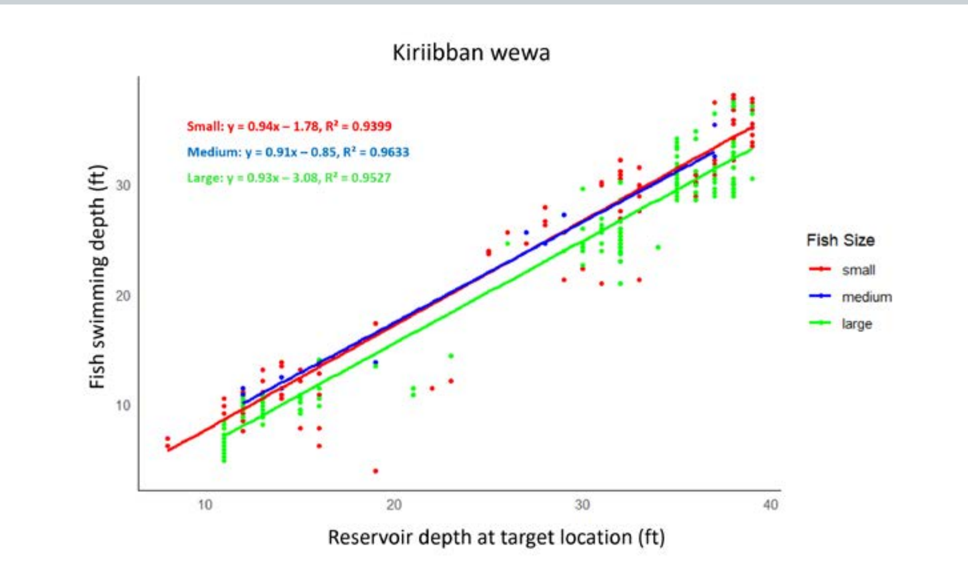

Figure 6.2.7: Correlation between fish swimming depth and corresponding reservoir depth at the target location in Kiriibban wewa

Table 6.2.3: DO and chlorophyll-a values measured at different depths at random locations in each reservoir, using a multipara water quality meter during the hydro-acoustic survey

Reservoir	Sampled location	Depth (ft)	DO (mg/L)	Chlorophyll-a (µg/L)
Kiriibban wewa	1	21.58±0.01	0.40±0.02	39.55±1.17
	2	29.9.±0.05	1.48±0.17	1.64±0.18
Handapanagala	1	22.73±0.01	3.89±0.14	24.29±2.77
Hakwatuna Oya	1	13.09±0.00	4.25±0.27	3.90±0.05
	2	30.49±0.00	1.00±0.03	4.75±0.11
	3	3.44±0.00	7.99±0.00	4.23±0.11
Mahawilachchiya	1	21.25±0.01	1.95±0.02	7.63±0.24
	2	1.00±0.00	9.28±0.00	3.52±0.01
Mahakanadarawa	1	25.66±0.00	1.63±0.04	41.19±16.74

Table 6.2.4: Total number of fish in each reservoir estimated through the sampled hydro-acoustic transect

Reservoir	Average swimming depth (ASD)/ft	Average width of transect at ASD/ft	Length of transect/ ft	Average surface area covered by transect/ ha	Number of fish targets covered by transect	Estimated total number of fish in the reservoir
Hadapanagala	17.7	2.2	12,566	0.253	77	80,426
Kiriibbanwewa	21.2	2.6	8,967	0.216	308	462,258
Mahakanadarawa	17.5	2.1	6,442	0.128	360	3,625,188
Hakwatunawa	23.7	2.9	8,131	0.220	582	960,364
Mahawilachchiya	12.0	1.5	8,765	0.120	212	2,104,388

Discussion

The aim of the present study is to assess the feasibility of using a commercially available hydro-acoustic fish finder as a tool for monitoring fish populations in reservoirs. The fish community in the agrarian reservoirs utilised for inland fisheries development primarily consisted of exotic species such as GIFT tilapia (Genetically Improved Farmed Tilapia), *Catla catla, Labeo rohita, Cirrhinus mrigala, Hypophthalmichthys molitrix, Hypophthalmichthys nobilis* and *Cyprinus carpio.* In addition, commercially important indigenous species such as *Etroplus suratensis, Puntius sarana, Channa striata* could be there. Indigenous GFP (*Macrobrachium rosenbergii*) are also stocked in these reservoirs, but since they are bottom dwelling, it is hard to observe through echosounders. Even scientific echosounders are not capable of distinguishing species underwater. Yet, verification of the commonly available species in the water could be possible by operating suitable fishing gear parallel to the acoustic survey, and the results could be meaningful. In this case, we are using hydro-acoustic data obtained from a fish finder during a bathymetric survey;

therefore, we could not verify at that time using a fishing gear.

There are attempts to use commercial grade fish finders for scientific surveys (Buscombe 2017; Nishikawa et al. 2025); however, the use of Deeper Smart Sonar CHIRP+2 fish finder is not evident. In that case, our small analysis might be the first attempt to use this portable, less expensive sonar device. Even scientific echosounders have limitations in detecting near surface and near bottom targets, and scientists have to find ways to overcome those limitations (Baran et al. 2017). In shallow water bodies, limitations are aggravated due to surface and bottom effects to the vertical acoustic beam; therefore, horizontal beaming could be an alternative if there is no misidentification of the size of the fish in its side aspect (Frouzova et al. 2005).

Since these commercial-grade sonar suppliers do not reveal the underlying mechanisms of identifying the fish targets separate from other living and non-living objects in the water column, it is always challenging to use this kind of apparatus for accurate measurements. Instead, we have to depend on indirect measurements and look for correlations between those measurements and population parameters taken by other means. The software application of Deeper Smart Sonar CHIRP+2 shows 3 size classes of fish but do not specify the real size range of each size class. When attempting to determine those size classes under a controlled environment it was found that the sonar recognised a fish <10 cm of size as a 'small' fish and 10–22 cm of size as a 'medium' fish. There were no >22 cm fish in the experiment pond. Sonar did not recognise dead specimens, and practically it was difficult to find a live specimen of bigger size to decide the upper limit of 'medium' and the fish of 'large' category.

The present study found that the reservoirs observed possess common and identical fish distribution patterns probably due to similar environmental conditions in those reservoirs. Fish were not seen closer to the surface, probably due to the disturbance created by the moving canoe or avoidance of higher temperatures by the fish at the surface. Hakwatuna Oya reservoir showed the highest average fish swimming depth. It suggests that the reservoir provides preferred conditions for fish to swim deeper. Figure 6.2.4 showed fish distribution over 30 ft, although the random measurements of DO at that depth were low. Kiriibbanwewa showed 2 clusters of fish distribution in which the number of fish targets was low in between 15 to 25 ft depth range. At the same depth range, very low DO values and unusually high chlorophyll-a values were observed. Fish are missing probably due to an algal bloom at that depth range. Mahakanadarawa also has high chlorophyll-a values around 25 ft of depth, and fish targets were found shallower than that.

Larger fish targets had the deepest mean swimming depth compared to the other 2 groups. This indicated that large fish tended to swim deeper than small ones. However, it is not known how large those fish are. This preference could be due to fishing pressure as well as their physiological capabilities to overcome competition for the limited resources. Since random measurements showed low DO levels at deeper layers, it can be a species like tilapia which can tolerate such conditions (Bergstedt et al. 2021). However, further research is needed to verify the size classes of fish identified by the fish finder before coming to concrete conclusions. Counting the number of targets would instead be a better option. The examined hydro-acoustic transect provides an average estimate of the total number of fish. To increase the accuracy of this estimate it is recommended to increase the survey length and/or increase the number of surveys throughout a longer period of time – preferably one year – to count the seasonal differences as well.

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