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Seasonal Hydro-Climatic Consequences on Fish Harvests in the Vavuniya Reservoir, Sri Lanka

A.E.S. Patrick^{1*} and S. Kuganathan²

¹Department of Bio-Science, Faculty of Applied Science, Vavuniya Campus, University of Jaffna, Sri Lanka

²Department of Fisheries, Faculty of Science, University of Jaffna, Sri Lanka
patrickvavuniyacampus@gmail.com

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Abstract

Vavuniya reservoir is a tropical lowland shallow irrigation tank located in Vavuniya District, Northern Province, Sri Lanka. As it is situated in the dry zone, experiencing the water scarcity probably due to the climate related changes which in turn affect the seasonal hydro-climatic factors recently. This study focused on the effects of seasonal hydro-climatic factors on fish harvests in this reservoir. The major hydro-climatic factors are monthly total rainfall (RF) and monthly mean water level (WL). RF, WL, catch/harvest and effort data were collected from January 2013 to December 2014. Semester and quarter wise categorization of both years were done based on RF and WL by using moving average techniques. There was no correlation between RF and WL ($p = 0.606$ & $r = 0.231$) due to irrigation. In 2013, the annual fish harvest was 16 130 kg and in 2014 it was 27 005 kg. The WL showed a strong negative correlation and a significant ($p=0.037$) relationship between most catchability variables compared with RF. Direct and the indirect effect of climate related changes influenced the seasonal pattern of this hydro-climatic factors which in turn affect the fish harvest and fish species survival in this reservoir. Findings of this study reflected the current changes in seasonality and its consequent threats to fisheries. Hence, optimal fish harvests can be achieved via rational understanding of this baseline information in Vavuniya reservoir.

Keywords: Seasonality, Hydro-climatic factors, Fish harvest.

Introduction

Vavuniya reservoir is a medium perennial reservoir which lies between 8°45'13.75 - 59.23" N latitude and 80°30'7.50 - 53.21" E longitude in Northern Province, Sri Lanka (Figure-1). This

reservoir spreads over about 1.328 km² of surface area. Major water sources of this reservoir are north-east monsoonal rains and inter-monsoonal rains and seasonal spilling from nearby reservoirs. The mean annual rainfall was 1000 – 1500 mm in Vavuniya District¹.

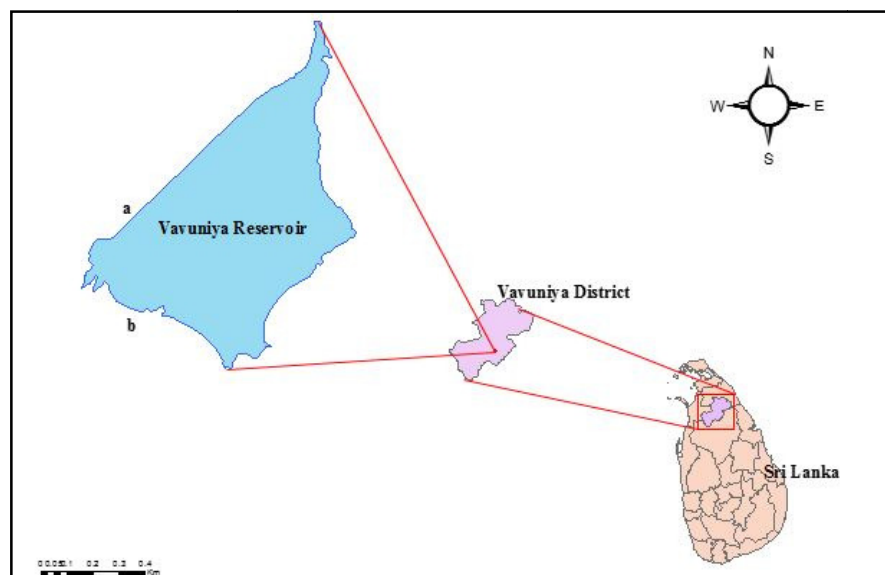


Figure-1

Map showing the study site (Vavuniya reservoir) (a) Poonthottam landing site, (b) Rampaikkulum (Urban drainage inlet)

Seasonal variations of the rainfall determine by the temporal weather characteristics and the global climate change in the Northern region Sri Lanka². Alterations in the seasonal hydro-climatic factors like rainfall and water level probably due to the climate related changes. Draining water for agriculture even from the dead storage resulted completely dried out from June to September 2012 and dramatic drop in water level occurred during September, 2014 in Vavuniya reservoir. A scientific study on hydro-climatic factors and its influences of fisheries management has never performed for Vavuniya reservoir. Effects of seasonal hydro-climatic factors on fishing practices, management strategies and fish biology remain highly disputed in Vavuniya reservoir.

Inland reservoirs are doted globally and sensor the climate change in number of ways which reveal the information about the effect of climate change via only proper understanding^{3,4}. Pronounced effects of global warming are now being observed in many inland lakes and reservoirs, with severe consequences for the ecosystem services they used to provide. This justifies the urgent need to study the present status of the inland fisheries in the Vavuniya reservoir to meet the sustainable and optimum fish harvests.

Materials and Methods

Data Collection: Weekly filed visits were made to landing sites in order to collect, catch, effort and water level data from January, 2013 to December 2014. Daily rainfall data were obtained from the Meteorology Department, Vavuniya and the monthly total rainfall (RF) were calculated. The monthly mean water level (WL) of the Vavuniya reservoir was calculated after getting the weekly data by direct observation. Monthly total

catch of the reservoir was estimated by using the daily fish catch data obtained from the logbook of the fishers.

Catch statistics for hydro-climatic categories: Determination of these quarters were done by calculating 3 month moving averages of monthly total rainfall patterns in order to obtain heavy, medium, low and very low quarters⁵. Additionally, 6 month moving averages were also calculated to categories high and low RF semester of the annum. Catch statistics were used to calculate fish species wise and total catch with respect to the above categories of the annum. Likewise water level based 4 quarters and 2 semesters were determined with respect to its catch statistics in both years.

Determination of catch and effort: Catch assessment surveys were conducted to obtain the necessary information (number of fishers, number of crafts and fishing gear). Fish catch data such as number and types of crafts and gear, commercial fish catches, fishing duration, fishing methods were obtained by using questionnaires and interviewing fishers. Mean Catch per Unit Effort (kg/fisher/day and kg/fishing gear/day) and other catchability variables such as fishing days/fisher/month, total number of boat days/month and total number of gillnet days/month were determined⁵.

Results and Discussion

Hydro-climatic factors in the Vavuniya reservoir: Although the rainfall was the major water source (North-East monsoon and 2nd inter-monsoon), dynamics of the water level in Vavuniya reservoir, Sri Lanka depended on irrigation as well. Consequently, the Pearson correlation coefficient between monthly total rainfall and monthly mean water level (Figure-2) was less positive and insignificant ($p= 0. 606$ and $r = 0.231$).

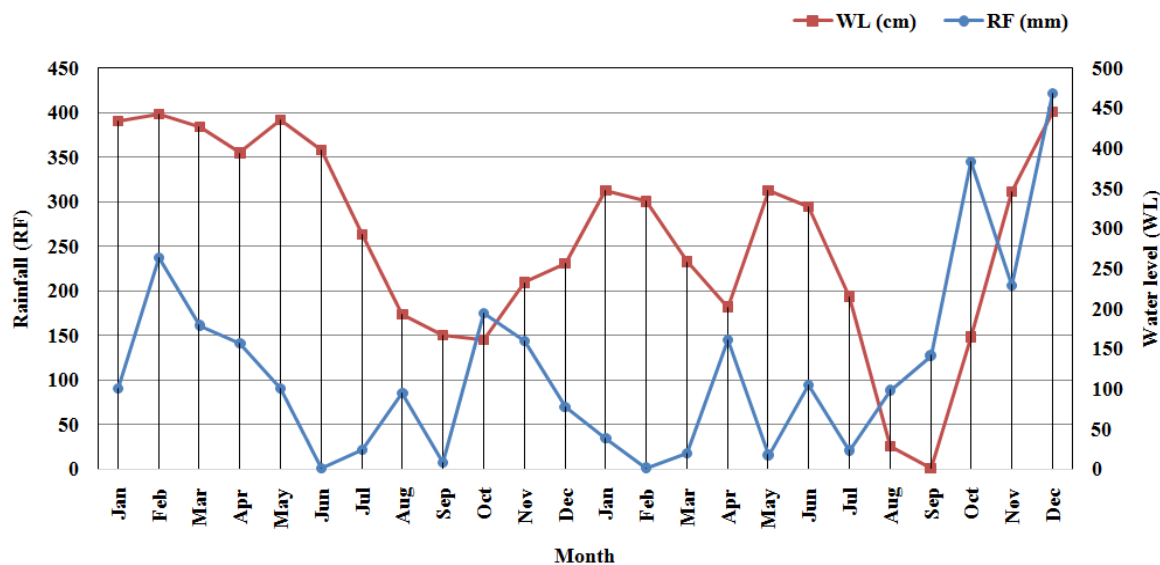


Figure-2

Seasonal fluctuation of hydro-climatic factors (rainfall [RF] and water level [WL] in Vavuniya reservoir) for the period of January, 2013 to December, 2014

In this reservoir the annual fish harvest in 2013 was very low (16 130 kg) compared to previous years⁶. This was mainly due to the unprecedented drought prevailed from June up to September, 2012 resulted complete eradication of fish, which in turn led to harvesting undersized fish (recently stocked fingerlings and naturally immigrated younger fishes) were the main reasons⁷. Long term water level fluctuation in reservoirs effects the fish population structure and the estimates of fish harvest and management⁸⁻¹⁰.

In 2014 the annual total fish harvest was 27 005 kg due to subsequent stocking, natural recruitment and increased efforts. However, dramatic decline in water level happened during July to September, 2014 due to over-extraction for irrigation even from the dead storage of this reservoir (Figure-3).

Almost all the indigenous fish species in the Vavuniya reservoir were vulnerable due to the water scarcity, observed in July 2014 (Figure-4). Therefore, Vavuniya reservoir fish production experiencing vulnerability probably because of climate related changes that affect the seasonality of hydro-climatic factors.

The direct cause may be due to the climate change and its consequent effects on the remarkable changes of rainfall patterns. And the indirect effect was irrational irrigation practices caused sudden drop in the water level. These kind of similar impacts were found in world wide.

Many inland fisheries are threatened by alterations to water regimes. In severe drought, cause vanishing of whole lakes and waterways in Africa¹¹. Fluctuations in the hydro-climatic factors influenced the catch (harvest) and effort and biology of fish, resulted the non-uniformity of the catch distribution in Vavuniya reservoir. This non-uniformity of the monthly catch distribution of each species was found to be significant ($p < 0.05$) throughout the years 2013 and 2014.

Catch statistics for rainfall based quarters: In Vavuniya District during the past couple of decades (1992 - 2012) the heavy rainfall based quarters were found among Sep-Nov, Oct-Dec and Nov- Jan quarters (Table-1).



Figure-3
Over extraction for irrigation leads to Zero WL during Aug – Sep, 2014



Figure-4
 Fish death in Vavuniya reservoir happened during July to August, 2014

Table-1
 Heavy rainfall (RF) based quarter of the past 2 decades in Vavuniya District

Year	Three months moving average of RF (mm)	Heavy RF based Quarter
1992	203.1	Sep-Oct-Nov
1993	389.4	Oct-Nov-Dec
1994	189.0	Sep-Oct-Nov
1995	143.7	Sep-Oct-Nov
1996	220.5	Oct-Nov-Dec
1997	326.4	Oct-Nov-Dec
1998	270.8	Nov-Dec-Jan
1999	255.9	Oct-Nov-Dec
2000	274.3	Nov-Dec-Jan
2001	233.4	Oct-Nov-Dec
2002	231.2	Oct-Nov-Dec

Year	Three months moving average of RF (mm)	Heavy RF based Quarter
2003	218.5	Nov-Dec-Jan
2004	262.3	Oct-Nov-Dec
2005	214.8	Oct-Nov-Dec
2006	187.9	Oct-Nov-Dec
2007	287.1	Oct-Nov-Dec
2008	234.9	Oct-Nov-Dec
2009	281.5	Oct-Nov-Dec
2010	283.8	Nov-Dec-Jan
2011	315.6	Nov-Dec-Jan
2012	432.8	Oct-Nov-Dec
2013	200.5	Feb-Mar-Apr
2014	361.0	Oct-Nov-Dec

During heavy rainy season fishers tend to cease fishing and involving in fish (fingerling) stocking as a management strategy. However, there was a shift in heavy rainfall based quarter occurred in 2013 as Feb-Apr, indicating irregular rainfall pattern. Consequently fishers continued fishing throughout the year 2013 without ceasing fishing and stocking in this heavy rainfall period unlike in the past years⁷.

This may be due to the consequences of climate related changes on the seasonal rainfall pattern in Vavuniya, Sri Lanka. The remarkable change in rainfall that decreasing trend in number of rainy days and mean annual rainfall in Vavuniya District due to climate change¹².

Among rainfall based quarters, the total harvest increased with decreasing rainfall (heavy rainfall to low rainfall quarters). Total quantity of fish harvested during low rainfall periods was always higher¹³. However, lower RF based quarter (Aug-Oct) received comparatively higher fish harvest than very low RF based quarter (May-Jul) in 2013. This happened due to the higher WL found in the very low RF based quarter compare to the low rainfall based quarter, pinpointing the importance of WL fluctuations.

In 2014 the trend of RF based quarters and its respective harvest was not similar to the year, 2013. The very low (Jan-Mar), low (Jul-Sep) and medium (Apr- Jun) rainfall based quarters indicated an increasing trend in the fish harvest e.g. 7 623 kg, 8 986 kg and 10 396 kg respectively.

However, heavy rainfall based (Oct-Dec) quarter showed zero harvests in 2014, since the water level played a major role than rainfall for the fish harvest in Vavuniya reservoir. In addition in September, 2014 WL was zero while there were a few pockets of water in the reservoir bed. Subsequently, heavy RF occurred from October to December 2014 contributed to the zero harvest due to stopping fish harvest. When reckoning the semester wise categorization, higher harvests (8 614 kg) occurred in lower RF semester (Apr- Sep) and lower harvest (7 516 kg) in higher RF semester (Oct-Mar) in 2013. In 2014 higher harvests (24 949 kg) observed in lower RF semester (Feb- Jul) and lower harvest (2 056 kg) in higher RF semester (Aug- Jan) of the same year (2014) indicating the impact of RF.

Catch statistics for water level based quarters: There was a steady increasing pattern in total fish harvests with decreasing WL in 2013. The WL based quarters were categorized as higher (Jan-Mar) = 1 409 kg, medium (Apr-Jun) = 4052 kg, Low (Jul-Sep) = 4561 kg and very low (Oct-Dec) = 6107 kg in 2013. In 2014, WL based quarters were found as very low (Sep-Nov), Low (Jun-Aug), medium (Mar-May) and high (Dec-Feb) and the higher harvests were observed from Mar- May (12 448 kg) and low harvests (3 736 kg) were in Dec- Feb (within the same year). Zero harvests were in Sep-Nov due to zero water level triggered in September as a result of over extraction of water for

cultivation (Plate 4.2). Zero catches in some months are very common in several countries especially in East Java zero catches were higher¹⁴. Reckoning the semester wise categorization, high WL semester (Jan- Jun) and low WL semester (Jul-Dec) were obtained in both years 2013 and 2014. In 2013 high WL semester (Jan- Jun) obtained lower harvests (5 462 kg) and low WL semester (Jul-Dec) got higher harvests (10 668 kg). However, in 2014 high WL semester got higher harvests (18 019 kg) and low WL semester obtained low harvests (8 986 kg) justified by the zero catches.

Annual seasonal fluctuations of catch and effort: Hydro-climatic factors (RF and WL) were the independent variables which affected the catch (harvest) and effort (catchability variables) in Vavuniya reservoir. Fishers used gill nets of 3½", 3¾", 4" and 4½" (stretched mesh sizes) as major fishing gear. However, in 2013, since larger fish were not available only 3½" and 3¾" gillnets were used, which resulted in reduction in the annual total harvest than 2014 (Table-2).

From April, 2014 fishers used gill nets of 4", 4½" and 4¾" and increased their effort to harvest higher number of larger fish (Table-2). Fishers could able to forecast declining WL in the latter part of the year 2014 as happened earlier in 2012. Thus, use of appropriate fishing methods and suitable changes in effort according to the seasonal changes in hydro-climatic factors are important for obtaining the optimal harvest particularly in Vavuniya reservoir.

Pearson correlation coefficient (r) between monthly total harvest and WL showed significantly (p=0.02) stronger negative correlation when compared with RF in 2013 and 2014 (Table-3). This was due to the significantly high contribution of *Oreochromis sp.* (79-89%) to the monthly total harvest. *Oreochromis sp.* catchability depended mainly on water level rather than rainfall⁵.

Increase in WL, significantly (p<0.05) reduced the catchability variables (total number of gillnet days/month, total number of boat days/month and number of fishing days/fisher/month) in 2013 and 2014 (Table-3). However, rainfall did not show any significant relationship with these catchability variables. Comparatively, RF occurring very short period and the resulted WL existing lengthen period. Thus, fishing efforts mainly depended on WL and slightly depended on the direct RF in Vavuniya reservoir.

There was a strong negative correlation between monthly average WL and Catch Per Unit Effort (CPUE) in kg/fisher/day. Setting gillnets and fishing in the reduced WL was easy in reservoirs. Due to the possibility of high CPUE, more fishers tend to engage in fishing for long duration during the lower WL periods. Negative relationship between the water level and CPUE in Nigerian reservoirs indicated the difficulty of harvesting fish with expanded volume of water¹⁵.

Table-2
Hydro-climatic factors and respective harvest data

Month of year 2013-2014	Hydro-climatic factors		Catchability								
	RF (mm)	WL (cm)	Total Harvest (kg)	Harvest Per Unit Effort		No. of fishing days per Fisher	No. of boat days		No. of Gillnet days		Total No. of Gillnet days
				kg/ fisher/ day	kg/ gear/ day		Canoe	ILT	3 ½"	3 ¾"	
Jan	100.9	390.7	479	0.63	0.11	11	119	25	425	225	650
Feb	264.4	398.1	412	0.84	0.17	11	125	22	400	225	625
Mar	179.6	384.5	519	1.08	0.18	11	119	25	450	250	700
Apr	157.5	354.9	707	1.62	0.26	19	213	NIU	900	450	1 350
May	100.8	392.3	953	1.05	0.13	20	225	NIU	650	1 200	1 850
Jun	1.7	358.1	2 392	2.34	0.30	23	256	NIU	700	1 450	2 150
Jul	24.5	263.5	1 331	1.70	0.12	18	200	NIU	950	1 900	2 850
Aug	95.3	173.9	1 953	1.40	0.13	24	261	NIU	975	1 975	2 950
Sep	8.3	150.6	1277	2.60	0.30	20	217	NIU	675	1 375	2 050
Oct	194.9	144.9	2 373	2.20	0.20	23	250	NIU	800	1 625	2 425
Nov	160.3	209.4	2 438	2.70	0.27	21	231	NIU	775	1 525	2 300
Dec	78.3	231.1	1 295	2.50	0.25	23	250	NIU	850	1 700	2 550
Jan	39	312.8	1 841	2.11	0.20	25	225	NIU	1550	1175	2 725
Feb	2	300.5	2 075	2.50	0.25	26	250	NIU	1670	1060	2 730
Mar	20	232.9	4 084	3.50	0.35	27	294	NIU	1475	875	2 940
Apr	162	181.9	5 212	8.92	0.90	27	350	NIU	840	860	2960*
May	18	312.8	2 853	2.51	0.25	26	288	NIU	650	1100	2850*
Jun	105	294.7	2 146	2.70	0.27	25	275	NIU	450	800	2690*
Jul	24	193.7	6 842	8.30	0.84	27	292	NIU	550	775	2875*

ILT-Inflated lorry tube, a modified fishing method used in newly flooded areas during spilling, (NIU) Not in use and gillnet types categorized according to stretched mesh sizes 3 ½, 3 ¾, 4½ & 4¾ inches (* 4½ & 4¾ inches are used for only 4 months period in 2014).

Table-3
Statistical summary of catchability variables with hydro-climatic factors

Catchability variables	Hydro-climatic factors							
	Rainfall (RF)				Water level (WL)			
	p-value		r-value		p-value		r-value	
	2013	2014	2013	2014	2013	2014	2013	2014
Total harvest	0.381	0.701	-0.278	0.178	0.020	0.003	-0.658	-0.922
CPUE (kg/gear/day)	0.750	0.255	-0.100	0.498	0.290	0.002	-0.327	-0.936
CPUE (kg/fisher/day)	0.200	0.253	-0.394	0.500	0.009	0.002	-0.713	-0.935
No. of fishing days/fisher	0.150	0.849	-0.430	0.089	0.010	0.017	-0.670	-0.842
No. of boat days	0.159	0.480	-0.430	0.323	0.020	0.038	-0.637	-0.782
No. of gillnet days	0.084	0.823	-0.518	0.105	0.004	0.037	-0.750	-0.784

Conclusion

Consequences of climate related changes via hydro-climatic fluctuations on the sustainable fish harvests in the Vavuniya reservoir were clearly visible. Unpredictable changes in the seasonal rainfall pattern which in turn affecting the water level directly and indirectly (irrigation). Fish harvests and fish survival mainly depended on these seasonal hydro-climatic factors. Therefore, rational understanding and more research activities needed locally and as well as regionally regarding inland fisheries with respect to the hydro-climatic changes.

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