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COMPARATIVE STUDY ON WATER QUALITY INDEX OF LAKE VS. ADJOINING TIDAL FED SHRIMP FARMS ALONG VEMBANAD LAKE, A RAMSAR SITE, KERALA, INDIA

Rosewine Joy
S.D.G. Centre, Presidency University, Bangalore, Karnataka, India
Email : rosewinejoy@presidencyuniversity.in

Abstract

Climate change and pollution is impacting ecosystems and life depending on same. Water bodies across world are impacted by these variability which influence the life and production process based on same. Aquaculture is one such food production system which is heavily influenced by the quality of environment for its sustainability and growth. Water quality Indexing (WQI) is an important tool applied in aquaculture to manage the water quality of the farming system. The index helps to comprise the water quality variation to one number and helps to analyse the same in an easy manner. We create four indexes for the study for each study zones, North, central and south zone from Vembanad Lake. The objective of the study is to understand how far WQI of the lake could influence the water quality index of the farm and secondly to assess how far water quality could be improve with human intervention. The methodology adopted for the study is an arithmetic weighted index method proposed by (Pesce & Wunderlin, 2000). The study point out that the water quality index of the lake has a higher influence on the water quality index of the farms. It also points out that though the water quality index of lake and farm area could be related, the water quality of the farms could be managed in the long run through various management practices.
Keywords: Climate change, Pollution, Water ecosystem, Aquaculture, Water quality Index.

Introduction

With the capture fishery leveling off in production, there is an increasing focus on aquaculture worldwide as a source of food fish. The joint report by the World Bank, FAO and the International Food Policy Research Institute (IFPRI) predicts that 62% of food fish will come from aquaculture by 2030. Henceforth the fisheries sector is undergoing a paradigm shift in focus from capture fishery to culture fishery. Invariability in many developing countries aquaculture is envisaged as an effective contributor to the nation's food and nutritional security, export earnings, income and employment generations, poverty eradication and gender equality. Being the second-largest producer of fisheries as well as the second-largest producer of aquaculture India has a leadership role in addressing various challenges in the sector effectively. Water quality is a major resource that determines the success of aquaculture. Though water quality is an important input in extensive shrimp farming, this is never recognized as an important variable in aquaculture economics.

Water quality Indexing is an important tool applied in aquaculture to manage the water quality of the farming system. The index helps to comprise the water quality variation to one number and helps to analyse the same in an easy manner. The development of general water quality indices by selecting different parameters and attributing weights for the parameters is a method developed primarily by (Horton, 1965). The three leading international index's currently in use for water quality indexing are Canadian Council of Ministers of the Environment Water Quality Index (CCME – WQI), Oregon Water Quality Index (OWQI) and National Sanitation Foundation Water Quality Index (NSF – WQI). Many studies have pointed out the effectiveness of Water quality Indexing as a management tool for assessing the water quality of the water body for differential use. Though the majority of the indexes are created to understand the suitability of water for human consumption and well being and create monitoring systems along these lines. In due course, many of the necessary variables important for aquatic life like fish, shellfish etc. get sidelines in this process.

Though there are around 300 water quality variables which could influence the water quality, water quality index is simplified by considering critical environmental variables which affect the quality of the aquatic body. (Simoes, Moreira, Bisinoti, Gimenez, & Yabe, 2008) to understand the water quality of Municipality of Las Rozas (north-west of Madrid, Spain), they use the National Sanitation Foundation Water Quality Index (NSF – WQI) for monitoring water quality for aquatic life. This index has nine parameters fecal coliform, pH, biochemical oxygen demand (BOD), total nitrogen, total phosphorus, temperature, turbidity, total residue, and dissolved oxygen. The result is expressed by a number between 0 and 100, divided in 5 quality ranges: (100 - 79) - Excellent Quality; (79 - 51) - Good Quality; (51 - 36) - Fair Quality; (36 - 19) - Poor Quality; [19 - 0] - Bad Quality (Chang, 2001). Another Index created for assessing water quality is the Canadian Council of Ministers of the Environment Water Quality Index (CCME WQI). This index has three elements *Scope* – the number of water quality parameters (variables) not meeting water quality objectives (*F*1); *Frequency* – the number of times the objectives are not met (*F*2); and *Amplitude*. the extent to which the objectives are not met (*F*3). The Oregon Water Quality Index (OWQI) is a single number that expresses water quality by integrating measurements of eight water quality variables (temperature, dissolved oxygen, biochemical oxygen demand, pH, ammonia nitrate nitrogen, total phosphorus, total solids, and fecal coliform (Cude, 2001)The water quality variables used for the indices are based on the Delphi method (Dalkey, 1968) When the values of WQI are in the range of 0– 25, the water must be classified as ''very bad''; for a WQI value in the range of 25–50 the water is classified as ''bad''; for WQI values in the range of 51–70 the water classification is ''medium''; finally, when the WQI values are within the range of 71–90 and 91–100 the water is classified as ''good'' and as ''excellent'', respectively (Jonnalagadda & Mhere, 2001)

Lumb *et al*. (2006) studied the water quality of Mackenzie – Great Bear sub-basin in Canada using the index method. Khan *et al*. (2003) applied the Canadian Water Quality Index (CWQI), and British Columbia Water Quality Index (BWQI) to three selected watersheds of Atlantic region: the Mersey River, the Point Wolfe River, and the Dunk River sites for various uses like agriculture, aquatic life, and drinking water. Simoes *et al*. (2008) used three parameters total phosphorous, turbidity and dissolved oxygen for creating one index and another by considering the index proposed by NSF to study the water quality of Me´dio Paranapanema Watershed in Sa˜o Paulo State, Brazil, as a simple pollution indicator for aquaculture activity. (Silva & Jardim, 2006) (André *et al*., 2011) used the concept of the minimum operator to develop their index, called Water Quality Index for protection of aquatic life (IQAPAL) based on only two parameters, Total Ammonia (TA) and Dissolved Oxygen (DO). (Pesce & Wunderlin, 2000) used is the arithmetic mean of three environmental parameters, Dissolved Oxygen (DO), Turbidity (T) and Total Phosphorus (TP) for creating the Index for pollution at SuquõÂa River in CoÂ rdoba City (Argentina). (Akkoyunlu & Akiner, 2012) used the National Sanitation Foundation Water Quality Index (NSF–WQI) to study the water quality of in Sapanca Lake Basin (Turkey) as well as made a minimalised index to understand the pollution scenario by using four water quality variables temperature, pH, dissolved oxygen (DO), total suspended solids (TSS), and electrical conductivity (EC) .The study found a eutrophication treat to Sapanaca Lake. The study by (Debels *et al*., 2005) used water quality indexing method (NSF-WQI) in Chillan River in Central Chile foran year in 18 sampling points on water quality variables .They modified the index applying principle component analysis and created an index with four variables (pH, temperature, conductivity and Dissolved Oxygen) (Smith, 1990) used. The Oregon Water Quality Index (OWQI) to study the water quality and applied minimum operator concept to find the index value for water suitability for a differential purpose like general purpose, bathing ,water supply and fish spawning (salmonids) in New Zealand.

Majority of the studies from India on water quality Indexing has followed a modified version of (NSF – WQI) which is based on (Horton, 1965). (Dwivedi & Pathak, 2007) studied the water quality of Mandakini river, Chitrakoot. The study uses 9 variables across 6 sampling stations to study the water quality of river for drinking purpose and found water could only be used post-treatment. Many Indian studies use the method proposed by Brown and Forsythe (1974). to index water quality to estimate suitability of water for drinking purpose (Rekha, George, & Rita, 2013); (Sajjad, Jyoti, & Uddin, 2014) etc **.**Most of the Indexing studies are on drinking water suitability .The Water quality indexing for aquatic life is peripheral and the current work is first of its kind for India. The study also is a pioneering work on indexing the water quality for a period of 12 years comparing the water quality of an ecosystem and a production system which use the ecosystem simultaneously. In general water quality index studies are for a shorter period of time and compare seasonal difference or compare water quality for suitability for differentiated uses.

Materials and Methods

The WQI is an index of water quality for a particular use. Mathematically, the index is an arithmetic weighting of normalized water quality measurements. To assess the water quality index for the lake we considered the published secondary data by Central pollution control board (CPCB). To understand the water quality of farms we used the unpublished secondary data of water quality data from the National Centre for Aquatic Animal Health, Cochin University of Science and Technology. We create four WQI indexes for this study. Two WQI for the Lake and two for the aquaculture farms in three zones. The first index for the Lake is (WQI_{lkc}) by incorporating variables temperature, salinity, pH, DO, BOD, Ammonia, nitrogen, Nitrite and Nitrate. The second Index for the Lake is (WQI_{lkind}) incorporating the water quality variables specified as DO, Ammonia nitrogen and pH, which are the variables specified by CPCB as necessary variables forthe propagation of Wild life and Fisheries. The third index is for water quality of farms (WQI_{fmc}) by incorporating variables temperature, salinity, pH, DO, Ammonia nitrogen, Nitrite and phosphate. The fourth Index is for water quality of farms by incorporating only three variables (WQI_{fmmi}). This minimum index is based on variables DO, Ammonia nitrogen and Salinity as these variables are having higher % of variability along the brackish water ecosystem. The method proposed by (Pesce & Wunderlin, 2000) and followed by (Sa´nchez, *et al*., 2007) is used for normalization of the water quality parameters and for respective weights. Water Quality Index is calculated as an objective index by using only measurable values. It could be calculated by incorporating subjective variables as well as

Water quality Index is calculated as

$$WQI = k\frac{\sum Ci \times Pi}{\sum Pi}$$

Where, *K* is a subjective constant (as the estimations are based on objective assessment, k is considered as1.. Ci is the value assigned to each parameter after normalization and Pi is the relative weight assigned to each parameter. Pi value range from 1 to 4, with 4 representing a parameter that has the most important for aquatic life and 1 represent the parameter that has a small impact. The Ci normalization and Pi relative weights for variables are discussed below.

Table 1 : Parameter considered for WQI Calculations

Parameters	Relative Weight (Pi)	Normalization factor Ci										
		100	90	80	70	60	50	40	30	20	10	0
		Analytical value										
Temperature	1	21	22	24	26	28	30	32	36	40	45	>45
Salinity	2	>15	>20	>25	>30	>35	<15	<10	<5	>35	40	>40
pH	1	7	8-Jul	7-8.5	9-Jul	6.5-7	6-9.5	10-May	11-Apr	12-Mar	13-Feb	14-Jan
DO	4	>7.5	>7	>6.5	>6	>5	>4	>3.5	>3	>2	>1	<1
Ammonia Nitrogen	3	<0.01	<0.05	<0.10	<0.20	<0.30	<0.40	<0.50	<0.75	<1	<1.25	>1.25
Nitrites	2	<0.005	<0.01	<0.03	<0.05	<0.10	<0.15	<0.20	<0.25	<0.50	<1.00	>1.00
BOD	3	<0.5	<2	<3	<4	<5	<6	<8	<10	<12	<15	>15
Nitrates	2	<0.5	<2.0	<4.0	<6.0	<8.0	<10.0	<15.0	<20.0	<50.0	<100.0	>100.0
Phosphate	1	<0.16	<1.60	<3.20	<6.40	<9.60	<16.0	<32.0	<64.0	<96.0	<160.0	>160.0

Due to the lack of available field data, the WQI proposed in this work does not take into account suspended solids, microbiological contamination nor toxic compounds; only parameters for which a complete data set was available for the study area were considered. Water quality index values are rated as Very bad, bad, Medium, Good, very good.

Results and Discussion

The analysis of the water quality index assessments are discussed below :

Water Quality Index (WQI) for Lake and Extensive shrimp farms along North Zone

With increasing water pollution and climatic variation, manging natural resources, along with development needs is going to be a challenge. The index method give us feedback on how well we could manage multiple needs without compromising the integrity of natural resources which are needed for sustainable growth.

Table 1.1 : Water Quality Index (WQI) for Lake and Extensive shrimp farms along North Zone

Year	WQI_{lkc}	Status	WQI_{lkind}	Status	WQI_{fmc}	Status	WQI_{fmmin}	Status
2000	75	Good	63	Medium	64	Medium	68	Medium
2001	76	Good	64	Medium	69	Medium	67	Medium
2002	70	Medium	64	Medium	75	Good	71	Good
2003	69	Medium	69	Medium	60	Medium	50	Bad
2004	68	Medium	70	Medium	69	Medium	68	Medium
2005	73	Good	75	Good	59	Medium	44	Bad
2006	65	Medium	63	Medium	61	Medium	48	Bad
2007	58	Medium	53	Medium	64	Medium	54	Medium
2008	58	Medium	53	Medium	69	Medium	76	Good
2009	65	Medium	59	Medium	69	Medium	57	Medium
2010	66	Medium	61	Medium	68	Medium	57	Medium
2011	71	Good	69	Medium	74	Good	64	Medium
2012	69	Medium	65	Medium	78	Good	72	Good

WQI_{lkc}- Comprehensive index for Lake;; WQI_{lkind}- Index for Lake with CPCB variables;; WQI_{fmc}- Comprehensive index for Farm;; WQI_{fmmin}-Minimum index for a farm.
YOY-Year on Year change
Source: Own calculation'

The comprehensive index for lake WQI_{lk} shows that the water quality was good only for 4 out of 13years. Rest of the 9 years the water quality was showing medium results. Comparing the index for 13 years only in 5 years water quality improved in comparison to the previous year while the rest of the years where found decreasing.. In case of WQ_{lkind}, which is created using the water quality parameters put forth by CPCB for the propagation of wild life and fishery, the index for lake shows that out of 13years,, except in one year all other years we were having medium water quality. Only one year we had good water quality for aquatic life. The year on year change shows, four out of twelve years water quality shows improvement.

The comprehensive index for farms WQI_{fmc} along the Vembanad Lake shows that 3/13 years where having good water quality while 10/13 years we were having medium water quality. The year on year assessment shows that only for three years the index is decreasing while the rest of the years it is increasing. The minimum index WQI_{fmmin} which is used to understand the farm water quality with minimum water quality variables which are the most important for brackish water, as well as the most variable parameters along this ecosystem shows that 3/13 years it was good, 7/13 years it was medium and 3/13 years it is bad. On an year on year scale for 5 years water quality was decreasing while for 7 years water quality was increasing. These index s are important as it gives us an indication on how well we could manage water quality in each zone at basin level and at a production system level. In the case of North zone, water quality is medium at basin level while a farm level more management efforts are required to handle the water quality improvement efforts

Table 1.2 : Water Quality Index (WQI) for Lake and Extensive shrimp farms along Central Zone

Year	WQI_{lkc}	Status	WQI_{lkind}	Status	WQI_{fmc}	Status	WQI_{fmmin}	Status
2000	67	Medium	54	Medium	64	Medium	58	Medium
2001	67	Medium	39	Bad	54	Medium	49	Bad
2002	76	Good	59	Medium	71	Good	68	Medium
2003	57	Medium	50	Bad	72	Good	64	Medium
2004	75	Good	65	Medium	59	Medium	48	Bad
2005	74	Good	61	Medium	61	Medium	57	Medium
2006	67	Medium	64	Medium	62	Medium	60	Medium
2007	66	Medium	71	Good	66	Medium	63	Medium
2008	57	Medium	54	Medium	64	Medium	60	Medium
2009	64	Medium	58	Medium	65	Medium	63	Medium
2010	63	Medium	53	Medium	60	Medium	51	Medium
2011	66	Medium	59	Medium	72	Good	68	Medium
2012	66	Medium	59	Medium	70	Good	72	Good

WQI_{lkc}- Comprehensive index for Lake;; WQI_{lkind}- Index for Lake with CPCB variables;; WQI_{fmc}- Comprehensive index for Farm;; WQI_{fmmin}-Minimum index forra farm.
YOY-Year on Year change Source: :Own calculation'

In the central zone, the comprehensive index for lake WQI_{lk} shows that the water quality was good only for 3 out of 13years. Rest of the 10 years the water quality was showing medium results. Comparing the index for 13 years only in 7 years water quality improved in comparison to the previous year while the rest of the years where found decreasing. In case of WQI_{lkind}, which is created using the water quality parameters put forth by CPCB for propagation of wildlife and fishery, the index for lake shows that out of 13years, 2 years water quality has reduced to the status of bad water quality, 1 year it was good and rest 10 years it was medium . The year on year change shows, 7/13 years water quality shows improvement.

The comprehensive index for farms WQI_{fmc} along the central zone of the Lake shows that 4/13 years where having good water quality while 9/13 years we were having medium water quality. The year on year assessment shows that for seven years the water quality index is decreasing while the rest of the years it is increasing. The minimum index WQI_{fmmin} which is used to understand the farm water quality with minimum water quality variables which are the most important for brackish water, as well as the most variable parameters along this ecosystem shows that 1/13 years it was good, 10/13 years it was medium and 2/13 years it is bad. On an year on year scale for 5 years water quality was decreasing while for 7 years water quality was increasing. In the case of Central zone, water quality at basin level and farm level especially minimum indexes shows bad water quality which invites management concerns on the degradation of resources and usage of resources for productive purposes like aquaculture

Table 1.3 : Water Quality Index (WQI) for Lake and Extensive shrimp farms along South Zone

Year	WQI_{lkc}	Status	WQI_{lkind}	Status	WQI_{fmc}	Status	WQI_{fmmin}	Status
2000	74	Good	73	Good	66	Medium	60	Medium
2001	76	Good	75	Good	49	Bad	36	Bad
2002	74	Good	71	Good	65	Medium	64	Medium
2003	72	Good	71	Good	76	Good	71	Good
2004	75	Good	73	Good	63	Medium	52	Medium
2005	68	Medium	64	Medium	71	Good	66	Medium
2006	64	Medium	61	Medium	75	Good	68	Medium
2007	68	Medium	75	Good	66	Medium	57	Medium
2008	56	Medium	40	Bad	75	Good	71	Good
2009	65	Medium	58	Medium	56	Medium	42	Bad
2010	56	Medium	40	Bad	55	Medium	51	Medium
2011	68	Medium	66	Medium	56	Medium	51	Medium
2012	62	Medium	55	Medium	57	Medium	49	Bad

WQI_{lkc}- Comprehensive index for Lake;; WQI_{lkind}- Index for Lake with CPCB variables;; WQI_{fmc}- Comprehensive index for Farm;; WQI_{fmmin}-Minimum index for a farm.
YOY-Year on Year change Source: :Own calculation'

In the South zone, the comprehensive index for lake WQI_{lk} shows that the water quality was good for 5 out of 13years. Rest of the 8 years the water quality was showing medium results. Comparing the index for 13 years only in 7 years water quality was decreasing the rest of the years it was improving. In case of WQI_{lkind},which is created using the water quality parameters put forth by CPCB for propagation of wildlife and fishery, the index for lake shows that out of 13 years, 2 years water quality has reduced to the status of bad water quality, 6 years it was good and rest 5 years it was medium. It is important to note that after 2004, the water quality has deteriorated to Bad and medium levels in these locations. The year on year change shows, 8/13 years water quality shows a decrease in water quality.

The comprehensive index for farms WQI_{fmc} along the south zone off the Lake shows that 1/13 years where having bad water quality while 7/13 years we were having medium water quality and 5/13 years water quality was good. The year on year assessment shows that for five years the water quality index is decreasing while the rest of the years it is increasing. The minimum index WQI_{fmmin} which is used to understand the farm water quality with minimum water quality variables which are the most important for brackish water, as well as the most variable parameters along this ecosystem shows that 2/13 years it was good, 8/13 years it was medium and 3/13 years it is bad. On an year on year scale for 5 years water quality was decreasing while for 7 years water quality was increasing. In case of South zone, water quality at basin level and farm level especially minimum indexes shows a decreasing trend towards Bad and Medium water quality status which is of management concern at basin level as well as for aquaculture farmers.

Conclusions

The study points out the relation between water quality of lake and farm and how far they are related using water quality indexing method. It also points out that the central region of the lake though had a higher influx of pollutants could manage same at farm level by imposing various community management measures in managing the pollutants and climatic variables. However we could find that though North zone relatively better water quality has poor community participation and South zone with high pollution as well lack community participation. The study substantiate how far water quality of lake and farm are related in tidal fed systems and even in non-industrial traditional farms water quality is managed in the long run through various management practices .

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