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ECOSYSTEM ASSESSMENT OF THOL BIRD SANCTUARY WITH SPECIAL REFERENCE TO BENTHIC MACRO INVERTEBRATE COMMUNITY

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INTRODUCTION:

Wetlands have been extensively used and abused, they have been appreciated for their serene beauty and treated with contempt for harbouring disease causing organisms and their vectors whereas large areas of wetlands have been destroyed or modified, numerous new wetlands areas have been created. Wetlands are specialized ecosystems which perform important ecological functions and have many ecological socio-economic and cultural values. Wetland of particular importance also needs to be protected not only for direct benefits to mankind but also for other life on earth. Thol Bird Sanctuary, a wetland with a potential of internationally importance is also found to be facing human disturbances like ONGC well, live stock grazing, agriculture in nearby areas and withdrawal of water for irrigation. The study would provide an opportunity to have an insight in knowing the status of benthic diversity apart from the water and sediment quality. This would be of use for conservation and management of the Thol wetland ecology as an integrated manner. The study will also create awareness with regard to characterization of the wetland form Benthic Macro invertebrate diversity angle. With this study wetland science in general will be promoted in this region. This synopsis presents the summary of some of the important component of the research work. Other aspects like experimental data, graphs, figures, values, photographs etc. will be dealt in details in the thesis.

REVIEW OF LITERATURE:

During past several decades much efforts has been expanded on conservation of nature and natural resources, including wetlands and on educating people about the need for

conservation. These efforts have been spearheaded by the IUCN and the WWF. Conservation does not necessarily imply complete protection against all kinds of human interference but allows for sustainable utilization or 'wise use' of natural resources. Protection however is often necessary where a resource is rare or seriously threatened. Whereas many sites have been protected variously by legislative measure, there is increased global emphasis on sustainable use of wetland resources.

The Directory of Indian wetland prepared first by the IUCN as a part of the Asian Wetland directory and revised by WWF-India (WWW and AWB, 1993; Nitin et al., 2014), forms the basic source of useful information on wetlands in the country. However, the first scientific mapping of wetlands of the country was carried out using satellite data of 1992–1993 by Space Applications Centre (SAC), Ahmedabad (SAC 2011) and is the latest inventory on Indian wetlands. The exercise classified wetlands based on the Ramsar Convention definition. Information on the ecological functions and values such as ground water recharge, control of floods and erosion or regulation of water quality but their value as habits for waterfowl and in some cases for other wildlife has been described in some detail.

In India, several wetlands have been declared protected areas as sanctuaries, national parks or nature reserves. In case of wetland, conserved outside the purview of the National Wetland Programme, the emphasis remains on one or more particular species and the ecological features of wetlands together with other characteristics species continue to be ignored.

The wide fluctuation in water level is a common feature in typical wetland or a reservoir and has some effect on their ecology i.e. nutrient exchange between pelagic and littoral zones of reservoir (Andrew and Pfiester, 1995). A strong correlation exists among physico–chemical properties, hence, a systematic calculation and interpretation of coefficient of correlation gives us an idea of rapid water quality monitoring (Arvinda et al., 1995). The quality of water

depends on its surface temperature, various gaseous as well as salt contents and other chemically linked biochemical factors (Kumar and Kapoor, 2006). Thus, the quality of water is reflected by the values of physico-chemical parameters of a water body.

There is increasing evidence that the condition of the bottom and the exchange of substances between sediment soil and water strongly influence water quality (Boyd, 1995). The soil strongly adsorbs phosphorous, and the capacity of soil to absorb phosphorous increases as a function of increasing clay content (Boyd and Munsiri, 1996). Erosion of the watershed results in suspended particles of mineral soil and organic matter entering in a wetland through run off. The chemical nature of sediment plays important role in betterment of productivity, plankton density and floral components.

As per the State Action Plan on Climate Change (SAPCC, 2014) of Climate Change Department, Government of Gujarat , Gujarat state, broadly falls within the ecological term of semi arid zone is naturally water scarcity prone area. To achieve good economic return and provide potable water, regular quality assessment has become the requirement. Here in this research work an effort is made to document the necessity of ecological assessment of wetland with special reference to aquatic pollution using benthic macro-invertebrates as indicators.

AIM:

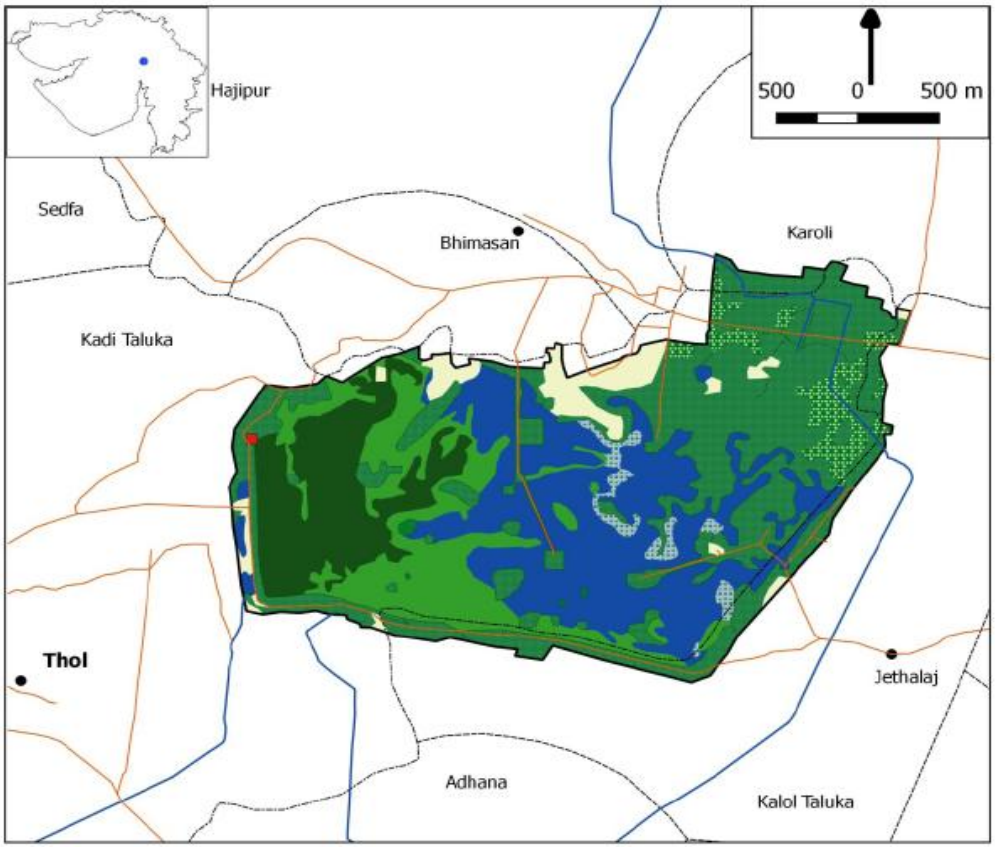
The aim is to know Thol Bird Sanctuary in terms of ecological factors like Water, Sediment, Primary Production and Benthic Macro invertebrate composition. The main **OBJECTIVES** of the study are:

1. To study seasonal variations of important Physico-chemical parameters.
2. To develop water quality index based on Physico-chemical parameters.

3. To study seasonal variations and composition, Saprobic Score and Diversity Score for Benthic Macro invertebrates and estimate the integrated water quality.
4. To study Primary Productivity of Thol Wetland Waters.
5. To study the sediment quality in terms of physico-chemical characteristics.

STUDY AREA:

Thol Bird Sanctuary (TBS) is located in Kadi taluka of Mehsana district, Gujarat (Fig 1). Owing to its high conservation value it was declared as a sanctuary in November 1988. It has a total area of 6.99 sq. km and 5.62 km periphery (PCCF & HoFF GoG, 2018 and Kamboj and Tatu, 2017). There is a continuous earthen bund on its western, southern and eastern periphery, which helps in collection of water that flows into it during the monsoon from the catchment area. The catchment area of this wetland is located to its north and north – east. Thol water body also supports a canal based irrigation system. It is always important to carry out studies related to environmental aspects on regular basis so as to monitor the changes in a dynamic ecosystem, as here in this case, the changing water regime of the Thol Wetland. It remains covered with water in the rainy season. During winter it begins to dry and by summer the wetland is separated into water bodies of varying size, the biggest being towards the western side. Cattle wading, water pumping for irrigation was found in some spots of the Wetland. The surrounding land use mainly falls into arable, grazing and forest type. The wetland was first evaluated by desktop assessment of Hydrological / drainage pattern reflected in Google time line images. The points are so decided that they are accessible as well as sample able in context with the logistical and safety constraints throughout the year. After the desktop evaluation, (USEPA; National wetland Condition Assessment: Site Evaluation guidelines, 2011) a field visit of TBSW was conducted for preliminary survey and to see the actual field drainage pattern in the wetland.



Source: GEER Foundation

Fig 1: Location of Thol Wetland

Later on, considering the approachability, anthropogenic pressures and annual water regime in the wetland, following three sampling locations were covered during the study. The general information of the sampling locations is as per Table no 1.

Table 1. Sampling Locations

Sr. No.	Details	Location 1	Location 2	Location 3
1	Name	Near Culvert no. 1	Front of Forest Camp Site	Near Culvert no. 4
2	Latitude	N 23° 07' 53.9''	N 23° 08' 01.8''	N 23° 08' 26.0''
3	Longitude	E 72° 24' 46.7''	E 72° 24' 01.3''	E 72° 23' 35.0''
4	Main Features	Comparatively minimal human intervention, proximity to catchment water influx and Narmada river water influx through canal	Comparatively maximum human intervention, Transit between the other two locations	Comparatively deeper region, water remains almost throughout the year

METHODOLOGY:

Seasonal sampling covering three seasons viz. summer, winter and monsoon during the year 2015 – 2019 for all three locations is planned with sampling design and frequency as reflected in Table no. 2.

Surface water grab samples were collected for physical and chemical analysis from three different locations. pH and temperature were measured on site. Dissolved Oxygen and COD were preserved at the sites itself using Winkler's reagent and Sulphuric acid respectively. The collected samples were brought to the laboratory on the same day and stored in a refrigerator for further physico chemical analysis following the standard methods (WEF, APHA AWWA, 2005). The values retrieved for physico-chemical parameters like pH, Conductivity (µs/cm), Total Dissolved Solids (mg/l), Nitrate (NO_3-N mg/l), Phosphate (PO_4^{-2} mg/l), Alkalinity as $CaCO_3$ (mg/l), Total Hardness as $CaCO_3$ (mg/l), Sodium (mg/l), Potassium (mg/l), Calcium (mg/l), Magnesium (mg/l), % Sodium (%), Sodium Absorption Ratio (SAR), Flouride, Chloride as Cl^- (mg/l), and Sulphate (SO_4^{-2} mg/l) were utilized (Parikh and Mankodi, 2011; CPCB, 1978). The Water Quality Index (WQI) has been calculated by taking into consideration the irrigation water standards of BIS, FAO Guide lines for irrigation water, criteria for designated best use as lay down by CPCB and through expert opinion on relative significance of the parameter (Raychaudhari et al., 2014).

An in situ measurement of primary production and production respiration ratio of the Thol wetland using light dark bottle methodology (Ajayan & Parmeshwara, 2014; Ashok, 2015; Selvaraj, 2005; Kohler, 1988 and Sarma, 2016) was carried out at sampling location 1 and Sampling location 3. A set comprising three (one dark and two light bottles) 300 ml capacity bottles were taken. In each set, one of the bottles was double coated with black paint and labeled. Each of the bottles were carefully filled with wetland water sample by keeping the bottles at 45^o angle with the water surface avoiding shaking or splashing so that no oxygen is

added to the water sample from outside. The bottles were suspended vertically from an indigenously made floating platform. The whole setup was placed in the water column in the area having continuous exposure to sunlight. The dissolved oxygen of one of the light bottles representing the initial dissolved oxygen value was fixed with Wrinkler's reagents. The in situ incubation was carried out for 3 hrs. After the incubation period the bottles were retrieved and the dissolved oxygen was immediately fixed in dark and light bottle with Wrinkler's reagents. Dissolved Oxygen levels were estimated using Wrinkler's titrimetric method. After the incubation period, dissolved oxygen is measured in all bottles and total oxygen produced is calculated by adding the oxygen consumed in the dark bottles to the oxygen produced in the corresponding light bottles. Total oxygen production was used to calculate gross primary production by multiplying its value with the conversion factor 0.375 (Odum, 1956; Ocean, 2016).

The concept of Bio monitoring i.e. using the native organisms living in water bodies as sensitive indicators of prevailing water quality is used during the study. Hand net was used for collecting the benthic macro invertebrates. Ample care was taken to ensure that all indicator families of Benthic Macro-invertebrates present are actually encountered. This was accomplished by sampling all different (micro) habitats in a sizeable stretch of the water body (Bhadrecha et al., 2016; CPCB, 2016). At each location; the water sampling point (GPS location) was fixed as reference point and keeping 250 m stretch on either side of it of the wetland bank; a total of 500 m X 1 m width of wetland stretch was covered for Benthic Macro-invertebrate collection. This 500 m stretch was divided into 5 sub stretches of 100 m length and in each sub stretch, Benthic Macro-invertebrate collection was carried out. All possible micro habitats such as aquatic vegetation on edges of the wetland banks, algae, pebbles, wetland bed, detritus, submerged and floating vegetations etc. were explored for collection of Benthic Macro-invertebrates by using hand net, sieve and hand picking with

forceps (Bhadrecha et al., 2016; CPCB, 2002). Collection procedure was repeated five times in each sub stretch. Five grab samples of silt was picked from the wetland bed by the plastic scoop/shovel and washed by wetland water in a sieve with mesh size 0.6 mm. The animals were then picked by forceps from the sieve and transferred into the tray. Net was also moved all along the edges of grasses/emergent aquatic vegetation all along the wetland bank and the animals were collected and transferred into the tray with forceps. The water plants/floating plants present near the sampling area was uprooted and washed directly into the net or into white tray so as to detach the animals. All animals thus collected were preserved in 4% formalin for further identification in laboratory. Benthic Macro-invertebrates were identified using 'Appendix: 6 Taxonomic Key for Biological Water Quality Evaluation of the Manual on Integrated Water Quality Evaluation (Zwart and Trivedi, 1994). The abundance of each animal observed during sampling was also noted down. The biological parameters using Benthic Macro-invertebrates analyzed were BMWP (Bio Monitoring Working Party) Score or Saprobic Score and Sequential Comparison Index or Diversity Score (CPCB, 1995, 2002 & 2016).

Table 2. Sampling Plan for the Study Period

Year	**2015 - 2016**												**2016 - 2017**												**2017 - 2018**												**2018 - 2019**	
Season	SUMMER-I			MONSOON-I				WINTER-I					SUMMER-II				MONSOON-II				WINTER-II				SUMMER-III				MONSOON-III				WINTER-III				SUMMER-IV	
Month	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr
Parameters	W S B	-	W	-	W S P/R PP Pl	-	W	-	W S B P/R PP Pl	-	W	-	W S B P/R PP Pl	-	W	-	W S P/R PP Pl	-	W	-	W S B P/R PP Pl	-	W	-	W S B P/R PP Pl	-	W	-	W S P/R PP Pl	-	W	-	W S B P/R PP Pl	-	W	-	W S B P/R PP Pl
W = Water Sample, S = Sediment Sample, B = Biomonitoring, P/R = Photosynthesis Respiration Ratio, PP = Primary Production, Pl = Plankton																																						

RESULTS:

Physico-chemical assessments : The water samples were analyzed for pH, Colour, Conductivity, Total Solids, Total Suspended Solids, Total Dissolved Solids, Chlorides, Total Hardness, Calcium Hardness, Magnesium Hardness, Alkalinity, Turbidity, Ammoniacal Nitrogen, Chemical Oxygen Demand, Biochemical Oxygen Demand, Dissolved Oxygen, Sulphates, Nitrates etc. The obtained average values of physico-chemical parameters are compared with IS:10500 Drinking Water Specifications and it is evident that the water quality is within the permissible limits. These obtained values are also within the usual range prescribed in FAO guidelines for irrigation water (Raychaudhari et al., 2014). However, the values of Chemical Oxygen Demand (COD) and Biochemical Oxygen Demand (BOD) are found to be comparatively high indicating accumulation of organic matter in wetland water. This is mainly imparted by organic detritus in the form of dried leaves, twigs, flowers etc. falling from the surrounding trees and shrubs into the wetland water. The water column also had a greenish hue due to phytoplankton growth indicating organic content.

Water Quality Index: Water Quality Index (WQI) of Thol Wetland is established from important physicochemical parameters in context with the irrigation usage. The average WQI values during the study period are found to be 40.56, 52.99, and 63.79 for the year 2015-16, 2016-17 and 2017-18 respectively. The overall average WQI is found to be 52.45 during the study period. For the year 2015-16, the value being <50 indicate excellent quality of water for irrigation purpose. The rest of the values fall within the range of 50 -150 indicates Good quality of water for irrigation purpose. Moreover, the water quality of Thol wetland shows average SAR (Abdul et al., 2010; Anant, 2012 and Ramkrishnaiah et al., 2009) value below 10 and average Electrical Conductivity (Abul et,al., 2010) value below 1500 µS/cm during the

study period. These values thus indicate the hazard class to be low. The average value of various physico chemical parameters of Thol wetland water reveals higher values of Total Dissolved Solids and Total Hardness during summer, which may be due to low water level and high rate of decomposition and evaporation thus concentrating the salts. This is also reflected by a comparative higher seasonal value of WQI in summer season. The WQI thus developed is a simple tool yet very useful for the water quality assessment and it can be used by all concerned for maintaining good health of the Thol wetland.

Biological Assessments: In all 14 families falling across 8 taxonomic groups were encountered. Overall Diversity Score value ranges from 4.77 to 5.5 and the Saprobic Score value ranges from 0.49 to 0.68. However, these values when compared with the BWQC (Biological Water Quality Criteria) developed by Central Pollution Control Board collectively indicate that the water quality of Thol wetland during the study is 'Moderately Polluted'. The Integrated water quality of Thol wetland is observed to be 'Moderately Polluted' owing to comparatively high organic content. The results of Physico-chemical analysis are in consonance with the BWQC developed by CPCB. Use of Biomonitoring for water quality assessment using Benthic Macro-invertebrates can be used as a complementary method along with the regular physico-chemical analysis for comprehensive water quality monitoring.

Primary Productivity: The value of total daily productivity (Gross Primary Productivity - GPP) ranged from 0.3 g $C/m^3/d$ to 16.883 g $C/m^3/d$ and the average value during the study period of 7.261 g $C/m^3/d$. It is also found that to the yearly primary production, summer season contributes maximum. The value of Photosynthesis – Respiration ratio (P/R) ranged from 2.607 to 0.032 against the average P/R ratio of 1.297 during the study period. A strong correlation of 0.9 is found to exist between Gross Primary Productivity and Photosynthesis

Respiration ratio. Field observations during the study period revealed that the Wetland water is enriched by organic detritus (Nancy et al., 1999; Rajyalakshmi and Premswarup, 1975). Aquatic birds were also found grazing and swimming in water and taking rest near the water edges. Moreover, there exists a relationship (Cornell et al., 2008; Zwart and Trivedi, 1994) between Gross Production (P) and Total Community Respiration (R), where P/R = 1 indicates a steady-state community and if the P/R is greater or less than 1 then organic matter either accumulates or is depleted respectively. During the in situ measurements, the Photosynthesis Respiration Ratio is found to be greater than 1 during winter and summer seasons. This indicates that there is an accumulation of organic matter in Thol Wetland. This finding was also substantiated by the fact that (i) organic detritus in the form of dried leaves, twigs, flowers etc. falling from the surrounding trees and shrubs and (ii) the water column visually appeared greenish due to lush phytoplankton growth indicating high organic content. However during monsoon season, the Photosynthesis Respiration ratio is found to be less than 1 indicating that Respiration activity is more than the Photosynthesis the reasons being organic content gets diluted during the monsoon season as well as the rapid depletion of organic content by the primary consumers.

REFERENCES:

1. Abdul Hameed M. Jawad Alobaidy, Haider S. Abid, Bahram K. Maulood (2010). Application of Water Quality Index for Assessment of Dokan Lake Ecosystem, Kurdistan Region, Iraq, Journal of Water Resource and Protection, 2, 792-798.
2. Anant J. Dhembare, (2012). Assessment of Water Quality Indices for Irrigation of Dynaneshwar Dam Water, Ahmednagar, Maharashtra, India, Scholars Research library, Archives of Applied Science Research, 4 (1):348-352.

3. Ajayan K.V. and Parameswara Naik T., (2014). Phytoplankton Primary Productivity in Lentic Water Bodies of Bhadravathi Taluk, Shimoga District, Karnataka, India, International Research Journal of Environment Sciences, Vol. 3(4), 34-41.
4. Ashok Kumar, (2015). Studies on Monthly and Seasonal Variations in Primary Productivity of Glacial fed Mountainous Goriganga River in Kumaun Himalaya, Uttarakhand, International Research Journal of Environment Sciences, India Vol. 4(3), 53-65.
5. Bhadrecha, M. H., Nitasha Khatri, and Sanjiv Tyagi, (2016). 'Rapid integrated water quality evaluation of Mahisagar river using benthic macroinvertebrates.' Environmental monitoring and assessment 188:254, 1-8.
6. Bureau of Indian Standards, (1992). Water Quality Standards in India, IS: 2296
7. Bureau of Indian Standards, (1986). Guidelines for the Quality of Irrigation Water, IS:11624.
8. Bureau of Indian Standards, (2012). Drinking Water Specifications, IS: 10500.
9. Cairns, J. and J. R. Pratt (1993). A history of biological monitoring using benthic macroinvertebrates. 10-27 in D. M. Rosenberg and V. H. Resh (editors). Freshwater biomonitoring and benthic macroinvertebrates. Chapman and Hall, New York.
10. Celsemy Eleutério Maia, and Kelly Kaliane Rego da Paz Rodrigues (2012). Proposal for an Index to Classify Irrigation Water Quality: a Case Study in Northeastern Brazil, R. Bras. Ci. Solo, 36:823-830.
11. Central Pollution Control Board, (1995). Parivesh News letter, Vol. II, Biomonitoring of Water.
12. Central Pollution Control Board (1978). Primary water quality criteria for various uses of fresh waters, New Delhi, ADSORBS/3/1978-79.

13. Central Pollution Control Board (2002). Parivesh News letter, Biomonitoring of Water Bodies Part – II.
14. Central Pollution Control Board (2007). Guidelines for Water Quality Monitoring, MINARS/27/2007-08.
15. Central Pollution Control Board (2016). 'Benthic Macro invertebrates of River Ganga', Prepared and Published by PR Division, CPCB, Delhi- 110032.
16. Climate Change Department, Government of Gujarat, (2014). State Action Plan on Climate Change (SAPCC) supported by TERI.
17. Cornell, Linda P., Klarer, David M. (2008). Patterns of Dissolved Oxygen, Productivity and Respiration in Old Woman Creek Estuary, Erie County, Ohio during Low and High Water Conditions, Ohio Journal of Science: Volume 108, Issue 3,31-43.
18. Gor Ami and Shah Arvind, (2014) .Water Quality Index of Mahi River, Vadodara, Gujarat, International Journal of Engineering Development and Research, Volume 2, Issue 3, 3214-3219.
19. Goutam Bala and Ambarish Mukherjee, (2010). Water Quality Index of Some Wetlands in Nadia District, West Bengal, India, International Journal of Lakes and Rivers, Volume 4, Number 1, pp. 21-26.
20. Kamboj R.D. and K. Tatu (2017): Important Wetland Destinations of Gujarat – A guide for ecotourists to explore some wetland jewels in Gujarat, Gujarat Ecological Education and Research (GEER) Foundation, Gandhinagar.
21. Koenings J.P., Emudson Jim A. et al., (1987). Limnology Field and Laboratory Manual: Methods for Assessing Aquatic Production, Number 71, Alaska Department of Fish and Game, Division of Fisheries Rehabilitation, Enhancement and Development.

22. Kohler Jan, (1998). Measurement of photosynthetic oxygen production, Rostock, Meerersbiol, Beitr., 17-21 6.
23. Nancy J. Leonard, Lili Wang and William J. Mitsch, (1999). Gross primary productivity and aquatic plant Biomass: Indicators of divergence in two constructed wetlands, Report no. The Olentangy River Wetland Research Park, GPP, page 69 – 76.
24. Nitin Bassia, M. Dinesh Kumarb, Anuradha Sharmac, P. Pardha-Saradhia, (2014) Status of wetlands in India: A review of extent, ecosystem benefits, threats and management strategies Journal of Hydrology: Regional Studies 2 1–19
25. Ocean (2016). Message in the Bottles. http://oceanexplorer.noaa.gov/explorations/ 02arctic/background/education/media/arctic_message.pdf, accessed on 24.12.2016
26. Odum, H.T. (1956). Primary Production in Flowing Waters. – Limnol. Oceanogr. Vol 1(2), 102-117.
27. Parikh, A. N. and Mankodi, P.C. (2011). Water Quality Assessment of Harni Pond of Vadodara, Gujarat, Electronic Journal of Environmental Science, Vol. 4, 55-59.
28. Principal Chief Conservator of Forest and Head of the Forest Force Govn. Of Gujarat (2018). https://forests.gujarat.gov.in, accessed on 21.12.2016 and 08.01.2018.
29. Pringault O., Tassas V. and Rochelle-Newall E., (2007). Consequences of respiration in the light on the determination of production in pelagic system, Biogeoscience, 4,105-114.
30. Qureshimatva U.M., Maurya R.R., Gamit S.B., Patel R.D and Solanki H.A. (2015). Determination of Physico-Chemical Parameters and Water Quality Index (Wqi) of Chandlodia Lake, Ahmedabad, Gujarat, India, Journal of Environmental & Analytical Toxicology, , 5:4, http://dx.doi.org/10.4172/2161-0525.1000288.

31. Ramakrishnaiah C. R., Sadashivaiah C. and Ranganna G., (2009). Assessment of Water Quality Index for the Groundwater in Tumkur Taluk, Karnataka State, India, E-Journal of Chemistry, 6(2), 523-530.
32. Rajyalakshmi, T., and T.V. Premswarup, (1975). Primary productivity in river Godavari India, Indian Journal of Fisheries, Vol. 22(1-2): 205-214.
33. Raychaudhuri, Mausumi, Raychaudhuri, S., Jena, S. K. Kumar, Ashwani and Srivastava R.C., (2014). WQI to Monitor Quality for Irrigation and Potable Use. DWM Bulletin No. 71 Directorate of Water Management, Bhubaneshwar, India, 43p.
34. Sarma Jayashree, (2016). A comparative study of Primary Productivity Estimation in the Selected Wetlands of Dimoria Tribel –belt in Kamrup Metro District, Assam, India, Imperial Journal of interdisciplinary Research (IJIR), Vol-2, Issue-5.
35. Selvaraj G.S.D.(2005). Estimation of Primary Productivity (Modified Light and Dark bottle Oxygen method), Mangrove Ecosystems: A manual for the Assessment of Biodiversity, page 199-200.
36. Siddhartha Sharma, Akepati S. Reddy (2013). Development of Water Quality Indices for Designated Best Uses of Surface Water Body, International Journal of Engineering Science and Innovative Technology (IJEST), Volume 2, Issue 5.
37. Space Applications Centre (SAC), (2011). National Wetland Atlas. SAC, Indian Space Research Organisation, Ahmedabad.
38. Stoner J. D. (1978). Water –Quality Indices for Specific Water Uses, Geological Survey Circular 770, United States Department of the Interior.

39. Surjeet Singh, N.C.Ghosh, Gopal Krihnan, Ravi Galkate, T. Thomas and R. K. Jaiswal (2015). Development of an Overall Water Quality Index for Surface Water in Indian Context, Current World Environment Vol. 10(3), 813-822.
40. Water Environmental Federation, APH Association (2005). Standard methods for the examination of water and wastewater. 21st edition, APHA, AWWA, WEF.
41. Williams, P.J. le B, and del Giorgio, P.A. (2005). Respiration in aquatic ecosystems, Oxford University Press, New York, 1-17, 103-121
42. World Wide Fund for Nature (WWF) and Asian Wetland Bureau (AWB), (1993). Directory of Indian Wetlands. World Wide Fund for Nature and Asian Wetland Bureau, New Delhi and Kuala Lumpur.
43. Yogendra K. and Puttaiah E. T., (2007). Determination of Water Quality Index and Suitability of an Urban Water body in Shimoga Town, Karnataka, Proceedings of Taal: The 12th World Lake Conference: 342-346.
44. Zwart D. de. (RIVM Bithoven, The Netherlands) and Trivedi R.C. (CPCB, Delhi, India), (1994). Manual on Integrated Water Quality Evaluation; Appendix: 6 Taxonomic Key for Biological Water Quality Evaluation, Indo-Dutch Project Report 802023003.

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