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Ecosystem Services and Fishery Production Dynamics of Wetland Ecosystem: An Appraisal of Alappuzha District of Kerala, India

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Abstract

Wetlands serve as home to innumerable flora and fauna and deliver critical ecological and societal functions which often tend to get ignored during the developmental process. An assessment of ecosystem service contribution of wetlands of Alappuzha was attempted under benefit transfer framework to raise awareness regarding its invaluable contributions. The district being home to a network of backwaters falling under coastal lagoons, coastal natural wetands dominated the share. Erosion regulation and sediment retention, food production and recreation were the major ecosystem functions contributing to total ecosystem value. An assessment of growth and variability of inland fisheries, the major provisioning good of the wetlands, revealed the significance of Prawn, Etroplus and Tilapia in fish landings. Analysis of change in the area of Vembanad Lake during 2002-2014 revealed growing anthropogenic pressure, with a reduction of 465 ha of area. Fisheries of the lake has been seriously affected by continuing reclamation, pollution, eutrophication and anthropogenic interventions which have to be regulated to stop the decline of wetlands of the district.

Key words: Wetlands, inland fish landing, ecosystem services, Kuttanad

Introduction

Wetlands referred to as the "kidneys" of earth are ecotones that occupy an intermediate position between dry land and open water. Wetland ecosystems cover 7% of the earth's surface and deliver 45% of the world's natural productivity and ecosystem services (MEA, 2005). Ecosystem services are defined as the benefits people derive from ecosystems – the support of sustainable human well-being that ecosystems provide (Costanza et al., 1997; de Groot et al., 2002, 2010; MEA, 2005). Millennium Ecosystem Assessment (MEA, 2005) has classified the marketed and non-marketed ecosystem services provided by wetland ecosystems in to 4 major categories, viz. provisioning service, regulating service, supporting service and cultural service. Inland fisheries, the major provisioning good of the wetland, holds a major role in determination of livelihood and economic status of dependent communities (IUCN, 1998; Dahdouh-Guebas et al. 2006; Opio et al., 2011; Bosma et al., 2012). Besides, it is the primary source of animal protein to which rural communities have access and hence assumes great significance in developing countries. Preserving wetlands as sources of fish, freshwater and as shields against floods, environmental pollution and distress of micro-climatic vagaries, is utmost important.

Wetlands are one of the important categories of the diverse ecosystems of India, occupying 4.63 per cent of geographical area of the country and supporting about a fifth of the known biodiversity (NWA, 2011; MoEFCC and GIZ, 2014). Kerala, with a total of 1 60 590 ha of wetland area, is one of the green states of India well known for its wetlands (NWA: Kerala, 2011). Alappuzha district, which has a whopping share of 16.24 % in the states wetland area, occupies the top rank among the 14 districts of the state. The district holds the distinction of having the highest share of the district geographic area under wetlands (20.76 %). The district also has majority of the water

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spread area of Vembanad - Kol - Wetland – System, one of the three Ramsar sites in Kerala and the largest estuarine system of the western coastal wetland, falling under its domain.

Hence an attempt was made to quantify the value of the ecosystem services of wetlands of Alappuzha district, under the benefit transfer framework. Benefit transfer is employed when it is too expensive or time consuming to produce primary economic valuation studies. This approach, though obviously glosses over many of the complexities involved, is simple, easy and appropriate for raising awareness and interest (Costanza et al., 2014; Eade & Moran, 1996) which is our primary concern in this study. The study also analyses the trend and variability in inland fish production of the district, the ecosystem indicator of the major provisioning service of the wetlands. Further, transition in the area of Vembanad lake spread across 3 districts over the last decade has been studied using LANDSAT TM/OLI images acquired. A graphical analysis of temporal trend in the fish production of the lake has been attempted henceforth using secondary data.

Materials and Methods

Basic benefit transfer adopted under our study assumes a constant unit ecosystem service value per hectare of ecosystem type and multiplies that value by the area of each type to arrive at aggregate totals. Data on area under different categories of wetlands in the Kerala state and Alappuzha district was acquired from National Wetland Atlas: Kerala (2011) published by the Space Application Centre (SAC), Indian Space Research Organisation. The most representative biome under the consolidated ecosystem valuation model of Costanza et al. (2014) was used as a proxy for each wetland category. Unit value ecosystem service co-efficients estimated for different biomes by de Groot et al. (2012) under the ecosystem services valuation model were suitably adopted in our study. The co-efficients were converted in to rupee equivalents using Purchasing power parity index published by the World Bank.

Once the ecosystem service value per unit area was assigned for each wetland category and function, equations (1), (2) and (3) were used to determine service value for each wetland category, for each service function and for the total ecosystem service value respectively:

$$ESV_K = A_K \ X \ VC_K \qquad (1)$$

$$ESV = \sum_K A_K \ X \ VC_K \qquad (2)$$

$$ESV_f = \sum_K A_K \ X \ VCkf \qquad (3)$$

where ESV_k, ESV, and ESV_f refer to the ecosystem service value of wetland category k, the total ecosystem service value, and the value of ecosystem service function f respectively; A_k is the area (ha) for land use category k; VC_k is the value coefficient (INR ha^{-1} yr^{-1}) for wetland category k; and VC_{kf} is the value coefficient (INR ha^{-1} yr^{-1}) for wetland category k with ecosystem service function type f.

Compound Annual Growth Rate (CAGR)

The following functional form was used to estimate the growth in inland fish production:

$$Y_t = Yo\ (1 + r) \qquad (4)$$

Transforming this to logarithmic form,

$$\text{In } Y_t = \text{In } Yo + t \text{ In } (1 + r) \qquad (5)$$

Here, Y_t is the variable for which growth is calculated, r is the compound growth rate and ln is natural logarithm.

Now, let In Y_o= b_1 and ln (1+r) = b_2

CAGR, r = (antilog b_2 - 1) x 100 (6)

Cuddy-Della Valle Index of Instability

Instability in inland fish production was estimated using Cuddy-Della Valle Index (Cuddy and Della Valle, 1978).

$$\text{Cuddy - Della Valle Instability Index (\%)} = CV \times \sqrt{1 - R^2} \qquad (7)$$

where CV is the coefficient of variation in per cent, and R^2 is the adjusted coefficient of determination from a time trend regression. SAS software was used for fitting log-linear and linear time trend regression employed to calculate CAGR and instability index.

Level-1T -precision and terrain corrected LANDSAT Satellite data were obtained for February 2002 (LANDSAT 7 Enhanced Thematic Mapper (ETM+) and February 2014 (LANDSAT 8 Operational Land Imager (OLI)) having spatial resolution of 30 m. Since the data sets were acquired in the same season i.e. in February, the sun angle, as well as the seasonal and the phenological differences were minimized. After performing different pre-processing operations (mosaicing, DN to radiance conversion, subsetting etc.), the corrected images with radiance values were used for modified normalized difference water index (MNDWI) calculation to extract water body (Xu, 2005, 2006). All the operations were carried out in ENVI 4.8 and ArcGIS 10.1 software packages.

Results and Discussion

The composition of ecosystem value of each broad category of wetland is presented in Fig 1. Coastal natural wetlands with a high value of 4 540.55 million rupee yr^{-1} contributed the maximum to the total ecosystem value of Alappuzha wetlands. This is due to the presence of a large network of backwaters in the district, particularly the renowned Vembanad lake, all of which fall in the class of coastal lagoons. It is to be noted that the district is characterised by an absence of coastal man-made wetlands.

Ecological functions performed by the wetlands of the district, valued and ranked in our study are depicted in Fig. 2. Erosion control and sediment retention has the highest value among the ecosystem functions performed by the wetlands of Alappuzha district. Riparian wetlands by virtue of their position in the landscape protect shorelines and stream banks against erosion and buffer shorelines against wave action. Wetlands also regulate runoff and river discharge along with providing drainage and natural irrigation. The water regulation function of the wetland holds the second position in terms of contribution to the total value, highlights its

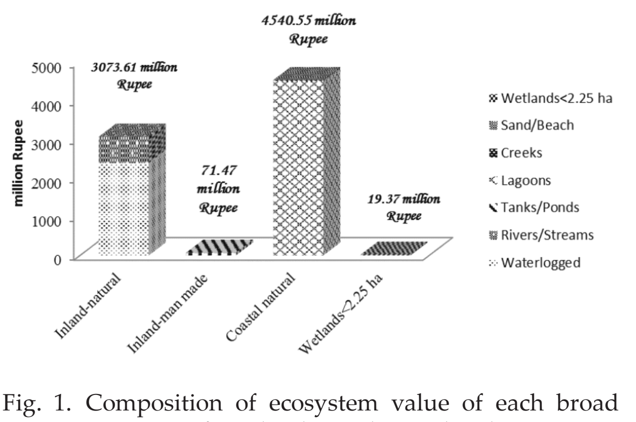

Fig. 1. Composition of ecosystem value of each broad category of wetland in Alappuzha district

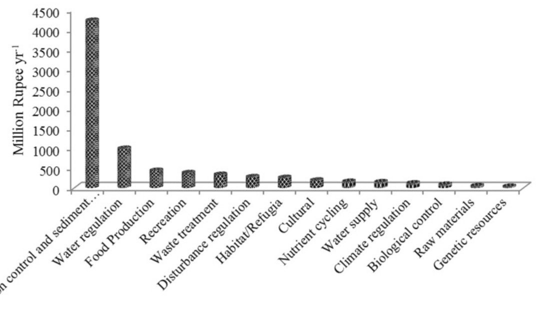

Fig. 2. Ecosystem functions contributing to the total ecosystem value arranged in the descending order

significance. However the district, especially the agriculturally significant Kuttanad region, famous for its paddy polders, is facing the fury of nature in the form of floods, more regularly now a days (MSSRF Study Report, 2007, Gopakumar, 2011). This has become recurrent following the continuing reclamation of wetlands of the region which is taking a toll on their water and disturbance regulating ability. Food production, the major provisioning service of the wetlands, occupies the third position among the functions. Alappuzha is well known for its inland fisheries potential which is the major provisioning good of the region. The sobriquet "Venice of the East" and the incessant tourist rush encountered in the region, rightly indicate the significance of recreation service as another important ecosystem function of the region's wetlands.

Fisheries, the major provisioning service of wetlands, make important contributions to local and national economies. Capture fisheries in coastal waters alone contribute US $ 34 billion to gross world product annually (MEA, 2005). Hence a detailed species wise analysis of growth and variability observed in fisheries during 2000-01 to 2012-13 was undertaken and the results are presented in Tables 1 and 2 along with the production data. The study concentrated only upon inland fisheries production, as marine production pertains to the catch from the open sea which clearly falls outside the class of wetlands. Inspite of being under the class of coastal lagoons, the fisheries of backwaters is counted under inland fish production. The composition of different species in inland fish landings of Alappuzha district, as per the latest available disintegrated annual data (2012-13) is depicted in Fig 3. Fin fish species' dominated, constituting 70 per cent of the catch. Prawns had been the highest contributor; both to shell fish catch and total inland catch, all throughout the study period with a share of 21.36 % in 2010-11 before coming down to 17.72 % in 2012-13. The share of prawns in total shell fish production lay in the range of 87- 93 % during the study period. These group of crustaceans also exhibited a highly significant growth rate of 4.23 %, although the instability associated was a comparatively high 15.51 (Table 1).

The estuarine zone plays an important role in the life cycle of many prawn/shrimp species and the Vembanad lake especially is a nursery for important prawns/shrimps like *Fenneropenaeus indicus*, *Penaeus monodon*, *Metapenaeus dobsoni, M. monoceros, M. affinis, Macrobrachium rosenbergii*. The fact that Alappuzha district has the largest and second largest area under backwaters and brackish water respectively also signals the dominance of these estuarine species in total catch. Etroplus and tilapia were the two major finfish categories which had dominant share in total inland fish production. *Etroplus suratensis*, popularly known as *Karimeen* is an endemic species highly valued for its delicacy. It is reported that Etroplus harvest has rapidly

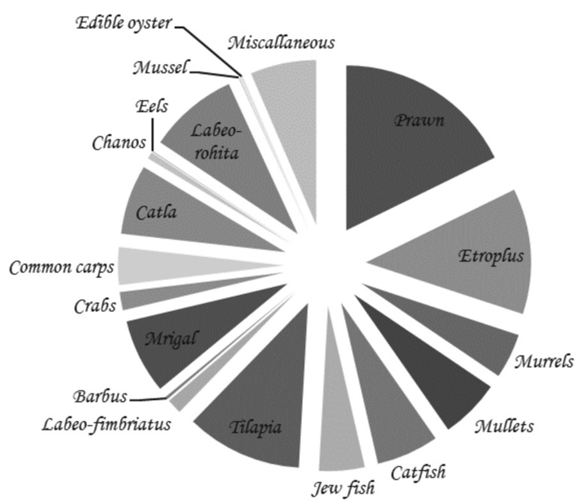

Fig. 3. Species wise composition of total inland fish landings during 2012-13

declined over the years due to the interference in natural water flows, increasing water pollution and unacceptable eutrophication in the backwaters (MSSRF study report, 2007; Krishnakumar & Dharmarajan, 2011). Consistent with the reports, the

Table 1: Variability in species wise fish landings and growth rate of shell fish

	Production (MT)				
Year	Prawn	Crabs	Mussel	Edible oyster	Shell fish -Total
2000-01	2389	219	0	0	2608
2001-02	2138	168	0	0	2306
2002-03	2110	190	0	0	2300
2003-04	2105	198	0	0	2303
2004-05	2131	196	0	0	2327
2005-06	1932	204	0	0	2136
2006-07	2102	206	0	0	2308
2007-8	2146	210	6	78	2440
2008-09	2220	217	13	87	2537
2009-10	2869	270	17	54	3210
2010-11	3415	276	18	55	3764
2011-12	3213	298	18	55	3584
2012-13	3597	363	16	62	4038
CAGR	4.23***	4.81 ***	18.49*	-6.91	4.55***
Cuddy-Della Valle II	15.51	13.51	22.9	17.92	14.94

***significance at 1per cent; *significance at 10 per cent growth in production of Etroplus was not significant, although Tilapia production grew at a significant rate of 2.20% over the study period (Table 2). Alappuzha district holds first and second place respectively in the total state production of these fin fish species'. However, the share of the district in state level production of these two groups had been remaining constant at 39.80 and 22% respectively throughout the study period. Catla and *Labeo rohita* are the two species' of finfish which exhibited

Table 2. Variability in species wise landing and growth rate of fin fish

Year	Production (MT)							
	Etroplus	Murrels	Mullets	Catfish	Jew fish	Tilapia (*Oreochromis*)	Common carps	*Labeo fimbriatus*
2000-01	1976	797	1058	1075	817	1838	607	259
2001-02	2787	746	744	920	645	1514	640	392
2002-03	1748	773	912	890	713	1642	536	197
2003-04	1796	634	961	888	743	1706	565	202
2004-05	1776	715	949	966	735	1651	546	233
2005-06	1842	742	986	1003	754	1756	582	242
2006-07	1849	744	989	1007	767	1798	583	243
2007-8	1880	756	1006	1024	780	1827	593	247
2008-09	1939	780	1038	1057	805	1884	612	255
2009-10	1934	786	1034	1063	796	1860	732	257
2010-11	1967	800	1052	1081	810	1892	721	262
2011-12	2200	816	1074	1103	827	2028	798	267
2012-13	2504	895	1188	1236	904	2306	747	299
CAGR (%)	0.62	1.17**	1.95***	1.81***	1.54***	2.20***	2.54***	0.55
Cuddy-Della Valle II	15.82	6.63	7.60	6.48	5.79	6.68	9.15	19.47

Year	Production (MT)						Finfish-Total
	Barbus	Mrigal	Catla	Chanos	Eels	*Labeo rohita*	
2000-01	48	836	581	117	14	784	10807
2001-02	39	805	516	67	18	619	10452
2002-03	39	716	543	132	12	667	9520
2003-04	40	760	552	106	12	712	9677
2004-05	43	751	522	105	12	704	9708
2005-06	45	780	569	111	14	731	10157
2006-07	45	782	570	110	15	732	10234
2007-8	46	795	579	112	15	744	10404
2008-09	47	820	597	116	15	767	10732
2009-10	47	1030	795	117	15	890	11356
2010-11	48	957	796	119	15	977	11497
2011-12	49	1405	1286	121	15	1666	13655
2012-13	56	1484	1387	136	17	1783	14942
CAGR (%)	1.99***	4.78***	7.23***	2.19*	1.29	6.97***	2.64***
Cuddy-Della Valle II	7.05	18.60	26.69	13.20	12.08	28.68	10.01

***,**,*-significance at 1,5 and 10 per cent respectively highest significant growth rate. Nevertheless, the instability associated with their production was also high (Table 2). During the study period, the share of shellfish in total inland production increased while that of finfish decreased, with the former's landings growing at a higher rate and instability than the latter's.

The overwhelming presence of Vembanad lake in Kuttanad has commanded the place a domineering position in the economic map of Kerala. Agriculture in Kuttanad owes its origin itself to areas reclaimed from the lake. It has been reported that the reclamation of backwater in Kuttanad started as early as 1833 as the region suffered deficits in food supply (Jeena, 2002). Around 63 % of the original area of the lake had been reclaimed by 1980 for agriculture and related purposes (Gopalan et al., 1983). Consequently, Vembanad which had an area of 36 329 ha in 1864, reached an abysmally low 12 504 ha by 2000. The present study which attempted to appreciate the changes in the area of lake lying across three districts, based on satellite data, found out a further decline of 465 ha during 2002-2014 period (Fig. 4). The major reason for continuing depletion and conversion of natural resources like wetlands is the failure to adequately account for their non-market environmental values in development decisions. If agriculture was the reason for erstwhile reclamation of the water body in this low lying flood plains, the current reason is growing tourism and springing up of urban sprawls (MSSRF Study Report, 2007). The consequence is that, important non-marketed benefits such as flood carrying capacity and provision of habitat for economically significant fish species have undergone a drastic degradation. Continuing reclamation and pollution coupled with anthropogenic interventions implemented to promote paddy cultivation, especially the Thanneermukkom salt water barrage, has seriously affected the fisheries of the lake. Kurup et al. (1993) reported 115 species of finfish, 6 species of penaeid shrimp, 4 species of palaemonid prawns and 3 species of crab from the lake during the year 1988-89. Study by Asha et al. (2014) in 2012-13 however documented only 80 species of finfish, 5 species of penaeid shrimps, 3 species of palaemonid prawns and 2 species of crabs. Figure 5 presents category-wise total catch of Vembanad lake and upstream south zone catch as reported in various studies (Kurup et al., 1993; Unnithan et al., 2001; Padmakumar et al., 2002; Asha et al., 2014). It reveals that along with the species diversity, fish catch of the lake had also undergone a decline of 39.08% from 7 202.1 T in 1988-89 to 4 387.31 T in 2012-13 following undesirable alterations in the lake ecology. The reduction in annual yield reflects the invariable reduction in the catch of all 4 categories of aquatic fauna. The figure also reveals that the annual yield from the south zone, which accounts for half of total area had been remaining around 500 t for the last three decades.

The lake which has been the ecological lifeline of the region is perceived to be in a serious crisis now. Reclamation which is being continued in spite of legal provisions like The Kerala Conservation of Paddy land and Wetland Act, 2008 has to be halted

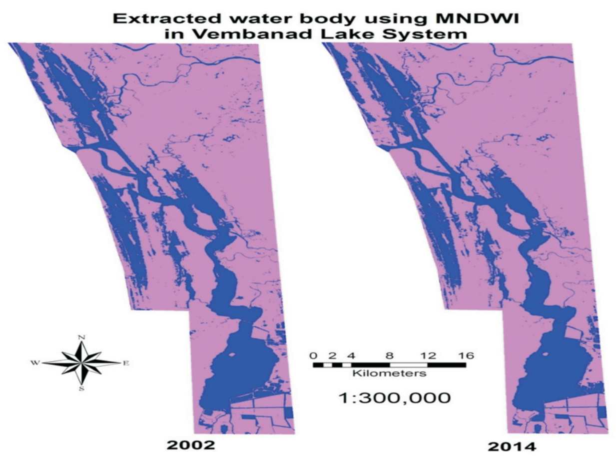

Fig. 4. Change in the area of Vembanad Lake based on satellite data: 2002-2014

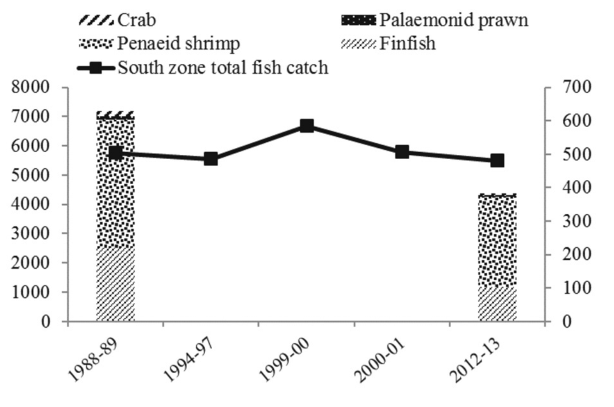

Fig. 5. Total and upstream south zone fish catch of Vembanad lake

and the lake area should be protected by means of demarcated ecotones as recommended by MSSRF. The salt water barrage should be modernised which would facilitate its timely opening and closing in accordance with the monitored salinity level in the lake. This along with removal of aquatic weeds from the lake would to a great extent reduce pollution and eutrophication in the lake with improved flushing. Also indiscriminate and destructive fishing using poison, explosives and nets of small mesh sizes should be completely stopped.

The wetlands of Alappuzha, especially Kuttanad is facing all major direct drivers of degradation including infrastructure development, land conversion, over exploitation, pollution and introduction of alien invasive species. The result is that wetlands are undergoing depletion of their functions. It is to be noted that when both the marketed and non marketed economic benefits of wetlands are included, the total economic value of unconverted wetlands is often greater than that of converted wetlands. This was our primary concern here is to raise awareness regarding the ecological significance of one of the most degraded ecosystems in the planet, the wetlands.

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