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Tradeoff Between the Coastal Wetland and Interlinked Ecosystem Services: A Case of Kazhuveli Coastal Wetland, India

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Abstract: Wetlands in India are an interconnected environment, complex, and a significant contributor to biodiversity and other living beings. Understanding the dynamics of spatial planning, preservation and conservation is becoming challenging for the authorities due to the overlap of their functions and services. Set against this backdrop, the present study was carried out to map the component-wise outputs of ecosystem services and their interlinkages of the Kazhuveli wetland, located near Puducherry using SWOT (Strength Weakness Opportunity Threat) Analysis and Causal Loop Diagram (CLD). The data was generated from 12 community-based focused group discussions and 10 key informant interviews among community groups living around the wetland. The results show that no synchronization occurs amongst the key service users (farmers, salt pan owners, fishermen, shrimp farm owners, and local communities), leading to an extra burden on the wetland. Furthermore, the primary stakeholders highlighted that the presence of shrimp farms leads to groundwater depletion and deterioration of surface water quality, resulting in depressed salt production, decreased fish production, and scaled-down agricultural practices.

Keywords: Coastal Wetland Ecosystem, SWOT analysis, Ecosystem Services, Causal Loop Diagram (CLD)

Coastal wetlands and their interlinked ecosystems like saltmarsh and mangroves that sustain biodiversity, fish production, sand dunes, and aquaculture activities are under tremendous pressure due to over-exploitation of resources and encroachment (Nordlund et al 2016, Carrasquilla-Henao and Juanes 2017, Sievers et al 2019, Silliman et al 2019). Due to anthropogenic pressure and impact of climate change, coastal wetland ecosystems are being lost or are undergoing depletion (Davidson 2014, Hamilton and Casey 2016). Hence, the biodiversity and the goods and services provided by them face a huge stress (IPBES Secretariat, 2019). Policy makers and the general public consider wetlands as “wasteland”, which leads to tremendous pressure on these wetlands (Rao et al 2019). Coastal wetlands continue to be one of the most threatened ecosystems, experiencing an annual physical loss of 0.7–1.2% (Davidson 2014), associated functions and services provided to local communities (Mulatu 2021). Wetlands provide livelihood support to local communities (Chuma et al 2012, Hardy et al 2013), alleviate poverty (Verma et al 2012), and provide stability for communities associated with them (Maund et al 2019). Globally, the aerial extent of the wetland ecosystem is estimated at 917 million hectares (Lehner and Doll 2004), generating an economic value of about US$15 trillion a year (MEA 2005), yet face threats (Zhou et al 2020). In recent decades, wetlands have undergone dramatic changes due to rapid urbanization, population explosion, dumping of solid and liquid wastes, encroachment, and degraded water quality, reducing their productivity, resulting in a reduction of water supply and quality, levels of soil nutrients, habitat fragmentation, vegetation and biodiversity loss, increased water pollution, and loss of provisioning services like medicinal plants (Saunders et al 2012), affecting livelihoods, and well-being of communities (Van Dam et al 2013, Morrison et al 2013). The urgency for immediate actions to prevent wetland degradation due to development and anthropogenic pressures with the active participation of communities and stakeholders needs no further elaboration (Gosling et al 2017). An enhanced understanding of the tradeoff between wetlands and other uses would aid policymakers and local authorities in making rational decisions that hinge on sustainability.

Ecosystem services provided by wetlands depend on the type of wetland, its association with different ecosystems, and the communities that depend on those services; hence, tradeoffs require customization of the content. The present study investigates the Kazhuveli wetland using strength, weakness, opportunities, and threats (SWOT) framework and applies the system thinking framework to generate information that could aid in narrowing down key issues and describing expressing them in generic terms (Kangas et al

2003) and help map ecosystem linkages, their interrelationships, and tradeoffs.

MATERIAL AND METHODS

Study location: The Kazhuveli Wetland is located in the eastern part of Villupuram district, Tamil Nadu, India, and lies between latitude 11.9576° N and 79.2902° E longitude. The wetland covers 13,200 hectares with a catchment area of 740 sq. km (Ramanujam 2005). Kazhuveli backwater is 12.5 km long and 370 meters broad. It is one of the most extensive brackish and semi-permanent wetlands in South India. Biophysically, the wetland consists of three parts: the Kazhuveli flood plain, Uppukali creek, and Yedayanthittu estuary. In 2021, the Government of Tamil Nadu (GoTN) declared Kazhuveli Wetland as Kazhuveli Bird Sanctuary under sub section (1) of section 18 of the Wild Life (Protection) Act, 1972 (Central Act 53 of 1972) (GoTN 2021). The wetland is considered a coastal wetland of international importance by the International Union for the Conservation of Nature and Natural Resources (IUCN). The wetland is hedged with naturally formed sand dunes that protect people from natural disasters like cyclones, storm surges, and tsunamis. This wetland offers multiple benefits to local communities in terms of grazing for livestock, timber for roof thatch, and fishing. Additionally, 18 revenue villages utilize direct benefits from the wetland, like grazing cattle, fishing, collecting reeds, fuelwood, minor forest produce and soil, paddy cultivation and aquaculture, and more than 150 villages benefit directly and indirectly from fishing, farming, pottery, shrimp farming, and salt farms (Fig. 1).

Methodology: The present study adopts a qualitative approach to comprehend the relationship between local communities and the Kazhuveli Wetland, in terms of livelihoods, linkage to different ecosystems and their services. Following an extensive literature review, field visits were made to the study area during November and December 2020. Communities living around the wetland pursue four types of livelihoods related to -shrimp farming, salt pan, fishing, and agriculture. A separate questionnaire was developed and deployed for each group of respondents. Shrimp farms are primarily located in the Kazhuveli flood plain and Uppukalli creek. During the initial field visit, a total of 10 villages were identified, four which were involved in shrimp farming, two in fishing and four in agriculture. Separate interviews were carried out with shrimp farm owners, workers, and technicians. In each village, four shrimp farmworkers, four owners, and two technicians were interviewed. Focused group discussions (FGDs) and interviews were conducted on-site, while shrimp farm culture operations were on. In the salt pans, two key informants, two salt pan owners, and one FGD was conducted among the women workers. An FGD was conducted in a fishing village adjoining the wetland, followed by an in-depth interview with an 80-year-old fisherman. With regard to agriculture, FGD were conducted in agricultural villages adjoining the wetland located within a radius of two kms. Care was taken to identify key informant interviews among farmers who had experience of more than 40 years to capture the present and past trends in agriculture. One mediator and reporter were deployed for carrying out the FGD, and the conversation recorded with prior permission from the respondents. All FGDs and key informant interviews (KIIs) reports were decoded, cleaned, and analyzed. Individual SWOT analysis results were produced for shrimp farm owners and workers, salt pan

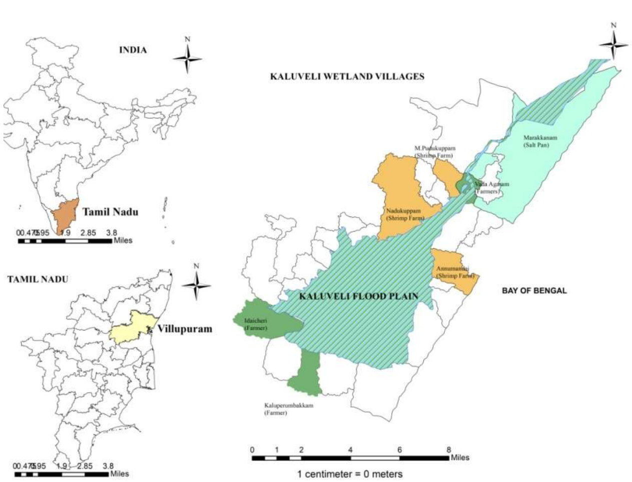

Fig. 1. Study location

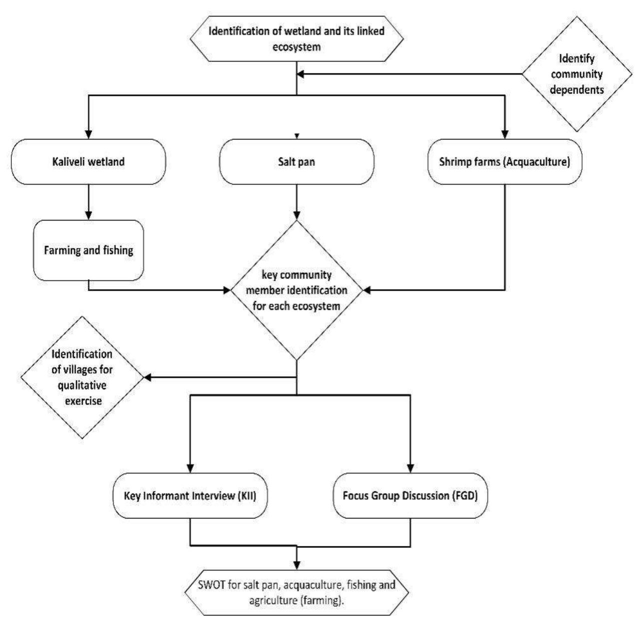

Fig. 2. Process flow of the study

owners and workers, fishermen, farmers, and agricultural laborers, who contributed to the overall SWOT concerning the wetland and its tradeoff between different services and in the construction of a CLD capturing key variables.

Selection of respondents: A total of 18 villages were selected to assess the dependence of local communities on the Kazhuveli Wetland. Objectives for the qualitative exercises were formulated based on a review of literature and stakeholder mapping. Respondents for individual interviews were identified and selected randomly based on the initial explorative visits. Respondents for FGD were identified based on suggestions provided by researchers well-versed with the local wetland characteristics and livelihoods associated with them. Before engaging communities in FGD and qualitative exercises, a five-step strategy was adopted (Fig. 2). Stakeholders were invited to the FGD at their workplace and at a time convenient to them. In-depth interviews were conducted in villages by engaging respondents having more than 20 years of experience and those stakeholders contact details duly recorded for future clarifications and engagements.

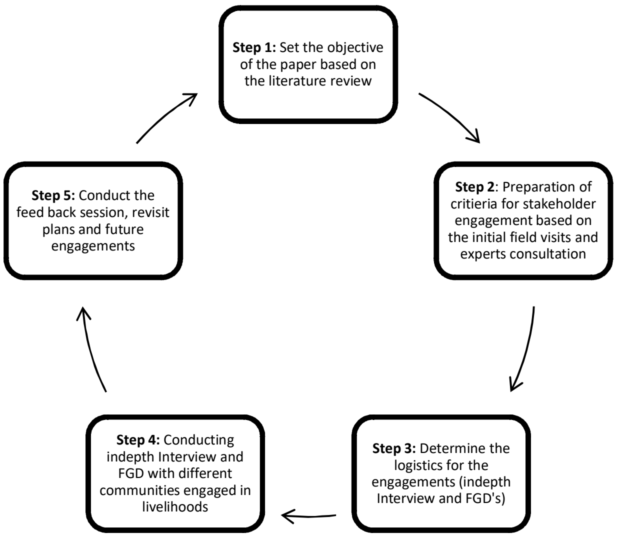

Fig. 3. Five-step strategy for community engagement for In-depth interview and FGD

Changes in Kazhuveli and associated ecosystem: In the recent decade, the Kazhuveli Wetland and associated ecosystems have undergone major changes due to anthropogenic activities. The range of activities that have impacted the wetland include encroachments, illegal poaching, construction of mega power industry, hydrocarbon extraction hotspot, construction of a harbor, over exploration of flora and fauna, transport of sediments and nutrients by surface drainage. Traditionally, the Kazhuveli Wetland is linked to a network of irrigation tanks that supplies surplus freshwater. Since the wetland is interrelated, there are different communities and villagers directly involved in utilizing the benefits from Kazhuveli Wetland.

RESULTS AND DISCUSSION

This section comprises two different sub-sections 1. Ecosystem tradeoff between Kazhuveli Wetland and

Table 1. Stakeholders in Kazhuveli wetland

Nature	Stakeholders	
	Primary	Secondary
National	Ministry of Environment, Forest, and Climate Change (MoEF&CC), National Wetland Authority.	National Biodiversity Authority (NBA)
State	State Wetland Authority (SWA)	Tamil Nadu Forest Department, State Biodiversity Board (SBB), Public Works Department (Water Resources).
District	Communities who directly utilize the services, namely, (i) Farmers (ii) Shrimp farmers (iii) Salt pan (iv) Fisherman (v) Potters etc. (vi) Associations (salt pan)	(I) District wetland authority (consists of all the department representation), (ii) Village panchayat heads, (iii) Village administrative officers, (iv) Non-governmental Organizations (NGO), (v) Research Institutes, (vi) Academicians
Definition of Key stakeholders covered in the present paper (Three FGD's were conducted in each category.		
Shrimp farmers	o Shrimp farm owners do business in aquaculture (marine or freshwater environment), producing shrimp or prawns for human consumption. o Shrimp farmworkers are those who work on daily or monthly wages in a shrimp farm.	
Salt Pan	o Salt pan owners own the salt pan or lease out land for the extraction of salt. o Salt pan workers are daily wagers	
Fishermen	o Fishermen, who harvest fish, prawns, and crabs from the Kazhuveli wetland	
Farmers	o Farmers involved in farming activities around the Kazhuveli wetland	

Source: Author's compilation based on discussion with Experts, 2020 associated wetlands using the CLD 2. Strengths, Weaknesses, Opportunities, and Threats (SWOT) analysis for shrimp farms, salt pan, fisheries and agriculture. The SWOT analysis and (CLD) are presented in Figure 2 and provide insights into the Kazhuveli Wetland, its associated ecosystems, and the interrelationships among the ecosystem services it provides for communities and highlight the complex tradeoffs in the light of its management as per the Wetland Conservation and Management Rules 2017. The District Wetland Conservation Committee is responsible for conservation, management, protection, and implementation of interventions in wetlands at the district level to ensure efficient and effective ecosystem services. The current work is likely to assist the district wetland authority by gaining an understanding of the current interrelationships and tradeoffs between the significant ecosystems and communities living around the Kazhuveli Wetland.

Causal loop diagram (CLD): The Kazhuveli Wetland consists of fresh water from the hinterlands and saltwater from the sea joining in Uppukalli creek. It plays a significant role in groundwater recharge, and is the primary source of groundwater recharge, an essential resource for irrigation and drinking water. The fact that nearly 60% of irrigation land in India primarily utilizes groundwater as source (Chindarkar et al 2019) needs to be taken into consideration. Farmers adjacent to the Kazhuveli are directly dependent on groundwater for irrigation for cultivation both during *Kharif* and *Rabi*. An increase in the number of borewell/tube wells leads to a reduction in the ground and surface water storage around the wetland (Figure 2 Agriculture loop B4), resulting in water scarcity. The affordability of modern irrigation systems by farmers is critical, and the pollution of surface water is a significant issue due to shrimp farms located in the northern part of the wetland. Water scarcity has forced farmers to seek alternative mechanism by changing cropping patterns, shift from water consuming crop to water-sensitive crops, restricting cultivation only for one of the two seasons (Agriculture loop B3). The shrimp farms in the Kazhuveli Wetland are categorized into two groups, licensed and non-licensed farms. License is provided by the Central Aquaculture Authority (CBA) based on the individual application by shrimp farmers. In the shrimp farm loop, the critical input is large quantities of surface and groundwater.

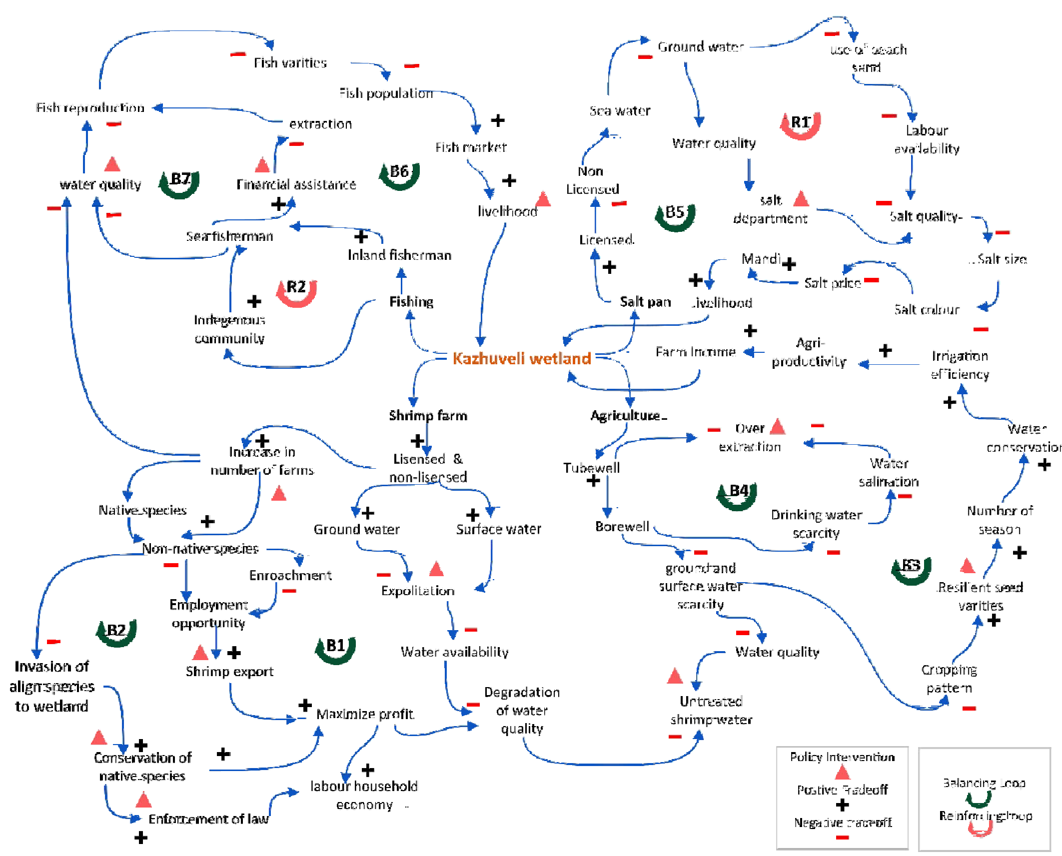

Fig. 4. Kazhuveli wetland and associated ecosystem services Causal Loop Diagram

Table 2. SWOT analysis results for Shrimp Farms in Kazhuveli

	Favorable	Unfavorable
Internal	Strength (S)	Weakness (W)
	• Pond culture and prior business experience • The vast area available near the coastal belt • Availability of groundwater as well as Kazhuveli water • Substantial business and employment opportunities for the local community • International export agencies collect the shrimp near the pond. • 80% of the ponds area is more than 1/2 acres (50 cents) • 90% of water extracted from the ground is reused for other cultures. • Shrimp farm farmers indicated that there is a strong desire to go back doing the shrimp culture business. • The wage for labor is high and less stressful compared to other work.	• Deficient business, whereas Operational capital, is more. • Less educated and lack of proper technical training • Access to aid from agencies like National Aquaculture Regulatory Authority or GoI. • Repeated business failures have made the farmers of Kazhuveli wetland abstain from the intensive shrimp seed stocking. • 80% of the farmers have completed their elementary education. • Culture facilities, such as a pond, dyke, water inlet, guardhouse, and others, were found to be well maintained. • Seasonal employment opportunity
	Opportunities (O)	Threats (T)
External	• Continuous market demand for shrimps • Shrimp price is relatively stable and tends to be better. • Transportation facilities are getting better. • Decreased cultured shrimp production at the regional level and closure of 3300 shrimp farm units in the Kazhuveli area.	• Environmental carrying capacity gets degraded due to high mining activities around the Kazhuveli wetland. • The procurement program of cultivation production facilities from the government is minimal. • Low availability of shrimp seeds • Increasing environmental pressures because of a decrease in plantation activity and other economic activity • Rapid economic activities in the area have reduced the mangrove area and water catchment, resulting in diminished aquatic environmental quality for aquaculture. • No government procurement system. • Low migration rate increases due to the closure of shrimp farms.

Preparation of field before for the year 2020

Preparation of field and canal connects to Kaluveli wetland for the year 2020

Storage of salt after the cultivation in 2020

Salt cultivation in the field ready to be shifted for storage

Before the forest department handled Kazhuveli Wetland, shrimp farmers were letting out untreated water into Kazhuveli, which eventually causing eutrophication and water pollution. Most of the unlicensed shrimp farmers have encroached on the government land (*Poramboke* land) (Figure 2: shrimp farm loop (B1)). Since the year 2017, due to the severe conservative measures of the forest department, the licensed shrimps are located around the Kazhuveli wetland is permitted to do culture but the non-licensed holders are forced to close the culture in between the culture. The shrimps were directly exported to China, Japan, and other countries. Most of the shrimp farmers use exotic species. Hence, the district forest officials have taken preventive measures to safeguard the native species by enforcing preventive measures among shrimp farmers adjacent to Kazhuveli (Figure 2 Shrimp Farm Loop (B2)).

Table 3. SWOT analysis for Salt Pan

	Favorable	Unfavorable
Internal	Strength (S)	Weakness (W)
	• One of the largest producers of salt in south India • Natural cultivated salt • Leased in land for salt cultivation. • Excessive labor availability • The salt production process is different from other sites in Tamil Nadu (Vedaranyam, Thoothukudi). • Traders collect the salt from the field itself.	• The leased land is a weakness for the cultivators as it may be taken back at any time by the owner with no prior notification. • There is no legal document for lease. It is only based on goodwill. • Lack of operation cost critical for salt cultivation. • Changing climatic variabilities.
	Opportunities (O)	Threats (T)
External	• Salt cooperative society fixes the cost of the salt bag (*Barthi*) • A merchant from Andhra Pradesh, Odisha, Karnataka used to come and purchase the salt.	• The quality of water from Kazhuveli getting worse after expansion of shrimp farming. • Unusual rain during the off-season. • District administration has banned collection of soft sand from dunes located near the sea for field preparation. • The majority of the people are moving away from this livelihood. • The rate of return is based on the climate, labor availability, price-fixing by the market. • If the check dam and the fishing harbor are built, this will lead to the non-availability of quality salt.

Table 4. SWOT analysis for fishermen

	SWOT Analysis for fisherman	
	Favorable	Unfavorable
Internal	Strength (S)	Weakness (W)
	• Availability of brackish water swamp and estuary fish • Competition is less for fishing. • Day to day income • Own boat use gives less stress to fisherman. • Family members are also involved in fishing. • Nearly 270 households are involved in the fishing activities either in Kaluveli and Yedayanthittu estuary. • The fish catch happens between 4 to 6 km in the Kaluveli wetland.	• Small size fishes exist. • Fish catch reduced in recent years due to the degradation of water quality. • Access to the fish market is less since it is wetland fish, crab, and prawn. • Mangrove patches also not developing much faster, and is not helping fish reproduction. • Due to forest department restrictions, fishers cannot go beyond the Vada Agaram village (in the Kazhuveli flood plain).
	Opportunities (O)	Threats (T)
External	• Since the family members (son) are part of fishing, they can also take forward fishing in the future. • Women used to sell fish in villages around the Kazhuveli wetland. • Youth has done advanced fish breeding in Uppukalli creek to increase the fish stock. • Apart from the fisherman, the people from other villages also catch the fish for their self-consumption in different parts of the Kazhuveli wetland.	• Increased shrimp farms reduce the water quality and fish stock in the Edaiyanthittu estuary and Uppukali creek. • There is a threat to fish stock if harbor construction is completed due to the inflow of big fiber boats from neighboring fisherman villages. • There is a threat to direct impact on livelihood activities due to development activities. • There is a conflict of interest between Kanthadu village and fisherman villages for fishing in the Kazhuveli wetland. • Invasion of alien fish variety, crab, and prawn can mix in the Kazhuveli wetland due to the unprotected shrimp/ fish culture. • Crab farming people ~~sell~~ market crab, reducing the importance of purchasing crab from fisherman.

Table 5. SWOT analysis for Agriculture

	SWOT Analysis for farmers	
	Favorable	Unfavorable
Internal	Strength (S) • Availability of both surface and groundwater. • Traditional system tanks are located in the upper reaches of the wetland that recharges the groundwater. • The fertility of agricultural land is high. • The availability of seeds is sufficient for farmers. • The availability of agriculture labor is sufficient. • Limited bore well availability in the farm located near a wetland.	Weakness (W) • Surface contamination is more due to shrimp farms. • The migration of youth is more from the wetland area. • Cultivation only during *Kharif* season. • Farmers living in the adjacent villages are migrating to Puducherry/ Chennai as daily wage laborers. • The availability of subsidies for the farmers is minimal. • Farmers are primarily practicing mono-cropping method.
External	Opportunities (O) • The possibility of rainwater penetration into the ground is high due to a check dam in the Kazhuveli Wetland area.	Threats (T) • Due to the high migration of youth, shift in farming to non-farm occupation. • Due to the construction of a check dam, waterlogging has intensified in agricultural land. • Due to the increase in the use of fertilizers, the eutrophication at Kazhuveli Wetland water would be more disturbing to the wetland species.

Salt production is an important and crucial livelihood activity for salt farmers located in Marakannam revenue village. Nearly 80% of the salt farmers use land leased from the landowners residing in Marakkanam town. This salt production in Marakkanam is a traditional method of brine evaporation (water with a high concentration of water) filled in the salt pans (Cherian et al 2019). Farmers use freshwater from Kazhuveli and groundwater and seawater from the Yedayanthittu estuary, respectively. Based on the qualitative interview, due to the poor quality of surface water, the color of the salt changes to a light shade. Hence, the per kilogram rate for the salt decreases in the market (Figure 1 Salt pan Loop (B5). One of the critical inputs to reduce the cost of labor was the use of coastal sand available at the Marakkanam dunes, which helps the laborers complete the salt pan preparatory work in 5-8 days. Recently, the Villupuram district administration has restricted sand excavation from the dunes and beaches that have high silica, gypsum, sodium sulfate, and carbonate content that are present around Kazhuveli Wetland (District Survey Report of Silica Sand 2019). Hence, salt farmers require more days to work on the preparation of the salt pan. Recently, farmers used ordinary sand from other places for land preparation, eventually increasing the number of workdays of laborers and sand. Once the salt is cultivated, the *mandi* located in Marakannam town, fix the price per *barthi* (140 kgs of the salt bag). The price of the salt depends on the color and size of the crystals during the year/ season. The *mandi* facilitates by providing human resources to the salt farmers to pack salt in *barthi* and fetch salt from the pan (Figure 2 shrimp farm loop R1). Based on the field visits and discussion, nearly 200 fishing households were engaged in fishing activities in the Kazhuveli Wetland every day, and they substantially depend on it for their livelihood. Fishermen are divided into inland and sea fishermen (Figure 2 Fishing Loop R2). Inland fishers limit their activities to Kazhuveli Wetland due to the impact of the eutrophication from the shrimp farm, water quality has deteriorated significantly over the years. Several fish varieties have become endangered in Kazhuveli compared to 10 years ago. Ecosystem around the Kazhuveli Wetland is under severe threat due to multiple disturbances, and hence, the livelihoods of numerous communities (farmer, fisherman, shrimp farm, and salt pan) depending on these ecosystems are at risk (Figure 2 Farm Income Loop).

SWOT for shrimp farms: Based on the multiple interactions with different levels of stakeholders, the SWOT analysis was performed among the major activities around the Kazhuveli Wetland which are shrimp farm, salt pans, fishing, and agriculture. The SWOT analysis for shrimp farms in Kazhuveli is presented in Table 2.

SWOT for salt pan: The salt pans in Marakannam are an important livelihood opportunity for the communities located nearly eight villages (Marakkanam Town, Karipalayam, Konamkuppam, Thazankadu, Narvakkam, Kaipanikuppam, Pallampakam and Kolathur) adjacent to the salt pans. These people are either workers or are leased for the salt pans. The detailed SWOT analysis is presented in Table 3 the pictures of the salt pans during the field survey are presented below.

CONCLUSION

The current study investigates the tradeoff between the wetland ecosystem services and communities living in the vicinity of the Kazhuveli Wetland. Recently, environmental awareness among the communities has increased because of the decline in livelihood opportunities. Based on the rigorous qualitative exercise, we found that community engagement plays a significant role in conservation. Communities engaged in livelihood activities predominantly use ground and surface water as critical raw material for their actions. The preservation of such resources and their efficient use would help them sustain their livelihood activities. The intervention by the Tamil Nadu Forest Department in restricting shrimp farms can help further in the restoration of other ecosystems. During the initial stage of the field visit, availability of primary data about the villagers and communities dependent on the nationally important wetland was deficient. Hence, the preparation of village-level data for those directly depending on the wetland and its associated ecosystem is critical. Such information would help policymakers and wetland managers understand problems in-depth and frame an effective implementation mechanism at the district level. Finally, government intervention towards the conservation of Kazhuveli Wetland should be aimed at improving groundwater and treating surface water to enable local communities sustain their livelihoods. Further, the involvement of stakeholders and identification of their preference on the conservation of Kazhuveli Wetland plays a critical role for the district administration for planning for the sustainable use of resources of the wetland.

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