LIMNOLOGICAL STUDY OF THRISSUR-PONNANI KOLE WETLANDS WITH SPECIAL REFERENCE TO THE ICHTHYOFAUNA

Thesis Submitted to the

University of Calicut

for the award of the degree of

Doctor of Philosophy in Zoology

By

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CERTIFICATE

This is to certify that the thesis entitled **"Limnological study of Thrissur-Ponnani kole wetlands with special reference to the ichthyofauna"** submitted to the University of Calicut for the award of Doctor of Philosophy is a bonafide account of research work carried out by **Ms. Parvathy C A** under my supervision. The work has not been submitted either partially or fully to any other university or institution for the award of any degree, diploma, fellowship, title or recognition. Also certify that the contents of the thesis have been checked using an anti-plagiarism database and no unacceptable similarity was found in the check.

Thrissur, **Dr. Vimala K John**

(Research guide)

DECLARATION

I hereby declare that the thesis entitled **"Limnological study of Thrissur-Ponnani kole wetlands with special reference to the ichthyofauna"** submitted to the University of Calicut for the award of the Degree of Doctor of Philosophy in Zoology is bonafide research work done by me under the supervision of **Dr. Vimala K John**, Assistant professor, Research and Postgraduate Department of Zoology, St. Thomas College (Autonomous), Thrissur.

I also declare that the material presented in this thesis is original and does not form the basis for the award of any other degree, diploma or other similar titles of any other university.

Thrissur,

PARVATHY C A

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It is said that real friends are the ones who come to our aid during the hardest time of our life. They laugh with us while the rest laugh at us. I can wholeheartedly point out such friends whom I consider to be my family members. They include co-researchers namely ***Ms. Meharban M P, Ms. Neethu, Ms. Josna Victoria K Johnson, Ms. Amrutha M*** *and all other scholars of my department. The sweet memories of the happiest moments of life spent with my friends gave me unforgettable nostalgia.*

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With heartfelt gratitude

PARVATHY C A

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ABBREVIATIONS

No.	-	Number
Ph	-	Percentage hydroxyl ion
mg/L	-	Milligrams per litre
WHO	-	World Health Organization
BIS	-	Bureau of Indian Standards
BOD	-	Biochemical Oxygen Demand
ppm	-	Parts per million
°C	-	Degree Celsius
DO	-	Dissolved oxygen
Kg	-	Kilogram
TDS	-	Total dissolved solids
CO_2	-	Carbon dioxide.
APHA	-	American Public Health Association.
CR	-	Critically endangered
DD	-	Data deficient
EN	-	Endangered
LC	-	Least concern
LRnt	-	Lower risk near threatened
LRlc	-	Lower risk least concern
NT	-	Near threatened
VU	-	Vulnerable
NA	-	Not available
CMFRI	-	Central Marine Fisheries Research Institute
ZSI	-	Zoological Survey of India

LIST OF MAPS

LIST OF PLATES

സംഗ്രഹം

ആവാസവ്യവസ്ഥയിൽ നദികൾ, തടാകങ്ങൾ, ചതുപ്പുകൾ, നെൽവയലുകൾ, തീരപ്രദേശങ്ങൾ എന്നിവയുൾപ്പെടെ വൈവിധ്യമാർന്ന പരിസ്ഥിതികൾ ഉൾക്കൊള്ളുന്ന തണ്ണീർത്തടങ്ങൾ പാരിസ്ഥിതിക സന്തുലിതാവസ്ഥ നിലനിർത്തുന്നതിനും ജൈവവൈവിധ്യത്തെ പരിപോഷിപ്പിക്കുന്നതിനും നിർണായകമായി നിലകൊള്ളുന്നു. അവയുടെ പ്രാധാന്യം പാരിസ്ഥിതിക അതിരുകൾക്കപ്പുറത്തേക്ക് വ്യാപിക്കുകയും മനുഷ്യന്റെ ക്ഷേമത്തിനും ദാരിദ്ര്യ നിർമാർജനത്തിനും സംഭാവന നൽകുകയും ചെയ്യുന്നു. 2018 മുതൽ 2022 വരെയുള്ള കാലയളവിൽ തൃശൂർ-പൊന്നാനി കോൾ തണ്ണീർത്തടങ്ങളിലെ പാരിസ്ഥിതിക ചലനാത്മകത, ഫിസിക്കോകെമിക്കൽ പാരാമീറ്ററുകൾ, മത്സ്യ സമൃദ്ധി, ഉൽപ്പാദനം എന്നിവയെക്കുറിച്ചുള്ള സമഗ്രമായ വിശകലനം പഠനം അവതരിപ്പിക്കുന്നു. തണ്ണീർത്തടങ്ങൾക്കുള്ളിലെ വിവിധ സ്ഥലങ്ങളിലുടനീളമുള്ള മത്സ്യ ഇനങ്ങളുടെ ഘടന, സമൃദ്ധി, വിതരണം എന്നിവയിലെ ഗണ്യമായ വ്യതിയാനങ്ങളും അജൈവ ഘടകങ്ങളുടെ ഫലങ്ങളും ഗവേഷണം വെളിപ്പെടുത്തുന്നു.

കേരളത്തിലെ തൃശൂർ, മലപ്പുറം ജില്ലകളിലെ കോൾ ഭൂമികളെ ഈ പ്രദേശങ്ങളുടെ നെല്ല് സമ്പുഷ്ടമായ കേന്ദ്രമായി പലപ്പോഴും വിശേഷിപ്പിക്കാറുണ്ട്. മലപ്പുറം ജില്ലയുടെ തെക്കുപടിഞ്ഞാറൻ മേഖലയിൽ സ്ഥിതി ചെയ്യുന്ന പൊന്നാനി കോൾ, വേമ്പനാട് കോൾ റാംസർ സൈറ്റിന്റെ ഏറ്റവും വടക്കുള്ള വിപുലീകരണമാണ്. മുരിയാടിനും പൊന്നാനി കോളിനും ഇടയിൽ ക്രമരഹിതമായി തിരഞ്ഞെടുത്ത ഏഴ് സ്ഥലങ്ങളായ മറഞ്ചേരി, മാവിൻചുവട്, തോളുർ, മുല്ലശ്ശേരി, ഏനാമാവ്, നെടുപുഴ, മുരിയാട് കോൾ തണ്ണീർത്തടങ്ങളിലാണ് പഠനം നടത്തിയത്. കോൾ തണ്ണീർത്തടങ്ങളിലെ മത്സ്യ ഉൽപാദനത്തെക്കുറിച്ചുള്ള പഠനങ്ങൾ നേരിട്ടുള്ള സന്ദർശനത്തിലൂടെയും ചോദ്യാവലിയിലൂടെയും നടത്തി. വിശദമായ ചോദ്യാവലി തയ്യാറാക്കുകയും അതിന്റെ അടിസ്ഥാനത്തിൽ മത്സ്യത്തൊഴിലാളികളിൽ നിന്ന് വിവരങ്ങൾ ശേഖരിക്കുകയും ചെയ്തു.

തൃശൂർ-പൊന്നാനി കോൾ തണ്ണീർത്തട ആവാസവ്യവസ്ഥയിലെ മത്സ്യങ്ങളുടെ വൈവിധ്യം പഠിക്കുക; ജലത്തിന്റെ ഫിസിയോ-കെമിക്കൽ പാരാമീറ്ററുകളും തൃശൂർ-പൊന്നാനി കോൾ തണ്ണീർത്തട മത്സ്യ വൈവിധ്യവും തമ്മിലുള്ള പരസ്പരബന്ധം പഠിക്കുക; തൃശൂർ-പൊന്നാനി കോൾ തണ്ണീർത്തട ആവാസവ്യവസ്ഥയിലെ കോൾ തണ്ണീർത്തടങ്ങളുടെ

വാർഷിക മത്സ്യ ഉൽപാദനം കണക്കാക്കുക; തൃശൂർ-പൊന്നാനി കോൾ തണ്ണീർത്തട ആവാസവ്യവസ്ഥയിലെ പങ്കാളികൾ ഉപയോഗിക്കുന്ന പരമ്പരാഗത മത്സ്യ കൊയ്ത്ത് രീതികൾ; തൃശൂർ-പൊന്നാനി കോൾ തണ്ണീർത്തട ആവാസവ്യവസ്ഥയിലെ മത്സ്യവിഭവങ്ങളുടെ സാമ്പത്തിക വിലയിരുത്തൽ, തൃശൂർ-പൊന്നാനി കോൾ തണ്ണീർത്തട മത്സ്യബന്ധനത്തിൽ പ്രാദേശിക സർക്കാരുകളുടെ ഇടപെടലുകൾ വിലയിരുത്തുക എന്നിവയാണ് ഇപ്പോഴത്തെ പഠനത്തിന്റെ ലക്ഷ്യങ്ങൾ.

തൃശൂർ കോൾ നീർത്തടത്തിൽ 23 കുടുംബങ്ങളിൽ നിന്നും 13 ഓർഡറുകളിൽ നിന്നുമുള്ള 46 മത്സ്യ ഇനങ്ങളെ ടാക്സോണമിക് ഐഡന്റിഫിക്കേഷൻ ചെയ്തു, മാസങ്ങളിലും പഠന സ്ഥലങ്ങളിലും സമൃദ്ധിയിലും ഘടനയിലും ശ്രദ്ധേയമായ വ്യത്യാസങ്ങൾ നിരീക്ഷിക്കപ്പെട്ടു. സൈപ്രിനിഫോംസ്, സിലൂറിഫോംസ്, അനാബന്റിഫോംസ് തുടങ്ങിയ ചില വിഭാഗങ്ങളുടെ ആധിപത്യം തണ്ണീർത്തട ആവാസവ്യവസ്ഥയിൽ ഈ വർഗ്ഗങ്ങളുടെ പാരിസ്ഥിതിക പ്രാധാന്യത്തെ സൂചിപ്പിക്കുന്നു. എന്നിരുന്നാലും, സമൃദ്ധിയിലെ ഇടിവ്, പ്രത്യേകിച്ച് സാമ്പത്തികമായും പാരിസ്ഥിതികമായും പ്രധാനപ്പെട്ട ജീവിവർഗ്ഗങ്ങളായ ആൻഗ്വില്ല ബെംഗലൻസിസ്, മാക്രോഗ്നാന്തസ് ഗെന്തേരി എന്നിവ സാധ്യതയുള്ള പാരിസ്ഥിതിക വെല്ലുവിളികളെ ഉയർത്തിക്കാട്ടുന്നു. വിവിധ സൈറ്റുകൾക്കിടയിൽ മത്സ്യ സമൃദ്ധിയിൽ കാര്യമായ വ്യത്യാസങ്ങളുണ്ടായിരുന്നു, ചില സൈറ്റുകൾ സ്ഥിരമായി മറ്റുള്ളവയേക്കാൾ ഉയർന്ന സമൃദ്ധി പ്രദർശിപ്പിക്കുന്നു. വൈവിധ്യ സൂചികകൾ വൈവിധ്യത്തിന്റെ മിതമായ നിലവാരത്തെ സൂചിപ്പിച്ചു, കാലവും സ്ഥലവും അനുസരിച്ച് ജീവിവർഗങ്ങളുടെ ഘടനയിലെയും സമൃദ്ധിയിലെയും വ്യതിയാനങ്ങളാണ് ഏറ്റക്കുറച്ചിലുകൾക്ക് കാരണം.

മത്സ്യ വൈവിധ്യവും ജലത്തിന്റെ ഗുണനിലവാര മാനദണ്ഡങ്ങളും തമ്മിലുള്ള പരസ്പര ബന്ധത്തെക്കുറിച്ച് നടത്തിയ വിശകലനത്തിൽ നിരവധി സുപ്രധാന കണ്ടെത്തലുകൾ കണ്ടെത്തി. സെനെന്റോഡോൺ കാൻസില, പരംബാസിസ് തോമാസി തുടങ്ങിയ ചില മത്സ്യങ്ങൾ ജലത്തിന്റെ താപനില, വായുവിന്റെ താപനില, ഓക്സിജൻ തുടങ്ങിയ ഒന്നിലധികം ഘടകങ്ങളുമായി ശക്തമായ പോസിറ്റീവ് പരസ്പരബന്ധം പ്രകടിപ്പിച്ചു. നേരെമറിച്ച്, അപ്ലോച്ചെലസ് ലൈനേറ്റസ് പോലുള്ള സ്പീഷീസുകൾ ചില പാരാമീറ്ററുകളുമായി നെഗറ്റീവ് പരസ്പരബന്ധം കാണിച്ചു, ഇത് അവയുടെ സംവേദനക്ഷമത അല്ലെങ്കിൽ ആ അവസ്ഥകൾ ഒഴിവാക്കുന്നതിനെ സൂചിപ്പിക്കുന്നു. ജലത്തിന്റെ ഗുണനിലവാര മാനദണ്ഡങ്ങളുടെ പരസ്പരബന്ധിതമായ സ്വഭാവവും ജല ആവാസവ്യവസ്ഥയിലെ ജല

രസതന്ത്രത്തിന്റെ സങ്കീർണ്ണതയും പഠനം എടുത്തുകാണിച്ചു. ജലത്തിന്റെ ഗുണനിലവാരം വിലയിരുത്തുന്നതിനും മലിനീകരണത്തിന്റെ ഉറവിടങ്ങൾ തിരിച്ചറിയുന്നതിനും ജലവിഭവങ്ങളും ആവാസവ്യവസ്ഥയും സംരക്ഷിക്കുന്നതിന് ഫലപ്രദമായ മാനേജ്മെന്റ് തന്ത്രങ്ങൾ നടപ്പിലാക്കുന്നതിനും ഈ ബന്ധങ്ങൾ മനസ്സിലാക്കേണ്ടത് അത്യാവശ്യമാണ്.

ഫിസിക്കോകെമിക്കൽ പാരാമീറ്ററുകൾ വിശകലനം 2018 നും 2019 നും ഇടയിലുള്ള താൽക്കാലിക വ്യതിയാനങ്ങൾ സൂചിപ്പിച്ചു. സൊസൈറ്റി പടവ്, അക്കറ്റോൻ എന്നിവയായിരുന്നു ഉയർന്ന മത്സ്യ ഉൽപാദന കേന്ദ്രങ്ങൾ, കുറഞ്ഞ ഉൽപാദന കേന്ദ്രങ്ങൾ നെടുപോട്ടയായിരുന്നു.

സുസ്ഥിര മാനേജ്മെന്റ് രീതികളുടെ പ്രാധാന്യം ഊന്നിപ്പറഞ്ഞുകൊണ്ട് സാമ്പത്തിക വിലയിരുത്തൽ പ്രാദേശിക സമ്പദ്വ്യവസ്ഥയ്ക്ക് മത്സ്യ ഉൽപാദനത്തിന്റെ ഗണ്യമായ സംഭാവന വെളിപ്പെടുത്തി. തൃശൂർ-പൊന്നാനി കോൾ തണ്ണീർത്തടങ്ങളുടെ പാരിസ്ഥിതിക ചലനാത്മകതയെയും സാമൂഹിക-സാമ്പത്തിക പ്രാധാന്യത്തെയും കുറിച്ച് ഈ പഠനം വിലപ്പെട്ട ഉൾക്കാഴ്ചകൾ നൽകുന്നു. ജൈവവൈവിധ്യം സംരക്ഷിക്കുന്നതിനും ഉപജീവനമാർഗത്തെ പിന്തുണയ്ക്കുന്നതിനും ഈ സുപ്രധാന ആവാസവ്യവസ്ഥയുടെ ദീർഘകാല സുസ്ഥിരത ഉറപ്പാക്കുന്നതിനും ശാസ്ത്രീയ ഗവേഷണം അറിയിക്കുന്ന സുസ്ഥിര മാനേജ്മെന്റ് തന്ത്രങ്ങൾ അനിവാര്യമാണ്.

ABSTRACT

Wetlands are encompass a diverse range of environments including rivers, lakes, marshes, rice fields and coastal areas, stand as vital ecosystems crucial for maintaining ecological equilibrium and fostering biodiversity. Their significance extends far beyond ecological boundaries and contributes to human well-being and poverty alleviation. The study presents a comprehensive analysis of the ecological dynamics, physicochemical parameters, fish abundance and production in the Thrissur-Ponnani kole wetlands over a period spanning 2018 to 2022. The research reveals significant variations in fish species composition, abundance, and distribution across different sites within the wetlands andeffectsof abiotic factors.

The kole lands in Thrissur and Malappuram districts of Kerala are often described as the rice hub of these regions. Ponnani kole, situated in southwestern region of Malappuram district, is the northern most extension of the Vembanad kole Ramsar site. The study was conducted in seven randomly selected site; Marancherry, Mavinchuvad, Tholur, Mullassery, Enamav, Nedupuzha and Muriad kole wetlands which lie between Muriyad and Ponnani kole. The studies of fish production in kole wetlands were done by direct visit and questionnaire. A detailed questionnaire was prepared and data collected from fishermen based on that.

The objectives of the present study are- to study the diversity of fishes in Thrissur-Ponnani kole wetland ecosystem; to study the interrelationship between physio-chemical parameters of water and Thrissur-Ponnani kole wetland fish diversity; to estimate the annual fish production by the kole wetlands of the Thrissur-Ponnani kole wetland ecosystem; traditional fish harvesting methods employed by stakeholders of the Thrissur-Ponnani kole wetlands ecosystem; economic evaluation of the fishery resources of Thrissur-Ponnani kole wetlands ecosystems and evaluation of the interventions by the local self governments in the Thrissur-Ponnani kole wetlands fishery.

Taxonomic identification done and was 46 fish species from 23 families and 13 orders, with notable variations in abundance and composition observed across months and study sites. The dominance of certain orders, such as Cyriniformes, Siluriformes, and Anabantiformes indicates the ecological importance of these taxa in the wetland ecosystem. However, declines in abundance, especially in economically and

ecologically important species like *Anguilla bengalensis* and *Macrognanthus guentheri*, highlight potential environmental challenges.

There was significant variations in fish abundance among different sites, with some sites consistently exhibiting higher abundance than others. Diversity indices indicated moderate levels of diversity, with fluctuations attributed to variations in species composition and abundance over time and space.

The analysis conducted on the correlation between fish diversity and water quality parameters revealed several significant findings. Some fish species, such as *Xenentodon cancila* and *Parambassis thomassi*, exhibited strong positive correlations with multiple parameters like water temperature, air temperature, and dissolved oxygen. Conversely, species like *Aplocheilus lineatus* showed negative correlations with certain parameters, indicating their sensitivity or avoidance of those conditions.

The study highlighted the interconnected nature of water quality parameters and the complexity of water chemistry in aquatic ecosystems. Understanding these relationships is essential for assessing water quality, identifying sources of contamination, and implementing effective management strategies to protect water resources and ecosystems.

Physicochemical parameters analysis indicated temporal variations between 2018 and 2019. High fish production sites were Society Padavu and Akattan, and low-production sites were Nedupotta.

Economic evaluation revealed the significant contribution of fish production to the local economy, emphasizing the importance of sustainable management practices. The present study provides valuable insights into the ecological dynamics and socio-economic significance of the Thrissur-Ponnani kole wetlands. Sustainable management strategies informed by scientific research are essential to preserve biodiversity, support livelihoods, and ensure the long-term sustainability of this vital ecosystem.

CHAPTER 1
INTRODUCTION

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1.1 Limnological study of Thrissur- Ponnani kole wetlands

Wetlands play a pivotal role in maintaining ecological balance and supporting a diverse array of biological species. These habitats encompass various environments such as rivers, lakes, marshes, rice fields, and coastal areas, contributing significantly to human well-being and poverty reduction. Those living in proximity to wetlands heavily depend on the services they provide, and the destruction of these habitats, Thompson, (2001).

The unavoidable consequence of industrial expansion in developing nations, exemplified by India, is environmental pollution. Industries exert influence on the physical, chemical, and biological properties of the environment. Water, a critical natural resource for life on earth, faces significant threats due to the indiscriminate discharge of domestic wastes and industrial effluents into rivers, reservoirs, and lakes during rapid development. This unregulated disposal degrades water quality, rendering it unsuitable for various applications, including household, agricultural, and industrial uses. The resulting contamination disrupts aquatic life, leading to widespread consequences throughout the aquatic ecosystem.

In this context, the kole wetland stands out for its water storage capacity, serving as an immediate reservoir during rainfall. This unique feature not only protects terrestrial ecosystems and their inhabitants from floods but also functions as an essential irrigation system, contributing to human well-being. The vast wetland area in Kerala enables effective management of the ecosystem's water balance, minimizing drought-related issues. Additionally, the kole wetlands play a crucial role in providing a low-cost source of local food, particularly fish, supporting poor communities that depend on fishing as a reliable and nutritious food source throughout the year.

In essence, this scientific perspective emphasizes the critical role of wetlands, such as the kole wetland, in maintaining ecological harmony and supporting human livelihoods, while also highlighting the urgent need to address the environmental challenges posed by industrial activities in developing nations. Water scarcity, affecting 1-2 billion people globally, is an escalating and severe issue, hindering food production, growth, and causing harm to human health and economic development (FAO, 2007). The decline in water quality exacerbates the prevalence of illnesses, especially among disadvantaged individuals in underdeveloped nations where technological solutions are scarce a matter of high certainty.

Natural phenomena like flooding play a crucial role in maintaining the ecological functioning of wetlands. For instance, floods act as a natural mechanism for transporting dissolved or suspended materials and nutrients into wetlands, sustaining the delivery of services to millions of people. Those dependent on floodplains for flood-recession agriculture, pasturage, and fish production particularly benefit. The loss of wetlands heightens the risk of destructive floods. Groundwater, replenished by wetlands, is vital for drinking water, while surface water plays a key role in maintaining groundwater levels. The anticipated impacts of global climate change include increased loss and degradation of wetlands, leading to the extinction or decline of species and affecting human populations reliant on these services (Finlayson *et al.,* 2005).

Massive anthropogenic activities render water supplies unsuitable for human use. Eutrophication, driven by an increase in sewage flow, accelerates algae development in aquatic bodies. Limnology, the study of inland waterways, focuses on biological productivity and various factors influencing it. Welch (1952) defines biological productivity as the production of living creatures in inland waters encompassing all types of waterways, whether running or standing, fresh or saltwater. Odum (1971) later defines limnology as the comprehensive study of fresh water, covering physical, chemical, geological, and biological aspects. Another perspective, as noted by Das (1989), characterizes limnology as the study of freshwater ecosystems embracing lakes, reservoirs, streams, ponds, marshes, and bogs in terms of their physical, chemical, and biological attributes.

1.2 Ichthyofaunal study of kole wetlands

Wetlands play a crucial role in maintaining natural cycles and supporting a wide range of biodiversity. Among the various services they provide, two significant ones are related to fish and water availability, which greatly impact human well-being.

Particularly in less developed countries, inland fisheries hold special importance as they often serve as the primary source of animal protein for rural communities (Finlayson *et al.,* 2005).

In the context of Thrissur, the wetlands are integral components of the Vembanad Kole wetland ecosystem, offering diverse ecological, biological, and human benefits (Srinivasan, 2010). These wetlands, known as kole wetlands, serve as a habitat for a variety of organisms, creating a healthy environment with a rich diversity of species. Additionally, the kole wetland acts as a suitable breeding ground for these organisms.

Both inland and coastal wetlands have a significant impact on the hydrological cycle, and communities rely heavily on them for essential needs such as irrigation, energy, and transportation. It's important to note that wetlands are sensitive to changes in hydrology, as highlighted by Finlayson *et al.,* (2005). This emphasizes the critical role of wetlands in sustaining various aspects of human life and the environment.

The kole wetlands, despite their immense ecological significance, are often undervalued by people who perceive them primarily as rice fields or places for collecting fish. This simplistic view is compounded by the extensive use of fertilizers and pesticides in rice cultivation to achieve high yields in a short period. Human activities, driven by rapid population growth, urbanization, and the exploitation of fragile habitats, have exerted a substantial influence on the environment over the past decade (Olorunfemi and Jimoh, 2000).

The kole wetlands face threats from over-exploitation and unregulated commercial fish farming, which pose serious risks to the diversity of species inhabiting these areas. Recognizing the importance of wetlands, there is a call for economic valuation to highlight their significance in conservation and development agendas (Finlayson *et al.,* 2005). Wetlands, including the kole wetlands, play a vital role in contributing to surface water and maintaining ecological balance. Flooding, a natural phenomenon, is crucial for the ecological functioning of wetlands, sustaining services that benefit millions of people. Many wetlands act as natural buffers, reducing the destructive impact of floods. In India, where freshwater bodies cover 1.37 million hectares, approximately 2,44,000 hectares are dedicated to fish cultivation (Rao and Prasad, 1998). The country stands as the sixth-largest global producer of fish, contributing significantly to Asian fisheries and aquaculture.

Inland fisheries in India, with a production of around 2.44 MMT, make the country the second-largest contributor to global inland fisheries. Abundant resources, including 1,31,334 km of river and canal length and 2.05 million hectares of reservoirs, underline the importance of Indian fisheries (Sone and Malu, 2000). Fish, as a vital vertebrate group, significantly impact human life by providing a rich source of food, offering meat that addresses nutritional challenges in the contemporary world. Beyond food, fishes contribute valuable by-products such as fish meal, fish glue, and fish oil (Ullah, 2015; Shaikh *et al.,* (2011). This introduction sets the stage for a deeper exploration of the intricate relationships between human activities, wetland ecosystems, and the critical role of fisheries in India.

According to the Food and Agriculture Organization (FAO), fish serve as a primary source of animal protein for about one billion people worldwide (FAO, 2000). Not only are they a crucial food source, but fish also play a vital role in indicating the health of water and aquatic ecosystems, making them excellent bio-indicators (Moyle and Leidy, 1992). Considered as man's foremost source of high-quality protein, fish contribute significantly to global animal protein consumption, constituting 16% of the total (FAO, 1997). Fish diets provide essential amino acids, lipids, traces of vitamin B Complex, and other non-protein nitrogenous forms. While fish contribute to 10% of animal protein in North America and Europe, this number rises to 17% in Africa, 26% in Asia, and 22% in China (FAO, 2000).

Today, the fisheries sector has evolved into a multibillion-dollar industry, providing employment opportunities and enhancing the economic positions of numerous countries worldwide (Nagabhushan and Hosetti, (2010); Khan and Hasan, (2011)). Fish, occupying the second trophic level, are a valuable component of aquatic ecosystems, especially from a fishing perspective (Dubey *et al.,* 2012). Beyond being a rich source of high-quality proteins, fish are also notable for their Omega-3 fatty acids (Tucker, 1997).

Understanding the effects of toxicants on fish is crucial for fish conservation and the sustainable growth of fisheries, given their essential role in the aquatic food chain and as a major source of protein in many nations' diets (Agnihotri and Chattopadhyay, 1992). Exploration into the scientific understanding of Indian freshwater fish fauna commenced in the nineteenth century, with pioneers such as Hamilton, Buchanan, and

McClelland laying the groundwork for systematic ichthyology. Day's comprehensive study identified approximately 1418 fish species in the region. Other researchers, including David and Menon, have furthered our understanding of India's freshwater fishes through their taxonomic studies and checklists. Inland fisheries, as a result, not only contribute to biodiversity knowledge but also play a significant role in the local economy. This introduction sets the stage for a deeper exploration of the scientific endeavors that have shaped our understanding of the importance of fish in ecosystems and human nutrition.

Freshwater fish not only hold economic value but also play a crucial role in the economic progress of communities. Understanding the intricate relationship between fish depletion and poverty, and vice versa, is essential. Contrary to some beliefs, evidence challenges both directions of this link (FAO, 2006). This study aims to conduct limnological analysis, assessing water quality and fish diversity at seven sites in the Thrissur-Ponnanai kole wetlands.

Limnology, a vital discipline, helps unravel how human activities and natural processes impact lakes, reservoirs, rivers, and wetlands. It is an interdisciplinary science that combines biology, chemistry, physics, and geology to study inland waters as complex ecological systems. By examining a range of human impacts on aquatic ecosystems, this investigation contributes to our understanding of how these environments are affected. Recognizing the limitations in addressing environmental problems, especially with increasing human population, industrialization, agricultural practices, and other anthropogenic activities, the science of limnology has become increasingly important. Developing cost-effective strategies to ensure the sustainability of freshwater systems for current and future generations is a pressing need.

Water, a fundamental component of ecosystems, is assessed for its physical, chemical, and biological properties to determine its quality. As human activities continue to impact water quality, establishing significant correlations between various parameters becomes crucial for effective water quality monitoring. This introduction sets the stage for a scientific exploration of the Thrissur- Ponnanai kole wetlands, examining both the ecological and human dimensions of these vital freshwater ecosystems.

Wetlands, like the Thrissur kole wetlands, play a crucial role in supporting a diverse and abundant array of fauna, making them highly productive ecosystems compared to other wetlands. However, certain practices, such as those observed in some capture fisheries, result in the discarding of up to 40% of the overall catch. In contrast, aquaculture offers greater control over the entire production process, including harvest, processing, and distribution (Howgate, 1995).

The introduction of alien species and the growth of certain fishes can have severe consequences for fish diversity in freshwater ecosystems. This study delves into the present status of freshwater fishes in the Thrissur kole wetlands, exploring the impact of unmanaged and non-scientific practices related to the introduction and culturing of alien fishes. The natural fish population is adversely affected by such activities.

Kole wetlands are significant as they serve as prolific fish spawning sites, witnessing active spawning during rainy seasons. Unfortunately, increased agricultural activities have negatively impacted fisheries in these wetlands (Srinivasan, 2010). This decline in wetland-dependent species is a global concern, particularly affecting those reliant on interior lakes and waterbirds dependent on coastal wetlands (Finlayson, 2005). This introduction sets the stage for a scientific examination of the Thrissur kole wetlands, addressing both the ecological importance and the challenges faced by these vital ecosystems.

1.3 Biodiversity

Biodiversity, a term encompassing the variety of living species across terrestrial, marine, and aquatic ecosystems, is crucial for the planet's health (UNEP, 1992). India stands as one of the mega biodiversity countries globally, ranking ninth in terms of freshwater mega biodiversity (Mittermeier and Mitemeir, 1997).

Biodiversity has three interconnected aspects: genetic diversity, species diversity, and environmental diversity (Bisby, 1995). The variety of species within an ecosystem is closely tied to the presence of living and nonliving elements. Biodiversity is essential for ecosystem protection, overall environmental quality, and understanding the intrinsic value of every species on Earth (Ehrlich and Wilson, 1991).

1.3 Fish diversity and physico-chemical parameters

Ichthyodiversity, referring to a wide range of fish species, can denote species within a community, life forms in different aquatic environments, or even genotypes within a fish population (Burton *et al.,*1992). Beyond its ecological importance, ichthyodiversity contributes to employment, alternative income, and the development of new industries (Goswami *et al.,* 2012).

This introduction lays the foundation for a scientific exploration into the significance of biodiversity, particularly ichthyodiversity, emphasizing its role in ecosystem health, environmental quality, and human well-being. The distribution and composition of fish species are closely linked to various factors, such as food sources, breeding locations, water conditions, depth, terrain, and physicochemical properties (Harris, 1995). An ecosystem's biological diversity reflects its adaptability and resilience (Sarkar *et al.,* 2017). Key factors like water quality and inter-species interactions influence the structure and composition of fish communities (Ullah, 2013). Recognizing the significance of water physicochemical characteristics for fish, this study explores essential features that shape fish assemblages (Ullah *et al.,* 2014). Biodiversity plays a pivotal role in stabilizing ecosystems, conserving environmental quality, and acknowledging the intrinsic value of all species on Earth (Vijaykumar *et al.,* 2008).

Ornamental fishes, characterized by their small size, vibrant colors, and unique shapes, hold a special place in aquatic environments (Dey, 1996). Water is often referred to as the essence of life, a critical resource for sustaining life on Earth. Clean and fresh water is a fundamental necessity for human survival (Faniran, 1991; Spalding and Exner, 1993). However, the presence of excess nutrients in water can lead to issues such as eutrophication, disrupting aquatic ecosystems and negatively impacting both recreational activities and the biota residing in lakes (William, 1998). Aquatic creatures, including fish, are significantly influenced by the physical environment, chemical quality, and biological interactions within their habitats (Hynes, 1960). Changes in water quality, often resulting from pollution sources like industrial and municipal pollutants, can lead to the loss of numerous aquatic species annually (Templeton, 1995).

Toxic substances in water, exacerbated by oxygen depletion, pose a significant threat to aquatic life (Kupchella and Hyland, 1989). With the ongoing loss of species due to pollution and habitat destruction, assessing species diversity and richness becomes crucial (May, 1986). The dispersion and abundance of fish in various ecosystems are influenced by factors such as food availability and substrate types (Balirwa, 1998).

Fish, being sensitive to abiotic factors like temperature, oxygen levels, pH, salinity, and water currents, are impacted by changes in the physicochemical properties of water bodies (Fryer, 1973; Reash and Pigg, 1990). Pollutants, particularly in aquatic environments, have a more pronounced effect on organisms compared to terrestrial environments (Ilavazhahan *et al.,* 2010). Aquatic pollution, a significant concern in fisheries and aquaculture industries, stems from industrial wastewater discharge, affecting crucial activities like respiration and osmoregulation in fish (Kumaraguru, 1995). Changes in water's physical, chemical, and biological properties can influence fish behavior and lead to mortality (Yadav *et al.,* 2007). Fish, closely related to mammals, exhibit ethological alterations that can serve as sensitive indicators of toxicity (Tiwari *et al.,* 2011).

Water pollution, resulting from a wide range of pollutants, including pesticides from agricultural fields, has become a global issue (Voegborlo *et al.,* 1999; Vutukuru *et al.,* 2005). Pesticide poisoning poses a severe threat to fish and other aquatic life, causing oxygen depletion, poisoning, and mass mortality (Jothi and Narayan, 1999). As water quality is essential for healthy growth, contamination can pose hazards to life (Gupta and Gupta, 1997). This introduction sets the stage for a scientific exploration into the impact of pollutants on aquatic environments, emphasizing the role of fish as bio-indicators of environmental pollution.

Fish, being highly sensitive to environmental conditions, rely on factors such as water temperature, turbidity, pH, dissolved oxygen, free carbon dioxide, alkalinity, and certain salts for their growth and development (Nikolsky, 1963). Alterations in these parameters can impact fish growth, development, and maturity (Jhingran, 1983). The production and availability of fish are intricately linked to the physicochemical conditions of their aquatic habitat (Singh, 1960). Freshwater fishing, especially in locations with limited alternative work opportunities, holds significant socioeconomic importance. However, freshwater resources, including kole wetlands, face threats from alien species aquaculture, water pollution, global warming, habitat loss, and other factors. This study aims to provide policy-relevant information on the status of native, alien, and translocated fish species in kole wetlands, contributing to biologically-based fisheries management.

Ecological quality assessments play a crucial role in ichthyofaunal research, using fish indicators to evaluate the ecological state of freshwater bodies like kole wetlands. Despite the importance of conservation, kole wetlands lag behind in ichthyofaunal research and ecological quality evaluation. Anthropogenic pressures, such as intensive rice farming, aquaculture, landfilling, overfishing, and destructive fishing techniques, pose significant threats to kole wetlands.

Conservation efforts are hindered by a lack of systematic documentation of the ichthyofauna in kole wetlands. While wetlands are generally designated as protected areas under the Ramsar Convention, kole wetlands may not receive comparable attention and conservation priorities. Limited scientific understanding of kole wetlands, including their faunal richness and ecological services, makes it challenging for non-scientists and biologists to grasp their precise relevance.

This introduction sets the stage for exploring the critical role of ichthyofauna in kole wetlands, emphasizing the need for comprehensive research and conservation measures to address the challenges posed by anthropogenic activities and environmental threats. Kole wetlands, identified as highly vulnerable and anthropogenically influenced, boast remarkable faunal richness and provide crucial ecological and social services. Understanding the biological diversity of fish and the associated ecological features is imperative for effective conservation and management. Unfortunately, there is a lack of continuous research and documentation on ichthyofauna in Thrissur's kole wetlands, with existing data primarily stemming from well-studied areas in other wetlands.

Fish diversity holds significance not only for ecosystem health but also for societal well-being. Challenges such as mismanagement, water quality issues, and the impact of alien fish species, coupled with non-scientific aquaculture practices, pose threats to inland water fisheries. Destructive fishing methods further contribute to habitat degradation and fish extinction.

Establishing reliable data on current fish diversity is crucial for formulating and implementing effective fisheries management regulations. Monitoring the status of conserved or managed species is essential for effective conservation strategies. Some isolated populations, though poorly investigated, may harbor cryptic endemic species with evolutionary importance. Habitat loss emerges as a severe conservation issue, particularly in seasonally semi-arid areas with numerous small streams sensitive to human pressures.

Coordinated efforts are necessary to preserve wetlands, safeguarding their biological and social functions through comprehensive campaigns for conservation and restoration. Small-scale fisheries, characterized by labor-intensive methods in harvesting, processing, and distribution, play a vital role in exploiting marine and inland water fishery resources. Unfortunately, these fragile ecosystems have witnessed alarming declines, with agricultural development, urbanization, and other conversions accounting for the loss of wetland areas.

This introduction emphasizes the critical need for scientific understanding, conservation initiatives, and coordinated efforts to address the multifaceted challenges faced by kole wetlands, ensuring their sustained ecological and societal contributions. Recent assessments, such as the comprehensive assessment of water management in agriculture, highlight a growing threat to wetlands, predicting potential losses and subsequent impacts on ecosystem services. This poses a significant challenge as wetlands play a crucial role in regulating and supporting ecosystem services, essential for river basin function, conservation of ecological fluxes, and sustainable agricultural output (FAO, 2008).

Water quality metrics are pivotal variables for analyzing aquatic diversity, as the physicochemical characteristics of the environment serve as primary factors sustaining aquatic life. Investigating the water quality criteria of the ecosystem becomes imperative due to seasonal variations caused by both anthropogenic activities and natural disasters affecting wetland water sources. The connection between fish populations and the physicochemical properties of wetlands is noteworthy. Excessive fertilizer inputs, eutrophication, acidification, heavy metal contamination, organic pollution, and unsustainable fishing practices emerge as key contributors to the degradation of reservoir water quality. These factors not only impact the socioeconomic functioning of the reservoir but also pose a threat to its structural biodiversity.

Recognizing these challenges underscores the importance of understanding and addressing the complex interplay between anthropogenic influences, natural dynamics, and their impact on wetland ecosystems. This introduction sets the stage for investigating the critical relationship between water quality and the diverse ecosystems of wetlands, emphasizing the need for sustainable practices and conservation measures.

Kole wetlands, integral to local livelihoods and the economy, face imminent threats leading to the decline of numerous fish species. Factors such as habitat loss, industrial pollution, over-exploitation, the introduction of alien species, and unregulated fish farming contribute to the precarious state of fish diversity in kole wetlands. The disappearance of common fish species raises concerns about environmental health and the stability of the ecosystem's food chain.

Monitoring the physiochemical characteristics of the environment, including oxygen levels, BOD, nitrate, sulfate, and salinity, is crucial for assessing water quality. The dependence of aquatic fauna on water quality underscores the impact of human activities on kole wetlands. Practices such as habitat destruction, industrial waste dumping, algal blooming, introduction of alien species, and indiscriminate pesticide and fertilizer use pose significant threats to fish diversity.

In response to these challenges, a proposed program aims to comprehensively study the Kole Wetlands in Thrissur. The overarching goal is to enhance understanding, particularly regarding the contribution of fish to the local economy. Specific objectives include compiling a list of fish species in kole wetlands, assessing habitat threats, and evaluating unscientific fishery practices. Addressing the imbalance in water quality characteristics and mitigating anthropogenic impacts are crucial for the conservation of fishery resources in kole wetlands. This introduction sets the context for a scientific exploration focused on sustainable practices and the preservation of this vital ecosystem.

1.4 Fish production and economic evaluation of kole wetlands

Kerala is blessed with myriads of kole wetlands. These kole wetlands exhibit high fish diversity supported by the subtropical climate. But due to climate change and anthropogenic activities, the ichthyofaunal diversity in the wetlands has been decreasing. This has affected not only the faunal diversity but also production of the fish in kole wetlands. There are many fishermen and people who highly depend on wetland fishery in Thrissur for livelihood and sustenance. Therefore, an attempt has been made to examine some important details of fish production and economic evaluation of fishery resources. Rice and fish are grown side by side on some of the Kole farms. When the lands are flooded following paddy harvest, fish is cultivated. The fish lings are raised in ponds until the paddy harvest is complete, and the fish is collected at least 10 days before the paddy farming operations begin. Sowing will be completed in Kole fields, where one crop of paddy and fish are grown, by October 15. The most common paddy kinds grown are 'Jyothi' (120 days) and 'Uma' (130 to 140 days). Water will be piped in for fish farming nearly 15 days following harvest. (Srinivasan, 2010).

Commercial and recreational fishing have significant economic and political repercussions in kole wetlands, which must be included in watershed management plans. While holistic approaches that consider social, economic, environmental, and technical factors should be used to promote fishery management, biodiversity issues should not be sacrificed for the sake of development; the conservation value of species and habitats should be given at least as much weight as economic and social factors. According to FAO, 18% of fish stocks or species groupings worldwide are overexploited, while 10% have become considerably depleted or are recovering from depletion (FAO, 2002).

Fishing-related populations are likely to be among the most susceptible socioeconomic working groups, particularly in developing nations, where institutional and human skills to deal with the inherent volatility of fishing activity are lower than in affluent ones. In that sense, fishing activity may be seen as a source of vulnerability, where vulnerability becomes a cause of poverty (FAO, 2006).

1.5 Traditional fish harvesting methods in kole wetlands: a sustainable approach for preserving fish diversity

The kole wetlands, nestled in the heart of Kerala, India, have been a rich source of biodiversity, particularly in terms of fish species. Over the years, however, the advent of modern fishing techniques has led to a decline in fish diversity, posing a threat to the sustainability of this crucial ecosystem. The present study delves into the significance of traditional fish harvesting methods in the kole wetlands, emphasizing their role in mitigating the adverse effects of over-exploitation and unsystematic fishing practices.

Fish have long been a staple in the diet of the local population, providing a cheap and nutritious source of food. However, the rapid advancement of modern fishing practices has raised concerns about the future of fish diversity in the Kole Wetlands. This decline is not only detrimental to the ecosystem but also jeopardizes the livelihoods of those dependent on fishing for sustenance.

The primary objective of the present study is to shed light on the escalating issue of decreasing fish diversity in the Kole Wetlands and to underscore the importance of reviving traditional fish harvesting methods. By examining the historical context and current challenges, this research aims to advocate for the preservation of traditional fishing practices as a sustainable alternative to modern techniques. The vulnerability of traditional fishing practices and knowledge will also be explored, setting the stage for the subsequent discussion on their potential revitalization. This section will delve into the unique aspects of traditional fishing methods, highlighting their minimal impact on fish populations compared to modern techniques. By drawing parallels between the two approaches, the aim is to underscore the sustainable nature of traditional practices and their potential to alleviate the pressure on fish diversity in the kole wetlands.

In short, this part seeks to address the critical issue of diminishing fish diversity in the kole wetlands by advocating for the revival of traditional fish harvesting methods. By establishing the historical context, examining the current scenario, and presenting a robust methodology, this research aspires to contribute valuable insights to the ongoing discourse on sustainable fisheries management. The preservation of traditional knowledge and practices emerges as a crucial element in ensuring the longterm ecological health of the kole wetlands and securing the livelihoods of local communities. The fishing practices are developed with modern techniques. So that the sustainability of fish diversity is reduced. The importance of traditional fish harvesting methods increased with reducing fish diversity by over-exploitation and unsystematic fishing practices in kole wetlands. Fishes were the cheap nutritious food for common people. Nowadays traditional fishing practices and traditional knowledge were highly vulnerable. Traditional fishing is very less stressful on fish populations when compared to the modern technique.

1.6 Objectives of the study

1. To study the diversity of fishes in Thrissur-Ponnani kole wetland ecosystem.
2. To study the interrelationship between physio-chemical parameters of water and Thrissur-Ponnani kole wetland fish diversity.
3. To estimate the annual fish production by the kole wetlands of the Thrissur-Ponnani kole wetland ecosystem
4. Traditional fish harvesting methods employed by stakeholders of the Thrissur-Ponnani kole wetlands ecosystem.
5. Economic evaluation of the fishery resources of Thrissur-Ponnani kole wetlands ecosystems.
6. Evaluation of the interventions by the local self-governments in the ThrissurPonnani kole wetlands fishery.

CHAPTER 2
REVIEW OF LITERATURE

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2.1 Limnological studies in wetlands of India

Paswan *et al.,* (2012) carried out a work on a study of certain physicochemical parameters of Borsola Beel (Wetland) of Jorhat. Hussian and Biswas (2011) investigated the Physicochemical characteristics of a floodplain lake of Dhemaji in upper Assam. Ganpati and Chacko (1951) have studied the effects of paper mill effluents on the water quality of the Godavari River at Rajamundry, they observed different aspects of physicochemical parameters of sewage inflowing into the river which is hazardous to human health and fish fauna. Pruthi (1933) studied the seasonal variations in the physicochemical parameters of tank water in the Indian museum. Physicochemical factors of the Ganga river at Patna were carried out by Singh and Bhowmick (1985), they studied the effect of sewage on the physicochemical parameters of river Ganga causes the deterioration of river water.

Kothandaraman *et al.,*(1963) conducted biological and physicochemical aspects of sewage entering the river at Ahmedabad. Basu (1966) reported the effluents of pulp paper mills affect the physicochemical changes in the Hoogly estuary at many disposal points. Kar (1984) reported on the limnology and fisheries of lake Sone in the Cachar district of Assam, India.

Hutchinson (1957) recorded that large numbers of chemical elements are found in polluted water bodies, according to their treatise on limnology. Iyengar (1939) and Rao (1985) have provided remarkable contributions in the field of limnology, hydrobiology, and the environmental quality of lotic aquatic environments. He made an investigation on the physicochemical parameters of two major reservoirs in Madras state. Limnology of freshwater bodies in India has been studied by Hynes (1970), Badola and Singh (1981), Singh (1988), Trivedy (1988), Hujare (2008), Karne *et al.,* (2009). Hynes (1975), Reddy and Graetz (1981), Smart *et al.,*(1985), and Warren (1979) has been conducted river ecosystems containing a surplus of phosphorus, nitrogen, organic matter, chloride-suspended solids, and pathogens, which control the nature of vegetation and fauna of aquatic body.

Unnai (1984) studied the Physicochemical characteristics of sewage-infected ponds in central India. The impact of domestic sewage and industrial wastes on Indian rivers has been reported by Anwar and Siddiqui (1988), Kulshreshtha *et al.,*(1988), Singh (1988), and Sinha *et al.,*(1989). Dakshini and Soni (1979) studied the water quality of the Yamuna River in Delhi. Srinivasan *et al.,*(1980) made work on the pollution status of River Kaveri and they observed that the quality of river Kaveri was deteriorating due to the continuous dumping of industrial and urban waste. Physicochemical parameters of Yamuna River at Agra have been reported by Sharma *et al.,*(1981) at their sewage draining points. Agrawal and Srivastava (1984) recorded the pollution study of the Ganga and Yamuna rivers and they studied major drains discharged into rivers.

Chattopadhyay *et al.,*(1984) conducted the pollution status of the Ganga River at Kanpur. Physicochemical parameters of river Ganga at Varanasi have been carried out by Shukla *et al.,*(1989) they reported that the chloride values are highest in summer and lowest in winter. Singh and Singh (1990) made research on the water of river the Subarnarekha (Ranchi) is harmful to man and crops. The impacts of industrial effluents from fertilizer factories and power plants on the physicochemical quality of river Indira were carried out by Tripathi and Adhikary (1990). Sandoyin (1991) made research on the physicochemical factors of Rhode River and he recorded the effects of effluents discharged from various sources that change the chemical, physical and biological nature of receiving water bodies.

Chandrashekhar (1996) investigated the ecological status of Saroornagar Lake in Hyderabad and he reported the diversity and density of aquatic animals, which is controlled by the factors like temperature of water, turbidity, transparency, and dissolved oxygen. Dhembare and Pondhe (1997) reported the physicochemical factors of Pravara area in Mahararshtra (India) and they studied correlations between chemical, physical and microbial characteristics of water, which are useful to indicate the quality of water. Shaw *et al.,*(1991) reported on the effects of industrial and sewage effluents on the quality of water in Rushikulya River Estuary. Physicochemical and bacteriological studies have been conducted in recent years at Akola (Maharashtra, India) by Fokmare (2002), and in Hyderabad (Andhra Pradesh, India) by Mary and Kausar (2004).

Bharti and Krishnamurthy (1992) studied the effect of paper mill effluent on the physicochemical characteristics of Kali river near Dandeli in Karnataka (India). Datar and Vashishtha (1992) investigated the quality of Betwa river water with reference to physicochemical aspects. Israli (1992) studied the occurrence of heavy metals in the water of river Ganga due to discharged effluents. Khatavkar and Trivedy (1992) conducted a high degree of pollution in Panchganga river near Kolhapur and Ichalkaranji.

The limnology of Sutledge River was studied by Gill *et al.,*(1993). Bilgrami *et al.,*(1993) recorded monthly and seasonal variations in physicochemical characteristics showing significant differences at various sampling stations of Ganga river. Singh *et al.,*(1993) investigated the impact of domestic and industrial waste from Agra and Mathura city on the physicochemical parameters of the Yamuna river. Pandey *et al.,*(1993) conducted a work on physicochemical parameters in Husain sagar lake at Hyderabad. Singh and Singh (1995) carried out the physicochemical factors of Sone river at Dalmilanagar in Bihar. Goel and Autade (1995) carried out the physicochemical characteristics of sewage entering the Panchaganga river in District Kolhapur (M.S.). Physicochemical factors of Gadchiroli lake for evaluating water quality were studied by Patil and Tijare (2001).

Sinha (2002) conducted studies on alterations in physicochemical parameters causing great damage to the riverine biota of the river Sai at Rae Bareli. Dwivedi and Pandey (2002) reported the physicochemical parameters of two ponds, Maqubara pond and Girija kund in Faizabad. Pandey and Pandey (2003) conducted a work on physicochemical factors of river Sharyu at Faizabad at city sewage discharge points. Unnisa and Khalilullah (2004) reported the industrial pollution on rivers and streams of Kattedan industrial area.

Singh and Matur (2005) investigated the physicochemical factors of freshwater of Ajmer city in Rajasthan (India) and they recorded the effect of over-exploitation and pollution on freshwater bodies. Parashar *et al.,*(2006) carried out the physicochemical parameters in the upper lake of Bhopal in Madhya Pradesh and they observed the quality of water for potability and they analyzed that the quality of water was better in winter than the summer season. Nnaji *et al.,*(2010) studied the pollution effect on the water quality of river Galma at Zaria in Nigeria and they observed that river water was favorable for fish production. Agarwal and Saxena (2011) studied the physicochemical factors of river Gagan at Moradabad (India) and they reported the degree of pollution due to different domestic and industrial activities.

Gupta *et al.,*(2011) studied physicochemical factors of different lakes of Jaipur at Rajasthan (India) and they observed that water from polluted lakes was unsuitable for drinking and water from unpolluted lakes was within the acceptable limit. The index of water quality of the water body in Shimoga town (Karnataka) was studied by Yogendra and Puttaiah (2007) and they observed poor quality of water. Prasad and Patil (2008) carried out the physicochemical factors of river Krishna (Western Maharashtra) at Arjunwad, Ghalwad, Shirti, Hasur, Narsinhwadi, Aurwad and they observed that physicochemical factors of river Krishna are within the limits of WHO and ICMR. Gupta and Shukla (2006) have observed the physicochemical factors of sewage water in Rajasthan. Sabbir *et al.,*(2010) studied the pollution status of the Mouri river at Khulna in Bangladesh and they noticed that the river water was unsuitable for most of the aquatic organisms.

Sayed and Gupta (2010) studied the physicochemical factors of rivers in the district Beed of Maharashtra (India) and they reported that the water of rivers in Beed district was moderately hard and unfit for drinking and for domestic use. Varunprasath and Daniel (2010) studied the physicochemical properties of the Bhavani river in Tamilnadu (India) and they reported physicochemical values to exceed the permissible limit at effluent discharge points. Pawar and Sonawane (2011) studied the physicochemical parameters of Kanher water body, Satara District (M.S.) India and they observed physicochemical parameters of the water body change seasonally. The physicochemical factors of stream Cekerek in Turkey for evaluating water quality were reported by Duran and Suicmez (2007).

Kamal *et al.,*(2007) investigated on physicochemical factors of Mouri river water at Khulna in Bangladesh. Patil and Dongare (2006) observed the physicochemical parameters of Aundh water bodies of Southern Maharashtra and they recorded the stress of human activities on the quality of the water body. Kshirsagar *et al.,*(2016) studied the correlation between physicochemical parameters like pH, BOD, DO, COD, Water Temperature, Total Hardness, Total Alkalinity, Chloride, Calcium, Phosphate, Nitrate, Turbidity and Ammonia of river Bhima at Pandharpur

(Maharashtra) and they observed the variations in parameters are because of pollution effect on the water body.

Narayan *et al.,*(2016) studied the physicochemical characteristics of Krishna river water at Bhuinj, District Satara (Maharashtra) India and they observed that the pH values are higher than the permissible limits of APHA. Srinivasulu *et al.,*(2016) made an investigation on the water quality of river Krishna during Pushkara (festival of rivers). Pawar and Vaidya (2012) studied the physicochemical factors of river Krishna at Wai in Satara district and they observed that physicochemical factors are within the prescribed limits of drinking water standards (IS: 10500, 1992). The physicochemical parameters in Sarawak river and its tributaries in Malaysia were studied by Sim and Tai (2018). Mandal *et al.,*(2012) studied the physicochemical factors of river Karola, West Bengal to evaluate the status of pollution and they noticed the river water was not safe for human consumption.

Ahangar *et al.,*(2012) studied the physicochemical factors of Anchar Lake in Kashmir (India) and they reported a correlation between 13 physicochemical factors giving considerable positive and negative trends. Bhalerao (2012) studied physicochemical parameters and Ichthyofauna of Kasar Sai Dam Hinjewadi, Pune, Maharashtra State (India) and he observed that physicochemical parameters change seasonally. Tiwari and Ranga (2012) studied the Diurnal changes in the physicochemical condition of Khanpura Lake, Ajmer (India) and they reported the impact of climate on the water body. Waghmare *et al.,*(2012) studied physicochemical factors of Jamgavan dam water of Hingoli District (Maharashtra State, India) and they reported physicochemical factors of dam water changes seasonally. Sharma *et al.,*(2012) studied the water quality of river Narmada, Madhya. Pradesh (India) and they observed that the physicochemical factors of Narmada water are within the permissible limits of WHO. Sujitha *et al.,*(2011) studied the physicochemical factors of river Karamana in Trivandrum district, Kerala (India).

Chaurasia and Tiwari (2011) studied the physicochemical factors of the Rapti river at Gorakhpur in Uttar Pradesh (India) and they observed that sugar factories and distilleries discharge poisonous effluents into the river which are harmful to human health. Muhibbu *et al.,*(2011) studied the physicochemical factors of stream effluent receiving at Obafemi Awolowo University Ile-Ife, Osun state, Nigeria and they observed adverse effects on the physicochemical factors of stream due to sewage discharge. Rana *et al.,*(2018) conducted the physicochemical parameters in Himalayan Lake Beni Tal (India) and they observed that the physicochemical factors like pH, conductivity, turbidity, DO, BOD, TDS, chlorides, nitrates, magnesium, and calcium are within a prescribed range of 15 WHO and BIS for drinking water.

Khabade *et al.,*(2013) studied the physicochemical factors of the river Panchaganga water near Ichalkaranji City (Maharashtra). The physicochemical factors of river Krishna were studied by Penjor *et al.,*(2013) and they observed that the physicochemical characteristics of river Krishna such as alkalinity, dissolved oxygen, etc. are within the normal range. Patil and Gujar (2014) studied the pollution status of river Urmodi in District Satara and they observed that air temperature, pH, turbidity, and water temperature are within normal range whereas BOD, COD, total alkalinity, and total hardness values were increased.

Sarwade and Kamble (2014) studied the physicochemical factors of river Krishna in Sangli district (M.S.) India and they observed that (in winter TDS was higher and in summer the alkalinity was higher) the river water was contaminated and polluted. Gujar *et al.,*(2015) studied physicochemical factors of river Koyana in Satara district (Maharashtra, India) and they reported that pH, Temperature, TDS, and Turbidity values are within the permissible limits and BOD, COD, Free CO2, Total alkalinity, Total hardness exceeds the permissible limits of water standard due to accumulation of domestic sewage, industrial effluents and man activities in the river. Chittora *et al.,*(2017) studied the physicochemical factors of different lakes in Udaipur City (Rajasthan) and they analyzed that the physicochemical factors are within the permissible limits.

Jafri Ahsan and Imtiyaz (2017) investigated on physicochemical factors of river Sone at Koilwar (Bihar, India) and they reported that pH, Electrical conductivity, and BOD is within the permissible limits and DO exceed the permissible limits of WHO. Nangmaithem and Basudha (2017) made a study on physicochemical factors in different water bodies of four districts in Manipur. Rajan and Anila (2018) observed the physicochemical factors of Pamba river (Kerala) and they analyzed that the quality of river water decreased.

2.1.1 Limnological studies in wetlands of Kerala

Nirmala (1996) has made a study on limnology of a natural freshwater lake in the high ranges of Kerala. Rakesh (2021) investigated the physico-chemical parameters, insect pests and parasitoid diversity in selected conventional and kaipad rice fields of North Kerala. George (2002) carried out the Environmental studies of some selected wetlands in malabar with special reference to birdlife. Nasir (2010) investigated the water quality assessment and isotope studies of vembanad wetland system. Fathibi (2021). Diversity and abundance of zooplankton in relation with physico-chemical parameters of Thrissur kole wetland with special emphasis in rotifera (Eurotatoria). George (2002) carried out the environmental studies of some selected wetlands in Malabar with special reference to birdlife.

2.2 Ichthyofaunal studies related to kole wetlands of Thrissur, Kerala

Antony (1977) have reported systematics, ecology, bionomics and distribution of the stream fishes of Trichur district. He reported 48 species of hill stream fishes from the Thrichur district. Abdul kader (1993) studied the fish and fisheries of inland eaters of Thrichur district. Sunil and Sneha (2021) made a study on fish diversity in Pullazhi kole wetlands of Thrissur, India after the deluge of 2019 and they reported 25 species of fish. Inasu (1991) recorded the systematic and bionomics of inland fishes of the Thrissur district.

2.3 Studies on wetlands of India

Nasir (2010) investigated the water quality assessment and isotope studies of Vembanad wetland system. Nirmala (1996) have made a study on Limnological studies of a natural freshwater lake in the high ranges of Kerala.

According to the study of Basavaraja *et al.,*(2014) the investigation of fish diversity and abundance in relation to the water quality of Anjanapura Reservoir, Karnataka, India. Oli *et al.,*(2013) recorded the seasonal variation in water quality and fish diversity of Rampur Ghol, a wetland in Chitwan, Central Nepal. Hora and Gupta (1940) recorded 58 species of fish from Kalimpong, Duars, and Siliguri Terai, North

Bengal. Bordoloi (2008) reported the problem and prospects of the wetland in the Jorhat district, Assam.

Kar *et al.,*(2006) made a study on fish diversity and conservation aspects in an aquatic ecosystem in north eastern India and reported 69 species of fish. Bhakta and Bandyopadhyay (2008) studied fish diversity in freshwater perennial water Bodies in East Midnapore. They documented 34 species from the investigated area. Panigrahi *et al.,*(2009) conducted a research program on indigenous ornamental fishes in some districts of South Bengal. They reported 30 species of indigenous ornamental fishes.

Bordoloi (2010) has recorded a comparative study on fish and fisheries between a closed and an open type wetland of the Jorhat, District, Assam, Deka (2005) have conducted the causes of fish depletion- A factor analysis approach. Patra (2011) has reported an investigation on catfish diversity in Karala River of Jalpaiguri district and reported 7 species belonging to 6 genera and 6 families. Saha (2013) conducted his study on fish diversity in Khanakul, Hooghly District of West Bengal, India. Saha and Patra (2013) made their study on the present status of ichthyofaunal diversity of the Damodar River in Burdwan district and recorded 46 species. Acharjee and Barat (2013) conducted the ichthyofaunal diversity of the Teesta River in the Darjeeling district and reported 65 cold-water fish species. Hashemi *et al.,*(2015) have studied the Fish species composition, distribution, and abundance in Shadegan Wetland.

Grubh *et al.,*(2018) made an investigation on Spatiotemporal variation in wetland fish assemblages in the Western Ghats region of India. Prasad *et al.,*(2009) conducted the Fish diversity and its conservation in major wetlands of Mysore. Bordoloi (2008b) reported a work on fish and fisheries of a closed and open type wetland of the Jorhat district, Assam.

Biswas and Boruah (2000) made an investigation on the Fisheries ecology of the North-Eastern Himalaya with special reference to the Brahmaputra River. Kottelat *et al.,*(1996) investigated Freshwater biodiversity in Asia with special reference to fish. Agarwala (1994) conducted the endangered sport fishes of Assam. In: Threatened fishes of India. Bordoloi (2007) conducted a survey on conserving wetland habitats to increase the abundance of fish diversity in the wetland of Assam. Jhingran and Dutta (1968) have conducted the inland fisheries resources of India. Nansimole *et al.,*(2014) made an investigation on the first report on fishery resources from four estuaries in

Trivandrum district, Kerala, India. Kumar *et al.,*(2013) have conducted studies on the ichthyofaunal diversity of the Karanja reservoir in Karnataka, India. Bassi *et al.,*(2014) investigated the status of wetlands in India: A review of extent, ecosystem benefits, threats, and management strategies.

Naganandani and Hosmani (1998) have conducted the significance of dissolved oxygen, biological oxygen demand, and water temperature for plenty of phytoplanktons in inland waters of the Mysore district at Hoskere Lake. Limnology of some community ponds of Rourkela was studied by Shivakumar *et al.,*(2000).

Mustapha and Omotosho (2005) have studied the physicochemical parameters of water which play an important role in the abundance and distribution of aquatic organisms of Moro Lake in Kwara state (Nigeria). Bandyopadhyay (2007) has observed that a river basin of the Indian subcontinent has a variation in great diversity and precipitation in the geo-hydrological characters. The physicochemical factors of an aquaculture body Bilikere Lake at Mysore city in Karnataka (India) studied by Sachidanandmurthy and Yajurvedi (2006) and they reported that the monthly changes in physicochemical factors of the water body and water body were suitable for fish culture.

Fishes are important members of the group of vertebrates in the riverine ecosystem. Many researchers have worked on the ichthyofaunal diversity. Narayanan *et al.,*(2005) conducted a study of ichthyofauna of Aymanam panchayat in Vembanad wetland, Kerala. Shelke (2018) reported 35 species of fish in Girna river district of Jalgaon (M.S.-India). Shillewar and Nanware (2008) carried out the diversity of fishes in Godavari river at Nanded (M.S. India) and they observed 26 fish species. Sarwade and Khillare (2010) reported the 60 fish species in Ujani wetland (M.S.). Patil and Gujar (2015) carried out the Ichthyofaunal diversity in Krishna River in the district Satara, Maharashra (India) and they reported 73 fish species. Forty-two fish species were recorded in Pakhanjoor reservoir in Kanker district (Chhattisgarh-India) by Minj and Agrawal (2015). USCB (2010) observed that globally more than 700 species of vascular plants vertebrates and invertebrates have been recorded to vanish.

Patil and Gujar (2014) recorded the Ichthyofaunal diversity in Urmodi river in the district Satara, Maharashra (India) and they reported 42 fish species. In Satara district diversity of fish was observed by different scientists such as Supugade *et al.,*(2007) in

Ghogaon reservoir. Jadhav *et al.,*(2011) in Koyana river conducted work on 58 species of fish. Nikam *et al.,*(2014) reported fish diversity of Ashti Lake, district Solapur (M.S.). Wani and Gupta (2015) carried out the ichthyofauna of Sagar Lake in Sagar city (M.P.). Jain (2017) made work on the ichthyofauna of various water sources in Uttar Pradesh and observed 61 fish species.

Hamilton (1822) conducted a work on the Icthyofauna in river Ganga and its branches. Selakoti (2018) had also 12 species of fish in Kumaun Himalayan river, Kosi at Almora, Uttarkhand (India). Bhilave and Deshpande (2007) observed the biodiversity of fishes in river Manjara and river Venna in Satara tahsil. Kharat *et al.,*(2012) studied ichthyofauna of Krishna river in Satara district at Wai (M.S.) and they recorded 51 species of fish. Jayabhaye and Lahane (2013) reported the ichthyofauna of Pimpaldari tank, district Hingoli (M.S.) and they observed 21 species of fish. The fishery diversity and distribution in Vembanad wetland system were recorded primarily by Shetty (1965), Kurup (1982), and Unnithan *et al.,*(2001).

A systematic list of 150 species of fish belonging to 100 genera under 56 families in the Vembanad backwater was studied by Kuttyamma *et al.,*(1975). Padmakumar *et al.,*(2002) reported the fishery decline in Vembanad wetlands. Bijoy Nandan *et al.,*(2012) studied the status of exploited fishery resources was studied by and the temporal pattern of fish production in Azhikode estuary. Anon (2009) reported the fisheries and socio-economic aspects of the Vembanad backwater. The seasonal and spatial variations in fishing intensity and gear-wise landings of the Vembanad backwater were examined by Kurup *et al.,*(1993). The impact of fluctuations in temperature from pre-monsoon to monsoon on the seasonal distribution and abundance of fish in the Vembanad estuarine system was pointed out by Menon *et al.,*(2000).

2.4 Studies on inland fish production in India

In India inland fish production is 104.37 Lakhs tones in 2019-2020. Kerala has reported inland fish production of 1.92 Lakhs Tones in 2018-2019 and 2.05 Lakhs in 2019-2020 (Fisheries Statistics, 2020). Agarwala (1996) reported their survey work on Limnology and fish productivity of Tamranga wetland in Bangaigaon district of Assam (India) with special reference to some productivity indicators. Bordoloi

(2008a) reported the Exploration of fish fauna, fish production, and habitat conservation of Nahotia and Potiasola wetland of Jorhat district, Assam. Asha *et al.,*(2014) studied the decline in diversity and production of exploited fishery resources in Vembanad wetland system: strategies for better management and conservation. Choudhury (1987) carried out an analysis of fish catch statistics in Dhir Beel, Assam.

2.5 Studies on traditional fish harvesting methods in India

Shaji and Laladhas (2017) recorded Monsoon floodplain fishery and traditional fishing methods in Thrissur district, Kerala. Their study sheds light on the unique fishing practices in this region, emphasizing the importance of understanding local techniques for sustainable fisheries management.

Ranjan *et al.,*(2021) have studied the Traditional fishing methods used by the fishermen in the Sundarban region, West Bengal, during the year 2020-2021 they studied fishing methods in Sundarban regions. According to their study, current socio-economic circumstances in Indian Sundarban regions show that their lifestyle is unsuitable for low family income due to large annual disasters such as cyclones, storms, floods, and the water's salinity. Chandra Das (2013) reported the fish harvesting method of island fishermen at Kaibartta of Majuli.

Bhilave (2018) recorded the Traditional fishing methods of Kolhapur district, he studied net fishing, line fishing, the use of arrows, harpoons, and barriers, set and mobile traps, night fishing, fish poisoning, and spearfishing are the common traditional methods of fishing. Prasad *et al.,*(2013) made an investigation on a few indigenous traditional fishing methods in Faizabad district of eastern Utter Pradesh, India. Adikant *et al.,*(2011) studied about traditional fishing techniques of tribes in Bastar region of Chattisgargh. Badola and Singh (1977) have reported the fishing methods in Garhwal Hills.

Baruah *et al.,*(2013) were made investigated the availability of different types of fish trapping implements in the Brahmaputra valley with the objective to study their respective dimensions, seasonal variation, abundance, catch, cost, variability of gears with species, season, and their mode of operation. Devi *et al.,*(2013) reported the traditional fishing methods in the central valley region of Manipur. Gurumayum and

Choudhury (2009) reported the fishing methods in the rivers of Northeast India. Lalthanzara and Lalthanpuii (2009) reported the traditional fishing methods in rivers and streams of Mizoram. Manna *et al.,*(2011) made and researched various fishing crafts and gear in the river Krishna.

Nirmale *et al.,*(2007) have recorded the use of 82 indigenous knowledge by the coastal fisher folk of the Mumbai district in Maharastra. Rathakrishnan *et al.,*(2009) have recorded the traditional fishing practices followed by fisher folks of Tamil Nadu. Remesan (2006) made a study on the inland fishing gear of North Kerala. Sarkar (1954) reported Artefacts of fishing and navigation from the Indus Valley. Srivastava *et al.,*(2002) conducted a study on fishing methods in streams of the Kumon Himalaya region of India. Suresh (2000) reported the unique fish aggregating method in Naga. Tynsong and Tiwari (2008) studied about traditional knowledge associated with fish harvesting practices of the War Khasi community in Meghalaya. Sebastian *et al.,*(2016) made an investigation the knowledge of fishing gears, crafts, and fishing methods in Kolleru Lake,

CHAPTER 3
MATERIALS AND METHODS

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3 Methodology for the objectives 1 & 2: Study of diversity of fishes and the interrelationship between physicochemical parameters of water in Thrissur-Ponnani kole wetland

3.1 Methods for fish sample collection in kole wetlands

The sampling duration for analysing fish diversity and water quality parameters was from January 2018 to December 2019. Fishes were sampled with the help of local fishermen. The water samples were collected at the depth one feet, between 8.00 am to 9.00 am and fish sampling was done using cast net (mesh size: 5mm ×5mm). The fish specimen collected were fixed in 4 to 5 % of formaldehyde solution in field after taking photos and subsequently transferred after 3-4 hours fixation and washing to rectified sprit in the laboratory. Large sized specimen was injected with 10% of formaldehyde and given a belly incision. Fish specimens were identified using stable characters both meristic and morphometric: the shape of the snout, presence or absence of barbels, number of dorsal fin rays, number of scales in lateral line, scale in transverse lines, pre dorsal scale etc. Literature on fish systematics and fauna such as Day (1878, 1889), Jayaram (1981, 1991), Menon (1964, 1987) and Talwar and Jinhgran (1991) were referred for identification.

3.2 Study area

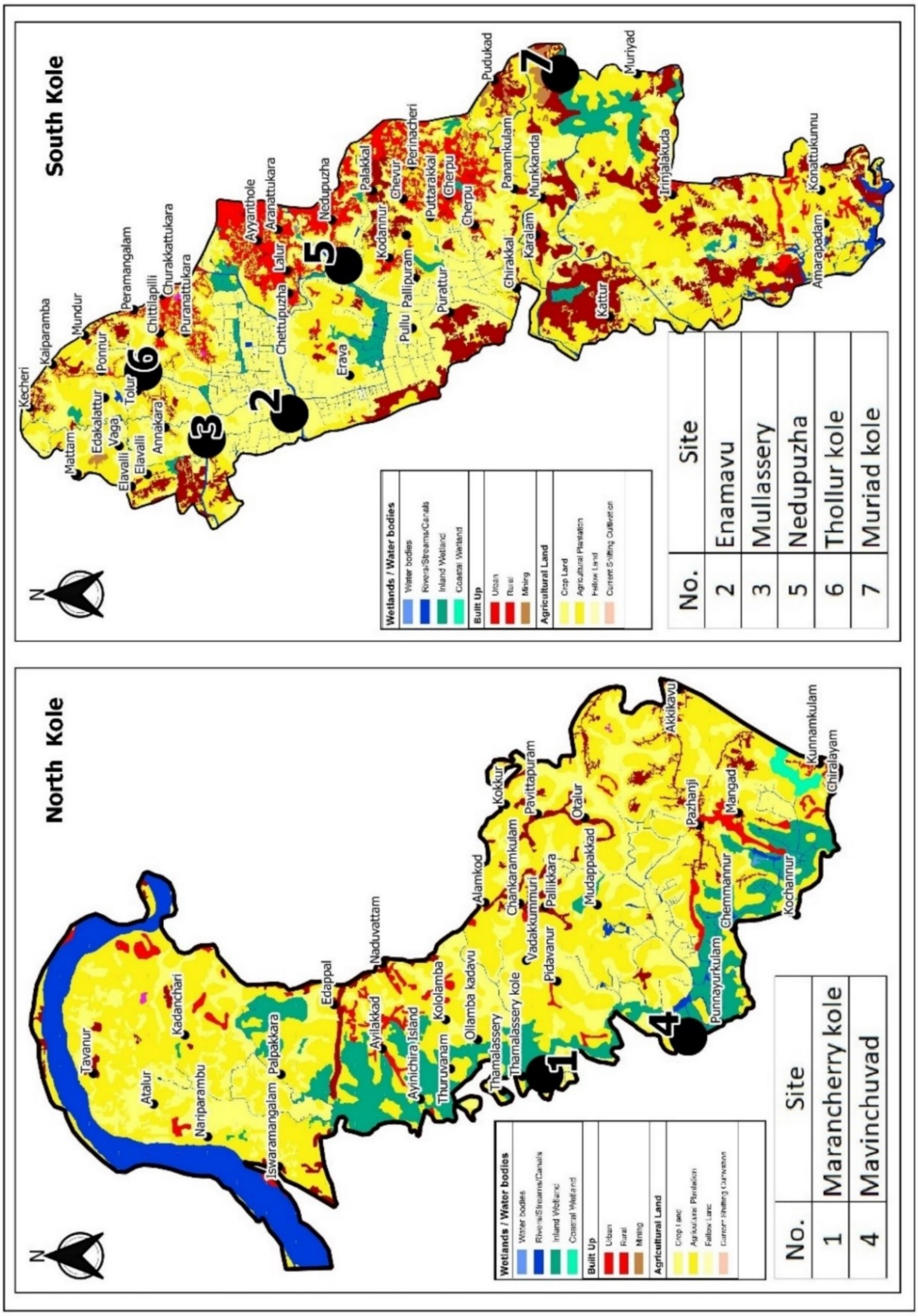
The kole lands are spread over Thrissur and Malappuram districts of Kerala. This is said to be the rice granary of these districts at par with Kuttanad the ‘Rice Bowl' of Kerala. Rice cultivation in kole lands is said to have started in the eighteenth century. kole lands lie between Bharathapuzha in the North and Chalakudy river in the South. It is located between 10^{o} 20' and 10^{o} 40' N latitudes and 75^{o} 58' and 76^{o} 11' E longitudes. The Muriyad wetland is situated 8 km northeast of Irinjalakuda town of Thrissur district. Kurumali-Karuvannur River is the northern boundary. The total field area is 1,215 ha. The Nedumthode (Thamaravalayam canal) running along the centre of the wetland is the major opening, which functions as the discharge outlet of floodwater and lets irrigation water into the fields. M.M. canal (Muriyad-Moorkanad Canal) is the only outlet for floodwater (Johnkutty and Venugopal, 1993).

Ponnani kole, situated in southwestern region of Malappuram district, is the northern most extension of the Vembanad kole Ramsar site. Ponnani kole, 20 km long extends from the southern bank of Bharathapuzha in the north to Narnipuzha in the south. The study was conducted in seven randomly selected sites; Marancherry, Mavinchuvad, Tholur, Mullassery, Enamav, Nedupuzha and Muriad kole wetlands (Table 1) which lay between muriyad and Ponnani (Map 1).

Table 1: Geographical coordinates of the study sites of Thrissur – Ponnani kole wetlands

Sites	Latitude	Longitude
Maranchery kole	10.72’59’	75.98’69’
Enamavu kole	10.51’03’	76.12’32’
Mavinchuvad kole	10.68’98’	75.99’23’
Mullassery kole	10.54’09’	76.10’82’
Tholur kole	10.57’21’	76.13’89’
Nedupuzha kole	10.48’47’	76.18’28’
Muriad kole	10.39’73’	76.25’68’

Map 1: Locations indicating sample collection for fish diversity and limnological study in Thrissur – Ponnani kole wetlands (2018-2019). Sample collection sites are marked in land and showing distribution of study sites in kole wetlands.



3.3 Biodiversity Indices

The type of diversity index is a mathematical measure of species diversity in each community. The following diversity indices were used in the study:

3.3.1 Shannon – Wiener diversity index (Shannon, 1948)

Shannon diversity index = H = ∑ pi In pi

Where,

pi = S / N

S = Number of individuals of one species

N = Total number of all individuals in the sample

In = Natural logarithm

3.3.2 Margalef's index (Margalef, 1958)

Margalef's index = (S – 1) / In N

Where,

S = Total number of species

N = Total number of individuals in the sample

In = Natural logarithm

3.3.3 Evenness Index (Pielou, 1966).

Evenness Index (e) = H / In S

Where,

H = Shannon – Wiener diversity index

S = Total number of species in the sample

In = Natural logarithm

3.3.4 Simpson Index (Simpson, 1949)

Simpson Index (D) = $\sum_{i=1}^{1} \quad pi^2$

Where,

p = Proportion (n/N) of individuals of one species found (n) divided by the total number of individuals found (N),

Σ = Sum of the calculation

s =Number of species

3.3.5 Dominance Index (Odum, 1971)

Dominance index C = = $\sum_{i=1}^{s} Pi^2$

Where,

C= Dominance Index

Pi= The proportion of individuals, I= 1, 2…, n

3.4 Collection of water samples for physicochemical analysis

Water was collected from seven sampling sites to analyze different physicochemical characters following standard protocols. New plastic bottles of 2-liter capacity were washed with distilled water and bottles were dried before sampling. BOD bottles of 300 mL capacity was also for sampling for analyzing dissolved oxygen.

The BOD bottles and sampling bottles were brought to the laboratory and estimations were done within 72 hours. Water and air temperature were measured in the field. pH, transparency, turbidity, total dissolved solids and conductivity and the chemical parameters, dissolved oxygen, alkalinity, acidity, fluoride, iron, magnesium, chlorides, salinity, sulphates, nitrate, hardness, and biochemical oxygen demand were tested. The physical and chemical parameters were tested in the laboratory of research institution and Kerala Water Authority using standard methods for the examination of water APHA (1995), Trivedy and Goel (1986), WHO (1984) and Kodarkar *et al.,* (1998).

3.5 Methods for physicochemical parameters analysis

Table 2: Parameters tested using portable digital equipments

Sl. No.	Parameters/ equipment used	Equipments brand
1	pH	LABMAN Digital pH Meter (LMPH10)
2	TDS	TDS Meter or Conductivity Tester Dist-1 TDS Meter Hanna (HI 98301)
3	Turbidity	SSU Digital Turbidity Meter
4	Electrical conductivity	TDS Meter or Conductivity Tester Dist-1 TDS Meter Hanna
5	Salinity meter	LABART Salinity refractometer 0~100 PPT(LRS-100)
6	Spectrophotometry	Manti Lab Digital Spectrophotometer

a) Nitrates (Jenkins & Medsken, 1964)

Nitrate ions analysis was done using Brucine method. The end point is colour change to yellow and measured spectrophotometrically at 410nm.

I. Standard nitrate solution: Dissolve 72.2 mg potassium nitrate (KNO_3) in distilled water in a volumetric flask and dilute to 1000 mL per litre, this solution contains 10 mg of nitrate.

II. Brucine solution with sulphanilic acid: Dissolve 1 gm brucine sulphate and 100 mg sulphanilic acid in 70 mL of hot distilled water. After adding 3 mL of concentrated HCI, cool and dilute to 100 mL with purified water.

III. Sodium Arsenite Solution: Dissolve 1.183 gm sodium arsenite ($NaASO_2$) in 100 mL of purified water. In 50 mL beakers, standard nitrate solutions ranging from 1 to 5 mL were poured and diluted to 5 mL each. A blank beaker with 5 mL of distilled water is included.

IV. Reagents: Standard nitrate solution: Dissolve 72.2 mg potassium nitrate (KNO_3) in distilled water in a volumetric flask and dilute to 1000 mL Per litre, this solution contains 10 mg of nitrate.

V. Brucine-sulphanilic acid solution: Dissolve 1 gm. brucine sulphate and 100 mg sulphanilic acid in 70 mL of hot distilled water. After adding 3 mL of concentrated HCI, cool and dilute to 100 mL with purified water.

VI. Sodium Arsenite Solution: In 100 mL of distilled water, dissolve 1.183 gm sodium arsenite ($NaASO_2$).

Procedure:

In 50 mL beakers, standard nitrate solutions ranging from 1 to 5 mL were poured and diluted to 5 mL each. A blank beaker with 5 mL of distilled water is included. A 1 mL solution of brucine-sulphanilic acid was added and well mixed. These solutions were transferred to a second set of beakers containing 10 mL of sulphuric acid. Both solutions were well mixed before being placed in the dark for 10 minutes. After 10 minutes, each beaker received 10 mL of distilled water and was left to cool for 2 hours and 30 minutes in the dark. After the blank was set to 100% transmittance, the absorbance of the standards was measured at 410 nm.

Calculation

1. Obtain a standard curve by plotting the absorbance of standards run by the above procedure against mg NO3-N/L. (The color reaction does not always follow Beer's law).

2 Subtract the absorbance of the sample without the brucine-sulfanilic reagent from the absorbance of the sample containing brucine-sulfanilic acid and determine mg NO3-N/L. Multiply by an appropriate dilution factor if less than 10 mL of sample is taken.

b) Sulphates (EPA, 1978)

Gravimetric method is used to determine the sulphates in a sample. The sulphate ions precipitate as barium-sulphate when barium chloride is added to the hydrochloric acid medium. The sulphate ion is measured by scattering light with barium sulphate and comparing the result to a standard curve in NTU using the Nephaloturbidometer response.

Reagents:

Standard Solution for Sulphates: 1 litre of solution is made by dissolving 1.814 gm of dry K_2S0_4 in distilled water. This solution contains sulphate ions at a concentration of 1 mg/L

II. Combine 60 gm NaCl and 5 mL concentrated HCI in 300 mL filtered water to create the NaCI-HCI reagent.

III. Glycerol-ethanol solution: Dissolve one part glycerol in two parts water.

Procedure:

In a series of volumetric flasks, 0 mL, 0.5 mL, 1.0 mL, 1.5 mL, 2.0 mL, 2.5 mL, and 3.0 mL of standard sulphate solution were added. The volume was raised to 100 mL by adding 10 mL of NaCI-HCI reagent and 20 mL of glycerol-ethanol solution. Each solution was placed in its own beaker and spun with a magnetic stirrer. 0.3 gm of $BaCl_2$ was added to each beaker while stirring, and the mixture was stirred for another minute. After 4 minutes, the turbidity was carefully measured.

c) Chlorides (Korkmaz, 2001)

Mohr's method is used to determine the chlorides in a sample. Silver nitrate reacts with chloride ions to form a white precipitate of silver chloride that is only slightly soluble. When all of the chlorides have precipitated, silver ions react with chromate to produce reddish brown silver chromate.

Reagents:

I. Standard solution of silver nitrate (0.02N): To make 1 litre of solution, dissolve 3.4 g of dry $AgNO_3$, (A.R.) in distilled water. Store in an amber-colored container away from light.

II. Potassium Chromate (5%): In 100 mL of filtered water, dissolve 5 g of K_2CrO_4.

In a conical flask, 50 mL of water was added, followed by 2 mL of K_2CrO_4. A trace of Erichrome black - T indicator is added to an aqueous solution containing calcium and magnesium ions at pH 10.0 As a result of the combination of calcium and magnesium ions, the solution turns wine red. Because EDTA has a strong affinity for calcium and magnesium ions, if enough of the reagent is applied, a new complex of blue color is generated at the conclusion of the titration.

Calculation:

$$\text{Chloride (mg/lit.)} = \frac{\mathbf{N} \text{ x mL.of } AgNO_3 \text{ x} 35.5 x 1000}{\text{mL. of samples}}$$

N=Normality of $AgNO_3$.

d) Total Hardness (Betz & Noll , 1950)

Hardness is calculated using the concentration of calcium and magnesium ions in water samples. The EDTA approach (Goetz et al., 1950 and Goetz et al.,1959) was used, which is based on the premise that adding EDTA and/or its sodium salt to a solution of particular cations results in the formation of a soluble complex. A trace of Erichrome black - T indicator is added to an aqueous solution containing calcium and magnesium ions at pH 10.0. The solution becomes wine red due to the complexation of calcium and magnesium ions. Because EDTA has a high affinity for calcium and magnesium ions, a new complex of blue color is formed at the end of the titration when a sufficient amount of the reagent is introduced.

I. Buffer solution:

a. Dissolve 16.9 gm ammonium chloride (NH_4CI) in 143 mL of concentrated ammonium hydroxide (NH4OH).

b. Dissolve 1.179 gm di-sodium EDTA and 0.780 gm of $MgSO_4$ $7H_2O$ in 50 mL of purified water. Combine solutions (i) and (ii) and dilute with distilled water to 250 mL.

II. EDTA (0.01 M) solution: Dissolve 3.273 gm of disodium salt of EDTA in distilled water and store in a plastic bottle to make 1 litre of solution.

III. Erichrome black T-indicator III: 0.40 gm Erichrome black T is ground with 100 gm NaCl.

IV. Sodium sulphide solution: Dissolve 5 gm of Na_2S. $9H_2O$ or 3.7 gm of Na_2S. $5H_2O$ in 100 mL of distilled water. To avoid oxidation, tightly close the bottle.

Procedure:

In a conical flask, a 50 mL sample of water was collected. This was mixed with 1 mL of buffer solution and 2-3 drops of Na_2S solution. 100-200 mg of Erichrome black - T indicator was added once the solution had become wine-red. The mixture was compared to a standard EDTA solution. The transition from wine red to blue signifies the end point. The calcium and magnesium hardness were calculated using the following procedure.

Calculation:

$$\text{Total hardness (mg/lit.)} = \frac{\text{mL.of EDTA used x1000}}{\text{mL.of samples}}$$

e) Oxygen Dissolved (DO) (APHA, 1989)

Winkler's idiometric modified azide (APHA, 1989) approach was used to determine the concentration of dissolved oxygen in water. The addition of divalent manganese solution to a water sample, followed by strong alkali, quickly oxidises manganese in the form of manganese hydroxide precipitate, giving an equivalent amount of dissolved oxygen in the water. Manganese oxides revert to a divalent state in the presence of iodide ions, with iodine liberation equal to the sample's original dissolved oxygen content. Iodine is then titrated using a standard sodium thiosulphate solution.

Reagents:

I. Sodium thiosulphate solution (0.025 N): Dissolve 24.82 gm of $Na_2S_2O_3$. $5H_2O$ in 1 litre of hot distilled water. Add 0.4 g of borax or a pallet of NaOH as a stabilizer. This is a 0.1 N stock solution. Dilute a 0.025 N solution four times to get a 0.025 N solution.

II. Alkaline iodide azide solution: To make 1 litre of solution, dissolve 700 gm of KOH and 150 gm of Kl in distilled water.

III. Dissolve 10 gm of NaN_3 in 40 mL of distilled water. Answers (I) and (II) should be combined.

IV. Manganous sulphate solution: Bring 200 mL of distilled water to a boil and add 100 gm of $MnSO_4 . 4H_2O$.

V. Starch solution (1%): Bring 100 mL filtered water to a boil and dissolve 1 gm starch in it.

VI. Sulphuric acid, concentrated: H_2S0_4 (specific gravity 1.84).

Procedure: In a BOD container, a 300 mL water sample was mixed with 2 mL of manganese sulphate and 2 mL of alkaline iodide azide solution. Dissolved oxygen is present when black precipitate occurs; dissolved oxygen is absent when white precipitate forms. After dissolving the brown precipitate in 2 mL of concentrated H_2S0_4, the solution was titrated using starch as an indicator against 0.025 N $Na_2S_2O_3$. The original dark blue tint fades to colorless at the end.

Calculation,

$$\text{Dissolved Oxygen (mg/L)} = \frac{\text{Normality of } Na_2S_2O_3 \text{ x } 1000 \text{x } 8 \text{x vol.of } Na_2S_2O_3}{V2(V1-V)/V1}$$

WhereV_1 =volume of sample bottle after placing the stopper.

V_2=volume of the part of the contents titrated.

V=volume of $MnS0_4$ and Kl added.

f) Biochemical Oxygen Demand (BOD) (Jouanneau *et al.,* 2014)

The BOD is the amount of oxygen required by bacteria under aerobic conditions to stabilize decomposable organic matter. Bacterial metabolic activities and organic matter breakdown need some dissolved oxygen. This oxygen utilization is regarded as a measure of the amount of degradable organic matter in the water sample.

Reagents

I. Phosphate buffer: To prepare a 1 litre solution, dissolve 8.5 g KH_2PO_4, 21.75 gm K_2HPO_4, 33.4 gm Na_2HPO_4, and 1.7 gm NH_4CI in distilled water. Set the pH to 7.2.

II.Magnesium Sulphate: To create 1 litre of solution, dissolve 82.5 gm of $MgSO_4$. $7H_2O$ in filtered water.

III.Calcium Chloride: To create 1 litre of solution, dissolve 27.5 gm of anhydrous $CaCl_2$ in distilled water.

I.Ferric Chloride: Dissolve 0.25 gm of FeCb. $6H_2O$ in distilled water to form 1 litre of solution.

II.Dilute 1000 mL of Sodium Sulphite (0.025N) Na_2SO_3 solution. It is necessary to dissolve 1.575 gm.

Procedure

Using 1 N H_2SO_4 or NaOH, neutralize the water sample to pH 7.0. Aerate distilled water using compressed air to make dilution water. For each liter of dilution water, add 1 mL of phosphate buffer, 1 mL of magnesium sulphate, 1 mL of calcium chloride, and 1 mL of ferric chloride and thoroughly mix. A water sample was diluted many times, ranging from 0.1 to 1%. Three 300 mL bottles were filled with diluting water and properly sealed to prevent air bubbles from forming. Bottle A's dissolved level was measured immediately, while bottle B was used as a blank and a water sample was added to bottle C. Two bottles were incubated for five days at 20°C.

Calculation:

$$\text{BOD (mg/L)} = \frac{(D_o - D_5)}{\text{mL of waste x Volume of BOD bottles}}$$

Where,

Do= Initial DO in the sample

Ds=DO after 5 days.

g) Acidity (mg/L) (APHA, 1995)

In a conical flask, 100mL of surface water samples were collected and two to three drops of methyl orange were added as an indicator. If the solution becomes yellow, there is no methyl orange acidity. Titrated against 0.05N NaOH if it becomes pink. The transition from pink to yellow is the climax. Then I added a few drops of phenolphthalein indicator and titrated with NaOH again until the solution became pink.

Methyl orange acidity (mg/L as $CaCO_3$) = $\frac{A \times N \text{ OF NaOH} \times 1000 \times 50}{\text{ml of sample taken}}$

Phenolpahthalin acidity (mg/L as $CaCO_3$) = $\frac{B \times N \text{ OF NaOH} \times 1000 \times 50}{\text{ml of sample taken}}$

Total acidity (mg/L as $CaCO_3$) = $\frac{(A+B) \times N \text{ OF NaOH} \times 1000 \times 50}{\text{ml of sample taken}}$

A=amount of NaOH used with methyl orange to adjust the pH of the sample to 3.7

B= The amount of NaOH used in titrating the sample from pH 3.7 to 8.3 with phenolphthalein.

h) Alkalinity (mg/L) (APHA, 1995)

The titrimetric approach was used to measure the alkalinity of surface water samples. In a 250 mL conical flask, 100 mL of surface water samples were obtained in triplicate, and drops of phenolphthalein alkalinity is zero; if the color shifts to pink, titrate with 0.1 N HCL until the color disappears. 2-3 drops of methyl orange were added to this solution, and the titration was repeated until the yellow hue changed to pink. The formula was used to calculate total alkalinity.

Total alkalinity (mg/L) = $\frac{MBR \times N \times 1000 \times 50}{\text{ml of sample taken}}$

Where,

MBR=mean burette reading

N=Normality of HCL (0.1 N)

i) Calcium (mg/L) (APHA, 1995)

The titrimetric technique was used to evaluate the calcium content of surface water samples. In 250 mL conical flasks, 50mL of surface water was collected in triplicate for each sample. This was mixed with 2mL of sodium hydroxide and 100mg of murexide indicator. Titration was performed against 0.01 M ethylene diamine tetra acetic acid (EDTA). The solution and titration were maintained until the end point, which was indicated by a color change from pale pink to purple, was reached. Calculation:

Calcium (mg/L) = $\frac{MBR \times 400.8}{\text{ml of sample taken (50 ml)}}$

Where,

MBR=mean burette reading

j) Magnesium (mg/L) (APHA, 1995)

The titrimetric technique was used to assess the chloride content of the surface water samples. Magnesium concentration is estimated using the following formula, which is dependent on the amount of EDTA solution used to determine hardness and calcium.

Hardness (mg/L) $= \frac{\text{MBR} \times \text{N} \times 1000}{\text{ml of sample taken}}$

Mg^{2+} (mg/L) $= \frac{\text{y} - \text{x} \times 400.8}{\text{Volume of samplex } 1.645}$

Where,

Y = EDTA used in hardness determination

X = EDTA used in calcium determination for the same sample volume

k) Iron (mg/L) (Skoog & West,1963)

The iron content of a surface water sample was measured using the spectrophotometric technique (Skoog & West, 1963). In a conical flask, 50 mL of surface water was collected. Add 10 mL of sodium acetate, 2 mL of hydroxylamine hydrochloride, 5 mL of phenanthroline solution, and 100 mL of distilled water. After 10 minutes, take a spectrophotometer measurement at 510 nm. A 10 mL buffer, 2 mL of hydroxylamine hyprochloride, 5 mL of phenanthroline solution, and 100 mL of distilled water were used to produce the blank. Standard iron solutions were generated using iron (11) ammonium sulphate hexahydrate to make standard graph. Five different concentrations (2, 4, 8, 10 and 12 mL) were placed in a conical flask and filled to a volume of 50 mL with distilled water. The identical chemical solution as in the samples was added, using the same process. The concentration of iron in surface water samples is obtained directly from the standard curve.

l) Fluoride (Marques & Coelho, 2013)

The SPADNS colorimetric method is used to estimate fluoride in water (Marques & Coelho, 2013). Fluoride reacts with the dye lake, dissociating a portion of it into a colourless complex anion (ZrF6 -); and the dye. As the amount of fluoride increases, the colour produced becomes progressively lighter. The reaction rare between fluoride and zirconium ions is influenced greatly by the acidity of the reaction mixture. If the proportion of acid in the reagent is increased, the reaction can be made almost instantaneous. Under such conditions, however, the effect of various ions differs from that in the conventional alizarin methods. The selection of dye for this rapid fluoride method is governed largely by the resulting tolerance to these ions. Colorimetric equipment: Spectrophotometer, for use at 570 nm, providing alight path of at least 1 cm.

Reagents

I. Standard fluoride solution first prepare stock fluoride solution by dissolving 1.0 mg anhydrous sodium fluoride (NaF) in distilled water and diluting to 1000 mL. Now dilute 100 mL of stock fluoride solution to 1000 mL with distilled water. 100 mL of standard fluoride solution = 10.0 pg F.

II. SPADNS solution dissolve 958 mg SPADNS, sodium 2-(parasulfophenylazo) - l, 8-dihydroxy - 3,6-naphthalene disulfonate, also called 4,5-dihydroxy - 3-(parasulfophenylazo) - 2,7-naphthalenedisulfonic acid trisodium salt, in distilled water and dilute to 500 mL. This solution is stable for at least 1 year if protected from direct sunlight.

III. Zirconyl-acid reagents dissolve 133 mg zirconyl chloride octahydrate, ZrOCl. $8H_20$, in about 25 mL distilled water. Add 350 mL conc HCI and dilute to 500 mL with distilled water.

IV. Acid Zirconyl-SPADNS reagent mix equal volumes of SPADNS solution and zirconyl-acid reagent. The combined reagent is stable for at least 2 years.

V. Reference solution add 10 mL SPADNS solution to 100 mL distilled water. Dilute 7 mL con. HC1 to 10 mL and add to the diluted SPADNS solution. The resulting solution used for setting the instrument reference point (zero), is stable for at least 1 year. Alternatively, use a prepared standard of 0 mg F - / L as a reference.

VI. Sodium arsenite solution dissolve 5.0 g $NaAsO_2$ and dilute to 1.0 L with distilled water.

Procedure

(a) Preparation of standard curve prepare fluoride standards in the range of 0 to 1.40 mg F- / L by diluting quantities of standard fluoride solution of 50 mL with distilled water. Pipet 5.00 mL each of SPADNS solution and zirconyl-acid reagent, or 10.00 mL mixed acid-zirconyl-SPADNS reagent, to each standard and mix well. Avoid contamination. Set photometer to zero absorbance with the reference solution and obtain absorbance readings of standards. Plot a curve of the mg fluoride-absorbance relationship. Environmental engineering prepare a new standard curve whenever a fresh reagent is made or a different standard temperature is desired. As an alternative to using a reference, set photometer at some convenient point (0.300 or 0.500 absorbance) with the prepared 0 mg F -1 L standard.

(b) Sample pre-treatment if the sample contains residual chlorine, remove it by adding 1 drop (0.05 mL) $NaAsO_2$ solution 10.1 mg residual chlorine and mix.

(c) Colour development use a 50 mL sample with distilled water. Adjust sample temperature to that used for the standard curve. Add 5 mL each of SPADNS solution and zirconyl-acid reagent, or 10 mL acid-zirconyl-SPADNS reagent; mix well and read absorbance, first setting the reference point of the photometer as above. If the absorbance falls beyond the range of the standard curve, repeat using a diluted sample.

Calculation

mg F-/L = $\frac{A}{mL\ sample} \times \frac{B}{C}$

where,

A = pg F- determined from plotted curve

B = final volume of diluted sample in mL

C = volume of diluted sample used for colour development in mL.

$$\text{mg F-/L} = \frac{Ao-Ax}{Ao-A1}$$

When the prepared 0 mg F- I L standard is used to set the photometer, alternatively fluoride concentration can be calculated as:

where,

A_O = Absorbance of the prepared mg F - / L standard,

A_1 = Absorbance of a prepared mg F - I L standard,

A_X = Absorbance of the prepared sample.

3.6 Methodology for the objecrtives 3 & 6: Estimation of annual fish production and evaluation of interventions by local self-governments in the kole wetlands of Thrissur-Ponnani.

3.6.1 Collection of fish production data in kole wetlands

The fish production was examined by using two methods- (i) direct visiting and spot verification of fish catch during the harvesting seasons and (ii) number of fishes reported by the fishermen in response to a following questionnaire (Deka et al., 2001; Jhingran and Dutta, 1968; Bordoloi, 2014). (Appendix- Questionnaire 1)

The fish production data were collected from the 32 sites of Thrissur to Ponnani kole wetlands (Table 2) and these are few of major fish harvesting centres of kole wetlands. For those fish species which could not be recorded during physical survey of kole wetlands data from questionnaire. Some species which could not be identified on the spot were brought to the laboratory and identified by using various standard literatures (Talwar and Jhingran, (1991); Jayaram, (1981); Dutta Munshi and Srivastava, (1988). The collected data were tabulated and examined for economic evaluation of fishery resources in kole wetlands.

3.6.2 The study sites of fish production data collection in kole wetlands

The fish production study sites of Thrissur- Ponnani kole wetlands comprising of the panchayats- Marancherry, Tholur, Vengidagu, Anthikkad, Adat and Arimpur. All sites were recorded in Table 3 and in Map 2 & Map 3. The study period spanned from August of one year to March of the following year, designated as 2019-2020, 2020-2021, and 2021-2022. Production data for three years was collected during the periods from August 2019 to March 2020, August 2020 to March 2021, and August 2021 to March 2022. The studies of production in kole wetlands were completed by direct visit and questionnaire. A detailed questionnaire was prepared (Appendix- Questionnaire 1), data collected from fishermen based on that.

3.6.3 Methodology for threats assessment of fishes in kole wetlands.

The assessment of threats facing the fishes of the Thrissur-Ponnani kole wetlands was conducted through a multifaceted approach integrating discussions with local fishermen and a comprehensive review of previous studies. This methodological framework allowed for a thorough examination of both experiential knowledge and existing scientific literature pertaining to the ecological dynamics and challenges encountered by fish populations within the kole wetlands.

3.6.3.1 Discussion with local fishermen:

- Engaged in structured discussions with local fishermen who possess invaluable experiential knowledge regarding the kole wetlands and its fish populations.
- Explored perceptions of environmental stressors, fishing pressures, and other anthropogenic factors influencing fish populations.

3.6.3.2 Literature review

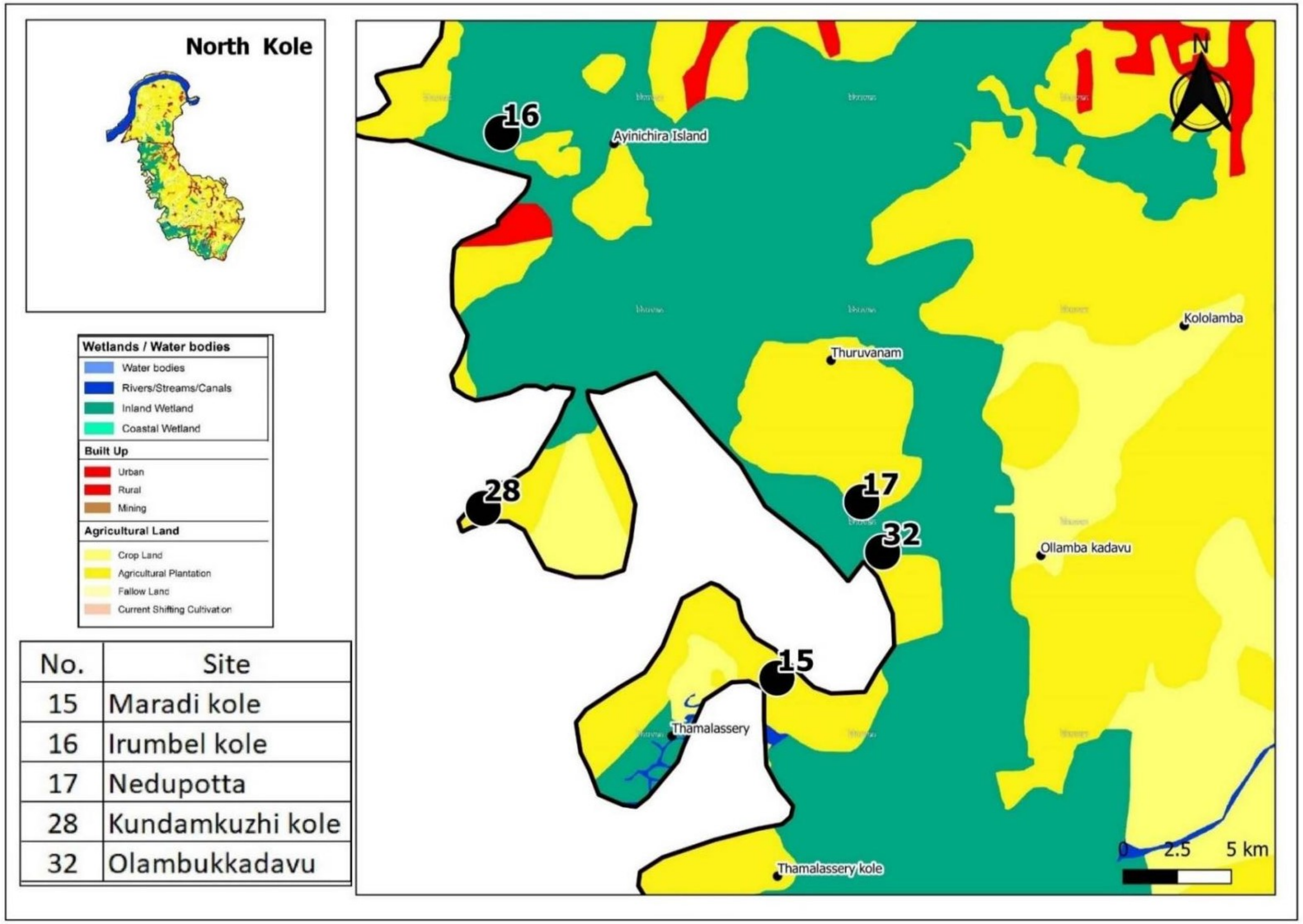
- Conducted a comprehensive review of previous studies, reports, and scientific literature addressing the ecological dynamics and threats to fish biodiversity within the Thrissur-Ponnani kole wetlands.
- Synthesized information on documented threats, including habitat degradation, pollution, overfishing, invasive species, and climate change impacts.

Table 3: The study sites of data collection of fish production

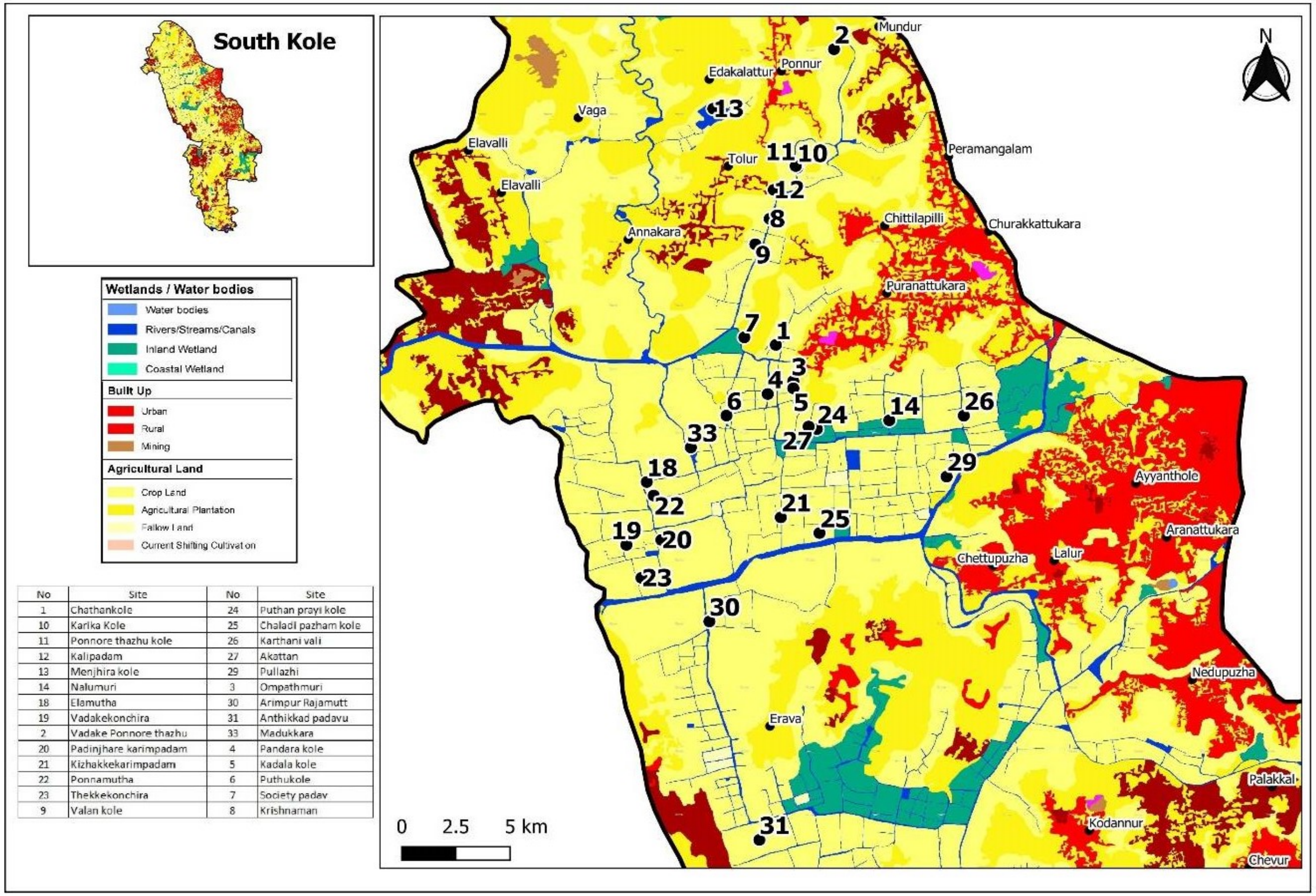
SL. NO.	Study sites	Latitude	Longitude
1.	Chathan kole	10.54’32’	76.13’60’
2.	Menjhira (Edakalathur)	10.58’13’	76.12’62’
3.	Kalipadam	10.56’88’	76.13’58’
4.	Valankole	10.55’94’	76.13’30’
5.	Puthan prayi kole	10.52’88’	76.14’24’

6.	Karika kole	10.57’17’	76.13’94’
7.	Ponnore thazhu	10.57’20’	76.13’91’
8.	Ompathmuri	10.53’66’	76.13’92’
9.	Krishnaman	10.56’35’	76.13’51’
10.	kurudan nalumuri	10.53’10’	76.15’40’
11.	Akattan	10.53’00’	76.14’19’
12.	Kadala kole	10.53’59’	76.13’90’
13.	Karthani vali	10.53’12’	76.16’56’
14.	Pandara kole	10.53’54’	76.13’51’
15.	Puthukole	10.53’17’	76.12’87’
16.	Society padavu	10.54’43’	76.13’12’
17.	Madukkara	10.53’02’	76.12’22’
18.	Maradi kole	10.73’91’	75.98’16’
19.	Kundamkuzhi	10.74’73’	75.97’26’
20.	Olambukadavu	10.74’56’	75.98’65’
21.	Nadupotta	10.74’60’	75.98’60’
22.	Irumbel	10.76’08’	75.97’23’
23.	Ponnamutha	10.51’96’	76.11’51’
24.	Elamutha	10.52’00’	76.11’46’
25.	Vadakkekonchira	10.51’32’	76.11’59’
26.	Thekkekonchira	10.50’90’	76.11’92’
27.	Kizhakkekarimpadam	10.51’55’	76.13’69’
28.	Padinjhare karimpadam	10.51’13’	76.11’98’
29.	Chaladipazham kole	10.51’25’	76.14’48’
30.	Pullazhi kole	10.52’14’	76.16’04’
31.	Arimpur rajamutt	10.50’06’	76.14’96’
32.	Anthikkad padavu	10.46’39’	76.12’92’

Map 2 Geographical locations indicating the fish production study sites of north kole wetlands (in Marancherry panchayat).



Map 3 Geographical locations indicating the fish production study sites of south kole wetlands.



No	Site	No	Site
1	Chathankole	24	Puthan prayi kole
10	Karika Kole	25	Chaladi pazham kole
11	Ponnore thazhu kole	26	Karthani vali
12	Kalipadam	27	Akattan
13	Menjhira kole	29	Pullazhi
14	Nalumuri	3	Ompathmuri
18	Elamutha	30	Arimpur Rajamutt
19	Vadakekonchira	31	Anthikkad padavu
2	Vadake Ponnore thazhu	33	Madukkara
20	Padinjhare karimpadam	4	Pandara kole
21	Kizhakkekarimpadam	5	Kadala kole
22	Ponnamutha	6	Puthukole
23	Thekkekonchira	7	Society padav
9	Valan kole	8	Krishnaman

3.7 Methodology for the objectives 5: Economic evaluation of the fish production in fishery resources of Thrissur-Ponnani kole wetland

3.7.1 Collection of data in kole wetlands

The investigation employed both primary and secondary data. To acquire primary data from various stakeholders, standardised pretested interview schedules were employed. In 2019-2021, a pilot survey was performed after which secondary data and relevant values were obtained from a variety of agencies and government entities. Various published reports were also referenced. Information was also gathered by following RTI queries (Appendix Table 20 & 21).

- Fisheries department Kerala
- Panchayats and cooperative banks of Vengidangu, Tholur, Maranchery, Arimpur, Anthikkad and Adat.

3.7.2 Market value method (Tamhankar, 2021)

Kole wetlands supply a variety of direct goods to humans. Market pricing for these direct outputs were used to monetize the economic worth of the items. Costs for various crops and fisheries were collected from a variety of stakeholders and market sources. Profits from direct activities were calculated using the market price of produce and net returns from farming and fishing. The total value from direct uses, and fishing was measured using average net returns per acre.

Total value of wetlands from farming and fishing;

$$V_i = \sum_{i=1}^{n} PiQi - Ci$$

Where,

V_i =Net returns from the resource (₹)

P_i = Price of the ith resource (₹/kg)

Q_i = Quantity of ith resource (kg)

C_i = Expenditure (₹)

3.8 Methodology for objective 4: Traditional fish harvesting methods in Thrissur-Ponnani kole wetlands

3.8.1 Collection of data in kole wetlands

Field survey, interview, questionnaire, evaluation of data by analysis as suggested by Baruah *et al.,* (2013); Shaji & Laladhas, (2013); Joseph & Narayanan, (1965) was used here. Fishermen provided information on general dimensions, materials, and building specifics.

The relevant data were collected from primary and secondary sources. Questionnaire is provided in appendix (Questionnaire 2). Survey and questionnaire for traditional fish harvesting method were carried out 21 villages (Tholur, Aadatt, Marancherry, Mullasserry, Aloor, Avittathur, Eravathoor, Karikkattuchal, Karim-banakadavu, Karuvannoor, Kundoor, Kuzhuchira, Moopanthodu, Nanthonithodu, Nenmanichira, Parippathodu, Poovathussery, Porakkulam, Venni- padam, Valoor, and Marianthur). Visits were made prior to the onset of the monsoon to collect data on gear fabrication/preparation, and during the monsoon to collect information on traditional fish harvesting methods. Hundred and ten fishermen were interviewed. The conventional wisdom and the associated information were obtained with the Prior Informed Consent (PIC). In addition various participatory research tools such as group discussions, semi-structured interviews, key informant surveys and site observations were used. Specific information on the gear used, the number of fish collected and historical data was collected through questionnaire. The name, age, time of fishing, and equipment used were also recorded. The mode of operation and harvest was observed. All the fishing equipment was photographed.

3.8.2 Statistical analysis

All data was consolidated in Excel sheets. Appropriate statistical tests were performed using the following software: Past ver. 4.03, R software. Graphs were generated using these two software and MS Excel. Statistical tests performed in addition to diversity indices mentioned in previous sections are:

- Mann Whitney U test- Comparison of species abundance between years.

- One way ANOVA- Compares the means of two or more independent groups in order to determine whether there is statistical evidence that the associated population means are significantly different.
- Two way ANOVA- To estimate how the mean of a quantitative variable changes according to the levels of two categorical variables
- Correlation (Pearson's)- The Pearson correlation measures the strength of the linear relationship between two variables. It has a value between -1 to 1, with a value of -1 meaning a total negative linear correlation, 0 being no correlation, and + 1 meaning a total positive correlation.

CHAPTER 4

RESULT AND DISCUSSION

CHAPTER 4

RESULT AND DISCUSSION

4.1 Result and discussion for the objectives 1 & 2: Study of diversity of fishes and the interrelationship between physicochemical parameters of water in Thrissur-Ponnani kole wetland

4.1.2 Checklist of fishes in kole wetlands

Table 4. List of ichthyofauna of Thrissur-Ponnani kole wetlands.

SL. NO.	Order /Family / Species	Common name	Local name	Remark on economic important	IUCN Status
I	**ORDER: SYNBRANCHIFORMES**				
a	**Family: Mastacembelidae**				
1	*Mastacembelus armatus* (Lacepede, 1800)	Zig Zag Tire Track Eel	Aral	Ornamental and food	LC
2	*Macrognanthus guentheri* (Day,1865)	Malabar Spiny Eel	Kallaral	Ornamental and food	LC
II	**ORDER: ANGUILLIFORMES**				
b	**Family: Anguillidae**				
3	*Anguilla bengalensis* (Grey,1831)	Long Fin Eel	Malinghal	Ornamental and food	NT
III	**ORDER: SILURIFORMES**				
c	**Family: Heteropneustidae**				
4	*Heteropneustes fossilis* (Bloch, 1794)	Stinging Catfish	Kadu	Ornamental and food	LC
d	**Family: Siluridae**				
5	*Ompok bimaculatus* (Bloch, 1794)	Indian Butter Catfish	Vala	Ornamental and food	NT
6	*Wallago attu* (Bloch & Schneider, 1801)	Freshwater Shark	Vala	Ornamental and food	VU
e	**Family: Bagridae**				
7	*Mystus armatus* (Day, 1865)	Kerala Mystus	Koori	Ornamental and food	LC
8	*Mystus montanus* (Jerdon, 1849)	Jerdon's Mystus	Kallenk oori	Ornamental and food	LC
9	*Mystus oculatus* (Valenciennes, 1840)	Malabar Mystus	Koori	Ornamental and food	LC
f	**Family: Horabagridae**				
10	*Horabagrus brachysoma* (Gunther, 1864)	Sun Catfish	Manjh koori	Ornamental and food	VU
g	**Family: Pangasiidae**				
11	*Pangasius bocourti* (Sauvage,1880)	Bocourt's Catfish	African vala	Ornamental and food	LC
IV	**ORDER: CYPRINIFORMES**				

h	**Family: Cyprinidae**				
12	*Systomus sarana* (Hamilton, 1822)	Olive Barb	Paral	Ornamental and food	LC
13	*Dawkinsia filamentosa* (Valenciennes,1844)	Filamentou s Barb	Poovali paral	Ornamental and food	LC
14	*Puntius vittatus* (Day, 1865)	Stripped Barb	Paral	Ornamental and food	LC
15	*Puntius mahecola* (Valenciennes, 1844)	Scarlet Barb	Paral	Ornamental and food	DD
16	*Puntius dorsalis* (Jerdon, 1849)	Long Snouted Barb	Paral	Ornamental and food	LC
17	*Labeo dussumieri* (Valenciennes, 1842)	Malabar Labeo	Rohu	Ornamental and food	LC
18	*Labeo rohita* (Hamilton, 1822)	Rohu	Rohu	Ornamental and food	LC
19	*Cyprinus carpio* (Linnaeus, 1758)	Common Carp	Carp	Ornamental and food	VU
20	*Labeo catla* (Hamilton, 1822)	Catla	Catla	Ornamental and food	LC
21	*Ctenopharyngodon idella* (Valenciennes, 1846)	Grass Carp	Grass	Ornamental and food	Not evaluat ed
i	**Family: Danionidae**				
22	*Devario malabaricus* (Jerdon, 1849)	Malabar Danio	Thupalam kothi	Ornamental and food	LC
23	*Amblypharyngodon melettinus* (Valenciennes, 1844)	Attentive Carplet	Vayambu	Ornamental and food	LC
24	*Esomus barbatus* (Jerdon, 1849)	Flying Barb	Paral	Ornamental and food	LC
25	*Rasbora dandia* (Valenciennes, 1844)	Common Rasbora	Thupall amkothi	Ornamental and food	LC
j	**Family: Cobitidae**				
26	*Lepidocephalichthys thermalis* (Valenciennes, 1846)	Common Spiny Loach	Manalaaron	Ornamental	LC
V	**ORDER: ANABANTIFORMES**				
k	Family : Anabantidae				
27	*Anabas testudineus* (Bloch, 1792)	Climbing Perch	Karipidi	Ornamental and food	LC
l	**Family: Osphronemidae**				
28	*Pseudosphromenus cupanus* (Cuvier, 1831)	Spiketail Paradise Fish	Karikanna	Ornamental	LC
m	**Family: Nandidae**				
29	*Nandus nandus* (Hamilton, 1822)	Leaf Fish	Porik	Ornamental and food	LC
n	**Family: Channidae**				
30	*Channa pseudomarulius* (Gunther, 1861)	Gaint Snake Head	Cholan bral	Ornamental and food	Not evaluat ed
31	*Channa gachua* (Hamilton, 1822)	Brown Snake Head	Vatton	Ornamental and food	LC
32	*Channa punctata* (Bloch, 1793)	Spotted Snake Head	Kadi bral	Ornamental and food	LC

33	*Channa striata* (Bloch, 1793)	Striped Snake Head	Varal,	Ornamental and food	LC
VI	**ORDER: CICHLIFORMES**				
o	**Family: Cichlidae**				
34	*Oreochromis mossambica* (Peters,1852)	Tilapia	Tilapia	Ornamental and food	NT
35	*Oreochromis niloticus* (Linnaeus, 1758)	Nile Tilapia	Tilapia	Ornamental and food	LC
36	*Pseudetroplus maculatus* (Bloch, 1795)	Orange Chromid	Potta	Ornamental and food	LC
37	*Etroplus suratensis* (Bloch, 1790)	Pearl Spot	Karimeen	Ornamental and food	LC
VII	**ORDER: TETRADONTIFORMES**				
p	**Family: Tetradontidae**				
38	*Carinotetraodon travancoricus* (Hora &Nair, 1941)	Malabar Puffer Fish	Puffer fish	Ornamental	VU
VIII	**ORDER: OVALENTARIA**				
q	**Family: Ambassidae**				
39	*Parambassis thomassi* (Day,1870)	Western Ghat Glassy Perchlet	Aattunandan	Ornamental and food	LC
40	*Parambassis dayi* (Bleeker, 1874)	Day's Glassy Perchlet	Nandan	Ornamental and food	LC
IX	**ORDER: ELOPIFORMES**				
r	**Family: Elopidae**				
41	*Megalops cyprinoides* (Broussonet, 1782)	Oxe Eye Tarpon	Valathan	Ornamental and food	DD
X	**ORDER: CLUPEIFORMS**				
s	**Family: Clupeidae**				
42	*Dayella malabarica* (Day, 1873)	Day's Round-Herring	Urulan Natholi	Ornamental and food	LC
XI	**ORDER: CYPRINODONTIFORMS**				
t	**Family: Aplocheilidae**				
43	*Aplocheilus lineatus* (Valenciennes, 1846)	Striped Panchax	Manathukanni	Ornamental and food	LC
XII	**ORDER: GOBIIFORMES**				
u	**Family: Gobiidae**				
44	*Glossogobius giuris* (Hamilton, 1822)	Golden Tank Gopi	Poolan	Ornamental and food	LC
XIII	**ORDER: BELONIFORMES**				
v	**Family: Hemiramphidae**				
45	*Hyporhamphus limbatus* (Valenciennes,1847)	Needle Fish	Koolan	Ornamental and food	LC
w	**Family: Belonidae**				
46	*Xenentodon cancila* (Hamilton, 1822)	Long Nosed Needle Fish	Koolan	Ornamental and food	LC

4.1.2.1 Fishes and taxonomical characters

Literature on fish systematics and fauna volumes such as Day (1878 & 1889), Jayaram (1981 & 1991), Menon (1999 & 1987) and Talwar and Jinhgran (1991) were referred for fish identification.

SYSTEMATIC ACCOUNT

I. **ORDER: ANGUILLIFORMES**

Family: Anguillidae (freshwater eels)

Anguilla bengalensis (Gray, 1831) (Plate 1, Fig.3)

Collected by Parvathy C A, Tholur kole wetland, 25.4.2018. Material compared with: 1 exs. Chathankode. 18.3.2001. Coll. K. C Gopi. Reg. No. ZSI/WGRC/IR.V.11905.

The body is eel like elongate cylindrical band-shaped and smooth, gill openings in the pharynx is narrow. The pectoral fins are present; head is long and compressed; snout is pointed; the scales are embedded in skin; the eyes are superior and small in middle of head; the mouth is terminal; the anterior is dull white and the pale bluish spots are present in body.

II. **ORDER: CLUPEIFORMES**

Family: Clupeidae (Herrings, Shads, Sardines)

Genus: Dayella

Dayella malabarica (Day, 1873) (Plate 11, Fig.42)

Collected by Parvathy C A, Enamav kole wetland, 2.5.2018. Material compared with: 1 ex. Thattekkad. 13.7.2015. Coll. Dr. B.H.C.K. Murthy. Reg. No.

ZSI/WGRC/IR.V.2762.

The body elongates and is sub cylindrical; moderate head with obtuse snout. Abdomen rounded; eyes are large, not visible from below ventral surface; lips thin, simple and two pairs of barbels present; lateral line complete; body is colored with longitudinal bands; dorsal fin with 16 rays and inserted opposite interspace between anal and pelvic fins; caudal fin emarginate; anal fin with 20 rays.

III. ORDER: CYPRINIFORMES

Family: Cyprinidae (Carplet)

Genus: Amblypharyngodon

Amblypharyngodon melettinus (Valenciennes, 1844) (Plate 7. Fig.23)

Collected by Parvathy C A, Nedupuzha kole wetland, 2.5.2018. Material compared with: 1 ex. Thattekkad. 11.vii.2015. Coll. Dr. B.H.C.K. Murthy. Reg. No. ZSI/WGRC/IR.V.2810.

The body is subcylindrical and moderately elongate; scales are small. The abdomen are rounded; the head is compressed and conical in shape; the mouth is wide and eyes are small and centrally placed; the lower lip is short with labial fold; the upper lip is absent; the lateral line is present and the caudal fin is forked;

Labeo dussumieri (Valenciennes, 1842) (Plate 5, Fig.17)

Genus: Labeo

Collected by Parvathy C A, Nedupuzha kole wetland , 25.4.2018. Material compared with: None. Earlier records.

The body moderately elongated, the abdomen rounded; the lips are thick with labial fold; the head is large; the lateral line scales are ranges from 53-60; the scales between lateral line and pelvic fin base are 5-6; single dorsal fin and bony plates never developed.

Labeo catla (Hamilton, 1822) (Plate 5, Fig.19)

Genus: Labeo

Collected by Parvathy C A, Nedupuzha kole wetland, 25.4.2018. Material compared with: 1 ex. Karnadaka. 12.7.2006. Coll. K Emmiliyamma. Reg. No. ZSI/WGRC/IR.V.13892.

Body is moderately elongated and abdomen rounded with large; head is large, rounded and scale less; barbels are absent; lower lip very thick; the snout bluntly rounded; the mouth wide and anterior and arched; scales are large and cycloid; eyes are large and visible from underside of the head; mouth upturned with prominent protruding lower jaw; the dorsal fins are long with 17-19 rays, inserted above the tip of pectoral fin; dorsal fins are spine less; the anal fin is short with 8 rays.

Puntius vittatus (Day, 1865) (Plate 4, Fig.12)

Genus: Puntius

Collected by Parvathy C A, Tholur kole wetland, 5.4.2019. Material compared with: 1 ex. Pamba. 7.3.2010. Coll. K C Gopi. Reg. No. ZSI/WGRC/IR. V2314.

The body is oblong and moderately compressed; head four black spots on side of body; the eye diameter 2-3 in head length; barbels are not present; the last unbranched dorsal fin ray is weak and smooth; the lateral line is broken after 3-6 scales and 20 scales in sequence; on the caudal base, there is a scattered black blotch; on the dorsal fin base is a crescent-shaped orange band present.

Puntius mahecola (Valenciennes, 1844) (Plate 4, Fig.15)

Genus: Puntius

Collected by Parvathy C A, Nedupuzha kole wetland, 5.4.2019. Material compared with: 1 ex. Thattekkad. 11.7.2015. Dr. B.H.C.K. Murthy. Reg. No. ZSI/WGRC/IR.V2795

A barb with last simple dorsal ray smooth; body depth 27–32% of SL; snout length of 7.2–9.7% of SL; a single pair of (maxillary) barbels, about ½ eye diameter long; lateral-line scales 22–23; a horizontally elongate black blotch about 1½ times as wide as high across 3½ scales of lateral line entirely behind anal-fin origin; black tip to caudal lobes with a red band below it.

Cyprinus carpio (Linnaeus, 1758) (Plate 6, Fig.20)

Genus: Cyprinus

Collected by Parvathy C A, Enamav kole wetland, 2.5.2018. Material compared with:

1 exs. Badhra dam. 8.08.1997. Coll. K C Emmiliyamma. Reg. No. ZSI/WGRC/IR.V.8813.

Body is elongated and is greyish to bronze in color; eyes are small;thick lips, barbels are present; the strong serrated spines are present in the dorsal and anal fin; scales are large; the dorsal spines are 3 and soft rays are 21 and anal spines are 3 and anal soft rays are 6; pectoral fins are large; mouth is downward turned.

Labeo rohita (Hamilton, 1822) (Plate 5, Fig.18)

Genus: Labeo

Collected by Parvathy C A, Enamav kole wetland, 2.5.2018. Material compared with: 3 exs. Bhoothathankettu. 25.11.2014. Coll. Dr. Md. Jafer Palot. Reg. No. ZSI/WGRC/IR.V.2752.

Body moderately elongated and head is large; snout truncated, generally projecting beyond mouth, overhanging the mouth, and mostly covered with tubercles; the abdomen rounded; mouth is inferior and moderate; eyes are moderately large; dorsal fin inserted ahead of pelvic fin with 26 rays and no spine; anal fin short with 8 rays; scales are large and caudal fin emarginate; anal fin short with seven or eight rays; pharyngeal teeth hooked.

Esomus barbatus (Jerdon, 1849) (Plate 7, Fig.24)

Genus: Esomus

Collected by Parvathy C A, Mullassery kole wetland, 25.4.2018. Material compared with: 1 ex. Periya chappra. 14.8.1994. Coll. P M Suresh. Reg. No. ZSI/WGRC/IR.V.6912.

Body elongates, strongly compressed; abdomen rounded and head is blunt; small snout blunt; mouth small and eyes are placed inferiorly; visible from the below ventral side;

two pairs of barbels are present with prominent lower jaw; lateral line is complete with 30-32 scales; the unbranched 6 dorsal fins are present.

Dawkinsia filamentosa (Valenciennes, 1844) (Plate 4, Fig.14)

Genus: Dawkinsia

Collected by Parvathy C A, Mavinchuad kole wetland, 5.4.2019 . Material compared with: 2 exs. Thattekkad. 11.vii.2015. Coll. Dr.B.H.C.K Murthy. Reg. No. ZSI/WGRC/IR.V.2763.

A deep black oval mark on lateral line above anal fin present; mouth is subterminal and the body depth is 3-3.5 cm in in total length; the dorsal fins are very long and fin rays are like filamentous extensions in males; a black band is present near the caudal fin lobe; a caudal blotch is present; the pectoral fin with one simple and 14 branched rays.

Puntius dorsalis (Jerdon, 1849) (Plate 5, Fig.16)

Genus: Puntius

Collected by Parvathy C A, Nedupuzha kole wetland, 15.4.2018 . Material compared with: None. Earlier records.

Body is oblong, compressed with small to large scales; abdomen rounded; single dorsal fin and the bony plates never developed jaws, palatine and pterygoid bones are toothless; dorsal fin inserted ahead of pelvic fin; head is short without scales; teethless jaws.

Rasbora dandia (Valenciennes, 1844) (Plate 7, Fig.25)

Genus: Rasbora

Collected by Parvathy C A, Muriad kole wetland, 5.7.2019. Material compared with: 1 ex. Thattekkad. 11.vii. 2015. Coll. Dr. B.H.C.K. Murthy. ZSI/WGRC/IR.V.2761

Body is elongate and compressed with rounded abdomen; head, mouth are is large and eyes is located laterally not visible from below; the lips are thin and the lower jaw is prominent; the scales are moderately sized;the snout slightly pointed; the dorsal fin includes 9 rays and inserted behind the origin of pelvic fin.

Systomus sarana (Hamilton, 1822) (Plate 4, Fig. 13)

Genus: Systomus

Collected by Parvathy C A, Tholur kole wetland, 25.4.2018. Material compared with: 1 ex. Thattekkad. 19.9.2016. Coll. Dr. Md. Jafer Palot. Reg. No. ZSI/WGRC/IR.V.21576.

The body is moderately elongate and deeply compressed; head is short and abdomen is rounded; a bluish horizontal line on flanks; lateral line is complete with 25-26 scales and a diffused black blotch on lateral line after 12th scale; caudal fin forked; the barbels are present on a single maxillary pair only; the dorsal fin origin equal distant between tip of snout and caudal fin; tip of the tail is black, opercula with black shot.

Ctenopharyngodon idella (Valenciennes, 1846) (Plate 6, Fig.21)

Genus: Ctenopharyngodon

Collected by Parvathy C A, Maranchery kole wetland, 2.4.2019. Material compared with: None. Earlier records

The body is slim and compressed; the mouth is sub-terminal and lacks barbels; the snout is short; the lateral line is slightly bent; the dorsal fin originates above or just ahead of the pelvic fin, and both the dorsal and anal fins are spineless; gill rackers are petite; the scales are cycloidal, dark-edged, and have a black spot at the base; adult grass carp are dark grey on the dorsal surface and lighter on the sides;the snout is very short, measuring less than the diameter of the eye.

Family: Danionidae

Devario malabaricus (Jerdon, 1849) (Plate 6, Fig. 22)

Genus: Devario

Collected by Parvathy C A, Nedupuzha kole wetland, 7.5.2018. Material compared with: 1 ex. Kallipara. 7.i.2015. Coll. Dr K.G. Emilyamma. Reg. No ZSI/WGRC/IR.V.2773;

Body is elongate and compressed with rounded abdomen; single dorsal fin. Body is coloured with bluish longitudinal bands; the mouth is anterior, cleft of mouth shallow not protractile and directly obliquely upwards; the head is moderately sized and lips are thin; dorsal spines 3 and dorsal soft rays 12, anal spine are 2 and anal soft rays are 15.

Family: Cobitiae (spiny loaches)

Lepidocephalichthys thermalis (Valenciennes, 1846) (Plate 7, Fig.26)

Genus: Lepidocephalichthys

Collected by Parvathy C A, Mullassery kole wetland, 2.5.2018. Material compared with: 1 exs. Thattekkad. 9.vii.2015. Coll. Dr. B.H.C.K. Murthy. ZSI/WGRC/IR.V.2759

Body moderately compressed and elongate; abdomen rounded; head is conical and shot with blunt snout; mouth is inferior; eyes are superior and small in anterior part of head; thick lips and teethless jaws and palate; barbels are present, one pair rostral, two pairs maxillary; dorsal fin inserted slightly ahead of pelvic fins without spine; short anal fin with 8 rays; caudal fin forked; lateral line absent; scales are small.

IV. ORDER SILURIFORMES

Family: Bagridae (river catfshes)

Mystus montanus (Jerdon, 1849) (Plate 2, Fig.8)

Genus: Mystus

Collected by Parvathy C A, Enamav kole wetland, 7.5.2018. Material compared with:

1 exs. Thattekkad. 11.vii.2015. Coll. Dr. B.H.C.K. Murthy. ZSI/WGRC/IR.V.2784.

Body compressed and moderately elongate; barbels are present and welldeveloped; abdomen rounded; head is moderate size, compressed and snout is rounded; mouth is wide and terminal, transverse; eyes are large; villiform teeth are present; four pairs of barbels are present; rayed dorsal fin inserted above last quarter of pectoral fin low of varying length.

Mystus oculatus (Valenciennes, 1840) (Plate 3, Fig.9)

Genus: Mystus

Collected by Parvathy C A, Enamav kole wetland, 6.4..2018. Material compared with: 1 exs. Thattekkad. 9.vii.2015. Coll. Dr. B.H.C.K. Murthy.

Body is compressed and moderately elongated; head of moderate size, compressed. Snout rounded; abdomen rounded; uniform villiform teeth are present; rayed dorsal fin inserted above last quarter of pectoral fin; eyes are supra-lateral and in anterior part of head not visible from below ventral surface; jaws are subequal with thin lips; lateral line complete, caudal fin forked.

Mystus armatus (Day, 1865) (Plate 2, Fig.7)

Genus: Mystus

Collected by Parvathy C A, Mavinchuad kole wetland, 4.12.2019. Material compared with: None. Earlier records

Body is compressed plain and occipital crest smooth; caudal fin with a dark blotch at base; the median longitudinal groove present; a dark blotch at base of caudal fin; median longitudinal groove extending beyond posterior border of orbit; adipose dorsal fin base longer than anal fin base; barbels are present and well-developed; mouth is wide. And obtuse; villiforms teeth are present; lateral line complete.

Family: Horabagridae

Horabagrus brachysoma (Günther, 1864) (Plate 3, Fig.10)

Genus: Horabagrus

Collected by Parvathy C A, Muriad kole wetland, 25.4.2018. Material compared with: None. Earlier records.

Body is moderately elongate and compressed body; teeth are present on mandibles and premaxillaries; well-developed eight barbels are present; dorsal fins with 8 rays and one spine; adipose dorsal fin is smooth; anal fin not confluent with caudal and it moderately short; lateral line is complete; large air bladder is present.

Family: Siluridae (Buttr catfshes)

Ompok bimaculatus (Bloch, 1794) (Plate 2, Fig.5)

Genus: Ompok

Collected by Parvathy C A, Tholur kole wetland, 7.5.2018. Material compared with: 1 ex. Koottikkal. 28. xi. 2014. Coll. Dr. Md. Jafer Palot. Reg. No. ZSI/WGRC/IR.V.2858.

The eyes are small and covered with the skin; the two pairs of long barbels are present; the dorsal fins and pelvic fins are small, the pectoral fins are well developed and anal fin is very long; teeth are villiform bands on jaws; barbels are two pairs; maxillary barbells are short than head length; anal fin long, inserted behind the dorsal fin; caudal fin deeply forked with a pointed edge.

Wallago attu (Bloch & Schneider, 1801) (Plate 2, Fig.6)

Genus: Wallago

Collected by Parvathy C A, Tholur kole wetland, 2.5.2018. Material compared with: 1 exs. Thattekkad. 9.vii.2015. Coll. Dr. B.H.C.K. Murthy. ZSI/WGRC/IR.V.2852.

Body elongated and compressed with large depressed head; mouth is sub-terminal. Eyes are small and thin lips; prominent and longer lower jaw present and jaws are sub-equal; adipose dorsal fin absent and pectoral fins with 15 rays and a smooth spine; pelvic fins with 10 rays; lateral line complete; teeth villiform in bands on jaws and in patches on palate; the snout is depressed; two pairs of barbels present, the maxillary barbels and mandibular barbels; the eyes and dorsal fins are small; the anal fin is very long.

Family: Heteropneustiae (stiging catfshes)

Heteropneustes fossilis (Bloch, 1794) (Plate 1, Fig.4)

Genus: Heteropneustes

Collected by Parvathy C A, Nedupuzha kole wetland, 5.4.2019 Material compared with: 1 exs. Thattekkad. 9.vii.2015. Coll. Dr. B.H.C.K. Murthy. ZSI/WGRC/IR.V.2847.

Body is elongated compressed and abdomen is rounded; head is greatly depressed and moderately sized; snout is flat; the mouth is terminal; eyes are small, lateral and located in the anterior part of head, not visible from the below ventral surface; jaws are subequal and lips fleshy; four pairs of barbels are present; dorsal fins are short and rayed inserted above the tip of pectoral fin; air bladder is reduced; villiform teeth are present; caudal fin rounded; lateral line complete.

Family: Pangasiidae

Pangasius bocourti (Sauvage, 1880) (Plate 3, Fig.11)

Genus: Pangasius

Collected by Parvathy C A, Muriad kole wetland, 25.4.2018. Material compared with: None. Earlier records.

Body elongated with moderate-sized and blunt head; body compressed and abdomen rounded; thin lips; snout rounded and mouth is sub-terminal; eyes are large visible from below ventral surface; jaws are sub-terminal with longer upper jaw; teeth are small; barbels are present on each of maxillary and mandibular; forked caudal fin; lateral line complete; adipose dorsal fin short and rayed dorsal fin inserted above last quartet of pectoral fin; pectoral fins with a serrated spine and 12 rays; pelvic fins with 8 rays and long anal fin with 32 rays.

V. ORDER: CYPRINODONTIFORMES

Family: Aplocheilidae (panchax)

Aplocheilus lineatus (Plate 12, Fig.43)

Genus: Aplocheilus

Collected by Parvathy C A, Maranchery kole wetland, 5.4.2019. Material compared with: 2 exs. Koottikkal. 28.xi.2014. Coll. Dr. Md. Jafer Palot. ZSI/WGRC/IR.V.2770

Body elongated, slender and compressed; long based anal fin and short based dorsal fin; mouth is moderately wide and terminal and head conical with thin lips; barbels are present; anal fin with 22 rays; dorsal fin with 8 rays and no spine; the mouth is broadly curved, and there is an iridescent white spot-on top of the head between the rear edges of the eyes; caudal fin rounded; lateral line absent; the scales are large; the upper and lower margins of the caudal fin are red; the pelvic fins have the second branched ray elongated into a filament that may stretch to the middle of the anal fin when pressed against the belly.

VI. ORDER: BELONIFORMES

Family: Belonidae (Needlefihes)

Xenentodon cancila (Hamilton-Buchanan, 1822) (Plate 12, Fig.46)

Genus: Xenentodon

Collected by Parvathy C A, Mullassery kole wetland, 4.12.2019. Material compared with: 1 exs. Thattekkad. 9.7.2015. Coll. Dr. B.H.C.K. Murthy. Reg. No. ZSI/WGRC/IR.V.2848.

Body elongated, compressed and subcylindrical; head and snouts are pointed and abdomen rounded; eyes are moderate and superior; villiform teeth present; scales small; both jaws are prolonged into a beak; a deep longitudinal groove along upper surface of head; the dorsal fin with 16 rays and no spine, inserted above anal fin; caudal fin truncate; anal fin with 15 rays.

Family: Hemiramphidae

Hyporhamphus limbatus (Valenciennes, 1847) (Plate 12. Fig.45)

Genus: Hyporhamphus

Collected by Parvathy C A, Mullassery kole wetland, 5.6.2019. Material compared with: None. Earlier records

The body is elongated and rounded; highly prolonged beak-like lower jaw present and upper jaw is very short; caudal fin forked and emarginate; lower jaw is longer than head length; head with scales and scales are small; jaws are elongated as a beak; teeth are present on jaws; gill openings are wide; dorsal fin located far posterior of body without spines.

VII. ORDER: ELOPIFORMES

Family: Elopidae

Megalops cyprinoides (Broussonet, 1782) (Plate 11, Fig.41)

Genus: Megalops

Collected by Parvathy C A, Enamav kole wetland, 25.4.2018. Material compared with: None. Earlier records.

Body is oblong and compressed; abdomen is rounded and head is large with blunt snout; mouth is anterior; lips thin; lower jaw is longer than the upper; dorsal fin with 19 rays inserted above pelvic base; lateral line straight and complete; eyes are lateral in middle of head, not visible from below ventral surface.

VIII. ORDER: SYNBRANCHIFORMES

Family: Mastacembelidae (spiny eels)

Macrognanthus guentheri (Day, 1865) (Plate 1, Fig.2)

Genus: Macrognathus

Collected by Parvathy C A, Tholur kole wetland, 4.12.2019. Material compared with: 1 exs. Kolumba.20.ix.2016. Coll. Dr. Md. Jafer Palot. Reg. No. ZSI/WGRC/IR.V.2771.

Body elongated, eel like and compressed; head and snout long; head and caudal fin is pointed; eyes are superior in the middle of head and small, not visible from below ventral surface; lips are thin; caudal fin rounded and separated from the dorsal and anal fins; lateral line and air bladder are present; anal fin with 3 spines and 52 rays; scales are small; small and pointed teeth present; eyes small, superior in the middle of head.

Mastacembelus armatus (Lacepede, 1800) (Plate 1, Fig.1)

Genus: Mastacembelus

Collected by Parvathy C A, Tholur kole wetland, 2.11.2018. Material compared with: 1 exs. Thattekkad. 13.7.2015. Coll. B.H.C.K Murthi. Reg. No. ZSI/WGRC/IR.V. 20909.

Body elongated, eel-like, and compressed; the mouth and caudal fins are pointed; snout long the and mouth is inferior with thin lips and sub-equal jaws; small teeth on jaws; dorsal fin inserted above the middle of the pectoral with 26 spines and 52 rays; anal fin with 3 spines and 34 rays; elongated air bladder; small eyes superior in the middle of head not visible from below ventral surface; the body is coloured dull brown with 1-3 darker longitudinal lines; dorsal spines 34 and dorsal soft rays are 74.

IX. ORDER: OVALENTARIA

Family: Ambassidae (Asiatic glassfihes/perchlets)

Parambassis dayi (Bleeker, 1874) (Plate 11, Fig. 39)

Genus: Parambassis

Collected by Parvathy C A, Enamav kole wetland, 4.12.2019. Material compared with: 1 ex. Thattekkad. 13.7.2015. Coll. Dr. B.H.C.K Murthy. Reg. No. ZSI/WGRC/IR.V.2725

Body is short and compressed; body silvery, glossed with purple, with a broad lateral burnished band; abdomen rounded; mouth is wide with sharp snout; jaws and palate with villiform teeth; caudal fin forked; scales are cycloid and small; lateral line continuous with 30 lateral line scales; teeth present on tongue; preopercular ridge denticulate except for one or two spines at angle.

Parambassis thomassi (Day, 1870) (Plate 11, Fig.40)

Genus: Parambassis

Collected by Parvathy C A, Nedupuzha kole wetland, 25.11.2018. Material compared with: 1 ex. Thattekkad. 19.9.2016. Coll. Dr. Md. Jafer Palot. Reg. No. ZSI/WGRC/IR.V.2744

Body short and deep, compressed; lower jaw longer than the upper and lips are thin; abdomen rounded; head short, compressed; snout sharp; mouth wide, eyes large, superior, may be visible from below ventral surface; caudal fin forked; jaws, palate, and tongue with villiform teeth; two dorsal fins, the first with about seven spines; and second 9 rays; anal fin with three spines and 9-17 rays; scales cycloid and small.

X. ORDER: CICHLIFORMES

Family: Cichlidae (pearlspot)

Etroplus suratensis (Bloch, 1790) (Plate 10, Fig.37)

Genus: Etroplus

Collected by Parvathy C A, Mullassery kole wetland, 4.12.2019. Material compared with: 5 exs. Thattekkad. 13.7.2015. Coll. Dr. B.H.C.K. Murthy. Reg. No. ZSI/WGRC/IR.V.2865.

Body oblong, compressed and elevated; the body with ctenoid scales; dorsal fin single with a spinous and soft part and anal fin with spines and soft part; large and simple air bladder present; dorsal fin with 18 spines and 15 rays and anal fin with 16 spine and 11 rays; lateral line incomplete; abdomen rounded; body with dark bands; thin lips; the caudal fin emarginate; scales are ctenoid.

Pseudetroplus maculatus (Bloch, 1795) (Plate 10, Fig.36)

Genus: Etroplus

Collected by Parvathy C A, Mullassery kole wetland, 2.7.2019. Material compared with: None. Many specimens were observed during the survey.

Each scale with reddish or brick coloured spot; lateral line incomplete with 35 scales in series; ground colour is yellowish; there are three blotches on body; the middle blotch larger than the other; the dorsal and anal fin tipped deep black. Family: Cichlidae

Oreochromis mossambica (Peters, 1852) (Plate 9, Fig.34)

Genus: Oreochromis

Collected by Parvathy C A, Mavinchuad kole wetland, 2.5.2019. Material compared with: 1 ex. Sholayar. 21.2.1996. Coll. P M Suresh. Reg. No. ZSI/WGRC/IR.V.9250.

Body is moderately elongate and snout is long; the forehead with relatively large scales; abdomen and snout are rounded, the adult males develop a pointed snout; scales cycloid; lateral line incomplete; mouth is large and terminal; eyes large and thin lips;

dorsal spines are larger than rays with 18 spines and 13 rays; the forehead scales are large; enlarged jaws with duck bill-like snout; anal spines are 3 and rays are 11.

Oreochromis niloticus (Linnaeus, 1758) (Plate 10, Fig.35)

Genus: Oreochromis

Collected by Parvathy C A, Nedupuzha kole wetland, 18.6.2018. Material compared with: None. Earlier records.

Body is moderately elongated with the presence of regular vertical stripes throughout depth of caudal fin; abdomen and snout are rounded; eyes large and head is small; thin lips; scales are cycloid; mouth is terminal and large; lateral line incomplete; dorsal spines are 15 and 12 soft rays; males are bluish pink, sometimes with a dark throat, belly, anal fin; females are usually brownish, silvery, or white; anal fin are 3 spines with 8 soft rays.

XI. ORDER: GOBIIFORMES

Family: Gobiidae (gobies)

Glossogobius giuris (Hamilton, 1822) (Plate 12, Fig.44)

Genus: Glossogobius

Collected by Parvathy C A, Tholur kole wetland, 2.5.2019. Material compared with: 1 exs. Thattekkad. 9.vii.2015. Coll. Dr. B.H.C.K. Murthy. Reg. No. ZSI/WGRC/IR.V.2753.

Body is elongated, head is highly compressed and flattened; body is laterally blotched and mouth is terminal; dorsal fins with small spots and pelvic fins attached to the body only from their anterior part; dorsal fins are simple with brownish spots and pelvic fins are grey; caudal fin is rounded; dorsal fins include 6 spines and 8 soft rays; body not eel-like and two dorsal fins separate or connected at their bases; pelvic fins jointed but attached to the body only from their anterior part; the body is brownish yellow with 5 to 6 dark and rounded spots on its sides.

XII. ORDER: ANABANTIFORMES

Family: Anabantiae (climbing perch)

Anabas testudineus (Bloch, 1792) (Plate 8, Fig.27)

Genus: Anabas

Collected by Parvathy C A, Tholur kole wetland, 25.4.2018. Material compared with:

3 exs. Koottikkal. 28.11.2014. Dr. Md. Jafer Palot. Reg. No. ZSI/WGRC/IR.V2718.

Body is oblong, head moderate and compressed; abdomen is rounded; mouth terminal and small; eyes are lateral in anterior part of head and not visible from below; the dorsal fins with 18 spines and 10 rays are inserted above the pectoral base; lateral line incomplete; air bladder present; anal fin with 10 spines and 11 rays; caudal fin rounded; the villiforms teeths are present on jaws.

Family: Nandidae

Nandus nandus (Hamilton, 1822) (Plate 8, Fig.29)

Genus: Nandus

Collected by Parvathy C A, Mullassery kole wetland, 2.5.2019. Material compared with: 1 exs. Kidagoor. 30.10.2000. Coll. B.H.C.K Murthi. Reg. No. ZSI/WGRC/IR.V. 11760.

The body is oblong and compressed; abdomen is rounded; head is large with terminal mouth and pointed snout; eyes are large and anterior and not visible from below ventral surface; the lower jaw is longer, lips are thin; the dorsal fins, spinal portion longer than soft portion and inserted above pectoral base, with 12 spines and 13 rays; caudal fin rounded; anal fins with three spines and 9 rays; large air bladder is present.

Family: Osphronemidae (paradise fish)

Pseudosphromenus cupanus (Cuvier, 1831) (Plate 8, Fig.28)

Genus: Pseudosphromenus

Collected by Parvathy C A, Enamav kole wetland, 6.5.2019. Material compared with: None. Earlier records.

Body oblong and compressed; abdomen rounded; head short, compressed; mouth is terminal, small and little protractile; snout blunt; eyes are superior, moderate, in anterior part of head, not visible from below ventral surface; a supra-branchial organ present; lips thin; jaws subequal, upper jaw longer villiform teeth on jaws; palate edentate; single dorsal fin, spinous part longer than soft part; inserted, above half of pectoral fin, with 14 spines and 8 rays; pelvic fins with one spine and five well-developed rays; anal fin with 14 spines and 9 rays; caudal fin lanceolate; scales are ctenoid; lateral line interrupted; air-bladder simple.

Family: Channidae (snakeheads)

Channa gachua (Hamilton, 1822) (Plate 9, Fig.33)

Genus: Channa

Collected by Parvathy C A, Tholur kole wetland, 5.4.2019. Material compared with:

2 exs. Ovungal. 10.7.2015 Coll. Dr. B.H.C.K Murthy. Reg. No. ZSI/WGRC/IR.V.2716

Body is small, elongated and sub cylindrical; pectoral fin extended to anal fin and mouth is large; abdomen rounded; head is large and compressed; mouth opening moderate; eyes lateral and moderate; snout obtuse; jaws are equal; both dorsal fin and anal fin free from caudal fin; mouth opening moderate; small scales; lateral line incomplete; caudal fin rounded; ventral side of body is bluish in color; dorsal side of body is light black grey.

Channa punctata (Bloch, 1793) (Plate 9, Fig.31)

Genus: Channa

Collected by Parvathy C A, Tholur kole wetland, 7.9.2018. Material compared with: None. Earlier records.

Body is small, elongated and sub cylindrical; abdomen rounded; mouth opening moderate; eyes lateral and moderate; snout obtuse; jaws are equal; pelvic fin more than half length of pectoral fin; pectoral fins plain; both dorsal fin and anal fin free from caudal fin; mouth opening moderate; small scales; caudal fin; dorsal fin long, inserted almost above pectoral with 29 rays and no spine; pelvic fin is more than half length of pectoral fin; pectoral fins plain.

Channa pseudomarulius (Günther, 1861) (Plate 8, Fig.30)

Genus: Channa

Collected by Parvathy C A, Tholur kole wetland, 5.7.2018. Material compared with: 3 exs. Thattekkad. 13.7.2015. Coll. Dr. B.H.C.K. Murthy. Reg. No. ZSI/WGRC/IR.V.2853;

Body is sub cylindrical and elongated; abdomen rounded; snout obtuse; eyes are lateral and in anterior part of head not visible from below ventral surface; mouth opening wide; lips moderate and jaws are equal; dorsal fin long, without spine and 29 rays; anal fin long and spineless with 28 rays; scales are small; gill openings are wide; dorsal fin long and free from caudal as anal fin; accessory respiratory organs are present.

Channa striata (Bloch, 1793) (Plate 9, Fig.32)

Genus: Channa

Collected by Parvathy C A, Nedupuzha kole wetland,5.6.2019. Material compared with: 2 exs. Thattekkad. 13.vii.2015. Coll. Dr.B.H.C.K. Murthy. Reg. No. ZSI/WGRC/IR.V.2846.

The body is sub-cylindrical with striped design and head is depressed; the scales are large; caudal fin rounded; the fully toothed and large mouth; body is striped longitudinally with white belly part; the scales are large and fully toothed mouth. Anal fin rays 25-29; lower jaw 4-7 canines behind a single row of villiform teeth; lateral line scales 55- 65.

XIII. ORDER TETRAODONTIFORMES

Family: Tetraodontidae (Puffer fish)

Carinotetraodon travancoricus (Hora & Nair, 1941) (Plate 10, Fig.38)

Genus: Carinotetraodon

Collected by Parvathy C A, Enamav kole wetland, 2.4.2019. Material compared with:

None. Earlier records.

Body moderately elongate and anteriorly sub cylindrical also compressed posteriorly; the snout obtusely rounded and abdomen rounded; eyes are large and located in the anterior part of head; dorsal fin is spineless and inserted slightly ahead of pelvic nearer tip of snout than caudal base with ten rays; commonly called puffer fish.

4.1.3 Ichthyofauna of kole wetlands

In the present study a total of 46 fish species representing 23 families and 13 orders were identified from seven distinct sites within the wetlands. The taxonomic composition revealed Cyriniformes as the most dominant order, comprising 15 species, followed by Siluriformes (8 species) and Anabantiformes (7 species). The other orders included Cichliformes (4 species), Ovalentaria (2 species), Beloniformes (2 species), and Synbrachiformes (2 species), while Clupeiformes, Cyprinodontiformes, Gobiiformes, Elopiformes, Tetradontiformes, and Anguilliformes each contributed a single species (Table 4). This distribution aligns with findings from Senthil *et al.,* (2012), reinforcing the consistency of these patterns across kole wetlands. All fishes reported had value as fishes with ornamental and food value. The study documented a diverse array of fish families, with Cyprinidae (11 species) followed by Danionidae (4 species), Channidae (4 species), Cichlidae (4 species), Bagridae (3 species), Mastacembelidae (2 species) and Ambassidae (2 species). This result is similar to the finding of Abujam *et al.,* (2012).

Thobias (1973) reported 56 species of fishes belonging to 22 families of nine orders from the Thrissur district, Kerala and Cyprinidae was the largest family recorded from Thrissur. The State of Environment Report for Kerala in 2005 reported a count of 202 freshwater fish species. The study of Abdul Kader (1993) the fish and fisheries of inland waters in Thrissur district recorded 151 species from 56 families, with 88 species inhabiting brackish waters and 67 in freshwater. He expressed concern on the trend of declining inland catches and attributed to human interference and the degradation of water quality. Similarly, Raju (2006) identified 112 freshwater fish species from river systems of Thrissur. Swapna *et al.,* (2012) studied the icthyofaunal diversity of kole wetlands of Kerala and reported 54 species of fishes belonging to 40 genera. Parvathy and Lakshmidevi (2018) studied the ichthyofaunal diversity in Puzhakkal kole wetlands and recorded 13 species in six months.

Previous studies in Thrissur kole provide valuable context. Francis, (2015) meticulously documented 59 fish species across 47 genera and 31 families. A significant proportion of these species, 18 in total, were identified as secondary freshwater fishes, underscoring the pronounced influence of estuarine species within the ecosystem. Thirty four of these species were documented during the present investigation, where as 25 species were not found. All the above studies found to be most prevalent Cypriniformes to be most prevalent as in present study. Kumar & Sneha*.,* (2021) in the Pullazhi kole wetlands recorded an alien fish *Pygocentrus nattereri* and foresaw the potential extinction of eight native fish species post-flood. According to Kumar & Sneha (2021), *Channa striatus* and *Channa pseudomarulius* emerged as prominent species following the flood. But the present study did not show the presence of unusual exotic fishes or dominance of Channa species. This could be due to different sampling methods and collection sites followed by two studies.

Assessment of conservation status, as per IUCN categories, revealed four species *Carinotetraodon travancoricus, Cyprinus carpio, Horabagrus brachysoma,* and *Wallago attu* designated as Vulnerable (VU). Three species *Anguilla bengalensis*, *Ompok bimaculatus,* and *Sarotherodon mossambica* were classified as Near Threatened (NT). *Puntius mahecola* and *Megalops cyprinoides* fell under the Data Deficient category. *Channa pseudomarulius* and *Ctenopharyngodon idella* was categorized as Not Evaluated, and the remaining 35 species were classified as Least

There findings are similar to the investigations by ATREE in 2008 and 2009 revealed the persistence of diverse fish and shellfish species in the southern section of Vembanad and recorded the IUCN documented species *Carinotetraodon travancoricus* (VU), *Cyprinus carpio* (VU), *Horabagrus brachysoma* (VU), *Wallago attu* (VU), *Anguilla bengalensis* (NT), *Ompok bimaculatus* (NT), and *Oreochromis mossambica* (NT). As demonstrated by the Thaneermukkom barrage's impact on Vembanad human interventions can have profound consequences on fish populations (Anon, 2007). Long-term monitoring and comprehensive assessments, especially for data-deficient and not evaluated species, are essential for formulating effective conservation measures. A study by Abdul Kader, (1993) gave an insight into the aquatic biodiversity of Thrissur district's inland waters. The current study conducted almost after three decades build on exsisting data and provide pointers to formulate conservation strategies.

This comprehensive documentation of the ichthyofaunal diversity and conservation status provides crucial insights for the sustainable management and conservation of the kole wetlands ecosystem. The identification of vulnerable and threatened species underline the importance of targeted conservation efforts to preserve the biodiversity and cological integrity of this unique wetland habitat.

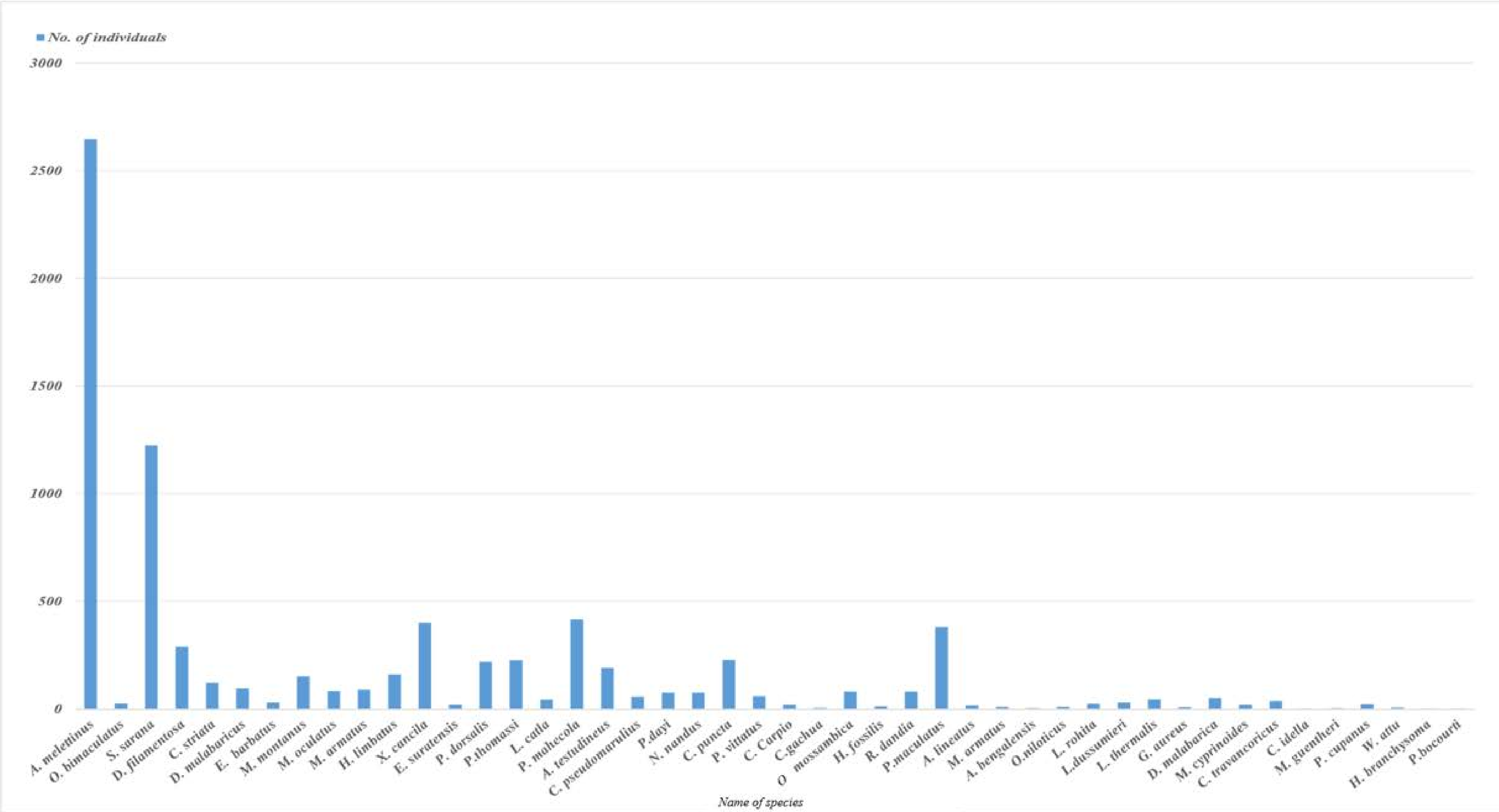


Figure 1. Fish species abundance of the Thrissur- Ponnani kole wetlands (2018-2019).

4.1.4 Fish species abundance across years in kole wetlands

The analysis of species abundance across study sites indicated only slight variations between the years 2018 and 2019. The Mann Whitney U was 1000.5. Z score is 0.44511 and P value 0.653 which means there is no significant difference between the species adundance in 2018 and 2019.

Table 5: A abundance of various fish species in 2018 and 2019.

Species	Fish abundance 2018	Fish abundance 2019
Rasbora dandia	34	26
Amblypharyngodon melettinus	1421	1226
Anabas testudineus	111	79
Anguilla bengalensis	4	0
Aplocheilus lineatus	11	5
Carinotetraodon travancoricus	21	15
Labeo catla	18	25
Channa gachua	4	1
Channa pseudomarulius	54	46
Channa punctata	112	92
Channa striata	83	38
Ctenopharyngodon idella	3	0
Cyprinus carpio	8	12
Dawkinsia filamentosa	178	112
Devario malabaricus	47	40
Esomus barbatus	13	18
Etroplus suratensis	14	6
Glossogobius aureus	5	2
Heteropneustes fossilis	7	3
Hyporhamphus limbatus	77	84
Labeo rohita	14	11
Macrognanthus guentheri	4	0
Mastacembelus armatus	6	2
Megalops cyprinoides	14	6
Mystus armatus	40	33

Mystus montanus	80	72
Mystus oculatus	49	39
Nandus nandus	37	39
Ompok bimaculatus	19	7
Oreochromis niloticus	2	6
Pangasius bocourti	2	1
Parambassis dayi	94	124
Parambassis thomassi	35	41
Pseudetroplus maculatus	210	170
Pseudosphromenus cupanus	16	6
Puntius dorsalis	128	113
Puntius mahecola	247	170
Puntius vittatus	37	22
Rasbora dandia	9	11
Sarotherodon mossambica	51	30
Systomus sarana	263	962
Wallago attu	4	2
Xenetondon cancila	238	161
Lepidocephalichthys thermalis	27	17
Dayella malabarica	31	35

There are species that experienced a decline in abundance from 2018 to 2019, such as *Rasbora dandia, Amblypharyngodon melettinus,* and *Anabas testudineus. Rasbora dandia* saw a decrease from 34 to 26*, Amblypharyngodon melettinus* from 1421 to 1226, and *Anabas testudineus* from 111 to 79 (Table 5). There is a significant surge in the abundance of *Systomus sarana*, which increased from 263 in 2018 to 962 in 2019. *Parambassis dayi* also saw an increase from 94 to 124. Some species maintained relatively stable populations across the two years, like *Cyprinus carpio,* which increased slightly from 8 to 12, and *Labeo catla,* which rose from 18 to 25.

However, certain species experienced a considerable decline or even complete disappearance from 2018 to 2019. For instance, *Anguilla bengalensis, Ctenopharyngodon idella,* and *Macrognanthus guentheri* went from small populations in 2018 to zero sightings in 2019 (Table 5) These fluctuations in fish abundance highlight the dynamic nature of aquatic ecosystems and the importance of monitoring and conservation efforts to ensure the sustainability of fish populations.

Variations in fish abundance were evident, with *Amblypharygodon melettinus* reaching peak abundance in March. November exhibited the highest species richness, with 9 species recorded. The most abundant species in November included *Pseudetroplus maculatus, Systomus sarana, Puntius mahecola, Puntius vittatus, Hyporhamphus limbatus, Channa punctata, Channa gachua, Rasbora dandia* and *Labeo catla* (Appendix table 1).

December showed a different composition of abundant species, *featuring Channa striata, Cyprinus carpio, Horobagrus branchysoma, Mystus armatus, Parambassis thomassi, Oreochromis niloticus, Nandus nandus, Mystus oculatus,* and *Oreochromis niloticus* as the most abundant. In February species such as *Anguilla bengalensis, Xenentodon cancila, Heteropneustes fossilis, Macrognathus guentheri* and *Channa pseudomarulius* were most abundant.

In April*, Puntius dorsalis* and *Esomus barbatus* were observed as abundant. These findings indicate that abundance pattern of fish species in kole wetlands change according to months. This change could reflect two basic reasons. Biological cycles of a particular species which cause increase of observable adults in an ecosystem. It could be due to increased number of individuals due to breeding or increased number of observed individuals due to behavior change. Both thes biological phenomenon may be driven by abiotic factors such as temperature, humidity, rainfall, depth of studying water in the kole fields etc. Another factor could be the agricultural practices which after the kole ecosystem leading to fish species differential responses. This hypothesis supported is by previous studies Abujam *et al.,* (2012) and Senthil *et al.,* (2012).

The results of the two-way ANOVA revealed statistically no significant difference between the years ($p = 0.7378$). Similarly, when considering both months and years together, there was no significant difference ($p = 0.2514$). The comparison between abundance of different months showed a significant difference ($p = 1.11e\text{-}24^*$) (Appendix Table 6).

A significant discrepancy was observed between species and site (p = 1.29e29*), indicating that variations in species composition were strongly influenced by the specific locations surveyed (Appendix Table 2).

Further investigation into the yearly trends in each sites revealed no significant disparity in fish composition between 2018 and 2019. This finding suggests that the fish populations within the kole wetlands remained relatively stable over the two-year period, potentially indicating minimal migration or external disturbances impacting the ecosystem. Moreover, no significant differences were observed between corresponding months within the same years. However, there was a notable contrast between different months of the same year, likely attributable to fluctuations in environmental factors such as rainfall and temperature, which vary seasonally within the kole wetlands. It is conceivable that this pattern persists across multiple years, indicating consistent temporal trends in fish distribution within specific months.

4.1.5 Fish species abundance across sites of Thrissur-Ponnani kole wetlands

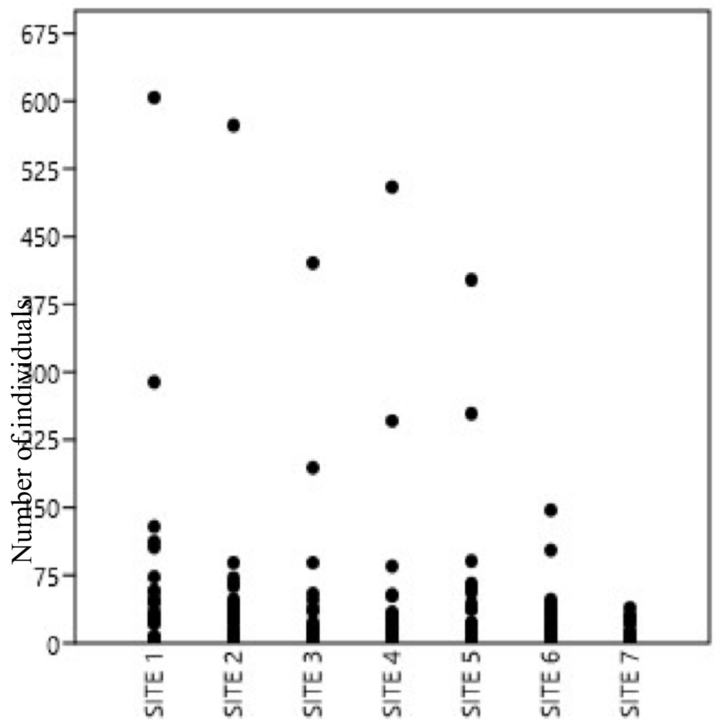


Figure 2: Spatial distribution of fish abundance in Thrissur-Ponnani kole wetlands.

The spatial distribution of fish abundance across different sites within the kole wetlands from January 2018 to December 2019 reveals noteworthy variations. Nedupuzha, identified as Site 1, exhibited the highest fish abundance of fishes, as depicted in Fig. 2. Following closely were Site 2 (Tholur), Site 4 (Enamavu) and Site 5 (Mullassery), each demonstrating substantial fish populations. In contrast, Site 9 (Muriad) consistently presented the lowest abundance throughout the study period (Figure 2).

Statistical analysis using the one-way ANOVA test indicated a significant difference in fish abundance among all sites (p=7872e-11*) (Appendix table 4). The prominence of Nedupuzha as the site with the highest fish abundance may be attributed to various environmental factors, including water quality, habitat suitability and potential anthropogenic influences. The identification of Nedupuzha as a site with consistently high abundance and Muriad with low abundances need further investigation for effective wetland conservation and management.

These findings reveals the intricate dynamics of ichthyofaunal abundance within the kole wetlands, emphasizing the significance of various factors, such as location, species composition, and month wise variations in shaping the observed variations.

Figure 3. Similarities of fish diversity in Thrissur-Ponnani kole wetlands-between study sites.

The different study sites showed the dendogram constructed using species abundance of each showed had two distinct clusters (Figure 3). The first cluster had Mavinchuad and Muriad. All other sites were in the second cluster. Maranchery and Mullassery exhibit the highest similarity, followed closely by the similarity observed between Enamav and Mullassery, as well as Maranchery. Conversely, Nedupuzha displays the greatest disparity when compared to the other sites in this cluster (Figure 3).

The notable similarity between Maranchery and Mullassery suggests a potential commonality in their environmental factors or management practices which was confirmed by grand truthing. Both sites possess large areas of agricultural lands, indicating that agricultural activities may play a significant role in shaping the similarity of fish abundance patterns. This shared characteristic feature could result from similar land use practices or environmental conditions favoring certain fish species. Microhabitat factors such as water quality, substrate type and aquatic vegetation could also be contributing to the resemblance in fish abundance patterns between these sites. Nedupuzha stands out from other sites. This could be attributed to factors such as differences in land use, habitat structure, or anthropogenic impacts, which result in divergent fish abundance patterns. This could be due to the uniqueness of Nedupuzha. Nedupuzha is characterised by many canals flowing through the region unlike other sites. While, Enamavu too has many canals, fishing activities are much higher than Nedupuzha.

4.1.6 Fish diversity in Thrissur-Ponnani kole wetlands

Table 6. Month wise diversity indices of ichthyofauna in kole wetlands for the year 2018.

DIVERSITY INDICES 2018	Jan	Feb	Mar	April	May	June	July	Aug	Sept	Oct	Nov	Dec
Taxa_S	26	36	33	31	31	14	12	13	24	32	31	30
Individuals	367	399	648	477	508	58	26	52	199	367	348	433
Dominance_D	0.1933	0.2475	0.2156	0.1397	0.2189	0.1094	0.1036	0.105	0.07639	0.1274	0.1315	0.1742
Simpson_1-D	0.8067	0.7525	0.7844	0.8603	0.7811	0.8906	0.8964	0.895	0.9236	0.8726	0.8685	0.8258
Shannon_H	2.348	2.306	2.329	2.608	2.285	2.389	2.375	2.385	2.821	2.654	2.673	2.46
Evenness_e^H/S	0.4024	0.2787	0.3111	0.438	0.3171	0.7787	0.8961	0.835	0.6999	0.4441	0.4672	0.3902
Margalef	4.233	5.844	4.943	4.864	4.815	3.202	3.376	3.037	4.345	5.249	5.126	4.777

Table 7: Monthly diversity indices of ichthyofauna in kole wetlands for the year 2019.

DIVERSITY INDICES 2019	Jan	Feb	Mar	April	May	June	July	Aug	Sept	Oct	Nov	Dec
Taxa_S	27	30	24	19	20	19	13	13	31	36	31	26
Individuals	440	441	468	317	337	71	45	35	282	541	371	562
Dominance_D	0.2586	0.1622	0.2597	0.2026	0.2755	0.1026	0.1042	0.0938	0.1286	0.1478	0.1201	0.1809
Simpson_1-D	0.7414	0.8378	0.7403	0.7974	0.7245	0.8974	0.8958	0.9061	0.8714	0.8522	0.8799	0.8191
Shannon_H	2.026	2.421	1.886	2.062	1.898	2.593	2.383	2.457	2.582	2.526	2.665	2.291
Evenness_e^H/S	0.2807	0.3753	0.2746	0.4136	0.3335	0.7038	0.8334	0.8973	0.4267	0.3474	0.4637	0.38
Margalef	4.272	4.763	3.741	3.126	3.265	4.223	3.152	3.375	5.317	5.561	5.071	3.949

Table 8. Month wise diversity indices of ichthyofauna in kole wetlands during the year 2018-2019.

DIVERSITY INDICES 2018-2019	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
Taxa_S	34	40	36	32	32	24	15	23	32	38	35	32
Individuals	802	844	1129	793	841	95	55	89	447	922	746	1029
Dominance_D	0.22	0.16	0.21	0.15	0.24	0.07	0.09	0.07	0.09	0.12	0.11	0.14
Simpson_1-D	0.77	0.83	0.78	0.84	0.75	0.92	0.9	0.92	0.9	0.87	0.88	0.85
Shannon_H	2.25	2.51	2.25	2.51	2.17	2.81	2.49	2.85	2.77	2.68	2.74	2.52
Evenness_e^H/S	0.27	0.31	0.26	0.38	0.27	0.69	0.8	0.75	0.5	0.38	0.44	0.39
Margalef	4.93	5.78	4.97	4.64	4.6	5.05	3.49	4.9	5.08	5.42	5.14	4.46

Table 9. The site wise diversity indices of ichthyofauna in kole wetlands during the year 2018-2019.

Diversity indices	Nedupuzha	Tholur	Maranchery	Enamav	Mullassery	Mavinchuad	Muriad
Taxa_S	31	37	24	32	31	27	27
Individuals	1807	1385	1004	1317	1321	669	289
Dominance_D	0.1571	0.1905	0.2308	0.1942	0.1475	0.09886	0.0765
Simpson_1-D	0.8429	0.8095	0.7692	0.8058	0.8525	0.9011	0.9235
Shannon_H	2.42	2.495	1.99	2.319	2.476	2.709	2.817
Evenness_e^H/S	0.3627	0.3275	0.3049	0.3178	0.3837	0.556	0.6196
Margalef	4	4.977	3.328	4.316	4.175	3.996	4.588

In 2018, Taxa richness (Taxa_S) ranges from 12 (July) to 36 (Feb) The number of individuals sampled varies from 26 (July) to 648 (March) across the months, reflecting monthly fluctuations in population sizes. Dominance_D values fluctuate between 0.07639 (Sept) and 0.2475 (Feb), indicating changes in the dominance of species within the community. (Table 6).

Simpson Diversity (Simpson_1-D) values range from 0.7525 (Feb) to 0.9236 (Sept), suggesting relatively high species diversity with some fluctuations over the months. Shannon Diversity (Shannon_H) values range from 2.306 (Feb) to 2.821 (Sept), indicating moderate to high diversity levels across the months. Evenness

(Evenness_e^H/S) varies from 0.2787 (Feb) to 0.8961 (July), Margalef indices range from 3.037(Aug) to 5.844 (Feb).

In 2019, fluctuations were observed across various ecological indices over the months, reflecting changes in the community composition and structure. Taxa richness (Taxa_S) ranges from 13 (July) to 36 (Oct), showing variation in the number of different species present. The number of individuals sampled varies from 35 (Aug) to 562 (Dec) across the months, indicating fluctuations in population sizes. Dominance_D values fluctuate between 0.09388 (Aug) and 0.2755 (May), indicating changes in the dominance of species within the community. Simpson Diversity (Simpson_1-D) values range from 0.7403 (March) to 0.9061 (Aug), suggesting relatively high species diversity with some fluctuations over the months (Table 7).

Shannon Diversity (Shannon_H) values range from 1.886 (March) to 2.665 (Nov), indicating moderate to high diversity levels across the months. Evenness (Evenness_e^H/S) varies from 0.2746 (March) to 0.8973 (Aug). Margalef indices range from 3.126 (April) to 5.561(Oct). Diversity indices were also calculated by clubbing data from provided for years 2018-2019 (Table 8). Taxa richness (Taxa_S) shows some variability throughout the year, ranging from 15 (July) to 40 (Feb) taxa. Similarly, the number of individuals sampled fluctuates, with the highest count recorded in March (1129) and the lowest in July (55). Consolidated Dominance_D values fluctuate between 0.07 (June) and 0.24 (May).

Simpson Diversity (Simpson_1-D) values range from 0.75 (May) to 0.92 (June), it is reciprocal to dominance index, which indicates few species are found in large numbers and all other species are equally distributed (Table 8). That also corresponds with the evenness index. Evenness (Evenness_e^H/S) varies from 0.26 (Mar) to high is 0.80 (July). The highevenness in July is where the number of species were very less but the number of individuals were equally distributed among the species.

Shannon diversity (Shannon_H) values range from 2.17 (May) to 2.85 (Aug), indicate that moderate level of diversity in kole wetlands. Margalef indices range from 3.49 (July) to 5.78 (Feb), indicating fluctuations in species richness over the year.

Margelef's index showed enhanced species richness after rice cultivation period. Similar observation was recorded by the Francis, (2015).

In 2018, maximum of 36 species were sampled in February and lowest species counts were reported in monsoon, July (12), August (13) and June (14). Number of individuals were highest post monsoon months of March (648) and May (508).

In 2019, maximum of 36 species were sampled in October and lowest species were reported in monsoon, July (13), August (13) and June (19). Number of individuals were highest in post monsoon months of October (541) and December (562).

In 2018-2019, maximum of 38 species were sampled in October and lowest species were reported in monsoon, July (15), August (23) and June (24). Number of individuals were highest post monsoon months of March (1129) and December (1029). All the years and combined period recorded the lowest number of individuals in July, June and August.

The dominance index values are very less (0.07-0.24), as usually the value range is 0-1.This is similar in all three calculations and indicates that number of individuals are almost equally distributed among the different species. The simpson1-D index values recorded were higher there (0.75to 0.92). The simpson index is the reciprocal to that of dominance index.

The evenness (ranges 0-1) shows how the number of individuals are equally distributed between the number of species. Some months exhibited high evenness (0.8961 -July) whereas other months showed less evenness. High evenness value was detected in July, June, and August, when the number of species and individuals was lower.

The highest number of taxa is observed in the Tholur and Enamav communities (37 and 32, respectively), while the lowest is in the Maranchery, Mavinchuad, and Muriad sites (24, 27, and 27, respectively). The highest number of individuals are found in the Nedupuzha site (1807), and the lowest is in the Muriad site (289) (Table 9). Nedupuzha has a high canal system and it harbours suitable microhabitat for fishes.

Dominance index indicates the proportion of the site's abundance accounted for by the most abundant species. The highest dominance was observed in the Maranchery site (0.2308), and the lowest is in the Muriad site (0.0765). Dominance index value is less in all sites. Simpson index represents the probability that two individuals randomly selected from the site will belong to different species and it the reciprocal to dominant index. The highest Simpson index (D-1) is observed in the Muriad site (0.9235), indicating high diversity, while the lowest is in the Maranchery site (0.7692). Shannon index measures the uncertainty in predicting the species identity of an individual randomly selected from the site. The highest Shannon index is observed in the Mavinchuad site (2.817), and the lowest is in the Maranchery site (1.99). Shannon index values are below 3, indicated modetate level of diversity.

Evenness index measures how evenly individuals are distributed among the different species. The highest evenness is observed in the Mavinchuad site (0.6196), while the lowest is in the Maranchery site (0.3049). Margalef richness index estimates the richness of a site taking into account the number of individuals and the number of taxa. The highest Margalef index is observed in the Tholur site (4.977), and the lowest is in the Maranchery site (3.328).

The site Tholur has the highest species richness and dominance. The site Muriad stands out for having the highest Simpson index. The Shannon index values observed here are all less than 3, suggesting a moderate level of diversity in Kole wetlands. The site Mavinchud has the highest Shannon index and evenness, suggesting a more balanced distribution of individuals among species. Similar range of diversity indices of Simpson, Shannon, Margalef and Dominance values are reported in kole wetlands of Thrissur by Francis, (2015) in case of Dominance, Shannon, Simpson and Margalef indices.

There are fluctuations in diversity indices across the months, suggesting temporal variability in biodiversity. For example, diversity indices tend to be higher during months with higher taxa richness and individual abundance. Months with lower taxa richness and individual abundance may exhibit lower diversity indices and higher dominance values.

During the rice cultivation season (October to February), number of individuals increased but species richness decreased. During the dewatering process of agriculture, all fish concentrate in puddles of rice fields and can be easily detected, which may explain the larger number of fish during this time. When paddy cultivation begins, the water level in paddy fields decreases. As a result, fish will be constrained to major canals exclusively, resulting in a decline in species richness observed during the paddy cultivation time (Francis, 2015).

Our findings align with the post-monsoon season exhibiting higher fish fauna diversity, consistent with the results obtained by Galib *et al.,* (2013). The observed seasonal variations in fish diversity may be attributed to factors such as water temperature, flow rates, and food availability. Understanding these factors is crucial for interpreting the observed changes.

Anthropogenic activities, such as pollution or habitat alteration, may contribute to assign reasons for observed fluctuations. A detailed investigation into local anthropogenic stressors is recommended. The ecological Succession make changes in fish diversity across months could be linked to ecological succession, where certain species thrive in specific environmental conditions. Long-term monitoring is essential to identify patterns and trends. The findings highlight the dynamic nature of fish diversity, emphasizing the need for adaptive management strategies that consider seasonal variations. Conservation efforts should focus on preserving critical habitats and addressing potential stressors that may contribute to fluctuations in fish diversity.

The observed fluctuations in diversity indices highlight the dynamic nature of the studied ecosystem over the 2018-2019 period. Environmental factors such as seasonal changes, habitat alterations, and anthropogenic influences may have contributed to the observed variations in biodiversity. High diversity and evenness indices indicate a balanced community structure, while fluctuations in dominance and richness indices may reflect ecological disturbances or natural variability. Further analysis, including environmental data and community composition assessments, would provide a more comprehensive understanding of the factors influencing biodiversity dynamics in the ecosystem.

4.1.7 Physicochemical parameters in Thrissur – Ponnani kole wetlands

The mean concentrations of various physicochemical parameters of kole wetlands were assessed, revealing noteworthy disparities between the years 2018 and 2019 (Table 9). In 2018, higher concentrations were noted for Alkalinity, Chloride, Electrical Conductivity, Fluoride, Nitrate, pH, Sulphate, and Turbidity. Conversely, in 2019, parameters such as BOD, Calcium, Dissolved Oxygen (DO), Iron, Magnesium, Salinity, Total Dissolved Solids (TDS), and Total Hardness exhibited elevated concentrations. A detailed analysis of different sampling sites unveiled distinct characteristics. Site 7, Tholur, exhibited the highest mean concentrations for Alkalinity, DO, Electrical Conductivity, Iron, and Nitrate. On the other hand, Site 1, Enamavu, displayed the highest mean concentrations for Salinity, TDS, Total Hardness, and Turbidity. It also registered the lowest mean concentrations for Calcium, Chloride, Fluoride, and Iron. Site 2, Marancherry, stood out with the highest mean concentrations solely in pH and Air Temperature. This site, however, recorded the lowest mean concentrations for Acidity, Alkalinity, BOD, Electrical Conductivity, Magnesium, Nitrate, Salinity, and Total Hardness (Table 10).

Tholur (site 7) consistently exhibits the highest concentrations for parameters like alkalinity, dissolved oxygen (DO), electrical conductivity (EC), iron, and nitrate. Enamavu (site 1) records the highest concentrations for salinity, total dissolved solids (TDS), total hardness, and turbidity.

Site 3, Mavinchuad, demonstrated the highest mean concentration of Chloride and, conversely, the lowest mean concentration of Turbidity (Table 11). These findings underscore the spatial and temporal variability in the distribution of physicochemical parameters across the monitored sites, providing valuable insights into the aquatic ecosystem dynamics.

Table 10: Variation in limnological parameters of Thrissur–Ponnani kole wetlands

Parameters	2018	2019	Overall
Acidity (mg/L)	15.89 ± 4.75	17.76 ± 5.73	16.83 ± 5.33
Air Temperature(◦C)	30.08 ± 1.47	29.98 ± 1.1	30.03 ± 1.3
Alkalinity(mg/L)	31.52 ± 10.95	28.45 ± 8.9	29.98 ± 10.06
BOD (mg/L)	1.68 ± 0.63	1.7 ± 0.58	1.69 ± 0.61
Calcium (mg/L)	20.35 ± 16.9	23.8 ± 13.44	22.07 ± 15.32
Chloride (mg/L)	48.21 ± 37.2	45.4 ± 33.49	46.8 ± 35.32
DO (mg/L)	6.66 ± 0.82	6.82 ± 1.04	6.74 ± 0.94
EC (µS)	0.41 ± 0.75	0.25 ± 0.11	0.33 ± 0.54
Fluoride (mg/L)	0.37 ± 0.56	0.24 ± 0.15	0.3 ± 0.41
Iron (mg/L)	1.1 ± 2.23	1.29 ± 2.43	1.19 ± 2.32
Magnesium (mg/L)	6.52 ± 5.98	7.04 ± 4.8	6.78 ± 5.41
Nitrate (mg/L)	8.26 ± 18.39	5.09 ± 5.51	6.68 ± 13.63
pH	6.96 ± 0.72	6.91 ± 0.71	6.93 ± 0.71
Salinity (ppm)	0.1 ± 0.15	0.91 ± 3.82	0.51 ± 2.72
Sulphate (mg/L)	44.82 ± 41.11	36.62 ± 26.91	40.72 ± 34.88
TDS (ppm)	144.88± 61.49	181.94 ±89.77	163.41 ± 78.93
Total hardness (mg/L)	58.03 ± 26.75	70.73 ± 38.66	64.38 ± 33.75
Turbidity (NTU)	44.92 ± 42.96	27.34 ± 34.48	36.13 ± 39.82
Water Temperature(◦C)	28.74 ± 1.4	28.64 ± 1.4	28.69 ± 1.4

Acidity: There's a slight increase from 2018 to 2019, which could indicate changes in water chemistry or inputs. Air and Water Temperature: Both air and water temperatures remained relatively stable over the two years, with minor fluctuations, suggesting consistent environmental conditions. Alkalinity: There's a decrease from 2018 to 2019, which might be attributed to alterations in the buffering capacity of the water body. BOD (Biochemical Oxygen Demand): The BOD levels remained consistent, indicating similar levels of organic pollutants in the water over the two years. Calcium, Chloride, Magnesium and Sulphate: These ions show fluctuations but with no clear trend, suggesting variable inputs or processes affecting their concentrations. Dissolved Oxygen (DO): DO levels remained relatively stable, indicating consistent oxygen availability for aquatic oganisms.

Electrical Conductivity (EC): Fluctuations are observed, possibly influenced by changes in dissolved solids or conductivity of the water. Fluoride, Iron, Nitrate, pH, Salinity, TDS (Total Dissolved Solids), Total Hardness and Turbidity: These parameters also show variations without a distinct trend, indicating dynamic water quality conditions influenced by multiple factors such as anthropogenic activities, natural processes, and seasonal variations.

Table 11: The mean and standard deviation values of physicochemical parameters in each sites.

Parameters	Enamavu	Maranchery	Mavinch uad	Mullasse ry	Muriad	Nedupuz ha	Thour	Overall
Acidity (mg/L)	16.41 ± 5.47	15.02 ± 4.31	17.33 ± 4.17	15.96 ± 5.48	16.98 ± 5.87	19.33 ± 5.5	16.75 ± 5.86	16.83 ± 5.33
Air Temperature(◦C)	30.04 ± 1.08	30.25 ± 2.21	30.08 ± 1.06	29.92 ± 0.88	30.12 ± 1.19	29.88 ± 1.12	29.92 ± 1.21	30.03 ± 1.3
Alkalinity(mg/L)	27.91± 6.87	28.4 ± 10.34	32.65± 12.2	29.38 ± 11.01	28.72 ± 9.06	30.11 ± 9.11	32.71 ± 11.03	29.98 ±10.06
BOD (mg/L)	1.56± 0.55	1.48 ± 0.57	1.64 ±0.71	2 ± 0.51	1.78 ± 0.66	1.82 ± 0.52	1.53 ± 0.61	1.69± 0.61
Calcium (mg/L)	18.78 ±9.25	23.95± 19.87	23.1 ±23.21	21.47± 16.69	24.48± 12.91	19.66 ± 9.77	23.08± 10.71	22.07± 15.32
Chloride (mg/L)	35.16 ±16.26	39.41± 18.43	64.7± 66.86	48.19± 36.42	51.33± 32.19	42.46± 17.73	46.37± 26.97	46.8 ±35.32
DO (mg/L)	6.73 ±0.86	6.85 ±0.84	6.75 ±1.28	6.69 ±0.82	6.6 ±1.03	6.66 ±0.87	6.9 ±0.85	6.74± 0.94
EC (µS)	0.25 ±0.09	0.23 ±0.09	0.3 ±0.37	0.3 ±0.34	0.38 0.78	0.41 ±0.73	0.43 ±0.81	0.33± 0.54
Fluoride (mg/L)	0.2 ± 0.09	0.31 ±0.43	0.25± 0.11	0.22 ±0.14	0.43 0.67	0.33 ±0.45	0.38 ±0.56	0.3 ±0.41
Iron (mg/L)	0.62 ±0.37	0.72 ±0.43	0.87± 1.1	1.15 ±1.66	1.69 4.17	1.17 ±1.07	2.13 ±3.81	1.19 ±2.32
Magnesium (mg/L)	7.07 ±10.04	5.49 ±2.73	6.67 ±5.2	5.37 ±2.74	7.87 5.49	7.57 ±4.91	7.42 3.02	6.78 ±5.41
Nitrate (mg/L)	3.29 ±1.48	2.94 ±1.08	3.55± 1.69	6.78 ±11.97	8.8 18.04	9.55 ±16.35	11.86± 22.98	6.68± 13.63
pH	7.05 ±0.44	7.09± 0.64	7.06 ±0.75	7.02± 0.8	6.66 0.73	6.87 ±0.79	6.81 ± 0.77	6.93± 0.71
Salinity(ppm)	0.1 ± 0.14	0.07± 0.02	0.08 ±0.05	0.78 ±3.31	0.88 3.95	0.91 ±4.13	0.74 ± 3.04	0.51± 2.72
Sulphate (mg/L)	41.7 ± 40.88	42.47± 35.93	43.47± 36.17	36.28± 34.88	37.48± 33.22	46.44± 39.83	37.22± 23.83	40.72± 34.88
TDS (ppm)	191.79± 131.04	166.48±4.57	155.83±81.11	169.92±2.31	160.43±2.93	146.77±0.31	152.68±2.57	163.41±8.93
Totalhardnes (mg/L)	69.84 ±34.44	58.1 ±30.32	64.9 ± 28.88	68.39± 56.43	63.12± 28.87	64.26 ±24.05	62.03 ±25.28	64.38 ±33.75
Turbidity (NTU)	41.6± 51.87	34.54 ±40.28	31.59± 34.76	34.85± 35.3	33.9 ±36.72	37.41± 42.09	38.98 ±39.46	36.13± 39.82
Water Temperature(◦C)	28.67± 1.24	28.46± 1.64	28.67 ± 1.58	28.58± 0.93	29.04± 1.46	28.75 ±1.45	28.67 ±1.46	28.69 ±1.4

The comparative analysis of water quality parameters across seven distinct sites revealed significant variations, offering insights into local environmental conditions and potential implications. Nedupuzha, exhibited the highest acidity (19.33 mg/L), possibly linked to industrial discharges or agricultural runoff, while Maranchery (Site 2) showcased the lowest acidity (15.02 mg/L), hinting at natural alkalinity or limited anthropogenic influence. Moreover, Maranchery recorded the highest air temperature (30.25°C), potentially influenced by urbanization or localized climatic factors, contrasting with Nedupuzha's lower air temperature (29.88°C), which could be attributed to its proximity to water bodies or vegetative cover (Table 11).

Tholur (Site 7) displayed the highest alkalinity (32.71 mg/L), indicative of geological attributes or anthropogenic activities such as agriculture, whereas Enamavu (Site 1) exhibited the lowest alkalinity (27.91 mg/L), likely influenced by natural factors like soil composition or vegetation type. Mullassery (Site 4) registered the highest BOD (2 mg/L), suggesting organic pollution from sewage or agricultural runoff, while Maranchery (Site 2) showcased the lowest BOD (1.48 mg/L), pointing towards effective wastewater treatment or reduced organic load. Further, Muriad (Site 5) recorded the highest water temperature (29.04°C), potentially influenced by environmental factors such as solar radiation or water flow dynamics, whereas Maranchery (Site 2) had the lowest water temperature (28.46°C), possibly due to local climatic variations or geographical features.

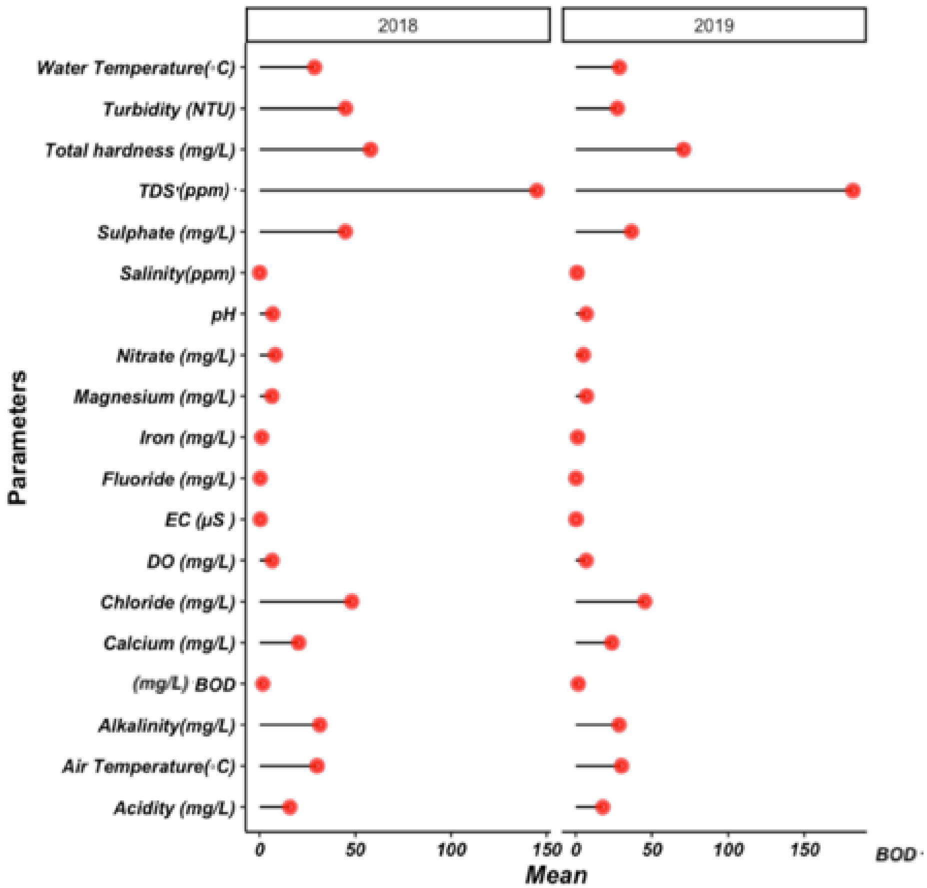
Site 5, Muriad exhibited the highest calcium content (24.48 mg/L), possibly influenced by geological formations or agricultural lime applications, whereas Site 1, Enamav demonstrated the lowest calcium levels (18.78 mg/L), potentially due to leaching or soil erosion. In terms of chloride content, Site 3 had the highest levels (64.7 mg/L), suggesting saline intrusion or anthropogenic inputs such as road salt or industrial discharge, while Site 1, Enamav exhibited the lowest chloride levels (35.16 mg/L).

Regarding dissolved oxygen (DO) levels, Site 7, Tholur displayed the highest content (6.9 mg/L), whereas Site 5, Muriad recorded the lowest DO levels (6.6 mg/L). Site 7, Tholur showed the highest electrical conductivity (0.43 µS), indicative of dissolved ion concentrations from geological sources or anthropogenic pollution, while Site 1, Enamav exhibited the lowest EC levels (0.25 µS), suggesting lesser dissolved solids or minimal anthropogenic influence. These observations highlight the diverse environmental factors influencing water quality across the studied sites.

Analysis of Variance (ANOVA) tests were conducted to understand the impact of various factors on environmental parameters in the Thrissur–Ponnani kole wetlands. ANOVA test analyzed the influence of different parameters on site. It found a significant difference between of parameters ($p = 0$) (Appendix Table. 10) in site-specific variations within the wetlands, but no significant differences were found between sites ($p = 0.9971$) (Appendix Table. 10). Here examined the combined influence of parameters, sites, and their interaction on environmental factors. While parameters showed a significant effect, neither sites nor the interaction between parameters and sites were statistically significant (Appendix Table. 10).

It found a significant effect between the month ($p= 3.3435e-06$), but neither the year nor the interaction between month and year had a significant impact ($p = 0.358$) (Appendix Table. 17). The interaction between parameters and year were significant ($p =4.268e-19$), but the year alone did not show significant differences ($p = 0.1977$) (Appendix Table.12). The site and years have no significant difference, because there may be the water is flooded every year mixed up parameters togather and the post flooding in Kerala also influences this pattern.

Figure 4: Temporal trends in mean water quality parameters of Thrissur–Ponnani kole wetlands in 2018 and 2019



The assessment of physicochemical parameters in this study reveals that all values fall within permissible limit (WHO, 2017), indicating that the water quality in the Thrissur-Ponnani kole wetlands is within acceptable ranges (Figure 4).

The dissolved oxygen content minimum level of 4 mg/L, in line with the ideal number for maintaining healthy aquatic life (Avvannavar and Shrihari, 2008). There were reported the dissolved oxygen levels of above 4 mg/L, meeting or exceeding recommended standards suggested that the water in the Thrissur-Ponnani kole wetlands is supportive of aquatic life

Agrawal and Saxena, (2011) suggested that the presence of higher DO levels, as noted is associated with plankton growth, while lower DO levels can indicate a decrease in the number of living creatures in the water system and higher anthropogenic activities. Raja *et al.,* (2008) & Kharat *et al.,* (2003) reported a decrease in DO levels linked to anthropogenic activities, contributing to a decline in fish diversity. Dissolved oxygen (DO) in assessing water quality is emphasized in the literature. Water odor, caused by a lack of DO due to aerobic breakdown of organic waste indicate the importance of oxygen for maintaining a healthy aquatic environment (Manivaskam, 1980). All aquatic species require dissolved oxygen for aerobic metabolism, making it a key indicator of water quality and organic contamination (Wetzel, 1975; Wetzel and Likens, 2006). These finding suggest the importand role of dissolved oxygen in aquatic life and also contributes to kole wetlands.

While all reported parameters in this study fall within permissible levels, the lowest mean concentrations are observed for calcium, chloride, fluoride, and iron. In contrast, pH and air temperature exhibit the highest mean concentrations at site 2, Marancherry. Maruthi *et al.,* (2000), reported the influence of temperature on chemical reactions in water bodies emphasizes the importance of considering temperature fluctuations in understanding water quality dynamics. Kundangar *et al.,* (1996) recorded the variation in water temperature, influenced by seasonal changes and atmospheric conditions, is a crucial factor in aquatic ecosystems.

Concerning alkalinity, which is crucial for the well-being of aquaculture species, the concentrations observed in the three bodies of water under investigation are reported to be within tolerance levels. This aligns with findings from Hujare (2008) and emphasizes the importance of maintaining appropriate alkalinity levels for the health and productivity of aquatic ecosystems.

Site 2 (Marancherry) displays the lowest concentrations of acidity, alkalinity, biochemical oxygen demand (BOD), electrical conductivity (EC), magnesium, nitrate, salinity, and total hardness. On the other hand, site 3 (Mavinchuad) exhibits the highest mean concentration of chloride and the lowest mean concentration of turbidity. The medium concentration of parameters at the Nedupuzha site corresponds with the highest diversity indices, challenging the notion that sites with extreme concentrations necessarily impact fish diversity.

Kaushik and Saksena, (1999) suggested that the water hardness, influenced by dissolved salts, is affected by factors such as evaporation, the addition of calcium and magnesium salts, and sewage infiltration. Sharma *et al.,* (2012) suggest that decreased hardness in winter may result from cation and anion settling. Tiwari and Ranga, (2012) recorded that the TDS levels, indicative of pollution from external sources.

Mishra and Yadav, (1978); Munawar, (1970); Goel *et al.,* (1980); Chourasia and Adoni, (1985). According to Sayed and Gupta (2010), rising chloride levels in rivers may result from the accumulation of organic waste, especially of animal origin. The chloride concentrations on kole wetlands exhibited moderate level and indicate low organic waste accumulation in kole wetlands of Thrissur.

Basu *et al.,* (2010) reported that temperature is identified as a pivotal physical parameter with significant implications for the biota within ecosystems Seasonal and daily fluctuations in water temperature, which are natural occurrences in water bodies, play crucial roles in shaping the reproductive ability, maturation, spawning period, and development of fish (Bhatt *et al.,* 1984).

Turbidity, another crucial parameter, is positively associated with alkalinity, a finding consistent with the observations of Sen *et al.,* (2011). The strong inverse relationship between turbidity and dissolved oxygen, especially during the monsoon season, aligns with previous studies by Joshi *et al.,* (2009) and Tidame and Shinde (2012). The rise in turbidity during the monsoon season, leading to decreased dissolved oxygen, is a significant ecological phenomenon that impacts the overall dynamics of aquatic systems. Pejman *et al.,* (2009) reported the inverse relationship between temperature and dissolved oxygen is a natural mechanism, where warmer water tends to become oxygen-unsaturated more quickly and holds less dissolved oxygen.

These above statements of various studies underlines the importance of the interplay between physical parameters, as changes in one parameter can have cascading effects on others, influencing the overall health of the kole wetlands of Thrissur.

4.1.8 Correlation between fish diversity and the waterquality parameters

The relationships between various fish species and a range of environmental parameters was analysed using Pearson’s correlation. The species like *Xenentodon cancila* and *Parambassis thomassi* show strong positive correlation with multiple parameters such as water temperature, air temperature, and dissolved oxygen. *Aplocheilus lineatus* demonstrate negative correlation with several parameters, suggesting their sensitivity or avoidance of those conditions. *Channa punctata, Rasbora dandia,* and *Mystus oculatus* show relatively strong positive correlation with multiple parameters such as water temperature, pH, and chloride levels, suggesting they may prefer or thrive in conditions associated with these parameters.

The correlation also shed light on the ecological tolerance of various fish species. Species with high positive correlation across multiple parameters, such as *Rasbora dandia, Mystus montanus,* and *Channa punctata,* may possess broader ecological tolerances, enabling them to thrive in diverse environmental conditions. Conversely, species with low or negative correlation with multiple parameters may be more specialized in their habitat requirements.

Etroplus suratensis shows weak to moderate positive correlation with parameters such as water temperature, pH, and turbidity, indicating some degree of association with these factors. It exhibits a slightly stronger positive correlation with calcium and magnesium levels, suggesting a potential preference for habitats with higher concentrations of these minerals. It shares similar environmental associations with some other species, such as *Puntius dorsalis, Parambassis thomassi,* and *Anabas testudineus*, which also display positive correlation with water temperature, pH, and calcium levels. While *Puntius dorsalis* and *Parambassis thomassi* show positive correlation with dissolved oxygen (DO) levels.

The weak negative correlation with DO could indicate a tolerance for slightly lower oxygen levels or a preference for specific oxygen conditions within its habitat. S. mossambica exhibits moderate to strong positive correlation with parameters such as turbidity, pH, total hardness, calcium, magnesium, chloride, and sulphate. It also shows weak to moderate positive correlation with parameters like BOD, nitrates, and TDS.

The *O. mossambica* shares certain environmental associations with other fish species, such as *P. maculatus, W. attu*, and *A. bengalensis*, which also display positive correlation with similar parameters like turbidity, total hardness, calcium, and magnesium levels. *O. mossambica* shows positive correlation with pH, while *A. lineatus* exhibits negative correlation. The positive correlation with turbidity, pH, and various ions such as calcium, magnesium, and chloride suggest that *O. mossambica* may inhabit environments with moderate to high levels of suspended particles and dissolved minerals. The association with BOD and nitrate levels indicates that *O. mossambica* may thrive in habitats with moderate organic pollution and nutrient availability.

Certain fish species may serve as indicators of environmental quality based on their correlation with specific parameters. Species like *Megalops cyprinoides* and *Horabagrus branchysoma* display strong positive correlation with parameters like turbidity and total hardness, suggesting their association with these environmental conditions. Monitoring the abundance or health of these species could provide insights into the overall environmental condition of their habitat. *Hyporhamphus* displays a notably strong positive correlation with turbidity, implying a potential preference for or adaptation to environments with higher turbidity levels. Some fish species may serve as indicators of environmental conditions due to their strong correlation with certain parameters. *Channa punctata* and *Mystus montanus* exhibit significant correlation with multiple parameters, suggesting their potential utility as indicators for assessing water quality and ecosystem health in their habitats.

C. pseudomarulius exhibits weak to moderate positive correlation with parameters such as pH, total hardness, calcium, magnesium, chloride, and BOD. It also shows moderate positive correlation with turbidity and nitrate levels, indicating some degree of association with these environmental factors. *C. pseudomarulius* shares certain environmental associations with other fish species, such as *Channa punctata, P. maculatus,* and *Pangasius bocourti,* which also display positive correlation with similar parameters like pH, total hardness, and chloride levels.

However, it differs from some species in its associations with specific parameters. *C. pseudomarulius* shows positive correlation with BOD, *Cyprinus carpio* exhibits weak correlation or even negative correlation with the same parameter. The positive correlation with pH, total hardness, calcium, and magnesium suggest that *C. pseudomarulius* may prefer habitats with slightly alkaline to neutral water and moderate to hard water conditions.

Anguilla bengalensis shows moderate to strong positive correlation with parameters such as turbidity, DO (Dissolved Oxygen), BOD (Biochemical Oxygen Demand), nitrate, chloride, and sulphate. It exhibits weak to moderate negative correlation with parameters like water temperature, air temperature, pH, EC (Electrical Conductivity), and salinity.

The positive correlation with turbidity suggests that *A. bengalensis* may prefer habitats with higher levels of suspended particles, which could indicate suitable feeding grounds or refuge from predators. Strong positive correlation with DO, BOD, nitrate, chloride, and sulphate indicate that *A. bengalensis* may thrive in freshwater environments with sufficient oxygenation and nutrient availability.

A. bengalensis shares certain environmental associations with other fish species, such as *Labeo dussumieri* and *Pangasius bocourti*, which also display positive correlation with turbidity and nitrate levels. However, it differs from some species in its associations with specific parameters. For instance, while *A. bengalensis* shows negative correlation with water temperature and pH, *Macrognanthus guentheri* exhibits positive correlation with these parameters. The negative correlation with water temperature suggests that *A. bengalensis* may prefer cooler habitats, which is typical for eel species known to inhabit freshwater bodies with stable temperatures. The negative correlation with pH indicates that *A. bengalensis* may favor slightly acidic to neutral water conditions.

Strong positive correlation with DO and BOD indicate that *A. bengalensis* is likely well-adapted to environments with adequate oxygen levels and organic matter for food. *M. cyprinoides* shows moderate positive correlation with turbidity, EC, salinity, and alkalinity. It exhibits weak to moderate negative correlation with parameters such as water temperature, air temperature, pH, DO, BOD, and total hardness. The positive correlation with turbidity suggests that *M. cyprinoides* may prefer habitats with higher levels of suspended particles, possibly indicating suitable feeding areas or spawning grounds. Moderate positive correlation with EC, salinity, and alkalinity indicate that *M. cyprinoides* may inhabit brackish water or estuarine environments, where these parameters are typically elevated. *M. cyprinoides* shares certain environmental associations with other fish species, such as *Pangasius bocourti*, which also displays positive correlation with turbidity and EC.

However, it differs from some species in its associations with specific parameters. For instance, while *M. cyprinoides* shows a positive correlation with salinity, *Ctenopharyngodon idella* exhibits a negative correlation with this parameter. The negative correlation with water temperature suggests that *M. cyprinoides* may prefer cooler habitats, which is typical for species inhabiting estuaries or coastal areas influenced by upwelling. The positive correlation with salinity indicates that *M. cyprinoides* may have some degree of tolerance to brackish water conditions, allowing it to exploit a wider range of habitats. Negative correlation with pH, DO, and BOD suggest that *M. cyprinoides* may be sensitive to water quality degradation associated with low oxygen levels and high organic pollution.

Understanding the environmental preferences of fishes is crucial for conservation and management efforts, especially in ensuring suitable habitat conditions for its survival and reproduction. Conservation strategies should focus on maintaining water quality parameters within the preferred range of fishes and mitigating anthropogenic impacts such as pollution and habitat degradation. Association with BOD may indicate that some fishes may inhabit areas with organic pollution or actively seek out prey in nutrient-rich environments. The preferences of fishes can also help in understand that habitat preferences, microhabitat selection and may even be used as ecological indicators.

By identifying species-environment associations, conservationists can prioritize habitat protection and restoration initiatives for species with specific environmental requirements. Additionally, monitoring changes in environmental conditions through the lens of these species can provide early warnings of ecosystem degradation or pollution. Research focusing on the physiological and ecological adaptations of fish species to their environments can provide deeper insights into species-environment interactions and inform more targeted conservation strategies.

Understanding these relationships is essential for assessing water quality, identifying sources of contamination, and implementing effective management strategies to protect water resources and ecosystems. There are many studies which document the interconnected of abiotic factors in aquatic ecosystem (Trivedi *et al.,* 2009; Shinde *et al.,* 2010; Avvannavar and Shrihari, 2008). Environmental conditions, as observed by Pouilly *et al.,* (2006); Rajagopal *et al.,* (2010); Khatoon *et al.,* (2013) and Srivastava & Srivastava (2011) have a profound impact on both the diversity of species and the trophic structure of fish assemblages.

The deterioration of water bodies is a multifaceted issue influenced by various factors, including inconsistent government policies in economics, environment, nature conservation, and development planning (Turner *et al.,* 2000). The lack of good governance and management further exacerbates the challenges associated with preserving aquatic ecosystems (Kumar *et al.,* 2014). Understanding the physicochemical characteristics of aquatic ecosystems is crucial for organizing fish assemblages, as these characteristics play a significant role in shaping the environmental conditions that influence aquatic life (Marchetti and Moyle, 2001; May and Brown, (2002).

4.2 Result and discussion for the objectives 3 & 6: Estimation of annual fish production and evaluation of interventions by local self-governments in Thrissur-Ponnani kole wetlands

4.2.1 The annual fish production of Thrissur - Ponnani kole wetlands

Assessment of fish production in the Thrissur – Ponnani kole wetlands, a three-year period spanning from June 2019 to May 2022 was consolidated. Data from the production years 2019-2020, 2020-2021, and 2021-2022 were collected at 32 selected sites within the kole wetlands. The site Society Padavu reported the highest fish production, followed by Akattan, while the lowest production was observed at the site Nedupotta (Table 12).

Table 12. Fish production of Thrissur-Ponnani kole wetlands during 2019-20, 2020-21 and 2021-22, in different sites.

Sl.no.	Study sites	Fish production in kg
1.	Akattan	39778
2.	Anthikkad	14197.38
3.	Arimur	3327.5
4.	Chaladi pazhamkole	7026.76
5.	Chathankole	18159
6.	Edakalathur	7381.2
7.	Elamutha	4791.15
8.	Irumbel	2325
9.	Kadala	7307.66
10.	Kalipadam	2326.47
11.	Karika	3694
12.	Karthani Vali	17754.13
13.	Kizhakke karimpadam	4023.18
14.	Krishnaman Padavu	25058.49
15.	Kundamkuzhi	4123.2
16.	Kurudan Nalumuri	5705
17.	Madukara	1281.08
18.	Maradi kole	1920.49
19.	Nedupotta	500
20.	Olambkadav	4919.55
21.	Ompathmuri	25145.83
22.	Padinjhare karimpadam	2508.3
23.	Pandara	11767.3
24.	Ponnamutha	3949
25.	Ponnore Thazhu	17237.03
26.	Pullazhi	11286.67
27.	Puthan Kole Prayi	5733.817
28.	Puthukole	8105.34
29.	Society Padav	43424
30.	Thekkechonchira	2733.2
31.	Vadakkechonchira	6459.54
32.	Valankole	16647.75

Fish production across various study sites, showcasing a spectrum of output levels ranging from high to low. Notable high-production sites include Akattan (39778 kg), Society Padav (43424 kg), Krishnaman Padavu (25058.49 kg), and Ompathmuri (25145.83 kg). Lower production levels are observed in sites such as Nedupotta (500 kg), Madukara (1281.08 kg), Maradi kole (1920.49 kg), and Irumbel (2325 kg) (Table 12).

In examining the high-production sites, effective management strategies and favorable environmental conditions likely contribute to robust fish breeding and growth. Society Padav, in particular, stands out with its substantial production, possibly indicating successful community management practices or the presence of extensive water bodies supporting diverse fish species. Akattan's high production also suggests favorable conditions for fish reproduction.

Besides, low-production sites like Nedupotta and Madukara raise concerns regarding potential environmental challenges or insufficient management efforts. Factors such as poor water quality, habitat degradation, overfishing, and climate variations could be contributing to the lower fish yields in these areas.

To further understand the dynamics at play, detailed assessments of environmental factors such as water quality, habitat diversity, and human impacts are recommended for both high and low-production sites. Implementing sustainable management practices tailored to the specific needs of each site could help improve fish habitat and promote breeding in low-production areas, while community-based approaches may enhance the sustainability of high-production sites in the long term.

The analysis of fish production across the study sites underscores the importance of considering a range of factors in fisheries management to ensure the sustainability and productivity of aquatic ecosystems. Data on fish production across study sites provides valuable insights for ecosystem management, conservation planning, and socio-economic development initiatives within the kole wetlands. By addressing the underlying factors driving variation in fish production, stakeholders can work towards maximizing the ecological and economic benefits derived from this vital natural resource.

4.2.2 Evaluation of species specific fish production in kole wetlands

The harvesting methods in this study were categorized into two main groups:

Major and minor harvesting methods. Major harvesting involves comprehensive water filtration using large nets, covering the entire area from one end to another through dredging. The collected fishes are then packed in boxes with or without ice and transported to the market for sale. This process typically spans 2-3 weeks, contingent on the specific harvesting area in a site. On the other hand, minor harvesting includes draining water resources prior to rice cultivation, where water is pumped into a canal system from the kole wetlands. The drained area is filtered using cast nets to collect fishes, and this method lasts about one month until the water is sufficiently drained. Minor harvesting also encompasses various other minor methods practiced by primary harvesters in kole wetlands throughout the year.

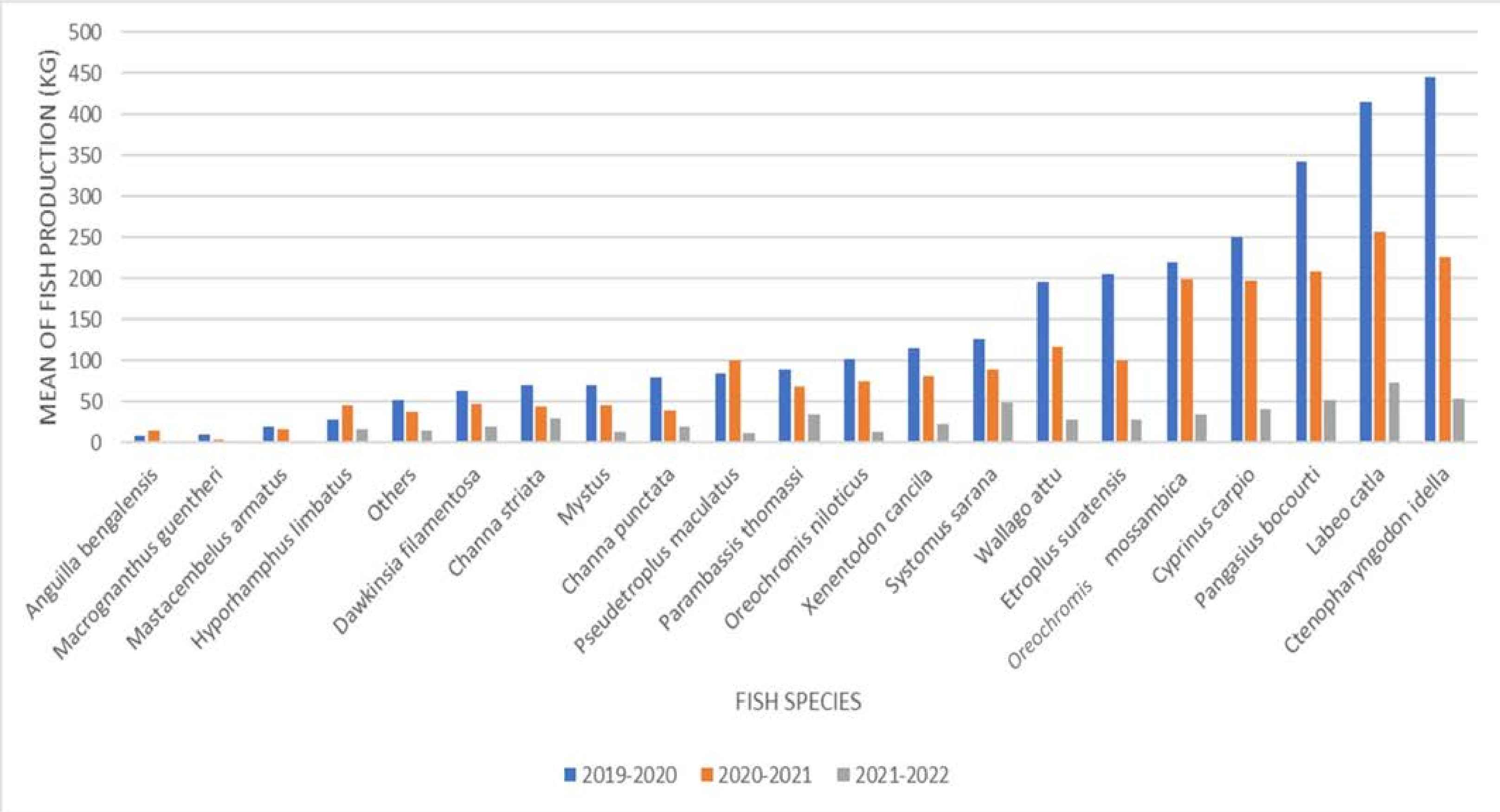
Table 13: Annual mean and standard deviation of fish species production in Thrissur-Ponnani kole wetlands.

Fish	2019-2020	2020-2021	2021-2022	Overall
Anguilla bengalensis	8.1±12.15	14.4±53.55	2.7±6.3	9.45±144.95
Macrognanthus guentheri	10.35±45.9	4.05±7.65	1.35±2.7	5.4±27
Mastacembelus armatus	19.35±52.65	16.2±49.5	1.35±2.25	12.15±42.3
Hyporhamphus limbatus	28.35±38.7	45±116.1	16.65±26.1	30.15±72.9
Others	51.75±52.2	38.25±62.1	15.75±21.6	35.1±50.4
Dawkinsia filamentosa	63.45±63	47.7±90.45	19.35±28.35	43.2±67.95
Channa striata	69.75±88.65	44.55±54.9	30.15±66.6	48.15±72.9
Mystus	70.65±76.5	45.9±57.15	13.05±18	43.2±60.75

Channa punctata	79.65±99.45	38.7±48.15	19.35±38.7	45.9±72
Pseudetroplus maculatus	83.7±103.95	100.8±282.15	12.15±22.5	65.7±177.3
Parambassis thomassi	90±63.45	67.5±31.95	35.1±13.95	64.35±40.95
Oreochromis niloticus	102.15±229.5	74.7±168.75	13.95±27	63.45±168.3
Xenentodon cancila	115.65±174.15	80.55±81.9	23.4±37.8	72.9±118.8
Systomus sarana	125.55±128.7	89.55±111.6	48.6±64.35	88.2±109.35
Wallago attu	194.85±346.05	117±287.55	27.45±44.1	113.4±268.65
Etroplus suratensis	205.2±506.25	100.8±299.25	27.9±56.25	111.15±346.95
Oreochromis mossambica	220.5±377.55	198±397.8	35.1±45.45	151.2±326.7
Cyprinus carpio	249.75±509.85	197.55±409.5	41.4±57.6	162.9±387
Pangasius bocourti	342.45±606.15	208.8±480.15	52.2±119.25	201.15±464.85
Labeo catla	414.45±722.25	257.4±576.45	73.8±93.15	248.4±551.7
Ctenopharyngodon idella	445.95±766.35	226.35±508.05	53.55±69.3	242.1±553.5

Note: "Mean" represents the annual mean, and "SD" represents the standard deviation of fish species production at each specific site within the Thrissur-Ponnani kole wetlands for the respective year.

Figure 5. Annual analysis of site- specific mean fish production trends in the kole wetlands of the Thrissur-Ponnani region.



When examining species-specific data of fish production in 2019-2022 (3 years), the average values highlighted *Labeo catla* as the most dominant species, contributing significantly with an average of 248.4 kg. Other notable contributors included *Ctenopharyngodon idella* (242.1 kg), *Pangasius bocourti* (201.15 kg), *Cyprinus carpio* (162 kg), and *Oreochromis mossambica* (151.2 kg).

Among the native species, *Wallago attu* led with a mean production of 113.4 kg, followed by *Etroplus suratensis* (111.15 kg), *Systomus sarana* (88.2 kg), *Anguilla bengalensis* (109.8 kg), *Xenentodon cancila* (72.9 kg), and *Pseudetroplus maculatus* (65.7 kg). On the lower end of the production scale were species such as

Macrognanthus guentheri (5.4 kg), *Mastacembelus armatus* (12.15 kg), *Hyporhamphus limbatus* (30.15 kg), and *Mystus* (The Mystus species include *Mystus montanus* and *Mystus armatus*) (43.2 kg) (Figure. 5).

In 2019-2020 *Ctenopharyngodon idella* emerged as the most prominent species, contributing significantly with an average of 445.95 kg. Followed by *Labeo catla* (414.45 kg), *Pangasius bocourti* (342.45 kg), *Cyprinus carpio* (249.75 kg), and *Oreochromis mossambica* (220.5 kg). Among native species, *Etroplus suratensis* led with a mean production of 205.2 kg, species such as *Anguilla bengalensis* (8.1 kg), *Macrognanthus guentheri* (10.35 kg), and *Mastacembelus armatus* (19.35 kg) reported the lowest mean production.

In 2020-2021 period, the dominant species shifted, with *Mastacembelus armatus*, *Labeo catla* taking the lead with an average production of 250.65 kg. This was followed by *Mastacembelus armatus, Ctenopharyngodon idella* (226.35 kg), *Pangasius bocourti* (200.7 kg), *Cyprinus carpio* (197.55 kg), and *Oreochromis mossambica* (198 kg). Among native fishes, *Anguilla bengalensis* exhibited dominance with a mean production of 318.6 kg, while *Wallago attu* (117 kg), *Etroplus suratensis* (100.8 kg), *Pseudetroplus maculatus* (117 kg), and *Systomus sarana* (89.55 kg) also contributed notably. Species with the lowest production during this period were *Macrognanthus guentheri* (40.5 kg), *Mastacembelus armatus (*0.36 box), *Channa striata* (44.55 kg), *Channa punctata* (38.7 kg*), Hyporhamphus limbatus* (45 kg), and Mystus (45.9 kg).

In the period spanning 2021-2022, the dominant species in fish production were identified as *Labeo catla*, contributing an average of 73.8 kg, followed by *Ctenopharyngodon idella* (53.55 kg), *Pangasius bocourti* (52.2 kg), *Cyprinus* carpio (41.4 kg), and *Oreochromis mossambica* (35.1 kg). Among native species, *Parambassis thomassi* led with a mean production of 35.1 kg, followed by *Channa striata* (30.6 kg), *Channa punctata* (19.35 kg), *Wallago attu* (27.45 kg), *Etroplus suratensis* (27.9 kg), and *Xenentodon cancila* (23.4 kg). Species with the lowest production during this period was *Mastacembelus armatus* (1.35 kg), *Anguilla bengalensis* (2.7 kg), *Pseudetroplus maculatus* (12.15 kg) and Mystus (13.05 kg). The highest production from major harvesting method was observed in 2019-2020, averaging 205.2 kg, while the lowest production occurred in 2021-2022, with an average of 35.55 kg. From minor harvesting methods, the peak production was noted in 2019-2020, averaging 62.55 kg, and the lowest production was observed in 20212022, with an average of 18 Kg (Table 13).

Among native species *Etroplus suratensis, Wallago attu,* and *Anguilla bengalensis* were the important contributions to fish production across the years. However, some species, like *Macrognanthus guentheri* and *Mastacembelus armatus*, consistently reported lower production levels throughout the period, indicating potential challenges in their breeding or ecological requirements.

Table 14: Comparison of year-wise and overall mean and standard deviation of fish species production in Thrissur-Ponnani kole wetlands from two harvesting methods.

This table provides a detailed analysis of the year-wise and overall mean, along with standard deviation, of fish species production in the Thrissur-Ponnani kole wetlands.

Type	2019-2020	2020-2021	2021-2022	Overall
Major	205.2±459	106.2±836.1	35.55±62.1	130.5±556.2
Minor	61.2±105.75	39.6±62.55	18±44.1	39.6±77.4

From 2019 to 2022, mean values for both major and minor harvesting methods exhibited a consistent decline in kole wetlands. There was a notable 50% reduction in fish production in both major and minor harvesting from 2019-2020 to 2020-2021. Additionally, the overall fish production in kole wetlands experienced a continual decline over the three-year period. Examining the standard deviation of fish production values in major harvesting methods, showed an approximate 40% increase from 2019-2020 to 2021-2022, indicating increased variability in production during this period (Table 14).

The species wise fish production in study sites are depicted in appendix table 19. Here, *Labeo catla* exhibited varying production values across kole wetlands, with the highest reported in Akattan and the lowest in Maradi and Nedupotta. *Channa punctata* and *Macrognathus guentheri* displayed their highest production values in Valankole, while the lowest were observed in Kurudan nalumuri. *Macrognathus guentheri* was absent in Puthan kole prayi, Ompathmuri, Nedupotta, Maradi, and Krishnaman padav. The species Channa striata demonstrated high production in Ompathmuri (151.65 kg) and low production in Nedupotta (5.4 kg). Species including *Ctenopharyngodon idella, Cyprinus carpio, Etroplus suratensis, Mastacembelus armatus, Mystus, Pangasius bocourti,* and *Wallago attu* recorded their highest yields in kole Akattan. *Ctenopharyngodon idella* reported its lowest production mean values in Nedupotta (Appendix Table 19).

Cyprinus carpio exhibited its lowest production in Nedupotta, *while Etroplus suratensis* displayed low production in Puthukole. *Mastacembelus armatus* was absent in Anthikkad, Society padav, Maradi, and Nedupotta, and Mystus reported very low production in Madukara. *Pangasius bocourti* displayed very low production in Arimur dhashamut, and *Wallago attu* had its lowest value in Madukara.

Hyporhamphus limbatus demonstrated the highest production in Krishnaman padav and the lowest in Nedupotta. *Oreochromis niloticus* reported a high production in Puthukole and the lowest in Kalipadam. *P. maculatus* was found in high abundance in Edakalathur and absent in Chaladi pazham kole. *Oreochromis mossambica* exhibited high production in Anthikkad and low production in Nedupotta, while *Systomus sarana* showed high production in Ompathmuri and low production in Thekkekonchira.

Xenentodon cancila displayed its highest production in Puthukole and the lowest in Padinjhare karimpadam (Appendix Table: 19).

Labeo catla, for instance, exhibited differing production values across kole wetlands, with the highest reported in Akattan and the lowest in Maradi and Nedupotta. Similarly, *Channa punctata* and *Macrognathus guentheri* displayed varying production values, with their highest yields observed in Valankole and the lowest in Kurudan nalumuri. The absence of *Macrognathus guentheri* in certain wetlands like Puthan kole prayi, Ompathmuri, Nedupotta, Maradi, and Krishnaman padav indicates potential habitat constraints or limited presence of suitable breeding grounds for this species in those areas.

The distribution patterns of other species also reflect localized environmental preferences and potential constraints. For instance, *Ctenopharyngodon idella, Cyprinus carpio, Etroplus suratensis, Mastacembelus armatus, Mystus, Pangasius bocourti,* and *Wallago attu* recorded their highest yields in kole Akattan. Besides, species like *Hyporhamphus limbatus, Oreochromis niloticus, Pseudetroplus, Oreochromis mossambica, Systomus sarana,* and *Xenentodon cancila* exhibited varying production values across different wetlands.

These findings underlines the importance of site-specific management strategies tailored to the ecological needs of individual species and wetland ecosystems. Understanding the factors influencing species distribution and productivity across kole wetlands is essential for effective conservation and sustainable management practices aimed at preserving biodiversity and supporting the resilience of aquatic ecosystems. By addressing habitat degradation, water quality issues, and overfishing pressure in specific wetland areas, stakeholders can work towards maintaining healthy fish populations and ensuring the long-term sustainability of kole wetland ecosystems.

4.2.1.1 Variations of fish production in kole wetlands

Table 15: The fluctuations in ichthyofaunal production within the ThrissurPonnani kole wetlands: Variations as percentages, with negative values indicating production increase and positive values signifying production decrease.

Place	Period 2019-2020 to 2020-2021 Percentage of difference in production	Period 2020-2021 to 2021-2022 Percentage of difference in production
Olambkadav	13.40%	-15.50%
Puthan kole prayi	30.10%	-9.00%
Nedupotta	0%	0%
Maradi	77.50%	0%
Kizhakkekarimpadam	100%	0%
Chaladipazhamkole	6.90%	8.20%
Ponnamutha	0%	17.90%
Elamutha	-18.60%	23.50%
Anthikkad	20.60%	25.10%
Thekkekonchira	10.60%	28.50%
Madukara	5.30%	33.80%
Pullazhi	22.80%	34.00%
Arimur Dhashamut	1.38%	42.20%
Karthani Vali	50%	48.90%
Kundamkuzhi	-42.80%	49.20%
Kurudan Nalumuri	44.60%	64.30%
Irumbel	-24.00%	65.00%
Ompathmuri	-44.10%	70.80%
Valankole	92.50%	73.00%
Chathankole	54.90%	78.90%
Pandara	55.50%	79.30%
Edakalathur	5.30%	79.70%
Ponnore thazhu	72.10%	83.20%
Karika	51.10%	84.30%
Kadala	-19.70%	85.70%
Krishnaman padav	68.60%	85.80%

Kalipadam	1.50%	91.50%
Akattan	9.70%	92.80%
Puthukole	92.30%	-12.50%
Society padavu	-46.60%	96.30%
Padinjare karimpadam	-13.10%	100%
Vadakkekonchira	20.80%	100%

There was a 22.1% decline in overall fish production from 2019-20 to 2020-2021. During the subsequent period from 2020-2021 to 2021-2022, the fish production experienced a significant decline of 87.8%. The sites with the highest decline in fish production included Kizhakkekarimpadam, showing a 100% decrease. Other sites with notable decreases were Valankole (92.5%), Maradi (77.5%), Ponnore Thazhu (72.1%), Krishnaman Padav (68.6%), Pandara (55.5%), and Chathankole (54.9%) (Table 15).

Table 15 illustrates changes in fish production across kole wetlands from 2019-20 to 2020-21, with negative values indicating an increase and positive values indicating a decrease in fish production. The site with the highest increase in fish production during this period was Society Padav (46%), followed by Ompathmuri (44%), Kundamkuzhi (42.8%), Irumbel (24%), Kadala kole (79.7%), Elamutha (18.6%), and Padinjare Karimpadam (13.1%). Nedupuzha and Ponnamutha reported no change in production. The smallest decline was observed in Arimur Rajamut (1.38%) and Kalipadam (1.5%).

In 2020-21 to 2021-22, only two sites, Olambkadav (15.5%) and Puthan Prayi kole (9.0%), experienced an increase in fish production. Three sites, namely Nedupotta, Maradi, and Kizhakkekarimpadam, reported no change in production. Significant decreases were noted in Vadakkechonchira (100%), Padinjarechonchira (100%), Society Padav (96.3%), Puthan Prayi kole (96.2%), Akattan (92.8%), Kalipadam (85.7%), Krishna man Padav (85.7%), Kadala (85.7%). The smallest decline was observed in Chaladipazham kole (8.2%), Ponnamutha (17.9%), Elamutha (23.5%), Anthikkad (25.1%), and Thekkekonchira (28.5%).

Fish production exhibited a consistent decline from 2019 to 2022 in various sites, including Ponnore Thazhu, Akattan, Anthikkad, Chaladipazham kole, Chathankole, Edakalathur (Menjhira), Kalipadam, Karika, Karthani Vali, Krishnaman Padavu, Kurudan Nalumuri, Madukara, Maradi, Pandara kole, Pullazhi, Thekkechonchira, and Valankole. In contrast, certain sites such as Ompathmuri,

Kundamkuzhi, and Kadala experienced an increase in fish production from 2019-2020 to 2020-2021. Additionally, some sites like Ponnamutha, Madukara, and Thekkechonchira reported only a slight decline during the same period.

4.2.1.2 Common dominant species in kole wetlands

The analysis identified *Labeo catla* as the most dominant and highly contributing species to fish production, consistently topping the list across all three production years. This was followed by *Ctenopharyngodon idella, Pangasius bocourti, Cyprinus carpio,* and *Oreochromis mossambica.* The highest production was reported in Society Padavu, with Akattan following closely, while Nedupotta exhibited the lowest productivity.

4.2.1.3 Dominant native species from kole wetlands

Among the native species*, Wallago attu, Etroplus suratensis, Systomus sarana, Anguilla bengalensis, Xenentodon cancila,* and *Pseudetroplus maculatus* were identified as prominent contributors. Conversely, *Macrognanthus guentheri, Mastacembelus armatus, Channa striata, Channa punctata, Hyporhamphus limbatus*, and *Mystus* exhibited lower production levels.

The introduction of exotic fish species into the kole wetlands has led to intense competition for food and habitat, resulting in a decline in native fish populations. Species like *Oreochromis mossambica, Labeo catla, Cyprinus carpio communis, Labeo rohita, Ctenopharyngodon idella,* and *Cirrhinus mrigala* have been observed in the habitat, contributing to this competition (Francis, 2015).

The findings from previous studies, as well as the observations from the present study, underlines the interconnectedness of various components within the kole wetland ecosystem. Changes in vegetation patterns can influence fish habitat and food availability, consequently impacting the foraging behaviors and distribution of piscivorous birds. Similarly, fluctuations in bird populations and feeding habits can have cascading effects on fish populations and overall ecosystem health.

The management practices in the kole wetlands exhibit significant gaps in oversight and primarily rely on local communities rather than formal state government fishery offices. This decentralized approach involves small-scale auctioning through entities such as gram panchayats, cooperative banks, and krishibhavans. However, a critical issue arises as there is a lack of systematic documentation and inquiry into fish harvesting data, exacerbating the potential ecological consequences.

The absence of proper management measures is evident in the unrestricted purchase of fish seeds by local inhabitants seeking economic benefits. Their limited awareness of scientific principles related to fish fauna poses a threat to the delicate ecological balance of the kole wetlands. Unchecked introduction of alien species, particularly since 2011, when the department of fisheries released 3000 seeds per hectare, further intensifies the ecological concerns. The release of alien fish species into the kole wetlands has the potential to disrupt the native ecosystem. Alien species often outcompete native ones for resources, leading to imbalances in population dynamics. Additionally, they may introduce diseases to which local fauna is not adapted. The lack of surveillance and documentation exacerbates the difficulty in assessing the ecological consequences of these introductions, hindering the formulation of effective conservation strategies (Result analysed based on questionnaire).

Understanding these complex biological interactions is crucial for effective wetland management and conservation efforts. Conservation strategies should aim to maintain the balance between fish populations, piscivorous bird communities, and aquatic vegetation to ensure the long-term sustainability of the kole wetlands. This involves implementing measures to preserve critical habitat, mitigate human disturbances, and promote the natural functioning of the ecosystem. By adopting an integrated approach that considers the needs of all key stakeholders, we can work towards safeguarding the ecological integrity and biodiversity of the kole wetlands for future generations.

4.2.1.4 Fish production decline in kole wetlands

A concerning trend of continuous decline in fish production was noted from 2019-2022 across various sites. Ponnore Thazhu, Akattan, Anthikkad, Chaladipazham kole, Chathankole, and others experienced a reduction, indicating potential challenges in sustaining fish populations. Some locations, such as Ompathmuri, Kundamkuzhi, and Kadala, exhibited a rise in production from 2019-2020 to 2020-2021. Minor reductions were recorded in sites like Ponnamutha, Madukara, and Thekkechonchira from 2019-2020 to 2020-2021.

The number and distribution range of fishes have been drastically reduced as a result of habitat change, overexploitation, and other anthropogenic pressures (Deka et al. 2005). Based on the questionnaire, the annual fish production of the wetland was predicted to be around 25.5 kg/ha by Bordoli, (2014). In this state, the use of unauthorised mesh sizes and a wide range of non-selective fishing gears such as mosquito nets indicates that most fishers do not comply with the existing fishery act and fishing regulations and are unconcerned about possible overexploitation of commercially important species stocks. Bordoli, (2014). In comparison to the other findings, he was judged to be low and most significant cause of fish decline is environmental degradation.

Yields range from 14 to 488 kg/ha/year, according to the Central Inland Fisheries Research Institute in Barrackpore. The average yield of 17 beels in the Brahmaputra valley is 134 kg/ha/year, while 6 beels in the Barak River yield 285 kg/ha (Sugunan and Sinha, 2001).

The decline in fish production aligns with findings from Deka, (2005) study in Assam, India, where factors such as management deficit, organic load interference, catchment condition, extrinsic influence, fishermen's ignorance, external environment, and aquaclture programs were identified as contributors to fish depletion. The study underscores the complex interplay of environmental and anthropogenic factors affecting fishery resources.

A study was carried out by Deka, (2005) in 54 wetlands across 13 districts in Assam, India, to assess the reasons of fish depletion. The study considered twentytwo variables and reported management deficit, organic load interference, catchment condition, extrinsic influence, fishermen's ignorance, external environment, and aquaculture programme are among the issues.

During 1988-1989, an alarming fall in fishing productivity (4387.31 t) was noted, with an anticipated annual yield of 7202 t in Vembanad (Kurup & Harikrishan, 2000). And it was claimed that the northern zone of the backwater, which had marine and estuary influences, produced more than the southern zone, which had fresh water influences.

Data on fish output, the Vembanad backwater fish production system experienced a considerable decrease. The fisheries in the Vembanad backwater will eventually collapse due to the barrier's faulty management, as well as illegal fishing operations such as the use of hostile gear, poison, and other anthropogenic activities (Asha *et al.,* 2014).

4.2.2 Threats facing the fish production in Thrissur-Ponnani kole wetlands

Qqq11+Conducting a long-term study on the factors impacting fish requires considerable time and is particularly challenging within the limited duration of this research. Building upon prior studies, this discourse delves into the multifaceted interplay of factors influencing fish production and the ecological balance of aquatic systems. It elucidates various threats to fish populations, emphasizing ecological factors, pesticide influences, migratory bird patterns, construction activities, aquatic weed proliferation, eutrophication dynamics, and the invasion of alien species within aquatic ecosystems.

The kole wetlands fish culture, facilitated by the fishery board, involves the introduction of fish fries weighing 100-350 kg fish fries into kole lands at the onset of the monsoon season. Common fish species include *Cyprinus carpio, Pangasius bocourti, Ctenopharyngodon idella, Oreochromis mossambica, Oreochromis niloticus,* and *Labeo catla.* However, the introduction of these cultured fishes may pose a threat to native fish species, leading to competition for food and space, thereby affecting the survival of native fauna.

The study of fish production and discovered that the depletion of fish stocks in the southern portion of the backwater was primarily caused by man-made impacts on the ecosystem, such as habitat alteration, reduction of natural grow out systems as a result of various activities such as intensification of rice cultivation and cropping pattern, physical barriers caused in the migratory pattern, overfishing, and pollution hazards caused by the excessive use of chemicals. (Kurup *et al.,* 1992). Pesticides, extensively used in the rice-cultivating fields within the kole wetlands to combat pests, emerge as a significant ecological concern. The unregulated application of these poisonous chemicals contributes to a decline in ichthyofauna by adversely affecting the fauna within the kole wetlands.

Heavy metals are the most concerning sort of aquatic pollutant because they not only degrade the life-sustaining quality of water but also harm both flora and fauna by interfering with different physiological, metabolic, and cellular processes (Shukla *et al.,* 2007; Yoon *et al.,* 2008). Toxicant contamination of the aquatic environment, particularly heavy metal pollution, has a negative impact on the survival of aquatic organisms, notably commercially significant fish species, which form the main group of aquatic system (Somaraj, *et al.,* 2005).

The presence of migratory birds in the kole wetlands has intensified in recent years, potentially due to climate changes altering their migratory patterns. The observation of piscivorous birds feeding on fish in the kole wetlands highlights the intricate ecological dynamics within this habitat with 19 species of piscivorous birds documented dining on 10 different types of fish, it becomes evident that these birds play a significant role in shaping fish populations in the wetland ecosystem (Vijayan, 1991).

The influx of these birds poses a threat to ichthyofauna by consuming substantial quantities of fish fries. Additionally, increased construction activities, such as bridge construction and deepening of kole canals, particularly in response to previous flooding events, contribute to the decline of native fish fauna. These activities elevate water turbidity for extended periods, disrupting the natural pathways of fish and leading to potential declines in fish populations.

The floating weeds cover the wetlands during pre- and post-cultivation periods, providing important habitat and food sources for various organisms. The presence of floating weeds like *Salvinia molesta, Eichhornia crassipes,* and *Cabomba caroliniana* further adds complexity to the ecological interactions within the kole wetlands (Francis, 2015). During cultivation (post-monsoon season), these plants are restricted to canals, could lead to eutriphication and potentially altering the availability of habitat and resources for fish.

Water hyacinth blocks various waterways in rivers and lakes, causing flooding during the monsoon season. Water hyacinth causes eutrophication, interferes with fishing, causes outbreaks of mosquito-borne diseases, and reduces the aesthetic value of inland wetlands (Sandliyan, 2003). Invasion of water cabbage/lettuce (*Pistia stratiotes*) and giant salvinia (*Salvinia molesta*) clogs irrigation ditches and agricultural areas. It also has an impact on aquaculture and agricultural yield (Sandliyan, 2003). Because of habitat degradation, pollution, overexploitation of aquatic resources, tourism, and the introduction of invasive exotic species, as well as alien viruses and parasites, global aquatic biodiversity is being lost at an alarming rate (Tripathi, 2015).

According to Talwar and Jhingran (1991), the introduction of commercially valuable fish species has led to a reduction in native fish populations. Many native species, particularly Indian major carps, have been critically depleted as a result of the introduction of commercially important exotic species such as Nile/red tilapia (*Oreochromis niloticus*), African catfish (*Clarias gariepinus*), Thai pangus (*Pangasiandon hypophthalmus*), and common carp (*Cyprinus carpio*) into various riverine systems (Sandilyan, 2016). Because of the significant incidence of tilapia species in interior waters in Kerala, native species such as Puntius dubius and *Labeo kontius* are facing local extinction (Sandilyan and Kathiresan, 2012). Tilapia, African catfish, Silver carp, and Gambusia are more common in Yamuna, and biomass is increasing year after year (Sandilyan and Kathiresan, 2012). In Kerala and Tamil Nadu, respectively, the invasion of ornamental sucker mouth catfishes (*Pterygoplichthys* *multiradiatus* and *Pterygoplichthys pardalis*) has caused in the decrease of commercially important inland native fish (Sandliyan, 2003)

Some negative ecological effects have been reported from the introduction of sailfin catfishes in the USA, in particular, disruption in the aquatic food chain and decline in abundance of native species as well as degradation of banks of water bodies owing to burrowing and tunneling activities (Devick, 1989; Hoover *et al.,* 2004; Page and Robins, 2006).

Many native species, particularly Indian major carps, have been critically depleted in various riverine systems as a result of the introduction of commercially important exotic species such as Nile/red tilapia (*Oreochromis niloticus*), African catfish (*Clarias gariepinus*), Thai pangus (*Pangasiandon hypophthalmus*), and common carp (*Cyprinus carpio*) (Singh *et al.,* 2014), (Singh *et al.,* 2013). Recent studies in several parts of India have revealed that freshwater fish biodiversity is depleting at an alarming rate as a result of the invasion of commercially important and ornamental, exotic fish species (Singh *et.al.,* 2014), and (Tripathi, 2015). Unauthorized activities are causing indiscriminate spread/proliferation of alien species in the wild, which slowly destroys native diversity and also affects the longterm ecological services offered. Furthermore, alien species have prepared the way for the introduction of novel infections, resulting in the breakout of new diseases (Tripathi, 2013), (Tripathi, 2015), (Singh *et al.,* 2006) and (Lakra *et al.,* 2008).

The alien species *Pterygoplichthys multiradiatus* and *Pterygoplichthys pardalis* overpopulation has led in the reduction of commercially important inland native fish in Kerala and Tamil Nadu, respectively (Singh *et al.,* 2013) (Bijukumar *et al.,* 2015). Several studies have clearly demonstrated that alien fishes frequently alter the aquatic ecology by changing water quality (e.g., increasing nitrogen and phosphorus concentrations) and causing the extinction of native fishes through predation (destroying eggs, larvae, subadults, and adults), damaging aquatic vegetation, and exploiting food resources (Tripathi, 2013), (Pimental, 2002), and (Husen, 2014).

A number of foreign fish species hybridise with indigenous species in the wild, depleting the natural genetic stock and contributing to long-term gene pool introgression (Pimental, 2002). Generally, aquarium fish invasion causes native species decrease and ecological devastation of the native system (Liang *et al.,* 2006). Goldfish has also been found to feed on the eggs, larvae, subadults, and adults of various native fishes (Richardson *et al.,* 1995). (Rowe *et al.,* 2001). Furthermore, it is a living carrier of a variety of pathogens and parasites (bacteria, viruses, protozoans, and metazoans) that it effortlessly transmits into the natural aquatic environment. This causes the spread of exotic aquatic diseases, resulting in significant economic and biodiversity losses (Tripathi, 2013).

The Platy (*Xiphophorus maculatus*) is an insectivore, is a possible food competitor for indigenous fishes such as *Haludaria fasciata, Pethia ticto, Puntius vittatus, Aplocheilus lineatus, Aplocheilus panchax,* and *Aplocheilus dayi* due to its foraging habit. Furthermore, it reaches sexual maturity in 3-4 months and becomes a potential pest in a new habitat in a short period of time (Krishnakumar *et al.,* 2009). *Poecilia reticulate* (Guppy) has been observed to kill native fish egg and larval forms in the United States. In the United States and Africa, it has developed as a direct food competitor for cyprinids, killifishes, and damselflies (Courtenary & Meffe,1989) and (Englund,1999) Furthermore, it is capable of transmitting iridoviruses, trematode and nematode parasites (Leberg and Vrijenhoek*,* 1994) and (Whittington & Chong*,* 2007).

The catch of alien invasive fishes predominate over the catch of native fishes in the fishery, and the inadvertent spread of alien invasive fishes caused by rapid aquaculture diversification and intensification has entered the Yamuna River, inflicting serious loss to the local fisheries. Singh *et al.,* (2014). Alien invasive fishes are regarded as one of the primary drivers of erosion or devastation of native fish biodiversity in freshwater ecosystems (Garca-Berthou, 2007), (Lakra *et al.,* 2008), (Singh *et al.,* 2011), and (Singh & Lakra, 2013). (Silva *et al.,* 2009). Inadvertently released invasive alien species can interact negatively with native species by modifying the quantity or quality of nutrients, competing for food and physical resources, changing habit structure, and impacting gene flow species diversity (Laprieur *et al.,* 2008) and (Xu H *et al.,* 2006).

It is now commonly acknowledged that alien species invasion is one of the most significant causes affecting fish biodiversity and breaking down geographical barriers. (Laprieur *et al.,* 2008) as well as (Xu H *et al.,* 2006). Tilapia, African catfish, silver carp, and gambusia have all been found to have disastrous effects on aquatic ecosystems (Singh *et al.,* 2011). Alien species can disrupt ecosystem functioning and are now acknowledged as primary agents of ecological change (Pimentel *et al.,* 2005; Byrnes *et al.,* 2007 and Zenetos *et al.,* 2010).

The more alien invasive fishes that are introduced into a location, the more likely it is that some of them may become invasive and cause ecological or economic damage (Clavero & Garcia –Berthau*,* 2005), (Jeschke & Strayer, 2005) and (Pysek and Richardson, 2006). This is consistent with Shukla and Singh (2013), who state that fertilisers are the primary contributors of copper, zinc, and mercury pollution in various media (Simkiss & Mason, 1984). Toxins and other unwanted compounds eventually make their way into water bodies with rain water. It degrades water quality, producing environmental imbalance and a slow but continuous deterioration of the ecosystem. As a result, aquatic creatures continue to perish (Ilavazhahan *et al.,* 2010).

4.2.3 Evaluation of local self-government interventions

Kole wetlands fisheries operate as self-governed public fishery sectors, conducting annual auctions through panchayats, cooperative banks, or krishibavan by kolewetland committees. Despite auction amounts being consistently lower than the production in kole wetlands, a significant decline in fish production was observed during the study periods, impacting the majority of sites.

4.2.3.1 Mode of marketing of fishes in kole wetlands

Fish marketing is primarily conducted locally by fishermen, with significant catches reaching city markets. Fish prices vary annually based on demand. Highly demanded species include *Channa striatus, Mastacembelus armatus, Macrognanthus guentheri, Oreochromis mossambica, Oreochromis niloticus, Heteropneustes fossilis, Hyporhamphus limbatus, Xenentodon cancila,* and *Etroplus suratensis.* High-value fish are packaged in boxes with two to three layers of ice. Local intermediaries handle small, economically unimportant, and large damaged fishes. Specific spots near kole fields are designated for marketing fish catch from kole wetlands. Small native fishes are predominantly marketed locally, while economically important larger fishes are sold in city markets, commanding higher prices due to regular market supply.

4.2.3.2 Tendering system and fishery operations

The kole wetlands fishery operates under a tendering system, wherein individuals secure the right to harvest fishes through a tendering process overseen by panchayat authorities. The tender amount varies based on the size of the koleland. Department of fisheries release fish fries annually, including cultured species like *Cyprinus carpio, Pangasius bocourti, Ctenopharyngodon idella, Oreochromis mossambica, Oreochromis niloticus,* and *Labeo catla.* Fishermen benefit from this fish culture along side native fish production.

There is a tendering amounts are relatively small compared to the total fish production value in each kole during the years 2019-2020. Additionally, there is a consistent decline in fish production from 2019-2020 to 2021-2022. The findings from the RTI queries conducted among the panchayat and authorities, as detailed in Appendix Tables 20 and 21, highlight a significant gap in consolidated data pertaining to fish species, total catch per species, and the year-wise breakdown of fish catch. Addressing these deficiencies through research endeavors becomes imperative to bridge these informational voids and enhance our understanding of local fisheries dynamics.

The prevalence of alien fish species, such as *Oreochromis niloticus, Oreochromis mossambica, Cyprinus carpio, Pangasius bocourti, Labeo catla,* and *Ctenopharyngodon idella*, in the kole wetlands raises concerns about their impact on the native fish fauna. While Tilapia, *Pangasius,* and *Cyprinus* were previously utilized for pisiculture before 2019, the dominance of *Ctenopharyngodon idella* is more prevalent in pisiculture uses in kole wetlands. Despite this, other commercial species remain common in the kole wetlands, indicating their widespread distribution as native fishes. The thriving population of Tilapia species across almost all kole wetlands of Thrissur exemplifies the invasive potential of alien species. The introduction of these commercial aliens, coupled with factors such as aquatic weeds, agricultural pesticides, and water quality changes, poses significant threats to the native fish fauna, underlines the need for conservation measures and further research to mitigate their impacts.

4.3 Result and discussion for the objectives 5: Economic evaluation of fish production in Thrissur-Ponnani kole wetland

4.3.1 Economic evaluation of fish production in kole wetlands.

Based on the data obtained from the study, we can calculate the total economic value from fish production in the kole wetlands.

Table 16: Economic value of fish production of Thrissur- Ponnani kole wetlands

Total area of kole wetlands under study	2605.828 hectare
Net return per hectare	Rs. 30312.30
Estimated total economic value from fish production	Rs. 78988660.68

The economic value derived from fish production in the kole wetlands is significant, amounting to approximately Rs. 78.99 million. This underscores the importance of the wetlands as a vital resource for the local economy, particularly in terms of supporting livelihoods through fisheries (Table 16).

The net return per hectare of Rs. 30,312.31 indicates the profitability of fish farming or fishing activities within the wetlands. This value reflects the revenue generated after accounting for production costs, suggesting that fish production in this area is economically viable.

The total area of the kole wetlands under study, spanning over 2605.828 hectares, provides the spatial context for understanding the scale of economic activity associated with fish production. These findings emphasize the economic significance of conserving and sustainably managing the kole wetlands to ensure the continued provision of valuable ecosystem services, such as fish production, which play a crucial role in supporting both local livelihoods and regional economies.

A previous study on economic evaluation of kole lands of Thrissur, Tamhankar, (2021) recorded the economic value from pisciculture was 119,635,964 (₹). The economic value derived from fish production represented one dimension of the overall economic importance of the wetland. Tamhankar, (2021) evaluated fish production at kole at a higher monetary value than this study but that was because of the difference in area assessed. Conservation of wetlands can only be spurred if there is a realistic economic benefit. Economic evaluation of fish production emphasizes the monetary return of kole conservation.

4.4 Result and discussion for objective 4: Traditional fish harvesting method in kole wetlands

4.4.1 Traditional fish harvesting methods

The current research on traditional fish harvesting methods used during the Monsoon floodplain fishery were Koodu, Ottal and Kuthuvala. Moreover, the handpicking and hunting are other fishing practices in kole wetlands of Thrissur.

4.4.2 Koodu

Koodu is the most common type of passive fish trap in Kerala. Bamboo, reed sticks, and midrib from the rachis of the coconut palm (eerkil in Malayalam) or Palmyra are used to make it. The main body and mouth are constructed separately. It is composed of two parts: the main body called Thallakkoodu (Thalla-mother, koodutrap) and the mouth called Pillakkoodu (Pilla-young). The main body is constructed from 100 sticks that are interwoven with 7-10 stitches together by coir rope at 15 cm intervals (Figure 6).

The horizontal free ends are knotted together then circularized by inserting a Pullani ring of suitable diameter. The tail portion of the main body is closed when the trap is in operation and the trapped fish is collected through this. In vernacular language, this part of the Thallakoodu is known as Peele (tail of bird)

The mouth of koodu is called pillakkoodu (also called thonnikkoodu). The 110 sticks (eerkils) were used to make pillakkoodu and these sticks are held together by five stitches of 15 cm gap.

The opposite side's free ends are interlaced so that the free parts of the sticks cross each other, leaving a circular path below and the anterior part wide to giving a conical shape (Figure 6). A bamboo pole of suitable length is cut into four pieces up to one-fourth of its length, and this fork is inserted into the angles of the interlaced sticks to keep it fit. This pillakoodu is then securely attached to the main body, without leaving any gaps for the fish to escape through.

It is fixed in the migratory path during the monsoon fishery, with its mouth in the line of water current. This traps the fish that migrate from the canals to the paddy field against the current. The koodu is superior to other devices in that it can trap all types of fish, regardless of size. The koodu reported in Annamanada Grama Panchayat.

Figure 6. Fish trap - Koodu

Figure 7. Fish trap - Ottal

4.4.3 Ottal

It is a common fish trap in Thrissur kole wetlands. The Ottal is made of 100-105 bamboo branches or bamboo sticks (Bambusa arundinaceae). The bamboo branches are stripped of their thorns, immersed in water for 20 days, and then sundried to cure, resulting in strong, insect-resistant branches. Initially, bamboo sticks/cleaned branches are tied on an iron ring with a diameter of 12-15 cm in such a way that 3 sticks per knot (34 knot x 3 sticks =102 sticks) (Figure 7).

The iron ring with 102 sticks hanging from it and serves as the Ottal's mouth. The hanging sticks are connected by five intertwines of coir rope spaced at 25 cm intervals. Inserting a ring of Pullani (a woody climber; *Calycopteris floribunda*) fabricated in appropriate diameter makes the free down end perfectly circular (pullani is cut in required length and kept tied on a coconut tree for 15 days to get a ring shape).

The mouth through which the trapped fish are extracted is softened by reeling with a coir or plastic rope. The traditional fisher folks of Marancherry, Tholur, Mullassery, Annamanada and Kuzhur Panchayat's have observed with Ottals. The fishermen use lights to locate and catch the fish. The ottal is used to catch fishes such as *Channa striata, Heteropeneustus fosslilis, C. marulius,* and *Wallago attu*.

4.4.4 Adichil

Adichil is made up of areca nut palm tree and it positioned in the water course. The areca nut palm is cut and cleaved into small poles with diameters of 1-2 cm and lengths of 8-10 ft with respect to the depth of the water column to be fixed. These are intertwined by 5-6 rows of strong coir rope after necessary curing by sun drying (Figure 8). It is a passive fish trap.

Adichil is supported by horizontal bamboo poles vertically in the watercourse and fixed across the channel. The midsection of Adichil is looped into a circle with a diameter of 0.5-1 m. The looping is done in such a way that a narrow gap at an angle of 35-45 is provided. The fish, which is swimming against the current, enters the loop and becomes entrapped. To collect the fish, the fishermen enter the loop through a ladder fixed outside the loop (Figure 8).

The Adichil is typically installed in major canals that connect to rivers. The Panchayat-built sluice proved to be an ideal location for installing the Adichil. Adichil is operated on for the first 5-6 days after the monsoon begins. The location of the Adichil in the watercourse is chosen based on the strength of the canal bank, fish movements, level of disturbance, and other factors.

According to an interview with the fishermen, the large scale catch will be on the last day, which will be marked by heavy landings of *Wallago attu, Barbodes subnasutus,* and *Horabagrus brachysoma.*

The location of the Adichil in the watercourse is chosen based on the strength of the canal bank, fish movements, level of disturbance, and other factors. Adichil's construction, maintenance, and management all require significant financial investment. An interview with the fishermen revealed that they spent approximately Rs. 45,000-50,000. A small Adichil costs between 5,000 and 10,000 rupees.

Adichil's construction, maintenance, and management all require a significant financial investment. An interview with the fishermen revealed that they spent approximately Rs. 45,000-50,000. A small Adichil costs between 5,000 and 10,000 rupees. Adichil construction and management are usually done by a group of 4-10 people, depending on the location, site and availability of fish.

Figure 8. Fish trap Adichil

4.4.5 Kuthuvala

Kuthuvala is a type of lift net with a mesh size of 10mm and a length of 5-6 feet attached well on a round girdle. Fishermen cast their nets in water with a moderate flow rate and watch intently. As the fish became trapped in the net, the moving of the fish was detected, and the net was lifted to collect the fish. Instead of the round girdle, two bamboo poles or galvanised iron (GI) pipes are sometimes used. The kuthuvala usually catches cichlids carplets, bagrids and small carps.

The hunting is usually done during the first 2-3 days when the flood plain's water at a low level. Local fishermen walk through the paddy field with knives and powerful lights. Fish that have migrated to the paddy field for pairing and lay eggs are tracked down and slashed with a knife. The fishermen pick fishes easily by hand and take advantage of the fish's rare behaviour during Ootha, in which they rarely flee when they see light or predators. The fishermen prefer to walk in small channels through which fish migrate to higher ground. This method is used to collect snakeheads and minor barbs that shoal into the paddy field.

It is a common fish trap in Thrissur kole wetlands. The Ottal is made of 100-105 bamboo branches or bamboo sticks (*Bambusa arundinaceae*). The bamboo branches are stripped of their thorns, immersed in water for 20 days, and then sundried to cure, resulting in strong, insect-resistant branches. Initially, bamboo sticks/cleaned branches are tied on an iron ring with a diameter of 12-15 cm in such a way that 3 sticks per knot (34 knot x 3 sticks =102 sticks).

The iron ring with 102 sticks hanging from it and serves as the Ottal's mouth. The hanging sticks are connected by five intertwines of coir rope spaced at 25 cm intervals. Inserting a ring of Pullani (a woody climber; *Calycopteris floribunda*) fabricated inappropriate diameter makes the free down end perfectly circular (pullani is cut in required length and kept tied on a coconut tree for 15 days to get a ring shape). The mouth through which the trapped fish are extracted is softened by reeling with a coir or plastic rope. The traditional fisher folks of Marancherry, Tholur, Mullassery, Annamanada and Kuzhur Panchayat's have observed with Ottals. The fishermen use lights to locate and catch the fish. The ottal is used to catch fishes such as *Channa striata, Heteropeneustus fosslilis, C. marulius,* and *Wallago attu*. All these methods have been documented in Shaji & Laladhas (2017) and no new traditional harvesting methods have been developed by the lead fishermen.

PLATE 1

Fig. 1. ***Mastacembelus armatus*** **(Lacepede, 1800)**

Fig. 2. ***Macrognathus guentheri*** **(Day, 1865)**

Fig. 3. ***Anguilla bengalensis*** **(Grey and Hardwicke, 1844)**

Fig. 4. ***Heteropneustes fossilis*** **(Bloch, 1794)**

PLATE 2

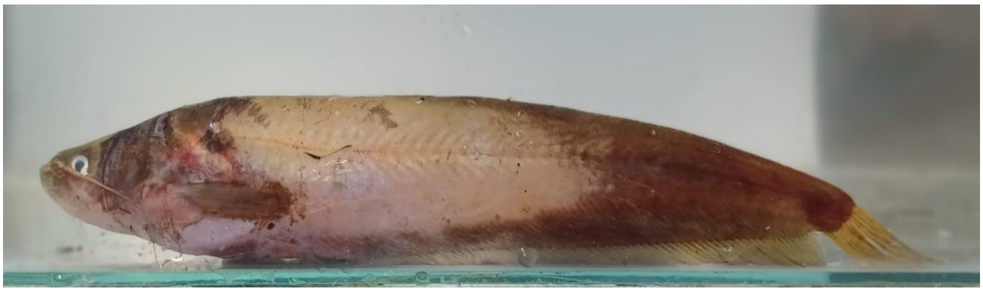


Fig. 5. *Ompok bimaculatus* (Bloch, 1794)

Fig. 6. *Wallago attu* (Schnider, 1801)

Fig. 7. *Mystus armatus* (Day, 1865)

Fig. 8. *Mystus montanus* (Jerdon, 1849)

PLATE 3

Fig. 9. ***Mystus oculatus*** **(Valenciennes, 1840)**

Fig. 10. ***Horabagrus branchysoma*** **(Günther, 1864)**

Fig. 11. ***Pangasius bocourti*** **(Sauvage, 1880)**

PLATE 4

Fig. 12. *Puntius vittatus* (Day, 1865)

Fig. 13. *Systomus sarana* (Hamilton, 1822)

Fig. 14. *Dawkinsia filamentosa* (Valenciennes, 1846)

Fig. 15. *Puntius mahecola* (Valenciennes, 1844)

PLATE 5

Fig. 16. ***Puntius dorsalis*** **(Jerdon, 1849)**

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Fig. 17. ***Labeo dussumieri*** **(Valenciennes, 1842)**

Fig. 18. ***Labeo rohita*** **(Hamilton, 1822)**

Fig. 19. ***Labeo catla*** **(Hamilton, 1822)**

PLATE 6

Fig. 20. *Cyprinus carpio* (Linnaeus, 1758)

Fig. 21. *Ctenopharyngodon idella* (Valenciennes, 1846)

Fig. 22. *Devario malabaricus* (Jerdon, 1849)

PLATE 7

Fig. 23. *Amblypharyngodon melettinus* (Valenciennes, 1844)

Fig. 24. *Esomus barbatus* (Jerdon, 1849)

Fig. 25. *Rasbora dandia* (Valenciennes, 1844)

Fig. 26. *Lepidocephalichthys thermalis* (Valenciennes, 1846)

PLATE 8

Fig. 27. ***Anabas testudineus*** **(Bloch, 1792)**

Fig. 28. ***Pseudosphromenus cupanus*** **(Cuvier, 1831)**

Fig. 29. ***Nandus nandus*** **(Hamilton, 1822)**

Fig. 30. ***Channa pseudomarulius*** **(Guenther, 1861)**

PLATE 9

Fig. 31. ***Channa punctata*** **(Bloch,1793)**

Fig. 32. ***Channa striata*** **(Bloch,1793)**

Fig. 33. ***Channa gachua*** **(Hamilton, 1822)**

Fig. 34. ***Oreochromis mossambica*** **(Peters, 1852)**

PLATE 10

Fig. 35. ***Oreochromis niloticus*** **(Linnaeus, 1758)**

Fig. 36. ***Pseudetroplus maculatus*** **(Bloch, 1795)**

Fig. 37. ***Etroplus suratensis*** **(Bloch, 1790)**

Fig. 38. ***Carinotetraodon travancoricus*** **(Hora & Nair, 1941)**

PLATE 11

Fig. 39. ***Parambassis dayi*** **(Bleeker,1874)**

Fig. 40. ***Parambassis thomassi*** **(Day,1870)**

Fig. 41. ***Megalops cyprinoides*** **(Broussonet, 1782)**

Fig. 42. ***Dayella malabarica*** **(Day, 1873)**

PLATE 12

Fig. 43. ***Aplocheilus lineatus*** **(Valenciennes,1846)**

Fig. 44. ***Glossogobius giuris*** **(Hamilton, 1822)**

Fig. 45. ***Hyporhamphus limbatus*** **(Valenciennes, 1847)**

Fig. 46. ***Xenentodon cancila*** **(Hamilton-Buchanan, 1822)**

PLATE 13

a.

b.

Figure 47.a & b: Fish harvesting in **Ompathmuri** kole wetland and packing of fishes in boxes for marketing (2020).

PLATE 14

a.

b.

Figure 48. a & b : Fish harvesting in **Kurudan nalumuri** kole wetland and packing of fishes in boxes for marketing (2020).

PLATE 15

a.

b.

Figure 49. a & b : Fish harvesting by filtering of canals in **Karika** kole wetland and packing of fishes in boxes for marketing (2022)

PLATE 16

a.

b.

Figure 50. a & b: Fish harvesting by in **Valankole** wetland and packing of fishes in boxes for marketing (2021)

PLATE 17

a.

b.

Figure 51. a & b: Fish harvesting in **Krishnaman padav** kole wetland and packing of fishes in boxes for marketing (2021)

PLATE 18

a.

b.

Figure 52. a & b: Fish harvesting in **Akattan** kole wetland and packing of fishes in boxes for marketing (2021)

PLATE 19

a.

b.

Figure 53. a & b: Fish harvesting in **Society padavu** kole wetland and packing of fishes in boxes for marketing (2022)

PLATE 20

a.

b.

Figure 54. a & b: Fish harvesting in **Ponnore thazhu** kole wetland and packing of fishes in boxes for marketing (2020)

PLATE 21

a.

b.

Figure 55. a & b: Fish harvesting in **Puthan prayi** kole and packing of fishes in boxes for marketing (2021)

PLATE 22

a.

b.

Figure 56. a & b: Fish harvesting in **Edakalathur** kole wetland and packing of fishes in boxes for marketing (2021)

PLATE 23

a.

b.

Figure 57. a & b: Fish harvesting in **Maradi** kole wetland and packing of fishes in boxes for marketing (2022)

PLATE 24

a.

b.

Figure 58. a & b: Fish harvesting in **Kizhakkekarimpadam** kole wetland and packing of fishes in boxes for marketing (2019)

PLATE 25

a.

Figure 59. a & b: Fish harvesting in **Elamutha** kole wetland and packing of fishes in boxes for marketing (2019)

PLATE 26

a.

Figure 60. a & b: Fish harvesting in **Akattan** kole wetlands (2019)

PLATE 27

a.

b.

Figure 62. a & b : Fish harvesting in **Arimpur** kole wetlands (2022)

PLATE 28

a.

b.

Figure 62. a & b : Fish harvesting in **Society padav** kole wetlands (2021)

PLATE 29

a.

b.

Figure 63. a & b : Fish harvesting in **Chathankole** wetlands (2021)

PLATE 30

a.

b.

Figure 64. a & b : Fish harvesting in **Valankole** wetlands (2020)

PLATE 31

a.

b.

Figure 65. a & b : Fish harvesting in **Olambukadav** kole wetlands (2021)

PLATE 32

a.

b.

Figure 66. a & b : Site and fish harvesting in **Irumbel** kole wetlands (2022)

PLATE 33

a.

b.

Figure 67. a & b : Fish harvesting in **Pullazhi** kole wetlands (2021)

PLATE 34

a.

b.

Figure 68. a & b : Fish harvesting in **Ponnamutha** kole wetlands (2022)

PLATE 35

a.

b.

Figure 69. a & b Fish harvesting in **Anthikkad** kole wetlands (2022)

PLATE 36

a.

b.

Figure 70. a & b: Fish harvesting in **Soceity padav** kole wetlands (2020)

PLATE 37

a.

b.

Figure 71. a & b : Fish catch in **Elamutha** kole wetlands of kole (2020)

PLATE 38

a.

b.

Figure 72. a & b : Fish harvesting in **Ompathmuri** kole wetlands (2021)

PLATE 39

a.

b.

Figure 73. a & b : Fish harvesting in **Chathankole** kole wetlands (2020)

PLATE 40

a.

b.

Figure 74. a & b : Fish harvesting in **Kalipadam** kole wetlands (2021)

PLATE 41

a.

b.

Figure 75 a & b : Kurudan nalumri kole wetlands (2022)

PLATE 42

a.

b.

Figure 76. a & b : Fish harvesting in **Puthukole kole** wetlands (2022)

PLATE 43

a.

b.

Figure 77. a & b : Fish harvesting in **Edakalathur** kole wetlands (2022)

PLATE 44

a.

b.

Figure 78. a & b: Fish harvesting in **Krishnaman padavu** kole wetlands (2020)

PLATE 45

Figure 79: Cast net- Fishing operations in Thrissur kole wetlands

Figure 80: Fishing pot for collection of live fishes in kole wetlands

PLATE 46

a.

b.

Figure 81 a & b: Fish harvesting in **Kalipadam** kole wetland and packing of fishes in boxes for marketing (2022)

RECOMMENDATION

- Aquatic life conservation laws and regulations to safeguard native fishes, should be introduced as quickly as feasible to protect fishery resources.
- Local residents, fisherman and farmers should be educated through workshops and training programmes on the need of conserving biodiversity and fish populations, which are declining owing to pesticide overuse, overfishing, use of commercial fishes, sustainability of fishery resources, and the consequences of destructive/illegal fishing methods.
- Non-native species introduction should be limited and should conduct detailed studies for the use of commercial fishes in order to safeguard endemic and indigenous species.
- The use of hazardous chemical pesticides in agricultural activities should be decreased.
- Periodical monitoring of the physicochemical properties of kole water, fish fauna, and other aquatic life of water bodies should be evaluated
- The government should bring out effective legislation, regulations, awareness programmes, and conservation plans for fish diversity and conservation in kole wetlands.
- Avoiding kole wetland filling, which indirectly causes a reduction in fish diversity due to habitat destruction in that region.
- Artificial reproduction techniques should be developed for native fish fauna. And the a live gene bank, are used to conserve endangered fish species. b. A gamete/embryo bank should be created.

SUMMARY

The research conducted on the Thrissur-Ponnani kole wetlands presents a comprehensive overview of the ecosystem, focusing on various aspects such as fish species diversity, physicochemical parameters, fish production, ecological factors influencing ichthyofauna, economic evaluation, and traditional fish harvesting methods. The study presents a comprehensive analysis of the ecological dynamics, physicochemical parameters, fish abundance, and production in the Thrissur-Ponnani kole wetlands over a period spanning 2018 to 2022. The study identified a total of 46 species from 23 families and 13 orders across seven distinct sites within the wetlands. The taxonomic composition revealed Cyriniformes as the most dominant order, followed by Siluriformes and Anabantiformes. Certain species experienced declines in abundance from 2018 to 2019, while others even disappeared completely. The abundance pattern varied across months, indicating seasonal fluctuations and potential breeding or behavioural influences.

There was variations in fish abundance among different sites, with Nedupuzha exhibiting the highest abundance. Diversity indices calculated for the years 2018-2019 indicated moderate levels of diversity in the kole wetlands, with fluctuations in dominance, Simpson diversity, evenness, and Shannon diversity indices. The analysis conducted on the correlation between fish diversity and water quality parameters showed some fish species, such as *Xenentodon cancila* and *Parambassis thomassi,* exhibited strong positive correlations with multiple parameters like water temperature, air temperature, and dissolved oxygen. Conversely, species like *Aplocheilus lineatus* showed negative correlations with certain parameters, indicating their sensitivity or avoidance of those conditions.

Further, the study shed light on the ecological tolerance of various fish species. Species with broad positive correlations across multiple parameters, like *Rasbora dandia* and *Mystus montanus,* may possess broader ecological tolerances, enabling them to thrive in diverse environmental conditions. Species with low or negative

correlations with multiple parameters may be more specialized in their habitat requirements.

Certain fish species emerged as potential indicators of environmental quality based on their strong correlations with specific parameters. *Megalops cyprinoides* and *Horabagrus branchysoma* displayed strong positive correlations with parameters like turbidity and total hardness, suggesting their association with these environmental conditions. *Channa punctata* and *Mystus montanus* exhibited significant correlations with multiple parameters, indicating their potential utility as indicators for assessing water quality and ecosystem health in their habitats.

Physicochemical parameters were assessed, revealing variations between 2018 and 2019, and variations observed across different sites. Factors such as BOD, calcium, dissolved oxygen, and salinity fluctuated without a distinct trend, indicating dynamic water quality conditions influenced by multiple factors. Fish production data collected over a three-year period showed variations across study sites, with some sites reporting high production levels while others exhibited lower yields. *Labeo catla* emerged as the most dominant species contributing significantly to fish production, followed by other species like *Ctenopharyngodon idella* and *Pangasius bocourti*. However, a concerning trend of continuous decline in fish production was noted over the study period, suggesting potential challenges in sustaining fish populations.

Various factors such as fish culture practices, pesticide impacts, migratory bird presence, aquatic weeds, eutrophication, and alien species invasion were identified as influencing ichthyofauna in the kole wetlands. These factors pose threats to native fish species and contribute to habitat degradation and declining fish populations. The economic evaluation revealed the significant economic value derived from fish production in the kole wetlands, highlighting its importance for supporting livelihoods and the local economy. The economic value derived from fish production in the kole wetlands amounted to approximately Rs. 78.99 million. Traditional fish harvesting methods such as Koodu, Ottal, Kuthuvala, handpicking and hunting were also documented, providing insights into the traditional practices of fish harvesting in the region.

The research provides valuable insights into the ecological, economic, and socio-cultural aspects of the Thrissur-Ponnani kole wetlands fishery. It underscores the need for sustainable management practices to address environmental challenges and ensure the long-term viability of fish populations and the wetland ecosystem.

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APPENDICES

Appendix Table 1: The month wise fish abundance of Thrissur-Ponnani kole wetlands

Species	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
Amblypharyngodon melettinus	349	303	473	265	381	10	10	13	84	257	213	289
Ompok bimaculatus	5	2	2	2	1	2	0	2	1	3	0	6
Systomus sarana	121	132	202	100	136	10	0	3	62	153	86	220
Dawkinsia filamentosa	47	33	27	11	23	15	0	3	23	38	34	36
Channa striata	8	13	12	16	16	2	3	0	0	16	19	16
Davario malabaricus	6	8	10	4	21	0	0	1	8	9	13	15
Esomus barbatus	3	7	2	6	4	2	0	0	1	4	2	0
Mystus montanus	9	8	19	14	10	1	0	5	9	18	19	40
Mystus oculatus	3	6	18	0	7	2	0	0	6	13	21	12
Mystus armatus	3	8	17	0	8	0	0	6	4	10	18	10
Hyporhamphus limbatus	19	12	12	33	5	0	3	0	10	32	14	20
Xenentodon cancila	31	60	78	31	38	2	2	2	37	40	36	42
Etroplus suratensis	0	3	2	3	3	1	0	2	3	1	2	0
Puntius dorsalis	11	26	16	35	18	1	6	0	27	22	31	26
Parambassis thomassi	21	21	33	22	11	9	8	6	9	18	28	40
Labeo catla	2	1	4	9	3	4	2	0	2	11	3	2
Puntius mahecola	32	32	37	79	41	1	3	10	20	58	35	69
Anabas testudineus	8	23	12	31	20	4	2	5	26	25	17	17
Channa pseudomarulius	0	16	5	8	0	0	0	9	2	4	12	0
Parambassis dayi	6	8	22	4	1	0	0	2	0	10	17	6
Nandus nandus	10	0	7	6	9	6	0	1	2	9	11	15
Channa punctata	25	17	19	29	17	0	0	2	0	42	36	40

Puntius vittatus	4	9	6	4	5	0	1	0	4	15	7	4
Cyprinus carpio	1	0	5	0	0	3	0	0	3	2	6	0
Channa gachua	0	1	0	0	0	0	0	0	0	3	0	1
Oreochromis mossambica	7	12	15	13	1	2	2	6	0	10	2	11
Heteropneustes fossilis	0	2	2	0	4	0	0	0	1	1	1	0
Rasbora dandia	8	6	8	9	4	4	0	0	6	10	9	16
Pseudetroplus maculatus	32	35	43	35	27	2	0	3	57	61	39	46
Aplocheilus lineatus	0	1	0	4	0	1	3	0	5	0	2	0
Labeo rohita	3	2	2	3	2	0	3	1	5	0	1	3
Mastacembelus armatus	0	2	0	2	0	0	0	0	0	3	0	1
Anguilla bengalensis	0	2	1	0	0	0	0	0	0	1	0	0
Oreochromis niloticus	0	4	1	0	0	0	0	2	0	0	1	0
Labeo dussumieri	3	0	0	1	0	2	0	1	7	8	3	5
Lepidocephalichthys thermalis	4	5	3	4	8	0	0	0	3	6	4	7
Glossogobius aureus	1	1	0	0	0	0	0	0	4	1	0	0
Dayella malabarica	5	10	0	7	7	8	6	0	5	2	0	0
Megalops cyprinoides	0	2	4	0	1	0	0	2	4	2	0	5
Carinotetraodon travancoricus	7	4	0	0	6	1	1	2	7	0	2	6
Ctenophayngodon idella	0	0	0	0	0	0	0	0	0	0	1	2
Macrognanthus guentheri	0	2	1	1	0	0	0	0	0	0	0	0
Pseudosphromenus cupanus	6	4	7	0	3	0	0	0	0	2	0	0
Wallago attu	1	0	2	0	0	0	0	0	0	2	1	0
Horabagrus branchysoma	1	0	0	0	0	0	0	0	0	0	0	1
Pangasius bocourti	0	1	0	2	0	0	0	0	0	0	0	0

Appendix Table 2: Results of Two-way ANOVA among different factors at kole wetlands.

Source of variation	Df	Sum Sq	Mean Sq	F value	P value
Species	44	43798	995.4	61.78	0
Sites	6	1975	329.1	20.43	*9.641e-24
Species:Sites	154	14818	96.22	5.972	*1.29e-97
Residuals	4835	77903	16.11	NA	NA

Appendix Table 3: Results of one-way ANOVA among species at kole wetlands

Source of variation	Df	Sum Sq	Mean Sq	F value	P value
Species	44	43798	995.4	52.51	0
Residuals	4995	94696	18.96	NA	NA

Appendix Table 4: Results of one-way ANOVA among sites at kole wetlands

Source of variation	Df	Sum Sq	Mean Sq	F value	P value
Sites	6	1608	268	9.854	*7.872e-11
Residuals	5033	136886	27.2	NA	NA

Appendix Table 5: Results of one-way ANOVA among years at kole wetlands

Source of variation	Df	Sum Sq	Mean Sq	F value	P value
Year	1	3.002	3.002	0.1092	0.7411
Residuals	5038	138492	27.49	NA	NA

Appendix Table 6: Results of Two-way ANOVA among different factors at kole wetlands

Source of variation	Df	Sum Sq	Mean Sq	F value	P value
Year	1	3.002	3.002	0.1121	0.7378
Month	11	3820	347.3	12.97	*1.11e-24
Year:Month	11	366.4	33.31	1.244	0.2514
Residuals	5016	134305	26.78	NA	NA

Appendix Table 7: Result of one -way analysis of variance for parameters

	Df	Sum Sq	Mean Sq	F value	P value
Parameters	18	4348766	241598	382	*0
Residuals	3173	2006863	632.5	NA	NA

Appendix Table 8: Result of one -way of analysis of variance for sites

Source of variation	Df	Sum Sq	Mean Sq	F value	P value
Sites	6	1102	183.6	0.09204	0.9971
Residuals	3185	6354527	1995	NA	NA

Appendix Table 9: Result of two-way ANOVA for parameters and sites.

Source of variation	Df	Sum Sq	Mean Sq	F value	P value
Parameters	18	4348766	241598	378.5	*0
Sites	6	1102	183.6	0.2877	0.943
Parameters:Sites	108	53216	492.7	0.772	0.9602
Residuals	3059	1952545	638.3	NA	NA

Appendix Table 10: Result of two-way analysis of variance

Source of variation	Df	Sum Sq	Mean Sq	F value	P value
Month	11	90836	8258	4.193	*3.435e-06
Year	1	1013	1013	0.5143	0.4734
Month:Year	11	23988	2181	1.107	0.3508
Residuals	3168	6239792	1970	NA	NA

Appendix Table 11: Result of two- way analysis of variance

Source of variation	Df	Sum Sq	Mean Sq	F value	P value
Parameters	18	4348766	241598	395.9	*0
Year	1	1013	1013	1.66	0.1977
Parameters:Year	18	81097	4505	7.383	*4.268e-19
Residuals	3154	1924753	610.3	NA	NA

Appendix Table 12: Result of two- way analysis of variance

Source of variation	Df	Sum Sq	Mean Sq	F value	P value
Sites	6	1102	183.6	0.09187	0.9972
Year	1	1013	1013	0.5067	0.4766
Sites:Year	6	1146	191	0.09557	0.9968
Residuals	3178	6352368	1999	NA	NA

Appendix Table 13: One-way Analysis of Variance (ANOVA) results for the impact of different parameters on water quality in Thrissur–Ponnani kole wetlands: A comprehensive statistical assessment.

Source of variation	Df	Sum Sq	Mean Sq	F value	P value
Parameters	18	4348766	241598	382	*0
Residuals	3173	2006863	632.5	NA	NA

Appendix Table 14: One Analysis of Variance (ANOVA) results for site-specific variation in environmental parameters within Thrissur–Ponnani kole wetlands: Statistical evaluation of significant differences

Source of variation	Df	Sum Sq	Mean Sq	F value	P value
Sites	6	1102	183.6	0.09204	0.9971
Residuals	3185	6354527	1995	NA	NA

Appendix Table 15: Two-way Analysis of Variance (ANOVA) results: Evaluating the influence of parameters, sites, and their interaction on environmental factors in Thrissur–Ponnani kole wetlands"

Source of variation	Df	Sum Sq	Mean Sq	F value	P value
Parameters	18	4348766	241598	378.5	*0
Sites	6	1102	183.6	0.2877	0.943
Parameters:Sites	108	53216	492.7	0.772	0.9602
Residuals	3059	1952545	638.3	NA	NA

Appendix Table 16: Two-way Analysis of Variance (ANOVA) Results for Monthly and Yearly Variability, as well as their Interaction, on Environmental Parameters in Thrissur–Ponnani kole wetlands.

Source of variation	Df	Sum Sq	Mean Sq	F value	P value
Month	11	90836	8258	4.193	*3.435e-06
Year	1	1013	1013	0.5143	0.4734
Month:Year	11	23988	2181	1.107	0.3508
Residuals	3168	6239792	1970	NA	NA

Appendix Table 17: Analysis of Variance (ANOVA) results: Assessing the impact of parameters, year, and their interaction on environmental factors in Thrissur–Ponnani kole wetlands.

Source of variation	Df	Sum Sq	Mean Sq	F value	P value
Parameters	18	4348766	241598	395.9	*0
Year	1	1013	1013	1.66	0.1977
Parameters:Year	18	81097	4505	7.383	*4.268e-19
Residuals	3154	1924753	610.3	NA	NA

Appendix Table 18: Analysis of Variance (ANOVA) Results: Investigating the effects of sites, year, and their interaction on environmental variables in Thrissur–Ponnani kole wetlands

Source of variation	Df	Sum Sq	Mean Sq	F value	P value
Sites	6	1102	183.6	0.09187	0.9972
Year	1	1013	1013	0.5067	0.4766
Sites:Year	6	1146	191	0.09557	0.9968
Residuals	3178	6352368	1999	NA	NA

Appendix Table 19: Distribution of fishes over study sites in kole wetlands

Fish	Place	Mean ± SD
Anguilla bengalensis	Krishnaman padav	0±0
Anguilla bengalensis	Maradi	0±0
Anguilla bengalensis	Nedupotta	0±0
Anguilla bengalensis	Pandara	0.71±0.77
Anguilla bengalensis	Puthukole	0.15±0.22
Anguilla bengalensis	Edakalathur	0.07±0.03
Anguilla bengalensis	Irumbel	0.27±0.4
Anguilla bengalensis	Kadala	0.18±0.4
Anguilla bengalensis	Kalipadam	0.19±0.4
Anguilla bengalensis	Kizhakkekarimpadam	0.03±0.04
Anguilla bengalensis	Olambkadav	0.03±0.04
Anguilla bengalensis	Vadakkekonchira	0.05±0.04
Anguilla bengalensis	Chaladipazhamkole	0.13±0.05
Anguilla bengalensis	Arimur Dhashamut	0.2±0.07
Anguilla bengalensis	Puthan kole prayi	0.07±0.07
Anguilla bengalensis	Thekkekonchira	0.08±0.07
Anguilla bengalensis	Madukara	0.06±0.08
Anguilla bengalensis	Ompathmuri	0.05±0.08
Anguilla bengalensis	Chathankole	0.04±0.09
Anguilla bengalensis	Karthani Vali	0.04±0.09
Anguilla bengalensis	Anthikkad	0.1±0.11
Anguilla bengalensis	Padinjare karimpadam	0.13±0.15
Anguilla bengalensis	Kundamkuzhi	0.12±0.19
Anguilla bengalensis	Society padavu	0.16±0.22
Anguilla bengalensis	Akattan	0.16±0.22

Anguilla bengalensis	Kurudan Nalumuri	0.14±0.28
Anguilla bengalensis	Ponnore thazhu	0.34±0.37
Anguilla bengalensis	Karika	0.23±0.38
Anguilla bengalensis	Ponnamutha	0.35±0.38
Anguilla bengalensis	Elamutha	0.24±0.41
Anguilla bengalensis	Valankole	0.25±0.42
Anguilla bengalensis	Pullazhi	0.34±0.57
Labeo catla	Nedupotta	0.16±0.07
Labeo catla	Maradi	0.64±0.68
Labeo catla	Arimur Dhashamut	1.11±0.75
Labeo catla	Karika	1.13±1.15
Labeo catla	Thekkekonchira	1.2±0.62
Labeo catla	Irumbel	1.24±0.7
Labeo catla	Puthan kole prayi	1.45±0.96
Labeo catla	Kizhakkekarimpadam	1.5±3.21
Labeo catla	Kalipadam	1.56±1.58
Labeo catla	Padinjare karimpadam	1.58±1.28
Labeo catla	Madukara	1.67±0.82
Labeo catla	Ponnamutha	1.72±0.87
Labeo catla	Elamutha	1.82±0.83
Labeo catla	Olambkadav	1.92±0.86
Labeo catla	Chathankole	10.5±15.87
Labeo catla	Karthani Vali	10.58±14.06
Labeo catla	Ompathmuri	14.17±13.23
Labeo catla	Krishnaman padav	15.67±25.21
Labeo catla	Kundamkuzhi	2.17±0.82
Labeo catla	Vadakkekonchira	2.33±2.58
Labeo catla	Akattan	22.67±32.09

Labeo catla	Society padavu	25.5±33.73
Labeo catla	Edakalathur	3.08±3.56
Labeo catla	Kadala	3.87±4.76
Labeo catla	Pandara	3.91±4.23
Labeo catla	Chaladipazhamkole	4.08±2.69
Labeo catla	Puthukole	4.75±8.95
Labeo catla	Kurudan Nalumuri	5.06±7.64
Labeo catla	Pullazhi	6.17±5
Labeo catla	Anthikkad	6.42±6.34
Labeo catla	Ponnore thazhu	8.54±16.45
Labeo catla	Valankole	9.05±19.59
Channa punctata	Nedupotta	0.13±0.05
Channa punctata	Padinjare karimpadam	0.14±0.19
Channa punctata	Madukara	0.17±0.07
Channa punctata	Ponnamutha	0.32±0.17
Channa punctata	Maradi	0.34±0.57
Channa punctata	Kundamkuzhi	0.38±0.55
Channa punctata	Karika	0.42±0.34
Channa punctata	Irumbel	0.44±0.56
Channa punctata	Elamutha	0.47±0.77
Channa punctata	Thekkekonchira	0.49±0.41
Channa punctata	Olambkadav	0.5±0.6
Channa punctata	Kizhakkekarimpadam	0.5±0.84
Channa punctata	Kadala	0.51±0.6
Channa punctata	Arimur Dhashamut	0.54±0.39
Channa punctata	Kalipadam	0.67±0.85
Channa punctata	Pullazhi	0.8±1.09
Channa punctata	Ponnore thazhu	0.87±1.09

Channa punctata	Vadakkekonchira	0.92±0.8
Channa punctata	Kurudan Nalumuri	1.14±1.32
Channa punctata	Pandara	1.18±1.9
Channa punctata	Anthikkad	1.25±0.82
Channa punctata	Chaladipazhamkole	1.39±1.25
Channa punctata	Edakalathur	1.41±1.11
Channa punctata	Krishnaman padav	1.42±1.67
Channa punctata	Akattan	1.46±1.05
Channa punctata	Puthan kole prayi	1.47±0.69
Channa punctata	Chathankole	1.55±2.22
Channa punctata	Karthani Vali	1.61±1.65
Channa punctata	Puthukole	1.64±1.85
Channa punctata	Society padavu	1.96±1.81
Channa punctata	Ompathmuri	2.7±2.21
Channa punctata	Valankole	3.82±5.91
Channa striata	Nedupotta	0.12±0.01
Channa striata	Maradi	0.14±0.11
Channa striata	Thekkekonchira	0.16±0.06
Channa striata	Padinjare karimpadam	0.18±0.18
Channa striata	Olambkadav	0.21±0.14
Channa striata	Madukara	0.22±0.1
Channa striata	Elamutha	0.22±0.16
Channa striata	Irumbel	0.28±0.16
Channa striata	Kadala	0.29±0.36
Channa striata	Ponnamutha	0.31±0.11
Channa striata	Kundamkuzhi	0.52±0.74
Channa striata	Puthukole	0.59±0.94
Channa striata	Karika	0.61±0.54

Channa striata	Kizhakkekarimpadam	0.67±1.03
Channa striata	Kalipadam	0.72±0.77
Channa striata	Ponnore thazhu	0.78±0.95
Channa striata	Krishnaman padav	0.82±0.93
Channa striata	Arimur Dhashamut	0.87±0.45
Channa striata	Chathankole	1.04±0.84
Channa striata	Vadakkekonchira	1.17±0.93
Channa striata	Karthani Vali	1.22±0.85
Channa striata	Puthan kole prayi	1.42±0.8
Channa striata	Kurudan Nalumuri	1.53±1.32
Channa striata	Akattan	1.56±1.14
Channa striata	Anthikkad	1.58±0.92
Channa striata	Edakalathur	1.61±1.07
Channa striata	Pullazhi	1.71±1.3
Channa striata	Pandara	1.89±3.98
Channa striata	Society padavu	2.06±1.83
Channa striata	Valankole	2.66±4.71
Channa striata	Chaladipazhamkole	3.25±1.86
Channa striata	Ompathmuri	3.37±3.46
Ctenopharyngodon idella	Nedupotta	0.12±0.01
Ctenopharyngodon idella	Thekkekonchira	0.37±0.35
Ctenopharyngodon idella	Maradi	0.46±0.76
Ctenopharyngodon idella	Kizhakkekarimpadam	0.5±1.22
Ctenopharyngodon idella	Karika	0.68±0.73
Ctenopharyngodon idella	Vadakkekonchira	0.83±1.33
Ctenopharyngodon idella	Arimur Dhashamut	0.95±0.61
Ctenopharyngodon idella	Puthan kole prayi	1.11±1.6
Ctenopharyngodon idella	Kalipadam	1.53±1.73

Ctenopharyngodon idella	Edakalathur	1.7±2.4
Ctenopharyngodon idella	Kundamkuzhi	1.74±1.21
Ctenopharyngodon idella	Ponnamutha	1.81±1.93
Ctenopharyngodon idella	Chaladipazhamkole	1.92±1.16
Ctenopharyngodon idella	Chathankole	10.18±15.58
Ctenopharyngodon idella	Ompathmuri	11.67±14.76
Ctenopharyngodon idella	Krishnaman padav	13.01±26.12
Ctenopharyngodon idella	Padinjare karimpadam	2.26±2.85
Ctenopharyngodon idella	Olambkadav	2.31±1.78
Ctenopharyngodon idella	Madukara	2.86±2.45
Ctenopharyngodon idella	Akattan	25.33±27.65
Ctenopharyngodon idella	Society padavu	28.68±33.57
Ctenopharyngodon idella	Kadala	3.06±3.58
Ctenopharyngodon idella	Irumbel	3.74±5.66
Ctenopharyngodon idella	Anthikkad	3.85±3.72
Ctenopharyngodon idella	Kurudan Nalumuri	3.95±6.32
Ctenopharyngodon idella	Pullazhi	4.5±3.74
Ctenopharyngodon idella	Elamutha	4.56±5.34
Ctenopharyngodon idella	Pandara	6.69±8.92
Ctenopharyngodon idella	Puthukole	6.89±14.28
Ctenopharyngodon idella	Valankole	7.89±17.24
Ctenopharyngodon idella	Ponnore thazhu	9.06±16.3
Ctenopharyngodon idella	Karthani Vali	9.22±13.5
Cyprinus carpio	Irumbel	0.85±0.73
Cyprinus carpio	Thekkekonchira	0.76±0.96
Cyprinus carpio	Puthukole	4.47±8.63
Cyprinus carpio	Valankole	1.21±1.91
Cyprinus carpio	Kurudan Nalumuri	4.28±7.93

Cyprinus carpio	Kadala	5.67±6.95
Cyprinus carpio	Krishnaman padav	15.55±25.01
Cyprinus carpio	Nedupotta	0.08±0.01
Cyprinus carpio	Arimur Dhashamut	0.6±0.7
Cyprinus carpio	Kizhakkekarimpadam	0.33±0.82
Cyprinus carpio	Maradi	0.45±0.76
Cyprinus carpio	Ponnore thazhu	0.57±0.79
Cyprinus carpio	Olambkadav	0.98±0.57
Cyprinus carpio	Karika	0.58±0.73
Cyprinus carpio	Chaladipazhamkole	1.02±0.91
Cyprinus carpio	Vadakkekonchira	0.67±1.03
Cyprinus carpio	Padinjare karimpadam	1.26±1.6
Cyprinus carpio	Elamutha	1.38±1.11
Cyprinus carpio	Kalipadam	1.05±1.22
Cyprinus carpio	Puthan kole prayi	1.87±1.27
Cyprinus carpio	Ponnamutha	1.38±1.49
Cyprinus carpio	Kundamkuzhi	1.51±1.53
Cyprinus carpio	Anthikkad	1.63±2.04
Cyprinus carpio	Edakalathur	2.02±2.17
Cyprinus carpio	Madukara	1.63±2.25
Cyprinus carpio	Chathankole	3.67±4.31
Cyprinus carpio	Pullazhi	3.71±6.09
Cyprinus carpio	Pandara	5.43±7.55
Cyprinus carpio	Karthani Vali	10±12.12
Cyprinus carpio	Ompathmuri	12.36±14.79
Cyprinus carpio	Society padavu	12.91±18.38
Cyprinus carpio	Akattan	15.39±20.33
Dawkinsia filamentosa	Kadala	0.1±0.06

Dawkinsia filamentosa	Madukara	0.13±0.03
Dawkinsia filamentosa	Chathankole	0.15±0.1
Dawkinsia filamentosa	Irumbel	0.24±0.22
Dawkinsia filamentosa	Elamutha	0.33±0.37
Dawkinsia filamentosa	Karthani Vali	0.38±0.17
Dawkinsia filamentosa	Thekkekonchira	0.41±0.46
Dawkinsia filamentosa	Ponnamutha	0.45±0.77
Dawkinsia filamentosa	Karika	0.52±0.74
Dawkinsia filamentosa	Padinjare karimpadam	0.52±0.98
Dawkinsia filamentosa	Nedupotta	0.53±0.15
Dawkinsia filamentosa	Arimur Dhashamut	0.54±0.72
Dawkinsia filamentosa	Maradi	0.57±0.24
Dawkinsia filamentosa	Pullazhi	0.59±0.77
Dawkinsia filamentosa	Ponnore thazhu	0.61±0.76
Dawkinsia filamentosa	Olambkadav	0.67±0.5
Dawkinsia filamentosa	Anthikkad	0.71±0.94
Dawkinsia filamentosa	Puthan kole prayi	0.72±0.32
Dawkinsia filamentosa	Kurudan Nalumuri	0.92±0.86
Dawkinsia filamentosa	Kizhakkekarimpadam	0.92±1.43
Dawkinsia filamentosa	Pandara	0.96±1.24
Dawkinsia filamentosa	Puthukole	1.14±1.52
Dawkinsia filamentosa	Edakalathur	1.28±1.05
Dawkinsia filamentosa	Kundamkuzhi	1.4±1.83
Dawkinsia filamentosa	Akattan	1.48±2.33
Dawkinsia filamentosa	Chaladipazhamkole	1.5±0.63
Dawkinsia filamentosa	Vadakkekonchira	1.5±1.18
Dawkinsia filamentosa	Krishnaman padav	1.87±1.68
Dawkinsia filamentosa	Kalipadam	1.89±1.88

Dawkinsia filamentosa	Valankole	1.93±2.08
Dawkinsia filamentosa	Society padavu	2.81±5.53
Dawkinsia filamentosa	Ompathmuri	3.17±1.72
Etroplus suratensis	Padinjare karimpadam	0.06±0.05
Etroplus suratensis	Nedupotta	0.2±0.07
Etroplus suratensis	Puthukole	0.22±0.16
Etroplus suratensis	Kizhakkekarimpadam	0.25±0.61
Etroplus suratensis	Thekkekonchira	0.27±0.21
Etroplus suratensis	Ponnamutha	0.32±0.34
Etroplus suratensis	Madukara	0.43±0.77
Etroplus suratensis	Edakalathur	0.46±0.64
Etroplus suratensis	Vadakkekonchira	0.54±0.75
Etroplus suratensis	Irumbel	0.75±1.16
Etroplus suratensis	Kalipadam	0.77±0.95
Etroplus suratensis	Maradi	0.89±1.15
Etroplus suratensis	Elamutha	0.92±1.26
Etroplus suratensis	Arimur Dhashamut	0.97±0.58
Etroplus suratensis	Kundamkuzhi	0.99±0.95
Etroplus suratensis	Kurudan Nalumuri	1.01±1.17
Etroplus suratensis	Kadala	1.08±0.79
Etroplus suratensis	Pandara	1.21±1.11
Etroplus suratensis	Karika	1.43±1.54
Etroplus suratensis	Puthan kole prayi	1.53±1.37
Etroplus suratensis	Olambkadav	1.66±1.17
Etroplus suratensis	Pullazhi	1.75±0.42
Etroplus suratensis	Krishnaman padav	1.77±2.59
Etroplus suratensis	Chaladipazhamkole	1.82±0.95
Etroplus suratensis	Anthikkad	1.83±1.13

Etroplus suratensis	Society padavu	15.85±22.92
Etroplus suratensis	Akattan	18.69±28.51
Etroplus suratensis	Karthani Vali	3.83±2.14
Etroplus suratensis	Ompathmuri	3.83±2.4
Etroplus suratensis	Valankole	3.93±7.91
Etroplus suratensis	Chathankole	4.36±4.77
Etroplus suratensis	Ponnore thazhu	6.95±15.25
Hyporamphus limbatus	Kadala	0.03±0.03
Hyporamphus limbatus	Nedupotta	0.08±0.01
Hyporhamphus limbatus	Karthani Vali	0.13±0.13
Hyporhamphus limbatus	Maradi	0.18±0.1
Hyporhamphus limbatus	Kurudan Nalumuri	0.18±0.14
Hyporhamphus limbatus	Olambkadav	0.19±0.07
Hyporhamphus limbatus	Chaladipazhamkole	0.22±0.11
Hyporhamphus limbatus	Kundamkuzhi	0.22±0.19
Hyporhamphus limbatus	Padinjare karimpadam	0.24±0.38
Hyporhamphus limbatus	Arimur Dhashamut	0.27±0.15
Hyporhamphus limbatus	Pullazhi	0.29±0.37
Hyporhamphus limbatus	Thekkekonchira	0.31±0.22
Hyporhamphus limbatus	Elamutha	0.35±0.57
Hyporhamphus limbatus	Ponnore thazhu	0.42±0.78
Hyporhamphus limbatus	Kalipadam	0.43±0.45
Hyporhamphus limbatus	Karika	0.43±0.77
Hyporhamphus limbatus	Pandara	0.43±0.77
Hyporhamphus limbatus	Irumbel	0.61±0.55
Hyporhamphus limbatus	Puthan kole prayi	0.62±0.45
Hyporhamphus limbatus	Kizhakkekarimpadam	0.67±1.21
Hyporhamphus limbatus	Valankole	0.75±1.16

Hyporhamphus limbatus	Anthikkad	0.84±0.66
Hyporhamphus limbatus	Puthukole	0.85±1.57
Hyporhamphus limbatus	Society padavu	0.89±0.92
Hyporhamphus limbatus	Akattan	0.89±0.92
Hyporhamphus limbatus	Madukara	0.91±1.1
Hyporhamphus limbatus	Chathankole	1.1±0.99
Hyporhamphus limbatus	Vadakkekonchira	1.17±1.17
Hyporhamphus limbatus	Ponnamutha	1.18±1.1
Hyporhamphus limbatus	Ompathmuri	3.09±4.96
Hyporhamphus limbatus	Krishnaman padav	3.26±6.29
Macrognanthus guentheri	Kizhakkekarimpadam	0.01±0.01
Macrognanthus guentheri	Olambkadav	0.01±0.02
Macrognanthus guentheri	Edakalathur	0.02±0.02
Macrognanthus guentheri	Ponnore thazhu	0.02±0.03
Macrognanthus guentheri	Pandara	0.02±0.03
Macrognanthus guentheri	Kundamkuzhi	0.02±0.05
Macrognanthus guentheri	Puthukole	0.02±0.05
Macrognanthus guentheri	Kurudan Nalumuri	0.04±0.07
Macrognanthus guentheri	Pullazhi	0.04±0.11
Macrognanthus guentheri	Vadakkekonchira	0.05±0.09
Macrognanthus guentheri	Irumbel	0.07±0.11
Macrognanthus guentheri	Society padavu	0.08±0.09
Macrognanthus guentheri	Akattan	0.08±0.09
Macrognanthus guentheri	Chathankole	0.08±0.18
Macrognanthus guentheri	Madukara	0.09±0.08
Macrognanthus guentheri	Padinjare karimpadam	0.11±0.13
Macrognanthus guentheri	Elamutha	0.12±0.1
Macrognanthus guentheri	Arimur Dhashamut	0.14±0.08

Macrognanthus guentheri	Anthikkad	0.17±0.23
Macrognanthus guentheri	Karika	0.43±0.44
Macrognanthus guentheri	Ponnamutha	0.45±0.43
Macrognanthus guentheri	Chaladipazhamkole	0±0
Macrognanthus guentheri	Kadala	0±0
Macrognanthus guentheri	Kalipadam	0±0
Macrognanthus guentheri	Karthani Vali	0±0
Macrognanthus guentheri	Krishnaman padav	0±0
Macrognanthus guentheri	Maradi	0±0
Macrognanthus guentheri	Nedupotta	0±0
Macrognanthus guentheri	Ompathmuri	0±0
Macrognanthus guentheri	Puthan kole prayi	0±0
Macrognanthus guentheri	Thekkekonchira	0±0
Macrognanthus guentheri	Valankole	1.75±3.16
Mastacembelus armatus	Chathankole	0.01±0.02
Mastacembelus armatus	Krishnaman padav	0.01±0.02
Mastacembelus armatus	Padinjare karimpadam	0.01±0.02
Mastacembelus armatus	Pullazhi	0.01±0.02
Mastacembelus armatus	Kadala	0.02±0.03
Mastacembelus armatus	Kundamkuzhi	0.02±0.03
Mastacembelus armatus	Kurudan Nalumuri	0.02±0.05
Mastacembelus armatus	Puthan kole prayi	0.02±0.05
Mastacembelus armatus	Kalipadam	0.03±0.03
Mastacembelus armatus	Elamutha	0.03±0.04
Mastacembelus armatus	Kizhakkekarimpadam	0.03±0.05
Mastacembelus armatus	Chaladipazhamkole	0.04±0.09
Mastacembelus armatus	Olambkadav	0.04±0.09
Mastacembelus armatus	Puthukole	0.06±0.04

Mastacembelus armatus	Edakalathur	0.06±0.05
Mastacembelus armatus	Thekkekonchira	0.06±0.05
Mastacembelus armatus	Irumbel	0.06±0.07
Mastacembelus armatus	Madukara	0.06±0.07
Mastacembelus armatus	Karthani Vali	0.06±0.09
Mastacembelus armatus	Vadakkekonchira	0.07±0.05
Mastacembelus armatus	Ponnore thazhu	0.07±0.08
Mastacembelus armatus	Arimur Dhashamut	0.19±0.07
Mastacembelus armatus	Karika	0.43±0.48
Mastacembelus armatus	Ponnamutha	0.67±0.75
Mastacembelus armatus	Pandara	0.71±1.61
Mastacembelus armatus	Anthikkad	0±0
Mastacembelus armatus	Maradi	0±0
Mastacembelus armatus	Nedupotta	0±0
Mastacembelus armatus	Valankole	1.45±2.36
Mastacembelus armatus	Ompathmuri	1.53±2.33
Mastacembelus armatus	Society padavu	1.58±2.29
Mastacembelus armatus	Akattan	1.58±2.29
Mystus	Madukara	0.04±0.05
Mystus	Nedupotta	0.1±0.01
Mystus	Padinjare karimpadam	0.11±0.17
Mystus	Arimur Dhashamut	0.2±0.15
Mystus	Elamutha	0.24±0.17
Mystus	Olambkadav	0.26±0.22
Mystus	Ponnamutha	0.28±0.11
Mystus	Maradi	0.34±0.16
Mystus	Karika	0.36±0.36
Mystus	Irumbel	0.43±0.34

Mystus	Kizhakkekarimpadam	0.5±0.84
Mystus	Thekkekonchira	0.51±0.25
Mystus	Puthukole	0.53±0.4
Mystus	Anthikkad	0.77±0.48
Mystus	Edakalathur	0.92±0.48
Mystus	Kurudan Nalumuri	0.93±0.74
Mystus	Karthani Vali	0.95±0.95
Mystus	Kadala	0.99±0.83
Mystus	Chaladipazhamkole	1.08±0.58
Mystus	Puthan kole prayi	1.14±0.72
Mystus	Pullazhi	1.16±0.7
Mystus	Pandara	1.19±1.15
Mystus	Kalipadam	1.21±0.92
Mystus	Chathankole	1.23±1.55
Mystus	Kundamkuzhi	1.26±1.4
Mystus	Valankole	1.27±1.76
Mystus	Ponnore thazhu	1.53±2.79
Mystus	Vadakkekonchira	1±0.89
Mystus	Ompathmuri	2.21±1.89
Mystus	Krishnaman padav	2.33±2.23
Mystus	Society padavu	2.83±2.99
Mystus	Akattan	2.83±2.99
Oreochromis niloticus	Padinjare karimpadam	0.06±0.07
Oreochromis niloticus	Kalipadam	0.08±0.05
Oreochromis niloticus	Madukara	0.09±0.04
Oreochromis niloticus	Kadala	0.1±0.07
Oreochromis niloticus	Kundamkuzhi	0.17±0.18
Oreochromis niloticus	Nedupotta	0.2±0.1

Oreochromis niloticus	Thekkekonchira	0.2±0.24
Oreochromis niloticus	Maradi	0.27±0.43
Oreochromis niloticus	Puthan kole prayi	0.31±0.34
Oreochromis niloticus	Olambkadav	0.51±0.6
Oreochromis niloticus	Ponnamutha	0.52±0.74
Oreochromis niloticus	Arimur Dhashamut	0.58±0.71
Oreochromis niloticus	Irumbel	0.59±0.78
Oreochromis niloticus	Elamutha	0.61±0.76
Oreochromis niloticus	Karika	0.67±0.73
Oreochromis niloticus	Kizhakkekarimpadam	0.67±1.21
Oreochromis niloticus	Kurudan Nalumuri	0.83±0.8
Oreochromis niloticus	Edakalathur	0.86±1.14
Oreochromis niloticus	Pullazhi	0.88±0.7
Oreochromis niloticus	Chaladipazhamkole	1.12±0.81
Oreochromis niloticus	Vadakkekonchira	1.17±1.17
Oreochromis niloticus	Anthikkad	1.35±0.78
Oreochromis niloticus	Pandara	1.41±1.9
Oreochromis niloticus	Chathankole	1.55±1.15
Oreochromis niloticus	Akattan	2.36±1.92
Oreochromis niloticus	Karthani Vali	2.67±3.61
Oreochromis niloticus	Valankole	3.08±4.76
Oreochromis niloticus	Ompathmuri	3.17±1.6
Oreochromis niloticus	Ponnore thazhu	3.24±4.15
Oreochromis niloticus	Krishnaman padav	3.76±5.68
Oreochromis niloticus	Society padavu	6.03±9.51
Oreochromis niloticus	Puthukole	6.65±15.85
Others	Madukara	0.03±0.04
Others	Padinjare karimpadam	0.06±0.09

Others	Valankole	0.13±0.11
Others	Ponnamutha	0.19±0.16
Others	Nedupotta	0.2±0.02
Others	Elamutha	0.25±0.16
Others	Olambkadav	0.25±0.19
Others	Maradi	0.31±0.13
Others	Pullazhi	0.36±0.34
Others	Karika	0.39±0.35
Others	Kadala	0.42±0.46
Others	Thekkekonchira	0.44±0.34
Others	Irumbel	0.45±0.31
Others	Kundamkuzhi	0.54±0.38
Others	Puthukole	0.59±0.35
Others	Kurudan Nalumuri	0.63±0.87
Others	Kizhakkekarimpadam	0.67±1.03
Others	Anthikkad	0.74±0.68
Others	Arimur Dhashamut	0.75±0.27
Others	Chathankole	0.75±0.74
Others	Puthan kole prayi	0.79±0.72
Others	Kalipadam	0.86±0.72
Others	Chaladipazhamkole	0±0
Others	Ponnore thazhu	1.11±1.6
Others	Edakalathur	1.17±0.74
Others	Karthani Vali	1.25±0.61
Others	Vadakkekonchira	1.25±0.99
Others	Pandara	1.36±1.17
Others	Society padavu	1.7±1.46
Others	Akattan	1.7±1.46

Others	Krishnaman padav	2.33±1.51
Others	Ompathmuri	3.5±3.27
Pangasius bocourti	Nedupotta	0.14±0.04
Pangasius bocourti	Arimur Dhashamut	0.29±0.35
Pangasius bocourti	Thekkekonchira	0.39±0.36
Pangasius bocourti	Karika	0.55±0.81
Pangasius bocourti	Puthukole	0.89±0.75
Pangasius bocourti	Elamutha	0.89±0.93
Pangasius bocourti	Maradi	0.9±0.87
Pangasius bocourti	Irumbel	1.02±0.87
Pangasius bocourti	Kalipadam	1.05±1.22
Pangasius bocourti	Padinjare karimpadam	1.05±1.55
Pangasius bocourti	Ponnamutha	1.17±1.12
Pangasius bocourti	Kizhakkekarimpadam	1.17±2.04
Pangasius bocourti	Kundamkuzhi	1.38±1.1
Pangasius bocourti	Olambkadav	1.66±1.14
Pangasius bocourti	Puthan kole prayi	1.68±1.19
Pangasius bocourti	Madukara	1.71±1.3
Pangasius bocourti	Karthani Vali	10.83±9.83
Pangasius bocourti	Chathankole	11.18±16.61
Pangasius bocourti	Ompathmuri	11.83±12.86
Pangasius bocourti	Krishnaman padav	12.6±27.73
Pangasius bocourti	Society padavu	17.7±23.84
Pangasius bocourti	Akattan	18.19±23.44
Pangasius bocourti	Edakalathur	2.02±2.08
Pangasius bocourti	Pandara	2.85±2.84
Pangasius bocourti	Chaladipazhamkole	2.92±1.72
Pangasius bocourti	Kurudan Nalumuri	2.92±4.24

Pangasius bocourti	Vadakkekonchira	2±1.9
Pangasius bocourti	Kadala	4.37±5.61
Pangasius bocourti	Pullazhi	6.5±4.85
Pangasius bocourti	Anthikkad	6.51±7.09
Pangasius bocourti	Ponnore thazhu	7.32±15.56
Pangasius bocourti	Valankole	8.9±19.19
Parambassis thomassi	Edakalathur	1.43±0.91
Pseudetroplus maculatus	Madukara	0.08±0.08
Pseudetroplus maculatus	Padinjare karimpadam	0.11±0.1
Pseudetroplus maculatus	Kurudan Nalumuri	0.15±0.18
Pseudetroplus maculatus	Nedupotta	0.16±0.02
Pseudetroplus maculatus	Thekkekonchira	0.18±0.17
Pseudetroplus maculatus	Ponnamutha	0.19±0.05
Pseudetroplus maculatus	Maradi	0.37±0.56
Pseudetroplus maculatus	Kizhakkekarimpadam	0.5±0.84
Pseudetroplus maculatus	Karika	0.52±0.61
Pseudetroplus maculatus	Kalipadam	0.57±0.73
Pseudetroplus maculatus	Puthan kole prayi	0.6±0.7
Pseudetroplus maculatus	Elamutha	0.64±0.88
Pseudetroplus maculatus	Irumbel	0.66±0.86
Pseudetroplus maculatus	Arimur Dhashamut	0.69±0.37
Pseudetroplus maculatus	Kadala	0.69±0.48
Pseudetroplus maculatus	Olambkadav	0.79±0.78
Pseudetroplus maculatus	Kundamkuzhi	0.86±1.09
Pseudetroplus maculatus	Edakalathur	0.87±0.95
Pseudetroplus maculatus	Chaladipazhamkole	0±0
Pseudetroplus maculatus	Puthukole	1.09±2.41
Pseudetroplus maculatus	Pullazhi	1.49±1.68

Pseudetroplus maculatus	Anthikkad	1.52±0.86
Pseudetroplus maculatus	Pandara	1.76±1.87
Pseudetroplus maculatus	Krishnaman padav	1±0.89
Pseudetroplus maculatus	Vadakkekonchira	1±0.89
Pseudetroplus maculatus	Karthani Vali	2.01±2.09
Pseudetroplus maculatus	Ompathmuri	2.17±0.75
Pseudetroplus maculatus	Valankole	2.24±3.49
Pseudetroplus maculatus	Chathankole	3.03±3.06
Pseudetroplus maculatus	Society padavu	7.22±10.22
Pseudetroplus maculatus	Akattan	7.22±10.22
Pseudetroplus maculatus	Ponnore thazhu	7.59±14.08
Oreochromis mossambica	Nedupotta	0.13±0.1
Oreochromismossambica	Maradi	0.49±0.52
Oreochromis mossambica	Thekkekonchira	0.55±0.49
Oreochromis mossambica	Padinjare karimpadam	0.55±0.81
Oreochromis mossambica	Ponnamutha	0.77±0.78
Oreochromis mossambica	Madukara	0.79±0.7
Oreochromis mossambica	Elamutha	0.95±0.75
Oreochromis mossambica	Karika	0.99±1.22
Oreochromis mossambica	Irumbel	1.04±0.78
Oreochromis mossambica	Arimur Dhashamut	1.09±0.78
Oreochromis mossambica	Kizhakkekarimpadam	1.17±2.4
Oreochromis mossambica	Puthukole	1.29±2.34
Oreochromis mossambica	Olambkadav	1.34±0.97
Oreochromis mossambica	Kundamkuzhi	1.54±1.43
Oreochromis mossambica	Kalipadam	1.76±2.59
Oreochromis mossambica	Vadakkekonchira	1.83±2.32
Oreochromismossambica	Puthan kole prayi	1.94±1.72

Oreochromismossambica	Society padavu	10.69±17.62
Oreochromis mossambica	Pandara	2.27±2.12
Oreochromis mossambica	Chaladipazhamkole	2.33±0.98
Oreochromis mossambica	Edakalathur	2.35±2.23
Oreochromis mossambica	Kurudan Nalumuri	2.47±2.17
Oreochromis mossambica	Kadala	2.74±3.72
Oreochromis mossambica	Karthani Vali	4.33±5.82
Oreochromis mossambica	Ompathmuri	6.53±6.94
Oreochromis mossambica	Chathankole	6.67±9.27
Oreochromis mossambica	Valankole	6.83±12.35
Oreochromis mossambica	Pullazhi	7±8.29
Oreochromis mossambica	Ponnore thazhu	8.76±17.9
Oreochromis mossambica	Krishnaman padav	9.01±12.84
Oreochromis mossambica	Akattan	9.04±17.71
Oreochromis mossambica	Anthikkad	9.08±10.85
Systomus sarana	Thekkekonchira	0.34±0.17
Systomus sarana	Irumbel	0.36±0.35
Systomus sarana	Puthukole	0.4±0.35
Systomus sarana	Maradi	0.51±0.51
Systomus sarana	Nedupotta	0.57±0.47
Systomus sarana	Ponnamutha	0.84±0.79
Systomus sarana	Arimur Dhashamut	0.97±0.86
Systomus sarana	Chaladipazhamkole	1.17±0.52
Systomus sarana	Elamutha	1.24±1.41
Systomus sarana	Pullazhi	1.33±0.61
Systomus sarana	Kalipadam	1.39±1.31
Systomus sarana	Kadala	1.45±1.39
Systomus sarana	Karika	1.47±2.33

Systomus sarana	Kurudan Nalumuri	1.5±1.14
Systomus sarana	Padinjare karimpadam	1.56±2.28
Systomus sarana	Ponnore thazhu	1.58±2.28
Systomus sarana	Puthan kole prayi	1.67±0.75
Systomus sarana	Madukara	1.67±1.21
Systomus sarana	Olambkadav	1.72±1.72
Systomus sarana	Valankole	1.79±2.61
Systomus sarana	Kundamkuzhi	1.87±1.79
Systomus sarana	Chathankole	2.04±1.85
Systomus sarana	Karthani Vali	2.08±0.92
Systomus sarana	Kizhakkekarimpadam	2.17±3.37
Systomus sarana	Anthikkad	2.33±0.41
Systomus sarana	Pandara	2.71±3.34
Systomus sarana	Edakalathur	3.21±2.87
Systomus sarana	Krishnaman padav	3.27±3.26
Systomus sarana	Vadakkekonchira	3.33±3.08
Systomus sarana	Akattan	4.42±2.15
Systomus sarana	Ompathmuri	5.84±5.55
Systomus sarana	Society padavu	6.25±4.92
Wallago attu	Chaladipazhamkole	1±0
Wallago attu	Kalipadam	0.72±0.69
Wallago attu	Karika	0.89±0.66
Wallago attu	Padinjare karimpadam	0.65±0.87
Wallago attu	Elamutha	1.64±1.62
Wallago attu	Ponnore thazhu	3.08±4.63
Wallago attu	Pandara	4.7±4.68
Wallago attu	Ompathmuri	3.67±4.72
Wallago attu	Valankole	1.47±1.81

Wallago attu	Krishnaman padav	5.7±7.99
Wallago attu	Madukara	0.09±0.04
Wallago attu	Nedupotta	0.17±0.06
Wallago attu	Arimur Dhashamut	0.94±0.41
Wallago attu	Thekkekonchira	0.41±0.55
Wallago attu	Maradi	0.56±0.95
Wallago attu	Puthan kole prayi	0.96±1.5
Wallago attu	Irumbel	0.9±1.07
Wallago attu	Kundamkuzhi	1.03±1.23
Wallago attu	Ponnamutha	0.96±1.23
Wallago attu	Kadala	1.7±1.31
Wallago attu	Olambkadav	1.46±1.34
Wallago attu	Anthikkad	2.33±1.37
Wallago attu	Edakalathur	1.86±2.2
Wallago attu	Kurudan Nalumuri	1.76±2.22
Wallago attu	Kizhakkekarimpadam	1.33±2.42
Wallago attu	Pullazhi	2±2.47
Wallago attu	Vadakkekonchira	2.5±2.51
Wallago attu	Puthukole	1.9±3.08
Wallago attu	Karthani Vali	3.72±5.6
Wallago attu	Chathankole	4.33±5.13
Wallago attu	Society padavu	15.35±21.85
Wallago attu	Akattan	11.52±17.12
Xenentodon cancila	Madukara	0.13±0.06
Xenentodon cancila	Padinjare karimpadam	0.16±0.19
Xenentodon cancila	Nedupotta	0.24±0.02
Xenentodon cancila	Maradi	0.33±0.16
Xenentodon cancila	Arimur Dhashamut	0.45±0.53

Xenentodon cancila	Olambkadav	0.53±0.5
Xenentodon cancila	Thekkekonchira	0.78±0.64
Xenentodon cancila	Irumbel	0.78±1.09
Xenentodon cancila	Ponnamutha	0.78±1.13
Xenentodon cancila	Society padavu	0.79±0.94
Xenentodon cancila	Akattan	0.79±0.94
Xenentodon cancila	Elamutha	0.84±1.1
Xenentodon cancila	Karika	0.95±0.88
Xenentodon cancila	Puthan kole prayi	1.25±0.87
Xenentodon cancila	Valankole	1.25±1.53
Xenentodon cancila	Kurudan Nalumuri	1.27±0.91
Xenentodon cancila	Kundamkuzhi	1.32±1.94
Xenentodon cancila	Kizhakkekarimpadam	1.33±2.16
Xenentodon cancila	Karthani Vali	1.5±1.09
Xenentodon cancila	Kalipadam	1.72±1.81
Xenentodon cancila	Chaladipazhamkole	1.75±0.52
Xenentodon cancila	Vadakkekonchira	1.83±1.6
Xenentodon cancila	Ponnore thazhu	1.92±3.07
Xenentodon cancila	Pandara	2.19±1.69
Xenentodon cancila	Krishnaman padav	2.21±3.89
Xenentodon cancila	Kadala	2.23±2.73
Xenentodon cancila	Edakalathur	2.64±2.35
Xenentodon cancila	Ompathmuri	2.83±1.17
Xenentodon cancila	Anthikkad	3.25±1.99
Xenentodon cancila	Pullazhi	3.25±2.09
Xenentodon cancila	Chathankole	3.7±5.06
Xenentodon cancila	Puthukole	7.34±9.86

Appendix Table 20: Details of RTI (Right To Information act)

Date of query	Agency to which RTI filed	Date of reply	Ref. No.
15-12-2022	Maranchery grama panchayat	12-01-2023	4000925/GPO/2022/4964
15-12-2022	Adat grama panchayat	06-01-2023	400693/GGR112/GPO/2022/8715
14-12-2022	Tholur grama panchayat	05-01-2023	400698/GGR112/GA/2022/7160
14-12-2022	Arimpur grama panchayat	04-01-2023	400694/GGR112/General/2022/7872
14-12-2022	Anthikkad grama panchayat	24-01-2023	400708/GGR112/GA/2022/5165
14-12-2022	Venkidangu	23-12-2022	400702/GGR112/GPO/2022/4827
14-12-2022	Fisheries depty director’s office -Ambakkad	07-01-2023	400708/GGR112/GA/2022/5165

Appendix Table 21. The consolidated table of Panchayats auction information based on RTI reply

SL. No.	Questions	Tholur Panchayat	Adat Panchayat	Vengidagu Panchayat	Arimpur Panchayat	Anthikkad Panchayat	Maranchery Panchayat
1	Auction participated persons no.	6	3 persons	1 persons	NA	NA	NA
2	Amount of auction	NA	870, 1820 & 222 Rs	2000 Rs -2018	NA	NA	NA
3	Any demands for auction	NA	Pay 200 Rs	NA	NA	NA	NA
4	Name of persons and amount of auction	NA	870, 1820 & 222 Rs	2000 Rs -2018	NA	NA	NA
5	Non-Auction years, kole name,	7 kole	NA	2016,17, 19,20,21,22	Not from 2010	NA	NA
6	Any harvesting details	NA	NA	NA	NA	NA	NA
7	Licenced fishermen	NA	NA	Yes, 48 persons	NA	Yes, 4 persons	NA
8	Fish culturing	NA	Yes, no details	2016-17	NA	NA	NA

	on auction kole			only			
9	Fisheries office's plans in kole wetlands	Intensive farming, Subhisha, Veetu, Biofloc.	Subhisha, Veetu, Biofloc.		NA	Janakeya, Subiksha, PMASY, Veetumuttathoru.	NA
10	Fish fry released years in koles	2017	2021-22	2016-17	NA	2011	NA
11	Number of fish fries released in each kole	3000/Hector		3000/Hector	NA	3000/Hector	NA

QUESTIONNAIRE 1

FISH PRODUCTION IN THRISSUR-PONNANI KOLE WETLANDS

Name of the fishermen:

Local area/ kole:

Job type- part time or full time:

Fish harvesting months:

Places of fishing, and name of obtained fishes :

1.

2.

3.

Harvesting time and amount of fish obtained:

1.

2.

3.

Average value of fish in market:

What are the threats to the fishes of kole wetland:

The operation of fish culture (If any) and harvesting in kole wetlands and what are the procedure for it:

Harvesting methods used:

Common species and amount obtained:

Previous years harvesting details:

Date:

QUESTIONNAIRE 2

TRADITIONAL FISH HARVESTING METHODS

Name of the fishermen:

Local area/ kole:

Job type: part time or full time:

Fish harvesting months:

Harvesting methods used:

Whether any tradional harvesting methods used or not? :

If yes, specify with the construction method of the harvesting method:

Common species and amount fishes obtained by traditional harvesting methods:

Previous year Traditional fish harvesting details:

Date:

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Inland Ornamental Fish Diversity of Thrissur Kole - Part of Vembanad Kole Wetland, Kerala, India

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Abstract: Present work investigates the ornamental fishes in Thrissur kole wetlands, part of Vembanad wetland, Ramsar site in India. The ornamental fishes are the significant indicator of ecosystem. The kole wetland ecosystem harbours fish diversity and provide important water reserve and economic benefits to local people. This study also deals with the assessment of physico-chemical parameters of water samples of kole wetlands of Kerala, from sampling stations during 2017-2018 and statistical studies have been carried out by calculating correlation coefficients between different pairs of parameters. During the study 32 species of ornamental fishes belonging to 9 orders and 14 families were recorded. Among these we reported one species *Heteropneustes fossilis* as endangered (EN), 23 fish species as Least concerned (LC) and one species *Mystus montanus* as vulnerable (VU). It is found that from December 2017 to May 2018, the Atmosphere temperature (AT) has a fairy strong positive correlation with Water temperature (WT) and negative correlation between EC, DO, Calcium and Salinity. The physico-chemical parameters from June 2018-Nov 2018, showed a strong positive correlation in between acidity and WT, AT and BOD, calcium and pH, EC and BOD, turbidity and salinity, etc. The measured mean value ranges of magnesium, calcium, fluoride and iron were 4.66-80.83 (mg/l), 9.21-28.65 (mg/l), 0.098-2.82 (mg/l) and 0.19-0.79 (mg/l), respectively. All the physicochemical parameters of Kole wetlands are within the desirable limit set by WHO.

Keywords: Ornamental fishes, Statistical analysis, Physico-chemical parameters, Kole wetlands

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Introduction

Kole wetlands are the habitat for many aquatic and semi- aquatic organisms. They have many ecological importance and role in it. In Kole wetlands fishes are the main factor for the contribution of local economy. It harbours the excellent source of ornamental fishes. Documentation and characterization of ornamental fish diversity is the pivotal to assure the sustainable development and conservation of the biodiversity. Fresh water fish diversity now faces serious threat by loss of habitat and urbanization. Also ornamental fish diversity indicate the health of the ecosystem. The inland fish diversity and physico-chemical parameters give important information about the ecosystem. The ornamental fishes are brightly coloured beautiful and well adapted to their natural habitat. In this study physico-chemical parameters like

Water Temperature (C), Air Temperature (C), pH, DO (mg/l), BOD, Turbidity (NTU), EC (µS), Salinity (ppm), Acidity (mg/l), Alkalinity (mg/l), Total hardness (mg/l), Calcium (mg/l), Magnesium (mg/l), Chloride (mg/l), Fluoride (mg/l), Iron (mg/l), Nitrate (mg/l), Sulphate (mg/l) and TDS (mg/l) were tested along with fish diversity. Water quality parameters are major influencing factor in ornamental fish diversity.

Materials and Methods

An extensive fish survey has been conducted to record the ornamental fish diversity during the December 2017- November 2018, from five sites of Kole wetlands of Thrissur (Figs. 1, 2), part of Vembanad Kole wetland, Ramsar site (Vembanad-Kole Wetland, 19/08/2002, Kerala, 151,250 ha. 09°50'N 076°45'E). The largest brackish, humid tropical wetland ecosystem on the southwest coast of India, fed by 10 rivers and typical of large estuarine systems on the western coast, renowned for its clams and supporting the third largest waterfowl population in India during the winter months (Ramsar Site Information Service, 2002).

The fish samples were collected monthly from five stations along with the water samples for the analysis of the water quality parameters. The station 1 has latitude and longitude (from Mean Sea Level) 10.694897 and 75.995939, respectively. This Kole land is distributed over two districts, Thrissur and Malappuram. The location of Station 2 (10.489587, 76.129288), Station 3 (10.489587, 76.129288), Station 4 (10.489587, 76.129288) and Station 5 (10.489587, 76.129288) are in the Kole Wetlands of Thrissur, central Kerala. The water samples were collected at the depth 1 ft and the depth is measured using a marked wooden stick. In all stations the fishes were captured by vessel net (mesh size 6 mm X 6 mm), gill net (variable mesh sizes), and cast net (5 mm X 5 mm mesh size). The fishes were preserved in 10% formalin and identified according to Talwar and Jhingran (1991) and Jayaram (1999, 2006) and were confirmed from CMFRI, Cochi. The parameters like water temperature, air temperature and dissolved oxygen were analyzed at spot. The pH was measured using pH meter, electrical conductivity and turbidity were measured by conductivity and turbidity meter. The DO and BOD were calculated using the portable DO meter. The chemical parameters like calcium, magnesium, chloride, sulphate, iron, nitrate and fluoride were calculated by standard titration method. Karl-Pearson correlation coefficient (r) was used for statistical significance.

Results and Discussion

The list of collected ornamental fishes, result of hydrological factors and correlation values are presented in Tables 1, 2, 3, 4 and 5. The ornamental fishes indicate the wealth of ecosystem, since it depends on the physico-chemical properties as well as biological characteristics.

A total of 32 species of ornamental fishes belonging to 9 orders and 14 families were recorded (Figs. 3, 4) from the five sites. Among these we found one species *Heteropneustes fossilis* as endangered (EN- IUCN Red List) category, 23 fish species as Least concerned (LC) and one species *Mystus montanus* as vulnerable (VU-IUCN Red List) category. The three species *Anguilla bengalensis, Ompak bimaculatus and Wallago attu* were categorised under Near Threatened (NT) and four soecies of fishes Megalops cyprinoides. *Anabas testudineus, Puntius mahecola* and *Puntius amphibiosus* were categorized as DD (Data Deficient). The order Cypriniformes (11 species) was dominant with several species namely *Amplypharyngodon melettinus, Rasbora dandia Puntius parrah, Puntius filamentosus*, *Puntius amphibiosus, Puntius vittatus*. *Puntius sophore*, *Puntius mahecola*, *Esomus barbatus, Puntius dorsalis* and *Lepidocephalus thermalis.* The orders Siluriformes and Anabantiformes include 6 species each whereas order Synbranchiformes, Cichiliformes and Beloniformes include 2 species each. The order Anguilliformes, Elopiformes and Gobiiformes include one species each. The most dominant family recorded was Cyprinidae which

Fig.1 : Vembanad Kole Wetlands, Kerala, India.

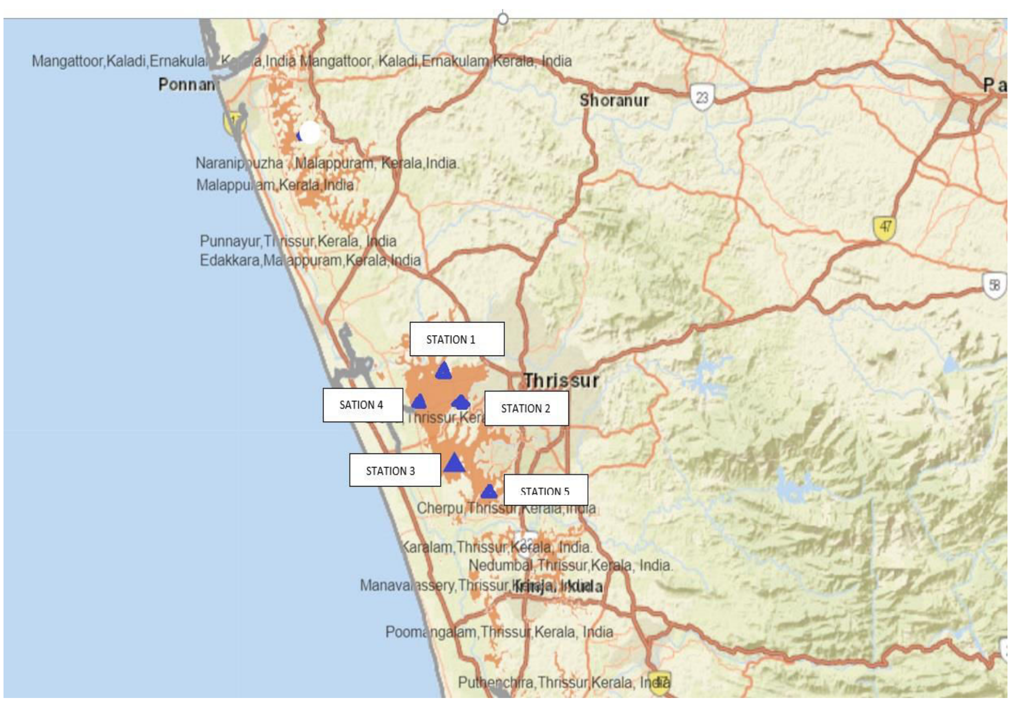

Fig. 2: Study sites of Kole Wetlands in Thrissur.

Table1: Collected ornamental fishes from Kole wetlands of Thrissur, Kerala -their status from all sampling stations

Order /Family/ Species	Common name	Local name	IUCN Status
Order : Synbranchiformes			
Family : Mastacembelidae			
1. *Mastacembelus armatus* (Lacepede, 1800)	Marble spiny eel	Aral	LC
2. *Macrognanthus guentheri* (F.Day, 1865)	Spiny Eel	Kallaral	LC
Order : Anguilliformes			
Family : Anguillidae			
3. *Anguilla bengalensis* (Grey and Hardwicke, 1844)	Long fin eel	Malinghal	NT
Order : Siluriformes			
Family : Heteropneustidae			
4. *Heteropneustes fossilis* (Bloch, 1794)	Stinging catfish	Kadu	EN
5. *Ompak bimaculatus* (Bloch, 1794)	Indian Butter-catfish	Vala	NT
6. *Wallago attu* (Schnider, 1801)	Freshwater shark	Vala	NT
7. *Danio malabaricus* (Jerdon, 1849)	Malabar danio	Thupalam kothi	LC
Family : Bagridae			
8. *Mystus armatus* (Day, 1865)	Kerala mystus	Koori	LC
9. *Mystus montanus* (Jerdon, 1849)	Jerdon's mystus	Kallenkoori	VU
Order : Cypriniformes			
Family : Cyprinidae			
10. *Amplypharyngodon melettinus* (Valenciennes,1844)	Attentive Carplet	Vayambu	LC
11. *Rasbora dandia* (Valenciennes,1844)	Black line fish	--	LC
12. *Puntius parrah* (Day, 1865)	Parrah barb	Paral	LC
13. *Puntius filamentosus* (Valenciennes,1844)	Olive barb	Poovaliparal	LC
14. *Puntius amphibiosus* (Valenciennes)	Scarlet barb	Urulan paral	DD
15. *Puntius vittatus* (Day,1865)	Stripped barb	Paral	LC
16. *Puntius sophore* (Hamilton, 1822)	Pool barb	Paral	LC
17. *Puntius mahecola* (Valenciennes,1844)	Wayanad barb	Paral	DD

18. *Esomus barbatus* (Jerdon,1849)	Flying barb	Paral	LC
19. *Puntius dorsalis* (Jerdon,1849)	Long snouted Barb	Paral	LC
Family: Cobitidae			
20. *Lepidocephalus thermalis* (Valenciennes, 1846)	Malabar loach	Koima	LC
Order *:* Anabantiformes			
Family : Channidae			
21. *Channa marulius* (Hamilton, 1822)	Snake Head	Cholan bral	LC
22. *Channa gachua* (Hamilton 1822)	Brown snake head	Vatton	LC
23. *Channa puntatus* (Day,1865)	Spotted snake head	Kadi bral	LC
24. *Channa striatus* (Bloch,1793)	Snake head	Varal	LC
Family : Anabantidae			
25. *Anabas testudineus* (Bloch,1792)	Climbing perch	Karipidi	DD
Family : Nandidae			
26. *Nandus nandus* (Hamilton,1822)	Leaf fish	Porik	LC
Order *:* Elopiformes			
Family : Elopidae			
27. *Megalops cyprinoides* (Broussonet,1782)	Tarpon	Valathan	DD
Order *:* Cichiliformes			
Family : Cichilidae			
28. *Etroplus suratensis* (Bloch)	Orange Chromidae	Pallathy	LC
29. *Etroplus maculatus* (Bloch)	Peal spot	--	LC
Order *:* Gobiiformess			
Family : Gobiidae			
30. *Glossogobius aureus*	Golden tank gopi	--	LC
Order *:* Beloniformes			
Family : Hemiramphidae			
31. *Hyporaphus limbatus* (Valenciennes,1844)	Needle fish	Koolan	LC
32. *Xenentodon cancila* (Hamilton,1822)	Long nosed needle fish	Koolan	LC

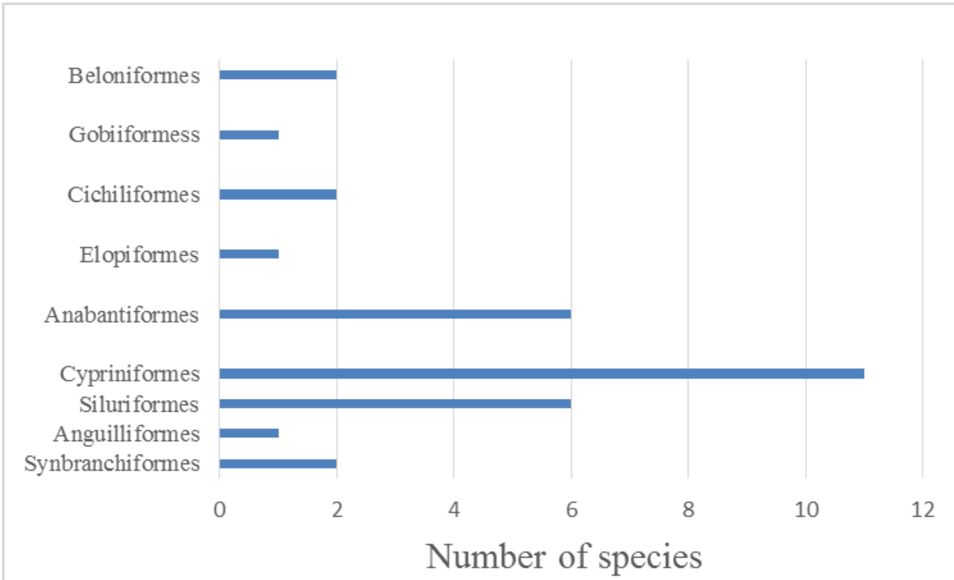

Fig. 3: Population of ornamental fish diversity under different orders.

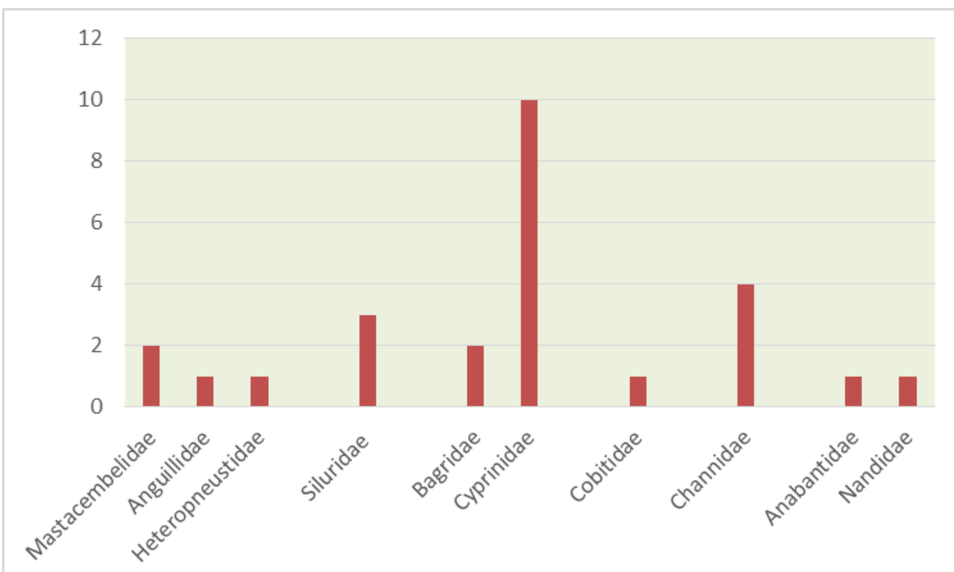

Fig 4: Population of ornamental fish diversity under different family

Table 2: The Physico-chemical parameters from Dec 2017- May 2018 (Pre- monsoon) from all stations

Physico-chemical parameters	**Site 1**	**Site 2**	**Site 3**	**Site 4**	**Site 5**
Water Temperature (C)	31	29	30	30	30
Air Temperature (C)	33	31	32	31	31
pH	6.85	7.11	6.56	6.9	7.7
DO (mg/l)	6.2	6.9	5.6	6.6	6.0
BOD	0.92	2.2	2.2	2.1	2.3
Turbidity (NTU)	95.65	108.26	85.4	65.7	103.03
EC (µS)	.3	.4	.2	.3	.3
Salinity(ppm)	.066	0.097	0.146	0.058	0.069
Acidity (mg/l)	16.33	18.5	15.1	11.85	17.16
Alkalinity(mg/l)	27.5	43.66	33.33	30.83	26.66
Total hardness (mg/l)	86.5	76.33	75.33	65.66	61
Calcium (mg/l)	17.68	28.32	28.65	18.55	16.20
Magnesium (mg/l)	4.66	5.06	7.66	7.12	5.20
Chloride (mg/l)	36.66	53.83	80.83	32.4	38.5
Fluoride (mg/l)	0.23	0.213	0.391	0.268	0.27
Iron (mg/l)	0.79	0.626	1.133	0.54	0.543
Nitrate (mg/l)	1.89	3.59	2.47	3.15	2.54
Sulphate (mg/l)	99.58	85.6	123.61	56.06	62.67
TDS (mg/l)	166.3	155.83	154.3	184.3	186.5

Table 3: The Physico-chemical parameters from June 2018-Nov 2018 (Monsoon and Post- Monsoon)

Physico-chemical parameters	**Site 1**	**Site 2**	**Site 3**	**Site 4**	**Site 5**
Water Temperature (C)	27	26	28	26	26
Air Temperature (C)	29	28	30	29	29
pH	7.53	7.21	7.06	7.03	6.95
DO (mg/l)	7.2	5.9	6.8	7.5	8.1
BOD	1.76	0.95	2.56	2.30	1.6
Turbidity (NTU)	4	1.96	2.48	10.2	6.51
EC (µS)	.2	.1	.3	.2	.2
Salinity(ppm)	0.059	0.054	0.052	0.095	0.056
Acidity (mg/l)	17.16	17	18.5	15.16	15.5
Alkalinity(mg/l)	28.66	30	37.16	30.84	33.33
Total hardness (mg/l)	59	38.1	53	49.83	56.16
Calcium (mg/l)	23.7	12.78	15.2	13.98	9.21
Magnesium (mg/l)	5.81	5.51	5.9	8.38	7.86
Chloride (mg/l)	32.83	30.33	31.16	53	31.33
Fluoride (mg/l)	0.215	0.096	0.184	2.82	0.186
Iron (mg/l)	0.55	0.19	0.19	0.66	0.466
Nitrate (mg/l)	3.96	4.93	3.84	4.17	4.03
Sulphate (mg/l)	30.51	32.06	44.43	28.05	13.9
TDS (mg/l)	122.5	98.83	119.16	145.3	134.6

Table 4: Correlation coefficient values among Physico-chemical parameters from Dec 2017 to May 2018.

	WT	AT	PH	DO	BOD	TB	EC	SA	AC	AL	TH	Ca	Mg	Cl	Fl	Fe	Nit	Sul
WT																		
AT	0.7905																	
PH	-0.2158	-0.5329																
DO	-0.4872	-0.4292	0.1777															
BOD	-0.7846	-0.8684	0.3081	0.0143														
TB	-0.264	0.0311	0.5071	0.0799	-0.0370													
EC	-0.5	-0.3952	0.4566	0.9048	8.59	0.4800												
SA	-0.3043	0.1273	-0.5124	-0.4983	0.3398	0.1076	-0.4811											
AC	-0.3037	0.0438	0.4356	0.0899	-0.0279	0.9955	0.4759	0.1777										
Al	-0.8354	-0.3620	-0.1971	0.5646	0.3707	0.2975	0.5340	0.4255	0.3698									
TH	0.3610	0.8263	-0.6099	0.0201	-0.7744	0.2216	0.0355	0.2204	0.2702	0.1979								
Ca	-0.6178	-0.0748	-0.5094	0.0202	0.3659	0.1698	-0.0191	0.8561	0.2577	0.8238	0.3015							
Mg	-0.104	-0.1736	-0.5634	-0.3742	0.4637	-0.7636	-0.6799	0.5066	-0.7267	0.0096	-0.2968	0.3531						
Cl	-0.3061	0.1242	-0.5105	-0.4986	0.3430	0.1071	-0.4813	0.9999	0.1770	0.4254	0.217	0.8558	0.5079					
Fl	0.0863	0.1115	-0.4538	-0.8101	0.3549	-0.3859	-0.9037	0.744	-0.3577	-0.1732	-0.1558	0.3695	0.8155	0.7449				
Fe	0.2329	0.5994	-0.7293	-0.6962	-0.1412	-0.0718	-0.7201	0.8467	-0.0139	0.0413	0.5084	0.5775	0.4621	0.8454	0.7608			
Nit	-0.915	-0.8231	0.1432	0.7229	0.6676	-0.0115	0.6029	0.0226	0.0212	0.7786	-0.3778	0.4368	0.1428	0.0242	-0.2606	-0.4416		
Sul	0.17933	0.67194	-0.6796	-0.5358	-0.2729	0.1745	-0.4875	0.8107	0.2381	0.1921	0.7007	0.6364	0.1985	0.8087	0.5342	0.9494	-0.4098	
TDS	0.24197	-0.39168	0.6175	0.0671	0.1203	-0.3256	0.0353	-0.7721	-0.4096	-0.6528	-0.7167	-0.8678	-0.0620	-0.7702	-0.2253	-0.7148	-0.0530	-0.859

AT = Air temperature, WT = Water temperature, TB = Turbidity, TDS = Total dissolved solid, EC = Electrical Conductivity, DO = Dissolved oxygen, BOD = Biological oxygen demand, Cl = Chloride, AL = Alkalinity, TH=Total hardness, Ca= Calcium, Mg= Magnesium, Fl= Fluoride, Fe= Iron, Nit= Nitrate, Sul= Sulphate, SA= Salinity, AC= Acidity

Table 5: Correlation coefficient values among physico-chemical parameters from June 2018-Nov 2018

	WT	**AT**	**PH**	**DO**	**BOD**	**TB**	**EC**	**SA**	**AC**	**AL**	**TH**	**Ca**	**Mg**	**Cl**	**Fl**	**Fe**	**Nit**	**Sul**
WT																		
AT	0.7905																	
PH	0.2285	-0.2312																
DO	-0.1701	0.3873	-0.3383															
BOD	0.6116	0.904	-0.2694	0.3808														
TB	-0.5057	0.0542	-0.4063	0.7090	0.3517													
EC	0.7905	1	-0.2312	0.3873	0.904	0.0542												
SA	-0.4138	-0.0393	-0.2133	0.3303	0.3716	0.8827	-0.0393											
AC	0.8596	0.3913	0.3673	-0.5994	0.1672	-0.8561	0.3913	-0.6693										
AL	0.5828	0.7556	-0.6444	0.1257	0.5818	-0.1675	0.7556	-0.2983	0.4042									
TH	0.3917	0.6507	0.1599	0.7657	0.5154	0.2538	0.6507	-0.0200	-0.0214	0.1624								
Ca	0.47798	0.15942	0.90113	- 0.15444	0.1733	-0.2268	0.1594	-0.0236	0.4196	-0.4185	0.4026							
Mg	-0.5204	0.1041	-0.6346	0.7837	0.31432	0.9479	0.1041	0.7221	-0.8617	0.0461	0.2485	-0.4815						
Cl	-0.3470	0.0302	-0.2481	0.3159	0.4400	0.8675	0.0302	0.9959	-0.6182	-0.2230	-0.0178	-0.0302	0.712					
Fl	-0.3577	0.0262	-0.2994	0.2989	0.436	0.8630	0.0262	0.9915	-0.6192	-0.1873	-0.0586	-0.0851	0.7208	0.9979				
Fe	-0.3977	0	0.0948	0.7132	0.2378	0.8536	8.14E-	0.7467	-0.7346	-0.4821	0.5085	0.2365	0.7063	0.7080	0.6717			
Nit	-0.5929	-0.890	0.0580	-0.6849	-0.7919	-0.2528	-0.8906	-0.0452	-0.1243	-0.4669	-0.9194	-0.2979	-0.2684	-0.0816	-0.0560	-0.3573		
Sul	0.7690	0.4011	0.2478	-0.6594	0.4179	-0.5249	0.4011	-0.1644	0.8309	0.3386	-0.2101	0.4183	-0.6303	-0.0978	-0.0927	-0.5314	- 0.0547	
TDS	-0.1822	0.4106	-0.3938	0.8802	0.5964	0.9148	0.4106	0.7101	-0.6583	0.0842	0.5870	-0.1097	0.8978	0.7124	0.7002	0.8243	- 0.6175	- 0.4383

AT = Air temperature, WT = Water temperature, TB = Turbidity, TDS = Total dissolved solid, EC = Electrical Conductivity, DO = Dissolved oxygen, BOD = Biological oxygen demand, Cl = Chloride, AL = Alkalinity, TH=Total hardness, Ca= Calcium, Mg= Magnesium, Fl= Fluoride, Fe= Iron, Nit= Nitrate, Sul= Sulphate, SA= Salinity, AC= Acidity

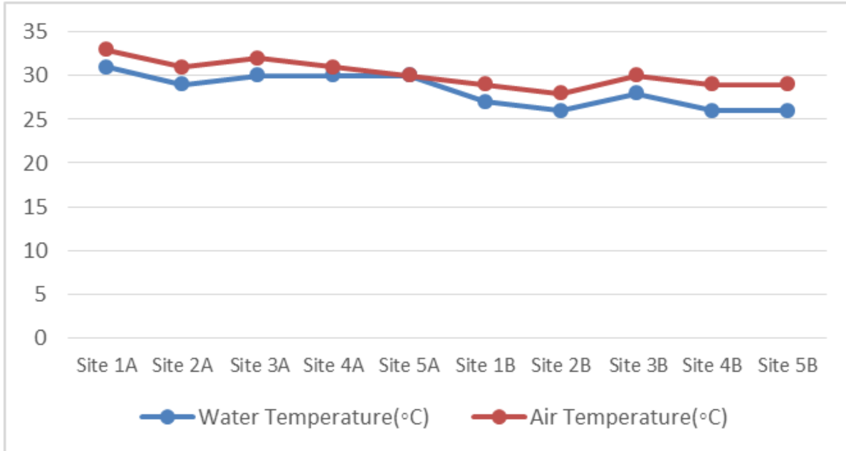

Fig. 5: Seasonal mean variations of Water temperature and Air temperature in Kole wetlands.

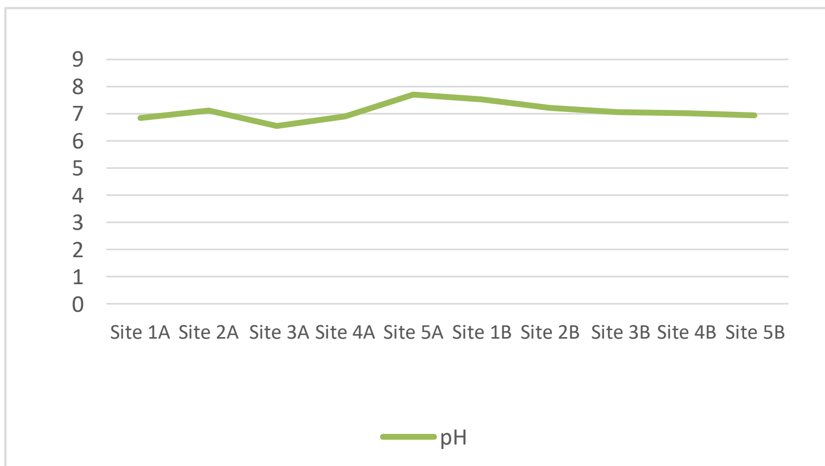

Fig. 6: Seasonal mean variations of pH in Kole wetlands.

includes 10 species of fishes. The second most dominant family was Channidae. From family Siluridae, three species were recorded. The families of Elopidae, Gobiidae, Nandidae, Anabantidae, Cobitidae, Anguillidae include one species each. The other reported fish families were Hemiramphidae, Cichilidae, Bagridae, Mastacembelidae which include two species each.

Seasonal variations of various physico-chemical parameters have been shown in Figures 5, 6, 7, 8 and 9. In the present study the water temperature ranged from 26-30 C (Tables 2, 3). The maximum temperature was 30 C recorded in the month of March and May, 2018. The minimum water temperature was recorded in the months of July and December. Water temperature plays an important role which influences the chemical, biochemical and biological characteristics of aquatic ecosystem.

The pH values of the water samples collected during the study ranged from 6.5 to 7.7. This indicated that the Kole water was moderate towards acidic values and within the desirable limit (6.5–8.5) of the Indian drinking water standard (BIS, 1991).

The value of dissolved oxygen varied from 6.9-8.8 mg/l at all stations. The EC value ranged from

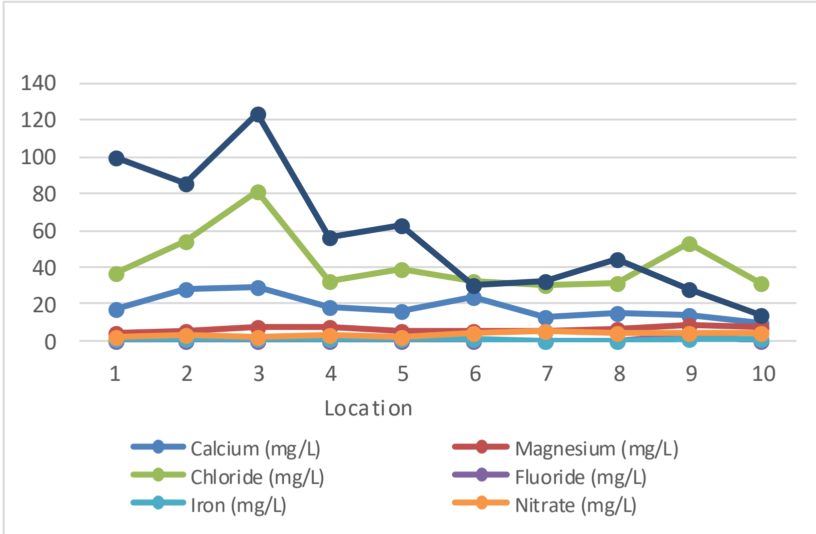

Fig. 7: Seasonal mean variations of Calcium, Chloride, Iron, Magnesium, Fluoride and Nitrate in Kole wetlands.

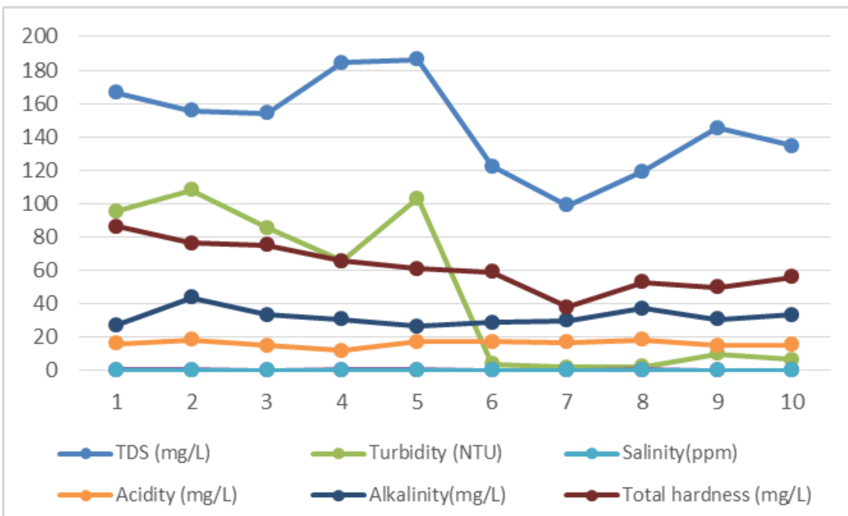

Fig. 8: Seasonal mean variations of TDS, Turbidity, Salinity, Acidity, Alkalinity and Total Hardness in Kole wetlands.

0.4 - 0.1 μS. TDS value ranged from 98-186.5 mg/l. The value of BOD ranges from 0.92-2.56 mg/l. The value of other parameters like salinity, alkalinity, acidity and turbidity ranged from 0.052-0.146 ppm, 27.5-43.66 mg/l, 11.85-18.5 mg/l and 4-108.26 NTU, respectively. The value of turbidity is very low and below 10 NTU in August, but in March the value of turbidity was higher above 100 NTU. The measured ranges of magnesium, calcium, fluoride and iron were 4.66-80.83 mg/l, 9.21-28.65 mg/l, 0.098-2.82 mg/l and 0.19-0.79 mg/l, respectively. The value of nitrate and phosphate ranged from 1.89-4.93 mg/l and 13.9-123.6 mg/l, respectively. The value of these parameters from all stations were found to be normal and desirable as recommended by WHO (2004).

The present study from Dec 2017 to May 2018 (Tables 4, 5) indicated that atmosphere temperature (AT) has a fairy strong positive correlation with water temperature and negative

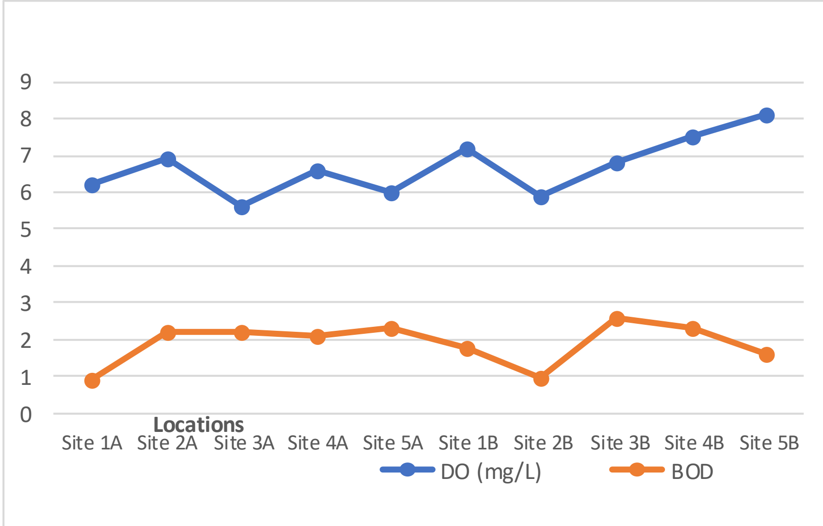

Fig. 9: Seasonal mean variations of DO and BOD in Kole wetlands.

Location = site 1A- site 5A (Dec 2017- May 2018: Pre- monsoon) and site 1B- site 5B (June 2018-Nov 2018: Monsoon and Post Monsoon)

correlation between EC, DO, calcium and salinity. Total hardness has negative correlation with atmosphere temperature (AT). AT has negative correlation with BOD, nitrate and positive correlation with total hardness. pH has negative correlation with salinity, alkalinity, total hardness (TH), calcium, Mg, chloride, fluoride, iron, sulphate etc., and also has positive correlation with turbidity (TB), EC and acidity. The parameter DO has a positive correlation with EC and negative correlation with alkalinity, iron, chloride, fluoride and sulphate. During this study, the physico-chemical parameters recorded a strong positive correlation between DO and EC, TB and AC, calcium and salinity, chloride and salinity. Also TDS showed strong negative correlation with calcium and nitrate. The total hardness showed positive correlation with the AT (Value=1). During this study the parameters recorded a strong positive correlation between AC and WT, AT and BOD, calcium and pH, EC and BOD, TB and salinity, TB and Mg, TB and Cl, TB and Fl, TB and TDS, salinity and Fl, salinity and Cl, alkalinity (Al) and TDS, TH and nitrate, Mg and Cl, Mg and TDS etc.

Conclusion

The Kole wetland aquatic system contain high faunal diversity and productivity. The present anthropogenic activities seriously threat the ecosystem, will affect the fish diversity.In the present investigation, we recorded 32 species of ornamental fishes belonging to 9 orders and 14 families from all stations. We reported one species *Heteropneustes fossilis* as endangered (EN-IUCN Red List) category, 23 fish species as Least concerned (LC) and one species *Mystus montanus* as vulnerable (VU-IUCN Red List) category. The three species *Anguilla bengalensis, Ompak bimaculatus and Wallago attu* were categorised under Near Threatened (NT) and four species of fishes *Megalops cyprinoides*, *Anabas testudineus*, *Puntius mahecola* and *Puntius amphibiosus* were categorized as DD (Data Deficient). The domestic sewage dumping, leaching of fertilizers and pesticides from rice cultivation and use of ichthyotoxic substances for fish capture seriously harms the diversity of ornamental fishes and the water quality. The result obtained in the present investigation would be helpful for the pure ichthyofaunal studies and effective management of the Kole wetlands of mid-Kerala. Till date it is unfortunate that the Kole wetlands of mid-Kerala has not received much attention from the ichthyological aspects. The documentation of the diversity of fishes is one of the need for adopting the proper conservation strategies of fish fauna. Also the regular monitoring of wetland water by analysis of physico-chemical parameters are appropriate for the conservation of ichthyofauna and management of water quality by corrective actions in the Kole wetlands.

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Evaluation of Water Quality in Thrissur-Malappuram Kole Wetlands of Kerala using Water Quality Index

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Abstract: This study assessed water quality of Kole wetlands in Thrissur-Malappuram which serves as a natural water reservoir. The Kole wetland water samples were collected from the four study areas and the chemical parameters were analysed. The Water Quality Index (WQI) was computed by weighted arithmetic index method. The WQI and possible usage of each category was analysed. It was observed that WQI of the site-1 and site-3 indicated "very poor" and "poor" water quality status, respectively. The site-2 represented very good status in water quality index and the site-4 indicated high pollution regarding WQI status and categorised as "unfit for consumption" and need proper treatment before use.

Keywords: Water Quality Index; Kole wetlands; Pollution, Physico-chemical parameters

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Introduction

Wetland ecosystems, including rivers, lakes, marshes, rice fields and coastal areas, provide many services that contribute to human well-being. water is the elixir of all life and quality water is essential for our existence. Kole wetlands works as a chief water resource of an area. Thrissur and Malappuram Kole wetlands are one of the major Kole wetland system in Kerala. It acts as an important natural reservoir in this area. The water quality of Thrissur- Malappuram Kole wetlands is very important, in which the water nourishes the irrigational resources by underground connections to wells, ponds, lakes and rivers. So, it is essential to monitor water quality of the Kole wetland. The study was conducted in Kole wetlands of Thrissur and Malappuram, one of the largest Kole wetland system in Kerala. The geology of study area composed of permanently water filled canals, seasonally submerged and rice cultivated lands. The Kole lands spread over villages, cities and may drain into brackish water lakes. The Kole wetlands of Thrissur is characterized by tropical wet and dry conditions. The main recharge source of water is by precipitation.

Materials and Methods

The 'Kole Lands' (Fig. 1) is spread over Thrissur and Malappuram districts of Kerala. This is said to be the Rice Granary of these districts at par with Kuttanad the 'Rice Bowl' of Kerala. Rice cultivation in Kole lands is said to have started way back in the eighteenth century. Kole lands lie between Bharathapuzha in the north and Chalakudy River in the south. It is located between 10^o 20' and 10^o 40' north latitudes and 75^o 58' and 76^o 11' east longitudes (Johnkutty and Venugopal, 1993). The Muriyad wetland is situated 8 km north east of Irinjalakuda town of Trissur district. Kurumali-Karuvannur River is the northern boundary. The total field area is 1,215 ha. The water spread is a narrow central strip running north to south from Karuvannur to Thommana. The Nedumthode (Thamaravalayam canal) running along the centre of the wetland is the major opening, which functions for the discharge of floodwater and letting irrigation water into the fields. M.M. Canal (Muriyad-Moorkanad Canal) is the only outlet for floodwater. Ponnani Kole, situated in south western region of Malappuram district, is the northern most extension of the Vembanad Kole, the Ramsar site. The study area is extending from southern bank of Bharathapuzha in the north to Narnipuzha in the south in a stretch of about twenty kilometers. The study was conducted at Site -1(Maranchery), Site-2 (Kuranniyur), Site-3 (Enamav) and Site-4 (Nedupuzha).

In this study Maranchery, Kuranniyur, Enamav and Nedupuzha as four sites of Thrissur Kole wetlands were selected and collection of water samples were conducted in random sampling method for the testing of physico-chemical parameters in August 2018. The water samples were analysed for pH, Alkalinity (mg/l), Total hardness (mg/l), Total hardness (mg/l), Calcium (mg/l), Magnesium (mg/l), Chloride (mg/l), Fluoride (mg/l), Iron (mg/l), Nitrate (mg/l), Sulphate (mg/l) and TDS (mg/l) as described by APHA (1995). The calculation of water quality index was done by weighted arithmetic index method (Brown *et al*., 1972) using MS excel. Using water quality index, water quality status classification was done according to Brown *et al*. (1970).

Calculation of Water Quality Index (*WQI*):

The weighted arithmetic index method (Brown *et al*., 1972) was used as follow:

Step 1:

Calculated the unit weight (Wn)

Factors for each parameter by using the formula $Wn = \frac{K}{Sn}$

$$\text{Where, } K = \frac{1}{\frac{1}{S_1}+\frac{1}{S_2}+\frac{1}{S_3}\ldots\ldots+\frac{1}{Sn}} = \frac{1}{\sum\frac{1}{Sn}} \quad (1)$$

Sn = Standard desirable value of the n^{th} parameters

On summation of all selected parameters unit weight factors, Wn=1 (Unity)

Step 2:

Calculated the sub-index (Qn) value by using the formula

$$Qn = \frac{[(Vn-Vo)]}{[(Sn-Vo)]} * 100 \quad (2)$$

Where, Vn= Mean Concentration of the n^{th} parameters

Sn= Standard desirable value of the n^{th} parameters

V_0= Actual values of the parameters in pure water

(Generally, V_0=0, for most parameters, except for pH)

$$QpH = \frac{[(VpH-7)]}{[(8.5-7)]} * 100 \quad (3)$$

Step 3:

Combining Step 1 and step 2, WQI is calculate as follows

$$\text{Over all WQI} = \frac{\sum WnQn}{\sum Wn} \quad (4)$$

Results and Discussion

A total of 12 parameters were determined out of which pH, Total hardness (mg/l), Calcium (mg/l), Magnesium (mg/l), Chloride (mg/l), Fluoride (mg/l), Iron (mg/l), Nitrate (mg/l), Sulphate

Table 1: Water Quality Index of sample of site -1

Physico-chemical parameters	Site 1, Sn	$\frac{1}{Sn}$	$A=\sum\frac{1}{Sn}$	$K=\frac{1}{A}$	$Wn=\frac{K}{Sn}$	Ideal value (V_o)	Mean Con.Value (V_n)	$M=\frac{Vn}{Sn}$	Qn=M×100	Wn×Qn
pH	8.5	0.117647059	4.738369	0.211043	0.024829	7	6.85	0.8058	80.588	2.0008
Turbidity (NTU)	5	0.2	4.738369	0.211043	0.042209	0	95.65	19.13	1913	80.74508
Alkalinity(mg/l)	200	0.005	4.738369	0.211043	0.001055	0	27.5	0.1375	13.75	0.014509
Total hardness (mg/l)	200	0.005	4.738369	0.211043	0.001055	0	86.5	0.4325	43.25	0.045638
Calcium (mg/l)	75	0.013333333	4.738369	0.211043	0.002814	0	17.68	0.235733	23.57333	0.066333
Magnesium (mg/l)	30	0.033333333	4.738369	0.211043	0.007035	0	4.66	0.155333	15.53333	0.109273
Chloride (mg/l)	250	0.004	4.738369	0.211043	0.000844	0	36.66	0.14664	14.664	0.012379
Fluoride (mg/l)	1	1	4.738369	0.211043	0.211043	0	0.23	0.23	23	4.853991
Iron (mg/l)	0.3	3.333333333	4.738369	0.211043	0.703477	0	0.79	2.633333	263.3333	0.019697
Nitrate (mg/l)	45	0.022222222	4.738369	0.211043	0.00469	0	1.89	0.042	4.2	0.019697
Sulphate (mg/l)	400	0.0025	4.738369	0.211043	0.000528	0	99.58	0.24895	24.895	0.013135
TDS (mg/l)	500	0.002	4.738369	0.211043	0.000422	0	166.3	0.3326	33.26	0.014039
Sum		4.73				1				87.91

Table 2: Water Quality Index of sample of site -2

Physico-chemical parameters	Site 2, Sn	$\frac{1}{Sn}$	$A=\sum\frac{1}{Sn}$	$K=\frac{1}{A}$	$Wn=\frac{K}{Sn}$	Ideal value (V_o)	Mean. Con. Value (V_n)	$M=\frac{Vn}{Sn}$	Qn=M×100	Wn×Qn
pH	8.5	0.117647	4.738369	0.211043	0.024829	7	7.21	0.848235	84.82353	2.106049
Turbidity (NTU)	5	0.2	4.738369	0.211043	0.042209	0	1.96	0.392	39.2	1.654578
Alkalinity(mg/l)	200	0.005	4.738369	0.211043	0.001055	0	30	0.15	15	0.015828
Total hardness (mg/l)	200	0.005	4.738369	0.211043	0.001055	0	38.1	0.1905	19.05	0.020102
Calcium (mg/l)	75	0.013333	4.738369	0.211043	0.002814	0	12.78	0.1704	17.04	0.047949
Magnesium (mg/l)	30	0.033333	4.738369	0.211043	0.007035	0	5.51	0.183667	18.36667	0.129205
Chloride (mg/l)	250	0.004	4.738369	0.211043	0.000844	0	30.33	0.12132	12.132	0.010241
Fluoride (mg/l)	1	1	4.738369	0.211043	0.211043	0	0.096	0.096	9.6	2.026014
Iron (mg/l)	0.3	3.333333	4.738369	0.211043	0.703477	0	0.19	0.633333	63.33333	44.55354
Nitrate (mg/l)	45	0.022222	4.738369	0.211043	0.00469	0	4.93	0.109556	10.95556	0.05138
Sulphate (mg/l)	400	0.0025	4.738369	0.211043	0.000528	0	32.06	0.08015	8.015	0.004229
TDS (mg/l)	500	0.002	4.738369	0.211043	0.000422	0	98.83	0.19766	19.766	0.008343
Sum		4.73			1					50.62

Table 3: Water Quality Index of sample of site -3

Physico-chemical parameters	Site 3, Sn	$\frac{1}{Sn}$	A=$\sum\frac{1}{Sn}$	K=$\frac{1}{A}$	Wn=$\frac{K}{Sn}$	Ideal value (V_o)	Mean. Con. Value (V_n)	M=$\frac{Vn}{Sn}$	Qn=M×100	Wn×Qn
pH	8.5	0.117647	4.738369	0.211043	0.024829	7	7.06	0.830588	83.05882	2.062234
Turbidity (NTU)	5	0.2	4.738369	0.211043	0.042209	0	2.48	0.496	49.6	2.093547
Alkalinity (mg/l)	200	0.005	4.738369	0.211043	0.001055	0	37.16	0.1858	18.58	0.019606
Total hardness (mg/l)	200	0.005	4.738369	0.211043	0.001055	0	53	0.265	26.5	0.027963
Calcium (mg/l)	75	0.013333	4.738369	0.211043	0.002814	0	15.2	0.202667	20.26667	0.057029
Magnesium (mg/l)	30	0.033333	4.738369	0.211043	0.007035	0	5.9	0.196667	19.66667	0.13835
Chloride (mg/l)	250	0.004	4.738369	0.211043	0.000844	0	31.16	0.12464	12.464	0.010522
Fluoride (mg/l)	1	1	4.738369	0.211043	0.211043	0	0.184	0.184	18.4	3.883193
Iron (mg/l)	0.3	3.333333	4.738369	0.211043	0.703477	0	0.19	0.633333	63.33333	44.55354
Nitrate (mg/l)	45	0.022222	4.738369	0.211043	0.00469	0	3.84	0.085333	8.533333	0.04002
Sulphate (mg/l)	400	0.0025	4.738369	0.211043	0.000528	0	44.43	0.111075	11.1075	0.00586
TDS (mg/l)	500	0.002	4.738369	0.211043	0.000422	0	119.16	0.23832	23.832	0.010059
Sum		4.73			1					52.9

Table 4: Water Quality Index of sample of site -4

Physico-chemical parameters	Site 4, Sn	$\frac{1}{Sn}$	A=s 1/Sn	$K=\frac{1}{A}$	$Wn=\frac{K}{Sn}$	Ideal value (V_o)	Mean. Con. Value (V_n)	$M=\frac{Vn}{Sn}$	Qn=M×100	Wn×Qn
pH	8.5	0.117647	4.738369	0.211043	0.024829	7	7.03	0.827059	82.70588	2.053471
Turbidity (NTU)	5	0.2	4.738369	0.211043	0.042209	0	10.2	2.04	204	8.610558
Alkalinity(mg/l)	200	0.005	4.738369	0.211043	0.001055	0	30.84	0.1542	15.42	0.016271
Total hardness (mg/l)	200	0.005	4.738369	0.211043	0.001055	0	49.83	0.24915	24.915	0.026291
Calcium (mg/l)	75	0.013333	4.738369	0.211043	0.002814	0	13.98	0.1864	18.64	0.052451
Magnesium (mg/l)	30	0.033333	4.738369	0.211043	0.007035	0	8.38	0.279333	27.93333	0.196505
Chloride (mg/l)	250	0.004	4.738369	0.211043	0.000844	0	53	0.212	21.2	0.017896
Fluoride (mg/l)	1	1	4.738369	0.211043	0.211043	0	2.82	2.82	282	59.51415
Iron (mg/l)	0.3	3.333333	4.738369	0.211043	0.703477	0	0.66	2.2	220	154.7649
Nitrate (mg/l)	45	0.022222	4.738369	0.211043	0.00469	0	4.17	0.092667	9.266667	0.043459
Sulphate (mg/l)	400	0.0025	4.738369	0.211043	0.000528	0	28.05	0.070125	7.0125	0.0037
TDS (mg/l)	500	0.002	4.738369	0.211043	0.000422	0	145.3	0.2906	29.06	0.012266
Sum		4.73			1					225

Table 5: Determination of WQI status of Kole wetlands based on Brown *et al*. (1970)

Site	Site name	WQI	Status
1	Marancherry	87.91	Very poor
2	Kuranniyur	50.62	Good
3	Enamav	52.9	Poor
4	Nedupuzha	225	Unfit for consumption

Table 6: Water quality status classification according to WQI by Brown *et al*. (1970).

Water quality index	Water quality status	Possible usage
0-25	Excellent	Drinking, Irrigation, Industrial
26-50	Good	Drinking, Irrigation, Industrial
51-75	Poor	Irrigation and Industrial
76-100	Very poor	Irrigation
>100	Unfit for consumption	Proper treatment required before use

(mg/l) and TDS (mg/l) were found to be within the permissible limits of BIS. The Turbidity was beyond the permissible limit in the sample of site-1 and site-4. The calculation of Water Quality Index of Maranchery (Site-1), Kuranniyur (Site-2), Enamav (Site-3) and Nedupuzha (Site-4) are shown in Tables 1, 2, 3 and 4, respectively. The classification of WQI and status evaluation of four sites according to Brown *et al*. (1970) are shown in Tables 5 and 6.

The study revealed that the water quality index and status vary with sites. As per Table 6 of water quality classification (Brown *et al*.,1970), the site-1 showed very poor water quality owing to its WQI of 87.91 which is in a range of 75-100 on WQI scale. The site-2 was near to good status of water quality as its WQI value (50.6) close to the upper limit of the range 26-50 on WQI scale and site-3 with "poor" water quality due to its WQI of 52.9. Based on the WQI results, water from site-1, site-2 and site-3 can be utilized for irrigation and industrial purposes. The site-4 indicated WQI of 225 which is far greater than 100 on WQI scale and it indicated high pollution and can be categorised as "unfit for consumption" and need proper treatment before use. In the context of high threat to Kole wetlands due to pollution by unmanaged use of pesticides and herbicides, this study shows the necessity of the periodical monitoring and analysis of WQI in Kole wetlands, which has pivotal role in irrigation and restoration of groundwater table in an area.

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