ECOSYSTEM VALUATION AND TROPHIC STRUCTURE DYNAMICS FOR SUSTAINABLE FISHERIES MANAGEMENT IN DIMBHE RESERVOIR, MAHARASHTRA

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fulfillment of the requirements
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M.F.Sc. (Fisheries Economics)

by

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Dated : 30th July, 2022

CERTIFICATE

Certified that the dissertation entitled **"ECOSYSTEM VALUATION AND TROPHIC STRUCTURE DYNAMICS FOR SUSTAINABLE FISHERIES MANAGEMENT IN DIMBHE RESERVOIR, MAHARASHTRA"** is a bonafide record of independent research work carried out by **Ms. Waghmare Sneha Dadarao** during the period of study from October 2021 to July 2022 under our supervision and guidance for the degree of **Master of Fisheries Science (Fisheries Economics)** and that the dissertation has not previously formed the basis for the award of any degree, diploma, associateship, fellowship or any other similar title.

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I hereby declare that the dissertation entitled "**ECOSYSTEM VALUATION AND TROPHIC STRUCTURE DYNAMICS FOR SUSTAINABLE FISHERIES MANAGEMENT IN DIMBHE RESERVOIR, MAHARASHTRA"** is an authentic record of the work done by me and that no part thereof has been presented for the award of any degree, diploma, associateship, fellowship or any other similar title.

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सारांश

अदम्य भूमि, नियमित मानसूनी बारिश, तापमान और उष्णकटिबंधीय जलवायु के विशाल विस्तार के कारण भारत में जलीय कृषि की अपार संभावनाएं है। जलाशय विभिन्न प्रकार की पारिस्थितिक और आर्थिक रूप से सेवाएं प्रदान करते हैं। भविष्य के पर्यावरणीय परिवर्तनों के लिए पारिस्थितिक गतिशीलता और पारिस्थितिकी तंत्र सेवाओं के प्रति प्रतिक्रिया करने वाले नीति निर्माताओं के लिए पारिस्थितिकी तंत्र के मूल्यांकन और पोषी संरचना को निर्धारित करने वाली ताकतों को समझना महत्वपूर्ण है। अध्ययन का प्रमुख उद्देश्य महाराष्ट्रा के डिंभ जलाशय में पारिस्थितिक तंत्र सेवाओं की पहचान करना और उनका आकलन करना और मछली समुदाय संरचना का विश्लेषण करना है। प्रावधान सेवाओं के लिए भुगतान करने की इच्छा (डब्ल्यू टी पी) का पता लगाने के लिए 160 घरेलू नमूनों से प्राथमिक डेटा एकत्र किया गया था। अध्ययन में छह अनंतिम सेवाओं (रोजगार, सिंचाई के लिए पानी, पीने के लिए पानी, जलविद्युत बिजली उत्पादन, ईंधन की लकड़ी, और मछली)के आर्थिक मूल्य का अनुमान लगाया गया है। निष्कर्षों से पता चला है कि डिंभ जलाशय में प्रावधान सेवाओं का औसत कुल आर्थिक मूल्य रु 138.2 लाख/वर्ष है। उत्तरदाताओं के भुगतान की इच्छा का पता लगाने के लिए सिंगल और डबल बाउंडेड आकस्मिक मूल्यांकन पद्धति (सी वी एम) का उपयोग किया गया है । सी वी एम में, तीन अलग-अलग बोली मूल्यों (पहली बोली, कम बोली और उच्च बोली, जो क्रमशः 250 रुपये, 100 रुपये, 250 रुपये से अधिक) के साथ डब्ल्यू टी पी का बेतरतीब ढंग से अनुमान लगाने के लिए द्विबीजपत्री विकल्प पद्धति के आधार पर लॉजिस्टिक मॉडल का उपयोग किया गया है।) शिक्षा, घर का प्रकार और मासिक घरेलू आय सेवाओं के प्रावधान के लिए डब्ल्यूटीपी के महत्वपूर्ण संभावित कारक थे। सीवीएम अध्ययन से पता चला है कि लगभग 53.8% उत्तरदाता ईंधन की लकड़ी के प्रावधान के लिए भुगतान करने को तैयार थे, और 42% उत्तरदाता पानी और चारे के लिए थे। अध्ययन के निष्कर्षों से पता चला है कि 5000 रुपये से कम की मासिक घरेलू आय वाले कच्चे घरों में रहने वाले उत्तरदाताओं को पानी, ईंधन, लकड़ी और चारा प्रावधान के लिए भुगतान करने की अधिक संभावना थी। चयनित जलाशय में पारिस्थितिकी तंत्र में पोषी संरचना और ऊर्जा प्रवाह का भी विश्लेषण किया गया है। परिणाम में पाया गया कि डिंभे जलाशय में चार पोषी स्तरों की पहचान की गई। मांसाहारी मछली के लिए उच्चतम पोषी स्तर 3.33 था, अर्थात, चन्ना स्ट्रेटा ने संकेत दिया कि खाद्य श्रृंखला कम थी, और उपलब्ध खाद्य ऊर्जा बड़ी थी। कुल प्राथमिक उत्पादन/कुल श्वसन (टी पी पी/टीआर) का मूल्य अनुमानित 0.667 है, जो डिंभ जलाशय के विकासशील चरण को दर्शाता है। इस प्रकार, जलाशय पारिस्थितिकी तंत्र का बेहतर प्रबंधन इसकी स्थिरता सुनिश्चित करने के लिए आवश्यक है। इस अध्ययन से पाया गया है कि स्थानीय लोगों की भागीदारी के साथ प्राकृतिक संसाधनों का संरक्षण भी आवश्यक है।

कीवर्ड: पारिस्थितिकी तंत्र मूल्यांकन, आकस्मिक मूल्यांकन विधि, Ecopath के साथ Ecosim

Abstract

India has enormous potential for aquaculture because of its vast expanses of untamed land, regular monsoon rains, temperature, and tropical climate. Reservoirs provide a variety of ecologically and economically services. Understanding the forces that determine ecosystem valuation and trophic structure is important for policymakers responding to ecological dynamics and ecosystem services to future environmental changes. The objectives of the study were to identify and assess the major ecosystem services and to analyze the fish community trophic structure in Dimbhe reservoir. Primary data from 160 household samples were collected to find the Willingness to Pay (WTP) for provisioning services. The study estimated the economic value of six provisional services (Employment, water for Irrigation, Water for Drinking, Hydroelectric power generation, fuel wood, and fishing) in the reservoir. Findings showed that the average total economic value of provisioning services in Dimbhe reservoir was Rs. 138.2 lakhs/ year. The single and double bounded Contingent Valuation Method (CVM) were used to find the willingness to pay of respondents. In CVM, the logistic model was used based on the dichotomous choice method to randomly estimate the WTP with three different bid values (First bid, low bid and high bid, which were Rs.250, Rs.100, more than Rs.250 respectively). Education, House type, Monthly household income were the significant potential factors for WTP for provisioning services. The CVM study showed that about 53. 8 % respondents were willing to pay for the provisioning of fuel wood, and 42 % respondents were WTP for water and fodder. The study's findings showed that the respondents living in kaccha houses with a monthly household income of less than Rs.5000 were more likely to pay for water, fuel, wood, and fodder provision. The trophic structure and energy flow were also analyzed in the selected reservoir ecosystem. The result found that, four trophic levels were identified in the Dimbhe reservoir. The highest trophic level was 3.33 for carnivorous fish, i.e., *Channa striata* indicated that the food chain was short, and the available food energy was large. The value of Total Primary Production /Total Respiration (TPP/TR) estimated 0.667, indicating the developing stage of the Dimbhe reservoir. Thus, the improved management of the reservoir ecosystem is necessary to ensure its sustainability. The study may be a revelation that conserving natural resources with the involvement of local people is essential.

Keywords: Ecosystem Valuation, Contingent Valuation Method, Ecopath with Ecosim.

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1. INTRODUCTION

Global fish production was estimated to be at a record high in 2018, reaching 179 million tonnes. Humans consumed 156 million tonnes of fish, equating to an annual supply of 20.5 kg per capita (FAO, 2020). Global capture fisheries reached their highest level with a total production of 96.4 million tonnes in 2018 (FAO, 2020). From 2010–2018, the estimated 39 million workforces engaged in capture fisheries production remained stable. The number of people employed in aquaculture increased by about 10%, from nearly 19 million to 21 million (FAO, 2020b).

Indian marine and aquatic resources are abundant and diverse, which sustain a thriving fish economy. In India, the fisheries sector has grown faster than the crop and livestock sectors (Kumar *et al.,* 2010). As it contributes to the livelihood of a large portion of the country's economically underprivileged population, the sector is recognized as a significant source of income and employment (Kumar *et al.,* 2010). According to estimates from the Indian government, nearly 16 million people in India depend on the primary fisheries sector for their livelihood, and almost twice that many depend on it along the value chain (Government of India, 2018).

The Maharashtra State holds a prominent position among Indian states, with the second largest geographical area (10 %) occupying the western and central part of the country. Maharashtra state ranks 7th with around 5 % of the country's fish production (Bhendekar *et al.,* 2018). The most crucial and underutilized water resource for the development of inland fisheries in the nation is known as a reservoir (Keshave *et al.,* 2014).

When Maharashtra is considered in terms of reservoirs, it has the highest number of completed dams and reservoirs in India, accounting for 1693 reservoirs (National Register of Dams, 2009). The state has about 2.79 lakh ha water spread area under reservoirs (India stat.com, 2002). These water bodies are intricate systems that display a variety of ecological interactions (Khan *et al.,* 2015). Dimbhe reservoir in Maharshtra are utilized for recreation, flood protection, energy production, flood control, and ecological services. Due to these factors, reservoir have emerged as most important resource.

Although renewable, the living aquatic resources are finite and must be correctly managed if their contribution to the nutritional, economic, and social well-being is sustained (FAO, 2020). It is widely acknowledged that ecosystem structure and function, particularly the trophic structure and biomass flows through species interactions, need to be considered to ensure the sustainability of the ecosystem's living aquatic resources (Christensen and Pauly, 1995).

Ecosystem services (ES) is a term that has gained widespread use by the Millennium Ecosystem Assessment (MEA), a global initiative set up in 1999 to assess how ecosystem change would affect human well-being (MEA, 2005). According to Millennium Ecosystem Assessment (MEA, 2005), the ES is 'the benefits people obtain from ecosystems. Ecosystem services provide natural resources and healthy ecological systems that produce environmentally and economically valuable goods and services (Warner *et al.,* 2008).

These ecosystem services are directly linked to various components of human well-being, such as security, basic materials for a good life (e.g., provision of nutritious food, shelter, and employment opportunities), health, and cordial social relation (Bateman *et al.,* 2011). The benefits that human beings depend on the flow of ES are non-existence if these services stop flowing (Solomatine, 2008). At present, however, many of these services provided by the ecosystem are undervalued (KC *et al.,* 2013)

Millennium Ecosystem Assessment (MEA) assessed the consequences of ecosystem change on human welfare. More than 1,360 experts from all over the world contributed to the MA between 2001 and 2005 MEA (2005) and defined four Ecosystem services categories as

1. **Provisioning Services –** Products and materials obtained from ecosystems, such as food, fibers, building materials, fresh water, energy, biochemicals, and genetic resources.

2. **Regulating services –** Regulation of ecosystem processes and the environment has advantages, including control of the climate, disease prevention, water purification, pollination, soil protection, carbon sequestration, and defense against extreme weather and natural hazards.

3. **Cultural services –**Non-monetary benefits from ecosystems that improve lives include spiritual and religious values, leisure and tourism, aesthetic value and landscape, inspirational value, education, research, sense of place, and cultural heritage.

4. **Supporting service –** Underpinning services enable other services to function, such as soil formation, nutrient cycling, and primary production.

Humans value ecosystem products and services produced by ecosystem structure in conjunction with regulatory, habitat/production, and other ecosystem activities. This value may result from a conviction that particular species or ecosystems are valuable for themselves or because of their advantages for humans. Ecosystem values are measures of how essential ecosystem services are to people - What they are worth. These values will contribute to better decision-making, ensuring that policy appraisals fully consider the costs and benefits to the natural environment (Atkinson *et al.,* 2018).

Valuation is attributing a value (either economic or non-economic) to something. Economic valuation aims to measure, in monetary terms, people's preferences for the benefits they obtain from ecosystem processes (Silvestri, 2010). Assessing the economic value is a significant theme in environmental and ecological economics, mainly because distortions derived from the non-incorporation of environmental benefits in economic decisions may cause environmental degradation (Costanza *et al.,* 1997).

According to the concept of Total Economic Value (TEV), the value of natural resources is frequently taken into account, which can be used to value ecosystem services (DEFRA, 2007). Economic values can be categorized broadly as either use values or non-use values. The sum of both these values provides the total economic value**.** Use values may be either direct or indirect.

1. Direct use value: where individuals make actual or planned use of an ecosystem service. Consumptive and non-consumptive are two types of direct use values (DEFR, 2007).

2. Indirect use value: Where individuals benefit from ecosystem services supported by a resource rather than directly using it. These ecosystem services are often not noticed by people until they are damaged or lost, yet they are significant (DEFR, 2007)

3. Option value: The importance that individuals place on having the choice to future utilization of a resource even if they are not current users (DEFR, 2007)

4. Non-use value: is derived simply from the knowledge that the natural environment is maintained (DEFR, 2007)

5. Bequest value: Where people place a high value on the ecosystem resource being passed down to future generations (DEFR, 2007)

6. Existence value: Derived from the existence of an ecosystem resource, even though an individual has no actual or planned use of it (DEFR, 2007)

Ecosystem health is closely related to sustainability, defined as meeting the current and future societal need for ecosystem services (Vaisakh *et al.,* 2017). Examining the productivity of an aquatic ecosystem is essential for proper biological assessment of the potential of the habitat (Vaisakh *et al.,* 2017). Dimbhe reservoir is good income source of fishers.

The trophic structure represents the various trophic stages depending on the organism's energy. Food preferences can describe how trophic interactions occur in food webs. Organisms' diets include various ecological factors, such as habitat use, energy intake, and prey-predator interactions. Therefore, the studies on productivity and fish gut content analyses are essential to improve knowledge about trophic structure and functioning of an ecosystem (Bernardi *et al.,*1987).

Ecosystem models play an essential role in supporting ecosystem approaches for sustainable utilization of resources by studying the aquatic ecosystem as a whole (Wang *et al.*, 2015). Such scientific tools will provide valuable information on the health of reservoir habitats and the capacity to support biological production and sustainable development (Panikkar *et al.,* 2008).

The Ecopath model is used to establish mass balance, which allows analysis of flows between trophic levels and thereby helps to study the status of an ecosystem in general. (Vaisakh *et al.,* 2017). Understanding the forces that determine trophic structure is thus essential for predicting the response of ecological dynamics and ecosystem services to future environmental changes (El-Sabaawi, 2018, Pethybridge *et al.,* 2020).

With the scenario mentioned above in mind, research gaps have been found in Dimbhe Reservoir, Maharashtra, and research questions pertinent to the study's purpose have been compiled.

Research gaps

- Literature review shows that ecosystem valuation studies had been carried out in wetlands, lagoons, and mangroves ecosystems, but very few studies focused on reservoir ecosystem valuation.
- Many trophic structure modelling studies have been taken in Maharashtra, but no studies focus on reservoir ecosystem valuation and trophic structure dynamics in Dimbhe reservoirs.
- In addition, the health of the reservoir ecosystem in terms of development has not been explored so far

Research questions

- What are the ecosystem services of Dimbhe reservoir fisheries?
- What is the economic value of goods and services provided by a reservoir?
- What is the current status of the Dimbhe reservoir ecosystem?
- What could be the evidence-based fisheries management strategy for changing the environment?

Hence the Proposed study in this regard has been conducted with the following objectives:

1. To identify and assess major ecosystem services provided by Dimbhe reservoir
2. To analyze fish community trophic structure and to provide inferences on ecosystem health of Dimbhe reservoir
3. To suggest evidence based strategies for the sustainable management of fisheries in reservoir ecosystems

2. REVIEW OF LITERATURE

A brief literature review is essential in the research process since it concentrates on the research topic while shedding light on earlier studies sheds light on previous studies. It also aids in developing a theoretical framework for the research problem, developing methodologies, and defining essential definitions and vocabulary. By doing so, the researcher can relate empirical data from earlier studies without repeating previously published work. An attempt has been made in this chapter to present a brief review of available literature related to relevant variables selected, which have a meaningful relation to the objective of the study and is organized under the following headings.

- Ecosystem services and ecosystem functions
- Reservoirs and their ecosystem services
- Ecosystem valuation methods and willingness to pay
- Ecopath and Ecosim as a modelling tool
- Placing fisheries within an ecosystem context
- Ecopath modelling study in a reservoir ecosystem

2.1 Ecosystem services and ecosystem functions

Ecosystem functions refer to various ecological, biological, or system characteristics or processes. Human populations profit directly or indirectly from ecosystem functions through consuming ecosystem goods (food) and services (waste assimilation).

Costanza *et al.* (1997) estimated the economic value of 17 ecosystem services for 16 biomes and the results showed that the significant ecosystem services were non-marketable, for which willingness to pay is significantly less. Results also showed that more value comes from coastal areas than terrestrial ones. The average value of the total global ecosystem was USD 19 trillion per year, which was greater than the global GDP at that time.

Sagoff *et al.* (2011) examined how economic and ecological criteria for identifying, measuring, and evaluating ecosystem services differ. It claimed that economic stakeholders (user groups) are generally good at identifying and pricing the services. The paper claimed that the conceptual gap between market-based and science-based methods of gathering data and applying knowledge-based attempts to determine the "value" of ecosystem services in a holistic sense.

Guo *et al*. (2001) estimated the annual economic value of ecosystem services provided by forest ecosystems in Xingshan County, Hubei Province, China. The finding showed that the annual value of the forest ecosystem services was 4838.5 US$ economic value of the forest ecosystem. Water conservation, soil conservation and gas regulation were three ecosystem services assessed and estimated economic value was 4388.4 US$.

Winkler R (2006) illustrated new dynamic approach as ‘simple pre-industrial economy–ecology model’ consisting of the three subsystems nature, economy and society, and their interdependencies to valuing ecosystem goods and services. The study stated, as the ecological valuation methods derive values from a cost-of-production approach. The exchange value of ecosystem services is the focus of economic valuation methods. Study provided the conceptual foundations for a new method of valuing ecosystem services that takes a balanced approach to the ecosystem, the economic system, and society.

Eaton and Sarch (1997) examined the value of wild resources used for food, raw materials, and firewood in the Hadejia-Nguru Wetlands of Nigeria. The study showed that harvesting doum palm fronds and selling the dried bundles yields a return of about N200 (US$2.50) per day, and making mats from the fronds N10 (US$0.13) per day.

Shyamsundar *et al.* (1996) estimated that the value of fuelwood was US$39 per household per year for communities surrounding the Mantadia National Park in Madagascar. With mean annual household income estimated to be US$279,

In a study of the mangrove wetlands of Bintuni Bay, Irian Jaya, Indonesia, the benefits of erosion control were estimated to be around US$950 per household (Ruitenbeek *et al.,* 1994)

Acharya (2000) estimated the value of replenishing and maintaining groundwater resources through the inundation of the wetlands during the wet season. The study suggested that the value of the recharge function is 1,147,000 Naira, or US$13,000, per day for the wetlands. Regarding groundwater irrigated agricultural production, a value of at least 2,860 Naira or US$33 per farmer per dry season was attributable to the present groundwater recharge rate.

In addition to conventional arguments based on intrinsic worth, the concept of ecosystem services offers a compelling justification for preserving biodiversity. In principle, it also provides a mechanism for optimizing investments in biodiversity conservation and directing them to where they are most helpful (Kinzig *et al.*, 2007).

2.2 Reservoirs and their ecosystem services

Baral *et al. (*2016) calculated the total economic value of the Jagadishpur reservoir by using direct, indirect, and non-use values. Findings showed that the reservoir's total annual economic value was 94.5million. According to the findings, local communities place a high value on future use value and are willing to invest in reservoir conservation and restoration.

Brito *et al.* (2018) assessed the impacts of changes in land use in the Guarapiranga reservoir watershed (Metropolitan Region of So Paulo, Southeast Brazil) on raw water quality and the costs of treating the public water supply. The result found that the cost of water treatment increased by 7.1 times along with the reduction in vegetation area. It resulted in a significant externality for system users of around US$ 6.6 million in 2010.

Jones *et al.* (2019) investigated smallholder farmer perceptions of ecosystem services (ES), ecosystem disservices (ED), and Human Well Being (HWB). Farmers appraised the significance of each benefit and harm for their HWB by identifying what nature-based benefits (ES) and problems (ED) they saw across each landscape. In this study, the results showed that ES significantly impacts HWB.

Loomis *et al.* (2005) estimated homeowners' willingness to pay for water leasing to maintain stable lake levels at an irrigation reservoir in a residential neighbourhood. The voter referendum responses for maintaining the lake level were analyzed using a binary logit model. The median willingness to pay (WTP) for lakefront residents was $368 per year, while the WTP for off-lake residents was $59 per year. Using the median WTP for lakefront and non-lakefront residents, they calculated that a $43,000 increase in homeowner association fees would be enough to lease enough water to reach the target higher lake level in an average year.

Brander (*et al.*, 2012) presented a meta-analysis of the economic valuation literature and the mangroves in Southeast Asia were valued using the estimated value function. The estimated foregone annual benefits in 2050 were US$ 2.2 billion, with a prediction interval of US$ 1.6–2.8 billion

2.3 Ecosystem Valuation Methods and willingness to pay

Harini *et al.* (2019) examined mangroves' economic and ecological values and the economic value was found as IDR 1,773,561,240 of which about 82% was available as indirect use value. The findings also showed that only 83.33% of the respondents were WTP.

Quoc *et al.* (2012) presented a comprehensive overview and summary of studies conducted to investigate mangrove forest ecosystem services. According to reviews in his study, valuation tools, such as Travel Cost (TC), were used for calculating recreation values. At the same time, Hedonic Pricing (H.P.) was linked to the aesthetic qualities of natural ecosystems. Conjoint Analysis (C.A.) and Contingent Valuation (CV) methods were used for calculating non-use values, such as the value of wildlife's existence.

Moran (1994) estimated foreign visitors' current non-consumptive value of protected wetland areas in Kenya as $450 million per year. No other direct or indirect advantages or possible returns from consumptive uses were taken into account in this assessment, which was made in addition to the current cash returns from tourism.

Gustavo *et al.* (2016) reviewed the literature about Mexico's economic valuation of ecosystem services and discovered 43 studies that estimated the economic benefits of 24 different ecosystem services using non-market valuation methods. The findings showed that the most popular method was contingent valuation, followed by the travel cost and choice experiment. They stated that the embedding effect and hypothetical bias are serious issues that must be addressed in future stated preference studies.

A valuation study of the coral reefs of the Phi Phi Islands, Thailand (Seenprachawong, 2001) showed the travel expenses (as an indication of the value of a trip) to be US$205 million per year. In addition, visitors' willingness to pay to increase biodiversity at Phi Phi was estimated at US$7 per visit.

Naime *et al.* (2020) analyzed the economic value of four ecosystem services along the Pacific Coast of Mexico's tropical dry forest's natural regeneration process. Using contingent and direct market valuation methods, the monetary value of two provisioning ecosystem services, forest products and fodder for calves, is estimated. The findings show a clear trade-off between regulating and provisioning ecosystem services in the early stages of natural regeneration.

In Malaysia, the protection of agricultural irrigation was valued at US$15 per hectare through water productivity in crop production by Kumari (1996).

Sachin *et al.* (2020) analyzed the benefits of the mangrove ecosystem in the Uttara Kannada district of Karnataka, India, for reservoir conservation and restoration. The study used the double bounded dichotomous method and the result reveals a high reliance on mangrove resources among the respondents, with 98 percent rating mangroves as the best energy source. In comparison to marine fishers and Gazni farmers, inland fishers are willing to pay a higher amount (Average Rs.1151.51) as a lifetime amount for the development and maintenance of mangroves.

Tuan *et al.* (2014) examined the factors for WTP of respondents for mangrove restoration in Thi Lai lagoon. The parametric and non-parametric test was used to find the WTP. The findings showed that the total economic value was VDR 15.7 billion, equivalent to about US$ 76 600 per year.

Suprapto *et al.* (2015) investigated the factors influencing respondents' willingness to pay (WTP) for mangrove restoration in Karimunjawa. The census method was used to schedule interviews with 502 people and the single bounded Contingent Valuation Method (CVM) was used to find respondents' WTP for the restoration. According to the findings, local communities are very much aware of the importance of the values provided by mangroves. According to the results, respondents with higher education and a higher income were more likely to pay for the mangrove restoration.

Debroy *et al.* (2014) used the contingent valuation method to determine the economic value of the Pichavaram mangroves for the residents of MGR Thittu (CVM). Data was collected using theory-based purposive sampling. Results showed that the total WTP of the population of MGR Thittu village was around INR. 199,564 (USD 4,435) per year. The findings also revealed that women have potential roles in the sustainable use of Pichavaram mangrove resources, which could aid them in gaining employment and able to support their families financially.

Pandit *et al. (2015)* calculated the value of selected goods and services of a 22 km stretch of Bramhaputra river in Assam. Depending on the situation, the market price method, revenue generation, and travel cost method were used for valuing goods and services. The total annual value of goods and services from a 22-kilometer stretch of the Bramhaputra river estimated was 47.8 crores.

Badola *et al.* (2010) assessed the ecosystem services of Corbett Tiger Reserve in India. Secondary sources were used to determine the direct cost, and socioeconomic surveys were used to determine the indirect and opportunity costs. The estimated recreational value of the reserve was the U.S. $167,619 per year. The cost per visitor being the U.S. $2.5. The size of the consumer surplus demonstrated that tourists were prepared to pay for wildlife recreation. The reserve's forests reduce carbon emissions by the U.S. $63.6 million, with an annual flow of U.S. $65.0 per hector.

Sondak *et al.* (2019) estimated the economic value of ecosystem services provided by Lansa mangrove forest, Word Sub-district, North Minahasa District, and North Sulawesi Province in Indonesia using the contingent valuation method. The findings showed that the Lansa mangrove forest's total economic value (TEV) as IDR 4,431,197,603.

Pandit et al. (2012) analyzed the people's perception of the importance of mangroves and their willingness to pay for their conservation. The findings showed that around 64.71 percent of the respondents agreed to pay for the conservation and restoration of mangroves even though they had low income and poor living standards.

2.4 Ecopath and Ecosim as a modelling tool

Modelling is a scientific approach to bringing ecosystem approaches to fisheries management. Ecopath is a tropical modelling approach used to model various aquatic ecosystems. Ecopath is a component of Ecopath with Ecosim software, a free modelling software suite. The aggregation of the species into functional groups is essential to perform the network analysis, and by providing the basic input parameters along with it, the model helps to estimate the ecosystem indicators, which help to explain the ecosystem better (Vaishakh *et al.,* 2017)

Polovina (1984) was the first to develop the Ecopath software, which analyzed the flow of information between species or groups of species in an aquatic ecosystem. The software was built primarily based on biomass estimates and food consumption relationships. In Ecopath, one of the most basic requirements of mass-balance models is that each group's input must equal its output (equilibrium conditions).

Christensen *et al.* (2000) explained that Ecopath with Ecosim is a software package that makes it simple to build, parameterize, and analyze mass-balance trophic models of aquatic and terrestrial ecosystems. The theory behind the models created with Ecopath and Ecosim is described briefly. It was discovered that using Ecopath proper, the intermediate state of an ecosystem also be used to parameterize systems of coupled difference and differential equations, which are used to depict changes in biomasses and trophic interactions in time (Ecosim) and ecospace (Ecospace).

Vaishakh *et al.* (2017) stated that the ecopath model was used to assess the effects of management measures on an aquatic ecosystem by displaying the effects on different functional groups before and after the measures were implemented. They stated that Ecopath is extremely useful in developing policies to implement ecosystem management principles. A mass balance model is instrumental in developing strategies for managing aquatic ecosystems by understanding the interactions between the various ecological components.

Walters *et al.* (1997) stated that Ecosim is a dynamic version of ecopath that was used to create ecosystem restoration models and can answer what-if questions about policy and ecosystem changes that would cause trophic interactions to shift equilibrium. They showed how the ECOSIM module of ECOPATH was used to study fishery response dynamics in any ecosystem where enough data is available to build a simple mass-balance model. It also shows how the inadequacy was corrected by employing a more complex delay differential equation structure that accounts for both number/body size and biomass dynamics.

2.5 Placing fisheries within an ecosystem context

Sehgal *et al. (2013)* examined the diversity and density of zooplankton in Dimbhe Reservoir, Maharashtra. The maximum zooplankton density recorded in Dimbhe was during the summer season with 5123 no. /100 liters, while in winter it was 1314 no. /100 liters. A total of seven species of zooplankton were recorded each during both seasons, with Copepoda being the most commonly observed order and Cypris species the most dominant

Mensah *et al.* (2019) used the Ecopath model to study Lake Volta fisheries' energy flows and species interactions. The study identified ten functional groups and annual yields of fish species estimated between 2015 and 2016. The lake's trophic structure was revealed to be separated into four main trophic levels by the findings. Bagrus had the highest trophic level of i.e.3.3. The calculated Ecotrophic efficiency value of the primary producers indicated that they were least exploited compared to the secondary producers. The lake system was classified as developmental based on system characteristics and ecosystem maturity.

Tecchio *et al.* (2013) analyzed the trophic network and omnivory rates in the ecosystem concentrated at the first-order consumer's trophic levels (TL-2) and the critical ecological functions.

Villanueva *et al.* (2006) studied the trophic dynamics of the Bagre reservoir, impounded in Burkina Faso. The data was analyzed using the Ecopath software between 1997 and 1998. Findings showed that the total fish biomass was 22.63 t km, with trophic levels 2 and 3 accounting for most. Fish-eating birds, crocodiles, and adult Lates were the top predators, followed by Hydrocynus species.

Banerjee *et al.* (2016) studied the trophic relationships and ecosystem functioning of the Bakreswar reservoir in India. The balanced Ecopath model was prepared for the Bakreswar reservoir. Results showed that the model was well suited for the system under consideration. The Bakreswar reservoir ecosystem was a moderately mature system with a vulnerable food web structure due to the lack of complexity. The high zooplankton biomass and TPP/TR value near unity indicate that the system was a healthy ecosystem.

Thapanand *et al.* (2007) described the trophic relationships in a newly impounded South East Asian reservoir (Pasak Jolasid near Bangkok, Thailand) to manage the multispecies fishery of that reservoir. A total of 36 ecological groups were considered for this study. The highest trophic levels were estimated to be 3.0 for *Channa striata* (Bloch), *Hampala macrolepidota* (Valenciennes), *Oxyeleotris marmorata* (Bleeker), Hemibagrus species, Mystus spp., and *Pangasius lanaurdii* (Bocourt). Most of the fish biomass ecological production takes place at TL2.

Angelini *et al.* (2006) studied the modelling energy flow in a large Neotropical reservoir to evaluate fishing and stability. The ITAIPU-1 (1983-1987) and ITAIPU-2 (1988-1992) models were used for this study. The result shows that the mean trophic level of the catch (yield) in ITAIPU-2 was high (2.8). Simulation in ITAIPU-1 (1983-1987) for five years resulted in biomass values similar to those obtained in ITAIPU-2 (1988-1992).

Khatun *et al.* (2021) studied the trophic model and ecosystem attributes of the Kaptai reservoir ecosystem in Bangladesh. Fourteen functional groups were recorded, considering their essential roles in the ecosystem, including nine fish groups and one prawn group. Findings showed that the total fish biomass was 6.245 t/km2. The estimated trophic levels were 1.0 for the primary producer, detritus, and 3.362 for the top predator (Snakehead). The highest trophic level suggests that the Kaptai ecosystem has a relatively longer trophic chain.

Deng *et al.* (2015) analyzed the trophic interactions and energy flows within the Manwan reservoir ecosystem on Lancang River in southwest China. Eighteen functional groups were considered for this study. The trophic structure analysis showed that the ecological system in the Manwan reservoir was divided into four primary trophic levels. The highest trophic level of 3.69 for piscivorous fishes revealed that the food chain was short, and the acquirable food energy was enormous.

Moreau *et al.* (2001) studied the Synoptic Ecopath model of biomass flows during two different static ecological situations, i.e., 1972 (high primary productivity) and 1974 (low productivity) in Lake Nakuru (Kenya). The results found that the ecotropic efficiencies for all groups were lower in 1972 than in the 1974 phase. Means In 1974, less abundant resources were there. The whole ecosystem displays those transfer efficiencies were very similar in both phases.

Philippsen *et al.* (2005) analyzed the possible impacts of small-scale fisheries on the structure and functioning of a tropical ecosystem in Itaipu reservoir in Brazil. Results showed that, fishing effects and predator-prey interactions were the main drivers explaining catch trends in the Itaipu reservoir fisheries. The highest trophic level was 4.37 for S. *brasiliensis*. The mean trophic level of the catch of the reservoir was 2.79. Itaipu reservoir found that it helps control the introduced species' negative impacts.

Geers *et al.* (2016) developed the Ecopath with Ecosim model to examine the impact of Gulf fisheries on ecosystem structure and maturity. There were 47 functional groups in the model used in this study. The results showed that the northern Gulf of Mexico was a relatively immature system with high levels of primary production, low levels of nutrient recycling, and moderate diversity.

2.6 Ecopath modelling study in the reservoir ecosystem

Theurkar *et al.* (2015) assessed the freshwater fish diversity of the Dimbhe dam in Maharashtra. It revealed ten species belong to 03 Orders, 04 Families, and 10 Genera. Order Cypriniformes dominant than Perciform and Siluriformes. *Oreochromis mossambicus* (Peter) was an exotic species from the family Cichlidae recorded in this investigation.

Gamito *et al.* (2015) analyzed the trophic food web model of a Ria Formosa lagoonal water reservoir built using a top-down modelling methodology. The result showed that six trophic levels were found in the study and the total primary production/total biomass (P/B ratio) was 10.52. Reservoir estimated as in development stage.

Pannikar *et al.* (2017) assessed the impact of environmental management measures to conserve fish stocks in India's tropical reservoir ecosystem. The mass-balanced reservoir ecosystem models were created for 1995–1996 and 2002–2003 to show the impacts on different groups before and after the introduction of fisheries management measures. Results showed that during the pre-ban phase, the primary producers were heavily exploited (E.E.> 0.88) in the system. According to the ecosystem indices examined, the result showed that the reservoir was more resilient during the post-ban phase than during the pre-ban phase.

Khan *et al. (*2021) studied the effects of two invasive species, African catfish *Clarius gariepinus* and *Oreochromis mossambicus*, on the food web in the Karapuzha reservoir ecosystem, Kerala, India. The results indicated that *C. gariepinus* had a TL of 3.38, while *O. mossambicus* had a TL of 2.32. Mixed trophic impact revealed the harmful effects of African catfish on all fish and crustaceans in the reservoir.

Khan *et al.* (2009) evaluated the effects of invasive fishes on the ecosystem's characteristics and the food web structure of a tropical reservoir in India. Results showed that the African catfish had a high TL (3.42), which could be explained by the fact that this group of fish preys on more fish than the other fish groups. The mean T.L. of the commercial fishery was 2.21. The mixed trophic impact results highlighted the importance of lower trophic levels in the ecosystem, particularly phytoplankton and detritus.

Figueredo *et al.* (2007) determined the effects of tilapia on the phytoplankton community and water conditions in a large tropical reservoir in south-eastern Brazil (Furnas Reservoir), two in situ experiments were conducted with three controls (no fish) and three tilapia enclosures (high fish density). This study demonstrated that environmental problems might arise after introducing O. niloticus into aquatic environments. Net cages were becoming increasingly popular, and cultivation methods, notably the daily addition of food, may hasten environmental damage.

Gubiani *et al.* (2011) used the Ecopath software to create standardized models in 30 Paraná, southern Brazil reservoirs. They looked into whether the eight characteristics listed in Odum's theory had any connections (estimated by Ecopath models and summarised in a Principal Component Analysis—PCA) and reservoir characteristics such as age and area. Results showed that axis one was negatively correlated with reservoir age, proving that older reservoirs appeared to be more developed (or senesced) as compared to the younger reservoirs

Pauly *et al.* (2001) recorded that the mean trophic level of fisheries landed on Canada's east and west coasts decreases by 0.03-0.10 per decade, which is equivalent to the global level.

Sakhare *et al.* (2016) analyzed 80 specimens of *Oreochromis mossambicus* collected from India's Borna Reservoir of Maharashtra. The results revealed that the food of juveniles mainly consisted of rotifers (35%), followed by copepods (30%), Chlorophyceae (20%), Bacillariophyceae (10%), and aquatic insects (5%).

Tambe *et al. (*2016) analyzed a descriptive study of *Senga armatusae* from fresh water fish *Mastcembelus armatus in the* Mula dam reservoir. The result showed that *Mastacembelus armatus* was infected by the species of the Cestode parasite of the genus Senga

Soni and Ujjania (2018) discussed the feeding habit and preferred food contents of *Cirrhinus mrigala* from the Ukai reservoir of Gujarat. The results showed that decay matter and plankton dominated gut contents and were considered the main food components during breeding, post-breeding, pre-breeding seasons, and pooled data. The study concluded *C. mrigala* was omnivorous in feeding habits.

Sakhare and Chalak (2014) analyzed 150 specimens of *Clarias batrachus* from Ambejogai in Maharashtra. The results showed that the food consisted of insect larvae, small fish, shrimp, and organic debris. Small fish and insect larvae were the primary food item in all the seasons.

Chandrvanshi *et al.* (2019) estimated the length-weight relationship and characterized the condition factor of *Catla catla* in Chhirpani Reservoir. The growth performance of *Catla catla* was found to be very good in the Chhirpani reservoir, and a study concluded that fish was suitable in this reservoir.

3. Research methodology

This chapter provides an overview of the significant ideas and parts of the conceptual framework used to perform the research. It covers the methods used during various stages of the research process, such as the data collecting, processing, and analysis phases, pilot studies, and sample techniques. It also covers the research design and describes how reliable and valid data was gathered. The strategy used for collecting primary data and the statistical methods used for analysis are discussed below.

- The locale of study
- Brief description of the study area
- Sampling procedure
- Operational definition and measurement of variables
- Data collection
- Statistical tools used

3.1 Locale of the study

The current study's objective was to find and evaluate the important ecosystem services in Dimbhe Reservoir in Maharashtra. For conclusions on the health of the Dimbhe reservoir's ecosystem by analyzing the trophic structure of the fish community.

3.1.1 Reasons for selecting the Dimbhe Reservoir

The ecosystem provides a wide range of goods and services to the human being. Even though people know most of the services, they are generally unaccounted for and unpriced, which remain outside the market domain. For maintaining sustainability, it is crucial to research trophic interaction and the pricing of ecosystem services in the Dimbhe reservoir. The Ecopath model has been used in other regions to examine the ecosystem health of reservoirs; Maharashtra has not yet seen this type of study. Because of the importance mentioned above, this topic was chosen for this research.

3.2 Brief description of the study area

Any development activity can be assessed only with a detailed understanding of the region's physical and natural characteristics and socio-economic status. Hence, an attempt has been made to describe the physical, biological, and socio-economic features of seven villages that depend on the Dimbhe reservoir for different ecosystem services.

3.2.1 Geographic location and extent

Ambegaon is a town and tehsil in Maharashtra's Pune district (Fig.3.1). It is located on the western edge of Pune city, near the foothills of the Sahyadri Mountains range. Tehsil Ambegaon has 3% of the Pune District's total rural population, indicating a lower population density than the rest. This taluka has divided into two parts due to rainfall patterns. The steep southern side of the taluka receives substantially less rainfall than the hilly northern section. Agriculture is the main occupation of this region, and it has three distinct farming seasons: the Kharif, Rabi, and summer crops. Tribal peoples live in this area and are now more reliant on fishing as a source of income. Mahadeo koli, Thakar, Kathodi, Katkari, Dhor, and Tokre Koli are some of the forest-dwelling tribes in the area.

The Kukadi project, which constructed five dams in the area, included the construction of the Dimbhe dam, situated in the Ghod basin. It is a masonry dam built on the Ghod River, a tributary of the Bhima River, and is located at latitudes of 19° 5′ 45″ and longitudes of 73° 44′ 30″, respectively. The length of the dam is 852 meters, and its height is 72.1 meters above the lowest foundation. Currently, nineteen communities are on the edges of the Dimbhe reservoir, which provides irrigation to 14,000 hectares of land. A 5 MW hydropower producing facility is located at the foot of the Dimbhe Dam, which has a 116-kilometer right bank canal and a 55-kilometer left bank canal

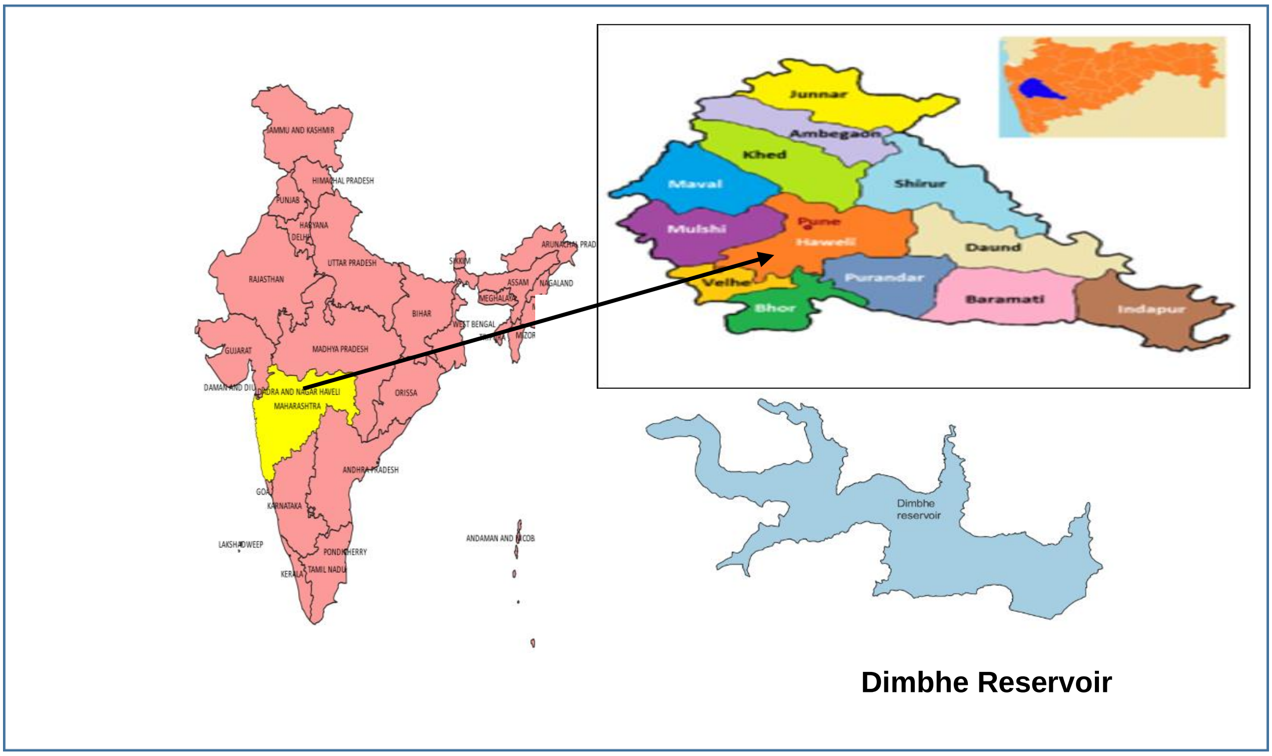

Figure 3.1 Location map of the study area

3.2.2 Morphometric features of Dimbhe Reservoir

The development of morphometric techniques was a significant advance in the quantitative description of the geometry of the drainage basins and their network. The morphometric features of the Dimbhe reservoir is given in Table 3.1.

Table 3.1 Morphometric features of Dimbhe Reservoir

Parameters	Unit
Length of the dam (m)	852
Maximum height of the dam	72.1
Live storage	12.5 TMC
Dead storage	28.31
The area under submergence in ha (FRL)	2202
Average water spread area	1278
Total catchment (ha)	30184
Maximum depth of the reservoir (m)	65.6
Mean depth of reservoir (m)	17

(Source: collected and compiled by the author during primary field data collection)

3.3 Sampling procedures

3.3.1 Selection of sampling sites

In the research region, a preliminary field investigation was conducted. This pre-survey visit gathered information about the total number of villages in the reservoir's vicinity, their fisher population details, religion, market distance, and caste details to develop the sampling process. A total of nineteen villages live on the fringes of Dimbhe reservoir. In this study, seven villages (Fig. 3.2) were selected as per population and dependency of services selected in Dimbhe reservoir by covering the whole reservoir region geographically. To ensure variability, the sample selection comprised fishers from all the communities. The interview schedules are given in Appendix-1.

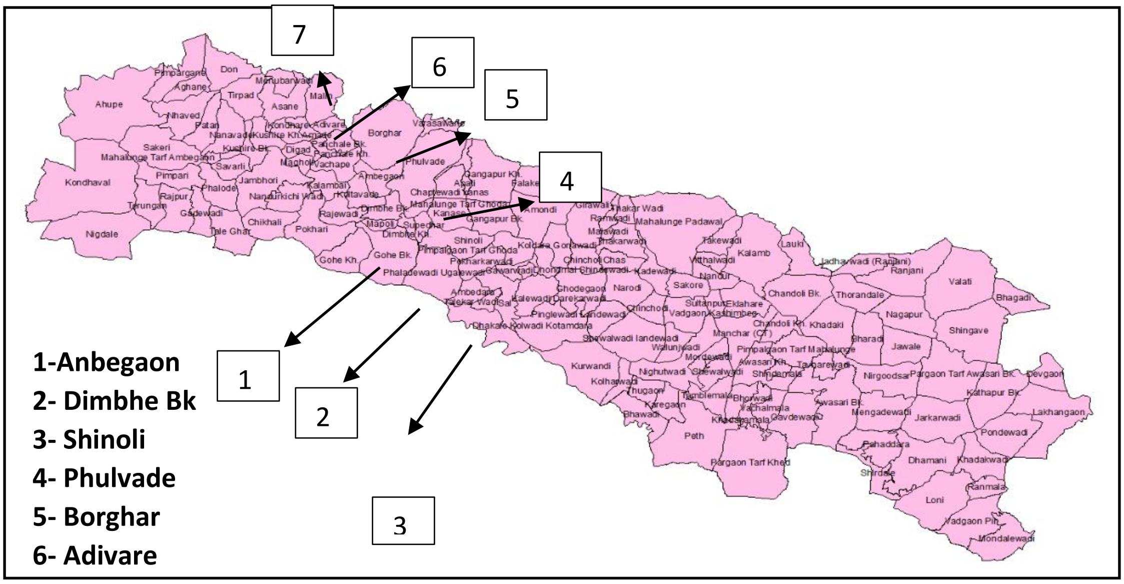

Figure 3.2 Location of sampling sites

3.3.2 Respondents

3.3.2.1 Fishers

Shabari Tribal Development Corporation Nashik has 317 registered fishermen. For fishing in the Dimbhe reservoir, about 19 fishing villages are registered. The participants in this study were fishermen from Adivare, Ambegaon, Borghar, Dimbhe Budruk, Phulvade, and Shinoli (Fig.3.3).

3.3.2.2 Farmers

Agriculture farmers who benefited from irrigating their land and feeding fodder to their cattle from Dimbhe reservoir were selected as respondents.

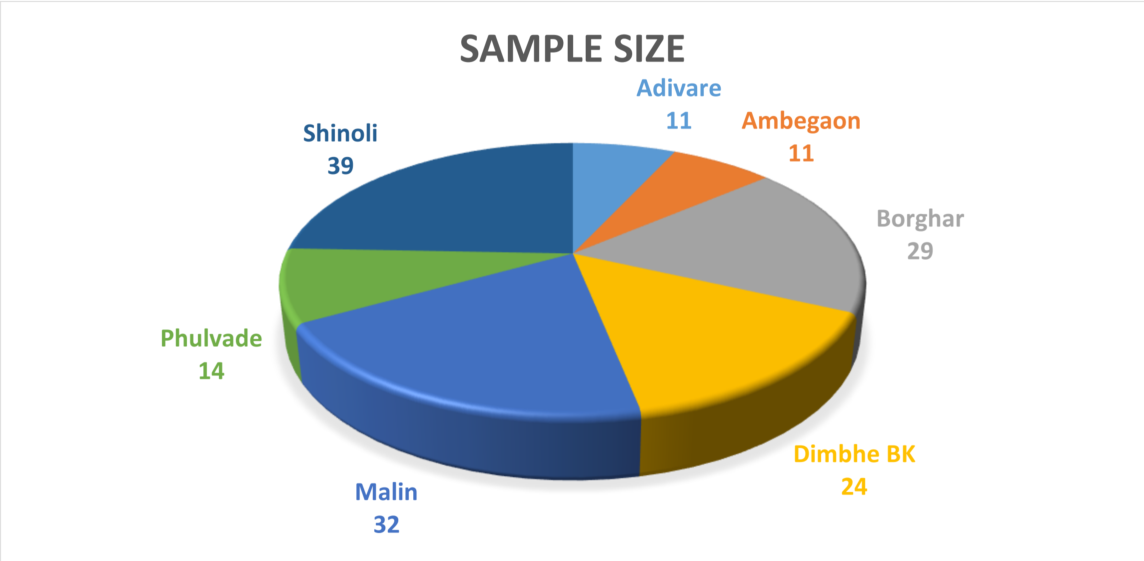

Figure 3.3 Sample size of proposed study

3.4 Selection of Variables in Socio-economic study

The data on the following socio-economic variables were collected from the respondents. Age, education, family type, family size, occupation, average monthly income, fishing experience, outstanding loans, and sources of credit were the different variables on which the data were collected. Standard classification procedures were adopted for the Dimbhe reservoir for each of these variables. The classification details are available in the section on results and discussion of this study.

3.4.1 Demographic and social parameters

Religion greatly influences individuals' social and cultural context in a particular location. Family size is a significant socio-economic indicator since it impacts household income, food consumption, and socio-economic well-being. The social and cultural environment of a population in a particular place is greatly influenced by religion (Khatun *et al.,* 2013). The degree to which fishers and farmers are literate and educated impacts their level of knowledge, the growth of their skills, their exposure to manufacturing technology and marketing strategies, and the degree to which they adopt new technology. The Empirical measurement for demographic and social parameters is given in the table 3.2

Table 3.2 The Empirical measurement for demographic and social parameters

Variables	**Operationalized definitions**	**Categories**	**Coding**
Demographic parameters			
Age	Number of respondents' completed years at the time of an inquiry, categorized according to the planning commission	<35	1
		36-45	2
		>45	3
Gender	Gender referred to the sex of respondents	Male	1
		Female	2
Family Type	Type of family the respondent lived in or belonged to	Nuclear	1
		Joint	2
Social Parameters			
Caste	The name of the Sub-Caste to which the respondent claims to belong to	ST	1
		SC	2
		OBC	3
		General	4

Education	Refers to whether the respondent attended formal educational institutions; and how many years one has completed therein	Uneducated	1
		Up to Higher Secondary	2
		Graduated	3
Marital Status	Whether the respondent is married or not	Married	1
		Unmarried	2

3.4.2 Economic parameters: Primary Occupation

The standard of living is determined by income, which correlates with practically all well-being measures. Every single respondent worked at least two different occupations. Fishing was the most common primary occupation (in terms of income), according to 80% of the respondents. Crop farming, followed by fishing, agriculture, and daily wage labour, was the most prevalent secondary occupation. The most crucial element for a better understanding of the socio-economic circumstances of fishers and farmers is income. To maintain a minimal standard of living, an individual should earn at least Rs. 5000 per month (or Rs. 60,000 per year), and anything less is considered low income (poor) mentioned in table 3.3. However, mean and absolute earnings were determined.

Table 3.3 Monthly Household Income of Respondents

Monthly Household Primary income	Categories	Values
Income	Low	<5000
	Medium	5000-10000
	High	>10000

3.4.3 Fishing occupation profile

A full description of the respondent's occupation in fishing is provided in the fishing employment profile (table.3.4.)

Table 3.4. Variables and operationalized definitions related to fishing

Parameter	Operationalized definition	Categories
Experience in fishing	Year of experience in fishing	Absolute number in years
Ownership of craft	Ownership of craft of respondent	Yes/No
Specification of craft	Type of craft the respondent possesses	Nav/tubes/other
Ownership of gear	Ownership of gear of respondent	Yes/No
Specification of gear	Type of gear the respondent possesses	Gillnet/ Cast net/ Drag net / Hook & line /any other
Fishing days per month	No. of days the respondent goes fishing	Absolute number of days
Fishing hours per month	No. of hours the respondent goes fishing	Absolute time in hours
Area of operation	The distance traveled on a fishing trip	Absolute distance in meters

3.4.4 Description of selected Household profile

Three types of houses in the study area were found (where some families live in their own houses while a few as rented. Traditional roofing techniques like thatch roofing require covering the roof with dry plants like straw, water reed, rushes, sedges, and others. A roof constructed of clay, ceramic, concrete, or slate tiles is known as a tile roof. The detailed information about respondents inside house facilities is provided table 3.5

Table 3.5 Variables related to household profile of respondents

Variables	**Categories**	**Coding**
Ownership of house	Rented	1
	Owned	2
Roof Type	Thatched	1
	Tilled	2
	Terraced	3
Electricity	Yes	1
	No	2
Gas Connection	Yes	1
	No	2
Drinking water facility	Public tap	1
	Well	2
	Tube Well	3
Ration Card	APL	1
	BPL	2
Toilet facility	Available in house	1
	Public toilet	2
	Open defecation	3

3.4.5 Utilization &dependence of Dimbhe reservoir ecosystem

Respondents depend on Dimbhe reservoir for their needs like fishing, aquaculture, cattle rearing, swimming, washing clothes, fuel wood, etc. If those services are unavailable, then the information about how much they want to pay is collected (table.3.6)

Table.3.6 Utilization &dependence of Dimbhe reservoir ecosystem

Particulars	**(√)**	**Amount (₹)**	**Particulars**	**(√)**	**Amount (₹)**	**Particulars**	**(√)**	**Amount (₹)**
Fishing			Water for another purpose			Cattle Rearing		
Agriculture			Bathing			Washing clothes		
Aquaculture			Swimming			Medicine		
Food			Water Sports			Others (if any)		
Drinking water			Firewood					

3.5 Data Collection

3.5.1 Tools of primary data collection

Primary data was collected using by following procedure/methods.

3.5.1.1 Primary observation

The primary observation method was used during sampling to get an idea about the reservoir ecosystem services. In this method, visual observation obtained information directly and limited interaction with people. Though very valuable, the information was limited to a few aspects. So, it was supported by detailed key informant interviews.

3.5.1.2 Key-informants interview

Key informants' interviews are qualitative in-depth interviews with people who know what is happening in the community. Key informant interviews aim to collect information from a wide range of people, including community leaders and professionals. Key informants' interviews were carried out using a detailed checklist to get a first-hand idea about the reservoir ecosystem services.

3.5.1.3 Personal interview with the respondent

The data was collected from the respondents who get benefited from Dimbhe reservoir ecosystem services with the help of structured schedules incorporating all parameters on which information is required.

3.5.2 Tools of secondary data collection

The details of the reservoir registered fish production of Dimbhe reservoir were collected from the department of fisheries, fisheries co-operative societies, and records. The Information about agriculture irrigation and hydroelectricity power generation was collected from the irrigation department. Data for provisioning drinking water was collected from Grampanchyat.

3.6 Contingent Valuation Method

The Contingent Valuation Method (CVM) is a well-established technique to measure the benefit of changes in the quality of the environment. The method is now widely accepted by environmental economists following many empirical and theoretical refinements, which took place in the 1970s and 1980s, mainly in the USA (Hanley *et al.,* 1995).

The main purpose of contingent valuation is to assign monitory values to goods and services for which there are no market prices or prices that do not accurately reflect their societal value. It is a highly flexible method applicable to a wide variety of scenarios, and it typically employs the survey technique to estimate values for non-market goods (Powe *et al.,* 2003). The method has become an integral part of the environmental assessment of development and basic infrastructural projects (Echessah *et al.,* 1997; Venkatachalam, 2004).

A realistic but hypothetical scenario is presented to respondents in a contingent valuation survey. They are then asked about the maximum sum of money they would be willing to pay (WTP) for an improvement from the status quo and the least sum of money they would be willing to accept (WTA) for deterioration from the status quo (Echessah *et al.,* 1997). Binary response models like logit and probit are fitted using the yes/no responses to the willingness to pay (WTP) questions, the offered amounts (dollar values provided for the WTP question), and extra information about the respondents' characteristics (Albertini, 1995).

Contingent Valuation measures the compensating or equivalent variation for good in question. WTP is thus defined as the amount that must be deducted from an individual's income to maintain their utility level. Maximum WTP is the amount of money the consumer is willing to give up to receive the service so that they are as well off as they were without the service (Onwujekwe, 2004).

In this study, CVM is applied to elicit the WTP of people for water, Fuelwood, and fodder. A dichotomous choice format, with one follow-up dichotomous-choice question and an open-ended follow-up question, was used to elicit the WTP. Descriptive statistics were used to assess people's willingness to pay to compare different categories of sample units in terms of their WTP.

3.6.1 Contingent Valuation By using Logit Model

In the model, the dependent variable was dichotomous, taking the value 1 or 0, i.e., a qualitative variable incorporated into the regression model as a dummy variable. While it is possible to generate the estimates for binary choice models using Ordinary Least Squares (OLS), this method violates certain fundamental principles of the classical regression model. The irregularities' heteroskedastic variances, non-normality, and questionable applicability of R2 as a measure of fit are a few of them.

The methods that are most frequently employed to estimate these models are the linear probability models (LPM), Probit model, and Logit model.

Consider the following simple model:

$$\boldsymbol{Y_i = \beta X_i + \varepsilon_i}$$

Where,

Y_i = is the dependent variable that takes two values, either 0 or 1

X_i = value of the attribute

ε_i = error term is a randomly distributed variable having a mean of 0 that is distributed independently.

Models such as above express the dichotomous Y_i in the form of a linear function of the explanatory variable X_i, are called Linear Probability Model (LPM). However, LPM models, when used in binary choice dependent variables, have the problem of generating predicted values that may fall outside 0,1 intervals violating the basic tenets of probability. The other issues are heteroscedasticity and generally

lower R^2 values. Therefore, the Probit and Logit models have been recommended to overcome the difficulties associated with LPM. The models use Maximum Likelihood Estimation (MLE) procedures. The cumulative logistic probability function, which is computationally more straightforward to employ than the cumulative normal function yet reasonably close to it, is the foundation of the Logit model. Both Logit and Probit are transformed such that a cumulative distribution is estimated, thereby eliminating the interval 0,1

The problem associated with LPM. The logistic cumulative probability function is represented by

$$\boldsymbol{P_i = f(Z_i) = \frac{1}{1 + e^{-z_i}}} \qquad \ldots\ldots 1$$

Where Pi is the probability that the i^th^ person will be in the first category,

$Z_i = \alpha + \beta X_i + \cdots + \beta X_n$

(X_i is the vector of attributes associated with an i^{th} person, α is a vector of the parameters to be estimated) and e represents the base of natural logarithms approximately equal to 2.718. In this equation Z_i range from positive infinity to negative infinity. The probability of WTP lies between 0 and 1. If we multiply both sides of the equation by $1 + e^{-z_i}$ results

$(1 + e^{-z_i})P_i = 1$

Dividing by P_i and then subtract 1 to the equation 1 lead to

$(1 + e^{-z_i})P_i = 1$

$$P_i = \frac{1}{1+e^{-z}}$$

$$1 = (1+e^{-z})P_i$$

$$1 = P_i + e^{-z} \times P_i$$

$$1 - P_i = e^{-z} \times P_i$$

$$\frac{P_i}{1-P_i} = \frac{1}{e^{-z}}$$

$$e^z = \frac{P_i}{1-P_i}$$

Now by taking natural logarithm on both sides

$$z = log_e\left(\frac{P_i}{1-P_i}\right)$$

This is the Logit probability model. Thus, the logistic model defined in the equation is based on the Logits of Zi, which is the stimulus index. A limited dependent variable technique was used to evaluate the factors affecting respondents' WTP. The Logit model of the following form was used:

$$Z_i = \ln ODDS = \ln \frac{P_i}{1-P_i} \alpha + \beta X_i$$

Where $Z_i = \log ODDS$ of willingness to pay and $X_1, X_2, \ldots X_i$ are the independent variables.

A Logit regression model examined factors influencing fishers' WTP for water, timber, and firewood in Dimbhe reservoir.

In logistic regression, an equivalent statistic to R^2 does not exist (Allison 2013). The maximum likelihood estimates used in the model estimations from logistic regression were obtained in an iterative procedure. The OLS technique to goodness-of-fit does not apply because they are not computed to reduce variance. So, to check the goodness of fit of logistic models, a test called the Hosmer Lemeshow test is used.

The Hosmer-Lemeshow (H-L) Statistic is another measure of lack of fit. H-L recommends partitioning the observations into ten equal-sized groups according to their predicted probabilities. The nominal chi-square values indicate the excellent fit of the model. (Hosmer, 2000)

3.6.1.1 Estimation of the logit model

A bivariate (Chi-squared) analysis was conducted to determine how each explanatory variable relates to the dependent variable. This analysis was also carried out to determine if each variable's influence was significant. The regression was first run to include all the variables. This was done because some variables on their own may not be substantial. However, their interaction with other variables may show that they contribute to influencing people's WTP. The highly correlated variables were eliminated from the model, along with the non-significant variables. Multicollinearity was prevented by doing this.

Table 3.7 Logit Model Specification

Variables	WTP for Water	WTP for Fuel wood	WTP for fodder
Willingness to pay			
Family status	Nuclear=0 Joint=1	Nuclear=0 Joint=1	Nuclear=0 Joint=1
Saving Behaviour	Bank= 0 No saving= 1	Bank= 0 No saving= 1	Bank= 0 No saving= 1
Gender	Male= 0 Female=1	Male= 0 Female=1	Male= 0 Female=1
Family size	<4=0 >4=1	<4=0 >4=1	<4=0 >4=1
Education	Uneducated=0 Educated=1	Uneducated=0 Educated=1	Uneducated=0 Educated=1
House Type	Kachha=0 Pakka=1	Kachha=0 Pakka=1	Kachha=0 Pakka=1
Secondary Occupation	Agriculture=0 Daily wage labour=1	Agriculture=0 Daily wage labour=1	Agriculture=0 Daily wage labour=1
Primary Occupation	Fishing=0 Agriculture=1	Fishing=0 Agriculture=1	Fishing=0 Agriculture=1
Monthly Household income	<10000=0 >10000=1	<10000=0 >10000=1	<10000=0 >10000=1
Age	<45=0 >45=1	<45=0 >45=1	<45=0 >45=1

The logit model specification for WTP for water, Fuel wood, and Timber is given in table 3.7. Different variables have been used to capture the WTP of the water, Fuelwood, and fodder. These variables have been further classified for the sake of convenience of analysis. The respondents' responses to the dependent variable were classified into two in all three cases. The number of respondents with WTP less than 100 was zero, and the number of respondents with WTP greater than 100 was 1.

While Table 4.15 gives the factors that determine the WTP of water for fuel wood and FTP for Fodder. The differences in the classification of WTP arose since the binary responses were highly skewed. Therefore, this classification enabled more reliable results to arrive at a reasonably normal distribution of responses in terms of 0s and 1s.

The independent variable family status was classified as 0 for the nuclear family while 1 for the joint family. The saving behavior of respondents was classified as 0 for bank and 1 for no saving. Similarly, the age group was classified as 0 for ages less than 45 and 1 for more than 45. The respondents with family size less than or equal to 4 were classified as 0 and 1 for having more than four family members. Uneducated respondents were classified as 0 while educated respondents as 1. The respondents having kaccha houses were classified as 0 and 1 for pakka houses. Those respondents having fishing as a primary occupation were classified as 0 and 1 for agriculture. The secondary occupation variable is 0 for Agriculture and 1 for daily wage labour. The respondents having an age less than or equal to 35 were classified as 0 while aging more than 35 as 1.

3.6.2 Double bounded logit model

A double-bounded technique involves asking respondents questions twice. Suppose the original query "Are you willing to pay BID for providing water, fuel, wood, and fodder?" receives a positive response in a WTP experiment. In that case, the follow-up question employs a greater bid value. Alternatively, the follow-up question employs a lower bid value if the response is no. The outcome is that the researcher can categorize each responder into one of four groups: "yes/yes," "yes/no," "no/yes," and "no/no," all of which correspond to shorter, more precise intervals around each respondent's WTP level.

The double-bounded model's mathematics is a simple expansion of the single-bounded model. The likelihood that a respondent will accept the first bid amount presented (BID) is

$$P^{y}{}_{i} = Prob(yes) = Prob\ (WTP_i \geq BID)$$

And the probability of obtaining no response is $(1 - P_i)$

In this discussion, we use the logit model so that $P^y{}_i$ takes the following form

$$P^y{}_i = G(\alpha + \beta\ BID_i)$$

Which leads to the conventional log-likelihood function for the binary choices.

$$L^{SB} = \sum_i y_i log P_i{}^y + \sum_i (1 - y_i) log(1 - P_i{}^y)$$

Where y_i equals one if the response is yes, and 0 otherwise.

In the context of the double bounded format, each participant is given two sequential bid values, the second of which is dependent on the first. The following response probabilities are derived using the logit model in accordance with Hanemann, Loomis, and Kanninen:

$$\mathrm{P_i{}^{yy}} = \frac{1}{1 + \mathrm{e}^{-(\alpha + \beta \text{ high bid})}}$$

$$\mathrm{P_i{}^{nn}} = 1 - \frac{1}{1 + \mathrm{e}^{-(\alpha + \beta \text{ low bid})}}$$

$$\mathrm{P_i{}^{yn}} = \frac{1}{1 + \mathrm{e}^{-(\alpha + \beta \text{ high bid})}} - \frac{1}{1 + \mathrm{e}^{-(\alpha + \beta \text{ first bid})}}$$

$$\mathrm{P_i{}^{ny}} = \frac{1}{1 + \mathrm{e}^{-(\alpha + \beta \text{ first bid})}} - \frac{1}{1 + \mathrm{e}^{-(\alpha + \beta \text{ low bid})}}$$

Where the first bid denotes the first bid value, Low BID is the following lower bid amount, and HIGH BID is the following higher bid amount.

There are now four components to the double-bounded log-likelihood function:

$$L^{DB} = \sum_i I^{yy}{}_i \log P^{yy}{}_i + \sum_i I^{yn}{}_i \log P^{yn}{}_i + \sum_i I^{ny}{}_i \log P^{ny}{}_i + \sum_i I^{nn}{}_i \log P^{nn}{}_i$$

The double-bounded model is predicated on an essential supposition: respondents have the same WTP value in mind when responding to both the initial and follow-up WTP questions.

3.7 Utilization and dependence of Dimbhe reservoir ecosystem

For thousands of years, people have used reservoirs to store water for domestic, industrial, and agricultural applications. Additionally, hydroelectric dams are an alternative to non-renewable energy sources, which account for most of the world's energy.

Economic Value of Provisioning Services in Dimbhe Reservoir

Primary ecosystem services provided by the Dimbhe Reservoir have been identified, and their economic values have been evaluated using the methodology from the Millennium Ecosystem Assessment. Ecosystem services are essential to human health, well-being, and the global economy. Guo *et al.,* 2001 estimated economic value of forest ecosystem also Baral *et al.,* 2016 calculated the economic value Jagadishpur reservoir. The following section discusses how each ecological service is valued economically.

3.7.1 Employment Generation

The Dimbhe Reservoir is a source to get work. The local community benefits significantly from the reservoir's employment prospects and the people involved in daily operations. In the study, the reservoir's man-day production was used to evaluate the economic value of employment. Employer-generated economic values have been calculated using the local pay rate. For five years, there have been seven employees working in Dimbhe reservoir Table (3.8)

The economic value of employment has been estimated in the study in terms of man-days generated by the Dimbhe reservoir. Thus, an estimated 356 days of man-days annually and a total of 1780 days for five years are generated for the employment of local people. The committee's monthly employee payment is based on their work criteria.

Table 3.8 Monthly payment of employs working in Dimbhe reservoir

Employment	Monthly Payment (Rs)
Motiram Dagadu Gelaje	9500
Namdev Balu Bhangare	9500
dema Dhavji Rade	5500
Shankar Dongru Dharade	5500
Narayan Budhha Bhokate	5500
Budhaji Damse	13500
Kunda Jadhar	5500

3.7.2 Water Provisioning

3.7.2.1 Irrigation

Reservoirs can function as reliable water sources for irrigation with slight seasonal variation because of their enormous amounts of water. Agriculture is one of several jobs people in Dimbhe are mostly or entirely engaged in. This area's primary occupation is agriculture. Bajara is the most widely farmed crop, with fruits like grapes, bananas, and potatoes and vegetables like tomato and potato. In this area, numerous Adivasi tribes work on a wage basis when they don't have any work. The season-wise price of crops concerning their irrigation mode is described in Annuxers-2.

3.7.2.2 Water for drinking purposes

Under Pokhari Pradeshik Gramin Nalpani Purvatha Yojana, the Dimbhe reservoir water was provided to 6 villages Jambhuri, Pokhari, Grohe, Rajewadi, Chikhali, and Mapoli. The water filtration unit of 10 lakh capacity is set up in Gohe. Chemicals were used for filtration before the supply of water to villages.

3.7.2.3 Fuelwood

Many communities living along the fringe of Dimbhe reservoir often depend on the forest area for fuel, wood, and energy requirements. The usage of fuel wood from the reservoir area is unrestricted. Depending on their family's needs, they collect Fuelwood daily, weekly, or monthly. Fuel wood's economic value is determined based on its current local market price.

3.7.2.4 Fodder/grazing

Grazing rights for their livestock, such as cattle, goats, and sheep, may be granted to the communities living in the reservoir's periphery settlements. The Adivasi communities primarily inhabit thatched homes constructed of fodders, which they harvest from the reservoir region in significant quantities. The economic worth of supplying fodder from the reservoir area has been assessed using typical forage quantities and the price of fodder on the local market.

3.7.2.5 Fishing

Fish is a significant source of protein for people worldwide. Fish is one of the most valuable wild foods that ecosystems supply and is crucial to the diet and economy of many populations. The economic value of fishing has been estimated in the study using production estimates and the local market price of the produce.

3.7.2.6 Hydroelectric power generation

Dams can use gravitational energy to generate low-cost electricity, and hydroelectric dams' source 19% of the world's electricity (Lindstorm *et al.,* 2012). In addition to irrigation and drinking, the Dimbhe reservoir water is used to produce electricity. The current capacity of the hydropower unit is 5 MW. The annual power generation is 17.99 million units.

3.8 Modeling Approach

Polovina (1984) first suggested the master equation, which Christensen *et al.* (2000further improved and expanded to create the Ecopath model. To explain energy flows among biological components, trophic interactions based on food web structure, and system maturity, this mass balance ecosystem model was built using dynamic simulation modelling software (Christensen *et al.,*2000; Christensen et al.,2004).

The creatures in the reservoir ecosystem are divided into functional groupings made up of a single species or a collection of populations based on similarities in habitat preferences and food components (Yodzis & Winemiller 1999). The energy balance of each system component is provided by

Consumption = Production + Respiration + Unassimilated food

which means the energy input and output of all living groups in the model must be balanced. The Ecopath model constructs a mass-balanced snapshot of an ecosystem presenting the interspecies interaction. Network analysis in EwE provides a linear food chain and predicts energy transfer efficiency at different trophic levels. Moreover, Ecopath also supports Odum's theory of ecosystem development (Odum, 1969) in terms of ecosystem state, maturity, efficiency, health, and development.

The Values for each biological parameter for the functional groups—Ecotropic effectiveness, diet composition (DC), consumption/biomass ratio (Q/B), production/biomass ratio (P/B), and functional group biomass (B) —were established to build the model (EE). Although accurate estimates of all parameters for each functional species group lead to greater confidence in model outputs, only three of the four (B, P/B, Q/B, and EE) primary inputs are necessary. EE is the proportion of total production and mortality and is generally not specified but is often estimated during model balancing if reasonable estimates of the other three parameters (B, P/B, and Q/B) are available.

The model assumes an equilibrium condition that inputs to any functional group are equivalent to outputs (biomass consumption by predation). It consists of linear equations representing the functional groups (Vassallo *et al.,* 2006).

3.9 Model Parameters

3.9.1 Biomass

The fish biomass was calculated by the annual catch data of Dimbhe reservoir. The average biomass for each group per unit area in the habitat area (tonnes/km2) was estimated. This was calculated from the equation of Gulland (1971).

B =Y/F, where Y is the annual average yield of each group and F is the fishing mortality coefficient obtained by subtracting M from Z, where M and Z are the natural and total mortality, respectively. The biomass for unexploited groups like phytoplankton, zooplankton, macrophytes, and insects was obtained from the same habitat area from other studies and similar ecosystems.

3.9.2 The production/biomass (P/B)

The production/biomass (P/B) ratios for functional groups with data were estimated using the empirical (regression) models incorporated in the Ecopath with Ecosim (EwE) software (www.ecopath.org) from FishBase (http://www.fishbase.org) or taken from other models. The P/B ratio is equivalent to fisheries biologists' instantaneous rate of total mortality (Z) (Allen, 1971). The Z values for all species were calculated using the length-converted catch curve routine in the FiSAT package (Gayalino *et al.,* 1996).

The Ecopath model considers a steady state for every ecotropic group, were gross production

(P = Z × B) is balanced by total mortality (Z), so the average biomass (B) remains constant. The empirical equation to determine Z for fish species was as follows (Beverton and Holt, 1993):

$$\boldsymbol{Z = K(L_\infty - L_{avg})/(L_{avg} + L_C)}$$

Where L_∞ defines the asymptotic length of fishes (in cm),

K is the Von Bertalanffy Growth Function (VBGF) (/a) curvature parameter,

L_{avg} is the average length (in cm) in the population,

L_C Represents the mean length at first capture into the fishery (cm).

3.9.3 Consumption/Biomass

The parameter food consumption expresses the volume of ingested food by a specific functional group relative to its biomass in a definite period. The consumption (Q) is the total production divided by the gross growth efficiency (GE). Consumption is the intake of food by a group over the period considered (Christensen et al., 2000), which was entered as the ratio of consumption to biomass (Q/B ratio).

An empirical regression equation was used for the prediction of Q/B from easy-to-quantify characteristics of the fishes (Palomares and Pauly, 1998). Some groups' consumption/biomass (Q/B) ratios were taken from other models. Fish diet composition was taken from FishBase (http://www.fishbase.org) and the previous work.

3.9.4 Diet Composition

Food interconnects different functional groups of an ecosystem. Therefore, it is a crucial prerequisite to know their diet composition to determine the dynamics of the ecosystem. Studies on the diet composition of fishes are limited in the Dimbhe reservoir. In this regard, the diet composition of the survey was taken from other kinds of literature. Notably, studying the diet of the same species from similar systems was our priority following the investigation of similar species from similar approaches. We calculated the average diet composition of fishes in every group as a single diet.

3.9.5 Ecotrophic efficiency (EE)

Ecotrophic efficiency (EE) defines the fractional production of every consumed group within the system that is transferred through the trophic web or exploited by the fishery. In the range of 0 and 1, this value should fall. EE greater than 1 implies that the input parameters are not physically possible. According to Christensen and Pauly (1992), EEs could be set as 0.95 for heavily exploited groups. Since there is no measuring procedure or empirical relationship to determine EE, the Ecopath calculated it as an output of the model (Christensen *et al.,* 2000). The model parameters were calibrated for all the group's EE values less than 1.0 and gross efficiency values (GE = P/Q) between 0.1 and 0.3 (Christensen *et al.,* 2000).

3.9.6 Description of ecological groups

Several vital characteristics include population parameters, similarities in ecological habitat (water column/sediment), feeding habits (filter feeders, mixed feeders, predators), types of food (herbivorous, carnivorous, detritivorous, omnivorous), physiological behavior, taxonomy, distribution and maximum obtained body size (micro-, meso- and macro-) have been taken into account for plotting the functional groups.

This study used 12 ecological groups to represent the reservoir ecosystem. Fish species were categorized and grouped according to their similarities in habitat, maximum body size, feeding habits, physiological behavior, and ecological distribution to keep homogeneous characteristics among the species within each group (Yodzis and Winemiller, 1999). Each group selected a representative species based on its importance in the fisheries and available information. In addition, the data collected from the local fishers near Dimbhe reservoir was also used to develop input parameters for the Ecopath model.

3.9.7 Description of ecological groups

Tilapia

Tilapia, *Oreochromis mossambicus*, is one of the dominant fishes in the South Indian reservoir ecosystem, and it feeds mainly on benthic algae, zooplankton, and zoobenthos. No major shifts in diet composition in this fish were observed. This fish is a voracious feeder and survives extreme conditions.

Channa striata

C*. striata* is the primary species in this group. This is an air-breathing fish, and there was a slight increase in this group's biomass after introducing the closed season regime in the reservoir. They are mainly piscivorous and voracious feeders.

Major Carps

C. *catla* is one of the critical members of major carp, belonging to the Cyprinidae family. Catla fish are surface and midwater feeders. It is a planktophagus and primarily feeds on zooplankton. Labeo rohita is one of the most essential Indian

Major Carps. Rohu is an omnivorous fish and is a column feeder. *Cirrhinus mrigala* is detritivorous fish that majorly feeds on detritus.

Mastacembalus armatus

Mastacembalus armatus is a common fish species of the Indian subcontinent. It can be found in various freshwater habitats in India's plains and hills. It is a member of the order Synbranchiformes' Mastacembelidae family. One of the most well-liked table fishes, it has mouthwatering flesh. It has a distinct flavor, distinctive texture, a high protein, oil, and vitamin C content, which leads to healthy market demand.

Garra lamta

Garra lamta is a species of ray-fined fishes hill stream fish in the family cyprinidae. They are associated with fresh water habitat. It is an herbivorous fish.

Cirrhinus fulungee

In the aquatic habitat, it consumes plant matter as a herbivorous fish.

Tor putitora

Tor putitora is an omnivore fish with a higher feeding preference for plant material than animal material.

Detritus

The detritus mass was estimated using an empirical relationship derived by Pauly et al. (1993) that relates detritus biomass to primary productivity and euphotic depth.

$$\log_{10} D = -2.41 + 0.954 \times \log_{10} PP + 0.863 \log_{10} E$$

Where D is the standing stock of detritus (g/cm^2) is primary productivity (g/cm^2 yr−1), and E is the euphotic depth (m).

3.9.7. Balancing the model

According to the Ecopath equation, each group must be balanced. It states that catches, consumption, biomass accumulation, and export cannot exceed production for a group. In Ecopath, each ecological group's energy 'imbalance' could be determined by its ecotropic efficiency (EE).

Therefore, the first step of balancing a model requires the adjustment of input parameters in a *way that EE does not exceed 1. In steady-state conditions, EE remains less than one, which makes sense in a realistic model. Excess biomass may assemble in the ecosystem or be lost by other mortality. EE greater than 1 for any group means its demand is too high to be sustainable.

During balancing the model, we also checked the Production/Respiration (P / R) ratio, which was expected to be within the thermodynamic constraints limit (0 to 1). Trophic levels (TLs) are the output in the Ecopath model. The output accuracy of TL depends on the input diet matrix. We did cross-check with FishBase concerning trophic levels and found the range within our output.

3.9.8. Network Analysis

After a preliminary model run, various system metrics and network flow indices analyzed the ecosystem stability and degree of system maturity (Odum 1969). When comparing various ecosystems, several indicators might be used. Total consumption (TC), total exports (TEX), total flows into detritus (TDET), and total respiration (TR) flows are the four energy flow components that make up the total system throughput (TST), which was computed as the sum of the four.

The ecosystem's primary and secondary productions were combined to form total production (TP). Total net primary production (NPP), which represents the bioenergetics of the ecosystem, is the net output of all the producers within it. The ratio of total direct result to total respiration (TPP/TR) measures ecological maturity. A TPP/TR value around 1 denotes an ecosystem that is at a mature stage, whereas a value higher than 1 denotes an ecosystem that is still in the early stages of development. Total biomass/total throughput ratio (B/T) measures the proportion of total biomass to the system's available energy. The value of B/T increases as an ecosystem age.

The alterations in the food chain were described using the system maturity index, connectance index (C), and system omnivory index (SOI). Finn's mean path length (FML) and Finn's cycling index (FCI) provided information about the ecosystem's degree of recycling (Christensen *et al*., 2000; Pauly *et al.,* 2000; Xu *et al.,* 2011).

Due to the unpredictability of the input parameters employed in the model, the Ecoranger procedure was used to simulate the unavailable input parameters and automatically change other input parameters of the internal system. After mass balance was achieved, the parameters used for input changed to the optimized values. The pedigree model was employed to assess and quantify the appropriateness of the input parameters and their level of uncertainty. Confidence levels were then given for each input parameter. The pedigree index was in the range of 0 to 1 for the data quality of the original input parameters of B, P/B, and Q/B.

4. RESULTS AND DISCUSSION

4.1 Socioeconomic profile of the respondents

Table 4.1 (A) describes the age profile of respondents and shows that 10 percent of the respondents are under 35 years while 62.5 percent of respondents are above 45 years. The gender profile of the respondents (Table 4.1B) shows that 80 percent of male respondents and only 20 percent of female respondents.

Regarding the family size (Table 4.1C), 15 percent of respondents has less than two family members while 32 percent of families has a large family size. While 16 (32%) belongs to the nuclear family of size 2 to 4, and 85 families (53%) had a large family size, i.e., more than four.

As far as education level is concerned, Table 4.1D gives the details in respect of the levels of education of respondents. Out of 160 respondents, 65 percent of respondents were uneducated because most of the families in Borghar, Adivare, Phulade, and Ambegaon are tribal communities, and the distance between school and villages are so far and also, they are not aware of the importance of schooling,

Table 4.1 E indicates the house type profile of the respondents. Most respondents (34%) living in tiled houses, while 33.1 % fof families living in thatched houses and they collected fodders from the Dimbhe reservoir periphery for house building. About 32.5 percent of respondent's living in terraced houses. The primary occupation profile of respondents (Table4.1F) shows that 68.8 percent of respondents have engaged in fishing as a primary occupation, whereas 16.9 percent respondents have agriculture and land, they are basically agriculture farmers. About 8.8 % of respondents are working in the service sector and 5.6% of respondents are doing daily wage labor.

All the respondents were having secondary occupations (Table 4.1G) which majorly includes agriculture (48%). The fishers, in off seasons works in agriculture or brick building.

About 83 percent of respondents has savings bank accounts. While 10% of respondents saved money in self-help groups. (Table 4.1H)

Total 66.9 percent of respondents has monthly income of less than ₹5000 (Table 4.1 I). While 30% of families has monthly income group between ₹5000-10000. Only 13% of families has a monthly income greater than ₹10000, and they seem to be living in pakka houses.

Table 4.1 Socioeconomic profile of the sample respondents

Table 4.1.A Age profile of respondents

Age (years)	Frequency	Percent (%)
<35	17	10.6
35-45	43	26.9
>45	100	62.5
Total	160	100.0

Table 4.1.B Gender profile of respondents

Gender	Frequency	Percent (%)
Male	128	80.0
Female	32	20.0
Total	160	100.0

Table 4.1.C Family size of respondents

Family Size (no's)	Frequency	Percent (%)
<2	24	15.0
2-4	51	31.9
>4	85	53.1
Total	160	100.0

Table 4.1.D Education of respondent

Education	Frequency	Percent (%)
Uneducated	104	65.0
Up to 12th	49	30.6
Graduated	7	4.4
Total	160	100.0

Table 4.1.E House type of respondents

House Type	Frequency	Percent (%)
Thatched	53	33.1
Tiled	55	34.4
Terraced	52	32.5
Total	160	100.0

Table 4.1.F Primary occupation of respondents

Primary Occupation	Frequency	Percent (%)
Fishing	110	68.8
Agriculture	27	16.9
Service sector	14	8.8
Daily wage Labour	9	5.6
Total	160	100.0

Table 4.1.G Secondary occupation of respondents

Secondary Occupation	Frequency	Percent (%)
Agriculture	48	30.0
Daily wage labour	91	56.9
Others	21	13.1
Total	160	100.0

Table 4.1 H Saving behaviour of respondents

Saving Behaviour	Frequency	Percent (%)
Bank	143	89.4
SHG	17	10.6
Total	160	100.0

Table 4.1 I Monthly household income of respondent

Monthly Household Income	Frequency	Percent (%)
<₹5000	91	56.9
₹5000-10000	48	30.0
>₹10000	21	13.1
Total	160	100.0

4.2 Village-wise socioeconomic profile

The seven villages were grouped into three clusters (Fig 4.1) to clarify the socioeconomic profile of 160 families. Village Dimbhe and Shinoli were grouped into the first cluster, Ambegaon, Phulvade, and Borghar as the second cluster, while Malin and Phulvade was the third cluster. These three clusters represent the whole sampling area.

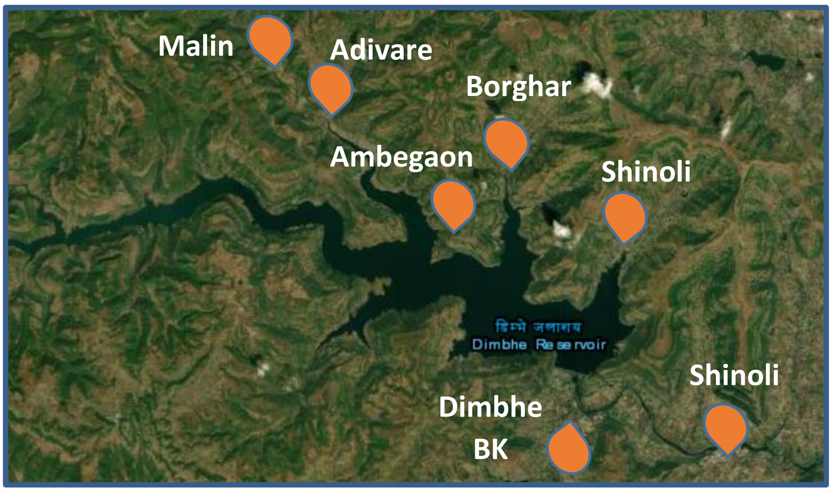

Fig.4.1 Three clusters representing the whole study samples.

As far as age is concerned, all the families in three clusters have an age more than 45 years, and specifically in cluster three, 72 percent of respondents with an age group more than 45. While in cluster cluster has 27 percent of respondents age in between 36 to 45. Very few (5%) respondents in Malin and Adivare has an age of less than 5%. The age profile (Fig.4.2) from all these three clusters showed that adults are more in cluster three as compared to other clusters.

Among all the three clusters, the male respondents are more than the females (Fig.4.3). However, in Cluster one has three female respondents, which is very low compared to other clusters.

As far as family type is concerned, the respondents in cluster one (Dimbhe and Shinoli) are living in 48 families in nuclear type, while 14 families in cluster three living in joint families. Compared to a joint family, most families living in the nuclear family, as shown in fig.4.4.

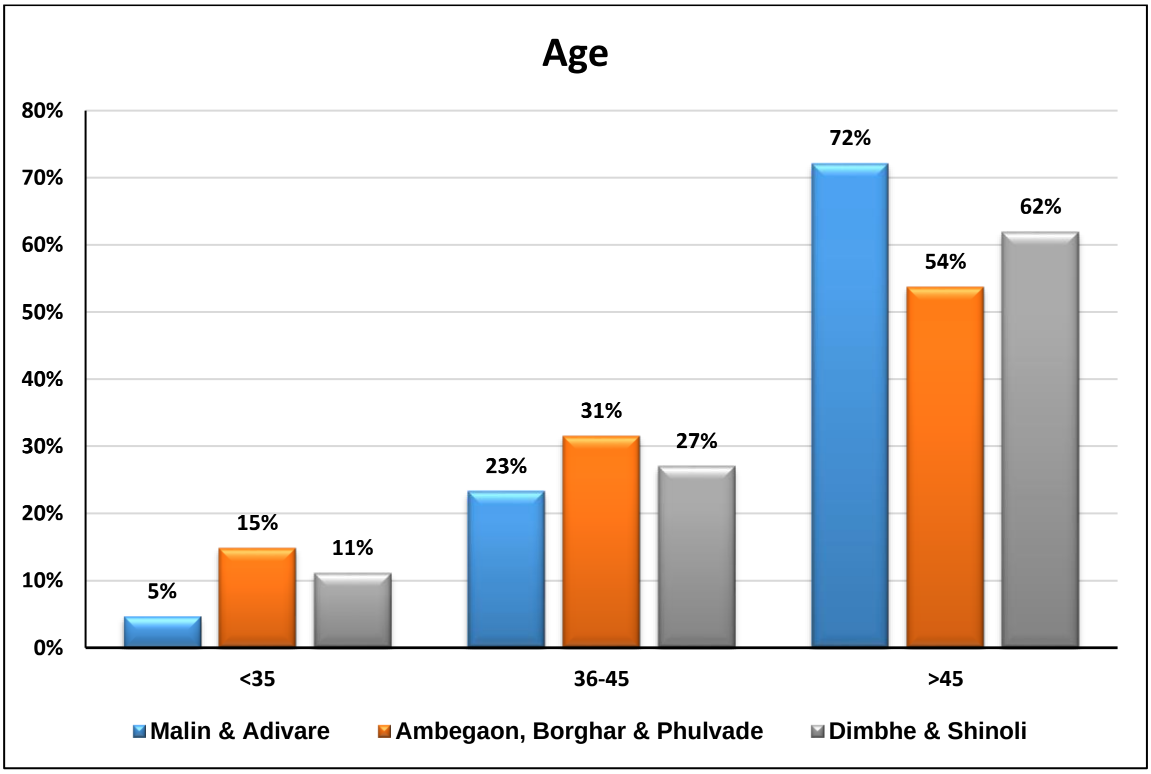

Fig. 4.2 Cluster-wise Age Profile of Study samples

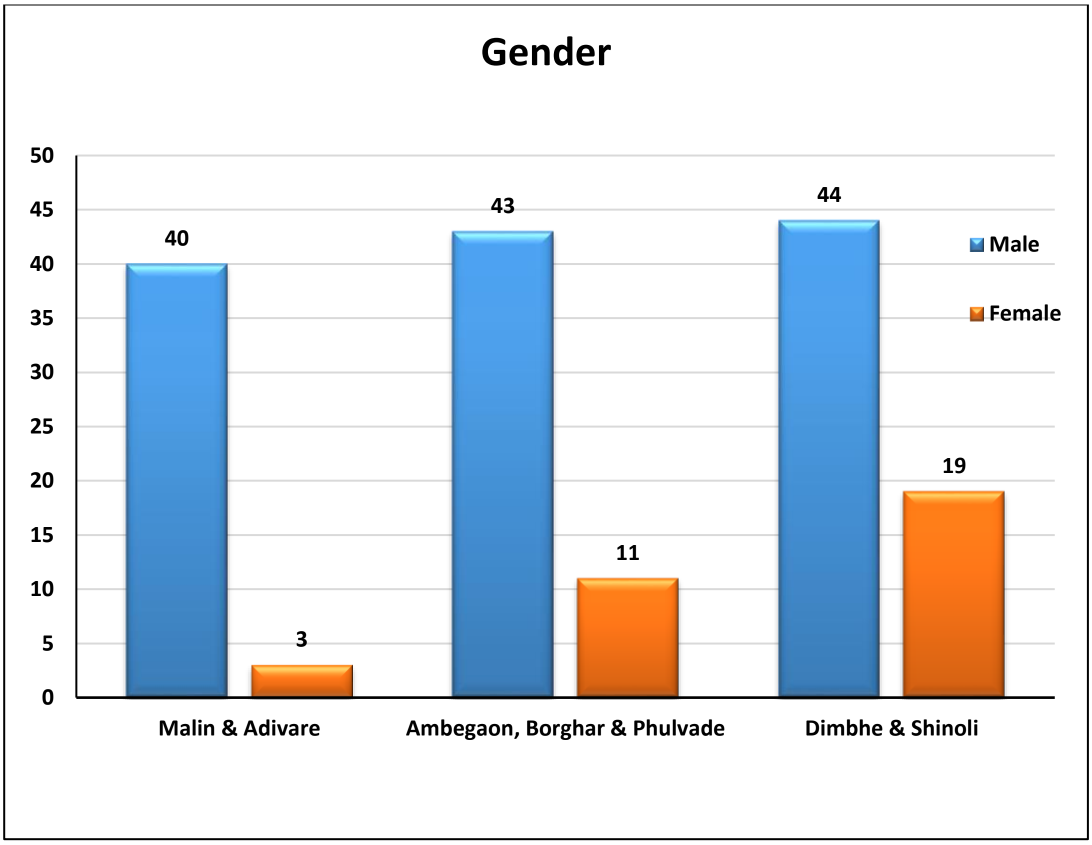

Fig. 4.3 Cluster-wise Gender Profile of Study sample

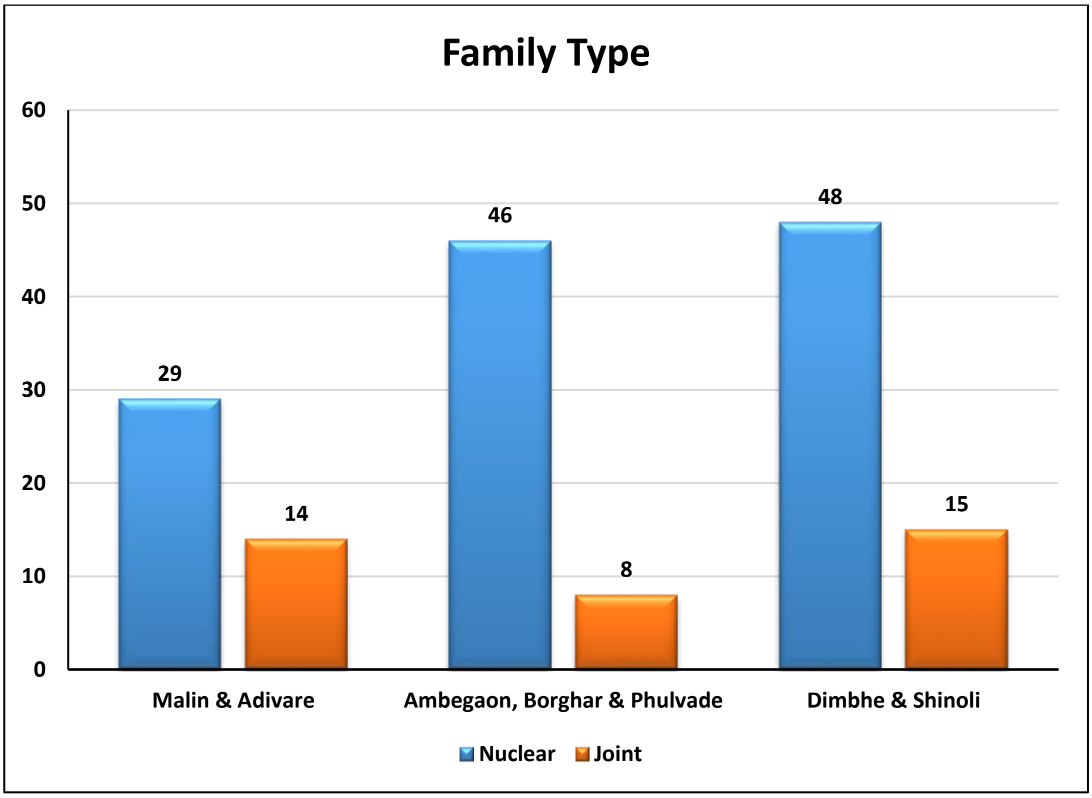

Fig. 4.4 Cluster-wise Family Profile of Study samples

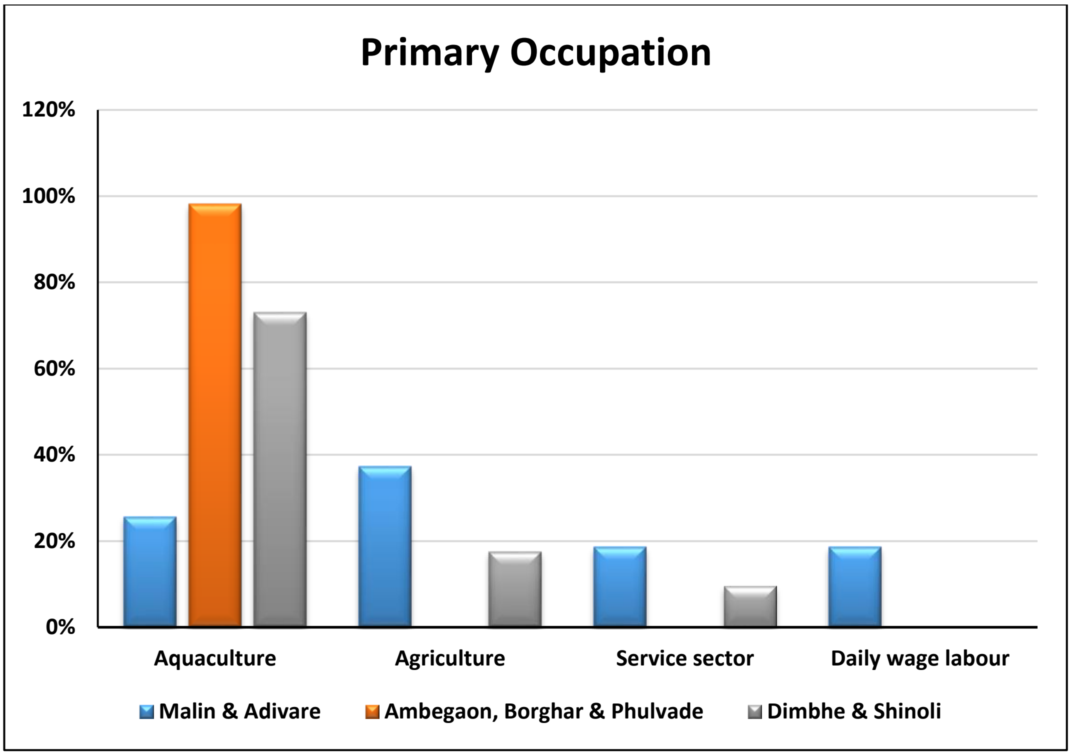

Fig. 4.5 Cluster-wise Primary Occupation profile of Study samples

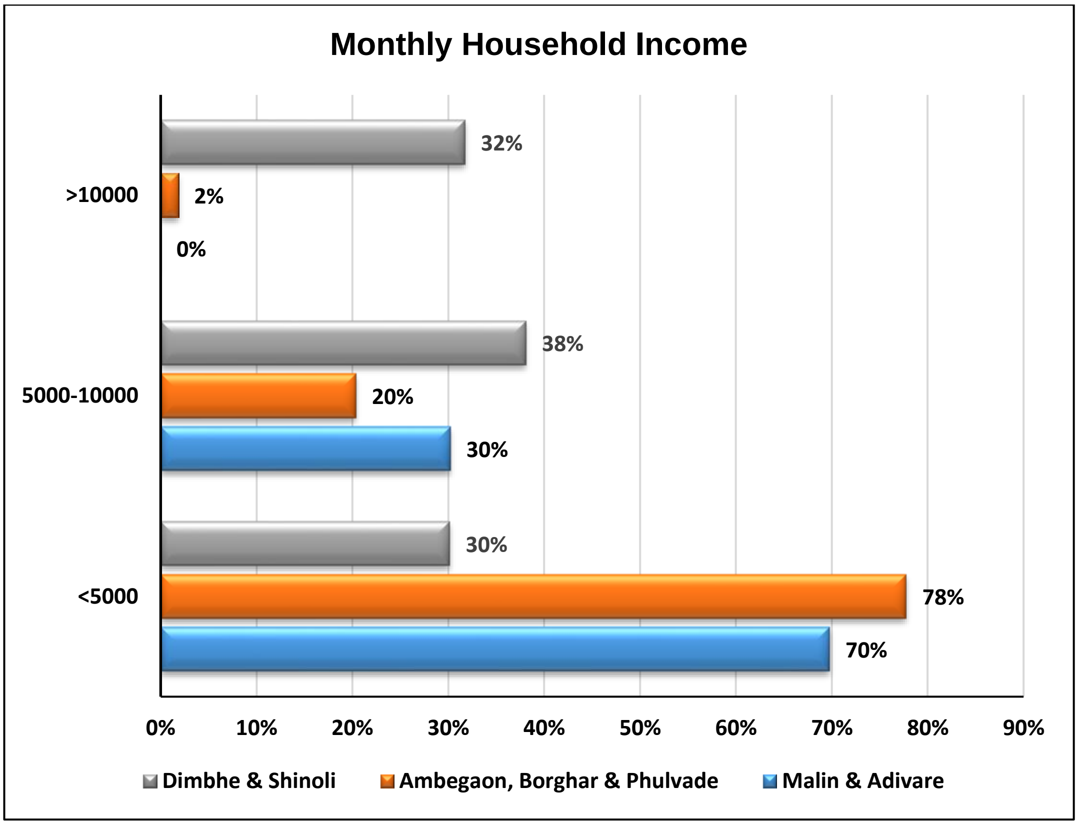

Fig. 4.6 Cluster-wise Monthly Household Income profile of the study sample

Most of the respondents in cluster two (Ambegaon, Borghar, and Phulvade) has fishing as their primary occupation (Fig.4.5). About 70% of respondents in cluster one has fishing as their primary occupation. While nearly 38% of families are doing agriculture in cluster three, few respondents in cluster two have agriculture as a primary occupation. About 20% of families in cluster three were doing service sector jobs. However, in cluster two, there is no one in the service sector because, in cluster three, most tribal communities live there, and as per this study, they are very few educated as compared to others.

About 32% of respondents in Dimbhe and Shinoli has monthly income more than ₹10000, while only 2% of respondents in cluster two has monthly income more than ₹10000. Most of the respondents (78%) in this cluster one has income less than ₹5000 because majority of the tribal peoples living in this area and they don't have strong income support by any proper occupation. About 70% of respondents in Malin and Shinoli has monthly income less than ₹5000 (Fig.4.6).

4.3 Willingness to Pay

The survey schedule was designed to capture people's responses regarding the willingness to pay for provisioning water, fuel, wood, and fodder (Table 4.2). As discussed in the section on data and methodology, the people in seven villages that were directly or indirectly dependent on the reservoir have taken. The three bid values were fixed, i.e., low bid (₹100), First bid (₹250), high bid (>₹250). Loomis *et al.*, 2005 also used CVM to estimate homeowners WTP for water leasing to maintain stable lake levels in irrigational reservoir.

Among all the respondents, 66 respondents were likely to pay provisioning water. In cluster one, about 41 respondents were WTP for provisioning water service. Among all the respondents, 66 respondents were likely to pay for water. In cluster one, about 41 respondents were WTP for provisioning water.

Table 4.2 Clusterwise Willingness to Pay for provisioning water, fuelwood, and fodder.

Clusters	Total Samples	WTP For Water	WTP for Fuel Wood	WTP for Fodder
1	63	41	38	35
2	54	10	23	15
3	43	15	25	16
Total	**160**	**66**	**86**	**66**

According to the objective of study to identify and assess the essential ecosystem services provided by Dimbhe reservoir. Responses of respondents of its use value were recorded regarding whether the respondents were willing to contribute to provisioning water, fuel, wood, and fodder. The WTP for water, fuel wood, and fodder were assessed using the logit model. Harini *et al.,* 2019 also evaluated the economic and ecological value of mangrove. The results presented in Table 4.3 gives the factors that determine the WTP for Water, fuel, wood, and fodder.

Table 4.3 Variables determine the respondent's WTP for Water, fuel wood, and fodder.

	Water		**Fuelwood**		**Fodder**	
	B	**Exp(B)**	**B**	**Exp(B)**	**B**	**Exp(B)**
Age (>45)	0.21	1.23	-0.07	0.93	0.01	1.01
Gender (Male)	-0.35	0.70	-0.15	0.85	-0.57	0.56
Family Status (Nuclear)	-2.89	0.00	1.06*	1.41	2.33	2.76
Family size (<4)	0.60	1.82	0.56*	1.76	0.80*	2.22
Education (Uneducated)	0.05	1.06	0.06	1.06	-0.12	0.88
House Type (Kaccha)	0.85*	2.35	0.81*	2.24	1.18*	3.25
Monthly income (<10000)	-2.38*	0.09	-0.03	0.96	-1.11*	0.32
Primary Occupation (Fishing)	-1.51*	0.22	-0.85*	0.42	-0.63	0.53
Secondary occupation (Agriculture)	-0.23	0.78	-0.36	0.69	-0.29	0.74
Saving Behaviour (Bank)	0.53	1.70	0.46	1.58	0.35	1.41
Constant	22.99	9.67	-21.69	.000	-20.31	.000

4.3.1 WTP for provisioning water, fuelwood, and fodder

The respondents' monthly income coefficient was negative and significant for WTP of water (Table 4.3). The respondents had a monthly income of less than ₹10,000 and were less likely to say yes to WTP (odd ratio of 0.92). For the respondents having monthly income of less than ₹10,000, the odds in favor of WTP decreased by around 8 percent. In the case of fuel wood, the coefficient for respondents' monthly income was negative. As income was less than ₹10,000, the odds in favor of WTP decreased by around 4 percent (odd ratio of 0.963). While in the case of fodder, the respondents with a monthly income of less than ₹10000 were less likely to say yes to WTP (odd ratio of 0.328). Lower the income, i.e., less than ₹10,000, the odds in favor of WTP decrease by around 68 percent. Baral *et al*.,2016

Similarly, the value of the coefficient for primary occupation was negative and significant for WTP for water. As a unit change, the respondents who had fishing as a primary occupation were less likely to say yes for WTP (odd ratio 0.221). Compared to agriculture as a primary occupation, the fisher's families' odds in favor of WTP decreased by around 78 percent. In the case of fuel wood, compared to agriculture, who had fishing as a primary occupation, they were less likely to say yes to WTP (0.424). The odds of the respondents having fishing as a primary occupation in favor of WTP decreased by around 58 percent.

The value of the coefficient for WTP for provisioning water, fuel, wood, and fodder was positive and significant regarding house type. The respondents living in kaccha houses were likelier to WTP for water, fuel wood, and fodder than pakka house families, exhibiting the odd log ratio of 2.351, 2.249, and 3.325, respectively.

The respondents in the kaccha house are more likely to pay for water 2.351 times compared to those in the pakka house. While in the case of fuel wood and fodder, the likelihood of WTP increases by log adding the ratio of 2.249 and 3.325, respectively.

The coefficient value for family status was positive and significant for the WTP of fuel wood. The respondents in nuclear families are likelier to have WTP than a joint family. The nuclear family respondent's WTP increases by a log odd ratio of 2.24. The respondents with a family size less than 4 are more likely to WTP for fuel wood (minimum family size less than four increases the WTP in favor of log odd ratio 1.176). The same parameter's coefficient value is positive and significant for the WTP of fodder. The respondents with a family size of less than four were more likely to pay for fodder than a family size of more than four; as a family size less than four increases, the WTP in favor of log odd ratio was 2.229.

The variables age, gender, secondary occupation, and saving behavior of the respondents were not significant, though with the expected sign. Although insignificant, these variables, age and gender, secondary occupation, and saving behaviour, have been listed in the results. This is because their inclusion had a bearing on other parameters that have emerged significant for determining WTP.

4.4 Double bounded Logit Model

4.4.1 Double bounded logit model for provisioning water

There was a positive relationship between WTP and respondents' education (Table.4.4). Compared to educated respondents, uneducated individuals were more likely to pay (log odd 2.56) because most tribal peoples on the periphery of Dimbhe reservoir were uneducated. They want to pay as they know the importance of the reservoir for them. Among all the respondents who said yes to the first bid value and were also ready to pay the follow-up high value (YY), they were more likely to say yes to WTP for water (25%). The coefficients for income were negative and significant for respondents who said yes to the increased offer (YY); as the income level increases beyond 10000/month, their WTP decreses (log odd 0.51).

When the bid value was reduced, the respondents with fishing as a primary occupation were less likely to say yes (log odd 0.34) as a reference point agriculture occupation. The respondents living in Kaccha house who said yes to the first offer and increased offer (YY) were less likely to pay than families in pakka house (4%). As far as the secondary occupation was concerned, the value of the coefficient was positive and significant.

Table 4.4 Double Bounded Logit Model: WTP for provisioning water

Variables	Probability (Yes, Yes)		Probability (Yes, No)		Probability (No, Yes)		Probability (No, No)	
	B	Exp(B)	B	Exp(B)	B	Exp(B)	B	Exp(B)
Age (<35 year)	0.52	1.69	-0.15	0.86	-19.2	0.00	-0.12	0.87
Gender (Male)	0.51	0.59	-0.46	0.62	1.41	4.11	-0.62	0.53
Family Status (Nuclear)	-2.16	0.00	2.17	0.47	1.07	0.45	1.40	0.53
Family size (<4)	0.52	1.68	0.22	1.24	-0.16	0.85	-0.13	0.87
Education (Uneducated)	0.94*	2.57	-0.74	0.47	-0.12	0.88	0.37	1.45
House Type (Kaccha)	-0.06	0.94	0.57	1.77	-0.30	0.73	-0.71*	0.48
Monthly Income (<10000)	-2.98*	0.05	1.21	3.35	0.80	2.26	0.15	1.16
Primary Occupation (Fishing)	-0.66	0.51	-1.03*	0.34	0.51	1.67	0.60	1.83
Secondary Occupation (Agriculture)	0.31	1.37	-0.64	0.52	-0.53	0.58	0.98*	2.67
Saving Behaviour (Bank)	1.13	3.11	-0.39	0.67	0.03	1.03	-0.99	0.37
Constant	2.11	4.01	-2.27	0.00	-2.95	0.00	-2.7	0.00

4.4.2 Double bounded logit model for provisioning fuel wood

The value of the coefficient was significant and positive for family size (table 4.5). The respondents with a family size of less than four were more likely to pay (19%) first bid value and increased bid value for provisioning fuel wood. The respondents who had fishing as a primary occupation were less willing to pay (log odd 0.47) at first bid value but not the increased bid value compared to those who had agriculture.

The respondents under age 35 were more likely to say yes for WTP (38%) at first bid value but not for follow-up high bid value than those over 35. When the bid value was reduced, the respondents who had fishing as a primary occupation were less WTP (log odd 1%) by taking agriculture as the reference point.

Table.4.5 Double Bounded Logit Model: WTP for provisioning for fuel wood

Variables	**Probability (Yes, Yes)**		**Probability (Yes, No)**		**Probability (No, Yes)**		**Probability (No, No)**	
	B	Exp(B)	B	Exp(B)	B	Exp(ss)	B	Exp(B)
Age (<35 year)	-0.86	0.42	1.34*	3.83	-0.22	0.79	-0.74	0.47
Gender (Male)	-0.27	0.75	0.49	1.63	1.09	2.98	-0.17	0.83
Family Status (Nuclear)	0.22	1.24	-0.23	0.79	0.75	2.11	0.44	1.52
Family size (<4)	0.65*	1.93	0.16	1.17	-0.08	0.91	0.20	1.23
Education (Uneducated)	-0.62	0.53	-0.08	0.91	0.14	1.15	0.02	1.02
House Type (Kaccha)	0.42	1.53	0.42	1.53	0.36	1.43	-0.48	0.61
Monthly income (<10000)	-0.10	0.90	0.15	1.16	0.77	2.17	-0.03	0.97
Primary Occupation (Fishing)	-0.16	0.84	-1.14*	0.32	-2.01*	0.13	0.90*	2.47
Secondary occupation (Agriculture)	-0.53	0.58	-0.75	0.47	-0.21	0.80	0.39	1.48
Saving Behaviour (Bank)	0.76	2.14	0.07	1.08	-0.65	0.52	-0.55	0.57
Constant	-1.28	0.27	-1.72	0.17	-3.04	0.04	-0.37	.068

4.4.3 Double bounded logit model for provisioning fodder.

The respondents living in the nuclear family were less likely to pay (1%) at low bid value but not at first bid value. The coefficient value was negative and significant for respondents with a monthly income of less than ₹10,000 (table 4.6). They were less WTP at first bid value and follow-up lower bid value. The lower the income lower will WTP. While respondents were WTP at first bid value but not for follow–up high-value results more likely to pay (log odd 4.8). The respondents who had fishing as a primary occupation were more likely to pay (22%) for providing fodder, taking agriculture as the reference point.

Table.4.6 Double Bounded Logit Model: WTP for provisioning Fodder

Variables	Probability (Yes, Yes)		Probability (Yes, No)		Probability (No, Yes)		Probability (No, No)	
	B	Exp(B)	B	Exp(B)	B	Exp(B)	B	Exp(B)
Age (<35 year)	0.06	1.06	0.72	2.07	-1.49	0.22	-1.16*	0.31
Gender (Male)	0.10	1.10	0.29	1.34	0.47	1.60	-0.07	0.92
Family Status (Nuclear)	0.77	2.15	0.80	2.21	-1.66*	0.18	1.16*	3.19
Family size (<4)	-0.56	0.55	0.18	1.20	0.27	1.31	-0.06	0.93
Education (Uneducated)	-0.55	0.57	-0.08	0.92	0.12	1.13	0.50	1.65
House Type (Kaccha)	0.66	1.93	0.14	1.15	-0.23	0.78	-0.05	0.94
Monthly income (<10000)	-0.99*	0.37	1.57*	4.82	-0.47	0.62	-0.60	0.54
Primary Occupation (Fishing)	0.01	1.00	-1.53*	0.21	0.79*	2.21	1.15*	3.17
Secondary occupation (Agriculture)	-0.53	0.58	-0.68	0.50	-0.36	0.69	0.17	1.18
Saving Behaviour(Bank)	0.19	1.21	1.11	3.05	0.63	1.88	-0.31	0.73
Constant	-1.47	0.22	-3.95	0.09	-1.15	0.31	-1.23	0.29

4.5 Valuation of Ecosystem Services

The total economic value of provisioning services in Dimbhe reservoir is given in the table 4.10.

4.5.1 Employment generation

The Dimbhe Reservoir is a source to get work. In the study, the reservoir's person-day production was used to evaluate the economic value of employment. Employer-generated economic values have been calculated using the local pay rate. A total of seven employees were working in Dimbhe reservoir. Thus, an estimated 356 days person-days, including holidays, annually (table 4.7). The average ₹654000 annual economic value is per the payment they receive. In the Corbet tiger reserve (Verma *et al.,* 2015), the estimated economic value for employment generation was 30 million annually.

Table 4.7 Year-wise man-days of employees in Dimbhe reservoir

Year	2017-2018	2018-2019	2019-2020	2020-2021	2021-2022
Man-days	312	312	312	312	312

4.5.2 Fuel wood

As stated earlier, the number of households living along the periphery of Dimbhe reservoir have been given full rights for fuelwood harvesting. According to the study, about 2113 households were directly dependent on reservoir areas for fuel wood requirements and the average annual household consumption per household as per their family composition was approximately 146 tons. Thus, approximately 146,000 kilograms of fuel wood were extracted annually from the Reservoir area. Using the local price of fuel wood as ₹7 / kilogram, the average economic value of fuel wood extracted from the reservoir equals ₹994,000. The economic value of fuel wood services was estimated US$ 346 per day in Corbett tiger reserve, (Badola *et al.,*2019)

4.5.3 Water Provisioning

4.5.3.1 Water for Drinking Purpose

Two approaches have been used to estimate the value of the provisioning of water. In Dimbhe reservoir, the marginal agricultural productivity due to irrigation benefits is estimated, and the households living along the fringes benefit from drinking water. A total of six villages directly benefits through Pokhari Pradeshik Gramin Nalpani Purvatha Yojana for drinking water. Also, the tribal communities utilize water for their livelihood. The average economic value of years for drinking water as per data collected from Grampanchayt was ₹2,040,140. Pandit *et al.,* 2012 also estimated the water for drinking purposes of households along 22 km of the stretch of Bramhaputra river, and they estimated economic value was ₹1683 lakh.

4.5.3.2 Water for Irrigation

Depending upon the season concerning crop farmed Irrigation Department fixed the price of water used for irrigation by different modes given in annuxer 3. The average estimated economic value of water for irrigation was

₹1,32,798. Pandit *et al.* estimated the economic value for irrigation in Brahmaputra river stretch was ₹23.71 lakhs.

Table.4.8 The five years water bill and local fund collected for irrigation in Dimbhe reservoir

Name of the Gram Panchayat	Water bill (₹)	Local Fund (₹)	Total (₹)
Dimbhe Budruk	32015	4275	36290
Dimbhe Khurda	53975	7210	61185
Supedhar	37245	4965	42210
Mahaluge Tarfe Ghoda	13765	1845	15610
Kanase	63095	8410	71505
Shinoli	206075	27470	233545
Gangapur	73180	9750	82930
Pimpalgaon Tarfe Ghoda	106505	14210	120715
Total	117171	78135	663990

4.5.3.3 Hydroelectric power generation

In addition to irrigation and drinking, the reservoir water was used to produce electricity. The current capacity of the hydropower unit was 5 MW. The annual electricity production was ₹17.99 million units and the average production for the five years through the unit is approximately ₹18 million. Conservatively assuming an average unit price of ₹4.7/unit, the economic value of annual electricity produced through the water from Dimbhe reservoir was equal to ₹84.6 million.

4.5.4 Fishing

The economic value of fishing has been estimated in the study using production estimates and the local market price of the produce (table 4.9). Average of the last five years of fish production (31,308 tons) data has taken, and concerning the price of fish, the estimated average economic value was ₹15,627,92

Table. 4.9 The market price of fish species in Dimbhe reservoir

Fish Species	Market Price (₹)
Channa striata	350
Oreochromis mossambicus	200
Mastacembalus armatus	200
Mystus krishnensis	200
Cirrhinus fulungee	100
Tor putitora	120
Hypselobarbus kolas	120
Garra lamta	100
Cyprinus carpio	100
Cirrhinus mrigala	120
Labeo rohita	120
Catla Catla	120

Table. 4.10 Valuation of provisional ecosystem services provided by Dimbhe reservoir

Provisioning Services	Value (lakhs)	% Share
Employment	6.50	5%
Drinking Water	20.4	15%
Agriculture Irrigation	1.30	1%
Hydroelectricity power generation	84.6	61%
Fuelwood	9.90	7%
Fisheries	15.5	11%
Total	138.2	100%

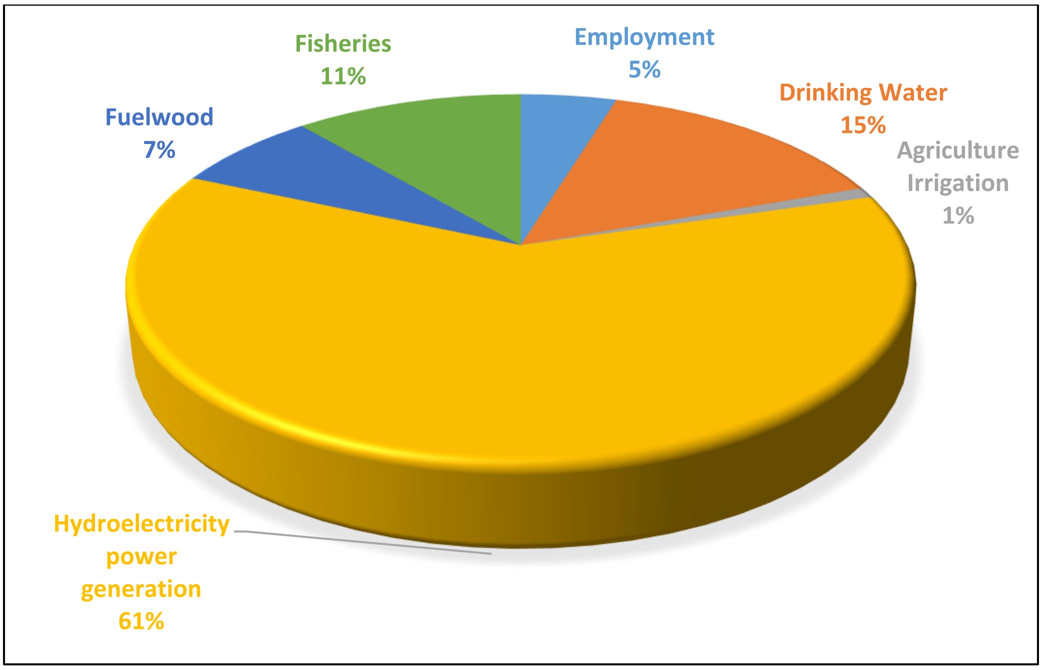

Figure.4.7 Share of different components in total economic value

Among the ecosystem services studied in the selected reservoir (Fig.4.7), Hydroelectricity power generation was the dominant component (61%) in terms of economic value, followed by drinking water (15%), fisheries (11%), fuel wood (7%), employment generation (5%) and 1 % for agriculture irrigation. As per the estimated economic value, fisheries contribute (11%), which indicates fisheries were good source of income for the tribal communities.

4.6 Attitudinal Statements on Dimbhe reservoir Management

A set of attitudinal questions was presented to respondents (table 4.11) and the score was recorded in terms of frequency of their response as strongly aree, agree, no opinion, disagree and strongly disagree. The first question asked to the respondents was 'reservoirs are becoming unproductive.' About 53% respondents strongly disagreed with that statement, but 46% respondents disagreed. About 13% respondents agreed with the statement that 'natural resources in Dimbhe reservoir are getting overexploited.' While 31% respondents strongly disagreed with that statement.

For the statement for 'distribution of the species has also been shifted,' about 25% respondents agreed as they were busy in fishing occupation and they had seen some fish species were not getting in much as earlier times they had. About 48% respondents strongly agreed with the statement for 'many of the traditional fish species have vanished.' While 14% respondents agreed with this statement but 49 respondents disagreed with the same statement.

As far as the statement 'climate change has a negative impact on the reservoir production' there were a total of 27% respondents were strongly agree, and 29% respondents had no opinion about it. For the statement ' Government has more responsibility,' more than average respondents strongly agreed while 22% respondents had no opinion. About 38% respondents strongly agree with the statement that 'Government and community have equal responsibility. However, 13% respondents were not having any opinion about this statement.

Table 4.11 Attitudinal Statements on Dimbhe reservoir Management

	Score				
Statement	Strongly disagree	Disagree	No Opinion	Agree	Strongly Agree
Reservoirs are becoming unproductive	53%	46%			
Natural resources in Dimbhe reservoir are getting overexploited	31%	38%	16%	13%	
The distribution of the species has also been shifted		29%		45%	25%
Conservation of Dimbhe Reservoir is essential to me				56%	43%
Some of the traditional species have vanished	8%	30%		14%	48%
Additional regulations should be implemented to conserve resources			0%	47%	51%
Implementation of protected areas is an efficient method of conservation			22%	38%	39%
Climate change harms reservoir production			29%	43%	27%
Co-management approach should be there in management			19%	55%	21%
Government has more responsibility			22%	28%	11%
Government and community have equal responsibility			13%	48%	38%
I am ready to participate in management activities			35%	17%	41%

4.7 Trophic structure

4.7.1 Comparison of Ecotrophic efficiencies (EE)

The primary input parameters for the Ecopath model are listed in table 4.12, including B, P/B, and Q/B for each functional group. The estimated output parameters (EE and trophic level) for 12 functional groups are summarized in table 4.11. The numbered value of the trophic level is fractional because it depends on the diet composition of this group and the trophic levels of its prey (Christensen & Pauly, 1992). Results of the automatic mass-balance method revealed that all estimated EE values were less than 1 for all samples. The EE values for various functional groups differed significantly in this reservoir ecosystem.

Table. 4.12 Basic input parameters in Ecopath modeling of Dimbhe reservoir

S.No.	Group Name	Biomass	P/B	Q/B
1	*Channa striata*	0.530	0.551	8.400
2	*Oreochromis mossambicus*	0.130	0.125	30.30
3	*Mastacembalus armatus*	0.0300	1.455	24.70
4	*Mystus krishnensis*	0.0700	0.700	17.50
5	*Cirrhinus fulungee*	0.690	0.650	20.40
6	*Tor putitora*	0.002	5.290	10.00
7	*Hypselobarbus kolas*	0.190	0.290	32.70
8	*Garra lamta*	0.580	0.496	25.30
9	*Cyprinus carpio*	0.170	0.091	16.10
10	*Cirrhinus mrigala*	0.970	0.0960	9.10
11	*Labeo rohita*	0.460	0.160	6.260
12	*Catla catla*	0.370	0.754	4.240
13	*Insects*	0.200	0.124	60.00
14	*Zooplankton*	0.110	20.0	80.0
15	*Macrophytes*	0.110	45.0	120.0
16	*Phytoplankton*	0.360	120.0	
17	*Detritus*	0.0400		

As shown in Table 5.1, low values of ecotropic efficiency were observed for Mahaseer (0.471), phytoplankton (0.647), zooplankton (0.750), and macrophytes (0.625). This showed that these groups are underexploited. The EE of primary producers in the lake Volta was also less than one that indicates they were least exploited. (Menshah *et al.*,2019) A high value of EE was noted for Tilapia (0.996), Mrigal (0.989), and Kolas (0.991) because these fish were exploited more.

4.7.2 The gross efficiencies

The analyzed gross efficiencies in the reservoir showed that the P/Q ratios (Table 4.13) were lowest for Kolas, Mrigal, and Tilapia, which might be due to the low density of their prey. The highest P/Q values observed for indigenous catfishes in the reservoir and this could be attributed to their carnivorous habits.

Table 4.13 Basic estimated parameters after mass balance process in Ecopath modeling of Dimbhe reservoir

S.No.	Group Name	Trophic level	Biomass	P/B	Q/B	Ecotrophic Efficiency
1	*Channa striata*	3.3	0.530	0.551	8.400	0.934
2	*Oreochromis mossambicus*	2.5	0.130	0.125	30.30	0.996
3	*Mastacembalus armatus*	3.1	0.0300	1.455	24.70	0.941
4	*Mystus krishnensis*	3.1	0.0700	0.700	17.50	0.960
5	*Cirrhinus fulungee*	2.7	0.690	0.650	20.40	0.968
6	*Tor putitora*	2.9	0.002	5.290	10.00	0.471
7	*Hypselobarbus kolas*	2.7	0.190	0.290	32.70	0.991
8	*Garra lamta*	2.1	0.580	0.496	25.30	0.980
9	*Cyprinus carpio*	2.6	0.170	0.091	16.10	0.994
10	*Cirrhinus mrigala*	2.5	0.970	0.0960	9.10	0.989
11	*Labeo rohita*	2.7	0.460	0.160	6.260	0.974
12	*Catla catla*	2.9	0.370	0.754	4.240	0.822
13	Insects	2.3	0.200	0.124	60.00	0.998
14	Zooplankton	2.1	0.110	20.0	80.0	0.750
15	Macrophytes	2.0	0.110	45.0	120.0	0.625
16	Phytoplankton	1.0	0.210	120.0		0.647
17	Detritus	1.0	0.0400			0.864

4.7.3 Balanced model and Trophic flow diagram

Analysis of the trophic structure indicated that the reservoir could be categorized into four primary trophic levels (Figure 4.8). The four trophic levels identified in the Dimbhe reservoir are typical of other reservoir ecosystems in temperate regions. Examples are Fenshuijiang and Manwan reservoirs in China (Brey, 2012b; Deng *et al*., 2015; Wu *et al.*, 2012).

The size of bubbles represents the biomass of each functional group in the reservoir. The biomass estimates of Mrigal and Mahaseer were the highest and lowest in the reservoir. Most functional groups were confined to trophic levels 2 and 3. The biomasses of functional groups at the base of the trophic level were high compared to the other levels. The highest trophic level was 3.3 for *Channa striata,* a value that is typical of top predator.

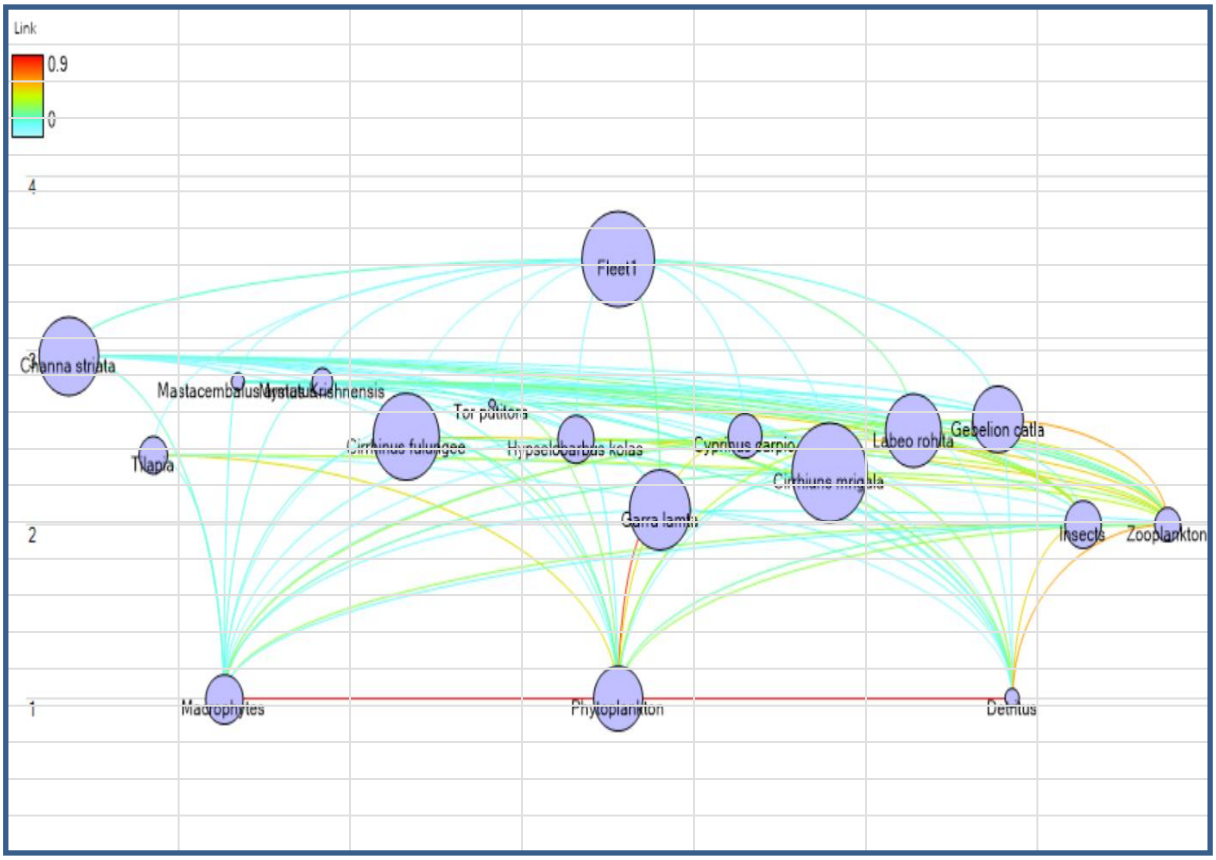

Figure 4.8 Flow diagram of the trophic structure and the functional groups in Dimbhe reservoir

4.7.4 Trophic level flows

Detritus and phytoplankton played an essential role in the ecosystem's food web and were considered primary components in the energy structure. The total energy flows from phytoplankton and detritus were higher than the flow originating from top predators.

The trophic level for each group was estimated according to the percentage of trophic levels utilized. Trophic flows directly impact this biological system's static organization, core operations, material flow, and communication of knowledge. Figure 4.8 displays the balanced network flow diagram, highlighting the relationships between biomass, energy flow, and consumption and the variety of biomass flows between functional groups and tropic levels. The Ecopath model included four trophic levels, and each trophic level used some trophic energy in respiration. According to the network analysis, the reservoir has two main energy pathways, including the phytoplankton and detritus pathways, which show trophic flows (Figure 4.8).

Figure 4.9 illustrates how the two energy pathways show a similar flow of energy to all other functional groups. Most biomass and fluxes were found in trophic levels I and II. The biomass distribution pyramid's guidelines were followed, and it was found that biomass declined with trophic level. The research was also revealed two main energy channels. The grazing food chain, which included phytoplankton, zooplankton, and piscivorous fish, was one example. One more involved the trophic interactions between recycling organic matter, detritus, and predators that feed on detritus and the detritus food chain.

The highest trophic level was 3.33 for carnivorous fish, i.e., *Channa striata* indicated that the food chain was short, and the available food energy was considerable. High-order primary consumers $(2.5 \leq TL \geq 3)$ were dominated by *Oreochromis mossambicus, Cirrhinus mrigala, Cyprinus carpio, Cirrhinus fulungee, Labeo rohita, Hypselobarbus kolas, Tor putitora, Catla Catla.* The low-order primary consumers $(2 \leq TL \geq 2.5)$ were dominated by *Garra lamta (2.1).*

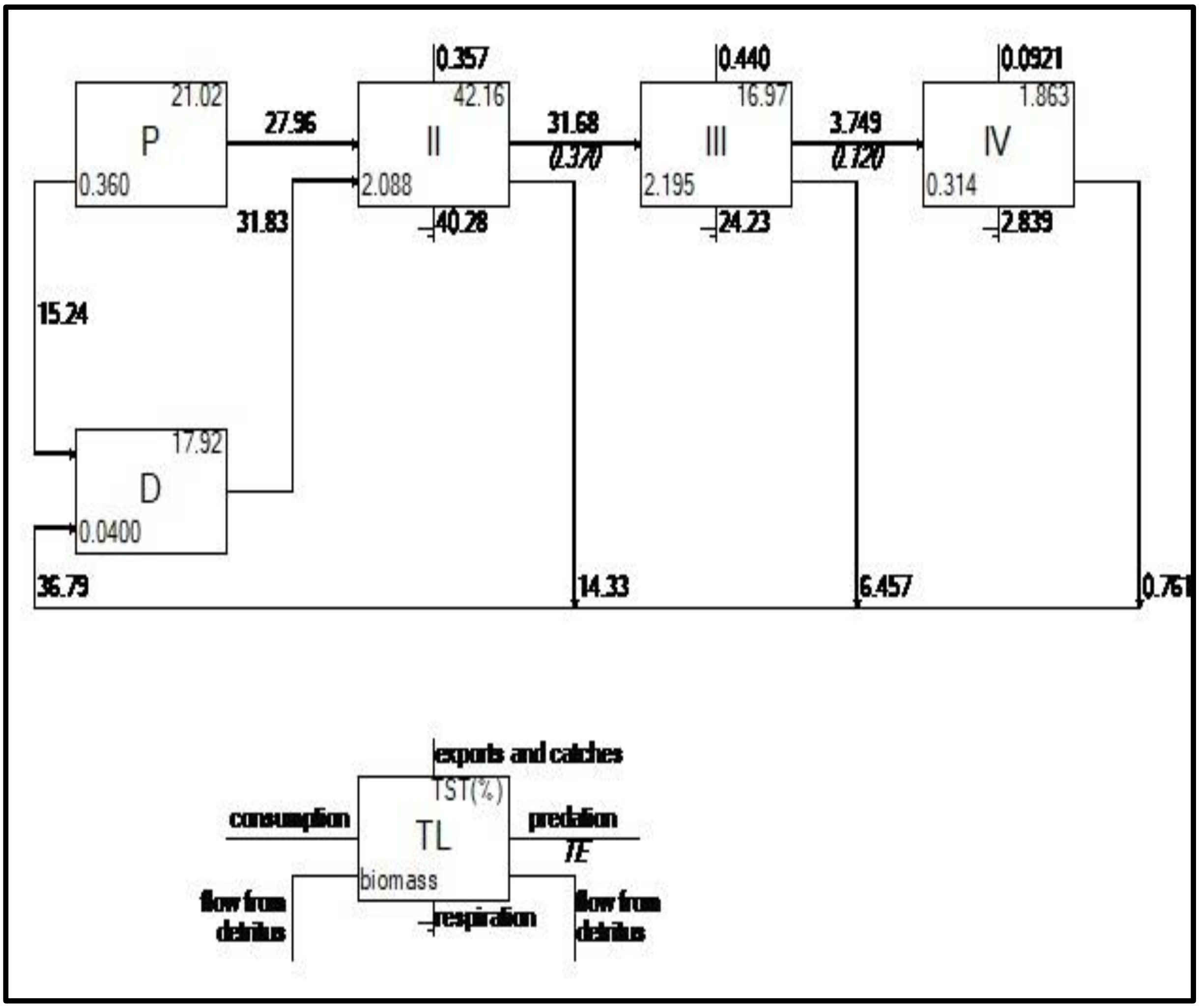

Figure 4.9 Flowchart of trophic interactions indicating biomass and production of each group and the significant flows connecting them. Flows are expressed in tons per square kilometer per year.

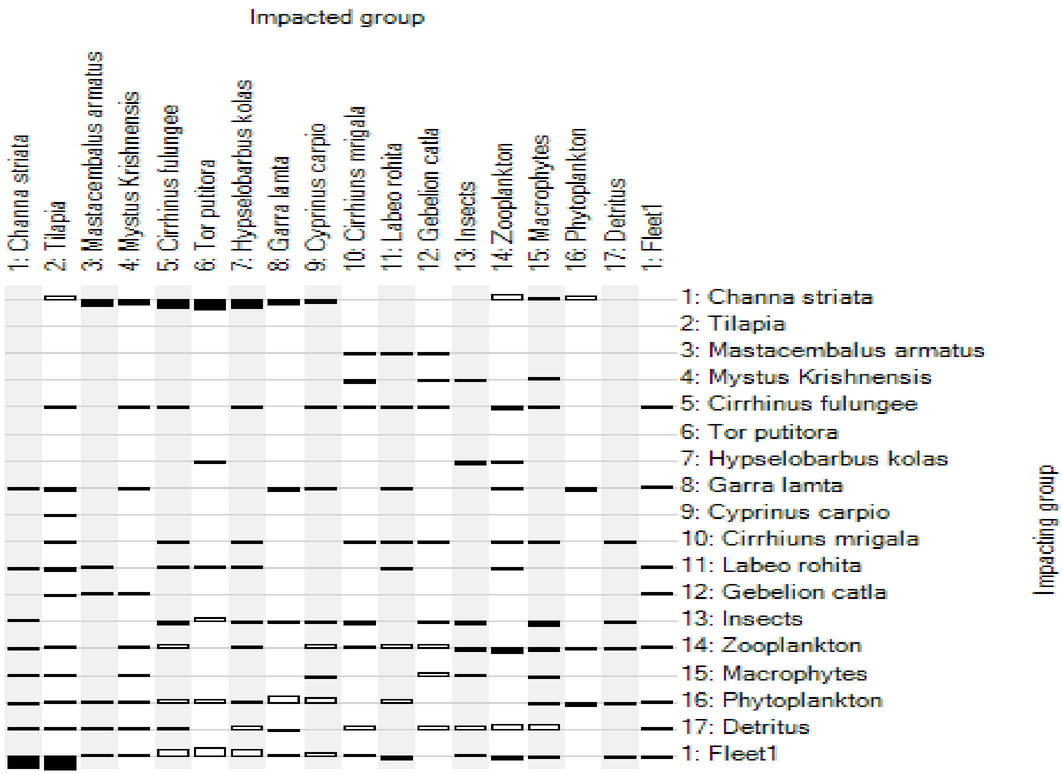

Figure 4.10. Mixed trophic impacts in Dimbhe reservoir. The bars pointing upwards indicate positive impacts, while the bars pointing downwards show negative impacts. The impacts are relative and comparable between groups. The impacts refer to a postulated change of biomass

4.7.5 Mixed trophic impacts

As shown in figure 4.11, Ecopath provides mixed trophic impacts on the ecosystem. Assessment of the effects that changes in one group's biomass will have on the biomass of the other groups in an ecosystem is possible thanks to mixed trophic impact (MTI) (Christensen and Walters, 2004). Nearly all other groups will benefit from increased detritus biomass or phytoplankton biomass. On the other hand, practically all other groups will suffer if the predatory fish's biomass increases (S. Gamito, K. Erzini 2005).

It is essential to remember that each functional group's diet should remain constant despite potential differences in the abundance of their varied prey as the first requirement for this routine. Different levels of harm would be caused to other groups by an increase in the number of fish groups with high TLs (three or more). This was mainly in the case of invasive fishes, *Channa striata*. An increase in this fish's abundance would negatively impact almost all fish groups, such as Indian Major Carps and *Garra lamta*. The other invasive species, *Oreochromis mossambicus,* adversely affects the indigenous fishes. Khan *et al*., 2009 also found high trophic level of African catfish in Karapuza reservoir ecosystem.

The impact of changes in zooplankton biomass would be less pronounced than for the phytoplankton group. A group was advantageous to its predators as well as its victims. Being a direct predator, it hurts its target (Khan *et al.,* 2009). Most other organisms can benefit from phytoplankton and detritus. The effects were most noticeable to their direct predators. For instance, phytoplankton had the most significant impact on zooplankton.

Table 4.14 Summary statistics of Dimbhe reservoir

Parameter	Value	Units
Sum of all consumption	92.652	t/km^2/year
Sum of all exports	6.707	t/km^2/year
Sum of all respiratory flows	68.13	t/km^2/year
Sum of all into detritus	35.211	t/km^2/year
Total system Throughout	202.70	t/km^2/year
Sum of all production	49.18	t/km^2/year
Net primary production	45.300	t/km^2/year
Total primary production/total respiration	0.665	
Total primary production/total biomass	8.931	
Total biomass/ total throughput	0.025	t/km^2/year
Net system production	-22.83	t/km^2/year
Total biomass (excluding detritus)	4.972	t/km^2/year
Connectance Index	0.318	
System Omnivory Index	0.182	

4.7.6 System summary statistics

The system statistics of Dimbhe reservoir are summarized in the table 4.14. Total primary production and total respiration ratio (TPP/TR), which Odum (1969) established, is a measure of an ecosystem's maturity. During the early phases of ecosystem development, the rate of primary production is greater than the rate of community respiration; as a result, TPP/TR is more significant than one. The ratio, however, tends to be close to one in mature systems since the cost of energy for maintenance tends to balance out the energy fixed. In this situation, the TPP/TR ratio of the Dimbhe reservoir is 0.665, which is less than 1, indicating that this reservoir was essentially in the developing stage. Deng *et al.,*2014 found Manwan reservoir as immature system as TPP/TR ratio was 2.67.

The difference between total primary and total respiration is net system production. In developing systems, the net system production will be high, but it will be nearly negative in developed ones. The reservoir's poor net system production (-22.83) demonstrates the system's advanced age.

It was also anticipated that maturity would affect the ratio of total primary production to total biomass. The maturity of this system was indicated by the value of the Dimbhe reservoir (8.931). For the most advanced stages of a system, one can anticipate an increase in total biomass/total throughput that reaches a maximum. This value was 0.025 in the Dimbhe reservoir.

4.8 Constraints faced by people who utilize the benefits of Dimbhe reservoir ecosystem services

4.8.1 Social constraints

Education

Katkari and Thakar tribal communities live on Dimbhe reservoir fringes. One reason for poor literacy rate is the distance between home and school. The awareness of education is also significantly less in these tribal communities.

Poverty and Indebtedness

The majority of the tribal communities live under the poverty line. The tribes follow fishing as their primary occupation, but they don't have proper boats and fishing nets fishing.

Lack of Cooperation among fishers

Most fishers are illiterate, so there is a lack of cooperation among them regarding the decision-making and leadership for a particular demand towards society or the fisheries department.

Conflicts between society and fishers

In a Large reservoir, two or more societies are working some conflicts are between them because the fisher is facing a lot of problems. Fishers also have issues related to the fishing areas and offseason and breaking the rules given by the cooperative society. Fish price, fishers are not following the fishing ban rules and regulations.

Lack of financial support

There is a lack of financial support for the poor fishers whose livelihood depends on reservoir fisheries. There is no government institute or fisheries department not offering any type of finance to them

Unemployment

During the offseason and fishing ban period, fishers are Unemployed because they don't know how to do the other work and business. They lack finance and can't start a new business for a short time, so they face livelihood problems in the offseason.

4.8.2 Environmental constraints:

Disease outbreak

Most of the families live in a thatched house adjacent to the reservoir. They use direct water for drinking purposes without filtration from the reservoir. Therefore, those families often face cold, cough, and fever problems. Fishers also face the problems of skin infection and fever.

4.9 Suggestions

According the findings of the study the majority tribal communities in this region are unbenefited the essential requirements like, good water for drinking, electricity, toilet facility etc.

The respondents were directly dependent on Dimbhe reservoir for their livelihood. But its utility has been ignored by inhabitants due to lack of awareness, lower household income and education.

Systematic records of fish species caught in the reservoir, gear used, and fishers' income need to be maintained by DoF to quantify the development. Fishiers co-operative need serious reforms to make them transparent while encouraging other institutional options. Thus, the improved management for reservoir ecosystem is necessary to ensure its sustainability.

Environmental valuation studies could endeavor where everyone's voice is heard through the benefits and costs of gain, regardless of how much a person contributed. This study has valued the restoration of reservoir in context of trophic structure modelling, in order to decide appropriate sustainable socio-economic development policies.

5. SUMMARY AND CONCLUSION

Reservoir ecosystem services provides outcomes that directly and indirectly affect human wellbeing, and these considerations can link well to an economic approach. The valuation of ecosystem goods and services has no virtue in itself but it is simply a tool to guide, humankind, in how to treat and utilize nature. The present study thoroughly evaluated three objectives. The first objective was to identify and assess the major ecosystem services provided by Dimbhe reservoir which aims to know the different types of ecosystem services in the reservoir and estimate the economic value of those identified services. The second objective was to analyze the fish community trophic structure in the Dimbhe reservoir which aims to know the biomass of different functional groups in the reservoir and in the future, it will help the policymakers by knowing the sustainability of particular fish species. The third objective was to provide evidence-based strategies for sustainable management in the reservoir ecosystem. All these objectives were studied by using primary data collected using a pre-tested well-structured interview schedule. The data was mainly collected from 160 key respondents from seven different villages using percentage analysis.

The socioeconomic characteristics of the sample respondents showed that 80 percent of the total respondents were males and 20% were females. About 62.5% of total respondents come under the age of more than 45. Concerning the house type, 34 percent of respondents lived in tilled houses while 53 respondents lived in thatched houses**.** The literacy status of the respondents revealed that 65 percent of the respondents were uneducated while 30 percent of respondents were educated up to higher secondary. The majority of the respondents were dependent on the reservoir for drinking water service. The result revealed that the majority (71%) of respondents earn monthly income from fishing as a primary occupation. The secondary occupations in which family members were engaged were agriculture (48%). As far as income is concerned 56.9 percent of respondents had a monthly household income of less than Rs.5000. About 30 percent of families had a monthly income between Rs. 5000-10000.

The seven villages were grouped into three clusters for a better understanding of the socioeconomic characteristics of 160 families. Village Dimbhe and Shinoli were the first cluster, Ambegaon, Phulvade, and Borghar were the second cluster, while Malin and Phulvade were the third clusters. As far as age is concerned, all the families in the three clusters had an age of more than 45. The study found that among all the three clusters, male respondents were more than females. Compared to a joint family, most respondents live in a nuclear family. The majority of respondents in cluster two (Ambegaon, Borghar, and Phulvade) had fishing as their primary occupation. About 78 percent of respondents in cluster two had a monthly household income of less than 5000 because the majority of the tribal peoples living in this area don't have strong income support by any proper occupation.

The survey schedule was designed to capture people's responses regarding the willingness to pay for provisioning water, fuel, wood, and fodder. The peoples who were directly or indirectly dependent on the reservoir were the study respondents. The three bid values were fixed, i.e., low bid (100), First bid (250), and high bid (>250). Among all the respondents, 41 percent, 53 percent, and 41 percent were likely to pay for fuel wood, fodder, and water, respectively.

The findings of the single bounded logit model showed that respondents living in a thatched house with a monthly income of less than Rs5000 were more likely to pay for water provision because the tribal communities utilize these services directly from Dimbhe reservoir and know the worth of the reservoir services. As far as family size is concerned the respondent’s family size of less than four was more likely to pay for fodder than a family size of more than four. The respondents in the kaccha house were more likely to pay for water i.e.,2.351 times compared to those living in the pakka house.

The results of the double-bounded logit model for WTP for water showed that the coefficients for income were negative and significant for education and monthly household income, respondents who said yes to the first offer and also ready to pay at follow-up high offer (YY). The respondents who had fishing as a primary occupation were WTP at first bid value only. The WTP for provisioning fuel wood in the double logit model showed that respondents with a family size of less than four were more likely to pay (19%) at first bid value and follow-up high bid value for provisioning fuel wood. The respondents living in the nuclear family were less likely to pay (1%) at low bid value but not at first bid value. The respondents had monthly income less than

Rs.10,000 were less WTP at first bid value and follow-up lower bid value. The lower the income lower will WTP.

The present study has estimated six provisional services provided by Dimbhe reservoir (Employment generation, water for drinking purposes, water for irrigation, hydroelectricity power generation, fuel wood, and fishing). Among the ecosystem services studied in the selected reservoir, hydroelectricity power generation was the dominant component (61%) and the estimated economic value was 84.6 lakh. Provisioning for drinking water has 15 percent share of the total economic value. The fisheries services contribute 11% to the total economic value and the estimated economic value was 15.5 lakh. As far as employment and fuel wood was concerned it has an estimated economic value of 6.50 lakh, and 9.90 lakh respectively.

A general perception of respondents regarding the Dimbhe reservoir management was assessed where different attitudinal questions were to respondents, and the score was recorded in terms of the frequency of their responses as strongly agree, agree, no opinion, disagree, and strongly disagree. The study revealed that About 38 percent of respondents strongly agree with the statement that 'Government and Community should have equal responsibility.

The findings of trophic structure in Dimbhe reservoir showed indicated that the reservoir was categorized into four primary trophic levels. Most functional groups were confined to trophic levels 2 and 3. The biomasses of functional groups at the base of the trophic level were high compared to the other levels. The highest trophic level was 3.3 for *Channa striata.* The mixed trophic impact of Dimbhe reservoir showed that an increase in *Channa striata* fish's abundance would negatively impact almost all fish groups, such as Indian Major Carps and *Garra lamta*. The other invasive species was *Oreochromis mossambicus,* which adversely affects the indigenous fishes.

The system statistics of the Dimbhe reservoir showed that the TPP/TR ratio of the Dimbhe reservoir was 0.665, which is less than 1, indicating that the Dimbhe reservoir was essentially in the developing stage. It was also anticipated that maturity would affect the ratio of total primary production to total biomass.

The major constraints faced by respondents show that the majority of tribal peoples in this region were found unbenefited the essential requirements like clear water for drinking, electricity, toilet facility, etc. The respondents were directly dependent on Dimbhe reservoir for their livelihood. But its utility has been ignored by inhabitants due to a lack of awareness, lower household income, and education. Systematic records of fish species caught in the reservoir, gear used, and fishers' income need to be maintained by DoF to quantify the development. Fisheries co-operative need serious reforms to make them transparent while encouraging other institutional options.

The estimated economic services and their economic value of Dimbhe reservoir show that the reservoir has great potential in terms of fishing and also other services. Therefore, developing appropriate conservation and management strategies guidelines will be of great importance to ensure the sustainable use of Dimbhe reservoir. Thus, the improved management of the reservoir ecosystem is necessary to ensure its sustainability.

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PLATES

Plate 1. House types of Respondents families

Plate 2. Preliminary field Investigation

Plate 3. Girl Taking water in the container for drinking purpose

Plate 4. Fishers while collecting fish

Plate 5. Women's are washing utensils and clothes in Dimbhe reservoir

Plate 6. Cattles are grazing along Dimbhe reservoir area

Plate 7. Key Informative Interviews in Adivare, Borghar, Dimbhe Budruk, Malin, Phulvade, Ambegaon, Shinoli

Plate 8. Data collection from Irrigation Department Dimbhe

Plate 9. Data Collection from Gram Panchayat Dimbhe

Plate 10. Hydeo-electricity power generation Unit Dimbhe

Plate 11. Filtration Unit in Gohe

APPENDIX 1

EVP:
Loc:
Lat-Long:

Interview Schedule

CENTRAL INSTITUTE OF FISHERIES EDUCATION
(*Indian Council of Agriculture Research*)
Versova, Mumbai-61
Fisheries Economics, Extension & Statistics Division

Ecosystem valuation and Trophic Structure Dynamics for Sustainable Fisheries Management in Dimbhe Reservoir, Maharashtra

A. Basic Details:

1- Name: ________________________ Sex: M / F Age:
Religion: Hindu/Muslim/Christian/Other: ________ Caste: General/ST/SC/OBC/Other: ________

2- Address: ____
Village: ____________ Taluk: ____________ District: ____________ Pin Code: ____________
Mobile no: ____________

3- Education: Uneducated /LP /UP /SSLC /Higher Secondary /Diploma /Graduation

4- Occupation:

5- House specifications:
a) Roof Type: Thatched/Tiled/Terraced/Other: __________ b) Rented/Owned
c) Electricity: Yes/No If yes, monthly bill: ₹_______ d) Gas Connection: Yes/No If yes, monthly bill: ₹_____
e) Drinking water facility: Public tap/Well/Tube well/others: _________ f) Ration Card: APL/BPL
g) Toilet facility: Available in house/ Public toilet/ Open defecation

6- Family Composition (Nos.):

7- Asset details:

Items	Year of purchase	Area/ Qty	Present Value (₹)
Physical assets:			
Land (acres) Agriculture: Aquaculture:			
House (Sq. ft.)			
Vehicle			
Gold (grams)			
Bank savings (₹)			
Others (Specify):			

Fishing assets:			
Boat (Owned/Rented)			
Fishing gear			
Others(Specify):			

8- Savings and Expenditure:

Average Monthly Expenditure		**Average Monthly Income**		**Savings**	
Item	**Amount(₹)**	**Item**	**Amount (₹)**	**Source**	**Amount(₹)**
Food		Fishing			
Clothing		Others			
Rent					
Education					
Medical					
Recreation					
Travel					
Personal					
Others					
Total		**Total**			

9- Savings Behavior: Chitty / post office / bank / SHG / individuals / No savings/ any other:

10- Credit Source, Level of Indebtedness, Utilization Pattern and Repayment:

Source of credit	**Amount taken(₹)**	**Purpose**	**RoI (%)**	**Year**	**Duration**	**Utilized for**	**Amount repaid(₹)**
Institutional:							
Banks							
Cooperatives							
Others: (specify)							
Non-institutional:							
Money Lender							
Friends							
Middle men							
Fish traders							
Pawn brokers							
Others: (specify)							

Total indebtedness = ₹

B. <u>Occupation Profile:</u>

1. Specification of Craft: Traditional/ Motorized; Local Name:
2. Ownership Status:
3. Type of gear used along with mesh size:
4. Experience in fishing(years):
5. Is fishing your main occupation? Yes/No

6. Do you have any alternative source of income? Yes/No. if yes, specify______________
7. How many days in a week do you go for fishing? Daily/ Alternatively/ Twice a week/ Once a week
8. Alternative Avocations:
   a. Do you prefer to have any alternative occupation? Yes/No
   b. If yes, List the alternative employment sectors that you prefer;

Alternative options	Extent of Interest (rank)	Awareness Level	Willingness to Involve
Tourism			
Aquaculture			
Agriculture			
Service sector			
Daily wage labour			
Others (Specify)			

High-(1), Medium-(2), Low-(3)

9. Training Needs:
   a. Have you received any job or skill trainings? Yes/No
      If yes, list type along with the name of organization given training:
      i. ii.
      iii. iv.
   b. Do you think that you need more training for a better alternative livelihood option? Yes/ No
      If yes, list out the trainings that you need
      i. ii.
      iii. iv.
   c. Are you willing to pay any money for the trainings that you have listed above? Yes/ No
      If yes, about what percent?

C. <u>Economics of Reservoir Fishing:</u>

1. Capital Investment on Fishing:

Items	Number	Length (m)	Cost (₹)	Year of purchase	Expected life(year)	Annual repair (₹)	Present Value	Source of Assistance	Contribution by fishers
Crafts									
Gears with Mesh size									
1.									
2.									
3.									
Batteries									
Oars									
Others									

License/Membership Fee:

2.Operational Cost per Fishing Trip:

Item	**Quantity/Trip**	**Rate(₹)**	**Total Cost(₹)**
Fuel Diesel Petrol Kerosene			
Fish bait			
Food expenses			
Crew wage			
Repair & Maintenances			
Petty expenses			
Others:			

3.Fishing details (Monthly)

Details/Month	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sept**	**Oct**	**Nov**	**Dec**
Fishing days/week												
Fishing hours/day												
No. of days of dry docking												
Area of operation												
Mesh size used(mm)												
Distance from reservoir bank												
Depth of fishing												
No. of hauls per trip and duration												
Major species caught												

4. Revenue generated based on the species wise fish landings

Species & Price	**Day 1 (Kg)**	**Day 2 (Kg)**	**Day 3 (Kg)**	**Day 4 (Kg)**	**Day 5 (Kg)**	**Day 6 (Kg)**	**Day 7 (Kg)**	**Day 8 (Kg)**	**Day 9 (Kg)**	**Day 10 (Kg)**

D. Utilization & dependence of Dimbhe reservoir ecosystem

How dependent is your household/livelihood income on Dimbhe reservoir?

- Very dependent
- Somewhat dependent
- Not very dependent
- Not dependent at all

Utilization, dependence pattern & amount to be paid (per day) if these resources are unavailable:

Particulars	(√)	Amount (₹)	Particulars	(√)	Amount (₹)	Particulars	(√)	Amount (₹)
Fishing			Water for other purpose			Cattle Rearing		
Agriculture			Bathing			Washing clothes		
Aquaculture			Swimming			Medicine		
Food			Water Sports			Others (if any)		
Drinking water			Firewood					

a. Water for Drinking

1. Is Dimbhe reservoir water the main source of water for drinking? YES/NO
2. What is the average quantity of water used for drinking in your home per day/month?
3. Do you incur any expenses for using drinking water from Dimbhe reservoir? YES/NO (specify) ₹________
4. What are the other sources of water?
5. Do you incur any expenses if water is not available? Specify how? and amount : ₹________ (monthly/yearly)

6. Are you purifying the water by any method? YES/NO
7. If YES; since when did you start purifying; Year/period__________
8. What are the methods adopted for purification?
   a. Boiling (specify the frequency of boiling and the type and quantum of fuel used)
   b. Aqua guard
   c. Ordinary filter
   d. Chemicals
   e. Traditional method(specify)
   f. Others (specify)

9.How much does it cost to purify the water: ₹________ monthly/yearly

10.Have you had any health problems due to dimbhe reservoir water? YES/NO

If YES, specify the period and the illness

b. Water for other purposes

1. Do you use reservoir water for bathing? Yes/No
2. Do you use reservoir water for washing clothes? Yes/No If yes, mention frequency: (Daily/Alternativey/Weekly/Monthly/Other:)
3. Do you use reservoir water for washing utensils? Yes/No If yes, mention frequency: (Daily/Alternativey/Weekly/Monthly/Other:)
4. What is the average quantity of water used for bathing & washing activities per day/month?
5. How often do you get Dimbhe reservoir water to irrigate your fields? (Daily/Alternativey/Weekly/Monthly/Other:)
6. What is the average quantity of water used for agriculture/aquaculture activities per day/month?
7. Are you paying any amount for the use of irrigation water? YES/NO
   If YES. ₹ ________(Monthly/Yearly)
8. Do you think an amount should be charged for the use of the irrigation water? YES/NO; If YES state the reasons?
9. Do you have any other source of irrigation? YES/NO If YES, specify
10. What is the frequency of water use from other sources for irrigation? (Daily/Alternativey/Weekly/Monthly/Other:)
11. How much amount you will incur if Dimbhe reservoir water is not available for irrigation? ₹________(Monthly/Yearly)
12. How much are you willing to pay for the irrigating water? ₹________(Monthly/Yearly)

c. For Timber & Firewood

1. Do you collect timber & firewood from reservoir ecosystem? Yes/No
   If yes, mention the frequency of collection: (Daily/Alternativey/Weekly/Monthly/Other:)
2. What is the average quantity of timber & firewood collected per day/month?
3. How much amount you will incur if this timber & firewood is not available? ₹________(Monthly/Yearly)
4. How much are you willing to pay for this timber & firewood if charged? ₹________(Monthly/Yearly)

d. For Fodder

1. Do you collect fodder from reservoir ecosystem? Yes/No. If yes, mention the frequency of collection: (Daily/Alternativey/Weekly/Monthly/Other:)
2. How you use this fodder? (Feeding animals/Thatching sheds/Other:________)
3. What is the average quantity of fodder collected per day/month?
4. How much amount you will incur if this fodder is not available? ₹________(Monthly/Yearly)
5. How much are you willing to pay for this fodder if charged? ₹________(Monthly/Yearly)

e. For Medicine

1. Do you collect medicinal plants from reservoir ecosystem? Yes/No. If yes, mention the frequency of collection: (Daily/Alternativey/Weekly/Monthly/Other:)
2. What is the average quantity of medicinal plants collected per month?
3. How much amount you will incur if this medicinal plants are not available? ₹________(Monthly/Yearly)
4. How much are you willing to pay for the medicinal plants if charged? ₹________(Monthly/Yearly

f. For recreation

g. For spiritual and heritage value

E. <u>Awareness and perception towards the environmental issues and ecosystem services</u>

1. General perception regarding Ecosystem services and environment in Dimbhe Reservoir:

Statement	Score	Reasons
Reservoirs are becoming unproductive		
Natural resources in Dimbhe reservoir are getting over exploited		
Distribution of the species has also been shifted		
Conservation on Dimbhe Reservoir is important to me		
Some of the traditional species has vanished		
Additional regulations should be implemented to conserve resources		
Implementation of protected areas is an efficient method of conservation		
Climate change has an negative impact on reservoir production		
Co-management approach should be there in management		
Government has more responsibility		
Government and community have equal responsibility		
Community have more responsibility		
I am ready to participate in management activities		

I am willing to pay money for resource management		

Strongly Agree (5), Agree (4) No opinion (3) Disagree (2), Strongly disagree (1)

2. Awareness and perception on indirect uses of Dimbhe reservoir ecosystem (Tick√)

Disease regulation		Water Purification	
Soil Erosion prevention		Breeding ground	
Climate regulation		Biodiversity conservation	
Carbon sequestration		Vulnerable species protection	
Genetic resource		Others If any:	
Nutrient recycling			

3. Do you think that Dimbhe reservoir has deteriorated/polluted over the years? YES/NO

   if YES, to what extent? 1. Slightly,2. Moderately, 3. Highly

4. Threats of Dimbhe reservoir ecosystem:

Threats	**Rank**	**Remarks**
Water pollution		
Reduced landing		
Waste dumping		
Climate change		
Siltation		
Deforestation		
Pollution		
Others		

F. Contingent valuation of the reservoir ecosystem

Suppose government is planning to provide some financial support for peoples wellbeing's in terms of schemes. The plan's objectives cannot be fully achieved without this financial contribution by the resident population. We would like to know about your willingness to contribute for this.

- Are you willing to contribute to such a fund? YES/NO; if NO record the reason & alternatives suggested and move to Section G

  If YES, follow the questions
- How much money would you and your family like to pay voluntarily as a one-time payment, to enjoy the improved benefits from the reservoir?
  a.₹1000 b. ₹750 c. ₹500 d. ₹250 e. ₹100 f. other: ₹__________
- How much money would you and your family like to pay voluntarily for annual maintenance, to enjoy the improved benefits from the reservoir?

  Initial amount: ₹___________

  According to the category within which this amount falls, select the next amount and ask the follow up question. (Depending on the sample, the class and amount may be modified)

A.	1-100	Ask for ₹ 200
B.	100-250	Ask for ₹ 450
C.	250-500	Ask for ₹ 1000
D.	500-1000	Ask for ₹ 1500
E.	>1000	Ask for ₹ 2000

- Would you be willing to pay ₹__________ (Start from the lowest bid amount) for the improved services and benefits of the reservoir? YES/NO

if YES, the ask for the maximum value willing to pay

If NO, enter this amount as next value stated (question 5)

- Next value stated ₹__________ (record the highest bid stated)
- If the government imposes a compulsory tax upon all the citizens of the city for use of the reservoir benefits, which ultimately will be used for managing it, how much do you think should be paid as tax? There won't be any membership benefits in such cases. ₹__________

If None, then Go to Section G

- According to the category within which this amount falls, select the next amount and ask follow up questions. (Modify to suit the sample)

A.	1-250	Ask for ₹ 25
B.	250-500	Ask for ₹ 100

Next value stated: ₹__________

- With your given income do you think you can pay the amount you have stated? You can still adjust the amount.
  Final value stated: ₹__________
- What is your preferred timing of payment? DAILY/MONTHLY/YEARLY
- Would you have to compromise on any item in the household budget in order to make this payment? (Record the statement)
- Are you aware of any fees collected for the entrance to the reservoir? YES/No? (specify)
- How much do you think should the entrance fee be for entering the site?
  ₹ 1-5
  ₹ 6-Rs.10
  ₹ 10-Rs.20
  ₹ 20-Rs.50
  >₹ 50

Enumerator Name:

Signature:

Date:

Interest of Respondent (tick)

Extremely interested	
Very interested	
Somewhat interested	
Slightly interested	
Not interested at all	

ANNEXURE 2

Crop Wise and Season wise price of Irrigated land

Kharif Season						
Crops	Irrigation		Canal (Rs)	Ponds (Rs)	Dams (Rs)	Streams (Rs)
	Irrigation of land for whole year (Rs.)	Irrigation of land once in year (Rs)				
Bajari	415	104	83	83	39	39
Red gram	415	104	83	83	39	39
Sunflower	415	104	83	83	39	39
Sugarcane/Banana	1575	394	293	293	224	224
Orchards	1185	296	224	224	168	168
Vegetables	900	225	83	83	39	39

Rabi season						
Crops	Irrigation		Canal (Rs)	Ponds (Rs)	Dam (Rs)	Streams (Rs)
	Irrigation of land for whole year (Rs)	Irrigation of land once in year (Rs)				
Jawar	750	188	117	117	59	59
Sunflower	750	188	117	117	59	59
Chickpea	750	188	117	117	59	59
Wheat	750	188	117	117	59	59
Sugarcane/Banana	3150	788	488	488	374	374
Orchards	2370	593	374	374	280	280
Vegetables	1800	450	117	117	59	59

Summer crop						
Crops	Irrigation		Canal (Rs)	Ponds (Rs)	Dam (Rs)	Streams (Rs)
	Irrigation of land for whole year (Rs)	Irrigation of land only once in year (Rs)				
Kadaval/ Maize	1330	333	234	234	117	117
Groundnut	1330	333	234	234	117	117
Sugarcane/Banana/Ghas	4710	1178	683	683	524	524
Orchards	3525	881	524	524	392	392
Vegetables	2700	675	234	234	117	117