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***Research Article***

# Bivalve fishery of Achara estuary of Sindhudurg coast, Maharashtra, India

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Aquatic resources, such as shellfish and finfish, have ecological, commercial, medicinal, and social importance. For this reason, communities have been harvesting these natural resources to meet their needs. The present study focused on documenting the fishing methods used to harvest bivalve resources in the Achara estuary of Sindhudurg district. This study highlights the bivalve fishery, specifically the clam and oyster harvesting operations performed by the fishers of Achara village. The data were collected solely through several visits and interactions with the fishers of the study area. The observations reveal that two clam species, *Polymesoda erosa* and *Hiatula diphos*, as well as two oyster species, *Saccostrea cucullata* and *Crassostrea cuttackensis*, were harvested from the Achara estuary. Oyster species were harvested more dominantly than the clam species. Therefore, more income generation from the oysters than the clam species. The highest CPUE values were recorded for the oyster *Saccostrea cucullata*, followed by *Crassostrea cuttackensis*, *Polymesoda erosa*, and *Hiatula diphos*, indicating species-specific variations in catch efficiency. Both clam and oyster fishery meet the nutritional and commercial needs of the fishers. This study concludes that sustainable fishing methods can minimise ecological impacts, maintain bivalve populations, and safeguard their habitats, thereby preserving natural resources and enhancing the livelihoods of coastal communities.

[**Keywords**: Achara estuary, Clam fishery, CPUE, Fishing methods, Oyster fishery, Socio-economics]

## Introduction

The coastal regions have a diverse range of habitats, such as backwater, estuary, mangrove, and seagrass beds, and these habitats support 30 % of coastal communities which rely on the rich, exploitable coastal and marine natural resources[1]. These habitats provide valuable food resources, revenue, and innumerable ecological services to society. Along the coastline, molluscs occupy a wide range of coastal habitats and are vital to the coastal community for both commercial and medicinal purposes[2].

Among molluscs, oysters, mussels, and clams are highly nutritious due to a good source of minerals, protein, and glycogen, and are easily palatable compared to other animal food sources[3]. Due to their nutritional value and income potential, molluscan species are widely exploited along the Indian coast[4]. Therefore, molluscan fisheries play a vital role in global aquaculture and marine ecosystems by harvesting a diverse group of molluscan species such as clams, oysters, mussels, chank, and squids. Around the world, most coastal populations harvest clams and oysters on a large scale[5]. Bivalves provide various ecological services, such as improving water quality and forming reef structures[6]. In addition to these roles, they are primarily harvested for food and as a livelihood source for coastal communities. These organisms are not only economically significant but also provide a valuable source of proteins, essential nutrients and livelihoods for millions of fishers and aquaculturists along coastal regions[3,7]. In the Gosthani estuary, 13 species of bivalves were harvested, with oysters being extensively collected, approximately 5.867 tons annually, as compared to other bivalve species[8]. However, along most parts of the Indian coastline, the harvested bivalve resources are dominated by clam species[4]. Similarly, the Bhatye estuary reported the harvesting of eight commercially important bivalve species, with clams accounting for the highest catch among them[9].

Along the Sindhudurg coast, the Achara estuary is one of the most diverse and dynamic coastal habitats for aquatic faunal resources, including shellfish, finfish, and crustaceans. This estuary extends inland up to 10–12 km. The Achara estuary is known as

Kandalvan Devrai for its dense mangrove forests. After reviewing the literature, it is found that there is no documentation on the bivalve fishery and the fishing methods used to harvest bivalve resources by the coastal community of Achara village. The main aim of this study is to highlight the bivalve fishery and the types of fishing methods used to harvest bivalve resources from the Achara estuary.

## Materials and Methods

### Study area

The Achara estuary is located (16°12'33.4" N; 73°26'33.0" E) along the West coast of Sindhudurg district in Maharashtra. It is formed by the confluence of the Achara River and the Arabian Sea, south of Achara village (Fig. 1). This estuary has a dense canopy of mangrove vegetation covering approximately 130 hectares, stretching inland for about 5 – 6 km. This mangrove forest is home to more than 20 species of mangroves, with the predominant species being *Avicennia*, *Rhizophora*, and *Sonneratia*.

### Data collection

In this investigation, a survey was conducted twice in a month from October 2023 to May 2024 at the Achara estuary. The surveys took place during low

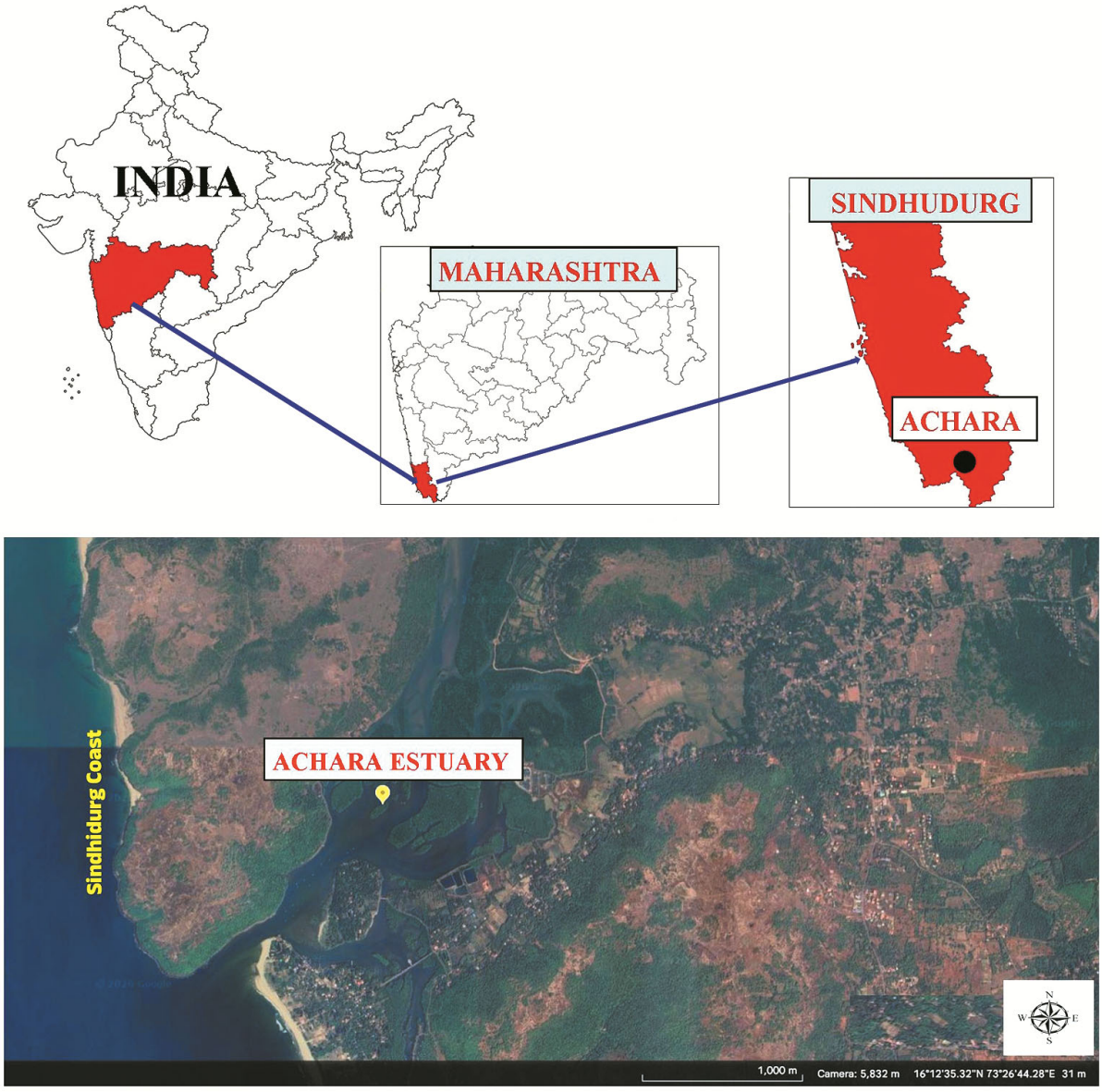


Fig. 1 — Study area: Satellite map of Achara estuary

tide by using a fibre boat with the help of local fishermen when the water level receded, and the intertidal zone was exposed. The tidal pattern in the estuary follows a semi-diurnal cycle, with two high tides and two low tides occurring approximately every 24 h. The timing of low tide shifts daily due to lunar influence, affecting the fishing schedule of local bivalve fishers. In the Achara estuary, fishers harvest bivalves only during daytime low tides, when the intertidal zone are exposed. During low tide, the fishers of Achara gather along the estuary to collect bivalve species. During field visits, data were collected through direct individual or group interviews with local fishermen using various questionnaires. Information was gathered from the fishers regarding the types of bivalve harvesting, fishing methods, and the gear and craft used during fishing operations.

The data on bivalve harvesting and economics were collected monthly but are presented in two distinct periods: October – December 2023 and January – May 2024. Information on bivalve harvesting was calculated based on the number of fishers engaged in bivalve collection, the quantity of bivalves harvested per fisher per day and the monthly harvest. The harvested catch is recorded in kilograms (kg). For economic assessment, regular visits were conducted to local markets to gather information from vendors. The valuation of bivalve resources was carried out based on the prices reported by sellers or vendors, and the income is expressed in Indian Rupees (INR).

#### CPUE analysis

The Catch Per Unit Effort (CPUE) was calculated using the daily total catch data, expressed as total weight in kilograms, and the corresponding daily fishing time spent by each collector. The CPUE was calculated following the method described by experts[10].

$$\text{CPUE} = \frac{\text{Total weight of bivalve catch (kg)}}{\text{Total fishing time/hrs/fisher}}$$

## Results

In the present study, the fishers of Jambulwadi, Pirawadi, Gaudwadi, and Achara villages were actively engaged in molluscan fishing operations. The molluscan fishery comprised clam and oyster species that were regularly exploited from the Achara estuary. During the study period, a total of 11 female and 3 male fishers were reported from Achara village and the surrounding area who engaged in molluscan fishing. This study reveals that two types of fishing operations were predominantly reported in the estuary: clam and oyster fisheries. A total of four species of bivalves were harvested, two each belonging to the clams and the oysters.

#### Clam fishery

Fishers mainly harvested the clam species *Polymesoda erosa*, which is commonly known as "Mahare" and *Hiatula diphos*, popularly called "Tode". The mangrove clam *P. erosa* is found in the intertidal zone or mudflats of mangrove vegetation, typically at a depth of 6 – 8 cm in the mud. In a fishing operation, fishers identify their presence in the mudflats with their feet or by making scratches in the mud with the knife (Fig. 2a, b). The mudflats are then dug with the knife to collect the buried clams. Harvesting of *P. erosa* is primarily done by male fishers due to the distribution of this species in deeper mangrove vegetation (Fig. 2c).

Another clam, *H. diphos*, was found in the sandy habitat of the intertidal zone of the estuary. *Hiatula diphos* is normally buried deeply in the sandy and mixed sandy-mudflats, at about 10 – 12 cm deep. Male fishers recognise the presence of *H. diphos* by identifying inhalant and exhalant siphonal openings on the sandy surface of the intertidal region. Then, the fishers dig in the identified sandy area with a spade or shovel to collect the buried clam species (Fig. 2d, e).

Both these clams were fished mainly by male fishers; they used crafts such as small non-mechanised boats (dinghies) or mechanised fibre boats for this fishing operation. The collected clams were washed in water and then stored in baskets (Fig. 2f).

#### Oyster fishery

The Achara estuary has high potential for oyster distribution along the stretch of mangrove vegetation. Two oyster species, namely *Saccostrea cucullata* and *Crassostrea cuttackensis*, were densely distributed along the intertidal mudflats region of the estuary. During low tide, as the water receded, the oyster beds in the intertidal region were exposed (Fig. 3a). Female fishers gather in the estuary and collect oysters by the handpicking method; moreover, they also use a knife to separate the attached oysters from the substratum (Fig. 3b, c). Fishers collect both the oyster species from the exposed intertidal zone and also from the oysters attached to the mangrove vegetation (Fig. 3d).

The harvested oysters were stored in baskets or small non-mechanised boats (*dinge*). In oyster fishing, fishers spent 3 – 4 h on the harvesting operation.

Harvested oyster species were sold in the local market as whole oysters or by collecting the flesh by opening the shells (Fig. 3e, f). Oyster flesh is


Fig. 2 — Clam harvesting by traditional hand-picking method: a) Fisher identify *P. erosa* clam by scratching method, b) Fishers identify *P. erosa* clam by feet pressing method, c) Fisher harvesting *P. erosa* clam by digging with knife, d) Fishers identify *H. diphos* clam by searching siphonal opening, e) Fishers harvesting *H. diphos clam* by digging with spade, and f) Harvested clam *H. diphos* stored in basket

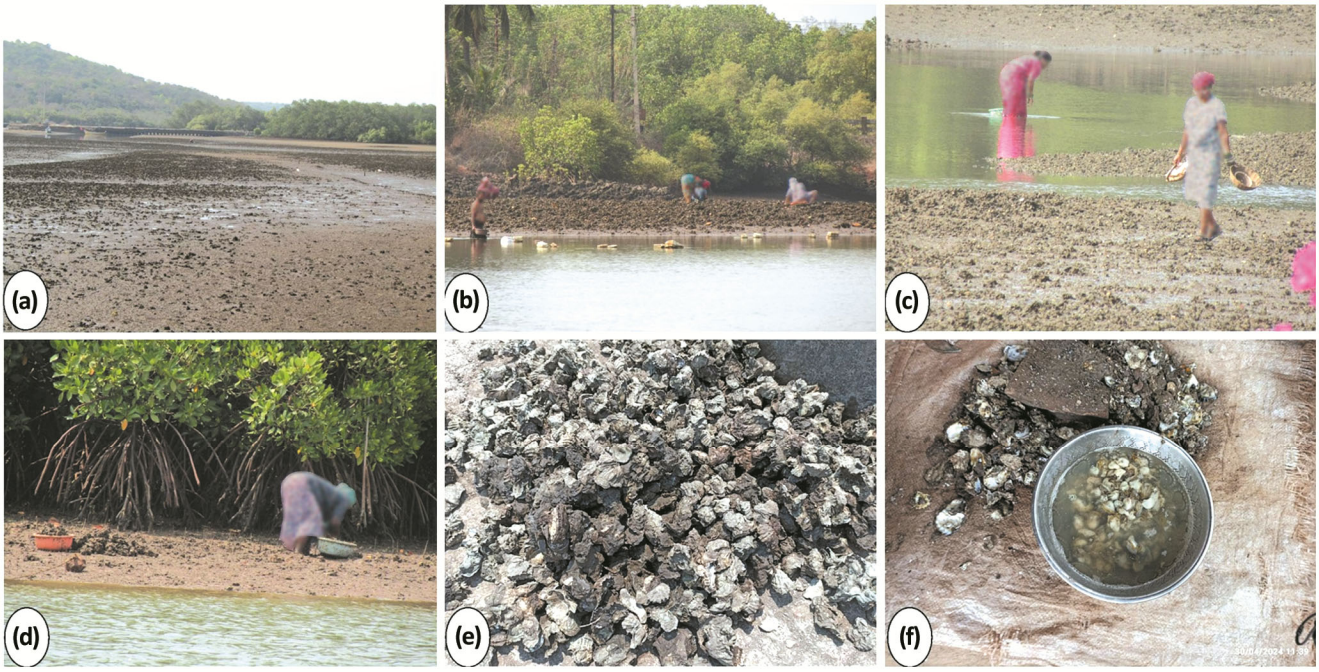


Fig. 3 — Oyster harvesting by traditional hand-picking method: a) Inter-tidal zone exposed during low tide showing oyster bed at Achara estuary, b) Fishers harvesting oyster *S. cucullatta* by Hand picking method, c) Fishers harvesting oyster *C. cattuckensis* by Hand picking method, d) Fishers harvesting mangrove forest associated oysters, e) Harvested oyster *S. cucullatta* and oyster *C. cattuckensis*, and f) Oyster flesh removed from shell

consumed as food and also sold in the market. The empty shells left after removing the flesh are sold for lime production. In oyster fishing, fishers used crafts and gear like knives, chisels, baskets, and small dinghies. Total 10 to 11 female fishers from Jambulwadi, Pirawadi, and Gaudwadi villages were particularly active in oyster fishing.

**Harvesting and economics**

In this study, the harvesting of bivalve species in the Achara estuary was recorded from October 2023 to May 2024. For analytical purposes, the data were divided into two periods: October – December 2023 (Table 1) and January – May 2024 (Table 2). A total of 14 fishers were actively involved in harvesting four commercially important bivalve species in the estuary. Among them, 11 were female fishers primarily engaged in collecting oyster species (*S. cucullata* and *C. cuttackensis*), while the remaining 3 were male fishers focused on harvesting the clam species (*H. diphos* and *P. erosa*). Total 33 days of fishing activity were carried out during October – December 2023, and 59 days were reported during January – May 2024.

During the study period, fishers harvested different bivalve species with varying daily catch stocks. The daily harvest ranged from 1 – 2 kg for *H. diphos*, 3 – 5 kg for *P. erosa*, 6 – 8 kg for *S. cucullata*, and 3 – 5 kg for *C. cuttackensis.* Among the four commercially exploited species, the highest total catch was recorded for *S. cucullata*, with 1,160 kg harvested during October – December 2023 and 2,027 kg during January – May 2024. This was followed by *C. cuttackensis*, with catches of 798 kg and 1,374 kg in the two study periods, respectively. In contrast, clam species showed comparatively lower harvest volumes. *Polymesoda erosa* yielded 393 kg during the first period and 714 kg in the second, while *H. diphos* registered the lowest catch, with 132 kg and 288 kg, respectively. These results indicate a significantly higher exploitation of oyster species compared to clams in the Achara estuary.

The income derived from bivalve harvesting is also presented in two periods, October to December 2023 and January to May 2024 and expressed in Indian Rupees (INR). Fishers received an average price of ₹50 per kg for the clam species *H. diphos*, ₹30 per kg for *P. erosa*, and ₹40 per kg for the oyster species *S. cucullata* and *C. cuttackensis*, respectively. The highest income was consistently generated from oyster species compared to clam species. Among the bivalves, *S. cucullata* generated the maximum income (₹46,400) during October – December 2023 and ₹82,800 during January – May 2024. This was followed by *C. cuttackensis*, which generated ₹31,920 and ₹54,960 during the respective periods. In contrast, clam species contributed comparatively lower income. *Polymesoda erosa* received higher revenue than *Hiatula diphos*, with earnings of ₹11,790 and ₹21,420 from *P. erosa*, and ₹6,600 and ₹14,400 from *H. diphos* in the two harvesting periods. These findings indicate that oyster species, particularly *S. cucullata*, played a more significant role in local fishers' economic returns than clams.

In this study, catch per unit effort (CPUE) was calculated to analyse the quantity (in weight) of

Table 1 — Harvesting and economic analysis of bivalves from the Achara estuary during October – December 2023

| Bivalves | No. of days | No. of fishers engaged | | Harvesting (Kg) | Revenue (₹) |
|---|---|---|---|---|---|
| | | M | F | | |
| *H. diphos* | 33 | 3 | - | 132 | 6600 |
| *P. erosa* | | | - | 393 | 11790 |
| *S. cucullata* | | - | 5 | 1160 | 46400 |
| *C. cuttackensis* | | - | 6 | 798 | 31920 |
| Total | | 3 | 11 | 2483 | 96710 |
| | | 14 | | | |

Table 2 — Harvesting and economic analysis of bivalves from the Achara estuary during January – May 2024

| Bivalves | No. of days | No. of fishers engaged | | Harvesting (Kg) | Revenue (₹) |
|---|---|---|---|---|---|
| | | M | F | | |
| *H. diphos* | 59 | 3 | - | 288 | 14400 |
| *P. erosa* | | | - | 714 | 21420 |
| *S. cucullata* | | - | 5 | 2070 | 82800 |
| *C. cuttackensis* | | - | 6 | 1374 | 54960 |
| Total | | 3 | 11 | 4446 | 173580 |
| | | 14 | | | |

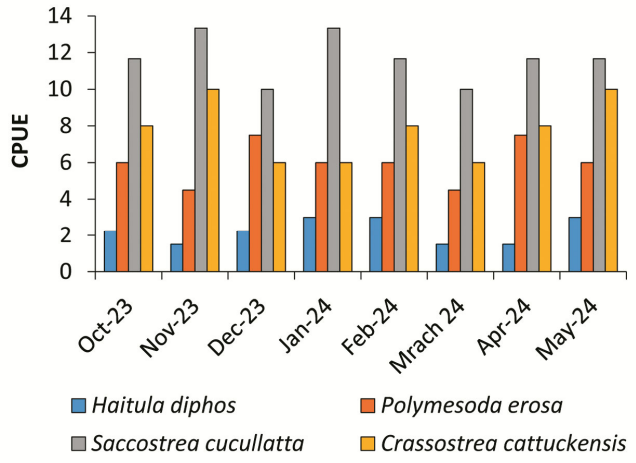


Fig. 4 — Catch per unit effort of bivalve at the Achara estuary

bivalve species harvested per unit of fishing effort (in hours). Monthly CPUE was determined for four bivalve species in the Achara estuary. Among four bivalve species, the highest CPUE values were recorded for the oyster *S. cucullata* (10.0 – 13.3), followed by *C. cuttackensis* (6 – 10), clam *P. erosa* (4.5 – 7.5), and *H. diphos* (1.5 – 3), respectively (Fig. 4). The CPUE trends reflect dynamic monthly variations in the rise and fall of bivalve catches, indicating fluctuations in species availability and harvesting efficiency throughout the study period.

## Discussion

Coastal communities primarily harvest bivalve resources such as clams, oysters, and mussels due to their high nutritional and significant commercial value[11]. Coastal communities rely on bivalve resources for their livelihoods, and these shellfish contribute approximately 10 % of the total animal-based food obtained from aquatic resources[12]. In the Bhatye estuary along the west coast of Maharashtra, clam resources serve as the primary source of income for bivalve fishers[13].

In the clam fishery, the two clam species, *P. erosa* and *H. diphos*, were fished by fishers in the Achara estuary. These two clam species are distributed in and around the mangrove vegetation and mudflats or sandy intertidal regions of the estuary. According to the literature, *P. erosa* is found in the upper stretches of mangrove vegetation. This clam is an ecological indicator species and plays a vital role in nutrient recycling and the food web of the estuarine ecosystem[14]. Clam *H. diphos* is a deep burrower, reaching depths of about 10 – 12 cm in sand. This clam is distributed over approximately 1.5 – 2 km along the sandy mudflats region of the estuary, near mangrove vegetation. In contrast, *P. erosa* clam is found in the upper reaches of mudflats, about 3.5 – 4 km within the mangrove forest. Due to their edibility and commercial value, both clams are harvested by fishers and sold in the nearby markets of Achara village.

In a recent study, among shellfish, the bivalve group (clams, mussels, oysters) is predominantly harvested along the southwest and southeast coasts of India for their meat and ornamental shells[7]. Bivalve resources such as the *Katelysia opima* clam are harvested on a large scale from the Asthamudi estuary[15]. Similarly, the Aghanashini estuary on the west coast of India is also targeted for bivalve species[16]. In the recent past, researchers reported that the Bhatye estuary is highly dynamic and has significant potential for a clam fishery, with clams being the dominant group harvested annually, compared to oysters and mussels[17]. According to the literature, bivalve production has increased significantly worldwide in coastal habitats due to high market demand[18,19].

In the present study, oyster species were exploited on a large scale. The oyster species *Saccostrea cucullata* and *Crassostrea cuttackensis* are harvested using the traditional hand-picking method. In the Achara estuary, the *Saccostrea cucullata* oyster was harvested more extensively than the *Crassostrea cuttackensis*. Along the west coast of India, oyster fishing is a primary source of income for coastal communities. Similarly, the east coast of India also reported large-scale oyster fisheries that support livelihoods and contribute to food security[20,21]. According to the study, the fishing communities in coastal regions are exclusively dependent on bivalve resources for food and commercial purposes[22]. In the Bhatye estuary, Ratnagiri, oyster fishing is carried out using the traditional hand-picking method[23].

Bivalve resources such as clams, oysters, and mussels are extensively exploited worldwide, including along the Indian coast, due to their high nutritional and medicinal value[24,25]. In addition to their food value, bivalves are also harvested for other purposes, such as the production of cement, calcium carbonate, and the creation of various decorative and jewellery items. Bivalves provide an important source of livelihood for coastal communities, and therefore, fishers are actively engaged in their harvesting.

In this study, a total of 14 fishers of the adjacent villages of the Achara estuary were massively

engaged in bivalve fishing. Of them, 11 fishers were female, and 03 were male. During both study periods, oyster species were harvested on a larger scale than the clams. Among the oysters, *S. cucullata* was the most dominantly harvested species, followed by *C. cuttackensis*. In comparison, the clam species *P. erosa* and *H. diphos* were harvested in small quantities. The highest catch of oyster species is positively correlated with the number of fishers engaged and the effort they exert during fishing.

In the Achara estuary, oysters are widely distributed along the intertidal mudflats. As the tide receded and the intertidal zones became exposed, fishers were able to easily collect oysters through hand-picking methods. Hence, the oyster catch reported a maximum than the clam species. On the other hand, clams like *H. diphos* and *P. erosa* are deeply buried in intertidal mudflats region of the estuary and mangrove vegetation. Therefore, fishers are using traditional fishing methods to harvest the clam resources. Interestingly, in other estuarine systems such as the Bhatye estuary, clam resources have been reported to yield higher catches than oysters[23]. Similarly, authors documented a comparable trend in the Gosthani estuary, where the oyster species *Crassostrea madrasensis* dominated the bivalve catch, followed by clam species[8]. This study indicates that catch volume is positively correlated with income, with the highest catches of oyster species generating greater revenue compared to clam species. However, researchers reported contrasting findings, with the highest annual income derived from clam species rather than oyster species[27].

High values of CPUE indicate that bivalve resources are abundantly available, suggesting a healthy wild stock in the Achara estuary. On the other hand, low CPUE values suggest a sparse distribution of bivalve species in specific habitats of the Achara estuary. In recent studies, CPUE was estimated for two oyster species, *Pinctada capensis* and *Saccostrea cucullata*, and reported higher CPUE for *P. capensis* than for *S. cucullata*[26]. This difference was attributed to the restricted distribution of *S. cucullata* in rocky habitats, which limits harvesting efficiency. In contrast, the present study recorded higher CPUE for *S. cucullata* than for other bivalve species, indicating its wider availability and easier accessibility in the Achara estuary. The lowest CPUE value recorded for *H. diphos* indicates that its stock is limited and confined to specific habitats. Therefore, measures are needed to expand the occurrence and distribution of *H. diphos* within the study area to support the sustainability of this natural resource.

## Conclusion

The Achara estuary is highly dynamic and has great potential for bivalve resources, such as clams and oysters. Due to their nutritional value and commercial importance, these bivalve resources are exploited by the fishers of Jambulwadi, Pirawadi, Gaudwadi and Achara villages to meet their needs. The bivalve group includes two species of clams, *P. erosa* and *H. diphos*, as well as two species of oysters, *S. cucullata* and *C. cuttackensis*, which are harvested using traditional methods. The oyster species, particularly *S. cucullata*, were harvested in significantly higher quantities and generated higher income compared to the clam species in the Achara estuary. Female fishers played a dominant role in oyster collection, while clam harvesting remained limited due to habitat constraints and lower resource availability. CPUE trends indicate fluctuating species abundance and harvesting efficiency, with oysters showing consistently higher productivity than clams throughout the study period. This study aids in understanding the ecological and economic roles of bivalve resources in coastal communities and highlights the need to identify overfishing and habitat degradation caused by human activity. This research supports the development of sustainable management practices to protect natural resources and the planning for the effective utilisation of bivalve resources in the Achara estuary. Ultimately, this attempt also helps ensure the food security and livelihoods of communities dependent on bivalve resources.

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## Conflict of Interest

The authors declare there is no conflict of interest.

## Ethical Statement

The study was conducted through field observations and data collection from bivalve fishers of the Achara estuary. Information was gathered with the voluntary consent of fishers, and no endangered or protected species were harmed during the research. The study

complied with institutional and ethical guidelines for environmental and socio-economic research.

## Authors Contribution

VML: Conducted the survey, data collection and writing of the manuscript. SST: Participation in survey, data collection and formulation of the questionnaires. NAK: Supervision and reviewing. SVL: Drafting of the manuscript and grammatical editing.

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