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Indigenous knowledge used in the gill net fishery practised along the Sindhudurg coast of Maharashtra, India

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Original Article

Abstract

The study of indigenous knowledge rooted within fishing communities provides valuable insights for research and sustainable resource management. Indigenous knowledge can provide guidelines for designing fisheries development projects that address priority issues within a fishing community. The present study attempted to explore the indigenous knowledge of fishers engaged in the gillnet fishery. The gillnet fishery is an important traditional fishery practiced in the coastal waters of Sindhudurg district. Data were collected from 75 gillnet fishers using the snowball sampling method and employing semi-structured interviews and non-participant observations. The study documented rich, varied, and potential IKS associated with the management of gillnet fishery, including dimensions of craft and gillnets, hanging coefficient, seasonal yield, species diversity and abundance, depth of operation, preference time for fishing, effects of wind direction, water colour, tides, and lunar cycle on fish catch, etc. Nine types of gillnets across three categories (drift, bottom-set, and trammel) were documented, operated at depths of 5-60 fathoms. Catches were highest between the 4th and 11th day of the lunar cycle, with species-specific seasonal peaks observed across all gillnet types. Wind direction exerted gear-specific effects on catch, and 93.33% of fishers reported intensification of water currents as the primary cyclone indicator. The documented IK provides a scientific basis for integrating traditional fishing practices into the management of small-scale coastal fisheries.

Keywords: *Traditional ecological knowledge, gillnet fishery, small-scale fisheries, Sindhudurg, Maharashtra*

Introduction

Indigenous knowledge (IK) refers to the body of knowledge developed and continuously refined by a community over time. It is based on experience, often practised over centuries, adapted to local culture and environment, and dynamic in nature. Indigenous knowledge has recently become the topic of research in both social and biological sciences, including fisheries (Nirmale *et al.*, 2007). Traditional knowledge is also referred to as indigenous technical knowledge, ethno-ecology, local knowledge, folk knowledge, traditional ecological knowledge, and people's science (Joa *et al.*, 2018). These terms have conceptual and semantic problems. In the present study, the term indigenous knowledge has been used to avoid ambiguity. In fisheries, there is a need to understand and study extensively the indigenous knowledge shared by a particular fisher community (Johannes, 1981). Solutions to fisheries lie outside the sector (Smith, 1981). It is necessary to understand the complexities of a fishing community before recommending and implementing any intervention designed to uplift its standard of living. The generation of indigenous knowledge has been a matter of survival for fishers who use it to overcome their specific localised problems. The knowledge of ecology and fish behaviour (Johannes, 1981), weather and oceanographic conditions, navigation (Worsley, 1971), fishing methods (von Brandt, 1972), vessel design and propulsion, processing, and trade has been effectively used by the fishers to harness local resources sustainably. The gillnet fishery is one of the prominent traditional fisheries practised along the Sindhudurg coast of Maharashtra. It is one of the most ideal fish-catching methods in terms of conservation and stock regulations due to its selective nature (Laxmappa *et al.*, 2014). Fishers operating various types of gillnets in the region likely harbour a vast body of indigenous knowledge

encompassing the design, method of fabrication, material used, depth and bottom of operation, timing of the operation, and seasonal abundance of fishery resources, to name a few. Documentation and assessment of traditional knowledge utilized in the gillnet fishery will generate a useful database and focus on the essential research needs. Similarly, the knowledge will help inform assessment and scientific management of the gillnet fishery in the region. According to Saha and Nath (2013), indigenous knowledge is used by local communities to solve problems and sustainably manage resources. Fishers have developed a unique system of knowledge, skills, and innovations related to fishing activities. This knowledge enables them to utilise natural resources sustainably through close interaction with their environment (Gadgil *et al.*, 1993). Living in close association with nature, fishers possess a strong indigenous knowledge system (Uskelwar *et al.*, 2017) and demonstrate an understanding of marine ecosystems through continuous observation and adaptation (Pukkalla and Rama Mohan, 2021). The findings of the present study further highlight that such knowledge can complement scientific stock assessment and ecosystem-based fisheries management, thereby supporting sustainable utilisation and conservation of marine resources. In

the above context, the present study was conducted to study the indigenous knowledge of fishers engaged in gillnet fishery and analyse the rationale behind its use.

Material and methods

The study was conducted in the purposively selected Sindhudurg district of Maharashtra State, as it is one of the maritime districts, where the traditional operation of gillnets forms an important fishery (Fig. 1). The district is endowed with a coastline of 121 kms. The total fisher population of the district is 32017 and is spread across 87 fishing villages; however, catches are landed at only 34 fish landing centres (Anon, 2021-22). A total of 75 respondents from 15 fishing villages in the district were interviewed following the snowball method (Bailey, 1987). The villages selected were located along the northern, middle, and southern regions of the district. Five villages were randomly selected from one block in each region for data collection.

The snowball method is a non-probability sampling technique in which existing study participants refer future participants from among their acquaintances. It is a useful tool for building

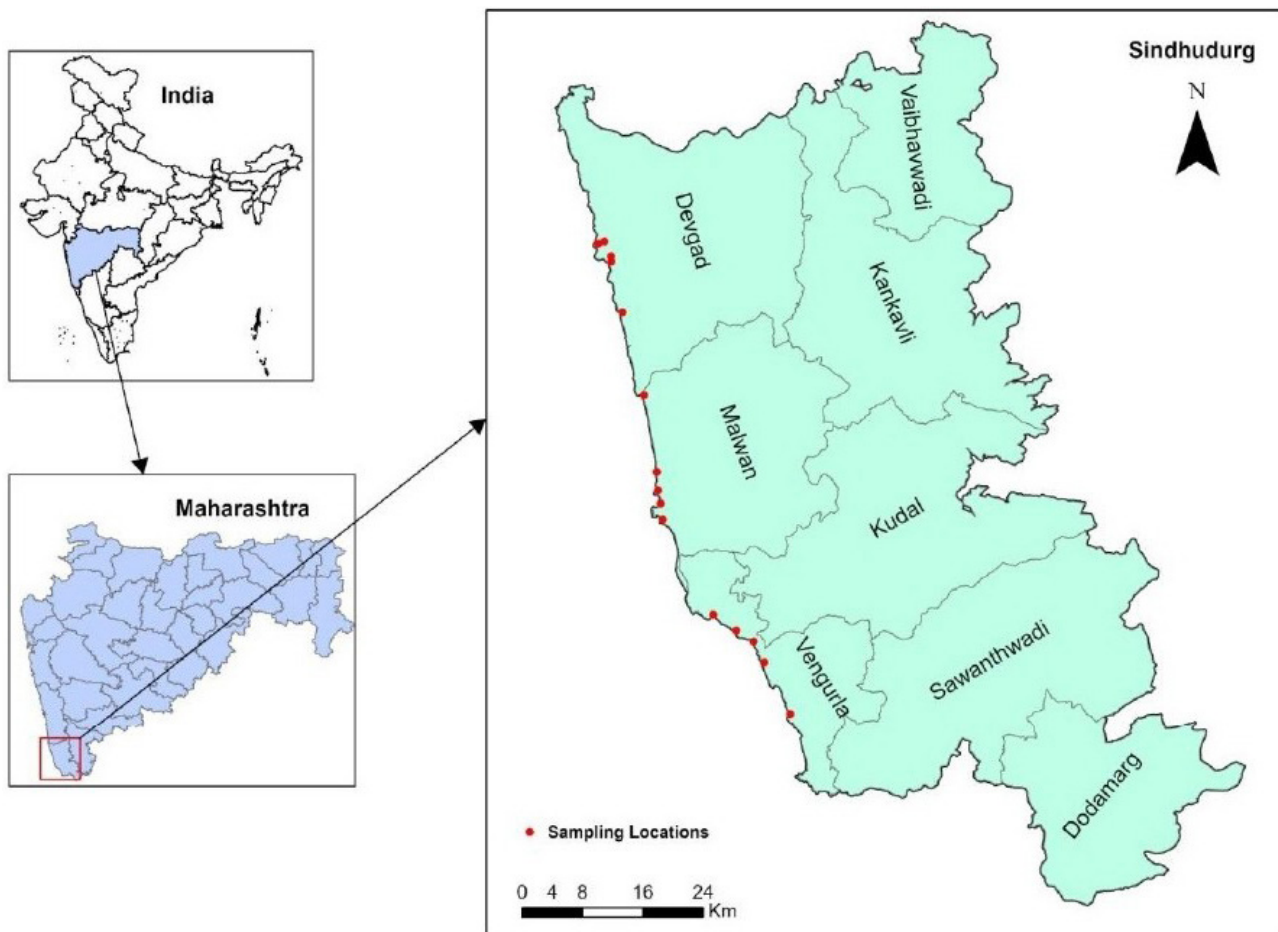


Fig. 1. Study area

a network and increasing the number of participants (Goode and Hatt, 1952). This technique was particularly appropriate for the present study as gillnet fishers in Sindhudurg constitute a small, close-knit community whose members are best identified through peer referral rather than conventional random sampling. The data were collected using a semi-structured interview schedule designed to capture the required information. Responses to a particular question that were frequently mentioned were considered to reflect aspects of indigenous knowledge. Responses were quantified as the percentage of respondents mentioning a given answer; answers reported by 50% or more of respondents were considered to reflect established indigenous knowledge practices of the community. The study findings were further supported by non-participant observation and documentary evidence, thereby providing triangulation of the data collected through interviews. PIC (Prior informed consent) was obtained from the fishers and their names, village names and ages were noted.

Results and discussion

Profile of respondents

The profile characteristics of respondents are given in Table 1. Age-wise distribution of respondents showed that the majority of fishers were above 50 years of age, followed by middle-aged fishers and the younger age group. Veteran fishers were observed to be engaged primarily in the fishery. Most had schooling up to high school. Table 1 indicates that respondents were almost equally represented across small and large family sizes. The majority of respondents possessed substantial fishing experience for over 15 years, reflecting the predominance of highly experienced individuals within the fishery. All respondents were from the *gaabit* community, classified under the constitutional Special Backward Class category.

Dimensions of fishing crafts

For ease of understanding, the results for overall length (OAL), width, depth, and fish hold capacity have been combined for each type of craft and are discussed accordingly (Table 2). The non-mechanised crafts (*pagar/hodi*) with an OAL up to 15-24 ft and width up to 3-5 ft operated 5-10 units of drift gillnets, viz., Indian oil-sardine gillnets, fringe scale sardine gillnets, mackerel/false trevally gillnets, and pomfret gillnets. Operation of seerfish gillnets involves the use of mechanised boats known locally as *balyav*, which are operated at a depth of 30-60 fathoms (*vav*). These crafts can carry 25-35 units of sear fish gillnets. The OAL range of these boats is between 32 and 40 ft, with a width between 6 and 17 ft and a depth

varying from 4.5 to 10 ft. The motorised fishing vessels are locally known as *paat/pagar* and are propelled by outboard engines (9.9 hp-25 hp). The OAL of these crafts ranged from 20 to 32 ft, with widths between 4 and 8 ft and depths ranging from 2 to 4 ft. They are used for operating drift gillnets, including mackerel/false trevally gillnets (*tarav/mand*), Indian oil-sardine gillnets (*tarli chi tiyani/kandali*), pomfret gillnets (*garpe*), bottom set nets [mackerel/false trevally gillnets (*budav*) and red snapper/grouper gillnets (*budi*)], and trammel nets (*disco*). The dimensions of the fishing crafts concerning OAL, width, depth, and fish hold capacity rely on the suitability of operating the number and type of gillnets in the particular environment, available resources, depth of operation, construction cost, availability of material, and fishers' experience acquired through continuous trial and error.

Materials used for the construction of fishing crafts

The study revealed that approximately 42.67% of fishers in Sindhudurg district used *undal* tree wood (*Calophyllum*

Table 1. Profile characteristics of respondents

No.	Profile characteristics	Categories	Respondents	
			Frequency	Percentage
1	Age	Young (up to 30 years)	5	6.67
		Middle-aged (31 to 50 years)	31	41.33
		Old (more than 50 years)	39	52.00
2	Marital status	Unmarried	11	14.67
		Married	64	85.33
3	Education	Illiterate	-	-
		Read only	-	-
		Read and write	-	-
		Primary school	8	10.67
		High school	50	66.67
4	Size of family	Small (< 4members)	38	50.67
		Large (> 4members)	37	49.33
5	Experience in fishing	up to 15 years	7	9.33
		up to 15-30 years	38	50.67
		More than 30 years	30	40.00
6	Community	<i>Gabit</i>	75	100.00
		<i>Bhandari</i>	-	-
		<i>Marath</i>	-	-
		<i>Kunbi</i>	-	-

Table 2. Dimensions of fishing crafts

Types of craft	Frequency	Percentage (%)
Non-mechanised crafts (<i>pagar/hodi</i>)	15	20
Mechanised crafts (<i>balyav</i>)	11	15
Motorised crafts (<i>paat/pagar</i>)	37	50

inophyllum) to construct the beams and frames of wooden fishing crafts. *Undal* tree wood is abundant in the Konkan region, as reported by Nirmale *et al.* (2007), and is inherently oily, providing natural water resistance. Additionally, 13.33% equipped their boats with outriggers (*undali*) made from the wood of the *pangera* tree, *Erythrina suberosa*, for stability. The lighter weight of this tree wood facilitates buoyancy. About 12% used a combination of *undal* wood for frames and *aini* tree wood, *Terminalia elliptica*, for frames and beams, respectively. While a few fishers used *aini* and *babul* tree wood, *Acacia arabica*, for decks and beams, respectively. *Aini* tree wood is known for its strength and durability. *Babul* tree wood is known for its flexibility and can absorb shock without breaking easily (Nirmale *et al.*, 2004).

Types of gillnets, mesh size, depth, and timing of operation

The gillnet fishery has historically been one of the dominant components of marine fisheries in the Sindhudurg district (Naik, 1998). Gillnets target Indian mackerel, false trevally, Indian oil sardine, fringe-scale sardine, pomfret, seer fish, snappers, groupers, and shrimps. A cursory look at Table 3 reveals the gear types, mesh sizes, material composition, and usage patterns of these gillnet types. Gillnets observed in the district can be broadly divided into the following types.

Drift gillnets

Mackerel/false trevally gillnets (*tarav/mand*): The gillnet used for targeting Indian mackerel/false trevally is locally known as *mand/tarav* with a mesh size of 48-58 mm. It is typically operated at a depth of 10 to 20 fathoms, usually at the surface layer. However, Waghmare *et al.* (2018a, b) previously reported that two separate gillnets with mesh sizes of 51 mm and 47 mm were operated for Indian mackerel and

false trevally, respectively. The present study observed fishers employing a single gillnet for both species. This operational shift is driven by fishers' observations that a single mesh size yields high catch proportions for both species, making it a more time-efficient and cost-effective harvesting strategy. The operational depth of gillnets recorded in the present study is up to 20 fathoms, which aligns with the findings of Waghmare *et al.* (2018 a,b). The depth is adjusted according to the availability of the targeted fish species using marked ropes (one fathom apart) known as *Sarki*, attached to the head rope, and a respective buoy placed at a distance of one unit apart (*ghadan*) from each other. Furthermore, the buoyancy and sinking rates were regulated by altering the ratio of floats to sinkers on the head and foot ropes, a technique consistent with methods described by Nirmale (2004). The fishing season for these gillnets typically extends from August to November and is commonly operated from 4-8 a.m. and 5-9 p.m. (*tambus*). The increased catch rates observed during these hours are due to the availability of fish food organisms and the reduced visibility, as reported earlier (Nirmale, 2007).

Indian oil sardine gillnets (*tarli chi tiyani/kandali*) and fringe scale sardine gillnets (*pedvya chi tiyani/kandali*): Indian oil sardine gillnet, locally known as *tarli chi tiyani or kandali*, has a mesh size of 36 mm. The net is operated at a depth of 5-15 fathoms (*vav*). Fringe-scale sardine gillnets, referred to as *pedvya chi tiyani or kandali*, have a mesh size of 34 mm and are typically operated at depths of 15-20 fathoms. Both types of gillnets are deployed at specific depths and during particular periods of the day in accordance with the availability of target resources. Fishers typically possessed multiple types of gillnets, which are selectively employed to exploit different pelagic fishery resources. Based on observations from preceding days regarding the relative catch composition, fishers preferentially operated Indian

Table 3. Types of gill nets used along the Sindhudurg coast of Maharashtra

Types of nets	Mesh size	Material	Frequency	Percentage (%)
Drift gill nets				
Mackerel/false trevally gill nets (<i>tarav/mand</i>)	48-58 mm	Monofilament (<i>sav</i>)	44	100
Indian oil-sardine gill nets (<i>tarli chi tiyani/kandali</i>)	36 mm	Monofilament (<i>sav</i>)	17	100
Fringe scale sardine gill nets (<i>pedvya chi tiyani/kandali</i>)	34 mm	Monofilament (<i>sav</i>)	4	100
Mackerel/false trevally gill nets (<i>bangda/saundala chi tiyani/kandali</i>)	36-48 mm	Monofilament (<i>sav</i>)	13	100
Pomfret gill nets (<i>garpe</i>)	114-130 mm	Monofilament (<i>sav</i>)	26	100
Seer fish gill nets (<i>aavta/dhangda</i>)	83-131 mm	Multifilament	17	100
Bottom set gill nets				
Mackerel/false trevally gill nets (<i>budav</i>)	48- 50 mm	Monofilament (<i>sav</i>)	40	100
Snapper/grouper gill nets (<i>budi</i>)	115-150 mm	Monofilament (<i>sav</i>)	37	100
Trammel nets				
<i>Disco</i> (inner layer) Outer (<i>tiyana</i>) <i>vagholdar</i>	(36) 140 mm	(Monofilament) Nylon	23	100

oil sardine and fringe-scale sardine gillnets during daytime hours. Fishing operations were continued as long as the target resources were available in appreciable quantities.

Mackerel/ false trevally gillnet (*bangda/saundala chi tiyani/kandali*): *Bangda/saundala chi tiyani/kandali* is the local term for mackerel/false trevally gillnet. They have a mesh size of approximately 36-48 mm and are typically operated at a depth of 10-20 fathoms. The depth of operation is consistent with the findings of Waghmare *et al.* (2018a, b) as discussed earlier. Fishing is primarily carried out during early morning and evening hours. Fishers reported higher catches of Indian mackerel and false trevally during these periods, which may be associated with an increased availability of food organisms for both species. Similar observations have been documented by Nirmale *et al.* (2007). Drift gillnets of varying mesh sizes are employed to exploit different size groups of mackerel and false trevally. The selectivity of gillnets is known to be strongly influenced by mesh size, which plays a critical role in determining the size composition of the catch (Sparre and Venema, 1992).

Pomfret gillnets (*garpel*): Pomfret gillnet, locally known as *garpel*, with a mesh size of about 114-130 mm, is generally operated in surface waters at depths of 10-20 fathoms during 4-9 a.m. Deployment of pomfret gillnets at specific depths and times was regulated based on the availability of pomfret resources in the fishing grounds. The fishing season for pomfret extended from September to October. The operational characteristics and seasonal pattern observed in the present study are in agreement with earlier findings reported by Nirmale *et al.* (2007) and Waghmare *et al.* (2018c).

Seer fish gillnets (*aavta/dhangda*): Seer fish gillnets, locally referred to as *aavta/dhangda* are differentiated by fishers based on mesh size and twine gauge. The mesh size of the units increased with the number of twines and generally ranged from 83 to 131 mm. Gillnet units, fabricated using twine No. 4 and 6, are locally called as *kondashi aavta/dhangda*, whereas those made up of twine No. 8, 10, and 12 are locally known *karal aavta/dhangda*. These gillnets are operated at 30-45 fathoms. The fishing season extends throughout the year; however, fishers report comparatively higher catches during the late monsoon and late summer seasons. A distinguishing feature of these gillnets was the incorporation of multiple units with varying mesh sizes within a single net. Such a configuration was intended to target a wide range of size groups of seer fish occurring at a particular depth. Given the high economic value of seer fish, operational strategies are optimised to enhance catch rates. To increase the catch rates, the depth of operation is adjusted with the help of marked (marked one fathom apart) ropes locally known as *sarki* as

discussed earlier. The operational characteristics observed in the present study are consistent with earlier reports by Waghmare *et al.* (2018d) and Nirmale *et al.* (2007).

Bottom set gillnets

Mackerel/ false trevally gillnets (*budav*): Fishers opined that as the fishery progresses, usually after October, mackerel and false trevally move towards the bottom, possibly in response to increasing sea surface temperature (Kizhakudan, 2014). To exploit mackerel and false trevally, which migrate towards the bottom with advancing fishing season, fishers employed bottom-set gillnets (*budav*), having a mesh size that varies from 48-50 mm. These nets are typically operated in bottom layers at depths of 10-20 fathoms during the early morning (5-9 a.m.) and evening (4-8 p.m.), commonly referred to as *tambus*. The Fishing season is from December to May.

Snapper/grouper gillnets (*budi*): Bottom-set gillnets targeting snappers/groupers are locally known as *budi*. The mesh size of these nets ranges from 115-150 mm, and they are operated at depths of 5-20 fathoms. Variations in both mesh size and depth of operation were observed when compared with earlier reports by Waghmare *et al.* (2018c). The observed reduction in mesh size may indicate increased fishing pressure or higher fishing intensity on these resources. These gillnets are operated from 5:30 p.m.-5:30 a.m., depending on the availability of resources.

Trammel nets: Trammel nets, locally known as *disco* nets, are three-layered gillnets primarily used to target shrimps. The outer layer (armour) is made up of larger meshes (140mm) and thicker nylon twine. The outer two layers are locally known as *vagholdar*. The middle layer (lint), locally known as *tiyana*, is made up of smaller meshes (36 mm) and monofilament twine. *Disco* nets are operated from 5-10 a.m., at depths of 5-15 fathoms, usually in the surface layer. Fishing season lasts from August to September. The results are consistent with those of Nirmale *et al.* (2007) regarding mesh size and depth of operation.

Dimensions of different gillnets used by fishers

Gillnets are long, wall-like nets composed of multiple rectangular panels of netting joined together. The ends of the head and foot ropes of two units are tied together. The first end of the first unit and the last end of the last unit are attached to a boat, anchor, or float, depending on the type of gillnets. Irrespective of the type, the dimensions of gillnets employed in a fishery are primarily influenced by fabrication cost, the nature of the fishing ground, and the depth of

operation. Fabrication cost increases proportionally with an increase in the dimensions and number of gillnet units. The operation of larger gillnet units over rocky bottoms increases the likelihood of net damage due to entanglement, particularly in the case of drift gillnets and bottom-set gillnets. Similarly, depth of operation also governs gear dimensions, with fishers operating in shallow waters generally employing gillnets of smaller dimensions.

A cursory examination of Table 4 indicates that the number of units operated per gillnet type varied among respondents, with each unit having a standard length and height. Among drift gillnets, mackerel/false trevally gillnets (*tarav/mand*), mackerel/false trevally gillnets (*bangda/saundala chi tiyani/kandalī*), Indian oil sardine gillnets (*tarli chi tiyani/kandalī*), and pomfret gillnets (*garpel*) were deployed in two-unit categories, indicating flexible strategies based on operational needs. In contrast, seer fish gillnets (*aavta/dhangda*) were uniformly used in larger configurations by all respondents. Bottom set gillnets showed variation as well: mackerel/false trevalley gillnets (*budav*) were operated in two-unit ranges, while snapper/grouper gillnets (*budī*) varied not only in the number of units used but also in the individual unit length. Trammel nets (*disco*), comprising an inner layer (*tiyana*) and an outer layer (*vagholdar*), were generally deployed in fewer units, though a portion of fishers used extended sets. The total length of gillnets depends on the number of units employed during operation and the size of the boat. The dimensions recorded in the present study are largely consistent with earlier reports for mackerel gillnets (Waghmare *et al.*, 2018a), pomfret gillnets (Waghmare *et al.*, 2018c), bottom-set gillnets (Waghmare *et al.*, 2018c), and trammel nets (Kazi *et al.*, 2010). However, the length of a single unit of trammel net reported earlier by Waghmare *et al.* (2018d) was slightly higher than that observed in the present study, which may be attributed to differences in the number of fishers surveyed, fishing grounds, and operational practices.

Crew size and wage distribution

Crew size varies from 2 to 6 members, depending on the type and size of gillnets and whether the craft is motorised, non-motorised, or mechanised. Non-motorised crafts were typically operated by 1-3 crew members, motorised boats by 3-5, and mechanised vessels by 4-6 crew members. Fishers using non-motorised crafts did not incur operational costs and shared profits equally among themselves. For motorised boats, fuel costs are first deducted, and the remaining profit is then shared equally among the crew members. Under the *shinari* system, the craft owner owns 50% of the total gillnet units, with the remaining units owned by the crew. Each fisher retains the catch from their own gillnet units. Fifty per cent

Table 4. Dimensions of different gill nets used along the Sindhudurg coast of Maharashtra

Dimensions	Frequency	Percentage
Drift gill nets		
Mackerel/false trevally gill nets (<i>tarav/mand</i>)		
Length 50 m-100 m and height 5-18 m per unit of gill net		
10-15 pieces (average total length 938 m)	17	38.64
15-20 pieces (average total length 1313 m)	27	61.36
Indian oil-sardine gill nets (<i>tarli chi tiyani/kandalī</i>)		
Length 50 m-100 m and height 5-15 m per unit of gill net		
5-10 pieces (average total length 563 m)	8	47.06
10-15 pieces (average total length 938 m)	9	52.94
Fringe scale sardine gill nets (<i>pedvya chi tiyani/kandalī</i>)		
Length 50 m-100 m and height 5-15 m per unit of gill net		
10-15 pieces (average total length 938 m)	4	100.00
Mackerel/false trevally gill nets (<i>bangda/saundala chi tiyani/kandalī</i>)		
Length 50 m-100 m and height 5-11 m per unit of gill net		
5-10 (average total length 563 m)	9	69.23
10-15 pieces (average total length 938 m)	4	30.77
Pomfret gill nets (<i>garpel</i>)		
Length 50-100 m and height 5-15 m per unit of gill net		
5-10 pieces (average total length 563 m)	17	65.38
10-15 pieces (average total length 938 m)	9	34.62
Seer fish gill nets (<i>aavta/dhangda</i>)		
Length 50 m-100 m and height 10-20 m per unit of gill net		
25-35 pieces (average total length 2250 m)	17	100.00
Bottom set gill nets		
Mackerel/false trevally gill nets (<i>budav</i>)		
Length 50-100 m and height 5-10 m per unit of gill net		
5-10 pieces (average total length 563 m)	16	40.00
10-15 pieces (average total length 938 m)	24	60.00
Snapper/grouper gill nets (<i>budī</i>)		
Length 50-100 m and height 9 m per unit of gill net		
5-10 pieces (average total length 563 m)	27	72.97
Length 100-150 m and height 9 m per unit of gill net		
5-10 pieces (average total length 938 m)	10	27.03
Trammel gill nets		
<i>Disco</i>		
Length 25-50 m and height 5-10 m per unit of gill net		
5-10 pieces (average total length 281 m)	19	79.17
10-15 pieces (average total length 468.75 m)	5	20.83

of the fuel cost is borne by the owner, while the remaining cost is shared among the crew. This system reduces expenses from the owner's perspective while allowing individual fishers to benefit from the catch of their owned units, reflecting an efficient and flexible operational strategy.

Material used for fabrication, floats and sinkers

Natural cotton-based fibre is not used for the fabrication of the gillnets in the present investigation. Therefore, indigenous knowledge in this regard could not be documented. A majority of respondents used monofilament twine (*sav*) for gillnets. Multifilament twine was used by one-fourth of the fishers. For flotation, almost all fishers used *chakate/bhyanda*; circular PVC sponge plastic floats (100-150 mm dia) tied to ropes and attached to the head rope at intervals. This arrangement ensured appropriate tension and positioning of drift gillnets. Fishers preferred float sizes larger than the mesh to prevent net entanglement, and no indigenous materials were employed for floats. All fishers reported using *shevta/sarki* buoys made of thermocol, attached at the end of each gillnet unit using a 3 mm rope (*sarki*) to provide buoyancy and adjust operational depth of drift gillnets. Although indigenous materials were not used for *shevta/sarki*, fishers demonstrated knowledge of Thermocol's buoyancy properties, ensuring effective use of these buoys. Signal buoys (*bavto*) made of bamboo stakes were used by all fishers; attached to one end of each gillnet, except in *budi* (snapper/grouper) gillnets, where buoys were fixed at both ends. Bamboo was preferred for its availability, lightweight and durability; thermocol enhanced buoyancy, while the cement block ensured stability in the water. Sinkers included materials such as cement, stones and lead. Cement rings (*khapre/bhakre*) with diameters of 100-150 mm were most common, while some used smaller cement sinkers (50-80 mm). About 36% of fishers used stones weighing 250-500 g as sinkers for bottom-set gillnets and lead (*shisha*) for trammel nets. *Nagar*, a moderate-sized stone (about 10 kg), is used to anchor bottom-set gillnets. It is attached to the bottom-set gillnets by a rope, locally known as *haatal*. These results on the use of local materials for sinkers are consistent with earlier observations (Nirmale *et al.*, 2007).

Maintaining hanging coefficient (taakawani)

Fishers maintain a hanging coefficient of 0.75 for all drift gillnets and bottom set gillnets (mackerel/false trevally gillnets (*budav*)) and a hanging coefficient of 0.50 for bottom set gillnets (snapper/grouper gillnets (*budi*)). In the case of trammel nets, a hanging coefficient of 0.50 is maintained for the inner layer and 0.70 for the outer layers. Fixing the net to

the headline or rope around all or some of its edges at any definite degree of closeness or openness of the meshes is called mounting, and the ratio of stretched netting length to rope length defines the hanging coefficient (Sreekrishna and Shenoy, 2001). A hanging coefficient of 0.75 is maintained by strengthening the first topmost mesh of gillnet webbing with additional multifilament twine (the process is locally known as *faara maarne*). The same process is repeated at a distance of forty meshes apart for the entire length of the gillnet webbing. Afterwards, the head rope is passed through the first row of meshes of the gillnet webbing. The next thirty meshes are stretched; the point on the head rope is marked. The next *faara* (strengthened mesh) is brought to this point and joined to the head rope with another rope (the process locally known as *taak maarne*). The procedure is repeated for meshes that adjoin the foot rope. In this way, a hanging ratio of 0.75 is maintained.

Maintaining a hanging coefficient of 0.50 is done by strengthening the first topmost mesh of the gillnet webbing with additional multifilament twine, as discussed above. The same process is repeated at a distance of forty meshes apart for the entire length of the gillnet webbing. Afterwards, the head rope is passed through the first row of meshes of the gillnets' webbing. The next twenty meshes are stretched, and the point on the head rope is marked. The next *faara* (strengthened mesh) is brought to this point and joined to the head rope with another rope. The procedure is repeated for meshes adjoining the foot rope. In this way, a hanging ratio of 0.50 is maintained. While a hanging coefficient of 0.70 is maintained for the outer layers of trammel nets. This is done by following the above procedure; however, in this case, seven meshes of gillnet webbing are stretched, and the point on the head rope is marked. The next strengthened mesh (*faara*) is brought to this point and joined to the head rope with another piece of rope. The main determinant of the range of lengths of fish caught by gillnets is the hanging coefficient. If the hanging coefficient is low, the net will hang more slack in the water than taut. In this case, it will entangle the fish (King, 1995).

Karslen and Bjarnasson (1986) found that the most suitable hanging ratios lie between 0.5 and 0.8, while Thomas (2001) stated that the typical hanging ratio, ranging from 0.5 to 0.7, is suitable for gillnets.

Seasonal variation in yield to various gillnets

Fishers provided detailed observations on seasonal variation in gillnet yields, reflecting their long-term engagement and intimate knowledge of the fishery. Only major responses

(>50%) considered for analysis are illustrated in Fig. 2. The observations are consistent with prior studies, such as Allison and Okadi (2013), who reported pronounced seasonal variation in gillnet yields in the lower Nun River, Niger Delta, Nigeria. The fishers' empirical knowledge demonstrated a nuanced understanding of temporal changes in fish abundance, which is critical for optimising fishing effort.

Seasonal abundance of different species in various gillnets

Fishers use gillnets as per the availability and abundance of different fish species. To avoid ambiguity and redundancy, the results of the seasonal abundance of different species in various gillnets are discussed together. Gillnets are highly selective gear (King, 1995), allowing smaller individuals to pass through the meshes while larger fish may escape when their head dimensions exceed the gilling capacity of the net (Sparre and Venema, 1992). In the present study, gillnets were used to exploit multiple target species, including

Indian mackerel, false trevally, Indian oil sardine, fringe-scale sardine, snappers, groupers, pomfrets, seerfish, and shrimps. However, substantial catches of non-target species with similar size selectivity were also recorded across different types of gillnets. An attempt was therefore made to document the diversity of non-target species captured by gillnets and their seasonal abundance.

Mackerel/false trevally gillnets (*tarav/mand*) exhibited a high winter abundance of Indian mackerel, false trevally, and *Leiognathus* spp., with croakers peaking in summer. Indian oil sardine and fringe-scale sardine were more abundant in summer, whereas wolf herring peaked in winter; lesser sardine (*Sardinella* spp.) recorded moderate winter catches with lower summer abundance. Indian oil sardine gillnets (*tarli chi tiyani/kandali*) yielded substantially higher summer catches of oil sardine, false trevally, croakers, and *Leiognathus* spp., and lesser sardine, fringe-scale sardine, and juvenile mackerel maintained moderate catch levels across seasons. Fringe-scale sardine gillnets (*pedvya chi tiyani/kandali*)

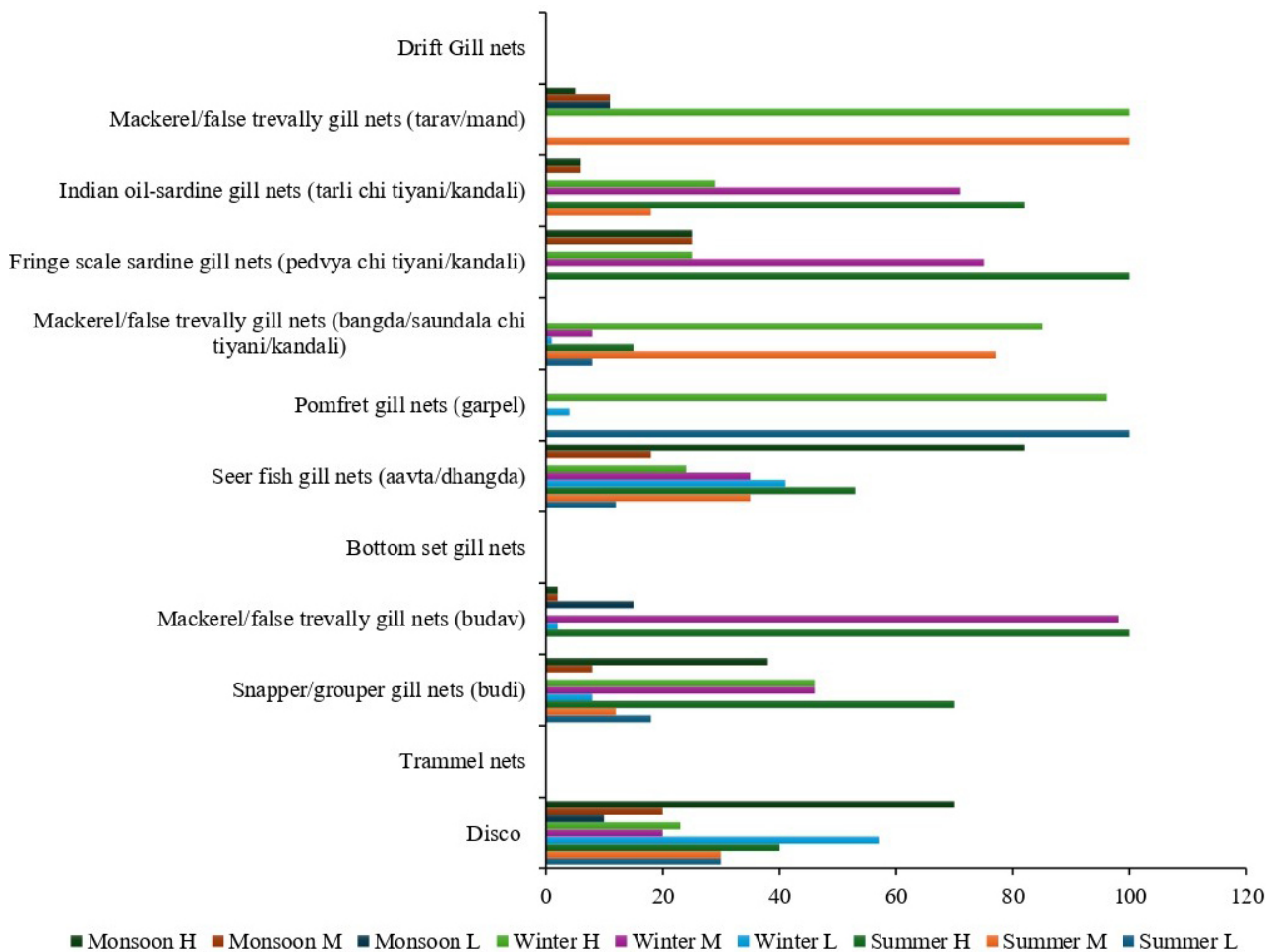


Fig. 2. Seasonal variations in yield to various gillnets

recorded a high summer abundance of fringe-scale sardine and juvenile oil sardine, with *Leiognathus* spp. and lesser sardine peaking in winter; juvenile false trevally remained moderate throughout.

In mackerel/false trevally gillnets (*bangda/saundala chi tiyani/kandali*), winter catches were dominated by Indian mackerel, false trevally, *Leiognathus* spp. and fringe-scale sardine, with croakers more abundant in summer and oil sardine moderate year-round. Pomfret gillnets (*garpe*) yielded substantially higher winter catches of silver pomfret and black pomfret, with markedly reduced catches in summer. Seer fish gillnets (*aavta/dhangda*) demonstrated peak abundance in the late monsoon, moderate occurrence in summer, and minimal catches in winter; associated species, including tunas, elasmobranchs, and dolphin fish, were also most abundant post-monsoon, while black kingfish and catfishes were rarely encountered.

Bottom-set gillnets (*budav*) recorded high summer abundance of Indian mackerel, false trevally, croakers, lesser sardine, and *Leiognathus* spp., with moderate winter occurrence; oil sardine and fringe-scale sardine remained moderate across both seasons. Snapper/grouper gillnets (*budi*) yielded peak grouper catches in late summer, and peak snapper catches in the late monsoon; portunid crabs were most abundant in late summer and moderate in winter. *Acanthopagrus* spp. and eels peaked in summer, while *Siganus* spp., juvenile sharks, and Asian seabass were commonly recorded during the late monsoon and summer; rays and lobsters were frequently reported as incidental catches. Trammel nets (*disco*) exhibited post-monsoon peaks in *Penaeus indicus* and *Metapenaeus affinis*

catch rates, whereas eels, catfishes, *Sillago* spp., carangids, and crabs remained consistently low throughout the fishing season. Fishers, by virtue of living in close association with the marine environment and harnessing the natural resources, possess rich knowledge on the ichthyofaunal diversity and its seasonal availability to gillnets.

Fish storage and preservation

A majority of fishers (85.33%) stored their catches in bamboo cane baskets locally known as *topali*, particularly in Sindhudurg district, where storage was generally for a short duration. These baskets are fabricated from locally available bamboo and are preferred due to their light-weight, low cost, and ease of handling. Similar use of bamboo cane baskets has been reported earlier by Nirmale *et al.* (2007). Preservation practices varied among respondents, with about 70% of fishers preserving fish using icing, 26% selling fish fresh, and approximately 4% adopting salt-drying. Icing was the most preferred method as it helps maintain freshness and quality; fish were typically stored in holds or containers with alternating layers of fish and ice in a 1:1 ratio. A small proportion of fishers preserved fish by salt-drying, applying salt at a fish-to-salt ratio of 1:1.7. In this method, fish were washed with seawater, layered alternately with salt for about 48 h, re-salted after turning and subsequently washed and sun-dried on mats made of coconut leaves. During salting, osmotic dehydration removes moisture from the flesh, facilitating effective drying (Nirmale *et al.*, 2007; Balachandran, 2001).

Effect of wind direction on fish catch

Multiple views on the effect of wind direction on fish catch and the operation of gillnets have been reported by fishers of Sindhudurg. Table 5 presents indigenous knowledge on the effects of wind direction on fish catch. It represents fishers' perceptions developed through prolonged interaction with the local marine environment. Accordingly, if strong winds from the south direction (*bardani*) during June-August stop blowing consecutively for forty-two days during the monsoon, the yield to gillnets is affected and catches decline during the subsequent year. Winds blowing from the southeast (*surmadi vara*) around mid-May to June cause turbulent conditions, leading fishers to avoid using gillnets. If the wind blows sporadically from the south (*yetcho varo*) after December, the yield to the drift gillnets is decreased, while it is enhanced in the case of the bottom set gillnets. Winds blowing from the northeast (*dhuri satros varo*) in October cause the water to become turbid and the bottom layers significantly cooler (*shel lagne*), resulting in a higher yield in drift gillnets. This effect is especially noticeable in surface water drift gillnets. Similarly, winds blowing throughout the day from the west

Table 5. Effects of wind direction on the availability of fish to the gill nets

Effects of wind direction	Responses
Strong winds blowing from the south direction (<i>bardani</i>) during June-Aug cease to blow consecutively for forty-two days during monsoon; the yield to gill nets is negatively affected.	23 (30.67)
Winds blowing from the south-east direction (<i>surmadi vara</i>) during mid-May to June result in stormy conditions	23 (30.67)
Wind blowing intermittently from southerly (<i>yetcho varo</i>) direction after December fetches very little catch to the drift gill net, and on the contrary, fetches high catch to the bottom set gill nets	22 (29.33)
Wind blowing from the north east direction (<i>dhuri satros varo</i>) during October results in water becoming turbid and bottom layers becoming relatively colder (<i>shel lagne</i>). More yield to drift gill nets is noticed in this situation.	15 (20.00)
Wind blowing from the west direction (entire day) during April to mid-May yields more catch to drift gill nets	10 (13.33)
Winds blowing from the north direction (<i>uparcho varo</i>) fetch a high catch to drift gillnets.	6 (8.00)
Wind blowing from an east direction (<i>matlayi</i>), then the sea fish move towards the bottom.	5 (7.00)
Wind blows from the south-west (<i>yet bhaylo varo</i>) direction, causing less catch in the gill net	4 (5.00)

(*bhaylo varo*) from April to mid-May result in higher yields for drift gillnets. A few fishers believed north winds (*uparcho varo*) improve catch, while east winds (*matlayi*) drive seer fish to deeper waters.

Fishers' perceptions highlight that practical knowledge of fish behaviour and gear efficiency is highly location-, species, season, and gear-specific. Such experiential knowledge, developed through prolonged interaction with the marine environment, plays a critical role in tactical fishing decisions, wherein fishers assess current and recent wind conditions in conjunction with their accumulated experience. Fish movements are strongly influenced by currents and wind direction and intensity, which indirectly affect fish migration patterns. Harden Jones *et al.* (1976) emphasised that currents are closely associated with most fish migrations, with fish often moving in the direction of prevailing currents, particularly under strong flow conditions (Gawn, 1950; Saunders, 1951). Empirical studies examining wind-catch relationships remain limited. For their tactical fishing decisions, fishers observe the present and near past winds and utilise past experiences of the winds and of the relationship between wind and fish availability. A thorough study of currents is necessary for understanding the mechanisms behind fish migrations and movements. There isn't enough scientific research regarding how wind affects fish behaviour. Walden and Schubert (1965) reported poor herring catches off East Anglia during easterly winds, whereas favourable catches were associated with westerly winds along the Danish west coast. Similarly, Jones and Scholes (1980) observed higher cod catches during northerly winds in autumn and winter, while plaice catches in the southern North Sea remained low irrespective of wind direction. They suggested that persistent wind regimes during spawning aggregation periods may establish links between wind directions and catch rates. Although most fishers strongly believe that wind direction influences fish abundance and availability, this locally derived knowledge has rarely been systematically validated through scientific investigation. Given its predominantly coastal and site-specific nature, documenting and scientifically evaluating such knowledge could provide valuable insights for fisheries research and management.

Effects of water colours on the availability of fish

Some fishers noted that clear water yields less catch to all types of gillnets, as noted by 24% of respondents. In contrast, some participants (16%) opined that muddy water results in higher catches in all gillnet types, while 9.33% indicated that brown and bluish water conditions yield moderate to relatively higher catches. Fishers reported that anchovies,

Indian mackerel, false trevally, croakers, and lobsters are mostly caught in bottom set gillnets [mackerel/ false trevally gillnets (*budav*)] in muddy water; trammel nets (*disco*) in muddy water yield more shrimp. In muddy water, croakers, snappers, groupers, lobsters, crabs, and pomfrets are caught more in bottom set gillnets, snapper/grouper gillnets (*budi*), and drift gillnets [mackerel/false trevally gillnets (*tarav/mand*)] respectively. In brown water, higher catches of sardines, croakers, and catfishes using drift gillnets and bottom set gillnets are reported.

Through experience, fishers have gained local ecological knowledge on the relationship between the colour of the water and the availability of fish. Muddy water is characterised by high concentrations of suspended particles and planktonic organisms, particularly diatoms and zooplankton. As zooplankton constitutes the primary food source for juvenile stages and small pelagic fishes, its abundance may explain the increased availability of fish in turbid waters. Moreover, gillnets are considered more efficient under turbid conditions, possibly due to reduced visual efficiency of sight-feeding fishes with increasing turbidity. Conversely, the occurrence of low fish abundance in clear water was attributed to the limited availability of food organisms. Murphy (1959) reported that surface gillnet catches of albacore (*Thunnus alalunga*) were significantly influenced by water transparency. Similarly, water colour and plankton content have been identified as useful indicators of surface water types (Macumo, 1957). Fishers also noted that occasional illumination of water due to fluorescent bacteria, particularly during new moon phases, enhances fish visibility, enabling them to detect and avoid gillnets, thereby reducing catch efficiency.

Effect of tides on fish catch and nets

The gravitational forces of the moon and the sun regulate oceanic tides, with the moon exerting a dominant influence due to its proximity to the Earth. About 16% of participants noted higher catches during the transition period (*modvni*), in seerfish gillnets and snapper/grouper gillnets. 9.33% of respondents opined that the probability of drift and bottom-set gillnets getting stuck in rocky bottom increases during high tide, and fish migrate opposite to the water current. Similarly, about 5.33% believed that during low tide, due to the water current, there is a possibility of getting disturbed bottom set gillnets, while high tide yields a moderate catch. Gillnets primarily capture actively swimming fish that encounter the net panels, and the increased current velocity during high tides may enhance fish movement and contact with the gear, thereby influencing catch rates (Nirmale *et al.*, 2007; Uskelwar *et al.*, 2017).

Effect of the lunar cycle on fish catch

Most fishers reported reduced catches in both drift gillnets (mackerel/false trevally: *tarav/mand*; seer fish: *aavta/dhangda*) and bottom-set gillnets (mackerel/false trevally: *budav*; snapper/grouper: *budi*) during new and full moon phases. These periods coincide with spring tides, which occur twice monthly when the Earth, Moon, and Sun are nearly aligned, generating strong tidal currents. Fishers indicated that the intensified currents during spring tides disturb gillnets, particularly those set in rocky areas, increasing the likelihood of net displacement and entanglement with substratum. Further, fishers reported that the period between the 4th day (*chaturthi*) to 11th day (*ekadashi*) of the lunar cycle yields high catch to drift gillnets [mackerel/false trevally gillnets (*tarav/mand*), seer fish gillnets (*aavta/dhangda*)], bottom set gillnets [mackerel/false trevally gillnets (*budav*) and snapper/grouper gillnets (*budi*)]. Fishers perceived that relatively calmer waters during this period allowed gillnets to remain properly positioned, resulting in increased catching efficiency. Similar influences of the lunar cycle on fishing efficiency have been documented earlier for dol nets, longlines, gillnets, bivalve fisheries, and stake nets, indicating a consistent relationship between lunar-driven tidal dynamics and fishing success (Nirmale *et al.*, 2007; Nirmale *et al.*, 2012; Gangan *et al.*, 2014; Uskelwar *et al.*, 2017).

Indicators of identification of resource availability in particular locations

Approximately 49% of fishers identify the availability of fishery by movement and shape of the fish shoals, including the swift movement of oil sardine shoals characterised by foamy appearance (*fes*), the rapid caudal fin movements of fringe scale sardine shoals, and Indian mackerel oval-shaped shoals with heads of individual fishes moving over the water surface at the gill region. Pelagic fishes are generally known to move in shoals (Bal and Rao, 1984; Ashaletha and Sheela, 2008; Salim and Antony, 2013). Drift gillnet operations are typically initiated concurrently with the appearance of such shoals, with nets deployed in a transverse or slightly curved orientation to maximise capture efficiency.

Indicators of cyclones/storms

The majority of respondents (93.33%) reported that an increase in water current intensity is an indicator of an imminent storm within a few hours. Additionally, 89.33% observed jerks while hauling nets before cyclonic events, and 82.67% reported that wind blowing from the southern direction served as a reliable indicator. Fishers also reported other signs, including seawater remaining unusually calm,

locally referred to as '*sushi marne*' (68%), mud entering water in the form of nodules locally known as *malaki* (60%), and nearshore waters slowly becoming turbid (49.33%). A few other indicators include unusual waves appearing at the surface in relatively deeper waters, locally known as a *lambar* (34.67%), the seabed making noise (26.67%), clouds appearing close to the horizon, locally called *mendhra or kupe* (18.67%), and distant rocks and mountains appear unexpectedly closer than they actually are. These observations are consistent with earlier reports by Nirmale *et al.* (2007), Santha *et al.* (2014), and Johnston (2015).

Fishers further noted that aquatic animals exhibit unusual behaviour preceding storms. The sudden disappearance of fish and surfacing of sea snakes (*mharuche*) were commonly reported, consistent with observations by Nirmale *et al.* (2007). Laevastu (1961) emphasised that fishers' experience allows them to recognise storm impacts on fish occurrence and migration, with storms limiting shoreward distribution (Robins, 1957). Similarly, Bernard (1973) observed porpoises leaving areas hours before storms, while Jones and Scholes (1980) reported herring and pilchards off Cornwall migrating to deeper waters at least ten hours before storm impact. Laevastu (1993) suggested that such pre-storm fish responses may result from internal wave activity or current changes induced by shifting surface pressure systems.

IK in Maharashtra's coastal fisheries has been previously documented by Nirmale *et al.* (2007) among fishers of Mumbai, encompassing craft construction, fish preservation, and tidal and storm indicators across multiple gear types, and by Uskelwar *et al.* (2017) in the estuarine stake net (*wan*) fishery of Ratnagiri, a fixed tidal gear. The present study extends this knowledge to the Sindhudurg coast, where gillnet fisheries, comprising drift, bottom-set, and trammel nets, targeting diverse pelagic and demersal assemblages are practised exclusively by the *gabiti* fishing community, representing a distinct socio-cultural and operational context. Several indigenous practices documented in this study, including depth regulation using marked ropes (*sarki*) and buoys (*ghadan*), the *shinari* profit-sharing system, gear-specific wind direction indicators, and adaptive gear consolidation strategies, have not been previously reported from the Maharashtra coast. The IK documented in this study is consistent with established scientific understanding of fish behaviour and environmental variability. Higher catch rates during early morning and evening hours correspond to diel activity patterns and reduced gear visibility, while increased catches in turbid waters reflect reduced visual detection of gillnets. Seasonal variations in fish availability reported by fishers align with known migration and distribution patterns. Such knowledge can complement conventional fisheries science, particularly in data-limited small-scale fisheries, by

providing fine-scale insights into species seasonality, fishing grounds, and gear selectivity.

Conclusion

The present study has generated an important database related to the use of indigenous knowledge in the gillnet fishery in the district. Knowledge regarding the selection of fishing grounds, gillnet operations, species composition and seasonal abundance, the influence of lunar cycles on fisheries, and resource allocation will help in designing appropriate management interventions. The study documented nine types of gillnets across drift, bottom-set, and trammel categories operated at depths of 5-60 fathoms, with species-specific seasonal abundance and peak catches between the 4th and 11th day of the lunar cycle. Scientific studies on catch composition and seasonal abundance in the gillnet fishery will help devise the optimum mesh size for the gillnet. Further, when combined thoughtfully with modern, science-based fishing methods, indigenous knowledge can significantly enhance fisheries management. Thus, integrating indigenous and modern approaches is essential for the holistic development of Indian marine capture fisheries.

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Author contributions

Conceptualization: SBA, VHN; Methodology: SBA, VHN; Data Collection: SBA, MBS, SSS; Data Analysis: SBA, MBS, SSS; Writing Original Draft: SBA, VHN, SYM; Writing Review and Editing: VHN, SYM, MBS, SSS; Supervision: AUP

Data availability

The data are available and can be requested from the corresponding author.

Conflicts of interest

The authors declare that they have no conflict of financial or non-financial interests that could have influenced the outcome or interpretation of the results.

Ethical statement

No ethical approval is required as the study does not include activities that require ethical approval or involve protected organisms/ human subjects/ collection of samples/ protected environments.

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References

- Allison, M. E. and D. Daniel Okadi. 2013. Gill net selectivity, seasonal, tidal and photoperiod variation in catch in the lower Nun River, Niger Delta, Nigeria. *Sci. Res. Essays*, 8 (3): 108-114.
- Anon. Fish Production Report. 2021-22. Department of Fisheries. Government of Maharashtra. Mumbai. 120 pp.
- Ashaletha, S. and S. Immanuel. 2008. Scope of ethnofisheries and sustainable marine fisheries management in India. *Indian J. Tradit. Knowl.*, 7 (2): 226-232.
- Bailey, K. D. 1987. Document Study. In: K. D. Bailey, (Ed). *Methods of Social Research*, New York, the Free Press. p. 293-319.
- Bal, D. V. and K. V. Rao. 1984. *Marine Fisheries of India*. Tata McGraw-Hill Publishing Company Ltd, New Delhi, India, 150 pp.
- Balachandran, K. K. 2001. Post-harvest technology of fish and fish products. Daya Publishing House, Delhi, 77 pp.
- Bernard, R. C. 1973. Porpoises predict storms. *Underwat. Nat.*, 8 (1): 43-44.
- Gadgil, M., F. Berkes and C. Folke. 1993. Indigenous knowledge for biodiversity conservation. *AMBIO-STOCKHOLM-22*, p. 151-156.
- Gangan, S. S., V. H. Nirmale, S. Y. Metar, N. D. Chogale, R. Pai, S. D. Patil and A. K. Balange. 2014. Validation of indigenous knowledge used in the management of bivalve fishery of South Konkan coast of Maharashtra. *J. Mar. Biol. Assoc. India*, 56 (2): 34-42.
- Gawn, R. W. L. 1950. Fish propulsion in relation to ship design. *Quart. Trans.Inst. Naval Architects*, 91 (3): 323-332.
- Goode, W. J. and P. K. Hatt. 1952. *Methods of Social Research*, McGraw Hill, New York, 23-25.
- Harden Jones, F. R., G. M. Walker and G. P. Arnold. 1976. Tactics of fish movement in relation to migration strategy and water circulation. In: *Advance in Oceanography, Proceedings of Oceanographic Assembly 1976* (eds. Charnock, H. and Deacon, G.). Blenheim Press, New York, p. 185-207.
- Joa, B., G. Winkler and E. Primmer. 2018. The unknown known-A review of local ecological knowledge in relation to forest biodiversity conservation. *Land Use Policy*, 79: 520-530.
- Johannes, R. E. 1981. Working with fishermen to improve coastal tropical fisheries and resource management. *Bull. Mar. Sci.*, 31 (3): 673-680.
- Johnston, I. 2015. Traditional warning signs of cyclones on remote islands in Fiji and Tonga. *Environ. Hazards*, 14 (3): 210-223.
- Karlson, L. and A. Bjarnason. 1986. Small scale-fishing with driftnets. FAO Fisheries Technical Paper No: 284, Rome, 64 pp.
- Kazi, T. G., A. S. Mohite and R. R. Jadhav. 2010. Design characteristics of mackerel encircling gill nets of Ratnagiri, Maharashtra. *Engineering and Technology in India*, p. 68-73.
- King, M. G. 1995. *Fisheries Biology: Assessment and Management*. Fishing News Book, Oxford, 341 pp.
- Kizhakudan, S. J., S. Raja, K. S. Gupta, E. Vivekanandan, J. K. Kizhakudan, S. N. Sethi and R. Geetha. 2014. Correlation between changes in sea surface temperature and fish catch along Tamil Nadu coast of India—an indication of impact of climate change on fisheries? *Indian J. Fish.*, 61 (3): 111-115.
- Laevastu, T. 1961. Weather and Fisheries. *WMO Bulletin*, p. 144-150.
- Laevastu, T. 1993. *Marine Climate, Weather and Fisheries. The effects of Weather and Climatic Changes on Fisheries and Ocean Resources*. Fishing News Books, Oxford, p. 102-103.
- Laxmappa, B, R. R. Bakshi and S. Konakondl. 2014. Impact study of Seine nets on Krishna River fishery in Mahabubnagar district, India 4 (4): 171-174.
- Macumo, R. 1957. Plankton as indicator of water masses and ocean currents. *Oceanogr. Mag.*, 9 (1): 55-63.
- Murphy, G. L. 1959. Effect of water clarity on albacore catches. *Limnol. Oceanogr.*, 4 (1): 86-93.
- Naik, S. D. 1998. Observations on large-scale destruction of fishing gear by the pufferfishes (family Tetraodontidae) along the south Konkan coast (west coast of India). *Indian J. Mar. Sci.*, 27: 421-425.
- Nirmale, V. H., S. S. Gangan, B. M. Yadav, P. Durgale and K. M. Shinde. 2012. Traditional knowledge on mud crab; ethnoecology of *Scylla serrata* in Ratnagiri coast, Maharashtra. *Indian J. Tradit. Knowl.*, 11 (2): 317-322.
- Nirmale, V. H., B. S. Sontakki, R. S. Biradar and S. Y. Metar. 2004. Assessment of indigenous knowledge of coastal fisherfolk of Greater Mumbai and Sindhudurg districts of Maharashtra. *Indian J. Tradit. Knowl.*, 3 (1): 27-36.
- Nirmale, V., B. S. Sontakki, R. S. Biradar, S. Y. Metar and S. L. Charatkar. 2007. Use of indigenous knowledge by coastal fisher folk of Mumbai district in Maharashtra. *Indian J. Tradit. Knowl.*, 6 (2): 378-382.

- Pukkalla, D. and K. R. Rama Mohan. 2021. Local knowledge and marine livelihoods among the South Indian fishing community. *J. Asian Afric. Stu.*, 56 (3): 549-557.
- Robins, R. C. 1957. Effects of storms on the shallow water fish fauna of southern Florida with new records of fishes from Florida. *Bull. Mar. Sci. Gulf. Carrib.* 7 (3): 266-275.
- Saha, R. K. and Nath, D. 2013. Indigenous Technical Knowledge (ITK) of fish farmers at Dhalai district of Tripura, NE India. *Indian J. Tradit. Knowl.*, 12 (1): 80-84.
- Salim, S. S. and P. Antony. 2013. Indigenous Technical Knowledge (ITK) in capture fisheries: A case study in Vypeen Island of Ernakulam district. *Discovery Nature.* 4 (11): 7-10.
- Santha, S. D., P. Gahana and V. S. Aswin, V. S. 2014. Local knowledge, early warning and coastal hazards: Participatory inquiry among fish workers in Kerala, India, *Action research*, 12 (3): 273-292.
- Saunders, H. E. 1951. Some interesting aspects of fish propulsion. *Soc. Nav. Arch. Mar. Eng., Ches. Sect.*, 3 pp .
- Smith, I. R. 1981. Improving fishing incomes when resources are overfished. *Mar. Policy*, 5 (1): 17-22.
- Sparre, P. and S. C. Venema. 1992. Introduction to tropical fish stock assessment. FAO Fisheries Technical Paper. 306 (1): 1-376.
- Sreekrishna, Y. and Latha Shenoy. 2001. "Fishing gear and craft technology", p. 332-336
- Thomas, S. N. 2001. *Gill nets of Kerala: A study on technological and operational aspects.* Thesis submitted to the Cochin University of Science and Technology in partial fulfillment of the requirements for the degree of doctor of philosophy, school of industrial fisheries, Cochin University of Science and Technology, Cochin, 333 pp.
- Uskelwar, L. S., V. H. Nirmale, B. P. Bhosale, S. Y. Metar and N. D. Chogale. 2017. Indigenous knowledge used in stake net (wan) fishery practiced along the Ratnagiri coast of Maharashtra. *J. Mar. Biol. Assoc. India*, 59 (2): 45-52.
- von Brandt, A. 1972. Fish catching method of the world, Fishing News (books) Ltd. West Byfleet, UK, p. 280-285.
- Waghmare, K., R. Sadawarte, A. Mohite, V. Mulye and J. Koli. 2018a. Design characteristics and technical specifications of mackerel gill nets of Sindhudurg, Maharashtra. *J. Exp. Zool. India.*, 21 (1): 373-378.
- Waghmare, K., R. Sadawarte, A. Mohite, V. Mulye and J. Koli. 2018 b. Technical specifications and design characteristics of pomfret gill nets of Sindhudurg, Maharashtra. *J. Exp. Zool. India.*, 21(1): 43-48.
- Waghmare, K., R. Sadawarte, A. Mohite, V. Mulye and J. Koli. 2018c. Red snapper gill nets of Sindhudurg: Design characteristics and specifications. *J. Exp. Zool. India*, 21 (1): 93-96.
- Waghmare K., R. Sadawarte, A. Mohite, V. Mulye and J. Koli. 2018d. Shrimp trammel nets of Sindhudurg, Maharashtra. *J. Exp. Zool. India*, 21(1): 83-88.
- Walden, H. and K. Schubert. 1965. Untersuchungen uber die Beizechungen zwischen Wind und Herrings Fangertrag in der Nordsee Ber Dt. Wiss. Meeresforsch, 17 (2): 194-221.
- Worsely, P. 1971. Knowledge: What Different Peoples Make of the World, (Profile Books, London), 65 pp.