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Balancing Catch and Conservation: Mesh Size Modifications in Traditional Dol net Along the Mumbai Coast

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Abstract

Dol nets are traditional bag nets widely used in artisanal fisheries along the northwest coast of India, particularly in Maharashtra, where they play a crucial role in supporting small-scale fisheries. Despite their importance, dol nets have been criticized for their non-selective nature, leading to high bycatch and juvenile capture. This study aimed to modify the cod-end of dol nets by incorporating a 35 mm square mesh panel to enhance gear selectivity and promote sustainable fishing practices. Experimental fishing was conducted off Madh Island, Mumbai, to assess the impact of this modification on catch composition, species diversity, and catch efficiency. The results revealed a significant reduction in the capture of juvenile fish in the upper cod-end (average 8.42 kg per haul) compared to the lower cod-end (average 13.15 kg per haul), where smaller species and juveniles were concentrated. 48 species from 25 families were recorded, including finfish, shrimp, prawns, crabs, cephalopods, and mantis shrimp, with a noticeable decrease in species diversity compared to previous studies, likely due to the mesh modification. Incorporating the square mesh panel improved size selectivity, with larger, commercially valuable species retained in the upper cod-end while juveniles and smaller species were sorted into the lower compartment. These findings demonstrate that gear modifications, such as larger mesh panels, can significantly reduce bycatch, enhance fishing sustainability, and contribute to the conservation of fishery resources in the region. This study highlights the potential of blending traditional fishing practices with modern innovations to achieve sustainable fisheries management.

Keywords:
Dolnets, Northwest coast, Gear Selectivity, Fishing, Square Mesh panel, Cod-end

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Introduction

Coastal communities are known for their strong fishing legacy, which passes from generation to generation. Fishing is more than just a source of income; it is a "way of life" for many coastal communities worldwide (Thompson *et al.,* 1983; Bavinck, 2001; Britton and Coulthard 2013; Urquhart and Acott, 2013). Stationary Bag Net is one of the leading indigenous fishing gears that supports the livelihood of several thousand people in the artisanal fisheries sector worldwide. Dol net is an indigenous version of bag net. The stationary bagnet of the northwest coast of India is locally called Dol net, Bokshi Jal, or Kavi Jal, whereas the northeast coast is called Behundijal. In Kerala, it is named "Oonivala." Dol net is an indigenous version of bag net. This net is a prevalent passive fishing technique practiced along India's northwest coast. It is one of the traditional fishing gears of India, especially in Gujarat and Maharashtra. In Maharashtra, the stationery bag net (locally termed as dol net) is one of the significant contributors as it is the essential traditional fishery of the state, with a large population of small-scale fisherfolk depending on it since time immemorial. Numerous studies have been conducted on this version of bag-net

(Khan, 1986; Khan, 1987). However, the first report on the operation of the dol net was from Maharashtra, wherein details about fixing the dol net were described (Setna, 1949). Raje and Deshmukh (1989) reported more information about setting wooden poles based on the principles of hydrodynamics. Knowledge of fishing techniques, fishing gear and crafts is needed for the scientific and sustainable exploitation of fish resources and fishery management (Raju *et al.,* 2016). Literature reported that the traditional fishing technique is an old-age method, and this knowledge is transferred orally from one generation to another in the fishing community (Saha *et al.,* 2015). A well-managed multi-species and multi-gear fishery are expected to employ gears with little overlap in selectivity, capturing target species at optimal and profitable sizes and promoting sustainable harvesting, thereby avoiding resource competition among gears and emergent socio-ecological poverty traps (McClanahan and Mangi, 2004; Cinner *et al.,* 2009). This balanced harvesting can maximize yields and minimize ecological effects (Zhou *et al*., 2010; Garcia *et al.,* 2012). Gear selectivity can influence the population size and structure, the composition of the associated food webs, and fishery productivity. As a result, gears can be actively managed to mitigate ecosystem damage, reduce fishing mortality of juveniles in the population, alleviate fishing pressure on specific species, and contribute to the recovery of critical functional groups, with subsequent ecological impacts (McClanahan *et al.,* 2008; Cinner *et al.,* 2009; Hicks and McClanahan, 2012). Despite being the most common traditional gear, which has a significant contribution to the fishery of Maharashtra, no such studies have been conducted for reducing the catch of juvenile and discard in dol net for sustainability, conservation, and fisheries resource management. Responsible fishing necessitates the fishing gears to preferentially catch the adult fish at a particular age, maximizing yield while permitting the juveniles and sub-adults to escape and minimizing the catch of nontargeted and protected organisms (Boopendranath and Pravin, 2005). Therefore, developing and innovating cod-end and modifying gears to improve nets' selective properties and increase marine fisheries' sustainability. Dol net is fishermen-friendly in terms of giving short-term economic benefits. However, due to the non-selective nature of fishing, the risk of long-term aggregate environmental impacts is an evident threat calling for modifications in the design and construction of Dol net. A study on mesh panel design assumes importance as it would facilitate reducing the impact of Dol net on non-target marine resources and efficiently contribute to the sustainable management of fishery resources. This study will assist in creating a database on the availability of several commercially important fish species and the quantity of their catch. This study can, thus, be used to design policies for the sustainability of fisheries in general and Dol net fishing in coastal areas.

Materials and Methods

The study was conducted in Mumbai Suburban (Madh Island) a group of several quaint fishing villages and farmlands in northern Mumbai (Figure: 1). The island is the hub for dolnet fisheries on the Mumbai coast of India. The major groups of fish landed are Bombay duck, pomfrets, clupeids, sciaenids, threadfins, ribbonfishes, tuna, grouper, penaeid and non-penaeid shrimps, and crabs (Anon., 2016). Data regarding indigenous fishing techniques, gear, and fishing methods were obtained from primary sources (Direct observations from extensive field works, and personal interviews).

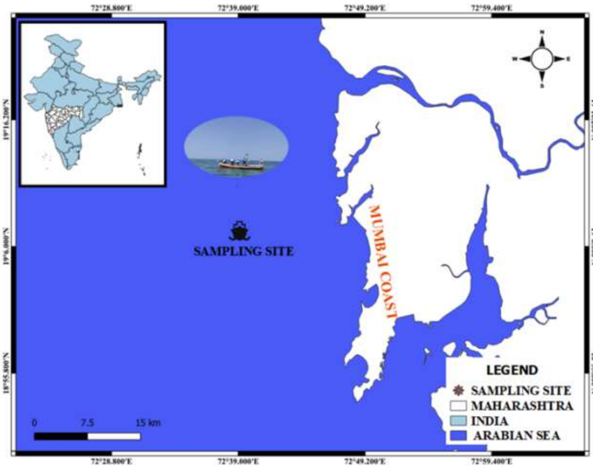

Fig. 1 Location map of the study

Table 1: Gear specifications

Specification	Measurements
Overall length (m)	45
Height (m)	7.5
Breadth (m)	22
Types of material	High-Density Polyethylene (HDP)
Cod-end mesh size of lower panel	8mm
Cod end mesh size of upper panel	35mm
Color of the net	Blue

Fishery-dependent data

Fishery-dependent data was collected during the investigation. The type of vessel used, the dimension of dol nets, and the mesh size of a different dimension of the net were measured from the mouth part to the cod ends of the dol net by using using “Digimatic caliper”, Colour of the net, distance travelled by dol-netters from the coast, the depth of operation and latitude and longitude were recorded

Method of operation

Experimental fishing is required prior setting of khunt into the muddy bottom during neap tide. The dol net operated with the help of ropes rigged to the khunts, which acted like fixed stations in the sea . The actual operation involved setting the net so that it faced the tide at its onset and hauling it before the change of tide. The khunt rigged with bridles and float ropes attached to thermocol marker floats were left in the sea after completion of the operation. The thermocol marker floats floating on the sea surface waters, thus indicating the specific site of the individual fishers, where the dol net operation was carried out during the fishing season. During experimental fishing, after reaching the fishing site, the ropes were located using marker floats. Then the rope attached to the float was pulled by the fishers. The net was tied at the four corner loops to the bridle with the help of slipknot and the net was then paid by releasing the cod end after tying it with a rope by a rolling hitch. The net was allowed to drift for some time, and then the net was set in the flowing water in the tidal current. The setting of the net required only 18- 20 minutes. Then the Hauling process started one hour before the turn of the tide. Hauling operation was initiated by locating the marker floats and pulling the float ropes to gain access to the bridle ropes. The head rope and foot rope of the net was then accessible which were hauled up immediately by fishers, taking 15–20 min and then the entire net was lifted onto the boat. When the net was hauled up, the catch was emptied from the cod end section into the plastic crates (Table2).

Table 2: Details of fishing operation

Fishing ground	**Muddy bottom**
Type of operation	
a) Based on the scale of operations	Small scale
b) Based on the number of vessels used	One boat
c) Based on the method of operation	Khunt basis
d) Based on target species	Acetes and Bombay duck
Depth of operation	11-15 meter
Method of finding fish shoal	Visual(current), wind direction
Time required for	
a) Time required for setting	18 min
b) Time required for hauling the net	15 min
Immersion period	3 hours
The average number of operations per trip	4 nos

Catch composition

Each haul, total catch weight and species abundance in biomass and numbers were recorded. After segregating the catch, species-wise biomass was measured using a digital weighing balance to estimate the catch composition (Figure 2). The sub-sample was brought to the laboratory where fish and shellfish caught during the net operation were segregated and identified to the family, genus, and species levels. Species identification was done following conventional taxonomic methods such as morphology, colour, texture patterns, morphometric measurements, and meristic counts following standard taxonomic literature (Fischer and Whitehead, 1974; Fischer and Bianchi, 1984; Talwar and Kacker, 1984), and internet websites such as WORMS (Eschmeyer and Fong, 2013), FishBase (Froese and Pauly, 2010) and Sealifebase (Palomares and Pauly, 2010). Samples were photographed using a digital camera/Mobile camera.

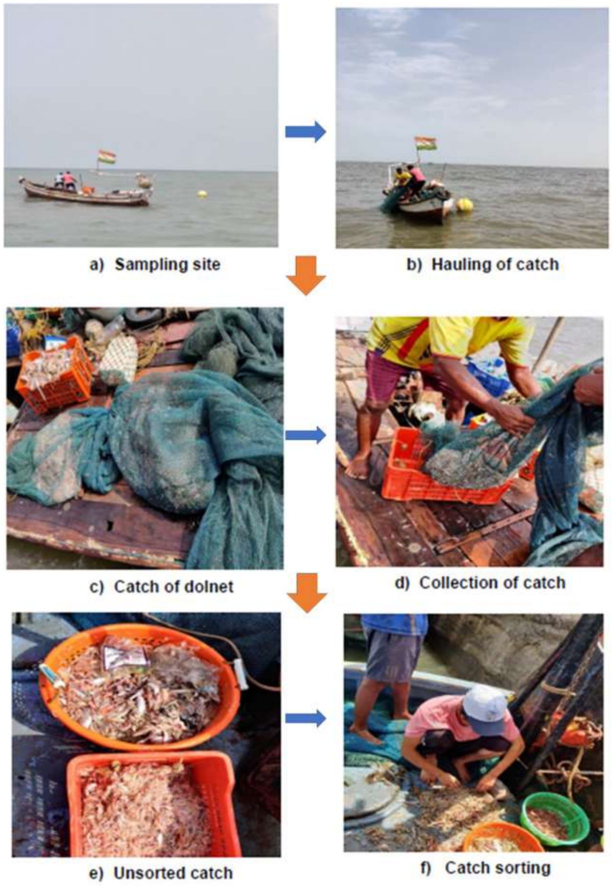

Fig. 2 Field sampling procedure and catch handling using Dolnet

Results and discussion

Design and Incorporation of Mesh Panels in Dol Nets

The dol net design used in this study, a traditional fishing gear with indigenous origins, was consistent with historical records of dol nets (Setna, 1931; Gokhalae,1957; Sehara & Karbhari, 1987). The net, measuring 45 meters in length with a wide rectangular mouth (22 m in length and 7.5 m in width) and a narrow cod-end (Figure 3; Table 1), reflects the typical conical structure of a bag net (Akerman, 1986). The use of high-density polyethylene (HDP) multifilament twine and a blue color for the net is a modern choice that mirrors earlier reports of polyethylene (PE) monofilament yarn being used in dol nets along the

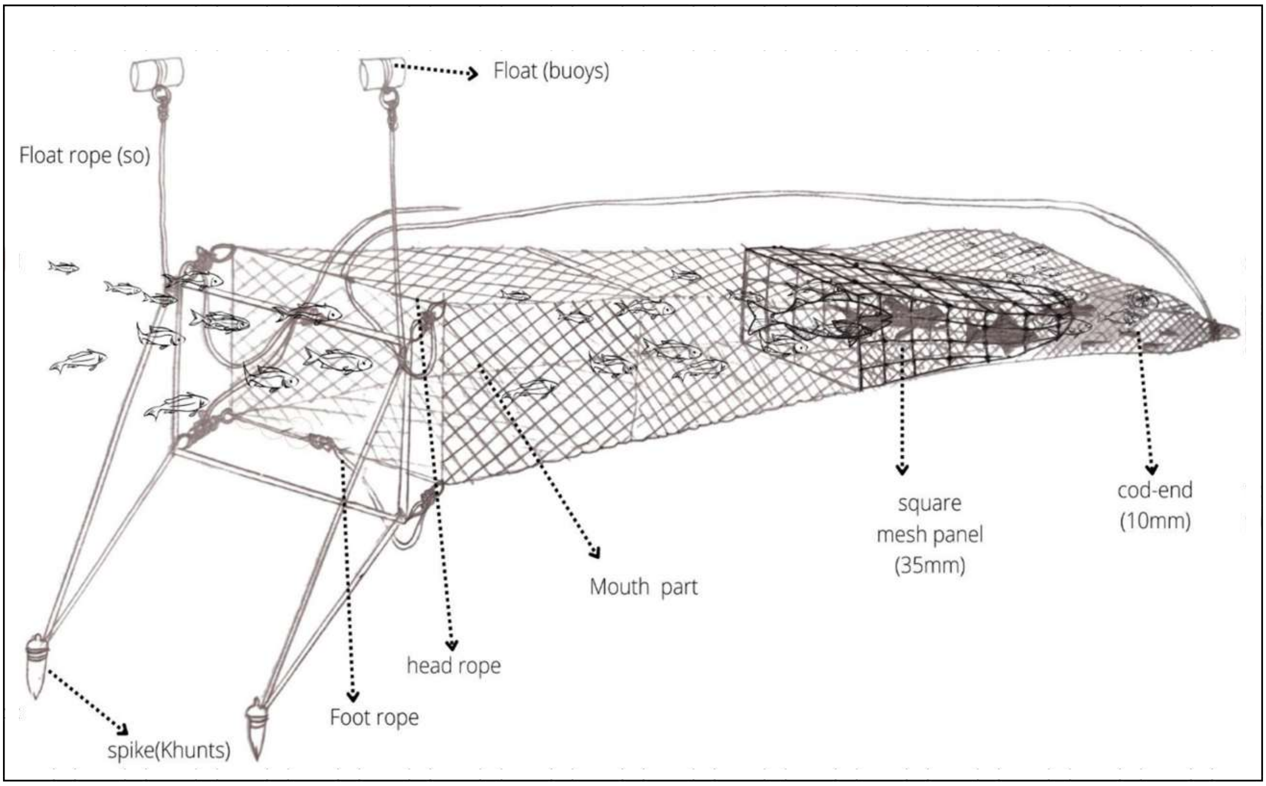

Fig. 3 Structural Design of Dolnet Operated in Sampling Trials

northwest coast of India (Khan, 1979; Sehara & Karbhari, 1987). The net was divided into three major sections-mouth, belly, and codend each composed of rectangular pieces of webbing joined by the lacing process. This structure, with larger meshes at the mouth and smaller meshes toward the cod-end, is critical for enhancing selective fishing practices. The integration of a 35 mm square mesh panel into the cod-end represents a critical modification aimed at enhancing bycatch reduction and promoting fishery sustainability. Previous research by Kathavrayan *et al.* (2002) demonstrated that a smaller 20 mm square mesh panel improved catch composition by allowing juvenile fish to escape while retaining larger, commercially valuable species. Further design improvements, including the transition from the conventional 20 mm mesh size to 30 mm and 40 mm, were also endorsed by Kunjipalu and Boopendranath (1993), showing that such adjustments enhance size selectivity and reduce the capture of undersized or juvenile fish. These results are consistent with contemporary fisheries management strategies that prioritize the use of selective fishing gear to minimize ecological impact and support sustainable fish populations. Additionally, the use of a thermocol bundle as a floating marker for fishing locations underscores the preservation of Indigenous fishing techniques within modern dol net operations. This method, combined with the compartmentalization of the cod-end into upper and lower sections through the installation of a square mesh panel, offers a refined balance between traditional practices and modern sustainability measures. In this configuration, the upper panel serves as a modified cod-end of 35mm mesh size, while the lower compartment functions as a conventional cod-end of 8mm mesh size . Raje & Deshmukh (1989) and Akerman (1986) have discussed the operation of similar dol nets in other regions, demonstrating their adaptability across different coastal environments. These nets are stationary, relying on the movement of water currents to guide fish into the cod end, making them highly energy-efficient and suitable for small-scale fisheries. Overall, the modifications introduced in the dol net design, especially the integration of more extensive and square mesh panels, hold promise for reducing bycatch and enhancing the efficiency of fishing operations. This study reinforces the idea that blending traditional gear with scientifically informed adjustments can contribute significantly to sustainable fishing practice.

Catch composition, catch per haul and species diversity

The present study yielded valuable insights into the catch composition and efficiency of dol nets, particularly focusing on the performance of the modified dol net design featuring a square mesh panel. The results indicated a clear difference in catch weight between the upper and lower compartments of the cod-end. The average catch per haul in the upper cod-end was 8.42 kg, while the lower cod-end recorded a higher average of 13.15 kg per haul (Figure 4). This disparity in catch weight is consistent with earlier findings by Kunjipalu and Boopendranath (1993), who observed that dol nets with larger mesh sizes in the cod-end resulted in a lower catch than traditional gear. The reduction in catch weight was attributed to the

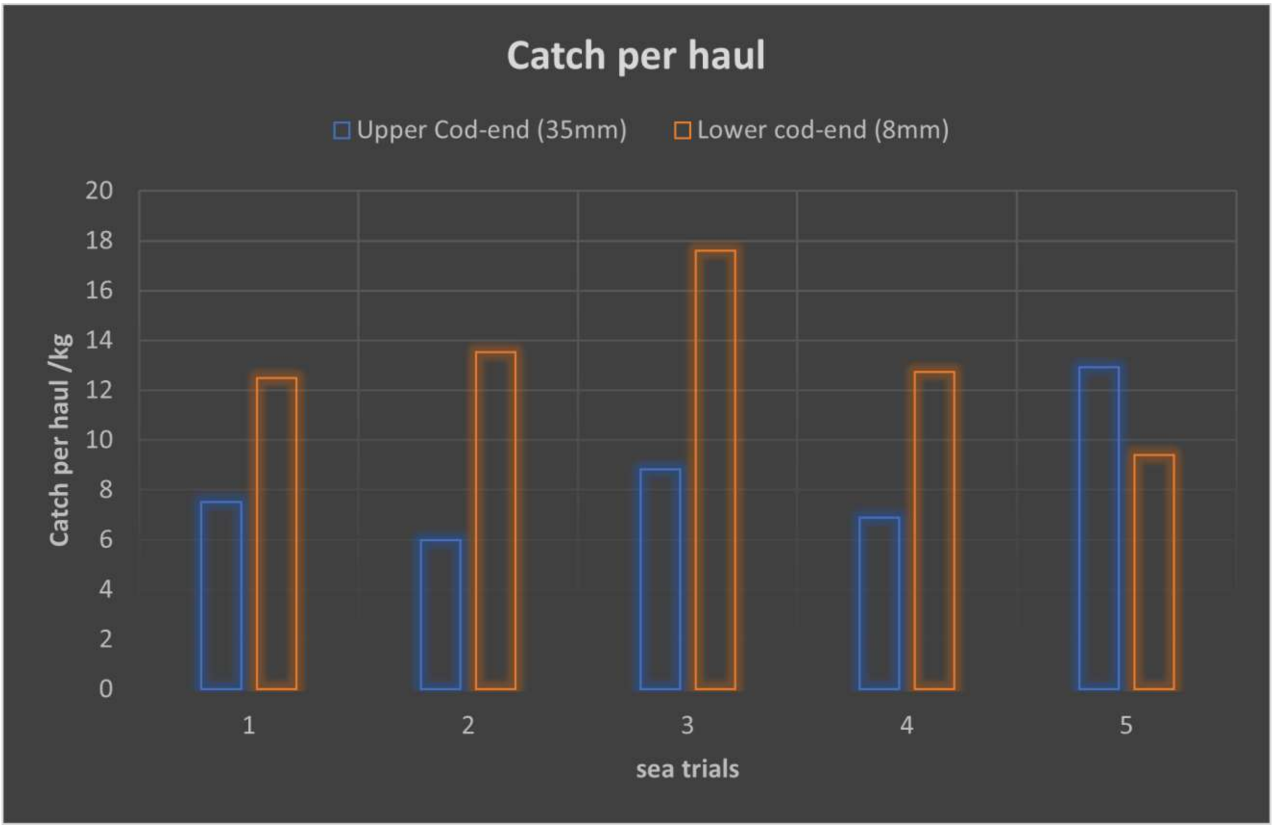

Fig. 3 Catch per haul of experimental fishing

escape of juvenile fish and bycatch, which improved the fishery's overall quality and sustainability. The integration of a 35 mm square mesh panel in the present study showed promising results in selective fishing, similar to the findings of Kathavrayan *et al.* (2002), where a 20 mm square mesh panel in stationary bag nets led to a significant reduction in juvenile fish and prawn catches. The installation of the square mesh panel in the cod-end allowed smaller and juvenile fish to escape, thus contributing to resource protection and sustainable fishery management. This highlights the role of gear modifications in reducing overfishing of juvenile species and protecting the ecological balance of the fishery. Regarding species composition, the study recorded a total of 48 species belonging to 25 families, including one species of elasmobranchs, 30 species of finfish, nine species of shrimp and prawn, five species of crabs, two species of cephalopods, and one species of mantis shrimp (Table 3). This diversity is lower than what was reported in previous studies from similar environments. For instance, Kumawat *et al.* (2015), Iburahim *et al.* (2017), and Pradhan *et al.* (2019) reported 66 species in a single-day bagnet catch from Bassein Koliwada, Mumbai, and 92 and 79 species from Karanja and Byander estuaries on the Maharashtra coast, respectively. Additionally, Rathees *et al.* (2019) documented 156 species from stationary bagnets in a different region, suggesting higher species diversity in other parts of the northwest coast. The difference in species diversity observed in the present study compared to previous literature could be due to a range of factors, including seasonal variation, fishing gear selectivity, and local ecological conditions. It is also possible that the modified dol net design, particularly the larger mesh size and square mesh panel, excluded smaller and less commercially valuable species, thus leading to lower species richness in the catch. In terms of species conservation, the reduced capture of juvenile fish through the use of square mesh panels aligns with the goals of sustainable fisheries management. These findings support earlier studies advocating for gear modifications to enhance selectivity and reduce bycatch. Such measures are critical for protecting fishery resources and ensuring the long-term viability of coastal fisheries along the northwest coast of India.

Impact of square mesh panels on species sorting and size

Incorporating a square mesh panel in the dol net design acted as an effective separator, facilitating species sorting by size. Larger fish were retained in the upper cod-end, reducing the time and labor needed for onboard catch sorting. Smaller species, such as *Acetes* spp. and juvenile fish, were primarily retained in the lower cod-end. This sorting efficiency is consistent with findings from separator trawl studies, where different selection properties in upper and lower compartments allow for effective species separation (Karlsen *et al.,* 2019). In multi-species fisheries, achieving size selectivity is crucial, and using square mesh panels contributes to better species separation. This was evident in the present study, where the upper cod-end retained larger, marketable species. At the same time, smaller fish and crustaceans, which

Table 3: Ichthyofaunal Diversity in Dol Net Catches Along Mumbai Coast

Order	Family	Common name	Scientific name	IUCN Status
Harpadontidae	Harpadontidae	Bombay-duck	*Harpadon nehereus* (Hamilton, 1822)	Near Threatened (NT)
Clupeiiformes	Clupeidae	White sardine	*Escualosa thoracata* (Valenciennes, 1847)	Least Concern (LC)
		Smoothbelly sardinella	*Amblygaster leiogaster* (Valenciennes, 1847)	Least Concern (LC)
	Engraulidae	Goldspotted grenadier anchovy	*Coilia dussumieri* (Valenciennes, 1848)	Least Concern (LC)
		Indian anchovy	*Stolephorus indicus* (Van Hasselt,1823)	Least Concern (LC)
		Hamilton's thryssa	*Thryssa hamiltonii* Gray, 1835	Least Concern (LC)
		Moustached thryssa	*Thryssa mystax* (Bloch & Schneider, 1801)	Least Concern (LC)
		Longjaw thryssa	*Thryssa setirostris* (Broussonet, 1782)	Least Concern (LC)
	Pristigasteridae	Tardoore	*Opisthopterus tardoore* (Cuvier, 1829)	Least Concern (LC)
Gadiformes	Bregmacerotidae		*Bregmaceros macclellandi* Thompson, 1840	Not Evaluated (NE)
Pleuronectiformes	Cynoglossidae	Largescale tonguesole	*Cynoglossus arel* (Schneider, 1801)	Data deficient (DD)
		Malabar tonguesole	*Cynoglossus macrostomus* Norman,1928	Vulnerable (VU)
Carangiformes	Carangidae	Shrimp scad	*Alepes djedaba* (Forsskål, 1775)	Least Concern (LC)
		Herring scad	*Alepes vari* (Cuvier, 1833)	Least Concern (LC)
		Yellowtail scad	*Atule mate* (Cuvier, 1833)	Least Concern (LC)
		Torpedo scad	*Megalaspis cordyla* (Linnaeus, 1758)	Least Concern (LC)
		Black pomfret	*Parastromateus niger* (Bloch, 1795)	Least Concern (LC)
		Talang queenfish	*Scomberoides commersonnianus* Lacepède, 1801	Least Concern (LC)
	Gobiidae		*Trypauchen vagina* (Bloch & Schneider,180	Least Concern (LC)
	Stromateidae	Silver pomfret	*Pampus argenteus* (Euphrasen, 1788)	Not Evaluated (NE)
	Tetradontidae	Smooth blaasop	*Legocephalus inermis* (Temminck & Schlegel, 1850)	Least Concern (LC)

		Oceanic puffer	*Lagocephalus lagocephalus* (Linnaeus, 1758)	Least Concern (LC)
		Half-smooth golden pufferfish	*Lagocephalus spadiceus* (Richardson, 1845)	Least Concern (LC)
	Trichiuridae	Largehead hairtail	*Trichiurus lepturus* Linnaeus, 175	Least Concern (LC)
	Sciaenidae	Belanger's croaker	*Johnius belangerii* (Cuvier, 1830)	Least Concern (LC)
		Sin croaker	*Johnius dussumieri* (Cuvier, 183	Least Concern (LC)
	Scombridae	Indian mackerel	*Rastrelliger kanagurta* (Cuvier, 1816)	Least Concern (LC)
		Indo-Pacific king mackerel	*Scomberomorus guttatus* (Bloch & Schneider, 1801)	Data deficient (DD)
Siluriformes	Ariidaes	Spotted catfish	*Arius maculatus* (Thunberg, 1792)	Not Evaluated (NE)
Anguilliformes	Muraenosocidae	Daggertooth pike conger	*Muraenesox cinereus* (Forsskål, 1775)	Least Concern (LC)
Carcharhiniformes	Carcharhinidae	Spadenose shark	*Scoliodon laticaudas* Muller & Henle, 1838	Near Threatened (NT)
Decapoda	Hippolytidae	Hunter shrimp	*Exhippolysmata ensisrostris* (Kemp,1914)	Not Evaluated (NE)
	Palaemonidae	Spider prawn	*Nematopaleomon tenuipes* (Henderson,1893)	Not Evaluated (NE)
	Penaeidae	Jinga shrimp	*Metapenaeus affinis* (H. Milne Edwards, 1837)	Not Evaluated (NE)
		Yellow shrimp	*Metapenaeus brevicornis* (H. Milne Edwards, 1837)	Not Evaluated (NE)
		Indian white prawn	*Penaeus indicus* H. Milne Edwards, 1837	Not Evaluated (NE)
		Rainbow shrimp	*Parapenaeopsis sculptilis* (Heller, 1862)	Not Evaluated (NE)
		Kiddi shrimp	*Parapenaeopsis stylifera* (H. Milne Edwards, 1837)	Not Evaluated (NE)
	Sergestidae	Jawla paste shrimp	*Acetes indicus* H. Milne Edwards, 1830	Not Evaluated (NE)
	Solenoceridae	Udang merah	*Solenocera crassicornis* (H. Milne Edwards, 1837)	Not Evaluated (NE)
	Portunidae		*Charybdis callianassa* (Herbst, 1789)	Not Evaluated (NE)
		Crucifix crab	*Charybdis feriatus* (Linnaeus, 1758)	Not Evaluated (NE)
		Yellowish brown crab	*Charybdis lucifera* (Fabricius, 1798)	Not Evaluated (NE)

typically have lower market value, were concentrated in the lower cod-end. These findings align with earlier reports by Kunjipalu and Boopendranath (1993), who observed improved size selectivity and better catch quality in nets with larger mesh sizes (30 mm and 40 mm) compared to traditional 20 mm mesh sizes. This selective fishing approach enhances the economic value of the catch by retaining larger fish and crustaceans, which fetch higher market prices, while reducing bycatch and the capture of juveniles, contributing to more sustainable fishing practices.

Conclusion

This study highlights that modifying traditional dol nets by incorporating a 35 mm square mesh panel significantly improves gear selectivity, fostering more sustainable fishing practices along the Mumbai coast. The modified design effectively reduces bycatch, particularly of juvenile fish, while retaining larger, commercially valuable species in the upper cod-end. Additionally, this modification enhances sorting efficiency, boosting the economic value of the catch and contributing to resource conservation. Compared to earlier studies, the observed reduction in species diversity is likely attributed to the exclusion of more minor, non-target species due to the larger mesh size. These findings emphasize the critical role of gear selectivity in small-scale, artisanal fisheries, showcasing the potential of blending modern gear modifications with traditional fishing methods to enhance sustainability. By minimizing the capture of juvenile fish and bycatch, the modified dol net aligns with global fisheries management goals, such as preserving marine biodiversity and ensuring the long-term sustainability of fishery resources. Future research should focus on assessing the seasonal and spatial variations in catch composition and the broader ecological effects of these gear modifications. Nonetheless, this study establishes a strong foundation for implementing selective fishing gear in artisanal fisheries along India's northwest coast, with implications for global fisheries management strategies.

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