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Optimizing Square Mesh Panel Placement in Dolnets to Reduce Juvenile Bycatch

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ABSTRACT

Field experiments were conducted from April, 2024 to March, 2025 at Karanja in Raigad district using a 55 m dolnet to identify the most effective square mesh panel placement for enhancing juvenile escapement, reducing bycatch, promoting sustainable fisheries management, minimizing economic losses, and ensuring operational feasibility. The dolnets were fitted with 40 mm square mesh panels installed at four positions: (A) upper panel adjacent to the codend, (B) upper panel 5 m ahead of the codend, (C) lower panel 5 m ahead of the codend, and (D) lower panel adjacent to the codend. A total of 60 standardized hauls were carried out, comprising 15 hauls for each configuration, to evaluate the juvenile catch of *Harpadon nehereus*. Statistical analysis revealed significant differences in escapement among the configurations, with F=173.38 and $p<0.001$. The maximum escapement was recorded in the upper panel positioned 5 m ahead of the codend, with a mean value of 7.72±0.49, whereas the lower panel positioned 5 m ahead of the codend showed the lowest escapement, with a mean value of 3.63±0.29. The findings demonstrated that strategic placement of the square mesh panel on the upper panel 5 m ahead of the codend significantly improved juvenile escapement without compromising commercial catch.

KEYWORDS: Dolnet selectivity, juvenile bycatch, square mesh panel

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Data Availability Statement: Legal restrictions are imposed on the public sharing of raw data. However, author have full right to transfer or share the data in raw form upon request subject to either meeting the conditions of the original consents and the original research study. Further, access of data needs to meet whether the user complies with the ethical and legal obligations as data controllers to allow for secondary use of the data outside of the original study.

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1. INTRODUCTION

Dolnets, locally known as bag nets, are major stationary fishing gears along the Maharashtra coast and significantly contribute to marine fish production (Iburahim et al., 2017). Operated year round along the Gujarat and Maharashtra coasts, offshore operations are typically suspended during the monsoon, though creek based fishing continues. Dolnets effectively target commercially important small pelagics such as *Harpadon nehereus*, *Coilia dussumeiri* and *Acetes indicus*, supporting artisanal livelihoods. In 2022 to 2023, Maharashtra recorded 0.446 mt of marine fish catch, accounting for 6 to 8% of India's total production, with dolnets contributing 23.9% of state landings and approximately 0.307 mt as reported earlier (Kumawat et al., 2015). Juvenile bycatch refers to the unintended capture of fish below their length at first maturity or minimum legal size, primarily due to inadequate mesh sizes and ineffective escape mechanisms in fishing gear (Broadhurst, 2000). In passive gears such as dolnets, juveniles are carried by tidal currents and retained in the codend when mesh sizes are smaller than the species specific L_{50}, the length at which 50 percent of individuals attain sexual maturity. Use of undersized mesh leads to removal of immature individuals, affecting stock replenishment and long term sustainability (Pauly et al., 2002; Prajith et al., 2017). Juvenile bycatch contributes to recruitment overfishing by eliminating future spawners, thereby reducing yield per recruit and increasing the risk of stock collapse (Hall et al., 2000; Ghosh et al., 2024). Globally, juvenile bycatch accounts for over 80 percent of marine captures, estimated at approximately 27 mt annually (Kelleher, 2005; Dineshbabu et al., 2022). Several technical measures have been developed to reduce juvenile bycatch in fisheries (Broadhurst, 2000; Hall et al., 2000; Steele et al., 2002; Boopendranath, 2012; Chaves, 2022). Among them, square mesh codends are widely adopted due to their operational simplicity and ease of installation (Ragonese and Bianchini, 2006; Sala et al., 2008; Brcic et al., 2016). Unlike diamond mesh, which collapses under tension, square mesh maintains an open configuration during towing or water flow, particularly in the codend region (Robertson and Stewart, 1988; He, 2007). This structural stability enhances escapement of undersized individuals, improving selectivity and reducing juvenile bycatch. Most of the studies in India and other countries have demonstrated that modifications in trawl design particularly the integration of square mesh codend or panels significantly improve gear selectivity and facilitate the escapement of juvenile fishes (Kunjipalu and Varghese, 1994; Broadhurst, 2000; Madhu et al., 2016; Prajith et al., 2017). In India, Dora and Mukherjee (2002) demonstrated that 40 mm square mesh panel (SMP) reduced juvenile prawn and finfish catch in the Hooghly estuary. Similarly, Kunjipalu et al. (2001) conducted detailed studies on the selectivity parameters of square mesh codend, proposing optimal mesh sizes for sustainable exploitation. Their findings have contributed to the development of science based guidelines for responsible fishing practices in India. Previous studies have not addressed the incorporation of square mesh in dolnets or identified suitable positions for its installation to mitigate juvenile bycatch. Preliminary investigations conducted by ICAR-CIFT in Maharashtra have indicated that SMPs can effectively reduce juvenile retention in dolnet operations. However, for effective implementation, it is essential that fishermen are adequately informed about the appropriate placement of these panels. Therefore, before widespread implementation, it is important to scientifically evaluate and validate the optimal location of SMPs under practical fishing conditions. The present study aimed to determine the ideal position for SMPs installation to maximize juvenile escapement, reduce bycatch and support sustainable fisheries management while minimizing economic losses to fishers and ensuring practical adaptability of the modified gear.

2. MATERIALS AND METHODS

2.1. Study area

The experimental trials were conducted from April, 2024 to March, 2025 at the Karanja fishing grounds in Raigad district, Maharashtra, located in the estuarine region adjacent to Mumbai. The trials were carried out onboard local dolnet fishing vessels that operated at depths ranging from 10 to 20 m, as shown in Figure 1.

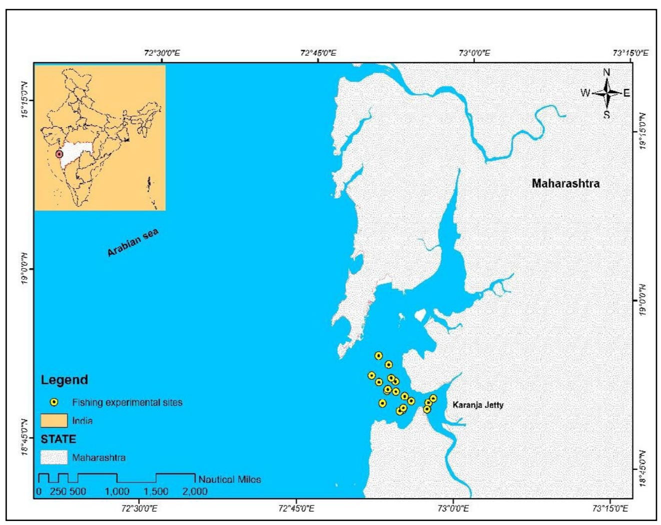

Figure 1: Map showing sampling sites for the catch composition study

2.2. Experimental design

A standard 55 m dolnet fabricated from high-density polyethylene (HDPE) was used for the experimental trials. The gear had a mouth circumference of approximately 15 m and a mesh depth of 2 m, with the hanging ratio maintained at 0.48 to ensure optimal mesh opening and stability during operation. The codend was constructed using 40 mm diamond mesh and was modified by incorporating 40 mm square mesh panels (SMPs) at four distinct positions: (A) the upper last corner near the codend, (B) the upper side 5 m ahead of the codend, (C) the lower side 5 m ahead of the codend, and (D) the lower side near the codend, as shown in Figure 2. The 40 mm mesh size was selected because it was very close to the minimum legal size (MLS) of the most common species, which ensured that juvenile fish could escape while marketable fish were retained (Kunjipalu et al., 2001; Prakash et al., 2008). Each experimental haul was carried out according to the conventional dolnet fishing methods practiced in the Karanja region, using 6 m LOA vessels equipped with 20 Hp diesel engines to maintain operational consistency. The duration of each set was maintained at 120±20 min. A total of 60 standardized hauls, comprising 15 hauls per configuration, were conducted to evaluate the juvenile catch of *Harpadon nehereus*. In this study, the term "configuration" referred to each distinct dolnet gear setup, representing the different design modifications tested during the experiment, including variations in codend structure or mesh arrangement.

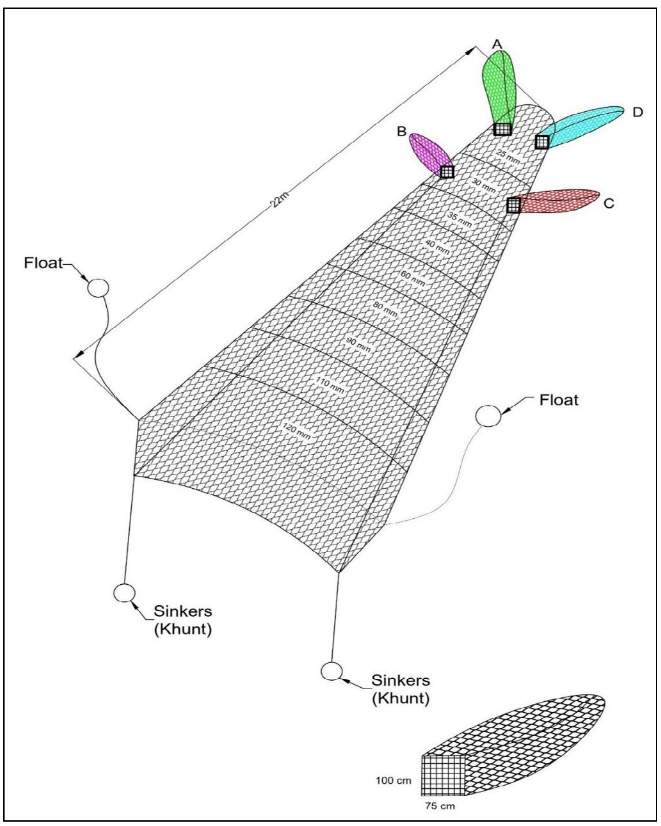

Figure 2: Design modifications in dolnet codend showing multiple square mesh panel

2.3. Data collection

For each haul, the total catch was segregated by species, with particular attention given to the number and biomass of juvenile individuals of *Harpadon nehereus*, which constituted the highest proportion of juvenile bycatch in this study. Length-frequency data were recorded for the dominant species using digital calipers with an accuracy of ±1 mm. Subsamples were cross-checked for consistency. Taxonomic identification was performed using standard taxonomic references (Talwar and Kacker, 1984; Subba Rao, 1989; Munro, 2000; Van Der Laan et al., 2014; Froese and Pauly, 2025) after preservation in 10% formalin at the Fishing Technology Laboratory of Mumbai Research Centre of ICAR-CIFT (Chakraborty et al., 2006). At the end of each haul, the catch was sorted onboard, and the retained juveniles were separated by species. Standard length (SL) and total weight were recorded using digital calipers with an accuracy of ±1 mm and weighing balances with an accuracy of ±0.01 g.

2.4. Statistical analysis

Descriptive statistics were calculated for the proportion and weight of juveniles in the catch for each panel location. One-way ANOVA was performed to test for significant differences in juvenile bycatch across panel locations (Kim, 2017). Tukey's HSD post hoc test was applied to identify the specific panel locations that differed significantly (Nanda et al., 2021). Box plots were generated for visual representation of the results. All analyses were performed using R version 4.5.0, and the level of significance was set at $p<0.05$ (Peng, 2016).

3. RESULTS AND DISCUSSION

A comparative evaluation of four SMP positions, namely Panels A, B, C, and D, was conducted using standardized experimental hauls at Karanja, Raigad, to identify the most effective SMP location for maximizing juvenile escapement and reducing bycatch in dolnets. Descriptive analysis revealed that Panel B, located on the upper side 5 m ahead of the codend, exhibited the highest mean escapement efficiency of 7.72±0.49, followed by Panel A with 6.55±0.32, Panel D with 5.78±0.73, and Panel C with 3.63±0.29, as shown in Table 1. Before conducting the one-way ANOVA, the dataset was tested and was found to meet the underlying statistical assumptions of normality using the Shapiro-Wilk test and homogeneity of variances using Levene's test. The ANOVA results revealed statistically significant differences among the SMP positions, with $F=173.38$ and $p<0.001$, as shown in Table 2. Post-hoc comparisons further showed that Panel B was statistically superior to all other positions at $p<0.001$. These results were aligned with the findings of Bullough et al. (2007), who reported a 34% reduction in undersized

Table 1: Descriptive statistics of juvenile retention across SMPs position

Panel	Mean retention	Standard deviation	Minimum	Maximum
A	6.55	0.32	6.0	7.1
B	7.72	0.49	7.0	8.6
C	3.63	0.29	3.2	4.1
D	5.78	0.73	4.7	7.2

Table 2: Statistical comparison of juvenile retention by SMPs position using ANOVA

Source	Sum of squares	df	Mean square	F value	*p* value
Between groups	157.225	3	52.408	173.38	<0.001
Within groups	16.173	56	0.289		
Total	173.398	59			

whiting when SMPs were placed 6 to 9 m ahead of the codend. Similar conclusions were drawn in earlier studies, which emphasized that SMPs installed in hydrodynamically active zones, particularly in the upper sections of trawls or extensions, substantially enhanced juvenile escapement (Graham and Kynoch, 2001; Suuronen, 2005; Madhu et al., 2016).

The poor escapement efficiency observed in Panel C, located near the lower codend, aligned with the findings of Cuende et al. (2020), who reported limited release efficiency in lower-placed panels due to reduced fish-panel contact and weaker hydrodynamic flow. Juvenile fish often exhibited a natural tendency to settle in lower regions, which further reduced their interaction with escape panels. Graham and Kynoch (2001) similarly observed that escape panels placed higher in the codend improved fish release, as fish remained more active in the upper water column.

The intermediate effectiveness observed in Panels A and D in this study further reaffirmed the aforementioned vertical effect. Specifically, Panel A, which was situated on the upper codend, exhibited a better escapement rate compared to Panels C and D but did not attain the performance observed in Panel B. This result could be attributed to its close proximity to the terminal codend, where fish exhibited reduced swimming ability and reactivity. Consequently, their chances of escape were reduced despite the panel being positioned within an effective hydrodynamic area. Conversely, Panel D, which was located on the lower extension area, exhibited moderate improvement over Panel C but was less effective than both Panels A and B, as shown in Figure 3.

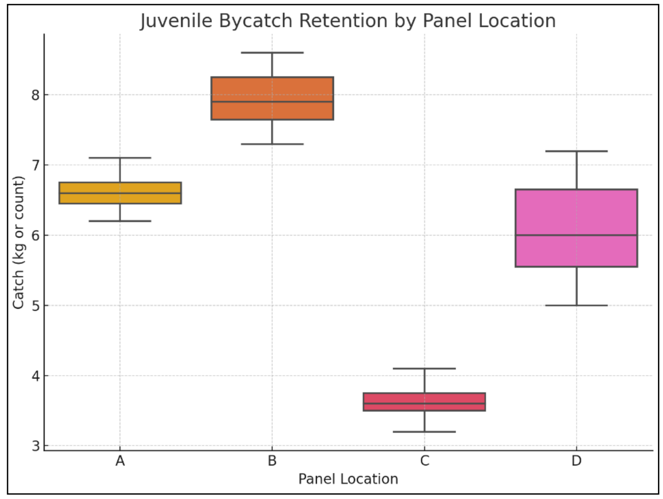

Figure 3: Comparative analysis of juvenile fish retention across four SMPs positions in dolnet

The results of the study indicated that escapement effectiveness was primarily driven by the interaction between species-specific behavioural characteristics, including vertical disposition and swimming stamina, and the hydrodynamic conditions within each panel area. The superior effectiveness of Panel B indicated that deployment of SMPs within an actively operating area, positioned appropriately anterior to the codend and above the midplane, maximized codend escapement (Cuende et al., 2020). The relative effectiveness of Panels A and D emphasized that both vertical placement and distance from the codend played significant roles, but the optimal balance was achieved when panels were positioned within regions of substantial flow and high activity of the target fish, as revealed by Panel B (Bullough et al., 2007; Suuronen, 2005; Prajith et al., 2017).

The ecological and economic benefits of SMP adoption extended beyond bycatch reduction. Increased escapement rates enhanced juvenile conservation and mitigated growth overfishing, whereas improved selectivity reduced discard mortality and sustained ecosystem equilibrium (Broadhurst, 2000; Madhu et al., 2016). SMP utilization corresponded with international sustainability frameworks, including the FAO Code of Conduct for Responsible Fisheries, thereby increasing opportunities for eco-certification and market access. Long-term stock stability enhanced consistent catch and income for fishers, thereby reinforcing livelihood security (Moussa et al., 2025). The effectiveness of Panel B served as a replicable model for passive gears in analogous ecosystems, supporting its integration into regional fisheries management regulations.

Tukey's HSD post hoc comparisons further confirmed the importance of panel positioning and showed that Panel B had significantly lower juvenile bycatch than Panels A, D, and C, with $p<0.05$ for all pairwise comparisons. Based on the mean values, the overall ranking of SMP effectiveness in reducing juvenile bycatch was Panel B followed by Panel A, Panel D, and Panel C, as shown in Table 3 and Figure 4.

The superior performance of Panel B was likely due to stronger water currents and increased fish activity in the upper water column, which enhanced the chances of juvenile fish encountering and escaping through the SMP, particularly under the passive gear dynamics typical of dolnets (Prajith et al., 2017). The effectiveness of bycatch reduction devices depended not only on mesh size but also on their precise positioning within the fishing gear (Eryasar, 2018). The present study provided further evidence in relation to dolnets, indicating that the vertical positioning of SMPs, particularly 5 m ahead of the codend on the upper face, optimized juvenile fish escapement and reduced bycatch. This supported a species behaviour-based approach to future gear modification in dolnet fisheries and demonstrated the ecological and regulatory benefits of placing SMPs in hydrodynamically active locations.

Table 3: Pairwise comparison of juvenile retention across SMPs positions

Comparison	Mean difference	95% CI lower	95% CI upper	*p* value
B vs A	1.17	0.98	1.36	<0.001
B vs C	4.09	3.89	4.30	<0.001
B vs D	1.94	1.74	2.13	<0.001
A vs C	2.92	2.72	3.12	<0.001
A vs D	0.77	0.57	0.97	<0.001
D vs C	2.15	1.95	2.35	<0.001

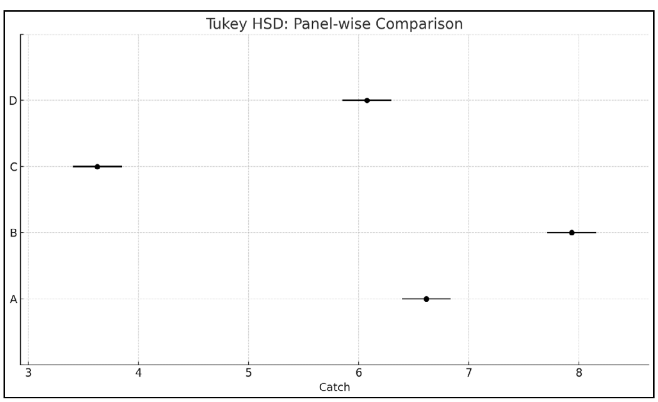

Figure 4: Panel wise juvenile catch retention using Tukey's HSD comparison

4. CONCLUSION

Vertically aligned square mesh escape panels in dolnets significantly enhanced gear selectivity and reduced juvenile bycatch. Panel B, positioned 5 m above the upper codend, was the most effective in minimizing juvenile Harpadon nehereus capture, highlighting species-specific vertical distribution patterns. This low-cost, behaviour-based modification supported sustainable fisheries management and minimum legal size compliance in data-limited tropical fisheries. Promotion of this new gear among small-scale fishermen and other relevant stakeholders could have helped reduce ecological impacts while maintaining the economic viability of small-scale fisheries.

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