Available online at www.ijpab.com

DOI: http://dx.doi.org/10.18782/2582-2845.9072

ISSN: 2582 – 2845

Ind. J. Pure App. Biosci. (2024) *12*(2), 8-19

Indian Journal of Pure & Applied Biosciences

Peer-Reviewed, Refereed, Open Access Journal

Review Article

A Study on the Selectivity of Different Fishing Gear

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Received: 18.01.2024 | Revised: 27.03.2024 | Accepted: 6.04.2024

ABSTRACT

The selectivity of fishing gears plays a pivotal role in shaping the dynamics of aquatic ecosystems and fisheries sustainability. Through a comprehensive examination of trawl nets, gill nets, and longlines, this paper delves into the factors influencing selectivity, including gear design, selectivity criteria, selectivity terminologies, selection curves, and impacts. Drawing upon scientific research, empirical evidence, and case studies from around the world, this paper highlights the effectiveness of different selectivity measures in balancing the extraction of target species with the conservation of non-target species and habitat integrity. By synthesizing current knowledge and emerging trends in fishing gear selectivity, this review paper offers valuable insights for policymakers, fishers, scientists, and conservationists striving to navigate the complex interplay between human exploitation and ecological resilience in aquatic environments.

Keywords: *Selectivity, fishing gear, gill net, trawl net, longline, selection curve.*

INTRODUCTION

The vast expanse of Earth's aquatic realms harbors a rich tapestry of aquatic life and a delicate equilibrium that human activities continually influence (Imran & Irfan, 2023). At the heart of this intricate dance lies the selectivity of fishing gear- a fundamental determinant in shaping the dynamics of fisheries and their ecological impacts (Meenakumari et al., 2009). As humanity grapples with the pressing need for sustainable resource utilization, understanding the selectivity of fishing gear assumes heightened significance. The nuanced mechanisms by which different gears discriminate among fish, both in terms of size classes and species, have profound implications for fisheries management and conservation (Marlen, 1991). Selectivity depends on the guiding principles of fishing techniques and the equipment's design elements (Madhu, 2018).

Cite this article: Bhanja, A., Payra, P., & Mandal, B. (2024). A Study on the Selectivity of Different Fishing Gear, *Ind. J. Pure App. Biosci. 12*(2), 8-19. doi: http://dx.doi.org/10.18782/2582-2845.9072

Fishing gear plays a pivotal role in the extraction of aquatic resources, influencing not only the quantity of the catch but also its composition. Fishing gear's selectivity refers to its ability to target specific species, sizes, or life stages while minimizing the capture of non-target organisms (Pope, 1966). This paper explores the diverse range of fishing gear and their varying degrees of selectivity, shedding light on these tools' ecological and economic implications.

Defining selectivity in fishing gear

Selectivity in fishing gear encompasses intentionally targeting specific species, sizes, or life stages and reducing bycatch or capturing non-target organisms. It is a delicate dance that seeks to optimize harvest efficiency while minimizing the ecological footprint (FAO, 1978).

The selectivity coefficient in fisheries refers to a numerical ratio that quantifies the efficiency of fishing gear in capturing or retaining fish of a particular size range. It is a crucial parameter used in selectivity curves to describe how the gear discriminates among different fish sizes.

The selectivity coefficient (S) is often represented as the probability of capture or retention for a fish at a specific size relative to the maximum probability of capture for that gear. It can be expressed as a function of fish length (L)

$S (L)= P (L)/ (P_{max})$

Where,

S(L) is the selectivity coefficient for fish of length L,

P(L) is the probability of capture or retention for fish of length L,

P_{max} is the maximum probability of capture for the gear.

Significance of gear selectivity (MacLennan, 1992; Aquaprojects Inc., 1995; Liang et al., 2014) (Figure 1.)

Traditional methods and their challenges

Traditional fishing methods, such as simple handlines, gillnets, and traps, have been employed for centuries. While these methods are often effective, they lack precision in species targeting. Gillnets, for example, can capture a wide range of species, including non-target and juvenile individuals, leading to overfishing and ecosystem disruption (National Geographic, 2024; & MPEDA, 2024).

Different gear selection curve

Bell-shaped selection curve

The concept of a bell-shaped gear selection curve refers to a graphical representation that illustrates the relationship between the size or age of captured individuals and the selectivity of a particular fishing gear (Aquaprojects Inc., 1995). The curve is shaped like a bell, indicating that the gear is most effective at capturing individuals of a certain size range, with decreasing efficiency for smaller and larger individuals. This curve is useful for determining selectivity for the majority of fixed fishing gear (Ecourse Online, 2012). Passive gear like gill net selectivity is represented by a bell-shaped selection curve. (Figure 2.)

Sigmoid-shaped selection curve

A sigmoid-shaped selection curve, often observed in fixed and mobile fishing gears, reflects the relationship between fish size and the efficiency of gear selection. In fixed gears, larger fish are prevented from entering, but smaller fish can escape in proportion to their size (Hussain, 2018). On the other hand, mobile gears allow smaller fish to pass through their meshes, making larger fish more susceptible to selection. As fish size increases, the percentage of retained fish also increases, resulting in an 'S' shaped selectivity curve (Sathianandan, 2017). A Sigmoid-shaped selection curve represents the trawl net selectivity. (Figure 3.)

Selectivity of different fishing gear

Gill net selectivity

About gill net

A gill net is a type of fishing gear that consists of a vertical panel of mesh fabric suspended in the water to capture fish (Hamely, 1975). It is one of the oldest and most widely used types of fishing gear globally. Gill nets operate by entangling fish in the mesh as they attempt to swim through it, using their gills to extract oxygen from the water.

Targeted species

Salmon, barracuda, mullet, cod, seabass, shad, sharks, tuna, swordfish, sturgeon, rockfish, etc. are some popular targeted species of gill net (NOAA, 2021).

Selection of gill net

Gill net selectivity refers to the ability of a gill net to capture or retain fish of different sizes. The selectivity of a gill net is crucial in fisheries management because it determines the range of fish sizes that are effectively caught by the gear. Understanding gill net selectivity helps in achieving sustainable fishing practices by allowing for the selective harvest of target species and reducing the capture of undersized or non-target species (Boopendranath, 2009).

Mesh Size: Mesh size is a critical factor in gill net selectivity. Larger mesh sizes tend to capture larger fish while allowing smaller ones to escape. Selecting an appropriate mesh size based on the size of the target species helps improve selectivity and minimize bycatch (Bhanja et al., 2022).

Mesh Material and Configuration: The material and configuration of the mesh used in the gill net can affect selectivity (MacLennan, 1992). Different materials may have varying degrees of flexibility and visibility, influencing fish behaviour and escape rates. Mesh configuration, such as diamond or square mesh, can also impact selectivity (Hamley, 1975).

Mesh Orientation and Hanging Ratio: The orientation of the mesh in the water column and the hanging ratio (the ratio of net length to net height) influence the effectiveness of the gill net (Kumova et al., 2015). Properly positioning the gill net and optimizing the hanging ratio can enhance selectivity by targeting specific depths and fish sizes (Holst et al., 1998). (Figure 4.)

Float and Lead Line Diameter: The diameter of the gill net's float line (top line) and lead line (bottom line) can affect its performance and selectivity. Thicker lines may discourage fish from crossing the net, while thinner lines may be less visible and allow for easier escape (Hanumanthappa & Neethiselvan, 2024).

Mesh Stretch and Tension: The mesh material's stretchiness and tension impact the gill net's performance. Properly tensioned nets maintain their shape and position in the water, improving selectivity by reducing the likelihood of entanglement and facilitating fish escape (Meenakumari et al., 2009).

Environmental Factors: Environmental conditions such as water temperature, current speed, depth, and seabed characteristics influence gill net selectivity. Understanding how these factors affect fish behaviour and movement helps optimize gill net deployment and selectivity (Boopendranath, 2019).

Regulatory Compliance: Compliance with regulations and management measures, including mesh size regulations, gear restrictions, and bycatch reduction requirements, is essential for ensuring the selectivity of gill nets and promoting sustainable fisheries management practices (FAO, 1978).

Interaction between fish and gill net:

Karlsen and Bjarnason (1986) described four ways in which fish can interact with the gill net or get caught.

Snagged: It refers to a fish getting caught after being stuck in post-orbital section in the mesh.

Gilled: It typically refers to the action of a fish becoming entangled or caught in the mesh of a gill net by its gills. Gill nets are designed to capture fish by allowing their heads to pass through the mesh while ensnaring them as they attempt to swim backwards.

Wedged: Refers to a situation where a fish is stuck or firmly lodged in concerning the dorsal fin within the structure of the gill net. It implies that the fish has become tightly secured or immobilized in the netting.

Entangled: Broadly describes a situation where a fish becomes caught or trapped in a gill net by different projections like teeth, maxillaries, fins, etc., without necessarily passing through the mesh. (Figure 5.)

Trawl net selectivity

About trawl net

A trawl net is a type of fishing net widely used in commercial fishing operations to catch fish and other species. It consists of a large, coneshaped net with a wide opening at the mouth and narrowing towards the cod end, where the catch is collected. Trawl nets are typically towed behind fishing vessels either along the seabed (bottom trawling) or through the water column (midwater trawling) (Main & Robertson, 1988).

Targeted species

The targeted species are the pelagic, demersal, and bottom (FAO, 2024). Shrimp, cuttlefish, crabs, flatfish, carangids, cod, snapper, grouper, sciaenids, perches, sardine, tuna, ribbonfish, mackerel, etc. are the targeted fishes of trawl net (Verghese, 1998; Mehanna, 2021; & Wikipedia, 2024).

Selection of trawl net

Trawl net selectivity refers to the ability of a trawl net to capture certain species or sizes of fish while allowing others to escape. Trawling is a highly efficient but controversial method. It involves dragging a net through the water, collecting everything in its path. Bottom trawling, in particular, can have severe ecological consequences by damaging seafloor habitats and capturing non-target species. Selectivity improvements, such as using Turtle Excluder Devices (TEDs) and Bycatch Reduction Devices (BRDs), have been introduced to mitigate these issues (Bhanja et al., 2022). (Figure 6.)

Mesh Size: The size of the mesh openings in the trawl net is one of the most important factors affecting selectivity. It seems that the selectivity of a trawl net is mostly determined by its mesh size. Typically, the length of the stretched entire mesh is used to describe the mesh size (FAO, 1978; & Chaurasia, 2021). Larger mesh sizes tend to allow smaller fish to escape, promoting size selectivity and reducing bycatch of undersized individuals (Bhanja et al., 2022).

Mesh Size = 2*d (Where, d is the length between two knots)

Mesh Shape and Configuration: The shape and configuration of the mesh panels in the trawl net can affect selectivity. The construction of fishing gear assemblies involves utilizing netting panels, with each panel composed of one or more precisely shaped geometric pieces. These shapes may include rectangles, trapezoids, or triangles, each featuring consistent mesh sizes and twine specifications (Boopendranath, 2019). The configuration of these individual components within the netting panels is achieved through adjustments in the number of meshes along the N-direction or T-direction, involving processes such as augmentation, reduction, or preservation (Boopendranath & Pravin, 2005). (Figure 7.)

Twine Thickness and Material: The thickness and material composition of the twine used in the trawl net can influence selectivity. Thinner twine may be more flexible and less likely to retain small fish, while certain materials may have different properties affecting the behaviour of fish and their ability to escape.

Escape Mechanisms: Some trawl nets are equipped with escape mechanisms such as sorting grids, escape windows, or bycatch reduction devices (BRDs) designed to allow non-target species to exit the net while retaining the target catch. These mechanisms can enhance selectivity and reduce bycatch (Edwin, 2021).

Hanging Ratio: The hanging ratio, which refers to the ratio of net length to net height, can affect the shape and performance of the trawl net. Optimal hanging ratios can promote better fish retention while minimizing bycatch (Madhu, 2018).

It is also called as hanging coefficient. It is a measure of how much of the netting material is submerged below the water surface when the gear is deployed (Boopendranath, 2019). (Figure 8.)

$$\text{Hanging coefficient } (E_h) = \frac{\textit{Hung length of the netting}}{\textit{Fully stretched length of the netting}}$$

Thus, Vertical hanging coefficient (E_v) = $\sqrt{1-E_h^2}$

Covered codend: Codend cover is a small mesh cover (usually 15-20 mm stretched mesh) over the cod end of the experimental net to measure the overall fish population that comes into contact with the gear in a given fishing region (Madhu, 2018). The small mesh cover retains the little fish that escape from the cod-end, and the total population encountered can be determined by adding the fish that are caught in both the gear and the cod-end cover (Pope et al., 1975). (Figure 9.)

Trouser trawl technique: In the trouser trawl technique, a single trawl is equipped with two cod-ends: one featuring the mesh size under investigation for selective properties, while the other boasts a significantly smaller mesh size (Boopendranath & Pravin, 2005).

Twine trawl technique: In the twine trawl technique, a single trawler drags two trawl nets at the same time. One trawl contains a tiny mesh cod-end, used to measure the overall population. The other trawl serves as an apparatus for experimenting with size composition (Madhu, 2018).

Alternate haul and parallel haul: In the alternate haul method, similar hauls must be made using an experimental trawl and a control trawl. On the other hand, fishing on the same ground at the same time by two vessels is necessary for the parallel haul method. One vessel tows the experimental gear, while the other tows the control gear (Pope et al., 1975).

Longlining selectivity

About longlining

Longlining is a commercial fishing technique that involves using a long mainline, or fishing line, with numerous baited hooks attached at intervals. This method is widely used for catching various fish species, including deep-sea and pelagic species. It is practiced in both coastal and offshore waters and is commonly employed by commercial fishermen around the world (Hamley & Skud, 1978).

Targeted species

The main targeted fishes for marine longline are billfish and tunas. yellowfin, bigeye, albacore, striped marlin, and broadbill swordfish are the most important (Sreedhar, 2019).

Selection of Longline

Longlining and hook-and-line methods are known for their species-specific targeting. By using various hook sizes, bait types, and depths, fishermen can tailor their gear to specific target species. However, challenges persist, as some species are more susceptible to capture than others, and unintended bycatch remains a concern (Hamley & Skud, 1978).

Hook Size and Type: A vast array of hook models and sizes are produced within the fishing industry. As highlighted by Quinn et al. (1985), the diversity in hook models surpasses the multitude of fish species themselves. Broadly categorized, hooks can be distinguished into the conventional J-shaped designs and the contemporary circle-shaped alternatives, which gained prominence in the late 1970s (Hovgård & Lassen, 2000). Within commercial fishing practices, hooks exhibit significant variability in size, with gape widths spanning the spectrum from under 0.5 cm (such as freshwater eel capture) to exceeding 10 cm in certain shark fisheries (Hovgård & Lassen, 2000). Bait size selection is likely influenced by its visual appearance (Løkkeborg & Bjordal, 1992). (Figure 10.) (Figure 11.)

Bait Type and Placement: The type of bait used on longline hooks can affect selectivity. Certain baits may attract specific species, while others may attract a wider range of species. The likelihood of a heightened release rate of attractants and an expanded field of smell distribution is anticipated with larger baits (Løkkeborg & Bjordal, 1992). Considering the broader feeding ranges associated with larger fish (Hart, 1986), there is a potential for an increased attraction of sizable individuals towards baited hooks with the extension of the attractant plume (Bjordal et al., 1983). Løkkeborg (1990) noted a discrepancy in catch rates in comparative analysis between artificial shrimp-flavoured bait and its natural shrimp counterpart. The average bait weighs 80 to 100 grams. If the bait is substantially larger than 120g, several target fish are likely to be missed (Sreedhar, 2019). Placing the bait strategically can help target desired species while minimizing bycatch.

Line setup: The mainline's length varies according to the fishing area, size of operation, and other factors. In large-scale longline fishing, the mainline can be up to 180 kilometres long. The diameter of the multifilament mainline varies from 4 to 11 mm according on the type of longline fishing. The mainline is composed of high-specific gravity polymers including hard twisted polyamide, polyvinyl chloride, and polyvinyl alcohol (Sreedhar, 2019). Branch lines can influence fish catch rate based on their material, length, thickness, and connection. Monofilament branch lines, had 10-29% higher catch rates for cod and haddock than multifilament branch lines. Thinner branch lines result in higher catch rates than thicker ones (Bjordal & Løkkeborg 1996). The length of the branch line changes with the fishing operation. Multifilament branch lines can be between 0.3 m to several meters long (Sreedhar, 2019). (Figure 12.) (Figure 13.)

Use of accessories: Several types of accessories are used in the construction of longlines. These accessories play a vital role in longline selectivity. Snapes, swivels, Floats, are important accessories used in longlines. A proper monofilament snap has a tight jaw that grabs the monofilament mainline, but a swivel snap or clip designed for rope gear has a jaw too large to grip the mainline (Sreedhar, 2019). The leaded swivels, available in diameters 38, 45, 60, and 75g, are the most often utilised in branch line construction (Sreedhar, 2019). The leaded swivels aim to either accelerate the rate at which the baited hook and gear sink, add weight to maintain the branch line deeper in the water or serve as a point of connection between the leader and the main body of the branch line. 165 to 360 mm hard plastic floats mainly used in monofilament longline. For tuna longlines, plastic floats must to have a pressure rating of no more than 200 to 300 metres.

Use of bycatch reduction devices: Incorporating BRDs, such as circle hooks, bird-scaring lines, or bait shields, can help reduce bycatch and increase selectivity in longline fishing (Avery et al., 2017; The Guardian, 2022; & Doherty et al., 2022). BRDs are designed to deter non-target species from taking the bait or to allow them to escape once hooked.

Terminologies used to characterize gear selectivity

Selection Length

In fishing gear selectivity, the selection length, or L_{50}, refers to the length of fish that allows a particular gear to let 50% of fish escape and 50% remain (Aquaprojects Inc., 1995).

Selection Range

It indicates the difference in fish sizes that the gear has effective fish retention probability of 25% and 75%. It provides information on the diversity of fish sizes that the gear can catch. If the range decreased then the selection curve became steeper (Aquaprojects Inc., 1995).

Selectivity Factor

It is a numerical value representing the degree of selectivity of a particular gear for a specific size range of fish at which 50% of fish can be retained. On other words selectivity factor is defined as the proportion between 50% retain length of fish and mesh size (Aquaprojects Inc., 1995; & Madhu, 2018).

Selectivity Factor

$$(SF)= \frac{50\%\, retain\ length\ of\ fish}{Mesh\ size}$$

Regulatory measures and certification programs

Governments and international organizations are implementing regulations to promote selective fishing practices. For example, the Indian Fisheries Act Indian Marine Fisheries Code (IMFC) was implemented to regulate marine fisheries activities (Mohamed et al., 2017). Certification programs like the Marine Stewardship Council (MSC) highlight sustainable fisheries that employ gear with minimal ecological impact. The Code of Conduct for Responsible Fisheries (the Code) was adopted in 1995 by FAO to elaborate technical guidelines for reducing bycatch and exploitation of nontargeting species (FAO, 2021). Compliance with these standards is becoming a priority for the fishing industry.

The Socio-Economic Impact of Selectivity

The shift towards more selective fishing methods benefits the environment and contributes to the long-term sustainability of fisheries (Marlen, 1991). By avoiding overexploitation of non-target species and minimizing habitat damage, selective fishing practices support the livelihoods of fishing communities (Aquaprojects Inc., 1995; Liang et al., 2014).

Table1. Size selectivity characteristics of some important fishing gears (Madhu, 2018)

Fishing Gear System	**Size Selectivity**
Gill nets	High
Hook and lines	High
Purse seine	Low
Trawl nets	Average to low
Entangling nets	Average to low
Traps	High
Trolling lines	High

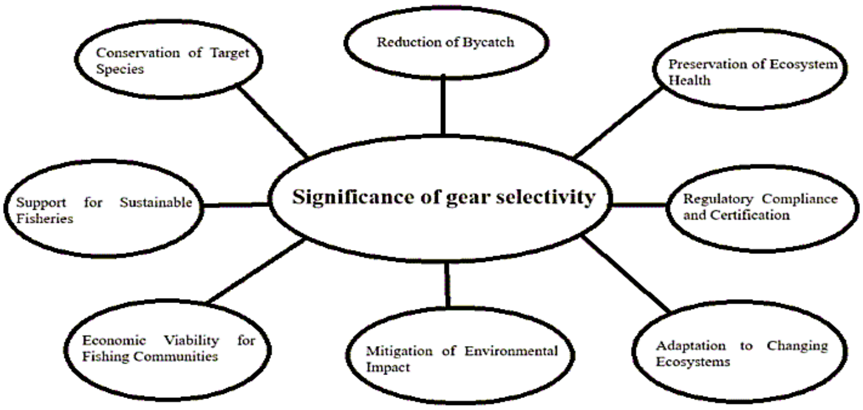

Figure 1. Significance of gear selectivity

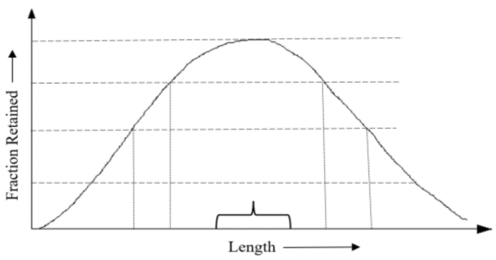

Figure 2. Bell-shaped selection curve

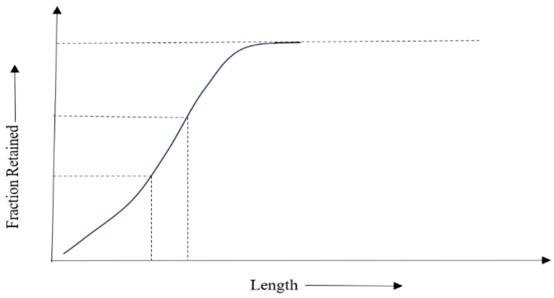

Figure 3. Sigmoid-shaped selection curve

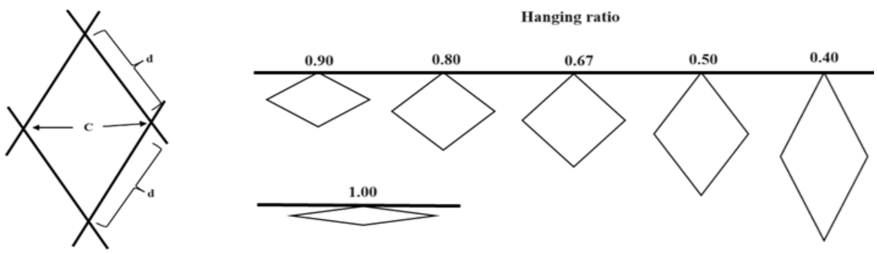

Figure 4. Mesh shapes and various hanging ratios of gill net (FAO, 1978)

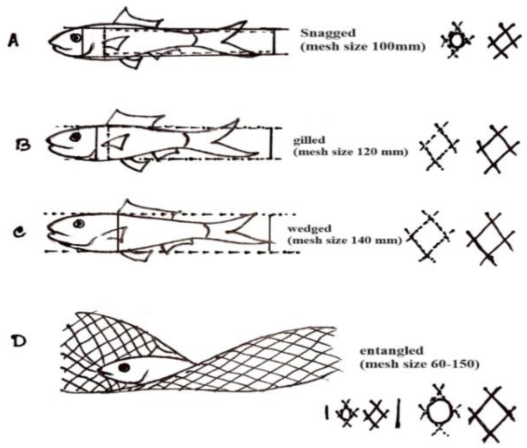

Figure 5. Interaction between fish and gill net (Karlsen and Bjarnason, 1986)

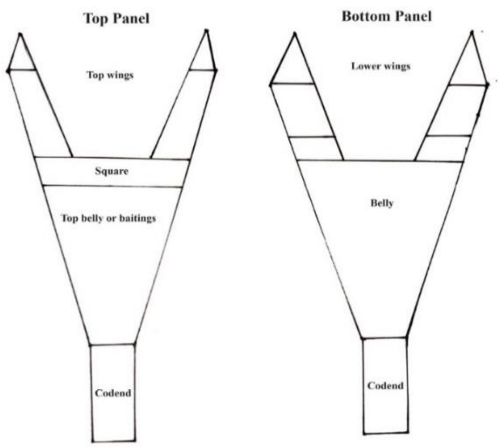

Figure 6. Basic trawl net design illustrating netting panels (Boopendranath, 2019)

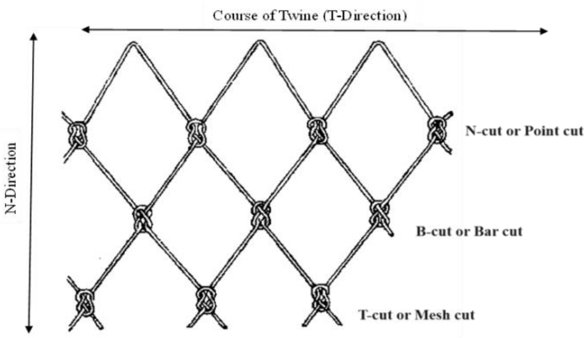

Figure 7. Types of cuts for shape the netting of gear (Boopendranath, 2019)

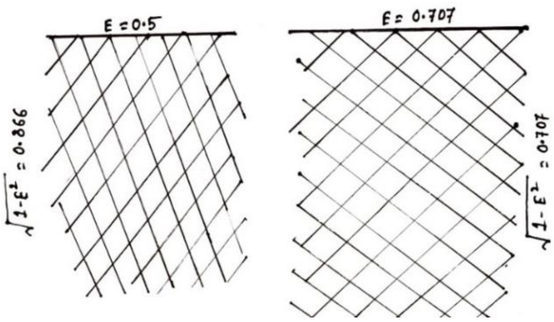

Figure 8. Hanging coefficient and net shaping (Boopendranath, 2019)

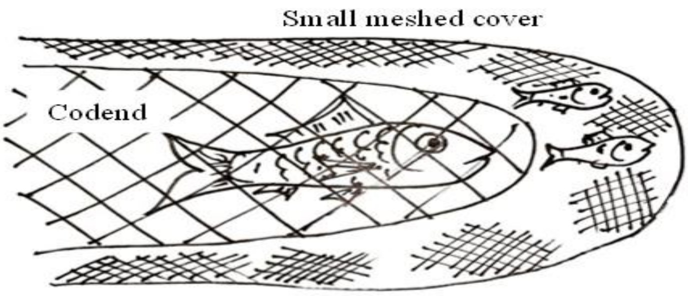

Figure 9. Cover codend technique (Boopendranath and Pravin, 2005)

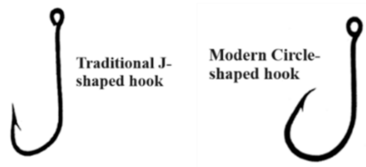

Figure 10. J-shaped hook and modern circle-shaped hook (Hovgård and Lassen, 2000)

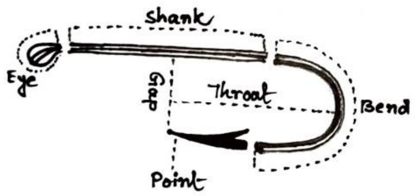

Figure 11. Basic parts of J-shaped hook (Bjordal and Løkkeborg 1996)

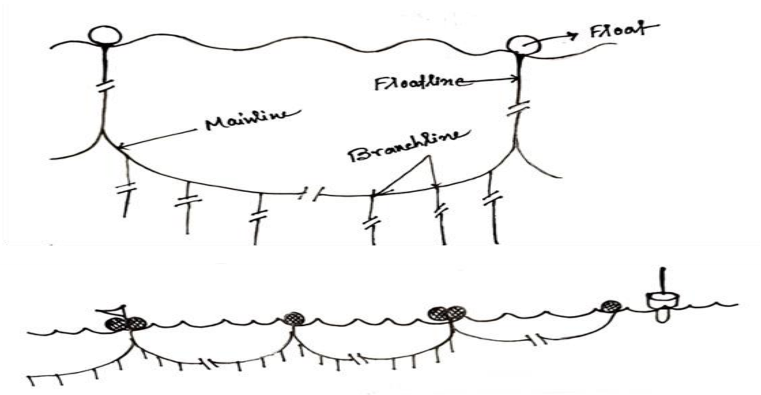

Figure 12. A typical longline set (Sreedhar, 2019)

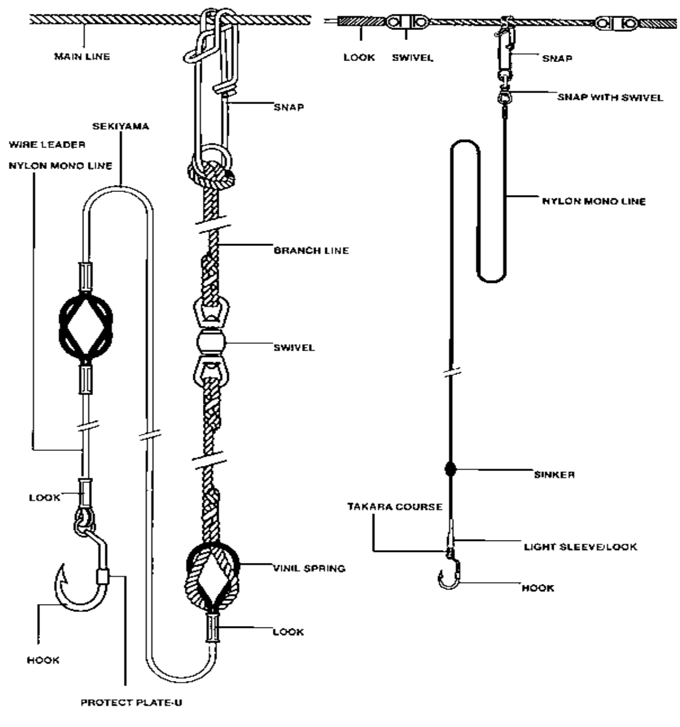

Figure 13. Branch line details of a longline gear (Bolaky, 2006)

CONCLUSION

The selectivity of fishing gear is a dynamic and evolving aspect of fisheries management. Balancing the need for efficient resource extraction with the preservation of ecosystems requires ongoing innovation, collaboration, and adherence to sustainable practices. As technology continues to advance and awareness of environmental impacts grows, the fishing industry is poised to adopt increasingly selective and eco-friendly approaches to ensure the longevity of our aquatic resources.

Acknowledgement:
I would like to sincerely thank my co-authors for their support and kind gesture to complete this manuscript in time.

Funding: NIL.

Conflict of Interest:
There is no such evidence of conflict of interest.

Author Contribution
All authors have participated in critically revising the entire manuscript and approving the final manuscript.

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