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Composition and Percentage Comparison of Bycatch between Conventional Gillnets and Modified Gillnets

Komposisi dan Perbandingan Persentase Bycatch antara Gillnet Konvensional dengan Gillnet Modifikasi

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Abstract

Sibolga, as one of the major fishing port cities in North Sumatra, is an area where surface gillnets are commonly used in pelagic fishing operations. However, the use of gillnets currently faces significant challenges, including high bycatch levels and threats to the sustainability of pelagic fish ecosystems. This study employed an experimental fishing method, specifically surface gillnet trials. The trials were conducted using gillnets with mesh sizes of 2" and 2.5". The results show that the modified gillnet with a 2.5-inch mesh size yields a significantly higher target catch percentage (HTU) of 73% compared to the conventional gillnet with a 2-inch mesh size, which yields only 27%. This significant difference highlights the importance of selecting the appropriate mesh size to optimize gear selectivity. The principle of geometric selectivity can explain the 46% difference in HTU between the two types of gillnets. Furthermore, the use of conventional gillnets with a 2-inch mesh size resulted in a higher HTS (62%) than modified gillnets with a 2.5-inch mesh size (38%). These data indicate that smaller mesh sizes tend to be less selective and capture more non-target species. A larger L value indicates this, compared to the length of the first fish caught (Lc), suggesting that the fishing practices employed do not threaten the sustainability of fish populations.

Keywords: Gillnet, Modification, Bycatch, Sustainable Fisheries

Abstrak

Sibolga, sebagai salah satu kota pelabuhan perikanan penting di Sumatera Utara, menjadi wilayah yang umum menggunakan gillnet permukaan (surface gillnet) dalam operasi penangkapan ikan pelagis. Namun, penggunaan gillnet saat ini masih menghadapi tantangan yang signifikan terkait tingginya hasil tangkapan sampingan (*bycatch*) dan ancaman terhadap keberlanjutan ekosistem ikan pelagis. Penelitian ini menggunakan metode eksperimental fishing yaitu melakukan uji coba dengan objek gillnet permukaan. Uji coba dilakukan menggunakanukuran mesh size gillnet yang digunakan adalah 2" dan 2,5". Hasil penelitian menunjukkan bahwa gillnet modifikasi dengan mesh size 2,5 inch menghasilkan persentase hasil tangkapan utama (HTU) yang jauh lebih tinggi, yaitu 73%, dibandingkan dengan gillnet konvensional mesh size 2 inch yang hanya mencapai 27%. Perbedaan signifikan ini mencerminkan pentingnya pemilihan ukuran mata jaring yang tepat dalam optimalisasi selektivitas alat tangkap. Perbedaan persentase HTU yang mencapai 46% antara kedua jenis gillnet ini dapat dijelaskan melalui prinsip selektivitas geometris. Selanjutnya penggunaan gillnet konvensional dengan mesh size 2 inch menghasilkan persentase hasil tangkapan sampingan (HTS) yang lebih tinggi, yaitu sebesar 62%, dibandingkan dengan gillnet modifikasi berukuran mesh size 2,5 inch yang menghasilkan HTS sebesar 38%. Data ini menunjukkan bahwa mesh size yang lebih kecil cenderung kurang

selektif dan menangkap lebih banyak spesies non-target. Hal ini dibuktikan dengan nilai L∞ yang lebih besar dibandingkan dengan panjang ikan pertama kali tertangkap (Lc), mengindikasikan bahwa praktik penangkapan yang dilakukan tidak mengancam keberlanjutan populasi ikan.

Kata kunci: *Gillnet*, Modifikasi, *Bycatch*, Perikanan Berkelanjutan

1. Introduction

Capture fisheries are an important sector in Indonesia's economic development. Capture fisheries cannot operate without supporting infrastructure, namely, fishing gear. One type of fishing gear that has potential for development at this time is surface gillnets. The city of Sibolga is one of the marine areas on the west coast of North Sumatra that commonly uses surface gillnets (Afriani et al., 2024). However, the use of gillnets currently faces significant challenges, including high bycatch and threats to the sustainability of pelagic fish ecosystems, leading to declines in fish stocks (Firnando et al., 2025). An important consideration when using gillnets is the mesh size, which must be appropriate for the target catch to yield abundant results (Anggrayni & Zainuri, 2022). The surface gillnets commonly used by fishermen generally have a relatively uniform mesh size of 1.5 inches. This condition will affect the amount of Catch and increase the chance of catching small and undersized fish. The principle of fish being caught in gillnets is that if the circumference of the fish is smaller than the mesh size, the fish will escape, but if the circumference of the fish is larger than or equal to the mesh size, the fish will be caught (Ohoiwait, 2024). This can certainly hurt the capture of bycatch and affect the sustainability of pelagic fish resources. This bycatch negatively impacts the sustainability of fish resources.

International regulations by the FAO in 2015 state that every fishing business is required to follow a code of conduct for fishing with 9 criteria, such as: high selectivity of Catch, equipment that does not damage the habitat, high-quality fish, no danger to fishermen, safe products for consumption, low bycatch, low impact on biodiversity, and no capture of protected and socially accepted fish (Monalisa et al., 2022). Although surface gillnets are relatively selective compared to other fishing gear, bycatch remains an important issue that needs to be addressed. This problem not only affects the population of these species but also the pelagic ecosystem as a whole. Afriani et al. (2024) state that gillnets used as fishing gear must meet environmental criteria. Previous studies on the environmental friendliness of surface gillnets in relation to pelagic fish catches have provided a general overview of the ecosystem impacts. Therefore, research on modifying mesh size to be more environmentally friendly is still very much needed. This modification of mesh size is expected to minimise bycatch and negative impacts on pelagic fish ecosystems, without significantly reducing fishing effectiveness. Mesh size greatly affects catch selectivity (Atmaja et al., 2017).

2. Material and Method

2.1. Time and Place

The research was conducted in the waters of Sibolga, using experimental fishing methods. Primary data were collected through direct field observation, including fish species, quantity, size, and capture location. The gillnet mesh sizes tested were 2 "(5 cm) and 2.5" (7.5 cm). Secondary data was obtained from relevant research literature. The method for selecting stations for catch collection was purposive sampling, in accordance with the research objectives. The description of each station is as follows: Station I: Poncan Gadang Island, Sibolga waters; Station II: Poncan Ketek Island, Sibolga waters; Station III: Panjang Island, Sibolga waters.

2.2. Methods

The design used in this study was a completely randomized design (CRD), assuming that environmental parameters were constant. The trial was conducted with two treatments (mesh size: 2 ", 2.5") and four replicates, resulting in eight experiments, each treatment using a 100 m long gillnet. The fishing operation was calculated in trips, and the data were analyzed using Analysis of Variance (ANOVA) at a 95% confidence level. To analyze the effects of treatments and examine their interactions, a Complete Randomised Design (CRD) statistical test equation (Anshory et al., 2025) was used.

2.3. Data Analysis

2.3.1. Composition of Catch

The total weight of the Catch is calculated using the equation of Bahri et al. (2024):

$$P = \frac{Ni}{W} \text{ x } 100\%$$

Explanation:

P = Percentage of fish species i (i = 1, 2,3, …n); Ni = Total number of fish species

2.3.2. Catch Ratio

The catch ratio needs to be known to determine the extent of catch productivity. The ratio is calculated using equation (Bahri et al., 2024): Catch Yield % = (Main Catch) / (Bycatch) X 100%.

2.3.3. Selectivity of Catch

To determine the level of selectivity, it is calculated based on the maturity level. The maturity level is obtained from Fishbase metadata literature. The length frequency distribution is calculated using the following equation:

$$K=1+3,3 \log N$$

Explanation:

K = number of classes; N = number of fish data; Next, class interval: P = R/K; P = class interval; R = longest fish length - shortest fish length; K = number of classes

2.3.4. Environmental Friendliness Level of Gillnets

Fishing gear that is environmentally friendly and has a positive impact on the sustainability of fish resources means that the catch bycatch must be less than the main Catch. The criteria for environmentally friendly fishing gear use the equation.

Table 1. Environmental friendliness level of gillnets

Observation	Criteria	Assessment
Bycatch Results	≤ 60%	Environmentally Friendly
	< 60%	Not Environmentally Friendly
Bycatch Results	≥ 60%	Environmentally Friendly
	< 60%	Not Environmentally Friendly
Fish Length	> Length at first maturity	Fish Fit for Catch
	< Length at first maturity	Fish Not Suitable for Catching
	≥ Catchable	Environmentally Friendly
	< Not worth catching	Not Environmentally Friendly

3. Result and Discussion

3.1. Composition and Percentage Comparison of Bycatch Between Conventional Gillnets and Modified Gillnets

Sibolga, one of the important fishing port cities in North Sumatra, is an area that commonly uses surface gillnets in pelagic fishing operations (Afriani et al., 2024). The waters around Sibolga are known to have abundant pelagic fish resources, particularly mackerel (*Rastrelliger kanagurta*) and tuna (*Euthynnus affinis*), which are the main targets of gillnet fishing in this area. However, the use of gillnets currently faces significant challenges, including high bycatch rates and threats to the sustainability of pelagic fish ecosystems (Firnando et al., 2025).

An important consideration when using gillnets is the mesh size, which must be appropriate for the target catch. Mesh size plays a crucial role in determining the selectivity of fishing gear and the sustainability of fish resources. According to Anggrayni & Zainuri (2022), differences in mesh size significantly affect the size of fish caught. Larger mesh sizes tend to catch larger fish and allow smaller or juvenile fish to escape, allowing them to grow and reproduce before being caught. Conversely, using mesh sizes that are too small can result in the capture of fish that are not yet ready to be caught, including juveniles that have not yet had a chance to reproduce.

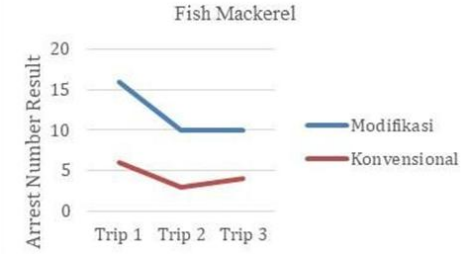

Figure 1. Mackerel

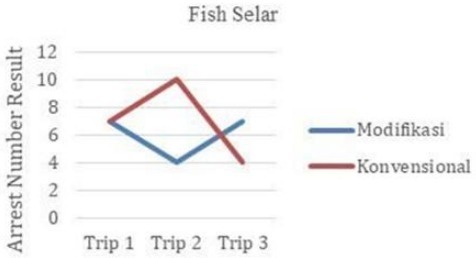

Figure 2. Selar

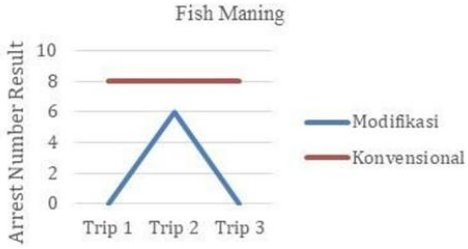

Figure 3. Maning

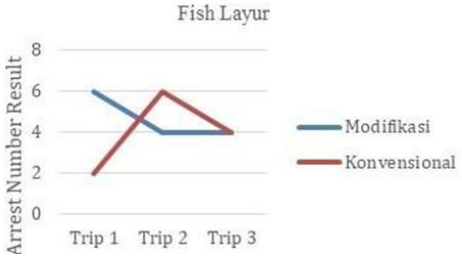

Figure 4. Layur

Figure 5. Kurisi

Table 2. Types and quantities of primary and secondary catches

No	Types of fish caught	Number of catches by gill net type					
		Trip 1	Trip 2	Trip 3	Trip 1	Trip 2	Trip 3
1	Mackerel	16	10	10	6	3	4
	Total		36			13	
			Bycatch				
2	Sardine	7	4	7	7	10	8
3	Mackerel	6	4	4	2	6	4
4	More Fish	0	6	0	8	8	8
5	Curlytail Fish	0	0	3	0	0	5
	Total		41			66	

Based on Table 2, the percentage of Main Catch (HTU) can be calculated by type of gillnet used: modified gillnets with a mesh size of 2.5 inches and conventional gillnets with a mesh size of 2 inches. The percentage is shown in Figure 6.

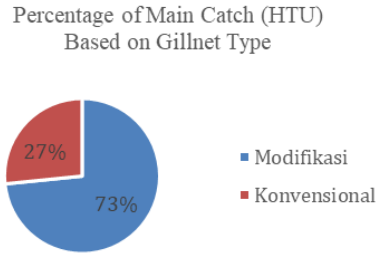

Figure 6. Percentage of main catch results

Figure 6 shows that modified gillnets with a mesh size of 2.5 inches produce a much higher percentage of main Catch (HTU), namely 73%, compared to conventional gillnets with a mesh size of 2 inches, which reach only 27%. This significant difference underscores the importance of choosing the right mesh size to optimize the selectivity of fishing gear. The 46% difference in HTU percentage between the two types of gillnets can be explained by the principle of geometric selectivity. According to research (Ohoiwait, 2024), mesh size is directly related to catch composition. Larger mesh sizes tend to allow small and juvenile fish to escape, thereby increasing the proportion of economically sized target fish.

According to Monalisa et al. (2022), in their study on gillnets, a mesh size of 2.5 inches offers better selectivity for target fish because it filters fish by size within the optimal length range for capture. Meanwhile, a mesh size of 2 inches tends to catch fish in a wider size spectrum, including juveniles and non-target species, thereby reducing the HTU percentage. Furthermore, regarding bycatch results for modified gillnets with a mesh size of 2.5 inches and conventional gillnets with a mesh size of 2 inches, the data are shown in Table 1, which shows more fluctuation but a higher bycatch percentage for conventional gillnets. This percentage is shown in Figure 7.

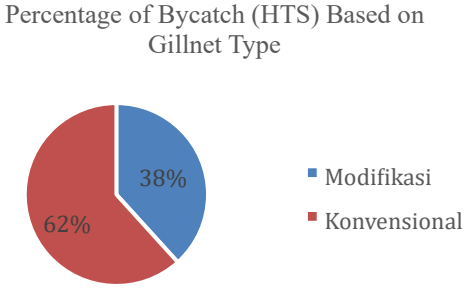

Figure 7. Percentage of bycatch results

Figure 7 shows that conventional gillnets with a 2-inch mesh size result in a higher HTS (62%) than modified gillnets with a 2.5-inch mesh size (38%). Mesh size is one of the main factors affecting the selectivity of gillnets. These data show that smaller mesh sizes tend to be less selective and catch more non-target species. Gillnets with smaller mesh sizes tend to catch fish in a wider range of sizes, including small fish that are often non-target species or juveniles of target species.

Conventional gillnets with a 2-inch mesh have smaller openings than modified gillnets, enabling them to catch fish across a wider size spectrum. This condition results in smaller fish being caught, including juveniles of target and non-target species. The net's smaller mesh size prevents small non-target fish from escaping, thereby increasing bycatch. In this fishing method, fish can be caught in four ways: gilled (caught in the gill cover), wedged (pinched), entangled, or snagged. Smaller mesh sizes increase the likelihood that small fish are caught by entanglement and snagging, which generally results in more non-target species being caught.

From this explanation, it can be concluded that, according to international regulations, namely the Code of Conduct for Responsible Fisheries (CCRF) by the FAO in 1995, modified gillnets with a mesh size of 2.5 inches are more recommended because they result in fewer bycatches than conventional gillnets with a mesh size of 2 inches. According to Atmaja & Nugroho (2017), regulating the minimum mesh size is one of the efforts to conserve fish resources. Research by Anshory et al. (2018) recommends determining the optimal mesh size based on the first-time gonadal maturity (Lm) of the target species, so that fish have the opportunity to reproduce at least once before being caught. Gillnets with larger mesh sizes may result in lower total catch volumes, their economic value is higher due to the larger size and higher quality of the target fish. This reinforces the argument that modified 2.5-inch gillnets are not only more selective but also more economically profitable.

3.2. Selectivity of Catch Size

The selectivity of fishing gear is a fundamental aspect of sustainable fisheries management. Gillnets, as one of the passive fishing gears widely used by fishermen, have selectivity characteristics determined by mesh size. The size of fish that can be caught is one indicator of environmental friendliness. To determine whether fish are suitable for catching, the calculation Lc50% > ½ L∞ is used. The results of the study show that both modified gillnets (2.5-inch mesh) and conventional gillnets (2-inch mesh) exhibit good selectivity for fish sizes suitable for capture. The results of the selectivity-level calculations for these gillnets are shown in Table 2.

Table 2. Length measurements of fish catches

No	Types of Fish	First Size Caught (Lc) and Asymptotic Length (L∞) in Catch Results per Fishing Trip											
		Gillnet Modification						Gillnet Conventional					
		Trip 1		Trip 2		Trip 3		Trip 1		Trip 2		Trip 3	
		Lc (cm)	L∞ (cm)	Lc (cm)	L∞ (cm)	Lc (cm)	L∞ (cm)	Lc (cm)	L∞ (cm)	Lc (cm)	L∞ (cm)	Lc (cm)	L∞ (cm)
1	Mackerel	21,7	26,9	21,5	23,4	20,5	27,5	21,7	22,8	21,8	22,9	21,8	23,5
2	Sardine	15,1	17,6	17,3	18,2	15,3	17,6	13,1	18,2	17,3	18,2	17,1	18,0
3	More Fish	51,5	57,8	50,2	55,8	51,5	57,8	41,5	46,4	42,2	48,1	41,1	47,3
4	Mackerel	0	0	28,1	34,7	26,1	33,9	17,2	20,8	23,1	26,5	23,3	26,9
5	Curlytail Fish	0	0	0	0	20,5	21,5	0	0	0	0	18,4	19,3

The table shows the sizes of fish caught during three fishing trips using modified and conventional gillnets. For some fish species, such as maning and kurisi, some fishing trips have values of 0 in some fishing trips, indicating that these fish were not caught at all. Overall, the fish caught in the three fishing trips show good gear selectivity, characterised by the Length of the first fish caught being greater than half of its maximum Length (Lc50% > ½ L∞). This is in line with research by Dewanti et al. (2019), which shows that gillnets with a mesh size of 3 inches are more selective than gillnets with a mesh size of 2 inches. This finding confirms that increasing the mesh size can improve the selectivity of fishing gear for larger fish.

Although both types of gillnets catch fish of a harvestable size, modified gillnets with a mesh size of 2.5 inches show superiority in terms of better selectivity. Research by Amir et al. (2025) shows that increasing the mesh size of gillnets can reduce the Catch of juvenile fish and increase the proportion of fish of economic size. This is in line with the principle of responsible fishing, which prioritizes the sustainability of resources.

An important aspect of this study is the evaluation of Catch feasibility by comparing the asymptotic Length (L∞) with the Length of the first fish caught (Lc). The analysis shows that, across all types of fish caught, both in modified and conventional gillnets, the fish were in the catchable category. This indicator is indicated by an L∞ value greater than the Length of the first fish caught (Lc), indicating that these fish have reached a size that allows them to reproduce at least once before being caught. This condition is very important in the context of sustainable fishery resources.

According to Firdaus (2021), catch suitability can be assessed from the ratio between the size of the fish when first caught and the size of the fish when first reaching gonadal maturity. If fish are caught at a size larger than the size at first gonadal maturity, then the fishing practice can be categorized as supporting fish stock sustainability.

From a fisheries management perspective, this study's results provide policymakers with important information. Although conventional gillnets with a mesh size of 2 inches still catch fish of a catchable size, transitioning to modified gillnets with a mesh size of 2.5 inches can be a proactive step in anticipating increasing fishing pressure. This is supported by research, Said et al. (2024), which states that the application of more selective fishing gear is an effective fisheries management tool in maintaining fish stock sustainability.

This study concludes that all fish species caught in modified gillnets with a 2.5-inch mesh and conventional gillnets with a 2-inch mesh were of harvestable size. This is evidenced by a larger L∞ value than the fish's length at first capture (Lc), indicating that the fishing practices carried out do not threaten the sustainability of fish populations. However, modified gillnets show better selectivity by catching fish that tend to be larger in size, thus better supporting the principle of responsible fishing

4. Conclusions

Modified gillnets with a mesh size of 2.5 inches produce a much higher percentage of primary catch (HTU), namely 73%, compared to conventional gillnets with a mesh size of 2 inches, which only achieve 27%. At the same time, conventional gillnets with a mesh size of 2 inches result in a higher HTS (62%) than modified gillnets with a mesh size of 2.5 inches (38%).

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