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The Relationship Between Lamp Light Intensity and Squid Fishing Production in Sea Waters of the East Coast of North Sumatra

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ABSTRACT

The purpose of this study was to examine the relationship between squid productivity and light intensity in the waters off the East Coast of North Sumatra. Research into the effects of different light colors is important because it is currently unknown which hue of light from flashing LED lights most effectively influences squid catch. The study was conducted in North Sumatra in January and February of 2024, with the waters off the province's east coast serving as the study site. Survey research, a form of non-experimental research, was used to collect data in the field. This study involved 16 repetitions and 2 treatments. The results indicated that the total weight of squid caught using white lights was 56,418kg, while the catch using yellow lights was 31,968kg. In total, the squid catch from both light colors amounted to 88,386kg. Interviews with fishermen revealed that squid caught by Bagan Pung fishermen are sold at IDR 30,000 per kg. Additionally, anchovies are sold for IDR 15,000 per kg, tembang fish for IDR 8,000 per kg, and layur fish for IDR 25,000 per kg.

INTRODUCTION

The western part of Indonesia, known as North Sumatra Province, has a very big marine and fisheries potential due to its geographical circumstances, which include a very vast sea area (**Stanford *et al*., 2013; Asbur *et al*., 2024**). Under these circumstances, the fishing industry has emerged as one of the main drivers of the North Sumatra Province's GDP. The marine and fisheries potential of North Sumatra is comprised of two components: capture fisheries and aquaculture. The former comprises the potential for 276,030 tonnes of annual production in the Malacca Strait and 1,076,960 tonnes in the Indian Ocean, while the latter is primarily produced through 20,000 hectares of pond cultivation (**Fadhilah *et al*., 2021**). On the other hand, the coastal region of North Sumatra has a coastline of 1300km, consisting of an east coast length of 545km, a west coast length of 375km, and 350km encompassing the Nias Islands and other new islands.

On the other hand, marine cultivation covers 100,000 ha, freshwater cultivation spans 81,372.84 ha, and public waters encompass 155,797 ha.

Squid are a group of molluscs from the Chepalopoda class *(Phyllum mollusca)* with a thin shell on their back (**Fadhilah *et al.*, 2021; Karuwal & Budiman, 2021**). The Loligonidae family has several genera, including *Loligo, Sepioteuthis* and *Uroteuthis*, which are distributed in tropical marine waters **(Riad, 2020)**. Genus *Uroteuthis* spp. belong to the animal kingdom, phylum Longinidae and species consisting of *U. chinensis*, *U. edulis* and *U. duvaucelii*. This genus is distributed in the shallow marine waters of the Indo-Pacific. The economic value of squid makes it one of the main catches of fishermen in the East Coast Sea Waters of North Sumatra (**Hidayati & Widayatun, 2021; Ingtyas *et al.*, 2021**). Squid fishing in the East Coast Sea Waters of North Sumatra is carried out by large and small fishermen using vessels measuring less than 5 gross tons equipped with 23 PK *Dongfeng* engines (A diesel engine is a type of internal combustion engine or a compression-triggered engine) and squid fishing equipment (*squid jigg*). The distance from the landing location to the fishing ground is 5-15 miles with a one day trip.

It is necessary to carry out proof or research that specifically examines the direct relationship between the intensity of light and the production of squid fish in marine waters. However, several environmental factors such as light, water temperature, depth and salinity can influence squid activity and behavior (**Wang *et al.*, 2021**). Squid are generally more active at night, and some squid species can exhibit daily vertical migration behavior, approaching the sea surface at night and deeper during the day. Light intensity can influence this behavior (**Burford & Robison, 2020**). Squid live in groups (schooling) when looking for food at night. The squid caught had different lengths of around 27, 35, 40, 60 and 80cm **(Jones *et al.*, 2021)**. This catch also resulted in juvenile sized squid. The large number of squid catches in November is because this month is the peak month for squid fishing **(Susiloningtyas *et al.*, 2014**). The peak season for catching squid is September-November, this occurs due to the influence of the east monsoon which is the peak season in Indonesia and the shift of west winds (**Kunarso *et al.*, 2019**).

Generally, fishing communities in North Sumatra Province use squid fishing rods, because the process of making fishing gear and the process of operating this fishing gear does not cost too much (**Athirah Sulaiman *et al.*, 2023; Zulkifli *et al.*, 2023**). Squid fishing equipment is generally still traditional but fishermen modify this fishing equipment with the addition of modern fishing aids such as LED lights to attract squid to the fishing rod **(Arkhipkin *et al.*, 2015**). Fishermen usually use LED lights with different colors. Squid fishing equipment has long been known and is operated by LED lights that are installed directly on the main fishing line with various light colors (**Nguyen & Winger, 2019**). Fishermen in North Sumatra Province use the color of the lights based on their wishes without paying attention to the effect on the catch.

The problem is that it is not yet known the effect of the color of light from flashing LED lights which is suitable and greatly influences squid catches, therefore it is deemed necessary to carry out research on the effect of several colors of light from flashing LED lights which provide maximum squid catches based on the color of the lights (**Marshall & Johnsen, 2017**). The aim of this research was to study the effect of the color of flashing LED lights with 4 color combinations, namely: Blue-Green (BH), Red-Blue (M-B), Red-Green (MH), White-Blue (BH) and to study the success of flashing LED light colors on the number of squid catches. Natural and artificial light cycles can influence squid reproductive patterns and feeding behavior **(Koueta & Boucaud-Camou, 2003)**. Lights around bodies of water can change this natural pattern. The use of lights in marine waters is often related to fishing activities. Lights can be used to attract plankton and fish to certain areas, which in turn can influence the squid's feeding patterns **(Villanueva *et al*., 2017)**. Apart from light, other factors such as water temperature, prey availability, and other environmental conditions also play an important role in squid production in marine waters **(Pratasik *et al*., 2022)**.

Capture fisheries are an economic enterprise that utilizes aquatic biological resources and fishing gear to produce fish to meet community needs **(Hart & Reynolds, 2002; Singh *et al*., 2020)**. Fishing gear is one of the main means for optimal and sustainable utilization and management of fish resources (**Jaya *et al*., 2022**). One form of fishing technology that is considered successful and is developing rapidly in the fishing industry to date is the use of light aids to attract the attention of fish during the fishing process **(Cooke *et al*., 2021)**. All types of fishing gear that use light aids in fishing technology are called lightfishing. In Indonesia, the intensity of the light used by fishermen varies depending on the type of fishing gear, target species, fishing ground and the financial capabilities of each fisherman **(van Oostenbrugge *et al*., 2002; Yamazaki *et al*., 2018; Yulisti *et al*., 2024)**. In the type of fishing gear, stick-on and floating gears use 2-4 pertromax lamps, purse seines use 8-10 lamps and on ship charts it can reach 20,000 watts **(Patty, 2010)**.

Each species of squid has different characteristics and environmental preferences. Therefore, it is important to consider the specific squid species and local environmental conditions when evaluating the relationship between light intensity and squid catcher production in marine waters. Further research and empirical data may be needed to understand in more detail these interactions. Therefore, this research aimed to analyze the relationship between light intensity and squid production in the sea waters of the East Coast of North Sumatra.

MATERIALS AND METHODS

This research was carried out in North Sumatra Province from January to February 2024. The research location was conducted in the waters of the East coast of

North Sumatra. The research method used a survey or non-experimental method, namely collecting data in the field **(Kusumawardhani *et al.*, 2017; Gordon *et al.*, 2023)**. This study used 2 treatments and 16 repetitions. The treatment used was as follows:

A = White light color treatment at night from 20.00-10.00 WIB.

B = Yellow light color treatment at night from 20.00-10.00 WIB.

The data collected were primary and secondary data. Primary data were obtained by following fishermen's trips on a floating chart. The data obtained included the total weight of the squid catch, the number of individuals and bycatch, while the secondary data were in the form of a literature study by comparing literature or research report results in accordance with the theme.

1. Research procedure

1.1. Preparation

Preparations were made prior to the departure of the ship towing the floating chart to the fishing ground, from 15:00 to 16:00 WIB. The preparations included checking the generator, the container for holding the catch, the fishing lights on the fuel supply chart, and the supplies needed while waiting for the catch on the floating chart.

1.2. Implementation

This research was carried out during the dark phase of the moon when the night starts to get dark around. At 20.10 WIB the nets began to be lowered. As the net was lowered, fish attracting lights began to be turned on. After 2-3 hours, the net was pulled using a roller. The time required for withdrawal was only 10 minutes. After that the fish was lifted onto the chart. Then the net was lowered again to wait for the next operation.

1.3. Data retrieval

Primary data collected in this research included the following: first, measuring light intensity using a lux meter; then, recording the position data on the floating chart using GPS (Global Positioning System), based on the location of the fishing area **(Wilson *et al.*, 2008)**; next, collecting data on the total weight of squid caught on the floating chart, as well as the number of individual squid, categorized by color; comparative data on the number of squid catches based on the total weight and the number of individual squid (kg) for each catch type; calculating the number of non-economic catches in each color category; and finally, analyzing secondary data, which was gathered through a literature study by comparing relevant research reports that align with the theme of this study.

1.4. Observed parameters

The parameters observed in this research included catches from floating charts with white lights and yellow lights at night from 20.00-20.10 WIB. The catch parameters observed include:

1. Oceanographic data which includes temperature, brightness and salinity and depth.
2. Total weight of squid for each white and yellow light.

3. Number of squid individuals per white and yellow light.

2. By catch results seen from the economic price aspect

2.1. Data analysis

Data on the total weight of squid and the number of individual squid were analyzed using the student t-test, while oceanographic data including temperature, brightness, salinity and depth were analyzed descriptively **(Martins *et al*., 2010; Sajikumar *et al*., 2020)**. If the calculated t value is greater than the t table value at 0.05, then there is a significant difference in the catch between the white and yellow light treatments. If the calculated t value is smaller than the t table value at 0.05, then the treatments do not show significant differences. The formula used in the Student's t-test was as follows:

$$t = (Y1 - Y2) / (Sp * \sqrt{(2/n)})$$

t : Deviation of the mean value
Y1: Squid catch (White) Y2: Squid catch (Yellow)
S: Standard deviation
n : Total number of repetitions (16 times)

RESULTS

Squid (*Loligo* sp.) is a soft animal with a cylindrical body and triangular fins that come together at the end **(Mironenko *et al*., 2021)**. Its characteristic is that it has an ink sac which functions to release ink which is used to avoid predators. Squid (*Loligo* sp.) belongs to the class Cephalopoda, order Teuthoidea, suborder Myopsida, and family Loliginidae. The distribution of squid (*Loligo* sp.) is widespread throughout Indonesian waters, from West Sumatra to the south of Irian Jaya (Papua), from the Strait of Malacca (North Sumatra) to the east, covering the waters of East Sumatra, the Java Sea, the Banda Sea, and the waters of Maluku/Arafura **(Wulandari *et al.*, 2023)**. Squids (*Loligo* sp.) are demersal or semi-pelagic, inhabiting coastal areas and continental shelves at depths of up to 400 meters. During the day, they gather in groups at the ocean floor, and at night, they spread out through the water column **(Robison, 2004)**. Squids are positively phototactic, meaning they are attracted to light **(Brodrick & Jékely, 2023; Martudi *et al*., 2023)**.

The utilization of squid resources has primarily relied on jigs, which use artificial bait designed to mimic the shape of shrimp. These jigs are either homemade by fishermen or produced in factories. Jigs are fishing tools specifically designed for catching squid or the cuttlefish, typically shaped like shrimp, fish, or other forms, with hooks on the tail but without barbs. Several methods have been employed to enhance the effectiveness of jigs, such as using shapes and color patterns that resemble natural prey, incorporating radium into parts of the fishing rod, and using flashing lights. These techniques aim to attract the

attention of squid, causing them to approach the fishing gear and get caught. However, scientific information regarding the application of these methods is still lacking. Additionally, it remains scientifically uncertain whether LED lamps are more effective than Petromax lamps for attracting squid. Therefore, research is needed to investigate the effect of different lighting in handline fishing gear on squid (*Loligo* sp.) catches. North Sumatra is one of the regions with significant potential for squid catches.

The process of catching squid using fishing rods involves several stages: preparation, squid-catching operations, and returning from the fishing grounds to the landing site. Before heading to the fishing grounds, fishermen prepare fuel, equipment, and squid fishing rods. Once all preparations are complete, the boat is ready to set sail for the fishing grounds. Upon arrival, the fishermen prepare their fishing gear and place the bait in the water. The bait is then left to set for approximately 5 to 10 minutes at a depth of around 45 meters.

To attract the squid, fishermen turn on the lights installed on the main fishing line (blits). Afterward, they slowly pull the fishing line. Hauling the line is done when the hook is attached to the squid, typically through its head, body, or tail. Once the hook catches the squid, the fisherman pulls gently until the squid is brought aboard the boat. The use of lights is essential for catching squid with fishing gear, as squid are positively phototactic—meaning they are attracted to light. Flashlights are typically used to lure the squid.

Initially, the light source used for handline squid fishing was the Petromax lamp. However, its use has been discontinued due to the high cost of kerosene fuel. Fishermen are now attempting to switch to tube lamps (Tublur Lamp) powered by small generators. Underwater lights are rarely used as fishing aids because they are more complicated to construct and more expensive. In theory, underwater lights provide lower light illumination than above-water lights **(Shen *et al.*, 2013; Suanda *et al.*, 2023)** because almost 100% of the light from underwater lights is absorbed by the water and not reflected out **(Miramirkhani & Uysal, 2018)**.

Squid fishing typically employs two types of lighting models, which are adapted to squid behavior **(Nakajima *et al.*, 2022; Syamsafitri *et al.*, 2023)**. The first method involves shining light on the water's surface, as squid are positively phototactic. Flashing lights are often tied to strings as a way of communicating with the squid. The light organs in squid are used for camouflage and communication with other animals.

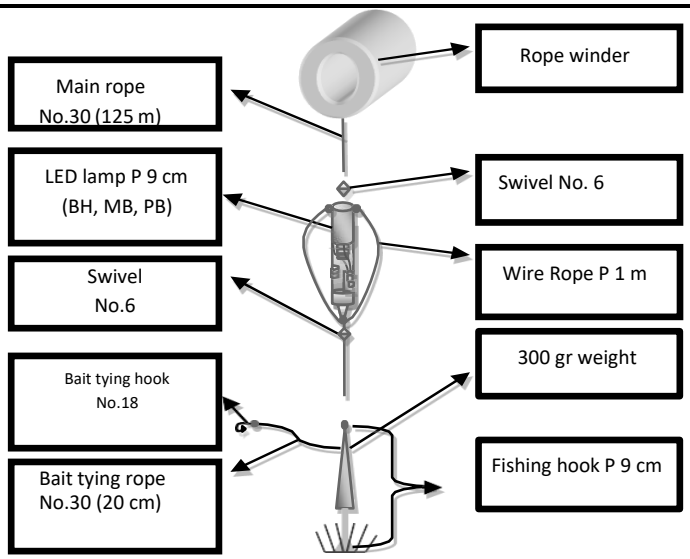

Fig. 1. Series of squid fishing equipment

The fishing gear used to catch squid is not widely used by Indonesian fishermen. However, considering that squid has a high protein content and is an economically important aquatic animal or a type of commercial aquatic animal. So catching squid using fishing gear needs to be further developed in Indonesia. Given that with the development of the business of catching squid using modern fishing equipment, it is proven that this business has high efficiency. Apart from that, catching squid with this equipment can overcome various national problems in the agricultural sector, including increasing the income of fishermen and fish farmers, creating productive jobs, increasing non-oil and gas foreign exchange and ensuring the availability of animal protein food.

In the field of fisheries, we not only study fish but also non-fish species such as shrimp, shellfish, and squid (*Loligo* sp.). In Indonesia, squid (*Loligo* sp.) are primarily caught using trawls, purse seines, fishing gear, and fishing rods. However, fishing rods are not widely used by Indonesian fishermen. Given that squid are high in protein and are economically important as a commercial aquatic species **(Aubourg *et al.*, 2021; Mather, 2010)**, the use of fishing rods for squid catching needs to be further developed in Indonesia. The development of the squid fishing industry using modern fishing equipment has proven to be highly efficient. Additionally, squid are more difficult to catch with nets at sea compared to some fish, due to their ability to move quickly in all directions. This is further supported by the fact that light-based fishing aids have been well developed in Indonesia, as light is essential for catching squid with fishing gear.

Table 1. Squid production in marine waters in North Sumatra Province in 2022 (Kementerian Kelautan dan Perikanan Republik, Indonesia, 2022)

Landing location	Regency/City	Harbor	Ship type	Types of fishing gear	Production volume	Production value
Harbor	Medan City	PP. Belawan	KM_0005	Drifting Gillnets, Oceanic Gillnets	1100	66816418
Harbor	Medan City	PP.Belawan	KM_0005	Fishing Rod	7530	461904214
Harbor	Medan City	PP. Belawan	KM_0005_0010	Fishing Rod Small]	367545	22713525969
Harbor	Medan City	PP. Belawan	KM_0005_0010	Pelagic Purse Trawl With One Vessel	22500	1402503011
Harbor	Medan City	PP. Belawan	KM_0005_0010	Squid Angling, Squid Fishing	47580	2900720082
Harbor	Medan City	PP. Belawan	KM_0010_0020	Fishing Rod Small	229808	14134163779
Harbor	Medan City	PP. Belawan	KM_0010_0020	Pelagic Purse Trawl With One Vessel	62600	3839090763
Harbor	Medan City	PP. Belawan	KM_0010_0020	Squid Angling, Squid Fishing	161924	9957847164

Harbor	Medan City	PP. Belawan	KM_0020_0030	Bouke Ami	1026424	63112430292
Harbor	Medan City	PP. Belawan	KM_0020_0030	Fishing Rod	194900	11980131574
Harbor	Medan City	PP. Belawan	KM_0020_0030	Small Pelagic Purse Trawl With One Vessel	86555	5319426370
Harbor	Medan City	PP. Belawan	KM_0020_0030	Squid Angling, Squid Fishing	283865	17461836677
Harbor	Medan City	PP. Belawan	KM_0050_0100	Small Pelagic Purse Trawl With One Vessel Boarded	500	30371099
Harbor	Medan City	PP. Belawan	KM_0100_0200	Bottom Trawl	589380	35874324229
Harbor	Central Tapanuli	PP. Sibolga	KM_0005	Arrow	2585	62874955
Harbor	Central Tapanuli	PP. Sibolga	KM_0005_0010	Arrow	2295	53714475
Harbor	Central Tapanuli	PP. Sibolga	KM_0010_0020	Boating Chart	950	23106850
Harbor	Central Tapanuli	PP. Sibolga	KM_0020_0030	Boating Chart	12145	284483225
Harbor	Central Tapanuli	PP. Sibolga	KM_0030_0050	Small Pelagic Group	2306	54876160

				Ring Trawl		
				Small Pelagic Group Ring Trawl		
Harbor	Central Tapanuli	PP. Sibolga	KM_0050_0100		2938	69133844

***Information*:** Production Volume (Kg), Production Value (Rp)

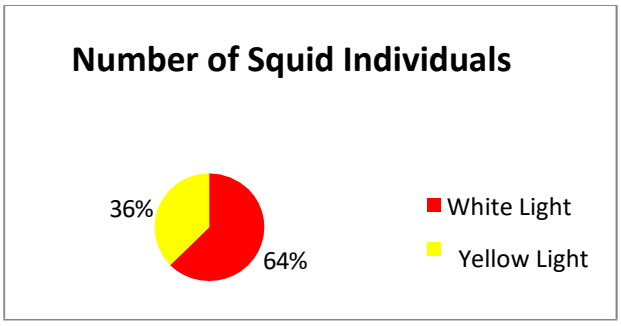

Fig. 2. Percentage of the number of individuals caught by squid with white lights and yellow lights

This research is in line with research conducted by **Mulyawan *et al*. (2015)** that white lights have a greater catch than other colored lights, where the squid catch is 64% compared to other lights. Other research supporting this study includes work by **Hakgeun *et al.* (2012)**, which found that squid are most attracted to blue light **(Matsui *et al.*, 2016)**. Additionally, white LED lights have the highest intensity compared to green and red lights. The combination of white and blue light in treatment D (White-Blue) produced a higher light intensity than the combinations in treatments A, B, and C, leading to a stronger response from the squid to the white-blue light combination. In contrast, research by **Jhaiaun *et al*. (2021)** found that blue lights resulted in lower catch rates compared to red and green lights. This can be explained by the fact that blue light, when present in bright water, reflects less light or emits light that is harder for squid to detect, resulting in lower catch rates compared to other colored lights.

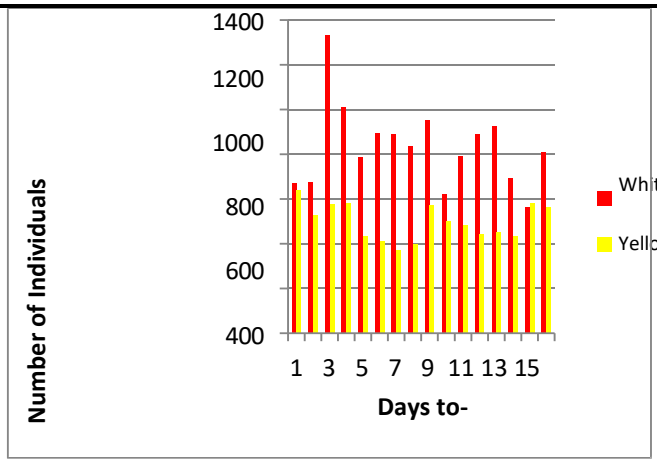

Fig. 3. Number of individuals caught squid

Squid caught in the waters of North Sumatra during this research have a high economic value for floating fishermen. From an economic perspective, squid are priced higher than anchovies. The total weight of squid caught using white lights was 56,418kg, while squid caught with yellow lights amounted to 31,968kg. The combined total catch of squid using both white and yellow lights was 88,386kg. According to interviews with fishermen, the price of squid caught by Bagan Pung fishermen is IDR 30,000 perkg. In comparison, anchovies are sold at IDR 15,000 perkg, tembang fish at IDR 8,000 per kg, and layur fish at IDR 25,000 per kg. The total catch from all species amounted to 209,627kg, with a total value of IDR 4,267,026. Therefore, squid catches have a high selling price, significantly contributing to the increase in fishermen's income.

DISCUSSION

The number of squid catches using floating charts in North Sumatra is relatively low, as squid are considered a by-catch in these operations. In Belawan waters, key environmental parameters such as temperature, brightness, and salinity were found to be normal for the survival of fish, especially squid, even during the western monsoon season. The water temperature during the study ranged from 25 to 27°C. According to **Rosa and Seibel (2010)**, squid typically inhabit waters with temperatures between 18 and 27°C, and they exhibit daily migration patterns, grouping at the bottom of the water during the day and spreading out in the water column at night. Shore squid live in bay waters and migrate to continental shelves, with some species in subtropical areas making seasonal migrations due to temperature fluctuations. Water temperature is influenced by solar radiation and the surrounding air temperature.

The salinity of the waters during the study ranged from 26 to 30ppt. The floating charts were not operated far from the port pier due to strong winds at night, which kept the salinity range within moderate levels. These findings align with **Soewito and Syarif (1990)**, who reported that squid thrive in waters with salinity ranging from 8.5 to 30ppt.

The water clarity, or brightness, during the study ranged from 2.7 meters to 3.4 meters. The water depth varied between 15.4 meters and 20.9 meters. In general, squid are found in coastal areas and continental shelves at depths of up to 400 meters, and several species can live in brackish waters.

Fisheries Management Area (WPP) 571, also known as Fishing Zone (ZPI) 571, is one of the internationally established zones for regulating and managing fish resources. The waters within WPP 571 include the coastal waters of North Sumatra Province, which have significant natural resource potential and are recognized as key squid fishing areas for fishermen in Medan Belawan. Small-scale fishermen in Medan typically fish in coastal waters between 5 and 12 miles offshore, as per Minister of Maritime Affairs and Fisheries Regulation No. 71 of 2016, which defines Fishing Route II as extending from 4 to 12 nautical miles measured from the lowest ebb tide.

Squid belong to the class Cephalopoda (phylum Mollusca) and are characterized by their thin shells on their backs **(Kershaw, 1983; Singh *et al.*, 2017; Yamaguchi *et al.*, 2020)**. The Loliginidae family includes several genera such as *Loligo*, *Sepioteuthis*, and *Uroteuthis*, all of which are found in tropical marine waters **(Riad, 2020)**. The *Uroteuthis* genus, which includes species like *U. chinensis*, *U. edulis*, and *U. duvaucelii*, is commonly found in shallow marine waters of the Indo-Pacific. The high economic value of squid makes it one of the main catches for fishermen in Belawan District, Medan City. Squid fishing in Medan is carried out by both large and small-scale fishermen using vessels of less than 5 gross tons, equipped with 23-horsepower Dongfeng engines and squid fishing gear (squid jigs). The distance from the landing location to the fishing grounds ranges from 5 to 15 miles, with a one-day fishing trip.

Key stakeholders in the squid fishing business in Medan include fishermen, small collectors, entrepreneurs (such as squid warehouse owners), and exporters. Squid are typically sold fresh and whole to small collectors and entrepreneurs. The involvement of entrepreneurs and small collectors is crucial to the squid fishing industry, as they provide the capital needed for fishermen to conduct their fishing activities.

CONCLUSION

Most fishermen in North Sumatra Province operate on both small- and large-scale levels. Small-scale fishermen primarily engage in squid fishing using vessels under five gross tonnage (GT), equipped with squid jigging gear. These fishermen typically go on single-day fishing trips, traveling 5–15 miles offshore in 9–12 meter boats powered by 23 PK Dongfeng engines, with two crew members on board. Each crew member operates 8–10 50-watt lamps. The primary reason for using artificial light is the squid's positive phototactic behavior, where bright lights attract squid, especially during nighttime fishing.

Squid fishing is the main source of income for local fishermen due to the high demand for squid. During the peak season, fishermen can earn around Rp. 2,700,000 per catch,

whereas in the lean season, earnings decrease to about Rp. 500,000. However, this income remains lower than the minimum wage (UMR) in Medan City. Once caught, the squid are sold to small collectors, who then resell them to business owners at predetermined prices. Additionally, fishermen can borrow money from these small collectors to finance their fishing operations.

The feeding and reproductive behavior of squid can be influenced by both natural and artificial light cycles. Artificial lights near water bodies can disrupt these natural patterns. In maritime environments, fishing activities that involve the use of lights can attract plankton and other small fish, which in turn influence the squid's feeding behavior. Along with light, other environmental factors, such as water temperature and prey availability, also affect squid production in marine environments.

In this study, a total of 31,968 kg of squid was caught using yellow lights, while 56,418 kg was caught using white lights. The combined total catch using both white and yellow lights amounted to 88,386 kg. According to interviews with fishermen and fish collectors, squid caught by floating chart fishermen are sold for Rp. 30,000 per kilogram. In comparison, layur fish are priced at Rp. 25,000 per kg, tembang fish at Rp. 8,000 per kg, and anchovies at Rp. 15,000 per kg.

Research also indicated that squid are most attracted to blue light. Among the different light types, white LED lights have the highest intensity compared to green and red LED lights. The combination of white and blue lights (treatment D) exhibited the highest light intensity, outperforming other combinations in treatments A, B, and C. As a result, squid responded more strongly to the white-blue light combination. However, despite the stronger intensity, blue light is less effective at attracting squid in bright water areas due to its lower perceptive strength compared to red and green lights. Blue light tends to reflect more, making it less effective at attracting squid in comparison to the other colors.

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