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Evaluation of Applied Tuna-Jacket, a Post-Harvest Technology of Tuna Handlines in Maluku Waters, Indonesia

Welem Waileruny[1], Eko Sri Wiyono[2*], Sani Sarimane[1], Delly DP Matrutty[1]

[1]Departement of Fisheries Resources Utilization, Faculty of Fisheries and Marine Science, Pattimura University Indonesia

[2]Departement of Fisheries Resources Utilization, Faculty of Fisheries and Marine Science, IPB University Indonesia

Corresponding author: eko-psp@apps.ipb.ac.id

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ABSTRACT

Tuna has a significant economic value in the world and is the third largest fishery commodity in Indonesia after shrimp and demersal fish. Tuna has a relatively high price compared to other fish commodities, and its demand continues to increase. Fishing gear suitable for catching large pelagic fish, such as tuna includes the handline fishing gear. Fishermen commonly use tuna handlines for this purpose, and Maluku fishermen specifically use them to catch the yellowfin tuna. However, tuna caught with handlines often face predation from other fish, and their quality diminishes as they struggle to escape. To improve the quality of the caught fish, a device known as the "tuna jacket" has been introduced. This handling device serves as a protective cover for fish under attack or being eaten by other fish. Additionally, the tuna jacket restricts the movement of captured fish, leading to their quicker death. This research aimed to analyze the effectiveness of using tuna jackets in handline fisheries in Maluku waters, Indonesia. The study's results indicate that tuna jackets are more effective compared to the control methods. However, fishermen have a negative perception of the tuna jacket since its use can reduce their income.

INTRODUCTION

Tuna is classified as a large pelagic fish with a wide range. One species of tuna that is widely caught in Indonesia, especially in Maluku waters, is the yellowfin tuna (*Thunnus albacares*). This species has a wide migratory range that extends from ropical to subtropical marine waters throughout the world and can be found in the Atlantic, Indian and Pacific Oceans, with the exception of the Mediterranean Sea **(Collete & Nauen, 1983; FAO, 1994)**. The distribution of the yellowfin tuna in Indonesia includes the western and southern regions of Sumatra, Java, Bali and Nusa Tenggara, the Banda Sea and its environs, the Sulawesi Sea, Tomini Bay, Maluku waters and West and North Papua (Pacific Ocean) **(Uktolseja *et al*., 1991; Wudianto & Nikijuluw, 2004)**.

The Banda Sea is a potential fishing ground for the yellowfin tuna in Indonesia **(Haruna *et al.*, 2019)**. The yellowfin tuna fishery in Maluku is dominated by small-scale handline fishermen. Handlines are considered to be an environmentally friendly fishing gear that has high selectivity and is operated using sustainable fishing techniques. The advantage of handlines fishing compared to other fishing gears is that the catch is of a large size and there is little variation in the size of the catch, making it a good raw material for loins **(Waileruny, 2014)**.

In order to improve the effectiveness of handline fishing gear, a device called tuna jacket was developed and introduced to protect the fish and speed up the process of lifting the tuna to the boat **(Rahmat & Thamrin, 2016)**. Tuna caught with handlines are often subject to predation by other fish. In addition, the quality of the tuna catch deteriorates as it struggles to escape. In an effort to improve the quality of the catch, a tuna jacket has been introduced. The tuna jacket is a handling tool that acts as a protective device or cover for caught fish that are being attacked or eaten by other fish. The tuna jacket is also used to restrict the movement of captured fish so that they die quickly. Once the fish individual is hooked, the tuna jacket is pulled down by the rope to cover the fish's body and limit its movement so that it can be transported quickly **(Kristiawan *et al.*, 2013)**.

In theory, the tuna jacket has some advantages for fishermen. However, after some time of its introduction, most of the fishermen in Maluku who previously used the tuna jacket have stopped using it. Therefore, it is necessary to evaluate the use of the tuna jacket. It is necessary to reassess the advantages and disadvantages of this fishing aid. This research aimed to analyze the level of effectiveness of using tuna jacket in handline fishery in Maluku waters, Indonesia.

MATERIALS AND METHODS

1) Materials

In order to assess the effect of installing a tuna jacket, we conducted fishing trials in Maluku waters using handlines either with a tuna jacket or without a tuna jacket (control) (Fig. 1). A fishing boat (length 11m, width 1m, height 85cm), 4 sets of hand lines and a tuna jacket were used for the fishing experiment. GPS was also used to record the position of the fishing areas. The digital camera was used to document important events during the research. To measure the length and weight of the catch, we used a one-meter tape measure and a weighing instrument.

Fig. 1. Research site, Seram Island and surrounding area **(Wikipedia, 2024)**

2) Data collection method

The tuna jacket tested in this research is a trapezoidal cage formed by 2 series of circles/rings with net walls. The materials used to make the circles/rings are 10mm diameter stainless steel and 6mm diameter PA rope. The cage ring consists of a main ring made of stainless steel with a circle diameter of 50cm and a second ring made of PA rope with a circle diameter of 15cm. In general, the choice of ring size is based on the average morphology of the tuna caught. The construction of the tuna jacket is largely determined by the shape and size of the tuna's body. The two rings are connected by a net with a mesh size of 5 inches. The distance between the main ring and the second ring is 80cm at full power (Fig. 2).

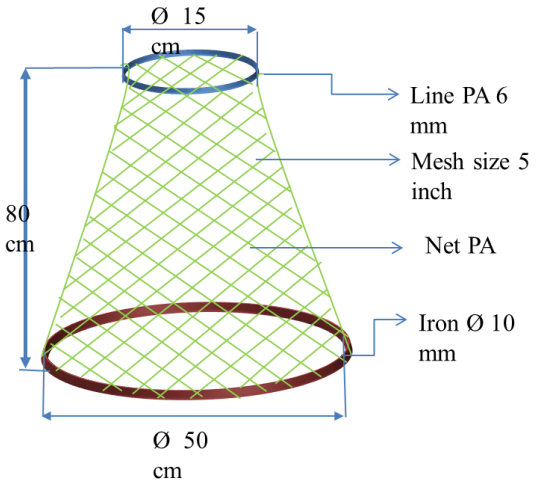

Fig. 2. Illustration of "tuna-jacket" and its components

To answer the research questions, experimental fishing was conducted in the waters of Maluku, Indonesia, in November-December 2020. Meanwhile, research on fishermen's perceptions of the use of tuna jackets was conducted on Ceram Island and

Ambon Island in 2021. Fishing trials were conducted in 28 replicates, with 14 replicates of each treatment. The replication in this research is the number of fishing hauls. To obtain these 28 replicates, 13 fishing trips were conducted, of which 7 trips were for experimental fishing with a tuna jacket and 6 trips without a tuna jacket.

In general, the method for collecting data on handline operations, whether using a tuna jacket or not, is as follows (Fig. 3):

(1) Preparation: The fishermen go to the fishing area. After finding the fishing area, the fisherman lowers the rod, with the bait attached to it, into the sea. The fisherman then waits to raise the rod until a fish eats the bait. While waiting for the bait to be eaten by the fish, in the tuna jacket experiment, a tuna jacket was prepared.

(2) When the bait is eaten and the fish is caught on the hook: the rod is lifted onto the boat. In tuna jacket research, before the fish is lifted into the boat, the caught fish is trapped in a tuna jacket by launching the tuna jacket to the end of the fishing line where the fish is caught, making sure that the fish is trapped inside the "tuna jacket".

(3) Hauling: At this stage, the fish is transported to the fishing boat as quickly as possible.

In order to measure the effectiveness of using a tuna jacket, the speed at which the fish was lifted was measured. Then, once the fish had been lifted onto the ledge, morphometric measurements of the fish were carried out (length, weight and body size).

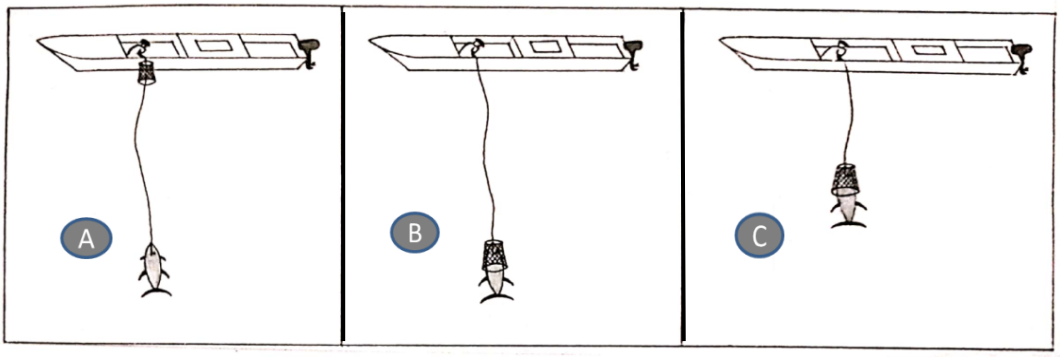

Fig. 3. Illustration of the tuna jacket used in handline fishing: **(A)** Caught fish, tuna jacket ready to be lowered; **(B)** Tuna already inside the jacket tuna; **(C).** Tuna ready to be hauled

In addition to investigating the technical effectiveness of using tuna jackets, this research also assessed fishermen's perceptions of the use of tuna jackets by conducting interviews with fishermen. Interviews were conducted with fishermen who used tuna jackets and those who did not. Interviews were conducted with 83 fishermen, 53 fishermen from Seram Island and 30 fishermen from Ambon Island.

3) Data analysis

The catches of each treatment are presented in tabular form. The time taken to hauling the fish out of the sea after catching is also shown in the table. To obtain information on the effectiveness of using a tuna jacket compared to not using a tuna jacket (control), hauling time and morphometric data of fish catches (length, weight and body size) were compared using ANOVA analysis. In addition to fish morphometrics, this study also measured fishing efficiency, which was measured by the time taken to haul the fish. The results of the ANOVA analysis of fish morphometrics were then used as a basis for conducting an ANOVA analysis to determine differences in the effectiveness of using tuna jackets. Meanwhile, questionnaire data from interviews with fishermen were tabulated and analyzed descriptively to obtain percentages for each fishing alternative.

RESULTS

Tuna fishing in Maluku is generally conducted using hand lines. The fishing boats used are classified as small, with a length of 8.5 - 11m, width of 0.8 - 1.0m, and equipped with an outboard engine of 15 - 40hp. Hand lines generally consist of a fishing line tied to a hook with bait attached. The bait may be natural or artificial. The fishing line is monofilament with factory size numbers 600, 700, 800 and 1000. The hooks used are stainless steel with size numbers 3, 6, 7 and 8. Hooks with smaller size numbers have larger sizes. A small size hook is used on a small diameter line. Similarly, a large hook is attached to a large diameter line.

Fishing is done in several stages: preparation, baiting, traveling to the fishing ground, fishing, and returning to the base. Preparations before heading to the fishing ground include gathering fuel, fishing equipment, support equipment, and logistics. These preparations are completed during the night. Fishermen typically depart for the fishing ground early in the morning, around 03:00 - 04:00. On their way, they catch bait fish such as squid and small pelagic fish. They usually arrive at the fishing ground between 06:30 and 09:00, depending on weather conditions, waves, and distance. They return to the base around 14:00 - 18:00, based on the tuna catch and weather conditions.

The location of the fishing grounds is generally based on the fishermen's experience from previous trips. Upon arriving at the fishing ground, they search for tuna schools by observing natural signs such as diving birds, jumping fish, dolphin schools, or floating objects like FADs (Fish Aggregating Devices). Once a tuna school is identified, the fishing operation begins. Based on field observations and interviews with fishermen, several handline fishing techniques used in Ambon, Maluku are described as follows:

1. **Slow motion technique**: The hook, tied with artificial bait, is slowly lowered to a depth of 50 - 80 meters so that the bait mimics a small swimming fish. A stone wrapped in coconut leaves acts as a weight, lowering the hook to the desired

depth. Once at depth, the line is jerked to release the hook from the stone. This technique keeps the hook and bait at that depth. It is called the slow motion technique because the bait is pulled slowly. This method is used when there are no visible signs of tuna schools on the surface and is often employed near FADs or floating objects.

2. **Live bait technique**: Live bait such as flying fish, mackerel, and squid are used. The bait fish are tied to a fishing rod and released into the water through tuna schools. The rod is then lowered to a depth of 50 - 80 meters. The live bait swims vertically, and when a tuna takes the bait, the line is pulled tightly to secure the hook in the fish's mouth. This technique, known locally as the "tada" method, blocks schools of tuna by attracting them with live bait. It is also used with schools of migrating dolphins, as tuna often accompany dolphins.
3. **Live bait with slow motion technique**: This method is similar to the first but uses live bait. Coconut leaves are used to bind stones attached to a hook, which is then lowered to a depth of 50 - 80 meters. At this depth, the live bait floats in the water column. When a tuna bites the bait, the line is pulled to hook the fish, which is then reeled in. This method is used with FADs, floating objects, dolphin schools, or visible tuna schools.
4. **Tonda (Trolling)**: Artificial bait is tied to a hook and the line is lowered horizontally to a depth of 60 - 80 meters, then pulled by a boat moving at medium speed. As the bait moves, it mimics a small fish swimming, attracting tuna to bite. This technique is called tonda, or trolling.

Once a tuna bites the bait and is hooked, it swims vertically to deeper depths, stretching the line attached to the boat. This allows the tuna jacket to be lowered through the line and cover the fish's body, reducing its resistance and making it easier to lift into the boat. The perpendicular position of the line to the boat during the lifting process allows all the above methods to be used with the tuna-jacket technique.

Effectiveness of tuna-jacket

This study involved 28 hauls, with each treatment requiring 14 hauls. In general, the results of this experiment show that the fish caught from the fishing experiment both with tuna jackets and controls (no tuna jackets) had an average catch weight (FW) of 20.93kg (σ =11.18) with an average fork length (FL) of 151cm (σ =17.05) and body size (BS) of 92cm (σ =14.88). The time required for hauling (HT) is 20.93 minutes (σ =11.18). Analyzing the data for each research treatment, it can be seen that handline tuna catches using a tuna jacket have a fork length (FL) of 133 - 225cm (150.23±27.63) with a weight per individual (FW) of 27 - 80kg (42.26±12.95). The hauling time to the boat (HT) for the tuna jacket treatment ranged from 5-17min/ individual, with an average hauling time of 10.1min (Table 1).

Table 1. Morphometrics and hauling time of handline catches with tuna jackets

Trip	Fish length (cm)	Body size (cm)	Fish weight (kg)	Hauling time (minutes)
1	133	84	33	7
2	134	86	34	8
3	135	76	31	8
4	137	68	28	5
5	139	69	27	5
6	143	101	47	10
7	149	103	48	11
8	151	102	49	12
9	153	105	50	12
10	155	103	50	13
11	155	97	41	9
12	156	108	52	14
13	157	98	45	10
14	225	130	80	17
Average	151.6	95.0	43.9	10.1

Meanwhile, tuna caught by handline without tuna jacket (control) had a fork length (FL) between 137-167cm (148.90± 30.75), body size (BS) between 69-115cm (90.43± 20.67) and weight (FW) between 28-59kg per individual (41.10± 1113.79) (Table 2). Hauling time (HT) ranged from 25-49min per individual with a mean of 31.8 min. The test of equality of means for the two treatments using ANOVA showed that fork length (FL), body size (BS) and weight (FW) of the fish caught were not significantly different ($P< 0.05$). Based on these results, a similarity test was then carried out for hauling time (HT). The results of the ANOVA analysis, which was used to compare the hauling time between the use of a tuna jacket and no tuna jacket, showed that the average hauling time for the tuna jacket and the control was significantly different ($P< 0.005$). The time taken to haul the fish to the boat was faster with the tuna jacket treatment than without the tuna jacket (control).

In addition to the above results, this study also recorded the presence of released tuna when the tuna jacket was used. There were two instances of fish being released during the process of loading the fish into the boat (hauling), while no fish were released in the control treatment.

Table 2. Morphometrics and hauling time of handline catches without tuna jackets

Trip	Fish length cm)	Fish body size (m)	Fish weight (kg)	Hauling time (min)
1	137	69	28	33
2	140	73	30	25
3	142	78	31	25
4	142	78	32	27
5	144	79	33	28
6	149	83	35	29
7	150	84	35	36
8	152	94	39	42
9	155	98	41	28
10	155	99	41	27
11	157	100	43	30
12	159	102	45	30
13	158	102	46	36
14	167	115	59	49
Average	150.5	96.7	38.4	31.8

Meanwhile, the results of the survey research using an interview approach with both tuna-jacket and no tuna-jacket (control) hand line fishermen showed that of the 83 respondents interviewed, all had different reasons regarding the effectiveness of tuna-jackets. Of the 63 respondents who no longer use tuna boots, 46 people (73.02%) stated that tuna boots were completely ineffective, while 26.98% stated that tuna boots were less effective. The fishermen who no longer use tuna-jackets say that, in their experience, tuna-jackets are more likely to sting the tuna they catch, although they all say that tuna-jackets are more efficient in terms of hauling time. According to them, the speed and lifting power are not proportional to the possibility of releasing the fish, because if the fish is released, they suffer a loss of approximately IDR 1 million (Table 3). On the other hand, fishermen also believe that the use of tuna pots has no effect on prices. It is precisely the size of the tuna that is the most dominant factor influencing the price. Large tuna (grade A) is more expensive than small tuna (grade B or C).

Table 3. Fishermen's perceptions regarding using tuna jackets

Location	Treatment	Respondents	Reason
Ambon Island	Tuna jacket	5 persons (16.7%)	Less hauling time, less power use
Seram Island	Tuna jacket	15 (28,3%)	Less hauling time, less power use, With or without a tuna jacket, both have the potential to release fish.
Ambon Island	Without tuna jacket	25 persons (83.3%)	The fish caught is easy to escape, losing fish means lost production and income, no fun, no challenge, complicated to operate, if the fish escapes, the "tuna jacket" is also lost, adding to the fisherman's loss.
Seram Island	Without tuna jacket	38 (71,7%)	Caught fish are easily released, loss of fish means loss of production and income, embarrassment to use the "tuna jacket" because it is considered incapable of catching tuna with tools.

DISCUSSION

The use of a tuna jacket significantly improves time efficiency, as demonstrated by this research. This finding aligns with the study conducted by MPAG and the Ministry of Maritime Affairs and Fisheries **(MMAF, 2018)**, which reported that tuna jackets increase the hauling time by 7-12 minutes compared to not using one. With a tuna jacket, the process of lifting the tuna takes approximately 10 minutes **(Kristiawan *et al.*, 2013)**.

Despite its benefits, many fishermen who previously used tuna jackets have stopped using them. One reason is that the use of tuna jackets often leads to fish being released. There are two main factors contributing to this issue:

1. **Fish rebellion**: When a tuna is hooked and a tuna jacket is deployed over the line, the approaching jacket can cause the fish to become agitated. The tuna will struggle and try to escape by increasing its swimming speed. Fishermen attempt to keep the tuna in a vertical position to ensure the jacket covers the fish’s head. However, the increased resistance from the fish, especially if it is large, can cause the line to break.
2. **Hook and mouth damage**: If the tuna is not kept in a vertical position but instead at an angle to the fishing line, the tuna jacket may not wrap around the tuna properly. Instead, it can hit the hook in the fish’s mouth, leading to tearing and eventually the fish being released (Fig. 4). Both scenarios are common and can result in the tuna being released back into the wild.

While the tuna jacket improves efficiency in hauling, the release of tuna can lead to reduced income for fishermen. This is a primary reason why many tuna fishermen in Maluku have ceased using tuna jackets. Moreover, fishermen often experience satisfaction from catching large tuna without the aid of a tuna jacket, valuing this accomplishment over the financial gain from fishing. As noted by **Handoko (2001)**, job satisfaction is a personal feeling aligned with individual goals and values. It is a crucial aspect of well-being for individuals and communities, including fishermen **(Pollnac *et al.*, 2008, 2011)**. Satisfaction and pride in catching fish without a tuna jacket are considered significant, even in tough economic times **(Trimble & Johnson, 2013; Pascaoe *et al.*, 2015; Sweke *et al.*, 2016)**.

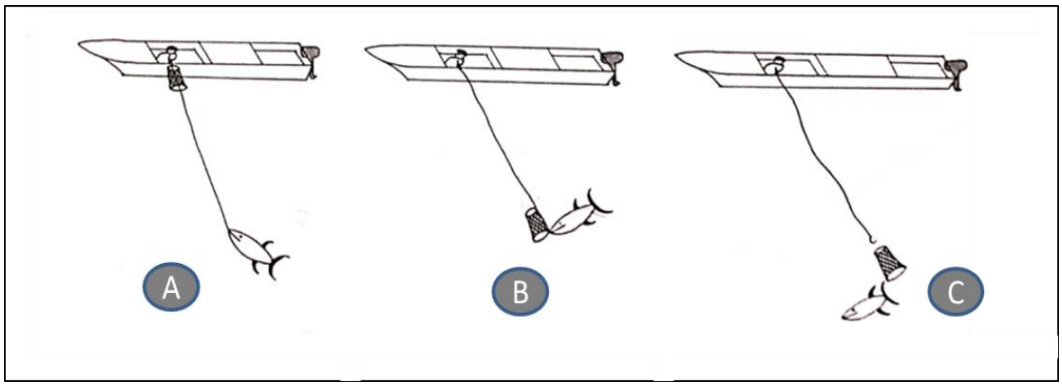

Fig. 4. Illustration of a released tuna: **(A)** The tuna is caught on the hook, the tuna jacket is ready to be lowered; **(B)** The position of the tuna is not vertical and the tuna jacket hits the hook in the mouth of the fish; **(C)** The tuna is released from the hook

CONCLUSION

The use of the Tuna-Jacket is more effective than the control in terms of hauling time when fishing for tuna with hand lines. The average hauling time with a tuna jacket was 10.1 minutes and without a tuna jacket was 31.8 minutes. With the use of a tuna-jacket, there is a higher probability of fish being able to escape after being caught than without a tuna-jacket. The use of a tuna jacket also reduces fishermen's job satisfaction, as they face fewer challenges when fishing.

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