



Environmental friendliness level of fish catching on the Southern coast of West Sumatera. An assessment using the analytical hierarchy process

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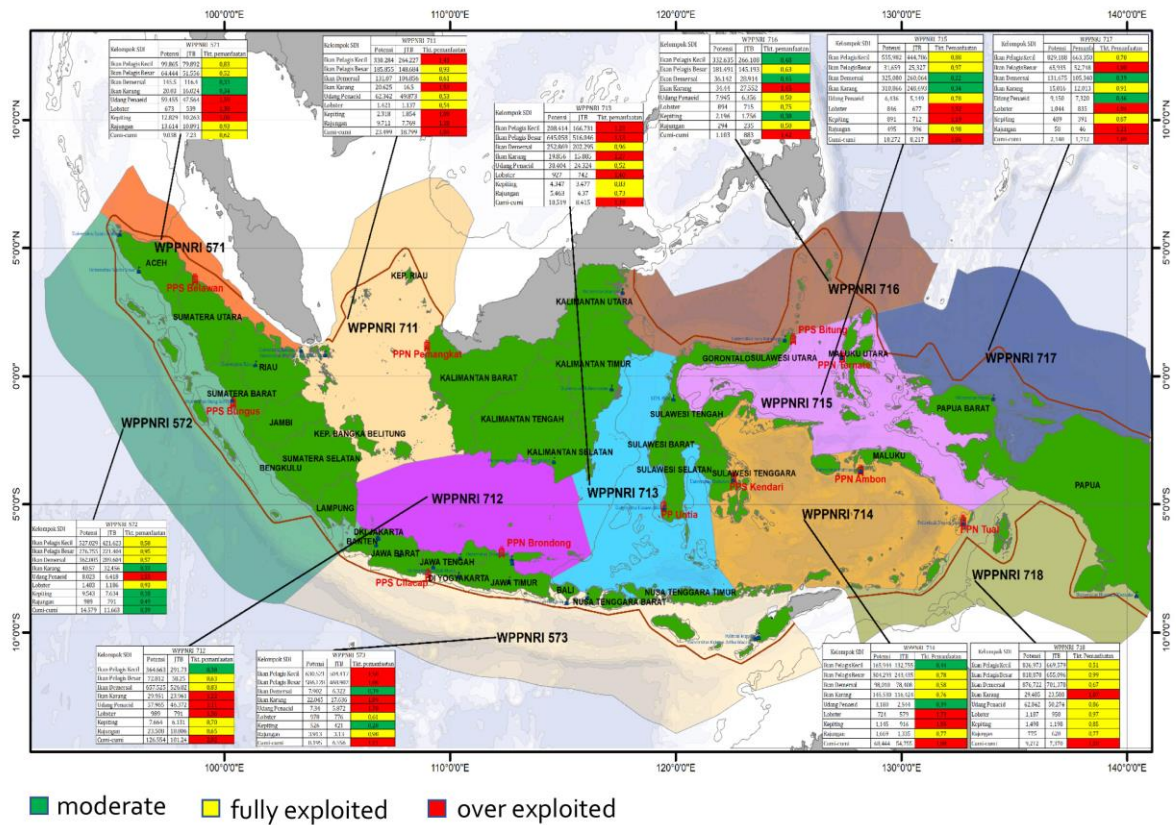
Abstract. The Indonesian sea area is much wider than the mainland and thus Indonesia has a wealth of fisheries that must be properly maintained and developed. One possibility is the use of environmentally friendly fishing gear to maintain the quality of waters and sustainable fisheries. In South Coastal waters, the types of fishing gear operated are seine net and Jorans. This research used a survey and data provided on the port. Also, the Analytical Hierarchy Process method was used. The Food and Agriculture Organization (FAO) environmental friendliness criteria was used to determine the friendliness of responsible fishing gear in accordance with the Code of Conduct for Responsible Fisheries (CCRF). The results show that the environmentally friendly fishing gear used on the southern coast of West Sumatra are the troll line and boat liftnet while seine net (payang) is a fishing gear that is not environmentally friendly.

Key Words: fishing gear, environmentally friendly, fish catching.

Introduction. Indonesia is a country whose dominant territory is sea compared to land which means that Indonesia has great wealth in the maritime and fisheries sector. Therefore, the water area needs to be well maintained and preserved. One of the ways to preserve the biodiversity and potential of sustainable fisheries is by using environmentally friendly fishing gears and technology. In Indonesia, fishing gears can be divided into several types, such as Joran, nets, and traps. Some fishing gear are classified as not environmentally friendly in terms of their construction and operation.

Environmentally friendly fishing gears and technology must be used to increase fishery productivity, employment in the sector, its contribution to the Gross Domestic Product (GDP), and foreign exchange (Tadjuddah 2017). Fishing gears used in Southern Coastal of west Sumatera Province are boat liftnet, seine net (payang), and trolling. This study aims to determine the level of friendliness of a fishing gear used on the southern coast of West Sumatra.

There are 11 fisheries management areas (FMAs) in Indonesia's marine seas. FMAs are established to improve management of fisheries. FMA is a management region for fisheries that includes interior waters, island waters, territorial sea, extra zones, and Indonesian exclusive economic zones. It also includes fisheries conservation, research, and development.



Sumber : Permen KP No. 18/PERMEN-KP/2014
 Kerpmen KP No 50/KEPMEN-KP/2017

Fisheries Management Areas (FMAs) in Indonesia's marine seas

Figure 1 (a) Status level of exploitation of fish resources in the eleven Fisheries Management Areas (FMAs) (FMA = WPP; WPP = Wilayah Pengelolaan Perikanan)
 (b) FMA 572: legend

| Details for the Fisheries Management Areas (FMAs) 572Kelompok SDI | FMA 572 | | |
|---|------------|-----------------|------------------|
| | Fish Stock | Allowable catch | Utilization Rate |
| Small pelagic fish | 527.029 | 421.623 | 0,5 |
| Large pelagic fish | 276.755 | 221.404 | 0,95 |
| Demersal fish | 362.005 | 289.604 | 0,57 |
| Coral fish | 40.57 | 32.456 | 0,33 |
| Penaeids | 8.023 | 6.418 | 1,53 |
| Lobsters | 1.483 | 1.86 | 0,93 |
| Crabs | 9.543 | 7.634 | 0,18 |
| Rajungan Crab | 989 | 791 | 0,49 |
| Squids | 14.579 | 11.663 | 0,39 |

Source: MMAF, 2017

According to stock assessment, in FMA 572, the maximum sustainable yield (MSY) of small pelagic fish utilizing acoustic methods was 527,029 tons per year, and the total allowed catches (TAC) were 421,623 tons annually. Large pelagic fish had a MSY of 276,755 tons per year and a utilization rate of 0.45. Demersal fish had MSY of 362,005 tons per year and a utilization rate of 0.57. The usage rate for all was moderate (yellow color) (Figure 1a, b) (MMAF, 2017; Suman et al 2016).

The condition of fish stocks that have been fully exploited needs to be evaluated and be exploited with the fishing gear that have the greatest potential to reduce fish stocks. The present study makes and assessment of fishing gear friendliness operated by

fishermen at FMA 572 considering aspects of fish stock biology and a broader environmental friendliness. This assessment involved fishermen and other stakeholders such as experts, consumers, and NGOs (following Zamroni, 2014).

Material and Method. The study was carried out in September 2020 in Southern Coastal Regency, West Sumatra, Indonesia. The study area was FMA 572 (Figure 1) The research method was the survey and data was collected through face to face interviews.

Data collection. Data obtained by interviewing and filling out questionnaires. Respondents were determined by random methods and according to field conditions or by purposive sampling. Respondents were people who were familiar with the fishing gear, fishing facilities, and fishing method such as the port employees, fisheries lecturers, and fishermen.

The reserach steps were data collection on fishing gears such as the number, type and size of fishing gear and filling out the questionnaire, namely the AHP weighting questionnaire based on nine criteria by Ministry of Marine Affairs and Fisheries (MMAF) (2012) by several respondents such as port officials, fisheries supervisors, fishermen, and fisheries lecturers.

Data analysis. Analysis was made using the Analytical Hierarchy Process (AHP) method which is based on the Code of Conduct for Responsible Fisheries (CCRF), nine criteria for environmental friendliness, as recommended by the Food and Agriculture Organization (FAO, 1995) and MMAF (2012): 1) High selectivity; 2) Does not damage the environment or habitat; 3) Produce high quality fish; 4) Does not endanger fishermen; 5) Does not endanger consumers; 6) Low by-catch; 7) Low impact on biodiversity; 8) It does not affect protected fish; and 9) Socially acceptable.

AHP is a simple effective and efficient decision making method for solving a problem through variables so that a problem will appear more structured and systematic (Razi & Fahrur 2016). According to Noor (2003), the use of the AHP method includes the following steps: define the problem; define alternatives; define criteria; establish priority amongst criteria using pairwise comparisons; calculate relative weights. The the goals to be achieved must be established by making a hierarchical chart and selecting criteria for achieving goals and making alternatives as choices in achieving the goals (Table 1 and Figure 2).

Table 1

A hierarchical chart and selecting criteria for achieving goals and making lternatives as choices in achieving the goals

| <i>Goals</i> | <i>Description</i> |
|--------------------|---|
| Goal | To determine the level of friendliness of each fishing tools in southern coastal waters |
| <i>Alternative</i> | <i>Description</i> |
| BL | Boat liftnet |
| S | Seine net (Payang) |
| TR | Trolling |
| <i>Criteria</i> | <i>Description</i> |
| HS | High selectivity |
| NIH | Has no impact on habitat |
| HQF | Produces high quality fish |
| NIF | Has no impact on fishermen |
| NOC | Production does not endanger consumers |
| BL | By-catch is low |
| LIB | Low impact on biodiversity |
| NIP | Has no impact on protected fish |
| SA | Socially acceptable |

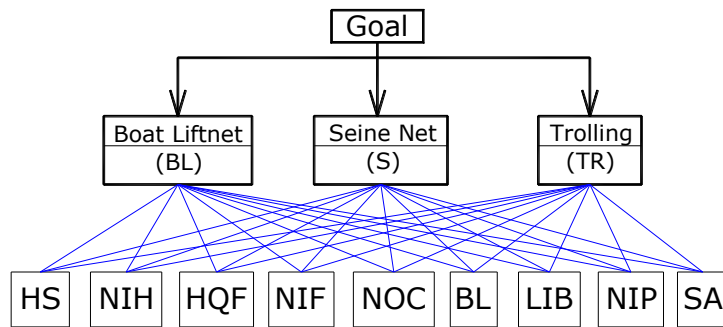


Figure 2. Hierarchy chart.
Source: Authors' elaboration

Setting priority elements in two stages, includes:

- To make pairwise comparisons (Table 2) by comparing alternatives according to the criteria used based on the nine MMAF criteria (2012).
- To make pairwise comparison matrix by assigning numbers or values to know the presentation of the relative importance of all alternatives.

Table 2

Alternative comparison format to be used for selected criteria

| Alternative A | Trolling 1 | Payang 2 | Boat Liftnet 3 |
|------------------|------------------|------------------|-------------------|
| Trolling | 1 | A _{1.2} | A _{1.3} |
| Payang | A _{2.1} | 1 | A _{2.3} |
| Boat liftnet | A _{3.1} | A _{3.2} | 1 |

The AHP process is used in this study to determine the level of environmental friendliness of fishing gear through steps: Assign a value to each fishing gear based on each of the environmental friendliness criteria (Table 1); then compare the values for each fishing gear between rows against columns (Table 2); the value given is based on a comparative scale of the important (Table 3) of the environmental friendliness of each fishing gear.

Table 3

Base scale of comparison

| Value of interest | Definition | Description |
|-------------------|---|--|
| 1 | The two alternatives are equally important | Two alternatives have the same effect on goals |
| 3 | One alternative is slightly more important than the other | Experience and judgment have little to support one alternative over the other |
| 5 | One alternative is more important than the other | Experience and assessment strongly support one alternative over other alternatives |
| 7 | One alternative is clearly more important than the other | One alternative is strongly supported and looks different in practice |

| | | |
|--------------|---|--|
| 9 | One alternative is absolutely more important than the other | Evidence supporting one alternative to another has the highest possible degree of difference |
| 2,4,6,8 | The value of two adjacent consideration values | This value is given when there are two compromises between the two options |
| The opposite | If alternative A gets one point and is compared to alternative B, then B gets the opposite value of alternative A | |

After making a comparison of each alternative with the other alternatives, the researcher synthesizes the results to get the value of the alternative (Hutagalung 2021), by following these steps:

- Calculates the sum of the values in each alternative column.
- Finds the eigenvector or eigenvalues, by dividing each value in one column by the number of columns of an alternative.
- After getting the eigenvalues, the next step is to add up each row of eigenvalues and to get the average value, namely the sum of the eigenvalues added on the rows is divided by the number of alternatives used. The next stage is to check the accuracy of the results obtained. The sum of the average values must be 1, and if the value is different, the calculation is wrong and must be recalculated.

Consistency Ratio (CR) and Consistency Index (CI) are calculated as follows:

$$CR = CI/IR$$

$$CI = (\lambda_{max} - n) / (n - 1)$$

λ_{max} = The largest eigenvalue of matrix A with size n

The value λ is obtained in the following way:

$$\lambda = (\text{result of total column value in alternative A} \times \text{mean of alternative A}) + (\text{result of total value of alternative column B} \times \text{mean of alternative B}) + (\text{sum of alternative column values n} \times \text{mean of alternative n}).$$

n = Number of Criteria

IR = Random Index

The random index value is obtained from a predetermined and provision table (Table 4).

Table 4

List of Random Index (IR)

| n | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 |
|----|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|
| IR | 0.00 | 0.00 | 0.58 | 0.90 | 1.12 | 1.24 | 1.32 | 1.41 | 1.45 | 1.49 | 1.51 | 1.43 | 1.56 | 1.57 | 1.59 |

Source: values for matrices of different sizes (Saaty, 1987)

The results are considered consistent if the level or CR value is ≤ 0.1 .

Weighting is the final process, by adding up each alternative, to determine the priority level of fishing gear of every alternative.

Results and Discussion

South coast fishing equipment. The most often used fishing tools in study area are the boat liftnet, payang and trolling (Table 5).

Fishing gear on the South Coast

| <i>Fishing gears</i> | <i>Amount</i> |
|----------------------|---------------|
| Boat liftnet | 65 |
| Seine net (payang) | 37 |
| Trolling | 5 |
| Total | 107 |

The fishing gear used in this study are presented in Figure 3, Figure 4. and Figure 5. A trolling with a large size of each eye, with a depth of 100 m is used on the southern coast of West Sumatra (Figure 3). The operation of the trolling is done by being towed by the ship while the ship is sailing. Three people operate this fishing gear. The target of trolling fishing is surface and large fish, using live bait such as tiger grouper (*Epinephelus fuscoguttatus*), pompano fish (*Caranx ignobilis*), mackerel fish (*Euthynnus affinis*), skipjack fish (*Katsuwonus pelamis*), which are live fish and look for food around coral reefs.

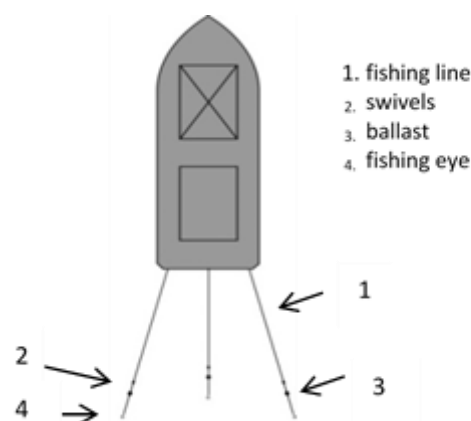


Figure 3. Trolling construction
Source: Authors' elaboration

The existing Seine net of Southern Coastal waters are small, being operated by 8-12 crew members (Figure 4). This gear is shaped like a bag and has a net length of 5 m, a mesh opening of 0.5 m, the body part has 0.75 m with a mesh size of 1.5 cm, the length of the net on the wing is 20 m, the mesh size is 30 cm. The boat is run by engine with 40 Horse Power. The nets are usually placed on the starboard side of the ship.

Seine net is operated like this: firstly, fish are gathered by concentrating the fishes using a Fish Aggregating Device (FADs); then, the net is lowered and the boat circles the FADs with a speed of 10 knots; after that, the ship stops and the rope is pulled towards the ship (OSPAR Commission 2020). Seine net fishing gear usually catches surface fishes such as anchovies (*Stolephorus* sp), tuna fish (*Euthynnus affinis*) and layur fish (*Trichiurus lepturus*).

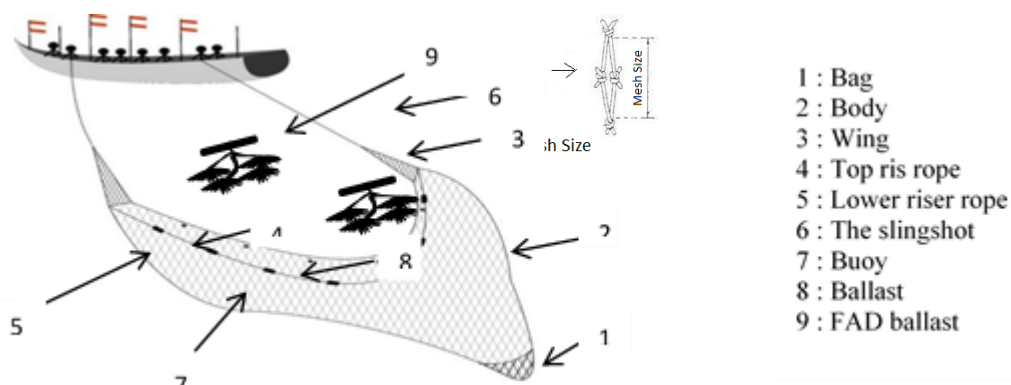


Figure 4. Seine net construction
Source: Authors' elaboration

The boat liftnet is the most often used fishing gear in the waters of the Southern Coast of West Sumatra (Figure 4). This is operated as follows: firstly, the nets are tied to the wooden frame, with a net size of about 25 mx 25 m, with a mesh size of 0.5 cm, then are lowered around 6.00 pm, when it gets dark; then, the lamps are turned on to attract the fish; after the fish have gathered, the lights are turned off and the side lights or the frame lights stay on so that the fish gather under the skeleton, and the net is pulled using a roller. The number of crew members 15-20. The fishing gear can catch fish at a distance of 40 miles to the sea. The distance is determined by the size of the ship weight, which can range 6-30 Gross Tonnage. The catch of boat liftnets is little tuna (*Euthynnus affinis*), layur (*Trichiurus lepturus*), anchovy (*Stolephorus commersonii*), and rakegilled mackerel (*Rastrelliger kanagurta*).

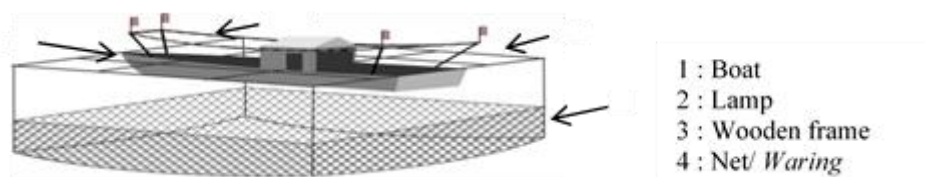


Figure 5. Boat liftnet construction
Source: Authors' elaboration

Level of environmental friendliness of fishing foals. The fishing gear in South Coast is analyzed with AHP analysis. Fishing gear found on the South Coast and considered in the analysis are trolling (Joran) seine net (payang) and boat liftnet. Each fishing gears is analyzed for its environmental friendliness level based on nine MMAF criteria by FAO (2018). A total of ten respondents where interviewd and they were grouped into three different categories of respondents, namently fishermen who operate each type of fishing gear, port authorities, and fisheries lecturers. They assigned value of interest (weights) to each fishing gear considering each criteria.

1) *High selectivity.* The value of each fishing gear was assessed considering the high selectivity criteria. It resulted that the weighted value of the trolling fishing gear was 0.6333, the lifting net weighted value was 0.2605, and the weighted value for the trolling fishing gear was 0.1062 (the lowest value) (Figure 6).

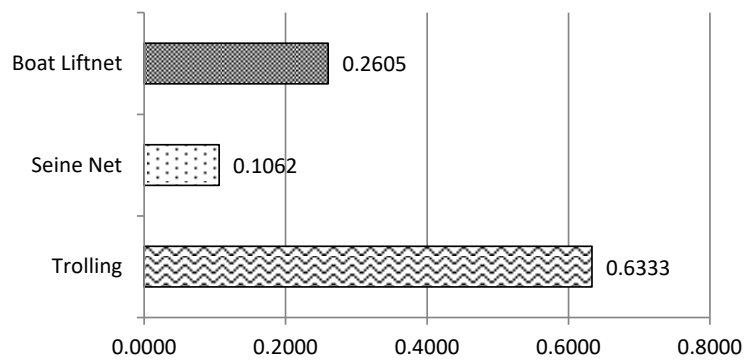


Figure 6. Comparison of weighted value of fishing gears considering: High selectivity criterion

Trolling fishing gear has the catch according to the size of the fishing line used, so that the size of the fish caught is relatively the same. The catch of the boat liftnet fishing gear is not much different in terms of the size of the ship and the size of the mesh size. The CR value is 0.0477, so it is consistent because it is ≤ 0.1 .

2) *No impact on the habitat.* The value of each fishing gear was assessed considering the criteria of not having an impact on the habitat. This criterion considers the fishing area where the fishing gear causes damage to the waters area. The weighted value of trolling is 0.7235 (the highest value), the weighted value of boat liftnet is 0.1932, and the weighted value of seine net is 0.0833 (the lowest meaning the highest damage on the habitat) (Figure 7).

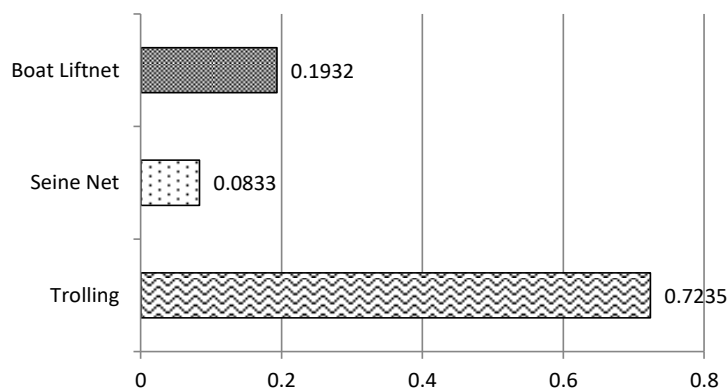


Figure 7. Comparison of weighted value of fishing gears considering: No damage to habitat criterion

No damage to the habitat criterion means that the gear does not cause damage to a large area so that it does not disturb the aquatic ecosystem. Trolling causes damage to relatively narrow water areas because it uses rod (Jorans) to catch fish in the waters, thereby reducing the impact of environmental damage. The boat liftnet is a fishing gear that causes damage in narrow water areas, where the boat liftnet operates by collecting fish in an area using lights so that the fish gather and the nets on the chart are lifted up. Seine net destroys the habitat where it operates by circling the fish school using FADs and nets and pulling the fish into the boat. The Consistency Ratio (CR = CI/IR) on the criterion that it does not affect the habitat is 0.0961, so it is consistent because it is ≤ 0.1 .

3) *Producing high quality fish.* The value of each fishing gear was evaluated using the criteria of producing high quality fish. Quality refers to freshness and live catch. The value of trolling fishing tool is 0.6333, boat liftnet 0.2605, and of payang fishing gear is

0.1062 (Figure 8). Caught fish are immediately put in ice to preserve freshness and quality.

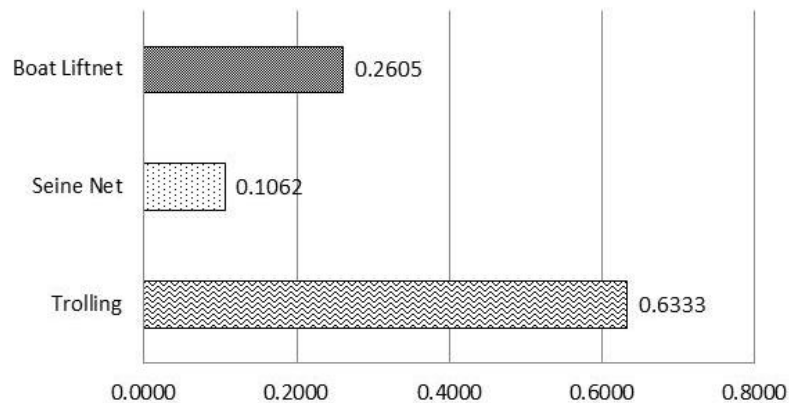


Figure 8. Comparison of weighted value of fishing gears considering: Producing high quality fish criterion

The percentage of dead and fresh fish is similar for boat liftnet and seine because time duration for the fishing operation process is relatively the same. The freshness of the fish using boat liftnet is better than seine net because the fishing time is different: the boat liftnet operates at night while the seine net operates during the daytime. The CR for producing high quality fish criterion is 0.0477, so it is consistent because ≤ 0.1 .

4) *No impact on fishermen.* The value of each fishing gear was also assessed considering the criterion that it has no impact on fishermen. This criterion considers fishermen safety at the time of operation. The weighted value of trolling fishing tool is 0.72 (the highest value), the weighted value of the boat liftnet is 0.19, and the weighted value of seine net is 0.08 (the lowest) (Figure 9). Operation of fishing gear can usually have an impact on fishermen's health and safety, but these hazards can vary. Trolling brings risks such as fishermen's hands can be exposed to the hook, boat liftnet fishing gear can make fishermen fall into the sea because they have to attach the net to the wooden frame, and seine net can cause extreme injuries or death due to the operation of the payang spreading the net with the boat running at high speed (if fishermen get caught in the net, they cannot be saved immediately because the net cannot be pulled directly). The CR value on the criterion that it does not affect fishermen is 0.0961, so it is consistent because it is ≤ 0.1 .

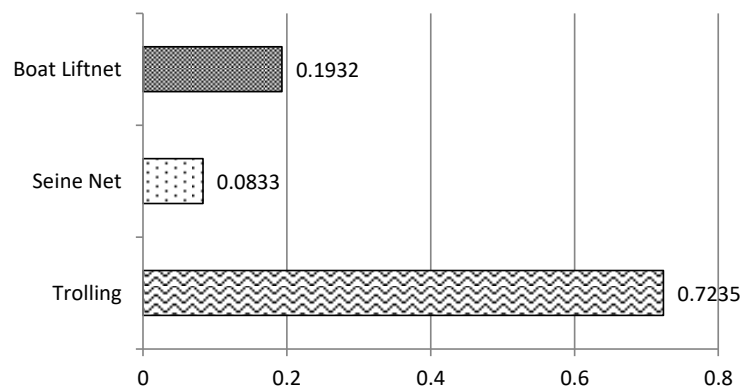


Figure 9. Comparison of weighted value of fishing gears considering: Has no impact on fishermen criterion

5) *Production does not harm consumers.* The value of each fishing gear was evaluated considering the requirement not to endanger consumers. In this context, the trolling fishing tool has a value of 0.59, and the boat liftnet is 0.25, and the seine net (payang) is 0.16 (Figure 10). The catch of trolling, boat liftnet and seine net do not endanger consumers. However, considering the specificity of the operation of each fishing gear, the trolling line is safer for consumers because the fish is caught using a rod and hook while boat liftnet and seine net using nets. In their case, the chart of the boat is lifted and the seine net is pulled up and can catch large amounts of fish. The garbage that is in the waters often also enters the nets and affects the quality of the fish. The CR value on this criterion is 0.060, therefore it is consistent because it is ≤ 0.1 .

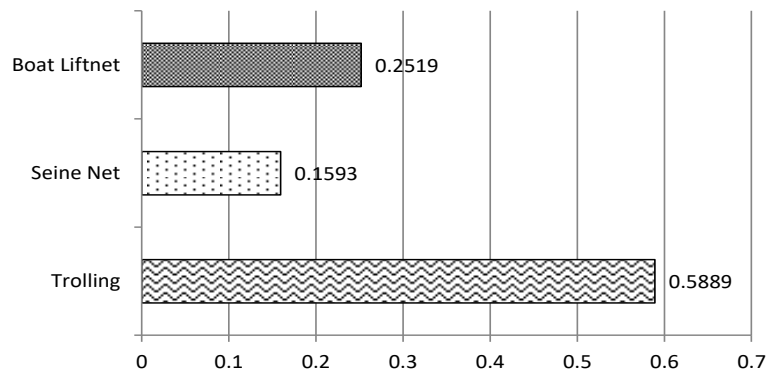


Figure 10. Comparison of weighted value of fishing gears considering: Production does not harm consumers criterion

6) *Minimum by-catch.* The value of each fishing gear using was evaluated using the low by-catch criterion. This criterion considers the selling value of the by-catch. Thus, the Trolling value is 0.68, the boat liftnet fishing gear is 0.20 and the seine net value is 0.12 (Figure 11). Fishing gear usually captures by-catch that may have a selling price or not. Trolling and boat liftnet have a low by-catch of less than 3 species and that have a selling price, while the payang by-catches have a low selling price in the market. The CR value of the by-catch criterion is 0.0330, so it is said to be consistent because it is ≤ 0.1 .

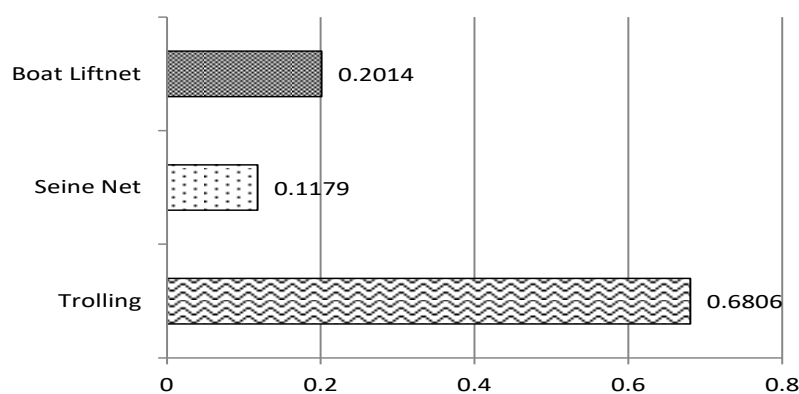


Figure 11. Comparison of weighted value of fishing gears considering: Minimum by-catch criterion

7) *Low impact on biodiversity.* The value of each fishing gear was evaluated considering its impact on marine biota and habitat. The resulting value for trolling is 0.68, for boat liftnet is 0.20, and for seine net is 0.12 (Figure 12). Operation of fishing gear in general can have an impact on biodiversity. Trolling operation can result in the death of some fish from various species but it does not affect the habitat. Deep boat liftnets operation can

result in the death of fish of various species and impact on narrow habitats. Seine net has a strong impact on the biodiversity.

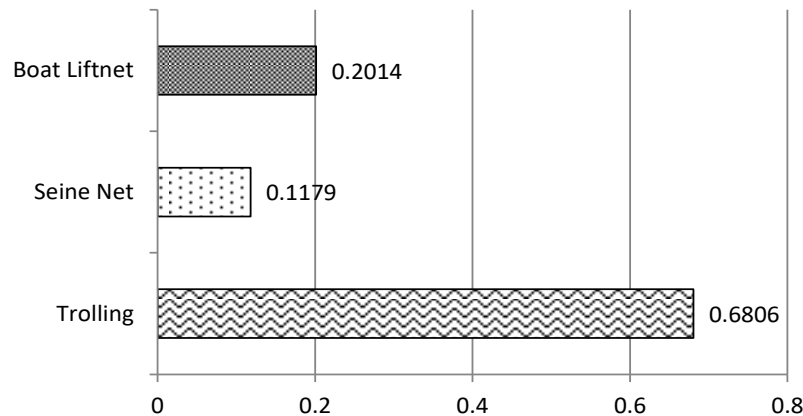


Figure 12. Comparison of weighted value of fishing gears considering: Low impact on biodiversity criterion

8) *Does not endanger the protected fish.* The value of each fishing gear was evaluated considering its impact on protected fish. The value for trolling is 0.685, for boat liftnet is 0.22, and for seine net is 0.093 (Figure 13). Fishing gear has the potential to catch fish in protected areas. All fishing gears studied can catch protected fish in addition to target fish. The CR value on the criterion that it does not affect protected fish is 0.0733, so it is consistent because it is ≤ 0.1 .

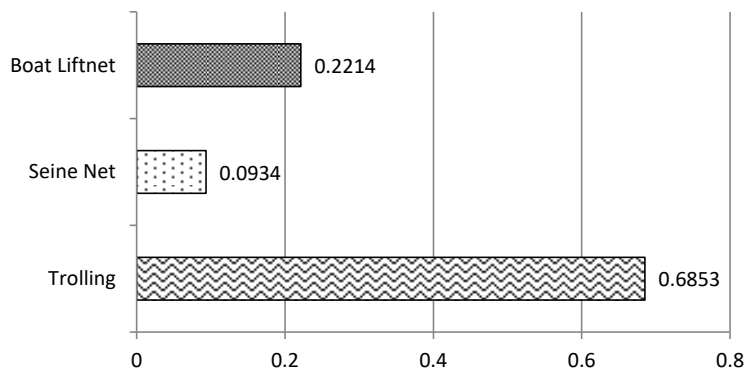


Figure 13. Comparison of weighted value of fishing gears considering: No harm to protected fish criterion

9) *Social acceptance.* The value of each fishing gear was evaluated considering its social acceptability. The value for trolling is 0.73, for boat liftnet is 0.19, and for seine net is 0.08 (Figure 14). Trolling and boat liftnet are socially accepted because they do not generate conflict with cultural customs, existing regulations, and they are socially beneficial, but they require an expensive investment. Seine net fishing gear is not socially acceptable because investment costs are expensive, contrary to regulations and bring low benefits. The CR value on the socially accepted criteria is 0.0544, so it is consistent because it is ≤ 0.1 .

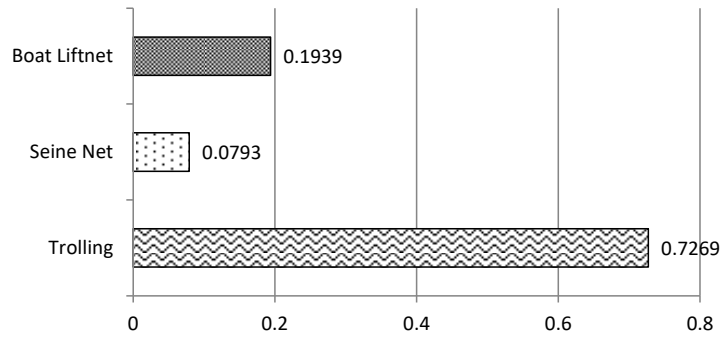


Figure 14. Comparison of weighted value of fishing gears considering: Social acceptability criterion

A comparative overview of values for the three fishing gears for all criteria are presented in Figure 15.

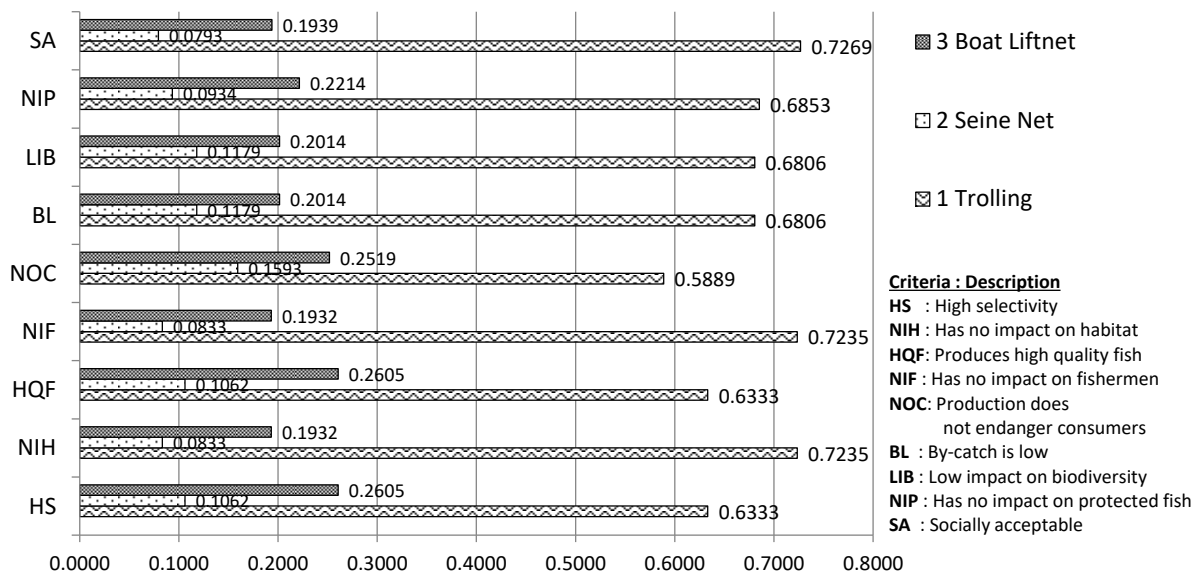


Figure 15. Comparative view of fishing gear environmental friendliness level for all criteria

The results of the analysis of the environmental friendliness evaluation of the fishing gear indicate that the most environmentally friendly one is the trolling, the second is the boat liftnet, while the seine net is not environmentally friendly. Seine net (payang) has a general priority level of criteria that is not environmentally friendly because it has a value of less than 1 or in 0.9468, while boat liftnet and trolling have values higher than 1 (Table 6).

Table 6.

Catching tools priority value

| Catching tools | Value |
|--------------------|--------|
| Trolling | 6.0759 |
| Boat liftnet | 1.9774 |
| Seine net (payang) | 0.9468 |

Two of the three analyzed fishing gears have the potential to bring conflicts, namely the boat liftnet and seine nets. The conflicts can result in the following situations.

- 1) Potential conflicts can arise in relation to catch areas/locations for fishing. Certain locations provided more fish than others. Consequently, conflicts may appear due to competition for best fishing locations.
- 2) Conflicts can occur due to differences between gears regarding their fishing capacity of the same type of fish. Vessels over 30 GT capacity which have more lights will attract more fish, affecting the orientation of the nearby fish targeted by smaller vessels and, thus, diminishing the catch of the latter.
- 3) Conflicts can arise from violations of territorial areas. For example, coastal waters are reserved for traditional fishermen, but fishermen who have more sophisticated fishing gear enter these waters and target the same type of fish as traditional fishermen.

Conflicts of interest can be avoided by implementing good management including access control over the type, size, and number of fishing gears and fishing locations/areas. For example, conflict of use of light at night between boat liftnet and seine net can be prevented by setting the distance among the boats and intensity of the light.

Conclusions. This paper presents the analysis of environmental friendliness of three types of fishing gears as they were used in the southern coastal waters of West Sumatra in September 2020. The nine criteria for environmental friendliness recommended by FAO (2018) and MMAF (2012) and the AHP (Analytical Hierarchy Process). The results show that trolling and boat liftnet fishing tool are environmentally friendly fishing gear, while the seine net fishing used in these waters is not environmentally friendly. To conserve biodiversity and maintain fish stocks in the study area, authors of this study recommend to gradually reduce the use of not environmentally friendly fishing gear (seine net) and to use fishing gear with a higher level of environmental friendliness (trolling and boat liftnet).

Conflict of interests: The authors declare no conflict of interest.

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