The zoning plan for coastal and small islands: an evaluation of its implementation on small-scaled fisheries in North Sulawesi Waters of Indonesia

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Abstract. The zoning plan for coastal and small islands (ZPCSI) is a marine spatial plan that determines the marine spatial structure and marine spatial zone. The North Sulawesi Province has issued the provincial regulation for the ZPCSI. However, there are some issues in North Sulawesi, such as the uncertainty of fishing grounds for small-scaled fishers, the overlap of fishing zones with other utilization, and conflicts among marine resources users. Therefore, this study was conducted to evaluate the implementation of ZPCSI related to the dynamics of small-scaled fisheries in the waters of North Minahasa, North Sulawesi. This study employed scoring and weighting methods to analyze oceanographic parameters, carrying capacity, and the utilization of fish aggregating devices (FADs). The oceanographic parameters considered were current speed, sea surface temperature, chlorophyll-*a*, wave height, carrying capacity was calculated based on coral reef, mangrove, and seagrass areas. The results indicated that the waters of North Minahasa are predominantly occupied by small-scaled fishers targeting tuna and skipjack using handlines. The existing fishing areas for tuna and skipjack are still within the North Sulawesi ZPCSI fishing zone but overlap with other utilization zones, potentially leading to conflicts. While the percentage of non-overlapping zones is only 18%, the percentage of fishing grounds with potential overlaps is greater at 82%. Potential conflicts between fishing zones and other use zones, such as conservation areas, port zones, shipping lanes, and underwater cable routes, typically occur in the fishing grounds. The recommended potential area for tuna and skipjack fishing is 13,397.85 hectares, while the area with sufficient development potential is 229,173.45 hectares. According to MMAF Regulation No. 7 of 2022 concerning the allocation of FADs in fishing zone III, the designation for placing FADs is outside the ZPCSI, possibly at a distance of 15.99 km, or 8.63 nautical miles, from the coastal area, with the furthest distance being 39.96 km, in addition to making it easier for small-scaled fishers to catch in the fishing zone by adding device for fishing in the form of placing FADs that are designed to be in the ZPCSI area specifically for small-scaled fishers.

Key Words: carrying capacity, conflict, fishing zones, overlay method small-scaled fisheries.

Introduction. The marine spatial plan known as the Coastal and Small Islands Zoning Plan (ZPCSI) determines the marine spatial structure and marine spatial zones. The ZPCSI rules also outline activities that are permitted, prohibited activities, and require stakeholder approval before they can be carried out. Law Number 27 of 2007 concerning the Management of Coastal Areas and Small Islands (ZPCSI Law) (MMAF 2007) is the framework for the provincial ZPCSI. ZPCSI was established in North Sulawesi Province through a Province Regulation (Provreg) concerning ZPCSI in North Sulawesi Province (Doman 2019). The establishment of the ZPCSI in North Sulawesi Province was enacted on March 14, 2017, through North Sulawesi Provincial Regulation (Provreg) No. 1 of 2017, concerning Zoning Plans for Coastal Areas and Small Islands of North Sulawesi Province for the period 2017-2037 (North Sulawesi Provincial 2017).

The division of areas in the ZPCSI is classified into four areas: General Utilization Areas, Conservation Areas (or Marine Protected Area – MPA), Specific National Strategic Areas, and Sea lines. Furthermore, each area is further divided into zones. The spatial utilization function of each zone has been agreed between various interest users and on the basis of applicable laws (Parjito et al 2022). The context of marine spatial zoning can increase stakeholder and community participation, promote ecosystem-based management and improve comprehensive management and utilization of marine area through social-ecological systems (Jacob et al 2023; Short et al 2023). Stakeholder and community participation aims to provide a transparent planning foundation and facilitate the creation and purpose for planning (Bonnevie et al 2023). The application of zoning can minimize potential conflicts of interest as the division of marine zones is based on respecting the interests of other users (Hastira et al 2022; Madarcos et al 2022; Short et al 2023). Establishing distinct geographic boundaries and management plans for specific areas can open opportunities for new economic growth (Short et al 2023).

North Sulawesi waters are included in the Eastern Indonesian waters, with great potential for yellow-fin tuna (*Thunnus albacares*) and skipjack tuna (*Katsuwonus pelamis*) fisheries. This is also confirmed in the study of Puansalaing et al (2021) that pelagic fish commodities including tuna and skipjack have a high and abundant distribution in Sulawesi waters. Tuna and skipjack are classified as economically important commodities and have great development opportunities in Indonesia after shrimp commodities (Nugraha & Mardlijah 2017). North Minahasa Regency is one of the regencies with high total marine capture fisheries production in North Sulawesi Province, amounting to 35,182 tons. The total catch of skipjack and tuna as the main commodities in 2020 includes 1,771 tons for skipjack and 2,742 tons for tuna (Regional Environment of North Sulawesi Agency 2021). This has led to the dependence of many coastal communities, especially small-scaled fishers, on the fisheries sector for livelihoods (Wildlife Conservation Society 2021). One of the largest number of fishers in North Sulawesi Province is in North Minahasa Regency with 2,169 fishers. This figure is the second highest after Mongondow Regency with 2,710 fishers. The total number of fishers in North Sulawesi Province reached 11,237 fishers (MMAF 2021a).

Capture fisheries zones according to the ZPCSI Provreg are categorized in general use areas along with other zones. This can trigger utilization conflicts between various interests. The issue of conflict over the spatial utilization of North Minahasa waters, North Sulawesi is also stated in the Regional Marine and Fisheries Service of North Sulawesi Agency (2019, 2021), that the many activities in North Minahasa waters will pose a threat of conflict. The existence of different interests between small-scaled fishers and private parties managing other utilization zones outside the fishing zone will interfere with the comfort and safety of small-scaled fishers (Manoppo 2013). Therefore, this study aims to evaluate the implementation of ZPCSI on the dynamics of small-scaled fisheries in North Minahasa waters, North Sulawesi. The results of the study can serve as a recommendation for the government to formulate a more appropriate fishing zone planning in line with the existing conditions of North Minahasa waters in North Sulawesi. Thus, marine spatial zoning planning can play an effective role in minimizing utilization conflicts in the North Minahasa waters of North Sulawesi and increasing fish resource production for small-scaled fishers in the region.

Material and Method

Description of the study sites. The study site is located in North Minahasa Regency, North Sulawesi Province (Figure 1). The study area is 14 miles from the coast towards the open sea with an area of 437,439.13 ha. The specific coordinates of the study site are presented in Table 1.

Table 1

Coordinates of the research location

Longitude	*Latitude*
124° 31' 34.732" E	2° 6' 30.700" N
125° 23' 50.094" E	2° 6' 29.052" N
124° 31' 34.715" E	1° 24' 12.601" N
125° 23' 52.243" E	1° 24' 11.720" N

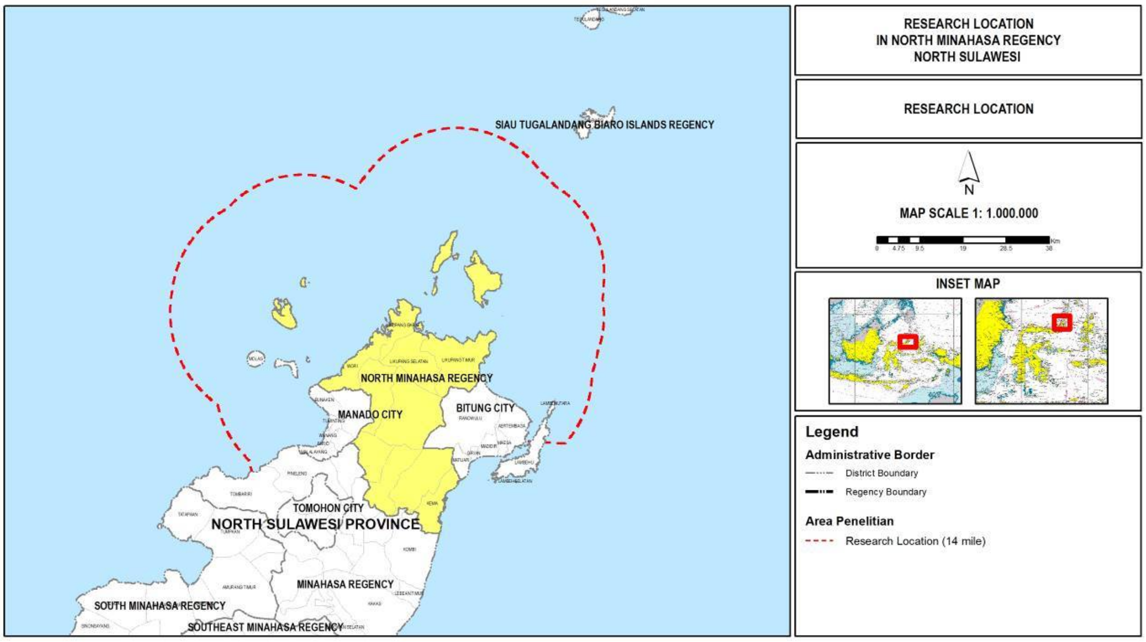

Figure 1. Research location in North Minahasa Regency, North Sulawesi.

Data and instruments. The data used in the study is categorized into 3 data variables, namely:
- oceanographic data such as chlorophyll-*a*, sea surface temperature (SST), salinity, dissolved oxygen, brightness, wave height, current speed and ocean depth. Each oceanographic parameter data was obtained through Copernicus Climate Change Service (C3S) ERA5 ECMWF atmospheric reanalysis of the global climate covering and Global Ocean Bio-geochemistry Analysis and Forecast for the period of March to November 2022;
- spatial utilization data such as conservation areas, port zones, tourism zones, aquaculture zones, capture fisheries zones, fish migration flows, shipping lanes, and undersea cable pipelines, obtained through North Sulawesi Provincial Regulation Number 1 of 2017 concerning Zoning Plans for Coastal Areas and Small Islands of North Sulawesi Province 2017-2037 (North Sulawesi Provincial 2017);
- habitat data, such as coral reef and mangrove areas obtained through North Sulawesi Province data set.

Data processing procedures. The collected study data (oceanographic data, spatial utilization, and habitat data) were processed using the Weighted Overlay method with the calculation of euclidean distance and classification through the reclassify tool (Figure 2).

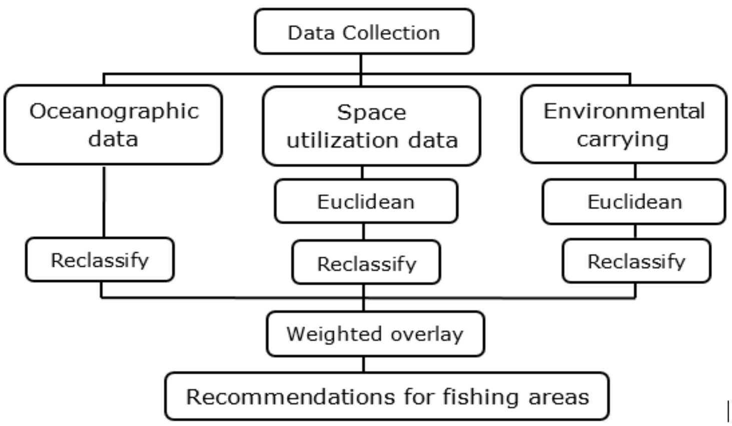

Figure 2. Data processing diagram.

The weighted overlay method is a spatial analysis by combining several raster maps related to certain factors that affect the resolution of research problems (Adininggar et al 2016; Irsyad et al 2022). Various kinds of research inputs will be combined in the form of grid maps with weigted factors from Analitycal Hieararchy Process (AHP) experts. Problem solving that has many criteria such as optimal site selection or suitability modeling can be solved using the weighted overlay method (Adininggar et al 2016).

The description of the study problem solving using the weighted overlay method is presented more specifically as follows:

- determine the scores and weights of criteria and sub-criteria using the AHP method first. There are 17 criteria used in the study, namely (1) chlorophyll-*a*; (2) SST; (3) salinity; (4) dissolved oxygen; (5) brightness; (6) wave height; (7) sea depth current speed; (8) distance of conservation areas; (9) port zones; (10) tourism zones; (11) aquaculture zones; (12) capture fisheries zones; (13) fish migration routes; (14) fisheries zones; (15) shipping lanes; (16) underwater cable pipelines; and (17) distance of coral reef areas and mangrove areas;
- oceanographic data need to be processed by performing classification through the reclassify tool. Data that was previously still general in nature will be classified according to the specified class as shown in Figure 3 and 4.

Data on areas utilization and environmental/habitat were determined based on distance. Therefore, it is necessary to calculate the distance by measuring the distance of two points/buffers based on distance through the "euclidean distance" tool so that a value can be given (Figure 5). The euclidean distance calculation is used to group the data in several predetermined clusters. Furthermore, classifying with the "reclassify" tool so that data that was previously still general will be made a class according to the specified class (Figure 6).

Analysis of location determination based on the value processed from the results of the "reclassify" analysis in the previous stage. The determination of weights refers to the variables that are most influential in determining the location of fishing ground. The analysis tool used is "weighted overlay" (Figure 7). The scale value column shows the value based on the class. The % influence column interprets the weight of the variable influence.

All parameters were reclassified into three classes and scored on a scale of 1-3 where 3 is the highest value and 1 is the lowest value. The class division can be seen in Table 2.

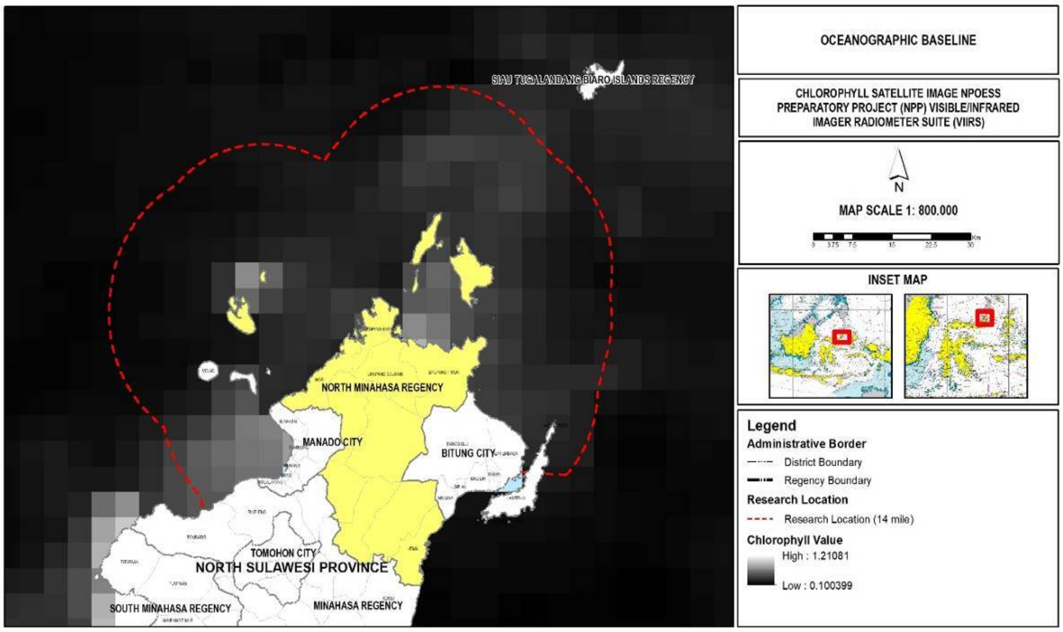

Figure 3. The oceanographic baseline file format has the extension TIFF.

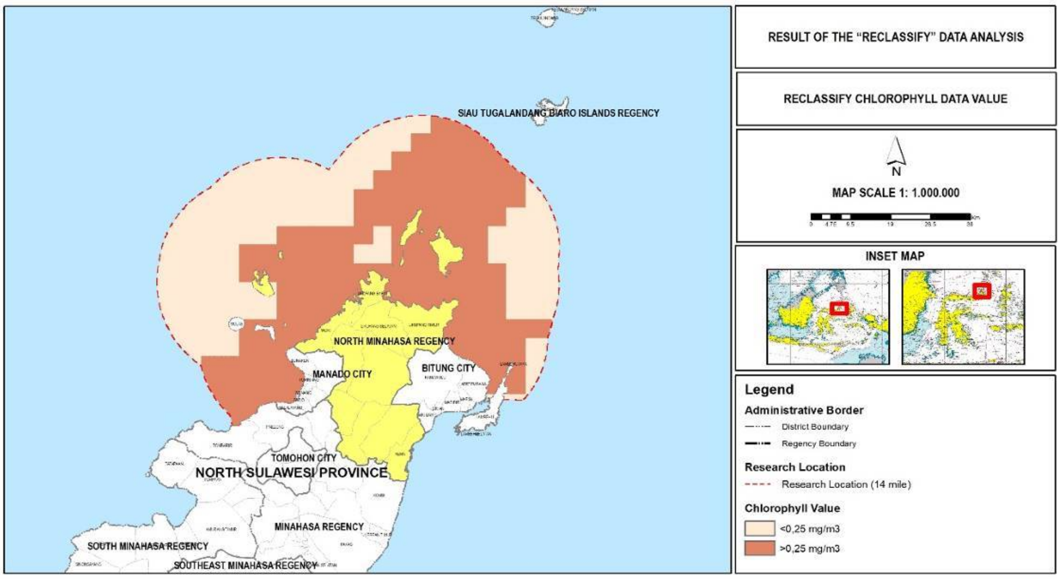

Figure 4. Result of the *reclassify* data analysis file format has the extension shape file.

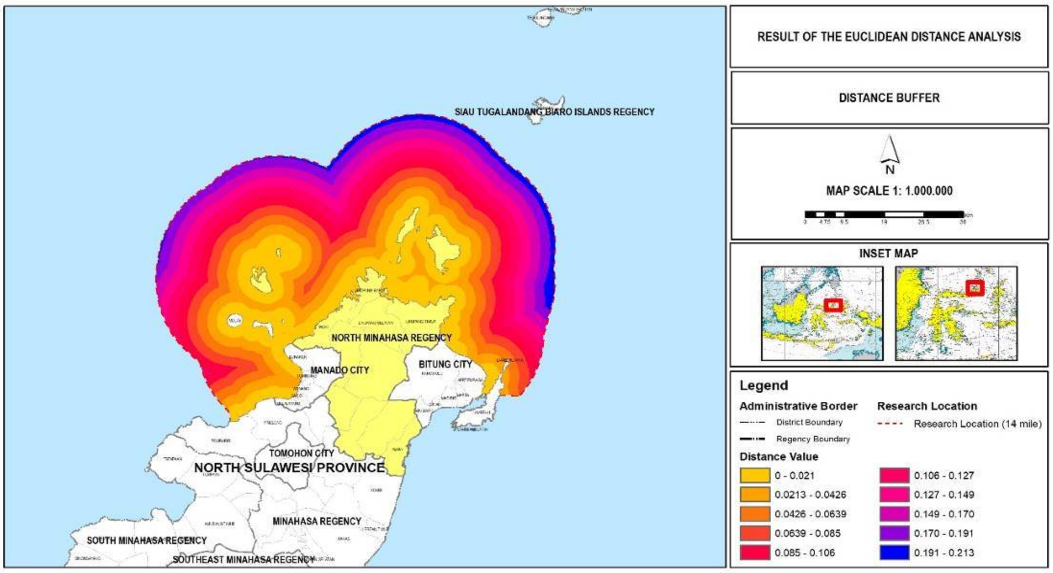

Figure 5. Result of the *Euclidean distance* analysis.

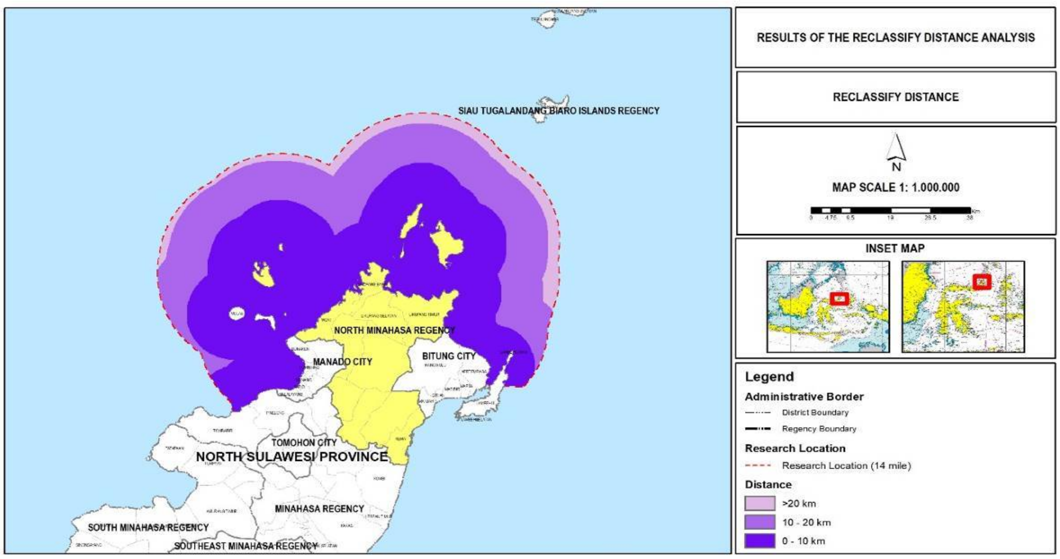

Figure 6. Results of the *reclassify* analysis.

Raster	% Influence	Field	Scale Value
Conservation_Area	3	Value	
		2	2
		3	3
		4	4
		5	5
		6	6
		7	7
		8	8
		9	9
		10	10
		NODATA	NODATA
Port_Area	3	Value	
		2	2
		3	3
		4	4
		5	5
		6	6
		7	7
		8	8
		9	9

Figure 7. Weighted overlay processing.

Table 2

Criteria for oceanographic parameters and environmental carrying capacity for fishing zone evaluation

Parameters	*Unit*	*Good*	*Medium*	*Bad*
Distance of coral reef zone to fishing ground (Wangi et al 2019)	km	0-10	10-20	> 20
Distance of mangrove zone to fishing ground (Wangi et al 2019)	km	0-10	10-20	> 20
Distance between conservation zone and fishing ground (Wangi et al 2019)	km	0-10	10-20	> 20
Distance of harbor zone from fishing ground (Wangi et al 2019)	km	> 20	10-20	0-10
Distance of sea channel zone (fish migration) (Wangi et al 2019)	km	> 20	10-20	0-10
Sea channel zone distance (shipping channel) (Wangi et al 2019)	km	> 20	10-20	0-10
Seaword zone distance (pipeline/marine cable) (Wangi et al 2019)	km	> 20	10-20	0-10
Distance between tourism zone and fishing ground (Wangi et al 2019)	km	> 20	10-20	0-10
Distance of aquaculture zone to fishing ground (Wangi et al 2019)	km	> 20	10-20	0-10
Chlorophyll-*a*	mg m^{-3}	> 0.25	0.25-0.12	< 0.12
Temperature	^{o}C	19-23 (skipjack)	24-30	> 30
		20-28 (yellowfin tuna)	29-30	> 30
Salinity (Sepri 2012)	mg L^{-1}	30-36		< 30 and > 36
Dissolved oxygen	mg L^{-1}	5-8		< 5 and > 8
Brightness	m	14-18		< 14 and > 8
Swimming layer (depth)	m	10-40 (skipjack)	40-80	> 80
		10-200 (yellowfin tuna)	200-400	> 400
Wave height (Wangi et al 2019)	m	0-1	1-2	≥ 3
Current speed (Wangi et al 2019)	m s^{-1}	0.1-0.3	0.3-0.4	> 0.4

Results

Small-scaled yellow-fin tuna and skipjack tuna fishing. The distribution of the number of fishers in the North Minahasa region is presented in Table 3. The number of fishers is grouped according to two sub-districts, namely East Likupang and West Likupang sub-districts. The total number of fishers according to the two sub-districts reached 2,168 fishers.

Table 3

Number of fishers in North Minahasa Regency

District	*Village*	*Number of fishers (people)*
East Likupang	Likupang II	1,000
	Likupang Kampung Ambon	159
West Likupang	Bulutui	300
	Munte	250
	Tarabitan	200
	Bahoi	100
	Jayakarsa	80
	Paputungan	79
Total		2,168

Source: Wildlife Conservation Society (2021).

The distribution of the type and number of fishing boats used by fishers in North Minahasa Regency is presented in Table 4. The types of boats used are divided into three, namely motor boats, outboard motors, and boats without motors. The average boats gross tonnage (GT) used by fishers of North Minahasa Regency is 5-100 GT. However, the most dominant average GT is < 5 GT.

Table 4

Distribution of fishing boats in North Minahasa Regency

Ship type	*GT size*	*Number of ships*
Motorboat	< 5	235
	5-10	133
	10-20	9
	20-30	2
	30-50	3
	50-100	4
Outboard motor	> 5	280
	5-10	70
	10-20	101
	20-30	30
Boat without motor		500
Total		1,367

Source: MMAF (2021b).

The distribution of fishing gear used by fishers of North Minahasa, North Sulawesi is shown in Table 5. Handline fishing gear is the dominant fishing gear used by North Minahasa fisher. The percentage of the use of handline has the highest value compared to other fishing gear at 30%. Handline fishing gear has a main structure in the form of a fishing reel, swivel, fishing line, sinker and hook. The structure of handline is presented in Figure 8.

Table 5

Distribution of fishing gear in North Minahasa Regency

Fishing gear group	*Type of fishing gear*	*Percentage (%)*
Hook and lines	Handlines	30
	Kite fishing	5
	Drift longline	8
	bottom longline	13
	Tuna longline	3
Gill nets	Fixed gill net	22
	Encircling gill net	4
	Drift gill net	3
Clamp and wounding gears	Arrow/Spearguns	6
Surrounding net	Purse seine	3
Lift nets	Boat lifnet	1
Traps	Basket trap	1
	Guiding barrier trap	1

Source: Wildlife Conservation Society (2021).

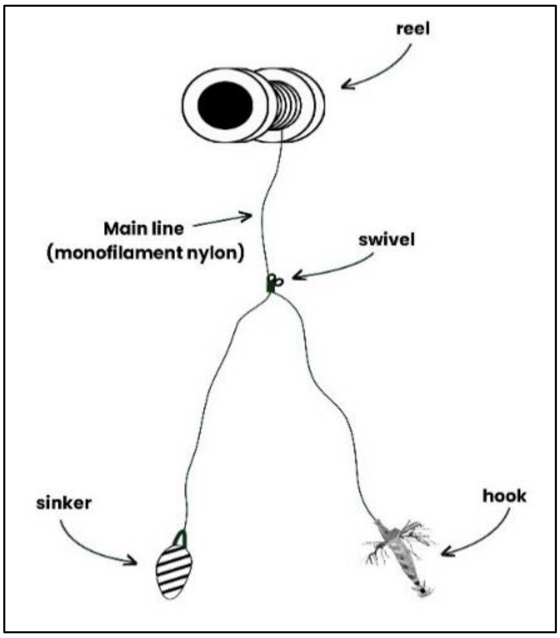

Figure 8. Handline structure.

Map of utilization zone of North Sulawesi waters, Minahasa according to ZPCSI. The marine spatial utilization zone map of North Minahasa waters according to the North Sulawesi ZPCSI document is shown in Figure 9.

There are 7 zones of marine spatial utilization and 4 structures of marine spatial utilization in the waters of North Minahasa, North Sulawesi (Figure 9). Each marine spatial utilization zone has a different area. Marine spatial utilization zone include aquaculture zone (1,627.35 ha), port zone (1,103.05 ha), tourism zone (2,569.11 ha), conservation area (81,885.77 ha), biota migration route (23,407.79 ha), public facility zone (697.54 ha), and capture fisheries zone (325,274.91 ha). Marine spatial structures operating around the water area include shipping lanes, submarine cable-ways.

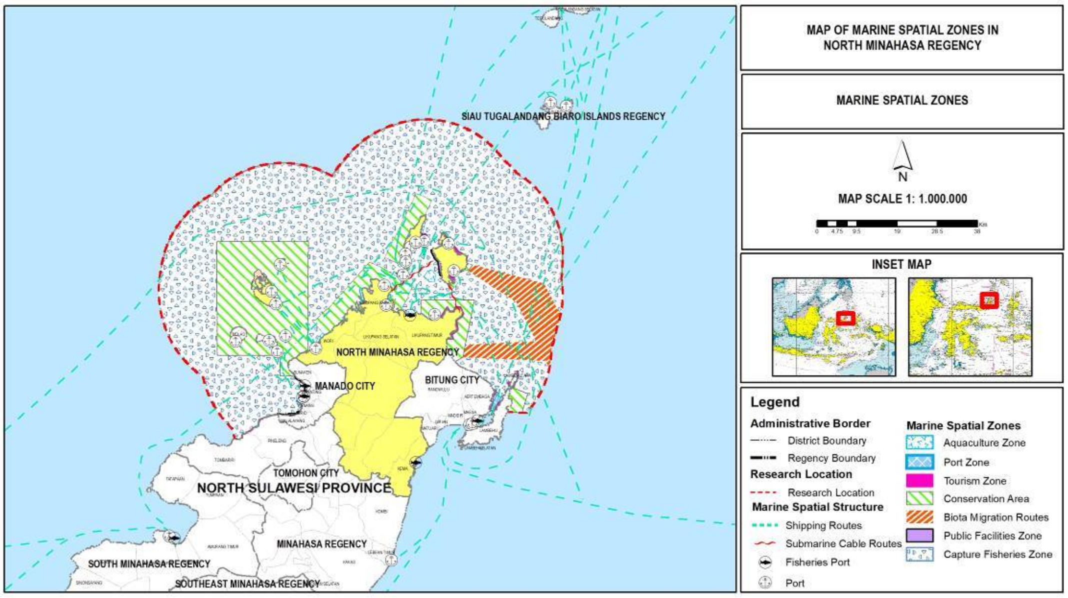

Figure 9. Marine spatial zones map of North Minahasa waters according to ZPCSI.

Map of the FADs North Sulawesi waters, North Minahasa. Fish aggregating devices (FADs), as defined in Article 1 of MMAF Regulation No. 7 of 2022 concerning the allocation of FADs in fishing zone III in the fisheries management area of the Republic of Indonesia (MFARI), have a function to attract fish (MMAF 2021d). These devices have been widely used in various regions worldwide and have been shown to enhance fishing efficiency and productivity. There are two main types of FADs: drifting FADs and sedentary FADs. Drifting FADs are deployed in open waters and move with ocean currents, attracting pelagic fish species such as tuna. Sedentary FADs, on the other hand, are anchored to the seabed and provide a stable structure for fish to aggregate around the FADs (Valles 2023).

The use of FADs has several benefits for fishing operations. By concentrating fish around these devices, fishers can save time and fuel by targeting fish in specific areas, increasing catch rates, and reducing the need for extensive searching (March & Failler 2022). The FADs also help to reduce bycatch of non-target species when properly designed and implemented (Chassot et al 2019). The deployment of FADs typically involves simple structures consisting of floats, anchor ropes, weights, attractors, guard houses, and marker poles (Suprianto et al 2017). The strategic placement of FADs in specific areas can contribute to sustainable fisheries management by optimizing fish aggregation and improving fishing efficiency.

In the case of the waters of North Minahasa, North Sulawesi, which fall within the management area of fisheries management area of the Republic of Indonesia (MFARI) 716, the distribution of FADs is outlined in MMAF Regulation No. 7 of 2022, as shown in Figures 10 and 11. This regulatory framework aims to support responsible and sustainable fishing practices in the region while maximizing the benefits of FADs utilization.

The distribution of FADs in MFARI 716 (Figure 10) and the distribution of FADs in North Minahasa waters (Figure 11) show that FADs are installed outside the ZPCSI area. The closest FADs distance from the coastal area from the east side is 60.8 km or approximately 32.82 nautical miles, while from the west side is 93.6 km or approximately 50.53 nautical miles.

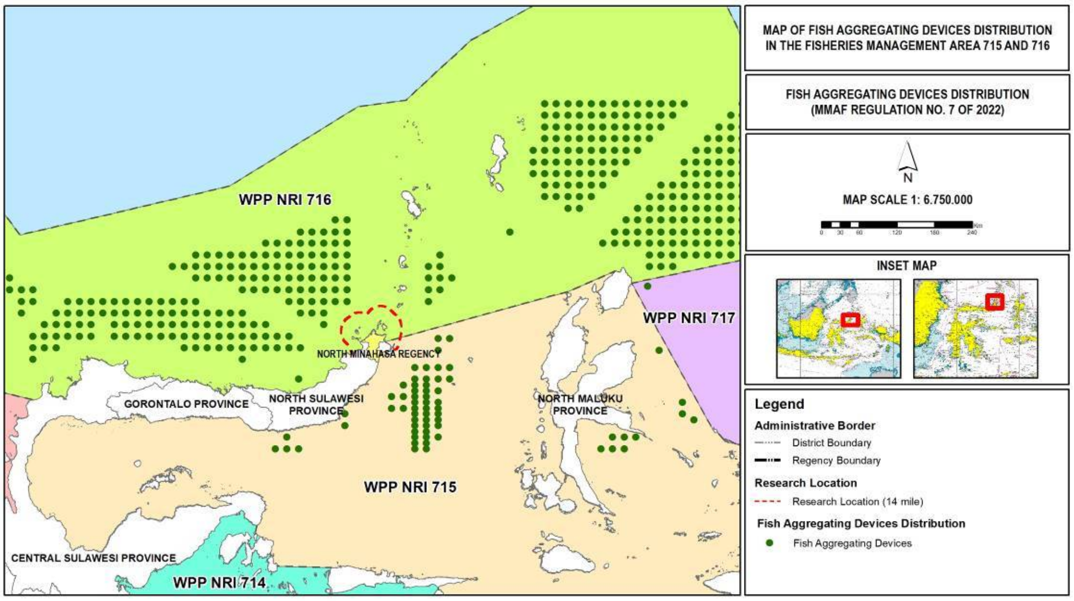

Figure 10. FADs distribution map in WPPNRI 716.

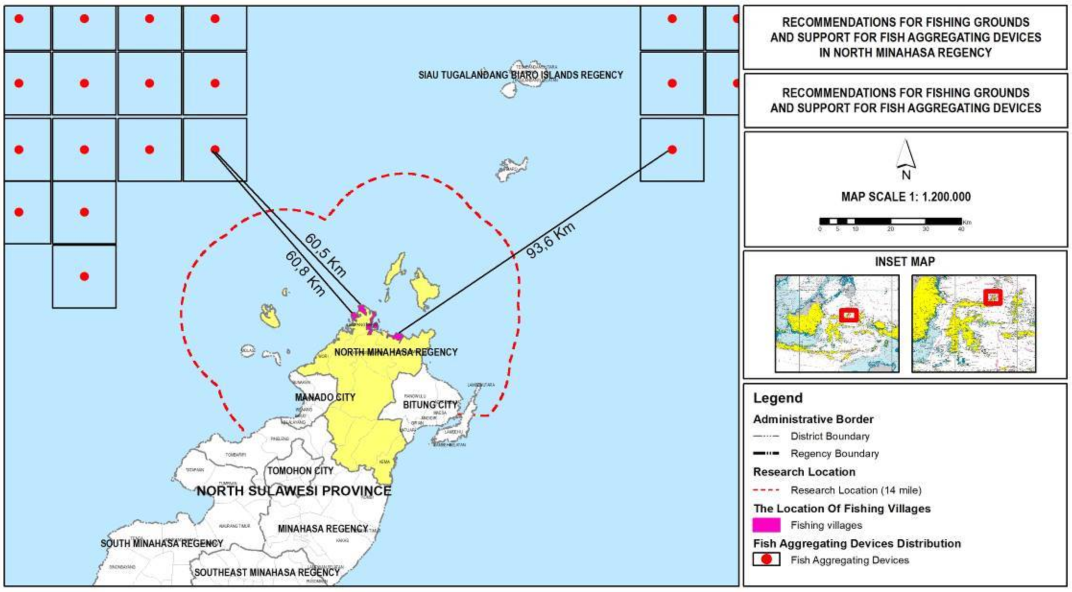

Figure 11. FADs distribution map in North Minahasa waters.

Existing fishing area in North Minahasa waters, North Sulawesi. The fishing grounds for tuna and skipjack as target fish in North Minahasa waters, North Sulawesi are presented in Figure 12.

Tuna and skipjack fishing ground coordinate in North Minahasa waters are interpreted in purple (Figure 12). Tuna and skipjack fishing ground coordinate are more widely distributed outside the study area which is more than 14 miles away. According to the study results, the fishing ground coordinates outside the research area, are related to the installation of FADs as a device to attract fish outside the research location. This causes more fish to gather in the area of the waters where FADs are installed. In fact, the spillover point is more in the conservation area and is more supported by environmental parameters. The number of FADs installed outside the ZPCSI area causes more potential fishing ground coordinates outside.

Furthermore, tuna and skipjack fishing grounds coordinates in ZPCSI will be overlaid with other utilization zones (aquaculture zone, port zone, tourism zone, conservation area, biota migration route, and public facility zone). The results of overlaying tuna and skipjack fishing grounds coordinates in North Minahasa waters with other utilization zones according to ZPCSI are presented in Figure 13.

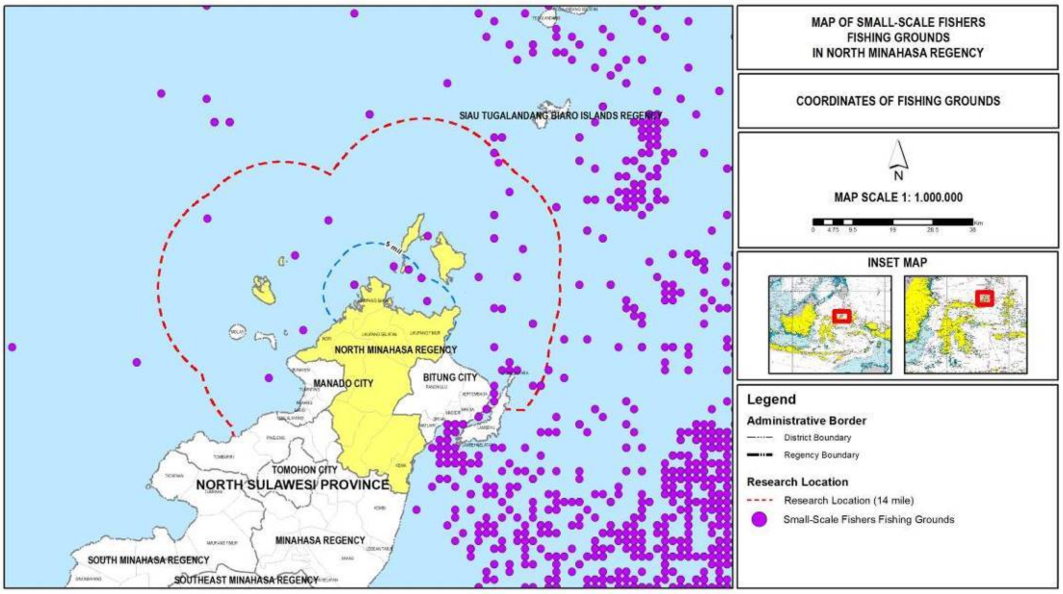

Figure 12. Tuna and skipjack fishing grounds in North Minahasa waters.

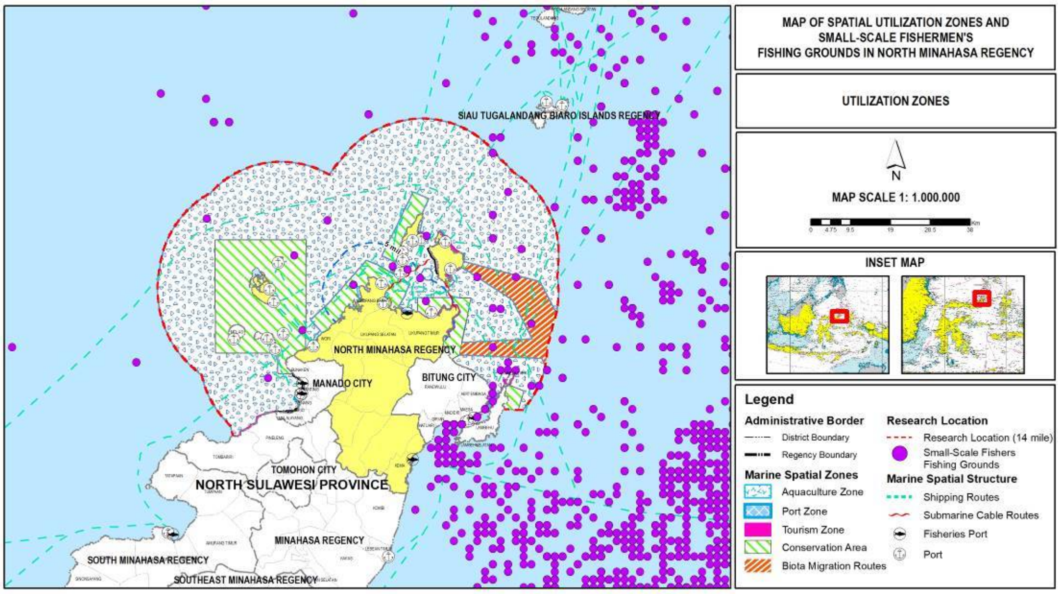

Figure 13. Results of overlaying tuna and skipjack fishing grounds coordinates in North Minahasa waters with other utilization zones according to the North Sulawesi ZPCSI document.

The overlay results interpret that there are several fishing grounds coordinates that overlap with other utilization zones (aquaculture zone, port zone, tourism zone, conservation area, biota migration route, and public facility zone), causing the risk of conflict. The potential conflict fishing zone in North Minahasa waters is presented in Figure 14.

Utilization zones with high potential for conflict are indicated by red dots (fishing grounds coordinates) while zones with no potential for conflict are indicated by green dots (fishing grounds coordinates) (Figure 14). The percentage of fishing grounds coordinates with potential conflicts has a higher value of 82% while the percentage of areas without potential conflicts is only 18%. Potential conflicts in fishing grounds are dominant in fishing grounds that overlapped with other utilization zones such as conservation areas, port zones, shipping lanes and submarine cable-ways.

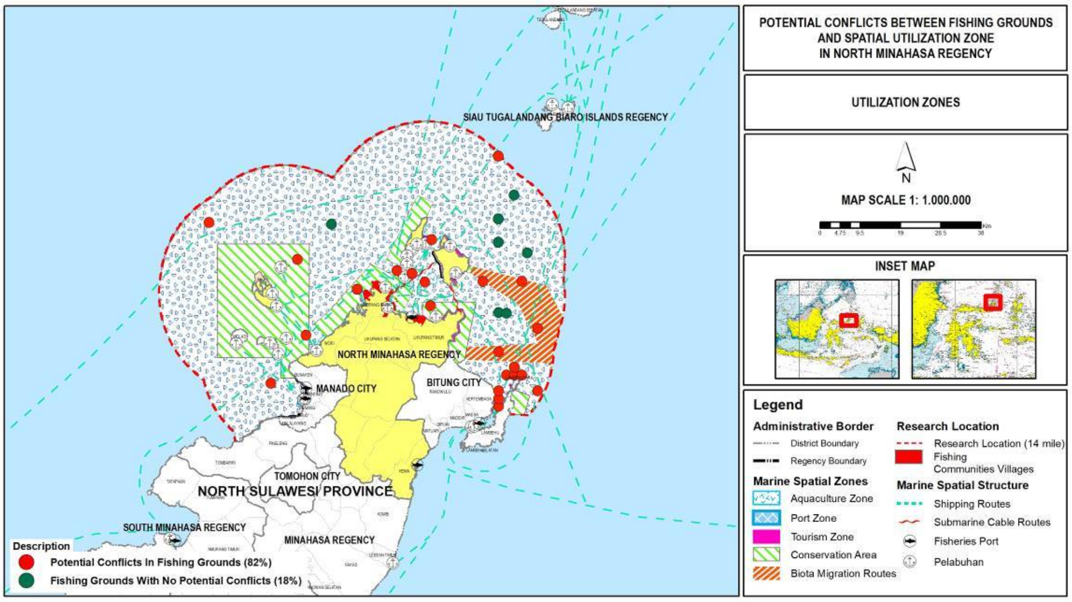

Figure 14. Potential conflicts between fishing grounds and other uses.

Evaluation of physical resilience of capture fisheries in determining fishing zone*.* The ZPCSI document only provides global capture area information. The evaluation results are obtained through a combination of various oceanographic parameters and water carrying capacity. The results of the evaluation of the determination of tuna and skipjack abundance areas in North Minahasa are presented in Figure 15.

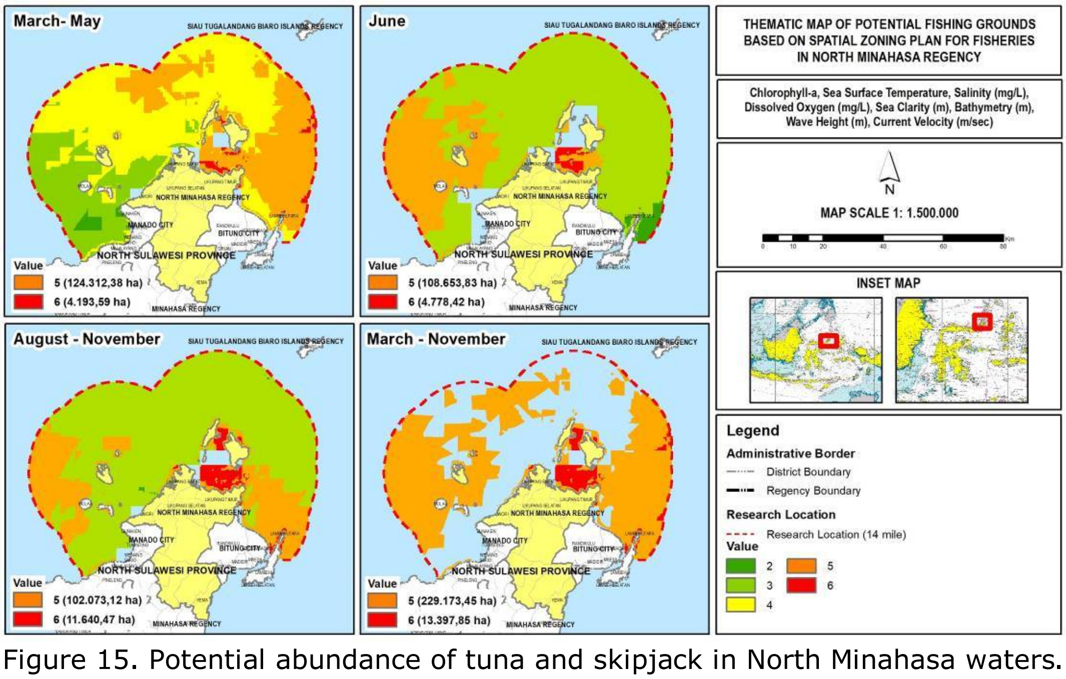

Figure 15. Potential abundance of tuna and skipjack in North Minahasa waters.

The map of potential abundance of tuna and skipjack in North Minahasa waters is shown in Figure 15. Green colour indicates areas with less potential abundance of tuna and skipjack, while red colour indicates more potential abundance. The possible area of potential commodity abundance in the March-November period is 229,173.45 ha for good commodity abundance (orange colour) and 13,397.85 ha for better commodity abundance (red colour). However, the abundance mapping is overall and has not been overlaid with other uses that are also in the area. The results of overlaying the potential abundance of tuna and skipjack with other uses are shown in Figure 16.

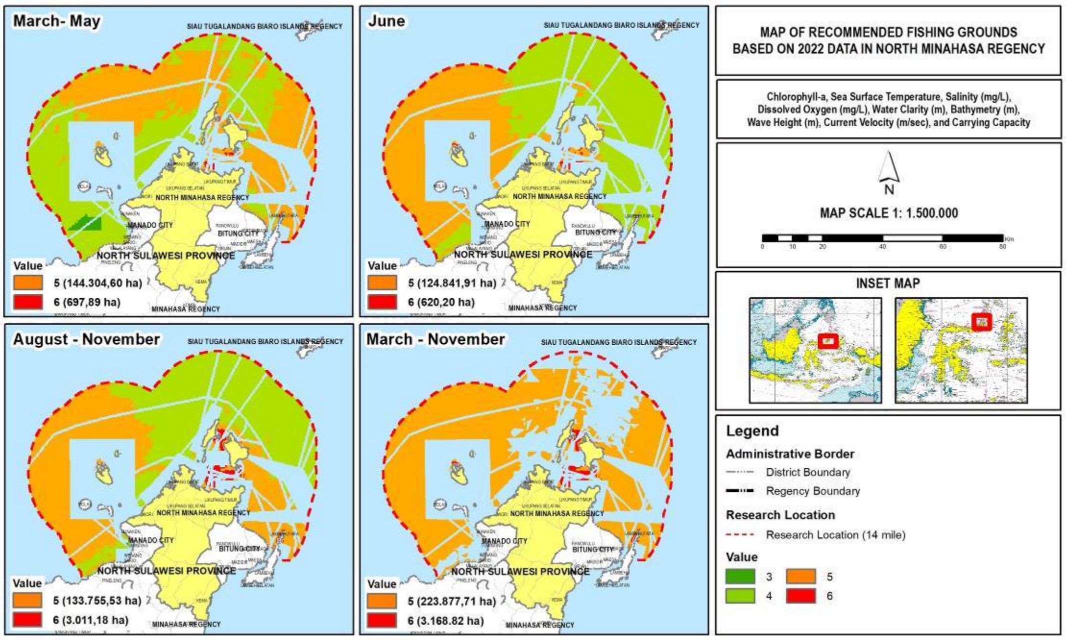

Figure 16. Results of overlaying tuna and skipjack abundance areas with other utilization zones.

The results of the overlay of tuna and skipjack abundance areas show a change in the value of the abundance area of 223,877.71 ha for areas with good abundance potential, while areas with very good abundance potential have an area value of 3,168.82 ha. The evaluation of existing fishing zones is also intended to minimize potential conflicts that occur so that convenience for all parties (small-scaled fishers and other utilization stakeholders) can be achieved.

Evaluation of FADs placement map in North Minahasa, North Sulawesi. The FAD placement evaluation was divided into 18 grids with the size of each grid being 18 x 18 km (Figure 17). The determination of the number and size of grids is based on MMAF Regulation 7 Year 2022 concerning the allocation of FADs in fishing line III in MFARI as well as MMAF's decision.

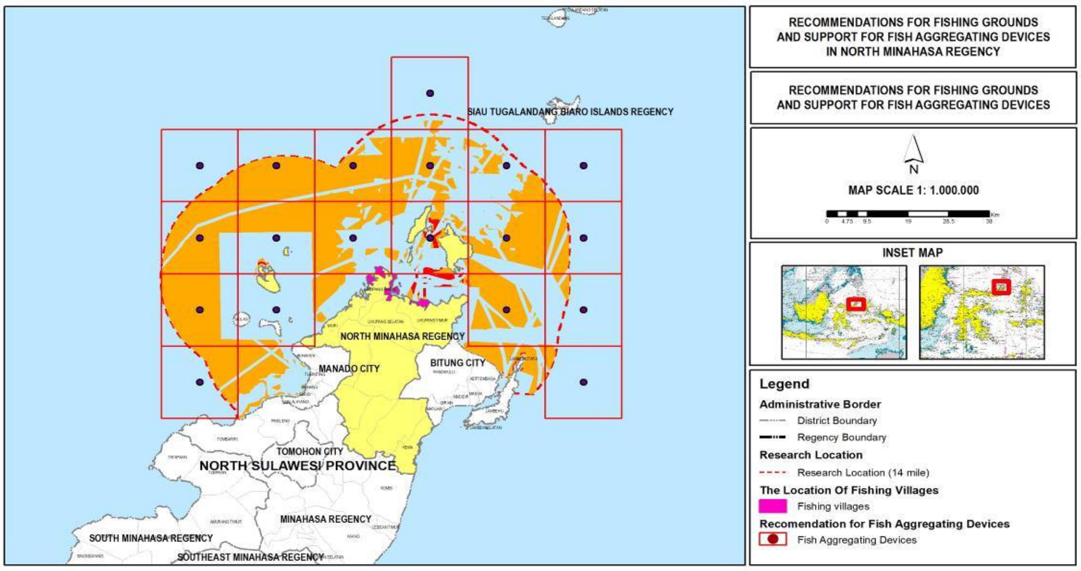

Figure 17. FADs placement design in North Minahasa waters.

Recommendations for the design of fishing potential zones. The recommendation map of tuna and skipjack potential fishing zone in North Minahasa waters is presented in Figure 18.

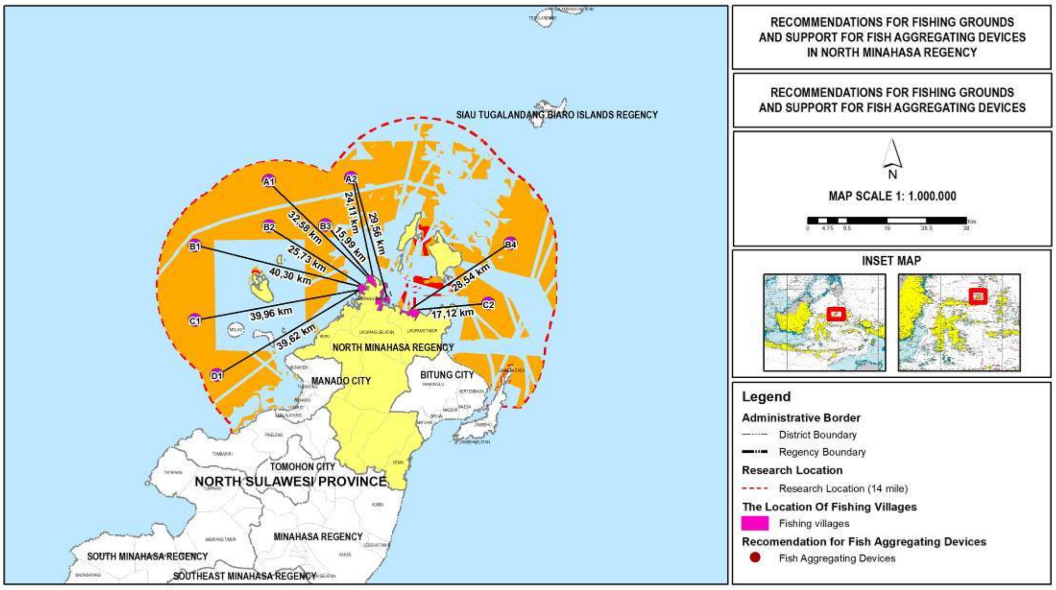

Figure 18. Recommendations for potential tuna and skipjack fishing areas in North Minahasa waters.

The two categories of recommendations for potential tuna and skipjack fishing zone in North Minahasa waters are the most potential area, with a surface of 13,397.85 ha, while the area with sufficient potential has a surface of 229,173.45 ha (Figure 18). The recommendation of potential fishing areas is also coupled with the support of FADs that are scattered in the recommended fishing zone. The closest distance of FADs installation from the coastal area is 15.99 km or approximately 10 nautical miles while the farthest distance is only about 39.96 km or approximately 24 nautical miles.

Discussion. Fishing activities in North Sulawesi are dominated by small-scaled fishers. The percentage of small-scaled fishers in the North Minahasa area of North Sulawesi reached 91.98% (Wildlife Conservation Society 2021). Small-scaled fisheries are defined as traditional fisheries that have limited capital and use relatively small labor. In addition, fishing activities are only carried out for local consumption with short fishing distances (near shore) (Halim et al 2020). These conditions indicate that small-scaled fishers have many limitations both in terms of facilities and infrastructure as well as financially, which causes the tendency for fishing activities to be carried out on a one-day fishing trip (Manoppo 2013). Traditional fisher or small-scaled fisher generally use longlines because they are simpler, cheaper, and easier to operate. Similarly, Hisyam et al (2020) stated that handline is a simple fishing gear that is also used to catch small pelagic fish.

These circumstances indicate that small-scaled fishers face numerous constraints in terms of infrastructure, financial resources, and the need to complete fishing trips within a single day (Marques & Feitosa 2022). These challenges are not unique to a particular region, as small-scaled fisheries worldwide often encounter similar limitations (Béné et al 2015). In fact, the importance of small-scaled fisheries extends beyond local communities. They also contribute significantly to global food security, nutrition, and economic well-being (FAO 2016). Recognizing this, FAO emphasizes the need to support and empower small-scaled fishers to enhance their livelihoods and ensure sustainable fishing practices (FAO 2017). Therefore, it is imperative for governments, institutions, and stakeholders to provide further attention and resources to promote the development and resilience of small-scaled fisheries globally (Béné et al 2015; FAO 2017). By addressing the infrastructure gaps, improving access to financial services, and promoting market opportunities, small-scaled fishers can overcome their constraints and contribute more effectively to local and global food security, as well as the overall socio-economic development (FAO 2016; Béné et al 2015).

The fishing zone in the waters of North Minahasa, North Sulawesi, according to the ZPCSI document has a total area of 325,274.91 hectares. The capture fisheries zone has the largest utilization area compared to other utilization zones. However, the designation of the area is still general for all types of fisheries commodities. The capture fisheries zone also overlaps with other utilization zones after overlay. The determination of the capture fisheries zone is based on Article 60 of MMAF Regulation No. 28 of 2021 concerning the implementation of marine spatial plans (MMAF 2021e). This determination considers various parameters such as existing marine spatial utilization, oceanographic parameters (currents, waves, surface temperature, chlorophyll, and salinity), coastal and small island ecosystems (mangroves, coral reefs, and seagrass beds), fish resources, marine socioeconomics, and maritime culture, coastal water resource balance, marine logistics systems, and disaster data and information.

In addition, the establishment of fishing zones is regulated in Article 2 of MMAF Regulation No. 59/2020 on fishing zones in Indonesia's Exclusive Economic Zone (EEZ) (MMAF 2020). It consists of three zones: fishing zone I, fishing zone II, and fishing zone III. The definitions of fishing zones I, II, and III are further explained in Article 3 of MPA Regulation No. 59/2020 (MMAF 2020):

- fishing zone I is divided into IA which covers waters 2 miles from the shoreline towards the open sea, and zone IB which covers waters beyond fishing zone I up to 4 miles;
- fishing zone II covers waters beyond fishing zone I up to 12 nautical miles;
- fishing zone III is outside fishing zone II and includes the Indonesian EEZ.

The diversity of utilization zones and fishing grounds coordinates that overlap with areas the fishing zone trigger conflicts in the waters of North Minahasa, North Sulawesi. The issue of conflicts related to spatial utilization of North Minahasa waters in North Sulawesi is also discussed in Regional Marine and Fisheries Service of North Sulawesi Agency (2019) and in Regional Environment of North Sulawesi Agency (2021). These documents highlight that various activities taking place in North Minahasa waters pose a threat of conflict. Conflicts of interest between small-scaled fishers and private parties managing other utilization zones outside the designated fishing zones can disrupt the comfort and safety of small-scaled fishers (Marques & Feitosa 2022). The development of activities in fishing grounds coordinates that overlap with other utilization zones contributes to the depletion of fish resources in coastal waters. Pollution activities and the use of environmentally unfriendly fishing gear degrade the quality of the coastal environment resulting in the destruction of fishing grounds (Regional Marine and Fisheries Service of North Sulawesi Agency 2019). The destruction of fishing grounds in coastal areas is a challenge for small-scaled fishers, as they face limited area and capital to conduct fishing activities further offshore.

Another issue highlighted in Dhoaly (2018) reporting is the difficulty of fishers in Minahasa Regency finding a safe place to moor their boats during bad weather. This difficulty is due to the construction of a 4 m high embankment on the beach and boat mooring area, making it more challenging for small-scaled fishers. Improper securing of boats in designated areas hampers fishing activities and increases the risk of damage to fishing boats. Fishing zone that overlaps with other utilization zones present many challenges, underscoring the importance of identifying potential fishing zones, especially for tuna and skipjack, by small-scaled fishers.

Uncertainty surrounding the potential tuna and skipjack fishing grounds in North Minahasa waters highlights the need to evaluate the fishing zones outlined in the North Sulawesi ZPCSI document. The ZPCSI document only provides global information on fishing grounds. The evaluation results are obtained by considering various oceanographic parameters and water carrying capacity. Any change in water carrying capacity will undoubtedly affect fishing activities. In addition, changes in oceanographic parameters can also have an impact on fish adaptation and behaviour. Each fishery commodity has a different tolerance range for oceanographic parameters, which are related to foraging and migration activities (Wangi et al 2019). MMAF Decree No. 121 of 2021, on tuna and skipjack management, also emphasizes the strong influence of oceanographic conditions, particularly temperature and salinity, on the abundance of tuna and skipjack resources (MMAF 2021c). The distribution of tuna and skipjack in waters is influenced by various internal and external factors. Internal factors are related to the biological condition of these commodities, while external factors are related to oceanographic parameters of the waters, such as temperature, salinity, density, depth of the thermocline layer, currents, oxygen levels, and food availability (Sepri 2012). Assessment of oceanographic parameters can help understand the water tolerance limits of each commodity. In addition, knowledge of oceanographic parameters suitable for tuna and skipjack can help in determining potential fishing grounds for these species (Kodama et al 2022). Evaluation of existing fishing zones aims to minimize potential conflicts and ensure convenience for all stakeholders, including small-scaled fishers and other utilization sectors.

Evaluation is not only carried out regarding the certainty of the fishing zone but also regarding the placement of FADs. Evaluation of FADs placement is conducted through a grid. The grid division for FADs placement evaluation aims to minimize conflicts that may arise during FADs installation. FADs as handline fishing aids often clash with fisher's nets. The installation of FADs is thought to interfere with the fishing line of net fisher and cause damage to the net, resulting in losses for fisher (Murua et al 2023). In addition, the indiscriminate installation of FADs in close proximity can disrupt fish migration patterns, disturb the balance of the ecosystem, and trigger conflicts between fishers.

The inclusion of FADs carrying capacity in the evaluation of potential tuna and skipjack fishing areas is also closely related to the role of FADs. FADs are expected to provide certainty of fishing areas to reduce the operational costs of small-scaled fishers. By acting as luring devices, FADs attract fish to congregate around them, facilitating fishers' access to fishing areas (Murua et al 2023). The insstallation of FADs leads to the aggregation of plankton communities in the operational area, attracting large numbers of small pelagic fish (Shadiqin et al 2018).

However, it is important to consider international experience and best practices in FADs placement to optimize their effectiveness. Studies conducted in different regions have highlighted the importance of strategic FADs placement for sustainable fisheries management. For example, in the Western Indian Ocean, studies have shown that well-designed FADs packages can increase fisheries productivity and contribute to socio-monetary development (Jaquemet et al 2011; Sadusky 2018).

Organizations around the world, such as the Indian Ocean Tuna Commission (IOTC) and the Western and Central Pacific Fisheries Commission (WCPFC), have developed tips and recommendations for FADs deployment to ensure accountable and sustainable fishing practices (Squires et al 2013; Shen & Song 2023). The best practice emphasizes the importance of thinking about ecological elements, along with oceanographic conditions and target species behaviour, in determining FADs placement techniques. Furthermore, collaboration among nations and stakeholders is vital in the control of FADs for shared fishing grounds. The regional projects, along with the Parties to the Nauru Agreement (PNA) and the Indian Ocean Commission (IOC), have been running closer to harmonizing FADs control practices and promoting cooperation among member states, strengthening regional fisheries management organizations to conserve and manage fish stocks more effectively (March & Failler 2022). Given these global references and reports, it is imperative to assess the position of FADs in the waters of North Minahasa, North Sulawesi, and ensure they are in line with sustainable fisheries control standards and international best practice. This evaluation should consider ecological concerns, collaboration among stakeholders, and socio-financial impacts on nearby fishing boats.

Fisheries development needs to consider and maintain carrying capacity and environmental quality to ensure sustainability and sustainable utilization (Gordon et al 2018; Hermanto et al 2019). This includes strategically placing FADs based on fish biological and environmental aspects to identify fertile waters with abundant fisheries resources (Murua et al 2023). The presence of oceanographic parameters and environmental/habitat are correlated with FADs placement assumptions. Information on oceanographic characteristics and environmental/habitat provides valuable insights on fish biology and environmental aspects.

International references emphasize the importance of ecological considerations in fisheries development and FADs placement. Studies conducted in various regions, such as the Pacific Islands and Indian Ocean, have highlighted the importance of aligning FADs placement with oceanographic and environmental conditions to maximize their effectiveness (Holmes et al 2019; Cao et al 2023). In addition, international agreements and guidelines, such as those developed by the Western and Central Pacific Fisheries Commission (WCPFC) and the Indian Ocean Tuna Commission (IOTC), emphasize the need for an ecosystem-based approach to fisheries management and FAD deployment (Squires et al 2013; Shen & Song 2023). This framework considers factors such as fish behaviour, oceanographic conditions, and ecological impacts when determining suitable areas for FADs deployment.

By integrating international experience and best practices, stakeholders can ensure that the placement of FADs in the waters of North Minahasa, North Sulawesi is in line with ecological considerations and promotes sustainable fisheries development. The determination of potential areas or more specific fishing zones for certain commodities provides certainty to small-scaled fishers regarding fishing locations and helps reduce the risk of conflict with other utilization zones in the fishing area. To support the recommendation of potential tuna and skipjack fishing areas, optimization of fishing facilities and infrastructure is essential to increase convenience for small-scaled fishers. Additional measures that could be taken include incentivizing the use of FADs, fuel incentives, building safe boat mooring sites, ensuring easy access to boat ramps for small-scaled fishers, and exploring other possible alternative solutions.

Conclusions. The North Sulawesi ZPCSI designates a total area of 325,274.91 ha as capture fisheries zones for all fisheries commodities, with FADs establishment locations located outside the ZPCSI area.

Small-scaled fishers dominate the fishing activities in North Minahasa waters, with a total of 2,168 fishers. Their target catch comprises tuna and skipjack commodities, primarily captured using handlines, accounting for approximately 30% of the catch fishers dominate the fishing activities in North Minahasa waters, with a total of 2,168 fishers. Their target catch comprises tuna and skipjack commodities, primarily captured using handlines, accounting for approximately 30% of the catch.

The existing fishing grounds for tuna and skipjack are encompassed within the North Sulawesi ZPCSI fishing zone but overlap with several other zones beyond the utilization zone. These overlaps have led to potential conflicts in fishing zones, constituting approximately 82% of the cases, while zones without conflict potential account for 18%.

The evaluation of environmental carrying capacity indicates that the total tuna and skipjack fishing grounds, without considering overlapping with other uses, amount to 229,173.45 ha for good commodity abundance and 13,397.85 ha for higher commodity abundance. However, after overlaying with other uses, the total tuna and skipjack fishing grounds remain at 13,397.85 ha for the most potential areas and 229,173.45 ha for moderately potential areas.

The recommendations for potential tuna and skipjack fishing zones encompass an area of 13,397.85 ha for the most potential areas, while areas with sufficient potential cover an area of 229,173.45 ha. Additionally, the tuna and skipjack fishing zone for small-scaled fisheries can be established within a 13,397.85 ha area. The placement of FADs is designed within the ZPCSI area, with a possible distance from the coastal area ranging from 15.99 km to approximately 8.63 nautical miles, with the farthest distance being about 39.96 km or approximately 21.57 nautical miles.

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