Mapping of potential zones for fishing white-spotted spinefoot (*Siganus canaliculatus*) through photogrammetric and cartometric methods in coral coastal waters, Luwu Regency, South Sulawesi

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Abstract. Information on small pelagic fishing areas for white-spotted spinefoot (*Siganus canaliculatus*) should be gathered in an effort to expand the fishing areas. This information can be collected through aerial photography technology using drones. This study aims to map the potential fishing grounds for white-spotted spinefoot in the coastal waters of Karang-karangan, Luwu Regency, South Sulawesi. The used method is a photogrammetric survey using drones and participatory mapping with a cartometric method approach. The results of the analysis show that the potential location for fishing white-spotted spinefoot in the study area is 762.08 hectares spread over 46 location points.
Key Words: cartometric, Luwu District, photogrammetry, potential fishing ground, *Siganus canaliculatus*.

Introduction. White-spotted spinefoot (*Siganus canaliculatus*) or locally known as Malaja is a mainstay fishery commodity in the coastal waters of Karang-karangan, Luwu Regency. Its distinctive aroma and taste make white-spotted spinefoot fish in Karang-karangan a favorite for every devotee (Halid & Mallawa 2017). White-spotted spinefoot fish are associated with seagrass beds as breeding, rearing and foraging areas (Kordi 2011). The existence of white-spotted spinefoot fish in the coastal waters of Karang-karangan is commonly found around the seagrass ecosystem of the *Enhalus acoroides* species with an area of 467.98 ha (Marhayana et al 2021). White-spotted spinefoot fish fishery is carried out by fishermen using fixed stake trap fishing gear and cathcing is done every day (Halid & Baso 2022). Halid (2018) reported that the calculated sustainable potential of white-spotted spinefoot fish in the coastal waters of Karang-karangan was 119,296 tons year^{-1} and the optimum fishing effort was 35,730 units year^{-1}.

By far, determination of fishing grounds has been carried out using remote sensing technology (Nurdin et al 2017; Fauziyah et al 2022) and geographic information systems (Shaari & Mustapha 2018; da Silva et al 2021). Zainuddin et al (2013) reported the use of remote sensing technology to map skipjack fishing potential zones in Bone Bay by combining sea surface temperature and chlorophyll-*a* images. Yunus et al (2019) mapped the potential areas of tuna in the Makassar Strait by combining images of sea surface temperature, chlorophyll-*a* and salinity. Rivai et al (2017) mapped potential fishing areas using the Gishotspot model approach in the Thousand Islands.

Information on fishing areas for small pelagic fish including white-spotted spinefoot should be collected in an effort to expand fishing areas with the assumption that the fishing area is still supported by the availability of environmental conditions suitable for the survival of the white-spotted spinefoot fish, namely coral reefs and seagrass beds. This information can be gathered through aerial photography technology (Kandrot & Holloway 2020), using drones (photogrammetry) and participatory mapping (cartometric) by involving fisherman catching white-spotted spinefoot. Therefore, this study aims to map potential fishing areas for white-spotted spinefoot in the coastal waters of Karang-karangan, Luwu Regency, South Sulawesi.

Material and Method. This research was conducted using a descriptive method by conducting surveys and direct observations in the field (Nazir 2003). The research was carried out at the white-spotted spinefoot fish production center, precisely in the coastal waters of Karang-karangan Village, Luwu Regency, South Sulawesi from October 2020 to January 2021. Geographical position of the research location is 3°7'35.85'' South Latitude and 120°15'58.0536'' East Longitude (Figure 1). The data collection method used in this study is divided into two, namely (a) photogrammetric survey using drones (Varela et al 2019; Gasparini et al 2020) and (b) participatory mapping using the cartometric method (Akbar et al 2020, 2021).

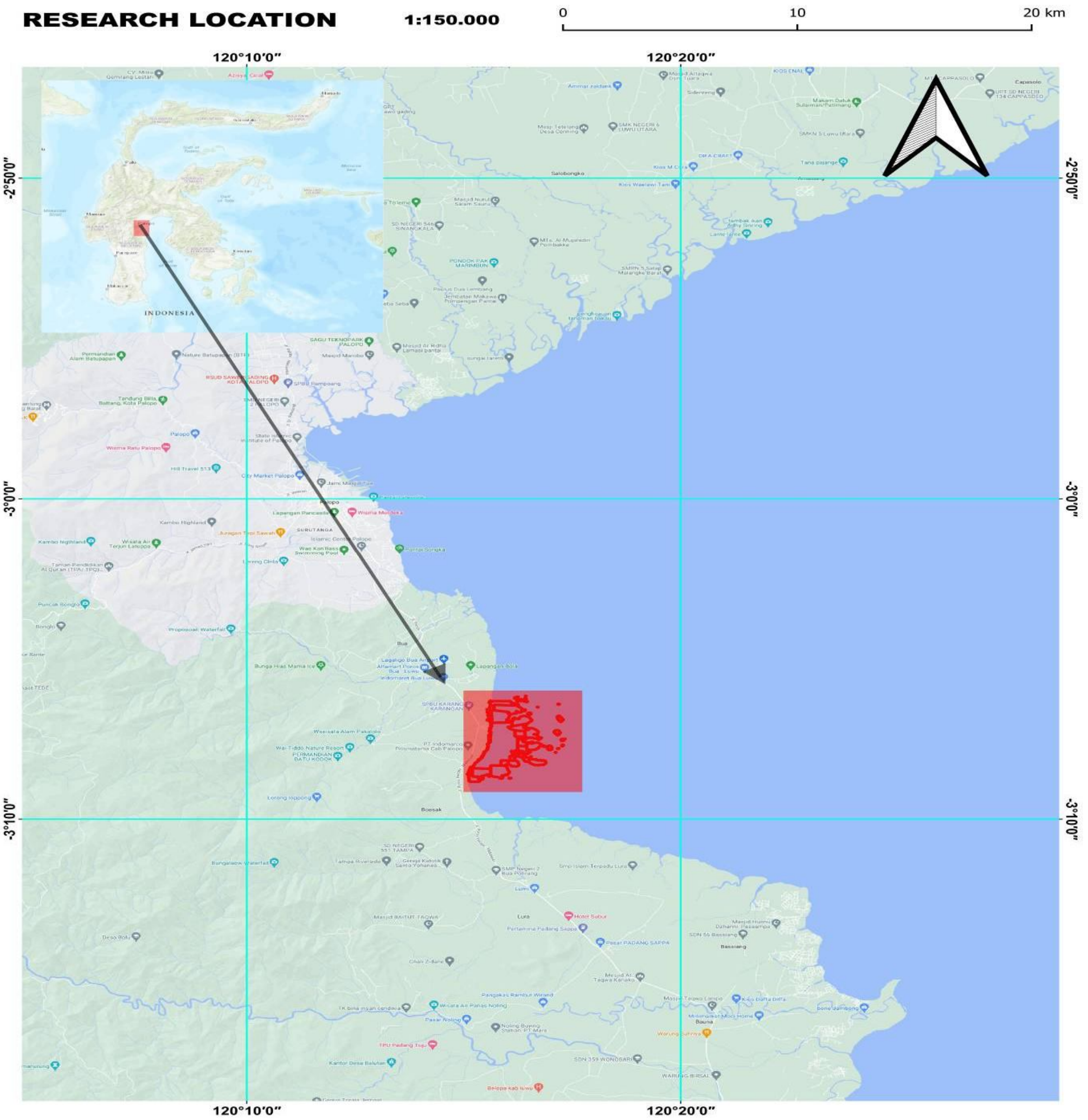

Figure 1. Research location.

Photogrammetric survey. A photogrammetric survey was conducted using the DJI Mavic Pro drone to obtain accurate and actual orthomosaic data for the research location, so that it can be used as a base map in calculating potential fishing zones. The stages of the photogrammetric survey are as follows:

1. Creating an Area of Interest (AoI) polygon covering the research area using open-source software Quantum GIS (QGIS);
2. Creating a flight mission path using the open-source software Mission Planner (ArduPilot);

3. Dividing the flight path into several missions according to the optimal flight duration of the Mavic Pro drone;
4. Carrying out drone flights for each of the previously prepared flying missions at an altitude of 200 m. Flights are carried out using the Litchi app for DJI installed on the smartphone;
5. Flights are carried out at 8-10 am and 16-17 pm to avoid the effect of the sun on the water in each recorded photo;
6. Equalizing the colors on each photo using Adobe Lightroom;
7. Processing individual photos into orthomosaic data to then be used as a base map for the next stage.

Participatory mapping. Participatory mapping was carried out to identify fishing zones. The method used is cartometric with the following stages:

1. The operator displays an aerial photo map overlaid with google satellite imagery using a projector;
2. Local fishermen as respondents were asked to indicate the location and mention the local name and perform manual delineation of fishing zones;
3. Operator performs layer digitization following the delineation of respondents using QGIS;
4. The results of the delineation are in the form of polygons and points which are then carried out by spatial analysis to obtain the area of the zone and the distance from the fishing base;
5. The distance matrix tool in QGIS was used for distance measurement and calculate area tool was used for the area measurement.

Data analysis. The results of the drone photo recording are then processed to produce orthomosaic data, namely the results of the processing in the form of a combination of photographs that have been geometrically corrected. Thus, they can be used for further spatial analysis. Photo data recorded using drones in this study were processed using Agisoft Metashape software. The workflows applied to the aerial photo processing are as follows:

1. Align photos is carried out to identify the points in each photo and perform the process of matching the same points in two or more photos. The align photos process will generate the initial 3D model, the camera and photo positions in each shot, and the sparse point clouds that will be used in the next step;
2. Dense point clouds are collections of high points in the thousands to millions of points generated by aerial photogrammetric processing or LIDAR (Light Detection and Ranging). Dense Point Clouds can later be processed further to produce a Digital Surface Model (DSM), Digital Terrain Model (DTM), and even input in the process of making orthophotos and other mapping purposes;
3. 3D or mesh models are one of the main outputs of aerial photo processing at Agisoft. The 3D model will be used as the basis for making Digital Elevation Model (DEM), both DSM and DTM, as well as orthophoto. The resulting mesh can also be exported to other formats for further processing in other software such as Google Sketchup, AutoCAD or ArcGIS;
4. The texture model is a 3D physical model of the features in the photo coverage area. Texture models can be exported into various 3D model formats which can later be used to create 3D models via other desktop software or through websites;
5. DEM is a digital terrain model in raster/grid format which is usually used in raster-based spatial analysis/GIS. DEM data can usually be derived from information on elevation, slope, aspect, direction, irradiation, to further modeling such as cut and fill, visibility, watershed creation and others. There are two terminologies related to DEM, namely DSM and DTM;
6. Orthophoto is an aerial photo that has corrected its geometric errors using DEM data and GCP data so that it can be used for mapping purposes without any scale inconsistencies throughout the photo coverage. Orthophotos can be created after the Dense Point Coulds, Mesh and DEM creation stages have been completed.

Results and Discussion. The results of photogrammetry and cartometry spatially indicate potential locations for catching white-spotted spinefoot fish in the coastal waters of Karang-karangan, Luwu Regency, South Sulawesi as shown in Figure 2.

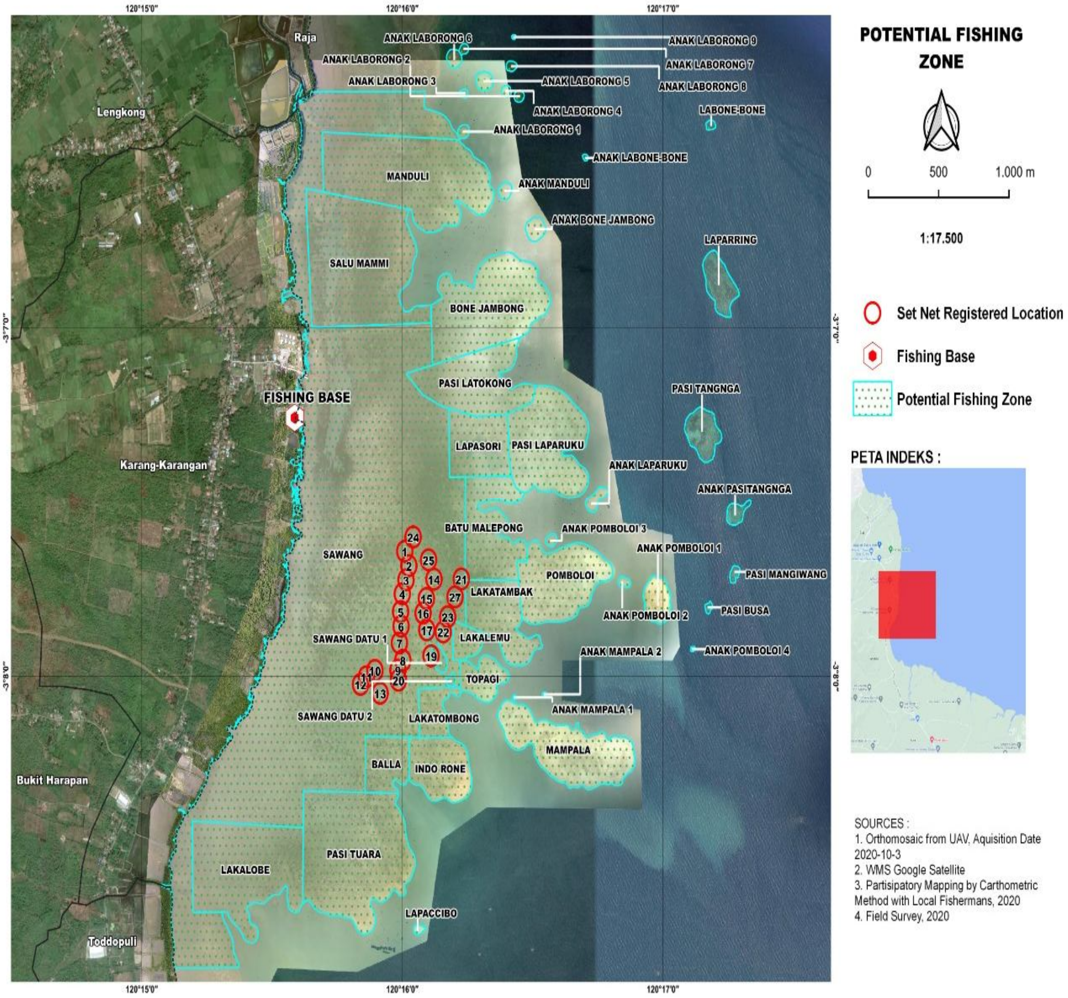

Figure 2. Map of potential fishing zone.

The location was factually identified based on information submitted by the white-spotted spinefoot fishermen (business actors) through a participatory approach. Figure 2 above shows that the potential locations for fishing white-spotted spinefoot in the coastal waters of Karang-karangan are spatially spread over 46 locations covering an area of 762.08 ha with details as shown in Table 1.

The results of field observations and verification showed that of the 46 potential locations there were several locations that were intensely used by fishermen to catch white-spotted spinefoot fish, namely Bone Jambong, Pasi Latokong, Lapasori, Pasi Laparuku, Batu Malepong, Sawang, Pamboloi, Sawang Datu, Indo Rone, Mampala. Pasi Tuara, Lakatombong and Balla. This is indicated by a number of the main fishing gear used by fishermen, namely fixed stake trap at that location. In addition, the concentration of fixed stake trap fishing gear also considers the existence of a seagrass ecosystem that thrives at that location (Figure 3) where the main function of the seagrass ecosystem is as a place for rearing and foraging for the white-spotted spinefoot fish species (Marhayana et al 2021).

Another consideration is that fishermen catching white-spotted spinefoot fish are still concentrated in that location because the condition of the water depth at the time of the highest tide and lowest low tide can still optimize the function of the fixed stake trap fishing gear. In addition, the distance from the fishing base to the fishing ground is still affordable by using a motor boat with a size of less than 5 GT, considering that white-spotted spinefoot fishing operations are carried out every day (Halid & Mallawa 2017).

Table 1
Potential locations for fishing white-spotted spinefoot in the coastal waters of Karang-karangan

No.	*Name of location*	*Area (ha)*
1	Anak Laborong 1	0.49
2	Anak Laborong 2	0.35
3	Anak Laborong 3	0.2
4	Anak Laborong 4	0.35
5	Anak Laborong 5	0.97
6	Anak Laborong 6	0.84
7	Anak Laborong 7	0.29
8	Anak Laborong 8	0.33
9	Anak Laborong 9	0.06
10	Balla	8.72
11	Batu Malepong	18.49
12	Bone Jambong	32.47
13	Anak Bone Jambong	1.38
14	Indo Rone	12.85
15	Labone-Bone	0.28
16	Anak Labone-Bone	0.1
17	Lakalemu	3.34
18	Lakalobe	36.12
19	Lakatambak	14.61
20	Lakatombong	5.56
21	Lapaccibo	0.32
22	Laparring	5.12
23	Lapasori	14.06
24	Mampala	23.88
25	Anak Mampala 1	0.06
26	Anak Mampala 2	0.07
27	Mmanduli	44.51
28	Anak Manduli	0.67
29	Pasi Busa	0.22
30	Pasi Laparuku	26.21
31	Anak Laparuku	1.12
32	Pasi Latokong	21.48
33	Pasi Mangiwang	0.45
34	Pasi Tangnga	4.93
35	Anak Pasitangnga	1.29
36	Pasi Tuara	46.32
37	Pomboloi	21.15
38	Anak Pomboloi 1	3.92
39	Anak Pomboloi 2	0.4
40	Anak Pomboloi 3	0.42
41	Anak Pomboloi 4	0.07
42	Salu Mammi	48.98
43	Sawang	351.09
44	Sawang Datu 1	1.44
45	Sawang Datu 2	0.37
46	Topagi	5.73

Figure 3. Distribution of fixed stake trap fishing gear and seagrass ecosystem.

Conclusions. It can be concluded that the photogrammetric and cartometric survey approaches that were carried out to obtain orthomosaic data on the potential fishing zone of white-spotted spinefoot fish were proven to be accurate and factual. There were 46 spot potential fishing zones with a total area of 762.08 ha that have been identified and spatially verified.

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Conflict of interest. The authors declare that there is no conflict of interest.

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