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Estimation Potential Fishing Zones of *Decapterus ruselli* Using Oceanography-Based Remote Sensing Data in the Bone Gulf, Indonesia

Alfira Yuniar[1], Mukti Zainuddin[1]* Safruddin[1], Muzzneena Ahmad Mustapha[2], Rachmat Hidayat[1], Siti Khadijah Srioktoviana[1], Dirgahayu Mirham[1]

[1]Faculty of Marine Science and Fisheries, Hasanuddin University. Jl, Perintis Kemerdekaan Km 10, South Sulawesi, 90245, Makassar, Indonesia
[2]Faculty of Science and Technology, Universiti Kebangsaan Malaysia, UKM, 43600, Bangi Selangor, Malaysia
* **Corresponding Author: mukti@unhas.ac.id**

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ABSTRACT

This study aimed to identify and map potential fishing zones of *Decapterus ruselli* (Scad fish) in the waters of Bone Gulf by utilizing remote sensing technology based on oceanographic parameters. Sea surface temperature (SST) and chlorophyll-a concentration (Chl-a) data obtained from MODIS-AQUA satellite imagery were used to determine the optimal habitat range, which is between 28.3–30.7°C for SST and 0.05–0.21mg m^{-3} for chlorophyll-a. Spatial analysis was conducted over six months (May – October 2024) and showed fluctuations in the area of potential zones influenced by seasonal dynamics. The widest zone was recorded in October (24.478.51km²), while the narrowest occurred in August (6.819.07km²). Model verification using actual capture data in September and October showed high spatial suitability, confirming the reliability of the satellite-based predictive approach. These findings prove that remote sensing is an effective method in mapping the spatial distribution of *Decapterus ruselli* and has the potential to support efficient and sustainable fisheries planning. The resulting potential zone maps can be used as a strategic reference for small-scale fisheries fleets and hence support ecosystem-based fisheries management in the waters of Bone Gulf, Indonesia.

INTRODUCTION

The need for sustainable exploitation of marine resources is increasing, thus encouraging efforts to optimizing fishing activities without neglecting the conservation of marine ecosystems **(Setiawan & Santiago, 2021; Suherman *et al*., 2025)**. One of the small pelagic species that has high economic value in Indonesian waters is *Decapterus ruselli* (known as scad fish) which makes a significant contribution to the welfare of coastal communities and the national fisheries economy **(Anna, 2017; Li *et al*., 2023; Yuniar *et al*., 2024)**. However, the spatial and temporal distribution of this species is highly influenced by oceanographic variables, which makes efficient and environmentally sound fishing strategies a challenge **(Wardani *et al*., 2021; Jaya *et al*., 2022)**.

Bone Gulf is one of the water areas that has high productivity **(Zainuddin *et al*., 2017; Safruddin *et al*., 2018)** and dynamic oceanographic conditions make them potential habitats for various types of pelagic fish **(Rumpa *et al*., 2022)**. Research shows that the utilization of *Decapterus ruselli* in Bone Gulf is still at a level that can be developed sustainably with an actual catch value of 52,543.67 tons year^{-1} compared to the maximum sustainable potential value (MSY) of 62,889.11 tons year^{-1} **(Irawati *et al*., 2021)**. This provides a great opportunity for capture optimization through spatial and temporal data-based approaches **(Rumpa *et al*., 2022)**.

Remote sensing technology has been widely used **(Rangwala *et al*., 2021; Xiong *et al*., 2021)** to detect potential fishing zones using satellite data such as MODIS (Moderate Resolution Imaging Spectroradiometer **(Balázs *et al*., 2022)**. These data are able to provide real-time information on environmental parameters such as sea surface temperature and chlorophyll-a distribution **(Nugraha *et al*., 2020; Abudarda *et al*., 2021; Muhammad *et al*., 2022)**. By utilizing remote sensing, spatial analysis can be performed to identify potential areas for optimal fishing, minimize the cost of fishing operations, and improve fisheries efficiency **(Syahdan *et al*., 2023)**. In addition, this approach also supports ecosystem-based fisheries management by considering the interaction among fish, the environment, and fishing activities **(Purwanto *et al*., 2023)**.

Research in Bone Gulf shows that the highest concentration of chlorophyll-a occurs in the eastern season with a range of 0.06 – 2.04mg m^{-3}, while sea surface temperatures range from 27.13– 37.09°C **(Rosalina *et al*., 2024)**. The data provide an indication of a relationship between seasons, oceanographic parameters and the availability of small pelagic fish **(Musgamy & Palloan, 2024)**. Furthermore, similar studies on the skipjack tuna species in Bone Gulf showed that the combination of sea surface temperatures between 28.5-30°C and chlorophyll-a concentrations between 0.10-0.20mg m^{-3} were positively correlated with the success rate of the catch **(Zainuddin *et al*., 2013, 2017)**. Although the targets of the sepsies are different, the ecological principles underlying these habitat preferences also apply to *Decapterus ruselli* which also shows an aggregation pattern based on environmental variability **(Safruddin *et al*., 2018)**.

Other studies also highlighted the aggregation behavior of *Decapterus ruselli* around the clumps (FADs/Fish Aggregating Devices) which is influenced by current speed, current direction, and sea surface temperature **(Pérez *et al*., 2020)**. Schooling tends to be concentrated under rumpon when temperatures exceed 30°C and currents move in the direction of 0- 60° indicating the importance of spatial-temporal understanding in capture operations **(Rumpa *et al*., 2022)**. Other studies also examined the capture potential of *Decapterus ruselli* generally focusing on bioeconomic, morphometric and population growth aspects show negative allometric growth patterns and condition factors >1 indicate good population health **(Olii *et al*., 2022; Marrec *et al*., 2023)**. However, there have not been many studies that directly integrate satellite-based oceanographic data with the spatial distribution of *Decapterus ruselli* in Bone Gulf. In fact, this understanding is very tight in the context of mitigating overfishing and increasing the effectiveness of small-scale fisheries fleets.

Therefore, this study aimed to estimate the potential catchment area of *Decapterus ruselli* in the waters of Bone Gulf by utilizing remote sensing technology. This study analyzed the relationship between sea surface temperature distribution and chlorophyll-a concentration with the spatial distribution of *Decapterus ruselli*, as well as compiling potential zone maps based on the integration of satellite imagery data and actual catches **(Musgamy & Palloan, 2024; Rosalina *et al*., 2024)**.This approach is expected to be able to provide practical information for fishers and stakeholders in supporting sustainable measurable fisheries management.

MATERIALS AND METHODS

1. Study area

This research was carried out in the Bone Gulf, South Sulawesi which is geographically located between 3–5° S and 120–122° E. This area is part of WPPNRI 713 and is known as a productive area for small pelagic fish such as *Decapterus ruselli*. The research was carried out during the period September - October 2024 coinciding with the monsoon transition season which affects the oceanographic dynamics in Bone Gulf. Bone Gulf is a semi-enclosed body of water located between the provinces of South Sulawesi and Southeast Sulawesi with depths varying from coastal waters to more than 2000-meters in the middle. This bathymetric structure influences the dynamics of the flow and the distribution of water masses in the bay (Fig. 1).

Sea surface temperature (SST) in Bone Gulf shows seasonal fluctuations with the highest temperature recorded in May at 29.13-32°C in the waters of Palopo and the lowest in March at 27.1-30.6°C in the waters of Bulukumba **(Hidayat *et al*., 2022)** . As for the concentration of chlorophyll-a, which is a primary productivity indicator, ranging from 0.2 - 0.4mg m^{-3} indicates a level of aquatic fertility that supports the presence of phytoplankton as the basis of the seafood chain. Currents in Bone Gulf are affected by double dominant mixed tides with higher current velocities in the central part of the bay compared to coastal areas. These variations in currents play an important role in the distribution of nutrients and plankton **(Jiménez-Quiroz *et al*., 2019)**.

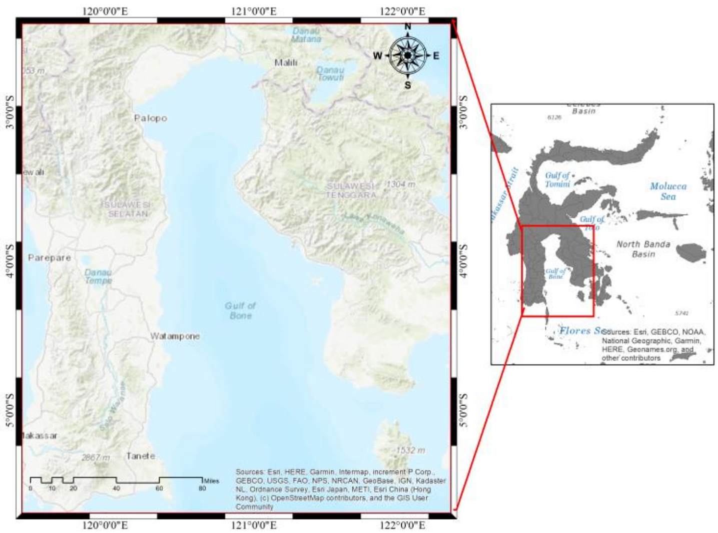

Fig. 1. Map of the study area in the Bone Gulf, Center Indonesian waters

2. Data collection

This study uses data on the catch of *Decapterus ruselli* in September and October 2024. These data were obtained through direct observation at the research site with a total catch of 425,000 tons trip^{-1} using purse seine fishing gear. Meanwhile, the monthly oceanographic variables were obtained from remote sensing data based on the period of catch data. The parameter data used are monthly data on sea surface temperature (SST) and chl-a. Monthly SST and chl-a data are downloaded via ocean color (https://oceancolor.gsfc.nasa.gov) MODIS (*Moderate Resolution Imaging Spectrodiometer*) AQUA Standard Mapped Images (SMI) with a resolution of 4 x 4 km.

RESULTS

1. Spatial distribution of oceanography parameters

To identify potential catchment areas for *Decapterus ruselli* in the Bone Gulf, an analysis was carried out on the main oceanographic parameters, namely sea surface temperature (SST) and chlorophyll-a obtained through MODIS-AQUA satellite data. These two parameters are indicators that have an influence on the spatial distribution of small pelagic species such as *Decapterus ruselli* which show high sensitivity to aquatic environmental dynamics.

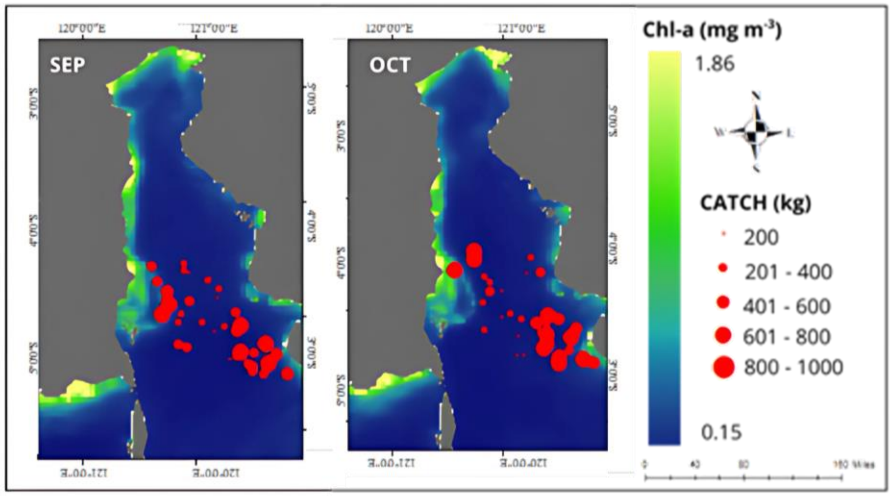

Fig. 2. Spatial distribution of chlorophyll-a to *Decapterus ruselli* catches in September and October 2024

The spatial overlay results of the SST (Fig. 2) and chlorophyll-a (Fig. 3) parameters show a dynamic and correlated distribution pattern, especially in the central to eastern part of Bone Gulf. The avatrition of sea surface temperature between the two months showed a shift in the distribution zone with a tendency to decrease in the same region with an increase in chlorophyll-a concentration. This phenomenon can also indicate upwelling or increased water fertility that has the potential to attract aggregation of *Decapterus ruselli*.

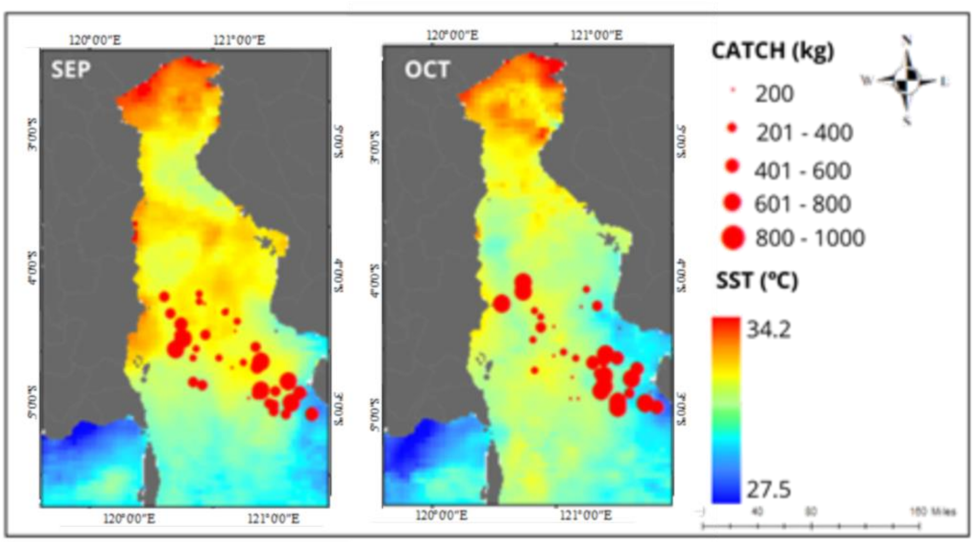

Fig. 3. Spatial distribution of sea surface temperature (SST) for *Decapterus ruselli* catches in September and October 2024

The spatial distribution of the mapped fish catch (Figs. 2, 3) shows a strong association with areas experiencing high chlorophyll-a concentrations and lower temperatures. The results of the distribution showed the potential value of oceanographic parameters in areas where *Decapterus ruselli* is often found with temperatures of around 28.3– 30.7°C and chlorophyll-a concentrations between 0.05 & 0.21mg m^{-3}. Furthermore, the map from this overlay is the basis for compiling the zones of potential fishing areas based on the optimal value of temperature and chl-a.

2. Spatial distribution of potential fishing zones of *Decapterus ruselli*

The results of temporal spatial analysis showed that in May, the potential fishing zones were dominated in the western and central coastal parts of Bone Gulf. This area corresponds to the beginning of the transition season from West to East, where temperatures and nutrients begin to stabilize. Furthermore, in June, the fishing zone extended to the middle of the sea indicating optimal environmental conditions at the beginning of the eastern season.

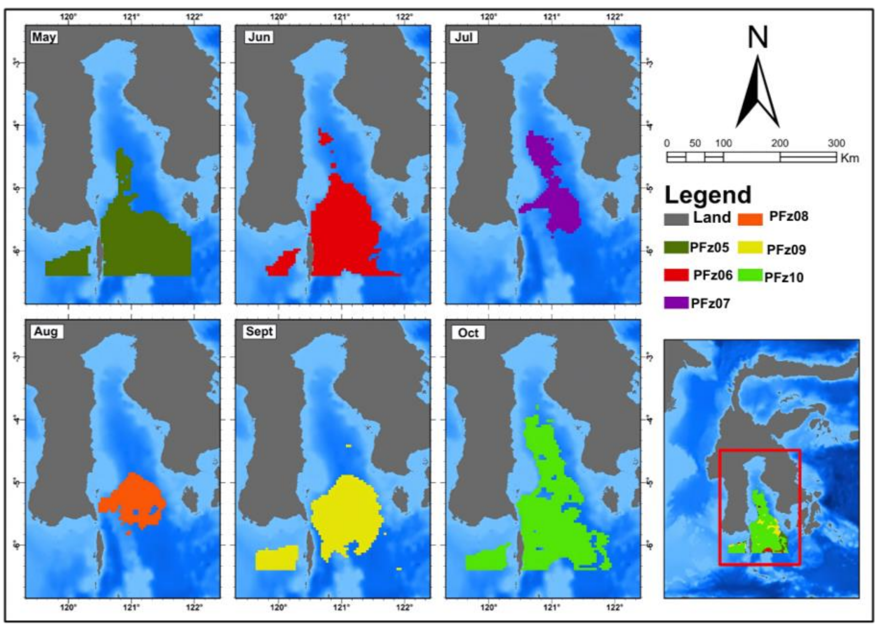

Fig. 4. Estimated fishing potential zones in May - October 2024

In July, the zone of potential fishing narrowed and shifted to the northeastern part indicating a shift in water mass or environmental pressure (current, salinity etc). Then in August, the potential fishing zone shifted to the southern side, the central area of Bone Gulf. This is possible due to seasonal changes in currents and more stable sea surface temperatures. Then in September, the area of potential catchment zones increased the spread in the central to southeast part of Bone Gulf. This indicates the peak period of productivity in the waters of Bone Gulf with near-optimal temperature and chlorophyll-a conditions. Finally, in October, the area of potential fishing zones spread to the center and the east of Bone Gulf. This is consistent with the results of previous temperature and chlorophyll-a images showing increased fertility and decreased temperature (Fig. 4).

In addition to spatial and temporal analysis of the results of the overlay of the map of potential fishing zones, the distance measurement of the area for each month is also shown in data displayed in Table (1).

Table 1. Area of potential fishing zone

PFz of *Decapterus ruselli* (Month)	**Area (km^2)**
May	21.907.91
June	19.053.20
July	7.978.47
August	6.819.07
September	15.915.69
October	24.478.51

The results of estimates from May to August show the highest fishing potential zone in May. Meanwhile, in this estimate, verification of the predictions and available catches was carried out (Fig. 5).

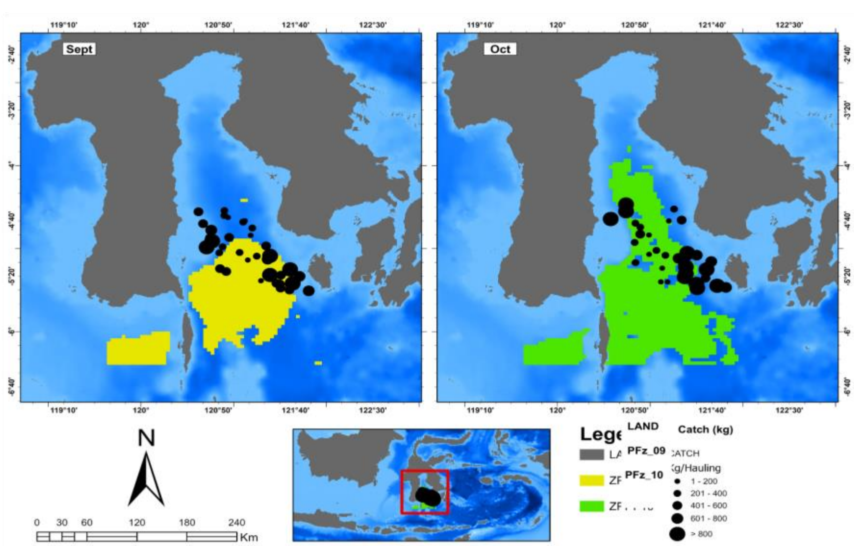

Fig. 5. Verification of the estimated potential fishing zone *of Decapterus ruselli* using catch data from September – October 2024

DISCUSSION

1. Remote sensing data integration and spatial validation: Estimating potential zone accuracy

The use of remote sensing technology in this study proved to be effective in identifying potential fishing zones for *Decapterus ruselli* in Bone Gulf waters **(Shaari & Mustapha, 2018)**. Based on a combination of two major oceanographic parameters such as sea surface temperature (SST) and chlorophyll-a concentration, zones with SST values between 28.3 & 30.7°C and chlorophyll-a between 0.05- 0.21mg m^{-3} were identified as optimal habitat for *Decapterus ruselli*. Spatial verification of actual catches in September and October 2024 shows a high match between potential zone estimates and catch points. The high catch distribution, especially >800kg, was mostly concentrated in the estimated zone area mapped using MODIS-AQUA data. This shows that the satellite-based approach is able to produce accurate and applicable spatial predictions in supporting fisheries operations **(Walker *et al*., 2023)**.

2. May-October PFz area fluctuations: Response to seasonal dynamics

Temporal spatial analysis from May to October showed significant fluctuations in the area of potential zones. The largest zone was found in October at around 24.448.51km^2, followed by May with an area of 21.907.91km^2 and June with 19.052.57km^2. On the contrary, July and August showed a narrowing incidence for the area of potential fishing zones (7.978.47km^2 in July and 6.819.07km^2 in August). This indicates the possibility of a decrease in fish abundance due to suboptimal environmental conditions.

During the Eastern season, surface temperatures tend to increase causing the thermocline layer to become stronger and inhibit the upwelling process. As a result, the availability of nutrients for phytoplankton is reduced which, in turn, lowers the concentration of chlorophyll-a **(Wirasatriya *et al*., 2021)**. This decrease is what causes *Decapterus ruselli* to distribute to other regions that are more productive, thus reducing the area of PFz. These findings are in line with those of **Rosalina (2024)** who reported that the highest chlorophyll-a occurred during the eastern season with concentration fluctuations between 0.06-2.04mg m^{-3}. On the other hand, temperatures can rise to 37.09°C, far exceeding the optimal threshold of *Decapterus ruselli,* triggering changes in spatial distribution patterns. The success of this zone detection strengthens the statement of **Syahdan *et al.* (2023)** that satellite technology is able to capture the dynamics of the marine environment with high precision, making it very useful for predicting fisheries productivity.

3. Significance of spatial verification: Basis for validation of non-verified month estimation models

Although actual catch data are only available for September and October, the verification results for those months are representative enough to be used as a benchmark for the validity of estimates from May to August. The pattern of spatial correspondence between the estimation zone and the catch point suggests that the environmental parameters used have reflected the ecological preferences of *Decapterus ruselli*. Therefore, the zones formed in previous months are believed to have high accuracy even though they have not been directly verified. For example, the large area of the PFz in May and June indicates near-optimal environmental conditions, most likely supporting the aggregation of the scad fish population. At that time, temperatures tend to be more stable and chlorophyll-a increases with the transition season. In contrast, the shrinkage of the zone in July and August may reflect a habitat that is no longer viable, as described in the study of **Rumpa *et al*. (2022)**, which showed that *Decapterus ruselli* prefers temperatures below 30°C and is better distributed during low current velocities as well as northeasterly dominant current directions.

This research has far-reaching implications for fisheries resource management strategies. With predictive and data-driven information on potential zones, fishermen can plan fishing operations more efficiently both in terms of location and time. Zones with high estimates in May, June, and October can be prioritized, while July–August require a conservative approach to avoid exploitation during low aggregation periods. This approach is also in line with the principles of ecosystem-based fisheries as outlined by **(Purwanto *et al*., 2024)** which emphasizes the importance of understanding the relationship between environmental dynamics and fish distribution in determining capture policies. Remote sensing technology provides an opportunity for integration between oceanographic data, spatial distribution, and catches, so that it can support policies that are adaptive to environmental changes.

CONCLUSION

This study shows that the use of remote sensing technology with oceanographic parameters of sea surface temperature and chlorophyll-a concentration can effectively identify potential fishing zones of Decapterus ruselli in the waters of Bone Gulf. The results of spatial mapping from May to October 2024 show fluctuations that reflect seasonal dynamics and the variability of the marine environment. The zones with the largest area were identified in October, followed by May and June, while July and August showed a narrowing of the area of potential habitat.

Spatial verification using actual catch data in September and October reinforces the accuracy of the zone estimation model. The distribution of catch is concentrated in the predicted zone, indicating that this spatial prediction model has high accuracy and can be used as a basis for fishing operational planning. Therefore, zone estimates in the previous months (May to August) that have not been directly verified can still be considered valid as an initial reference in the management of catchment areas

These findings also make an important contribution to the sustainable management of small- and medium-scale fisheries, by providing spatial information that can lead fishers to more efficient and environmentally friendly catch locations. The prediction map can be used as a tool in decision-making for ecosystem-based fisheries management, as well as support overfishing mitigation efforts by considering local oceanographic dynamics. Thus, the integration of satellite data and actual catches is able to provide a solid scientific basis to improve fisheries effectiveness and fishermen's welfare in Bone Gulf in a sustainable manner. This study recommends the application of routine monitoring based on remote sensing and the integration of real-time oceanographic data, as the main strategy in the management of small pelagic fisheries in Indonesia.

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REFERENCES

Anna, Z. (2017). Indonesian Small Pelagic Resource Accounting. KnE Life Sciences, 2(6), 29. https://doi.org/10.18502/kls.v2i6.1017.

Hidayat, R.; Zainuddin, M.; Safruddin. and Wiyono, E. S. (2022). Identification of potential areas for upwelling based on characteristics of eddies event in the Bone gulf. IOP Conference Series: Earth and Environmental Science, 1119(1). https://doi.org/10.1088/1755-1315/1119/1/012083.

Irawati, A.; Baso, A. and Najamuddin. (2021). Bioeconomic Analysis of Indian Scad (Decapterus ruselli) in the Bone bay Waters of South Sulawesi. International Journal of Environment, Agriculture and Biotechnology, 6(1), 112–119. https://doi.org/10.22161/ijeab.

Jaya, I.; Satria, F.; Wudianto Nugroho, D.; Sadiyah, L.; Buchary, E. A.; White, A. T.; Franklin, E. C.; Courtney, C. A.; Green, G. and Green, S. J. (2022). "Are the working principles of fisheries management at work in Indonesia?" Marine Policy, 140(March), 105047. https://doi.org/10.1016/j.marpol.2022.105047

Jiménez-Quiroz, M.; del C.; Cervantes-Duarte, R.; Funes-Rodríguez, R.; Barón-Campis, S. A.; García-Romero, F.; de J.; Hernández-Trujillo, S.; Hernández-

Becerril, D. U.; González-Armas, R.; Martell-Dubois, R.; Cerdeira-Estrada, S.; Fernández-Méndez, J. I.; González-Ania, L. V.; Vásquez-Ortiz, M. and Barrón-Barraza, F. J. (2019). Impact of "The Blob" and "El Niño" in the SW Baja California Peninsula: Plankton and environmental variability of Bahia Magdalena. Frontiers in Marine Science, 6(FEB). https://doi.org/10.3389/fmars.2019.00025.

Li, M.; Xu, Y.; Sun, M.; Li, J.; Zhou, X.; Chen, Z. and Zhang, K. (2023). Impacts of Strong ENSO Events on Fish Communities in an Overexploited Ecosystem in the South China Sea. Biology, 12(7), 1–19. https://doi.org/10.3390/biology12070946.

Marrec, L.; Bank C. and Betrand, T. (2023). Solving the stochastic dynamics of population growth. Ecology and Evolution,13(8), 1-20. https://doi.org/10.1002/ece3.10295.

Purwanto, H. B.; Sunarto, S.; Setyono, P.; Rindarjono, M. G.; Rachmadhan, A. A.; Sakti, M. B. G. and Hidayat, A. (2024). Water Resources Management Model Based On Regional Development: Case Study Of Magetan Regency, Indonesia. Tropical and Subtropical Agroecosystems, 27(1). https://doi.org/10.56369/tsaes.5106.

Rumpa, A.; Najamuddin.; Safruddin. and Hajar, M. A. I. (2022). Fish behavior based on the effect of variations in oceanographic condition variations in FADs Area of Bone Bay Waters, Sulawesi, Indonesia. Biodiversitas, 23(4), 1875–1883. https://doi.org/10.13057/biodiv/d230421.

Safruddin.; Hidayat, R. and Zainuddin, M. (2018). Effects of environmental factors on anchovies stolephorus sp distribution in bone Gulf, Indonesia. AACL Bioflux, 11(2), 387–393.

Setiawan, G. and Santiago, F. (2021). Collaborative Governance for Sustainable Development in Indonesia's Fisheries and Marine Resources Governance. https://doi.org/10.4108/eai.6-3-2021.2306836.

Shaari, N. R. and Mustapha, M. A. (2018). Predicting potential rastrelliger kanagurta fish habitat using MODIS satellite data and GIS modeling: A case study of exclusive economic zone, Malaysia. Sains Malaysiana, 47(7), 1369–1378. https://doi.org/10.17576/jsm-2018-4707-03.

Suherman, A.; Hernuryadin, Y.; Suadela, P.; Furkon, U. A. and Amboro, T. (2025). Transformation of Indonesian captre fisheries governance: Review and prospects. Marine Policy, 174(June 2024), 106619. https://doi.org/10.1016/j.marpol.2025.106619.

Walker, R. S.; Ferguson, J. R.; Olmeda, A.; Hamilton, M. J.; Elghammer, J. and Buchanan, B. (2023). Predicting the geographic distribution of ancient Amazonian archaeological sites with machine learning. PeerJ, 11. https://doi.org/10.7717/peerj.15137.

Wardani, F. I.; Nadiarti, N.; Nelwan, A. F. P. and Jamal, M. (2021). Vulnerability analysis of pelagic and demersal fisheries in the Indian Ocean, Fisheries Management Area 572, Indonesia. IOP Conference Series: Earth and Environmental Science, 763(1), 0–11. https://doi.org/10.1088/1755-1315/763/1/012040.

Wirasatriya, A.; Susanto, R. D.; Kunarso, K.; Jalil, A. R.; Ramdani, F. and Puryajati, A. D. (2021). Northwest monsoon upwelling within the Indonesian seas. International Journal of Remote Sensing, 42(14), 5437–5458. https://doi.org/10.1080/01431161.2021.1918790.

Yuniar, A.; Zainuddin, M.; Srioktoviana, S. K.; Mustapha, M. A.; Farhum, A. and Safruddin. (2024). Relationship between eddy and scads (Decapterus spp.) abundance in the northwest of Banda Sea, Indonesia. IOP Conference Series: Earth and Environmental Science, 1410(1). https://doi.org/10.1088/1755-1315/1410/1/012039.

Zainuddin, M.; Farhum, A.; Safruddin, S.; Selamat, M. B.; Sudirman, S.; Nurdin, N.; Syamsuddin, M.; Ridwan, M. and Saitoh, S. I. (2017). Detection of pelagic habitat hotspots for skipjack tuna in the Gulf of Bone-Flores Sea, southwestern Coral Triangle tuna, Indonesia. PLoS ONE, 12(10), 1–19. https://doi.org/10.1371/journal.pone.0185601.