The stock assessment of *Siganus* spp. in the seagrass ecosystem

Nurdiana Azis, Ma’ruf Kasim, Sjamsu A. Lawelle, Akhmad Mansyur, Roslindah D. Siang, Wa O. Piliana

Faculty of Fisheries and Marine Sciences, Halu Oleo University, Kendari, Southeast Sulawesi, Indonesia. Corresponding author: N. Azis, nurdiana@uho.ac.id

Abstract. Assessment of fish stocks is essential for collecting, analyzing, and reporting the condition of fish so that sustainable fishing output can be predicted. The study aimed to assess the status of *Siganus* spp. fishing as a measure of population stability, as well as the efficiency and sustainability of fishing on seagrass ecosystems. This research method uses a participatory approach through surveys of catch results and fishing locations around seagrass habitats in the Pasarwajo Gulf region of Southeast Sulawesi, Indonesia. The research site's seagrass ecosystem has emerged as a promising fishing area in Southeast Sulawesi, Indonesia. The potential for seagrass ecosystem production is still below effort and yield, so that it can be increased for small-scale fisheries by 21.69%. The production capacity of capture fisheries from the seagrass ecosystem for *Siganus* spp. is only 13.32%, and the catch composition still include juveniles, while the fishing location is in the coastal area. The current state of fishing operations at the research site is not sustainable, necessitating the implementation of various policies such as managing the siganid fishing zone, restricting the use of catch tools, and designing seagrass ecosystems that are suitable for the life of *Siganus* spp.

Key Words: business status, seagrass ecosystem, capture, sustainability.

Introduction. Seagrass ecosystems are known to provide critical habitat for various fish species, including siganids, which are found in these environments and have the potential for cultivation (Rauf 2018). However, the impact of fishing on seagrass ecosystems and the associated fish assemblages can be significant. Overfishing can lead to reduced fish abundance, decreased diversity, and a loss of functional roles within these systems (Vieira et al 2020). Moreover, the removal of biomass through fishing can disrupt ecological processes, such as nutrient provisioning and sediment processing, which are essential for the maintenance of seagrass productivity (Watkins et al 2023). The fishing activity around seagrass ecosystems can actually be separated from other fishing productions, as the life cycle of some of the predominantly caught consumption fish (more than 50%) is associated with the existence of an aquatic ecosystem. According to data from the Fisheries and Marine Office of Buton Regency (2021), that the Buton district uses the majority of its 49.06% annual fishing output, which reaches 25,543 tons, to satisfy the local consumer’s demands. Less than 39.14% has been used to meet trade needs. Local processing industries on a micro and small scale, including freezing, polishing, and drying, represents the remaining 11.80%. McArthur & Boland (2006) consider aquatic ecosystems as indicators of the residence of fish, for certain species, including edible species. The aquatic ecosystem's existence closely correlates with the presence of fish resources. According to Wahyudin (2022), every additional one hectare of seagrass ecosystem could improve the carrying capacity of their waters to support a fish biomass of 9,049.3 kilograms or equivalent to a habitat value of USD 5,816.16 per hectare per year. The economic value of seagrass ecosystem and fish resources linkages amounted USD 5,792.05 ha^{-1}, meaning that the economic loss of seagrass as their capacity to provide fish production amounts USD 5,792.05 year^{-1}, with a 47.31% linear correlation between fish production and the existence of the seagrass ecosystem. The correlation between the existence of the seagrass ecosystem and the catch effort is

20.26%, and every addition of one hectare of seagrass ecosystems can increase by 135 the number of fishing trips with nets.

The status and sustainability of fish stocks, including those of the Siganus species, are critical concerns in fisheries management. The sustainability of fishing activities involving Siganus species around seagrass ecosystems is a multifaceted issue. (Parawansa et al 2020) provides evidence that the rabbitfish, *Siganus guttatus*, which has a significant economic value, is under increased fishing pressure due to high market demand. This necessitates comprehensive management strategies to ensure the sustainability of the species, particularly by observing different gonad maturity levels (GML) and feeding habits in seagrass versus coral reef ecosystems. Rauf (2018) discusses the potential for rabbitfish cultivation in seagrass ecosystems, indicating that suitable environmental conditions are critical for sustainable aquaculture practices. Latuconsina et al (2022) further support the need for technical fisheries management approaches, such as using the size at first maturity as a reference for catch size and designating specific seagrass habitats for conservation or fishing.

Stock assessments in seagrass ecosystems are critical for understanding the dynamics of fish populations and informing sustainable management practices. Seagrass habitats, due to their high productivity and complex structure, support diverse fish communities, including commercially important species (Gullström et al 2002). However, there are challenges in monitoring fish stocks in these areas, as conventional stock assessment methods may not be directly applicable due to the complexity and local nature of seagrass-associated fisheries (Fitzgerald et al 2018). Marine reserves, which include seagrass habitats, have been used as a management tool to conserve local biodiversity and have provided a means to assess changes in fish assemblages over time, although the effectiveness of these reserves can vary (Kiggins et al 2020). Additionally, adapting stock assessment methods to the unique conditions of seagrass ecosystems is necessary to ensure effective management and conservation of these valuable habitats (Fitzgerald et al 2018; Gullström et al 2002). Interestingly, while traditional stock assessment methods rely heavily on catch and effort data (Xiao 1998), recent advancements have been made in data assimilation techniques, such as Monte Carlo formulations, to integrate observations with complex dynamical models (Grønnevik & Evensen 2001). Additionally, the health of fish populations has been identified as an important factor that influences productivity, which has been somewhat overlooked in conventional assessments (Lloret et al 2012). The aim of this research was to determine the status of fishing activities based on fish stocks in seagrass areas at one of the *Siganus* spp. fishing sites in Indonesia, particularly in the waters of Pasarwajo Gulf.

Material and Method

Description of the study sites. The research employs two primary approaches, namely: (1) surveys and data collection and (2) data analysis using a set of analytics aimed at mapping the fishing potential. Data and information was collected using qualitative and quantitative approaches related to the focus or target aspects, such as: (i) fishing potential, which involves observing the type, quantity, and density of fish, particularly the baron fish; (ii) the social, economic, and cultural conditions of communities; (iii) ecosystem conditions, which involve information about the physical and chemical conditions of the waters; and (iv) analyzing the correlation between fish density and the environmental conditions of the waters.

The survey results were used as a basis for compiling the studied area's potential against its carrying capacity. Several techniques were used for the data collection, including: (1) data collection of potential catch, (2) questionnaires, (3) methods of participatory rural appraisal (PRA) and in-depth interviews, and (4) measurement of the state of the watershed's ecosystem. The primary data collection technique employed the following methods in detail: (a) The participatory method involved conducting field observations. (b) Creating a questionnaire, which involved 150 respondents, by formulating a list of targeted questions. Data obtained were further processed to obtain the curve of maximum sustainable yield (MSY). According to Sparre & Venema (1998), yield per recruitment (Y/R) and biomass per recruit (B/R) can be determined from the Beverton and Holt equation as follows:

$$(Y/R) = E.U^{M/K_1}\left[-\frac{3U}{1+m} + \frac{3U^2}{1+2m} + \frac{U^2}{1+3m}\right]$$

$$U = 1 - \frac{L_C}{L_\infty}$$

$$m = \frac{1-E}{M/K}$$

$$(B/R) = \frac{Y/R}{F}$$

Where:
Y - yield;
R - recruitment;
E - exploitation ratio, namely the proportion of deaths due to fishing compared to total mortality (natural + fishing);
U - the proportion of length that can still be achieved after the first capture length (Lc) compared to the theoretical maximum length (L∞);
L_C - first capture length;
L_∞ - theoretical maximum length;
M - natural mortality;
K - growth coefficient von Bertalanffy;
m - growth to death ratio;
B – biomass;
F - mortality due to fishing.

The mortality rate estimation was also analyzed using Virtual Population Analysis (VPA), based on the modified model of Jones & van Zalinge (1981) adapted to accommodate length frequencies.

$$Nt = C_t.(M + F_t)/F_t$$

Where:
N_t - mortality rate;
C_t - the terminal catch;
M - natural mortality;
F_t - fishing mortality.

Sparre & Venema (1998) developed two equations for the catch of a year class. One equation relates the catch of a year class at a specific age to the population size and mortality rates:

$$C_{(t_1,t_2)} = N_{(t_1)} * \left(\frac{F}{Z}\right) * [1 - \exp(-Z * (t_2 - t_1))]$$

Where:
C - catch;
t_1 - first time;
t_2 - second time;
N - population;
F - fishing mortality coefficient;
Z - proportionality coefficient.

The FiSAT-II program, length frequency analysis method (ELEFAN-I) was used to calculate the asymptotic length (L_∞) and growth coefficient (K), both of which are based on the Von Bertalanffy growth equation. The values of L∞ and K were projected, and the estimated growth parameters (L_∞, K, and t_0) were inserted into the Von Bertalanffy equation assuming that the value of t_0 is zero, reference by Pauly & Gaschutz (1979) and Somers (1988):

$$Lt = L_{\infty}\left(1 - e^{-K(t-to)}\right) + St_s + S_{to}$$

$$St_t = \left(\frac{CK}{2\pi}\right).\sin(2\pi(t - t_s))$$

$$St_0 = \left(\frac{CK}{2\pi}\right).\sin(2\pi(t_0 - t_s))$$

Where:
S_t - seasonal oscillation components at age t;
S_{t0} - seasonal component at t_0;
C - seasonal oscillation amplitude ($0 \leq C \leq 1$);
K - a growth coefficient;
t_s - time (age) of onset of the rapid growth season;
t_0 - age when the length of the fish is zero;
t - age of fish (in years);
L_t - the length at age t;
L_{∞} - the mean length the fish.

The normal distribution is as follows:

$$\bar{L_j} = \frac{-a_j}{b_j}$$

While its standard deviation (σ) is $aj = (-\Delta L/b_j)^{1/2}$
Where:
ΔL - the constant class size.

Also, a separation index (SI) is computed:

$$\text{SI} = \Delta\bar{L_j}/\Delta\sigma_j$$

Where:
$\Delta\bar{L_j}$ - the difference between two successive means;
$\Delta\sigma_j$ - the difference between their estimated standard deviations.

The separation of length–frequency samples into their component is an iterative process in that every identified component is subtracted from the remainder of the sample using the Gaussian function:

$$N_{2i+1} = N_i - \left(\frac{1}{\sigma_j\sqrt{2n}}\exp\left[-\frac{(L_i - L_j)^2}{2\sigma^2{}_j}\right]\right)$$

$$N_2{}^{i+1} = N_{i+} - \left\{\left[\frac{1}{\sigma_j\sqrt{2n}}\right]EXP\left[-\left[\frac{(L_i - L_j)^2}{2\sigma_{i2}}\right]\right]\right\}$$

Where:
N_i - number of individuals (frequency) in the i-th length class in the initial length-frequency histogram;
N_{2i+1} - frequency after the j^{th} Gaussian component is subtracted from the data in the i-th class. This is part of the iteration in the decomposition process;
σ - standard deviation;
L_j - length in frequency class;
L_j - length in frequency class Gaussian j;
Exp - exponential function;
π – constant.

Total mortality rate (Z) and natural mortality rate (M) were estimated using the FiSAT-II program, and the catch curve converted into fish length was used to determine the mortality parameters. According to Pauly Model (1980), the natural mortality rate (M) is calculated using empirical relationships, including the following:

$$\log(M) = -0.0066 - 0.279 \log(L_\infty) + 0.6543 \log(K) + 0.4634 \log(T)$$

Where:
M - natural mortality (year^{-1});
L_∞ - asymptotic maximum length (cm);
K - growth rate (year^{-1});
T - average habitat temperature (°C).
The values of L_∞,to be used should refer to or approximate total length.

Results. For management purposes, the stock analysis was performed, with the Maximum Sustainable Yield (MSY) reached at a level of effort of 0.421 and the relative yield at size magnitudes of 0.039 Y/R (Yield/Recruit) and 0.626 B/R (Biomass/Recruit). Furthermore, the allowable rate of effort is 0.355, with a relative yield of 0.05 Y/R and 0.466 B/R. The current profitability value is 0.278. At relative yield values of 0.03 Y/R and 0.626 B/R, the current effort can still be increased by 21.69% to reach the allowable effort, as depicted by the MSY curve shown in Figure 1.

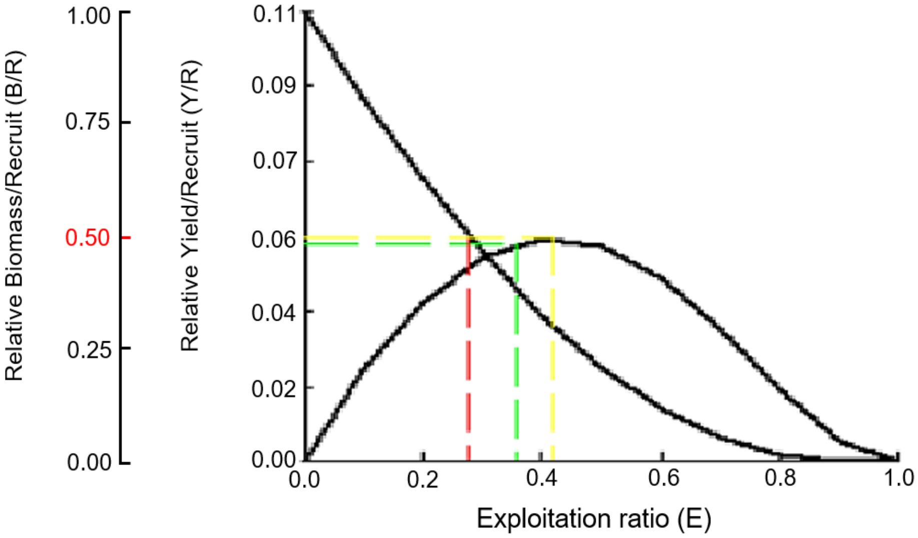


Figure 1. Curve of maximum sustainable yield of *Siganus* spp. at the research station.

The Visual Population Analysis (VPA). The Visual Population Analysis (VPA) results revealed that the siganid fish population structure at the study site appeared to have more survivors than total deaths. Nevertheless, catch-related deaths are more prevalent in all age groups, including fingerlings and juveniles, and adults. This phenomenon also applies to groups of varying sizes. Particularly, mortality due to capture is more prevalent in adolescent sizes, whereas adult sizes tend to be smaller, increasing the likelihood of natural death. Therefore, the population structure of large adult siganid fish that die naturally differs from the population that survives. Another finding was that the peak accumulation of both siganid fish death factors (natural death and catch) was at a length of 17.0 cm. The occurrence of peak fishing mortality at such a size suggests that siganid exploitation in the waters of the Gulf of Pasarwajo is not optimal due to the high number of natural siganid deaths in all sizes. Figure 2 illustrates this point more clearly.

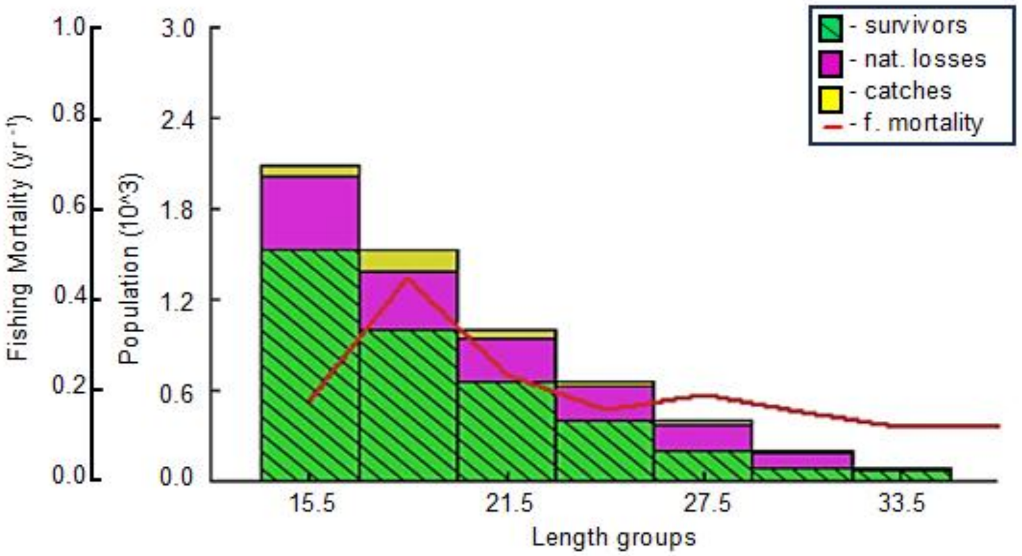


Figure 2. Stock assessment of *Siganus* spp. based on visual population analysis structure.

Frequency distribution of the total length of fish. The highest frequency (37 times) is at the midlength (ML) of 13.55 cm of the class 21.1–15 cm interval that occurred on September 13th, 2023. This suggests that fishermen currently have the highest chance of producing a *Siganus* spp. catch at a total length between 21 and 15 cm (Figure 3).

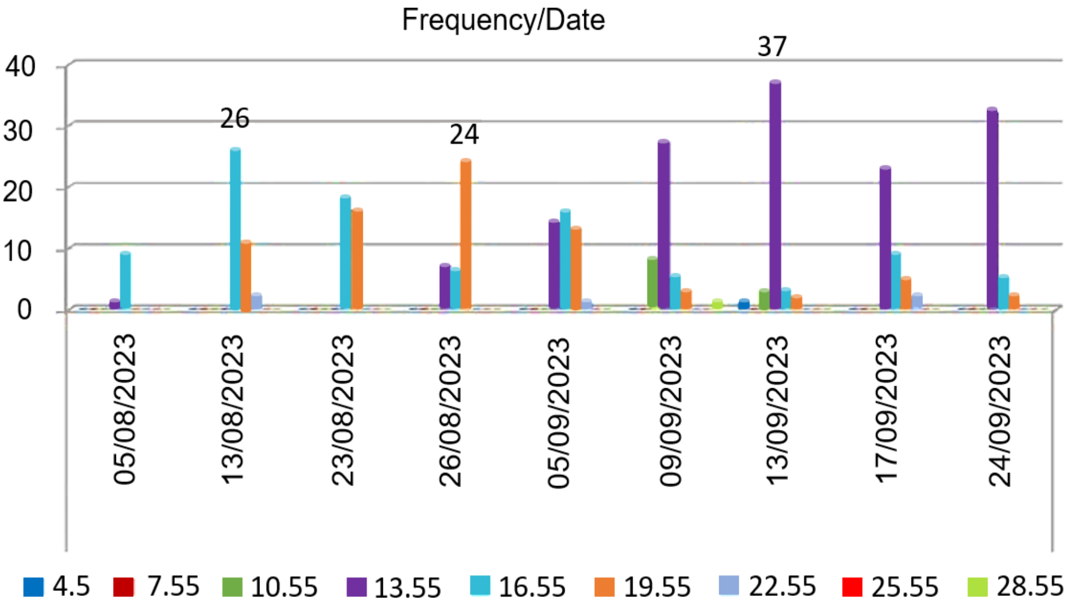
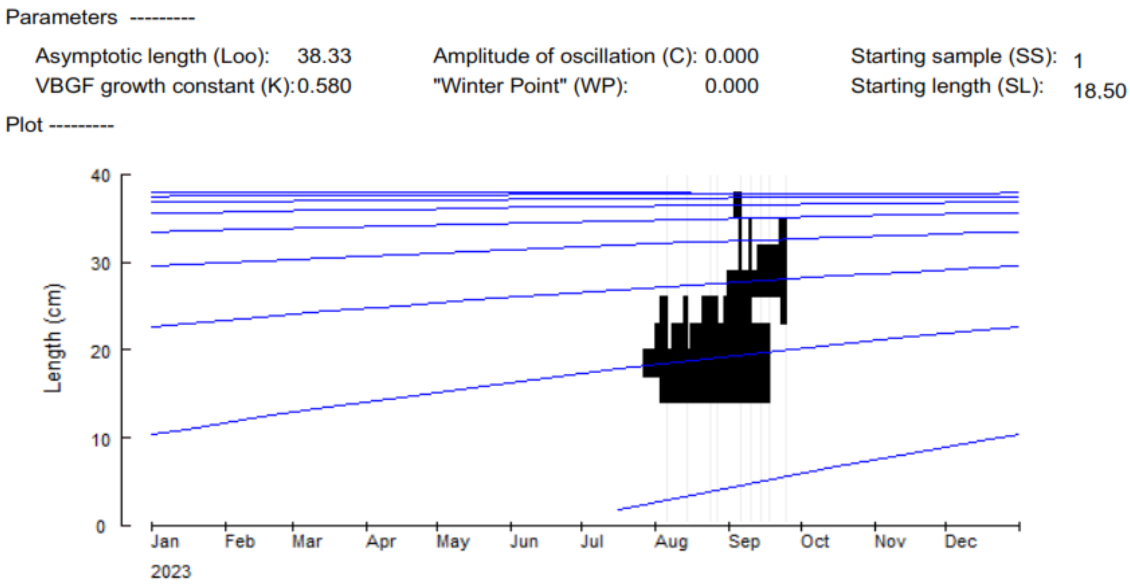


Figure 3. Frequency distribution of presence in each midlength class of the total length of the *Siganus* spp.

Siganis fish stock assessment based on growth constant Von Bertalanffy. The frequency spread of the presence on each ML results in a constant growth rate of 0.58, and the asymptotic length measures 38.33 cm. This indicates that a fisherman can catch siganid fish specimens sizing up to a maximum length of 38.33 cm (Figure 4).


Parameters ---------

Asymptotic length (Loo): 38.33
VBGF growth constant (K): 0.580
Amplitude of oscillation (C): 0.000
"Winter Point" (WP): 0.000
Starting sample (SS): 1
Starting length (SL): 18.50

Plot ---------

Figure 4. Stock assessment based on the growth function and the length frequency of the *Siganus* spp.

The stock analysis, based on catch length measurements, reveals that the siganid baby fish measures 4.32 cm, the teen siganid measures 7.17 cm, and the adult siganid measures 10.01 cm. The dominant teen siganid fish, measuring 13.55 cm in size, currently dominates the waters of the Bay of Pasarwajo, with a catch frequency of 37 times per trip.

Siganid fish stock assessment based on normal distribution separation. The siganid fish possesses the highest capacity for digging at a maximum length of 19.5 cm. Figure 5 illustrates the length distribution of the digging-capable siganid fish.

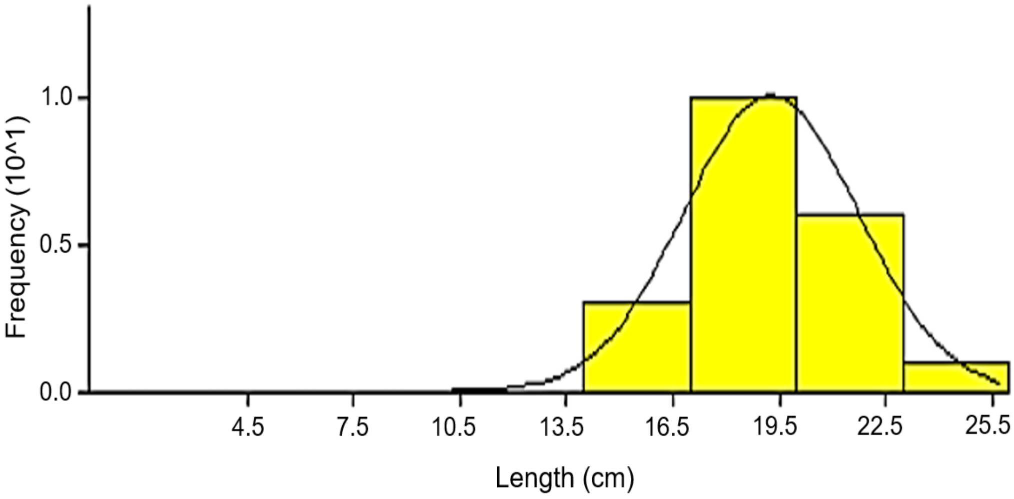


Figure 5. Stock assessment of the *Siganus* spp., based the on Bhattacharyya's normal distribution separation method.

Siganid fish stock assessment based on mortality. Pauly's analysis of the siganid fish's natural deaths revealed of approximately 1.17 year^{-1}. This is closely associated with a constant of 0.58, the presence of 38.33 cm-long asymmetrical siganid fish, and a water temperature ranging from 29^{o}C. Furthermore, we found that the known catch mortality rate (F) was 0.10, with an effort rate of 0.12. This results in a total siganid fish death rate of 1.29 in the Gulf of Pasarwajo (Figure 6).

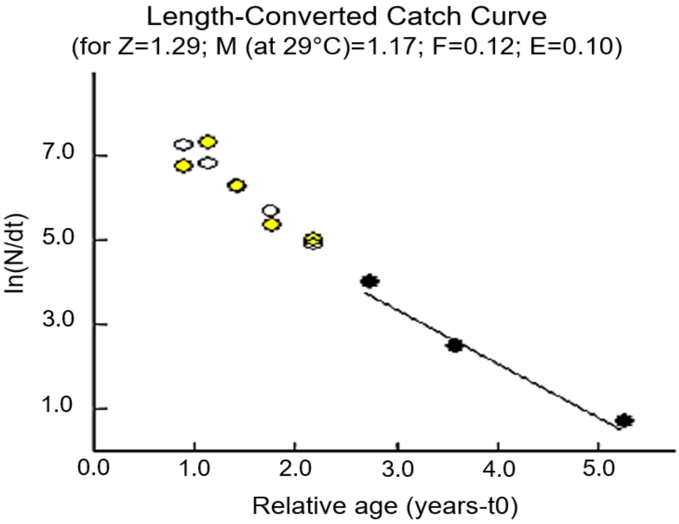


Figure 6. Stock assessment based on the conversion length of the total *Siganus* spp. catch in the waters of Pasarwajo Bay.

Discussion. The yield per recruit analysis is a method used to determine the relationship between fishing mortality and the yield obtained from each recruit in a fish stock. This approach assumes that all individuals in a cohort are level of effort vulnerable to fishing once they reach a certain size (Deriso 1982). The specific level of effort of 0.421 yielding a maximum sustainable yield (MSY) was not previously reported. However, the concept of MSY is central to fisheries management, in order to maintain fish stocks at sustainable levels, by identifying an optimal fishing effort that maximizes long-term catch without depleting the population (Chávez 2020). MSY as a limit reference point can be beneficial for sustainability if fishing mortality is kept below the level that achieves MSY (Chávez 2020). The implications of different population models on the estimation of MSY, indicating that the optimal fishing mortality rate may vary depending on the model used (Deriso 1982; Skonhoft & Gong 2016). The complexity of achieving MSY across different species and fishing methods suggests that a global MSY may not be attainable for all species simultaneously (Deriso 1982).

From an ecological perspective, it can be concluded that the *Siganus* spp. fish maintains its natural sustainability due to the abundance of populated fish, as evidenced by the dominant color. Reviewing the economic benefits reveals that they are not optimal, due to the small size of the captured fish and the limited production volume. The suggests that the captured specimens remain in the early stages of adolescence, indicating that the capture device's size is too small.

The relationship between life history characteristics and population dynamics could be relevant for understanding the survivorship of different fish species (Bjørkvoll et al 2012). Multispecies assessment models, including VPA, are important tools in fisheries management (Livingston 1986). Factors that could influence fish population dynamics were not studied for siganid fish populations, by applying VPA to that species. Without such information, it is not possible to draw conclusions about the survivorship and mortality of siganid fish populations from the context provided (Bjørkvoll et al 2012; Livingston 1986).

The length-weight relationships (LWRs) were determined for six finfish species from Pulicat Lagoon, India, including one siganid species, but does not provide information on the likelihood of catching siganid fish at specific lengths (Nallathambi et al 2019). Hehre et al (2016) explore the correlation between increased seaweed production and siganid catch but do not provide a specific size range for the highest catch probability, to identify the size at which fishermen are most likely to catch siganid fish. Eranza et al (2015) address the rapid growth of the seaweed industry in Indonesia and its socio-economic determinants, including the role of women and child labor, but do not directly address the impact on siganid catch. Hamuna et al (2023) study the length-weight relationship and condition factors of eight fish species, including two siganid species, in Youtefa Bay, Indonesia, but again does not address the probability of catching siganid fish at certain lengths. Tresnati et al (2019) focus on the reproductive biology of the siganid fish *Siganus canaliculatus*, without mentioning catch probabilities.

Fishermen can indeed catch small-sized siganid fish, which are marine herbivorous fish commonly found in shallow waters. Pauli et al (2020) discuss how fishing practices select for certain traits, leading to populations dominated by smaller fish due to the preferential capture of larger individuals. This could imply that smaller fish, potentially including siganids, are more prevalent in certain fished populations (Pauli et al 2020). A variety of fishing gears are used in Bangladesh, which could potentially be used to catch small siganid fish if they are present in the local ecosystem (Siddiq et al 2013). Fishing can lead to smaller fish sizes in general, and a variety of fishing gears are employed that could be suitable for catching small fish, including siganids, if they are present in the fishing area (Pauli et al 2020; Siddiq et al 2013).

The assessment of siganid fish stocks uses a method based on the normal distribution separation. There is an empirical relationship between the Bhattacharyya distance and classification error for multimodal data, which could be relevant if siganid fish stock data exhibited multimodal characteristics (Choi & Lee 2001). The biology and mariculture of siganids, provide a context for their ecological and biological significance, but does not delve into stock assessment methods (Lam 1974). Chen et al (2003) highlight the limitations of assuming a normal distribution for errors in fisheries data, suggesting that these often contain outliers that can lead to biased estimates in stock assessment models. This suggests that while the Bhattacharyya distance could be useful for certain types of data, its application to the siganid fish stock assessment might be complicated by the presence of atypical errors and outliers. In summary, while the Bhattacharyya distance has been studied as a tool for error estimation in multimodal data, its direct application to the siganid fish stock assessment is not explicitly discussed in the available literature. Moreover, the assumption of normal distribution errors in fish stock assessment is challenged, indicating that robust methods may be more appropriate for such data, which could affect the reliability of methods based on normal distribution separation, such as those utilizing the Bhattacharyya distance (Chen et al 2003; Choi & Lee 2001). The natural mortality rate (M) in this study for the Siganid fish species was reported to be around 1.17 year^{-1}. Tresnati et al (2020) reports a value of 0.74 year^{-1} in the Makassar Strait and somewhat higher at 0.79 year^{-1} in the Gulf of Bone for the white spotted rabbitfish (*Siganus canaliculatus*) The low natural mortality indicates that current environmental conditions and dynamics in the two seaways seem to be suitable for maintaining healthy rabbitfish populations. These values are close to the figure mentioned in the question but are not identical. It is interesting to note that the natural mortality rates provided in these papers are specific to the studied regions and time frames. Mortality rates can vary due to a multitude of factors, including environmental conditions, predation pressure, and fishing activities. The slight discrepancy between the rates in the papers may reflect such regional and temporal variations. The natural mortality rates of siganid species differ with the geographical locations, which is crucial for the management and conservation of these fish populations (Gonzaga 2020; Prihatiningsih et al 2022).

Conclusions. A good stock assessment of siganid fish necessitates a holistic and sustainable approach that takes into account not only economic but also social and environmental aspects. It strives to safeguard fisheries resources and offers benefits to both communities and marine ecosystems. The seagrass ecosystem's potential for fishery commodities, in the Pasarwajo Gulf Buton region, is preserved due to a fishing activity which remains below the effort, yield, and permissible biomass, allowing for a 21.69% increase in small-scale fishing, corresponding to a fishing production increase of 13.32%.

Acknowledgements. This research was carried out with UHO Internal BLU funding in 2023. The authors express their highest gratitude to the rector of Halu Oleo University and the Institute for Research and Community Service of Halu Oleo University. Thanks also to the regional government of Buton Regency, research informants, and all parties who have contributed to this research.

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

References

Bjørkvoll E., Grøtan V., Aanes S., Sæther B. E., Engen S., Aanes R., 2012 Stochastic population dynamics and life-history variation in marine fish species. The American Naturalist 180(3):372-387.

Chávez E. A., 2020 Maximum sustainable yield, maximum economic yield and sustainability in fisheries. Journal of Aquaculture & Marine Biology 9(1):15-17.

Chen Y., Jiao Y., Chen L., 2003 Developing robust frequentist and Bayesian fish stock assessment methods. Fish and Fisheries 4(2):105-120.

Choi E., Lee C., 2001 Estimation of classification error based on the Bhattacharyya distance for multimodal data. IEEE 2001 International Geoscience and Remote Sensing Symposium 4:1874-1876.

Deriso R. B., 1982 Relationship of fishing mortality to natural mortality and growth at the level of maximum sustainable yield. Canadian Journal of Fisheries and Aquatic Sciences 39(7):1054-1058.

Eranza D. R. D., Alin J. M., Bahron A., Mahmud R., 2015 Determinants of women's participation in seaweed farming in the Regency of Jeneponto, South Sulawesi, Indonesia. Mediterranean Journal of Social Sciences 6(5):43-45.

Fitzgerald C. J., Delanty K., Shephard S., 2018 Inland fish stock assessment: applying data-poor methods from marine systems. Fisheries Management and Ecology 25(4):240-252.

Gonzaga A. M., 2020 Population dynamics of the white spotted rabbitfish (*Siganus canaliculatus* Park, 1797) in Panguil Bay, Philippines. International Journal of Innovative Science and Research Technology 5(9):295-301.

Grønnevik R., Evensen G., 2001 Application of ensemble-based techniques in fish stock assessment. Sarsia 86(6):517-526.

Gulland J. A., 1965 Estimation of mortality rates. Annex to Arctic Fisheries Working Group Report. ICES CM Gadoid Fish, 9 p.

Gullström M., de la Torre Castro M., Bandeira S. O., Björk M., Dahlberg M., Kautsky N., Öhman M. C., 2002 Seagrass ecosystems in the western Indian Ocean. AMBIO: a Journal of the Human Environment 31(7):588-596.

Hamuna B., Indrayani E., Agamawan L. P. I., 2023 Length-weight relationship of eight species of fish caught by traditional Papuan fishers in Youtefa Bay, Indonesia. European Journal of Ecology 9(2):9-16.

Hehre E. J., Meeuwig J. J., 2016 A Global analysis of the relationship between farmed seaweed production and herbivorous fish catch. PloS One 11(2):e0148250.

Jones R., Van Zalinge N. P., 1981 Estimates of mortality rate and population size for shrimp in Kuwait waters. Kuwait Bulletin Marine Science 2:273-288.

Kiggins R. S., Knott N. A., New T., Davis A. R., 2020 Fish assemblages in protected seagrass habitats: Assessing fish abundance and diversity in no-take marine reserves and fished areas. Aquaculture and Fisheries 5(5):213-223.

Lam T. J., 1974 Siganids: their biology and mariculture potential. Aquaculture 3(4):325-354.

Latuconsina H., Kamal M. M., Affandi R., 2022 Growth and reproductive biology of white-spotted rabbitfish (*Siganus canaliculatus*) on different seagrass habitats in Inner Ambon Bay, Indonesia. Biodiversitas 23(1):273-285

Livingston P. A., 1986 Incorporating fish food habits data into fish population assessment models. In: Contemporary studies on fish feeding: the proceedings of GUTSHOP'84. Asilomar Conference Center, Pacific Grove, California, USA, Springer Netherlands, pp. 225-234.

Lloret J., Faliex E., Shulman G. E., Raga J. A., Sasal P., Muñoz M., Casadevall M., Ahuir-Baraja A. E., Montero F. E., Repullés-Albelda A., Cardinale M., Rätz H. J., Vila S., Ferrer D., 2012 Fish health and fisheries, implications for stock assessment and management: the mediterranean example. Reviews in Fisheries Science 20(3):165-180.

McArthur L. C., Boland J. W., 2006 The economic contribution of seagrass to secondary production in South Australia. Ecological Modelling 196(1-2):163-172.

Nallathambi M. N. J., Arumugam U., Jayasimhan P., Chandran S., Paramasivam K., 2019 Length-weight relationships of six tropical estuarine fish species from Pulicat lagoon, India. Journal of Applied Ichthyology 36(1):125-127.

Parawansa B. S., Ali S. A., Nessa N., Rappe R. A., Indar Y. N., 2020 Biological analysis of adult rabbitfish (*Siganus guttatus* Bloch, 1787) in seagrass and coral reef ecosystems at Laikang Bay, Takalar Regency. IOP Conference Series: Earth and Environmental Science 473(1):012006.

Pauli B. D., Bartuseviciute V., Heino M., 2020 Fishing can turn big fish into small fish. Frontiers for Young Minds 8:e112.

Pauly D., Gaschutz G., 1979 A simple method for fitting oscillating length growth data, with a program for pocket calculators. ICLARM Newsletter 2(1):15-17

Prihatiningsih N., Muchlis N., Taufik M., Amri K., Hartati S. T., 2022 Some indicators for assessing stock of golden rabbitfish (*Siganus guttatus*, Bloch 1787) in Wakatobi Waters, Southeast Sulawesi, Indonesia. IOP Conference Series. Earth and Environmental Science 1033(1):012025.

Rauf A., 2018 Analysis of land suitability and carrying capacity of rabbitfish (*Siganus canaliculatus*) culture in seagrass ecosystem in coastal areas of Barru District, South Sulawesi. Torani Journal of Fisheries and Marine Science 2(1):15-22.

Siddiq M. A., Miah M. I., Ahmed Z. F., Asadujjaman M., 2013 Present status of fish, fishers and fisheries of dogger beel in Hajigonj Upazila, Chandpur, Bangladesh. Journal of Aquatic Science 1(2):39-45.

Skonhoft A., Gong P., 2016 Maximum sustainable yield harvesting in an age-structured fishery population model. Natural Resource Modeling 29(4):610-632.

Somers I. F., 1988 On a seasonally oscillating growth function. Fishbyte 6(1):8-11.

Sparre P., Venema S. C., 1998 Introduction to tropical fish stock assessment. Part 1: Manual. FAO Fisheries Technical Paper 306:192-218.

Tresnati J., Omar S. B. A., Tuwo A., 2019 Some reproductive biology studies of rabbitfish *Siganus canaliculatus* (Park, 1797) from the Southern coastal waters of Jeneponto, South Sulawesi, Indonesia. Biosciences Biotechnology Research Asia 16(3):617-624.

Tresnati J., Omar S. B. A., Tuwo A., 2020 Population dynamics of the white spotted rabbitfish (*Siganus canaliculatus* Park, 1797) in Makassar Strait and Gulf of Bone, Indonesia. IOP Conference Series: Earth and Environmental Science 492(1):012093.

Vieira M. L. M., de Lima C. L. A., de Souza J. R. B., Feitosa J. L. L., 2020 Effects of beach seine fishing on the biodiversity of seagrass fish assemblages. Regional Studies in Marine Science 40:101527.

Wahyudin Y., 2022 [Economic analysis of seagrass ecosystem and fish resources linkages in seagrass bed conservation area of Bintan Island]. Akuatika Indonesia 7(2):42-49. [in Indonesian]

Watkins H. V., Munger R. B., Côté I. M., 2023 Effects of sea cucumber fishing on tropical seagrass productivity. Ecosphere 14(5):e4543.

Xiao Y., 1998 Two simple approaches to use of production models in fish stock assessment. Fisheries Research 34(1):77-86.

*** Fisheries and Marine Office of Buton Regency, 2021 Fisheries production data for Buton Regency, Southeast Sulawesi Province. Fisheries and Marine of Buton Regency, 68 p.

Received: 06 December 2024. Accepted: 28 October 2025. Published online: 30 November 2025.

Authors:
Nurdiana Azis, Department of Fisheries Agribusiness, Faculty of Fisheries and Marine Science, Halu Oleo University, Kendari, Indonesia, e-mail: nurdiana@uho.ac.id
Ma'ruf Kasim, Department of Water Resource Management, Faculty of Fisheries and Marine Science, Halu Oleo University, Kendari, Indonesia, e-mail: marufkasim@uho.ac.id
Sjamsu Alam Lawelle, Department of Fisheries Agribusiness, Faculty of Fisheries and Marine Science, Halu Oleo University, Kendari, Indonesia, e-mail: Sjamsualam@uho.ac.id
Akhmad Mansyur, Department of Fisheries Agribusiness, Faculty of Fisheries and Marine Science, Halu Oleo University, Kendari, Indonesia, e-mail: akhmadmansyur@uho.ac.id
Roslindah Daeng Siang, Department of Fisheries Agribusiness, Faculty of Fisheries and Marine Science, Halu Oleo University, Kendari, Indonesia, e-mail: roslindahdgsiang@uho.ac.id
Wa Ode Piliana, Department of Fisheries Agribusiness, Faculty of Fisheries and Marine Science, Halu Oleo University, Kendari, Indonesia, e-mail: wpiliana@uho.ac.id

How to cite this article:
Azis N., Kasim M., Lawelle S. A., Mansyur A., Siang R. D., Piliana W. O., 2025 The stock assessment of *Siganus* spp. in the seagrass ecosystem. AACL Bioflux 18(6):2653-2664.