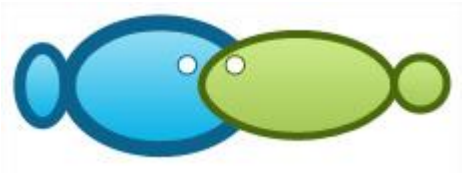

Urgent call for sustainable management of Indian halibut, *Psettodes erumei*, resource in the Spermonde Islands

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Abstract. The Spermonde Islands are at the center of the world's coral triangle, crossed by the Wallace Line, so its resources must be managed sustainably. The Indian halibut *Psettodes erumei* is the most primitive species of flatfish, which is thought to have suffered from exploitation. This research aims to assess the utilization status of the *P. erumei* stock in the Spermonde Islands. The *P. erumei* samples were taken from the fishers catch who landed at the Fish Landing Port, Makassar City. The population and exploitation parameters observed were growth, mortality, selectivity curve, capture probability, virtual population, and recruitment. The number of *P. erumei* samples obtained during the research was 419, with an average length of 28.9 cm (between 6.7 and 77.5 cm). The asymptote length ($L\infty$) was 78.75 cm and the growth rate (K) was 0.73, while the growth performance index (φ) was 3.85. The first capture length (Lc) was 16.39 cm, the capture length at probability 0.25 (L_{25}) was 14.24 cm, at 0.75 (L_{75}) it was 18.55 cm, and at the time of full recruitment to the capture fishery (L_{100}) it was 22.5 cm. The total death rate (Z) was 4.07, the instantaneous natural death rate (M) was 0.72, and the fishing death rate (F) was 3.353. Current exploitation (E) was estimated at 0.82, indicating that the current exploitation level is far beyond the limit of sustainable utilization (0.5). The condition of being highly exploited indicates that a sustainable management is urgently needed.
Key Words: growth, mortality, capture, virtual population, recruitment.

Introduction. The Indian halibut, *Psettodes erumei*, is a flatfish species primarily found in the Indian and Pacific Oceans (Fishbase 2023). In Indonesia, *P. erumei* is found in almost all Indonesian coastal waters, especially in the waters of the island of Java, the eastern part of Sumatra Island, the northern part of Java Island, the waters of Kalimantan Island, the waters of South Sulawesi Island, the waters of Arafuru, to the north, including the Bay of Bengal, and to the east, in the waters of Papua Island (Wiadnya & Setyohadi 2014). Like other members of its family, *P. erumei* is considered the most primitive of the flatfish species, having a thicker, less compact body and migrating eyes located on the edge of the head rather than entirely on top. *P. erumei* is a demersal fish caught by trawling, edge seine, jermal, and sero. *P. erumei* usually lies on the bottom with one side of its body facing down. The side facing downwards is flat and white or very pale, while the side facing upwards is convex and colored, the body color usually matching the surrounding environment (Nontji 2005).

P. erumei lives on muddy bottom surfaces in coastal and deeper areas, including wild fish that eat bottom animals, especially shrimp. *P. erumei* can reach a length of 50 cm, generally 20-40 cm. *P. erumei* are found on sand and mud bottoms (Hensley 1997; Kuiter & Tonozuka 2001), usually profoundly buried in the substrate during the day, but hunting at night (Kuiter & Tonozuka 2001). They often swim in an upright position (Hensley 1997)

and are mainly piscivorous (Ramanathan & Natarajan 1980). They are mainly sold fresh (Fischer et al 1990) and are also used smoked and frozen (Frimodt 1995). They are processed into fish flour (Ravelson 1990). The results of previous research show that the density of *P. erumei* in East Kutai Regency waters is 39.68 kg km^{-2}, denser than other commercial fish caught in the same waters, like *Epinephelus* sp. (38.20 kg km^{-2}), shrimp (16.86 kg km^{-2}), and squid (2.44 kg km^{-2}) (Juliani 2013).

About 20 years ago, in Indonesia, *P. erumei* was considered a fishery resource that had no economic value, therefore they were not utilized optimally, and they were subjected to a relatively low level of fishing effort. At that time, *P. settodes erumei* was not a catch target, but only a trash fish caught together with other types of demersal fish with high economic value. In 2016, Adela et al (2016) predicted that it is possible that *P. erumei* could become an export or domestic consumption commodity, in the future. In less than ten years, this prediction became a reality because there was an increase in the market demand for this species, that became a target for fishing. Currently, *P. erumei* is thought to be subjected to over-fishing. This research aimed to assess the status of utilization of the *P. erumei* stock on the Spermonde Islands by observing the population and exploitation parameters. Spermonde Islands is part of the State Fisheries Management Area of the Republic of Indonesia, number 713 (Koeshendrajana, Rusastra & Martosubroto 2019). Spermonde Islands have a high diversity of corals, being located in the world's coral triangle, crossed by the Wallace Line, therefore they also have a high diversity of coralfish (Tresnati et al 2019; Yasir et al 2019; Ulfah et al 2020; Tuwo & Tresnati 2020).

Material and Method. The sample specimens of *P. erumei* were collected from the catch of fishers who landed at the Fish Landing Port, Makassar City. Fishermen catch *P. erumei* in the waters of the Spermonde Islands, namely ose of Lumu-lumu Island, Lanyukang Island, Bonebatang Island, Panambung Island, Langkai Island, Kodingarengkeke Island, Kodingarenglompo Island, Barrang Lompo Island, Barrangcaddi Island, and along the west coast of South Sulawesi (Figure 1).

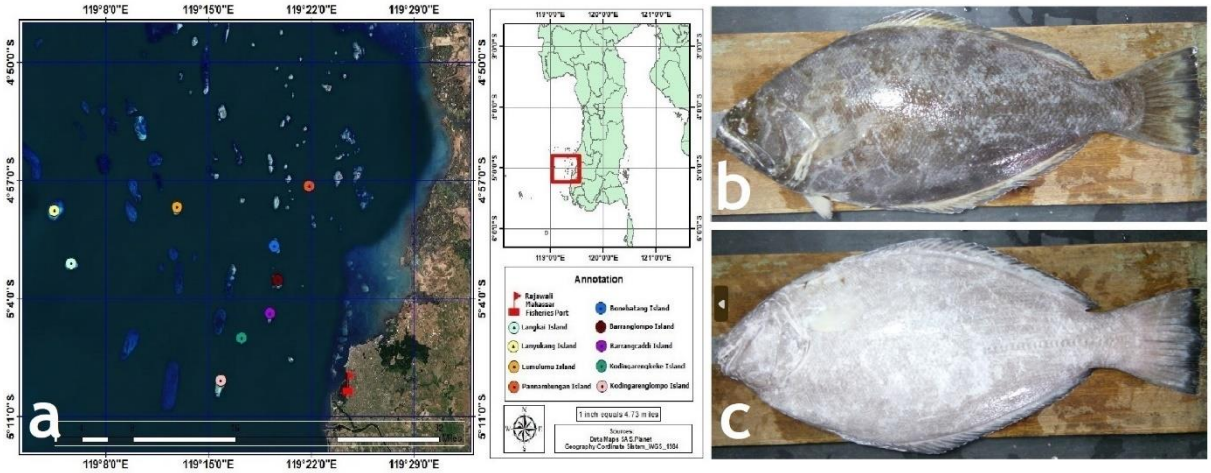

Figure 1. Fishing areas of *Psettodes erumei* (a); *Psettodes erumei* specimen seen from the dorsal side (b); *Psettodes erumei* specimen seen from the ventral side (c).

The total length of *P. erumei* was measured using a ruler to the nearest 1.0 mm. *P. settodes erumei* samples were taken every mid-month. Population parameters of *P. erumei* were analyzed by dividing the total length into 24 classes using 3 cm intervals.

P. erumei age groups were separated using the Bhattacharya method by dividing the fish into several length ranges (Sparre & Venema 1999). To obtain the estimated value of the asymptote length (L∞) and the growth rate coefficient (K) of *P. erumei*, the Response Surface Analysis assistance of ELEFAN I was used, in the program FISAT II. Theoretical life when the length of *P. erumei* was equal to zero (to) was estimated using the empirical formula (Pauly 1983): log (-t_o) = - 0.3922 – 0.2752 (log L∞) – 1.038 (log K).

The total mortality rate for *P. erumei* was calculated using the Beverton and Holt formula (Sparre & Venema 1999):

$$Z = K\ (\frac{L\omega - L}{L - L'})$$

Where:
Z - the total mortality rate for *P. erumei* (year);
L - the average length of captured *P. erumei* (cm);
L' - the minimum length of *P. erumei* caught (cm).

The natural mortality rate of *P. erumei* was estimated by Pauly (1983):

$$\log (M) = -0{,}0066 - 0{,}279 \log L_\infty + 0{,}6543 \log K + 0{,}4634 \log T$$

Where:
M - the *P. erumei*'s natural mortality rate ($year^{-1}$);
T - mean water temperature measured in the Spermonde Islands (^oC).

The average seawater temperature data was taken from the Makassar Meteorological and Geophysical Station. Capture mortality rate of *P. erumei* was estimated using the equation (Sparre & Venema 1999):

$$Z = F + M \text{ or } F = Z - M$$

Where:
F - the capture mortality rate from ($year^{-1}$).

The exploitation rate (E) of *P. erumei* was estimated using the Beverton and Holt equations (Sparre & Venema 1999):

$$E = F / Z$$

The selectivity curve is estimated using linear regression to obtain the first capture length (L50 or Lc) and capture length values at probabilities of 0.25 (L25), 0.75 (L75), and 1 (L100). The selectivity curve was obtained using FISAT II (Gayanilo et al 2005).

ELEFAN I (nonparametric assessment of the von Bertalanffy Growth Function – VBGF - Fit) and II software were used to estimate recruitment patterns with FISAT II (Gayanilo et al 2005).

Relative Yield per Recruitment (Y'/R) of *P. erumei* was estimated by using the Beverton and Holt equation (Sparre & Venema 1999), namely:

$$Y/R' = E \times U^{M/K}(1 - \frac{3U}{1+m} + \frac{3U^2}{1+2m} - \frac{U^3}{1+3m})$$

$$U = 1 - \frac{L'}{L\infty}\ E = \frac{F}{Z}$$

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

P. erumei caught in full Y'/R obtained using FISAT II (Gayanilo et al 2005).

Results. The number of *P. erumei* samples obtained during the research were 419, with an average length of 28.9 cm (for lengths from 6.7 to 77.5 cm). The asymptote length (L_∞) and growth rate (K) of *P. erumei* were 78.75 cm and 0.73, respectively (Figure 2). The growth performance index (φ) of *P. erumei* obtained according to the growth parameter rate (0.73) was 3.85 (Figure 3). The average first capture length (L_c or L_{50}) was 16.39 cm, and the capture lengths at probabilities 0.25 (L_{25}) and 0.75 (L_{75}) were 14.24 cm and 18.55 cm, respectively (Figure 4). Fish were fully recruited to the capture fishery (L_{100}) at a size of approximately 22.5 cm.

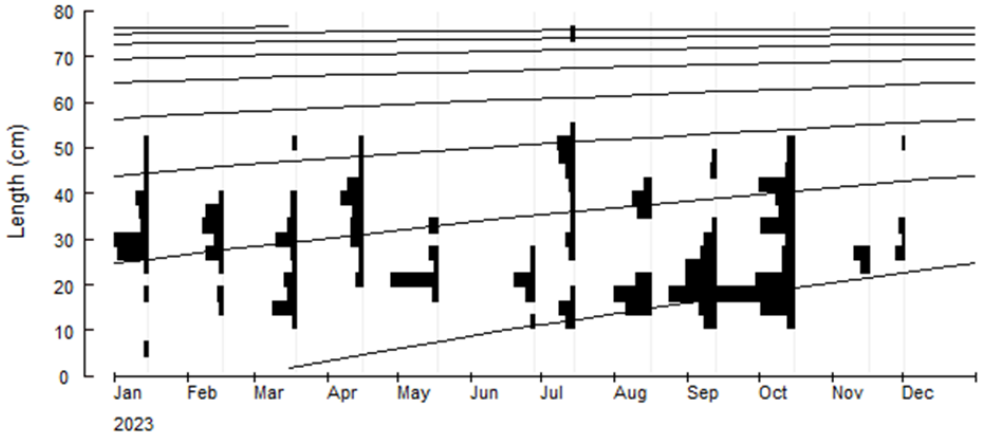

Figure 2. Growth curve of *Psettodes erumei* in Spermonde Islands.

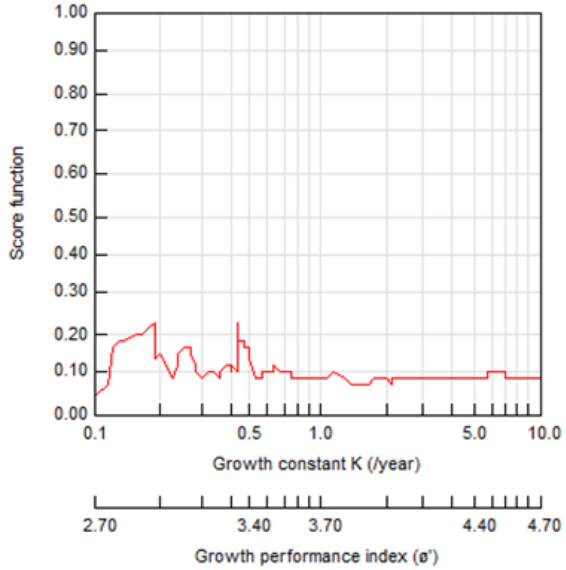

Figure 3. Growth performance index of *Psettodes erumei* in Spermonde Islands.

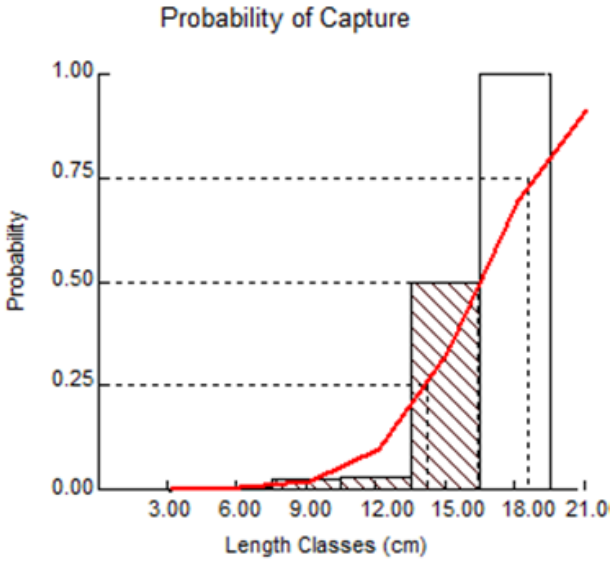

Figure 4. Capture probability of *Psettodes erumei* in Spermonde Islands.

The total mortality was 4.07 yr^{-1}, natural mortality was 0.72 yr^{-1}, fishing mortality was 3.35, and exploitation rate was 0.82 yr^{-1} (Figure 5).

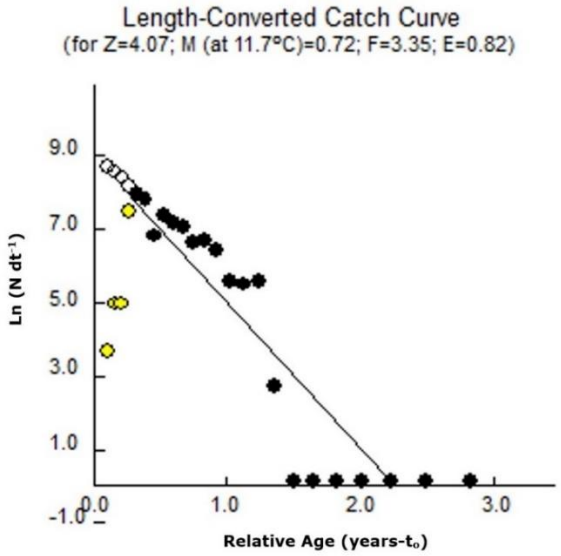

Figure 5. Total mortality curve of *Psettodes erumei* in Spermonde Islands.

Virtual population analysis shows that stock loss due to natural mortality was dominant only up to 12 cm (Figure 6). Fish become more susceptible to fishing gear after 12 cm, then fishing-related deaths increase rapidly and eventually exceed natural deaths from 15 cm onwards. The maximum fishing mortality of 5.04 was recorded at 51 cm.

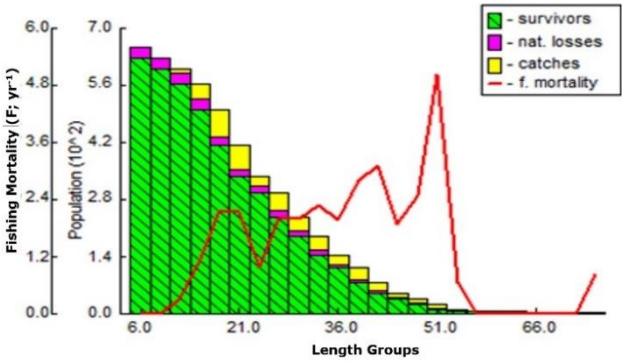

Figure 6. Virtual population curve of *Psettodes erumei* in Spermonde Islands.

Recruitment occurs twice a year (Figure 7). The relative yield per recruit (Y'/R) (0.028) at the current exploitation ($E_{current}$ = 0.82, blue line) was lower than the relative yield per recruit (Y'/R) (0.063) at the maximum allowable exploitation (E_{50} = 0.50, yellow dotted line) (Figure 8).

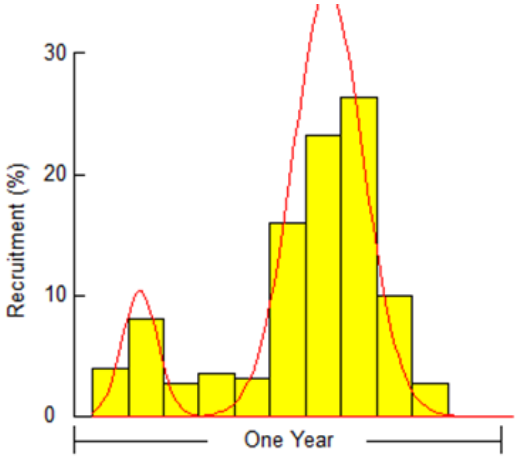

Figure 7. Recruitment curve of *Psettodes erumei* in Spermonde Islands.

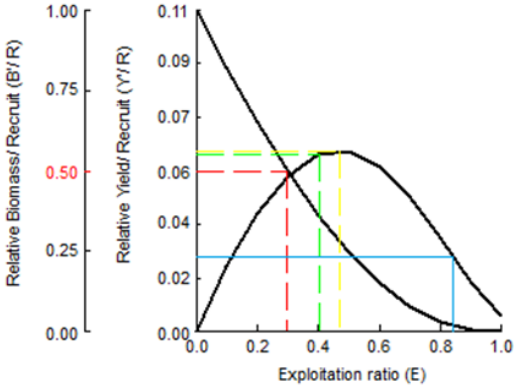

Figure 8. Relative yield per recruit (Y'/R) curve of *Psettodes erumei* in Spermonde Islands.

Discussion. The need for a rational assessment of *P. erumei* in Spermonde Islands is based on concerns about the sustainable use of stock and biodiversity on Spermonde Islands, part of the world's coral triangle, also crossed by the Wallace line. The growth performance index value φ of the *P. erumei* in the Spermonde Islands was more significant than in the Oman Sea (3.85) or in the Persian Gulf (3.10) (Gilanshahi et al 2012). It is also higher than for the *P. erumei*, found in the coastal waters of Brunei Darussalam (2.99) (Silvestre & Garces 2004). Many factors, including water conditions, physiological conditions, and food availability, can cause this spatial variation. The growth performance index value φ, which is higher than in other waters, indicates that the water conditions, physiological conditions, and food availability in Spermonde Islands are very supportive for the life of *P. erumei*. Biologically, fish that have a fast growth rate, such as *P. erumei*, have good potential to be domesticated as farmed fish in the sea or brackish water ponds.

Theoretically, the natural death coefficient is directly proportional to the growth coefficient (K) and inversely proportional to the asymptotic length (L_∞). Therefore, *P. erumei* in Spermonde Islands, which is characterized by a high growth rate of 0.73 year^{-1} and a relatively shorter lifespan of 4 years (if the assumption of recruitment occurring twice a year is accepted), was found to have a natural mortality coefficient (M) which is relatively small (0.72 year^{-1}). The M/K ratio obtained in this study (0.99) is within the normal range, as is the value suggested by Beverton and Holt (between 1.0 and 2.5) (Beverton & Holt 1959). The Z/K ratio of 5.6 indicates that *P. erumei* in Spermonde Islands is dominated by mortality. A Z/K ratio of 1.0-2.0 is considered growth-dominated, and for more than 2.0, it is death-dominated. The condition of the population, which is dominated by deaths due to fishing, shows that the population of *P. erumei* in the Spermonde Islands is threatened by its continual exploitation, so an urgent sustainable management plan is needed.

Previous research showed that the first maturity gonad length (Lm) of *P. erumei* was 38.20 cm in the Oman Sea, near the Persian Gulf (Ghabarza et al 2021), 41.1 cm in the Bombay waters, India (Pradhan 1962), 37.1 cm at Porto Novo, India (Ramanathan & Natarajan 1979). Lm was bigger than the length of the first catch (Lc), indicating that *P. erumei* in Spermonde Islands is caught or dies before spawning. Deaths due to fishing must be equal to natural deaths, resulting in an optimal exploitation level, namely 0.50 (Gulland 1969). The results of this study indicate that *P. erumei* in the Spermonde Islands is exploited far beyond the optimal exploitation levels. The yield per recruitment confirms this finding. The relative yield per recruitment at the current exploitation was lower than the one at the maximum allowable exploitation, indicating that *P. erumei* exploitation in the Spermonde Islands was higher than the maximum allowable fishing level. The current fishing mortality rate of *P. erumei* in Spermonde Islands exceeds by far the optimal fishing efforts, endangering its sustainability. Therefore, urgent efforts are needed to maintain the sustainability and continuity of *P. erumei* catch in the Spermonde Islands. Sustainable management of *P. erumei* resources in the Spermonde Islands can only occur if the fish can reproduce at least once during their lifetime. This can be achieved if the length at first capture (Lc) is more significant than at first maturity (Lm). FAO has also warned against the outrageous consumerism, urgently calling for a sustainable management of the

populations suffering over-exploitation. This is based on the fact that the increasing world's population raises demand for additional food. In contrast, nature's ability to produce food declines, due to the environmentally unfriendly utilization patterns (Tuwo et al 2022).

Conclusions. The fast growth rate and high growth performance index indicate that *P. erumei* has the potential to be domesticated as farmed fish. The first maturity length, more significant than the first catch length, indicates that the *P. erumei* in the Spermonde Islands were caught or died before spawning. The relative yield per recruit at the current exploitation is lower than at the maximum allowable exploitation, indicating that the *P. erumei* exploitation in the Spermonde Islands was higher than the maximum allowable fishing level. The condition of highly exploited, which is dominated by deaths due to fishing, shows that an urgent sustainable management plan is needed.

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

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