

# Population parameters and exploitation analysis of long tongue sole, *Cynoglossus lingua*: Implications for fisheries sustainability in the Spermonde Islands, Indonesia

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**Abstract.** Population characteristics and utilization levels can affect fisheries' sustainability. Effective fisheries management is crucial to maintaining the ecological, economic, and social benefits of resources in the Spermonde Islands. Maintaining these benefits is a prerequisite for presenting ethical fisheries management, conservation of biological resources, and community welfare. This study aimed to analyze the parameters of growth, mortality, exploitation, and recruitment of long tongue sole, *Cynoglossus lingua*, population in the waters of the Spermonde Islands, contributing to efforts to manage resources sustainably and maintain the balance of the marine ecosystem. Sampling was carried out from January to December 2024. The population parameters and utilization levels analyzed were growth, mortality, exploitation, and recruitment. The results showed that *C. lingua* in the Spermonde Islands had an asymptote length ( $L_{\infty}$ ) of 48.07, a growth coefficient ( $K$ ) of 0.51, and a growth performance index ( $\phi'$ ) of 3.071. It had a capture probability ( $L_{50}$ ) of 33.43, a total mortality rate ( $Z$ ) of 2.94, a natural mortality rate ( $M$ ) of 1.04, and a fishing mortality rate ( $F$ ) of 1.90. The exploitation rate ( $E$ ) was 0.64, there were two recruitments per year at sizes of 1.53 cm and 6.83 cm, the relative yield per recruit ( $Y/R'$ ) was 0.028, and the relative biomass per recruit ( $B/R'$ ) was 0.326. The study found that the *C. lingua* population in the Spermonde Islands had better growth parameters than those of tonguefish and other species. However, the high level of exploitation seriously threatens the survival of the population. Integrated management techniques use should be attempted to control the level of exploitation, manage appropriate catch sizes, and maintain recruitment periods. Integrated management will ensure the sustainability of the fishery and the continued ecological, economic, and social benefits provided by the *C. lingua* population.

**Key Words:** growth, mortality, exploitation rate, recruitment, overfishing.

**Introduction.** The Spermonde Islands, located in the Makassar Strait in Southwest South Sulawesi, Indonesia, have diverse marine resources such as demersal, pelagic, and reef (Anshari 2023; Amran et al 2024). Long tongue sole fish, *Cynoglossus lingua*, is a popular and widely consumed demersal fish, and several species have been developed through intensive cultivation (Xing et al 2020). Long *C. lingua* is a member of the Cynoglossidae family with an economic and ecological role in coastal areas around the world (Baeck et al 2011). This fish is elongated, it has an anal fin that is fused with the caudal fin and dorsal fin, and is widely found in coastal waters (Aung 2018). This fish undergoes metamorphosis or changes in body shape from symmetrical larvae to asymmetrical when it becomes a juvenile (Power et al 2008). *C. lingua* is consumed more in developed countries, such as the United States, Japan and Europe, than in Indonesia (Tresnati et al 2018).

*C. lingua* represents a significant fishery resource valued for its palatable meat. However, the high market demand results in threats to this resource's survival due to intense fishing activities. As a result of using environmentally unfriendly fishing gear, the *C. lingua* population is being adversely affected in several places (Sulistiono et al 2011). In addition, using trawls on the seabed surface damages the habitat of *C. lingua*. This habitat destruction disrupts the life cycle from spawning to growth. This damage impacts the sustainability of fisheries because the loss of one species can cause the loss of a whole food chain, that can impact the balance of the ecosystem. Handling the damage caused by overfishing faces additional obstacles due to the lack of accurate data and information. Accurate data on population dynamics are essential for informed management decisions. Steps that can be taken amidst these difficulties are to act proactively, such as making stricter fishing regulations, using more environmentally friendly fishing gear, and maintaining important habitats so that the future of the sea remains rich and diverse and future generations can still enjoy *C. lingua*. Therefore, effective management of fisheries resources requires accurate data on population parameters and exploitation levels. This study aims to analyze the parameters of growth, mortality, exploitation, and recruitment of the *C. lingua* population in the waters of the Spermonde Islands.

The data collection and analysis methods are essential for fisheries' resource management (FAO 2018). In fisheries' resource management, it is important to consider the ecosystem and not just focus on catch (Garcia et al 2003). With the population and level of exploitation and understanding of *C. lingua*, a more sustainable management strategy can be created that benefits fishermen and maintains the balance of the marine ecosystem. This balance is expected to significantly contribute to efforts to manage *C. lingua*'s resources sustainably and maintain the balance of the marine ecosystem of the Spermonde Islands.

**Material and Method.** *C. lingua* samples were collected from fishermen's catches landed at the Paotere Fish Auction Place in Makassar City, South Sulawesi, Indonesia (Figure 1a). *C. lingua* sample collection (Figure 1 b and c) was carried out for one year, from January to December 2024.

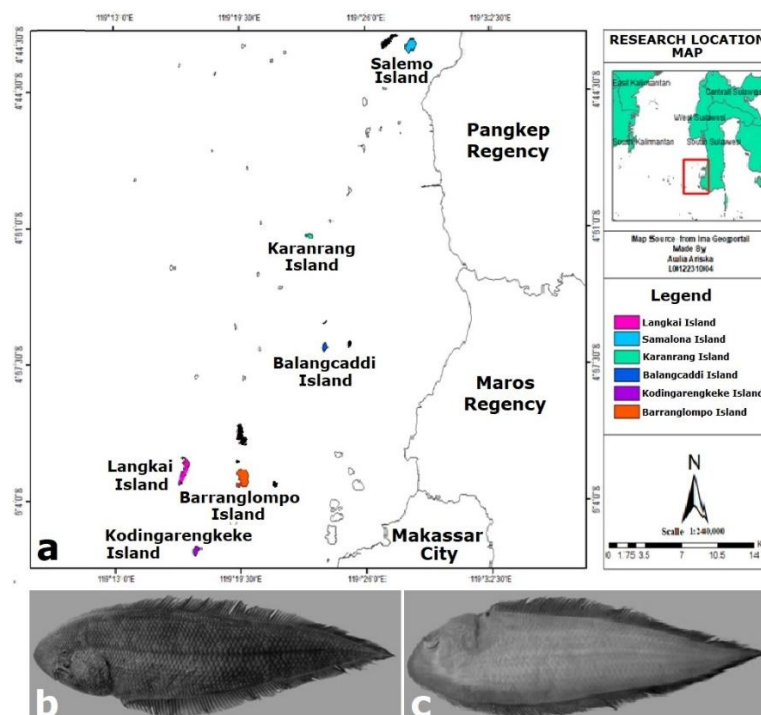


Figure 1. Participatory map of *Cynoglossus lingua* fishing areas in the Spermonde Islands, South Sulawesi, Indonesia. (a) Front view, (b) Back view.

Based on the results of participatory mapping, it is known that the samples came from fishermen's catches operating in the waters around Langkai Island, Salemo Island, Karanrang Island, Balangcaddi Island, Kodingarengkeke Island, Barrang Lompo Island.

The parameter measured was total length, using a ruler with an accuracy of 1 mm. The population parameters and utilization levels analyzed were age group, growth, mortality, exploitation level, and recruitment. The growth analysis used is the formula of Von Bertalanffy (Sparre & Venema 1999), namely:

$$L_t = L_\infty (1 - e^{-k(t-t_0)})$$

Where:

$L_t$  - the length of the fish at age  $t$  (cm);

$L_\infty$  - the asymptote length of the fish (cm);

$K$  - the growth rate coefficient (year<sup>-1</sup>);

$T$  - age (years);

$t_0$  - the theoretical age of the fish at length equal to zero (years).

The asymptote length  $L_\infty$  and the growth coefficient ( $K$ ) were estimated using the ELEFAN I program in the FISAT II software package (Gayanilo et al 2005). The theoretical age ( $t_0$ ) was estimated using the empirical equation of Pauly (1980), namely:

$$\log (-t_0) = - 0.3922 - 0.2752 (\log L_\infty) - 1.038 (\log K)$$

Where:

$t_0$  - the theoretical age of the fish when its length is equal to zero (years);

$L_\infty$  - the asymptotic length of the fish (cm);

$K$  - the growth rate coefficient (year<sup>-1</sup>).

The growth performance index (GPI) or phi-prime ( $\phi'$ ) was calculated using the following equation (Pauly & Munro 1983):

$$\phi' = \text{Log} (K) + 2 \text{Log} (L_\infty)$$

The total mortality rate was calculated using the Beverton and Holt formula (Sparre & Venema 1999):

$$Z = K \left( \frac{L_\infty - L'}{L - L'} \right)$$

Where:

$Z$  - the total mortality rate (year<sup>-1</sup>);

$L$  - the average length of catch (cm);

$L'$  - the minimum length of fish caught (cm).

Natural mortality ( $M$ ) was calculated using Pauly's Empirical formula (Pauly 1980):

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

Where:

$M$  - the natural mortality rate (year<sup>-1</sup>);

$L_\infty$  - the asymptotic length of fish (cm);

$K$  - the growth coefficient (year<sup>-1</sup>);

$T$  - the average water surface temperature measured in the Spermonde Islands (30.2°C).

Fishing mortality ( $F$ ) was calculated by subtracting total mortality ( $Z$ ) from natural mortality ( $M$ ) using the equation:

$$F = Z - M$$

The exploitation rate ( $E$ ) was determined by comparing the fishing mortality rate ( $F$ ) to the total mortality rate ( $Z$ ) (Pauly 1980):

$$E = F/Z$$

The fisheries status was determined based on: (1) If  $E > 0.5$  or  $F > M$ , then the fisheries status is over-exploited; (2) If  $E = 0.5$  or  $F = M$ , then the fisheries status is MSY; and (3) If  $E < 0.5$  or  $F < M$ , then the fisheries status is under-exploited.  $M$ ,  $F$ ,  $Z$  and  $E$  can be converted to percentage values using the equation (Rothschild 1977):

$$Y = (1 - e^{-X}) \times 100$$

Where:

$X$  - the  $M$  (natural mortality).

The relative yield per recruit ( $Y'/R$ ) was estimated using the Beverton and Holt equation (Sparre & Venema 1999):

$$Y'/R = E \times U^{M/K} \left( \frac{3U}{1+m} + \frac{3U}{1.2m} - \frac{U}{1+3m} \right)$$

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

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

Where:

$E$  - exploitation rate or fishing pressure;

$F$  - fishing mortality;

$M$  - natural mortality;

$Z$  - total mortality;

$K$  - von Bertalanffy growth coefficient ( $\text{year}^{-1}$ );

$L_\infty$  - asymptotic length;

$L_c$  - length at first capture;

$U$  - remaining length proportion;

$Y'/R$  - efficiency of yield per recruit;

$M/K$  - fish life strategy;

$L_c/L_\infty$  - impact of fishing gear selectivity.

Catch with full  $Y'/R$  was obtained using FISAT II (Gayani et al 2005).

**Results.** The asymptotic length or infinite length ( $L_\infty$ ) and growth rate coefficient ( $K$ ) values of the growth curve of *C. lingua* (Figure 2) were 48.07 cm and 0.51. The growth performance index of *C. lingua* was 3.071.

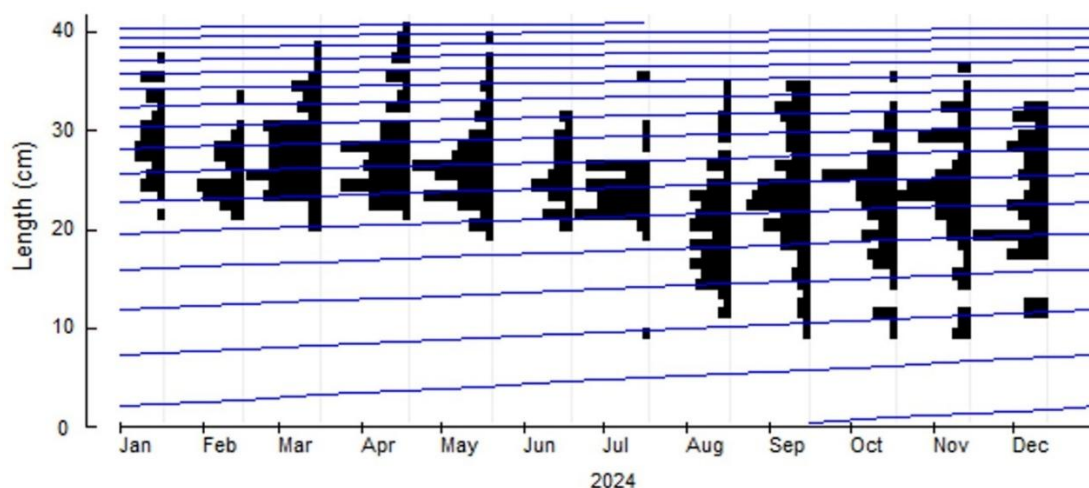


Figure 2. Growth curve of *Cynoglossus lingua* in Spermonde Islands, South Sulawesi, Indonesia.

The capture probability curve shows:  $L_{50}$  of 33.43,  $L_{25}$  of 24.44 and  $L_{75}$  of 37.16 (Figure 3).

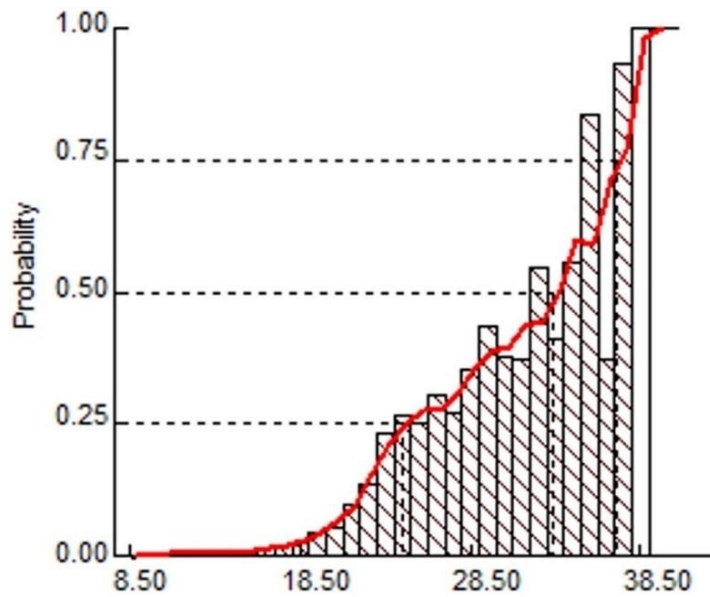


Figure 3. Probability of capture of *Cynoglossus lingua* in Spermonde Islands, South Sulawesi, Indonesia.

The total mortality rate ( $Z$ ) was 2.94, the natural mortality rate ( $M$ ) was 1.04, the fishing mortality rate ( $F$ ) was 1.90, and the current exploitation rate ( $E$ ) was 0.64. These exploitation rates indicate that the *C. lingua* stock in the Spermonde Islands has exceeded the value of 0.5 or has been overfished. Virtual population analysis shows that stock losses due to fishing begin to increase at a size of around 20 cm (Figure 4).

There were two recruitments in a year, at sizes of 1.53 cm and 6.83 cm (Figure 5a). The relative yield per recruit ( $Y/R'$ ) was 0.028 (Figure 5b), and the relative biomass per recruit was 0.326 ( $B/Y'$ ) (Figure 5c).

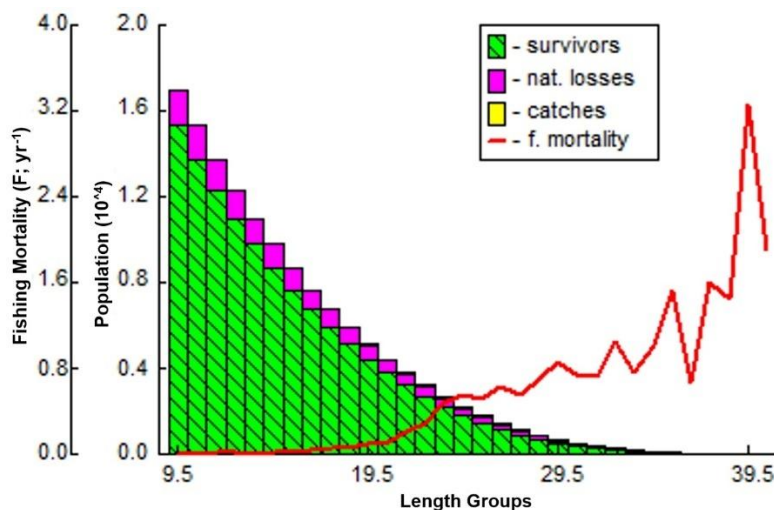


Figure 4. Virtual population curve of *Cynoglossus lingua* in the Spermonde Islands, South Sulawesi, Indonesia.

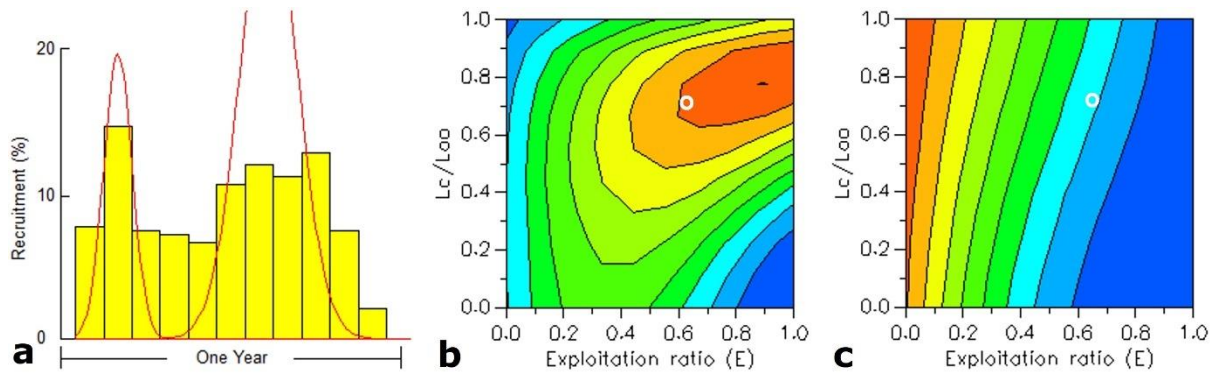


Figure 5. Recruitment curve (a), relative yield per recruit (b), and relative biomass per recruit (c) of *Cynoglossus lingua* in the Spermonde Islands, South Sulawesi, Indonesia.

## Discussion

**Growth.** The asymptotic length ( $L_{\infty}$ ) estimates the theoretical maximum length a species could attain if its growth was not limited by time. Empirical  $L_{\infty}$  is rarely achieved due to mortality pressure, environmental variability, and genetic constitution. The  $L_{\infty}$  value is an important parameter in the study of fish population dynamics that shows significant variations among species and even among intraspecific populations in different environments. Differences in genetic architecture, availability of trophic resources, thermal regime of the waters, intensity of fishing pressure, and various biotic and abiotic conditions of the environment can cause variations in  $L_{\infty}$  values. In terms of sustainable fisheries management, determining  $L_{\infty}$  is very important. This parameter is incorporated into various management models to estimate fish stocks, determine the catchable size (e.g., through the derivation of length at the first catch,  $L_c$ ), and evaluate the impact of exploitation activities on population structure. It is important to remember that individuals who have not reached  $L_{\infty}$  size often have not reached gonadal maturity; therefore, premature capture of individuals can disrupt the reproductive potential of the population as a whole. In addition, temporal changes in  $L_{\infty}$  values within the same population can serve as sensitive cues to changes in environmental conditions. For example, a decrease in  $L_{\infty}$  values may indicate increased environmental stress or degradation of habitat quality that affects the growth physiology of the species.

The maximum length ( $L_{\max}$ ) of *C. lingua* caught in the waters of the Spermonde Islands ( $L_{\max}$  40.5 cm) was longer than *C. lingua* caught in Chilika Lagoon, India ( $L_{\max}$  37.1 cm). When compared to other sole fish, the maximum length of *C. lingua* caught in the waters of the Spermonde Islands is longer than *C. puncticeps* ( $L_{\max}$  of 32.1 cm), *C. lida* ( $L_{\max}$  of 28.3 cm) caught in Chilika lagoon, India (Karna et al 2018), *C. quadrilineatus* caught in Makran Coast, Pakistan ( $L_{\max}$  of 31.65 cm) (Eido et al 2024), *C. cynoglossus* caught in Pabean Bay, Indramayu, West Java ( $L_{\max}$  of 12.6 cm) (Gustiarisanie et al 2016), and *Solea solea* caught in the South Aegean Sea ( $L_{\max}$  of 31.1 cm) (Cerim & Ateş 2020). *C. lingua* caught in the waters of the Spermonde Islands ( $L_{\infty}$  of 48.07 cm) is longer than other flatfish species that live in tropical waters, such as the *Cynoglossus* spp. caught in the coastal waters of Kerala, India ( $L_{\infty}$  16.63 cm) (Jayaprakash 1998) and *C. quadrilineatus* caught in the waters of the Makran Coast, Pakistan ( $L_{\infty}$  33.32 cm) (Eido et al 2024). Meanwhile, *C. lingua* caught in the waters of the Spermonde Islands ( $L_{\infty}$  48.07 cm) is much shorter than flatfish species that live in subtropical and temperate waters, such as southern flounder *Paralichthys lethostigma* ( $L_{\infty}$  56–66 cm) (Matlock 1991; Safrit & Schwartz 1998; Stunz et al 2000; Fischer & Thompson 2004).

Growth parameters can provide an overview of fish life span and growth pattern (Gogoi et al 2021). The growth rate coefficient ( $K$ ) is an essential parameter that shows the long-term dynamics in a species' growth.  $K$  fundamentally shows the growth speed of fish in approaching the asymptote length ( $L_{\infty}$ ). With a  $K$  value of 0.51 in the Spermonde Islands, the *C. lingua* population showed a relatively high growth rate toward its asymptote length. Theoretically, species or populations with higher  $K$  values will reach a significant

fraction of their maximum size in a shorter time than species with lower K values. The pattern of growth observed is a rapid initial phase followed by a decline in growth rate with increasing age and approaching  $L_{\infty}$ . The growth rate coefficient (K) is a parameter influenced by various biological and ecological factors, such as water temperature regime, food resource availability, metabolic rate, and environmental stress levels. A high K value can indicate habitat conditions that support rapid growth, such as abundant food sources or ideal water temperatures for physiological growth processes.

The K value determines population productivity in fisheries resource management. A high K value indicates that the fish can reach its asymptotic length quickly (Pasingi et al 2021). High K values tend to have a shorter life cycle, sexual maturity at an earlier age, and a faster generational turnover rate. Based on this type of data, the determination of catch size regulations, the calculation of maximum sustainable yield potential, and the creation of flexible and efficient fisheries management strategies can be done easily. The K value of *C. lingua* found in the Spermonde Islands ( $0.51 \text{ year}^{-1}$ ) is lower than that of the *Cynoglossus* spp. population in Indian waters ( $0.73 \text{ year}^{-1}$ ) (Jayaprakash 1998) and the K value of the tongue sole fish *C. quadrilineatus* in the Makran Coast, Pakistan ( $0.55 \text{ year}^{-1}$ ) (Eido et al 2024). Compared to herbivorous fish, the K value of *C. lingua* is also higher, for example lower than that of the White-Spotted Rabbitfish, *Siganus canaliculatus* ( $E 0.82$ ) (Suwarni et al 2020a).

The growth performance index ( $\Phi'$ ) is a composite metric used in fish population dynamics studies to facilitate comparison of growth efficiency across species or populations. Asymptote length ( $L_{\infty}$ ) and growth rate coefficient (K), two key growth parameters of the von Bertalanffy model, can be combined into a single value, avoiding separate interpretation of both parameters. This is the main advantage of this index. The  $\Phi'$  value of 3.071 in *C. lingua* in the Spermonde Archipelago provides a broad picture of the growth success of this species, considering the potential maximum size that can be achieved and the growth rate to reach that size. Higher  $\Phi'$  values generally indicate better growth performance. The advantage of  $\Phi'$  as an analytical tool is the ability to compare relative growth effectiveness between intraspecific populations inhabiting different habitats and between different species. This allows researchers to comparatively evaluate how different types of fish "perform" in terms of growth in their respective environments. The different  $\Phi'$  values between populations or species in different environments can indicate the influence of environmental factors on the growth process. A better environment, such as the availability of sufficient food resources and an ideal temperature regime, tends to improve growth performance, which is reflected in higher  $\Phi'$  values. In addition, the differences in growth performance as measured by  $\Phi'$  can indicate special ecological adaptations or evolutionary divergence between populations or species. Populations or species that have adapted effectively to their local environment may show better growth performance than populations or species that are less adapted. The results of the calculation of the  $\Phi'$  value based on the  $L_{\infty}$  and K values show that the  $\Phi'$  value of *C. lingua* from the Spermonde Islands is more significant than in *Cynoglossus* spp. from Indian waters ( $2,305 \text{ year}^{-1}$ ) (Jayaprakash 1998) and *C. quadrilineatus* from the Makran Coast, Pakistan ( $2,786 \text{ year}^{-1}$ ) (Eido et al 2024). Gear selectivity (L50, L25, and L75 parameters) provide important information about the possibility of catching fish based on their size. The L50 value of 33.43 cm in *C. lingua* in the Spermonde Islands indicates that individuals with a length of 33.43 cm have a 50% chance of being caught by the gear used in the study. L50 is often considered the primary selection measure of fishing gear; it shows where the gear begins to function well against the target species. In addition, the L25 value of 24.44 cm indicates that fish with a length of 24.44 cm have a 25% chance of being caught by fishing gear. This value indicates the lower size range limit at which fishing gear begins to catch target fish consistently. Fish with a length below L25 have a relatively small chance of being caught or retained by fishing gear.

**Mortality and catch size.** The mortality can provide an insight into the composition of fish stocks (Gogoi et al 2021). In the study of fish population dynamics, mortality rate is an important parameter that measures the proportion of individuals in a population that are lost due to various causes over time. Mortality rates are usually calculated annually.

The total mortality rate ( $Z$ ) of  $2.94 \text{ year}^{-1}$  indicates that a large proportion (about 94.7%) of the *C. lingua* population in the Spermonde Islands dies annually due to fishing activities and natural factors. The total mortality rate serves as a comprehensive tool to indicate the level of mortality pressure experienced by the population. The natural mortality rate ( $M$ ) of  $1.04 \text{ year}^{-1}$  indicates that about 64.6% of the *C. lingua* population dies annually due to non-anthropogenic factors. Predation by other species, disease outbreaks, old age mortality (Shija 2024), and the impact of unfavorable environmental conditions are some of the causes of this natural mortality. Considered an intrinsic property of the species, natural mortality is influenced by complex interactions with its environment. Temperature is one of the factors that significantly influence the environment because it plays an important role in the life of fish in the water (Wang et al 2023). The fishing mortality rate ( $F$ ) of  $1.90 \text{ year}^{-1}$  indicates that around 85.0% of the *C. lingua* population dies yearly due to fishing activities. The fishing mortality rate measures how intensely the target population utilizes fishery resources. In contrast, an  $L_{75}$  value of 37.16 cm indicates that a fish 37.16 cm long has a 75% chance of being caught. This value marks the upper limit of the size range where the gear is almost entirely effective in capturing the target species, and fish larger than  $L_{75}$  have a greater chance of being caught. In this case, the selection range, calculated as the difference between  $L_{75}$  and  $L_{25}$ , or 12.72 cm, represents the gradient of gear selection effectiveness. A narrow selection range indicates a sharp selectivity, where the size difference between captured and escaped fish is relatively small, while a wide selection range indicates strong selection.  $L_{50}$ ,  $L_{25}$ , and  $L_{75}$  values are important for fisheries management. This information indicates the size of fish susceptible to a particular gear. For example, suppose  $L_{50}$  is smaller than the size at which the fish reaches the first gonadal maturity ( $L_m$ ). In that case, the gear is likely to capture many immature fish, potentially threatening the sustainability of the population. By understanding the nature of gear selectivity, fisheries regulations can be made to ensure fishing at an appropriate amount for management objectives such as optimizing catch or protecting juveniles. In addition, the selection range and  $L_{50}$  are used as comparative parameters to assess the selectivity of various types of fishing gear (Park et al 2011; Scanu et al 2021).

**Exploitation.** The exploitation rate is crucial for determining the fishery's impact on the fish population (Oliveira et al 2020). The exploitation rate indicates the overall mortality caused by fish capture. In the population of *C. lingua* in Spermonde, a value of  $E$  of 0.64 indicates that fish capture activities contribute to fish mortality with 64% of all population members. Typically, the exploitation rate determines the level of resource use. The optimal  $E$  value, which corresponds to the maximum sustainable (MSY) yield, is frequently associated with a value of 0.5. Because of this, an  $E$  value higher than 0.5, as 0.64 in the case of *C. lingua*, is frequently cited as an indication of overexploitation. However, even though *C. lingua* in the Spermonde waters is not a by-product of the trawl net, the population of *C. lingua* in the Spermonde peninsula has already shown signs of fish capture. The exploitation rate of *C. lingua* in the Spermonde is much higher than that of other species of sole, such as *Cynoglossus senegalensis* ( $E=0.31$ ), which is found on the coast of Greater Accra, Ghana (Amponsah et al 2023).

The fishing gear fishermen used to catch *C. lingua* in the waters of the Spermonde Islands is a modified trawl net that is smaller in size and operated using a smaller boat. Despite its smaller size, the pressure generated on the stock is more significant than commercial trawls that catch sole fish *C. lachneri* in Indian Waters (Sharma & Jaiswar 2024). The more significant fishing pressure in the waters of the Spermonde Islands may be due to the number of trawl nets operating, which is much greater than that of commercial trawls.

The waters of the Spermonde Islands are included in the Fisheries Management Area of the Republic of Indonesia Block 713 which suffers from high fishing pressure (Kantun et al 2018). Several species of coral fish in these waters have experienced overfishing, such as dusky parrotfish *Scarus niger* ( $E=0.79$ ) (Fatimah et al 2021), blue-barred parrotfish *Scarus ghobban* ( $E=0.90$ ) (Mutiara et al 2021), yellowfin parrotfish *Scarus flavipectoralis* ( $E=0.78$ ) (Ramla et al 2021), and bleeker's parrotfish *Chlorurus bleekeri* ( $E=0.63$ ) (Mansyur et al 2021). Several species of coral and seagrass fish in the

waters of the Spermonde Islands have also suffered overfishing, for example the white spotted rabbitfish *Siganus canaliculatus* ( $E=0.75$ ) (Suwarni et al 2020b). The E value above 0.5 clearly illustrates the condition of overfishing in the coral, seagrass and demersal communities in the waters of the Spermonde Islands.

**Recruitment.** Analysis of recruitment patterns in *C. lingua* in the Spermonde Islands found two periods of recruitment of new individuals per year, 1.53 cm and 6.83 cm, respectively. This phenomenon indicates the presence of spawning activity, which may last for an extended period or be divided into two distinct groups or spawning waves throughout the year. Each spawning wave produces a new group (inoculation group) of the identified population. This recruitment is related to stock conditions. Of the 20 flatfish stocks studied, six cases had a statistically significant stock-recruitment relationship (Cushing 1971; Cushing 1973; Iles 1994). The two different recruitment sizes may indicate differences in environmental conditions during the spawning period and the development of the larval and juvenile phases. For example, the 1.53 cm recruitment is likely to have originated from spawning in a season with environmental conditions that favored the survival of larvae and facilitated rapid initial growth to reach that size. Meanwhile, the 6.83 cm recruits likely originated from spawning in different seasons with environmental conditions that resulted in different initial growth patterns, such as longer growth rates. With two recruits emerging each year, the age structure and population size can become more complex as two new groups enter at different times. These two new groups can influence overall population dynamics, such as average growth rates, mortality rates, and population responses to exploitation pressure.

A thorough understanding of recruitment patterns is essential for sound fisheries management. Different management strategies, such as establishing fishing seasons or limiting the size of fish that can be caught, can be tailored to the entry of recruits into the exploitable stock, given the two different recruitment periods. A protection during the spawning and recruitment periods is critical for maintaining the population.

Theoretical models such as relative yield per recruit ( $Y/R'$ ) and relative biomass per recruit ( $B/R'$ ) are used to evaluate yield and biomass per recruit.  $Y/R'$  estimates the relative catch (in weight) each recruited individual can generate into an exploited population considering the exploitation rate, growth and mortality patterns. A  $Y/R'$  value of 0.028 for *C. lingua* in the Spermonde Islands indicates that, under current conditions, the relative potential catch per recruited individual is 0.028 units of weight. A low  $Y/R'$  value may indicate three things: (1) If the first catch size ( $L_c$ ) is too small compared to the size at which the fish reach optimal growth in weight, then much potential growth and catch may be lost because the fish are caught before they reach larger sizes; (2) If the exploitation rate is very high, most of the fish may die before they reach larger sizes, then the catch per recruit will decrease; and (3) If the  $Y/R'$  value is also influenced by growth rate ( $K$ ) and natural mortality rate ( $M$ ), then this combination of parameters can produce a low  $Y/R'$  value even though exploitation is not too high. Meanwhile, by considering similar factors,  $B/R'$  estimates the relative biomass (total weight) of the exploitable population per recruit. The  $B/R'$  value of 0.326 in *C. lingua* indicates that the average relative biomass of the exploitable population per recruit is 0.326 units. A low  $B/R'$  value may indicate high fishing pressure or fishing at a size that has not yet made a significant contribution. Because the  $Y/R'$  and  $B/R'$  values are highly dependent on population parameters and fishing gear used, comparisons with other studies should be cautiously made. However, the implications of high exploitation rates can provide a general idea of the possibility of low values.

**Implications for fisheries sustainability.** This study shows several important things that must be considered to maintain the sustainability of *C. lingua* utilization. First and foremost, controlling the catch size and selecting the appropriate fishing gear is very important. The parameters  $L_{50}$ ,  $L_{25}$ , and  $L_{75}$  indicate the fish size susceptible to fishing. More selective fishing gear size and adjustment are needed to avoid catching immature fish. The selectivity of various fishing gear can be compared for choosing more environmentally friendly fishing gear. Controlling the level of exploitation is very important because excessive fishing pressure can endanger the population's survival. Therefore,

fishing should be limited through regulating fishing seasons, quota restrictions, or fishing gear restrictions. Also, it is essential to protect the recruitment period. Knowledge of complex recruitment patterns is needed to determine the right time for management. Maintaining fish stocks will be easier by protecting recruitment through the creation of fishing regulations or marine protected areas. Analysis of growth parameters such as  $L_{\infty}$  and  $K$  provides important information about population dynamics and growth potential. These data are very important for estimating fish stocks, determining the appropriate fish size for fishing, and evaluating the impact of fishing. Ineffective fisheries management, the growth characteristics of target species must be considered. Fifth, it is important to continuously monitor environmental conditions. Changes in fish growth parameters can indicate changes in the fish's environment.

**Conclusions.** *C. lingua* in the Spermonde Archipelago has the highest growth potential compared to other species and populations. *C. lingua* grows rapidly and has superior overall growth performance. Gear selection provides important information on catchable size management. High total mortality rates, dominated by fishing-related mortality, result in high exploitation rates, indicating possible overexploitation. Two recruitment periods per year were identified that may impact population structure. High exploitation rates and fishing at suboptimal or small sizes are thought to contribute to relatively low production values and biomass per recruit.

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