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Biological reproduction of mackerel scad, *Decapterus macarellus* (Cuvier, 1833) caught by purse-seine net in Majene Waters, West Sulawesi, Indonesia

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Abstract. *Tenriware, Nur M, Nasyrah AFA. 2023. Biological reproduction of mackerel scad,* Decapterus macarellus *(Cuvier, 1833) caught by purse-seine net in Majene Waters, West Sulawesi, Indonesia. Biodiversitas 24: 3012-3018.* Mackerel scad, *Decapterus macarellus* Cuvier, 1833 is an economically important fish resource as an income source for fishermen in Majene waters, West Sulawesi. This study aims to determine some aspects of reproductive biology, including sex ratio, gonadal somatic index (GSI), gonad maturity stage (GMS), and the size at the first maturity. The sampling was carried out at the Fish Landing Sites in the Coastal Waters of Pangali-Ali Village, East Banggae District, Majene District, West Sulawesi Province, Indonesia. Each specimen was measured to the total length with digital calipers and body weight using a digital weighing scale. Initial sex assessment was noticed at the time of dissection, and gonadal maturity was also assessed. A total of 275 specimens consisting of 177 males and 98 females were obtained from April to July 2017. The result indicates that the sex ratio between males and females deviated from an expected 1:1: and was not balanced. This species spawns in April at the size of 173.4 mm and 168.6-178.3 mm for males and 189.1 mm or the range of 182.6-195.8 mm for females.

Keywords: Biology, mackerel scad, spawning season, sex ratio, West Sulawesi waters

Abbreviations: GMS: Gonad Maturity Stage; GSI: Gonad Somatic Index

INTRODUCTION

Mackerel scad, *Depacterus macarellus* Cuvier, 1833 is an economically important species inhabiting tropic and subtropic water in the world (Shiraishi et al. 2010; Silooy et al. 2021; Zhang et al. 2020). In Indonesian waters, mackerel scad is mostly caught such as in the waters of Bone Bay (Dahlan et al. 2015), Latuhalat Water, Nusaniwe District, Ambon, Indonesia (Ongkers et al. 2016), the water of Banda Bay, Maluku, Indonesia (Senen et al. 2017), Ambon Island waters (Pattikawa et al. 2018), Doreri Bay, Manokwari District, West Papua Province, Indonesia (Lahumeten et al. 2019), Manado Bay and Kema Bay, North Sulawesi (Manginsela et al. 2020), Prigi Waters Trenggalek District, East Java, Indonesia (Bintoro et al. 2020), Samudera Hindia (Widiyastuti et al. 2020) and Belawan Ocean Fishing Port, North Sumatra Province, Indonesia (Fadhilah et al. 2021). It means that mackerel scad is distributed throughout Indonesian waters.

Particularly in West Sulawesi, Indonesia, mackerel scad is one of the fish that become the driver of economic fishermen because this fish is the dominant catching over other fishes (Nur et al. 2017a). In general, mackerel scad has been found in Majene waters consisting of three types, namely *Decapterus macrosoma* Bleeker, 1851, *Decapterus russelli* Rüppell, 1830, and *D. macarellus*. Among three species of these species, mackerel scad *D. macarellus* is the most abundant with a high economic value, so the fisherman made this species the main target of their catch by using purse seine as the main fishing gear. One of the decreasing population stocks is catching.

Purse seine is one of the fishing gears in Majene District which has a lot of catches in one fishing trip. Some catching of mackerel scad using purse seine is also done in Bualemo Banggai District (Anggawangsa et al. 2014), Banda Sea (Silooy et al. 2019), Bulukumba Waters, South Sulawesi, Indonesia (Asni et al. 2019), and Belawan Ocean Fishing Port, North Sumatra Province (Fadhilah et al. 2021). The concerns about operating a purse seine catch the small pelagic fish that have not yet matured into their gonads, including scads. This allows for overfishing that goes beyond biological limits. Therefore, it is pivotal that fishing using this gear can be sustainable. One way is to pay attention to the size of the fish caught. This is important and should be the main concern of fishermen to maintain the preservation of the mackerel scad population stock.

Uncontrolled mackerel scad exploitation is a threat to its sustainability and can further destroy the livelihood of the local fishers. The utilization of a potential fish resource must be based on the principle of sustainable management which pays attention to its sustainability and also can be used in the future (Isroni et al. 2019; Hasan and Islam 2020; Latuconsina et al. 2022). Fisheries source is a renewable resource; hence with wise management, Indonesian people can savor the benefit, especially for the economy (Hasan and Widodo 2020; Hasan et al. 2021). Fisheries management requires basic analysis and information, one of which is related to biological aspects (Muhtadi et al. 2022; Patawari et al. 2022; Hasan et al. 2023). The study of biological aspects is an important thing to do because it is implicit in fisheries management (Costa et al. 2020). The utilized sustainably of small pelagic fish is also needed information about biological aspects (Silooy et al. 2019).

Research about the biological aspect of mackerel scad has been studied in some waters, such as reproductive potential (Sululu et al. 2022; Fatma et al. 2022; Latuconsina et al. 2022), the biological aspect in Samudera Hindia, West Sumatera Block (Widiyastuti et al. 2020), some biological aspect in Ambon Island waters (Pattikawa et al. 2018), reproductive biology from Cabo Verde (Costa et al. 2020). Although the mackerel scad fish is an essential fishery resource in West Sulawesi, its biological characteristics have not been studied sufficiently. Some studies that have been carried out include reproduction at the Kasiwa Mamuju Fishing Port (Nur et al. 2017a), and growth patterns in Majene Waters (Nur et al. 2017b). The aim of this research was to determine the sex ratio, gonad maturity stage, gonadal somatic index, and the size of the first gonad maturity to contribute to stock management of mackerel scad *D. macarellus* in Majene Waters, West Sulawesi Province, whenever implemented.

MATERIALS AND METHODS

Study area

Sampling was carried out at the Fish Landing Sites in the Coastal Waters of Pangali-Ali Village (3°32'41.2" S and 118°58'04.7" E) and Makassar Strait (117°59’12,847”-118°25’8,386” and 2°43’23,786”-3°23’4,715” S), East Banggae Sub-district, Majene District, West Sulawesi Province, Indonesia from April to July 2017. The sample was obtained using purse seine (Figure 1).

Majene water (Figure 1**)** include in Makassar Strait Water. The sea temperature in this area is 26-31℃, the current is 0.05-0.30 m/sec (Rasyid et al. 2014), and the salinity is 25-28 ppt (Agustinus et al. 2022). Another while, this water has a high chlorophyll concentration, and also the upwelling is frequent, especially in the east season (Inaku 2015).

Length and weight measurement

The specimens were measured for total length with digital calipers and body weight was weighed with digital scales. The specimens were dissected, and the sex and gonad maturity stage was determined morphologically by macroscopic examination of the gonad.

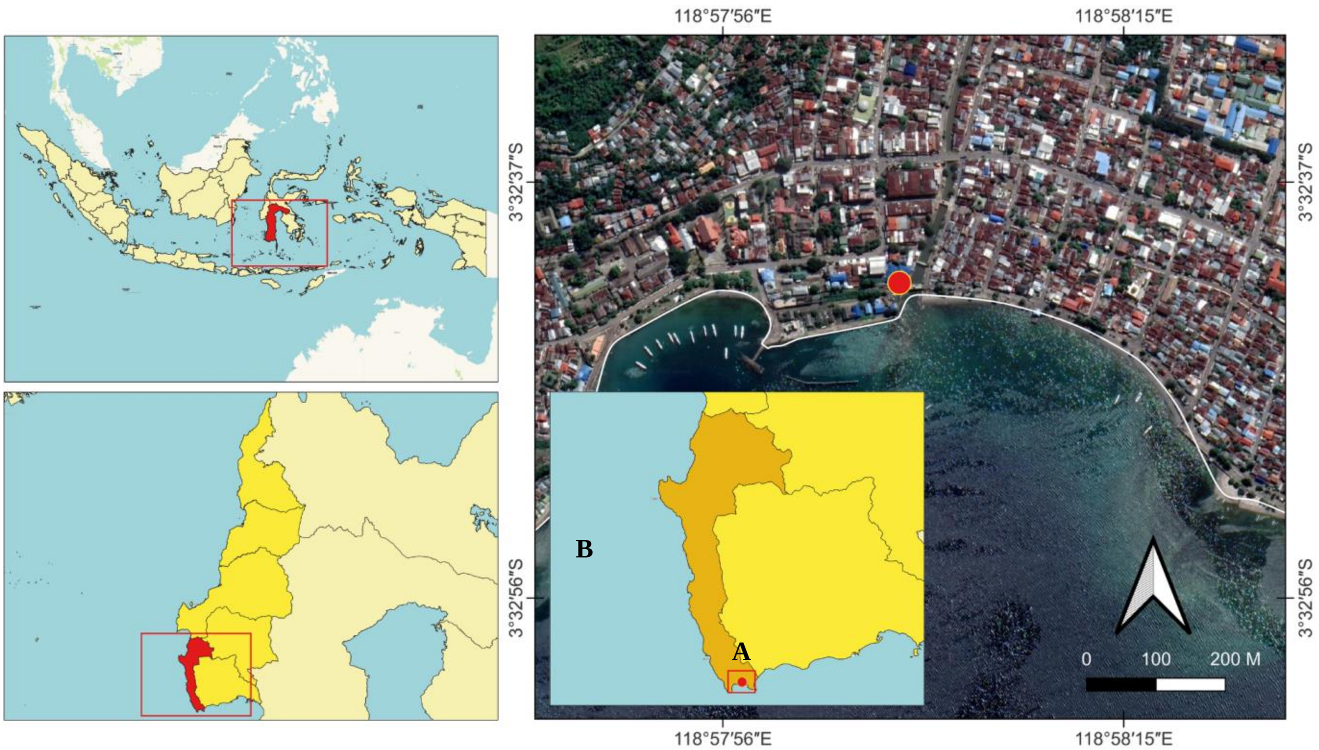

Figure 1. Sampling location of Majene Waters, West Sulawesi, Indonesia. A. Fishing base (Pangali-Ali Village), B. Fishing Ground

Sex ratio

The sex ratio is determined by calculating the ratio of the frequency of male and female fish. Furthermore, the results of the comparison are continued with the *chi-square test* (Zar 2010). To find out the balance of the sex ratio, the following formula:

$$Sex\ ratio = \frac{\sum M}{\sum F} x\ 100$$

Where:
∑M : number of males
∑F : number of females

GSI estimate

The gonadal maturity stage was analyzed by grouping data on fish that had not yet matured and matured. The gonadal somatic index is calculated by the formula (Araujo et al. 2019):

$$GSI = \frac{Wg}{W} x\ 100$$

Where:
Wg : gonad weight (g)
W : body weight (g)

The fish size of the first gonad matured was calculated by Spearmen-Karber method (Udupa 1986), with the formula:

M= (Xk + X/2) - (X, Σpi)

Where the length range was estimated using the equation:

antilog [m ± 1,96 √(var (m))]
var (m) = (X)2 x Σ [(pixqi) / (ni-1)]

Where:
M : size at first maturity (antilog of m)
m : logarithm of fish length at first maturity
Xk : logorithm of length class median at 100% matured fish
X : increment of the logarithm of length class median
pi : number of matured fish and each length class ratio (ri/ni)
ri : number of matured fish at class I
ni : number of fish samples at class i
qi : 1-pi

Data analysis

The data were analyzed by descriptive statistics (frequency, percentages, and graphs) and inferential statistics (*chi-square test*). The data were summarized by using Microsoft Excel 2019 version.

RESULTS AND DISCUSSION

Sex ratio

The total number of fish caught was 275 individuals, consisting of 177 males and 98 females. The specimen of male and female mackerel scad can be seen in Figure 2. Mackerel scad has a range of lengths of 122-220 mm and weight 69-283,5 g, while the range of length of females was 194-212 mm and weight 66.1-249.1 g. The sex ratio that has been found can be seen in Table 1. Based on Table 1, the sex ratio is 1.81:1.00, or the number of male fish is more than the female fish, or it is not balanced. This is confirmed by further Chi-square analysis, which shows that the sex ratio of male and female fish is not 1:1 ($\alpha = 0.05$; $X_{count} = 8.0200$; $X_{table} = 7.81$; db = 3).

Gonad Maturity Stage (GMS)

In the gonad maturity stage, every fish species is cyclical or seasonal. Germ cell renewal, differentiation, development, and release of sperm or oocytes throughout each reproductive cycle result in changes in the gonads that characterize the reproductive phase of the species, whether it will spawn or have spawned. The gonad of the mackerel scad can be seen in Figure 3.

The result found five gonadal maturity stages, namely GMS I immature (not yet developing), GMS II maturing (early development), GMS III mature (gonadal maturity), GMS IV fully mature (end development) and GMS V resting (spawning). Gonad maturity stage indicates the level of sexual maturity of the fish. Most of the metabolic products are used during the developmental phase of the gonads. GMS frequency (%) in this study is presented in Figure 4.

Gonad Somatic Index (GSI)

GSI of mackerel scad fish in this study can be seen in Figure 5 and Table 2. Based on Figure 5 and Table 2, the IGS value of *D. macarellus* fish in West Sulawesi waters ranged from 0.001-5.0375% for male fish and 0.0679-7.3842% for female fish. Furthermore, based on this, the highest IGS value in male fish was found in April then decreased from May to July. The same things were also obtained for female fish, the highest IGS was found in April then decreased from May to June and increased again in July.

In this study, the size of first maturity was calculated 173.4 mm and 168.6-178.3 mm for males and for females at a size of 189.1 mm or a range of 182.6-196.8 mm. This shows that mackerel scad female fish matures earlier than males.

Table 1. The number distribution of mackerel scad

Month	Number		Sex ratio	
	Male	Female	Male	Female
April	7	3	1.00	2.33
May	18	2	1.22	1.00
June	108	49	2.20	1.00
July	44	24	1.83	1.00
Total	177	98	1.81	1.00

Figure 2. Specimen of mackerel scad

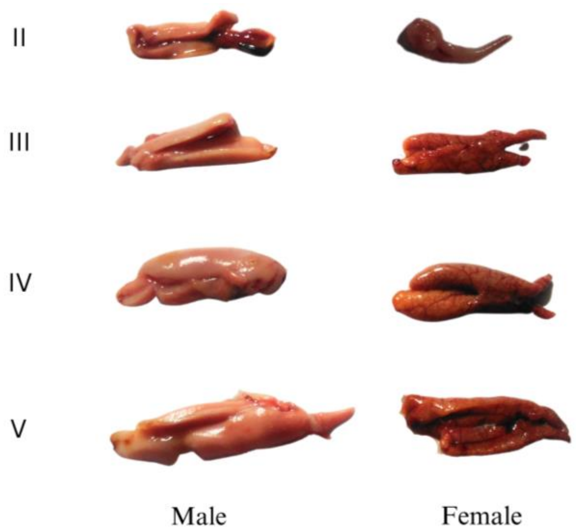

Figure 3. Gonad maturity stage of mackerel scad

Table 2. Gonad somatic index of mackerel scad

Month	Male		Female	
	Average	Range	Average	Range
April	3.4166-5.0735	4.2320 ± 0.8288	0.7675 - 3.8206	2.4034 ± 1.0794
May	0.0013-0.0413	0.0111 ± 0.0101	0.1280 - 5.0847	1.5656 ± 1.3706
June	0.0512-4.0695	0.4302 ± 0.4706	0.0679 - 0.8758	0.3625 ± 0.2172
July	0.0733-2.9695	0.5283 ± 0.6478	0.1038 - 7.3842	1.1472 ± 2.2461

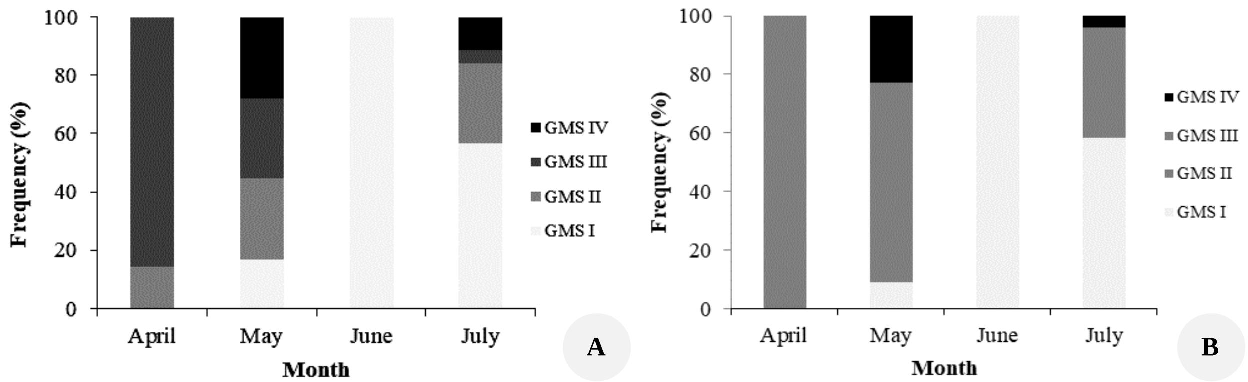

Figure 4. The frequency of gonadal maturity stage of mackerel scad was: A. Males; and B. Female

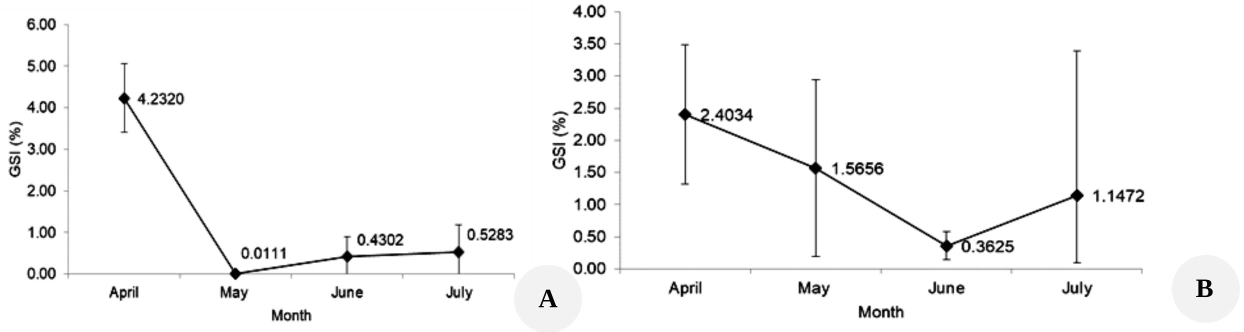

Figure 5. Gonad somatic index of mackerel scad was: A. Male; and B. Female

Discussion

The overall population was female-biased and validated by Chi-square test. According to the result found that the number of males is higher than that of females. An unbalanced sex ratio is also found in other areas, such as *D. macrosoma* in the waters of Bone Bay and in the waters of Barru Regency, *D. macarellus* in the waters of the Banggai Islands, Central Sulawesi (Dahlan et al. 2015) and the waters of Maharashtra India (Poojary et al. 2015). This is a different matter, whereas in other studies, a balanced sex ratio of 1:1 was obtained, such as *D. ruselli* in Ambon Island (Ongkers et al. 2016), mackerel scad in Ambon Bay (Genisa 1998), Pemangkat Fish Port, West Kalimantan (Faizah and Sadiyah 2020) and *Decapterus* spp. inhabiting the waters of Southeast Maluku, Eastern Indonesia (Ajub et al. 2022). A female-biased sex ratio and the first size of sexual maturity in *Megalaspis cordyla* Linnaeus, 1758 member of the family Carangidae reported (Qamar and Panhwar 2018) whereas the male-dominated population of *Scomberoides commersonnianus* Lacepède, 1801 and *Scomberoides tol* Cuvier, 1832 in Pakistan was gathered (Qamar et al. 2020).

According to (Poojary et al. 2015) reproductive potential in a fish community is largely determined by the number of females available for egg production, the male sex ratio can greatly affect population structure and stock continuity. It is feared that the female ratio in this study will affect the mackerel scad population in the future.

Based on Figure 2, it was obtained that the GMS had the highest value in April where 86% of male fish and 100% of female fish had mature gonads (GMS III and IV). A decrease in mature fish occurred in the next month, namely in May, until it reached the lowest in June, where the fish was dominated by a young level of maturity (GMS I and GMS II). External factors are temperature and food, and internal factors are steroid hormones and gonadotropins, which function to regulate gonad maturity. Furthermore, the high GMS of mackerel scad in April is thought to be the time used for spawning.

The gonad somatic index is considered an indicator of the gonad maturity stage (Arizmendi-Rodriguez et al. 2012). The average GSI value during the study period can also indicate the existence of one spawning season for a fish species (Roy et al. 2014). Knowing the fish spawning season, this data is very important for evaluating stock potential and sustainable fisheries management. The highest GSI value in male fish was found in April then decreased from May to July. The same things were also obtained for female fish, the highest GSI was found in April then decreased from May to June and increased again in July. Based on this, it is highly suspected that April is the time for *D. macarellus* to spawn. Several mechanisms can control the timing of gonadal maturation, such as the harness and variability of the abiotic environment, the availability of food for the fish and their generation, and the habitat. Therefore, variations in the reproduction time of the mackerel scad population can be related to the factors mentioned above.

The results indicate that the scad *Decapterus* sp. in several waters had different spawning seasons. The spawning season for several types of mackerel scad from the genus *Decapterus* according to them are *Decapterus maruadsi* Temminck & Schlegel, 1843, *Decapterus macrosoma* Bleeker, 1851 in the East China Sea spawning from May to August, *D. macarellus* from April to July. Meanwhile *D. macrosoma* in the South Indian Ocean spawned from March to May and November to December (Ohshimo et al. 2014), *D. macrosoma* was in February, August, and October in the San Fernando Coastal Waters, Romblon, Philippines (Rada et al. 2019). Furthermore, in Indian waters, *D. macrosoma* reproduced continuously with two spawning peaks, namely February, June, October and December (Balasurabramanian and Natarajan 2000), in the East China Sea *D. tabl* spawned from May to July (Ohshimo et al. 2014). Furthermore, (Shiraishi et al. 2010) in the waters of Kyusu Jaoan also confirmed that the spawning peak of this species occurred from February to April. However, according to (Gonzales et al. 2021) the reproductive season for *D. macrosoma* in the summer, when the temperature is relatively high, before the rainy season, when the biological productivity of nearshore waters should be relatively high because the nutrient runoff is more than adjacent fields, which produce plankton which serves as food for the fish larvae that spawn during the summer (Pepin and Penney 2000; Arevalo et al. 2023). Fish must reproduce within a year to maximize offspring throughout their life. Fish larvae must hatch into a habitat that can provide suitable food, protection from predators, and new abiotic conditions, while eggs are laid in shallow water or coastal areas where temperature increases rapidly with increasing air temperature. The result of the spawning season can be as designed for effective management to protect the population of fish in the future (Asriyana and Halili 2021).

Several studies regarding the size of the first gonad maturity were also the same as this study, including studies on male mackerel scad in the waters of Bone Bay, where males were 195 mm in size and females were 210 mm (Dahlan et al. 2015). Mackerel scad male in Ambon Bay which matured with a total length of 163 mm and females of 155 mm (Senen et al. 2017), *D. macrosoma* in the San Fernando Coastal Waters, Romblon, Philippines female and male respectively were 15.29 cm and 17.22 cm (Rada et al. 2019), then in India (Balasurabramanian and Natarajan 2000), stated that male and female *D. macrosoma* reached maturity at 157 mm respectively (15.70 cm) and 158 mm (15.80 cm), then Japan’s Kyusu waters with a value of 232 mm or 23.20 cm (Shiraishi et al. 2010), *Decapterus kurroides* Bleeker, 1855 in Iligan Bay, Philippine matured at a length of 172 mm for female fish and 176 mm for male fish (Rosa et al. 2022).

According to several studies, the size at first maturity is caused by various factors such as environment, habitat, and biological characteristics. Previous studies on *Decapterus* spp. demonstrated that growth and reproduction characteristics differ among different habitats (Ohshimo et al. 2014). According to (Rada et al. 2019) that the growth of fish in areas of high waters temperature (low latitude areas) is faster, and the size of the sex maturity is smaller compared to areas of low water temperature (high latitude areas), the effect of this factor seems to be true for fish. *D. macrosoma* in Philippine waters which is located in the tropics with an average temperature of warmer seawater, thus affecting the sexual maturity of *D. macrosoma* at shorter distances compared to high latitudes. The same thing applies to this research. Furthermore, Lagler et al. (1977) states the internal factors that influence when fish first mature, such as differences in species, age, size, and physiological characteristics of the fish, and the ability to adapt to the environment. The external factors that influence it such as food, temperature, currents, and the presence of individuals of the same sex and spawning grounds.

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