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The reproduction performance of catching *Planiliza subviridis* (Teleostei: Mugilidae) in different moon periods from Jepara Coast, Central Java, Indonesia

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Abstract. *Yudiati E, Yuniarti T, Trianto A, Arifin Z, Ruliaty L, Soleh M, Naryaningsih A, Suryati. 2024. The reproduction performance of catching* Planiliza subviridis *(Teleostei: Mugilidae) in different moon periods from Jepara Coast, Central Java, Indonesia. Biodiversitas 25: 1823-1830.* Mullets (*Planiliza subviridis* Valenciennes 1836) are highly promising species for aquaculture development. Information on the reproductive performance of wild-caught fish is crucial for enhancing mullet production. This study aimed to assess the gonadal maturity level of female mullets captured during full and new moon phases. Sampling using lift nets was conducted from June to July 2023, comprising 104 individuals, 51 during the new moon and 53 during a full moon. Fish caught during different moon phases were measured for gonad maturation level (GML) and morphometric parameters (body weight, total length, head length, body width, and head width), assessed for gonad somatic index (GSI), fecundity, and egg diameter. Over 50% of individuals were at GML III during dark moon phases, while during bright moon phases, only 10-15% were at GML III; GSI ranged from 0.6-15%. The fecundity of GML I and II females was higher during the full moon (220,212-395,000 eggs per individual) compared to the new moon, while GML III females during dark moon phases ranged from 225,000-250,000 eggs. Mullets exhibit increased reproductive output during the new moon phase and engage in synchronous spawning during moonlight cycles. Therefore, prospects for mullet culture appear promising, with cultivation and domestication suggested during new moon periods.

Keywords: Biology, lunar, mullets, reproduction

INTRODUCTION

The mullets (Teleostei: Mugilidae) are economically valuable commercial fish species in Indonesia (Wigati and Syafei 2013; Yulianto et al. 2020), Taiwan (Lee et al. 2023), Mediterranian (Abdel-Tawwab et al. 2023; Saygin 2024), and around the world (El-Hawarry 2018). Due to their specific catadromous characteristics and the traffic between distinctive environments, the mullet fish habitually live in estuary brackish waters and fresh water in rivers with warm climates and coastal vegetation (Hasan et al. 2023; Pereira et al. 2024). Some of them also inhabit tropical areas (Andrade-Gómez and de León 2024), subtropical (Lee et al. 2023), and temperate climate areas (Whitfield and Durand 2023). Due to its cosmopolitan types, high market value, short-lived development, strong tolerance to captivity, and omnivorous feeding habits, this fish species has been identified as a potential species for aquaculture diversification globally (Abou-Gabal et al. 2018).

Much of the commercial Grey mullet aquaculture relies on wild-caught fry, which is cost-effective but unsustainable (Whitfield and Durand 2023). Problems concerning mullet stock and catch become more complicated due to global warming and environmental pollutants. Lee et al. (2023) reported that the catch of Grey mullet in the Taiwan Strait decreased annually. The rise in sea surface temperature may be the main reason for the abovementioned decrease. Conversely, sertraline affects feeding, reproduction, and physiological changes (Hubená et al. 2023). The data on the decreasing number of catches and the lesser sizes of mullet caught was also noted by Yulianto et al. (2020) in Aceh Waters, Indonesia. Rofi'i et al. (2022) reported that the mullet exploitation rate in Kutai, Kalimantan, Indonesia, reached 0.64 per year, higher than the optimum (0.50). This may be due to the overexploitation and overfishing, which similarly occurred in Turkey (Çiloğlu and Akgümüş 2019).

The quantity of Guavina guavina, Anchovy (Anchovia clupeoides), Centropomus pectinatus, and at least 15 other species revealed significant changes corresponding to the moon phase. Mass and individuals were higher during the new moon (Ramos-Júdez et al. 2021). The study of fish gonadal maturation is of significant relevance in understanding the ecology and reproduction of fish species. The moon's illumination reflected from the sun changes across the lunar month according to its relative position. The lunar cycle modifies the rhythmic activity patterns of fish. (Lopes et al. 2023). The periodic changes in moonlight cue gonadal development and gamete release (Ikegami et al. 2014). It is a strong suggestion that the lunar cycle plays a significant role in affecting the biological rhythms and reproduction (Golmoradizadeh et al. 2021), and releasing hormones such as melatonin. In their study, Golmoradizadeh et al. (2021) suggested that lunar periodicity is a key external regulator for ovarian activity, highlighting the spawning phenomenon. Conversely, Lopes et al. (2023) reported that ocular melatonin and metabolic parameters exhibited higher concentrations during the new moon.

Therefore, to overcome the problem of overexploitation of mullet fish (Çiloğlu and Akgümüş 2019; Rofi'i et al. 2022), sustainable management of mullet populations requires information on the optimal timing for stocking broodstock as an initial step towards domestication. Initial data on the reproductive performance of wild-caught fish is crucial for future broodstock domestication and mullet aquaculture. This underscores the need for advancements in breeding technologies. Hence, this research aims to explore the influence of full and new moons on mullet gonadal maturation and identify relevant morphometric measurements. The findings are anticipated to offer valuable insights for mullet fish resource management and contribute significantly to the understanding of wild-caught fish reproduction.

MATERIALS AND METHODS

Sample collection

This fish sample was collected at Marine Science Technopark, a nearby shrimp pond located in the north Java Sea, Teluk Awur Coast, with a latitude of 6°37'19.04"S and a longitude of 110°38'13.81"E. The water was clear with a slightly gentle current, and the seabed was covered by muddy sand sediment. One hundred and four fish were collected from June to July 2023. This area is well-known since plentiful fish was abundant. Surrounding local people and fishermen regularly catch fish from these waters and mangrove areas.

Fish were captured based on the lunar phases, including the full and new moon. The flathead grey mullets (Mugil) were caught using a stationary lift net operated by a fisherman at the beachside. The lift net frame was positioned at a height of 8 meters above sea level, with a net size of 6×6 meters and a mesh size of 1 cm (Figure 1). The observation was administered with female fish with a total length of over 20 cm. Captured fish were separated, and only females were selected as the sample. The sampled fish were anesthetized using clove oil placed in a PVC pipe singularly to avoid stress and transported to the laboratory. Fresh fish were then brought to the laboratory for further examination. Morphometric and genetic analyses were conducted in the Laboratory of Science Technopark, Faculty of Fisheries and Marine Science, Universitas Diponegoro (UNDIP), Indonesia.

Morphological measurements

The sampled fish were measured basically by Yulianto et al. (2020) for A. Head length; B. Total length; C. Body width; and D. Head width (Figure 2) with calipers, and their total weight was measured with analytical balance (0.0001) g (Ohauss).

Gonad analysis

Gonad maturity level (GML) was determined based on the morphology of the gonads. (Effendie 2012; Freitas et al. 2024).

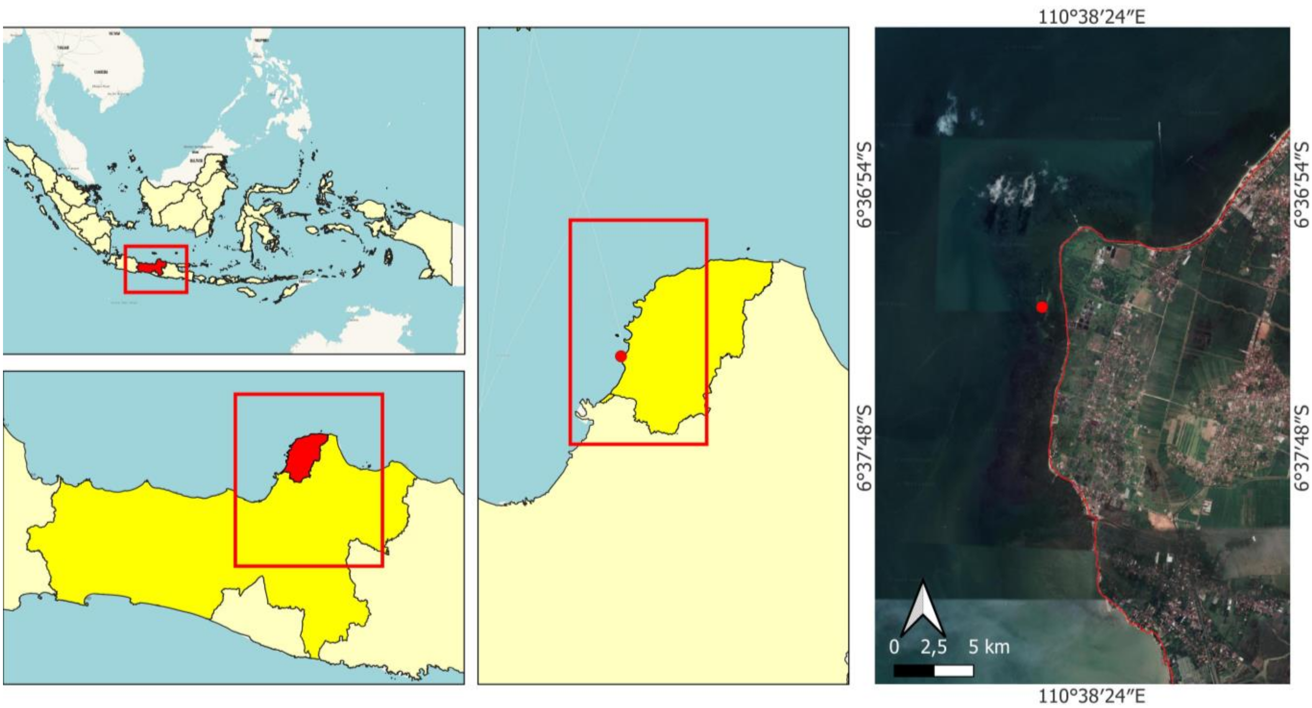

Figure 1. The map of Teluk Awur Coastal, Java Sea, Jepara, Central Java, Indonesia, showing sampling locations. Fish collected with lift net

To calculate the gonadosomatic index (GSI), the weight of the gonad and the total body weight of the fish (including the gonad) were measured. The GSI was calculated using the following equation:

GSI = (GW / TBW) x 100%

GSI = Gonadosomatic Index,

GW = Gonad Weight,

TBW = Total Body Weight.

Fecundity was calculated by collecting eggs from female fish with GML I, GML II, and GML III. Fecundity analysis was performed using the gravimetric method (Effendie 2012) with the formula:

F = (NE x WSG) / GW

F = fecundity,

NE = number of sample eggs,

WSG = weight of sample gonad (grams),

GW = gonad weight

Egg diameter was observed using a microscope (Olympus, USA) with an ocular micrometer. One gram of each sample was taken randomly from three parts of the gonad: posterior, median, and anterior. The diameters were then observed using the microscope and calibrated with an objective micrometer beforehand.

Water quality parameters

Dissolve Oxygen, water temperature (Water Quality Checker "Amstast"), Salinity (Atago Refractometer), pH (pH meter RoHS), turbidity (Secchi disk), Total Ammonia Nitrogen (640 nm), Nitrite (530 nm) and Nitrate (543 nm) was applied spectrophotometrically (Shimadzu 1900) and titrimetric methods analyzed Total Organic Matter. The seawater quality was done in July and observed twice a day (morning and evening) during fish caught.

Data analysis

The data was then statistically analyzed and R-Studio was applied to ascertain the differences between treatments. The data was verified by one-way analysis of variance (ANOVA) to determine whether the treatment had a significant effect (α=0.05) or not. LSD was used to assess the differences.

RESULTS AND DISCUSSION

Fish capture in different lunar periods

The fish genus found in Teluk Awur Coastal is *Planiliza subviridis* Valenciennes 1836 (Figure 3). It is morphologically characterized by dorsal spines (total): 4-5; dorsal soft rays (total): 8-9; anal spines: 3; anal soft rays: 9. Dark greenish dorsally, brownish over head, white ventrally; 3-6 indistinct, dark stripes along upper rows of scales; greyish dorsal fins; caudal fin bluish with black margin. Yellowish pectoral fin and may have a blue spot at fin origin.

The 104 female mullets used in this study comprised 51 during the new moon and 53 during the full moon (Figure 4).

The percentage of the mullets (58.5%) in GML I is higher compared to GML II (36.5%) and GML III (5%) (Figure 4). Similar data regarding fish catch was also reported from mangrove fishes in Brazil (Ramos-Júdez et al. 2021). The number of fish was higher in terms of individuals (32%) and mass (34%) during the new moon periods. This is likely because these fish have already finished spawning in the open sea and return to coastal waters in mangrove areas to find food, thus getting caught by fishermen (Ghiffary et al. 2018); it also causes only a few fish with GML III to be caught by the net.

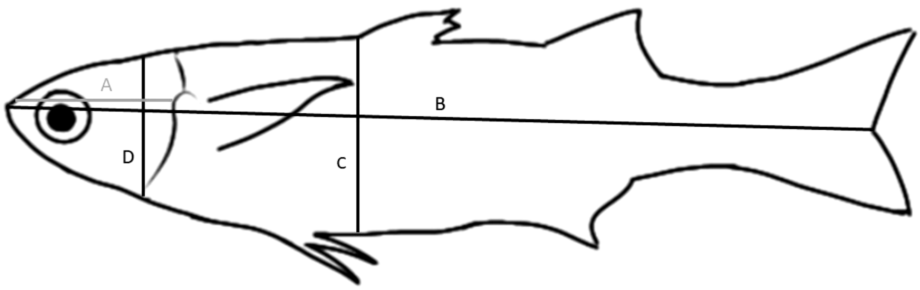

Figure 2. The morphometric measurements in the present study

Figure 3. The mullet (*P. subviridis)* in Teluk Awur Coast

The percentage of mullets in GML I, GML II, and GML III during the new and full moon phases is relatively similar (Figure 4). The influence of lunar phases closely tied to tides significantly impacts the behavior of fish in coastal areas, both for residents' fish and for those that forage along the shoreline before returning to their original habitats after high tide. According to Ihsan et al. (2021), the tidal patterns in coastal waters strongly affect the distribution and abundance of fish related to the lunar phases. In Jepara (Bonauli et al. 2016). Spring tides occur during the new and full moon phases, while neap tides occur during the first and third quarter moon phases. Spring tides have stronger tidal forces than neap tides, allowing them to bring more fish into coastal waters. As a result, catch rates were greatest during spring tides in the new and full moon periods.

Morphometric parameters

Both lunar phases did not show significant differences (α=0.05) in the body weight, total length, and head length in GML I and GML II. However, during GML III, both moon phases had a significant effect (α=0.05) on the body weight, total length, and head length (Figures 5A, 5B, and 5C).

The abdominal and head widths of the mullets captured during the full and new moon in all GML did not show a significant difference (α=0.05) (Figure 6). This indicates that during lunar phases, the size of the mullets' body and head widths remains the same in all GML.

Based on Figures 5 and 6, especially in GML III, it is evident that fish caught during the new moon have smaller body weight, total length, and head width compared to those caught during the full moon, but they have the same abdominal width as full moon fish. This indicates that fish caught during the new moon tend to mature gonads faster than those caught during the full moon. Broodstock mullets caught during the new moon exhibit dominant width morphometrics compared to length morphometrics and vice versa. Furthermore, our study conducted in Teluk Awur, Jepara's coastal waters, showed that during both full and new moon phases, larger-sized and heavier mullets did not necessarily exhibit higher levels of gonad maturation than smaller and lighter ones, particularly in GML III.

Food availability during spring tides affects the fish population, especially female fish that require ample food for gonad development. Similar to our works, in their study, Stewart et al. (2021) hypothesized that this observation results from the visual nocturnal feeding nature of Australian sciaenid (*Atractoscion atelodus* Günther 1867), with schools of fish using the increased ambient light in the water column during the brighter part of the lunar phase to feed intensively. In contrast, our data revealed that light was limited in new moon periods, and feed availability was inadequate, resulting in less body weight, total length, and head length.

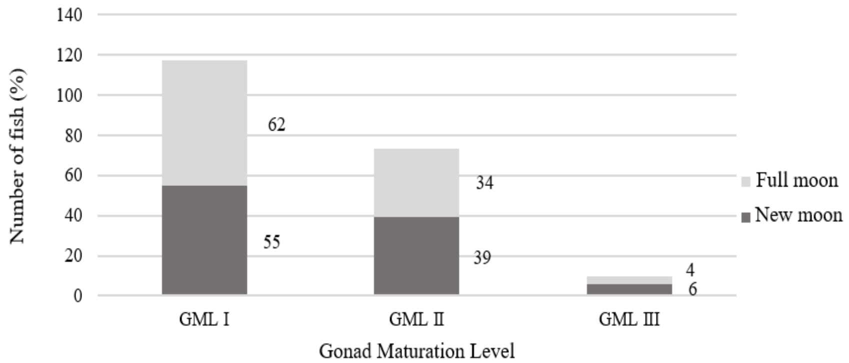

Figure 4. Number of fish captured in different moon phases in different gonad maturation levels at Jepara Coast

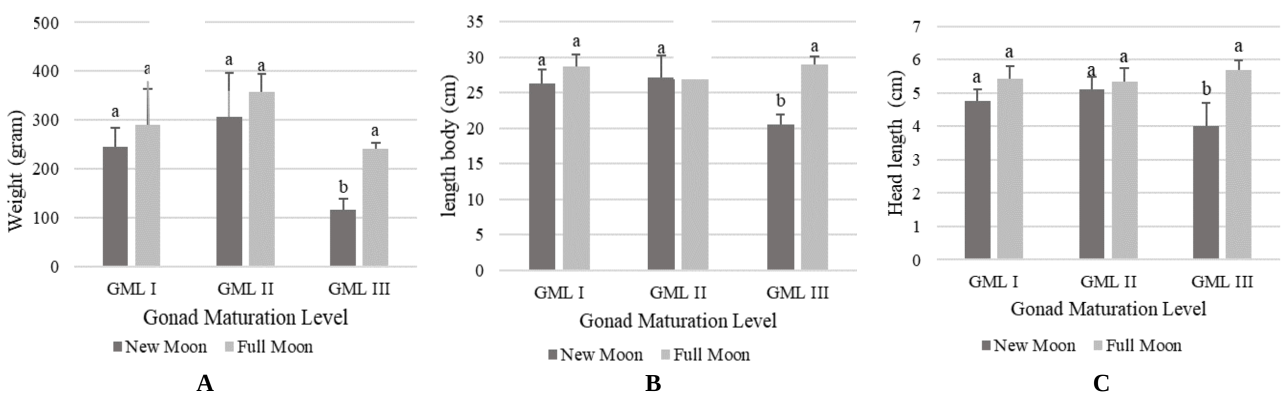

Figure 5. A. Body weight; B. Total length; and C. Head length of *P. subviridis* compared with gonad maturation level at different lunar phases. Means with different lowercase letters (a, b) are significantly different between moons (α=0.05)

Ikegami et al. (2014) reported that melatonin is an endogenous transducer of the environmental dark/light cycle. Melatonin rises in the pineal gland and blood around the new moon period and reduces throughout the full moon period, which is in agreement with our data. In synchronizing with melatonin variation, melatonin mRNA receptor(s) loads are higher during the new moon than during the full moon. Lopes et al. (2023) denoted similar facts in melatonin and metabolic parameters in their experiments regarding Amazonian fish (*Brycon amazonicus* Spix and Agassiz 1829).

The gonadal maturation of mullets is varied in different areas. Based on the research conducted on the eastern coast of Andhra Pradesh, India (Kurma and Babu 2016), a minimum length of 16 cm was identified as the gonad maturity level for the mullets (*Mugil cephalus* Linnaeus 1758) and in Mayangan Beach, West Java, the mullets (*Molgarda engeli* Bleeker 1858) reached gonad maturity at 14.5 cm. Similar to the study of mullets from India's West Coast (Bhakta et al. 2024), our study observed that mullets on the Jepara coast reached their gonad maturity approximately 14 cm in total length (data unavailable).

Reproduction factors

The new and full moon phases did not have a significant effect (α=0.05) on the gonadosomatic index (GSI) and gonad weight of mullets in GML I and GML II. However, these had a significant effect (α=0.05) on GML III. The GSI values in GML I ranged from 0.83% to 0.93%, and in GML II ranged from 0.88% to 1.10%. In the dark moon phase, the GSI value in GML III reached 14.88%, while in the bright moon phase, it was 0.956%. Similar results were observed in the gonad weight of captured females of the mullets (Figure 7).

During New Moon phases, over 50% of individuals were at GML III, while during Full Moon phases, only 10-15% were at GML III. Therefore, the spawning cycle of mullets in the wild is suspected to occur during the new moon. However, a study by Ratnaningsih et al. (2022) found that wild-caught mullets in Karangsong Waters, Indramayu, West Java, showed the highest GML III and IV occurrence in February.

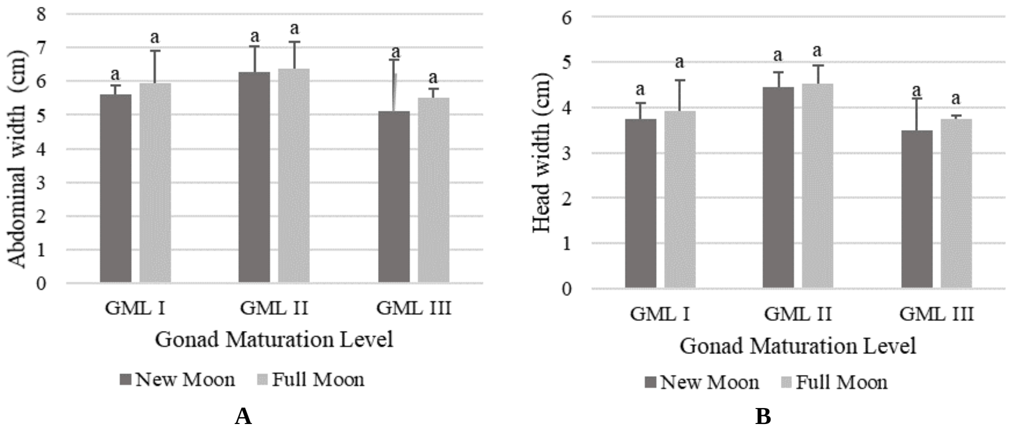

Figure 6. A. Abdominal width; and B. Head width of *P. subviridis* compared with gonad maturation level at different lunar phases. Means with similar lowercase letters (a) are not significantly different between moons (α = 0.05)

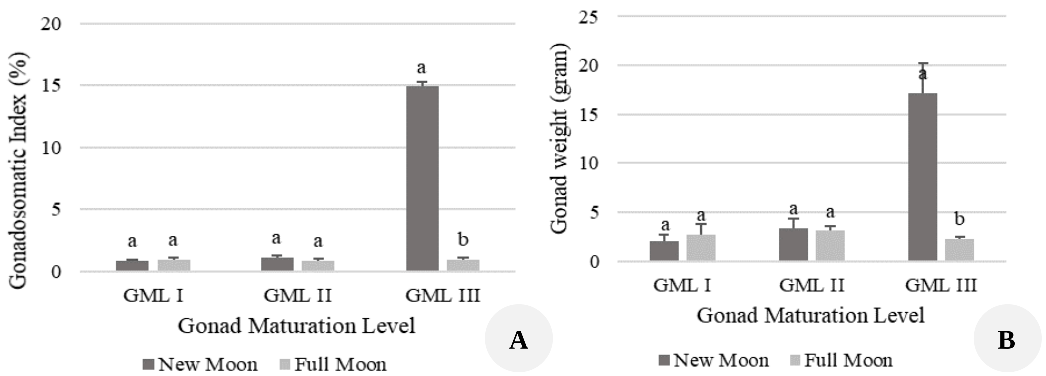

Figure 7. A. Gonadosomatic Index; B. Gonad weight in different moon phases. Means with different lowercase letters (a, b) are significantly different between moons (α = 0.05)

Gonadal maturity in fish is closely related to the reproductive cycle. According to Abdel-Tawwab et al. (2023), gonadal development is influenced by internal factors (immune parameters, lipid profile, hormonal effects, and fish species) and external factors (temperature, light intensity, food, and environment), as reported by Hubená et al. (2023). The reproductive cycle occurs due to environmental signals captured by the central nervous system, which affects the hypothalamus to secrete gonadotropin-releasing hormone (GnRH). The blood then carries GnRH to the pituitary gland, which stimulates the secretion of follicle stimulating hormone (FSH) and luteinizing hormone (LH). FSH and LH influence gonadal development and maturation (testes and ovaries) and spawning in fish (Ramos-Júdez et al. 2021). Lubzens et al. (2010) suggest that FSH plays a major role in promoting vitellogenesis, which is gametogenesis from early to late stages. At the same time, LH is involved in gametes' final maturation and release (ovulation).

The hormone estradiol present influences the gonadal maturity of female fish in the fish's body, as estradiol levels affect vitellogenin synthesis during vitellogenesis in the liver, thereby accelerating oocyte growth. Similar findings were reported by Ramos-Júdez et al. (2021) based on their laboratory assays on flathead grey mullet (*M. cephalus*). Gonadal maturation begins with fulfilling the fish's nutritional needs, and the remaining energy is utilized for gonadal maturation and growth. (Kurma and Babu 2016). Additionally, environmental factors such as temperature and habitat influence the speed of gonadal maturation by affecting hormone responses and the provision of nutrients for gonadal maturation in fish. Significant gonadal development occurs before spawning and is an integral part of fish reproduction preceding the spawning process (Mousa et al. 2018).

Effendie (2012) states that the gonadosomatic index (GSI) will increase as the gonad maturation level increases and will decrease after the fish have finished spawning. This indicates that when fish reach a higher level of gonad maturation, their GSI also increases. However, after the fish have completed spawning, the gonadosomatic index tends to decrease. The development of the gonads is associated with an increase in gonad weight, which subsequently affects the average GSI value.

The gonadosomatic index can serve as a simple measure of reproductive capacity (Ibañez and Colín 2014). This supports the idea that the reproductive capacity during the full moon is significantly different, with a higher GSI value during the new moon in GML III compared to the GSI during the full moon (α=0.05). Our data revealed that the eggs produced during the dark moon are 231,219 eggs, larger than the fecundity during the Full moon phase, which is 105,791 eggs. Both the bright moon and dark moon phases significantly affect the fecundity of the mullets (Figure 8). In GML I, the gonad is thin and translucent, and the oocyte is very small and not in good shape. In GML II, the oocyte is pale yellow colored, bigger than in GML I, fairly well shaped, and still small. The gonad is yellow and orange bright, filling out the body cavity; the oocyte is well-shaped and bigger. Generally, the development of egg morphology in the new moon is slightly more mature (Figure 9).

The magnitude of this fecundity value reflects the adaptation effort of the mullets in maintaining their population in the wild. Variability in fish fecundity can arise due to various adaptations to the environment in which the mullets live (Stewart et al. 2021).

The spawning frequency can be estimated by examining the distribution of mature egg diameters in the gonad, primarily by observing the pattern of diameter distribution. Measurements of the mullet's egg diameters in GML I, GML II, and GML III showed consistent size uniformity during the new and full moon phases. This suggests that the mullets belong to the group of synchronous spawners, where they release their eggs simultaneously in a short period during the same spawning season. Similar findings were reported by Albieri and Araújo (2010), who identified *Mugil liza* Valenciennes 1836 as synchronous spawners.

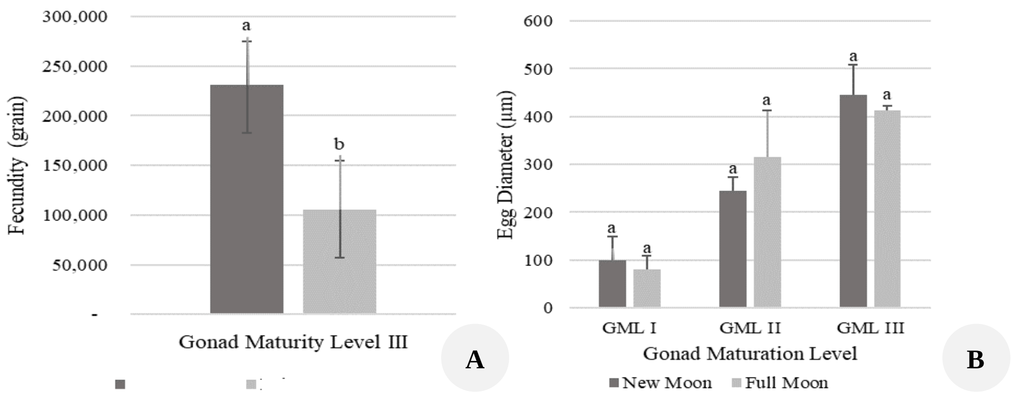

Figure 8. A. Fecundity as a total number of eggs; and B. Egg diameter of *P. subviridis*. Means with different lowercase letters (a, b) are significantly different between moons (α = 0.05)

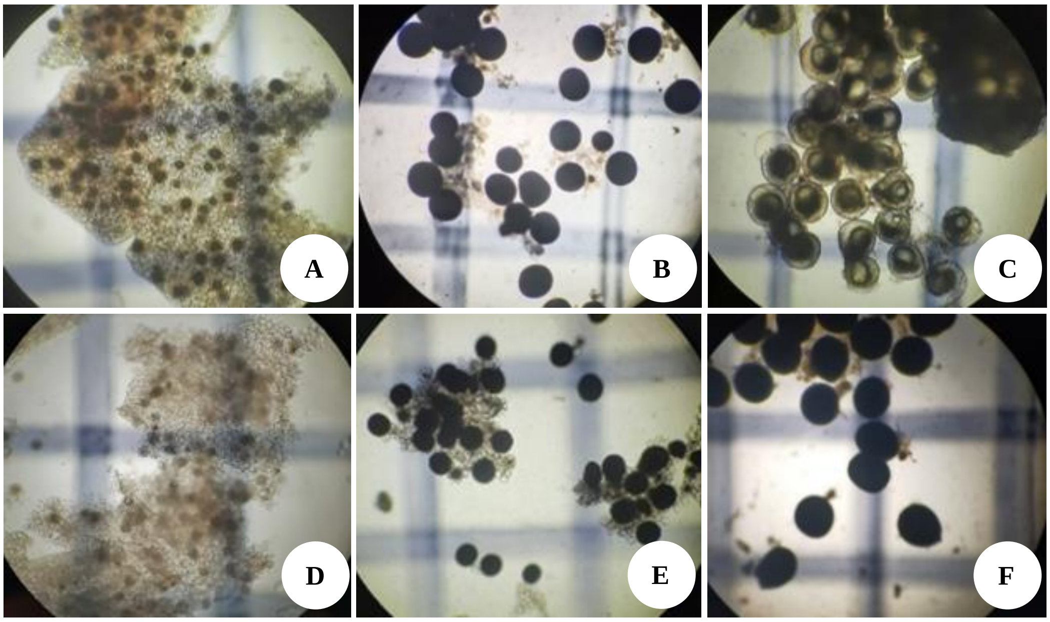

Figure 9. Morphology of *P. subviridis* egg from Teluk Awur Coast in the new and full moon. A. GML I, new moon; B. GML II, new moon; C. GML III, new moon; D. GML I, full moon; E. GML II, full moon; F. GML III, full moon

Table 1. Fluctuation of water quality parameters in Jepara Coast taken in the morning and evening

Parameter	Morning	Evening
Dissolved Oxygen (ppm)	7.40	8.05
Water temperature	28	32.6
Salinity (ppt)	30	30
pH	8.40	8.45
Transparency (cm)	92	80
Total Ammonia Nitrogen (TAN)(mg/L)	0	0
Nitrite (mg/L)	0	0.002
Nitrate (mg/L)	0.01	0.007
Total Organic matter (mg/L)	81.17	81.17

Water quality parameters

The seawater quality parameters in Jepara Coast are shown in Table 1. The reproductive features of *P. subviridis* from Jepara Coast may be mostly affected by dissolved Oxygen, pH, total alkalinity, and transparency. For marine ecosystems, DO and pH are considered critical biological components. The ideal DO level has to be more than 3.5 mg/L (Bhakta et al. 2024). Similar to other Indonesian regions, such as Kutai, Kalimantan (Rofi'i et al. 2022), the temperature is still an ideal requirement for *M. cephalus* to grow. Growth and reproduction will be delayed if an aquatic habitat is more acidic (pH<4) or more alkaline (pH>9.5) (Bhakta et al. 2024). In our study, DO levels were constantly found to be greater than 6.0. pH levels were constantly higher than 7.0, representing a proper habitat for coastal and aquatic resources in the studied ecosystem. Regarding fish domestication, data on seawater quality parameters in fish natural habitats are needed. Water quality in fish culture and cultivation must be considered to meet and fulfill the requirements.

This research suggests capturing and domesticating broodstock during the new moon to improve the prospects of mullet aquaculture. This would also support conserving mangrove areas while maintaining a sustainable environment.

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