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Reproductive Biology of *Rastrelliger kanagurta* from Sin Ma Coastal Water

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INFORMATION

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ABSTACT

Abstract
This study was conducted to determine the reproductive biology of *Rastrelliger kanagurta* in the Sin Ma coastal water from June 2024 to May 2025. During the study period, females are more outnumber than the males with the sex ratio of 1 male:1.23 female in Sin Ma coastal water. Gonad maturity stage V (ripe) was observed in almost all months. The result showed the gonad maturity of Indian mackerel occurred throughout the year with the peak between March to May. The GSI maximum values females were recorded 4.52 in Sin Ma. The fecundity of females varied from 52795 to 224955 with an average of 130909 ± 52945.55 eggs. Fecundity was positively correlated with total length (r=0.93), body weight (r=0.86) and ovary weight of fish (r=0.89).

Keywords
Rastrelliger kanagurta, Sex ratio, Gonad maturity, Fecundity, Sin Ma coastal

1. Introduction

The Indian mackerel (*Rastrelliger kanagurta*) is a species of mackerel under the family Scombridae of order Perciformes. Distinguishing characteristics of the family Scombridae are elongated and fusiform body, an adipose eyelid, separated dorsal fins, finlets present behind the dorsal and anal fins, and a deeply forked caudal fin. *Rastrelliger kanagurta* is commonly known as Indian mackerel and locally known as Pa-La-Tu. Mackerel is a relatively short-lived species distributed across the Indo-West Pacific tropics, occurring at depths ranging from 10 m to 100 m, and commonly found above 25 m (Akib et al., 2015). Myanmar is included among the native distribution countries of mackerel species. Comprehensive knowledge base on reproductive biology aspect of particular fish is required in providing scientific advice for fisheries management and sustainable exploitation in the near future (Morgan, 2008).

Studies on spawning frequency and season, size at first maturity, fecundity, sex ratio, macroscopic staging of gonads, and gonadosomatic index can assess the reproductive potential of individual fish (Scott et al., 2005). Gonadal somatic index (GSI) is one of the important parameters in fish biology, providing detailed insights into reproduction, reproductive status of species, and assisting in determining the breeding period of fish (Etim, et al., 2000). The ability to reproduce is a key indicator of fish stock growth (Marquez et al., 2003). Fecundity is another key indicator of fish growth. Fecundity can be used as a measure of an organism's productivity, which is strongly influenced by state of environmental conditions, growth, age, female size, reproductive strategy and spawning pattern of the species (Lambert, 2008).

Thus, the present study aimed to classify the maturity stages of gonads, to record the monthly changes of gonadal development stages, to characterize the sex ratio, to find out the gonadosomatic index (GSI), to estimate the length at first maturity, and to determine the fecundity in relation to fish length, fish weight and gonad weight of *R. kanagurata* from

the Sin Ma coastal water for the study of reproductive biology.

2. Materials and Methods

The Indian mackerel, *Rastrelliger kanagurta,* was collected monthly from Sin Ma coastal water, Pathein Township, Ayeyarwady Region (Fig. 1). A total of 360 numbers of Indian mackerel were collected randomly from purse seines and gillnets from Sin Ma coastal water (lat 16.74N and long 94.35 E) during June 2024 to May 2025. Freshly fish samples were transported to the lab in ice and individual fish was examined the measurement of total length (cm), total weight (g), and gonad weight (g). The total length (TL) of each fish was measured to the nearest 0.5 cm using a measuring board and the total weight (TW) of the sample fishes were recorded to the nearest 1 g using an electronic balance. The gonads were weighed to the nearest 0.001 g using an electronic balance. The fish was then dissected to determine the sex and maturity stage. Ovaries were preserved in 5% neutral formalin for subsequent fecundity studies.

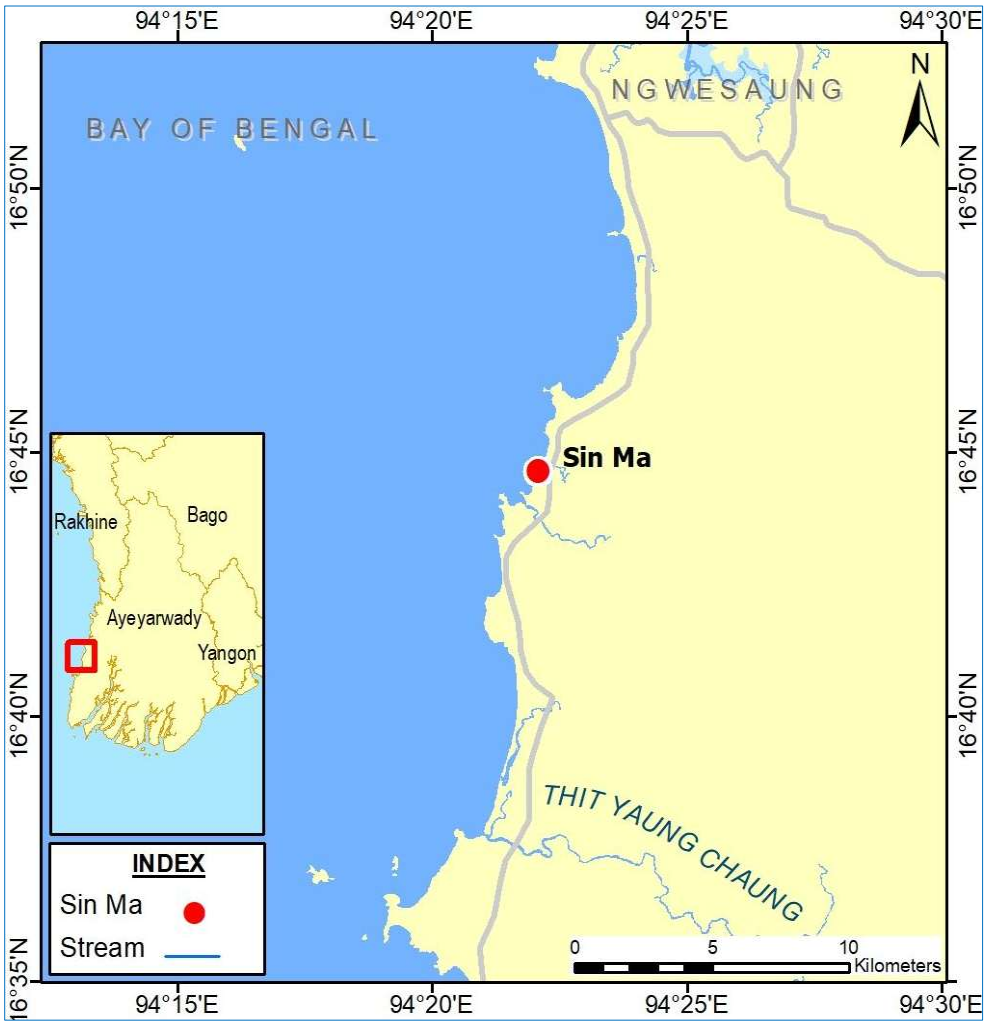

Fig. 1. Map of the study area

2.1. Sex Ratio

Sex was determined by macroscopic examination based on the color of gonad. Month-wise sex ratios were measured by comparing the number of females and males recorded each month during the sampling period. Chi- square (X^2) analysis test was used to assess sex ratio deviation from the expected ratio of 1:1 by according to the formula (Kenney and Keeping, 1951) as follow (*Equation 1*).

$$X^2 = \frac{\Sigma(O - E}{E} \quad (1)$$

where O is observed frequency of males or females and E is expected frequency of males or females.

2.2. Monthly Percentage Variation of the Gonad Maturity Stages

After detaching the gonads from the fish specimen, six maturity stages of females and males categorized (immature, early maturing, maturing, mature, ripe and spent) were recorded which was based on the observation of the gonad such as the coloration of the gonads, the size of ovary in relation to body cavity, and its appearance (whether bulging, half shrunk or flaccid; the presence of blood vessels on the ovary), and the appearance of ova as followed the key suggested by Pradhan and Palekar (1956).

2.3. Gonado- Somatic Index (GSI)

GSI is used as an indicator of the stage of ovary maturation and degree of ripeness. GSI was calculated for each maturity

stage of both sexes using gonads in fresh condition collected from June 2024 to May 2025 according to the *Equation 2* given by Cailliet et al. (1986).

$$GSI = \frac{Weight\ of\ gonads\ (g)}{Body\ weight\ (g)} 100 \quad (2)$$

where GSI is *Gonado-Somatic Index*.

2.4. Fecundity

Fecundity of *R. kanagurta* was based on 25 female ripe ovaries (Stage V) with 25 specimens ranging from 18.9 to 29.8 cm TL and from 159.89 to 278.56 cm BW. The 1mg of ripe ovary was taken as sub-sample from three parts of ovary i.e., anterior, middle and posterior and the number of ova were observed under a microscope. The fecundity was determined by the *Equation 3* given by Sinha (1995).

$$F = \frac{nG}{g} \quad (3)$$

where F is fecundity, n is number of eggs in the sub sample, G is total weight of the ovary and g is weight of the subsample.

Fecundity in relation to fish total length, fish weight and gonad weight were calculated by applying the method of least square (Sparre and Venema, 1992) based on *Equation 4*.

$$F = a + bX \quad (4)$$

where F is fecundity, a is constant, b is exponent and X *is* fish length (or) fish weight (or) gonad weigh.

3. Results

3.1. Sex Ratio

A total of 360 fish samples from the Sin Ma coastal water were sexed to determine monthly variation. Of these, 162 were males and 198 were females in Sin Ma. Monthly variations in the male-to-female ratio from Sin Ma coastal waters are presented in Table 1.

Table 1. Monthly variation sex ratio of *Rastrelliger kanagurta* from Sin Ma coastal water

Month	No. of fish	Sin Ma	
		Sex ratio (M:F)	Chi square (X^2)
24-June	30	1:1.14	0.13
July	30	1:1.31	0.53
August	30	1:1	0
September	30	1:1.14	0.13
October	30	1:1.5	1.2
November	30	1:1	0
December	30	1:1.31	0.53
25-January	30	1:1.14	0.13
February	30	1:1.5	1.2
March	30	1:1.31	0.53
April	30	1:1.14	0.13
May	30	1:1.31	0.53
Total	360	1:1.23	0.42

Females generally outnumbered males in all collected samples, with an overall sex ratio of 1:1.23 (male:female) in Sin Ma. Based on this ratio, females were more dominant than males. In the chi-square test, the critical value at the 5% significance level ($p < 0.05$) is 3.84. The chi-square values from Sin Ma coastal waters ranged from 0 (November) to 1.2 (October, February), with an average of 0.42. Thus, the overall chi-square results indicated no significant difference between the number of males and females across all months compared to the expected 1:1 ratio (at the 5% significance level).

3.2. Percentage Occurrence of Different Maturity Stages

In Sin Ma, Immature and early maturing males (stage I & II) occurred almost all months except March and April. Their percentages were lowest in May (3%) and highest in October (40.0%). Males with maturing testes (stage III) were found in the months and highest percentage occur in November, and lowest percentage occur in August. Fish with mature testes (stage IV) occurred in all months with peak in February. Monthly percentage range of mature males were 25% (March) - 88.2% (October). Males in stage V (ripe) were observed in all months expect October and September with peak in April (61.5%). Spent testes in stage V were recorded in all months and the percentage range of 9% (October) – 30.5% (March).

Females with immature and early maturing ovaries (stage I & II) were found in all months except March and April. These quantities were high in October, and 58 September. The female with maturing ovaries (stage III) were recorded in all months with their percentage range of 5% (August) – 28.4% (November). Mature female (stage IV) occurred in considerable quantities in all months. Higher percentages were observed in November, January, February and March.

Females in stage VI (ripe) were observed in all months expect October with peak in April (56.5%). The percentages of spent females (stage V) ranged from 10% (September) - 24% (February). In the present study indicated that the male and female gonad at the ripe maturity stage (V) were available throughout the year. But it is clear that from the availability of the various stages of maturity during the various months maximum gonad maturity occurs during the month of March, April and May. Based on the gonad maturity stages every month, these species spawn throughout the year with major peaks in March to May.

3.3 Gonadosomatic Index

Monthly variation in the gonadosomatic index (GSI) was analyzed to quantify gonadal development and confirm the spawning period. Individual GSI values were calculated and expressed as monthly means. Marked differences were observed between sexes, with peak GSI values recorded in April and May for both males and females, indicating a higher proportion of ripe individuals during these months. In Sin Ma, male GSI values ranged from 1.31 to 3.98 (mean ± SD: 2.72 ± 0.88), while female values ranged from 1.75 to 4.52 (mean ± SD: 3.03 ± 0.96). Male GSI values were lowest in October and highest in April. Females exhibited elevated GSI values in March, April, and May, with the lowest values in October (Fig. 3).

3.4. Fecundity

Fecundity estimation was based on 25 ovaries in maturity

stages IV, V and VI with the size ranged from 18.1 cm to 29.4 cm total length, from 158.89g to 278.56 g body weight and from 3.14g to 10.27g ovary weight. The fecundity varied from 52795 ova (18.1 cm, 159.89g, 3.87g) to 224955 ova (29.4 cm, 278.56g, 10.27g) with an average fecundity of 130909 ± 52945.55.

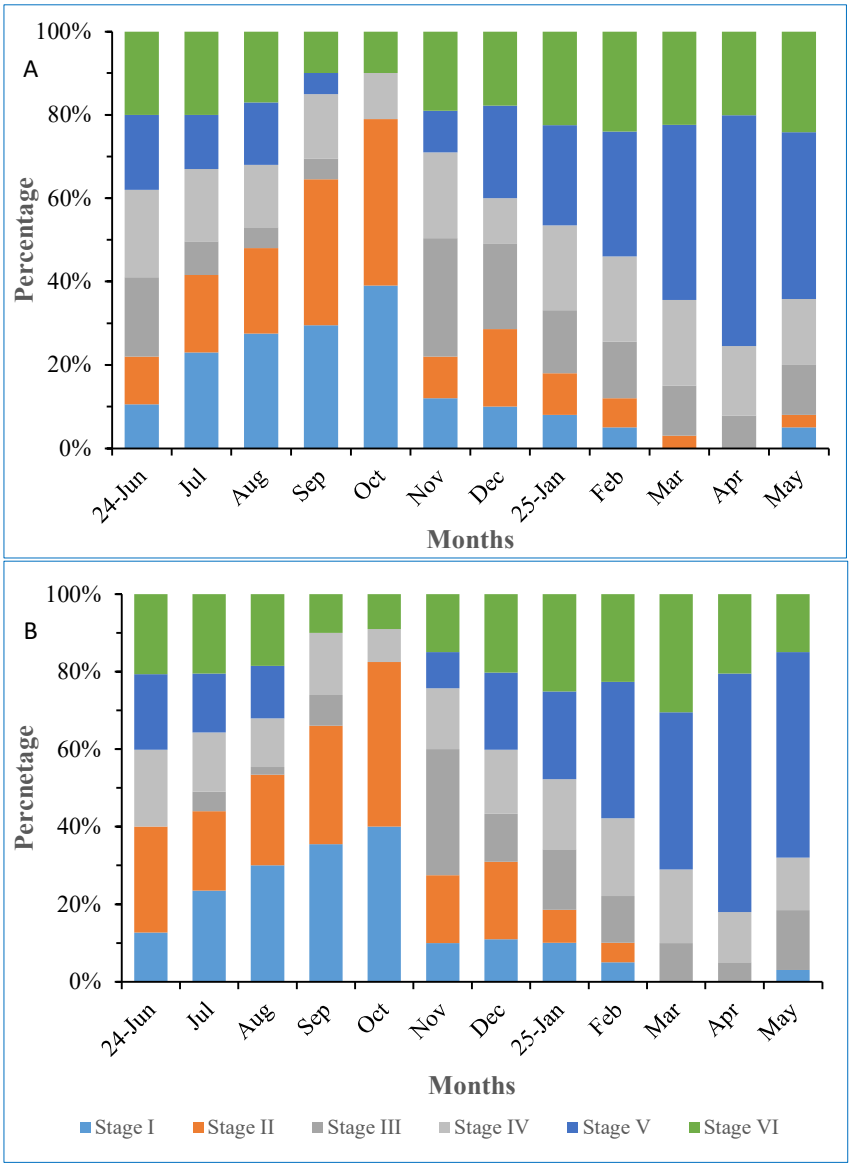

Figure.4.2. Monthly variation of different maturity stage in male and female *Rastrelliger kanagurta* from Sin Ma

In the present study, the linear relationship between fecundity and body length showed that the fecundity increased in direct proportional to fish length (fig. 4.5). The relationship between fecundity and ovary weight, and fish weight was found in linear, and fecundity increased with the increased in ovary weight and body weight (fig.4.6). The resultant correlation coefficient r values indicated that there was a positive relationship between fecundity and total length and total weight and ovary weight, $p<0.05$ indicating that the fecundity generally increased with increasing length, weight and gonad weight.

4. Discussion

The present study on the sex ratio of *R. kanagurta* showed that females outnumbered males. The Chi-square test applied to the monthly samples indicated that there was no significant difference in almost all months of the study period. Similarly, Shama, et al. (2011), Zaki, et al. (2016), Bhendarkar, et al. (2013) and Win, et al. (2023) reported that the number of Indian mackerel females was generally higher than that of males in the Sultanate of Oman, the Mahout coast, and the coastal region of Myanmar, respectively. Conversely, males outnumbered females in Indian mackerel populations along the Mangalore coast (Hulkoti, 2005) and in the southern waters of West Java (Nurfaiqah, et al., 2023).

Six developmental stages (immature, early maturing, maturing, mature, ripe, and spent) of female *R. kanagurta* were identified based on the color and size of the gonads. Observations of male and female gonadal maturity showed the presence of the ripe stage (Stage V) in all months during the study period.

The monthly gonad maturity levels indicated that spawning occurs throughout the year, with peak activity in March, April, and May for both sexes. In the coastal region of Myanmar, Stage V maturity of Indian mackerel was most dominant in May, accounting for 53.46% (Win, et al., 2023). Beraki, et al. (2024) reported that the spawning season of Indian mackerel in the Massawa coastal waters of the Southern Red Sea, Eritrea, extended from July to November, with peak spawning in September for females and October for males.

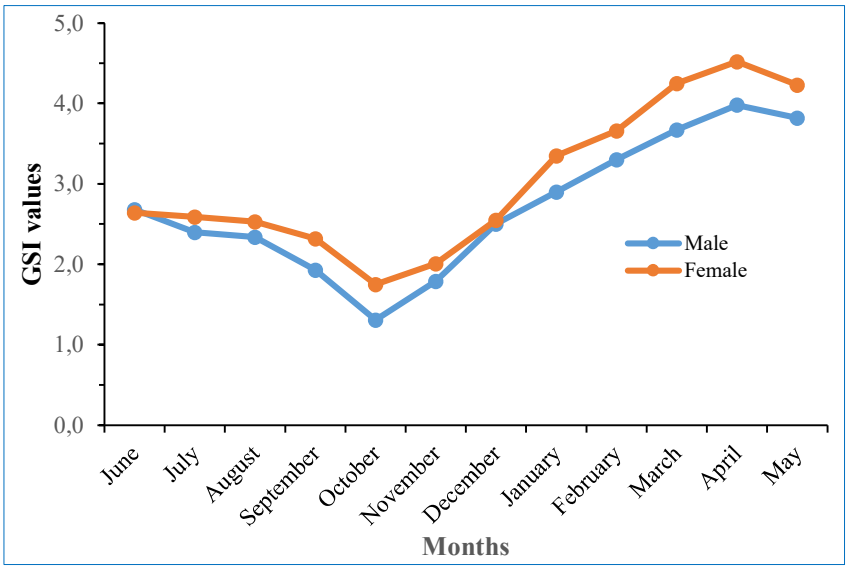

Fig. 3. Monthly variation of GSI value of *Rastrelliger kanagurta* from Sin Ma

The GSI value of female *R. kanagurta* was consistently higher than that of males throughout the study period. The GSI values recorded ranged from 1.00 to 4.01 in males and from 1.11 to 4.93 in females. The highest GSI values were observed in April, followed by March, May, and June 2024 across all study areas. Also, Yohannan and Abdurahiman (1998) reported that Indian mackerel *R. kanagurta* was assumed to be prolific breeder due to their spawning over the year when they have favorable temperature and availability of food for spawning. Bhendarkar, et al. (2013) reported that the GSI values of both females and males were highest in April and lowest in January along the Ratnagiri Coast, Maharashtra, India. Similarly, gonadal maturity of Indian mackerel in Takalar coastal waters was observed year-round, with a peak in July and August, and GSI values ranging from 0.928 to 4.490. The consistently higher GSI values in females compared to males are attributed to their reproductive status and somatic development (Olii, et al., 2023). Fecundity analysis determines the number of eggs produced by female fish. Fecundity can vary depending on species, season, and location. In the present study, the number of eggs in the ovaries ranged from 52,795 (18.1 cm TL, 159.89 g BW, 3.87 g GW) to 224,955 (29.4 cm TL, 278.56 g BW, 10.27 g GW), with an average of 130,909 eggs. Fish at advanced stages of gonadal maturity contained more eggs to be released during spawning.

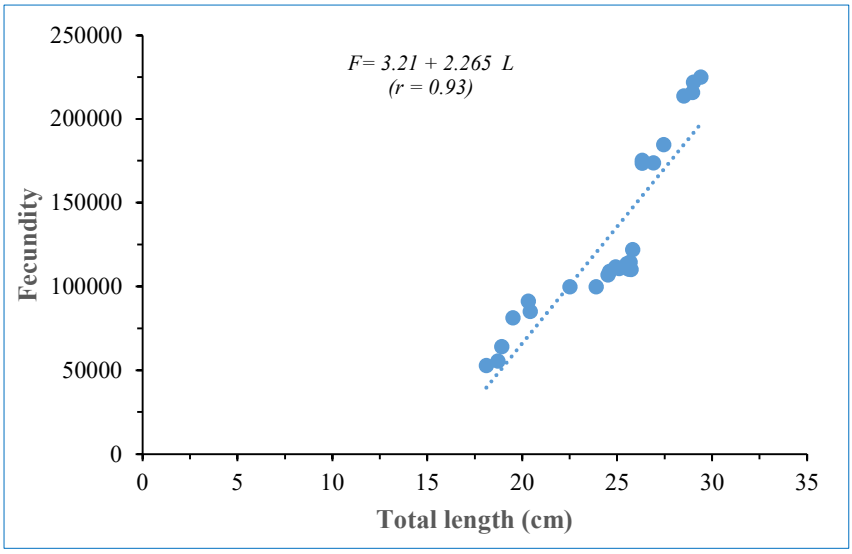

Fig. 5 Relationship between fecundity and total length of *Rastrelliger kanagurta* from Sin Ma coastal water

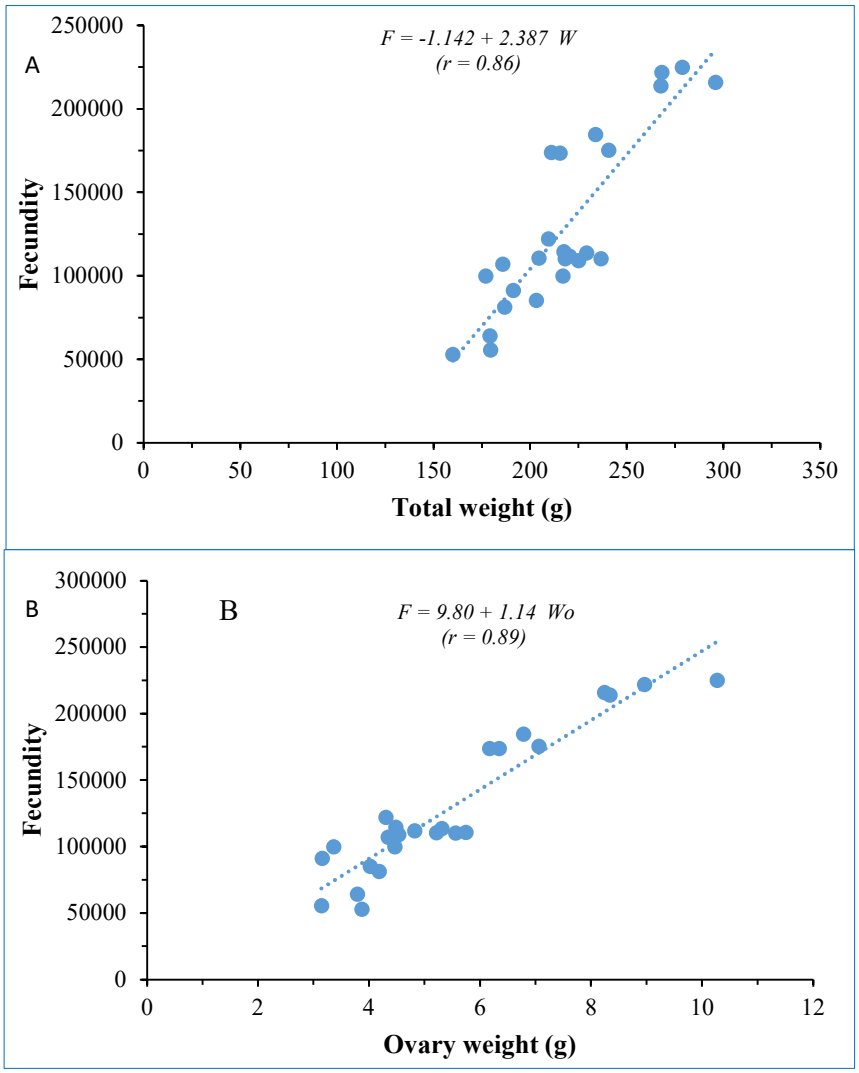

Fig. 6. Relationship between fecundity and (A) body weight, and (B) ovary weight of *Rastrelliger kanagurta* from Sin Ma coastal water

Bhendarkar, et al. (2013) reported that fecundity in female *R. kanagurta* ranged from 55,264 eggs (22.7 cm TL, 120 g BW) to 314,568 eggs (29.9 cm TL, 304 g BW), with an average of 108,266 eggs along the Ratnagiri Coast, Maharashtra, India. In the western waters of Aceh, fecundity ranged from 28,542 to 123,760 eggs (Arrafi, et al., 2016). The fecundity obtained in the present study is higher than those reported by Bhendarkar, et al., (2013) and Arrafi, et al. (2016). Olii (2018) noted that gonads at the same maturity stage but with different weights and lengths can yield different fecundity values.

According to the correlation coefficient (***r***) values obtained in the present study, the fecundity of *R. kanagurta* was positively correlated with total length (***r*** = 0.896), body weight (***r*** = 0.873), and ovary weight (***r*** = 0.937) and ($p<0.05$). The logarithmic relationships between fecundity and total length, total weight and ovary weight were found to be linear, indicating that fecundity increased with the increases in length, body weight and ovary weight. Fecundity showed a stronger relationship with ovary weight than with total length or body weight. Nurfaiqah, et al. (2023) reported a positive correlation between fecundity and fish weight (***r*** = 0.8594) in Indian mackerel from the southern waters of West Java, with a significant coefficient of determination.

5. Conclusions

The reproductive biology of *R. kanagurta* in the Chaung Tha coastal area was examined from June 2024 to May 2025. Based on observations of the percentage occurrence of mature fish and gonadosomatic index values, it can be concluded that *R. kanagurta* exhibits continuous breeding throughout the study area, with a distinct spawning peak between February and June. The species is characterized by high reproductive potential, as indicated by fecundity estimates. Fecundity was positively correlated with fish length, body weight, and ovary weight. The findings of the present study contribute valuable knowledge on the feeding and reproductive dynamics of this species, providing insights that can inform sustainable fisheries management.

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