DOI: 10.31398/tpjf/29.2.2022-0024

RESEARCH ARTICLE

First Report on the Reproductive Biology of the Redtail Scad *Decapterus kurroides* Bleeker, 1855 in Iligan Bay, Southern Philippines

Harry Kenn T. Dela Rosa[1]*, Mariefe B. Quiñones[1], Cesaria R. Jimenez[1], Jerry P. Garcia[1], Dionel L. Molina[1], Jeanette J. Samson[1], Margarita C. Paghasian[2]

[1]*Research Division - Mindanao State University at Naawan. Pedro Pagalan St. Poblacion, Naawan, Misamis Oriental 9023 Philippines*
[2]*Mindanao State University – Maigo School of Arts and Trades, Poblacion, Maigo, Lanao del Norte 9206 Philippines*

ABSTRACT

This study provided the first report on the reproductive biology of the redtail scad, *Decapterus kurroides*. The reproductive activity of the redtail scad was assessed to characterize its sex ratio, spawning period, length at maturity, and fecundity. Meanwhile, remote sensing data on environmental variables were accessed from Giovanni online data system. Fish samples were collected monthly from October 2017 to September 2018 from both commercial and municipal landed catches. Male *D. kurroides* was found to have a larger size than the female in terms of mean total length and mean body weight, but it did not differ significantly from the female ($t = 1.31$, $df = 1{,}348$, $p = 0.19$). Collected male and female samples were mostly in the 15.1 – 18.0 cm size class. Overall sex ratio exhibited female dominance (1.2:1), which significantly deviated from the 1:1 ratio ($x^2 = 8.17$, $p = <0.05$). As expected for tropical fish, spawning of *D. kurroides* occurred year-round, with peak spawning in December and minor spawning events in March and August, as reflected in the monthly percent occurrence of different gonad maturity stages and gonadosomatic index evolution. Among the environmental variables evaluated, sea surface temperature appeared to have more influence on the spawning of *D. kurroides* followed by chlorophyll-*a* concentration. Females matured at a length of 17.2 cm, while males matured at a length of 17.6 cm. Absolute fecundity ranged from 6,416 to 197,672 eggs per female with a mean of 61,733 ± 3,955 and increased proportionally with gonad weight. Information from this study may be used to formulate effective management strategies for the resource.

*Corresponding Author: *harrykenn.delarosa@msunaawan.edu.ph*
Received: *July 11, 2022*
Accepted: *November 14, 2022*

Keywords: *Decapterus kurroides, fecundity, Iligan Bay, length at maturity, sex ratio, spawning*

1. INTRODUCTION

Knowledge of some aspects of reproductive biology, such as sex ratio, length at maturity, gonadal development, fecundity, and gonadosomatic index (GSI), is crucial in understanding the productivity and resilience of fishery resources (Cochrane 2002; Bradford et al. 2014; Lowerre-Barbieri et al. 2017). Hence, the significance of understanding how reproductive biology influences population production is becoming more apparent and receiving wide attention among resource management practitioners (Worm et al. 2009). To wit, information on the reproductive biology of a species is an index for evaluating the reproductive potential and estimation of stock size, determining the spawning period, and preventing the exploitation of juvenile individuals (Neves et al. 2020). However, in most cases, data and information on reproductive biology are unavailable (Williams et al. 2016), such as in the case of the redtail scad *Decapterus kurroides* Bleeker, 1855.

The redtail scad *D. kurroides* (Fig. 1) is a member of the red-fin *Decapterus* group. It belongs to the order Carangiformes, family Carangidae, and under the class Caranginae, which includes jacks, pompanos, trevallies, and other scads (Kimura et al. 2013). It is the oldest member of the red-fin *Decapterus* group, which Bleeker first described

Figure 1. Redtail scad *Decapterus kurroides* Bleeker, 1855 from Iligan Bay, showing its silvery-white body and distinct red fins of the red-fin Decapterus group.

in 1855 from a single sample from Ambon, Indonesia (Kimura et al. 2013). The *Decapterus* red-fin group also includes *D. tabl*, *D. akaadsi*, and *D. smithvanizi*, which closely resemble each other (Delloro et al. 2021). However, *D. kurroides* has an elongated, comparatively deep, and compressed body compared to other species of the red-fin *Decapterus* group (Kimura et al. 2013). This species feed on small planktonic invertebrates and grew to 45.0 cm in total length (Belga et al. 2018) and distributed in the Indo-West Pacific from the Red Sea (Gulf of Aqaba) to Western Australia, Taiwan, Indonesia, north to the Philippines and Okinawa, and east to Fiji (Smith-Vaniz 1999; Kimura et al. 2013).

In the Philippines, particularly in Iligan Bay, *D. kurroides* and other round scads have been exploited along with other small pelagic fishes like anchovies and sardines (Zaragoza et al. 2004). A survey conducted from October 2017 to September 2018 reported 59.92 MT of round scads in the different fish landing sites around Iligan Bay, of which 22.80% (13.66 MT) were *D. kurroides* (Jimenez et al. 2020a). Moreover, its population trend is diminishing due to excessive fishing, evidenced by 400% capture increases reported in China, Hong Kong, Indonesia, Taiwan, the Philippines, and Singapore since 1978 (Smith-Vaniz et al. 2018). However, despite its economic importance, there is a dearth of information regarding its reproductive biology in the Philippines and elsewhere. This study was the first attempt to describe the reproductive characteristics of the commercially important *D. kurroides*. Existing literature concerning *D. kurroides* mainly dealt with stock assessments and growth studies (Lavapie-Gonzales 1991; Lavapie-Gonzales et al. 1997; Pastoral et al. 2000; Wang et al. 2011; Palla et al. 2018; De Guzman and Rosario 2020), the concentration of trace elements in the tissues (Agusa et al. 2005), morphology (Chang et al. 1976; Tzeng et al. 2003), and parasitic infestation (Ho et al. 2000; Amin et al. 2011; Cruz-Lacierda and Nagawasa 2017) while reproductive biology studies were limited only to other *Decapterus* species (i.e., Tiews et al. 1971; McBride et al. 2002; Ohshimo et al. 2006; Shiraishi et al. 2010; Rada et al. 2019).

Henceforth, this study was conducted to describe the reproductive characteristics of *D. kurroides*, such as sex ratio, macroscopic gonad development, gonadosomatic index (GSI) evolution, fecundity, and length at first maturity. The continuous exploitation of *D. kurroides* without regulatory measures such as catch quotas, imposition of the closed fishing season, and minimum legal-size limit potentially inflict a deleterious effect on the resource. Therefore, baseline information on the reproductive characteristics of *D. kurroides* from this study provides the necessary science-based support for resource management. Understanding reproductive dynamics is key to adopting effective strategies for sustainable management and conservation of exploited fishery resources (Neves et al. 2020).

2. MATERIALS AND METHODS

2.1 Study area

Iligan Bay is one of the most productive fishing grounds in the southern Philippines (Abrea et al. 1986). It is Northern Mindanao's largest bay, connecting to the Bohol Sea, one of the Philippines' most important traditional fishing grounds for round scads (Pastoral et al. 2000). It is bordered on the northeast by Gitagum, Misamis Oriental, and on the northwest by Plaridel, Misamis Occidental. The southern part is bounded on the west by Clarin, Misamis Occidental, and on the east by Maigo, Lanao Del Norte. Iligan Bay is located between coordinates 8° 30' 31" north and 123° 43' 15" east (Fig. 2). The Bay's mouth is 350 miles wide and covers an estimated 2000 square kilometers (Camarao 1983). Data from MODIS Aqua satellite and MERRA 2 Model in 2002-2016 showed that Iligan Bay has a mean sea surface temperature of 28.98±0.06 °C, an ocean rainfall of 6.19±0.24 mm day-1, a chlorophyll-a concentration of 0.30±0.01 mg m-3, and euphotic depth of 73.35±0.80 m (giovanni.gsfc.nasa.gov). Furthermore, there are around 165 fish species caught in Iligan Bay, including *D. kurroides*, *D. macrosoma*, *D. macarellus*, and *D. tabl* (Jimenez et al. 2020a). A total of 6,809 fishing boats operate in Iligan Bay, of which 69% are motorized while 31% are non-motorized, with 34 fishing gear types and methods (Jimenez et al. 2020a). Moreover, spatial mapping of fish aggregating devices (FADs), locally known as "payao," recorded 138 units in Iligan Bay which are used to attract fishes such as tuna and round scads (Jimenez et al. 2020b;

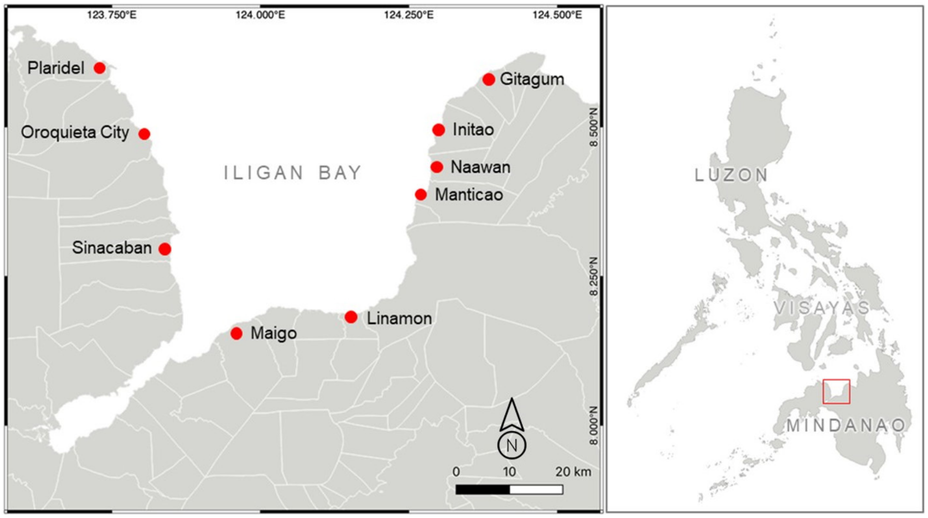

Figure 2. Locations of the landing sites around Iligan Bay where fish samples were collected from commercial and municipal landed catch

Beverly et al. 2012). Before the conduct of the study, proper coordination and permission with the different local government units (LGUs) through the Municipal Agriculture Office (MAO) and the Municipal Environment and Natural Resources Office (MENRO) were established.

2.2 Data collection

Specimens of *D. kurroides* were collected monthly (n = ≥17) from October 2017 to September 2018 in nine landing sites around Iligan Bay. Individual total body length was taken from the tip of the snout to the extended end of the caudal fin origin vertically to the ventral midline of the body using a tape measure to the nearest 0.1 cm, while wet body weight was measured to the nearest 1 g using Tanita® SD-004 digital weighing scale (Gaygusuz et al. 2006; Al Nahdi et al. 2016). After the length and weight measurements were acquired, *D. kurroides* samples were sexed. Since there were no external morphological characteristics to determine the sexes of *D. kurroides*, samples were dissected, and sexes were determined through visual examination of the gonads (McBride et al. 2002). Male gonads (Fig. 3A) appeared white with a smooth appearance, while female gonads (Fig. 3B) had a yellow to brown color with a granular appearance. Gonad weight was measured to the nearest 0.01 g using a pocket digital weighing scale.

Gonad maturity of *D. kurroides* samples was determined through visual examination of the gonads following the maturity scale adapted from Sreenivasan (1981, see Table 1) for *Decapterus macrosoma* with modifications based on Brown-Peterson et al. (2011). The scale utilized the proportion occupied by the gonad in the body cavity and the general physical characteristics of the gonads.

Fecundity, or the total number of eggs in a female gonad, was determined using ripe female gonads (Stage IV) only to ensure that oocytes included in the count were sufficiently destined to be spawned (Murua et al. 2003). Therefore, fecundity estimation with earlier or latter stages of gonad maturity may cause overestimation or underestimation of fecundity. Fecundity estimates were obtained following the gravimetric method (Bagenal and Tesch 1978; Murua

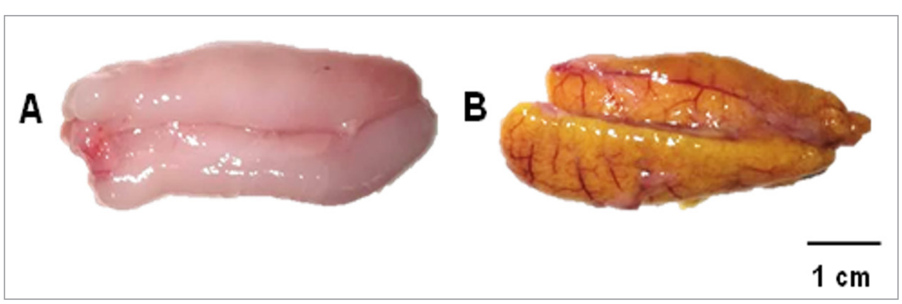

Figure 3. Male (A) and female (B) gonads of *Decapterus kurroides* from samples collected in Iligan Bayt

Table 1. Gonad maturity scale with descriptions of the different gonad maturity stages (Sreenivasan 1981; Brown-Peterson et al. 2011)

Maturity Stages	Ovary	Testes
Stage I: Immature	Thin, small, tubular, pinkish, and occupies 1/3 of the body cavity. Blood vessels are not distinct.	Thin, pale pinkish, slightly flattened, and occupies 1/3 of the body cavity.
Stage II: Developing	Large, tube-like, dusky yellow occupies 1/2 of the body cavity. Blood vessels start to appear.	Pale whitish and occupies 1/2 of the body cavity.
Stage III: Mature	Bright yellow and occupies 3/4 of the body cavity. Blood vessels are very distinct.	Whitish and occupies 3/4 of the body cavity.
Stage IV: Ripe	Bright yellow and occupies the whole-body cavity.	Whitish and occupies the whole-body cavity.
Stage V: Running	The body cavity is wholly filled with the pale yellowish ovarian lobes. Ovary walls are thin, and eggs extrude under slight pressure.	Testis occupies the whole-body cavity, and sperm extrude under slight pressure.
Stage VI: Spent	Ovaries are bloodstained and flaccid, occupying 1/4 to 3/4 of the body cavity.	Bloodshot and shrunken occupying ≤3/4 of the body cavity.
Stage II^R: Recovering	Small, tubular, and pale reddish to pinkish with visible blood vessels.	Pale reddish occupying less than 1/3 of the body cavity. Body wall appears wrinkled.

et al. 2003). Three aliquot samples were isolated in each gonad lobe and were weighed using Ohaus® Pioneer™ analytical balance to the nearest 0.001 g. Each aliquot sample was fixed in a fabricated 1 cc counting chamber, and mercury-free Gilson's fluid was added to enhance the separation of individual eggs (Friedland et al. 2005). Images of each aliquot sample were obtained using Olympus® TG-4 digital camera in microscope mode, which were then processed in Microsoft Windows® Paint 3D™ for image quality adjustments prior to counting.

Meanwhile, environmental parameters such as sea surface temperature, precipitation, chlorophyll-*a* concentration, and surface wind speed for each sampling month were obtained from the Giovanni online data system, developed, and maintained by NASA GES DISC (Acker and Leptoukh 2007). Remote sensing data of the variables mentioned above were obtained in the form of NASA standard time-series area average visualization, produced by computing spatial averages over the user-selected area from October 1, 2017 to September 30, 2018. The region of interest (user-selected area) was selected via a bounding box through coordinates 123.8544, 8.2612, 124.2389, 8.6017, pinpointing Iligan Bay (Fig. 4). Dataset search was done through variable selection using the keyword search. Monthly data were downloaded as Microsoft Excel Comma-Separated Values (.csv) file to avoid data gaps in other resolutions such as daily, 3-hourly, or hourly resolutions.

Figure 4. Location of the region of interest (orange box) or the user-selected area (bounding box coordinates; 123.8544, 8.2612, 124.2389, 8.6017) for dataset generation

2.3 Data management and analysis

The percent occurrence of the different gonad maturity stages was determined monthly for each sex. Gonad development and spawning season of *D. kurroides* in the sampling area were determined through the gonadosomatic index (GSI) evolution. Sex-specific GSI, which is the proportion of the gonad mass to the body mass of the fish, was calculated for each sample following the formula recommended by McBride et al. (2002):

$$GSI = \frac{Gonad\ weight}{Bodyweight\ -\ Gonad\ weight}\ x100$$

Mean monthly GSI values were computed by dividing the total GSI values of each month by the corresponding number of fish examined.

The number of eggs contained in a female gonad was calculated using the formula recommended by Murua et al. (2003):

$$F = (\Sigma_i\ (O_i\ /\ W_i))\ /n \times W_o$$

Where *F* is the fecundity, O_i is the number of eggs in the aliquot sample, W_i is the weight of the aliquot sample, W_o is the weight of the whole ovary/gonad, and *n* is the number of aliquots.

Length at maturity, denoted as L_m, is the length at which 50% of the fish population has reached maturity (Nandikeswari 2016). Only mature collected fish samples were included in this analysis. The cumulative percentage of samples was calculated against their length groups at 1 cm class intervals. A logistic function was fitted to the cumulative percentage of samples for each body size class using least squares regression to estimate the total length (TL) at 50% maturity (L_{50}). The maturity curve was constructed by plotting the cumulative percentage against length groups in a logistic curve. The male and female L_m were estimated separately following the equation of a logistic function (Karna and Panda 2011):

$$M\ (TL) = \frac{1}{[1 + e^{(aTL+b)}]}$$

Where *M(TL)* is the mean length at TL, and *a* and *b* are constants.

2.4 Statistical analysis

The normality of data was assessed using the Shapiro-Wilk Test. The difference between male and female total lengths, body weights, and the number of samples was tested using Student's T-test. The sex ratio of *D. kurroides* expressed as the number of females to males in the monthly sample (Schill et al. 2010) was investigated by month. The Chi-square goodness of fit test was used to determine if the monthly sex ratio had deviated from the ratio of 1:1 at a 95% confidence level (Quang et al. 2015).

To establish the relationship between environmental parameters and gonadosomatic index, between male and female monthly mean GSI, between fecundity and the total length, between fecundity and body weight, and between fecundity and gonad weight, simple linear regression analyses were conducted. Moreover, the correlation between male and female mean monthly GSI was determined using Pearson product-moment correlation coefficient. All statistical tests were analyzed using the Paleontological Statistics (PAST) software (v.4.03) (Hammer et al. 2001).

3. RESULTS

3.1 Size composition

A total of 1,349 *D. kurroides* samples were collected from landed catches from October 2017 to September 2018 in Iligan Bay. Individuals ranged from 9.20 cm to 44.50 cm in total length (TL) and 7.00 g to 864.00 g in body weight (Table 2). Male *D. kurroides* had larger sizes in terms of mean total length (17.72±0.19 cm) and mean body weight (67.26±3.44 g) than females. Although there was no significant difference between male and female total lengths (t = 1.31, df = 1,348, p = 0.19), body weights differed significantly between sexes (t = 2.52, df = 1,348, p = 0.01). Length-frequency distribution showed that most of the male (33.76%) and female (34.38%) *D. kurroides* were in the 15.00–18.00 cm TL size class (Fig. 5).

3.2 Sex ratio

From the 1,349 *D. kurroides* samples collected, females were more prevalent (53.89%) than males (46.11%), with a female-to-male ratio of 1.2:1 (Table 3). The number of female and male *D. kurroides* during the sampling period did not differ significantly (*t* = 0.74, *df* = 11, *p* = 0.46). However, the

Table 2. Minimum, maximum, and mean values of total length (cm) and body weight (g) of male, female, and pooled samples of *Decapterus kurroides* in Iligan Bay

Sex	n	Total Length (cm)			Body Weight (g)		
		Min	Max	Mean±SEM	Min	Max	Mean±SEM
Male	622	10.20	44.50	17.72 ± 0.19	9.00	864.00	67.26 ± 3.44
Female	727	9.20	31.40	17.42 ± 0.13	7.00	281.00	58.27 ± 1.48
Pooled	1349	9.20	44.50	17.56 ± 0.11	7.00	864.00	62.42 ± 1.78

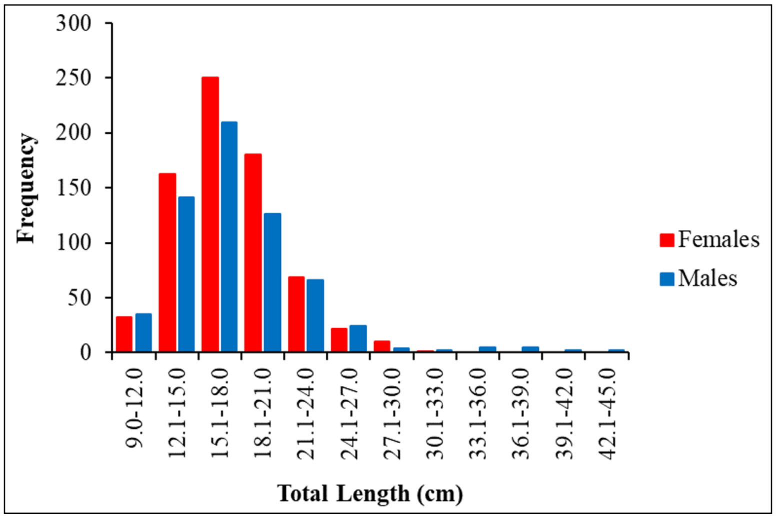

Figure 5. Length-frequency distribution of male (n=622) and female (n=727) *Decapterus kurroides* samples collected in Iligan Bay

Table 3. Monthly sex ratios (female:male) and statistical test for deviation for *Decapterus kurroides* in Iligan Bay

Sampling Months	Number of Samples			Sex Ratio	Statistical test for deviation	
	Female	Male	Total		x^2 *(df=1)*	*p-value*
October 2017	8	9	17	1:1.1	0.06	0.81
November 2017	28	13	41	1:0.46	5.49	0.02*
December 2017	31	12	43	1:0.39	8.40	<0.05*
January 2018	53	51	104	1:0.96	0.04	0.84
February 2018	49	39	88	1:0.80	1.14	0.29
March 2018	73	49	122	1:0.67	4.72	0.03*
April 2018	102	85	187	1:0.83	1.55	0.21
May 2018	98	66	164	1:0.67	6.24	0.01*
June 2018	70	66	136	1:0.94	0.12	0.73
July 2018	77	73	150	1:0.95	0.11	0.74
August 2018	79	103	182	1:1.3	3.16	0.08
September 2018	59	56	115	1:0.89	0.08	0.78
Pooled	**727**	**622**	**1349**	**1.2:1**	**8.17**	**<0.05***

**significant at 5% level ($x^2t_{1,\,0.05} = 3.84$)*

female-to-male ratio deviated significantly from 1:1 (x^2 = 8.17, *df* = 1, *p* = 0.004). Monthly data showed that females generally predominated the samples, but males were more common in October 2017 and August 2018. All computed sex ratios deviated from the theoretical sex ratio of 1:1, yet significant deviations were only observed in November 2017, December 2017, March 2018, and May 2018.

3.3 Gonad maturity stages and gonadosomatic index (GSI)

All stages of gonad maturity were observed during the study period; however, the percent occurrence of such stages varied monthly for both sexes (Figure 6). Immature individuals dominated the samples (42.18%), while those in the recovering stage were the least abundant (2.74%). The immature stage was more pronounced for both sexes from January 2018 to September 2018, although immature males were overwhelmingly abundant in October 2017. Furthermore, individuals with mature gonads were relatively abundant during December 2017 for both males (58.33%) and females (61.29%). Meanwhile, the gonadosomatic index (GSI) varied significantly (t = 4.37, p = <0.05) between males and females, and fluctuations in GSI mean monthly values were evident as presented (Fig. 7). Male and female *D. kurroides, h*aving multiple peaks within a year, attained a major peak on December (male GSI = 1.53%; female GSI = 4.81%) and sharply declined on February (male GSI = 0.36%; female GSI = 0.57%) and started to peak again on March (male GSI = 0.72%; female GSI = 2.41%). Female spawning waned in April (GSI = 1.93%) while that of the male was slightly prolonged (GSI = 0.91%), then both marginally receded in May (male GSI = 0.91%; female GSI = 1.73%) with minimal fluctuations until September. Monthly GSI monitoring showed that the GSI of male and female *D. kurroides* fluctuated simultaneously, at least most of the months, with few exceptions. However, this simultaneous fluctuation appears to be weak (R = 0.21, p = 0.51). The changes in the percent occurrence of the different maturity stages coincided with the fluctuations in GSI. Moreover, simple regression analysis showed that variability in GSI was more explained by sea surface temperature (R^2 = 0.13, F(1,10) = 1.47, R = 0.36, p = 0.25) compared to chlorophyll *a* concentration (R^2 = 0.10, F(1,10) = 1.06, R = 0.31, p = 0.33), precipitation (R^2 = 0.08, F(1,10) = 0.85, R= 0.28, p = 0.38), and surface wind speed (R^2 = 0.11, F(1,10) = 1.29, R = 0.33, p = 0.28) as shown in Fig. 8. Values of the four environmental variables determined during the sampling period were presented in Table 4.

3.4 Length at sexual maturity

The length at which 50% of the females and males of *D. kurroides* attain sexual maturity was calculated at 17.2 cm TL and 17.6 cm TL, respectively, as shown by the maturity curve (Fig. 9 A-B). Length-frequency data revealed that 48.83% of females and 56.27% of males in the collected samples had a length of less than the calculated length at sexual maturity. Furthermore, 22.42% of females and 22.52% of males in the collected samples were already mature before reaching the calculated length at sexual maturity.

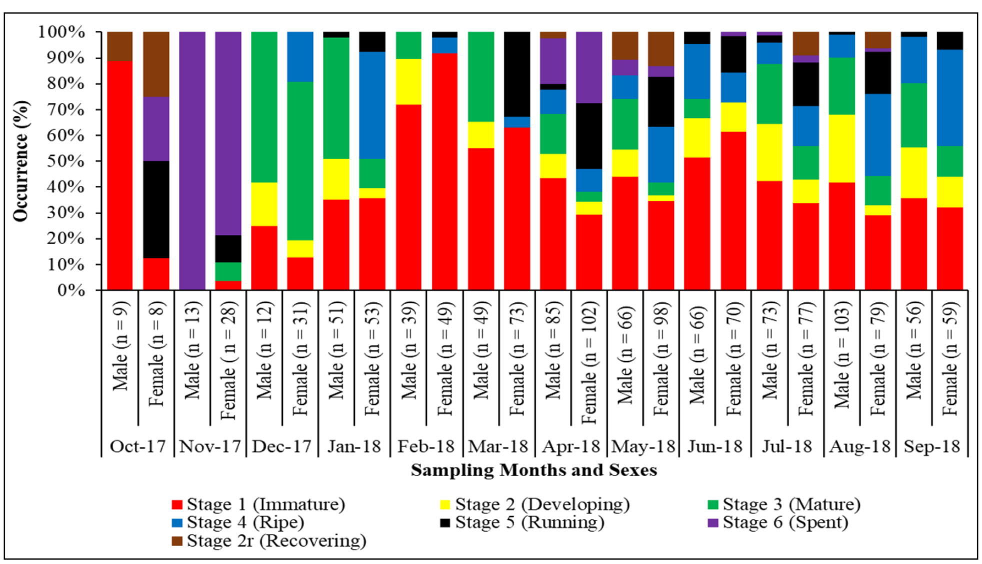

Figure 6. Percent occurrence of different gonad maturity stages of male and female *Decapterus kurroides*

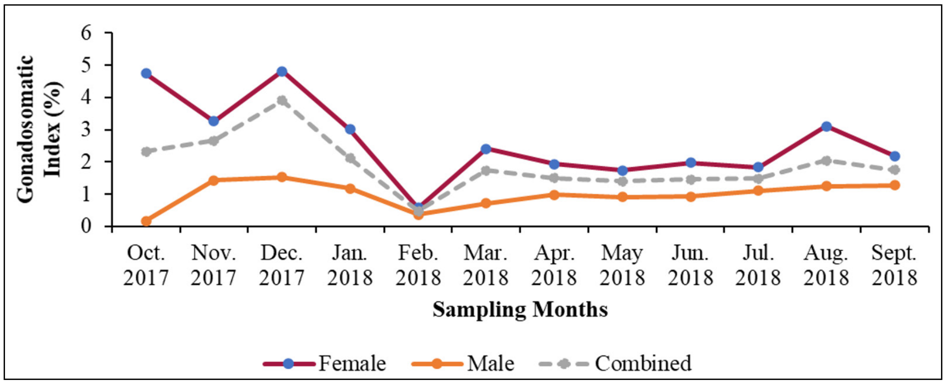

Figure 7. Monthly mean gonadosomatic index (GSI) of *Decapterus kurroides* in Iligan Bay

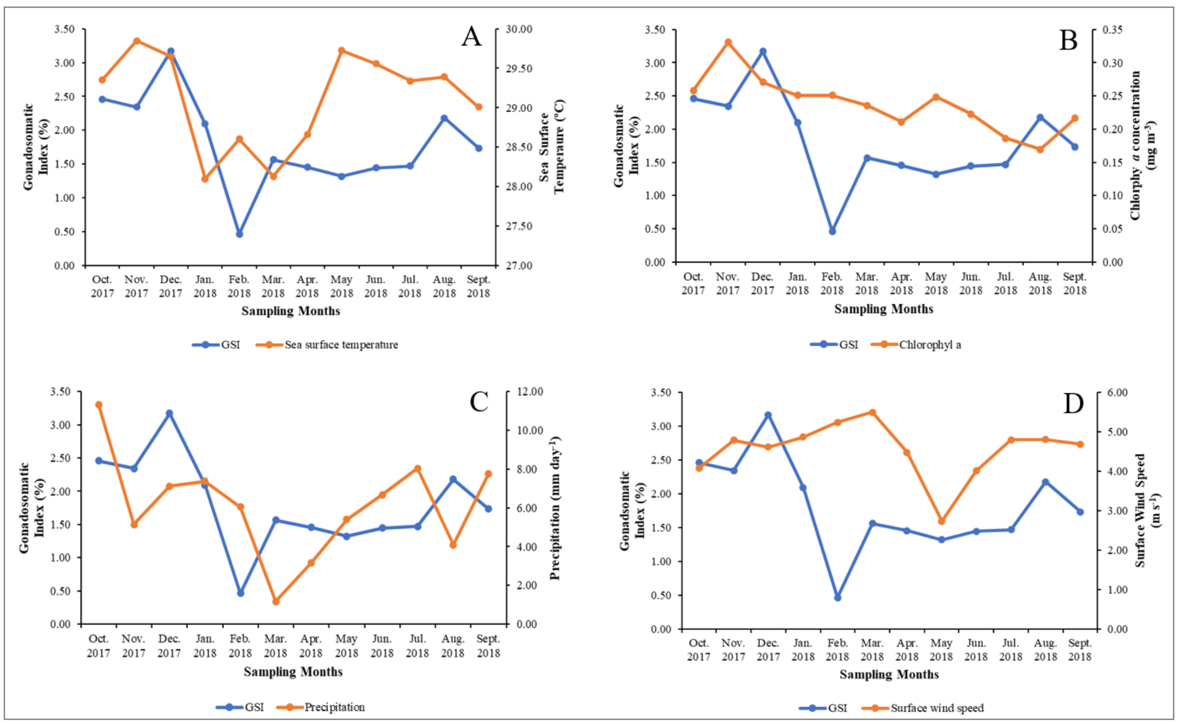

Figure 8. Monthly mean GSI of *Decapterus kurroides* and monthly mean (A) sea surface temperature, (B) chlorophyll *a* concentration, (C) precipitation, and (D) surface wind speed in Iligan Bay.

Table 4. Minimum, maximum, and mean values of environmental variables in Iligan Bay obtained from NASA GES DISC from October 1, 2017 to September 30, 2018

Variables	Unit	Minimum	Maximum	Mean±SEM
Sea surface temperature	°C	28.10	29.85	29.11±0.18
Precipitation	mm day^{-1}	1.17	11.34	6.11±0.76
Chlorophyll a concentration	mg m^{-3}	0.16	0.33	0.24±0.01
Surface wind speed	m s^{-1}	2.74	5.49	4.55±0.20

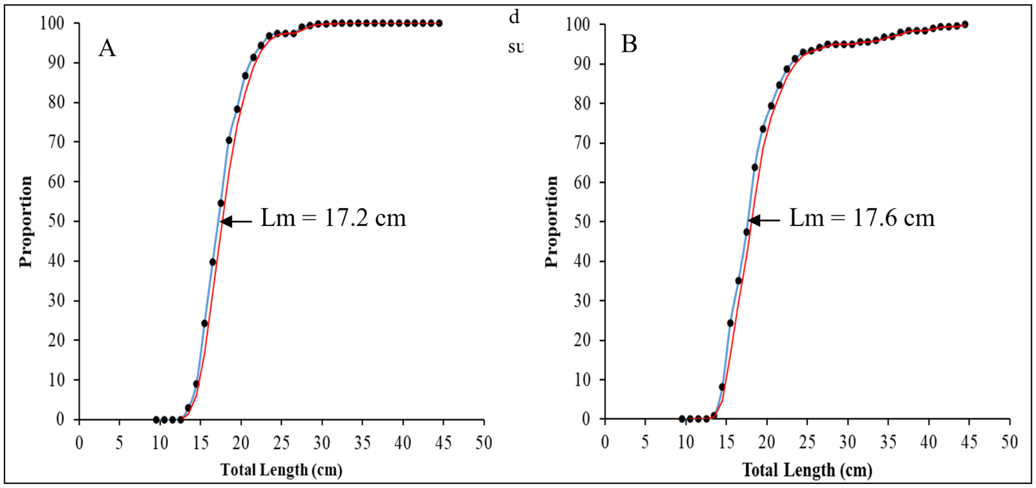

Figure 9. Estimated length at 50% maturity of female (A) and male (B) *Decapterus kurroides* in Iligan Bay. (Blue lines indicate observed length at 50% maturity while red lines indicate predicted length)

3.5 Fecundity

Absolute fecundity was determined in 71 samples with sizes ranging from 13.80 cm TL to 23.2 cm TL with corresponding body weights ranging from 25.00 g to 128.00 g. The absolute fecundity ranged from 6,416 to 197,672 eggs (mean: 61,733 ± 3955) for the gonads weighing between 0.50 g – 11.75 g. The linear relationship between fecundity (F) and total length (L), body weight (W), and gonad weight (WO) were established as: F = -24406.26 + 4688.65 L (R^2 = 0.075, F(1,69) = 9.56, R = 0.27, p=0.02), F = 23716.54 + 603.30 W (R^2 = 0.14, F(1,69) = 10.86, R = 0.37, p = 0.002), and F = 18359.50 + 15919.36 WO (R^2 = 0.63, F(1,69) = 115.74, R = 0.79, p = <0.001), respectively. Comparatively, variation in fecundity can be more explained by the variation in the gonad weight of *D. kurroides* than by total length and body weight.

4. DISCUSSION

Decapterus kurroides commonly have a length of 30.00 cm but can grow to 45.00 cm in total length (Belga et al. 2018). The maximum length of male (44.50 cm TL) and female (31.40 cm TL) *D. kurroides* in Iligan Bay were substantially larger than those reported from Palawan (21.4 cm) (Palla et al. 2018), Lingayen Gulf (25.5 cm) (De Guzman and Rosario 2020), Visayan Sea (28.5 cm), Davao Gulf (24.5 cm) (Lavapie-Gonzales 1991), and Samar Sea (29.5 cm) (Lavapie-Gonzales et al. 1997). This variation in the observed maximum size of *D. kurroides* between different geographic locations could result from inherent differences in growth between sub-populations as observed in other marine fishes such as *T. lepturus* (Clain et al. 2021) or could be attributed to spatial variation in fishing pressure and habitat condition (Wilson et al. 2010). Although maximum lengths of male and female *D. kurroides* in Iligan Bay are relatively larger, sizes are more common in the 15.1 cm to 18.0 cm TL despite exhaustive sampling from landed catch in several landing sites possibly because of size-selective fishing in which *D. kurroides* are harvested primarily by ring net. Size-selective fishing is projected to alter the size structure of an exploited fish resource toward small individuals (Chen et al. 2018). Increasing exploitation intensity through fishing could significantly reduce large individuals' relative abundance (Graham et al. 2005).

The dominance of female *D. kurroides* in the randomly collected samples was also observed in other round scad species, such as the *Decapterus russelli* in Malabar Coast, India (Manojkumar 2005) and *Decapterus macarellus* in Ambon, Indonesia (Silooy et al. 2021). The deviation from the 1:1 ratio is unlikely for most aquatic organisms, such as fishes (Khatun et al. 2018). However, many populations have been observed to have consistently biased sex ratios (Reichard et al. 2014). The female-biased sex ratio of *D. kurroides* in Iligan Bay could be a good indicator of the reproductive potential of fish communities as determined by the number of females available for oocyte production according to Sululu et al. (2022) based on *D. macarellus* samples in Bagamoyo, Tanzania. Meanwhile, the male-dominated sex ratio, which was observed in October 2017 and August 2018, is not uncommon, as it has been observed in other *Decapterus* species (Poojary et al. 2015; Widiyastuti et al. 2020), but this may have detrimental effects on the population and viability of the stock

(Ospina and Piferrer 2008).

Based on the progression of the gonadosomatic index and the proportion of developed gonads, *D. kurroides* spawning in Iligan Bay peaks in December, with smaller spawning events occurring in March and August. The correlation of GSI to sea surface temperature and chlorophyll-*a* concentration during the sampling period demonstrates that the peak spawning of the species in December can be attributed to the temperature of the surrounding environment and food availability (Wootton 1990). Due to the nutrient supply brought about by the rainy season, the relatively high dry season temperatures (December to May) are conducive to plankton growth (Gonzales et al. 2021). In the case of *D. kurroides* in Iligan Bay, a relatively high chlorophyll-*a* concentration (0.27 mg m-3) in December allows larvae to receive enough food for growth and survival. As this is the first attempt to characterize the reproduction of *D. kurroides*, there are no comparable data on the spawning period. The multiple spawning peaks displayed by *D. kurroides* in Iligan Bay are comparable to those seen in other round scad species, including *D. macrosoma* in San Fernando, Romblon (Rada et al. 2019), *D. macarellus* in Cabo Verde, Lisbon, Portugal (Costa et al. 2020), and *D. russelli* in India (Poojary et al. 2015). The presence of individuals with mature, ripe, and running gonads throughout the year in varying degrees may indicate a prolonged spawning for *D. kurroides*, similar to *D. russelli* (Poojary et al. 2015) or it may be attributable to the partial spawning behavior of round scads. Consequently, *D. kurroides* spawns year-round, which is consistent with the observations of Lowe-McConnell (1987) and Longhurst and Pauly (1987) about other tropical marine fishes.

In this study, the length at maturity of male and female *D. kurroides* is estimated for the first time. In Mangaluru Coast, India, round scads, especially *D. russelli*, mature at a length of 16.0-18.0 cm TL (Ashwini et al. 2016), similar to *D. kurroides* in Iligan Bay. In contrast, *D. macrosoma*, which has a maximum length of 35.0 cm (Smith-Vaniz 1986), would achieve maturity between 18.0 cm and 20.0 cm in the waters of Palawan and Manila Bay (Tiews et al. 1971). The exceptionally low length at maturity of D. kurroides may represent a compensatory reaction of the resource to elevated mortality caused by fishing (Rochet and Marty 2009). Although the naturally large *D. kurroides* matured at a smaller size than smaller species of round scad, it is important to note that size at maturity is influenced by multiple factors, including genetic differences, environmental variables, fishing pressure, and food availability (Alm 1959; Wootton 1990). However, this smaller size at maturity in *D. kurroides* may offer a selective advantage under heavy fishing pressure, as late-maturing individuals are more likely to be captured prior to sexual maturity (Borisov 1977; Beacham 1983; Rowell 1993). Meanwhile, the observed harvesting of *D. kurroides* in Iligan Bay before reaching its length at maturity indicates that the resource is being exploited irresponsibly and may lead to growth overfishing in which small individuals are deliberately harvested before they have had the chance to reproduce (Diekert 2012). The overexploitation of juveniles or immature individuals may negatively impact future recruitment and stock conservation (Myers et al. 1997). The early maturation seen in *D. kurroides* in Iligan Bay may imply that the species is evolving toward earlier maturation prior to reaching the length at maturity to ensure survival (Borisov 1977; Rago and Goodyear 1987; Law and Grey 1989; Law 2000), as a significant percentage of individuals below the length at maturity are caught during fishing activities in the bay.

Fecundity is an essential aspect of the life history of fish populations (Bagenal 1973), but data are less available than other aspects of the reproductive biology of fishes (Tomkiewicz et al. 2003). Fecundity estimates for *D. kurroides* in this study are the first record for the species. Its maximum fecundity of 197, 672 eggs per female is relatively higher than *D. russelli,* which recorded a maximum absolute fecundity of 152,123 eggs per female (Poojary et al. 2015), and *D. macrosoma* with 106,000 eggs per female (Tiews et al. 1971). With this, *D. kurroides* in Iligan Bay has a higher potential number of offspring and higher reproductive capacity than other round scad species. Although it is known that fecundity varies with body length and weight (Lambert 2008), the relationship is not clear in this study. However, the relationship between fecundity and gonad weight showed that for *D. kurroides*, the number of eggs increases in proportion to gonad weight. This indicates that gonad weight could be used in accurately estimating the fecundity of *D. kurroides* than the body length and weight (Bhatt et al. 1977). In either case, like any other fishes, the fecundity of *D. kurroides* may be affected by several factors such as female size, egg size, reproductive strategy, spawning pattern, and modulation by environmental conditions (Lambert 2008), which were not explored in this study.

ACKNOWLEDGMENT

The authors are very grateful to the Commission on Higher Education – Discovery Applied Research and Extension for Trans-/Inter Disciplinary Opportunities (CHED-DARETO) for providing the research fund. To the top management of Mindanao State University at Naawan and Mindanao State University – Maigo School of Arts and Trades for their regular support for the sustained implementation of the research project. To the Municipal/City Agriculture Office and Municipal/City Environment and Natural Resources Office of the different municipalities around Iligan Bay for the warm accommodation extended to the project, especially during field visits and samplings. To our very active field enumerators and volunteers who untiringly assisted in collecting data and samples, our heartfelt gratitude. We also acknowledge the assistance extended by Asst. Prof. Sandra M. Moscoso in generating the map and remote sensing data. Lastly, the authors would like to express utmost gratitude to the two anonymous reviewers who offered suggestions and comments to develop this paper further.

AUTHOR CONTRIBUTIONS

Dela Rosa HKT: Conceptualization, Formal analysis, Investigation, Data curation, Writing - original draft, Reviewing and editing. **Quiñones MB**: Conceptualization, Methodology, Validation, Writing - reviewing and editing. **Jimenez CR**: Conceptualization, Methodology, Validation, Writing - reviewing and editing, Supervision. **Garcia JP**: Investigation. **Molina DL**: Investigation. **Samson JJ**: Investigation. **Paghasian MC**: Conceptualization, Methodology.

CONFLICTS OF INTEREST

The authors declare that they have no known competing financial or personal interests that could have appeared to influence the work reported in this paper.

DATA AND REPRODUCIBILITY

The datasets generated and analyzed during the current study are available from the corresponding author upon reasonable request.

ETHICS STATEMENT

This study did not deal with live animals nor humans as subjects.

REFERENCES

Abrea RC, Mendoza NM Mendoza, Reyes CS, Angsinco LC, Acuña RE, Tumanda, MM. 1986. Small-scale fisheries of Iligan Bay. https://agris.fao.org/agris search/search.do?recordID=PH19910016609. Cited 10 Nov 2021.

Acker JG, Leptoukh G. 2007. Online analysis enhances use of NASA earth science data. Eos, Transactions American Geophysical Union. 88(2):14–17. https://doi.org/10.1029/2007EO020003

Agusa T, Kunito T, Yasunaga G, Iwata H, Subramanian A, Ismail A, Tanabe S. 2005. Concentrations of trace elements in marine fish and its risk assessment in Malaysia. Marine Pollution Bulletin. 51(8-12):896–911. https://doi.org/10.1016/j.marpolbul.2005.06.007

Al Nahdi A, Garcia de Leaniz C, King AJ. 2016. Spatio temporal variation in length-weight relationships and condition of the ribbonfish *Trichiurus lepturus* (Linnaeus, 1758): implications for fisheries management. PLoS ONE. 11(8):e0161989. https://doi.org/10.1371/journal.pone.0161989

Alm G. 1959. Connection between maturity, size, and age in fishes. Rep. Inst. Freshwat. Res. Drottningholm. 40, 5–145.

Amin OM, Heckmann RA, Van Ha N. 2011. Description of two new species of *Rhadinorhynchus* (Acanthocephala, Rhadinorhynchidae) from marine fish in Halong Bay, Vietnam, with a key to species. Acta Parasitologica. 56(1):67–77. https://doi.org/10.2478/s11686-011-0004-3

Ashwini L, Benakappa S, Anjanayappa HN, Akshay L. 2016. Length-weight relationship and condition Factor of *Decapterus russelli* from Mangaluru Region. International Journal of Engineering Science and Computing, IJESC. 6(6).

Bagenal TB, Tesch FW. 1978. Chapter 5, Age and growth. In: Bagenal T, editor. Methods for Assessment of Fish Prodution in Fresh Waters. IBP Handbook No. 3, Blackwell Scientific Publications, 3rd edn. pp. 101-136.

Bagenal TB. 1973. Fish fecundity and its relations with stock and recruitment. Rapports et Proces-Verbaux des Reunions, Conseil International pour FExploration de la Mer 164:186–198.

Beacham TD. 1983. Variability in size and age at sexual maturity of haddock *(Melanogrammus aeglefinus)* on the Scotian Shelf in the Northwest Atlantic. Department of Fisheries and Oceans, Fisheries Research Branch, Pacific Biological Station. https://doi.org/10.13140/RG.2.1.3515.3127

Belga Jr PB, Abrenica BT, Paran JS, Bacalso RT. 2018. Stock assessment of small pelagic fishes caught by ring net fishery in the Camotes Sea, Central Visayas, Philippines (2003–2012). The Philippine Journal of Fisheries. 25(1):95–106. https://doi.org/10.31398/tpjf/25.1.2017C0009

Beverly S, Griffiths D, Lee R. 2012. Anchored fish aggregating devices for artisanal fisheries in South and Southeast Asia: benefits and risks. RAP publication. Thailand: FAO Regional Office for Asia and the Pacific. 20, p.4. https://www.fao.org/3/a-i3087e.pdf

Bhatt VS, Dalal SG, Abidi SAH. 1977. Fecundity of the freshwater catfishes *Mystus seenghala* (Sykes), *Mystus cavasius* (Ham), *Wallagonia attu* (Bloch) and *Heteropneustes fossilis* (Bloch) from the plains of northern India. Hydrobiologia. 54(3):219–224. https://doi.org/10.1007/BF00014288

Borisov VM. 1977. The selective effect of fishing on the population structure of species with a long-life cycle. J. Ichthyol. 18(6):896–904.

Bradford MJ, Randall RG, Smokorowski KS, Keatley BE, Clarke KD. 2014. A Framework for Assessing Fisheries Productivity for the Fisheries Protection Program. Ontario, Canada: Fisheries and Oceans Canada, Canadian Science Advisory Secretariat. 30 pp.

Brown-Peterson NJ, Wyanski DM, Saborido-Rey F, Macewicz BJ, Lowerre-Barbieri SK. 2011. A standardized terminology for describing reproductive development in fishes. Marine and Coastal Fisheries. 3(1):52–70. https://doi.org/10.1080/19425120.2011.555724

Camarao GC. 1983. Relative abundance of commercial fish species in Iligan Bay. CCRD Technical Paper. Iligan City: MSU-Iligan Institute of Technology. 103 pp.

Chang KH, Chen CP, Ni IS. 1976. Morphometric study of the red scad, *Decapterus kurroides* aka-adsi Abe, in the waters of Taiwan. Journal of Taiwan Fisheries Society. 4(2):37–43. https://dx.doi.org/10.29822%2fJFST.197606.0005

Chen YT, Kuan TC, Chih-Hao H. 2018. Fishing and temperature effects on the size structure of exploited fish stocks. Scientific Reports. 8:7132. https://doi.org/10.1038/s41598-018-25403-x

Clain C, Stewart , Fowler A, Diamond S. 2021. Reproductive biology of largehead hairtail (*Trichiurus lepturus*) in south-eastern Australia. Aquaculture and Fisheries. 8(2):148-158. https://doi.org/10.1016/j.aaf.2021.09.008

Cochrane KL, editor. 2002. A Fishery Manager's Guidebook: Management Measures and Their Application. FAO Fisheries Technical Paper No. 424. Italy: Food and Agriculture Organization of the United Nations. 231 pp.

Costa M, Cruz D, Monteiro L, Evora K, Cardoso L. 2020. Reproductive biology of the mackerel scad *Decapterus macarellus* from Cabo Verde and the implications for its fishery management. African Journal of Marine Science. 42(1):35–42. https://doi.org/10.2989/1814232x.2020.1721328

Cruz-Lacierda ER, Nagasawa K. 2017. First record of *Norileca indica* (Isopoda, Cymothoidae) parasitic on *Selar crumenophthalmus* and *Decapterus kurroides* (Perciformes, Carangidae) in the Philippines. Comparative Parasitology.84(1):60–63. https://doi.org/10.1654/1525-2647-84.1.60

De Guzman MF, Rosario GR. 2020. Length-weight relationships of marine fishes caught by Danish seine in Lingayen Gulf. International Journal of Fisheries and Aquatic Studies. 8(6):16–18. https://doi.org/10.22271/fish.2020.v8.i6a.2353

Delloro Jr ES, Babaran RP, Gaje AC, Cambronero PT, Alama UB, Motomura H. 2021. First record of slender red scad, *Decapterus smithvanizi* (Actinopterygii: Perciformes: Carangidae), from the Philippines. Acta Ichthyologica et Piscatoria. 51(3):233–239. https://doi.org/10.3897/aiep.51.63117

Diekert FK. 2012. Growth overfishing: the race to fish extends to the dimension of size. Environmental and Resource Economics. 52(4):549–572. https://doi.org/10.1007/s10640-012-9542-x

Friedland KD, Ama-Abasi D, Manning M, Clarke L, Kligys G, Chambers RC. 2005. Automated egg counting and sizing from scanned images: rapid sample processing and large data volumes for fecundity estimates. Journal of Sea Research. 54(4):307–316. https://doi.org/10.1016/j.seares.2005.06.002

Gaygusuz, Ö, Gürsoy Ç, Özuluğ M, Tarkan AS, Acıpınar H, Bilge G, Filiz H. 2006. Conversions of total, fork and standard-length measurements based on 42 marine and freshwater fish species (from Turkish Waters). Turkish Journal of Fisheries and Aquatic Sciences. 6(2): 79–84.

Gonzales BJ, Palla HP, Ylagan AR, Cabadongga BM, Manzano ZT, Mutia MM, Marcelino GO, Pasion TT, De Luna AF. 2021. Spawning of *Decapterus macrosoma* (Bleeker, 1851) "Galunggong" in Tablas Island, Romblon, Philippines: with Inferences on its Reproductive Ecology and Management. Asian Journal of Biodiversity. 12(1). https://doi.org/10.7828/ajob.v12i1.1392

Graham NAJ, Dulvy NK, Jennings S, Polunin NVC. 2005. Size-spectra as indicators of the effects of fishing on coral reef fish assemblages. Coral Reefs. 24(1): 118–124. https://doi.org/10.1007/s00338-004-0466-y

Hammer Ø, Harper DAT, Ryan PD. 2001. PAST: Paleontological software package for education and data analysis. Paleontologia Electronica. 4(1):1–9. https://palaeo-electronica.org/2001_1/past/issue1_01.htm

Ho JS, Lin CL, Chen SN. 2000. Species of *Caligus* Müller, 1785 (Copepoda: Caligidae) parasitic on marine fishes of Taiwan. Systematic Parasitology. 46(3):159–179. https://doi.org/10.1023/A:1006342120411

Jimenez CR, Molina DL, Garcia JP, Quiñones MB, Dela Rosa HKT, Samson JJ, Paghasian MC. 2020a. Species composition, abundance, and catch trends of roundscads Decapterus spp. in Iligan Bay, Northern Mindanao, Philippines. Journal of Environment and Aquatic Resources. 5:28–42. https://doi.org/10.48031/msunjear.2020.05.03

Jimenez CR, Quiñones MB, Paghasian MC, Garcia JP, Dela Rosa HKT, Molina DL, Samson JJ. 2020b. Stock assessment, fishery and reproductive dynamics of roundscads, *Decapterus* spp. in Iligan Bay. Terminal Report submitted to CHED. pp 71.

Karna SK, Panda S. 2011. Growth estimation and length at maturity of a commercially important fish species i. e., *Dayscieaena albida* (Boroga) in Chilika Lagoon, India. European Journal of Experimental Biology. 1(2):84–91.

Khatun D, Hossain MY, Parvin MF, Ohtomi J. 2018. Temporal variation of sex ratio, growth pattern and physiological status of *Eutropiichthys vacha* (Schilbeidae) in the Ganges River, NW Bangladesh. Zoology and Ecology. 28(4):343–354. https://doi.org/10.1080/21658005.2018.1520680

Kimura S, Katahira K, Kuriiwa K. 2013. The red-fin Decapterus group (Perciformes: Carangidae) with the description of a new species, *Decapterus smithvanizi*. Ichthyological Research. 60(4):363–379. https://doi.org/10.1007/s10228-013-0364-9

Lambert Y. 2008. Why should we closely monitor fecundity in marine fish populations? Journal of Northwest Atlantic Fisheries Science. 41:93–106. https://doi.org/10.2960/J.v41.m628

Lavapie-Gonzales F, Ganaden SR, Gayanilo Jr FC.

1997. Some Population Parameters of Commercially Important Fishes in the Philippines. Quezon City: Department of Agriculture-Bureau of Fisheries and Aquatic Resources. 121 pp. https://hdl.handle.net/20.500.12348/2648

Lavapie-Gonzales F. 1991. Growth, mortality, and recruitment of *Decapterus kurroides* in Davao Gulf, Philippines. Fishbyte. 9(2):6–9. https://hdl.handle.net/20.500.12348/3095

Law R, Grey DR. 1989. Evolution of yields from populations with age-specific cropping. Evolutionary Ecology. 3(4):343–359. https://doi.org/10.1007/BF02285264

Law R. 2000. Fishing, selection, and phenotypic evolution. ICES Journal of Marine Science, 57(3):659–668. https://doi.org/10.1006/jmsc.2000.0731

Longhurst AR, Pauly D. 1987. Ecology of Tropical Oceans. London: Academic Press. https://doi.org/10.1016/C2009-0-02861-X

Lowe-McConnell RM. 1987. Ecological studies on tropical fish communities. Cambridge: Cambridge University Press. https://doi.org/10.1017/CBO9780511721892

Lowerre-Barbieri S, DeCelles G, Pepin P, Catal´an IA, Muhling B, Erisman B, Cadrin SX, Al´os J, Ospina-Alvarez A, Stachura MM. 2017. Reproductive resilience: A paradigm shift in understanding spawner-recruit systems in exploited marine fish. Fish and Fisheries. 18(2):285–312. https://doi.org/10.1111/faf.12180

Manojkumar PP. 2005. Maturation and spawning of *Decapterus russelli* (Ruppell, 1830) along the Malabar Coast. Indian Journal of Fisheries. 52(2):171–178. http://eprints.cmfri.org.in/id/eprint/202

McBride R, Stengard F, Mahmoudi B. 2002. Maturation and diel reproductive periodicity of round scad (Carangidae: *Decapterus punctatus*). Marine Biology. 140(4):713–722. https://doi.org/10.1007/s00227-001-0759-4

Murua H, Kraus G, Saborido-Rey F, Witthames PR, Thorsen A, Junquera S. 2003. Procedures to estimate fecundity of marine fish species in relation to their reproductive strategy. Journal of Northwest Atlantic Fishery Science. 33:33–54.

Myers RA, Hutchings JA, Barrowman NJ. 1997. Why do fish stocks collapse? The example of cod in Atlantic Canada. Ecol Appl 7(1):91–106. https://doi.org/10.2307/2269409

Nandikeswari R. 2016. Size at first maturity and maturity stages of *Terapon jarbua* (Forsskal, 1775) from Pondicherry Coast, India. Journal of Fisheries. 4(2): 385–389. https://doi.org/10.17017/jfish.v4i2.2016.150

Neves JB, Gubiani EA, Leandro da Silva PR, Baumgartner D, Baumgartner G. 2020. Reproduction of fishes of the Verde River, upper Paraná River Basin, Brazil. Revista de Biología Tropical. 68(3):833–846. https://doi.org/10.15517/rbt.v68i3.40411

Ohshimo S, Yoda M, Itasaka N, Itasaka N, Ichimaru T. 2006. Age, growth and reproductive characteristics of round scad *Decapterus maruadsi* in the waters off west Kyushu, the East China Sea. Fisheries Science. 72:855–859. https://doi.org/10.1111/j.1444-2906.2006.01227.x

Ospina- Álvarez N, Piferrer F. 2008. Temperature dependent sex determination in fish revisited: Prevalence a single sex ratio response pattern, and possible effects of climate change. PLoS ONE. 3(7):e2837. https://doi.org/10.1371/journal.pone.0002837

Palla HP, Pagliawan HB, Rodriguez EF, Montaño BS, Cacho GT, Gonzales BJ, Bonnell C, Fowler T. 2018. Length-weight relationship of marine fishes from Palawan, Philippines. Palawan Scientist. 10:17–28.

Pastoral PC, Escobar Jr SL, Lamarca NJ. 2000. Round scad exploration by purse seine in the South China Sea, Area III: Western Philippines. Proceedings of the SEAFDEC Seminar on Fishery Resources in the South China Sea, Area III: Western Philippines. Bangkok:

Secretariat, Southeast Asian Fisheries Development Center. 49–64. http://hdl.handle.net/20.500.12066/4344

Poojary N, Tiwari LR, Sundaram S. 2015. Reproductive biology of the Indian scad, *Decapterus russelli* (Ruppel, 1830) from the Maharashtra waters, Northwest Coast of India. Journal of the Marine Biological Association of India. 57(1):1–8. https://doi.org/10.6024/jmbai.2015.57.1.01792-11

Quang DM, Giang NTT, Tien NTK. 2015. Reproductive biology of the mudskipper *Boleophthalmus boddarti* in Soc Trang. Academia Journal of Biology. 37(3):362–369. https://doi.org/10.15625/0866-7160/v37n3.6720

Rada BG, Ramos EB, Riva CJ, Royo NR. 2019. Preliminary study on spawning period and length at maturity of shortfin scad, *Decapterus macrosoma*, (Bleeker, 1851), Perciformes: Carangidae) from the coastal waters of San Fernando, Romblon. The Philippine Journal of Fisheries. 26(1):35–43. https://doi.org/10.31398/tpjf/26.1.2018-0014

Rago PJ, Goodyear CP. 1987. Recruitment mechanisms of striped bass and Atlantic salmon: comparative liabilities of alternative life histories. Amer. Fish. Soc. Symp. 1:402–416.

Reichard M, Polačik M, Blažek R, Vrtílek M. 2014. Female bias in the adult sex ratio of African annual fishes: interspecific differences, seasonal trends and environmental predictors. Evolutionary Ecology. 28(6):1105–1120. https://doi.org/10.1007/s10682-014-9732-9

Rochet MJ, Marty L. 2009. Effects of fishing on the population. In: Jakobsen T, Fogarty MJ, Megrey BA, Moksness E, editors. Fish Reproductive Biology: Implications for Assessment and Management, Second Edition. pp. 172–206. Chichester, UK: Wiley-Blackwell Scientific Publications

Rowell CA. 1993. The effects of fishing on the timing of maturity in North Sea cod (*Gadus morhua* L.). In: Stokes K, McGlade JM, Law R, editors. The exploitation of evolving resources. Lecture Notes in Biomathematics, Vol 99. Berlin, Heidelberg: Springer. pp. 44–61. https://doi.org/10.1007/978-3-642-48394-3_4

Schill DJ, LaBar GW, Mamer ER, Meyer KA. 2010. Sex ratio, fecundity, and models predicting length at sexual maturity of redband trout in Idaho desert streams. North American Journal of Fisheries Management. 30(5):1352–1363. https://doi.org/10.1577/M10-021.1

Shiraishi T, Tanaka H, Ohshimo S, Ishida H, Morinaga N. 2010. Age, growth and reproduction of two species of scad, *Decapterus macrosoma* and *D. macarellus* in the waters off southern Kyushu. Japan Agricultural Research Quarterly. 44(2):197–206. https://doi.org/10.6090/jarq.44.197

Silooy FD, Tupamahu A, Matrutty DDP, Pattikawa JA. 2021. Sex ratio, age group and length at first maturity of mackerel scad (*Decapterus macarellus* Cuvier, 1833) in the Southern waters of Ambon, Eastern Indonesia. IOP Conference Series: Earth and Environmental Science. 777(1):1–6. https://doi.org/10.1088/1755-1315/777/1/012008

Smith-Vaniz WF, Borsa P, Carpenter KE, Obota C, Jiddawi N, Yahya S. 2018. *Decapterus kurroides.* The IUCN Red List of Threatened Species. [accessed 2019 Oct 6]. 2018:e.T20431513A67871600. http://dx.doi.org/10.2305/IUCN.UK.2018-2.RLTS.T20431513A67871600.en

Smith-Vaniz WF. 1999. Carangidae. In: Carpenter KE, Niem VH, editor. FAO Species Identification Guide for Fishery Purposes. The Living Marine Resources of the Western Central Pacific. Volume 4. Bony Fishes. Part 2 (Mugilidae to Carangidae). Rome, Italy: Food and Agricultural Agriculture Organization of the United Nations. pp. 2659–2756

Smith-Vaniz, WF. 1986. Carangidae. In: Smith MM, Heemstra PC, editors. Smith's Sea Fishes. Berlin:Springer. pp. 638–660.

Sreenivasan PV. 1981. Maturity and spawning in *Decapterus dayi* Wakiya. Journal of the Marine Biological Association of India. 23(1&2):19–

28. http://eprints.cmfri.org.in/id/eprint/1351

Sululu JS, Lugendo BR, Benno BL. 2022. Reproductive Potential of the Mackerel Scad, *Decapterus macarellus* (Cuvier, 1833) in the Coastal Waters of Tanzania. Tanzania Journal of Science. 48(1):88–98. https://doi.org/10.4314/tjs.v48i1.8

Tiews K, Ronquillo IA, Caces-Borja P. 1971. On the biology of round scads (*Decapterus* Bleeker) in Philippine waters. The Philippine Journal of Fisheries. 9(1-2):45–71.

Tomkiewicz J, Morgan MJ, Burnett J, Saborido Rey F. 2003. Available information for estimating reproductive potential of Northwest Atlantic groundfish stocks. J. Northw. Atl. Fish. Sci. 33:1–21. https://doi.org/10.2960/J.v33.a1

Tzeng TD, Wang SJ, Yeh SY. 2003. Temporal and spatial variation of morphology for the red scad (*Decapterus kurroides*) in the adjacent waters off Taiwan. Journal-Fisheries Society of Taiwan. 30(3):217–226.

Wang XH, Qiu YS, Zhu GP, Du FY, Sun DR, Huang SL. 2011. Length-weight relationships of 69 fish species in the Beibu Gulf, northern South China Sea. Journal of Applied Ichthyology. 27(3):959–961. https://doi.org/10.1111/j.1439-0426.2010.01624.x

Widiyastuti H, Pane ARP, Fauzi M, Hidayat T. 2020. The biological aspect of mackerel scad (*Decapterus macarellus* (Cuvier, 1833)) in Samudera Hindia (West Sumatera Block). Omni-Akuatika Journal of Fisheries and Marine Research. 16(3):92–98. http://dx.doi.org/10.20884/1.oa.2020.16.3.851

Williams BC, Kruse GH, Dorn MW. 2016. Interannual and spatial variability in maturity of walleye pollock *Gadus chalcogrammus* and implications for spawning stock biomass estimates in the Gulf of Alaska. PLoS ONE. 11(10):e0164797. https://doi.org/10.1371/journal.pone.0164797

Wilson SK, Fisher R, Pratchett MS, Graham NAJ, Dulvy NK, Turner RA, Cakacaka A, Polunin NV. 2010. Habitat degradation and fishing effects on the size structure of coral reef fish communities. Ecological Applications 20(2): 442-451. https://doi.org/10.1890/08-2205.1

Wootton RJ. 1990. Ecology of Teleost Fishes. Fish and Fisheries Series 1. Reproduction. London: Chapman and Hall. 161-67.

Worm B, Hilborn R, Baum JK, Branch TA, Collie JS, Costello C, Fogarty MJ, Fulton EA, Hutchings JA, Jennings S, Jensen OP. 2009. Rebuilding global fisheries. Science. 325(5940):578–585. https://doi.org/10.1126/science.1173146

Zaragoza EC, Pagdilao CR, Moreno EP. 2004. Overview of the Small Pelagic Fisheries. In: Department of Agriculture-Bureau of Fisheries and Aquatic Resources. Turbulent Seas: The Status of the Philippine Marine Fisheries. Cebu City: Coastal Resource Management Project. pp. 32–37