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Present Heat Index Effect on the Fecundity and Growth of *Decapterus macrosoma* in the Selected Fishing Waters of Caraga Region, Philippines

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ABSTRACT

The fecundity of fish can be utilized to predict the fish catch in the future becoming to be the most vulnerable to the negative impact of global warming. This study aimed to determine the effect of heat index on the growth and fecundity of *D. macrosoma* "Budloy" from the selected locations of marine waters in Caraga region. The study was conducted at Buenavista, Agusan del Norte, Placer Surigao del Norte, and Tandag Surigao del Sur where Shortfin scad is common. This study used Stratification random sampling to collect the samples. To calculate the present heat index of the sampling areas, present temperature and humidity during the capture of fish samples were determined. To determine the fecundity, six parameters of *D. macrosoma* were calculated: length, body weight, total weight of ovary, weight of ovary samples, number of eggs, and maturity stage of *D. macrosoma* ovaries. In terms of the correlational analysis between heat index and length of *D. macrosoma*, results showed that there is a moderate positive correlation, with r= .55, p= .000; for heat index and weight, results were found to have a strong positive correlation, with r = .71, p = .000. Based on the findings on the correlation between heat index and fecundity, with r =.007, p = .959, results indicate that although there is a positive correlation between heat index and growth, there is no significant relationship between heat index and fecundity. Based on the computed values of the heat index, growth, and fecundity of *D. macrosoma* samples in all sites, it is concluded that Buenavista waters have the highest numerical value of the reproductive potential of *D. macrosoma* as the basis for predicting the fish catch in the future.

Key Words	Heat index, growth, fecundity, Shortfin scad, reproductive potential
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INTRODUCTION

The fecundity of fish can be utilized to predict the fish catch in the future. As global warming is likely to be the greatest threat in the 21st century (Solar Impulse Foundation, 2022), the fecundity of fish is also becoming to be the most vulnerable to the negative impact of global warming. Earth has entered a new era of rapid and potentially irreversible climate warming triggered by greenhouse gas emissions caused by human activities (Albouy et al., 2020). They also stated that oceans have taken up 93% of the extra energy (IPCC, 2019); and that has been accumulated in the Earth system in recent decades, and its temperature has increased much faster since 1991 than has been recorded previously (Cheng et al., 2019; Albouy et al., 2020).

Climate change brought changes in the oceanic environment and is predicted to have a large socioeconomic impact through their effects on commercial fisheries (Barange et al., 2014; Bell et al., 2013; King et al., 2015; Ijima, 2019). These changes in temperature were found to have negative impacts on marine biota, including negative impacts on the fecundity of fish. Little is known about the effects of heat index to the growth and fecundity of Decapterues macrosoma (Albouy et al., 2020).

The world's marine ecosystems are continuously experiencing aquatic biological change at an unprecedented rate. Climate change, pollution, overfishing, invasive species, habitat loss and degradation, and over-exploitation are all contributing to the prevailing threats in aquatic ecosystems (Arthington et al., 2016). The intensifying resource of marine fish faces a multitude of threats that are ultimately driven by the increasing human population (Harding et al., 2018), projected to reach 9.7 billion human population in the year 2050 (United Nations, 2017). The increase in the human population resulted in overfishing. In the study of Asni & Tauhid (2019), overfishing was observed wherein the maximum sustainable yield (MSY) of shortfin scads fish in Bulukumba waters in 2016-2017 exceeded the maximum sustainable production (MSY) of 10,739 tons/year. According to Ye and Gutierrez (2017), one-third of the world's fish stocks are currently classified as overfished. Anthropogenic climate change has the potential to alter human and natural systems conditions such that the onset of unprecedented climatic extremes will outpace evolutionary and adaptive capabilities (Tan et al., 2018). Fish is more valuable than a diamond (Sumaila, 2021). This directly supported the idea that fish and fisheries directly impact millions of people around the globe by feeding (Hicks et al., 2019) and providing livelihoods (Sumaila, 2019).

According to Gola et al. (2021), recent studies showed that the human population increase resulted in serious issues of marine litter. Human-generated wastes like plastics are breakdown into smaller pieces and are continuously accumulated in the marine environment in a form of microplastics. Microplastics are generally composed of polyvinyl chloride (PVC), polyethylene terephthalate (PET), polystyrene (PS) and nylon, etc. Microplastics (MPs) smaller than 5 mm, have become an emerging global concern (Phuong, 2022). In the study by Wootton et al. (2021), it was found that 49% of all fish sampled globally for microplastic ingestion had plastic (an average of 3.5 pieces per fish), with fish from North America ingesting more plastic than fish from other regions. The concentration of these microplastics is increasing at an unprecedented, alarming rate, which not only affects the marine environment, but it is directly affecting marine life Gola et al. (2021). The need for consistent guidelines in methods used to evaluate microplastic in fish, to ensure data are unambiguous, comparable, and can be widely used to support mitigation and management strategies in marine life conservation Wootton et al. (2021). According to Zhang et al. (2019), microplastics are potentially contributed to climate warming. This indicates that presence of microplastics in marine environment will contribute to

In tropical regions, the reproduction-related physiological activities of fish are greatly affected by the environmental temperature. As such, tropical fish are particularly sensitive to climate change since they develop in a relatively stable thermal marine environment (Brule et al. (2022). Climate change-amplified temperature anomalies resulted in alarming threats to coral reef ecosystems. According to Magel et al. (2020), “while much focus has been placed on the effects of heat stress on scleractinian corals-including bleaching, mortality, and loss of reef structural complexity-and many studies have documented changes to reef fish communities arising indirectly from shifts in benthic composition, the direct impacts of heat stress on reef fish are much less well understood”.

According to PSA and Lamarca (2017), the Philippines is an archipelago that is made up of 7,641 islands which made the country blessed with rich marine fishing grounds. The fishing industry is of great contribution to the country as it provided employment to over 1.6 million Filipinos. In 2017, the Philippines had a population of about 103 million, and the mean per capita consumption of fish and fishery products of 40kg per year or 109 grams per day with a total intake of fish and fishery products at 12.8%. They also highlighted that the increase in the Philippine population and the occurrence of improved fishing technology brought stress to the country’s marine and coastal ecosystem, thereby greatly affecting fishery resources. The data of (the PSA) Philippine Statistics Authority showed that there is a decrease in the volume of fisheries production by sector in the Philippines which was 941,870.86 metric tons in 2018; 968,758.60 metric tons in 2019; and 952,188.62 metric tons in 2020 (PSA, 2021). In the study of Joson et al. (2019) to the *Sardinella lemuru* (Bleeker 1853) species from Balayan Bay, Batangas, they stated that as the human population steadily increased, the demand for the fish also increased, such that the fish population may be threatened with overexploitation, and fecundity of fish is also threatened. Another pressing threat to the fishery sector is climate change. Boyce et al., (2022) stated that climate change is impacting virtually all marine life.

Uncontrolled fishing efforts along with economic growth, and the threat of climate change (Boyce et al., 2022) will result in the decline of capture fisheries and productivity (Asni & Tauhid, 2019). However, there is no control instrument for the exploitation of shortfin scads *(Decapterus macrosoma)* fish until now, hence, there is a concern that the sustainability of shortfin scads fish resources will be threatened (Asni & Tauhid, 2019).

The *Decapterus macrosoma (Shortfin scad*) Budloy is a schooling species that typically occurs in open waters (Magallanes et al. (2022). This fishery serves as a source of income for the coastal community in some parts of the world and is also found in the Philippines (Jimenez et al., 2020). It is commonly distributed in tropical waters such as the Indo-Pacific, East Africa, Red Sea, Eastern Pacific, Galapagos Islands, and Peru (Smith-Vaniz and Williams 2016). In the Philippines, *D. macrosoma* is one of the popular commercial species caught in many parts of the country (Magallanes et al. 2022; Sangalang and Quinay, 2015). According to Jimenez et al. (2020), the *Decapterus macrosoma* was a cheap source of protein for Filipinos and its low price made this known as a poor man’s fish. However, overexploitation is threatening the natural stock of *Decapterus macrosoma* due to increased fishing pressure brought about by increasing demand resulting from the continuous increase of the human population Jimenez et al. (2020). According to Rinali et al. (2017), to predict the fish catch in the future, a fecundity study should be conducted to know the reproductive potential of fish. Rilani et al. (2017) studied the fecundity in Sardinella fimbriata in Alas Strait; Kudale et al. (2016), studied the fecundity in Sardinella fimbriata from Karwar waters. The result showed that the value of R2=0.984 is closer to one, thus there is a highly positive relationship between fecundity and the standard length of S. fimbriata (Kudale et al., 2016). The study of Gonzales et al. (2021) investigates the spawning characteristics vis a vis fisheries management of *D. macrosoma* in the waters of Romblon Province, however, no studies conducted on the growth parameters and fecundity of *D. macrosoma*. To address the issue, the study was conducted to help predict the Shortfin scad (Budloy) future fish catch in the three water areas of Buenavista, Agusan del Norte, Placer, Surigao del Norte and Tandag, Surigao del Sur.

Therefore, there is a need to generate in depth knowledge on the determination of the effect of heat index on the growth and fecundity of *D. macrosoma* (Shortfin scad) “Budloy” from the marine waters in Buenavista, Agusan del Norte; Placer, Surigao del Norte; and Tandag, Surigao del Sur, Caraga. Also, the findings will help to predict the fish catch from the selected sampling stations.

MATERIALS AND METHODS

Research Design

This study used a quantitative experimental research design with a test configuration performed in a laboratory. Before, during, and after the test experiments, comparative assessments, study guides, and related articles were considered to ensure that it is clear and cut evidence to provide adequate results that could be based on by future researchers who would follow suit in the same or related research. The collected data were analyzed using correlation measures to determine the heat index, growth, and fecundity of *D. macrosoma* relationship in various sampling areas.

Research Locale

The study sites were conducted in three different coastal areas in the Caraga region, particularly on the selected waters of Agusan del Norte, Surigao del Norte, and Surigao del Sur. *D. macrosoma* fish species were commonly found and selected on purpose by the researchers in each area respectively at Buenavista, Agusan del Norte; Placer, Surigao del Norte; and Tandag, Surigao del Sur. These sampling areas were considered market fishing grounds areas due to the large volume of fish caught in Caraga Region, Philippines where three sampling areas were located.

Sampling Technique

During the wet season (November-December), where the (Shortfin scad) *D. macrosoma* are abundant (Magallanes et al., 2022), specifically around 5:00 o’clock in dawn on November 26, 2022, fresh *D. macrosoma* fish samples were collected. Newly catch *D. macrosoma* fish samples were bought from local fishermen from the three sampling sites, along the seashores of Buenavista, Agusan del Norte; Placer, Surigao del Norte; and Tandag, Surigao del Sur where local fishermen landed their newly catch fish. The ten kilos’ samples of fish in every station were placed in a separate container. The air temperature and relative humidity of the area during the collection of samples from local fishermen were determined and recorded using the alcohol laboratory thermometer. Examination, weighing and measuring of the growth, maturity stages of the ovary and counting of eggs were conducted at Biology Laboratory of Agusan National High School-Senior High School Building, Butuan City. The estimation of fecundity, and mature and ripe ovaries of *D. macrosoma* were examined using a light microscope.

Data Gathering Procedure

The researchers requested permission to collect *D. macrosoma* fish species and conduct fecundity tests through sending a request letter to the City Agriculture, and Bureau of Fisheries and Aquatic Resources office. The air temperature and relative humidity of the area was determined and recorded using the alcohol laboratory thermometer. Present heat index was calculated using the meteorological heat index calculator of the National Weather Services of the National Oceanic and Atmospheric Administration. Dissection of fish samples for ovary extraction were carried out in the laboratory of Agusan National High School-Senior High School. Examination, weighing and measuring of the growth, maturity stages of ovary and counting of eggs were conducted at Biology Laboratory, Agusan National High School, Senior High School Building, Butuan City. For the estimation of fecundity, mature and ripe ovaries of *D. macrosoma* were examined using a compound microscope. The numerical data for heat index, length, and weight of the fish samples were then used to obtain the fecundity in each sampling area.

Statistical Treatment of Data

To facilitate data analysis and interpretation, the following statistical treatments were applied in this study.

Growth of *D. macrosoma*

In the laboratory, the individual length of fish samples in three sampling areas were independently taken to the nearest centimeter in a straight line via a ruler following the TL method - from the anterior tip of the longest jaw to the most posterior part of the caudal fin to the nearest centimeter scale respectively (Laevastu 1965). The length is measured from the most forward point of the head, with the mouth closed to the farthest tip of the tail compressed while the fish is lying on its side. The weight of the specimens was taken by an electric balance and the weights were recorded to the nearest gram.

Fecundity of *D. macrosoma*

Fecundity has been considered as the number of ripening eggs in the female fish prior to spawning (Bagenal and Braum, 1978). The ovary of the individual fish was taken out carefully and placed in an individual container. Gravimetric method or weight method (Lagler, 1956) was used for estimation of the fecundity of *D. macrosoma.* Gravimetric method offers the best possibility of minimizing error due to its simple and easy sampling techniques. The Gravimetric method has been used for its greater efficacy over the other methods. The Gravimetric or weight method has been successfully used by Doha and Hye (1970), Boonkusol et al. (2020), Kaban et al. (2019), Limbu et al. (2021). The gravimetric method was done by the following way, before estimation of the fecundity of the fish species under study, ovaries were cut into sections from where pieces were removed and weighed in the nearest gram. This value was proportional to the total ovary weight; the number of eggs (F 1) for the sub-sample was estimated by using the following equation:

The mean of sub-sample fecundities (F1, F2, F3, …), the individual fecundity for each female fish was calculated by the following equation:

$$\text{Fecundity } (F_e) = \frac{F1 + F2 + F3 + \ldots}{\text{Total number of samples}}$$

$$\text{Fecundity } (F1) = \frac{\text{No. of eggs in sub sample x Gonad weight}}{\text{Weight of sub sample}}$$

Present Heat Index

The present heat index of the selected locations was calculated using the meteorological heat index calculator of the National Weather Services of the National Oceanic and Atmospheric Administration. Descriptive analysis was utilized to compare the present heat index of the three selected locations in Caraga.

Heat Index and Growth

Analysis of correlation was used to identify if there is a significant relationship between the heat index and growth of *Decapterus macrosoma* within the waters of Buenavista, Placer, and Tandag.

Heat Index and Fecundity

Analysis of correlation was utilized to identify if there is a significant relationship between the present heat index and fecundity of *Decapterus macrosoma* within the waters of Buenavista, Placer, and Tandag.

Reproductive Potential of D. macrosoma

Correlational and descriptive analyses were utilized to determine the reproductive potential of *Decapterus macrosoma* as the basis in predicting the fish catch in the future along the waters of Buenavista, Placer, and Tandag, Caraga Region, Philippines.

RESULTS AND DISCUSSION

Length, and Weight of Fish

The individual length, and weight measurement of fish is extremely important in aquaculture, both production systems and breeding programs (Fernandes, et al., 2020). Most of the current methods are based on manual measurements.

Table 1. Average Length (mm) and Weight (g) of (Shortfin scad) *Decapterus macrosoma* in Selected Waters of Caraga.

Location	Length (mm)	Weight (g)
Buenavista	289.300	262.019
Placer	187.200	187.856
Tandag	280.700	399.938

Table 1 shows the average length and weight in each sampling area, which includes the length of fish in millimeter, and the weight of fish in grams. According to Dash et al (2019), length-weight relationships are used to derive the 'condition factor', and an index often utilized to describe 'well-being' of fishes, if the heavier fishes belonging to a particular length class are in better condition than the lighter counterparts.

Further, Sani et al. (2010) stated that the length-weight relationship (LWR) is essential for fisheries management and conservation in gathering crucial information on biomass for any stock by directly collecting data on fish weight is quite complicated, time-consuming and expensive, but such information can be easily derived without any hassle by just converting the ubiquitously available length-based data.

In the study of Famoofo and Abdul (2020) on the biometry, and length-weight relationships of sixteen fish species in Lekki Lagoon, the researchers explained that length-weight data are often used to study the indication of fatness or general well-being of fish. However, the small sample size may lead to an overestimation of the length-weight relationship of fish.

In the study of Afdhila (2019) on the length-weight relationship and condition factors of *D. macrosoma*, their results showed *D. macrosoma* had a negative allometric growth pattern with a value of b = 2,61. "The value of 103,46 from the relative weight conditions factor indicates a stable water condition and the value of 3,00 from the factor of Fulton's conditions indicates allows the availability of abundant food that support the life of *Decapterus* macrosomafish well." Further, based on related studies that also conduct weight and length of fish, their findings showed that weight and length relationships were significantly interrelated (R2>0.942) (Kara, et al., 2020).

In this study, the results of the length-weight data were obtained from the research conducted on seventy-nine fish samples from the waters of Buenavista, Agusan del Norte; Placer, Surigao del Norte; and Tandag, Surigao del Sur. Table 1 shows that fish sample in Buenavista has the highest average length of fish samples which is 289.300 mm, while Tandag has the highest average weight of 399.938 grams. Thus, based on the results of the descriptive analyses of data, it shows that the increase in lengtht of *D. macrosoma* does not follow an increase in weight. This is supported by the study of Famoofo and Abdul (2020), wherein they explained that the length-weight relationship is greatly affected by many factors related to pollution, population variability, sampling season, availability of food, feeding intensity, fish size, age, sex, stage of maturation, and estimation methods. Hence, the growth of *D. macrosoma* in terms of length and weight may vary and does not follow a length-weight pattern.

Fecundity is defined as the total number of eggs present in the ovary of a fish. This also refers to the ability of an individual or group of fish to generate a certain number of offspring over the course of a certain amount of time.

Number of Eggs

Table 2. Average number of eggs of ovary sample of (Shortfin scad) *Decapterus macrosoma* in Selected Waters of Caraga

Location	Average No. of Eggs
Buenavista	1098
Placer	625
Tandag	739

Table 2 shows the average number of eggs of the ovary sample of *Decapterus macrosoma* (Budloy). From the three selected waters in Caraga, ovaries of forty-five females of *Decapterus macrosoma* were used. Matured eggs were counted manually which was taken from an ovary sample of individual fish. In this study, Batch Fecundity technique by De Vlaming (1983) was utilized to determine the fecundity of fish samples. Batch Fecundity refers to the number of eggs spawned per batch, and the sum of batch fecundities represents the realized annual fecundity; and estimate fecundity from field measurements (i.e., total length (TL), relative weight [Wr], or ovary weight) were determined to estimate reproductive potential (Lenaerts et al., 2021).

Based on the result of the descriptive analysis of the average number of eggs of the ovary samples of *Decapterus macrosoma* (Budloy) in selected waters of Caraga, among the three selected water sampling areas, the most abundant average fish eggs area was Buenavista, Agusan del Norte with one thousand nine hundred-eight (1098) average count, while Placer, Surigao del Norte has the least number of eggs with six hundred twenty-five (625) average count, and Tandag, Surigao del Sur has seven hundred thirty-nine (739) average count of eggs. The result showed a wide range of difference in terms of values of the number of eggs in the three selected water areas. This result can be explained using the study of Servili et al. (2020), variations in temperature, and photoperiod are known to strongly affect the timing and the spawning period in several fish species. According to Segvili et al. (2020), the temperature, changes in salinity, and water acidification are also directly associated with reduction of sperm quality and reproductive output. Thus, the average number of eggs of ovary samples of *Decapterus macrosoma* (Budloy) in the selected waters of Caraga were varied due to the differences in some environmental factors such temperature, and salinity of the sampling areas.

Maturity Stage of Eggs

From the waters of Buenavista, Placer, and Tandag, matured ovaries of forty-five female *Decapterus macrosoma* were used. Table 3 shows the average maturity stage of eggs of *Decapterus macrosoma* in the three selected sampling areas. Fifteen (15) female fish ovaries were observed to be in the maturity stage III-IV in the waters of Buenavista, Agusan del Norte; and thirty (30) female fish ovaries are in maturity stage I-II in Placer, Surigao del Norte and Tandag, Surigao del Sur waters.

Table 3. Average Maturity Stage of Eggs of (Shortfin scad) *Decapterus macrosoma* in Selected Waters of Caraga

Location	Maturity Stage of Eggs	Number of Female Samples
Buenavista	III-IV	15
Placer	I-II	20
Tandag	I-II	10

Based on the observation of individual ovary sample of morphology and histology of *D. macrosoma* in the selected Caraga waters, the proportion of the maturity stage of ovaries dominated by maturity stage I-II that was observed in Placer, Surigao del Norte and Tandag, Surigao del Sur *D. macrosoma* samples, while the maturity stage of ovaries III-IV was less found which was only in the waters of Buenavista.

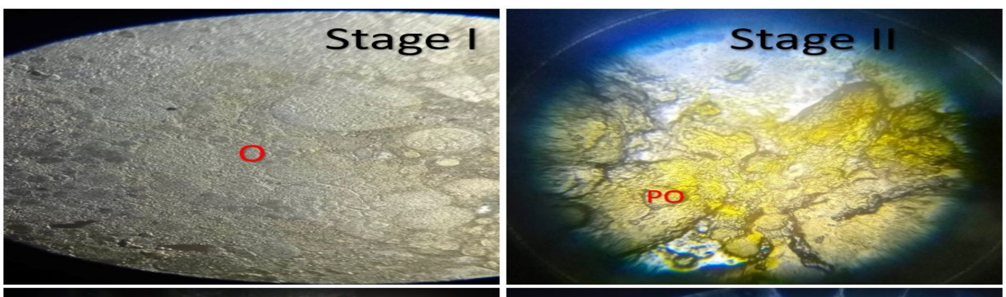

Fig. 1. Ovary Histology of (Shortfin scad) *Decapterus macrosoma*

Figure 1: (a-d) Ovaries of *D. macrosoma* at different stages of maturation¯ (a) Stage I: Immature (Placer, Surigao del Norte); (b) Stage II: Early Maturation (Tandag, Surigao del Sur); (c) Stage III: Later Maturation (Buenavista, Agusan del Norte); (d) Ripe and running (Buenavista, Agusan del Norte); (O) Oogonia; (PO) Primary oocyte; (PVO) Primary vitellogenic oocyte; (SVO) Secondary vitellogenic oocyte Based on the external characteristics of the ovary and on the internal organization of oocytes, it was possible to classify the ovary of bigeye tuna into four states of maturity, which are described below.

Shown in Figure 1 are the different stages of ovary maturation of *Decapterus macrosoma*. Stage I–Immature: The ovaries filled up with oogonia and oocytes in perinucleolar stage. This kind of ovary was found in females with the fork length ranging from 62.0 to 150.0 cm (average of 112.6 cm); Stage II-Early Maturation: The ovaries were bigger than the former stage, showed oocytes at early lipidic and vitellogenesis stage; Stage III-Later Maturation: Pre-hydrate and hydrated oocytes were present, some oogonia and perinucleolar oocyte stages were still present in the ovary; Stage IV-Ripe and Running: The ovary showed oocytes at different stages, with most of them being at oogonia and perinucleolar stage.

In the study of Rilani et al. (2017), among the 750 S. fimbriata catch, the total of gonad stage IV was found in 28 fishes and the total stage V was found in 41 fishes. Based on the results, there is a high difference in the average number of eggs observed.

In this study, the descriptive analysis result on the average maturity stage of eggs showed that many of the samples were in maturity stages I-II. According to Rilani et al. (2017), the maturity of ovaries indicates the spawning potential of fish. Also, the average maturity stage of eggs can be supported by the conclusion of Sulistino et al. (2011) that, variations in the maturity of ovaries are caused by the changes in the annual rainy season, the condition of fish and geographical location.

Ratio of Male and Female Fish

Table 4. Average Maturity Stage of Eggs and Ratio of (Shortfin scad) *Decapterus macrosoma* in Selected Waters of Caraga

Location	Ratio	
	Male	Female

Buenavista	3	15
Placer	11	20
Tandag	20	10

Table 4 shows the ratio of male and female fish samples from the three selected waters in Caraga. The *Decapterus macrosoma* samples consist of eighteen (18) from the waters of Buenavista, Agusan del Norte, thirty-one (31) from Placer, Surigao del Norte, and thirty (30) from Tandag, Agusan del Sur. From the waters of Buenavista, male and female ratio is 3:15; Placer fish sample ratio is 11:20; and Tandag is 20:10. Data shows that Buenavista and Placer fish sample ratio showed a higher rate in female fish, and lower female rate in Tandag waters. The highest number of *D. macrosoma* male sample is twenty (20) from Tandag, Surigao del Sur; eleven (11) males from Placer, Surigao del Norte, and three (3) male fish samples from Buenavista, Agusan del Norte.

In the study of Geffroy & Wedeking (2020), a total of 155 fish (96 females and 59 males were collected during the wet and dry seasons. The female to male ratios of *S. pleugostigma* were significantly different from the ratio of 1:1 within the dry (21 females and 12 males) and the wet seasons (75 females and 45 males).

In this study, the observed male and female *D. macrosoma* ratio can be supported by the study of Geffroy and Wedeking (2020). In fishes, sex is determined by genetics, the environment or an interaction of both. Geffroy and Wedeking (2020) stated that, "temperature is among the most important environmental factors that can affect sex determination". Consequently, changes in temperature at critical developmental stages of fish can induce biases in primary sex ratios. "However, early sex ratios can also be biased by sex-specific tolerances to environmental stresses that may, in some cases, be amplified by changes in water temperature" (Geffroy and Wedeking, 2020).

Further, this is also supported in the study of Edmands 2021 which stated that, the rising global temperatures pose a threat to population sex ratios, which, particularly when ratios are male biased, can lead to mate shortages, lower population growth and adaptive potential, and raise extinction risk. Moreover, according to Sass et al. (2022), "sex differentiation may often dictated by genetics, environmental conditions, and population density during critical embryonic development periods".

The heat index is an index that combines air temperature and relative humidity during the actual collection of fish samples from the local fishermen at 5:00 o'clock of dawn in the three sampling areas. Heat index changes at a constant temperature with increasing air moisture. Table 5 shows the heat index in the selected waters in Caraga. Tandag has the highest heat index of 39 °C, and the lowest heat index value is 27 °C in Placer. According to Opitz et al. (2016), heat index is increasing worldwide due to land-use development and climate change. This explains urban temperatures may be up to 10 °C warmer than the surrounding suburban.

Table 5. Calculated Heat Index in the Selected Sampling Areas in Caraga

Location	Heat Index (°C)
Buenavista	29
Placer	27
Tandag	39

Correlational analysis was utilized to determine the significant relationship between the heat index and growth of *D. macrosoma* in terms of length and weight. Correlational analysis is a statistical tool to test if two variables have any kind of relationship, whereas p-value tells us if the result of an experiment is statistically significant.

Significant relationship is determined through correlational analysis. It is a statistical method used to measure the strength of the linear relationship and association of variables. In this study, the present heat index of the three selected water areas was calculated using the meteorological heat index calculator of the National Weather Services of the National Oceanic and Atmospheric Administration, and the growth of *D. macrosoma* was determined through the length and weight of fish samples.

Changes in temperature specifically climate change affecting marine ecosystems worldwide and there have been measurable and increasing consequences to fish populations. As such, affecting the individual physiology of fish including growth and population dynamics. (Cheung et al., 2013; García-Reyes et al., 2015; Hoegh-Guldberg & Bruno, 2010).

Table 5. Correlational Analysis between the Heat Index and the Growth of (Shortfin scad) *Decapterus Macrosoma*

Factor	r-value	p-value	Remark
Length (mm)	0.546	0.00	Reject Ho
Weight (g)	0.708	0.00	Reject Ho

Tested at 0.05 Level of Significance

Table 5 shows the result of the correlational analysis between the heat index and growth in terms of length and weight of *Decapterus macrosoma*. The Pearson Correlation Coefficient was used to answer the hypothesis if there is a significant relationship between the present heat index and growth of *Decapterus macrosoma* within the waters of Buenavista, Placer, and Tandag which is tested on 0.05 significant difference. Heat index and length of *D. macrosoma* samples in the three selected waters of Caraga were found to have a moderate positive correlation, $r = .55$, $p = .000$. The result indicates that there is a significant relationship between the present heat index and growth in length of *Decapterus macrosoma* within the waters of Buenavista, Placer, and Tandag. Heat index and weight of *D. macrosoma* samples in the three selected waters of Caraga were found to have a strong positive correlation, $r = .71$, $p = .000$. The result indicates that there is a significant relationship between the present heat index and growth in weight of *Decapterus macrosoma* within the waters of Buenavista, Placer, and Tandag. The results indicate that there is a tendency for high heat index values to go with high length values and vice versa; and there is a tendency for high heat index values to go with high weight values and vice versa.

In this study, the significant relationship between the present heat index and growth of *Decapterus macrosoma* is supported by the study of Lavin et al. (2022) that temperature showed significant relationship with the body size of fish. The larger-bodied species of fish may experience the strongest temperature-size responses. They also found out that temperature was more important than dissolved oxygen concentration in determining the maximum body length of fish.

According to Lavin et al. (2022), the temperature-dependent characteristic is driving a reduction in the maximum body length of fish in the warmer temperatures. In the study of Servili et al., (2020), the highest mean body depth (BD) was observed in *Dagetichthys lakdoensis* (6.0 ± 0.14 cm) and automatically had the highest mean body girth (BG) value (13.0 ± 0.55 cm) of the fishes. The least mean body depth value was observed in *Pellonula afzeliusi* (2.5 ± 0.20 cm) with (5.7 ± 0.51 cm) mean body girth value as the fish species with the least body girth value.

According to Servali et al. (2020), the varying temperature greatly influence the fish size, age, and degree of muscular development. Further, the availability of food, life history of fish, and environmental conditions also influence the development of fish. However, in the study of Denderen et al. (2020), they concluded that higher temperatures increase the metabolic rate of ectothermic organisms up to a certain level and make them grow faster. Hence, growth of fish is sensitive to temperature which is frequently used to predict the long-term effects of climate warming on ectotherms. They further concluded that growth also depends on ecological factors and evolutionary adaptation.

The result of this study is also supported by the Temperature-Size Rule (TSR) which describes how ectothermic species grow faster and mature at a smaller size when reared at warmer temperatures (Atkinson, 1994). The result can also be explained based on the findings of Ljungström et al. (2020), that "spatial and temporal variation in temperature is the generally invoked driver but food abundance and quality are also emphasized". This can also be explained in the study of Ikpewe et al. (2022), which stated that, "the increasing sea temperatures are predicted to decrease body size of marine ectotherms based on the temperature size rule". This will impact fisheries yields, but empirical evidence of the process is still limited.

Table 6. Correlational Analysis between the Heat Index and the Fecundity of (Shortfin scad) *Decapterus Macrosoma*

Factor	r-value	p-value	Remark
Fecundity	0.0077	0.959	Accept Ho

Tested at 0.05 Level of Significance

Table 6 shows the result of the correlational analysis between the heat index and fecundity of *Decapterus macrosoma*. The Pearson Correlation is used to answer the hypothesis if there is a significant relationship between the present heat index and fecundity of *Decapterus macrosoma* within the waters of Buenavista, Placer, and Tandag which is tested on 0.05 significant difference. Heat index and fecundity of *D. macrosoma* samples in the three selected waters of Caraga were found to have no correlation, r = .007, p = .96. The result indicates that there is no significant relationship between the present heat index and fecundity of *Decapterus macrosoma* within the waters of Buenavista, Placer, and Tandag. The results indicate that although technically there is a positive correlation, but the relationship between heat index and fecundity is weak, the nearer the value is to zero, the weaker the relationship.

Location	Frequency	Percent	Cumulative Percent
Placer	20	44.4	44.4
Buenavista	15	33.3	77.8
Tandag	10	22.2	100.0
Total	45	100.0	

The result is supported in the study of Zak and Reichard (2020), that female fish exposed to fluctuating temperatures effectively compensated egg production for their smaller size. They concluded that there was no difference in absolute fecundity between thermal regimes and body-size corrected fecundity was higher in females in fluctuating temperatures. This indicates that the heat index has no direct effect on the fecundity of fish. Also, the findings of Zak and Reichard (2020) suggest that the expression of life history traits such as fecundity and their associations under stable temperatures are a poor representation of the relationships obtained from ecologically relevant thermal fluctuations. This can be further explained in the study of Dillon et al. (2016) that "temperature, light intensity and food availability fluctuate in predictable daily and seasonal cycles and organisms adapt their endogenous biorhythms to optimize performance". This indicates that the numerical value of the fecundity of fish is unstable due to daily and seasonal fluctuations of the temperature as well as the heat index. The result of the study can be further explained in Lavin et al. (2020), that fecundity or reproductive output of fish depends on the interactions of population abundance, size structure, reproductive condition, and varies geographically and from year to year.

Table 7. Descriptive Analysis of the Fecundity of (Shortfin scad) *Decapterus Macrosoma* in the Buenavista, Placer, and Tandag

Table 7 shows the result of the descriptive analysis of the fecundity of *Decapterus macrosoma* in Buenavista, Placer, and Tandag. The data shows that Placer has the highest percentage of fecundity in the cumulative percent which is 44.4%. This indicates that among the three selected locations of the study, Placer has the highest reproductive potential of *Decapterus macrosoma* as the basis in predicting the fish catch in the future. Tandag has the lowest percentage of fecundity in the cumulative percent which is 22.2% while Buenavista fish samples has 33.3%. This indicates that among the three selected locations of the study, Tandag has the highest reproductive potential of D*ecapterus macrosoma.*

In the study of Ali et al. (2020) on the reproductive potential of fish, the potential fecundity of fish was determined through fecundity-weight correlation of fish. The results of their study showed that absolute fecundity of the fish varied from 3559 to 15712 ova, while relative fecundity (per gram of body weight) ranged from 30.52 to 63.45 ova. The average absolute fecundity recorded was 7698.4 ova whereas the average relative fecundity was 43.85 ova per gram body weight. Fecundity was found to have a strong correlation with total weight (R2=0.6375), total length (R2=0.5379), ovary weight (R2=0.5804), while low correlation was observed with ovary length (R2=0.2880).

The result can be explained in the study of Petit et al. (2020), wherein they stated that, "reproductive success of aquatic animals depends on a complex web of relationships between the environment, the attributes of the reproductive individuals and human-induced selection". They stated that these factors can directly or indirectly affect the fecundity of fish and can also be compensated for certain external impacts. Parental effects include the influence that the phenotype and environmental conditions in which individuals develop exert on the phenotype of their offspring, and they can even have transgenerational impact.

Table 8. Descriptive Analysis between the Average Fecundity and Average Weight of Ovary of (Shortfin scad) *Decapterus Macrosoma*

Location	Average Fecundity	Average Weight of Ovary (g)
Buenavista	1 098	3.30
Tandag	739	2.15
Placer	625	1.44
Total	2 462	

Based on the study of Thorne et al. (2020), the impact of lifelong exposure to two concentrations (0.7 and 5.3 μg/L) of the antidepressant fluoxetine - often used to treat depression, and sometimes obsessive-compulsive disorder, fish highly affects its fecundity. When exposed to the highest concentration of fluoxetine (5.3 μg/L), fish were smaller at maturation, but they more frequently engaged in mating. They also concluded that, in both fluoxetine treatments females roughly doubled their overall fecundity while egg fertilization rates were the same for exposed and unexposed fish. The result of their study indicates that the fecundity of fish is highly affected by different environmental factors.

However, according to Lenaerts et al. (2021), ovary weight was the strongest predictor of fecundity. Their findings study supported the result of our study that fecundity is strongly predictable by the weight of fish. Based on the results shown in Table 8, *D. macrosoma* samples in Buenavista waters has the highest average ovary weight of 3.30 grams, and the highest average fecundity of 1 098. This indicates that Buenavista waters has the highest numerical value of reproductive potential of *Decapterus macrosoma* as the basis in predicting the fish catch in the future. *D. macrosoma* samples in Placer waters has the lowest average ovary weight of 1.44 grams, and the lowest average fecundity of 625. This indicates that Placer waters have the lowest numerical value of reproductive potential of *Decapterus macrosoma* as the basis in predicting the fish catch of the selected waters in Caraga in the future.

In the study of Osho and Usman (2019), the concluded that "fecundity was weakly correlated with total length and standard length. However, there were negative correlations between fecundity and condition factor, egg size and condition factor, total length and condition factor with the values of -0.113, -0.030 and -0.270, respectively. Among all correlated variables, fecundity and gonad weight were the highest". According to Oshom and Usman (2019), the results may be attributed to different factors such as sex, age, state of maturity, size, state of stomach fullness and environmental factors affecting fish in water bodies. In their study, the sampled fish exhibited wide variations in the number of eggs, with larger samples producing more eggs than the smaller ones. However, they concluded that the highest number of eggs was not found in the largest fish and the lowest number of eggs was not found in the smallest fish. This was also like the study of Murua et al. (2013) wherein different fish species present a lot of differences in their reproductive potential. Hence, fecundity of fishes varies, depending on the reproductive characteristics of a species, changes in environmental conditions such as temperature, food availability, habitat and predation intensity. Similarly, in the study of Mekkawy and Hassan (2011), they stated that variability in fecundity may be attributed to age, sex, size weight, gonad weight and locality. In the study of Olurin and Savage (2011), the result showed that a range of 1711 to 4000 for *P. obscura* weighing between 161.94 and 380.78 g from the Oshun River, Southwest Nigeria. There was a high correlation coefficient between the Fecundity (F) and Gonad Weight (GW), which is r = 0.992. Hence, fecundity and growth may vary which are attributed to different species characteristics, food availability and environmental factors.

CONCLUSION

Based on the fecundity values of the (Shortfin scad) *D. macrosoma* samples in all sites, it is concluded that Buenavista waters has the highest numerical value of reproductive potential of *D. macrosoma* as the basis for predicting the fish catch in the future. The large disparity in fecundity values obtained across all three sites is attributable to the differentiated values of the ovary weight of the fish samples. Even though the study indicates that there is a significant relationship between fecundity and growth in terms of length and weight of *D. macrosoma*, there are still varied environmental factors need to be considered in determining the fecundity. As such, results showed that fecundity values of *D. macrosoma* has no significant relationship with the present heat index within the three selected waters in Caraga region.

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