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Population dynamics and fecundity estimates of Long-spined Black Sea Urchin *Diadema savignyi* (Audouin, 1890) from the Red Sea, Saudi Arabia

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ABSTRACT

Sea Urchin is not only the crucial keystone species for the coral reef restoration but also it has antimicrobial and anti-cancer activities. This study undertaken to focus on length weight relationship, size fecundity distribution and the estimation of fecundity from the long-spined Sea Urchin, *Diadema savignyi* at the coastal water of the middle Red Sea, Saudi Arabia. A total of 633 specimen of *D. savignyi* has been collected from the coastal water of Obhur Creek during the sampling time. In each species, total length (TL) measured as a $TW = 11.908 \times 0.9995$ ($R^2 = 0.8975$) through the linear regression graph and digital slide callipers and, individual body weight estimated by the digital balance. The natural and fishing mortality 2.02/yr and 0.19/yr respectively has documented from study area. The Asymptotic length value (L_{∞}) (cm) were estimated 7.35 where the growth coefficient (K) was 0.67 from the monthly length-frequency numeric data by using FAO FISAT II software for generating and estimating the population parameters and age. However, the recruitment pattern was observed to be increased gradually with the maximum recruitment peak between the months of September and October 2021. Therefore, the estimation of fecundity varied from 49,226 ova (total length 3.1 cm) to 466,133 ova (total length 6.8). As a result, analysis of the relationship between the absolute fecundity (F) and total length (TL), and between the fecundity and drained body weight (DW), revealed a linear regression model with a positive and significant relationship at $p < 0.05$. This is the first approach to study the detailed population dynamic of the ecologically and economically important tropical long spine sea urchin (*D. savignyi*) endemic to the region. However, the result so far obtained from this research would greatly be useful towards the understanding of the detailed population structure and growth patterns that will undoubtedly help us to develop captive breeding, seed production, culture protocols, conservation strategies and isolation bioactive compounds of this high-valued species incommensurate with national and international perspectives.

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1. Introduction

The sea urchin, Echinodermata: Echinoidea, is an important marine bioresource to be used in many scientific fields including biology, ecology, biodiversity, aquaculture, conservation, and evolution (Farina et al., 2020). However, they are also used as raw material for the production of food, particularly the product of pro-

cessing the gonads of sea urchins known as "Sea Urchin Roe" or "Uni," which is considered a valuable delicacy in Asia, the Mediterranean, and the Western Hemisphere (Rahman et al., 2013). Due to its geographical location in the southern Indian Ocean, the Arabian Gulf is also considered a focal point for the emergence of many diverged taxa, making it known for its unique culture and stunning marine environment (Sale et al., 2011). There are unique coastal and marine environments in the Gulf region, including the Red Sea, the Gulf of Aqaba, the Gulf of Suez, and the Gulf of Aden, not least of which is the extraordinary system of coral reefs, invertebrates and their associated animals and plants (Fine et al., 2019). Nevertheless, there are also extensive shallow shelves, noted for their marine life and corals. The red sea is the habitat of over 1,200 species of fish 1,000 invertebrate species, and 200 soft and hard corals (Atta et al., 2019). However, the Red sea, Arabian Gulf and Indian Ocean faunas have received more attention than the

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Gulf coast of Oman. In the past, the echinoderm fauna has explored through the ecological survey and relatively unexplored region was documented (Dibattista et al., 2016). Among these highly endemic fauna, recently found around greater than 20 species of sea urchins in the coral reef communities of the Gulf regions, such as *Triplonectes gratilla*, *Diadema setosum*, *D. savignyi*, *Echinothrix diadema*, *Toxopneustes pileolus*, *Echinometra mathaei*, *Echinothrix calamaris*, *Salmacis bicolor*, *Heterocentrotus mammillatus*, *Prionocidaris pistillaris*, *Stomopneustes variolaris*, *Microcyphus rousseaui*, *Echinostrephus molaris*, *Echinoneus cyclostomus*, *Asthenosoma marisrubri*, *Asthenosoma varium*, *Prionocidaris baculosa*, *Phyllacanthus imperialis*, *Echinodiscus auritus*, *Lovenia elongata*, *Clypeaster* spp. Etc (Zeina, Darweesh and Hellal, 2016). Some of the commercially, biologically and ecologically important species of regular echinoid sea urchins are included. Among them, the most commercial species of regular sea urchin, *T. gratilla* and *D. savignyi* are found abundantly in the Gulf of Aqaba and the North-western parts of Red Sea (Guirguis, 2010).

The tropical echinoid (*D. savignyi*) are mostly abundant and ecologically important species in the Red Sea, Saudi Arabia (Guirguis, 2010). However, they usually inhabit the intertidal zone where depth and pressure are not high. It is also found in the shallow water body of the east coast of Africa, Indo-Pacific region, and western Indian Ocean. It has been habituated in sandy flats and coral reef areas of warm water near coasts. *D. savignyi* has included long spines with a round body and black anal sac (O'Loughlin, 1998). It can grow to 90 mm in diameter with colour of solid blue or green lines on the body wall. The male and female *D. savignyi* lay eggs in the water column at the same days and finally it turns into a pluteus larvae. It usually lay about millions of eggs in once a month during lunar cycle (Rahman et al., 2012). The development of *D. savignyi* has been depended on the water temperature, food availability and salinity. It is considered for ecologically important herbivores through the control and stability of algae and coral reef. Algal blooms occurred in the Caribbean reef due to the declined of *Diadema* species by outbreaking of diseases between 1983 and 1984 as well as the overfishing of herbivorous fishes (Myhre and Acevedo-Gutiérrez, 2007).

The density of sea urchin has been played an important role for the structure dynamics of algal and coral reef communities that affected the biomass and distribution of macro algae and coral. Sea urchin has been regarded as an omnivorous that intake algae and controlling the algal distribution in the shallow reef. It can be taken invertebrates such as zoanths, sponges, and coral tissues that affecting the coral recruitment and mortality. Sea urchin deposited sediment in the reef regions and fulfil the important ecological roles that considered it as a keystone species. It is one of the major bioeroder in the oceanic system (Sangil and Guzman, 2016).

In the modern era, sea urchin used to evaluate field such as ecology, biology, and evolution. Sea urchin gonads are well known for nutrients and their delicacy, and the shell of sea urchin used not only as a raw material but also directly used as ornamental product of many ways. Sea urchin gonad has an anticancer and inflammatory activity, and it has been used as remedy to control body condition, provided sexual strength of men and treatment of diseases. The bioactive compounds have isolated from the sea urchin gonads such as polyunsaturated fatty acids (PUFAs). It has been applied to treat arrhythmia, cardiovascular and cancer diseases for a recent decade (Solari et al., 2021).

Feeding ecology of sea urchins are well known for intaking algae. Although, temperate and sub-tropical regions seagrass are the common source of nutrition, and it is considered a minor source for feeding of sea urchin. Sea urchin have been balancing the algae community in the coral reef and costal area by grazing and protecting algal bloom in the ocean water. Furthermore, the interaction of sea urchin and marine algae were not fully under-

stood in Brazilian waters that observed low number of algae in their gut contents (Cordeiro, Harborne and Ferreira, 2020). However, sea urchin exhibited a high degree of food selectivity in the area where they usually lived. Food intake may differ in summer and winter based on calory content. Therefore, the somatic index and reproductive growth have a good relationship with feeding ecology of sea urchin (Siikavuopio et al., 2007).

They are commonly inhabited shallow-water coral reefs in the benthic region of the sea floor, making up over 50 % of the overall number of urchins in the rocky area and over 90 % on the calcareous pavement as they reach an average peak density of 70.3–87 / m² and grooves on the 88 calcareous pavement at water depth of 1.5 m (Labbé-Bellas et al., 2016). However, some urchins can occur at a depth ranging between 0 and 90 m in shallow water amongst seagrass meadows and 90 muddy sublittoral zone (Rahman et al., 2013). The purple sea urchin, for instance, thrives well 91 in the midst of strong wave surge and churning aerated water (Hakim et al., 2019).

Sea urchin research is very recent in Saudi Arabia and few systematic works have been done with distribution, but no work has been yet conducted on the feeding ecology, population dynamics and characteristics and gonadal index with the species of *D. savignyi*. Due to the high of nutritional, pharmaceutical and neurocritical values of sea urchin gonads and shell, it is very essential to utilize the population dynamics, growth pattern, and reproductive system of the highly endemic sea urchin fauna in the Saudi Arabia coastal waters (Mos, Byrne and Dworjanyn, 2016). The present study has been undertaken to determine the size frequency distribution length-weight relationship, fecundity, and population characteristics of *D. savignyi* in Obhur, Saudi Arabia.

2. Materials and methods

2.1. Study area

The study was conducted in Sharm Obhur (Obhur creek) island near Obhur region of north Jeddah seashore, Red Sea. The Obhur island (Sharm Obhur) have degraded environmentally at least 11 km length by the human activities (Guirguis, 2010). The area was selected to observe the sea urchin population characteristic and fecundity estimation (Fig. 1).

2.2. Sample collection and maintenance

The length and weight data from the monthly samples of the commercially important sea urchin (*D. savignyi*) was collected from the northern (middle) area of the Red Sea, Saudi Arabia between January, and December 2021. It lies between the latitude of 21°71'03"N and longitude of 39°09'60"E. A mesh bag attached to a maypole was used by divers for collection. The collected sea urchin has transported to the laboratory of biology, King Abdulaziz University immediately and were maintained in aerated closed aquarium before use for the experiment.

2.3. Length-weight measurement

The Each live individual specimen of *D. savignyi* was documented to the nearest 0.01 mm (Total Length) by using the digital vernier calliper and weighed to the nearest 0.01 g using for the electric balance.

2.4. Fecundity estimation

The various mature size of female *D. savignyi* were chosen for the measurement of fecundity based on their size (g). The total



Fig. 1. Location of sampling area at Obhur region of north Jeddah seashore, Red Sea.

length of sea urchin has been documented by digital scale and drain weight were measured. The gonad of *D. savignyi* were collected by injecting 0.5 M KCL until the seeding all eggs (Dautov, Dautova and Kashenko, 2020). Three replications were taken during the estimation of total fecundity from the 60 matures female sea urchin (*D. savignyi*). After the collection of eggs, it has diluted by fresh saline water and 0.1 mL aliquot of the egg suspension were counted under a compound microscope.

2.5. Data analysis

The data were analysed using FISAT (FAO-ICLARM Stock Assessment Tools) software. The best growth curve in arriving fitted

curve through the maximum number of patterns of the length-frequency distribution was based on the ELEFAN I procedure. With the aid of the best growth curve, the Von Bertalanffy growth function (VBGF) parameters (L_{∞}) and (K) were calculated (Elganainy and Amin, 2012) and the resulting values were used to estimate the growth performance index (ϕ') in terms of length growth of (*D. savignyi*) using the following formula:

$$\phi' = \text{Log}_{10}K + 2\text{Log}_{10}L$$

The linear relationship $W = aL^b$ was applied to achieve the length-weight relationship. W, L, (a) and (b) represents the weight, the total length, the intercept and the relative growth rate or the slope respectively. The least squares linear graph regression on

log-log transformed data were used to estimate the values of (a) and (b) parameters as $\text{Log}_{10}W = \text{Log}_{10}a + b\text{Log}_{10}L$. The coefficient of determinant (r^2) was used as an indicator the quality of the linear regression (Schneider, Hommel and Blettner, 2010). In addition, the statistical significance level r^2 and 95 % confidence intervals of the parameters (a) and (b) were estimated.

To find the length of the *D. savignyi* at any ages, the inverse Von Bertalanffy growth equation was used (Spence and Turtle, 2017). Then, the non-linear squares estimation method was used in fitting VBGF to estimate the length-at-age curve. The Von Bertalanffy growth function formula:

$$E = \frac{F}{Z} = \frac{F}{F + M}$$

where L_t , L_∞ , K , t , and t_0 are respectively represent the mean length at age t , the asymptotic length, the growth coefficient, the age of the specimens and the hypothetical age at which the length is zero (Grandcourt, Abdessalaam and Francis, 2006).

Length converted catch curve was used to compute the total mortality (Z) whereas the empirical relationship was used to calculate the natural mortality (M):

$$\text{Log}_{10}M = -0.0066 - 0.279\text{log}_{10}L_\infty + 0.6543 \text{log}_{10}K + 0.4634 \text{log}_{10}T.$$

Definitions of the above parameters remain the same with T representing mean annual habitat water temperature. After computing the Z and M values, which are the total mortality and natural mortality respectively, the fishing mortality (F) value was easily estimated using the linear relationship:

$$F = Z - M$$

However, the estimated values of the above expression make it possible to reckon the exploitation level (E) of *D. savignyi* using the equation:

$$E = \frac{F}{Z} = \frac{F}{F + M}$$

The retrograde projection of the set of available length-frequency data on the length axis as clarified in FiSAT II was used in discovering the recruitment pattern of the stock (Lassen and Medley, n.d.). The relative strength of pulse and number of pulses per year was determined by series of length-frequency data using the parameter L_∞ , K and t_0 ($t_0 = 0$) described above. The NORMSEP procedure in FiSAT II was also used to determine the Normal distribution of the recruitment patterns (Pauly and Soriano, 1986). Furthermore, The SPSS version 16.1.0 was used to calculate the population structure and length frequency data of *D. savignyi*.

3. Result

3.1. Sample collection and measurement

A total number of 633 live *D. savignyi* specimens were collected during the entire experimental period and each individual was measured to the nearest 0.05 mm for total length (TL) using vernier calliper and weighed to nearest 0.01 g for the total weight (TW) using digital electronic balance (Table 1). However, the asymptotic length value (L_∞) (cm) was 7.35 where growth coefficient was 0.67 (Table 2).

3.2. Population structure of *D. Savignyi*

3.2.1. Size structure and length-weight relationship

The scattered plot shows the length-weight relationships of *D. savignyi* from the northern (middle) area in the Red sea, Saudi Arabia where length on the X-axis and weight on the Y-axis. However,

the parameters such as growth constant (a) and relative growth rate were estimated to be 0.9995 and 11.908, respectively. The equation $TW = 11.908TL^{0.9995}$ was obtained at the end of the result. The biometric relationship displayed a positive correlation between length and weight ($R^2 = 0.8975$). (Fig. 2).

3.3. Population parameters and stock status of *D. Savignyi*

3.3.1. Growth parameters

The growth curve of a pooled length size distribution of *D. savignyi* is shown in Table 1. The growth parameters of Von Bertalanffy growth formula were estimated as asymptotic length (L_∞) = 7.35 cm and growth coefficient (K) = 0.67 yr^{-1} (Table 2). The values of L_∞ and K were used for the calculation of growth performance index ($\phi' = \text{Log}_{10}K + 2\text{Log}_{10}L$), which was found to be 2.70 (Fig. 3).

The estimation of growth coefficient (K) per year has been utilized after the direct fit of length frequency data (ELEFAN 1). This value also showed the presence of a range of length-classes of *D. savignyi* that were captured is belongs to two cohort's seasons. The black and white bars in the restructured length-frequency distribution are positive and negative deviations from the weighted moving average. The potential longevity ($t_{\text{max}} = 5/K$) was estimated as 2.40 years indicating that the *D. savignyi* can live for not more than 6.5 years in the habitat where the study was carried out (Fig. 4).

3.4. Mortality and exploitation rate

The percentage of a fishstock's population or biomass that is taken out annually is known as its exploitation rate, and it is often quantified by fishing mortality. The distribution of fishing mortality throughout the population's age or length composition is referred to as the "exploitation pattern". The total mortality estimated values of $Z = 2.26$ for *D. savignyi* through the analysis of length converted catch curve (Fig. 5). However, the estimation of natural and fishing mortality were 2.04/yr and 0.22/yr respectively during the average temperature of 28 °C. The determination of exploitation level of *D. savignyi* was not high in the Obhur Creak (Fig. 5).

3.5. Recruitment pattern of *D. Savignyi*

The recruitment pattern of sea urchin (*D. savignyi*) has been observed throughout the study, hence the maximum recruitment peak found on the month between September and October 2021. The highest peak of recruitment at almost 19 % showed on October where the minimum percentage of recruitment was initiate (<1%) in May 2021 (Fig. 6).

The fallouts of the length-structured VPA of *D. savignyi* together with the length-weight relationship is depicted in Fig. 7. The result indicates that the fishing mortality was at a very minimal rate at 4.5 cm mid-length group and the highest mortality rate of 0.8 was at 6.5 cm mid-length group. The survival rate was high at minimum length and a sharp decline as the length increases. However, the fishing mortality was comparatively low over mid lengths from 1.5 cm to 3.5 cm and the values were higher from 5.5 cm to 6.5 cm mid-length (Fig. 7).

The exploitation rate of *D. savignyi* was estimated to be $E = 0.42$ /yr. The results revealed that the stock is underfished based on the assumption from Guland (1983) that an optimum exploitation of a stock become apparent when $E = 0.5$ or when fishing mortality equal to total mortality of the species. The empirical estimated result ($E = 0.42$ /yr.) could be associated with both intrinsic and

Table 1
Monthly pooled length-frequency data of *D. savignyi* from the coastal waters of the northern (middle), Red sea during the one-year experimental period between January and December 2021.

SI	Jan	Feb	March	Apr	May	Jun	July	Aug	Sep	Oct	Nov	Dec
1.5	1			1								1
2	1			1		1						1
2.5	1		1	1	1							1
3	1											1
3.5		2				1		1	2		2	1
4.5	1	1				1	7	1	15		6	5
5	1	3				1	19	4	35	37	20	15
5.5	3	3	5	7	13	5	21	17	1	17	2	8
6	21	15	15	20	32	13	6	17	1	4	2	8
6.5	20	16	21	21	6	16		15			1	16
7	4	10	10	2		10		1			1	6
7.5		1	2			1		1			1	1
Total	54	51	54	53	52	49	53	57	54	58	35	64

Table 2
Population parameters of sea urchin (*D. savignyi*) in the coastal water of the northern (middle) area, Red sea, Saudi Arabia.

Parameters	<i>Diadema savignyi</i>
Asymptotic length value (L_{∞}) (cm)	7.35
Growth coefficient or constant (K) per year	0.67
Natural mortality estimation(M)	2.02
Fishing mortality (F) per year	0.19
Total mortality (Z) per year	2.23
Exploitation (E)	0.09
Length range (cm)	1.5–7.5
Sample number	634
Average temperature ($^{\circ}$ C)	28
Growth performance (ϕ)	2.70
Potential longevity ($t_{max} = 5/K$) years	2.40

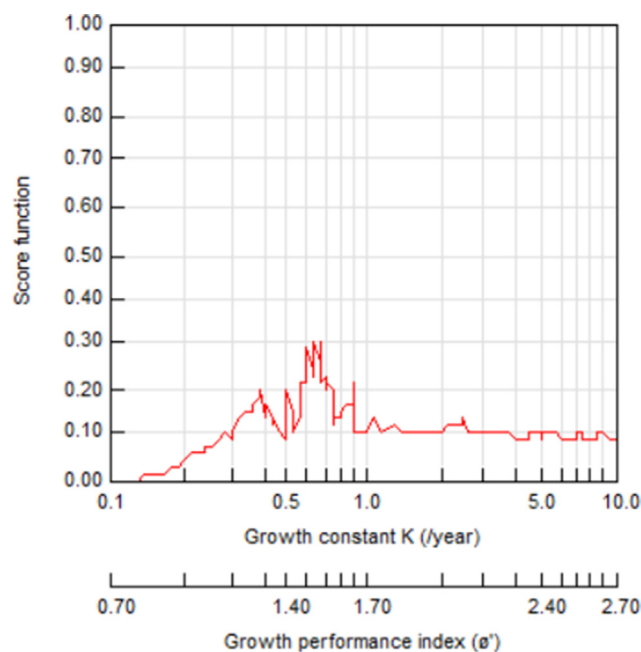


Fig. 3. The growth performance index (ϕ' - phi prime) of sea urchin (*D. savignyi*).

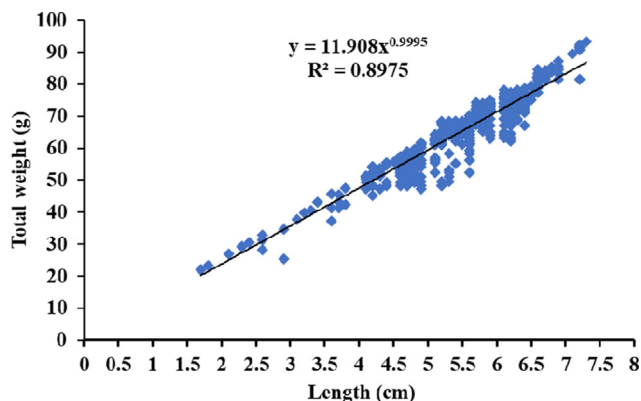


Fig. 2. Length weight relationship of *D. savignyi* from in the coastal water of northern (middle) area, Red sea, Saudi Arabia.

extrinsic factors. Nevertheless, high demand, as well as continuous harvesting and unstrained exportation of the species show a likelihood of overexploitation and depletion of *T. gratilla* stocks in the future. Fig. 8 represents the relative yield per recruit and biomass per recruit of the species at ogive option of $E_{50} = 0.42 \text{ yr}^{-1}$.

3.6. Cumulative probability of capture

The predicted highest length of *D. savignyi* value and 95 % confidence interval are generated from the intersection of overall highest converted length at the various in lines shown in Fig. 9. The figure estimates the probability of capture at the first size extreme length 7.5 cm, and this value is less than the average converted length 5.0 cm.

3.7. Fecundity

This is the first study so far on the estimation of fecundity of *Diadema savignyi* collected from the Northern (middle) Red Sea, Saudi Arabia. A total 60 females *Diadema savignyi* samples were used to estimate the absolute and the relative fecundity. The fecundity varied from 49,226 ova (total length 3.1 cm) to 466,133 ova (total length 6.8). The power relationship between absolute and relative to the total length and weight demonstrated that a positive and significant relationship at $p < 0.05$ (Fig. 10). As shown in Fig. 10, the relationship between the average absolute and relative fecundity and the total fish length could be described by the following power form:

$$F_{abs} = 0.085877151 L^{3.016} \quad (R^2 = 0.99)$$

$$F_{rel} = 0.029092551 L^{2.0004} \quad (R^2 = 0.98)$$

Where, F_{abs} is the absolute fecundity, F_{rel} , the relative fecundity and L is the total length in cm. The power relationships between F_{abs} -BW and F_{rel} -BW can be expressed as: line y and \times , z , respectively.

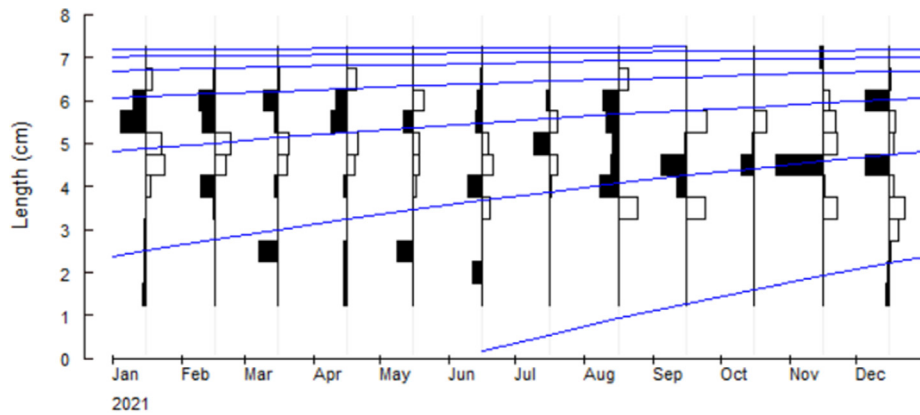


Fig. 4. Growth curve of *D. savignyi* by ELEFAN 1 superimposed on the restructured length-frequency diagram ($L_{\infty} = 12.38$ cm and $K = 1.7/\text{yr.}$).

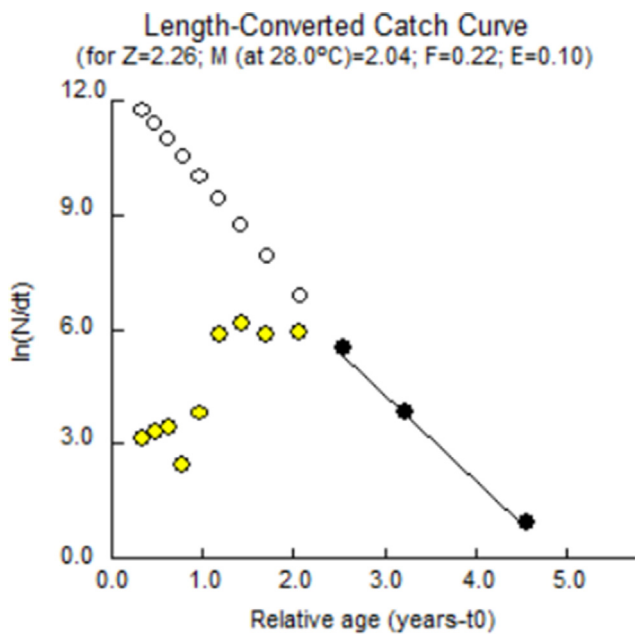


Fig. 5. Length-converted catch curve of *D. savignyi* in the coastal water of middle area, Red sea, Saudi Arabia.

$$F_{abs} = 0.067389133 W^{1.8935} \quad (R^2 = 0.95)$$

$$F_{rel} = 0.005862715 W^{0.913} \quad (R^2 = 0.89)$$

4. Discussion

The length-weight relationship has focused on the studies of population characteristics and fecundity of the Sea Urchin. The gonadal development, alteration, or metamorphosis, feeding rate, and maturity was documented through the FISAT (FAO-ICLARM Stock Assessment Tools) software (M Al-Beak, 2015). However, the Asymptotic length (L_{∞}) is one of the key factors to identify the stock may shrink or grow for the long time in the ocean through the von Bertalanffy growth function (VBGF). The Asymptotic length (L_{∞}) of *D. savignyi* has been found to be 7.35 cm along with the growth coefficient (K) value of 0.67 yr⁻¹. Similarly, a study was revealed that in Southern Guimaras in Malaysia and found different values of $L_{\infty} = 11.30$ and $K = 1.30$. from the species of *T. gratilla* (Regalado et al., 2011). It is interestingly important in the

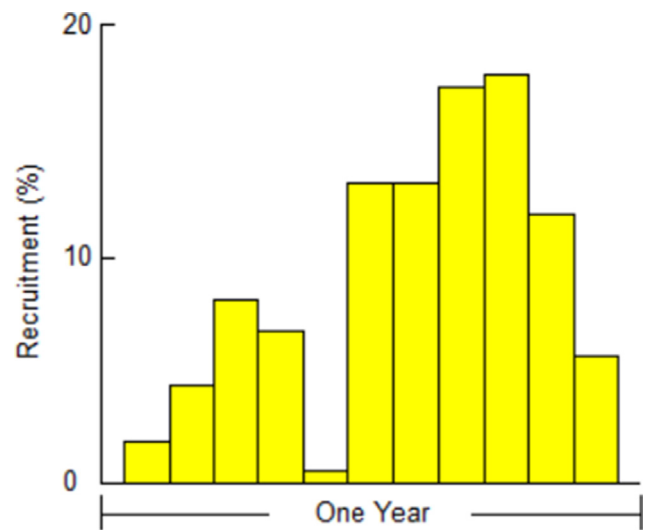


Fig. 6. Recruitment pattern of *D. savignyi* in the coastal water of northern (middle) area, Red sea, Saudi Arabia from January to December 2021.

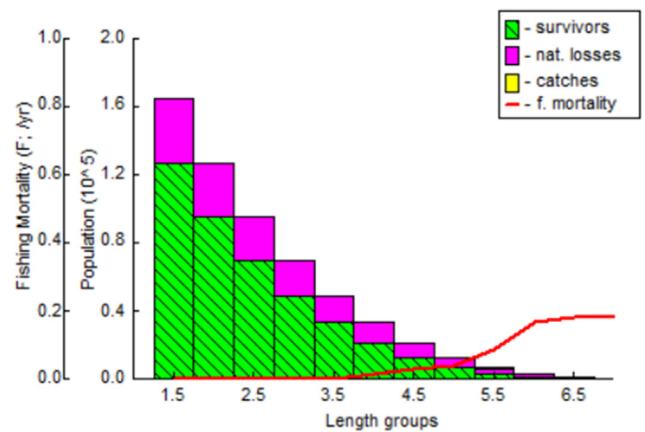


Fig. 7. Length structured virtual population analysis (VPA) of *D. savignyi* in the coastal water of northern (middle) area, Red Sea, Saudi Arabia.

aspect of *D. savignyi* that first time observed stock assessment in the abhor island, Saudi Arabia.

Moreover, natural and fishing mortality indicated the present status of fish stock in the fisheries. In the studies, natural mortality (M) and fishing mortality (F) have been documented 2.02 yr⁻¹ and

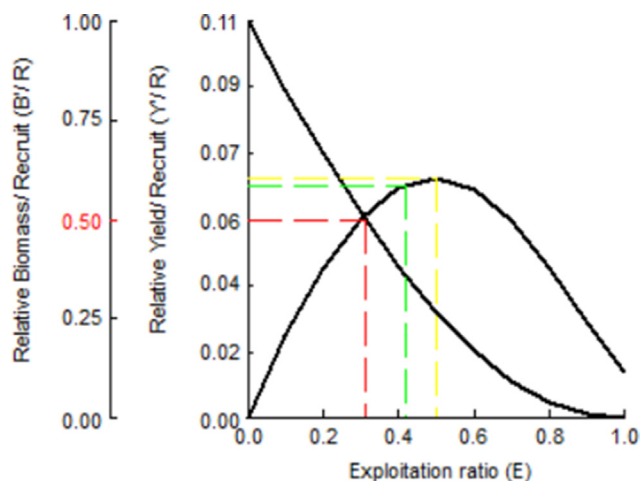


Fig. 8. Relative yield per recruit and biomass per recruit curves for *D. savignyi* in the Obhur Creak, Kingdom of Saudi Arabia.

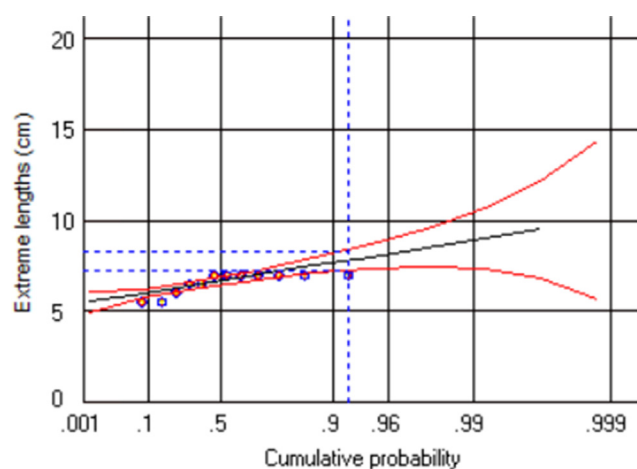


Fig. 9. Cumulative probability of *D. savignyi*. The predicted maximum length value and the 95% confidence interval are obtained from the intersection of the overall maximum length with the.

0.19/yr respectively from the *D. savignyi*. The natural mortality (M) and fishing mortality (F) were not found to be high in these fisheries my causes of lack of predatory and high organic matter (Boyd et al., 2020). Furthermore, the exploitation level (E) has found to be 0.10 which suggested that it is very low not responsible for the demolish fisheries.

In the absence of unexploited natural resources, it is often tedious to estimate natural mortality (M) empirically, therefore based on the knowledge of the life history characteristics of *D. savignyi*, a qualified guess of M was estimated (Romero-Gallardo et al., 2018). Even though, research suggests that once the juveniles of *D. savignyi* are beyond the parental care, natural mortality initially is relatively high. However, the resulted higher natural mortality than the fishing mortality showed a clear indication that the stock is under-fished, which means the lower the F value, the lower the exploitation rate. Moreover, yield is optimized when fishing mortality equals to natural mortality and exploitation rate at 0.5 is considered optimum level, and so when the exploitation rate is more than 0.5, the stock is said to be over-fished (Demirel, Zengin and Ulman, 2020).

The total instantaneous mortality, $Z = 2.23$ /yr. of *D. savignyi* in our study was more than the F value, which could be attributed to factors such as predations as some urchins have been observed

attacking and preying on each other, disease, overpopulation of the stock and other exogenous factors that lead to death of urchins before attaining their expected lifespan (Estes et al., 2009). Sea urchins are most often killed by bad weather and heavy rainfall. However, mortality in urchins could be attributed to the fact that the juveniles are not targeted in the fishery or caught as bycatch since the larger the size of urchin caught, the larger the size of gonad and the price at market. It means there is a pragmatic approach to modeling age-specific mortality, which makes the mature urchins an explicit interest in the fishery (Steneck, 2013). In simple terms, M could be dichotomized into intrinsic and extrinsic effects in the fishery.

The reliability of M determined by M/K ratio is in the range of 1.22–2.50 for most fish species. However, the M/K ratio (2.02/0.67) of 3.01 obtained was within the above range, indicating that the natural mortality estimates were reliable for *D. savignyi* in the present study site. The ratio Z/K denotes predominance of growth on the mortality of the population if is < 1 and > 1 shows predominant of mortality on growth. Conversely, ratio $Z/K = 1$ means mortality is at a state of equilibrium on the population with the growth. The result ($Z/K = 2.23/0.67 = 3.33$) obtained from the present study showed that the mortality of *D. savignyi* was predominant on growth.

Again, from the probability curve of capture, the values estimated for the size at first capture was slightly less than the average converted length which showed that smaller size is also caught in the fishery. This also means that smaller sizes are not giving the opportunity to mature into full adult size before harvesting (Hunter, Speirs and Heath, 2015). Moreover, it could be attributed to small size net and illegal fishing gears used in the harvesting of the species. It is therefore recommended that large mesh sized nets of above 8.5 cm can be used for sustainability of the fishery.

The growth performance index (ϕ) obtained is the basis for comparison of growth indicators with the von assumption of Bertalanffy model. The index is the accurate and genuine procedure of computing the average growth parameters of a particular species (Okamoto et al., 2020). Henceforth, it should not differ significantly from compared values of different groups of data for the same kinds. However, the result obtained for ϕ (2.70) in *D. savignyi* seemed to be in the acceptable range. For the reason that a comparable study conducted by Shipp et al. (2015), who obtained the value of $\phi = 2.43$. The classified growth performance index between the range of 2.65 to 3.32 is considered as a slow growth rate (Alaba OLOPADE, 2019). However, natality in population ecology is the scientific term for birth rate. Along with mortality rate, natality rate is used to calculate the dynamics of a population. They are the key factors in determining whether a population is increasing, decreasing or staying the same in size (Kindsvater et al., 2016). Natality is the greatest influence on a population's increase. The slow growth performance of *T. gartilla* obtained in the present study could be attributed to natality as it has a paramount influence to cause a population to increase or decrease. Therefore, natality in the study site should be discouraged.

Natality in population ecology is the scientific term for birth rate. Along with mortality rate, natality rate is used to calculate the dynamics of a population. They are the key factors in determining whether a population is increasing, decreasing or staying the same in size. Natality is the greatest influence on a population's increase.

In our study, the recruitment pattern of *D. savignyi* was found to be continuous throughout the year. The lowest and the highest percentage of recruitments were observed in May (1 %) and September (<19 %), respectively. Until now, there has been no published report on the recruitment of *D. savignyi* in Red in Saudi Arabia. However, the previous study of recruitment pattern of another species of *T. gratilla* in Southern Guimaras waters revealed that the

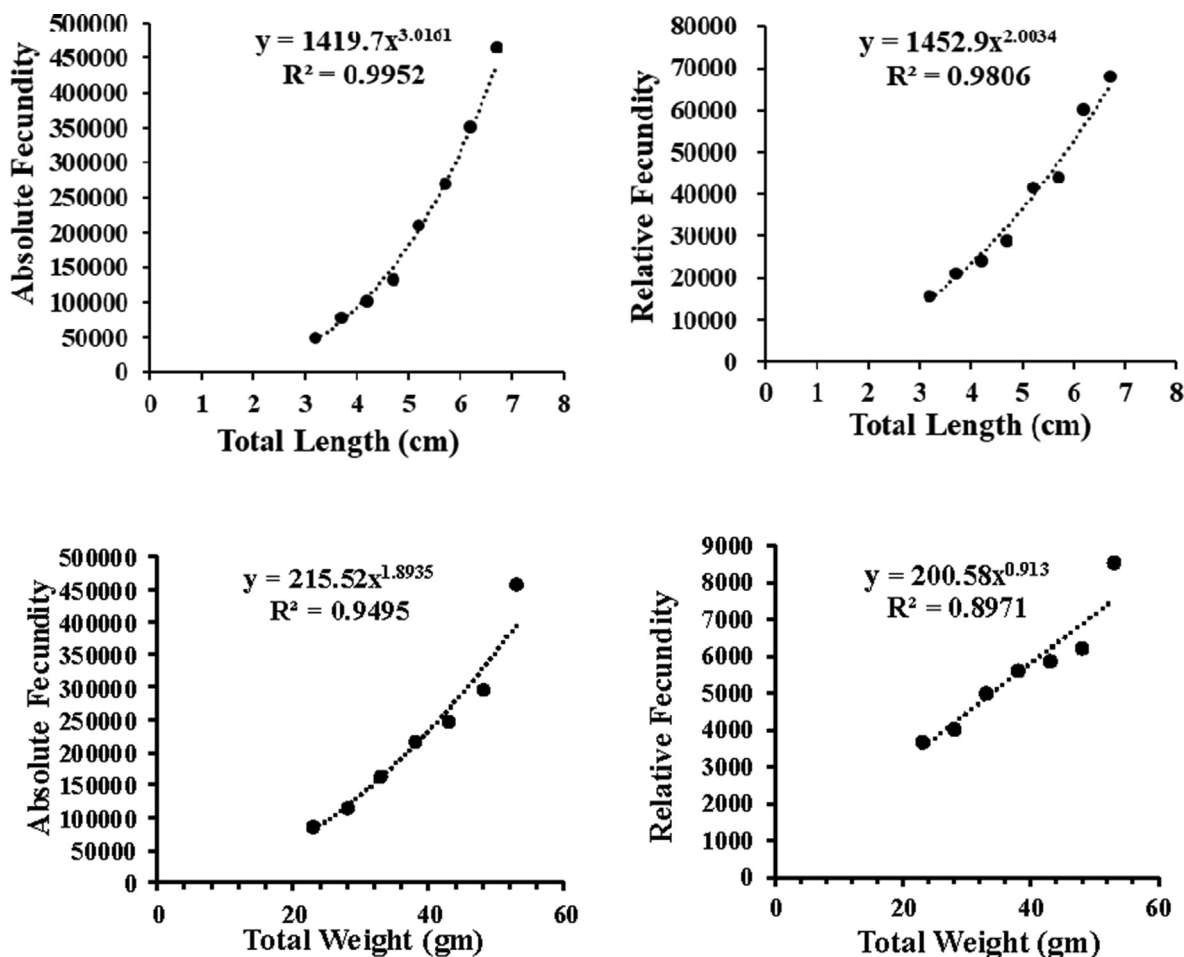


Fig. 10. Relationship between the absolute fecundity (F) and total length (TL) also revealed linear regression model with a positive and significant relationship at $p < 0.05$.

recruitment occurred almost throughout the year with two peaks separated by four to five months (Seymour et al., 2013). The present study demonstrates that *D. savignyi* attained a maximum size of 7.5 cm within the 6.5 years of age. Previous study demonstrated that an individual with 6.5 to 7.5 cm on the other coast of Kenya can be 3 to 5 years old (Muthiga, 2003). The vary results comparisons can be said that lifespan and size is dependent on the location of the species natural habitat and other factors. It indicated that *D. savignyi* has high growth coefficient in this area and it may for high organic matter due to the industrial area.

5. Conclusion

D. savignyi is a fast-growing species compare to the other Sea Urchin in the world. The population has documented less natural mortality and fishing mortality that wild stocks are still not minimal, and the stocks can be said 633 to be not exploited Therefore, it is to be threatened for the biodiversity such as algae and seagrass community on the coral reef. Furthermore, regular monitoring of stocks and analysis of capture data will allow for improve management of the fishery for better conservation of the resource as well as more profitable and sustainable fishing.

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Declaration of Competing Interest

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

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