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# External Morphology and Some Biometric Characteristics of the Deep-water Redfish *Actinopyga echinites* (Echinodermata, Holothuroidea) in Cabgan Island, Barobo, Surigao del Sur, Philippines

Marnelle B. Sornito[1,2*], Venus E. Leopardas[2,3], Elgen M. Arriesgado[2,4], Mariefe B. Quiñones[2,3], Emilie G. Tubio[2,3]

[1]School of Graduate Studies, Mindanao State University at Naawan, Naawan, Misamis Oriental 9023 Philippines
[2]Sea cucumber Research and Development Center, Mindanao State University at Naawan, Naawan, Misamis Oriental 9023 Philippines
[3]College of Science and Environment, Mindanao State University at Naawan, Naawan, Misamis Oriental 9023 Philippines
[4]School of Marine Fisheries and Technology, Mindanao State University at Naawan, Naawan, Misamis Oriental 9023 Philippines

[*]Corresponding author: marnelle.sornito@gmail.com

**ABSTRACT**

*Actinopyga echinites* (Jaeger, 1833) is among the most exploited holothurians for exports in the Philippines. Despite its economic significance, the lack of management initiatives resulted in declining wild stocks. This study provides information on external morphology and biometric characteristics like length-weight relationship and condition factor of *A. echinites* for proper management and sustainability. The study was conducted in dry (March to May 2021) and wet (June to August 2021) seasons in Cabgan Island, Barobo, Surigao del Sur, where two stations with three plots (10 × 10m) were laid as monitoring stations. The results revealed that *A. echinites* showed coloration and shape variation to adapt to their environment. Higher mean length (7.7cm) and significantly higher mean weight (41.5g) were observed in *A. echinites* in Station 2 than the ones in Station 1 ($p < 0.05$). Both stations had a higher length (7.8cm and 8.4cm) and weight (38.4g and 49.7g) during wet than dry months, but only Station 2 showed significant differences for the two parameters. The population showed a negative allometric growth resulting in its leaner shape, with the slope of regression lines being 1.89 and 1.82 in Station 1 and 1.75 and 1.97 in Station 2 for the dry and wet months, respectively. Both stations recorded high condition factors but significantly higher during the wet season ($p < 0.05$). Further study on the reproductive biology and environmental characteristics is needed to enhance scientifically sound management interventions for the conservation and sustainability of *A. echinites* populations.

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## INTRODUCTION

The sea cucumber *Actinopyga echinites* (Jaeger, 1833) is one of the most commercially exploited holothurians in Mindanao (Brown et al., 2010). Despite being commonly known as "deep-water redfish," the species is abundant in shallow seagrass beds and reef flats in the tropical countries of Asia, Africa, and Indian Ocean regions (Conand et al., 2013; Setyastuti et al., 2018). Currently, edible sea cucumbers have undergone intense fishing pressure to supply the market demand (Bennet and Basurto, 2018), leading to the decline of most commercially exploited sea cucumber populations. This includes *A. echinites*, which is among the eight sea cucumber species registered as vulnerable in the IUCN red list (Conand et al., 2014). However, the paucity of information on the biology, ecology, and fisheries hinders the formulation and implementation of management initiatives of this species.

There are different factors needed to evaluate the status of a particular species. Morphological data are one of the factors needed to serve as the basis for the taxonomic identification and characterization of phenotypic plasticity of an individual to the environment (Ebert et al., 1996). The information on length-weight relationships is a valuable parameter for fisheries research and management purposes (Natan et al., 2015). They estimate the weight at age or biomass estimates from the total reported catch weight and length distributions and help obtain condition indices (Gerritsen and McGrath, 2007; Ahmed et al., 2019). The obtained biomass estimates are significant in assessing the status of sea cucumber stocks (Purcell et al., 2010). The condition factor obtained from the length-weight relationship determines the well-being or fatness of species (Ahmed et al., 2018). Hence, these different aspects are prerequisites to evaluate sea cucumbers for proper management and sustainability (González-Wangüemert et al., 2016).

Several studies have been conducted concerning biological parameters such as length-weight distributions, and condition factors of some sea cucumber species (Natan et al., 2015; Ahmed et al., 2018a, 2020b; Veronika et al., 2018); However, studies for *A. echinites* were limited and are conducted outside the Philippines such as in New Caledonia (Conand, 1982); Papua New Guinea (Kinch et al., 2008) and La Reunion (Kohler et al., 2009). This study was conducted to bridge this information gap by determining the morphology and biometric characteristics such as length-weight relationship and condition factor of *A. echinites* in Cabgan Island, Barobo, Surigao del Sur in dry and wet seasons.

## MATERIALS AND METHODS

### Sampling Collection

This study was conducted in Cabgan Island in Barobo, Surigao del Sur, one of the sea cucumbers exploited fishing grounds in the province. Two stations with three plots measuring 10×10m and 20m distance were established on the island and laid parallel to the shore (Fig. 1). Station 1 (8.5663°N, 126.1642°E) is a shallow, multi-species seagrass bed dominated by *Cymodocea rotundata* with a 61% coarse sand substrate. On the other hand, Station 2 (8.5660°N, 126.1621°E) is a seaweed area mixed with *Halimeda sp*., *Hormophysa sp*., *Padina sp*., and *Sargassum sp*. The local sea cucumber gatherers identified the two habitats as the most prevalent places occupied by these species, making such areas their main fishing grounds. There were 529 *A. echinites* individuals collected from the two stations (279 individuals in Station 1; 250 in Station 2). Samples were collected at different times throughout the year: Dry season from March to May 2021 and the wet or rainy season from June to August 2021. The Philippine Atmospheric, Geophysical, and Astronomical Services Administration (PAG-ASA) reported the designation of the dry and rainy seasons.

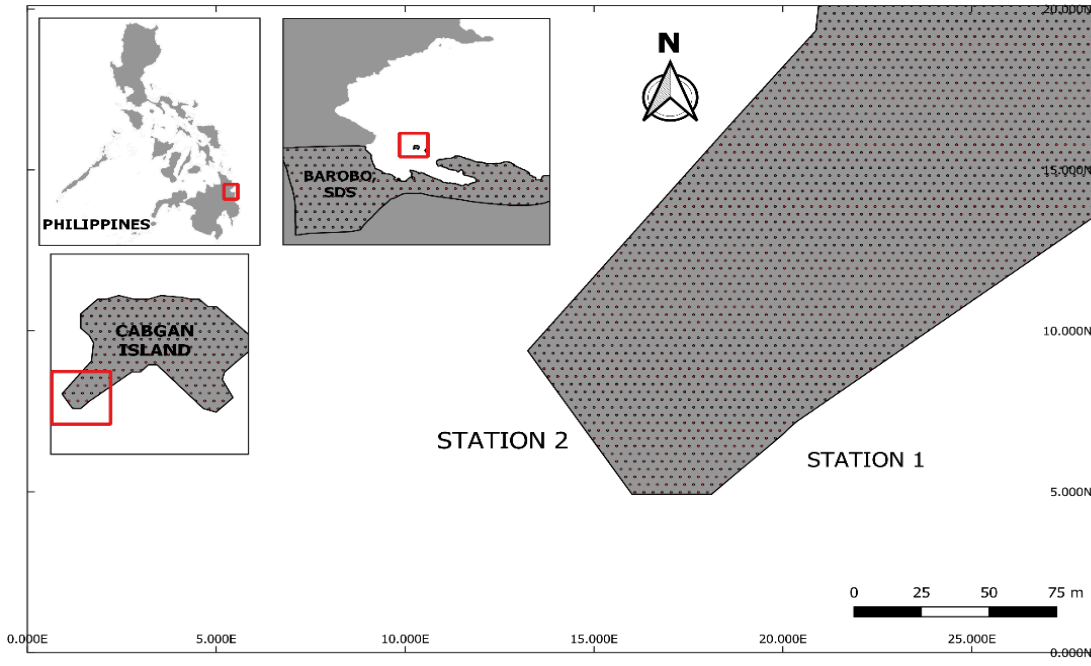



**Figure 1.** The Sampling Site of the Study.

**Identification of Specimens**

For species identification, external morphological examination and microscopic analysis through spicule collection were conducted. External characteristics of each organism were examined and recorded following Appeltans (2002) (Tab.1). External morphological differences between juvenile and adult *Actinopyga echinites* were recorded if juveniles were present. Juveniles were characterized by the presence of five short truncate teeth closed by a black-colored sphincter, twenty peltate whitish tentacles, and white Cuvierian tubules that were low in number (Weidemeyer, 1994). Adults were characterized by twenty peltate brownish tentacles and light pink Cuvierian tubules (Weidemeyer, 1994).

Aside from external morphological examinations, tissue subsampling was conducted by collecting ossicles from ten (10) representative individuals of random size in each station in every sampling following Ahmed *et al*. (2019). Ossicles were taken from three positions (dorsal and ventral body walls and tentacles) and placed in an Eppendorf tube. A few drops of 3.5% bleach were added to the tissue for dissolution. The sampled ossicles were transferred in a glass slide and examined under a compound microscope at × 40 magnifications in the laboratory. Microphotography was also performed through a camera phone.

**Size Measurements**

Every month of the sampling period, all specimens of *Actinopyga echinites* found in the sampling plots were placed in a pail of seawater and brought to the shore for length and weight measurements. Total length (TL) was measured from the mouth to the anus using a tape measure (0.1cm precision), taking care to avoid body contraction. The total drained weight (TW) was measured with a digital scale (1.0g precision). The measurement in length and weight were repeated up to three times and getting the average to avoid biases of the sample measurements.

**Data Analysis**

The data collected for the morphological examination was descriptive. Pictures were used to show the distinguishing morphological characteristics of *Actinopyga echinites*, including the ossicle features.

Length-weight relationships were computed for specimens by a regression analysis using MS Excel software, following the model of Pauly (1984),

$$\boldsymbol{W = aL^b}$$

**Table 1.** External morphological characters and their potential states identify sea cucumbers in the family Holothuriidae (Appeltans, 2002).

| **External morphological character** | **Possible character states** |
|---|---|
| overall shape | *i*) cylindrical, *ii*) oval, or *iii*) quadrangular |
| tentacle shape | *i*) peltate, *ii*) disc-like, *iii*) bushy, or *iv*) composite-like - looking like a packed-up bouquet |
| position of mouth | *i*) terminal to subterminal, or *ii*) clearly ventral |
| position of anus | *i*) terminal, *ii*) super terminal, *iii*) subdorsal or *iv*) clearly dorsal |
| average number of tentacles | *i*) maximum of 20 or *ii*) more than 20 |
| arrangement of ventral tube feet | *i*) spread over radial and interradial areas or *ii*) majority restricted to radial areas only |
| presence of anal papillae or anal teeth | *i*) absence of anal teeth or anal papillae, ii) presence of anal teeth, iii) presence of anal papillae |
| rugosity of body wall | *i*) smooth to touch or *ii*) rough to touch |
| hardness of body wall | *i*) soft or *ii*) hard |
| body coloration | *i*) light brown, *ii*) dark brown, or *iii*) white |
| Cuvierian tubules | *i*) absent or *ii*) present |
| color of Cuvierian tubules | *i*) white or *ii*) pink |
| expel ability of Cuvierian tubules | *i*) expellable or *ii*) not expellable |

where *W* is the wet body weight (g), a is the intercept, *L* is the total length (cm), and *b* is the slope of the regression line.

Condition factor of sea cucumber was calculated following Froese (2006),

$$CF = \frac{W}{TL^3} \times 100$$

where *W* is the wet body weight (g), *TL* is the total length (cm), and *CF* is the condition factor.

### Statistical Analysis

Parameters were analyzed using PAST Software (v.4.03) (Hammer et al., 2001). Normality of data was assessed using the Shapiro-Wilk test, and whenever necessary, the log-transformation log (x + 1) was used. Allometric growth occurred when either $b > 3$ (negative) or $b < 3$ (positive). The *CF* difference between the two stations and seasons was also tested using Student's T-test if the data are normally distributed or Mann-Whitney Test when data are non-parametric. The significant difference shows $p$-value $< 0.05$.

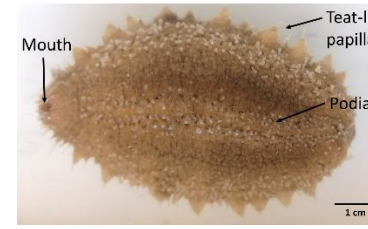
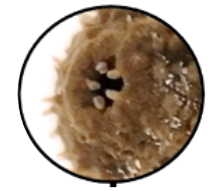
## RESULTS AND DISCUSSION

### Morphological Characteristics

Table 2 describes the external features of *Actinopyga echinites* collected in Cabgan Island, Barobo, Surigao del Sur, which are the same characteristics described for an adult *A. echinites* (Purcell et al., 2012). The color of *A. echinites* varied from light beige to brownish-black in the dorsal body and have an elongated shape (Fig. 2), although they tend to become ball- or oval-shaped when disturbed. Echinoderms exhibit phenotypic plasticity in response to varying environmental conditions (Ebert, 1996). This phenotypic plasticity and adaptation enhance survival and increase the fitness of individuals. In the case of *A. echinites*, individuals would adapt by having identical coloration to their surrounding environment to avoid predators. Unlike juveniles, adults are not cryptic, do not bury, and stay only above the sediments (Weidemeyer, 1994). For these reasons, they are more yellowish-brown to brownish-black when they are in the seaweed area and light beige in the sandy and rubble parts. In addition, their body also caters to various macroalgae, which makes them difficult to find. Holothurians are generally elongate in shape; however, the unique feature of *Actinopyga* was that they turn like a "ball" when disturbed. Since *Actinopyga* species do not have sticky and expellable Cuvierian tubules, unlike the genera *Bohadschia*, *Holothuria*, and *Pearsonothuria* (Becker and Flammang, 2010), this "ball-like" feature might be the defense mechanism of species belonging to the genus *Actinopyga*. Juveniles were absent during the sampling, probably due to their cryptic behavior.

Two types of ossicles were observed in the samples. These are rod and rosette types (Fig. 3), although each ossicle type had different variations. The ossicles of *A. echinites* were variable and complex. They have various rods and rosette types, providing rigidity and protection to the organism.

**Table 2.** External morphological characteristics observed in *Actinopyga echinites* from Cabgan Island, Barobo, Surigao del Sur.

| Character | State | Pictures |
|---|---|---|
| Color | variable, ranging from light beige to brownish-black | |
| Dorsal | with fine dark marks, surrounded by pimply papillae; arch | see Fig. 2 |
| Ventral | flattened, surrounded by light-brown podia arranged within ambulacra |   |
| Anus | dorsal, surrounded by five conical white anal teeth |  |
| Mouth | ventral, with 20 brown, stout, peltate tentacles |  |
| Shape | elongate, tending to "oval" when disturbed | see Fig. 2 |
| body wall | Rough | |
| Cuvierian tubules | not expellable, pink color, fine and unbranched |  |

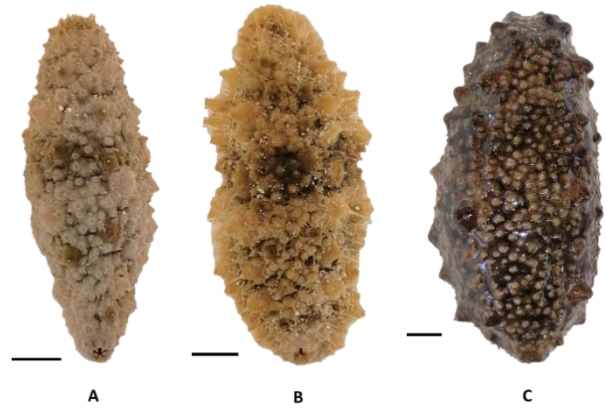



**Figure 2.** Three specimens of *Actinopyga echinites* from Cabgan Island showed variation in coloration from light beige (A), yellowish-brown (B), and brownish-black (C). Bar = 1 cm.

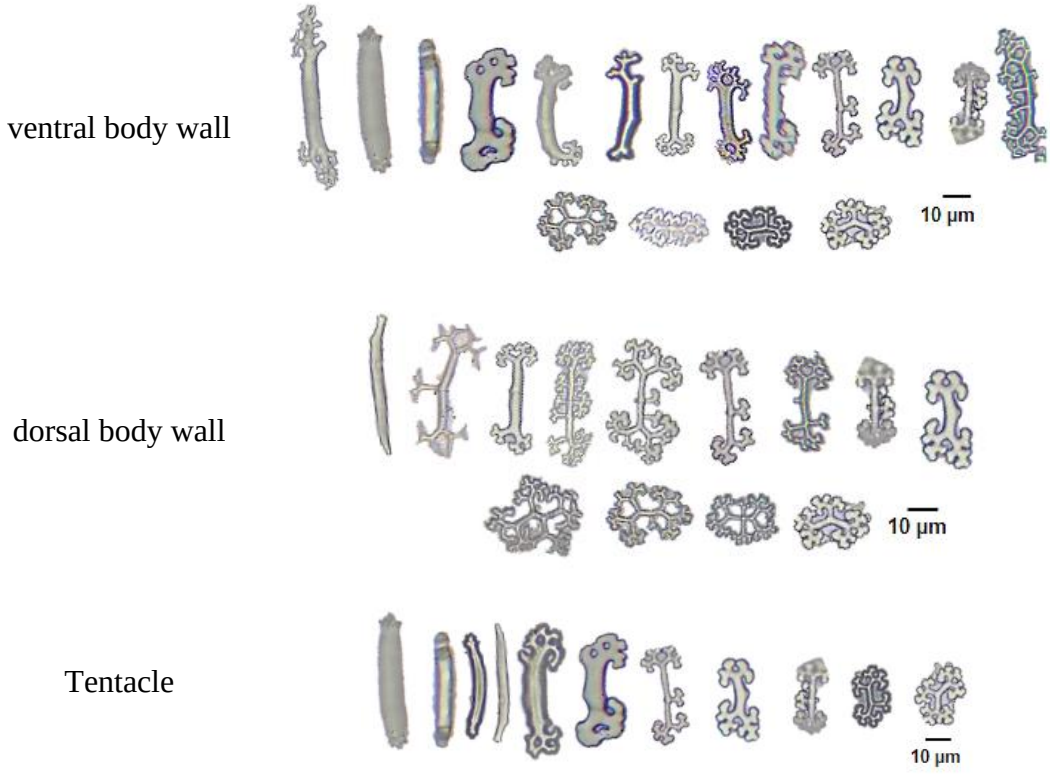



**Figure 3.** Observed types of ossicles collected in the ventral and dorsal walls and tentacles of *Actinopyga echinites*. Shown are different sizes and morphology of rod and rosette-type ossicles.

**Size Composition**

This study showed a higher mean total length and weight of A. echinites in Station 2 than Station 1 (Tab. 3). However, only the mean total weight of A. echinites showed significant differences ($p < 0.05$). Furthermore, each station's dry vs. wet season comparison showed a higher mean length and weight of A. echinites during the wet season than in the dry season. However, only Station 2 showed a significant difference in the mean total length and weight between the two seasons ($p < 0.05$). During the dry season, A. echinites had a length ranging from 4.0–11.0cm and a weight of 7.0–130.0g for Station 1 and 4.0–10.5cm and 9.0–105.0g in Station 2. In contrast, the length and weight sizes of A. echinites during the wet season were 5.5–23.0cm and 12.0–129.0g, respectively, in Station 1 and 5.0–13.5cm and 14.0–130.0g in Station 2.

**Table 3.** Summary of the sizes (maximum, minimum, mean, and standard error of the mean) of *Actinopyga echinites* between the two stations and seasons collected in Cabgan Island, Barobo, Surigao del Sur. Means followed by letters show a significant difference ($p < 0.05$, Student's T-test).

| Station | Season | N | Total Length (cm) | | | | Total Weight (g) | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | $L_{min}$ | $L_{max}$ | $L_{mean}$ | SE | $W_{min}$ | $W_{max}$ | $W_{mean}$ | SE |
| 1 | Dry | 188 | 4.0 | 11.0 | 7.3 | 0.1 | 7.0 | 130.0 | 38.1 | 1.8 |
| | Wet | 91 | 5.5 | 12.0 | 7.8 | 0.1 | 13.0 | 129.0 | 38.4 | 1.9 |
| **Mean** | | | **4.8** | **11.5** | **7.6** | **0.1** | **10.0** | **129.5** | **38.2$^{b}$** | **1.9** |
| 2 | Dry | 146 | 4.0 | 10.5 | 7.1$^{a}$ | 0.1 | 9.0 | 105.0 | 33.3$^{b}$ | 1.6 |
| | Wet | 104 | 5.0 | 13.5 | 8.4$^{b}$ | 0.2 | 14.0 | 130.0 | 49.7$^{a}$ | 2.7 |
| **Mean** | | | **4.5** | **12.0** | **7.7** | **0.2** | **11.5** | **117.5** | **41.5$^{a}$** | **2.1** |

The results showed a significantly higher mean weight of *A. echinites* in Station 2 (characterized by seaweeds area) than in Station 1 (seagrass beds). These were also observed for *Holothuria arguinensis*, where a higher density of light and smaller individuals were found at seagrass beds with low organic matter content (Domínguez-Godino and Gonzáles-Wangüemert, 2020). Accordingly, this habitat complexity in the seagrass beds could support the large population density of smaller and lighter *A. echinites* individuals.

Higher mean size values recorded during wet months may be due to the differences in the maturity stage of the sea cucumber individual. There is a positive correlation between the gonad tubule size and maturity stages, such as in *A. mauritiana* in the Solomon Islands (Ramofafia et al., 2001). The species have attained a maximum gonad weight during mature stages of 63.5g and 44.1g for males and females,

respectively, which also correspond to their heavier body weight. Thereby, the lighter weight of *A. echinites* populations during dry months might indicate that the gonads are still at the early maturity stage or the species have spawned. The latter showed a higher possibility as studies revealed that the spawning cycle of *A. echinites* in New Caledonia corresponded to the warm season (Conand, 1982) and increased solar radiation (Kohler et al., 2009). In contrast, the higher mean weight during the wet season could be that the gonads develop to mature for another spawning event. However, subsequent research focusing on the species' reproductive biology is needed.

In this study, the sizes of *A. echinites* specimens were variable and smaller compared to the average length (20cm), the maximum length of 35cm, and weight (300g) in the Western Central Pacific Region (Kinch et al., 2008). Aside from *A. echinites*, most commercially exploited sea cucumbers have reduced sizes like Samar and Leyte (Dela Cruz et al., 2015) and Rasa Island Wildlife Sanctuary, Narra, Palawan (Dolorosa et al., 2017). Although body sizes are not a good indicator of age and longevity, length was assumed greater in a natural, undisturbed environment (Conand et al., 2013). Thus, the high fishing pressure in Barobo, Surigao del Sur negatively affects the population size of *A. echinites*. This is the same for *H. scabra*, whose population dramatically decreases with fishing activities despite suitable environmental conditions (Hasan, 2005) and other commercially-exploited sea cucumbers in Samar and Leyte (Dela Cruz et al., 2015).

The length-weight relationships of *A. echinites* in Stations 1 and 2 in two seasons showed negative allometric growth characteristics ($b < 3$) (Fig. 4). The results suggest *A. echinites* individuals were leaner, same for other holothurians (Ahmed et al., 2018; Veronika et al., 2018). Furthermore, our study showed a positive correlation between length and weight, which is consistent with prior studies in adult *Holothuria scabra* (Yussuf and Yahya, 2020) and for *H. arenicola*, *H. atra*, *H. pardalis*, and *H. verrucosa* (Ahmed et al., 2018). The $r^2$ values were 0.54 and 0.52 in Station 1 and 0.51 and 0.73 in Station 2 for the dry and wet seasons, respectively. The higher $r^2$ values of $> 0.7$ in Station 2 during the wet season indicated a better population fit for the length-weight relationship model. The length-weight relationship of *A. echinites* in New Caledonia showed $a = 1.31$, $b = 1.96$, $r^2 = 0.4$ n = 58 (Kohler et al., 2009), which has a higher slope ($b$) value than the study but has a lower $r^2$ value, although both studies showed negative allometric relationship.

The condition factors of *A. echinites* were $6.9 \pm 0.2$ and $8.0 \pm 0.3$ in Station 1 for dry and wet seasons, respectively, and $8.0 \pm 0.3$, and $8.6 \pm 0.3$ for Station 2; these

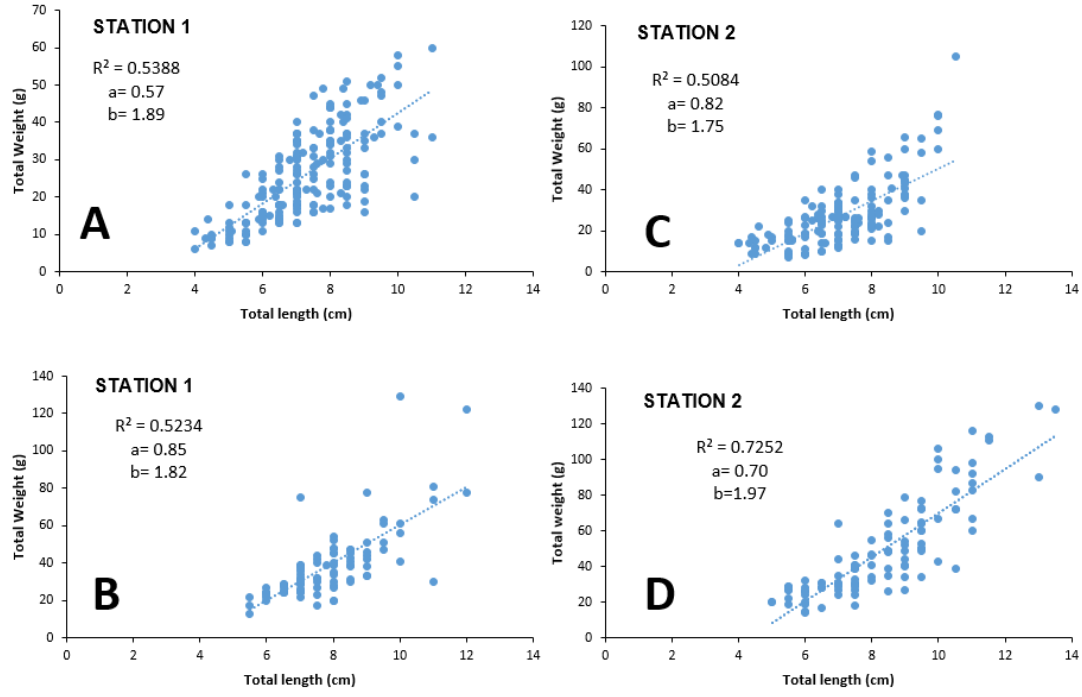



**Figure 4.** Length-weight relationships of *Actinopyga echinites* in the Two (2) stations in the dry (A, C) and wet (B, D) season collected in Cabgan Island, Barobo, Surigao del Sur.

values were statistically higher in the wet season compared to the dry season in each station (Mann Whitney test, $p < 0.05$) (Tab. 4). However, a comparison of the condition factor of the two stations revealed significant differences only during the dry season. A condition factor is used to compare the well-being of organisms and the environment's health (Pauly, 1983). The differences in the condition factors in both the stations and seasons may be due to varied environmental parameters that could affect the "well-being" of the species (Ahmed et al., 2019). Accordingly, the higher the condition factor, the species attained better condition. Both stations showed higher condition factors during the wet season in the present study. Environmental factors such as storms and rainfall may have possibly helped transport nutrients and organic matter needed by *A. echinites* species. This also coincided with the higher mean weight during wet months. A higher condition factor was observed in Station 2 than in Station 1 during dry months. Station 1 is shallower than Station 2 and was exposed during the lowest low tides. Therefore, Station 1 became an unsuitable habitat for sea cucumbers during the dry season due to the long periods of desiccation which may pose health risks to the species.

This was also observed on the sea cucumber *Holothuria arguinensis* showing low density in the highest part of the intertidal zone of Ria Formosa Lagoon due to high exposure of radiance during summer (Domínguez-Godino and Gonzales-Wangüemert, 2020). Nevertheless, values of the condition factors in the present study are higher, indicating the species are in good physical condition.

**Table 4.** Condition factor of *Actinopyga echinites* between the two stations and seasons collected in Cabgan Island, Barobo, Surigao del Sur.

| Station | Season | N | Condition Factor | | | |
|---|---|---|---|---|---|---|
| | | | $CF_{max}$ | $CF_{min}$ | $CF_{mean}$ | SE |
| 1 | Dry | 188 | 17.2 | 1.7 | 6.9 | 0.2 |
| | Wet | 91 | 21.9 | 2.3 | 8.0 | 0.3 |
| Mean | | | | | 7.5 | |
| 2 | dry | 146 | 22.6 | 2.3 | 8.0 | 0.3 |
| | wet | 104 | 18.7 | 3.4 | 8.6 | 0.3 |
| Mean | | | | | 8.3 | |

## CONCLUSION AND RECOMMENDATION

The study provides valuable results on some biological aspects of *Actinopyga echinites* in Cabgan Island, Barobo, Surigao del Sur needed for stock enhancement and management. *Actinopyga echinites* populations showed phenotypic plasticity such as varying coloration and the tendency to form ball-shaped when disturbed. These are some of their adaptive mechanisms to enhance their environment's survival. *Actinopyga echinites* in Cabgan Island had smaller average sizes in Station 1 in both seasons. The populations showed negative allometry where length increment is faster than weight increment resulting in their leaner shape. Variations in the condition factor between seasons suggest possible differences in the habitat's environmental parameters, such as high solar radiance during dry months and high nutrients and organic matter inputs during wet months. Further study on the reproductive biology and environmental variables and characteristics that could influence the size and spatial distribution of the species is needed to enhance scientifically sound management interventions for the conservation and sustainability of *A. echinites* populations.

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