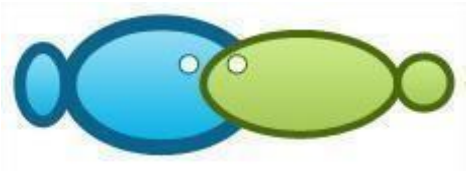

Length-weight relationship and condition factor of wild-caught juvenile Napoleon wrasse (*Cheilinus undulatus* Rüppell, 1835) in Tandubas, Tawi-Tawi, Philippines

[1,2]Khadiza H. Imlan, [1]Yashier U. Jumah, [1]Wahaymin M. Jamil, [1]Gerly-Ayn J. Tupas, [1]Merilyn Q. Amlani, [1]Rizal Jhunn F. Robles, [1]Abdulnaser I. Imlan, [1]Raziman A. Mad-nuri, [1]Abdurizal A. Eldani

[1] Aquaculture Department, College of Fisheries, Mindanao State University-Tawi-Tawi College of Technology and Oceanography, College of Fisheries, Sanga-Sanga, Bongao, Tawi-Tawi, Philippines; [2] Department of Fisheries, College of Fisheries, Mindanao State University-Sulu, 7401 Patikul Site, Sulu, Philippines; Corresponding author: K. H. Imlan, khadizaimlan@msutawi-tawi.edu.ph

Abstract. The Napoleon wrasse (*Cheilinus undulatus*) is an ecologically and economically significant reef species native to Indo-Pacific coral reefs region, but it is increasingly threatened by overfishing and habitat degradation. Despite its endangered status under the IUCN and CITES Appendix II, there are limited data available on the growth patterns and physical condition of juvenile *C. undulatus*, especially in the wild. Thus, this study aimed to assess the length-weight relationship (LWR) and condition factor (K) of wild-caught juvenile *C. undulatus.* A total of 150 juvenile *C. undulatus* were bought from fishermen in Tandubas, Tawi-Tawi, Philippines. Samples were analyzed for its total length and weight using standard biometric methods. The LWR analysis of wild *C. undulatus* revealed a positive allometric growth pattern (b = 3.09), indicating that the fish grew more in weight than length, a typical trend in juvenile fishes. A coefficient of determination (R^2) of 0.92) demonstrated a fitness of the data on the positive linear equations. It suggest the positive correlation of weight and total length in juvenile *C. undulatus.* Furthermore, the average K of 1.543 indicated that the juvenile *C. undulatus* were in good physical condition, suggesting favorable environmental conditions in their natural habitat. Overall, the study implicates the coral-reef conditions of Tandubas, Tawi-Tawi where *C. undulatus* thrive.
Key Words: coral reef fisheries, endangered species, growth-pattern, k-value, Labridae.

Introduction. The Napoleon wrasse (*Cheilinus undulatus* Rüppell, 1835) is a large, reef-associated fish found across Indo-Pacific coral reefs (Romero & Injani, 2015). As one of the most iconic and ecologically significant reef fishes, it plays a vital role in coral reef ecosystems by regulating populations of invertebrates such as sea urchins and crown-of-thorns. Aside from its role in the ecosystem, *C. undulatus* is also important for culture and the economy, especially in Southeast Asia where it's very popular in the live reef food fish trade (Sadovy et al., 2003; Gillett, 2010). Because it sells for a high price, it's been heavily caught in Indonesia, the Philippines, and Malaysia. Together with habitat loss, this has caused its population to go down a lot. That's why it has been listed as endangered and it's also included in CITES Appendix II (Russell, 2004), which controls its trade between countries (Poh & Fanning, 2012). Despite its conservation status, limited scientific information is available on the species' population structure, growth patterns, and life history traits, particularly in the wild. Recent study of Romero & Injani, (2015) have explored aspects of captive breeding and larval development. However, studies on the length-weight relationship (LWR) of this species in the wild are extremely scarce. To date, no published LWR studies have focused specifically on wild *C. undulatus* populations in the southern Philippines particularly in Tawi-Tawi. Thus, this study aims to determine the LWR of wild *C. undulatus*, contributing baseline data that can be used for future stock

assessments, conservation planning, and sustainable management of this ecologically and economically valuable species.

Material and Method

Sampling site and experimental species. The sampling was done at the Floating Cage Station, College of Fisheries, Mindanao State University - Tawi-Tawi College of Technology and Oceanography, Sanga-Sanga, Bongao, Tawi-Tawi, Philippines. The measurements were taken immediately after the species arrived from the collecting site at the sampling site on September 16, 2024. Juvenile *C. undulatus* was used as the experimental species. These juveniles were bought from the coastal waters of Tandubas, Tawi-Tawi, Philippines and were transported to the experimental site via boat. Upon arrival, the fish were subjected to a 30-minute acclimatization period before being gradually released into the cage.

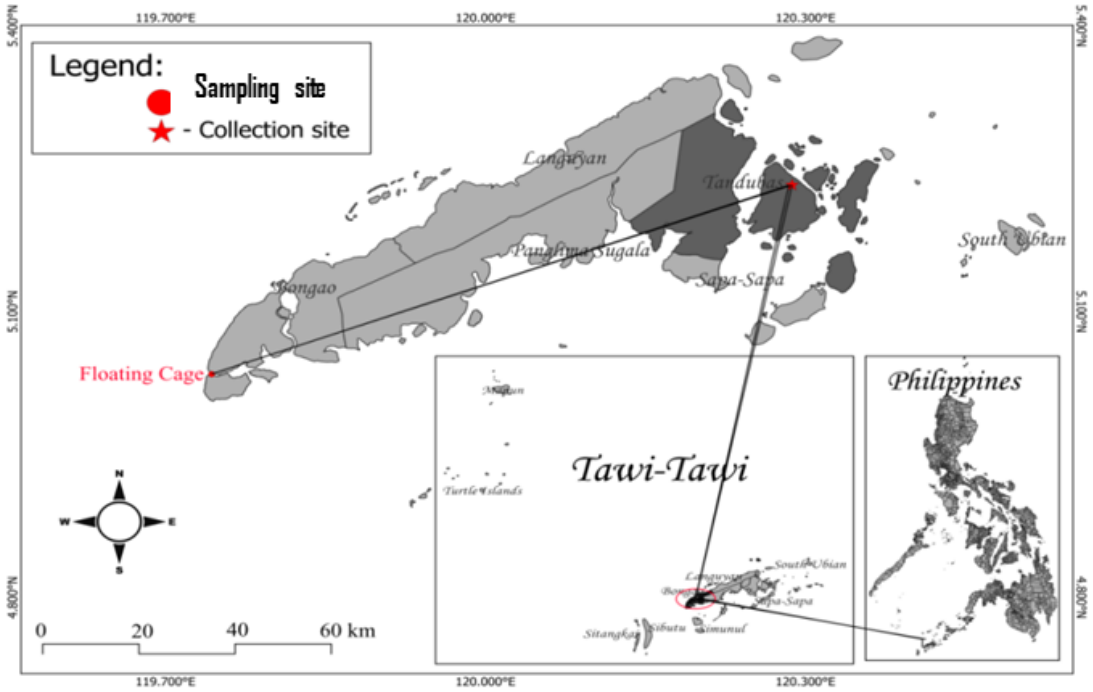

Figure 1. Map showing the sampling and collection site.

Sampling. One hundred fifty (150) wild-caught juvenile *C. undulatus* were individually scope and anesthetized using clove (*Syzygium aromaticum*) oil at one (1) drop L^{-1}. Paralyzed fish was measured for its total length (cm) and weight (g) individually using ruler (brand) and portable digital weighing scale (brand) respectively. Fish were immediately returned to conditioning cage for fast recovery.

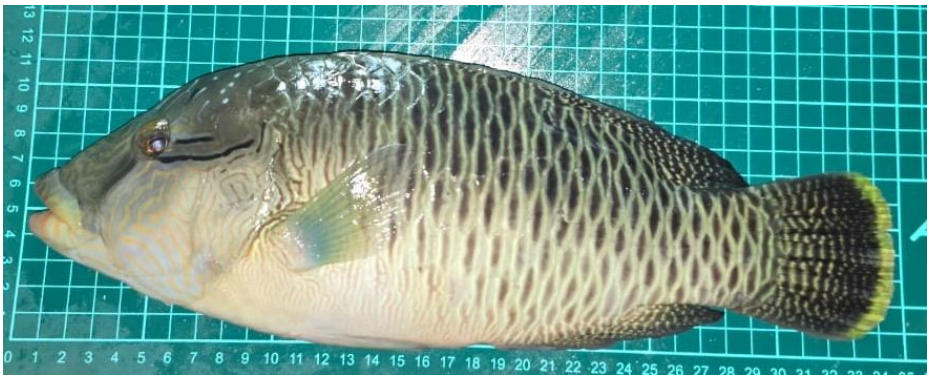

Figure 2. Juvenile *C. undulatus*.

Growth pattern analysis. The Allometric Linear Model (ALM) was applied to calculate the "a" and "b" parameters through the measurement of weight (g) and length (cm) changes. The LWR was determined using the formula described by Pauly, (1983):

$$W = aL^b$$

where: W = weight of fish (g);
L = total length of fish (cm);
a = describes the rate of change of weight with length (intercept);
b = weight at unit length (slope).

To estimate the parameters 'a' and 'b', the equation was logarithmically transformed into the linear form:

$$\log W = \log a + b \log L$$

Condition factor. The condition factor (K) was calculated to assess the general health and well-being of the fish using Fulton's formula (Fulton, 1902):

$$K = W/L^3 \times 100$$

where: K = condition factor;
L = total length of fish (cm);
W = weight of fish (g).

Then, the scaling factor of 100 was used to bring the K close to the unit.

Statistical analysis. All data were entered in Microsoft Excel™ (2016) and generate linear equation (y = mx+b) to show positive correlation and fitness (R^2).

Results

Length-weight relationship and condition factor. Results demonstrate a "positive allometric" growth pattern for the wild juvenile *C. undulatus* with the computed "b" value of 3.09. Total length (TL) and weight (W) of *C. undulatus* ranged from 210 to 704 g and 27 to 35 cm, respectively. Mean TL and W were 30.70 cm and 446.68 g respectively. Measurements of total length (cm) and body weight (g) were subjected to linear regression analysis. The analysis yielded a coefficient of determination (R^2) of 0.92, indicating strong linear relationship between length and weight in the sampled juveniles. The result of the condition factor of wild *C. undulatus* with average computed absolute relative condition factor (k-value) 1.533 for wild-caught *C. undulatus*. Results are presented in both the Figures 3 and 4 and Table 1.

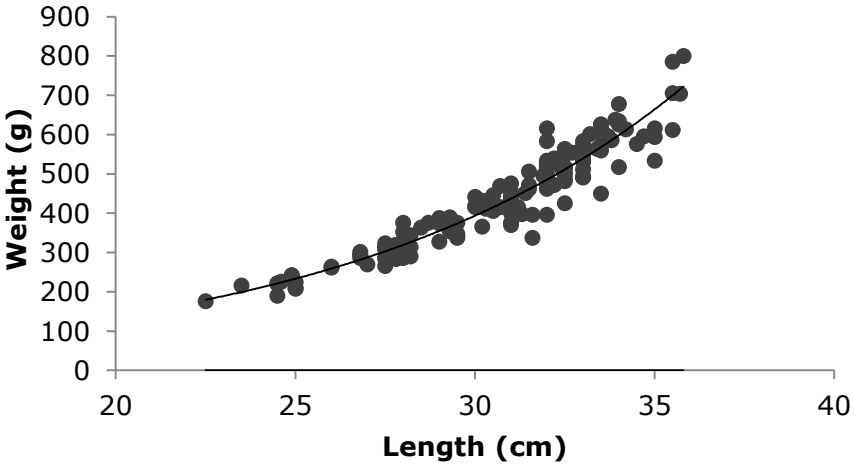

Figure 3. The length-weight relationship of wild juvenile *C. undulatus*.

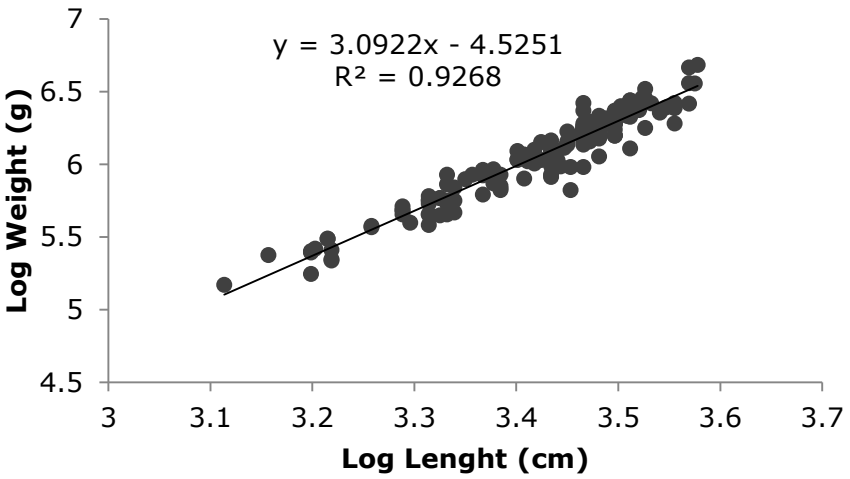

Figure 4. Log length-weight relationship of wild juvenile *C. undulatus*.

Table 1

Length-weight relationship of Napoleon wrasse after a period of 90 culture days

Variables	*a*	*b*	*R^2*	*K-value*	*Growth pattern*
Wild	0.01	3.09	0.92	1.53	Positive allometric

Discussion. The present study revealed the LWR of wild *C. undulatus* a positive allometric growth pattern with parameters a = 0.01 and b = 3.09, meaning the fish became proportionally heavier as they grew longer. However, LWR in juvenile *C. undulatus* has not been yet studied. Tan et al., (2019) found poor growth in *Epinephelus coioides* as their weight didn't really increase along with their length. Reef fishes in marine protected area often show larger size, higher biomass, and advantageous life-history traits than adjacent fished populations, although biophysical context also shapes these outcomes (Fidler et al., 2018; Fidler et al., 2021). In the the same region, Tawi-Tawi, Philippines, coral reef fishes show mixed growth patterns, with positive allometry reported for a minority of species and isometric growth most common (Muallil et al., 2023). Our study supports these results, showing that fish in healthy reefs grow better because they have enough food, shelter, and good environmental conditions.

However, LWR values can still change with the season, breeding stage, location, environmental conditions, and fishing activity (Karna et al., 2012). In the area where fish are overfished or stressed populations, lower b-values (indicative of isometric or even negative allometric growth) have been described. Therefore, the positive growth trend observed in this study suggests that, despite its globally endangered status, the sampled population of *C. undulatus* in Tandubas, Tawi-Tawi may still be in relatively good condition likely promoting from the province's rich reef systems and less intensive exploitation compared to other regions. Compared to other large reef-associated fish like groupers *Epinephelus* spp., *C. undulatus* displays a more prolonged growth line and larger maximum size. Groupers tend to show faster early-stage growth but do not reach the same maximum sizes. Moreover, groupers are more sedentary and exhibit site fidelity, whereas *C. undulatus* range widely and actively across reef zones, contributing to their biomass accumulation (Heemstra & Randall, 1993). The ecological status of *C. undulatus* in Tawi-Tawi also benefits from relatively low development pressure and healthy coral reef habitats, making it one of the few areas where wild populations continue with some stability. Lunar periodicity may further influence the growth and reproductive cycles of wrasses. Romero & Injani, (2015) noted that *C. undulatus* exhibits lunar-synchronized spawning, particularly during the third-quarter moon, which affects activity patterns, feeding behavior, and possibly growth rhythms. Despite this, the global population of *C. undulatus* continues to decline. Overexploitation especially of large reproductive adults combined with habitat loss and high market demand, has led to the

species being listed as Endangered by the IUCN (Sadovy et al., 2003). The size and slow reproductive cycle of this species make recovery difficult once populations are depleted.

The present study shows a strong positive correlation ($R^2 = 0.92$) between length and weight in wild *C. undulatus*, showing that the LWR model fits. According to Goodman & Pauly, (1993), an R^2 value above 0.80 suggests that the LWR is robust and can reliably estimate fish biomass in the wild. This high coefficient implies that body weight in *C. undulatus* can be accurately predicted from length measurements, which is particularly valuable in fieldwork where non-lethal, rapid assessments are essential. Similar findings have also been reported in groupers, another group of ecologically and commercially important reef-associated apex predators. The study of Das et al., (2022) revealed an R^2 of 0.91 in wild *Epinephelus fuscoguttatus* (brown-marbled grouper), while Achmad et al., (2022) reported an R^2 of 0.94 in *E. coioides* (orange-spotted grouper), indicating consistent reliability of LWR models in these species. In both cases, the strong correlation was used as a source for biomass estimation and population monitoring, specifically in the context of fisheries management and conservation. Other reef fish studies echo these results. Mazumder et al., (2016) observed a high R^2 (0.93) in *Lutjanus malabaricus* (Malabar snapper), highlighting that reef-associated carnivorous fish often display strong LWRs when sampled from healthy habitats. These values not only reflect the mathematical strength of the model but also show biological consistency and the fish's likely growth in uninterrupted environments.

Moreover, the calculated condition factor ($K = 1.53$) specifies that the fish were in generally healthy condition. The K-values above 1 are commonly associated with fish that are well-fed and in good physiological shape. In fisheries biology, the condition factor is often used as a simple indicator of well-being, and high values usually reflect abundant food availability, low parasite load, and favorable environmental conditions (Weatherley & Gill, 1987). K is a suitable indicator of a fish's overall health and well-being. It offers insight into how well a fish is feeding (Fetouh & El-Far, 2023). In length-weight analyses, fish that are heavier at a given length are generally interpreted as being in better condition (Froese, 2006). The study of Anam & Mostarda, (2012) shows b-values greater than 3 in *Thalassoma lunare* and *Cheilinus trilobatus* from coral reefs in Kenya, suggesting comparable growth characteristics. This kind of growth is common in strong, deep-bodied fish and suggests that the fish we sampled were doing well, likely because they had good habitat, enough food, and little stress. Since there's not much information on this species' LWR in the wild, especially in the southern Philippines, this study helps fill that gap.

Conclusions. The length–weight relationship (LWR) of wild *C. undulatus* showed positive allometric growth ($b = 3.09$), with a strong correlation ($R = 0.92$) and a good condition factor ($K = 1.53$). This means the fish were generally healthy and growing well in good environmental conditions. Since this species is endangered and there isn't much biological data on it, these results give useful baseline information for future stock assessments, conservation, and even possible aquaculture. LWR analysis is a helpful way to understand their growth and can support the sustainable management of *C. undulatus*.

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Authors Contributions. KHI - Conducted the study, Writing, Resources, Methodology, Data curation, Funding acquisition, Visualization, Formal analysis; YUJ - Conceptualization, Resources, Methodology, Supervision, Visualization, Formal analysis, Writing – review and editing; WMJ, GAJT, and MQA – Writing – review and editing; RJFR, AII, and RAMN – Conducted the study, Writing – review and editing; AAE – Conceptualization, Writing – review and editing.

Conflicts of Interest. The authors declare that there is no conflict of interest.

Data Availability. The data supporting the findings of this study are available from the corresponding author upon reasonable request.

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Authors:
Khadiza Hairul Imlan (KHI), Aquaculture Department, College of Fisheries, Mindanao State University-Tawi-Tawi College of Technology and Oceanography, Sanga-Sanga, Bongao 7500 Tawi-Tawi, Philippines, e-mail: khadizaimlan@msutawi-tawi.edu.ph
Yashier Upling Jumah (YUJ), Aquaculture Department, College of Fisheries, Mindanao State University-Tawi-Tawi College of Technology and Oceanography, Sanga-Sanga, Bongao 7500 Tawi-Tawi, Philippines, e-mail: yashierjumah@msutawi-tawi.edu.ph
Wahaymin Maing Jamil (WMJ), Aquaculture Department, College of Fisheries, Mindanao State University-Tawi-Tawi College of Technology and Oceanography, Sanga-Sanga, Bongao 7500 Tawi-Tawi, Philippines, e-mail: wahayminjamil@msutawi-tawi.edu.ph
Gerly-Ayn Jaafar Tupas (GAJT), Aquaculture Department, College of Fisheries, Mindanao State University-Tawi-Tawi College of Technology and Oceanography, Sanga-Sanga, Bongao 7500 Tawi-Tawi, Philippines, e-mail: gerlyayntupas@msutawi-tawi.edu.ph
Merilyn Que Amlani (MQA), Aquaculture Department, College of Fisheries, Mindanao State University-Tawi-Tawi College of Technology and Oceanography, Sanga-Sanga, Bongao 7500 Tawi-Tawi, Philippines, e-mail: merilynamlani@msutawi-tawi.edu.ph
Rizal Jhunn Falcatan Robles (RJFR), Aquaculture Department, College of Fisheries, Mindanao State University-Tawi-Tawi College of Technology and Oceanography, Sanga-Sanga, Bongao 7500 Tawi-Tawi, Philippines, e-mail: rizaljhunnrobles@msutawi-tawi.edu.ph
Abdulnaser Idjan Imlan (AII), Aquaculture Department, College of Fisheries, Mindanao State University-Tawi-Tawi College of Technology and Oceanography, Sanga-Sanga, Bongao 7500 Tawi-Tawi, Philippines, e-mail: abdulnaserimlan@msutawi-tawi.edu.ph
Raziman Abdulla Mad-nuri (RAMN), Aquaculture Department, College of Fisheries, Mindanao State University-Tawi-Tawi College of Technology and Oceanography, Sanga-Sanga, Bongao 7500 Tawi-Tawi, Philippines, e-mail: razimanmad-nuri@msutawi-tawi.edu.ph
Abdurizal Aminulla Eldani (AAE), Aquaculture Department, College of Fisheries, Mindanao State University-Tawi-Tawi College of Technology and Oceanography, Sanga-Sanga, Bongao 7500 Tawi-Tawi, Philippines, e-mail: abdurizaleldani@msutawi-tawi.edu.ph

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