Growth, Mortality and Exploitation Levels of *Sphyraena sphyraena* (Pisces: Sphyraenidae) and *Apsilus fuscus* (Pisces: Lutjanidae) in Ghanaian Waters

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ABSTRACT

Sphyraena sphyraena (Linnaeus, 1758) and *Apsilus fuscus* (Valenciennes, 1830) are commercially important fish species in Ghana. The stocks are exploited mainly by the artisanal and semi-industrial fisheries. Growth and mortality rates, and exploitation levels of the two stocks in inshore waters of Ghana were assessed as a contribution to fill the knowledge gap on the species. Samples were obtained from three landing sites along the coast of Ghana from February to July, 2017. Length-frequency data were used to estimate growth, mortality and exploitation ratios. The modal class for *S. sphyraena* was 37.0–39.9 cm total length (TL) and 34.0–35.9 cm TL for *A. fuscus*. The length and weight relationships established that growth in *S. sphyraena* was negative allometric, whereas that of *A. fuscus* was isometric. The estimated growth parameters from the length frequency data fitted with the von Bertalanffy growth function were asymptotic length (L_{∞}) of 69.9 cm TL for *S. sphyraena* and 53.5 cm TL for *A. fuscus*. The growth constant (K) was calculated as 1.64 yr⁻¹ for *S. sphyraena* and 0.50 yr⁻¹ for *A. fuscus*. The mean length-at-first capture (L_c) was found to be lower than the mean length at sexual maturity (L_m) for both species. The sex ratio showed a dominance of females over males in *S. sphyraena*, and 1:1 for *A. fuscus*. The total mortality rate (Z) for *S. sphyraena* was more than for *A. fuscus*. The estimated natural mortality (M) was 1.88 yr⁻¹ for *S. sphyraena* and 0.74 yr⁻¹ for *A. fuscus* whilst fishing mortality (F) rate was 3.04 yr⁻¹ for *S. sphyraena* and 0.93 yr⁻¹ for *A. fuscus*. The exploitation ratio showed that both fish stocks were exploited over the optimum levels. The estimated population parameters of the species obtained from the study, therefore, might be useful for the sustainable management of the stocks.

Keywords: Artisanal fisheries, Fish stock assessment, Growth and mortality parameters, Length-frequency distribution.

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I. INTRODUCTION

Pelagic species make up majority of fish catches that are landed which is about 80 % of the total fish catch, whilst demersal species constitute 20% of total fish catch in Ghana [1]. Among other fisheries resources that are commercially important in Ghanaian waters are Sphyraenidae and Lutjanidae for which *Sphyraena sphyraena* (European barracuda) and *Apsilus fuscus* (African forktail snapper) respectively belong [2], [3]. The high commercial value of these fishes has resulted in low fish densities in catches due to fishing pressure [2], with evidence in poor fish landings which suggests that the Maximum Sustainable Yield (MSY) may have been surpassed [4].

Sphyraena sphyraena is a tropical and subtropical fish species mostly occur in the Atlantic, Pacific and Indian Oceans. In West Africa, the distribution of the species extends from Morocco to Angola. The species is caught amongst schools of commercially-important small pelagics [5], [6]. *Apsilus fuscus* is also distributed along West African coast, from Congo to Ghana; and it is exploited by artisanal, recreational and industrial fisheries in many West

African nations [7]-[10]. The African forktail snapper is a demersal species which inhabits rocky bottoms [11], deep coral and rock reefs [12]. They are mostly caught in the commercial octopus fishery [13].

Growth and mortality parameters as the biological characteristics of the fish species are important for baseline information to understand the population dynamics of fish stocks that are exploited by fishery. In [14], the population dynamics of obtuse barracuda, *Sphyraena obtusata*, were studied in south-west coast of India to determine biological parameters of the fishery resource. In spite of the commercial importance of these fisheries resource in Ghanaian waters, few reports on the occurrence in artisanal and transshipment landings [8], [15], relative abundance and food preferences [5] of barracuda are known. Again, the literature on growth, mortality and exploitation ratios of these species are not available from Ghanaian waters. Hence, this study aims at determining the growth and mortality parameters, and exploitation pattern of *S. sphyraena* and *A. fuscus* caught by traditional fisheries along Ghanaian coast in the Gulf of Guinea.

II. MATERIALS AND METHODS

A. Study Area

This study was conducted along the coast of Ghana, specifically in Sekondi, Elmina, and Tema fish landing sites (Fig. 1). The Tema Fishing Harbour (5.6413° N, 0.0154° E) in the Greater Accra Region is the largest fishing harbour in the country, followed by Albert Bosomtwi-Sam Fishing

Fig. 1. Map of study area showing sampling sites.

Harbour (ABS) in Sekondi (04°55'00"N, 01°46'00"W) in the Western Region, and the Elmina fish landing site (5°5'0"N, 1°21'0"W) in the Central Region. These landing sites were chosen because of their major contribution to fisheries in Ghana. Traditional canoes of all sizes and inshore trawlers in all the three landing sites exploit commercially important fishes including *S. sphyraena* and *A. fuscus*. Purse seine, hook and line and bottom trawl gears are employed in the exploitation of the fisheries resources [16].

B. Methods

Fish samples were collected monthly from February 2017 to July 2017. The sampling sites were visited once every month where specimens of varied sizes were randomly obtained directly from the fishermen. Specimens were then preserved on ice and transported to the laboratory. Fish identification was done using identification keys [11], [17]. Total length (TL) were measured to the nearest 0.1 cm using the fish measuring board, and the body weight of each specimen was weighed to the nearest 0.01 g using the Ohaus Ranger 7000 model electronic balance. Specimens were dissected and the sex of each fish was identified by visual examination of gonads.

Total lengths were used to determine the length-frequency distributions; and the relationship between total length and body weight was expressed by:

$$BW = aTL^b \text{ [18], [19]}$$

where BW (g) is fish body weight, TL (cm) the total length, 'a' intercept and 'b' the slope. The condition factor (K) of the fish was determined from the relationship:

$$K = \frac{BW}{TL^3} \times 100 \text{ [18]}$$

A Chi-square (χ^2) test was undertaken to compare the male-female ratios per month with the hypothesized sex-ratio of 1:1.

The estimates of growth parameters were obtained by procedures of [20] as incorporated in FiSAT. And the total mortality (Z) parameters were estimated from procedures outlined in [21], [22]. The natural mortality (M) was estimated from the empirical formula as:

$$\log(M) = -0.0066 - 0.279 \log(L_\infty) + 0.6543 \log(K) + 0.463 \log(T) \text{ [23]}$$

where M is the natural mortality, K and L_∞ are growth parameters of the von Bertalanffy growth function and T ($^{\circ}\text{C}$) is the annual mean sea surface temperature of the study area.

The level of exploitation (E) of the fish stocks were calculated from the equation:

$$E = \frac{F}{Z} \text{ [24]}$$

where E is the exploitation ratio, F the fishing mortality [22] and Z the total mortality.

III. RESULTS

A total of 420 specimens of *S. sphyraena* were examined. The length measurements were grouped in a pooled sample into 3 cm class intervals and size groups ranging from 10.0–12.9 cm to 64.0–66.9 cm TL (Fig. 2 a). The pooled samples showed a unimodal length-frequency distribution with a modal length class of 37.0–39.9 cm TL.

Fig. 2(b) shows a length-frequency distribution of overall specimens of 423 of *A. fuscus* that were obtained. The length classes ranged from 20.0–21.9 cm to 50.0–51.9 cm TL. The pooled samples showed a unimodal frequency distribution with a modal length of 34.0–35.9 cm TL.

Fig. 1. Length-frequency distributions for: (a) *Sphyraena sphyraena*, and (b) *Apsilus fuscus* samples obtained from coastal waters of Ghana.

The monthly length-frequency distribution of *S. sphyraena* fitted with growth curve is shown in Fig. 3(a). The March samples had the highest specimens whereas the June samples had the least specimens. The February samples showed polymodal peaks, whilst March and July showed bimodal. The April, May and June samples all showed unimodal peak. The monthly length-frequency distribution of *A. fuscus* fitted with growth curve is shown in Fig. 3(b). The April samples had the highest specimens whereas the March samples had the least specimens. The February to July samples appeared to show unimodal peak.

Fig. 3. Monthly length-frequency distributions of: (a) *Sphyraena sphyraena*, and (b) *Apsilus fuscus* fitted with growth curve obtained by ELEFAN I routine (N = sample size).

The relationship between total length (TL) and body weight (BW) of *S. sphyraena* specimens studied over the study period is shown in Fig. 4 (a). The smallest fish size was 10.5 cm TL and weighed 11.8 g whilst the largest fish size was 66.5 cm TL with a weight of 1319.8 g. The expression $BW = 0.0118TL^{2.75}$ shows an exponential relationship between total length and body weight. The regression showed a strong correlation for *S. sphyraena* ($r=0.99$) between the variables. The regression coefficient 'b' differed statistically ($b=2.75 \pm 0.11$; $P < 0.05$, student's t-test) from the hypothetical value of 3.0. Hence, *S. sphyraena* showed negative allometric growth. The relationship between total length (TL) and body weight (BW) of *A. fuscus* is shown in Fig. 4 (b). The smallest fish size was 20.3 cm TL with a corresponding BW of 94.0 g whilst the largest fish size was 50.9 cm TL and weighed 1399.6 g. The expression $BW = 0.0172TL^{2.84}$ shows an exponential relationship between TL and BW. The regression showed a strong correlation for *A. fuscus* ($r=0.97$) between the variables. The regression coefficient 'b' did not differ statistically ($b=2.84 \pm 0.12$; $P < 0.05$, student's t-test) from the hypothetical value of 3.0. Hence, *A. fuscus* exhibited isometric growth.

Fig. 4. Length-weight relationships of: (a) *Sphyraena sphyraena*, and (b) *Apsilus fuscus* samples obtained from coastal waters of Ghana.

The variations in condition factor of *Sphyraena sphyraena* was shown in Fig. 5 (a). The lowest K value for males (0.37) was recorded in size class 64.0–66.9 cm whilst that of females (0.38 ± 0.04) was recorded in size class 58.0–60.9 cm. The highest K value for males (0.72) and females (0.54) were both recorded in size class 31.0–33.9 cm (Fig. 5a). Condition factor of *A. fuscus* is presented in Fig. 5 (b). The lowest K value for males (0.94) was recorded within size class 44.0–45.9 cm. The lowest K value for females (0.95 ± 0.03) was recorded within size class 42.0–43.9 cm. The highest K value for males (1.09) and females (1.08 ± 0.03) were recorded in size class 24.0–25.9 cm (Fig. 5b).

Fig. 5. Condition factor of (a) *Sphyraena sphyraena*, and (b) *Apsilus fuscus* samples obtained from coastal waters of Ghana.

The monthly sex ratios of *S. sphyraena* and *A. fuscus* are shown in Tables 1 and 2 respectively. A total of 282 *S. sphyraena* specimens were sexed, out of which 134 were males and 148 females. A total of 263 *A. fuscus* were sexed, out of which 132 were males and 131 females. The male to female ratio was 1:1.1 for *S. sphyraena* specimens and 1:1 for specimens of *A. fuscus* studied over the six months period.

TABLE 1: MONTHLY SEX RATIOS (FEBRUARY 2017 TO JULY 2017) OF *SPHYRAENA SPHYRAENA* SAMPLES OBTAINED FROM COASTAL WATERS OF GHANA

Month	Number of specimens		Sex ratio M:F	χ^2	P _(0.05)
	Male	Female			
February	17	20	1:1.2	0.85	NS
March	21	27	1:1.3	0.60	NS
April	29	26	1.1:1	0.57	NS
May	22	27	1:1.2	0.71	NS
June	21	28	1:1.3	0.51	NS
July	24	20	1.2:1	0.35	NS
Total	134	148	1:1.1	0.79	NS

TABLE 2: MONTHLY SEX RATIOS (FEBRUARY 2017 TO JULY 2017) OF *APSILUS FUSCUS* SAMPLES OBTAINED FROM COASTAL WATERS OF GHANA

Month	Number of specimens		Sex ratio M:F	χ^2	P _(0.05)
	Male	Female			
February	23	27	1:1.2	0.57	NS
March	20	16	1.3:1	0.50	NS
April	20	19	1.1:1	0.87	NS
May	22	24	1:1.1	0.77	NS
June	19	23	1:1.2	0.60	NS
July	27	22	1.2:1	0.48	NS
Total	131	131	1:1	0.10	NS

(a)

(b)

Fig. 6. Powell-Wetherall plot for estimating the asymptotic length of: (a) *Sphyraena sphyraena*, and (b) *Apsilus fuscus* samples obtained from the coastal waters of Ghana.

Powell-Wetherall Plot for estimating the asymptotic length (L_∞) and Z/K of *S. sphyraena* is shown in Fig. 6 (a). The asymptotic length of *S. sphyraena* was estimated at 69.9 cm TL and Z/K was 2.99, and K (1.64/yr) was growth coefficient of the species. Powell-Wetherall Plot for estimating the asymptotic length (L_∞) and Z/K of *A. fuscus* is shown in Fig. 6 (b). The asymptotic length of *A. fuscus* was estimated at 53.5 cm TL and Z/K was 3.32 and K (0.50/yr) was growth coefficient of the species.

The Fig. 7 (a) illustrates the probability of capture for *S. sphyraena* samples. The length at first capture (L_{C50}) was estimated at 39.3 cm TL. In Fig. 7 (b), the probability of capture for *A. fuscus* samples was shown. The length at first capture (L_{C50}) was also estimated at 32.8 cm TL.

(a)

(b)

Fig. 7. Probability of capture of: (a) *Sphyraena sphyraena*, and (b) *Apsilus fuscus* in the fishery.

The length-converted catch curve of *S. sphyraena* is shown in Fig. 8 (a). The total mortality (Z), natural mortality (M) and fishing mortality (F) of *S. sphyraena* were estimated at 4.92/yr, 1.88/yr and 3.04/yr respectively. The estimated exploitation ratio (E) for *S. sphyraena* was 0.62. Whereas, Fig. 8 (b) shows the length-converted catch curve of *A. fuscus*. The estimates of Z , M and F of *A. fuscus* were 1.67/yr, 0.74/yr and 0.93/yr respectively. The estimated E for *A. fuscus* is 0.56.

Fig. 8. Length-converted catch curve of: (a) *Sphyraena sphyraena*, and (b) *Apsilus fuscus* samples obtained from the coastal waters of Ghana.

IV. DISCUSSION

The overall length-frequency distributions depict a single cohort for *Apsilus fuscus* (Fig. 2b) and two cohorts for *Sphyraena sphyraena* (Fig. 2a). This could be explained that younger fish might have catch up with older generations due to the decline in growth rate with increase in age. Thus, younger fish cohort distributions superimpose on the older ones [22], which made it difficult to clearly identify the cohorts in the stock as well as the monthly modal alterations in ELEFAN I routine (Fig. 3). Maximum size reported by [25], [26] were larger than the size recorded in the present study (66.5 cm TL) for *Sphyraena sphyraena*. Larger maximum sizes were also recorded for *S. obtusata* and *S. afra* [27], [28]. Maximum size (49.8 cm TL) of *Sphyraena sphyraena* in Greek waters were reported by [29] which is smaller than the size recorded in the present study. Again, maximum sizes reported by [30], [31] for *Sphyraena idastes* and *Sphyraena ensis* were lower than the maximum size recorded in the present study. Nevertheless, the observed maximum length of *Apsilus fuscus* (50.9 cm TL) did not differ much from [32] who recorded 52.7 cm TL while working on the same species in Cape Verde. Varied values were recorded for other lutjanid species like *Lutjanus peru*, *Lutjanus malabaricus*, *Lutjanus fulgens* and *Lutjanus fulviflamma* [33], [34].

The length-weight relationship of *Sphyraena sphyraena* specimens showed a significant relationship and a strong

correlation. The exponent ‘*b*’ differed significantly ($b=2.75\pm0.11$; $P<0.05$) from 3. Such a fish is said to exhibit negative allometric growth. This kind of growth pattern has been reported to be characteristic of barracuda, where the individuals grow faster in length than in weight [31], [35], thus in contrast with other bumpy, heavy-bodied fishes. Negative allometry for *S. sphyraena* in the Egyptian Mediterranean waters were reported by [36]. Similar observation has been reported for *S. barracuda* and *S. ensis* in Florida Bay and Gulf of California respectively [31], [37]. Similarly, a strong correlation between length and weight was exhibited by the *Apsilus fuscus* in this study. The exponent ‘*b*’ did not differ significantly ($b=2.84\pm0.12$; $P<0.05$) from 3. This implies isometric growth suggesting that the fish become less slender as it increases in length and exhibit plump growth [38]. Again, positive allometry were reported for *A. fuscus* in Nigeria and Cape Verde waters [32], [39]. Negative allometry for other snapper species have also been reported by these authors [40], [41]. Consequently, [42] reported near-isometric growth for *L. synagris* and *L. buccanella* and isometric growth for *L. vivanus* in the same study. According to [43], differences in the length-weight relationship can be found with regards to sex, sexual maturity, season and even time of the day as a result of stomach filling; therefore, changes in ‘*b*’ value can be found in different developmental stages, first sexual maturity and when important environmental changes occur. Again, the differences in growth patterns may be due to factors such as temperature, food availability, prey-predator relationships, changes in the environmental condition, maturity stage, differences in sample number and sampling period, experimental design, and gear differences [43], [44]. The ‘*b*’ value obtained in the present study could be ascribed to one, or a combination of most of the factors mentioned above.

Condition factor is an expression of relative fatness of fish and generally, larger values of *K* indicates better condition of the fish. In Fig. 5a, the results of the condition factor (*K*) in *S. sphyraena* showed that smaller size groups exhibit higher *K* values than in the larger size groups. Similarly, in *A. fuscus*, smaller size groups showed higher *K* values than the larger size groups (Fig. 5b). The results of the present study affirms the general rule that, the highest values of the condition factor occur in the smallest size groups [45]. Again, report by [46] indicates that *K* values are higher in small fishes and lower in fish having large size due to voracious feeding nature of juvenile fishes. The results of condition factor can be used to deduce the well-being of the fish species studied and it is based on the theory that heavier fish of a given length are in better condition [43] and therefore, used as an index of growth and feeding intensity [47]. From the present study, smaller sizes of *S. sphyraena* and *A. fuscus* had better condition indicating the fish species might have a better feeding regime. The lower *K* values recorded in the larger sizes of *S. sphyraena* and *A. fuscus* might have resulted from reduced feeding which translates into little lipids and fats deposition [34], [48]. This therefore, indicates less weight gain relative to length and agrees with report by [47] that, condition factor relatively decreases due to the gradual increase in length. Again, [49] commented that high

condition factor values indicate favourable environmental conditions and low values indicate less favourable environmental conditions. The results of the present study indicate that *A. fuscus* showed the highest K value between the two fish species. And drawing inference from this, its possible that *A. fuscus* in Ghanaian waters thrived in a favourable habitat with abundant food, suitable environmental conditions and were feeding well.

Sex ratio can change considerably among species, or differ between populations, or even among different years for the same population [50]. However, in most populations, the male:female ratios are non-significantly different from unity according to [50] as observed in this study for *S. sphyraena* and *A. fuscus*. Similar results for *S. sphyraena* studied from the Egyptian Mediterranean waters off Alexandria and *S. jello* off the Persian Gulf respectively were reported by [25], [51]. Similar results were reported for other lutjanid species such as *Lutjanus guttatus* (1:1.05) and *Lutjanus argentiventris* (1:0.9) [52].

In this study, the asymptotic length of *S. sphyraena* (69.9 cm TL) differed from reports for other related species like *S. obtusata* (47.0 cm TL) [53] and for *S. barracuda* (40.4 cm TL) [54] and *S. afra* (192.7 cm TL) [27]. However, the asymptotic length of *A. fuscus* (53.5 cm TL) obtained in this study was lower than that reported (64.0 cm TL) by [55] for the same species in Cape Verde. According to [56], variations in estimates of asymptotic lengths may be attributed to factors such as differences in maximum observed length, sampling methods, nature of data, computation methods used and the obtained length frequency. The von Bertalanffy growth coefficient estimated for *S. obtusata*, *S. barracuda* and *S. afra* were relatively lower than in the present study [27], [28], [57]. The relatively high growth rate shown by *S. sphyraena* in this study might depicts the response by the fish stock to the intense fishing pressure [56]. A report by [36] indicate a slower growth rate for *S. sphyraena* in the Egyptian Mediterranean waters and suggested that variation in growth rate may result from disparity in food abundance or size composition of the stock. Again, report by [14] indicate that regional differences in growth rate are common among the same exploited species and attributes this to sample strength and size. Also, [20] submitted that growth parameters differ from species to species and also stock to stock even within the same species as a result of different environmental conditions. Again, the von Bertalanffy growth coefficient of *A. fuscus* in the current study is similar with results of *Lutjanus adetii* (0.68/yr) and *Apsilus dentatus* (0.47/yr) [58]. The estimated growth rate of *A. fuscus* can be explained that, snappers especially the tropical populations are generally slow growing and long lived [59], [60].

The mortalities in the *S. sphyraena* stocks were due to fishing rather than natural causes. These agreed with the observations from [12], [27], [36]. Observations made for the *A. fuscus* population from the Hawaiian archipelago and eastern Australia confirms the report that snappers have low rates of natural mortality [58]-[60]. This therefore, suggests that the mortality due to fishing might be the dominant cause of *S. sphyraena* and *A. fuscus* stocks control rather than natural mortality caused by age, predation, lack of

food, spawning stress, diseases and pollution [56], [57]. The estimated exploitation ratios of *S. sphyraena* ($E=0.62$) and *A. fuscus* ($E=0.56$) in this study were higher than the optimum exploitation level ($E_{0.5}$) for sustainable fishery. In other words, these stocks are currently exploited beyond the optimal level for sustainable yield for the fishery.

V. CONCLUSION

In conclusion, the current exploitation levels of *S. sphyraena* and *A. fuscus* suggest that any further expansion in the current exploitation rates will accelerate the rate of the stock depletion as the stocks are already experiencing high fishing pressure.

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