Morphometric Relationship, Growth, and Condition Factor of Flyingfish, Hirundichthys oxycephalus during spawning season

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Abstract. Flyingfish, Hirundichthys oxycephalus together with its congener species has become a major artisanal fishery resource from the Seram Sea, an area between Seram and Papua Island. However, biological information about this species has been poorly documented. Our current study focused on the growth and morphometric relationships of spawning cohorts during spawning season (June to October 2013). Flyingfish which were trapped in bale-bale, an egg aggregation device for flying fish, were collected offshore of the Southeastern Seram Sea. Total samples of 1693 with Fork Length (FL) ranged from 156.15mm to 245.52mm and total weight from 53.15gr to 115.45gr. Von Bertalanffy growth functions (L∞) for pooled sexes were FL = 251mm [1-e (1.82 (t+0.060)), K=1.82 and t0 = 0.060. Morphometrically, significant differences were observed for all individuals between sexes (F=14.20, P=0.0002), sampling locations (F=88.48 P<0.0001) and sampling period (F=138.84, P<0.0001). Condition factor of the fish generally declined in July-August. During spawning season, this fish tended to form single spawning cohort. The results of this study provide a significant understanding of the life history of this valuable fish inhabiting this particular region that rarely receives scientific investigation. For management purposes, harvesting eggs including broodstocks will lead to critical population depletion.

1. Introduction

Flying fish of the family Exocoetidae consist of more than 50 species that are globally distributed over subtropical and tropical regions [5, 7, 21, 18, 50, 53]. Ecologically, they play a very significant role in the network food chain in the waters [41, 51, 52]. The most notable external characteristics of this fish are their elongates dorsal and pectoral fins which enable them to jump out of the sea and glide at incredible distances (50-400m) over the sea which gives rise to their common name. They can attain maximum sizes up to 27.0 cm fork length and weighs 115.45 gram. inhabiting mainly in surface waters along the coast and often in the open waters, flying fish feed on zooplankton and some time on small fish. As such, flying fish have been regarded as an intermediary in the bioenergetic transfer. In addition, stomach content analysis of Dolphin and number of tunas have shown that flying fish is the main prey [42].

Like their counterparts of flying fish species, H. oxycephalus is one that dominates the catch in some waters [25, 14, 7, 29]. Fishery of this fish includes both harvesting the adults as well as their ovulating eggs commonly found attached to floats some [30, 29, 23]. Given their high price in the market, the eggs has been considered as an export commodity in number of countries including in
Indonesia [3, 23, 29]. Exploitation of this species remain hardly monitored in Indonesia, however, record to date indicates that flying fish of this particular species has been regularly exploited since 2002 along side with other species [47].

Following their wide ranges of distribution including in Indonesian waters, Flying fish, Hirundichthys oxycephalus has been also found in Seram Seacovering an area between North Seram Island of Maluku Province and South Papua Island ranging from Kaimana to Fak-Fak water [47]. Despite their ecological and economic value, not many studies have been conducted on this group of fish and thus information on their basic biological parameters including growth performances remain largely sparse. As a consequence future fisheries management based on certain models such as age-based stock assessment for this particular fish within their distributional range and habitat may rely on studies from else where [6, 37, 36, 13, 11, 26]. The above fisheries model require age and growth data which often becomes problematic in tropical waters including in Indonesia. Otolith has been used to construct growth models of flying fish-from various waters using different pairs suggesting that one appears to be better interpreted than the others [32, 7]. Lenght-based analysis has been also applied to construct growth models in the past for flying fish [19, 35, 34, 4]. However, this appears not to be the case for Indonesia flying fish population. This is in contrast with the fact that flying fish inhabiting this study area has been exploited for decades [48] yet scientific data of their biological properties required for better management remain unavailable. Given the importance of this fish supporting regional fisheries off the coast of Seram Sea, South of Kaimana and Fak Fak waters, this was the first study to understand morphometric parameters, growth, and condition factor of H. oxycephalus in this particular region. This study also enables intraspecific growth coefficient comparison between regions derived from different study sites.

2. Methodology

2.1. Collection details

Flying fish of H. oxycephalus samples examined in this study (n=1693) were collected in one season of a commercial fishing trip of five months starting from June until October 2013. Three fishing grounds were designated as Kaimana regional waters, Fak-Fak regional waters and East Seram regional waters, an area that geographically lying between 1260 - 1320 East and -30N and -20 South (Fig. 1). Flying fish specimens were obtained from the commercial fishing operation that regularly collects flying fish eggs over these three fishing grounds. Following spawning season of flying fish in these areas, Fish Aggregation Devices (FAD) that made of coconut leaves attached to the floating rafts were deployed. The FADs were attached to the fishing boat and drifted away follow the direction of sea current. Total soaking time of the FAD was approximately 20-22 hours starting from 06.00hrs until 04.00hrs in the morning. Following the release of their eggs that attach to the coconut leaves, most fish were then got entangled by their adhesive filament, difficult to release themselves and finally died. During the removal or harvest of these ovulating eggs, dead flying fish were then taken out together and used as specimens for this study.

On board, fish were identified following description of [16] measured to the fork length (FL) using calipers vernier to the nearest 1 mm and weight (Wt) in grams of every individual fish using an electric balance to the nearest 0.01g. Sex of individual fish was determined by visual assessment of the gonads and their respective maturity stages were determined through microscopic examination following [19].
2.2. Length-weight relationships
Length-weight relationships (LWRs) were estimated using the log form of the allometric growth equation \( W = aL^b \), where \( W \) = the expected weight; \( L \) is Fork Length; \( a \) is the intercept or initial growth coefficient and \( b \) is the slope of the regression line [27]. The values of constants, \( a \) and \( b \) were calculated using the least square method.

As has been shown in previous studies, we also assumed that if \( b \) was equal to 3, the relationship was considered to be isometric [40]. Correspondingly, if \( b \) value differs from 3 indicates allometric growth. Analysis of length-weight relationships was also made independently for both sexes (male and female), locations and on a monthly basis covering the entire sampling periods of five months and compared by using Analysis of Covariance [49]. ANCOVA was then used to examine our notion of whether the regression values resulted differ significantly from the null hypothesis for isometric growth (H0: \( b = 3 \)) [29]. Length frequency distribution of flying fish for combined sexes from the respective sampling location was plotted for the purposes of cohort analysis of the population [20].

2.3. Growth Method
In order to estimate growth parameters of the von Bertalanffy growth function for flying fish of the study area, separate age group data were analyzed applying Bhattacharya methodology [22, 44, 24]. Length frequency data was converted to estimate age composition and enable calculation of growth rate following the function of von Bertalanffy as follows:

\[
L_t = L_\infty \left[ 1 - \exp^{k(t-t_0)} \right]
\]  

(1)

where: \( L_t \) = length in millimeter at age(mm); \( L_\infty \) = asymptotic length(mm); \( K \) = growth coefficient (year); \( t_0 \) = the hypothetical age when theoretical length is equal to zero and \( t \) = age. The value of \( K \) and \( L_\infty \) asymptotic were determined as whilst \( t_0 \) was calculated using the formula proposed by Pauly (1983) as follows:

\[
Log(-t_0) = (-0.3922) - (0.2752) \times Log(L_\infty) - 1.038 \times (LogL)
\]  

(2)

Further more, an age of the flying fish in this study was estimated based on the size of the group use derivatives formula of von Bertalanffy's follows:

\[
t_0 = \left( t + \left( \frac{1}{K} \right) \right) \times \left( \ln(L_\infty - L_t) / L_\infty \right)
\]  

(3)

2.4. Condition Factor
Condition factor is an expression of fish fitness which is stated in number and was analyzed using the formula of the relative condition factor (Kn) [10, 11-12] as follows:
where: $K_n = \text{relative condition factor of each individual fish}$, $W = \text{weight of fish (g)}$, $W = a L^b$ (average weight obtained from weight-length relationship), $L = \text{body length of fish (mm)}$, $a$ and $b = \text{parameter of length-weight relationship}$.

3. Results
Between June until October 2013, a total of 1693 flying fish were sampled from the three designated fishing sites within the Seram Sea. Since sampling was conducted during spawning season, sex determination was relatively straight forward. Female fish ($n = 866$) accounted for the majority of samples than male ($n = 827$), which composed only 48%. In overall, mean Fork Length of the flying fish sampled from East Seram ($211.51 \pm 16.69$ SD) tended to be larger than the mean sizes for those samples from Kaimana ($190.58 \pm 9.99$) and Fak-Fak waters ($189.71 \pm 12.19$), respectively. Further analysis to examine these mean sizes show significant differences (F-test: 1244.61 $P < 0.0001$). Interestingly, however, length frequency distribution throughout sampling time (months) indicate the similar consistency of trend. At the early sampling month in June, the small size of Flying fish (< 200mm FL) were present but later disappear in the succeeding months and dominated by larger sizes until in October. This size spectrum might, however, account for only about 55.6% of their maximum size of 457.2mm which is often recorded. Similar size pattern was also recorded under females and males category, as flying fish from East Seram remains larger than the mean size for the fish for two other fishing sites as Kaimana and Fak-Fak (Table 1.).
Figure 2. Length frequency distribution of Flying fish, *H. oxycephalus* sampled at the three fishing sites from June to October 2013.
Table 1. Fork Length (mm) of H. oxycephalus by sex category sampled from three different sampling sites.

| Site      | Sex   | Mean ± SD | Range       | n  |
|-----------|-------|-----------|-------------|----|
| Kaimana   | Female| 218.5 ± 9.77 | 208.7-228.3 | 267|
|           | Male  | 230.4 ± 5.4  | 225.0-235.8 | 262|
| East Seram| Female| 267.3 ± 7.1  | 260.2-274.4 | 353|
|           | Male  | 242.9 ± 16.0 | 226.9-258.9 | 325|
| Fak-Fak   | Female| 226.5 ± 8.2  | 218.3-234.7 | 246|
|           | Male  | 210.1 ± 10.1 | 200.0-220.2 | 240|

3.1. Length-weight relationship
The length-weight relationship (LWR) calculated for H. oxycephalus comparing females and males, sampling sites and months have shown strong significant differences (Table 2). The overall analysis for length-weight relationship coefficient (b) has shown a negative allometry and significantly different from a value of 3 (Student’s t-test: P<0.001), indicating that this species grows towards length rather than in weight. Overall values of b calculated for the three sampling locations regardless of sex also less than 3 (0.529-2.53). Further analysis in incorporating sex within location also consistently shown negative allometric growth, b (0.682-1.81) (Table 2). It was also noted that the fish appears to have similar growth pattern at early to mid stages when they attained about 85.1% of their maximum sizes. Following this, the females and males fish tended to perform different growth trajectories in terms of length and weight (Fig. 3).

Table 2. Summary of the length-weight analysis for females and males H. oxycephalus by locations. Two locations showed not significant difference (*) and only one (East Seram) showing differences in their morphometric relationship.

| Location     | N    | a   | b   | R²  | F     | P     |
|--------------|------|-----|-----|-----|-------|-------|
| Kaimana      | Male | 262 | -2.396 | 1.81 | 0.680 | 2.72  | 0.099*|
|              | Female| 267 | -2.005 | 1.642 | 0.704 |
| East Seram   | Male | 325 | -1.320 | 1.373 | 0.833 | 13.80 | <0.0001|
|              | Female| 352 | -1.941 | 1.634 | 0.809 |
| Fak-fak      | Male | 240 | 0.241  | 0.682 | 0.099 | 0.10  | 0.7497*|
|              | Female| 246 | 0.116  | 0.735 | 0.171 |

3.2. Growth
The estimated parameters of the von Bertalanffy growth model of the current study are presented. In overall, the analysis did reveal significant differences in mean size distributions as well as morphometric growth prompting separate analysis of such growth model (Table 4). These were further supported by the fact that although there were no significant differences between females and males of flying fish at Kaimana (F = 2.72; P = 0.009) and Fak-Fak (F = 0.10; P = 0.7497) fishing sites. However, the significant difference of morphometric growth that occurs between females and males at East Seram fishing sites provide strong evidence to perform separate further analysis.
The von Bertalanffy growth function calculated by using Fork Length and estimated age (month) of the flying fish were then fitted for the respective fishing sites as follows:

**East Seram:** $$L_t = 251.30\times\left[1-e^{0.4469(t+0.2260)}\right]$$

**Kaimana:** $$L_t = 246.19\times\left[1-e^{0.2268(t+0.4587)}\right]$$

**Fak-Fak:** $$L_t = 245.96\times\left[1-e^{0.2268(t+0.4587)}\right]$$

**Table 3.** Growth coefficient of flying fish (*Exocoetidae*) of this and from other studies.

| Location                  | Growth equation        | Growth Coel/year | Reference |
|---------------------------|------------------------|------------------|-----------|
| East Seram Sea            | $L_t = 251[1-e(1.8(t+0.23)]$ | 1.8              | This study |
| Flores Sea, Makassar Str. | $L_t = 182[1-e(1.3(t+0.074)]$ | 1.3              | [3]       |
| Taiwan East               | $L_t = 254[1-e(2.6(t+0.0042)]$ | 2.6              | [7]       |
| Barbados Sea              | $L_t = 245[1-e(2.9(t+0.0078)]$ | 2.9              | [41]      |

**Figure 3.** Analysis of Covariance comparing two regression lines of length-weight relationships between females and males of *H.oxycephalus* within locations of East Seram fishing sites.

It appears that growth parameters from the three fishing sites were different. The growth coefficient (K) of the flying fish from East Seram was the largest compared to their counterparts from the two other sites. This could-excel rate maximum growth towards the asymptotic size ($L_\infty$) of the flying fish inhabiting East Seram Sea that tends to attain the larger size than their congener species from Kaimana and Fak-fak waters. In order to have a comprehensive comparison, similar parameters from different study sites and flying fish species were also presented. Our overall estimated value for the asymptotic size ($L_\infty$) for *H.oxycephalus* in this study ranges from 246mm-251mm (FL). These sizes are in fact within the range of asymptotic sizes reported from other studies except from the Taiwan (Table 3). Growth coefficient (K) of *H.oxycephalus* from this study ranged from 0.2268-0.4469 per month and in average, however, the value was 1.8/year. This was slightly higher when compared with *H.oxycephalus* in the Flores Sea and Makassar Strait which had the value of K =1.3/year but remain lower than that of EastTaiwan (K=0.0075 or2.6/year and *H.aflin* is from Barbados with K=0.0085/dayor 2.99/year.
Figure 4. Fork length in mm at relative age and fitted von Bertalanffy growth model for Flying fish (*Hirundichthys oxycephalus*) sampled from Kaimana, East Seram and Fak-Fak fishing site from June – October 2013.

3.3. **Condition factor**

In general, mean condition factor of flying fish *H. Oxycephalus* from our study varies slightly starting from the highest value of 1.0015 in June to the lowest value of 1.0004 in July before rebounded again in the following months reaching the value of 1.0007 in October (Figure 5). In terms of the respective study sites, however, interesting variations were reasonably obvious. Condition factor of the flying fish from East Seram waters dropped sharply from June (1.0028) to July (1.0009) and gradually decreased towards the following months reaching the lowest value of (Kn) about 1.0049 in October. This is slightly different for the two other fishing sites (Kaimana and Fak-Fak) whereas despite their values of Kn also drop from June (1.0011 and 1.0004, respectively) to July (1.0003 and 1.0035, respectively), but not in a sharp fashion compared to those flying fish from East Seram waters. If on the other hand, condition factor of Flying fish from the East Seram waters continue to drop and level off in September to October, this was not the case for the Kaimana and Fak-Fak waters as the Kn values showed a trend of slightly increased after July towards the following months. Eventually, condition factor of the flying fish from Fak-Fak waters attain the highest value of about 1.0009 but then decline towards October though the value remains higher than previous months.
3.4. Discussion

Length frequency distribution provides very useful insight pictures of fish population structure which can be applied also in fisheries management. There are numbers of benefits in getting the right and appropriate knowledge of the size structure of fish population as it provides fundamental knowledge of fish population parameters including growth, reproduction, changes in size and recruitment processes. Understanding of these parameters would further provide an initial indicator of potential disruption occurring within the population. Presence of the relatively larger size of Flying fish in this study (208.7mm-274.4mm, FL) and lack of small size range could be due to the gear used throughout sampling process. If in the other studies, drifted gill net or dip net were often used to collect samples [45, 7, 14] however, fish specimens in this study were taken by “Bale-bale” (local name), a Fish Aggregation Device provided to attract Flying fish to attach their ovulated eggs. All samples presence in Bale-bale were infact trapped by the adhesive filament of the ovulated eggs and consequently only a mature and relatively larger size of the fish dominate the catch, mean while the small sizes were absence. Entering the spawning season in June until October is also another reason of catching more larger size of fish. This study appears to be the first providing such record of size spectrum in the region while waiting for further study covering the entire size range and reproductive season. One interesting finding of this study is that the existing size trajectories appear to confirm one cohort of Flying fish population within the respective study sites that arrive to spawn (Figure 2). Although the argument of whether flying fish considered as the batch or synchronous spawners remains [17], the fact is that the reproductive activities vary among and perhaps within regions and quite possible between genera as well as species. [33] Reported two spawning periods of *H. affinis* found in the eastern Caribbean Sea. *Prexocoetus brachypterous*, a relatively small (112-117mm SL) Flying fish species from the northeastern Gulf of Mexico has been also reported perform two rhythms [45]. Meanwhile a prolong reproductive activity has been recorded also by several members of Flying fish in Japanese waters including *H. Oxycephalus* of the current study [15]. The present study strongly indicated that spawning periods of *H. Oxycephalus* in Seram Sea occurs between June to October as shown by their maturity stages data. In Taiwan however, *H. Oxycephalus* spawns one month earlier in May and last in August [7]. This slight disagreement might be due to different sampling periods during this study which took place for only five months. Until a further and comprehensive study is made, current data suggest that the Flying fish eggs fisheries in Seram Sea must be undertaken with caution. Over harvesting the eggs in the current spawning cohort will very serious implication of the next population.

![Figure 5. Variations of the values of condition factor of *H. Oxycephalus* sampled from East Seram, Kaimana, and Fak-Fak waters.](image-url)
In overall, our estimation of b values was not within the normal and expected range for fish, i.e b = 2.5-3.5 [11], suggesting that growth of H. oxycephalus in our study is negative allometric. An attempt to analyze length-weight relationship by sex within the respective location also depict a similar pattern of deviations from the hypothetical value of 3 indicating that they put more energy to grow in length than in biomass [10, 1]. This was presumably due to more than half of the total fish caught in drift rum pong (bale-bale) were in their spawning phase. This result is in fact in accordance with previous studies reporting on the negative growth of this fish including in Flores Sea and Strait of Makassar [3], in Binuanguen Banten waters. [9] Also found a negative allometric growth of flying fish collected from the waters of West Africa, as well as Hirundichthys coromandelensis from the waters of India [42], and H. affinis from Brazil [28, 31]. Living on the surface of the open waters, certain strategies have to be developed including body shape, mass and parts like wings that enable them to avoid predation. Having body shape like torpedo enable the Flying fish to accelerate the speed and break the surface waters. Supported by the relatively large wing like pectoral fins, less body mass help the fish to jump out the water and glide over a quite distances (about 200m) [9, 15]. There was no significant difference in b values between females and males samples taken from Kaimana and Fak-Fak waters suggesting that both populations might experience similar performance in growth. This is not the case however for females and males Flying fish from East Seram waters. Given that number of sample size was reasonably high, the statistical procedure in this analysis could be ignored [6]. The argument of [6] that the exponent b value of fish could be associated with size range appears to be the case for the Flying fish from East Seram Sea as they tend to be larger in size. Whether these facts were associated also with less fishing pressure in the area, food availability (quality, quantity), spawning dynamics (season and time), fatness of the species, water temperature, salinity, gonadal maturity, length range that proposed by [11] remain unclear and require further investigation to cover such a full ranges of all possible factors.

Values of asymptotic length (L∞) estimated from the von Bertalanffy growth model for combined sexes were much higher (326mm, FL) than the maximum length actually observed in the current study (260-274mm FL). This value was also higher than most of the previous studies ever reported [3, 34] as well as its counterpart from Taiwan east waters [7]. The asymptotic value of the two sampling sites (Kaimana and Fak-Fak) were lower, however higher for east Seram sea. Comparing with other previous studies, however, it was slightly higher than in Barbados, Flores and Makassar Strait [3, 34] and in eastern Taiwan [7]. One possible explanation for this may lay on on the lower estimation of the von Bertalanffy parameters K value which is often reported in other species [5]. This is in contrast with estimation of the von Bertalanffy parameters for Flying fish from Barbados and Flores sea and Makasara Strait that tends to grow faster and attain slightly smaller asymptotic length [33, 3]. This slight discrepancy in their growth parameters likely occurred may be because of the estimated parameters that were based on the final stages of growth as samples in this study lacking smaller sizes. Age estimation for Flying fish quite varies and remain an issue including the use of length frequency analysis [8] as well as otolith [34, 7]. It has been often argued that fish length is an unreliable measure for estimating fish age. On the other hand, hard structures like otoliths may also provide unclear pictures of the fish age, especially in many tropical environments. The argument is however, all possible methods could be exercised provided that proper sampling procedures have been followed. For many pelagic species especially in the tropical environment, hards parts like otolith are often difficult to discernagecompared with their counter parts in subtropical or temperate waters. Despite such, the use of fish length included in the current study to estimate flying fish age showed a reasonable estimation of one - two years of age (± 25months) that helps to calculate growth parameters presented here. This was apparently also in accordance with the similar species from Taiwan [7]. Age estimation for its congener species H. affinis [32, 8] also showed consistent age pattern (two years) with the current study. Certainly, ability to grow faster and attain maturity stages at the early age has been considered as remarkable startegyreflecting a phenotypic compensatory response to maintain population [46]. Following spawning, many flying fish H. Oxycephalus died on their adhesive filament leaving unsolved questions of whether the event was due to unfit condition after spawning or because of reaching their maximum age limit.
A sharp decrease of condition factor of Flying fish in the present study has been observed coincided with spawning activity. Although the respective values vary among sampling sites, the mean estimated values of condition factor showed a consistent pattern of declining towards during spawning season (Figure 6). Shrink condition of the stomach wall of fish undergoing spawning was observed, begun shrinking and become small. A similar condition has been reported also for fish from the Malaka Strait and the Flores Sea. [3] Reported that condition factor of female fish was also decreased in April, which was predicted to be the peak spawn season of this fish. Similar pattern of declining in Knvalue have been also observed in various fish species and become an indicator of spawning processes like species of the family Triglidae [30, 41] in Trachurusmediterraneusat Eastern Adriatic Sea, and also in Serranus script from North Atlantic sea [54]. Given that condition factor is influenced by the reproduction, feeding of individuals and the habitat quality, the value can be useful tool providing information on the general condition of fishes presence in particular habitat.

4. Conclusion
• During spawning season, this fish tended to form single spawing cohort; Morphometric relationship significant differences was observed for all individuals between sexes, sampling locations and sampling periode; Condition factor of the fish generally declined in July-August: indication spawn peak season
• For management purposes, harvesting eggs including broodstocks will lead to critical population depletion.

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