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Biological Aspects of Shortfin Scad (*Decapterus macrosoma*) in Makassar Waters, South Sulawesi, Indonesia

A Asni, Hamsiah, Rustam and Ilmiah

Fisheries Resource Utilization Study Program, Fisheries and Marine Sciences Faculty,
Muslim University of Indonesia, Makassar, Indonesia

Email: asni.andi@yahoo.co.id

Abstract. The shortfin scad is a pelagic fisheries resource that plays an important role in the economy of the South Sulawesi marine fisheries sector. Besides its use for consumption by local communities, shortfin scad are also used as bait in the tuna fishery and exported frozen. Over the past five years there has been a decline in catches caused by uncontrolled exploitation. To date, there is still no control over the exploitation of shortfin scad, and it is feared the sustainability of shortfin scad as a fisheries resource is threatened. This research aimed to analyse specific aspects of shortfin scad biology for this population, including sex ratio, size at first maturity, and growth pattern. The study was conducted in the waters off Makassar, in South Sulawesi, Indonesia, using direct observation with a survey method. Fish samples were obtained from catches landed by fishermen at the Paotere fishing harbour in Makassar City. Sampling was conducted from early April to early August 2017. The shortfin scad sample obtained comprised 201 male fishes and 169 female fishes. The results showed that the sex ratio of the shortfin scad (male:female) was 1.1:1.0. The shortfin scad reached first maturity at a fork length of 18.24 – 19.54 cm for males and 16.45 – 17.24 cm for females. The Gonad Maturity Index (GMI) of male fish was dominated by immature gonad classes (GMI I and GMI II), while for females GMI III and GMI IV dominated the sample, indicating that females mature earlier than males. Male and female growth patterns were allometric positive with $b > 3$, indicating that the gain in weight was faster than the increase in length.

1. Introduction

The coastal fishing areas in South Sulawesi, Indonesia include the Makassar Strait, Flores Sea and the Gulf of Bone. The types of fish that are caught in these waters are quite diverse. Small pelagic fish caught include yellowtail, bloaters, shortfin scad, sardinella, selaroides, sardines, and anchovies. However, shortfin scad is one of the fish most commonly caught in South Sulawesi and contributes a large proportion of the catch volume. The shortfin scad (*Decapterus macrosoma*) is one of several fish species caught with fishing gear such as chart, gill nets, mini-trawls (*payang*), and purse seine nets. Besides being used for human consumption, shortfin scad are also used as bait by tuna fishery companies and exported frozen. The high demand for shortfin scad is likely to lead to further increases in exploitation, as fishermen are stimulated to increase their fishing effort in order to fulfil market demand. It is feared that fishing effort above the optimal level will affect the sustainability of shortfin scad as a fisheries resource.

The volume of shortfin scad resources in the waters around South Sulawesi has been estimated at 83,996 tons [1]. Although the shortfin scad is a naturally abundant fish with quite large stocks, if it is exploited excessively and continuously without responsible and sustainable management, it is highly



likely that fish populations will decline. Studies have reported that the shortfin scad fishery in the Makassar Strait is approaching the maximum sustainable yield [2], and that the exploitation rate of shortfin scad in the Makassar Strait and Flores Sea has reached 95% [3]. The high exploitation of shortfin scad with uncontrolled fishing can threaten the sustainability of this fishery, and lead to the loss of the economic potential it provides.

This shortfin scad fishery needs optimal and sustainable fisheries management to maintain its sustainability and the welfare of fishermen. Studies on biological aspects of the shortfin scad are necessary as a basic consideration in fisheries management efforts. Thus, the purpose of this study was to determine the biological aspects of shortfin scad including sex ratio, gonad maturity index, size at first maturity, and growth pattern.

2. Research Methods

2.1. Data collection

This study was conducted using survey methods. Shortfin scad samples were collected from fish caught by fishermen in the waters around Makassar and landed at the fish landing site in Paotere fishing harbour, Makassar City. Fish sampling took place eight times from early April to early August 2017 at two week intervals. The fork length of each fish sampled was measured with a fish ruler (precision of 1 mm), and the weight was determined using digital scales with a precision of 0.1 g. The determination of sex and gonad maturity was performed after dissecting the fish. Gonad colour and shape was observed through a magnifying glass to determine the sex and the Gonad Maturity Index (GMI). Morphological classification of the gonad maturity index of male and female fish sampled followed Effendie [4] with some modification. The gonads were then removed and weighed using digital scales with a precision of 0.01 g.

2.2. Data analysis

2.2.1. Sex ratio. Sex ratio (male:female) was evaluated using the Chi-Square test (χ^2) [5] to test the hypothesis [6] as follows:

H_0 : There is no significant difference between male and female abundance (sex ratio not significantly different from 1:1)

H_1 : There is a significant difference between male and female abundance (sex ratio $\neq$ 1:1)

Decision rule:

If: $\chi^2_{\text{count}} < \chi^2_{\text{table}} (\alpha; n^{-1})$, then H_0 is not rejected
 $\chi^2_{\text{count}} > \chi^2_{\text{table}} (\alpha; n^{-1})$, then H_0 is rejected, H_1 may be accepted

2.2.2. Size at first maturity. The size at first maturity (m) was estimated using the Spearman Karber method [6,7], from the following equation:

$$\log m = X_k + \frac{X}{2} - \left(X \sum p_i \right)$$

Where:

X_k = logarithm of the last class median at which 100% of fish have mature gonads

X = log size increment

X_i = logarithm of median

$p_i = r_i/n_i$

r_i = the number of fish with mature gonads in the i -th class

n_i = number of fish in the i -th class

$q_i = 1 - p_i$

$$\text{Variance} = X^2 \sum_i^n \left[\frac{p_i * q_i}{n_i - 1} \right]$$

The 95% confidence interval is thus determined as: $m \pm Z_{\alpha/2} \sqrt{\text{variance}}$

2.2.3. Gonad Maturity Index. The gonad maturity index was determined based on morphological characteristics. Morphological determination takes into account the gonad shape, length, and colour as well as the development of gonad contents according to the Cassie method [4].

2.2.4. Length weight relationship. The relationship of fork length and body weight of shortfin scad was analysed by sex and determined using the following formula [4]:

$$W = a L^b$$

which is equivalent to $\log W = \log a + b \log L$

where: W = body weight (g)
 L = fork length (mm)
 a = constant (intercept),
 b = exponential growth regression coefficient

3. Result and Discussion

3.1. Sex ratio

In the context of fish population structure, it is important to observe the sex of fish in order to compare the number of males and females. The percentages of male and female shortfin scad in the study sample were 54.32% and 41.85%, respectively. This yields a sex ratio of 1.1:1.0.

The Chi-Square test showed there is no significant difference ($p > 0.05$) between the numbers of male and female fish sampled from waters around Makassar. This indicates that the sex ratio of this shortfin scad population is balanced (close to 1:1). A balanced sex ratio should promote reproduction so that the shortfin scad fish (*D. macrosoma*) stock is maintained. Ideally, the ratio of male and female fish in a seaway should not be significantly different each time the fish are sampled. The sex ratio of male to female shortfin scad fish (*D. macrosoma*) in the waters of Sadeng, Yogyakarta has been reported as 57.96%:45.68% or 1.4:1 [8]. The sex ratio of male:female shortfin scad in the Makassar Strait and the Gulf of Bone has previously been reported as 3.02:1.00 and 1.75:1.00, respectively [9], and 20.32% more males than females [10]. In all these cases, the number of male fish was higher than that of females. However other studies have reported a higher number of females than males, with 55.85% more female than male fish ($13.18 > 6.64$) in Javanese waters [11], and a sex ratio (male:female) of 1 : 2 in Banda Aceh [12]. Meanwhile, it seems that the sex ratio between male and female fish in the Gulf of Ambon is always balanced [13].

3.2. Gonad Maturity Level

Gonad Maturity Level (GML) of shortfin scad fish during the observation period differed between male and female fish. Overall, the male shortfin scad sampled were dominated by immature gonad levels, with GML I and GML II (respectively 34% and 28%) comprising over 60% of the sample. Conversely, the female shortfin scad sample was dominated by maturing and mature gonad levels, GML III and GML IV (respectively 32% and 24%), collectively over half (56%) of the sample. With a majority of female shortfin scads in GML III (38%) and GML IV (34%), it was found that most female fish in Yogyakarta had mature gonads [8]. Conversely, other studies found that fish caught in the Makassar Strait were dominated by young and immature fish (GML I and GML II), for both male (73.80%) and female (77.27%) shortfin scads. However a study in the Gulf of Bone found, as in this study, that more male fish had immature fish gonads (77.33%) compared to females (48.54%) [14].

Knowledge regarding the gonad maturity index is indispensable in aquatic biology since it can be used to determine the ratio of reproductive and non-reproductive fish in a water body [4]. Furthermore, it is considered that the gonads of fish living in tropical waters will be mature faster than in temperate regions, and tend to spawn throughout the year. The percentage of fish with mature gonads can be used to identify the spawning season. The peak spawning season can be predicted by looking for a high percentage of high gonad maturity level.

3.3. Size at first maturity

The study of the first size of mature gonad vertically can be used as an indicator of the pressure on a fished population. The results showed that the male shortfin scad fish (*D. macrosoma*) reach the first size of mature gonad at fork lengths (FL) in the range of 18.24–19.54 cm (95% confidence level); meanwhile for female shortfin scad fish first maturity was reached in the range of 16.45–17.24 cm (95% confidence level). Shortfin scad fish (*D. macrosoma*) have been reported as reaching first maturity at an average fork length of 19–20 cm [14].

However these findings differ from those found by previous researchers at other sites. At some, maturity was reached at smaller sizes. For example one study in Ambon Bay found that *D. macrosoma* reached first maturity at an average length of 15 cm [13], while another reports male shortfin scad reaching first maturity at a total length of 163 mm, and females at 155 mm [12]. Meanwhile in the Java Sea shortfin scad matured at 15.53 cm [1], and in the waters of Barru District some shortfin scad spawned at a total length of 15 cm [15].

Conversely, at several sites the size at first maturity was considerably larger than in this study. For example, in the waters of Sadeng Gunung Kidul, the size at first maturity of male and female shortfin scad respectively was 247 mm and 250 mm FL [8]. Other studies have reported sizes at first maturity of 250 mm [11]; 196 - 201 mm FL for males and 198–203 mm FL for female fish [10]; 232 mm FL based on observation of female egg maturity, at a presumed age of two years old [16]; 153 mm FL for males and 158 mm FL for females [17]; while the size range of shortfin scad fish at Likupang Bay, North Sulawesi was 8.4 - 25.2 cm [18].

These different results are likely due to the method or approach used and the size metric measured, as well as to actual differences in length. In this study fork length was used, while some previous studies used total length. The use of fork length was chosen in this study with the consideration of accuracy in measurement. One of the other most likely factors is that of exploitation pressure; this can cause the reproduction process to become accelerated, as a natural reproductive strategy to avoid extinction. The size of each fish at first maturity tends to be different, even within the same species [19]. The size at which gonads mature is related to growth, and together with environmental factors influences growth and reproductive strategies. Fish that are under pressure because of overfishing, tend to mature at a smaller size.

3.4. Length weight relationship of shortfin scad

Analysis of shortfin scad length weight relationships showed that both male and female fishes exhibited an allometric growth pattern ($b > 3$), with b values of 3.37 for males and 3.73 for females (Figures 4 and 5). A value of $b > 3$ indicates that the weight gain of the shortfin scad fish is proportionally faster than the increase in body length [4]. Allometric positive length weight relationships for shortfin scad have also been reported from Ambon ($b = 3.56 - 3.63$) [20]. However, at several other sites shortfin scad showed allometric negative growth [5]. For example in Sandeng Gunung Kidul with a b value of 2.88 [8]; in Banda Aceh [12]; in the waters of Maluku, Papua, and Banda Sea including Halmahera ($b = 2.42-2.55$), and in Ambon Bay ($b = 2.30$) [21]. Biologically, the value of b is related to fish condition, which in turn depends on food availability, age, sex, and gonad maturity [4].

The correlation coefficient for both male and female fish in this study was positive and very strong ($R^2 = 0.90$; Fig. 1 & 2). This shows that there is a close relationship between body weight and the fork

length in male and female shortfin scad fish caught in the seas around Makassar. The F test of the regression coefficient between the fork length and the body weight of male and female shortfin scad fish showed no significant difference ($p > 0.05$). This indicates that in general male and female shortfin scad fish have similar patterns in terms of weight gain and body length. A similarly strong length weight relationship for shortfin scad with a positive correlation coefficient and very strong correlation ($R^2 = 0.956-0.997$) has been reported from Ambon [20].

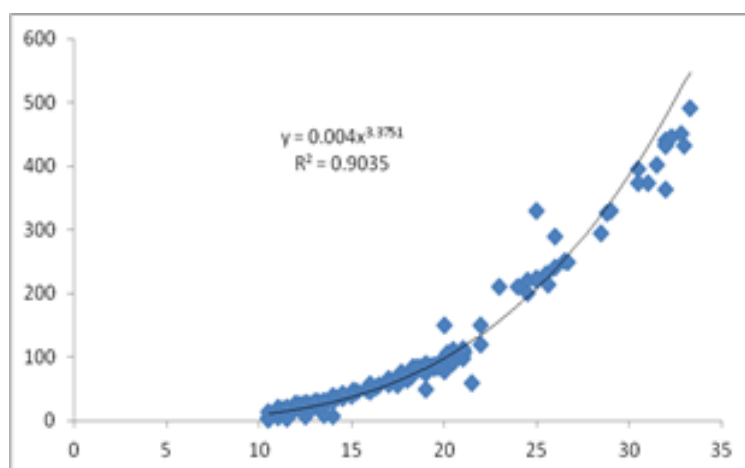


Figure 1. Length Weight Relationship of Male Shortfin Scad

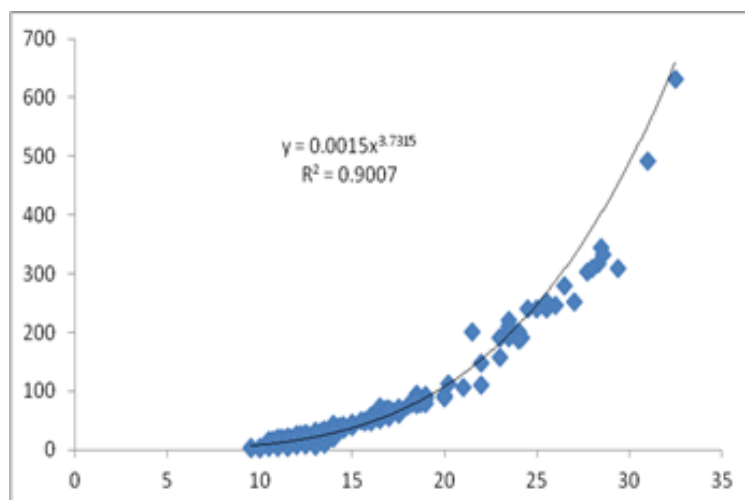


Figure 2. Length Weight Relationship of Female Shortfin Scad

3.5. Fisheries management of shortfin scad

Fish are generally considered as a renewable resource. Fish stocks have the ability to recover and increase in abundance if fishing follows appropriate rules; for example regarding mesh size, environmentally friendly fishing techniques, fishing seasons, etc. An optimal and environmentally friendly fishery has the goal of maintaining fish stocks as a renewable resource, meaning that the resource has the ability to breed to improve stock abundance naturally. Therefore fishery management efforts are required for the control of fish resources that are exploited, taking into consideration future stock abundance. From a biological aspect, management needs to consider the readiness of fish to be caught in terms of the size at which fish are caught and the size at first maturity. Fish that are ready to be caught should generally be above the size at first maturity and the majority should have spawned.

The smallest size caught in this study was 12.82 cm for male and 12.02 cm for female fishes. This means that the male and female fishes in Makassar sea waters may be captured at sizes below first

maturity. However when using nets with a mesh size of 2 inches or 50.80 mm, the smallest size caught was 255 mm, while the $\frac{1}{2}$ L₈ value for the fish was 200 mm. The SF value obtained by calculating the selectivity of the fishing gear was 5.02 [8]. The SF value is large enough to show that mini purse seine gear can be considered a selective capture device for shortfin scad. The value of $L > \frac{1}{2}$ L₈ indicates that the fish caught are generally large enough. The results of the first measurements of gonad maturity obtained values of L_m 50% for male and female fish of 247 mm and 250 mm, respectively, while the L_c 50% was 255 mm. This shows that in general the fish caught were dominated by fish that have experienced gonad maturation and can be expected to have spawned. Based on the data, the most suitable season for shortfin scad fishing in the study location was the time after spawning, around July and August. This is in accordance with the results of a study in Ambon Bay that found *D. macrosoma* peak recruitment could be expected in July-August and November-December [21].

Fish are not ready to be captured when they are still too small and their gonads are still immature, so they have not had a chance to be able to reproduce and contribute recruits to the stock. The results of the study showed that 37.8% of male fish and 53.32% of female fish had mature gonads, meaning that around 62.2% and 46.68%, respectively, were still immature. As just over half of female fish had mature gonads, it is likely that some of these fish had reproduced and contributed to the maintenance of the stock, and thus future shortfin abundance is likely reasonably secure with the currently used mesh size. However, as a precautionary measure, the mesh size should be enlarged so that a higher proportion of bigger fish are caught, and the proportion of fish that have spawned (GML V, spent) could be increased. It is proposed that the mesh size should be enlarged to 2.5 inches, a common mesh size for mini purse seine nets elsewhere [5].

4. Conclusion

Sex ratio of shortfin scad during the study period was not significantly different or balanced (1:1). Shortfin scad in this population reached first maturity at fork lengths in the range 18.24–19.54 cm for males and 16.45–17.24 cm for females. The dominant Gonad Maturity Index (GML) categories were GML I and II for males and GML III and IV for female. The growth pattern of shortfin scad was allometric positive ($b > 3$), with fish gaining weight faster than the increase in body length.

In order to provide optimal and sustainable production of the shortfin scad (*D. macrosoma*) in South Sulawesi waters, especially in the study site, fisheries management measures are necessary. These should include controls on the number of fishing gear, the use of environmentally friendly fishing gear, net mesh size, seasonal closures of fishing grounds and or the creation of conservation areas.

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