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Article

Population Dynamics of the Spotted Scat *Scatophagus argus* (Linnaeus, 1766) in Pak Panang Bay, Nakhon Si Thammarat, Thailand

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Abstract

Population dynamics of the spotted scat, *Scatophagus argus* (Linnaeus, 1766), at Pak Panang Bay were studied by using length frequency distribution data during March 2006 to June 2007. The length-weight relationship equation showed that *S. argus* is an allometric growth species. The asymptotic length (L_∞) and the curvature growth (K) were 17.87 cm and 0.47 year^{-1}, respectively. Based on L_∞ and K, the total mortality rate during the study period was estimated at 2.97 year^{-1}; natural mortality and fishing mortality rate were estimated at 1.30 year^{-1} and 1.67 year^{-1}, respectively. The recruitment was prolonged with one peak per year during May to July. A 56 % reduction in the current exploitation state was recommended on the basis of relative yield per recruit analysis. Mitigation measures for the species including gear restriction in the coastal zone are also discussed.

Keywords: Spotted scat, growth, mortality, yield per recruits, Pak Panang Bay

Introduction

The Spotted scat (*Scatophagus argus*) is an euryhaline teleost fish, which is widely distributed in the near shore waters of the Indo-Pacific [1] between 1 to 4 m deep [2]. *S. argus* is euryhaline and can be found in freshwater, brackish-water and marine habitats but frequently occurs among mangroves because they serve as the main feeding ground for *S. argus*, which feeds on worms, crustaceans, insects and plant matter [3]. *S. argus* can grow as large as 38.0 cm in total length (TL) but are commonly found to be 20 cm TL [3]. Although the current state of *S. argus* has not yet been evaluated [4], demand and fishing pressure on this species is thought to have increased, at least for the stocks in Thai waters. Because *S. argus* is a popular aquarium fish [5] and also a marketed species with a high price (i.e. about 150 - 350 Thai Bath per kg in large scat).

One of the important fishing grounds of *S. argus* in Thai waters is Pak Panang Bay in the Gulf of Thailand, Several fishing gears were used to catch fish in this zone such as cast nets, stow nets, common life nets, gillnets, long line, spear, fish and crab traps, trawl nets, push nets etc. The numbers of species that are researched in this bay were 70 fish species belonging to 68 genera and 44 families [6]. Like other fishery target species in this fishing area, the fishers in the bay have experienced decreases in *S. argus* catches with the capture size becoming smaller, which may be due to over-fishing. Moreover, the fishing resources in Pak Panang Bay have been in tremendous decline due to nonselective gears, such as push and trawl nets, operated within the coastal zone, about 3,000 m from shore, and they catch small fish which are immature [7].

To come up with academic information to support appropriate fisheries management, a population dynamics of *S. argus*'s stock in Pak Panang Bay is desired. Therefore, this paper presents the population parameters and the relative yield per recruit of this species, by using the length-based method, which is necessary in formulating management and conservation policies as well as in the future development of the fishery for Spotted Scat in Pak Panang Bay.

Materials and methods

Data Collection

Three sampling stations were selected (**Figure 1**), and fixed by using the Garmin-GPSmap 76CSx. The field samplings were conducted from March 2006 to June 2007. Samplings were conducted monthly during the spring-tide period. The fish samplings were conducted by using a push net dragging the circumscribed sampling area for around 30 min. Fish samples were packed and kept in ice then brought to Walailak University about 50 km from the bay. Species identification was made and *S. argus* in the subsamples were measured in terms of total length (TL, to the nearest 0.1 cm) and weighted (to the nearest 0.1 g).

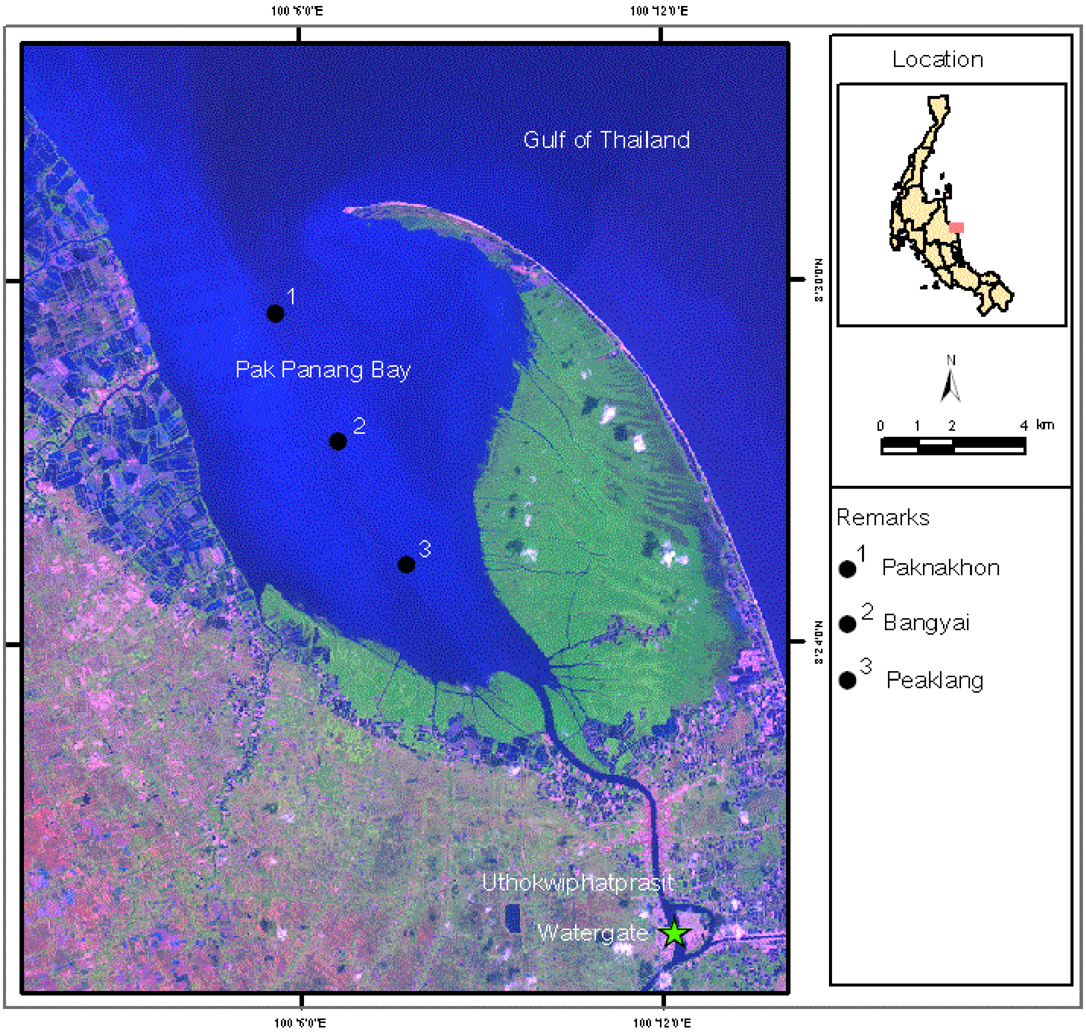

Figure 1 Pak Panang Bay and sampling stations (1, 2 and 3).

Data Analysis

Length-weight relationship was obtained by regression analysis, and fitted to power function (Eq. 1) and a linear function (Eq. 2) [8].

$$W = aL^b \quad (1)$$

$$\ln W = \ln a + b \ln L \quad (2)$$

where W represents weight (g); L represents total length (cm), a is the intercept (condition factor) and b is the slope (growth coefficient). The parameters a and b were estimated using power regression and the coefficient of determination (R^2) to show the correlation level of the relationship.

Length frequency data (LFD) was classified into 1 cm intervals. The "FiSAT II" (FAO-ICLARM Stock Assessment Tool) software [9] was used as a tool for estimating parameters for the von Bertalanffy growth formula (VBGF):

$$L_t = L_\infty \left[1 - \exp(-K^{(t-t_0)})\right] \quad (3)$$

where, L_t is the predicted length at age t (cm), L_∞ is the asymptotic length (cm), K is the curvature parameter (yr^{-1}) and t_0 is the "age" at which $L_t = 0$ [10]. L_∞ and K were estimated as described by [11] and t_0 was therefore obtained from the empirical equation [12]:

$$\log_{10}(-t_0) = -0.3922 - 0.2752 \log_{10}(L_\infty) - 1.038 \log_{10}(K), \quad (4)$$

Size at maturity in fish was predicted by using the life history model [13].

$$L_m = L_\infty \left[\frac{1}{1 + (\frac{M}{3K})}\right] \quad (5)$$

where, L_m is the length at 50 % of maturity and M is the natural mortality rate.

The natural mortality rate (M) was estimated from the empirical linear relationship model of Pauly (1980), using an average surface water temperature (T) in Pak Panang Bay of 30.0 ºC.

$$\log_{10} M = -0.0066 - 0.279 \log_{10} L_\infty + 0.6543 \log_{10} K + 0.463 \log_{10} T \quad (6)$$

The LFD were converted to age-frequency distribution via Eq (7):

$$t = \left[(\frac{1}{K}) \ln(\frac{L_\infty}{L_\infty - L_t})\right] + t_0 \quad (7)$$

The total mortality rate Z, was then estimated from the length-converted catch curve in which the natural logarithms of the numbers in each age class were plotted against age [14,15]. The fishing mortality rate (F) was calculated as Z-M and the exploitation rate (E) was then estimated as F/Z.

The recruitment pattern was figured out through LFD and incorporated the parameters from VBGF [9]. Probabilities of capture were estimated from the detailed analysis of ascending relative yield per recruit (Y'/R), which performed the analysis based on the given selection [16]. The Y'/R analysis was performed for five size levels at first capture (L_c) versus the present size of 50 % retention (L_{50}), two L_c values smaller than the present L_{50} and two L_c values greater than the present L_{50}.

Results

The length-weight relationship of *S. argus* (Eq. 8) had high R^2 value (0.93) and the exponent was significantly different from 3 (P-value < 0.05). Therefore, it is assumed that the growth of this species is "allometric" (i.e. the increase in weight is non-proportional to the length; **Figure 2**).

$$W = 0.0562TL^{2.7021} \quad (8)$$

The growth curves superimposed on monthly LFD are shown in **Figure 3**. Growth parameters from the von Bertalanffy growth formula for *S. argus* were estimated as L_∞ =17.87 cm and K = 0.47 yr^{-1}. For these estimates through ELEFAN I, the index of goodness-of-fit of the growth curve (R_n) was 0.158. The M-Value was 1.30 yr^{-1} and, from this figure, the length at 50% of maturity, L_m of *S. argus* in the Pak Panang Bay was 9.92 cm, indicating it takes about 1.5 yr to approach L_m. From the length convert catch curve, Z-value was 2.97 yr^{-1}, with an R^2-value = 0.997 and a confidence interval of the Z-value between 2.65 to 3.30 (**Figure 4**). From the obtained values of M and Z, therefore, the F-value was 1.67 yr^{-1} and the exploitation rate (E) was 0.56.

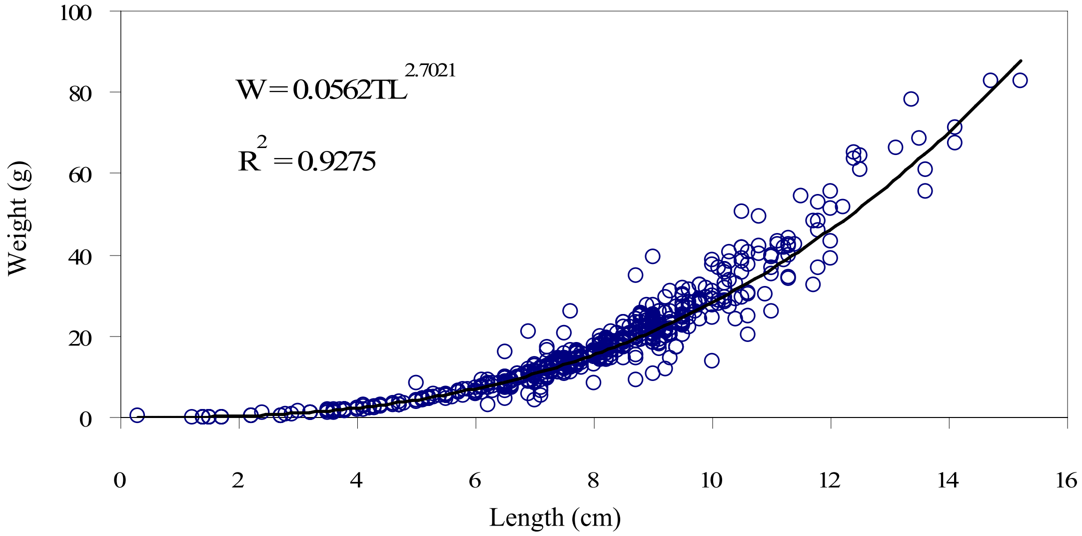

Figure 2 Length-weight relationship of *S. argus* in Pak Panang Bay.

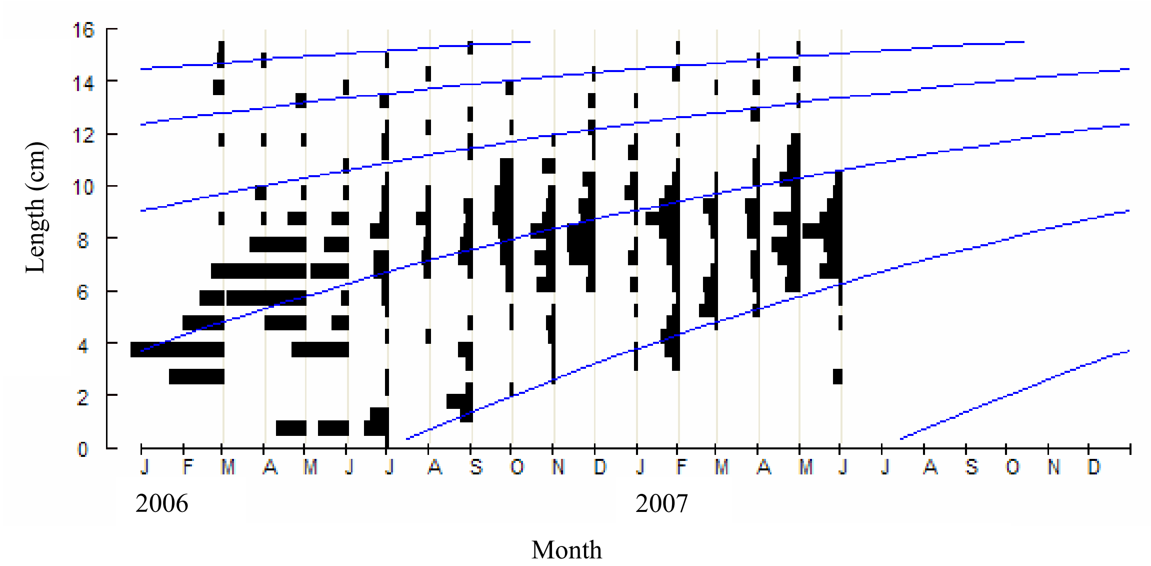

Figure 3 Growth curve of *S. argus*, superimposed on the length frequency distribution of the samples.

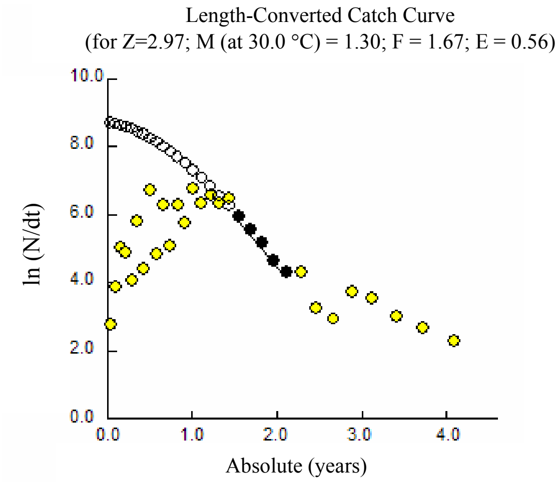

Figure 4 Length converted catch curve of *S. argus* in Pak Panang Bay.

The recruitment was continuous with a single peak per year and the peak of recruitment was found in the seasonal-change periods that is the late summer season change to the early rainy season, between May and July (**Figure 5**). From the probability of capture analysis (**Figure 6**), L_{50} of *S. argus* in Pak Panang river was 2.22 cm, which indicated that push net fishers caught many small fish, which eventually turned to be by-catch. In the current fishing situation ($L_c = L_{50}$), a trend of over-exploitation was observed since the E-value (0.56), is higher than the exploitation rate that yielded a maximum Y'/R (E_{max} = 0.394). The higher value of E is indicative of over-fishing during the studied period. This assumption is based on [17], in which suitable yield is optimized when F = M, (i.e. when E is more than 0.50 the stock is generally considered to be over-fished). By varying to three different L_c by increasing L_c, a higher yield of *S. argus* can be obtained and a higher amount of *S. argus* stock in Pak Panang Bay (**Figure 7**).

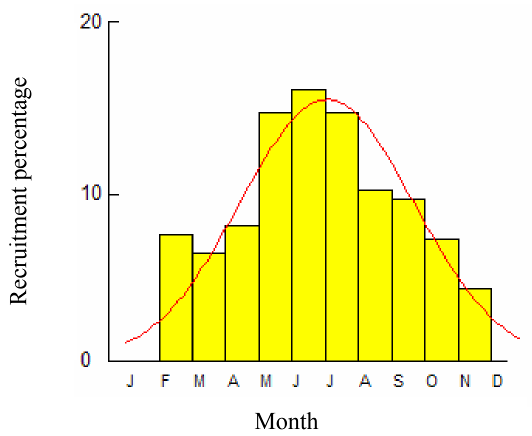

Figure 5 The percentage monthly recruitment of *S. argus*.

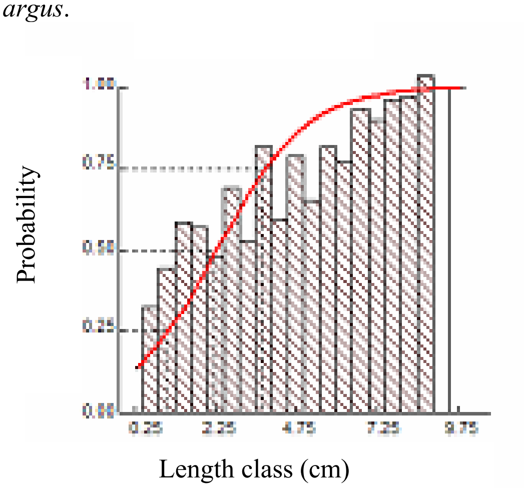

Figure 6 Probability of capture of *S. argus*.

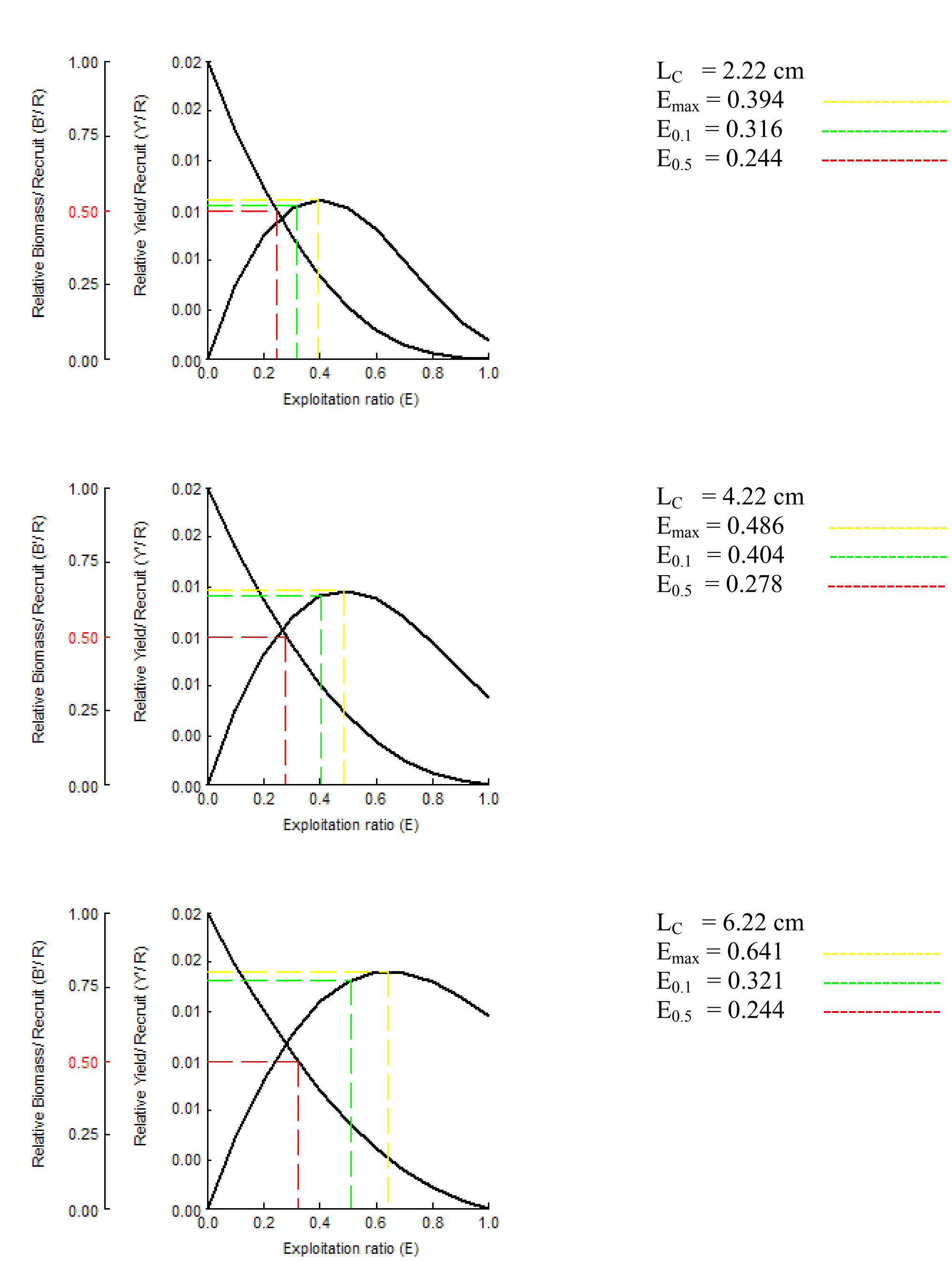

Figure 7 Relative yield per recruitment, Y'/R, (arbitrary units) of *S. argus* in Pak Panang Bay.
Remarks: E_{max} (exploitation rate which produces maximum yield), $E_{0.1}$ (exploitation rate at which the marginal increase of relative yield-per-recruit is $1/10^{th}$ of its value at E = 0) and $E_{0.5}$ (value of E under which the stock has been reduced to 50 % of its unexploited biomass).

Discussion

The exponent value of the length-weight relationship did significantly differ from three, hence the growth pattern of *S. argus* is allometric, which means that the body proportion of fish is transformed during growth and is similar to findings reported from the Philippines [18]. Recruitment of *S. argus* appeared to be continuous throughout the year as mentioned by [19] but peaked between May to July supporting the result of others [20] that sub-adults *S. argus* are abundant during July to September. The result shows that the peak of recruitment from May to July that was not different when compared to the peak of spawning periods, from March to May, predicted by another author for the same species [19].

FiSAT, the software program for population study, is most widely used to study of fish and other aquatic invertebrates population dynamics [21-23] because it is suitable for biologists who are not experts in statistics and it is easy to understand and use [24]. Additionally, the software is neither copy-protected nor copy-righted. From Y'/R analysis it is evident that *S. argus* is heavily exploited. To lessen the fishing intensity, [25] the mentioned E-value, which corresponds to 10 % of the maximum rate of Y'/R increase with increasing E ($E_{0.1}$), is a good determinant of the optimum fishing strategy. Deriso [26] observed that $E_{0.1}$ is desirable because it is lower than E_{max} and therefore, provides a buffer to avoid growth over-fishing and does not reduce the yield to any great extent nor does it bring about a severe reduction of the spawning biomass [27]. Therefore, in attempting to sustain the *S. argus* stock in the Pak Panang Bay, an exploitation rate of 0.316 is recommended. The author suggests that a 56 % reduction of the current exploitation state is optimal for future fishing.

The high exploitation rate (E = 0.56) and small asymptotic length (17.87 cm), compared to the maximum length of 38.00 cm in the adjacent Manila Bay [28] indicated that this fish is highly exploited in Pak Panang Bay. Moreover, fishing at the current rate by push nets, exploited gears, catches extremely small fish (2.22 cm) very much less than the size at 50 % maturity. This is very dangerous, because push nets are non-selected gears that catch on multi-species of multi-size. From the overall results it could be concluded that present fishing pressure is very high and it is essential to reduce this to sustain the production of *S. argus*'s stock in Pak Panang Bay because fishers catch small fish, leading to a growth in over-fishing because the individuals are small and harvested before recruitment. From the study the principle policy should be to limit the use of push net gears and other non-selected gears in coastal zone (3,000 m) and strictly enforce this policy in Pak Panang Bay.

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