



# STUDY ON BIOMASS, VALUE AND BIODIVERSITY OF FISHES BY UNDERWATER VIDEOGRAPHY AT SELECTED ARTIFICIAL REEFS IN PENINSULAR MALAYSIA



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ISBN 978-967-0633-79-4

1. Fishes--Habitat.
  2. Artificial reefs.
  3. Marine biodiversity.
  4. Aquatic biodiversity.
  5. Government publications--Malaysia.
- I. Ahmad Ali. II. Hamizah Nadia Alias@Yusof.  
III. Mohd Saki Noor. IV. Nor Azman Zakaria.  
V. Mohd Sukri Muda. VI. Wahab Daud.  
VII. Title.  
597

Published by:

Jabatan Perikanan Malaysia  
Kementerian Pertanian dan Industri Makanan  
Wisma Tani, Aras 1-6, Blok Menara 4G2, Presint 4  
62628 Putrajaya.  
Tel: 03-8870 4000  
Fax: 03-8890 3794  
Email: hqhelp@dof.gov.my  
<http://www.dof.gov.my>

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This publication should be cited as follows;

Muhammad Amirullah Al Amin, A., Ahmad, A., Hamizah, N.A., Mohd Saki, N., Nor Azman, Z., Mohd Sukri, M. and Wahab, D. (2020). Study on Biomass, Value and Biodiversity of Fishes by Underwater Videography at Selected Artificial Reefs Sites in Peninsular Malaysia. SEAFDEC/MFRDMD/SP/53.51pp.

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## EXECUTIVE SUMMARY

Artificial reefs (ARs) are immersed structures placed on seabed intentionally to imitate some characteristics of natural reefs such as to attract and assemblage of various marine fauna and flora. This study was conducted in 2019 at 10 ARs sites comprising of two confiscated fishing vessels sites, six concrete sites and two decommissioned oil rig platform or Rig to Reef (RTR) sites in coastal waters of Kelantan, Terengganu, Pahang and Johor. The objectives of this study were to estimate biomass, value (in Malaysian Ringgit) and biodiversity of fishes at all AR sites. Visual observation was conducted by eight SCUBA divers using close-up and wide angle still photo and video cameras to record fish assemblages, species identification and to estimate size and weight of each species. Angling was also conducted to catch fish for taxonomy identification and to record individual length-weight. Data were analysed by counting of fish and individual weight was estimated using length-weight of specimens caught by angling. Based on data obtained, the range of commercial fish biomass was between 129 – 6,047 kg/site. The highest biomass was at Cuboid Anti-Trawler ARs, located near Pulau Tinggi with a total value of RM 84,759.60 and the lowest was at Confiscated Fishing Vessels ARs, located near Pulau Kapas with a total value of RM 1,824.50. Meanwhile, the range of fish biodiversity according to Simpson's Diversity Index was between 0.07 – 0.33. Highest biodiversity was recorded at Recreation 2 ARs located near Sungai Merchong. Inversely, the lowest biodiversity was recorded at RTR 43 metric tons ARs located near Pulau Kapas. The range of species richness was between 14 - 46 species. The highest species richness was recorded at Confiscated Fishing Vessel ARs, located in coastal waters of Kuala Kemasin. Inversely, the lowest species richness was recorded at RTR 18 metric tons ARs located near Pulau Kapas. In general, larger size and more numbers of ARs modules will attract and aggregate more demersal and pelagic fishes compared to the smaller and less number of modules.

## RINGKASAN EKSEKUTIF

Tukun tiruan ialah struktur yang ditenggelamkan di dasar laut bertujuan menyamai ciri-ciri terumbu karang semulajadi untuk mengumpulkan pelbagai fauna dan flora marin. Kajian ini telah dijalankan pada tahun 2019 di sepuluh tapak tukun yang terdiri daripada dua tapak tukun vesel rampasan, enam tapak tukun konkrit dan dua tapak tukun pelantar minyak (RTR) di perairan Kelantan, Terengganu, Pahang dan Johor. Objektif kajian ini ialah untuk menganggarkan biomassa, nilai (dalam Ringgit Malaysia) dan kepelbagaian spesies ikan pada tukun tiruan. Pemantauan secara visual telah dijalankan oleh lapan orang penyelam SCUBA menggunakan kamera rakaman video dan gambar jarak dekat dan bersudut luas untuk merakam kumpulan ikan, pengecaman spesies dan menganggarkan saiz dan berat bagi setiap spesies. Kaedah memancing juga dijalankan untuk mengumpulkan sampel ikan bagi tujuan identifikasi taksonomi, merekod panjang-berat bagi setiap sampel ikan yang diperolehi. Analisa data dilakukan dengan mengira bilangan ikan dan menganggarkan berat ikan menggunakan maklumat yang diperolehi melalui sampel ikan yang dipancing. Berdasarkan data yang diperolehi, julat biomassa ikan ialah di antara 129 – 6,047 kg/tapak. Biomas tertinggi telah direkodkan pada tukun Kuboid Penghalang Pukat Tunda yang dilabuhkan di perairan Pulau Tinggi dengan nilai sebanyak RM 84,759.60. Manakala, biomas terendah pula direkodkan pada tukun Vesel Rampasan yang dilabuhkan di perairan Pulau Kapas dengan nilai sebanyak RM 1,824.50. Selain itu, julat indek biodiversiti mengikut Simpson's Diversity Index ialah di antara 0.07 – 0.33. Biodiversiti tertinggi telah direkodkan pada tukun Rekreasi 2 yang terletak di perairan Sungai Merchong. Sebaliknya, biodiversiti terendah pula direkodkan pada tukun RTR 43 metrik tan yang terletak di perairan Pulau Kapas. Julat kelimpahan spesies ialah di antara 14 - 46 spesies dengan kelimpahan spesies tertinggi direkodkan pada tukun Vesel Rampasan yang dilabuhkan di Kuala Kemasin. Manakala, kelimpahan spesies terendah pula direkodkan pada Tukun RTR 18 metrik tan di perairan Pulau Kapas. Secara umumnya, tukun yang bersaiz besar dan mempunyai bilangan yang banyak akan menarik dan mengumpulkan lebih banyak ikan demersal dan pelagik berbanding tukun yang bersaiz kecil dan sedikit jumlahnya.

## 1. INTRODUCTION

Ahmad *et al.*, (2013) stated that artificial reefs (ARs) in Malaysia are referred to any man-made structures or natural objects placed in marine water body to provide new habitat for fish and other flora and fauna, and at the same time prevent the encroachment of destructive gears such as trawls into marine protected areas (MPAs). A total of 215 new ARs sites were established from 2006 - 2019 in Malaysia by the Department of Fisheries Malaysia (DoFM). The main reason for the deployment of ARs since 1975 was due to fish stock decline in the coastal waters (Wong, 1981).

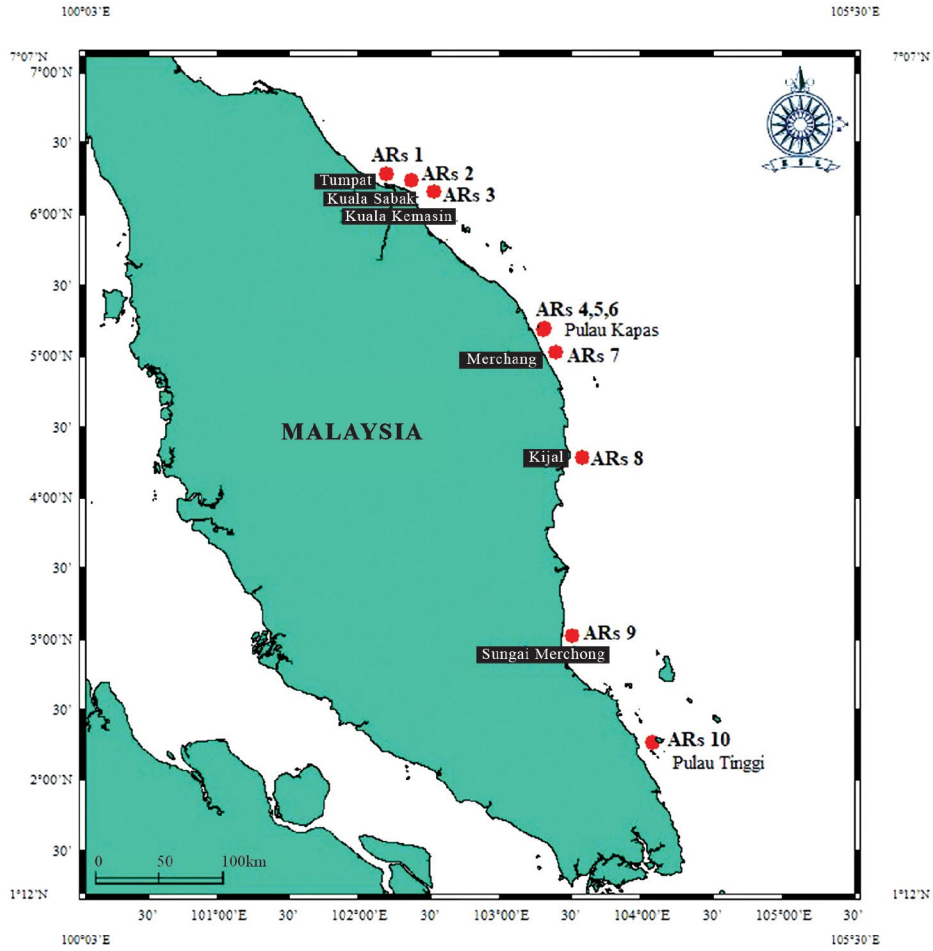
The scantiness of substratum and lively habitat in congruent bottom areas stands out as one of the most common problems in the coastal area (D'Itri, 1986). According to Ilana *et al.* (2002) this situation occurred because such areas are not generally considered to be dynamic in terms of fish yield. Hueckel *et al.* (1989) and Bohnsack *et al.* (1997) reported that development of ARs to form new irregular rocky structure in the sea bottoms is usually applied to provide new fishing ground and enhance harvesting efficiency, and has great prospective for the habitat rehabilitation and mitigating as well as one of the steps to improve the problem of reducing fish resources in the coastal waters. It is believed that the development of ARs can brace a various indigenous fish assemblage of a region comprising nektonic pelagic fishes as well as benthic and demersal species (Ilana *et al.* 2002).

Several research on biodiversity of fishes at ARs in Malaysia were conducted as reported by Wong (1981); Wong (1991); Jothy (1986); Abdul Razak and Mohammed Pauzi (1991); Abdul Razak and Ismail (1994); Raja Mohammad Noordin *et al.* (1994); Sukarno *et al.* (1994); Daud and Mohd Zakaria (2007); Mohamed Pauzi *et al.* (2010) and Ahmad *et al.* (2013). However, research on biomass of fishes at ARs is still scanty. At present, only one paper on biomass of fishes at concrete ARs was published by Mohamed Pauzi *et al.* (2010).

## 2. MATERIALS AND METHODS

In this study, monitoring was conducted at 10 selected ARs sites comprising of two confiscated fishing vessels sites (one in State of Kelantan and one in State of Terengganu), six concrete sites (one site in each State of Pahang and Johor, two sites in each State of Kelantan and Terengganu) and two decommission oil rig platform (RTR) sites in State of Terengganu. The locations of respective ARs are shown in **Figure 1**.





**Figure 1:** Location of study sites in Peninsular Malaysia

Monitoring data were taken after ARs were placed between one month to 10 years. Normally, ARs were effective in attracting and aggregating various fish species few months after placement. All the study sites were located between 3.7 – 8.9 nautical miles (nm) from coastline. All ARs were placed between year of 2009 - 2019. Each site was placed with 1 - 23 ARs modules with different structural designs and materials. Specifications of ARs placed at respective site is shown in **Table 1**.

**Table 1:** Specifications of ARs used in this study

| Location/<br>State            | Type of ARs                            | Type of<br>Sediment | Water<br>Depth<br>(Meter) | Distance<br>from<br>Coastline<br>(Nautical<br>Miles) | Measurement in<br>Meter (Length x<br>Width x Height) | Coverage<br>Area (m <sup>3</sup> ) | No. of<br>Module/site | Year of<br>Placement | Duration of<br>Placement<br>During<br>Study |
|-------------------------------|--|---------------------|---------------------------|--|--|------------------------------------|-----------------------|----------------------|---|
| Tumpat/<br>Kelantan           | Soft-bottom<br>ARs 1                   | Muddy sand          | 17                        | 4.2  | 3 x 3 x 3.6  | 454                                | 14                    | 2009                 | 10 years                                    |
| Kuala<br>Sabak/<br>Kelantan   | Soft-bottom 3<br>ARs 2                 | Muddy sand          | 21                        | 4.3  | 3.75 x 3.75 x 3.85                                   | 758                                | 14                    | 2009                 | 10 years                                    |
| Kuala<br>Kemasin/<br>Kelantan | Confiscated<br>Fishing Vessel<br>ARs 3 | Muddy sand          | 24                        | 8.9  | 25.5 x 4 x 5   | 14,688                             | 18                    | 2019                 | 3 months                                    |
| Pulau Kapas/<br>Terengganu    | RTR 43 Metric<br>tons<br>ARs 4         | Sandy               | 23                        | 3.8  | 11.1 x 11.1 x 3                                      | 370                                | 1                     | 2017                 | 2 years                                     |
| Pulau Kapas/<br>Terengganu    | RTR 18 Metric<br>tons<br>ARs 5         | Sandy               | 23                        | 3.9  | 6 x 6 x 2  | 72                                 | 1                     | 2017                 | 2 years                                     |
| Pulau Kapas/<br>Terengganu    | Confiscated<br>Fishing Vessel<br>ARs 6 | Sandy               | 25                        | 4.1  | 19.2 x 3.5 x 5                                       | 1,680                              | 5                     | 2019                 | 1 month                                     |
| Merchang/<br>Terengganu       | Cube<br>ARs 7                          | Sandy               | 31                        | 4.9  | 2.5 x 2.5 x 2.5                                      | 281                                | 18                    | 2009                 | 10 years                                    |
| Kijal/<br>Terengganu          | Cube<br>ARs 8                          | Sandy               | 21                        | 4.8  | 2.5 x 2.5 x 2.5                                      | 281                                | 18                    | 2009                 | 10 years                                    |
| Sungai<br>Merchong/<br>Pahang | Recreation 2<br>ARs 9                  | Sandy               | 10                        | 3.7  | 1.8 x 1.8 x 1.85                                     | 108                                | 18                    | 2010                 | 9 years                                     |
| Pulau<br>Tinggi/<br>Johor     | Cuboid Anti-<br>trawler<br>ARs 10      | Sandy mud           | 17                        | 5.8  | 3.5 x 3.5 x 3  | 845                                | 23                    | 2017                 | 2 years                                     |

Visual observation was conducted using close-up and wide angle video and still photo cameras to record fish assemblages especially with regard to their interaction with the ARs as well as fish biodiversity as suggested by Ahmad *et al.* (2013). A total of 1 - 5 modules were used as sampling units at each site for estimation of fish biomass and identification of fish species. Eight divers equipped with three video and three still photo cameras were sent off to execute the monitoring tasks during 2 – 3 scheduled dives a day. Angling using hook and lines was also conducted to catch fish for taxonomy and individual length-weight measurement. Biomass and biodiversity data were obtained by observations of fishes recorded by videos and photos. Weight of individual fish species were estimated using length-weight of specimens caught by angling. The numbers of fishes/module were quantified by estimation and direct visual counting by divers and from video grabs and still pictures.

Since no single method may yield a faunal assessment that is clearly more accurate or precise than others, fish aggregations and fish species associated with the ARs were assessed using a combination of several methodologies. This included non-destructive visual observation via transect, fixed stationary points as well as search pattern for fishes as recommended by Tessier *et al.* (2005); Stephen *et al.* (2000) and Bombace *et al.* (2000). When the number of fish was small (less than 20 individuals) such as groupers, rabbit fish, snappers, crabs and lobsters, the total count was made by divers. For large population especially of *Lutjanus lutjanus*, *Lutjanus madras* and *Archamia fucata*, the number of fish/module were estimated as suggested by Stephen *et al.* (2000).

Calculation process for estimation of biomass for **each species** in this study is shown below:

**(i) Average number of particular species in 1m<sup>3</sup>**

$$= (A+B)/2*$$

$$= K$$

Note: (A and B = volume of ARs in m<sup>3</sup>)

(2\* = 2m<sup>3</sup> frame from underwater video, calculation of this volume is depending on visibility at ARs. If visibility is excellent, area covered will be larger.)

**(ii) Biomass in 1m<sup>3</sup>**

$$= K \times P*$$

$$= Y \text{ (kg)}$$

Note: (P\* = average weight of that particular species (kg). Weight of each particular species was recorded from specimens caught by angling.)

**(iii) Total volume of ARs at a particular site**

$$= A \text{ (m}^3\text{)}$$

Note: (This volume was calculated based on size and number of ARs, area of ARs covered on the sea floor and distance of fish from outside of ARs structure)

**(iv) Total biomass at each ARs site**

$$= Y \times A$$

$$= Z \text{ (kg/site)}$$

Identification of fish species were confirmed based on references made to Ahmad *et al.* (2019); Annie *et al.* (2018); Bergbauer and Kirschner (2014); Ahmad *et al.* (2012); Anderson (2010); Annie Lim and Albert (2009); Allen (2009); Department of Fisheries Malaysia (2009), and Andrea and Antonella Ferrari (2006). The biodiversity of fishes were estimated by using Simpson's Diversity Index (D) (Simpson's Diversity Index, 2020). Where 'D' is a measure of diversity which takes into account the number of species present, as well as the relative abundance of each species.

The two main factors taken into account when measuring diversity are species richness and evenness. Where richness is a measures of the different number of species present in a particular area. However, diversity not only depends on richness, but also on evenness. Evenness compares the similarity of the population size of each of the species present. As species richness and evenness increase, so diversity increases. The value of 'D' ranges between 0 and 1. With this index, 0 represents infinite diversity and 1 means no diversity. Simpson's Diversity Index was calculated as equation below:

$$D = \sum n(n-1)/N(N-1)$$

n = the total number of organisms of a particular species

N = the total number of organisms of all species

D = Simpson's Diversity Index

### 3. RESULTS

#### 3.1. Species Richness at All Study Sites

A total of 88 species belonging to 32 families that made up of 81 species of Osteichthyes, three species of Chondrichthyes and four species of Crustacean were recorded. These included 54 commercially important fishes and 34 coral fishes. Commercial fishes were dominated by species from families of Lutjanidae, Carangidae, Caesionidae and Siganidae. Large numbers of *Lutjanus* spp. were found schooling close to the modules and also occupying the top parts and holes of all ARs. High value demersal fishes classified as resident species such as *Lutjanus russellii*, *Lutjanus johnii*, *Plectorhinchus gibbosus*, *Diagramma pictum*, *Epinephelus coioides* and *Cephalopholis formosa* were mostly found confined within or in close affinity to the ARs structures. However, high value pelagic fishes preferred to swim in the middle and upper part of the ARs. These were species such as *Selaroides leptolepis*, *Alepes vari*, *Caranx sexfasciatus*, *Gnathanodon speciosus*, *Scomberoides commersonianus*, *Carangoides gymnostethus* and *Atule mate* which were classified as visiting species. These fishes were frequently observed to swim at mid-water and a distance away from the ARs as compared to the resident species.

In term of commercial species recorded at all sites, the number were ranged from 4 - 167,200 individuals. Numbers of commercial species were ranged between 11 - 33 species. The

highest number of fishes per site was recorded at ARs 8 located in Kijal, Terengganu at 192,170 individuals, followed by ARs 3 located in Kuala Kemasin, Kelantan (137,927 individuals) and ARs 10 located in Pulau Tinggi, Johor with 115,216 individuals. Data from visual observation at all study sites showed that the most dominant and commercially important species were *Lutjanus lutjanus* (167,200 individuals) followed by *Lutjanus madras* (100,500 individuals) and *Pterocaesio chrysozona* with 49,390 individuals. *Lutjanus lutjanus* were ranged from 1,000 - 54,000 individuals per site, 200 - 36,800 individuals for *Lutjanus madras* and 230 - 36,000 individuals for *Pterocaesio chrysozona*. The highest number of *Lutjanus lutjanus* (54,000 individuals) were recorded at ARs 8 followed by *Lutjanus madras* (36,800 individuals) at ARs 10 and *Pterocaesio chrysozona* (36,000 individuals) at ARs 3. Meanwhile, the lowest numbers of *Lutjanus lutjanus* (1,000 individuals) were recorded at ARs 6, *Lutjanus madras* (200 individuals) at ARs 5 and *Pterocaesio chrysozona* with 230 individuals at ARs 10. All these species were classified as resident species and were found swimming in close affinity to the ARs structures. In term of species richness, the highest number of species was recorded at ARs 3 with 33 commercial species out of 46 species followed by ARs 9 with 23 commercial species out of 39 species and ARs 10 with also 24 commercial species out of 38 species.

Details on species richness and total number of fish by species recorded during this study are shown in **Table 2**.

**Table 2:** Species richness and total number of fish at respective ARs site.

| No. | Species                              | Family        | ARs 1 | ARs 2 | ARs 3  | ARs 4  | ARs 5 | ARs 6 | ARs 7  | ARs 8  | ARs 9 | ARs 10 | Total number by species |
|-----|--------------------------------------|---------------|-------|-------|--------|--------|-------|-------|--------|--------|-------|--------|-------------------------|
| 1   | <i>Lutjanus lutjanus</i> (C)**       | Lutjanidae    | 1,400 | 2,800 | 14,400 | 12,000 | 5,000 | 1,000 | 28,800 | 54,000 | 1,800 | 46,000 | 167,200                 |
| 2   | <i>Lutjanus madras</i> (C)           | Lutjanidae    | 560   | 2,240 | 7,200  | 5,000  | 200   | 800   | 18,000 | 28,800 | 900   | 36,800 | 100,500                 |
| 3   | <i>Archamia fucata</i> (NC)***       | Apogonidae    |       | 7,000 | 19,980 |        |       |       | 10,440 | 20,520 | 3,960 | 2,438  | 64,338                  |
| 4   | <i>Apogon aureus</i> (NC)            | Apogonidae    |       | 4,900 | 13,320 |        |       |       | 11,880 | 22,680 | 3,600 | 2,300  | 58,680                  |
| 5   | <i>Pterocaesio chrysozona</i> (C)    | Caesionidae   |       | 1,680 | 36,000 | 2,000  | 2,500 | 500   | 2,160  | 4,320  |       | 230    | 49,390                  |
| 6   | <i>Neopomacentrus cyanomos</i> (NC)  | Pomacentridae | 1,400 | 8,400 | 12,600 | 500    | 1,800 | 500   | 9,360  | 2,808  | 1,800 | 460    | 39,628                  |
| 7   | <i>Apogon</i> sp. (NC)               | Apogonidae    |       |       | 8,640  | 2,000  | 500   |       |        | 17,280 |       |        | 28,420                  |
| 8   | <i>Apogon endekataenia</i> (NC)      | Apogonidae    |       | 70    |        |        |       |       |        | 19,080 | 2,340 | 3,680  | 25,170                  |
| 9   | <i>Selaroides leptolepis</i> (C)     | Carangidae    |       |       | 18,000 |        |       | 50    | 3,600  |        |       | 2,300  | 23,950                  |
| 10  | <i>Archamia bleekeri</i> (NC)        | Apogonidae    |       | 3,920 |        |        |       |       |        |        | 2,880 | 11,500 | 18,300                  |
| 11  | <i>Apogon cavifitensis</i> (NC)      | Apogonidae    |       |       |        |        |       |       | 9,000  |        | 2,808 | 2,162  | 13,970                  |
| 12  | <i>Lutjanus kasmira</i> (C)          | Lutjanidae    |       |       |        | 80     |       |       | 720    | 10,080 | 2,520 |        | 13,400                  |
| 13  | <i>Apogon nigrocincta</i> (NC)       | Apogonidae    |       |       |        |        |       |       | 8,280  |        | 460   |        | 8,740                   |
| 14  | <i>Lutjanus vitta</i> (C)            | Lutjanidae    | 140   |       | 1,800  | 1,000  | 500   | 700   | 540    | 720    | 900   | 920    | 7,220                   |
| 15  | <i>Lutjanus quinque-lineatus</i> (C) | Lutjanidae    |       |       |        | 100    |       |       | 360    | 3,600  | 180   |        | 4,240                   |

|    |                                     |               |       |       |       |    |     |    |       |       |       |       |       |
|----|-------------------------------------|---------------|-------|-------|-------|----|-----|----|-------|-------|-------|-------|-------|
| 16 | <i>Lutjanus russellii</i><br>(C)    | Lutjanidae    | 1,120 | 560   | 180   | 80 | 15  | 30 | 900   | 360   | 540   | 322   | 4,107 |
| 17 | <i>Pomacentrus</i> sp.<br>(NC)      | Pomacentridae |       |       | 18    |    |     |    |       | 1,800 |       | 1,840 | 3,658 |
| 18 | <i>Siganus javus</i> (C)            | Siganidae     | 168   | 840   | 1,548 | 60 |     |    |       |       | 900   | 92    | 3,608 |
| 19 | <i>Chromis</i> sp. (NC)             | Pomacentridae |       |       |       |    |     |    |       | 3,600 |       |       | 3,600 |
| 20 | <i>Caesio cuning</i><br>(C)         | Caesionidae   | 504   | 1,120 | 720   | 50 | 50  |    |       | 288   | 540   | 230   | 3,502 |
| 21 | <i>Sphyraena forsteri</i> (C)       | Sphyraenidae  |       | 400   |       |    |     |    | 2,880 |       |       |       | 3,280 |
| 22 | <i>Karalla daura</i><br>(C)         | Leiognathidae |       |       |       |    |     |    |       |       | 2,160 |       | 2,160 |
| 23 | <i>Sphyraena jello</i><br>(C)       | Sphyraenidae  |       |       | 720   |    |     |    |       |       |       | 1,380 | 2,100 |
| 24 | <i>Atule mate</i> (C)               | Serranidae    |       |       |       |    |     |    |       |       | 1,800 |       | 1,800 |
| 25 | <i>Cephalopholis boenak</i> (C)     | Serranidae    | 70    | 140   | 360   | 20 | 10  |    | 288   | 288   | 144   | 368   | 1,688 |
| 26 | <i>Pempheris malabarica</i> (NC)    | Pempheridae   |       | 560   |       |    |     |    | 108   | 90    | 720   |       | 1,478 |
| 27 | <i>Diagramma pictum</i> (C)         | Haemulidae    |       | 84    | 360   | 40 |     | 20 | 108   | 180   | 144   | 368   | 1,304 |
| 28 | <i>Neopomacentrus azystron</i> (NC) | Pomacentridae |       | 140   |       |    |     |    | 252   | 360   | 198   | 230   | 1,180 |
| 29 | <i>Alepes vari</i> (C)              | Carangidae    |       |       |       |    |     | 50 |       |       | 1,080 |       | 1,130 |
| 30 | <i>Labroides dimidiatus</i> (NC)    | Labridae      |       |       | 11    | 25 |     | 3  | 324   | 360   | 8     | 69    | 800   |
| 31 | <i>Lutjanus johnii</i><br>(C)       | Lutjanidae    | 56    |       | 90    |    |     |    | 36    |       | 36    | 460   | 678   |
| 32 | <i>Caesio caerulaurea</i> (C)       | Caesionidae   |       |       | 540   |    |     |    |       |       |       |       | 540   |
| 33 | <i>Plotosus lineatus</i><br>(C)     | Plotosidae    |       |       |       |    | 500 |    |       |       |       |       | 500   |
| 34 | <i>Scolopsis monogramma</i> (C)     | Nemipteridae  | 56    |       |       | 10 |     |    | 288   |       | 90    |       | 444   |

|    |                                     |                |     |    |  |  |  |   |    |     |    |     |     |     |    |     |    |     |     |
|----|-------------------------------------|----------------|-----|----|--|--|--|---|----|-----|----|-----|-----|-----|----|-----|----|-----|-----|
| 35 | <i>Caranx sexfasciatus</i> (C)      | Carangidae     |     |    |  |  |  |   |    |     |    | 360 |     |     |    |     |    |     | 360 |
| 36 | <i>Carangoides gymnostethus</i> (C) | Carangidae     |     |    |  |  |  |   |    |     |    |     | 360 |     |    |     |    |     | 360 |
| 37 | <i>Siganus canaliculatus</i> (C)    | Siganidae      |     |    |  |  |  |   |    |     | 50 |     |     |     |    |     |    | 230 | 316 |
| 38 | <i>Scolopsis vosmeri</i> (NC)       | Nemipteridae   | 14  | 42 |  |  |  |   |    | 10  | 10 | 11  |     |     | 54 | 36  | 72 | 69  | 308 |
| 39 | <i>Epinephelus bleekeri</i> (C)     | Serranidae     |     |    |  |  |  | 6 |    |     |    | 54  |     |     |    | 108 | 36 | 92  | 296 |
| 40 | <i>Pempheris</i> sp. (NC)           | Pempheridae    |     |    |  |  |  |   |    | 200 |    | 54  |     |     |    |     |    |     | 254 |
| 41 | <i>Neopomacentrus</i> sp. (NC)      | Pomacentridae  |     |    |  |  |  |   |    |     |    |     |     | 250 |    |     |    |     | 250 |
| 42 | <i>Sphyraena obtusata</i> (C)       | Sphyraenidae   |     |    |  |  |  |   |    |     |    | 234 |     |     |    |     |    |     | 234 |
| 43 | <i>Heniochus diphreutes</i> (C)     | Chaetodontidae | 20  | 28 |  |  |  |   | 10 |     |    | 50  |     |     | 36 | 36  | 46 |     | 226 |
| 44 | <i>Cephalopholis formosa</i> (C)    | Serranidae     |     |    |  |  |  |   |    |     |    |     |     |     | 72 | 36  | 69 |     | 213 |
| 45 | <i>Chiloscyllium hasseltii</i> (C)  | Hemiscylliidae | 28  | 56 |  |  |  |   | 6  |     |    | 36  |     |     |    |     | 72 |     | 198 |
| 46 | <i>Lutjanus malabaricus</i> (C)     | Lutjanidae     |     |    |  |  |  |   |    |     |    | 54  |     | 8   | 54 |     | 69 |     | 185 |
| 47 | <i>Epinephelus coioides</i> (C)     | Serranidae     | 11  |    |  |  |  | 5 |    |     |    | 11  |     |     | 36 | 18  | 46 |     | 181 |
| 48 | <i>Choerodon schoenleinii</i> (C)   | Labridae       |     |    |  |  |  |   |    |     |    |     |     |     | 36 | 72  | 46 |     | 154 |
| 49 | <i>Epinephelus areolatus</i> (C)    | Serranidae     |     |    |  |  |  |   |    |     |    | 72  |     | 15  |    | 54  |    |     | 151 |
| 50 | <i>Siganus guttatus</i> (C)         | Siganidae      | 28  |    |  |  |  |   |    |     |    | 72  |     |     |    |     | 46 |     | 146 |
| 51 | <i>Monodactylus argenteus</i> (NC)  | Monodactylidae | 140 |    |  |  |  |   |    |     |    |     |     |     |    |     |    |     | 140 |
| 52 | <i>Pomacentrus milleri</i> (NC)     | Pomacentridae  |     | 70 |  |  |  |   |    |     |    |     |     |     |    |     | 46 |     | 116 |
| 53 | <i>Lethrinus lentjan</i> (C)        | Lethrinidae    |     | 70 |  |  |  |   |    |     |    |     |     |     |    |     | 46 |     | 116 |



|    |      |                                     |                |    |   |   |   |    |   |    |   |    |    |     |   |  |     |    |     |     |
|----|------|-------------------------------------|----------------|----|---|---|---|----|---|----|---|----|----|-----|---|--|-----|----|-----|-----|
| 54 | (C)  | <i>Dascyllus</i> sp. (NC)           | Pomacentridae  |    |   |   |   |    |   |    |   |    |    |     |   |  |     |    | 115 | 115 |
| 55 |      | <i>Pomacanthus annularis</i> (C)    | Pomacanthidae  | 28 | 5 |   |   |    |   |    |   |    | 18 | 36  |   |  |     |    | 23  | 110 |
| 56 |      | <i>Plectorhynchus gibbosus</i> (C)  | Haemulidae     |    |   |   |   | 36 |   |    |   |    | 36 |     |   |  |     |    |     | 108 |
| 57 | (C)  | <i>Carangoides</i> sp.              | Carangidae     |    |   |   |   |    |   |    |   |    |    | 108 |   |  |     |    |     | 108 |
| 58 | (C)  | <i>Plotosus canius</i>              | Plotosidae     |    |   |   |   |    |   |    |   |    |    |     |   |  | 108 |    |     | 108 |
| 59 | (NC) | <i>Petroscirtes</i> sp.             | Blenniidae     |    |   |   |   | 54 |   |    |   |    |    | 54  |   |  |     |    |     | 108 |
| 60 |      | <i>Plectropomus areolatus</i> (C)   | Serranidae     |    |   |   |   | 18 |   |    |   |    | 54 | 7   |   |  |     |    |     | 79  |
| 61 | (NC) | <i>Pterois ruselli</i>              | Scorpaenidae   |    |   |   |   | 72 |   |    |   |    |    | 5   |   |  |     |    |     | 77  |
| 62 |      | <i>Leptojulius cyanopleura</i> (NC) | Labridae       |    |   |   |   |    |   |    |   |    |    |     |   |  |     |    | 69  |     |
| 63 | (NC) | <i>Arothron stellatus</i>           | Tetraodontidae | 5  | 4 | 4 | 5 | 18 | 4 | 5  | 4 |    |    |     |   |  | 4   | 23 |     | 63  |
| 64 |      | <i>Diploprion bifasciatum</i> (NC)  | Serranidae     |    |   |   |   |    |   |    |   | 56 |    |     | 5 |  |     |    |     | 61  |
| 65 |      | <i>Thalassoma lunare</i> (NC)       | Labridae       |    |   |   |   | 36 |   | 5  |   |    |    |     |   |  | 18  |    |     | 59  |
| 66 | (C)  | <i>Lutjanus argentimaculatus</i>    | Lutjanidae     |    |   |   |   | 18 |   |    |   |    |    |     |   |  | 36  |    |     | 54  |
| 67 |      | <i>Centriscus scutatus</i> (NC)     | Centriscidae   |    |   |   |   | 18 |   | 20 |   |    |    |     |   |  |     |    |     | 38  |
| 68 |      | <i>Gnathanodon speciosus</i> (C)    | Carangidae     |    |   |   |   | 36 |   |    |   |    |    |     |   |  |     |    |     | 36  |
| 69 |      | <i>Scolopsis torquatus</i> (NC)     | Nemipteridae   |    |   |   |   |    |   |    |   |    |    |     |   |  |     |    | 36  | 36  |
| 70 |      | <i>Aluterus monocerus</i> (C)       | Monacanthidae  |    |   |   |   | 36 |   |    |   |    |    |     |   |  |     |    |     | 36  |

|    |  |                |  |    |  |  |  |    |  |   |    |   |  |    |  |  |  |  |    |   |      |
|----|--|----------------|--|----|--|--|--|----|--|---|----|---|--|----|--|--|--|--|----|---|------|
| 71 | <i>Pateobatis jenkinsii</i> (C)        | Dasyatidae     |  |    |  |  |  | 18 |  |   |    |   |  | 1  |  |  |  |  |    | 9 | 28   |
| 72 | <i>Charybdis</i> sp. (C)               | Portunidae     |  | 28 |  |  |  |    |  |   |    |   |  |    |  |  |  |  |    |   | 28   |
| 73 | <i>Sargocentron rubrum</i> (NC)        | Holocentridae  |  | 28 |  |  |  |    |  |   |    |   |  |    |  |  |  |  |    |   | 28   |
| 74 | <i>Epinephelus erythrurus</i> (C)      | Serranidae     |  |    |  |  |  |    |  |   |    |   |  |    |  |  |  |  | 23 |   | 23   |
| 75 | <i>Charybdis feriatus</i> (C)          | Portunidae     |  |    |  |  |  | 22 |  |   |    |   |  |    |  |  |  |  |    |   | 21.6 |
| 76 | <i>Scomberoides commersonianus</i> (C) | Carangidae     |  |    |  |  |  | 18 |  |   |    |   |  |    |  |  |  |  |    |   | 18   |
| 77 | <i>Charybdis natator</i> (C)           | Portunidae     |  |    |  |  |  | 18 |  |   |    |   |  |    |  |  |  |  |    |   | 18   |
| 78 | <i>Coradion chrysozonus</i> (C)        | Chaetodontidae |  |    |  |  |  |    |  |   | 18 |   |  |    |  |  |  |  |    |   | 18   |
| 79 | <i>Scomberomorus commerson</i> (C)     | Carangidae     |  |    |  |  |  | 11 |  |   |    |   |  |    |  |  |  |  |    |   | 11   |
| 80 | <i>Lutjanus sebae</i> (C)              | Lutjanidae     |  |    |  |  |  |    |  |   |    |   |  | 10 |  |  |  |  |    |   | 10   |
| 81 | <i>Deodon lituosus</i> (NC)            | Deobotidae     |  |    |  |  |  |    |  |   |    | 4 |  |    |  |  |  |  |    |   | 8    |
| 82 | <i>Scorpaenopsis</i> sp. (NC)          | Scorpaenidae   |  | 4  |  |  |  |    |  |   |    |   |  |    |  |  |  |  |    |   | 8    |
| 83 | <i>Arothron hispidus</i> (NC)          | Tetraodontidae |  |    |  |  |  |    |  |   |    |   |  |    |  |  |  |  | 7  |   | 7    |
| 84 | <i>Echeneis naucrates</i> (NC)         | Echeneidae     |  |    |  |  |  |    |  |   |    | 4 |  |    |  |  |  |  |    |   | 6    |
| 85 | <i>Ostracion</i> sp. (NC)              | Ostraciidae    |  |    |  |  |  |    |  | 5 |    |   |  |    |  |  |  |  |    |   | 5    |
| 86 | <i>Epinephelus fuscoguttatus</i> (C)   | Serranidae     |  |    |  |  |  | 4  |  |   |    |   |  |    |  |  |  |  |    |   | 4    |
| 87 | <i>Taeniura lymma</i> (C)              | Dasyatidae     |  |    |  |  |  |    |  |   |    |   |  |    |  |  |  |  | 4  |   | 4    |
| 88 | <i>Balistoides viridescens</i> (NC)    | Balistidae     |  |    |  |  |  |    |  |   |    |   |  |    |  |  |  |  |    |   | 4    |

|  |       |        |         |        |        |       |         |         |        |         |         |
|--|-------|--------|---------|--------|--------|-------|---------|---------|--------|---------|---------|
| Total number of fishes by ARs          | 5,748 | 35,249 | 137,927 | 23,281 | 11,095 | 3,944 | 108,774 | 192,170 | 33,017 | 115,216 | 666,421 |
| Total number of species by ARs         | 18    | 28     | 46      | 25     | 14     | 17    | 32      | 36      | 39     | 38      |         |
| Total Number of commercial species     | 14    | 14     | 33      | 16     | 11     | 12    | 23      | 20      | 23     | 24      |         |
| Total Number of non-commercial species | 4     | 14     | 13      | 9      | 3      | 5     | 9       | 16      | 16     | 14      |         |

\*ARs 1: Soft-bottom, Tumpat

ARs 2: Soft-bottom 3, Kuala Sabak

ARs 3: Confiscated Fishing Vessel, Kuala Kemasin

ARs 4: RTR 43 Metric tons, Pulau Kapas

\*\*C: Commercial fish

\*\*NC: Non-commercial fish

ARs 5: RTR 18 Metric tons, Pulau Kapas

ARs 6: Confiscated Fishing Vessel, Pulau Kapas

ARs 7: Cube, Merchang

ARs 8: Cube, Kijal

ARs 9: Recreation 2, Sungai Merchong

ARs 10: Cuboid Anti-trawler, Pulau Tinggi

### **3.2. Biomass, Value and Biodiversity of Fishes at Soft-Bottom ARs (ARs 1)**

A total of 18 species recorded at ARs 1 where 14 out of the total species were commercial species. The most abundant species at this site were *Lutjanus lutjanus* and *Neopomacentrus cyanomos* with 1,400 individuals followed by *Lutjanus russellii* with 1,120 individuals. Other species were ranged between 5 - 560 individuals. Total biomass was estimated at 1,203 kg with an average of 85.9 kg/module. The highest biomass was *Lutjanus russellii* with 728 kg followed by *Caesio cunning* (252 kg) and other species were ranged between 1.7 - 42 kg. The value of commercial fish was estimated about RM 26,451.04. Details are shown in **Table 3**.

**Table 3:** Biomass and value of commercial fishes at Soft-Bottom ARs, Tumpat (ARs 1)

| No. | Species                        | Family         | Local name                  | Estimate no. of fish (individual) /site | Average weight of fish / individual (g) | Biomass of fish /site (kg) | Price of fish / kg (RM) | Value of fish (RM) |
|-----|--------------------------------|----------------|-----------------------------|---|---|----------------------------|-------------------------|--------------------|
| 1   | <i>Lutjanus lutjanus</i>       | Lutjanidae     | Kunyit-kunyit               | 1,400                                   | 20                                      | 28                         | 10                      | 280.00             |
| 2   | <i>Lutjanus madras</i>         |                | Kunyit madras               | 560                                     | 25                                      | 14                         | 10                      | 140.00             |
| 3   | <i>Lutjanus vitta</i>          |                | Kunyit remong               | 140                                     | 70                                      | 9.8                        | 15                      | 147.00             |
| 4   | <i>Lutjanus russellii</i>      |                | Merah tanda                 | 1,120                                   | 650                                     | 728                        | 25                      | 18,200.00          |
| 5   | <i>Lutjanus johnii</i>         |                | Jenahak tanda               | 56                                      | 700                                     | 39.2                       | 25                      | 980.00             |
| 6   | <i>Siganus javus</i>           | Siganidae      | Dengkis jawa                | 168                                     | 250                                     | 42                         | 15                      | 630.00             |
| 7   | <i>Siganus guttatus</i>        |                | Dengkis tompok              | 28                                      | 350                                     | 9.8                        | 15                      | 147.00             |
| 8   | <i>Caesio cuning</i>           | Caesionidae    | Delah pinang                | 504                                     | 500                                     | 252                        | 20                      | 5,040.00           |
| 9   | <i>Epinephelus coioides</i>    | Serranidae     | Kerapu bintik jingga        | 11.2                                    | 1,200                                   | 13.4                       | 25                      | 336.00             |
| 10  | <i>Cephalopis boenak</i>       |                | Kerapu belang perang        | 70                                      | 50                                      | 3.5                        | 8                       | 28.00              |
| 11  | <i>Pomacanthus amularis</i>    | Pomacanthidae  | Taring pelanduk cincin biru | 28                                      | 700                                     | 19.6                       | 5                       | 98.00              |
| 12  | <i>Chiloscyllium hasseltii</i> | Hemiscylliidae | Yu cicak lampai             | 28                                      | 1,500                                   | 42                         | 10                      | 420.00             |
| 13  | <i>Scolopsis monogramma</i>    | Nemipteridae   | Pasir-pasir jalur gelap     | 56                                      | 30                                      | 1.7                        | 3                       | 5.04               |
| 14  | <i>Scolopsis vosmeri</i>       |                | Pasir-pasir pipi putih      | 14                                      |   |                            |                         |                    |
| 15  | <i>Heniochus diphreutes</i>    | Chaetodontidae | Bagang sirip filamen        | 20                                      | NA                                      | NA                         | NA                      | NA                 |
| 16  | <i>Neopomacentrus cyanomos</i> | Pomacentridae  | Kepal batu                  | 1,400                                   |   |                            |                         |                    |
| 17  | <i>Monodactylus argenteus</i>  | Monodactylidae | Bawal bulan perak           | 140                                     |   |                            |                         |                    |
| 18  | <i>Arothron stellatus</i>      | Tetraodontidae | Buntal pasir bintang        | 5                                       |   |                            |                         |                    |
|     | Total                          |                |                             |   |   | 1,203                      |                         | 26,451.04          |
|     | Average                        |                |                             |   |   | 85.9                       |                         |                    |

Biodiversity of fishes at this site according to Simpson's Diversity Index (D) was 0.18 (N = 5,748) with 18 total number of species. In term of percentage, *Lutjanus lutjanus* and *Neopomacentrus cyanomos* recorded the highest at 24.36% followed by *Lutjanus russellii* (19.48%) and *Lutjanus madras* at 9.74%. Details are shown in **Table 4**.

**Table 4:** Simpson's Diversity Index (D) at Soft-Bottom ARs, Tumpat (ARs 1)

|       | Species                        | Number of individual species /site (n) | n (n-1)                       | Percentage % |
|-------|--------------------------------|--|-------------------------------|--------------|
| 1     | <i>Lutjanus lutjanus</i>       | 1,400                                  | 1958600                       | 24.36        |
| 2     | <i>Lutjanus madras</i>         | 560                                    | 313040                        | 9.74         |
| 3     | <i>Lutjanus vitta</i>          | 140                                    | 19460                         | 2.44         |
| 4     | <i>Lutjanus russellii</i>      | 1,120                                  | 1253280                       | 19.48        |
| 5     | <i>Lutjanus johnii</i>         | 56                                     | 3080                          | 0.97         |
| 6     | <i>Siganus javus</i>           | 168                                    | 28056                         | 2.92         |
| 7     | <i>Siganus guttatus</i>        | 28                                     | 756                           | 0.49         |
| 8     | <i>Caesio cuning</i>           | 504                                    | 253512                        | 8.77         |
| 9     | <i>Epinephelus coioides</i>    | 11.2                                   | 114.24                        | 0.19         |
| 10    | <i>Cephalopis boenak</i>       | 70                                     | 4830                          | 1.22         |
| 11    | <i>Pomacanthus annularis</i>   | 28                                     | 756                           | 0.49         |
| 12    | <i>Chiloscyllium hasseltii</i> | 28                                     | 756                           | 0.49         |
| 13    | <i>Scolopsis monogramma</i>    | 56                                     | 3080                          | 0.97         |
| 14    | <i>Scolopsis vosmeri</i>       | 14                                     | 182                           | 0.24         |
| 15    | <i>Neopomacentrus cyanomos</i> | 1,400                                  | 1958600                       | 24.36        |
| 16    | <i>Monodactylus argenteus</i>  | 140                                    | 19460                         | 2.44         |
| 17    | <i>Heniochus diphreutes</i>    | 20                                     | 380                           | 0.35         |
| 18    | <i>Arothron stellatus</i>      | 5                                      | 20                            | 0.09         |
| Total |                                | N = 5,748                              | $\sum n (n-1) = 5,817,962.24$ | 100          |

$$D = \frac{\sum n (n-1)}{N (N-1)} = 0.18$$

### 3.3. Biomass, Value and Biodiversity of Fishes at Soft-Bottom 3 ARs (ARs 2)

A total of 28 species recorded at ARs 2 where 14 out of the total species were commercial species. The most abundant species were *Neopomacentrus cyanomos* with 8,400 individuals followed by *Archamia fucata* (7,000 individuals), *Apogon aureus* (4,900 individuals) and *Archamia bleekeri* with 3,920 individuals. Other species were ranged between 4 - 2,800 individuals. Total biomass was estimated at 1,367.4 kg with an average 97.7 kg/module. The highest commercial fish biomass was *Caesio cunning* with 448 kg followed by *Lutjanus russellii* (280 kg) and *Siganus javus* with 252 kg. Other species were ranged between 3.5 - 140 kg. The value of commercial fish was estimated about RM 24,020.50. Details are shown in **Table 5**.

**Table 5:** Biomass and value of commercial fishes at Soft-Bottom 3 ARs, Kuala Sabak (ARs 2)

| No. | Species                        | Family         | Local name                  | Estimate no. of fish (individual) /site | Average weight of fish / individual (g) | Biomass of fish /site (kg) | Price of fish / kg (RM) | Value of fish (RM) |
|-----|--------------------------------|----------------|-----------------------------|---|---|----------------------------|-------------------------|--------------------|
| 1   | <i>Lutjanus lutjanus</i>       | Lutjanidae     | Kunyit-kunyit               | 2,800                                   | 20                                      | 56                         | 10                      | 560.00             |
| 2   | <i>Lutjanus madras</i>         |                | Kunyit madras               | 2,240                                   | 30                                      | 67.2                       | 10                      | 672.00             |
| 3   | <i>Lutjanus russellii</i>      |                | Merah tanda                 | 560                                     | 500                                     | 280                        | 25                      | 7,000.00           |
| 4   | <i>Lethrinus lenjian</i>       | Lethrinidae    | Landok calit merah          | 70                                      | 400                                     | 28                         | 15                      | 420.00             |
| 5   | <i>Diagramma pictum</i>        | Haemulidae     | Kaci mandi abu              | 84                                      | 600                                     | 50.4                       | 20                      | 1,008.00           |
| 6   | <i>Caesio cuning</i>           | Caesionidae    | Delah pinang                | 1,120                                   | 400                                     | 448                        | 20                      | 8,960.00           |
| 7   | <i>Pterocaesio chrysozona</i>  |                | Sulit jalur emas            | 1,680                                   | 20                                      | 33.6                       | 5                       | 168.00             |
| 8   | <i>Siganus javus</i>           | Siganidae      | Dengkis jawa                | 840                                     | 300                                     | 252                        | 15                      | 3,780.00           |
| 9   | <i>Cephalopholis boenak</i>    | Serranidae     | Kerapu belang perang        | 140                                     | 50                                      | 7                          | 5                       | 35.00              |
| 10  | <i>Diploprion bifasciatum</i>  |                | Kerapu sebekah              | 56                                      |   |                            |                         |                    |
| 11  | <i>Pomacanthus annularis</i>   | Pomacanthidae  | Taring pelanduk cincin biru | 5                                       | 700                                     | 3.5                        | 5                       | 17.50              |
| 12  | <i>Chiloscyllium hasseltii</i> | Hemiscylliidae | Yu cicak lampai             | 56                                      | 2,500                                   | 140                        | 10                      | 1,400.00           |
| 13  | <i>Archamia fucata</i>         | Apogonidae     | Sebekah                     | 7,000                                   |   |                            |                         |                    |
| 14  | <i>Apogon endekataenia</i>     |                | Sebekah                     | 70                                      |   |                            |                         |                    |
| 15  | <i>Archamia bleekeri</i>       |                | Sebekah                     | 3,920                                   |   |                            |                         |                    |
| 16  | <i>Apogon aureus</i>           |                | Sebekah                     | 4,900                                   |   |                            |                         |                    |
| 17  | <i>Neopomacentrus cyanomos</i> | Pomacentridae  | Kepal batu                  | 8,400                                   |   |                            |                         |                    |
| 18  | <i>Pomacentrus milleri</i>     |                | Kepal batu                  | 70                                      |   |                            |                         |                    |
| 19  | <i>Neopomacentrus azystron</i> |                | Kepal batu                  | 140                                     |   |                            |                         |                    |
| 20  | <i>Pempheris malabarica</i>    | Pempheridae    | Sepat                       | 560                                     |   |                            |                         |                    |
| 21  | <i>Hentochus diphreutes</i>    | Chaetodontidae | Bagang sirip filamen        | 28                                      | NA                                      | NA                         | NA                      | NA                 |
| 22  | <i>Sargocentron rubrum</i>     | Holocentridae  | Sebekah karang sirip hijau  | 28                                      |   |                            |                         |                    |
| 23  | <i>Scolopsis vosmeri</i>       | Nemipteridae   | Pasir-pasir pipi putih      | 42                                      |   |                            |                         |                    |
| 24  | <i>Arothron stellatus</i>      | Tetraodontidae | Buntal pasir bintang        | 4                                       |   |                            |                         |                    |
| 25  | <i>Balistoides viridescens</i> | Balistidae     | Jebong titan                | 4                                       |   |                            |                         |                    |

|    |                          |              |                            |     |    |         |    |           |
|----|--------------------------|--------------|----------------------------|-----|----|---------|----|-----------|
| 26 | <i>Sphyaena forsteri</i> | Sphyaenidae  | Kacang - kacang mata besar | 400 | NA | NA      | NA | NA        |
| 27 | <i>Charybdis</i> sp.     | Portunidae   | Ketam                      | 28  | NA | NA      | NA | NA        |
| 28 | <i>Scorpaenopsis</i> sp. | Scorpaenidae | Depu                       | 4   |    |         |    |           |
|    |                          | Total        |                            |     |    | 1,367.4 |    | 24,020.50 |
|    |                          | Average      |                            |     |    | 97.7    |    |           |



Biodiversity of fishes at this site according to Simpson's Diversity Index (D) was 0.14 (N = 35,249) with a total of 28 species. In term of composition percentage, *Neopomacentrus cyanomos* recorded the highest at 23.83% followed by *Archamia fucata* (19.86%) and *Apogon aureus* at 13.90%. Details are shown in **Table 6**.

**Table 6:** Simpson's Diversity Index (D) at Soft-Bottom 3 ARs, Kuala Sabak (ARs 2)

|       | Species                        | Number of individual species /site (n) | n (n-1)                      | Percentage % |
|-------|--------------------------------|--|------------------------------|--------------|
| 1     | <i>Lutjanus lutjanus</i>       | 2,800                                  | 7837200                      | 7.94         |
| 2     | <i>Lutjanus madras</i>         | 2,240                                  | 5015360                      | 6.35         |
| 3     | <i>Lutjanus russellii</i>      | 560                                    | 313040                       | 1.59         |
| 4     | <i>Lethrinus lentjan</i>       | 70                                     | 4830                         | 0.20         |
| 5     | <i>Diagramma pictum</i>        | 84                                     | 6972                         | 0.24         |
| 6     | <i>Caesio cuning</i>           | 1,120                                  | 1253280                      | 3.18         |
| 7     | <i>Pterocaesio chrysozona</i>  | 1,680                                  | 2820720                      | 4.77         |
| 8     | <i>Siganus javus</i>           | 840                                    | 704760                       | 2.38         |
| 9     | <i>Cephalopholis boenak</i>    | 140                                    | 19460                        | 0.40         |
| 10    | <i>Diploprion bifasciatum</i>  | 56                                     | 3080                         | 0.16         |
| 11    | <i>Pomacanthus annularis</i>   | 5                                      | 20                           | 0.01         |
| 12    | <i>Chiloscyllium hasseltii</i> | 56                                     | 3080                         | 0.16         |
| 13    | <i>Archamia fucata</i>         | 7,000                                  | 48993000                     | 19.86        |
| 14    | <i>Apogon endekataenia</i>     | 70                                     | 4830                         | 0.20         |
| 15    | <i>Archamia bleekeri</i>       | 3,920                                  | 15362480                     | 11.12        |
| 16    | <i>Apogon aureus</i>           | 4,900                                  | 24005100                     | 13.90        |
| 17    | <i>Neopomacentrus cyanomos</i> | 8,400                                  | 70551600                     | 23.83        |
| 18    | <i>Pomacentrus milleri</i>     | 70                                     | 4830                         | 0.20         |
| 19    | <i>Neopomacentrus azystron</i> | 140                                    | 19460                        | 0.40         |
| 20    | <i>Pempheris malabarica</i>    | 560                                    | 313040                       | 1.59         |
| 21    | <i>Heniochus diphreutes</i>    | 28                                     | 756                          | 0.08         |
| 22    | <i>Sargocentron rubrum</i>     | 28                                     | 756                          | 0.08         |
| 23    | <i>Scolopsis vosmeri</i>       | 42                                     | 1722                         | 0.12         |
| 24    | <i>Arothron stellatus</i>      | 4                                      | 12                           | 0.01         |
| 25    | <i>Balistoides viridescens</i> | 4                                      | 12                           | 0.01         |
| 26    | <i>Sphyraena forsteri</i>      | 400                                    | 159600                       | 1.13         |
| 27    | <i>Charybdis</i> sp.           | 28                                     | 756                          | 0.08         |
| 28    | <i>Scorpaenopsis</i> sp.       | 4                                      | 12                           | 0.01         |
| Total |                                | N = 35,249                             | $\sum n (n-1) = 177,399,768$ | 100          |

$$D = \sum n (n-1) / N (N-1) = 0.14$$

### **3.4. Biomass, Value and Biodiversity of Fishes at Confiscated Fishing Vessel (ARs 3)**

A total of 46 species were recorded at ARs 3 where 33 out of the total species were commercial species. The most abundant species were *Pterocaesio chrysozona* with 36,000 individuals followed by *Archamia fucata* (19,980 individuals), *Selaroides leptolepis* (18,000 individuals) and *Lutjanus lutjanus* with 14,400 individuals. Other species were ranged between 4 - 13,320 individuals. Total biomass was estimated at 5,005 kg with an average 278.1 kg/module. The highest biomass was *Pterocaesio chrysozona* with 1,080 kg followed by *Siganus javus* (619 kg) and other species ranged between 1.4 - 540 kg. The value of commercial fish was estimated about RM 68,679.00. Details are shown in **Table 7**.

**Table 7:** Biomass and value of commercial fishes at Confiscated Fishing Vessel ARs, Kuala Kemasin (ARs 3)

| No. | Species                            | Family       | Local name              | Estimate no. of fish (individual) /site | Average weight of fish / individual (g) | Biomass of fish /site (kg) | Price of fish / kg (RM) | Value of fish (RM) |
|-----|------------------------------------|--------------|-------------------------|---|---|----------------------------|-------------------------|--------------------|
| 1   | <i>Caranx sexfasciatus</i>         | Carangidae   | Belokok putih           | 360                                     | 700                                     | 252                        | 20                      | 5,040              |
| 2   | <i>Selaroides leptolepis</i>       |              | Selar kuning            | 18,000                                  | 30                                      | 540                        | 10                      | 5,400              |
| 3   | <i>Gnathanodon speciosus</i>       |              | Gerong belang           | 36                                      | 700                                     | 25                         | 30                      | 756                |
| 4   | <i>Scomberoides commersonianus</i> | Haemulidae   | Talang lima jari        | 18                                      | 3,500                                   | 63                         | 12                      | 756                |
| 5   | <i>Plectorhinchus gibbosus</i>     |              | Kaci kakap              | 36                                      | 1,200                                   | 43.2                       | 18                      | 777.6              |
| 6   | <i>Diagramma pictum</i>            |              | Kaci mandi abu          | 360                                     | 1,400                                   | 504                        | 20                      | 10,080             |
| 7   | <i>Lutjanus lutjanus</i>           | Lutjanidae   | Kunyit-kunyit           | 14,400                                  | 25                                      | 360                        | 10                      | 3,600              |
| 8   | <i>Lutjanus vitta</i>              |              | Kunyit remong           | 1,800                                   | 70                                      | 126                        | 15                      | 1,890              |
| 9   | <i>Lutjanus malabaricus</i>        |              | Merah mata hitam        | 54                                      | 1,500                                   | 81                         | 30                      | 2,430              |
| 10  | <i>Lutjanus russellii</i>          |              | Merah tanda             | 180                                     | 600                                     | 108                        | 25                      | 2,700              |
| 11  | <i>Lutjanus madras</i>             |              | Kunyit madras           | 7,200                                   | 30                                      | 216                        | 10                      | 2,160              |
| 12  | <i>Lutjanus johnii</i>             |              | Jenahak tanda           | 90                                      | 600                                     | 54                         | 25                      | 1,350              |
| 13  | <i>Lutjanus argentimaculatus</i>   | Serranidae   | Kakap merah             | 18                                      | 1,200                                   | 21.6                       | 30                      | 648                |
| 14  | <i>Plectropomus areolatus</i>      |              | Kerapu sunoh ekor pepat | 18                                      | 1,200                                   | 21.6                       | 35                      | 756                |
| 15  | <i>Epinephelus bleekeri</i>        |              | Kerapu ekor gelap       | 54                                      | 600                                     | 32.4                       | 35                      | 1,134              |
| 16  | <i>Epinephelus areolatus</i>       |              | Kerapu bintik bulat     | 72                                      | 400                                     | 28.8                       | 30                      | 864                |
| 17  | <i>Epinephelus fuscoguttatus</i>   |              | Kerapu harimau          | 4                                       | 1,500                                   | 5.4                        | 35                      | 189                |
| 18  | <i>Cephalopholis boenak</i>        |              | Kerapu belang perang    | 360                                     | 50                                      | 18                         | 8                       | 144                |
| 19  | <i>Epinephelus coioides</i>        | Caesionidae  | Kerapu bintik jingga    | 11                                      | 300                                     | 3.2                        | 25                      | 81                 |
| 20  | <i>Caesio cuning</i>               |              | Delah pinang            | 720                                     | 250                                     | 180                        | 20                      | 3,600              |
| 21  | <i>Caesio caerulaurea</i>          |              | Delah biru emas         | 540                                     | 50                                      | 27                         | 15                      | 405                |
| 22  | <i>Pterocaesio chrysozona</i>      | Siganidae    | Sulit jalur emas        | 36,000                                  | 30                                      | 1,080                      | 5                       | 5,400              |
| 23  | <i>Siganus javus</i>               |              | Dengkis jawa            | 1,548                                   | 400                                     | 619                        | 15                      | 9,288              |
| 24  | <i>Siganus guttatus</i>            |              | Dengkis tompok oren     | 72                                      | 350                                     | 25.2                       | 15                      | 378                |
| 25  | <i>Scomberomorus commerson</i>     | Scombidae    | Tenggiri batang         | 11                                      | 2,000                                   | 21.6                       | 35                      | 756                |
| 26  | <i>Sphyraena jello</i>             | Sphyraenidae | Alu-alu belang          | 720                                     | 500                                     | 360                        | 15                      | 5,400              |

|    |                                |                |                        |        |       |       |    |           |
|----|--------------------------------|----------------|------------------------|--------|-------|-------|----|-----------|
| 27 | <i>Sphyaena obtusata</i>       |                | Kacang dampak          | 234    | 100   | 23.4  | 8  | 187.2     |
| 28 | <i>Pateobatis jenkinsii</i>    | Dasyatidae     | Pari naga              | 18     | 4,000 | 72    | 20 | 1,440     |
| 29 | <i>Chiloseyllum hasseltii</i>  | Hemiseyilliida | Yu cicak lampai        | 36     | 2,000 | 72    | 10 | 720       |
| 30 | <i>Charybdis feriatius</i>     | Portunidae     | Ketam salib            | 22     | 80    | 1.7   | 25 | 43.2      |
| 31 | <i>Charybdis natator</i>       |                | Ketam jalur            | 18     | 80    | 1.4   | 25 | 36        |
| 32 | <i>Aluterus monoceris</i>      | Monacanthida   | Barat-barat            | 36     | 500   | 18    | 15 | 270       |
| 33 | <i>Apogon sp.</i>              | Apogonidea     | Sebekah                | 8,640  |       |       |    |           |
| 34 | <i>Apogon aureus</i>           |                | Sebekah                | 13,320 |       |       |    |           |
| 35 | <i>Archamia fucata</i>         |                | Sebekah                | 19,980 |       |       |    |           |
| 36 | <i>Heniochus diphreutes</i>    | Chaetodontida  | Bagang sirip filamen   | 50     | NA    | NA    | NA | NA        |
| 37 | <i>Arothron stellatus</i>      | Tetraodontidae | Buntal pasir bintang   | 18     |       |       |    |           |
| 38 | <i>Neopomacentrus cyanomos</i> | Pomacentridae  | Kepal batu             | 12,600 |       |       |    |           |
| 39 | <i>Pomacentrus sp.</i>         |                | Gombin                 | 18     |       |       |    |           |
| 40 | <i>Scolopsis vosmeri</i>       | Nemipteridae   | Pasir-pasir pipi putih | 11     |       |       |    |           |
| 41 | <i>Labroides dimidiatus</i>    | Labridae       | Nuri                   | 11     |       |       |    |           |
| 42 | <i>Thalassoma lunare</i>       |                | Nuri bulan             | 36     |       |       |    |           |
| 43 | <i>Petroscirtes sp.</i>        | Blenniidae     | Bleni                  | 54     |       |       |    |           |
| 44 | <i>Pterois ruselli</i>         | Scorpaenidae   | Depu                   | 72     |       |       |    |           |
| 45 | <i>Pempheris sp.</i>           | Pempheridae    | Sepat                  | 54     |       |       |    |           |
| 46 | <i>Centriscus scutatus</i>     | Centriscidae   | Pisau kering           | 18     |       |       |    |           |
|    |                                | Total          |                        |        |       | 5,005 |    | 68,679.00 |
|    |                                | Average        |                        |        |       | 278.1 |    |           |

Biodiversity of fishes at this site according to Simpson's Diversity Index (D) was 0.14 (N = 137,927) with 46 total number of species. In term of percentage, *Pterocaesio chrysozona* recorded the highest at 26.10% followed by *Archamia fucata* (14.49%) and *Selaroides leptolepis* at 13.05%. Details are shown in **Table 8**.

**Table 8:** Simpson's Diversity Index (D) at Confiscated Fishing Vessel ARs, Kuala Kemasin (ARs 3)

|    | Species                            | Number of individual species /site (n) | n (n-1)    | Percentage % |
|----|------------------------------------|--|------------|--------------|
| 1  | <i>Caranx sexfasciatus</i>         | 360                                    | 129240     | 0.26         |
| 2  | <i>Selaroides leptolepis</i>       | 18,000                                 | 323982000  | 13.05        |
| 3  | <i>Gnathanodon speciosus</i>       | 36                                     | 1260       | 0.03         |
| 4  | <i>Scomberoides commersonianus</i> | 18                                     | 306        | 0.01         |
| 5  | <i>Plectorhinchus gibbosus</i>     | 36                                     | 1260       | 0.03         |
| 6  | <i>Diagramma pictum</i>            | 360                                    | 129240     | 0.26         |
| 7  | <i>Lutjanus lutjanus</i>           | 14,400                                 | 207345600  | 10.44        |
| 8  | <i>Lutjanus vitta</i>              | 1,800                                  | 3238200    | 1.31         |
| 9  | <i>Lutjanus malabaricus</i>        | 54                                     | 2862       | 0.04         |
| 10 | <i>Lutjanus russellii</i>          | 180                                    | 32220      | 0.13         |
| 11 | <i>Lutjanus madras</i>             | 7,200                                  | 51832800   | 5.22         |
| 12 | <i>Lutjanus johnii</i>             | 90                                     | 8010       | 0.07         |
| 13 | <i>Lutjanus argentimaculatus</i>   | 18                                     | 306        | 0.01         |
| 14 | <i>Plectropomus areolatus</i>      | 18                                     | 306        | 0.01         |
| 15 | <i>Epinephelus bleekeri</i>        | 54                                     | 2862       | 0.04         |
| 16 | <i>Epinephelus areolatus</i>       | 72                                     | 5112       | 0.05         |
| 17 | <i>Epinephelus fuscoguttatus</i>   | 4                                      | 9.36       | 0.00         |
| 18 | <i>Cephalopholis boenak</i>        | 360                                    | 129240     | 0.26         |
| 19 | <i>Epinephelus coioides</i>        | 11                                     | 105.84     | 0.01         |
| 20 | <i>Caesio cuning</i>               | 720                                    | 517680     | 0.52         |
| 21 | <i>Caesio caerulaurea</i>          | 540                                    | 291060     | 0.39         |
| 22 | <i>Pterocaesio chrysozona</i>      | 36,000                                 | 1295964000 | 26.10        |
| 23 | <i>Siganus javus</i>               | 1,548                                  | 2394756    | 1.12         |
| 24 | <i>Siganus guttatus</i>            | 72                                     | 5112       | 0.05         |
| 25 | <i>Scomberomorus commerson</i>     | 11                                     | 105.84     | 0.01         |
| 26 | <i>Sphyraena jello</i>             | 720                                    | 517680     | 0.52         |
| 27 | <i>Sphyraena obtusata</i>          | 234                                    | 54522      | 0.17         |
| 28 | <i>Pateobatis jenkinsii</i>        | 18                                     | 306        | 0.01         |
| 29 | <i>Chiloscyllium hasseltii</i>     | 36                                     | 1260       | 0.03         |
| 30 | <i>Charybdis feriatus</i>          | 22                                     | 444.96     | 0.02         |
| 31 | <i>Charybdis natator</i>           | 18                                     | 306        | 0.01         |
| 32 | <i>Aluterus monocerus</i>          | 36                                     | 1260       | 0.03         |
| 33 | <i>Apogon sp.</i>                  | 8,640                                  | 74640960   | 6.26         |
| 34 | <i>Apogon aureus</i>               | 13,320                                 | 177409080  | 9.66         |
| 35 | <i>Archamia fucata</i>             | 19,980                                 | 399180420  | 14.49        |
| 36 | <i>Heniochus diphreutes</i>        | 50                                     | 2489.76    | 0.04         |

|       |                                |            |                               |      |
|-------|--------------------------------|------------|-------------------------------|------|
| 37    | <i>Arothron stellatus</i>      | 18         | 306                           | 0.01 |
| 38    | <i>Neopomacentrus cyanomos</i> | 12,600     | 158747400                     | 9.14 |
| 39    | <i>Pomacentrus</i> sp.         | 18         | 306                           | 0.01 |
| 40    | <i>Scolopsis vosmeri</i>       | 11         | 105.84                        | 0.01 |
| 41    | <i>Labroides dimidiatus</i>    | 11         | 105.84                        | 0.01 |
| 42    | <i>Thalassoma lunare</i>       | 36         | 1260                          | 0.03 |
| 43    | <i>Petroscirtes</i> sp.        | 54         | 2862                          | 0.04 |
| 44    | <i>Pterois ruselli</i>         | 72         | 5112                          | 0.05 |
| 45    | <i>Pempheris</i> sp.           | 54         | 2862                          | 0.04 |
| 46    | <i>Centriscus scutatus</i>     | 18         | 306                           | 0.01 |
| Total |                                | N= 137,927 | $\sum n(n-1) = 2,696,583,007$ | 100  |

$$D = \sum n(n-1)/N(N-1) = 0.14$$

### 3.5. Biomass, Value and Biodiversity of Fishes at RTR 43 Metric Tons ARs (ARs 4)

A total of 25 species were recorded at ARs 4 where 16 out of the total species were commercial species. The most abundant species were *Lutjanus lutjanus* with 12,000 individuals followed by *Lutjanus madras* (5,000 individuals), *Pterocaesio chrysozona* (2,000 individuals) and *Apogon* sp. with 2,000 individuals. Other species were ranged between 5 - 1,000 individuals. Total biomass was estimated at 1,009.4 kg. The highest biomass was *Lutjanus lutjanus* with 600 kg followed by *Lutjanus madras* (125 kg) and other species ranged between 0.5 - 90 kg. The value of commercial fish was estimated about RM 11,057.50. Details are shown in **Table 9**.

**Table 9:** Biomass and value of commercial fishes at RTR 43 metric tons ARs, Pulau Kapas (ARs 4)

| No.   | Species                         | Family         | Local name              | Estimate no. of fish (individual) /site | Average weight of fish / individual (g) | Biomass of fish /site (kg) | Price of fish / kg (RM) | Value of fish (RM) |
|-------|---------------------------------|----------------|-------------------------|---|---|----------------------------|-------------------------|--------------------|
| 1     | <i>Diagramma pictum</i>         | Hemulidae      | Kaci                    | 40                                      | 800                                     | 32                         | 20                      | 640.00             |
| 2     | <i>Lutjanus rusellii</i>        | Lutjanidae     | Tanda                   | 80                                      | 500                                     | 40                         | 25                      | 1,000.00           |
| 3     | <i>Lutjanus vitta</i>           |                | Remong                  | 1,000                                   | 50                                      | 50                         | 15                      | 750.00             |
| 4     | <i>Lutjanus madras</i>          |                | Kunyit madras           | 5,000                                   | 25                                      | 125                        | 10                      | 1,250.00           |
| 5     | <i>Lutjanus lutjanus</i>        |                | Kunyit-kunyit           | 12,000                                  | 50                                      | 600                        | 10                      | 6,000.00           |
| 6     | <i>Lutjanus quinquelineatus</i> |                | Kunyit lima garis       | 100                                     | 70                                      | 7                          | 10                      | 70.00              |
| 7     | <i>Lutjanus kasmira</i>         |                | Kunyit jalur biru       | 80                                      | 70                                      | 5.6                        | 10                      | 56.00              |
| 8     | <i>Siganus javus</i>            |                | Siganidae               | Dengkis jawa                            | 60                                      | 250                        | 15                      | 15                 |
| 9     | <i>Siganus canaliculatus</i>    |                | Dengkis bintik putih    | 50                                      | 150                                     | 7.5                        | 15                      | 112.50             |
| 10    | <i>Pterocaesio chrysozona</i>   | Caesionidae    | Sulit jalur emas        | 2,000                                   | 45                                      | 90                         | 5                       | 450.00             |
| 11    | <i>Casio cuning</i>             |                | Delah pinang            | 50                                      | 300                                     | 15                         | 20                      | 300.00             |
| 12    | <i>Chiloscyllium hasseltii</i>  | Hemiscyllidae  | Yu cicak                | 6                                       | 2,500                                   | 15                         | 10                      | 150.00             |
| 13    | <i>Cephalopholis boenak</i>     | Serranidae     | Kerapu belang perang    | 20                                      | 300                                     | 6                          | 5                       | 30.00              |
| 14    | <i>Epinephelus oreolatus</i>    |                | Kerapu bintik bulat     | 5                                       | 150                                     | 0.8                        | 30                      | 22.50              |
| 15    | <i>Scolopsis vosmeri</i>        | Nemipteridae   | Pasir-pasir pipi putih  | 10                                      |   |                            |                         |                    |
| 16    | <i>Scolopsis monogramma</i>     |                | Pasir-pasir jalur gelap | 10                                      | 50                                      | 0.5                        | 3                       | 1.50               |
| 17    | <i>Arothron stellatus</i>       | Tetraodontidae | Buntal pasir bintang    | 5                                       |   |                            |                         |                    |
| 18    | <i>Ostracion</i> sp.            | Ostraciidae    | Kaban tanda             | 5                                       |   |                            |                         |                    |
| 19    | <i>Neopomacentrus cyanomos</i>  | Pomacentridae  | Puyu laut/kepal batu    | 500                                     |   |                            |                         |                    |
| 20    | <i>Labroides dimidiatus</i>     | Labridae       | Nuri                    | 25                                      |   |                            |                         |                    |
| 21    | <i>Thalassoma lunare</i>        |                | Nuri bulan              | 5                                       |   |                            |                         |                    |
| 22    | <i>Pempheris</i> sp.            | Pempheridae    | Sepat                   | 200                                     |   |                            |                         |                    |
| 23    | <i>Apogon</i> sp.               | Apogonidae     | Sebekah                 | 2,000                                   |   |                            |                         |                    |
| 24    | <i>Heniochus diphreutes</i>     | Cheotodontidae | Bagan sirip filamen     | 10                                      | NA                                      | NA                         | NA                      | NA                 |
| 25    | <i>Centriscaus scutatus</i>     | Centriscidae   | Pisau kering            | 20                                      |   |                            |                         |                    |
| Total |                                 |                |                         |   |   | 1,009.4                    |                         | 11,057.50          |

Biodiversity of fishes at this site according to Simpson's Diversity Index (D) was 0.33 (N = 23,281) with 25 total number of species. In term of percentage, *Lutjanus lutjanus* recorded the highest at 51.54% followed by *Lutjanus madras* at 21.48%, *Pterocaesio chrysozona* and *Apogon* sp. with 8.59%. Details are shown in **Table 10**.

**Table 10:** Simpson's Diversity Index (D) at RTR 43 metric tons ARs, Pulau Kapas (ARs 4)

|    | Species                         | Number of individual species / site (n) | n (n-1)                | Percentage % |
|----|---------------------------------|---|------------------------|--------------|
| 1  | <i>Diagramma pictum</i>         | 40                                      | 1560                   | 0.17         |
| 2  | <i>Lutjanus rusellii</i>        | 80                                      | 6320                   | 0.34         |
| 3  | <i>Lutjanus vitta</i>           | 1,000                                   | 999000                 | 4.30         |
| 4  | <i>Lutjanus madras</i>          | 5,000                                   | 24995000               | 21.48        |
| 5  | <i>Lutjanus lutjanus</i>        | 12,000                                  | 143988000              | 51.54        |
| 6  | <i>Lutjanus quinquelineatus</i> | 100                                     | 9900                   | 0.43         |
| 7  | <i>Lutjanus kasmira</i>         | 80                                      | 6320                   | 0.34         |
| 8  | <i>Siganus javus</i>            | 60                                      | 3540                   | 0.26         |
| 9  | <i>Siganus canaliculatus</i>    | 50                                      | 2450                   | 0.21         |
| 10 | <i>Pterocaesio chrysozona</i>   | 2,000                                   | 3998000                | 8.59         |
| 11 | <i>Casio cuning</i>             | 50                                      | 2450                   | 0.21         |
| 12 | <i>Chiloscyllium hasseltii</i>  | 6                                       | 30                     | 0.03         |
| 13 | <i>Cephalopholis boenak</i>     | 20                                      | 380                    | 0.09         |
| 14 | <i>Epinephelus oreolatus</i>    | 5                                       | 20                     | 0.02         |
| 15 | <i>Scolopsis vosmeri</i>        | 10                                      | 90                     | 0.04         |
| 16 | <i>Scolopsis monogramma</i>     | 10                                      | 90                     | 0.04         |
| 17 | <i>Arothron stellatus</i>       | 5                                       | 20                     | 0.02         |
| 18 | <i>Ostracion</i> sp.            | 5                                       | 20                     | 0.02         |
| 19 | <i>Neopomacentrus cyanomos</i>  | 500                                     | 249500                 | 2.15         |
| 20 | <i>Labroides dimidiatus</i>     | 25                                      | 600                    | 0.11         |
| 21 | <i>Thalassoma lunare</i>        | 5                                       | 20                     | 0.02         |
| 22 | <i>Pempheris</i> sp.            | 200                                     | 39800                  | 0.86         |
| 23 | <i>Apogon</i> sp.               | 2,000                                   | 3998000                | 8.59         |
| 24 | <i>Heniochus diphreutes</i>     | 10                                      | 90                     | 0.04         |
| 25 | <i>Centriscus scutatus</i>      | 20                                      | 380                    | 0.09         |
|    | Total                           | N= 23,281                               | ∑ n (n-1)= 178,301,580 | 100          |

$$D = \frac{\sum n(n-1)}{N(N-1)} = 0.33$$



### **3.6. Biomass, Value and Biodiversity of Fishes at RTR 18 Metric Tons ARs (ARs 5)**

A total of 14 species were recorded at ARs 5 where 11 out of the total species were commercial species. The most abundant species were *Lutjanus lutjanus* with 5,000 individuals followed by *Pterocaesio chrysozona* (2,500 individuals), *Neopomacentrus cyanomos* (1,800 individuals) and *Lutjanus vitta* with 500 individuals. Other species were ranged between 4 - 200 individuals. Total biomass was estimated at 441.8 kg. The highest biomass was *Lutjanus lutjanus* with 250 kg followed by *Pterocaesio chrysozona* (112.5 kg) and other species were ranged between 2 - 25 kg. The value of commercial fish was estimated about RM 4,321.25. Details are shown in **Table 11**.

**Table 11:** Biomass and value of commercial fishes at RTR 18 metric tons ARs, Pulau Kapas (ARs 5)

| No.   | Species                        | Family         | Local name           | Estimate no. of fish (individual) /site | Average weight of fish / individual (g) | Biomass of fish /site (kg) | Price of fish / kg (RM) | Value of fish (RM) |
|-------|--------------------------------|----------------|----------------------|---|---|----------------------------|-------------------------|--------------------|
| 1     | <i>Lutjanus risellii</i>       | Lutjanidae     | Tanda                | 15                                      | 0.45                                    | 6.8                        | 25                      | 168.75             |
| 2     | <i>Lutjanus vitta</i>          |                | Remong               | 500                                     | 0.05                                    | 25                         | 15                      | 375.00             |
| 3     | <i>Lutjanus madras</i>         |                | Kunyit madras        | 200                                     | 0.025                                   | 5                          | 10                      | 50.00              |
| 4     | <i>Lutjanus lutjanus</i>       |                | Kunyit-kunyit        | 5,000                                   | 0.05                                    | 250                        | 10                      | 2,500.00           |
| 5     | <i>Pterocaesio chrysozona</i>  | Casionidae     | Sulit jalur emas     | 2,500                                   | 0.045                                   | 112.5                      | 5                       | 562.50             |
| 6     | <i>Casio cunning</i>           |                | Delah pinang         | 50                                      | 0.35                                    | 17.5                       | 20                      | 350.00             |
| 7     | <i>Epinephelus bleekeri</i>    | Serranidae     | Kerapu bintik        | 6                                       | 0.5                                     | 3                          | 35                      | 105.00             |
| 8     | <i>Cephalopholis boenak</i>    |                | Kerapu belang perang | 10                                      | 0.3                                     | 3                          | 5                       | 15.00              |
| 9     | <i>Epinephelus coioides</i>    |                | Kerapu bintik jingga | 5                                       | 0.4                                     | 2                          | 30                      | 60.00              |
| 10    | <i>Epinephelus areolatus</i>   |                | Kerapu bintik bulat  | 5                                       | 0.4                                     | 2                          | 30                      | 60.00              |
| 11    | <i>Plotosus lineatus</i>       | Plotosidea     | Semilang karang      | 500                                     | 0.03                                    | 15                         | 5                       | 75.00              |
| 12    | <i>Arothron stellatus</i>      | Tetraodontidae | Buntal pasir bintang | 4                                       |   |                            |                         |                    |
| 13    | <i>Neopomacentrus cyanomos</i> | Pomacentridae  | Puyu laut            | 1,800                                   |   |                            |                         |                    |
| 14    | <i>Apogon sp.</i>              | Apogonidae     | Sebekah              | 500                                     |   |                            |                         |                    |
| Total |                                |                |                      |   |   | 441.8                      |                         | 4,321.25           |

Biodiversity of fishes at this site according to Simpson's Diversity Index (D) was 0.29 (N = 11,095) with 14 total number of species. In term of percentage, *Lutjanus lutjanus* recorded the highest at 45.07% followed by *Pterocaesio chrysozona* (22.53%) and *Neopomacentrus cyanomos* at 16.22%. Details are shown in **Table 12**.

**Table 12:** Simpson Diversity Index (D) at RTR 18 metric tons ARs, Pulau Kapas (ARs 5)

|    | Species                        | Number of individual species / site (n) | n(n-1)                    | Percentage % |
|----|--------------------------------|---|---------------------------|--------------|
| 1  | <i>Lutjanus rusellii</i>       | 15                                      | 210                       | 0.14         |
| 2  | <i>Lutjanus vitta</i>          | 500                                     | 249500                    | 4.51         |
| 3  | <i>Lutjanus madras</i>         | 200                                     | 39800                     | 1.80         |
| 4  | <i>Lutjanus lutjanus</i>       | 5,000                                   | 24995000                  | 45.07        |
| 5  | <i>Pterocaesio chrysozona</i>  | 2,500                                   | 6247500                   | 22.53        |
| 6  | <i>Casio cuning</i>            | 50                                      | 2450                      | 0.45         |
| 7  | <i>Epinephelus bleekeri</i>    | 6                                       | 30                        | 0.05         |
| 8  | <i>Cephalopholis boenak</i>    | 10                                      | 90                        | 0.09         |
| 9  | <i>Epinephelus coioides</i>    | 5                                       | 20                        | 0.05         |
| 10 | <i>Epinephelus areolatus</i>   | 5                                       | 20                        | 0.05         |
| 11 | <i>Plotosus lineatus</i>       | 500                                     | 249500                    | 4.51         |
| 12 | <i>Arothron stellatus</i>      | 4                                       | 12                        | 0.04         |
| 13 | <i>Neopomacentrus cyanomos</i> | 1,800                                   | 3238200                   | 16.22        |
| 14 | <i>Apogon sp.</i>              | 500                                     | 249500                    | 4.51         |
|    | Total                          | N= 11,095                               | $\sum n(n-1)= 35,271,832$ | 100          |

$$D = \frac{\sum n(n-1)}{N(N-1)} = 0.29$$

### 3.7. Biomass, Value and Biodiversity of Fishes at Confiscated Fishing Vessel (ARs 6)

A total of 17 species were recorded at ARs 6 where 12 out of the total species were commercial species. The most abundant species were *Lutjanus lutjanus* with 1,000 individuals followed by *Lutjanus madras* (800 individuals), *Lutjanus vitta* (700 individuals), and *Pterocaesio chrysozona* with 500 individuals. Other species were ranged between 1 - 250 individuals. Total biomass of commercial species was estimated at 129.1 kg with an average 25.8 kg/vessel. The highest biomass was contributed by *Lutjanus vitta* with 35 kg followed by *Lutjanus lutjanus* (25 kg) and *Lutjanus madras* with biomass of 20 kg. Other species were ranged between 1.5 - 15 kg. The value of commercial fish was estimated about RM 1,824.50. Details are shown in **Table 13**.

**Table 13:** Biomass and value of commercial fishes at Confiscated Fishing Vessel ARs, Pulau Kapas (ARs 6)

| No. | Species                        | Family        | Local name          | Estimate no. of fish (individual) /site | Average weight of fish / individual (g) | Biomass of fish /site (kg) | Price of fish / kg (RM) | Value of fish (RM) |
|-----|--------------------------------|---------------|---------------------|---|---|----------------------------|-------------------------|--------------------|
| 1   | <i>Lutjanus lutjanus</i>       | Lutjanidae    | Kunyit-kunyit       | 1,000                                   | 25                                      | 25                         | 10                      | 250.00             |
| 2   | <i>Lutjanus madras</i>         |               | Kunyit madras       | 800                                     | 25                                      | 20                         | 10                      | 200.00             |
| 3   | <i>Lutjanus vitta</i>          |               | Kunyit remong       | 700                                     | 50                                      | 35                         | 15                      | 525.00             |
| 4   | <i>Lutjanus sebae</i>          |               | Merah coreng        | 10                                      | 150                                     | 1.5                        | 35                      | 52.50              |
| 5   | <i>Lutjanus malabaricus</i>    |               | Merah mata hitam    | 8                                       | 350                                     | 2.8                        | 30                      | 84.00              |
| 6   | <i>Lutjanus russellii</i>      |               | Merah tanda         | 30                                      | 400                                     | 12                         | 25                      | 300.00             |
| 7   | <i>Diagramma pictum</i>        | Haemulidae    | Kaci mandi abu      | 20                                      | 450                                     | 9                          | 20                      | 180.00             |
| 8   | <i>Epinephelus areolatus</i>   | Serranidae    | Kerapu bintik bulat | 15                                      | 150                                     | 2.3                        | 30                      | 67.50              |
| 9   | <i>Diploprion bifasciatum</i>  |               | Kerapu sebekah      | 5                                       |   |                            |                         |                    |
| 10  | <i>Pterocaesio chrysozona</i>  | Caesionidae   | Sulit jalur emas    | 500                                     | 30                                      | 15                         | 5                       | 75.00              |
| 11  | <i>Pateobatis jenkinsii</i>    | Dasyatidae    | Pari naga           | 1                                       | 2,500                                   | 2.5                        | 25                      | 62.50              |
| 12  | <i>Selaroides leptolepis</i>   | Carangidae    | Selar kuning        | 50                                      | 40                                      | 2                          | 6                       | 12.00              |
| 13  | <i>Alepes vari</i>             |               | Pelata bali         | 50                                      | 40                                      | 2                          | 8                       | 16.00              |
| 14  | <i>Neopomacentrus</i> sp.      | Pomacentridae | Kepal batu          | 250                                     |   |                            |                         |                    |
| 15  | <i>Neopomacentrus cyanomos</i> |               | Kepal batu          | 500                                     |   |                            |                         |                    |
| 16  | <i>Labroides dimidiatus</i>    | Labridae      | Nuri                | 3                                       |   |                            |                         |                    |
| 17  | <i>Echeneis naucrates</i>      | Echeneidae    | Tapak kasut         | 2                                       |   |                            |                         |                    |
|     |                                | Total         |                     |   |   | 129.1                      |                         | 1,824.50           |
|     |                                | Average       |                     |   |   | 25.8                       |                         |                    |

Biodiversity of fishes at this site according to Simpson's Diversity Index (D) was 0.17 (N = 3,944) with 17 total number of species. In term of percentage, *Lutjanus lutjanus* recorded the highest at 25.35% followed by *Lutjanus madras* (20.28%) and *Lutjanus vitta* at 17.75%. Details are shown in **Table 14**.

**Table 14:** Simpson's Diversity Index (D) at Confiscated Fishing Vessel, Pulau Kapas (ARs 6)

|    | Species                        | Number of individual species /site (n) | n(n-1)                 | Percentage % |
|----|--------------------------------|--|------------------------|--------------|
| 1  | <i>Lutjanus lutjanus</i>       | 1,000                                  | 999000                 | 25.35        |
| 2  | <i>Lutjanus madras</i>         | 800                                    | 639200                 | 20.28        |
| 3  | <i>Lutjanus vitta</i>          | 700                                    | 489300                 | 17.75        |
| 4  | <i>Lutjanus sebae</i>          | 10                                     | 90                     | 0.25         |
| 5  | <i>Lutjanus malabaricus</i>    | 8                                      | 56                     | 0.20         |
| 6  | <i>Lutjanus russellii</i>      | 30                                     | 870                    | 0.76         |
| 7  | <i>Diagramma pictum</i>        | 20                                     | 380                    | 0.51         |
| 8  | <i>Epinephelus areolatus</i>   | 15                                     | 210                    | 0.38         |
| 9  | <i>Diploprion bifasciatum</i>  | 5                                      | 20                     | 0.13         |
| 10 | <i>Pterocaesio chrysozona</i>  | 500                                    | 249500                 | 12.68        |
| 11 | <i>Pateobatis jenkinsii</i>    | 1                                      | 0                      | 0.03         |
| 12 | <i>Selaroides leptolepis</i>   | 50                                     | 2450                   | 1.27         |
| 13 | <i>Alepes vari</i>             | 50                                     | 2450                   | 1.27         |
| 14 | <i>Neopomacentrus</i> sp.      | 250                                    | 62250                  | 6.34         |
| 15 | <i>Neopomacentrus cyanomos</i> | 500                                    | 249500                 | 12.68        |
| 16 | <i>Labroides dimidiatus</i>    | 3                                      | 6                      | 0.08         |
| 17 | <i>Echeneis naucrates</i>      | 2                                      | 2                      | 0.05         |
|    | Total                          | N= 3,944                               | $\sum n(n-1)= 2695284$ | 100          |

$$D = \frac{\sum n(n-1)}{N(N-1)} = 0.17$$

### 3.8. Biomass, Value and Biodiversity of Fishes at Cube ARs (ARs 7)

A total of 32 species were recorded at ARs 7 where 23 out of the total species were commercial species. The most abundant species were *Lutjanus lutjanus* with 28,800 individuals followed by *Lutjanus madras* (18,000 individuals), *Apogon aureus* (11,880 individuals) and *Archamia fucata* with 10,440 individuals. Other species were ranged between 18 – 9,360 individuals. Total biomass was estimated at 3,096 kg with an average 172 kg/module. The highest biomass was *Lutjanus lutjanus* with 864 kg followed by *Lutjanus russellii* (720 kg) and other species were ranged between 10.8 – 540 kg. The value of commercial fish was estimated about RM 49,876.20. Details are shown in **Table 15**.

**Table 15:** Biomass and value of commercial fishes at Cube ARs, Merchang (ARs 7)

| No. | Species                           | Family        | Local name              | Estimate no. of fish (individual) /site | Average weight of fish / individual (g) | Biomass of fish /site (kg) | Price of fish / kg (RM) | Value of fish (RM) |
|-----|-----------------------------------|---------------|-------------------------|---|---|----------------------------|-------------------------|--------------------|
| 1.  | <i>Lutjanus lutjanus</i>          | Lutjanidae    | Kunyit-kunyit           | 28,800                                  | 30                                      | 864                        | 10                      | 8,640.00           |
| 2.  | <i>Lutjanus madras</i>            |               | Kunyit madras           | 18,000                                  | 30                                      | 540                        | 10                      | 5,400.00           |
| 3.  | <i>Lutjanus johnii</i>            |               | Jenahak tanda           | 36                                      | 1,000                                   | 36                         | 25                      | 900.00             |
| 4.  | <i>Lutjanus russellii</i>         |               | Merah tanda             | 900                                     | 800                                     | 720                        | 25                      | 18,000.00          |
| 5.  | <i>Lutjanus vitta</i>             |               | Kunyit remong           | 540                                     | 150                                     | 81                         | 15                      | 1,215.00           |
| 6.  | <i>Lutjanus kasmira</i>           |               | Kunyit jalur biru       | 720                                     | 100                                     | 72                         | 10                      | 720.00             |
| 7.  | <i>Lutjanus quinqueineatus</i>    |               | Kunyit lima garis       | 360                                     | 30                                      | 10.8                       | 10                      | 108.00             |
| 8.  | <i>Lutjanus argenteimaculatus</i> |               | Kakap merah             | 36                                      | 2,000                                   | 72                         | 30                      | 2,160.00           |
| 9.  | <i>Lutjanus malabaricus</i>       |               | Merah mata hitam        | 54                                      | 500                                     | 27                         | 30                      | 810.00             |
| 10. | <i>Diagramma pictum</i>           | Haemulidae    | Kaci mandi abu          | 108                                     | 1,300                                   | 140.4                      | 20                      | 2,808.00           |
| 11. | <i>Plectorhinchus gibbosus</i>    |               | Kaci kakap              | 36                                      | 1,500                                   | 54                         | 18                      | 972.00             |
| 12. | <i>Epinephelus coioides</i>       | Serranidae    | Kerapu bintik jingga    | 36                                      | 700                                     | 25.2                       | 25                      | 630.00             |
| 13. | <i>Cephalopholis boenak</i>       |               | Kerapu belang perang    | 288                                     | 50                                      | 14.4                       | 5                       | 72.00              |
| 14. | <i>Plectropomus areolatus</i>     |               | Kerapu sunoh ekor       | 54                                      | 1,500                                   | 81                         | 55                      | 4,455.00           |
| 15. | <i>Cephalopholis formosa</i>      |               | Kerapu garis biru       | 72                                      | 800                                     | 57.6                       | 20                      | 1,152.00           |
| 16. | <i>Pterocaesio chrysozona</i>     |               | Sulit jalur emas        | 2,160                                   | 40                                      | 86.4                       | 5                       | 432.00             |
| 17. | <i>Scolopsis monogramma</i>       | Nemipteridae  | Pasir-pasir jalur gelap | 288                                     | 50                                      | 14.4                       | 3                       | 43.20              |
| 18. | <i>Scolopsis vosmeri</i>          |               | Pasir-pasir pipi putih  | 54                                      |   |                            |                         |                    |
| 19. | <i>Selaroides leptolepis</i>      | Carangidae    | Selar kuning            | 3,600                                   | 20                                      | 72                         | 10                      | 720.00             |
| 20. | <i>Sphyaena forsteri</i>          | Sphyraenidae  | Kacang-kacang mata      | 2,880                                   | 40                                      | 115.2                      | 5                       | 576.00             |
| 21. | <i>Pomacanthus amularis</i>       | Pomacanthidae | Taring pelanduk         | 18                                      | 700                                     | 13                         | 5                       | 63.00              |
| 22. | <i>Apogon nigrocincta</i>         | Apogonidae    | Sebekah                 | 8,280                                   |   |                            |                         |                    |
| 23. | <i>Apogon cavitiensis</i>         |               | Sebekah                 | 9,000                                   |   |                            |                         |                    |
| 24. | <i>Apogon aureus</i>              |               | Sebekah                 | 11,880                                  |   |                            |                         |                    |
| 25. | <i>Archamia fucata</i>            |               | Sebekah                 | 10,440                                  |   |                            |                         |                    |
| 26. | <i>Neopomacentrus cyanomos</i>    |               | Pomacentridae           | Kepal batu                              | 9,360                                   |                            |                         |                    |

|     |                                |                |                      |     |    |  |       |           |
|-----|--------------------------------|----------------|----------------------|-----|----|--|-------|-----------|
| 27. | <i>Neopomacentrus azysiron</i> |                | Kepal batu           | 252 |    |  |       |           |
| 28. | <i>Labroides dimidiatus</i>    | Labridae       | Nuri                 | 324 |    |  |       |           |
| 29. | <i>Choerodon schoenleinii</i>  |                | Ketarap bintik hitam | 36  | NA |  | NA    | NA        |
| 30. | <i>Pempheris malabarica</i>    | Pempheridae    | Sepat                | 108 |    |  |       |           |
| 31. | <i>Heniochus diphreutes</i>    | Chaetodontidae | Bagang sirip filamen | 36  | NA |  | NA    | NA        |
| 32. | <i>Coradion chrysozonus</i>    |                | Bendera belang       | 18  | NA |  | NA    | NA        |
|     |                                | Total          |                      |     |    |  | 3,096 | 49,876.20 |
|     |                                | Average        |                      |     |    |  | 172   |           |

Biodiversity of fishes at this site according to Simpson Diversity Index (D) was 0.14 (N = 108,774) with 32 total number of species. In term of percentage, *Lutjanus lutjanus* recorded the highest at 26.48% followed by *Lutjanus madras* (16.55%) and *Apogon aureus* at 10.92%. Details are shown in **Table 16**.

**Table 16:** Simpson’s Diversity Index (D) at Cube ARs, Merchang (ARs 7)

|       | Species                          | Number of individual species /site (n) | N (n-1)                     | Percentage % |
|-------|----------------------------------|--|-----------------------------|--------------|
| 1     | <i>Lutjanus lutjanus</i>         | 28,800                                 | 829411200                   | 26.48        |
| 2     | <i>Lutjanus madras</i>           | 18,000                                 | 323982000                   | 16.55        |
| 3     | <i>Lutjanus johnii</i>           | 36                                     | 1260                        | 0.03         |
| 4     | <i>Lutjanus russellii</i>        | 900                                    | 809100                      | 0.83         |
| 5     | <i>Lutjanus vitta</i>            | 540                                    | 291060                      | 0.50         |
| 6     | <i>Lutjanus kasmira</i>          | 720                                    | 517680                      | 0.66         |
| 7     | <i>Lutjanus quinquelineatus</i>  | 360                                    | 129240                      | 0.33         |
| 8     | <i>Lutjanus argentimaculatus</i> | 36                                     | 1260                        | 0.03         |
| 9     | <i>Lutjanus malabaricus</i>      | 54                                     | 2862                        | 0.05         |
| 10    | <i>Diagramma pictum</i>          | 108                                    | 11556                       | 0.10         |
| 11    | <i>Plectorhinchus gibbosus</i>   | 36                                     | 1260                        | 0.03         |
| 12    | <i>Epinephelus coioides</i>      | 36                                     | 1260                        | 0.03         |
| 13    | <i>Cephalopholis boenak</i>      | 288                                    | 82656                       | 0.26         |
| 14    | <i>Plectropomus areolatus</i>    | 54                                     | 2862                        | 0.05         |
| 15    | <i>Cephalopholis formosa</i>     | 72                                     | 5112                        | 0.07         |
| 16    | <i>Pterocaesio chrysozona</i>    | 2,160                                  | 4663440                     | 1.99         |
| 17    | <i>Scolopsis monogramma</i>      | 288                                    | 82656                       | 0.26         |
| 18    | <i>Scolopsis vosmeri</i>         | 54                                     | 2862                        | 0.05         |
| 19    | <i>Selaroides leptolepis</i>     | 3,600                                  | 12956400                    | 3.31         |
| 20    | <i>Sphyraena forsteri</i>        | 2,880                                  | 8291520                     | 2.65         |
| 21    | <i>Apogon nigrocincta</i>        | 8,280                                  | 68550120                    | 7.61         |
| 22    | <i>Apogon cavitiensis</i>        | 9,000                                  | 80991000                    | 8.27         |
| 23    | <i>Apogon aureus</i>             | 11,880                                 | 141122520                   | 10.92        |
| 24    | <i>Archamia fucata</i>           | 10,440                                 | 108983160                   | 9.60         |
| 25    | <i>Neopomacentrus cyanomos</i>   | 9,360                                  | 87600240                    | 8.60         |
| 26    | <i>Neopomacentrus azystron</i>   | 252                                    | 63252                       | 0.23         |
| 27    | <i>Labroides dimidiatus</i>      | 324                                    | 104652                      | 0.30         |
| 28    | <i>Choerodon schoenleinii</i>    | 36                                     | 1260                        | 0.03         |
| 29    | <i>Pempheris malabarica</i>      | 108                                    | 11556                       | 0.10         |
| 30    | <i>Heniochus diphreutes</i>      | 36                                     | 1260                        | 0.03         |
| 31    | <i>Coradion chrysozonus</i>      | 18                                     | 306                         | 0.02         |
| 32    | <i>Pomacanthus annularis</i>     | 18                                     | 306                         | 0.02         |
| Total |                                  | N= 108,774                             | $\sum n (n-1) = 1668676878$ | 100          |

$$D = \sum n (n-1) / N (N-1) = 0.14$$



### 3.9. Biomass, Value and Biodiversity of Fishes at Cube ARs (ARs 8)

A total of 36 species were recorded at ARs 8 where 20 out of the total species were commercial species. The most abundant species were *Lutjanus lutjanus* with 54,000 individuals followed by *Lutjanus madras* (28,800 individuals), *Apogon aureus* (22,680 individuals) and *Archamia fucata* with 20,520 individuals. Other species were ranged between 4 – 19,080 individuals. Total biomass was estimated at 4,564.8 kg with an average 253.6 kg/module. The highest biomass was *Lutjanus lutjanus* with 1,350 kg followed by *Lutjanus madras* (864 kg) and other species ranged between 10.8 – 540 kg. The value of commercial fish was estimated about RM 66,618.00. Details are shown in **Table 17**.

**Table 17:** Biomass and value of commercial fishes at Cube ARs, Kijal (ARs 8)

| No. | Species                          | Family            | Local name              | Estimate no. of fish (individual) /site | Average weight of fish / individual (g) | Biomass of fish /site (kg) | Price of fish / kg (RM) | Value of fish (RM) |
|-----|----------------------------------|-------------------|-------------------------|---|---|----------------------------|-------------------------|--------------------|
| 1.  | <i>Lutjanus lutjanus</i>         | Lutjanidae        | Kunyit-kunyit           | 54,000                                  | 25                                      | 1,350                      | 10.00                   | 13,500.00          |
| 2.  | <i>Lutjanus madras</i>           |                   | Kunyit madras           | 28,800                                  | 30                                      | 864                        | 10.00                   | 8,640.00           |
| 3.  | <i>Lutjanus russellii</i>        |                   | Merah tanda             | 360                                     | 1,500                                   | 540                        | 25.00                   | 13,500.00          |
| 4.  | <i>Lutjanus kasmira</i>          |                   | Kunyit jalur biru       | 10,080                                  | 40                                      | 403.2                      | 10.00                   | 4,032.00           |
| 5.  | <i>Lutjanus quinque-lineatus</i> | Serranidae        | Kunyit lima garis       | 3,600                                   | 40                                      | 144                        | 10.00                   | 1,440.00           |
| 6.  | <i>Lutjanus vitta</i>            |                   | Kunyit remong           | 720                                     | 150                                     | 108                        | 15.00                   | 1,620.00           |
| 7.  | <i>Epinephelus blekeri</i>       |                   | Kerapu ekor gelap       | 108                                     | 600                                     | 64.8                       | 35.00                   | 2,268.00           |
| 8.  | <i>Plectropomus areolatus</i>    |                   | Kerapu sunoh ekor pepat | 7                                       | 1,500                                   | 10.8                       | 30.00                   | 324.00             |
| 9.  | <i>Epinephelus coioides</i>      |                   | Kerapu bintik jingga    | 18                                      | 800                                     | 14.4                       | 25.00                   | 360.00             |
| 10. | <i>Epinephelus areolatus</i>     |                   | Kerapu bintik bulat     | 54                                      | 400                                     | 21.6                       | 30.00                   | 648.00             |
| 11. | <i>Cephalopholis boenak</i>      |                   | Kerapu belang perang    | 288                                     | 100                                     | 28.8                       | 5.00                    | 144.00             |
| 12. | <i>Cephalopholis formosa</i>     | Kerapu garis biru | 36                      | 400                                     | 14.4                                    | 20.00                      | 288.00                  |                    |
| 13. | <i>Diagramma pictum</i>          | Haemulidae        | Kaci mandi abu          | 180                                     | 1,500                                   | 270                        | 20.00                   | 5,400.00           |
| 14. | <i>Caesio cunning</i>            | Caesionidae       | Delah pinang            | 288                                     | 200                                     | 57.6                       | 20.00                   | 1,152.00           |
| 15. | <i>Pterocaesio chrysozona</i>    |                   | Sulit jalur emas        | 4,320                                   | 30                                      | 129.6                      | 5.00                    | 648.00             |
| 16. | <i>Carangoides gymnotethus</i>   | Carangidae        | Demuduk nyior-nyior     | 360                                     | 1,200                                   | 432                        | 25.00                   | 10,800.00          |
| 17. | <i>Carangoides sp.</i>           |                   | Demuduk                 | 108                                     | 800                                     | 86.4                       | 20.00                   | 1,728.00           |
| 18. | <i>Pomacanthus annularis</i>     | Pomacanthidae     | Taring pelanduk cincin  | 36                                      | 700                                     | 25.2                       | 5.00                    | 126.00             |
| 19. | <i>Neopomacentrus cyanomos</i>   | Pomacentridae     | Kepal batu              | 2,808                                   |   |                            |                         |                    |
| 20. | <i>Neopomacentrus azystron</i>   |                   | Kepal batu              | 360                                     |   |                            |                         |                    |
| 21. | <i>Pomacentrus sp.</i>           |                   | Puyu laut               | 1,800                                   |   |                            |                         |                    |
| 22. | <i>Chromis sp.</i>               |                   | Gombing                 | 3,600                                   |   |                            |                         |                    |
| 23. | <i>Pempheris malabarica</i>      | Pempheridae       | Sepat                   | 90                                      |   |                            |                         |                    |
| 24. | <i>Heniochus diphreutes</i>      | Chaetodontidae    | Bagang sirip filamen    | 36                                      | NA                                      | NA                         | NA                      | NA                 |
| 25. | <i>Deodon liturosus</i>          | Deodontidae       | Buntal duri             | 4                                       |   |                            |                         |                    |
| 26. | <i>Echeneis naucrates</i>        | Echeneidae        | Tapak kasut             | 4                                       |   |                            |                         |                    |

|     |                               |              |                        |        |    |         |    |           |
|-----|-------------------------------|--------------|------------------------|--------|----|---------|----|-----------|
| 27. | <i>Apogon</i> sp.             |              | Sebekah                | 17,280 |    |         |    |           |
| 28. | <i>Apogon endekataenia</i>    | Apogonidea   | Sebekah                | 19,080 |    |         |    |           |
| 29. | <i>Apogon aureus</i>          |              | Sebekah                | 22,680 |    |         |    |           |
| 30. | <i>Archamia fucata</i>        |              | Sebekah                | 20,520 |    |         |    |           |
| 31. | <i>Labroides dimidiatus</i>   | Labridae     | Nuri                   | 360    |    |         |    |           |
| 32. | <i>Thalassoma lunare</i>      |              | Nuri                   | 18     |    |         |    |           |
| 33. | <i>Choerodon schoenleinii</i> |              | Ketarap bintik hitam   | 72     | NA | NA      | NA | NA        |
| 34. | <i>Scolopsis vosmeri</i>      | Nemipteridae | Pasir-pasir pipi putih | 36     |    |         |    |           |
| 35. | <i>Pterois ruselli</i>        | Scorpaenidae | Depu                   | 5      |    |         |    |           |
| 36. | <i>Petroscirtes</i> sp.       | Blenniidae   | Bleni                  | 54     |    |         |    |           |
|     |                               | Total        |                        |        |    | 4,564.8 |    | 66,618.00 |
|     |                               | Average      |                        |        |    | 253.6   |    |           |

Biodiversity of fishes at this site according to Simpson's Diversity Index (D) was 0.15 (N = 192,170) with 36 total number of species. In term of percentage, *Lutjanus lutjanus* recorded the highest at 28.1% followed by *Lutjanus madras* (14.99%) and *Apogon aureus* at 11.8%. Details are shown in **Table 18**.

**Table 18:** Simpson's Diversity Index (D) at Cube ARs, Kijal (ARs 8)

|    | Species                         | Number of individual species /site (n) | n(n-1)                     | Percentage % |
|----|---------------------------------|--|----------------------------|--------------|
| 1  | <i>Lutjanus lutjanus</i>        | 54,000                                 | 2915946000                 | 28.10        |
| 2  | <i>Lutjanus madras</i>          | 28,800                                 | 829411200                  | 14.99        |
| 3  | <i>Lutjanus russellii</i>       | 360                                    | 129240                     | 0.19         |
| 4  | <i>Lutjanus kasmira</i>         | 10,080                                 | 101596320                  | 5.25         |
| 5  | <i>Lutjanus quinquelineatus</i> | 3,600                                  | 12956400                   | 1.87         |
| 6  | <i>Lutjanus vitta</i>           | 720                                    | 517680                     | 0.37         |
| 7  | <i>Epinephelus bleekeri</i>     | 108                                    | 11556                      | 0.06         |
| 8  | <i>Plectropomus areolatus</i>   | 7                                      | 45                         | 0.00         |
| 9  | <i>Epinephelus coioides</i>     | 18                                     | 306                        | 0.01         |
| 10 | <i>Epinephelus areolatus</i>    | 54                                     | 2862                       | 0.03         |
| 11 | <i>Cephalopholis boenak</i>     | 288                                    | 82656                      | 0.15         |
| 12 | <i>Cephalopholis formosa</i>    | 36                                     | 1260                       | 0.02         |
| 13 | <i>Diagramma pictum</i>         | 180                                    | 32220                      | 0.09         |
| 14 | <i>Caesio cuning</i>            | 288                                    | 82656                      | 0.15         |
| 15 | <i>Pterocaesio chrysozona</i>   | 4,320                                  | 18658080                   | 2.25         |
| 16 | <i>Carangoides gymnostethus</i> | 360                                    | 129240                     | 0.19         |
| 17 | <i>Carangoides</i> sp.          | 108                                    | 11556                      | 0.06         |
| 18 | <i>Neopomacentrus cyanomos</i>  | 2,808                                  | 7882056                    | 1.46         |
| 19 | <i>Neopomacentrus azystron</i>  | 360                                    | 129240                     | 0.19         |
| 20 | <i>Pomacentrus</i> sp.          | 1,800                                  | 3238200                    | 0.94         |
| 21 | <i>Chromis</i> sp.              | 3,600                                  | 12956400                   | 1.87         |
| 22 | <i>Pempheris malabarica</i>     | 90                                     | 8010                       | 0.05         |
| 23 | <i>Heniochus diphreutes</i>     | 36                                     | 1260                       | 0.02         |
| 24 | <i>Deodon liturosus</i>         | 4                                      | 12                         | 0.00         |
| 25 | <i>Echeneis naucrates</i>       | 4                                      | 12                         | 0.00         |
| 26 | <i>Apogon</i> sp.               | 17,280                                 | 298581120                  | 8.99         |
| 27 | <i>Apogon endekataenia</i>      | 19,080                                 | 364027320                  | 9.93         |
| 28 | <i>Apogon aureus</i>            | 22,680                                 | 514359720                  | 11.80        |
| 29 | <i>Archamia fucata</i>          | 20,520                                 | 421049880                  | 10.68        |
| 30 | <i>Labroides dimidiatus</i>     | 360                                    | 129240                     | 0.19         |
| 31 | <i>Thalassoma lunare</i>        | 18                                     | 306                        | 0.01         |
| 32 | <i>Choerodon schoenleinii</i>   | 72                                     | 5112                       | 0.04         |
| 33 | <i>Scolopsis vosmeri</i>        | 36                                     | 1260                       | 0.02         |
| 34 | <i>Pomacanthus annularis</i>    | 36                                     | 1260                       | 0.02         |
| 35 | <i>Pterois ruselli</i>          | 5                                      | 20                         | 0.00         |
| 36 | <i>Petroscirtes</i> sp.         | 54                                     | 2862                       | 0.03         |
|    | Total                           | N = 192,170                            | $\sum n(n-1) = 5501942567$ | 100          |

$$D = \sum n(n-1)/N(N-1) = 0.15$$

### **3.10. Biomass, Value and Biodiversity of Fishes at Recreation 2 ARs (ARs 9)**

A total of 39 species recorded at ARs 9 where 23 out of the total species were commercial species. The most abundant species were *Archamia fucata* with 2,960 individuals followed by *Apogon aureus* (3,600 individuals), *Archamia bleekeri* (2,880 individuals) and *Apogon cavitiensis* with 2,808 individuals. Other species were ranged between 4 – 2,520 individuals. Total biomass was estimated at 2,035.8 kg with an average 113.1 kg/module. The highest biomass was *Lutjanus russellii* with 324 kg followed by *Siganus javus* (270 kg) and other species were ranged between 3.6 – 243 kg. The value of commercial fish was estimated about RM 36,727.20. Details are shown in **Table 19**.

**Table 19:** Biomass and value of commercial fishes at Recreation 2 ARs, Sungai Merchong (ARs 9)

| No. | Species                         | Family         | Local name              | Estimate no. of fish (individual) /site | Average weight of fish / individual (g) | Biomass of fish /site (kg) | Price of fish / kg (RM) | Value of fish (RM) |
|-----|---------------------------------|----------------|-------------------------|---|---|----------------------------|-------------------------|--------------------|
| 1   | <i>Lutjanus lutjanus</i>        | Lutjanidae     | Kunyit-kunyit           | 1,800                                   | 30                                      | 54                         | 10                      | 540.00             |
| 2   | <i>Lutjanus russellii</i>       |                | Merah tanda             | 540                                     | 600                                     | 324                        | 25                      | 8,100.00           |
| 3   | <i>Lutjanus madras</i>          |                | Kunyit madras           | 900                                     | 30                                      | 27                         | 10                      | 270.00             |
| 4   | <i>Lutjanus vitta</i>           |                | Kunyit remong           | 900                                     | 60                                      | 54                         | 15                      | 810.00             |
| 5   | <i>Lutjanus johnii</i>          |                | Jenahak tanda           | 36                                      | 1,200                                   | 43.2                       | 25                      | 1,080.00           |
| 6   | <i>Lutjanus kasmira</i>         |                | Kunyit jalur biru       | 2,520                                   | 30                                      | 75.6                       | 10                      | 756.00             |
| 7   | <i>Lutjanus quinquelineatus</i> |                | Kunyit lima garis       | 180                                     | 30                                      | 5.4                        | 10                      | 54.00              |
| 8   | <i>Plectorhinchus gibbosus</i>  | Haemulidae     | Kaci kakap              | 36                                      | 1,300                                   | 46.8                       | 18                      | 842.40             |
| 9   | <i>Diagramma pictum</i>         |                | Kaci mandi abu          | 144                                     | 800                                     | 115.2                      | 20                      | 2,304.00           |
| 10  | <i>Epinephelus bleekeri</i>     |                | Kerapu ekor gelap       | 36                                      | 1,300                                   | 46.8                       | 35                      | 1,638.00           |
| 11  | <i>Cephalopholis boenak</i>     | Serranidae     | Kerapu belang perang    | 144                                     | 300                                     | 43.2                       | 5                       | 216.00             |
| 12  | <i>Epinephelus coioides</i>     |                | Kerapu bintik jingga    | 54                                      | 1,500                                   | 81                         | 25                      | 2,025.00           |
| 13  | <i>Cephalopholis formosa</i>    |                | Kerapu garis biru       | 36                                      | 400                                     | 14.4                       | 20                      | 288.00             |
| 14  | <i>Caesio cuning</i>            | Caesionidae    | Delah pinang            | 540                                     | 450                                     | 243                        | 20                      | 4,860.00           |
| 15  | <i>Siganus javus</i>            | Siganidae      | Dengkis jawa            | 900                                     | 300                                     | 270                        | 15                      | 4,050.00           |
| 16  | <i>Siganus canaliculatus</i>    |                | Dengkis bintik putih    | 36                                      | 150                                     | 5.4                        | 15                      | 81.00              |
| 17  | <i>Atule mate</i>               | Carangidae     | Pelata                  | 1,800                                   | 30                                      | 54                         | 20                      | 1,080.00           |
| 18  | <i>Alepes vari</i>              |                | Pelata bali             | 1,080                                   | 200                                     | 216                        | 15                      | 3,240.00           |
| 19  | <i>Scolopsis monogramma</i>     | Nemipteridae   | Pasir-pasir jalur gelap | 90                                      | 40                                      | 3.6                        | 3                       | 10.80              |
| 20  | <i>Scolopsis vosmeri</i>        |                | Pasir-pasir pipi putih  | 72                                      |   |                            |                         |                    |
| 21  | <i>Scolopsis torquatus</i>      |                | Pasir-pasir             | 36                                      |   |                            |                         |                    |
| 22  | <i>Chiloscyllium hasseltii</i>  | Hemiscylliidae | Yu cicak lampai         | 72                                      | 1,800                                   | 129.6                      | 10                      | 1,296.00           |
| 23  | <i>Plotosus canius</i>          | Plotosidae     | Semilang                | 108                                     | 1,400                                   | 151.2                      | 20                      | 3,024.00           |
| 24  | <i>Karalla daura</i>            | Leiognathidae  | Kekek jalur             | 2,160                                   | 15                                      | 32.4                       | 5                       | 162.00             |
| 25  | <i>Neopomacentrus azystron</i>  | Pomacentridae  | Kepal batu              | 198                                     |   |                            |                         |                    |

|         |                                |               |                      |       |    |    |         |           |
|---------|--------------------------------|---------------|----------------------|-------|----|----|---------|-----------|
| 26      | <i>Neopomacentrus cyanomos</i> |               | Kepal batu           | 1,800 |    |    |         |           |
| 27      | <i>Pempheris malabarica</i>    | Pempheridae   | Sepat                | 720   |    |    |         |           |
| 28      | <i>Apogon endekataenia</i>     | Apogonidea    | Sebekah              | 2,340 |    |    |         |           |
| 29      | <i>Apogon aureus</i>           |               | Sebekah              | 3,600 |    |    |         |           |
| 30      | <i>Archamia ficata</i>         |               | Sebekah              | 3,960 |    |    |         |           |
| 31      | <i>Apogon nigroincta</i>       |               | Sebekah              | 460   |    |    |         |           |
| 32      | <i>Apogon cavitensis</i>       |               | Seriding             | 2,808 |    |    |         |           |
| 33      | <i>Archamia bleekeri</i>       |               | Sebekah              | 2,880 |    |    |         |           |
| 34      | <i>Arothron stellatus</i>      | Tetradontidae | Buntal pasir bintang | 4     |    |    |         |           |
| 35      | <i>Arothron hispidus</i>       |               | Buntal pasir bintik  | 7     |    |    |         |           |
| 36      | <i>Deodon lituosus</i>         | Deodontidae   | Buntal duri          | 4     |    |    |         |           |
| 37      | <i>Taeniura lymna</i>          | Dasyatidae    | Pari karang          | 4     | NA | NA | NA      | NA        |
| 38      | <i>Labroides dimidiatus</i>    | Labridae      | Nuri                 | 8     |    |    |         |           |
| 39      | <i>Scorpaenopsis</i> sp.       | Scorpaenidae  | Depu                 | 4     |    |    |         |           |
| Total   |                                |               |                      |       |    |    | 2,035.8 | 36,727.20 |
| Average |                                |               |                      |       |    |    | 113.1   |           |

Biodiversity of fishes at this site according to Simpson's Diversity Index (D) was 0.07 (N = 33,017) with 39 total number of species. In term of percentage, *Archamia fucata* recorded the highest at 11.99% followed by *Apogon aureus* (10.90%) and *Archamia bleekeri* at 8.72%. Details are shown in **Table 20**.

**Table 20:** Simpson's Diversity Index (D) at Recreation 2 ARs, Sungai Merchong (ARs 9)

|    | Species                          | Number of individual species /site (n) | n (n-1)  | Percentage % |
|----|----------------------------------|--|----------|--------------|
| 1  | <i>Lutjanus lutjanus</i>         | 1,800                                  | 3238200  | 5.45         |
| 2  | <i>Lutjanus russellii</i>        | 540                                    | 291060   | 1.64         |
| 3  | <i>Lutjanus madras</i>           | 900                                    | 809100   | 2.73         |
| 4  | <i>Lutjanus vitta</i>            | 900                                    | 809100   | 2.73         |
| 5  | <i>Lutjanus johnii</i>           | 36                                     | 1260     | 0.11         |
| 6  | <i>Lutjanus kasmira</i>          | 2,520                                  | 6347880  | 7.63         |
| 7  | <i>Lutjanus quinquelineatus</i>  | 180                                    | 32220    | 0.55         |
| 8  | <i>Plectorhinchus gibbosus</i>   | 36                                     | 1260     | 0.11         |
| 9  | <i>Diagramma pictum</i>          | 144                                    | 20592    | 0.44         |
| 10 | <i>Epinephelus bleekeri</i>      | 36                                     | 1260     | 0.11         |
| 11 | <i>Cephalopholis boenak</i>      | 144                                    | 20592    | 0.44         |
| 12 | <i>Epinephelus coioides</i>      | 54                                     | 2862     | 0.16         |
| 13 | <i>Cephalopholis formosa</i>     | 36                                     | 1260     | 0.11         |
| 14 | <i>Caesio cuning</i>             | 540                                    | 291060   | 1.64         |
| 15 | <i>Siganus javus</i>             | 900                                    | 809100   | 2.73         |
| 16 | <i>Siganus canaliculatus</i>     | 36                                     | 1260     | 0.11         |
| 17 | <i>Atule mate</i>                | 1,800                                  | 3238200  | 5.45         |
| 18 | <i>Alepes vari</i>               | 1,080                                  | 1165320  | 3.27         |
| 19 | <i>Scolopsis monogramma</i>      | 90                                     | 8010     | 0.27         |
| 20 | <i>Scolopsis vosmeri</i>         | 72                                     | 5112     | 0.22         |
| 21 | <i>Scolopsis torquatus</i>       | 36                                     | 1260     | 0.11         |
| 22 | <i>Chiloscyllium hasseltii</i>   | 72                                     | 5112     | 0.22         |
| 23 | <i>Plotosus canius</i>           | 108                                    | 11556    | 0.33         |
| 24 | <i>Karalla daura (ikan baja)</i> | 2,160                                  | 4663440  | 6.54         |
| 25 | <i>Neopomacentrus azystron</i>   | 198                                    | 39006    | 0.60         |
| 26 | <i>Neopomacentrus cyanomos</i>   | 1,800                                  | 3238200  | 5.45         |
| 27 | <i>Pempheris malabarica</i>      | 720                                    | 517680   | 2.18         |
| 28 | <i>Apogon endekataenia</i>       | 2,340                                  | 5473260  | 7.09         |
| 29 | <i>Apogon aureus</i>             | 3,600                                  | 12956400 | 10.90        |
| 30 | <i>Archamia fucata</i>           | 3,960                                  | 15677640 | 11.99        |
| 31 | <i>Apogon nigrocineta</i>        | 460                                    | 211140   | 1.39         |
| 32 | <i>Apogon cavitiensis</i>        | 2,808                                  | 7882056  | 8.50         |
| 33 | <i>Archamia bleekeri</i>         | 2,880                                  | 8291520  | 8.72         |
| 34 | <i>Arothron stellatus</i>        | 4                                      | 12       | 0.01         |



|       |                             |           |                          |      |
|-------|-----------------------------|-----------|--------------------------|------|
| 35    | <i>Arothron hispidus</i>    | 7         | 42                       | 0.02 |
| 36    | <i>Deodon liturosus</i>     | 4         | 12                       | 0.01 |
| 37    | <i>Taeniura lymma</i>       | 4         | 12                       | 0.01 |
| 38    | <i>Labroides dimidiatus</i> | 8         | 56                       | 0.02 |
| 39    | <i>Scorpaenopsis</i> sp.    | 4         | 12                       | 0.01 |
| Total |                             | N= 33,017 | $\sum n (n-1)= 76063124$ | 100  |

$$D = \sum n (n-1)/N (N-1) = 0.07$$

### 3.11. Biomass, Value and Biodiversity of Fishes at Cuboid-AT ARs (ARs 10)

A total of 38 species were recorded at ARs 10 where 24 out of total species were commercial species. The most abundant species were *Lutjanus lutjanus* with 46,000 individuals followed by *Lutjanus madras* (36,800 individuals), *Archamia bleekeri* (11,500 individuals) and *Apogon endekataenia* with 3,680 individuals. Other species ranged between 9 – 2,438 individuals. Total biomass was estimated at 6,047.2 kg with an average 262.9 kg/module. The highest biomass was contributed by *Sphyræna jello* with 1,656 kg followed by *Lutjanus lutjanus* (1,380 kg) and other species were ranged between 2.8 – 920 kg. The value of commercial fish was estimated about RM 84,759.60. Details are shown in **Table 21**.

**Table 21:** Biomass and value of commercial fishes at Cuboid-AT ARs, Pulau Tinggi (ARs 10)

| No. | Species                        | Family        | Local name             | Estimate no. of fish (individual) /site | Average weight of fish / individual (g) | Biomass of fish /site (kg) | Price of fish / kg (RM) | Value of fish (RM) |
|-----|--------------------------------|---------------|------------------------|---|---|----------------------------|-------------------------|--------------------|
| 1   | <i>Lutjanus lutjanus</i>       | Lutjanidae    | Kunyit-kunyit          | 46,000                                  | 30                                      | 1,380.0                    | 10                      | 13,800.00          |
| 2   | <i>Lutjanus madras</i>         |               | Kunyit madras          | 36,800                                  | 25                                      | 920.0                      | 10                      | 9,200.00           |
| 3   | <i>Lutjanus johnii</i>         |               | Jenahak tanda          | 460                                     | 1,500                                   | 690.0                      | 25                      | 17,250.00          |
| 4   | <i>Lutjanus russellii</i>      |               | Merah tanda            | 322                                     | 600                                     | 193.2                      | 25                      | 4,830.00           |
| 5   | <i>Lutjanus vittata</i>        |               | Kunyit remong          | 920                                     | 150                                     | 138.0                      | 15                      | 2,070.00           |
| 6   | <i>Lutjanus malabaricus</i>    |               | Merah mata hitam       | 69                                      | 1,500                                   | 103.5                      | 30                      | 3,105.00           |
| 7   | <i>Epinephelus bleekeri</i>    | Serranidae    | Kerapu ekor gelap      | 92                                      | 600                                     | 55.2                       | 35                      | 1,932.00           |
| 8   | <i>Cephalopholis boenak</i>    |               | Kerapu belang perang   | 368                                     | 50                                      | 18.4                       | 5                       | 92.00              |
| 9   | <i>Epinephelus coioides</i>    |               | Kerapu bintik jingga   | 46                                      | 1,000                                   | 46.0                       | 25                      | 1,150.00           |
| 10  | <i>Epinephelus erythrurus</i>  |               | Kerapu tompok awan     | 23                                      | 120                                     | 2.8                        | 10                      | 27.60              |
| 11  | <i>Cephalopholis formosa</i>   |               | Kerapu garis biru      | 69                                      | 800                                     | 55.2                       | 20                      | 1,104.00           |
| 12  | <i>Caesio cuning</i>           | Caesionidae   | Delah pinang           | 230                                     | 200                                     | 46.0                       | 20                      | 920.00             |
| 13  | <i>Pterocaesio chrysozona</i>  |               | Sulit jalur emas       | 230                                     | 30                                      | 6.9                        | 5                       | 34.50              |
| 14  | <i>Siganus javus</i>           | Siganidae     | Dengkis jawa           | 92                                      | 300                                     | 27.6                       | 15                      | 414.00             |
| 15  | <i>Siganus guttatus</i>        |               | Dengkis tompok oren    | 46                                      | 150                                     | 6.9                        | 15                      | 103.50             |
| 16  | <i>Siganus canaliculatus</i>   |               | Dengkis bintik putih   | 230                                     | 150                                     | 34.5                       | 15                      | 517.50             |
| 17  | <i>Selaroides leptolepis</i>   | Carangidae    | Selar kuning           | 2,300                                   | 15                                      | 34.5                       | 10                      | 345.00             |
| 18  | <i>Pateobatis jenkinsii</i>    | Dasyatidae    | Pari naga              | 9                                       | 5,000                                   | 46.0                       | 20                      | 920.00             |
| 19  | <i>Diagramma pictum</i>        | Haemulidae    | Kaci mandi abu         | 368                                     | 1,300                                   | 478.4                      | 20                      | 9,568.00           |
| 20  | <i>Sphyræna jello</i>          | Sphyrænidae   | Alu-alu belang         | 1,380                                   | 1,200                                   | 1,656.0                    | 10                      | 16,560.00          |
| 21  | <i>Pomacanthus annularis</i>   | Pomacanthidae | Taring pelanduk cincin | 23                                      | 700                                     | 16.1                       | 5                       | 80.50              |
| 22  | <i>Choerodon schoenleinii</i>  | Labridae      | Ketarap bintik hitam   | 46                                      | 2,000                                   | 92.0                       | 8                       | 736.00             |
| 23  | <i>Labroides dimidiatus</i>    |               | Nuri                   | 69                                      |   |                            |                         |                    |
| 24  | <i>Leptojulius cyanopleura</i> |               | Nuri                   | 69                                      |   |                            |                         |                    |
| 25  | <i>Neopomacentrus azystron</i> | Pomacentridae | Kepal batu             | 230                                     |   |                            |                         |                    |
| 26  | <i>Neopomacentrus</i>          |               | Kepal batu             | 460                                     |   |                            |                         |                    |

|         |                              |                |                        |        |    |         |    |           |
|---------|------------------------------|----------------|------------------------|--------|----|---------|----|-----------|
| 27      | <i>Pomacentrus</i> sp.       |                | Kepal batu             | 1,840  |    |         |    |           |
| 28      | <i>Pomacentrus milleri</i>   |                | Gombin                 | 46     |    |         |    |           |
| 29      | <i>Dascyllus</i> sp.         |                | Puyu laut              | 115    |    |         |    |           |
| 30      | <i>Apogon endekataenia</i>   | Apogonidea     | Sebekah                | 3,680  |    |         |    |           |
| 31      | <i>Apogon aureus</i>         |                | Sebekah                | 2,300  |    |         |    |           |
| 32      | <i>Apogon cavitiensis</i>    |                | Sebekah                | 2,162  |    |         |    |           |
| 33      | <i>Archamia fucata</i>       |                | Sebekah                | 2,438  |    |         |    |           |
| 34      | <i>Archamia bleekeri</i>     |                | Seriding               | 11,500 |    |         |    |           |
| 35      | <i>Lethrinus lenifan</i>     | Lethrinidae    | Landok calit merah     | 46     | NA | NA      | NA | NA        |
| 36      | <i>Hentiochus diphreutes</i> | Chaetodontidae | Bagang sirip filamen   | 46     | NA | NA      | NA | NA        |
| 37      | <i>Arothron stellatus</i>    | Tetraodontidae | Buntal pasir bintang   | 23     |    |         |    |           |
| 38      | <i>Scolopsis vosmeri</i>     | Nemipteridae   | Pasir-pasir pipi putih | 69     |    |         |    |           |
| Total   |                              |                |                        |        |    | 6,047.2 |    | 84,759.60 |
| Average |                              |                |                        |        |    | 262.9   |    |           |

Biodiversity of fishes at this site according to Simpson's Diversity Index (D) was 0.27 (N = 115,216) with 38 total number of species. In term of percentage, *Lutjanus lutjanus* recorded the highest at 39.93% followed by *Lutjanus madras* (31.94%) and *Archamia bleekeri* with 9.98%. Details are shown in **Table 22**.

**Table 22:** Simpson's Diversity Index (D) at Cuboid-AT ARs, Pulau Tinggi (ARs 10)

|    | Species                        | Number of individual species /site (n) | n(n-1)                     | Percentage % |
|----|--------------------------------|--|----------------------------|--------------|
| 1  | <i>Lutjanus lutjanus</i>       | 46,000                                 | 2115954000                 | 39.93        |
| 2  | <i>Lutjanus madras</i>         | 36,800                                 | 1354203200                 | 31.94        |
| 3  | <i>Lutjanus johnii</i>         | 460                                    | 211140                     | 0.40         |
| 4  | <i>Lutjanus russellii</i>      | 322                                    | 103362                     | 0.28         |
| 5  | <i>Lutjanus vitta</i>          | 920                                    | 845480                     | 0.80         |
| 6  | <i>Lutjanus malabaricus</i>    | 69                                     | 4692                       | 0.06         |
| 7  | <i>Epinephelus bleekeri</i>    | 92                                     | 8372                       | 0.08         |
| 8  | <i>Cephalopholis boenak</i>    | 368                                    | 135056                     | 0.32         |
| 9  | <i>Epinephelus coioides</i>    | 46                                     | 2070                       | 0.04         |
| 10 | <i>Epinephelus erythrurus</i>  | 23                                     | 506                        | 0.02         |
| 11 | <i>Cephalopholis formosa</i>   | 69                                     | 4692                       | 0.06         |
| 12 | <i>Caesio cuning</i>           | 230                                    | 52670                      | 0.20         |
| 13 | <i>Pterocaesio chrysozona</i>  | 230                                    | 52670                      | 0.20         |
| 14 | <i>Siganus javus</i>           | 92                                     | 8372                       | 0.08         |
| 15 | <i>Siganus guttatus</i>        | 46                                     | 2070                       | 0.04         |
| 16 | <i>Siganus canaliculatus</i>   | 230                                    | 52670                      | 0.20         |
| 17 | <i>Selaroides leptolepis</i>   | 2,300                                  | 5287700                    | 2.00         |
| 18 | <i>Pateobatis jenkinsii</i>    | 9                                      | 72                         | 0.01         |
| 19 | <i>Diagramma pictum</i>        | 368                                    | 135056                     | 0.32         |
| 20 | <i>Sphyræna jello</i>          | 1,380                                  | 1903020                    | 1.20         |
| 21 | <i>Pomacanthus annularis</i>   | 23                                     | 506                        | 0.02         |
| 22 | <i>Choerodon schoenleinii</i>  | 46                                     | 2070                       | 0.04         |
| 23 | <i>Labroides dimidiatus</i>    | 69                                     | 4692                       | 0.06         |
| 24 | <i>Leptojulius cyanopleura</i> | 69                                     | 4692                       | 0.06         |
| 25 | <i>Neopomacentrus azystron</i> | 230                                    | 52670                      | 0.20         |
| 26 | <i>Neopomacentrus cyanomos</i> | 460                                    | 211140                     | 0.40         |
| 27 | <i>Pomacentrus sp.</i>         | 1,840                                  | 3383760                    | 1.60         |
| 28 | <i>Pomacentrus milleri</i>     | 46                                     | 2070                       | 0.04         |
| 29 | <i>Dascyllus sp.</i>           | 115                                    | 13110                      | 0.10         |
| 30 | <i>Apogon endekataenia</i>     | 3,680                                  | 13538720                   | 3.19         |
| 31 | <i>Apogon aureus</i>           | 2,300                                  | 5287700                    | 2.00         |
| 32 | <i>Apogon cavitiensis</i>      | 2,162                                  | 4672082                    | 1.88         |
| 33 | <i>Archamia fucata</i>         | 2,438                                  | 5941406                    | 2.12         |
| 34 | <i>Archamia bleekeri</i>       | 11,500                                 | 132238500                  | 9.98         |
| 35 | <i>Lethrinus lentjan</i>       | 46                                     | 2070                       | 0.04         |
| 36 | <i>Heniochus diphreutes</i>    | 46                                     | 2070                       | 0.04         |
| 37 | <i>Arothron stellatus</i>      | 23                                     | 506                        | 0.02         |
| 38 | <i>Scolopsis vosmeri</i>       | 69                                     | 4692                       | 0.06         |
|    | Total                          | N= 115,216                             | $\sum n(n-1) = 3644329326$ | 100          |

$$D = \sum n(n-1)/N(N-1) = 0.27$$

#### 4. DISCUSSION AND CONCLUSION

According to Mohamed Pauzi *et al.* (2010), total weight of commercial fishes recorded at Cuboid ARs was 16.5 kg/module after 11 months of deployed in Setiu, 5.1 kg/module after five months deployed in Kuala Terengganu and 96.7 kg/module after 11 months also deployed in Kuala Terengganu. Their research was conducted between 5 – 11 months after deployment compared to ARs in this study which were deployed between one month to 10 years. In term of Simpson's Diversity Index (D), Cuboid ARs deployed in Setiu and two sites in Kuala Terengganu were 0.919, 0.725 and 0.493 respectively. The ranged of 'D' value for this study were between 0.07 – 0.33. The results showed that biodiversity of fishes at all sites were higher compared to the previous study conducted by Mohamed Pauzi *et al.* (2010). As species richness and evenness increase, so diversity increases. With this index, 0 represents infinite diversity and 1 means no diversity.

The ARs module studied by Mohamed Pauzi *et al.* (2010) only weighted about 10 metric tons, measured 2 m (length) X 2 m (width) X 3 m (height) and recorded only 5 – 9 species. Number of species recorded during this study was ranged between 14 – 46 species. The higher number of species for this study (46 species) were due to bigger size of confiscated fishing vessels (ARs 3) measured 25.5 m (length) X 4 m (width) X 5 m (height)/module, large coverage area and higher number of modules per site (18 modules). The lowest species richness (14 species) was recorded at a single RTR module near Pulau Kapas (ARs 5) weighted about 18 metric tons and measured 6 m (length) X 6 m (width) X 2 m (height). The coverage area only 72 m<sup>3</sup> compared to 14,668 m<sup>3</sup> at ARs 3. For instance, at another RTR module (ARs 4) weighted about 43 metric tons with 11.1 m (length) X 11.1 m (width) X 3 m (height), 25 species of fish were recorded. As a conclusion, the highest number of species/module was recorded at ARs 4 followed by ARs 5 and ARs 6 with 25 species, 14 species and three species respectively.

The highest biomass was recorded at ARs 10 with 6,047.2 kg (262.92 kg/module). This site covered sea floor area about 845 m<sup>3</sup> that consisted of 23 modules of concrete ARs with measurement of 3.5 m (length) X 3.5 m (width) X 3 m (height). The lowest biomass was recorded at ARs 6 with 129.1 kg (25.8 kg/module). In terms of biomass/module, ARs 4 recorded the highest with 1,009.4 kg followed by ARs 5 (441.9 kg) and ARs 10 at 262.9 kg. In term of value, the highest was recorded at ARs 10 with RM 84,759.60 followed by ARs 3 (RM 68,679.00) and ARs 8 at RM 66,618.00. The lowest value was recorded at ARs 6 with RM 1,824.50. Summary of species biodiversity, biomass and value are shown in **Table 23**.

Based on this finding, higher number of module, bigger size of ARs and longer time of deployment will attract more diversity of fishes. According to Ahmad *et al.* (2013), bigger size of ARs are also functioning effectively as hindrance to illegal trawling. Those ARs have by now developed into new habitats not only for fish, but also for other marine flora and fauna.

In general, the ARs program in the eastcoast of Peninsular Malaysia has achieved its objectives in increasing fishery resources and deterring illegal trawling in the coastal area. This information was based on observation made by Southeast Asia Marine Resources Institute (ISMAT) researchers and fishers. The most suitable materials are steel and reinforced concrete. Durability of fishing vessel covered with thick fiberglass is still under study. The larger size, large coverage area and higher number of modules of ARs are superior to the smaller, less coverage area and fewer number in attracting fishes. The large size ARs is excellent in performing the dual functions of creating new habitats on its' surface and deterring the encroachment of trawlers. The DoFM through ISMAT is continuing in their endeavor to seek the progress of other new designs of ARs that will be able to closely imitate the natural reefs. The decision by the DoFM policy makers to construct large, heavy and robust artificial reefs using durable materials such as reinforced concrete, oil and gas platform and confiscated fishing vessels covered with thick fiberglass were successfully functioned as expected. As a conclusion, coastal resource enhancement program in Malaysia is partially achieve by ARs program.

**Table 23:** Summary of biodiversity of species and biomass

| <b>Name of ARs</b> | <b>Number of Module</b> | <b>Number of Fish Species Recorded</b> | <b>Average Number of Species/Module</b> | <b>Total Biomass/Site (kg)</b> | <b>Average Biomass/Module (kg)</b> | <b>Value of Fish/site (RM)</b> |
|--------------------|-------------------------|--|---|--------------------------------|------------------------------------|--------------------------------|
| ARs 1              | 14                      | 18                                     | 1.3                                     | 1,203                          | 85.9                               | 26,451.04                      |
| ARs 2              | 14                      | 28                                     | 2                                       | 1,367.4                        | 97.7                               | 24,020.50                      |
| ARs 3              | 18                      | 46                                     | 2.5                                     | 5,005                          | 278.1                              | 68,679.00                      |
| ARs 4              | 1                       | 25                                     | 25                                      | 1,009.4                        | 1,009.4                            | 11,057.50                      |
| ARs 5              | 1                       | 14                                     | 14                                      | 441.8                          | 441.8                              | 4,321.25                       |
| ARs 6              | 5                       | 17                                     | 3.4                                     | 129.1                          | 25.8                               | 1,824.50                       |
| ARs 7              | 18                      | 32                                     | 1.8                                     | 3,096                          | 172                                | 49,876.20                      |
| ARs 8              | 18                      | 36                                     | 2                                       | 4,564.8                        | 253.6                              | 66,618.00                      |
| ARs 9              | 18                      | 39                                     | 2.2                                     | 2,035.8                        | 113.1                              | 36,727.20                      |
| ARs 10             | 23                      | 38                                     | 1.6                                     | 6,047.2                        | 262.9                              | 84,759.60                      |
| <b>Total</b>       | <b>130</b>              |  |   | <b>24,899.5</b>                |                                    | <b>374,334.79</b>              |

## **5. ACKNOWLEDGEMENT**

The authors wish to express greatest gratitude to the Director General of Department of Fisheries Malaysia for providing financial supports to conduct this study. A special thanks to Mr. Raja Bidin bin Raja Hassan, Deputy Director General (Development) of Department of Fisheries Malaysia for his support of this publication.

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ISBN 978-967-0633-79-4



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