ASSESSMENT OF FISH BIODIVERSITY AROUND ARTIFICIAL AND NATURAL REEFS IN TERENGGANU WATERS, MALAYSIA

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DEDICATION

I dedicate this thesis to

My loving parents for their encouragement and support

Also, this thesis is dedicated to my wife who has been

a great source of motivation and inspiration.

Abstract of thesis presented to the Senate of Universiti Malaysia Terengganu in fulfillment of the requirement for the degree of Master of Science

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The effectiveness of artificial reefs (ARs) influencing fish composition, biodiversity and biomass were studied from May 2005 to September 2007 in the coastal waters of Kuala Terengganu. Three selected artificial reefs - TRs (tire reefs), CRs (concrete reefs) and CTRs (mixed concrete with tire reefs); and also neighboring natural reef (NRs) were investigated. Two different survey methods *viz*. fishing survey and diving visual census, were followed using hand-line/gillnet operation, stationary visual census and underwater video recording. Altogether, 142 species belonging to 43 families and 88 genera were identified at both artificial and natural reef sites.

In case of fishing survey during August – September, 2006, a total number of 36 fish species (848 individuals) were encountered. The CRs supported high fish diversity (31 species: pelagic – 14, demersal - 12 and benthic - 5) followed by CTRs (29 species: pelagic - 12, demersal - 14 and benthic - 3), and TRs (22 species: pelagic - 9, demersal - 8 and benthic - 5) in

the order. Three species notably, *Lutjanus vitta, Diagramma pictum* and *Seriola fasciata* were exclusively found at CRs indicating their preference to those habitats. The NRs signified 21 species (pelagic - 7, demersal - 11 and benthic - 3), with an additional exclusive fish, *Oxycheilinus digramma*. The (mean) CPUE (Catch per Unit Effort) was significant different ($P < 0.05$) for both pelagic and demersal groups than benthic fishes. The fishing yield was also high at CRs (2.16 kg/standard catch) followed by CTRs (1.43 kg/standard catch), TRs (0.8 kg/standard catch), and NRs (0.61 kg/standard catch). The cluster analysis (Bray-Curtis similarity) and multi-dimensional scaling (MDS) plots based on CPUE of faunal abundance (root-transformed data) revealed that both artificial and natural reef samples could be ideally distinguished into 4 groups (similarity: 56%). While Groups - 1, 2 and 3 were characterized by the species associated with artificial reefs, Group - 4 represented population at the natural reef environment.

The underwater visual census (April – September, 2007) naturally provided high fish diversity/abundance values as compared to fishing survey. In a stationary point count, 112 species (34 families and 66 genera) were identified, where NRs supported 70 species followed by CRs (67), CTRs (63), and TRs (56). However, fish abundance was high at the CRs (1745 ± 1385 ind $25m^{-2}$) (mean ± 1SD) followed by CTRs (862 ± 400 ind $25m^{-2}$), NRs (627 ± 423 ind $25m^{-2}$), and TRs (267 ± 160 ind $25m^{-2}$) respectively. Species such as *Lutjanus lutjanus* (big-eye snapper) and *Pterocaesio chrysozona* (gold-band fusilier) were predominant in these areas. The Bray-Curtis similarity and MDS plots based on faunal abundance per quadrate (root-transformed data) revealed 6 groups (similarity: 42%). While Group-1 was characterized by

species associated with NRs, Groups - 2 to 5 represented population exclusive to the artificial reef environment. It is striking that in both cases (i.e. fishing survey and/or visual census), the groupings have followed the same pattern separating those two different (artificial/natural) environments. Furthermore, the underwater video recording served as an evidence/support for fish species identification and the status of reef structures.

The species-environment relationship was examined by Spearman rank (2 tailed) test. While temperature and salinity influenced the reef fish diversity at CTRs, water depth and turbidity found important at NRs. The relationship between faunal assemblages and habitat characteristics (i.e. number and size of holes, space between models and vertical relief) was examined through linear regression test. Among others, the number of holes was found significant different ($P < 0.05$) with species availability and their abundance. The smaller sized holes/space sustained rich species diversity than big holes that attracted more abundance. The greater fish abundance was also associated with low-vertical relief structures. The present study also demonstrated that fish community structure varied accordingly with reef design, and the CRs supported high species diversity and abundance.

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PENILAIAN TERHADAP KEPELBAGAIAN IKAN DI SEKITAR TUKUN TIRUAN DAN SEMULAJADI DI PERAIRAN TERENGGANU, MALAYSIA

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Kajian keberkesanan penggunaan tukun tiruan dalam mempengaruhi komposisi ikan, biodiversiti dan biomass telah dilakukan bermula daripada Mei 2005 hingga September 2007 di perairan pantai Terengganu. Tiga jenis tukun tiruan dipilih untuk kajian ini iaitu tukun tayar (TRs), tukun konkrit (CRs) dan campuran tukun tayar dan konkrit (CTRs); dan tukun semula jadi iaitu terumbu karang (NRs). Penyampelan adalah menggunakan dua kaedah utama, iaitu penangkapan ikan dan pemerhatian secara langsung dan selaman visual. Penangkapan ikan adalah menggunakan pancing dan pukat insang. Pemerhatian langsung adalah berdasarkan kaedah pemerhatian setempat dengan bantnan rakaman video. Terdapat 142 spesis daripada 43 famili dan 88 genus ikan dikenal pasti daripada kesemua lokasi tukun tiruan dan tukun semula jadi.

Dalam penyampelan perikanan yang dilakukan daripada Ogos hingga September, sebanyak 36 spesies ikan (848 individu) telah diperhatikan. Tukun jenis CRs diperhatikan menampung kepelbagaian biodiversiti ikan yang

paling tinggi iaitu sebanyak 31 spesies: ikan pelagik - 14, ikan demersal - 12 dan ikan benthik - 5) manakala tukun jenis CTRs (29 spesies: pelagik-12, ikan demersal - 14 dan ikan benthik - 3), dan TRs (22 spesies: pelagik - 9, ikan demersal - 8 dan ikan benthik - 5). Tiga jenis spesies iaitu *Lutjanus vitta, Diagramma pictum* dan *Seriola fasciata* hanya diperhatikan di CRs dan ini menunjukkan pemilihan mereka terhadap tukun jenis ini. Bagi terumbu karang semula jadi, kajian ini menjumpai 21 spesies (pelagik - 7, ikan demersal - 11 dan benthik - 3), serta seekor ikan yang eksklusif iaitu *Oxycheilinus digramma*. Purata bagi CPUE (Catch per Unit Effort) menunjukkan perbezaan yang signifikan ($P < 0.05$) terhadap kewujudan ikan pelagik dan kumpulan ikan demersal serta benthik. Hasilan pancingan adalah tinggi di CRs (2.16 kg/ tahap tangkapan) dikuti oleh CTRs (1.43 kg/tahap tangkapan), TRs (0.8 kg/tahap tangkapan), dan NRs (0.61 kg/tahap tangkapan). Analisis perkelompokan (clustring analysis') (kesamaan Bray-Curtis) dan skala kepelbagaian (Multi-dimensional scaling') (MDS) berdasarkan CPUE menunjukkan sampel di kawasan tukun dan karang dapat dibahagikan kepada empat kumpulan (terdapat persamaan 56%). Kumpulan 1,2 dan 3 menunjukkan spesies yang bersekutu dengan tukun, manakala Kumpulan 4 menunjukkan spesies yang sebersekutu dengan terumbu karang.

Penyampelan visual (April – September, 2007) memberikan nilai biodiversiti dan kelimpahan ikan yang tinggi berbanding kaedah memancing. Teknik visual ini mengenalpasti 112 spesies ikan (34 famili dan 66 genus). 70 spesies ikan daripada NRs diikuti oleh CRs (67), CTRs (63), dan TRs (56). Bagaimanapun kelimpahan adalah tertinggi di CRs (1745 ± 1385 ind 25 m^{-2}) (min ± 1SD) diikuti CTRs (862 ± 400 ind 25 m^{-2}), NRs (627 ± 423 ind 25 m^{-2}),

dan TRs (267 ± 160 ind 25 m^{-2}). Daripada pemerhatian, didapati spesies *Lutjanus lutjanus* (kunyit-kunit) dan *Pterocaesio chrysozona* (pisang-pisang) mendominasi kawasan kajian. Kaedah kesamaan Bray-Curtis dan plot MDS berdasarkan kelimpahan ikan mendapati terdapat 6 jenis kumpulan ikan (persamaan 42%). Kumpulan 1 merupakan spesies bersekutu dengan NRs, kumpulan 2 hingga 5 mewakili populasi yang eksklusif kepada persekitaran tukun. Kedua-dua kaedah persampelan (penangkapan dan bancian visual), memberikan perkumpulan ikan yang sama yang mengasingkannya berdasarkan persekitaran tukun dan kawasan karang. Ini disokong dengan rakaman video bagi mengenal pasti spesies ikan dan keadaan struktur-struktur tukun tiruan tersebut.

Perhubungan diantara Spesies dan kawasan persekitaran dianalisa berdasarkan kepada ujian pangkat Spearman (2 hala). Suhu dan kemasinan memberikan kesan kepada diversiti ikan di tukun CTRs, kedalaman dan kekeruhan didapati penting bagi kawasan NRs. Hubungan di antara perkumpulan ikan dan ciri-ciri habitat (bilangan dan saiz lubang, jarak diantara tukun dan tinggi tukun) diuji menggunakan regresi linear. Bilangan lubang memberikan perbezaan yang bererti ($P<0.05$) untuk kehadiran dan kelimpahan spesies. Lubang yang kecil didapati menampung diversiti ikan yang tinggi, manakala lubang besar memberikan kelimpahan yang tinggi. Kelimpahan yang tinggi juga diberikan oleh struktur tukun yang lebih rendah. Kajian ini menunjukkan komuniti ikan adalah berbeza berdasarkan kepada rekabentuk tukun dan kawasan CRs didapati menampung kepelbagaian dan kelimpahan ikan yang lebih tinggi.