UNIVERSITI PUTRA MALAYSIA

BIOLOGICAL CHARACTERIZATION OF WILD COBIA, Rachycentron canadum (LINNAEUS, 1766) OFF DUNGUN COAST, TERENGGANU, MALAYSIA FOR STOCK MANAGEMENT AND AQUACULTURE

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By

BABATUNDE TAOFIK ADEMOLA

Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfilment of the Requirements for the Degree of Doctor of Philosophy

August 2016

DEDICATION

I dedicate this work to my parents who have set a pace for me that take me to reach this extent in life, and to my family and friends

Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfilment of the requirement for the degree Doctor of Philosophy

BIOLOGICAL CHARACTERIZATION OF WILD COBIA, *Rachycentron canadum* (LINNAEUS, 1766) OFF DUNGUN COAST, TERENGGANU, MALAYSIA FOR STOCK MANAGEMENT AND AQUACULTURE

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Chairperson : Assoc. Prof. S. M. Nurul Amin, PhD
Faculty : Agriculture

Investigation of some aspects of biology of a recreationally and commercially important fish, cobia, *Rachycentron canadum* in Dungun coast, Malaysia was conducted between April 2014 and May 2015. A total of 249 specimens were opportunistically collected from the catches of trawl net, gill net and by hooks and line. The total length ranged from 39.20 to 143.00 cm (88.29 ± 1.28 cm), fork length ranged from 37.50 to 124.00 cm (78.69 ± 1.09 cm) while the wet weight ranged from 0.50 to 20.40 kg (5.51 ± 0.26 kg). There was no significant difference in all the morphometric characters between sexes except for head width (HW) ($p < 0.05$). Ten (10) out of the seventeen (17) truss distances in the body landmarks of cobia showed significant differences between males and females. The equation of length-weight (LW) relationship for combined sex was $W = 0.000002FL^{3.3204}$ ($R^2 = 0.92$). The growth of cobia in Dungun water followed positive allometric as the growth coefficient (b) was higher than 3. Observed length frequency of both sex followed a normal distribution pattern and there was a predominance of cobia in the medium size range from 65 - 85 cm fork length for the females and 55 - 90 cm for the males. The sex ratio of females to males was 1:1.18 and it was not significantly different from the expected 1:1 ($X^2 = 2.12$ df = 1; $p < 0.05$). Growth parameters of von Bertalanffy growth formula for cobia estimated were $L_\infty = 142.00$ cm, $K = 1.20$ yr^{-1}, while natural mortality rates (M), fishing mortality rate (F), total mortality (Z) and Exploitation rate (E) estimated were 1.34, 0.95, 2.29 and 0.41 respectively. The maximum allowable limit of exploitation (E_{max}) was estimated to be 0.56. The sizes attained by cobia at the end of age 1 (year) was 99.28 cm. The estimation of fork length at first maturity (L_{mat}) from the plot of gonadosomatic index (GSI) against fork length (FL) indicated early maturation of males compared to females with respective value of 70 cm and 72 cm. Males with mature gonads were encountered throughout the year, while the proportion of mature females was higher in March and November, and this may be taken as the peak of the spawning period, even though

females with hydrated oocyte were also obtained in April, May, June, July and September. The mean batch fecundity (BF) for all matured females with hydrated oocytes was ranged from 54886 to 4316648, (11,37,317 ± 183712) while average eggs per gram of ovary were ranged from 2108 to 5413 (3427.032 ± 128.73) . Weak positive correlation (r^2 = 0.48) was found between the BF and female fork length with equation BF = 38732.03FL-2200000. Similarly, BF was significantly correlated with ovary-free body weight (r^2 = 0.56). Histological data support continuous spawning characteristics of cobia as oocyte size frequency distribution showed progressive batch development. Increase in GSI was observed from September to November and it reached the peak in March which corresponds to the period when the highest proportion of matured females was caught. Study on the stomach content of the cobia, *R. canadum* in Dungun coast, showed that the bony fish was the dominant group in the diet with crustacean and mollusc contributing less. The percentage index of relative important (% IRI) values of fish, crustacean and mollusc were 72.27%, 2.98% and 24.75% respectively. Out of the 231 cobia specimens examined in this study, 111 were found to contain food in their stomach, out of which 98 had at least one identifiable prey items. Gut content analysis revealed that fish was consumed by cobia all the year round with *Hilsa* sp., *Alepes* sp. and *Carangides* sp. being the frequently encountered species. Higher stomach fullness index (SFI) was recorded in the month of April, June and November with values of 2.88, 2.06 and 2.42 respectively while lower SFI was in the month of May and August with values of 0.67 and 0.86 respectively. The percentage of empty coefficient (EC) was higher in October, August and July with values of 80%, 70% and 69% respectively, intermediate in the remaining month as values were about 50%. This stomach fullness index SFI and EC suggest moderate feeding intensity of cobia in the waters of Dungun. The proximate and chemical composition of cobia species from Dungun and its seasonal changes was examined. The result showed that lipids content was significantly ($p < 0.05$) higher in females (6.38 ± 0.19) than males (5.44 ± 0.11). No significant ($p < 0.05$) difference was found in the moisture, ash, total cholesterol and malondialdehyde (MDA) based on season, sex and feeding regime. In the fatty acid (FA) composition of the muscle tissue, the unsaturated class was dominant followed by saturated FA followed by the monoenes. Similar trend was found in the liver. Total n-3 poly-unsaturated fatty acid (PUFA) was higher compared to the total PUFA (n-6) in the muscle, and the total PUFA (n-6) was significantly ($p < 0.05$) higher in the muscle during the monsoon. Other FA classes that showed significant ($p < 0.05$) seasonal differences in the muscle were pentadecanoic acid, palmitoleic acid and linoleic acid. However, in the liver, the total saturated, total monones, total PUFA (n-6) and total PUFA (n-3) showed significant ($p < 0.05$) seasonal variation. The FA composition of males and females cobia did not show significant ($p < 0.05$) differences. During starvation in cobia, a significant reduction in total PUFA n-6, pentadeconoic acid, and palmitoleic acid was observed in the muscle. The result of this work suggests adult cobia in Malaysia preferred bony fishes as food while it reproductive period was continuous and cobia lipid profiles contained appreciable quantity of PUFA such as docosahexaenoic, eicosapentaenoic and arachidonic acids and it can be promoted for human consumption.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Doktor Falsafah

PENCIRIAN BIOLOGI IKAN HARUAN TASEK LIAR, *Rachycentron canadum*(LINNAEUS, 1766) DI PANTAI DUNGUN, TERENGGANU, MALAYSIA UNTUK PENGURUSAN STOK DAN AKUAKULTUR

Oleh

BABATUNDE TAOFIK ADEMOLA

Ogos 2016

Pengerusi : Prof. Madya S. M. Nurul Amin, PhD
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Kajian aspek-aspek biologi bagi ikan yang penting secara komersial dan rekreasi, *Rachycentron canadum* di Dungun, Malaysia telah dijalankan di antara April 2014 dan Mei 2015. Sejumlah 249 spesimen telah dikumpul secara rawak dari tangkapan pukat tunda, pukat hanyut dan tangkapan kail dan pancing. Jumlah panjang adalah dari 39.20 hingga 143.00 cm (88.29 ± 1.28 cm, min ± SE), panjang badan adalah dari 37.50 hingga 124.00 cm (78.69 ± 1.09 cm, min ± SE) manakala berat basah adalah dari 0.50 hingga 20.40 kg (5.51 ± 0.26 kg, min ± SE). Tiada perbezaan ketara pada semua karekter-karekter mofometrik di antara jantina kecuali pada lebar kepala (HW) ($p < 0.05$). Sepuluh (10) daripada tujuh belas (17) jarak truss pada bahagian badan haruan tasik telah menunjukkan perbezaan ketara di antara jantan dan betina. Persamaan panjang-berat (LW) bagi kedua-dua jantina adalah $W = 0.000002FL^{3.3204}$, $R^2 = 0.92$ manakala "b" pada eksponen ini menunjukkan pertumbuhan haruan tasik di perairan Dungun bersifat alometrik positif. Kekerapan panjang bagi kedua-dua jantina telah diperhatikan diikuti dengan corak taburan normal dan terdapat banyak haruan tasik pada saiz sederhana di antara 65 - 85 cm panjang badan bagi betina dan 55 - 90 cm bagi jantan. Nisbah jantina bagi betina dengan jantan adalah 1:1.18 dan ini tidak menunjukkan perbezaan ketara dengan nilai jangkaan 1:1 ($X2 = 2.12$ df = 1; $p = 0.145$). Parameter pertumbuhan formula pertumbuhan von Bertalanffy untuk Ikan Aruan Tasek dianggarkan sebagai $L_\infty = 142.00$ cm, $K = 1.20$ thn^{-1}, manakala kadar semula jadi kematian (M), kadar memancing kematian (F), jumlah kematian (Z) dan kadar eksploitasi (E) dianggarkan adalah 1.34, 0.95, 2.29 dan 0.41 masing-masing. Had maksimum yang dibenarkan eksploitasi (Emax) dianggarkan 0.56. Saiz yang dicapai oleh Ikan Aruan Tasek di akhir zaman 1 (tahun) adalah 99,28 cm.Anggaran panjang badan pada kematangan pertama (Lmat) dari plot indeks gonadosomatik (GSI) berlawanan panjang badan (FL) menganggarkan kematangan awal pada jantan berbanding betina dengan nilaian sebanyak 70 cm dan 72 cm. Ikan jantan dengan gonad yang matang telah ditemui sepanjang tahun, manakala nisbah ikan betina yang matang adalah lebih tinggi pada Mac dan November dan ini boleh

diambil kira kerana puncak tempoh pembiakan, walaupun ikan betina dengan oosit terhidrat juga telah didapati pada April, Mei, Jun, Julai dan September. Min kumpulan fekunditi (BF) untuk semua ikan betina yang telah matang dengan oosit yang terhidrat adalah dari 54886 hingga 4316648, (11,37,317 ± 183712, min ± SE) manakala purata telur per gram dari ovary adalah dari 2108 hingga 5413 (3427.032 ± 128.73, min ± SE) . Korelasi positif yang lemah (r^2 =0.48) telah ditemui di antara kumpulan fekunditi (BF) dan panjang badan betina dengan persamaan BF= 38732.03FL - 2200000. Secara kebetulan, BF adalah berkolerasi ketara dengan ovary-berat badan bebas (r^2= 0.56). Data histologi menyokong pembiakan berterusan haruan tasik kerana kekerapan taburan saiz oosit telah menunjukkan perkembangan kumpulan yang menggalakkan. Pertambahan GSI telah diperhatikan dari September hingga November dan ia mencapai puncak pada Mac yang berkait dengan tempoh semasa nisbah tertinggi ikan betina yang telah matang ditangkap. Kajian berkenaan kandungan perut haruan tasik, Rachycentron canadum di pantai Dungun, Malaysia telah menunjukkan bahawa ikan bertulang adalah kumpulan dominan di dalam diet dengan krustasia dan molusk kurang menyumbang dan peratus indeks kepentingan relatif mereka (% IRI) bernilai 72.27, 2.98 dan 24.75 secara berturutan. Daripada 231 spesimen haruan tasik yang telah diperiksa di dalam kajian ini, 111 telah didapati mempunyai makanan di dalam perut mereka, dengan 98 daripada mereka sekurang-kurangnya mempunyai satu barangan mangsa yang boleh dikenal pasti. Analisis kandungan perut telah mendedahkan bahawa ikan yang telah dimakan oleh haruan tasik pada sepanjang tahun dengan *Hilsa* spp, *Alepes* spp dan Carangids spp paling banyak dijumpai. Indeks kepenuhan perut (SFI) yang lebih tinggi telah direkodkan pada bulan April, Jun dan November dengan nilai-nilai 2.88, 2.06 dan 2.42 secara berturutan manakala SFI yang lebih rendah adalah pada bulan Mei dan Ogos dengan nilai-nilai 0.67 dan 0.86 secara berturutan. Peratusan koefisien kosong (EC) adalah lebih tinggi pada Oktober, Ogos dan Julai dengan nilai-nilai 80%, 70% dan 69% secara berturutan, berkedudukan tengah pada bulan yang selebihnya dengan nilai kira-kira 50%. Indeks kepenuhan perut SFI dan EC mencadangkan kekerapan makan yang sederhana bagi haruan tasik di perairan Dungun. Komposisi proksimat and kimia bagi spesies haruan tasik dari Dungun, Malaysia dan perubahan-perubahan musimnya telah diperiksa. Keputusan telah menunjukkan kandungan lipid adalah ketara ($p < 0.05$) lebih tinggi pada ikan betina (6.38 ± 0.19) daripada ikan jantan (5.44 ± 0.11). Tiada perbezaan ketara ($p < 0.05$) telah ditemui pada kelembapan, abu, jumlah kolestrol dan malondialdehyde (MDA) berdasarkan musim, jantina dan regim pemakanan. Dalam komposisi asid lemak (FA) bagi tisu otot, kelas tidak tidak tepu adalah dominan diikuti dengan FA tepu dan kemudian monoenes. Perkara sama juga telah ditemui pada hati. Jumlah n-3 asid lemak poli – tak tepu (PUFA) adalah lebih tinggi berbanding dengan jumlah PUFA (n-6) di dalam otot, dan jumlah PUFA (n-6) adalah lebih tinggi ($p < 0.05$) di dalam otot pada musim hujan. Kelas-kelas FA lain telah menunjukkan perbezaan musim yang ketara ($p < 0.05$) pada otot adalah asid pentadecanoic, asid palmitoleic dan asid linoleic. Walau bagaimanapun, di dalam hati, jumalah tepu, jumlah monones, jumlah PUFA (n-6) dan jumlah PUFA (n-3) telah menunjukkan variasi musim yang ketara ($p < 0.05$). Walau Bagaimana pun, komposisi FA bagi ikan jantan dan ikan betina tidak menunjukkan perbezaan yang ketara ($p < 0.05$). Ketika haruan tasik berada dalam keadaan kelaparan, pengurangan ketara dalam jumlah PUFA n-6, asid pentadeconoic dan asid palmitoleic telah dijumpai pada otot. Keputusan kajian ini mencadangkan haruan tasik dewasa di Malaysia memilih ikan bertulang sebagai makanan manakala tempoh pembiakan adalah berterusan dan lipid haruan tasik mengandungi kuantiti PUFA yang penting

seperti asid docosahexaenoic, eicosapentaenoic dan arachidonic dan ia boleh digunakan untuk makanan manusia.

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Finally, may Allah be praised, through His mercy all good is accomplished.

I certify that a Thesis Examination Committee has met on 4 August 2016 to conduct the final examination of Babatunde Taofik Ademola on his thesis entitled "Biological Characterization of Wild Cobia, *Rachycentron canadum* (Linnaeus, 1766) off Dungun Coast, Terengganu, Malaysia for Stock Management and Aquaculture" in accordance with the Universities and University Colleges Act 1971 and the Constitution of the Universiti Putra Malaysia [P.U.(A) 106] 15 March 1998. The Committee recommends that the student be awarded the Doctor of Philosophy.

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Declaration by graduate student

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BF	Batch Fecundity
DoF	Department of Fisheries
dph	Days Post Hatch
E	Exploitation rate
EC	Empty Coefficient
EEZs	Exclusive Economic Zones
ELEFAN	Electronic Length Frequency Analysis
E_{max}	Maximum allowable limit of exploitation
FAO	Food and Agricultural Organization
FCR	Feed Conversion Ratio
FiSAT	FAO ICLARM Stock Assessment Tools
GSI	Gonadosomatic Index
IRI	Index of Relative Importance
K	Fulton Condition Factor (K)
K	Growth co-efficient of VBGF
$L\infty$	Asymptotic length
L_{mat}	Length at Maturity
L_{max}	Predicted extreme length
M	Natural mortality
MSY	Maximum Sustainable Yield
SFI	Stomach Fullness Index
VSI	Viscerosomatic Index

CHAPTER 1

INTRODUCTION

1.1 Background of the study

Fish population is a renewable natural resource if exploited in a sustainable way. Hence, fishery represents an important source of revenue to the economy of many countries and an important food sector for humans (Dwivedi *et al*., 2009). It is an important food resource for humans, accounting for about 15.7 % of the global animal protein consumption (FAO, 2010). Increasing trends of human activities, overfishing, fish habitat destruction, habitat fragmentation and pollution have been identified as threats to aquatic biodiversity. Fish population are been subjected to natural control processes that constantly modify the structure and abundance of their population in various life cycle stages in response to these factors (Milner *et al*., 2003).

Cobia is the only species of the family Rachycentridae. They are migratory warm water species widely distributed in subtropical, tropical and temperate marine waters except in the eastern Pacific (Briggs, 1960). They migrate to deeper water in fall and winter (Shaffer and Nakamura, 1989). Cobia is a non-target species in capture fisheries as most cobia landings were from recreational fishing. This may be due to the fact that adult cobia is solitary. Cobia constitutes 0.1% of landing between 2007 and 2010 in Karnakata coast, India (Rohit and Bhat, 2012). Similarly, in Malaysia, cobia accounts for 0.1% the total landings in 2014 (DoF, 2014). Countries where cobia fishing is high exceeding 1000 metric tons per annum include Malaysia, Brazil, Iran, Philippines and Pakistan (FAO, 2009). Cobia is found associated with a wide range of habitat including rock, mud, sand and gravel bottom as well as buoying objects. This benthopelagic nature may have enhanced nonselective carnivorous feeding behavior reported for cobia, exploring prey from water column, benthic and open water (Meyer and Franks, 1996; Smith, 1995; Rohit and Bhat, 2012). They also establish commensal relationship with rays (Smith and Merriner, 1982). However, various feeding studies reveal geographic difference in the diet of cobia and their spawning grounds are areas of abundant prey (Richards, 1967; Lefebvre and Denson, 2012). Currently, there is no published information on the diet composition of cobia in Malaysian waters. Cobia exhibit extended batch spawning and peak spawning seasons vary with geographical locations. Their spawning behaviour in Malaysia has not been reported.

The first attempt to culture cobia using naturally spawned eggs collected from the wild was carried out by Hassler and Rainville (1975) and held in captivity for 131 days. The performance of cobia observed in the rearing trial in terms of hatching rate, growth rate, readiness to except supplemented feed and hardiness indicated that cobia has potential for culture. Collection of wild larvae could not be utilized for commercial production due to limited and inconsistency in the availability; hence there is a need to adapt cobia to captive spawning. Biological characteristics of cobia

has make it reputed for mariculture, like high growth rate (K) = 2.6 (kg/yr^{-1}) in the wild (Ganga *et al.*, 2012), 6kg in 1 year in captivity (Chou *et al.*, 2001), and high fecundity up to 2.88×10^6 (van der Velde *et al.*, 2010). It also possess a good flesh quality, diseases resistant and value of feed conversion ratio (FCR) which is a measure of the ratio between feed input and output of 1.05 has been reported for cobia in juvenile stage (Resley *et al*., 2006) and FCR of 2.0 in adult (Benetti *et al*., 2008a). Adaptability for captivity breeding and high market demand especially in Europe has been attributed to cobia (Gopakumar *et al*., 2011; Benetti *et al.,* 2010). In addition to this, cobia has nutritional biochemical compounds in a balanced composition, essential amino acids, polyunsaturated fatty acids, fat content and microelements in a good proportion (Liu *et al*., 2009). Therefore, consumption of cobia fish may be a good complimentary in human diet. Production of cobia increased 7000 folds from 1995 to 2005, estimated global production in 2007 was 30,000 tonnes while in 2012 it was estimated to be 41000 tonnes valued US$71 million (FAO, 2012). In Malaysia, aquaculture of cobia remains undeveloped.

As cobia gaining more acceptances for aquaculture, it potential remains unexploited in Malaysia. At present, there is lack of information on stock assessment, morphomemtric features, feeding ecology and reproductive biology of wild cobia of Malaysia waters. This information is necessary for the development of indigenous broodstocks and for management purposes.

1.2 Statement of problem

Although cobia is an important component in the landing statistic in Malaysia, there is lack of published information on basic biological aspects like morphometry, reproductive cycle, sex ratio, fecundity, food habits and nutritional values. Cobia culture is still underdeveloped in Malaysia. Its market value as a food fish as been identified in Europe, China, and Taiwan, where its aquaculture production is on the increase. The understanding of biology, ecology and nutritional quality of the Malaysian stock will be a prerequisite for the broodstock development and its aquaculture development. Till date, assessment of food habit, reproductive biology, population structure and nutritional chemical composition of cobia population is Malaysia has not been documented. Even though the capture of cobia was high in Malaysia, study of the population dynamic and stock assessment has not been carried out. This is necessary to avoid overfishing. Current research therefore focuses on some biological aspects and chemical composition cobia in Peninsular Malaysia. This information is essential for sustainable management and proper utilization of wild cobia, and possibly recommending it for aquaculture in Malaysia.

1.3 Research hypothesis

The hypotheses of this research are:

i) Morphology and condition indices of cobia is influenced by habitat water quality parameters and food preference, hence examination of morphometric parameter and condition factors would reflect habitat differences.
ii) As the capture of cobia is high in Malaysia, there is possibility of overfishing and overexploitation.
iii) Gonad development, spawning, and fecundity of cobia in Dungun coast, Malaysia are attuned with geographical location and environment. It is assumed that spawning season would be different in from other locations.
iv) The food preference of cobia in Malaysia would be different from other locations due to differences in the population assemblage and species coexistence.
v) *R. canadum* is a top carnivore by nature and it will have numbers of essential fatty acids that will make it a good choice of food fish.

1.4 Objectives of the research

The specific objectives of this research are:

i) To document the morphometric characteristics, of Wild cobia population off Dungun coastal waters of Terengganu, Malaysia using traditional and truss morphometric methods.
ii) To study the population dynamics and stock assessment of *R. canadum* in coaster water of Dungun.
iii) To determine the reproductive cycle, spawning season, sex ratio and fecundity of *R. canadum* in Dungun coast and its correlation with its feeding pattern.
iv) To investigate the food and feeding habits of cobia and seasonal changes in diet composition.
v) To determine the nutritional properties of wild cobia in Dungun coast, Malaysia.

1.5 Organization of the study

This thesis is subdivided into seven chapters:

i) Chapter one: This chapter gives an overview of cobia capture and its status in Malaysia, the problem statement, significance of the study and objectives.
ii) Chapter two: This contains a review of literature on cobia fisheries and aquaculture, population biology, feeding habits, population parameter and

genetics. This chapter provides a background for formulation of hypothesis, understanding research problems and adopting appropriate methodologies to accomplish the study objectives of this research.

iii) Chapter three: This chapter present a brief overview of general research methodology used to accomplish the objectives of this research including the statistical analysis.

iv) Chapter four: In this chapter, a detail of the first objective of this research was presented. Information on the morphometric characteristics determined by traditional and truss analysis of *Rachycentron canadum* in Dungun, Malaysia were provided therein.

v) Chapter five: Herein, information on the population dynamics and key stock parameters was given. Population structure and length–weight relationship of cobia was also reported.

vi) Chapter six: This chapter was based on the third objective. Findings on the reproductive cycle, spawning season, sex ratio and fecundity of *Rachycentron canadum* in Peninsular Malaysia were presented.

vii) Chapter seven: Investigation on the food habits of cobia, *Rachycentron canadum and* seasonal changes in feeding pattern as contained in the third objective.

viii) Chapter eight: Nutrition composition of cobia and its suitability as human food supplement was reported.

ix) Chapter nine: This was the final chapter and it represents the summary, conclusions and recommendations for future research.

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