COBIA (Rachycentron canadum)

A SELECTED ANNOTATED BIBLIOGRAPHY ON AQUACULTURE, GENERAL BIOLOGY & FISHERIES

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compiled by

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for

The CNPq Research Project

Feeding Tomorrow’s Fish:
Environmental and Economically Sustainable Aquafeeds and Feeding Regimes for Marine Aquaculture

AquaMar

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BACKGROUND & PREPARATION OF THIS DOCUMENT

The present document contains a comprehensive list of publications dealing with cobia (*Rachycentron canadum*) aquaculture, general biology and fisheries, and was prepared using Aquatic Science and Fisheries Abstracts (ASFA) and other online electronic databases.

The work was conducted with the support of The Brazilian National Council for the Development of Science and Technology (CNPq), and prepared as part of the activities of the AquaMar Research Project “Feeding Tomorrow’s Fish: Environmental and Sustainable Aquaculture Feeds and Feeding Regimes for Marine Farming”. The project is funded by the CNPq’s under “Science without Borders – Special Visiting Researcher” programme. It mainly focuses on practical and more urgent subjects in feeding and nutrition of farmed marine fish and shrimp, for the potential benefit of Brazilian farmers. The literature review is part of the research programme that is carried out by the AquaMar research team. The programme also includes technical visits to local farmers, feed manufacturers, laboratory and field experiments with target species.

ANTECEDENTES E PREPARAÇÃO DESTE TRABALHO

Esta revisão contém uma ampla lista de publicações sobre a aquicultura, biologia geral e pesca do Bijupirá (*Rachycentron canadum*) e foi preparada utilizando bases de dados como Aquatic Science and Fisheries Abstracts (ASFA) dentre outras.

O trabalho foi conduzido com apoio do CNPq, Conselho Nacional de Desenvolvimento Científico e Tecnológico, como parte das atividades do Projeto de Pesquisa AquaMar “Alimentando o peixe de amanhã: ração e regímen alimentares ambiental e economicamente sustentáveis para a produção de aquicultura marinha”. O projeto é financiado pelo CNPq dentro do Programa Ciência sem Fronteiras – modalidade Pesquisador Visitante Especial. O foco principal está em atender as questões práticas mais urgentes sobre alimentação e nutrição de peixes e camarões marinhos cultivados, em benefício dos aquicultores brasileiros. A revisão da literatura é parte deste programa de pesquisa que é conduzido pela equipe de pesquisa AquaMar. O programa também inclui visitas técnicas aos criadores e experimentos em campo e laboratório com as espécies alvo.

FOR BIBLIOGRAPHIC CITATION

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1. **GENERAL BIOLOGY & FISHERIES**


   Genetic divergence within and between wild populations of cobia, *Rachycentron canadum* (L.) was assessed by means of microsatellite analysis in the Persian Gulf and Oman Sea. Ten microsatellite markers were used to estimate the level of genetic diversity within six wild populations of cobia and the degree of genetic differentiation between them was compared. Mean observed and effective allele number was 12.357 and 8.319, respectively. Mean observed and expected heterozygosity was 0.655 and 0.874, respectively. Based on Analysis of Molecular Variance highest F-statistics (0.063) was observed when comparing specimens from Dayer Port zone and Pozm of Chabahar zone. Highest genetic distance (0.258) and lowest genetic resemblance (0.223) were observed between specimens from Dayer Port zone and Beds of Chabahar zone. The present study showed that at least three different populations of *Rachycentron canadum* were found in the northern coasts of Persian Gulf and Oman Sea.


   Cobia (*Rachycentron canadum*) is a migratory pelagic species that is found in tropical and subtropical seas of the world, except in the central and eastern Pacific Ocean. In the western Atlantic Ocean, cobia migrate to Chesapeake Bay in spring and summer to spawn, and the productive waters of the Bay are believed to constitute important foraging grounds. Cobia are known to move to areas of high food abundance, particularly crustacean abundance. Although Chesapeake Bay is an important destination for migrating cobia, feeding habits of cobia in the Bay have never been thoroughly examined. Our study documents cobia feeding habits in Chesapeake Bay between June and July 1997 and compares findings with similar cobia studies from North Carolina and the northern Gulf of Mexico.


   Resistance of juvenile cobia, *Rachycentron canadum*, to low salinity, low temperature and high nitrite concentrations were examined under laboratory conditions. After acclimating juveniles to a salinity of 20 g/L (27.3 °C), salinity was decreased by 2 g/L/day. The first fish died at a salinity of 8 g/L and 80% of fish were dead within 24 hours of exposure to 2 g/L. Acclimation of fish to 22.6 °C (21 g/L salinity) followed by a temperature reduction of 0.53 °C/day resulted in initial mortality at 12.9 °C. The median-lethal temperature was 12.1 °C and all fish were dead by the time the temperature reached 10.4 °C. Fish exposed for 96 hours to nominal less than or equal to 32 mg/L nitrite-N survived. Results of this study indicate that cobia juveniles require a salinity and temperature of > 8.0 g/L and > 12.9 °C, respectively, and that environmental nitrite should not be deleterious at concentrations normally found in aquaculture systems.


   Juvenile cobia (*Rachycentron canadum*) (total length 15.± 0.92 cm and weight 19.26 ± 4.5 g) were exposed to different concentrations of ammonia-N (unionized plus ionized ammonia as nitrogen), using the static renewal method at different salinity levels of 5, 20, and 35ppt at pH 8.1 and 25 °C. The 24, 48, 72, 96 h LC₅₀ values of ammonia-N for *R. canadum* juveniles were 60.28, 48.57, 37.42, 22.73 mg l⁻¹ at 35‰; 51.25, 43.63, 28.17, 19.05 mg l⁻¹ at 20‰; and 39.48, 25.31, 19.50, 8.13 mg l⁻¹ at 5‰, respectively. The 24, 48, 72, 96 h LC₅₀ values of NH₃-N (unionized ammonia as nitrogen) were 1.81, 1.46, 1.12, and 0.68 mg l⁻¹ at 35‰; 1.75, 1.49, 0.96, and 0.65 mg l⁻¹ at 20‰; and 1.52, 0.97, 0.71, and 0.31 mg l⁻¹ at 5‰, respectively. As the salinity decreased from 35 to 5‰, susceptibility of ammonia-N increased by 34.5, 47.88, 50.56, and 64.23% after 24, 48, 72, and 96 h exposure, respectively. Furthermore, we found that exposure of fish to ammonia-N caused an increase in oxygen consumption of 129.1, 157.5, and 192% and a decrease in the ammonia excretion level of 53.4, 38.2, and 23.3% with respect to the control.

Female cobia, *Rachycentron canadum*, were sampled on their spawning grounds in the northern Gulf of Mexico to study changes in proximate analysis (protein, lipid, carbohydrate, and ash) of the ovaries during gonadal maturation. Four major stages of oocyte development were studied: stage 1, previtellogenesis; stage 2, vitellogenesis; stage 3, final maturation; and stage 4, postovulation. Cobia is a multiple spawning fish; therefore, ovaries engaged in a sequential round of oogenesis were distinguished as stages 1’ and 2’. Protein was the major constituent of cobia ovaries and its contribution remained fairly constant (49-55% of the dry weight) throughout all stages of development. Lipid was the second most abundant component but the levels, ranging from 21 to 41%, changed depending on the stage of ovarian development. Lipid concentration increased from stage 1 through 3 and decreased slightly in stage 4; it was lower in stage-1 than in stage-1’ ovaries but was the same in stages 2 and 2’. Carbohydrate was the least abundant component (3-4%) whereas ash ranked third (6-20%). Most cobia were in prespawning condition (stages 1-3) when they arrived in the northern Gulf of Mexico in April and May; some prespawning fish (stages 1 and 2) were also observed in August and September about a month or two before migration to the overwintering grounds normally occurs. Cobia undergoing sequential spawning episodes (stages 1’ and 2’) were captured from April through August. Gonosomatic indices (GSI) were calculated both for ovarian developmental stage and for month of capture. Mean GSI increased as ovarian development proceeded and decreased during postovulation; GSI for month of capture was highest during April and May when the prespawning fish first appeared in northern Gulf of Mexico waters.


Currently, ocean acidification is occurring at a faster rate than at any time in the last 300 million years, posing an ecological challenge to marine organisms globally. There is a critical need to understand the effects of acidification on the vulnerable larval stages of marine fishes, as there is potential for large ecological and economic impacts on fish populations and the human economies that rely on them. We expand upon the narrow taxonomic scope found in the literature today, which overlooks many life history characteristics of harvested species, by reporting on the larvae of *Rachycentron canadum* (cobia), a large, highly mobile, pelagic-spawning, widely distributed species with a life history and fishery value contrasting other species studied to date. We raised larval cobia through the first 3 weeks of ontogeny under conditions of predicted future ocean acidification to determine effects on somatic growth, development, otolith formation, swimming ability, and swimming activity. Cobia exhibited resistance to treatment effects on growth, development, swimming ability, and swimming activity at 800 and 2100 µatm pCO2. However, these scenarios resulted in a significant increase in otolith size (up to 25% larger area) at the lowest pCO2 levels reported to date, as well as the first report of significantly wider daily otolith growth increments. When raised under more extreme scenarios of 3500 and 5400 µatm pCO2, cobia exhibited significantly reduced size-at-age (up to 25% smaller) and a 2-3 days developmental delay. The robust nature of cobia may be due to the naturally variable environmental conditions this species currently encounters throughout ontogeny in coastal environments, which may lead to an increased acclimatization ability even during long-term exposure to stressors.


Five reproductive classes of cobia *Rachycentron canadum*, caught along the Gulf of Mexico and the southeast Atlantic coast of the U.S.A., are described during the annual reproductive cycle. These are based upon changes in the testicular germinal epithelium and the stages of germ cells that are present: early maturation, mid maturation, late maturation, regression and regressed. During early maturation, the germinal epithelium is continuous from the testicular ducts to the periphery of the testis and active spermatogenesis occurs throughout the testis. In mid maturation, the germinal epithelium near the ducts becomes discontinuous, but it remains continuous distally. In late maturation, a discontinuous germinal epithelium extends all along the lobules to the testicular periphery; lobules are swollen with sperm and there is minimal spermatogenesis. The regression class is characterized by a discontinuous epithelium throughout the testis, sperm storage and widely scattered spermatocysts. Spermatogonial proliferation also occurs along the lobule walls and at the periphery of the testes. In regressed testes, spermatogonia exist only in a continuous or
discontinuous germinal epithelium, although residual sperm are nearly always present in the lobules and ducts. The presence or absence of sperm is not an accurate indicator of reproductive classes. At the periphery of the testis in the regression and regressed classes, the distal portions of lobules elongate as cords of cells containing spermatogonia and Sertoli cells. All reproductive classes can be identified in paraffin sections, although plastic sections provide better resolution. Using maturation classes defined by changes in the germinal epithelium to describe testicular development and spermatogenesis gives a more accurate picture than does using the traditional terminology.


Reproductive biology of the cobia, *Rachycentron canadum*, is described from four coastal areas in the southern United States. Samples were obtained from recreational fishermen between December 1995 and November 1997 from the southeastern United States (Morehead City, NC, to Cape Canaveral, FL), the eastern Gulf of Mexico (Ft. Myers to Crystal River, FL), the north-central Gulf of Mexico (Destin, FL, to Chandeleur Islands, LA) and the western Gulf of Mexico (Port Aransas, TX). Histological evidence of spawning occurred from April through September in all areas. Some female cobia (17-32%) throughout the Gulf of Mexico had spent or regressed ovaries by July. Gonadosomatic index peaked between May and July throughout the region. Ovaries of females from all areas contained both postovulatory follicles (POF) and oocytes in final oocyte maturation (FOM) during all months of the reproductive season. Batch fecundity was calculated by using three different methods: oocytes >700 µm were fixed in 1) Gilson’s fixative or 2) 10% neutral buffered formalin (NBF), and 3) oocytes undergoing FOM were sectioned for histological examination. Mean batch fecundity ranged from 377,000 ± 64,500 to 1,980,500 ± 1,598,500 eggs; there was no significant difference among methods. Batch fecundity calculated with the NBF method showed a positive relationship with fork length (P=0.021, r²=0.132) and ovary-free body weight (OFBW; P=0.016, r²=0.143). Relative batch fecundity was not significantly different among months during the spawning season and averaged 53.1 ± 9.4 eggs/g OFBW for the NBF method and 29.1 ± 4.8 eggs/g OFBW for the FOM method. Although spawning frequencies were not significantly different among areas (P=0.07), cobia from the southeastern United States and north-central Gulf of Mexico were estimated to spawn once every 5 days, whereas cobia from the western Gulf of Mexico were estimated to spawn once every 9 to 12 days.


Juvenile cobias *Rachycentron canadum* were exposed to decreasing salinity (~1% per day) in a series of five experiments to assess their low-salinity resistance. All fish survived for 24 h at a salinity of 2‰, but 73% died within 24 h of a reduction to 1% salinity. Plasma osmolality decreased significantly with decreasing salinity. Fish held for 7 d at 2, 5, or 8‰ after an approximately 1% daily reduction differed significantly in plasma osmolality; fish held at a salinity of 2‰ exhibited significantly lower plasma osmolality than fish in the other treatments. Doubling the environmental Ca concentration did not affect plasma osmolality. The results indicate that cobias have limited euryhaline abilities but not enough to sustain low-salinity culture operations.


Total mercury (Hg) concentrations were determined in the tissues of 11 species of pelagic fishes, with a special emphasis on apex predators (large vertebrates). Highest mercury concentrations were observed in blue marlin (*Makaira nigricans*), Carcharhinid sharks (genus *Carcharhinus*) and little tunny (*Euthynnus alletteratus*), ranging from 1.0 to 10.6 ppm. Moderate to low concentration (< 1.0 ppm) were observed in greater amberjack (*Seriola dumerilii*), blackfin tuna (*Thunnus atlanticus*), cobia (*Rachycentron canadum*), king mackerel (*Scomberomorus cavalla*), little tunny (*Euthynnus alletteratus*), wahoo (*Acanthocybium solandri*), yellowfin tuna (*Thunnus albacares*) and dolphinfish (*Coryphaena hippurus*). For the majority of species examined, contaminant loads of mercury did not vary significantly between two consecutive years (2002 and 2003) and between two adjacent locations (Texas and Louisiana). The relationship between Hg concentration and fish size was also explored in certain species. Several species showed a positive relationship between mercury level and body size. Natural dietary tracer, stable isotopes of nitrogen also showed that Hg levels in fish tissues were positively associated with trophic position. Our findings in this study not only added to
the information on mercury contamination in pelagic fish, but also furthered our understanding on mercury accumulation in these fish.


Total mercury (Hg) concentration was determined in the tissues of 10 pelagic fishes in the northern Gulf of Mexico, and dietary tracers (stable isotopes and fatty acids) were used to evaluate the relationship between Hg and feeding history. Highest Hg levels were observed in blue marlin (Makaira nigricans), cararcharinid sharks (Carcharhinus spp.), and little tunny (Euthynus alletteratus), ranging from 1.08 to 10.52 ppm. Moderate to low concentrations (<1.0 ppm) were observed in blackfin tuna (Thunnus atlanticus), cobia (Rachycentron canadum), dolphinfish ( Coryphaena hippurus), greater amberjack (Seriola dumerili), king mackerel (Scomberomorus cavalla), wahoo (Acanthocybium solandri), and yellowfin tuna (Thunnus albacares). For the majority of species examined, Hg concentrations did not vary significantly between location (Texas vs. Louisiana) or collection period (2002 and 2003). Significant positive relationships between Hg concentration and body size and (or) weight were detected for 6 of the 10 taxa examined. Hg concentration was also positively associated with trophic position. Three natural associations were identified using stable isotope and fatty acid signatures. Still, no connection between these natural trophic associations and Hg concentration was observed, suggesting that Hg concentration in pelagic fishes was more closely linked to trophic position and size than feeding history.


Cobia (Rachycentron canadum) is a promising candidate species for aquaculture. In order to evaluate potential problems resulting from husbandry practices, we conducted a study aimed to characterize their hematological response to acute stress. Levels of cortisol, glucose, lysozyme and ceruloplasmin were measured at five time intervals over 24 h following stress induction and compared to baseline levels. In this species stress had a rapid and short-term effect on cortisol and a fast but extended impact on glucose concentrations. We observed a short suppressive effect of stress on lysozyme activity, and late but continuous increase in ceruloplasmin throughout the study. This is the first report on baseline and stress response levels of these parameters in cobia, providing an indication of times for the examination of various indicators of stress.


Cage-farmed cobia (Rachycentron canadum) juvenile is susceptible to Photobacterium damsela subsp. piscicida resulting in low survival rate. This study aims to realize the breeding habit of cobia reared from wild cobia juvenile caught by set net in Taitung area, as well as intending to evaluate growth performance and disease resistance of their progeny. Results showed that the natural spawning of cobia brooder reared from wild-caught cobia juvenile had not found in captivity. Fertilized eggs must be obtained from induced spawning. The growth rate of wild-caught cobia juvenile is much faster than inbred cobia. The disease resistance of their progeny is also markedly stronger than inbred cobia. This study proved that using the wild-caught cobia as brood fish is one of important strategy to improve the growth performance and disease resistance.


The effects of salinity on the growth and energy budget of juvenile cobia, Rachycentron canadum, were evaluated. Triplicate tanks with ten fish per tank (initial weight 17.58 ± 0.26 g/fish, mean ± SD) reared at salinities of 5, 10, 15, 20, 25, 30, and 35 ppt were fed with fresh squid to satiety for 15 d. Results indicated that there were no significant differences in daily ration level in wet weight (RL_w), dry weight (RL_d), and energy (RL_e) of the fish. There were also no significant variations in daily fecal production (f_e) and apparent digestibility coefficient of energy (ADC_e) among salinity treatments. Specific growth rates (SGR_w) in wet weight (SGR_w), dry weight (SGR_d), and energy (SGR_e) showed domed curves relative to salinity. Quadratic regression analyses of SGR_w, SGR_d, and SGR_e against salinity indicated that the optimal salinity for maximal growth of juvenile cobia was 29.9, 29.9, and 28.5 ppt, respectively. Similar to the trend of SGR, food conversion efficiency for juvenile cobia in wet weight (FCE_w), dry weight (FCE_d), and energy (FCE_e) increased with the increases in salinity, maximized at 30 ppt, and then decreased when salinity reached 35 ppt.

Cobia (*Rachycentron canadum*) is a pelagic, migratory species with a transoceanic distribution in tropical and subtropical waters. Recreational fishing pressure on Cobia in the United States has increased substantially during the last decade, especially in areas of its annual inshore aggregations, making this species potentially susceptible to overfishing. Although Cobia along the Atlantic and Gulf coasts of the southeastern United States are currently managed as a single fishery, the genetic composition of Cobias in these areas is unclear. On the basis of a robust microsatellite data set from collections along the U.S. Atlantic coast (2008-09), offshore groups were genetically homogenous. However, the 2 sampled inshore aggregations (South Carolina and Virginia) were genetically distinct from each other, as well as from the offshore group. The recapture of stocked fish within their release estuary 2 years after release indicates that some degree of estuarine fidelity occurs within these inshore aggregations and supports the detection of their unique genetic structure at the population level. These results complement the observed high site fidelity of Cobias in South Carolina and support a recent study that confirms that Cobia spawn in the inshore aggregations. Our increased understanding of Cobia life history will be beneficial for determining the appropriate scale of fishery management for Cobia.


General morphology and coloration of young cobia, 12.6-55.0 mm SL, are described and illustrated. Prejuveniles were taken in offshore Gulf of Mexico surface nekton collections during June and July. Smallest fish were found 30–40 miles offshore, whereas larger specimens, 45-140 mm SL, have been most frequently taken in inshore localities. June collections of prejuveniles suggest late April or May spawning in northern Gulf waters.


By the vertical polyacrylamide gel electrophoresis, five isozymes (LDH, MDH, ME, POD, EST) from several tissues (brain, heart, muscle, kidney, gonad, liver, blood, spleen, pancreas) of *Rachycentron canadum* were studied. The results showed that all isozymes presented tissue specificity. These specificities were related to their special physiological function. Compared with other teleosts, the isozymic phenotypes of *R. canadum* were much simple with, which may be related to its generic diversity.


Cobia *Rachycentron canadum* juveniles (119.7 mm TL, weight 8.5 g) were reared for 10 wk at three salinity levels: 5 ppt, 15 ppt, and 30 ppt. Growth and survival were determined through biweekly sampling. Blood samples obtained at termination of the study were analyzed to determine hematocrit, blood osmolality, and total protein. Results indicated that the overall growth of fish was significantly affected by salinity. Mean (± SE) total length (TL) and weight of fish reared at a salinity of 30 ppt were 201.7 ± 2.6 mm and 47.6 ± 1.9 g, respectively, followed by fish reared at 15 ppt (182.2 ± 1.7 mm, 34.1 ± 1.6 g), and 5 ppt (168.3 ± 5.8 mm TL, 28.3 ± 2.3 g). Differences in specific growth rates among treatments for the 10-wk period were also significant. No differences were detected in mean survival among fish reared at salinities of 5, 15, and 30 ppt (84, 94, and 94%, respectively). However, fish reared at salinity 5 ppt appeared to be in poor health as skin lesions, fin erosion, and discoloration were evident. Analysis of blood revealed that, while no differences existed among treatments with respect to plasma total protein, fish reared at a salinity of 5 ppt exhibited significantly reduced hematocrit (25% vs. > 30%) and plasma osmolality values (318 vs. > 353 mmol/kg) relative to fish reared at higher salinities. Cobia can tolerate exposure to low salinity environments for short periods of time without mortality; however, moderate to high salinities are required for sustained growth and health of this species.

Seafood containing heavy metals as a result of environmental contamination causes toxicity in human beings. To evaluate such kind of contamination, our study targeted the analysis of metals such as lead, copper, cadmium, mercury, and arsenic in muscle tissue of the fish. The fish commonly consumed such as Brama brama (Pomfret), Rachycentron canadum (Surmai/King Fish), Rastrelliger kanagurta (Mackerel), Eleutheronema tetradactylum (Ravas/Indian salmon), and Metapenaeus monoceros (Brown Prawn) were collected from four different docks in the city. The heavy metals in tissue samples of fish were estimated using voltammetric and cold vapor atomic absorption spectrophotometer. Heavy metal concentration in the tissues varied significantly depending upon the locations from where the fish were collected. Although the concentration of arsenic, copper, cadmium, and lead were in normal range, the concentration of mercury was found to exceed the daily permissible levels (1kg/g) as a food source for human consumption. We have analyzed heavy metals from different locations in Mumbai-Versova dock, Sassoon dock, Navi Mumbai dock, and Mazgaon dock.


The results of trolling line operations conducted for the first time in Goa waters by the Directorate of Fisheries, Panaji, during the yrs 1956-68 have been discussed. These operations, in later years, led to starting of a small commercial fishery. The trolling line catches are constituted by Scomberomorus commerson, Chorinemus lysan, Caranx sansan, Sphyraena sp, Chirocentrus dorab, Rachycentron canadus, Euthynnus affinis and Thynnus macropterus. The size groups, gonadal condition and food of Scomberomorus commerson and Chorinemus lysan which were the 2 main spp in the fishery have been described.


The family Rachycentridae, contains a single cosmopolitan species, Rachycentron canadum, found primarily in tropical and subtropical waters, except those of the eastern Pacific (Briggs 1960). Cobia are a highly prized recreational species that are also taken incidently in commercial fisheries. In the western Atlantic, cobia fish occurs from Massachusetts to Argentina but are most common along the U.S. Atlantic and Gulf coasts. Cobia are usually absent from northern Gulf of Mexico and temperate Atlantic waters along the U.S. coast during late fall and winter when they are found off the Florida Keys. Cobia migrates north along the Atlantic and Gulf coasts during spring, reappearing in the northern Gulf during March and April. Cobia is taken off Louisiana and Texas associated with oil and gas platforms or rafts of Sargassum.


Cobia (Rachycentron canadum) is a highly prized recreational species of worldwide distribution in tropical and subtropical seas, but the development, distribution, and ecology of its early life stages are poorly known. Eggs are spherical, average 1.24 mm in diameter, and have a single oil globule (mean diameter 0.45 mm). The perivitelline space is narrow and the embryo heavily pigmented. Eggs hatch in about 24 h at 29 ºC based on the relationship between egg diameter and water temperature to predict development time in other marine fishes. Larvae hatch at about 2.5 mmSL. Cobia spawns in both estuarine and shelf waters during the day, and eggs and larvae are usually collected in the upper meter of the water column. Larvae are recognized by the large supraorbital ridge with a single spine, laterally swollen pterotics, heavy body pigmentation, minute epithelial spicules covering the body integument, and a pair of moderate-to-large, simple spines on either side of the angle of the posterior preoperculum. Only 70 larvae < 20 mmSL were collected and identified from the Gulf of Mexico between 1967 and 1988; most occurred between June and September at surface temperatures greater than or equal to 25 ºC, salinities > 27 ppt, and within the 100 m depth contour. Similar patterns of head spination provide evidence of a sister-group relationship between cobia (Rachycentron canadum) and dolphinfish rather than that previously hypothesized between cobia and remoras.

The partial toxicity tests of copper (Cu\(^{2+}\)), zinc (Zn\(^{2+}\)) and cyanide (CN\(^{-}\)) for young cobia (*Rachycentron canadum*) fishes 45 days-old were conducted in Doson station during ten days (yr 2005). These three toxic substances affected strongly the growth rate of the Cobia fish (length and weight of the body), even at the lowest treated concentration. The LC values of copper, zinc and cyanide were 0.32 mg l\(^{-1}\); over mg l\(^{-1}\) and 0.049 mg l\(^{-1}\), respectively. Based on the statistical analysis of growth rate of cobia by determining IC\(_{25}\), IC\(_{50}\), NOEC and LOEC values, we have addressed the safe concentrations of these two heavy metals and cyanide in the environmental aquaculture which must be lower than 0.025 mg Cu l\(^{-1}\), 0.5 mg Zn l\(^{-1}\) and 0.005 mg CN l\(^{-1}\), respectively. The result also showed that cyanide was the most toxic to Cobia, followed by copper and zinc.


The levels of growth hormone, estradiol, progesterone, testosterone and chorionic gonadotropic hormone in the muscles of cultured and wild *Sparus macrocephalus*, *Plectorhynchus cinctus*, *Rachycentron canadum*, *Nibea japonica*, *Pampus argenteus* in the Zhanjiang sea area were determined by radioimmunoassay (RIA). The result showed that the level of each hormone was different with different fish species, and their distributions were as follows. The highest levels of growth hormone, estradiol, progesterone, testosterone and chorionic gonadotropic hormone in the 5 species of cultured and wild fishes occurred in cultured and wild *Nibea japonica*, cultured *Sparus macrocephalus* and wild *Rachycentron canadum*, cultured and wild *Pampus argenteus*, cultured *Nibea japonica* and wild *Plectorhynchus cinctus* respectively. The level of each hormone in the cultured fish was obviously higher than the same species of the wild fish (p<0.01). The levels of the 5 kinds of hormones in the muscles of cultured *Sparus macrocephalus* were 6.94, 4.01, 2.81, 2.42 and 2.99 times those of wild *Sparus macrocephalus* respectively, those of cultured *Plectorhynchus cinctus* were 5.68, 2.51, 2.15, 2.13 and 1.93 times those of wild *Plectorhynchus cinctus* respectively, those of cultured *Rachycentron canadum* were 46.11, 1.71, 1.63, 5.50 and 2.91 times those of wild *Rachycentron canadum* respectively, those of cultured *Nibea japonica* were 6.60, 2.75, 2.83, 3.58 and 5.38 times those of wild *Nibea japonica* respectively, and those of cultured *Pampus argenteus* were 2.55, 2.67, 2.49, 2.52 and 2.70 times those of wild *Pampus argenteus*, respectively. It suggested that RIA would be an effective method for determining hormone levels of aquatic products.


Cobia *Rachycentron canadum* has recently been recognized as a potential candidate for aquaculture because this species exhibits high growth rates during the larval and juvenile stages. A series of salinity tolerance tests were performed on larval cobia in order to identify the salinity requirements of this species during culture. The effect of spawning salinity on larval tolerance is also discussed. The 18-h survival of cobia larvae 3, 5, 7 and 9 days post-hatch (dph) following abrupt transfer to salinities ranging from 4 to 48 ppt was evaluated using logistic regression. The salinity range within which 90% of the larvae would be expected to survive appeared to be age-dependent and was narrowest at 3 dph (20.1-35.6 ppt) and wider at 7 and 9 dph (7.5-32.8 ppt). The 18-h tolerance of larvae to abrupt changes in salinity was unaltered by spawning salinities of 28.0 and 36.5 ppt. In the second part of the study, rearing salinities were dropped by 5 ppt day\(^{-1}\) from 32-34 ppt (control) to 5, 10, 15 and/or 20 ppt beginning on 1, 4, 7, 10 or 13 dph. Larval survival from hatching through 10 days following the initial drop in salinity was significantly (P<0.05) lower (<2%) in the low salinity treatments than the control (12-15%) when the salinity drop was initiated 1 and 4 dph. No significant differences in larval survival were detected between the control (12.5%) and 20 ppt treatment (8.9%) when the salinity drop began on 7 dph but survival in the 10 ppt treatment (3.2%) was significantly lower than the control. When the salinity drop was initiated on 10 dph, no significant differences in survival (10.7-14.7%) were detected among treatments. Finally, no significant differences in survival (9.6-15.4%) were found when the salinity drop was initiated 13 dph and terminated 22 dph. However, when a similar study was extended to 28 dph survival from 13 to 28 dph was significantly lower in the 5 (49.4%) and 10 (72.5%) ppt treatments than the control (96.5%) due to disease. No significant differences in standard length were observed for larvae within each experiment irrespective of rearing salinity. The results of this study indicate that rearing cobia larvae in salinities as low as 15 ppt may be possible beginning 13 dph.

Chemokines are small, secreted cytokine peptides known principally for their ability to induce migration and activation of leukocyte populations and regulate the immune response mechanisms. The cobia (*Rachycentron canadum*), a marine finfish species, has a great potential for net cage aquaculture in the South China Sea. We isolated and characterized a CC chemokine cDNA from cobia-designated RcCC2. Its cDNA is 783 bp in length and encodes a putative protein of 110 amino acids. Homology and phylogenetic analysis revealed that the RcCC2 gene, which contains four conserved cysteine residues, shares a high degree of similarity with other known CC chemokine sequences and is closest to the CCL19/21 clade. The mRNA of RcCC2 is expressed constitutively in all tested tissues, including gill, liver, muscle, spleen, kidney, head kidney, skin, brain, stomach, intestine and heart, but not blood, with the highest level of expression in gill and liver. The reverse transcription quantitative polymerase chain reaction was used to examine the expression of the RcCC2 gene in immune-related tissues, including head kidney, spleen and liver, following intraperitoneal injection of the viral mimic polyriboinosinic polyribocytidylic acid, formalin-killed *Vibrio carcharii* (bacterial vaccine) and phosphate-buffered saline as a control. RcCC2 gene expression was up-regulated differentially in head kidney, spleen and liver during 12 h after challenge. These results indicate that the RcCC2 gene is inducible and is involved in immune responses, suggesting RcCC2 has an important role in the early stage of viral and bacterial infections.


A pugheaded cobia (*Rachycentron canadum*) captured in the Northcentral Gulf of Mexico represents the first record of pugheaded in cobia. The specimen, a 4-year-old gravid female, exhibited considerable distortion of the premaxillary and maxillary bones, with the length of the snout 46% shorter than that of a normal cobia of the same length. The anomaly had no apparent effect on feeding, since the stomach contained a substantial amount of food, and the fish was the same length expected of a normal 4-year-old cobia.


A review of available scientific information on the age, growth, and reproduction of cobia, *Rachycentron canadum*, from United States waters of the Gulf of Mexico and Atlantic Ocean is provided. Periodicity of annulus formation on sectioned sagittae has been partially validated by marginal-increment analysis, and age in years is estimated as the number of observed opaque bands. Growth in length for both sexes is rapid through age 2. Females grow faster and live longer than males and dominate all age groups. Gulf males reached age 9 and 1,390 mm FL; females reached age 11 and 1,651 mm FL. Atlantic males reached age 14 and 1,360 mm FL; females reached age 13 and 1,420 mm FL. Ages 2 - 5 dominated the age structure of Gulf and Atlantic samples. Cobia were fully recruited to the northeastern Gulf recreational fishery at age 4, and the instantaneous rate of total mortality (Z) estimated for fully recruited cobia ages 4 - 8 was 0.75. Cobia have an extended spawning season throughout their range in United States waters, averaging five months (mid-April-August) in the Atlantic Ocean and six months (April-September) in the Gulf of Mexico. Some Gulf females appear to cease spawning by July. Female cobia can obtain sexual maturity as small as 700 mm FL. Histological analysis shows cobia are a multiple spawning species; females are estimated to spawn once every five days throughout most of the U.S. region. Batch fecundity increases significantly with FL and ovary-free body weight (OFBW); mean relative batch fecundity is 53.1 ± 9.4 eggs/g OFBW. While the testis of males contain sperm year-round, spermatogenesis only takes place from February - August, and spermatogonial proliferation is observed during non-spawning months.


This paper represents the first study describing specifically the diet of juvenile *Rachycentron canadum*.

We examined 1005 cobia, *Rachycentron canadum*, from recreational catches in the northeastern Gulf of Mexico from 1987 to 1995. Specimens ranged from 325 to 1651 mm fork length (FL); females had a mean FL of 1050 mm (n=730) and were significantly larger than males that had a mean FL of 952 mm (n=275). The overall male to female ratio was 1:2.7. Ages of 565 cobia were estimated from thin-sectioned otoliths ( sagittae). Marginal-increment analysis of sagittal otoliths showed a single annual minimum during June. Male cobia (n=170; 525-1330 mm FL) ranged from age 0 to 9, and females (n=395; 493-1651 mm FL) ranged from age 0 to 11. The relationship of observed fork length and age was described by the von Bertalanfly growth equation for males FL. = 1171 (1-exp [-0.432( t+1.150)]) and for females FL. = 1555 (1-exp [-0.272( t+1.254)]). Growth in length for both sexes was relatively fast through age 2, after which growth slowed gradually. Estimates of the von Bertalanfly growth equation parameters L. and K were significantly different for males and females, whereas estimates for t. were not significantly different. Sagittal otolith weight was a good predictor of age. The instantaneous rate of total mortality (Z) estimated by catch curve analysis for fully recruited ages 4-8 was 0.75.


Age and growth of *Rachycentron canadum* (L.) was studied in northern and eastern Australia to provide data for a preliminary assessment of the stock and to explore possible fisheries management strategies using minimum legal lengths. Fish collected from commercial and recreational fisheries ranged in size and weight from 125 to 1633 mm fork length (FL) and 0.031 to 55 kg respectively. The annual growth increments in sectioned otoliths formed by November-December were analyzed. Estimated ages ranged from 0 to 7 yr for both genders. Longevity was estimated to be at least 13 yr. Von Bertalanfly growth function parameters were L. = 1160 mm FL, K =0.63 yr^-1 and t. = -0.21 yr^-1. *Rachycentron canadum* reach 600 mm FL in their first year and over 1000 mm FL in 3 years. Natural and total mortalities were estimated at 0.35 yr^-1 and 0.85 yr^-1, respectively. Populations of *R. canadum* may be vulnerable to growth overfishing under the current minimum legal length of 750 mm total length (TL) in Queensland waters. An increase in minimum legal length to 850 mm TL is recommended.


Estimated landings of cobia from the Indian EEZ by the commercial fishing vessels are mostly by catch in hooks and line cum gillnet and trawl nets. However, the catches are substantial compared to that reported in several other countries of Asia. The species is also gaining considerable importance as a favoured candidate species for sea farming using cages. Very little is known about the fishery and biological characters such as maturation, fecundity and feeding preferences of cobia in Indian seas. Study indicated a fast growth rate with estimates of L. = 184 cm (FL) and K = 2.6 (yr^-1) in cobia. The total mortality rate (Z) was estimated as 5.18, natural mortality (M) was 2.01 and fishing mortality (F) was 3.17 with an exploitation rate (E) of 0.61. The length at first capture (Lc50) estimated from the catch curve was 72 cm. Fecundity was found to be high and variable, with mean fecundity estimated as 12, 37, 545 eggs with a coefficient of variation (CV) of 16.7. As inferred from the oocyte development pattern, spawning activity is brief and fish is classified as synchronous ovulatory type. The growth parameters and condition factor estimated in this study indicate that relatively high growth rates are also possible in wild stocks considering that food is abundant and the environmental temperature is in the optimum range. Feeding preferences indicated balistid fish and shrimps with a wide variety of food items includingfinishes, crustaceans and molluscs present.


The genetic diversity of cobia, *Rachycentron canadum* populations in the Persian Gulf and Oman Sea were assessed using microsatellite technique. We removed about 3-5g of pectoral and dorsal fin tissue from 184 samples in winter 2006 and spring 2007, and stored it in pure ethylic alcohol (96%). Polymerase chain reactions (PCR) were conducted on the target DNA using 10 paired microsatellite
primers. The dendrogram was constructed and drawn using MEGA software package version 4. Based on the analysis of molecular variance, the highest $F_{ST}$ (0.063) was observed when comparing specimens from Dayer Port and Pozm zones. Significant differences ($P<0.01$) were not observed between $Rst$ recorded for the specimens studied in the same region but were observed between $Rst$ recorded for different regions. The dendrogram of genetic distance showed two major clusters: the Bushehr and Dayer populations were in one cluster, and the remaining four populations in the other. The second cluster was further separated into two sub-clusters: the Lengeh and Bandar Abbas populations composed one cluster and the Pozm and the Beris populations were in the other cluster. The present study showed that at least three different populations of $R$. canadum are living in the Persian Gulf and Oman Sea. The populations include Bushehr, Bandar Abbas and Chabahar populations.


Nuclear-encoded microsatellites and mitochondrial DNA (mtDNA) sequences were assayed from cobia *Rachycentron canadum* sampled in waters offshore of Virginia (U.S. Atlantic), Mississippi and Louisiana (Gulf of Mexico), and Taiwan (Southeast Asia). Global exact tests and analysis of molecular variance revealed that cobia from U.S. waters were homogeneous for alleles and genotype distributions at 27 nuclear-encoded microsatellites and were homogeneous in mtDNA haplotype distribution, whereas both genetic markers in cobia from Taiwan differed significantly from those of cobia in U.S. waters. Based on these genetic differences, use of cobia broodstock from Southeast Asia in U.S. aquaculture facilities is not recommended. Results are compatible with the use of cobia broodstock from either the U.S. Atlantic or the Gulf of Mexico for aquaculture at U.S. facilities; caveats to the exchange of broodstock between these two regions are discussed.


Six experiments were designed to determine the optimal anaesthetic dosage of tricaine methanesulphonate (TMS) and clove oil that could be used safely on juvenile cobia *Rachycentron canadum* of two sizes [G1=4.9 ± 0.8 g; G2=13.9 ± 3.1 g]. We documented the stage of anaesthesia and the acute toxicity as 96 h LC50 (lethal concentration 50% population) at various exposure times of the two anaesthetics. At 10 min induction time, the TMS 96 h LC50 was 93.9 mg L$^{-1}$ in G1 and 97.0 mg L$^{-1}$ in G2. Compared with clove oil, the 96 h LC50 was 60.0 mg L$^{-1}$ in G1 and 69.8 mg L$^{-1}$ in G2. The difference between the two groups (G1, G2) did not influence anaesthesia safety ($P>0.05$). *Rachycentron canadum* achieved stage 3 anaesthesia more rapidly at a lower clove oil concentration level (40 mg L$^{-1}$, 10 min) than TMS (60 mg L$^{-1}$, 10 min), but the recovery period of clove oil, was significantly longer. Clove oil was the most effective in reducing the short-term stress induced by routine biometry (20 mg L$^{-1}$, 10 min) and also by transporting (1 mg L$^{-1}$, 8 h). Whereas, for long-term exposure, 40 mg L$^{-1}$ TMS was found to be safe.


The cobia, *Rachycentron canadum*, is a coastal pelagic species that supports both recreational and commercial fisheries in the southeastern United States. Cobia exhibit seasonal migrations in the Gulf of Mexico and along the U.S. Atlantic coast, but the extent to which those fish migrate is not well-documented. This study was conducted to determine the seasonal movements and migratory behavior of cobia in southeastern U.S. waters in order to develop information pertinent to effective regional management of the cobia fishery. From 1988 through July 2007, participants in an angler-cooperative research program tagged and released 15,003 cobia ranging from Gulf waters off Texas to Atlantic waters off Virginia, and 962 (6.4%) of those fish were recaptured. Data indicate a general migratory trend of cobia over-wintering in south Florida coastal waters, followed by northerly movement in late winter and early spring along both coasts of the Florida Peninsula to spawning grounds in northern Gulf and central U.S. Atlantic coastal waters. A subsequent return to south Florida waters in late fall was common. Results of this research support the regional scale of cobia management currently implemented by the Gulf of Mexico and South Atlantic Fishery Management Councils.
The technique of homologous cloning and Rapid Amplification of cDNA Ends (RACE) was used to amplify full length cDNA gene of immunoglobulin light chain (K chain) from cobia (Rachycentron canadum Linnaeus). The full length cDNA of k in cobia is 969 bp, containing a 3’ untranslated region (UTR) of 188 bp, a 5’ UTR of 52 bp, and an open reading frame (ORF) of 729 bp, encoding 242 amine acids. The estimated molecular weight of Ig k is 26,255 kD, and the theoretical isoelectric point is 7.52. The deduced IgK amino acid sequences of cobia were compared with those of other teleost species. For the constant region of IgK, higher percentage similarity was obtained from comparisons between R. canadum and Seriola quinquergadiata and between R. canadum and Salmo salar, which was higher than 77%. For the variable region, higher percentage similarity was obtained from comparisons between R. canadum and S. quinquergadiata, which reached 87%. By the phylogenetic tree of immunoglobulin light chain constant region, IgK amino acid sequences of cobia were clustered with S. quinquergadiata (1,2,3) and Ictalurus punctatus G chain which belong to the type of k chain, so IgL of cobia was supposed to type of k. Salmo salar L2 chain, Danio rerio L2 chain, Cyprinus carpio L chain that belong to the type of A, chain were clustered together. The expression of IgK gene in healthy cobia was initially measured by semi-quantitative RT-PCR. It was found that the expression of the IgK existed more obviously in liver and gill than in other tissues, but they were hardly expressed in intestine and brain. The expression of the target gene in head kidney, spleen, intestine and gill increased obviously after cobia was immunized by intraperitoneal injection with Vibrio carchariae strain JT2, while the expression in liver decreased. The result indicated that head kidney, spleen, intestine and gill are main organs for IgK production after stimulation, and play a critical role in host-pathogen interaction.

Pericardial adhesions are reported in diseased hearts of Rachycentron canadum (Linnaeus). The epicardium and pericardium are either tightly fused or connected by numerous thick collagenous adhesions over most of the heart surface.

The species was cytogenetically analyzed by different methodologies, including Ag-NOR and chromomycin A1 (CMA3)/DAPI staining, C-banding, early replication banding (RGB), and in situ fluorescent hybridization with probes for 18S and 5S ribosomal genes and for telomeric sequences (TTAGGG)n. The results obtained allow a detailed chromosomal characterization of the Atlantic population. The chromosome diversification found in the karyotype of the cobia is apparently related to pericentric inversions, the main mechanism associated to the karyotypic evolution of Perciformes. The differential heterochromatin replication patterns found were in part associated to functional genes. Despite maintaining conservative chromosomal characteristics in relation to the basal pattern established for Perciformes, some chromosome pairs in the analyzed population exhibit markers that may be important for cytotaxonomic, population, and biodiversity studies as well as for monitoring the species in question.

To support the growing interest in marine fisheries research in areas such as biotelemetry, tagging, and tracking, we assessed the ability of various sedatives to facilitate this research in juvenile cobias Rachycentron canadum (~300 g), namely, tricaine methanesulfonate (MS-222; 150 mg/L), carbon dioxide (CO2; ~750 mg/L), eugenol (60 mg/L), benzocaine (150 mg/L), and pulsed-DC electrosedation (100 V, 30 Hz, 25% duty cycle, 5-s exposure). Induction times (CO2 [z] > benzocaine [y] > eugenol [y] > MS-222 [y] > electrosedation [x]), recovery of equilibrium (CO2 [z] > eugenol [z] > MS-222 [y] > benzocaine [y] > electrosedation [x]), and responsiveness to tactile
stimulus (eugenol [z] > MS-222 [y] > benzocaine [y] > CO₂ [xy] > electrosedation [x]) differed significantly among the sedative treatments (treatments with the same letters are not significantly different). Total handling time from initial sedative exposure to recovery differed among the sedatives as well (CO₂ [z] > eugenol [y] > benzocaine [x] > MS-222 [x] > electrosedation [w]), with cumulative means ± SEs of 5.9 ± 0.2 min for CO₂, 4.1 ± 0.2 for eugenol, 2.7 ± 0.2 min for benzocaine and MS-222, and 1.0 ± 0.2 min for electrosedation. Physiological responses differed significantly over time, with transient increases in plasma cortisol, glucose, osmolality, and lactate that were resolved within 6 h. The overall magnitude of the physiological responses differed among sedatives, depending on the response variable; however, in each case, CO₂ elicited the greatest response. Although variations in induction and recovery times were observed, it is likely that these differences can be reasonably accommodated within the context of typical research by adjusting the sedative treatments or allowing for longer induction and recovery times as needed.


Stomach wall of fish, Rachycentron canadus (L.) infected with adult nematodes Raphidascaris sp. shows degeneration of stomach wall, erosion of gastric mucosa at the site of contact with the nematode and abnormalities in the blood vessels and underlying muscle layers. Detached gastric cells are accumulated in the lumen and appear as granular mass. Giant cell formation in the damaged superficial layer was obvious.


We documented inshore spawning of the recreationally important cobia (Rachycentron canadum) in Port Royal Sound (PRS) and St. Helena Sound (SHS), South Carolina, during the period from April to June in both 2007 and 2008. Histological analysis of ovaries confirmed the presence of actively spawning females inshore, and gonadosomatic index (GSI) values from females collected inshore (mean=7.8) were higher than the values from females caught offshore (mean=5.6); both of these mean values indicate that spawning occurred locally. Additionally, we conducted an ichthyoplankton survey in 2008 and found cobia eggs and larvae as far as 10 and 15 km inshore from the mouths of SHS and PRS, respectively. A study of egg development that we conducted in 2007 and 2008 using hatchery-reared cobia eggs provided descriptions of embryological development of cobia. Comparison of visual and quantitative characteristics of the field-collected eggs with those of the hatchery-reared eggs allowed positive identification of eggs collected in plankton samples. The ages of field-collected eggs and presence of females with hydrated oocytes in PRS and SHS observed in our ichthyoplankton survey and histological analysis indicated that wild cobia spawn in the afternoon and early evening. The inshore migration of cobia from April to June, the presence of actively spawning females, significantly higher GSI values, and the collection of eggs inside PRS and SHS all confirm that these estuaries provide spawning habitat for cobia. Because of the potential for heavy exploitation by recreational anglers as cobia move inshore to spawn in South Carolina, current management strategies may require review.


The biochemical composition of muscle of Canadian sergeant fish, Rachycentron canadum (Linnaeus) was reported. The contents of protein and fat of the muscle of Canadian sergeant fish were 21.2% and 5.5% respectively. The ratios of essential amino acids deicious amino acids to total amino acids were 50.39% and 44.92%. The ratio of unsaturated fatty acids to total fatty acids was 65.2%, and the ratios of EPA and DHA to total fatty acids were 4.5% and 12%. The result indicated that the ratio of essential amino acid and deicious amino acid to total amino acid in muscle of Canadian sergeant fish were the highest when the Canadian sergeant fish weigh about 3.4kg. The nutritive value and deicious extent of Canadian sergeant fish, Rachycentron canadum (Linnaeus) were better than other fish as sea group in cultured net-cage.

Cobia, *Rachycentron canadum*, is an economically important fish which mainly distributes in tropical warm waters worldwide. In order to collect enough data to study the status of germplasm resources of this fish, 10 pairs of microsatellite markers of the *R. canadum* population from the Mississippi of the southeast United States were selected to analyze the genetic diversity of the *R. canadum* population around Zhanjiang waters of the South China Sea. Five pairs of the markers proved useful and assessed the genetic diversity of 48 individuals of *R. canadum*. The results show that the numbers of alleles and effective alleles and the values of polymorphism information content and heterozygosity ranged from 2-9, 1.552 9-7.339 7, 0.324 2-0.856 3, and 0.356 0-0.863 8, respectively, indicating that the diversity of the *R. canadum* population around Zhanjiang waters was relatively high, even higher than that of the *R. canadum* population in the Mississippi by comparison. It is suggested that adequate measures should be taken to protect *R. canadum* resources in China before it is disturbed by human activities.


*Rachycentron canadum* (Linnaeus, 1766) is recorded for the Todos os Santos Bay (State of Bahia, Brazil) Three specimens were analyzed, collected in Itapema Beach, Santo Amaro da Purificacao Municipality (about of 12 degree 42'S - 38 degree 45'W), measuring between 178,4 mm and 307,4 mm in total length Gut contents, morphometrics and meristics data, as well as a diagnosis, are presented for the examined specimens, which are housed in the collection of the Laboratorio de Ictiologia, Universidade Estadual de Feira de Santana.


Gonadal maturation of cobia, *Rachycentron canadum*, was evaluated by examining 508 specimens from its recreational fishery. Specimens were collected off southeast Louisiana to northwest Florida by hook-and-line during February through October 1987-1991. Fork lengths (FL) of these fish ranged from 580-1,530 mm, with corresponding weights of 2.0-43.5 kg. The female: male ratio was 1:0.37. Using a combination of oocyte size-frequency and histological assessment of many of the fish, we determined that females were ripe from May through September, with atretic oocytes occurring in some fish from July through October. Degenerating hydrated oocytes in July and October and the presence of resting ovaries in July suggest two major spawning periods; however, monthly gonosomal indices peaking in May, followed by a steady decline, do not support that finding. Ovaries were placed into undeveloped, early developing, mid-developing, or late developing categories based upon oocyte size-frequency distributions. Developing ovaries had two or three modes of oocytes larger than 30 µm. Batch fecundity was estimated to be 2.6×10⁸ to 1.91×10⁹ oocytes, depending on the size of fish/ovaries. The smallest female with oocytes exhibiting vitellogenesis was 834 mm FL. This fish was 2 years old based its otolith evaluation. The smallest male with an abundance of spermatozoa in its testes was 640 mm FL and 1 year old based on otolith evaluation; smaller males were not examined. Females larger than 840 mm FL had vitellogenic oocytes in March and April. A few fish still had vitellogenic oocytes in early October, but none did by late October. When Gilson's fluid was used to assess ovarian tissue, the fresh weight of the tissue was reduced by 20% after being stored for 3 months. The diameter of oocytes shrunk about 25% in Gilson's fluid which was 11% less than those fixed in formalin, embedded in paraffin, and sectioned. Tissue sections from specific individuals, each demonstrating a variety of different developmental stages, were similar regardless of whether they were obtained from the anterior, middle, or posterior portion of either ovary.


Cobia, *Rachycentron canadum* is a migratory marine species that have recently gained popularity as foodfish in the aquaculture market and for stocking. Unfortunately, when culturing this specie, aquaculturists may unknowingly expose these fish to temperature extremes not normally experienced in situ. We set out to test for the critical thermal minimum temperatures of juvenile cobia by exposing them to a simulated freeze, at a drop rate of 0.33 °C per hour. We observed and documented behavioral effects due to low temperature exposure using criteria for loss of equilibrium and death. We determined that the median temperature for loss of equilibrium was 12.1 ± 0.40 °C and the median lethal temperature was 9.7 ± 0.28 °C for low temperature tolerance. We
recommend that precautions be taken well before water temperatures reach 13 °C in a freeze scenario.


The stomach contents of 403 cobia, *Rachycentron canadum*, caught in the Northcentral Gulf of Mexico recreational fishery from April through October of 1987-1990 were examined. Cobia ranged from 373-1,530 mm in fork length. Of the 403 stomachs, 287 (71.2%) contained at least one identifiable prey taxon. Crustaceans, consisting primarily of portunid crabs, were the predominant food. Crustaceans occurred in 79.1% of the stomachs and comprised 77.6% of the total number of identifiable prey. The second most important prey category was fish, which was dominated by hardhead catfish, *Arius felis*, and eels. Fish occurred in 58.5% of the stomachs but only accounted for 20.3% of the total number of prey. The importance of fish as prey increased with increasing size (length) of cobia, with the largest size class of cobia (1,150-1,530 mm FL) showing the highest percent frequency occurrence of fish prey (84.4%). There were no significant differences between the diets of male and female cobia. Species composition of the diet indicated that cobia examined in this study were generalist carnivores in their feeding habits and fed primarily on benthic/epibenthic crustaceans and fishes. However, the occurrence of pelagic prey provided evidence of diversity in the foraging behavior of cobia. Feeding cobia indicated their dependence upon prey availability rather than upon a few specific food organisms.


Population genetics has been recognized as a key component of policy development for fisheries and conservation management and aquaculture development. This study aims to evaluate the genetic diversity and population structure of native cobia (*Rachycentron canadum*) in the Gulf of Thailand and Andaman Sea, establishing the existing population distributions and contributing information to aid in the development of policy, prior to extensive aquaculture development. Microsatellite analysis of natural cobia populations in these two ocean basins shows similar levels of gene diversity at 0.844 and 0.837, respectively. All populations and almost all microsatellite loci studied show significant heterozygote deficiency. Genetic differentiation between local populations is low and mostly not significant (RST = -0.0109 to 0.0066). The population shows no marked structure over the long geographic barrier of the Thai-Malay peninsula, either when analyzed using pairwise genetic differences or evaluated without predefined populations using STRUCTURE. Additionally, a Mantel test shows no evidence of isolation by distance between the population samples. The significant heterozygote deficiency at most of the loci studied could be explained by the possibility of null alleles. Alternatively, given the behavior of forming small spawning aggregations, seasonal migration, and hitchhiking on large marine animals, the population genetics could be complex. The population of cobia at each location in Thai waters may be inbred, as a result of breeding between relatives, which would reduce heterozygosity relative to Hardy-Weinberg frequencies, while some of these populations could be making long distance migrations followed by admixture between resident and transient groups. This migration would cause population homogeneity in allele frequencies on a larger geographic scale. The results suggest that fisheries management for this species should be considered at both national and international levels, and until the possibility of local adaptation is fully investigated, policy development should apply the precautionary principle to ensure the preservation of genetic diversity and the sustainability of local and regional fisheries.


Age, growth, fecundity and distribution of cobia, *Rachycentron canadum*, were studied. Data were collected primarily from lower Chesapeake Bay and adjacent mid-Atlantic waters. Age analysis by scale methods, growth estimates by use of Bertalannfy's equation, and observations of juvenile cobia indicate rapid growth. Ten age groups were represented in scale collections from 284 fish, 4.2–56.4 inches in fork length. Males and females can mature at two and three years, respectively. Growth equations are: males, \( L_t = 49(1-e^{-0.21(t+0.67)}) \), \( W_t = 59(1-e^{-0.17(t+0.62)}) \); females, \( L_t = 59(1-e^{-0.20(t+0.63)}) \), \( W_t = 120(1-e^{-0.10(t+0.60)}) \). Fecundity in hundreds of thousands of eggs was evaluated as a function of body weight where fecundity was equal to 0.98 times the weight in pounds minus 6.39.
The spawning season, late June through mid-August, was defined through observation of gonadal tissue. A disproportionate sex ratio for areas within Chesapeake Bay was noted, 74:26 and 28:72 males to females, for eastern and western shore areas respectively. A possible relation between spawning and a high ratio of males to females was noted for eastern shore areas.

Fish are potentially submitted to water acidification when reared in recirculating aquaculture systems. This study evaluated the responses of juvenile cobia Rachycentron canadum after acute exposure to acid water. Juvenile cobia (12.6 ± 0.5 g; 14.2 ± 0.2 cm) were acutely exposed to four pH levels (7.9 (control), 6.5, 6.0, and 5.5). After 24 h of exposure to different pH values, fish were sampled for physiological and histopathological evaluation. Acid water affected physiological parameters and induced morphological histopathologies on gill and skin of juvenile cobia, and these effects were more conspicuous with decreasing pH values. Acid stress induced blood acidosis in juvenile cobia, coupled to a decrease in bicarbonate (HCO$_3^-$) and saturated O$_2$ (sO$_2$) in fish blood. On the other hand, haematocrit, haemoglobin and glucose concentration increased their values (P <0.01) comparing to control level. Hyperplasia with completely fusion of secondary lamella was observed in all pH treatments (6.5; 6.0 and 5.5), while telangiectasia and proliferation of chloride cells were present for fish exposed to pH 6.0 and 5.5. In skin hyperplasia and hypertrophy of mucous cells, necrosis of these cells for fish exposed to pH 6.0 and 5.5 was observed. The results of this study demonstrate that acute acid water exposition affected physiology and histopathology in juvenile cobia, especially at pH values below 6.5. Accordingly, particular attention must be given to pH during cobia reared in recirculating aquaculture.

Cobia Rachycentron canadum is a fast growing fish with world-wide potential for aquaculture, and has been considered for rearing in recirculating aquaculture systems (RAS). Nitrate is considered the least toxic nitrogenous product in the ammonia nitrification process, but as it may accumulate in RAS, toxic levels can be reached. The objective of this study was to evaluate the acute toxicity and the histopathological effects of nitrate on juvenile cobia. Juveniles (6.87 ± 0.36g; 11.8 ± 0.19cm) were acutely exposed to six concentrations of nitrate (500-3000ppm NO$_3^-$/N) plus a control during 96h. At the end of this period of exposure, juvenile cobia were sampled for histopathological evaluation. The estimated LC$_{50}$ of nitrate to juvenile cobia was equal to 2407 and 1829mg/L NO$_3^-$/N at 24 and 96h, respectively. Cobia exposed to sub-lethal nitrate concentrations showed histopathologic alterations in the gills, esophagus and brain. The gills revealed epithelial hyperplasia with complete lamellar fusion, telangiectasia, and lamellar shorting induced by necrosis, and the esophagus presented hyperplasia of epithelium and mucus cells. In the brain, glial cells proliferation, satellitosis (microglial cells surrounding neurons with swollen and prenecrotic neurons), and Virchow-Robin spaces (enlarged perivascular spaces, EPVS) were observed. The results of the present study indicate that juvenile cobia have a high tolerance to acute exposure of nitrate. However, assorted histopathological responses were observed for cobia at sub-lethal nitrate concentrations. Therefore, further studies are needed to estimate safe chronic nitrate levels for juvenile cobia culture.

Nitrogenous compounds can be toxic to aquatic animals especially when they are reared at high stocking densities. Cobia (Rachycentron canadum) is a fast growing fish currently reared in cages, but with expanding production in intensive recirculating aquaculture systems (RAS). Therefore, the objective of this study was to evaluate the acute toxicity of ammonia and nitrite to juvenile cobia. Juveniles (1.74 ± 0.11 g for ammonia and 0.88 ± 0.06 g for nitrite toxicity evaluation) were acclimated to test conditions (temperature 26 °C and salinity 22‰) and acutely exposed to ammonia (0.25-1.30 ppm NH$_3$-N) and nitrite (30-210 ppm NO$_2$-N) at 0.2 fish L$^{-1}$. Tests were run in 50 L semi-static tanks, experimental water was fully renewed daily, and all test concentrations plus the controls were run in triplicate. Mortality, feeding and swimming behavior were observed during 96 h, toxic concentrations for 50% the population and the respective 95% confidence intervals for
Cobia ceased to eat at 0.62 (0.56-0.70) ppm NH$_3$-N and 76.1 (73.2-79.0) ppm NO$_2$-N. Swimming behavior was affected at higher concentrations: 0.80 (0.74-0.85) ppm NH$_3$-N and 88.8 (82.6-95.5) ppm NO$_2$-N. Even higher concentrations were necessary to kill juvenile cobia, LC50-96 h for ammonia was estimated at 1.13 (1.06-1.19) ppm NH$_3$-N, and within the range of concentrations tested for nitrite it was not possible to estimate the LC50-96 h, as only 30% of the individuals died at the highest concentration after 96 h (210 ppm NO$_2$-N). The results of the present experiments demonstrate that ammonia could be problematic at relatively low levels for the intensive rearing of juvenile cobia; however, it is unlikely that the high levels of nitrite needed to harm juvenile cobia would be reached in a well designed and properly operating RAS.


The fishery and food of cobia, *Rachycentron canadum* caught off Karnataka, south-west coast of India was studied during 2007-2010. An estimated 302 t was landed annually along this coast which formed 0.1% of the total fish catch of the region. Peak landings were recorded during October followed by April. Gillnets landed large sized cobia and contributed to the bulk of the catch (53%). Maximum catch by this gear was during September-October. Next dominant gear was trawl which landed fishes of all size groups with maximum catch during April-May. Trawl landings contributed 45% of the total cobia landings. The fishery was comprised of fishes of length range 26 - 125 cm TL with the mean at 58 cm. Juveniles dominated the catch. Contents of 177 non-empty stomachs were analysed for the index of relative importance (IRI) and prey specific abundance (PSA). *R. canadum* was found to be nonselective generalist carnivore feeder, foraging on micronektonic pelagic or benthic organisms (crustaceans, fish and molluscs) available in the epipelagic waters. Teleost fish (55%), crustaceans (35%) and molluscs (10%) contributed to the diet. *Decapterus russelli* (18.0%) and *Encrasicholina devisi* (10.0%) were the dominant finfish groups; *Acetes* sp. (21.1%) followed by crabs (*Charybdis* spp. and *Portunus* spp.) with an IRI of 12.9% were dominant among crustaceans and squids (*Loligo* spp.) (5.8%) and octopus (4.1%) comprised the dominant molluscs prey items.


Information on the biology and fisheries of cobia, *Rachycentron canadum*, is compiled and reviewed in the FAO species synopsis style. Topics include taxonomy, morphology, distribution, reproduction, pre-adult and adult stages, food, growth, migration, population characteristics, and various aspects of exploitation. Data and information were obtained from unpublished as well as published sources.


Cobia is an important offshore cage culture fish in Taiwan. The factors influencing its chemical compositions were investigated in this study. An extraordinary feature present in cobia was that its meat accumulated a high amount of fat. The fat content in the ventral meat was 2 times higher than that of dorsal meat in the same fish. There was remarkable variation in fat among different size of fish. The amount was significantly and positively correlated with fish size. The predominant free amino acids (FAA) were taurine (Tau), glycine, alanine and glutamic acid. The FAA tended to decrease gradually as fish size increased. A dipeptide, anserine (Ans), was detected in the meat of cobia. Among ATP-related compounds (ARC), inosine monophosphate (IMP) was the most predominant compound. The amount of IMP in dark meat and viscera were much lower than that in ordinary meat. Both ARC and IMP had no significant correlation with fish size. The wild cobia had higher moisture content than that of cultured fish; however, the fat in dorsal or ventral meat of the former was significantly lower than the latter. The content of Tau in wild cobia was higher than cultured fish. Ans level was not significantly different between wild and cultured cobia. However, another dipeptide, carnosine was detected only in wild fish. The seasonal variations of fat and taste compounds such as FAA and ARC showed that the cobia was probably tastier at August to December. This fish was more easily spoiled than other fish. The pH value in white muscle was usually lower than 6.0, which is similar to that of pelagic fish. The drastic degradation of ATP and AMP occurred at the initial 3 hour of storage at 4 °C, and AMP accumulated. The rapid degradation
of IMP to inosine and hypoxanthine took place, after decomposition, and hypoxanthine became the dominant compound. The K value of 27% was proposed as the limit of quality acceptability. Conclusively, due to its good taste and high lipid content, this fish is suitable for serving as sashimi (raw fish), roasted, and smoked products.

57. Su, Y., Feng, J., Guo, Z., Xi, L. & Wang, J. (2008). Morphological studies on the development of lymphoid organs in cobia Rachycentron canadum. Marine Fisheries Research, 29(4), 7-14. Histological and histochemical methods were applied to study the development of the head kidney, spleen and thymus in cobia Rachycentron canadum, during 1-44 day posthatch (dph). The pronephric ducts were first observed, near which some primordial haemopoietic stem cells were observed 3 d later. The haemopoietic stem cells gradually differentiated into erythrocytes and large lymphocytes. The spleen developed later, and soon became rich in blood capillaries and erythrocytes, but had only a few macrophages. The thymus was the last lymphoid organ appeared but developed very quickly. An outer zone and inner zone in the thymus could be observed clearly. It was concluded that the sequence of appearance of lymphoid organs, from first to last, was head kidney, spleen and thymus. Before the small lymphocytes developed, cellular types involved in non-specific immunity mechanisms, such as macrophage and reticular cells, were observed in the lymphoid organs. The respective lymphoid organ anlage became thymus, head kidney and spleen successively. No plasma cells were observed in the samples, indicating that the lymphoid organs were not fully grown during this period.

58. Su, Y., Guo, Z., Xu, L., Jiang, J., Wang, J. & Feng, Y. (2012). Identification of a cobia (Rachycentron canadum) CC chemokine gene and its involvement in the inflammatory response. Fish & Shellfish Immunology, 32(1): 204-210. The chemokines regulate immune cell migration under inflammatory and physiological conditions. We investigated a CC chemokine gene (RcCC1) from cobia (Rachycentron canadum). The full-length RcCC1 cDNA is comprised 673 nucleotides and encodes a four-cysteine arrangement 99-amino-acid protein typical of known CC chemokines. The genomic DNA of RcCC1 consists of three exons and two introns. Phylogenetic analysis showed that RcCC1 was closest to the MIP group of CC chemokines. Quantitative real-time RT-PCR (qRT-PCR) analysis revealed RcCC1 was constitutively expressed in all tissues examined, with relative strong expression in gill, blood, kidney, spleen, and head kidney. The RcCC1 transcripts in the head kidney, spleen, and liver were quickly up-regulated after stimulation with formalin-inactivated Vibrio carchariae (bacterial vaccine) or polyriboinosinic polyribocytidylic acid (poly I:C). These results indicate RcCC1 not only plays a role in homeostasis, but also may be involved in inflammatory responses to bacterial and viral infection.

59. Su, Y., Xu, L., Feng, J., Guo, Z. & Wang, J. (2007). Study on the morphology of peripheral blood cells of juvenile cobia Rachycentron canadum. South China Fisheries Science, 3(1), 48-53. The peripheral blood was collected from cobia (Rachycentron canadum) on the 60th day after hatching, and blood cells were studied by light microscope. Five types of blood cells were observed as follow: erythrocyte, lymphocyte, monocyte, neutrophil and thrombus cells. The erythrocyte counts and leukocyte counts of cobia was $2.97 \pm 0.82 \times 10^9$ ind. mL$^{-1}$ and $1.39 \pm 0.94 \times 10^8$ ind. mL$^{-1}$, respectively. The percentages of lymphocytes, neutrophils, monocytes and thrombocytes in total leucocytes, were $(53.00 \pm 8.51)\%$, $(17.59 \pm 4.28)\%$, $(4.78 \pm 1.37)\%$ and $(24.63 \pm 4.08)\%$, respectively. Neither eosinophil nor basophil was found. The quantity of erythrocytes was much larger than that of leucocytes. Among the leucocytes, the lymphocytes were the most abundant, while that of monocytes was the least. The immature and dividing erythrocytes were found. The small lymphocytes with pseudopod and large lymphocytes with the villus were observed also. In addition, the monocyte, neutrophil and thrombus cells were recognized by different shapes of nucleolus.

60. Sun, L., Chen, H. & Huang, L. (2006). Effect of temperature on growth and energy budget of juvenile cobia (Rachycentron canadum). Aquaculture 261(3), 872-878. Growth and energy budget of juvenile cobia (initial body weight ~22 g) at various temperatures (23, 27, 31 and 35 °C) were investigated in this study. Maximal ration level (RL max, %/day) increased as temperature (T, °C) increased from 23 °C to 31 °C but decreased at 35 °C, described as a quadratic equation: $RL_{max} = -0.023T^2 + 1.495T - 17.52$. Faecal production (f, mg g$^{-1}$ day$^{-1}$) increased with increased temperature (T, °C), described as a power function: $ln f = 0.738lnT - 0.806$. As temperature increased, feed absorption efficiency in dry weight (FAE$_{dw}$, %), protein (FAE$_p$, %) and
energy (FAE_e, %) all increased first and then decreased, but the variation of feed absorption efficiency was small, with ranges of 89.59-91.08%, 92.91-94.71%, 93.92-95.32%, respectively. Specific growth rate in wet weight (SGR_e, %/day), dry weight (SGR_d, %/day), protein (SGR_p, %/day) and energy (SGR_e, %/day) showed a domed curve relative to temperature (T, °C), described as quadratic equations: SGR_e = -0.068T^2 + 3.878T - 50.53, SGR_d = -0.079T^2 + 4.536T - 59.64, SGR_p = -0.084T^2 + 4.783T - 63.08 and SGR_e = -0.082T^2 + 4.654T - 60.99, and SGR_e, SGR_d, SGR_p and SGR_e maximized at 28.5 °C, 28.6 °C, 28.4 °C, 28.5 °C, respectively, as calculated from the regression equations. The relationships between feed conversion efficiency in wet weight (FCE_e, %), dry weight (FCE_d, %), protein (FCE_p, %), energy (FCE_e, %) and temperature (T, °C) also took on a domed curve described as quadratic equations: FCE_e = -0.726T^2 + 39.71T - 473.8, FCE_d = -0.276T^2 + 15.31T - 190.6, FCE_p = -0.397T^2 + 22.05T - 277.9 and FCE_e = -0.350T^2 + 19.39T - 239.9, and FCE_e, FCE_d, FCE_p, and FCE_e maximized at 27.4 °C, 27.8 °C, 27.7 °C and 27.7 °C, respectively, as calculated from the regression equations. Energy budget of juvenile cobia fed satiation was 100 = 5F + 67(U+R) + 28G at water temperature 27 °C and 100 = 5F + 70(U+R) + 25G at water temperature 31 °C, where C is food energy, F is faeces energy, (U+R) is excretion energy and metabolism energy, and G is growth energy.


Prevention is the most viable disease management strategy in aquaculture, and prevention is primarily driven by strategies to avoid or minimize the effects of stress. Unfortunately, there is little information available regarding the stress physiology of emerging aquaculture species or appropriate experimental stressing protocols for these fishes, and thus very little context in which to evaluate mitigation strategies. Accordingly, the stress response of cobia was evaluated following exposure to 2 experimental stressors: low water and air exposure. Juveniles were exposed to air for 1min (AIR EXPOSURE), held for 15min in water lowered to the fish's lateral midline (LOW WATER), or unchallenged (CONTROL) prior to the collection of blood samples at 0 (pre-challenge), 0.5, 1, 2, 6, 12, 24, 48, and 72h post-challenge. Both stressors elicited classical haematological changes indicative of the generalized stress response, however, the magnitude of the response was consistently greater in the AIR EXPOSURE group. Plasma cortisol, glucose, and lactate concentrations increased rapidly in the AIR EXPOSURE and LOW WATER groups, peaking within 1h of challenge. Cortisol returned to basal levels rapidly, whereas glucose and lactate remained elevated for a longer period of time. Regardless of the stressor used, fish recovered within 12h of the challenge. The primary and secondary responses of juvenile cobia challenged with low water and air exposure appear to respond in a similar fashion to other species exposed to these experimental stressors. Both low water and air exposure are suitable experimental stressors for use in cobia based on their ability to induce a classical stress response and ease of implementation.


We collected 478 specimens of Cobia, *Rachycentron canadum*, from Hormozgan province waters during October 2005–September 2006, and studied reproductive parameters such as spawning season, sex ratio, maturity stages, fecundity and ova diameter. The maturity and spawning season were investigated through macroscopic and microscopic (ovarians histology) observation. Studying average Gonado-Somatic Index (GSI), the percent of maturity stages and ova diameter average changes revealed that the spawning occurred from July to the beginning of September. The total male to female sex ratio was 1.3:1.0 which was significantly different from the normal ratio, 1:1 (P<0.05). The highest sex ratio difference was seen in April. The average absolute fecundity was 1,684,954 eggs. Our records indicated that the maximum ova diameter was 0.575 mm belonging to the stage 4 and the minimum was estimated at 0.250 mm belonging to the stage 2. Ova diameter average increased from April onwards and its peak was in July. We found the Cobia has partial synchronism in oocytes and is a total spawner species.


The reproductive biology of 315 cobia fish, *Rachycentron canadum*, from northeastern Australia was studied for an 18-month period. Cobia ranged from 181 to 1,470 mm FL (0.06-55 kg). Length-
frequency distributions of males and females did not differ significantly. The sex ratio of females to males was 2.18:1. Histological data showed that cobia developed hydrated oocytes during a protracted spawning season between September and June. Gonadosomatic index peaked from October to December, coinciding with the monsoon or 'wet' season. Estimated length at first maturity for female cobia was 671 mm FL. Length at 50% maturity (L50) for females was estimated at 784 mm FL (1-2 years of age). Batch fecundity ranged from 577,468 to 7,372,283 eggs with a mean of 2,877,669 (+SD 1,603,760) eggs. Relative batch fecundity was 249 eggs per g, and no relationship between relative fecundity and fork length was found. There was a significant positive relationship between the total number of eggs produced and fork length. Spawning frequency, estimated by the post-ovulatory follicle method, was 7.6 days. Based on the detection of hydrated oocytes in fish caught at night, it seems cobia spawns at night. Cobia also feed throughout the spawning period. This is the first report on the reproductive biology of cobia in Australian waters, and provides valuable data for future population assessments of cobia throughout the Indo-Pacific.

64. Wagmare, K.B., Sundaram, S. & Mestry, A.Y. (2009). An emerging commercial fishery of Rachycentron canadum (Linnaeus, 1766) at New Ferry Wharf, Mumbai. Marine Fisheries Information Service technical and extension series, 201, 10-11. The landings of Rachycentron canadum have increased considerably at New Ferry Wharf, Mumbai, India. Hook and liners have started targeting this resource because of its high commercial returns.

65. Zheng, X., Ding, Z.K, Xu, Y., Monroig, O., Morais, S., Tocher, D.R. (2009). Physiological roles of fatty acyl desaturases and elongases in marine fish: Characterisation of cDNAs of fatty acyl Δ6 desaturase and elovl5 elongase of cobia (Rachycentron canadum). Aquaculture, 290(1-2), 122-131. In the present paper, we investigated the expression of fatty acyl desaturase and elongase genes in a marine teleost, cobia, a species of great interest due to its considerable aquaculture potential. A cDNA was cloned that, when expressed in yeast, was shown to result in desaturation of 18:3n-3 and 18:2n-6, indicating that it coded for a Δ6 desaturase enzyme. Very low desaturation of 20:4n-3 and 20:3n-6 indicated only trace Δ5 activity. Another cloned cDNA enabled elongation of 18:4n-3, 18:3n-6, 20:5n-3 and 20:4n-6 in the yeast expression system, indicating that it had C18-20 and C20-22 elongase activity. Sequence comparison and phylogenetic analysis confirmed that it was homologous to human ELOVL5 elongase. However, the cobia Elov15 elongase also had low activity toward C24 HUFA. The cobia Δ6 desaturase had a preference for 18:3n-3, but the elongase was generally equally active with both n-3 and n-6 substrates. Expression of both genes was 1-2 orders of magnitude greater in brain than other tissues suggesting an important role, possibly to ensure sufficient docosahexaenoic acid (DHA, 22:6n-3) synthesis in neural tissues through elongation and desaturation of eicosapentaenoic acid (EPA; 20:5n-3).

2. AQUACULTURE

2.1. DISEASES & HEALTH


67. Beveridge, I. & Campbell, R.A. (1989). Chimaerarhynchus n. g. and Patellobothrium n. g., two new genera of trypanorhynch cestodes with unique poeciloacanthous armatures, and a reorganization of the poeciloacanthous trypanorhynch families. Systematic Parasitology, 14(3), 209-225. Chimaerarhynchus rougetae n. g., n. sp. is described from Squalus acantius and Centrophorus sp. from the coast of Senegal, and differs from all other trypanorhynch genera in having a chainette composed of dissimilar elements, that is, double-winged hooks alternating with pairs of hooks each with a single lateral wing. The new genus is allocated to the Gymnorhynchidae Dollfus, 1935.
Challenged by an intraperitoneal injection of supplemental Glu for 10, 20, 30, and 40 days. Following these dietary treatments, the fish were fed diets containing graded levels (0%, 0.1%, 0.2%, 0.4%, 0.8%, and 1.6%) of this study evaluated the optimal concentration of the dietary incorporation for enhancing the resistance to glucan in Photobacterium damselae.
showed that cobia fed the diet containing 0.4%, 0.8%, and 1.6% Glu showed a significantly (p<0.01) enhanced resistance against *P. damselae* subsp. *piscicida*. In experiment 2, the weight gain and survival of cobia did not significantly differ (p>0.05) after being fed the diets containing 0%, 0.5%, 1.0%, and 2.0% Glu for 15 weeks. The challenge tests showed that fish fed the diet containing 0.5% Glu for 10, 20, and 30 days showed significantly (p<0.01) enhanced resistance against *P. damselae* subsp. *piscicida*. On the other hand, cobia fed the diet containing 0.5% Glu for 10 days showed significantly (p<0.001) enhanced resistance against *S. iniae*. Results obtained from the two experiments strongly demonstrated that oral administration of 0.5% Glu for 10 days enhanced the resistance of cobia against *P. damselae* subsp. *piscicida* and *S. iniae* infections.


In order to diagnose the disease of *Rachycentron canadum* suspected of lymphocystis disease, the histopathologic changes in the fish and the morphology of the virus particles were observed under optic and electronic microscope. The results showed that the papilloma tissues in the derm of the *Rachycentron canadum* were actually constituted by many lymphocystis cells which aggregated tightly. The size of the lymphocystis cells varied and ranged from 10 to 150 µm in diameter. Infected cells were round, cone-shaped or anomalous. A thick enveloped membrane layed in outside of lymphocystis cell. A lot of basophilic inclusion bodies existed in the lymphocystis cell and most of them were located on the edge of the cytoplasm. Under electronic microscope, there were a lot of particles icosahedron-shaped in the cytoplasm of infected cells and the size of the viruses was approximately 220 nm in diameter. In addition, swollen lymphocystis cells were observed in heart, liver, spleen and head kidney under optic microscope. According to the results above, the disease was diagnosed as lymphocystis disease. The main histopathologic changes of the other organs under optic microscope show that the damage to heart presents as cardiac cell vacuolar degeneration and swelling of cardiac muscle fiber; lymphocytosis and melanin-macrophage centers present in interrenal tissue and spleen; denaturalization and necrosis emerge in renal tubule epithelial cell; livers shows fatty degeneration of hepatocyte; and the gill lamellar epithelial cells are swollen.


Farming of cobia (*Rachycentron canadum*) is one of the important maricultured fish species in Taiwan. However, bacterial diseases have plagued cobia aquaculture industry. In this study, based on the growth characteristic, morphological, and biochemical properties of an isolated bacterium, from diseased fish of a were similar to those of *Photobacterium damselae* subsp. *piscicida*. The 16S rRNA sequence showed 99% identity with *P. damselae* subsp. *piscicida* (GenBank accession number AY147860). The pathogenicity experiments were tested by intraperitoneal injection (IP) in juvenile cobia (16 ~ 20 g). After 45 hours, IP at 1.2 x 10^7 CFU/ml and 1.2 x 10^8 CFU/ml of bacterial suspension did not show any clinical symptom. After 70 hours, lesions of white, circumscribed areas were scattered throughout the parenchyma of spleen, kidney and liver. Bacteria of homogenous colonies were re-isolated form spleen and kidney of moridund cobia after bacterial challenge and identified as the same species. Histologically, the acute focal necrosis with bacterial clumps were apparent. Genus-specific sequence of 16S rRNA of pasteurellosis were amplified by PCR using the Car1 and Car 2 primer. A 267 bp amplicom was observed in all the nodules organ and bacterial suspension. The technique is capable of rapid identification of the pasteurellosis in fish.


Cultured cobia, *Rachycentron canadum*, of 45-80 g exhibited anaemia and ascites, and a mottled red and grey, extremely enlarged kidney with cream-coloured patches or spherical nodules. Cumulative mortality was about 90% within 1 month. Extrasporogenic or sporogenic stages of a myxosporean appeared in the blood, glomerulus, renal tubules and renal interstitium. The renal tubules were the main target tissue of the parasite and were completely occluded by sporogenic pseudoplasmoids at various degrees of maturity. Many sporogenic stages were attached to the border of the epithelium of the renal tubules. Mature spores were seen in the lumen of the tubules. They were elongated or spherical with numerous refractile granules in the cytoplasm. The polar
filament formed 3-5 coils. No bacteria or viruses were isolated from the diseased fish. Based on the results of microbiological, histopathological and electron microscopical examinations, the cobia disease was believed to be caused by a *Sphaerospora*-like myxosporean. This is the first report of a myxosporean in cobia in aquaculture.


Establishment and characterization of two cobia, *Rachycentron canadum*, cell lines derived from cobia brain (CB) and cobia fin (CF) are described. Caudal fin and brain from juvenile cobia were dissociated for 30 and 10 min, respectively, in phosphate-buffered saline containing 0.25% trypsin at 25 °C. The optimal culture condition for both dissociated cells (primary cell culture) was at 28 °C in Leibovitz-15 medium containing 10% foetal bovine serum. The cells have been sub-cultured at a ratio of 1:2 for more than 160 passages over a period of 3 years. Origin of the cultured cells was verified by comparison of their sequences of mitochondrial cytochrome oxidase subunit I genes (cox I) with the cox I sequence from cobia muscle tissue. The cell lines showed polyploidy. No mycoplasma contamination was detected. Susceptibility to grouper iridovirus was observed for the CB cell line but not the CF cell line. Both cell lines expressed green fluorescent protein after being transfected with green fluorescent reporter gene driven by the cytokegalovirus promoter.


Viral nervous necrosis (VNN) is a worldwide disease among marine fishes. In Taiwan, VNN disease was first identified in 2 species of hatchery-reared grouper, *Epinephelus fuscoguttatus* and *E. aakaaya* in 1994. Since then, increasing mortalities have occurred among groupers *Epinephelus* spp., and also among European eels *Anguilla anguilla* L., yellow-wax pompano *Trachinotus falcatus*, firespot snapper *Lutjanus erythropterus* B., barramundi *Lates calcarifer*, cobias *Rachycentron canadum*, humpback groupers *Cromileptes altivelis* and Chinese catfish *Parasilurus asotus*. In the present study, samples were collected from affected fishes and processed for reverse transcriptase (RT) PCR amplification and virus isolation in cell culture. Infected cells (GF-1 cell line) exhibited cytopathic-effect characteristics of grouper nervous necrosis virus (GNNV). A RT-PCR product of approximately 830 bp was amplified from the brain homogenate of tested samples and sequenced. The nucleotide and deduced amino acid sequences of the amplified RT-PCR products from all isolates were strongly homologous (>97%) with the corresponding region of the published sequence of red-spotted grouper nervous necrosis virus (RGNVV). Therefore, all Taiwan NNV (nervous necrosis virus) isolates studied in this report belong to the RGNNV genotype. We used 5 neutralizing monoclonal antibodies (MAbs) against GNNV to analyze the antigenic relationship of Taiwan NNV isolates and striped jack nervous necrosis virus (SJNNV). The results of neutralization tests revealed that all Taiwan NNV isolates were closely related, but antigenically different from SJNNV in 3 neutralizing epitopes. To our knowledge, this is the first description of NNV infection in European eels, yellow-wax pompano, firespot snapper, cobia and Chinese catfish, and the first reported instance of natural NNV infection in freshwater fishes causing high mortality.


The objectives of our study is to determine the antibiotic susceptibility of this organism to different antibiotics to determine the discriminatory power of the molecular typing methods. In this study, 50 *Photobacterium damselae* subsp. *damselae* isolates from *Scomber australasicus* and *Rachycentron canadum* were collected in Taiwan and their resistance to 15 different antimicrobial agents was determined. In addition, random amplification of polymorphic DNA (RAPD) and pulsed-field gel electrophoresis (PFGE) were performed to study the epidemiology and clonal relationship of *P. damselae* subsp. *damselae*. The results showed that the 50 isolates generated 25 typeable profiles with multidrug resistance to 3-7 antimicrobials. The results also indicate that the RAPD and PFGE methods have high discriminatory power for molecular subtyping. *Photobacterium damselae* subsp. *damselae* isolates from fish to examine for multidrug resistance to antimicrobials. RAPD and PFGE methods revealed the high discriminatory power for molecular subtyping and provided information that could be used for risk assessment of *P. damselae* subsp. *damselae* infections. These results may help in epidemiological investigations of *P. damselae*.
subsp. *damselae* and may be useful in controlling or treating *P. damselae* subsp. *damselae* infections in aquaculture and clinical therapy.


Alpha-2-macroglobulin (α-2-M) is a broad spectrum protease inhibitor which is abundant in the plasma of vertebrates and several invertebrates. The α-2-M was purified from cobia (*Rachycentron canadum*) plasma by a four-step procedure: polyethylene glycol fractionation, affinity chromatography, hydrophobic interaction chromatography and ion exchange chromatography on Fast Protein liquid chromatography system in the present study. It migrated as one protein band with a molecular mass of about 360 kDa in the native state, whereas in SDS-PAGE it was about 180 kDa under non-reducing condition. This result revealed that the native protein was a dimer. In addition, it was cleaved into two different fragments of molecular mass about 93 and 87 kDa when reduced by dithiothreitol (DTT). The anti-protease activity of the purified α-2-M was apparently decreased as temperature elevated above 50 °C. The α-2-M exhibited highest protease inhibitory activity at pH 9. The results indicate that the α-2-M is a heat-labile and alkaline protease inhibitor. The purified α-2-M exhibited more than 50 protease inhibitory activity against extracellular products (ECP) of *Vibrio alginolytius* isolated from diseased cobia. It seems that the protease activities in ECP may be affected by the plasma α-2-M. The protease inhibitory activities of cobia plasma or purified α-2-M were decreased when incubated with 10 mM methylamine for 30 min. The α-2-M cDNA consisted of 4611 bp with an open reading frame of 4374 bp had been cloned from cobia liver. This sequence contained thioester domain (GCGEQ) and thirteen predicted N-linked glycosylation sites. In addition, the amino acid sequence of thioester domain and genes of adjacent regions of cobia α-2-M were further compared with sequences of known fish species in GenBank. The unweighted pair group method using arithmetic average (UPGMA) was employed to construct the phylogenetic trees of α-2-M among different fish species (freshwater fish, sea water fish and primitive fish), and all these fish species were then clustered into three groups. The cobia α-2-M was closer to that of sea water fish than that of freshwater fish based on its similarity of amino acid sequence and phylogenetic analysis of the partial gene.


This work reports the isolation of a serum lectin from cobia fish (*Rachycentron canadum*) named RcaL. Immunomodulatory activity on mice splenocyte experimental cultures through cytotoxic assays and cytokine production were also performed. RcaL was obtained through precipitation with ammonium sulphate and affinity chromatography on a Concanavalin A-Sepharose 4B column. The ammonium sulphate fraction F3 showed the highest specific hemagglutinating activity and was applied to affinity chromatography. The lectin was eluted with methyl-α-D-mannopyranoside. RcaL showed highest affinity for methyl-α-D-mannopyranoside and D-mannose; eluted fractions of RcaL agglutinated rabbit erythrocytes (titre, 128°) retained 66 % of chromatographed lectin activity, and the obtained purification factor was 1.14. Under reducing conditions, a polypeptide band of 19.2 kDa was revealed in sodium dodecyl sulphate polyacrylamide gel electrophoresis (PAGE). PAGE confirmed RcaL as an acidic protein revealed in a single band. Cytotoxic and immunomodulatory assays with RcaL in mice splenocyte cultures showed that the lectin was not cytotoxic and induced higher interferon gamma and nitric oxide production in splenocyte cultures. Purified RcaL induced preferential Th1 response, suggesting that it acts as an immunomodulatory compound.


Direct attachment of *C. virgatum* to the halfbeak *Hyporhamphus unifasciatus* and to the copepod *Lernaeolophus sultanus* parasitizing a cobia, *Rachycentron canadum*, is reported from Mississippi waters. A list of the fishes known to be associated with this barnacle is provided.

Three new species of *Goezia* from fishes in North America are described and supplemental data for *G. minuta* and several unidentified adults and larvae are presented. Males, especially their caudal papillae, are necessary to identify most species. For the new species, *G. pelagia* sp. nov. from *Rachycentron canadum* and *Chaetodipterus faber* in the northern Gulf of Mexico possesses 12-19 preanal, two para-anal, and four postanal pairs of papillae: *G. kliksi* sp. nov. from *Pogonias cromis* in Lake Borgne, Louisiana, has 10-16 preanal, two para-anal, and five postanal pairs of papillae, and *G. sinamora* sp. nov. from *Tilapia aurea, Micropterus salmoides,* and *Morone saxatilis* in freshwater habitats in Florida possesses 13-16 preanal, two para-anal, and three postanal pairs of papillae. Records on several unidentified females without corresponding males and other assorted specimens are included to reveal a more complete understanding of hosts and localities for species of *Goezia.* Characteristics provided in a table distinguish the 18 nominal species parasitizing both fishes and aquatic reptiles throughout the world. Observations are also provided on pathology, attachment, and life histories of selected species. Whereas most species of *Goezia* cause conspicuous lesions in fishes, few infected fishes are actually diseased. Also, those diseased fishes are often components of recently established host-parasite relationships.


The present study was performed to investigate the effects of various levels of dietary *Bacillus subtilis* and chitosan on the growth performance, non-specific immunity and protection against *Vibrio harveyi* infection in cobia, *Rachycentron canadum.* Fish were fed with the control diet and six different experimental diets containing three graded levels of *B. subtilis* at $2 \times 10^9$ CFU g$^{-1}$ (0.0, 1.0, 2.0 g kg$^{-1}$ diet) for each of two levels of chitosan (3.0 and 6.0 g kg$^{-1}$ diet). The results of 8 weeks feeding trial showed that the survival rate ranged from 81.3% to 84.0% with no significant difference ($P>0.05$). The SGR (%) in the fish fed with dietary treatments was significantly higher than that of the control fish except diet 6 group with 2.0 g kg$^{-1}$ *B. subtilis* and 3.0 g kg$^{-1}$ chitosan. The serum lysozyme activities were significantly higher in 6.0 g kg$^{-1}$ chitosan groups and no significant differences were observed among *B. subtilis* levels. The serum ACP activities were significantly higher in 3.0 g kg$^{-1}$ chitosan groups at 0.0 and 1.0 g kg$^{-1}$ *B. subtilis* levels; at low chitosan level, the cobia fed diets with 1.0 g kg$^{-1}$ *B. subtilis* had significantly higher serum ACP activity, but at high chitosan level, the cobia fed diets with 2.0 g kg$^{-1}$ *B. subtilis* had significantly higher serum ACP activity. The phagocytosis and respiratory burst activity in the fish fed with dietary treatments was significantly higher than that of the control fish except diet 3 group with 6.0 g kg$^{-1}$ chitosan. Moreover, fish fed the diet containing 2.0 g kg$^{-1}$ *B. subtilis* and 6.0 g kg$^{-1}$ chitosan had significantly higher post-challenge survival on the 7th day following *V. harveyi* infection and post-challenge survival showed clearly the synergistic effect of chitosan and *B. subtilis.* Based on these results, the combination of 1.0 g kg$^{-1}$ *B. subtilis* and 6.0 g kg$^{-1}$ chitosan is optimal for the growth, innate immunity and disease resistance of cobia with an 8-week oral administration.


The present study was performed to investigate the effects of a commercially available probiotic product (compound probiotic) containing *Bacillus subtilis* $7.0 \times 10^6$ CFU g$^{-1}$, *Bacillus licheniformis* $3.0 \times 10^6$ CFU g$^{-1}$, *Lactobacillus* spp. $5.0 \times 10^6$ CFU g$^{-1}$ and *Arthrobacter* spp. $1.0 \times 10^6$ CFU g$^{-1}$ on the growth performance, non-specific immunity and protection against *Vibrio harveyi* infection in cobia (*Rachycentron canadum*). Fish were fed diets containing six graded levels of compound probiotic (0.0, 1.0, 2.0, 3.0, 4.0 and 5.0 g kg$^{-1}$) for 8 weeks. The results showed that the survival rate ranged from 81.1% to 84.4% with no significant difference among dietary treatments ($P>0.05$) after feeding experiment. Dietary compound probiotic significantly increased the specific growth rate (SGR), serum lysozyme, alternative complement pathway (ACP) activity, phagocytosis percentage (PP) and respiratory burst activity of head-kidney macrophages of cobia. Moreover, feeding of supplemented diets containing compound probiotic resulted in significantly lower mortality against the pathogens *Vibrio harveyi* compared with the control group. To elevate the growth and immune resistance ability of cobia, an optimal dose of dietary compound probiotic administration determined by second-order polynomial regression analysis was 3.3 g kg$^{-1}$, on the basis of the SGR and mortality after challenge with *V. harveyi.*

Evidence indicates that the worm infection causes hyperplastic, metaplastic and hypertrophic changes involving respectively connective tissue, epithelial and muscle cells of the fish intestine. The worm attachment to the intestinal wall causes destruction of the villi, degeneration and necrosis of the mucosal epithelium. Cell types resembling epitheloids, lymphocytes, macrophages and cells of unknown identity aggregate at the infected area in response to inflammation. Excessive mucus secretion has also been observed.


The research of probiotics for aquatic animals is increasing with the demand for environment-friendly aquaculture. The candidate probiotics were isolated from the waste liquid produced during the fermentation process of hydrogen generation and based on their *in vitro* antagonistic activity towards aquatic pathogens to screen and evaluate their application in aquaculture in this study. The waste fermented liquid showed significant antagonism to *Vibrio vulnificus*, *Listonella anguillarum*, *Photobacterium damselae* subsp. *piscicida* and *Streptococcus* sp. Of the 4 strains isolated from the fermented waste liquid, 2 fulfilled the probiotic criteria of inhibiting the growth of aquatic pathogens, not causing mortality of cobia (*Rachycentron canadum*) following oral administration at 10^7-10^8 CFU/ml bacterial concentration, and increasing the growth and survival of copepod *Pseudodiaptomus annandali* by incubation in bacterial suspension of 10^7-10^8 CFU/ml and microalgae (*Isochrysis galbana* tmi) together. Antagonistic activities of potential probiotics through 4.5- and 24-hour incubation before pathogen inoculation were better than no pretreatment.


Photobacteriosis and streptococcosis are the most threatening diseases in cage-cultured cobia, *Rachycentron canadum*, due to high mortality of 50-80% and annual outbreaks in Taiwan. Garlic, *Allium sativum*, has long been known to have broad antibacterial properties. This study aimed to examine the *in vitro* antibacterial activities of garlic and the effects of dietary garlic on disease resistance against *Photobacterium damselae* subsp. *piscicida* and *Streptococcus iniae* and on growth in cobia. The results revealed the marked inhibitory effect of garlic against both *P. damselae* subsp. *piscicida* and *S. iniae*, and feeding garlic diet significantly conferred resistance to challenge with *P. damselae* subsp. *piscicida* or *S. iniae*. Cobia fed garlic powder at doses of 0.5 and 1.5g/kg b.w. for 28days produced significantly (p<0.05) lower mortality after a challenge with *P. damselae* subsp. *piscicida* and higher percent weight gain. Cobia fed garlic powder at a dose of 1.2g/kg b.w. for 21days and at doses of 0.4 and 1.2g/kg b.w. for 28days provided significant (p<0.01) resistance against *S. iniae* infection. A diet containing garlic powder at a dose of 1.2g/kg b.w. for 28days provided significant (p<0.05) protection against *P. damselae* subsp. *piscicida* plus *S. iniae* combined infection in cobia.


A pathogenic bacterial strain JT2 was isolated from cobia (*Rachycentron canadum*). Morphological observation showed that it was a mobile short-rod gram negative bacterium with polar flagella and translucent. It was proved to be the pathogen of the cobia (*Rachycentron canadum*) by the challenge test. The traditional physiological and biochemical experiments were done, and API-1D32E system were applied in the bacterial classification. Identified with Biolog-GN (gram negtive) system again, results showed that strain JT2 was similar to that of *Vibrio carchariae* in most of the phenotypes. To investigate the phylogenetic position of this pathogen, 16S rDNA of JT2 was sequenced and compared with that of other related strains. Molecular phylogenetic dendrogram was constructed based on the genetic distance analysis. The results showed that strain JT2 exhibited the highest
levels of similarity to the *V. carchariae*. Analysing all the results of several methods, strain JT2 was identified as *Vibrio carchariae*.


Viral nervous necrosis (VNN) has spread worldwide among cultured marine fish with the number of susceptible host species continuing to grow (Munday and Nakai 1997). Affect fish exhibit a range of neurological signs, such as abnormal swimming behaviour and pale-grey discoloration of the body. In Khanh Hoa (Viet Nam), grow-out fish (*groupers*-Epinephelus spp., sea bass-Lates calcarifer and cobia Rachycentron canadum) had been suffering from a disease characterized by similar clinical signs with high mass mortality. Histological investigations in moribund fish revealed marked vacuolation in the retina and brain. The size of vacuolation was varying from 4-30 µm with different shape from oval to circle. These results indicate the presence of VNN in cultured marine fish in Khanh Hoa.


Four species of sea lice were found parasitic on ten species of marine fishes either cultured in the coastal ponds or occurring in the sea water supply canals in the Philippines. They are: *Caligus epidemicus* Hewitt, 1971 on Acanthurus mata (Cuvier), Epinephelus coioiodes (Hamilton), Glossogobius celebius (Valenciennes), Liza parma (Cantor), Lutjanus argentimaculatus (Forsskael), Monodactylus argenteus (Linnaeus), Oreochromis urolepis hornorum (Trewavas), Oreochromis mossambicus (Peters), Rachycentron canadum (Linnaeus), and Siganus guttatus (Bloch); *Caligus quadratus* Shiino, 1954 on L. argentimaculatus and S. guttatus; Lepeophtheirus sigani n. sp. on S. guttatus; and Pseudoaligus uniartus n. sp. on S. guttatus and L. argentimaculatus. These ten species of fishes are new host to *C. epidemicus*, except for *O. mossambicus* which has been reported to carry *C. epidemicus* from Taiwan. *Caligus quadratus* is new to the Philippines and the two species of fish harboring it are the new host. While *L. sigani* was found only on *S. guttatus*, *P. uniartus* was recovered mostly from *S. guttatus*, and *C. quadratus*, largely from *L. argentimaculatus*. *Caligus epidemicus* exhibits extremely low host specificity and was found on all species of fishes examined.


Cobia, Rachycentron canadum L., is a very important aquatic fish that faces the risk of infection with the bacterial pathogen *Photobacterium damselae* ssp. *piscicida*, and there are few protective approaches available that use multiple antigens. In the present study, potent bivalent antigens from *P. damselae ssp. piscicida* showed more efficient protection than did single antigens used in isolation. In preparations of three antigens that included recombinant heat shock protein 60 (rHSP60), recombinant α-enolase (rENOLASE) and recombinant glyceraldehyde-3-phosphate dehydrogenase (rGAPDH), we analysed the doses that elicited the best immune responses and found that this occurred at a total of 30 µg of antigen per fish. Subsequently, vaccination of fish with rHSP60, rENOLASE and rGAPDH achieved 46.9, 52 and 25% relative per cent survival (RPS), respectively. In addition, bivalent subunit vaccines - combination I (rHSP60 + rENOLASE), combination II (rENOLASE + rGAPDH) and combination III (rHSP60 + rGAPDH) - were administered and the RPS in these groups (65.6, 64.0 and 48.4%, respectively), was higher than that achieved with single-antigen administration. Finally, in combination IV, the trivalent vaccine rHSP60 + rENOLASE + rGAPDH, the RPS was 1.6%. Taken together, our results suggest that combinations of two antigens may achieve a better efficiency than monovalent or trivalent antigens, and this may provide new insights into pathogen prevention strategies.


The occurrence of *Parapetalus occidentalis* Wilson (Copepoda, Caligidae) on sea cage-cultured cobia (*Rachycentron canadum*) at Penghu Islands (Pescadores) was reported. *P. occidentalis* was specific to cobia among the Penghu sea cage-cultured fish. Two health conditions of cultured cobia (healthy market size and diseased juvenile) were examined. The abundance of *P. occidentalis* on
market-size cobia cultured in Erkan, Chiyuan and Chuwan farming areas was 0.04, 7.39, and 6.17, respectively; however, on moribund cobia, these values were 0.47, 29.58, and 7.20, respectively. The overall sex ratio of adult *P. occidentalis* (1932 parasites) on cobia was 10.3: 1, females to males. The fecundity of gravid female *P. occidentalis* averaged 120 eggs per parasite. Tentative treatments were performed by completely enclosing the cage within tarpaulins; treatment with 10 ppm Parasiticide-MS for 1 h was efficacious at removing *P. occidentalis* from cobia, without toxic side effects to the treated fish. Although *P. occidentalis* has not yet caused a serious problem for Penghu cobia aquaculture, its high abundance makes it as a potentially serious risk.


Acute bacterial septicemic infection in sea cage-cultured juvenile cobia (*Rachycentron canadum*) has occurred at Penghu (Pescadores) Islands, Taiwan, since October of 1999 with a 30-80% mortality rate. Diseased fish exhibited no apparent surface lesions; however, the kidney and spleen demonstrated swelling and white tubercles. The bacterium was identified as *Photobacterium damselae* ss. *piscicida*, based on the results of the API-20E system and Bioron Mono-Pp kit. The pathogenicity of the isolate to cobia was confirmed by intraperitoneal injection and immersion. From histological examinations, multifocal necrosis and/or granulomatatous inflammation were found in tissue sections. Drug sensitivity testing indicated this pathogen were sensitive to amoxicillin, chloramphenicol, oxolinic acid, oxytetracycline, trimethoprim-sulfamethoxazole (SXT), and flumequine in 1999. However, amoxicillin-, chloramphenicol-, and oxytetracycline-resistant *Photobacterium damselae* ss. *piscicida* were isolated in 2000. SXT-, oxolinic acid- and flumequine-resistant *P. damselae* ss. *piscicida* were isolated from sea cage-cultured cobia at Penghu in 2002, 2006, and 2007, respectively.


In recent year, the iridoviral infections in marine-culture fish have become a problem in aquaculture in Taiwan. The host range includes many seawater fish like red sea bream, grouper, perch and cobia. An iridoviral agent was isolated from disease grouper. Based on its general properties and viral morphology, we propose the name Grouper iridovirus of Taiwan (TGIV). Diseased fish observed an enlarged spleen and the hypertrophy cell observed in liver, spleen, kidney and gills. These kinds of pathological changes were similar with iridoviral infection of red sea bream (RSIV) in Japan. This study first use the cell line we had established, grouper swim bladder cell (SB cell) and grouper brain cell (GB), and other two fish cell lines GF cell (grouper fin cell) and BF-2 cell (blue-gills fish fin cell). In the susceptibility study, TGIV and RSIV were inoculated onto the cell line we established, grouper swim bladder cell (SB cell); grouper brain cell (GB), and other two fish cell lines GF cell (grouper fin cell) and BF-2 cell (blue-gills fish fin cell). GB cell (grouper brain cell), GF cell (grouper fin cell) and BF-2 cell (blue-gills fish fin cell). Compared the susceptibility of virus infect cell, TGIV inoculated onto SB cells appeared cytopathic effect of cell rounding. That's RSIV tend to propagated in GF cells. Otherwise, use TGIV and RSIV primer for PCR, and the result showed the RSIV primer can detect the TGIV from virus challenge fish. And the same result in use TGIV primer to detect RSIV. Further use the anti-RSIV monoclonal antibody immunofluorescent staining, compared with strong signal in positive control (RSIV), the fluorescent found in TGIV was slight. Those results showed the two viruses were similar but there's a little different between them. In addition, the ill cobia and giant perch were iridoviral-like infectious and the virus isolation and PCR detection were analysis. The cytopathic effect observed on SB cells. For PCR detection, there's only primer sets referred to RSIV could amplified the viral DNA and no PCR product was amplified use TGIV primer sets.


Two experimental runs were undertaken to assess the effect of levamisole supplementation on the non-specific immunity of cobia fingerlings, as well as on its resistance to *Photobacterium damselae* subsp. *piscicida* infection. Levamisole was given to cobia fingerlings through feed incorporation at a dosage of 500 and 1000 mg/kg feeds. Control feed is without levamisole. Cobia fingerlings were
fed to satiation with control and levamisole supplemented feeds for two weeks. One day after the last feeding, blood was collected from 10 fish samples from each replicate for the analysis of non-specific immune response, including potential killing and phagocytic activities of blood leukocytes and bactericidal and lysozyme activities of blood plasma. Challenge experiment using P. damsela subsp. piscicida was also undertaken after the immunostimulation. Five (Run I) and 15 (Run II) experimental and control fish were intraperitoneally injected with 10⁶ CFU/fish, and mortality was monitored up to five days post-injection. Results show that levamisole supplementation has no significant effect on lysozyme activity of blood plasma. Bactericidal activity, on the other hand, is significantly higher (P<0.05) in levamisole treated fish than the control fish. Potential killing activity of blood leukocytes also increased significantly (P<0.05) in levamisole treated fish compared to the control. Similar results were obtained for phagocytic activity of blood leucocytes where higher index of phagocytosis was observed in cobia fingerlings fed with levamisole supplemented feeds. Dose-response was also observed in the activities of blood leukocytes with higher killing activities at 1000 mg/kg dose than at 500 mg/kg dose. Significantly lower (P<0.05) cumulative mortality was observed in immunostimulated fish (16-30%) than control fish (70-93%) after experimental challenge with P. damsela subsp. piscicida. Results of this study showed that levamisole can enhance the non-specific immune response of cobia fingerlings, thus increasing its resistance to potential infection.


The farming of new fish, cobia (Rachycentron canadum) began in Taiwan several years ago. Soon after the initial 3 years of farming, the average survival rate fell below 20%. The major pathogens were identified as Vibrio alginolyticus, V. parahaemolyticus and Photobacterium damsela subsp. piscicida. In this study we used the inactivated pathogens as antigen to immune cobia. The effectiveness of this multivalent vaccine was evaluated by the serum antibody as assayed and level of protection after challenge in an aquarium trial, and in an actual cage farm trial.


Cobia (Rachycentron canadum), a warm water fish recently commercially cultured in Taiwan, has encountered severe mortalities with survival rates often below 20%. The major causative pathogens were Vibrio alginolyticus, Vibrio parahaemolyticus and Photobacterium damsela subsp. piscicida. We prepared a combined three inactivated bacterins antigen preparation and vaccinated cobia. This mixture of bacterins was safe, and the immune response in cobia stimulated specific antibody in 1 week that remained for at least 6 weeks until the end of the aquarium trial. Its efficacy in protecting fish was evaluated in aquarium and field trials. In the aquarium challenge, the vaccine gave a relative percentage survival of 93.8%, 91.1% and 84.7% after challenge with V. alginolyticus, V. parahaemolyticus and P. damsela subsp. piscicida, respectively. In two farm trials using two batches of fish from different hatcheries, one vaccination gave a survival rate of 86-92%. A single vaccination of three combined inactivated bacteria into cobia elicited specific antibodies, and protected fish in both the laboratory aquarium challenge and a farm trial.


This study investigated the pathogenesis of Photobacterium damsela subsp. piscicida, isolated from swollen kidney of diseased cobia (Rachycentron canadum) in the fish. The virulence tests were conducted in cobia (10 g) and the LD₅₀ values of P. damsela subsp. piscicida was 1.03×10⁵ cfu/g fish body weight; the LD₅₀ value of extracellular products (ECP) from P. damsela subsp. piscicida in cobia (10 ± 0.5 g) was 126 μg protein/g fish body weight. Phospholipase was partially purified from ECP of P. damsela subsp. piscicida by using anion exchange columns (Q Sepharose High Performance, RESOURCE Q and Mono Q) on High Performance Liquid Chromatography (HPLC). Partially purified phospholipase fraction contained 30 kDa and 14.3 kDa protein band on SDS - PAGE, and the 14.3 kDa protein band exhibiting phospholipase activity on Native - PAGE. The partially purified phospholipase was lethal to cobia. All the cobias were killed after intraperitoneal (i.p.) injection of the partially purified phospholipase with a dose of 7 pg protein/g fish body weight.
within 72 hours. This phospholipase may play an important role in the pathogenesis of _P. damsela subsp. piscicida_ infection in the cobia.


An outbreak of serious mortality among the cultivated juvenile cobia _Rachycentron canadum_ L. (weighing 8-10 g) characterized by a swollen intestine containing transparent yellow fluid (ascites and gastroenteritis) occurred in August 2001 in Taiwan. Ten motile bacterial strains, C3d1-C3d10, were isolated from head kidney (an organ located near the head of the fish) and/or the intestinal yellow fluid on tryptic soy agar supplemented with 1% NaCl (TSA1) and/or thiosulphate citrate bile salt sucrose (TCBS) agar plates. These strains were characterized and identified as _Vibrio harveyi_ (V. carchariae) on the basis of biochemical characteristics, and comparisons with those of three reference strains, originally identified as _V. harveyi_ or _V. carchariae_. The strain C3d1 was selected as a representative strain for virulence tests and was found lethal to the cobia with an LD_{50} value of 7.48×10^4 colony forming units g^{-1} fish body weight. All the moribund/dead fish exhibited gastroenteritis as that observed in natural outbreak. The same bacteria could be reisolated from kidney and the transparent yellow fluid of swollen intestine of fish after bacterial challenge using TSA1 and TCBS plates. This is a first report showing that _V. harveyi_ (V. carchariae) is the causative agent of gastroenteritis in the cobia.


The first documented outbreak of monogenean and myxosporean parasites associated vibrosis and photobacteriosis in cobia _Rachycentron canadum_ cultured in the Penghu islands of Taiwan is reported. Monogenean infested fish showed dark skin pigmentation, haemorrhage and severe ulcer on the head. Microbial analysis of these fish revealed the presence of _V. alginolyticus_, _V. vulnificus_ and _V. parahaemolyticus_. Internally affected fish with no apparent external indications showed paleness of liver and kidney and white tubercles in the spleen. A pure culture of bacteria isolated from these organs was biochemically characterised as _Photobacterium damselae_ ssp. _piscicida_ (Ph. _D. piscicida_). Myxosporean parasite was found in the renal tubules.


The fast growth and high feed conversion rate of cobia make it become a new potential species for marine cage culture. However, the disease cause by parasites, bacteria and viruses is one of the major hurdles of cobia culture. Because there is no cure for virus diseases, the cloning and characterization of MX gene that is related to virus tolerance of other land animals are conducted. The total length of MX cDNA is cloned by PCR with degenerate primers, and RACE. Six hours after the adding of 50ng/kl of poly I:C, the inducibilities of MX expression are found in cobia cell lines derived from brain, and kidney. Cloning and analysis of MX promoter is being conducted.


Cobia, _Rachycentron canadum_, is the only member of the family Rachycentridae (Order Perciformes) and as a warm-water fish is to be found in tropical and subtropical waters. The species has been reported in eastern Mediterranean waters and it is likely that in this particular case, cobia is lessesian. Cobia has been farmed in Taiwan since the early 1990s and today nascent cobia aquaculture operations operate throughout South East and Eastern Asia, in Gulf of Mexico and Caribbean Sea as well as in the United States. Many other nations are presently considering adopting cobia as a new species for aquaculture. Production by aquaculture experienced a 7000-fold increase from 1995 to 2005. The increased interest in the species has evolved due in large part to its many excellent characteristics which include good growth, with production of 6 kg live weight fish being possible over a year-long production cycle. Cobia are accepting of pond, net pens and recirculation-based culture; their fillet quality is high and meat delectable; They readily take formulated feeds and respond well to alternate proteins in their diets. Like other species new to aquaculture however, enlarged farming activities have been accompanied by increased incidence of commonly-encountered and emerging diseases. As an aid to current and potential producers as well
as researchers, the following provides an overview of the published literature on cobia diseases, parasites and physical deformities.


Aquaculture of cobia has gained popularity in the last decade, and this species is now farmed in several countries in Latin America and Asia. Despite recent improvement in production techniques that allowed the expansion of the industry, little is known about the diseases that affect cobia during the larviculture stage. In this article we investigated the cause of mass mortalities occurring 13-20 d post-hatching in 3 cycles of cobia larviculture. Wet mounts from diseased larvae gills revealed the presence of cyst-like basophilic inclusions. DNA from the cysts was extracted and PCR amplified using the 16S rRNA gene universal primers for prokaryotes. The amplified products were sequenced and analyzed using BLAST, finding a similarity of 99% with Endozoicomonas elysicola, a Gram-negative bacterium. Confirmation of E. elysicola was conducted by designing a specific probe for in situ hybridization. Specific primers were also designed for diagnostic purposes. This is the first report of epitheliocystis in cobia larvae and also the first report of E. elysicola as an epitheliocystis-causing agent.


Monogenoideans infecting the rectum of the wild checkered puffer fish, Sphoeroides testudineus (Tetraodontidae), and the pyloric ceca of the cultured cobia, Rachycentron canadum (Rachycentridae), from the northern coast of the Yucatan Peninsula, Mexico, were morphologically identified as Pseudempleurosoma carangis Yamaguti, 1965 and Pseudempleurosoma gibsoni Santos, Mourão and Cárdenas, 2001 (Dactylogyridae), respectively. Morphometric comparison between the paratypes of P. carangis and those from S. testudineus showed that the latter differ only in the length of the body, germarium, and dorsal anchors. Similarly, a small form of P. gibsoni based on body size was detected in the present study. These metric differences may be attributable to the host effect, i.e., S. testudineus / R. canadum versus Caranx lugubris (Carangidae) (type host of P. carangis) from Hawaii and Paralichthys filamentosus (Sciaenidae) (type host of P. gibsoni) from Brazil, or by the degree of maturity, or both. In view of these considerations, new illustrations and several supplemental observations for P. carangis and P. gibsoni are provided. The present findings also represent new geographical records, and new sites of infection, e.g., rectum and pyloric ceca, for species of Pseudempleurosoma, and the first known endoparasitic monogenoideans infecting tetraodontid and rachycentrid fishes in Mexico.


Two new species of philometrid nematodes, Philometra gymnothoracis n. sp. and Philometroides marinus n. sp., are described from female specimens collected from the body cavity of the spotted moray, Gymnothorax moringa (Cuvier) (Muraenidae, Anguilliformes), and the cobia, Rachycentron canadum (Linnaeus) (Rachycentridae, Perciformes), respectively, from off the Atlantic coast of South Carolina. Philometra gymnothoracis n. sp. is mainly characterized by the conspicuously depressed mouth, the presence of 8 small cephalic papillae arranged in 4 submedian pairs, the esophagus with an anterior bulbous inflation, 2 small papilla-like caudal projections, the body length of the gravid female 435-760 mm, short ovaries, the length of larvae from the uterus 474-544 μm, and by the location in the host (body cavity). Philometroides marinus n. sp. differs from its congeners parasitizing marine and brackish water fishes mainly in having small cuticular bosses only on the anterior part of the body; in possessing 4 markedly large cephalic projections, each with 2 minute papillae, 2 large caudal projections, and in the location in the host (body cavity); the body length of subgravid and gravid females is 130-550 mm and that of larvae from the uterus 600-642 μm

Eight species of Hemiuroidea are reported: Allostomachicola secundus Yamaguti, 1958 from Chirocentrus nudus (Chirocentridae); Ectenurus trachuri from Trachurus trachurus, Caranx kalla, Scomberoides commersonianus (Carangidae) and Rachycentron canadum (Rachycentridae); Erilepturus hamati Manter, 1947 from Lutjanus russelli (Lutjanidae), Otolithes ruber (Sciaenidae), Pseudorhombus hirsutus (Bothidae), Scomberoides commersonianus (Carangidae) Therapon sp. (Theraponidae); Lectichocidium angustovum Yamaguti, 1953 from Caranx kalla (Carangidae); Lectichocidium acutum, Chauhan, 1945 from Trichiurus lepturus (Trichiuridae), Aponurus laguncula Looss, 1907 from Siganus oramin (Siganidae); Lecithaster indicus Srivastava, 1935 from Otolithes ruber; Aphanurus sossichii Looss, 1907 from Sardinella perforata, Ilisha elongata (Clupeidae), Thryssa whiteheadi (Engraulidae) and Mulloidichthys auriflamma, (Mullidae).


For the purpose of this chapter, red sea bream iridovirus disease (RSIVD) is caused by infection with red sea bream iridovirus. RSIVD is a significant cause of mortality in farmed red sea bream (Pagrus major) and more than 30 other species of cultured marine fish belonging mainly to the orders Perciformes and Pleuronectiformes. The first outbreak of RSIVD was recorded in cultured red sea bream in Shikoku Island, Japan in 1990. Since then, the disease has caused mass mortalities in cultured fish populations in the western part of Japan, mainly among juvenile red sea bream. Affected fish become lethargic, exhibit severe anaemia, petechiae of the gills, and enlargement of the spleen. The disease is characterised by the appearance of enlarged cells stained deeply with Giemsa solution in the histopathological observations of the spleen, heart, kidney, intestine and gill of infected fish. Following an account of some general information for the design of surveillance programmes, details are given of some diagnostic methods. The methods currently available for surveillance, detection, and diagnosis of RSIVD are listed in a table, together with their ratings against purpose of use. Corroborative diagnostic criteria and diagnostic/detection methods to declare freedom are also included.


A tetrameric lectin, with hemagglutinating activity toward rabbit erythrocytes and with specificity toward d-mannosamine and d(+)-mannose, was isolated from the ovary of a teleost, the cobia Rachycentron canadum. The isolation protocol comprised ion exchange chromatography on CM-cellulose and Q-Sepharose, ion exchange chromatography by fast protein liquid chromatography (FPLC) on Mono Q, and finally gel filtration by FPLC on Superose 12. The lectin was adsorbed on all ion exchangers used. It exhibited a molecular mass of 180 kDa in gel filtration on Superose 12 and a single 45-kDa band in sodium dodecyl sulfate-polyacrylamide gel electrophoresis, indicating that it is a tetrameric protein. The hemagglutinating activity of the lectin was stable up to 40 °C and between pH 4 and pH 10. All hemagglutinating activity disappeared at 60 °C and at pH 1 and pH 13. The hemagglutinating activity was doubled in the presence of 0.1 μM FeCl3. The lectin exerted antibacterial activity against Escherichia coli with 50% inhibition at 250 μg. There was no antifungal activity toward Coprinus comatus, Fusarium oxysporum, Mycosphaerella arachidicola, and Rhizoctonia solani at a dose of 300 μg. The lectin exhibited maximal mitogenic response from mouse splenocytes at a concentration of 14 μM.


Vibrio alginolyticus was isolated from cobia (Rachycentron canadum) for the first time from floating marine cages placed near the Penghu Island, Taiwan during an epizootic outbreak in October of 2000. The identity of the isolate was confirmed as Vibrio alginolyticus by biochemical test. The epizootic was effectively controlled by the oral administration of oxytetracycline.


To detect Photobacterium damselae ssp. piscicida using the PCR technique and plating method. Two strains of P. damselae ssp. piscicida were isolated from cultured cobia (Rachycentron canadum) at two different fish farms in Taiwan. A pair of primers was designed to detect the
capsular polysaccharide gene of *P. damselae* ssp. *piscicida* by PCR. Reference strains of different genus and different clinical strains were used for this study. The expected product (410 bp) was obtained from both *P. damselae* ssp. *piscicida* and *P. damselae* ssp. *damselae*, and they were differentiated by culturing on thiosulphate citrate bile salts-sucrose agar (TCBS-1). *Photobacterium damselae* ssp. *damselae* grew on TCBS-1 producing green colonies whereas *P. damselae* ssp. *piscicida* did not grow. The methods used are cost and labour effective when compared with the other methods and commercially available kits. This work provides an integrated set of methods to identify the species *P. damselae* and to differentiate *P. damselae* ssp. *piscicida* from *P. damselae* ssp. *damselae*.


The occurrence of disease caused by *Vibrio alginolyticus* in sea cage farming of hatchery produced cobia juveniles is reported in this paper. The affected animals showed signs of surfacing, sluggish swimming and bilateral exophthalmia followed by acute mortality. The bacterial pathogen *Vibrio alginolyticus* was isolated from systemic lesions of infected moribund cobia fingerlings which was confirmed based on biochemical characteristics. Further the 16S ribosomal RNA of the isolate was amplified and BLAST analysis of the sequence confirmed that the pathogen is *V. alginolyticus*. Histologically, the liver of affected fish showed fatty change, the eyes revealed congestion as well as infiltration of polymorphonuclear cells in the choroid layer and acute glomerulonephritis was observed in the kidney.


A new species of *Parapetalus* collected from the fish *Rachycentron canadus* (Linnaeus) is described in detail. Affinity of this species is discussed with other related members of the genus.


The first confirmed case of *Anisakis simplex* infection of the marine cage cobia, *Rachycentron canadum* (L.), was recorded in Taiwan. The case investigation revealed the presence of third-stage larvae (L3) in either the stomach lumen or abdominal cavity of the cobia but never within the musculatures. Larvae were mainly encapsulated in the peritoneal mesentery on the outer surface of the stomach wall and occasionally on the liver surface. Part of the diet fed to the cobia includes chopped raw fish, and of these, seven species were found to harbor these larvae (as paratenic hosts), indicating that these particular fish might be the larval sources for this infection. To illustrate the course of infection and distribution of this parasite inside cobia, both juvenile and adult cobia were experimentally infected with live L3 by oral transmission. The prevalence of infection reached 100% at the end of all trials. The course of the infection was assessed after necropsy by histological and ultrastructural observations. A. simplex L3 recovered from various locations within juvenile cobia at different post-infection (p.i.) times were at the L3 stage and did not grow significantly. The L3 either adhered to or penetrated into the gastric mucosa of cobia by 2 h p.i. By 25 d p.i., many were trapped within the submucosa and encapsulated by fibroconnective tissue. This phenomenon was more apparent in adult cobia, such that 37.5-86.0% of the injected L3 were primarily found encapsulated within the gastric submucosa. Based upon a PCR-RFLP assay, the larvae encountered in this study were identified as having a recombinant genotype of *A. simplex* sensu stricto and *A. pegreffii*. Based upon the results of this study, strategies to ensure the safety of seafood manufactured from cobia and to prevent the potential risks of anisakiasis or allergies risk to consumers were suggested.


Antibiotic susceptibility tests were carried out by K-B diffusion method on 41 vibrio strains isolated for one year both from farming seawater (18 strains) and digestion guts (23 strains) of the cobia, *Rachycentron canadum*. We chose 10 different species of antibiotics and refered to NCCLS
performance standards for antimicrobial susceptibility testing, while taking *Staphylococcus aureus ATCC25923* and *Escherichia coli ATCC25922* to control the test. Results showed that the most effective antibiotic for inhibiting growth of vibrio strains were Chloramphenicol (percentage of sensitive strains was 100%) and Gentamicin (percentage of sensitive strains from water and intestine was 100% and 90% respectively), followed by Norfloxacin, Compound Sulfamethoxazole Polymyxin B. It also showed that Penicillin G and Ampicillin were non-effective to majority of vibrio strains in the intestine, as 78% and 60% strains resisted to Penicillin G and Ampicillin respectively. Strains from farming water and intestine of cobia showed different sensitivity to the same antibiotic. 4 strains which resisted to 3 or more than 3 species antibiotics were sieved from this study.


Lymphocystis disease virus (LCDV) is the causative agent of lymphocystis disease. In this study, the mcp gene of LCDV and the cty b gene of the host fish were selected as molecular markers, and the phylogenetic relationships between LCDV and its host were analyzed. The 25 LCDV isolates examined in this study were attributed to seven LCDV genotypes: genotype I (LCDV-1), genotype II (LCDV-cn, etc.), genotype III (LCDV-rf), genotype IV (LCDV-rc and LCDV-sb), genotype V (LCDV-cb), genotype VI (LCDV-tl), and genotype VII (LCDV-sa). Genotype VII is a new genotype. LCDV1 was found to have differentiated first, followed by LCDV-rf; then LCDV-tl; LCDV-cb; and then LCDV-sa; and by LCDV-rc and LCDV-sb; and finally by LCDV-cn, LCDV-C, and LCDV-jf. From the host evolutionary perspective, *Rachycentron canadum* was found to have differentiated first, followed by *Trichogaster leeri*, *Chanda baculis*, and *Sebastes schlegeli*, *Lateolabrax sp.*, *Sparus aurata*, *Platichthys flesus*, and *Paralichthys olivaceus*. Comparison of the phylogenies of the host fish species and LCDVs revealed no significant evidence of cospeciation between LCDVs and their host fish. In-depth studies of the genetic variation in LCDVs can enhance our understanding of the mechanism of LCDV infection, which may provide important insights into the prevention and treatment of lymphocystis disease.

### 2.2 ECONOMICS & MARKETING


The farming of cobia (*Rachycentron canadum*) in offshore floating cages has been a subject of recent research efforts and commercial ventures in Brazil. This study presents an economic feasibility analysis of an experimental farm off the coast of Pernambuco, northeastern Brazil. Different levels of productivity (5, 10 and 15 kg m$^{-3}$), sale prices (R$ 7.00, R$ 11.00 and R$ 15.00 kg$^{-1}$) and farm size (6, 12 and 24 cages of 1,600 m$^2$) were considered. Given these scenarios, the offshore farming of cobia will only be profitable when the sale price is R$ 15.00 kg$^{-1}$ and the productivity is equal or higher than 10 kg m$^{-3}$. If the sale price is R$ 11.00 kg$^{-1}$, cobia farming would only be feasible if 15 kg m$^{-3}$ are produced in 12 or more cages. Feed ranged from 39.8 to 76.4% of operating expenses according to the productivity level. Offshore farming of cobia in northeastern Brazil may be economically feasible, but it becomes more attractive with an increased number of production units. The needs for capital may be beyond the financial means of small/medium-sized producers.


Marine cage culture is one of the fastest growing seafood supply methods and the most potential ones. Among the cage culture industries today, Japan leading the world with 2.14 billion USD worth annual production and Norway contributed more than half a million metric tons of Atlantic salmon production in 2002, leading the world farmed salmon production exceed 1 million tons. The industry structure of Norway and Japan are very different. Norwegian salmon mostly exported as fresh gutted whole fishes while Japan supply almost all fishes for domestic market live. The scale of the farmers are also different; Norwegian farmers produces 10 times the quantity of those Japanese
yellowtail farmers averagely. However, landing price of Japanese yellowtail kingfishes are 2-3 times more than Norwegian salmon which enable Japanese yellowtail kingfishes annual revenue close to the revenues of Norwegian farm salmon. Analysis in the Industry Life Cycle point of view, it is very clear that Japanese yellowtail kingfish industry fall into the declining stage. Norwegian salmon industry may sitting either at the Shake off stage or just past the mature stage which needed to be observed for a longer term. Both Norway and Japan cage culture industry have similar financial character. With lower self own capital and higher ration of liquid asset; operate under higher finance financial leverage. This study applied benchmarking over Norwegian salmon, Japanese yellowtail kingfish and Taiwan cobia cage culture during 1992 and 2002 on the industry scale and productivity. The result can be used as a guide on developing Taiwan cobia cage farming industry. Finally, the study find that Taiwan marine cage culture cobia has good potentials to be a very competitive product and suggest Taiwan cobia industry needed to be improved on productivity, marketing, R&D and socioeconomic structure reinforcement.


The economic benefit of the culture industry is a key factor affecting industry development. Based on related studies of the production economy of cobia cage culture, this study investigated operational outcomes of the industry, and reviewed various factors influencing industry profits in order to compare its advantages and disadvantages. Data were sourced from the fishers' economic survey data concerning Taiwan's cobia cage culture from 2002 to 2007. Data contents were divided into biological data and economic followed by a then multi-variable statistical analysis. This study investigated whether different years and different culture areas affected production input and output during the culture processes of cobia cage culture operators. Furthermore, biological and economic variables affecting industry management performance were studied. Results showed that different regions and years have significant effects on both the input and output of cobia culture, as unit production input costs of cobia tend to increase on a yearly basis. Production costs at Penghu are higher than those of Pingtung. In terms of cost structure, the main production costs are dominated by feed costs in Penghu, and by feed, personnel, and maintenance costs in Pingtung. In terms of profit, the overall cobia culture achieved excellent productivity in 2003, with benefit-cost ratios of 1.41 in Penghu and 2.77 in Pingtung. The greater profits achieved in Pingtung rather than in Penghu are mostly related to the scale of operation. The benefit-cost ratio was the highest in 2007, reaching 2.95, while in the same year, productivity reached over 1.9, indicating that excellent managerial performance was achieved in that year. In terms of biology, both fish breeding specifications and survival rate may affect management performances. Lastly, the analysis chart of cost input and principal components of productivity highlights the key factors affecting the production performance of individual culture operators. Future studies can conduct in-depth surveys on individual operators, as such surveys would help to identify those with poor culture performance and operators with good culture performance, as the discrepancy would provide reference for adjusting cobia culture strategies and operational management for decision-makers.


In recent years, cobia has become an emerging farmed species in Asia due to its quick growth and high economic value. This study collects biological and economic data affecting the economic performance of cobia farming in three countries, namely Taiwan, China, and Vietnam. The data are collected by questionnaire sampling and analyzed by multivariate statistical analysis in order to compare the key factors affecting the production and economy of cobia farming in these three countries. The results show that Taiwan, China, and Vietnam have significant differences in input intensities and profitability. China has the highest input intensity (3372.42 TWD/m³), as its high stocking density increases feed input. Taiwan has the highest unit input cost (103.44 TWD/kg), as the high quality of the product increases the price of cobia in Taiwan, which offsets the high product costs. In terms of profitability, the benefit-cost ratio is over one in all three countries, indicating that the profitability of cobia farming is good in all three countries. Profitability analysis shows that fingerlings in China achieve 36.50, which is the highest among the three countries; whereas Taiwan has the highest feed profitability of 0.78, which reveals that the fingerlings produced in China are competitive in both price and quality, while Taiwan has the best feed management efficiency. The production costs and profitability of Vietnam fall between those of
Taiwan and China. Feed cost is the main expenditure in cobia culture; thus, good feed management could effectively reduce production costs and increase business performance. The feed quality and input management model of Taiwan, in conjunction with the fingerling quality and stock model of China, could provide future reference for farming management in such areas as feed input and selection of fingerling.


In this study, we use the survey data of 1998-2002 to analysis the production economic of cobia cage aquaculture industry. The results showed seed cost and diet cost were highest in direct costs; wage was highest in indirect costs. The mean net profit of 1998-2002 was bad; benefit-income ratio and profit rate were negative. We found the man-made technical inefficiency were greater than not-man-made technical inefficiency from Cobb-Douglas stochastic production frontier model. The adoption of recommended large cage and increased aquaculture are found to be critical for improved performance of cobia fish farmer.


The structure of cost and return for cobia cage culture in Taiwan was studied by considering two major factors, geographical location and production scale. Although the geographical location had little influence on the input intensities, the production scale would have a significant impact on the cost structure. However, the performances of profitability were significantly affected by not only the individual main effects but also their interaction. As a result, the studied effects on the cost and return were quantitatively estimated by a series of statistical models, in turn quantitatively measured by a set of indices. A short-term strategy of the management suggested that the best choice regarding profitability is to locate the farming system with a large-scale operation in the coastal waters of Pindong. Additionally, the profitability could be further increased by selecting better quality fingerlings and feeds based on a set of the computed indices. A long-term strategy of the management strongly recommends that to increase the system size in cobia production would be much more profitable due to the positive economies of scale. Finally, a future study shall be interested in whether current speed has a limiting effect on the profitability.


This article presents an analysis of the profitability and intensity of cobia culture by small-scale farmers in Vietnam, especially focusing on current feeding practices and perceptions regarding adoption of manufactured diets. Bioeconomic modelling is used so the interactions between biological and economic processes can be analyzed. Overall, it is found that cobia farming is moderately to highly profitable when compared to other aquaculture species in Vietnam. Culture practices and the level of intensity of cobia farming differ significantly across Vietnam. Initial stocking density, total number of fish stocked, number and size of cages, and quantity of feed used are all higher in southern Vietnam than the north. The higher level of intensification in the south leads to significantly higher total costs, productivity and profitability. The dominant cost source is feed, which is predominantly low-value fish. To capture the environmental and potential economic benefits of adopting pelleted diets, then negative farmer perceptions regarding relatively slow growth rates, and lack of availability compared with low-value fish need to be overcome.


Finfish mariculture farmers in Vietnam are making careful practice change decisions in reaction to a number of economic drivers. These economic drivers are centred on trends of increasing input costs and decreasing output prices. In general, mariculture farmers are adapting to the cost-price squeeze in a number of ways, including increasing stocking densities and area, and by adopting risk-reducing strategies (decreasing grow-out periods and using a larger number of smaller ponds to spread mortality risk). However, there is still a shortage of good quality low-cost fingerlings which is constraining farmers’ ability to adapt to the cost-price squeeze. The dominant input cost source is feed. Most farmers are still reliant on trash-fish feeds. With low and decreasing feed conversion
ratios for trash-fish, there is decreasing incentive for these farmers to change to pelleted diets. Southern Asian seabass farmers have made the practice change to pellets, but feed conversion ratios are high preventing significant economic gains from making the change. This research highlights two key areas where policy, research and extension initiatives can have a significant impact on the long-term economic and environmental viability of mariculture operations in Vietnam while protecting fish stocks: firstly, ensuring the widespread availability of low-cost hatchery–produced fingerlings, and secondly, encouraging practice change from trash-fish diets to the well-managed use of manufactured pelleted diets.


The ecological impacts of intensive tropical coastal mariculture have reduced its potential economic gains from making the change. This research highlights two key areas where policy, research and extension initiatives can have a significant impact on the long-term economic and environmental viability of mariculture operations in Vietnam while protecting fish stocks: firstly, ensuring the widespread availability of low-cost hatchery–produced fingerlings, and secondly, encouraging practice change from trash-fish diets to the well-managed use of manufactured pelleted diets.

2.3 FARMING SYSTEMS


A five-phase method for the evaluation and selection of tropical marine fish for intensive culture is proposed and the application of the first four phases is presented for the Caribbean region. In phase-1, an initial list of 50 species was prepared from 2175 present in the Western Central Atlantic, based on their commercial importance, and certain relevant biological features. Phase 2 includes economic and technological development considerations. Eleven preselected, four non-preselected, and six traditionally cultivated species (controls) were evaluated in phase-3 using a score and weighting factor method with four categories, established according to the point score. Species preselection by environment and culture system (phase-4) was carried out according to estimated performance at the site and culture system under Caribbean conditions, as well as the species' tolerance to environmental factors and the total score obtained as final criteria. To be finally selected, species must be subject to practical pilot-scale (phase 5) trials with technical, financial and ecological feasibility analyses. Yellowtail amberjacks, Seriola spp., and cobia, Rachycentron canadum, ranked first for open water cage and supra-littoral tank culture. Ranking in the second category were Florida pompano, Trachinotus carolinus, pompano, Trachinotus falcatus, and common snook, Centropomus undecimalis, which were selected for ponds and floating cages on estuarine and coastal waters, and Nassau grouper, Epinephelus striatus and mutton snapper, Lutjanus analis, which were selected for cages on coastal or offshore clear waters. Two of the exotic tropical species: barramundi, Lates calcarifer and mangrove red snapper, Lutjanus argentimaculatus, as well as one of the subtropical control species: red drum, Sciaenops ocellatus, were highly scored and ranked in the first two priority categories, thereby confirming the effectiveness of the selection method applied.


The ecological impacts of intensive tropical coastal mariculture have reduced its potential for expansion. The increasing opposition to projects such as shrimp farms and the eutrophication of coral reef habitats in the tropics is among the chief incentives driving offshore operations. Tropical off-the-coast and offshore mariculture is a growing industry with considerable economic and ecological potential. However, its growth in the tropics will require a major allocation of capital, knowledge and planning resources to tropical nations, most of which are poor, underdeveloped, lack infrastructure and are distant from target markets. Hence, the benefits and costs of off-the-coast and offshore farms in tropical regions are not directly comparable, since extensive pond aquaculture and other low-tech production systems
benefit the rural poor, whereas offshore mariculture is currently restricted to corporate initiatives which have the capacity for large capital investment, import of technology and assumption of significant risks. Individual offshore farmer ownership and operation in the tropics is therefore still a substantial socioeconomic challenge due to the large initial investment required. While the warm climate regime between the tropics of Cancer and Capricorn offers numerous advantages and potential for the cultivation of various marketable species, these are different to the species reared in temperate offshore farms. Whereas this may appear to be a trivial point, it is essential to note that the high cost and capital investment involved in offshore mariculture dictates the production of high-value species intended for export to the rich developed world. Most offshore projects have thus, focused on high-value predator species such as cobia, snapper, amberjack, seabream, red drum, pacific threadfin, seabass and tuna.


The diminution of marine fish populations due to over-fishing has stimulated the increase of mariculture activities, including in cages located near the coast. However, these activities may be detrimental influence to marine sediments near the culture sites in coastal sites. The first open-ocean mariculture operation began during 2002 south of Culebra Island, Puerto Rico to culture the fish Rachycentron canadum and Lutjanus analis. The purpose of this study was to evaluate the concentrations of total organic nitrogen (TON), total carbon (TC), and organic matter (OM) in marine sediments near the mariculture site to determine the spatial and temporal dynamics of these nutrients during the first culture period. Results indicate significant differences in the concentration of TON between the cage and control sites. The L. analis cage had a higher mean concentration of TON (0.442 mg N/g) than the R. canadum cage (0.380 mg N/g) and control site (0.300 mg N/g). TC and OM mean concentrations were not significantly different; however, mean TC concentrations had fluctuations similar to those of the mean TON concentrations. TON and TC mean concentrations were significantly different over time, with an increase in the mean TON (0.66 mg N/g) and TC (199 mg C/g) concentrations from April 2003 to August 2003, with a peak in June 2003, which agreed with the increase in the mean monthly feed input at the culture site (12,947 kg) and the increase of wastes because the fish had reached a commercial weight (4.5 kg). Harvesting began in June 2003, so numbers of fish decreased during subsequent months. Organic matter decreased during June, but peaked during October 2003. Although the increase of the nutrient concentration is relatively low compared with other studies, data represent only the first year of mariculture activity. As the company increases the number of cages, this site should be monitored to determine possible increases in nutrient concentrations in the sediments.


Hatchery and growout technology for the reliable production of cobia (Rachycentron canadum) and other candidate species for offshore aquaculture are discussed in this paper. Most recently, we have been working towards the development of sustainable microbial management in live feeds and larval rearing tanks, including disinfection methods and the use of probiotic bacteria. The strategy is to out-compete contaminant, pathogenic microbes by "competitive exclusion", increasing digestibility and boosting the immune system of the larvae, thus avoiding the need for antibiotic treatments to prevent and control disease outbreaks. Strains have been selected based on research conducted with red drum (Sciaenops ocellatus) larvae and tilapia (Oreochromis sp.) juveniles, as well as with cultures of rotifers (Brachionus sp.) and Artemia nauplii. The selection had been based on antagonistic properties towards bacteria pathogenic to fish such as Vibrio sp., enhancement of digestion and food conversion efficiency, and enhancement of overall growth and survival. Both cobia and mutton snapper exhibit very good potential for commercial aquaculture development in net cages in the SE U.S. and the Caribbean. Cobia exhibits extraordinary rates of development and growth. During Snapperfarm's demonstration project off Culebra Is., Puerto Rico, cobia grew to an average of 6.03 kg (SD=2.4; CV=39%) or 13.3 lb in one year, ranging in size from 1.7-9.1 kg (4-20 lb). Estimated survival rate is > 95%, and feed conversion rates (FCR) is 1:1. However, accurate final values will only be known once all fish are harvested. Snapperfarm has been harvesting 500-1000 kg of cobia per week (1,000-2,000 lb/week). Fish are being shipped to the continental U.S., where they are being sold fresh for US$ 8/kg to the high-end market. Thus far, no noticeable
environmental impact has been ever detected in the areas surrounding the cages. The technology for producing cobia from egg to market is in place.


Growth rates of hatchery-reared cobia (*Rachycentron canadum*) cultured in submersible cages off Puerto Rico and the Bahamas were comprehensively studied and are presented, discussed and compared to those of other teleosts. Cobia grew to averages of 6.035kg (specific growth rate (SGR)=2.10%/day) in 363days at the Puerto Rico site (PR) and 3.545kg (SGR=2.04%/day) in 346days at the Bahamas site (BA). Growth in length is best expressed by the equations: $y = 12 + 0.18x$; $r^2 = 0.59$ at PR and $y = 12 + 0.16x$; $r^2 = 0.86$ at BA. The Laird-Gompertz model was used to represent growth in weight to best express the rate of decline in growth rate with age ($a = 0.006194$ PR and $a = 0.006323$ BA), which occurred at the onset of precocious maturation for this species at 2.0-4.5kg in 300days post hatch (dph). The exponents (b) of length-weight relationships calculated ($3.31$ at PR and $3.20$ at BA) demonstrate that cultured cobia exhibit greater condition factors than their wild counterparts ($b = 2.8$) and explain the morphological differences observed between wild and culture cobia. Final stocking densities of 5 and 15kg/m3 were estimated at PR and BA, respectively. Average water temperatures for the duration of the growout cycle were 27.8°C at PR and 25.5°C at BA. Results show that growth rates of cobia vary widely and suggest a negative effect of lower temperature and increasing stocking density. These trials also demonstrate, for the first time, that growout of cobia is technically feasible in submerged open ocean cages.


Due to its extraordinary growth rate and to its adaptability to aquaculture, cobia (*Rachycentron canadum*) is one of the species that show the greatest potential for a commercial-oriented production. It is also a fish that is naturally spread in practically every region in the Americas and the Caribbean. In the international markets, meanwhile, cobia enjoys good demand and firm prices. For all these reasons it is interesting to see the experiences described in this article, from the technology of spawning in hatcheries to the growout in open-sea summerged cages.


There are four cage farms in the offshore of Hsiao Liu Chio Island. The types of cage include PVC frame cage, submerged free frame cage (soft cage), circular PE frame cage and submersible circular PE frame cage. The main cultured species include amberjack *Seriola dumerili*, orange spotted grouper *Epinephelus coioides*, cobia *Rachycentron canadum*, red fish *Lutjanus erythropterus* and red sea bream *Pagrus major*. In addition, scat *Scatophagus argus*, lembus rudderfish *Kyphosus vaigiensis*, small scal-blackfish *Girella* sp. and five-striped damselfish *Abudedefduf vaigiensis* could be served as additional culture species. The ectoparasite of *Neobenedeniais sp.*, sea lice *Caligus sp.*, *Dactylogyrus sp.* and digestive tract disease have ever been occurred in those cage culture area. At present, the serious problem of cage culture is the marketing. The status and problems of offshore cage culture are presented in this report. Further improvement of culture techniques and developing directions will be discussed.


Offshore cage aquaculture is regarded as the most important aquaculture industry in Taiwan. It has been realized that the key to the successful development of this industry in Taiwan lies on preventing and minimizing the damage by typhoons, which occur during summer and fall, the peak-growing season. To play safe, this industry started in the protected bay area of Penghu islands in 1977. Even under such consideration, the traditional square wooden frame cages used then could not stand the surge of typhoon and severe losses were encountered. The discouragement impeded further development of this industry until early 90s when some durable type cages were developed and Norwegian salmon cage culture industry had shown remarkable growth. Without rigid frame, a flexible submerged cage system was developed in Taiwan and had been welcome by the farmers since. Successful cases using Norwegian polarCirkel cages also provided another popular alternative. In recent years, a submergible cage system, which was developed jointly by industry,
government, and research institutes, has survived well through several strong typhoons. The regained confidence in farmers, supportive government policy, and a favorable international and domestic market has facilitated significant increase of investment and expansion of this industry. There are about ten high price fishes being cultured in 1,500 offshore cages. Among them, cobia (*Rachycentron canadum*) is recognized as the most promising species for its fast growth and great market potential. Well-established hatchery industry guarantees stable and sufficient fry supply. A 6-8 kg weight gain can be obtained in one year. Production has reached 1,000 mt in 1999, of which 450 mt was exported to Japan at a price of US$ 50-60/kg. Being equipped with typhoon-resistant cage systems and possessing with experience and technologies on the suitable cultured species, the industry is moving on the right track. However, strategies still need to be formulated and implemented regarding the integration of research and development resources from all sectors to establish an efficient cage culture model suitable for tropical and subtropical sea and ensure sustainable development of this new industry.


The success of aquaculture in Taiwan over the years has resulted in tremendous capital investment and the development of advanced techniques and technologies. However, after the collapse of the shrimp farming industry in the late 1980s, the government has devoted much effort to the development of modern offshore fish farming as a top priority for its national aquaculture plan. The recent and continuing expansion of cobia (*Rachycentron canadum*) cage farming in inshore areas, and the intention to develop offshore potential, has led to questions on the degree of the ecological impact that can be anticipated in the future. In this paper we first briefly review the history of aquaculture development in Taiwan particularly focusing on marine cage culture. We then outline the challenges facing Taiwanese cage aquaculture including potential environmental impacts. To solve these problems, some technical solutions for sustainable cage aquaculture are proposed including the employment of benthic fauna as environmental indicators, developing new types of feed processing technology to reduce the pollution load, adopting good feeding and management practice to reduce feed loss, monitoring the feeding behavior by video camera. It remains of paramount importance to protect marine resources for the overall fisheries and aquaculture development. The Taiwan Offshore Aquaculture Association (TOAA) will therefore enthusiastically support different projects assisting the government in managing the natural resources and in preserving the environment.


Interest in cobia, *Rachycentron canadum*, cultured has shown significant growth in recent years, but few hatcheries are available to support this developing industry. To facilitate the transport of cobia between facilities, four 24-h experiments were conducted to examine the effects of density, temperature, and actual versus simulated transport on juvenile cobia (1.5–3.0 g) survival. Mortality during actual transport at fish densities of 5, 10, and 15 kg/m$^3$ (2.9 ± 0.6, 2.9 ± 1.8, and 6.3 ± 0.8%, respectively) did not differ by treatment but was significantly higher than that during simulated transport at each density (0%). No differences in mortality were found following simulated shipping at 19, 21, and 25 °C at 15 kg/m$^3$. Significantly greater mortality occurred when juveniles were packed at 25 kg/m$^3$ (10.4 ± 0.7%) than at 20 kg/m$^3$ (1.9 ± 1.6%) and 15 kg/m$^3$ (0.1 ± 0.1%). Recovery following simulated and actual shipping was high in all treatment groups. Under the conditions examined, results indicate that transport density should not exceed 20 kg/m$^3$.


Due to the advantages of fast growth, less diseases and high nutrition value, cobia *Rachycentron canadum* has become one of the major marine cultivated species and the scale of culture has expanded rapidly in recent years in China. This paper reviews the biology, artificial breeding and fry culturing, net-cage farming, nutritional requirement, disease and genetic diversity of cobia. The prospect for the future study is also presented.


For some years now there has been talk of a ‘new star’ in aquaculture. Cobia grows extremely fast, has a mild, white flesh with practically no bones, and it is a marine fish, which gives it an advantage
in important whitefish markets. Until now, farmed production has been very limited, but developments in Vietnam indicate that this fish is to be reckoned with in the coming years.

135. **Hung, L.T. & Huy, H.P.V. (2007).** Analysis of feeds and fertilizers for sustainable aquaculture development in Viet Nam. In: M.R. Hasan, T. Hecht, S.S. de Silva & A.G.J. Tacon (eds.). *Study and analysis of feeds and fertilizers for sustainable aquaculture development. FAO Fisheries Technical Paper*. No. 497. FAO, 2007, pp. 331-361. Aquaculture in Viet Nam has become an important economic activity. Total production in 2004 exceeded 1.22 million tonnes, accounting for approximately 40% of the country's total fisheries output. Seaweed, fish, crustaceans and molluscs are produced in a wide array of freshwater and marine culture systems at various levels of intensity under mono or polyculture conditions. Extensive aquaculture is practiced in ponds, rice fields and reservoirs. Chinese, Indian and common carp are the preferred fish in these systems and animal manure is the principal input. Improved extensive and semi-intensive aquaculture is practised in ponds with higher levels of nutrient and feed inputs. Integrated livestock/fish farming is being promoted to optimise the use of on-farm nutrient resources. Intensive aquaculture is undertaken mainly in smaller ponds, cages and tanks. Snakeheads, pangasiid catfish and red tilapia are main species produced in intensive freshwater systems. Trash fish is the most important feed or feed ingredient for snakeheads and pangasiid catfish, while pellets and farm-made feeds are the main inputs in intensive catfish and red tilapia aquaculture systems. Coastal aquaculture is dominated by black tiger shrimp (*Penaeus monodon*) farming, particularly in the Mekong Delta and coastal provinces of Central Viet Nam. There have been significant advances in the intensification of shrimp farming in Viet Nam. Most shrimp farms are now operated on a semi-intensive scale, while intensive shrimp farming is making rapid advances. Shrimp in intensive systems are fed on commercially manufactured pellet feeds, while semi-intensive and improved extensive system employ trash fish as the major feed ingredient. Other marine species farmed in Viet Nam include eight grouper species, Asian seabass/barramundi (*Lates calcarifer*), cobia (*Rachycentron canadum*), yellowtail/greater amberjack (*Seriola dumerili*), seabream and snapper and four species of lobster of the genus *Panulirus*. Trash fish is the principal feed for all of the above marine species. The aquafeed industry in Viet Nam started in 1998. In 2004, the industry produces 300 000-350 000 tonnes of pelleted feed for fish and 150 000-200 000 tonnes of shrimp feed. Despite these developments farm-made feeds still play a vital and major role in Vietnamese aquaculture. Trash fish is the major component of farm-made feeds. However, the supply of trash fish is limiting the development of the sector, unless rapid advances are made to reduce the cost of manufactured feeds. Bulk of fishmeal, soybean meal, wheat flour and marine by-products used by feed manufacturers are imported. Aquaculture in Viet Nam is targeted to grow at over 20% per annum to 2010. To attain this national goal it is essential that aquaculture becomes more intensive. It also means that more feed and nutrient inputs are needed and this poses several challenges that have to be met. The challenges revolve particularly around the availability and supply of feed ingredients and the dwindling supply of trash fish. For the sector to develop in a sustainable manner there is a need to focus on alternatives to fishmeal and trash fish, farmer education and for government to formulate enabling policy and legislation to facilitate the development of the aquatic feed industry.

136. **Kaiser, J.B. & Holt, G.J. (2001).** Cobia aquaculture. 46th American Fisheries Society Symposium: Aquaculture in the 21st Century, Phoenix, AZ (USA), Aug 22, 465-469. Cobia *Rachycentron canadum* is a migratory species distributed worldwide in warm temperate waters excluding the eastern Pacific. They are commonly referred to as ling, lemonfish, crab eater, and sergeant fish, among other names (Shaffer and Nakamura 1989). Cobia, considered low in overall abundance, is primarily targeted by recreational fishermen, particularly for its tenacity when hooked and good, flesh quality. Research was conducted on this species as early as 1975, when cobia were raised from eggs collected in tows along the edge of the Gulf Stream off the coast of North Carolina (Haslerr and Rainville 1975). However, serious efforts to spawn and raise larval cobia from captive broodstock were not initiated until the 1990s at U.S. and Asian aquaculture facilities. Cobia is considered an excellent species for aquaculture because of its rapid growth rate and good flesh quality. Several Asian countries, led by Taiwan, presently culture cobia commercially, growing the fish to harvest in nearshore and offshore net pens. Currently, in the United States, cobia culture is in the research phase and since the initial spawning success reported in 1996 by Franks et al. (2001) other laboratories have succeeded in spawning this species in captivity (Dodd 2001; Arnold et al. 2002; Benetti 2002; Kilduff et al. 2002).
produced in aquaculture but have still not made the definitive breakthrough: some of them are considered to be particularly promising candidates for aquaculture. A lot of them are already being farmed on a large scale operation with any species and has been identified as a limiting factor with regard to marine fish production. One group of cobia broodstock at FAML have been induced to spawn naturally using only photoperiod and water temperature manipulations 12 times over a three year period beginning in April 2001. These particular broodstock fish were initially collected from the wild in 1999 and raised from sub-adult until sexually mature. Currently, there are three groups of mature cobia being maintained in systems at FAML, the latter two being cultured fish from the May 2001 spawn. In addition to the larger fish, thirteen juvenile wild-caught cobia fish were obtained in August 2003 in an effort to raise groups of both wild and cultured fish for future spawning efforts. The larvae from these spawns have been raised in recirculating tank systems in order to study larval rearing protocol, rearing density, nutritional requirements, and salinity tolerance of cobia. In addition, excess eggs and larvae have been shipped to various facilities engaged in both research and commercial aquaculture in the US in an effort to further the knowledge base with cobia. An overview of the current cobia program at FAML as well as future plans with this species will be the topic of the presentation.


Global aquaculture is growing at a breathtaking speed. The quantities produced every year are not only increasing, the range of species farmed is also broadening. Some of them will probably remain niche products in the foreseeable future but others have the potential to conquer the world market. The time it takes from the development of efficient farming technology to large-scale production of a fish species is constantly decreasing. The success story of Pangasius proves that, provided the quality and the price are right, it often takes only a few years for a ‘new’ fish species to capture the world market. While most fishes are currently still produced in the freshwater segment, it seems that the future will soon belong to marine species. This article presents several species that are considered to be particularly promising candidates for aquaculture. A lot of them are already produced in aquaculture but have still not made the definitive breakthrough: some of them for...
technological reasons, others due to economic considerations. At present, there are two fish species that are considered to stand a particularly good chance of market success: Atlantic cod (Gadus morhua) and cobia (Rachycentron canadum).


Aquaculture in Taiwan began more than 300 years ago. In general, the history of aquaculture development in Taiwan can be divided in three stages: 1) Traditional stage (1661-1962); 2) Prosperous stage (1963-1987); and, 3) Transition stage (1988-present). At present, Taiwan is recognized as one of the countries with the most advanced and practical aquaculture technologies in the world. The significant achievements of aquaculture in Taiwan are the development of mass propagation and culture techniques for many aquaculture species including grass prawn, grey mullet, milkfish, tilapia, eel, and cobia among others. Biotechnological achievements are also noteworthy and these include the production of transgenic fish for the aquarium industry (e.g. zebrafish), development of molecular diagnostic techniques for most viral diseases of prawns, and the use of bioproducts for disease prevention in prawns. As aquaculture continued to prosper which contributed significantly to the country's fisheries production, food supply, rural livelihood, employment generation and socio-economic growth, problems were also encountered which resulted in the partial collapse of the industry. And the fact that most aquafarmers are too profit-oriented, overseeing these problems in exchange for higher production also resulted in negative effects on the aquaculture industry in the long run. Some government rules and policies, as well as bureaucracy, hinder the advancement of the industry towards sustainable aquaculture. With the current situation of the aquaculture industry in Taiwan, which is somehow not in harmony of what is happening in the world aquaculture, there is an urgent need to propose strategies that can sustain the industry in the future, including: strengthening of traditional techniques (e.g. on mass larval production); scientific research on nutrition and health; development of environment-friendly aquaculture systems; value-addition among processed aquaculture products; and, institutional cooperation locally, nationally and internationally.


Cobia, Rachycentron canadum, is a widely distributed species from the Indo-Pacific waters to the southern Atlantic Ocean. In Taiwan, it is an indigenous and an ideal species for cage culture. Due to its high market value in both domestic and international markets, the technology for its culture has rapidly developed in the past few years. These include mass propagation through natural spawning of captive broodstocks, larval rearing techniques, nursery production in tanks, ponds and nearshore cages, and grow-out culture in offshore cages. Reproduction in captivity is relatively easy because sexual maturity often occurs within 2 years of culture. Spontaneous spawning occurs year around at water temperatures of 23-27 °C, with peak during spring and autumn. Fertilized eggs hatch within 21-37 h at water temperature of 31-32 °C. Larval growth is fast, and larvae are vitally robust and environment tolerant compared to other marine fishes. Fry can be mass-produced in outdoor ponds at relatively low cost. Weaning of fry from 20 days old onwards to pellet feeds is feasible. Nursery rearing from 10-30 to 1000 g can be done in either outdoor ponds or nearshore cages. Major diseases affecting cobra include bacterial (pasteurellosis, vibriosis and streptococciosis), parasitic (myxosporidea, Trichodina, Neobenedenia and Amyloodinium infestations), and viral (lymphocystis) ones. In recent years, intensive and super-intensive recirculation systems for nursery (from 2 to 100-150 g) were developed with survival rates of more than 90%. In nursery and grow-out offshore cages, 100-600 g cobra were cultured within 1-1.5 years when they reached 6-8 kg for export to Japan, or 8-10 kg for the domestic market. Currently, around 80% of marine cages in Taiwan are devoted to cobra culture. However, some problems still exist in cobra culture that needs to be addressed and solved to increase production. These include high mortality due to stress during transport from nursery tanks/inshore cages to grow-out cages and diseases during nursery and grow-out culture resulting in low survival, and consequently poor harvest.


Cobia, Rachycentron canadum, also known as Canadian sergeant fish, black kingfish, lemonfish, or ling and locally as hai li or hai lei, is now being cultured in offshore sea cages in Taiwan because of its good meat quality and fast growth rate (Su et al. 2000, Liao 2003). The meat of cultured cobia contains higher fatty acid, specifically eicosapentaenoic acid (EPA) and docosohexaenoic acid.
(DHA) and vitamin E levels compared to other marine cultured species (Shiau 1999). About 60 percent is edible. The white meat is highly suitable for sashimi and other Chinese cuisines because of its tender but firm texture (Liao 2003). Cobia culture in Taiwan began in the early 1990s and the technology for mass fry production was completed in 1997 (Chang et al. 1999). It has stood out as a popular species for cage aquaculture compared with other marine fish species, including grouper and snapper. Total cobia production increased from 1,800 tons in 1999 to 3,000 tons in 2001, but plunged to 1,000 tons in 2002 because of a high incidence of disease and losses from strong typhoons. Production recovered to almost 3,000 tons in 2003 and is projected to reach 5,000 tons in 2004 if favorable culture conditions can be maintained and problems minimized. Cobia produced in offshore cages were mainly for export but as domestic consumer acceptability increased local demand accelerated. This has, in turn, resulted in higher market prices. With the increasing interest of cage farmers in Taiwan in the culture of cobia, technology improvements for mass larval rearing, nursery and growout production were recently introduced to meet the increasing demand in both domestic and international markets.

144. Liao, I.C. & Leaño, E.M. (eds.) (2007). Cobia Aquaculture: Research, Development and Commercial Production. Asia Fisheries Society, The Fisheries Society of Taiwan, World Aquaculture Society and National Taiwan Ocean University, 178 pp. This book provides a great deal of information in all aspects of cobia aquaculture and utilization, which will be useful for individuals interested in research or those interested in putting up small- or commercial-scale operations. As an added spice, a list of wonderful cobia recipes is included in the Appendix, where consumers will be guided on the proper way to prepare delicious cobia dishes.

145. Liu, S.M., Hsia, M.P. & Huang, C.M. (2006). Accumulation of butyltin compounds in cobia Rachycentron canadum raised in offshore aquaculture sites. *Science of the Total Environment*, 355(1-3), 167-175. Butyltin residues (monobutyltin, MBT; dibutyltin, DBT; tributyltin, TBT; tetrabutyltin, TeBT) in the sea water and in the cobia (*Rachycentron canadum*) from aquaculture sites located offshore of Penuh island, Taiwan, were collected and quantified. The average concentrations of MBT, DBT, TBT and TeBT in sea water were n.d. -- 28 ± 3, 4.0 ± 0.6 -- 88 ± 13, n.d. -- 43 ± 4, and n.d. -- 7 ± 1 ng l⁻¹, respectively. The total butyltin (sum of MBT, DBT, TBT, TeBT) residues in the skin, dorsal muscle, ventral muscle, dark muscle, and liver of the cobia were in the range of 72 ± 12 -- 2270 ± 85, 79 ± 11 -- 688 ± 33, 82 ± 14 -- 1715 ± 104, 93 ± 13 -- 803 ± 47, and n.d. -- 52,745 ± 252 ng g⁻¹ (wet weight), respectively. Although in this study in most cases, the highest concentration of total butyltin residues was found in liver or skin, in some cases, the highest concentration was found in muscle tissue. The crude lipid content in the skin, dorsal muscle, ventral muscle, dark muscle, and liver of these cobia was in the range of 7.9 ± 0.1 -- 28 ± 1%, 11.7 ± 0.8 -- 29 ± 1%, 11.5 ± 0.3 -- 44 ± 3%, 24.2 ± 0.4 -- 48.4 ± 0.4%, and 55.7 ± 0.1 -- 87.7 ± 0.4% (wet weight), respectively. The concentrations of crude lipid content, and the concentrations of total butyltin residues in these tissues were not correlated.

146. Morales, A.G., Alfaro, M., Cabarcas Nuñez, A. & Alston, D.E. (2006). Effects of two open-water submerged cages stocked with cobia *Rachycentron canadum* and red snapper *Lutjanus analis* on the benthic macroinvertebrate population at Culebra, Puerto Rico. *Proceedings of the Gulf and Caribbean Fisheries Institute*, 57:1024-1025. Two sediment core samples were taken bimonthly from (October 2002 to October 2003) southwest of Culebra Island, Puerto Rico. At each sample site (cage center and 40 m north, south, east and west) near two open-cages stocked with cobia (*Rachycentron canadum*) or red snapper (*Lutjanus analis*), and at a control site. Macroinvertebrate were separated with a 0.5 mm mesh sieve. Mean abundance of total soft-bottom invertebrates from all stations varied from a minimum of 694 ind/m² during October to 3,336 ind/m² during April 2003. A total of 72 families were identified from collections in project site, Culebra, Puerto Rico. *Polychaetae* (29), *Mollusks* (21) and *Crustaceans* (22). No general pattern of distribution between stations at both cages and control station has been observed in the soft-bottom macrobenthic communities in relation to he organic inputs. Only, central stations at both cages showed significant differences with respect to the other stations.

The development of commercial aquaculture in Belize dates back to the early 1980s when the farming of the Pacific white shrimp (Litopenaeus vannamei) was established through commercial experimentation. The success of this endeavour during the early phases of the industry led to the rapid expansion of shrimp farming to a total of 18 farms with a total production area of 2 790 hectares in 2005. To date, seven farms remain operational with a production area of 1 247 hectares as a result of disease events and major decline in global market prices in 2000 which continues to impact the financial sustainability of these operations. By mid-2000, the species portfolio was expanded to the commercial production of tilapia (Oreochromis niloticus) and cobia (Rachycentron canadum). Other species that have been attempted in the past have been the culture of red fish (Sciaenops ocellatus), a number of African cichlids for the aquarium trade, the Australian red claw (Cherax quadricarinatus), the Caribbean spiny lobster (Panulirus argus) and the queen conch (Strombus gigas). The most successful was the production of conchs juvenile between 1987 and 1992. The primary objective of the project was to develop laboratory techniques for the cultivation of queen conch larvae in an on-shore hatchery facility.


Organic loading under a submerged fish cage in commercial operation has been quantified for the first time in the open ocean. Sediment traps out to 100 m sampled the loading continuously over the 15 months of a complete grow-out cycle for cobia (*Rachycentron canadum*). Typically 4% or 5% of the feed arrived directly to the sediment, although this benthic percentage became much higher in the last two months of this study. Almost all the loading (90%) Lands within 30 m of the cage mooring block. The loading consists of fragments of feed pellets that wash out from the mouths and gips of the fish. The fragments sink rapidly and almost vertically; they are not carried horizontally into large dilution volumes. Dispersal on the sediment surface is much more extensive than dispersal in the water. This study developed expeditious and cost-effective techniques for sampling and analyzing organic loading, using a minimum of technological resources.


Numerical models are increasingly important for planning and permitting of marine fish farms. Models range from simple one-box simulations to complex mainframe-oceanic models potentially capable of managing entire coastal systems. We have developed a GIS-based simulation model to visualize and quantify temporal and spatial effects of fish farms. *AquaModel* was designed for administrators, who establish regulations, for operators, who wish to plan farms and obtain permits and for investors, who wish to assess risks and opportunities. The model provides a real-time, three-dimensional simulation of the growth and metabolic activity of penned fish as well as the associated flow and transformation of nutrients, oxygen, and particulate wastes in adjacent waters and sediments. The farm model resides within the EASy Marine Geographic Information System (www.runeasy.com), and thus all environmental information from field measurements to satellite imagery are readily available for model development and use. *AquaModel* consists of a description of advective and turbulent flow, a PZN description of plankton dynamics, a carbon-based description of fish growth and metabolism within the farm, and description of benthic sedimentation distribution and resuspension. *AquaModel* has been applied to salmon (*Salmo salar*) and cobia (*Rachycentron canadum*) farms. *AquaModel* is relatively easy to operate, but the integrated GIS system allows the user to expand into complex analyses. Future directions include adaptation of *AquaModel* for integrated aquaculture and expansion into a real time farm operation tool through the use of feedback sensors or probes to optimize fish farm operations.


Cobia (*Rachycentron canadum*) is an emerging aquaculture candidate for both offshore cage culture and land-based systems such as recirculating aquaculture systems. The ability to grow cobia at salinities other than oceanic (~34 ppt) could present culturists with additional production opportunities with this species. Culture at low salinities could also reduce the incidence of disease.
and simplify water management. In two trials of 8 weeks each, this study investigated growth and survival of juvenile cobia reared at salinities of 5, 15, and 30 ppt. The trials were conducted in 456-L tanks, with 10 fish per tank. Water temperature was maintained at 27±1 °C and dechlorinated municipal tap water (0 ppt, 56.8 ppm Ca\(^{2+}\)) was added to seawater (30 ppt, 325.3 ppm Ca\(^{2+}\)) in order to achieve treatment salinities. Early juveniles were used in both trials with average initial weights of 6.0 g for the first trial and 6.7 g for the second trial. During both trials, fish were fed to satiation twice daily with a diet prepared on site, and the amount fed was measured to determine feed efficiency. Fish from each tank were counted and weighed collectively each week until the end of each of the 8-week trials to monitor growth and survival. Survival among treatments was not significantly different in the first trial, but in the second trial survival was significantly lower in the 5 ppt treatment (68.3%) than in the 15 (90%) or the 30 ppt (92.5%) treatments. Feed efficiency was extremely high in both trials with all treatments ranging between 1.05 and 1.13. Fish reared at a salinity of 5 ppt grew as well or better than the fish reared at salinities of 15 and 30 ppt (mean weight gained, 96.2-115.3 g). This study indicates that culture of cobia juveniles may be practical in salinities as low as 5 ppt.


Recent changes in production trends for marine finfish aquaculture in the Asia-Pacific region are reviewed based on FAO fisheries statistics data from 1996-2006. Production of marine finfish in the region increased 4.7% between 2005 and 2006 from 1,148,892 to 1,203,165 tonnes. Overall value for the same period increased 3.1% from US$ 4.09 billion to US$ 4.22 billion. The largest producer was China at 715,000 tonnes in 206 valued at US$ 734 million, representing nearly 60% of total production volume but only 17% of total value, suggesting that much of Chinese production is of low-value species. Production data by volume and value are presented for countries in the Asia-Pacific region along with production trends for selected species including milkfish *Chanos chanos*, barramundi *Lates calcarifer*, grouper (Family Serranidae), Japanese amberjack *Seriola quinquergadiata* and cobia *Rachycentron canadum*.


Aquaculture is a significant commercial activity throughout Latin America and the Caribbean with 31 of the 44 countries in the region involved in aquaculture and the industry generating more than 200 000 jobs. The development of the aquaculture sector is highly uneven, with two countries, Chile and Brazil, accounting for 72 percent of the total production, of which an estimated 70 percent is derived from cage culture. Twenty three countries produce only two percent of the total. Eighty-one of the 332 species cultured throughout the world are farmed in the region, with a total aquaculture production of 1.3 million tonnes valued at US$5.2 billion in 2004. These figures represent 2.9 percent of the world aquaculture harvest and 8.2 percent of the value. Most of these are high-value finfish (almost 900 000 tonnes), with the majority produced in cage systems from the sub-Antarctic waters of southern Chile to the Gulf of California, northern Mexico. The majority of the cages (more than 90 percent) used in Latin America and the Caribbean are located in Chile and are dedicated to salmon farming. This document focuses mainly on two species groups: salmonids (salmon and trout) and tilapia, species that are farmed both in cages and also in tanks and ponds. Regional aquaculture development has been heavily dependent on the existence of development plans and the commitment of local governments. This has been the case in Chile where salmon aquaculture has shown an impressive growth during the last 20 years. In Chile, cage culture occurs in freshwater, brackish and marine environments. Because of the significant environmental pressures caused by aquaculture, especially the impact of cage culture in freshwater systems, the salmon industry has introduced some closed recirculation systems in the lakes of southern Chile. In the case of seawater production, the use of cages has grown at a rate of 10 to 15 percent annually. Research is needed to find ways to mitigate the environmental impacts of cage culture and to better understand the dynamics and interrelations between all the users of the aquatic resource. The rapid growth of aquaculture has led to a close interaction with the agricultural sector in order to find new raw materials that can replace fishmeal and fish oil, whose availability and price are limiting factors to both sectors’ growth.

Is cobia one of the most promissory aquaculture species? Many people rely on that possibility, and much scientific literature continued to be created around this species. This article describes an experience carried out in the central region of Brazil, by using different feeds and with temperature variations along the year. Results seem to support the reasons of those who are confident on this species.


Cobia (*Rachycentron canadum*) is widely recognized as an emerging aquaculture species. Its culture has attracted the interest of research institutions and the private sector in Brazil. In order to better understand and the performance of cobia culture in Brazil, an experimental production of this species was conducted off the coast of Rio de Janeiro, Brazil, in near-shore cages. The average water temperature is around 25 °C, ranging from a low of 19 °C in the winter up to 30 °C in the summer. Depth in the area averages 6-7 m and the site is fairly protected from the open sea, characterizing an area with limited carrying capacity. Cobia (50 days of age, weight 1.5 ± 1 g and total length 7 ± 3 cm), were reared in a three-phase system in near-shore cages for 12 months according to the following protocol: Phase 1 (nursery = 1 month; stocking density was 0.02 kg m⁻³ or 130 individuals m⁻³. Fish were fed four times daily with a dry diet [50% crude protein and 9% fat, INVE, Grantsville, UT, USA]). Phase 2: This intermediary phase lasted for 4 months, from March to July 2008. Upon finishing the nursery phase, fish were kept in the same cages, but the mesh size was increased to 12 mm. The initial stocking density was 4.6 kg m⁻³ and from this moment, cobia was fed three times per day on frozen cut sardines (Family Clupeidae). Phase 3 (grow-out = 8 months, from August 2008 to March 2009, fish were reared in a cylindrical cage 2.3 m high and 7.5 m in diameter, providing the volume of 90 m³ (mesh size was 20 mm). Initial stocking density for the grow-out phase was 3.1 kg m⁻³ and cobia was also fed on frozen cut sardines). At the end of this evaluation, the average weight of cobia was 4.2 kg, but fish as large as 6 kg were present. These results are indicative of the great potential for cobia farming in Brazil. Because commercial diets available at the time these fish were reared were not of good quality, growth performance was evaluated with cobia fed on cut frozen sardines. Even though trash fish still is an important source of food for cobia reared in Asia, this practice should not be simulated in Brazil, as it is not likely to be sustainable. This is the first report of cobia grow-out in Brazil, and the results are very promising. The successful culture of cobia in near-shore cages is an interesting alternative for low-income fishermen, who would not be able to afford the cost of offshore production. However, the carrying capacity of these sites should be rigorously evaluated to avoid compromising the environment.


Cobia offer many desirable culture characteristics, including ease of spawning in captivity, fast growth, and adaptability to net pen and tank culture. They also readily accept a wide variety of commercial diets. Current work on cobia by the International Initiative for Sustainable and Biosecure Aquafarming is standardizing larviculture, studying diets for juveniles, and examining low-salinity growout.


Two trials were undertaken to examine the growth response of juvenile cobia, *Rachycentron canadum*, at varying temperatures. The initial trial was conducted to determine the effect of various temperatures (18, 23, and 29 °C) on weight gain and feed efficiency. The second trial investigated the effect of elevating water temperature in which fish maintained at 18°C and 23 °C to a temperature close to their optimum (29 °C). The latter study was undertaken in order to determine the effect of thermal shifts upon subsequent growth response of the species. Such information will assist commercial producers in developing various culture guidelines. As anticipated, differences (P < 0.01) in weight gain were recorded among all treatments, although remarkably, feed efficiency did not differ for cobia reared at 23 °C and 29 °C. Following thermal shift, cobia subjected to the largest temperature change (18-29 °C) illustrated an immediate growth response, but specific
growth rates (SGR) did not exceed that of cobia held at 29 °C for the duration of the trial. Nevertheless, when SGR were examined using fish of similar size (i.e., derived from different time points during the study) evidence for growth compensation was obtained. This study illustrates that cobia can be held at reduced temperatures, without detrimental impact on future performance, as a means of maintaining animals at smaller size for production and experimental purposes: 'Cold banking'.


Cobia, Rachycentron canadum, is currently grown by marine aquaculture in Taiwan, particularly on Penghu Islet. Although the effect of marine aquaculture on the environment has been the subject of many studies, an understanding of its environmental impact has yet to be attained, and the continuing expansion of cage farming has caused noticeable ecological declines. Nevertheless, useful tools to measure this environmental degradation are scant. The results of this study suggest that the combination of a geographic information system (GIS) with redox potential and sulfide measurements can be used to definitively assess the condition of the benthic environment near cobia aquaculture sites and to help develop environmental monitoring programs. These applications could easily be adopted to assess multiple marine environmental conditions.


After four years of research mainly focused on developing the technology for the hatchery production of mutton snapper, Lutjanus analis, the Aquaculture Center of the Florida Keys (ACFK) started stocking commercial grow-out cages in Puerto Rico in August 2002 with the shipment of 8,000 mutton snapper, and 15,000 cobia, Rachycentron canadum, fingerlings. Since then, the company has begun its incorporation into the Norwegian veteran firm of Marine Farms ASA, which has assumed the direction of the hatchery while maintaining its original staff. During the period of December through February, ACFK improved its production potential by adding a liquid oxygen tower, a new water treatment system with doubled water flow capacity, a diesel powered generator, and a last generation computer monitoring-alarm system. Improvements were also made in the live food rearing protocols, which have resulted in a reliable sustained production in excess of 1 billion rotifers per day, and a renovated copepod harvest system which is used to complement the larval live diets. Production in 2003 started with the shipment of 25,000 cobia fingerlings to Puerto Rico, followed by smaller shipments to Martinique, Texas, central Florida, Massachusetts, Louisiana, and Alabama. In addition, several hundred thousand cobia yolk fry have been shipped to various research institutions around the United States in a collaborative attempt to support their research efforts. At present, ACFK is conducting a new production run aiming to fulfill 2 different orders of 20,000 and 30,000 cobia fingerlings to Bahamas, and Puerto Rico, which will conclude this year's production effort. The Aquaculture Center of the Florida Keys continues to break new ground by contributing to the very limited supply of hatchery reared marine fish fingerlings in the United States. Despite its commercial status, ACFK continues research and development, maintaining its goal to refine the technology required for the consistent production of high quality fingerlings. We continue to adapt, improve, and invent new ways of going about our business, from broodstock management of cobia, with the goal of obtaining natural viable spawns year around as accomplished with mutton snapper, to larval rearing techniques, in trying to determine the best methodology for improving first feeding, weaning, and grading, as well as shipping and stocking strategies. Currently ACFK's client in Puerto Rico, Snapperfarm, is harvesting 1,000-2,000 lbs. of farmed cobia each week, which is being sold in Miami at an approximate wholesale price of $4 / lb for gutted whole fish. These cobia, which originated in a mid-July 2002 spawn at ACFK are averaging close to 20 lbs. and a 1:1 food conversion rate after 12 months in the cages. Our endeavors have shown cobia to be a prime candidate species for future development of marine farming ventures in the Caribbean and the Gulf of Mexico region, with easy access to the booming US fresh seafood market.

cobia (27 to 46 days post-hatch (dph)) were tested for salinity tolerance via abrupt transfer from 35ppt salinity water to salinities ranging from 0ppt to 55ppt. Results indicated 100% survival at 24h post-transfer at salinities between 11ppt and 45ppt. Using two different salinities within the range tested in the tolerance trials (12ppt and 32ppt), a 24h simulated shipping trial was conducted comparing final survival between the two salinities at each of four packing densities (5kg/m³, 10kg/m³, 15kg/m³, and 20kg/m³). At packing densities above 10kg/m³, survival was significantly enhanced at 12ppt relative to rates in the higher salinity (32ppt) treatments. Additionally, there were no apparent effects on post-transport aquaculture performance of the fish shipped at high densities in reduced salinity water. Results of this study suggest that cobia fingerling producers can optimize their current shipping methods and protocols by increasing stocking densities in closed containers, allowing for reductions in labor, material, and mass-dependent transport costs.


Currently, there are about 1,500 cages, ranging from 216 m³ to 1,884 m³, operated in the coastal waters off Penghu, Pingtung, Ilan, and Hsinchu Prefectures in Taiwan. Over 80% of these cages are devoted to cobia culture. Cobia attains maturation at 9-10 kg and spawns spontaneously from March to October. Incubation takes 30 hours at 24-26 °C. Larval rearing takes about 45 days for the fry to reach 8-10 cm. Nursing takes another 25-30 days to reach 30 g. The fish are then transferred to marine cages for growout culture. They can reach 6-8 kg in cages in one year. About 1,500 mt of cobia was produced in Taiwan in 1999. Of which, over 450 mt of 6-8 kg whole fish was marketed to Japan at cage-side prices of 150-180 NTS/kg (US$ 5-6/kg). The preliminary success suggests that there is a great potential for marine cage aquaculture of cobia in Taiwan.


This paper describes the environmental conditions and the current status of cage farming in Taiwan. Each year, about three to four typhoons land somewhere in Taiwan during the period from late June to early October. Farming sites are mainly distributed in inshore or offshore waters of Penghu and Pingtung Counties. A flexible submerged cage system has been popularly employed by the local farmers. Over 60 modern floating or submergible cages have been imported since 1996. Fourteen species have been cultured in cages. Fish in cages are fed raw fish and moist and dry pellets. Ectoparasitic infections occur in some species. The merits of fast growth, strong disease resistance and low production cost in cobia have prompted the farmers to select the fish as the first candidate for culture.


Effects of ration (from starvation to satiation) and temperature (21 °C, 27 °C and 31 °C) on growth and nitrogen budget of young cobia (initial body weight about 10 g) were studied, and the relationship between specific growth rate (SGR) and ration as well as temperature and the nitrogen budget were established in this paper. The results showed that at a given temperature, as ration increased, SGR increased significantly, exhibiting a linear pattern described as a simple function at 33 °C whereas a decelerating pattern described as a logarithmical equations at 27 °C and 21 °C. At a given ration, except for starvation, as temperature increased, SGR increased or first increased then decreased, all described as quadratic functions. At a given temperature, as ration increased, feed conversion efficiency (FCE) increased at 21 °C and 33 °C whereas first increased then decreased at 27 °C. At a given ration (except for the starvation), as temperature increased, FCE increased or first increased then decreased and peaked at 27 °C for fish fed restricted food while there was no significant difference between 27 °C and 33 °C though FCE peaked at 33 °C for fish fed satiation. Over the experimental ration and temperature range excretion nitrogen of young cobia increased significantly with increasing ration and temperature.


The effects of water temperature at 23, 27, 31, 33 and 35 °C on growth and bioenergetics of cobia *Rachycentron canadum* with initial body weight about 10, 30, 70 and 200 g were investigated in
this paper. ANOVA showed that food consumption, fecal production, nitrogenous excretion, growth rate and metabolic rate of cobia were affected significantly by both water temperature and fish size. However, the relationships between food energy and feces, excretion, growth and metabolism energy exhibited linear curves and seemed independent of water temperature and fish size in the present study. For each fish size growth increased with temperature up to 33 °C and then declined at 35 °C. The optimal temperature for growth (\( T_{opt} \)) of 10–200 g cobia was 33 °C. For each water temperature growth was negatively correlated to fish size and the model, SGR = a + blnW or SGR = aw^b, provided a good fit to the data obtained for 10–200 g cobia. Food conversion efficiency (FCE) was highest at 31 °C and lowest at 35 °C for each size cobia. The optimal temperature for FCE (\( T_{opt,FCE} \)) of 10–200 g cobia was 31 °C. An increasing trend of FCE with fish size was seen at each temperature and indicated that larger cobia had a superior capacity of food utilization. Energy budgets of cobia were also influenced significantly by water temperature and fish size. The proportion of food energy lost in feces and excretion for cobia was small (<15%) and a large proportion of food energy was allocated to growth and metabolism. The ratios of metabolism energy to assimilated energy (range: 57%–84%, average: 69%) were much higher than the ratios of growth energy to assimilated energy. For cobia fast growth was attributable mainly to large food consumption though improved energy utilization with increased fish size at 27–33 °C made a certain contribution.


The culture of sargeant fish, or cobia (Rachycentron canadum) and eel (Anguilla spp.) in the Philippines is discussed. Market potentials for the cultured products are examined.


At present, forty-one cage culture systems are operated in Penghu. Their productions are approximately equal to 3,200 tons in 1998. The highest production of fish in cage culture is *Rachycentron canadum* (40%). *Pagrus major* (25%) is the second most important species. Over 70% of the fish in cage culture are distributed in Penghu areas except one species, *R. canadum*. The number of different fish species in cage culture fluctuates every year because of the fish price in the commercial markets. The fish feeds in cage culture include trash fish, dry feed, and moist feed. Seasonal variations of different feeds are present in cage culture. The four different designs of cage culture are fixed-flotation, semi-flexible, flexible, and semi-submersible. The future trends of cage culture systems will be operated in the commercial size. Typhoon is the potential threat in cage culture and this factor correlates with the cage designs, fish species, and fish body size. In conclusion, monsoons, typhoons, and commercial market sizes are three of the most important factors affecting cage culture in Penghu areas.


The patterns of growth of fish vary through time, depending on age and size. In aquatic communities, changes in environmental factors (e.g., temperature, light, depth, and water velocity) primarily affect food availability and influence growth. Temperature has manifold effects on the physiology and habitat choice of fish, and is one of the most important environmental factors affecting fish growth. Fish used in the study were obtained from the commercial hatchery farm in Penghu areas. Each fish was weighed and randomly assigned to cages. Fish were fed to satiation twice each day on commercial fish food. Surface water temperature was measured daily with a thermometer to 0.1 °C. Specific growth rate (G) was calculated for the study period: \( G = \frac{\log(W_2 - \log(W_1))}{(t_2 - t_1)} \), where \( W_2 \) = wet weight at \( t_2 \) days and \( W_1 \) = wet weight at day \( t_1 \). We found that growth rates of cobia varied considerably with water temperature. The values of growth rates were highest between 28 °C and 32 °C and then decreased below 20 °C. A correlation between water temperature and growth rates of cobia showed that increased temperature increased the amount of food required for maintenance, and increased the amount of food eaten by the fish. Pearson correlation coefficients of 0.70 implied that half of the growth rate variation was from temperature variation. It is apparent from our study that the relationship between water temperature and growth rates may provide a way of estimating cobia growth under different water temperature fed on...
maximum ration through a period of time. We concluded that water temperature influences cobia growth rates in its variant environment.


The purpose of this investigation was to assess the environmental conditions at two proposed fish farm sites at Nevis, West Indies. Samples were taken from one sampling location at the proposed nursery site, one sampling location at the proposed on-growing site and one sampling location between these two sites as a reference. Grab samples were taken to describe the benthic fauna and to determine the grain size, organic content and the content of nitrogen, phosphorus, zinc and copper of the sediment. Oxygen, salinity, temperature and transparency of the water were measured. Water currents during a month were also measured. The conditions at the three sites were good. The oxygen content in the water column was between 5.6 ml/l and 6.5 ml/l in October 2005. The sediment was sandy and the organic content was 4.2-4.9%. The chemical content was low, and the bottom fauna was rich and healthy, with diversity around 5. The maximum current at the nursery site was 28.6 cm/s and the water current direction was mainly northward or southward.


Cobia (*Rachycentron canadum*) is an excellent aquaculture candidate and culture of this species continues to develop worldwide. Current culture practices generally include larviculture and production of early juveniles on land with final growout occurring in ocean cages. Data indicate that production and/or growout of juveniles in land based recirculating systems may be hampered by growth depression in fish held at even relatively low densities. The current study investigated the responses of early cobia juveniles cultured at three different stocking densities (0.04, 0.22, and 0.44 g of fish/L) over a 10-week period in a recirculating aquaculture system. Water temperature was maintained at 27±1 °C and salinity was 32.0±3.0 ppt. Fluorescent light banks were used to maintain a light/dark cycle of 14 h light/10 h dark. Early juveniles used in this trial had an average initial weight of 6.7±0.2 g and were stocked at 3, 10, or 20 per tank in order to reach target stocking densities. Fish were fed to satiation twice daily with a commercial diet and the amount fed was measured to determine feed efficiency. Fish from each tank were counted and weighed collectively each week until the end of the trial to monitor growth and survival. In addition, fish from the control (0.04 g/L) tanks were individually marked via clipping of the pectoral fins and weighed individually each week. Survival was high (≥96% in all treatments) and there were no significant differences among treatments. Growth was also not significantly different among treatments with weight gains between 2523 and 2747% of initial weight (SGR ranging from 5.18 to 5.29). Feed efficiency of the control (0.96±0.02) was significantly lower than that of the 0.22 g/L treatment (1.04±0.03).


The potential of growing larval and juvenile cobia, *Rachycentron canadum*, in ponds was investigated. Larval cobia, obtained from tank spawning of wild-caught adults, were stocked 48-72-h post-hatch at a rate of 700,000/ha into three fertilized 0.25-ha ponds. At one week post-stocking (WPS), fish were observed consuming formulated feed. Growth was rapid, with specific growth rates (SGR) ranging from 12.5-19.2% body weight/day. At harvest (5 WPS) fish reared in two ponds weighed 7.9 and 9.3 g and total length (TL) was 118.9 and 129.3 mm, respectively (all fish reared in remaining pond died the night prior to harvest due to aerator failure). Feed conversion ratio (FCR) was 3.8 for both ponds and survival was 5.3 and 8.5%. Low survival rates were thought to be due primarily to cannibalism. Immediately after harvest, fish were restocked into two 0.25-ha ponds at a stocking rate of 14,400/ha. Fish were fed formulated, pelleted feeds. Growth was rapid up to ~9 WPS, after which pond water temperatures declined. Ponds were harvested at 13 and 15 WPS, respectively. Final weight of fish was 309.9 and 362.5 g. Final TL was 343.1 and 355.7 mm. FCR was 3.8 and 4.5 and survival was 27.5 and 30.5%. Major losses of fish were associated with avian predators and possibly a toxic algal bloom. Results of trials indicate that cobia larvae and juveniles can be reared in pond-based culture system, however additional research is needed to refine this approach.

Research was conducted at the South Carolina Department of Natural Resources Waddell Mariculture Center to evaluate the potential for captive reproduction of cobia, *Rachycentron canadum*, in outdoor tanks and ponds. In May 2001, adult cobia (3 males, 1 female, and 1 suspected female) obtained from a local high salinity estuary were stocked into an outdoor tank (32,000-L) receiving ambient estuary water. Spawning occurred within 2 days after stocking. Over the course of 3 consecutive days, a total of 3.6 million eggs were collected with roughly equal numbers collected during each 24-hour period. Mean fertilization rate was 58.1%. Hatching occurred at approximately 24 hours after initiation of each spawning event. Mean percent hatch was 27.5%. Fish were relocated to a 0.25-ha circular pond 10 days after tank spawning activity ended. One female received pelleted GnRHa before stocking. Eggs were observed 3 days after stocking and at 12 days after hatching, approximately 50,000 larvae were harvested. In May and June 2002, three groups of recently caught adult cobia, each consisting of 3 males and 1 female, were placed in one of three outdoor tanks. Spawning occurred within 2-4 days after stocking of Tanks 1 and 2. During a single spawning event, a total of 2.1 million and 560,000 eggs were collected from Tanks 1 and 2, respectively. Relative batch fecundity of females stocked in Tanks 1 and 2 was estimated to be 79.2 and 20.9 eggs/g, respectively. No fertile eggs were collected from Tank 2. Percent fertilization and hatch of eggs collected from Tank 1 was 3.2% and 1.5%, respectively. No spawning activity of fish stocked in Tank 3 occurred. Findings reveal that naturally conditioned recently caught adult cobia can readily spawn soon after capture and that ponds can be utilized for reproduction of this species in the U.S.


The effect of feeding three commercial diets on production characteristics and body composition of juvenile cobia, *Rachycentron canadum* reared using recirculating aquaculture systems (RASs) was assessed in a 56-d growth trial. Juvenile cobia (mean weight±SE, 29.2±0.7 g) were stocked into three 8-m$^3$ tanks in each of four RASs at an initial density of 1.2 kg/m$^3$. After stocking, fish were fed one of three commercial diets: Hybrid Striped Bass diet (HSB; 44% protein, 12% lipid), Finfish Gold diet (GOLD; 42% protein, 16% lipid), or Marine Grower diet (MG; 50% protein, 15% lipid), all at a targeted feed rate of 3-5% of body weight per day. At 2-week intervals, 10% of the population of each tank was collected to determine mean weight, weight gain, specific growth rate (SGR), feed conversion efficiency (FCE), and biomass. At the end of the rearing trial, the entire population of each tank was harvested to determine production characteristics and survival. In addition, fish were sampled to determine whole-body composition, hepatosomatic index, intraperitoneal fat ratio, energy retention (ER), protein efficiency ratio (PER), and protein productive value (PPV). Final weight (311.0 g), weight gain (281.8 g), SGR (4.23% per day), FCE (85.7%), biomass (11.20 kg/m$^3$), and ER (32.7%) of fish fed the MG diet were significantly greater than those of fish fed the HSB and GOLD diets. No differences in survival, gross energy, ash, or crude lipid content existed among fish fed the three diets. Lowest dry matter content, lowest PPV, and highest protein content were observed in fish fed the HSB diet. Highest PER was observed in fish fed the GOLD diet. Although the cost of production per kilogram for rearing juvenile cobia with the MG diet would be greater, this cost could be offset by the 15% reduction in rearing time required as compared with the HSB and GOLD diets.


The objective of this study was to investigate the growth rate and feed conversion ratio (FCR) of juvenile cobia, *Rachycentron canadum*, in different flow velocities. In experiment A, fifteen groups of fish with an initial mean weight of 14.35 g were reared for 28 days in one of five flow velocities: 0, 5, 10, 15, and 20 cm/s. In experiment B, fifteen groups of fish with an initial mean weight of 30 g were reared for 21 days in the same velocities as in experiment A. In experiment C, fish weighing an average 77 g were raised for 21 days in 0, 10, 20, 30, and 40 cm/s. The optimal velocities in terms of growth rate were 10 cm/s for fish of 10-30 g (experiment A), 20 cm/s for fish of 30-60 g (experiment B), and 23 cm/s for fish of 60-200 g (experiment C); the optimal velocity increased as the fish weight increased. FCR and specific growth rate (SGR) also significantly ($p<0.05$)
corresponded to the flow velocity for the different sized juveniles with the optimal FCR and weight gains occurring at 10-23 cm/s. FCR rapidly increased when the velocity exceeded 35 cm/s, regarded as the maximum flow velocity for fish growth.

2.4. GENETICS & REPRODUCTION

173. Arnold, C.R., Kaiser, J.B. & Holt, G.J. (2002). Spawning of cobia Rachycentron canadum in captivity. Journal of the World Aquaculture Society, 33(2), 205-208. Cobia is a promising candidate for aquaculture because of its rapid growth rate, hardiness, and flesh quality. They can grow to 4-6 kg in 1 yr and are considered to have the greatest potential among candidate species for production in cage systems. Commercial scale aquaculture for food or stock enhancement of any fish requires significant numbers of fingerlings and consistent production. Research at the University of Texas at Austin Marine Science Institute Fisheries and Mariculture Lab (FAML) has focused on controlled spawning of cobia using water temperature and photoperiod manipulation as described by Arnold et al. for spotted seatrout Cynoscion nebulosus. The goal is to develop tank spawning during the natural reproductive period and to investigate extending and controlling spawning by inducing gonadal maturation at other times of the year. Major challenge for marine culturists has been synchronizing the capture of ripe male and female fish for spawning research. This is especially true with regards to a large, active, pelagic species such as cobia, and conditioning broodstock in order to control spawning might be one solution to this problem. Consistent, high quality egg production of cobia is the first step towards understanding the life history, development, and biology of this species for future production. Current research at FAML provides an additional method of egg production which would not require capturing new broodstock each year or the need to construct outdoor ponds for spawning efforts as is currently the practice in Taiwan.

174. Caylor, R.E., Biesiot, P.M. & Franks, J.S. (1994). Culture of cobia (Rachycentron canadum): cryopreservation of sperm and induced spawning. Aquaculture, 125(1-2), 81-92. Studies toward the development of cobia (Rachycentron canadum) aquaculture were initiated. Methods of cryopreserving cobia sperm were compared and sperm motility was assessed after long-term frozen storage. Sperm stored in 10% dimethyl sulfoxide, 3 mM glucose, and 10% raw chicken egg yolk showed approximately 100% motility upon thawing after more than 1 year of storage at -80 °C. Sperm motility declined after about 60 min at room temperature, but approximately 100% motility could be restored by addition of a few drops of 5 mM theophylline. Ripe, wild-caught female cobia was held in recirculating seawater systems and ovulation was induced by injection of human chorionic gonadotropin at a concentration of 275 IU/kg of body weight. Fertilization was attempted using the cryopreserved sperm. Although fertilization did not occur, we are optimistic that cobia aquaculture is feasible.

175. Chen, H., Sun, L., Hu, J. & Yan, Y. (2006). Biological characteristics and artificial breeding technique in a large scale of cobia, Rachycentron canadum. Marine Sciences, 30(2), 5-9. The biological characteristics such as morphology, distribution, feeding, reproduction and larval and juvenile development, and the artificial breeding technique of cobia (Rachycentron canadum) were illustrated simply in the paper. In marine cage culture 2-3 years old cobia selected as a broodstock could be artificially induced to spawn time after time during the period of their reproduction seasons by enhancing nutrition and using hormones. The whole reproduction period lasted from April to October at Daya Bay and the suitable temperature and salinity for cobia reproduction were 25-31 °C and 30-34, respectively. In this paper the fertilization rate was 30%-60% and the hatching rate was 55%-82% for cobia. Large-scale artificial breeding for cobia was carried out in outdoor ponds, and under the conditions of temperature 26-32 °C and salinity 28-33, cobia fry could reach 8-11 cm in total length for sale after 35-40 d breeding.

176. Faulk, C.K. & Holt, G.J. (2008). Biochemical composition and quality of captive-spawned cobia Rachycentron canadum eggs. Aquaculture, 279(1-4), 70-76. Interest in the commercial production of cobia Rachycentron canadum continues to rise as additional insight is gained into the hardy and fast growing nature of this species. However, research regarding the biochemical composition of captive-spawned eggs and egg and larval quality remains scarce. Such data is essential as a common bottleneck to production is a steady supply of
fingermings for grow-out. This study quantified the biochemical composition and quality of cobia eggs produced over 2 spawning seasons by broodstock on a traditional 'trash fish' diet which is commonly fed to tank spawning cobia. Throughout the study, batch fecundity, proportion of floating eggs and percent hatch averaged >1 million eggs, similar to 0.8 and 70%, respectively. Batch fecundity was significantly higher during the second spawning season as a result of the increased size of the females which weighed 18/22 kg and 22/26 kg at the beginning of each season. A positive correlation was found between the proportion of floating eggs and hatch rate for both spawning seasons. No correlations were found between egg composition (total lipid (30.0±1.1% dry wt), protein (25.4±2.2% dry wt), carbohydrate (2.4±0.3% dry wt), vitamin E (10.2±0.6 µg/g wet wt) or dry weight (119.1±5.5 µg/egg)) and egg quality (proportion of floating eggs, hatch rate, larval growth and larval survival). Further, no differences in egg composition were noted between seasons or over the course of each season. The fatty acid composition of cobia eggs varied between seasons possibly due to changes in the quality of frozen feed (fish, shrimp, squid) given to the broodstock. The only correlation between the fatty acid profile and egg quality was a decrease in the proportion of floating eggs as the total amount of n-3 highly unsaturated fatty acids increased. No relationship between egg quality and amino acid content was noted with the most prominent amino acids being glutamate, leucine, alanine, proline, lysine and aspartate nor were any differences detected between spawning seasons.


Two mature female cobia, Rachycentron canadum, injected with a single dose of human chorionic gonadotropin (HCG) at 275 IU/kg of body weight, and one non-injected male spawned spontaneously in captivity. Oocytes aspirated from each female prior to injection were maturing vitellogenic oocytes nearing the final oocyte maturation (FOM) stage and averaged 625 µm in diameter. Both females spontaneously spawned similar to 42 hours post-injection; spawned oocytes ranged 1.1 - 1.3 µm in diameter. Fertilized eggs hatched similar to 26 hours later. Estimates for number of eggs spawned (both females combined) and hatched were 3.2 million and 320,000, respectively. Aspects of embryogenesis and larval growth/development were observed. Critical survival period for larvae was day 3 at which time termination of yolk sac absorption occurred and first feeding commenced. Enriched rotifers, wild zooplankton, and artificial food were offered larvae during larval rearing treatments. Larvae contained in a black tank and fed a high density diet of enriched rotifers exhibited highest survival and were reared through day 13, post-hatch. The study documents the spontaneous spawning of wild-caught male and female R. canadum from the Gulf of Mexico, and provides comments on fertilization, hatching and larval development. Results of the study strongly suggest that R. canadum exhibits potential as aquaculture species.


Cobia, Rachycentron canadum has emerged as one of the topmost finfish species for mariculture. In India, cobia broodstock was developed and induced breeding was achieved for the first time at Mandapam Regional Centre of the Central Marine Fisheries Research Institute (CMFRI), Cochi, India. The broodstock was developed in sea cages of 6 m diameter and 3.5 m depth. Sexes were separated about two months prior to the onset of breeding season and stocked in separate cages. During March 2010, a female with intra-ovarian egg diameter of 700 µm along with two males were selected for induced spawning. The brooders were induced with human chorionic gonadotropin (hCG) at doses of 500 IU per kg body weight for female and 250 IU per kg body weight for males. Spawning was noted after 39 h of intra-muscular injection. The total eggs spawned were estimated as 2.1 million. About 90% fertilization was recorded (fertilized eggs amounted to 1.9 million). The eggs were collected using a 500 µm mesh net and stocked in incubation tanks at varying densities. The eggs hatched after 22 h of incubation at a temperature range of 28-30 °C. The percentage of hatching was 80% and the total number of newly hatched larvae was estimated as 1.5 million.

Research Institute for Marine fisheries has completed the artificial spawning technology of cobia *Rachycentron canadum*. The result of this study showed that the maturation point can be controlled by regulating the starting point of growing out process and dosage of some vitamins as well as minerals thereby the high number of matured fished at same time can be avoided to extend seed production time in spawning season. The dosage of LHRIiA hormone used to inject into fishes of 20g/kg of female fish and 10g/kg of male fish yielded maximum average eggs shed, highest fertilization and hatching rate, high quality of larvae and highest survival rate of 5 days-larvae. Larvae reared in a semi-recirculation system (amount of water exchange per day is 200%) with density of 50 individual per liter and fed with raw feed had high survival and high growth rate. Indeed, cobia seed production can be actively done for sea farming of this species.


181. **Liu, C., Liu, L., Wang, Z. & Li, Y. (2005).** Studies on molecular genetic characteristics of cobia *Rachycentron canadum*. *Journal of Tropical Oceanography*, 24(1), 77-85. Molecular genetic characteristics of cobia *Rachycentron canadum* was studied. Random amplified polymorphic DNA (RAPD) technique was used to investigate the genetic variation of natural population of cobia. Totally 119 loci were obtained with 17 primers. The percentage of polymorphic loci (F) was about 80.85%. The genetic distance (D) between the individuals was 0.2600 on average. The Neis gene diversity index (H) was 0.3009 on average. The Shannon information index was 0.4498 on average. The results show that the nuclear genetic variability of cobia was comparatively rich. The restriction fragment length polymorphism (RFLP) of mitochondrial DNA (mtDNA) of cobia was studied using 19 restriction endonucleases recognizing 5, 6 base pairs. The physical map of mtDNA has been constructed based on 6 endonucleases selected from 20 restriction endonucleases. A 850-hp segment of the mtDNA cytochrome b was amplified using primers like 5'-GTG ATC TGA AAA ACC GTT G-3' and 5acO-AAT AGG AAG TAT CAT TGC GGT TTG ATG-3'. The RFLP of mtDNA cytochrome b of cobia was studied using 18 restriction endonucleases recognizing 4-6 base pairs. The assay showed that the genetic marker was suitable for studies on cobia genetics and breeding.

182. **Luo, J., Liu, C. & Huang, X. (2007).** Preliminary study on artificial breeding of *Rachycentron canadum* in pond. *Marine Fisheries Research*, 28(1), 13-18. Study was conducted on artificial breeding of *Rachycentron canadum* in pond. Through anatomizing the intestine of larvae, the variety of biological diets for initial feeding was decided. The results indicated that the biggish nauplius of Copepod were fitter than Rotatoria in being initial diet of *Rachycentron canadurn* larvae. According to the measurement of the body length and weight, *Rachycentron canadurn* grew very well under the condition of pond artificial breeding, with the body length of 7 days old larvae and 30 days old seedling reaching 1 centimeter and 15 centimeter, respectively.

183. **Luo, J., Liu, C. & Luo, W. (2005).** Studies on breeding parent fish of *Rachycentron canadum* in netting tank and artificial seed breeding. *Marine Fisheries Research*, 26(2), 18-25. At the end of December, 14 uninjured *Rachycentron canadum* aging over 1.5 years, were selected and moved from the netting tanks in sea to big cement pools with covers on land, so that they were intensively cultured. About four months intensive culture, the *Rachycentron canadum* became mature and spawned naturally, about one week earlier than the fish cultured in the netting tanks of sea. In indoor nursing pools with seawater specific gravity of 1.020 ± 0.5, pH from 8.1 to 8.4, 26 hours and 24 hours of hatching were required respectively when the water temperatures were 27.0 °C and 29.2 °C. The hatching rate is from 88.8% to 93.5%. The fry suffered from a peak of death during 7th to 9th day and the color of fry changed from reddish brown to black obviously around the 11th day. After one month's culture, the result is that 150 000 *Rachycentron canadum*, with the length of 6.0 cm were produced and the survival rate was about 9%.

The techniques of homology cloning and anchored PCR were used to clone the IL-1 β gene from cobia (*Rachycentron canadum* Linnaeus). The full length cDNA of IL-1 β is 1,104 bp, containing a 5' untranslated region (UTR) of 108 bp, an ORF of 741 bp, a encoding polypeptide of 246 amino acids with an estimated molecular mass of 27.68 kDa, and a 3' UTR of 255 bp. The searches for nucleotides and protein sequence similarities with BLAST analysis indicated that the deduced amino acid sequence of cobia IL-1 β was homologous to the IL-1 β in other fish species and even the mammalian. Conserved signature sequences of ILI β gene family and several potential glycosylation sites were found in the cobia IL-1 β deduced amino acid sequence. Analysis with the Signal P software revealed that there was no signal peptide in the sequence, which was common with the other known IL-1 β molecules. Just as other nonmammalian IL-1 β genes sequenced to date, the sea perch IL-1 β lacked an aspartic acid in cut region of mammalian IL-1 β which was required for cleavage by ICE (interleukin-1 converting enzyme).

185. Renshaw, M.A., Pruett, C.L., Saillant, E., Patton, J.C., Rexroad III, C.E. & Gold, J.R. (2005). Microsatellite markers for cobia, *Rachycentron Canadum*. *Gulf of Mexico Science*, 23(2), 248-252. Polymerase chain reaction (PCR) primers are reported for 35 nuclear-encoded microsatellites developed from a genomic library of cobia (*Rachycentron canadum*). All 35 microsatellites were tested for reproducibility and polymorphism using 24 cobia sampled offshore of Ocean Springs, MS. Thirty-three of the microsatellites were found to be polymorphic; genotypes at seven of these differed significantly from Hardy-Weinberg (HW) expectations, possibly because of the presence of null alleles. Levels of allele and gene diversity (expected heterozygosity) were lower on average than values reported previously for other marine fishes. The 26 micro-satellites whose genotypes were in HW equilibrium should provide useful tools for future studies of cobia relating to both stock assessment and aquaculture.

186. Renshaw, M.A., Saillant, E., Bradfield, S.C. & Gold, J.R. (2006). Microsatellite multiplex panels for genetic studies of three species of marine fishes: red drum (*Sciaenops ocellatus*), red snapper (*Lutjanus campechanus*), and cobia (*Rachycentron canadum*). *Aquaculture*, 253(1-4), 731-735. Multiplex panels of nuclear-encoded microsatellites were developed for three species of marine fishes of interest to both public and private aquaculture ventures: red drum (*Sciaenops ocellatus*), red snapper (*Lutjanus campechanus*), and cobia (*Rachycentron canadum*). The multiplex panels will be useful in a variety of applications, including strain and hybrid identification, parentage assignment, pedigree reconstruction, estimating genetic diversity and/or inbreeding, mapping of quantitative trait loci, and marker-assisted selection. The panels also will be useful in studies of stock structure of 'wild' populations. Comparison of costs for expendable supplies revealed that four- and eight-panel multiplexes reduced expenditures four- and eight-fold, respectively, relative to single microsatellite gels. Personnel time also was reduced significantly.

187. Ruan, Y., Zhou, W., Li, G. & Zhang, Q. (2014). On mtDNA cytochrome b gene sequence variation of Cobia (*Rachycentron canadum*). *Marine Fisheries/Haiyang Yuue*, 36(2), 97-101. *Rachycentron canadum* is a species widely distributed in warm waters of the bottom of the Atlantic, Indian and western Pacific. It is also a kind of important economic fish. For a long time, affected by natural and human factors, the number of wild Rachycentron canadum has decreased sharply. In order to provide valuable and referable data for the making of Rachycentron canadum conservation policy and for management of the shrinking population, researches on genetic diversity needs to be started. In this study, 883 bp mtDNA cytochrome b sequences from 34 individuals collected from Lianyangang (LYG, n=11), Zhoushan (ZS, n=8), Fangcheng (FC, n=15) were sequenced. Results were as follows: 1. Genetic diversity: Five variable sites detected in aligned sequences defined six haplotypes, the average haplotype (h) and nucleotide diversity (π) were 0.324 and 0.0004 respectively, indicating a low genetic diversity. LYG contained the highest values of genetic diversity, the haplotype and nucleotide diversity were 0.473 ± 0.162 and 0.00057 ± 0.00593 respectively, whereas ZS showed no genetic variation. 2. Genetic differentiation: Pairwise FST from LYG to ZS and FC were 0.029 (P = 0.00) and 0.042 (P = 0.00) respectively, and FST between ZS and FC was -0.04803 (P<0.00), indicating that there was only relatively low differentiation between LYG and the other two populations, and no obvious differentiation was found in ZS and FC. Analysis of Molecular Variance (AMOVA) showed that most of genetic variation in three populations distributed within populations. This may be due to the fact that the East China Sea, South China Sea and the Yellow Sea have continuity, which promotes groups of communication between genes. Chinese offshore Rachycentron canadum showed low genetic diversity (Hd = 0.324 ± 0.103, Pi = 0.0004), and FST, AMOVA and TCS network showed no genetic variation and no
obvious geographical pattern system within populations. 3. Population expanding: The haplotype network was star-like, Tajima’s D and Fu’s Fs values in three populations of combined neutrality tests were significantly negative (FST= -1.92240, P<0.00; FST= -5.735, P<0.00), indicating that cobia in coastal waters of China had experienced populations expansion in history. According to observed r value (0. 364), the deduced population expansion of Cobia occurred about 3.1- 1.2 million years ago, in last glacial of the maximum. 4. We can speculate that these three groups maybe belong to the same population, for their geographic genetic differentiation was not obvious. It should be noted that these results do not exclude the possibility of difference in other regions for the number of geographic populations and samples is small. In order to understand and assess the genetic diversity of *Rachycentron canadum*, we need to use AFLP fingerprinting, microsatellite DNA and relevant techniques, which can understand the genetic differentiation of *Rachycentron canadum* and provide a theoretical basis for the protection of wild germplasm.


Year-round control of the spawning cycle of cobia (*Rachycentron canadum*) has been established by using water temperature manipulation. To compare the effectiveness of using this method to induce volitional spawning in cobia, two 80 m³ recirculating aquaculture systems (RAS) were used. Temperatures in one of the maturation tanks ('Mat 1') were maintained between 27 and 29 °C for 12 months of the 15.5-month study period. Temperatures in the second maturation tank ('Mat 2') were allowed to fluctuate naturally throughout the year and ranged from 20 to 32 °C. A total of 101 spawning events occurred in the tanks between the spring of 2008 and the summer of 2009 (3 April 2008 to 17 June 2009). Of the 38 total spawning events in Mat 1, 17 of them (44.7% of all Mat 1 spawning events) occurred during the off-season (fall and winter). The egg viability rates did not differ significantly (P>0.05) between on- and off-season spawns in Mat 1. Conversely, cobia broodstock exposed to natural water temperatures (no environmental manipulation) in Mat 2 followed the natural pattern of warm water (>26 °C) dependence, limiting egg production to spring and summer seasons. This method of water temperature manipulation allows for effective control of the cobia reproductive cycle without compromising egg viability.


N-3 highly unsaturated fatty acids (HUFAs), eicosapentaenoic (EPA) and docosahexaenoic acids (DHA), are particularly important in the physiological procedures of human beings and animals. However, human and animals including some marine fish species can not synthesize HUFAs from linoleic and linolenic acids since they have no or less activity of Δ6 or Δ5 fatty acid desaturases and elongase that are a key for the synthesis of HUFAs. Therefore, they have to ingest HUFAs from their diets for the normal growth and development. Actually, this is a question that should be further explored in some marine fishes. Cobia (*Rachycentron canadum*) is a worldwide marine fish in tropical, subtropical and warm temperate seas. Cobia is an excellent candidate for aquaculture because of its fitting to wide salty, high resistance to diseases, and rapid growth, reaching 6-10 kg in 12-14 months. Marine fish is main source of HUFAs, DHA and EPA for human beings. With the decline of fishing and rapidly expanding aquaculture, feed-grade fishing has reached sustainable limits. A developing cobia commercial fishery needs to solve sustainable developing problems of artificial nutrition feed, using plant products to replace fish products, in which the basis of nutrition, physiology and biochemistry of cobia is necessary to study. Accordingly, Δ6 fatty acid desaturase, a key enzyme in the synthesis of HUFAs in cobia was studied in our experiments. Δ6 fatty acid desaturase cDNA of cobia (*Rachycentron canadum*) was cloned and sequenced as well as its expression in different tissues was determined. Total RNA was extracted from the liver of juvenile cobia and amplified using real time-PCR (RT-PCR). The amplified product was a fragment with 743bp. The sequence of the fragment of Δ6 fatty acid desaturase from cobia showed great identity (87%) with that of European seabass (*Dicentrarchus labrax*). The protein sequence of the fragment included two transmembrane regions and two histidine boxes which were composite characteristics of a microsomal fatty acid desaturase. The enzyme gene expression in different tissues of cobia was determined using real-time quantity PCR (RTQ-PCR) and their expressive orders were as follows: brain > liver > heart, intestine, spleen, kidney and gill > muscle and skin; while no expression was detected in adipose tissue. A conclusion is that cobia has Δ6 fatty acid desaturase, which is a key enzyme for the synthesis of HUFAs. The enzyme gene is maximally expressed in the brain of the fish suggesting that the HUFAs have an important role in central nervous system.
190. **Zhang, H., Mao, L., Feng, J., Guan, Y., Xu, H. & Su, Y. (2011)** Full-length cDNA cloning and tissue expression of major histocompatibility complex (MHC)-I α from cobia (*Rachycentron canadum*). *South China Fisheries Science*, 7(1), 8-17. We cloned the MHC-I α gene from cobia (*Rachycentron canadum*) by homology cloning and RACE PCR. The full-length cDNA of MHC-I α comprises 1330 bp with a 76 bp 5' untranslated region (UTR), a 189 bp 3' UTR and a 1065 bp open reading frame (ORF), encoding a polypeptide of 354 amino acid residues with a predicted molecular weight of 40.10 kDa and a theoretical isoelectric point of 5.70. According to the phylogenetic tree and amino acid similarity comparison, the homology of MHC-I α amino acids between cobia and some known fishes and human (*Homo sapiens*) varies from 27.9% to 67.1%. The putative protein sequence shows some important features including leader peptide, α 1, α 2, α 3, CP/TM/CYT regions and conserved cysteines, etc. Real-time PCR result indicates that MHC-I α expresses in all detected tissues at different expression levels. High expression is detected in head kidney; moderate expression is detected in gill, spleen and intestine; while low expression is detected in heart, brain and muscle.

191. **Benetti, D.D., Orhun, M.R., Sardenberg, B., O’Hanlon, B., Welch, A., Hoenig, R., Zink, I., Rivera, J.A., Denlinger, B., Bacoat, D., Palmer, K. & Cavalin, F. (2008).** Advances in hatchery and grow-out technology of cobia *Rachycentron canadum* (Linnaeus). *Aquaculture Research*, 39(7), 701-711. This paper describes advances in hatchery and grow-out technology of cobia (*Rachycentron canadum*, Linnaeus). In 2007, methods for capture, transport, acclimation, sampling, conditioned spawning, larval rearing, fingerling production, nursery, shipping and grow-out have been perfected. Survival rates ranging from 17.5% to 35% were achieved from egg to shipping size fingerlings (1.0g) in 2007 at the University of Miami Experimental Fish Hatchery, with production of approximately 20000 fingerlings per 12000L tank. Wild and F1 broodstock cobia have been conditioned to spawn through temperature manipulation producing viable eggs for experimental and production level larval rearing trials in several hatcheries. Brood fish have also been induced to spawn using hormones. Cobia appear to be susceptible to infestations by parasitic protozoa such as *Amyloodinium ocellatum* and to infections caused by deleterious bacteria such as *Photobacterium* spp. and *Vibrio* spp. Prophylactic methods used to prevent and control epizootic diseases at the hatchery are summarized. Improved techniques for cage management were implemented, and both novel designs of submerged cages deployed in exposed areas and traditional gravity cages in protected areas have been used for commercial ongrowing of cobia in the Americas and the Caribbean region.

192. **Benetti, D.D., Sardenberg, B., Welch, A., Hoenig, R., Orhun, M.R., & Zink, I. (2008).** Intensive larval husbandry and fingerling production of cobia *Rachycentron canadum*. *Aquaculture*, 281(1-4), 22-27. Methods and results of two larval rearing trials of cobia (*Rachycentron canadum*) are presented. These trials were designed to test the efficacy of protocols developed over several years of research in cobia larviculture at the UMEH. The protocols incorporate the use of probiotics and prophylaxis, minimize microalgal use, and include commercially available ingredients for live feed enrichment. During the trials, fertilized eggs were stocked at 400/L and incubated in 1000-L cylinder-conical tanks with flow-through seawater at 500% daily exchange rate. Moderate aeration and pure oxygen were used to maintain dissolved oxygen concentrations above saturation (6.5 mg/L at 26 °C). Hatching occurred at 22-24 h post fertilization. Two day-post-hatch (dph) yolk-sac larvae were stocked in four 12,000-L cylinder-conical tanks at 5 and 10 larvae/L. Beginning on 3 dph, larvae were fed microalgae (*Isochrysis galbana* C-strain) at low concentrations (5-10,000 cell/mL) and enriched rotifers (*Brachionus plicatilis*) at 3-5/mL through 9 dph. Beginning on 7 dph, enriched Artemia (*Artemia franciscana* GSL Strain) nauplii were fed to larvae at 0.1-1/mL. Cobia larvae were reared at water temperatures ranging from 24.3 to 31.8 °C. Water quality parameters were within normal ranges for seawater: salinity 26-34 ppt, pH 7.92-8.16, and NH₃<0.18 mg/L. Vigorous aeration and supplemental oxygen were used at all times during both larval rearing trials to maintain adequate water movement and levels of dissolved oxygen (DO) (7.0-9.0 mg/L). Water was filtered down to 10 µm using standard sand filters filled with broken glass media and bag filters prior to...
entering the tanks. Daily water exchange rates in the tanks ranged from 100% at 3 dph to 500% from 17 dph onwards. Between 20 and 22 dph, all post-larvae were fully weaned onto dry starting diets. Survival rates of post-larvae measuring 1.5-2.0 cm SL and weighing 0.5 g at 20-22 dph were estimated to be ≥50%. Further mortality during the nursery stage to 3-5 cm and 1-3 g fingerlings prior to shipping at 27 dph brought the overall survival rate to an average of 25.7%. Survival rates of fingerlings cultured in tanks initially stocked at lower densities (5 larvae/L) was significantly higher (P=0.0078). From 15 dph, post-larvae and fingerlings were daily graded by size with large individuals singled out and stocked into another tank. These trials generated 125,328 fingerlings in four tanks in just two months, levels of production that could sustain a commercial operation and indicate that cobia aquaculture can be viable in the Americas.

193. Chang, S.L., Hsieh, C.S., Cheng, S.H., Cheng, C.S., Chen, T.I. & Liao, I.C. (2001). The spawning performance, early development and larval rearing of cobia Rachycentron canadum. 6th Asian Fisheries Forum Book of Abstracts, p.37. Cobia, Rachycentron canadum, can spawn naturally in the captivity. Mean spawning frequency is high with 3.6 spawnings/female/per year in 80 m² round concrete pond if the feeding activity is normal. Spawning was found all year around with the peak spawning in spring and autumn. There was no obviously difference of spawning occurrence among the lunar cycles. Some spawning occurred even in rainy day or tropical depression. The spawning of cobia was not interrupted in summer and winter season in south part of Taiwan if water temperature could be controlled at range of 23-27 °C. Fertilized eggs of cobia are spherical, transparent, floating pelagic eggs. Water hardened, mean diameter of fertilized eggs was 1.33 mm (1.26-1.4 mm) and contained a single oil globule. Eggs began to hatch at 31 h after fertilization when incubated at 25 °C. Total length of newly hatched larvae increased over time from 3.5 mm at hatching to 4.0, 4.7 and 5.1 mm respectively at 12 h, 24 h, and 72 h post hatching. First exogenous feeding occurred at 60-64 h post hatching when held at 24-25 °C. Copepod nauplii were a preferred live prey at first feeding. Larval rearing yielded best survival using the green water rearing technique compared to clear water system. The skin of larvae is susceptible to be infected by protozoa Epistylis sp. and diatom Nitzschia sp. Metamorphosis occurred around 11 days post hatching when reared at 26-28 °C. The characteristic of white lateral stripe formed gradually while dorsal skin color changed from reddish brown to dark green during metamorphosis. Developing fry exhibited positive phototaxis post metamorphosis and preferred to stay on the upper layer of rearing water at night. Young juveniles ranging 30-60 mm can be obtained at sufficient food condition after 20 days post hatching. In order to reduce the production cost, the grading of fry can be conducted for first stage of nursery or/and weaning on 1 mm floating pellet feed at the same larval rearing pond.

194. Faulk, C.K. & Holt, G.J. (2005). Advances in rearing cobia Rachycentron canadum larvae in recirculating aquaculture systems: live prey enrichment and greenwater culture. Aquaculture, 249(1-4), 231-243. Cobia Rachycentron canadum is a relatively hardy species which exhibits high rates of growth during the larval and juvenile periods. Currently, this species is considered to be a good candidate for commercial production in recirculating aquaculture systems. However, little information is available regarding the nutritional requirements of cobia larvae in such systems, and this information is required to advance commercial technologies for the successful production of cobia fingerlings. Experiments were conducted to examine the effects of enriching rotifers and Artemia with live algae or commercial preparations on the growth and survival of cobia R. canadum larvae and to evaluate the benefits of adding live algae to the systems. Prey items were enriched with live Isochrysis galbana, live Nannochloris oculata, Algamac 2000, Algamac 2000 supplemented with 10% or 20% Aquagrow arachidonic acid, or Algamac 3050. In addition, larvae fed prey enriched with Algamac 2000 were reared in the presence of live I. galbana (~40,000 cells ml⁻¹) or N. oculata (~80,000 cells ml⁻¹). Significant differences in the fatty acid composition of the rotifers and Artemia were found among treatments. Generally, prey enriched with the commercial preparations contained higher levels of highly unsaturated fatty acids than those enriched with live algae. Furthermore, a positive correlation was found between dietary docosahexaenoic acid (DHA) and the amount of DHA measured in the whole body tissues of 16-day-old larvae. Larval growth (measured as standard length) and survival of 16-day-old larvae were significantly higher (P<0.05) when larvae were fed prey enriched with the commercial preparations (14.7-15.2 mm; 12.0-15.6%) compared to N. oculata (11.8 mm; 4.4%). However, when larvae were reared on N. oculata enriched rotifers and subsequently fed Algamac 2000 enriched Artemia there were no significant differences in growth or survival compared to larvae which were fed both rotifers and Artemia enriched with Algamac 2000.
This suggests that the enrichment of rotifers may be less important than the enrichment of Artemia. No significant differences in growth or survival were found when larvae were fed prey enriched with live *I. galbana* (13.5 mm; 8.2%) or commercial preparations (12.4-12.6 mm; 12.9%). However, the presence of live algae (*I. galbana* or *N. oculata*) in the rearing tanks significantly improved larval survival to 23.3% and 24.7%, respectively. The results of this study suggest that enriching rotifers and *Artemia* with live *I. galbana* or commercial preparations such as Algalac 2000 and 3050 in conjunction with greenwater culture systems improves the growth and survival of cobia larvae in recirculating aquaculture systems.


Cobia *Rachycentron canadum* is a fast-growing, pelagic marine species that has recently attracted aquaculturists in both the research and commercial sectors. The typical method of grow-out for this species is in outdoor systems where production is limited to locations and seasons conducive for adequate growth and survival. Expanding the culture of cobia to indoor recirculating aquaculture systems (RAS) would allow for the production of fingerlings throughout the year and extend production to cooler regions. Two rearing trials were conducted to examine the growth and survival of cobia from hatching through 4 (trial 1, T1) or 35 (trial 2, T2) g in RAS. Cobia larvae were reared in circular tanks placed in a raceway to control water temperature and quality. During early juvenile grow-out, fish were transferred without grading to a second raceway on 29 dph (T1) or over a period of grading from 29-43 dph (T2). Larval growth (1-22 dph) measured as standard length was similar for both trials ranging from ~3.9 to 14.7 mm. However, larval growth measured as wet weight (0.033 g, T1; 0.026 g, T2) or dry weight (5.7 mg, T1; 3.9 mg, T2) was significantly greater on 22 dph during T1 as was the ratio between myotome height and standard length. These differences may have resulted from an increase in initial densities from 8.7 larvae l⁻¹ (T1) to 14.7 larvae l⁻¹ (T2) which apparently caused an increase in food competition and overall aggression. During juvenile grow-out, cobia reached 4.0 g on 43 dph in T1 and 35.4 g on 71 dph in T2 matching weights achieved during grow-out in outdoor ponds. Over the course of both trials, survival was similar to that reported in outdoor ponds. Mean survival ± S.D. during the early rearing phase (hatching through 29 or 43 dph) averaged 13.2 ± 3.2% and 10.4 ± 3.2% corresponding to final densities of 0.9 ± 0.2 and 1.2 ± 0.4 fish/l for T1 and T2, respectively. During the first grow-out phase (29-43 dph), survival of fish moved into the open raceway was 64.5% in T1 and 88.7 % in T2. Survival of cobia during the second grow-out phase (43-71 dph) for T2 was 92.5%. The results of this study indicate that cobia can be successfully cultured in indoor systems from hatching through at least 35 g without negatively affecting growth or survival.


Cobia aquaculture has been gaining momentum internationally and has spread to more than 23 countries, half of them in the Asia-Pacific region. Envisaging the prospects of cobia farming in India, broodstock development was initiated and the first successful induced breeding was achieved in March 2010. Larviculture was experimented in Fibre Reinforced Plastic (FRP) tanks as well as Reinforced Cement Concrete (RCC) tanks and protocols were evolved. Green water technique employing the microalga, Nannochloropsis oculata was used. The critical stage for the larvae was from 5 to 9 days post-hatch (dph), when cumulative mortality reached around 90%. Enriched rotifers were fed from 3 to 10 dph and enriched *Artemia* nauplii from 9 to 18 dph. Weaning with larval inert feed was initiated from 18 dph and grading was carried out once in four days to avoid cannibalism. The study was conducted for 31 days and the final larval survival noted in the FRP and RCC tanks were 2 and 1%, respectively. At the end of the experiment, the specific growth rate of larvae in the FRP system was 30.1% of body weight per day, while the same in RCC tank was 28.3% of body weight per day. The low survival and specific growth rate of larvae in the RCC tanks could be attributed to the low densities of live feed maintained. The present experience indicated that cobia seed production can be successfully practised and by refining the methodology, the survival and growth can be enhanced to achieve commercial level fingerling production.

This study reports the effect of different rearing densities on the growth and survival of cobia *Rachycentron canadum* larvae in a closed recirculating aquaculture system.


Cobia *Rachycentron canadum* is a marine finfish species with emerging global potential for mariculture. Positive culture attributes include capacity for natural and induced tank spawning, growth rates in excess of 6 kg/year, high disease resistance, high survival rates (post-larviculture stage) in tanks and net pens, adaptability to commercially available extruded diets, and high-quality fillets suitable for the sashimi as well as white tablecloth restaurant markets. Nonetheless, cobia production faces several bottlenecks limiting industrial expansion including limitations in fingerling production per unit volume. This paper will provide an overview of production limitations, and focus on recent spawning and larviculture research results and ongoing research initiatives.


Taiwan now has over 90 finfish species in which larviculture is possible. Billions of finfish fry can be produced annually. The use of modern and advanced techniques in larviculture has won Taiwan a leading position in the world. This achievement can be attributed to: (1) successful broodstock management, including broodstock collection and cultivation, maturation and spawning, and egg collection and incubation, (2) complete larval rearing using outdoor and indoor systems, and (3) establishment of techniques of live food preparation for larval feeding. Cannibalism, difficulties in water quality control, and disease outbreak often cause mass mortality in the rearing larvae. However, the obstacles that hinder the development of larvae at their later stages are being overcome. Through a systematic understanding of the complex behavioral patterns of finfish larvae, cannibalism can somewhat be controlled under larviculture conditions. Control strategies often involve physical manipulations such as grading and feeding adjustments. For water quality and disease control, an indoor larval rearing system has recently been established. It adopts ozone or chlorine to disinfect fertilized eggs, the rearing water, and facilities. Additionally, utilization of the green water technique in rearing larvae and of ozone-disinfected recirculating water in weaning larvae has improved the hygiene of the systems. For instance, the average survival rate in the fry of grouper used to be less than 0.1% until they attained a size of about 2 cm. With the improved system, grouper fry grow from 3 to 10 cm with almost no mortality or viral infection, with a feed conversion rate of 0.7–0.9 and a daily weight increase rate of 4–27%. Application of live food enrichment techniques with selected nutrients for short and long terms has proven beneficial to larval growth. Studies determining the optimal environmental requirements of larvae have been essential towards successful larviculture. This paper mainly discusses developments and advanced techniques of finfish larviculture in Taiwan.


Marine fish, unlike freshwater species, have been generally considered to have a limited ability to biosynthesize long-chain polyunsaturated fatty acids (LC-PUFA) from C18 precursors due to apparent limited enzymatic activities involved in the pathway. Although LC-PUFA play important physiological roles throughout the entire life cycle, requirements for early life stages are especially high and provision of preformed LC-PUFA in egg lipids appears critical to support the formation of developing tissues where these compounds accumulate. No studies, however, have been conducted to explore the capability of marine fish embryos (here referring to life stages from zygote to the oesophagus opening) for *de novo* synthesis of the LC-PUFA required for normal growth and development. The present study aimed to investigate the activation of the LC-PUFA biosynthetic pathway during embryogenesis of the marine teleost cobia (*Rachycentron canadum*). First, a fatty acyl elongase with sequence similarity to mammalian elongase of very long-chain fatty acids 4 (Elovl4) was isolated, and its biochemical function characterized showing that it catalyzed the production of very long-chain fatty acids (VLC-FA) including both saturated and polyunsaturated fatty acids with chain lengths ≥24 carbons. Notably, cobia Elovl4 was able to elongate 22:5n-3 to 24:5n-3 and thus could play a key role in the biosynthesis of docosahexaenoic acid (22:6n-3), a critical fatty acid in neural tissues. Subsequently, the fatty acid dynamics of embryos at different developmental stages and the temporal expression patterns of target genes including *elovl4*, and the
formerly characterized elovl5 elongase and Δ6 fatty acyl desaturase, were analyzed in order to elucidate the overall activation of the LC-PUFA biosynthetic pathway in cobia embryos. Our results indicated that expression of the LC-PUFA biosynthetic pathway in cobia embryos is initiated at 12-18h post-fertilization.

201. Nguyen, H.Q., Reinertsen, H., Rustad, T., Tran, T.M. & Kjørsvik, E. (2012). Evaluation of egg quality in broodstock cobia Rachycentron canadum L. Aquaculture Research, 43(3), 371-385. Twenty egg batches spawned naturally from 17 different females over two spawning seasons were used to evaluate the egg quality of cobia Rachycentron canadum. A reduction in egg size was observed towards the end of the spawning season for both years. The proportion of floating eggs demonstrated a positive linear relationship with both yolk-sac larval survival ($r^2=0.91$, $P<0.05$) and batch larval production ($r^2=0.80$, $P<0.01$). Viable egg batches (i.e. fertilization success $>50$%) were of higher batch fecundity, had larger eggs and a higher proportion of floating eggs than non-viable batches (i.e. 0% fertilization success). Also, biochemical analyses revealed that these viable eggs had significantly higher protein and amino acid contents. A multiple regression model based on the proportion of floating eggs, batch fecundity and fertilization success provided the most accurate predictions of batch larval production ($r^2=0.95$, $P<0.001$). Similarly, using the egg content of arginine/glycine and methionine significantly increased the correlation coefficient in the multiple regression model predicting larval deformity ($r^2=0.92$, $P<0.002$). This study reveals that accurate determination of egg quality in cobia can be improved using a combination of several variables rather than a single variable.

202. Nguyen, H.Q., Reinertsen, H., Wold, P.A., Tran, T.M. & Kjørsvik, E. (2011). Effects of early weaning strategies on growth, survival and digestive enzyme activities in cobia (Rachycentron canadum L.) larvae. Aquaculture International, 19(1), 63-78. The effects of weaning strategies of cobia (Rachycentron canadum L.) larvae to commercial microdiets, either from rotifers or from Artemia, on growth, survival and enzymatic digestive capacity, were investigated. In the first experiment, cobia larvae were weaned from rotifers by co-feeding with a microdiet (Otohime) from 8, 13 or 20 days post-hatching (dph). The larvae in the control treatment were fed rotifers (2-12 dph), Artemia nauplii from 7 dph, and co-fed with the microdiet from 20 dph. In the second experiment, the larvae were weaned from Artemia, which was fed to the larvae from 7 dph, by co-feeding with a microdiet (NRD) from 8, 13 or 18 dph. The larvae in control treatment were fed rotifers, then Artemia to the end of the experiment (28 dph). Weaning of cobia larvae onto a microdiet directly from rotifers significantly reduced growth, survival and digestive capacity of the larvae and did not lead to larval acceptance of the microdiet, compared to those weaned from Artemia in the first experiment. Early weaning of cobia larvae onto NRD microdiet (on 8 or 13 dph) from Artemia in the second experiment also reduced growth, survival rate and gut maturation index, compared to those fed live feed. With available microdiets, weaning of cobia larvae could start from Artemia at around 18 dph in order to obtain comparable growth, survival and gut maturation to larvae fed live feed.

203. Nhu, V.C., Dierckens, K., Nguyen, H.T., Hoang, T.M.T., Le, T.L., Tran, M.T., Nys, C. & Sorgeloos, P. (2010). Effect of early co-feeding and different weaning diets on the performance of cobia (Rachycentron canadum) larvae and juveniles. Aquaculture, 305(1-4), 52-58. Cobia (Rachycentron canadum) is a very fast growing species. This can only be achieved if sufficient amounts of feed are provided from early larval development onwards. In this study, we examined the effects of early co-feeding and different co-feeding formulated diets on growth, survival and vitality of cobia larvae and juveniles. Two experiments were conducted to test the possibility of early co-feeding of the two formulated diets for cobia larvae (8-18dph) and one experiment was conducted to compare the effect of three formulated diets for cobia juveniles (20-38dph). During the larval stage, two formulated diets: ProtonA+ and an experimental diet (INVE, Belgium) were used along with live food from eight days post hatch (dph) and 13dph compared to 18dph as the control. Results from the study indicated that early co-feeding of ProtonA+ from eight dph had a significantly positive effect on growth ($P<0.05$), but not on survival and stress resistance in a salinity stress test ($P>0.05$) of cobia larvae. In the second trial, no significant difference ($P>0.05$) was detected between all treatments in terms of growth, vitality and survival.

The cobia, *Rachycentron canadum*, is a high-value marine fish species with high potential for commercial-scale culture. However, as with other marine finfish species, production issues limit industrial expansion for cobias. While successful elsewhere, pond production is limited in the U.S. due to climatic constraints, and provides minimal production security, consistency, predictability, and disease control. This article outlines several production runs that varied in stocking density but yielded similar results of about one fingerling per liter. This low production rate is so far typical for cobia culture in the U.S. and necessitates further research into system design and protocols.


The purpose of this study was to determine if concentrated algal paste could effectively replace live algae during the greenwater stage of cobia fingerling production without negative impact upon larval growth or survival. Mean cobia survival per tank from 2 dph through post weaning at 28 dph for the live algae treatment was $24.44 \pm 2.43\%$ (mean ± SD) as compared to $24.47 \pm 2.48\%$ for the algal paste treatment. Furthermore, the number of fish produced per liter for the live algae treatment was $2.44 \pm 0.24$ fish/L compared to $2.47 \pm 0.25$ fish/L recorded from the algal paste treatment. Mean fish weight for cobia weanlings from the live algae treatment was $0.417 \pm 0.059$ g compared to $0.411 \pm 0.026$ g for the algal paste treatment. These observations demonstrate that during the greenwater stage of cobia larviculture, live algae can be completely replaced with commercially available, concentrated algal paste without negative impact upon cobia growth, survival, or resultant weaning production per unit volume.


The purpose of this study was to investigate the applicability of a compound diet co-used with live food in cobia, *Rachycentron canadum*, diets. Cobia larvae (4.31 ± 0.0191 mm) were fed with live food (rotifer and *Artemia nauplii*) and a micro diet from day 1. Starved larvae were treated as the control group. Rotifers were enriched with *Super Selco* (INVE Belgium) for 4 h at a rate of 0.25 g Super Selco per 10° rotifers and *Artemia nauplii* were enriched for 6 h at a rate of 1.5g yeast (INVE) per gram of *Artemia* cyst. Microdiet was approximately 150 – 250 µm in diameter with the proximate composition marked (crude protein 57.5%, crude lipid 12.4%, crude fibre 1.6%, ash 13.3% and L-lysine 2.2%). Larvae were assigned to three groups and treated with starvation, feeding with microdiet and live food, respectively. Larvae were reared in 70 L plastic tanks at a density about 70-80 ind. L⁻¹ with slight aeration. Food was supplied four times (at 8:00, 12:00, 16:00 and 20:00 hours). Statistics were run with SPSS 11.0 software. Results revealed that co-feeding live food and a microdiet may solve the problems of digestion and assimilation faced by marine fish larvae fed with only formulated diets. Co-feeding live food and a microdiet may improve the growth, survival and may reduce the daily supply of live food.


The potential of growing larval and juvenile cobia, *Rachycentron canadum*, in ponds was investigated. Larval cobia, obtained from tank spawning of wild-caught adults, were stocked 48-72-h posthatch at a rate of 700,000/ha into three fertilized 0.25-ha ponds. At one week post-stocking (WPS), fish were observed consuming formulated feed. Growth was rapid, with specific growth rates (SGR) ranging from 12.5-19.2% body weight/day. At harvest (5 WPS) fish reared in two ponds weighed 7.9 and 9.3 g and total length (TL) was 118.9 and 129.3 mm, respectively (all fish reared in remaining pond died the night prior to harvest due to aerator failure). Feed conversion ratio (FCR) was 3.8 for both ponds and survival was 5.3 and 8.5%. Low survival rates were thought to be due primarily to cannibalism. Immediately after harvest, fish were restocked into two 0.25-ha ponds at a stocking rate of 14,400/ha. Fish were fed formulated, pelleted feeds. Growth was rapid up to 9 WPS, after which pond water temperatures declined. Ponds were harvested at 13 and 15 WPS, respectively. Final weight of fish was 309.9 and 362.5 g. Final TL was 343.1 and 355.7 mm. FCR was 3.8 and 4.5 and survival was 27.5 and 30.5%. Major losses of fish were associated with avian predators and possibly a toxic algal bloom. Results of trials indicate that cobia larvae and juveniles can be reared in pond-based culture systems, however additional research is needed to refine this approach.

Research was conducted at the South Carolina Department of Natural Resources Waddell Mariculture Center to evaluate the potential for captive reproduction of cobia, Rachycentron canadum in outdoor tanks and ponds. In May 2001, adult cobia (3 males, 1 female, and 1 suspected female) obtained from a local high salinity estuary were stocked into an outdoor tank (32,000-L) receiving ambient estuary water. Spawning occurred within 2 days after stocking. Over the course of 3 consecutive days, a total of 3.6 million eggs were collected with roughly equal numbers collected during each 24-hour period. Mean fertilization rate was 58.1%. Hatching occurred at approximately 24 hours after initiation of each spawning event. Mean percent hatch was 27.5%. Fish were relocated to a 0.25-ha circular pond 10 days after tank spawning activity ended. One female received pelleted GnRHa before stocking. Eggs were observed 3 days after stocking and at 12 days after hatching, approximately 50,000 larvae were harvested. In May and June 2002, three groups of recently caught adult cobia, each consisting of 3 males and 1 female, were placed in one of three outdoor tanks. Spawning occurred within 2-4 days after stocking of Tanks 1 and 2. During a single spawning event, a total of 2.1 million and 560,000 eggs were collected from Tanks 1 and 2, respectively. Relative batch fecundity of females stocked in Tanks 1 and 2 was estimated to be 79.2 and 20.9 eggs/g, respectively. No fertile eggs were collected from Tank 2. Percent fertilization and hatch of eggs collected from Tank 1 was 3.2% and 1.5%, respectively. No spawning activity of fish stocked in Tank 3 occurred. Findings reveal that naturally conditioned recently caught adult cobia can readily spawn soon after capture and that ponds can be utilized for reproduction of this species in the U.S.


Cobia Rachycentron canadum, the sole representative of the family Rachycentridae, is a migratory pelagic species that occurs in tropical and subtropical seas except for the eastern Pacific (Arnold et al. 2002). It is a gonochoristic species that has demonstrated the capacity for high fecundity and ease of induced and natural spawning in captivity (Holt et al. 2007, Benetti et al. 2008a). They are multiple batch spawners with a protracted spawning period (Faulk and Halt 2003, Benetti et al. 2008b). The information available on the timing of gonadal maturation in different parts of the world indicates that cobia spawn from April through September with the peak in spring and early summer (Kilduff et al. 2002, Faulk and Halt 2003).

2.6. NUTRITION & FEEDING


The feeding stimulatory effects of nucleotides and their related compounds on juvenile cobia (Rachycentron canadum) were investigated. Among these nucleotides only inosine-5'-monophosphate (IMP), guanosine-5'-monophosphate (GMP), uridine-5'-monophosphate (UMP), and adenosine-5'-diphosphate (ADP) showed high feeding stimulative responses. In contrast, nucleosides, nitrogen bases, and ribose were not effective. The optimal concentrations of IMP, GMP, UMP, and ADP for juvenile cobia were 2.9, 8.1, 2.8, and 6.6 mmol/kg dry pellets, respectively. These effects of the nucleotides were synergistic when supplemented in pairs. The synergic effects disappeared when the 4 nucleotides were supplemented together.


This study compared the effect of amino acids (L-methionine, L-proline, betain hydrochloride) fortified test diets containing graded levels of soy-protein for juvenile cobia. In the test of adding one amino acid to pure soy-protein diet as a feeding stimulant, the results showed that the best feed intake rates were 1.84% for L-methionine replaced at level of 1.5%, 4.57% for L-proline replaced at level of 1.15% and 1.35% for betain hydrochloride replaced at level of 0.14%. Fortified amino acids
(L-methionine, L-proline, betain hydrochloride) as feeding stimulants were added to soy-protein replacement diets to find the best substitute level for juvenile cobia. The results showed the survival rate still maintain at 100% when the fish fed with diets of soy-protein replaced at levels of 20%, 60% and 80% for 3 weeks period. The highest feed intake rate was 6.2% when fish fed with diet of soy-protein replaced level at 0% and the lowest feed intake rate was 1.8% when fish fed with diet of soy-protein replaced level at 100%. However, the best weight gain and feed conversion ratio (FCR) occurred at soy-protein replaced level at 20%. They were 263% and 0.88, respectively. The results suggested that using amino acids as feeding stimulants added to soy-protein based diet at level of 20% could get the best feed intake, survival, weight gain and FCR results.


Fish meal sparing is more difficult for nutritionally demanding carnivorous fishes, but economic considerations and the limited supply of fish meal continue to incentivize investigations of alternative protein sources for aquafeeds. A promising alternative to traditional, marine-origin fish meal is fish meal derived from undesirable freshwater species, such as the invasive Asian carp *Hypophthalmichthys* spp. To assess the relative value of such ingredients, we evaluated growth performance of juvenile hybrid Striped Bass (White Bass *Morone chrysops* × Striped Bass *M. saxatilis*, initial weight, 21.9 ± 0.2 g [mean ± SE]), Rainbow Trout *Oncorhynchus mykiss* (15.1 ± 0.2 g), and Cobia *Rachycentron canadum* (57.2 ± 0.5 g) reared for 8 weeks on practical diets containing different levels of menhaden fish meal (MFM), Asian carp meal (CFM), or a 50:50 blend of these ingredients such that 0, 20, 40, or 60% of the estimated digestible protein content was derived from fish meal. Growth performance was generally consistent across taxa, and weight gain tended to increase with fish meal inclusion, regardless of its origin. However, Cobia did perform better on CFM-based diets, suggesting that MFM or CFM can yield improved performance for some taxa or life stages, but these differences are likely to be marginal in most circumstances. We conclude CFM is a suitable and perhaps lower-cost alternative to MFM in feeds for carnivorous fishes.


The present study was conducted to investigate the effects of dietary β-1,3-1,6-glucan (BG) from *Schizophyllum commune* on the innate immune response in cobia (*Rachycentron canadum*). Cobia (50-80 g) were fed a basal diet and supplemented with either 0 (control group) or 0.5% BG (glucan group) for 60 days. The superoxide anion (O$_2^-$), superoxide dismutase (SOD) concentration and lysozyme activity were analyzed at days 0, 1, 3, 6, 12, 20, 30, 40, 50 and 60. The results showed that the concentration of O$_2^-$ and SOD and activity of lysozyme in cobia at BG group was higher than those of the control group. They attained the highest levels at day 12, 20 and 24 after feeding, respectively. However, the concentration of O$_2^-$ on 30 day, SOD on 40 day and activity of lysozyme on 40 day of the fish at BG group, dropped back to the same levels as the control group. The results in this study showed that oral administration of 0.5% BG for 6 days enhanced immunity of the cobia, but prolonged use of BG would not increase the immunity of the cobia. Care therefore must be taken to maximize its effectiveness with suitable period.


The present study was conducted to compare the effect of microcapsule methionine or crystalline methionine in low-fishmeal diets on protein metabolism and digestive enzyme activities in cobia (*Rachycentron canadum*). Seven iso-nitrogen and iso-lipid diets, including fishmeal (positive control), low-fishmeal (negative control) and five types of methionine supplementation of crystalline L-methionine (MET), hydroxyl-methionine calcium (MHA), cellulose-acetate-phthalate coated methionine (CAP), resin coated methionine (RES) and tri-palmitin-polyvinyl alcohol coated methionine (TPA), respectively were prepared to investigate utilization of coated and crystalline methionine in intestine of juvenile cobia. Each treatment was randomly assigned to triplicate groups of 20 fish with initial weight of (5.40 ± 0.07) g per aquarium. Fish were maintained in flow-through aquaria for eight weeks at water temperature ranged from 29 °C to 31 °C. The results showed that
trypsin activities of intestine of fish fed microcapsule methionine were significantly higher than those of fish fed crystalline methionine and the positive control diet ($P<0.05$). Compared to positive and negative groups, fish fed the diets with MET and TPA had significant difference in liver GOT activities ($P<0.05$). After feeding 0.5 h, Na$^+$, K$^+$-ATP activities in intestine of fish fed MET were significantly higher than those of fish in other groups ($P<0.05$). After feeding 3 h, Na$^+$, K$^+$-ATP activities of fish fed RES and positive control diet increased and was higher than those of fish fed CAP and MHA, and those activities of fish fed positive control diets and microcapsule methionine were significantly higher than those of fish fed MHA and MET after feeding 8 h ($P<0.05$). It could be concluded that cobia fed low fishmeal diet with crystalline methionine could improve their metabolism of amino acid and synthesis of protein. Microcapsule could contribute to control methionine release in intestine and enhance the activities of intestinal protease.

We evaluated the effects of supplemental coated and crystalline methionine (Met) on the growth performance and feed utilization of juvenile cobia (Rachycentron canadum Linnaeus) in a 60-d feeding trial. Fish groups were fed one of six isonitrogenous and isolipidic diets: 1) fishmeal control; 2) un-supplemented experimental (low-fish-meal diet deficient in Met); or 3) one of four Met diets supplemented with crystalline L-Met, cellulose-acetate-phthlate coated L-Met, acrylic-resin coated L-Met, or tripalmitin-polyvinyl alcohol coated L-Met. The test diets were fed to triplicate groups of cobia (initial body weight 5.40 ± 0.07 g) twice a day. The weight gain and specific growth rate of the fish fed the RES diet were highest among the Met-supplemented groups and were 23.64% and 7.99%, respectively, higher than those of the fish fed with the un-supplemented experimental diet ($P<0.05$). The protein efficiency ratio of the fish fed the MET diet was significantly higher than that of the fish fed the un-supplemented experimental diet and the fish in the other methionine supplementation groups ($P<0.05$). Our results suggest that supplementation of crystalline Met in low-fish-meal diets promotes the growth performance of juvenile cobia.

Two growth trials were conducted to investigate the optimal concentrations of dietary protein and lipid for cobia, a pelagic fish showing great potential for offshore cage culture in tropical and subtropical waters. In the first trial, casein was added to a fish meal-based basal diet to replace starch to render protein concentration gradation ranging between 36% and 60%. All seven diets were estimated to be isonenergetic. After an 8-week growth trial, juvenile cobia (initial weight 33 g) fed the diets containing protein concentrations of 44%, 48% and 52% generally attained higher weight gain and feed conversion than the other groups. Polynomial regression analysis revealed a weight gain peak at a dietary protein concentration of 44.5%, which is regarded as the most suitable level for maximum fish growth. In the second trial, the cobia were fed seven isonitrogenous and isoenergetic test diets containing lipid concentrations ranging from 3% to 18%. Growth of the fish (initial weight 41 g) was lowest when the dietary lipid concentration was 3%. Weight gain increased with increasing lipid inclusion and then leveled off. The broken-line analysis that best expressed the response pattern shows a breakpoint when dietary lipid concentration was 5.76%. No significant growth enhancement was observed when the lipid levels were increased beyond the breakpoint to the highest lipid concentration tested (18%).

An 8-week feeding trial was conducted with cobia to determine the amount of soybean meal that could replace fish meal in formulated diets without reducing growth. Juvenile cobia (initial mean weight, 32 g) were fed 48% crude protein diets in which dietary protein was supplied by brown fish meal or a mixture of hexane extracted soybean meal and the fish meal, resulting in 10%, 20%, 30%, 40%, 50% and 60% of fish meal protein being replaced by soybean protein. The fish readily accepted all seven experimental diets and no fish died during the trial. Detrimental effects on growth performance were obvious when half of the fish meal protein was replaced by soybean protein. There existed a significant difference in fish weight gain, feed conversion ratio (FCR), protein efficiency ratio (PER) and net protein utilization (NPU) when the replacement level for fish meal protein was increased from 40% to 50%, indicating that up to 40% of fish meal protein can be
replaced by soybean meal protein without causing reduction in growth and protein utilization. On the other hand, quadratic regression analysis shows a growth optimum at 16.9% replacement of fish meal protein by soybean meal protein. Lipid concentrations in the cobia muscle increased significantly as dietary soybean meal increased. Muscle concentrations of free threonine and histidine decreased as use of the soybean meal increased in the diets. Since methionine concentration in the test diets decreased from 2.52 to 1.36 g 16 g N as the soybean meal protein replacement level was increased from 0% to 60% while all other essential amino acids remained relatively constant, dietary requirement of methionine was calculated assuming it was equally available between the two proteins. The broken-line model analysis based on fish weight gain shows a breakpoint when dietary methionine+cystine concentration was 2.66 g 16 g N or 1.28 g 100 g diet.


This paper deals with the feeding and growth of larval *Rachycentron canadum*. The results show that larvae begin to feed at the age of 3 days at 28-32 °C. The yolk is absorbed completely at the age of 6 days. At the age of 6-7 days, the larvae, which does not feed from the outside, enters the period of PNR. The initial feeding rate is low, then slowly reaches the peak when the yolk is exhausted and follows with decreasing. The highest initial feeding rate is 50%. The growth rate of larvae before feeding is 0.86 mm/d. When they enter feeding period the unfed larvae almost stop growing. At the same time the growth rate of feeding larvae decreases to 0.64 mm/d. The relationship between the feeding larvae total length (L) and days of age of the feeding larvae within 8 days after hatching may be presented with $L=3.4327e^{0.2275}(\text{mm})$, $R^2=0.9763$. The relationship between mouth gape ($\gamma$) and total length (x) of the feeding larvae within 10 days after hatching may be presented with $\gamma=0.1203x-0.2275$, $R^2=0.9636$.


The chemical compositions of fifteen commercial feeds of cobia (*Rachycentron canadum*) from six feed manufacturers were analyzed. The effect of two diets designated as A (low protein: 46.3%, low fat 16.8%) and B (high protein: 48.6%, high fat: 19.9%) on the chemical compositions and meat quality of the fish raised in a practical commercial production scale were also investigated. The commercial cobia feeds had different sizes and shapes according to the culturing stages of the fish. The moisture contents of the feeds ranged from 3.56% to 9.91%, ash 9.40% to 13.32%, protein 41.15% to 50.86%, fat 10.85% to 21.34%, and carbohydrate 15.24% to 24.32%. The major fatty acids were C16:0 and C18:1n-9. The levels of n-3 polyunsaturated fatty acids including EPA and DHA were also high (ranged from 6.05% to 14.22% and from 4.42% to 14.81%, respectively); suggesting that the feeds contained good levels of fish oil. When two finisher diets were fed to two groups of cobia for two months to grow the fish to their marketable size (566 kg/fish), the protein, fat, ATP-related compounds, free amino acids and anserine in both dorsal (D) and ventral (V) meats of the fish tended to increase with a raise of 2.37% protein plus a raise of 3.14% fat in the diets. The fatty acid profiles of D and V meats from A and B groups were relatively similar to those of the two diets. The predominant fatty acids were C16:0, C18:1n-9, C16:1n-7, EPA and DHA. However, n-6/n-3 ratios in both D and V meats changed from 0.51 or 0.50 to 0.66 or 0.69 with the raise of protein and fat levels in the diets.


The condition factor of 31 cage-cultured cobia (*Rachycentron canadum*) with body weight ranging from 1.5 to 8730 grams was significantly and positively correlated with body weight for fish below 1.4 kg ($r=0.79$), while no good correlation was found among fish above 1.4 kg. The pH value of white muscle in cobia was between 5.5 and 6.3, which was similar to that of pelagic fishes. The levels of ammonia and urea were low in cobia. This is also similar to the most teleosts. No significant correlation was found between fish body weight and pH, ammonia and urea. There were large variations in fat and moisture contents of white muscle among different size of cobia, but not in protein and ash. The fat level in the ventral meat was two times higher than that of the dorsal meat of the same fish. Fat contents of both dorsal and ventral meats were significantly and positively correlated with body weight ($r=0.8$ and 0.78, respectively). In contrast, moisture content
decreased gradually as fish body weight increased. The predominant free amino acids (FAAs) in cobia were taurine, glycine, alanine and glutamic acid. The contents of these FAAs and total FAAs tended to decrease as body weight increased. When comparing with glycine, alanine and glutamic acid, taurine was most significantly and negatively correlated with fish size. Anserine, a dipeptide, was detected in the meat of cultured cobia, and its content ranged from 14 to 80 mg/100g; however, it was not significantly correlated with fish body weight. Inosine monophosphate (IMP) was the most prominent component of ATP-related compounds. Both ATP-related compounds and IMP had no significant correlation with fish size.


The present study was carried out to investigate the number of daily feeding sessions that results in maximum growth of juvenile cobia under laboratory conditions. Groups of eight fish (110 g) were randomly distributed in twenty 500-L tanks and hand-fed a commercial diet for 60 days. The same amount of feed was offered daily, divided in 1, 2, 3, four or six meals. None of the parameters associated with growth performance (survival, weight gain, specific growth rate, feed intake, condition factor or size variation) showed any significant differences among treatments. Although under the present conditions feeding frequency had no effect on the growth performance of cobia larger than 110 g, in commercial farming operations where large numbers of fish are kept within a single rearing structure, fish may have aggressive interactions during feeding. Under these conditions, it is difficult to ensure that all cobia are fed to satiation and thus it is usual to provide two or more meals per day. The present results indicate that for an individual cobia the provision of more than one daily meal has no significant effect on growth performance.


Cobia, large tropical marine fish with high-value, high-quality white flesh, have potential as a premier aquaculture species. They exhibit generally excellent culture characteristics that include adaptability to commercial feeds. Ongoing research at Virginia Tech is examining the nutritional requirements of the carnivorous fish and diet formulations that cut fishmeal use.


Two, 6 week feeding trials were conducted to evaluate the impacts of protein and lipid on weight gain, feed efficiency ratio values and biological indices of juvenile cobia (Rachycentron canadum). Utilizing a 2x3 factorial design, experimental diets containing two levels of crude protein (CP; 40 and 50%) and three levels of lipid (6, 12 and 18%), providing 14.4, 15.1 and 16.6 kJ available energy/g dry diet (calculated), respectively, were formulated for use in both feeding trials. In the first trial, cobia (initial weight 49.3 g per fish) was randomly assigned to one of the six experimental diets and fed to apparent satiation twice daily. At the end of the first trial, weight gain in cobia was not significantly impacted by protein levels with values ranging from 333% (50% CP) to 353% (40% CP). However, lipid significantly (P<0.05) affected weight gain with fish fed the diet containing 18% total lipid returning the lowest growth of 293%. Feed efficiency ratio values were not significantly impacted by dietary protein or lipid levels and ranged from 0.46 (50% CP/18% lipid) to 0.51 (50% CP/6 and 12% lipid). Survival was significantly impacted by protein and lipid with fish fed the diets containing 50% CP and 18% lipid having lower (P<0.05) survival rates of 90%. In the second trial, smaller fish were utilized (7.4 g average initial weight) under identical experimental conditions and dietary formulations. Weight gain was not significantly affected by protein or lipid levels and ranged from 1099% in fish fed the diet containing 40% CP/18% lipid to 1305% in fish fed the diet containing 50% CP/12% lipid. Feed efficiency ratio values, visceral somatic and hepatosomatic indices were significantly affected by protein and/or lipid. Muscle and liver lipid were impacted by dietary lipid (P=0.0203 and 0.0012, respectively). Muscle protein was significantly impacted by dietary protein levels, while liver protein was affected by both main effects. Dietary protein and lipid had no impact on muscle ash. These data suggest that juvenile cobia can thrive on a wide range of protein and lipid levels, as well as a range of protein to energy ratios. Positive impacts of optimizing the protein component in terms of economic and environmental concerns, coupled with the ability to maintain the rapid growth rates this species are
renowned for at lower dietary lipid levels, point towards beneficial consequences of further refinement of commercial cobia production feeds.


An 8-week feeding trial was conducted to evaluate the effect of dietary carbohydrate sources on the growth performance and hepatic carbohydrate metabolic enzyme activities of juvenile cobia. Six experimental diets were formulated to contain 20% glucose, sucrose, maltose, dextrin, corn starch and wheat starch respectively. The results indicated that fish fed the wheat starch and dextrin diets showed significantly better weight gain, specific growth rate and protein efficiency ratio compared with those fed the other diets. However, fish fed the glucose diet had a significantly lower survival and condition factor than those fed the other diets. There were significant differences in the total plasma glucose and triglyceride concentration in fish fed diets with different dietary carbohydrate sources. Haematocrit, haemoglobin, red blood cell and leucocytes were significantly affected by the dietary carbohydrate sources. The activities of glucose-6-phosphate dehydrogenase (G6PD), 6-phosphofructokinase (PFK) and fructose-1,6-bisphosphatase (FBPase) were significantly affected by the dietary carbohydrate sources, while fish fed the glucose diet showed higher G6PD, PFK and FBPase activities than those fed the other diets. These data indicated that dextrin and wheat starch were the most optimal carbohydrate sources for juvenile cobia.


The aim of this study was to examine the effects of the immunostimulant combination (IC) containing β-glucan, A3α-peptidoglycan, vitamin C and vitamin E on the growth performance, non-specific immunity and protection against *Vibrio harveyi* infection in cobia (Rachycentron canadum). Fish were fed diets containing six graded levels of IC (0, 1, 2, 3, 4 and 5 g kg⁻¹ diet) for 8 weeks. The results showed that the survival rate ranged from 81.1 to 84.4% with no significant difference among all the groups (P>0.05) after the feeding experiment. Dietary IC significantly increased the specific growth rate (SGR), serum lysozyme, alternative complement pathway (ACH50) activity, phagocytosis percentage (PP) and respiratory burst activity of head kidney macrophages of cobia. Moreover, feeding of supplemented diets containing 3.0 g kg⁻¹ IC resulted in significantly lower mortality against the pathogens, *V. harveyi* compared with the control group. To elevate the growth and immune resistance ability of cobia, the optimal dose of dietary IC administration, determined by second-order polynomial regression analysis was 3.43 and 2.71 g kg⁻¹ diet, respectively, on the basis of the SGR and mortality after challenge with *V. harveyi*.


Sixty juvenile cobia (*Rachycentron canadum*; 28.3±0.13 g wet wt) were randomly distributed into each of 12 tanks in a recirculation unit (n=5 tank⁻¹). Fish were fed one of two diets (47:8 or 47:20 protein:lipid) at 6-8% body wt d⁻¹ for 6 weeks. Each week, the composition of fish (n=5) from each dietary treatment was calculated by measuring the impedance (resistance and reactance) of a current (x µA AC and kHz) passed through a live animal. Electrodes were positioned at morphologically discrete points on the dorsal left hand side of the animal. After bioimpedance (BIA) assessment, the identical fish were sacrificed and their body composition determined using traditional, chemical methods. Results generated by chemical analyses were regressed against BIA data. Linear regression analysis was performed utilizing compositional analysis (protein, lipid and ash) as the observed values and BIA assessment for the predicted. Regressions for each body composition parameter produced high correlations in all relationships: resistance (in parallel) and protein (adj. R²=0.9569), resistance (in parallel) and total body water (adj. R²=0.9894), reactance (in parallel) and total body ash (adj. R²=0.8547), reactance (in series) and dry matter (adj. R²=0.9272) and reactance (in series) and fat-free mass (adj. R²=0.9916). The F value tests (P<0.0001), revealed significant correlations between the independent and dependent variables for each body composition parameters. Correlations for each regression indicate strong linear relationships between impedance and proximate analysis variables with values of 1:1. This indicates that this
BIA methodology can be utilized as an inexpensive, non-lethal, on the farm determination of proximate composition.


The ontogeny of the digestive system of cobia Rachycentron canadum from hatching to 22 days post-hatch (dph) (20.1 mm standard length) was examined with light microscopy. The activities of selected pancreatic enzymes were also determined during this period in order to optimize current rearing methods for this species. At hatching (3.6 mm), the digestive tract consisted of a relatively undifferentiated, straight tube positioned dorsally to the yolk sac. The major morphological changes in the digestive tract primarily occurred over the first 1-4 dph (3.6-4.4 mm). During this time, larvae began exogenous feeding (3 dph) and the digestive tract differentiated into five histologically distinct regions: buccopharynx, oesophagus, stomach anlage, anterior intestine and posterior intestine. Yolk reserves were exhausted by 5 dph (4.5 mm) and the oil globule began rapidly decreasing in size disappearing entirely by 9-10 dph (6.3-6.8 mm). Gastric glands differentiated at this time, and by 12 dph (8.1 mm) surface mucous cells of the stomach anlage stained positive for neutral mucosubstances. By 16 dph (11.6 mm), the blind sac (fandic region) of the stomach formed as did the pyloric caeca which initially appeared as a single protrusion of the anterior intestine just ventral to the pyloric sphincter. Generally, enzyme activities (U larva⁻¹) for amylase (0.0-1.8), chymotrypsin (0.0-7902.4), trypsin (0.2-16.6) and lipase (9.3-1319.0) were measurable at or soon after hatching and increased steadily from c. 8-22 dph (5.7-20.1 mm). The results of this study are discussed in terms of current and future weaning practices of this species.


Cobia culture has been rapidly gaining in popularity since the early 1990s; however, the relative success of modified commercial diets in aquaculture has delayed the need for specific research into the nutritional requirements of cobia. Recent work has determined optimum dietary protein and lipid levels in juvenile cobia at 45 and 5-15% dry weight, respectively. Maximum growth and feed conversion ratios have been recorded at 27-29 °C in juvenile cobia with an optimum ration level determined at 9% initial body weight per day. There is limited information on amino acid and essential fatty acids (EFA) requirements in cobia. Several studies have explored alternate protein sources in juvenile cobia with relative success observed with meat meal, yeast-based protein and various plant based sources including soybean meal. There is no literature on the vitamin or mineral requirements of cobia or the nutritional requirements of larger fish. Therefore future research should focus on the amino acid, EFA, vitamin and mineral requirements of cobia while the protein, lipid and energy requirements of larger cobia should be addressed. Additional work on feed ingredients, choice and palatability would also aid in maximizing culture production while minimizing costs thereby producing a more sustainable product.


To study the effects of galacto-oligosaccharides (GOS) on the growth performance, serum immunological and biochemical factors of cobia (Rachycentron canadum), we supplemented GOS in the feed at different levels (0, 0.2%, 0.4%, 0.8% and 1.6%) and fed the cobia for 8 weeks. The supplemented level (>0.4%), improves the growth rate insignificantly (P>0.05). The activity of serum lysosome and superoxide dismutase is improved significantly by GOS supplementation. However, the catalysase activity is inhibited significantly. The serum biochemical factors including the total protein, albumin, globulin, total bilirubin and direct bilirubin are influenced significantly by GOS supplementation, but no significant influence is observed on the indirect bilirubin. The concentration of serum cholesterol is significantly higher in the experimental group supplemented with 0.2% GOS than in the control, and the concentration of aspartate aminotransferase (AST) is significantly lower in the group supplemented with 0.4% GOS than in the control. The AST activity decreases with the increase of GOS concentration when GOS concentration is lower than 0.8%. In conclusion, the growth rate and immunological function of cobia can be improved by GOS supplementation in the feed at proper level, and the optimal concentration is 0.2% similar to 0.4%.

The effects of partially substituting fishmeal with 4 soybean products in diet of juvenile cobia *Rachycentron canadum* were studied. The cobia juveniles with an initial weight of 50 g were fed one of 8 experimental diets and a basal diet for 8 weeks. The fishmeal-based basal diet contained 44.5% crude protein and 12.5% crude lipid. The experimental diets were of a 2 (soybean replacement levels: 20 and 40% of fish meal protein) x 4 (soybean products) design. The 4 soybean products evaluated were: solvent-extracted soybean meal (SBM), Fermented SBM (with *Bacillus subtilis*: FSM), De-antinutrient SBM (ROS) and Soy concentrate (SPC). The results of the feeding trial showed that the growth, FCR, PER and NPU of the fish fed with the 40% ROS diet were significantly worse than other groups. The growth and condition factor of the fish that fed with the SBM and FSM diets, when the replacement level was increased from 20 to 40%, were comparatively better than other groups, indicating their suitability as the dietary protein source for the cobia.


This study was conducted to use rapeseed as a protein source to replace a part of fish meal on the growth of cobia. In seven diets the control group was supplemented with 65% of fish meal, experiment group were supplied with rapeseed meal 5%, 10% and 15% that fish meal were decrease to 62%, 59% and 56%, respectively. Other three diets were supplemented with phytase 400, 600, 800 (FTU/kg diet). The diets were fed to duplicate groups of cobia (mean initial weight 62 g) and feeding rate were 5% body weight per day. Protein and lipid in diets has no significance difference. After six weeks feeding, rapeseed supplemented 10% is the optimal replacement. Phytase supplemented has no significance on the weight gain and feed efficiency.


Cobia (*Rachycentron canadum*), highly profitable and major farmed marine fish in net cages, is high growth rate up to 4-6 kg in one year and feed efficiency about 1.3-1.6. In this experiment, the morphology of the GI tract and digestive enzyme activity (pepsin, trypsin, chymotrypsin, amylase, amino-peptidase N and alkaline phosphatase activity of stomachs, pancreases and intestine) in cobia and grouper (carnivorous), tilapia (polyphagia) and grass carp (herbivore) was measured to test whether cobia with high growth rates possess a unique GI tract and high digestive enzyme activity. The data showed that cobia had the highest pancreatic aminopeptidase N activity compared with other three species. The activities of pepsin and pancreatic chymotrypsin in cobia were lower than those in grouper but higher than those in tilapia and grass carp. The activity of intestinal alkaline phosphatase was higher than that in grass carp, and the activities of intestinal trypsin, pancreatic trypsin and amylase were the lowest compared with other three species. This result suggests that cobia has the better ability of digestion and absorption in amino acid. The characteristics of pepsin, trypsin and chymotrypsin by using Western Blotting and the comparisons of the structure in stomach, pancreas and intestine among species are undergoing.


A 10-week feeding trial was conducted to estimate the optimum dietary manganese requirement for juvenile cobia, *Rachycentron canadum* L. The basal diet was formulated to contain 501 g kg⁻¹ crude protein from vitamin-free casein, gelatin and fish protein concentrate. Manganese sulphate was added to the basal diet at 0 (control group), 6, 12, 18, 24 and 36 mg Mn kg⁻¹ diet providing 5.98, 7.23, 16.05, 23.87, 28.87 and 41.29 mg Mn kg⁻¹ diet, respectively. Each diet was randomly fed to three replicate groups of cobia for 10 weeks, and each tank was stocked with 30 fish (initial weight, 6.27 ± 0.03 g). The manganese concentration in rearing water was monitored during the feeding period and was < 0.01 mg L⁻¹. Dietary manganese level significantly influenced survival ratio (SR), specific growth ratio (SGR), feed efficiency ratio (FER) and the manganese concentrations in the whole body, vertebra and liver of cobia. When the dietary manganese level rose from 5.98 mg kg⁻¹ to 23.87 mg kg⁻¹, the superoxide dismutase (SOD; EC 1.15.1.1) activities in liver also increased (P<0.05). But there was no significant change in SOD activities for the groups fed with diets containing manganese level higher than 23.87 mg kg⁻¹. On the basis of broken-line regression of SGR, manganese concentration in whole body and vertebra the manganese requirements of juvenile cobia.
cobia were 21.72 mg kg\(^{-1}\), 22.38 mg kg\(^{-1}\) and 24.93 mg kg\(^{-1}\) diet in the form of manganese sulphate, respectively.


Vitamin B\(_6\) or pyridoxine in the form of pyridoxal phosphate participates as a prosthetic group of enzymes in a large number of metabolic reactions, particularly those associated with the metabolism of proteins and amino acids. With the success of artificial propagation and larval production, the culture of cobia becomes widely distributed in southern coastal provinces of China (especially in Guangdong and Hainan Provinces) as well as Southeast Asia. However, currently the growth of cobia heavily depends on trash fish and the development of formulated feeds for cobia is still in its infancy. The objective of this study is to detect the optimal requirement of pyridoxine in diet of juvenile cobia *Rachycentron canadum*. Basal diet was formulated using vitamin-free casein, gelatin and fish protein concentrate as the protein source. The graded levels of PN (0, 2, 4, 8, 16 and 32 mg/kg diet) were added to the basal diets to formulate six experimental diets containing 0.22, 1.89, 3.87, 7.54, 14.75 and 29.88 mg PN/kg diet, analyzed by HPLC, respectively. Each diet was fed to three replicate groups of cobia in 300 L tanks for 9 weeks, and each tank was stocked with 25 fish (initial weight 3.23±0.06 g). The water salinity was from 30 to 34, temperature fluctuated from 28 to 32 °C and dissolved oxygen was above 7 mg/L. The results showed that specific growth rate (SGR) have an increasing trend with the increase of dietary pyridoxine (from 0.22 to 3.87 mg/kg), but no significant differences were observed among diets containing 3.87 mg/kg PN or above. The contents of PN and AST in liver of fish fed diets with 3.87 mg/kg were significantly higher than the treatments with the contents of PN lower than 3.87 mg/kg, however, there were no significant differences among diets containing 3.87 - 29.88 mg/kg PN. The contents of PLP and the activities of ALT of the diet containing 7.54 mg/kg PN were significantly higher than the diets containing PN < 7.54 mg/kg, however, no significant differences were discovered among diets containing PN > 7.54 mg/kg. The dietary pyridoxine requirement was estimated to be 3.09 - 3.26 mg/kg by the broken-line model based on the SGR, and the activities of ALT in fish liver.


A 10-week feeding trial was conducted to estimate the optimum dietary selenium (Se) requirement for juvenile cobia, *Rachycentron canadum* L. The basal diet was formulated to contain 50.6% crude protein from vitamin-free casein, gelatin. A control diet (no added seleno-DL-methionine) and five experimental diets containing 0.20, 0.40, 0.60, 0.80 and 1.00 mg seleno-DL-methionine kg\(^{-1}\) were prepared. Each diet was randomly fed to triplicate groups of juvenile cobia with initial weight 6.27±0.03 g in a flow-through system. The Se concentration in rearing water was monitored during the feeding period, and was not detectable. The dietary Se level significantly influenced the survival, specific growth rate (SGR), feed efficiency and the Se concentrations in the whole body and vertebra of cobia. The Se-dependent glutathione peroxidase (EC 1.11.119) activity increased with an increase in the dietary Se levels (P<0.05). Hepatic glutathione reductase (EC 1.6.4.2) activity was the highest in fish fed the diet with 0.21 mg Se kg\(^{-1}\), and declined with an increase in the dietary Se levels. Based on broke-line regression of SGR, the Se concentration in the whole body and vertebra, the Se requirements of juvenile cobia were 0.788, 0.811 and 0.793 mg Se kg\(^{-1}\) diet in the form of seleno-DL-methionine, respectively.


The effects of replacing fish meal (FM) with shrimp waste meal (SWM) in diets fed to juvenile cobia (*Rachycentron canadum*) were investigated through a 6-week trial. SWM was added to replace FM at fractions of 0%, 10%, 20% and 25% of the diet. The result showed the survival rates of the fish were higher than 86.7%. The weight gain and feed conversion rate showed an increasing trend as the SWM proportion in diet increased from 0% to 25%, but the protein efficiency ratio showed a decreasing trend in efficiency. In addition, the hepatosomatic index increased significantly when the SWM percentage was 20% and 25%. There were no significant differences in the protein and ash concentration of the muscle among all dietary groups. However, the muscle lipid content was low when fish fed in diets with high SWM level. Chitinase activity was extremely high in the pyloric caeca tissue of cobia, and increased specific activities of chitinase were only found in the foregut of cobia fed diets containing 10% SWM for a 6-week period. A challenge test
showed that SWM could not enhance cobia resistance to *Photobacterium damselae ssp. piscicida* infection. Our results suggest that the administration of a 10% SWM diet could potentially reduce the use of FM in the diet of cobia.


A six-week feeding trial was conducted to evaluate the use of a yeast-based, certified organic protein source as a replacement for fish meal in diets for cobia. Five experimental diets were formulated to provide 40% crude protein and 11% dietary lipid (dry matter basis) with the yeast-based protein source replacing Special Select (R) menhaden fish meal at 25%, 50%, 75% and 100% of dietary protein. Ten juvenile cobia (initial weight 11.5 g/fish) were randomly stocked in triplicate 300 l circular fiberglass tanks (n=30 treatment) and hand-fed the diets based upon total tank biomass two times daily at 0900 and 1400 h. Fish were group weighed weekly to monitor performance and adjust feeding rations. Water temperature and salinity were maintained at 27 °C and 15%, respectively. At the end of the feeding trial, weight gain, ranging from 86% to 512%, and feed conversion ratio values, ranging from 1.9 to 5.8, were significantly affected by the inclusion of the yeast-based protein source, with decreasing values as inclusion levels of the yeast-based protein source rose above 25% of dietary protein. Cobia fed the diet containing 25% of dietary protein from the yeast-based protein source had equal weight gain and feed conversion ratio values as fish fed the control diet composed of 100% fish meal (503 vs. 512 and 1.9 vs. 1.9, respectively). Biological indices including hepatosomatic index, visceral somatic index and muscle ratio were all similarly affected by inclusion of the yeast-based protein source, with significant impacts when inclusion levels rose above 25% of dietary protein. As with the weight gain and feed efficiency ratio values, fish fed the diet containing 25% of protein from the yeast-based source had similar values as those observed in the control animals. This study represents the first attempt to utilize an organically certified protein source as a replacement for fish meal in diets for juvenile cobia. Although levels of inclusion of the yeast-based protein source above 50% of dietary protein resulted in detrimental effects on production characteristics, the data clearly suggest that, at a minimum, 25% of dietary protein can be provided by this yeast-based protein in diets for cobia.


An eight week feeding trial was conducted to examine the impacts of organically certifiable alternate protein sources on growth, feed efficiency, biological indices, fillet proximate composition and fillet quality in juvenile cobia. Diets were formulated to be isonitrogenous and isocaloric. The control diet provided 45% crude protein from Special Select (R) menhaden fish meal and 10% total lipid. The remaining diets were formulated with 25 and 40% inclusion of NuPro (R) (an organically certified yeast-derived protein source), and 40% inclusion of organically certified soybean meal, soybean isolate, or hemp seed meal. Two additional diets were formulated to contain a mixture of all organic protein sources at 23% with 8% fish meal or 25% and no fish meal. Diets were fed to triplicate groups of juvenile cobia (initial weight 10 g/fish) in 300 L circular tanks connected as part of a recirculating aquaculture system. Weight gain ranged from 167 to 1138% increase from initial weight and was similar for all fish fed diets containing 40% of any given alternate protein source. Fish fed the blended diet with 8% fish meal exhibited significantly lower weight gain, SGR, and FE ratio values than all other fish. Cobia fed the diet without any fish meal did not survive to the end of the study. Biological indices such as muscle ratio (MR), visceral somatic index (VSI), and packed cell volume (PCV) were all similar between fish fed the control diet and those fed diets with up to 40% alternate protein. Fish fed the diet with only 8% fish meal had significantly lower MR, PCV, and plasma protein, and significantly higher VSI. All fish exhibited similar fillet proximate composition for protein, lipid, dry matter, and ash except for those fed the diet containing 8% fish meal. Alternate protein source did appear to impact the fillet texture of cobia. Generally speaking, plant protein sources returned higher textural characteristics than the fish meal control. At all time points and all texture parameters, cobia fed the diet containing hemp seed meal returned the highest values except for distance to rupture in the final time point. Results indicate that up to 40% fish meal protein can be replaced by any of the organically certifiable alternate proteins that were used in this study without detrimental impacts to weight gain, feed efficiency, biological indices, or fillet composition in juvenile cobia. Our results also suggest that alternate proteins have differential
effects upon final product quality, which may have implications in terms of cobia processing and development of industrial products.


Two separate 8 week feeding trials were conducted to examine the impacts of fish meal replacement with an organically certifiable yeast-based protein source with and without supplementation of methionine, tryptophan, and taurine to diets for juvenile cobia. In the first trial, diets were formulated to contain 41% crude protein and 13% lipid, and a yeast-based protein replaced fish meal at 50 and 75% of dietary protein with and without supplemental taurine at 0.5 g/100 g dry diet. The control diet contained 100% herring fish meal. Methionine and tryptophan were added to all diets except the control to resemble the amino acid profile of fish meal. Results from this study indicated that fish fed diets supplemented with taurine exhibited significantly higher weight gain and better feed efficiencies than all other fish. Diet significantly impacted biological indices such as muscle ratio (MR), visceral somatic index (VSI), and hepatosomatic index (HSI). The 75% yeast-based protein diet without taurine returned the lowest MR values and the highest VSI and HSI values. In the second trial, diets were formulated to contain 43% crude protein and 11% lipid, with the control diet containing 100% herring fish meal and the same yeast-based protein replacing fish meal at 50, 75, and 100% of dietary protein. All diets except the control were supplemented with taurine at 0.5 g/100 g dry diet. Results from this study indicated that increasing amount of yeast-based protein led to decreased weight gains and feed efficiencies regardless of taurine supplementation. However, weight gain and feed efficiencies did increase when compared to a previous study [Lunger, A.N., McLean, E., Craig, S.R., 2007. The effects of organic protein supplementation upon growth, feed conversion and texture quality parameters in juvenile cobia (Rachycentron canadum). *Aquaculture* 264, 342–352] using identical diet formulations except for taurine supplementation. MR values tended to decrease while VSI and HSI values tended to increase with increasing fish meal replacement. It is obvious from the results from both of the present studies that taurine supplementation does have a significant impact on growth and feed efficiency of juvenile cobia when they are fed diets containing high levels of plant-based proteins as replacements for fish meal. Additionally, alternate proteins, especially those of plant and yeast-based origin can be incorporated at very high levels in diets for cobia with proper amino acid supplementation.


A 60-day feeding trial in seawater floating cages (1.5 x 1.5 x 2.5 m) was conducted to investigate the effects of dietary rapeseed meal (RM) levels on feed intake, growth, survival, digestion and protein metabolism in relation to gene expression of juvenile cobia (initial body weight 94.6 g). Five isonitrogenous (crude protein 450 g kg⁻¹ of dry matter) and isoenergetic (20 kJ g⁻¹) practical diets were formulated by replacing 0 (the control), 125, 250, 375 and 500 g kg⁻¹ fish meal protein with RM protein. Each diet was randomly fed to triplicate groups of fish, and each cage was stocked with 20 fish. Fish were fed twice daily (06:00 and 18:00) to apparent satiation. The survival ranged from 96.7 to 98.3%, and no significant difference was observed among dietary treatments (P>0.05). With increasing dietary RM levels, feed intake (FI), specific growth rate (SGR) and feed efficiency (FE) decreased. Fish fed the diet with 250 g kg⁻¹ or more protein from RM had significantly lower SGR and FE than the control group (P<0.05), but there was no significant difference in FI at this level compared with the control group (P>0.05). Apparent digestibility coefficients (ADCs) of dry matter (DM), crude protein and energy significantly decreased with increasing dietary RM levels (P<0.05). Fish fed the diet with 250 g kg⁻¹ or more protein from RM had significantly lower ADC values of crude protein and energy compared with the control group (P<0.05). Whole-body crude protein and crude lipid decreased with increasing dietary RM levels. Fish fed the diet with 500 g kg⁻¹ protein from RM had significantly lower whole-body crude protein and crude lipid compared with the control group (P<0.05). However, whole-body moisture and ash showed opposite trends with crude protein and crude lipid. Moisture, crude protein and crude lipid contents in cobia muscle showed similar trends with those in whole body. There were no significant differences in plasma ammonia, urea, cholesterol and amino acids among fish fed the experimental diets (P>0.05). Fish fed the diet with 500 g kg⁻¹ protein from RM had significantly lower aspartate aminotransferase (AST) activity in liver than the control group (P<0.05). Hepatic insulin-like
growth factor I (IGF-I) gene expression level was significantly decreased in fish fed the diet with 500 g kg\(^{-1}\) protein from RM compared with the control group \(P<0.05\). However, IGF-I gene expression level in dorsal muscle was significantly increased in fish fed this diet compared with the control group \(P<0.05\). No significant differences were observed in target of rapamycin (TOR) expression levels in cobia liver and dorsal muscle at different RM levels \(P>0.05\). Results of the present study indicated that protein from RM could substitute 125 g kg\(^{-1}\) fish meal protein without influencing the growth, feed utilization and protein metabolism in cobia. The higher substitution levels of RM induced negative influences on feed intake, growth and hepatic IGF-I expression level.


A growth experiment was conducted on cobia \((Rachycentron canadum)\), initial weight 108.2 g ± 3.0 g) to investigate the effects of dietary corn gluten meal (CGM) levels on the fish growth, whole body composition and protein metabolism in relation to specific gene expression. Five isonitrogenous (crude protein 45%) and isoenergetic (gross energy 20 kJ g super\(^{-1}\)) practical diets were formulated by replacing 0% (the control), 17.5%, 35.0%, 52.5%, and 70.0% of fish meal (FM) protein with CGM protein. No significant differences were observed in the survival, feed intake (FI), specific growth rate (SGR), feed efficiency (FE) and protein productive value (PPV) among fish fed diets with 0%, 17.5%, 35.0%, and 52.5% of CGM protein. However, these indices were significantly lower in fish fed the diet with 70.0% of CGM protein than those in fish fed the control diet \(P<0.05\). The whole-body crude protein and lipid contents were significantly lower while the whole-body moisture content was significantly higher in fish fed the diet with 70.0% of CGM protein compared with the control group \(P<0.05\). When 70.0% of FM protein was replaced by CGM, plasma total protein and cholesterol contents were significantly lower than those in the control group \(P<0.05\). Fish fed the diet with 70.0% of CGM protein had significantly lower hepatic insulin-like growth factor 1 (IGF-I) expression levels than those in the control group \(P<0.05\). However, no significant differences were observed in hepatic target of rapamycin (TOR), dorsal muscle IGF-I and TOR expression levels among dietary treatments. Results of the present study indicated that 52.5% of FM protein could be replaced by CGM in the diets without significant influences on the growth, feed utilization and protein metabolism of juvenile cobia. The present results might be useful for developing cost effective and sustainable cobia dietary formulations.


The study was conducted in Cam Ranh, Vietnam, in 1000-L tanks supplied with recirculated and biofiltered saltwater (33ppt and 28.4 °C) to evaluate the potential use of lizard fish \((Saurida undosquamis)\) or blue crab \((Portunus pelagicus)\) acid silage protein for juvenile cobia (23-25 g). Six isoenergetic test moist diets (4915-5125 kcal kg\(^{-1}\)), using either raw fish diet, fish silage diet (FSD), raw crab diet, crab silage diet (CSD), mixed raw fish-raw crab diet or mixed fish-crab silage diet (MSD), as part of the protein sources in the steam-cooked diets, were fed to satiety to triplicate groups of 20 fish each for a 6-week growth trial. \(\text{Y}_{2}\text{O}_{3}\) was added as an inert indicator to determine the apparent digestibility coefficients (ADC) for macro nutrients and gross energy. Weight gain (185-286%) and specific daily growth rate (2.5-3.2% per day) were significantly higher in cobia fed the raw-based diets and FSD than in fish fed CSD and MSD (34-90 and 0.7-1.5% per day). Feed conversion ratios (FCR) were significantly higher in the groups fed CSD and MSD diets (2.1-6.5) than the groups fed the other diets (1.0-1.2), resulting in significantly lower protein productive values (0.1-0.2) in the groups fed CSD and MSD than in the other groups (0.3-0.4). The FCR results were confirmed by significantly lower ADC values in fish fed CSD and MSD than those in fish fed the other diets. We thus conclude that the present raw-based diets were better utilized by juvenile cobia than silage-based diets, particularly the diet made from crab silage.


A 10-wk feeding trial was conducted to determine dietary choline requirement for juvenile cobia. The basal diet was formulated to contain 47.1 g crude protein 100 g\(^{-1}\) dry weight from vitamin-free casein, gelatin and fish protein concentrate. This premix provided methionine at 1.05%, slightly less
than the optimal requirement of cobia (1.19%), so endogenous synthesis of choline from methionine would be limited. Choline chloride was supplemented to the basal diet to formulate six purified diets containing 133 (control group), 350, 548, 940, 2017 and 3981 mg choline kg⁻¹ diet, respectively. Each diet was randomly fed to triplicate groups of juvenile cobia with initial average weight 4.2±0.4 g in a flow-through system. Dietary choline level significantly influenced survival, feeding rate, weight gain, feed efficiency ratio, hepatosomatic index, as well as the choline concentrations in the liver and muscle of cobia. Broke-line regression of weight gain, liver and muscle choline concentration yield choline requirements of 696, 877 and 950 mg choline kg⁻¹ diet in the form of choline chloride, respectively. In addition, dietary choline supplementation significantly increased muscle lipid content of cobia. Potential manipulation of muscle lipid and associated flavor and texture by choline supplementation warrants further investigation.


The effects of different dietary soya lecithin levels on the growth and body composition of cobia, Rachycentron canadum were investigated. Five isontrigeneous and isoenergetic diets containing 8% of oil mixture of cod liver oil/corn oil (2:1, w/w) and diets contained graded level of soya lecithin from 0 to 4% were 1% increment. After 6 weeks experimental trial, cobia fed diet containing 3% soya lecithin had significantly higher weight gain than those fed the other treatment groups. Survival rates for all treatments were above 93%.


Appropriate food of suitable nutritional value is crucial for first-feeding stages of the larvae of cobia Rachycentron canadum, a very fast growing marine fish species. Best survival and growth results in cobia larviculture have been reported with a starter diet of HUFA-enriched rotifers and – as mouth size permits – followed by freshly-hatched and eventually HUFA-enriched Artemia nauplii. Using the smaller-sized Vietnam Artemia franciscana (AF) strain instead of the Great Salt Lake A. franciscana strain, it has been shown that the rotifer-feeding period could be shortened with 3 days, resulting in significant improvements in larval survival and growth. This study verified the possibility to feed umbrella-stage Artemia for further shortening and eventually completely substituting rotifer start feeding. The experiment was conducted in 200-L tanks and lasted 18 days. AF umbrella Artemia was used as sole feed during the whole rotifer feeding period (UAF), compared to the use of enriched rotifers for the first 2 days followed by AF-umbrella (ER+UAF) and the use of enriched rotifers as control (ER). The feeding incidence of UAF treatments was significantly lower (P<0.05) in the 1st feeding day, however, the ingestion and digestion of AF were evident. Growth and survival as well as deformities at day 18 post-hatching were not significantly different for all treatments (P>0.05). The viability of cobia larvae after exposure to high salinity stress was lower in the ER treatment at day 8 post-hatching, but higher at day 18 post-hatching (P<0.05). The ability of cobia larvae to ingest and digest AF umbrella at first feeding as well as the nutritional suitability of AF umbrella is discussed. The possibility to use umbrella-stage Artemia opens an opportunity to simplify the rearing protocol and to reduce production costs of cobia larviculture.


A study was conducted to determine the effects of dietary phospholipid (PL) levels in cobia (Rachycentron canadum) larvae with regard to growth, survival, plasma lipids and enzymes of lipid metabolism. Fish with an average weight of 0.4 g were fed diets containing four levels of PL (0, 20, 40 and 80 g kg⁻¹ dry matter: purity 97%) for 42 days. Final body weight (FBW), weight gain (WG) and survival ratio were highest in the 8% PL diet group and mortality was highest in PL-free diet group. We examined the activities of lipoprotein lipase (LPL) and hepatic lipase (HL) in liver, lecithin-cholesterolacyltransferase (LCAT) in plasma as well as plasma lipids and lipoprotein. LCAT activity showed a decrease of more than two-fold in PL-supplemented diet groups compared with the PL-free diet group. HL activity was highest in the 8% PL diet group and the other three groups showed no difference. LPL activity was significantly higher in the PL-supplemented diet groups than in the PL-free diet group. The dietary intervention significantly increased plasma
phospholipids and total cholesterol (TC) levels, and the higher free cholesterol (FC) level contributed to the TC level. However, the fish fed PL exhibited a significantly decreased plasma triglyceride (TG) level. The lipoprotein fractions were also affected significantly by the PL. The PL-supplemented diet groups had significantly higher density lipoprotein (HDL) compared with the PL-free diet group, but showed a marked decrease in very low-density lipoprotein (VLDL). The results suggested that PL could modify plasma lipoprotein metabolism and lipid profile, and that the optimal dietary PL level may well exceed 80 g kg$^{-1}$ for cobia larvae according to growth and survival.

247. Ouyang, L. & Guo, X. (2009). Effects of temperature on the feeding and growth of fish. *Studia Marina Sinica*, 49, 87-95. Temperature is the critical factor for feeding and growth of fish. Results of studies indicated that, under different temperature, some parameters, such as food consumption (C), specific growth rate (SGR) and ecological conversion efficiency (Eg) changed remarkably. Different fish species had different responsive model to temperature. This paper introduced that the relationship between temperature and growth and feeding of some fishes, including Atlantic cod (*Gadus morhua*), sea bass (*Dicentrarchus labrax*), Northern pike (*Esox lucius*), arctic char (*Salvelinus alpinus*), cobia (*Rachycentron canadum*), turbot (*Scophthalmus maximus*), and so on, which were studied for a long time in abroad. At the same time, at home, some researchers had found out some rules in their works. Many rules could be described as equations. These researches have very important significance on assessment of fishery resources and aquaculture.

248. Qiao, Y.G., Tan, B.P., Mai, K.S., Ai, Q.H., Zhang, W.B. & Xu, W. (2013). Evaluation of iron methionine and iron sulphate as dietary iron sources for juvenile cobia (*Rachycentron canadum*). *Aquaculture Nutrition*, 19(5), 721-730. An 8-week experiment was designed to determine the optimum dietary iron requirement of juvenile cobia *Rachycentron canadum* (mean initial weight, 15.89 ± 0.84 g) with iron sulphate (*FeSO$_4$$\cdot$7H$_2$O) and iron methionine (*FeMet*) as iron sources, using a semi-purified diet based on casein and white fish meal as the protein sources. The basal diet was supplemented with 0, 30, 60, 120, 240 and 480 mg iron kg$^{-1}$ dry diet from either *FeSO$_4$* or *FeMet*, respectively. Survival was not significantly affected by the all dietary treatment. Weight gain (WG), feed efficiency (FE), serum catalase activity (SCAT), and haemoglobin were significantly affected by any of the dietary treatments from both of two iron sources. Based on broken-line regression analysis of WG, FE and SCAT, a minimum requirement for dietary iron was recommended to be 80.5-94.7 mg kg$^{-1}$ from *FeSO$_4$* and 71.3-75.1 mg kg$^{-1}$ from *FeMet*. Iron supplement to the basal diet had no significant effect on haematocrit, erythrocyte count, iron concentration in whole body and fillet. Our experiment also showed that the bioavailability of *FeMet* and *FeSO$_4$* to juvenile cobia was similar for WG and FE, and the relative bioavailability of *FeMet* and *FeSO$_4$* to juvenile cobia was 275% for maximum SCAT.

249. Ren, M., Ai, Q. & Mai, K. (2014). Dietary arginine requirement of juvenile cobia (*Rachycentron canadum*). *Aquaculture Research*, 45(2), 225-233. A 9-week feeding trial was conducted to estimate the dietary requirement of arginine in juvenile cobia in indoor flow-through and aerated aquaria. Six isonitrogenous and isoenergetic practical diets were formulated to contain graded levels of arginine ranging from 1.76% to 3.75% (dry weight) at about 0.4% increments replaced by equal proportions of glycine. Survival was not significantly different among dietary treatments. Specific growth rate (SGR) and feed efficiency ratio (FER) increased with increasing dietary arginine up to the 2.96% diet ($P<0.05$), and thereafter declined. The whole body crude protein content was significantly affected by dietary arginine ($P<0.05$), while moisture, crude lipid and ash showed no significant differences among dietary treatments. The essential amino acid contents of muscle were not significantly affected by dietary arginine. The serum nitric oxide synthase activities in fish fed diets with arginine from 2.18% to 3.75% were significantly higher than activities in fish fed the diet with 1.76% arginine ($P<0.05$). On the basis of SGR and FER, the optimal dietary arginine requirements of juvenile cobia were estimated to be 2.85% of the diet (6.20% of dietary protein) and 2.82% of the diet (6.13% of dietary protein), respectively, using second-order polynomial regression analysis.

A 9-week feeding trial was conducted to investigate the effect of dietary carbohydrate level on the growth performance, body composition and apparent digestibility coefficient and digestive enzyme activities of juvenile cobia. Six isonitrogenous and isolipidic diets containing graded levels of starch (1.3%, 6.5%, 12.5%, 18.4%, 24.2% and 30.4%) were fed to juvenile cobia. Specific growth rate (SGR), feed efficiency ratio (FER) and protein efficiency ratio (PER) increased with increasing dietary starch up to 18.4% (P<0.05), and thereafter SGR declined but FER and PER remained nearly the same. Apparent digestibility coefficient of starch reduced significantly when dietary starch up to 30.4%. Fish fed the diets with starch from 18.4% to 30.4% showed higher amylase activities in intestinal tract than those fed diets containing starch 1.3% and 6.5% (P<0.05). Significantly higher whole-body lipid contents were observed in fish fed the diets containing higher starch. Whole-body moisture content was inversely correlated with whole-body lipid content, while protein and ash showed no significant differences. Plasma glucose, hepatosomatic index, liver glycogen and liver lipid increased with an increasing dietary starch. Based on SGR and FER, the appropriate dietary starch supplementations of juvenile cobia were estimated to be 21.1% and 18.0 % of diet respectively.


An 8-week feeding trial was conducted to evaluate the use of local poultry by-product meal (PBM) in replacement of imported fishmeal in the diets of cobia, Rachycentron canadum. Six isolipidic (12%) and isoproteic (45%) experimental diets were formulated using PBM to replace fishmeal at 20, 40, 60, 80 and 100% dietary protein. Eleven juvenile cobia (initial mean weight of 30.7±0.78 g) were randomly stocked in 300-L circular fibreglass tanks and hand-fed based on the total biomass of each tank, twice a day at 0900 h and 1500 h. The fish were group weighed at 2-week intervals to monitor their growth performance in order to adjust the feeding ratio. At the end of the feeding trial, weight gains (WGs) ranging from 221 to 322% were obtained. The specific growth rate (SGR), WG and protein efficiency ratio (PER) for fish fed with PBM-based diets were not significantly different (P>0.05) when compared to fish fed the control diet. The best SGR was recorded for fish fed with 60PBM diet, which was significantly higher (P<0.05) than those fed the control diet with values at 2.40±0.01 and 1.97±0.26%/day, respectively. The FCR of 1.83±0.05 for fish fed the 60PBM diet was not significantly different (P>0.05) when compared to those fed the control diet. The PBM source and dietary level did not significantly (P>0.05) affect the hepatosomatic index of the fish. The results from this study suggested that PBM could replace 100% dietary fishmeal without adversely affecting the growth performance, but an optimal replacement level at approximately 60% was recommended for better growth performance and efficient feed utilization.


The potential beneficial effects of supplementing live feeds with mannan oligosaccharide (MOS; BioMos®) upon cobia Rachycentron canadum larval performance were examined. Characteristics of fish examined included survival to weaning, growth, ability to withstand osmotic stress and the degree of development of the brush border of the intestine. Live feeds included rotifers (Brachionus plicatilis) and Artemia which were enriched for 24 h with a commercial enrichment media alone or in combination with 0.2% (dry weight basis) MOS. Salinity challenges were performed at 6 days post-hatch (dph) and at 7, 13, and 14 dph (0 and 65 g L⁻¹ for 6 dph; 0 and 55 1 7+ dph) corresponding to transitions in feeding, to examine the ability of larval cobia to survive stress. Differences (P<0.05) in survival, favoring cobia receiving MOS-supplemented feeds were discerned at 6 and 7 days post-hatch (dph) when fish were challenged at 0 g L⁻¹ and at 13 dph when challenged with 55 g L⁻¹ salinity water. Electron microscopy of the mid-intestine of developing larvae revealed that MOS-supplemented diets enhanced (P<0.05) the height of microvilli while reducing (P<0.05) the occurrence and size of supranuclear vacuoles. Supplementation of diets with MOS could assist cobia larvae in maintaining alloostasis especially when reared at sub-optimal salinities.


The morphological development of larval cobia Rachycentron canadum from 3 days post hatch (dph) until weaning (27 dph) was examined using S.E.M. Two groups of fish were studied: a
control group (CF), reared under standard feeding protocol, and a group in which prey items were enriched with supplemental taurine (4 g l⁻¹ day⁻¹; TF). TF fish grew faster (P<0.001), attained greater size (mean ± s.e. 55.1±1.5 v. 33.9±1.0 mm total length) and had better survival (mean ± s.e. 29.3±0.4 v. 7.1±1.2 %) than CF fish. Canonical variance analysis confirmed findings with respect to differences in growth between the treatment groups with separation being explained by two cranial measurements. S.E.M. revealed that 3 dph larvae of *R. canadum* (in both groups) possess preopercular spines, superficial neuromasts on the head and body, taste buds in the mouth, an olfactory epithelium which takes the form of simple concave depressions, and primordial gill arches. Gill filaments start to form as early as 6 dph and lamellae buds are visible at 8 dph in both groups. In CF fish, the cephalic lateral line system continues its development at 12-14 dph with invagination of both supra- and infraorbital canals. At the same time, a thorn-like or acanthoid crest forms above the eye. At 14 dph, invaginations of the mandibular and preopercular canals are visible and around 22 dph enclosure of all cranial canals nears completion. In CF larvae, however, completely enclosed cranial canals were not observed within the course of the trial, i.e. 27 dph. In TF larvae, grooves of the cephalic lateral line system form 4 days earlier than observed in CF larvae of *R. canadum* (i.e. at 8 dph), with enclosure commencing at 16 dph, and completed by 27 dph. Along the flanks of 6 dph larvae of either treatment, four to five equally spaced neuromasts delineate the future position of the trunk lateral line. As myomeres are added to the growing larvae, new neuromasts appear such that at 16 dph a neuromast is associated with each myomere. By 27 dph, the trunk lateral line starts to invaginate in CF larvae, while it initiates closure in TF larvae. These findings elucidate important features of the larval development of *R. canadum* and show that dietary taurine supplementation benefits larval development, growth and survival in this species. Moreover, they suggest a conditional requirement for taurine in larval *R. canadum*.


Commercial aquaculture feeds rely heavily on fishmeal and fish oil, which can be expensive and ecologically unsustainable. To evaluate the efficacy of reduced fishmeal diets for outgrowth, a dietary study was conducted on the finfish cobia, *Rachycentron canadum*. NMR-based metabolomic techniques were used to assess the effect of decreasing dietary fishmeal on the health of the cobia. Filtered serum 1H NMR spectra analysed by principal components analysis (PCA) showed cobia fed reduced fishmeal diets were metabolically different than cobia on control diets. In particular, tyrosine and betaine increased in cobia fed reduced fishmeal diets while glucose decreased, suggesting that these cobia were not receiving the necessary nutritional components required for energy and growth. The formulated control diet contributed to enriched growth and significantly elevated lactate levels suggesting enhanced gut microflora metabolism in response to dietary components. The results show that NMR-based metabolomic analysis is a useful tool in aquaculture studies.


The morphology and histology of the digestive system of *Rachycentron canadum* was studied using anatomy and light microscope. The results showed that the digestive tract in *R. canadum* was consisted of buccal-pharynx cavity, esophagus, stomach, pyloric caeca, foregut, midgut and hindgut. The buccal-pharynx cavity was large, and its mucosa was composed of stratified squamous epitheliums with a few goblet cells. The esophagus was very short, and stratified and simple columnar squamous epitheliums were identified. The stomach was expanded and Y-shaped and many goblet cells were observed in the epitheliums of cardiac stomach and pyloric stomach. Many gastric glands cells were found under the mucosa of the stomach. The pyloric caeca were very developed, and the intestine was short and divided into three parts: foregut, midgut and hindgut. The average intestinal coefficient of *R. canadum* was calculated, which was about 0.43. From foregut to hindgut, the number of goblet cells and intestinal villus reduced gradually. The digestive glands were composed of liver and pancreas. The liver lobule was not clear but its hepatic cells were rich in fat. Pancreas was diffused and the exocrine section of pancreas was consisted of many pancreatic acinar cells. The pancreas islets were located in the exocrine section.


A constraint for the expansion of cobia aquaculture is the availability of high quality formulated diets which reduce or eliminate fish meal (FM) protein. Therefore, the nutritive value of a novel soybean cultivar, Navita™ (Navita, non-genetically modified and selectively bred soy), and regular, commodity soybean meal (SBM, de-hulled, defatted, roasted and solvent-extracted) was evaluated for cobia, *Rachycentron canadum* via separate digestibility and growth trials. In the first experiment Navita's apparent digestibility coefficients (ADC) were higher than those of SBM for nearly every nutrient evaluated. Crude protein ADCs were 82 and 69% for Navita and SBM, respectively. Apparent DC for amino acids ranged from 68 to 109% for Navita whereas, amino acid ADCs for SBM varied from 42 to 98%. The feeding trial utilized fish of a size that more closely resembles commercial cobia stocking (1.8 kg), and was conducted over a 91-day period. Experimental diets (iso-nitrogenous and iso-energetic) were formulated such that 67% of the FM protein in the reference diet was replaced by either a combination of SBM + soy protein concentrate (SPC, Solae Profine®) labeled MXSB-diet, or by a combination of SPC + Navita; Navita-diet, hereafter. A fourth experimental diet had 80% of the FM protein replaced by a combination of Navita + SPC and was identified as Navita-high. No significant differences (P>0.05) were observed in fish fed the experimental diets for feed conversion ratio, protein efficiency ratio, feed efficiency, mean daily intake, gross protein intake, gross energy intake, visceral somatic index, muscle ratio, and hepatosomatic index. Fish fed the Navita-high diet had the lowest fish in:fish out ratio (FIFO) at 0.9±0.16. These results indicate that Navita meal can be incorporated at very high levels in the diet of marine carnivorous fish such as cobia with no detriment to performance, making it a prime candidate for FM replacement in aquafeeds.


A 4x3 factorial experiment was conducted for two weeks to determine the effects of ration level ranging from satiation to satiation and water temperature at 21, 27 and 33 °C on growth, fecal production, nitrogenous excretion and energy budget of 10-g-size cobia in this study. Over the temperature range, 21-33 °C, maximal ration (Rmax, % per day), optimal ration (Ropt, % per day) and maintenance ration (Rmain, % per day) all increased with temperature (T, °C), described as a quadratic equation Rmax=0.046T2+2.906T-35.97 (R2=0.989), a simple equation Ropt=-0.533T-8.001 (R2=0.993), and a quadratic equation Rmain=0.028T2-1.350T-17.18 (R2=1), respectively. Both fecal production (f, mg g⁻¹ d⁻¹) and nitrogenous excretion (u, mg g⁻¹ d⁻¹) were affected significantly by ration and temperature and increased as ration and temperature increased. Feed absorption efficiency (FAE, %) varied small over the whole ration and temperature ranges though the effects of ration and temperature were significant in some data. Juvenile cobia grew fastest at 33 °C when fed at satiation but the growth rate was equal or better at 27 °C when food was restricted, whereas the fish showed overall significant lower growth rates at 21 °C except for the starved treatment. Among three temperatures specific growth rate in wet weight (SGRw, % per day), dry weight (SGRd, % per day), protein (SGRp, % per day) and energy (SGRe, % per day) all increased with ration, showing decelerating growth-ration relationships described as logarithmical equations at 27 and 21 °C and a linear growth-ration relationship described as a simple equation at 33 °C. Apart from starvation ration with a negative linear growth-temperature relationship growth all increased with temperature, described as quadratic functions. Two-way ANOVA showed that ration and temperature had an interaction on growth. By using multiple regression analysis the relationships between specific growth rate (SGR, % per day) and ration level (RL, % per day) as well as temperature (T) took the forms: SGRw=11.97+1.23ln(RL+1)+0.91T-0.0212+0.16ln(RL+1) (R2=0.962), SGRd=17.04+0.72ln(RL+1)+1.11T-0.0212+0.12ln(RL+1) (R2=0.968), SGRp=18.25+0.20ln(RL+1)+1.28T-0.033+0.15ln(RL+1) (R2=0.972) and SGRe=20.83+0.85ln(RL+1)+1.40T-0.033+0.15ln(RL+1) (R2=0.969). Feed conversion efficiency in wet weight (FCEw, %), dry weight (FCEd, %), protein (FCEp, %) and energy (FCEe, %) at 27 and 33 °C was much higher than that at 21 °C, and the maximal FCE occurred at sub-satiation (i.e. feeding group 3) and 27 °C. All the relationships between FCE and temperature were described as quadratic equations. Feed conversion efficiencies of juvenile cobia at satiation ration were: 100C=7.0F+7.7U+69.0R+16.4G (or 100A=81R+19G) at 33 °C, 100C=6.8F+7.9U+68.0R+17.3G (or 100A=80R+20G) at 27 °C and 100C=6.3F+8.4U+77.2R+8.2G (or 100A=90R+10G) at 21 °C, where C is food energy, A is assimilated energy, F is feces energy, U is excretion energy, R is metabolism energy and G is growth energy.

Growth and nitrogen budget of young cobia (initial body weight 28g in average) at different ration levels (from starvation to satiation) for different feed types (i.e., NSF-natural sardine fish, CEFF-commercial eel formulated feed and CMFF-commercial marine-fish formulated feed) were studied, and the relationships between growth as well as nitrogenous excretion and ration were established in this paper. The results showed that as ration increased specific growth rate (SGR) of young cobia increased with a decelerating pattern for NSF and CEFF and with a linear pattern for CMFF. Among three feed type groups young cobia had a similar SGR between NSF and CEFF, but the SGR for NSF and CEFF was much higher than that for CMFF.


Growth, faecal production, nitrogenous excretion and energy budget of juvenile cobia (initial body weight similar to 28 g) at different ration levels (RL, % per day) ranging from starvation to ad libitum for three feed types, i.e., natural sardine fish (NSF), commercial eel formulated feed (CEFF) and commercial marine-fish formulated feed (CMFF), were investigated in this study. Both feed type and ration level affected significantly faecal production (F, mg g⁻¹ day⁻¹), and nitrogenous excretion (u, mg g⁻¹ day⁻¹). Feed type, not ration level, for the NSF-fed and CEFF-fed groups and both feed type and ration level for the CMFF-fed group affected significantly feed absorption efficiency (FAE, %). For each feed type group, faecal production and nitrogen excretion increased whereas feed absorption efficiency in dry weight (FAEₚₑ, %), protein (FAEₚₚ, %) and energy (FAEₑₑ, %), with a small variation, tended to decrease as ration increased. Specific growth rate in wet weight (SGRₑₑ, % per day), dry weight (SGRₚₑ, % per day), protein (SGRₚₚ, % per day) and energy (SGRₑₑ, % per day) for the NSF-fed and CEFF-fed groups was much higher than that for the CMFF-fed group, and the growth-ration relationship was a decelerating curve described as a logarithmic equation for the NSF-fed and CEFF-fed group, and a linearity described as a simple equation for the CMFF-fed group. There was a significant difference of the slopes in the regression equations among three feed type groups by analysis of covariance. Multiple regression analysis showed that the relationships between specific growth rate (SGR, % per day) and ration level in dry weight (RLₚₑ, % per day) as well as feed type (D1, D2) were SGRₑₑ=2.226+4.022ln(RLₚₑ+1)-0.895D1-2.705D2, SGRₑₑ=2.686+4.422ln(RLₚₑ+1)-1.014D1-2.969D2, SGRₑₑ=2.481+4.316ln(RLₚₑ+1)-1.122D1-2.943D2 and SGRₑₑ=2.339+4.972ln(RLₚₑ+1)-0.954D1-3.053D2. Feed conversion efficiency in wet weight (FCEₑₑ, %), dry weight (FCEₚₑ, %), protein (FCEₚₚ, %) and energy (FCEₑₑ, %) for the NSF-fed and CEFF-fed groups was much higher than that for the CMFF-fed group, and with increased ration FCE increased or first increased then decreased for the NSF-fed and CEFF-fed groups and increased significantly for the CMFF-fed group. Energy budgets of juvenile cobia at satiation ration were 100A=59R+41G for NSF-fed group, 100A=67R+33G for CEFF-fed group and 100A=83R+17G for CMFF-fed group, where A is assimilated energy R is energy spent in metabolism and G is energy stored as growth.


Suitable feeding schedule and ration level for young cobia (Rachycentron canadum) weighing about 10 g were established by studying their diet feeding rhythm and body composition, specific growth rate and food conversion efficiency at different ration levels. An obvious diet feeding rhythm of young cobia was observed. Feeding mainly proceeded by day and was most active during the periods of 06:00-08:00 and 18:00-20:00, forming two feeding peaks in a day. Feeding decreased remarkably in the darkness of night and no feeding happened during the period of 00:00-04:00, which formed a feeding vale in a day. Thus it could be seen that the feeding rhythm of young cobia was characterized by daytime feeding and inclined to twilight feeding. Five ration levels (RL) were set as follows: starvation, 3%, 6% and 9% of initial body weight per day, and satiation. The protein and lipid contents in the body of young cobia generally increased with increased ration, with a marked decrease of lipid content at 6% ration and no significant difference of protein content from 3% to satiation ration.
261. Sun, L., Chen, H., Huang, L., Wang, Z. & Yan, Y. (2006). Growth and energy budget of juvenile cobia (Rachycentron canadum) relative to ration. Aquaculture, 257(1-4), 214-220. Growth, faecal production, nitrogenous excretion and energy budget of juvenile cobia (initial body weight 10 g or so) at five ration levels (starvation, 3%, 6% and 9% of initial body weight per day, and ad libitum) were investigated. Feed consumption, faecal production and growth of juvenile cobia were directly measured. Faecal production (f, mg g⁻¹ d⁻¹) increased with the increase of ration level (RL, % per day), described as ln(f+1)=1.1804 ln(RL+1)-0.0619. Feed absorption efficiency (FAE, %) decreased as ration level increased, but the variation of feed absorption efficiency (FAE, %) was small, with ranges of 81.44-87.17% 96.57-98.377%, and 94.21-96.54% for FAE₈, FAE₆, and FAE₄, respectively. The relationship between ration level (RL, % per day) and specific growth rate in wet weight (SGR₈, % per day), dry weight (SGR₆, % per day), protein (SGR₆, % per day) and energy (SGR₄, % per day) were decelerating curves described as logarithmical equations: SGR₈=3.8759 ln(RL+1)-3.7164, SGR₆=5.1068 ln(RL+1)-5.2477, SGR₄=5.5611 ln(RL+1)-5.6094 and SGR₄=6.1282 ln(RL+1)-7.4385. Feed conversion efficiency in wet weight (FCE₈, %), dry weight (FCE₆, %), protein (FCE₆, %) and energy (FCE₄, %) increased with ration level, peaked at 9% per day ration and then decreased at higher ration level. Energy intake (C), energy retained as growth (G) and energy lost in faeces (F) were estimated directly and energy allocated to excretion (U) and metabolism (R) were calculated by difference (U+R)-C-F-G. The partial energy budget of juvenile cobia at satiation ration was 100C=7F+76(U+R)+17G.

262. Tan, B., Chen, G., Shi, G. & Wu, Z. (2006). Alimentary canal contents of cobia (Rachycentron canadum). Journal of Zhanjiang Ocean University, 26(1), 12-15. The species, numbers and sizes of the alimentary canal contents of cobia larvae of 1-20 days after hatching (DAH) cultured in ponds were studied by anatomization and observation with optical anatomical lens. The results showed that the first-feeding occurred on 2 DAH, and preyed mainly on copepod nauplius, larval copepod and cladocera, the recipe was chiefly composed of copepod, and large zooplanktons. Larval shrimp and crab could also be fed from 13 DAH. There was significant difference in food selective indexes between the two stages.

263. Trushenski, J., Schwarz, M.H., Bergman, A., Rombenso, A.N. & Delbos, B.C. (2012). DHA is essential, EPA appears largely expendable, in meeting the long-chain polyunsaturated fatty acid requirements of juvenile cobia. Rachycentron canadum. Aquaculture, 326(329), 81-89. Cobia may require both eicosapentaenoic (EPA) and docosahexaenoic (DHA) acids to meet dietary n-3 long-chain polyunsaturated fatty acid (LC-PUFA) demand. Growth performance is reduced when LC-PUFA-rich fish oil is replaced with soybean oil, a LC-PUFA deficient lipid, in cobia diets, but individual requirements for EPA and DHA have not been quantitatively determined. We assessed the growth performance and tissue fatty acid composition of juvenile cobia fed a fish oil-based positive control diet (FISH), a soy oil-based negative control diet (SOY), or experimental diets based on soy oil supplemented with EPA, DHA, or both at 50% or 100% of the concentrations typically observed in fish oil: (SOY+50% EPA, SOY+100% EPA, SOY+50% DHA, SOY+100% DHA, SOY+50% BOTH, SOY +100% BOTH). Growth performance of fish fed the SOY was impaired relative to those fed the FISH diet. Supplementing the soybean oil-based diet with DHA, alone or in combination with EPA, restored performance. EPA supplementation had no effect on growth performance. Fatty acid composition of cobia fillet, liver, brain, and eye tissues was significantly affected by diet, but tissue profile change among fish fed any of the soy oil-based diets was less overt in the brain compared to the periphery. Diets supplemented with DHA and/or EPA resulted in increased tissue levels of these fatty acids, however, the maximal levels were observed in the FISH treatment. Our data suggest the dietary n-3 LC-PUFA requirement of juvenile cobia can be largely satisfied by DHA, and that EPA, if required, is required only in trace amounts. Soybean oil supplemented with DHA is an effective alternative to fish oil in juvenile cobia diets.

264. Trushenski, J., Schwarz, M.H., Lewis, H., Laporte, J., Delbos, B., Takeuchi, R. & Sampaio, L.A. (2011). Effect of replacing dietary fish oil with soybean oil on production performance and fillet lipid and fatty acid composition of juvenile cobia Rachycentron canadum. Aquaculture Nutrition, 17(2), 437-447. As a marine carnivore exhibiting exceptionally high growth rates, cobia are considered a species for which fish oil (FO) replacement may be difficult. However, partial, if not complete, FO replacement is necessary to ensure sustainability. We evaluated the effects of graded substitution of dietary FO with soybean oil (SO) in cobia culture. Feeds contained FO (100% FO), SO (0% FO) or blends of the two (67% FO, 33% FO) as the supplemental lipid source. Production performance was
largely unaffected by partial replacement of FO with SO: feed intake and final weight were reduced only in the 0% FO dietary treatment. Fillet total lipid fatty acid (FA) composition differed among the dietary treatments, closely approximating dietary FA profile. As increasing amounts of FO were replaced, SO-associated FA became enriched within the fillet lipid at the expense of FO-associated FA. Fillet lipid classes were associated with a particular FA signature, regardless of dietary FA profile. SO can replace a substantial amount of dietary FO; however, juvenile cobia appear to exhibit a nominal requirement for intact long-chain polyunsaturated FA. Therefore, aggressive FO replacement may result in essential fatty acid deficiencies unless the feeds can be amended with alternative sources of these essential nutrients.


Sparing of marine resources in aquafeeds can be environmentally and economically advantageous; however, fish meal (FM) replacement can affect the production performance and physiological competence. Phospholipids are increasingly understood to be involved in maintaining growth and vigour in fish and may be deficient in reduced FM formulations. Accordingly, we evaluated the growth and stress tolerance of juvenile cobia fed typical (50% FM) or reduced FM feeds (12% FM) with or without phospholipid amendment [1% marine lecithin (12% FM + Marine PL) or soy lecithin (12% FM + Soy PL)] for 6 weeks in triplicate tanks (N = 3) in a recirculation aquaculture system. The 50% FM feed yielded significantly superior growth and growth efficiency in comparison with the 12% FM and 12% FM+ Soy PL feeds, but the 12% FM+ Marine PL feed yielded comparable results to 50% FM feed. A low-water stress challenge induced elevated plasma glucose, cortisol and lactate levels in all treatments. However, a significant interaction (diet - stress) effect suggested a lesser cortisol response among fish fed the 12% FM+ Marine PL and 50% FM diets. These findings demonstrate that growth performance and, perhaps, resilience of cobia raised on reduced FM feeds may be improved by the addition of marine-origin phospholipid to the diet.


The high cost and limited availability of fish oil makes plant-derived lipids attractive for aquafeed manufacturing, but replacing fish oil with these lipids can result in long-chain polyunsaturated fatty acid (LC-PUFA) deficiencies. Fatty acid metabolism, specifically the efficiency of LC-PUFA utilization, may be influenced by the dietary saturated fatty acid (SFA) content versus that of C18 polyunsaturated fatty acids (PUFAs). We assessed the growth and tissue composition of Cobia Rachycentron canadum (55.3 ± 0.2 g initial weight [mean ± SE]; 10 fish/tank, 3 tanks/diet) fed diets (~49% protein, ~10% lipid) containing fish oil; 22.6(n-3)-amended standard, partially hydrogenated, or fully hydrogenated soybean oil; and these same soybean oils supplemented with soybean lecithin for 8 weeks. Although survival (range = 97–100%), final weight (160–189 g), and feed conversion ratio (1.40–1.52) were unaffected by diet, differences were observed in weight gain (185–241%), specific growth rate (1.87–2.19% body weight/d), and feed intake (2.94–3.44% body weight/d). Significant effects of soybean oil type on final weight, weight gain, feed conversion ratio, specific growth rate, and feed intake were noted, with standard soybean oil generally outperforming the other soybean lipids when oil types were pooled across phospholipid supplementation treatments, whereas phospholipid supplementation had no significant effect on any of the performance measures. Differences in dietary fatty acid profile yielded differences in tissue composition. Feeding standard soybean oil resulted in the most greatly modified profiles, whereas the profiles of fish fed fully hydrogenated, completely saturated soybean oil were most similar to those of the fish oil–fed fish. The magnitude of profile change was greatest in the liver and fillet tissues and smallest in the eye and brain tissues. Although further research is necessary to demonstrate whether SFA-rich lipids can effectively reduce the LC-PUFA requirements of Cobia, it is clear that SFA-rich oils offer a strategic advantage in minimizing the effects of fish oil replacement on tissue fatty acid profile.


Polyunsaturated fatty acids (PUFAs) have been used as biomarkers in pelagic ecosystems although previous studies have failed to quantify the timing of conservation of dietary PUFAs in pelagic
fishes and invertebrates. Here we investigated the influence of diet upon the timing of conservation of PUFAs throughout multiple trophic exchanges in larval and juvenile cobia (Rachycentron canadum) and their prey. Cobia, rotifers (Brachionus plicatilis), and Artemia (Artemia franciscana) were fed laboratory processed or natural diets resembling prey and dietary modification of fatty acid signatures was quantified using two-source mixing models. Specimens were collected throughout the experiment to track dietary influences over time. Cobia larvae underwent significant dietary modification of PUFAs after 24 h and conserved > 90% of dietary PUFAs after an average of 6 days. Similar results were identified in juvenile cobia as significant dietary modification of PUFAs took place after 3 days and > 90% were conserved after an average of 12 days. In addition, no significant ontogenetic changes in PUFA signatures were identified in juvenile cobia throughout the 30-day experiment. PUFA signatures in prey items (rotifers and Artemia) underwent significant dietary modification in 24 h, with over 90% incorporation after 5-7 days. Results from this study support the premise that fatty acids are promising dietary indicators and may be useful for future studies examining trophic relationships in marine ecosystems and habitat use of marine fishes.


Cobia (8.4 ± 0.1 g body weight) were fed to satiation with three test diets of high plant protein-based ingredients and different lysine to arginine ratios, and one commercial diet (currently used for cobia rearing in Vietnam as a control for growth) for 6 weeks. The test diets contained 206 g marine ingredients kg⁻¹, including fishmeal, krill meal and fish protein concentrate (in order of high to low inclusion), while the rest of the dietary protein was a blend of soya and pea protein concentrate, wheat protein and sunflower meal. Crystalline lysine and arginine were added in the test diets to produce either a balanced lysine to arginine ratio (BL/A; 1.1) and a high or low lysine to arginine ratio (HL/A; 1.8 and LL/A; 0.8, respectively). There were no significant differences in final body weight, weight gain, feed conversion ratio or protein gain between cobia fed BL/A- and commercial control diet (CCT). Cobia fed BL/A diet performed better than fish fed either HL/A- or LL/A diet. This was partly due to a higher feed intake and lipid gain in cobia fed BL/A diet as compared to HL/A- and LL/A diet.


A two-month feeding trial was conducted to evaluate the effects of partial substitution of fish meal with soybean meal with different levels (0, 5%, 10%, 20% and 30%) in diet for cobia (Rachycentron canadum). The juvenile cobias with initial body length of 12.77±1.03 cm and initial body weight of 7.9±2.12 g were randomly assigned to 15 floating cages (2 m x 2 m x 0.8 m) at a rate of 30 fish each cage with triplication. The fish were fed twice daily at a feeding rate of 3-5%. The results showed that the fish fed fish meal by less than 10% had no significant reduction in growth and feed utilization (P>0.05). When the fish meal in the diets were replaced by 20%, however, there were significant differences in the relative weight gain ratio (RWGR), feed conversion rate (FCR), survival rate (SR), condition factor (CF) and internal organs weight rate (IOWR) between control group and the experimental groups (P<0.05). When the replacement level increased to 30%, the IOWR was significant difference between control group and experimental ones (P<0.05). The optimal dietary soybean-fish meal ratio was 1:1.8 in the basic diet contained 20% soybean meal for cobia.


Using the orthogonal test design L9(3⁴), nine practical diets containing different vitamin E (40, 45, 50 mg/kg), vitamin C (500, 750, 1000 mg/kg), choline (3000, 5000, 8000 mg/kg) and inositol (200, 400, 600 mg/kg) respectively were fed to cobia (Rachycentron canadum) with mean body length of 17.78±1.70 cm and body weight of 28.96±9.78 g. Each diet was fed to 3 replicate groups of cobias for 60 days. The fish were fed twice every day and daily feeding rate was 3% to 5% wet weight. The results were as follows: Weight gain rate of cobia for control and treatments from No.1 to No.9 were 80.82%, 251.39%, 327.45%, 54.37%, 99.24%, 231.28%, 69.12%, 107.19%, 91.47%, and 69.51%, feeding conversion ratio were 2.13, 1.78, 1.63, 2.05, 1.88, 1.85, 2.02, 1.96, 2.03 and 1.97. Analysis of variance indicated that the optimal supplementations of vitamin E, vitamin C, choline and inositol were 45 mg/kg, 750 mg/kg, 3000 mg/kg and 400 mg/kg, respectively.

A study was undertaken to evaluate the effect of the dietary lipid level on growth, feed utilization, lipid deposition and lipid metabolism by cobia juveniles. Three isonitrogenous diets containing 47% crude protein with increasing dietary lipid levels 5%, 15% and 25% (DM, dry matter) were fed to satility to triplicate groups of 20 fish (7.71 g) for 6 weeks. At the end of the feeding trial, fish fed diets containing 5% and 15% lipid showed a higher growth than those fish fed with 25% lipid. Though daily feed intake (DFI) decreased with increasing dietary lipid, there was no significant difference in daily energy intake (DEI) among treatments. As dietary lipid level increased, energy retention (EI), daily energy gain (DEG), daily lipid intake (DLI), daily lipid gain (DLG), viscero-somatic index (VSI), intraperitoneal fat ratio (IPF) and body lipid content increased dramatically and the 25% group had the highest values. Hepatosomatic index (HSI) and muscle lipid content were higher at 25% lipid group than 5% lipid group, but no significant different was found between 15% and 25% lipid group. Activities of G6PD and ME were reduced with increasing lipid intake, but activities of IDH and 6PGDH did not change among groups. In conclusion, high dietary lipid levels above 15% produced little practical benefit because of higher fat accretion in cobia.


The proximate composition of Cobia (Rachycentron canadum) varies greatly and is difficult to discern by their appearance. In this study, a non-destructive electromagnetic (EM) scan method was applied to estimate the proximate composition of cobia. The predictive equations were obtained to assess the index of quality. Cobia, weighing 2880-8340 g, were scanned with an EM scan. The analytical results of the proximate composition indicated that the moisture content decreased while lipid content increased as the body weight of cobia increased. Results also showed a negative relationship between moisture and lipid contents ($R^2=0.965$). Ash and protein contents of cobia showed no significant differences with the body weight level in this study ($p > 0.05$). The TOBEC (total body electrical conductivity) value, body weight, fork length, and proximate composition were used to develop feasible predictive equations. The $R^2$ values of the equation for moisture, lean body mass, ash, and protein were 0.981, 0.983, 0.941, and 0.984, respectively. The $R^2$ value of the predictive equation for lipids was lower at 0.784. To evaluate the feasibility of the equation by paired t-test, the body weight, fork length, and TOBEC value of moisture and lipid contents of six new samples were checked by the predictive equation and experimental measurements. Results showed no significant differences between them. It is feasible to use equations for non-destructive analysis to predict the proximate composition of cobia.


Taurine, which has multiple important physiological roles in teleost fish and mammals, is an amino acid not found in alternative protein sources not derived from animals. Although taurine is found in fish-meal-based feeds, its high water solubility leads to lower taurine levels in reduction-process-based feeds, which marine carnivores such as cobia Rachycentron canadum are adapted to in their natural diets. Graded taurine supplementation (0, 0.5, 1.5, and 5.0%) added to a traditional fish-meal-based formulation was examined in two growth trials with cobia: one initiated with 10-g individuals and the second initiated with 120-g individuals. During the first trial, in which growth as weight gain ranged from 123 to 139 g per fish, there was an increase in dietary taurine and a decrease in the feed conversion ratio from 1.04 to 0.99. During the second trial, in which growth ranged from 227 to 313 g gained per fish, there was no significant difference in performance characteristics between dietary treatments. Messenger RNA transcript expression levels for two of the genes involved in taurine synthesis, cysteine dioxygenase (CDO) and cysteamine dioxygenase (ADO), as well as the membrane-bound taurine transporter, TauT, were also measured at the conclusion of the second trial. Increasing dietary taurine in a diet containing 34.5% fish meal did not result in significantly different growth or production characteristics in cobia, but did result in significantly increased taurine levels in fillet, liver, and plasma.

Fishmeal (FM) replacement in diets for intensive aquaculture has become a high priority area for the global aquaculture industry. In this study, a twelve week growth trial was conducted with juvenile cobia (18 g initial weight) to examine the effects of non-genetically modified soybean meals as potential replacement protein sources. Genetically modified (GM) crops and their intended and unintended effects have become major topics of controversy worldwide, with several regions banning their use in food and feeds. Therefore, it is especially critical to develop and evaluate non-GM feedstuffs for use in aquaculture diets where GM products are prohibited as the global aquaculture industry continues its expansion to meet increasing demands. Navita Premium Feed Ingredients (NPFI's) 3010 solvent extracted meal and 3032 cold-pressed cake meal were utilized to replace 50, 60 or 70% and 40, 50, or 60% of FM protein, respectively and were compared to a FM based reference formulation. None of the experimental diets performed significantly different from the reference diet in terms of weight gain (WG) or specific growth rate (SGR). However the 3010 50% diet performed significantly better than the 3032 50 and 60% diets in regard to WG, SGR, and protein efficiency. There were no significant differences between the seven diets at the conclusion of the trial in regard to their effects on filet quality as determined by organoleptic testing. These two non-GM soybean protein sources appear to be valuable FM replacement options for juvenile cobia, with none of the typical indicators of intestinal enteritis developing as has been observed in various other teleost species when high quantities of commodity soybean meal have been utilized.


Optimization of the protein to energy ratio in juvenile cobia (Rachycentron canadum) would allow the production of diets that maximize growth without the addition of excess energy that may increase costs or even be detrimental to the health of the fish. During a 6-week growth trial, juvenile cobia (5.6±0.5 g fish⁻¹ initial weight) were fed five isonitrogenous and isolipidic diets containing various protein to energy ratios using starch as the energy source. At the end of the trial, some fish were analysed for body composition characteristics while the rest were used to examine the excretion of dietary starch in the feces. Survival and growth were not significantly affected, but feed efficiency (ranging from 0.64 to 0.94) and daily consumption (ranging from 45.3 to 64.1 g kg⁻¹ of body weight d⁻¹) were affected. No reduction in consumption due to excess energy was noted. Analysis of the fecal carbohydrate data showed a linear relationship between dietary inclusion and excretion of carbohydrates with no sign of reaching saturation. Results of this study suggest that cobia can utilize dietary carbohydrates up to at least 340 g kg⁻¹ of dry diet with an optimal protein to energy ratio of approximately 34 mg protein kJ⁻¹ metabolizable energy.


The effect of feeding three commercial diets on production characteristics and body composition of juvenile cobia Rachycentron canadum reared using recirculating aquaculture systems (RASs) was assessed in a 56-d growth trial. Juvenile cobia (mean weight ± SE, 29.2 ± 0.7 g) were stocked into three 8-m³ tanks in each of four RASs at an initial density of 1.2 kg/m³. After stocking, fish were fed one of three commercial diets: Hybrid Striped Bass diet (HSB; 44% protein, 12% lipid), Finfish Gold diet (GOLD; 42% protein, 16% lipid), or Marine Grower diet (MG; 50% protein, 15% lipid), all at a targeted feed rate of 3–5% of body weight per day. At 2-week intervals, 10% of the population of each tank was collected to determine mean weight, weight gain, specific growth rate (SGR), feed conversion efficiency (FCE), and biomass. At the end of the rearing trial, the entire population of each tank was harvested to determine production characteristics and survival. In addition, fish were sampled to determine whole-body composition, hepatosomatic index, intraperitoneal fat ratio, energy retention (ER), protein efficiency ratio (PER), and protein productive value (PPV). Final weight (311.0 g), weight gain (281.8 g), SGR (4.23% per day), FCE (85.7%), biomass (11.20 kg/m³), and ER (32.7%) of fish fed the MG diet were significantly greater than those of fish fed the HSB and GOLD diets. No differences in survival, gross energy, ash, or crude lipid content existed among fish fed the three diets. Lowest dry matter content, lowest PPV, and highest protein content were observed in fish fed the HSB diet. Highest PER was observed in fish fed the GOLD diet. Although the cost of production per kilogram for rearing juvenile cobia
with the MG diet would be greater, this cost could be offset by the 15% reduction in rearing time required as compared with the HSB and GOLD diets.


The effect of different commercially available marine fish diets on production characteristics and body composition of juvenile cobia *Rachycentron canadum* reared in production-scale recirculating aquaculture systems was evaluated in a 57-d growth trial. Juvenile cobia (mean weight ± SE, 26.7 ± 0.9 g) were stocked at an initial density of 1.2 kg/m^3_. After stocking, fish were fed one of three closed-formula diets formulated for carnivorous marine finfish (coded diet A, 50% crude protein: 22% crude lipid; diet B, 49% crude protein: 17% crude lipid; and diet C, 48% crude protein: 17% crude lipid), all at a targeted feed rate of 3–5% body weight per day. At 2-week intervals, 10% of the population of each tank was sampled to determine mean weight, weight gain, specific growth rate, feed conversion efficiency, and biomass. At the termination of the trial, the entire population of each tank was harvested to determine the same characteristics and survival. In addition, fish were sampled to determine relative changes in whole body composition, energy retention, protein efficiency ratio, and protein productive value. Final weight (203.3 g), specific growth rate (3.6%/d), feed conversion efficiency (92.2%), biomass (7.3 kg/m^3_), and protein productive value (25.2%) of fish fed the high-lipid diet A were significantly higher than those of fish fed the other two diets. No differences in whole body composition were observed among fish fed the three diets with the exception of dry matter composition. Contrary to previous reports, the results of the current study indicate that juvenile cobia reared in production-scale recirculating aquaculture systems fed high-lipid diets exhibit protein sparing and better growth.


Limited availability and high prices underscore the need to use fish oil more judiciously in aquafeeds. Most alternative lipids contain little to no n-3 long-chain (LC) polyunsaturated fatty acids (PUFAs). If alternative lipids are fed exclusively, growth performance may be impaired and tissue fatty acid composition may be altered in fish such as the cobia *Rachycentron canadum_. Alternative lipids that are rich in saturated fatty acids (SFAs) and monounsaturated fatty acids (MUFAs) may increase the efficiency of LC-PUFA metabolism and may limit or attenuate the tissue LC-PUFA loss associated with fish oil sparing. Cobias (weight [± SE] = 77.4 ± 0.2 g) were fed diets containing either fish oil (control) or a 50/50 blend of fish oil and standard soybean oil, partially hydrogenated soybean oil, fully hydrogenated soybean oil, pork lard, or beef tallow. After 8 weeks, the feed conversion ratio (mean ± SE = 1.56 ± 0.04), weight gain (180 ± 6%), and specific growth rate (1.83 ± 0.04% of body weight/d) were equivalent among groups. Dietary fatty acid profiles influenced tissue composition; fatty acid profiles of control fish were more similar to those of fish that received higher levels of SFAs and MUFAs than to those of fish that were fed higher levels of C18 PUFAs. The SFA- and MUFAs-rich lipids, such as fully hydrogenated soybean oil and beef tallow, may be useful in reducing the fish oil quantities needed in cobia feeds while maximizing fillet LC-PUFA content.


A 10-week feeding trial was conducted to determine the optimal requirement of cobia (*Rachycentron canadum* Linneaus) for dietary ascorbic acid (AA). Graded levels of L-ascorbyl-2-polyphosphate (LAPP) were supplemented in basal diet to formulate six semi-purified diets containing 2.70 (the control diet), 8.47, 28.3, 80.6, 241 and 733 mg AA equivalent kg^-1_ diet, respectively. Each diet was randomly fed to triplicate groups of fish in flow-through plastic tanks (300 L), and each tank was stocked with 25 fish with average initial weight of 4.59 ± 0.36 g. Observed deficiency signs included poor growth, higher mortality and lower feeding rate (FR) in the fish of the control group. Fish fed the control diet had significantly lower weight gain (WG), lower feed efficiency ratio (FER) and lower tissue AA concentrations in fish liver and muscle. With the increase of dietary AA, the survival, WG, FER, hepatic and muscular AA concentrations of cobia significantly increased and then levelled off. The dietary AA requirement of cobia was
estimated to be 44.7 mg kg$^{-1}$ based on WG, 53.9 mg kg$^{-1}$ or 104 mg kg$^{-1}$ based on either hepatic or muscular AA concentration, respectively.


Present study analyse the use of formulated diets which can be modified and adapted to Cobia nutrient exigencies when cultured in different life stages and farming systems.


The dietary zinc (10,20,30,40 and 50 mg/kg) was added to the purified diet (Zinc content 5.65 mg/kg) based on albumin as the protein source, in order to meet the dietary zinc content of 15.97, 25.66, 33.90, 45.85 and 55.88 kg/mg. The feeding trial on cobia (Rachycentron canadum) was conducted for eight weeks. The results showed that there were no significant differences in feed conversion rate on cobia fed the experimental diets regardless of concentration of supplemental zinc compared to fish fed the basal diet; but the survival rate, weight gain rate and serum alkaline phosphatase (AKP) activity were significantly affected by dietary zinc level (P<0.05). There was a significant difference in zinc concentrations in muscle, bone, liver and serum for the fish fed the diet with different zinc concentrations. In muscle, bone and liver, the fish fed the high-Zinc diet had significantly higher zinc concentrations than that in the fish fed the low-Zinc diet. The survival rate, weight gain rate, serum alkaline phosphatase activity and zinc concentrations in fish tissues and serum were responded in broken-lines models to increase in dietary zinc levels.


This paper deals with nutrient requirements of farmed cobia. They are analysed in different aspects: nutritional value of protein, dietary phosphorous requirement, fatty acids in diets and their accumulation in tissue of cobia. Other aspects are summarized as follows: arginine & lysine requirements, optimal supplementation of vitamin E, vitamin C, choline and inositol in cobia diets, mineral requirements like dietary Zinc and digestive enzymatic activities in several tissues of cobia.


The objective of the study was conducted to determine the effects of two diets (ice fresh trash fish and formulated feed) on the activity of digestive enzymes (protease, trypsin, amylase and lipase) in stomach, proximal intestines and liver of juvenile cobia (Rachycentron canadum). The diets were fed to the juveniles with initial mean weight of 10.79±2.12 g for 14 days indoor flow-through and aerated aquaria at a rate of 20 individuals per tank with triplication. The results showed that the juveniles fed the ice fresh trash fish had significantly higher protease activity in the stomach than the juveniles fed the formulated feed (P<0.05), but the case were contrary in the proximal intestines and liver (P<0.05). There was significantly higher activity of trypsin in the stomach of the animals fed the ice fresh trash fish than that in the stomach of the animals fed the formulated feed (P<0.05), but the case were contrary in the proximal intestines and liver (P<0.05). The significantly higher activity of lipase was found in the liver of the fish fed the ice fresh trash fish than that in the fish fed the formulated feed (P<0.05), and there was no significant difference in lipase activity in the stomach and the intestines in the fish fed the two diets (P>0.05). The juveniles fed the ice fresh trash fish had significantly higher amylase activity in the stomach than the juveniles fed the formulated feed (P<0.05). For the same enzyme, the case in the intestines was opposite to that in the stomach, and there was no significant difference in lipase activity in the liver in the fish fed the two diets (P>0.05). The changes in the four enzymatic activities between the two groups in the experiment suggested that the different diets had different effect on activities of the digestive enzymes, and the enzymes activities showed tissue specificity for cobia juveniles.

A 2 x 3 factorial feeding trial including 3 levels of iron (100, 200, and 300 mg/kg diet) and 3 levels of zinc (30, 110, and 190 mg/kg diet) was conducted to determine the optimum dietary iron and zinc supplemental levels in juvenile cobia, Rachycentron canadum. The fish (initial average weight 7.0g) were stocked into 0.3 m³ plastic tanks at a rate of 13 individuals per tank and fed the diets for 56 days with triplication. There were significant differences in survival, weight gain, total red blood cell count, iron concentration in muscle, and zinc and iron levels in bone and liver in cobia fed the diets containing different iron and zinc levels (P<0.05). The activity of serum alkaline phosphatase (AKP) and feed conversion rate were significantly influenced by the interaction of iron and zinc (P<0.05). It is suggested from the survival and weight gain that the optimum supplemental levels in juvenile cobia commercial diet be 200 mg/kg diet for iron and 110 mg/kg diet for zinc.

285. Yasumaru, F. & Lemos, D. (2014). Species specific in vitro protein digestion (pH-stat) for fish: method development and application for juvenile rainbow trout (Oncorhynchus mykiss), cobia (Rachycentron canadum), and Nile tilapia (Oreochromis niloticus). Aquaculture, 426-427, 74-84. Aqua feed manufacture requires flexible formulations and effective methods to screen suitable feed ingredients. In vitro digestion may assist in the characterization and quality control of protein in feedstuffs for fish species once standardized species-specific digestive enzyme extracts are available. This study aimed to develop a species-specific in vitro enzymatic method to assess protein digestion in fish under the pH-stat concept. Two carnivorous (rainbow trout, Oncorhynchus mykiss, and cobia, Rachycentron canadum) and one omnivorous (Nile tilapia, Oreochromis niloticus) fish species were used as models. Crude digestive enzyme extracts were recovered from stomach and pyloric caeca or intestine of individuals of different weight groups, feeding status, and farming systems. The hydrolytic capacity of the species-specific enzyme was standardized on purified protein substrates and measured as degree of protein hydrolysis (DH) in the pH-stat assay. A group of twenty-four feed ingredients, including fish meals and by-products of plant and animal origin, was assessed for DH using the recovered enzymes from stomach and pyloric caeca/intestine. Ingredients were hydrolyzed with fish (i) stomach extract, (ii) pyloric caeca/intestine extract or (iii) stomach enzymes followed by pyloric caeca/intestine extract. Among plant by-products, cotton seed meal presented the highest DH with stomach plus pyloric caeca/intestine enzymes, followed by soy protein concentrate and soybean meals. Blood meals were the land animal by-product with higher DH outputs compared to poultry by-product meals and feather meals. No significant difference was observed among the DHs of fish meals. The significance of measuring the DH with stomach enzyme extract is still not well understood but, overall, the pre-hydrolysis of feedstuffs with stomach enzymes increased pyloric caeca/intestine DH value. For cage and pond farmed Nile tilapia, ingredient DHs followed the same trend, describing a significant correlation and a high determination coefficient regression. Routine use of the method may yet depend on the prompt availability of more practical sources of enzymes. The determination of the degree of protein hydrolysis by the in vitro pH-stat with species-specific enzymes has shown to be a precise method that may be a useful tool to rank feed ingredients, and also an accessory method in the quality control of feedstuffs.

286. Zhou, H., Chen, G. & Lin, X.T. (2012). Effects of partial replacement of fish meal by three types of protein sources on growth performance and approximate compositions of juvenile cobia (Rachycentron canadum). Fisheries Science/Shui chan Kexue, 31(6), 311-315. Five isonitrogenous and isocaloric diets were prepared based on fish meal (D1). Experimental diets were formulated with fish meal replacement by defatted soybean meal for 10% (D2) and 20% (D3), by corn gluten meal for 10% (D4), and by beer yeast meal 10% (D5), and fed juvenile cobia (Rachycentron canadum) (with body weight of 30–38 g) for 35 days to investigate the effects of replacing fish meal in formulated diet on growth and approximate compositions. There was no significant difference in survival rate between the treatment groups and the control group (P>0.05). There were significantly lower final body weight, weight gain, food conversion efficiency, protein efficiency ratio and specific growth rate in D3 compared to D1 (P<0.05), without showing significant difference between other groups (P>0.05). The juvenile cobia in D3 showed significantly lower crude fat content in muscles compared to fish fed D1 and D5 (P<0.05) diets. The hepatosomatic index was significantly lower in the juvenile cobia fed D3 diet than in fish fed rest experimental diets (P<0.05). There were no significant differences in visceral index, hepatopancreas rude fat content and Fulton's condition factor in all treatment groups (P>0.05). The results suggests that defatted soybean meal, corn gluten meal and beer yeast meal could replace up until 10% of fish meal for diet without causing significant effects. However, if replacement reaches
20% of alternative protein meal, negative effects on growth, food consumption rate and proximate composition are outcome. Similarly, experimental cobia (R. canadum) health is compromised.

287. Zhou, H., Chen, G., Shi, G., Zhang, J. & Dong, X. (2014). The effects of different diet protein sources on carbon and nitrogen isotope fractionation of juvenile cobia Rachycentron canadum L. Journal of Tropical Oceanography/Redai Haiyang Xuebao, 33(5), 35-40. In order to investigate the effects of different diet protein sources on carbon and nitrogen isotope fractionation of juvenile cobia Rachycentron canadum L., three isonitrogenous and isocaloric diets were formulated. The protein source in D1 was fish meal; beer yeast meal and corn gluten meal protein replaced 10% fish meal in D2 and D3, respectively. The diets were fed to juvenile coba for 24 days. The results showed that, when 10% fish meal was replaced, the weight gain rate (WGR) of cobia decreased significantly. The carbon isotope ratio δ13C of cobia increased in time and nitrogen isotope ratio δ15N decreased in time in all groups. Although the change speeds of δ15N were different, the whole fish and muscle of cobia fed with different diets reached isotope equilibrium states with their diets when the feeding experiment was accomplished. When 10% fish meal was replaced by beer yeast meal (corn gluten meal), the carbon isotope fractionation Δ13C decreased while nitrogen isotope fractionation Δ15N increased in the whole fish and muscle of cobia; Δ13C of the whole fish decreased from 4.19‰ to 3.94‰ and 3.63‰, Δ13C of the muscle decreased from 4.46‰ to 3.98‰ (to 3.67‰), and Δ15N of the whole fish increased from 0.18‰ to 0.88‰ (to 0.94‰), Δ15N of the muscle increased from 0.18‰ to 0.74‰ (to 0.87‰). When the three diets with different protein sources were fed, the variation trends of Δ13C and Δ15N were similar between whole fish and muscle of cobia, but the change speed of whole fish δ15N was slower than that of muscle. These results indicated that cobia muscle can represent the δ13C and δ15N characters of whole fish in trophic level study of ecosystem (long time scale), but cannot represent the change process of whole fish δ15N in metabolic physiology study (short time scale).

288. Zhou, Q.C., Mai, K.S., Tan, B.P. & Liu, Y.J. (2005). Partial replacement of fishmeal by soybean meal in diets for juvenile cobia (Rachycentron canadum). Aquaculture Nutrition, 11(3), 175-182. An 8-week feeding experiment was conducted in floating cages (1.5 x 1.0 x 2.0 m) to determine the potential use of defatted soybean meal (roasted and solvent-extracted) as a partial replacement of fishmeal in the isonitrogenous (approximately 450 g kg\(^{-1}\) CP [crude protein]) diet for juvenile cobia with an initial average weight of about 8.3 g. Diets were formulated to include 0, 100, 200, 300, 400, 500 and 600 g kg\(^{-1}\) (diets D0, D10, D20, D30, D40, D50 and D60, respectively) of fishmeal protein being substituted by defatted soybean meal without methionine supplementation. The results showed that weight gain rate decreased significantly when the replacement level of fishmeal protein was increased from 400 g kg\(^{-1}\) to 500 g kg\(^{-1}\), and the D60 diet was the lowest in all groups. These results indicate that up to 400 g kg\(^{-1}\) of fishmeal protein can be replaced by defatted soybean meal without causing significant reduction in growth. Feed conversion ratio (FCR) and protein efficiency ratio (PER) were significantly affected by the replacement level of fishmeal protein being substituted by defatted soybean meal, when the replacement level of fishmeal protein was 200 g kg\(^{-1}\) (diet, D20), FCR was the lowest and PER was the highest. There were no significant differences in the moisture, lipid, crude protein and ash content in whole body and muscle, while lipid content in liver increased as the dietary soybean meal replacement levels increased. There were significant differences in haemoglobin, haematocrit, red blood cell, plasma glucose and triglyceride concentration in fish fed diets with different soybean meal replacement levels. Results of this trial indicated that the optimum level of fishmeal protein replacement with defatted soybean meal, determined by quadratic regression analysis was 189.2 g kg\(^{-1}\), on the basis of maximum weight gain.

289. Zhou, Q.C., Tan, B.P., Mai, K.S. & Liu, Y.J. (2004). Apparent digestibility of selected feed ingredients for juvenile cobia Rachycentron canadum. Aquaculture, 241(1-4), 441-451. Apparent digestibility coefficients of dry matter (DM), crude protein (CP), crude lipid (CL), gross energy (GE), phosphorus, and amino acids in Peruvian fish meal, defatted soybean meal/roasted and solvent-extracted, defatted soybean meal/solvent-extracted, poultry meal, meat and bone meal, peanut meal, rapeseed meal, and corn gluten meal were determined for juvenile cobia. A reference diet (RF) and test diets (consisting of 70% RF diet and 30% of the feedstuff) were used with 0.5% Cr\(_2\)O\(_3\) as an external indicator. The juvenile cobia, averaging 10 g, was stocked in 300-l fiberglass tanks at a density of 20 fishes per tank. Feces were collected from triplicate groups of fish using a fecal collection column attached to the fish rearing tank. Apparent digestibility coefficients of dry matter, crude protein, crude lipid, and gross energy were highest for fish meal and corn gluten meal.
Statistics indicated that apparent dry matter digestibility for juvenile cobia ranged 60.42-87.56% for animal products and corn gluten meal and 58.52-70.51% for soybean meals, peanut meal, and rapeseed meal. The protein and lipid from both plant and animal sources were well digested by cobia. Apparent protein and lipid digestibility ranged 87.21-96.27% and 91.59-96.86%, respectively, for animal products, and 88.97-94.42% and 92.38-96.93%, respectively, for plant products. The cobia demonstrated a high capacity to utilize phosphorus in the ingredients. The apparent phosphorus digestibility ranges of animal feedstuffs and plant feedstuffs were 62.36-71.22% and 56.32-69.76%, respectively. Amino acid availability reflected protein digestibility, except in meat and bone meal, for which the availability of some amino acids was lower, possibly due to protein damage during processing. Digestibility information could promote the use of ingredient substitutions in least-cost formulated diets for cobia.


An 8-week feeding trial was conducted to quantify the dietary lysine requirement of juvenile cobia with an initial average weight of 1.25 g reared in indoor flow-through and aerated aquaria. Six isonitrogenous and isoenergetic practical diets (44% CP and 16% lipid) containing six levels of dietary lysine ranging from 1.15 to 3.25% (dry weight) at about 0.4% increments, using fish meal and wheat gluten as sources of intact protein, supplemented with crystalline amino acids. Equal amino acid nitrogen was maintained by replacing lysine with nonessential amino acid mixture. Each diet was randomly assigned to three aquaria and was fed to apparent satiation by hand four times daily. The results indicated that there were significantly differences in growth performance and feed utilization among the treatments. Maximum weight gain, special growth rate and protein efficiency ratio occurred at 2.38% dietary lysine; but with the increase of dietary lysine from 2.38 to 3.25%, weight gain, special growth rate and protein efficiency ratio did not significantly increase. The hepatosomatic index, visceral somatic index, condition factor, crude protein content in whole body and main composition in muscle were significantly affected by dietary lysine levels; however moisture, lipid and ash content in whole body were not significantly affected by the dietary lysine. There were significant differences in total serum protein, glucose and triacylglycerol concentrations in fish fed diets with different dietary lysine levels. Haematocrit and leucocyte count were significantly affected by dietary lysine level, but haemoglobin and red blood cell count were not significantly affected. Lysine concentration in serum was significantly increased with the increase of dietary lysine level from 1.15 to 2.38%. Broken-line analysis on the basis of special growth rate showed that the dietary lysine requirement of juvenile cobia was 2.33% of dry diet (5.30% dietary protein).


An 8-week feeding trial was conducted to establish the dietary vitamin E requirement of juvenile cobia. The basal diet was supplemented with 10, 20, 30, 40, 60, 120 mg vitamin E kg\(^{-1}\) as all-rac-α-tocopheryl acetate. The results indicated that fish fed the diets supplemented vitamin E had significantly higher specific growth rate, protein efficiency ratio, feed efficiency and survival rate than those fed the basal diet. It was further observed that vitamin E concentrations in liver increased significantly when the dietary vitamin E level increased from 13.2 to 124 mg kg\(^{-1}\). Fish fed the basal diet had significantly higher thiobarbituric acid-reactive substances concentrations in liver than those fed the diets supplemented vitamin E. Fish fed the diets supplemented with 45.7 and 61.2 mg kg\(^{-1}\) vitamin E had significantly higher red blood cell and haemoglobin than those fed the basal diet, while fish fed the diets supplemented with 61.2 and 124 mg kg\(^{-1}\) vitamin E had higher immunoglobulin concentration than those fish fed the basal diet. Lysozyme and superoxide dismutase were significantly influenced by the dietary vitamin E level. The dietary vitamin E requirement of juvenile cobia was established based on second-order polynomial regression of weight gain and lysozyme to be 78 or 111 mg all-rac-α-tocopheryl acetate kg\(^{-1}\) diet, respectively.


An 8-week feeding experiment was conducted to quantify the dietary methionine requirement of juvenile cobia (initial weight of 11.61±0.16 g, mean±SD) reared in indoor flow-through and aerated aquaria. Six amino acid test diets (44% CP and 16% lipid), using fish meal and wheat gluten as intact protein sources supplemented with crystalline amino acids, were formulated to contain graded
levels of methionine (0.61%, 0.83%, 1.05%, 1.30%, 1.48% and 1.68% of dry diet, respectively) at a constant dietary cystine level of 0.67%. Each diet was randomly assigned to three aquaria. Growth performance and feed utilization were significantly influenced by the dietary methionine levels (P<0.05). Maximum weight gain, specific growth rate and protein efficiency ratio occurred at 1.05% dietary methionine (P<0.05). The hepatosomatic index, viscerosomatic index and condition factor were not significantly affected by dietary methionine levels (P>0.05). There were no significant differences in protein, lipid, ash and moisture contents in whole body or muscle, also red blood cell count and plasma protein content for fish fed graded methionine levels of diets; however, hemoglobin, hematocrit, leukocyte, plasma glucose and triacylglycerol concentrations showed significant differences among these treatments (P<0.05). Methionine concentration in plasma significantly increased with an increase of dietary methionine (P<0.05). Quadratic regression analysis of specific growth rate against dietary methionine levels indicated that the optimal dietary methionine requirement for maximum growth and feed utilization of juvenile cobia is 1.19% of dry diet in the presence of 0.67% cystine (corresponding to 2.64% of dietary protein on a dry weight basis).


A 10-week feeding trial was conducted to evaluate the potential use of poultry by-product meal (PBM) as a partial replacement of fish meal protein in the commercial diets for juvenile cobia. Five isonitrogenous (approximately 45%) and isolipidic (about 11%) diets were formulated to contain graded levels of PBM, and fish meal protein was replaced with a pet food-grade PBM at 15, 30, 45, 60% level (PBM15, PBM30, PBM45, PBM60, respectively) without lysine and methionine supplementation. The reference diet (PBM0) contained fish meal and soybean meal as protein sources. Each diet was fed to groups of 20 juvenile cobia initially averaging approximately 5.8 g in triplicate 500-l tanks twice daily to apparent satiation. The results showed that growth performance and survival for fish fed PBM-supplemented diets were not significantly lower compared to fish fed the reference diet (P>0.05). However, protein efficiency ratio and feed efficiency ratio were significantly affected by the replacement level of fish meal protein with PBM, fish fed the PBM30 and PBM45 diets had higher PER and FER than fish fed the reference diet and the other diets. The condition factor, viscerosomatic index and intraperitoneal fat ratio were not significantly affected by the dietary treatments, however, fish fed the PBM45 diet had a higher hepatosomatic index than fish fed the other diets. There were no significant differences in moisture, crude lipid, ash, calcium and phosphorus content in whole body among all treatments, but the fish fed the reference diet had higher crude protein in whole body than fish fed the PBM-supplemented diets. There were no differences in liver superoxide dismutase, catalase, glutathione S-transferase and glutathione peroxidases activities among fish fed the experimental diets. Hematocrit, hemoglobin, red blood cell and total immunoglobulin were not significantly affected by the replacement level of fish meal protein with PBM. With the exception of plasma glucose content, there were no significant differences in plasma triglyceride, cholesterol and total protein concentration in fish fed the experimental diets. The results of this study indicated that good quality terrestrial PBM can successfully replace fish meal in the commercial diets for cobia, and the optimal level of fish meal replacement with PBM was determined by quadratic regression analysis to be 30.75% on the basis of maximum protein efficiency ratio.

2.7 PROCESSING & STORAGE


The combined effects of hydrolysis time, temperature, pH, and ratio of enzyme to substrate on the degree of hydrolysis (DH) of cobia frame were determined using Response Surface Methodology. The effects of these factors were employed using a three-level factors face centered central composite design. The proximate compositions of cobia frame and cobia hydrolysate powder were determined as well. The generated model equation gave a quadratic fit with experimental data. It is suggested that hydrolysis conditions for obtaining the optimum DH using Alcalase® were: temperature of 58°C, hydrolysis time of 134 min, pH of substrate at 9.4, and an enzyme
concentration of 8.3%. Proximate analyses revealed that cobia frame contained 47.0% protein, 27.6% fat, and 24.8% ash, whereas cobia frame hydrolysate powder contained 88.8% protein, 0.58% fat, and 5.05% ash. The high protein content indicated that cobia frame hydrolysate is a potential ingredient for food and feed.


The combined effects of hydrolysis time, temperature, pH, and ratio of enzyme to substrate on the degree of hydrolysis (DH) of cobia frame were determined using Response Surface Methodology. The effects of these factors were employed using a three-level factors face-centered central composite design. The proximate compositions of cobia frame and cobia hydrolysate powder were determined as well. The generated model equation gave a quadratic fit with experimental data. It is suggested that hydrolysis conditions for obtaining the optimum DH using Alcalase registered were: temperature of 58 degree C, hydrolysis time of 134 min, pH of substrate at 9.4, and an enzyme concentration of 8.3%. Proximate analyses revealed that cobia frame contained 47.0% protein, 27.6% fat, and 24.8% ash; whereas cobia frame hydrolysate powder contained 88.8% protein, 0.58% fat, and 5.05% ash. The high protein content indicated that cobia frame hydrolysate is a potential ingredient for food and feed.


Acid-treated cobia (Rachycentron canadum) skin was extracted in a retort (121 °C) to obtain retorted skin gelatin hydrolysates (RSGHs) containing antioxidant peptides with noticeable antioxidant properties. To improve the antioxidant activity of cobia RSGHs, five processing factors including alkali concentration, alkali pretreatment time, phosphoric acid concentration (PC), water/skin ratio (WS) and retorting time (RT) in RSGH production were screened using a fractional factorial design to identify critical factors. It indicated that PC, WS and RT had significant effects on α, α-diphenyl-β-picrylhydrazyl (DPPH) scavenging by RSGHs. Subsequently, the optimization of PC, WS and RT on the DPPH scavenging of RSGHs was studied using a central composite design to collect data that resulted in a response surface modeling. The highest value for the predicted DPPH scavenging (10mg/mL RSGH) was 73.63% (PC=6.5%, WS=1 and RT=180min), and it exhibited 39.9% more scavenging of DPPH than that of original RSGH. Recently, a number of studies indicated that peptides derived from different protein hydrolysates can act as potential antioxidants. Fish proteins possess high availability for us, and their hydrolysates might be used as a good source of antioxidants. Fish skin gelatin may provide an alternative source for food-grade gelatin because the amount of the skin waste from the fish processing industry is considerably large. No enzymatic hydrolysis or ultrafiltration treatments are needed; the antioxidant cobia retorted skin gelatin hydrolysates (RSGH) can be produced by thermal hydrolysis. Besides, the degree of thermal hydrolysis (121 °C) had significant effects on the α, α-diphenyl-β-picrylhydrazyl scavenging and lipid peroxidation inhibition of cobia RSGH. Moreover, we identified the critical processing variables in the RSGH making and suggested the optimized condition for the antioxidant RSGH production. The edible and water-soluble cobia RSGH is considered a potential candidate to develop natural antioxidants and food supplements.


The body of Rachycentron canadum Linnaeus was anatomiand compared, and the nutritive value of muscle was analyzed and evaluated in this paper. The results showed that the flesh rate was 68.7% and the body was cylindraceous. The area of skin was 21 times of the body length. The content of protein in the muscle of Rachycentron canadum Linnaeus was 21.2%. The content of total amino acids was 65.05%, the ratio of lysine was the highest and Met is No. 1 of the limitative amino acids. The ratio of unsaturated fatty acids to total fatty acids was 65.2%, and the ratios of EPA and DHA to total fatty acids were 4.5% and 12% respectively. The results indicated that Rachycentron canadum Linnaeus has a high flesh ratio and good nutritive quality, and so it has high nutritive and official values. Rachycentron canadum Linnaeus with body weight of 3-4 kg has the highest protein nutrition and delicious level in muscle. The muscle in this stage is perfect for human consumption.

Cobia, *Rachycentron canadum* (500 g) cultured in pond cages for a 3-month experiment were fed two moist diets based on raw fish with or without added fish silage. No significant differences in nutritional composition were observed between the fillet groups, which were of high quality with a balance of essential and non-essential amino acids (EAA/NEAA = 1) and medium levels of omega-3 fatty acid composition (210 g kg⁻¹ total fatty acids). The total quality index method and quantitative descriptive analysis from both groups were correlated throughout storage ($r^2 = 0.83-0.86$). After 15 days iced storage, the scores of most attributes were low compared to maximum accepted values. The thiobarbituric acid reactive substances and microbial counts were also below the accepted limits after the storage trial. It might be concluded that the nutritional composition and the fillet quality were similar for the groups fed raw fish with or without added fish silage, and the estimated shelf life for cobia was $>15$ days.


For a fish to be suitable for aquaculture, means that it must meet certain characteristics, such as its adaptation to farming conditions, resistance against disease, reproduction ability, etc. But there is a test that is crucial: it must be accepted by the market. This article describes a gastronomy trial conducted in Brazil by presenting different dishes made from cultured cobia ('beijupira'). The results provide important information on the possible preferences of potential cobia consumers.


Gelatin was obtained from cobia (*Rachycentron canadum*) skins, which is an important commercial species for marine fish aquaculture, and it was compared with gelatin from croaker (*Micropogonias furnieri*) skins, using the same extraction methodology (alkaline/acid pre-treatments). Cobia skins gelatin showed values of protein yield, gelatin yield, gel strength, melting point, gelling point and viscosity higher than the values found from croaker skins gelatin. The values of turbidity and Hue angle for cobia and croaker gelatins were 403 and 74 NTU, and 84.8° and 87.3°, respectively. Spectra in the infrared region had the major absorption band in the amide region for both gelatins, but it showed some differences in the spectra. The proline and hydroxyproline contents from cobia skins gelatin (205 residues/1000 residues) was higher than from croaker skins gelatin (188 residues/1000 residues). SDS-PAGE of both gelatins showed a similar molecular weight distribution to that of standard collagen type I. Therefore, cobia skins could be used as a potential marine source of gelatin obtainment for application in diversified industrial fields.


In order to study the sterilization and quality effects of ozone water on cobia fillets, flowing ozone water at various concentrations of 4 mg L⁻¹, 5 mg L⁻¹, 6 mg L⁻¹ and 7 mg L⁻¹ was experimented to screen the optimal condition at 15 °C Comparing the effects of sterilization ratio, sensory evaluation and color difference in different groups, we find that the treatment with 7 mg L⁻¹ flowing ozone water for 10 min on cobia fillets gets a better sterilization ratio of 81.12% without reducing the quality.


We investigated the effect of three kinds of freezing point regulators including CaCl₂, NaCl and Vc on cobia (*Rachycentron canadum*) by single factor comparison experiment. 4% CaCl₂ treatment for 60 min decreased freezing point to -1.21°C; 2% NaCl treatment for 90 min decreased freezing point from -1.01 °C to -1.36 °C; 0.5% Vc treatment for 30 min decreased freezing point to -1.30 °C. Orthogonal experiment was conducted to determine the best proportion between NaCl and Vc. The results show that treatment with 3% NaCl and 0.3% Vc for 60 min decreased freezing point by 60.4%, from -1.01 °C to -1.62°C.

The effect of aqueous solutions of ascorbic acid (AA) on the rancidity development in cobia (Rachycentron canadum) fillets during frozen storage was studied. Cobia fillets were treated with ascorbic acid (AA 0.25% and AA 0.5%) then stored at -18 °C up to 6 months. Rancidity development was measured by several biochemical indices including free fatty acids (FFA), peroxide value (PV), and thiobarbituric acid (TBA) and complemented by the sensory analysis (odor, consistency and appearance). In addition, pH and expressible moisture (EM) were measured during 6 months storage. Proximate composition was also determined in the first day. TBA, PV and FFA levels increased on all treatments due to lipid oxidation. Ascorbic acid showed antioxidative effect on cobia fillets during frozen storage as indicated by TBA, PV and FFA levels. Results showed that free fatty acid, primary and secondary oxidation products, EM and pH value of AA-treated samples were significantly lower than those of the control samples ($P<0.05$). A gradual decrease ($P<0.05$) in sensory analysis were observed as the storage time increased. Results of our investigation revealed that ascorbic acid retarded oxidative changes in frozen cobia fillets whereas AA 0.25% was not as effective as AA 0.5% on oxidative stability. Best oxidation inhibition results on fish fillets were obtained when employing a 0.5% AA solution.


The present research focuses on the nutritional value of the lipid retention associated with frozen cobia (Rachycentron canadum). The effect of a previous soaking in an aqueous ascorbic acid (AA) solution on the fatty acid profile of fish fillets during a further frozen storage period (-18 °C) was investigated. Two different AA concentrations were tested (0.25% and 0.50%) and compared to control conditions. As a result of the frozen storage period (up to 6 months), marked decreases were found in the contents of fatty acid groups such as monounsaturated, polyunsaturated and n-3 polyunsaturated, as well as in the n-3/n-6 ratio. However, a preserving effect on such fatty acid parameters could be observed resulting from the previous AA treatment, which was greater when applying the 0.50% AA concentration. Assessment of the polyne index indicated an increased lipid oxidation development during the frozen storage time; this increase was partially inhibited by the previous AA soaking.


In this study changes in fatty acids profile during frozen storage at -18 °C of cobia (Rachycentron canadum), caught from the Persian Gulf (Bandar Abbas) were studied. Changes in saturated fatty acids (SFAs), monounsaturated fatty acids (MUFAs), polyunsaturated fatty acids (PUFAs), EPA+DHA/C16, n-3 PUFA/n-6 PUFA (n-3/n-6) and polyunsaturated fatty acids /saturated fatty acids (PUFA/SFA) were investigated during a six- month storage at -18 °C. Eighteen fatty acids were found in cobia, with higher percentage of saturated fatty acids (46.07%), monounsaturated fatty acids (33.72%) and polyunsaturated fatty acids (15.44%). The MUFAs and PUFAs reduced from 33.72 to 26.26% and 15.44 to 10.78%, respectively. Palmitic acid (C16:0, 27.42% of total fatty acids) and stearic acid (C18:0, 12.62%) were the dominant saturated fatty acids. The major unsaturated fatty acids were determined as docosahexaenoic acid (C22:6n3, 5.76%), oleic acid (C18:1n9, 25.76%) and linoleic acid (C18:2n6, 4.38%). As a result of the frozen storage (up to 6 months), marked content decreases were found in fatty acid groups such as monounsaturated, polyunsaturated and n-3 polyunsaturated, as well as in the n-3/n-6 ratio and it means that the nutritional value of cobia has decreased.


Antioxidants have been widely used as additives to provide protection against oxidative degradation of foods by free radicals. The effect of thyme essence (*Zataria multiflora* Boiss) on the rancidity development in cobia (Rachycentron canadum) fillets during frozen storage was studied. Cobia fillets were treated with thyme essence (250 and 500 ppm) and then stored at −18°C for up to 6 months. Rancidity development was measured by several biochemical indices including free fatty
acids (FFA), peroxide value (PV), thiobarbituric acid (TBA), and complemented by sensory analysis (flesh odor, consistency, and appearance). Also, pH and expressible moisture were measured during 6-month storage. Proximate composition was also determined in the first day. TBA, PV, and FFA levels increased in all treatments due to lipid oxidation. Thyme essence showed an antioxidative effect in cobia fillets during frozen storage as indicated by TBA, PV, and FFA levels. Results showed that FFA, primary and secondary oxidation products, expressible moisture (EM), and pH of thyme essence treated samples were significantly lower than those of the control samples (p<0.05). Thyme essence retarded oxidative changes in frozen cobia fillets, and the best oxidation inhibition was obtained using thyme essence at 500 ppm.


Between 1990 and 1994, samples of three shellfish species (i.e. blue crab, *Callinectes sapidus*; crayfish, *Procambarus acutis*; and river shrimp, *Macrobachium ohionii*) and 16 fish species and were collected at six sites along the lower Mississippi River by the Louisiana Department of Environmental Quality, Office of Water Resources in coordination with the US Environmental Protection Agency. The fish species included: bigmouth buffalo (*Ictiobus cyanellus*); blue catfish (*Ictalurus furcatus*); channel catfish (*Ictalurus punctatus*); cobia (*Rachycentron canadum*); flathead catfish (*Pylodictis olivaris*); freshwater drum (*Aplodinotus grunniens*); largemouth bass (*Micropterus salmoides*); red drum (*Sciaenops ocellatus*); red snapper (*Lutjanus campechanus*); smallmouth buffalo (*Ictiobus bubalus*); spotted gar (*Lepisosteus oculatus*); striped bass (*Morone saxatilis*); white bass (*Morone chrysops*); and white crappie (*Pomoxis annularis*). Organic compound and heavy metal concentrations were measured in 161 composite fish tissue samples where each composite included three to 10 individual fish. Nineteen chemicals, found at measurable levels in sample tissues, were used in calculations of lifetime excess cancer and non-cancer risks due to fish consumption. We calculated: 574 chemical-specific cancer risks; 41 total cancer risks; and 697 margins of exposure based on a consumption rate of one 8-ounce meal per week (0.032 kg/day), a body weight of 70 kg and reported cancer potency factors and reference doses. We identified nine species of concern (blue catfish, carp, channel catfish, cobia, crayfish, flathead catfish, red drum, spotted gar and striped bass) based on total cancer risk greater than 10^-4 or margin of exposure greater than 1, and whether or not samples collected in subsequent years resulted in lower risks. The compounds primarily responsible for the elevated risks were aldrin, dieldrin, alpha-benzene hexachloride, gamma-benzene hexachloride, heptachlor epoxide, arsenic and mercury.
3.  AUTHOR INDEX

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