ISSN 1330–061X
CODEN RIBAEG

UDK: 598.583.1:591.2
Review

PARASITES, DISEASES AND DEFORMITIES OF COBIA

E. McLean, G. Salze, S. R. Craig

Summary

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 are lessespian. 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.

Key words: cobia, diseases, parasites, deformities

Ewen McLean, Ph. D. is Director of the Virginia Tech Aquaculture Center (VTAC) and Professor of Fisheries, Dept. Fisheries & Wildlife Sciences, 100 Cheatham Hall, Blacksburg, VA 24061–0321, USA. Guillaume Salze is a graduate student in aquaculture and Steven R. Craig, Ph. D. Head of the VTAC Nutrition Group and Associate Professor in the Virginia–Mayland College of Veterinary Medicine, Dept. Large Animal Clinical Sciences, Duckpond Drive, Blacksburg, VA 24061–1103, USA. Corresponding author: emclean@vt.edu

INTRODUCTION

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. With the exception of the Eastern Pacific, cobia has a global distribution. The species has been reported in eastern Mediterranean waters (Golani and Ben Tuvia, 1986) and it is likely that in this particular case, cobia are lessespian. Although the Suez Canal–based intermingling of Red Sea and Mediterranean species has been commented on for over a century (Keller, 1882; Fox, 1929; Por, 1971) it remains possible that Mediterranean–based cobia may be derived from the Atlantic entering via the Strait of Gibraltar (Golani et al., 2002). The worldwide distribution of cobia represents a significant advantage since this means that there would be little need to introduce broods from other areas with the associated risks of disease transfer and environmental damage from escapees. Cobia has been farmed in Taiwan since the early 1990s (Liao et al., 2004) 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 (FAO, 2007). The increased interest in the species has evolved due in large part to its many excellent characteristics which include good growth (Lunger et al., 2007a), 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 (Schwarz et al., 2006); their fillet quality is high and meat delectable (Duncan et al., 2007); They readily take formulated feeds (Craig et al., 2006) and respond well to alternate proteins in their diets (Lunger et al., 2006; 2007b).

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.

DEFORMITIES, DISEASES AND PARASITES OF COBIA

There has been no detailed review of the diseases, parasites and deformities of cobia but the rapidly expanding information base suggests that it is likely cobia succumb to the myriad of ailments that afflict other warm water fishes. There is some evidence however, to suggest that in the wild, when compared to other large pelagic species, cobia appear less susceptible to parasitic infestations (Williams and Williams, 1996). Nevertheless, in the wild cobia harbor all the usual classes of parasite (flukes, worms and copepods) that infest the gastrointestinal tract, gills and skin (Schaffer and Nakamura, 1989) and also may become infected with exotic species during cultivation. For example, Bunkley — Williams and Williams (2006) reported previously unrecorded parasites (*Brooklynella hostilis*, *Cryptocaryon irritans* and *Ichthyobodo*) of cobia in Puerto Rican waters. The latter were translocated on infected cobia derived from Florida. The impact of parasitoids on cobia aquaculture production has thus far been fairly restricted although Penghu County, Taiwan ranked parasitic infections second only to bacterial diseases with infection rates of 28% in farmed cobia. Generally, the impact of parasites on animal health is correlated with the level of infestation. At the very least, minor infections can cause reductions in growth and perhaps more important, provide portals for the entry of other agents of disease.

CRUSTACEAN PARASITES

If untreated, epizootics of parasitic crustacea can result in serious economic losses during mariculture and ten species are reported to infest cobia. Parasitic crustaceans often possess attachment organs that are employed to anchor into host tissues. Others may move freely on the host's surface causing widespread necrosis and disruption of the protective mucus covering of the skin at anchor points. The size and age of the host, host health status, the species of parasite, and developmental stages present, affect the severity of the disease. Severe wounding can result in host death due to osmotic imbalance or by providing entry points for other pathogens. Economic losses incurred other than direct mortality of farmed fish are generally due to reduced growth of infected fish, negative impacts on edible tissues and costs associated with treatments. Cultured cobia are susceptible to the sea lice *Caligus lalandei* (Chang and Wang, 2000), *C. epidemicus* (Ho et al., 2004) and in the Peng–hu region of Taiwan, Ho and Lin (2001) reported tinfestations by *Parapetalus occidentalis*. In the wild, cobia have been reported with *C. coryphaenae* (Causey, 1953), *Lernaeolophus sultanus* in conjunction with the barnacle *Conchoderma virgatum* (Dawson, 1969), *Tuxophorus caligodes*, *Euryphorus nordmanni*, *L. longiventris*, *L. hemiramphi*, and *C. haemulonis*, (Bunkley–Williams and Williams, 2006).

METAZOAN PARASITES

Digenean parasites have been described from cobia of Atlantic, Pacific and Indian Oceans and the Gulf of Mexico and South China Sea. As an example of the diversity of Digenea that inflict cobia, the following lists those found on adults taken from the Gulf of Tonkin and South China Sea, Vietnam (Arthur and Te, 2006): *Aponurus carangis*, *Bucephalus varicus*, *Derogenes varicus*, *Dinurus selari*, *Lepidapedon megalaspi*, *Neometanematobothrioides* *rachycentri*, *Paracryptogonimus morosovi*, *Phyllodistomum parukhini*, *Stephanostomum imparispine*, *Tormopsolus filiformis* and *Tubulovesicula angusticauda*. Other species of digenean that have been isolated from cobia include the following: *Tormopsolus spatulum*, *Pseudolepidapedon pudens*, *Lecithochirium monticellii*, *Stephanostomum dentatum*, *S. cloacum S. pseudoditrematis*, *S. microsomum*, *S. rachycentronis*, *Mabiarama prevesiculata*, *Plerurus digitatus*, *Sclerodistomum rachycentri* and *S. cobia* (Linton, 1905; Sogandares–Bernal and Hutton, 1959; Madhavi, 1976; Hafeezullah, 1978; Shen, 1990; Bunkley–Williams and Williams, 2006; Bray and Cribb, 2003).

Monogenetic trematodes, more usually referred to as flukes or flatworms, parasitize the skin, gills and fins of fishes. Some species may be found in the gut, body cavity and even blood vascular system. They attach to the host via a variety of suckers and hooks located at their posterior end (opisthaptor) while using the anterior end or prohaptor for feeding and to assist movement. Monogeneans are often host–specific and stationary and *Dionchus rachycentris* and *D. agassizi* which infest the gills of cobia have been described in wild fish (Hargis, 1955; Bunkley–Williams and Williams, 2006; Bullard et al., 2000). In sub–adult caged–reared cobia, *Neobenedenia girellae* has been recorded (Lopez et al., 2002; Ogawa et al., 2006), causing extensive necrosis of the dorsal head region which, together with *Streptococcus* infection, ultimately caused blindness in infected animals (Chiau et al., 2004).

Tapeworms are members of the Class Cestoidea and in fishes two life–cycle stages may be found: adult worms inhabiting the intestinal tract while plerocercoids are found in the viscera and muscle tissues. Tapeworms can reduce growth rates and have a negative impact of feed efficiencies in captive animals. Moreover, for some species a negative impact on host reproductive performance has been observed. Cobia have been reported with infestations of *Nybelinia bisulcata*, *Callitetrarhynchus gracilis*, *Rhinebothrium flexile*, *Rhynchobothrium longispine* and *Trypanorhyncha* sp.

Nematodes or roundworms are commonly present even in healthy fish but when their abundance is large, roundworm infestations may cause death. Roundworms are generally cylindrical, smooth and long worms which distinguishes them from the segmented tapeworms. Similar to tapeworms however, nematodes can reduce reproductive performance and have a negative impact on feed conversion efficiencies leading to reduced growth and overall performance of cultured fish. Economic loss can also occur due to the burrowing of worms into various tissues including musculature. Nematodes can cause hemorrhaging and the development of granulomatous tissue resulting in visible bumpy or nodular appearance that can downgrade the value of fillets. Bruce and Cannon (1989), describe *Iheringascaris inquires* from the stomach of cobia caught in Australian waters which may be synonymous with *Contracecum megacephalum* (Oschmarin, 1963) taken from the stomach of a cobia from the South China Sea. *Mabiarama prevesiculata* derived from the stomach of cobia has been described from specimens taken in Brazil whereas *Goezia pelagia* was isolated from fish in the Gulf of Mexico (Bunkley–Williams and Williams, 2006). Arthur and Te (2006) also include *Anisakis* sp. and *Philometroides* sp. isolated from cobia in Vietnamese waters. To date no information is available on roundworm infestations in captive cobia but in other cultured species serious infections have been associated with serious tissue necrosis around the sites of intestinal intrusion. This may provide portals for bacterial and other infections.

Acanthocephalans, also referred to as spiny–headed worms are recognized by the evaginable proboscis crowned with several rows of recurved hooks (Kabata, 1985). The acanthocephalans cause damage to host tissues due to their attachment process in the gut and encapsulation of larval stages in muscle and other tissues. *Serrasentis sagittiferus* (Blaylock and Whelan, 2004) and *S. nadakali* (Bunkley–Williams and Williams, 2006) have been reported for adult wild cobia.

MYXOSPORIDIA

Myxosporidian parasites are a major cause for concern during cobia aquaculture. Chen et al. (2001) reported mass mortalities of 45–80 g cobia due to a *Sphaerospora*–like myxosporidean infestation with 90% mortalities within 30 days of detection. Infected fish exhibited discoloration, anaemia and enlarged kidneys that expressed cream–colored spherical nodules. Extrasporogonic or sporogonic stages of the *Sphaerospora* were observed in the blood, glomerulus and renal tubules with the latter sometimes being completely occluded by sporogonic pseudoplasmodia. In order to complete their life cycle, myxosporidian parasites require an intermediary invertebrate host, such as an annelid or bryozoans. Without intimate knowledge of the mechanisms involved in the transmission of this parasite however, and especially the prevalence of its intermediary host, its importance from an aquaculture perspective will be difficult to estimate. According to Blaylocka et al. (2004) species of *Myxidium*, *Ceratomyxa, Myxobolus*, and *Kudoa* have the potential to debilitate and kill cobia in culture.

PROTOZOAN PARASITES

Problems due to ciliophoran parasites are generally reported during the hatchery phase of production and *Trichodina* have been recorded from cobia during the nursery stage (FAO, 2007). The parasite was isolated from the skin and gills of infected fish and was associated with lethargy and inappetance and chronic, but a low levels of mortality coupled with secondary infections. Cobia also succumb to the prostomatean *Cryptocaryon irritans* which causes marine white spot. This ciliated protozoan, which was first described by Sikama (1937), is an obligate parasite of marine fish (Dickerson and Dawe, 1995) and is considered an emerging problem for mariculture. Cryptocaryonosis is characterized by white bumps on the skin of infected fish some of which may merge to create larger white–colored masses. *Cryptocaryon* can also infect and damage the gills leading to ionic imbalance, mucus clogging and in the most severe cases, death. Damage caused to epithelia by the invasive theront stage of the life cycle may offer a portal for secondary infections. Juvenile cobia exhibit cryptocaryonosis (Bunkley–Williams and Williams, 2006) and the same authors report another ciliated protozoan *Brooklynella hostilis* as being responsible for the death of 30,000 potentially stressed juvenile cobia in Puerto Rico. Brooklynellosis, more commonly referred to as slime–blotch or clownfish disease, is characterized by body discoloration, lethary, inappetance, increased mucus production and coughing where the gills are infected. *Brooklynella* reproduce by binary fission so that infections can rapidly build and spread in enclosed environments such as recirculating systems. Often, Brooklynellosis is associated with opportunistic diseases.

Although generally considered to pose only limited risk, coccidiosis has also been observed in cobia (FAO, 2007). Infections were associated with exophthalmia, abdominal swelling and encystments within hepatic tissues. The parasitic flagellate *Ichthyobodo* infests gills and skin of its hosts and has become a serious issue during mariculture operations, especially when undertaken in tanks and Bunkley–Williams and Williams (2006) isolated this parasite from cobia from fish in a commercial aquaculture operation in Puerto Rico. The stalked colonial ciliate *Epistylis* has also been reported to grow on larval cobia (FAO, 2007). This parasite appears as a fluffy grey/white or brown/red–colored growth on the skin and fins of infected animals and may even be isolated from the mouth and gills. Severe infestations with *Epistylis* are often associated with secondary infections and are indicative of poor water quality and high organic loads. Several methods are available to combat fish infected with external protozoan parasites and these usually involve some form of bath (formalin— or copper–based). Experimental vaccines employing attenuated strains of parasitic protozoa or recombinant antigenic surface proteins have been developed and may prove useful for cobia aquaculture in the future.

Cobia are also afflicted by members of the Dinophyceae. These dinoflagellates such as *Amyloodinium ocellatum*, causative agent of velvet disease. *Amyloodinium* has been reported as a problem in juvenile animals (Kaiser and Holt, 2005). The obligate feeding trophont stage of *A. ocellatum* can cause hyperplasia, inflammation and necrosis at infected sites and disrupt gas exchange in the gills. Skin infestations cause fish to flash and chafe, whereas gill clogging triggers a coughing response. Severe infestations of *Amyloodinium* may trigger rapid mortality. Hope exists for the development of a vaccine however, since serum from fish immunized with dinospore fractions kills the parasite in cell culture (Noga and Levy, 1995)

BACTERIAL PATHOGENS

As might be anticipated, since the first attempts to culture cobia over 15 years ago, losses due to bacterial infections has risen. Outbreaks of vibriosis, mycobacteriosis, furunculosis and streptococcosis are commonly encountered (Liao et al., 2004) and a bacterial disease caused by *Photobacterium* sp has been identified as a major emerging problem for cobia throughout the production cycle (Lopez et al., 2002; Liu et al., 2003; Rajan et al., 2003; Chen and Hsu, 2005). Clinical signs of photobacteriosis, also termed pseudotuberculosis or fish pasteurellosis, include skin ulceration and a build up of whitish granulomatous tissue on the kidney, liver and spleen. Photobacteriosis in caged cobia has resulted in 80% mortalities at some sites which have led to research to evaluate the usefulness of vaccines (Chen, 2001) and dietary immunostimulants to control or reduce losses due to *P. damselae* and *Streptococcus iniae* outbreaks. Thus, incorporation of β–1,3–1,6–glucan at 0.5% of the diet was found to enhance resistance of cobia to *P. damselae* and *Streptococcus iniae* challenge (Chang et al., 2006), whereas levamisole at 500–1000 mg kg^{-1} diet reduced the virulence of *P. damselae* apparently by enhancing the leukocyte response of 12–25 g juveniles (Leaño et al., 2003). Since *Photobacterium* is ubiquitously found in the gut of marine fish it is likely that the intestine represents a major portal of entry for this pathogen. Therefore, it is possible that benefits may accrue from using dietary mannan oligosaccharides since these complex carbohydrates appear to assist in maintaining and enhancing the barrier integrity of the cobia gut (Salze et al., 2008).

Cobia from all stages of the production cycle may succumb to vibriosis, the clinical signs of which vary from no external indications through to a darkening of the skin, lethary, inappetance, exophthalmia, swollen abdomen, pale gill color, erosion and hemorrhage in the fins and skin lesioning. Internally, ascites may be present in the peritoneal cavity and the host liver and kidney may pale in color while the spleen may have white tubercules present. Several species of *Vibrio* have been isolated from moribund farmed cobia including *V. alginolyticus*, *V. harveyi*, *V. parahaemolyticus* and *V. vulnificus* (Rajan et al., 2001; Lopez et al., 2002; Liu et al., 2004) and vibriosis has accounted for ≤45% mortalities in cage–stocked juvenile cobia. A vaccination trial of cobia using a polyvalent preparation, comprising inactivated *Vibrio alginolyticus*, *V. parahaemolyticus* and *P. damselae* subsp. *piscicida*, induced appearance of specific antibody 1 week post–injection which was detected until the end of the trial at 6 weeks. Laboratory testing of the vaccine resulted in < 80% relative percent survival of cobia following various challenges. Moreover, the vaccine increased survival of fish in two separate farm trials at two locations using fish from two broodstocks. Because it is known that a maternal transfer of humoral specific and non–specific immunity occurs in certain teleosts, as exemplified by sea bream immunized against *P. damsela* subsp. *piscicida* (Hanif et al., 2005), it is possible that both the egg and larval stages of cobia might benefit from broodstock vaccination programs leading to increased survival of weanlings, the supply of which presently represents the most pressing issue in cobia culture (Salze et al., 2008).

Lowry and Smith (2006) reported the presence of multiple pathogens in juvenile cobia exhibiting swimming disorientation, which included *Aeromonas hydrophila*, *Citrobacter* sp. and *Mycobacterium marinum*. They also observed emaciation, lethargy, ulcerative dermal lesions, exophthalmia, granulomas throughout the spleen, liver, anterior and posterior kidney, heart, pancreas and mesenteric tissues in a limited number of specimens. They concluded that the major cause of the observed swimming anomalies was *M. marinum* encystment in the brain. Interestingly, similar swimming irregularities have been described for fish infected with nodavirus.

VIRAL DISEASES

There is a limited information base with respect to viral diseases in cobia. Nevertheless, Chi et al. (2003) reported deaths of cobia due to the β–nodavirus NNV (nervous necrosis virus) which was isolated from epithelial cells of the skin and in intestinal epithelia. Around 30% of stocked animals succumbed to the disease which has spurred interest in developing a recombinant NNV vaccine. In general, nodavirus is associated with mass mortalities in larval fishes and this infection is often accompanied with changes in fish behavior, including spiral swimming patterns which result due to lesioning of neural tissue. In other marine species, nodavirus may be transmitted vertically and carrier states have been reported in susceptible fish (Rogers and Furones, 1998) such that development of disease–free broodstock may become problematic. At present there are a number of groups examining the feasibility of producing nodavirus vaccines which may be of significant importane to cobia production in the future. The susceptibility of cobia to red sea bream iridiovirus (RSIV) is considered low when compared to other species of cultured marine fish (Sano et al., 2001) and while not necessarily fatal lymphocyctis outbreaks occur during the nursery phase of cobia production (Liao et al., 2004). Lymphocystis has been reported in sea–stocked cobia of 25–30 cm in Pingtung County, Taiwan. The skin lesions associated with this virus were white to pale pink in color and of 0.3–1.5 cm diameter occurring mainly on the pectoral and caudal fin as well as the trunk. Cobia infected by TGIV, or grouper iridovirus of Taiwan, expressed severe hypertrophy of the liver, spleen, gill and kidneys.

DEFORMITIES AND MISCELLANEA

Conspicuous features of cultivated cobia are mouth deformities which are often characterized by a reduction in length of the upper jaw (Salze et al., 2008; Fig. 1). This abnormality, termed mandibular macrognathia, has also been observed in fish caught in the Gulf in Mexico (Franks, 1995) and since inflicted animals continue to grow relatively well it would appear that this likely genetic deformity (Salze et al., 2008) has limited negative consequences to the fish. Nevertheless, inflicted animals may find this deformity an impediment when competing for food. In the hatchery environment a number of other gross body deformities are observed including crooked back and stumped body syndromes, where the vertebral column is out of alignment or overall proportions of the animal are compressed. Whether these apparent osteological pathologies have a nutritional, genetic, or other cause remains to be established. Physical damage to fins and eyes, including cataracts, are also observed in larval, juvenile and sub–adult fish which may be due to net and tank collisions and, or nipping; cannibalism represents a significant problem from ~14 dph to 24 g and is likely also responsible for the occurrence of minor body lesions on weanlings and juveniles. Howse et al. (1975) reported the fusion or connection of the epicardium and pericardium of wild caught cobia together with numerous thick collagenous adhesions over most of the heart surface but these deformities were of unknown etiology. Anecdotal evidence suggests that extended periods of cold banking (Schwarz et al., 2007) may result in back deformities and scoliosis at 25–30% levels have been reported following cold banking. There may however, be a fish age/size dependency to this occurrence. Cold banking also results in fin erosions which may however, result due to nutritional deficiencies since fish do not feed well at temperatures below 18°C. Anecdotal observations suggest that for smaller animals (~ 30–50 g), cold banking may result in scoliosis–like symptoms. Especially when cultured in tanks, head bobbing, where the head of the fish exits the water column is common but the cause of this behavior remains unknown.

DEDUCTIONS

Around the world, disease epidemics are responsible for billions of dollars in losses to the aquaculture industry every year. A major feature of the cultivation of candidate aquaculture species is the emergence of existing and sometimes new diseases for which the farmer may be ill–prepared. Cobia are no exception to this general rule of thumb and it would appear that as time passes the variety of diseases encountered with this species increases. Cobia have already surrendered to many of the more common diseases and parasites of cultured warm water fishes and, in an growing number of cases, disease has become restrictive to the expansion of intensive cage operations. Ex-

Figure 1. Deformities of the maxilla, which may include twisting, shortening and gaping leading to a proportionally lenghtened, although normal lower jaw (madibular macrognathia) are commonly encountered in cultured cobia.
Slika 1. Deformacije maksile (svijanje, skraćenje, zijevanje), dok je u normalno uzgojenih cobia čeljust manja

perimental and planned studies with a new generation of vaccines nonetheless anticipate development of a more cautious industry and this is particularly the case for new land–based biosecure cobia production units. The recent experiences gained with diet–based immunostimulants and probiotics herald fourth generation prepared feeds that may provide the means to reduce dependency on antibiotic and other chemical treatments to control diseases and parasites. Even given these advances however, it is imperative that appropriate measures should be taken to develop more rigorous disease prevention programs. Such actions should take account of all stages in the production cycle and include development of disease–free broodstock and gametes. Innovations with regard to disease screening and control might include creation of non–lethal disease–specific diagnostic tools as well as increased use of recirculating life support system technologies to enhance overall production biosecurity.

Sažetak

PARAZITI, BOLESTI I DEFORMACIJSKE PROMJENE KOD VRSTE COBIA

E. McLean, G. Salze, S. R. Craig

Cobia, *Rachycentron canadum*, jedna je od predstavnica porodice Rachycentridae (Red Perciformes) i kao toplovodna riba nađena je u tropskim i suptropskim vodama. Ova je vrsta ustanovljena u istočnim vodama Sredozemlja. Cobia se na Tajvanu uzgaja od ranih 1990–ih, a danas se njezin uzgoj proširio na jugoistočnu i istočnu Aziju, Meksički zaljev i Karibe, kao i SAD. Mnogi narodi rade na prilagodbi kobije kao nove vrste za uzgoj, jer je vrlo zanimljiva zbog svojih odličnih karakteristika kao što su dobar rast s produkcijom od 6 kg žive težine tijekom uzgojnog perioda od godine dana. To je vrsta koja je pogodna za uzgoj na razne načine kao što su kavezi i recirkulirajući sustavi. Meso joj je visoke kakvoće, a rado uzima peletiranu hranu. No, kao i kod svih intenzivnih uzgoja najveći su problem bolesti. Mnogi potencijalni proizvođači i istraživači rade na rješavanju toga problema pa postoji niz publikacija koje obrađuju tu temu. Tako i ovaj rad daje literaturni pregled o bolestima, nametnicima i fizikalnim deformacijama kod kobije.

Ključne riječi: cobia, bolesti, nametnici, deformacije

REFERENCES

Arthur, J. R., Te, B. Q. (2006): Checklist of the parasites of fishes of Viet Nam. FAO Fish. Tech. Pap. 369/2, Rome, Italy. 133 pp.

Blaylock, R. B., Whelan, D. S. (2004): Fish health management for offshore aquaculture in the Gulf of Mexico. *In:* Efforts to Develop a Responsible Offshore Aquaculture Industry in the Gulf of Mexico: A Compendium of Offshore Aquaculture Consortium Research, C. J. Bridger (ed). Mississippi–Alabama Sea Grant Consortium, Ocean Springs, MS, MASGP–04–029, 129–161.

Blaylock, R. B., Bullard, S. A., Whipps, C. M. (2004): *Kudoa hypoepicardialis* sp. n. (Myxozoa: Kudoidae) and associated lesions from the heart of se-

Ewen McLean, Ph. D. is Director of the Virginia Tech Aquaculture Center (VTAC) and Professor of Fisheries, Dept. Fisheries & Wildlife Sciences, 100 Cheatham Hall, Blacksburg, VA 24061–0321, USA. Guillaume Salze is a graduate student in aquaculture and Steven R. Craig, Ph. D. Head of the VTAC Nutrition Group and Associate Professor in the Virginia–Mayland College of Veterinary Medicine, Dept. Large Animal Clinical Sciences, Duckpond Drive, Blacksburg, VA 24061–1103, USA. Corresponding author: emclean@vt.edu

ven perciform fishes in the northern Gulf of Mexico. Journal of Parasitology, 90, 584–593.

Bray, R. A., Cribb, T. H. (2003): Species of *Stephanostomum* Looss, 1899 (Digenea: Acanthocolpidae) from fishes of Australian and South Pacific waters, including five new species. Systematic Parasitology, 55, 159–197.

Bruce, N. L., Cannon, L. R. G. (1989): *Hysterothylacium*, *Iheringascaris* and *Maricostula* new genus, nematodes (Ascaridoidea) from Australian pelagic marine fishes. Journal of Natural Histpry, 23, 1397–1441.

Bullard, S. A., Benz, G. W., Braswell, J. S. (2000): *Dionchus* postoncomiracidia (Monogenea: Dionchidae) from the skin of blacktip sharks, *Carcharhinus limbatus* (Carcharhinidae). Journal of Parasitology, 86, 245–250.

Bunkley–Williams, L., Williams, E. H. Jr. (2006): New records of parasites for culture cobia, *Rachycentron canadum* (Perciformes: Rachycentridae) in Puerto Rico. Revista de Biologia Tropical, 54, (suppl. 3), 1–7.

Causey, D. (1953): Parasitic copeopoda of Texas coastal fishes. Publications of the Institute of Marine Sciences, 3, 7–16.

Chang, C. F., Yang, J. H., Chang, S. L. (2006): Application of dietary â–1, 3–1, 6–glucan in enhancing resistance of cobia (*Rachycentron canadum*) against *Photbacterium damselae* subsp. *Piscicida* and *Streptococcus iniae* infections. Journal of Taiwan Fisheries Research, 14, 75–87.

Chang, P., Wang, Y. (2000): Studies on the caligusiasis and benedeniasis of marine cage cultured fish in Pingtung area of Taiwan. In Liao I. C. and Lin C. K. (Eds.), Proceedings of the First International Symposium on Cage Aquaculture in Asia, 2000. Asian Fisheries Society.

Chen, H. E. (2001): Evaluation of antigens from *Photobacterium damselae* subsp. *piscicida* using cobia (*Rachycentron canadum*) antiserum. M. Sc. Thesis, National Cheng Kung University, Tainan, Taiwan, 67pp. (In Chinese)

Chen, S. C., Hsu, C. (2005): Studies on the pathogenicity and pathology of photobacterium damselae subsp. piscicida on *Rachycentron canadum*. Journal of the Fisheries Society of Taiwan, 32, 4.

Chen, S. C., Kou, R. J., Wu, C. T., Wang, P. C., Su, F. Z. (2001): Mass mortality associated with a *Sphaerospora*–like myxosporidean infestation in juvenile cobia, *Rachycentron canadum* (L.), marine cage cultured in Taiwan. Journal of Fish Diseases, 24, 189–195.

Chi, S. C., Shieh, J. R., Lin, S. (2003): Genetic and antigenic analysis of betanodaviruses isolated from aquatic organisms in Taiwan. Diseases of Aquatic Organisms, 55, 221–228.

Chiau, W. Y., Chou, C. L., Shih, Y. C. (2004): Marine aquaculture in Chinese Taipei: Status, institutions and challenges. APEC Bulletin on Marine Resource Conservation and Fisheries, 6, 15–20.

Craig, S. R., Schwarz, M. H., McLean, E. (2006): Juvenile cobia (*Rachycentron canadum*) can utilize a wide range of protein and lipid levels without impacts on production characteristics. Aquaculture, 261, 384–391.

Dawson, C. E. (1969): Records of the barnacle *Conchoderma virgatum* from two Gulf of Mexico fishes. Proceedings of the Louisiana Academy of Science, 32, 58–62.

Dickerson, H. W., Dawe, D. L. (1995): *Ichthyophthirius multifiliis and Cryptocaryon irritans*, pp. 181–227 In: Woo, P. T. K., Fish Diseases and Disorders, Vol 1, Protozoan and Metazoan Infections. Cambridge: CAB International.

Duncan, M., Craig, S. R., Lunger, A. N., Kuhn, D. D., Salze, G., McLean, E. (2007): Bioimpedance assessment of body composition in cobia *Rachyentron canadum* (L. 1766). Aquaculture, 271, 432–438.

FAO (2007): Cultured aquatic species information program: *Rachycentron canadum*. http: //www. fao. org/fi/website/FIRetrieveAction. do? dom=cultur especies&xml=Rachycentron_canadum. xml.

Fox, H. M. (1929): Cambridge expedition to the Suez Canal. Summary of results. Transactions of the Zoological Society of London, 22, 643–863.

Franks, J. S. (1995): A pugheaded cobia (*Rachycentron canadum*) from the north central Gulf of Mexico. Gulf Research Reports, 9, 143–145.

Golani, D., Orsi Relini, L., Massutí, E., Quignard, J. P. (2002): CIESM Atlas of Exotic Species in the Mediterranean. Vol. 1. Fishes. F. Briand (ed.). 256 pages. CIESM Publishers, Monaco.

Golani, D., Ben–Tuvia, A. (1986): New records of fishes from the Mediterranean coast of Israel including red sea immigrants. Cybium 10: 285–291.

Hargis, W. J. (1955): Monogenetic trematodes of Gulf of Mexico fishes. Part IV. The superfamily Capsaloidea. Transactions of the American Microscopical Society, 74, 203–225.

Hafeezullah, M. (1978): Acanthocolpid trematodes of marine fishes of India, with considerations on synonymies in the group. Bulletin of the Zoological Survey of India, 1, 29–36.

Hanif, A., Bakopoulos, V., Leonardos, I., Dimitriadis, G. J. (2005): The effect of sea bream (*Sparus aurata*) broodstock and larval vaccination on the susceptibility by *Photobacterium damsela* subsp. *piscida* and on the humoral immune parameters. Fish and Shellfish Immmunology, 19, 345–361.

Ho, J. S., Lin, C. L. (2001): *Parapetalus occidentalis* Wilson (Copepoda, Caligidae) parasitic on both wild and farmed cobia (*Rachycentron canadum*) in Taiwan. Journal of the Fisheries Society of Taiwan, 28, 305–316.

Ho, J., Kim, I., Cruz–Lacierda, E. R., Nagasawa, K. (2004): Sea lice (Copepoda, *Caligidae*) parasitic on marine cultured and wild fishes of the Philippines. Journal of the Fisheries Society of Taiwan, 31, 235–249.

Howse, H. D., Franks, J. S., Welford, R. F. (1975): Pericardial adhesions in the cobia, *Rachycentron canadum* (Linnaeus). Gulf Research Reports 5, 61–62.

Kabata, Z. (1985): Parasites and Diseases of Fish Cultured in the Tropics. Taylor & Francis, London & Philadelphia, 318 pp.

Kaiser, J. B., Holt, G. J. (2005): Species profile: Cobia. SRAC Publication No. 7202. 6 pp.

Keller, C. (1882): Die Fauna in Suez Canal und die Diffusion der mediterraneen und erythraischen Tierwelt. Naturweiss, 28, 39.

Leaño, E. M., Chang, S. L., Guo, J. J., Chang, S. L., Liao, I. C. (2003): Levamisole enhances non–specific immune response of cobia, *Rachycentron canadum*, fingerlings. Journal of the Fisheries Society of Taiwan, 30, 321–330.

Liao, I. C., Huang, T. S., Tsai, W. S., Hseueh, C. M., Chang, S. L., Leano, E. M. (2004): Cobia culture in Taiwan: current status and problems. Aquaculture, 237, 155–165.

Linton, E. (1905): Parasites of fishes of Beaufort, North Carolina. Bulletin of the Bureau of Fisheries for 1904, 24, 321–428.

Liu, P., Lin, J., Chuang, W., Lee, K. (2004): Isolation and characterization of pathogenic *Vibrio harveyi* (*V. carchariae*) from the farmed marine cobia fish *Rachycentron canadum* L. with gastroenteritis syndrome. World Journal of Microbiology & Biotechnology, 20, (5), 495–499.

Liu, P. C., Liu, J. Y., Lee, K. K. (2003): Virulence of *Photobacterium damselae* subsp *piscicida* in cultured cobia *Rachycentron canadum*. Journal of Basic Microbiology, 43, 499–507.

Lopez, C., Rajan, P. R., Lin, J. H., Kuo, T., Yang, H. (2002): Disease outbreak in seafarmed cobia (*Rachycentron canadum*) associated with *Vibrio* spp., *Photobacterium damselae* ssp. *piscicida*, mongenean and myxosporean parasites. Bulletin of the European Association of Fish Pathologists, 22, (3), 206–211.

Lowry, T., Smith, S. A. (2006): *Mycobacterium* sp. Infection in cultured cobia (*Rachycentron canadum*). Bulletin of the European Association of Fish Pathologists, 26, 87–92.

Lunger, A. N., Craig, S. R., McLean, E. (2006): Replacement of fish meal in cobia diets using an organically certified protein. Aquaculture, 257, 393–399.

Lunger, A. N., McLean, E., Gaylord, T. G., Craig, S. R. (2007a): Taurine addition to alternative dietary proteins used in fish meal replacement enhances growth of juvenile cobia (*Rachycentron canadum*). Aquaculture, 271, 401–410.

Lunger, A. N., McLean, E., Craig, S. R. (2007b): The effects of organic protein supplementation upon growth, feed conversion and texture quality parameters in juvenile cobia (*Rachycentron canadum*). Aquaculture, 264, 342–352.

Madhavi, R. (1976): Digenetic trematodes from marine fishes of Waltair Coast, Bay of Bengal. Family Acanthocolpidae. Rivista di Parassitologia, 37, 115–128.

Noga, E. J., Levy, M. G. (1995): Dinoflagellida (Phylum Sarcomastigophora). pp 1–26, In: P. T. K. Woo, (Ed.). Fish diseases and disorders, vol. 1, protozoan and metazoan infections. CABI, Wallingford, UK.

Ogawa, K., Miyamoto, J., Wang, H. C., Lo, C. F., Kou, G. H. (2006): *Neobenedenia girellae* (Monogenea) infection of cultured cobia *Rachycentron canadum* in Taiwan. Fish Pathology, 41, 51–56.

Oschmarin, P. G. (1963): A new species of nematode *Contracaecum megacephalum* sp. nov. from fish of the South China Sea. GeFmintofauna Cheloveka, Zhivotnykj i Rasten: Bor'ba Nime (85–Let. Skrjabin), pp. 186–190.

Por, F. D (1971): One hundred years of Suez Canal — a century of Lessepsian migration: retrospect and viewpoints. Systematic Zoology, 20, 138–159.

Rajan, P. R., Lopez, C., Lin, J. H., Yang, H. (2001): *Vibrio alginolyticus* infection in cobia (*Rachycentron canadum*) cultured in Taiwan. Bulletin of the European Association of Fish Pathologists, 21, 228–234.

Rajan, P. R., Lin, J. H., Ho, M. S., Yang, H. L. (2003): Simple and rapid detection of *Photobacterium damselae* ssp. *piscicida* by a PCR technique and plating method. Journal of Applied Microbiology, 95, 1375–1380.

Rodgers, C. J., Furones, M. D. (1998): Disease problems in cultured marine fish in the Mediterranean. Fish Pathology, 33, 157–164.

Salze, G., McLean, E., Schwarz, M., Craig, S. R. (2008): Dietary mannanoligosaccharide enhances salinity tolerance and gut development in larval cobia. Aquaculture, in press.

Sano, M., Minagawa, M., Sugiyama, A., Nakajima, K. (2001): Susceptibility of fish cultured in subtropical area of Japan to red sea bream iridiovirus. Fish Pathology, 36, 38–39.

Schwarz, M. H., McLean, E., Craig, S. R. (2006): Research experience with cobia: larval rearing, juvenile nutrition and general physiology, pp. 1–19, In: I C. Liao and E. M. Leaño (Eds). Cobia Aquaculture: Research, Development and Commercial Production. The Fisheries Society of Taiwan, Keelung Taiwan, and National Taiwan Ocean University, Keelung, Taiwan.

Schwarz, M. H., Mowry, D., McLean, E., Craig, S. R. (2007): Performance of advanced juvenile cobia reared under different thermal regimes: Evidence for compensatory growth and a method for cold banking. Journal of Applied Aquaculture, 16, 71–84.

Schaffer, R. V., Nakamura, E. L. (1989): Synopsis of biological data on the cobia, *Rachycentron canadum* (Pisces: Rachycentridae). NOAA Technical report NMFS 82, FAO Fisheries Synopsis 153. 21 p.

Shen J. W. (1990): Digenetic trematodes of marine fishes from Hainan Island. Beijing: Science Publications, 228 pp. (In Chinese, English summary).

Sikama, Y. (1937): Preliminary report on white spot disease in marine fishes. Suisan–Gakukai–Ho, 7, 149–160.

Sogandares–Bernal, F., Hutton, R. F. (1959): Studies on helminth parasites from the coast of Florida. IV. Digenetic trematodes of marine fishes from Tampa, Boca Ciega Bays, and the Gulf of Mexico. 3. Quarterly Journal of the Florida Academy of Sciences, 21, 259–273.

Williams, E. H. Jr., Williams, L.. B. (1996): Parasites of Offshore Game Fishes of Puerto Rico and the Western Atlantic. Puerto Rico Department of Natural and Environmental Resources, San Juan, PR and the University of Puerto Rico, Mayaguez, PR., 382 pp.

Received: 14. 12. 2007.
Accepted: 3. 3. 2008.