Expansion of the Soft Crab Fishery in Mississippi Using Cultured Blue Crabs

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ABSTRACT

The Gulf Coast Research Laboratory in Ocean Springs, MS has successfully operated a hatchery for blue crabs (*Callinectes sapidus*) for over five years. The ability to reliably produce "seed" crabs has great potential for expanded development of soft crab fisheries in the northern Gulf of Mexico and Caribbean. Hatchery-reared blue crabs are stocked as juveniles into non-vegetated, one -quarter acre ponds and fed a diet of manufactured feed and scrap fish. When crabs reach 40 to 50 mm carapace width, bushlines constructed of wax myrtle are placed across the pond in close proximity to provide shelter for pre-molt and molting crabs. Peeler crabs collected in the bushlines are harvested and maintained in recirculating shedding systems until they molt. Small soft-shell portunid crabs are currently imported into the U.S. for sale as "cocktail" or "appetizer" crabs and demand exceeds supply. Pond culture of soft crabs would greatly reduce pressure on natural populations and would allow for expansion of the fishery independent of wild stocks. Continuing market demand, profitability to the fishermen, and regional familiarity with pond cultured products all suggest that blue crab aquaculture for soft shell production could be an economically viable enterprise and would provide a measure of conservation to the fishery.

KEY WORDS: Blue crab aquaculture, Mississippi, soft crabs

Expansion de la Industria de Jaiba Blanda en Mississippi Usando Jaibas Azules Cultividas

El laboratorio de investigación de la Costa del Golfo en Ocean Springs, Mississippi ha operado con exito un vivero de jaibas azules (*Callinectes sapidus*) por mas de cinco años. La abilidad de producir semillas de jaibas formalmente tiene un gran potencial para la expanción del desarrollo industrial de jaiba blanda en el norte del Golfo de Mejico y el Caribe. Jaibas azules provenientes del vivero de cria son almacenados como juveniles dentro de estanques de un cuarto de acre sin vegetación y son alimentados con una dieta de alimento manufacturado y trozos de peces. Cuando las jaibas alcanzan un tamaño de caparazon de 40 a 50 mm, lineas de matorrales contruidos con *Myrica cerifera* son colocadas cerca unas de otras atravez del estanque para proveer proteccion a las jaibas que estan cercanas a mudar o estan mudando. Jaibas que estan cambiando el caparazón en las lineas de arbustos son capturados y mantenidos en sistemas de recirculacion hasta que ellas muden. Pequenas jaibas nadadoras con caparazón blando estan siendo importadas a Estados Unidos para ser vendidas como jaibas en cocteles o aperitivo y su demanda excede el suministro. Estanques de cultivo de jaibas blandas van a reducir grandemente la presión en poblaciones naturales y van a permitir la expansión de la pesca independiente de poblaciones silvestres. Continuando la demanda del Mercado, rentabilidad del pescador, y su familiaridad regional con productos de estanques todo sugiere que la acuicultura para la producción de jaiba azul blanda va ha ser economicamente viable y va ha proveer una medida de conservación a la industria pesquera.

PALABRAS CLAVE: Acuicultura de jaiba azul, Mississippi, jaiba blanda

Développement de la Pécherie de Crabe Mou dans le Mississippi à l'Aide de Crabes Bleus Produits par Aquaculture

MOTS CLÉS: Aquaculture de crabes blues, Mississippi, crabe mou

INTRODUCTION

The fishery for blue crabs, *Callinectes sapidus*, is one of the largest and most valuable coastal fisheries in the United States. Recruitment rates of blue crabs in the northern Gulf of Mexico (nGOM) have been high but variable over the last nine years; however, the abundance of juvenile crabs in fishery-independent surveys in Louisiana, Mississippi, and Alabama has declined significantly suggesting post-settlement mortality is increasing (Perry et al. 2008 2009, Riedel et al. 2010). In addition, commercial harvest of blue crabs in the GOM has declined by one third over the last two years (Gulf States Marine Fisheries Commission, Blue Crab Subcommittee 2008). Continued significant downward trends in juvenile abundances of blue crabs and other estuarine dependent species, such as sand seatrout, suggest that we may be approaching a critical threshold in sustainability of some fisheries resources in the nGOM (Riedel et al. 2010). It is clear that the fishing community will face severe challenges in the near future as landings decrease and management of wild stocks becomes more stringent. The recent oil spill in the Gulf of Mexico originating from the Deep Water Horizon (DpH) oil platform explosion on April 20, 2010 will likely result in loss of recruitment and depending upon the length and spatial distribution of the spill, may impact population sustainability. Hatchery-reared blue crabs can supply "seed" crabs for grow-out to soft-crabs with negligible impact to wild stocks. Current protocols for blue crab hatchery operations at the Gulf Coast Research Laboratory (GCRL) use the spawn of a single wild-caught female to stock larval tanks. The female crab is returned to the wild after the eggs hatch.

Prior Research

Blue crab research at GCRL has focused on factors affecting fisheries production, population dynamics, natural history, recruitment and settlement dynamics, and soft-shelled crab production using re-circulating seawater systems. In 2002, the GCRL became part of the Blue Crab Advanced Research Consortium (BCARC), a partnership between the University of Maryland's Center of Marine Biotechnology (COMB), the University of Southern Mississippi, Smithsonian Environmental Research Consortium, the Virginia Institute of Marine Science, and North Carolina State University. Scientists in the Consortium made groundbreaking progress in understanding basic blue crab biology and in developing blue crab larval culture techniques. The entire life cycle of the blue crab was completed in captivity at COMB making mass production of juveniles possible. Using technology developed at COMB, the GCRL built a blue crab hatchery in 2004 for the production of juveniles for laboratory and pond culture studies.

The ability to reliably produce "seed" crabs has great potential for expanded development of the soft crab fishery in northern Gulf states, a region that has historically produced fishery products through pond culture. Expansion of the soft crab fishery in the Gulf has been and continues to be limited by the lack of supply of peeler crabs (Perry et al. 1982, Perry et al. 2001). Closure of areas to fishing in some states and lack of a directed peeler fishery hinders availability of shedding crabs. Shedding facilities have traditionally depended on buying peelers taken in the hard crab fishery and most states have provisions for harvest of crabs under 5 inches in carapace width (CW) for shedding. Continuing declines in numbers of juvenile blue crabs in northern Gulf estuaries based on fishery-independent long-term monitoring surveys (Perry et al. 2008, 2009, Riedel et al. 2010) may trigger management recommendations that restrict harvest and eliminate retention of undersize crabs. Pond culture of soft crabs would greatly reduce pressure on natural populations and would allow for expansion of the fishery independent of wild stocks. Demand for softshells has exceeded domestic supply in the Gulf (Otwell and Koburger 1985). With continued expansion of gaming and tourist-related development it is expected that demand will increase. Soft crabs are considered the "money crabs" along the Gulf of Mexico and are popular in restaurants, as well as being sold through seafood markets. Economic data on soft crabs, other than ex-vessel value, is generally lacking. Lipton (2001) examined landings and prices for soft and peeler crabs from 1990 - 1999 along the East Coast of the U.S. He found increased production and higher product prices for soft and peeler crabs driven by increased market demand both domestic and foreign. After adjusting for inflation, he found peeler crabs were worth 56% more in 1999 compared with 1990. Continuing market demand, profitability to the fishermen, and regional familiarity with pond cultured products all suggest that blue crab aquaculture for soft shell production would be an economically viable enterprise and one that would provide a measure of conservation to the fishery. Of particular interest to restaurants along the Gulf is the availability of soft-shelled crabs between 2½ and 3 inches carapace width (CW). Availability of small, appetizer soft crabs is limited by the dependence of the soft-shell industry on trap-caught peelers (traps select for larger size) and management regulations that restrict harvest of small crabs in most states. Currently, restaurants on the Mississippi Gulf Coast buy small imported soft-shelled crabs from markets along the East Coast. Pond culture of peeler crabs would allow for production of these smaller, valuable soft-shells, and there is great interest in having a local source. Organoleptic tests between wild-caught and pond reared crabs have been conducted in Mississippi, with the greatest percentage of participants selecting pond-reared crabs over wild-caught.

MATERIALS AND METHODS

Hatchery Production

The hatchery facility consists of a 1220 ft^2 hatchery building and a 400 ft^2 building used for seawater preparation/storage and for rotifer (*Branchionus rotundiformis* ss) culture. The hatchery building consists of a larval culture room and a dry lab and is used for quarantine and spawning of females, larval rearing, microscopy, larval food preparation, and *Artemia* culture. The blue crab hatchery contains four independent larval rearing systems. Each system consists of a 1,000 L fiberglass larval rearing tank with a 400 L fiberglass filter reservoir. The filter reservoir contains a magnetically driven system pump, a protein skimmer and skimmer pump, a trickle filter and an upflow biological filter. Seawater (28‰) is prepared using filtered, dechlorinated city water and BioSea® Marine Mix. The *Artemia* culture system consists of a water table with five 20 L cone-shaped hatchers. Aeration and suspension of cysts are accomplished with air stones placed in the bottom of the hatchers. Two double 40W florescent light fixtures provide constant lighting. The system is surrounded by ceiling to floor black curtains. Newly hatched, and 24-hour and 48-hour enriched *Artemia* are produced for feedings. Rotifers are raised in four systems using pre-filtered (1µm) UV sterilized production water (28‰). Each semi-continuous high density rotifer culture system consists of a 100 L cone-shaped culture tank, oxygen concentrator, feeding pump, sodium carbonate pump, air supply, and heater. Heaters with controllers maintain water temperature at 28°C. Rotifers are fed *Nannochloropsis* 3600®. Feeding rates are set and maintained via automated feeders at the rate of 1 ml per 1 million rotifers per hour. Production is maintained at 3,000 to 5,000 individuals/ml. Rotifer tanks are harvested daily by removing approximately 30% water by volume.

Ovigerous females with early sponges are obtained from cooperating fishermen. Crabs are disinfected, held in quarantine aquaria for 24 hours, examined for parasites and disease, and then transferred into 100 L hatching tanks if disease free. Female crabs are returned to the wild after spawning. Zoeae are harvested, counted, and placed in culture systems that have been stocked with 50 million rotifers. Zoeae are stocked at 100,000/system with a total culture capacity of 400,000 individuals. Early zoeae are fed a diet of rotifers and algae; later stages are also fed with Cyclop-eeze® and newly hatched and enriched *Artemia*. Zoeae are fed twice daily. Daily plunge samples are taken from the culture tanks and the number of zoeae, rotifers, and *Artemia* are determined. Rotifers are feed at the rate of 50 million/system/day. *Artemia* are fed from 300,000 to 1 million/day based on zoeal development and residual counts. Temperature (25°C) and salinity (28‰) are monitored daily; ammonia, nitrite, and nitrate are monitored twice weekly. Tanks are harvested when megalopae appear, usually within 24 - 30 days of stocking. Survival rates to megalopae have been as high as 45%. Megalopae are harvested daily over a 2 - 4 day period and transported in aerated coolers partially filled with seawater (28‰) to the intermediate juvenile grow-out systems for acclimation to low salinity.

Intermediate Grow-out in Raceways

Harvested megalopae and late stage zoeae are placed in large-volume (4,000 - 6,000 L) recirculating raceways at the GCRL's Thad Chochran Marine Aquaculture Center at Cedar Point. Megalopae may be stocked up to 40,000 individuals/system with system volume adjusted to maintain a density of 10 individuals/L. Structure (bio-barrels) is added to the tanks to provide cover for molting crabs thus reducing cannibalism. Temperature, salinity, pH, nitrate, and nitrite levels are monitored daily. The amount of food added to the system is calculated according to the volume of the water. Feeding regimes are adjusted over time to coincide with the predicted growth of the juveniles. Feeds include frozen adult *Artemia salina*, Cyclop-eeze®, and food pellets of varying sizes specially formulated to meet the nutritional requirements of crustaceans. At grow-out week 4, juvenile crabs are fed a pelletized diet only.

After the first week of grow-out, salinities in the systems are gradually lowered by the addition of freshwater. Over the four to eight week grow-out period, juvenile crabs are acclimated from salinities of 28‰ to 3‰. At harvest the raceways are drained, the crabs are counted, and the average size (carapace width (CW) in mm) and weight (g) of an aliquot of juveniles is determined. The harvested crabs are placed in ice chests on wet netting and transported to the Lyman Fish Hatchery for pond grow-out.

Juvenile Grow-out in Ponds

Standard pond treatment methods are used to prepare the ponds for crab culture. The pond is drained, the bottom allowed to dry, and the soil tilled. Soil samples are taken of the pond bottom, and the pH of the soil adjusted by applying agricultural lime, if necessary. Cotton seed meal is applied (280 kg/ha) as an organic fertilizer source to create a plankton bloom. The pond is filled with well water to a 0.3 m depth and allowed to set for two days. Thereafter, the pond depth is raised 0.3 m per day until filled. Commercially formulated salt (Fritz) is added during filling to obtain a salinity of 1 ppt. When the water depth reaches ~1 m, ponds are aerated. The predominant size of ponds in use for blue crab grow-out is one-quarter acre.

Once the pond has been prepared, juvenile crabs are introduced. The number of juvenile crabs stocked per pond depends upon the number available from the grow-out facility. Ponds can be stocked up to a maximum of 15,000 crabs. The initial total biomass (g) of the crabs is calculated based on the number of crabs added and their average weight. The crabs are fed daily in the early morning (7:00) and mid-afternoon (15:00). For two weeks, juveniles are fed daily a 40-45% protein commercial sinking starter feed at the rate of 10% of their initial biomass. Food is broadcast over the pond surface. At week three, fish pieces (~2-5 cm) are added at the rate of 25% of the diet by weight. Every two days the amount of fish in the diet is increased by 25% and the amount of commercial feed is reduced by 25% until the crabs on are a diet completely comprised of fish.

Pond measurements of dissolved oxygen (mg/L) and temperature (°C) are taken daily. Salinity (ppt), pH, alkalinity (mg/L), and water hardness (mg/L) are monitored biweekly, or as needed. These water quality parameters may be adjusted using standard aquaculture techniques, if necessary.

To harvest crabs, bushlines are placed in the pond when crabs reach ~ 40 to 50 mm CW. Ponds are non-vegetated so that the bushlines provide the only vegetated shelter in the pond. Bushlines made from line with wax myrtle attached at 1.5 m intervals along the line are set in the pond in a linear fashion. Multiple lines are spaced ~ 2 m apart. The bushlines rest just above the bottom of the pond. Pre-molt crabs are attracted to the bushes for shelter and protection during molting. Bushlines are checked daily by wading in the pond. Each bush is lifted and shaken into a dip net. The crabs are checked individually to see if they show signs of molting. Peelers (40 - 50 mm) and softshells (70 - 80 mm) are removed from the pond and placed in a moist, burlap-filled bucket. The wax myrtle bushes are replaced once the leaves begin to disintegrate, which is typically every three to four weeks.

Following harvest, pre-molt crabs are held in standard shedding systems until they molt. After the second week of harvesting, larger predatory crabs are removed from the ponds by using baited standard commercial crab traps equipped with escape rings. All crabs removed from the ponds or shedding trays are counted and weighed.

Once the pond has been fished out, the pond is drained and any remaining crabs are counted and weighed, percent survival is calculated, and food conversion ratios (amount of food given/total amount weight gain of harvested crabs) are determined.

RESULTS

Culture studies of blue crabs in the GCRL hatchery (Z1-megalopae) have resulted in continued improvements in system operation, feeding regime, and harvest techniques. With these improvements survival has increased to ~50% of the stocked zoeae, with megalopae comprising most of the harvest (~80%). These results are somewhat higher than those obtained by Zmora et al. (2005). Survival in initial grow-out has ranged from 6 - 10% (5 week holding period).

Daily feeding rate in the pond grow-out was 2.4 to 12.9 pounds/day. Survival in pond grow-out with the bushline harvesting technique was ~7%. Typical pond grow-out survival rates are 4 - 12%. The highest survival rate obtained from pond grow-out was ~28%, in which the crabs had a low initial stocking density and overwintered in the ponds. A total of 562 soft shell crabs were harvested from the shedding system. Cannibalism was the dominant factor in the number of soft shell crabs produced.

DISCUSSION

Research is needed in methods that will enhance survival of juvenile crabs prior to stocking them in ponds. Megalopae harvested from the hatchery are transported to grow-out raceways containing seawater of the same salinity as the larval systems (28 ‰). Salinity is lowered over time until the young crabs are acclimated to the pond salinity (1 ‰). Juveniles are held until they reach the C5/C6 stage (~ 15 to 20 mm carapace width) and moved. This stage was chosen based on studies by Zmora et al. (2005) where crabs were reared for release into the wild, and there was a long transport time to the release site. For pond stocking, we anticipate that this size could be reduced. Decreasing the acclimation period will increase survival as the small crabs can be moved to the ponds sooner. Daniels and Eggleston (2009) decreased acclimation period and stocking size for crabs in North Carolina and we anticipate that we too will be able reduce size at stocking and accelerate the acclimation rate.

For the bushline experiment, the pond was overstocked with crabs. Overstocking a pond exacerbated cannibalism, the most common difficulty of blue crab aquaculture. For future experiments, stocking densities will be lowered to prevent competition for habitat and resources. Future studies will also include varying harvesting techniques, including use of "snare booms" and traps filled with vegetation.

Blue crab pond aquaculture has great potential to supply small soft-shell crabs to market. Small soft-shell swimming crabs are currently imported into the U.S. for sale as "cocktail" or "appetizer" crabs and demand exceeds supply. Pond culture of soft crabs would greatly reduce pressure on natural populations and would allow for expansion of the fishery independent of wild stocks. Continuing market demand, profitability to the fishermen, and regional familiarity with pond cultured products all suggest that blue crab aquaculture for soft shell production would be an economically viable enterprise and would provide a measure of conservation to the fishery.

POTENTIAL FOR CARIBBEAN DEVELOPMENT

Nine species of *Callinectes* are distributed throughout the Caribbean, with six species having potential for soft crab fishery development. Perry et al. (1992) noted that species with the highest potential for fishery development belonged to the "*bocourti*" group. These species are the most euryhaline, are located in areas accessible to fishing and are large in size. The species in this group include *C. rathbunae*, *C. maracaiboensis*, *C. bocourti* and *C. sapidus*.

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