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Short communication

Potential of sites in northern Cuba for developing an industry of the native mangrove oyster (*Crassostrea rhizophorae*)

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ABSTRACT. Mangrove oysters (*Crassostrea rhizophorae*) were collected and raised for seven months at four sites (Punta Pargo, Jorobado, Cañete, and Enfermería) around Bahía Sagua La Grande on the north coast of Cuba, to determine which site offered the best conditions for cultivation of this commercially important species. Monthly measurements of oyster height were taken on 30 oysters randomly collected from each study site. Only oysters raised at Punta Pargo and Enfermería reached the mean commercial size (>40 mm) within the study period; these oysters were significantly larger than oysters raised at Cañete and Jorobado. No significant differences in survival between the sites were observed. Punta Pargo and Enfermería showed the best potential for oyster farming in the Bahía de Sagua area. Despite human impact on runoff caused by damming of the adjacent river, water quality remains acceptable for oyster cultivation. With proper stock management and production of selected fast-growing oysters in hatcheries, oyster farming can become an important aquaculture industry in Cuba.

Keywords: *Crassostrea rhizophorae*, growth, salinity, culture sites, Mar Caribe, Cuba.

Aquaculture has long been recognized with the potential to stimulate economic growth, create jobs, and provide food security in the Caribbean (CRFM, 2014). Aside from commercial production of aquaculture species in Belize and Jamaica, and improvements in cultivation technology in shrimp farming in Cuba, the Dominican Republic and Jamaica, aquaculture in most Caribbean countries is in the early stages of development (CRFM, 2014). Biological information on many aspects relating to aquaculture in this region is not available and is essential for promoting development of this industry.

Cuba is the largest aquaculture producer of fish and shrimp in the Caribbean (>20,000 ton in 2004), but this activity is still conducted with traditional, extensive technologies, mainly for fish production in reservoirs kept under natural conditions with community participation (FAO, 2005). Most of the species raised in Cuba are introduced (tilapia, carp, and whiteleg shrimp), which make up >95% of total aquaculture production. One of the few native species with high farming potential is the mangrove oyster (*Crassostrea rhizophorae* Guilding), which has been identified as one of the most important bivalves with farming potential in the Caribbean (Lodeiros *et al*., 1999; Lodeiros & Freites, 2008). In Cuba, oyster production of ~1500 ton per year is mainly based on fishing, although some local farming is conducted (Betanzos *et al*., 2014).

The fishing effort, combined with pollution, reduction in the use of inorganic fertilizers on farm land, and damming of rivers have caused a decline in productivity in coastal waters where oyster grow-out is conducted, which has caused in turn a decline in natural oyster populations (Baisre & Arboleya, 2006; Betanzos & Arencibia, 2010; Rivero-Suárez, 2012; Betanzos & Mazón-Suástegui, 2014). To increase production, information about oyster growth under culture conditions and physical and chemical parameters of potential farming sites is required. Since most aquaculture activities in Cuba are conducted inland, there is a great potential for expanding oyster production along the coast.

Important oyster growing areas in Cuba are located around Bahía Sagua La Grande, where ~20% of Cuban production is extracted (Betanzos *et al*., 2014). A lack of basic biological and environmental information of

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farming high valuable species in Cuba highlights the need for studies leading to higher production to generate income. The aim of this study was to determine what sites around Bahía Sagua La Grande offer the best conditions for farming the mangrove oyster.

Bahía Sagua La Grande is located in the northern coast of Cuba (Fig. 1). Four traditional sites where oyster fishing is conducted were selected to recruit and grow oysters. The four sites at 1) Punta Pargo, 2) Jorobado, 3) Cañete, and 4) Enfermería, are mangrove habitats.

In October 2009, 250 spat collectors made from 50 to 60 cm long branches of red mangrove, *Rhizophora mangle*, were set at each site. Spat collectors were tied among the mangrove roots at the forest edge at 1 m depth. One month after setting, collectors were retrieved and the branches where no spat settled were discarded to avoid new recruitment. The collectors were returned to the water and maintained until 50% of the spat reached 20 mm shell height. New recruits settled during this period were discarded. The collectors were moved in December 2009 to the intertidal zone and grow-out continued for five months with little or no maintenance.

Water temperature (±0.1°C), dissolved oxygen (±0.1 mg L^{-1}), and pH were measured with a multimeter each month. Salinity was measured with a handheld refractometer (±0.1), and transparency (%) was measured with a Secchi disc. All measurements were taken during high tide when oysters were submerged at least 30 cm. Approximate chlorophyll-*a* concentration was obtained from the Aqua Modis satellite images from the NASA database.

Measurements of oyster height were taken monthly on 30 oysters randomly collected from each site. Mood's median test was used to determine differences in oyster growth between sites. With this information, absolute growth (mm) was determined. The number of live oysters on three randomly selected spat collectors was counted at each site to determine total survival (%). One way ANOVA, followed by Fisher's LSD test, were used to determine differences in growth between sites.

Only oysters cultured in Punta Pargo and Enfermería reached the mean commercial size (>40 mm) within the study period (Table 1). These oysters were significantly larger than oysters grown at Cañete and Jorobado (χ^2 = 149.46, P < 0.05). There was no significant difference in survival among the sites. Mean survival was 77.7 ± 2.1% at Punta Pargo, 75.6 ± 1.8% at Jorobado, 78.6 ± 2.0% at Cañete, and 72.5 ± 2.7% at Enfermería.

There was little variation on salinity (Fig. 2) water temperature, dissolved oxygen, pH, and turbidity among the four sites (Table 2). With the exception of April, when salinity was at its lowest at all sites (33.5 ± 1.07), Enfermería had the highest salinity (>37.9) during the other months and Punta Pargo had the lowest salinity throughout the study (<37). Variations in environmental parameters are shown in Table 2. No di-

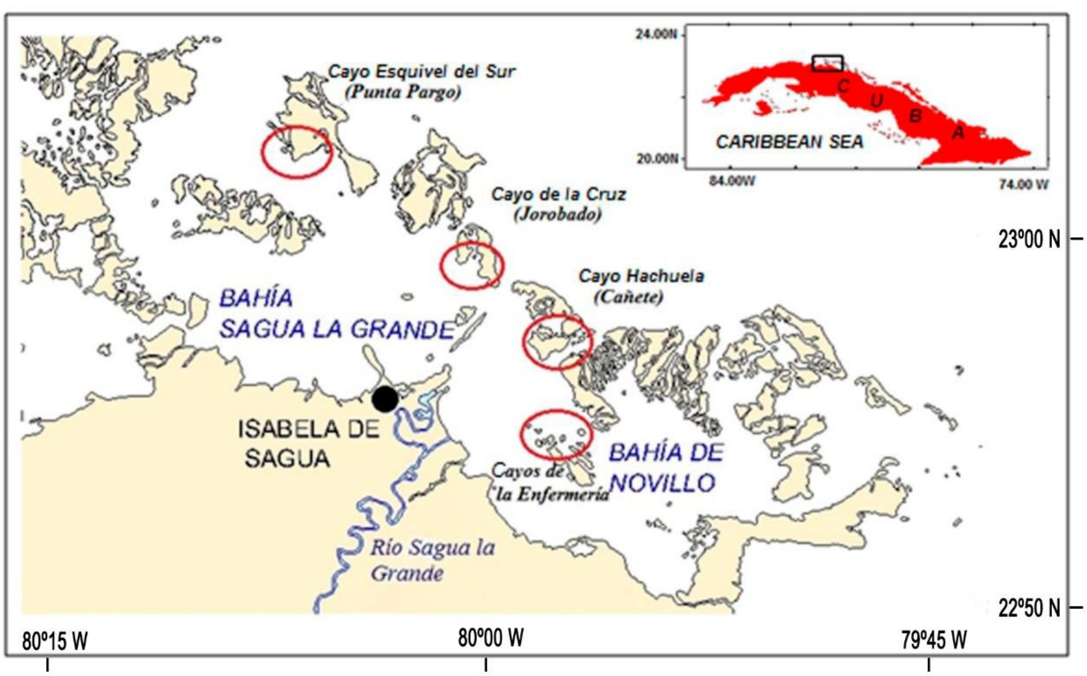

Figure 1. Location of four study sites in northern Cuba evaluated for their potential to grow the mangrove oyster *Crassostrea rhizophorae*.

Table 1. Mean (± SD) shell height of mangrove oyster *Crassostrea rhizophorae* during the sampling times. Different superscripts between sites during each month indicate significant differences.

Month	Punta Pargo	Jorobado	Cañete	Enfermería
December	18.6 ± 5.7[a]	17.9 ± 6.7[a]	18.8 ± 6.7[a]	19.3 ± 5.3[a]
January	30.0 ± 5.0[a]	26.9 ± 5.6[b]	27.0 ± 6.1[b]	29.6 ± 5.7[a]
February	34.3 ± 6.9[a]	31.4 ± 5.7[b]	30.9 ± 6.5[b]	34.3 ± 5.8[a]
March	37.5 ± 6.5[a]	34.0 ± 5.5[b]	33.4 ± 6.2[b]	39.5 ± 6.3[a]
April	40.0 ± 6.7[a]	35.0 ± 5.6[b]	34.8 ± 6.6[b]	40.9 ±5.9[a]
May	40.8 ± 5.5[a]	36.6 ± 5.4[b]	36.8 ± 5.7[b]	43.2 ± 4.7[a]

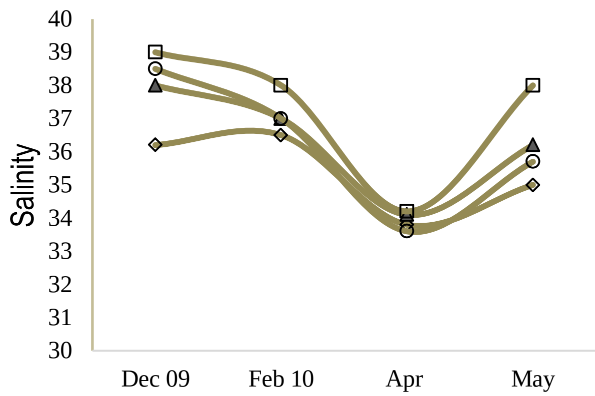

Figure 2. Mean salinity recorded at the experimental sites during the study period. □ Enfermeria; Δ Jorobado; ○ Cañete; ◊ Punta Pargo.

fferences in chlorophyll-*a* content between sites could be determined from the MODIS images.

Oysters cultured in Punta Pargo and Enfermería had the most rapid growth, despite the relative lack of differences in water quality between the sites. A previous study in the same sites showed that oyster meat yield (Lenz & Boehs, 2010) was greater at Punta Pargo (5.9%) and Enfermería (5.2%) while the lowest production was recorded in Cañete (4.9%). Seston quality (Freites *et al.*, 2010), especially at Enfermería, may have contributed to these differences in growth and meat production, since previous studies in the same area have reported that seston quantity between these sites is very similar (Rivero-Suárez, 2012). For example, different groups of microalgae showed similar seasonal density fluctuations (Rivero-Suárez, 2012), and the MODIS images suggest little or no variation in chlorophyll-*a* content between sites during this study.

Lower salinity has been recorded to the west and north of the Río Sagua La Grande. This is consistent with the great circulation patterns of the Gulf Stream, the Antilles Current, and the Florida Current (Gyory *et al.*, 2013a, 2013b). These currents bring marine water from the southeast in the Atlantic Ocean and move freshwater runoff from northern Cuba to the north and northwest, reducing salinity. In a previous study, sites south of the river (higher salinity) showed slower oyster growth, suggesting that *C. rhizophorae* is positively affected by freshwater runoff and negatively affected by reduced runoff from dam construction of the rivers (Baisre & Arboleya, 2006; Betanzos *et al.*, 2010). Tropical oysters appear to benefit from lowered salinities; for example, filtration rates in *C. rhizophorae* were highest at salinity of 25 (Madrigal *et al*., 1985; Alarcón & Zamora, 1993), which may explain the significant correlation between *C. rhizophorae* growth and salinity (Betanzos *et al.*, 2010; Betanzos & Mazón-Suástegui, 2014). Salinity likely affects composition and quality of seston, which influences growth rates of oysters cultured in these waters (Paterson *et al.*, 2003). In addition to lower salinities, runoff is an important source of nutrients that contribute to increase natural productivity (Nixon, 1995), and in turn may improve growth of filter feeding animals.

In the 1970s in this area, it was common to produce commercial-sized oysters (>50 mm) in five months (Sáenz, 1965; Simpson *et al.*, 1974; Nikolic *et al.*, 1976). The maximum mean size recorded in our study is lower, and even at the site with the most rapid growth, only a fraction of the oysters reached commercial size (>40 mm). The declining trend in oyster production since the 1980s is attributed to coastal pollution and reduced runoff resulting from dam construction along the Río Sagua La Grande, leading to higher salinity and lower nutrients (Betanzos & Arencibia, 2010).

Growth of oysters in this study was lower than oysters cultivated under subtidal conditions (Rivero-Suárez, 2012). Aerial exposure and reduced time oysters have to feed is species-dependent, but it usually leads to stress from desiccation, high temperatures, direct solar radiation, and lack of food and oxygen (Iglesias *et al.*, 2012; Angel-Dapa *et al.*, 2015). However, inter-tidal culture has the benefits of reduced maintenance because accumulation of biofouling of collectors and oysters is reduced by frequent air expo-

Table 2. Mean temperature (°C), transparency (%), pH, and dissolved oxygen (DO) at each site during the study period.

	Punta Pargo			
	Temp.ºC	Transp.	pH	DO
Dec 09	27		8.9	6.7
Feb 10	22.5	88		
Apr	26.5		8.3	6.6
May	26.3	75		
		Jorobado		
Dec 09	27.4		8.9	6.8
Feb 10	23.1	86		
Apr	25.9		8.6	6.9
May	26.6	75		
		Cañete		
Dec 09	27.8		8.9	6.1
Feb 10	24.2	86		
Apr	25.6		8.4	6.3
May	27	73		
		Enfermería		
Dec 09	28.2		8.5	6.1
Feb 10	24.6	83		
Apr	25.4		8.2	6
May	27.8	70		

sure. Due to reduced growth rates along this coast in recent years, a combination of sub- and inter-tidal systems may help improve production, while keeping production costs low. Survival remained high (>75%) in our study, consistent with survival values for cultivated *C. rhizophorae* at tropical locations in Venezuela, ranging from 53% (Lodeiros *et al*., 2007, Buitriago *et al*., 2009) to up to 94% (Hernández *et al*., 1998).

Punta Pargo and Enfermería showed the best potential for oyster farming in Bahía de Sagua. Despite human interference of runoff, water quality remains acceptable for oyster farming. With stock management and production of improved oysters (*e.g.*, faster growth and resistance to higher salinities) in hatcheries, the oyster industry can develop into an important aquaculture activity in Cuba.

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