Status of *Rangia cuneata* clams in Lake Borgne Louisiana after closure of the Mississippi River Gulf Outlet

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Introduction

The purpose of this report is to summarize data obtained in a 2018 study of Rangia clams and other invertebrates in Lake Borgne, Louisiana (Poirrier et al. 2018). The Lake Pontchartrain Basin Foundation provided funding and field and technical assistance for this study. The Mississippi River Gulf Outlet (MRGO) began operation in 1968. It was constructed to provide a direct route for large ships to pass directly from the Gulf of Mexico to an industrial complex near New Orleans. Due to high maintenance costs that exceeded economic benefits, damage to adjacent wetlands, flooding of New Orleans due to its contribution to the Hurricane Katrina storm surge and the need for future hurricane protection, the channel was closed to navigation in 2008 and damned in 2009 (Poirrier 2013, Shaffer et al. 2009). Operation of this large direct connection to the Gulf caused Lake Borgne salinity to increase to 8-22 (Shaffer et al. 2009) after MRGO construction and decrease to 3-10 (Lane et al. 2019) after closure. *Rangia* clams occur in low salinity Atlantic and Gulf Coast estuaries at salinities less than18 (Lasalle and de la Cruz 1985), but are most abundant in oligohaline waters that range in salinity from fresh to 5. These clams experience less competition and predation at oligohaline levels due to the lack of abundant and specialized species that occur at higher salinities.

Shell beaches backed by berms more than a meter high once characterized the Lake Borgne facing shorelines of the Biloxi Marsh Complex and the western shore of Lake Borgne, with *Rangia* clam shell deposits (Kemp and Day 2017). Because Rangia clams are more abundant at the lower salinities, increased salinity from the operation of the MRGO likely decreased clam densities. Fewer clams would have then caused less shell production in the sediment resulting in insufficient shells to maintain shoreline berms that help prevent erosion of the Biloxi marsh. On the other hand, the lower salinities after closure created a salinity regime that is conducive to the development of clams that produce more shell, resulting in the restoration of shoreline protection from shell berms. The lower salinities also provide conditions where appropriate management could accelerate repopulation of Lake Borgne by Rangia as discussed below.

The density of Rangia clams in Lake Borgne prior to the construction of the MRGO is unknown. However, abundant Rangia shells along the shore and in Native American middens indicate that high densities must have been present. During the operation of the MRGO, Abadie (1998) found the following numbers (N) of clams >20mm per m^2 at sites Bor2 (172), Bor3 (72) and Bor4 (57) and some recruitment of clams ≤5 mm in 1997(see Fig 1below from Poirrier et al 2018 for location of study sites). Samples obtained by Poirrier (unpublished data) in 2004 and 2005 did not include any clams (>20mm). In 2004 at site Bor3 he found 201 clams ≤5 mm and 29 clams 6-20 mm and at site Bor4 14, 6-20 mm clams/m^2. In 2005, at Bor2 and Bor3 he found14, 6-20 mm clams/m^2 and at Bor4 he found 86, 6-20 mm clams/m^2.

The current post-MRGO salinity range of 3-10 provides a suitable habitat for robust Rangia growth and reproduction, so recovery to levels that support berms is anticipated. Studies sponsored by the Lake Pontchartrain Foundation and conducted by Poirrier, Kerisit and Caputo (2018) found evidence of recovery of Rangia populations in western Lake Borgne. A prolonged period of decreasing salinity from 2014 – 2017 documented in LPBF Hydrocoast data (Poirrier et al. 2018) produced an overall shift in community structure of Lake Borgne from an oyster-

Mulinia to a Rangia ecozone. Ecozones are different benthic invertebrate communities in the Pontchartrain Basin established by Poirrier and Lopez that occur along the estuarine salinity gradient (Poirrier and Caputo 2015b, Conner et al. 2018).

Lake Borgne Benthic Community

Samples were collected from Lakes Maurepas and Pontchartrain in December 2017 and from Lake Borgne in February 2018 (see Fig 1below from Poirrier et al 2018 for site locations). A PRIMER cluster analysis of benthic invertebrate samples from Lakes Maurepas, Pontchartrain and Borgne generated two dissimilar groups (Poirrier et al. 2018). Group A included all Lake Maurepas and all Lake Pontchartrain replicates and 3 replicates from site Bor1and 1 replicate from site Bor 2 from the southwestern lobes of Lake Borgne.

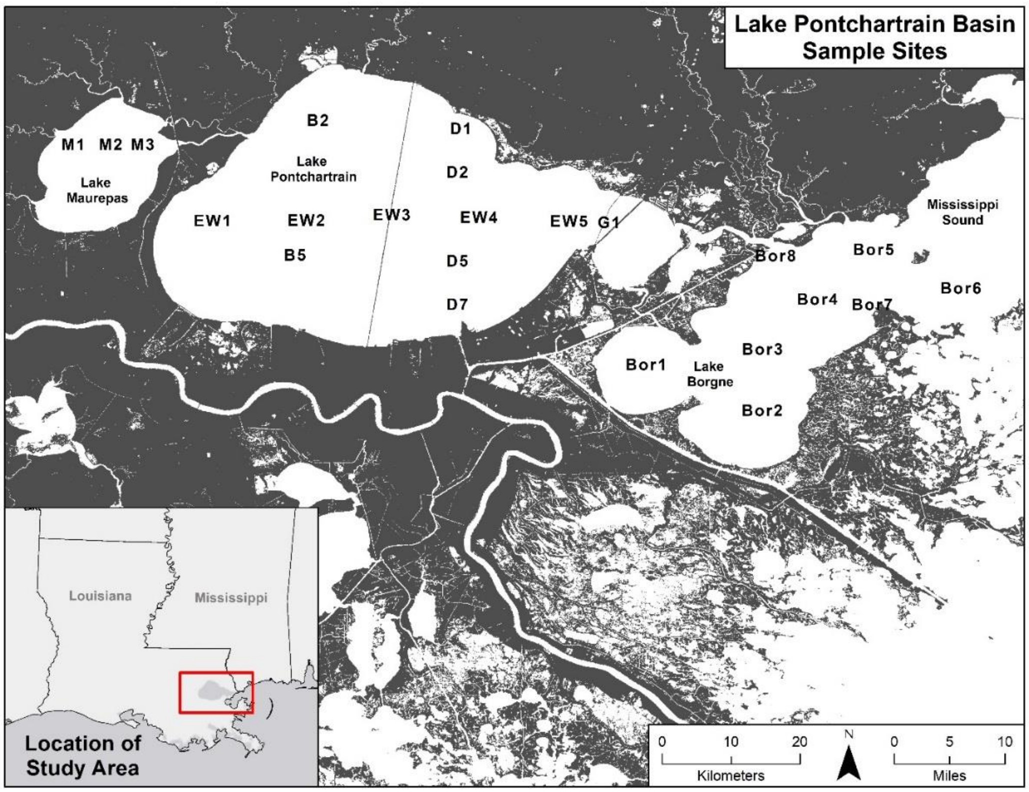

Figure 1. Benthic invertebrate and sediment sampling sites in Lakes Maurepas, Pontchartrain and Borgne.

Group B was composed of the rest of the Lake Borgne samples. A SIMPER analysis of taxa that contributed most to the separation of groups A and B indicated a separation of a high and low salinity *Rangia* ecozone with no evidence of the presence of oysters or abundant brackish clams *Mulinia* or other taxa indicative of the Oyster/*Mulinia* ecozone. High densities of the capitellid polychaete *Mediomastus*, an indicator of hypoxia, was important in separating group B. The grouping of samples from the southwestern lobes of Lake Borgne with Pontchartrain samples documents that a Rangia community similar to Lake Pontchartrain occurs in western Lake Borgne.

2018 Lake Borgne Rangia clam densities

Mean densities from three replicate petite Ponar samples collected in February 2018 did not find clams at Bor4 and Bor6, but they were present at other sites (Fig 10 from Poirrier et al. 2018). Of the sites that had clams, sites Bor3 and Bor7 had 1-5 mm clams but did not have clams greater than 5 mm. Three petite Ponar samples are not adequate to sample large clams when then occur at low densities. We used a small rake dredge which we towed for about three minutes to sample clams greater than 20 mm. Although these samples were not quantitative they helped document the presence or absence of large clams. The tow dredge did not collect clams at sites Bor6 and Bor7 (Table 8 from Poirrier et al 2018). Site Bor6 was the only site where clams were not detected using both sampling techniques. It was the most eastern and saline site. Sites Bor1 and Bor2 had the highest number of large clams in Ponar and tow rake samples. Overall, these results indicate good recruitment and high densities of clams in western Lake Borgne where shell beaches backed by berms were once present (Kemp and Day 2017) and the presence of recruitment and large clams in other areas of the Lake.

The mean site density of clams > 20 mm was 86 m^2 at the western site B2 (Table 8 from Poirrier et al 2018). The highest mean overall density of clams > 20 mm for all Lake Pontchartrain sites was 126 m^2 reported by Abadie (1998) from 1996 and 1997 samples. Her highest mean site density from three replicate samples was 602 in eastern Lake Pontchartrain. With recovery and management these high densities are likely to occur in western Lake Bornge with increasing episodes of salinity regimes that support vigorous Rangia reproduction and growth.

During this study Lake Borgne had shifting salinity salinities above 2, suitable for spawning and planktonic larval survival. Cain (1973) also found that in Chesapeake Bay, *Rangia* spawning occurred at temperatures greater than 15^{o} C. Spawning and recruitment in Lake Borgne occurred prior to our February 2 field work which recorded bottom temperatures of 11.2-13.8^{o} C. Indicating that, as suggested by Fairbanks (1963), *Rangia* spawning and recruitment in the Pontchartrain Basin occurs throughout the year. Kevin de Santiago a benthic ecologist with the LPBF reviewed Lake Pontchartrain Hydrocoast data and found that salinity shifts which occurred prior to February 2018 sampling could have been responsible for spawning and recruitment of ≤5 mm clams.

Low recruitment of 1-5 mm clams and no or few large clams in eastern Lake Borgne sites Bor4, Bor5, Bor6 and Bor7 may be related to higher salinities and hypoxia which sets up with salinity stratification. Inshore pulses of more saline waters needed to trigger spawning and required for embryo and larval survival might be too low in dissolved oxygen to provide this function. However, recruitment of 1-5 mm clams was high at sites Bor3 and Bor 8 which did not have clams larger than 6 mm indicating a problem with survival of small clams rather than recruitment. Further studies of correlations between salinity regimes in the Hydrocoast data and

Rangia recruitment are needed and should be rewarding. Interstitial sediment salinity, when higher than surface salinity, may also have a role in recruitment.

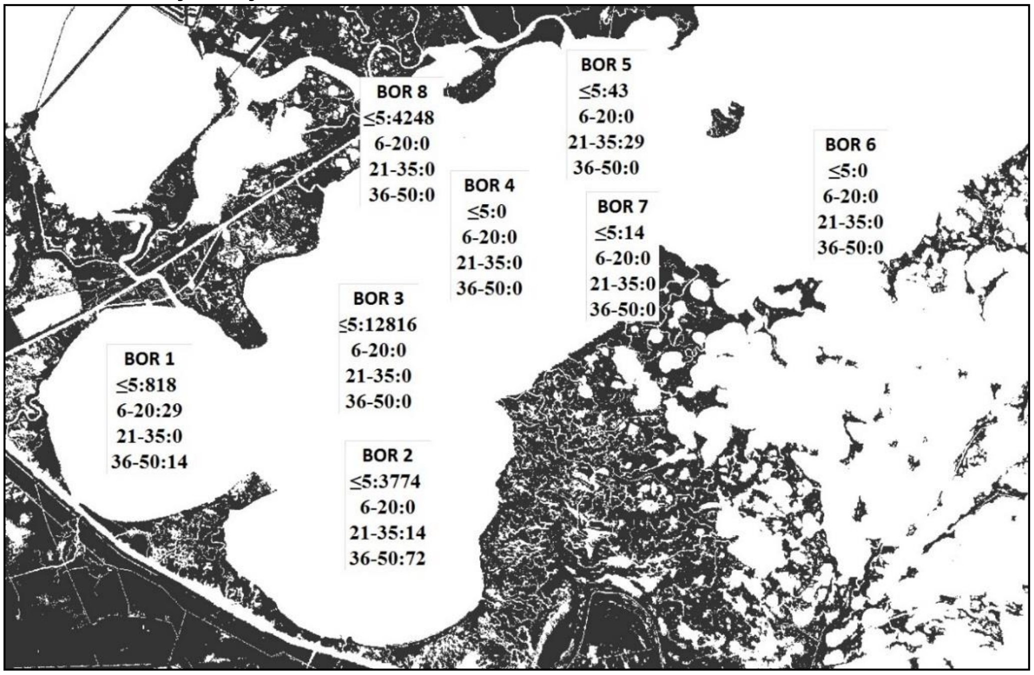

Figure 10. Map of Lake Borgne with mean density (N/m^2) of *Rangia* clam size classes in 2018 at all sites.

Table 8. Size distribution of *Rangia* clams ≥ 21 mm in 5 mm size classes from tow dredge samples from Lake Borgne sites.

Site	21-25 mm	26-30 mm	31-35 mm	36-40 mm	41-45 mm	46-50 mm	> 50 mm
Bor1	0	0	0	12	34	29	2
Bor2	25	8	4	4	2	1	1
Bor3	0	1	5	0	0	1	0
Bor4	0	3	2	6	0	0	0
Bor5	1	1	2	2	2	0	3
Bor6	0	0	0	0	0	0	0
Bor7	0	0	0	0	0	0	0
Bor8	0	2	1	4	1	1	0

2018 Shell Abundance in Lake Borgne

Shells present in one liter replicate sediment samples taken from the three estuarine Lakes were different. Mean weights in grams were 69.7 for Maurepas, 48.3 for Pontchartrain and 5.2 for Borgne. Shell and shell hash were mainly *Rangia*, but one Lake Pontchartrain site and two Lake Borgne sites had some oyster shell hash. Site Bor2 (Fig.12 from Poirrier et al 2018) had the highest shell weight of Lake Borgne sites and was in the range of eastern Lake Pontchartrain sites. This supports the view that clam and shell production are increasing in southwestern Lake Borgne.

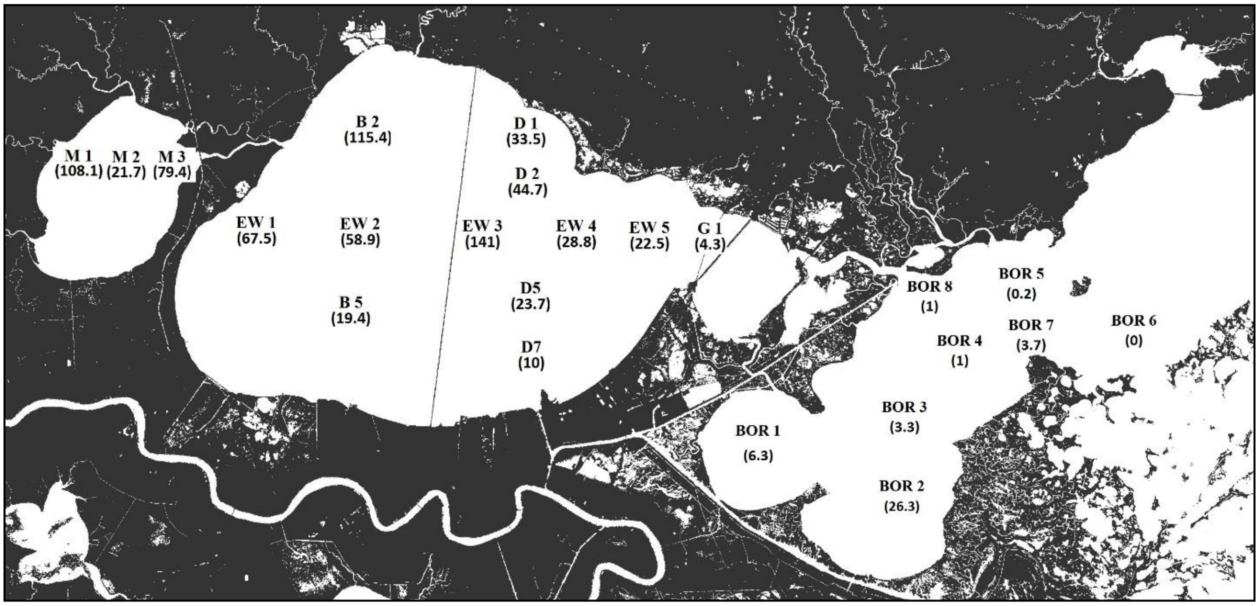

Figure 12. Mean weights of bivalve shells in grams in one liter of sediment from three petite Ponar samples from sites in Lakes Maurepas and Pontchartrain during December 2017 and Lake Borgne during February 2018.

Effects of disturbances on Lake Pontchatrain Rangia Clams

Poirrier and his associates conducted studies of Rangia densities in Lake Pontchartrain from 1996 through 2018. Information about changes in the densities of clams in adjacent Lake Pontchartrain should also apply to Lake Borgne. An important lesson learned from these studies is that clam population levels are very dynamic and natural disturbances such as salinity changes from El Nino Southern Oscillation Shifts and tropical cyclones produce changes in large clam abundance. These interact with anthropogenic, disturbances such as the shell dredging, operation of the MRGO and the Bonnet Carre Spillway etc. and unknown factors such as disease and changes in weather and climate. A straight line trajectory of increase should not be expected in clam restoration efforts, but like financial investments increases and decreases occur, but overall benefits accrue over the long term.

A brief review of the history of large clam densities in Lake Pontchartrain from Poirrier and Caputo (2015a) is as follows. Studies conducted in 1969-1972 (Tarver and Dugas 1973), 1978-1980 (Sikora and Sikora 1982) and 1982-1983 (Poirrier et al.1984) indicated declines in large clams (> 20 mm) in Lake Pontchartrain from 1954 baseline densities reported by Suttkus et al (1954). This drop was attributed to intensive commercial shell dredging that removed the clams but also fluidized the bottom of the lake, limiting recruitment (USACE 1987). Densities increased to 1954 levels after dredging was stopped in 1990, but large clams were still absent from a 250 km^2 area of Lake Pontchartrain subject to regular stratification caused by saltwater intrusion from the MRGO (Abadie and Poirrier 2000).

The post-dredging increase in large clam density from 1996 through 2000 was regarded as a return to normal conditions. However, this recovery was abruptly reversed by a 96% population decrease between 2000 and 2001, after the extreme drought of 1998-2000 gave rise to more extensive stratification and spread of high salinity bottom water. *Rangia* can survive at high salinities so Poirrier and Caputo (2015a) determined that the precipitous population decline was not a direct result of high salinity but, instead, to overgrowth by, and competition from the hooked mussel, *Ischadium recurvum*. Sustained periods of higher salinity in Lakes Borgne and Pontchartrain appear to favor establishment of a different benthic community. When the drought ended the hooked mussel declined and Rangia clams began to recover.

In 2005 Lake Pontchartrain experienced a direct hit from Hurricane Katrina, which produced a storm surge that eliminated clams and severely disturbed from 50% of the Lake bottom (Poirrier et al 2008). Katrina was followed by Rita in 2005 that produced an additional disturbance. Clams began to recover but Hurricane Gustav caused another disturbance and recovery was reversed by Isaac in 2010. Poirrier and Caputo (2015a) found that after four years without disturbances large increased to 1953 and 1997 levels. Much to our surprise, a recent study Poirrier et al (2018) found a decrease in Lake Pontchartrain salinities due to a long-term salinity decrease below two, which did not support Rangia clams reproduction and reduced clam abundance by eliminating young clams from the population. However, this was the salinity shift that contributed to the recovery of Lake Borgne clams.

Enhancement of Lake Borgne Rangia Clam Populations and Benefits to Coastal Louisiana.

Rangia clam populations and associated shell production could be increased by managing salinity and moving clams. Rangia clams require salinity shifts of plus or minus five to stimulate spawning and a salinity above two for embryo development and larval survival (Cain 1973, 1975). Salinity control structures should to be operated to provide periods that have salinity regimes that promote successful reproduction of Rangia. The Lake Pontchartrain Foundation Hyrdocoast Program and data collected by Comite Resources provide a summary of prevailing salinity throughout the Pontchartrain Basin that could be used to monitor where clam recruitment occurred and could predict where salinity management is needed. In addition, benthic ecozones established by Poirrier and Caputo (2015b) through studies supported by the Lake Pontchartrain Basin Foundation provide information on the distribution of Rangia and other ecozones in the Pontchartrain Basin.

Rangia populations could be enhanced by dredging mature clams from sites where they are abundant during periods when they are ready to spawn and placing them in areas that provide the needed salinity shift for spawning and larval development. This would stock mature clams and stimulate the production of thousands of small clams from each pair of male and female clam stocked.

Field and laboratory studies of factors that affect reproduction and the survival of young clams in Louisiana Rangia populations need to be conducted. Salinity values may be different from those of Cain (1973, 1975) and other factors may be involved. Rangia clams dominate the numerous oligohaline estuaries of coastal Louisiana. This report focused on shell production that produce shoals which extend into the water column and berms that stabilize eroding shorelines in Lake Borgne, but learning how to manage clam populations would also provide benefits to coastal restoration in the rest of Louisiana. Clams provide food for fish, crabs, shrimp and waterfowl. Shell production provides reef habitat by converting silt and clay sediment to hard shell bottoms. Clams filter suspended particles from the water to obtain food for growth and reproduction. Because of their abundance, they can improve water quality by removing suspended sediment, phytoplankton, and bacteria from the water column, which reduces eutrophication and increases water clarity and stabilizes bottom sediment. When clams are abundant, filtration increases water clarity which allows grass beds to expand into deeper water and enhances sediment build up. Clams can also colonize oyster habitat during low salinity periods and produce shells, which serve as oyster cultch. Natural production of shells by clams served as pioneer substratum for bottom reefs which helped build the Louisiana coast and also have an important, but unrecognized role in its sustainability. The environmental services that they provide for the restoration of coastal Louisiana could be enhanced through proactive restoration and management.

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