

TEXAS PARKS AND WILDLIFE DEPARTMENT – COASTAL FISHERIES DIVISION

Emaciated Black Drum Event

Baffin Bay and the upper Laguna Madre

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Executive Summary

September 2012, Texas Parks and Wildlife Department – Coastal Fisheries Division (TPWD-CF) staff received reports from commercial fish house operators and recreational fishermen regarding the condition and quality of black drum (*Pogonias cromis*) caught in the Baffin Bay complex of the upper Laguna Madre ecosystem (e.g. “skinny” or emaciated black drum with gelatinous fillets). These fish, typically caught in the Baffin Bay area, responded normally when hooked with rod and reel and showed normal coloration. From a subset of *P. cromis* examined, TPWD found an average of 15% underweight (n=57). Results from a lipid analysis of emaciated fish versus fish presumed to be normal showed the lipid content of the emaciated fish was seven times less than expected. TPWD-CF gill net catch rates as well as recreational and guided trip landings for the upper Laguna Madre (ULM) system have showed increasing trends over the past thirty years. While coastwide commercial landings for *P. cromis* have remained constant since 2007, a decrease in landings for the upper Laguna Madre was offset by an increase in landings for the lower Laguna Madre in 2012. Primary food sources for *P. cromis* in Baffin Bay are invertebrates with the largest component being the dwarf surf clam (*Mulinia lateralis*). High salinity levels in Baffin Bay resulting from an on-going drought may be leading to a decrease in *M. lateralis* populations as well as other invertebrates. As the population of *P. cromis* in the upper Laguna Madre ecosystem has been increasing for almost 30 years, a reduction in *M. lateralis* could potentially reduce the carrying capacity of *P. cromis* within Baffin Bay and adjacent areas of the upper Laguna Madre. The benthic community of Baffin Bay has not been characterized since the early 2000’s. Therefore, an updated assessment of Baffin Bay’s benthic community that includes *M. lateralis* is recommended in order to characterize the community status and relate it to environmental conditions. Additionally, a gut content or tissues analysis (elemental or stable isotope) of *P. cromis* could be beneficial in further tracking the impact of a potential decline in food sources. TPWD-CF staff will continue to address any concerns the public has regarding this situation and contact will be made with local commercial fish houses to determine if there are any further impacts.

Summary Report

Introduction

In early September 2012, Texas Parks and Wildlife Department – Coastal Fisheries Division (TPWD-CF) staff received the first notification from a commercial fish house in Riviera, TX of “skinny” black drum (*Pogonias cromis*) with “jelly-like” fillets in Baffin Bay. This was followed by a second report on September 18, 2012 when TPWD-CF received reports from Fisherman’s Market about emaciated *P. cromis* with characteristics similar to those previously reported. In early October, various reports were received by staff from recreational fishermen about skinny *P. cromis* with mushy, white, or small fillets. Recreational fishermen reported that despite the fish appearing skinny, the drum responded normally when hooked with rod and reel. In 2003, TPWD investigated skin lesions on *P. cromis*, but this is the first investigation of emaciated *P. cromis* in Baffin Bay and adjacent areas of the upper Laguna Madre (ULM). To investigate the probable cause of decreased quality and condition of *P. cromis*, several meetings were held among TPWD-CF staff from October through December 2012, with updates submitted to upper management. Steps taken to address the situation included characterizing the condition and population status of *P. cromis*, salinity trends and prey availability in Baffin Bay. Results are outlined in the following report.

Upper Laguna Madre/Baffin Bay *P. cromis*

Along the Texas coast, *P. cromis* are most numerous in the ULM/Baffin Bay ecosystem and have been shown to exhibit earlier maturation in this area compared to other Texas bay systems (Bumguardner et al. 1996). Additionally, Osburn and Matlock (1984) found that *P. cromis* (210-510 mm TL) movement between Texas bay systems was minimal and considered Texas bays to be closed systems with respect to the *P. cromis* population. However, Osburn and Matlock (1984) did detect extensive movement within bay systems attributed to year round foraging behavior. Bumguardner et al. (1996) suggested that an early maturing resident population may result in an increased spawning population which may serve to compensate for increased larval mortality under the harsh, hypersaline conditions of the ULM. Additional effects of salinity on adult *P. cromis* in the Baffin Bay area includes reports of glazed eyes presumably a result of the highly saline waters, which have been known to exceed 80‰ (Simmons and Breuer 1962). From these observations, *P. cromis* in Baffin Bay are clearly subjected to conditions different from those of the other Texas bay systems.

Pogonias cromis primarily feed on the dwarf surf clam (*Mulinia lateralis*) and other sessile bivalves (Pearson 1929, Gunter 1945, Miles 1949, Simmons and Breuer 1962, Cate and Evans, 1994). Martin (1979) completed an extensive study of the foraging behavior of *P. cromis* in tributaries of Baffin Bay (Alazan Bay and Laguna Salada). The dominate prey items in non-empty stomachs were comprised of *M. lateralis* (94.4% in Alazan Bay and 72.0% in Laguna Salada) followed by *Amygdalum papyrium* (58.3% in Alazan Bay and 36.0% in Laguna Salada) and *Tagelus plebeius* (9.7% in Alazan Bay and 50.0% in Laguna Salada). Smaller drum (<300 mm TL) were found to consume higher frequencies of softer prey including Amphipods and Polychaetes. This agrees with work done by Pearson (1929). Other crustacean and fish forage items were fairly minimal and not considered significant (Martin 1979).

Due to the fact that gut content analysis is the primary means of diet assessments in the above studies, expected differential digestion rates of the various food items (e.g. soft bodied Polychaetes versus hard shelled Molluscs) may have impacted the analyses of these data. While the information we glean from these studies is very useful, it is important to keep this potential bias in mind.

***P. cromis* Condition**

To determine the condition of the fish, TPWD staff performed necropsies, condition factor analysis and lipid profile analysis. TPWD-CF fall 2012 gill nets collected *P. cromis* in both Baffin Bay and the ULM for analysis. The J.F.K. Causeway area in the ULM was used as a reference site, 26 miles north of Baffin Bay, for comparison because commercial fishermen relocated this area for improved fillet quality.

Externally, suspected emaciated fish exhibited reduced white muscle along the dorsal spine giving the “skinny” appearance. Necropsies demonstrated reduced white, gelatinous filets with little to no digestate in the gut and internal organs appearing atrophied (Figure 1). All fish were void of other known maladies such as skin lesions or glazed eyes.

A Fulton condition factor (K) was calculated using the following equation:

$$K = (WW/TL^3)*100,$$

where WW is whole wet weight and TL is total length. This condition factor is commonly used to assess general health and is based on work by Fulton (1904). Using this approach, fish from Baffin Bay showed a mean K of 1.19 (min=1.06, max=1.38, n=37, TL=219-596 mm) while those from the JFK causeway area showed a mean K of 1.36 (min=1.18, max=1.53, n=30, TL=295-592). For an additional comparison, K values were calculated for *P. cromis* collected in the upper Laguna Madre from 1992 to 1994 (Bumgardner et al. 1996). Mean K was 1.33 (min=0.87, max=1.71, n=427, TL=400-600 mm).

Expected weight was calculated according to Harrington et al. (1979) in which total length and whole weight data from *P. cromis* collected from the Texas Coast were fitted to the following exponential equation:

$$WW = a*TL^b,$$

where WW and TL are as described above, a= -4.856, and b= 3.001. Logarithmic transformations resulted in the following linear equation:

$$\log WW = \log a + b*\log TL,$$

We used this relationship to calculate expected whole wet weight of *P. cromis* using total length measurements of fish collected from TPWD gill nets and compared actual wet weight calculations to expected wet weight calculations as follows:

$$(\text{Actual wet weight} / \text{Expected wet weight})*100 = K_{\text{relative}}$$

This is often referred to as a relative condition factor (K_{relative}) and allows us to assess the amount of deviation of an individual fish from the species specific average weight at a given length (La Cren 1951). K_{relative} is often considered a more useful condition factor than the Fulton condition factor (K) outlined earlier though we feel examination of both values is the most robust approach.

From these calculations we found that fish from Baffin Bay were, on average, 15% under weight (K_{relative} mean= 85.26%, min=75.81%, max=98.2%, n=37) (Table 1). Fish caught near the JFK Causeway during this same period of time were about 3% underweight (K_{relative} mean= 96.72%, min= 84.27%, max=109.27%, n=30) (Figure 2).

An additional lipid profile analysis conducted by Dr. Delbert Gatlin at Texas A&M University at College Station showed that the lipid content of the underweight fish was over seven times less than that expected for a presumable normal fish (Figure 2).

Based on analysis presented emaciation of *P. cromis* was confirmed and shown to be limited to Baffin Bay area.

Brown Tide Assessment

The Brown tide organism (*Aureoumbra lagunensis*) is reported to occur at varying levels of bloom concentrations, since its occurrence in the ULM ecosystem in 1990. Water samples were collected initially collected at fish collection sites and provided to Dr. Paul Zimba with Texas A&M University Corpus Christi - Center for Coastal Studies (TAMUCC-CCS) for analysis of *A. lagunensis* concentrations. A literature review was conducted to address a potential connection between *A. lagunensis* and *P. cromis* food stocks, focusing on *M. lateralis*. Water samples were found to contain low concentrations of the brown tide organism. *A. lagunensis* bloom was initially identified in late March, subsiding in late summer 2012. The effects of brown tide appear to be negligible to both *P. cromis* and prey items, suggesting the contribution of the *A. lagunensis* bloom to the condition of *P. cromis* may be negligible and overridden by other factors.

Status of ULM *P. cromis*

TPWD-CF routine gill net sampling in the ULM ecosystem, including Baffin Bay, shows an increasing population trend for *P. cromis* since 1983 (Figure 2). Annual private landings for *P. cromis* in the upper Laguna Madre have continued to increase over the past 29 years with a peak from 1993-1997 (Figure 3). Annual guided landings have also continued to increase over the past 29 years with a peak from 1999-2000 (Figure 4).

Status of *P. cromis* commercial fishery

Based on Trip Ticket Program reported landings from 2007 to 2012, the average annual estimated coastwide commercial landings by weight for black drum is 1.65 million lbs (ranging from 1.47 million lbs in 2008 to 1.79 million lbs in 2011). The average annual ex-vessel value of the catch was \$1,484,545 per year. The ULM system, which extends from the southern end of Corpus Christi Bay to the southern end of the Land Cut (approximately 61.5 miles and includes Baffin Bay), contributes significantly to coastwide landings, ranging from 60% to 76% by weight since 2007. However, while the reported coastwide landings for 2012 was 1.6 million lbs, the ULM's contribution to the coastwide total of 46% was the lowest reported since 2007.

On average, an estimated 373,865 individual black drum were landed annually coastwide, ranging from 356,641 in 2008 to 386,076 in 2007. The ULM system contributes on average 64% of this total annually, with the fewest landed during 2012 with 157,009 individuals or 44% of the total.

Since 2007, commercially landed black drum taken from the ULM were on average 11 mm longer (ranging from 3 to 20 mm) than the coastwide average (524 mm) and the average weights were 2% to 12% more than the coastwide average of 2.015 kg (4.44 lbs). In 2011, the mean lengths, both coastwide and in the ULM were the longest recorded since 2007.

Baffin Bay typically contributes in the range of 63% to 75% of the entire ULM system landings. In 2011, Baffin Bay landings dropped to 55% of the total landings and dropped again in 2012 to 46% of the

landings attributed to the entire ULM system. Baffin Bay saw roughly a 33% drop in production by weight in 2012.

Overall, the commercial *P. cromis* fishery in the ULM system may have been affected by any one or combination of numerous environmental events occurring in 2011. These events included record or near record high average salinities (a result of the ongoing drought), record high air temperatures, increased brown tide abundance, or the September 2010 fish kill in Baffin Bay that was attributed to a harmful algal bloom in which *P. cromis* comprised 11% of the fish killed. Nevertheless, 2011 landings from the ULM system, while still significant, were the lowest reported since 2007. In numbers of individual fish, the lowest estimates for the ULM system occurred in 2011, although each fish weighed more. These above-average weights could possibly be due to an abundant food source and/or the documented early sexual maturity of black drum, a trait unique to the system. A possible shift in fishing effort from Baffin Bay to the ULM proper, as a result of the above-mentioned environmental events, is indeed indicated by reported landing locations. Nevertheless, from both the local and the coastwide perspective, commercial landings of black drum remain robust along the Texas coast.

Salinity Trends

Despite having very different underlying salinity regimes, the major estuaries of the Texas coast all appear to be operating in near unison to low frequency climate forcing signals, namely the El Niño-Southern Oscillation (ENSO) indices of Niño 3.4 sea surface temperature anomaly, atmospheric Southern Oscillation sea level pressure anomaly, and Pacific Decadal Oscillation sea surface temperature anomaly (Tolan 2007). Analyzing the salinity records recorded by TPWD-CF routine monitoring from 1982-2004, Tolan (2007) was able to show that most of the variation in salinity was related primarily to five fundamental frequencies (1.02, 1.94, 3.55, 5.33, and 10.67 years), and these periodicities closely correspond with frequencies related to the ENSO measures. The correlation of the ULM to the coastwide derived first mode of the Empirical Orthogonal Function was 0.836. The influence of these low frequency signals is evident in the mean salinity time series presented in Figure 5, where the 5.33 year cycle (most closely associated with the Niño 3.4 sea surface temperature anomaly) appears to have the greatest degree of influence on the salinity structure of this estuary.

The ULM, and especially the Baffin Bay complex, is considered to be a hypersaline (>40‰) estuary with mean salinity of 36.5 ‰ (SD = 10.8, n = 6,688). From the time series in Figure 5, it is clear that the estuary rarely maintains salinity near the mean for any extended period of time, but rather experiences dramatic swings in salinity ranging from brackish conditions (e.g., flooding conditions present in 1992 and 2010) to periods of extended drought and salinities in excess of 60‰ (e.g., 1990, 1997, and the ongoing drought of 2011-2012) (Figure 8). More notable than the magnitude of the high salinity conditions experienced in the Baffin Bay complex (TPWD-CF routine monitoring bag seine sampling has recorded salinity in excess of 90‰) are the durations of these high salinity events. For example, the period around 1990 saw average salinities > 50‰ maintained for more than 2 calendar years, and these extended high salinity conditions were also noted from the period around 2000-2002. These decadal oscillations of high salinities are a prominent feature in Baffin Bay. The most recent high salinity event, beginning in 2011 and continuing through the 2012 calendar year, appears to be a manifestation of this decadal oscillation. The temporal duration of this event is also in the same magnitude of previous high salinity events.

***P. cromis* Forage**

Confirmation of emaciated *P. cromis* raised concerns of prey availability in Baffin Bay. Efforts to address these concerns focused on the dominant food stock, *M. lateralis*, as an indicator species in Baffin Bay.

This included a literature review and spatial analysis of distribution (Appendix A), and power analysis to determine potential sample effort (Appendix B).

Spatial and seasonal trends in data as discussed in Appendix A indicate *M. lateralis* densities increase along a spatial gradient from ULM proper into the tributaries of Baffin Bay. Observations indicate lower densities of *M. lateralis* are consistently observed in the summer months while higher densities are observed in the winter, spring, and fall. From the data analyzed, it is difficult to determine a specific season in which peak abundance occurs as the timing of seasonal sampling was inconsistent throughout the study period. However, *M. lateralis* density and overall abundance may vary with yearly fluctuations in rainfall and other meteorological events (Montagna and Kalke 1995). A potential reduction of *M. lateralis* in Baffin Bay could be a combination of factors, including poor recruitment, over predation, as well as naturally occurring seasonal changes (i.e. low population densities seen during late summer and fall) and the benthic community response to a prolonged drought. A complete report of findings is located in Appendix A.

In order to determine the level of sampling effort needed to detect population changes in *M. lateralis*, data from previous Regional Coastal Assessment Project was utilized (Nicolau and Nuñez, 2004; Nicolau and Nuñez, 2005a; Nicolau and Nuñez, 2005b; Nicolau and Nuñez, 2006). Based on a power analysis, the total number of samples needed to detect a 50% difference in *M. lateralis* densities would be 296 pairs of samples (Figure 3). If a 15% target for change is desired, then the sampling effort would increase to 10,000+ pairs of samples. The smaller the % difference, the larger the sample size becomes due to the extreme amount of natural variability seen in the density levels of *Mulinia* within Baffin Bay.

Synopsis

Concerns of “skinny” *P. cromis* with “jelly-like” fillets prompted TPWD staff to investigate the condition of *P. cromis* in Baffin Bay. Through a series of steps outlined in the report, staff confirmed emaciated *P. cromis* limited to Baffin Bay. Emaciated condition of *P. cromis* raised concerns of reduced prey availability in Baffin Bay. Efforts to address these concerns included a literature review of the dominant food stock, *Mulinia lateralis* populations in Baffin Bay. A potential reduction of prey (i.e. *M. lateralis*) in Baffin Bay could be a combination of factors, including poor recruitment, over predation, as well as naturally occurring seasonal changes (i.e. low population densities seen during late summer and fall) and a prolonged drought. As the population of *P. cromis* in the ULM has been increasing for almost 30 years, a reduction in food sources could potentially reduce the carrying capacity of *P. cromis* within Baffin Bay and adjacent areas of the ULM resulting in the emaciated drum.

Future Efforts

As of January 14, 2013, reports from a fish-house operator in Riviera, TX indicated fish caught at the mouth of Baffin Bay and within Baffin Bay appeared healthy (i.e. not emaciated and normal muscle tissue). TPWD-CF staff will continue to make contact with commercial fish-house operators to monitor the impacts of the situation and determine when commercial fishing in Baffin Bay returns to pre-event levels as some of the commercial fishermen relocated to other areas. Any unusual fillets from fish landed by commercial fisherman will be examined by TPWD-CF staff and documented. Additional information on the current status of the benthic community, including *M. lateralis*, in Baffin Bay as well as gut content or tissues analysis (elemental or stable isotope) of *P. cromis* could be beneficial in further tracking the impact of a potential decline in food sources or an ecosystem-wide trophic shift in its feeding mode of the species. As this event was localized, brief, and specific to one species, TPWD-CF staff will continue to respond to all questions regarding the issue.

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Table

Table 1. Data collected from TPWD-CF 2012 fall gill nets from Baffin Bay and the upper Laguna Madre (ULM) of *P. cromis*. Samples for %Wet Lipid sent off to Dr. Delbert Gatlin at A&M College Station for analysis (* denotes control or “healthy” fish to be compared to five underweight fish).

Date Collected	Location Collected	Length (mm)	Weight (kg)	Expected weight(kg)	Actual/Expected (K _n)	K	% wet lipid
10/16/12	Baffin Bay	431	0.97	1.12219	86.44%	1.21155	*4.62400
10/16/12	Baffin Bay	486	1.27	1.60915	78.92%	1.10636	0.77448
10/16/12	Baffin Bay	462	1.06	1.38226	76.69%	1.07493	0.87920
10/16/12	Baffin Bay	429	0.90	1.10663	81.33%	1.13991	3.13434
10/16/12	Baffin Bay	463	1.21	1.39126	86.97%	1.21911	2.32812
10/16/12	Baffin Bay	596	2.53	2.96834	85.23%	1.19504	0.62429
10/25/12	Baffin Bay	332	0.50	0.51279	97.51%	1.36633	
10/25/12	Baffin Bay	316	0.39	0.44214	88.21%	1.23596	
10/25/12	Baffin Bay	333	0.43	0.51743	83.10%	1.16449	
10/25/12	Baffin Bay	334	0.47	0.52211	90.02%	1.26142	
10/25/12	Baffin Bay	487	1.34	1.61910	82.76%	1.16016	
10/25/12	Baffin Bay	410	0.82	0.96597	84.89%	1.18977	
10/25/12	Baffin Bay	242	0.19	0.19853	95.70%	1.34063	
10/25/12	Baffin Bay	219	0.12	0.14712	81.57%	1.14248	
10/25/12	Baffin Bay	221	0.14	0.15119	92.60%	1.29703	
10/25/12	Baffin Bay	246	0.18	0.20854	86.31%	1.20911	
10/25/12	Baffin Bay	409	0.78	0.95892	81.34%	1.14005	
10/25/12	Baffin Bay	425	0.93	1.07596	86.43%	1.21148	
10/25/12	Baffin Bay	370	0.58	0.70986	81.71%	1.14505	
10/25/12	Baffin Bay	350	0.59	0.60083	98.20%	1.37609	
10/25/12	Baffin Bay	400	0.74	0.89698	82.50%	1.15625	
10/25/12	Baffin Bay	411	0.88	0.97306	90.44%	1.26753	
10/25/12	Baffin Bay	428	0.90	1.09891	81.90%	1.14792	
10/25/12	Baffin Bay	386	0.68	0.80602	84.36%	1.18235	
10/25/12	Baffin Bay	400	0.68	0.89698	75.81%	1.06250	
10/25/12	Baffin Bay	409	0.80	0.95892	83.43%	1.16928	
10/25/12	Baffin Bay	402	0.77	0.91051	84.57%	1.18526	
10/25/12	Baffin Bay	360	0.57	0.65383	87.18%	1.22171	
10/25/12	Baffin Bay	296	0.31	0.36337	85.31%	1.19533	
10/25/12	Baffin Bay	355	0.54	0.62695	86.13%	1.20700	
10/25/12	Baffin Bay	391	0.73	0.83777	87.14%	1.22122	
10/25/12	Baffin Bay	328	0.43	0.49447	86.96%	1.21856	
10/25/12	Baffin Bay	344	0.46	0.57044	80.64%	1.13001	
10/25/12	Baffin Bay	344	0.49	0.57044	85.90%	1.20371	
10/25/12	Baffin Bay	317	0.35	0.44635	78.41%	1.09873	
10/25/12	Baffin Bay	347	0.51	0.58550	87.10%	1.22062	

Date Collected	Location Collected	Length (mm)	Weight (kg)	Expected weight(kg)	Actual/Expected (K _n)	K	% wet lipid
11/14/12	JFK	395	0.77	0.86375	89.15%	1.24939	
11/14/12	JFK	381	0.78	0.77510	100.63%	1.41033	
11/14/12	JFK	438	1.06	1.17778	90.00%	1.26149	
11/14/12	JFK	471	1.47	1.46466	100.36%	1.40687	
11/14/12	JFK	498	1.49	1.73135	86.06%	1.20642	
11/14/12	JFK	449	1.19	1.26879	93.79%	1.31464	
11/14/12	JFK	409	0.95	0.95892	99.07%	1.38852	
11/14/12	JFK	458	1.25	1.34666	92.82%	1.30111	
11/14/12	JFK	505	1.76	1.80542	97.48%	1.36659	
11/14/12	JFK	444	1.11	1.22686	90.47%	1.26816	
11/14/12	JFK	567	2.30	2.55566	90.00%	1.26177	
11/14/12	JFK	456	1.12	1.32909	84.27%	1.18120	
11/14/12	JFK	410	0.92	0.96597	95.24%	1.33486	
11/14/12	JFK	400	0.80	0.89698	89.19%	1.25000	
11/14/12	JFK	555	2.33	2.39675	97.21%	1.36294	
11/15/12	JFK	295	0.35	0.35970	97.30%	1.36333	
11/15/12	JFK	444	1.30	1.22686	105.96%	1.48523	
11/15/12	JFK	552	2.38	2.35808	100.93%	1.41501	
11/15/12	JFK	548	2.27	2.30717	98.39%	1.37938	
11/15/12	JFK	592	2.84	2.90896	97.63%	1.36884	
11/15/12	JFK	451	1.33	1.28583	103.44%	1.44985	
11/15/12	JFK	478	1.44	1.53096	94.06%	1.31850	
11/15/12	JFK	512	1.78	1.88156	94.60%	1.32620	
11/15/12	JFK	468	1.57	1.43684	109.27%	1.53166	
11/15/12	JFK	475	1.62	1.50230	107.83%	1.51159	
11/15/12	JFK	421	1.13	1.04585	108.05%	1.51437	
11/15/12	JFK	447	1.24	1.25191	99.05%	1.38835	
11/15/12	JFK	371	0.68	0.71563	95.02%	1.33164	
11/15/12	JFK	447	1.27	1.25191	101.45%	1.42194	
11/15/12	JFK	409	0.89	0.95892	92.81%	1.30083	

Figures

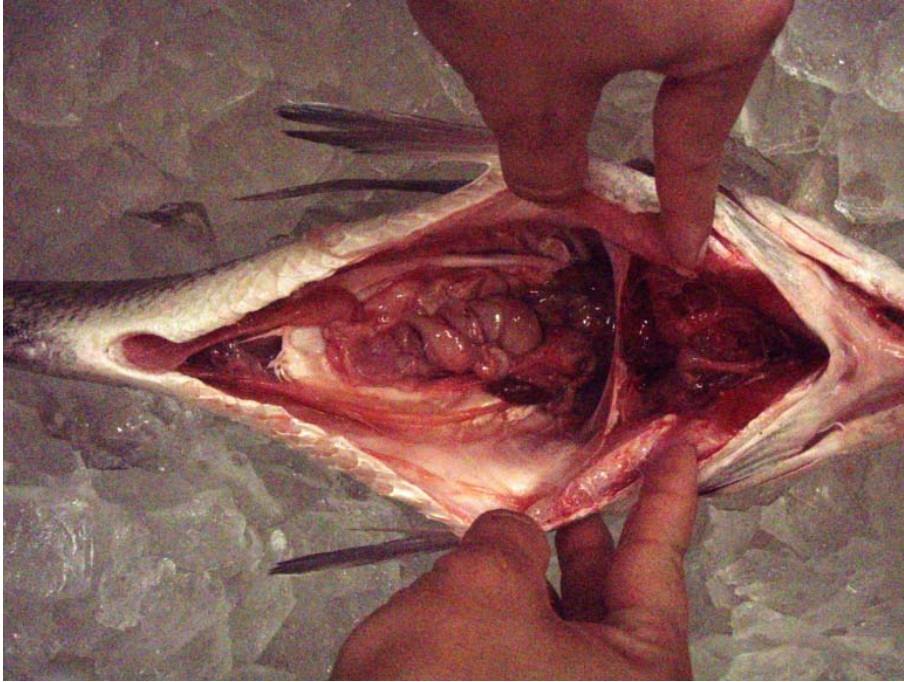


Figure 1. Image of inside cavity and organs of emaciated *P. cromis*

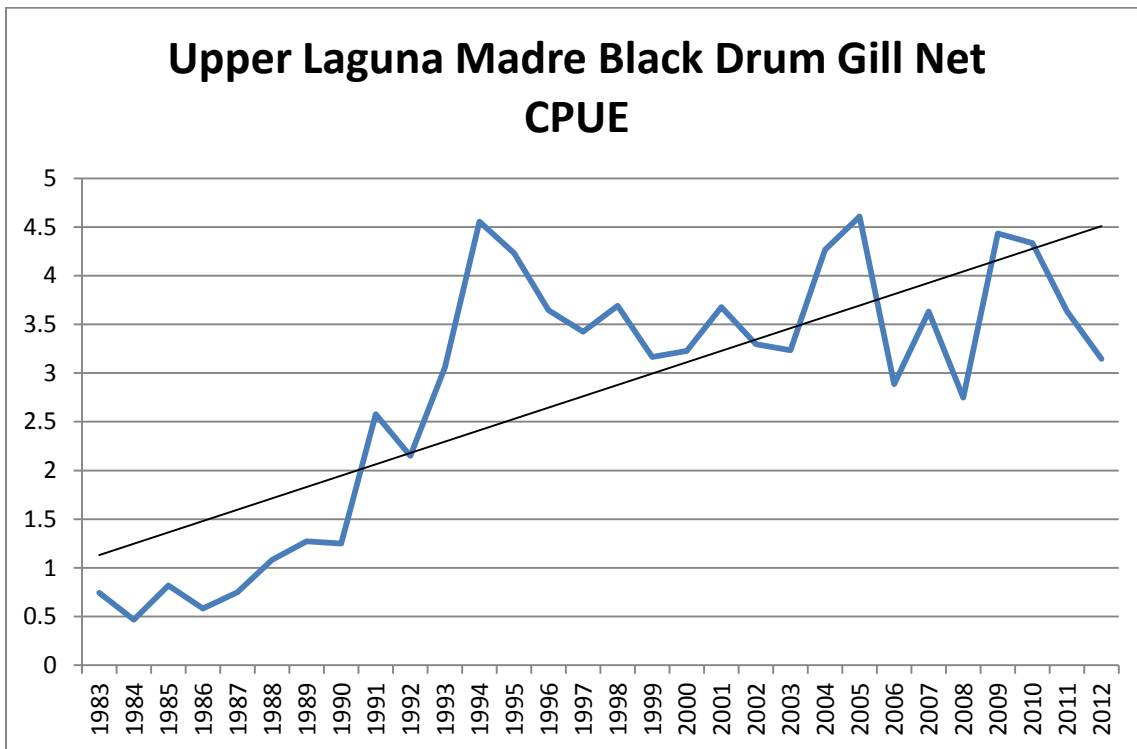


Figure 2. Annual catch per hour of black drum (*P. cromis*) in ULM gill nets using TPWD data from 1983-2012.

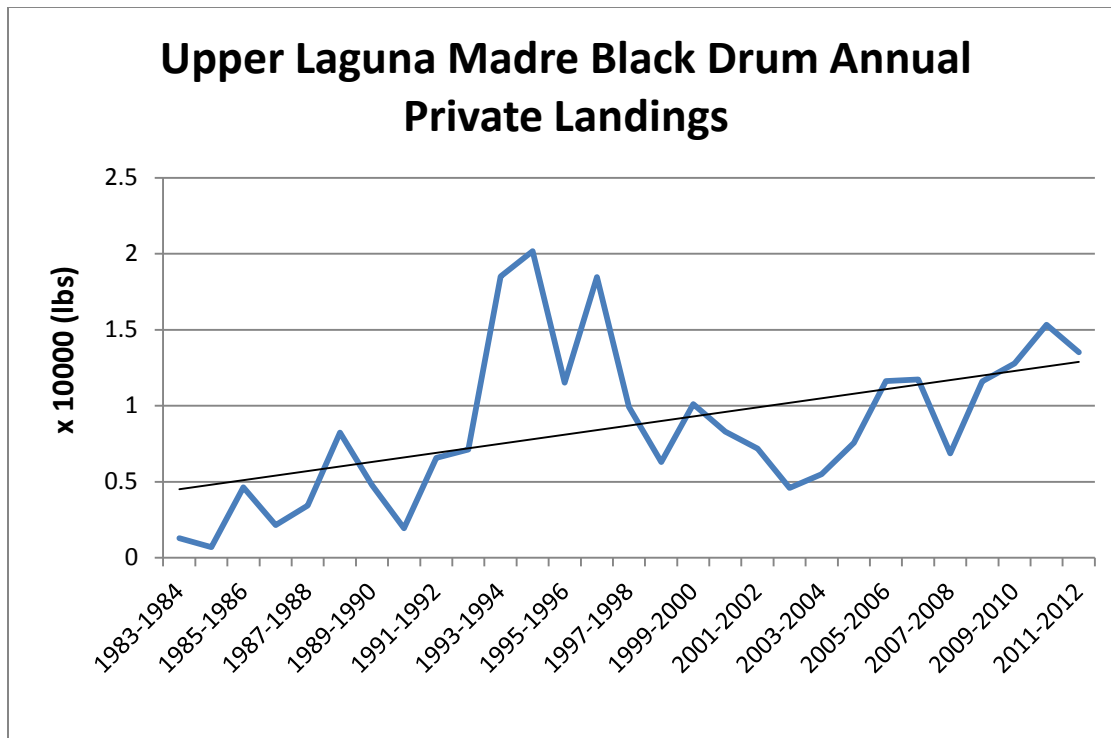


Figure 3. Annual private landings in pounds for black drum (*P. cromis*) in the upper Laguna Madre (1983-2012).

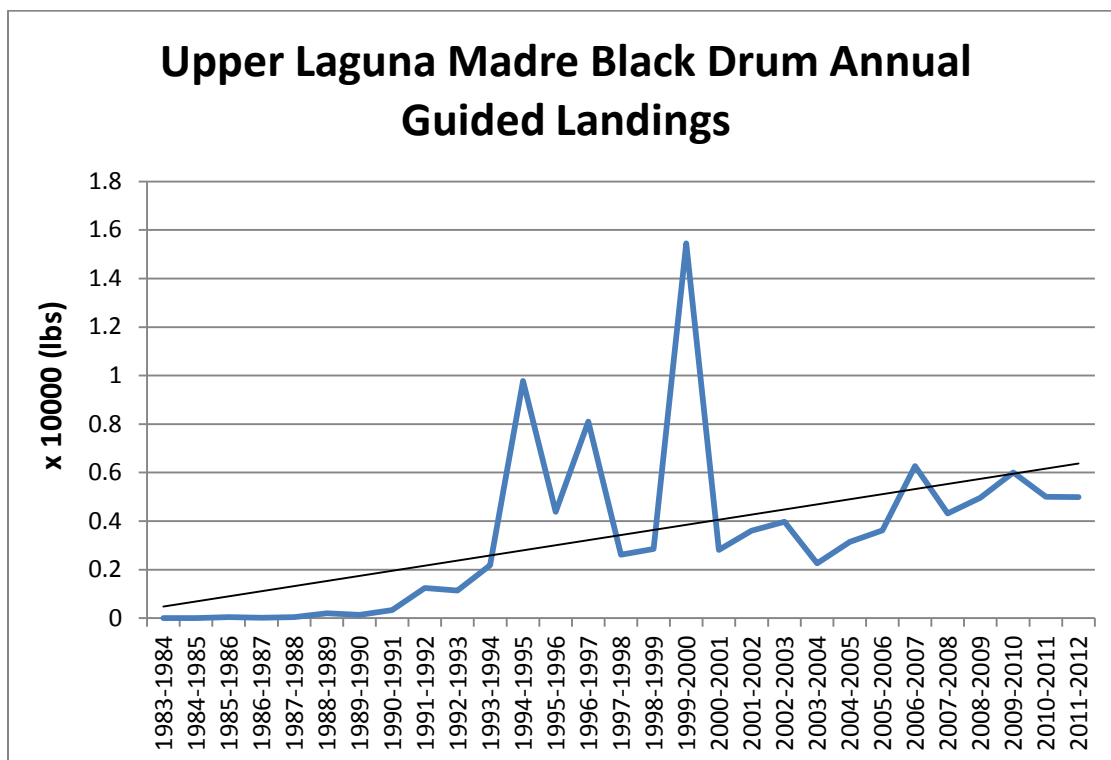


Figure 4. Annual guided landings in pounds for black drum (*P. cromis*) in the upper Laguna Madre (1983-2012)

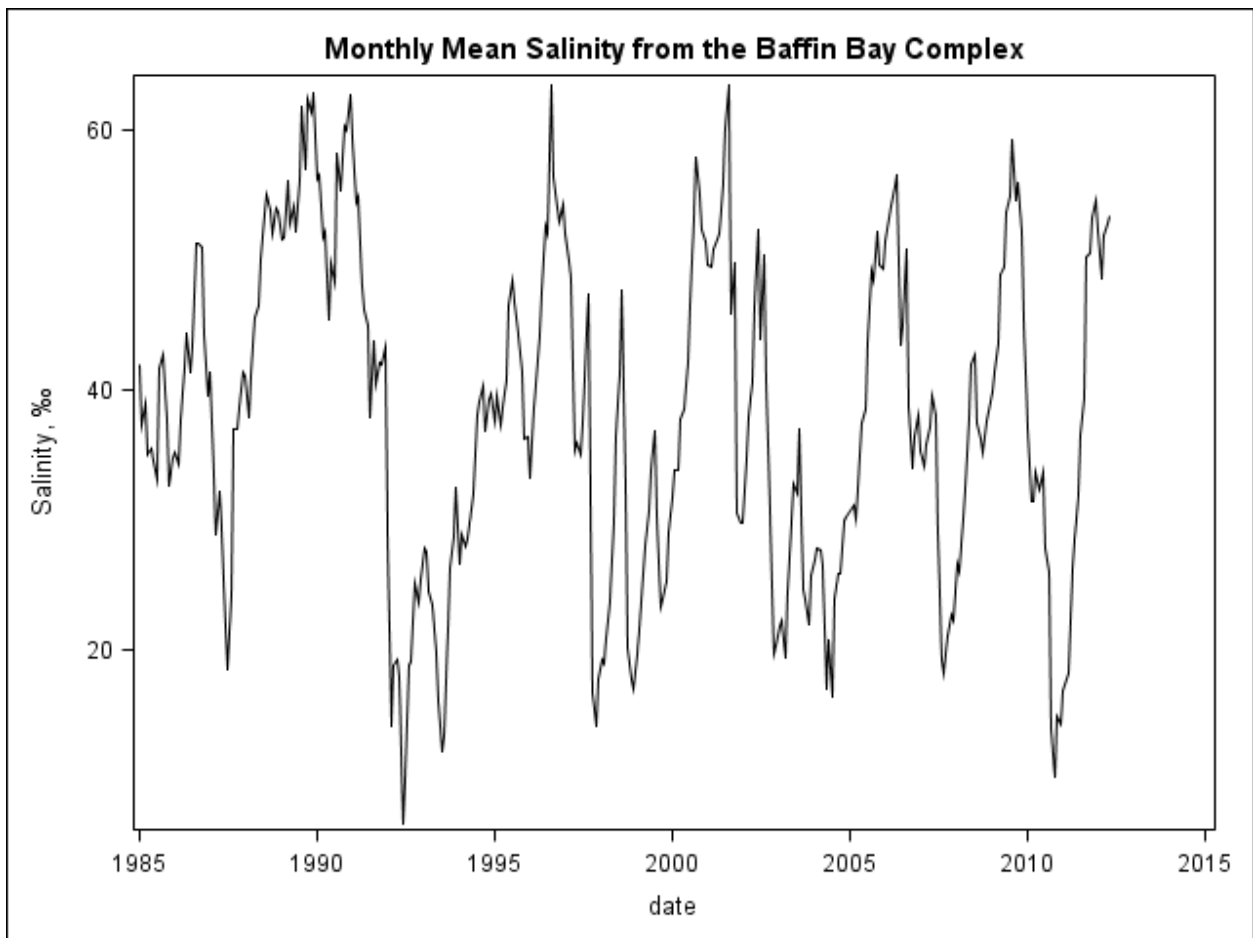


Figure 5. Monthly mean salinity levels from the Baffin Bay Complex using TPWD-CF Resource Sampling data from 1985-2012.

Appendix A

***Mulinia lateralis* in Baffin Bay**

Concerns for limited food resources associated with emaciated black drum (*Pogonias cromis*) resulted in a literature review of the dwarf surf clam (*Mulinia lateralis*). *Mulinia lateralis* is documented as a dominant food source of black drum in Baffin Bay and has been referred to as the “drum shell” due to its recognized dietary importance to the black drum by the commercial fisheries (Pearson 1929; Gunter 1945; Miles 1949; Simmons and Breuer 1962; TWDB 1983; Cate and Evans 1994). *Mulinia lateralis* is described as a triangularly shaped bivalve ranging in size from 8 to 12 mm. The bivalve color is uniformly white with a tannish-brown periostracum (Tunnell et.al 2010). With a North American distribution from Maine to Florida to Texas, *M. lateralis* has been characterized as the dominant bivalve in Baffin Bay (Parker 1959; Mackin 1971; Brown et.al 1977; TWDB 1983; Nicolau and Nuñez 2004, 2005a, 2005b, 2006; Tunnell et.al 2010). Observations in Baffin Bay suggest this species has a seasonal life cycle, with peak recruitment occurring in spring and population declines in late summer to fall (Montagna et. al 1993). Salinity tolerance ranges from 5‰ to 80‰ (Montagna et al. 1993). Lough (1975) characterized optimal temperature and salinity conditions for maximizing both larval survival and growth for up to 8 to 10 days was between 20°C and 26°C and between 23 ‰ and 32‰. Another investigation reported that successful spawning and development typically occurred in salinities between 15‰ and 30‰ and water temperatures between 10°C and 30°C (Calabrese 1969). *Mulinia lateralis* has been characterized as an early succession organism with a short generation time, capable of successfully spawning at 3 mm in length (approximately 60 days) and is hypothesized to have the potential to manage phytoplankton blooms (Montagna et al. 1993).

Mulina lateralis is characterized (Montagna et.al 1993) as an important species in the upper Laguna Madre/Baffin Bay ecosystem due to its:

- widespread distribution and high densities;
- rapid population growth; and
- food source for fish and wildlife.

Spatial analysis of *Mulinia. lateralis* in Baffin Bay

A spatial distribution analysis of *M. lateralis* was conducted to identify areas within Baffin Bay where populations are known to occur (Figures 1 – 3). In order to assess the status and distribution of *M. lateralis* in Baffin Bay, graduated symbol maps of *M. lateralis* density (number per m²) in Baffin Bay and its tributaries were created with ArcGIS version 10.0 using data collected by personnel from Texas A&M University-Corpus Christi Center for Coastal Studies (TAMUCC-CCS) in coordination with the Environmental Protection Agency - National Coastal Assessment (EPA - NCA) (Nicolau and Nuñez 2004, 2005a, 2005b, 2006). Breaks in mapped 2001 data (Figure 1) are different from those used for the other years of the study (Figures 2 and 3) (Jenk’s natural breaks method for 2001 data was utilized for Figure 1 while the Jenk’s natural breaks method for all data was used for Figures 2 and 3). Data collected from this study provides the most recent known record of population trends for *M. laterlis* in Baffin Bay.

TAMUCC-CCS annual reports document the monitoring efforts conducted for the Coastal Bend Bays and Estuaries Program (CBBEP) from 2001 to 2004. The initial efforts consisted of quarterly baseline monitoring over a two year period (2001 and 2002). The formation of cooperative partnerships between Texas Parks and Wildlife Department (TPWD), CBBEP, TAMUCC-CCS, and the EPA, resulted in the coupling of the 2001 and 2002 data analysis and a program restructuring to a single sampling event

during the summer index period. This period represented a “worst case scenario”, in which water quality conditions might be the most stressful to the biota (Nicolau and Nuñez, 2005a).

Benthic samples were collected in Baffin Bay from 2001 through 2004 (Figures 1 – 3), with a majority of the sampling occurring in 2001 (n=27) and 2002 (n=31), and fewer collections in 2003 (n=5) and 2004 (n=7). Each sample consisted of a minimum of five replicates using a cylindrical PVC push corer (10.16 cm diameter) at randomly selected locations. Replicate core samples were averaged and abundance data were extrapolated to density (#/m²). For the present analysis, averaged replicate samples were averaged by season within each year to enable comparisons. However, samples were not collected every season each year and the number of samples collected per season and per year, as described above, varied. Because of the completely randomized collection procedures, the non-uniform spatial distribution of the sampling locations in Baffin Bay, and patchy nature of *M. lateralis* populations, spatial interpolation techniques were not used in the data analysis.

Densities of *M. lateralis* in 2001 ranged from 0 to 2,590.3/m² with a median of 0/m², with densities observed at seven out of 27 sites. Samples were collected in summer (July and August) and fall (November) with highest densities observed in the fall. During the summer event, *M. lateralis* was observed at 7% sites and in the fall, it was found at 46 % of the sites sampled. *Mulinia lateralis* densities were greatest in 2002 ranging from 0 to 29,184.6/m² with a median density of 1,874.9/m². Samples were collected in the winter (February), spring (May), and summer (August) with highest densities observed in winter and spring although sample size was much lower in the summer and densities observed at nearly all the sites (Figure 2). *Mulinia lateralis* was observed at 100% of the sites sampled during the winter and spring and was found at 80% of the sites sampled during the summer. During 2003 and 2004, samples were only collected in the summer (August and July, respectively). *Mulinia lateralis* densities ranged from 0 to 567.4/m² with a median of 74.0/m² in 2003 and 0 to 1036.1/m² with a median of 197.4/m² in 2004. During these sampling events, *M. lateralis* was observed at 80% and 71% of the sites respectively. The range of data in 2002 was much greater than any other year and using these same breaks for 2001 data would hide seasonal variability of *M. lateralis* density. Data from 2003 and 2004 were, however, plotted using the natural breaks determined from the whole data set. This was done to facilitate comparison between years as samples for 2003 and 2004 were only collected in the summer.

Spatial trends in the data seem to indicate that *M. lateralis* densities increase as we move farther into Baffin Bay and its tributaries from the upper Laguna Madre (ULM). This is further supported by the much lower densities and a higher number of zero density sites in the NCA samples from the ULM (not included in this analysis) and has been observed in other studies as well (Martin 1979; Montagna and Kalke 1995). Additionally, lower densities of *M. lateralis* are consistently observed in the summer months while higher densities are observed in the winter, spring, and fall (figure 1 – 3). From the present data, it is difficult to determine which season tends to see a peak in abundance of *M. lateralis* as seasonal sampling was inconsistent throughout the study period; however, *M. lateralis* density and overall abundance may vary with fluctuations in salinity and other meteorological events (Montagna and Kalke 1995). Potential reduction of benthic population including *M. lateralis* in Baffin Bay could be a combination of factors, including poor recruitment, over predation, as well as naturally occurring seasonal changes (i.e. low population densities seen during late summer and fall) and prolonged drought conditions with salinities greater than 40‰.

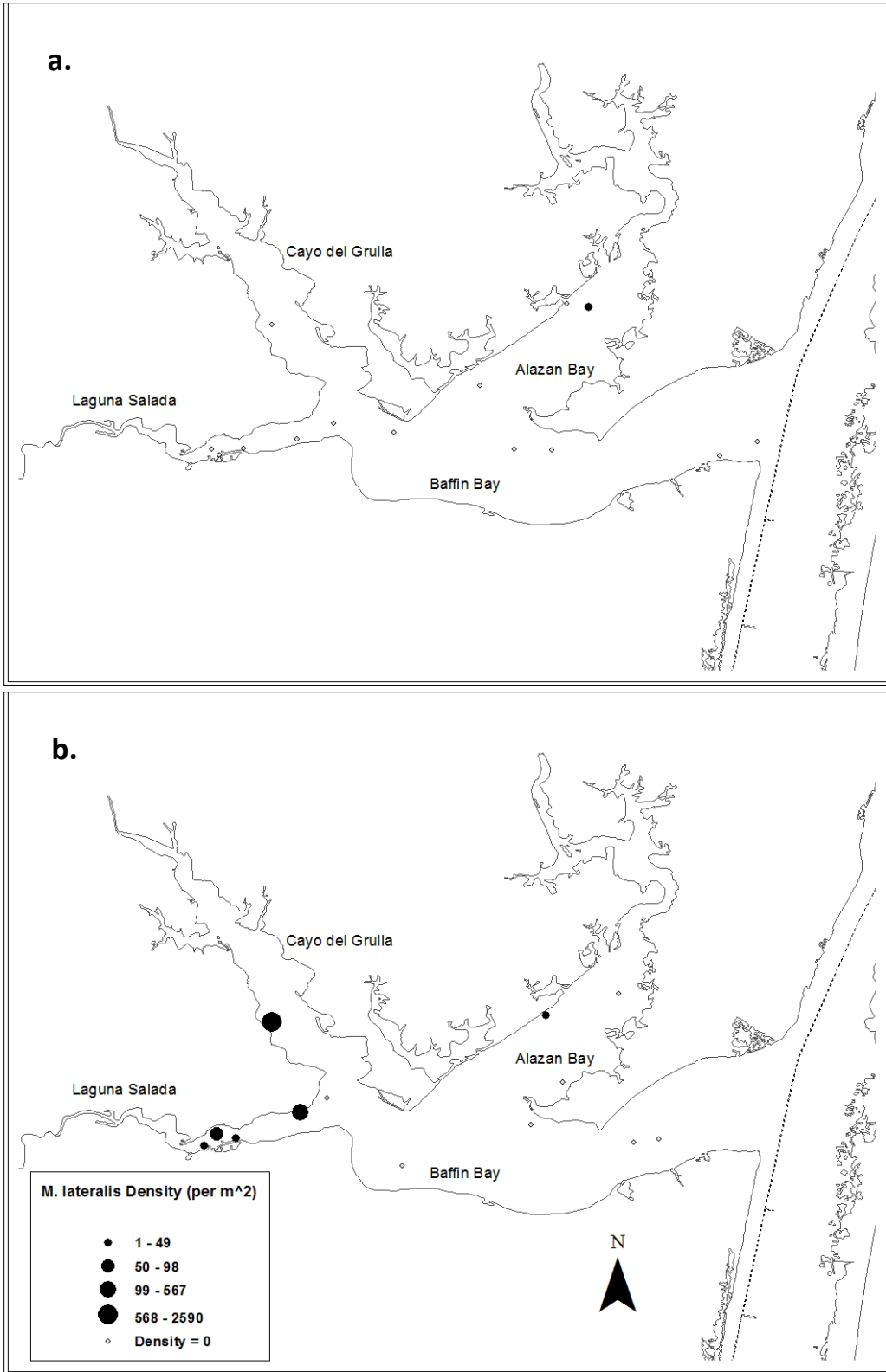
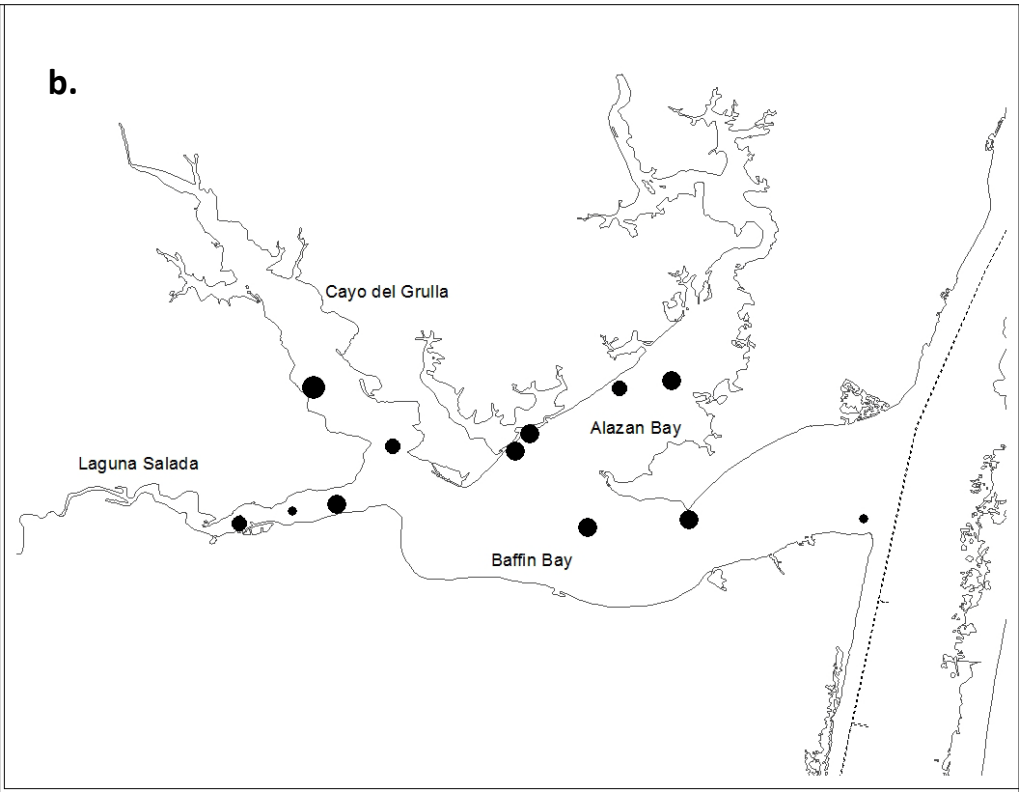
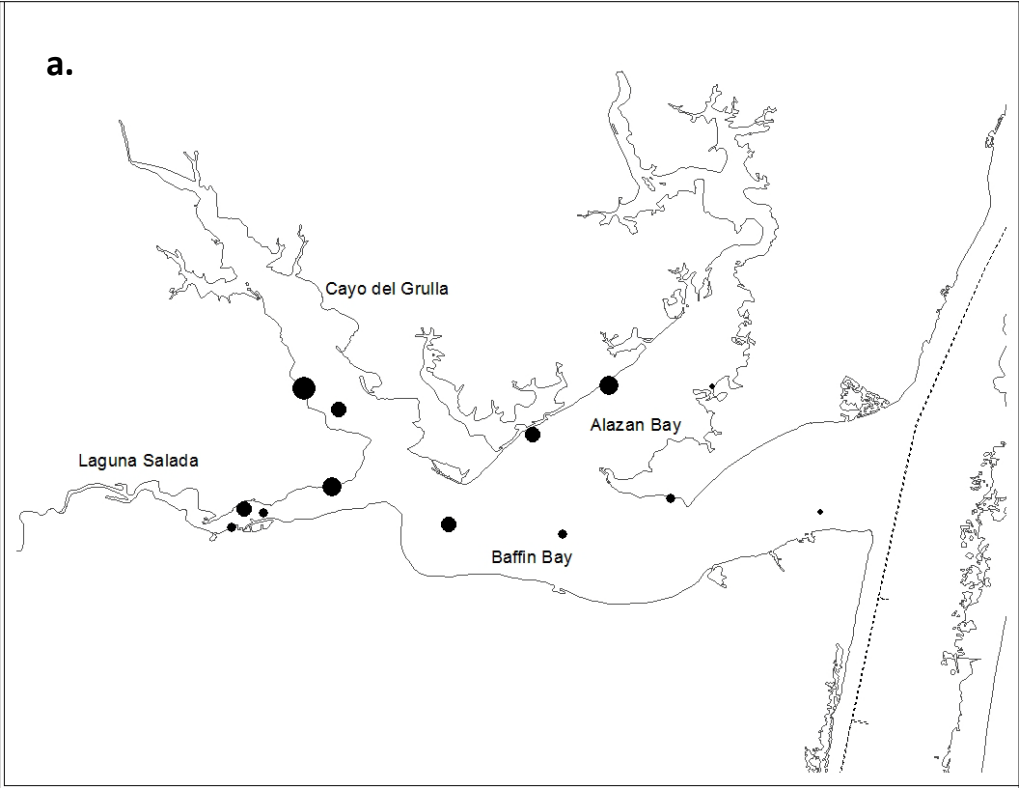


Figure 1. *Mulinia lateralis* density (per m²) for Baffin Bay and its tributaries in summer (July and August) 2001 (a) and fall (November) 2001 (b).



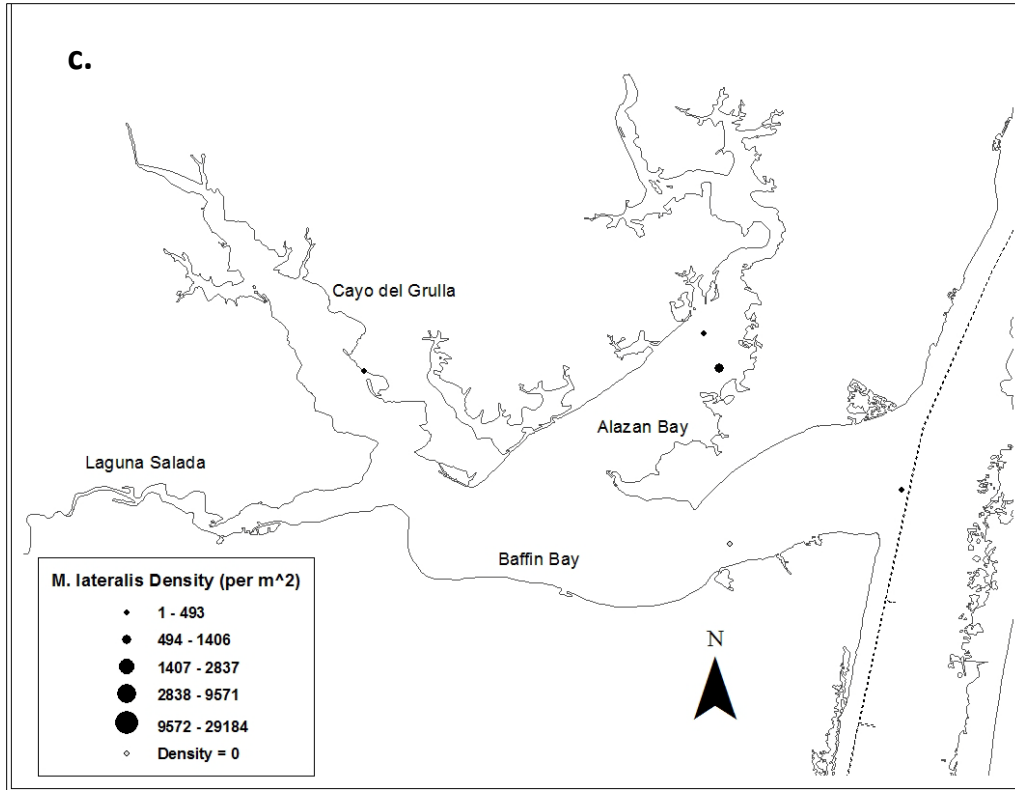


Figure 2. *Mulinia lateralis* density (per m²) for Baffin Bay and its tributaries in winter (February) 2002 (a), spring (May) 2002 (b), and summer (August) 2002 (c).

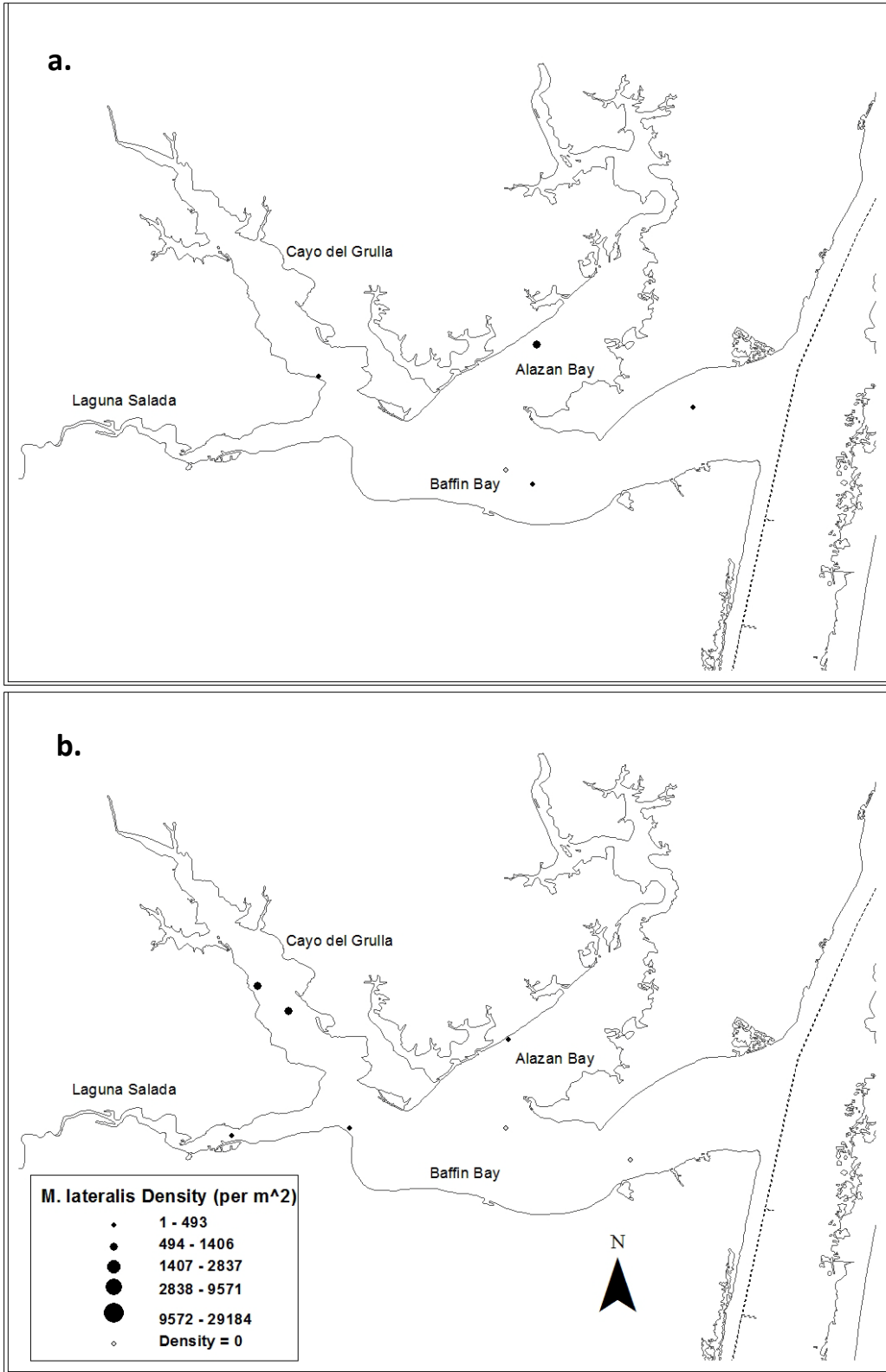


Figure 3. *Mulinia lateralis* density (per m²) for Baffin Bay and its tributaries in summer (August) 2003 (a) and summer (July) 2004 (b).

Appendix B

***Mulinia lateralis* Sample Size Analysis**

In order to determine the level of sampling effort needed to detect population changes in *M. lateralis*, data from previous Regional Coastal Assessment Project was utilized (Nicolau and Nuñez, 2004; Nicolau and Nuñez, 2005a; Nicolau and Nuñez, 2005b; Nicolau and Nuñez, 2006). The number of samples from the upper Laguna Madre and Baffin Bay complex totaled 160. These data served as foundation for a prospective power analysis. Due to seasonal differences among the sampling years, the 'summer index period' was chosen because this season had the greatest temporal coverage. The 70 samples from Baffin Bay complex were used for a bootstrap permutation in order to simulate a paired t-test analysis. From the original 70 samples, a random sample of size N=50 (with replacement) was drawn and ordered one to N. A second random set of 50 samples was drawn with replacement, and these were also ordered one to N. Each set of ordered observations were then classified as a paired sample, simulating a "Before" and "After" sample of a hypothetical location in the bay. The value for the difference in *Mulinia* density was defined as the 'After sample subtracted from the Before'. In this context, the expected difference for each sample is zero.

This procedure was then repeated 500 times to obtain bootstrap estimates of the mean difference, as well as the standard deviation of the difference. Figure 1 shows a profile plot of one of these simulations. Differences between the paired samples ranged from -12,914 to 16,289, with a mean difference of 699 (SD = 4,280, see Figure 2). Based on a power analysis using these estimates, the total number of samples needed to detect a 50% difference in *Mulinia* densities would be 296 pairs of samples (Figure 3). If a 15% target for change is desired, then the sampling effort would increase to 10,000+ pairs of samples. The smaller the % difference, the larger the sample size becomes due to the extreme amount of natural variability seen in the density levels of *Mulinia* within Baffin Bay.

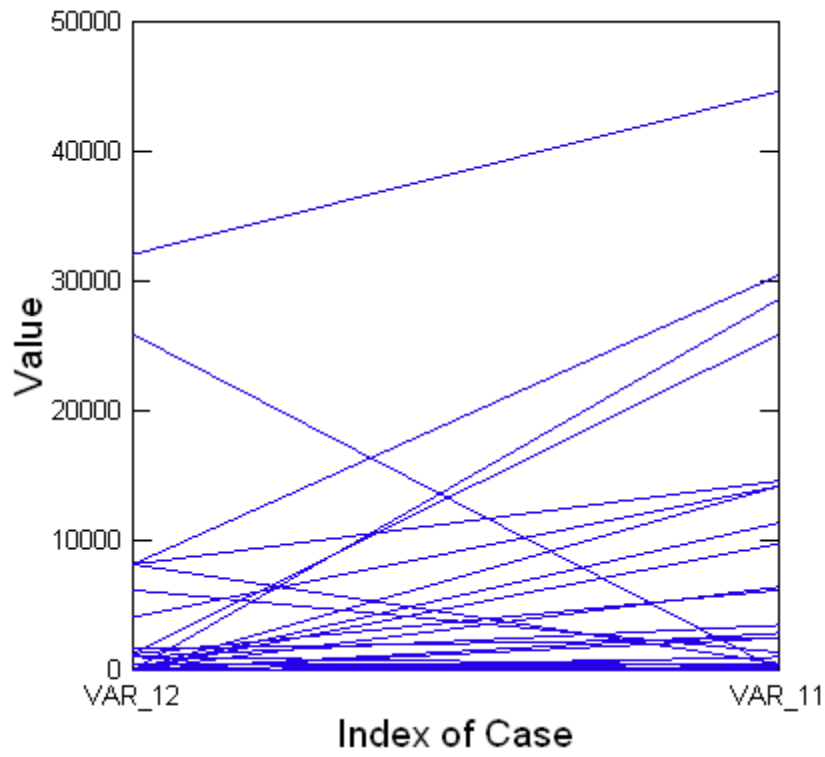


Figure 1. Profile plot for one of the 500 cases of 50 paired samples (Before = VAR_12, After = VAR_11) used in the bootstrap estimate of mean difference.

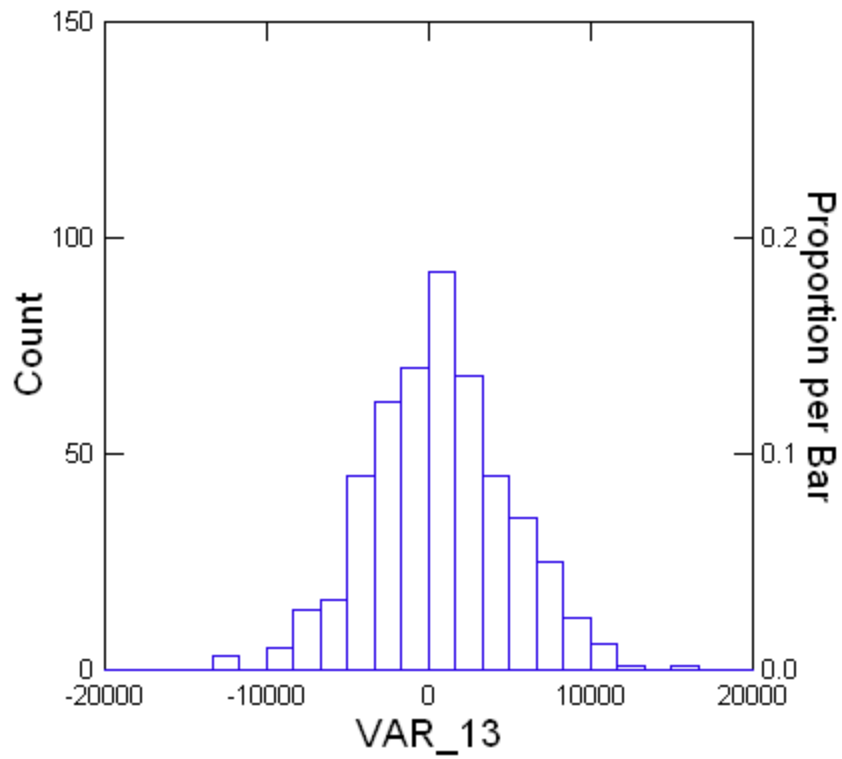


Figure 2. Histogram plot showing the distribution of the 'difference' value for the 500 bootstrapped simulations.

Power Curve (Alpha = 0.050)

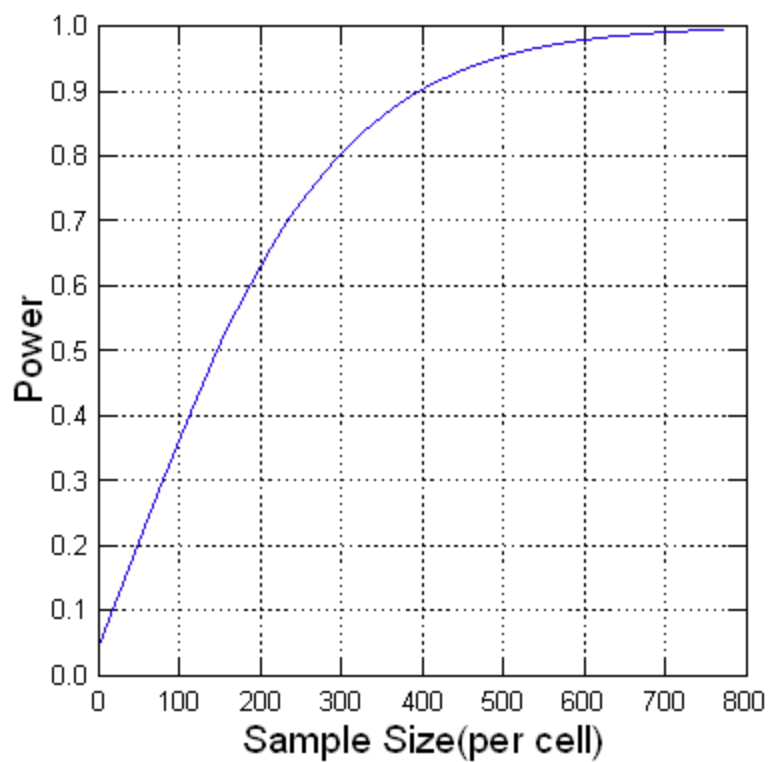


Figure 3. Power curve for detecting a 50% difference in *Mulinia* densities in Baffin Bay.