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# THE DEMOGRAPHIC HISTORY OF THE SCALY PEARL OYSTER IN FOUR ANCHIALINE PONDS ON SAN SALVADOR ISLAND, BAHAMAS

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## ABSTRACT

Scaly Pearl Oysters, *Pinctada longisquamosa*, have been discovered in five inland ponds on San Salvador Island, Bahamas. We conducted a multi-year demographic survey (hinge length measurements and growth rate experiments) on four of these populations (Mermaid Pond, Oyster Pond, Six-Pack Pond and Little Lake) covering three significant storm events. Two of the ponds (Mermaid and Oyster) are protected from severe weather by virtue of their small size (low wave generation), rich prop-root habitat (providing solid "anchorage"), and active conduits, while the other two populations (Six Pack and Little Lake) are exposed to severe weather because of their large surface areas (high wave potential), lack of solid substrate, and little to no sea-water turn-over making them susceptible to severe fluctuations in salinity following heavy rainfall. We suggest that dissimilarities in population demographics are due, at least in part, to variations in habitat characteristics resulting in a gradient of hurricane susceptibility among the various oyster habitats. The Mermaid and Oyster populations are least susceptible to hurricane exposure, while Six Pack and Little Lake populations experience dramatic episodes of decimation in correlation with hurricane events. Mermaid and Oyster Pond populations appear to exhibit periods of progressive senescence punctuated by hurricane correlated episodes of spawning/ rejuvenation. Scaly Pearl Oysters appear to follow a modified Bertalanffy growth curve, growing faster as juveniles and progressively slower as they reach maturity. Oysters from Oyster and Mermaid Ponds appear to grow almost twice as fast as those from Six Pack Pond in the first year of growth.

## INTRODUCTION

### Geography and Geological History

San Salvador is a small island (161 square kilometers) located off the eastern margin of the Great Bahamas Bank in the Caribbean. It is part of the tectonically passive Bahamian platform that appears to be subsiding at a rate of 1 cm/$10^3$ years (Sealy 2006). The structure of the Bahamas appears to be the result of a long depositional history of shallow water sedimentation that has been occurring since the Cretaceous period 65 million years ago (Carew and Mylroie 1995). Different from many islands found in the tropics, the Bahamas are not volcanic in origin and all the rocks below the surface are a type of shallow water carbonate formed only near the surface. Unlike any other place in the world, rocks found at depths of 20,000 feet are the same as those found at the surface today suggesting that geographical conditions have been more or less the same for the whole of the Bahamas History (Sealey 2006).

The most recent impact on the geology of the Bahamas is the Pleistocene Ice Age almost 2 million years ago and was marked by four periods of glaciation separated by three interglacial periods. During periods of glaciation, snow accumulation transferred enough of the world's water to land to causing significant changes in sea level. In the last glacial period, sea level dropped 140 m compared to today's shoreline. During the Ice Ages the mass of the island also increased as a result of wind driven dune formation and the lithification of sand grains into various limestones. The repeated exposure and inundation of the island resulted in a series of ridges and swales, many of which have inland ponds. It is likely that the ponds we see today started to develop just after the last glacial period 6-10,000 years ago, suggesting that life in the ponds has had a relatively short time to diversify compared to the iguanas or finches on the Galapagos islands which have had as many as 2 million years to diversify.

The subsurface of San Salvador is riddled with caves, conduits and blue holes (vertical holes that connect via conduits directly to the ocean.) Due to the considerable number of conduits and blue holes within the island a continuous freshwater lens, common on most islands, does not extend from coast to coast of San Salvador (Davis and Johnson 1988). A freshwater lens exists where fresh water meets salt water and is separated by a brackish layer referred to as a mixing zone. On islands where rainfall surpasses evaporation the freshwater lens is periodically recharged. On an island like San Salvador where evapotranspiration exceeds rainfall 11 months of the year, the lens is not recharged, and as sea level rises, ponds and lakes are filled with saltwater or even hypersaline water instead of fresh (Sealey 2006).

Ponds and lakes are commonly found in the low-lying areas between dune ridges. Nearly one third of San Salvador's surface area contains interior lakes and estuaries that are either marine or hypersaline in nature. The majority of marine ponds are 1-2 meters deep, and lack direct surface connection to the ocean, though many are connected through extensive subsurface conduits within the island's interior. Conduits allow for the twice-daily exchange of seawater when sea level elevation is greater than the elevation of the pond. This daily flux creates a cool nutrient-poor environment, as opposed to the warm and relatively nutrient-rich conditions found in the more hypersaline ponds. Hypersaline ponds are often characterized as non-tidal bodies of water. Hypersaline conditions are created by extensive evaporation during the dry season leaving a salt content greater than seawater (35 ppt). Seasonal alternations of precipitation lead to potentially large fluctuations in the water chemistry of these hypersaline ponds (Davis and Johnson 1988).

By virtue of their physical characteristics, our four study sites exemplify a gradient of susceptibility to hurricane events. We define hurricane susceptibility as an inability to buffer pond water against storm-driven changes in temperature and salinity thereby protecting resident oyster populations. Mermaid and Oyster Ponds are least susceptible to hurricane activity by virtue of their small surface areas (low wave generation), red mangrove prop-root habitat for stable anchorage, and most importantly, active conduits allowing twice-daily exchange of water. Even in the event of hurricanes, Oyster Pond experiences only transient fluctuations in salinity, while Mermaid pond is characterized by moderate fluctuations in salinity. The other two ponds, Six Pack and Little Lake, are more exposed to hurricane activity by virtue of their large surface areas (conducive to wave propagation during storms), lack of stable prop-root anchorage, and absence of significant conduit-driven water exchange. Deluges of freshwater from storm activity can lead to large fluctuations in salinity due to the absence or insignificant activity of conduits in Six Pack and Little Lake. Dramatic changes in temperature and salinity can significantly affect the population demographics of invertebrates in pond communities.

## Climate

San Salvador is a maritime country with a sub-tropical climate, experiencing two seasons summer, May to November, and winter, December through April. Though it receives rainfall all year round, twice as much falls in the summer season as in the winter season (Sealey 2006). The island experiences Northeast trade winds that are interrupted periodically by cold fronts from North America in winter, and by hurricanes in the summer and fall. Given the diameter of tropical storms (800 km) it is likely that the Bahamas will be affected by tropical disturbances at least once a year. The island averages 42 inches of rainfall per year of which twenty-five percent is derived from hurricane activity (Shaklee 1994). Hurricane season coincides with part of the island's rainy season, and is officially from May 1 through November 30th. In the last century, 44 tropical systems have passed within 60 km of the island. Since 1999, three hurricanes have struck San Salvador Island: Floyd (Sept. 14, 1999) with 155 mph winds and heavy rainfall (16 inches), Frances (Sept. 2, 2004) with 145 mph winds and less rain (5 inches), and most recently Noel (Nov. 2, 2007) with modest 80 mph winds and heavy rainfall (24 inches). The periodic frequency of storms makes San Salvador an ideal place to study the effects of environmental disturbance on population dynamics.

## Natural History of the Scaly Pearl Oyster

Scaly Pearl Oysters, *Pinctada longisquamosa*, are relatively sessile bivalves (Subclass Lamellibranch, Family Pteriidae) first discovered in the Florida Keys (Dunker, 1852; Mikkelsen et al., 2004). Pteriidae, meaning winged ones, are more closely related to Burnt mussels and Black Mangrove Oysters than edible oysters of the family Ostreidae. The family also includes pearl oysters and winged oysters (Temkin, 2006). In initial studies, *P. Longisquamosa* on San Salvador were mis-identified as *P. imbricata* due to similarities in shell shape. Recent publications by Mikkelsen et al. (2004) helped to correctly identify the species as *P. longisquamosa*. Like other Lamellibranchs, *P. Longisquamosa* are filter feeders that use gill cilia to capture algal phytoplankton. Adults use byssal threads to attach to stable substrate and are commonly found in 1-2 meters of water. Colonization appears to be controlled by a combination of salinity, substrate, water depth, and water clarity. Data from Florida Bay populations suggests that fluctuations in salinity, which could be seasonal or influenced by irregular extremes of high or low salinities within the Florida Bay system, have significant influence over local population density (Mikkelsen et al., 2004). Dramatic changes in salinity stress an oyster population and can induce spawning, potentially affecting the life history patterns of resident oysters. Depending on the duration and intensity of the stress, spawning can be accompanied by severe adult mortality (Gervis and Sims 1992; Cole, et al. 2005).

Much of what we know of the reproductive life history of the Scaly Pearl Oyster is inferred from the commercially valued Atlantic Pearl Oysters for which there is abundant literature. Atlantic Pearl Oysters are protandrous hermaphrodites, developing first as males and undergoing a sexual transformation into females as they increase in size (Mackenzie et al., 2003). These oysters breed by releasing their gametes into the water column where fertilization occurs. Embryos then develop into veliger larvae commonly known as "spat". After one month, veliger larvae settle, attach to a hard substrate and metamorphose into 0.2 mm juveniles (Ruffini, 1984). Reproduction appears to take place throughout the year, though seasonal spawning also occurs under conditions of constant temperature and food. The Atlantic Pearl Oyster appears to have a short spawning season (November to January) followed by a long spawning season from January to June (Urban 2000). Reproductive peaks during the colder months are attributed to nutrient rich upwellings, which simultaneously cool the water while stimulating an increase in phytoplankton, which fuels primary production (Mackenzie et al., 2003). This energy is used to increase the size of gonads, which is reflected in higher reproductive output. Oysters grow very rapidly following a von Bertalanffy growth curve. Under optimal conditions oysters can grow to 50-70 mm in one year (Urban 2002).

In this study we examined the population dynamics of the Scaly Pearl Oyster focusing on documenting growth rates of reproductive cohorts through time. Using hinge length measurements collected periodically from January 2001 through June 2009 we have set out to compare the population demographics of these four ponds by examining breeding patterns and constructing growth curve models. Using this we hope to investigate how habitat mediates the effects of hurricanes on the life history trajectories of different populations of oysters.

## METHODS AND MATERIALS

Beginning in 2001, Oysters were collected from Oyster, Six Pack and Mermaid Ponds over the course of 9 years from randomly placed transect lines. Just recently, we began collecting data from a fourth population in Little Lake. Oysters were collected, measured, and returned. Hinge length for each oyster was measured and recorded with calipers. Oysters from every size class were also collected, measured, tagged, caged, and anchored in the pond for future determination of individual growth rates. Oxygen, pH, & salinity were determined using a Hydrolab Quanta™ probe. A Shimadzu TOC-5050A was used to test the dissolved organic carbon. Total dissolved nitrogen was tested using a Shimadzu TOC-Ccsn with a TMN-1 nitrogen module. Nitrates were tested using a Lachat QC8000 Autoanalyzer. Surface areas were determined using Google Earth and GE Path.

## RESULTS

### Physical Characteristics of the Ponds

To date, five live populations of *Pinctada longisquamosa* have been discovered on San Salvador Island, Bahamas: in Oyster Pond, Mermaid Pond, Six Pack Pond and recently discovered populations in Little Lake and South Stout Lake. Populations in the two marine ponds, Mermaid and Oyster, are the least susceptible to hurricane exposure due to their ability to buffer large deluges of freshwater and maintain relatively stable salinity levels. Oyster pond appears to maintain consistent levels of salinity year to year, while Mermaid Pond experiences moderate fluctuations (Figures 1,2).

Water analysis revealed that these ponds have lower solute concentrations than Six Pack Pond and Little Lake, including lower levels of organic carbon, $NO_3$, $NH_4$, salinity and pH (Figure 1). Both ponds have relatively small surface areas (low wave generation during storms), and are served by conduits, underground caverns connecting the ponds to the sea, that exert a measurable tidal influence and buffer against deluges of freshwater (Figure 2).

Six Pack and Little Lake are most susceptible to hurricane exposure and experience extreme fluctuations in salinity in the event of heavy rainfall. Both ponds are characterized by higher solute concentrations (Figure 1), and storm-driven fluctuations in salinity due to the absence or insignificant activity of conduits (Figure 1,2). The surface areas of these ponds are ten times greater than those of the lower solute ponds (Mermaid and Oyster) making them more conducive to wave propagation during storm events (Figure 1).

| Pond | DO mg/L | pH units | TDS g/L | Organic C ppm | NH4+ ppb | NO3 ppb | TDN ppm | 5 yr Salinity Fluctuation | Pond Size (1000 sq m) |
|---|---|---|---|---|---|---|---|---|---|
| Little Lake | 8.71 | 8.16 | 40.1 | 11.24 | 6.93 | 31.7 | 0.66 | 20.8 g/L | 1,528 |
| Six Pack Pond | 7.85 | 8.08 | 38.1 | 16.32 | 7.62 | 30.8 | 0.47 | 15.4 g/L | 762 |
| South Stout Lk. | 8.2 | 7.91 | 33.4 | TBD | TBD | TBD | TBD | TBD | 317 |
| Mermaid pond | 7.7 | 7.55 | 32.4 | 3.97 | 5.38 | 17.3 | 0.48 | 7.5 g/L | 104 |
| Oyster Pond | 7.7 | 7.38 | 34.8 | 2.85 | 5.34 | 15.95 | 0.22 | 1.4g/L | 71 |

**Figure 1.** Water chemistry from representative (non-hurricane) years and surface areas for 5 ponds harboring *P. longisquamosa*. Top 2 (shaded) = modestly hypersaline. Bottom 3, = marine salinities. (TBD= to be determined). Fluctuation = [highest recorded salinity – lowest recorded salinity].

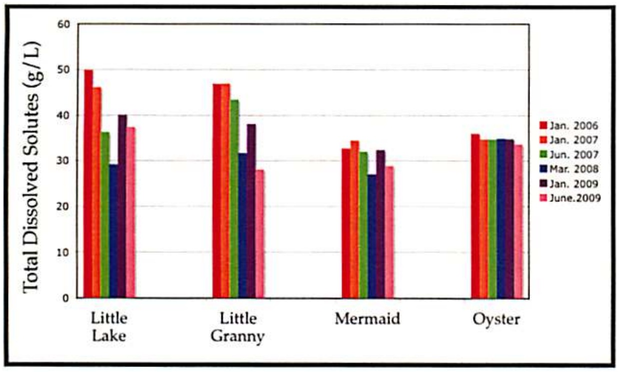


**Figure 2.** Multiple measurements of salinity over four years revealing relative levels of salinity disturbance and stability in four ponds.

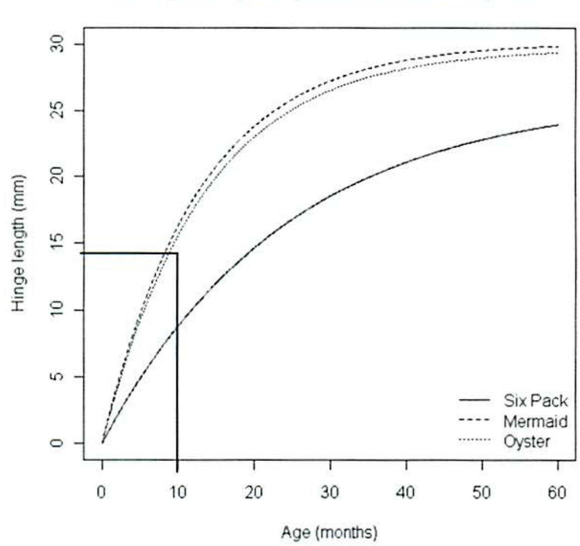


**Figure 3.** Growth curves modeled from oyster hinge-length recapture data from January – June, 2009.

## Growth Data

In order to relate oyster size to age we developed a von Bertalanffy growth model. Using recapture data collected from January 2009-June 2009, we fit a von Bertalanffy growth curve to data from Six Pack, Oyster and Mermaid Ponds. The equation for a von Bertalanffy growth curve is given below, where Lt is the length of oysters at time t, and $L_\infty$ represents the maximum hinge length of an oyster. The growth rate coefficient (K) determines the shape of the curve by how quickly an oyster approaches its maximum hinge length, $L_\infty$. The $t_0$ parameter shifts the growth curve along the age axis to allow for a non-zero body length at age zero. We estimated the VBGF parameters using the Fabens method.

$$L_t = L_\infty[1 - e^{-K(t-t_0)}]$$

For Scaly Pearl Oysters in Six Pack Pond we estimated $L_\infty$= 26.12 and k=0.4937, for oysters in Oyster Pond we estimated $L_\infty$= 29.68 and k=0.8911, and for oysters in Mermaid Pond we estimated $L_\infty$= 30.12 and k=0.9340 (Figure 3). For all three we used a least squares criterion with code written in R. Using these parameter estimates and a hypothetical hinge length we were able to calculate the age of an oyster at a given hinge length.

The oysters from the hurricane-sensitive Six-Pack population exhibited slower growth than those from either Oyster or Mermaid Ponds (our storm-buffered populations), averaging 1 mm in the first month of growth, while those in Oyster and Mermaid Ponds averaged 2.2 mm and 2.3 mm/ month respectively. During the first year of growth, oysters from Six Pack Pond grew 10.1 mm, while those from Oyster and Mermaid Pond grew almost twice as fast, averaging 17.5 mm and 18.3 mm.

## Demography

Oyster Pond Community.

Of the 3 populations we studied most continuously, the Oyster Pond community showed the greatest resilience to hurricane events. This population was characterized by a normal distribution of hinge lengths and a wide range of size classes (Figure 4). Hurricanes Floyd and Frances had little effect on the population as evidenced by survival of even the oldest oysters (hinge lengths of 40 mm). From January 2005 to January 2008 there was a steady increase in mean hinge length and gradual loss of juvenile oysters (senescence). By January 2007 and persisting through March 2008 there were no juvenile oysters (A, B and C class sizes) present in the population. In March, 2008, (4 months after hurricane Noel) there appears to have been a spawning event that rejuvenated the Oyster Pond population (last panel).

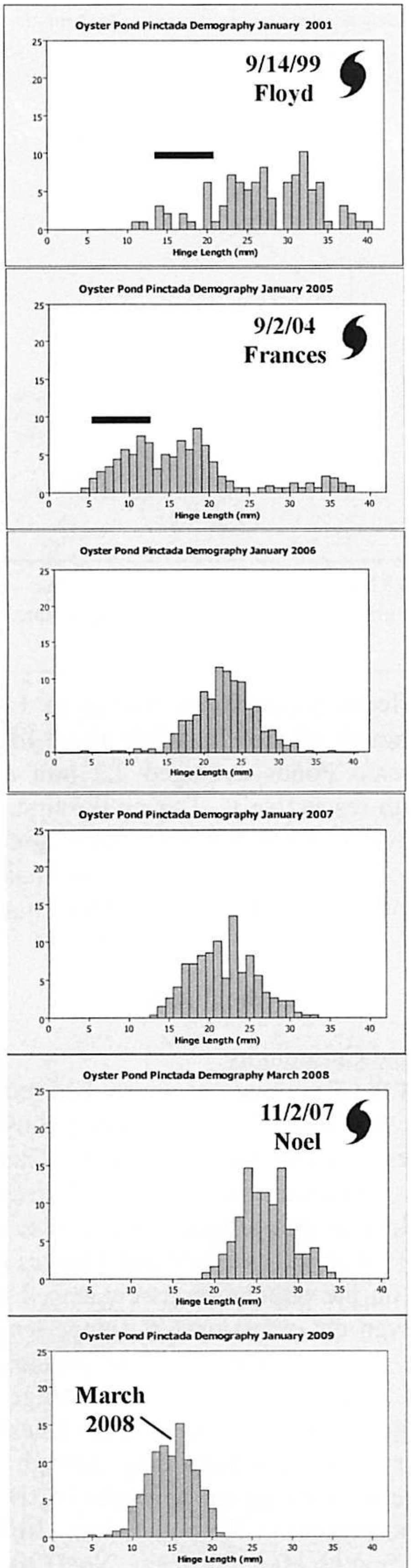


**Figure 4.** Oyster Pond demography. Horizontal bars indicate storm spawn.

Hurricane Noel in September 2007, with almost twice as much rainfall as Hurricanes Floyd and Frances, appeared to have the most serious impact on the Oyster Pond population. The large deluge of freshwater appears to have induced a delayed "suicide-spawning event" four months later. Larger oysters with a mean hinge length of 26.1 mm that initially survived Hurricane Noel, participated in the March breeding season and then died off, resulting in the large decrease in mean hinge length of the population. Using the von Bertalanffy growth model, it can be suggested that Jan. 2009 oysters with approximately 15.5 mm hinge lengths are the result of this suicide-spawning event.

<u>Six Pack Pond Community.</u>

The oyster population of Six-Pack Pond is most susceptible to hurricanes with the largest oysters rarely exceeding 25 mm in hinge length (Figure 5). In this habitat, dramatic examples of population decimation were observed following hurricane events in 1999, 2004, and 2008. In January 2001, Six Pack Pond was conspicuous for having an abundance of small oysters of a similar size. It was initially hypothesized that Hurricane Floyd (1999) had eliminated the larger oysters, and provoked a massive "suicide-spawning" event leading to a population dominated by a small uniform cohort of juveniles (Cole et al. 2005). Hurricane induced population decimation coupled with spawning, became known as the "Hurricane Hypothesis." It was also suggested that Six Pack Pond supported a population of oysters with stunted growth rates due to the hypersaline conditions.

From data collected in January 2001 there is evidence of two distinct cohorts. The larger cohort appears to be the spawn of Hurricane Floyd. Using the von Bertalanffy growth curve we were able to identify that 16 months following the hurricane these oysters should have reached 13.1 mm, see horizontal bar (17 months is used instead of 16 mo. to account for 30 day larval stage), which is very close to the average of the first reproductive cohort. By 10 mm, 50% of oysters in Six Pack Pond should have reached matur-

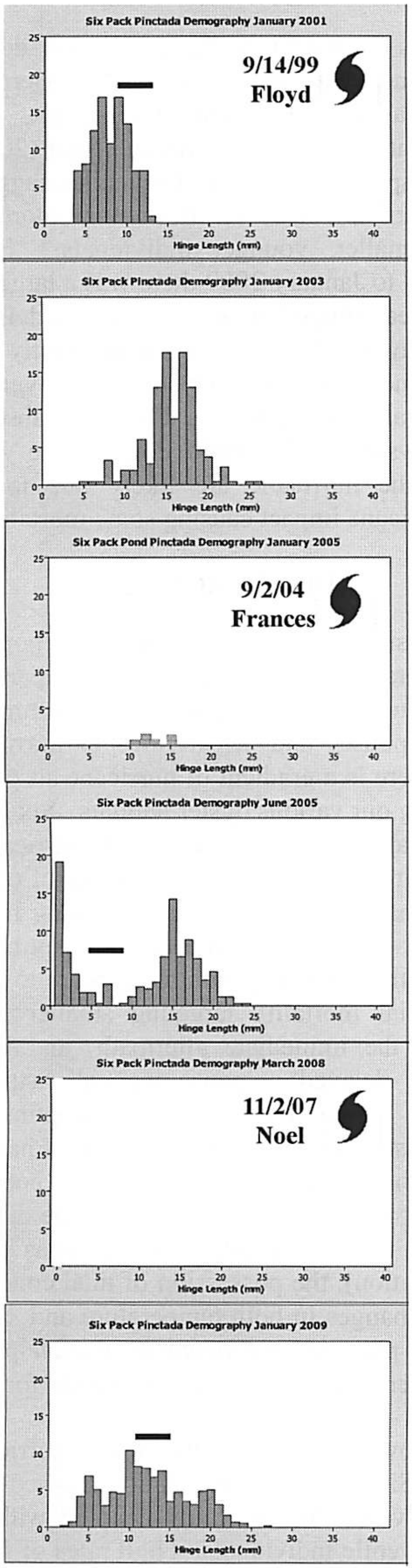


**Figure 5.** 6-Pack oyster demography. Horizontal bars = storm spawn.

ity, so it is likely that a July breeding event from the storm-spawn progeny produced the second reproductive cohort of 6-7 month oysters with hinge lengths of 6.5 mm.

In January 2003 hinge length data revealed that the oysters had doubled in size showing that hypersaline conditions were not stunting maximal growth (though we did not find that growth rates are slower). In January 2005, two months after Hurricane Frances (2004), only 6 individual oysters were found, once again demonstrating the decimating effects of hurricanes on the Six Pack Pond population and providing further support for the hurricane hypothesis. The partial recovery of the adult population in June suggests the occurrence of a refuge phenomenon. This portion of the population appeared to recover early enough to participate in the March breeding season, producing a reproductive cohort in June 2005 with hinge lengths around 4 mm. The uniform cohort of 1 mm oysters is likely the result of a July breeding season. From June 2005 through January 2007 the Six Pack population maintained relatively stable state population dynamics. A lack of larval recruitment in these months is attributed to the inevitable growth of spawn from March breeding events, leading to the absence of oysters in size class A during our January data-collection visits.

Hurricane Noel in September of 2007, with almost twice as much rainfall as the previous two storms, further supported the hurricane hypothesis. This hurricane event, like the previous two, appeared to annihilate the entire oyster population. Recovery from Hurricane Noel was slower, indicated by the absence of a March breeding event. By January 2009 there was partial recovery of the refuge population, and the emergence of a storm-induced reproductive cohort, which 14 months following the storm, are characterized by a 12 mm hinge length. The smallest reproductive cohort, with less than 6 mm hinge lengths, appear to have been the result of July breeding events.

<u>Mermaid Pond Community.</u>

The Mermaid Pond population closely resembles the Oyster population, and is

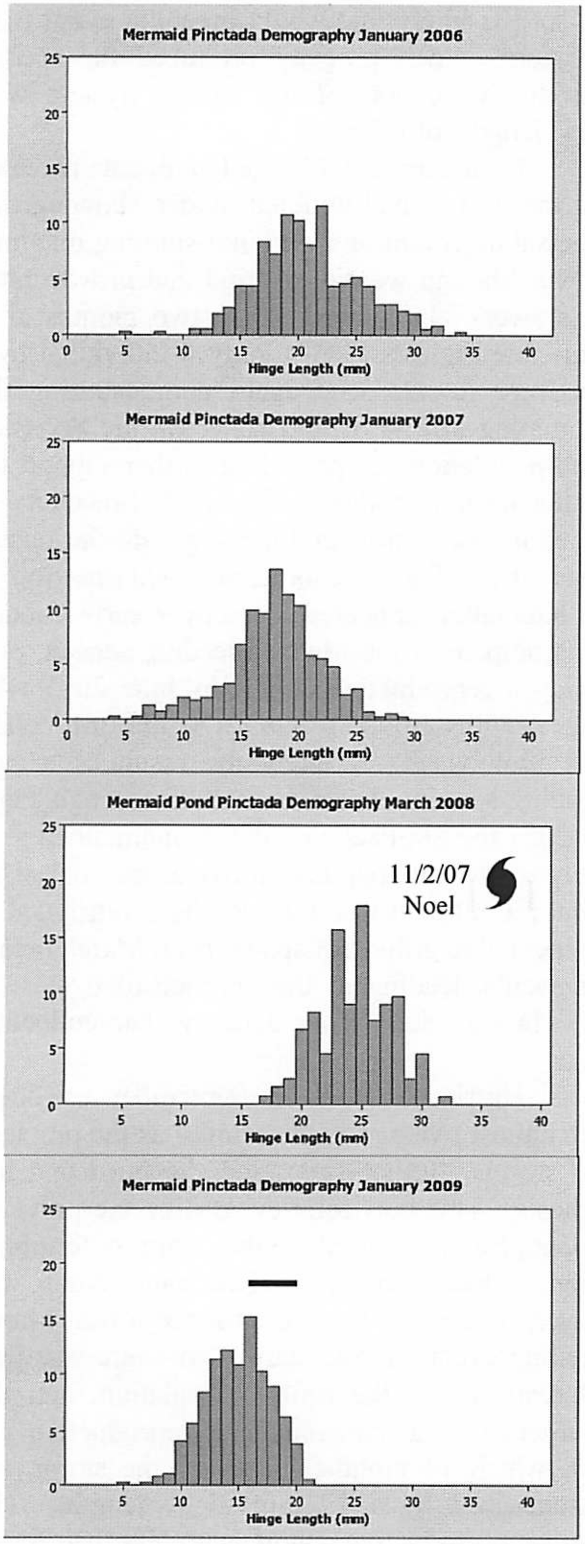


**Figure 6.** Mermaid Pond oyster demographics. Horizontal bar = storm spawn.

characterized by a normal distribution with the largest oysters reaching 35mm in hinge length. Unlike the Oyster Pond Population, the presence of juveniles (< 8mm) in the population during non-hurricane years indicates that the Mermaid Pond population is not growing senescent. The adult population survived Hurricane Noel (2007), but the conspicuous absence of juveniles suggests that the hurricane lead to differential mortality targeting smaller, younger individuals. From March 2008 to January 2009 there was a large decrease in mean hinge length, suggesting a delayed "suicide-spawning" event that almost exactly parallels the one observed in Oyster Pond over the same interval. Unlike Oyster Pond, the absence of larger oysters in Mermaid Pond in the years following the hurricane are likely due to the greater hurricane impact causing some mortality.

## DISCUSSION

We suggest that dissimilarities in population demographics are due, at least in part, to variations in habitat characteristics resulting in varying responses and sensitivities to hurricane impact. There is a gradient of hurricane susceptibility among our various oyster habitats. Six Pack and Little Lake are most susceptible to hurricanes. In both environments dramatic examples of population decimation were observed following hurricane events. Mermaid Pond is less susceptible to hurricanes, though heavy rainfall appears to lead to differential mortality targeting smaller individuals (in the immediate aftermath) and large adults in a delayed response we call "suicide spawning". Oyster Pond is least susceptible to hurricane disturbance showing the greatest habitat stability. The Oyster and Mermaid Pond populations appear to be buffered from hurricane disturbances due to their smaller surface areas (low wave generation), the possession of tidal conduits (buffering changes in both temperature and salinity), and the presence of *Rhizophora mangle* prop-roots that serve as a protective substrate for anchorage.

Following each of the three hurricane events, the Six Pack Pond population showed evidence of severe adult mortality coupled with an influx of juvenile individuals. High rates of mortality observed after spawning have been attributed to a combination of environmental effects on the weakened post-spawning oysters (Southgate and Lucas, 2008). Studies of salinity tolerances show that increased adult mortality is observed during prolonged periods of low surface salinity (Al-sayed et al., 1997). Curiously, larvae have wider salinity tolerances than adults and studies show an inverse relationship between level of mortality and salinity, rather than an abrupt change from near total survival to near total mortality as observed in adult populations subjected to reduced salinities (Ota, 1957). This suggests that dramatic changes in temperature and salinity may lead to adult mortality while simultaneously triggering spawning events, a phenomenon which we have termed "suicide-spawning" episodes. Spawning in marine bivalves oysters is often associated with temperature extremes or sudden changes in the environment (Taylor, 2004). The maritime climate of the Bahamas creates relatively stable environmental conditions punctuated by severe storm events. During stable intervals between hurricanes, both hurricane-sensitive and buffered populations may exhibit periods of progressive senescence. We have begun to suspect that normal seasonal storms may provide an essential trigger for spawning in these oysters. A pond that is over-protected from dramatic shifts in temperature or salinity may in fact exhibit lower fecundiity due to a failure of synchrony in gamete release. Such a pond (Oyster Pond) may exhibit progressive senescence until visited by a particularly severe storm that overcomes the habitats natural buffering influence. In such habitats, a Hurricane event appears to even have a rejuvenating effect on the oyster population. It is curious that these storm-induced spawning events can have delayed lethal effects on the adults ("suicide spawning"). In ponds exhibiting greater sensitivity to storm-driven environmental changes (Mermaid Pond), even normal, seasonal storms may be sufficient to create synchronous spawning episodes. This would account for the more consistent appearance of juveniles in Mermaid Pond even in years without hurricane activity. In Six Pack Pond, there is very little protection from storm-driven changes in salinity and temperature. Consequently, it may not be surprising that juveniles are a common sight. The down-side is that particularly severe storms appear to annihilate the adult population even while stimulating a massive synchronous spawning event.

The rapid recovery of the adult population in 6-Pack Pond following both Hurricane Frances and Noel, suggests that there is a "refuge phenomenon" in which adult oysters are somehow escaping the toxic, brackish, shallow waters, possibly taking refuge in the deeper central waters of the pond. Cahn (1949) observed similar results from a study in Ago Bay, Japan. An abrupt decline in salinity from 30% to 16% increased mortality among oysters at the surface, but did not affect those at lower depths where salinity is more stable. We hypothesize that a deep-water halocline in Six Pack Pond (which reaches depths over four meters) may provide a refuge during freshwater inundation events, though evidence suggests that total adult extermination has occurred historically suggesting a failure of this adult refuge phenomenon (Floyd 1999).

Of the three storm events, those with large amounts of rain appear to have had greater impact than those with only strong winds. Hurricane Floyd (16 inches of rain and strong wind) and Hurricane Noel (24 inches) appear to have had a greater impact than Hurricane Frances with only with only 5 inches of rain. Evidence suggests that Hurricane Floyd, with a combination of strong winds and rain, was most destructive in Six Pack. Hurricane Noel with heavy rainfall (24 inches) appeared to have the greatest impact on all three oyster populations, leading to the largest subsequent decrease in mean hinge length due, in part, to mortality among the largest oysters, and to hurricane-induced spawning that lead to juvenile recruitment.

Scaly Pearl Oysters appear to follow a modified Bertalanffy growth curve, growing faster as juveniles and progressively slower as they reach maturity. The remarkably slow growth of the Six Pack Pond population is the probably the result of the hypersaline conditions of the pond itself. Studies of *Pinctada* species revealed that oysters are tolerant of a wide range of salinities though optimal growth is not observed over the extent of the entire range (Ota, 1957). Growth rate is closely correlated to heart rate (Gervis and

Sims 1992), which is elevated at a certain range of reduced salinity. Growth of adult oysters observed at salinities of 45, 40, 34, 30 and 25 ppt., was significantly depressed at salinities of 45, 40 and 25 ppt (Taylor, 2009). Salinity influences both the growth and survival of oysters, affecting oxygen consumption, electrolyte balance and the rate of particle transport over the gills. Spawning stress also reduces the growth of Pearl oysters as it does with a variety of other bivalves. Nasr (1984) noted a decreased rate of growth in mature *P. margaritifera* that coincided with the spawning season. Due to periodic hurricane disturbance, fluctuating salinity and spawning stress may also contribute to the slower growth rates observed in Six Pack Pond.

The dissimilar physical characteristics of these four ponds, two hurricane-buffered, and two hurricane-sensitive, have created a unique natural experiment to observe the effects of hurricane disturbance on population dynamics. The discrepancy in growth rates has implications for interpreting the schedule for sex change in Scaly Pearl Oysters. In initial observations it appeared as if the Six Pack Pond population was exhibiting precocious protandrous sex-reversal (becoming a female at a smaller size). Matching age to size reveals the stage at which sex change occurs in all three ponds, whether it is determined by age, or size. We have initiated a study tracking the development of oocytes to gain further insight into the seasonal development of the gonad. We hope this research will give us a deeper understanding of the Scaly Pearl oyster, particularly concerning its growth and development and the relative role of environmental influences on growth, sex determination and reproduction.

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