A paleoecological and ecological investigation of the effects of freshwater on estuarine bivalves

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INTRODUCTION

Faka-Union Bay, an estuary in the Ten Thousand Islands National Aquatic Preserve in southwest Florida, is fed by a vast canal system that has been draining a 250km^2 cypress slough into the estuary since its construction thirty years ago. Average annual flow into the bay is 300ft^3/s, which is approximately 100 times the volume of water it received prior to the canal's construction. This freshwater influx has dramatically depressed the salinity of Faka-Union Bay. Essentially, we are in the midst of a large-scale experiment to determine the effects of fresh water on estuarine fauna; this study begins to gather the results of that experiment.
The control for the experiment is Blackwater Bay, an estuary approximately 8 km northwest of Faka-Union Bay. It is fed by the Blackwater River, whose drainage has not been significantly affected by development. During the dry season, Faka-Union Bay maintains a salinity level within 5 parts per thousand (ppt) of Blackwater Bay, and ranges from 30-40 ppt. In the wet season, the salinity of Faka-Union Bay drops to as much as 20 ppt below that of Blackwater Bay. This study seeks to identify the ecological effects of this freshwater pollution on the estuarine bivalves of Faka-Union Bay, through statistical comparison to Blackwater Bay.

METHODS

Field locations were selected on or near the axis of each estuary. At each site, the location was noted with a GPS unit, characteristics of the immediate area were described, and four two-gallon samples were taken with a shovel. The depth of sampling in the substrate was approximately three to six inches. The depth of water at each site was .5-1.5 m at low tide. Each sample was wet-sieved in the field, retaining particles greater than 3 mm (primarily shells and shell fragments), and bagged and labeled. Non-mollusc particles (including sea grasses, mangrove wood chips, and living annelids, echinoderms, and crustaceans) were noted and discarded. Unsieved sediment samples were taken at each site taken for later size analysis. At each site, samples were collected from areas of muddy substrate and, if found, sandy substrate. The mollusc samples were rinsed, dried, and carefully examined to remove all living or articulated molluscs. The life assemblage was stored in a 70% solution of isopropyl alcohol; the death assemblage was stored in specimen display boxes and ziplock bags. All molluscs were sorted, identified by species, and counted. Articulated molluscs were counted with the life assemblage, and bivalves were counted by beaks, to eliminate the chance of over-counting a species whose posterior fragments were readily identifiable.

DIVERSITY MEASURE

The Shannon-Weiner Diversity Index was calculated for each sample and for the aggregated samples collected at each site. The Shannon-Weiner Index, first used in information science (Renyi 1987), is a measure of the uncertainty of predicting the classification of any one data point (in this case, the species of any given shell), which is a function both of how many species are present and how dominant or rare each species is. The formula for the index is $H' = -\sum p(x) \ln p(x)$, where H' is the Shannon-Weiner Index for a sampled community and p(x) is the percentage each species represents of the entire assemblage (Pielou 1975). A sample with only one species, however numerous, would have an index value of 0; a sample with 1000 specimens distributed evenly over 20 species would have an index value of 3.00. Because it incorporates both numerically common species (p(x)) and rare species (ln p(x)), while remaining largely independent of sample size, the Shannon-Weiner index is used extensively in diversity studies (Pielou 1975). Figures 1 through 4 show the mean Shannon-Weiner values (plus or minus one standard deviation) for the life and death assemblages of Faka-Union Bay and Blackwater Bay.

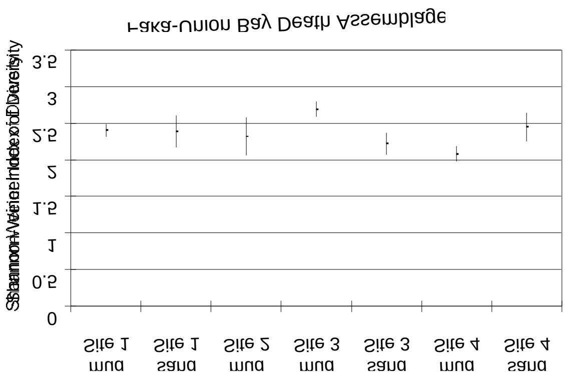


Figure 1

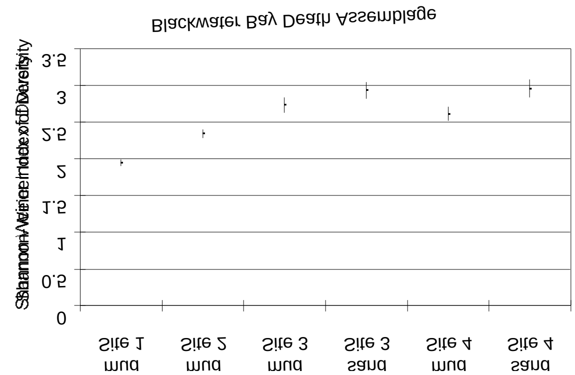
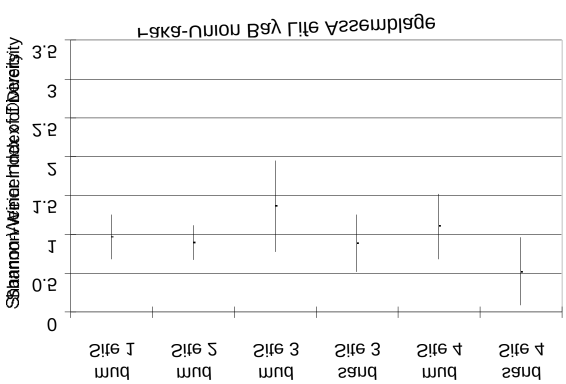


Figure 2



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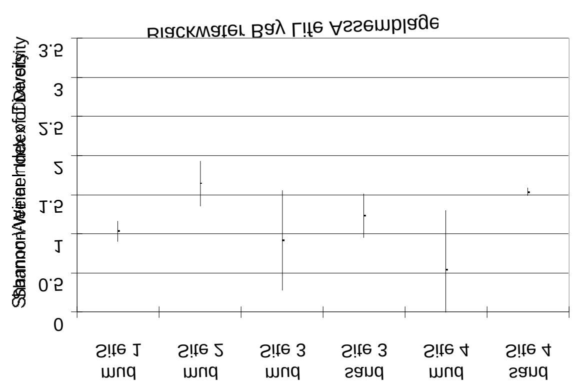

Figure 4

RESULTS

Life and death assemblage analysis (see faunal lists, Tables 1 and 2) showed that every site contained shells of organisms not present in the life assemblage. How much of the difference between the life and death assemblage is due to an actual change in species richness and how much is due to bioclast transport cannot be conclusively determined, but can in some cases be constrained by the pristine state (the relative lack of taphonomic alteration) of certain valves. Each of the common species in the estuary had numerous pristine valves, indicating that they have traveled very little, if at all, from the substrate in which they were found in life.

Life and death assemblage analysis reveals the dramatic difference between the life assemblages of the two estuaries. Blackwater Bay's samples show a gradational change in species assemblage down the estuarine axis; in Faka-Union, the same three species, *Macoma constricta*, *Macoma tenta*, and *Tellina mera*, dominate the life assemblage from the mouth of the freshwater canal almost to the Gulf of Mexico. In Blackwater Bay, six species are common (i.e., represent more than 5% of the assemblage): *Tellina mera* (25%), *Carditamera floridana* (19%), *Corbula contracta* (11%), *Codakia orbiculata* (8%), *Nuculana acuta* (6%), and *Anomalocardia auberiana* (5%) (Figure 4). The remaining 36% consists of 10 species, each comprising 1-4% of the life assemblage, and 8 species, each representing less than 1% of the assemblage. The Faka-Union Bay life assemblage is dominated by four species that together make up more than three-quarters of the living molluscs: *Macoma constricta* (24%), *Macoma tenta* (21%), *Tellina mera* (19%), and *Carditamera floridana* (15%). Of the other 20 species present, 7 comprise 1-4% of the assemblage, and 13—more than half of the species present—comprise less than 1% each (Figure 5). Such extraordinary dominance of a population by so few species often indicates an ecological imbalance. The rapid population growth implied by these numbers suggests that either too many of these species are successfully reproducing or else too few are dying. The latter could be a result of the removal from the system of a keystone predator driven regionally extinct by the ecological alterations resulting from the freshwater increase: if predation was the primary check on these species growth, the removal of that predator would free them to out-compete other bivalves.

Another species whose population changed dramatically between the life and death assemblage

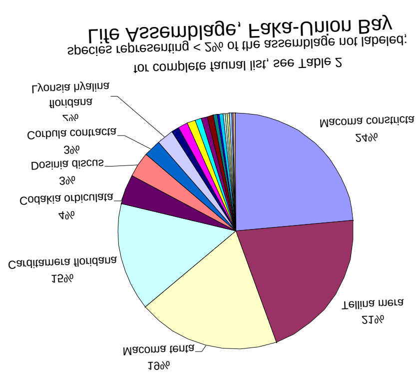

Figure 6

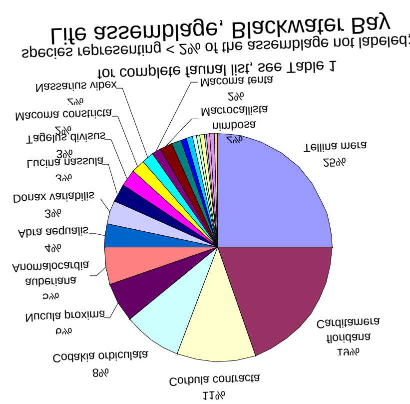

Figure 5

is *Anomalocardia auberiana*, a small venerid clam that is the only species that comprises the same proportion of the death assemblage in the two estuaries (7%). Researchers in Florida Bay found that *Anomalocardia auberiana* is the index species for a near-shore sub-environment characterized by significant fluvial activity and the lowest salinity of the four identified sub-environments (Turney and Perkins, 1972). *Anomalocardia* occupies a niche of that description in the death assemblage of the two estuaries studied here: in both bays, its distribution is heavily concentrated near the mouths of the freshwater source. It is still found there in the life assemblage of Blackwater Bay (Figure 7), but is completely absent from that region in Faka-

Table 1: Blackwater Bay death assemblage, dominance ranked
* designates those appearing in the life assemblage

Carditamera floridana *
Crepidula maculosa *
Anomalocardia auberiana *
Lucina nassula *
Abra aequalis *
Tellina mera *
Pisania tincta *
Turitella acropora
Hiatella arctica *
Corbula contracta *
Nassarius vibex *
Cerithium muscarum *
Chione cancellata *
Macoma constricta *
Nucula proxima *
Tellina alternata
Laevicardium mortoni *
Tagelus divisus *
Codakia orbiculata *
Tagelus plebius *
Crepidula aculeata
Tellina iris
Crepidula plana
Tellina versicolor
Mulina lateralis *
Seila adamsi
Noetia ponderosa
Macoma tenta *
Bulla striata
Semele proficua
Crepidula fornicatus
Crassinella martinicensis *
Anadara transversa
Anadara floridana
Haminoea succinea
Calyptraea centralis
Brachidontes exustus
Lyonsia hyalina floridana
Martesia striata
Lucina cf nuttalli
Nuculana acuta *
Melongena corona
Chione sp.
Diodora cayenensis
Prunum apicinum
Cylinella tenuis
Olivella dealbata
Haminoea antillarum
Cyrtopleura costata
Littorina angulifera
Glycymeris pectinata
5 unidentifiable species

Table 2: Faka-Union Bay death assemblage, dominance ran
* designates those appearing in the life assemblag

Tellina iris
Tellina mera *
Cerithium muscarum *
Anomalocardia auberiana *
Macoma constricta *
Tagelus plebius *
Bulla striata
Nassarius vibex *
Pisania tincta *
Diodora cayenensis
Diplodonta punctata
Haminoea succinea
Crepidula plana
Melongena corona
Lucina nassula
Macoma tenta *
Abra aequalis
Codakia orbiculata *
Crepidula aculeata
Hiatella arctica *
Brachidontes exustus
Crepidula maculosa
Prunum apicinum
Crepidula fornicatus
Laevicardium mortoni *
Turitella acropora
Lucina cf nuttalli
Haminoea elegans
Haminoea antillarum *
Tagelus divisus *
Dosinia discus *
Carditamera floridana *
Chione cancellata
Mulina lateralis
Tellina versicolor
Bittiolum varium
Glycymeris pectinata
Noetia ponderosa
Epitonium rupicolum
Lyonsia hyalina floridana *
Polinices duplicatus *
Martesia striata
Tegula fasciata
Cylinella tenuis
Dinocardium robustum
Ensis minor *
Epitonium matthewsae
Henrya morisini
Nuculana acuta
Seila adamsi
Tellina alternata
Calyptraea centralis
Nucula proxima *
Olivella dealbata
Petricola pholadiformus
Tellina similis
5 unidentifiable species

Appearing in the life assemb
but not the death assemblag
Ensis minor
Macrocallista nimbosa

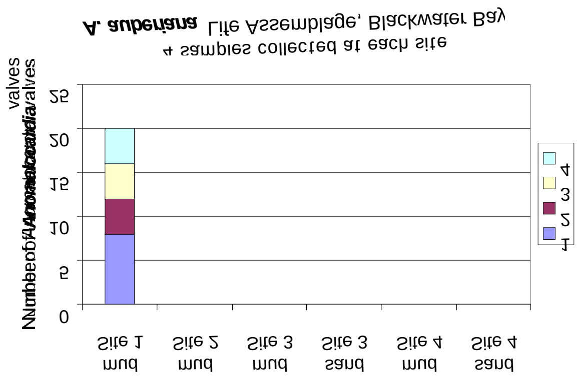

Figure 7

Figure 8

Union Bay. In the Faka-Union life assemblage, *Anomalocardia* is present as only two specimens, both taken from the Gulf side of the estuary—much further from the canal's mouth than would be predicted by Turney and Perkins or by the pattern of its own death assemblage (Figure 8). This suggests that the water in the majority of the estuary has become too fresh too allow even a fairly fresh water-tolerant species to survive; the ecosystems appear to be moving downstream to follow the retreating salinity gradient.

Sediment analysis size was undertaken but is incomplete: mud-sized sediments consistently clumped into sand-sized particles during dry-sieving. Repeated efforts to resolve this (including washing the sediment with acetone to dissolve organic solvents and with distilled water to dissolve halite crystals) proved unable to prevent the clay from clumping. The 2-3-phi fraction is therefore inflated, and the silt- and clay-sized fraction (<4phi) reduced (Figure 9).

The statistically significant differences between the life and death assemblage of Faka-Union Bay, not observed in Blackwater Bay, suggest that the ecosystems of Faka-Union Bay are adapting to the new ecological conditions presented by the quantities of fresh water flowing down Faka-Union Canal.

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