Impacts of a New Tidal Inlet on Estuarine Nekton:
The Opening of Packery Channel in Corpus Christi Texas.

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IMPACTS OF A NEW TIDAL INLET ON ESTUARINE NEKTON: The opening of Packery Channel in Corpus Christi, Texas.

Technical Report

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Abstract

In the Gulf of Mexico the vast majority of commercially important species are estuarine-dependent with larvae migrating through tidal inlets, where they use estuaries as "nursery" grounds. Access to high quality habitats in estuarine areas via tidal inlets is critical for reproduction, growth, survival, and sustainability of these populations. Packery Channel, a natural tidal inlet, has been closed since the 1930's due to sedimentation. The US Army Corps of Engineers recently dredged and permanently reopened this inlet to allow water exchange from the Gulf of Mexico into the Laguna Madre near Corpus Christi Bay, Texas. We established seven locations at varying distances from Packery Channel to assess the impact of this new inlet on estuarine nekton. Within each location we selected two sampling sites in seagrass meadows dominated by *Halodule wrightii* and collected triplicate nekton samples (10 m^2) twice per season using an epibenthic sled. Sampling took place prior to the opening of Packery Channel (October 2004 – May 2005) and one year after (July 2005 – April 2006). We found distinct differences in nekton mean densities post-channel opening. Our results show that estuarine-dependent nekton are using Packery Channel as a means of ingress into the estuary. Economically important species such as red drum and penaeid shrimp were more abundant post-opening and their mean sizes were significantly smaller. These results suggest that the Packery Channel may have important implications to fisheries along the Texas coast by allowing newly recruiting nekton access to the extensive seagrass meadows of the Laguna Madre.

Introduction

In the Gulf of Mexico 75% of commercially important species are estuarine-dependent (Chambers 1992). Many economically and ecologically important nekton species live and spawn in coastal waters where their larvae migrate through tidal inlets into estuaries and use these shallow areas as “nursery” grounds (Weinstein 1979, Baltz et al. 1993, Kneib 1993, Minello 1999). Access to high quality habitat in estuarine areas via tidal inlets is critical for reproduction, growth, survival, and sustainability of these populations.

Many areas along the Gulf coast are characterized by long chains of barrier islands interrupted by tidal inlets allowing water exchange between the Gulf of Mexico and bay systems. Most of the tidal inlets along this chain of islands exist permanently because of construction of jetty breakwaters and dredging (Britton and Morton 1989). Packery Channel, a natural tidal inlet, was periodically open until the 1930s but has since been closed due to sedimentation. It is located in the southeast corner of Corpus Christi Bay at the Mustang/Padre Island boundary.

A project by the US Army Corps of Engineers began in 2003 to dredge and permanently reopen this inlet to allow water exchange from the Gulf of Mexico into Corpus Christi Bay and the Laguna Madre. The Laguna Madre is a negative estuary as a result of the following: limited freshwater input, evaporation exceeds precipitation, shallow bathymetry, microtidal tide regime, limited circulation, and limited connection with the Gulf of Mexico (Britton and Morton 1989, Tunnell 2002). Given that the Laguna Madre is one of five negative estuaries in the world (Javor 1989), the new inlet may affect the dynamics of the hypersaline lagoon.

Few studies have assessed the impact of reopening a tidal inlet to estuarine organisms. Reid (1957) examined the impacts of opening Rollover Pass in the Galveston Bay system in Texas from 1954-1956. He found that fish populations were not significantly altered, although there was a fluctuation in shrimp species. Reid also suggested that stenohaline marine forms were immigrating into the bay system after the opening of the inlet, due to higher salinity levels. Once the inlet was partially blocked (due to erosion) the bay seemed to revert back to its natural condition. This study is significant because it contains some of the only published data that examines the effects of opening an inlet on fish and crustacean abundance (Simmons and Hoese 1959).

The opening of Packery Channel will result in water exchange between the Gulf of Mexico with Corpus Christi Bay and the upper Laguna Madre, which is expected to alter salinity levels of the estuarine system (US Army Corps of Engineers 2003). According to the final Environmental Impact Statement by the US Army Corps of Engineers (2003), this project will periodically reduce hypersaline conditions in the upper Laguna Madre. From a fisheries perspective this channel will create a direct link between the Gulf of Mexico and nearby estuarine habitats (e.g., seagrass meadows) for juvenile fishes and crustaceans. A new inlet into the estuarine system should result in higher fisheries productivity from adjacent habitats that are currently inaccessible from other inlets.

The opening of Packery Channel may have important ecological impacts on estuarine species living in the upper Laguna Madre. Many of these species spawn offshore in the Gulf of Mexico, typically near inlets. Their eggs, larvae, and juveniles recruit into estuarine habitats through the inlet. These habitats are often termed nursery habitats due to the high productivity, survival, and growth rates of juveniles into adults (Minello 1999, Beck et al. 2001). As a result, the new inlet will provide an opportunity for newly recruiting nekton to use the extensive seagrass meadows of the upper Laguna Madre.

Juvenile fishes and crustaceans use shallow estuarine areas as nursery habitat, where they have protection from predation and access to abundant food sources to support rapid growth (Heck and Thoman 1981, Levin et al. 1997, Minello 1999, Stunz et al. 2002*b*). Rapid growth rates reduce the time juvenile fish and invertebrates spend at sizes most vulnerable to predation. Changes in the dynamics of the upper Laguna Madre due the opening of Packery Channel could influence growth rates of estuarine-dependent species. A new means of ingress into these habitats via Packery Channel could increase food availability and dissolved oxygen levels, as well as lower salinity levels, which could potentially change the quality of the habitats adjacent to Packery Channel. It has been shown that modest changes in daily growth rates can cause major changes in recruitment levels of fish (Houde 1987). Small daily differences in growth rates in the first year of life can result in large differences (1-2 orders of magnitude) in the number of individuals becoming sexually mature (Houde 1987). Understanding the effects of the environment on growth rates during the first year of life of fishes is essential to understanding the role of the environment in regulating the abundance of marine fishes (Buckley et al. 1999).

The opening of Packery Channel provided a unique opportunity to examine the impacts of a new tidal inlet on adjacent estuarine seagrass habitats, and therefore juvenile fishes and crustaceans. The purpose of this study was to characterize nekton use of habitats adjacent to Packery Channel prior to opening of the new inlet and to monitor seasonal changes after opening.

Methods

Study Location

The Laguna Madre is a bar-built coastal lagoon that is bordered by barrier islands to the east and the mainland to the west. The Rio Grande Delta divides it into two separate lagoons: the Laguna Madre of Texas, USA, to the north, and the Laguna Madre de Tamaulipas, Mexico, to the south. Together these two lagoons form the largest of five hypersaline systems in the world (Javor 1989). The Laguna Madre, Texas contributes more than one-half of the state's inshore finfish catch (Hedgpeth 1967). It is a coastal embayment that extends 445 km from Corpus Christi Bay, Texas to Rio Soto la Marina, Mexico, with a mean width of ~7 km (Tunnell 2002). The mean depth is slightly less than 1 m (Britton and Morton 1989). In Texas it extends 200 km south from Corpus Christi Bay to the Mexico border (Quammen and Onuf 1993), and is separated into two sub-units (the upper Laguna Madre and lower Laguna Madre) by the Land Cut south of Baffin Bay (Tunnell 2002). The upper Laguna Madre and lower Laguna Madre are connected by the Gulf Intracoastal Waterway (GIWW). The Laguna Madre is protected by Padre Island from the high-energy Gulf of Mexico. Padre Island extends the entire length of the Laguna Madre, interrupted only by Mansfield Pass, a man-made inlet into the lower Laguna Madre (Tunnell 2002). Salinities in the upper Laguna Madre are typically 40 ppt (Quammen and Onuf 1993), but historically salinities have reached 86 ppt (Britton and Morton 1989).

This lagoon-system may be directly affected by the opening of Packery Channel due to water exchange with the Gulf of Mexico. Sites will be selected in seagrass meadows predominated by *Halodule wrightii* at varying distances from the opening of Packery Channel. Seagrass meadows are the primary habitat in this area and *H. wrightii* is the dominant seagrass in the upper Laguna Madre due to its ability to tolerate high salinities (Britton and Morton 1989).

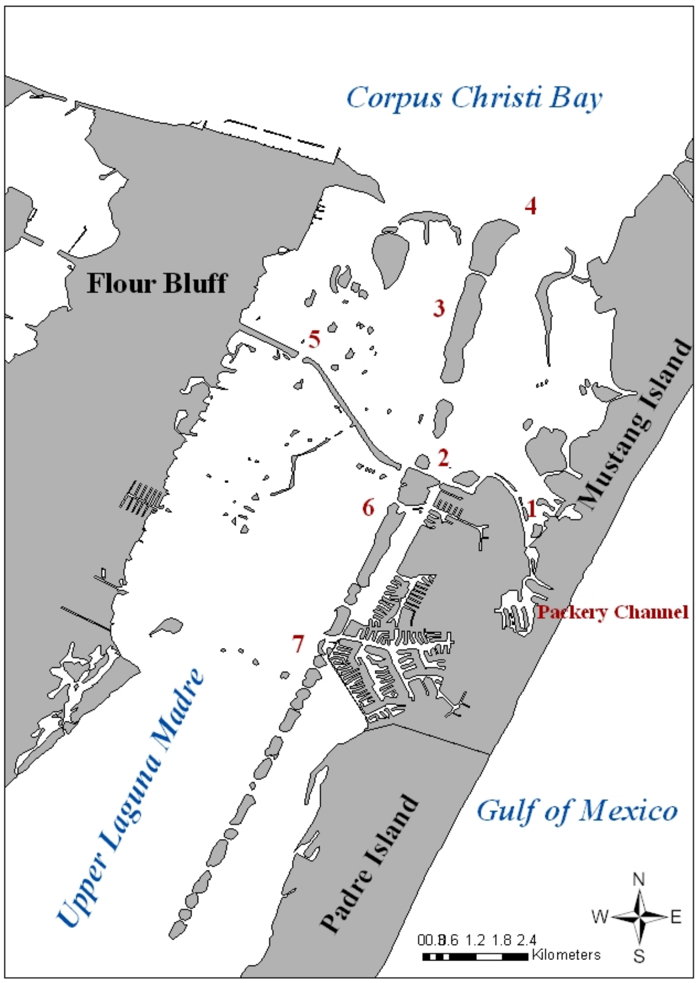

Figure 1. Map representing the sampling locations in the Upper Laguna Madre, Texas.

Delineation of sites and sampling

We established a total of seven locations at varying distances from the Packery Channel opening (Fig. 1) but not further than 10 km. We hypothesized that areas within 10 km of Packery Channel would be the most influenced. Within each location there were two sampling sites (14 total sites). We selected locations starting from seagrass meadows nearest the opening of the Packery Channel (near the TX 361 bridge) and approximately 1 km thereafter extending north in the Laguna Madre towards Corpus Christi Bay, south into the Laguna Madre, and NW toward Flour Bluff. Each sampling occurred in *H. wrightii* meadows, the dominant habitat type in the area (Quammen and Onuf 1993).

We collected a total of 84 nekton samples using an epibenthic sled seasonally for two years; one-year prior to the opening of Packery Channel and one-year after. We took six replicate samples at each location (three per site), twice seasonally, for a total of 84 samples. The only exception was summer when we only collected 42 samples both pre- and post-opening since Packery Channel opened midway into the summer season. The epibenthic sled used consists of a metal frame with an opening of 0.6 m (length) by 0.75 m (height) with a 1-mm mesh conical plankton net. It was pulled ~17 m, which covers 10 m^2 of bottom. This has been shown as effective gear for sampling nekton in seagrass meadows (Stunz et al. 2002*a*). The sampling dates for both pre- and post-opening follow respectively: fall (October 2004-November 2004; October 2005-November 2005), winter (February 2005; February 2006), spring (March 2005-April 2005; March 2006-April 2006), and summer (May 2005; July 2005). The samples were rough-sorted in the field and pre-served in 10% formalin. In the lab, nekton were sorted, identified to lowest possible taxon, measured, and pre-served in 70% ethanol. Fish were measured to the nearest 0.1 mm (SL) and crustaceans were measured to the nearest 0.1 mm total carapace width (CW) for crabs or total length (TL) for shrimp. If more than 20 individuals were caught for each species, the largest and smallest and 20 other random individuals were measured. Brown shrimp (*Farfantepenaeus aztecus*), pink shrimp (*Farfantepenaeus duorarum*), and white shrimp (*Litopenaeus setiferus*) were all were grouped into "penaeid shrimp" because many of them were in an unidentifiable range (10 – 18 mm TL) (Rozas and Minello 1998). Of the identifiable penaeid shrimp, brown shrimp were the predominant species.

At each of the sites (14 total) water temperature (°C) and dissolved oxygen (ppm) were measured using a YSI DO 200 meter. Salinity (ppt) was measured using a refractometer, and water depth was also recorded during each sampling period.

Statistical Analysis

To assess the overall impact of Packery Channel on the adjacent habitats, we grouped all locations and seasons and used a Student's *t*-test ($\alpha = 0.05$) to determine differences in mean densities of nekton before and after the opening of Packery Channel. We also assessed differences among sites and locations using a two-way Analysis of Variance (ANOVA). Significant ANOVA results were further analyzed using Tukey's post-hoc multiple comparison procedure to determine specific differences among locations (Day and Quinn 1989, Raposa et al. 2003). We tested differences in nekton density seasonally pre- verses post-opening by choosing several commercially important species that have different seasonal recruitment patterns and may not have been dominant in all seasons. We used a Student's *t*-test ($\alpha = 0.05$) to compare species densities pre-verses post-opening. We converted the total catch to density (organisms/m^2) and then used the log transformation (log (x+1)) to minimize heteroscedasticity. Size differences pre- and post-opening were also tested using the above species of fish. Mean lengths for each species were computed and pre- and post-opening were compared using a Student's *t*-test ($\alpha = 0.05$).

Although it was not the focus of this study, physical parameters (dissolved oxygen (mg/L), salinity (‰), temperature (ºC), and depth (cm)) were analyzed by season pre- and post-opening. Dissolved oxygen, salinity, and temperature are not reported for the summer samples pre-opening.

Results

Physical Parameters

There were significant differences in water depth (cm), temperature (ºC), and salinity (‰) seasonally pre- verses post-opening (Table 1). Dissolved oxygen, water temperature, and salinity were not measured during the summer sampling pre-opening due to instrument malfunction. Dissolved oxygen (mg/L) was not different during fall, winter, or spring pre- verses post-opening ($P = 0.893$; $t = 0.135$; $df = 40$; $1- \beta = 0.943$; $P = 0.294$; $t = 1.061$; $df = 54$; $1- \beta = 0.959$; $P = 1.000$; $t = 0.000$; $df = 13$; $1- \beta = 0.956$). Water depth, temperature, and salinity were all significantly higher fall post-opening ($P = 0.005$; $t = -2.951$; $df = 40$; $P = 0.003$; $t = -3.122$; $df = 48$; $P < 0.001$; $t = -5.513$; $df = 48$). In the winter water depth was significantly lower post-opening ($P < 0.001$; $t = 5.361$; $df = 54$), and both water temperature and salinity were significantly higher post-opening ($P < 0.038$; $t = -2.125$; $df = 54$; $P < 0.001$; $t = -12.814$; $df = 54$). Similar to fall, water depth, temperature, and salinity were all significantly higher in the spring post-opening ($P < 0.001$; $t = -5.213$; $df = 54$; $P < 0.001$; $t = -5.196$; $df = 54$; $P < 0.001$; $t = -12.060$; $df = 54$). Water depth was not different pre- verses post-opening during the summer ($P = 0.136$; $t = 1.537$; $df = 26$; $1- \beta = 0.810$).

Table 1. Physical parameters (with standard errors, S.E.) for both pre-opening, October 2004-July 2005, and post-opening, July 2005-April 2006 are listed below. Measurements were taken at each sampling site twice each season (28 total) for fall, winter, and spring. There are a few missing parameters due to instrument malfunction and only depth was measured in the summer pre-opening (May 2005). Measurements for summer post-opening were only taken once. Results of the comparison between pre- and post-opening using a Student's *t*-test (P-value) for each parameter are also listed. An * listed indicates that the value was significant.

	Pre-			Post			
Parameter	Mean	SE	n	Mean	SE	n	P
Fall							
Water depth (cm)	30	(2.6)	14	38	(1.7)	28	0.005*
Dissolved oxygen (mg/L)	7.76	(0.2)	14	7.53	(0.3)	28	0.893
Water temperature (°C)	22.9	(1.3)	22	26.8	(0.2)	28	0.003*
Salinity (‰)	33	(0.4)	22	40	(0.7)	28	0.001*
Winter							
Water depth (cm)	37	(1.6)	28	22	(1.6)	28	0.001*
Dissolved oxygen (mg/L)	8.18	(0.2)	28	7.90	(0.1)	28	0.294
Water temperature (°C)	14.0	(0.6)	28	15.8	(0.2)	28	0.038*
Salinity (‰)	29	(0.2)	28	37	(0.3)	28	0.001*
Spring							
Water depth (cm)	21	(1.3)	28	35	(2.0)	28	0.001*
Dissolved oxygen (mg/L)	7.07	(0.3)	28	7.33	(0.2)	28	1.000
Water temperature (°C)	21.6	(0.5)	28	24.1	(0.2)	28	0.001*
Salinity (‰)	27	(0.2)	28	39	(1.1)	28	0.001*
Summer							
Water depth (cm)	35	(1.1)	14	30	(1.6)	14	0.136
Dissolved oxygen (mg/L)	NA	(NA)	0	6.75	(0.5)	14	NA
Water temperature (°C)	NA	(NA)	0	33.3	(0.4)	14	NA
Salinity (‰)	NA	(NA)	0	40	(0.8)	14	NA

Nekton Density

Locations and sites were analyzed to assess differences between sites within each location and differences among all locations. There was no statistically significant interaction between site and location therefore sites were combined within each location ($P = 0.848$; $F = 0.446$; $df = 6$, $1\text{-}\beta = 0.950$). Differences within each location pre- and post-opening are illustrated in Fig. 2. All seasons were combined for each location to give an overall view of how each of the locations changed pre- verses post-opening. Although there were differences in some locations, they were combined for further analysis.

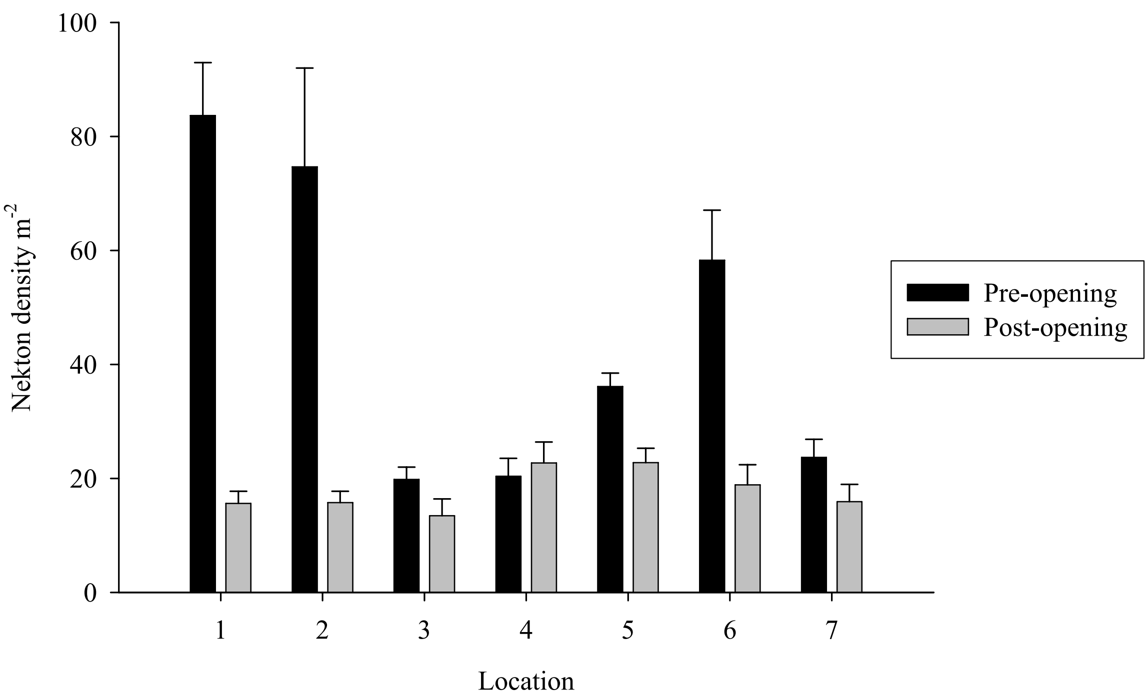

Figure 2. Overall mean densities of all nekton collected at each location over all seasons both pre-opening (October 2004 – May 2005) and post opening (July 2005 – April 2006). The two sites per location were combined since there was no significant interaction between location and site.

Overall, there were significantly higher densities of nekton pre-opening ($P<0.001$; $t = 10.791$; $df = 586$) than post-opening (Fig. 3). Crustaceans dominated nekton total catch pre- and post-opening, 96% and 89% respectively. Grass shrimp dominated the crustacean abundance both pre- and post-opening, 83% and 52% respectively. The significant difference in total nekton pre- verses post-opening can be attributed to the difference in grass shrimp densities. There were significantly fewer grass shrimp post opening than pre-opening ($P < 0.001$; $t = 13.740$; $df = 586$). There were no significant differences in mean densities of fish or crustaceans (excluding grass shrimp) pre- verses post-opening ($P = 0.092$; $t = 1.687$; $df = 586$; $1-\beta = 0.743$; $P = 0.368$; $t = -0.901$; $df = 586$; $1-\beta = 0.950$) (Fig. 4).

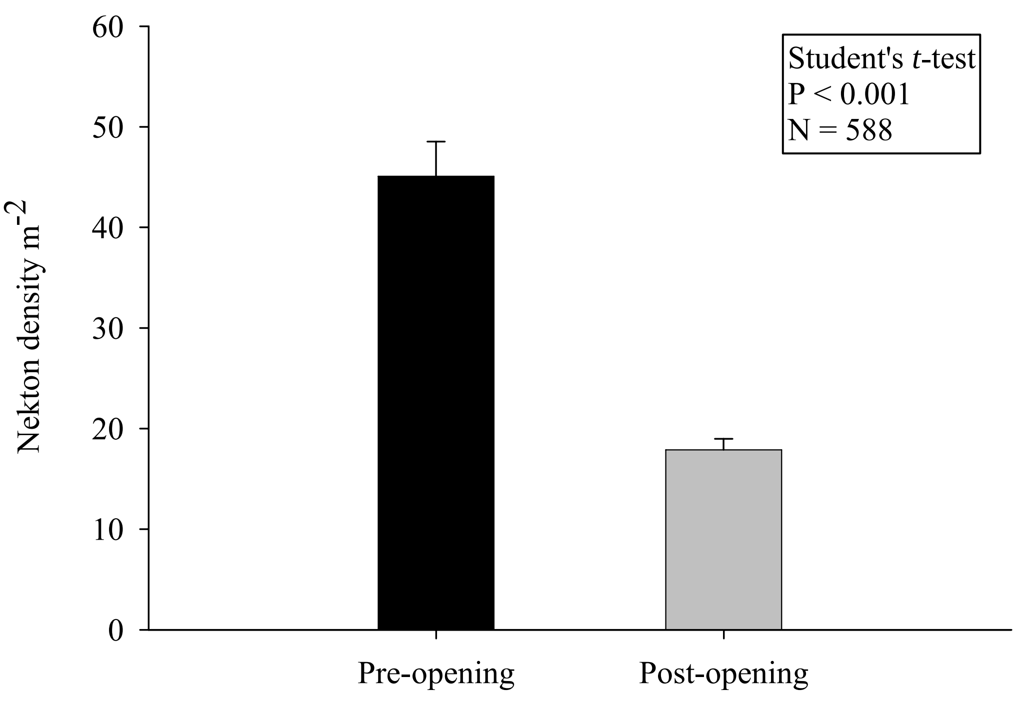

Figure 3. Mean nekton densities over all seasons pre- and post-opening for all locations and sites combined.

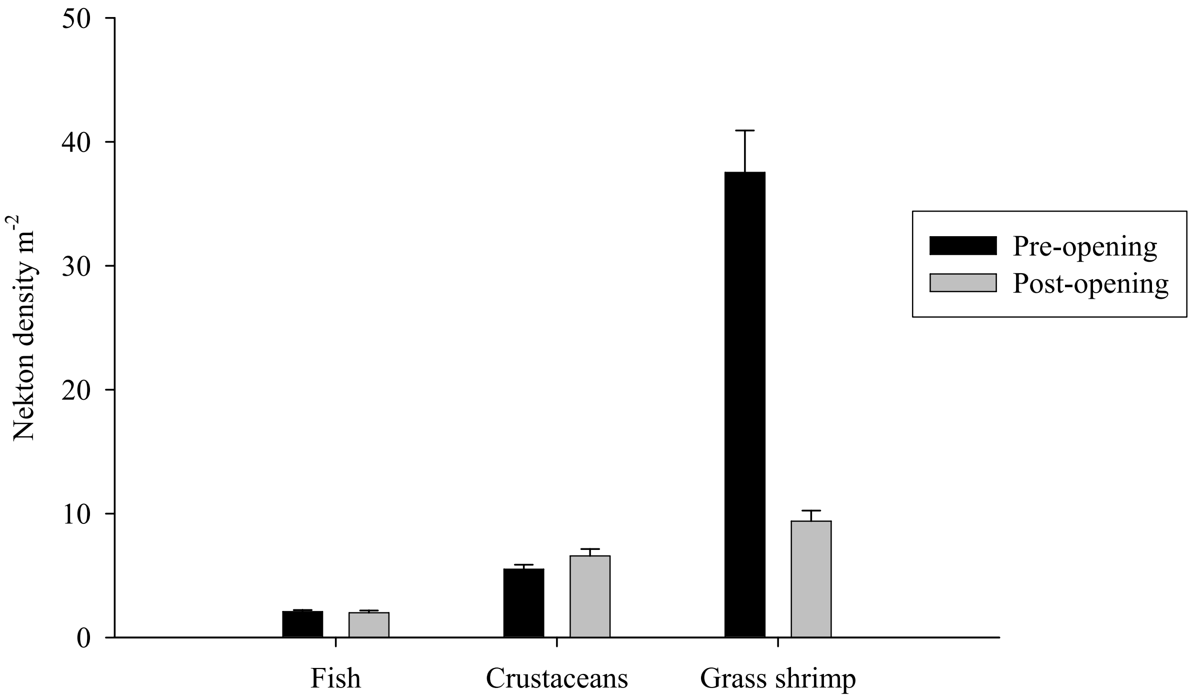

Figure 4. Mean densities of fish, crustaceans (excluding grass shrimp), and grass shrimp pre- and post-opening over all seasons and all locations. Means and standard error bars were calculated from 586 samples for all three groups.

Table 2 summarizes mean densities seasonally of all species and groups of nekton that were collected pre- and post-opening. The total number of organisms collected (total catch) for each group are listed seasonally pre-opening, post-opening, and overall (combined pre- and post-opening). Relative abundance (RA %) was calculated seasonally for both fish and crustaceans separately, and only includes species that have an RA of at least 0.1%. An overall RA (%) was also calculated by combining both pre-opening and post-opening seasonally. Killifish (Fundulidae) and pipefish (*Syngnathus* spp.) were the most abundant fishes (53.7% and 24.1%) in the fall pre-opening. Killifish, pipefish, and darter gobies (*Gobiosoma boleosoma*) were the most abundant fishes (36.0%, 25.3%, and 20.8%) in the fall post-opening. In the winter killifish and pinfish (Lagodon *rhomboides*) were the most abundant fishes (39.0% and 30.9%) pre-opening; post-opening pinfish, killifish, and Atlantic croaker (*Micropogonias undulatus*) were the most abundant fishes (37.3%, 18.6%, and 16.0%). In the spring pinfish, killifish, and code gobies (*Gobiosoma robustum*) were the most abundant fishes (47.6%, 21.2%, and 15.5%) pre-opening; post-opening pinfish and darter gobies were the most abundant (45.2% and 21.8%). Pinfish and code gobies were the most abundant fishes in the summer both pre-opening (54.6% and 20.4%) and post-opening (35.2% and 18.6%). Grass shrimp (*Palaemonetes* spp.) were the most abundant crustaceans over all seasons both pre- and post-opening (refer to Table 2). The mean sizes of all fish and crustaceans collected were also recorded and have been summarized in Table 3.

Table 2. Mean densities, number per m^2 (with standard errors, S.E.) of all nekton collected are shown seasonally for both pre-opening, October 2004-July 2005, and post-opening, July 2005-April 2006. All locations and sites were combined for overall mean densities by season. Each mean density is calculated from a total of 84 samples taken each season, with the exception of summer when only 42 samples were collected each pre- and post-opening sampling. The mean number of total fish and crustaceans are also listed by season. The total number of organisms caught (total catch) is given seasonally for pre-opening, post-opening, and overall (pre- and post-opening combined) for all groups and species. The relative abundance (RA) is listed seasonally for fishes and crustaceans, and only includes species or groups that have a relative abundance of at least 0.1% for pre-opening, post-opening, and overall (pre- and post-opening combined).

	Pre				Post					
Species	Mean	S.E.	Total Catch	RA (%)	Mean	S.E.	Total Catch	RA (%)	Overall Total Catch	Overall RA (%)
Fall										
FISHES										
Total Fishes	2.217	(0.142)	1862		1.519	(0.080)	1279		3141	
Anchoa mitchilli					0.005	0.000	4	0.3	4	0.1
Citharichthys spilopterus	0.001	0.000	1	0.1					1	
Cynoscion nebulosus	0.001	0.000	1	0.1	0.001	0.000	1	0.1	2	0.1
Fundulidae	0.256	(0.082)	1000	53.7	0.020	(0.011)	130	10.2	1130	36.0
Eucinostomus argenteus					0.012	0.004	10	0.8	10	0.3
Gobionellus boleosoma	0.035	(0.016)	29	1.6	0.744	(0.136)	624	48.8	654	20.8

Gobiosoma bosc					0.001	0.000	1	0.1	1	
Gobiosoma robustum	0.333	(0.054)	280	15.0	0.099	(0.031)	83	6.5	363	11.6
Unidentified Gobiidae					0.002	0.000	2	0.2	2	0.1
Hippocampus zosterae	0.015	(0.005)	13	0.7	0.002	0.000	2	0.2	15	0.5
Hypsoblennius hentz	0.005	(0.006)	4	0.2	0.001	0.000	1	0.1	5	0.2
Lagodon rhomboides	0.010	(0.000)	8	0.4	0.018	0.004	15	1.2	23	0.7
Lobotes surinamensis					0.001	0.000	1	0.1	1	
Lutjanus griseus					0.002	0.000	2	0.2	2	0.1
Menidia beryllina	0.054	(0.070)	45	2.4	0.014	(0.037)	12	0.9	57	1.8
Microgobius gulosus	0.015	(0.024)	13	0.7	0.002	0.000	2	0.2	15	0.5
Opsanus beta	0.007	0.005	6	0.3	0.001	0.000	1	0.1	7	0.2
Scartella cristata	0.001	0.000	1	0.1					1	
Sciaenops ocellatus	0.012	0.004	10	0.5	0.032	(0.006)	27	2.1	37	1.2
Symphurus plagiusa	0.004	(0.008)	3	0.2	0.013	(0.009)	11	0.9	14	0.4
Syngnathus spp.	0.533	(0.051)	448	24.1	0.414	(0.043)	348	27.2	796	25.3
Synodus foetens					0.001	0.000	1	0.1	1	
Unidentified fish					0.001	0.000	1	0.1	1	
CRUSTACEANS										
Total Crustaceans	36.798	(2.016)	30910		22.882	(1.436)	19221		50131	
Alpheus heterochaelis	0.017	(0.003)	14		0.002	0.000	2		16	
Callinectes sapidus	0.277	(0.085)	233	0.8	0.114	(0.036)	96	0.5	329	0.7
Libinia spp.	0.001	0.000	1						1	
Palaemonetes spp.	32.962	(2.536)	27688	89.6	15.656	(1.857)	13151	68.4	40839	81.5
Penaeid Shrimp	1.180	(0.139)	991	3.2	1.958	(0.172)	1645	8.6	2636	5.3
Tozeuma carolinense	2.204	(0.578)	1851	6.0	5.062	(1.733)	4252	22.1	6103	12.2
Xanthidae	0.157	(0.050)	132	0.4	0.089	(0.021)	75	0.4	207	0.4

	Pre				Post					
Species	Mean	S.E.	Total Catch	RA (%)	Mean	S.E.	Total Catch	RA (%)	Overall Total Catch	Overall RA (%)
Winter										
FISHES										
Total Fishes	2.752	(0.075)	1361		3.833	(0.157)	2385		3746	
Anchoa mitchilli	0.002	0.000	2	0.1					2	0.1
Chasmodes bosquianus	0.001	0.000	1	0.1					1	
Citharichthys spilopterus	0.008	0.000	7	0.5	0.049	(0.016)	41	1.7	48	1.3
Cyprinodontidae	0.632	(0.113)	531	39.0	0.196	(0.073)	165	6.9	696	18.6
Gobionellus boleosoma	0.051	(0.011)	43	3.2	0.451	(0.066)	379	15.9	422	11.3
Gobiosoma robustum	0.244	(0.048)	205	15.1	0.014	(0.007)	12	0.5	217	5.8
Unidentified Gobiidae	0.005	0.000	4	0.3	0.064	(0.055)	54	2.3	58	1.5
Hippocampus zosterae	0.013	(0.012)	11	0.8					11	0.3
Lagodon rhomboides	0.500	(0.079)	420	30.9	1.162	(0.228)	976	40.9	1396	37.3
Menidia beryllina	0.007	(0.031)	6	0.4	0.001	0.000	1	0.0	7	0.2
Micropogonias undulatus	0.020	(0.009)	17	1.2	0.693	(0.249)	582	24.4	599	16.0
Mugil cephalus	0.004	(0.008)	3	0.2	0.067	(0.114)	56	2.3	59	1.6
Opsanus beta					0.001	0.000	1		1	
Paralichthys lethostigma	0.007	0.005	6	0.4	0.008	(0.006)	7	0.3	13	0.3
Sciaenops ocellatus	0.001	0.000	1	0.1	0.004	(0.008)	3	0.1	4	0.1
Symphurus plagiusa					0.005	0.000	4	0.2	4	0.1
Syngnathus spp.	0.123	(0.023)	103	7.6	0.123	(0.035)	103	4.3	206	5.5
Synodus foetens					0.001	0.000	1		1	
Unidentified fish	0.001	0.000	1	0.1					1	
CRUSTACEANS										
Total Crustaceans	50.154	(3.780)	42129		13.850	(1.110)	11634		53763	

Alpheus heterochaelis	0.004	0.000	3						3	
Callinectes sapidus	0.243	(0.038)	204	0.5	0.450	(0.060)	378	3.2	582	1.1
Palaemonetes spp.	47.965	(6.109)	40291	95.6	8.715	(1.889)	7321	62.9	47612	88.6
Penaeid Shrimp	0.605	(0.086)	508	1.2	3.564	(0.556)	2994	25.7	3502	6.5
Tozeuma carolinense	1.132	(0.238)	951	2.3	0.994	(0.540)	835	7.2	1786	3.3
Unidentified crab	0.001	0.000	1						1	
Xanthidae	0.204	(0.031)	171	0.4	0.126	(0.035)	106	0.9	277	0.5

	Pre				Post					
Species	Mean	S.E.	Total Catch	RA (%)	Mean	S.E.	Total Catch	RA (%)	Overall Total Catch	Overall RA (%)
<u>Spring</u>										
FISHES										
Total Fishes	2.317	(0.120)	1946		1.933	(0.120)	1624		3570	
Anchoa mitchilli					0.005	(0.006)	4	0.2	4	0.1
Citharichthys spilopterus	0.011	0.004	9	0.5	0.021	(0.007)	18	1.1	27	0.8
Cyprinodontidae	0.492	(0.156)	413	21.2	0.029	(0.029)	24	1.5	437	12.2
Gobionellus boleosoma	0.163	(0.054)	137	7.0	0.762	(0.169)	640	39.4	777	21.8
Gobiosoma robustum	0.358	(0.045)	301	15.5	0.026	(0.016)	22	1.4	323	9.0
Unidentified Gobiidae	0.005	0.000	4	0.2	0.099	(0.088)	83	5.1	87	2.4
Hippocampus zosterae	0.015	(0.005)	13	0.7					13	0.4
Hyporhamphus unifasciatus	0.001	0.000	1	0.1	0.001	0.000	1	0.1	2	0.1
Lagodon rhomboides	1.102	(0.181)	926	47.6	0.819	(0.150)	688	42.4	1614	45.2
Leiostomus xanthurus	0.035	(0.044)	29	1.5	0.049	(0.024)	41	2.5	70	2.0
Menidia beryllina	0.017	(0.023)	14	0.7	0.024	(0.098)	20	1.2	34	1.0
Microgobius gulosus	0.005	0.000	4	0.2					4	0.1
Micropogonias undulatus	0.006	0.000	5	0.3	0.027	(0.008)	23	1.4	28	0.8

Mugil cephalus					0.001	0.000	1	0.1	1	
Ophichthus gomesii					0.002	0.000	2	0.1	2	0.1
Opsanus beta	0.004	0.000	3	0.2					3	0.1
Orthopristis chrysoptera	0.004	0.000	3	0.2	0.001	0.000	1	0.1	4	0.1
Paralichthys lethostigma	0.001	0.000	1	0.1	0.001	0.000	1	0.1	2	0.1
Prionotus tribulus					0.001	0.000	1	0.1	1	
Symphurus plagiusa					0.004	0.000	3	0.2	3	0.1
Syngnathus spp.	0.098	(0.013)	82	4.2	0.058	(0.013)	49	3.0	131	3.7
Synodus foetens	0.001	0.000	1	0.1	0.002	0.000	2	0.1	3	0.1
CRUSTACEANS										
Total Crustaceans	47.185	(4.688)	39635		10.871	(0.558)	9132		48767	
Alpheus heterochaelis	0.011	(0.009)	9						9	
Callinectes sapidus	0.438	(0.043)	368	0.9	0.317	(0.188)	266	2.9	634	1.3
Palaemonetes spp.	38.901	(9.349)	32677	82.4	2.580	(0.659)	2167	23.7	34844	71.4
Penaeid Shrimp	5.867	(0.750)	4928	12.4	7.301	(0.519)	6133	67.2	11061	22.7
Tozeuma carolinense	1.206	(0.225)	1013	2.6	0.576	(0.269)	484	5.3	1497	3.1
Xanthidae	0.762	(0.100)	640	1.6	0.098	(0.036)	82	0.9	722	1.5

	Pre				Post					
Species	Mean	S.E.	Total Catch	RA (%)	Mean	S.E.	Total Catch	RA (%)	Overall Total Catch	Overall RA (%)
<u>Summer</u>										
FISHES										
Total Fishes	1.945	0.135	817		1.629	0.086	684		1501	
Anchoa mitchilli	0.040	0.050	17	2.1					17	1.1
Blenniidae					0.002	0.000	1	0.1	1	0.1
Citharichthys spilopterus	0.002	0.000	1	0.1					1	0.1

Cynoscion nebulosus					0.002	0.000	1	0.1	1	0.1
Cyprinodontidae	0.148	0.086	62	7.6	0.074	0.036	31	4.5	93	6.2
Eucinostomus argenteus					0.381	0.138	160	23.4	160	10.7
Gobionellus boleosoma	0.031	0.016	13	1.6	0.452	0.141	190	27.8	203	13.5
Gobiosoma robustum	0.398	0.077	167	20.4	0.267	0.037	112	16.4	279	18.6
Unidentified Gobiidae					0.012	0.000	5	0.7	5	0.3
Hippocampus zosterae	0.014	0.000	6	0.7					6	0.4
Lagodon rhomboides	1.062	0.232	446	54.6	0.195	0.028	82	12.0	528	35.2
Leiostomus xanthurus	0.026	0.012	11	1.3	0.002	0.000	1	0.1	12	0.8
Lutjanus griseus					0.007	0.000	3	0.4	3	0.2
Lutjanus spp.	0.019	0.022	8	1.0	0.002	0.000	1	0.1	9	0.6
Menidia beryllina					0.002	0.000	1	0.1	1	0.1
Microgobius gulosus	0.014	0.007	6	0.7	0.010	0.009	4	0.6	10	0.7
Opsanus beta	0.002	0.000	1	0.1	0.010	0.000	4	0.6	5	0.3
Orthopristis chrysoptera	0.038	0.017	16	2.0	0.002	0.000	1	0.1	17	1.1
Paralichthys lethostigma	0.002	0.000	1	0.1					1	0.1
Syngnathus spp.	0.140	0.026	59	7.2	0.202	0.053	85	12.4	144	9.6
Synodus foetens	0.007	0.000	3	0.4					3	0.2
Unidentified fish					0.005	0.000	2	0.3	2	0.1
CRUSTACEANS										
Total Crustaceans	32.943	2.872	13836		15.533	1.267	6524		20360	
Alpheus heterochaelis	0.005	0.000	2		0.005	0.000	2		4	
Callinectes sapidus	0.040	0.008	17	0.1	0.048	0.018	20	0.3	37	0.2
Palaemonetes spp.	23.040	5.028	9677	69.9	11.157	1.444	4686	71.8	14363	70.5
Penaeid Shrimp	3.095	0.261	1300	9.4	0.826	0.198	347	5.3	1647	8.1
Tozeuma carolinense	6.331	1.011	2659	19.2	3.369	1.431	1415	21.7	4074	20.0
Xanthidae	0.431	0.106	181	1.3	0.129	0.133	54	0.8	235	1.2

Table 3. Mean sizes, mm, (with standard errors, S.E.) for all species or groups caught pre-opening, October 2004-July 2005, and post-opening, July 2005-April 2006, are listed seasonally. Mean sizes (standard length for fish, total length for shrimp, and carapace width for crabs) were calculated from n number of species measured each season pre- and post-opening. If more than 20 individuals were caught for each species or group, the largest and smallest and 20 other random individuals were measured.

	Pre-			Post		
Species	Mean	S.E.	n	Mean	S.E.	n
Fall						
FISHES						
Anchoa mitchilli				24.7	(0.73)	4
Citharichthys spilopterus	12.0	(0.00)	1			
Cynoscion nebulosus	26.8	(0.00)	1	8.9	(0.00)	1
Fundulidae	18.6	(0.63)	681	17.4	(0.47)	130
Eucinostomus argenteus				23.9	(1.34)	10
Gobionellus boleosoma	28.5	(1.05)	29	18.7	(0.63)	510
Gobiosoma bosc				20.2	(0.00)	1
Gobiosoma robustum	15.5	(0.57)	282	14.9	(0.39)	83
Gobiidae				20.7	(1.33)	2
Hippocampus zosterae	19.2	(0.58)	13	17.1	(0.41)	2
Hypsoblennius hentz	32.8	(2.47)	4	61.0	(0.00)	1
Lagodon rhomboides	66.2	(0.70)	8	62.1	(1.07)	15
Lobotes surinamensis				48.3	(0.00)	1
Lutjanus griseus				71.7	(4.71)	2
Menidia beryllina	19.3	(0.89)	45	27.9	(0.52)	12
Microgobius gulosus	23.2	(0.90)	13	29.6	(0.62)	2
Opsanus beta	55.3	(1.29)	6	33.4	(0.00)	1
Scartella cristata	40.3	(0.00)	1			
Sciaenops ocellatus	23.0	(1.12)	10	8.9	(0.24)	27
Symphurus plagiusa	31.0	(0.59)	3	17.2	(0.91)	11
Syngnathus spp.	46.4	(2.16)	451	47.8	(2.32)	348
Synodus foetens				79.6	(0.00)	1
Unidentified fish				10.4	(0.00)	1
CRUSTACEANS						
Alpheus heterochaelis	20.2	(0.97)	14	19.4	(0.02)	2
Callinectes sapidus	15.9	(0.85)	208	8.7	(0.73)	94
Libinia spp.	19.0	(0.00)	1			

Palaemonetes spp.	14.5	(0.53)	1816	13.3	(0.44)	1726
Penaeid Shrimp	26.7	(2.04)	797	28.4	(1.20)	1326
Tozeuma carolinense	24.2	(0.67)	669	21.3	(0.66)	752
Xanthidae	9.5	(0.46)	131	7.3	(0.44)	74

	Pre-			Post		
Species	Mean	S.E.	n	Mean	S.E.	n
<u>Winter</u>						
FISHES						
Anchoa mitchilli	19.0	(0.10)	2			
Chasmodes bosquianus	49.7	(0.00)	1			
Citharichthys spilopterus	17.8	(1.00)	7	15.9	(0.80)	41
Fundulidae	20.6	(0.57)	468	24.3	(0.50)	167
Gobionellus boleosoma	16.8	(0.61)	44	19.3	(0.64)	370
Gobiosoma robustum	16.9	(0.52)	205	19.7	(0.60)	12
Gobiidae	9.5	(0.04)	4	9.5	(0.07)	53
Hippocampus zosterae	22.1	(0.18)	11			
Lagodon rhomboides	16.9	(0.47)	408	13.6	(0.46)	588
Menidia beryllina	19.2	(0.14)	5	29.7	(0.00)	1
Micropogonias undulatus	17.8	(0.40)	17	12.1	(0.29)	311
Mugil cephalus	22.5	(0.09)	3	23.1	(0.19)	39
Opsanus beta				39.3	(0.00)	1
Paralichthys lethostigma	11.7	(0.42)	6	10.7	(0.35)	7
Sciaenops ocellatus	68.8	(0.00)	1	67.50	(1.16)	2
Symphurus plagiusa				32.6	(0.86)	4
Syngnathus spp.	69.4	(1.47)	103	66.6	(2.19)	103
Synodus foetens				11.5	(0.00)	1
Unidentified fish	8.8	(0.00)	1			
CRUSTACEANS						
Alpheus heterochaelis	22.6	(1.38)	3			
Callinectes sapidus	14.4	(0.93)	203	9.2	(0.66)	370
Palaemonetes spp.	14.4	(0.52)	1718	14.9	(0.48)	1139
Penaeid Shrimp	20.6	(1.36)	452	16.3	(0.82)	1457
Tozeuma carolinense	28.4	(0.44)	550	29.0	(0.53)	258
Unidentified crab	6.3	(0.00)	1			
Xanthidae	5.6	(0.36)	171	5.0	(0.26)	106

	Pre-			Post		
Species	Mean	S.E.	n	Mean	S.E.	n
<u>Spring</u>						
FISHES						
Anchoa mitchilli				11.5	(0.08)	4
Citharichthys spilopterus	25.9	(0.93)	9	18.2	(1.02)	17

Fundulidae	22.1	(0.62)	348	20.2	(0.25)	24
Gobionellus boleosoma	20.0	(0.84)	128	20.0	(0.83)	479
Gobiosoma robustum	21.2	(0.59)	301	22.3	(0.74)	21
Gobiidae	10.1	(0.11)	4	10.0	(0.06)	81
Hippocampus zosterae	24.5	(0.29)	13			
Hyporhamphus unifasciatus				15.1	(0.00)	1
Lagodon rhomboides	19.1	(0.85)	668	18.3	(0.72)	540
Leiostomus xanthurus	33.7	(0.60)	29	36.3	(1.05)	41
Menidia beryllina	17.4	(0.94)	14	17.2	(0.21)	19
Microgobius gulosus	38.2	(0.34)	4			
Micropogonias undulatus	24.7	(0.45)	5	15.7	(1.08)	23
Mugil cephalus				25.2	(0.00)	1
Ophichthus gomesi				172.3	(1.50)	2
Opsanus beta	72.1	(1.07)	3			
Orthopristis chrysoptera	14.3	(0.25)	3	10.5	(0.00)	1
Paralichthys lethostigma	25.7	(0.00)	1	8.8	(0.00)	1
Prionotus tribulus				48.6	(0.00)	1
Symphurus plagiusa				47.4	(0.29)	3
Syngnathus spp.	65.6	(2.91)	82	63.1	(2.14)	49
Synodus foetens	72.4	(0.00)	1	62.4	(3.84)	2
CRUSTACEANS						
Alpheus heterochaelis	24.6	(0.64)	9			
Callinectes sapidus	17.0	(1.01)	362	11.9	(0.59)	171
Palaemonetes spp.	15.4	(0.63)	1755	15.2	(0.53)	708
Penaeid Shrimp	22.4	(1.23)	2003	19.6	(1.18)	2517
Tozeuma carolinense	30.6	(0.59)	566	25.3	(0.86)	272
Xanthidae	6.1	(0.35)	568	6.1	(0.33)	82

	Pre-			Post		
Species	Mean	S.E.	n	Mean	S.E.	n
Summer						
FISHES						
Anchoa mitchilli	16.8	(0.22)	15			
Blenniidae				8.0	(0.00)	1
Citharichthys spilopterus	54.9	(0.00)	1			
Cynoscion nebulosus				10.1	(0.00)	1
Fundulidae	19.9	(0.39)	62	21.4	(0.63)	31
Eucinostomus argenteus				9.7	(0.16)	138
Gobionellus boleosoma	24.1	(0.73)	13	9.1	(0.20)	173
Gobiosoma robustum	23.5	(0.38)	166	22.1	(0.58)	112
Gobiidae				8.8	(0.06)	4
Hippocampus zosterae	19.7	(0.70)	6			
Lagodon rhomboides	25.2	(0.60)	328	38.3	(0.93)	82

Leiostomus xanthurus	44.4	(1.01)	11	50.3	(0.00)	1
Lutjanus griseus				15.5	(0.15)	3
Lutjanus spp.	18.4	(0.55)	8	24.7	(0.00)	1
Menidia beryllina				16.7	(0.00)	1
Microgobius gulosus	42.6	(0.56)	6	22.6	(0.73)	4
Opsanus beta	15.6	(0.00)	1	73.9	(4.20)	4
Orthopristis chrysoptera	20.6	(0.45)	16	50.9	(0.00)	1
Paralichthys lethostigma	102.0	(0.00)	1			
Syngnathus spp.	45.7	(3.14)	59	59.0	(2.31)	85
Synodus foetens	60.3	(1.67)	3			
CRUSTACEANS						
Alpheus heterochaelis	23.3	(0.35)	2	18.7	(0.52)	2
Callinectes sapidus	16.4	(0.72)	17	7.3	(0.84)	20
Palaemonetes spp.	14.9	(0.60)	847	17.8	(0.56)	829
Penaeid Shrimp	34.9	(1.42)	817	22.3	(2.07)	305
Tozeuma carolinense	24.2	(0.70)	679	22.3	(0.89)	239
Xanthidae	4.7	(0.35)	174	7.2	(0.35)	47

Seven species of fishes and crustaceans that have different seasonal recruitment patterns and that may not have been dominant in all seasons, were then analyzed seasonally to detect specific differences in densities pre- verses post-opening: red drum (*Sciaenops ocellatus*), pinfish (*Lagodon rhomboids*), Atlantic croaker (*Leiostomus xanthurus*), southern flounder (*Paralichthys lethostigma*), killifish (Fundulidae), blue crab (*Callinectes sapidus*), and penaeid shrimp. For the purpose of analysis, all killifish collected (*Cyprinodon variegates*, *Adinia xenica*, *Fundulus grandis*, *Fundulus similis*, and *Lucania parva*) were grouped into the family Fundulidae. *Cyprinodon variegatus*, which is in the Cyprinodontidae family, was also included in the Fundulidae family.

In the fall, there were significantly higher mean densities of red drum post-opening ($P = 0.011$; $t = -2.579$; $df = 166$) than pre-opening. In the winter we also found significantly higher mean densities of pinfish ($P = 0.030$; $t = -2.185$; $df = 166$) and Atlantic croaker ($P<0.001$; $t = -4.137$; $df = 166$) post-opening. There was no significant difference in southern flounder mean densities in the winter pre- verses post-opening ($P = 0.826$; $t = -0.220$; *df* = 166; $1-\beta = 0.950$). Killifish densities were analyzed over all seasons, and there were significantly fewer killifish post-opening ($P<0.001$; $t = 8.331$; *df* = 586). There was no significant difference in blue crab mean densities pre- verses post-opening when combining fall, winter, and spring densities ($P = 0.075$; $t = 1.783$; *df* = 502; $1- \beta = 0.958$). Penaeid shrimp were analyzed overall all seasons both pre- and post-opening, and there were significantly higher mean densities of penaeid shrimp post-opening ($P<0.001$; $t = -4.379$; *df* = 586) (Fig. 5).

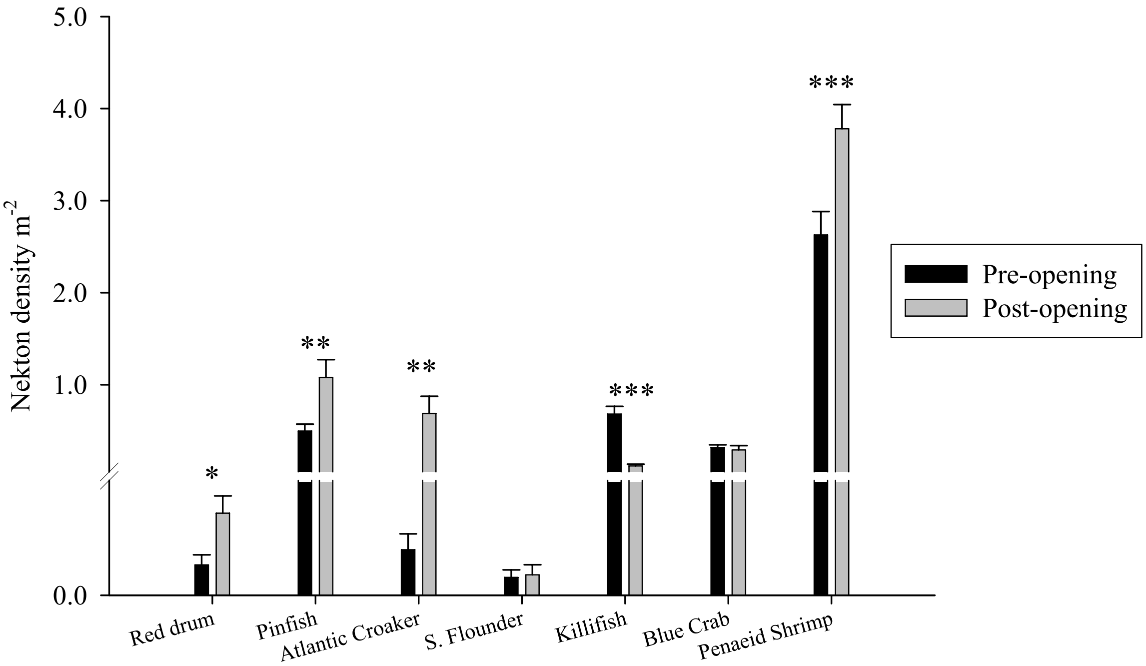

Figure 5. Mean densities of selected fishes and crustaceans pre- and post-opening over all locations and different seasons. Red drum mean densities were calculated from fall samples, pinfish and Atlantic croaker mean densities were calculated from winter samples, southern flounder mean densities were calculated from winter samples, killifish and penaeid shrimp mean densities were calculated over all seasons, and blue crab densities were calculated from fall, winter, and spring samples. Student's *t*-test was performed on the selected fishes and crustaceans; * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

Table 4. Mean densities, in number per m^2, of selected fish and crustaceans (with standard error, S.E.) for both pre-opening and post-opening are summarized below. Red drum mean densities were calculated from fall samples; pinfish and Atlantic croaker mean densities were calculated from winter samples; southern flounder mean densities were calculated from winter samples; killifish mean densities were calculated by combining all seasons; blue crab mean densities were calculated by combing fall, winter, and spring densities; penaeid shrimp mean densities were calculated by combining all seasons. Results of the comparison between pre- and post-opening using a Student's *t*-test (P-value) for each species are also listed. An * listed indicates that the value was significant.

	Pre-		Post		
Species	Mean	S.E.	Mean	S.E.	P
Red drum *Sciaenops ocellatus*	0.012	(0.004)	0.032	(0.007)	0.011*
Pinfish *Lagodon rhomboides*	0.498	(0.075)	1.080	(0.194)	0.030*
Atlantic croaker *Micropogonias undulatus*	0.018	(0.006)	0.690	(0.185)	0.001*
Southern flounder *Paralichthys lethostigma*	0.007	(0.003)	0.008	(0.004)	0.826
Killifish Fundulidae	0.682	(0.083)	0.119	(0.019)	0.001*
Blue crab *Callinectes sapidus*	0.319	(0.030)	0.294	(0.046)	0.075
Penaeid Shrimp	2.628	(0.256)	3.782	(0.262)	0.001*

The mean size of some fish and decapod crustacean species differed pre- verses post-opening. In the fall, red drum were significantly smaller post-opening than pre-opening ($P < 0.001$; $t = 7.608$; *df* = 35). Pinfish and Atlantic croaker were also significantly smaller in the winter ($P = 0.030$; $t = 13.521$; *df* = 994; $P < 0.001$; $t = 8.910$; *df* = 326). There was no difference in size of southern flounder pre- verses post-opening ($P = 0.628$; $t = 0.499$; *df* = 11; $1- \beta = 0.950$). Size differences of blue crabs were analyzed over fall, winter, and spring as with the mean densities. Blue crabs were significantly smaller ($P < 0.001$; $t = 18.486$; *df* = 1406) post-opening. Penaeid shrimp were also significantly smaller post-opening over all seasons ($P < 0.001$; $t = 17.110$; *df* = 9671) (Table 5, Fig. 6). Fundulidae were excluded from the size analyses because of variability in size due to multiple species.

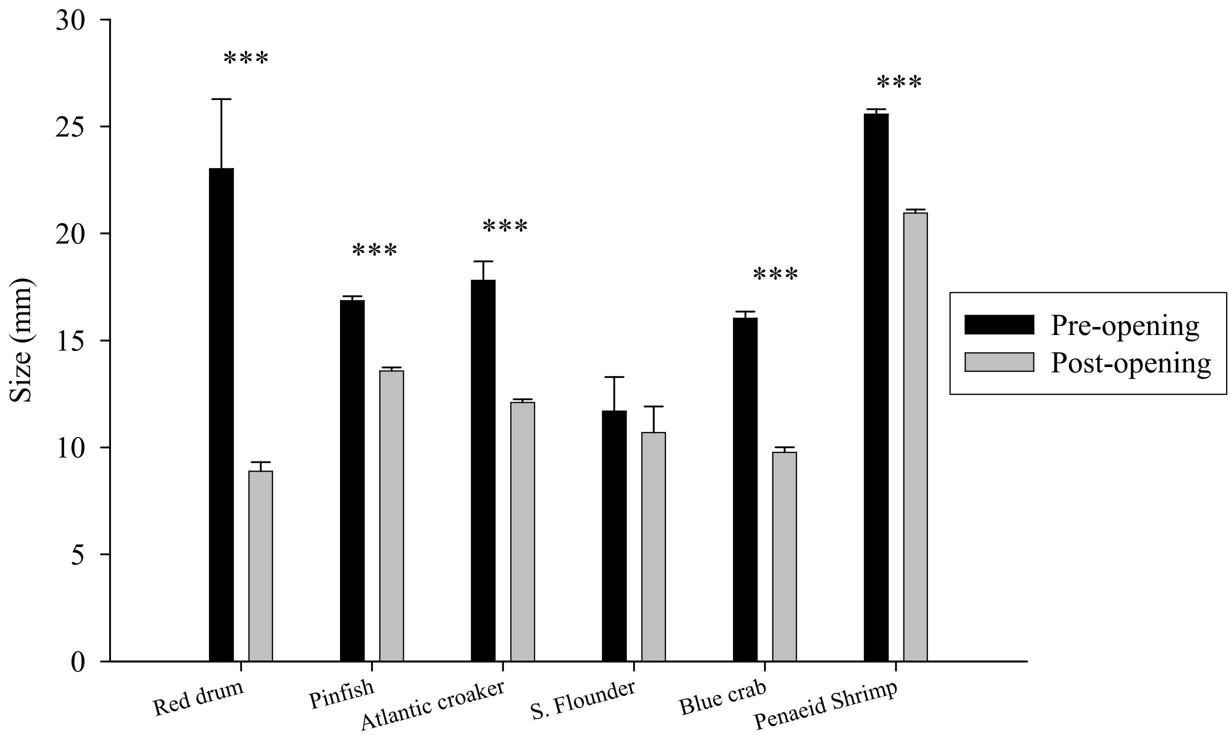

Figure 6. Mean sizes of selected fishes and crustaceans pre- and post-opening over all locations and different seasons. S. Flounder = Southern Flounder. Red drum mean sizes were calculated from fall samples; pinfish, Atlantic croaker, and southern flounder mean sizes were calculated from winter samples; blue crab sizes were calculated from fall, winter, and spring samples; penaeid shrimp mean sizes were calculated over all seasons. Student's *t*-test was performed on the selected fishes and crustaceans; * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

Table 5. Mean sizes, mm, of selected fish and crustaceans (with standard error, S.E.) for both pre-opening, October 2004-July 2005, and post-opening, July 2005-April 2006, are listed below. Mean sizes (standard length for fish, total length for shrimp, and carapace width for crabs) were calculated from n number of species measured each season pre- and post-opening. If more than 20 individuals were caught for each species or group, the largest and smallest and 20 other random individuals were measured. Red drum mean sizes were calculated from fall samples; pinfish, Atlantic croaker, and southern flounder mean sizes were calculated from winter samples; blue crab mean sizes were calculated by combing fall, winter, and spring densities; penaeid shrimp mean sizes were calculated by combining all seasons. Results of the comparison between pre--opening and post-opening using a Student's *t*-test (P-value) for each species are also listed. An * listed indicates that the value was significant.

	Pre-			Post			
Species	Mean	S.E.	n	Mean	S.E.	n	P
Red drum *Sciaenops ocellatus*	23.020	(3.259)	10	8.881	(0.431)	27	0.001*
Pinfish *Lagodon rhomboides*	16.852	(0.215)	408	13.570	(0.173)	588	0.001*
Atlantic croaker *Micropogonias undulatus*	17.806	(0.887)	17	12.102	(0.149)	311	0.001*
Southern flounder *Paralichthys lethostigma*	11.700	(1.588)	6	10.700	(1.210)	7	0.236
Blue crab *Callinectes sapidus*	16.028	(0.314)	208	9.843	(0.241)	94	0.001*
Penaeid Shrimp	25.579	(0.226)	4069	20.957	(0.156)	5605	0.001*

Discussion

This study was designed to assess the impact of opening a tidal inlet on estuarine nekton in adjacent habitats. Along with measuring differences in nekton densities we also measured differences in water quality. Some of the physical changes to the area were unexpected. Although this was not the main focus of the study we did see some distinct changes in water quality parameters such as depth, temperature, and salinity. Water depth was significantly higher post-opening in fall and spring seasons, whereas it was significantly lower post-opening in the winter and summer seasons. This may be attributed to increase in tidal fluctuations with the opening of Packery Channel, especially in the areas that are most near the channel. Water temperature and salinity were significantly higher post-opening in fall, winter, and spring. The final Environmental Impact Statement by the US Army Corps of Engineers (2003) projected periods of reduced hypersaline conditions in the upper Laguna Madre, but our study did not find these conditions. This may be due to other environmental conditions over the timeframe of the project. Packery Channel did not appear to have any impact on the dissolved oxygen levels of the surrounding areas because there was no significant difference in fall, winter, or spring. Water parameters were only taken twice seasonally resulting in high variability in conditions depending on the date sampled.

Packery Channel had the greatest impact on nekton densities in sampling locations 1, 2, and 6. These locations showed the greatest difference in overall nekton density pre- verses post-opening, which suggests that locations closest to Packery Channel were impacted the most significantly and similarly. Although some differences in locations were seen it was important to look at an overall impact of Packery Channel to the entire adjacent area, so all locations were combined for further analysis.

There were large differences in overall abundance of nekton pre- verses post-opening with all locations and sites combined. There were significantly fewer nekton post-opening. However, drastic declines in grass shrimp abundance appear to be driving these differences. Fish and crustacean abundances (excluding grass shrimp) were not different pre- verses post-opening. Grass shrimp densities were the most affected in locations that were the closest to the actual channel. Pre-opening these were lagoonal areas covered in dense seagrass beds that experienced little tide fluctuation and current. Once Packery Channel was open these locations changed from backwater lagoons to increased current areas. We observed seagrass loss in locations nearest the pass probably due to long periods of exposure due to very low tides post-opening. Grass shrimp select for seagrass cover to forage for food and to decrease predation (Morgan 1980; Orth et al. 1984), so with a lack of water and possibly a high rate of seagrass cover loss in some areas grass shrimp densities sharply decreased post-opening.

There did not appear to be major impacts on the overall fish abundances in the surrounding habitats of Packery Channel. The relative abundances of fish over each season show little change in composition. Killifish and pipefish were both predominant in the fall samples both pre- and post-opening. In the winter, spring, and summer killifish, pinfish, and either darter or code gobies were the predominant species both pre- and post-opening. With the exception of pinfish, these fish are resident species of estuaries. The opening of Packery Channel potentially has a greater impact on species that recruit to estuarine habitats through a tidal inlet.

We chose several ecologically and economically important species that have varied seasonal recruitment patterns and examined differences in their densities pre-verses post-opening. Red drum are an economically important fishery along the Gulf coast, and prior to Packery Channel newly settled red drum did not have access to the extensive nursery habitats of the upper Laguna Madre due to the large distance from the nearest tidal inlet. Post-opening we saw significantly higher densities of juvenile red drum in habitats adjacent to Packery Channel. Similar patterns were seen for other estuarine-dependent recruiting species such as pinfish, Atlantic croaker, and penaeid shrimp. We did not see a difference in southern flounder, but we collected very low densities post-opening. Atlantic croaker densities increased the most drastically post-opening. However, we saw a significant decline in killifish densities post-opening, which are shore fishes that remain within the estuary. This is similar to the trend we saw with grass shrimp, which may be due to changes in tidal fluctuations and increased current flow in some of the closest sampling locations. Blue crab densities were nearly equal pre- and post-opening. This suggests that blue crabs have a very wide dispersal pattern and were able to disperse nearly 35 km from Aransas Pass, the closest tidal inlet, to the upper Laguna Madre.

Size differences of these economically important species also give insight into the use of Packery Channel as a means of recruitment to the upper Laguna Madre. All of the economically important species, except for southern flounder, were significantly smaller post-opening. Juvenile red drum settle into seagrass between 6-8 mm SL (Holt et al. 1983, Rooker and Holt 1997) and the mean size of red drum post-opening was approximately 9 mm SL. This suggests that red drum were recruiting to these areas via

Packery Channel, as we observed very few of the newly settled size pre-opening. Red drum densities were low in the fall post-opening because Packery Channel was not fully dredged. Although densities of blue crabs were not different pre- verses post-opening, the blue crabs collected post-opening were significantly smaller, which suggests they were recruiting via Packery Channel. Southern flounder were caught in such low densities that their mean size was not different pre- verses post-opening. Pinfish, Atlantic croaker, and penaeid shrimp all had the same pattern as with red drum in that they were significantly smaller post-opening. This pattern suggests that economically important fishes are using Packery Channel as a means of recruitment to the nursery grounds of the upper Laguna Madre.

Since many economically important fish require access to estuaries for nursery grounds for their early life stages, tidal inlets play a critical role in this process. Packery Channel now provides access to the very productive upper Laguna Madre as nursery grounds for nekton that recruit through inlets such as red drum, blue crabs, and penaeid shrimp. Packery Channel could potentially translate into higher fisheries productivity. At the conclusion of this study, the Packery Channel had substantial flow, but was still under construction. Further dredging is planned to deepen and widen the channel. These activities will dramatically increase flow and likely result in higher recruitment potential for nekton that rely on these tidal currents for access to estuarine nursery habitats. Further studies are needed to assess the long-term impact of Packery Channel on specific species as well as the Upper Laguna Madre.

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