



**HULL BIOFOULING OF  
BEAUMONT RESERVE FLEET VESSELS  
DUTTON, DEL VALLE, HATTIESBURG VICTORY,  
AND PIONEER CRUSADER**



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## EXECUTIVE SUMMARY

As part of its non-retention vessel disposal program, the U.S. Maritime Administration oversees transfers of ships from reserve fleet locations to ship-breaking facilities. These vessels may pose a high risk of hull-mediated invasions because their underwater surfaces can be heavily fouled by aquatic organisms, and many of the vessels have a long residence time at their destination ports before they are dismantled. As a result, the Maritime Administration has implemented in-water hull cleaning as one management option to reduce the risk of transferring nonnative species to new coastal regions where they may become established.

This study is one in a series that examines the biological growth on obsolete vessels and evaluates the effectiveness of in-water hull cleaning as a vector management option. The extent of biofouling of four Beaumont Reserve Fleet vessels at Beaumont, Texas, was examined. Three vessels, HATTIESBURG VICTORY, DEL VALLE, and PIONEER CRUSADER, were sampled for biological characterization, and one vessel, DUTTON, was sampled for extent of biofouling before hull cleaning, after hull cleaning, and after transit from Beaumont to Brownsville, Texas, where the ship was dismantled.

The sampling design was similar to that implemented on previous biological surveys. Samples were collected with the help of professional divers. Diving was conducted using surface-supplied air and real-time audio and visual communications with a surface team. The surface team included a diver master and two scientists who directed the divers toward the locations where samples, photographs, and video were taken. Generally, 50 samples per sampling iteration were collected from the hull and the stern appendages of the vessels using a stratified random sampling design consisting of transects and starboard to port locations within transect. At each location, a 6-inch diameter PVC sampler was used to scrape approximately a 182 cm<sup>2</sup> area of the hull. Samples were stored in cloth bags, examined and photographed at the fleet, and transferred to the laboratory for sorting, enumeration, and identification of organisms.

A total of 286 samples was available for analysis. DUTTON samples were accompanied by photographs of the hull (photo-quadrats). The system used for the photo quadrats consisted of an underwater camera and a "clear-water box" that provided a standard image area for all photographs. Samples were analyzed for differences in species abundance and composition across surveys, transects, and locations using multivariate analyses. Photo-quadrats were analyzed by the point-count method to determine percent cover of biofouling species (mussels, barnacles, hydroids, algae, etc.) and bare hull. Videos were examined to characterize type and extent of coverage.

The total number of taxa found across all ships and surveys was 103, corresponding to 81 distinct species. Freshwater and brackish water species predominated in the samples. The biofouling community was numerically dominated by Conrad's false mussel, *Mytilopsis leucophaeata*, and the barnacle *Balanus subalbidus*. These two species accounted, respectively, for 87% and 7% of total abundance. The remaining species each accounted for 2% or less of total abundance. *M. leucophaeata* and *B. subalbidus* were

common among all ships and surveys, followed by the amphipod *Apocorophium lacustre*, algae, nematodes, and colonial organisms.

The total species number and abundance differed among ships, and this difference was attributed to age of vessel. The DEL VALLE and PIONEER CRUSADER were newer than the DUTTON and HATTIESBURG VICTORY, and remained active longer. Therefore they had less time to develop dense biofouling assemblages, and harbored fewer species, than the latter two ships. There were no differences in abundance or species composition among transects or locations on the hull, except for a tendency for algae to occur more frequently near the waterline.

Of all the species collected in the surveys, 30 were native in Texas, 12 were cryptogenic (origin unknown), and 6 were introduced. Four of the introduced species were found in Beaumont (the bryozoan *Conopeum chesapeakeensis*, the hydroids *Cordylophora caspia* and *Garveia franciscana*, and the polychaete *Ficopomatus enigmaticus*), and two species were found only in the post-transit survey of the DUTTON in Brownsville (the amphipods *Laticorophium baconi* and *Monocorophium acherusicum*). Except for *C. chesapeakeensis*, the nonnative species are known to occur, or are likely to occur, elsewhere along the Gulf coast. The presence of *C. chesapeakeensis* in the Gulf of Mexico constitutes a new introduction record for this species outside its native range, provided its identification is confirmed.

In-water hull cleaning of the DUTTON was successful at removing on average 82% of the biofouling cover, substantially reducing the number of mussels and barnacles. However, hull cleaning had little or no effect on the frequency of occurrence of hard-shelled organisms and associated species in the samples of the post-cleaning and post-transit surveys. The top eleven most common species in the pre-cleaning samples were still common in the post-cleaning and post-transit samples. "New" species not present in the pre-cleaning survey were also found in the post-transit survey, suggesting that species may attach in route, which represents an additional risk for species transfers and introductions mediated by ocean-going vessels.

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## 1.0 INTRODUCTION

As part of its non-retention vessel disposal program, the U.S. Maritime Administration oversees transfers of ships from National Defense Reserve Fleet (NDRF) locations to ship-breaking facilities. The vessels are towed from their fleet to other geographic locations where ship breaking takes place. Because many vessels have been laid up for long periods of time, their underwater surfaces can be heavily fouled by aquatic organisms and their transfer may create a risk of biological invasion at destination ports. This report is the fourth in a series that documents the biofouling of obsolete vessels, as well as the effectiveness of in-water hull cleaning as a vector management option.

In this study, we examine biological growth on the hull of four vessels at the Beaumont Reserve Fleet (BRF), in Beaumont, Texas. Three vessels, HATTIESBURG VICTORY, DEL VALLE, and PIONEER CRUSADER, were sampled for biological characterization, and one vessel, DUTTON, was sampled for extent of biofouling before hull cleaning, after hull cleaning, and after transit from Beaumont to Brownsville, Texas, where the ship was dismantled. As in previous surveys, the objectives of the present study were to 1) identify and quantify the biota associated with the underwater surfaces of BRF vessels, 2) describe differences in biofouling between the pre-cleaning, post-cleaning, and post-transit biological surveys (DUTTON only), and (3) examine the biogeographic status and distribution of species with respect to their possible transfer from the BRF to destination ports.

The HATTIESBURG VICTORY and DUTTON were World War II Victory ships built in 1945. The SS HATTIESBURG VICTORY was in service as a cargo ship until October 1948, when it entered the NDRF. It was reactivated in 1951 for service in Korea and in 1965 for service during the Vietnam War. In 1985 the HATTIESBURG VICTORY was painted and repaired for a test of reactivation, but after 30 days in service the ship was again deactivated and returned to the BRF, where it was downgraded to non-retention status. It was sold to a ship-breaking company in 2008 and slated for dismantling in late 2008.

The USNS DUTTON was launched as cargo ship under the name SS TUSKEGEE VICTORY. It entered the NDRF in 1952 where it was renamed as DUTTON and placed in service as a survey ship until November 1958. It was downgraded to non-retention status in 1980, and sold for dismantling to All Star Metals, Inc., Brownsville, Texas, in September 2007.

The DEL VALLE and PIONEER CRUSADER were built as break bulk cargo ships in 1968 and 1962, respectively. The DEL VALLE, laid up in the NDRF in 1983, was a retention ship as of September 2005, and was sold to a ship breaker in 2008. The SS PIONEER CRUSADER was launched as SS AMERICAN CRUSADER and renamed. It entered the NDRF in 1981 and was downgraded to non-retention status in 1989. These

two vessels were newer than the HATTIESBURG VICTORY or the DUTTON, and remained active longer; therefore, they had less time to develop dense biofouling assemblages. One other vessel, the crane ship DIAMOND STATE, was initially selected for biological characterization, but a reconnaissance video taken from the hull before sampling was to start revealed little biofouling growth, mostly limited to a thin layer of algae. This ship had not yet been downgraded to non-retention status, and was activated as recently as in July 2006. Because its hull did not harbor extensive biological growth, biological sampling was canceled on this ship and was instead conducted on the HATTIESBURG VICTORY, one of several vessels chosen as candidates for biological characterization.

## 2.0 METHODS

### 2.1 WATER CHARACTERISTICS

The BRF is located in the Neches River estuary near Beaumont, Texas. The salinity in this part of the river is in the tidal freshwater to oligohaline range. Salinity, conductivity, temperature, dissolved oxygen, and pH were measured on-site to characterize the environment encountered by the biota at the time of sampling. Data were collected at 3 locations within the fleet and over the course of the biological surveys (Figure 2-1). One of the water quality stations was established near the vessel DIAMOND STATE, in the deeper portion of the basin where the fleet is located (Figure 2-1). The second water quality station was established near the DUTTON, at the center of the fleet, and the third water quality station was established near DEL VALLE, adjacent to the main river channel. A Yellow Springs Instrument (YSI Inc., Yellow Springs, Ohio) multiparameter probe with automatic temperature and salinity compensation was deployed at approximately 1 meter intervals from the surface of the water to the maximum lightweight draft of the vessels. These data characterized local conditions at the time of sampling, but did not characterize the conditions to which the biota is exposed over the course of the year. In Brownsville, water quality parameters were measured at the All Star Metals slip, where the DUTTON was sampled after transit from Beaumont.

### 2.2 BIOLOGICAL SURVEYS

The DUTTON was surveyed over three separate dives, two in Beaumont and one in Brownsville. The vessel was surveyed on September 24 and 25, 2007, prior to hull cleaning; on September 27 immediately after hull cleaning; and on October 5 upon arrival in Brownsville after transit from Beaumont across the western Gulf of Mexico. The vessel departed the BRF on October 2, 2007, and arrived at the All Star Metals slip in the afternoon of October 4. The ship was taking on water and listing about 10 degrees to starboard when it was brought into the slip. As a consequence, the ship rested on the banks of the slip and portions of the hull were inaccessible for sampling.

Biological sampling on the other three vessels was conducted on the following dates: September 24 and 25, 2007, on the DEL VALLE; September 26 on the PIONEER CRUSADER; and September 27 and 28 on the HATTIESBURG VICTORY. Location of vessels in the BRF is shown in Figure 2-1.

Samples were collected with the help of professional divers. Diving was conducted using surface-supplied air and real-time audio and visual communications with the surface team. The surface team included a diver master and two scientists who directed two of the divers toward the locations where samples and photo-quadrats were to be taken. Diving services for the DUTTON were provided by Underwater Services International (Gainesville, Florida), and for the other three vessels and the video reconnaissance of the DIAMOND STATE by Tiburon Divers, Inc. (Houston, Texas) under subcontract from Sea Sub Systems (Indian Rocks Beach, Florida).

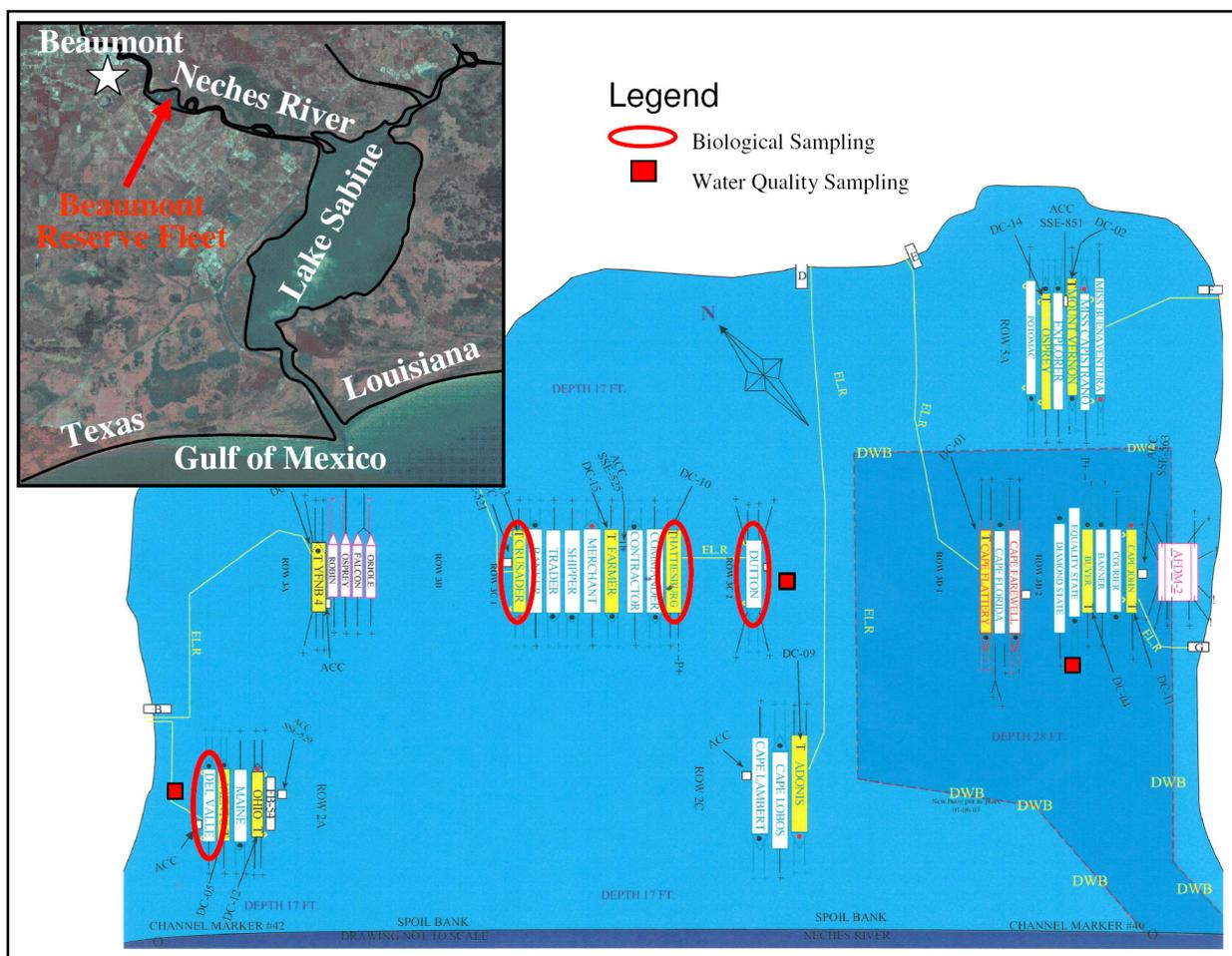


Figure 2-1. Map of the Beaumont Reserve Fleet showing the locations of the ships and the biological and water quality characterization sites.

The sampling design was similar to that previously employed to survey other vessels (Davidson et al. 2006; Versar 2008a, b, c). Samples were taken at three depths (near the waterline, mid-depth, and bottom of the hull) along eight transects (Figure 2-2). The DUTTON and HATTIESBURG VICTORY were 455 feet long, with a lightweight draft of 9.5 feet. Transects were positioned 55 feet apart from each other from anchor chain to

stern. The DEL VALLE was 522 feet long with a lightweight draft of 14.7 feet, and the PIONEER CRUSADER was 561 feet long with a lightweight draft of 13.3 feet. Transects in these two vessels were positioned 65 feet and 72 feet apart from each other, respectively. Five samples were collected per transect (except as noted below): starboard upper, starboard lower, bottom, port lower, and port upper. The first transect near the bow did not have a flat bottom; therefore, only four samples were collected from this transect. Eleven additional samples were taken from the underwater appendages of each vessel, including the stern tube, rudder, and propellers. The divers swam under the vessels from one side to the other and back to complete two sampling transects.

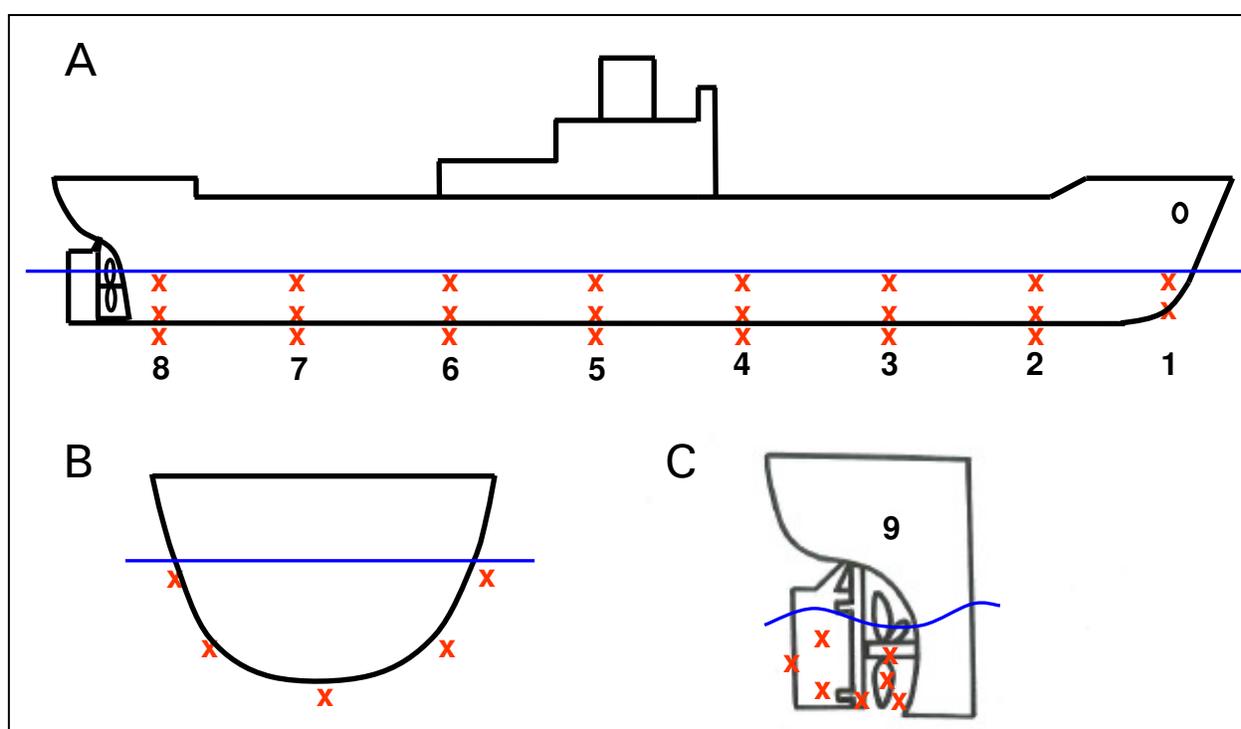


Figure 2-2. Sampling design. Samples and photo-quadrats were taken at 8 transects across the hull of the vessels (A). Five samples per transect were generally collected: starboard upper, starboard lower, bottom, port lower, and port upper (B). The first transect did not have a flat bottom; therefore, only four samples were collected from this transect (except for the DEL VALLE). In addition, samples were collected from the underwater appendages of the vessels including the stern tube, rudder, and propellers (C). Underwater appendage locations were labeled as Transect 9.

The above general scheme was used with the following exceptions: (1) In the post-transit survey of the DUTTON, bottom and port samples were not taken from Transects 2, 3, and 4 because these areas were not accessible to the divers. Likewise, port samples were not taken from Transects 5 and 6. A total of 37 samples was collected during the

post-transit survey of the DUTTON. (2) A bottom sample was collected from Transect 1 of the DEL VALLE. (3) The lower port and bottom samples from Transect 6 of the PIONEER CRUSADER were lost during diving, and were not retaken. No bottom sample was taken from Transect 8 either, but an additional target bottom sample was taken from Transect 7. Target samples were also taken from the upper and lower surfaces of the bilge keel and the rudder pintle. Target samples were aimed at collecting specific biological features identified in real-time video, and were either transferred into the sample bags by hand or taken with the sampler. (4) In the HATTIESBURG VICTORY, target samples were also taken from the upper and lower surfaces of the bilge keel.

At each sampling location, one diver positioned an underwater camera against the surface of the hull and photographed the biota covering the hull. The second diver then collected a sample from a random point within approximately a one-meter radius of the photo-quadrat location. A sampler constructed from a 6-inch (15.2 cm) diameter PVC pipe with a 4-inch adapter to attach the sample bag, was used to collect the biota (Figure 2-3). A diver placed the 6-inch end of the sampler against the hull of the ship and attached a numbered cloth bag to the opposite end. A 3-inch scraper applied between the hull and the sampler was used to remove the biological material from the hull, which was then collected in the sample bag. The PVC sampler was curved at a 45 degree angle, so that the sample would fall straight down into the bag. The bag was twisted closed and tied off before being removed from the sampler to minimize sample loss.



Figure 2-3. Sampler constructed from a 6-inch (15.2 cm) diameter PVC pipe with a 4 inch adapter. A diver placed the 6-inch end of the sampler against the hull of the ship, and attached a numbered cloth bag to the 4-inch end. A scraper was used to remove the biological material from the hull, which was then collected in the cloth bag.

An area of approximately 182 cm<sup>2</sup> of hull was scraped for each sample. The bag number was relayed to the surface so that detailed notes could be taken on the location at which each sample was collected. Sample bags were stored in a mesh dive bag and returned to the surface, usually in groups of 10 bags corresponding to 2 sampling transects. Upon retrieval, all bags were immediately transferred to 5-gallon buckets with in situ marine water. Protexo bags manufactured by HUBCO (Hutchinson, Kansas) were used. Each bag was made of tightly woven white cotton cloth, and measured 10 x 17 inches (25.4 x 43.2 cm). Each bag included a drawstring that, in addition to a rubber band, kept the bag closed after sample collection. Fifty samples were collected per ship for biological characterization, except for the DEL VALLE, from which 49 samples were collected. Fifty additional samples were collected from the DUTTON after hull cleaning, and 37 samples after transit. A total of 286 samples among all ships was available for analysis of species abundance and composition. Each of the DUTTON samples was accompanied by a photo-quadrat, but no underwater photos were taken from the other ships.

The system used for the photo-quadrats consisted of an underwater camera with a "clear-water box" attached to the front of the lens and two strobe lights mounted above the box at 45 degree angles. This system provided a standard image area for all photographs. In addition, the divers carried a video camera that provided real-time visual communication with the surface and video footage of the hull and the associated biota.

### **2.3 SAMPLE PROCESSING AND TAXONOMY**

A visual examination of each sample was carried out in the field. Bags were opened, inverted, and rinsed into a plastic dissecting tray (12 x 18 inches, 2.5 inch deep), and the sample was examined and photographed. Notes were taken as to the condition of the biota (potential live versus dead material), and the general kinds and quantity of organisms. This general procedure was conducted on as many samples as possible. Some samples could not be photographed on site because of time constraints.

After examination, the contents of the tray were carefully poured back into the sample bag, and a label was added to the inside of the bag. Bags were then tightly closed with twist ties and rubber bands, and transferred to a propylene phenoxtyol (POP) solution to relax the organisms for easier identification. A 0.15 % solution was made by adding 15 ml of POP to 1 L of warm tap water, and then mixing 9 L of in situ water into the solution (Green and Lambert 1994). After 30-60 min in the relaxant, bags were placed in 1-gallon plastic jars (3-5 bags per jar), and a buffered solution (10%) of formalin in seawater was added to preserve the organisms. In the laboratory, samples were stored in formalin until further processing and identification of organisms.

In the laboratory, samples were washed through nested 250- $\mu$ m and 64- $\mu$ m sieves. The finer 64- $\mu$ m fraction of the sample was retained and stored for later examination. The

250- $\mu\text{m}$  fraction was sorted under dissecting microscopes to separate organisms into major categories (i.e., mussels, barnacles, micro-crustaceans, etc.). Organisms in these major categories were identified to species level whenever possible and counted (non-colonial species only). Some organisms required further examination by specialist taxonomists for identification or confirmation. Voucher specimens of these organisms were placed in separate vials and sent to the specialists.

Due to time constraints, live and dead material were not separated in the field; however, the bulk component of each sample consisted of organisms that were alive at the time of collection. No obvious signs of dead material (e.g., exo-skeletons of crustaceans) were found in the samples upon examination in the field or in the laboratory, except for the empty tests of barnacles.

## 2.4 ANALYSIS

Samples were analyzed for differences in species numbers, composition, and abundance by transect and position (waterline, mid-depth, bottom, appendages) across the hull of the ship using multivariate analysis methods. Plots were constructed to examine sample configuration and to identify any tendency for samples to form groups according to the location from where they were taken from the hull. Species counts (square-root transformed) were subjected to non-metric multidimensional scaling (MDS) ordination on a Bray-Curtis similarity matrix using routines in the PRIMER (Plymouth Routines in Multivariate Ecological Research) v.6 statistical package (Clarke and Gorley 2006). The Group Average method was used to link samples in the analysis. Non-metric MDS constructs a plot in which samples are arranged in rank order according to their relative similarity. Samples that are similar in species composition and abundance are placed in close proximity to one another, whereas dissimilar samples are placed further apart. Because abundance for colonial species (bryozoans and hydroids) cannot be provided, the MDS analysis was repeated for presence/absence data using the full matrix of species and Sørensen's similarity index (Clarke and Gorley 2006). The analysis was also conducted on the post-cleaning and post-transit samples of the DUTTON to identify gradients in species abundance and composition among surveys.

Photo-quadrats were examined by quantifying the percent cover of nine distinguishable categories of biofouling in each image: algae, barnacle, barnacle seat/organism remnant, crustacean, hydroid, mussel, sponge, hull, and "other". Images were analyzed using the point count method to determine percentage cover of each category by superimposing a grid of 7 rows by 13 columns and populating each cell by 1 random point for a total of 91 random points. The area of hull analyzed from the image was 158  $\text{cm}^2$  (approximately 9.5 x 17 cm), for a density of 1.7 points per  $\text{cm}^2$  of hull (Figure 2-4). Points that were indistinguishable because the image was too dark were removed from the analysis. Thus the analysis provides percent cover of observable hull. Percent cover data (arcsine square-root proportion-transformed) were analyzed by MDS.

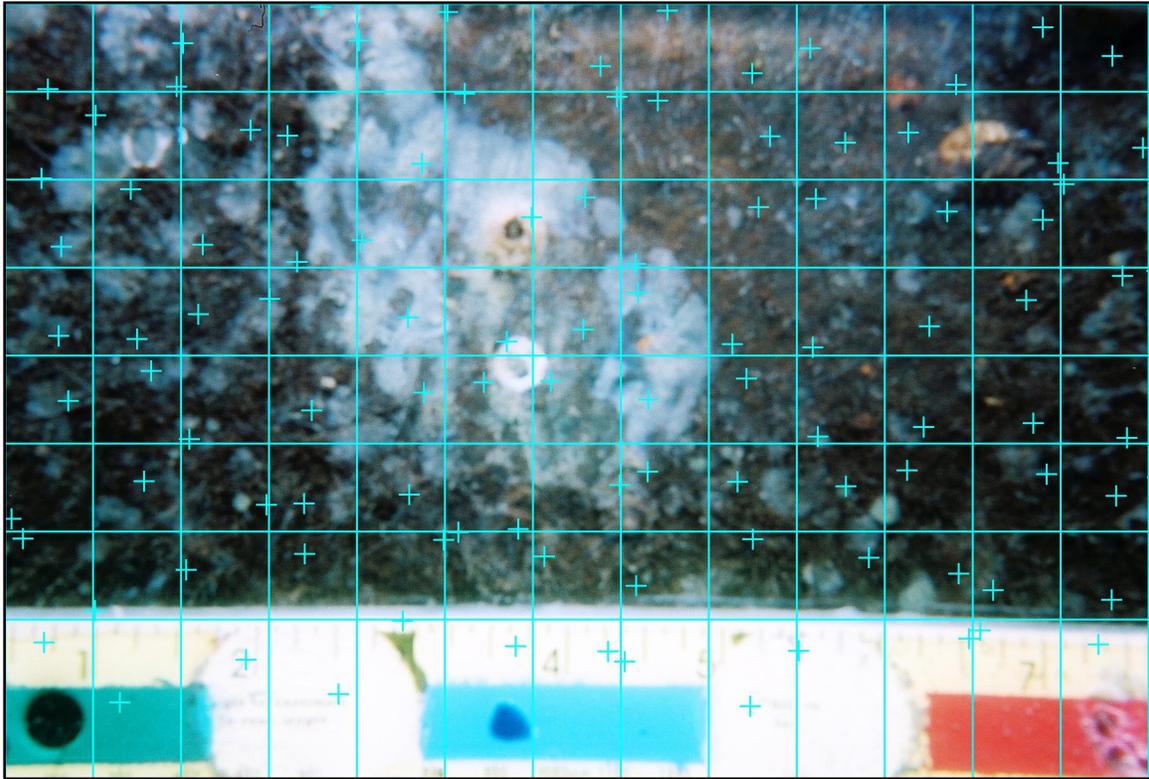


Figure 2-4. Grid of random points superimposed on an underwater photograph taken from the lower port side of Transect 4 (165 ft from the bow) of the DUTTON prior to hull cleaning. Images were analyzed using the point count method to determine percentage cover of each of 9 categories of biofouling. Hydroids, algae, barnacles, and a sponge (center of image) can be observed in this photograph.

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## 3.0 RESULTS AND DISCUSSION

### 3.1 WATER CHARACTERISTICS

The salinity at the Beaumont Reserve Fleet (BRF) at the time of sampling (September 2007) was in the oligohaline range (Figure 3-1). However, based on the large number of freshwater species collected during the surveys, salinity is probably lower during periods of high river discharge, typically between December and April (USGS data at Beaumont). In a study that characterized the benthos of the Neches River estuary before and after pollution abatement (Harrel and Hall 1991), surface salinity at a station upstream from the BRF varied seasonally between approximately 1 and 11 psu (practical salinity units), but during years of high river flow surface salinity was typically below 2 psu. In the deeper basin near the DIAMOND STATE, salinity increased with depth from 1.9 psu near the surface to 8.2 psu at the 10-m depth (Figure 3-1). Water temperature was uniform between 28.5 °C and 28.9 °C, and dissolved oxygen ranged from 6.1 mg/l near the surface to 3.4 mg/l at the 6-m depth near the DUTTON. Salinity at the All Star Metals slip in Brownsville was much higher than in Beaumont, near ocean strength, and water temperature was slightly higher (Figure 3-1).

### 3.2 SPECIES ASSEMBLAGES

The total number of taxa found across all ships and surveys was 103, corresponding to 81 distinct species (Table 3-1). The most common species was Conrad's false mussel, *Mytilopsis leucophaeata*, which accounted for 87% of total abundance. There were 40,755 individuals of this species, far exceeding the abundance of any other species. The majority were small recruits. The next most common species, the barnacle *Balanus subalbidus*, only accounted for 7% of abundance and 3,262 individuals. Secondary numerical dominants were a leptoplanid flatworm (*Turbellaria* sp. A), accounting for 2% of abundance, and the polychaete *Boccardiella ligerica*, accounting for 1% of abundance. The remaining species each accounted for less than 1% of the total abundance.

In terms of frequency of occurrence, *M. leucophaeata* and *B. subalbidus* were represented in 84-96% and 40-80% of the samples, respectively. The amphipod *Apocorophium lacustre* occurred less frequently, in 22-62% of the samples. Other common taxa were algae, nematodes, and colonial organisms (Table 3-1).

Among the colonial species, the bryozoan *Bowerbankia gracilis* was common in all ships, and the bryozoan *Conopeum chesapeakeensis* was common in three of the four ships. Additionally, the kamptozoans *Urnatella gracilis* and *Barentsia* sp. A, the bryozoan *Fredericella indica*, and the hydroid *Cordylophora caspia*, were common and abundant on the DUTTON, but had low occurrence in the other three ships (Table 3-1). The hydroid

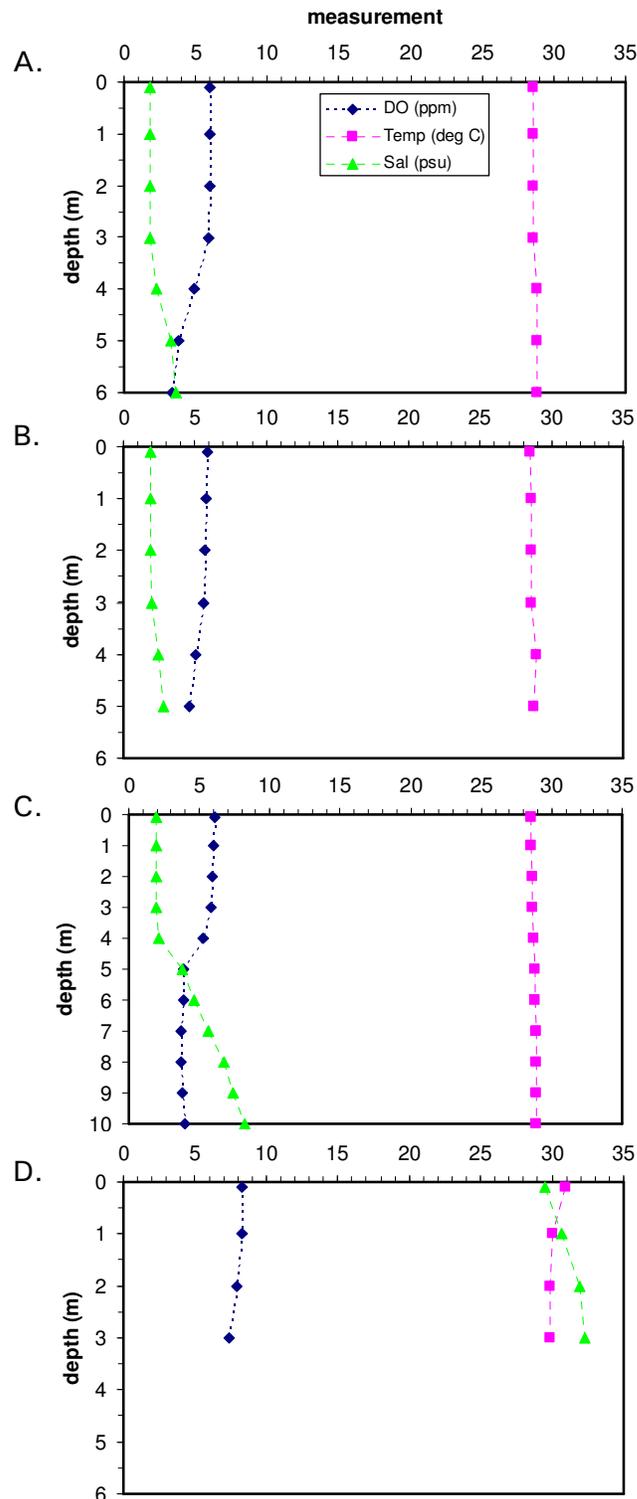


Figure 3-1. Salinity, temperature, and dissolved oxygen of the water in Beaumont (A-C), and Brownsville (D), Texas, during the biological surveys of Beaumont Reserve Fleet vessels. Readings were taken on September 25, 2007, between 8 and 9 a.m., at water quality stations near the DUTTON (A), DEL VALLE (B), and DIAMOND STATE (C); and on October 5, 2007, ~1 p.m., at the All Star Metals slip in Brownsville (D).

*Garveia franciscana* was common on the PIONEER CRUSADER, but had low occurrence in the other three ships.

By ship, 54 taxa and 15,900 individuals were collected from the DUTTON in Beaumont, 43 taxa and 14,000 individuals from the HATTIESBURG VICTORY, 40 taxa and 6,000 individuals from the DEL VALLE, and 37 taxa and 2,300 individuals from the PIONEER CRUSADER. Thus, the DUTTON and the HATTIESBURG VICTORY, being older ships, had more kinds and greater abundance of organisms than the other two ships. The PIONEER CRUSADER had been active for a longer period of time, and therefore exhibited the least amount of biological growth. The same species were generally present in all ships, except for insect larvae, which had low frequency of occurrence and some species were present in some ships but not in others.

Of the 103 taxa collected across ships and surveys, 30 were native in Texas, 12 were cryptogenic, and 6 were introduced (Table 3-1). Of the remaining taxa, 50 were genus or higher level identifications with native species present in Texas, and 5 were of undetermined status.

Many of the species found in Beaumont are cosmopolitan in rivers and lakes. The origin of these species is uncertain, and thus the species are classified as cryptogenic. They include several oligochaete species of the genera *Nais* and *Pristina*, and the freshwater bryozoan *Fredericella indica* (Table 3-1, Appendix B). Other estuarine and marine species of broad distribution were also classified as cryptogenic, and included the polychaetes *Boccardiella ligerica* and *Nereis* cf. *falsa*, the amphipod *Apocorophium lacustre*, and the tanaid *Sinelobus stanfordi*.

One kamptozoan of the genus *Barentsia* (*Barentsia* sp. A) was common on the DUTTON and was present on the other three ships. We have been unable to identify the species from the available literature. The branching pattern of this species resembles that of *Barentsia ramosa* described for California (Wasson 1997). However, the Beaumont specimens are diminutive, certainly not "a giant among the kamptozoans" (Wasson 1997). Unlike *B. ramosa*, the Beaumont specimens do not form erect tufts, have only secondary and tertiary zooids, and nodes only at the branching points, with long stalks between the nodes. The colonies are wrapped around the stems of *Cordylophora caspia* and *Garveia franciscana*; the kamptozoan is very small in comparison and thus easily missed among the hydroids. Until further identification, we consider this species as cryptogenic.

The introduced, nonnative species consisted of one bryozoan, *Conopeum chesapeakeensis*; two hydroids, *Cordylophora caspia* and *Garveia franciscana*; one polychaete, the Australian shipworm *Ficopomatus enigmaticus*; and two amphipods, *Laticorophium baconi* and *Monocorophium acherusicum*.

The bryozoan *Conopeum chesapeakeensis* was described for Chesapeake Bay by Banta et al. (1995) as *Membranipora chesapeakeensis*. It was later transferred to

*Conopeum*, a genus of wide distribution with many similar species. Like other cheilostomate bryozoans, *C. chesapeakensis* forms encrusting colonies on barnacles, shells, and other surfaces, but it also grows vertically in the form of ribbons and tufts. This kind of growth is very characteristic of the species, but the Beaumont specimens consisted only of encrusting colonies. *C. chesapeakensis* has been introduced to Suisun Bay, California. The Beaumont specimens constitute a range expansion of this species, provided that the species identification is confirmed.

The hydroid *Cordylophora caspia* is native to the Caspian and Black Seas. Its range has been extended by shipping, and today the species is found in temperate and subtropical regions around the world, typically in rivers and streams and brackish waters of estuaries. *C. caspia* is common in the Gulf of Mexico, as is *Garveia franciscana*, another hydroid of wide distribution and same possibly origin (Davidson et al. 2007). Both species are important fouling organisms and are considered pests of water intake systems of power plants, where they can heavily coat surfaces and cause high economic costs. Specimens of these species for which we had stems but not hydranths could not be reliably identified to species, and are therefore referred to as Bougainvilliidae sensu Calder (1988).

*Ficopomatus enigmaticus* is a warm-water polychaete worm that builds white calcareous tubes on hard surfaces such as rocks, concrete, wood, and shell. It can occur as single tubes or form dense aggregations on hulls, pilings, locks, power plant intake and discharge pipes, and other structures. It has been widely reported from temperate and warm waters of the Atlantic Ocean, Pacific Ocean, and Mediterranean Sea, to where it was transferred by shipping from native regions in the Indian Ocean.

*Laticorophium baconi* and *Monocorophium acherusicum* are members of a family of tube-building amphipods that occur on a variety of surfaces, including floating platforms, buoys, and seagrass beds. They were collected from the DUTTON in Brownsville but were not found in Beaumont.

The native range of *Laticorophium baconi* is probably the Eastern Pacific Ocean (Bering Sea to Peru) from where it was introduced to Hawaii, South China Sea, and Australia (Davidson 2007). It has been previously reported from the Gulf of Mexico and Atlantic coast of Florida in high salinity environments (LeCroy 2004). Gulf of Mexico records are relatively recent (since 1977), so it is easy to envision its transport through the Panama Canal on ship hulls (LeCroy 2004). *L. baconi* was also found in each of the post-transit surveys conducted on Suisun Bay Reserve Fleet vessels.

The native range of *Monocorophium acherusicum* is unknown but it probably was the Northeast Atlantic from where it dispersed widely by shipping to the Atlantic, Pacific and Indian Oceans (Davidson 2007). Numerous records of this species exist for the Gulf of Mexico.

Table 3-1. Species recorded in biological samples of four Beaumont Reserve Fleet vessels. The frequency of occurrence (percent of samples) in each survey and the biogeographic status of species in Texas waters is shown. Because not all the 64- $\mu$ m samples were examined, frequency of occurrence for copepods and ostracods is not provided; "P" indicates presence. Surveys: Pre-C = pre-cleaning; Post-C = post-cleaning; Post-Tr = post-transit. Status: I = introduced (nonnative species); C = cryptogenic; N = native; NP = native species present; ? = undetermined.

Species	DUTTON			DEL VALLE	CRUSADER	HATTIES-BURG	Status
	PRE-C	POST-C	POST-TR				
<b>Algae</b>							
Algae sp. A	60	54	43	59	36	44	?
<b>Amphipods</b>							
<i>Apocorophium lacustre</i>	62	28	22	29	22	40	C
Corophiidae spp. (juv.)	0	0	8	0	0	0	NP
<i>Erichthonius brasiliensis</i>	0	0	3	0	0	0	N
<i>Grandidierella bonnieroides</i>	0	0	3	0	0	0	N
<i>Hourstonius laguna</i>	6	6	11	0	4	0	N
<i>Laticorophium baconi</i>	0	0	24	0	0	0	I
<i>Melita nitida</i>	22	18	0	6	0	2	N
<i>Monocorophium acherusicum</i>	0	0	38	0	0	0	I
<b>Acari (mites)</b>							
Acari sp. A	0	2	0	0	0	0	?
Acari sp. B	2	0	0	0	0	0	?
<i>Limnesia</i> sp.	0	2	0	0	0	0	NP
<b>Bivalves</b>							
<i>Mytilopsis leucophaeata</i>	92	92	84	94	86	96	N
<b>Chaetognatha (arrow worms)</b>							
Chaetognatha	0	0	3	0	0	0	NP
<b>Cirripedia (barnacles)</b>							
<i>Balanus subalbidus</i>	66	76	65	73	40	80	N
barnacle cypris	P						NP
Cirripedia spp. (juv.)	2	4	16	8	2	2	NP
<b>Copepods</b>							
<i>Acartia</i> sp.	P						NP
<i>Acartia tonsa</i>	P						N
Calanoida spp. Indeterminant	P	P					NP
<i>Coullana canadensis</i>	P			P			N
Cyclopoida spp. Indeterminant		P					NP
<i>Eurytemora affinis</i>	P						N
<i>Halicyclops</i> sp.	P			P			NP
Harpacticoida spp. Indet.	P						NP
<i>Nitokra</i> sp.	P	P		P			NP
<i>Oithona</i> sp.	P						NP
<i>Pseudodiaptomus pelagicus</i>			P				N
<i>Schizopera</i> sp.	P						NP

Table 3-1. (Continued)							
Species	DUTTON			DEL VALLE	CRUSADER	HATTIES-BURG	Status
	PRE-C	POST-C	POST-TR				
<b>Decapods (shrimps and crabs)</b>							
Brachyura spp. Indeterminant	2	10	11	4	0	2	NP
<i>Callinectes</i> sp. (juv.)	6	6	3	6	2	4	NP
Decapoda spp.	0	8	3	0	4	2	NP
<i>Macrobrachium carcinus</i>	2	2	0	4	0	2	N
Penaeidea sp. Indeterminant	0	2	0	0	0	0	NP
<i>Rhithropanopeus harrisi</i>	16	6	0	18	0	6	N
Xanthidae spp.	2	0	3	0	0	0	NP
<b>Ectoprocta (bryozoans)</b>							
<i>Bowerbankia gracilis</i>	66	56	41	49	24	60	N
<i>Conopeum chesapeakeensis</i>	56	42	54	51	6	86	I
<i>Fredericella indica</i>	74	68	51	27	4	16	C
<b>Entoprocta (kamptozoans)</b>							
<i>Barentsia</i> sp. A	58	48	32	12	20	18	C
<i>Urnatella gracilis</i>	80	74	49	12	2	36	N
<b>Fish</b>							
<i>Gobiosoma</i> sp. (juv.)	0	0	3	0	0	0	NP
<b>Gastropods</b>							
Gastropoda spp.	4	2	3	0	0	0	NP
<i>Odostomia</i> sp.	0	2	0	0	0	0	NP
<b>Hydroids</b>							
Bougainvilliidae spp.	10	18	43	6	0	0	NP
<i>Cordylophora caspia</i>	72	46	19	10	16	2	I
<i>Garveia franciscana</i>	26	14	8	6	60	2	I
<b>Insects</b>							
<i>Bezzia/Palpomyia</i> spp.	4	0	0	0	0	2	NP
Ceratopogonidae spp.	2	0	0	0	0	0	NP
Chironomini spp. (early instar)	0	2	0	0	0	0	NP
<i>Climacia?</i>	0	0	0	0	2	0	NP
<i>Culicoides</i> sp.	0	0	0	0	0	2	NP
<i>Cyrnellus fraternus</i>	0	2	0	0	4	2	N
<i>Dicrotendipes lucifer</i>	2	4	0	18	4	12	N
<i>Dicrotendipes</i> sp.	34	10	3	31	2	28	NP
<i>Endochironomus</i> sp.	0	2	0	0	0	0	NP
<i>Goeldichironomus</i> sp.	0	0	0	2	4	2	NP
Hydroptilidae spp.	0	0	0	0	2	2	NP
<i>Microtendipes pedellus</i> group	0	0	0	0	2	0	N
<i>Nanocladius alternantherae</i>	2	0	0	0	0	0	N
<i>Nanocladius distinctus</i>	8	2	0	4	6	0	N
<i>Parachironomus carinatus</i>	0	0	0	0	2	2	N
<i>Parachironomus</i> nr. <i>pectinatellae</i>	0	0	0	0	2	0	N
<i>Polypedilum flavum</i>	2	0	0	0	0	0	N

Table 3-1. (Continued)							
Species	DUTTON			DEL VALLE	CRUSADER	HATTIES-BURG	Status
	PRE-C	POST-C	POST-TR				
<b>Insects (Continued)</b>							
<i>Polypedilum illinoense</i> group	2	0	0	0	0	0	N
<i>Polypedilum</i> sp.	2	0	0	0	0	0	NP
<i>Sisyra</i> sp.	0	0	0	2	0	0	NP
<i>Stelechomyia perpulchra</i>	0	2	0	0	0	0	N
<i>Stenochironomus</i> sp.	0	0	0	0	0	2	NP
<i>Tanytarsus</i> sp.	10	4	0	12	2	4	NP
<i>Tribelos</i> sp.	0	2	0	2	0	4	NP
<i>Xenochironomus xenolabis</i>	0	0	0	2	0	2	N
<b>Isopods</b>							
<i>Uromunna reynoldsi</i>	2	2	0	0	0	0	N
<b>Nematodes (roundworms)</b>							
Nematoda spp.	58	40	35	41	36	80	NP
<b>Oligochaetes</b>							
<i>Dero</i> sp.	28	6	0	6	8	28	NP
Naididae spp.	4	2	0	0	0	0	NP
<i>Nais communis</i>	20	6	0	0	0	2	C
<i>Nais pardalis</i>	2	0	0	0	0	0	C
<i>Nais variabilis</i>	8	4	0	2	4	14	C
<i>Pristina aequisetata</i>	16	8	0	2	8	20	C
<i>Pristina leidyi</i>	20	4	0	0	0	4	C
<i>Pristina osborni</i>	2	0	0	0	0	0	C
<i>Pristina</i> sp.	2	2	0	0	0	0	NP
<i>Tubificoides</i> sp.	0	0	5	0	0	0	NP
<b>Ostracods</b>							
Ostracoda spp.	P						NP
<b>Polychaetes</b>							
<i>Boccardiella ligerica</i>	38	24	11	16	18	52	C
Capitellidae spp.	0	0	3	0	0	0	NP
<i>Ficopomatus enigmaticus</i>	6	2	0	2	0	0	I
<i>Mediomastus ambiseta</i>	0	0	3	0	0	0	N
<i>Mediomastus</i> sp.	0	0	3	0	0	0	NP
Nereididae spp.	14	2	5	6	2	2	NP
<i>Nereis cf. falsa</i>	10	2	5	16	6	36	C
<i>Ophryotrocha</i> sp.	0	0	5	0	0	0	NP
<i>Podarke obscura</i>	0	0	3	0	0	0	N
<i>Polydora</i> sp.	0	0	11	0	0	0	NP
Serpulidae spp. (juv.)	8	2	16	2	0	0	NP
Spionidae spp.	18	8	30	10	8	0	NP
<i>Streblospio benedicti</i>	0	0	8	0	0	0	N
<b>Porifera (sponges)</b>							
<i>Ephydatia fluviatilis</i>	8	2	0	12	2	34	N

Table 3-1. (Continued)							
Species	DUTTON			DEL VALLE	CRUSADER	HATTIES-BURG	Status
	PRE-C	POST-C	POST-TR				
<b>Tanais</b>							
<i>Sinelobus stanfordi</i>	22	12	35	22	0	4	C
<b>Turbellaria (flatworms)</b>							
<i>Stylochus</i> sp.	4	16	5	4	8	14	NP
Turbellaria sp. A	46	34	11	12	10	48	?
Turbellaria sp. B	6	0	0	0	0	0	?

### 3.3 DIFFERENCES BETWEEN SHIPS, SURVEYS, AND LOCATIONS ON THE HULL

Community organization was similar among ships. The biofouling community was numerically dominated by barnacles and Conrad's false mussels. Barnacles did not form a continuous layer over the hull, but both the hull and the barnacles were encrusted by abundant soft growth provided by filamentous algae, bryozoans, kamptozoans, hydroids, and sponges. The mussels were generally small and were attached to the barnacles (Figure 3-2).

Multivariate analyses of abundance and presence-absence data did not show differences in community organization among ships (Figure 3-3), nor were differences among transects or locations on the hull, except for a tendency for algae to occur more frequently near the waterline. However, soft growth (biomass) was higher on the DUTTON, and harbored more species, than in the other three ships. The DUTTON and HATTIESBURG VICTORY also exhibited significantly ( $p < 0.0001$ ) higher mean abundance of hard-shelled organisms (barnacles and mussels) than the other two ships (Figure 3-4).

Generally, the older the ship the more species and higher growth were present on the hull. Growth, as revealed by the underwater video footage, was highest on the DUTTON and lowest on the DIAMOND STATE, an active ship. The three other ships had intermediate growth, but nevertheless none of the ships had the heavy growth provided by the thick canopy of bryozoans, or the thick layer of mussels, of Suisun Bay and James River Reserve Fleet vessels, respectively (Versar 2008a, b, c). In comparison to those other vessels, Beaumont Reserve Fleet ships had light to moderate growth.

In comparing the pre-cleaning, post-cleaning, and post-transit surveys of the DUTTON, the multivariate analysis of abundance and species composition showed no differences among surveys (MDS diagram not shown). These results indicate that the dominant biofouling species were prevalent in the samples of all surveys. The top eleven most common species in the pre-cleaning samples ( $> 50\%$  occurrence, Table 3-1) were still common in post-cleaning and post-transit samples. Among these species, Conrad's false mussel, *Mytilopsis leucophaeata*, the barnacle *Balanus subalbidus*, and the bryozoan *Conopeum chesapeakensis* occurred as frequently in the pre-cleaning as in the post-cleaning and post-transit samples (Table 3-1), although their abundance was substantially reduced by hull cleaning.

The most significant difference between DUTTON surveys was the loss of all the oligochaete and most insect species and the appearance of fifteen "new" species in the post-transit survey. Seven of these "new" species were polychaetes, five were amphipods, one was a chaetognath (arrow worm), one a fish, and one a marine oligochaete. These species occurred in low frequency, except for the amphipods *Monocorophium acherusicum* and *Laticorophium baconi* which were present in 38% and 24% of the post-transit samples, respectively, and their combined abundance was 56 individuals.

The multivariate analysis of photo-quadrat data revealed no differences in percent cover of organisms based on transect or position along the hull, except for generally higher algal cover near the waterline. Algae and hydroids (which concealed most of the barnacles) were the most prominent features of the pre-cleaning survey in the analysis of photo-quadrat data, and bare hull predominated in the post-cleaning and post-transit surveys (Figure 3-5). On average, 82% of the space in the post-cleaning survey, and 86% of the space in the post-transit survey, was bare hull. In the MDS diagram, differences between surveys were due to differences in the relative proportions of bare hull and algal, hydroid, and sponge cover (Figure 3-6).

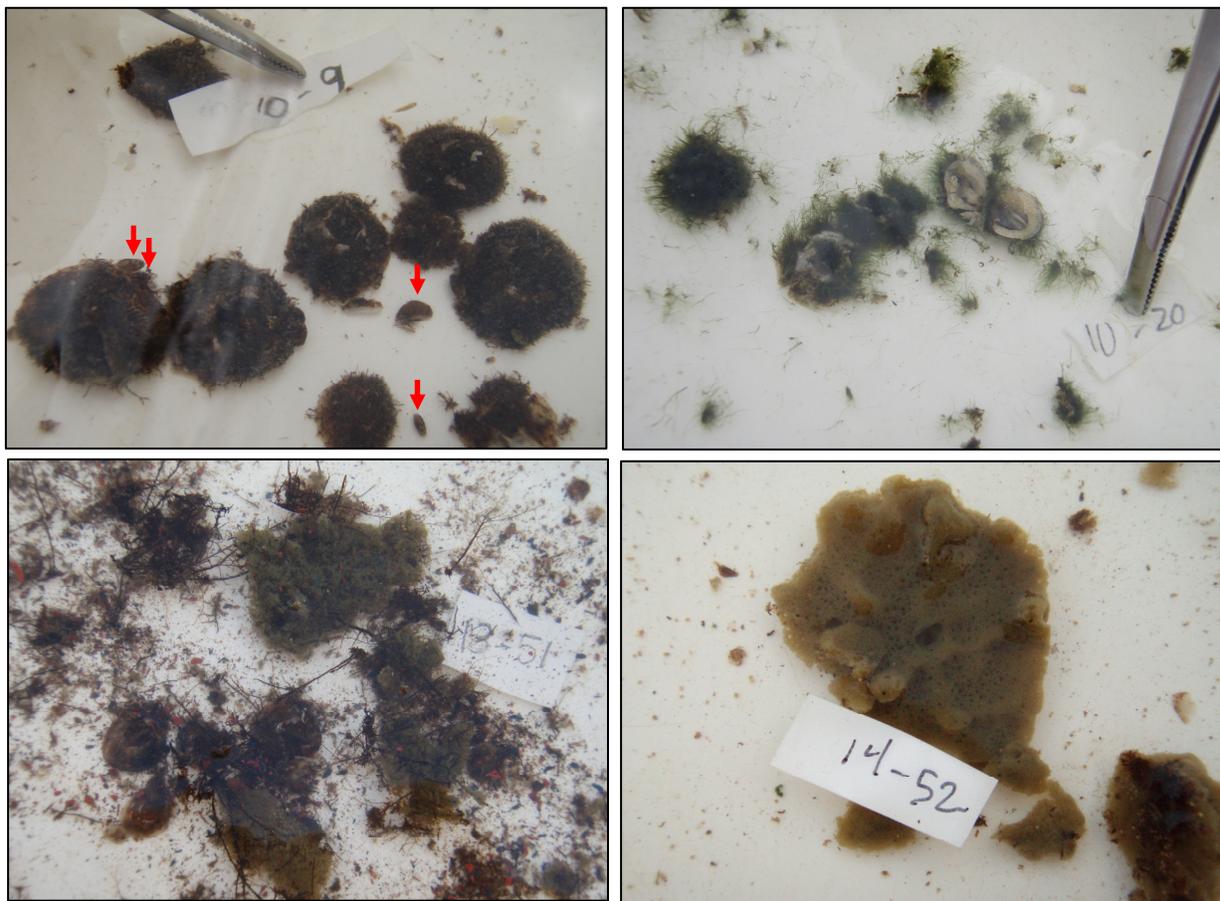


Figure 3-2. Photographs of samples taken during the biological surveys of Beaumont Reserve Fleet vessels. Clockwise from upper left panel: (a) upper port side of Transect 2 of the DUTTON prior to hull cleaning, showing barnacles covered by hydroids, bryozoans, and mussels (mussels indicated by arrows); (b) upper port side of Transect 5 (mid ship) of the DUTTON prior to hull cleaning, showing barnacles and algae; (c) the sponge *Ephydatia fluviatilis*, collected from the rudder pintle bearing of the PIONEER CRUSADER; (d) bottom of Transect 5 of the DEL VALLE, showing hydroids and sponges.

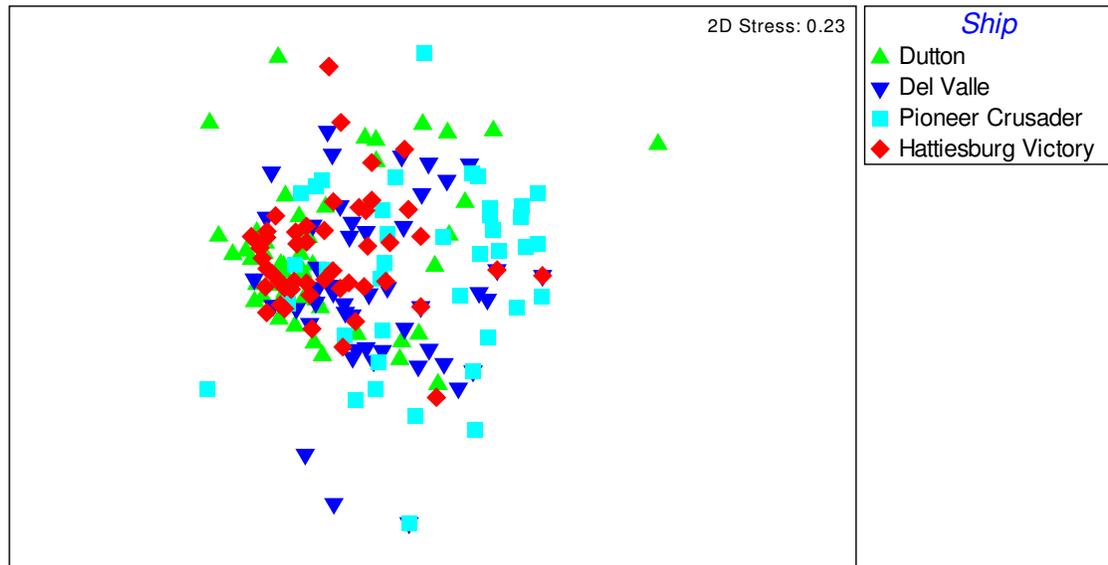


Figure 3-3. Multivariate analysis of presence-absence data, showing no differences in biofouling community organization among ships (i.e., no separate groups of samples in the diagram).

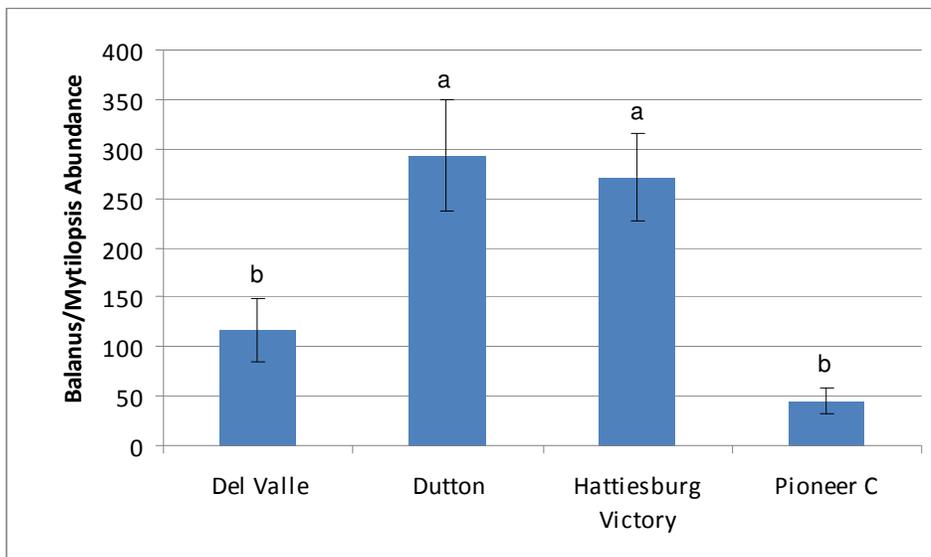


Figure 3-4. Differences in mean abundance (+/- one standard error) per sample of hard-shelled organisms in four Beaumont Reserve Fleet vessels, tested by ANOVA. The letters indicate the results of the Duncan test, whereby mean abundance did not differ significantly for ships with the same letter.

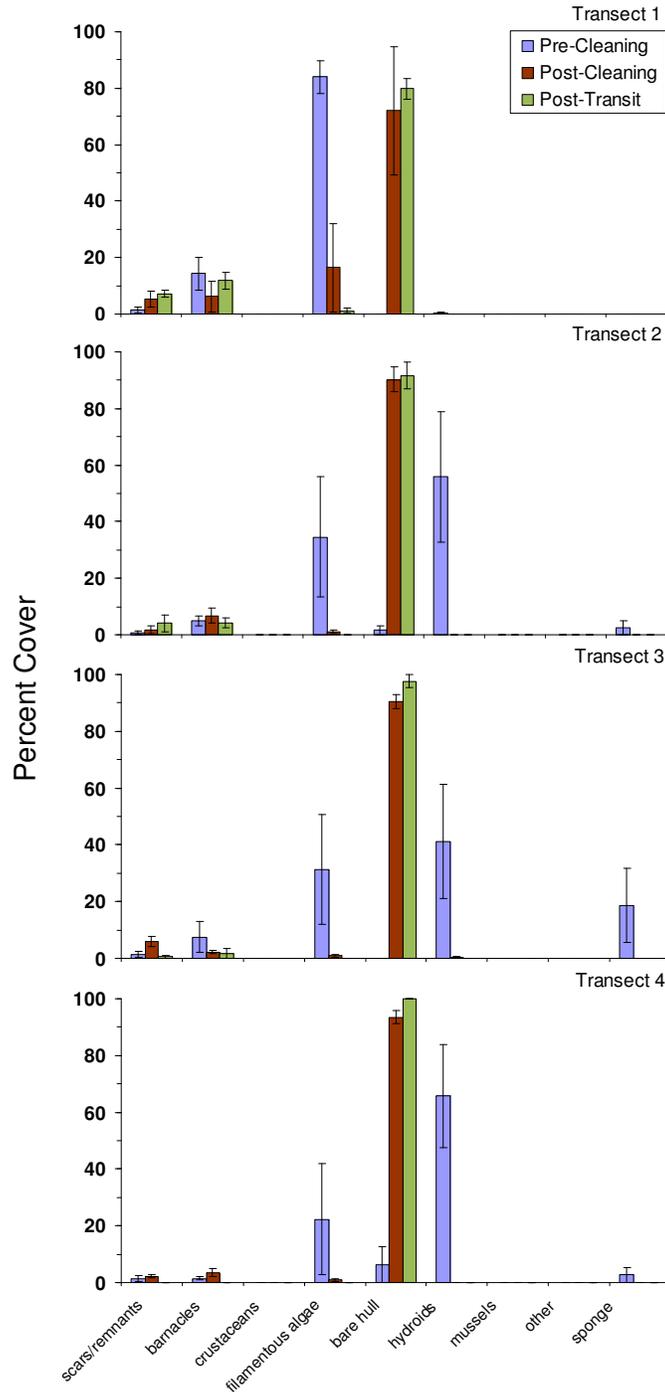


Figure 3-5. Differences in percent cover between DUTTON surveys. The mean (+/- one standard error) percent cover of 9 categories of biofouling estimated from photo quadrats is shown.

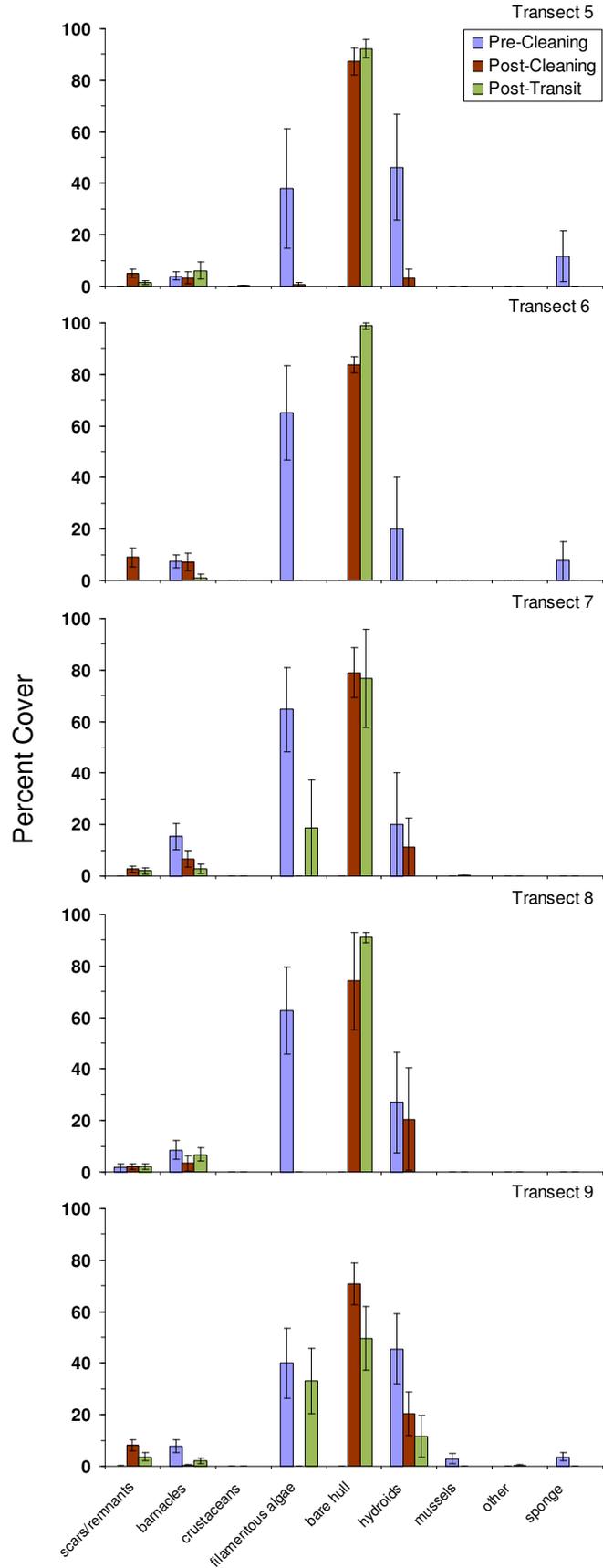


Figure 3-5. (Continued)

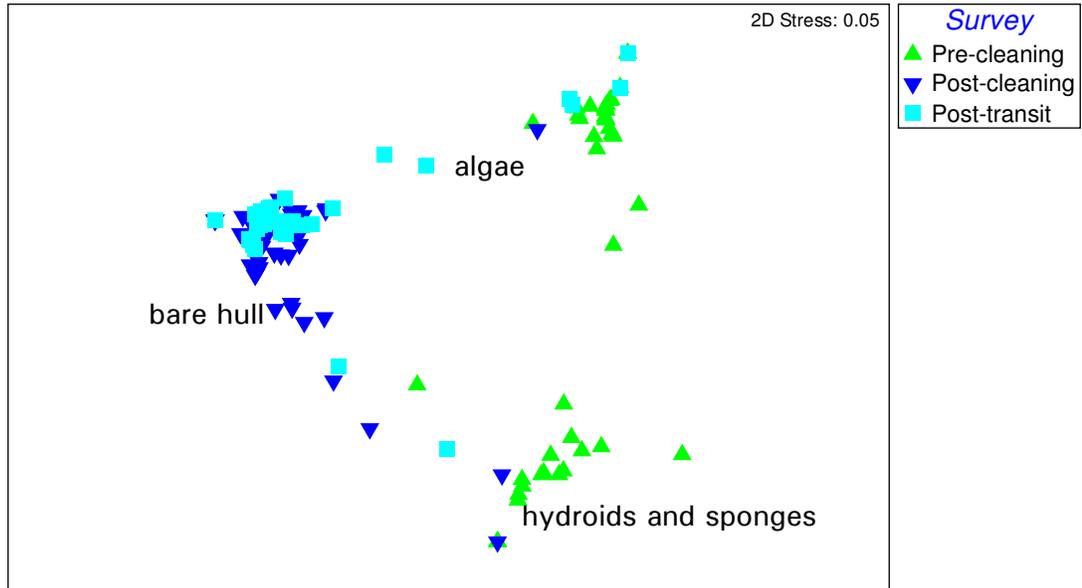


Figure 3-6. Multivariate analysis of DUTTON photo-quadrat data. No differences were observed in percent cover of organisms based on transect or position along the hull, but differences between surveys were indicated by differences in the relative proportions of bare hull, algal, hydroid, and sponge cover.

### 3.4 RISK OF SPECIES INTRODUCTIONS

Many of the species found in the Beaumont surveys were cosmopolitan in freshwater, such as the oligochaetes, the hydroid *Cordylophora caspia*, the sponge *Ephydatia fluviatilis*, the bryozoan *Fredericella indica*, the kamptozoan *Urnatella gracilis*, and most of the insect larvae. Freshwater species are stenohaline, but some extend into brackish waters. It is unlikely that these brackish water species would survive exposure to full strength seawater for extended periods of time, but may survive brief periods of exposure on ship hulls during voyages. In addition, some of the freshwater species inhabiting slightly brackish water may survive high salinity in the form of dormant stages (Fell 1992). For example, freshwater sponges produce gemmules, which are masses of cells surrounded by resistant coats that permit sponges weather periods of stress and disperse into other habitats. The statoblasts of freshwater bryozoans have a similar function (Pennak 1989). These stages can subsequently regenerate colonies when conditions improve and upon arrival of their ship vector to a freshwater port.

Estuarine species extending into tidal freshwater regions are generally tolerant of a wide range of environmental conditions, and may also survive full strength seawater while harbored among the biofouling community of ocean-going vessels. Indeed, except for the freshwater oligochaetes and the insect larvae, 24 (67%) of the 36 estuarine and brackish water species found in the pre-cleaning and post-cleaning surveys of the DUTTON, were also found in the post-transit survey. While the salinity in Brownsville is near ocean strength, species brought there by shipping might disperse into sheltered areas of reduced salinity and colonize brackish waters in rivers and streams.

All but four of the species found in Beaumont were either native or cryptogenic, and all of the genera and higher level taxa had native species present in Texas. Of the four nonnative species, at least three (*Cordylophora caspia*, *Garveia franciscana*, and *Ficopomatus enigmaticus*) are likely to occur elsewhere along the Gulf coast. Only the presence of the bryozoan *Conopeum chesapeakeensis*, if confirmed, constitutes a new introduction record for this species outside its native range. This species was common in both the pre-cleaning and the post-transit surveys. Two other nonnative species, the amphipods *Laticorophium baconi* and *Monocorophium acherusicum*, were collected only in the post-transit survey, and both are known to occur throughout the Gulf of Mexico.

It is interesting to note the presence of one fish and 11 "new" invertebrate species in the post-transit survey of the DUTTON (Table 3-1). These were high salinity species not collected in Beaumont. It is possible that these species were picked at the ship-breaker slip while the DUTTON rested on the banks of the slip. However, the species are likely to have attached during the voyage of the ship across the western Gulf of Mexico. We also found numerous new species attached to the hulls of the JASON and QUEENS VICTORY during their final voyage from California to Texas (Versar 2008c), pointing to additional risk of transfers and introductions at destination ports by rapid colonization of species at sea.

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## 4.0 SUMMARY AND CONCLUSIONS

1. Biological characterization surveys were conducted on the hull of four Beaumont Reserve Fleet vessels, DUTTON, HATTIESBURG VICTORY, DEL VALLE, and PIONEER CRUSADER. Extent of biofouling was also examined on the DUTTON after hull cleaning and after transit from Beaumont to Brownsville, Texas. The surveys yielded a total of 103 taxa corresponding to 81 distinct species. Freshwater and brackish water species predominated. Across all surveys, 30 species were native in Texas, 12 were cryptogenic, and 6 were introduced.
2. The biofouling community was dominated by Conrad's false mussel, *Mytilopsis leucophaeata*, and the barnacle *Balanus subalbidus*. Numerically, *M. leucophaeata* accounted for 87% of total abundance, *B. subalbidus* for 7%, and the remaining species each for 2% or less of total abundance. Mussels and barnacles were common on all ships and surveys, followed by the amphipod *Apocorophium lacustre*, algae, nematodes, and colonial organisms. There were no differences in abundance or species composition among transects or locations on the hull, except for a tendency for algae to occur more frequently near the waterline.
3. The total species number and abundance differed among ships, and this difference was attributed to age of vessel. The DEL VALLE and PIONEER CRUSADER were newer than the DUTTON and HATTIESBURG VICTORY, and remained active longer. Therefore they had less time to develop dense biofouling assemblages, and harbored fewer species, than the latter two ships.
4. All but four of the species found in Beaumont were either native or cryptogenic, and all of the genera and higher level taxa had native species present in Texas. Of the four species introduced, three are likely to occur elsewhere along the Gulf coast. The presence of the bryozoan *Conopeum chesapeakensis* in the Gulf of Mexico constitutes a new introduction record for this species outside its native range, provided its identification is confirmed.
5. In-water hull cleaning of the DUTTON was successful at removing on average 82% of the biofouling cover, substantially reducing the number of mussels and barnacles. However, hull cleaning had little or no effect on the frequency of occurrence of hard-shelled organisms and associated species in the samples of the post-cleaning and post-transit surveys. The top eleven most common species in the pre-cleaning samples were still common in the post-cleaning and post-transit samples.
6. "New" species not present in the pre-cleaning survey were collected in the post-transit survey of the DUTTON, suggesting that species may attach to the hull in route, which represents an additional risk for species transfers and introductions.

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## APPENDIX A SPECIES ABUNDANCE

1000 series samples = DUTTON pre-cleaning; 1100 = DUTTON post-cleaning; 1200 = DUTTON post-transit; 1300 = DEL VALLE; 1400 = PIONEER CRUSADER; 1500 = HATTIESBURG VICTORY

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Species	1301	1302	1303	1304	1305	1306	1307	1308	1309	1310	1311	1312	1313	1314	1315	1316	1317	1318	1319	1320	1321	1322	1326	1327	1328	1329	1330	1332
Algae sp. A	P	P		P	P	P	P		P	P	P			P		P				P	P		P		P		P	P
Apocorophium lacustre	1	1		2			7	1									1						1	1				1
Balanus subalbidus	10	81	10	52	3	47	35	9	38		1	34		5	10		1	1	2	7		1	25	6				2
Barentsia sp. A		P							P										P							P		
Bezzia/Palpomyia spp.																												
Boccardiella ligérica	9	9		3					2																			
Bougainvilliidae spp.		P		P																								
Bowerbankia gracilis	P	P		P		P	P	P	P			P		P	P					P	P		P					
Brachyura spp.					1																							
Callinectes sp. (juv.)			1						2																			
Cirripedia spp. (juv.)														P					P									
Climacia?																												
Conopeum chesapeakeensis				P	P	P	P	P	P			P			P		P						P	P		P		
Cordylophora caspia								P							P		P					P						
Culicoides sp.																												
Cymellus fraternus																												
Decapoda spp.																												
Dero sp.	1	5																										
Dicrotendipes lucifer	1	1		2		1			1			2			1													
Dicrotendipes sp.	1	3		2		2		1	2					1		1							2					1
Ephydatia fluviatilis			P									P							P	P								
Ficopomatus enigmaticus																												
Fredericella indica		P	P	P								P		P									P					
Garveia franciscana								P																				
Goeldichironomus sp.																								1				
Hourstonius laguna																												
Hydroptilidae																												
Macrobrachium carcinus																												
Melita nitida																			1									
Microtendipes pedellus group																												
Mytilopsis leucophaeata	1127	867	43	507	141	58	290	82	296	4	2	134	7	20	22		23	6	8	11		17	31	1	1	12		34
Nais communis																												
Nais variabilis		2																										
Nanocladius distinctus																												
Nematoda spp.	P	P			P	P			P	P			P	P	P											P		
Nereididae spp.			2							1															1			
Nereis cf. falsa	5	3		1			7	1	1			1																
Parachironomus carinatus																												
Parachironomus nr. pectinatellae																												
Pristina aequiseta	3																											
Pristina leidy																												
Rhithropanopeus harrisii			1					2					1				2		1			2			1			
Serpulidae spp. (juv.)																												
Sinelobus stanfordi				1																				1				
Sisyra sp.										1																		
Spionidae spp.		3			2	1																						
Stenochironomus sp.																												
Stylochus sp.			2																									
Tanytarsus sp.	1	2										1			1													
Tribelos sp.		1																										
Turbellaria sp. A		1				1						2			1													
Umatella gracilis										P										P	P							
Xenochironomus xenolabis																										1		











APPENDIX B  
SPECIES BIOGEOGRAPHY AND  
LIFE HISTORY INFORMATION

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Phylum	Class	Species/Taxon Name	Common Name	Status in Texas	Geographical Distribution		Salinity (psu)		Temperature (°C)		Substrate Preference-adults	Developmental mode	Feeding mode	Reference
					Native range	Invaded range	Range	Optimum	Range	Optimum				
Crustacea	Tanaidacea	Sineleobus stanfordi	tanaid	cryptogenic	Unknown, cited for the Pacific Ocean, Northwest Atlantic, Caribbean, Gulf of Mexico (but not Texas), Southwest Atlantic and Southeast Atlantic	Possibly Northeast Pacific, Southwest Pacific	0-45+	0.5-30			epibenthic	brooder	suspension feeder; detritus feeder	Cohen and Carlton 1995, Davidson et al. 2007
Hexapoda	Insecta	Sisyra sp.	spongillafflies	native species present			freshwater				Larvae: parasite of freshwater sponges	aquatic larvae and pupae, adult terrestrial stage		
Annelida	Polychaeta	Spionidae spp.	polychaete or bristle worm	native species present										
Hexapoda	Insecta	Stelechomyia perpulchra	non-biting midge	native	Eastern and Southern North America in rivers and streams						Larvae: epibenthic on dead wood	aquatic larvae and pupae, adult terrestrial stage		Merritt and Cummins 1996
Hexapoda	Insecta	Stenochironomus sp.	non-biting midge	native species present			freshwater				Larvae: epibenthic burrower on macrophytes and wood	aquatic larvae and pupae, adult terrestrial stage	collector-gatherer	Merritt and Cummins 1996
Annelida	Polychaeta	Streblospio benedicti	polychaete or bristle worm	native	Northwest Atlantic, Gulf of Mexico	Northeast Atlantic, Mediterranean Sea, Black Sea, Northeast Pacific	brackish to euhaline				infaunal tube-building	planktonic larvae	interface feeder	Cohen and Carlton 1995
Platyhelminthes	Turbellaria	Stylochus sp.	flatworm	native species present										
Hexapoda	Insecta	Tanytarsus sp.	non-biting midge	native species present			freshwater				Larvae: epibenthic on aquatic vegetation	aquatic larvae and pupae, adult terrestrial stage	collector-filterers and gatherers	Merritt and Cummins 1996
Hexapoda	Insecta	Tribelos sp.	non-biting midge	native species present			freshwater				Larvae: epibenthic burrower on aquatic vegetation	aquatic larvae and pupae, adult terrestrial stage	collector-gatherer	Merritt and Cummins 1996
Annelida	Oligochaeta	Tubificoides sp.	tubificid marine worm	native species present			brackish to euhaline							
Platyhelminthes	Turbellaria	Turbellaria sp. A	flatworm	?										
Platyhelminthes	Turbellaria	Turbellaria sp. B	flatworm	?										
Entoprocta		Urnatella gracilis	nodding heads	native	Cosmopolitan in rivers and lakes; possibly native to North America	Range possibly extended by shipping	0-5				epibenthic, epibiont	budding; planktonic larvae	suspension feeder	Weise 1961
Crustacea	Isopoda	Uromunna reynoldsi	isopod	native	Northwest Atlantic (North Carolina to Georgia), Caribbean, Gulf of Mexico	Panama Canal	<1-15				epibenthic	brooder	herbivore; detritus feeder	Heard 1982
Crustacea	Decapoda	Xanthidae spp.	mud crabs	native species present										
Hexapoda	Insecta	Xenochironomus xenolabis	non-biting midge	native	Streams, rivers and lakes of North America, South America, Europe, and Asia		freshwater				Larvae: burrower on freshwater sponges	aquatic larvae and pupae, adult terrestrial stage	predator	Merritt and Cummins 1996