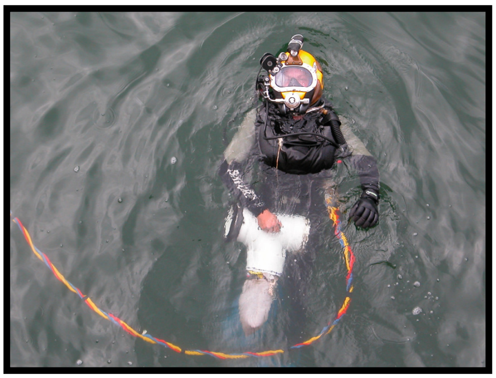
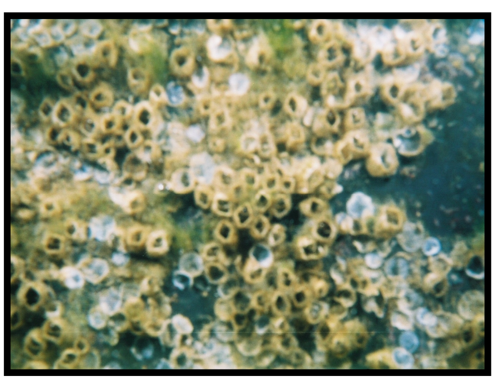




HULL BIOFOULING OF SUISUN BAY RESERVE FLEET VESSELS

QUEENS VICTORY & JASON BEFORE AND AFTER TRANSIT FROM CALIFORNIA TO TEXAS

Prepared for

U. S. Maritime Administration
Office of the Environment
Washington, D.C.

Prepared by

Roberto J. Llansó
Kristine Sillett

Versar, Inc.
Ecological Sciences and Applications
9200 Rumsey Road
Columbia, Maryland 21045

June 2008

ACKNOWLEDGEMENTS

We thank Versar's laboratory staff for sample processing, and those who contributed to the identification of species: Lisa Scott and Suzanne Arcuri (Versar), Tim Morris and Nancy Mountfort (Cove Corporation, Lusby, Maryland), Jeff Cordell (University of Washington), and John Ljubenkov (Pauma Valley, California). We are grateful to Brian Vogel (Maritime Administration, Western Region) and Chris Green (Green Environmental Services, Laguna Vista, Texas) for helping with field logistics, and to Carolyn Junemann for support and insight throughout the project. Underwater Resources, Inc. (San Francisco, California), and Underwater Services International (Gainesville, Florida) provided diving services.

This Page Intentionally Left Blank

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 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 summarizes biofouling of obsolete vessels and evaluates the effectiveness of in-water hull cleaning as a vector management option. In this study we examined the biota associated with the underwater surfaces of two Suisun Bay Reserve Fleet (SBRF) vessels, the QUEENS VICTORY and the JASON. Both vessels were surveyed in Alameda, CA, prior to towing, and in Brownsville, TX, after transit and hull cleaning. Hull cleaning took place off the coast of South Texas.

The QUEENS VICTORY, a World War II Victory Ship, was built in 1945 and added to the SBRF in June 1952 after 7 years of service. The JASON was built in 1943 and commissioned by the Navy as USS JASON in 1944. It was re-designated repair ship in 1957, and transferred to the SBRF in July 1996. Both ships were turned over to ship-breaking companies in December 2006 and surveyed shortly afterwards.

Sampling design was as in previous biological surveys. Samples were collected with the help of professional divers using a stratified random sampling protocol consisting of transects (anchor chain to stern) and positions at three depths (below the waterline, mid-depth, and bottom) across the hull. Additional samples were taken from the underwater stern appendages (stern tube, rudder, and propellers), bilge keel, and seachest. A total of 192 samples each of 182 cm^2 surface area were taken from both ships, 92 samples before transit (pre-cleaning samples) and 100 samples after transit and hull cleaning (post-cleaning samples). Samples were accompanied by photographs of the biota (photo-quadrats) and video, except in the pre-cleaning survey of the QUEENS VICTORY, for which no photographs or video were available. 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.

Across all surveys, 147 taxa (species or species groups) were recorded in the biological samples. The biofouling community prior to hull cleaning was dominated by the barnacle *Balanus improvisus*, the bryozoan *Conopeum chesapeakensis*, and by abundant isopod crustaceans. In addition, four species of amphipods, two species of flatworms, and the hydroid *Garveia franciscana* were prevalent in the samples. Barnacles, bryozoans, and hydroids formed a thick mat over most of the hull surface of the QUEENS VICTORY, but not the JASON. The JASON exhibited areas of bare hull and paint among patches of barnacles and bryozoans. Nonnative species in California (27 species) predominated in the pre-cleaning samples. These species included the invasive Asian clam, *Corbula amurensis*.

Multivariate analyses of species presence-absence and abundance data revealed differences between surveys and ships, but not between transects or locations on the hull of the ships. The QUEENS VICTORY had more species per sample and higher total number of species than the JASON. This difference was attributed to the lower biofouling cover observed on the JASON. The post-transit (= post-cleaning) survey of the QUEENS VICTORY yielded a higher number of species than the pre-transit survey. Many of the post-transit species were juveniles recently settled on the hull. Seventy-three percent of the post-transit species were "new", not recorded in the pre-transit samples. Four species unknown to occur in Texas were found in both the pre-transit and post-transit surveys, and were therefore transferred from California. In addition, numerous juvenile specimens in the post-transit samples were tentatively identified as belonging to the Asian clam *Corbula amurensis* and the flatworm *Stylochus franciscanus*, species unknown to occur in Texas. The transfer of the Asian clam to Texas on Suisun Bay ship hulls would be particularly worrisome, because of the invasive capabilities of this species, and the dramatic effects that this clam has had on the San Francisco Bay estuary.

The effectiveness of in-water hull cleaning could not be fully evaluated, since percent cover data from the QUEENS VICTORY prior to hull cleaning were not available. The JASON already exhibited a large proportion of bare hull before cleaning. However, after cleaning, on average only 63% to 68% of the hull of both ships consisted of bare space, which suggests that hull cleaning may not have been as effective as desired. Bare hull, barnacles, and algae were prominent features of the post-cleaning surveys.

Comparisons between the QUEENS VICTORY and the JASON suggested a relationship between the initial amount of biofouling and the number of species in the post-transit surveys. Species settlement and attachments while in transit may be enhanced by the amount of biofouling and the three-dimensional structure provided by the initial community. Therefore, a management strategy for which obsolete ships are allowed to depart the fleet without hull cleaning may increase the risk of species transfers and introductions at destination ports.

TABLE OF CONTENTS

I:\WPSHARED\DEPT.74\MARAD\Jason\14292-DR.doc

LIST OF FIGURES

Figure No. **Page**

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 locations to ship-breaking facilities. The vessels are towed from their fleet to other geographic locations where ship-breaking takes place. Because the vessels have been laid up for long periods of time, they are usually heavily fouled by aquatic organisms and their transfer may pose a high risk of hull-mediated biological invasions at destination ports. This report is the third in a series that examines biological growth on obsolete vessels and evaluates the effectiveness of in-water hull cleaning as a vector management option.

In this study the extent of biofouling on the hull of two Suisun Bay Reserve Fleet (SBRF) vessels, QUEENS VICTORY and USS JASON, is examined. The vessels were transferred from California to Texas via the Panama Canal. Because of the inter-oceanic nature of the transfer and the wide range of latitude encountered by the vessels during their voyage to Texas, the biogeographical implications of the transfer are significant. In a another study of a SBRF vessel, the OCCIDENTAL VICTORY, we found several species in the post-transit survey that were absent from the pre-transit surveys. Some of these species were oceanic instead of estuarine, suggesting that species attachments during long voyages are possible and increase the risk of nonnative species transfers to destination ports.

As with the OCCIDENTAL VICTORY study, the objectives of the present study were to: 1) identify and quantify the biota associated with the underwater surfaces of the QUEENS VICTORY and the JASON, and 2) examine the biogeographic status and distribution of species with respect to their possible transfer from California to Texas. Because the cleaning of the hulls of the QUEENS VICTORY and JASON took placed in the Gulf of Mexico near the coast of Texas, post-cleaning and post-transit biological surveys were not conducted separately, but were combined into one survey conducted in Brownsville, Texas.

The QUEENS VICTORY, a World War II Victory Ship, was built in 1945 and added to the SBRF in June 1952 after 7 years of service. The JASON was built in 1943 and commissioned by the Navy as USS JASON in 1944. It was re-designated repair ship in 1957, and transferred to the SBRF in July 1996. Both ships were turned over to ship-breaking companies in December 2006 and surveyed shortly afterwards.

This Page Intentionally Left Blank

2.0 METHODS

2.1 WATER CHARACTERISTICS

Water column parameters were measured on-site to characterize the environment that the biota encountered at the time of sampling. Parameters included temperature, salinity, conductivity, dissolved oxygen, and pH. Data were collected over the course of the biological surveys using a Yellow Springs Instruments multiparameter probe with automatic temperature and salinity compensation (YSI Inc., Yellow Springs, Ohio). Water parameter measurements were recorded at 1 meter intervals from the water surface to the maximum lightweight draft of the vessels. These data characterized local conditions at the time of sampling, but did not characterize exposure at the berth location in Suisun Bay or during towing of the vessels to their final destination.

2.2 VESSEL SURVEY

Each vessel was surveyed over two separate dives, one in Alameda, California, and one in Brownsville, Texas. The QUEENS VICTORY was towed from Suisun Bay to Alameda on December 28, 2006, and surveyed December 29. It departed San Francisco Bay January 2, 2007, and arrived in the Gulf of Mexico on February 22. The hull was cleaned 30 miles off the South Texas coast on February 26 and surveyed after cleaning February 28 and March 1, 2007, in Brownsville.

The JASON was towed to Alameda on January 4, 2007, and surveyed on January 5 and 6. It departed San Francisco Bay one day later and arrived in the Gulf of Mexico on February 15, passing the QUEENS VICTORY in transit. Because of adverse weather conditions, the hull of the JASON could not be cleaned until February 22, and the post-cleaning survey took place five days later in Brownsville on February 27 and 28, 2007.

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 were provided by Underwater Resources, Inc. (QUEENS VICTORY in Alameda) and Underwater Services International, Inc. (QUEENS VICTORY in Brownsville, JASON).

The sampling design was similar to that previously employed to survey other vessels (Davidson et al. 2006; Versar 2008a, b). Samples were taken at three depths (below the waterline, mid-depth, and bottom of the hull) along eight transects (Figure 2-1). The QUEENS VICTORY was 455 feet long, with a lightweight draft of 9.5 feet. Transects were positioned 55 feet apart from each other starting from the anchor chain and ran across the hull. The JASON was 530 feet long. Transects in this vessel were positioned 70 feet apart from each other starting from the anchor chain. Five samples were collected per transect: 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 the vessel, including the stern tube, rudder, and propellers. This general scheme was employed on both vessels with the following exceptions: (1) Transect 5 of the QUEENS VICTORY was not sampled in Alameda because a tug boat was positioned nearby, only 6 samples were taken from the stern appendages because of nightfall, and one sample was taken from a blanked seachest. (2) The bottom sample of Transect 8 of the JASON was not taken because the hull did not have a flat bottom near the stern; instead, a sample was taken from the bilge keel. In Alameda, sampling was conducted from a barge positioned on the port side of the vessels. In Brownsville, the vessels were moored to the dock, with the port-side facing the dock. The divers swam under the vessels to the starboard side and back to complete two sampling transects.

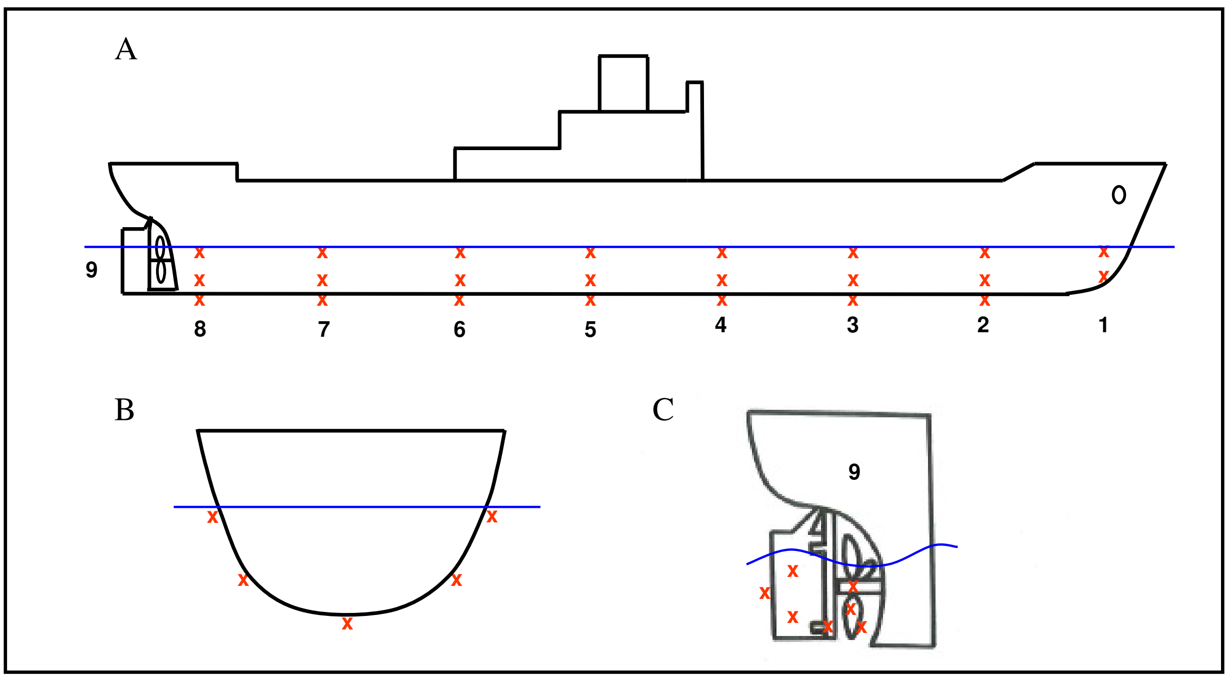


Figure 2-1. Sampling design. Samples and photo-quadrats were taken at 8 transects across the hull of the QUEENS VICTORY and JASON, with some exceptions (see text) (A). Five samples per transect were collected: starboard upper, starboard lower, bottom, port lower, and port upper (B). The first transect did not have a flat bottom; therefore, only four samples were collected from this transect. In addition, samples were collected from the underwater appendages of the vessel (C) including the stern tube, rudder, and propellers. Stern appendages were labeled as Transect 9.

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, T-shaped PVC pipe connector was used to collect the biota (Figure 2-2). A diver placed one end of the sampler (A in Figure 2-2) against the hull of the ship. The other end of the sampler (B in Figure 2-2) was sealed with neoprene; a slit in the neoprene barrier allowed the diver to insert a 3-inch scraper into the sampler and scrape biota from the hull. This sample was collected into a numbered cloth bag that was attached to the T-end of the sampler (C in Figure 2-2). The bag was twisted closed and tied off before being removed from the sampler to minimize sample loss. An area of approximately 182 cm^2 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. Forty-two samples were collected from the pre-cleaning survey of the QUEENS VICTORY, and 50 samples each from the post-cleaning QUEENS VICTORY survey and the pre-cleaning and post-cleaning JASON surveys. A total of 192 samples were processed for species abundance and composition. Most samples were accompanied by photo-quadrats, except in the pre-cleaning survey of the QUEENS VICTORY, for which no photographs or video were available.

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 on the diver's barge or at the dock. 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 constrains.

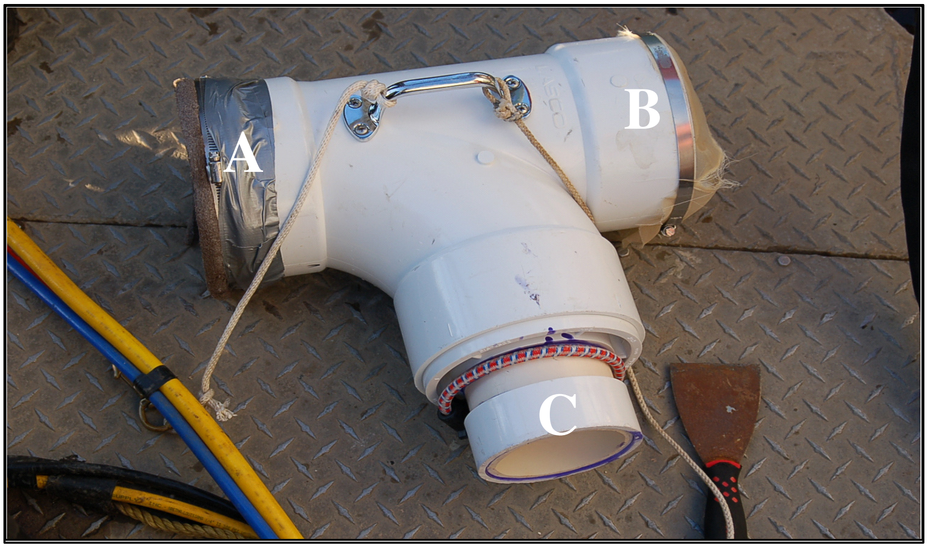


Figure 2-2. Sampler constructed from a 6-inch (15.2 cm) diameter PVC pipe with a 4-inch adapter. A diver placed the 6-inch end of the sampler against the hull of the ship, and attached a numbered cloth bag to the 4-inch end. A scraper was used to remove the biological material from the hull, which was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

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 phenoxytol (POP) solution to relax the organisms for easier identification. A 0.15 % solution was made by adding 15 ml of POP to 1 L 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-μm and 64-μm sieves. The finer 64-μm fraction of the sample was retained and stored for later examination. The 250-μm fraction was sorted under dissecting microscopes to separate organisms into major categories (e.g., bryozoans, barnacles, crustaceans). Organisms in these major categories were identified to species level whenever possible and counted (non-colonial species only) if their abundance in a sample was low (usually <100); otherwise, their abundance was estimated. This last procedure differed from that used in the processing of samples from previous ships, where all organisms were counted. Some organisms required further examination by specialist taxonomists for identification or confirmation. Voucher specimens of these organisms were put 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 number, 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 their location on 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 conducted on the pre-cleaning and post-cleaning samples to identify gradients in species abundance and composition.

Photo-quadrats were examined by quantifying the percent cover of nine distinguishable categories of biofouling in each image: bryozoan, hydroid, barnacle, barnacle seat/organism remnant, crustacean, encrusting species, algae, 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 cm^2 (approximately 9.5 x 17 cm), for a density of 1.7 points per cm^2 of hull (Figure 2-3). 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 were analyzed by MDS on a Bray-Curtis similarity matrix based on transformed data (arcsine of the square root of p, where p is a proportion).

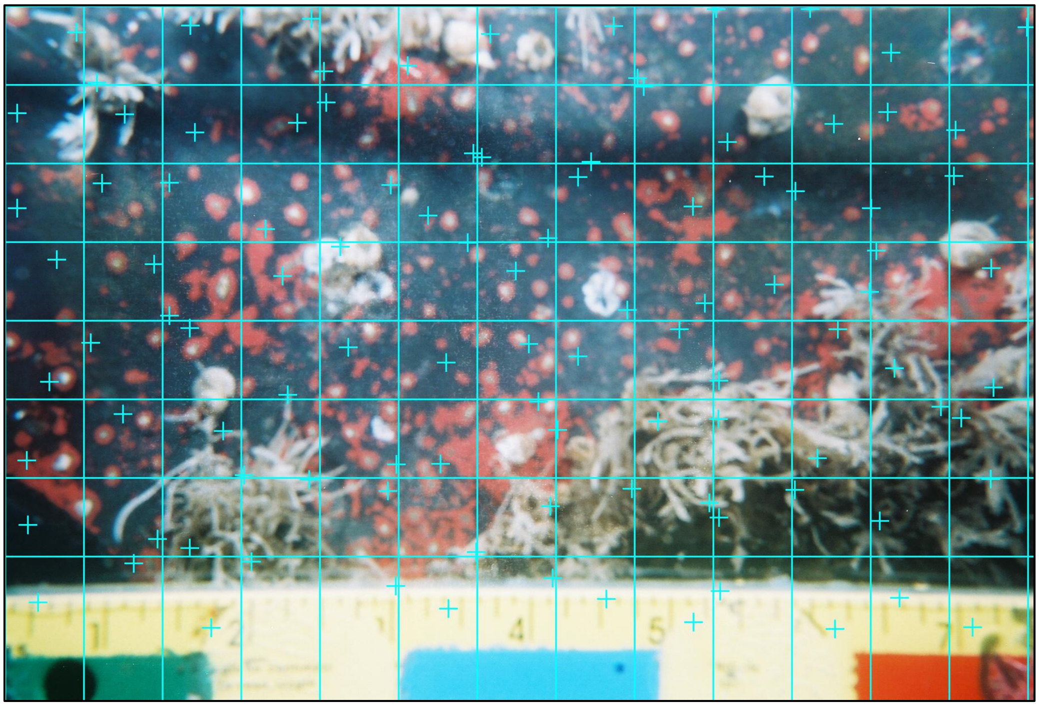


Figure 2-3. Grid of random points superimposed on an underwater photograph taken from the lower starboard side of Transect 4 (mid ship) of the JASON prior to hull cleaning. Images were analyzed using the point count method to determine percentage cover of each of 9 categories of biofouling. The area of hull analyzed from the image (first seven rows), was 158 cm^2 (approximately 9.5 x 17 cm). A ruler in inches was added to the lower edge of the clear-water box. Barnacles, bryozoans, paint, and bare hull can be seen in this photograph.

3.0 RESULTS AND DISCUSSION

3.1 WATER CHARACTERISTICS

Water characteristics varied little with depth during the pre-cleaning surveys, whereas during the post-cleaning surveys salinity was slightly higher, and temperature and dissolved oxygen lower, at depth than near the surface (Figure 3-1). Water temperature was ten degrees lower in Alameda than in Brownsville, whereas salinity was similar in both locations and near ocean strength (Figure 3-1). These were the water characteristics encountered during the course of the surveys. However, during the voyage from California to Texas, and in Suisun Bay, biofouling organisms are typically exposed to a wide range of salinity and temperature. The ships travel from the Pacific Ocean to the Gulf of Mexico through the Panama Canal, and during this voyage the fouling community encounters salinities ranging between 0 and 37 psu (practical salinity units), and temperatures ranging between 10ºC and 32ºC (Davidson et al. 2007). In Suisun Bay, variable freshwater flows in the Sacramento and San Joaquin river valleys produce wide fluctuations in salinity that range from approximately 0 to 22 psu (Davidson et al. 2006). Organisms exposed to these conditions usually display physiological and behavioral adaptations that allow them to withstand the rigorous physical environment of the estuarine habitats in which they live. Therefore, they are likely to be tolerant of the changes in salinity and temperature expected near the Panama Canal and in the receiving waters of destination ports.

3.2 SPECIES ASSEMBLAGES

The biological samples collected from the hull of the QUEENS VICTORY and the JASON yielded at total of 147 taxa, of which 63 were identified to the species level and 29 to the genus level. The remaining taxa (hereafter referred to as species) could be identified only to higher taxonomic levels of resolution. By ship, 123 species were recorded from the QUEENS VICTORY and 82 species from the JASON. Some species, especially those collected during the post-cleaning surveys, were juveniles and therefore difficult to distinguish. Table 3-1 lists all species, gives their frequency of occurrence in the surveys, and presents their biogeographic status in California waters. Appendix A shows their abundance in the samples. Appendix B presents invasion status, distribution, habitat, and life history information. Because the sorting of the 64-μm fraction of the sample required a large amount of effort beyond the scope of this study, only a subset of these samples was examined. The 64-μm fraction was dominated by copepods and the juveniles of many of the species retained on the 250-μm sieve. The copepods found included water column (*Acartia tonsa*, *Oithona* sp., *Paracalanus* sp., *Pseudocalanus* sp.) and benthic (harpacticoid) species. Some of these species were also found in the 250-μm fraction. Copepod species are listed in Table 3-1, but their frequency of occurrence is not provided, since not all of the 64-μm fractions were examined.

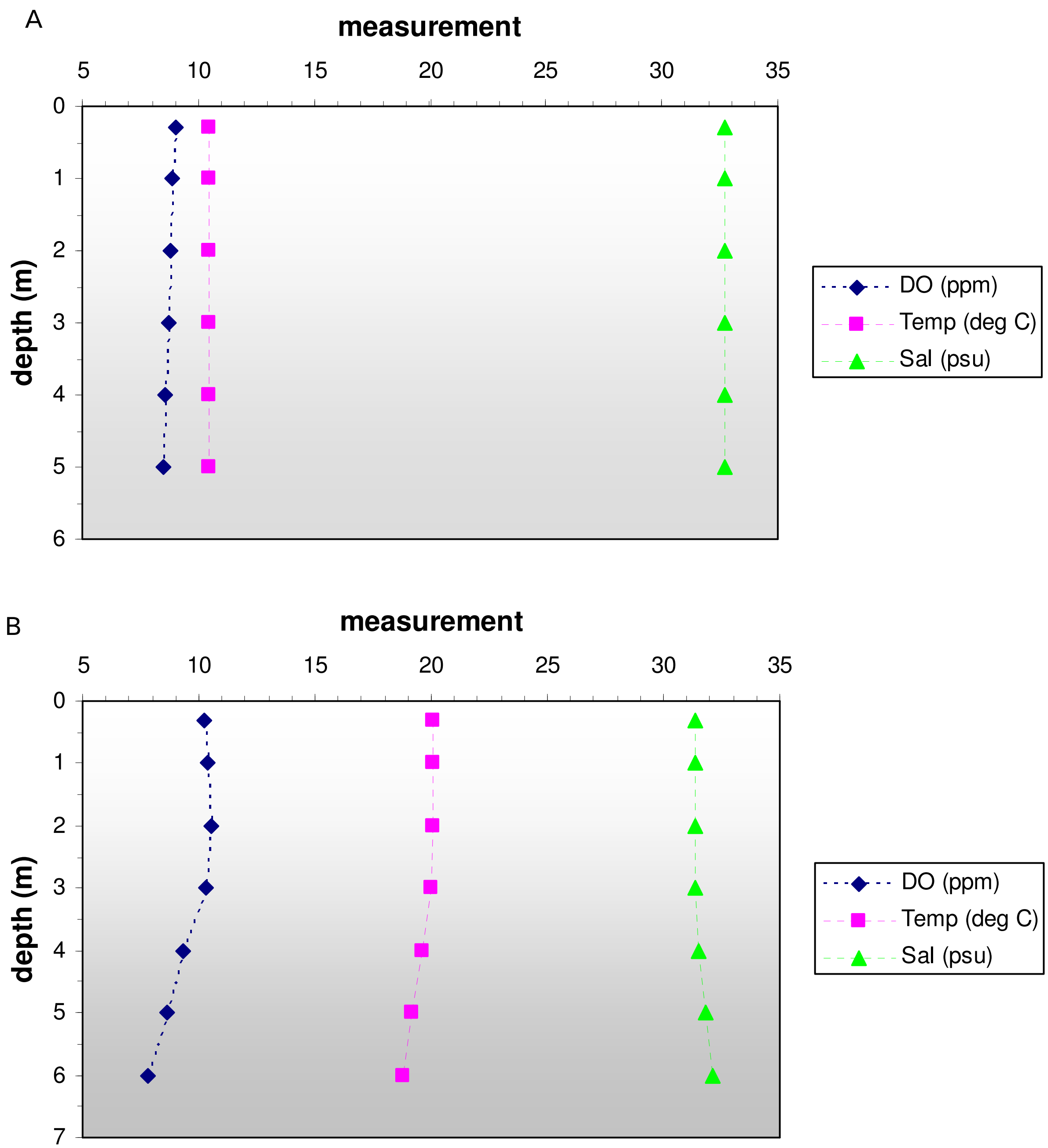


Figure 3-1. Salinity, temperature, and dissolved oxygen in (A) Alameda, CA, on January 4, 2007, 16:00 hrs, during the pre-cleaning survey of the JASON, and (B) Brownsville, Texas, on February 28, 2007, 17:30 hrs, during the post-cleaning survey of the QUEENS VICTORY.

Table 3-1. Species recorded in the biological samples. The frequency of occurrence (percent of samples) in pre-cleaning and post-cleaning surveys; the biogeographic status of species in California waters; and whether the species was present on the OCCIDENTAL VICTORY (Versar 2008a) is shown. Because not all the 64-μm samples were examined, frequency of occurrence for copepod species is not provided; "P" indicates presence. Status: I = introduced (nonnative species); C = cryptogenic; N = native; NP = native species present; NR = no record/not present in California. ? = undetermined. Vessels: QV = QUEENS VICTORY, JS = JASON, OV = OCCIDENTAL VICTORY. *The post-cleaning survey is also the post-transit survey.

Group	Species	% Samples				Status	Present in OV
		Pre-cleaning		Post-cleaning*			
		QV	JS	QV	JS		
Algae	Algae sp. A	7	2	28	60	?	x
	Algae sp. B	0	0	4	0	?	x
	Algae sp. C	0	0	2	0	?	
	Algae sp. D	0	0	0	48	?	
	Algae sp. E	0	2	0	0	?	
Amphipoda	*Americorophium spinicorne*	55	50	0	0	N	x
	Ampelisca abdita	5	2	0	0	I	
	Amphipoda spp. (Ind.)	0	0	2	0	NP	
	Ampithoe valida	10	0	0	0	I	x
	Aoridae spp.	0	0	4	0	NP	
	Caprella equilibra	0	0	6	6	C	x
	Caprella scaura	0	0	2	0	I	
	Caprella sp. (Ind.)	0	0	2	4	NP	x
	Corophiidae spp. (juv.)	0	0	2	0	NP	x
	Deutella incerta	0	0	0	2	NR?	
	Elasmopus cf. *rapax*	0	0	12	42	I	
	Eochelidium sp.	2	0	0	0	I	
	Ericthonius brasiliensis	0	0	18	16	C	
	Gammaropsis sp.	0	0	4	0	NP	
	Gammarus daiberi	2	0	0	0	I	x
	Grandidierella japonica	17	2	0	0	I	
	Incisocalliope derzhavini	98	60	0	0	I	x
	Jassa marmorata	2	16	2	0	I	x
	Jassa slatteryi	0	2	0	0	C	x
	Jassa sp. (juv.)	2	0	0	8	NP	x
	Laticorophium baconi	0	0	48	56	C	x
	Lembos sp.	0	0	0	2	NR	
	Melita nitida	60	50	2	0	I	x

Table 3-1. (Continued)							
		% Samples					
		Pre-cleaning		Post-cleaning*			
Group	**Species**	**QV**	**JS**	**QV**	**JS**	**Status**	**Present in OV**
Amphipoda	*Monocorophium acherusicum*	83	78	36	18	I	x
	Paracaprella pusilla	0	0	4	0	NR	
	Podocerus brasiliensis	0	0	12	0	C	
	Ptilohyale littoralis	2	2	0	0	C	x
	Stenothoe valida	17	4	44	0	I	*Stenothoe* sp.
Anthozoa	Anthozoa sp. A	2	0	0	0	?	
	Anthozoa sp. B	0	0	2	0	?	
	Anthozoa spp. (Ind.)	0	0	4	0	NP	
Ascidiacea	*Ciona intestinalis*	2	0	0	0	I	
	Tunicates?	0	0	4	0	NP	x
Bivalvia	Bivalvia sp. B	0	0	28	0	?	
	Bivalvia sp. C	0	0	10	0	?	
	Bivalvia sp. D	0	0	4	0	?	
	Bivalvia sp. E	0	0	2	0	?	
	Bivalvia sp. F	0	0	4	0	?	
	Bivalvia spp. (Ind.)	5	0	2	4	NP	x
	Corbula amurensis	29	8	0	0	I	*Corbula* sp.
	Corbula amurensis? (Bivalvia sp. A)	0	0	28	0	I	
	Mytilidae spp. (juv.)	0	0	4	0	NP	x
Chaetognatha	Chaetognatha spp.	0	0	8	6	NP	x
Cirripedia	*Balanus amphitrite*	0	0	64	20	I	x
	Balanus improvisus	98	98	88	42	I	x
	barnacle cypris	0	0	100	0	NP	x
	Cirripedia spp. (juv.)	2	0	84	38	NP	
	Lepas anatifera	0	0	8	0	N	x
Copepoda	*Acartia tonsa*	P	P	P	-	N	x
	Amphiascoides sp.	-	P	-	-	NP	x
	Calanoida spp. (Ind.)	-	P	-	-	NP	
	Corycaeus amazonicus	-	-	P	-	C	
	Cyclopoid sp. A	-	P	-	-	?	
	Cyclopoida spp. (Ind.)	P	P	-	-	NP	
	Diarthrodes sp.	P	-	-	-	NP	x
	Diosaccidae spp.	-	-	P	-	NP	
	Euterpina acutifrons	P	-	-	-	N	
	Harpacticidae spp.	-	-	P	-	NP	
	Longipedia sp.	-	-	P	-	NP	

Table 3-1. (Continued)							
		% Samples					
		Pre-cleaning		Post-cleaning*			
Group	**Species**	**QV**	**JS**	**QV**	**JS**	**Status**	**Present in OV**
Copepoda	*Mesochra* sp.	P	-	-	-	NP	x
	Nitokra sp.	-	P	-	-	NP	x
	Oithona sp.	P	-	-	-	NP	x
	Paracalanus sp.	-	P	-	-	NP	
	Pseudocalanus sp.	-	P	-	-	NP	
	Schizopera sp.	P	P	P	-	NP	x
	Tisbe sp.	-	P	-	-	NP	
Cumacea	*Nippoleucon hinumensis*	2	0	0	0	I	
Decapoda	Brachyura spp. (Ind.)	0	0	4	0	NP	crab megalop
	Callinectes sp.	0	0	4	64	NP	
	Pachygrapsus transversus	0	0	4	0	N	
	Porcellanidae spp. (juv.)	0	0	4	0	NP	
	Rhithropanopeus harrisii	2	0	34	0	I	
Ectoprocta	*Bowerbankia gracilis*	2	0	0	0	I	
	Bugula sp. A	2	0	0	0	?	
	Bugula stolonifera	5	0	0	0	I	x
	Conopeum chesapeakensis	100	100	90	86	I	x
Gastropoda	Aeolidacean nudibranch (juv.)	0	0	6	2	NP	
	Gastropoda	0	0	6	0	NP	x
	Nudibranchia spp. (juv.)	0	0	6	0	NP	x
	Okenia plana	26	8	2	0	I	
Hydrozoa	*Campanularia* sp.	0	0	22	0	C	
	Campanulariidae spp.	0	0	2	0	C	
	Clytia cf. *hemisphaerica*	0	0	48	14	C	*Clytia* sp.
	Clytia sp. A	0	0	4	6	C	
	Clytia sp. B	0	0	8	0	C	
	Eudendrium sp?	2	0	4	2	NP	
	Garveia franciscana	74	82	66	72	I	x
	Halecium sp.	0	0	76	6	NP	
	Obelia geniculata	0	0	60	10	C	
	Obelia sp.	0	0	4	2	C	
	Oceanidae spp.	0	0	4	0	NP	
	Rhizocaulus verticillatus	0	0	4	0	N?	
Insecta	Chironomidae spp.	2	2	0	0	NP	x
	Simuliidae spp.	2	0	0	0	NP	
Isopoda	*Cirolana* cf. *parva*	0	0	2	0	NR	

Table 3-1. (Continued)							
		% Samples					
		Pre-cleaning		Post-cleaning*			
Group	**Species**	**QV**	**JS**	**QV**	**JS**	**Status**	**Present in OV**
Isopoda	*Cirolana harfordi*	0	2	0	0	C	
	Gnorimosphaeroma oregonensis/insulare	93	76	30	14	N	x
	Limnoria tripunctata	2	2	0	0	I	
	Paranthura japonica	0	4	0	0	I	
	Synidotea laticauda	100	88	0	0	I	x
	Uromunna ubiquita	100	62	0	0	N	x
Mysidacea	*Siriella thompsonii*	0	0	0	2	N	
Nemertina	Nemertina spp.	2	0	0	2	NP	x
Oligochaeta	Oligochaeta spp.	14	2	6	0	NP	x
Osteichthyes	fish eggs/larvae	0	0	18	6	NP	x
Polychaeta	Amphinomidae spp.	0	0	2	0	NP	
	Autolytinae spp. (Ind.)	0	2	0	4	NP	
	Boccardiella ligerica	67	48	0	0	I	x
	Brania californiensis	0	2	0	0	N	
	Capitella capitata	0	0	2	0	C	
	Capitella sp. (juv.)	0	0	8	0	C	
	Dipolydora socialis	0	0	2	2	C	
	Eteone sp.	0	0	0	2	NP	*E. californica*
	Ficopomatus enigmaticus	2	0	2	0	I	
	Neanthes succinea	0	4	0	0	I	x
	Nereididae spp. (Ind.)	7	2	0	4	NP	
	Odontosyllis sp.	0	0	36	0	NP	
	Phyllodocidae spp. (juv.)	0	0	0	4	NP	
	Polydora cornuta	31	44	0	0	C	x
	Polydora sp.	0	0	0	2	NP	
	Polydora websteri	0	0	0	6	N	
	Polynoidae spp. (juv.)	2	6	2	0	NP	
	Proceraea cornuta	0	0	4	0	C	
	Sabellidae spp.	0	2	0	0	NP	
	Serpula sp.	0	0	4	0	NP	
	Serpulidae spp. (juv.)	2	0	12	0	NP	x
	Spionidae spp. (juv.)	0	0	10	24	NP	x
	Syllidae spp. (juv.)	0	0	2	4	NP	x
	Syllis sp.	2	0	0	0	NP	
	Terebellidae spp. (juv.)	0	0	2	0	NP	

Table 3-1. (Continued)

Group	Species	% Samples Pre-cleaning QV	JS	Post-cleaning* QV	JS	Status	Present in OV
Polychaeta	*Typosyllis alternata*	0	2	0	0	C	x
Sipuncula	Sipuncula spp. (juv.)	0	0	6	0	NP	
Tanaidacea	*Sinelobus stanfordi*	12	2	6	0	I	x
	Zeuxo coralensis	0	0	2	24	NR	
Turbellaria	Leptoplanidae (Turbellaria sp. A)	52	38	0	0	C	x
	Stylochus franciscanus	93	62	0	0	N	x
	Stylochus franciscanus? (juv.)	0	0	44	58	N	
	Turbellaria sp. B	0	0	2	0	?	
	Turbellaria sp. C	0	0	2	0	?	
	Turbellaria spp.	2	0	4	0	NP	
	Unidentified sponge-like organism	7	8	0	4	?	x

Samples were dominated by the barnacle *Balanus improvisus*, the bryozoan *Conopeum chesapeakensis*, and by isopod crustaceans. Isopods were numerically dominant, with over 16,000 individuals of *Uromunna ubiquita*, 13,000 individuals of *Gnorimosphaeroma oregonensis* and *Gnorimosphaeroma insulare*, and 10,000 individuals of the introduced species *Synidotea laticauda* collected in the samples of the QUEENS VICTORY (Appendix A). Isopods were also among the most abundant species on the JASON, but their numbers were considerably lower than in the QUEENS VICTORY, with 6,000 individuals of *U. ubiquita*, 4,000 individuals of *S. laticauda*, and 884 individuals of *G. oregonensis* and *G. insulare* recorded in the samples.

In terms of frequency of occurrence, *C. chesapeakensis*, and *B. improvisus* were dominant, followed by the isopod species noted above. *C. chesapeakensis*, *B. improvisus*, *U. ubiquita*, and *S. laticauda* occurred in 98-100% of the pre-cleaning samples taken from the QUEENS VICTORY, and in 62-100% of the pre-cleaning samples taken from the JASON (Table 3-1). In addition to these organisms, most pre-cleaning samples from both ships had hydroids (one species, *Garveia franciscana*), abundant amphipod crustaceans (four species, three introduced) and flatworms (two species, “Turbellaria” in Table 3-1). Two species of polychaete annelids, the introduced *Boccardiella ligerica* and the cryptogenic (i.e., of uncertain origin) *Polydora cornuta*, were also common in the samples. One species of special concern in San Francisco Bay, the invasive Asian clam *Corbula amurensis*, was found in 29% and 8% of the pre-cleaning samples of the QUEENS VICTORY and the JASON, respectively.

Barnacles, bryozoans, and hydroids formed a thick mat over most of the QUEENS VICTORY hull surface, but not over the JASON. The JASON had many areas of bare hull and paint showing among patches of barnacles and bryozoans. This was one of the main characteristics that distinguished this ship. The layer of barnacles, bryozoans, and hydroids of the pre-cleaning survey provided three-dimensional habitat and structure for other species, particularly abundant crustaceans. This was also noted in previous surveys (Davidson et al. 2006, Versar 2008a). The bryozoan *Conopeum chesapeakensis* is both encrusting and branching. It grows horizontally over barnacles and other surfaces, including the stems of hydroids, and vertically in the form of erect bilaminar fronds and strands. It provides food and shelter for many organisms, and probably accounts for the large number of species found in the fouling community of SBRF ships.

During the pre-cleaning surveys in Alameda, 73 species were collected (Table 3-1). Of these, 8 were native in California, 6 were cryptogenic, and 27 were introduced (Table 3-1). Of the remaining species, 26 were genus or higher level identifications with native species present in California, and 6 were of undetermined status. Introduced species predominated in the surveys. Of the same pre-cleaning species, 12 species were native to Texas, 5 were cryptogenic, 4 were introduced (also introduced in California), 25 had native species present, and 20 (to our knowledge) were not known to occur in Texas. The remaining species were of undetermined status in Texas. The potential for introduction in Texas, therefore, existed for 20 species, half of which were species introduced to or invasive in California. There was also potential for the further transfer and range extension of 4 species already introduced to Texas.

During the post-cleaning surveys in Brownsville, 102 species were collected (Table 3-1). The majority (74 species) were found only in the post-cleaning surveys, although the biogeographical range of 58 of these species also included California. While some of these "new" species may have been undetected in the initial pre-transit surveys, it is more likely that these species settled on the ships during the long voyage along the Pacific and Gulf of Mexico coasts. Twenty-eight species were common to both the pre-cleaning and post-cleaning surveys, and therefore were transfers from California.

Among the species transferred from California, two were classified as cryptogenic in Texas (the amphipod *Stenothoe valida* and the tanaid *Sinelobus stanfordi*), 3 as introduced (the amphipod *Monocorophium acherusicum*, the polychaete *Ficopomatus enigmaticus*, and the hydroid *Garveia franciscana*), and 4 as not recorded in Texas waters (the isopods *Gnorimosphaeroma oregonensis* and *Gnorimosphaeroma insulare*, the nudibranch gastropod *Okenia plana*, and the bryozoan *Conopeum chesapeakensis*). These last 4 species are the most significant, as they are not known to occur in Texas and were transferred from Suisun Bay in the biofouling community of both ships. The isopods and the bryozoan were also quite prevalent in the samples. In addition, numerous specimens from the post-cleaning surveys were tentatively identified as juveniles of two species unknown from Texas. One of this species, the Asian clam *Corbula amurensis* is well known as invasive in San Francisco Bay, and the other, the flatworm *Stylochus franciscanus*, is native to California and not known to occur outside its range.

Two of the species that were found only in the post-cleaning surveys, the amphipod *Laticorophium baconi* and the barnacle *Balanus amphitrite*, are considered to have been introduced in the Gulf of Mexico. The presence of these species on the hulls of the QUEENS VICTORY and the JASON is significant because the movement of ships across oceans has the potential to contribute to the dissemination and further range extension of nonnative species, as may be the case with these two species or other species that attach while the ships are in transit.

3.3 REVISIONS TO TAXONOMY AND BIOGEOGRAPHIC STATUS

Since the OCCIDENTAL VICTORY report, the taxonomy of some of the species that we reported has been updated. Better and larger specimens allowed revision of the identity of two amphipod species. The amphipods *Allorchestes* sp. and *Jassa staudei* are now *Ptilohyale littoralis* and *Jassa marmorata*, respectively. The dominant bryozoan *Conopeum osburni* has been re-identified as *Conopeum chesapeakensis*. As noted by Davidson et al. (2006), the identification of *C. osburni* from San Francisco Bay was regarded as tentative, since the genus *Conopeum* is taxonomically difficult and the morphology of the various species can vary considerably due to growth conditions. *C. chesapeakensis* was described for Chesapeake Bay by Banta et al. (1995) as *Membranipora chesapeakensis* n. sp. Colonies of this species were described as erect, ribbon-shaped or bilaminar, just as those that are so typical of the hulls of SBRF ships. Additional characteristics such as the presence of a setigerous collar (secretion) in the distal portion of the zooid, distinguish this species from other membraniporid cheilostomes (Banta et al. 1995). The setigerous collar is hard to see unless the animal is sectioned and examined under a high power microscope. Otherwise, *C. chesapeakensis* resembles other *Conopeum* species. Knobs and spines that are sometimes used to recognize species can be induced by environmental factors, and may not be reliable in the identification of species. *C. chesapeakensis* is most probably native in Chesapeake Bay, but it appears to have been unrecognized in surveys conducted in the Bay. It fits the characteristics of an undescribed species of *Membranipora* reported early on for Chesapeake Bay by Dudley (1973). Recent molecular analyses conducted on *Conopeum* confirm that specimens of *C. chesapeakensis* from Chesapeake Bay are similar to those collected from Suisun Bay and different from *C. osburni* (Davidson et al. 2008). Therefore, the biogeographic status of this bryozoan in SBRF ships has been changed from native to introduced.

Upon further research, and in accordance with Davidson et al. (2008), the status in California of two other species has been changed. The barnacle *B. improvisus*, which is native to the east coast of North America, was considered cryptogenic in the OCCIDENTAL VICTORY report. It is now regarded as introduced in Suisun Bay. Likewise, the amphipod *Caprella equilibra* was considered native in the OCCIDENTAL VICTORY report, and is now regarded as cryptogenic in Suisun Bay. We have also identified the Turbellaria sp. A of the OCCIDENTAL VICTORY as a leptoplanid flatworm of uncertain origin (cryptogenic). We have been unable to associate this species with any of the species of Turbellaria described from California. The eye arrangement, general characteristics, and color pattern of this species is somehow similar to those of *Euplana gracilis* from the east coast of North America. Our leptoplanid flatworm may turn out to be an introduced species in Suisun Bay. It was abundant in the pre-transit surveys, but was not collected in Brownsville.

3.4 DIFFERENCES BETWEEN SHIPS, SURVEYS, AND LOCATIONS ON THE HULL

The QUEENS VICTORY had more species per sample and higher total number of species than the JASON (Figure 3-2). We attribute this difference to the lower barnacle and bryozoan cover observed on the hull of the JASON, probably due to this ship having been longer in service than the QUEENS VICTORY. Underwater photographs or video of the hull of the QUEENS VICTORY were not taken in Alameda, therefore differences in the percentage of biofouling cover between ships cannot be contrasted. However, the photo-quadrats of the JASON revealed an unusually large proportion of bare space and paint prior to hull cleaning (Figure 3-3). In addition, many of the pre-cleaning JASON samples had low biomass, whereas pre-cleaning QUEENS VICTORY samples generally had high biomass (Figure 3-4).

The post-cleaning surveys of both ships had fewer species per sample than the pre-cleaning surveys. In terms of total number of species, however, more species were collected in the post-cleaning survey of the QUEENS VICTORY than in the pre-cleaning survey (Figure 3-2). This pattern was not observed in the JASON. The organisms found in Brownsville were generally small juveniles, recently settled on the hull. We found heavy settlement of barnacle larvae (cypris and small juveniles) on the QUEENS VICTORY. Several hydroid species were also collected from the QUEENS VICTORY in Brownsville, but not from the JASON. It is possible that high biofouling cover on the QUEENS VICTORY may have resulted in high number of species in Brownsville, as higher biomass and structural complexity increases space available for settlement and generally leads to increased diversity (Davidson et al. 2008). Alternatively, the differences between the QUEENS VICTORY and the JASON could have been due to different encounter rates of larvae by the ships. This is unlikely, however, as larvae of several species would have had to be present in the water column at the same time for one ship but not for the other. Interestingly, the JASON spent more time in the Gulf of Mexico waiting to be cleaned than the QUEENS VICTORY. The cleaning of the hulls took place off the coast of South Texas. Our data suggest that letting the ships depart without hull cleaning may increase the risk of species transfers and introductions not only from the original assemblage but from additional attachments that the original assemblage may facilitate.

The observed differences between surveys and ships were reinforced by the multivariate analyses of species presence-absence and abundance data (Figure 3-5). Pre-cleaning and post-cleaning samples and ships formed distinct groups in the MDS plots. The analyses also revealed higher variability in community organization in the JASON (the samples are more spread in the diagram) than in the QUEENS VICTORY. No clear patterns in the samples were observed based on transect or position on the hull (MDS diagrams not shown). As with the OCCIDENTAL VICTORY, most of the original assemblage of mobile crustaceans (isopods, amphipods, and tanaids) was reduced or eliminated after transit (Table 3-1), either by the effects of the voyage or by the hull cleaning.

3.5 PERCENT COVER

No percent cover data were available from the QUEENS VICTORY pre-cleaning survey. Post-cleaning data showed a high proportion of bare space (hull/paint). Bare hull (range 34-97%, average 63%) and barnacles (range 1-59%, average 24%) predominated in the post-cleaning survey (Figure 3-6), followed by barnacle seats (scars/remnants), hydroids, and bryozoans. Hydroid cover ranged from 1% to 33% in 10 photo-quadrats, and bryozoan cover ranged from 1% to 9% in 12 photo-quadrats. Multivariate analysis of QUEENS VICTORY photo-quadrat data revealed no differences in percent cover of organisms based on transect or position along the hull (MDS diagram not shown). This also can be observed in Figure 3-6.

Percent cover data from the JASON showed a high proportion of bare space (hull/paint) in both the pre-cleaning and post-cleaning surveys (Figure 3-7). Bare hull (range 7-98%, average 65%), barnacles (range 0-79%, average 18%), and bryozoans (range 0-57%, average 13%) predominated in the pre-cleaning survey, and bare hull (range 0-100%, average 68%) predominated in the post-cleaning survey, followed by barnacle seats (scars/remnants) and algae. Barnacle seat cover ranged from 1% to 68% in 31 photo-quadrats (average 15%), and algal cover ranged from 1% to 99% in 16 photo-quadrats (average 48%). Thus, although patchy, algal growth was one of the most prominent features of the post-cleaning survey of the JASON. Algal growth occurred almost exclusively near the waterline (Figure 3-7). Note the large error bars in Figure 3-7, indicating a large variability in biofouling percent cover on the JASON. Biofouling percent cover on the QUEENS VICTORY was more uniform throughout the hull (Figure 3-6).

Multivariate analysis of JASON photo-quadrat data also revealed no differences in percent cover of organisms based on transect or position along the hull, except for higher algal cover near the waterline. A large degree of overlap between surveys in the MDS diagram indicates large amounts of bare space in both the pre-cleaning and post-cleaning surveys (Figure 3-8). Differences between surveys are also suggested by the spread of points in the diagram, due to differences in the relative proportions of algae, barnacles, and scars/remnants (Figure 3-8).

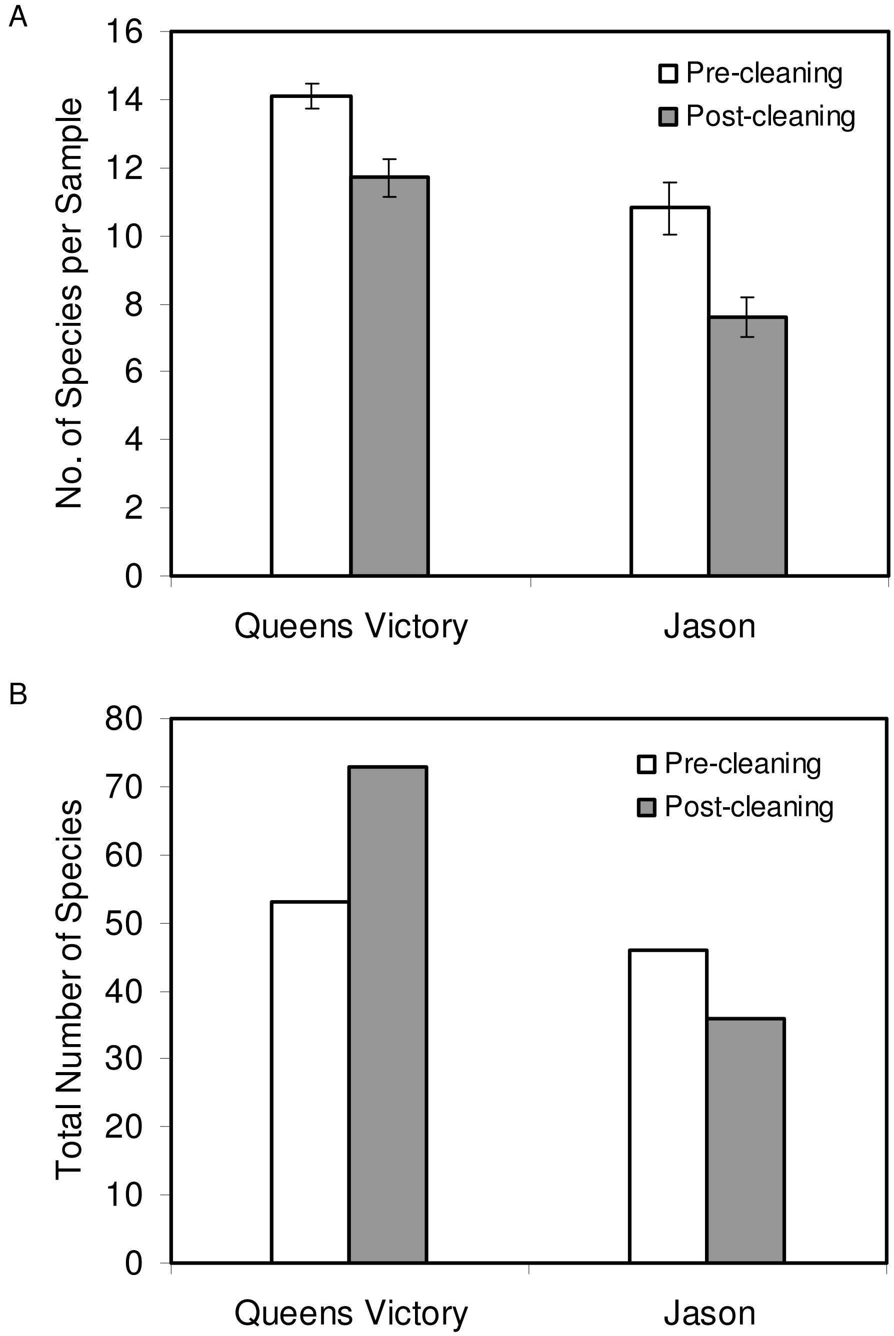


Figure 3-2. Mean number (+/- one standard error) of species per sample (A) and total number of species (B) collected during the biological surveys of the QUEENS VICTORY and the JASON in Alameda, CA, (pre-cleaning) and Brownsville, TX (post-cleaning). More species were collected from the QUEENS VICTORY in Brownsville than in Alameda, mostly juveniles of species not sampled in Alameda. Counts include only distinct taxa.

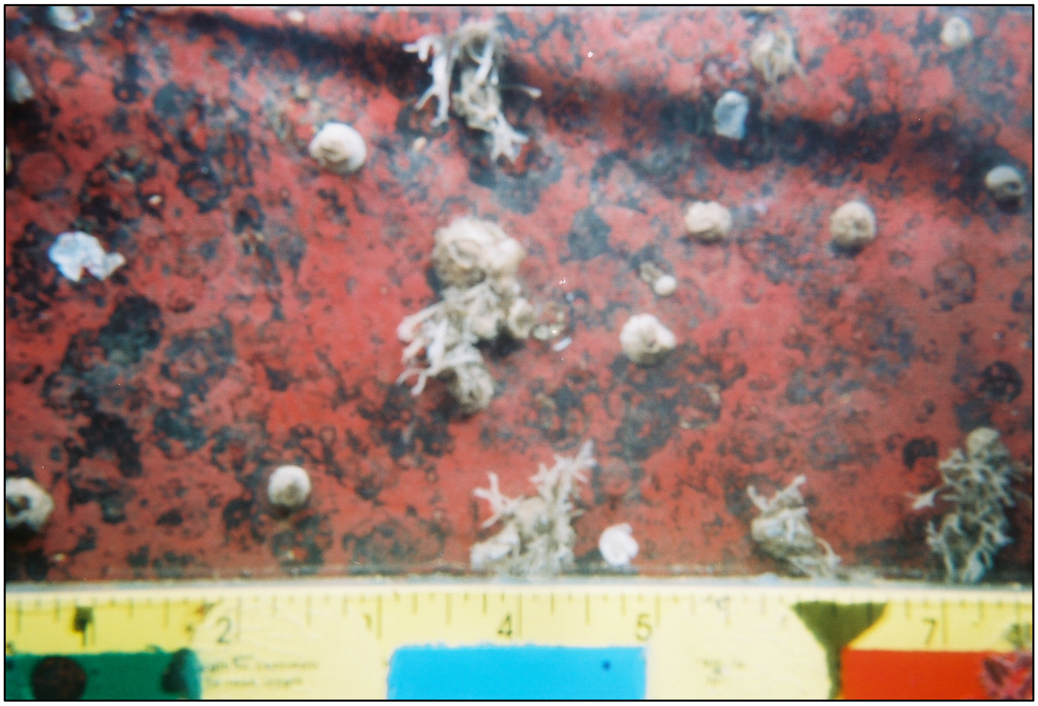


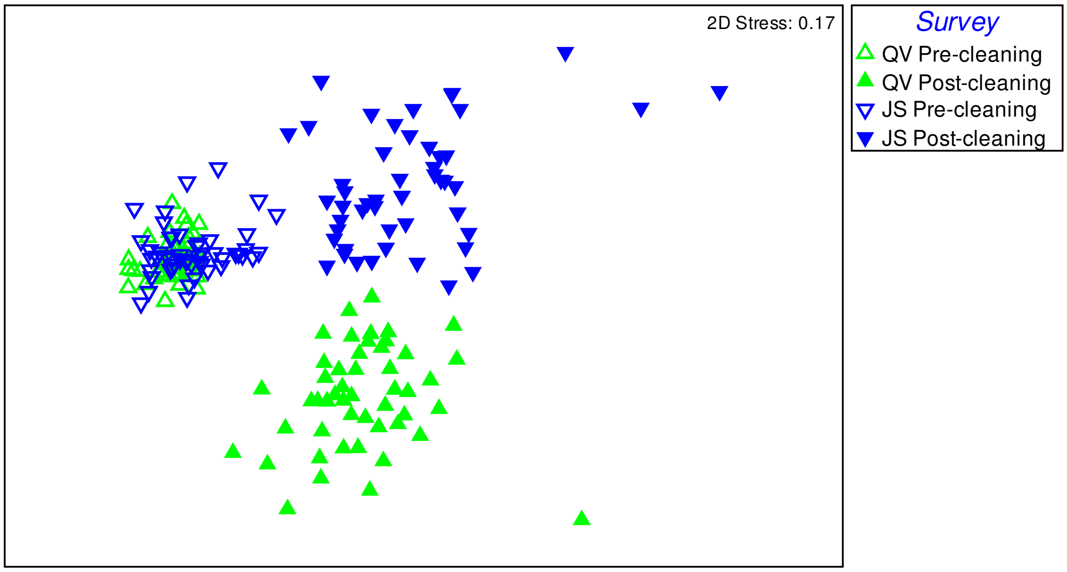
Figure 3-3. Underwater photograph taken from the hull of the JASON prior to hull cleaning showing areas of bare space and paint. This photograph is from the lower starboard side of Transect 5 (mid ship).

A

B

Figure 3-4. Photographs of samples taken during the pre-cleaning surveys of the JASON (A) and the QUEENS VICTORY (B), showing differences in biomass. Sample A is from the stern tube, and sample B is from the bottom of Transect 6 (mid ship).

A



B

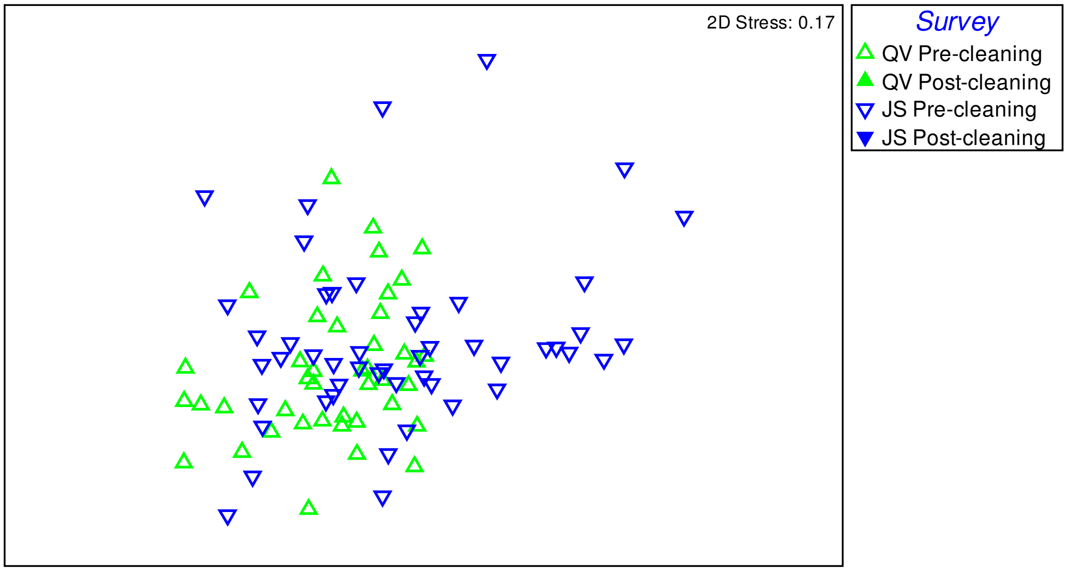


Figure 3-5. Multivariate analysis of species presence-absence data. Surveys form distinct groups in the diagram (A), indicating differences in community organization between pre-cleaning and post-cleaning samples, and between ships. The bottom diagram (B) is a subset of A showing the greater variability of the pre-cleaning samples of the JASON (more spread in the diagram).

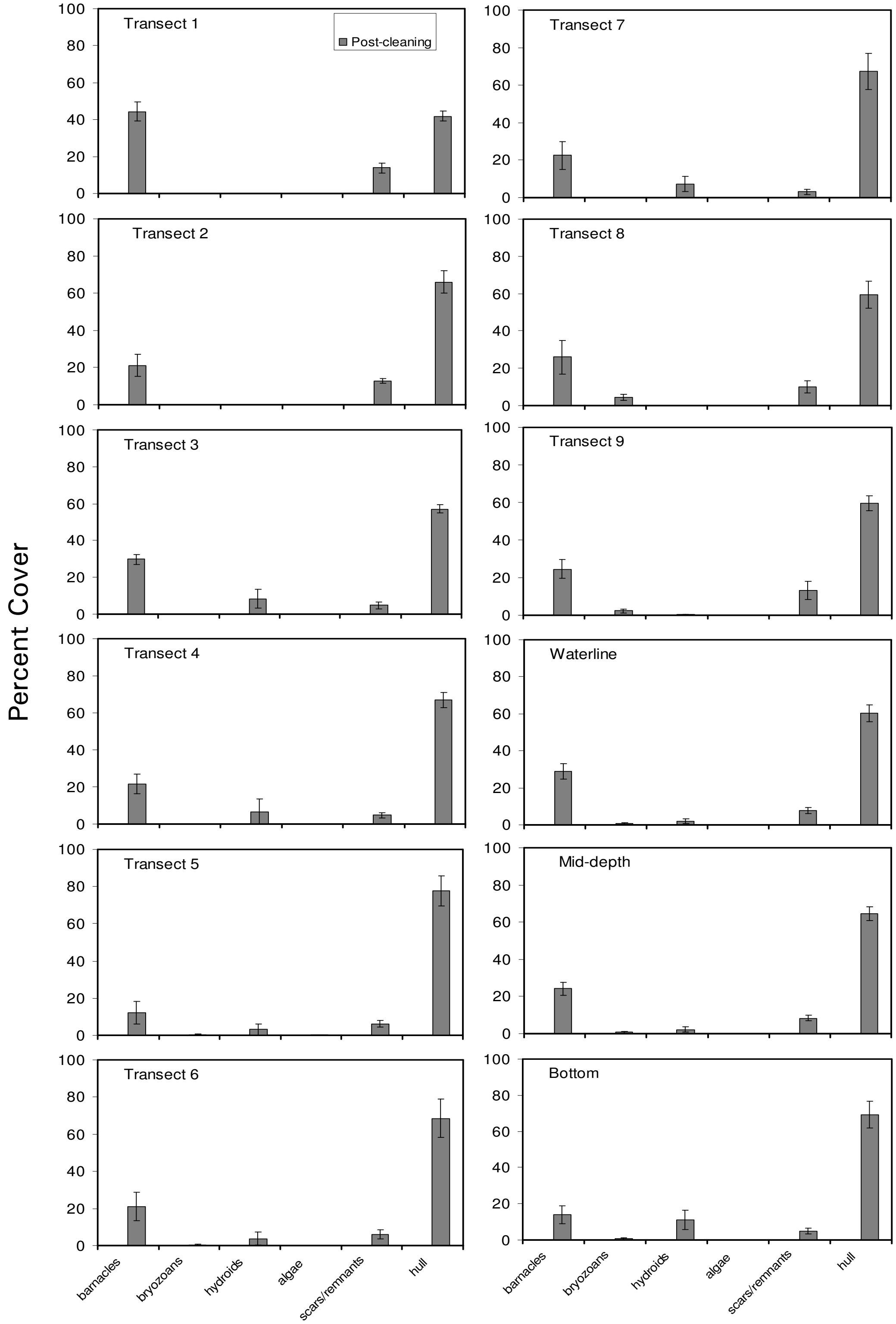


Figure 3-6. Biofouling percent cover of the QUEENS VICTORY after hull cleaning. The mean +/- one standard error of 6 prominent categories estimated from photo-quadrats is plotted by transect and position on the hull.

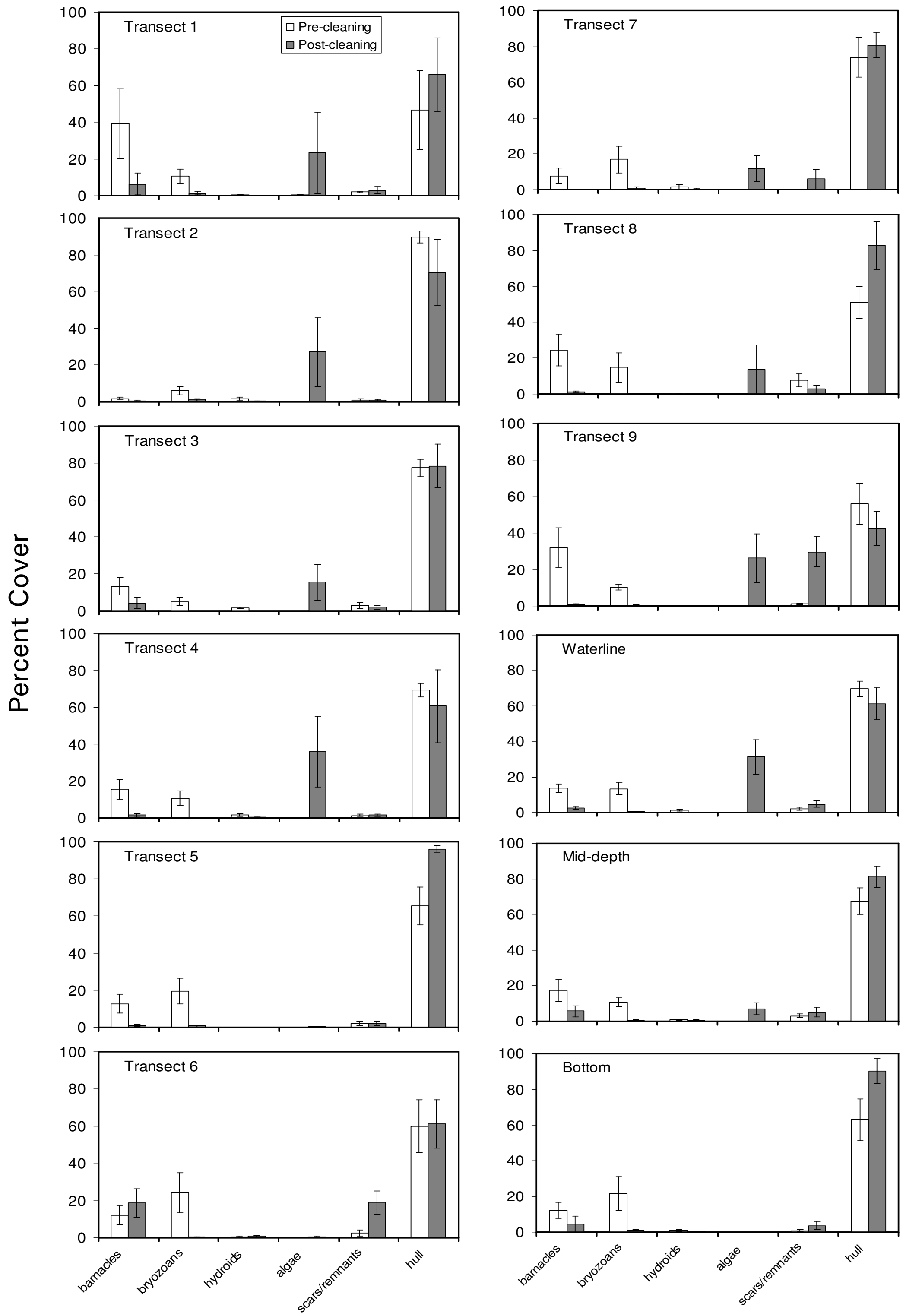


Figure 3-7. Biofouling percent cover of the JASON before and after hull cleaning. The mean +/- one standard error of 6 prominent categories estimated from photo-quadrats is plotted by transect and position on the hull.

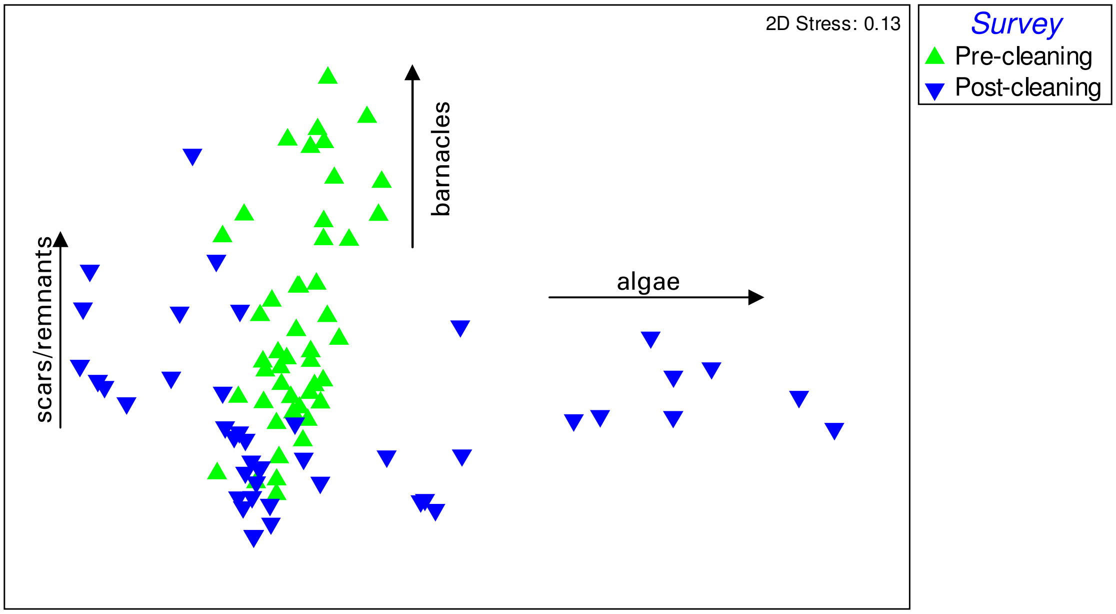


Figure 3-8. Multivariate analysis of JASON photo-quadrat data. There were no differences in percent cover of organisms based on transect or position along the hull, but differences between surveys are suggested in the diagram. Overlap between surveys indicates large amounts of bare hull in both surveys.

3.6 RISK OF SPECIES INTRODUCTIONS

We do not know the effectiveness of hull cleaning on the QUEENS VICTORY, since pre-cleaning percent cover data were not available. After hull cleaning, on average 63% of the hull consisted of bare space. Considerable barnacle cover, with scattered patches of bryozoan and hydroid growth, was present. The JASON exhibited a high proportion of bare hull prior to cleaning. After cleaning, bare hull increased only slightly from 65% to 68% on average, and new algal growth was observed near the waterline. Again, we do not know how effective hull cleaning was because the amount of biofouling that the ships carried into the Gulf of Mexico after their voyage was not evaluated. We can surmise effects of both in transit and in-water hull cleaning. However, given that the proportion of bare hull on both ships was on average only 63% to 68% after cleaning, hull cleaning may not have been as effective as desired.

The most surprising finding of the present study was the high number of species present on the hull of the QUEENS VICTORY after transit from California relative to the pre-transit survey. The JASON also had a high number of species in the post-transit survey, although not as high as in the pre-transit survey.

Numerous "new" species were collected from both ships in the post-transit surveys. In addition, some of the initial dominant species were still quite prevalent in the post-transit surveys. At least 20 of the species collected from both ships in California are not known to occur in Texas. Therefore, the potential for introduction existed for these species, half of which were either nonnative or invasive in California. Among the pre-transit species found in Brownsville, four species, the isopods *Gnorimosphaeroma oregonensis* and *Gnorimosphaeroma insulare*, the nudibranch *Okenia plana*, and the bryozoan *Conopeum chesapeakensis*, would be new records in Texas if they became established.[1] Additionally, juveniles of the Asian clam *Corbula amurensis* were tentatively identified as present on the QUEENS VICTORY, and the flatworm *Stylochus franciscanus* as present on both ships in the post-transit surveys. These specimens were very small, so these identifications remain subject to review.

The implication of our findings is that not only the species of the original assemblage may be transferred to destination ports with the movement of obsolete ships, but that a host of new species may settle in transit and contribute to the dissemination and further range extension of species across oceans and regions within oceans. It is possible that the settlement or attachment of these species on the ships while in route may be enhanced by the original biofouling community, especially where three dimensional structure is involved. Comparisons between the QUEENS VICTORY and the JASON suggested a relationship between the initial amount of biofouling and the number of species in the post-transit surveys. Allowing ships to depart the fleet without hull cleaning may increase the risk of species transfers and introductions. Thus a management strategy where in-water hull cleaning is conducted at the berth location and achieves a more thorough removal of the base layer of hard-shelled and associated colonial organisms should be a priority in the management and disposal of obsolete vessels. The results of this and a previous study also suggest considerable variability in biofouling among ships. Therefore, conclusions based on the study of one ship cannot be extended to other ships without considerations of vessel age, length of berthing, and seasonal and annual variability in biofouling.

[1] *Conopeum chesapeakensis* was found in the biofouling assemblage of Beaumont Reserve Fleet vessels, but those identifications remain tentative and it is unknown whether this species occurs elsewhere in Texas.

This Page Intentionally Left Blank

4.0 SUMMARY AND CONCLUSIONS

1. Pre-cleaning and post-cleaning surveys of biofouling were conducted on the Suisun Bay Reserve Fleet vessels QUEENS VICTORY and JASON. The surveys yielded a total of 147 taxa, 63 of which could be identified to species level, and 29 to genus level. Among the species found in the pre-cleaning surveys conducted in Alameda, 27 species (37% of all taxa) were nonnative in California waters, and included the invasive Asian clam, *Corbula amurensis*.

2. The biofouling community prior to hull cleaning was dominated by the barnacle *Balanus improvisus*, the bryozoan *Conopeum chesapeakensis*, and by abundant isopod crustaceans. Additionally, four species of amphipods, two species of flat-worms, and the hydroid *Garveia franciscana* were prevalent in the samples. Barnacles, bryozoans, and hydroids formed a thick mat over most of the QUEENS VICTORY hull, but not the JASON. The JASON exhibited areas of bare hull and paint among patches of barnacles and bryozoans. Analysis of photo-quadrat data did not indicate differential concentrations of organisms among transects or in sheltered areas of the hull such as the stern appendages.

3. Species composition and abundance differed among surveys and between ships. The QUEENS VICTORY had more species per sample and higher total number of species than the JASON. This difference was attributed to the lower biofouling cover observed on the JASON. The post-transit (= post-cleaning) survey of the QUEENS VICTORY yielded a higher number of species than the pre-transit (= pre-cleaning) survey. Many of the species found in the prost-transit surveys were juveniles recently settled on the hull, and the majority (73%) of these species were found only in the post-transit samples.

4. The effectiveness of in-water hull cleaning could not be fully evaluated, since percent cover data for the QUEENS VICTORY prior to cleaning were not available. The JASON already exhibited a large proportion of bare hull before cleaning. However, after cleaning, on average only 63% to 68% of the hull of both ships consisted of bare space, which suggests that hull cleaning may not have been as effective as desired. Bare hull, barnacles, and algae were prominent features of the post-cleaning surveys.

5. Comparisons between the QUEENS VICTORY and the JASON suggested a relationship between the initial amount of biofouling and the number of species in the post-transit surveys. Species settlement and attachments while in transit may be enhanced by the amount of biofouling and the three-dimensional structure provided by the initial community. Therefore, a management strategy for which obsolete ships are allowed to depart the fleet without hull cleaning may increase the risk of species transfers and introductions at destination ports.

This Page Intentionally Left Blank

5.0 REFERENCES

AMBS (Australian Museum Business Services). 2002. Port Survey for Introduced Marine Species – Sydney Harbour. Australian Museum Business Services, Sidney, Australia. On line: http://www.livingharbour.net/pdf/finalreport1.pdf (Accessed: June 2008).

Banta, C.W., F.M. Perez, and S. Santagata. 1995. A setigerous collar in *Membranipora chesapeakensis* n. sp. (Bryozoa): implications for the evolution of cheilostomes from ctenostomes. Invertebrate Biology 114:83-88.

Beckman, C. and R. Menzies. 1960. The relationship of reproductive temperature and the geographical range of the marine woodborer *Limnoria tripunctata*. Biological Bulletin 118:9-16.

Blake, J.A. 1969. Reproduction and larval development of *Polydora* from northern New England (Polychaeta: Spionidae). Ophelia 7:1-63.

Boyd, M.J., T.J. Mulligan, and F.J. Shaughnessy. 2002. Non-Indigenous Marine Species of Humboldt Bay, California. A Report to the California Department of Fish and Game. Humboldt State University, Arcata, California.

Bushek, D. and S. Boyd. 2006. Seasonal abundance and occurrence of the Asian isopod *Synidotea laevidorsalis* in Delaware Bay, USA. Biological Invasions 8:697-702.

CA Fish & Game. 2002. A Survey of Non-Indigenous Aquatic Species in the Coastal and Estuarine Waters of California. California Department of Fish & Game, Office of Spill Prevention and Response, Sacramento, California.

Carlton, J.T. 1979. Introduced Invertebrates in San Francisco Bay. Pp. 427-444 In: San Francisco Bay: The Urbanized Estuary; Investigations into the Natural History of San Francisco Bay and Delta with Reference to the Influence of Man. Pacific Division of the American Association for the Advancement of Science, San Francisco, California.

Chapman, J.W. 2007. Gammaridea. Pp. 545-618 In: Carlton, J.T. (ed.), The Light and Smith Manual. Intertidal Invertebrates from Central California to Oregon. Fourth Edition. University of California Press, Berkeley, California.

Chapman, J.W. and J.T. Carlton. 1994. Predicted discoveries of the introduced isopod, *Synidotea laevidorsalis* (Miers, 1881). Journal of Crustacean Biology 14:700-714.

Clarke, K.R. and R.N. Gorley. 2006. PRIMER v6: User Manual/Tutorial. PRIMER-E, Plymouth Marine Laboratory, Plymouth, United Kingdom.

Cohen, A.N. 2005. Guide to the Exotic Species of San Francisco Bay. San Francisco Estuary Institute, Oakland, California. On line: www.exoticsguide.org (Accessed: June 2008).

Cohen, A.N. and J.T. Carlton. 1995. Nonindigenous Aquatic Species in a United States Estuary: A Case Study of the Biological Invasions of the San Francisco Bay and Delta. Report submitted to the U. S. Fish and Wildlife Service, Washington D.C. and the National Sea Grant College Program, Connecticut Sea Grant (NOAA Grant Number NA36RG0467).

Cohen, A.N. and J.W. Chapman. 2005. Rapid Assessment Channel Survey for Exotic Species in San Francisco Bay - November 2005. Final Report for the California State Coastal Conservancy. San Francisco Estuary Institute, Oakland, California.

Cohen, A.N., L.H. Harris, B.L. Bingham, J.T. Carlton, J.W. Chapman, C.C. Lambert, G. Lambert, J.C. Ljubenkov, S.N. Murray, L.C. Rao, K. Reardon and E. Schwindt. 2005. Rapid assessment survey for exotic organisms in southern California bays. Biological Invasions 7:995–1002.

Cohen, A.N. and 11 authors. 2002. Project Report for the Southern California Exotics Expedition 2000: A Rapid Assessment Survey of Exotic Species in Sheltered Coastal Waters. California Department of Fish and Game, State Water Resource Control Board, and National Fish and Wildlife Foundation.

Conlan, K.E. 1990. Revision of the crustacean amphipod genus *Jassa* Leach (Corophioidea: Ischyroceridae). Canadian Journal of Zoology 68:2031-2075.

Corkett, C.J. and I.A. McLaren. 1978. The biology of *Pseudocalanus*. Advances in Marine Biology 15:1-231.

Davidson, I.C., L.D. McCann, P.W. Fofonoff, M.D. Sytsma, and G.M. Ruiz. 2008. The potential for hull-mediated species transfers by obsolete ships on their final voyages. Diversity and Distributions 14:518-529.

Davidson, I., G. Ruiz, M. Sytsma and P. Fofonoff. 2006. Hull Biofouling on the Vessels POINT LOMA and FLORENCE in the Reserve Fleet at Suisun Bay, CA: A Pilot Study with Respect to Potential Transfer of Non-native Species. Report submitted to the U. S. Maritime Administration, Washington D.C. Aquatic Bioinvasion Research & Policy Institute, Portland, Oregon.

Davidson, I., G. Ruiz, M. Sytsma, P. Fofonoff, B. Mohammad, L. McCann, C. Zabin, and S. Altman. 2007. A Post-Voyage Analysis of Hull Biofouling on the Vessels POINT LOMA and FLORENCE After Transit from California to Texas. Report submitted to the U. S. Maritime Administration, Washington D.C. Aquatic Bioinvasion Research & Policy Institute, Portland, Oregon.

Dudley, J.E. 1973. A note on the taxonomy of three mebraniporine ectoprocts from Chesapeake Bay. Chesapeake Science 14:282-285.

Grassle, J.F. and J.P. Grassle. 1974. Opportunistic life histories and genetic systems in marine benthic polychaetes. Journal of Marine Research 32:253-284.

Green, G. and P. Lambert. 1994. Protocols for Reference and Voucher Collections of Aquatic Invertebrates Stored at the Royal British Columbia Museum. Report to Royal British Columbia Museum, Victoria, British Columbia, and Environment Canada, North Vancouver, British Columbia.

Hyman, L.H. 1953. The Polyclad flatworms of the Pacific Coast of North America. Bulletin of the American Museum of Natural History 100:269-391.

Johnson, W.S. and D.M. Allen. 2005. Zooplankton of the Atlantic and Gulf Coasts. Johns Hopkins University Press, Baltimore, Maryland.

Kudenov, J.D. and L.H. Harris. 1995. Family Syllidae Grube, 1850. Pp. 1-97 In: Blake, J.A., B. Hilbig, and P.H. Scott (eds.). Taxonomic Atlas of the Benthic Fauna of the Santa Maria Basin and Western Santa Barbara Channel. The Annelida Part 2. Polychaeta: Phyllodocida (Syllidae and Scale-bearing families), Amphinomida, and Eunicida, Volume 5. Santa Barbara Museum of Natural History, Santa Barbara, California.

LeCroy, S. 2002. An Illustrated Identification Guide to the Nearshore Marine and Estuarine Gammaridean Amphipoda of Florida. Volume 2. Florida Department of Environmental Protection, Tallahassee, Florida.

LeCroy, S. 2004. An Illustrated Identification Guide to the Nearshore Marine and Estuarine Gammaridean Amphipoda of Florida. Volume 3. Florida Department of Environmental Protection, Tallahassee, Florida.

Maloney, E., R. Fairey, A. Lyman, K. Reynolds and M. Sigala. 2006. Introduced Aquatic Species in California Open Coastal Waters. Final Report submitted to California Department of Fish & Game, Office of Spill Prevention and Response, Sacramento, California.

McCain, J.C. 1968. The Caprellidae (Crustacea: Amphipoda) of the Western North Atlantic. United States National Museum Bulletin 278, Smithsonian Institution Press, Washington, D.C.

Redmond, M.S., K.J. Scott, R.C. Swartz, and J.K. Jones. 1994. Preliminary culture and life-cycle experiments with the benthic amphipod *Ampelisca abdita*. Environmental Toxicology and Chemistry 13:1355-1365.

Uebelacker, J.M. and P.G. Johnson. 1984. Taxonomic Guide to the Polychaetes of the Northern Gulf of Mexico. Final Report to the U.S. Department of the Interior, Minerals Management Service, 7 vols.

Versar, Inc. 2008a. Hull Biofouling of Suisun Bay Reserve Fleet Vessel Occidental Victory Before and After Transit from California to Texas. Report to U.S. Maritime Administration, Office of the Environment, Washington D.C. Versar, Inc., Columbia, Maryland.

Versar, Inc. 2008b. Hull Biofouling of James River Reserve Fleet Vessel Mississinewa Before and After In-water Cleaning. Report to U.S. Maritime Administration, Office of the Environment, Washington D.C. Versar, Inc., Columbia, Maryland.

Williams, A.B. 1984. Shrimps, Lobsters, and Crabs of the Atlantic Coast. Smithsonian Institution Press, Washington, D.C.

Winston, J.E. 1977. Distribution and ecology of estuarine ectoprocts: A critical review. Chesapeake Science 18:34-57.

APPENDIX A

SPECIES ABUNDANCE

400 & 600 series samples = pre-cleaning; 500 & 700 series samples = post-cleaning
0 = present; blank = species not found in sample

QUEENS VICTORY	Samples																																	
Species	401	402	403	404	405	406	407	408	410	412	413	414	415	416	417	418	419	420	421	422	423	424	425	426	427	428	429	430	431	432	433	434	435	436
Aeolidacean nudibranch																																		
Algae sp. A																																		
Algae sp. B																																		
Algae sp. C																																		
Americorophium spinicorne	10	75	190	232	19	12				11	2	2				1	1	1		3	1				29			11	1	7			1	
Ampelisca abdita																		2			1													
Amphinomidae sp.																																		
Amphipoda spp. indeter.																																		
Ampithoe valida					1																													
Anthozoa sp. A																												1						
Anthozoa sp. B																																		
Anthozoa spp.																																		
Aoridae																																		
Balanus amphitrite																																		
Balanus improvisus	>100	>100	>100	>100	>100	>100	100	100	>100	>100	>100	>100	>100	100	>300	58	>400	>100	>300	>300	100	100	>500	>100	100	>100	<100	>200	100	>300		>500	>300	>200
Barnacle cypris																																		
Bivalvia sp. B																																		
Bivalvia sp. C																																		
Bivalvia sp. D																																		
Bivalvia sp. E																																		
Bivalvia sp. F																																		
Bivalvia spp.																				1														
Boccardiella ligerica		3	6	5		1	1			2		8	3		9	1			5	9	2	2	2	1		1		1	9			2	1	1
Bowerbankia gracilis								0																										
Brachyura																																		
Bugula sp.A								0																										
Bugula stolonifera								0																					0					
Callinectes sp.																																		
Campanularia sp.																																		
Campanulariidae																																		
Capitella capitata																																		
Capitella sp.																																		
Caprella equilibra																																		
Caprella scaura																																		
Caprella sp.																																		
Chaetognatha																																		
Chironomidae						1																												
Ciona intestinalis																												1						
Cirolana cf. parva																																		
Cirripedia																			4															
Clytia cf. hemisphaerica																																		
Clytia sp. A																																		
Clytia sp. B																																		
Conopeum chesapeakensis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Corbula amurensis		1	16			1										2				1	2						1		1		1			
Corbula amurensis?																																		
Corophiidae sp.																																		
Dipolydora socialis																																		
Elasmopus cf. rapax																																		
Eochelidium sp.																				1														
Ericthonius brasiliensis																																		
Eudendrium?																						0												
Ficopomatus enigmaticus									1																									
fish egg																																		
Gammaropsis spp.																																		
Gammarus daiberi			1																															
Garveia franciscana		0		0			0	0	0	0		0	0	0	0		0	0	0	0	0	0	0	0		0		0	0	0	0	0	0	
Gastropoda																																		
Gnorimosphaeroma oregonensis/insu	31	>100	>100	>100	>100	>500	>100	>100			>100	>100	>100	<100	>800	>300	>400		>800	>800	<100	<100	>300	>100	>500	>100	<100	>700	>200	>600	>400	>400	>400	>600
Grandidierella japonica	1		5		2											1		1				1		1										
Halecium sp.																																		
Incisocalliope derzhavini	18	310	205	115	96	64	18	31	17	34	43	65	116	2	13	14	129	115	95	57	14	13	93	13	45	10		287	15	62	6	58	177	9
Jassa marmorata										1																								
Jassa sp.																															1			
Laticorophium baconi																																		
Lepas anatifera																																		

QUEENS VICTORY	**Samples**																																	
Species	401	402	403	404	405	406	407	408	410	412	413	414	415	416	417	418	419	420	421	422	423	424	425	426	427	428	429	430	431	432	433	434	435	436
Limnoria tripunctata																1																		
Melita nitida	6	59	133	75	38	2				4		1		2	1	1	1		1						53			1	3				6	
Monocorophium acherusicum	10	36	20	41	8	3	4	3	1	1	2	15	2		3	1	5	5	5	6	2	2	8	3		3		12	4	5	2	10	10	
Mytillidae sp.																																		
Nemertina			2																															
Nereididae									1															1							1			
Nippoleucon hinumensis												1																						
Nudibranchia																																		
Obelia geniculata																																		
Obelia sp.																																		
Oceanidae																																		
Odontosyllis sp.																																		
Okenia plana		4	3	3	7	1	1			3						2		1							1									
Oligochaeta												5	5																					
Pachygrapsus transversus																																		
Paracaprella pusilla																																		
Podocerus brasiliensis																																		
Polydora cornuta		3	6	1	5	3		3					2						2	1												1		
Polynoidae		2																																
Porcellanidae																																		
Proceraea cornuta																																		
Ptilohyale littoralis	1																																	
Rhithropanopeus harrisii																							1											
Rhizocaulus verticillatus																																		
Serpula sp.																																		
Serpulidae													1																					
Simuliidae						1																												
Sinelobus stanfordi					52																													
Sipuncula																																		
Spionidae																																		
Sponge-like organism								0	1																									
Stenothoe valida	4		1														3						1									2	1	1
Stylochus franciscanus	6	15	13	6	9	16	4	4	13	20	8	9	9		14	3		8	13	13	6	5	7	5	4	13	7	9	6		6	15	6	8
Stylochus franciscanus?																																		
Syllidae																																		
Syllis sp.																																		
Synidotea laticauda	>100	>500	>500	>500	>100	>500	100	100	>100	>100	>100	>100	>100	100	>300	>300	>400	>100	>300	>300	100	100	>500	>100	>100	>100	<100	>500	200	>300	>300	>300	>600	>200
Terebellidae																																		
Tunicates?																																		
Turbellaria sp. A		3		4		1			3	5		1			2			1	7	3	3		6	1		2	1	1			2		2	1
Turbellaria sp. B																																		
Turbellaria sp. C																																		
Turbellaria spp.																									1									
Unidentifiable fragment																																		
Uromunna ubiquita	>100	>1000	>1000	>1000	>500	>1000	>100	>100	>500	>500	>100	>100	>200	>100	>300	>300	>700	>500	>300	>300	>100	>100	>500	>200	>500	>200	<200	>1000	>500	>300	>600	>600	>200	>200
Zeuxo coralensis																																		
Grand Total	387	2211	2301	2182	1037	2206	428	441	737	781	455	507	638	404	1742	985	2039	834	1832	1795	431	423	1918	525	1333	530	509	2724	1039	1574	1319	1888	1704	1220

QUEENS VICTORY																																		
Species	437	438	439	440	441	442	443	444	501	502	503	504	505	506	507	508	509	510	511	512	513	514	515	516	517	518	519	520	521	522	523	524	525	526
Aeolidacean nudibranch																																		1
Algae sp. A	0		0	0									0					0				0	0					0				0	0	
Algae sp. B																																		
Algae sp. C																						0												
Americorophium spinicorne		1	1			2	1																											
Ampelisca abdita																																		
Amphinomidae sp.																							1											
Amphipoda spp. indeter.																											1							
Ampithoe valida			1	1		1																												
Anthozoa sp. A																																		
Anthozoa sp. B																		1																
Anthozoa spp.																																	1	1
Aoridae																																		
Balanus amphitrite									2	6	1	1	16	4			4	7	2	2		28	4			4	2		1			1	48	
Balanus improvisus	>100	>200	>200	>200	>200	>100	>100	>300	71	86	99	59	33	48	32	44	108	78	105	66	32	55	70		26	57	52		23	37	21	30	146	9
Barnacle cypris										0		0			0	0						0												0
Bivalvia sp. B										1				1					1	1	1			1		1			1				1	
Bivalvia sp. C																										1								
Bivalvia sp. D																																		
Bivalvia sp. E																																		
Bivalvia sp. F																																		
Bivalvia spp.					1															1														
Boccardiella ligerica			2	3	1	10	4	1																										
Bowerbankia gracilis																																		
Brachyura																								1										
Bugula sp.A																																		
Bugula stolonifera																																		
Callinectes sp.												1																						
Campanularia sp.																						0				0								
Campanulariidae																																		
Capitella capitata																															1			
Capitella sp.																						1									1			
Caprella equilibra												1																						
Caprella scaura																																		
Caprella sp.																																		
Chaetognatha																		1						1										
Chironomidae																																		
Ciona intestinalis																																		
Cirolana cf. parva																																		
Cirripedia									12	1	14	7	10	26	15		40	14	55	11	9	40	8	8	24	37	5		22	10	52		122	66
Clytia cf. hemisphaerica															0					0		0	0	0	0				0				0	0
Clytia sp. A																																		
Clytia sp. B																				0						0								
Conopeum chesapeakensis	0	0	0	0	0	0	0	0	0		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		0	0	0		0	0
Corbula amurensis				1		4	4																											
Corbula amurensis?												1										1			3	1			1					
Corophiidae sp.										1																								
Dipolydora socialis																										1								
Elasmopus cf. rapax																											1							
Eochelidium sp.																																		
Ericthonius brasiliensis										1	1																							
Eudendrium?																0													0					
Ficopomatus enigmaticus																				1														
fish egg									1												2		1		1				2		2			
Gammaropsis spp.										1									2															
Gammarus daiberi																																		
Garveia franciscana		0	0	0	0	0		0			0	0	0	0	0	0			0	0	0				0			0	0	0	0		0	0
Gastropoda																																	1	
Gnorimosphaeroma oregonensis/insu	>100	>700	>800	>800	>800	>200	<100	>300											3	1				1		2		1				1	2	
Grandidierella japonica																																		
Halecium sp.									0		0		0		0	0	0	0		0	0	0			0	0	0		0	0	0	0	0	0
Incisocalliope derzhavini	3	5	2	6	9	4	6	76																										
Jassa marmorata											1																							
Jassa sp.																																		
Laticorophium baconi									1	2	2			1			3	4	2	2		1	3											1
Lepas anatifera																			3		2										1			

QUEENS VICTORY																																		
Species	437	438	439	440	441	442	443	444	501	502	503	504	505	506	507	508	509	510	511	512	513	514	515	516	517	518	519	520	521	522	523	524	525	526
Limnoria tripunctata																																		
Melita nitida	2	4	3	4	5	7	2	1																										
Monocorophium acherusicum			2		4	8	4	5	1	2		1					1									2		1						
Mytillidae sp.																																		
Nemertina																																		
Nereididae																																		
Nippoleucon hinumensis																																		
Nudibranchia																															1			
Obelia geniculata											0	0	0					0	0	0		0	0	0	0		0			0		0	0	
Obelia sp.													0																					
Oceanidae																																		
Odontosyllis sp.																			3	1	2					1			3				4	
Okenia plana							1											1																
Oligochaeta	9		2	8	9								1										1											
Pachygrapsus transversus																					1													
Paracaprella pusilla																											1							
Podocerus brasiliensis									1																									
Polydora cornuta	1	1						4																										
Polynoidae																					1													
Porcellanidae																																		
Proceraea cornuta																		4																
Ptilohyale littoralis																																		
Rhithropanopeus harrisii									1									1		1			1				3	1	1		1		2	1
Rhizocaulus verticillatus																																		
Serpula sp.																																	1	
Serpulidae																						2			1	1								
Simuliidae																																		
Sinelobus stanfordi			7	12		2	1						1																					
Sipuncula																																		
Spionidae																			1															1
Sponge-like organism	0																																	
Stenothoe valida																	4	9			1	3	2				1					2	2	
Stylochus franciscanus	6	5	7	7	4	8	9	13																										
Stylochus franciscanus?											1			1			2			2		3	3				1				3		4	3
Syllidae																																		2
Syllis sp.								1																										
Synidotea laticauda	>100	>500	>300	>300	>300	>200	<100	>300																										
Terebellidae																																	1	
Tunicates?																																		
Turbellaria sp. A				4	1	3																												
Turbellaria sp. B																						1												
Turbellaria sp. C																		1																
Turbellaria spp.																			1		1													
Unidentifiable fragment																					0													
Uromunna ubiquita	>100	>500	>300	>300	>300	>300	>100	>500																										
Zeuxo coralensis												1																						
Grand Total	421	1916	1627	1646	1634	849	432	1501	90	101	119	72	61	81	47	44	162	121	178	89	52	135	94	12	55	108	67	3	54	47	83	34	335	85

QUEENS VICTORY

Species	527	528	529	530	531	532	533	534	535	536	537	538	539	540	541	542	543	544	545	546	547	548	549	550	**Grand Total**
Aeolidacean nudibranch															1				1						3
Algae sp. A			0	0			0	0							0	0					0				0
Algae sp. B			0								0														0
Algae sp. C																									0
Americorophium spinicorne																									614
Ampelisca abdita																									3
Amphinomidae sp.																									1
Amphipoda spp. indeter.																									1
Ampithoe valida																									4
Anthozoa sp. A																									1
Anthozoa sp. B																									1
Anthozoa spp.																									2
Aoridae																					1	1			2
Balanus amphitrite		3	21	7	4			8	12		1		2	9	11	5			2	4		3	4		229
Balanus improvisus		20	199	66	6		43	55	66	2	25	46	114	32	34	5		3	20	77	27	95	51		9331
Barnacle cypris																0	0		0						0
Bivalvia sp. B									1		1									4		4	4		23
Bivalvia sp. C									1											1		1	1		5
Bivalvia sp. D							2								1										3
Bivalvia sp. E													2												2
Bivalvia sp. F								1					2												3
Bivalvia spp.																									3
Boccardiella ligerica																									96
Bowerbankia gracilis																									0
Brachyura							1																		2
Bugula sp.A																									0
Bugula stolonifera																									0
Callinectes sp.															1										2
Campanularia sp.		0			0				0		0	0	0		0						0		0		0
Campanulariidae										0															0
Capitella capitata																									1
Capitella sp.									1													1			4
Caprella equilibra					16							1													18
Caprella scaura												1													1
Caprella sp.			2																						2
Chaetognatha				1															1						4
Chironomidae																									1
Ciona intestinalis																									1
Cirolana cf. parva																				1					1
Cirripedia	2	57	80	48	9			86	67		42	94	56	2	55	130		61	135	202	87	68	34		1927
Clytia cf. hemisphaerica		0			0		0	0	0	0			0	0	0	0	0		0		0	0	0		0
Clytia sp. A				0						0															0
Clytia sp. B			0						0																0
Conopeum chesapeakensis	0	0	0	0	0	0	0	0	0	0	0	0	0		0	0		0	0	0	0	0	0	0	0
Corbula amurensis																									35
Corbula amurensis?		2	1		1		1		5		1	6	1									1			26
Corophiidae sp.																									1
Dipolydora socialis																									1
Elasmopus cf. rapax			1	1									1								1		1		6
Eochelidium sp.																									1
Ericthonius brasiliensis					1			2					2		2				2	1			2		14
Eudendrium?																									0
Ficopomatus enigmaticus																									2
fish egg		2				1				1															13
Gammaropsis spp.																									3
Gammarus daiberi																									1
Garveia franciscana	0	0	0			0	0	0			0	0	0	0		0		0	0	0		0	0	0	0
Gastropoda			1						1																3
Gnorimosphaeroma oregonensis/insu			1	12				1	3				5	1		1						1			13067
Grandidierella japonica																									12
Halecium sp.	0	0		0	0	0	0	0	0		0	0	0		0	0			0	0	0	0	0	0	0
Incisocalliope derzhavini																									2470
Jassa marmorata																									2
Jassa sp.																									1
Laticorophium baconi			2		1		2	2				1	2		6	2		1		5	1	1	1		49
Lepas anatifera			1																						7

QUEENS VICTORY																									
Species	527	528	529	530	531	532	533	534	535	536	537	538	539	540	541	542	543	544	545	546	547	548	549	550	**Grand Total**
Limnoria tripunctata																									1
Melita nitida																					1				416
Monocorophium acherusicum		1	1	4	7		1					1	4	1		1			1	1		2			288
Mytillidae sp.			1										1												1
Nemertina																									2
Nereididae																									3
Nippoleucon hinumensis																									1
Nudibranchia										1		1													3
Obelia geniculata		0		0		0		0	0	0	0	0	0		0	0	0		0	0		0	0		0
Obelia sp.												0													0
Oceanidae			0	0																					0
Odontosyllis sp.				1	2		2	3	5		1	2		1	1					2		3	2		39
Okenia plana																									28
Oligochaeta							1																		41
Pachygrapsus transversus			1																						2
Paracaprella pusilla									1																2
Podocerus brasiliensis			1				2	2	6				1												13
Polydora cornuta																									33
Polynoidae																									3
Porcellanidae													4									3			7
Proceraea cornuta													1												5
Ptilohyale littoralis																									1
Rhithropanopeus harrisii									2			1	5							2	1	2	1		28
Rhizocaulus verticillatus												0	0												0
Serpula sp.							1																		2
Serpulidae							1						1						1						8
Simuliidae																									1
Sinelobus stanfordi																						12	1		88
Sipuncula							3		1				2												6
Spionidae				1							1											1			5
Sponge-like organism																									1
Stenothoe valida		2	5	5	2		5	13	8			1	3			2				1	3	3	2		92
Stylochus franciscanus																									332
Stylochus franciscanus?		5						2	1		2	3		1	2	6			3	3	2	2			55
Syllidae																									2
Syllis sp.																									1
Synidotea laticauda																									10300
Terebellidae																									1
Tunicates?														2	2										4
Turbellaria sp. A																									66
Turbellaria sp. B																									1
Turbellaria sp. C																									1
Turbellaria spp.																									3
Unidentifiable fragment																									0
Uromunna ubiquita																									16300
Zeuxo coralensis																									1
Grand Total	2	92	317	146	49	1	65	175	181	4	74	158	209	49	116	152	0	65	166	304	124	204	104	0	56191

JASON	Samples																																			
Species	601	602	603	604	605	606	607	608	609	610	611	612	614	615	617	618	619	621	622	624	626	627	628	629	630	631	632	633	634	635	636	637	638	639	640	641
Aeolidacean nudibranch																																				
Algae																																				
Algae sp. D																																				
Algae sp. E	0																																			
Americorophium spinicorne	3	3		1	2					2	1	1		2					3					2	2				4	1			3	4	10	2
Ampelisca abdita																											1									
Autolytinae sp.																																				
Balanus amphitrite																																				
Balanus improvisus	43	38	100	142	18	20	15		31	75	139	79	96	68	29	31	1	56	84	27	33	8	48	55	70	86	23	147	38	72	2	20	18	111	241	101
Bivalvia spp.																																				
Boccardiella ligerica	7	3	2	4				1	1		2			1				1		2			3	2		8	1	1				3				
Brania californiensis																																				
Callinectes sp.																																				
Caprella equilibra																																				
Caprella sp.																																				
Chaetognatha																																				
Chironomidae					1																															
Cirolana harfordi																																		1		
Cirripedia																																				
Clytia cf. hemisphaerica																																				
Clytia sp. A																																				
Conopeum chesapeakensis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Corbula amurensis			1																																	
Deutella incerta																																				
Dipolydora socialis																																				
Elasmopus cf. rapax																																				
Ericthonius brasiliensis																																				
Eteone spp.																																				
Eudendrium?																																				
fish larvae																																				
Garveia franciscana	0	0				0	0	0		0	0	0	0	0	0	0	0	0			0	0	0	0	0	0	0	0		0	0	0	0	0		0
Gnorimosphaeroma oregonensis/insulare	101		6	2	17		3	1	2	25	6	2		8				1	3	6					2	6		1	3	13		2	41	31	22	8
Grandidierella japonica				1																																
Halecium sp.																																				
Incisocalliope derzhavini	1	1					3	1		1	1	6						1	1			4	1			1	155					170	83	1		10
Jassa marmorata	1									1									2	1										2				2		
Jassa slatteryi	1																																			
Jassa sp.																																				
Laticorophium baconi																																				
Lembos sp.																																				
Limnoria tripunctata																																1				
Melita nitida	5		3				1			4	1			6						4	1							1				6	10	7	3	
Monocorophium acherusicum		5	9	6			4				5	4	1	3	4			6	6	6	2	7	3	6	4		13	4		2	1	45	19	1		2
Neanthes succinea																																				
Nemertina																																				
Nereididae										1																										
Obelia geniculata																																				
Obelia spp.																																				
Okenia plana																																				
Oligochaeta																																				
Paranthura japonica																																	1			
Phyllodocidae																																				
Polydora cornuta			1	1		1	1				1			1				1							1		3	2		1		5	1	1	1	2
Polydora spp.																																				
Polydora websteri																																				
Polynoidae																																1				
Ptilohyale littoralis																														1						
Sabellidae																												1								
Sinelobus stanfordi	16																																			
Siriella thompsonii																																				
Spionidae																																				
Sponge-like organism	0								0																											
Stenothoe valida																																				
Stylochus franciscanus	3	5	5	2					1	5		6		2	2		3	2	1	2				2	2	2	4	5	3	1			7	7	8	
Stylochus franciscanus?																																				

JASON	**Samples**																																		
Species	601	602	603	604	605	606	607	608	609	610	611	612	614	615	617	618	619	621	622	624	626	627	628	629	630	631	632	633	634	635	636	637	638	639	640	641
Syllidae																																				
Synidotea laticauda	2		1	1	2	1		1		12	2	18	12	2	1	3	1	19	6	10	2	13	1		12		58		3	12	1	153	239	16	53	50
Turbellaria sp. A	4		1																	1			1			2		2	1		1	5		3		
Typoyllis alternata												1																								
Uromunna ubiquita	5	2	32	1	1		1			6		21			3		1	7		4			17			63	>1500	21	4	6		391	61			
Zeuxo coralensis																																				
Grand Total	192	57	161	161	41	22	28	4	35	132	158	138	109	93	39	34	6	94	106	63	38	32	75	67	93	173	1758	185	56	111	5	807	483	185	338	175

JASON

Species	642	643	644	645	646	647	648	649	650	651	652	653	654	655	701	702	703	704	705	706	707	708	709	710	711	712	713	714	715	716	717	718	719	720	721	722
Aeolidacean nudibranch																																				
Algae		0													0	0		0	0	0			0	0	0		0	0	0	0			0	0	0	
Algae sp. D															0	0		0			0		0	0	0		0	0	0	0			0	0	0	
Algae sp. E																																				
Americorophium spinicorne		291	3		6	39	155	20					4	9																						
Ampelisca abdita																																				
Autolytinae sp.							1																													
Balanus amphitrite																																				
Balanus improvisus	59	54	388	137	32	29	58	31	37	81	35	162	194	38	1	2	2	1							2											
Bivalvia spp.																																				
Boccardiella ligerica	1		7	1		2					3	3	16	6																						
Brania californiensis							1																													
Callinectes sp.															1	2								3	1						2	4	1	1	3	3
Caprella equilibra																																				
Caprella sp.																																				
Chaetognatha																																				1
Chironomidae																																				
Cirolana harfordi																																				
Cirripedia																	5							2												
Clytia cf. hemisphaerica																										0										
Clytia sp. A																																				
Conopeum chesapeakensis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		0	0			0	0	0	0	0	0	0		0	0	0	0	0
Corbula amurensis						4	3				1																									
Deutella incerta																																				
Dipolydora socialis																																				
Elasmopus cf. rapax																	1								3		2							1		
Ericthonius brasiliensis																																				
Eteone spp.																																				
Eudendrium?																																				
fish larvae																													1			15				
Garveia franciscana	0	0	0	0	0	0	0	0	0	0	0		0	0		0	0				0				0	0	0		0	0		0		0	0	0
Gnorimosphaeroma oregonensis/insulare	1	337	15	3	22	53	49	55	1	1	7	5	8	6																						
Grandidierella japonica																																				
Halecium sp.																					0															
Incisocalliope derzhavini	88	149	1	1	154	26	87	251	12	2		3	6	272																						
Jassa marmorata		2					1																													
Jassa slatteryi																																				
Jassa sp.																									1											
Laticorophium baconi																2	2								2		1					3			2	1
Lembos sp.																																				
Limnoria tripunctata																																				
Melita nitida	2	330	1		7	55	75	2		2	6	1	4	8																						
Monocorophium acherusicum	47	26	15	14	20	36	4	15	19	19	9	12	40	75											1							1				
Neanthes succinea		1				1																														
Nemertina																																				
Nereididae																																				
Obelia geniculata																					0															
Obelia spp.																																				
Okenia plana		2					1	4						1																						
Oligochaeta				1																																
Paranthura japonica						1																														
Phyllodocidae																																				1
Polydora cornuta	4	10					2	7					1	10																						
Polydora spp.																																				
Polydora websteri																																				
Polynoidae		1						1																												
Ptilohyale littoralis																																				
Sabellidae																																				
Sinelobus stanfordi																																				
Siriella thompsonii																																				
Spionidae																									1							1			1	
Sponge-like organism								0						0																		2				
Stenothoe valida						1	1																													
Stylochus franciscanus		3	18	4	2			3				6	8	1																						
Stylochus franciscanus?																1	10							1	11							3			18	3

JASON																																				
Species	642	643	644	645	646	647	648	649	650	651	652	653	654	655	701	702	703	704	705	706	707	708	709	710	711	712	713	714	715	716	717	718	719	720	721	722
Syllidae																																				
Synidotea laticauda	111	1116	11	12	581	177	265	341	171	100	10	14	17	355																						
Turbellaria sp. A		2	1	3	2	2		4			2	1	3																							
Typoyllis alternata																																				
Uromunna ubiquita	42	>600	47	46	451	24	202	>2100				101	248	263																						
Zeuxo coralensis																								1												
Grand Total	355	2926	507	222	1279	450	905	2834	240	205	73	308	550	1044	2	7	21	1	0	0	0	NO OR	0	7	22	0	3	0	1	0	2	29	1	2	24	9

JASON																													
Species	723	724	725	726	727	728	729	730	731	732	733	734	735	736	737	738	739	740	741	742	743	744	745	746	747	748	749	750	**Grand Total**
Aeolidacean nudibranch														1															1
Algae		0	0	0			0	0	0			0	0	0		0					0	0				0	0	0	0
Algae sp. D		0	0				0	0				0		0							0	0				0	0		0
Algae sp. E																													0
Americorophium spinicorne																													573
Ampelisca abdita																													1
Autolytinae sp.			3																		1								5
Balanus amphitrite			1		1	1		2		1				2	9			1									8	1	27
Balanus improvisus		4			4		1	5				5	4	1	6		1	2	3	1	6		7		1		3		3562
Bivalvia spp.						1															1								2
Boccardiella ligerica																													81
Brania californiensis																													1
Callinectes sp.	1	3			8	6	4	2		1	10	8	6	3	7	3	8	2		3	10	8	2		3		1	21	141
Caprella equilibra															1			1										1	3
Caprella sp.															1			1											2
Chaetognatha		1			2																								4
Chironomidae																													1
Cirolana harfordi																													1
Cirripedia	2	2	2		4	21	9	3		13					5		42	17	1			1	6			1	9	270	415
Clytia cf. hemisphaerica						0		0	0		0					0			0										0
Clytia sp. A																	0										0	0	0
Conopeum chesapeakensis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		0	0	0	0	0		0	0		0	0	0
Corbula amurensis																													9
Deutella incerta																												2	2
Dipolydora socialis						1																							1
Elasmopus cf. rapax		1	6			1		1				4	3	4	33	2		2	2	2	3		15	3			42	62	193
Ericthonius brasiliensis					3										7		1	1	1				3				10	3	29
Eteone spp.																1													1
Eudendrium?						0																							0
fish larvae														2															18
Garveia franciscana	0	0		0	0	0	0	0	0	0	0		0	0	0	0	0	0	0	0	0	0		0	0		0	0	0
Gnorimosphaeroma oregonensis/insulare			2							1							1				1		1			1	2		884
Grandidierella japonica																													1
Halecium sp.						0					0																		0
Incisocalliope derzhavini																													1493
Jassa marmorata																													12
Jassa slatteryi																													1
Jassa sp.												1		1			1												4
Laticorophium baconi		4	4		3	2	1	2			2	14	8	22	31	15	7	9	3		7		1		11	2	50	20	231
Lembos sp.																					1								1
Limnoria tripunctata																													1
Melita nitida																													545
Monocorophium acherusicum					1			2							1								1			1	3	2	532
Neanthes succinea																													2
Nemertina																	1												1
Nereididae			1									1																	3
Obelia geniculata								0								0						0					0		0
Obelia spp.		0																											0
Okenia plana																													8
Oligochaeta																													1
Paranthura japonica																													2
Phyllodocidae																		1											2
Polydora cornuta																													58
Polydora spp.						1																							1
Polydora websteri						3							3					3											9
Polynoidae																													3
Ptilohyale littoralis																													1
Sabellidae																													1
Sinelobus stanfordi																													16
Siriella thompsonii													1																1
Spionidae							1	2				4			1	3	1						2			1		2	20
Sponge-like organism																					1								3
Stenothoe valida																													2
Stylochus franciscanus																													125
Stylochus franciscanus?		3	7		13	32	25	61		32	7	19	12	16	48		8	71	3	1	13		43		3	1	21	12	498

JASON																													
Species	723	724	725	726	727	728	729	730	731	732	733	734	735	736	737	738	739	740	741	742	743	744	745	746	747	748	749	750	**Grand Total**
Syllidae			3																									1	4
Synidotea laticauda																													3988
Turbellaria sp. A																													41
Typoyllis alternata																													1
Uromunna ubiquita																													6271
Zeuxo coralensis			1				1	2				1	5		1	2	1			1						1	3		20
Grand Total	3	18	30	0	39	69	42	82	0	48	19	57	42	52	151	28	72	111	13	8	44	9	81	3	18	8	152	397	19879

APPENDIX B

SPECIES BIOGEOGRAPHY AND LIFE HISTORY INFORMATION

						Geographical Distribution		Salinity (psu)	
Phylum	Class	Species/Taxon Name	Common Name	California Invasion Status	Status in Texas	Native range	Invaded range	Range	Optimum
Crustacea	Copepoda (Calanoida)	Acartia tonsa	calanoid copepod	native	native	Atlantic Ocean, Pacific Ocean, Indian Ocean	Caspian Sea; Baltic Sea; Black Sea, European brackish waters	freshwater to hypersaline	5-30
Mollusca	Gastropoda	Aeolidacean nudibranch (juv.)	sea slug	native species present	native species present				
Chlorophyta		Algae sp. A	algae	?	?				
Chlorophyta		Algae sp. B	algae	?	?				
Chlorophyta		Algae sp. C	algae	?	?				
Chlorophyta		Algae sp. D	algae	?	?				
Chlorophyta		Algae sp. E	algae	?	?				
Crustacea	Amphipoda	Americorophium spinicorne	amphipod	native	no record/not present	Northeast Pacific	Snake River (Idaho), Pearl Harbor (Hawaii) on hull of USS Missouri	tidal fresh to brackish	0-7 reprod. range
Crustacea	Amphipoda	Ampelisca abdita	amphipod	introduced	native	Northwest Atlantic, Gulf of Mexico	California (very common in San Francisco Bay)	10-35	>20
Crustacea	Copepoda (Harpacticoida)	Amphiascoides sp.	harpacticoid copepod	native species present	native species present	Cosmopolitan		brackish to euhaline	
Annelida	Polychaeta	Amphinomidae spp.	fire worm	native species present	native species present				
Crustacea	Amphipoda	Amphipoda spp. indeterminant	amphipod	native species present	native species present				
Crustacea	Amphipoda	Ampithoe valida	amphipod	introduced	native	Northwest Atlantic, Gulf of Mexico	Northeast Pacific		polyhaline to euhaline
Cnidaria	Anthozoa	Anthozoa sp. A	sea anemone	?	?				
Cnidaria	Anthozoa	Anthozoa sp. B	sea anemone	?	?				
Cnidaria	Anthozoa	Anthozoa spp. Indeterminant	sea anemone	native species present	native species present				
Crustacea	Amphipoda	Aoridae (possibly Grandidierella japonica)	amphipod	native species present	native species present				
Annelida	Polychaeta	Autolytinae spp. Indeterminant	polychaete or bristle worm	native species present	native species present				
Crustacea	Cirripedia	Balanus amphitrite	acorn barnacle	introduced	introduced	Indo-West Pacific, but limits of native range are uncertain	North Atlantic, Southwest Atlantic, Western Pacific Ocean, Northeast Pacific (California to Panama)	52	10
Crustacea	Cirripedia	Balanus improvisus	Bay barnacle	introduced	native	Western Atlantic Ocean	Northeast Atlantic, Caspian Sea, North Pacific Ocean	0-?	5-25
Crustacea	Cirripedia	barnacle cypris	barnacle larval stage	native species present	native species present				
Mollusca	Bivalvia	Bivalvia sp. A (Corbula amurensis?)	Asian clam	introduced	no record/not present	Bivalvia sp. A may be juveniles of Corbula amurensis, with native range in the Northwest Pacific	Corbula amurensis has been introduced to San Francisco Bay		
Mollusca	Bivalvia	Bivalvia sp. B	clam	?	?				
Mollusca	Bivalvia	Bivalvia sp. C	clam	?	?				
Mollusca	Bivalvia	Bivalvia sp. D	clam	?	?				
Mollusca	Bivalvia	Bivalvia sp. E	clam	?	?				
Mollusca	Bivalvia	Bivalvia sp. F	clam	?	?				
Mollusca	Bivalvia	Bivalvia spp. Indeterminant	clam	native species present	native species present				
Annelida	Polychaeta	Boccardiella ligerica	polychaete or bristle worm	introduced	cryptogenic	Northeast Atlantic	Baltic Sea, Northeast Pacific, South Atlantic Ocean, and possibly (cryptogenic range), Northwest Atlantic and Gulf of Mexico	0-30	2-20
Ectoprocta	Gymnolaemata	Bowerbankia gracilis	creeping bryozoan	introduced	native	Western Atlantic Ocean	Northeast Atlantic, Northeast Pacific, Hawaii, Indian Ocean	3-30	
Crustacea	Decapoda	Brachyura spp. Indeterminant	crabs	native species present	native species present				
Annelida	Polychaeta	Brania californiensis	polychaete or bristle worm	native	no record/not present	Southern California			
Ectoprocta	Gymnolaemata	Bugula sp. A	bryozoan or moss animal	?	?		California harbors species of Bugula are probably introduced species, although native species are present in the outer coast		
Ectoprocta	Gymnolaemata	Bugula stolonifera	bryozoan or moss animal	introduced	possibly introduced	Northwest Atlantic	Europe, Mediterranean, Panama, Saudi Arabia, possibly Southern California harbors		
Crustacea	Copepoda (Calanoida)	Calanoida spp. Indeterminant	calanoid copepod	native species present	native species present				
Crustacea	Decapoda	Callinectes sp.	Atlantic swimming crab	native species present	native species present				
Cnidaria	Hydrozoa	Campanularia sp.	hydroid	cryptogenic	native species present	Worlwide range in temperate waters	Range possibly extended by shipping. Campanularia species in San francisco Bay are possibly introduced.		
Cnidaria	Hydrozoa	Campanulariidae spp.	hydroid	cryptogenic	native species present	Worlwide range in temperate waters	Range possibly extended by shipping		
Annelida	Polychaeta	Capitella capitata	polychaete or bristle worm	cryptogenic	native	Cosmopolitan		0.3-36	
Annelida	Polychaeta	Capitella sp. (juv.)	polychaete or bristle worm	cryptogenic	native species present				
Crustacea	Amphipoda	Caprella equilibra	skeleton shrimp	cryptogenic	native	Cosmopolitan	Range possibly extended by shipping		
Crustacea	Amphipoda	Caprella scaura	skeleton shrimp	introduced	native	Cosmopolitan	Range possibly extended by shipping		
Crustacea	Amphipoda	Caprella sp. Indeterminant	skeleton shrimp	native species present	native species present				
Chaetognatha		Chaetognatha spp.	arrow worm	native species present	native species present				
Hexapoda	Insecta	Chironomidae spp.	non-biting midge larvae	native species present	native species present				
Chordata	Ascidiacea	Ciona intestinalis	sea vase	introduced	cryptogenic	Worlwide range, from the tropics to the subarctic; Native range possibly Northeast Atlantic	South Atlantic, Northeast Pacific, Southwest Pacific (Australia, New Zealand), and possibly (cryptogenic range) Northwest Atlantic		
Crustacea	Isopoda	Cirolana cf. parva	isopod	no record/not present	native	Eastern Tropical Pacific, Tropical Atlantic, Gulf of Mexico, Caribbean Sea		euhaline	
Crustacea	Isopoda	Cirolana harfordi	isopod	cryptogenic	no record/not present	Northeast Pacific; Northwest Pacific? (Cryptogenic)	Australia		
Crustacea	Cirripedia	Cirripedia spp. (juv.)	barnacle	native species present	native species present				
Cnidaria	Hydrozoa	Clytia cf. hemisphaerica	hydroid	cryptogenic	cryptogenic	Worlwide range in temperate waters	Australia, Hawaii; range possibly extended by shipping	5-35	20-35
Cnidaria	Hydrozoa	Clytia sp. A	hydroid	cryptogenic	?				
Cnidaria	Hydrozoa	Clytia sp. B	hydroid	cryptogenic	?				
Ectoprocta	Gymnolaemata	Conopeum chesapeakensis	bryozoan or moss animal	introduced	no record/not present	Chesapeake Bay	San Francisco Bay. Newly described species in a taxonomically difficult genus. Species of Conopeum have been reported as invasive in different parts of the world.		
Mollusca	Bivalvia	Corbula amurensis	Asian clam	introduced	no record/not present	Northwest Pacific	San Francisco Bay, CA.	0.1-32	5-25
Crustacea	Amphipoda	Corophiidae spp. (juv.)	amphipod	native species present	native species present				
Crustacea	Copepoda (Poecilostomatoida)	Corycaeus amazonicus	cyclopoid copepod	cryptogenic	native	Eastern Atlantic Ocean, Gulf of Mexico	Pssibly Southern California, Gulf of California		
Crustacea	Copepoda (Cyclopoida)	Cyclopoid sp. A	cyclopoid copepod	?	?				
Crustacea	Copepoda (Cyclopoida)	Cyclopoida spp. Indeterminant	cyclopoid copepod	native species present	native species present				

						Geographical Distribution		Salinity (psu)	
Phylum	Class	Species/Taxon Name	Common Name	California Invasion Status	Status in Texas	Native range	Invaded range	Range	Optimum
Crustacea	Amphipoda	Deutella incerta	skeleton shrimp	no record/not present?	native	Northwest Atlantic, Caribbean, Gulf of Mexico	California? (See CA Fish & Game 2002)		
Crustacea	Copepoda (Harpacticoida)	Diarthrodes sp.	harpacticoid copepod	native species present	native species present			brackish to euhaline	
Crustacea	Copepoda (Harpacticoida)	Diosaccidae spp.	harpacticoid copepod	native species present	native species present				
Annelida	Polychaeta	Dipolydora socialis	polychaete or bristle worm	cryptogenic	native	Northwest Atlantic, Gulf of Mexico, South Atlantic Ocean (Falkland Islands), Eastern Pacific (Chile)	Cryptogenic in the Northeastern Pacific and possibly the Western Pacific Ocean (Sea of Japan, Australia)		
Crustacea	Amphipoda	Elasmopus cf. rapax	amphipod	introduced	native	Tropical and warm temperate waters	California		
Crustacea	Amphipoda	Eochelidium sp.	amphipod	introduced	no record/not present	Northwest Pacific (Japan, Korea)	Northeast Pacific (Puget Sound, San Francisco Bay, Los Angeles Harbor)		
Crustacea	Amphipoda	Ericthonius brasiliensis	amphipod	cryptogenic	native	Western Atlantic Ocean	Widely distributed, probably introduced in much of its range: Mediterranean Sea, Northeast and Northwest Pacific, Hawaii, Southeast Pacific, Indian Ocean	15-38	18-35
Annelida	Polychaeta	Eteone sp.	polychaete or bristle worm	native species present	native species present				
Cnidaria	Hydrozoa	Eudendrium sp?	stickyhydroid	native species present	native species present	World-wide species distribution			
Crustacea	Copepoda (Harpacticoida)	Euterpina acutifrons	harpacticoid copepod	native	native	Cosmopolitan		>19	
Annelida	Polychaeta	Ficopomatus enigmaticus	Australian shipworm	introduced	introduced	Indian Ocean	Atlantic Ocean, Gulf of Mexico, Black Sea, Caspian Sea, Mediterranean Sea, Pacific Ocean	6-35	10-30
Chordata	Osteichthyes	fish eggs		native species present	native species present				
Crustacea	Amphipoda	Gammaropsis sp.	amphipod	native species present	native species present				
Crustacea	Amphipoda	Gammarus daiberi	amphipod	introduced	no record/not present	Northwest Atlantic	San Francisco Bay, CA.	1-15	1-5
Cnidaria	Hydrozoa	Garveia franciscana	Rope Grass hydroid	introduced	introduced	Unknown, possibly Indian Ocean	Northwest Atlantic, Northeast Atlantic, Southwest Atlantic, Gulf of Mexico, Northeast Pacific, Southwest Pacific, Black Sea, Caspian Sea	1-35	5-25
Mollusca	Gastropoda	Gastropoda	marine snail	native species present	native species present				
Crustacea	Isopoda	Gnorimosphaeroma insulare	pillbug	native	no record/not present	Northeast Pacific		freshwater to brackish	0-2
Crustacea	Isopoda	Gnorimosphaeroma oregonensis	Oregon pillbug	native	no record/not present	North Pacific		brackish to salt	
Crustacea	Amphipoda	Grandidierella japonica	amphipod	introduced	no record/not present	Northwest Pacific (Japan)	Northeast Pacific		
Cnidaria	Hydrozoa	Halecium sp.	hydroid	native species present	native species present	World-wide species distribution			
Crustacea	Copepoda (Harpacticoida)	Harpacticidae spp.	harpacticoid copepod	native species present	native species present				
Crustacea	Amphipoda	Incisocalliope derzhavini	amphipod	introduced	no record/not present	West Pacific	San Francisco Bay, CA, to Yaquina Bay, OR	6-32	
Crustacea	Amphipoda	Jassa marmorata	amphipod	introduced	native	Northwest Atlantic (Newfounland to Texas)	Northeast Atlantic, Mediterranean, South Atlantic, Pacific Ocean, Indian Ocean		
Crustacea	Amphipoda	Jassa slatteryi	amphipod	cryptogenic	no record/not present	Pacific and Atlantic Oceans, Mediterranean Sea			
Crustacea	Amphipoda	Jassa sp. (juv.)	amphipod	native species present	native species present				
Crustacea	Amphipoda	Laticorophium baconi	amphipod	cryptogenic	introduced	Possibly native to Northeast Pacific and Peru	Hawaii, Northwest Pacific, Southwest Pacific, Florida, and Gulf of Mexico	?-39	polyhaline to euhaline
Crustacea	Amphipoda	Lembos sp.	amphipod	no record/not present	native species present				
Crustacea	Cirripedia	Lepas anatifera	pelagic goosneck barnacle	native	native	Cosmopolitan in tropical and temperate oceans (pelagic)			
Crustacea	Isopoda	Limnoria tripunctata	marine gribble	introduced	possibly native	Unknown; world-wide species distribution in sub-tropical waters	Considered to have been transported to the Pacific Coast in the hulls of wooden ships and dispersed on ship hulls or log shipments.	30-39	
Crustacea	Copepoda (Harpacticoida)	Longipedia sp.	harpacticoid copepod	native species present	native species present				
Crustacea	Amphipoda	Melita nitida	amphipod	introduced	native	Northwest Altantic, Caribbean, Gulf of Mexico	Northeast Pacific, Northeast Altlantic	0-30	3-20
Crustacea	Copepoda (Harpacticoida)	Mesochra sp.	harpacticoid copepod	native species present	native species present			brackish to salt	
Crustacea	Amphipoda	Monocorophium acherusicum	amphipod	introduced	introduced	Unknown, possibly Northeast Atlantic from where it was originally described	Northwest Atlantic, Gulf of Mexico, Brazil, Northeast Pacific, Northwest Pacific, Hawaii, Southwest Pacific, Indian Ocean	0-38	
Mollusca	Bivalvia	Mytilidae spp. (juv.)	mussel	native species present	native species present				
Annelida	Polychaeta	Neanthes succinea	pile worm	introduced	native	Atlantic Ocean, Gulf of Mexico	Northeast Pacific, Southwest Pacific	2.5-65	
Nemertina		Nemertina spp.	ribbon worm	native species present	native species present				
Annelida	Polychaeta	Nereididae spp. Indeterminant	pile worms	native species present	native species present				
Crustacea	Cumacea	Nippoleucon hinumensis	cumacean	introduced	no record/not present	Northwest Pacific (Japan)	Northeast Pacific		
Crustacea	Copepoda (Harpacticoida)	Nitokra sp.	harpacticoid copepod	native species present	native species present	Cosmopolitan		brackish to euhaline	
Mollusca	Gastropoda	Nudibranchia spp. (juv.)	sea slug	native species present	native species present				
Cnidaria	Hydrozoa	Obelia geniculata	hydroid	cryptogenic	cryptogenic	Unknown, cited for the Pacific and Atlantic Oceans	Cryptogenic in all its range; molecular analyses suggest several cryptic species.		
Cnidaria	Hydrozoa	Obelia sp.	hydroid	cryptogenic	cryptogenic	World-wide species distribution			
Cnidaria	Hydrozoa	Oceanidae spp.	hydroid	native species present	native species present	Possibly Turritopsis sp., a species complex of wide distribution			
Annelida	Polychaeta	Odontosyllis sp.	polychaete or bristle worm	native species present	native species present				
Crustacea	Copepoda (Cyclopoida)	Oithona sp.	cyclopoid copepod	native species present	native species present	Cosmopolitan		brackish to euhaline	
Mollusca	Gastropoda	Okenia plana	sea slug	introduced	no record/not present	Western Pacific Ocean	California		
Annelida	Oligochaeta	Oligochaeta spp.	oligochaete	native species present	native species present				
Crustacea	Decapoda	Pachygrapsus transversus	mottled shore crab	native	native	Atlantic Ocean (NC to Uruguay, Angola), Mediterranean, Eastern Pacific Ocean (CA to Peru)	Range possibly extended by shipping		
Crustacea	Copepoda (Calanoida)	Paracalanus sp.	calanoid copepod	native species present	native species present	Cosmopolitan		brackish to salt	
Crustacea	Amphipoda	Paracaprella pusilla	skeleton shrimp	no record/not present	native	Caribbean Sea, Gulf of Mexico, Tropical South Atlantic	China, Hawaii, Suez Canal		
Crustacea	Isopoda	Paranthura japonica	isopod	introduced	no record/not present	Northwest Pacific	Northeast Pacific		
Annelida	Polychaeta	Phyllodocidae spp. (juv.)	polychaete or bristle worm	native species present	native species present				
Crustacea	Amphipoda	Podocerus brasiliensis	amphipod	cryptogenic	native	Cosmopolitan in tropical and warm temperate seas	Hawaii, possibly introduced in California harbors		

						Geographical Distribution		Salinity (psu)	
Phylum	**Class**	**Species/Taxon Name**	**Common Name**	**California Invasion Status**	**Status in Texas**	**Native range**	**Invaded range**	**Range**	**Optimum**
Annelida	Polychaeta	Polydora cornuta	mud worm	cryptogenic	native	North Atlantic, Gulf of Mexico	Possibly introduced with oyster culture, ballast water and on hulls in the NE Pacific (BC to CA), NW Pacific (Russia, Japan, Korea), SW Pacific (Australia, New Zealand), and SE Atlantic (Argentina, Brazil)	brackish to salt	
Annelida	Polychaeta	Polydora sp.	mud worm	native species present	native species present				
Annelida	Polychaeta	Polydora websteri	shell worm	native	native	Unknown, cited for Northwest Atlantic, Gulf of Mexico, and North Pacific Ocean	New Zealand, Australia, Hawaii; range possibly extended by osyster culture		
Annelida	Polychaeta	Polynoidae spp. (juv.)	scale worm	native species present	native species present				
Crustacea	Decapoda	Porcellanidae spp. (juv.)	porcelain crab	native species present	native species present				
Annelida	Polychaeta	Proceraea cornuta	polychaete or bristle worm	cryptogenic	cryptogenic	Arctic, North Atlantic (Labrador to NC, Norway to English Channel)	Cryptogenic in the North Pacific (Japan, Washington, California) and the Gulf of Mexico (West Florida Shelf)		
Crustacea	Copepoda (Calanoida)	Pseudocalanus sp.	calanoid copepod	native species present	no record/not present	Widespread in cold water in the Northern hemisphere		brackish to salt	
Crustacea	Amphipoda	Ptilohyale littoralis	amphipod	cryptogenic	no record/not present	Northwest Atlantic (Southern Maine to North Carolina)	Possibly Northeast Pacific (Southern Alaska to Baja California)		
Crustacea	Decapoda	Rhithropanopeus harrisii	white-fingered mud crab	introduced	native	Northwest Atlantic (New Brunswick to Florida), Gulf of Mexico (Mississippi to Veracruz, Mexico)	Northeast Atlantic, Northeast Pacific, Black Sea, Caspian Sea, Inland Lakes of Texas	0-40	0-20
Cnidaria	Hydrozoa	Rhizocaulus verticillatus	horesetail hydroid	native?	native?	North Atlantic, North Pacific			
Annelida	Polychaeta	Sabellidae spp.	fan worms	native species present	native species present				
Crustacea	Copepoda (Harpacticoida)	Schizopera sp.	harpacticoid copepod	native species present	native species present			brackish to euhaline	
Annelida	Polychaeta	Serpula sp.	plume worm	native species present	native species present	World-wide species distribution			
Annelida	Polychaeta	Serpulidae spp. (juv.)	plume worm	native species present	native species present				
Hexapoda	Insecta	Simuliidae spp.	black flies	native species present	native species present				
Crustacea	Tanaidacea	Sinelobus stanfordi	tanaid	introduced	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
Sipuncula		Sipuncula spp. (juv.)	peanut worm	native species present	native species present				
Crustacea	Mysidacea	Siriella thompsonii	mysid or fairy shrimp	native	native	Warm temperate waters of Pacific, Indian, and Atlantic Oceans			
Annelida	Polychaeta	Spionidae spp. (juv.)	polychaete or bristle worm	native species present	native species present				
Crustacea	Amphipoda	Stenothoe valida	amphipod	introduced	cryptogenic	Cosmopolitan in tropical and temperate oceans (including the Gulf of Mexico), but its native range is unknown	Considered a recent introduction to the Northeast Pacific		polyhaline to euhaline
Platyhelminthes	Turbellaria	Stylochus franciscanus	flatworm	native	no record/not present	Coast of California			
Annelida	Polychaeta	Syllidae spp. (juv.)	polychaete or bristle worm	native species present	native species present				
Annelida	Polychaeta	Syllis sp.	polychaete or bristle worm	native species present	native species present				
Crustacea	Isopoda	Synidotea laticauda	isopod	introduced	no record/not present	Northwest Pacific	Northeast Pacific (SF Bay, California Coast, Willapa Bay), Southwest Pacific, North Atlantic (Europe, US Mid-Atlantic States)		
Annelida	Polychaeta	Terebellidae spp. (juv)	polychaete or bristle worm	native species present	native species present				
Crustacea	Copepoda (Harpacticoida)	Tisbe sp.	harpacticoid copepod	native species present	native species present	Cosmopolitan			
Chordata	Ascidiacea	Tunicates?	sea squirt	native species present	native species present				
Platyhelminthes	Turbellaria	Turbellaria sp. A (Leptoplanidae)	flatworm	cryptogenic	?				
Platyhelminthes	Turbellaria	Turbellaria sp. B	flatworm	?	?				
Platyhelminthes	Turbellaria	Turbellaria sp. C	flatworm	?	?				
Platyhelminthes	Turbellaria	Turbellaria spp. (too small)	flatworm	native species present	native species present				
Annelida	Polychaeta	Typosyllis alternata	polychaete or bristle worm	cryptogenic	cryptogenic	Cosmopolitan	Cryptogenic in all its range: Arctic Ocean, North Pacific Ocean (AK-Panama, Japan), Southwest Pacific (Australia), Northwest Atlantic (ME to FL), Mediterranean Sea, Gulf of Mexico (West Florida Shelf)		
		unidentified sponge-like organism		?	?				
Crustacea	Isopoda	Uromunna ubiquita	isopod	native	no record/not present	Northeast Pacific			
Crustacea	Tanaidacea	Zeuxo coralensis	tanaid	no record/not present	cryptogenic	Cosmopolitan: Pacific (Japan, Panama Canal), Atlantic (Florida Keys, SW Shelf off Florida Bay, Brazil), and Indian Oceans			

	Temperature (ºC)					
Species/Taxon Name	Range	Optimum	Substrate Preference-adults	Developmental mode	Feeding mode	Reference
Acartia tonsa			planktonic	eggs released; planktonic larvae	omnivore; suspension feeder	Johnson and Allen 2005
Aeolidacean nudibranch (juv.)						
Algae sp. A						
Algae sp. B						
Algae sp. C						
Algae sp. D						
Algae sp. E						
Americorophium spinicorne		8-23	epibenthic tube-building	brooder	herbivore; detritus feeder; suspension feeder	Davidson et al. 2006
Ampelisca abdita	-2-27	>10	epibenthic tube-building	brooder	suspension feeder	Redmond et al. 1994, Cohen and Carlton 1995, LeCroy 2002
Amphiascoides sp.			infaunal, epibiont	brooder	herbivore; detritus feeder; suspension feeder	
Amphinomidae spp.			epibenthic	planktonic larvae	carnivore	
Amphipoda spp. indeterminant						
Ampithoe valida			epibenthic tube-building	brooder		Cohen et al. 2002, Cohen and Carlton 1995
Anthozoa sp. A						
Anthozoa sp. B						
Anthozoa spp. Indeterminant						
Aoridae (possibly Grandidierella japonica)			epibiont	brooder	herbivore; detritus feeder	
Autolytinae spp. Indeterminant						
Balanus amphitrite	1.5-40	15-32	epibenthic	planktonic larvae	suspension feeder	Davidson et al. 2007
Balanus improvisus	-2-38	14-30	epibenthic	planktonic larvae	suspension feeder	Davidson et al. 2008
barnacle cypris						
Bivalvia sp. A (Corbula amurensis?)			infaunal	planktonic larvae	suspension feeder	Davidson et al. 2006
Bivalvia sp. B						
Bivalvia sp. C						
Bivalvia sp. D						
Bivalvia sp. E						
Bivalvia sp. F						
Bivalvia spp. Indeterminant						
Boccardiella ligerica			infaunal	demersal eggs laid in strings in burrows; planktonic larvae	interface feeder	Davidson et al. 2006
Bowerbankia gracilis			epibenthic	brief planktonic larvae	suspension feeder	Winston 1977, Cohen and Carlton 1995
Brachyura spp. Indeterminant						
Brania californiensis			epibenthic	epigamy, planktonic larvae	carnivore	Kudenov and Harris 1995
Bugula sp. A			epibenthic	planktonic larvae	suspension feeder	Cohen and Carlton 1995
Bugula stolonifera			epibenthic	planktonic larvae	suspension feeder	Cohen and Carlton 1995
Calanoida spp. Indeterminant						
Callinectes sp.			epibenthic	brooder, planktonic larvae, molting stages		
Campanularia sp.			epibenthic	brooder, planktonic larvae	suspension feeder	Cohen and Carlton 1995
Campanulariidae spp.			epibenthic, planktonic	with or without planktonic medusae	suspension feeder	Cohen and Carlton 1995
Capitella capitata	-0.5-27		infaunal tube-building	egg cases, planktonic larvae	deposit feeder	Grassle and Grassle 1974, Carlton 1979, CA Fish & Game 2002
Capitella sp. (juv.)			infaunal	egg cases, planktonic larvae	deposit feeder	Cohen and Carlton 1995
Caprella equilibra			epibiont	brooder	carnivore/omnivore	McCain 1968, CA Fish & Game 2002
Caprella scaura			epibiont	brooder	carnivore/omnivore	McCain 1968, CA Fish & Game 2002
Caprella sp. Indeterminant			epibiont	brooder	carnivore/ommivore	
Chaetognatha spp.						
Chironomidae spp.						
Ciona intestinalis			epibenthic	planktonic larvae	suspension feeder	Cohen and Carlton 1995
Cirolana cf. parva			epibenthic, epibiont	brooder	herbivore; detritus feeder	
Cirolana harfordi			epibenthic, epibiont	brooder	herbivore; detritus feeder	AMBS 2002, Cohen et al. 2005
Cirripedia spp. (juv.)						
Clytia cf. hemisphaerica	-2-30	6-30	epibenthic, planktonic	asexual reproduction and planktonic medusa	suspension feeder, carnivore	Davidson et al. 2007
Clytia sp. A			epibenthic, planktonic	asexual reproduction and planktonic medusa	suspension feeder, carnivore	Cohen and Carlton 1995
Clytia sp. B			epibenthic, planktonic	asexual reproduction and planktonic medusa	suspension feeder, carnivore	Cohen and Carlton 1995
Conopeum chesapeakensis			epibenthic	brooder, planktonic larvae (inferred)	suspension feeder	Davidson et al. 2008
Corbula amurensis	8-23		infaunal	planktonic larvae	suspension feeder	Davidson et al. 2006
Corophiidae spp. (juv.)						
Corycaeus amazonicus			planktonic		herbivore; carnivore	Johnson and Allen 2005
Cyclopoid sp. A						
Cyclopoida spp. Indeterminant						

	Temperature (ºC)					
Species/Taxon Name	Range	Optimum	Substrate Preference-adults	Developmental mode	Feeding mode	Reference
Deutella incerta			epibiont	brooder	carnivore/omnivore	McCain 1968, CA Fish & Game 2002
Diarthrodes sp.			infaunal, epibiont	brooder	herbivore; detritus feeder; suspension feeder	
Diosaccidae spp.			epibenthic			
Dipolydora socialis			infaunal and epifaunal tube-building	egg capsules attached to tube wall, planktonic larvae	interface feeder	CA Fish & Game 2002
Elasmopus cf. rapax			epifaunal, epibiont	brooder		LeCroy 2002, Cohen et al. 2005
Eochelidium sp.			epifaunal, planktonic	brooder	herbivore; omnivore	CA Fish & Game 2002
Ericthonius brasiliensis			epibiont tube-building	brooder	herbivore; detritus feeder; suspension feeder	Davidson et al. 2007
Eteone sp.						
Eudendrium sp?			epibenthic	brooder, planktonic larvae	suspension feeder	
Euterpina acutifrons			pelagic	brooder	herbivore; suspension feeder	Johnson and Allen 2005
Ficopomatus enigmaticus		>18	epibenthic tube-building	planktonic larvae	suspension feeding	Cohen and Carlton 1995, Cohen 2005
fish eggs						
Gammaropsis sp.			epibenthic, epibiont	brooder	herbivore; detritus feeder	
Gammarus daiberi	?-32		epibenthic, pelagic	brooder	herbivore; detritus feeder; omnivore	Cohen and Carlton 1995, Davidson et al. 2006
Garveia franciscana	0-35	10-32	epibenthic	brooder, planktonic larvae	suspension feeder	Cohen and Carlton 1995, Davidson et al. 2007
Gastropoda						
Gnorimosphaeroma insulare			epibenthic	brooder	herbivore; detritus feeder	Davidson et al. 2006
Gnorimosphaeroma oregonensis			epibenthic	brooder	herbivore; detritus feeder	Davidson et al. 2006
Grandidierella japonica			infaunal and epibenthic tube-building	brooder	herbivore; detritus feeder	Cohen and Carlton 1995
Halecium sp.			epibenthic	brooder, planktonic larvae	suspension feeder	
Harpacticidae spp.			epibenthic			
Incisocalliope derzhavini			epibiont			Cohen and Carlton 1995
Jassa marmorata			epibenthic tube-building	brooder	suspension feeder; predator	Cohen and Carlton 1995
Jassa slatteryi			epibenthic tube-building	brooder		Conlan 1990, Maloney et al. 2006
Jassa sp. (juv.)			epibenthic tube-building	brooder		Conlan 1990
Laticorophium baconi			epibenthic	brooder	herbivore; detritus feeder; suspension feeder	LeCroy 2004, Davidson et al. 2007
Lembos sp.						
Lepas anatifera		19-25	epibenthic, epibiont	planktonic larvae	suspension feeder	
Limnoria tripunctata	10-30	15-30	wood-boring	brooder, parental care of juveniles	wood feeder	Beackman and Menzies 1960, Cohen and Carlton 1995
Longipedia sp.			infaunal	brooder		
Melita nitida			epibiont	brooder	herbivore; detritus feeder; omnivore	Cohen and Carlton 1995, Davidson et al. 2006
Mesochra sp.			infaunal, epibiont	brooder	herbivore; detritus feeder; suspension feeder	
Monocorophium acherusicum	-2 -30	10-30	epibenthic tube-building	brooder	herbivore; detritus feeder; suspension feeder	Cohen and Carlton 1995, LeCroy 2004, Davidson et al. 2007
Mytilidae spp. (juv.)			epibenthic			
Neanthes succinea	-2-34		Infaunal and epibenthic	planktonic eggs; planktonic larvae	carnivore; detritus feeder; omnivore	Cohen and Carlton 1995, Davidson et al. 2006
Nemertina spp.						
Nereididae spp. Indeterminant						
Nippoleucon hinumensis			infaunal and epibenthic	brooder	detritus feeder?	Cohen and Carlton 1995
Nitokra sp.			infaunal, epibiont	brooder	herbivore; detritus feeder; suspension feeder	
Nudibranchia spp. (juv.)						
Obelia geniculata			epibenthic and planktonic	asexual reproduction and planktonic medusa	suspension feeder; carnivore	Davidson et al. 2007
Obelia sp.			epibenthic and planktonic	asexual reproduction and planktonic medusa	suspension feeder; carnivore	Davidson et al. 2007
Oceanidae spp.			epibenthic, planktonic	with or without planktonic medusae	suspension feeder	
Odontosyllis sp.			epibenthic	pelagic spawning of ovigerous worms (epigamy), planktonic larvae	carnivore	
Oithona sp.			planktonic		suspension feeder; carnivore	
Okenia plana			epibenthic, epibiont	geleatinous egg masses attached to substrate, planktonic larvae	predator of bryozoans	Cohen and Carlton 1995
Oligochaeta spp.						
Pachygrapsus transversus			epibenthic	planktonic larvae	carnivore; omnivore	Williams 1984, CA Fish & Game 2002
Paracalanus sp.			planktonic		herbivore; detritus feeder; suspension feeder	Johnson and Allen 2005
Paracaprella pusilla			epibiont	brooder	carnivore; omnivore	McCain 1968
Paranthura japonica			epibenthic	brooder	herbivore, detritus feeder	Cohen and Carlton 1995, CA Fish & Game 2002, Cohen et al. 2005
Phyllodocidae spp. (juv.)						
Podocerus brasiliensis			epibiont, tube-building	brooder	herbivore, detritus feeder	Cohen and Chapman 2005, Chapman 2007

	Temperature (ºC)					
Species/Taxon Name	Range	Optimum	Substrate Preference-adults	Developmental mode	Feeding mode	Reference
Polydora cornuta			epibenthic tube-building, epibiont	brooder (egg capsules attached to tube wall), planktonic larvae	interface feeder	Blake 1969, Cohen and Carlton 1995 (as Polydora ligni)
Polydora sp.						
Polydora websteri			epibenthic, boring in oysters	brooder, planktonic larvae	interface feeder	
Polynoidae spp. (juv.)						
Porcellanidae spp. (juv.)						
Proceraea cornuta			epibenthic tube-building, epibiont	schizogamy, planktonic larvae	carnivore	Uebelacker and Johnson 1984, CA Fish & Game 2002
Pseudocalanus sp.			pelagic		herbivore	Corkett and McLaren 1978
Ptilohyale littoralis			epibenthic, epibiont	brooder		Boyd et al. 2002, Cohen et al. 2005
Rhithropanopeus harrisii		20-31	epibenthic, among oysters	brooder, planktonic and benthic larvae	omnivore	Williams 1984, Cohen and Carlton 1995
Rhizocaulus verticillatus			epibenthic	brooder, planktonic larvae	suspension feeder	
Sabellidae spp.						
Schizopera sp.			infaunal, epibiont	brooder	herbivore; detritus feeder; suspension feeder	
Serpula sp.			epibenthic tube-building	planktonic larvae	suspension feeder	
Serpulidae spp. (juv.)						
Simuliidae spp.						
Sinelobus stanfordi			epibenthic	brooder	suspension feeder; detritus feeder	Cohen and Carlton 1995, Davidson et al. 2007
Sipuncula spp. (juv.)			infaunal and epifaunal, burrower	planktonic larvae	filter and deposit feeder	
Siriella thompsonii			epibenthic, planktonic	brooder	filter feeder	
Spionidae spp. (juv.)						
Stenothoe valida			epibiont, commensal	brooder	carnivore; detritus feeder; omnivore	Cohen and Carlton 1995, Davidson et al. 2007
Stylochus franciscanus						Hyman 1953
Syllidae spp. (juv.)						
Syllis sp.			epibenthic	schizogamy, planktonic larvae	carnivore	
Synidotea laticauda				brooder		Chapman and Carlton 1994, Cohen and Carlton 1995, Bushek and Boyd 2006
Terebellidae spp. (juv)			infaunal and epifaunal, tube-building	planktonic larvae	deposit feeder	
Tisbe sp.			epibenthic	brooder	herbivore; detritus feeder; suspension feeder	
Tunicates?			epibenthic		suspension feeder	
Turbellaria sp. A (Leptoplanidae)						
Turbellaria sp. B						
Turbellaria sp. C						
Turbellaria spp. (too small)						
Typosyllis alternata			epibenthic	schizogamy, planktonic larvae	carnivore	Uebelacker and Johnson 1984, Davidson et al. 2006
unidentified sponge-like organism						
Uromunna ubiquita			epibenthic	brooder		CA Fish & Game 2002, Appendix A
Zeuxo coralensis			epibenthic	brooder		