

Overview of 2004/05 Rapid Assessment Shore and Channel Surveys for Exotic Species in San Francisco Bay

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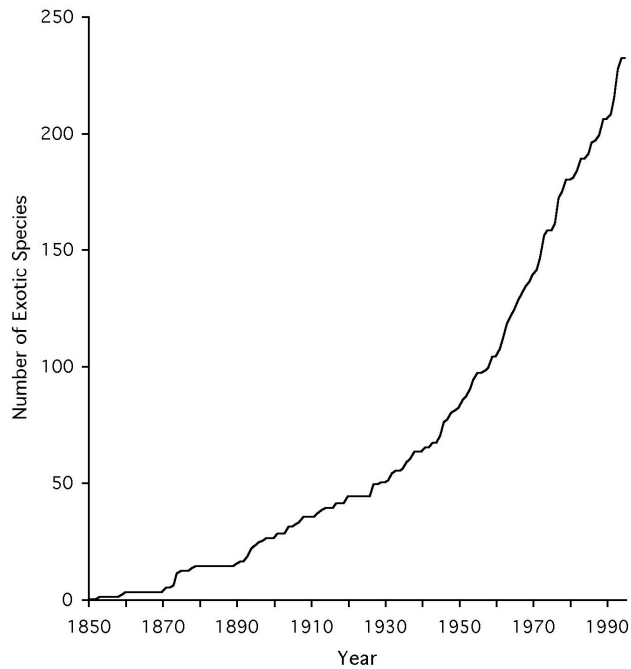
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Introduction

Exotic species constitute one of the main environmental stressors in the San Francisco Estuary. Major environmental and economic impacts which exotic species have caused or contributed to include the large-scale alteration of species composition; the reduction of native populations through competition, predation and other effects, including the actual or potential extirpation of certain species; impacts on fisheries; interference with the restoration of native populations and habitats; changes in the rate of marsh accretion or erosion; the destruction of maritime structures and vessels; and the nuisance fouling of boats, buoys, waterways and various components of water supply systems (Cohen & Carlton 1995). Exotic organisms dominate many important and extensive habitats and biotic assemblages in the salt, brackish and fresh waters within reach of the tides, including the salt to freshwater soft-bottom benthos, the salt and brackish water fouling communities, the brackish and freshwater zooplankton communities, the freshwater fish and, increasingly, the saltwater marsh vegetation. In many of these environments, exotic species may account for up to 100% of the common species and over 90-95% of the numbers of individuals and biomass (Cohen & Carlton 1995, 1998). Furthermore, the rate at which exotic species are becoming established in this ecosystem has been increasing, from an average of about one new species per year prior to 1960 to an average of nearly four species per year since then (Fig. 1; Cohen & Carlton 1998). Because of these factors, San Francisco Bay is generally recognized as one of the most heavily invaded aquatic ecosystems in the world.

Figure 1. Cumulative Number of Established Exotic Species Identified in San Francisco Bay (after Cohen & Carlton 1998)



We report here on shoreline and channel Rapid Assessment (RA) surveys of exotic species conducted in San Francisco Bay in 2004 and 2005. The surveys utilized methods initially developed in four RA surveys conducted in the Bay in 1993-1997, and sampled several of the same stations as in the prior surveys (Tables 1 and 2). The 2004 shoreline survey was funded jointly by the California State Coastal Conservancy, the Association of Bay Area Governments/San Francisco Bay-Delta Science Consortium, the National Geographic Society and the Rose Foundation. The U.S. Food and Drug Administration facility in Alameda provided laboratory space. The 2005 channel survey was funded by the California State Coastal Conservancy. The San Francisco BayKeeper provided a boat and two volunteers, Geoff Potter and Jim Hayward. Detailed reports and datasheets for the two surveys are attached.

Table 1. Shoreline Sites Sampled by San Francisco Bay Rapid Assessment Surveys 1993-2004

	Type of Site	1993	1994	1996	1997	2004
Alviso Marina	dock	X				
Angel Island Ferry dock, Sausalito	dock		X			
Antioch Marina	dock	X				
Ballena Bay Marina, Alameda	dock			X	X	
Berkeley Aquatic Park boat dock	dock		X		X	
Berkeley Marina	dock		X			
Bethel Island-Beacon Harbor Marina	dock	X	X	X	X	
Brisbane Lagoon	intertidal					X
Coast Guard Island Marina	dock	X	X	X	X	X
Coyote Point Marina	dock	X	X	X	X	X
Crown Beach, Alameda	intertidal			X		
Emeryville Marina boat ramp	intertidal/dock	X	X			
Fruitvale Bridge, Oakland	intertidal/pilings			X		X
Keil Cove, Tiburon	intertidal		X			
Lake Merritt boat docks, Oakland	dock	X	X	X		
Loch Lomond Yacht Harbor	dock	X	X	X	X	
Martinez Marina	dock	X	X	X	X	
Mission Rock Resort docks	dock	X		X		
Napa River-JFK Park boat ramp	dock	X	X	X	X	
Napa River-Main Street dock	dock		X			
Napa River-Moore's Landing	dock					X
Napa River-Napa Valley Marina	dock					X
Petaluma River Turning Basin	dock	X	X	X	X	X
Pier 39 Marina, San Francisco	dock	X	X	X	X	X
Pillar Point Marina, Half Moon Bay	dock		X		X	
Point Molate, Richmond	intertidal		X			
Point San Pablo Yacht Harbor	dock	X	X	X	X	X
Port Sonoma	dock	X	X	X	X	X
Presidio Yacht Harbor, Sausalito	dock	X	X	X	X	X
Redwood Creek-Peninsula Marina	dock		X			
Redwood Creek-Pete's Harbor	dock		X	X	X	X
Redwood Creek-USGS dock	dock	X				
Richmond Marina boat ramp	dock	X	X	X	X	X
Rio Vista fishing dock	dock	X				
Rodeo Marina	dock		X	X	X	X
Romberg-Tiburon Center, Tiburon	dock		X			
San Leandro Marina	dock	X	X	X	X	X
Sierra Point Marina	dock					X
Suisun City docks	geloplankton				X	
Treasure Island Marina	dock	X				
Vallejo boat ramp	dock	X	X	X	X	

Table 2. Channel Sites Sampled by San Francisco Bay Rapid Assessment Surveys 1993-2005

	Type of Site	1993	1996	2005
Carquinez Bridge	buoy	X	X	X
San Pablo Bay #11	dolphin			X
San Pablo Bay #8	buoy	X	X	X
Central Bay #12	buoy			X
Central Bay #2	buoy	X	X	X
Harding Rock	buoy	X	X	X
South Bay #2	buoy		X	X
San Mateo Bridge	pylon	X	X	X
Dumbarton Bridge	pylon	X	X	X

Objectives

The surveys were intended to assist with some key actions that are essential in addressing the exotic species problem:

- Accurately assessing the extent of invasion in the Bay;
- Detecting newly-arrived exotic species;
- Developing a better understanding of how populations of exotic organisms multiply and spread through the Bay; and
- Increasing the public's and policymakers' awareness of exotic species in the Bay.

Document the Extent of Invasion. The shore and channel surveys provide a synoptic overview of the composition and distribution of exotic organisms in selected habitats throughout San Francisco Bay.

Detect New Invasions. As described in the Results, the shore survey found and identified some species that had not been previously recorded on the Pacific Coast of North America, and found others that had been reported rarely in the past and that were not thought to be established in the Bay

Understand the Spread of Invasions. The shore and channel survey reveal similar overall patterns of distribution and dominance by exotic species in the Bay, with the number of exotic species at a site generally increasing toward the mouth of the Bay, but the fraction of the species diversity that is exotic generally increasing away from the mouth of the Bay. Comparisons of the current survey data with that from earlier surveys should show whether these overall patterns have changed, and how the distributions of particular exotic species has changed over time. Understanding these aspects of the distribution and population dynamics of exotic species is basic to assessing the potential for ecological or economic impacts.

Increase Public Awareness. Without public awareness of exotic species, it is difficult for policymakers to support management or regulatory initiatives to deal with them. Information from previous RA surveys has raised public awareness and influenced state and national policy initiatives. The last San Francisco Bay RA shoreline survey, in 1997, is described at some length

in a recently published popular book (Burdick 2005). A writer and a photographer for *National Geographic* magazine accompanied the 2004 survey, which was described in a recent article in the magazine (McGrath 2005). The survey is also documented on a website (http://www.californiabiota.com/cabiota/sfbras_2004.htm), and photographs of several specimens collected by the survey are included in an internet field guide to exotic species (<http://www.exoticguide.org>).

Approach

The approach used in the RA surveys for exotic species was initially developed in San Francisco Bay surveys conducted in 1993-97, and applied since then to several other estuarine and marine waters (Table 3). For the shoreline survey, we assembled a team of taxonomic experts (Table 4) to sample and identify organisms at 15 sites within the Bay, many of which had been sampled by RA surveys in the 1990s. Sampling primarily focused on dock fouling along with adjacent soft-bottom benthos, nearby intertidal sites, subtidal lagoon habitats and buoy fouling. For the channel survey we used two taxonomists who sampled by free diving on channel markers and other structures at 9 sites along the main channels along the axis of the Bay.

Table 3. Rapid Assessment Surveys for Exotic Organisms Conducted in Marine and Estuarine Waters

Year	Region Surveyed	Organizers (Institutions)
1993	San Francisco Bay	Andrew Cohen (U.C. Berkeley)
1994	San Francisco Bay	Andrew Cohen (U.C. Berkeley)
1996	San Francisco Bay	Andrew Cohen (U.C. Berkeley)
1997	San Francisco Bay	Andrew Cohen (San Francisco Estuary Institute)
1998	Puget Sound	Helen Berry (Washington Department of Natural Resources) Andrew Cohen (San Francisco Estuary Institute) Claudia Mills (U. Washington/Friday Harbor Laboratory)
1999	Southern British Columbia	Valerie McDonald (Biologica) Colin Levings (Canada Department of Fisheries & Oceans)
2000	3 Washington Bays	Helen Berry (Washington Department of Natural Resources) Andrew Cohen (San Francisco Estuary Institute)
2000	Massachusetts	Judith Pederson (MIT Sea Grant)
2000	Rhode Island	Kevin Cute (Rhode Island Coastal Marine Resources Center)
2000	Southern California	Andrew Cohen (San Francisco Estuary Institute)
2001	Washington outer coast	Mary Sue Brancato (Olympic Coast NMS)
2002	Panama Canal	Andrew Cohen (San Francisco Estuary Institute)
2002	Washington outer coast	Mary Sue Brancato (Olympic Coast NMS)
2003	Tomales Bay, California	Edward Grosholz (U.C. Davis)
2003	New England-New York	Judith Pederson (MIT Sea Grant)
2004	San Francisco Bay	Andrew Cohen (San Francisco Estuary Institute)
2004	Southern England	Peter Dyrinda (University of Swansea)

Table 4. Taxonomic Expertise of Survey Participants

Participant	Area of expertise
Dale R. Calder	Hydrozoa
James T. Carlton	Mollusca, Decapoda
John W. Chapman	Amphipoda, Isopoda, Cumacea, Mysidacea
Andrew N. Cohen	Tanaidacea, Sphaeromatidae, Cirolanidae, Bryozoa
Leslie H. Harris	Polychaeta
Taiju Kitayama	Macroalgae
Gretchen and Charles Lambert	Ascidiacea
Christina Piotrowski	general marine invertebrate taxonomy
Michelle Shouse	general marine invertebrate taxonomy
Luis Solórzano	Macroalgae

For the shoreline survey, sampling was conducted in the morning, specimens were initially examined in the field, and then transported to the laboratory in insulated containers and examined in live or fresh condition on the same day in which they were collected. For the channel survey, initial sorting and examination was conducted in the field, and samples were transported to the laboratory in insulated containers and examined in live or fresh condition within 1-2 days. Examination of live or fresh material facilitates identification especially where colors or forms of soft-bodied organisms are lost or distorted by preservation techniques. Specimens were fixed and preserved by appropriate techniques, and representative voucher specimens were deposited in curated collections. Organisms were classified by invasion status as native, cryptogenic or exotic, using a "weight of the evidence" approach as defined in Cohen (2004); organisms that were not identified to a sufficiently low taxon to determine their invasion status were classified as indeterminate.

Overall Results

The shore survey produced 896 records of 294 distinct taxa. Of these, 232 taxa were sufficiently identified to determine their invasion status, with 81 (35%) determined to be native, 38 (16%) cryptogenic and 113 (49%) exotic. The channel survey produced 236 records of 100 taxa. Invasion status was determined for 72 taxa, with 23 (32%) being native, 15 (21%) cryptogenic and 34 (47%) exotic. Thus the overall percent of taxa that are exotic is estimated to be 49-65% for the shore survey and 47-68% for the channel survey.

These numbers varied from site to site, with the number of exotic taxa generally being higher at the sites closer to the mouth of the Bay in the shore survey and without a clear pattern in the channel survey. The fraction of the taxa that are exotic was generally higher at the sites further from the mouth of the Bay in both surveys. For example, in the shore survey the overall range of estimates for the number of exotic taxa dropped from 25-54 exotic taxa per site near the mouth of the Bay to 17-21 exotic taxa per site at the lowest salinity sites located in the Petaluma and

Napa Rivers upstream from San Pablo Bay; and the overall range of estimates for the fraction of taxa that are exotic rose from 31-50% near the mouth of the Bay to 69-77% in the San Pablo Bay tributaries. Similarly, in the channel survey the overall range of estimates for the fraction of taxa that are exotic rose from 13-66% in the Central Bay to 67-94% in Carquinez Strait and 90-100% at Dumbarton Bridge in the southern part of the South Bay.

The shore survey identified some new exotic species and found others that had not been reported for several decades. Two hydroids and a ctenostome bryozoan are apparently new records for the Pacific Coast, and a sponge and another ctenostome had not been collected for over 50 and about 35 years, respectively.

References

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