F1-167

JUL 3 0 1997

# United States Department of the Interior

FISH AND WILDLIFE SERVICE

IN REPLY REFER TO:

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**Sacramento Fish and Wildlife Office**
**3310 El Camino Avenue, Suite 130**
**Sacramento, California 95821-6340**

July 28, 1997

Mr. Lester S. Snow
Executive Director
CALFED Bay-Delta Program
1416 Ninth Street, Suite 1155
Sacramento, California 95814

Subject: San Francisco Estuary Institutes's Category III Exotic Species Control Proposals

Dear Mr. Snow:

The Sacramento Fish and Wildlife Service Office supports the eight proposals submitted by the San Francisco Estuary Institute for exotic species research and control in the Sacramento-San Joaquin Bay-Delta estuary. These eight projects fit within the recommended actions in the Delta Native Fishes Recovery Plan and will help recover listed species in the estuary.

The Service recommends funding of these projects. Such projects are consistent with our mission of preserving fish and wildlife and recovering natural ecosystems and watersheds.

If you have any questions or concerns about the above, contact Robert Pine at (916) 979-2725.

Sincerely,

Patricia Lennard

for Wayne S. White
Field Supervisor

CC: San Francisco Estuary Institute, Richmond, California



I-003831

F1-167



**a. Project Title:** Nonindigenous species invasions in San Francisco Bay and Delta: Patterns and effects of ballast water delivery on invasion rates.

**Applicant's Name:** The San Francisco Estuary Institute.

**Principal Investigator:** Dr. Andrew N. Cohen, SFEI; and Dr. Gregory M. Ruiz, Smithsonian Environmental Research Center.

**b. Project Description and Objectives.** The overall objective of this project is to measure the effect of ballast management practices on the delivery and subsequent invasion of San Francisco Bay and other estuaries by nonindigenous species. We will: (1) measure changes in the volume of foreign ballast water and its biota associated with changes in ballast management (exchange) over time; (2) measure the rate of new invasions that occur over the same time period. These data for the San Francisco Estuary, combined with similar data being developed for Chesapeake Bay and Prince William Sound, will allow us to test the relationships between ballast water delivery and invasion. More specifically, we will test the following hypotheses:

- Ballast water exchange reduces the density and diversity of foreign biota arriving in estuaries;
- An increase in ballast water exchange will result in a decreased rate of new invasions;
- Significant variation exists in the rate of new invasions among estuaries that is independent of supply (of organisms), indicating some sites are more susceptible to invasion;
- Among estuaries, the San Francisco Estuary is the most susceptible to new invasions when controlling for supply.

**c. Approach/Tasks/Schedule.** This project will directly measure the patterns of release and invasion of nonindigenous species associated with ballast water of ships arriving in the San Francisco Bay and Delta. More specifically, it will estimate for San Francisco Bay the annual volume of discharged ballast water that originates from foreign ports; the biota (organism density and diversity) associated with this ballast water; the effect of ballast water management (exchange) on release of foreign ballast water and biota; and the patterns of invasion associated with ballast water discharge and ballast water management.

This is a three-year project, with annual progrees reports provided at 12 and 24 months, and a Final Report at 36 months after the start date of the project.

**d. Justification for Project Funding by CALFED.** The San Francisco Bay Estuary is recognized as the most invaded aquatic ecosystem in North America, with more than 200 introduced invertebrates, fish, plants, and microorganisms. The introduction of nonindigenous species has been identified as a critical factor affecting the health of the Bay/Delta Estuary by water agencies, environmental groups, the CCMP, BCDC, USFWS, CALFED and others. It is one of the seven non-flow factors targeted for research and management by Category III funding, and is one of the main stressors listed by the technical teams as appropriate for near-term funding and priorities. Nonindigenous species may in general affect and have affected all of the priority habitats listed in this RFP. Researchers have also demonstrated or suggested that nonindigenous species have caused significant negative impacts on several priority species (salmon, trout, Delta smelt, sturgeon).

Ballast water is probably the largest mechanism operating today to transport aquatic organisms around the world and release them into new environments. Information on the biota in the ballast water imported into the Estuary, which has never before been sampled, is needed in order to assess risks and determine effective control mechanisms, and to understand the contribution of different factors to the scale, patterns and rate of invasions in the Estuary.

**e. Budget Costs and Third Party Impacts.** The budget is $222,520 in the first year, $217,600 in the second year, $221,075 in the third year. No third party impacts are anticipated.

**f. Applicant Qualifications.** The San Francisco Estuary Institute (SFEI) is a non-profit research institute charged with fostering scientific understanding of the Estuary. SFEI's Biological Invasions Program researches issues of scientific and policy interest related to the introduction of nonindigenous species into marine and freshwater ecosystems. The research program is directed toward five objectives: (1) assisting efforts to prevent future invasions through scientific and policy research on vectors and the control of vectors; (2) developing an effective regional monitoring program to identify new invasions and track the spread of nonindigenous species that are present in the region; (3) understanding how factors in the environment affect the success of invasions; (4) assessing the impacts of invasions; (5) prioritizing and assessing efforts to control nonindigenous species that are present in the region.

The Smithsonian Environmental Research Center (SERC) has the largest ballast water research program in the country. A large component of SERC's invasion research examines the volume, content, dynamics, and management of ballast water, as well as resutling invasions. As a result of SERC's research, more is now known about ballast water delivery patterns, associated biota, and management for ships entering Chesapeake Bay than anywhere else in the U. S., and perhaps the world.

Principal Investigator, Dr. Andrew Cohen received M. S. and Ph. D. degrees in Energy and Resources from the University of California at Berkeley. He is the author of a 1995 USFWS report on nonindigenous species in the San Francisco Estuary and of papers on other aspects of marine and aquatic invasions. Dr. Cohen has also worked on and written about water system planning and economics, public health and contaminants in fish, and environmental mitigation; and has written articles and books for the general public on water and environmental policy and history. His work on invasions in the Estuary was profiled last year in the *New York Times* Science Page, and he was recently nominated to co-chair the Western Regional Panel on Aquatic Nuisance Species. He currently directs the San Francisco Estuary Institute's research program on biological invasions.

Co-Principal Investigator, Dr. Gregory M. Ruiz developed and heads a large, collaborative research program at the SERC that addresses a broad range of issues in marine and estuarine invasion biology. SERC is located on Chesapeake Bay, near the middle of the U. S. Atlantic coast, and its invasion ecology program has focused much of its attention to date on the Chesapeake as a model system to examine patterns and mechanisms of invasion. A core group of about 10 researchers based at SERC have developed collaborative research programs regionally, nationally and internationally. Within the U. S., Ruiz's program has active research projects in Alaska, California, Florida, and Massachusetts, and it has developed collaborative overseas research in Australia, Israel, Italy, Netherlands, and New Zealand.

**g. Monitoring and Data Evaluation.** Annual reports and the draft final report will be submitted to researchers with experience in ballast water sampling and biological invasions for review and comment. In addition, any persons recommended by CALFED will be asked to review these reports. Is is anticipated that articles based on the results of this study will be prepared for submission to peer-reviewed journals.

**h. Local Support/Coordination with other programs/Compatibility with CALFED objectives.** All habitats and species included as priorities in the Ecosystem Restoration Program Plan could be directly or indirectly affected by exotic species introduced in ballast water, and thus stand to benefit from increases in our knowledge of the biological composition, patterns of transport, and effectiveness of control of ballast water, and the susceptibility of different regions to ballast water invasions, all of which will be furthered by this project.

This project will coordinate will parallel ballast water sampling programs and exotic species surveys being conducted in Chesapeake Bay and Prince William Sound, in order to compare rates, patterns and contributing factors of invasions.

# Nonindigenous species invasions in San Francisco Bay and Delta: Patterns and effects of ballast water delivery on invasion rates


| | |
|---|---|
| Principal Investigator: | Andrew N. Cohen<br>San Francisco Estuary Institute<br>1325 South 46th Street<br>Richmond, CA 94804<br>phone: (510) 231-9423<br>fax: (510) 231-9414<br>email: acohen@sfei.org |
| Co-Principal Investigator: | Gregory M. Ruiz<br>Smithsonian Environmental Research Center<br>Edgewater, MD |
| Organization Type: | Nonprofit research institute<br>503(c)(3) nonprofit organization |
| Tax identification number: | 94-2951373 |
| Contact person: | Andrew Cohen |
| Project Group Type: | Services |

## Introduction: Biological Invasions in the Estuary

The San Francisco Bay Estuary is recognized as the most invaded aquatic ecosystem in North America, with more than 200 introduced invertebrates, fish, plants, and microorganisms. The introduction of nonindigenous species has been identified as a critical factor affecting the health of the Bay/Delta Estuary by water agencies, environmental groups, the CCMP, BCDC, USFWS, CALFED and others. It is one of the seven non-flow factors targeted for research and management by Category III funding, and is one of the main stressors listed by the technical teams as appropriate for near-term funding and priorities. Nonindigenous species may in general affect and have affected all of the priority habitats listed in this RFP. Researchers have also demonstrated or suggested that nonindigenous species have caused significant negative impacts on several priority species (salmon, trout, Delta smelt, sturgeon).

The San Francisco Estuary Institute has initiated a research program to address issues of scientific and policy interest related to the introduction of nonindigenous species into marine and freshwater ecosystems. The research program is directed toward five objectives: (1) assisting efforts to prevent future invasions through scientific and policy research on vectors and the control of vectors; (2) developing an effective regional monitoring program to identify new invasions and track the spread of nonindigenous species that are present in the region; (3) understanding how factors in the environment affect the success of invasions; (4) assessing the impacts of invasions; (5) prioritizing and assessing efforts to control nonindigenous species that are present in the region. Proposals in several of these areas are being submitted in the current funding cycle.

## Project Description and Approach

The transport of organisms across and between oceans in ships' ballast water is probably the largest vector for the introduction of exotic freshwater and estuarine organisms operating today. Assessing the risks, possible mechanisms for control, and the costs of control of this vector in the Estuary requires knowledge of the types, abundances, and sources or organisms being transported into the Estuary. To date there has been no biological sampling of the ballast water imported into the Bay/Delta system.

This project will directly measure the patterns of release and invasion of nonindigenous species associated with ballast water of ships arriving in the San Francisco Bay and Delta. More specifically, we will estimate for San Francisco Bay the annual volume of discharged ballast water that originates from foreign ports; the biota (organism density and diversity) associated with this ballast water; the effect of ballast water management (exchange) on release of foreign ballast water and biota; and the patterns of invasion associated with ballast water discharge and ballast water management.

This project operates synergistically and collaboratively with on-going research in San Francisco Bay, Chesapeake Bay, and nationally to address key management issues as well as basic questions concerning marine invasion processes. Our current research is now measuring (1) national shipping traffic and ballast management patterns, (2) biological characteristics of ballast water arriving to the Chesapeake Bay and Prince William Sound, and (3) previous patterns of invasion in San Francisco Bay, Chesapeake Bay, and Prince William Sound. This project will first examine the relationship(s) between ballast water delivery and invasion in the San Francisco Bay, assessing the effect of changing ballast water supply on invasion over time. However, through these other programs, we will also test the relationship(s) between ballast water supply and invasion among estuaries across the nation. This is a key step toward assessing the effectiveness of ballast management practices in limiting future invasions, and it will begin to test for variation in the susceptibility of different estuaries to invasion.

Proposed Research

The overall objective of this project is to measure the effect of ballast management practices on the delivery and subsequent invasion of San Francisco Bay and other estuaries by nonindigenous species. We will: (1) measure changes in the volume of foreign ballast water and its biota associated with changes in ballast management (exchange) over time; (2) measure the rate of new invasions that occur over the same time period. These data for San Francisco Bay, combined with similar data for Chesapeake Bay and Prince William Sound, will allow us to test the relationships between ballast water delivery and invasion. More specifically, we will test the following hyptheses:

- Ballast water exchange reduces the density and diversity of foreign biota arriving to estuaries;
- An increase in ballast water exchange will result in a decrease rate of new invasions;
- Significant variation exists in the rate of new invasions among estuaries that is independent of supply (of organisms), indicating some sites are more susceptible to invasion;
- Among estuaries, San Francisco Bay is the most susceptible to new invasions when controlling for supply.

Methods

Our approach combines a synthesis of shipping traffic and ballast water delivery from existing data with direct measures of ballast water biota and invasion rates in the field. We will use methods already developed and successfully implemented by the Principal Investigators (e.g., Cohen and Carlton 1996, Smith et al. 1996, Ruiz et al. 1997), and these are described below.

To estimate cumulative volumes of foreign ballast water arriving to ports over time, including the changes due to ballast water exchange, we will measure the number of vessels arriving (by vessel class and origin) and the volume of ballast water released per vessel class in San Francisco Bay; similar measures will be taken

in existing research programs by Ruiz in Chesapeake Bay and Prince William Sound. First, for each class of vessel (e.g, bulk carrier, RoRo, etc.), we will obtain records of all arrivals and the their port of origin. These data are available directly from local maritime exchanges. Second, we will characterize the amount of ballast water released to each port by origin, age, and vessel class. This will involve direct boarding of vessels to interview the captain, mate, or engineer on vessels about the quantity and history of their ballast water. These data will be collected by the U.S. Coast Guard and SERC throughout the country, using a random sampling design within each vessel class and port system. In addition, we will collect additional data to both augment and ground-truth these data when boarding vessels to sample ballast water biota (see below).

To measure density and diversity of organisms arriving in ballast, we will sample the ballast water of approximately 30 vessels per year (90 vessels in total) that arrive to San Francisco Bay and Delta ports from overseas. We will restrict our sampling to those vessel classes that routinely release ballast water (most likely bulk carriers and general cargo ships), based upon the above surveys. Furthermore, vessels will be selected for sampling to maximize the number of source regions and transit times available. We expect approximately 50% of these vessels will have exchanged ballast water, based upon our experience in Chesapeake Bay. Our sampling effort will be distributed evenly across seasons, allowing us to test for seasonal patterns in exchange and ballast water biota over time. A similar sampling effort is also underway in Chesapeake Bay and Prince William Sound.

Methods used in biological analyses of ballast water will follow those we developed and applied to our previous and on-going sampling of vessels. These methods are detailed in Smith et al. (1996) and Carlton et al. (1995). Although we will select particular source regions and transit times for sampling, the actual selection of vessels will result from a random selection of vessels that meet these criteria (as above). For each ship sampled, we will follow the protocol below:

1. Sample Collection:
   - Record ballast source: vessel and tank type, last port of origin, voyage duration, amount and origin of ballast.
   - Measure physical variables: temperature, salinity, and oxygen (using YSI meters at surface and 1-5 meters depth.
   - Biological sampling: plankton net tows, pulled vertically for the depth of tank (3-5 replicate tows), using 0.3m dia. plankton net (80micron mesh); samples kept cool with aeration for transport to lab for visual inspection; samples fixed in buffered formalin to be transferred to EtOH after 2-5 days; whole water samples opportunistically to examine microzooplankton; dip-netted samples to collect large macrofauna (e.g., fish, decapods, etc.) that are visually obvious. Preserved samples analyzed in lab under compound microscopes.

2. Biological Analyses:

- Analysis of Live Plankton: If possible, live plankton is examined in fresh samples to characterize health by appearance, morphological damage, swimming behavior, reaction to stimuli; characterization of morphotypes and fragile taxa noted.
- Analysis of Preserved Plankton (tows or whole water): Standard sorting, identification, and enumeration; voucher confirmation by taxonomic experts.

To measure the rate of new invasions, we will conduct two types of surveys. First, for each year, an annual survey of local fouling and float communities will be conducted using two separate methods: (1) Field-based collections from standard stations visited by Cohen and his colleagues over the past 5 years—these collections are described in a separate proposal ("Effects of Flood-year Disturbance on Species and Guild Structure of Invaded Communities") which would continue these field collections through the period of this study. (2) Deployment of standardized settling plates (developed and used by Ruiz in Chesapeake Bay) to quantify abundance and diversity of nonindigenous species associated with fouling communities at many of these same sites. At each site, distributed throughout the Bay and Delta, arrays of settling plates (3PVC and 1 wooden plate, to detect boring organisms) will be suspended from docks @ 1m water depth for 2 months to accumulate "mature" communities for analysis; these plates will be returned to the lab to identify all species and estimate abundance using point-count methods, and total counts for some species. Surveys will be conducted each spring or summer. All nonindigenous species will be preserved and sent to taxonomic experts for verification of identity. Second, throughout the project period, we will compile all new records of invasions that are reported by publications, reports, and various research groups and agencies in the region. A similar, parallel effort is underway in the Chesapeake Bay and Prince William Sound, allowing direct comparisons and tests of our hypotheses across sites (see above).

We will use standard statistical techniques (e.g., ANOVA, linear regression) to test for (a) differences in biota between exchanged and non-exchanged ballast water, (b) a relationship over time between ballast water exchange or ballast water biota and invasion rate, (c) a relationship between ballast water volume/biota and invasion rate across sites, and (d) differences in the rate of invasions (=susceptibility) while controlling for supply.

**Location/Geographic Boundaries**

This project will sample and analyze ballast water from ships calling at ports in the San Francisco Estuary, including freshwater ports (Sacramento and Stockton) and brackish/salt water ports (which are found from Suisun Bay to the South Bay).

**Expected Benefits**

Past introductions of nonindigenous species have affected all of the priority habitats and probably affected many of the priority species listed by CALFED (although these

interactions have not been well studied), and future introductions occurring through ballast water discharges could affect any of the priority species and most or all of the priority habitats. As this project provides information and analysis that is needed for efforts to prevent or reduce introductions via ballast water discharges, it will be of benefit to these habitats and species.

**Background and Biological/Technical Justification**

The worldwide transfer and introduction of nonindigenous species by human activities is fundamentally changing marine and estuarine communities. For example, we now know of approximately 400 nonindigenous marine and estuarine species for the coastal U. S., and over 200 of these occur in the San Francisco Bay estuary alone (Cohen and Carlton 1996). Some of these species are having significant impacts on natural resources and ecosystems, imposing economic losses on industry and fisheries, and creating threats to human health. Although the full extent of invasion impacts remains poorly resolved, we surmise that the cumulative impacts on invaded communities rival or exceed those of other anthropogenic changes.

It is clear that invasions have occurred in most global regions, but there is considerable variation in the number of known invasions among regions and estuaries (Ruiz et al. 1997a). More nonindigneous species have been reported for San Francisco Bay than any other estuary in the world, and the total number exceeds that currently known from other estuaries by 80 to 140 species, depending on the estuary.

The reason for this variation is unclear. It may result from among-estuary differences in (a) the supply of nonindigneous species or (b) the susceptibility to invasion. These are not mutually exclusive hypotheses and may both contribute to patterns of spatial variation for invasions. Historically, many human activities have contributed to the transfer of nonindigenous species in marine environments, and the extent and relative importance of each transfer mechanism may have played an important role in patterns of invasion.

Today, the global movement of ballast water by ships appears to be the single largest vector for the transfer of nonindigneous marine species. In 1991 alone, U.S. ports received an estimated 79 million metric tons of ballast water from foreign ports (the equivalent of 2.4 million gallons/hr; Carlton 1995). Ballast water consists of water pumped into dedicated tanks or cargo holds for trim and stability during oceanic voyages. Ballast water often originates from a port (i.e., bay or estuary), with water containing a rich diversity of planktonic organisms. Ballast water is discharged into receiving ports when loading or delivering cargo, inoculating the ecosystem with nonindigenous species. If plankton is viable and becomes established, these organisms can cause major ecological and economic disruptions in the recipient ecosystem, with numerous examples in San Francisco Bay, Chesapeake Bay, the Great Lakes, and elsewhere.

The National Invasive Species Act of 1996 (NISA), passed by the U.S. Congress, has singled out ballast water as a major cause of biological invasions and proposes specific management strategies to limit the rate of future invasions. Specifically, NISA will encourage ballast water management that involves ballast water exchanage: replacement of foreign coastal water and it's plankton with oceanic water, reducing the liklihood of successful invasions. As part of NISA, the U.S. Coast Guard and the Smithsonian Environmental Research Center (SERC) will measure the volume of ballast water and rate of ballast water exchange on vessels arriving to San Francisco Bay and elsewhere. This backgound of information on arrivals and ballast water exchange, combined with active research programs in the San Francisco Bay and Chesapeake Bay regions, provides an exceptional opportunity to measure (1) the relationship between supply and invasion rate of nonindigenous species and (2) the effectiveness of ballast water exchange in reducing the rate of new invasions.

**Proposed Scope of Work**

The work described under "Project Description and Approach" will be conducted over a three-year period. The first phase (3 months) will consist of making arrangements for boarding and sampling ships, setting up the laboratory, and manufacturing and field esting the settling plate arrays. The second phase (27 months) will consist of ballast and field sampling. The third phase (6 months) will consist of completing the taxonomic work, andata analysis, and writing the report.

For the first two years we will provide an annual progress report to CALFED on the ballst water sampling program and settling plate survey, and a final report at the end of the third year.

**Monitoring and Data Evaluation**

Annual reports and the draft final report will be submitted to researchers with experience in ballast water sampling and biological invasions for reveiew and comment. In addition, any persons recommended by CALFED will be asked to review these reports. Is is anticipated that articles based on the results of this study will be prepared for submission to peer-reviewed journals.

**Implementability**

As has been our practice in Chesapeake Bay, permission to board and sample the ballast water of arriving ships will be obtained through shipping agents and ships' officers. The principal investigator and ballast water sampling technicians will hold scientific collecting permits (issued by the State of California) for the duration of the project. No other permits are required for this project. There are no other anticipated implementation issues.

## Budget Costs

| Project Tasks — FY1998 | Hrs | Sal & Ben | Overhead | Service | Other Costs | Total Cost |
|---|---|---|---|---|---|---|
| A. Personnel | | | | | | |
| A. Cohen | 365 | 21298 | 11075 | | | 32373 |
| Technician A | 1460 | 46837 | 24355 | | | 71192 |
| Technician B | 1460 | 40982 | 21311 | | | 62293 |
| B. Equipment | | | | | 17200 | 17200 |
| C. Supplies | | | | | 4725 | 4725 |
| D. Travel | | | | 2238 | | 2238 |
| E. Taxonomic Consulting | | | | 7500 | | 7500 |
| F. Publication costs | | | | | | 0 |
| G. SERC subcontract | | | | 25000 | | 25000 |
| TOTAL | | 109117 | 56741 | 34738 | 21925 | 222520 |

| Project Tasks — FY1999 | Hrs | Sal & Ben | Overhead | Service | Other Costs | Total Cost |
|---|---|---|---|---|---|---|
| A. Personnel | | | | | | |
| A. Cohen | 365 | 22364 | 11629 | | | 33993 |
| Technician A | 1460 | 49173 | 25570 | | | 74743 |
| Technician B | 1460 | 43026 | 22374 | | | 65400 |
| B. Equipment | | | | | | 0 |
| C. Supplies | | | | | 5040 | 5040 |
| D. Travel | | | | 2625 | | 2625 |
| E. Taxonomic Consulting | | | | 10500 | | 10500 |
| F. Publication costs | | | | 300 | | 300 |
| G. SERC subcontract | | | | 25000 | | 25000 |
| TOTAL | | 114563 | 59573 | 38425 | 5040 | 217600 |

| Project Tasks — FY2000 | Hrs | Sal & Ben | Overhead | Service | Other Costs | Total Cost |
|---|---|---|---|---|---|---|
| A. Personnel | | | | | | |
| A. Cohen | 365 | 23480 | 12210 | | | 35690 |
| Technician A | 1460 | 51626 | 26845 | | | 78471 |
| Technician B | 1460 | 45187 | 23497 | | | 68684 |
| B. Equipment | | | | | | 0 |
| C. Supplies | | | | | 5040 | 5040 |
| D. Travel | | | | 2177 | | 2177 |
| E. Taxonomic Consulting | | | | 5513 | | 5513 |
| F. Publication costs | | | | 500 | | 500 |
| G. SERC subcontract | | | | 25000 | | 25000 |
| TOTAL | | 120293 | 62552 | 33190 | 5040 | 221075 |

**Budget Explanation**

Equipment

(FY 1998 only)
2 dissecting microscopes @ $7000 ea = $14,000
2 fiber optic light sources @ $600 ea = $1,200
YSI salinity/temperature meter @ $1,000
Oxygen meter with probe @ $1,000
Total FY 1998 =$17,200

Supplies

(Rates estimated for FY 98, assume rate increases of 5%/yr. The amounts to be used are given for a full year: calculate at 75% of these amounts in FY1998, 100% in FY1999, 50% in FY2000)
plankton net, bottles and line @ $1,000/yr
chemical preservatives @ $500/yr
glassware (jars, bottles, aquaria) @ $1,500/yr
photographic film and processing @ $300/yr
micellaneous lab and field supplies @ $500/yr
settlement substrates: $2,500 in yr 1; $500/yr in following years

Travel

(Rates estimated for FY 98, assume rate increases of 5%/yr.)
3500 miles/yr @ $0.30/mile
A. Cohen travel to SERC (1 trip/yr): rt travel @ $500; car rental, 1 wk. @ $250; lodging, 5 nights @ $100; per diem, 5 days @ $30; fuel & tolls @ $50

Taxonomic Consulting

(Rates estimated for FY 98, assume rate increases of 5%/yr. The amount of service needed is given for a full year: calculate at 75% of these amounts in FY1998, 100% in FY1999, 50% in FY2000)
Taxonomic consultation @ $10,000/yr

Subcontract to SERC @ $25,000/yr

Itemized below in separate table.

**Schedule**

Phase 1 (3 months):
Permissions, laboratory set up, settling plate array manufacture & testing.

Phase 2 (27 months):
Ballast water sampling, settling plate survey, taxonomics work, data entry.

Phase 3 (6 months):
Data analysis, preparing final report.

Annual reports will be delivered at 12 and 24 months, final report at 36 months.

| **Budget for Smithsonian Institution** | | | |
|---|---|---|---|
| | **1998** | **1999** | **2000** |
| **A. Personnel** | | | |
| **Salary** | | | |
| 1. Co-PI: Ruiz (1 mo/yr) | (SI Contribution) | (SI) | (SI) |
| 2. Senior Technician (2 mos/yr) | 5,096 | 5,272 | 5,480 |
| 3. Junior Technician (1 mo/yr) | 2,072 | 2,156 | 2,241 |
| Subtotal Salary | 7,168 | 7,428 | 7,721 |
| | | | |
| **Benefits @ 27.1%** | 1,943 | 2,013 | 2,092 |
| | | | |
| **Total Salary + Benefits** | 9,111 | 9,441 | 9,813 |
| | | | |
| **B. Supplies** | 1,379 | 967 | 503 |
| | | | |
| **C. Travel** | | | |
| 1. Airfare (6 RT to San Francisco/yr) | 3,000 | 3,000 | 3,000 |
| 2. Car Rental (4 weeks/yr) | 1,000 | 1,000 | 1,000 |
| 3. Lodging (30d@ $100/d for 3 ind/yr) | 3,000 | 3,000 | 3,000 |
| 4. Per diem (30d@ $30/d x 3/yr) | 2,700 | 2,700 | 2,700 |
| 5. Fuel and tolls | 300 | 300 | 300 |
| Subtotal Travel | 10,000 | 10,000 | 10,000 |
| | | | |
| **D. Publication Costs** | 500 | 500 | 500 |
| | | | |
| **E. Total Direct Costs** | 20,990 | 20,908 | 20,816 |
| | | | |
| **F. Indirect Costs** | | | |
| 1. Overhead 24.87% of Personnel | 2,266 | 2,348 | 2,440 |
| 2. G&A @ 7.5% of Direct Cost + Overhead | 1,744 | 1,744 | 1,744 |
| | | | |
| **TOTAL COST** | 25,000 | 25,000 | 25,000 |

## Applicant Qualifications

A. Andrew N. Cohen

*1. Biosketch*

Dr. Cohen received an M. S. and Ph. D. in Energy and Resources from the University of California at Berkeley. He is the author of a 1995 USFWS report on nonindigenous species in the San Francisco Estuary and of papers on other aspects of marine and aquatic invasions. Dr. Cohen has also worked on and written about water system planning and economics, public health and contaminants in fish, and environmental mitigation; and has written articles and books for the general public on water and environmental policy and history. His work on invasions in the Estuary was profiled last year in the *New York Times* Science Page, and he was recently nominated to co-chair the Western Regional Panel on Aquatic Nuisance Species. He currently directs the San Francisco Estuary Institute's research program on biological invasions.

*2. Relevent Recent Publications*

Carlton, J. T. and A. N. Cohen. Episodic global dispersal in shallow water marine organisms: The case history of the European green crab *Carcinus maenas, J. Biogeogr.* (in press).

Cohen, A. N. The exotic species threat to California's coastal resources, *Proc. California and the World Ocean '97 Conference,* March 24-27, 1997, San Diego CA (in press).

Cohen, A. N. The invasion of the estuaries. *Proc. 2nd International Spartina Conf.,* Mar. 20-22, 1997, Olympia WA (in press).

Carlton, J. T. and A. N. Cohen. Periwinkle's progress: The Atlantic snail *Littorina saxatilis* establishes a colony on Pacific shores, *Veliger* (in press).

Cohen, A. N. and J. T. Carlton. Transoceanic transport mechanisms: The introduction of the Chinese mitten crab *Eriocheir sinensis* to California, *Pac. Sci.* 51(1): 1-11, 1997.

Cohen, A. N. Biological invasions of the San Francisco Bay and Delta, *Proc. Nat'l Forum on Nonindigenous Species Invasions in U. S. Marine and Fresh Waters,* U. S. Capitol Building, Washington DC, Mar. 22, 1996.

Cohen, A. N. and J. T. Carlton. *Nonindigenous Aquatic Species in a United States Estuary: A Case Study of the Biological Invasions of the San Francisco Bay and Delta.* U. S. Fish and Wildlife Service, Washington DC, Dec. 1995.

Cohen, A. N., J. T. Carlton and M. C. Fountain. Introduction, dispersal and potential impacts of the green crab *Carcinus maenas* in San Francisco Bay, California, *Mar. Biol.* 122: 225-237, 1995.

*3. Relevant Testimony*

San Francisco Bay Regional Water Quality Control Board, Jan. 22 1997: Testimony on biological invasions in San Francisco Bay.
California State Water Resources Control Board, Oct. 5, 1994: Testimony on biological invasions in California waters.

*4. Project Sampling*

Cohen will be responsible (with SERC assistance) for setting up a ballast sampling laboratory and managing the ballast sampling program in the San Francisco Bay Area, for o-ordinating the program for comparability in methods and analysis with Chesapeake Bay and Prince William Sound programs, and for managing the writing of the annual and final reports for delivery to CALFED.

B. Gregory M. Ruiz

*1. Biosketch*

EDUCATION:

B.A., University of California, Santa Barbara, CA, 1980
Ph.D., Zoology, University of California, Berkeley, CA, 1987

EXPERIENCE:

Research Assistant, Bodega Marine Laboratory, University of California, Bodega Bay, California, 1980-1981.
Laboratory & Teaching Assistant, University of California, BBodega Marine Laboratory and Berkeley, California, 1982-1986.
Postdoctoral Research Associate, Friday Harbor Laboratories, University of Washington, Friday Harbor, Washington, 1987-1988.
Postdoctoral Research Associate, Oregon Institute of Marine Biology, University of Oregon, Charleston, Oregon, 1988-1989.
Visiting Instructor, Oregon Institute of Marine Biology, University of Oregon, Charleston, Oregon, 1989 and 1994 (summers).
Staff Scientist, Smithsonian Environmental Research Center, Edgewater, Maryland, 1989-present.

RESEARCH INTERESTS:

Invasion biology, including especially patterns invasion and impacts. Ecological parasitology and the role of parasites in host population dynamics and evolution. Population and community ecology of marine invertebrates. Predator-prey interactions with emphasis on prey population dynamics and behavoral responses of prey to predators. Larval recruitment of marine invertebrates.

PROFESSIONAL ACTIVITIES:

Member: American Society of Parasitologists, British Ecological Society, Ecological Society of America, Estuarine Research Federation, Wader Study Group. Committees: Institutional Animal Care & Use Committee, Smithsonian Environmental Research Center (1994-); BallastWater Work Group, Chesapeake Bay Commission (1994); Exotic Species Work Group, U.S. EPA Chesapeake Bay Program (1994). Reviewer (Journals): Auk, Canadian Journal of Zoology, Conservation Biology, Coral Reefs, Journal of Experimental Marine Biology and Ecology, Marine Biology, Marine Ecology Progress Series,Wader Study Group Bulletin (North American Editor 1987-1995).

RELEVANT PUBLICATIONS (5 Recent):

Ruiz, G.M., J.T. Carlton, E.D. Grosholz and A.H. Hines. 1997. Global invasions of marine and estuarine habitats by non-indigenous species: Mechanisms, extent, and consequences. Am. Zool. (in press).

Geller, J.B., E. Walton, E. Grosholz, and G. Ruiz. 1997. Cryptic invasion of Carcinus based upon molecular phyologeography. Molecular Ecol. (in press).

Grosholz, E.D. and G.M. Ruiz. 1996. Predicting the impact of introduced species: lessons from the multiple invasions of the European green crab. Biol. Conserv. 78:59-66.

Ruíz, G.M., P.F. Fofonoff, A.H. Hines, A. F. VonHolle, and L.D. McCann. 1997. Analysis of nonindigenous species invasions of the Chesapeake Bay (USA). Part I. Report to U.S. Fish and Wildlife Service, 298pp. (in review).

Smith, L.D., M.J. Wonham, L.D. McCann, D.M. Reid, G.M Ruiz, and J.T. Carlton. 1996. Biological invasions by nonindigenous species in U.S. waters: Quantifying the role of ballast water and sediments. Final report to U.S. Coast Guard and Dept. of Transportation, 130pp.

*2. Experience with Related Projects.*

Over the past 8 years, Ruiz has developed and heads a large, collaborative research program at the Smithsonian Environmental Research Center (SERC) to address a broad range of issues in marine and

estuarine invasion biology. SERC is located on Chesapeake Bay, near the middle of the U.S. Atlantic coast, and its invasion ecology program has focused much of its attention to date on the Chesapeake as a model system to examine patterns and mechanisms of invasion. A core group of approximately 10 researchers is based at SERC, and has developed collaborative research programs with others regionally, nationally and internationally. For example, within the U.S., Ruizís program has active research projects in Alaska, California, Florida, and Massachusetts, and it has developed collaborative overseas research in Australia, Israel, Italy, Netherlands, and New Zealand.

SERC has the largest ballast water research program in the country. A large component of SERCís invasion research examines the volume, content, dynamics, and management of ballast water, as well as resutling invasions. As a result of this research, we now know more about ballast water delivery patterns, associated biota, and management for ships entering Chesapeake Bay than anywhere else in the U.S., and perhaps the world. A brief outline of this ballast research is provided below:

Ballast Water Management and Delivery Patterns

- Characterized the cumulative volume, source regions, and ballast exchange rates for commercial vessels arriving to Chesapeake Bay (1993-1997)
- Characterized the cumulative volume, source regions, and ballast management practices for U.S. Navy vessels arriving to Chesapeake Bay (1995-1997)
- Initiating program with U.S. Coast Guard to measure frequency of ballast water exchange on commercial vessels arriving from overseas to ports throughout the U.S. (1997)

Ballast Water Content

- Measured physical attributes and biological (esp. plankton) content of ballast water of approximately 150 commercial ships and 30 U.S. Navy vessels arriving to Chesapeake Bay (1993-1997)
- Initiating program to measure content of ballast water of commercial vessels arriving to ports in Alaska (1997)
- Measured survival of organisms, comparing initial versus final densities, in ballast water on commercial and military vessels (n=15) arriving to Chesapeake Bay from Germany, Israel, Italy, Netherlands, Spain and from domestic ports (1995-1997)
- Tested ability of organisms arriving in ballast water from foreign ports to survive and reproduce in laboratory conditions (temperature and salinity) that mimic local field conditions (1995-1997)
- Tested the efficiency of ballast water exchange in removing entrained plankton and introduced tracers from ballast tanks on commercial and military vessels (n=6) (1996-1997)

Patterns of NIS Invasion

- Documenting the history and mechanisms of NIS invasion for the Chesapeake Bay to include all major taxonomic groups that includes creation of detailed database on the biology, distribution, ecology, and impact of each species (see attached) (1995-1997)
- Documenting the history and mechanisms of NIS invasion for the Indian River Lagoon (Florida) that includes these same elements (1996-1997)

3. *Project Responsibilities*

Ruiz will be involved in all aspects of design, implementation, and analysis. Ruiz and SERC will have primary responsibility for initiation of ballast sampling program, and especially training of project technicians in San Francisco Bay. In addition, Ruiz and SERC will participate fully in surveys of San Francisco Bay, and will continue parallel research programs at Chesapeake Bay and Prince William Sound locations.

Item 8

# NONDISCRIMINATION COMPLIANCE STATEMENT

COMPANY NAME

SAN FRANCISCO ESTUARY INSTITUTE

The company named above (hereinafter referred to as "prospective contractor") hereby certifies, unless specifically exempted, compliance with Government Code Section 12990 (a-f) and California Code of Regulations, Title 2, Division 4, Chapter 5 in matters relating to reporting requirements and the development, implementation and maintenance of a Nondiscrimination Program. Prospective contractor agrees not to unlawfully discriminate, harass or allow harassment against any employee or applicant for employment because of sex, race, color, ancestry, religious creed, national origin, disability (including HIV and AIDS), medical condition (cancer), age, marital status, denial of family and medical care leave and denial of pregnancy disability leave.

## CERTIFICATION

*I, the official named below, hereby swear that I am duly authorized to legally bind the prospective contractor to the above described certification. I am fully aware that this certification, executed on the date and in the county below, is made under penalty of perjury under the laws of the State of California.*

OFFICIAL'S NAME

Margaret R. Johnston

DATE EXECUTED

July 25, 1997

EXECUTED IN THE COUNTY OF

Contra Costa County

PROSPECTIVE CONTRACTOR'S SIGNATURE

PROSPECTIVE CONTRACTOR'S TITLE

Executive Director

PROSPECTIVE CONTRACTOR'S LEGAL BUSINESS NAME

San Francisco Estuary Institute