



IN REPLY REFER TO:

United States Department of the Interior

FISH AND WILDLIFE SERVICE

FI-169

JUL 30 1997

1

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,

Pat Wayne S. White
Field Supervisor

CC: San Francisco Estuary Institute, Richmond, California

a. Project Title: Exotic Species Invasions and the Changing Biodiversity of the San Francisco Estuary: Developing the Information Resources

Applicant's Name: The San Francisco Estuary Institute. 97 JUL 28 PM 2: 57

Principal Investigator: Dr. Andrew Cohen, SFEI; Dr. James T. Carlton, Williams College.

b. Project Description and Objectives. The overall goal of the project is to locate, identify, assess, compile and describe information resources that will enable researchers to track changes over historic time in the Estuary's biota, including the establishment and spread of exotic species and shifts in the relative abundance of native and exotic species. The information resources that will be the focus of this project are of two main types: (1) biological material that has been collected from the Estuary; and (2) the observations and unpublished field notes on the Estuary made by biologists who worked in the Estuary in the 1930s, 1940s and 1950s. These information resources will be described or compiled and made available to researchers, institutions and the general public through published documents and the internet.

c. Approach/Tasks/Schedule. Regarding biological material, the main tasks to be completed include surveying researchers, curators and others regarding the whereabouts of material from the Estuary; visiting museums and other repositories in order to examine and assess this material; and organizing the information on this material and making it available through a guidebook and web site.

Regarding observations and field notes, the main tasks to be completed include interviewing key biologists who worked in the Estuary in the 1930s, 1940s or 1950s; photocopying their field notes; transcribing the interview tapes and key portions of the field notes; providing copies of the tapes and transcriptions to libraries; and publishing a summary and abstract of the interviews.

This is a two-year project. The guidebook will be completed within 18 months, the web site, bound transcripts, and summary and abstract within 24 months.

d. Justification for Project Funding by CALFED. In recent work we documented more than 200 introduced invertebrates, fish, plants and microorganisms that had become established in the Estuary (Cohen and Carlton 1995). For many if not most of these organisms, information on their arrival and spread was developed from unpublished material or personal communications of observations, or from re-examination of archived material collected from the Estuary. Material and information of this sort is scattered in museums and other repositories around the country; while much important information on the past state of the Estuary is preserved only in the memories of older biologists and has never been written down. It became clear that while there is a tremendous amount of useful information to be gleaned from these sources, it is difficult to access and in some cases in imminent danger of being lost. This project will take important and urgently-needed steps toward preserving this information, organizing it and making it more available to biologists and others with an interest in the Estuary. What is at stake is information that is essential to understanding the patterns and impacts of biological invasions and other stressors in the Estuary, and the patterns of change in the Estuary's biota.

e. Budget Costs and Third Party Impacts. The total cost of this project is \$321,136, of which \$192,593 is budgeted for the first year and \$128,543 for the second 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. The Institute conducts or provides science support for four major programs: the San Francisco Estuary Regional Monitoring Program for Trace Substances, the Bay Area Wetlands Ecosystem Goals Project, the Bay Area Watershed Science Program, and the Biological Invasions Program.

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; (3) understanding how factors in the environment affect the success of invasions; (4) assessing the impacts of invasions; and (5) developing, prioritizing and assessing methods to control nonindigenous species.

Dr. Andrew N. Cohen directs SFEI's research program on biological invasions. He is the co-author of the 1995 USFWS report on nonindigenous species in the San Francisco Estuary and of papers on other aspects of marine and aquatic invasions. He has written numerous articles for the general public on water and environmental policy, a guide to the ecology of the San Francisco Estuary, and a book on the history of Carquinez Strait. Dr. Cohen has worked on and written about water system planning and economics, public health and contaminants in fish, and environmental mitigation. His work on biological 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.

Dr. James T. Carlton is the Director of the Maritime Studies Program at Williams College-Mystic Seaport, which offers an undergraduate academic program in the Science, Policy, Literature and History of the Sea. He has studied the changing biodiversity of the San Francisco Estuary for over 30 years, and was co-editor of *Light's Manual*, the main taxonomic guide to marine invertebrates on the California coast. He is internationally recognized for his work on aquatic biological invasions, marine biodiversity, and marine extinctions. Recent national and international positions include: Co-Chair, Committee on Biological Diversity in Marine Systems, National Academy of Sciences/National Research Council (1993-1995); Chair, Working Group on Introductions and Transfers of Marine Organisms, International Council for the Exploration of the Sea (ICES) (1991-); Committee on Ships' Ballast Operations, Marine Board, National Academy of Sciences/National Research Council (1994-1996); U. S. Delegation to the Marine Environmental Protection Committee (MEPC) of the United Nations International Maritime Organization (1995-); Pacific Science Council, National Academy of Sciences/National Research Council (1997-). Honors received include: Fellow, American Association for the Advancement of Science (1994); Distinguished Research Fellow, U. C. Bodega Marine Laboratory (fall 1996); and Pew Fellow in Environment and Conservation (1996-99).

- g. Monitoring and Data Evaluation.** The drafts descriptions of biological material will be submitted to the museum or other repository that possesses or owns the material to be reviewed for accuracy and completeness before publication in the guide book. The draft summary and abstract of each interview will be submitted to the interviewee to review for accuracy.
- h. Local Support/Coordination with other programs/Compatibility with CALFED objectives.** This project will help to preserve and make available information that is essential to understanding past patterns and impacts of exotic species invasions and other stressors, to determining how the Estuary's biota has changed as a result of these stressors, and to assessing previous states of the Estuary that may guide us in setting goals for restoration. The information developed by this project will augment historic information that was gathered for the EcoAtlas and could be incorporated in the EcoAtlas, and will be of use to the Ecosystem Goals Project.

**Exotic Species Invasions and the Changing Biodiversity of the
San Francisco Estuary: Developing the Information Resources**

Principal Investigators: Andrew N. Cohen
San Francisco Estuary Institute
1325 South 46th Street
Richmond, CA 94804
phone: (510) 231-9423
fax: (510) 231-9414
email: acohen@sfei.org

James T. Carlton
Director, Maritime Studies Program
Williams College-Mystic Seaport
Mystic, CT 06355-0990

Organization Type: Nonprofit research institute
503(c)(3) nonprofit organization

Tax identification number: 94-2951373

Contact person: Andrew N. 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, some of which have had substantial impacts on native species (Cohen and Carlton 1995). 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 have affected all of the priority habitats listed in this RFP. Negative interactions with exotics that have been suggested as impacting priority species include predation (salmon, Delta smelt), competition (splittail), hybridization (Delta smelt), interference with migration (salmon) and creating a contaminant pathway (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; (3) understanding how factors in the environment affect the success of invasions; (4) assessing the impacts of invasions; (5) developing, prioritizing and assessing methods 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 overall goal of the project is to locate, identify, assess, compile and describe information resources that will enable researchers to track changes over historic time in the Estuary's biota, including the establishment and spread of exotic species and shifts in the relative abundance of native and exotic species. The information resources that will be the focus of this project are of two main types: biological material that has been collected from the Estuary; and the observations and unpublished field notes of biologists who worked in the Estuary in the 1930s, 1940s and 1950s. These information resources will be described or compiled and made available to libraries, museums, researchers and the general public through published documents and the internet.

Methods—Biological Material

This portion of the project will locate, identify, assess and describe the biological material that has been collected and archived from the San Francisco Estuary,

including collections held by museums, schools and resource agencies and significant personal collections held by scientists and other individuals. This will be accomplished by:

- 1) Surveying (by letter and/or by telephone or personal interview) curators of museum collections, academic and agency taxonomists and ecologists, biological consulting firms, malacological and botanical societies, and other individuals and groups who may have or may know the whereabouts of collections of biological material from the Estuary. An effort will be made to comprehensively catalogue all significant collections of material made prior to 1970, and key material collected since.
- 2) Visiting museum and other facilities to examine these collections, verify their identify, and assess and compile information on the type, quantity and condition of material, the extent to which organisms have been identified, whether the material is being maintained or is deteriorating, and any other relevant matters, as well as recording any identifying numbers, recording dates and location of collection, name of collector, and references to published papers based on the collection, and copying any relevant accompanying notes or references. It is anticipated that in addition to visiting repositories in California, that several days will be spent at each of the following institutions examining their collections: the National Museum of Natural History at the Smithsonian Institution in Washington DC; the Academy of Natural Science in Philadelphia PA; the American Museum of Natural History in New York; the Peabody Museum of Natural History at Yale University in New Haven CT; and the Museum of Comparative Zoology at Harvard University in Cambridge MA.
- 3) On these visits museum curators and scientists will be interviewed in person regarding the existence and whereabouts of additional material that should be included in this assessment, until all obvious sources of information and material have been tapped.
- 4) This information will then be assembled and indexed in a guide book to the biological material collected from the Estuary. This guide will be printed and bound in hardcover, with copies provided to institutions and individuals that provided access to their collections and to other appropriate institutions, and the remainder sold at the cost of production, with funds used as discussed below.
- 5) The information in the guidebook will also be made available to reseachers and the public on a searchable web site. Any funds received from the sale of the books produced by this project will be used to help pay for periodic updating or expansion of the information available on the site, with additional funds sought as needed.

Methods—Observations and Field Notes

The project will interview key academic and agency biologists who worked in the Estuary in the 1930s, 1940s or 1950s, in order to assemble information on the changing biota and environmental conditions in the ecosystem over that period and up to the present. The interviews will be conducted by the principal investigators, allowing knowledgeable probing of these scientists' recollections. Their field notes on the biota in the Estuary will be photocopied and reviewed, and copies made of illustrations or photographs that provide useful information on the historic biota or environmental conditions in the Estuary.

The interviews will be recorded and transcribed. Field notes judged to be of particular significance will also be transcribed. Copies of the interview tapes and hardbound copies of the entire transcripts and relevant supporting material will be produced and provided to key libraries in the Bay/Delta region.

The principal investigators will prepare an abstract and summary of the interviews. This will be printed and bound in hardcover, with copies provided to the interviewees and to appropriate institutions, and the remainder sold at the cost of production with funds used for updating and expanding the web site, as noted above.

Location/Geographic Boundaries

This research will locate, identify, assess, compile and/or describe information resources that deal with changes in biodiversity throughout the Estuary.

Expected Benefits

Stressors. By locating, identifying and assessing biological materials and developing and compiling information on historical changes in biodiversity, this project will provide a base of information from which to assess the operation and effects over time of all twelve major stressors identified by the CALFED Technical Team Reports and listed in this RFP. Included will be direct, first-hand observations of the operation of these stressors over historical time. This project focuses in part on one major stressor—the introduction, spread and impacts of exotic species—as a direct alteration of biodiversity.

Priority Habitats. This project will provide a base from which to analyze changes in biodiversity, to some extent in all of the priority habitats listed in this RFP, but primarily in the following:

- Tidal perennial aquatic habitat (freshwater)
- Seasonal wetland and aquatic habitat
- Saline emergent wetlands habitat (tidal)
- Midchannel islands and shoal habitat

Benefits. The information on available material collected from the Estuary, and the information on observations by trained biologists in years past will assist in:

- understanding how stressors and the biota have changed over time, and how they have interacted;
- developing a clearer picture in particular of the establishment and spread of exotic species in the Estuary, and of the relationship between the expansion or decline of populations of native and exotic species; and
- determining past levels and patterns of abundance of native and desirable species, to help in setting appropriate restoration goals.

This information will augment other historical data on the Estuary developed in conjunction with the EcoAtlas, and will be of use to the Ecosystem Goals Project.

Background and Biological/Technical Justification

In recent work we documented more than 200 introduced invertebrates, fish, plants and microorganisms that had become established in the Estuary (Cohen and Carlton 1995). For many if not most of these organisms, the information on their arrival and spread was developed from unpublished material or personal communications of observations, or from re-examination of archived material collected from the Estuary. Material and information of this sort is scattered in museums and other repositories around the country; while much important information on the past state of the Estuary is preserved only in the memories of older biologists and has never been written down. It became clear that while there is a tremendous amount of useful information to be gleaned from these sources, it is difficult to access and in some cases in imminent danger of being lost. This project will take important and urgently-needed steps toward preserving this information, organizing it and making it more available to biologists and others with an interest in the Estuary. What is at stake is information that is essential to understanding the patterns and impacts of biological invasions and other stressors in the Estuary, and the patterns of change in the Estuary's biota.

Proposed Scope of Work

The proposed scope of work regarding Biological Material is to:

- 1) Locate, identify, assess and describe the biological material that has been collected from the Estuary and retained in museum or other collections, aiming for a comprehensive catalogue of significant collections made prior to 1970 and of key material since.
- 2) Make this information available through a published guide to these resources, and through a searchable web site.

The proposed scope of work regarding Observations and Field Notes is to:

- 1) Interview key biologists who worked in the Estuary in the 1930s, 1940s and 1950s to record their observations on the biota and environmental conditions of the Estuary and on changes over time; and to obtain copies of their field notes on the Estuary.
- 2) Produce transcriptions of these interviews and key portions of the field notes, and produce a summary and abstract of the interviews.
- 3) Make this information available by depositing hardbound copies of the full transcriptions and copies of the interview tapes with key libraries in the Bay/Delta region, and by publishing the summary and abstract of the interviews.

The deliverables will be the guidebook, the interview tapes, the transcripts and the summary and abstract of the interviews. This information will also be disseminated on the internet, as described above.

Monitoring and Data Evaluation

The draft descriptions of biological material will be submitted to the museum or other repository that possesses or owns the material to be reviewed for accuracy and completeness before being published in the guidebook. The draft summary and abstract of each interview will be submitted to the interviewee to check for accuracy.

Implementability

There are no anticipated implementation issues. No permits are required for this work.

Literature Cited

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*. U. S. Fish and Wildlife Service and National Sea Grant College Program/Connecticut Sea Grant, Washington DC.

Budget Tables

TASK 1 BIOLOGICAL MATERIAL	Direct Hours	Direct Salary & Benefits	Overhead	Service Contracts	Other Direct Costs	Total Cost
YEAR 1						
Task 1a: Research						
Andrew Cohen	160	9,336	4,855			14,191
James Carlton	60		300	3,000		3,300
Analyst 3	1,220	39,138	20,352			59,489
Analyst 2	730	17,564	9,133			26,697
Equipment					5,000	5,000
Supplies					500	500
Travel					14,570	14,570
Communications					1,000	1,000
YEAR 2						
Task 1b: Report						
Andrew Cohen	80	4,901	2,549			7,450
James Carlton	80		420	4,200		4,620
Analyst 3	480	16,168	8,408			24,576
Supplies					500	500
Indexing			200	2,000		
Travel					1,350	
Publication					10,000	10,000
Web Site					2,000	2,000
SUBTOTAL - TASK 1/YR 1		66,037	34,639	3,000	21,070	124,747
SUBTOTAL - TASK 1/YR 2		21,070	11,576	6,200	13,850	49,146
SUBTOTAL - TASK 1/YR 1+2		87,107	46,216	9,200	34,920	173,893

TASK 2 OBSERVATIONS AND FIELD NOTES	Direct Hours	Direct Salary & Benefits	Overhead	Service Contracts	Other Direct Costs	Total Cost
YEAR 1						
Task 2a: Research						
Andrew Cohen	280	16,338	8,496			24,834
James Carlton	140		700	7,000		7,700
Analyst 2	180	4,331	2,252			6,583
Equipment					1,000	1,000
Supplies					500	500
Travel					9,730	9,730
Communications					1,000	1,000
Transcription			1,500	15,000		16,500
YEAR 2						
Task 2a: Research						
Andrew Cohen	200	12,254	6,372			18,625
James Carlton	100		525	5,250		5,775
Supplies					500	500
Travel					7,526	7,526
Communications					800	800
Transcription			1,000	10,000		11,000
Task 2b: Report						
Andrew Cohen	160	9,803	5,097			14,900
James Carlton	80		420	4,200		4,620
Travel					1,350	1,350
Indexing			300	3,000		3,300
Publication					11,000	11,000
SUBTOTAL - TASK 2/YR 1		20,669	12,948	22,000	12,230	67,847
SUBTOTAL - TASK 2/YR 2		22,056	13,714	22,450	21,176	79,397
SUBTOTAL - TASK 2/YR 1+2		42,725	26,662	44,450	33,406	147,243

TASKS 1 + 2 TOTALS	Direct Hours	Direct Salary & Benefits	Overhead	Service Contracts	Other Direct Costs	Total Cost
SUBTOTAL - TASK 1+2/YR 1		86,706	47,587	25,000	33,300	192,593
SUBTOTAL - TASK 1+2/YR 2		43,126	25,291	28,650	35,026	128,543
TOTAL - TASKS 1+2/YR 1+2		129,832	72,878	53,650	68,326	321,136

Budget Explanation

Year 1 rates: car rental @ \$50/day or \$250/wk
 fuel & tolls @ \$10/day
 lodging @ \$100/day for 1-2 people
 per diem @ \$35/day/person
 mileage @ \$0.30/mile
 Year 2 rates: increase Year 1 rates by 5%

TASK 1a - RESEARCH Year 1 Year 2

Equipment

Computer, etc. 5000

Travel

NMNH, Washington DC (2 trips, 10 days total; air travel: 2@500)
 Harvard, MCZ, Cambridge MA (3 days; air travel: 1@500)
 Yale, Peabody, New Haven CT (5 days; air travel: 1@500)
 AMNH, New York NY (3 days; air travel: 1@500)
 Acad. Nat. Sci., Philadelphia PA (5 days; air travel: 1@500)
 Other (15 days; air travel: 3 @ \$200, 2@500)

air travel-subtotal:	4600
car rental:	1025
fuel & tolls:	410
lodging:	4100
per diem:	1435
mileage: 10,000 mi.	<u>3000</u>
TASK 1a TRAVEL - TOTAL	14570

Communications

database searches, reports, publications, fax, shipping 1000

TASK 1b - REPORT

Travel-Task 1b

air travel: Year 2=1 trip @ \$500	500
lodging: Year 2=6 days	630
per diem: Year 2=6 days	<u>220</u>
Task 1b TRAVEL - TOTAL	1350

Publication

production of 500 hardbound copies of the guide book (@ \$20)
 for distribution to libraries, museums and researchers 10,000

Web Site

making the report available as a searchable database on
 the internet 2000

TASK 2a – RESEARCH	<u>Year 1</u>	<u>Year 2</u>
<u>Equipment</u>		
Recording equipment	1000	
<u>Travel</u>		
Year 1 rates: air travel for Task 2a @ avg rt of \$400		
car rental @ \$50/day or \$250/wk		
fuel & tolls @ \$10/day		
lodging @ \$100/day for 1-2 people		
per diem @ \$35/day/person		
mileage @ \$0.30/mile		
Year 2 rates: increase Year 1 rates by 5%		
air travel: Year 1=10 trips; Year 2=8 trips	4000	3360
car rental: 2 weeks each year	500	525
fuel & tolls: 12 days each year	120	126
lodging: Year 1=30 days; Year 2=20 days	3000	2100
per diem: Year 1=50 days; Year 2=30 days	1750	1100
mileage: Year 1=1200 mi.; Year 2=1000 mi.	<u>360</u>	<u>315</u>
Task 2a TRAVEL - TOTAL	9730	7526
<u>Communications</u>		
database searches, reports, publications, fax, shipping	1000	1000
 TASK 2b – REPORT		
<u>Travel</u>		
air travel: Year 2=1 trip @ \$500		500
lodging: Year 2=6 days		630
per diem: Year 2=6 days		<u>220</u>
Task 2b TRAVEL - TOTAL		1350
<u>Publication</u>		
production of 20 hardbound copies of the entire transcripts (@ \$50) and 500 hardbound copies of the summary (@ \$20) for distribution to libraries, museums and researchers		11,000

Schedule

Task 1: Assess and Describe Biological Material

Begin research at the start date of the project
Complete research by 12 months after the start date of the project
Produce guide book by 18 months "
Produce web site by 24 months "

Task 2: Compile Observations and Copy Field Notes

Begin research at 2 months after the start date of the project
Complete research by 20 months "
Produce bound transcripts by 24 months "
Produce summary and abstracts by 24 months "

Third Party Impacts

No third party impacts are anticipated.

San Francisco Estuary Institute

The San Francisco Estuary Institute (SFEI) is a non-profit research institute charged with fostering scientific understanding of the Estuary. The creation of SFEI responds to a recommendation of the Comprehensive Conservation and Management Plan (CCMP) for the San Francisco Estuary adopted by the Governor of California and the Administrator of the U.S. Environmental Protection Agency in late 1993. The Institute's 22 staffmembers provide an interdisciplinary team of scientists, education specialists, data analysts, and support personnel. The Institute also employs graduate students and undergraduate interns from area Universities. The Institute conducts or provides science support for four major programs: the San Francisco Estuary Regional Monitoring Program for Trace Substances, the Bay Area Wetlands Ecosystem Goals Project, the Bay Area Watershed Science Program, and the Biological Invasions Program.

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) developing, prioritizing and assessing methods to control nonindigenous species that are present in the region.

Current projects of the program include:

- Developing methods for prioritizing efforts to control exotic marsh plants in the Estuary.
- Assessing the potential range and abundance of zebra mussels in California waters.
- Research on the introduction of organisms in the marine baitworm trade.
- Research on the invasion of the California coast by a Japanese foraminifer.
- Developing a regional monitoring plan for exotic organisms.
- Modelling the effect of invasion "incubators" on the success of obligate sexually-reproducing invaders.
- Review of open coast invasions, with a case study of the invasion of the Southern California Bight by a New Zealand sea slug.

Andrew N. Cohen
Environmental Scientist
San Francisco Estuary Institute

Dr. Cohen directs the San Francisco Estuary Institute's research program on biological invasions. He is the co-author of the 1995 USFWS report on nonindigenous species in the San Francisco Estuary and of papers on other aspects of marine and aquatic invasions. He has written numerous articles for the general public on water and environmental policy, a guide to the ecology of the San Francisco Estuary, and a book on the history of Carquinez Strait. Dr. Cohen has worked on and written about water system planning and economics, public health and contaminants in fish, and environmental mitigation. His work on biological 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.

Selected Publications

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).

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. *Gateway to the Inland Coast: The Story of the Carquinez Strait*. California State Lands Commission, Sacramento CA, 1996.

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.

Cohen, A. N. *An Introduction to the Ecology of the San Francisco Estuary*, San Francisco Estuary Project, Oakland, 1990, 1991.

Expert Testimony

San Francisco Bay Regional Water Quality Control Board, Jan. 22 1997: Biological invasions.

California State Water Resources Control Board, Oct. 5, 1994: Biological invasions.

California State Water Resources Control Board, Nov. 13 & 16, 1991: Water system management.

U. S. Senate, Committee on Energy and Natural Resources, Subcommittee on Water and Power, Mar. 18, 1991: Water system management.

James T. Carlton
Director, Maritime Studies Program
Williams College-Mystic Seaport

Dr. Carlton is the Director of the Maritime Studies Program at Williams College-Mystic Seaport, which offers an undergraduate academic program in the Science, Policy, Literature and History of the Sea. He has studied the changing biodiversity of the San Francisco Estuary for over 30 years, and co-edited *Light's Manual*, the main taxonomic guide to marine invertebrates on the California coast. He is internationally recognized for his work on aquatic biological invasions, marine biodiversity, and marine extinctions. Recent national and international positions include: Co-Chair, Committee on Biological Diversity in Marine Systems, National Academy of Sciences/National Research Council (1993-1995); Chair, Working Group on Introductions and Transfers of Marine Organisms, International Council for the Exploration of the Sea (ICES) (1991-); Committee on Ships' Ballast Operations, Marine Board, National Academy of Sciences/National Research Council (1994-1996); U. S. Delegation to the Marine Environmental Protection Committee (MEPC) of the United Nations International Maritime Organization (1995-); Pacific Science Council, National Academy of Sciences/National Research Council (1997-). Honors received include: Fellow, American Association for the Advancement of Science (1994); Distinguished Research Fellow, U. C. Bodega Marine Laboratory (fall 1996); and Pew Fellow in Environment and Conservation (1996-99).

Research Interests

Alterations to marine biodiversity: biological invasions (the ecological and environmental impacts and the biogeography and dispersal mechanisms of introduced species in marine, estuarine and freshwater environments) and marine neoextinctions (the processes controlling, and the diversity of, the extinction of marine organisms (particularly invertebrates) in historical time).

Recent Publications (examples since 1993)

- J. T. Carlton and J. Geller. 1993. Ecological roulette: The global transport and invasion of nonindigenous marine organisms. *Science* 261: 78-82
- J. T. Carlton. 1993. Neoextinctions of marine invertebrates. *American Zoologist* 33: 499-509
- C.A. Butman and J. T. Carlton. 1995. National Research Council, Understanding marine biodiversity: A research agenda for the nation. National Academy Press, Washington, D.C. 180 pp.
- J.T. Carlton, D. M. Reid, and H.van Leeuwen. 1995. Shipping Study. The role of shipping in the introduction of non-indigenous aquatic organisms to the coastal waters of the United States (other than the Great Lakes) and an analysis of control options. The National Sea Grant College Program/Connecticut Sea Grant Project R/ES-6. Department of Transportation, United States Coast Guard, Washington, D.C. and Groton, Connecticut. Report Number CG-D-11-95.
- J. T. Carlton. 1996. Marine bioinvasions: the alteration of marine ecosystems by nonindigenous species. *Oceanography* 9: 36-43.
- J. T. Carlton. 1996. Biological invasions and cryptogenic species. *Ecology* 77: 1653-1655.
- J. T. Carlton. 1996. Pattern, process, and prediction in marine invasion ecology. *Biol. Conserv.* 78: 97-106.

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