Written Testimony of
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To the
U.S. House of Representatives
Subcommittee on Fisheries Conservation, Wildlife, and Oceans
Thursday, 14 November 2002

I am a Senior Scientist at the Smithsonian Environmental Research Center (SERC), where I head the Marine Invasion Research Laboratory – the largest research program in the U.S. to focus on the invasion of coastal ecosystems by non-native species. This research group provides synthesis, analysis, and interpretation of invasion-related patterns on a national scale (see Appendix 1 for further details).

Today, I wish to highlight the current state of knowledge and predictive ability for invasions of marine and freshwater ecosystems. Against this backdrop, I will review key elements and approaches necessary to reduce the risk of new invasions and their unwanted impacts.

Current Knowledge & Predictive Ability

Thousands to tens of thousands of non-native species arrive to U.S. waters each year by myriad human activities, which breach existing geographic barriers to dispersal --- such as ocean basins and continents. Upon delivery and release, a subset of organisms survive local conditions in the recipient environment, a smaller subset become successfully established, and a still smaller subset is known to have significant impacts on economies, ecological functions, fishery resources, and human health.

The rate of newly detected aquatic invasions has increased exponentially in many locations, both within the U.S. and overseas. Many different transfer mechanisms, or vectors, have caused invasions. ***The relative importance of individual vectors has varied geographically and temporally, reflecting differences in vector operation and probable differences in susceptibility of ecosystems to invasion***.

If current practices continue, ***the rate of species transfer is expected to increase even further,*** as existing trade activities expand and new trade activities develop. Invasion rates should increase with increasing rates of transfer.

For example***, the scale of commercial shipping --- a major transfer mechanism, by itself responsible for most known marine invasions --- is projected to increase many fold over the next 20 years***, resulting in more ships, larger ships, faster ships, and more trading partners (sources of invaders). Each of these attributes will likely operate to increase the number of species delivered, and concentrations of organisms (within and across species) associated with shipping. In the absence of management actions, intended to reduce organism transfer, we should expect an increase in invasions to result.

The extent and impact of aquatic invasions have become increasingly clear in the past few decades, warranting the great public concern that has resulted. However, ***there remain some fundamental gaps in knowledge, and especially predictive ability, for invasion ecology that have significant implications for management.***

First, although invasion rates should increase with organism transfer, ***the quantitative "dose-response" relationship --- between the number of propagules (organisms) released and invasion success (establishment) --- is poorly resolved and may vary geographically.***

Second, ***our predictive capability for both unintentional and intentional introductions is very limited at the present time.***

For unintentional introductions, like ship-mediated transfer, it remains extremely difficult to predict which species will invade, when they will invade, where they will invade, and what they will do. The identity of many transferred organisms is still not

resolved. For example, U.S. ports receive approximately 50,000 commercial vessel arrivals per year that originate overseas, a minimum of tens-to-hundreds of species are associated with each ship (in ballast tanks and on hulls), and the species composition is simply not known in advance for any one arrival. Even when identified, key aspects of biology and ecology for many (if not most) species are unknown. Thus, it is often not possible to predict when a species can survive in the recipient environment (i.e., the various aquatic habitats of the U.S.) or how it will perform --- in terms of abundance, spread, and impact. Our predictive capability surrounding unintentional transfers is very limited at the present time.

Even for intentional introductions, a high level of uncertainty can exist about the outcome of introduction. This results from limited information about biology and ecology, but also a fundamental uncertainty about whether behavior (i.e., population dynamics and ecology) in the native range can predict behavior in a novel environmental and biological setting. The current controversy surrounding the Asian oyster *Crassostrea ariakensis* provides an illustrative example. Although under consideration for introduction in Chesapeake Bay, very little information is available on the species, limiting predictions about the possible performance and effects within Chesapeake Bay and the Atlantic coast of North America.

Management of the Shipping Vector

Management of the shipping vector is the most appropriate strategy, as a first step, to reduce aquatic invasions and their impacts for multiple reasons. First, on a national scale, shipping is the largest single source of known invasions, currently and cumulatively, to coastal marine ecosystems and the Great Lakes. Second, in my opinion, ship-mediated introductions --- composed mainly of organisms transferred in ballasted materials and on hulls --- cannot be effectively managed on a species-by-species basis (as outlined above).

Implementation of ballast water management, including ballast water exchange and alternative technologies, should reduce the rate of invasions.

It is however important to recognize some of the possible limitations (or unknown aspects) of ballast management.

- ***Ballast management only addresses a portion of the problem***. For ship-mediated transfer, the relative importance of ships' hulls versus ballast tanks is often not clear --- since some organisms can be transferred by either mode. Although shipping is a dominant vector, other non-shipping vectors are also contributing to invasions.
- ***The level of reduced invasions expected for various management actions is unknown, resulting from uncertainty about the dose-response relationship for invasions***. Although a reduction in invasions should result from ballast water management, we simply don't know "how low to go" in reducing species transfer --- which is a source of uncertainty about the appropriate goal or "standards" for treatments.

These gaps in knowledge underscore the need for research and analyses, which measure (a) changes in species transfer and invasion patterns in response to management actions and (b) provide the scientific understanding of dose-response relationships and invasibility needed to guide management.

The Role of Tracking Ballast Management & Delivery

Measuring changes in the ballast water delivery and management provides one measure of management effect. ***Tracking shipping and ballast discharge patterns for all vessel arrivals --- both those from foreign ports and domestic ports --- should be fully implemented to assess the effect of management on ship-mediated transfer.*** First, reporting by vessels informs us of how ballast water delivery, and arrival of hull surface (as a possible source of organisms), varies among ports and changes over time. Second, measurements of the effect of particular treatments (e.g., ballast water exchange or alternative treatment) on organism transfer, when combined with vessel reporting, provide an important short-term proxy of treatment efficacy --- estimating how overall management practices influence delivery of organisms by shipping.

The Role of Ecological Surveys

By comparison, ecological surveys measure the long-term changes in actual invasions associated with various management schemes.

Ecological surveys (hereafter surveys), using standardized and repeated field measures, are a fundamental building block for invasion science and invasion management --- providing critical information for prevention and control. Surveys are used to assess the following key attributes of invasions in our waters:

- The source(s) of invasions, in terms of geographic origin and mechanism of introduction (or vector);
- How invasion patterns vary in space and time; and
- How effective management actions, including ballast water management, are in reducing the rate of new invasions.

Surveys provide a tracking system to determine which species have colonized, or are in the process of colonizing, our aquatic habitats. With knowledge about the taxonomic identity and biology of these organisms, it is often possible to identify the mechanism or vector of introduction. This tells us which vectors and geographic source regions have resulted in successful invasions, historically and presently.

Analysis of survey data --- the cumulative picture across all non-native species identified --- can be used to estimate the relative importance of vectors or geographic source regions in space or time. Such an assessment of vector importance (possibly by source region) can be used to prioritize where prevention efforts are best directed, to reduce the largest number of future invasions.

Beyond informing and directing initial management actions, ***surveys provide an essential feedback system to assess how well prevention measures work in reducing new invasions***. Although we can assess the change in delivery of organisms by a particular vector, and how this is affected by management actions (as above), this does not tell us the effect of management action(s) on the actual number of invasions. Since we don't know enough about the quantitative "dose-response" relationship between number of organisms delivered and invasion success, it is critical to actually measure the efficacy of management action by invasion rate. Thus, should invasions continue to occur at an unacceptable rate (despite management actions), this indicates that further steps are required.

Susceptibility to Invasion

Surveys also inform our understanding of which ecosystems are most susceptible to invasions, providing key information about dose-response relationships and factors that contribute to invasion resistance. Although invasions can occur in all ecosystems, there is clearly a great deal of variation in the number of established invasions among systems. Analysis of this pattern, using standardized surveys and shipping data (outlined above) across many bays and habitats, can be used to test for correlation with specific biological or environmental characteristics --- elucidating which factors explain most of this variation. This approach can identify a suite of factors that may affect the success or failure of non-native species to establish --- such as salinity regime, habitat disturbance, flow regime, or biological diversity --- and help focus management actions to particular regions or habitats that are most vulnerable.

I recommend this approach (using surveys) to test statistically for factors that influence susceptibility to invasion, combined with an experimental approach. This additional, experimental step is used to test whether there is a cause-effect relationship, or simply an association, between invasion outcome and particular factors. Thus, analyses of actual invasion patterns by surveys are necessary but not sufficient, by themselves, to guide management decisions about susceptibility or resistance to invasions.

In my view, ***experimental measures and field surveys should operate together --- in a well-coordinated fashion under one program, rather than separate programs --- to strengthen the inferences drawn about invasion susceptibility***. This is further enhanced by detailed vector information for the same localities. In the case of the shipping vector, this would include not only ballast discharge and management data (as above) but also some tracking of organism supply characteristics (pathway surveys) for ballast water and hull fouling.

Early Detection – Rapid Response

I would like to draw a distinction between the "ecological surveys" and efforts associated with an "early detection – rapid response system". The former are designed to provide key information about sources and rates of invasion --- across different sites, habitats, and environmental conditions --- and essentially track how sources and rates are changing over time. This information is used to direct and evaluate management actions, focused largely on vectors and pathways of invasion. Although surveys may provide some "early detection capability" this is not the primary goal.

In contrast, ***an "early detection – rapid response system" would require a more focused effort to detect a limited number of known***

"target" species of concern. To have an early warning system would require frequent monitoring of specific habitats for a finite suite of organisms. In my opinion, it is not feasible to monitor for all organisms on a frequent basis --- and allow for rapid response --- due to obvious logistical and cost constraints. The goal of "early detection" is to trigger particular management actions (e.g., eradication, containment, etc.) for the target species. Using a focused list of species for such early warning detection, it is possible presently to locate "sentinel sites" for detection at locations with specific habitat and environmental conditions appropriate for the target species.

Development of some rapid-response capability has merit, but I place a much higher premium on prevention efforts --- including management actions, vector tracking, and ecological surveys (to estimate changes in invasions and efficacy of management actions). This stems from the fact that:

- Early detection will locate only a subset of the target "high-impact" species that colonize;
- The effects of most invasions cannot be adequately predicted at the present time;
- Successful control and eradication will likely be limited to a fraction of those organisms detected.

A list of target "high-impact" organisms can be compiled, based upon experience elsewhere in the world, providing the basis for an early detection system. However, ***a "target list approach" will necessarily include a small subset of future "high-impact" organisms, as many additional species that are ecologically potent (i.e., will have significant impacts) will not appear on any such list*** --- simply because they do not have a previous record of high-impact invasions. Thus, when a new incursion occurs, both for organisms on and off the target list, it will often be difficult to assess the likely impact and to decide on an appropriate trigger for rapid response.

Planned Introductions

There are many species for which planned imports and introductions have received little scrutiny from an invasion perspective. Examples include organisms used for bait or food --- such as the Vietnamese Nereid worm and the Chinese snakehead fish (although importation of the latter has recently been banned, following an invasion in Maryland). In addition, the recent discussion surrounding a possible introduction of the Asian oyster *C. ariakensis* to Chesapeake Bay underscores the lack of a coherent framework or policy surrounding intentional marine introductions.

It is highly desirable to have an established framework for evaluation and approval of intentional introductions that is consistent among geographic regions. This approach recognizes that organisms can spread beyond political boundaries. Ideally, such a framework would include better tracking of imports, which are poorly characterized in terms of quantity, source, and species identity --- making evaluation of invasion risks problematic. In addition, improved information exchange on intentional introductions, especially with the International Council for the Exploration of the Sea (ICES), would be an important improvement.

Conclusion

In my opinion, ***the national strategy for aquatic invasions should focus predominantly on prevention.*** A strong program to reduce future invasions of unwanted species requires: (a) management actions to restrict or interrupt the scale of unintentional transfers, (b) tracking systems to measure the short-term response of management action on transfer, and (c) ecological surveys to assess the efficacy of management actions on invasion patterns and rates, and to identify new vectors as they emerge. A parallel program should exist to rigorously screen intentional (planned) introductions, providing a formal cost-benefit analysis aimed at reducing the likelihood of introduction for "high impact" species and those species for which considerable uncertainty exists about impacts.

Control measures such as mitigation and eradication efforts, including rapid-response, can have merit. However, such measures are idiosyncratic to the target species, the results are somewhat uncertain, and this approach can only hope to address a small subset of problems associated with invasions following establishment. ***As a result, I believe prevention is a more efficient, reliable, and cost-effective strategy to limit invasions and invasion impacts, when compared to control measures, and should be the primary focus for available resources.***

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FIELDS OF INTEREST:

Invasion Biology; population and community ecology; ecological parasitology and the role of parasitism in host evolution; predator-prey interactions; larval recruitment of marine invertebrates.

PROFESSIONAL HISTORY:

1989-Present	Senior Scientist, Smithsonian Environmental Research Center, Smithsonian Institution.
1993-Present	Participating Faculty Member, MEES Program, University of Maryland.
1996-2000	Consultant in Research, Department of Biological Sciences, George Washington University.
1988-1989	Postdoctoral Research Associate, Oregon Institute of Marine Biology, University of Oregon.
1987-1988	Postdoctoral Research Associate, Friday Harbor Laboratories, University of Washington.

SELECTED RECENT PUBLICATIONS (of 36 total):

Ruiz GM & CL Hewitt. In press. Toward understanding patters of coastal marine invasions: a prospectus. In: Invasive aquatic species of Europe (E Leppakoski, S Olenin, & S Gollasch, eds.), Kluwer Academic Press.

Miller AW, CL Hewitt, & GM **Ruiz**. 2002. Invasion success: Does size really matter? Ecology Letters 5: 159-162

Drake LA, K-H Choi, GM **Ruiz**, & FC Dobbs. 2001. Microbial inventories in ballast water of ships arriving in Chesapeake Bay. Biological Invasions 3:193-199.

Ruiz, GM, TK Rawlings, FC Dobbs, LA Drake, T Mullady, A Huq, and RR Colwell. 2000. Worldwide transfer of microorganisms by ships. Nature 408: 49-50.

Ruiz, GM, P Fofonoff, JT Carlton, MJ Wonham, AH Hines. 2000. Invasions of Coastal Marine Communities in North America: Apparent Patterns, Processes, and Biases. Annual Review of Ecology & Systematics 31: 481-531.

Grosholz, ED, GM **Ruiz**, CA Dean, KA Shirley, JL Maron, and PG Connors. 2000. The impacts of a nonindigenous marine predator on multiple trophic levels. Ecology 81: 1206-1224.

Wonham, MJ, JT Carlton, GM **Ruiz**, and LD Smith. 2000. Fish and ships: relating dispersal frequency to success in biological invasions. Marine Biology 136:1111-1121.

Ruiz, GM, P Fofonoff, AH. Hines, and ED. Grosholz. 1999. Nonindigenous species as stressors in estuarine and marine communities: Assessing impacts and interactions. Limnology & Oceanography 44:950-972.

LaVoie, DM, LD Smith, and GM **Ruiz**. 1999. The potential for intracoastal transfer of nonindigenous species in the ballast water of ships. Estuarine Coastal & Shelf Science 48:551-564.

Smith, LD, MJ Wonham, LD McCann, GM **Ruiz**, A.H. Hines and J.T. Carlton. 1999. Invasion pressure to a ballast-flooded estuary and an assessment of inoculant survival. Biological Invasions 1:67-87.

OTHER PROFESSIONAL ACTIVITIES:

Committees: U.S. representative to the Working Group on Introductions and Transfers of Marine Organisms, International Council for the Exploration of the Sea (2001 to present); Scientific & Technical Advisory Committee, U.S. EPA Chesapeake Bay Program (2001- present); Steering Committee for Global Invasive Species Program (1999-2000); Advisory Committee for National Aquatic and Marine Invasion Clearinghouse (1999 to present); Ballast Water Work Group, Chesapeake Bay Commission (1994); Exotic Species Work Group, U.S. EPA Chesapeake Bay Program (1994 to present); Ballast Water and Shipping Committee, Aquatic Nuisance Species Task Force (1997-2001); Steering Committee for Marine Bioinvasions Conference (1999, 2001).

APPENDIX 1

Role of the Smithsonian Institution in Coastal Invasion Research:

Marine Invasion Research Laboratory, Smithsonian Environmental Research Center (May 2002)

Overview

The Smithsonian Environmental Research Center (SERC), located on the shore of Chesapeake Bay, is a leading national and international center for research in the area of non-native species invasions in coastal ecosystems.

SERC has developed the largest research program in the U.S. to focus on coastal invasions.

A primary goal of SERC's Marine Invasion Research Laboratory is to provide the fundamental science that is critical to develop effective management and policy in this topic area. In short, SERC's invasion research bridges the gap between science and policy, to develop a scientific understanding that is key to guide and evaluate management strategies for invasive species.

The Marine Invasion Research Laboratory has a staff of approximately 20 biologists, who conduct research throughout the country and overseas. Since it's inception 10 years ago, the laboratory has been a nationwide training center in invasion ecology for roughly 35 technicians, 4 graduate students, 5 postdoctoral researchers, and 40 undergraduate summer interns. The students and technicians arrive from all over the country, staying for 3 months to many years. Many participants in this program have gone on to graduate training and academic or government positions in Alabama, California, Connecticut, Hawaii, Massachusetts, Tennessee, Washington, Washington D.C.

Research Program

As a national center, SERC's Marine Invasion Research Laboratory provides synthesis, analysis, and interpretation of invasion-related patterns for the country. Under the National Invasive Species Act of 1996, the U.S. Coast Guard and SERC created the National Ballast Water Information Clearinghouse, hereafter Clearinghouse, to collect and analyze national data relevant to coastal marine invasions (see Box 1). Established at SERC in 1997, the Clearinghouse measures:

- **Nationwide Patterns of Ballast Water Delivery and Management**. All commercial ships arriving to all U.S. ports from overseas report information about the quantity, origin, possible control measures for their ballast water - a primary mechanism for transfer of non-native marine species throughout the world. At present, SERC receives roughly 20,000 such reports per year. Every two years, SERC provides a detailed analysis and report to U.S. Coast Guard and Congress on the patterns of ballast water delivery by coastal state, vessel type, port of origin, and season. A key issue is the extent to which ships undertake ballast water exchange, a management technique to flush potential invaders out of the tanks prior to arrival in U.S. waters. SERC's analyses are used by U.S. Coast Guard and Congress to assess national needs with respect to ballast water management and to track program performance.
- **Rates and Patterns of U.S. Coastal Invasions**. SERC has developed and maintains a ***national database of marine and estuarine invasions*** to assess patterns of invasion in space and time. This database compiles a detailed invasion history of approximately 500 different species of plants, fish, invertebrates, and algae that have invaded coastal states of the North America. Among multiple uses, the database identifies which species are invading, as well as when, where, and how they invaded; it also summarizes any existing information on the ecological and economic impacts of each invader. Over the long-term, this database will help assess the effectiveness of various management strategies (such as ballast water management, above) in reducing the rate of invasions. More broadly, this information is a valuable resource for many user groups --- from resource managers and scientists to policy-makers and industry groups.

Box 1

Except from the National Invasive Species Act of 1996

NATIONAL BALLAST INFORMATION CLEARINGHOUSE-

(1) IN GENERAL- The Secretary shall develop and maintain, in consultation and cooperation with the Task Force and the Smithsonian Institution (acting through the Smithsonian Environmental Research Center), a

clearinghouse of national data concerning--
(A) ballasting practices;
(B) compliance with the guidelines issued pursuant to section 1101(c); and
(C) any other information obtained by the Task Force under subsection (b).
(2) REPORT- In consultation and cooperation with the Task Force and the Smithsonian Institution (acting through the Smithsonian Environmental Research Center), the Secretary shall prepare and submit to the Task Force and the Congress, on a biannual basis, a report that synthesizes and analyzes the data referred to in paragraph (1) relating to--
(A) ballast water delivery and management; and
(B) invasions of aquatic nuisance species resulting from ballast water.

SERC has further expanded the scope of Clearinghouse activities to improve the quantity and quality of data on coastal marine invasions that are used to (a) assess the rates and patterns of invasion and (b) inform key management decisions at national, regional, and local levels. Through competitive grants, we have initiated two components in this area, including:

- **Nationwide Field Surveys.** SERC has implemented an ambitious program of field surveys to detect new invasions, as well as measure contemporary patterns and effects of invasions, for 15-20 different bays throughout the country (see Figure 1). Our intent is to expand this program to include additional regions, providing a national baseline of information with which to evaluate invasion rates. The resulting information will contribute to the national database (above) and will be used both to document patterns of invasion and to assess the effects of management on invasion rates (as discussed above).
- **Comprehensive National Database.** SERC has established a formal agreement (Memorandum of Understanding) with the U.S. Geological Survey's Caribbean Research Center to develop a comprehensive database of all freshwater and marine invasions in the United States. SERC maintains a database of exotic marine species (above), and the U.S.G.S. maintains a complementary database for exotic freshwater species. Our goal is to functionally link these databases, creating web-based access to key information about each species for managers, researchers, policy-makers and the public.

In addition to the Clearinghouse role of analysis and interpretation of national data, SERC also conducts research to understand underlying mechanisms of species transfer, invasion, and ecological effects of invasions. This research serves a dual purpose of advancing our fundamental knowledge of invasion processes and using this knowledge to improve prediction and management strategies for invasions. Some selected examples of our research in these areas, funded by external grants and contracts, include:

- **Measuring the Patterns and Processes of Species Transfer Associated with Shipping.** The Marine Invasion Research Laboratory has measured the density and diversity of organisms in the ballast water of approximately 450 different commercial vessels, primarily oil tankers and bulk cargo carriers that arrived to Chesapeake Bay and Port Valdez, Alaska. This has been a collaborative and cooperative research program with the shipping industry, over the past 8 years, to better assess the risks of invasion and effectiveness of various management techniques to reduce that risk. We are now expanding this research to include container ships arriving to San Francisco Bay, expanding existing measures to include a different vessel type and geographic region than the previous studies.
- **Assessing the Magnitude and Consequences of Pathogenic Microorganism Transfer by Ships.** Very little is known about the relative risks of pathogens, both for humans and commercially important species, which are transferred in ballast water. SERC's invasion program is measuring the concentration of microorganisms and human pathogens, including *Vibrio cholerea* (causitive agent of epidemic human cholera), discharged into U.S. waters with the ballast water of ships. In addition, we are conducting experiments to test the viability and potential significance of these transfers to result in newly established populations, or invasions, of pathogenic organisms.
- **Measuring the Ecological Impacts of Non-Native Species.** SERC has implemented a broad range of field-based and experimental studies to measure the effects of marine invasions in coastal ecosystems, including impacts on commercial fishery resources. Much of this work to date has focused on the European green crab (*Carcinus maenas*) impacts in California and New England. We have also implemented experiments in California and Virginia to test for effects of particular fouling organisms on invaded communities, and the extent to which this is exacerbated by human disturbance (e.g., pollutants, hypoxia, etc.). The overall goal of work in this area is to understand and predict impacts of invasions across a diverse array of coastal communities.
- **Testing Invasibility of Communities.** We have just begun manipulative laboratory and field experiments to test environmental and biological factors that influence invasibility of marine communities. Our work in this area focuses on microorganisms and invertebrates. The main objective of this research is to measure the dose-response relationship between delivery of organisms and subsequent invasion, and how this may vary across different environmental and biological conditions. This approach has direct bearing on the effect (and target) for management strategy to reduce the delivery of non-native organisms by ships or other vectors.
- **Feasibility of Eradication and Control of Established Marine Invasions.** SERC has also initiated work to test the feasibility of eradication and control for a non-native marine snail in San Francisco Bay. This is effectively a demonstration project to

critically examine management strategies, based upon key habitat and biological characteristics, and develop the decision process (i.e., under what conditions and for which species) and capacity for eradication.

Geographic Coverage

SERC's Marine Invasion Research Laboratory, with staff based at Chesapeake Bay and San Francisco Bay, has established research sites throughout the U.S. to implement its research programs, in collaboration with researchers from approximately 25 different academic institutions and federal or state agencies. For example, active projects and collaborations are on-going in the following states: Alaska, California, Connecticut, Florida, Maine, Maryland, Massachusetts, Michigan, New Jersey, Oregon, Rhode Island, Texas, Virginia, Washington, and Washington D.C.

Internationally, SERC has become increasingly active over the past 5 years. A primary goal of the international program is to foster information exchange and build complementary, comparative, and collaborative research programs. For example, the Marine Invasion Research Laboratory has active collaborations in many areas of invasion ecology with the Centre for Research on Introduced Marine Pests (CSIRO, Australia). This includes comparative analyses of invasion patterns and effects, as well as development of an international standard for databases on marine invasions. Another long-term collaboration exists with scientists in Israel, where we have measured changes in the ballast water communities during roughly 20 different voyages between Israel and Chesapeake Bay. SERC also has been a participant and sponsor of international conferences and workshops on marine invasion ecology.

Although SERC programs are active at the national and international scales, a great deal of this effort has also focused on understanding invasion issues at the regional scale. In fact, this program has conducted research on invasions in nearly every coastal state in the country, producing regional understanding as well. Examples include:

- **Analysis of invasion patterns for Chesapeake Bay over the past 400 years,** representing the first such analysis for the Chesapeake as well as any estuary in the eastern U.S. This documents the invasion history of 160 non-native species established in this Bay.
- **Analysis of extent of invasions for Prince William Sound, Alaska**, providing the most detailed analysis in the world to assess the risks of invasion for a high-latitude system.

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SERC Marine Invasion Research Sites

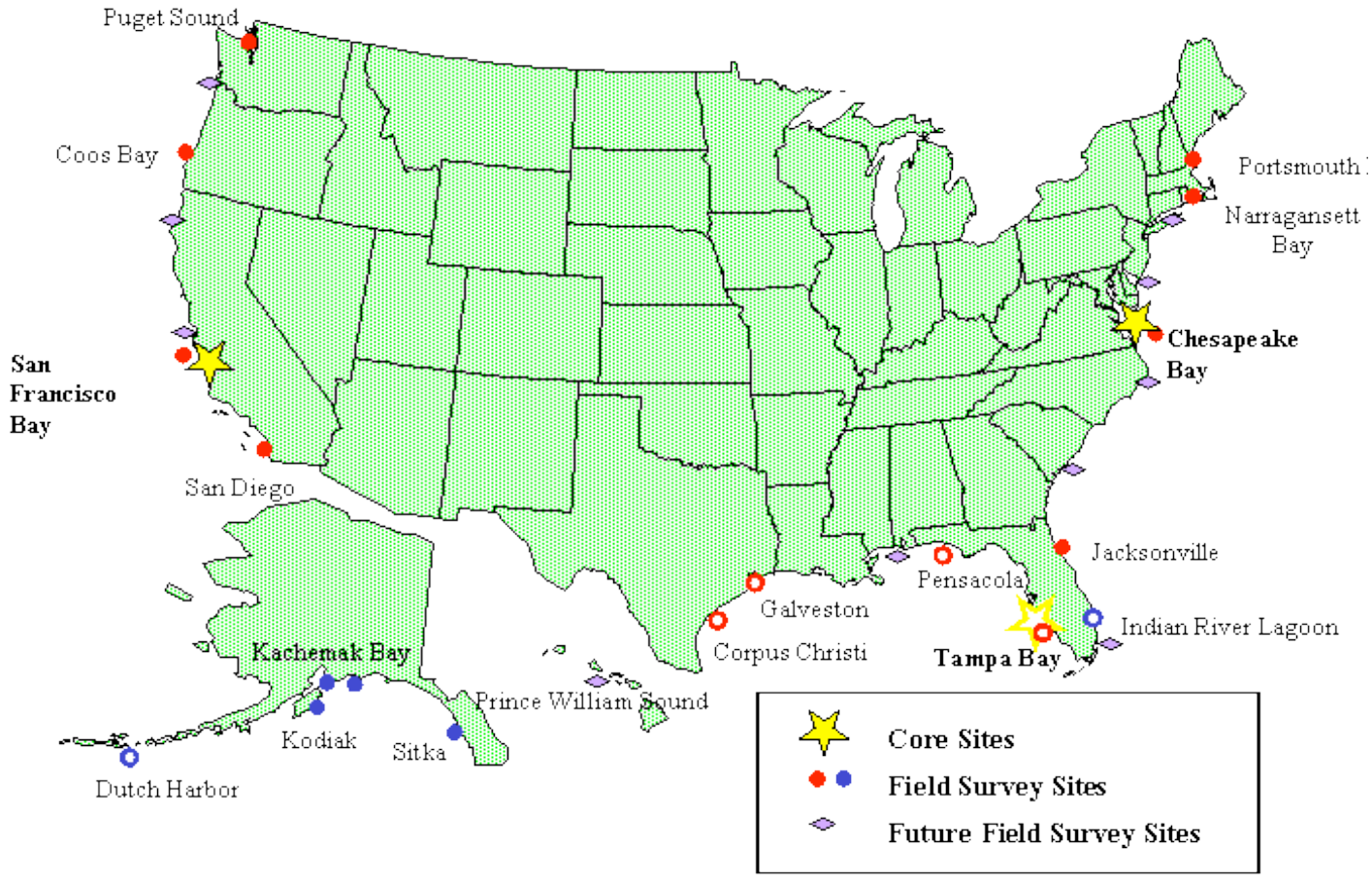

Figure 1. Distribution of field surveys to detect invasions, and measure invasion patterns, in U.S. coastal waters. Surveys completed by SERC through 2001 are shown as filled symbols (● baseline survey, H core sites), whereas surveys in 2002 are shown as open symbols. Symbol color refers to funding source. Future surveys planned at additional sites shown as open symbols (◊). Alaska (to the left) and Hawaii (to the right) are shown at the bottom of the figure.