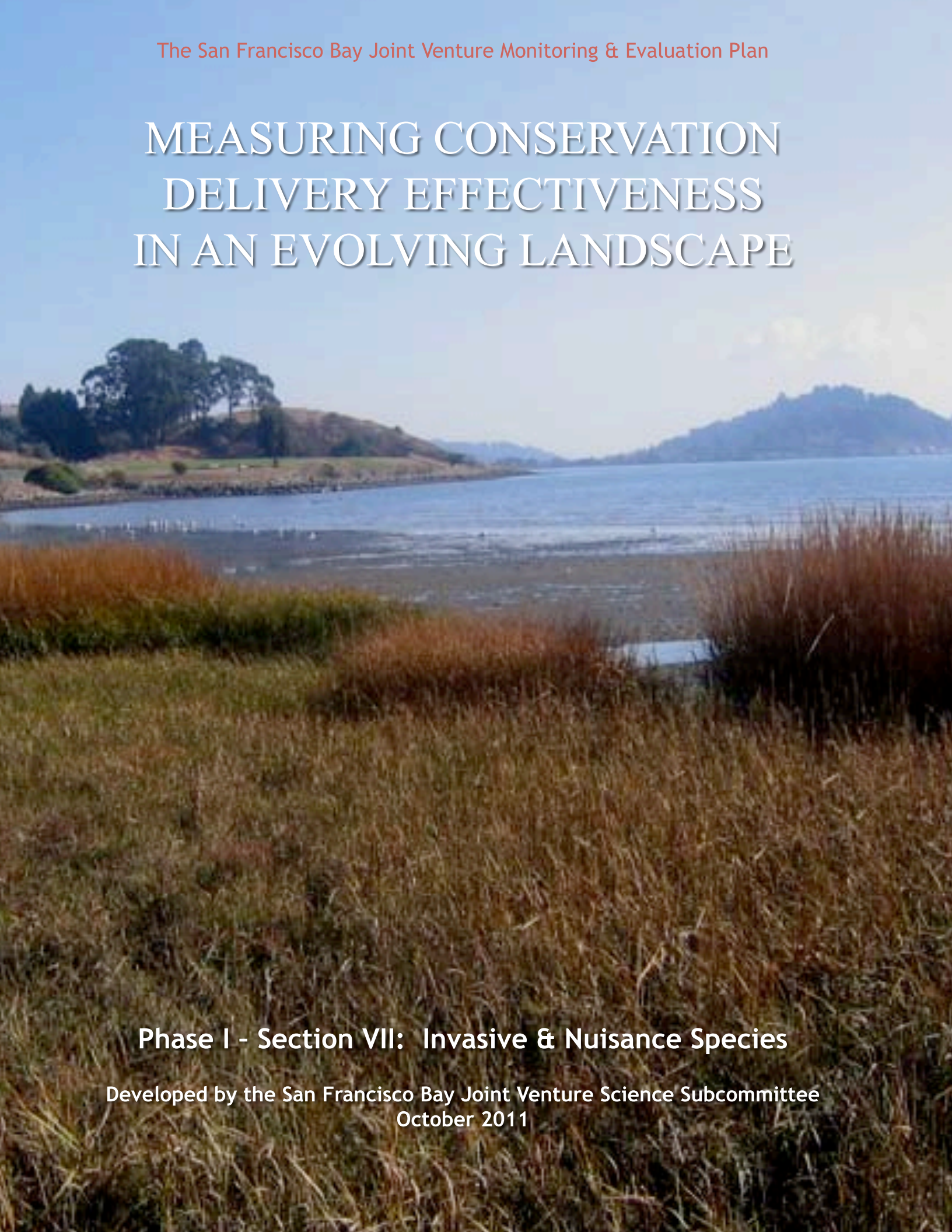
The San Francisco Bay Joint Venture Monitoring & Evaluation Plan

MEASURING CONSERVATION DELIVERY EFFECTIVENESS IN AN EVOLVING LANDSCAPE



Phase I - Section VII: Invasive & Nuisance Species

Developed by the San Francisco Bay Joint Venture Science Subcommittee

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The SFBJV Science Coordinator designed and compiled the information presented in this document section. She accepts the responsibility of accurately reflecting the information provided by all participants.

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Cover photo: Invasive *Spartina* cordgrass at Blackie's Pasture in 2006 by Christina Sloop

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VII. Invasive and Nuisance Species

Invasive species control and management are major challenges San Francisco Bay Joint Venture (SFBJV) partners face in their work to conserve, restore and enhance wetland ecosystems throughout the SFBJV region. As the effectiveness of SFBJV projects is evaluated, non-native invasive species will play a role in how target wetland ecosystems and organisms respond to the implemented restoration and enhancement actions. Thus, providing a framework to detect and monitor invasive species is essential to the success of many SFBJV goals.

Addressing habitat conservation in the context of invasive plants or animals requires risk assessment (Stohlgren and Schnase 2006, Raghu et al 2006), since their impacts can be assessed from both a negative and positive perspective. Invasive or nuisance species can, for example, depredate or out-compete natives, degrade habitat for trust resources and thereby impede success of multi-million dollar restoration projects (Pimentel et al 2005, Mack et al 2000). In some cases, invasive species also impede water flow, and cause economic damage to commercial harvest, or impede shipping, and some can also change ecosystem structure and function via permanent soil changes or soil accretion, or changes in food web that could impact commercial fisheries or other economic activities (Pimentel et al 2005, Leung et al 2002). The management and removal of invasive species is associated with high cost worldwide, and once invasives become established, their permanent removal may become impossible and/or cost prohibitive (Pimentel et al 2005). In contrast, invasive species may also provide positive ecosystem services such as carbon sequestration, nutrient uptake, sediment accumulation to counterbalance sea level rise, detritus for food web support, etc. (Ewel and Putz 2004). The management challenge is how to determine which species are truly “bad” on the balance in order to most efficiently allocate scarce management resources (Stohlgren and Schnase 2006, Ewel and Putz 2004).

In order to avert future species invasions, and expanded colonization by established invaders or nuisance species, prevention (e.g., ballast water restrictions, addressing potential vectors such as the horticultural nursery trade, etc.), paired with Early Detection/Rapid Response (EDRR) are key strategies that provide the most cost-efficient means of avoiding or minimizing economic or ecological costs of invasive species.

Invasive or nuisance species prevention and EDRR are currently being implemented by several partner entities around the San Francisco Bay Area:

- Addressing plants, these include: the Bay Area Early Detection Network (BAEDN) in partnership with the California Invasive Plant Council (Cal-IPC), and Weed Management Areas (WMAs).
- Addressing aquatic plants, algae, and invertebrates they include: the National Oceanic and Atmospheric Administration (NOAA), the Smithsonian Environmental Research Center, the Center for Research on Aquatic Bioinvasions (CRAB), and the Romberg Tiburon Center.

Because these organizations often manage distinct regions or species, the nine-county networks’ collective response to invasive species would be enhanced by an umbrella entity facilitating communication between existing efforts (Figure 7.1).

As evidenced, for example, by the hybrid *Spartina* invasion throughout San Francisco Bay tidal marshes and mudflats in recent decades, restoration success can be seriously challenged by the colonization and proliferation of invasive species. The invasive hybrid *Spartina (S. alterniflora x S. foliosa)* as many other successful invasive species, is an "ecosystem engineer" whose establishment changes the fundamental structure and function of the invaded ecosystem (Crooks 2002). Invasive *Spartina* so threatens the integrity of SFB tidal marsh and tidal flat ecosystems by permanently impeding use by some focal species (e.g., shorebirds, whose mudflat foraging habitats disappear with invasive hybrid *Spartina* colonization). Similarly, invasive or nuisance species can become direct threats to target species as predominant predators or primary competitors. As a nuisance predator to Snowy Plover chicks, for example, native California Gulls can have a detrimental effect on recruitment success of the endangered plovers and other sensitive species.

A regional monitoring and evaluation framework must therefore inform long-term detection, control and management of invasive and nuisance species most detrimental to critical resources and ecosystems, as well as provide a mechanism to detect novel invasions of recognized invasive and nuisance species projected to affect wetland conservation, restoration and enhancement. In addition, it is crucial that such a framework also consider the response of target invasive species to climate change and other expected large-scale anthropogenic changes to the SFBJV region wetland ecosystems and restoration areas. Secondary effects of invasive species control on native species are also of high concern, and need to be closely examined to determine appropriate strategies and response actions.

At this time, this Plan section is not designed to present a detailed monitoring program with schedules and protocols, data management specifics, and other concrete details. Instead it is to establish an overall framework to provide general guidance to SFBJV partners in the assessment of the status and trends of invasive and nuisance species as indicators of habitat condition and effectiveness of SFBJV conservation, enhancement, or restoration implementation actions. More details will be developed throughout phase II of the M&E planning process (see *Next Steps* section below).

This Invasive And Nuisance Species Section Currently Provides:

- A framework to assess the effectiveness of SFBJV conservation delivery projects in the context of the challenge that invasive species pose to focal habitats (*Bay wetlands, regional riparian and seasonal wetlands and coastal areas*) and organisms (*wetland birds and special status species*) at the project and San Francisco Bay Area regional scale;
- An outline of monitoring and evaluation objectives addressing key questions for invasive species control and management at the project and San Francisco Bay Area regional scales;
- Specific invasive species recommendations as appropriate for integration with existing monitoring and control programs, and use of metrics, protocols, data repositories, and information needs/research priorities.

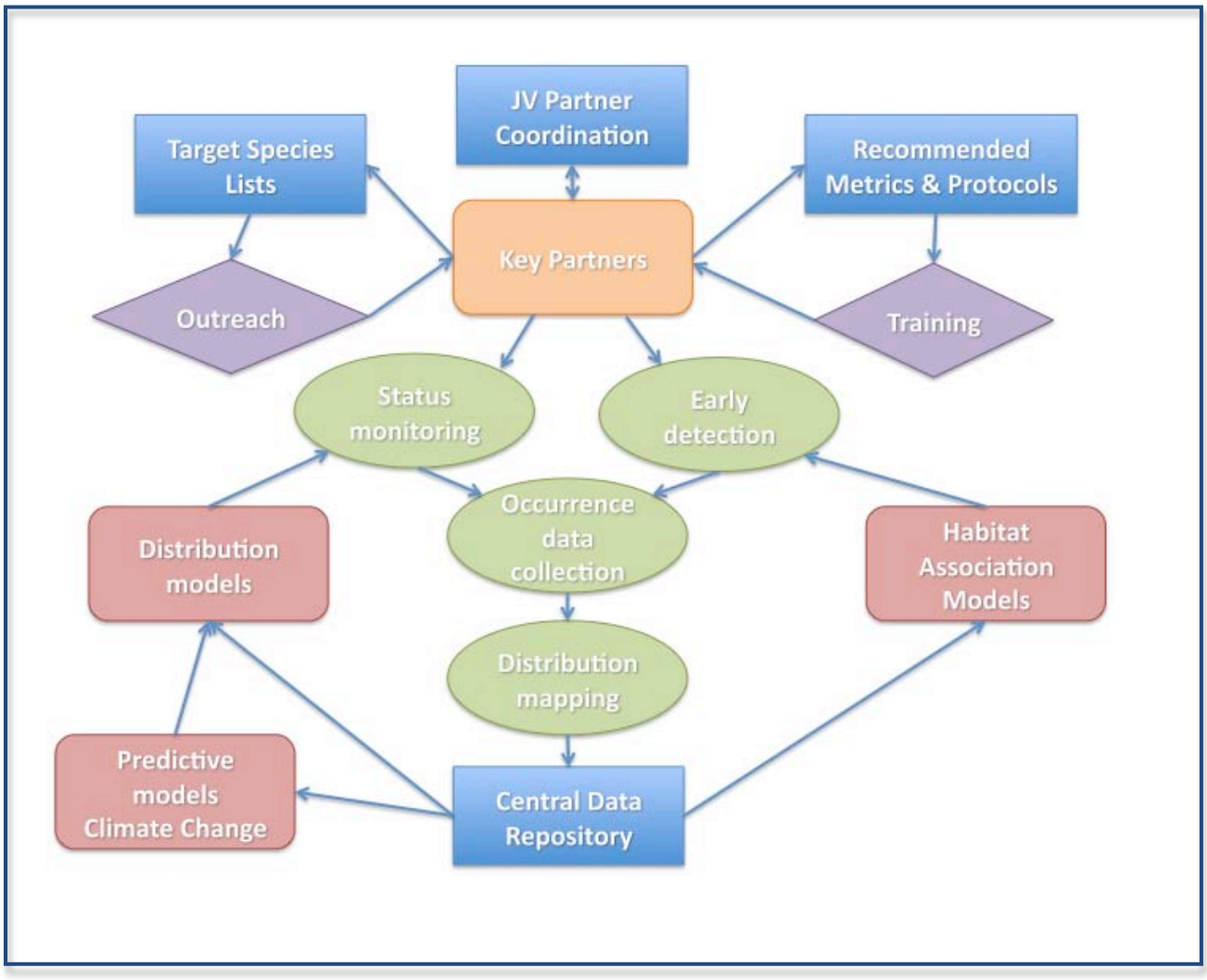

Figure 7.1: Draft Conceptual Model of SFBJV partner integration for long-term detection and monitoring of invasive and nuisance species.

Focus Team Process & Participants

In a series of in-person meetings and phone conferences, the invasive and nuisance species focus team established focus-specific M&E and research objectives, relevant metrics, protocols, and data repositories, key partners, and existing programs for potential integration. All M&E Plan focus teams convened on May 26, 2011 for a daylong professionally facilitated workshop to vet and identify the top priorities of the identified monitoring, evaluation and research objectives. Focus team participants included:

Name	Affiliation
Archbald, Gavin*	San Francisco State University
Brusati, Elizabeth*	California Invasive Plant Council
Chapple, Dylan*	Save the Bay
Gluesenkamp, Daniel*	Calflora and BAEDN
Hogle, Ingrid	San Francisco Estuary Invasive Spartina Project
Johnson, Doug*	California Invasive Plant Council
Marriott, Meg*	US Fish & Wildlife Service - San Francisco Bay NWR Complex
Perlmutter, Mike*	Bay Area Early Detection Network (BAEDN)
Sloop, Christina	*Team coordinator,* San Francsico Bay Joint Venture
Williams, Andrea	Marin Municipal Water District and BAEDN
Zaremba, Katy*	San Francisco Estuary Invasive Spartina Project

*Participated in prioritization of objectives at May 2011 workshop.

Focal Habitats and Species

The Bay Area Early Detection Network's Response List[1], Cal-IPC's Invasive Plant Inventory[2], and SFEI's CRAB list[3] & species gallery[4] include some of the following target invasive plants and animals. Some of these species are already serious problems in SFBJV region ecosystems while others have not yet established, but could pose a threat if they do. The wetland habitats for the suite of considered focal invasive species in the SFBJV region include:

San Francisco Bay, Coastal Ocean & Estuaries:[5]

Established in SFBJV region: Asian Clam (*Corbula amurensis*), Atlantic Oyster Drill (*Urosalpinx cinerea*), Chinese Mitten Crab (*Eriocheir sinensis*), European Green Crab (*Carcinus maenas*), Exotic Oyster (*Crassostrea gigas*), Fan Worm (*Terebrasabella heterouncinata*), Inland Silverside (*Menidia beryllina*), Invasive Rockweed (*Ascophyllum nodosum)*. *Potential invaders:* Wakame (*Undaria pinnatifida*), Wireweed alga (*Sargassum muticum*), Mediterranean alga (*Caulerpa taxifolia).*

Creek and Riparian Ecosystems (coastal and Bay watersheds):

Giant reed (*Arundo donax*), water primrose (*Ludwigia hexapetala*), South American spongeplant (*Limnobium laevigatum*), hydrilla (*Hydrilla verticillata),* purple loosestrife (*Lythrum salicaria),* giant salvinia (*Salvinia molesta),* parrotfeather (*Myriophyllum aquaticum*), Eurasian watermilfoil *(Myriophyllum spicatum*), Brazilian waterweed (*Egeria densa),* water hyacinth *(Eichhornia crassipes),* Sakhalin knotweed (*Polygonum sachalinense*), Japanese knotweed (*Polygonum cuspidatum*), red sesbania/scarlet wisteria (*Sesbania punicea*), curlyleaf pondweed (*Potamogeton crispus*))

[1] http://www.baedn.org/index.php?option=com_content&view=section&layout=blog&id=6&Itemid=5
[2] http://www.cal-ipc.org/ip/inventory/weedlist.php.
[3] http://www.sfei.org/nis/
[4] http://www.exoticsguide.org/species_list.html
[5] Exotic species introduced and established in the marine or brackish waters of San Francisco Bay Estuary are outlined in Appendix 7.1.

Tidal marshes & associated Upland Ecotones:

Spartina hybrids (*S. alterniflora* x *foliosa*), dense-flowered cordgrass (*Spartina densiflora*), common cordgrass (*Spartina anglica*), saltmeadow cordgrass (*Spartina patens),* Algerian sea lavender (*Limonium ramosissimum*), perennial pepperweed (*Lepidium latifolium*), brassbuttons (*Cotula coronopifolia*)

Salt Ponds & Islands/levees:

Spartina hybrids (*S. alterniflora* x *foliosa*), *Spartina densiflora*, Algerian sea lavender (*Limonium ramosissimum*).

Seasonal Wetlands (moist grasslands, diked wetlands & vernal pools):

Pennyroyal (*Mentha pulegium*), Italian rye grass (*Lolium multiflorum*), mannagrass (*Glyceria declinata*), perennial pepperweed (*Lepidium latifolium*), spotted knapweed (*Centaurea maculosa*).

Performance Targets

There are no specific performance targets outlined in the SFBJV Implementation Plan (2001) aimed at the control of invasive species. We recognize a need for performance targets for this section that are generally aimed at avoiding new invasions and minimizing the spread of invasive species, as well as maximizing implementation of effective prevention, control, and EDRR actions regionally, and at SFBJV partner project sites. The performance targets specified in several existing region-wide efforts (e.g., BAEDN, ISP) should be considered in the next planning phases for adoption in the upcoming SFBJV Implementation Plan revision.

Monitoring and Evaluation Objectives

Priority M&E Objectives and Associated Metrics

To assess SFBJV project effectiveness, and to determine the threat of invasive species to native wetland ecosystems at SFBJV projects, the following M&E objectives should be implemented. A key assumption we make here is that identified "target invasives" overall and generally are deleterious to native target species, outlined in the other sections of this Plan. However, it should also be noted that some existing "invasives" are well established and have been found to have ecological benefits to target species (e.g. *Corbula amurensis*, Lovvorn et al. in review).

Summarized below are the highest priority M&E objectives the invasive species focus group recognized based on several criteria:

1) Ease of implementation
2) Long-term importance;
3) A natural "early" step;
4) Usefulness for managing or modeling;
5) Ability to help manage JV "effectiveness"; and
6) Cost-effectiveness.

- **Priority M&E Objective 1:** *Pre- and Post-Implementation Monitoring of Target Invasives; Project Scale.* Implement pre- and regular post-implementation surveys of SFBJV project and neighboring sites,[6] for the EDRR of target invasive or nuisance species from lists determined by a coordinated SFBJV region partnership effort.[7]

- **Priority M&E Objective 2:** *Success Monitoring to Evaluate Control Efficacy; Project scale.* Monitor the efficacy of existing control methods in an adaptive management framework. Determination of which treatments are effective, and at what costs or impacts, will help managers choose the most effective and methods to target any given invasive or nuisance species.

- **Priority M&E Objective 3:** *Long-term Monitoring of Extant Target Invasive or Nuisance Species; - Project scale.* Implement regular surveys of SFBJV project and reference sites to assess the distribution, abundance and spread of established populations of recognized target invasive or nuisance species and, delineate "clean areas." Prioritize management actions to keep "clean" areas free of invasives & nuisance species. This should be integrated with existing monitoring frameworks as much as possible. Regularly evaluate and prioritize species for control/eradication treatment.

Relevant Metrics

Priority M&E Objective 1:

Recommended Metrics

Prediction of/searching for animal occurrences: EDRR metrics & technology

- Prior occurrence data & related habitat parameters
- Spread rate
- *In situ* abiotic variables (e.g., salinity, moisture, soil texture, tidal datum)
- Amount of area searched (Comprehensiveness of surveys for invasives, especially in target habitats)
- Frequency of detection by motion detection cameras (to pick up moving targets)
- Trapping rate
- Count surveys

Mapping of plant occurrences

- Presence/absence data via geographic coordinates or polygons
- Distance and cover estimates
- Polygon size

[6] Refers to lands or habitats just outside of or adjacent to planned projects sites.
[7] Including Cal-IPC, BAEDN, WMAs, SFEI, SERC, CRAB, resource agencies, and other partners.

- Percent cover of patches
- Co-occurring plant species
- Vertical range

Protocols

- Specific protocols may vary by species or guild, scale, and goals

Considerations

- Details of data collection will vary by habitat goals, individual species goals, statistical power of different methods, and available links to pre-existing data.
- Build on and inform existing programs and regulatory mandates
- Match data collection methods to central database requirements.
- Need basic data collection standards across projects; *A standard recommended template was recently developed by California Early Detection Network (CAEDN), Cal-IPC, and Sonoma Ecology Center. This template was integrated into the design of new Calflora reporting tools and taught in training courses by Cal-IPC.*
- Use methods that are as simple and cost-effective
- Distinguish between those invasive or nuisance species that can be eradicated or controlled vs. those that are well established and nearly impossible to eradicate or control.

Priority M&E Objective 2:

Recommended Metrics

Evaluation of treatment efficacy & impacts:

- GIS analysis in time and space
- Measures of effort, efficiency and cost-effectiveness at project sites obtained from a centralized database,
- Matrix developed to judge response to removal, including for example:
- Percentage chemical treated area, kill estimates in chemically-treated areas, at 2-month and 1-year intervals post treatment,
- Drift of herbicide applications,
- Effect on non-targeted species,
- Comparison across control methods,
- Other,
- Ecological cost of treatment vs. non-treatment to species of management concern,
- Seed production and viability of seed bank pre and post control.

Information on invasive species impacts to help land managers determine which species to focus on

- Habitat types invaded
- Spread rate
- Negative ecological effects on species of management concern
- Potential for re-colonization

Priority M&E Objective 3:

Metrics

Prediction of/searching for animal occurrences: EDRR metrics & technology

- Prior occurrence data & related habitat parameters
- Spread rate
- *In situ* abiotic variables- i.e. salinity, moisture, soil texture
- Amount of area searched (Comprehensiveness of surveys for invasives, esp. in likely/target habitats)
- Frequency of detection by remote sensing cameras (to pick up moving targets)
- Trapping rate
- Count surveys

Mapping of plant occurrences

- Presence/absence data via geographic coordinates/polygons
- Distance and cover estimates
- Polygon size
- Percent cover of patches
- Co-occurring plant species
- Vertical range

Protocols

- Specific protocols may vary by species and scale/guild and goals.

Relevant Protocols

- Invasive species monitoring info
- EDRR methodology Also, the SFAN EDRR protocols have great guidelines for early detection and rapid response.
- Invasive species prioritization
- Other existing & effective protocols for certain types of invaders, such as e.g., Invasive Spartina, and Giant Reed.
- Prevention - plants
- Monitoring - plants
- Mapping methods
- Aquatic Invasive species monitoring protocol
- Voucher reporting, CRAM method for assessing wetland health includes metrics for assessing native/non-native cover at marshes
- Marin Open Space District's vegetation management strategy has a great objective-based framework for monitoring terrestrial invasions.
- Species distribution models aimed at the project scale could support ground searches
- Occurrence reporting protocols and tools developed by Calflora

Research & Information/Action Needs

Priority Information/Action Needs

- **Priority Information/Action Need 1:** *Coordination of Targets; Regional Scale.* Regularly coordinate the update of available lists of target invasive species by periodic consulting with land managers and experts on control/eradication status and projected new targets. Promote early detection and reporting of new invasions, including spread into habitat/vegetation types the species had not yet been known to invade.
- **Priority Information/Action Need 2:** *Coordination of Methods – Regional Scale.* Regionally coordinate, standardize and continually improve methods for the prevention, control and management and EDRR of target invasive species. Share, as appropriate, metrics, protocols, and control and management strategies of existing noxious invasive species populations in the region.
- **Priority Information/Action Need 3:** *Rapid Response Partnerships; Project Scale.* Develop partnerships to facilitate rapid response of detected incipient populations of target invasive species at SFBJV project sites.

Other Information/Action Needs

- Best Management Strategies- Project & Regional Scale - Best management strategies are needed to prevent and minimize new infestations at SFBJV target wetland project sites and surrounding areas addressing:
  - *Regular assessment of which species we need to most aggressively control and in what scenarios.*
  - *Regular evaluation of how we can maximize EDRR in the region*
  - *Regular assessment of what level of monitoring will be most cost effective and realistic.*
  - *Regular determination of how our control efforts are performing and the best methods for control.*
- Outreach Coordination – Regional Scale - Coordinate promotion and outreach for regional invasive species prevention programs and measures.
- Training Coordination – Regional Scale - Coordinate training workshops to promote the use of vetted metrics, protocols, and control and management strategies for existing invasive species populations in the region.
- Weed Specimen Vouchering – Regional Scale - Promote and facilitate the increase of documentation for even common invasive plants (i.e. in herbaria or observations in Calflora) by encouraging vouchering as part of a monitoring program, especially if recording new plants for given areas. The California Department of Food and Agriculture Herbarium will identify and store weed specimens at no cost.
- Implementation – Regional Scale - Determine the feasibility and willingness of multiple agencies or organizations to financially contribute to a single entity to map, monitor, and manage invasive species around the San Francisco Bay.[8]

[8] The Florida Exotic Pest Plant Council (FLEPPC) may serve as a model for such a proposed multi-partner collaboration in this endeavor: http://www.fleppc.org/

- Coordinate Funding Needs – Regional Scale - Determine the time investment and costs that effective monitoring efforts require by local landowners or organizations and assess whether stakeholders are willing and able to participate. Help coordinate funding requests where needed.
- Decision-Support Tool – Regional Scale - Prepare a decision support framework to help partners decide which invasive species require immediate response, with what degree of intensity (control vs. eradication goals), and what control methodology to implement. The framework needs to address stage of invasion and EDRR of new or small infestations versus long-term control management of existing ones to prevent further spread.
- Integrated Training Opportunities; project & Regional scale – At regular intervals inform and train project partners and land managers on integrated approaches for monitoring and treatment options for target invasive species.
- Integration of Existing/Mandated monitoring Efforts; project & Regional scale – Establish a process to build a community-vetted clearinghouse to share information on monitoring, so it will become possible to better integrate with existing monitoring efforts.[9]
- Monitoring of Prevention Programs; Regional Scale –Every five years, check in with regional prevention programs to assess their program efficacy (i.e. ships aren't dumping ballast water, nurseries aren't selling weed seed contaminated soil, and plants known to be invasive).

Priority Research Needs

Priority Research Need 1: *Occurrence Lists & Range Maps of Extant Invasive or Nuisance Species; Project & Regional scale.* Develop & maintain up-to-date habitat-specific lists and distribution maps of target invasive species already extant at SFBJV project wetland types or in adjacent areas.

Priority Research Need 2: *Impacts on Natives & Ecosystem Processes; Project & Regional Scale*. Investigate how specific invasive species affect native fauna and flora and the key ecosystem services we want wetlands to provide at SFBJV projects sites and throughout the region.

Priority Research Need 3: *Occurrence Lists of Expected Invasive and Nuisance Species; Project & Regional scale.* Develop and maintain habitat-specific or geographically focused lists of target invasive or nuisance species expected to colonize.

[9] The Florida Exotic Pest Plant Council (FLEPPC) may serve as a model for a proposed clearinghouse of info. http://www.fleppc.org/

Other Research Needs

- Invasive Plan Seed Bank Longevity; Project & Regional Scale. Gather information on invasive species seed bank longevity, to determine species importance and to formulate effective management plans. [10]
- Risk of occurrence modeling of target invasives; project & regional scale - Develop and maintain a predictive "risk of occurrence" search model for target species (based on life history attributes, dispersal modes, invasion corridors, vectors of spread, invisibility of areas, and known locations).
- Climate Change Impact Models; Project & Regional Scale - Assess and model how climate change could affect the distribution of existing non-native species, as existing nuisance species could become significantly more or less invasive with projected climate shifts.
- Riparian Bird Impacts[11] – Investigate the threats posed to riparian land bird species from invasive bird species throughout the SFBJV region.
- Invasive or Nuisance Species Impact[12]; Regional Scale. Determine the effects of invasive or nuisance species on relevant special status species.
- Special status Species Effects; Regional Scale[13] - Establish the site-specific threats posed to special status species from invasive and nuisance species.
- Nuisance Species Ecology; Regional Scale[14] - Conduct research on the ecology and distribution of exotic or nuisance species directly threatening special status species
- Remote Sensing Use; Project & Regional Scale - Determine what remote sensing imagery types can detect which non-native species at what time of year, at what scale and in what context to determine whether remote sensing would be a useful tool to monitor particular species.
- Potential for spread; Project & Regional Scale - Determine the ability of invasive plants to carry out key life history transitions: disperse, germinate, grow and reproduce, that vary under abiotic and biotic conditions found across the San Francisco Bay Estuary.
- Seed Sources for Restoration; Project & Regional Scale - Assess what native and invasive seed sources are likely to affect the community composition of new wetland restoration projects.

[10] Calflora is starting this effort.
[11] This objective links directly with research objectives outlined in the riparian landbird section module.
[12] This objective links directly with research objectives outlined in the special status species section module.
[13] This objective links directly with research objectives outlined in the special status species section module.
[14] This objective links directly with research objectives outlined in the special status species section module.

Data Management

Deciding on which spatial data storage platform to promote in the various contexts relevant to invasive or nuisance species is important. Here are objectives to consider for integration of relevant data management practices.

- Coordination of Distribution Data– Regional Scale - Coordinate ways for multiple organizations, agencies, and citizen groups to collect existing and new data on invasive species distributions at a regional scale. Develop data collection and reporting standards and link datasets with databases that are already well known, such as Calflora. For existing data, determine spatial data format, willingness to share data, and the process to get all data into one central data repository accessible by all members. *Considerations: Many existing datasets require extensive reformatting to be uploaded to a general database. Also, many agencies are hesitant to share data, especially if collected on private property. Note: Cal-IPC and BAEDN have collected thousands of occurrences in hundreds of datasets, and added them to Calflora*.
- Data Sharing Platform – Regional Scale – Determine the best spatial data storage platform to promote for region-wide use (i.e. Calflora integrates new data with nearly 100,000 Bay Area occurrence records, assimilating checklists, point occurrences, polygons and lines, and any other data format; SFEI's wetland tracker).
- Centralized Data Sharing – Regional Scale - Make distribution mapping and population status data available to all at a central repository. Encourage partners to regularly contribute & update data to existing invasive species information tools.
- Data Integration – Regional Scale - Integrate existing geodatabases and maps into a single online geodatabase that would enable region-wide monitoring of invasive species
- Integration of Existing/Mandated Monitoring Efforts; project & Regional scale – Encourage sharing of data every time existing survey programs are implemented within management, regulatory or other contexts.

Existing Programs and Tools

Programs

- Audubon, California Department of Fish and Game, East Bay Regional Parks District, Don Edwards San Francisco Bay National Wildlife Refuge, Save the Bay, Sonoma Land Trust, California State Parks and other public landowners or NGOs are conducting invasive species control and management on public lands and preserve sites throughout the SFBJV region
- Bay Area Early Detection Network (BAEDN) coordinates detection and rapid response efforts on all public and private lands across the nine counties of the San Francisco Bay Area, including EDRR implementation & prioritization of local noxious weeds
- Calflora – Since the early 1990s Calflora has provided data on California wild plants, with approximately 2 million occurrence records, 20,000 checklists, and 20,000 monthly users monthly. In addition to a popular public portal, BAEDN, CNPS, Cal-IPC, NPS and other agencies have contracted to build specialized tools to support managers and planners.
- California Department of Fish and Game - California Aquatic Invasive Species Management Plan.

- California Invasive Plant Council provides a statewide invasive plant inventory, interactive database, and priority lists. Their mission is to protect California's lands and waters from ecologically damaging invasive plants through science, education and policy. The Cal-IPC works closely with agencies, industry and other nonprofit organizations to support research, restoration work, and public education.
- California State Parks conducts an Inventory, Monitoring and Assessment Program.
- Don Edwards San Francisco Bay National Wildlife Refuge The Fish and Wildlife Service has launched an Inventory and Monitoring (I&M) Program on national wildlife refuges, based at the Don Edwards San Francisco Bay NWR. Their Weed Inventory and Monitoring Plan is used in conjunction with the (Draft) South San Francisco Bay Weed Management Plan, to gather information and guide management of the highest priority weed species within the Project Area (Don Edwards San Francisco Bay NWR and Eden Landing Ecological Reserve).
- Invasive Spartina Project is a coordinated regional effort among local, state and federal organizations dedicated to preserving California's extraordinary coastal biological resources through the elimination of introduced species of *Spartina* (cordgrass).
- Invasive Species Council of California (ISCC) and California Invasive Species Advisory Committee (CISAC) - The ISCC is an inter-agency council that helps to coordinate and ensure complementary, cost-efficient, environmentally sound and effective state activities regarding invasive species.
- National Institute for Invasive Species Science (NIIS) is a consortium of government and non-government organizations formed to develop cooperative approaches for invasive species science that meet the urgent needs of land managers and the public. Administratively housed at the U.S. Geological Survey Fort Collins Science Center in Colorado, the NIIS provides a hub for invasive species science collaboration, coordination, and integration across agencies and disciplines. Integration of SFBJV region invasive species data with NIIS might help link SFB region efforts to those at a national level.
- National Park Service (NPS) and other public agencies monitor for invasive species, prioritizing mapping and control, but not spread or impact assessment. Methods exist for distributing invasive species alerts between partners.
- Laguna de Santa Rosa Foundation – Coordinates a program for invasive pennyroyal (*Mentha pulegium)* removal from vernal pool wetlands throughout the Santa Rosa Plain in Sonoma County. Also coordinated a program on removal of invasive water primrose (*Ludwigia hexapetala).*
- California Horticultural Invasives Prevention partnership – Coalition of nonprofits working with the horticultural industry groups, encouraging the industry to shift away from invasive plants.
- San Francisco Estuary Institute - Biological Invasions program & CRAB.
- Resource Conservation Districts (RCD's)– Consult with private landowners and provide resources to encourage landowners to manage their lands for ecological values.
- University programs – Conduct research on species ecology and control (e.g., Kathy Boyer's lab at San Francisco State University).
- Weed Management Areas (WMAs) - Coalitions of agencies, nonprofit organizations, and landowners that conduct invasive species removal, control and management.

Tools

- Calflora – Searchable database of all 8,375 currently recognized vascular plants in California, including 20,000 photographs. Calflora is working with BAEDN and Cal-IPC to collect and map weed data across California. It supports a variety of methods of collecting and assimilating weed data, including Smart Phone applications, photo uploads, and a metadata catalog . This online interactive mapping tool can, among other features, generate a parcel-specific list of invasive species in surrounding areas. Calflora's Smart phone app tool Observer allows volunteer-based citizen-science mapping of occurrences of native and invasive flora. The database includes all forms of mapping data (lines, polygons, points, checklists) and also includes equally comprehensive native plant data, including records for non-rare plants that are important for climate change prediction and adaptation planning.
- Global Invasive Species Team (GIST): Archived online resource, that was defunded in 2009 by the Nature Conservancy, but should be reinstated.
- GeoWeed - GeoWeed is a geospatially enabled data collection and management tool for invasive plant project managers. GeoWeed allows the weed manager and their field crews to record locations of invasive (or any) plants for early detection and management. Plant population sizes and locations may be tracked over time to monitor change using GPS points or polygons. Treatments and labor can optionally be tracked at multiple resolutions. Updates are underway to integrate GeoWeed with Calflora to create GeoWeed in the Cloud.

Key Partners

- Audubon California
- Richardson Bay Audubon Center & Sanctuary
- Bay Area Early Detection Network
- California –Invasive Plant Council
- California Department of Fish and Game
- California State Parks
- Center for Research on Aquatic Bioinvasions – San Francisco Estuary Institute
- East Bay Regional Parks District
- Invasive Spartina Project
- Marin Audubon
- National Park Service
- NOAA National Marine Fishery Service[15]
- Resource Conservation Districts
- San Jose State University,
- San Francisco Bay National Estuarine Research Reserve
- Smithsonian Environmental Research Center[16]
- San Francisco State University – Romberg Tiburon Center
- Sonoma Ecology Center
- Sonoma Land Trust
- US Fish and Wildlife Service –National Wildlife Refuges
- Weed Management Areas

[15] Aided with eradication of non-native alga *Ascophyllum nodosum* in *SF Bay*
[16] Focused on Marine Invasion research in San Francisco Bay area in partnership with Romberg Tiburon Center

Next Steps - A Phased Approach

In this first planning phase, each M&E Plan focus section features priority objectives and references supporting information determined by the SFBJV science sub-committee. This information will be utilized in planning Phase II to secure implementation funding for the outlined priority objectives, and as a basis for further Plan development to continue to refine and integrate the overall Plan objectives as our knowledgebase evolves. Phase III will evaluate and incorporate additional conservation goals and target performance objectives into an upcoming revision of the SFBJV Implementation Plan (originally released in 2001). We therefore consider the M&E Plan a "living document" that will change over time with continually refined and focused content. For more details on the planning phases, please refer to the Introduction & Overview section of this plan under *Planning Phases – A "Living Document."*

Future Challenges For Invasive and Nuisance Species Related Monitoring And Research Include:

- Linking effects of conservation delivery actions to invasive and nuisance species status.
- Determining appropriate management strategies and desired outcomes relevant to target habitats.
- Refining monitoring objectives with focus on measuring conservation or management action impact or progress against specified outcomes relevant to invasive and nuisance species control.
- Maximizing integration with other regional and national invasive and nuisance species management and control initiatives.

References

Anderson, L. W. J. 2005. "California's Reaction to *Caulerpa taxifolia*: A Model for Invasive Species Rapid Response." Biological Invasions Vol. 7: pp. 1003-1016.

Bayne, B. L. 2002. A physiological comparison between Pacific oysters *Crassostrea gigas* and Sydney Rock oysters *Saccostrea glomerata*: food, feeding and growth in a shared estuarine habitat. *Mar. Ecol. Prog. Ser.* 232: 163-178.

Carlton, J. T. J. K. Thompson, L. E. Schemel, F. H. Nichols. 1990. Remarkable invasion of San Francisco Bay (California, USA) by the Asian clam *Potamocorbula amurensis*. I. Introduction and dispersal. Mar. Ecol. Prog. Ser. 66: 81-94.

Chew, K. K. 2003. Ecological and Biological Considerations for the Introduced Pacific Oyster to the West Coast of the United States. In: *The Ecology of Crassostrea gigas in Australia, New Zealand, France and Washington State*.

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." United States Fish and Wildlife Service, National Sea Grant College Program, Connecticut Sea Grant. Washington, D.C., University of California at Berkeley, Williams College – Mystic Seaport. http://nas.er.usgs.gov/Publications/SFBay/sfinvade.html , accessed May 9, 2011.

Cohen, A. N. and J. T. Carlton. 1997. Transoceanic Transport Mechanisms: Introduction of the Chinese Mitten Crab, *Eriocheir sinensis*, to California. Pacific Science 51: pp. 1-11.

Cook, S. F., Jr. and R. L. Moore. 1970. Mississippi silversides, *Menidia audens* (Atherinidae), established in California. Trans. Amer. Fish. Soc. 99:

Crooks J. A. 2002. Characterizing ecosystem-level consequences of biological invasions: The role of ecosystem engineers. Oikos 97: 153–166.

Ewel, J. J., and F. E Putz. 2004. A place for alien species in ecosystem restoration. Front Ecol Environ 2: 354–360.

Fimrite, P. 2009. "Snails Threaten Tomales Bay Olympia Oysters." San Francisco Chronicle, August 14, 2009. http://articles.sfgate.com/2009-08-14/bay-area/17176913_1_crabs-habitat-predators , accessed May 9, 2011.

Grosholz, E. D., G. M. Ruiz, C. A. Dean, K. A. Shirley, J. L. Maron, P. G. Connors. 2000. "The Impacts of a Nonindigenous Marine Predator in a California Bay." Ecology Vol. 81: pp. 1206-1224.

Grosholz, E. D., G. M. Ruiz.1995. "Spread and Potential Impact of the Recently Introduced European Green Crab, *Carcinus maenas*, in Central California." Marine Biology Vol. 122: pp. 239-247.

Grossinger R., J. Alexander, A.N. Cohen, and J. N. Collins 1998. Introduced Tidal Marsh Plants of the SF Estuary- Regional Distribution and Priorities for Control. San Francisco Estuary Institute, Oakland, CA. http://www.sfei.org/node/2173, accessed: May 11, 2011.

Kimbro, D. L., E. D. Grosholz, A. J. Baukus, N. J. Nesbitt, N. M. Travis, S. Attoe, C. Coleman-Hulbert. 2009. "Invasive Species Cause Large-Scale Loss of Native California Oyster Habitat by Disrupting Trophic Cascades." Oecologia Vol. 160: pp. 563-575.

Kuris, A. M., C. S. Culver. 1999. "An Introduced Sabellid Polychaete Pest Infesting Cultured Abalones and its Potential Spread to other California Gastropods." Invertebrate Biology Vol. 118: pp. 391-403.

Leung, B., D. M. Lodge, D. Finnoff, J. F. Shogren, M. A. Lewis, and G. Lamberti. 2002. An ounce of prevention or a pound of cure: bioeconomic risk analysis of invasive species. Proc. R. Soc. Lond. B 269: 2407–2413.

Lovvorn, J. R., S. E. De La Cruz, J. Y. Takekawa, L. E. Shaskey, V. K. Poulton, and S. E. Richman. *In Review.* Niche partitioning, threshold food densities, and species abundance in diminishing habitats for diving ducks. Ecological Monographs.

Mack, R. N., D. Simberloff, W. M. Lonsdale, H. Evans, M. Clout, and F. Bazzaz, 2000. Biotic invasions: Causes, epidemiology, global consequences and control. Issues in Ecology 5: 1–19.

Naylor, R. L., S. L. Williams, D. R. Strong. 2001. "Aquaculture – A Gateway for Exotic Species." Science. Vol. 294: pp. 1655-1656.

Pimentel, D., R. Zuniga, and D. Morrison. 2005. Update on the environmental and economic costs associated with alien-invasive species in the United States. Ecological Economics 52: 273–288.

Raghu, S., R. C. Anderson, C. C. Daehler, A. S. Davis, R. N. Wiedenmann, D. Simberloff, R. N. Mack. 2006. Adding Biofuels to the Invasive Species Fire? Science 313: 1742.

SFBJV Implementation Strategy. 2001. Restoring The Estuary. A Strategic Plan for the Restoration of Wetlands and Wildlife in the San Francisco Bay. Implementation Strategy for the San Francisco Joint Venture

Stohlgren, T. J. and J. L. Schnase. 2006. Risk Analysis for Biological Hazards: What We Need to Know about Invasive Species. Risk Analysis 26: 163-173.

Thornber, C. S., B. P. Kinlan, M. H. Graham, J. Stachowicz. 2004. "Population Ecology of the Invasive kelp *Undaria pinnatifida* in California: Environmental and Biological Controls on Demography." Marine Ecology - Progress Series. Vol. 268: pp. 69-80.

University of California, Integrated Pest Management Program (UC IPM). 2006. “Scientists Untangle Seaweed's Effect on Other Species,” University of California, Agriculture and Natural Resources.

Zaleski, S. F., S. N. Murray 2006. Taxonomic Diversity and Geographic Distributions of Aquarium-Traded Species of *Caulerpa* (Chlorophyta: Caulerpaceae) in Southern California, USA. Marine Ecology - Progress Series Vol. 314: pp. 97-108

Appendices

Appendix 7.1: Examples of invasive aquatic species, including their impacts to focal habitat, and method of introduction, if known:

Established in SFBJV region:

- **Asian Clam** (*Corbula amurensis*): Reduces blooms of floating algae that are necessary to support native invertebrates and fishes. Achieves extremely high densities and displaces native organisms (Carlton et al. 1990), although recent studies have found that it has high foraging value for diving waterfowl (Lovvorn et al. in review).
- **Atlantic Oyster Drill** (*Urosalpinx cinerea*): A predatory whelk snail that was introduced through ballast water and now thrives by taking advantage of available nutrients in the ecosystem and preying on 80-90% of California's only native oyster populations (Fimrite 2009, Kimbro et al. 2009).
- **Chinese Mitten Crab** (*Eriocheir sinensis*): Clogs fish salvage facilities, creates losses for fisheries, and is a potential vector for human lung fluke. Commercially valuable and may have been introduced to establish a new fishery or possibly via ballast water, yet it is believed to have been intentionally released in California in 1992 (Cohen and Carlton 1997).
- **European Green Crab** (*Carcinus maenas*): It is highly invasive along the entire coast of California and preys on numerous native species in the coastal environment (Grosholz and Ruiz 1995). It dramatically reduces native clams and shore crabs, and threatens regional shellfish production. May have been introduced from the eastern U.S. with packing material for lobsters or bait worms, or perhaps via ballast water (Grosholz et al. 2000).
- **Exotic Oyster** (*Crassostrea gigas)*: This oyster invaded SFB in 2006. It grows faster than native SFB oysters and up to four times in size. Evidence suggests it would out-compete native oysters for food or space, overgrow them, or impair their growth with metabolites or feces (Bayne 2002; Chew 2003).
- **Fan Worm** (*Terebrasabella heterouncinata*): A sabellid polychaete introduced from South Africa, now parasitizes the shells of abalone and several other native gastropods (Kuris and Culver 1999, Naylor et al. 2001).
- **Inland Silverside** (*Menidia beryllina*): Consumes and competes with native fishes including endangered Delta smelt. Intentionally introduced outside of the Bay-Delta for aquatic insect control, but its spread into the Delta was likely aided by unauthorized releases (Cook and Moore 1970).
- **Invasive Rockweed** (*Ascophyllum nodosum)*: First introduced to SFB in 2002, infestations of this brown Atlantic coast alga have been recurring in 2004 and most severely in 2008. Volunteer control and monitoring efforts guided by NOAA are continuing. (http://www.sanctuarysimon.org/monterey/sections/other/whats_invasive_rockweed.php)

Potential invaders:

- **Wakame** (*Undaria pinnatifida*): A Japanese marine alga that was introduced to California in 2000 and has since spread along the coast from hull fouling (Thornber et al. 2004).
- **Wireweed alga** (*Sargassum muticum*): The invasive alga was accidentally introduced with oysters from Japan in the 1940s and is now widespread along the California coast and excludes many tide pool and subtidal native species (UC IPM 2006).
- **Mediterranean alga** (*Caulerpa taxifolia):* The invasive alga was introduced near San Diego by a release from an aquarium tank in 2001, and may pose a threat to the San Francisco Bay in the future (Anderson 2005, Zaleski and Murray 2006).

The San Francisco Bay Joint Venture is a partnership of public agencies, environmental organizations, the business community, local governments, and landowners working cooperatively to protect, restore, increase, and enhance wetlands and riparian habitat in the San Francisco Bay Watersheds. We bring an ecosystem and collaborative approach to developing and promoting wetland and riparian habitat conservation throughout the Bay Area.

The Joint Venture Management Board

Nonprofit and Private Organizations

Bay Area Audubon Council
Bay Area Open Space Council
Bay Planning Coalition
Citizens Committee to Complete the Refuge
Ducks Unlimited
National Audubon Society
Pacific Gas & Electric Company
PRBO Conservation Science
Save the Bay
Sierra Club
The Bay Institute

Public Agencies

Bay Conservation and Development Commission
California State Coastal Conservancy
California Department of Fish and Game
California Resources Agency
Contra Costa Mosquito and Vector Control District
National Fish and Wildlife Foundation
NOAA National Marine Fisheries Service
Natural Resources Conservation Service
SF Bay Regional Water Quality Control Board
San Francisco Estuary Partnership
U.S. Army Corps of Engineers
U.S. Environmental Protection Agency
U.S. Fish and Wildlife Service
U.S. Geological Survey
Wildlife Conservation Board

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