**Project Category:** Coastal/Marine

**Project Title:** Predicting the vulnerability of nearshore species and habitats to climate change effects

**Project Leader/Administrator: Dr. Deborah A. Reusser**, USGS Western Fisheries Research Center, Newport Oregon field station, 541-867-4045, dreusser@usgs.gov. Dr. Reusser is the USGS lead on the "species at risk" project and has the lead for developing the web implementation.

**Cooperators/Partners:**
**Erin Stockenberg,** FWS, R1 Inventory & Monitoring, erin_stockenberg@usgs.gov, 360-604-2586. Collaborator for testing ecoinformatics tools to address management questions for FWS.
**Tim Counihan**, USGS, tcounihan@usgs.gov, 509-538-2299, ext 281. Expert in anadromous fishes, and will provide expertise related to assessing fish vulnerability, including trophic impacts on salmon resulting from changes in estuarine prey availability.
**Jill Hardiman**, USGS, jhardiman@usgs.gov, 509-538-2299, ext 201. Bioenergetics and GIS.
**Rebecca Loiselle**, USGS, 541-867-5041, rloiselle@usgs.gov. Ms. Loiselle is the lead for synthesizing biotic data, and will expand this effort to additional nearshore areas.
**USGS programmers**: Have the lead on migrating the existing MS Access *PCEIS* database to the web.
**Dr. Henry Lee II**, U.S. EPA, lee.henry@epa.gov, 541-867-5001. Dr. Lee leads EPA's "species at risk" climate project, including developing the conceptual framework.

**Project Summary:** The primary objective of the research is to develop a rule-based decision support system to predict the relative vulnerability of nearshore species to climate change. The approach is designed to be applicable to fishes and invertebrates with limited data by predicting risk from readily available data, including species' biogeographic distributions and natural history attributes. By evaluating multiple species and climate stressors, the approach allows an assessment of climate vulnerability across habitat types and the impact of specific climate alterations as well as their cumulative impact.

**Background and Need:** Nearshore ecosystems (used here to indicate primarily estuarine species/habitats but inclusive of marine species out to 200m depth) are undergoing rapid environmental changes, including temperature increases, ocean acidification, and habitat loss from sea level rise (SLR). These climate alterations will result in a host of ecological impacts, ranging from species' range shifts to loss of ecosystem functions to regional/global extinctions. However, the impacts of these climate alterations vary substantially among species according to both exposure of their habitat to the specific climate alteration as well as their life history and physiological traits. For example, a 2-meter SLR rise will have major impacts on emergent marsh species and habitats but a trivial effect on continental shelf species. Similarly, impacts of ocean acidification on bivalves and other calcified benthos and zooplankton will depend upon the shell structure and composition of the species. With warming, southern prey species may migrate northward, and potentially disrupt food webs. These climate alterations will result in a host of ecological impacts, ranging from species' range shifts to loss of ecosystem functions to regional/global extinctions. In particular, intertidal and estuarine species/habitats, and their associated ecosystem functions and services, are highly vulnerable because of several stressors impinging upon these habitats in concert (e.g., SLR, air and water temperature, etc.). For management to respond in a scientifically-sound fashion to these impacts, it is critical to know which species/habitats are at the greatest risk and which climate stressors are the "biggest problem" by habitat type. To address these needs, the EPA and USGS have instituted a pilot project to predict the vulnerability of nearshore species and habitats at risk to climate change. The research proposed here would expand this effort, including a greater focus on the direct and indirect effects on salmon and other estuarine fishes.

**<u>LCC Conservation Goals Addressed by Project:</u>**

*Promote communications and collaborations:* The public web site that assesses species and habitat vulnerabilities, described below, is both a decision support tool for managers and an outreach tool to the public. The invitation-only data entry portion of the web site will allow regional experts to input biotic data and is a mechanism to foster collaboration with the research community.

*Enhance resource management through applied science & tech transfer*: Identifying the species and habitats at greatest risk enables resource managers to identify high risk areas as well as the types of climatic stressors of greatest concern. One of the primary objectives of the public website and associated decision support tools is for information transfer to resource managers.

*Identify opportunities for coordinated management strategies*: By assessing the vulnerability of multiple species across taxa, the project allows managers to address risks in a coordinated fashion instead of by assessing isolated species.

*Establish/contribute to landscape scale baseline information for key ecosystem components and/or services:* The project will generate two major landscape-scale products. The first is the "climate alteration by habitat matrix" that synthesizes knowledge on habitat-specific climate stressors and the magnitude of change. The second product is the website where researchers, managers, and the public can assess the relative vulnerability of species and habitats to specific climate stressors at ecoregional scales.

*Ecological or Ecosystem Response to System/Climate Change:* The framework provided by the "climate alteration by habitat matrix" will assist managers in focusing mitigation efforts by reducing scientific uncertainty as to which climate stressors impact each habitat and, in out years, the extent of the habitat-specific climatic change. Additionally, an analysis of the species and habitats at greatest risk would help in identifying those requiring the greatest level of protection (e.g., via marine protected areas, reduced take, etc.).

*Applicability to conservation and adaptation decisions:* Identification of the species and habitats at greatest risk provide the basic information needed by managers to develop mitigation schemes and prioritize actions.

**Objectives:** The goal of the proposed research is to extend the ongoing EPA/USGS "species at risk" project in the Northeast Pacific (NEP; Northern California through Gulf of Alaska). The major objectives of the **Species at Risk Research** are to: 1) develop a rule-based approach to predict the relative vulnerability of near-coastal species to climate alterations based on biogeographic distributions and life history attributes; 2) apply this methodology to fish, invertebrates, and macroalgae in the NEP; 3) assess how species' vulnerabilities vary geographically and across habitats; and 4) develop a web-based tool to inform the public and researchers as well as to serve as a decision support tool for managers. To gain a more complete perspective on the effects of climate change geographically and across different habitats, the approaches are being designed to evaluate the vulnerability of species with limited data, and not just a few well studied species. Achieving these goals entails developing an ecoinformatics framework and tools, synthesizing the distributions and natural history attributes of coastal/estuarine species, synthesizing climate projections by region, and developing rule sets to utilize the synthesized data to predict the relative risk to near-coastal/estuarine species. Figure 1 gives a conceptual overview of our approach.

**Methods:** Data limitations preclude using niche or physiologically-based models to predict climate effects on most nearshore species. To address this limitation, U.S. EPA and USGS are developing a framework and the baseline information to predict the relative vulnerability of nearshore species and habitats modified from approaches used in conservation science. The framework integrates a database synthesizing biotic information (Pacific Coast Ecosystem Information System, *PCEIS*), climate alterations by habitat, three integrated approaches to predicting vulnerability, "metarules" synthesizing results from the individual approaches, and decision support tools and metrics hosted on a web site (Fig. 1). Of the three approaches for predicting vulnerability, the "rarity matrix" is the most general approach and is based on three attributes that can generally be extracted from existing sources: 1) geographic distribution as measured by the global number of MEOW ecoregions; 2) habitat specificity; and 3) global population status. The second approach, “life history rules”, are suites of rules specific to nearshore environments and species and are based generally on a population’s stability or to a species’ vulnerability to a climate driver (e.g., bivalves with aragonite shells are more vulnerable to ocean acidification). The life history rules will often provide more detailed predictions than the rarity matrix. Because both approaches are based on species’ attributes, they do not require quantitative estimates of climate changes. The third, and most data intensive approach, the “climate change exposure rules”, predicts vulnerability by explicitly linking species tolerances and life history traits to projected environmental changes in habitat(s) occupied by the species. While the predictions are at the species level, aggregating species by a suite of environmental characteristics (e.g., depth, salinity, substrate type) generates a vulnerability assessment by habitat type.

Linking these three vulnerability approaches allows us to make estimates of relative vulnerability even for species with limited data. Based on a proof of concept of the rarity approach with >160 chiton species on the Pacific Coast (Reusser and Lee, in press) and synthesis of life history attributes for >650 nonindigenous species in the North Pacific (Lee and Reusser, in review), we anticipate that we will be able to generate vulnerability predictions based on the rarity matrix for most near coastal fish, decapods, and echinoderms within the first year, as well as a subset of these based on the life history rules. In part, this extensive analysis is possible because we will draw on an ongoing USGS project to synthesize intertidal and subtidal fish and invertebrate data, including the NOAA RACE trawl data, regional surveys (e.g., EMAP), literature, and online sources (e.g. OBIS).

Inherent in the research is the continued development of *PCEIS* as the ecoinformatics tool to synthesize species’ global distributions by The Nature Conservancy’s “Marine Ecosystems of the World” (MEOW) biogeographic schema and key natural history attributes (see http://www.epa.gov/geoss/ami/pacific-coast.html for an earlier implementation). Specifically, we are modifying *PCEIS* to better capture climate affected attributes (e.g., shell structure) and migrating it from an MS Access database to the web. Another inherent component of the research is the development of a “climate alteration by habitat” matrix to link habitat-specific climate changes to species. A portion of the qualitative versions of the matrix is shown in Fig. 2; the next step is to fill in the matrix with actual projections of climate change by habitat by MEOW ecoregion. The last component is the development of a web-based implementation of the framework. The initial web site will be restricted to experts for data entry on species’ distributions and natural history, and a prototype of this version will be available in June 2011. Then we will develop an open site that will include several decision making tools as well as the ability to generate reports on vulnerability by individual species or habitat.

**Geographic Extent:** The “Marine Ecosystems of the World” (MEOW; Spalding et al., 2007) is the framework we are using to synthesize ranges of marine/near-coastal species at regional and global scales. To capture the entire North Pacific LCC area, we will target taxa and habitats that occur in any of five MEOW ecoregions – Gulf of Alaska, Fjord Lands, Puget Sound, Oregonian, and Northern California. However, species’ distributions are evaluated globally over all 232 MEOW ecoregions.

**5. Partnerships/Leveraging/Cost Sharing:** The project builds on the extensive leveraging between USGS and EPA and brings USFWS into this partnership. Development of the website will allow regional experts to input biotic data into the online database, greatly increasing the potential for developing partners with state, tribal, academic, and NGO groups. In terms of cost, the EPA has funded a $150K IAG with USGS to develop the website for the species at risk, USGS has funded Dr. Reusser’s and Ms. Loiselle’s participation in the climate change research for FY11, and EPA is allocating 1+ FTEs (Dr. Lee) to the species at risk project plus a post-doc through FY11.

**Timeline of Products and Outcomes:**

| | |
|---|---|
| Prototype of the restricted website for expert data input | Oct. 2011 |
| Restricted website available for expert data input | Dec. 2011 |

| | |
|---|---|
| Rarity analysis & "climate alteration by habitat matrix" for N. Pacific species/habitats | Jan. 2012 |
| Prototype of the public website | Jun. 2012 |
| Life history rules analysis of targeted N. Pacific species/habitats | Apr. 2012 |
| Public website access | Sept. 2012 |
| Final Report to USFWS (including peer reviewed papers over the life of the project) | Jan. 2013 |

**Disclaimer Regarding Data Sharing:** Data must be approved through EPA's quality assurance review before it can be released.

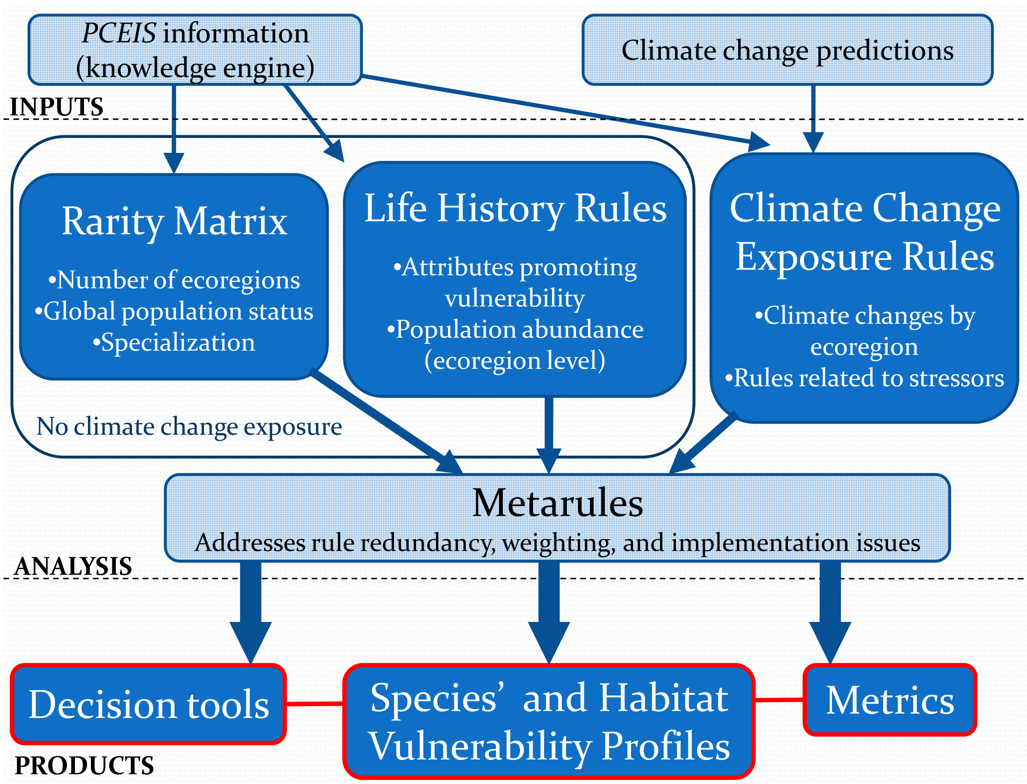

Figure 1: Overview of the framework for predicting relative vulnerability of nearshore species.

| Habitat Type 1° | 2° | 3° | 4° | ↑ Air Temp | ↑SST | ↑OA | ↑SLR | Δ precip | Δ LULC |
|---|---|---|---|---|---|---|---|---|---|
| Estuarine | Benthic | Supralittoral | | H | L | L | M | M | L/M |
| | | Intertidal | Tide flat | H | H | L/H | H | H | L/M |
| | | | Marsh | H | L | L | H | H | H |
| | | Shallow subtidal | | TR | H | L/H | P | L | L/M |
| | | Deep subtidal | | TR | H | L/H | L | TR | M |

Figure 2: Portion of "climate alteration by habitat" matrix. H = large environmental change; M = moderate change; L/M = low to moderate change; L/H = low to high environmental change (= high uncertainty); P = positive change (e.g., increase in area of habitat); TR = trivial change. SST = sea surface temperature; OA = ocean acidification; SLR = sea level rise; LULC = land use, land cover.