Fishery Specific Habitat Objectives - West Coast Pilot Draft Report

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EXECUTIVE SUMMARY

The Magnuson-Stevens Fishery Conservation and Management Act (MSA) recognizes that one of the greatest long-term threats to commercial and recreational fisheries is the continued loss of marine, estuarine, and other aquatic habitats. Because of this, the MSA established a mandate for regional fishery management councils to identify and describe essential fish habitat (EFH) for the fisheries that they manage [MSA Sec. 305(b)(1)(A)]. Federal agencies must then consult with the National Marine Fisheries Service (NMFS) to conserve EFH for those managed fisheries. However, quantifying the benefits of habitat conservation actions and prioritizing those actions remains a daunting challenge because of the many potential habitats used by stocks, the broad geographic distributions of stocks, and the numerous anthropogenic effects on fish habitat. The purpose of this pilot project is to contribute to rebuilding and maintaining selected stocks managed by the Pacific Fishery Management Council (PFMC) by developing a process to create targeted habitat conservation objectives and strategies for implementation by NMFS and PFMC.

This pilot project is comprised of five species, including groundfish and salmon species. We chose four focal groundfish species and one salmon species via a team of experts from the NMFS Northwest and Southwest Fishery Science Centers, NMFS West Coast Regional Office, NMFS Greater Atlantic Regional Fisheries Office, NMFS Office of Habitat Conservation, NMFS Office of Science and Technology, the Pacific and Mid-Atlantic Fishery Management Councils, and the Pacific States Marine Fisheries Commission (PSMFC). The four groundfish species are black rockfish (*Sebastes melanops*), bocaccio (*Sebastes paucispinis*), English sole (*Parophrys vetulus*), and lingcod (*Ophiodon elongatus*). The selected salmon was Oregon Coast coho salmon (OC coho) (*Oncorhynchus kisutch*). While the focus of this report and pilot effort is on these 5 focal species, the positive impacts from achieving the habitat objectives would also benefit other species with similar habitat utilization.

Before habitat objectives could be identified for specific stocks, we needed to decide whether sufficient information on the life history, population estimates, and habitat usage exists to determine habitat objectives. The amount and specificity of information will determine whether habitat objectives can be qualitative or quantitative. It was determined based on a decision framework that there was only sufficient data for qualitative (ranking) habitat objectives for the groundfish species, while quantitative objectives were possible for the salmon species.

The development of qualitative objectives for groundfishes utilized a combination of conceptual models and a two phase quantitative risk assessment to evaluate the relative risk of potential anthropogenic stressors. Phase 1 was a coast-wide proof of concept with readily available stressor data, while Phase 2 focused on two specific geographic regions – the Puget Sound and Southern California Bight – with a focus on finding more appropriate stressor data for more robust risk scores. The habitat data we used were spatial habitat suitability probabilities prepared as part of the groundfish Essential Fish Habitat Environmental Impact Statement (EFH EIS) (NMFS 2005a). Stressor data for the first phase was taken from Halpern et al. (2009), which included many of the broad scale impacts along the West Coast of the United States. Stressor data for the second phase was compiled from a broad range of sources (see Table 1 and details in Appendices 8 and 9).

The results of the risk assessment were intended to be a framework to establish a prioritization of stressors and qualitative habitat objectives. For the first phase we incorporated only readily available data due to the time restrictions of the pilot project. The stressors identified in the conceptual models were not adequately represented in the stressor data from Halpern et al. (2009). In addition, the accuracy of stressor data for our purposes was not quantified and spatial scale mismatches may exist between Halpern and our project. In the second phase of this pilot project, we identified a more focused geographic range with greater potential for existing and available stressor data, specifically for those stressors identified in conceptual modeling. We then completed a revised risk assessment analysis with the methodology updated to address input from the PFMC Science and Statistical Committee and Habitat Committee. Those results facilitated the development of habitat objectives to address stressors that contribute to the risk of the focal species, and the habitat objectives can be influenced by NMFS and PFMC.

Due to the available habitat use and population level data, it was not possible to identify quantitative habitat objectives for the focal groundfish species. Therefore, we propose the following qualitative objective: "*Decrease exposure to priority stressors (those ranked high and medium) to recover degraded focal species habitat, protect high functioning focal species habitat, and decrease overall risk to focal species.*" High functioning habitat is defined, for this purpose, as habitat that has water and sediments free from contaminants and the sediment composition, depth, dissolved oxygen levels, temperature, prey abundance and diversity, and available shelter necessary to support the focal species at all life stages present in the biogeographic region.

The Oregon Department of Fish and Wildlife (ODFW) developed quantitative habitat objectives in the Oregon Coast Coho Conservation Plan (OCCCP) (ODFW 2007), and NMFS is working with ODFW on the development of additional quantitative habitat objectives for use in the NMFS recovery plan for OC coho. We provide an overview of the framework for developing these objectives in support of the Recovery Plan. This framework follows a conceptual model similar to the model that uses qualitative objectives, in which habitat-based key ecological attributes (KEAs) are linked to a set of anthropogenic threats.

Remaining work to be completed includes spatial analysis to determine areas where KEAs that are currently functioning can be protected and where KEAs impacted by threats could be restored, and limiting factors and life cycle modeling to determine amounts of restoration required to meet the recovery plan goals. A pilot life cycle modeling effort focusing on the Salmon River independent spawning population revealed that the OCCCP's current focus on tributary habitat restoration might be significantly improved with additional restoration efforts in main stems, floodplains, and estuary habitats.

ACKNOWLEDGEMENTS

Additional expertise to select focal species and guide various aspects of the project was provided by Kristan Blackhart (NMFS Office of Science and Technology), Lou Chiarella (NMFS Greater Atlantic Region), Jessica Coakley (Mid-Atlantic Fishery Management Council), Jason Cope (NMFS Northwest Fisheries Science Center), Steve Copps (NMFS West Coast Region, Oregon & Washington Coastal Area Office), Eric Danner (NMFS Southwest Fisheries Science Center), Melissa Haltuch (NMFS Northwest Fisheries Science Center), Owen Hamel (NMFS Northwest Fisheries Science Center), Chris Moore (Mid-Atlantic Fishery Management Council), Jen Steger (NMFS Restoration Center), Ian Taylor (NMFS Northwest Fisheries Science Center), and Jim Thorson (NMFS Northwest Fisheries Science Center). Funding for Phase 1 and 2 of this pilot project was provided by the NMFS Office of Habitat Conservation.

1. INTRODUCTION

1.1 PROJECT PURPOSE

The National Marine Fisheries Service (NMFS), regional fishery management councils (FMCs), states, and partners have made significant strides to establish annual catch limits, accountability measures, and rebuilding plans to achieve long-term productivity and sustainability of our nation's fisheries. Despite progress, certain stocks appear to respond poorly and/or belatedly to rebuilding measures (Milazzo 2011). The health of these and other stocks may be linked to their dependence on particular habitats during critical life stages. Protecting and restoring such habitats will help NMFS, FMCs, states, and partners achieve their sustainable fisheries goals. To do this, we must do a better job identifying, prioritizing, and quantifying conservation actions that will support habitat-limited fish stocks.

However, because of the many potential habitats used by stocks, the broad geographic distributions of stocks, and many ways that people can affect fish habitat, quantifying the benefits of and prioritizing habitat conservation actions remains a daunting challenge. The purpose of this pilot project is to contribute to rebuilding and maintaining selected stocks managed by the Pacific Fishery Management Council (PFMC) by developing a process to create targeted habitat conservation objectives and strategies for implementation by NMFS and PFMC, and for possible application to other managed stocks. The project's main objectives were:

- Identify 2-4 focal species of habitat-limited managed fishes. It was expected that these species would include both groundfishes and salmon;
- Develop initial fishery-specific habitat conservation objectives for each species;
- Develop a plan for NMFS to target existing habitat conservation efforts to meet these objectives, including necessary management, monitoring, and evaluation needs; and
- As needed, identify data gaps for developing future fishery-specific habitat conservation objectives that may be more specific and quantifiable than initial objectives.

Being a pilot effort, a secondary purpose of this endeavor was to evaluate the utility of the approach taken, identify additional information and/or resources needed to improve upon results, and ultimately recommend whether or not NMFS and PFMC should pursue future efforts for the West Coast and/or NMFS should expand efforts into other regions. Recommendations regarding data gaps, approach, and next steps are provided below in section 4.

For this pilot project, we chose four groundfish species and one salmon species as initial focal species: black rockfish, bocaccio rockfish, English sole, lingcod, and OC coho. These species show strong affinity for inshore, estuarine, and/or nearshore habitats, have habitat that is vulnerable to degradation, and occur within geographic areas where NMFS implements authorities for habitat conservation through protection, threat reduction, and restoration measures.

West Coast estuaries, nearshore, and marine environments include a variety of habitats that are important for various life stages of many groundfish stocks and most salmon stocks. Both the distribution and function of these habitats are affected by numerous human-induced stressors. As these habitats are differentially used by particular life stages, the risk from various stressors and the optimal habitat conservation strategies ameliorating these stressors are expected to vary by life stage. Therefore, habitat objectives should be couched in the context of key habitat stressors, the contribution of individual stressors to populations, and NMFS' ability to address those stressors using existing authorities and programs.

This pilot was broken out into two phases. Phase 1 occurred from June 2014 to June 2015. During Phase 1, we completed our four main objectives and presented our findings to the PFMC Science and Statistical Committee (SSC) and the Habitat Committee (HC) for their review during the June 2015 Council meeting. The two committees provided extensive feedback, including:

- The HC recommended focusing on a smaller geographic area(s) where more and better stressor data is available
- Both HC and SSC recommended increasing the quality of the stressor data being input into the risk assessment analysis
- The SSC suggested separating or removing the productivity, or recovery, factors from the sensitivity axis
- The SSC expressed a concern for the inherent quantitative nature of the risk assessment, despite the qualitative nature of the data and analysis goals
- The SSC expressed a concern with the scaling of exposure scores, specifically where the scaling did not did not account for the absolute exposure to each stressor in each region

Feedback from both Committees prompted our pilot team to develop a Phase 2.
Phase 2 occurred from August 2015 to November 2016. Phase 2 incorporated many of the suggestions of the Habitat and Science and Statistical Committees, including a re-focus on

specific geographic areas, hiring a GIS specialist to incorporate a wide range of stressor data, removing the recovery factors from our sensitivity axis. There were several concerns expressed by the SSC that we were unable to address due to the nature of our analysis, including the scaling of exposure scores and the inherent quantitative nature of the risk assessment methodology. Both of these concerns are important to consider when assessing the risk scores in this report.

This two-phase pilot project builds upon previous West Coast efforts, including the NMFS Essential Fish Habitat Environmental Impact Statement (EFH EIS) for Groundfish (2005a), the California Current Integrated Ecosystem Assessment (CCEA), the NMFS Habitat Assessment Prioritization Working Group (HAPWG), which prioritized West Coast stocks regarding the need for improved habitat assessments to inform fisheries management and EFH designations (see Blackhart, 2014), and the ongoing recovery planning for Oregon Coast coho salmon (OC coho) (NMFS 2013).

NMFS and PFMC Authorities and Programs

NMFS and the PFMC are authorized through several acts of Congress to direct and manage habitat conservation efforts to rebuild and maintain sustainable fisheries and recover protected species. Under the Magnuson-Stevens Fishery Conservation and Management Act (MSA), the PFMC identifies and describes EFH for species under its jurisdiction using the best available scientific information and minimizes the adverse effects of fishing activities on EFH to the extent practicable. NMFS provides recommendations to federal agencies on any action or proposed action to minimize the adverse effects of non-fishing activities on EFH. MSA also affords NMFS the authority to provide funding and technical expertise to restore fishery and coastal habitat. Under the Endangered Species Act (ESA), NMFS provides reasonable and prudent alternatives to federal agencies when needed to ensure Federal actions do not jeopardize the continued existence of a species or destroy or adversely modify critical habitat. NMFS must also develop and implement recovery plans that include recommendations for actions needed to restore threatened and endangered species to the point that they no longer need the protection of the Act. Under the Pacific Coastal Salmon Recovery Fund, NMFS administers competitive grants and leverages additional funds to conserve and restore habitats for Pacific salmon and steelhead in California, Oregon, Washington, Idaho, and Alaska.

While these authorities provide broad opportunities for NMFS and PFMC to protect and restore the habitats necessary to maintain and recover fish species, they also apply extensive requirements on both organizations. The PFMC manages 119 species, each requiring EFH identification, description, and protection. In addition, a number evolutionarily significant units of coho salmon and Chinook salmon managed by the PFMC are also listed as either threatened or endangered under the ESA. The broad geographic distributions and habitats used by these species, along with the many ways in which humans can affect fish habitat, can make prioritizing and quantifying the benefits of habitat conservation actions a daunting challenge. However, developing methods to prioritize habitats for conservation efforts will be essential to ensure these conservation efforts deliver measurable outcomes.

With MSA and ESA authorities and existing restoration programs in mind, fishery-specific habitat conservation objectives can elevate the importance of habitat conservation for federally managed and listed focal fishes, and can inform:

- EFH and ESA consultations
- Future PFMC EFH reviews and initiatives under its Fishery Management Plans and Fishery Ecosystem Plan,
- ESA recovery efforts
- Restoration efforts by NMFS and partners
- Future research and data needs documents.

These were considered when developing protection and restoration strategies to achieve the habitat conservation objectives identified in this pilot project. Detailed description of the habitat conservation authorities afforded to NMFS and the PFMC considered in this pilot project can be found in Appendix E.

1.2 DECISION FRAMEWORK

Before habitat objectives could be identified for specific stocks, we needed to decide whether sufficient information on the life history, population estimates, and habitat usage exists to determine habitat objectives. The amount and specificity of information will determine whether habitat objectives can be qualitative or quantitative. *Qualitative habitat objectives* include ranking (high, medium, low) of habitat conservation efforts, while *quantitative habitat objectives* constitute estimates of the amounts of habitat protection and restoration that can be directly related to changes in the productivity of fish stocks. In the absence of quantitative objectives, qualitative objectives can be useful in prioritizing conservation efforts.

A simple decision framework highlights choices to determine whether qualitative or quantitative habitat objectives can be established for a stock of interest (Figure 1). The first criterion in the decision framework is whether habitat associations (i.e., what life stages use which habitats) are known for a candidate stock. If habitat associations are unknown, it is difficult to propose specific habitat objectives that may benefit the stock. Since the pilot project's objectives included management actions the NMFS WCR or Restoration Center

(RC) could readily address, the first criterion was refined to ask whether associations in *coastal* habitats (freshwater, estuarine, or nearshore <60 m) are known. The second criterion in the decision framework is whether there are logical habitat protection or restoration actions targeting these habitats. If not, habitat conservation actions are not applicable. The third and most stringent criterion in the decision framework determines whether relationships between habitats and species are quantifiable and can be directly related to the productivity of different life stages. If not, objectives might still be rankable by multiple criteria, but cannot be used to quantify the benefits of the conservation actions to stock productivity. For most commercially fished stocks, this final criterion is difficult to meet. Nevertheless, Pacific salmon (e.g. OC coho, Nickelson and Lawson 1998) have benefited from life cycle models incorporating habitat limiting factors, and therefore quantitative habitat objectives for these stocks are feasible.

In Phase 1 of the pilot project, we initially examined *qualitative habitat objectives* in the context of a risk assessment framework. Habitat associations are known for many West Coast groundfish stocks, and have been formalized in Habitat Suitability Probability models (Brown et al. 2000, NMFS 2005b), which are literature-based assessments of the relative strength of habitat associations for particular species life stages. When combined with existing habitat maps (Copps et al. 2007, Halpern et al. 2009), these associations can be mapped for the Pacific Coast. Likewise, various potential anthropogenic stressors that can be managed through EFH consultations and other habitat conservation activities have been quantified for the Pacific Coast (Halpern et al. 2009). We combined these two sets of information to develop draft interim qualitative habitat objectives for the groundfish focal species by providing conceptual models of how habitat stressors affect life stage-specific habitat of the four groundfish stocks, and a risk analysis incorporating sensitivity and exposure to determine which anthropogenic stressors pose the greatest risk, which stressors can be addressed through EFH/ESA consultations and restoration activities, and which stressors show the greatest response to habitat conservation.

In addition, we discuss the development of additional *quantitative habitat objectives* for OC coho based on ongoing efforts to determine habitat-specific recovery plan goals, strategies and actions. Draft objectives for habitat protection and restoration have been developed by Oregon Department of Fish and Wildlife in the OC Coho Conservation Plan and included in the draft ESA Recovery Plan. These objectives are being further refined to better link to life-stage specific habitat requirements, and quantified in order to assess the potential benefits of habitat restoration and protection actions on the viability (sustainability) of OC coho populations. While these habitat objectives have not been fully completed, we provide an overview of how they will be examined using existing data and life cycle models under development.

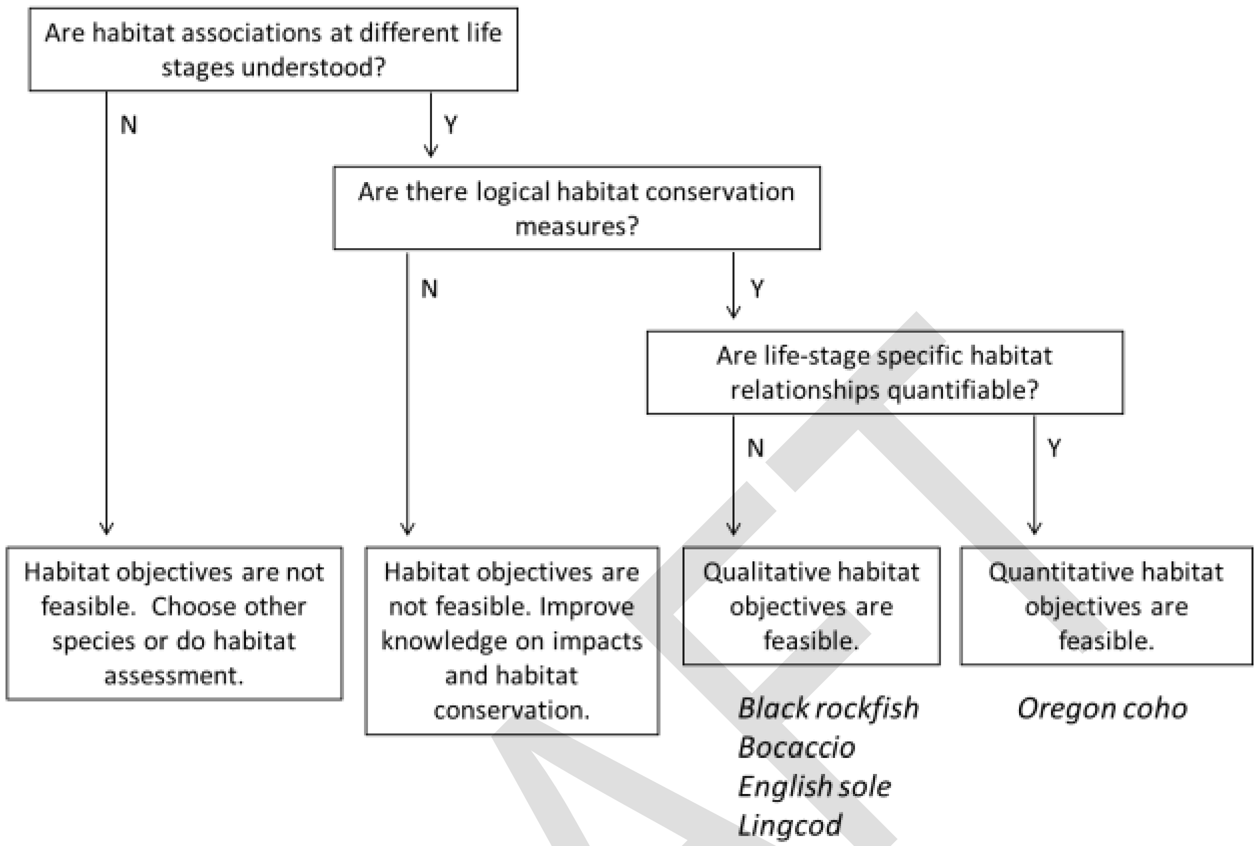


Figure 1. Decision framework for determining whether fishery-specific habitat objectives can be determined, and if those objectives can be quantitative or qualitative. Focal species are listed under their respective outcomes.

2. GROUNDFISH

2.1 FOCAL SPECIES SELECTION

Groundfish focal species.

We selected the focal species in Phase 1 of this pilot project by using best professional judgment after taking into consideration the decision framework and analyzing data compiled on West Coast fish stocks from the Northwest and Southwest Habitat Assessment Prioritizations (Blackhart 2014). No single factor determined the final selection of a species.

Factors considered when selecting groundfish focal species:

Using information compiled in Blackhart (2014), we initially considered species that scored "High" (≥3 out of 5) for habitat dependence, habitat disturbance, and fishery status:

Strength of dependency on specific habitat types. This criterion narrowed the list of potential species to those that are either habitat specialists or those that are highly associated with a particular habitat type. This facilitated the development of the habitat objectives and also increased the ability to detect a response of the focal species to habitat conservation actions or management measures. Strength of dependency was determined using Appendix B2 to the West Coast Groundfish FMP (PFMC 2005) and expertise of the Team, in addition to Blackhart (2014).

Habitat disturbance. This criterion was used to identify species that use habitats that are likely to be adversely affected by anthropogenic activity that may limit the health or productivity of the species. We considered species that met at least three of the five disturbance criteria, where their habitat is: 1) disturbed due to fishing or 2) non-fishing activities, 3) whether the primary habitat of a life stage of a fish stock is vulnerable to disturbance based on a location that is accessible or heavily used, or a 4) habitat that is demonstrably rare or 5) vulnerable and slow to recover from disturbance.

Status of the fishery. Species that were not rebuilding despite the end of overfishing would be given preference, all else being equal. Status of the fishery was taken from Blackhart (2014). While the intent of this pilot project was to identify habitat objectives for species that are not rebuilding, and may be limited by habitat, species that are either rebuilding or are rebuilt were selected based on the other factors. We felt that because this is a pilot project, a "proof of concept" approach using healthy stocks was appropriate.

After considering the above initial filter criteria, we further refined the potential focal species by considering the following:

Occurrence in estuarine or nearshore marine areas. This factor was used to narrow the potential species to those that occur, in at least one life history stage, in either estuarine or nearshore marine areas. Estuaries and nearshore areas are where most of the NMFS habitat conservation actions (i.e., EFH/ESA consultations and restoration projects) occur and where these existing programs can have the greatest effect on groundfish populations. Occurrence in estuarine or nearshore areas was based on Appendix B2 to the West Coast Groundfish FMP (PFMC 2005) and the expertise of the Team. This was one of the most important factors because it identified the species that can benefit most from existing NMFS habitat programs.

Finally, we considered the following factors to select the final focal species using best professional judgment:

Generation time. The generation time (age to maturity) of candidate species was considered, as a relatively short generation time would better facilitate detecting responses to habitat conservation actions and management measures. Generation time was based on information found in the Habitat Use Database (HUD) (NMFS 2005b) and professional expertise of the Team, and the species ultimately chosen ranged from short to longer term generation times.

Geographic distribution. The group of species was selected with the intent to cover the entire West Coast. Geographic range was taken from Appendix B2 to the West Coast Groundfish FMP (PFMC 2005) and the expertise of the Team.

Diversity of the focal species. The group of species was selected to represent diversity in both life history strategies (pelagic spawning and eggs; demersal spawners with nest guarding; and live bearers) and taxonomy (families Sebastidae, Hexagrammidae, and Pleuronectidae).

Data availability. Species with data on habitat associations were given preference over those that lacked such data. This will increase the ability to detect the response of the species to habitat conservation actions and management measures. Most species considered had sufficient habitat association data available for this project, and those selected had both habitat association data and completed stock assessments. The availability of data on the focal species was based on the expertise of the Team.

Focal groundfish species and their habitats

We identified four focal species of groundfishes for this pilot project that represent diversity in both taxonomy and life history strategies:

Black rockfish (*Sebastes melanops*, Family Sebastidae)

Geographic distribution. Black rockfish range from southern California (Huntington Beach) northward to the Aleutian Islands, occurring most commonly north of San Francisco.

Occurrence in estuarine or nearshore marine areas. Both adults and juveniles of black rockfish are found in estuaries and nearshore marine areas. Young-of-the-year settle nearshore.

Strength of dependency on specific habitat types. The transition from pelagic to benthic habitat is marked by a distinct inshore movement to estuaries, tide pools, and nearshore depths of less than 20 m. Small juveniles can often be found in shallow rocky reefs, artificial structure, eelgrass, and kelp beds, in temperatures between 8-18°C (Boehlert and Yoklavich 1983). Adults are found over high-relief rocky reefs and in and around kelp beds, boulder fields, and artificial reefs. According to Blackhart (2014), black rockfish are habitat specialists, with juveniles using kelp beds and adults/juveniles associating with pinnacles.

Generation time. More than 50% of black rockfish from the northern stock reach maturity by age 9-10 and in the southern stock by age 7-8. Although time to maturity is relatively long, we felt that the combination of: 1) use of estuaries or nearshore areas; 2) specificity of habitats used; and 3) status of the fishery make black rockfish a suitable species for this pilot project.

Life history. Black rockfish have internal fertilization and are live-bearers. Larvae and early juveniles are pelagic.

Status of the fishery. Black rockfish are an important commercial and recreational species. Blackhart (2014) reports that black rockfish off Oregon and Washington are at risk or vulnerable to overexploitation and are experiencing local depletion.

Boccacio (*S. paucispinis*, Family Sebastidae)

Geographic distribution. Bocaccio range from the Gulf of Alaska in the north, southward to Punta Blanca, Baja California. Their center of abundance is between Oregon and northern Baja California. Boccacio was selected as a focal species to provide a rockfish species that is common south of San Francisco, where black rockfish are less common.

Occurrence in estuarine or nearshore marine areas. Juvenile bocaccio are found in shallow nearshore waters and move to deeper offshore waters as they grow.

Strength of dependency on specific habitat types. Juveniles frequently settle over rocky areas associated with algae or on sandy areas with eelgrass or drift algae. Boccacio are reported to occur in waters with salinities of 31-34 ppt, temperatures from 6 – 15.5 °C and dissolved oxygen levels from 1.0 – 7.0 ppm (MBC Applied Environmental Sciences 1987).

Generation time. More than 50% of bocaccio reach maturity by ages 3-4.

Life history. Bocaccio have internal fertilization and are live-bearers. Larvae and early juveniles are pelagic.

Status of the fishery. Bocaccio are an important commercial and recreational species. Blackhart (2014) reports that bocaccio stocks are rebuilding from an overfished condition. The Puget Sound/Georgia Basin distinct population segment is listed as "endangered" under the ESA. The Southern distinct population segment, found from Northern California to Mexico, is listed as a species of concern.

English sole (*Parophrys vetulus*, Family Pleuronectidae)

Geographic distribution. English sole are widely distributed on the West Coast, from Nunivak Island in the southeast Bering Sea and Agattu Island in the Aleutian Islands, to San Cristobal Bay, Baja California Sur.

Occurrence in estuarine or nearshore marine areas. Small juveniles settle in the estuarine and shallow nearshore areas all along the West Coast, but are less common in southerly areas, particularly south of Point Conception. Juveniles reside primarily in shallow-water coastal, bay, and estuarine areas. As they grow, they move to deeper water.

Strength of dependency on specific habitat types. English sole are classified in Blackhart (2014) as being habitat specialists or are highly associated with estuaries, that use estuaries as nursery areas (north) or highly associated with estuaries (south). Juvenile English sole settle in shallow-water, soft-bottom marine and estuarine environments along the Pacific Coast. Adults and juveniles prefer soft bottoms composed of fine sands and mud (Ketchen 1956) but also are reported to occur in eelgrass habitats. Juveniles demonstrate 'close approximation' of optimal growth temperature at 13°C (Yoklavich, 1982), with a lethal level of 26.1°C (Ames et al, 1978).

Generation time. English sole mature as early as 1 year, with more than 50% mature at ages 2-3.

Life history. English sole are pelagic spawners with external fertilization. Both eggs and larvae are pelagic.

Status of the fishery. English sole are a commercially-important species, but are less important to the recreational fishery. Blackhart (2014) reports that there is no evidence to suggest that English sole off California are currently vulnerable to overexploitation and recent assessments off Oregon and Washington indicate that stocks are healthy. Although the population of English sole on the West Coast is healthy, we felt that the availability of habitat data on English sole, combined with the short generation time, makes this an ideal candidate species for this pilot project.

Lingcod (*Ophiodon elongata*, Family Hexagrammidae)

Geographic distribution. Lingcod are widely distributed along the West Coast, from Punta San Carlos, Baja California to off Shumagin Island in the Gulf of Alaska.

Occurrence in estuarine or nearshore marine areas. Lingcod occupy the estuarine-mesobenthal zone, occurring from intertidal areas to 475 m. Spawning generally occurs in shallow waters 3-10 m below mean lower low water. Small juveniles settle in estuaries and shallow waters along the coast and move into deeper water as they grow. Juveniles are common in most large estuaries between Puget Sound and San Pedro Bay, California.

Strength of dependency on specific habitat types. Juveniles settle in estuaries and shallow nearshore areas, primarily in sandy and rocky habitat. Adults prefer deeper water, in general, and have a strong affinity for rocky substrates. Spawning occurs in rocky habitats at depth of 10-40m. According to Blackhart (2014), lingcod use specialized spawning and nursery areas. Lingcod eggs are attached to substrate in masses inside crevices or under boulders or rocky shelf areas, between 3-30 meters depth (Cass et al 1990). These eggs require high flow (10-15 cm/s) to properly oxygenate interior of egg mass (Giorgi and Congleton, 1984).

Generation time. Lingcod reach maturity as early as age 3, with more than 50% reaching maturity by age 4-5.

Life history. Lingcod are demersal spawners, with females depositing eggs in nests that are guarded by the males until hatching. Larvae and early juveniles are pelagic. Later juveniles settle in estuarine or shallow-water marine habitats.

__Status of the fishery.__ Lingcod support important commercial and recreational fisheries along the West Coast. According to Blackhart (2014), there is no evidence to suggest that lingcod stocks are currently vulnerable to overexploitation, but it has occurred in the past. However, like English sole, we felt that the availability of lingcod habitat data made this species an ideal candidate for this pilot project.

2.2 CONCEPTUAL MODELS

As part of Phase 1, a series of conceptual models were created to provide a straightforward representation of habitat associations by life stage, along with potential stressors to those habitats to create clear linkages between focal species and relevant stressors. Information on habitat association for the four groundfish species by life stage was collected from the HUD. The HUD provides information on habitat based on broad habitat zones (estuary, inland sea, nearshore, shelf, etc.) and substrate type (bedrock, algal beds, artificial reef, etc.), as well as a value for habitat suitability (low = 0.33, moderate = 0.66, high = 1). The habitat types are also broken down by broad categories, estuarine, inland sea, coastal intertidal or nearshore, and shelf. These habitat associations were used in conjunction with information from the literature to create two forms of conceptual model, a simple life cycle model overlaid onto habitat use information, and a series of models for each broad habitat zone (Figure 2 example of black rockfish, other species in Appendix B), with specific stressors impacting that species in the habitats of that zone (Figures 3 example of black rockfish, other species in Appendix B).

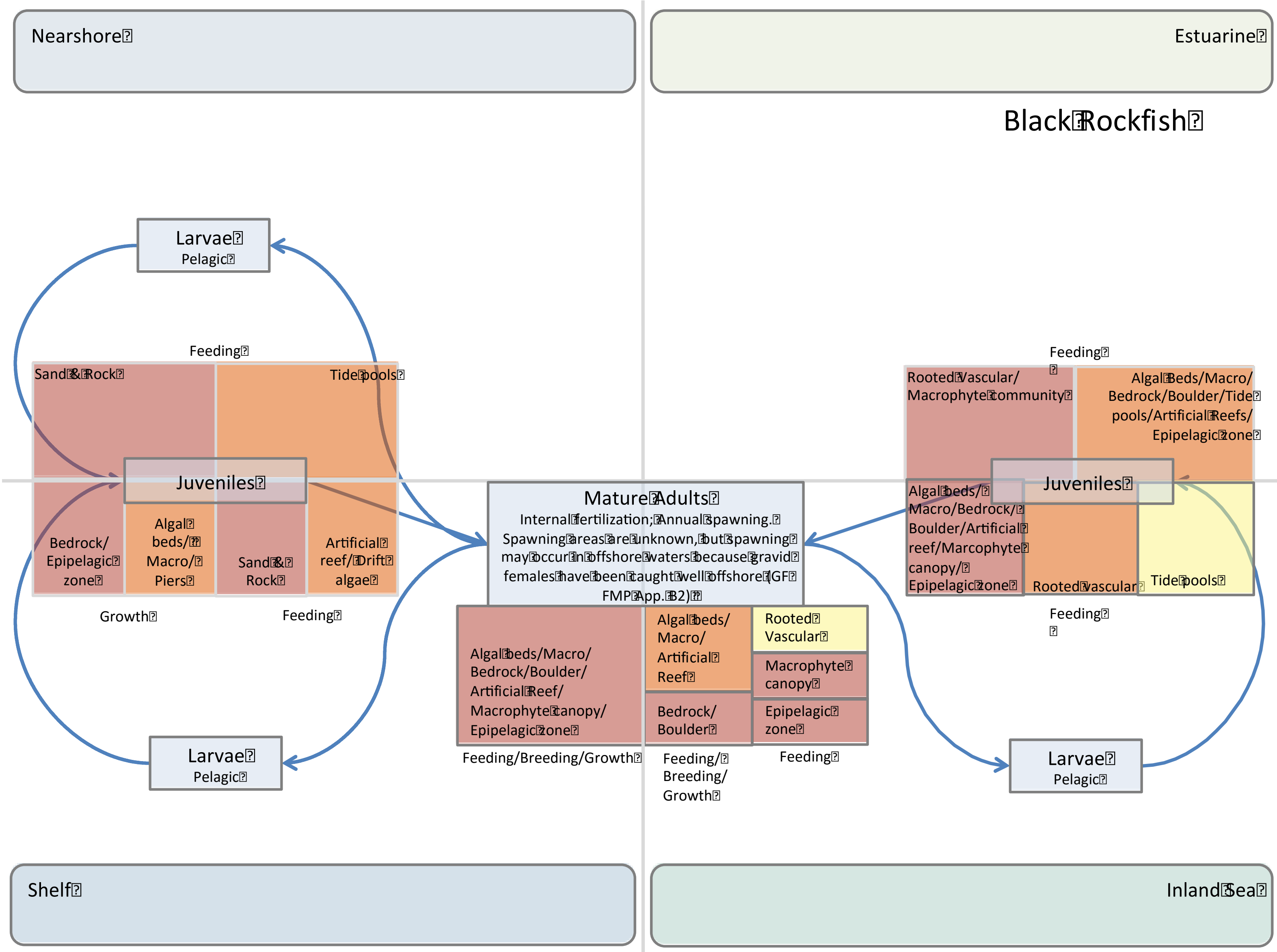
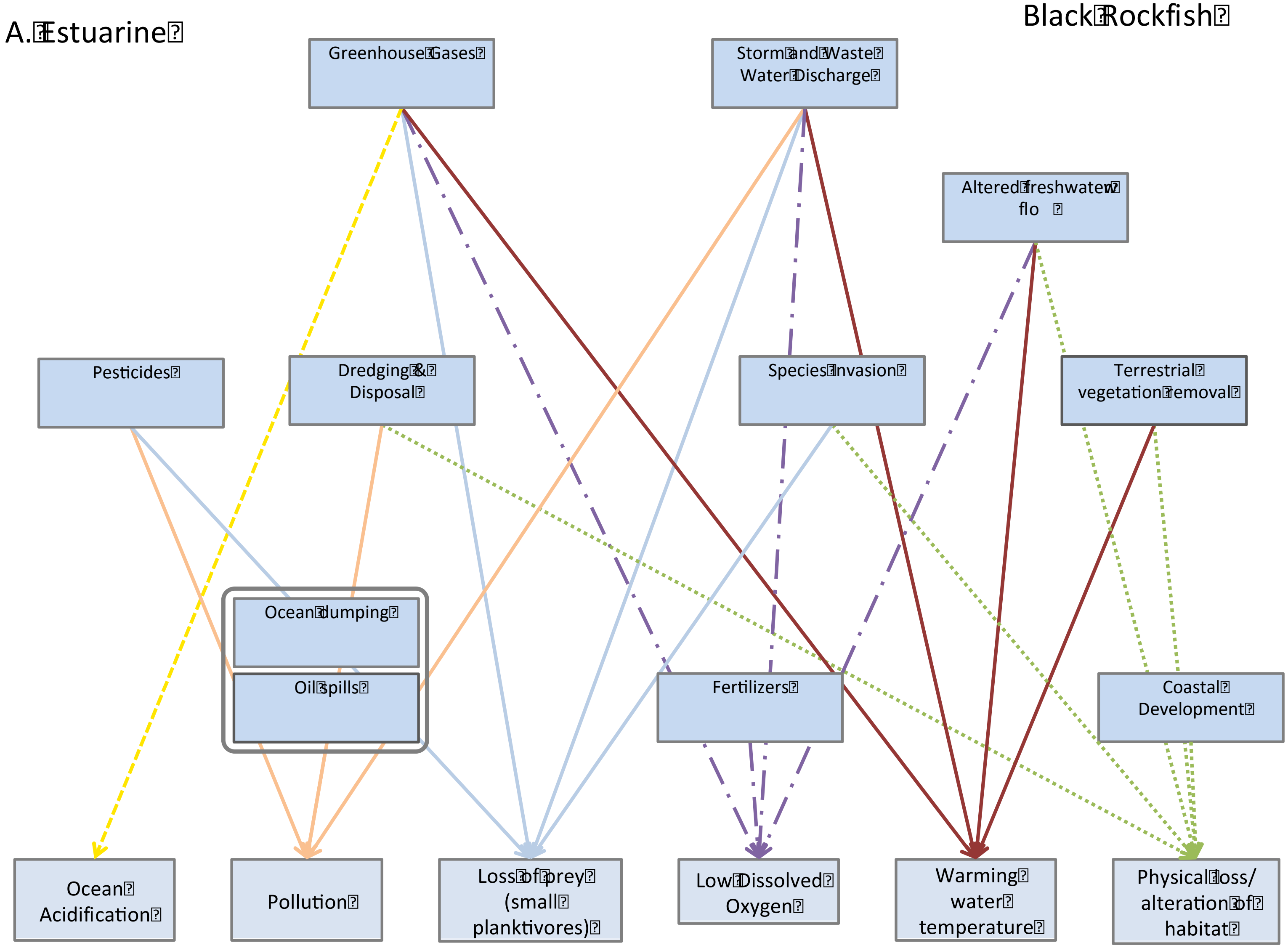


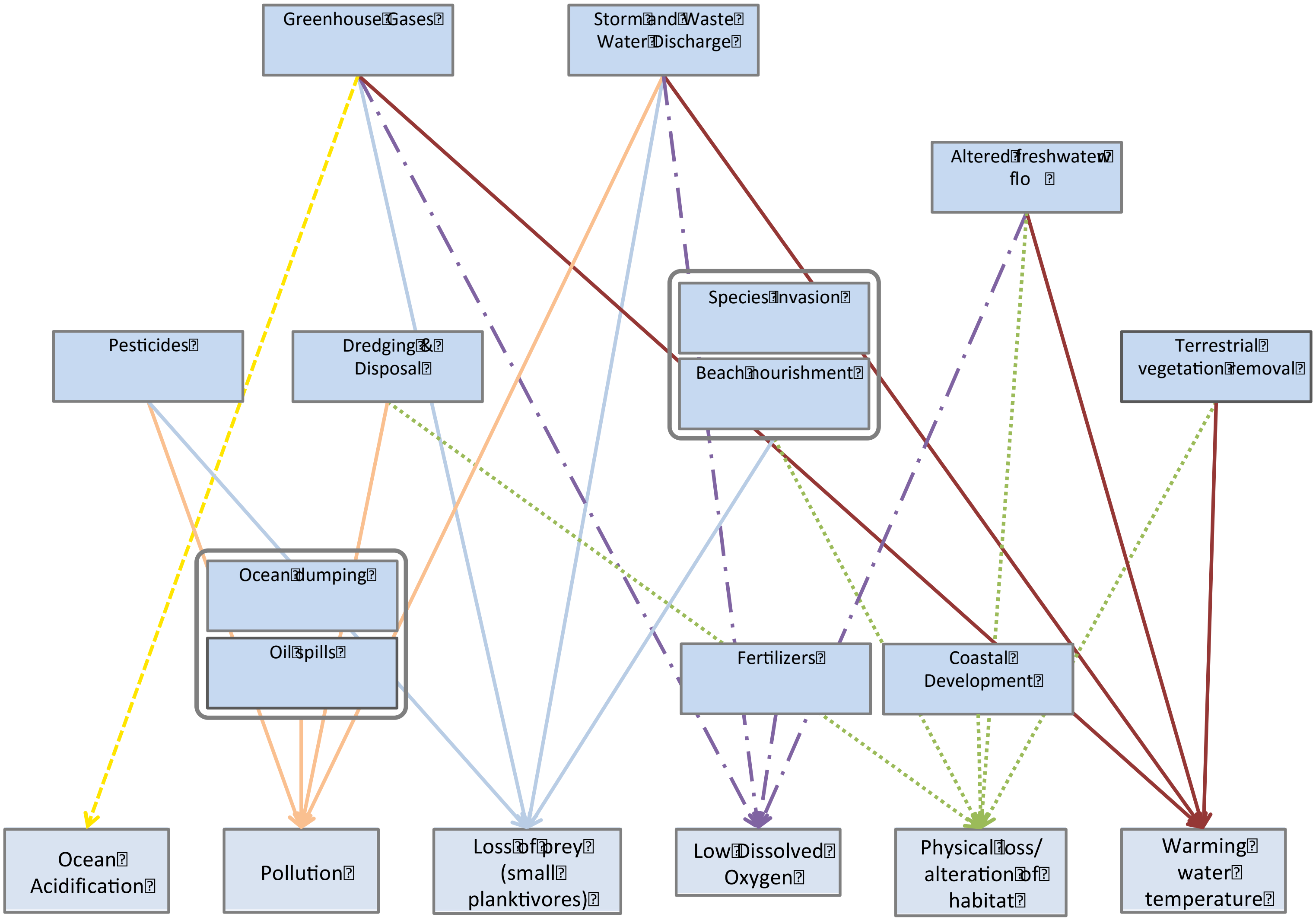
Figure 2. Black rockfish life cycle – habitat use model, life stage boxes overlap with habitat boxes indicates habitat use by that life stage. Solid lines with arrows indicate maturation. Habitat box color indicates habitat suitability (yellow = low, orange = moderate, red = high). Information on activities within certain habitats is from Pacific Coast Groundfish EFH FEIS.

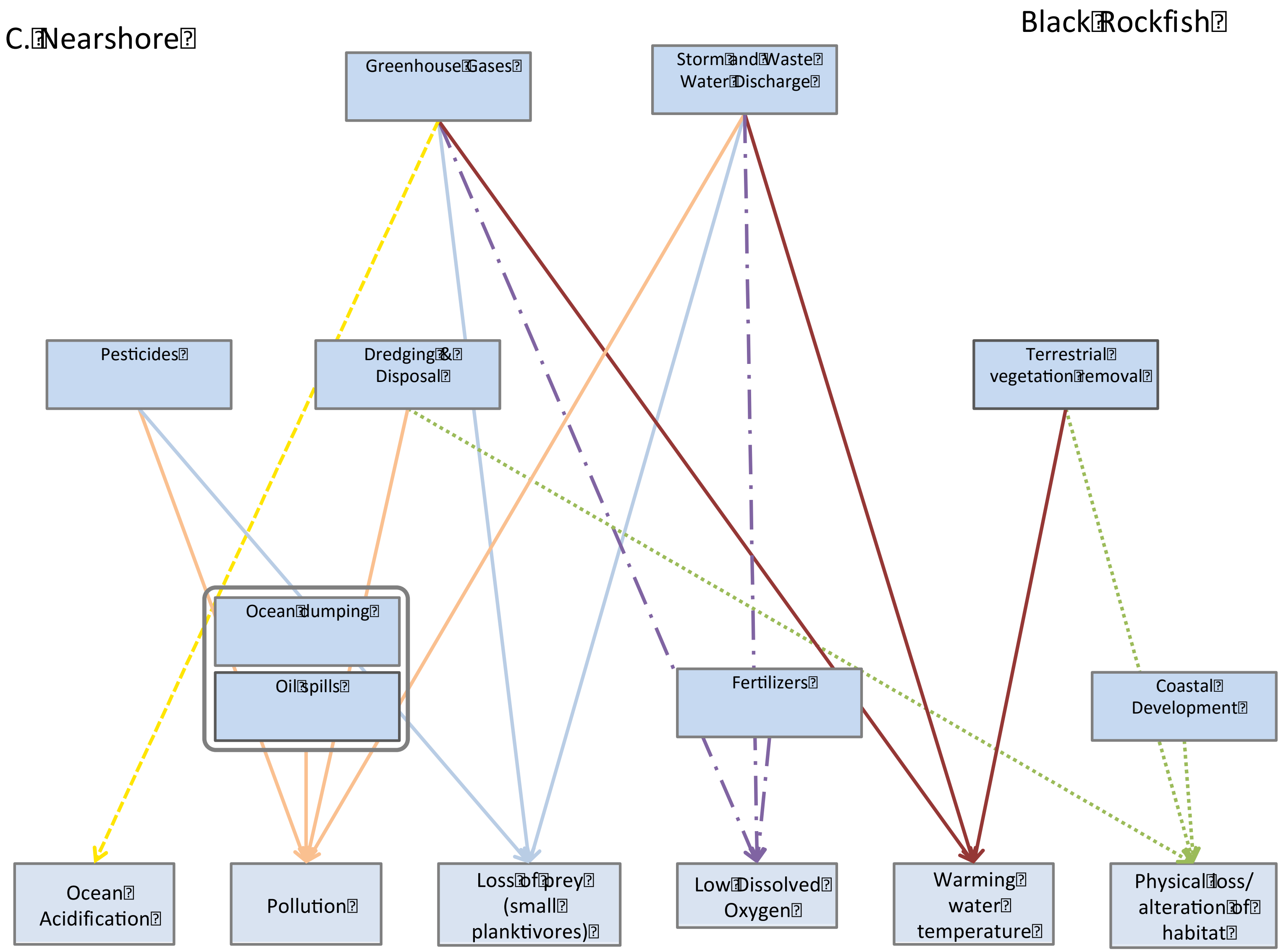
Black Rockfish



B. Inland Seas

Black Rockfish





C. Nearshore
Black Rockfish
Greenhouse Gases
Storm and Waste Water Discharge
Pesticides
Dredging & Disposal
Terrestrial vegetation removal
Ocean dumping
Oil spills
Fertilizers
Coastal Development
Ocean Acidification
Pollution
Loss of prey (small planktivores)
Low Dissolved Oxygen
Warming water temperature
Physical loss/ alteration of habitat

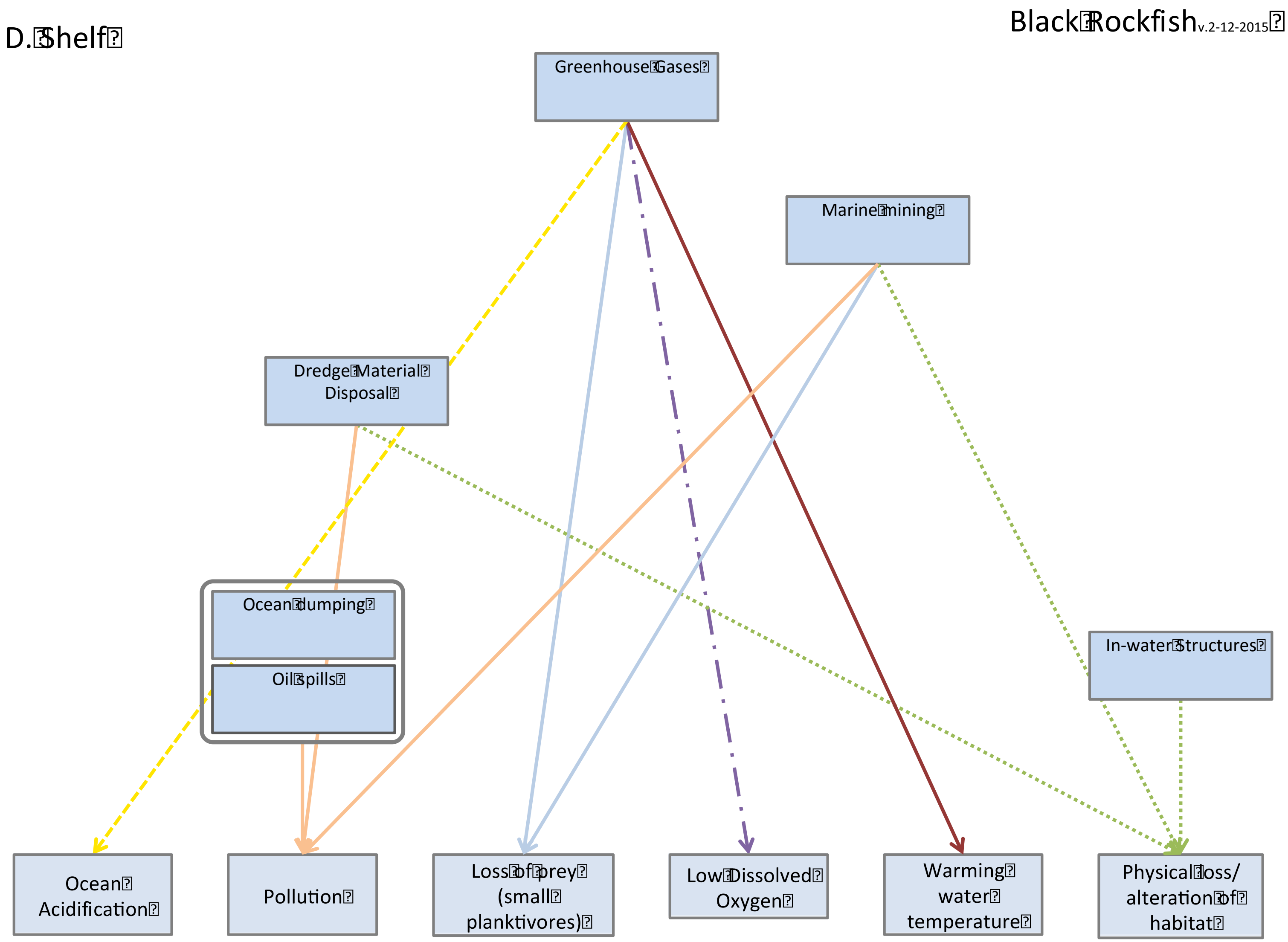


Figure 3. Conceptual model of the relationship between stressors on black rockfish in broad habitat zones. (A. Estuary, B. Inland Seas, C. Nearshore, D. Shelf). Lines color and formatting representative of different stressors.

2.3. RISK ASSESSMENT

Quantitative risk assessment is an analytical tool used in numerous applications, evaluating a risk, a value of potential for loss, based on magnitude of potential loss and the probability that loss will occur. This framework has been applied in a fisheries context as Productivity and Susceptibility Analysis (PSA) to assess vulnerability of various fish stocks to management practices (Hobday et al. 2007, Patrick et al. 2009, Patrick et al. 2010). The PSA technique has also been adapted to examine the relative risk associated with non-fisheries threats based on an exposure-sensitivity framework (Andrews et al. 2011, Hamel et al. 2012). We have adapted the approach in Andrews et al. (2011) to assess the risk of non-fisheries threats to the four focal groundfish species and their habitats as a means to prioritize habitat conservation objectives. This risk assessment framework provides only a relative value of risk, not an absolute value, and therefore we can use these risk scores to prioritize conservation goals in a qualitative manner.

We calculated the risk to the four focal groundfish species from selected non-fisheries and fisheries threats in both phases of the pilot project. During Phase 1, we incorporated data for the entire West Coast of the United States, and during Phase 2, we focused on two specific geographic regions, the Puget Sound and the Southern California Bight. Phase 1 acted as a broad scale proof of concept, while Phase 2 provided more focused and specific data inputs for more actionable results. The risk assessment analysis was based on two axes, exposure-habitat vulnerability (EHV) axis and the sensitivity (S) axis. The EHV axis incorporates information on spatial extent and magnitude of stressors on the species at various life stages based on Habitat Suitability Probability (HSP) data taken from NMFS EIS (2005a), and the vulnerability of the habitat types occupied by the species (also based on HSP data) to those stressors. The sensitivity axis incorporates information on the sensitivity of each species populations to the various stressors. We did not have the data needed to evaluate risk by the habitat zones used in the conceptual models (i.e., estuarine, inland seas, nearshore, shelf), so we were unable to differentiate risk by habitat zone.

A relative risk value for each stressor (i) was calculated for each species (s), life stage (j), and broad geographical region (k) as follows:

$$R_{sijk} = \sqrt{(EV-1)^2 + (S-1)^2} \quad (1)$$

These risk values were then combined across life stages for each species, weighted based on adult equivalence (AEQ) values (See section 2.3.3 for details on AEQ calculations).

The stressor data used for Phase 1 was taken from Halpern et al. (2009), and included 17 non-fishery stressors along the California Current[1]. These data incorporate a number of the stressors identified in the conceptual models as having potential negative impacts to the focal species, but there were many not included or not adequately addressed (Table 1). These data were readily available and were of the requisite broad spatial scale data, and so despite recognizing some drawbacks they were used in Phase 1 to allow for a proof of concept. In Phase 2, described in more detail below, we use stressor data that is better aligned with our conceptual model results (Table 1).

[1] https://www.nceas.ucsb.edu/globalmarine/ca_current_data

Table 1. Stressors to groundfish focal species identified by conceptual model and the stressor data used in the risk assessment analysis, broken down into Phase 1 data from Halpern et al. 2009, and then the two focal areas in Phase 2. Abbreviations separated by a slash "/" were stressors whose abbreviations differed between Phase 1 and 2. *Stressors not explicitly identified in the conceptual modeling, but included in the risk assessment. †These stressors were eventually removed from the Phase 2 analysis due to large scale differences in the stressor data.

Conceptual Model	**Phase 1 (Halpern et al. 2009)**	**Phase 2 – Puget Sound**	**Phase 2 – Southern California Bight**	**Abbrev.**
Altered freshwater flow	Sediment Increase, Sediment Decrease	Watershed Assessment (water flow) & National Hydrography Dataset Plus V2	National Hydrography Dataset Plus V2	Al
Beach nourishment	-	-	Beach Nourishment History (1920 – 2000), Beach Placement Areas	Bn
Bottom trawling	-	Bottom Trawling Fishing Intensity (2002-2006)	Bottom Trawling Fishing Intensity (2002-2006 & 2006-2010)	Bt
Coastal development	Coastal Development	Urban Growth Areas, PSNERP Impervious (>50%), & Shorezone	Urban Areas, Costal Armoring, Coastal Structures and Barriers, Impervious Surface, &	Cd
Dredging and disposal	-	USACE Ocean Disposal Sites	USACE Ocean Disposal Sites	D
Fertilizers	Nutrient Input, Organic pollution	†Halpern et al. 2009 Data	†Halpern et al. 2009 Data	N, Op
Greenhouse gasses	OA, SST, UV radiation	†Halpern et al. 2009 Data	†Halpern et al. 2009 Data	OA, SST, UV
In-water structures	-	Overwater Structures	Overwater Structures	Ows
Marine mining	-	-	-	-
Ocean dumping/ Marine debris	Ocean Based Pollution, Trash/ Coastal Waste	No Data	California Coastal Cleanup Data	T/Md

Oil spills	Offshore oil	Oil Spill Incidents (WA DOE & PSTF), DARRP Case Locations	Oil Spill Incidents (OSPR & PSTF), DARRP Case Locations	Os
Oil/gas exploration and development	Offshore oil	-	BOEM Oil Platforms, BOEM Oil and Natural Gas Wells, & CA DOC Active Oil and Gas	Og
Pesticides	Organic pollution, Inorganic pollution	†Halpern et al. 2009 Data	†Halpern et al. 2009 Data	Ip, Op
Recreational boating	-	Marinas, Boat Facilities, WDFW Water Access Sites	Boat Launch Sites & Marinas	Rb
Invasive Species	Species invasion	ISC (Tunicates, Spartina), NAS Invasive Species, Shorezone (Sargassum)	Invasive Species on Overwater Structures & *Sargassum horneri* presence	Is
Storm and waste water discharge	Organic pollution, Inorganic pollution	PARIS Active Outfalls & Combined Sewer Overflows	Intermediate Discharges, Minor Discharges, Major Wastewater Discharge, & Major Stormwater Discharge	Ww
Submarine pipeline/ cable installation	-	Submarine Cables	Submarine Cables, Pipelines, & Outfall Pipes and Diffusers	Sc
Terrestrial vegetation removal	-	-	-	-
Water intake structures	Power plants	-	Power Plant Entrainment	Wi
**Aquaculture*	*Aquaculture*	*Commercial Shellfish Harvest Sites & Fish Net Pens*	*CDFW Aquaculture Leases*	*A/Aq*
**Commercial Shipping*	*Shipping Activities*	*Commercial Vessel Density (2009 – 2010)*	*Commercial Vessel Density (2009 - 2010)*	*Cs*
**Derelict Fishing Gear*	*No Data*	*Derelict Gear Removed*	*Derelict Gear Removed*	*Dfg*

2.3.1 Exposure-Habitat Vulnerability Axis

The EHV axis scores were calculated in two parts: exposure of fish to the stressor and vulnerability of the habitat to the stressor. We calculated exposure values by spatially overlaying habitat use data with relative intensity of the stressors across the entire West Coast, and then summed by large geographic region (Salish Sea, Northern, Central, and Southern; based on the sub-regions in the 5-year Review of Pacific Coast Groundfish EFH[2]). The habitat use data consisted of the HSP scores from NMFS EIS (2005a), with species/habitat association for benthic substrate and depth and latitude from the NMFS' HUD. The stressor data used was the relative intensity of 17 non-fishery stressors along the California Current from Halpern et al. (2009). The exposure scores were calculated as follows:

$$E_{sijk} = \sum_{l=1}^{n_l} HSP_{sjl} * SI_l \qquad (2)$$

where E is exposure, by species (s), stressor (i), life stage (j), and region (k), HSP is the habitat suitability probably score, and SI is the stressor intensity, both by 1-km^2 grid cell (l).

To assess the vulnerability of the habitats inhabited by the focal species we used the habitat vulnerability scores of various ecosystem types to a number of stressors as was determined by expert judgment (Appendix C; Teck et al. 2010). To appropriately scale the expert habitat vulnerability scores to each species and life stage, we calculated a relative use of ecosystem type by overlaying species-life stage specific HSP scores with relative coverage of 18 ecosystems types by 1-km^2 grid cell (Appendix B; ecosystem type data from Halpern et al. 2009):

$$Ho_{esjk} = \sum_{l} HSP_{sjl} * E_l \qquad (3)$$

where Ho is habitat overlap, by ecosystem type (e), species (s), life stage (j), and region (k), HSP is the habitat suitability probably score, and E_l is relative coverage of ecosystem type, both by by 1-km^2 grid cell (l). These Ho values were then compared to the total habitat overlap of a species-life stage by region to get a relative habitat use by ecosystem type for each species, life stage, region (rHo_{esjk}). These relative habitat use scores were then used to calculate a weighted average habitat vulnerability across all ecosystem types (e) of expert scored habitat vulnerability (V) by stressor (i), species (s), life stage (j), and region (k):

[2] Salish Sea includes the Strait of Juan de Fuca, the Strait of Georgia, Puget Sound, and all connecting channels and adjoining waters, and the waters around and between the San Juan Islands; the Northern region includes areas from the Salish Sea to Cape Mendocino; Central region includes areas from Cape Mendocino to Point Conception; Southern region includes areas south of Point Conception.

$$V_{sijk} = \sum_{e=1}^{18} rHo_{esjk} * V_{ei} \qquad (4)$$

To calculate the final value for the EHV axis the habitat vulnerability scores are normalized across all life stages for each species between 1-3. The exposure scores were standardized between 1-3 as below to allow for magnitude changes to be apparent in the risk values in a sensitivity analysis:

$$Norm(E_{sijk}) = \left(\left(\frac{E_{sijk}}{\sum_{l=1}^{n_k} HSP_{sjl}} \right) \times 2 \right) + 1 \qquad (5)$$

Then the final value for EHV scores calculated (Table in Appendix F):

$$EV_{sijk} = \sqrt{Norm(E_{sijk}) * Norm(V_{sijk})} \qquad (6)$$

2.3.2 Sensitivity Axis

The sensitivity axis scores were determined using the same methodology as Andrews et al. (2011). The scoring was broken into two components: a species' resistance to a stressor and a species' ability to recover from a stressor. Resistance factors were scored on a stressor-by-stressor basis and based on the primary literature and expert opinion. Resistance factors were broken into mortality, behavioral response, and physiological response of each species to each stressor. The recovery factors do not vary with stressors, and were based on life history characteristics including fecundity, age at maturity, reproductive strategy, and population connectivity, in addition there was a recovery factor related to current status of the stock. See Appendix D for details on sensitivity scoring criteria.

2.3.3 Life Cycle Models

Conceptually, risks to older life stages with higher reproductive value are expected to contribute more to population level impacts than earlier lifestages with large natural mortality rates. To weight life-stage specific risk scores, we calculated adult equivalents from simple life tables of each species. Life tables described transitions among up to four stages: egg to larva, larva to juvenile recruit, juvenile to adult, and adult stages. As rockfish do not lay eggs, black rockfish and bocaccio had only the latter three stages. Transitions were calculated using stage-specific instantaneous mortality rates (m_i) and life stage duration (d_i) obtained from stock assessments, peer reviewed publications, and (where necessary) agency reports. Duration of the adult stage was based on the age in each stock assessment at which cumulative maturity rate surpassed 50%. Where stage-specific parameters were not available for specific species, data from surrogate species (e.g., rates for blue rockfish for bocaccio) were used. Instantaneous mortality rates for English sole eggs, larvae, and juveniles, so data from European plaice (*Pleuronectes platessa*), a surrogate species with similar habitat-specific life stage transitions, were used instead.

We used the stage-specific survival estimates ($s_i = exp\ (-m_i * d_i)$) to calculate adult equivalent rates, the probability an individual at a given life stage would survive through remaining life stages. Hence, for any life stage *i*,

$$AEQ_i = \prod_i^4 s_i \qquad (7)$$

Adult equivalent rates were then scaled to sum to 1, and used to weight sensitivity and EHV scores in the risk analysis (Table 2). In most cases, these weightings were much higher for the adult stage than juvenile life stages, reflecting the high levels of mortality associated with earlier transitions.

Table 2. Duration, instantaneous mortality, and total survival by life stage for the four groundfish stocks, and AEQ and AEQ weights calculated from survival scores.

Species	Life Stage	Duration		References	Instantaneous mortality	References	Survival	AEQ	AEQ weight
Black rockfish	larva-juvenile	105	days	Miller &Shanks 2004	0.06400	Zabel et al. 2011	0.0012	0.00097	0.0006
	Juvenile-adult	260	days	Buckley 1997	0.00004	Buckley 1997	0.9894	0.80607	0.4970
	adult	10	years	Six & Horton 1977, Ralston &Dick 2003	0.16000	Ralston & Dick 2003	0.8147	0.81471	0.5024
Bocaccio	larva-juvenile	90	days	Tolimieri &Levin 2005	0.06400	Zabel et al. 2011	0.0032	0.00035	0.0005
	juvenile-adult	275	days	Zabel et al. 2011	0.00571	Adams & Howard 1996	0.2078	0.11076	0.1719
	adult	4	years	Field et al. 2010	0.15000	Field 2011	0.5331	0.53311	0.8275
English sole	egg-larva	4	days	Barss 1976	0.06800	Zijlstra et al. 1982	0.7619	0.00034	0.0007
	larva-juvenile	63	days	Barss 1976	0.05200	Zijlstra et al. 1982	0.0378	0.00045	0.0010
	juvenile-adult	730	days	Barss 1976	0.00500	Zijlstra et al. 1982	0.0260	0.01180	0.0253
	adult	3	years	Stewart 2007	0.26000	Stewart 2007	0.4541	0.45409	0.9730
Lingcod	egg-larva	40	days	Love 2011	0.00901	Giorgi & Congleton 1984, Low & Beamish 1978	0.6973	0.00003	0.0001
	larva-juvenile	90	days	Hamel et al. 2009, Love 2011	0.06400	Zabel et al. 2011	0.0032	0.00004	0.0001
	juvenile-adult	600	days	Hamel et al. 2009	0.00571	Adams &Howard 1996	0.0324	0.01262	0.0314
	adult	5	years	Jagielo & Wallace 2005	0.18000	Hamel et al. 2009	0.3890	0.38904	0.9684

2.3.4 Phase 2 Methodology Updates

Phase 2 of the Fishery Specific Habitat Objectives Project has improved upon the methodology, based on input from the SSC and HC, and expanded the breadth of data utilized in the modeling. To increase the pool of applicable data sources, we have identified two smaller geographic areas to focus on, Puget Sound and the Southern California Bight, while maintaining a broad enough scope to yield results that are relevant to PFMC and NMFS West Coast Region. We expected that with better data, the relative risks proposed by these stressors would be more realistic, and it would be possible to develop specific qualitative habitat objectives for the groundfish focal species for use in NMFS habitat conservation efforts.

Our goals for Phase 2 were to identify a more focused geographic range with greater potential for existing and available stressor data for stressors identified in conceptual modeling, and complete a revised risk assessment analysis with the methodology updated to address input from the PFMC Science and Statistical Committee, and finally to develop habitat objectives to address stressors that contribute to risk of the focal species and that can be influenced by NMFS actions.

2.3.4.1 Focal Area Selection

In an effort to increase the amount of existing stressor data available, while maintaining a broad scope of interest to NMFS and the PFMC, we narrowed the geographic range from the entire West Coast to the Puget Sound and the Southern California Bight. These two locations are both highly studied areas that provided the team with access to quality spatial data for many of the stressors identified in our conceptual modeling efforts. In addition, they provide a broad range of habitat types, from open coast, to inland sea, and estuarine habitats across a broad latitudinal range. These two areas also fit within the criteria of importance to broad habitat conservation goals for NMFS, PFMC, and West Coast stakeholders at large.

The study regions were defined as follows: Puget Sound, which includes U.S. waters and watersheds from the strait of Juan de Fuca to South Puget Sound to the Strait of Georgia (Figure 4), and the Southern California Bight, which includes all waters within the EEZ and watersheds from Point Conception south to the border of the U.S. and Mexico (Figure 5).

Figure 4: Puget Sound region boundary used for Phase 2 data processing and analysis.

Figure 5: Southern California Bight region boundary used for Phase 2 data processing and analysis.

2.3.4.2 Sensitivity Review

In reviewing Phase 1 results, the team decided that our sensitivity scores may be improved by looking to outside experts to review our scoring efforts. We asked 3 experts in the field of groundfish ecology who were not part of the original group of scorers to re-score the sensitivity and received input from one of them. Below is a summary of those score changes.

The SSC also suggested removing the “recovery factors” from our sensitivity scores. These factors are based on the species populations’ ability to recover from stress. Within species these numbers are completely stressor independent. Since we are only comparing stressors within species and not amongst them, the information serves more to dilute and confuse the final risk scores than contribute to positive habitat conservation objectives.

2.3.4.3 Risk Assessment Methodological Changes

The risk assessment analysis for Phase 2 was run in the same fashion as Phase 1, with some minor adjustments. With the smaller geographic focus, we adopted a substantially smaller grid size, 30 m as compare to 1 km, for our stressor data. This change better reflects the localized habitat issues with the smaller scale, but also caused an overall reduction of exposure scores. As a result of the overall lower exposure scores in Phase 2, the standardization used in Phase 1, (where the total exposure of a stressor of an area was divided by the total habitat score for that area) would have resulted in negligible exposure, due to the relatively large magnitude of the total habitat scores. This method was used to allow the evaluation of the sensitivity of risk scores to a change in exposure relative to the total habit score in an area. In Phase 2, a sensitivity analysis was run to assess the uncertainty around our risk scores using a percentage change in overall exposure, regardless of the total habitat score (See Section 2.3.5.3).

With the new stressors, we also calculated new habitat vulnerabilities, which required some translation between the stressors we used and the stressors graded in Teck et al. (2010). With the addition of new stressors, there was not a 100% agreement between all of the stressors included in the risk assessment and those in Teck et al. (2010). We therefore had to make some decisions on the most appropriate stressor included in Teck et al. (2010) to use for those used in the risk assessment. Those decisions are outlined here: for beach nourishment, the "sediment input: increase" stressor was used; for marine debris, the "pollution input: trash, urban runoff" was used; for oil spills, the "pollution input: organic" stressor was used; for overwater structures, the "benthic structures (e.g. oil rigs)" stressor was used; for storm and wastewater discharge, the "nutrient input" stressors were used; for submarine pipeline and cables, the "benthic structures (e.g. oil rigs)" stressor was used; for water intake structures, the "power, desalination plants" stressor was used.

The habitat data in the Habitat Suitability Probability (HSP) scores used for this project to date are very coarse for the Puget Sound, one or two values for the entire area in many cases. As a result, we instead created our own habitat suitability maps using a comprehensive benthic habitat map, provided by The Nature Conservancy (TNC) and the habitat associations in the Habitat Use Database (HUD). The bottom type and depth were the defining characteristics of the map that were translated to those same, or in some cases best approximations, categories within the HUD and the corresponding habitat suitability was applied to that area. Within the HUD there are categorical association values of "strong," "medium," "weak," and "absent." These categories were translated to values of 1.0, 0.66, 0.33, and 0 respectively.

2.3.4.4 Stressor Data

Data Processing:
All data layers and outputs were produced on a 30m grid, matching NOAA's CCAP land cover data (NOAA, 2010). All data layers were converted to 30m grid ArcGIS raster files in ArcGIS 10.3. Each unique dataset was transformed into a 0 to 1 scale using either a simplified presence (1) /absence (0) approach to calculate a "stress value" for each dataset, or a kernel density analysis to determine hot spots of a stressor. A presence/absence method was used for dataset that are permanent structures (such as a pier) or stressors related to human use (such as a beach nourishment site, recreational boating access point). A kernel density analysis method was used for datasets of stressors that occurred in the past or were temporary observations, such as oil spills and derelict fishing gear, since they are no longer present in the system, and the density of their occurrence is a better representation of the potential stress the events had on the system.
For the presence/absence approach, each dataset was given a "scale value" and an "extent value," which then resulted in a "stress value" (stress value = scale value multiplied by extent value). The scale represented the presence of a particular stressor. For example, if a dataset included a polygon that represented area of beach nourishment, it was given a scale value of 1 (the stressor is present). If there was an extent, for example, only 60% of the area outlined by the polygon was nourished, then it was given an extent value of 0.6 to represent the extent of the stressor within the area. If there was no extent information, it was given a value of 1 for extent (making the assumption that the extent is the full area of the stressor). Stress value was calculated by the scale value multiplied by the extent value.

A kernel density analysis method was used to determine hot spots for three data categories: oil spills, invasive species, and derelict fishing gear. These datasets represent observations or events in the past that can act as a proxy for the intensity of the stressor. For example, if a series of oil spills happen in a particular area, the kernel density analysis will show a hot spot, which is used to represent a higher intensity of the stressor, and in turn, higher stress value.

When more than one data layer was available for a stressor data category, the stress values from each layer were summed and rescaled from 0 to 1.

Data Gaps
Despite the increase in the pool of applicable stressor data by focusing on the Puget Sound and the Southern California Bight regions, there are still data gaps. In Puget Sound, spatially explicit information was not available on Beach Nourishment sites, and data on marine debris was limited and inconsistent, and therefore, not included in the analysis. In addition, for both Puget Sound and the Southern California Bight, recreational boating data was

limited to the sites or marinas where recreational boats would launch, and did not include the actual footprint of use by recreational boaters.

Limitations of the data

We are using the best available data for each region. The data within each category represents the relative intensity of a stressor within a region, and stressors should not be compared across regions. This is due to the different types of data available in each region. Stressor values were calculated based on scale and extent of a stressor. The presence/absence approach assumed that if a stressor was present, then it received the highest value (1). However, within a dataset, different types of stressors may vary in the scale of stress that it would have on fish habitat. For example, within the shoreline armoring dataset in the coastal development category, a concrete bulkhead may have a different impact than a wooden bulkhead. In the future, scale values can be modified to better represent the scale of stress of a particular stressor.

In general, data were available for presence of a stressor, but we had less information on whether stressors were absent from particularly areas. In the current analysis, absence potentially represents both confirmed absence of a stressor and lack of data in that particular area for the stressor category.

Due to time and funding limitations, it was not possible to use more advanced modeling techniques to synthesize the data. Certain datasets would be better represented using a dispersive plum model (such as alterations to freshwater flow or wastewater discharge). However, this was not completed for these datasets, and a simple presence/absence approach was taken.

2.3.5 Risk Assessment Results

2.3.5.1 Phase 1 Risk Scores

The composite species risk scores, weighted across life stages by adult equivalents, were plotted by sensitivity and EHV, with those high with high risk scores in the top right of the plot, those with low risk scores in the bottom left (Figures 6-9). Across all species and geographic regions ocean acidification (OA) had the highest risk scores, with a single exception stemming from the combination of high sensitivity, broad scale exposure, and large habitat vulnerability (see Appendix F for detailed tables). The exception was black rockfish in the Salish Sea, where invasive species had a slightly higher risk score (1.84) compared to OA (1.80). Some of the other stressors that had high scores across multiple species and geographic regions included invasive species, sea surface temperature, and atmospheric deposition. Across species and geographic regions, stressors with the lowest risk scores generally included sediment increase, sediment decrease, power plants, and shipping activities. There were some differences across species, including aquaculture, with relatively low risk scores for English sole, but moderate to high scores for other species. UV radiation also exhibited differences among species, with relatively low risk scores for English sole and lingcod, while relatively higher risk scores for black rockfish and bocaccio. The differences within a species across geographic regions were subtler, but still apparent as with SST for bocaccio, with low risk in the Salish Sea, but relatively high risk in the northern and central regions.

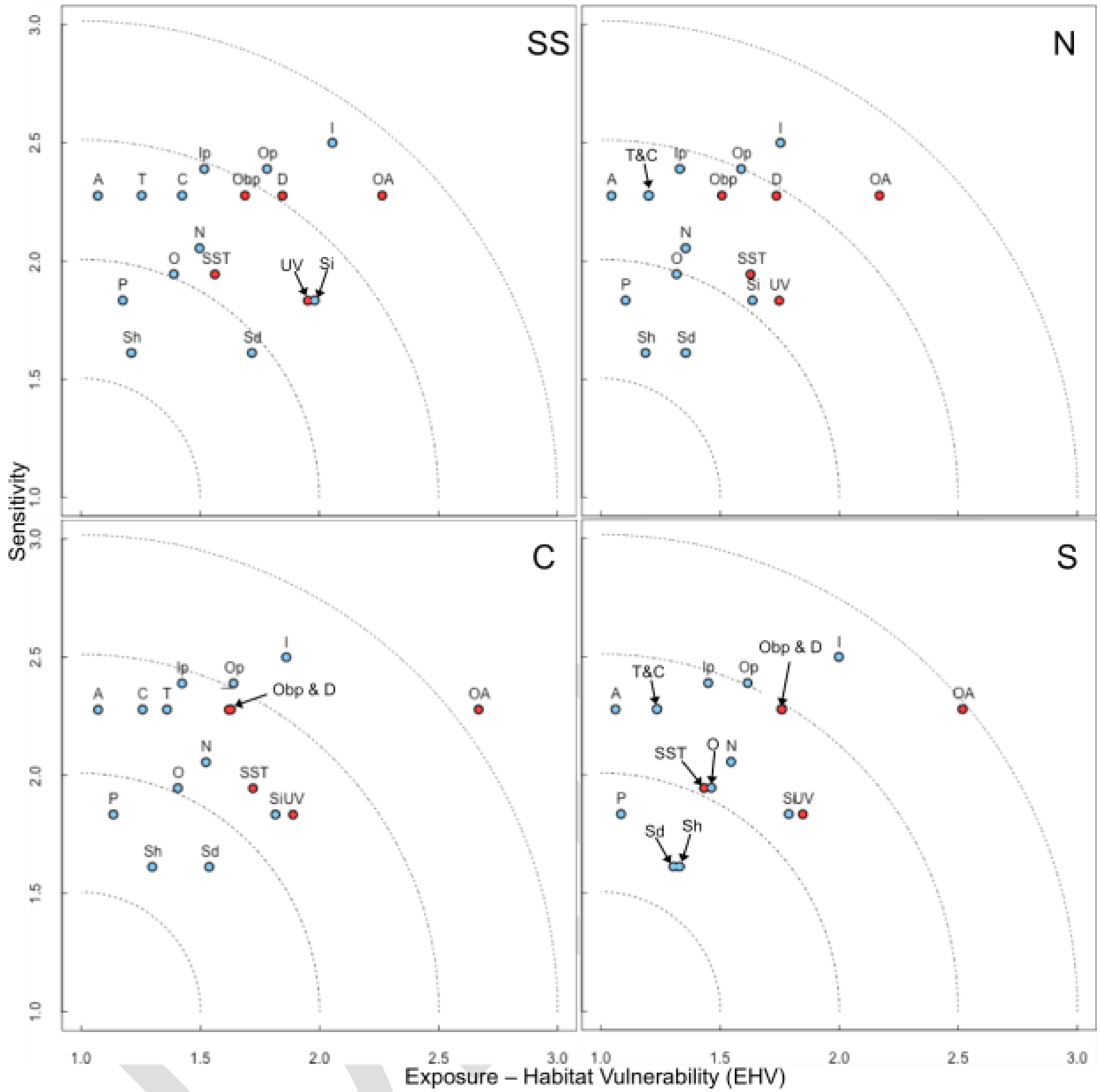


Figure 6. Phase 1 black rockfish risk scores plotted by sensitivity and EHV by geographic region (SS – Salish Sea, N – Northern, C – Central, S – Southern). Red circles indicate stressors that are not within the regulatory purview of this project. Letters indicate the stressor (A – Aquaculture, C – Coastal Engineering, D – Atmospheric Deposition, I – Invasive Species, Ip – Inorganic Pollution, N – Nutrient Input, O – Offshore Oil, OA – Ocean Acidification, Obp – Ocean Based Pollution, Op – Organic Pollution, P – Power Plants, Sd – Sediment Decrease, Sh – Shipping Activities, Si – Sediment Increase, SST – Sea Surface Temperature, T – Trash/Coastal Waste, UV – UV Radiation).

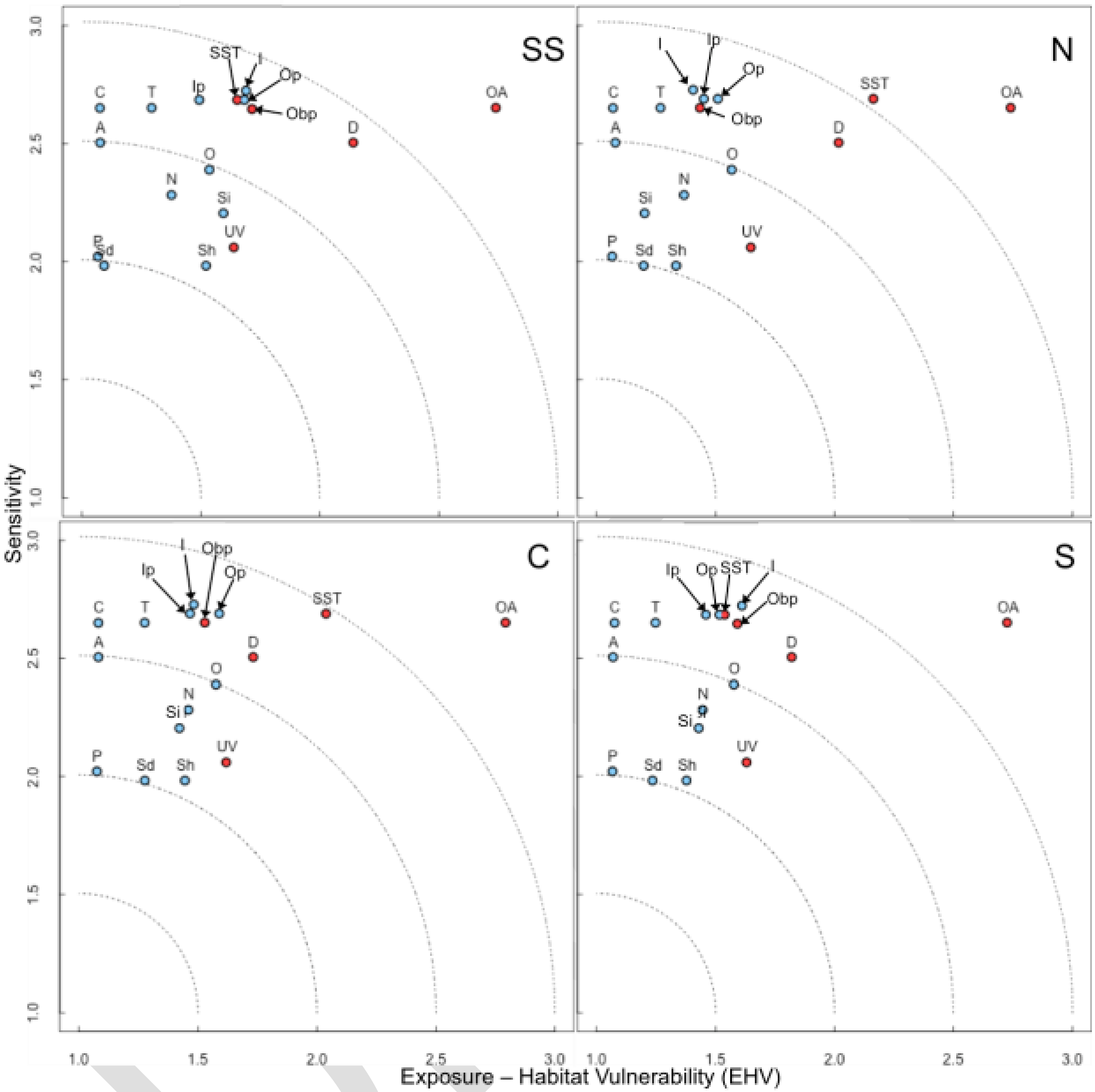


Figure 7. Phase 1 bocaccio risk scores plotted by sensitivity and EHV by geographic region (SS – Salish Sea, N – Northern, C – Central, S – Southern). Red circles indicate stressors that are not within the regulatory purview of this project. Letters indicate the stressor (A – Aquaculture, C – Coastal Engineering, D – Atmospheric Deposition, I – Invasive Species, Ip – Inorganic Pollution, N – Nutrient Input, O – Offshore Oil, OA – Ocean Acidification, Obp – Ocean Based Pollution, Op – Organic Pollution, P – Power Plants, Sd – Sediment Decrease, Sh – Shipping Activities, Si – Sediment Increase, SST – Sea Surface Temperature, T – Trash/Coastal Waste, UV – UV Radiation).

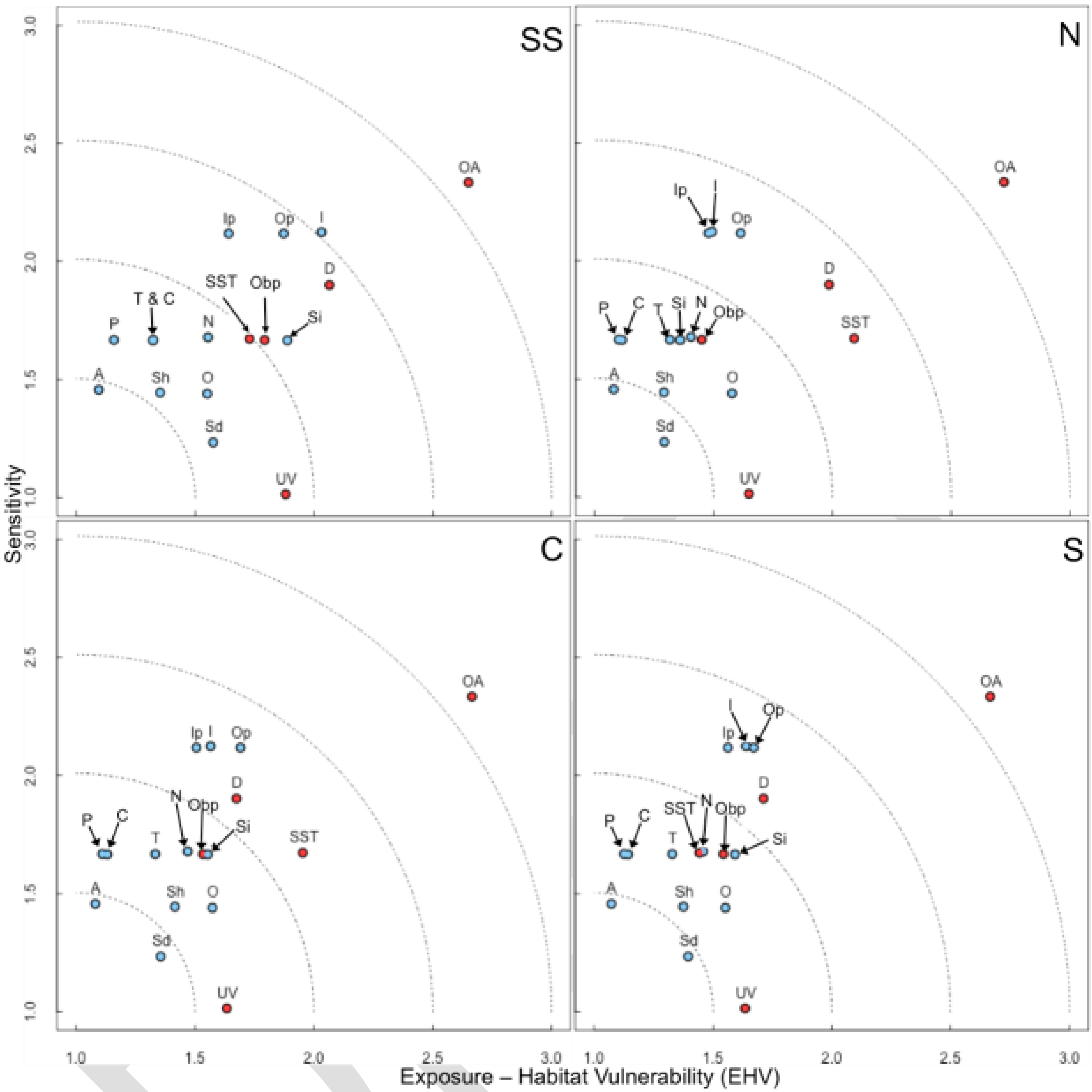


Figure 8. Phase 1 English sole risk scores plotted by sensitivity and EHV by geographic region (SS – Salish Sea, N – Northern, C – Central, S – Southern). Red circles indicate stressors that are not within the regulatory purview of this project. Letters indicate the stressor (A – Aquaculture, C – Coastal Engineering, D – Atmospheric Deposition, I – Invasive Species, Ip – Inorganic Pollution, N – Nutrient Input, O – Offshore Oil, OA – Ocean Acidification, Obp – Ocean Based Pollution, Op – Organic Pollution, P – Power Plants, Sd – Sediment Decrease, Sh – Shipping Activities, Si – Sediment Increase, SST – Sea Surface Temperature, T – Trash/Coastal Waste, UV – UV Radiation).

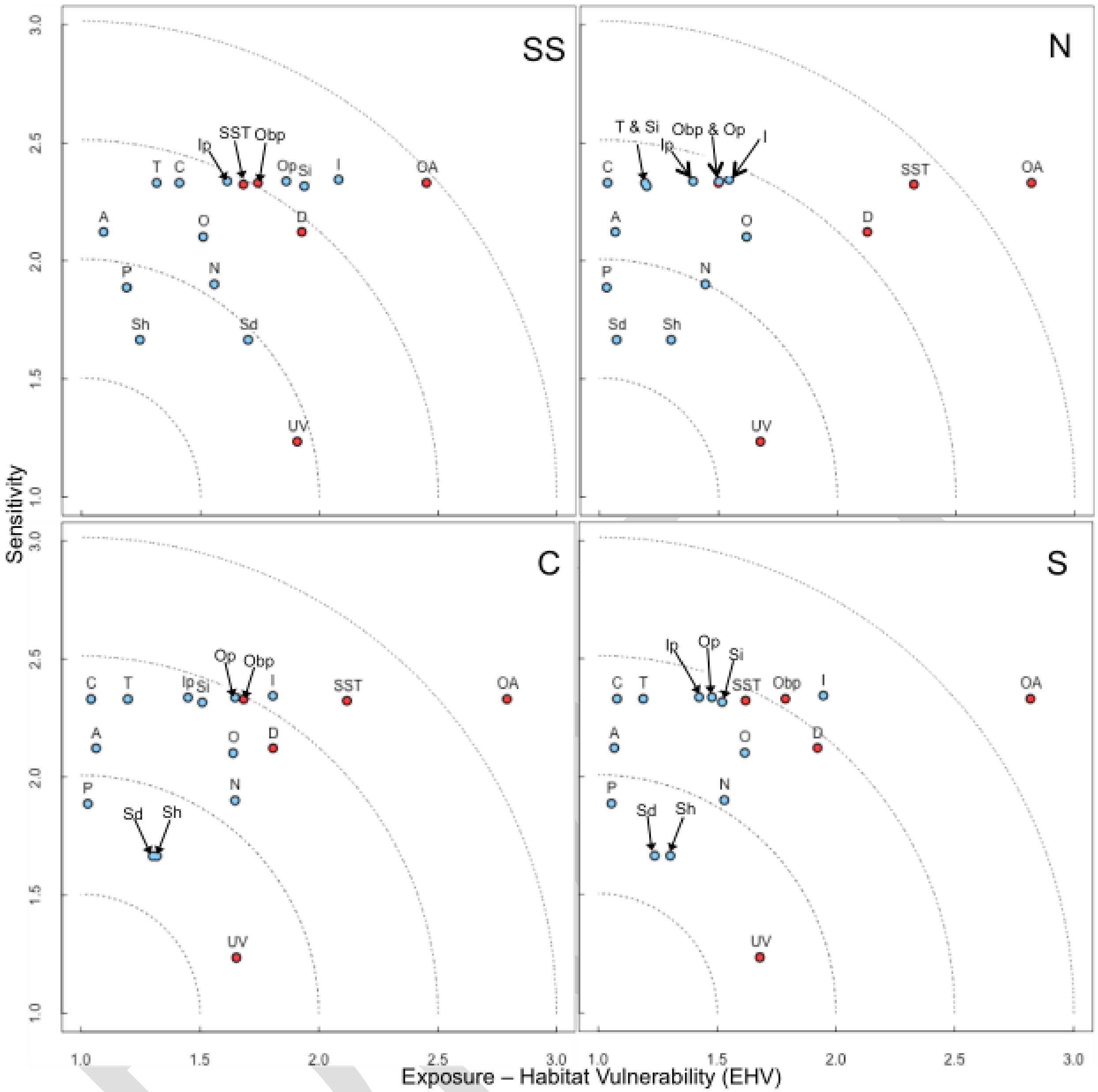


Figure 9. Phase 1 lingcod risk scores plotted by sensitivity and EHV by geographic region (SS – Salish Sea, N – Northern, C – Central, S – Southern). Red circles indicate stressors that are not within the regulatory purview of this project. Letters indicate the stressor (A – Aquaculture, C – Coastal Engineering, D – Atmospheric Deposition, I – Invasive Species, Ip – Inorganic Pollution, N – Nutrient Input, O – Offshore Oil, OA – Ocean Acidification, Obp – Ocean Based Pollution, Op – Organic Pollution, P – Power Plants, Sd – Sediment Decrease, Sh – Shipping Activities, Si – Sediment Increase, SST – Sea Surface Temperature, T – Trash/Coastal Waste, UV – UV Radiation).

2.3.5.2 Phase 2 Risk Scores

The risk plots for Phase 2 looked rather different than the Phase 1 scores. One notable difference was the removal of the broad scale climate change related stressors, which often dominated the risk scores in Phase 1. Two stressors showed consistently high risk scores across all species and regions: bottom trawling and derelict fishing gear. For derelict fishing gear, the high risk scores for lingcod, black rockfish, and bocaccio, are more related to a high sensitivity scores than exposure-habitat vulnerability, while with English sole the risk was a combination of moderately high sensitivity and exposure-habitat vulnerability. The pattern was quite a bit more mixed with respect to bottom trawling, however. Bottom trawling for groundfishes south of Admiralty Inlet was banned by the Washington Legislature in 1989 (Palsson et al. 1996) and the rest of Puget Sound in 2010. Because of this, the habitat is no longer being impacted by bottom trawling and the focal species are exposed to the residual effects of past trawling only. The effects of past trawling in Puget Sound are expected to be lower than in areas where bottom trawling is permitted. Therefore, risk from this activity was likely overestimated in Puget Sound compared to the Southern California Bight. On the low end of risk scores, two stressors were again consistently low. Altered freshwater flow and water intake structures showed very low risk scores across most species and regions, with a moderate increase in sensitivity and exposure in black rockfish for both regions. On the whole there was not a large difference between stressors in the Puget Sound and Southern California Bight, with the exception of bottom trawling, which was significantly higher in Southern California. There were some minor differences between regions that were not as stark, such as black rockfish's oil spills risk score in the Puget Sound (2.00) being higher than in the Southern California Bight (1.61) was the most substantial. In fact, the risk for black rockfish in terms of oil spills in the Puget Sound was the highest risk outside derelict fishing gear.

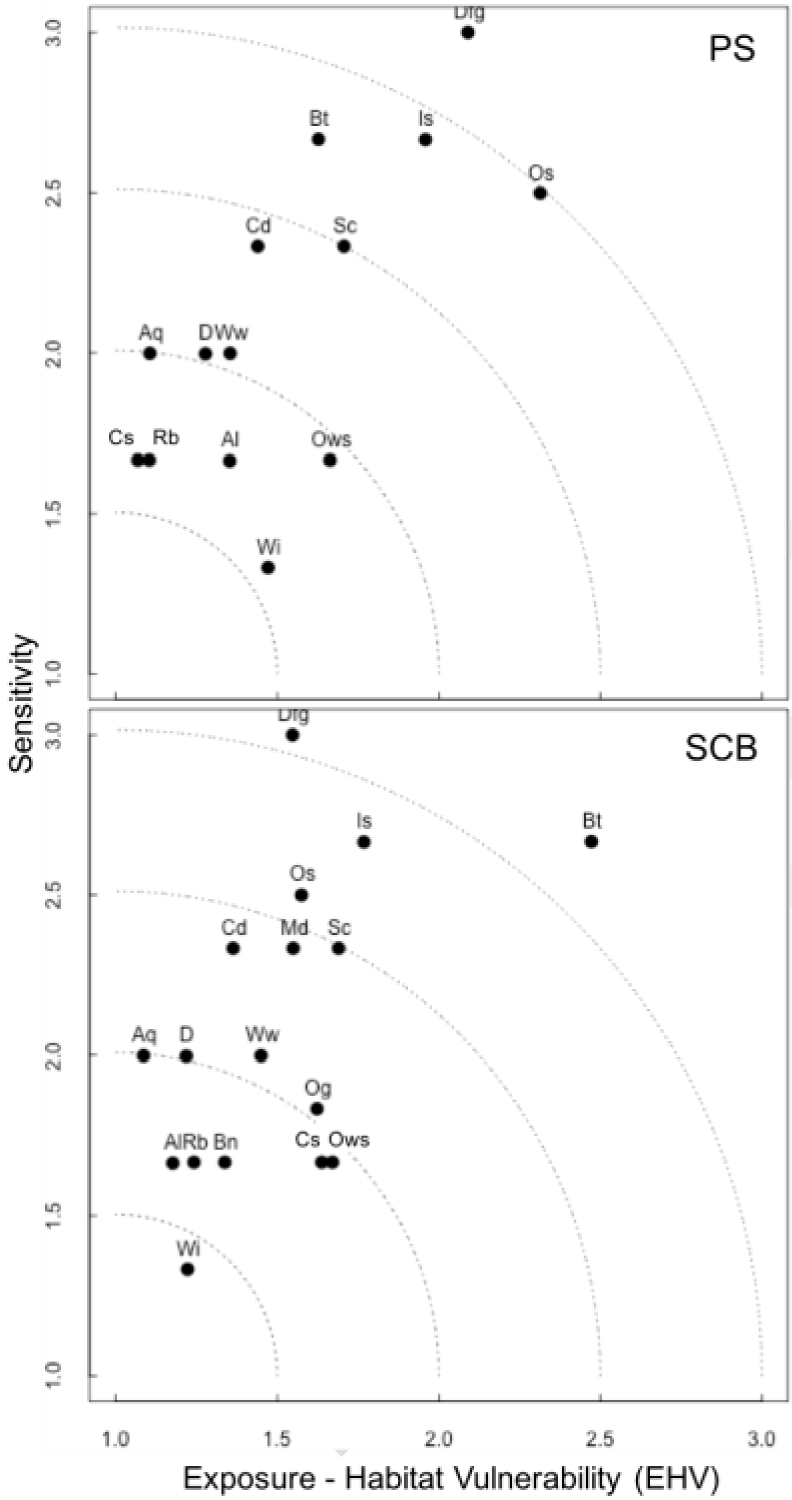


Figure 10. Phase 2 black rockfish risk scores plotted by sensitivity and EHV by geographic region (PS = Puget Sound, SCB = Southern California Bight). Letters indicate the stressor (Al = Altered Freshwater Flow, Aq = Aquaculture, Bn = Beach Nourishment, Bt = Bottom Trawling, Cd = Coastal Development, Cs = Commercial Shipping, Dfg = Derelict Fishing Gear, D = Dredging & Disposal, Is = Invasive Species, Md = Marine Debris, Og = Oil and Gas Exploration, Os = Oil Spills, Ows = Over Water Structures, Rb = Recreational Boating, Ww = Storm and Wastewater Discharge, Sc = Submarine Cables and Pipelines, Wi = Water Intake Structures).

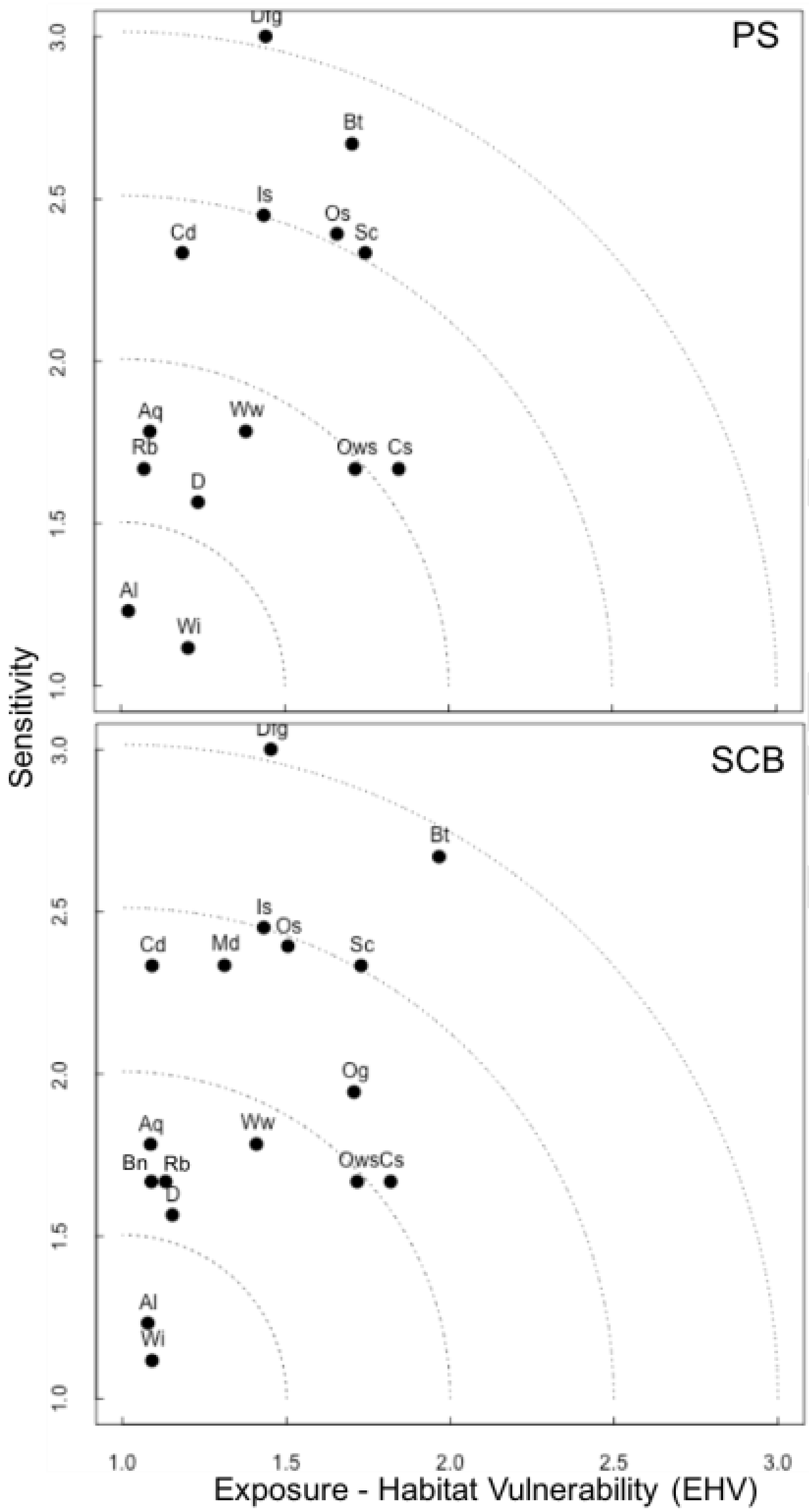


Figure 11. Phase 2 bocaccio risk scores plotted by sensitivity and EHV by geographic region (PS = Puget Sound, SCB = Southern California Bight). Letters indicate the stressor (Al = Altered Freshwater Flow, Aq = Aquaculture, Bn = Beach Nourishment, Bt = Bottom Trawling, Cd = Coastal Development, Cs = Commercial Shipping, Dfg = Derelict Fishing Gear, D = Dredging & Disposal, Is = Invasive Species, Md = Marine Debris, Og = Oil and Gas Exploration, Os = Oil Spills, Ows = Over Water Structures, Rb = Recreational Boating, Ww = Storm and Wastewater Discharge, Sc = Submarine Cables and Pipelines, Wi = Water Intake Structures).

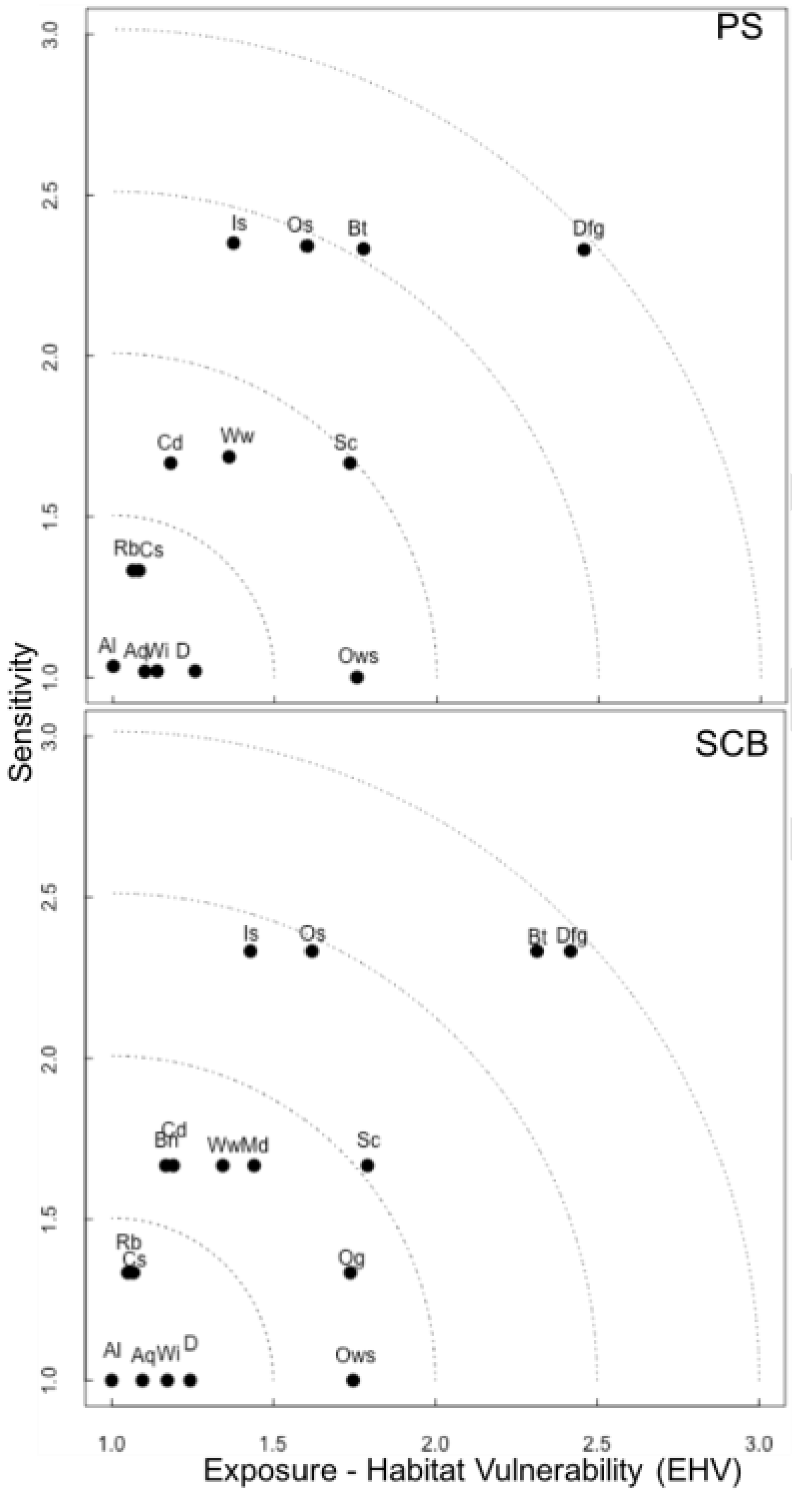


Figure 12. Phase 2 English sole risk scores plotted by sensitivity and EHV by geographic region (PS = Puget Sound, SCB = Southern California Bight). Letters indicate the stressor (Al = Altered Freshwater Flow, Aq = Aquaculture, Bn = Beach Nourishment, Bt = Bottom Trawling, Cd = Coastal Development, Cs = Commercial Shipping, Dfg = Derelict Fishing Gear, D = Dredging & Disposal, Is = Invasive Species, Md = Marine Debris, Og = Oil and Gas Exploration, Os = Oil Spills, Ows = Over Water Structures, Rb = Recreational Boating, Ww = Storm and Wastewater Discharge, Sc = Submarine Cables and Pipelines, Wi = Water Intake Structures).

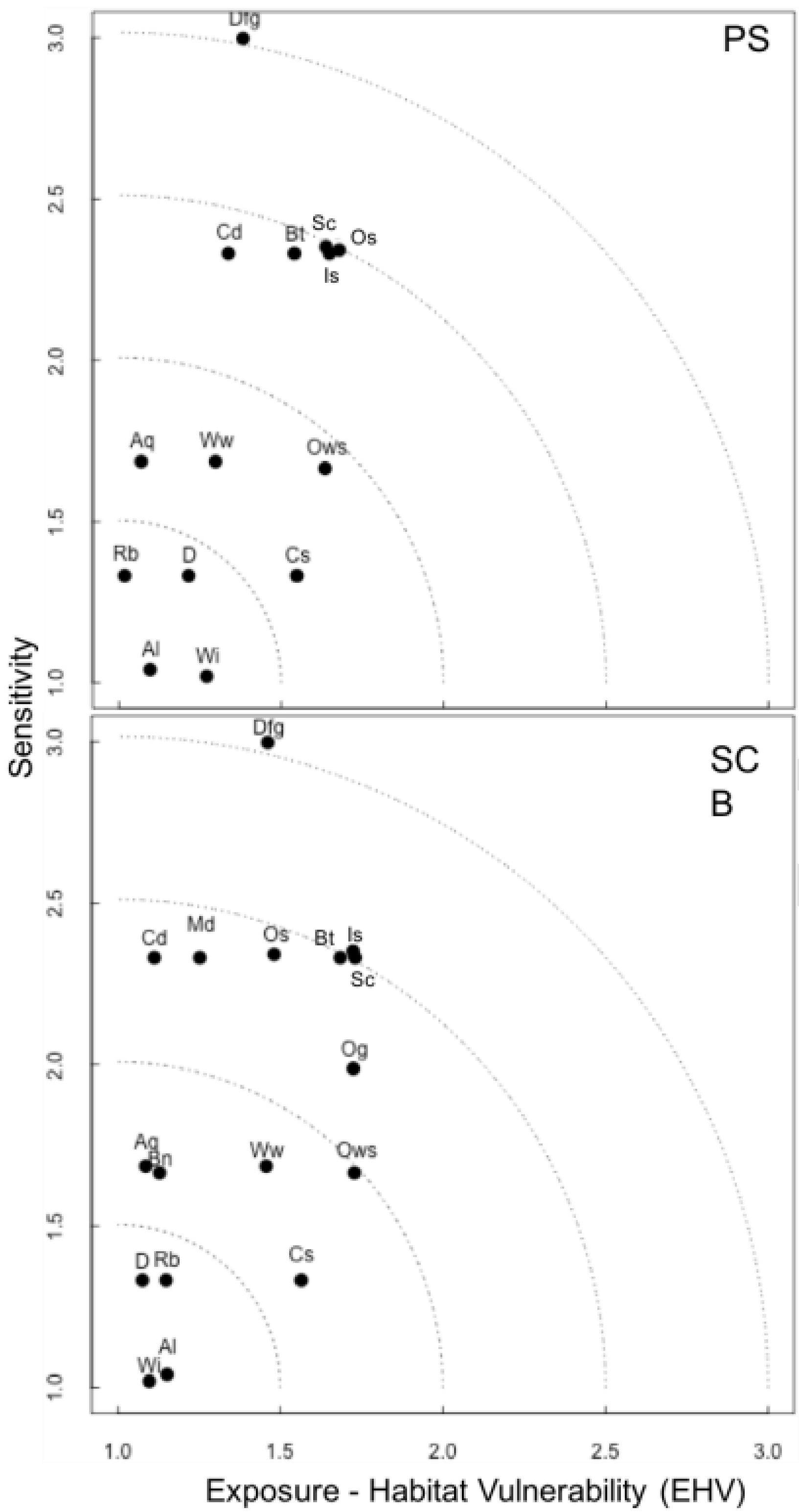


Figure 13. Phase 2 lingcod risk scores plotted by sensitivity and EHV by geographic region (PS = Puget Sound, SCB = Southern California Bight). Letters indicate the stressor (Al = Altered Freshwater Flow, Aq = Aquaculture, Bn = Beach Nourishment, Bt = Bottom Trawling, Cd = Coastal Development, Cs = Commercial Shipping, Dfg = Derelict Fishing Gear, D = Dredging & Disposal, Is = Invasive Species, Md = Marine Debris, Og = Oil and Gas Exploration, Os = Oil Spills, Ows = Over Water Structures, Rb = Recreational Boating, Ww = Storm and Wastewater Discharge, Sc = Submarine Cables and Pipelines, Wi = Water Intake Structures).

2.3.5.3 Uncertainty of Risk Results

In an attempt to assess the uncertainty of our risk score results, we ran a simple sensitivity analysis for the exposure sores. We individually increased each exposure by 5%. This increase was done after the spatial analysis, so there was no interaction with habitat use data, just a simple 5% increase in total exposure. The risk analysis was then re-run for each iteration of individual stressor increase, with the resulting change in risk score showing a relative sensitivity to a change in exposure (Table 3). In addition, to visualize this sensitivity, or uncertainty of the analysis, we plotted the Exposure-Habitat Vulnerability axis scores, with the difference between the standard score and the 5% increased score as the magnitude for the error bars (Figures 14 -17).

A few trends appear when looking at these results, namely that certain stressors have large increases in risk through both geographic regions and species, while some have a smaller increase. There is a trend of small point-source type stressors, like altered freshwater flow and water intake structures, to have a generally larger increase in risk scores. Conversely, the broad scale stressors which have relatively large initial exposures, like derelict fishing gear and coastal development, show smaller increases in risk with a 5% increase to exposure. These trends are likely due to the normalization of the exposure scores, when an initially small exposure score is increased individually its normalized exposure score may increase proportionately greater than the 5% absolute increase. The resulting risk score will then also be proportionately greater. The converse is true with the initially large risk scores, where an increase of 5% may not increase the normalized exposure score much at all, and thus the resulting final risk score will also not have a substantial increase.

Another thing to note is the very low percent increase for English sole in the Southern California Bight, which is likely due to the overall low presence of the species, as this area is the southern extent of their range. With very little habitat in the area, the 5% increase in exposure will not increase risk appreciably, and the normalization effect seen with individual stressors doesn't apply when all of the exposure scores are low. On the whole there is some significant sensitivity to changes in exposure inherent in these risk scores, which is important to consider when thinking about the stressor data quality.

Table 3. Percent change of species risk score based on a 5% increase of each stressor individually.

	Black rockfish		**Bocaccio**		**English sole**		**Lingcod**	
	PS	**SCB**	**PS**	**SCB**	**PS**	**SCB**	**PS**	**SCB**
Altered Freshwater Flow	48.47%	22.16%	23.91%	43.20%	187.47%	0.00%	59.30%	51.48%
Aquaculture	33.25%	6.00%	1.49%	4.13%	63.45%	0.03%	1.99%	2.71%
Beach Nourishment	-	24.51%	-	5.37%	-	0.01%	-	3.83%

Bottom Trawling	24.50%	2.52%	2.42%	5.73%	3.87%	1.03%	3.40%	4.35%
Coastal Development	38.53%	7.57%	0.97%	1.42%	3.52%	0.03%	2.16%	0.89%
Commercial Shipping	59.27%	1.49%	0.20%	1.00%	7.11%	0.00%	1.88%	2.21%
Derelict Fishing Gear	1.83%	5.42%	1.07%	2.62%	0.01%	0.00%	1.07%	1.55%
Dredging	54.52%	12.93%	7.05%	13.04%	31.23%	0.11%	149.92%	9.62%
Invasive species	31.34%	9.75%	1.93%	4.29%	1.98%	0.00%	3.91%	4.28%
Marine Debris	-	9.67%	-	3.84%	-	0.07%	-	1.84%
Oil and Gas Exploration	-	25.67%	-	13.31%	-	0.03%	-	7.85%
Oil Spills	16.53%	10.18%	3.14%	5.66%	3.25%	0.00%	4.00%	3.47%
Overwater Structures	101.15%	32.68%	8.60%	19.13%	15.60%	0.09%	10.10%	11.95%
Recreational Boating	64.85%	20.58%	1.61%	6.97%	6.00%	0.00%	4.16%	14.28%
Storm and Wastewater Discharge	57.20%	14.37%	5.11%	12.10%	6.13%	0.00%	6.24%	9.41%
Submarine Pipeline Cable	44.82%	14.30%	3.74%	8.42%	9.10%	0.21%	4.08%	5.22%
Water Intake Structures	19.56%	44.55%	25.03%	76.98%	49.08%	0.60%	34.19%	83.23%

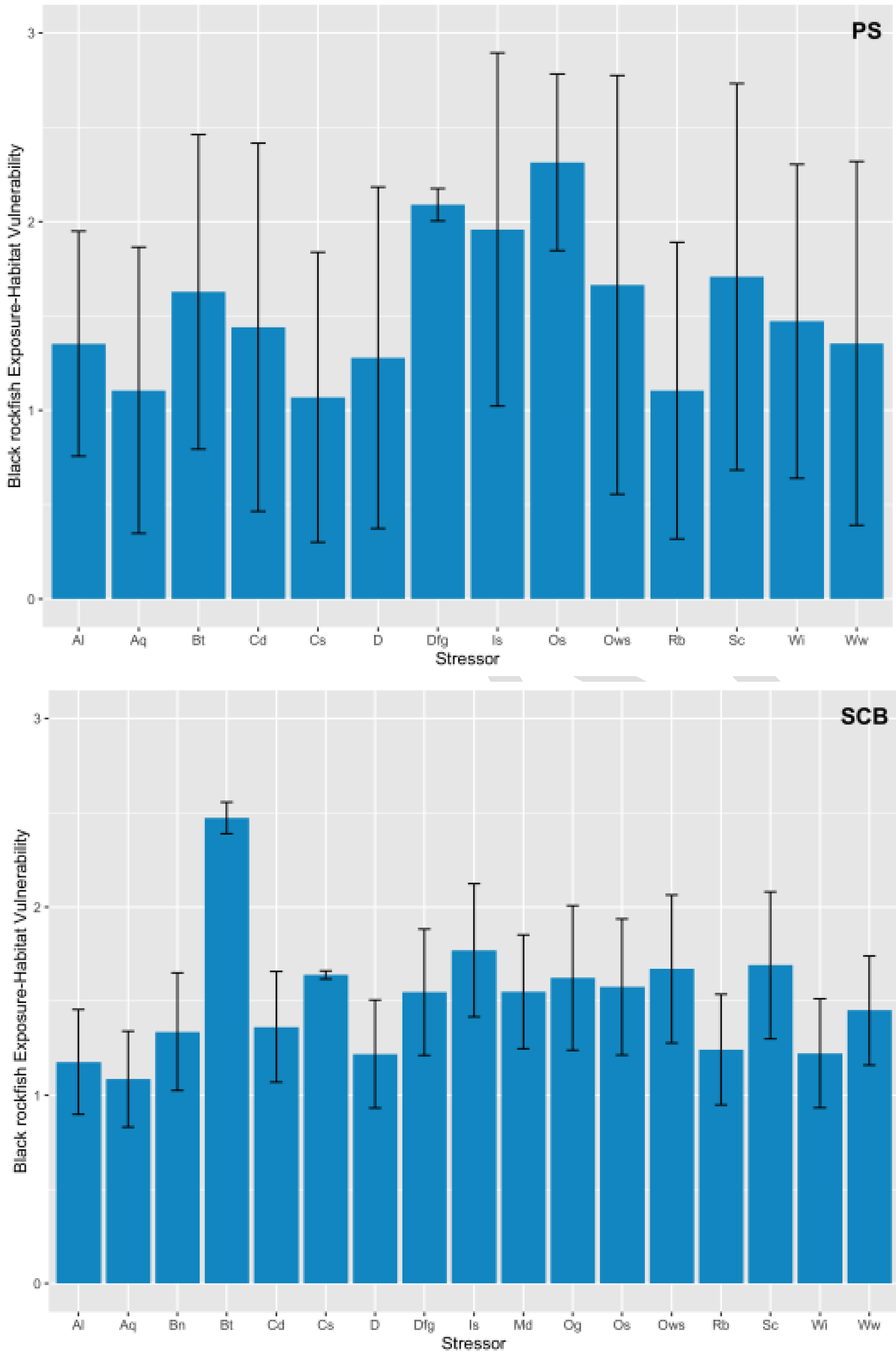


Figure 14. Black rockfish exposure-habitat vulnerability (EHV) scores in Puget Sound (PS) and Southern California Bight (SCB) with error bars representing the magnitude change in EHV with a 5% increase to each stressor individually.

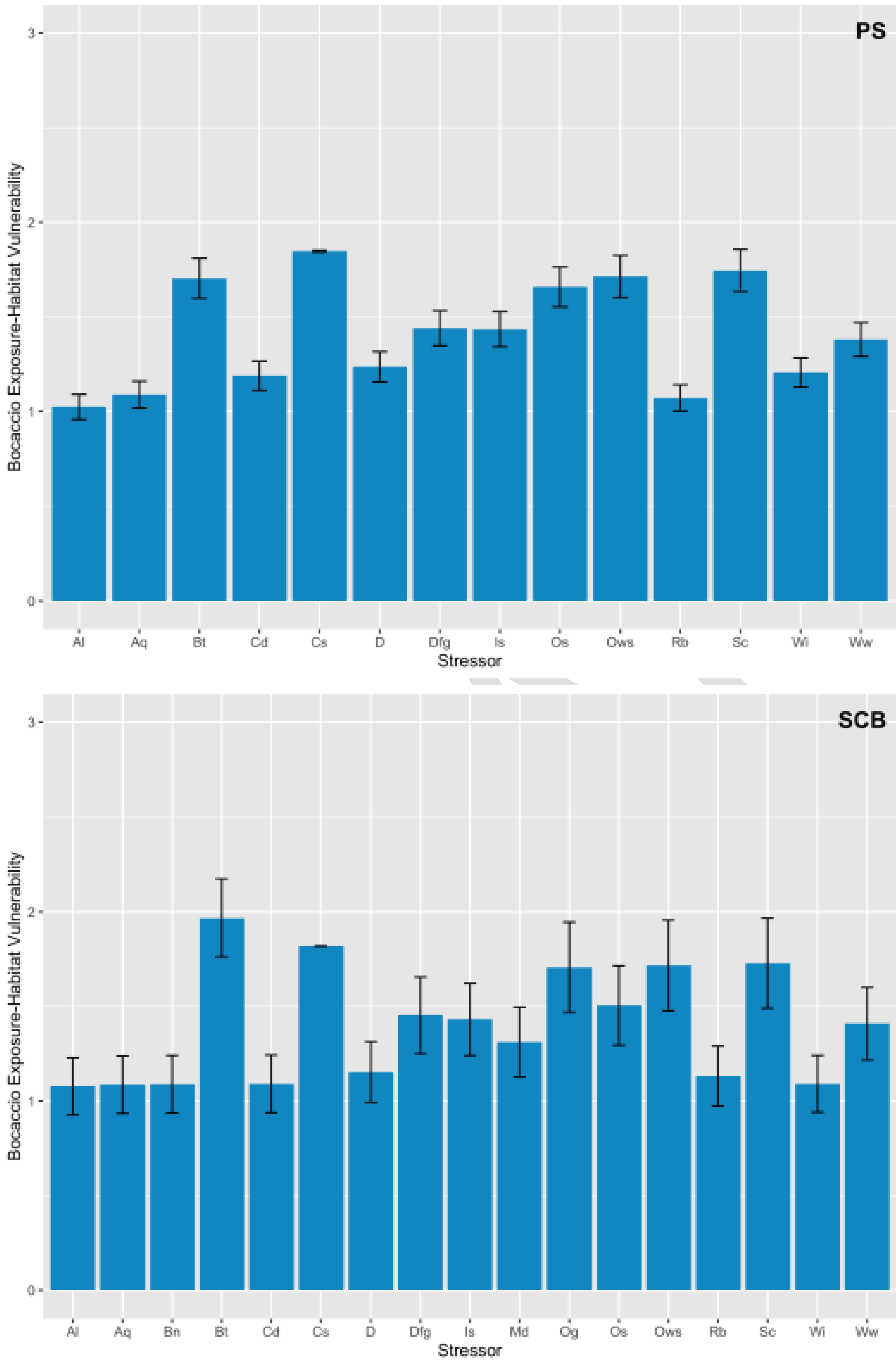


Figure 15. Bocaccio exposure-habitat vulnerability (EHV) scores in Puget Sound (PS) and Southern California Bight (SCB) with error bars representing the magnitude change in EHV with a 5% increase to each stressor individually.

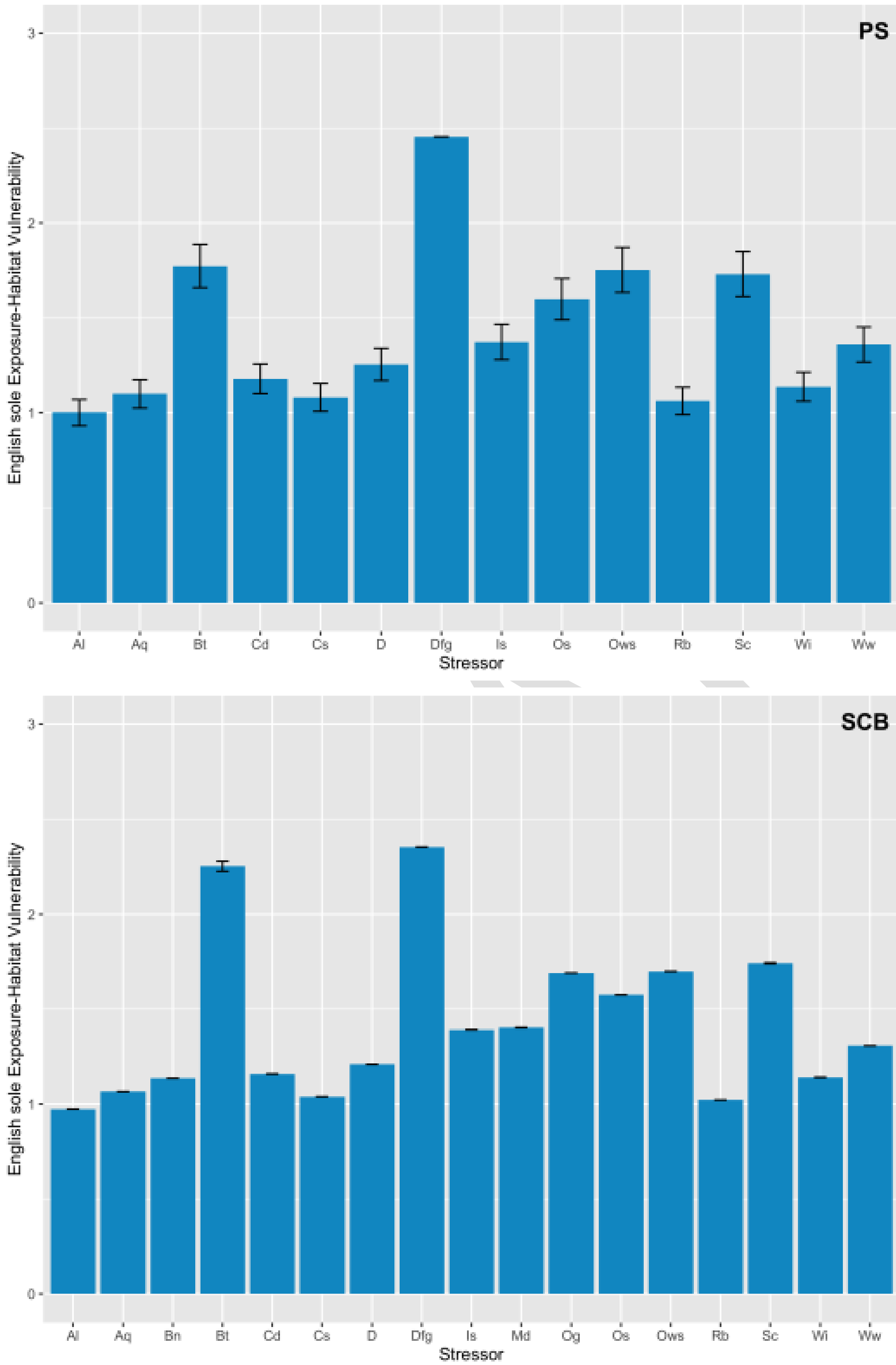
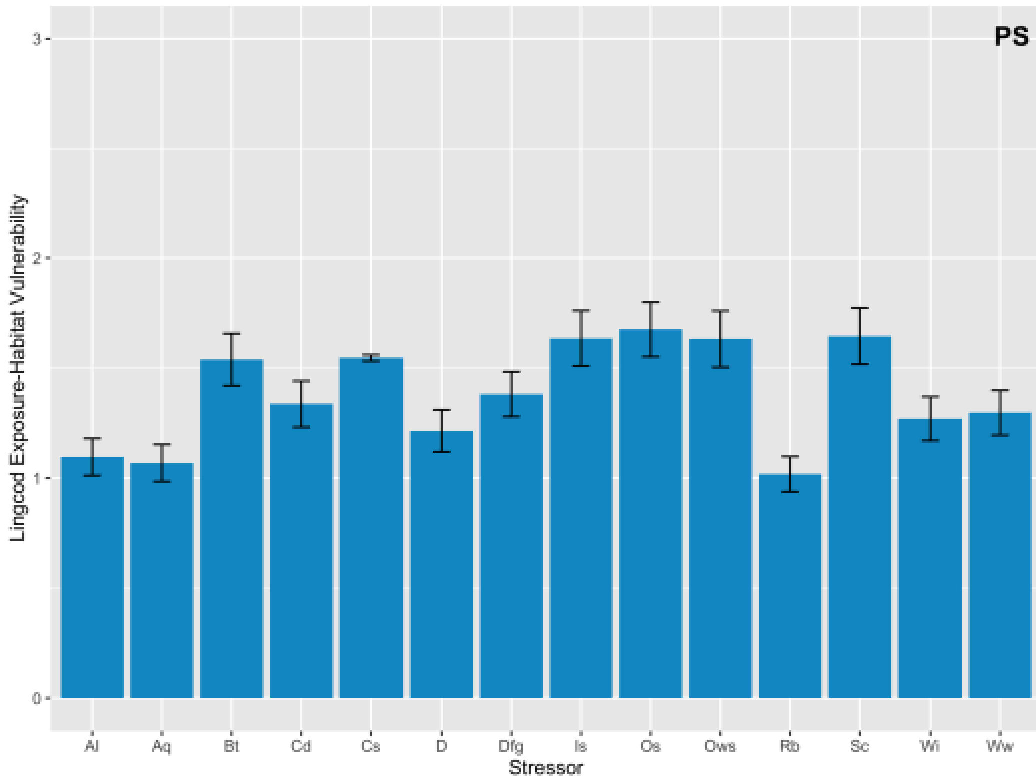


Figure 16. English sole exposure-habitat vulnerability (EHV) scores in Puget Sound (PS) and Southern California Bight (SCB) with error bars representing the magnitude change in EHV with a 5% increase to each stressor individually.



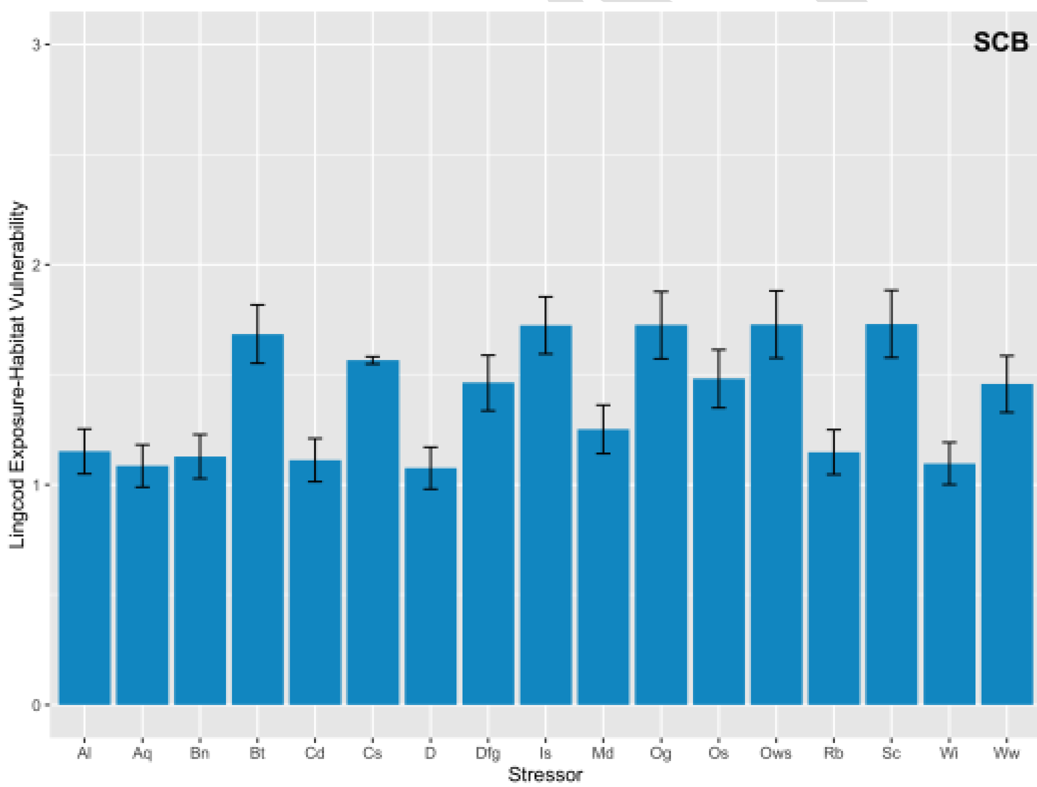


Figure 17. Lingcod exposure-habitat vulnerability (EHV) scores in Puget Sound (PS) and Southern California Bight (SCB) with error bars representing the magnitude change in EHV with a 5% increase to each stressor individually.

2.4 STRESSOR PRIORITIZATION

As discussed above, the process developed during this pilot effort is intended to identify priority stressors that NMFS and PFMC can address through habitat protection and restoration efforts and therefore decrease overall risk to focal species. For example, with comprehensive and appropriately-scaled data on habitat stressors, we could generate results that allow us to rank or prioritize stressors based on their overall contribution to risk for a focal species:

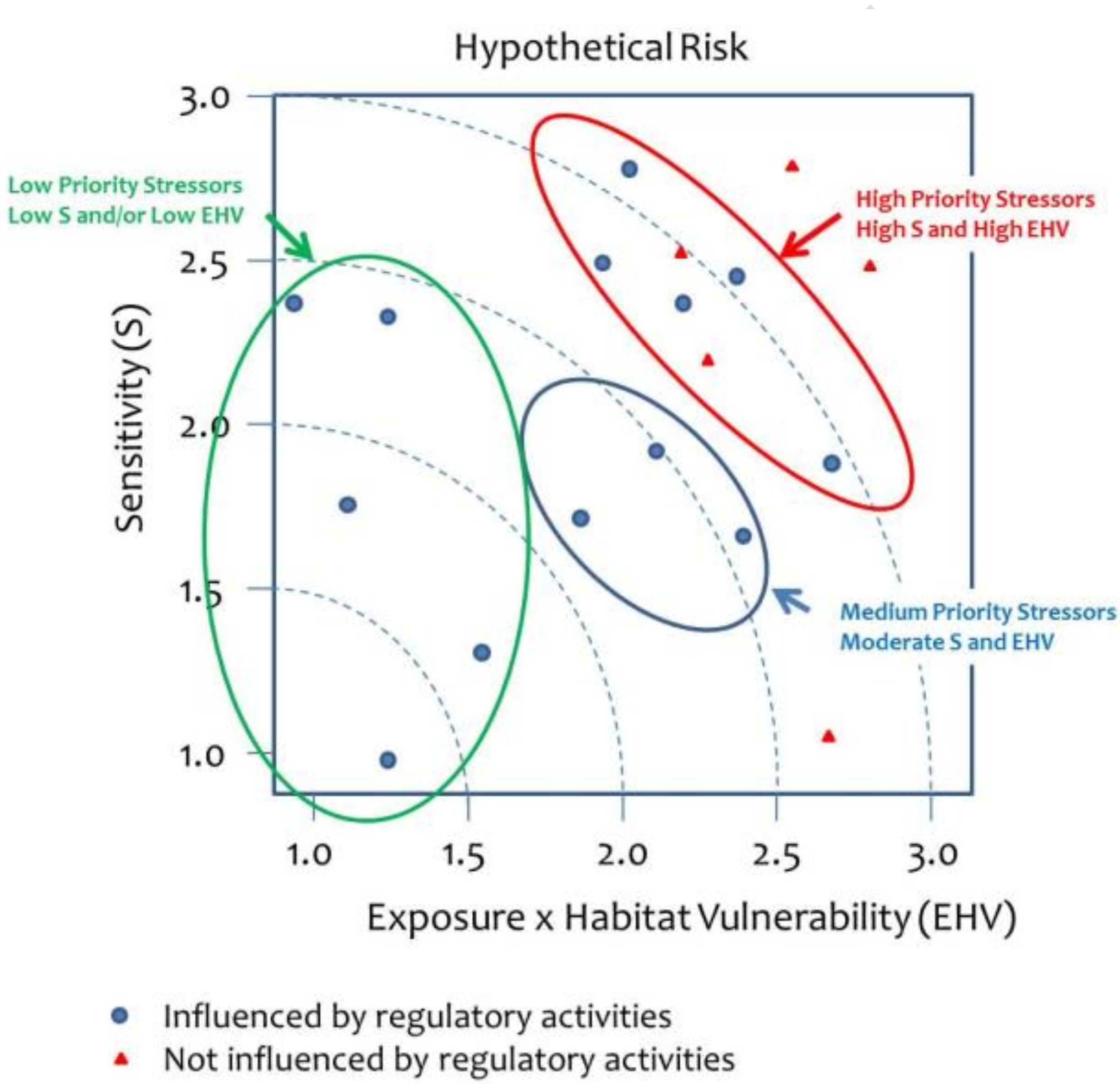


Figure 18. Hypothetical stressor prioritization.

In the hypothetical model results above, we distinguish those stressors that may be influenced by NMFS and PFMC regulatory authorities (i.e., coastal development, water quality, etc.) and those that are not (e.g., UV radiation, ocean-based pollution, sea-surface temperature), which would need to be managed at larger geopolitical levels such as international treaties. We then identified high, medium, and low priority stressors based on overall risk and contribution of EHV to that risk. The conservation tools available to NMFS and PFMC (e.g., EFH conservation recommendations, habitat restoration) can only influence the exposure of species and their habitats to stressors but would not change the actual sensitivity of a species if they were exposed to a stressor. We should still account for sensitivity in our objectives, ensuring the exposure to stressors with high risk scores based on high sensitivities are not increased, but the lack of influence on sensitivity suggests we should focus efforts on EHV. Based on this reasoning, high priority stressors are those that may be influenced by our regulatory authorities and that have high overall risk and high EHV. Medium priority stressors are those with moderate overall risk and EHV. Low priority stressors are those with low overall risk, those with high risk but with low contribution of EHV, or those that NMFS and PFMC cannot influence.

2.4.1 Stressor Prioritization – Coast Wide (Phase 1)

Using the risk plots to prioritize the stressors at the geographic area-wide scale, as described above, did not produce results that the Team viewed as realistic in Phase 1. This is more likely due to the data that were available for the risk analysis than the analysis methods, which was both limited in its scope and its quality or applicability. Here we use English sole in the Salish Sea as an example to illustrate this point.

Figure 18 shows the prioritized risk plot for English sole in the Salish Sea. This figure highlights some of the drawbacks of relying on the Halpern et al. (2009) data for such an analysis. High priority stressors include invasive species (I), organic pollutants (Op), and inorganic pollutants (Ip). Medium priority stressors include sediment increase (Si), nutrients (N), coastal engineering (C), trash (T, coastal waste), and oil rigs (O). Low priority stressors are power plants (P), shipping (Sh), sediment decrease (Sd), and aquaculture (A).

While several stressors fell out as expected (e.g., Op, Ip, N, P, A, Sh), others did not. For example, coastal engineering ranked as a medium priority stressor equal to trash (marine debris). This was based largely on the EHV score. However, it is important to note that the coastal engineering data used by Halpern et al. (2009) is limited to linear extent of consolidated and riprap structures, which is shoreline armoring. This is problematic for at least two reasons. First, exposure to the effects of shoreline armoring extends some distance into nearshore waters and cannot be represented by simple linear data. Shoreline armoring, for example, reflects waves, which can increase erosion and the loss of finer sediments used by English sole juveniles. Second, shoreline armoring usually results in a loss of intertidal habitats that are used by juvenile English sole. In order to adequately represent the effects of shoreline armoring and shoreline development, the exposure layer needs to account for all effects in the nearshore and the data need to be expanded to include other types of shoreline structures. If that were done, we expect that the exposure, and therefore the risk, of coastal engineering would increase significantly.

Oil rigs present a greater risk to English sole in this analysis than power plants, shipping, sediment decrease, or aquaculture. Despite the lack of oil platforms in the Salish Sea, the higher risk value comes from a significantly higher habitat vulnerability score and a slightly higher sensitivity score. This high risk is due to the high potential impact to English sole in the Salish Sea if oil platforms were to be built. It is important to recognize these future risks, but we need to prioritize those stressors we can influence directly through reducing exposure in the near-term.

Sediment decrease is ranked as a low priority stressor with a low exposure value in this analysis, but is generally considered a major issue in the Salish Sea. Shoreline armoring in the Salish Sea is extensive and interrupts the delivery of sediments that are eroded from feeder bluffs along the shoreline. These eroded sediments replace sediments that are carried offshore by drift cells. The loss of these sediments is recognized as a major contributor to changes in sediment composition in nearshore waters. However, the sediment decrease data used in Halpern et al. includes only those sediments captured behind dams. If this loss of sediments from other structures were accounted for, sediment decrease would likely be a higher priority.

Invasive species (I) has the highest risk score, higher than even the water quality stressors (Op, Ip, N). In the Salish Sea, and Puget Sound in particular, these water quality stressors are generally recognized as the being among the greatest threats to the marine ecosystem. However, exposure to this stressor was modeled as a function of shipping tonnage as a proxy for ballast water release in ports, perhaps a suitable proxy for coast-wide assessment but not ideal for smaller geographic regions like the Salish Sea. Therefore, in the view of the team, invasive species, while perhaps broadly important, likely present a lower risk to English sole in the Salish Sea than water quality stressors, coastal engineering, and sediment decrease.

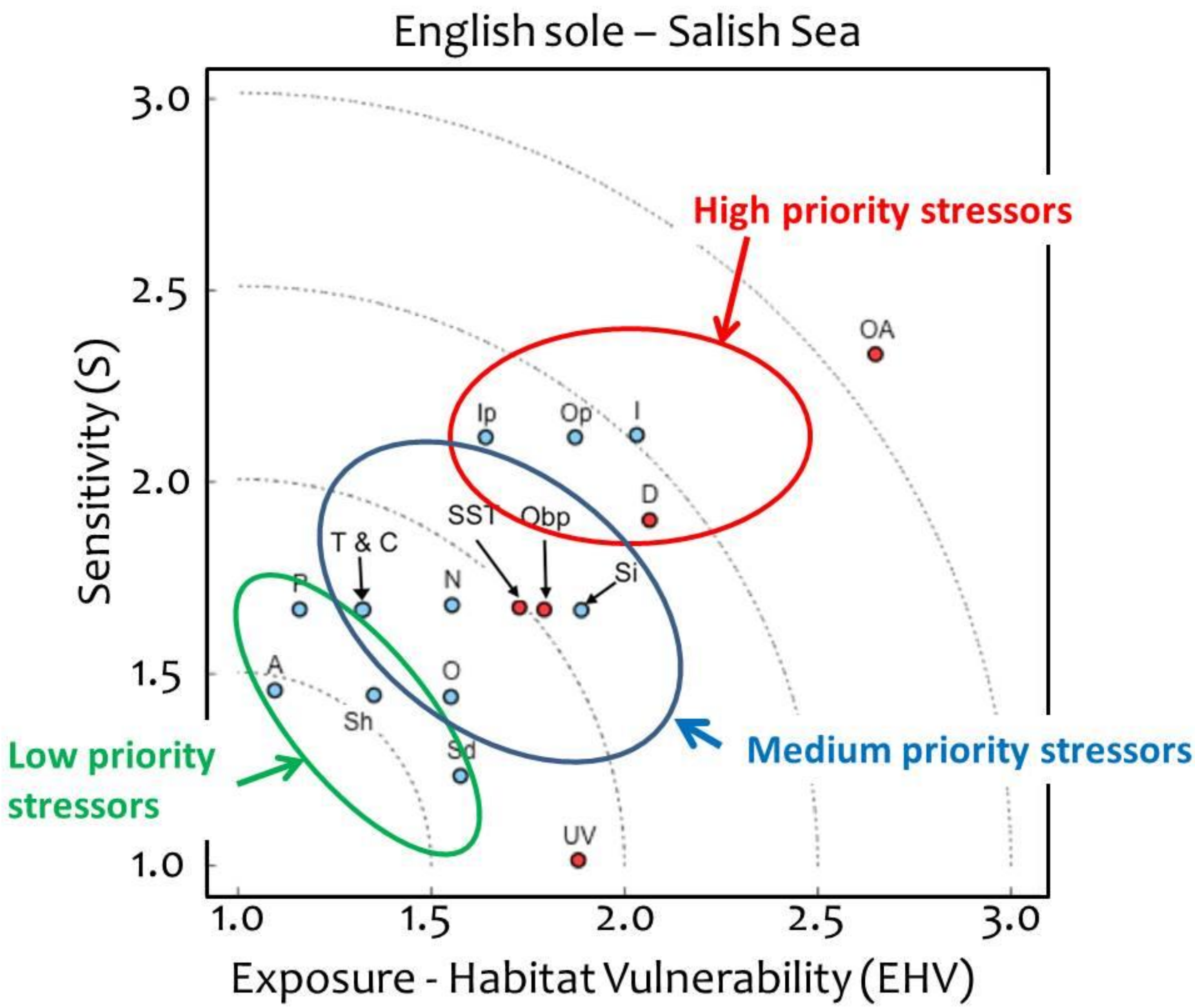


Figure 19. Phase 1 English sole risk scores plotted by sensitivity and EHV. Red circles indicate stressors that are not within the regulatory purview of this project. Letters indicate the stressor (A – Aquaculture, D – Atmospheric Deposition, C – Coastal Engineering, Ip – Inorganic Pollution, N – Nutrient Input, Obp – Ocean Based Pollution, Op – Organic Pollution, O – Offshore Oil, P – Power Plants, Sd – Sediment Decrease, Si – Sediment Increase, I – Species Invasion, T – Trash/Coastal Waste, OA – Ocean Acidification, SST – Sea Surface Temperature, UV – UV Radiation).

Even those stressors that fell out as expected were based on general models may not be appropriate for fine scale analysis. For example, the organic pollution exposure data are based on diffusion models that may give a good overall indication of risk but are not suitable at finer-scales.

Given the above data inadequacies, it was not possible to rank or prioritize stressors or determine their relative risk to each groundfish species. While the data were inadequate to the task, the general approach appeared sound, and we moved into Phase 2, where we identified other sources of data that were more suited to this type of analysis, providing that better data are available. We expected that with better data, the relative risks proposed by these stressors would be more realistic, and allow for the development of qualitative habitat objectives for use in NMFS habitat conservation efforts.

In addition to improving the quality of data incorporated into the analysis, we discussed a new approach for estuarine habitat objective prioritization based on initial results. The AEQ weighting gives a very large weighting to adult stages (greater than 50% in all species, and above 95% for two, see Table 2). However, the adults of many species, including the selected groundfish focal species, do not occur in estuaries or their abundance is low. Since many of the regulatory actions available to NMFS occur in the estuaries, this may result in an over-prioritization in adult life stage risk scores and de-emphasize estuarine habitat concerns. Unfortunately, the current status of sub-adult habitat data is lacking for many species, including the selected groundfish species. Therefore, we felt it best to continue to use the more adult-centric method of AEQ weighting, despite the recognition that it may not be ideal for estuarine habitat prioritization. Moving forward, better estuarine habitat and sub-adult habitat data should be recognized as an important data gap to be addressed.

2.4.2. Stressor Prioritization – Puget Sound and Southern California Bight (Phase 2)

The Phase 2 analysis produces results that are more realistic results than were found in Phase 1. This reflects the more fine-scale data available for the smaller areas analyzed in this phase – Puget Sound and the Southern California Bight. However, as described below, the resulting prioritization still reflects the data gaps for the stressors examined.

We again, use English sole, this time in Puget Sound, as an example to illustrate this point (Figure 19). High priority stressors include derelict fishing gear (Dfg), bottom trawling (Bt), oil spills Os), and invasive species (Is). Medium priority stressors are submarine cables (Sc), storm and wastewater discharge (Ww), and coastal development (Cd). Low priority threats from Phase 2 include overwater structures (OWS), recreational boating (Rb), commercial shipping (Cs), dredging (D), aquaculture (Aq), water intake structures (Wi), and altered freshwater flow (Al).

As in Phase 1, some stressors fell out as expected while other did not. For example, derelict fishing gear is identified as a high priority due to high scores for both EHV and S. This is a reasonable outcome, as derelict fishing gear has been identified as a significant threat to Puget Sound and the subject of an extensive removal effort since 2002. Bottom trawling, on the other hand, shows the second greatest risk to English sole. However, as discussed earlier, bottom trawling is banned in Puget Sound so that the focal species are exposed to the residual effects of past trawling only, not to ongoing effects.

Storm and wastewater discharge (Ww) ranked lower than expected, being a medium priority. However, storm and wastewater are widely recognized as major threats to water quality in Puget Sound (DOE and King County 2011) and was expected to be higher priority stressor for English sole. This may be due to the dataset used in the analysis, which is for point sources, not non-point sources which are a major contributor to pollutant loads in Puget Sound (Rau 2015). Incorporating non-point sources of pollution, as well as incorporating diffusion modeling of flow from point sources, into the analysis would likely increase the exposure-habitat vulnerability score and would likely elevate this stressor to high priority. Coastal development was also ranked lower than expected, as this is also widely recognized as a major habitat stressor.

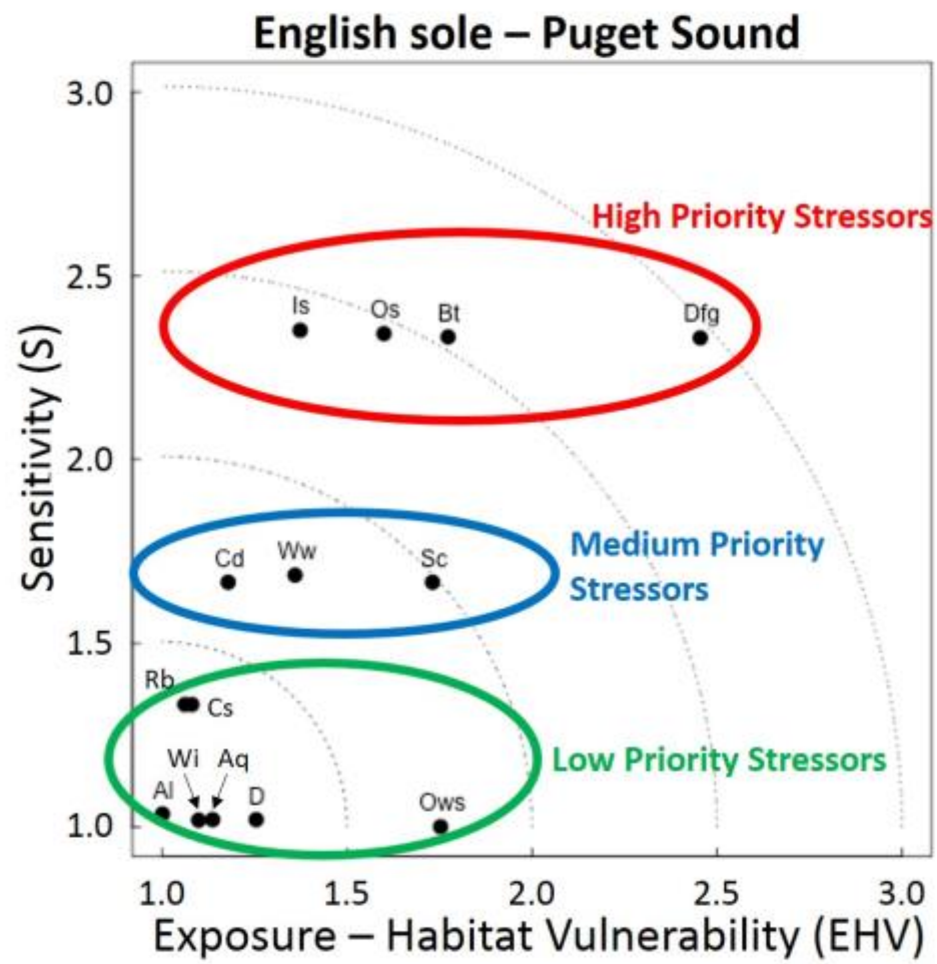


Figure 20. Phase 2 English sole risk scores plotted by sensitivity and EHV in Puget Sound. Letters indicate the stressor (Al = Altered Freshwater Flow, Aq = Aquaculture, Bn = Beach Nourishment, Bt = Bottom Trawling Cd = Coastal Development, Cs = Commercial Shipping, Dfg = Derelict Fishing Gear, D = Dredging & Disposal, Is = Invasive Species, Os = Oil Spills, Ows = Over Water Structures, Rb = Recreational Boating, Ww = Storm and Wastewater Discharge, Sc = Submarine Cables and Pipelines, Wi = Water Intake Structures). Similar issues apply to all the focal species in both geographic areas.

Despite these issues, however, the Phase 2 analysis and prioritization appears to be a more realistic picture of the habitat stressors in Puget Sound. Those that, based on the experience of the team, are usually considered to be significant threats to habitat in Puget Sound fell out as either high or medium priority. All of the low priority stressors fell out as expected. However, as in Phase 1, the analysis could be improved with better data.

The stressor prioritization for all the focal species in both locations are summarized in table 4. While the prioritizations varied, somewhat, among the species and areas, the high priority stressors for black rockfish, bocaccio, and lingcod were identical (derelict fishing gear, oil spills, bottom trawling, invasive species, submarine cables and pipelines, coastal development, and marine debris). English sole differed from these species where submarine cables and pipelines, coastal development, and marine debris were medium priority stressors. There was more variation in the medium and low priority stressors, with lingcod and English sole being at lower risk from this suite of stressors than the two rockfish species. Within a species, the prioritization did not differ between areas, except for altered freshwater flow and black rockfish.

As noted with the example of English sole in Puget Sound described above, the Phase 2 prioritization gave a more realistic picture of the relative risk posed by the stressors examined. Few of the stressors were categorized as low priority for black rockfish (2), bocaccio (1), and lingcod (4), while seven were classified as low priority for English sole. This stems partially from the lower sensitivity scores for English sole than the other species, as well as the low habitat use for Southern California, which resulted in lower exposure scores in that region. This may indicate that the first three species are at greater risk from the stressors analyzed or that the data gaps in habitat use and stressors exposure are confounding the picture. An example of this is bottom trawling in Puget Sound, where the exposure may have been overestimated. It is important to note, however, that even if bottom trawling is a significant risk factor for the focal species, it is regulated by the State of Washington and outside of the purview of NMFS for EFH or ESA consultations. Although Phase 2 did give more realistic results, it is clear that there remains room for improvement.

Table 4. Summary results of stressor prioritization for the four focal species and two geographic areas. SoCal = Southern California Bight, PS = Puget Sound, H = high priority, M = medium priority, and L = low priority.

	Black Rockfish		**Boccacio**		**Lingcod**		**English Sole**	
Stressor	**SoCal**	**PS**	**SoCal**	**PS**	**SoCal**	**PS**	**SoCal**	**PS**
Derelict fishing gear	H	H	H	H	H	H	H	H
Oil spills	H	H	H	H	H	H	H	H
Bottom trawling	H	H	H	H	H	H	H	H
Invasive species	H	H	H	H	H	H	H	H
Submarine pipeline cable	H	H	H	H	H	H	M	M

Coastal development	H	H	H	H	H	H	M	M
Marine debris	H	NA	H	NA	H	NA	M	NA
Storm/wastewater discharge	M	M	M	M	M	M	M	M
Overwater structures	M	M	M	M	M	M	L	L
Aquaculture	M	M	M	M	M	M	L	L
Commercial shipping	M	M	M	M	M	M	L	L
Dredging	M	M	M	M	L	L	L	L
Recreational boating	M	M	M	M	L	L	L	L
Oil and gas explanation	M	NA	M	NA	M	NA	M	NA
Beach nourishment	M	NA	M	NA	M	NA	M	NA
Altered freshwater flow	L	M	M	M	L	L	L	L
Water intake structures	L	L	L	L	L	L	L	L

2.5 GROUNDFISH HABITAT OBJECTIVES

As noted earlier in this document, it was not possible to identify quantitative habitat objectives for the focal groundfish species. Therefore, we are limited to the following qualitative objective:

Decrease exposure to priority stressors (those ranked high and medium) to recover degraded focal species habitat, protect high functioning focal species habitat, and decrease overall risk to focal species.

High functioning habitat is defined, for this purpose, as habitat that has water and sediments free from contaminants and the sediment composition, depth, dissolved oxygen levels, temperature, prey abundance and diversity, and available shelter necessary to support the focal species at all life stages present in the biogeographic region.

Although there remain some data gaps that, if filled, would improve the analysis and may change the prioritization of some stressors (e.g., storm and wastewater discharge), it is unlikely that any of the high or medium priority stressors would be reduced to low priority. Therefore, with the exception of bottom trawling in Puget Sound, because the objective includes stressors ranked both high and medium, it would not change the stressors of greatest concern.

NMFS and PFMC can use the habitat conservation objective and the identification of high priority stressors, to implement strategies under our existing authorities and programs. For example:

<u>MSA and ESA consultations</u>

- Make EFH conservation recommendations to action agencies that address priority stressors and limiting factors (*see conceptual models*) to focal species' habitat that would result from proposed actions.

- Refer to habitat objectives when making EFH conservation recommendations to reinforce their importance to a sustainable fishery and healthy ecosystem.
- Consider the impacts to focal species' habitat during ESA consultations; and select those conservation measures that provide the desired level of protection to ESA-listed species while also addressing the limiting factors for focal species.
- Reference focal species in NMFS Public Consultation Tracking System (PCTS) when a Federal action may adversely affect its EFH (use the "FMP" and "species/other" fields) to allow enhanced monitoring of activities that may increase risk to focal species.
- Provide regular updates to PFMC Habitat Committee; solicit feedback on aligning protection and restoration objectives with benefits to fisheries.
- Consider fisheries-specific protection and restoration objectives during EFH 5-year reviews; and consider incorporating as non-fishing conservation recommendations, and/or conservation measures applied to fishing activities.

<u>Restoration activities</u>

- Continue to request information regarding benefits of proposed projects to focal species (e.g., English sole) in NOAA Restoration Center funding opportunities.
- Track/measure progress/benefits of restoration projects to managed species (e.g. English sole).
- Within the framework of the NOAA Restoration Center's established priorities and guidelines, look for opportunities to benefit habitat for both managed species and ESA-listed species with focused restoration efforts (e.g., geographic area, habitat zone).

<u>Non-regulatory habitat conservation efforts</u>

- Share and promote activities to implement habitat objectives through conservation-based partnerships (e.g., Pacific Marine and Estuarine Fish Habitat Partnership, National Marine Sanctuaries, regional partnerships)

<u>Research, monitoring and assessment</u>

- Conduct research and assessments to address information gaps regarding stressors and their effects to managed species. In particular, the following are some key data gaps identified in the process of this pilot project:
    - Sub-adult habitat data for all 4 groundfish species
    - Diffusion model for dispersive stressors like altered freshwater flow, oil spills, and storm and wastewater discharge.
    - Assessment of non-point storm and wastewater discharge.
    - Estimates of remaining impacts where removal data was used, like derelict fishing gear and marine debris.
    - Delineate the spatial extent and patterns of stressors that are currently in point data format (aquaculture shellfish beds, recreational boating)

    - Identify focal marine and coastal invasive species known to have impact on fisheries and fish habitat, and inventory known observations of these species. There is an inland aquatic focus to currently available invasive species database.
    - Leverage data from EFH consultations to identify stressors, and engage in projects to delineate the spatial extent of the stressor (for example, EFH data was leverage identify and delineate dredge and fill sites for a ten-year period in Southern California Bight).
- Conduct research and assessments to better understand the effect of protection and restoration actions on species' exposure to stressors.
- Collect monitoring data on managed species (e.g., English sole) in restoration projects within their habitats.

3. SALMON

Quantitative habitat objectives are feasible when the relationships between habitat quantity and quality and population limitations are well understood, habitat conservation actions have logical links to population benefits, and the linkages between habitat and population responses can be quantified.

While most fisheries stocks are too large and their habitat associations are too poorly quantified to estimate the habitat conservation objectives with any certainty, Pacific salmon stocks represent one group of commercial fisheries for which quantitative habitat objectives are feasible. Many salmon ESUs and steelhead DPSs on the Pacific coast are currently federally listed under the Endangered Species Act, and therefore require critical habitat designations and recovery plans specifying conservation actions that would facilitate recovery and delisting. Moreover, most listed species are defined in terms of populations, which are a much smaller spatial extent than groundfish or coastal pelagic stocks. Finally, our general understanding of the relationships between habitat and salmon survival during rearing periods in rivers and estuaries is broad and continues to grow, and estimates exist for marine survival under a broad range of marine conditions. These qualities make quantitative habitat objectives feasible for Pacific salmon, and in this report we focus on developing new quantitative objectives for OC coho, which was once the most numerous species in commercial and recreational catches off the Oregon Coast during the 1950s through the 1970s (ODFW 2007), but which currently is under tight harvest restrictions and constrains other salmon fisheries. We use a quantitative life cycle model that incorporates both variation in coho life histories and address how habitat restoration might influence the parameters affecting the harvest control rule. We focus our modeling on the Salmon River, a small independent population with relatively comprehensive data on life history variation.

3.1 SALMON FOCAL SPECIES SELECTION

The process for selecting a focal species (we use the term species in this section when referring to Evolutionarily Significant Units (ESU) and Distinct Population Segments (DPS) that are listed under the ESA) of salmon differed from that used for the focal groundfish species. We agreed that the focal salmon species should be one with a recovery plan completed or in development for which NMFS can make a measurable difference through habitat conservation activities. This excluded several salmon stocks such as the Klamath that are not listed, and listed species in the Columbia River, where a combination of hydroelectric, habitat, hatchery and harvest issues are the driving forces limiting species recovery. To further ensure support and engagement from the PFMC, we chose to focus on a salmon species that affects Council-managed fisheries. We chose OC coho, a "threatened" species under the ESA, based on the previous criteria and the following information:

- The recovery plan for OC coho is in the final stages of development, allowing us to potentially contribute additional actions and objectives.

- Due to their listed status and potential risk from harvest, OC coho are managed to achieve a low total exploitation rate that limits ocean salmon fisheries, especially south of Cape Falcon, Washington.
- OC coho are being fished at low harvest rates because populations have not yet recovered to the point where they can be delisted. NMFS and ODFW have determined that the loss of functioning habitat plays a large role in slowing the rate of recovery, and NMFS intends to include in the draft Recovery Plan quantitative habitat-based criteria that would meet conditions for delisting, so it was timely that the process for establishing these quantitative habitat objectives could be highlighted in this pilot project.

3.2 BACKGROUND

OC coho is an ESU of coho salmon that NMFS first listed as threatened in 1998 and, after several Federal court cases and listing determinations, retained the status as threatened in 2011. The geographic setting for OC coho includes the Pacific Ocean and the freshwater habitat (rivers, streams and lakes) along the Oregon Coast from the Necanicum River near Seaside on the north to the Sixes River near Port Orford on the south (Lawson et al. 2007). The ESU matches PFMC's stock unit designated as OCN under the Salmon FMP. Lawson et al. (2007) established historical population boundaries and identified a total of 56 historical populations, which were classified as either Dependent or Independent in five strata (Figure 27).

The abundance of OC coho has ranged from estimated historic levels as high as one and two million spawners to a low of about 20 thousand. This table also shows exploitation rates for OC coho, which were as high as 90% before listing, and were reduced to less than 15% since 1994, reflecting the constraints imposed after listing.

In 1998, NMFS determined that "For coho salmon populations in Oregon, the present depressed condition is the result of several longstanding, human-induced factors (e.g., habitat degradation, water diversions, harvest, and artificial propagation) that serve to exacerbate the adverse effects of natural environmental variability from such factors as drought, floods, and poor ocean conditions (50 C.F.R. § 227 1998)."

3.3 HABITATS AND OC COHO POPULATION LIMITATIONS

The NMFS listing determination in 2011 described factors supporting a conclusion that OC coho meets the definition of 'threatened' and noted the Biological Review Team (BRT) "analysis of freshwater habitat trends for the Oregon Coast (which) found little evidence for an overall improving trend in freshwater habitat conditions since the mid-1990s, and evidence of negative trends in some strata, " and that "current protective efforts are insufficient to provide for freshwater habitat conditions capable of producing a viable ESU" (Wainright 2007).
Of the several factors that contributed to listing, the primary factor that continues to impede progress towards ESA and 'broad sense' recovery is degraded riverine rearing habitat for juvenile coho salmon (for some populations, spawning and estuarine rearing habitat are also important). Broad sense recovery goals are "goals defined in the recovery planning process that go beyond the

requirements for delisting, to address, for example, other legislative mandates or social, economic, and ecological values" (NMFS Proposed Recovery Plan for Oregon Coast Coho Salmon 2013). Furthermore, the BRT determined that dams, harvest, and hatcheries are not currently impeding recovery, and the recovery plan includes recommendations on future policies. As a result, ODFW and NMFS are focusing recovery/conservation efforts on protecting and restoring habitat as the primary limitation to rebuilding OC coho populations.

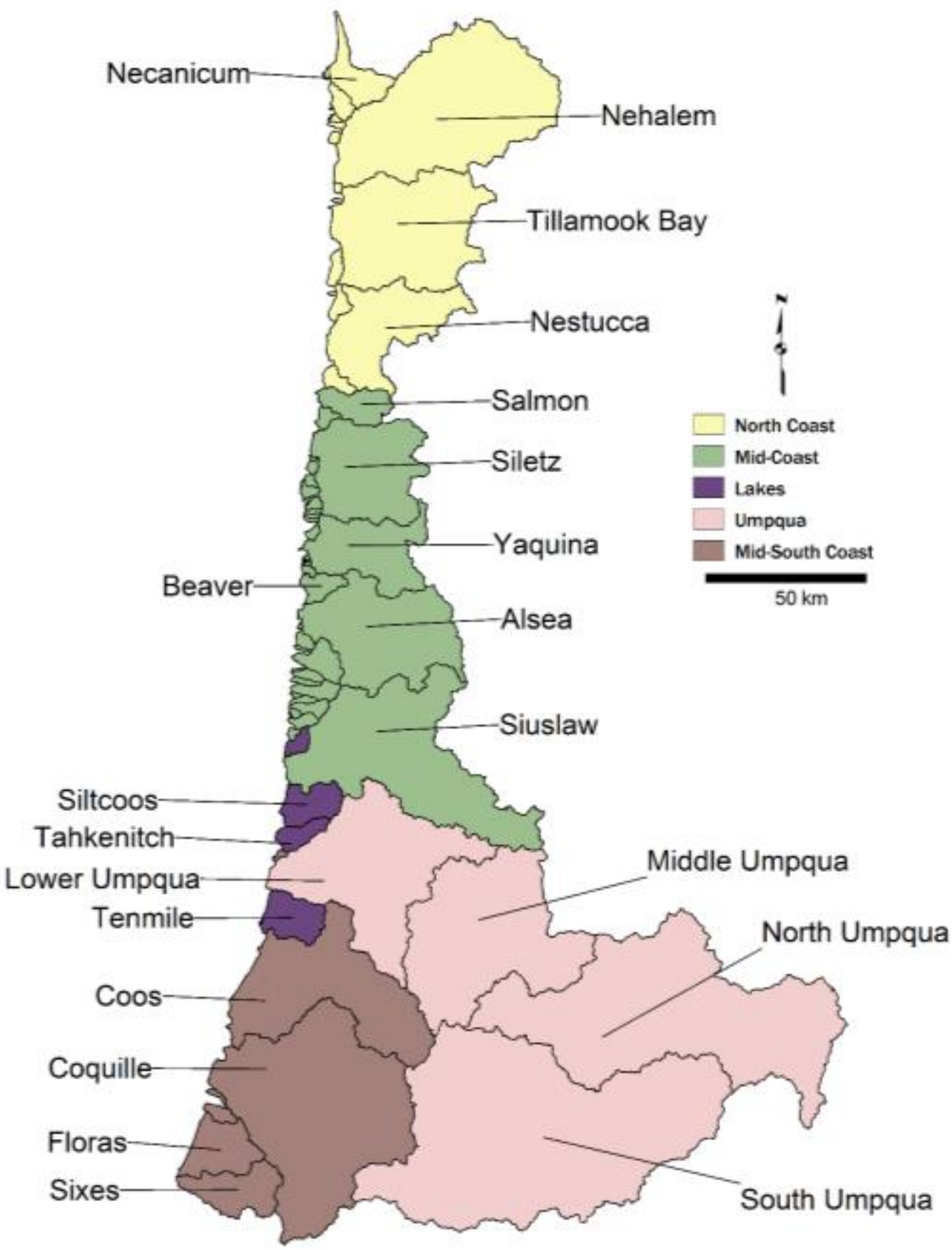


Figure 21. Spawning populations of OC coho, in five substrata. Watersheds that are not labeled are considered non-independent populations.

A partnership of ODFW, OWEB, NMFS, the National Fish and Wildlife Foundation and the Wild Salmon Center, is currently applying concepts from Open Standards (http://cmp-openstandards.org/about-os/) to establish a common framework of habitat elements relevant to OC coho recovery. Starting with ODFW habitat monitoring information, the partnership is using this common framework, along with approaches adapted from NMFS Northwest Fisheries Science Center habitat analyses in other areas, to describe habitat components, key ecological attributes (KEAs) of those components, habitat indicators, stresses, and threats – all leading to the development of strategic action plans for protecting and restoring coho habitat and ecosystem processes. Habitat components are the main large-scale habitat features in rivers and include mainstem rivers, tributaries, freshwater non-tidal wetlands, off-channel habitat, estuaries, uplands, and lakes (Fig. 22). Key ecological attributes are features of these habitat components that are important for OC coho. The draft list of core KEAs includes elements in Table 6.

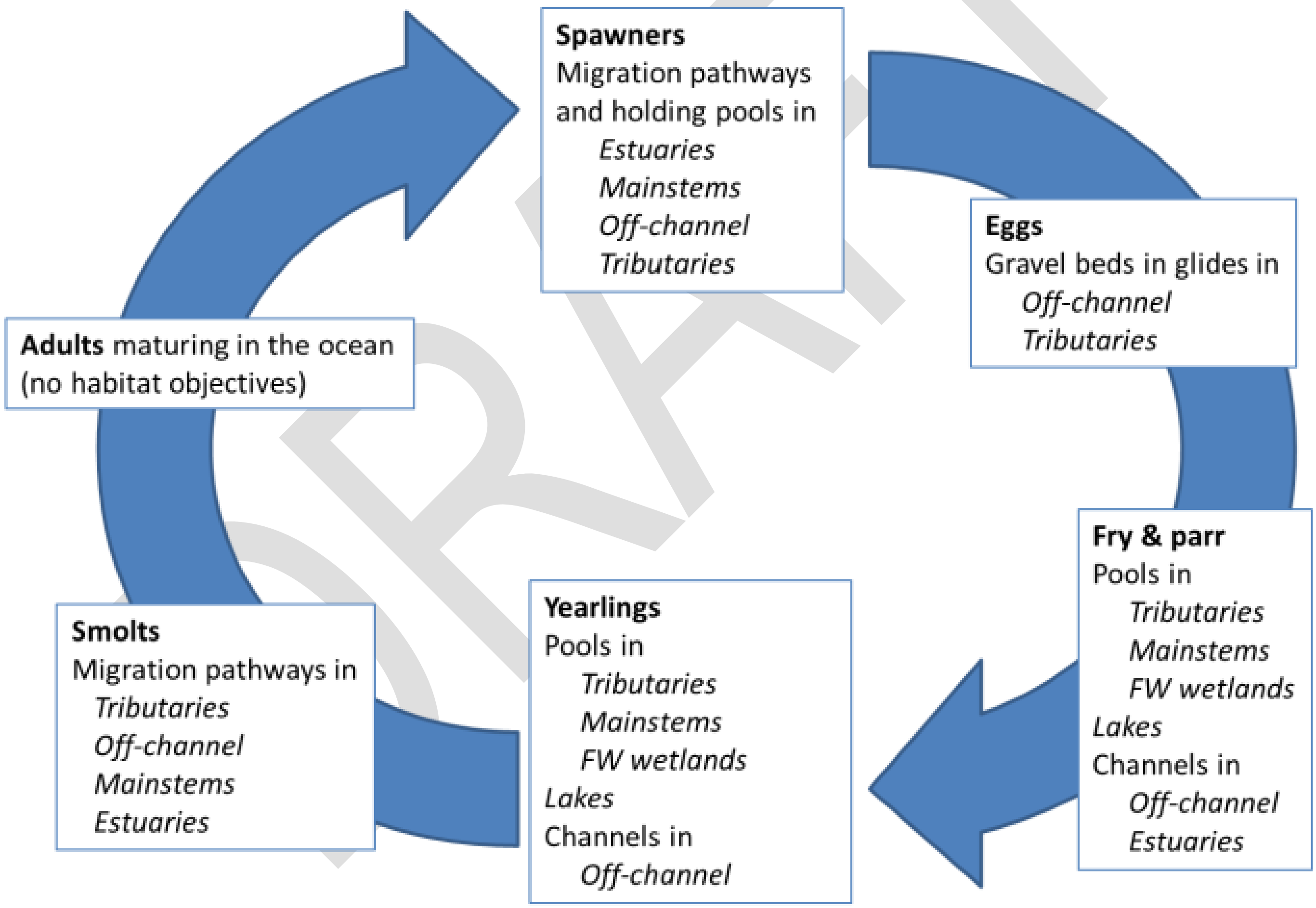


Figure 22. Conceptual model linking habitat components (in italics) with life stages of the OC coho life cycle.

An important goal of this effort is to identify strategic habitat conservation strategies and actions that directly relate to major limiting factors in the life cycle. The process for this framework and one that has proceeded in other recovery planning efforts (e.g., Beamer et al. 2005) is:

1) identify the key life stages and their habitat use patterns (Fig. 22)
2) within watersheds, identify areas with high potential for habitat use
3) address what KEA's need to be targeted for restoration or conservation (Table 5)
4) identify what habitat actions, where in the watershed, are necessary to protect and restore key ecosystem processes and habitat features.

Table 5. Draft development of habitat components and their associated life stages linked to Key Ecological Attributes and their core stresses. Stresses arise from several possible threats, a subset of which is associated with each habitat component.

Habitat Component	Core KEAs	Core Stresses
Upland	Connectivity Landscape array of structural diversity	
Tributaries Spawners Eggs Fry & parr Yearlings	Habitat complexity Riparian Function Geomorphic processes Water quality Lateral connectivity	Inc. water temp Lack of pools Red. frequency of wood in streams Red. size of wood in streams Red. riparian width (buffer size) Red. riparian wood Red. extent of habitat
Mainstem Fry & parr Yearlings	Habitat complexity Riparian Function Geomorphic processes Water quality	Inc. water temp Lack of pools Red. frequency of wood in streams Red. size of wood in streams Red. riparian width (buffer size) Red. riparian wood Red. extent of habitat Inc. velocity reducing rearing habitat
Off-channel Spawners Eggs Fry & parr Yearlings	Habitat complexity Riparian Function Lateral connectivity Longitudinal connectivity	Inc. water temp Lack of pools Red. frequency of wood in streams Red. size of wood in streams Red. riparian width (buffer size) Red. riparian wood Red. extent of habitat Inc. velocity reducing rearing habitat
Lakes Fry & parr Yearlings	Habitat complexity Connectivity Water quality	
FW wetlands Fry & parr Yearlings	Hydraulic connectivity	Increased water temperature Reduced quantity for access Reduced for habitat availability
Estuaries Spawners Fry and parr	Landscape array of habitats	Red. Habitat diversity Red. Frequency of wood

Threats-- subsets of this list for each Habitat Component
Timber harvest Gravel/placer mining Culverts and other barriers Removal of beavers and beaver ponds Roads/railroads Urbanization Levees, dikes and bank armoring Water withdrawals Stormwater/wastewater Dredging Dams Invasive species Grazing and other agriculture Fertilizers/pesticides

Like other salmon and steelhead recovery plans, the OC coho plans identify anthropogenic threats to rearing habitats. These are equivalent to risk factors identified in the qualitative analysis of groundfish, and as we followed in the qualitative analysis, conceptual models are being used to link various threats to stressors and KEAs.

Currently, the OCCCP and the NMFS TRT, BRT and draft recovery plan documents all focus on freshwater rearing habitat, especially winter rearing habitat. Summer rearing and spawning habitat are potentially limiting as well. As shown in Table 5, stresses associated with these limitations include: reduced extent of habitat, including pools and ponds, large instream and riparian wood, coarse sediment supply and connectivity; altered riparian species complexity; increased water velocity, water temperature, toxins, turbidity, and nutrients; reduced DO, and increased fine sediment.

Human activities that are associated with these stresses include: levees, dikes, bank armoring, removal of beavers and beaver ponds, urbanization, incompatible/poorly managed Roads/Railroads, water withdrawals, incompatible/poorly managed stormwater/wastewater, dredging, incompatible/poorly managed grazing and other agricultural practices, fertilizers/pesticides, incompatible/poorly managed timber harvest, invasive species, and climate change. Some of these have greater potential than others to restore productivity and capacity to particular coho salmon life stages.

3.4 DEVELOPING QUANTITATIVE HABITAT OBJECTIVES FOR OC COHO SALMON

Quantitative estimates of the habitat protection and restoration needed to achieve broad sense recovery goals have already been developed and presented in the OCCCP. Previously, Oregon's habitat-based management actions for coho have largely been built around the concept of habitat limiting factors (Nickelson 1998, Nickelson and Lawson 1998), focused on the capacity of systems to produce yearling smolts that have extensively reared in tributary habitats, the dominant life history pattern for Oregon coho. ODFW has proposed restoration and protection targets (see Table 6) for tributaries supporting each spawning population. Because their habitat monitoring has been focused on streams that can be waded, the ODFW estimates do not include main-stem, off-channel, or estuary habitats. However, a number of other life history types exist that may use these habitats based on differing residency patterns. Monitoring studies across the Pacific Northwest have revealed that brood years include a significant contribution of migrant fry, which may rear in relatively unmonitored mainstem habitats and floodplains or in estuaries (Suring et al. 2015). Likewise, coho may migrate downstream as parr in the fall (Bennett et al. 2011). In addition, fish that have migrated to estuary or floodplain habitats may migrate back into the river

Table 6. Summary of habitat conservation and protection objectives for independent populations of OC coho (directly from OCCCP, Appendix 2, ODFW 2007) in systems not strongly dominated by lake influence.

Population	3% Marine Survival				High Quality Habitat Miles			
	Spawner Goal[1]	Adult Recruit Goal[2]	Observed Spawners[3]	Estimated Observed Recruits[4]	Total Needed[5]	Current[6]	Additional[7]	Current % of Total Needed
Necanicum	3,545	4,171	628	739	50	9	41	18%
Nehalem	28,091	33,048	5,857	6,891	393	82	311	21%
Tillamook	10,909	12,834	1,896	2,231	153	27	126	17%
Nestucca	5,455	6,417	2,262	2,661	76	32	45	41%
Salmon	1,364	1,604	227	267	19	3	16	17%
Siletz	7,909	9,305	2,284	2,687	111	32	79	29%
Yaquina	13,636	16,043	3,923	4,615	191	55	136	29%
Beaver	2,182	2,567	1,365	1,606	31	19	11	63%
Alsea	12,273	14,439	3,075	3,618	172	43	129	25%
Siuslaw	36,273	42,674	9,069	10,669	508	127	381	25%
Lower Umpqua	21,818	25,668	7,872	9,261	306	110	195	36%
Middle Umpqua	25,636	30,160	4,125	4,853	359	58	301	16%
North Umpqua	5,182	6,096	1,525	1,794	73	21	51	29%
South Umpqua	29,727	34,973	4,831	5,684	416	68	349	16%
Coos	16,636	19,572	12,526	14,736	233	175	58	75%
Coquille	22,909	26,952	7,705	9,065	321	108	213	34%
Floras	4,364	5,134	1,366	1,607	61	19	42	31%
Sixes	1,364	1,604	189	222	19	3	16	14%
Total	249,273	293,262	70,725	83,206	3,491	991	2,501	28%

[1]Spawner goal @ 1.1% marine survival (Table 2) divided by 0.03/0.011.

[2]Spawner goal @ 3% marine survival/(1-0.15). 15% is maximum allowable harvest rate under Amendment 13 during periods of 3% marine survival.

[3]The average number of spawner observed during years with a 3% marine survival rate from 1990-2003.

[4]Observed spawners @3% marine survival /(1-0.15).

[5]The adult recruit goal divided by 0.03 (marine survival) to obtain an estimate of the number of smolts needed. The number of smolts needed was then divided by 2,800 (smolts/mile produced by HQ habitat -based on Nickelson 1998).

[6]The observed recruits divided by 0.03 (marine survival) to obtain an estimate of the number of smolts needed. The number of smolts needed was then divided by 2,800 (smolts/mile produced by HQ habitat -based on Nickelson 1998).

[7]Total miles high quality habitat needed - current miles high quality habitat

system as "nomads" (Koski 2009). This life-history variation likely has a strong environmental component responding to dynamic variation in habitat productivity and capacity (Greene et al. 2009). Ignoring this life history and focusing on the species-typical yearling outmigration may discount potential resilience of the population to dynamic environmental factors such as instream flow and temperature conditions. Conversely, attention to alternative life histories can reveal additional opportunities for habitat conservation such as estuary restoration (Greene and Beechie 2004, Jones et al. 2014). Following this logic, the draft recovery plan for Oregon coho proposes a strategy that builds a portfolio of habitat conservation actions addressing multiple life-history types (NMFS 2015).

Unlike habitat conservation efforts, harvest management of coho salmon occurs annually by setting maximal allowable harvest levels using a harvest control rule. This rule is essentially a matrix a matrix of two annually variable aspects of coho salmon populations: population size of the current cohort subject to harvest and expected marine survival of the cohort (Suring and Lewis 2013). Both factors could conceivably be improved via habitat conservation. Population size is expressed as a proportion of full seeding by adults, so habitat conservation might increase harvest if it improves capacity for a greater number of juveniles, or paradoxically may reduce harvest if it offers more habitat for adults (i.e., because full seeding would occur at a higher level than previously). Habitat conservation could also afford higher harvest if it shifted the distribution of life history types toward those with higher marine survival.

In this chapter we use a dynamic life cycle model to address the question of whether habitat objectives might be informative in managing opportunities for commercial harvest. This approach contrasts with the groundfish model in a several ways: 1) it is quantitative in nature, i.e., it produces specific predictions about how habitat conservation may influence harvest, and 2) it focuses on habitat restoration as a potential management strategy. The life cycle model examines coho salmon in the Salmon River, one of the 21 independent spawning populations of the OR coho ESU. This population has well-documented life history variation despite its small size (Jones et al. 2014). Like most Oregon Coast populations, coho salmon in the Salmon River spawn and rear in a network of tributaries, each with varying degrees of restoration potential and habitat loss. Tributary populations share potential downstream rearing habitat in the mainstem, floodplains, and the estuary. Hence, habitat conservation could be applied to a variety of subsystems as well as several habitat types. Importantly, the Salmon River watershed comprises a fraction of the total watershed area for the Oregon coho ESU, so assumptions are required to downscale harvest to this single population. Likewise, predictions concerning the benefits of habitat restoration would need to be extrapolated to other watersheds with care, as different watersheds likely have different levels of habitat loss. This portion of the report 1) describes the modeling framework to address these issues, 2) models several general habitat conservation scenarios and then applies them to the Salmon River situation, and 3) evaluates whether particular levels of habitat conservation shift population dynamics into conditions more amenable to conditions for more successful and sustainable harvest.

3.6 A QUANTITATIVE LIFE CYCLE MODEL

Quantitative life cycle models are needed along with additional habitat data in order to estimate the amounts of conservation in different habitat components that can contribute to meeting recovery goals and sustainable harvest. Models have been used to evaluate quantitative benefits of other habitat conservation actions (e.g., Zabel et al., 2008, Walters et al. 2013). Similar approaches are feasible for OC coho because current adult population sizes are known, juvenile freshwater and marine survival have been estimated (Nickelson 1998, Johnson et al. 2005), impaired habitat can be mapped (Greene et al. 2015), and relationships between habitat conservation and improvements to productivity and capacity can be estimated (Nickelson and Lawson 1998, Johnson et al. 2005).

We use a stage-structured, stochastic life-cycle model to predict population responses to management actions. The structure of our model follows the Sacramento Winter-run Chinook salmon life-cycle model developed by Hendrix et al. (2014). The model tracks cohorts as they transition between not only life-stages (e.g. egg, fry, parr), but also habitats (tributary, mainstem, estuary). Transition probabilities between habitats are either density-independent functions of habitat-specific survival and environmental covariates (e.g. flow) and or a density-dependent stock-recruit function parameterized with habitat-specific capacity and survival. For density-dependent transitions, rather than assuming density-dependent mortality for all excess production in a habitat, we implement density-dependent migration (Greene and Beechie 2004). For example, as fry rearing habitat fills in the tributaries excess production migrates downstream; these migrants take up residence lower in the watershed if capacity is available, and if not, continue to the estuary. The combination of density-independent and dependent migration between habitats permits multiple life-history pathways to be expressed in the model (Fig. 29). Further, we assume that differential size-based marine survival is associated with habitats and duration spent in freshwater (e.g., Bilton et al. 1982). Therefore, our model allows us to evaluate how improvements to a single habitat alter life-history expression and ultimately influences population-level performance at later life stages.

Life-History Types

The life-cycle model tracks the fate of four life-history types referred to here as fry, parr, nomads, and yearling (Fig. 29), in accordance with what is observed in coastal Oregon coho populations like the Salmon River (Jones et al., 2014). Fry are individuals that migrate to the estuary in their age-0 summer (Chapman 1962, Koski 2009) where they rear until they migrate to the marine environment (Fig. 29, Appendix 11; transitions 1, 3, 7, 11). Parr remain in freshwater (either in their natal tributary or in available habitat downstream) for their age-0 summer and migrate to the estuary to rear for their age-0 winter (Rebenack et al. 2014, Bennett et al. 2015) before moving to the marine environment (transitions 1, 2, 6, 11). Nomads migrate to the estuary in their age-0 summer similar to fry, but return to freshwater habitats to rear for their age-0 winter (Koski 2009) until they migrate to the marine environment (transitions 1, 3, 5, 10). Yearling are the archetypical coho salmon life-history type, rearing in freshwater for a full year prior to migration to the marine environment (Sandercock 1991). All four life-history types considered migrate to the ocean for their age-1 summer. The Southern Oregon/Northern California Coast Coho Salmon ESU recovery plan (NMFS 2014) includes two less common life-history types that migrate earlier or later to the marine environment: parr that migrate directly to sea (transitions 1, 2, 8, 14) and yearling that rear for a second summer (transitions 1, 2, 4, 9, 12, 13). We include these life-history types in the conceptual model, but currently do not consider them in our life-cycle model.

Spatial Complexity

Within the stage-structured life cycle model we also implement the realistic spatial complexity of a watershed. We incorporate this spatial complexity in the model by 1) assigning individual reaches their own unique capacities occupied by sub-populations that experience different, but temporally correlated environmental variation, and 2) applying a transition matrix that permits juveniles in a given reach access to available capacity in downstream reaches (i.e. all juvenile migration is unidirectional in the downstream direction). Thus, our model attempts to capture the reality that available rearing habitat capacity to an emergent fry depends on where it is in the spatial network of the watershed. To insure the model was immune to artifacts created by serially cycling through reaches (and therefore giving the first modeled reaches precedence), we assigned at each time step all mobile fish to a common pool of emigrants, and tracked the proportions of this pool from each natal reach through subsequent stages.

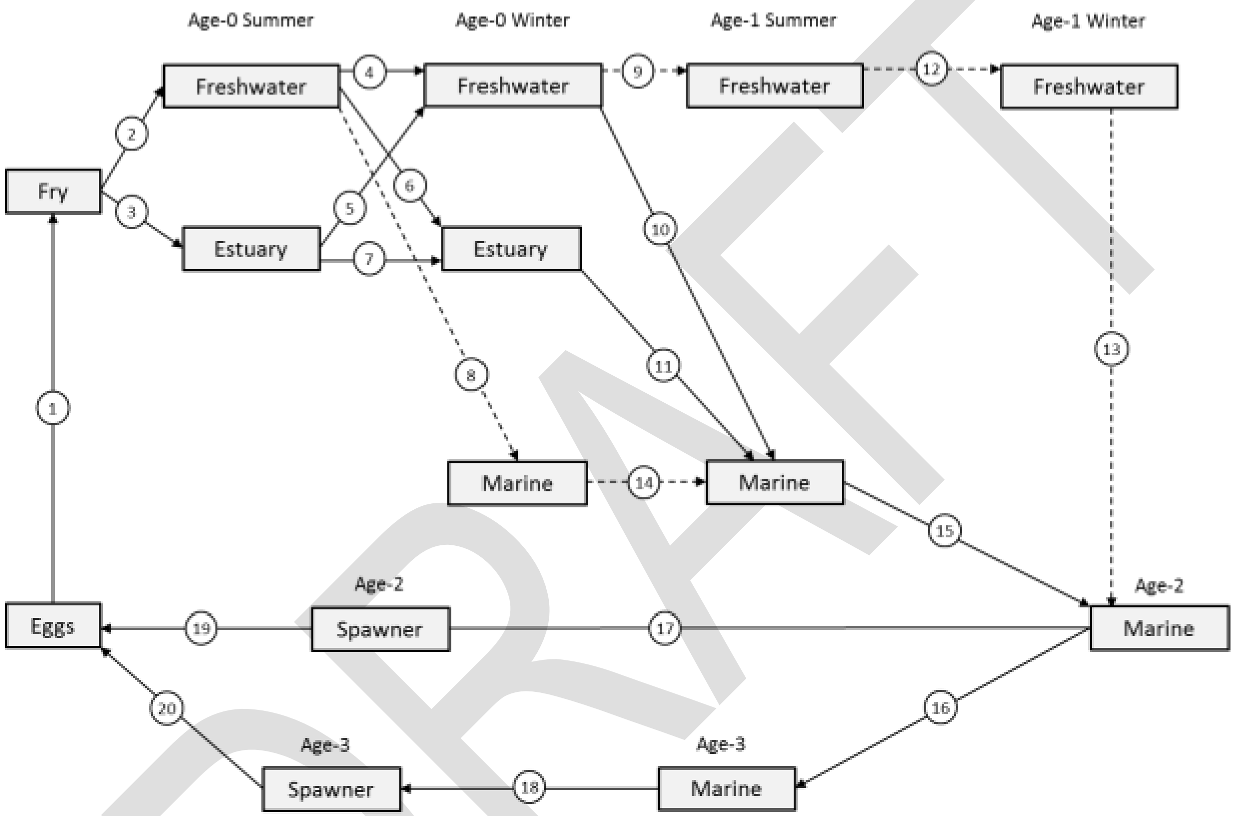


Figure 23. Conceptual life history pathways of Coho salmon populations. Habitat specific life-stages are indicated by boxes and arrows indicate transitions between stages. Numbered circles correspond to the unique function that describes each stage transition. The recovery plan for the Southern Oregon/Northern California Coast ESU of coho salmon includes an additional two life-history types indicated here by a dashed line: sub-yearling that migrate to sea in the fall of their age-0 year and stream-type that migrate to sea at age-2.

Environmental Variability

To evaluate population resilience to environmental variation, we introduce random variation to transition probabilities in both the marine and freshwater environments. We approximate the generic effects of temporal variation in ocean conditions on marine survival by drawing from a normal distribution with a life-history-type-specific mean and standard deviation marine survival. Freshwater environmental variability is incorporated from models fit to streamflow and fry, parr, or smolt production at 10 life-cycle monitoring sites on the Oregon Coast. We used the resulting models to simulate fry, parr, and smolt movement in response to streamflow at each individual reach, incorporating environmental variation using the mean and standard deviation of observed streamflows drawn from a lognormal distribution. Variation in streamflow was temporally correlated (e.g. high streamflow years were generally high in all reaches, with some between-reach variability); however, spatial autocorrelation was not considered (i.e. streamflow in nearby reaches are not necessarily more similar than far apart reaches).

Application to the Salmon River

The Salmon River is a small, coastal watershed in north-central Oregon (Fig. 21, 24). Extensive monitoring of the coho population has quantified relative abundance and survival for multiple life-history types (Jones et al. 2014). Combined with reach-level habitat capacity data, the Salmon River is well-suited for applying our life-cycle model. Wherever possible we parameterized the model with either direct estimates of survival or capacity reported in Jones et al. (2014), updates

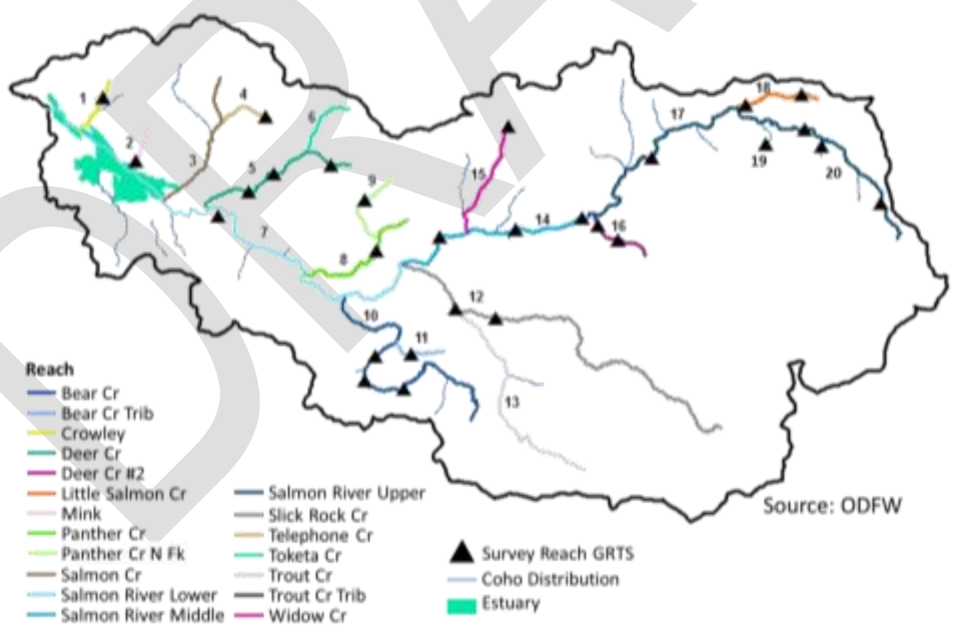


Figure 24. Map of the Salmon River, showing reaches that are accessible to Coho salmon, the estuary, and GRTS survey locations used in ODFW's status and trends monitoring.

to Nickelson (1998; K. Anlauf-Dunn, pers. comm.), or from personal communication from those familiar with the system. Where parameter estimates did not exist (e.g. estuary survival) we found a parameterization that produced reasonable population trajectories. Survival and capacity estimates for all life stages and seasons are reported in Table 1 with notes and data sources.

Juvenile habitat capacity and survival

Tributaries and mainstem

The Salmon River was segmented into 17 tributary reaches and 4 mainstem reaches where all spawning and freshwater rearing would occur in the model. Populations have access to available capacity within their own spawning reach and, for fry and later life stages, in reaches that are not at capacity downstream. We used previously estimated parr per river km for the summer capacity (47,168 total parr). For the seasons when reach-scale estimates of capacity were not available, watershed-scale estimates were applied by assuming total spawning, spring, and winter capacity were distributed across reaches in similar proportions to summer capacity. That is, the reaches with highest parr capacity also had the highest, spawning, spring, and winter capacity. This is a necessary assumption and may not reflect reality if parr capacity or spawning capacity is not similarly distributed in the watershed. The restoration scenarios presented below evaluate changes in capacity at the reach-scale and assumes the restoration action improves capacity for all life-stages within the reach by an equal amount (e.g. a restoration action that doubles egg capacity also doubles fry, parr, and yearling capacity).

Floodplains and estuary

Floodplain and estuary habitat are assumed to be equally accessible to all populations. Habitat capacity (20,000) is based on estimations of channel area and capacity-level densities solicited via personal communication with regional scientists. These values are based on current densities, not historical estimates, and model-derived estimates of high densities based on body size relationships (Grant and Kramer 1990) predict much higher densities at capacity. Nevertheless, we chose the conservative estimate because the model based on Grant and Kramer (1990) is based primarily on freshwater habitats and has substantial error due to log-allometric relationships. Restoration scenarios presented below evaluate changes to estuary capacity. There are no survival estimates for fry that over-summer in the estuary or parr that over-winter. For our model we assumed estuary survival was 10-times greater for parr than for fry. Model results were not sensitive to different parametrizations of estuary survival, although in combination with empirical estimates of marine survival, chosen estuary survival rates may be lower than what naturally occurs.

Marine survival
Survival in the marine environment was a function of life-history type. We first applied life-history-type-specific marine survivals according to estimates made in Jones et al. (2014) and more recent unpublished data from the Salmon River (pers. Comm. Kim Jones, ODFW). However, preliminary model simulations suggested the population would go extinct under these marine survival estimates. Therefore we adjusted the life-history specific marine survival parameters to produce spawner abundances and life-history type proportions that would be realistic for the Salmon River. Differences between the estimated and adjusted survival terms were modest relative to the variation we expect to see in these parameters. For simplicity, we assumed all marine mortality occurred between age-1 and age-2. Capacity of the marine environment was assumed not to be limiting.

Adult returns

Harvest

Harvest control rules for the LHT-LCM model were set according to the 2013 technical revision to the OCN Coho Work Group Harvest Matrix (Suring and Lewis, 2013). The harvest control rule specified in this document (Fig. 31) used parent spawner status (spawner criteria) and predicted marine survival to set maximum harvest rates. Both of these values are available in the LHT-LCM model. The HCR specifies spawner criteria for the three regions of the Oregon coast (North, North-Central and South-Central), the Salmon River Specific criteria was based on the ratio of the miles of available spawning habitat in the Salmon River to that in the entire North Central region. For real-world harvest management, the wild adult coho salmon survival is predicted by the two-variable GAM ensemble forecast (Suring and Lewis, 2013). In the LHT-LCM model, observation error (truncated normal (0, 0.01, -0.05, 0.05)) was added to the calculated MSI values to mimic the error associated with the GAM ensemble forecast. The marine survival index is based on the smolt to adult return ratio. This is calculated directly from the model outputs, i.e. total smolts / total returns.

% Seeding level of parent spawners		Forecast marine survival (%): ≤ 2	≤ 4.5	≤ 8	>8
		V. Low	Low	Med	High
> 75	High	≤ 8	≤ 15	≤ 30	≤ 45
≤ 75	Med	≤ 8	≤ 15	≤ 20	≤ 28
≤ 50	Low	≤ 8	≤ 15	≤ 15	≤ 25
≤ 19	V. Low	≤ 8	≤ 11	≤ 11	≤ 11
≤ 4	Critical	0-8	0-8	0-8	0-8

Figure 25. Harvest control rule for Oregon coho. Different harvest rates (% of forecast return) are specified for each combination of parent seeding level in freshwater and forecast marine survival.

Maturation
For simplicity, we assumed all fish matured at age-3. This assumption results in no overlapping generations. Multiple age classes of spawners contribute life-history diversity that can stabilize a population by spreading cohort risk across several spawning years (Schindler et al. 2010, Moore et al. 2014). Thus, our simplifying assumption may produce more cohort variability than would be expected if age-2 coho occur in the Salmon River spawning population.

Straying
Our model is spatially explicit and natal reaches in the watershed represent individual sub-populations that adults home to for spawning. However, without some straying sub-populations that go extinct within a model simulations would never be recolonized. Therefore, we evaluated varying levels of straying applied to all populations in all reaches. We simulated stray rates ranging from nonexistent to quite high for salmon populations (0, 0.01, 0.05, 0.15, 0.25, 0.5, 0.75, and 1.0), and found that stray rate had very little effect on adult returns except at the highest (unrealistic) levels. For baseline and restoration scenarios, stray rate was set at 0.15.

Analysis of model output

This modeling effort attempts to answer how various scenarios such as restoration of habitat capacity result in better productivity for the population as a whole. We are also interested in whether certain scenarios increase stability of the population, which would be reflected in long-term variation of the population. The Oregon coho life cycle model described here includes environmental conditions that approximate the range of variation found in the real world. To assure that this variation did not differ for different scenarios, we simulated variable marine survival and freshwater transitional probabilities for multiple simulation runs, stored them, and applied to each scenario. The observed differences among scenarios (Figure 4) compared to a baseline set of runs could then be examined independent of the environmental variation using a relative change metric:

$$Average\ relative\ change\ from\ baseline = \frac{\sum_1^n Scenario_n/Baseline_n}{n}$$

where n is the number of simulation runs, and $Scenario_n$ and $Baseline_n$ are the scenario and baseline averages, respectively, for a given run. The coefficient of variation (CV) produced by each run was used as a proxy for the population's resilience, on the assumption that higher CV indicates a less stable and less resilient scenario outcome.

3.7 MODEL RESULTS

The central questions to the life cycle model are whether restoration of particular habitat types changes the suite of expressed life histories, and thereby improves sustainable harvest to meet long-term recovery goals. As noted in Table 6, ODFW has proposed a 6-fold increase in miles of high-quality tributary habitat in the Salmon River, which is predicted to result in a similar increase in adult spawners. The life cycle model can be used to test these habitat objectives, and compare tributary restoration with restoration in other habitat types. We can also test other habitat-related concerns arising from the Recovery Plan. For example, existing habitat restoration projects have not been rigorously evaluated for their benefits to coho salmon populations. Are these "random acts of kindness" as productive as larger investments in particular habitats or more systematic habitat portfolios? This is an extension of the so-called "SLOSS" (single large or several small) debate in conservation biology (Simberloff and Abele 1982) with real potential consequences for coho salmon populations.

We first evaluated the effect of habitat restoration on life history types. As shown in Fig. 32, increasing restoration shifted the frequency of life history types to longer freshwater residence and reducing the three estuarine-dependent taxa. A 6-fold increase in tributary habitat capacity shifted most juveniles and adults to the typical yearling and parr life history types, but in comparison to more moderate restoration (a doubling of tributary habitat capacity), the change in life history types was relatively small. In contrast, a 6-fold change in all freshwater habitat produced a much greater change, increasing the proportion of yearlings and greatly decreasing the proportions of nomads and parr migrants.

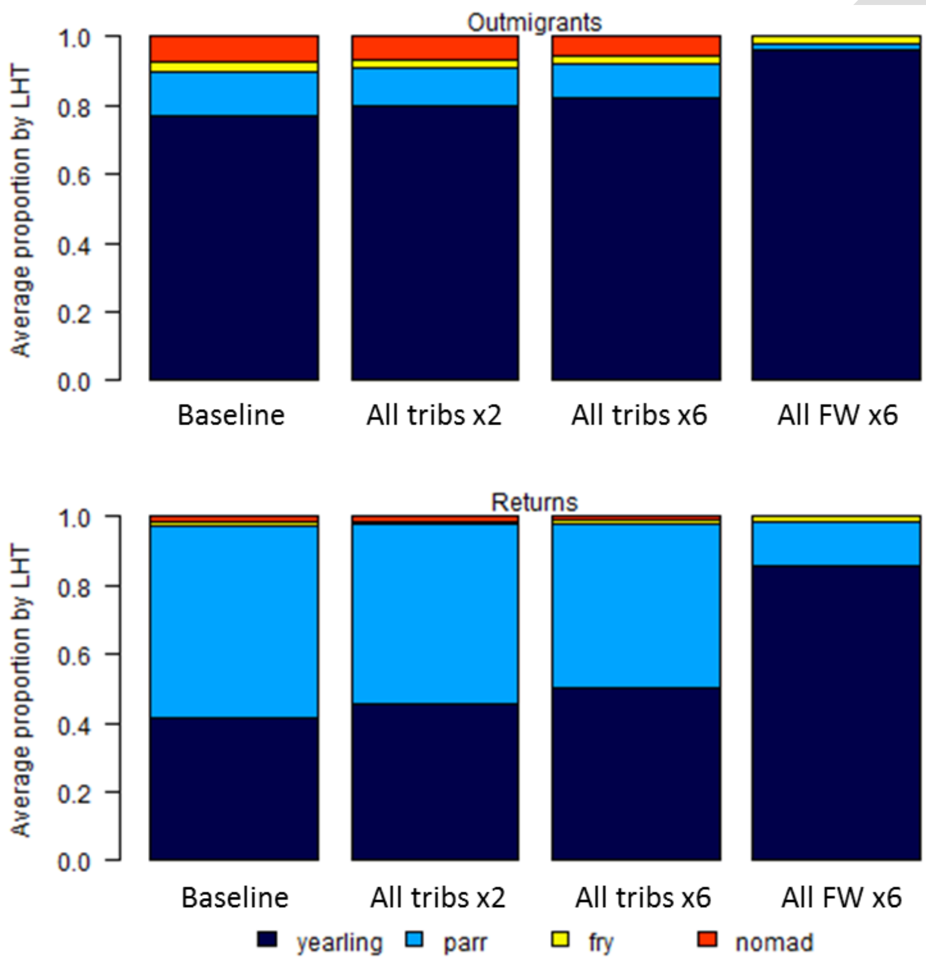


Figure 26. Distribution of life history types in juveniles (top panels) and adults (bottom panels) under baseline conditions, when tributary habitat capacity is doubled (x2) or increased 6-fold, or when all freshwater habitats (including mainstem but not estuary) are increased by 6-fold.

While these improvements resulted in an improvement in both adult escapement and harvest, these levels did not approach the 6-fold increase in spawners in ODFW's plan. Rather, the benefit resulted in about a doubling of adult returns and a 50% increase in harvest rate (Fig. 33). We also evaluated whether adding mainstem restoration would provide additional benefits to adult returns and harvest, and while this did result in a three-fold increase in adult returns and a nearly a 2.5-fold increase in harvest. However, this scenario also did not approach the 6-fold increase in spawners advocated in the plan. Based on the Salmon River-specific results, we hence might expect the habitat objectives proposed in Table 6 to be overly optimistic.

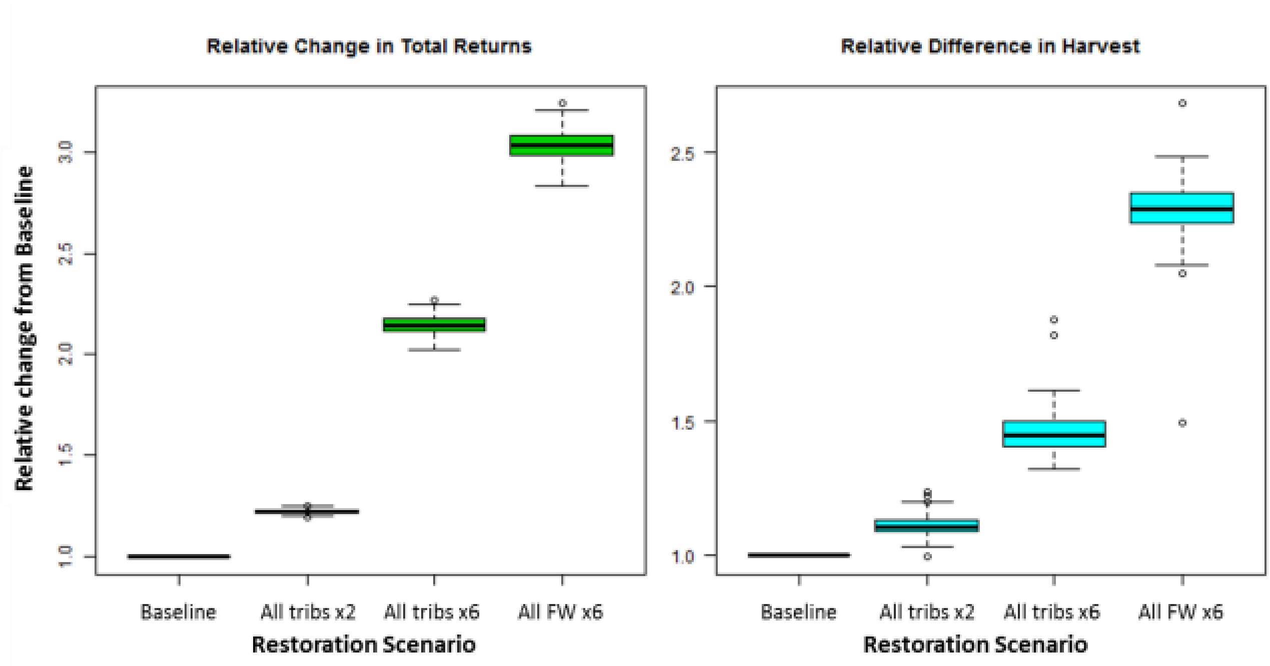


Figure 27. Relative change in spawning adults (left panel) and change in harvest (right panel) when tributary habitat capacity is doubled or increased 6-fold, or when all freshwater habitats (including mainstem but not estuary) are increased by 6-fold.

We next evaluated whether single large restoration efforts would have differential benefits as smaller dispersed benefits, by modeling an increase in total area restored within one reach or dispersed across reaches. We ran "single large" scenarios for estuary, mainstem, and lower, middle, and upper tributaries, as well as "severall small" scenarios for each habitat type, lumping mainstem and estuary together for one scenario since they both represented habitats shared by fish rearing in tributaries. In addition, we ran a habitat portfolio scenario that dispersed the same amount of restoration into all five habitat types.

We found estuary restoration resulted in the largest increase in both harvest (Fig. 34) and adult spawners (not shown), nearly double the benefit of the next best single large restoration of floodplains and mainstem. Multiple small restoration efforts generally had poorer benefits than single large restoration efforts within the same habitat type, although a habitat portfolio approach (restoration of all habitat types) resulted in the best "several small" restoration scenario, likely due to the addition of estuary habitat restoration. In general, restoring downstream habitats providing access to a greater proportion of the entire population appeared to have the most beneficial effects on future harvest opportunities and returning adults by extension.

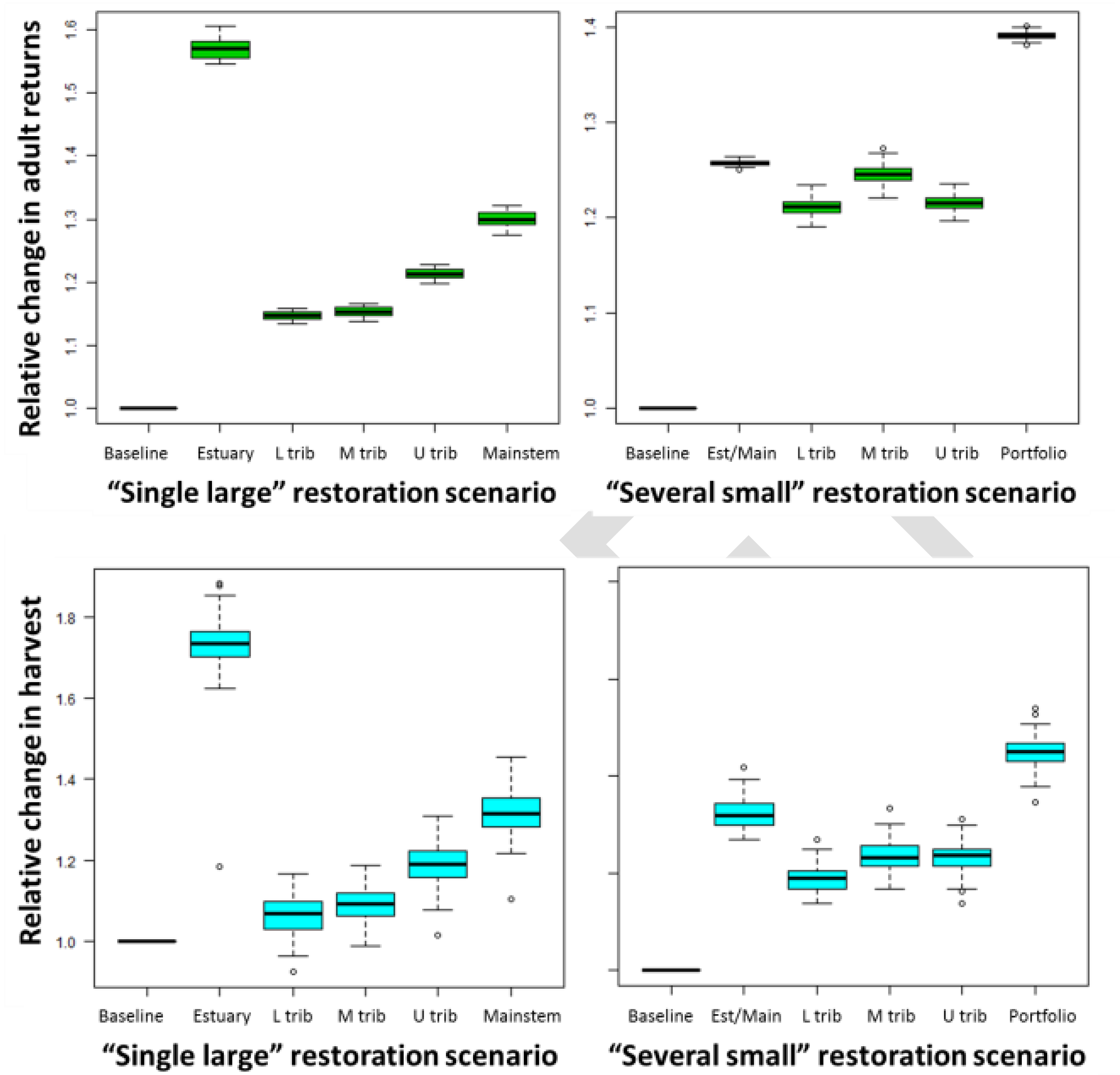


Figure 28. Relative change in adult returns (top panels) and harvest (bottom panels) under scenarios when single habitat types were restored ("single large", left panels) or the same amount of restoration was dispersed over multiple reaches "several small", right panels) within estuary and mainstem, different groups of tributaries, or in a portfolio that included all habitat types (including estuary). Note the different y-axis scales in the top panels; the scale is similar for the bottom panels.

4. RECOMMENDATIONS REGARDING FUTURE WORK

Our team recommends that future work build upon this two-phase pilot effort by improving analyses to allow for specific qualitative habitat conservation objectives to be developed for the existing groundfish focal species, before expanding efforts to additional species. Additionally, we recommend that ODFW and the NWFSC continue to collaborate on collecting and analyzing habitat data and adding to previous modeling efforts to use expanded quantitative analyses to inform the state and Federal efforts to conserve and recover OC coho. Specific recommendations are described below.

4.1 GROUNDFISH SPECIES

4.1.1 Phase 1 Recommendations and Outcomes

Smaller Spatial Scale

Future work should focus on smaller geographic areas subject to human-induced stressors where high numbers of EFH and ESA consultations and/or restoration actions occur (e.g., San Francisco Bay, Southern California, Puget Sound). By focusing on smaller-scale areas, higher resolution and more specific/appropriate data can be used, allowing us to better identify the contribution of stressors to overall risk at a workable geographic scale.

Stressor Information for Groundfish Stocks

One of the primary data gaps that would inform our analysis is habitat stressor information. Because of limited time and resources, in Phase 1, we used only that stressor information available in Halpern et al. (2009). The results of the analysis would be improved with updated information regarding the stressors included in Halpern's work, and with compilation of spatial data regarding stressors identified in the conceptual models but not included in Halpern's work. Our team identified the following data gaps and potential sources:

- Updated pesticide data
- Dredge footprint data - US Army Corps of Engineers
- Dredge disposal areas - NOAA charts
- Beach nourishment
- Location of submarine cables and pipelines - NOAA charts
- Trawling data - Groundfish EFH catalogue
- Intake structures - NPDES database
- Terrestrial vegetation removal - C-CAP data (look to Great Lakes and Chesapeake for methodology on zone of influence into aquatic areas)
- Coastal development - Environmental Sensitivity Index
- Updated ocean acidification data
- Updated UV data
- Updated SST data
- Updated invasive species data

Habitat Use Information for Groundfish Species

In addition to improved spatial stressor data, the habitat use data is based solely on the HSP scores from the groundfish EFH Environmental Impact Statement (EIS) (NMFS, 2005a), with species/habitat association for benthic substrate and depth and latitude from the NMFS' HUD.

While there have been some updates to this database since 2005, none of those updates have been translated into the spatial HSP data layers used in this project. In support of the current groundfish EFH 5-year review, the NWFSC and SWFSC, working in collaboration with Oregon State University and UC Santa Cruz, are updating the ecological knowledge base integral to the HUD, the Oracle front end of that database, and the groundfish EFH online data catalogue. It is anticipated that these undertakings will be completed by summer 2016. Moving forward, these updates will provide more robust habitat data, which as the backbone to much of the quantitative risk assessment will significantly increase the quality of the resultant risk scores.

Outcome

By incorporating some or all of the above updates we will provide risk scores in which we will have confidence to develop qualitative habitat objectives for use in NMFS habitat conservation efforts. In addition, future efforts should move towards including quantitative elements in the habitat conservation objectives to better inform habitat protection and restoration priorities. By incorporating some of the above recommendations we can have more confidence in the risk scores, and therefore further analyses would become appropriate. For example, sensitivity analyses of the groundfish risk assessments could examine the degree to which risk scores change as exposure values are decreased through habitat restoration, mitigation, and protection.

4.1.2 Phase 2 Recommendations and Outcomes

Phase 2 incorporated the main recommendations from Phase 1 - focus on smaller geographic areas and obtain area-specific datasets.

Stressor Information for Groundfish Stocks

The lack of habitat stressor information at the appropriate scale was identified as one of the primary data gaps during Phase 1. Phase 2 attempted to address this gap by focusing on smaller geographic areas, where finer-scale stressor data are available. Although data on some stressors were available at this smaller scale, there were a number of stressors with poor data quality or data gaps. The data that were available at these smaller scales allowed us to better identify the relative contribution of the individual stressors to overall risk in these areas. However, moving forward the increased and improved spatial data on these stressors will allow us to greatly improve these habitat prioritizations.

Habitat Use Information for Groundfish Species

In addition to improved spatial stressor data, habitat use was based on the HSP scores from the groundfish EFH Environmental Impact Statement (EIS) (NMFS, 2005a) in Southern California, while benthic habitat data from an extensive mapping effort led by The Nature Conservancy was used for the Puget Sound in conjunction with species/habitat association for benthic substrate and depth and latitude from the NMFS' HUD. While there have been some updates to this database since 2005, none of those updates have been translated into the spatial HSP data layers used in this project. The HUD and the HSP models are currently being updated as part of the ongoing groundfish EFH revision process. It is anticipated that these undertakings will be completed in the near future. Moving forward, these updates will provide more robust habitat data, which as the backbone to much of the quantitative risk assessment will significantly increase the quality of the resultant risk scores.

Future work

The available data on habitat use by the focal species, at the scales analyzed in this pilot project, are qualitative only and are limited to the distribution (presence/absence) of the species over the various habitat types. This is classified in the EFH regulatory guidance (50 CFR 600.815(a)(iii)) as Level 1 data. Using such data, the team was able to develop qualitative habitat objectives based on the relative risk posed by a range of stressors, but was unable to develop quantitative habitat objectives. Quantitative habitat objectives, for example the number of acres of eelgrass necessary for a sustainable black rockfish fishery, require quantitative data, such as habitat-related densities (Level 2), growth, reproduction, or survival rates (Level 3), and habitat-specific production rates (Level 4). Unfortunately, while Level 2 data are available in some areas, data at the higher levels are unavailable for any species managed under the groundfish FMP. Until such data becomes available, we are limited to qualitative habitat objectives only.

Future work should concentrate on obtaining higher level, quantitative data, which would allow the development of quantitative objectives. Higher level data would also allow the PFMC and NMFS to refine the identification and description of EFH for groundfishes, which are now based solely on Level 1 data and very broadly identified and described.

4.2 OC COHO

4.2.1 Phase 1 Recommendations and Outcomes

Future work should build upon previous conservation and recovery efforts for OC coho, using risk assessment and life stages analyses as described in this paper to identify and prioritize habitat conservation actions to contribute to recovery. Protection of ecosystem functions and salmon habitat that are in good condition will be critical to long-term conservation of OC coho. This includes management of agricultural, forest, floodplain, and estuarine areas.

In order to ensure cost-effective restoration of degraded habitat, it will be important to fill significant data gaps, including non-wadeable streams, wetlands, and estuaries and conduct state-of-the art quantitative analyses linking habitat with OC coho response. These are key steps to articulating, from the fish and ecosystem perspectives, the best opportunities to deliver protective and restorative efforts for OC coho. However, as numerous previous recovery efforts have shown, understanding the best available science related to salmon is necessary, but not the only step – obtaining funding and local support and cooperation are required if the scientific recommendations are to be successfully implemented.

4.2.2 Phase 2 Recommendations and Outcomes

The dynamic life cycle model examined some of these questions for a single independent spawning population. Using the model, we were able to examine come of the current habitat objectives driving restoration priorities in the Oregon Coast, as defined by the OCCCP (Table 6). First, it appears that the overall objective of a 6-fold increase in high-quality tributary habitat is insufficient to restore coho salmon populations to the levels of proposed adult spawners. It should be noted that the analysis we ran, focused on habitat capacity, is not exactly the same as an increase in high-quality habitat (which might increase survival as well as capacity). Nevertheless, it appears that a much more substantial increase is needed to meet the spawner return goals. Secondly, the current approach of small, distributed restoration in tributaries appears to offer fewer benefits than the same approach in lower portions of the river or single larger restoration projects in the mainstem and estuary. It should be stressed that a unanalyzed benefit of dispersed restoration is spatial diversification, which could allow populations to respond to large-scale impacts. Regardless, the "random acts of kindess" approach to restoration funding should be revisited, possibly following the concept of habitat portfolios with restoration in all habitats.

Finally, the model predicts that reaches shared by migrants from multiple spawning reaches are likely to be of the highest value for restoration. These reaches include mainstem, floodplain, and estuary habitats. Unfortunately, ODFW's monitoring strategy does not currently include assessment of these habitats, so it will be difficult to apply this model's predictions to other river systems without significant additional habitat monitoring. Our model thereby highlights important gaps in habitat status and trends.

5. APPENDICES

Appendix A. Literature Cited
Appendix B. Conceptual Models
Appendix C. Vulnerability Data
Appendix D, Sensitivity Criteria
Appendix E. Regulatory Authority
Appendix F. Phase 1 Risk Analysis Tables
Appendix G. Phase 2 Risk Analysis Tables
Appendix H. Phase 2 Data Source Details
Appendix I. Phase 2 Stressor Data References
Appendix J. Phase 2 Risk Prioritization Plots

Appendix A. Literature Cited

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Appendix B. Conceptual Models

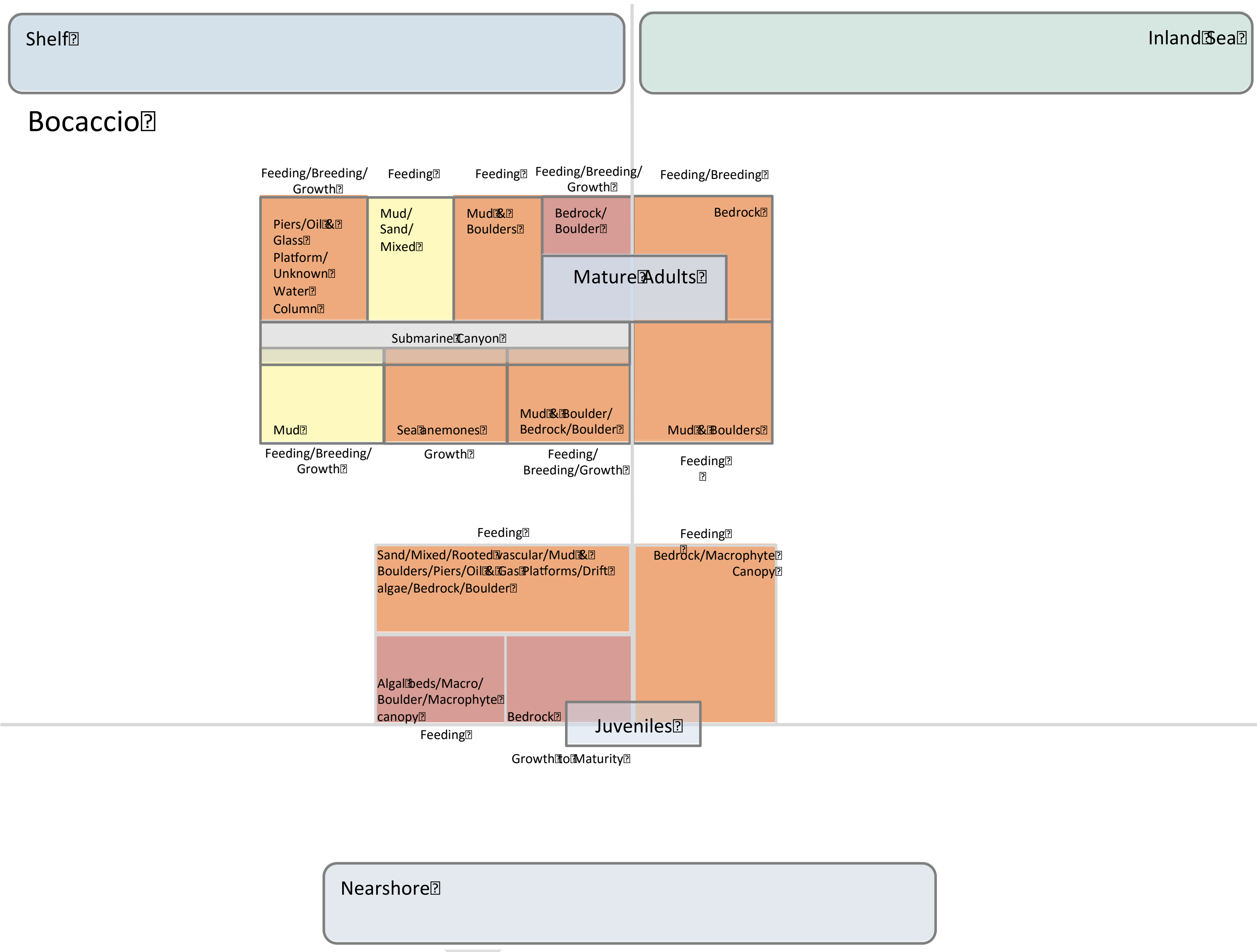


Figure 1. Bocaccio life cycle – habitat use model, life stage boxes overlap with habitat boxes indicates habitat use by that life stage Habitat box color indicates habitat suitability (yellow = low, orange = moderate, red = high). Information on activities within certain habitats is from Pacific Coast Groundfish EFH FEIS.

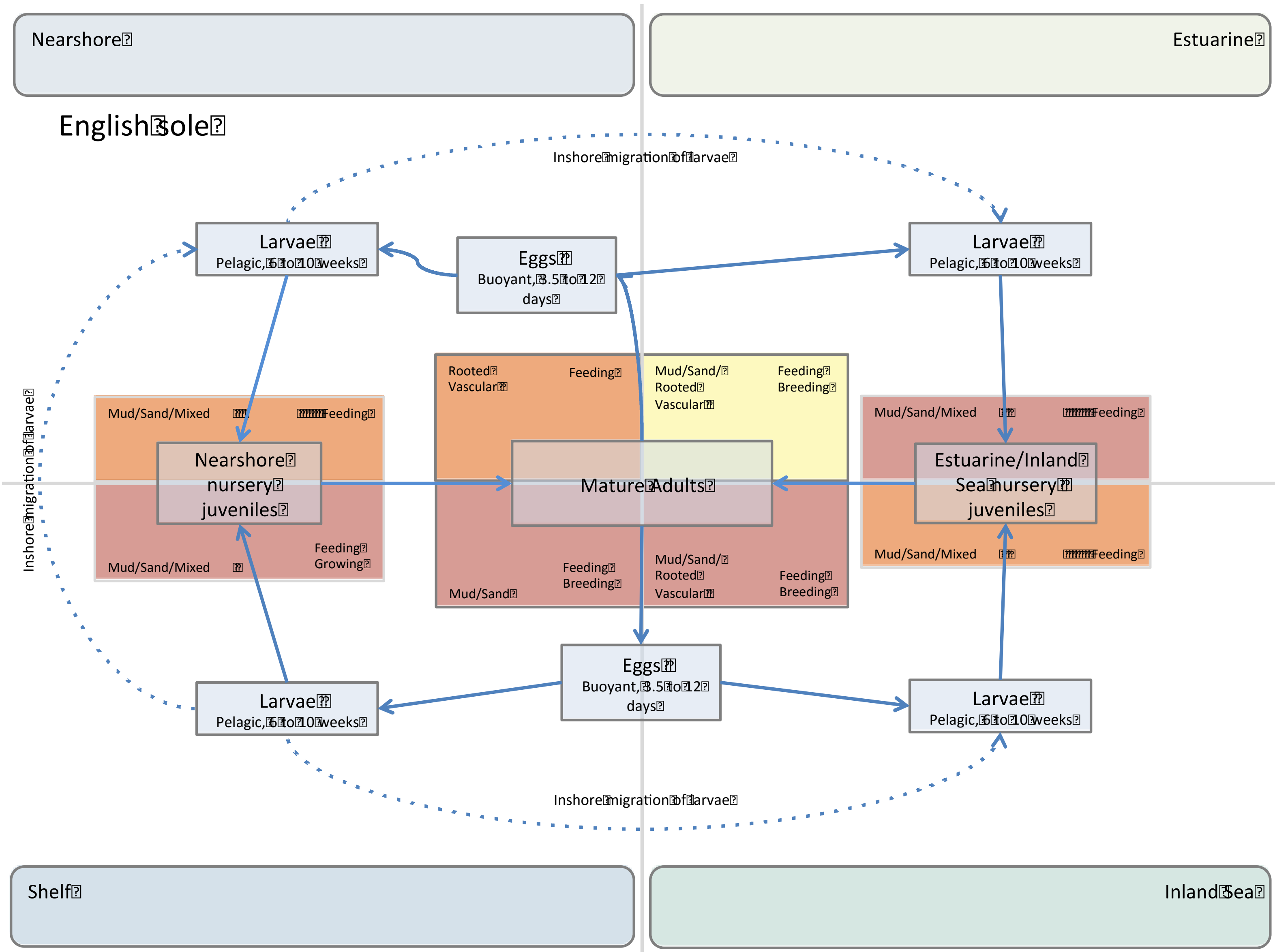


Figure 2. English sole life cycle – habitat use model, life stage boxes overlap with habitat boxes indicates habitat use by that life stage. Solid lines with arrows indicate maturation, while dotted lines indicate migration. Habitat box color indicates habitat suitability (yellow = low, orange = moderate, red = high). Information on activities within certain habitats is from Pacific Coast Groundfish EFH FEIS.

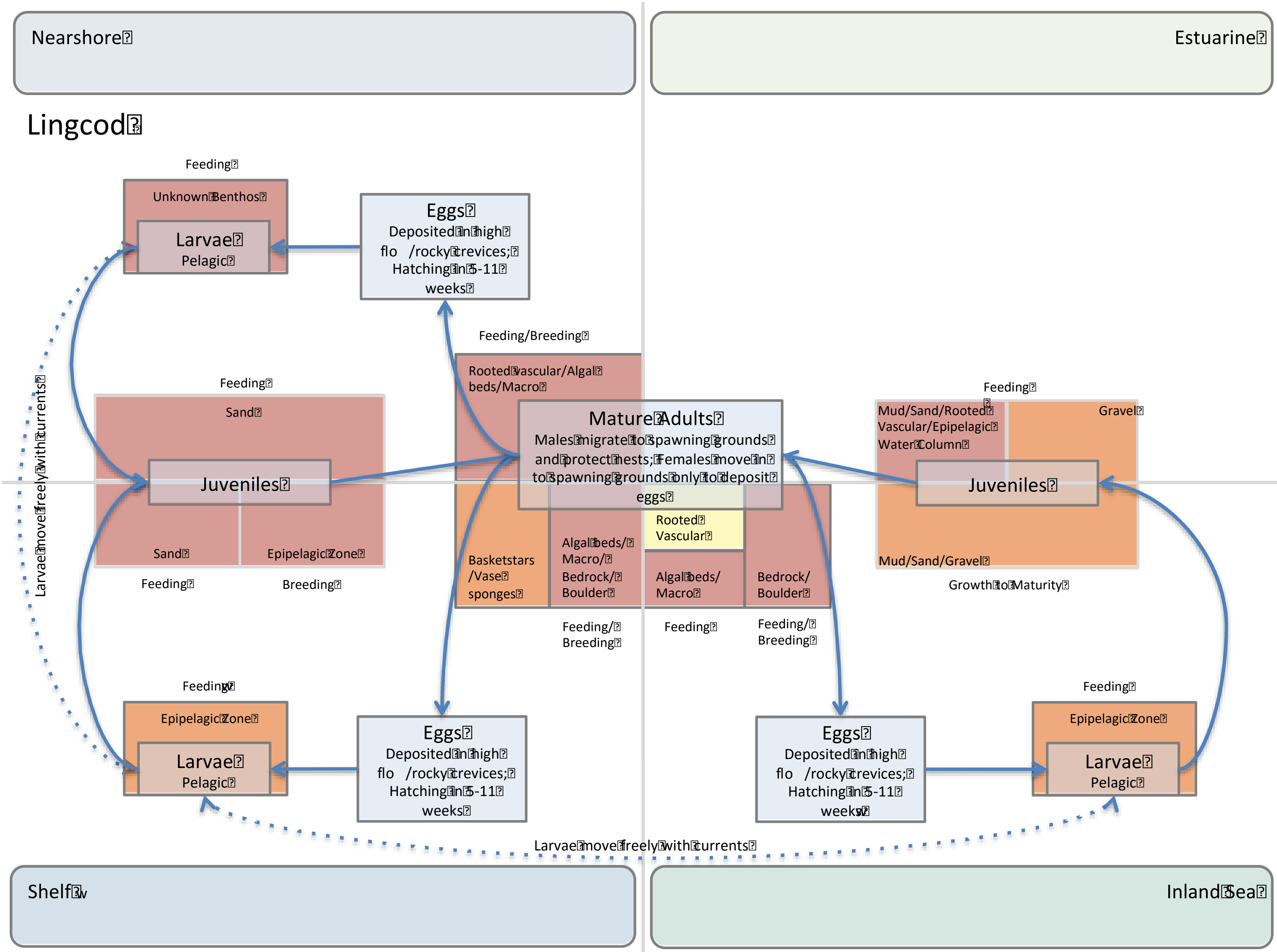


Figure 3. Lingcod life cycle – habitat use model, life stage boxes overlap with habitat boxes indicates habitat use by that life stage. Solid lines with arrows indicate maturation, while dotted lines indicate migration. Habitat box color indicates habitat suitability (yellow = low, orange = moderate, red = high). Information on activities within certain habitats is from Pacific Coast Groundfish EFH FEIS.

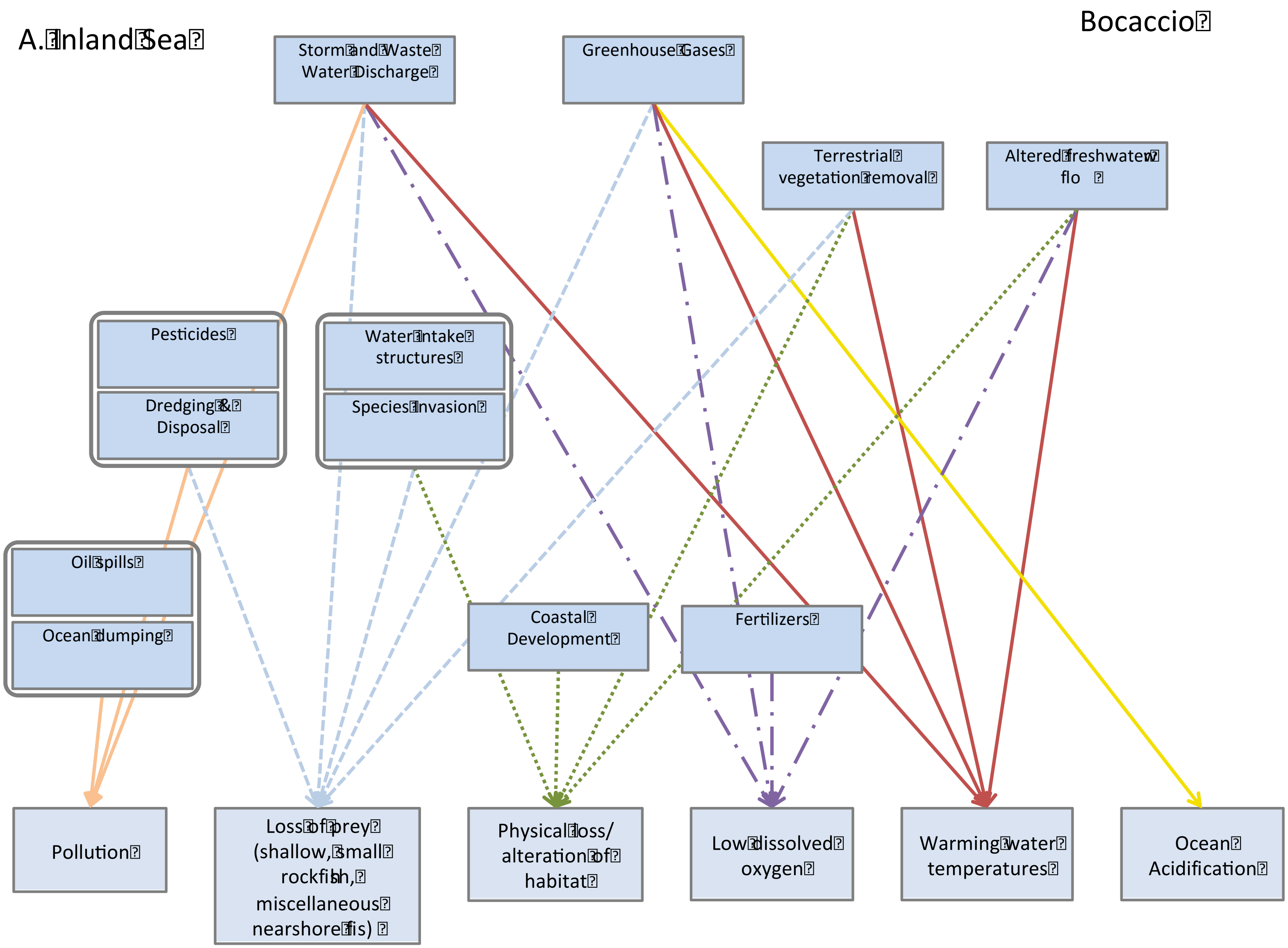
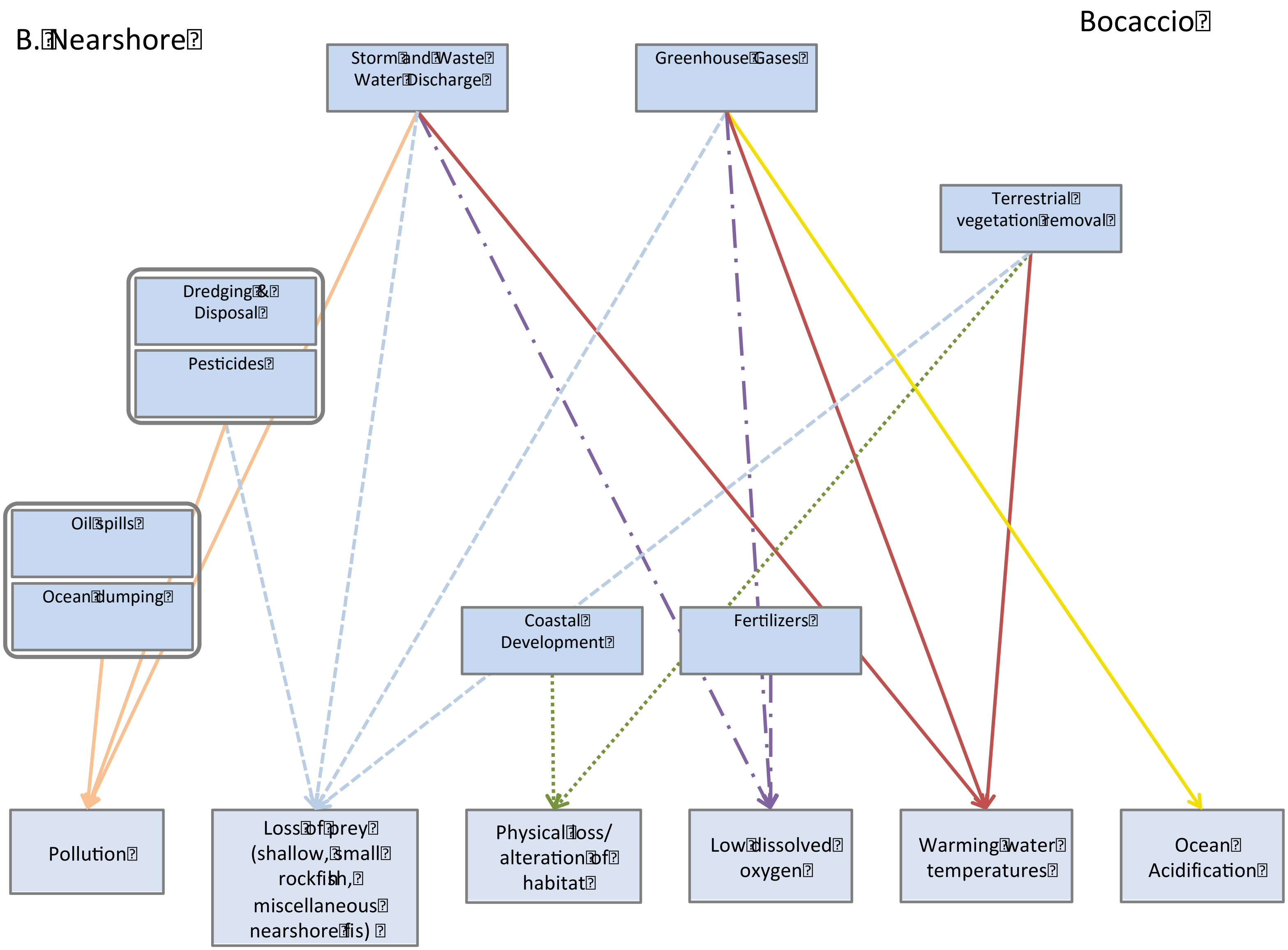


Figure 4. Conceptual model of the relationship between stressors on bocaccio rockfish in broad habitat zones. (A. Inland Seas, B. Nearshore, C. Shelf). Lines color and formatting representative of different stressors.



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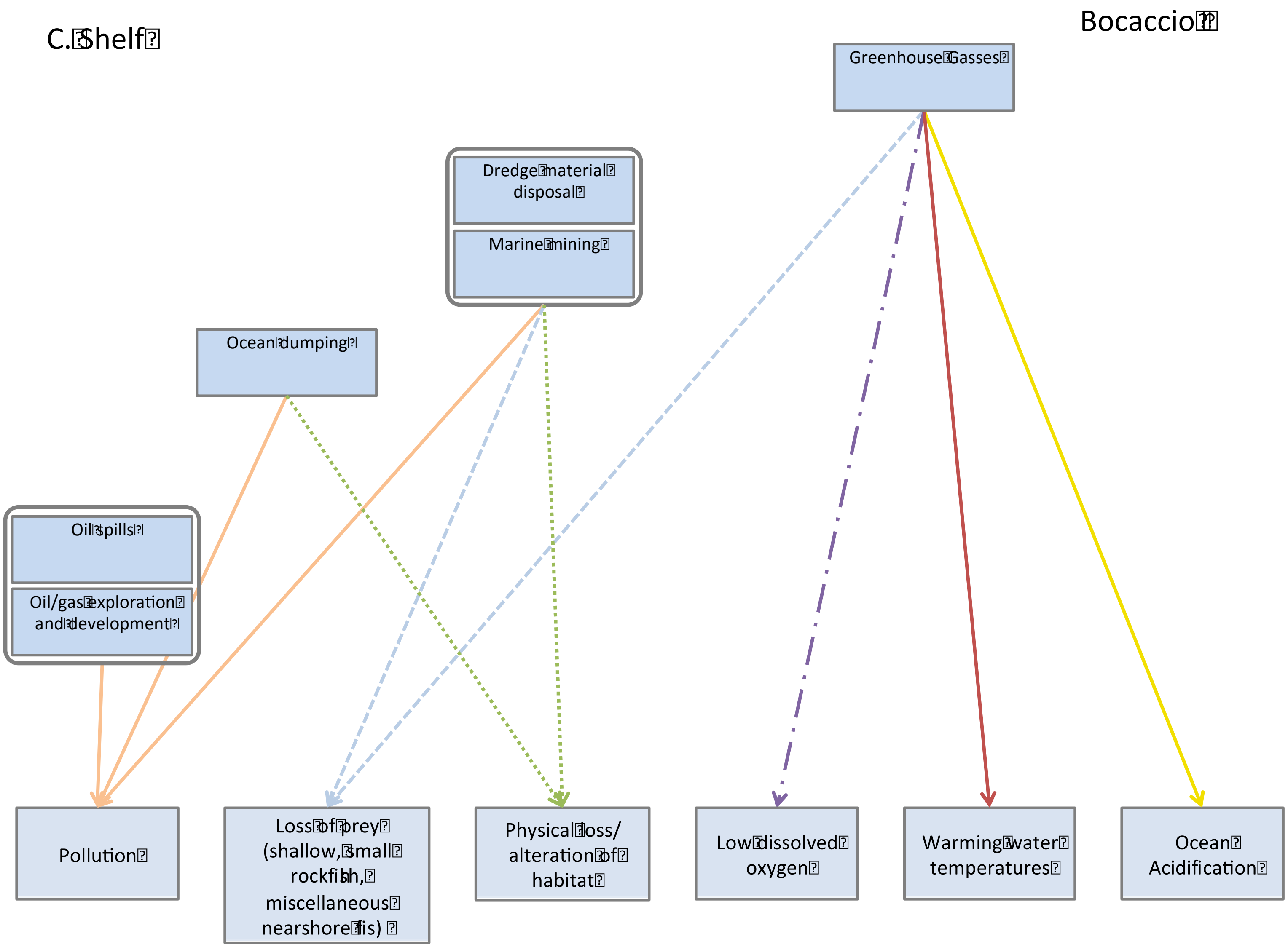

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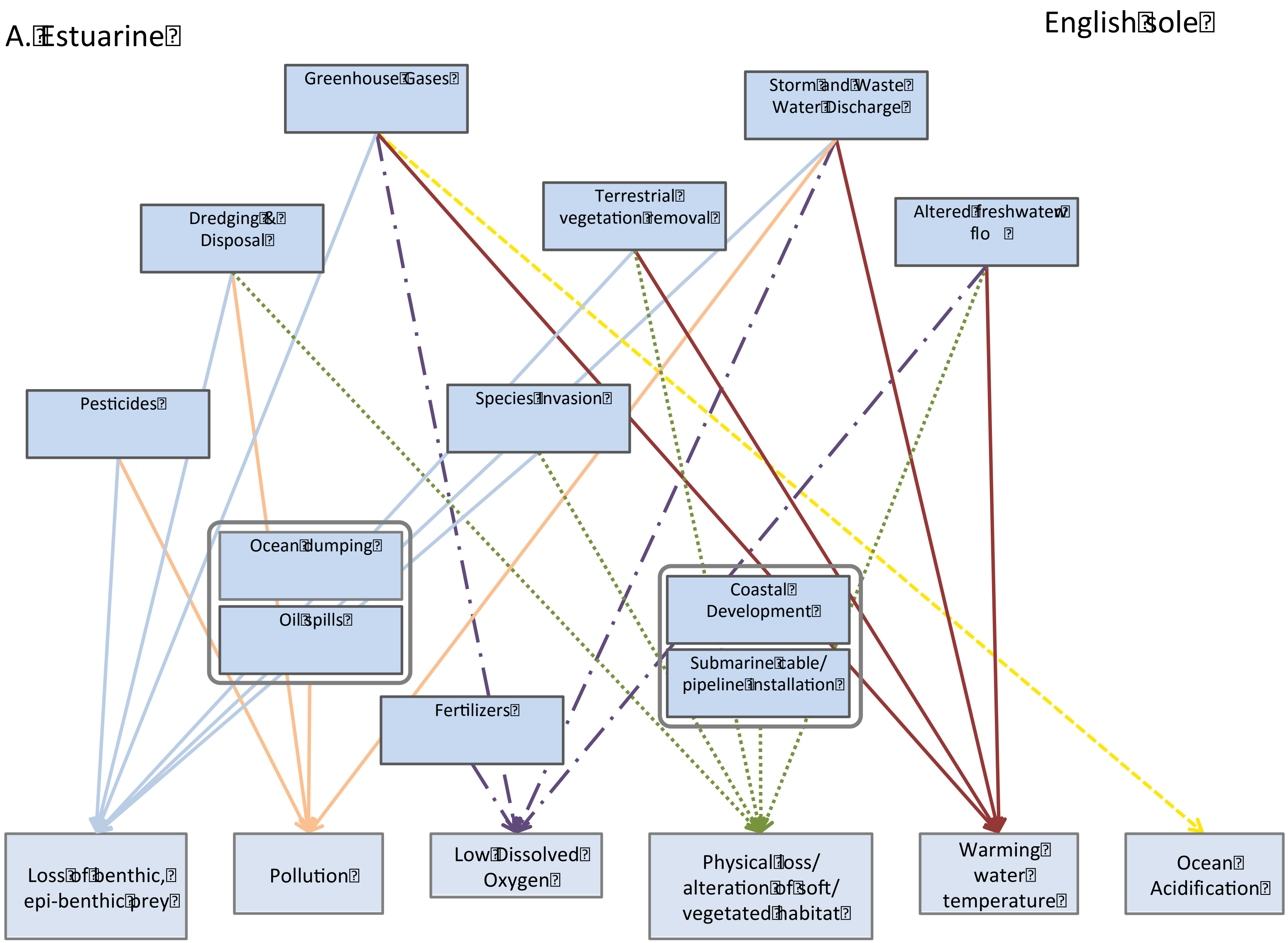
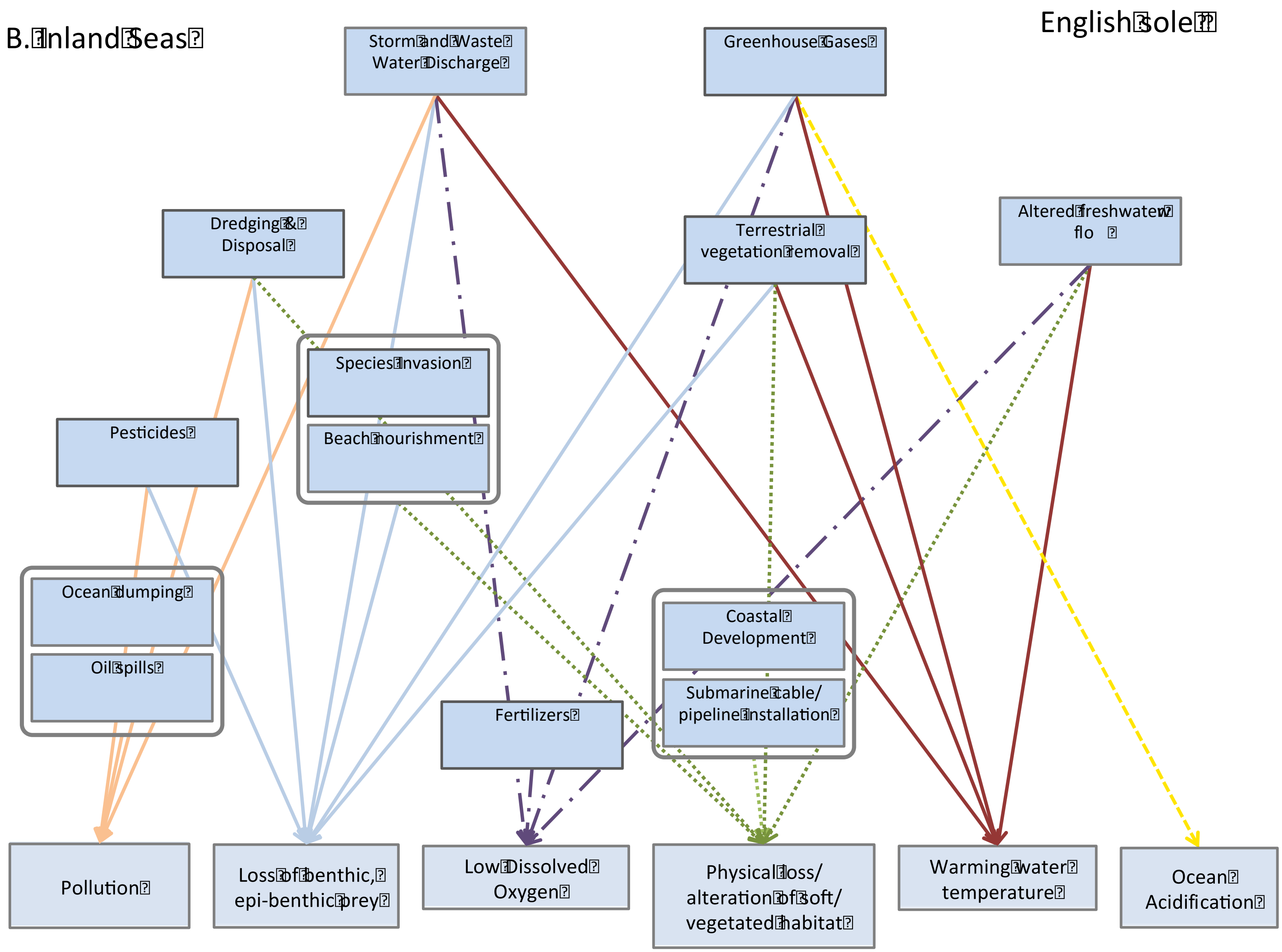


Figure 5. Conceptual model of the relationship between stressors on English sole in broad habitat zones. (A. Estuary, B. Inland Seas, C. Nearshore, D. Shelf). Lines color and formatting representative of different stressors.



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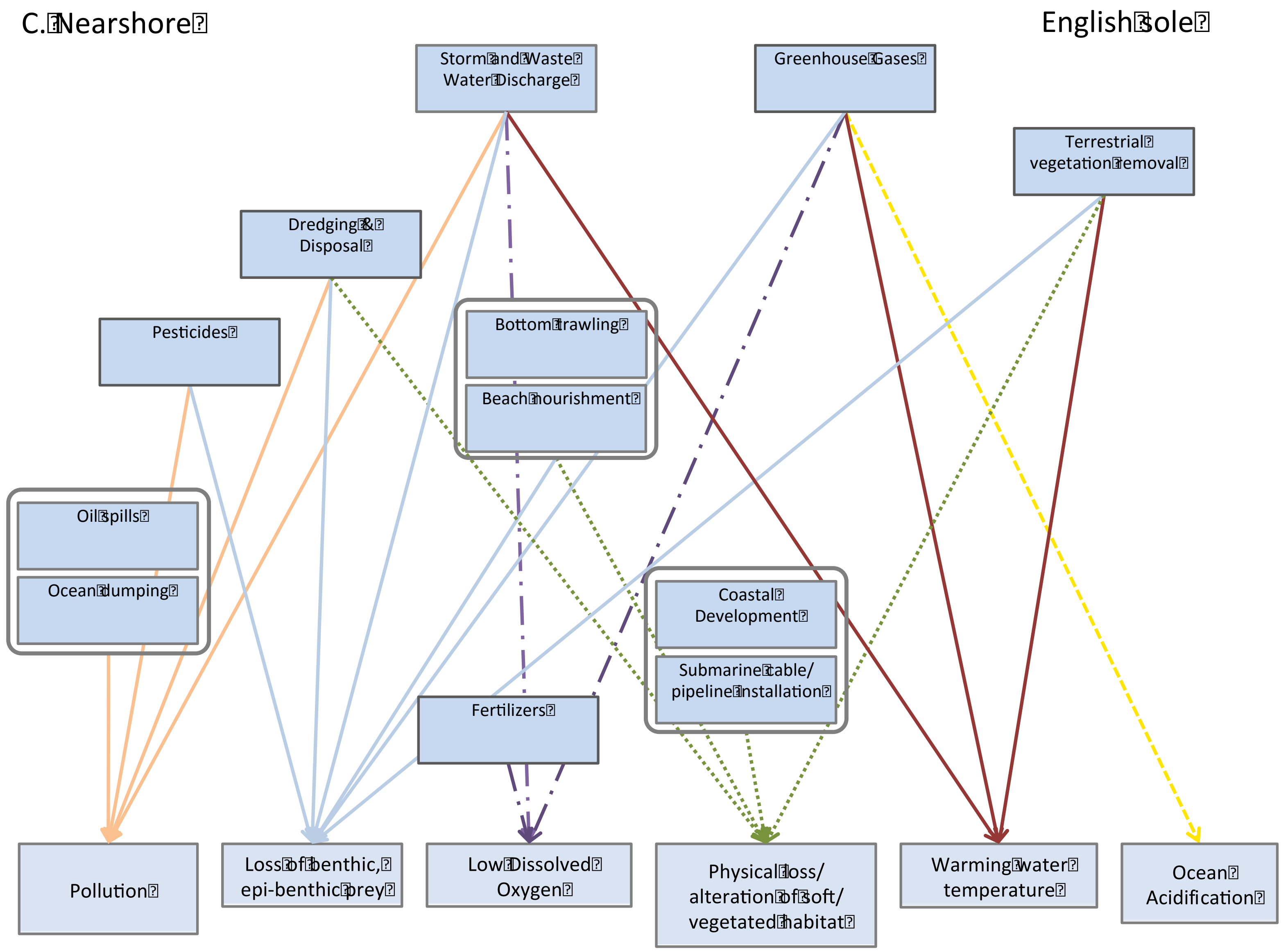

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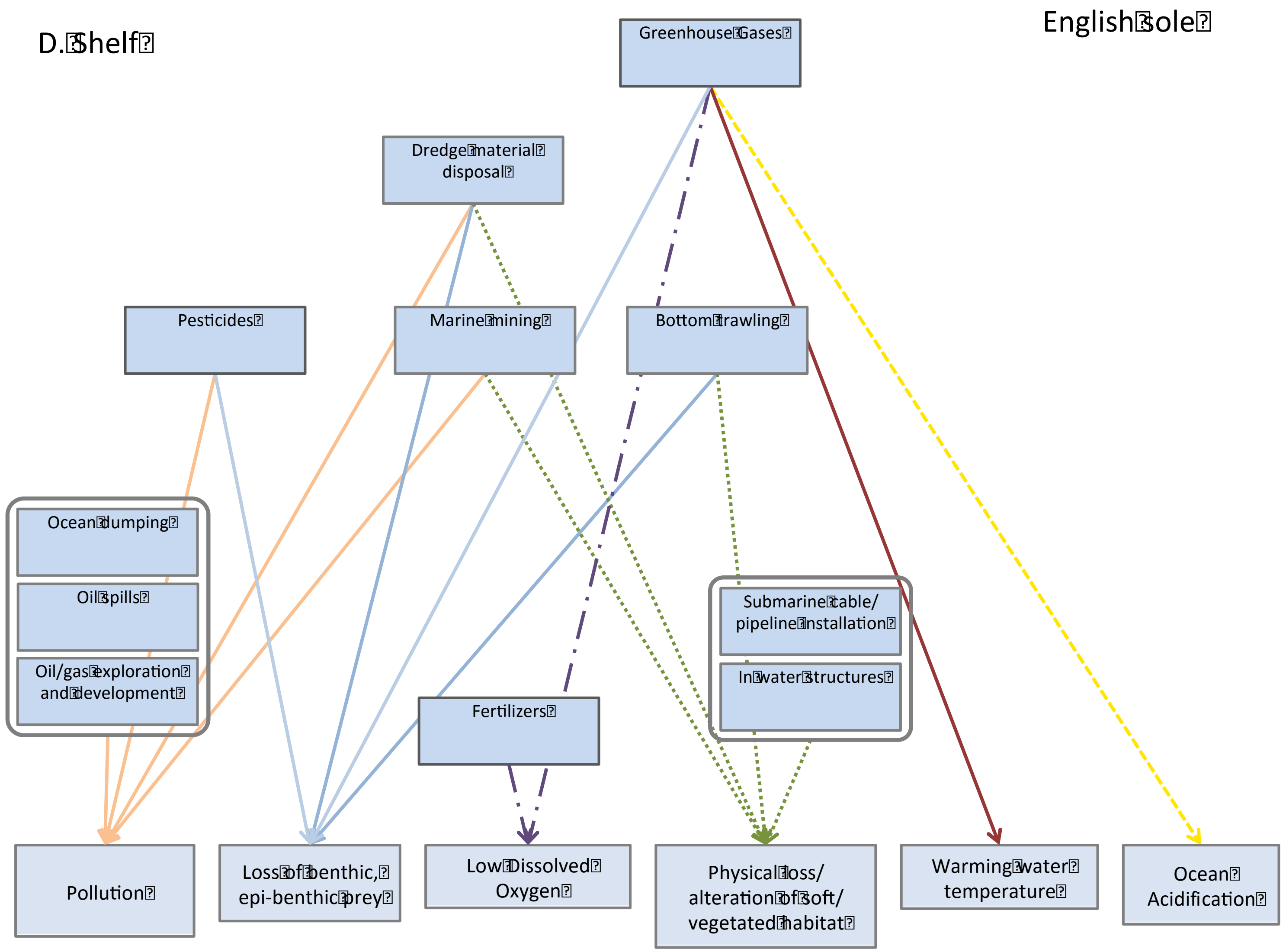

Figure 5. Conceptual model of the relationship between stressors on English sole in broad habitat zones. (A. Estuary, B. Inland Seas, C. Nearshore, D. Shelf). Lines color and formatting representative of different stressors.

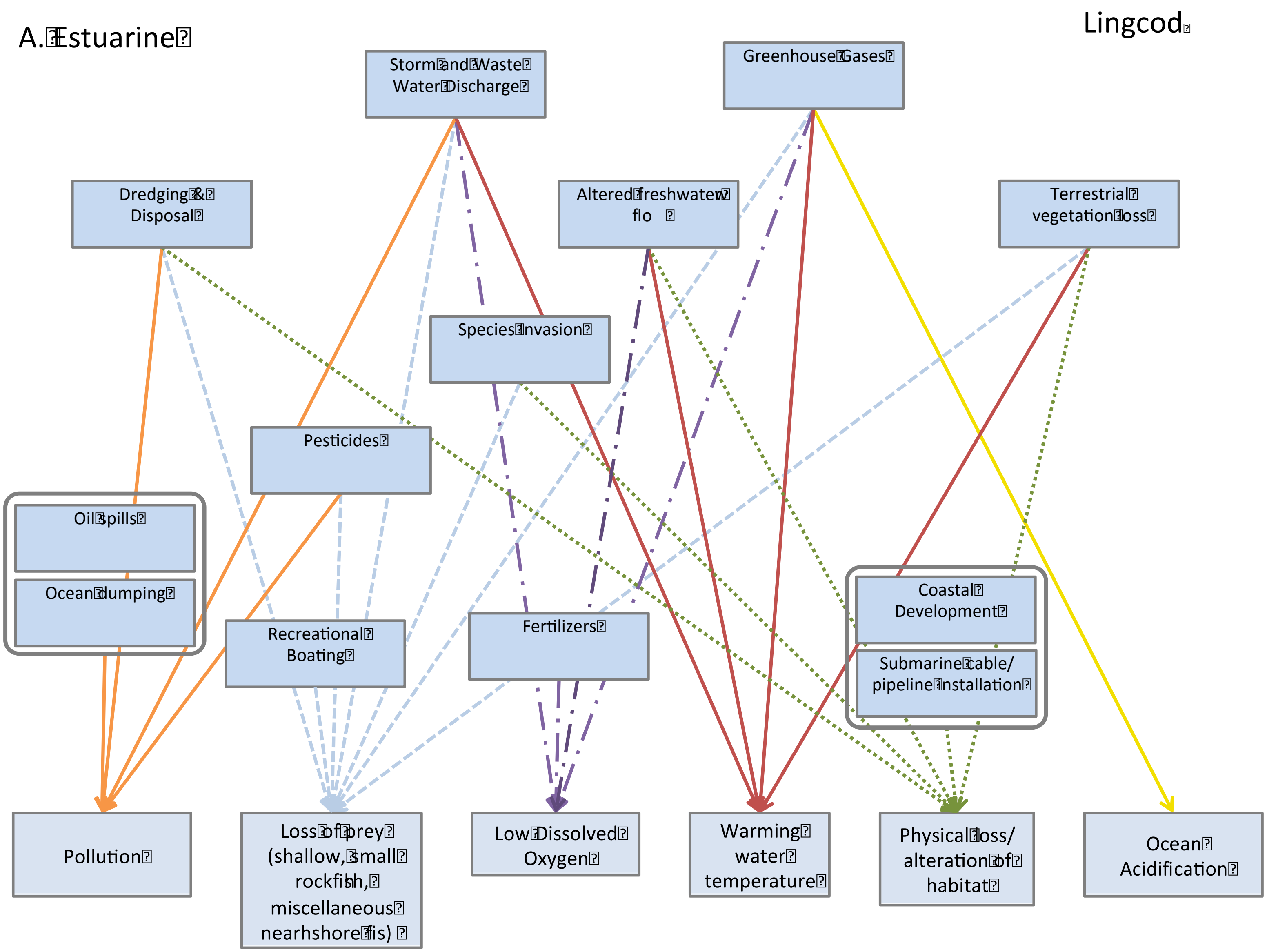

Figure 6. Conceptual model of the relationship between stressors on lingcod in broad habitat zones. (A. Estuary, B. Inland Seas, C. Nearshore, D. Shelf). Lines color and formatting representative of different stressors.

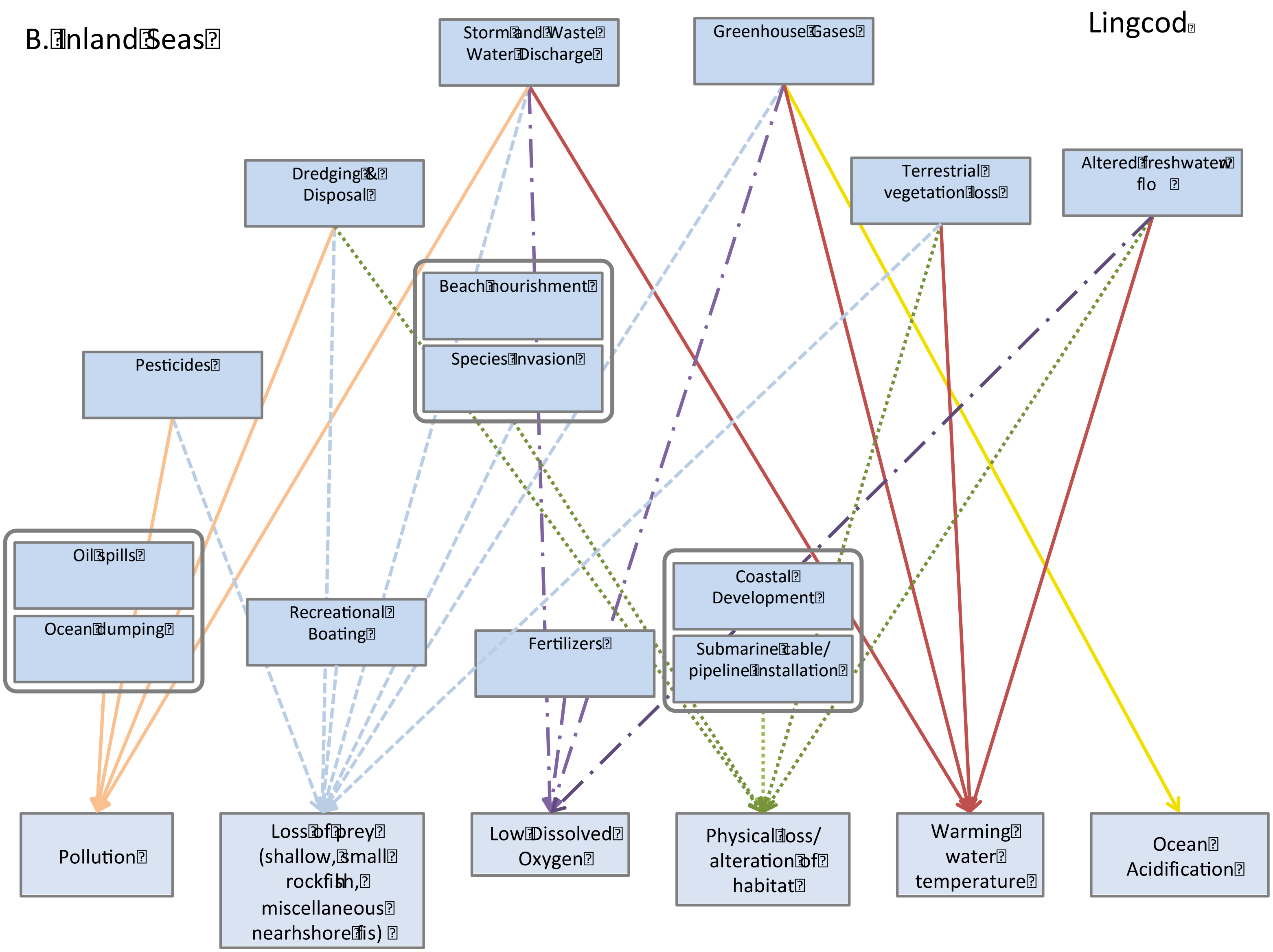

Figure 6. Conceptual model of the relationship between stressors on lingcod in broad habitat zones. (A. Estuary, B. Inland Seas, C. Nearshore, D. Shelf). Lines color and formatting representative of different stressors.

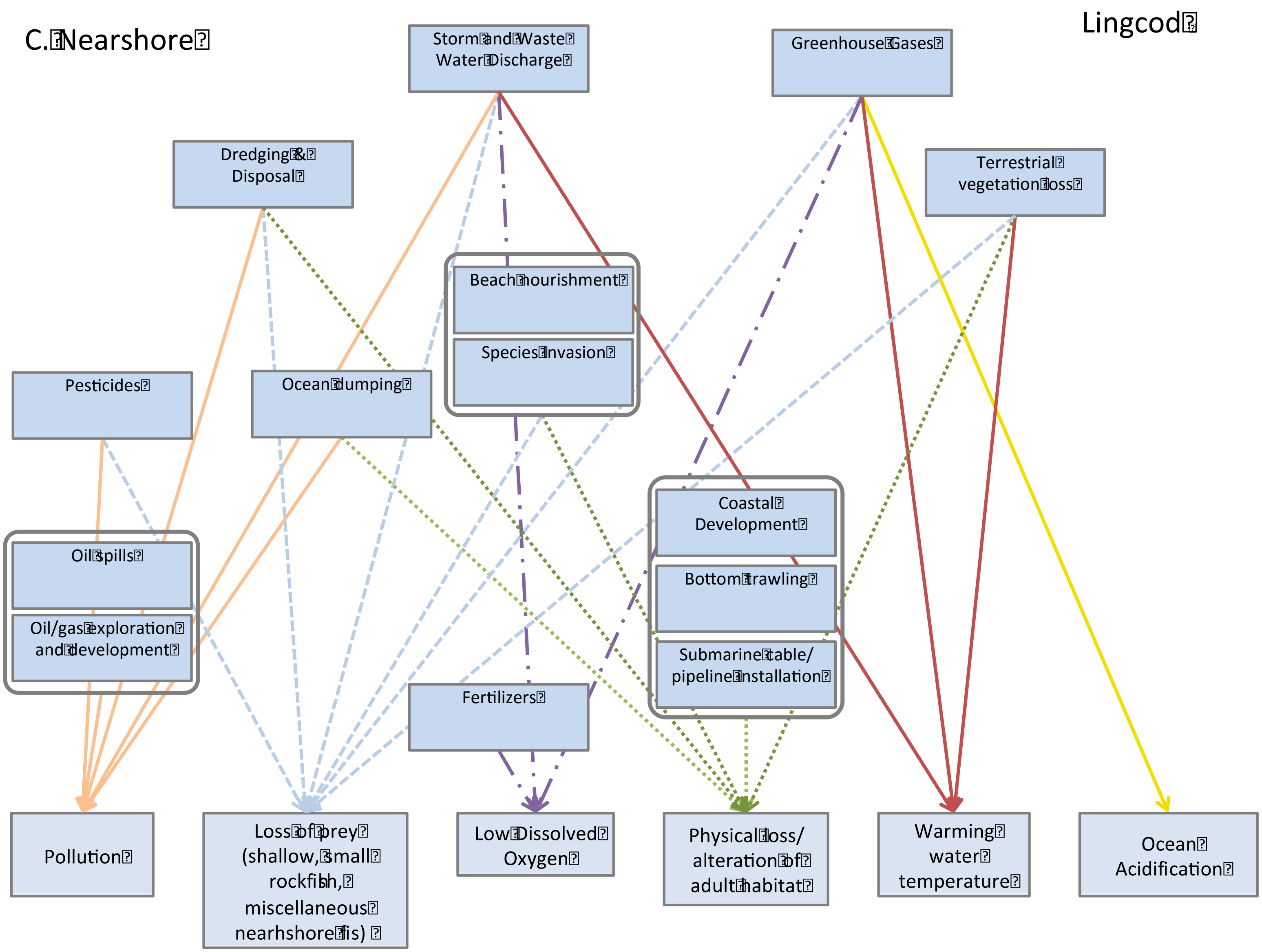

Figure 6. Conceptual model of the relationship between stressors on lingcod in broad habitat zones. (A. Estuary, B. Inland Seas, C. Nearshore, D. Shelf). Lines color and formatting representative of different stressors.

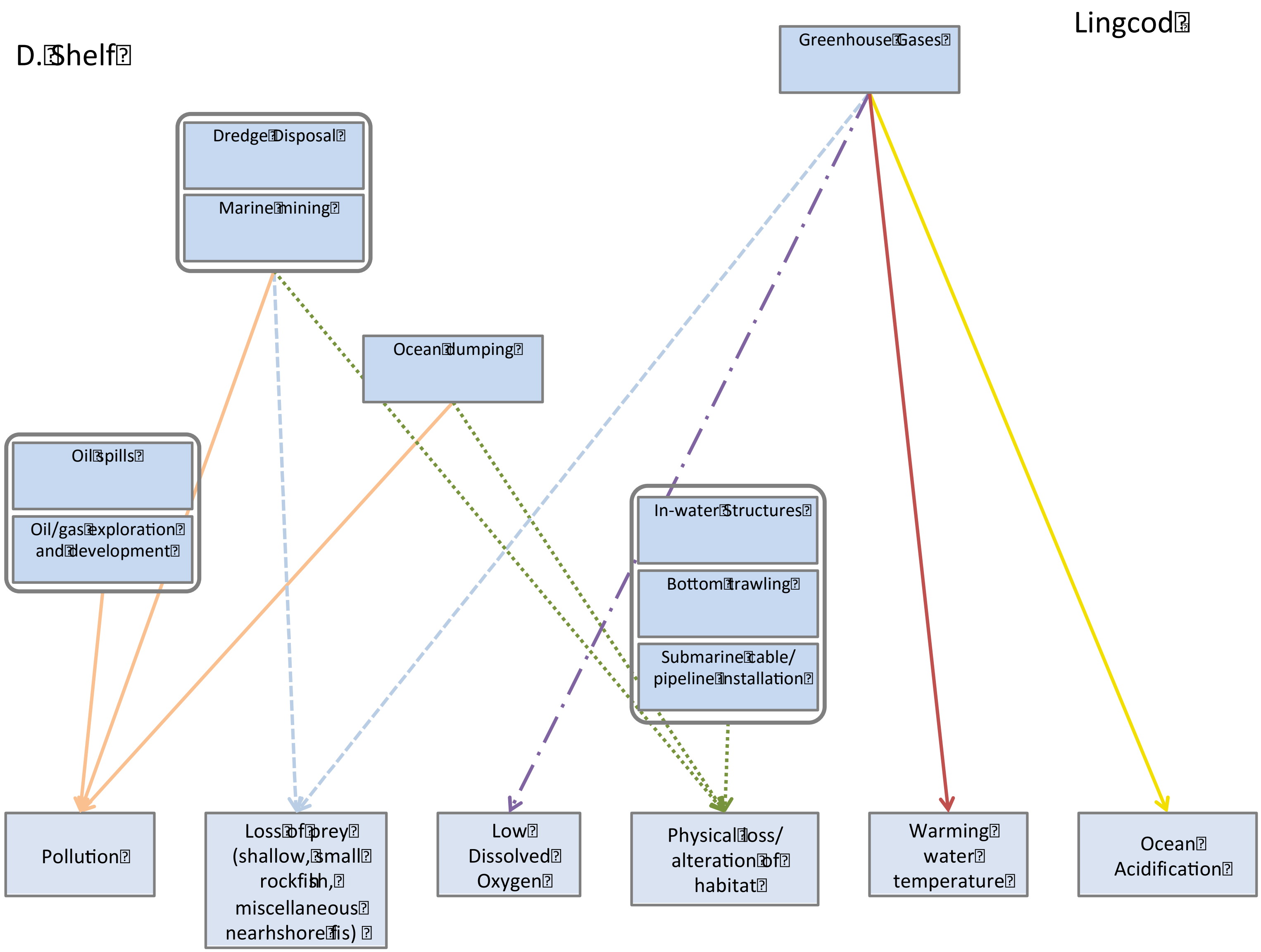

Figure 6. Conceptual model of the relationship between stressors on lingcod in broad habitat zones. (A. Estuary, B. Inland Seas, C. Nearshore, D. Shelf). Lines color and formatting representative of different stressors.

Appendix C. Vulnerability Data

Vulnerability data adapted* from Teck et al. 2010.

Habitat Vulnerability	Aquaculture	Coastal Engineering	Coastal Waste	Inorganic pollution	Invasive species	Nutrient input	Ocean Acidification	Atmospheric Deposition	Ocean-based Pollution
Canyons	0	0	0.8	1.3	0	0.575	2.6	1.3	0.9
Deep waters	0	0	0.8	1.3	0	1.7	2.7	0.9	0
Hard deep	0	0	0	0	0	0	3.4	0	0
Hard shelf	0.175	0	0.4	1.1	1.5	1.425	2.7	1.2	1
Hard slope	0	0	0.9	0	0	0.575	2.3	0.7	1.3
Kelp Forest	0.15	1.3	0.7	1.3	2.4	1.05	2	1	0.9
Mud flats	0.45	2.05	1.2	1.3	3	1.375	2.4	1.3	1.3
Rocky intertidal	0.5	1.6	1.1	1.2	2.6	0.95	3.1	1.1	1.3
Rocky Reef	0.375	0.9	1.2	1.5	1.8	1.1	2.2	1.1	1
Salt marsh	0.325	2.6	1.1	1.4	2	1.3	2.4	1.4	1.1
Seagrass	0.575	1.35	0.9	0.9	1.7	0.95	2.1	1	0.9
Seamounts	0	0	0	0	0	0	2.6	0	0
Shallow soft	0.125	0.6	1	0.8	1.3	0.375	1.2	0	0.4
Soft deep	0	0	1.9	1.9	1.1	0	2.5	0	0
Soft shelf	0.275	0.2	0.9	1.6	0.7	1.1	2.6	1.1	0.8
Soft slope	0.125	0	1.2	2	0	0	3.4	0	0
Surface waters	0.35	0.1	1.1	1.6	0.3	1.45	3.2	1.6	1.4
Suspension-feeding reefs	0.375	2.4	1	1.4	2.1	2.175	2.5	1.3	0

Habitat Vulnerability	Offshore oil activities	Organic pollution	Power Plants	Sediment Decrease	Sediment Increase	Shipping Activities	SST	UV
Canyons	2.3	1.2	0	0	1.4	0	1.7	0
Deep waters	0	1.3	0.2	0	0	0	1.9	0.8
Hard deep	0	0	0	0	0	0	0	0
Hard shelf	2.4	1.3	0	0	0	0	1.9	0
Hard slope	2.3	0	0	0	1	0	1.2	0
Kelp Forest	1.6	1.3	0.8	0.1	1.4	0	2.9	1.6
Mud flats	2.4	1.9	1.3	2.3	1.4	0.4	1.8	1.7
Rocky intertidal	0.9	1.3	1.5	0.8	1.5	0.2	2.7	2.3
Rocky Reef	1.7	1.5	1.1	0	1.1	0.3	2.2	1.7
Salt marsh	1.8	1.4	1.2	2.4	1.4	0	1.8	1.9
Seagrass	1.6	1.1	0.5	0.8	1.3	0.3	1.9	1.5
Seamounts	0	0	0	0	0	0	0	0
Shallow soft	1.4	1.4	0.5	0.6	0.8	0	0	0
Soft deep	0.4	2.5	0	0.4	1.2	0	0.5	0
Soft shelf	2.2	1.5	0.2	0.3	0	0.3	1.7	0
Soft slope	1.4	2	0	0	0	0	0.6	0
Surface waters	0.4	1.5	1.5	0	0.2	1.5	2.5	2.5
Suspension-feeding reefs	2	1.5	0	1.6	1.4	0	2.2	1.8

*The following adaptations were made to fit Halpern et al. 2009 habitat and stressor data used in risk assessment: Merged habitat types “Hard 0-60m” and “Hard 60-200m” into “Hard shelf.” Used the “Soft 60-200m” as “Soft shelf,” while “Soft 0-60m” was used as “Shallow soft.” Used a mean value for vulnerabilities for Aquaculture, Coastal Engineering, Nutrient Input, Ocean Dumping. Used

“Pollution Input: Atmospheric” as an analogue for “Atmospheric Deposition,” “Climate change: Sea Surface Temperature Change” for “SST,” “Pollution Input: Trash, Urban Runoff” for “Coastal Waste,” “Benthic Structures (eg., oil rigs)” for “Offshore Oil”.

Appendix D. Sensitivity Criteria

Sensitivity Criteria from Andrews et al. 2011

Criteria	Explanation of criteria	Sensitivity score		
Resistance factors		*Low (1)*	*Moderate (2)*	*High (3)*
1. Mortality	Direct effect of the threat on population-wide average mortality rate of a species	Negligible	Sub-lethal	Lethal
2a. Behavior	Population-wide effect of threat on behavior of a species	Response reduces sensitivity	Response does not change sensitivity	Response increases sensitivity
2b. Physiology	Population-wide effect of threat on physiology of a species	Response reduces sensitivity	Response does not change sensitivity	Response increases sensitivity
Recovery factors		*Low (1)*	*Moderate (2)*	*High (3)*
3. Current status	Status of the species based on management targets	$X > B_{40}$	$B_{40} > X > B_{25}$	$X < B_{25}$
4a. Fecundity	The population-wide average number of offspring produced by a female each year	$> 10^3$	$> 10^2 - 10^3$	$< 10^2$
4b. Age at maturity	Population-wide average age at maturity	< 2 years	2 – 4 years	> 4 years
4c. Reproductive strategy	The extent to which a species protects and nourishes its offspring	External fertilization and no parental care	Internal fertilization or parental care but not both	Internal fertilization and parental care
4d. Population connectivity	Realized exchange with other populations based	Regular movement/exchange	Occasional movement/exchange	Negligible movement/exchange

	on spatial patchiness of distribution, degree of isolation, and potential dispersal capability	within the California Current	within the California Current	within the California Current

Appendix E. Regulatory Authorities

Magnuson-Stevens Fishery Conservation and Management Act. In 1996, Congress amended the Magnuson-Stevens Fishery Conservation and Management Act (MSA) to recognize the importance of habitat to the viability of commercial and recreational fisheries. MSA defined EFH as a national program for conservation and management of U.S. fishery resources, and pledged to facilitate the long-term protection of EFH. EFH includes all habitats necessary for federally managed species to complete their life cycles. NMFS works with the eight regional fishery management councils (FMCs) to identify and describe EFH for federally managed species under their jurisdiction using the best available scientific information. EFH includes all types of aquatic habitat—wetlands, coral reefs, seagrasses, rivers, and more, and has been described for approximately 1,000 managed species to date.

Under the MSA, FMCs are required to include conservation and management measures in their fishery management plans (FMPs) to prevent overfishing and rebuild overfished stocks, and to protect, restore, and promote the long-term health and stability of the fishery (Magnuson-Stevens Fishery Conservation and Management Reauthorization Act of 2006). In addition, FMCs may comment and make recommendations concerning federal actions that may affect managed species habitat, and must comment and make recommendations concerning federal actions that substantially affect the habitat of anadromous managed species (e.g., Pacific salmon). Pursuant to Section 305(b) of the MSA, federal agencies must consult with NMFS regarding any actions authorized, funded, or undertaken, or proposed to be authorized, funded or undertaken that may adversely affect EFH. Federal agencies must provide NMFS with a written assessment of the effects of that action on EFH. NMFS will provide the federal agency with EFH Conservation Recommendations regarding measures that can be taken by that agency to conserve EFH, if it is determined that the proposed action will adversely affect EFH. EFH Conservation Recommendations may include actions to avoid, reduce, or compensate for the impacts of federal actions on EFH.

Endangered Species Act. In 1973, Congress passed the Endangered Species Act (ESA) to conserve threatened and endangered species and their ecosystems. The listing of a species as endangered makes it illegal to "take" (harass, harm, pursue, hunt, shoot, wound, kill, trap, capture, collect, or attempt to do these things) that species (Endangered Species Act 1973, §3(19)). Similar prohibitions usually extend to threatened species.

Pursuant to section 4(f) of the ESA, recovery plans are developed and implemented for the conservation and survival of endangered and threatened species (Endangered Species Act 1973, §4(f)). Recovery plans identify actions needed to restore threatened and endangered species to the point that they no longer need the protection of the Act. They serve as a guide for species recovery by providing strategies and recommendations towards recovery, and they can help prioritize limited resources.

Federal agencies may be allowed limited take of species through interagency consultations with NMFS or USFWS. Effects to the listed species must be minimized and in some cases conservation efforts are required to offset the take. Pursuant to section 7 of the ESA, federal agencies must consult on all activities or programs of any kind authorized, funded, or carried out, in whole or part, that may jeopardize the continued existence of any species listed under the ESA, or destroy or adversely modify designated critical habitat of any listed species (Endangered Species Act 1973, §7(2)). Should an action be determined by NMFS to jeopardize a species or adversely modify critical habitat, NMFS will provide Reasonable and Prudent Alternatives (RPAs) to the federal agency. Incidental take statements provided as part of non-jeopardy section 7 consultations include terms and conditions from NMFS. And, as part of the consultation process, NMFS also may provide conservation recommendations to the federal agency for further protection and recovery of listed species.

Recovery of Pacific salmon species that are listed as threatened or endangered under ESA is directly tied to implementation of recovery plans, ESA consultations, and habitat restoration decisions involving NMFS West Coast Region managers. While the ESA is inherently a species conservation act, it is important in the recovery of salmon species that may contribute to commercial (or recreational) fisheries. The ESA operates in conjunction with the EFH provisions of the MSA in supporting and sustaining fishery opportunities.

Restoration Programs.

NMFS has multiple programs that contribute to marine habitat restoration, including those implemented by the NOAA Restoration Center (RC) and the Pacific Coastal Salmon Recovery Fund (PCSRF). The RC is devoted to restoring the nation's coastal, marine, and migratory fish habitat, and focuses on four main habitat restoration approaches: opening rivers, reconnecting coastal wetlands, restoring corals, and rebuilding shellfish populations. The RC works with local, regional and national, public, private, and government partners to determine where the biggest impact can be made and where funding and technical assistance are needed the most. Partners contribute staff time, expertise, and local knowledge of restoration issues, and often bring additional funding to projects to leverage federal dollars. Funding for restoration projects is provided to partners through grants and cooperative agreements under the RC's Community-Based Restoration Program.

The PCSRF was established by Congress in 2000 to reverse the declines of Pacific salmon and steelhead, supporting conservation efforts in California, Oregon, Washington, Idaho, and Alaska. NMFS is charged with administering PCSRF's competitive grants process, and has awarded states and tribes a total of over $1.1 billion. The program has also leveraged over $1.3 billion in total state in-kind, and other matching, funds. With funding support and job creation, states and tribes have undertaken over 11,000 projects, resulting in significant changes in salmon habitat conditions and availability.

NMFS WCR and RC staff participate in a number of partnerships that contribute to the science and implementation of habitat restoration, including Pacific Marine and Estuarine Fish Habitat Partnership, Joint Ventures, and National Estuary Programs, among others. These partnerships administer, contribute to, influence, and/or track restoration efforts in coastal areas in Washington, Oregon and California.

Appendix F. Phase 1 Risk Analysis Tables

Table 1. A – Black Rockfish Exposure Scores. Exposure scores calculated by spatial overlay of habitat use data with relative intensity of the stressors across the entire West Coast, divided by regions, abbreviated as SS – Salish Sea, N – Northern, C – Central, S – Southern.

	Juveniles				Adults			
	SS	N	C	S	SS	N	C	S
Aquaculture	0	0	0	0	0	0	0	0
Atmospheric Deposition	146	208	45	6	205	921	184	16
Coastal Engineering	26	23	9	1	35	0	10	2
Coastal Waste	0	7	24	1	0	0	32	2
Inorganic Pollution	43	63	21	2	57	23	46	3
Invasive Species	105	189	51	6	145	192	144	17
Nutrient Input	54	94	33	3	73	84	94	6
Ocean Acidification	141	225	87	10	196	1029	370	28
Ocean-Based Pollution	94	161	50	6	130	246	160	17
Offshore Oil Activities	0	0	0	0	0	0	0	0
Organic Pollution	68	128	36	4	91	113	101	6
Power Plants	1	0	0	0	2	0	0	0
Sediment Decrease	86	108	52	3	115	44	156	6
Sediment Increase	136	205	82	9	187	290	276	21
Shipping Activities	33	31	31	3	49	330	158	14
Sea Surface Temperature	56	77	23	0	80	846	197	1
UV Radiation	160	214	88	10	221	1032	367	27

Table 1. B – Bocaccio Exposure Scores. Exposure scores calculated by spatial overlay of habitat use data with relative intensity of the stressors across the entire West Coast, divided by geographic regions, abbreviated as SS – Salish Sea, N – Northern, C – Central, S – Southern.

	Larvae				Juveniles				Adults			
	SS	N	C	S	SS	N	C	S	SS	N	C	S
Aquaculture	0	0	0	0	0	0	0	0	0	0	0	0
Atmospheric Deposition	288	12228	4578	2341	165	6536	1795	814	76	994	995	663
Coastal Engineering	5	44	255	137	3	5	28	28	0	0	1	1
Coastal Waste	0	59	434	160	0	15	80	36	0	0	1	0
Inorganic Pollution	19	822	1254	737	12	382	274	227	2	7	65	58
Invasive Species	146	4612	3564	1469	85	2428	1070	526	37	118	426	291
Nutrient Input	38	2733	2618	994	22	1322	748	316	8	48	275	114
Ocean Acidification	245	14456	9075	3936	140	7417	3620	1365	64	1155	2033	1129
Ocean-Based Pollution	152	4655	3944	1601	87	2420	1317	573	41	205	624	368
Offshore Oil Activities	0	0	0	8	0	0	0	2	0	0	0	1
Organic Pollution	67	2846	2768	888	39	1359	811	274	13	38	265	78
Power Plants	0	0	15	87	0	0	4	22	0	0	0	1
Sediment Decrease	0	3851	3474	1357	0	1774	1023	439	0	109	386	163
Sediment Increase	221	7327	6732	2526	127	3824	2340	863	51	165	1016	455
Shipping Activities	122	3382	3865	1504	69	1670	1642	536	40	397	1015	483
Sea Surface Temperature	80	11902	5302	418	47	6127	2297	146	16	874	1290	101
UV Radiation	246	14115	8929	3625	141	7299	3551	1254	63	1148	1989	1026

Table 1. C – English Sole Exposure Scores. Exposure scores calculated by spatial overlay of habitat use data with relative intensity of the stressors across the entire West Coast, divided by geographic regions, abbreviated as SS – Salish Sea, N – Northern, C – Central, S – Southern.

	Larvae				Juveniles				Adults			
	SS	N	C	S	SS	N	C	S	SS	N	C	S
Aquaculture	3	0	0	0	1	0	0	0	2	0	0	0
Atmospheric Deposition	2363	11286	2655	0	863	8401	2267	0	2224	16418	5824	2769
Coastal Engineering	285	78	76	0	91	44	79	0	207	32	83	38
Coastal Waste	0	26	119	0	0	30	130	0	0	49	225	59
Inorganic Pollution	662	869	314	0	214	671	319	0	451	588	801	636
Invasive Species	1703	3987	1268	0	592	3216	1205	0	1445	3613	3165	1452
Nutrient Input	834	2442	821	0	276	2047	793	0	607	2120	2253	950
Ocean Acidification	2255	12626	4980	0	810	9563	4227	0	2050	18288	11798	4697
Ocean-Based Pollution	1544	4044	1647	0	544	3195	1489	0	1376	4282	4071	1697
Offshore Oil Activities	0	0	0	0	0	0	0	0	0	0	0	7
Organic Pollution	1035	2566	1040	0	353	2162	986	0	787	2172	2410	822
Power Plants	18	1	0	0	6	1	0	0	12	0	14	40
Sediment Decrease	1297	3067	1052	0	397	2586	1009	0	831	3165	2947	1292
Sediment Increase	2152	6216	2846	0	772	5247	2559	0	1877	5882	7172	2641
Shipping Activities	616	2994	2256	0	243	2173	1871	0	761	4945	5489	1904
Sea Surface Temperature	915	9728	3319	0	328	7539	2772	0	742	14065	7438	545
UV Radiation	2541	12385	4840	0	899	9334	4120	0	2223	18143	11542	4333

Table 1. D – Lingcod Exposure Scores. Exposure scores calculated by spatial overlay of habitat use data with relative intensity of the stressors across the entire West Coast, divided by geographic regions, abbreviated as SS – Salish Sea, N – Northern, C – Central, S – Southern.

	Eggs				Larvae				Juveniles				Adults			
	SS	N	C	S	SS	N	C	S	SS	N	C	S	SS	N	C	S
Aquaculture	7	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
Atmospheric Deposition	2805	3946	480	16	328	11628	2503	993	1003	8894	1240	489	139	1056	259	206
Coastal Engineering	479	85	154	31	4	5	24	36	107	22	12	25	21	0	5	6
Coastal Waste	0	0	156	20	0	26	101	50	0	20	52	30	0	0	19	2
Inorganic Pollution	904	734	476	15	21	488	327	275	228	435	160	143	38	16	54	25
Invasive Species	2145	2301	811	24	168	3382	1391	603	674	2959	680	294	99	164	186	167
Nutrient Input	1106	1499	623	14	42	1825	979	391	298	1560	484	201	49	68	123	42
Ocean Acidification	2733	4052	799	30	279	13165	5044	1674	931	9512	2497	827	133	1174	526	337
Ocean-Based Pollution	1902	2040	725	21	176	3633	1756	670	627	2955	862	328	90	250	215	169
Offshore Oil Activities	0	0	0	0	0	0	0	4	0	0	0	2	0	0	0	0
Organic Pollution	1347	1636	601	15	74	1794	1102	343	388	1596	547	178	61	86	127	25
Power Plants	27	2	0	5	0	0	5	28	6	0	2	15	1	0	0	2
Sediment Decrease	1821	1488	784	25	0	2716	1281	528	410	2166	622	270	77	43	202	77
Sediment Increase	2642	3355	910	20	250	5223	3205	1058	881	4845	1581	525	126	246	364	192
Shipping Activities	623	667	257	6	145	3273	2293	663	302	2057	1135	326	35	426	235	126
Sea Surface Temperature	1141	2866	74	0	98	10639	3285	192	369	7645	1632	97	55	952	302	28
UV Radiation	3135	4029	799	25	281	12984	4937	1548	1025	9510	2443	767	150	1181	520	293

Table 2. A – Black Rockfish Habitat Vulnerability Scores. Habitat vulnerability scores are calculated as weighted averages of scores from Teck et al. 2010, with weights being assigned based on habitat use data spatially overlaid with ecosystem types across the entire West Coast, divided by geographic regions, abbreviated as SS – Salish Sea, N – Northern, C – Central, S – Southern.

	Juveniles				Adults			
	SS	N	C	S	SS	N	C	S
Aquaculture	0.21	0.23	0.32	0.20	0.21	0.05	0.12	0.18
Atmospheric Deposition	0.40	0.32	0.78	0.88	0.40	0.27	0.51	0.61
Coastal Engineering	0.82	0.91	1.02	0.44	0.81	0.07	0.22	0.38
Coastal Waste	0.81	1.00	0.90	0.62	0.80	0.18	0.36	0.44
Inorganic Pollution	0.78	0.88	1.02	1.04	0.78	0.33	0.59	0.67
Invasive Species	1.32	1.52	1.79	1.60	1.30	0.41	0.90	1.05
Nutrient Input	0.57	0.58	0.91	1.09	0.56	0.32	0.62	0.70
Ocean Acidification	1.37	1.49	2.12	2.21	1.36	0.70	2.76	1.51
Ocean-Based Pollution	0.55	0.57	0.85	0.84	0.54	0.24	0.50	0.58
Offshore Oil Activities	1.30	1.50	1.64	1.99	1.29	0.60	1.08	1.20
Organic Pollution	1.14	1.38	1.33	1.30	1.13	0.39	0.73	0.82
Power Plants	0.52	0.59	0.65	0.27	0.51	0.06	0.19	0.24
Sediment Decrease	0.73	0.80	0.76	0.22	0.71	0.05	0.15	0.22
Sediment Increase	0.78	0.95	0.95	0.49	0.77	0.08	0.23	0.38
Shipping Activities	0.10	0.07	0.12	0.03	0.09	0.01	0.02	0.06
Sea Surface Temperature	0.68	0.55	1.45	1.60	0.69	0.45	0.89	1.10
UV Radiation	0.52	0.46	0.92	0.36	0.51	0.05	0.20	0.39

Table 2. B – Bocaccio Habitat Vulnerability Scores. Habitat vulnerability scores are calculated as weighted averages of scores from Teck et al. 2010, with weights being assigned based on habitat use data spatially overlaid with ecosystem types across the entire West Coast, divided by geographic regions, abbreviated as SS – Salish Sea, N – Northern, C – Central, S – Southern.

	Larvae				Juveniles				Adults			
	SS	N	C	S	SS	N	C	S	SS	N	C	S
Aquaculture	0.08	0.07	0.10	0.10	0.17	0.17	0.19	0.18	0.21	0.22	0.22	0.19
Atmospheric Deposition	0.05	0.02	0.08	0.07	0.41	0.46	0.64	0.50	0.74	0.89	0.90	0.88
Coastal Engineering	0.36	0.32	0.44	0.45	0.44	0.37	0.31	0.42	0.14	0.14	0.19	0.14
Coastal Waste	0.52	0.50	0.59	0.64	0.86	0.82	0.76	0.81	0.85	0.77	0.79	0.67
Inorganic Pollution	0.44	0.40	0.50	0.53	1.00	1.01	1.08	1.00	1.48	1.39	1.34	1.14
Invasive Species	0.73	0.66	0.84	0.89	1.02	1.01	0.95	1.12	0.48	0.67	0.73	0.88
Nutrient Input	0.22	0.20	0.27	0.28	0.61	0.66	0.78	0.70	0.75	0.92	0.94	0.97
Ocean Acidification	0.69	0.62	2.11	0.85	1.60	1.68	2.24	1.74	2.44	2.38	2.56	2.27
Ocean-Based Pollution	0.24	0.21	0.29	0.30	0.52	0.55	0.61	0.59	0.54	0.67	0.70	0.76
Offshore Oil Activities	0.73	0.70	0.84	0.90	1.54	1.60	1.70	1.62	1.77	1.92	1.93	1.95
Organic Pollution	0.73	0.69	0.83	0.89	1.30	1.29	1.26	1.29	1.42	1.35	1.34	1.21
Power Plants	0.29	0.26	0.34	0.35	0.37	0.32	0.27	0.34	0.14	0.14	0.19	0.13
Sediment Decrease	0.33	0.31	0.42	0.40	0.47	0.40	0.34	0.40	0.21	0.21	0.27	0.18
Sediment Increase	0.45	0.41	0.51	0.55	0.47	0.41	0.28	0.46	0.01	0.02	0.07	0.14
Shipping Activities	0.01	0.00	0.01	0.01	0.11	0.10	0.13	0.09	0.20	0.20	0.22	0.12
Sea Surface Temperature	0.11	0.04	0.14	0.15	0.65	0.73	1.00	0.83	1.27	1.43	1.40	1.40
UV Radiation	0.08	0.03	0.13	0.12	0.07	0.02	0.04	0.11	0.00	0.00	0.00	0.02

Table 2. C – English Sole Habitat Vulnerability Scores. Habitat vulnerability scores are calculated as weighted averages of scores from Teck et al. 2010, with weights being assigned based on habitat use data spatially overlaid with ecosystem types across the entire West Coast, divided by geographic regions, abbreviated as SS – Salish Sea, N – Northern, C – Central, S – Southern.

	Larvae				Juveniles				Adults			
	SS	N	C	S	SS	N	C	S	SS	N	C	S
Aquaculture	0.18	0.08	0.05	NA	0.26	0.19	0.23	NA	0.26	0.23	0.23	0.20
Atmospheric Deposition	0.30	0.04	0.05	NA	0.61	0.42	0.71	NA	0.69	0.73	0.72	0.58
Coastal Engineering	0.70	0.38	0.25	NA	0.73	0.48	0.42	NA	0.64	0.31	0.35	0.38
Coastal Waste	0.69	0.57	0.34	NA	0.98	0.96	0.94	NA	0.98	0.94	0.94	0.95
Inorganic Pollution	0.62	0.47	0.28	NA	1.14	1.10	1.28	NA	1.26	1.39	1.35	1.26
Invasive Species	1.12	0.78	0.48	NA	1.30	1.11	1.01	NA	1.17	0.85	0.91	0.97
Nutrient Input	0.45	0.24	0.16	NA	0.77	0.65	0.85	NA	0.81	0.84	0.84	0.74
Ocean Acidification	1.10	0.73	2.58	NA	1.93	1.74	2.09	NA	2.13	2.26	2.20	2.05
Ocean-Based Pollution	0.45	0.25	0.16	NA	0.68	0.56	0.67	NA	0.68	0.65	0.66	0.60
Offshore Oil Activities	1.06	0.81	0.48	NA	1.74	1.69	1.89	NA	1.82	1.93	1.91	1.81
Organic Pollution	0.95	0.80	0.47	NA	1.44	1.44	1.46	NA	1.48	1.50	1.48	1.47
Power Plants	0.45	0.30	0.19	NA	0.49	0.40	0.35	NA	0.43	0.28	0.30	0.33
Sediment Decrease	0.63	0.37	0.24	NA	0.69	0.51	0.47	NA	0.63	0.38	0.40	0.41
Sediment Increase	0.69	0.48	0.29	NA	0.67	0.52	0.36	NA	0.54	0.24	0.28	0.37
Shipping Activities	0.08	0.01	0.01	NA	0.16	0.11	0.18	NA	0.18	0.20	0.19	0.15
Sea Surface Temperature	0.51	0.07	0.08	NA	0.99	0.66	1.10	NA	1.13	1.17	1.15	0.95
UV Radiation	0.44	0.06	0.07	NA	0.39	0.04	0.09	NA	0.35	0.02	0.04	0.04

Table 2. D – Lingcod Habitat Vulnerability Scores. Habitat vulnerability scores are calculated as weighted averages of scores from Teck et al. 2010, with weights being assigned based on habitat use data spatially overlaid with ecosystem types across the entire West Coast, divided by geographic regions, abbreviated as SS – Salish Sea, N – Northern, C – Central, S – Southern.

	Eggs				Larvae				Juveniles				Adults			
	SS	N	C	S	SS	N	C	S	SS	N	C	S	SS	N	C	S
Aquaculture	0.27	0.17	0.21	0.35	0.05	0.04	0.05	0.08	0.26	0.20	0.22	0.19	0.26	0.19	0.18	0.19
Atmospheric Deposition	0.62	0.17	0.35	0.60	0.03	0.01	0.02	0.04	0.64	0.54	0.69	0.50	0.60	1.04	1.10	1.05
Coastal Engineering	0.85	0.75	1.01	1.16	0.23	0.20	0.23	0.37	0.71	0.41	0.37	0.46	0.82	0.09	0.09	0.16
Coastal Waste	0.99	1.00	1.03	0.98	0.33	0.32	0.36	0.55	0.96	0.92	0.90	0.93	0.97	0.55	0.46	0.52
Inorganic Pollution	1.11	0.86	0.92	0.92	0.28	0.26	0.29	0.45	1.14	1.16	1.25	1.11	1.09	1.18	1.06	1.04
Invasive Species	1.42	1.44	1.60	1.64	0.47	0.42	0.48	0.75	1.27	1.00	0.94	1.08	1.40	1.21	1.45	1.38
Nutrient Input	0.77	0.49	0.61	0.79	0.14	0.12	0.14	0.23	0.78	0.72	0.82	0.70	0.76	1.19	1.31	1.22
Ocean Acidification	1.92	1.39	1.53	1.75	0.44	0.39	2.51	0.71	1.94	1.86	2.14	1.80	1.87	2.54	2.64	2.50
Ocean-Based Pollution	0.70	0.50	0.61	0.67	0.15	0.13	0.16	0.25	0.68	0.59	0.65	0.59	0.69	0.86	0.96	0.94
Offshore Oil Activities	1.73	1.46	1.55	1.59	0.46	0.45	0.50	0.77	1.74	1.75	1.84	1.70	1.70	2.16	2.25	2.15
Organic Pollution	1.44	1.41	1.43	1.31	0.47	0.45	0.50	0.77	1.41	1.41	1.41	1.40	1.42	1.31	1.26	1.22
Power Plants	0.55	0.57	0.67	0.55	0.19	0.16	0.19	0.30	0.48	0.35	0.32	0.38	0.54	0.08	0.08	0.13
Sediment Decrease	0.79	0.71	0.97	0.90	0.21	0.20	0.22	0.34	0.67	0.45	0.41	0.47	0.75	0.09	0.06	0.11
Sediment Increase	0.76	0.86	0.96	1.09	0.28	0.26	0.30	0.46	0.63	0.41	0.31	0.49	0.75	0.05	0.10	0.20
Shipping Activities	0.16	0.03	0.06	0.15	0.00	0.00	0.00	0.01	0.17	0.14	0.18	0.12	0.15	0.06	0.01	0.04
Sea Surface Temperature	1.01	0.29	0.52	1.06	0.06	0.02	0.04	0.09	1.03	0.85	1.08	0.80	0.99	1.68	1.78	1.73
UV Radiation	0.51	0.23	0.49	0.87	0.05	0.01	0.04	0.07	0.39	0.03	0.05	0.08	0.49	0.04	0.08	0.16

Table 3. Sensitivity Scores. The sensitivity scores were calculated by applying a methodology adapted from Andrews et al. 2011, using a combination of available information from the scientific literature and expert opinion.

	Black Rockfish		Bocaccio			English Sole			Lingcod			
	Juveniles	Adults	Larvae	Juveniles	Adults	Larvae	Juveniles	Adults	Eggs	Larvae	Juveniles	Adults
Aquaculture	1.94	1.75	2.00	2.13	1.94	1.69	1.63	1.38	1.94	1.81	2.00	1.75
Atmospheric Deposition	1.94	1.75	2.13	2.13	1.94	1.81	1.88	1.63	2.06	1.94	2.00	1.75
Coastal Engineering	1.81	1.88	1.63	2.00	2.06	1.31	1.50	1.50	2.06	1.44	1.88	1.88
Coastal Waste	1.81	1.88	2.00	2.00	2.06	1.69	1.50	1.50	1.56	1.81	1.88	1.88
Inorganic Pollution	1.94	1.88	2.13	2.13	2.06	1.81	1.88	1.75	2.06	1.94	2.00	1.88
Invasive Species	2.06	1.88	2.13	2.25	2.06	1.94	2.00	1.75	2.06	2.06	2.13	1.88
Nutrient Input	1.81	1.63	2.13	2.00	1.81	1.81	1.75	1.50	2.06	1.94	1.88	1.63
Ocean Acidification	1.81	1.88	2.25	2.00	2.06	1.94	1.88	1.88	2.06	2.06	1.88	1.88
Ocean-Based Pollution	1.81	1.88	2.00	2.00	2.06	1.69	1.50	1.50	1.56	1.81	1.88	1.88
Offshore Oil Activities	1.56	1.75	1.88	1.75	1.94	1.56	1.25	1.38	1.56	1.69	1.63	1.75
Organic Pollution	1.94	1.88	2.13	2.13	2.06	1.81	1.88	1.75	2.06	1.94	2.00	1.88
Power Plants	1.56	1.63	2.13	1.75	1.69	1.81	1.50	1.50	1.56	1.94	1.63	1.63
Sediment Decrease	1.44	1.50	1.63	1.63	1.69	1.31	1.50	1.25	1.56	1.44	1.50	1.50
Sediment Increase	1.56	1.63	1.63	1.75	1.81	1.31	1.50	1.50	2.19	1.44	1.63	1.88
Shipping Activities	1.44	1.50	1.63	1.63	1.69	1.31	1.38	1.38	1.56	1.44	1.50	1.50
Sea Surface Temperature	1.69	1.63	2.13	2.13	2.06	1.69	1.63	1.50	1.94	1.81	1.75	1.88
UV Radiation	1.69	1.50	2.13	1.88	1.69	1.81	1.38	1.13	2.06	1.94	1.50	1.25

Table 4. A – Black Rockfish Normalized Exposure Scores. Exposure scores were standardized between 1 – 3 using equation 5 above. Geographic regions abbreviated as SS – Salish Sea, N – Northern, C – Central, S – Southern.

	Juveniles				Adults			
	SS	N	C	S	SS	N	C	S
Aquaculture	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Atmospheric Deposition	2.67	2.46	1.80	2.02	2.64	2.56	1.80	2.03
Coastal Engineering	1.29	1.16	1.16	1.24	1.28	1.00	1.04	1.14
Coastal Waste	1.00	1.05	1.42	1.11	1.00	1.00	1.14	1.10
Inorganic Pollution	1.49	1.44	1.38	1.42	1.46	1.04	1.20	1.19
Invasive Species	2.20	2.32	1.91	2.05	2.16	1.32	1.62	2.05
Nutrient Input	1.62	1.66	1.59	1.55	1.58	1.14	1.41	1.37
Ocean Acidification	2.61	2.58	2.55	2.69	2.57	2.74	2.60	2.74
Ocean-Based Pollution	2.07	2.13	1.89	2.01	2.04	1.42	1.69	2.09
Offshore Oil Activities	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Organic Pollution	1.77	1.90	1.65	1.61	1.73	1.19	1.44	1.35
Power Plants	1.02	1.00	1.00	1.00	1.01	1.00	1.00	1.00
Sediment Decrease	1.98	1.76	1.92	1.57	1.92	1.07	1.67	1.39
Sediment Increase	2.56	2.44	2.47	2.55	2.49	1.49	2.19	2.34
Shipping Activities	1.38	1.22	1.56	1.58	1.39	1.56	1.68	1.90
Sea Surface Temperature	1.64	1.54	1.41	1.04	1.64	2.43	1.85	1.04
UV Radiation	2.83	2.50	2.56	2.68	2.77	2.74	2.59	2.72

Table 4. B – Bocaccio Normalized Exposure Scores. Exposure scores were standardized between 1 – 3 using equation 5 above. Geographic regions abbreviated as SS – Salish Sea, N – Northern, C – Central, S – Southern.

	Larvae				Juveniles				Adults			
	SS	N	C	S	SS	N	C	S	SS	N	C	S
Aquaculture	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Atmospheric Deposition	2.97	2.45	1.81	2.03	2.98	2.51	1.81	2.03	2.98	2.48	1.80	2.02
Coastal Engineering	1.03	1.01	1.05	1.06	1.04	1.00	1.01	1.04	1.00	1.00	1.00	1.00
Coastal Waste	1.00	1.01	1.08	1.07	1.00	1.00	1.04	1.05	1.00	1.00	1.00	1.00
Inorganic Pollution	1.13	1.10	1.22	1.32	1.14	1.09	1.12	1.29	1.06	1.01	1.05	1.09
Invasive Species	2.00	1.55	1.63	1.65	2.02	1.56	1.48	1.67	1.96	1.17	1.34	1.45
Nutrient Input	1.26	1.32	1.47	1.44	1.26	1.31	1.34	1.40	1.20	1.07	1.22	1.18
Ocean Acidification	2.68	2.71	2.61	2.73	2.69	2.72	2.63	2.74	2.69	2.72	2.63	2.75
Ocean-Based Pollution	2.04	1.55	1.70	1.70	2.05	1.56	1.59	1.73	2.07	1.30	1.50	1.57
Offshore Oil Activities	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Organic Pollution	1.46	1.34	1.49	1.39	1.47	1.31	1.36	1.35	1.33	1.06	1.21	1.12
Power Plants	1.00	1.00	1.00	1.04	1.00	1.00	1.00	1.03	1.00	1.00	1.00	1.00
Sediment Decrease	1.00	1.46	1.62	1.60	1.00	1.41	1.46	1.56	1.00	1.16	1.31	1.25
Sediment Increase	2.52	1.87	2.20	2.11	2.53	1.89	2.05	2.10	2.35	1.24	1.82	1.70
Shipping Activities	1.83	1.40	1.69	1.66	1.82	1.39	1.74	1.68	2.06	1.59	1.82	1.75
Sea Surface Temperature	1.55	2.41	1.94	1.18	1.57	2.42	2.03	1.19	1.41	2.30	2.04	1.16
UV Radiation	2.68	2.67	2.59	2.59	2.69	2.69	2.60	2.59	2.65	2.71	2.60	2.59

Table 4. C – English Sole Normalized Exposure Scores. Exposure scores were standardized between 1 – 3 using equation 5 above. Geographic regions abbreviated as SS – Salish Sea, N – Northern, C – Central, S – Southern.

	Larvae				Juveniles				Adults			
	SS	N	C	S	SS	N	C	S	SS	N	C	S
Aquaculture	1.00	1.00	1.00	NA	1.00	1.00	1.00	NA	1.00	1.00	1.00	1.00
Atmospheric Deposition	2.71	2.51	1.86	NA	2.74	2.49	1.86	NA	2.79	2.53	1.80	2.03
Coastal Engineering	1.21	1.01	1.02	NA	1.18	1.01	1.03	NA	1.17	1.00	1.01	1.01
Coastal Waste	1.00	1.00	1.04	NA	1.00	1.01	1.05	NA	1.00	1.00	1.03	1.02
Inorganic Pollution	1.48	1.12	1.10	NA	1.43	1.12	1.12	NA	1.36	1.05	1.11	1.24
Invasive Species	2.23	1.54	1.41	NA	2.19	1.57	1.46	NA	2.16	1.34	1.44	1.54
Nutrient Input	1.60	1.33	1.27	NA	1.56	1.36	1.30	NA	1.49	1.20	1.31	1.35
Ocean Acidification	2.63	2.69	2.61	NA	2.63	2.69	2.61	NA	2.65	2.71	2.63	2.74
Ocean-Based Pollution	2.12	1.54	1.53	NA	2.10	1.57	1.57	NA	2.11	1.40	1.56	1.63
Offshore Oil Activities	1.00	1.00	1.00	NA	1.00	1.00	1.00	NA	1.00	1.00	1.00	1.00
Organic Pollution	1.75	1.34	1.34	NA	1.71	1.38	1.38	NA	1.63	1.20	1.33	1.30
Power Plants	1.01	1.00	1.00	NA	1.01	1.00	1.00	NA	1.01	1.00	1.00	1.01
Sediment Decrease	1.94	1.41	1.34	NA	1.80	1.46	1.38	NA	1.67	1.30	1.41	1.48
Sediment Increase	2.56	1.83	1.92	NA	2.56	1.93	1.97	NA	2.51	1.55	1.99	1.98
Shipping Activities	1.45	1.40	1.73	NA	1.49	1.38	1.71	NA	1.61	1.46	1.76	1.71
Sea Surface Temperature	1.66	2.31	2.08	NA	1.66	2.34	2.06	NA	1.60	2.31	2.03	1.20
UV Radiation	2.84	2.66	2.57	NA	2.82	2.65	2.57	NA	2.79	2.69	2.59	2.61

Table 4. D – Lingcod Normalized Exposure Scores. Exposure scores were standardized between 1 – 3 using equation 5 above. Geographic regions abbreviated as SS – Salish Sea, N – Northern, C – Central, S – Southern.

	Eggs				Larvae				Juveniles				Adults			
	SS	N	C	S	SS	N	C	S	SS	N	C	S	SS	N	C	S
Aquaculture	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Atmospheric Deposition	2.63	2.61	1.91	1.67	2.98	2.52	1.81	2.03	2.76	2.60	1.81	2.02	2.55	2.56	1.79	2.08
Coastal Engineering	1.28	1.03	1.29	2.33	1.02	1.00	1.01	1.04	1.19	1.00	1.01	1.05	1.24	1.00	1.02	1.03
Coastal Waste	1.00	1.00	1.30	1.85	1.00	1.00	1.03	1.05	1.00	1.00	1.03	1.06	1.00	1.00	1.06	1.01
Inorganic Pollution	1.53	1.30	1.90	1.64	1.13	1.06	1.11	1.29	1.40	1.08	1.10	1.30	1.43	1.02	1.17	1.13
Invasive Species	2.25	1.94	2.54	2.01	2.02	1.44	1.45	1.63	2.18	1.53	1.44	1.62	2.11	1.24	1.57	1.87
Nutrient Input	1.64	1.61	2.18	1.59	1.26	1.24	1.32	1.41	1.52	1.28	1.32	1.42	1.54	1.10	1.38	1.22
Ocean Acidification	2.59	2.65	2.52	2.29	2.69	2.72	2.63	2.73	2.63	2.71	2.63	2.73	2.48	2.73	2.61	2.76
Ocean-Based Pollution	2.11	1.83	2.38	1.89	2.06	1.47	1.57	1.69	2.10	1.53	1.56	1.69	2.00	1.37	1.66	1.88
Offshore Oil Activities	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Organic Pollution	1.78	1.67	2.14	1.64	1.45	1.23	1.36	1.36	1.68	1.29	1.36	1.37	1.67	1.13	1.39	1.13
Power Plants	1.02	1.00	1.00	1.21	1.00	1.00	1.00	1.03	1.01	1.00	1.00	1.03	1.01	1.00	1.00	1.01
Sediment Decrease	2.06	1.61	2.49	2.09	1.00	1.35	1.41	1.55	1.72	1.39	1.41	1.57	1.85	1.06	1.62	1.40
Sediment Increase	2.54	2.37	2.73	1.87	2.51	1.68	2.03	2.10	2.55	1.87	2.03	2.10	2.40	1.36	2.11	2.00
Shipping Activities	1.36	1.27	1.49	1.27	1.88	1.43	1.74	1.69	1.53	1.37	1.74	1.68	1.39	1.63	1.72	1.66
Sea Surface Temperature	1.66	2.17	1.14	1.00	1.59	2.39	2.06	1.20	1.65	2.37	2.06	1.20	1.61	2.40	1.92	1.15
UV Radiation	2.83	2.65	2.52	2.07	2.70	2.69	2.59	2.60	2.80	2.71	2.59	2.60	2.67	2.74	2.59	2.53

Table 5. A – Black Rockfish Normalized Habitat Vulnerability Scores. Habitat vulnerability scores were normalized between 1-3 for each species across all life stages and geographic regions, abbreviated as SS – Salish Sea, N – Northern, C – Central, S – Southern.

	Juveniles				Adults			
	SS	N	C	S	SS	N	C	S
Aquaculture	1.15	1.15	1.22	1.13	1.14	1.03	1.08	1.12
Atmospheric Deposition	1.28	1.22	1.56	1.63	1.28	1.18	1.36	1.43
Coastal Engineering	1.58	1.65	1.74	1.31	1.58	1.04	1.15	1.26
Coastal Waste	1.58	1.72	1.64	1.44	1.57	1.12	1.25	1.31
Inorganic Pollution	1.56	1.63	1.73	1.75	1.56	1.23	1.42	1.48
Invasive Species	1.95	2.09	2.29	2.15	1.94	1.29	1.64	1.76
Nutrient Input	1.40	1.41	1.66	1.78	1.40	1.22	1.44	1.50
Ocean Acidification	1.99	2.08	2.53	2.60	1.98	1.50	3.00	2.09
Ocean-Based Pollution	1.39	1.41	1.61	1.60	1.38	1.17	1.36	1.41
Offshore Oil Activities	1.93	2.08	2.18	2.44	1.93	1.43	1.78	1.87
Organic Pollution	1.82	1.99	1.96	1.94	1.81	1.28	1.52	1.59
Power Plants	1.37	1.42	1.46	1.19	1.36	1.04	1.13	1.17
Sediment Decrease	1.52	1.57	1.54	1.15	1.51	1.03	1.10	1.15
Sediment Increase	1.56	1.68	1.68	1.35	1.55	1.05	1.16	1.27
Shipping Activities	1.06	1.04	1.07	1.01	1.06	1.00	1.00	1.03
Sea Surface Temperature	1.49	1.39	2.04	2.16	1.49	1.32	1.64	1.79
UV Radiation	1.37	1.33	1.66	1.25	1.36	1.02	1.14	1.27

Table 5. B – Bocaccio Normalized Habitat Vulnerability Scores. Habitat vulnerability scores were normalized between 1-3 for each species across all life stages and geographic regions, abbreviated as SS – Salish Sea, N – Northern, C – Central, S – Southern.

	Larvae				Juveniles				Adults			
	SS	N	C	S	SS	N	C	S	SS	N	C	S
Aquaculture	1.06	1.05	1.07	1.08	1.13	1.13	1.14	1.14	1.16	1.17	1.18	1.14
Atmospheric Deposition	1.04	1.02	1.06	1.05	1.32	1.36	1.50	1.39	1.58	1.70	1.70	1.68
Coastal Engineering	1.28	1.25	1.35	1.35	1.35	1.29	1.24	1.33	1.11	1.11	1.15	1.11
Coastal Waste	1.41	1.39	1.46	1.50	1.68	1.64	1.60	1.63	1.67	1.60	1.62	1.53
Inorganic Pollution	1.34	1.31	1.39	1.42	1.78	1.79	1.85	1.78	2.16	2.08	2.05	1.89
Invasive Species	1.57	1.52	1.65	1.70	1.79	1.78	1.74	1.87	1.38	1.53	1.57	1.69
Nutrient Input	1.18	1.15	1.21	1.22	1.48	1.52	1.61	1.55	1.58	1.72	1.74	1.76
Ocean Acidification	1.54	1.48	2.65	1.66	2.25	2.31	2.75	2.36	2.90	2.86	3.00	2.78
Ocean-Based Pollution	1.19	1.16	1.22	1.23	1.41	1.43	1.48	1.46	1.42	1.53	1.55	1.59
Offshore Oil Activities	1.57	1.54	1.66	1.70	2.20	2.25	2.33	2.26	2.38	2.50	2.51	2.53
Organic Pollution	1.57	1.54	1.64	1.69	2.01	2.01	1.99	2.01	2.11	2.05	2.04	1.95
Power Plants	1.23	1.20	1.26	1.27	1.29	1.25	1.21	1.27	1.11	1.11	1.14	1.10
Sediment Decrease	1.25	1.24	1.33	1.31	1.37	1.31	1.26	1.31	1.16	1.17	1.21	1.14
Sediment Increase	1.35	1.32	1.40	1.43	1.37	1.32	1.22	1.36	1.01	1.01	1.06	1.11
Shipping Activities	1.01	1.00	1.01	1.01	1.09	1.08	1.10	1.07	1.16	1.16	1.17	1.10
Sea Surface Temperature	1.08	1.03	1.11	1.12	1.51	1.57	1.78	1.64	1.99	2.12	2.09	2.09
UV Radiation	1.06	1.03	1.10	1.09	1.05	1.01	1.03	1.08	1.00	1.00	1.00	1.01

Table 5. C – English Sole Normalized Habitat Vulnerability Scores. Habitat vulnerability scores were normalized between 1-3 for each species across all life stages and geographic regions, abbreviated as SS – Salish Sea, N – Northern, C – Central, S – Southern.

	Larvae				Juveniles				Adults			
	SS	N	C	S	SS	N	C	S	SS	N	C	S
Aquaculture	1.14	1.06	1.04	NA	1.20	1.14	1.17	NA	1.20	1.17	1.17	1.15
Atmospheric Deposition	1.23	1.02	1.03	NA	1.47	1.32	1.54	NA	1.53	1.57	1.56	1.45
Coastal Engineering	1.54	1.29	1.19	NA	1.56	1.37	1.32	NA	1.49	1.24	1.27	1.29
Coastal Waste	1.53	1.44	1.26	NA	1.76	1.74	1.72	NA	1.76	1.73	1.72	1.73
Inorganic Pollution	1.48	1.36	1.22	NA	1.88	1.85	1.99	NA	1.98	2.08	2.04	1.98
Invasive Species	1.87	1.60	1.36	NA	2.01	1.86	1.78	NA	1.90	1.65	1.70	1.75
Nutrient Input	1.35	1.18	1.12	NA	1.59	1.50	1.65	NA	1.62	1.65	1.65	1.57
Ocean Acidification	1.85	1.56	3.00	NA	2.50	2.35	2.62	NA	2.65	2.75	2.70	2.59
Ocean-Based Pollution	1.34	1.19	1.12	NA	1.52	1.43	1.52	NA	1.52	1.50	1.51	1.46
Offshore Oil Activities	1.82	1.62	1.37	NA	2.35	2.31	2.46	NA	2.41	2.49	2.48	2.40
Organic Pollution	1.73	1.62	1.36	NA	2.12	2.11	2.13	NA	2.14	2.16	2.15	2.14
Power Plants	1.34	1.23	1.14	NA	1.38	1.31	1.27	NA	1.33	1.21	1.23	1.25
Sediment Decrease	1.48	1.28	1.18	NA	1.53	1.39	1.36	NA	1.48	1.29	1.31	1.31
Sediment Increase	1.53	1.36	1.22	NA	1.51	1.40	1.27	NA	1.42	1.18	1.21	1.28
Shipping Activities	1.05	1.00	1.00	NA	1.12	1.08	1.14	NA	1.14	1.15	1.14	1.11
Sea Surface Temperature	1.39	1.05	1.06	NA	1.76	1.51	1.85	NA	1.87	1.90	1.89	1.73
UV Radiation	1.33	1.04	1.05	NA	1.30	1.03	1.06	NA	1.27	1.01	1.03	1.03

Table 5. D – Lingcod Normalized Habitat Vulnerability Scores. Habitat vulnerability scores were normalized between 1-3 for each species across all life stages and geographic regions, abbreviated as SS – Salish Sea, N – Northern, C – Central, S – Southern.

	Eggs				Larvae				Juveniles				Adults			
	SS	N	C	S	SS	N	C	S	SS	N	C	S	SS	N	C	S
Aquaculture	1.21	1.12	1.16	1.26	1.04	1.03	1.04	1.06	1.20	1.15	1.16	1.15	1.20	1.14	1.13	1.14
Atmospheric Deposition	1.47	1.13	1.26	1.46	1.02	1.01	1.01	1.03	1.48	1.41	1.52	1.38	1.45	1.78	1.84	1.80
Coastal Engineering	1.64	1.57	1.76	1.88	1.17	1.15	1.18	1.28	1.53	1.31	1.28	1.35	1.62	1.07	1.07	1.12
Coastal Waste	1.75	1.76	1.78	1.74	1.25	1.24	1.27	1.41	1.72	1.70	1.68	1.70	1.73	1.42	1.35	1.40
Inorganic Pollution	1.84	1.65	1.70	1.70	1.21	1.19	1.22	1.34	1.87	1.88	1.95	1.84	1.83	1.90	1.81	1.79
Invasive Species	2.07	2.09	2.21	2.24	1.35	1.32	1.37	1.57	1.96	1.76	1.71	1.82	2.06	1.92	2.10	2.05
Nutrient Input	1.59	1.37	1.47	1.60	1.11	1.09	1.11	1.17	1.59	1.55	1.62	1.53	1.58	1.90	1.99	1.93
Ocean Acidification	2.46	2.05	2.16	2.33	1.33	1.30	2.91	1.54	2.47	2.41	2.62	2.36	2.42	2.93	3.00	2.90
Ocean-Based Pollution	1.53	1.38	1.46	1.51	1.12	1.10	1.12	1.19	1.51	1.45	1.49	1.44	1.52	1.65	1.72	1.71
Offshore Oil Activities	2.31	2.10	2.17	2.20	1.35	1.34	1.37	1.58	2.32	2.33	2.39	2.29	2.29	2.63	2.70	2.63
Organic Pollution	2.09	2.07	2.09	2.00	1.35	1.34	1.38	1.58	2.07	2.07	2.07	2.06	2.07	2.00	1.96	1.92
Power Plants	1.41	1.43	1.51	1.42	1.14	1.12	1.14	1.22	1.36	1.26	1.24	1.29	1.41	1.06	1.06	1.10
Sediment Decrease	1.60	1.54	1.73	1.69	1.16	1.15	1.17	1.25	1.51	1.34	1.31	1.36	1.57	1.07	1.05	1.08
Sediment Increase	1.58	1.65	1.73	1.83	1.21	1.20	1.22	1.35	1.48	1.31	1.24	1.37	1.57	1.04	1.08	1.15
Shipping Activities	1.12	1.02	1.05	1.11	1.00	1.00	1.00	1.00	1.13	1.11	1.13	1.09	1.11	1.05	1.01	1.03
Sea Surface Temperature	1.76	1.22	1.40	1.80	1.05	1.01	1.03	1.07	1.78	1.64	1.82	1.60	1.75	2.27	2.35	2.31
UV Radiation	1.39	1.17	1.37	1.66	1.04	1.01	1.03	1.05	1.29	1.02	1.04	1.06	1.37	1.03	1.06	1.12

Table 6. A – Black Rockfish Normalized Exposure-Habitat Vulnerability Scores. The standardized exposure and habitat vulnerability scores were combined, using equation 6 above, to yield the final exposure-habitat vulnerability axis scores for each species and life stage, broken down by geographic regions, abbreviated as SS – Salish Sea, N – Northern, C – Central, S – Southern.

	Juveniles				Adults			
	SS	N	C	S	SS	N	C	S
Aquaculture	1.07	1.07	1.11	1.06	1.07	1.01	1.04	1.06
Atmospheric Deposition	1.85	1.73	1.67	1.82	1.84	1.74	1.56	1.70
Coastal Engineering	1.43	1.39	1.42	1.28	1.42	1.02	1.10	1.20
Coastal Waste	1.26	1.34	1.53	1.27	1.25	1.06	1.19	1.20
Inorganic Pollution	1.53	1.53	1.54	1.57	1.51	1.13	1.30	1.33
Invasive Species	2.07	2.21	2.09	2.10	2.04	1.31	1.63	1.90
Nutrient Input	1.51	1.53	1.62	1.66	1.49	1.18	1.42	1.43
Ocean Acidification	2.28	2.31	2.54	2.64	2.26	2.03	2.79	2.39
Ocean-Based Pollution	1.70	1.73	1.74	1.79	1.68	1.29	1.52	1.72
Offshore Oil Activities	1.39	1.44	1.48	1.56	1.39	1.19	1.33	1.37
Organic Pollution	1.80	1.95	1.80	1.77	1.77	1.23	1.48	1.46
Power Plants	1.18	1.19	1.21	1.09	1.18	1.02	1.06	1.08
Sediment Decrease	1.74	1.66	1.72	1.34	1.70	1.05	1.35	1.27
Sediment Increase	2.00	2.03	2.04	1.85	1.97	1.25	1.60	1.72
Shipping Activities	1.21	1.13	1.29	1.26	1.21	1.25	1.30	1.40
Sea Surface Temperature	1.56	1.46	1.70	1.50	1.56	1.79	1.74	1.37
UV Radiation	1.96	1.82	2.06	1.83	1.94	1.68	1.72	1.86

Table 6. B – Bocaccio Normalized Exposure- Habitat Vulnerability Scores. The standardized exposure and habitat vulnerability scores were combined, using equation 6 above, to yield the final exposure-habitat vulnerability axis scores for each species and life stage, broken down by geographic regions, abbreviated as SS – Salish Sea, N – Northern, C – Central, S – Southern.

	Larvae				Juveniles				Adults			
	SS	N	C	S	SS	N	C	S	SS	N	C	S
Aquaculture	1.03	1.03	1.04	1.04	1.07	1.06	1.07	1.07	1.08	1.08	1.08	1.07
Atmospheric Deposition	1.75	1.58	1.39	1.46	1.99	1.85	1.64	1.68	2.17	2.05	1.75	1.85
Coastal Engineering	1.15	1.12	1.19	1.20	1.18	1.14	1.12	1.17	1.05	1.05	1.07	1.06
Coastal Waste	1.19	1.18	1.26	1.27	1.29	1.28	1.29	1.31	1.29	1.27	1.27	1.24
Inorganic Pollution	1.23	1.20	1.30	1.37	1.43	1.40	1.44	1.51	1.51	1.45	1.47	1.44
Invasive Species	1.77	1.53	1.64	1.67	1.90	1.67	1.61	1.77	1.64	1.34	1.45	1.57
Nutrient Input	1.22	1.24	1.33	1.32	1.37	1.41	1.47	1.47	1.38	1.36	1.46	1.44
Ocean Acidification	2.03	2.00	2.63	2.13	2.46	2.51	2.69	2.54	2.80	2.79	2.81	2.76
Ocean-Based Pollution	1.56	1.34	1.44	1.45	1.70	1.49	1.53	1.59	1.72	1.41	1.52	1.58
Offshore Oil Activities	1.25	1.24	1.29	1.31	1.48	1.50	1.53	1.51	1.54	1.58	1.58	1.59
Organic Pollution	1.51	1.44	1.57	1.53	1.72	1.62	1.65	1.64	1.67	1.47	1.57	1.48
Power Plants	1.11	1.10	1.13	1.15	1.14	1.12	1.10	1.14	1.05	1.05	1.07	1.05
Sediment Decrease	1.12	1.34	1.46	1.45	1.17	1.36	1.36	1.43	1.08	1.16	1.26	1.19
Sediment Increase	1.84	1.57	1.75	1.74	1.86	1.58	1.58	1.69	1.54	1.12	1.39	1.37
Shipping Activities	1.36	1.19	1.31	1.29	1.41	1.22	1.38	1.34	1.54	1.36	1.46	1.38
Sea Surface Temperature	1.29	1.58	1.47	1.15	1.54	1.95	1.90	1.40	1.68	2.21	2.07	1.56
UV Radiation	1.69	1.66	1.69	1.68	1.68	1.65	1.64	1.68	1.63	1.65	1.61	1.62

Table 6. C – English Sole Normalized Exposure- Habitat Vulnerability Scores. The standardized exposure and habitat vulnerability scores were combined, using equation 6 above, to yield the final exposure-habitat vulnerability axis scores for each species and life stage, broken down by geographic regions, abbreviated as SS – Salish Sea, N – Northern, C – Central, S – Southern.

	Larvae				Juveniles				Adults			
	SS	N	C	S	SS	N	C	S	SS	N	C	S
Aquaculture	1.07	1.03	1.02	NA	1.09	1.07	1.08	NA	1.10	1.08	1.08	1.07
Atmospheric Deposition	1.82	1.60	1.39	NA	2.01	1.81	1.70	NA	2.07	1.99	1.67	1.71
Coastal Engineering	1.36	1.14	1.11	NA	1.36	1.17	1.17	NA	1.32	1.11	1.13	1.14
Coastal Waste	1.24	1.20	1.14	NA	1.33	1.32	1.34	NA	1.32	1.32	1.33	1.33
Inorganic Pollution	1.48	1.23	1.16	NA	1.64	1.44	1.49	NA	1.64	1.48	1.51	1.56
Invasive Species	2.04	1.57	1.39	NA	2.10	1.71	1.61	NA	2.03	1.49	1.56	1.64
Nutrient Input	1.47	1.25	1.19	NA	1.57	1.43	1.47	NA	1.55	1.40	1.47	1.46
Ocean Acidification	2.21	2.05	2.80	NA	2.57	2.52	2.61	NA	2.65	2.73	2.67	2.67
Ocean-Based Pollution	1.69	1.36	1.31	NA	1.79	1.50	1.54	NA	1.79	1.45	1.53	1.54
Offshore Oil Activities	1.35	1.27	1.17	NA	1.53	1.52	1.57	NA	1.55	1.58	1.57	1.55
Organic Pollution	1.74	1.47	1.35	NA	1.90	1.71	1.71	NA	1.87	1.61	1.69	1.67
Power Plants	1.17	1.11	1.07	NA	1.18	1.14	1.13	NA	1.16	1.10	1.11	1.13
Sediment Decrease	1.69	1.35	1.26	NA	1.66	1.42	1.37	NA	1.57	1.29	1.36	1.39
Sediment Increase	1.98	1.58	1.53	NA	1.97	1.64	1.58	NA	1.89	1.35	1.55	1.59
Shipping Activities	1.23	1.18	1.32	NA	1.29	1.22	1.39	NA	1.35	1.29	1.42	1.38
Sea Surface Temperature	1.52	1.55	1.48	NA	1.71	1.88	1.95	NA	1.73	2.10	1.96	1.44
UV Radiation	1.95	1.66	1.64	NA	1.91	1.65	1.65	NA	1.88	1.65	1.63	1.63

Table 6. D – Lingcod Normalized Exposure- Habitat Vulnerability Scores. The standardized exposure and habitat vulnerability scores were combined, using equation 6 above, to yield the final exposure-habitat vulnerability axis scores for each species and life stage, broken down by geographic regions, abbreviated as SS – Salish Sea, N – Northern, C – Central, S – Southern.

	Eggs				Larvae				Juveniles				Adults			
	SS	N	C	S	SS	N	C	S	SS	N	C	S	SS	N	C	S
Aquaculture	1.10	1.06	1.08	1.12	1.02	1.02	1.02	1.03	1.09	1.07	1.08	1.07	1.10	1.07	1.07	1.07
Atmospheric Deposition	2.52	2.33	2.33	2.31	1.89	1.88	2.76	2.05	2.55	2.56	2.63	2.54	2.45	2.83	2.80	2.83
Coastal Engineering	1.45	1.27	1.51	2.09	1.09	1.07	1.09	1.15	1.35	1.15	1.14	1.19	1.41	1.03	1.04	1.08
Coastal Waste	1.32	1.33	1.52	1.79	1.12	1.12	1.15	1.22	1.31	1.31	1.32	1.34	1.32	1.19	1.19	1.19
Inorganic Pollution	1.68	1.46	1.80	1.67	1.17	1.13	1.16	1.31	1.62	1.42	1.47	1.55	1.61	1.39	1.45	1.42
Invasive Species	2.16	2.02	2.37	2.12	1.65	1.38	1.41	1.60	2.07	1.64	1.57	1.72	2.08	1.54	1.82	1.96
Nutrient Input	1.61	1.49	1.79	1.59	1.18	1.16	1.21	1.28	1.56	1.41	1.46	1.47	1.56	1.45	1.66	1.53
Ocean Acidification	1.97	1.72	1.56	1.56	1.74	1.59	1.35	1.45	2.02	1.91	1.66	1.67	1.93	2.14	1.81	1.93
Ocean-Based Pollution	1.79	1.59	1.86	1.69	1.52	1.27	1.32	1.42	1.78	1.49	1.53	1.56	1.74	1.50	1.69	1.80
Offshore Oil Activities	1.52	1.45	1.47	1.48	1.16	1.16	1.17	1.26	1.52	1.53	1.55	1.52	1.51	1.62	1.64	1.62
Organic Pollution	1.93	1.86	2.12	1.81	1.40	1.28	1.37	1.46	1.87	1.63	1.68	1.68	1.86	1.50	1.65	1.47
Power Plants	1.20	1.20	1.23	1.31	1.07	1.06	1.07	1.12	1.17	1.12	1.11	1.15	1.19	1.03	1.03	1.05
Sediment Decrease	1.81	1.57	2.08	1.88	1.08	1.25	1.28	1.39	1.61	1.36	1.36	1.46	1.71	1.06	1.30	1.23
Sediment Increase	2.00	1.98	2.17	1.85	1.75	1.42	1.58	1.68	1.94	1.56	1.59	1.69	1.94	1.19	1.51	1.52
Shipping Activities	1.24	1.14	1.25	1.19	1.37	1.19	1.32	1.30	1.31	1.23	1.40	1.36	1.24	1.31	1.32	1.30
Sea Surface Temperature	1.71	1.63	1.26	1.34	1.29	1.55	1.46	1.13	1.71	1.97	1.94	1.39	1.68	2.34	2.13	1.63
UV Radiation	1.98	1.76	1.86	1.85	1.67	1.65	1.63	1.66	1.90	1.66	1.64	1.66	1.91	1.68	1.66	1.68

Table 7. Normalized Sensitivity Scores. The sensitivity scores were normalized between 1-3 across all species and life stages.

	Black Rockfish		Bocaccio			English Sole			Lingcod			
	Juveniles	Adults	Larvae	Juveniles	Adults	Larvae	Juveniles	Adults	Eggs	Larvae	Juveniles	Adults
Aquaculture	2.44	2.11	2.56	2.78	2.44	2.00	1.89	1.44	2.44	2.22	2.56	2.11
Atmospheric Deposition	2.44	2.11	2.78	2.78	2.44	2.22	2.33	1.89	2.67	2.44	2.56	2.11
Coastal Engineering	2.22	2.33	1.89	2.56	2.67	1.33	1.67	1.67	2.67	1.56	2.33	2.33
Coastal Waste	2.22	2.33	2.56	2.56	2.67	2.00	1.67	1.67	1.78	2.22	2.33	2.33
Inorganic Pollution	2.44	2.33	2.78	2.78	2.67	2.22	2.33	2.11	2.67	2.44	2.56	2.33
Invasive Species	2.67	2.33	2.78	3.00	2.67	2.44	2.56	2.11	2.67	2.67	2.78	2.33
Nutrient Input	2.22	1.89	2.78	2.56	2.22	2.22	2.11	1.67	2.67	2.44	2.33	1.89
Ocean Acidification	2.22	2.33	3.00	2.56	2.67	2.44	2.33	2.33	2.67	2.67	2.33	2.33
Ocean-Based Pollution	2.22	2.33	2.56	2.56	2.67	2.00	1.67	1.67	1.78	2.22	2.33	2.33
Offshore Oil Activities	1.78	2.11	2.33	2.11	2.44	1.78	1.22	1.44	1.78	2.00	1.89	2.11
Organic Pollution	2.44	2.33	2.78	2.78	2.67	2.22	2.33	2.11	2.67	2.44	2.56	2.33
Power Plants	1.78	1.89	2.78	2.11	2.00	2.22	1.67	1.67	1.78	2.44	1.89	1.89
Sediment Decrease	1.56	1.67	1.89	1.89	2.00	1.33	1.67	1.22	1.78	1.56	1.67	1.67
Sediment Increase	1.78	1.89	1.89	2.11	2.22	1.33	1.67	1.67	2.89	1.56	1.89	2.33
Shipping Activities	1.56	1.67	1.89	1.89	2.00	1.33	1.44	1.44	1.78	1.56	1.67	1.67
Sea Surface Temperature	2.00	1.89	2.78	2.78	2.67	2.00	1.89	1.67	2.44	2.22	2.11	2.33
UV Radiation	2.00	1.67	2.78	2.33	2.00	2.22	1.44	1.00	2.67	2.44	1.67	1.22

Table 8. A – Black Rockfish Risk Scores. The risk scores for each species were calculated from the normalized exposure-habitat vulnerability and sensitivity scores, using equation 1 above. Scores were calculated by life stage and geographic regions, which are abbreviated as SS – Salish Sea, N – Northern, C – Central, S – Southern.

	Juveniles				Adults			
	SS	N	C	S	SS	N	C	S
Aquaculture	1.45	1.45	1.45	1.45	1.11	1.11	1.11	1.11
Atmospheric Deposition	1.68	1.62	1.59	1.66	1.39	1.33	1.25	1.32
Coastal Engineering	1.30	1.28	1.29	1.25	1.40	1.33	1.34	1.35
Coastal Waste	1.25	1.27	1.33	1.25	1.36	1.33	1.35	1.35
Inorganic Pollution	1.54	1.54	1.54	1.55	1.43	1.34	1.37	1.37
Invasive Species	1.98	2.06	1.99	2.00	1.69	1.37	1.48	1.61
Nutrient Input	1.32	1.33	1.37	1.39	1.01	0.91	0.98	0.99
Ocean Acidification	1.77	1.79	1.97	2.05	1.83	1.68	2.24	1.93
Ocean-Based Pollution	1.41	1.42	1.43	1.46	1.50	1.36	1.43	1.52
Offshore Oil Activities	0.87	0.90	0.91	0.96	1.18	1.13	1.16	1.17
Organic Pollution	1.65	1.73	1.65	1.64	1.54	1.35	1.42	1.41
Power Plants	0.80	0.80	0.81	0.78	0.91	0.89	0.89	0.89
Sediment Decrease	0.92	0.86	0.91	0.65	0.97	0.67	0.76	0.72
Sediment Increase	1.26	1.29	1.30	1.16	1.31	0.92	1.07	1.15
Shipping Activities	0.59	0.57	0.63	0.61	0.70	0.71	0.73	0.78
Sea Surface Temperature	1.15	1.10	1.22	1.12	1.05	1.19	1.16	0.96
UV Radiation	1.39	1.29	1.46	1.30	1.15	0.95	0.98	1.09

Table 8. B – Bocaccio Risk Scores. The risk scores for each species were calculated from the normalized exposure-habitat vulnerability and sensitivity scores, using equation 1 above. Scores were calculated by life stage and geographic regions, which are abbreviated as SS – Salish Sea, N – Northern, C – Central, S – Southern.

	Larvae				Juveniles				Adults			
	SS	N	C	S	SS	N	C	S	SS	N	C	S
Aquaculture	1.56	1.56	1.56	1.56	1.78	1.78	1.78	1.78	1.45	1.45	1.45	1.45
Atmospheric Deposition	1.93	1.87	1.82	1.84	2.03	1.97	1.89	1.90	1.86	1.79	1.63	1.67
Coastal Engineering	0.90	0.90	0.91	0.91	1.57	1.56	1.56	1.57	1.67	1.67	1.67	1.67
Coastal Waste	1.57	1.57	1.58	1.58	1.58	1.58	1.58	1.59	1.69	1.69	1.69	1.68
Inorganic Pollution	1.79	1.79	1.80	1.82	1.83	1.82	1.83	1.85	1.74	1.73	1.73	1.72
Invasive Species	1.94	1.86	1.89	1.90	2.19	2.11	2.09	2.14	1.79	1.70	1.73	1.76
Nutrient Input	1.79	1.79	1.81	1.81	1.60	1.61	1.62	1.63	1.28	1.27	1.30	1.30
Ocean Acidification	2.25	2.24	2.58	2.30	2.13	2.16	2.30	2.19	2.45	2.44	2.46	2.42
Ocean-Based Pollution	1.65	1.59	1.62	1.62	1.71	1.63	1.64	1.66	1.81	1.72	1.75	1.76
Offshore Oil Activities	1.36	1.36	1.36	1.37	1.21	1.22	1.23	1.22	1.54	1.56	1.56	1.56
Organic Pollution	1.85	1.83	1.87	1.86	1.92	1.88	1.89	1.89	1.80	1.73	1.76	1.73
Power Plants	1.78	1.78	1.78	1.78	1.12	1.12	1.12	1.12	1.00	1.00	1.00	1.00
Sediment Decrease	0.90	0.95	1.00	1.00	0.90	0.96	0.96	0.99	1.00	1.01	1.03	1.02
Sediment Increase	1.22	1.06	1.16	1.15	1.40	1.25	1.25	1.31	1.33	1.23	1.28	1.28
Shipping Activities	0.96	0.91	0.94	0.94	0.98	0.92	0.97	0.95	1.14	1.06	1.10	1.07
Sea Surface Temperature	1.80	1.87	1.84	1.78	1.86	2.01	1.99	1.82	1.80	2.06	1.98	1.76
UV Radiation	1.91	1.89	1.91	1.90	1.50	1.48	1.48	1.50	1.18	1.19	1.17	1.18

Table 8. C – English Sole Risk Scores. The risk scores for each species were calculated from the normalized exposure-habitat vulnerability and sensitivity scores, using equation 1 above. Scores were calculated by life stage and geographic regions, which are abbreviated as SS – Salish Sea, N – Northern, C – Central, S – Southern.

	Larvae				Juveniles				Adults			
	SS	N	C	S	SS	N	C	S	SS	N	C	S
Aquaculture	1.00	1.00	1.00	NA	0.89	0.89	0.89	NA	0.45	0.45	0.45	0.45
Atmospheric Deposition	1.47	1.36	1.28	NA	1.67	1.56	1.50	NA	1.39	1.33	1.12	1.14
Coastal Engineering	0.49	0.36	0.35	NA	0.76	0.69	0.69	NA	0.74	0.68	0.68	0.68
Coastal Waste	1.03	1.02	1.01	NA	0.74	0.74	0.75	NA	0.74	0.74	0.75	0.74
Inorganic Pollution	1.31	1.24	1.23	NA	1.48	1.40	1.42	NA	1.28	1.21	1.22	1.25
Invasive Species	1.78	1.55	1.50	NA	1.90	1.71	1.67	NA	1.52	1.21	1.25	1.28
Nutrient Input	1.31	1.25	1.24	NA	1.25	1.19	1.21	NA	0.87	0.78	0.82	0.81
Ocean Acidification	1.88	1.79	2.31	NA	2.06	2.02	2.09	NA	2.12	2.18	2.13	2.13
Ocean-Based Pollution	1.21	1.06	1.05	NA	1.03	0.83	0.86	NA	1.04	0.80	0.85	0.86
Offshore Oil Activities	0.85	0.82	0.80	NA	0.58	0.57	0.61	NA	0.71	0.73	0.73	0.71
Organic Pollution	1.43	1.31	1.27	NA	1.61	1.51	1.51	NA	1.41	1.27	1.31	1.30
Power Plants	1.23	1.23	1.22	NA	0.69	0.68	0.68	NA	0.69	0.67	0.68	0.68
Sediment Decrease	0.77	0.48	0.42	NA	0.94	0.79	0.76	NA	0.62	0.37	0.42	0.45
Sediment Increase	1.03	0.67	0.63	NA	1.17	0.93	0.89	NA	1.11	0.75	0.87	0.89
Shipping Activities	0.41	0.38	0.46	NA	0.53	0.50	0.59	NA	0.57	0.53	0.61	0.58
Sea Surface Temperature	1.13	1.14	1.11	NA	1.14	1.25	1.30	NA	0.99	1.29	1.17	0.80
UV Radiation	1.55	1.39	1.38	NA	1.01	0.79	0.79	NA	0.88	0.65	0.63	0.63

Table 8. D – Lingcod Risk Scores. The risk scores for each species were calculated from the normalized exposure-habitat vulnerability and sensitivity scores, using equation 1 above. Scores were calculated by life stage and geographic regions, which are abbreviated as SS – Salish Sea, N – Northern, C – Central, S – Southern.

	Eggs				Larvae				Juveniles				Adults			
	SS	N	C	S	SS	N	C	S	SS	N	C	S	SS	N	C	S
Aquaculture	1.45	1.45	1.45	1.45	1.22	1.22	1.22	1.22	1.56	1.56	1.56	1.56	1.12	1.11	1.11	1.11
Atmospheric Deposition	1.93	1.81	1.76	1.76	1.62	1.56	1.49	1.51	1.86	1.80	1.69	1.69	1.45	1.59	1.38	1.45
Coastal Engineering	1.73	1.69	1.74	1.99	0.56	0.56	0.56	0.58	1.38	1.34	1.34	1.35	1.40	1.33	1.33	1.34
Coastal Waste	0.84	0.84	0.93	1.11	1.23	1.23	1.23	1.24	1.37	1.37	1.37	1.38	1.37	1.35	1.35	1.35
Inorganic Pollution	1.80	1.73	1.85	1.80	1.45	1.45	1.45	1.48	1.67	1.61	1.62	1.65	1.47	1.39	1.41	1.40
Invasive Species	2.03	1.95	2.16	2.01	1.79	1.71	1.72	1.77	2.07	1.89	1.87	1.92	1.72	1.44	1.56	1.64
Nutrient Input	1.78	1.74	1.84	1.77	1.46	1.45	1.46	1.47	1.45	1.39	1.41	1.41	1.05	1.00	1.10	1.04
Ocean Acidification	2.26	2.13	2.13	2.12	1.89	1.88	2.43	1.97	2.05	2.05	2.10	2.04	1.97	2.26	2.24	2.26
Ocean-Based Pollution	1.11	0.98	1.16	1.04	1.33	1.25	1.26	1.29	1.55	1.42	1.43	1.45	1.53	1.42	1.50	1.55
Offshore Oil Activities	0.94	0.90	0.91	0.92	1.01	1.01	1.01	1.03	1.03	1.03	1.04	1.03	1.22	1.27	1.28	1.27
Organic Pollution	1.91	1.87	2.01	1.85	1.50	1.47	1.49	1.52	1.78	1.68	1.70	1.70	1.59	1.42	1.48	1.41
Power Plants	0.80	0.80	0.81	0.84	1.45	1.45	1.45	1.45	0.91	0.90	0.90	0.90	0.91	0.89	0.89	0.89
Sediment Decrease	1.13	0.97	1.33	1.17	0.56	0.61	0.62	0.68	0.90	0.76	0.76	0.81	0.97	0.67	0.73	0.71
Sediment Increase	2.14	2.13	2.22	2.07	0.93	0.70	0.80	0.88	1.29	1.05	1.06	1.13	1.63	1.35	1.43	1.43
Shipping Activities	0.81	0.79	0.82	0.80	0.67	0.59	0.64	0.63	0.74	0.71	0.78	0.76	0.71	0.73	0.74	0.73
Sea Surface Temperature	1.61	1.57	1.47	1.48	1.26	1.34	1.30	1.23	1.32	1.48	1.45	1.18	1.50	1.89	1.75	1.47
UV Radiation	1.93	1.83	1.88	1.87	1.59	1.58	1.58	1.59	1.12	0.94	0.93	0.94	0.94	0.71	0.69	0.72

Table 9. Combined Species Risk Scores. The combined species risk scores are weighted means of risk scores for each life stage, with life stage weights assigned based on AEQ values from life-cycle models (see section 2.2.3 for details). Species level risk scores were calculated for each geographic region, abbreviated as SS – Salish Sea, N – Northern, C – Central, S – Southern.

	Black Rockfish				Bocaccio				English Sole				Lingcod			
	SS	N	C	S	SS	N	C	S	SS	N	C	S*	SS	N	C	S
Aquaculture	1.28	1.28	1.28	1.28	1.51	1.51	1.51	1.50	0.47	0.46	0.46	1.14	1.13	1.13	1.13	1.13
Atmospheric Deposition	1.53	1.48	1.42	1.49	1.89	1.82	1.67	1.72	1.40	1.34	1.13	0.45	1.46	1.59	1.39	1.46
Coastal Engineering	1.35	1.31	1.31	1.30	1.65	1.65	1.65	1.65	0.74	0.68	0.68	0.68	1.39	1.33	1.33	1.33
Coastal Waste	1.30	1.30	1.34	1.30	1.67	1.67	1.67	1.67	0.74	0.74	0.75	0.74	1.37	1.35	1.35	1.35
Inorganic Pollution	1.48	1.44	1.45	1.46	1.76	1.74	1.75	1.75	1.29	1.22	1.23	1.25	1.47	1.40	1.41	1.40
Invasive Species	1.84	1.71	1.73	1.80	1.86	1.77	1.79	1.83	1.53	1.23	1.26	1.28	1.73	1.45	1.57	1.65
Nutrient Input	1.17	1.12	1.18	1.19	1.34	1.33	1.36	1.36	0.88	0.79	0.83	0.81	1.06	1.01	1.11	1.05
Ocean Acidification	1.80	1.74	2.10	1.99	2.40	2.40	2.44	2.39	2.12	2.18	2.13	2.13	1.97	2.25	2.23	2.25
Ocean-Based Pollution	1.45	1.39	1.43	1.49	1.80	1.70	1.73	1.75	1.04	0.80	0.85	0.86	1.53	1.42	1.50	1.55
Offshore Oil Activities	1.02	1.01	1.04	1.06	1.49	1.50	1.50	1.50	0.71	0.73	0.72	0.71	1.22	1.27	1.28	1.26
Organic Pollution	1.59	1.54	1.53	1.52	1.82	1.76	1.79	1.76	1.42	1.27	1.31	1.30	1.59	1.43	1.49	1.42
Power Plants	0.85	0.85	0.85	0.84	1.02	1.02	1.02	1.02	0.69	0.68	0.68	0.68	0.91	0.89	0.89	0.89
Sediment Decrease	0.94	0.77	0.83	0.69	0.99	1.00	1.02	1.01	0.62	0.38	0.43	0.45	0.97	0.67	0.73	0.71
Sediment Increase	1.29	1.10	1.18	1.15	1.35	1.23	1.28	1.28	1.11	0.76	0.87	0.89	1.62	1.34	1.41	1.42
Shipping Activities	0.65	0.64	0.68	0.70	1.11	1.04	1.08	1.05	0.57	0.53	0.61	0.58	0.71	0.73	0.74	0.73
Sea Surface Temperature	1.10	1.15	1.19	1.04	1.81	2.05	1.98	1.77	0.99	1.28	1.17	0.80	1.49	1.87	1.74	1.46
UV Radiation	1.27	1.12	1.22	1.20	1.24	1.24	1.23	1.23	0.88	0.65	0.64	0.63	0.94	0.72	0.70	0.72

Appendix G. Phase 2 Risk Assessment Tables

Table 1. A – Phase 2 Black Rockfish Exposure Scores. Exposure scores calculated by spatial overlay of habitat use data with relative intensity of the stressors in two defined geographic regions, abbreviated as PS – Puget Sound, and SCB – Southern California Bight.

	Juvenile		Adults	
	PS	SCB	PS	SCB
Altered Freshwater Flow	1.012	1.000	1.012	1.000
Aquaculture	1.000	1.001	1.000	1.001
Beach Nourishment	NA	1.002	NA	1.001
Bottom Trawling	1.009	1.174	1.009	1.147
Coastal Development	1.001	1.015	1.001	1.008
Commercial Shipping	1.000	1.126	1.000	1.189
Derelict Fishing Gear	1.031	1.012	1.031	1.009
Dredging and Disposal	1.000	1.001	1.000	1.000
Invasive Species	1.010	1.023	1.010	1.020
Marine Debris	NA	1.036	NA	1.016
Oil and Gas Exploration	NA	1.000	NA	1.000
Oil Spills	1.031	1.003	1.031	1.004
Overwater Structures	1.001	1.001	1.001	1.000
Recreational Boating	1.000	1.000	1.000	1.000
Storm and Wastewater Discharge	1.000	1.038	1.000	1.009
Submarine Pipeline Cable	1.006	1.003	1.006	1.002
Water Intake Structures	1.000	1.000	1.000	1.000

Table 1. B – Phase 2 Bocaccio Exposure Scores. Exposure scores calculated by spatial overlay of habitat use data with relative intensity of the stressors in two defined geographic regions, abbreviated as PS – Puget Sound, and SCB – Southern California Bight.

	Larvae		Juveniles		Adults	
	PS	SCB	PS	SCB	PS	SCB
Altered Freshwater Flow	1.001	1.000	1.012	1.000	1.000	1.000
Aquaculture	1.000	1.000	1.000	1.000	1.000	1.000
Beach Nourishment	NA	1.001	NA	1.001	NA	1.000
Bottom Trawling	1.057	1.162	1.009	1.151	1.031	1.066
Coastal Development	1.000	1.003	1.001	1.002	1.000	1.000
Commercial Shipping	1.530	1.322	1.396	1.334	1.745	1.328
Derelict Fishing Gear	1.003	1.005	1.032	1.007	1.004	1.001
Dredging and Disposal	1.001	1.003	1.000	1.002	1.002	1.000
Invasive Species	1.001	1.018	1.011	1.030	1.001	1.008
Marine Debris	NA	1.007	NA	1.003	NA	1.000
Oil and Gas Exploration	NA	1.000	NA	1.000	NA	1.000
Oil Spills	1.018	1.008	1.032	1.004	1.007	1.001
Overwater Structures	1.001	1.001	1.002	1.000	1.000	1.000
Recreational Boating	1.000	1.000	1.000	1.000	1.000	1.000
Storm and Wastewater Discharge	1.000	1.032	1.000	1.023	1.000	1.003
Submarine Pipeline Cable	1.015	1.006	1.005	1.005	1.015	1.002
Water Intake Structures	1.000	1.026	1.000	1.017	1.008	1.000

Table 1. C – Phase 2 English Sole Exposure Scores. Exposure scores calculated by spatial overlay of habitat use data with relative intensity of the stressors in two defined geographic regions, abbreviated as PS – Puget Sound, and SCB – Southern California Bight.

	Larvae	Juveniles	Adults	
	PS	PS	PS	SCB
Altered Freshwater Flow	1.012	1.002	1.000	1.000
Aquaculture	1.004	1.001	1.000	1.000
Beach Nourishment	NA	NA	NA	1.000
Bottom Trawling	1.010	1.038	1.041	1.146
Coastal Development	1.009	1.011	1.016	1.005
Commercial Shipping	1.007	1.001	1.000	1.000
Derelict Fishing Gear	1.528	1.578	1.710	1.324
Dredging and Disposal	1.016	1.014	1.003	1.001
Invasive Species	1.000	1.001	1.001	1.001
Marine Debris	1.007	1.001	1.000	1.004
Oil and Gas Exploration	NA	NA	NA	1.001
Oil Spills	NA	NA	NA	1.000
Overwater Structures	1.008	1.016	1.009	1.002
Recreational Boating	1.000	1.002	1.000	1.000
Storm and Wastewater Discharge	1.020	1.001	1.000	1.000
Submarine Pipeline Cable	1.000	1.000	1.000	1.011
Water Intake Structures	1.000	1.009	1.008	1.006

Table 1. D – Phase 2 Lingcod Exposure Scores. Exposure scores calculated by spatial overlay of habitat use data with relative intensity of the stressors in two defined geographic regions, abbreviated as PS – Puget Sound, and SCB – Southern California Bight.

	Eggs		Larvae		Juveniles		Adults	
	PS	SCB	PS	SCB	PS	SCB	PS	SCB
Altered Freshwater Flow	1.014	1.000	1.001	1.000	1.001	1.000	1.012	1.000
Aquaculture	1.005	1.000	1.000	1.000	1.001	1.000	1.000	1.000
Beach Nourishment	NA	1.012	NA	1.000	NA	1.000	NA	1.000
Bottom Trawling	1.001	1.000	1.067	1.162	1.033	1.166	1.009	1.047
Coastal Development	1.008	1.093	1.000	1.001	1.001	1.002	1.001	1.001
Commercial Shipping	1.513	1.540	1.598	1.326	1.610	1.326	1.419	1.371
Derelict Fishing Gear	1.018	1.000	1.002	1.004	1.014	1.003	1.031	1.014
Dredging and Disposal	1.018	1.068	1.002	1.002	1.002	1.003	1.000	1.000
Invasive Species	1.008	1.054	1.001	1.013	1.001	1.007	1.010	1.075
Marine Debris	NA	1.270	NA	1.002	NA	1.004	NA	1.002
Oil and Gas Exploration	NA	1.000	NA	1.000	NA	1.000	NA	1.000
Oil Spills	1.030	1.242	1.010	1.004	1.013	1.009	1.030	1.001
Overwater Structures	1.009	1.085	1.001	1.000	1.002	1.002	1.001	1.000
Recreational Boating	1.003	1.004	1.000	1.000	1.001	1.000	1.000	1.000
Storm and Wastewater Discharge	1.001	1.313	1.000	1.021	1.000	1.025	1.000	1.004
Submarine Pipeline Cable	1.005	1.000	1.024	1.005	1.011	1.006	1.006	1.001
Water Intake Structures	1.000	1.272	1.000	1.016	1.009	1.022	1.000	1.004

Table 2. A – Black Rockfish Habitat Vulnerability Scores. Habitat vulnerability scores are calculated as weighted averages of scores from Teck et al. 2010, with weights being assigned based on habitat use data spatially overlaid with ecosystem types across defined geographic regions, abbreviated as PS – Puget Sound, and SCB – Southern California Bight.

	Juvenile		Adults	
	PS	SCB	PS	SCB
Altered Freshwater Flow	0.31	0.26	0.35	0.35
Aquaculture	0.25	0.12	0.26	0.19
Beach Nourishment	0.98	0.48	0.81	0.66
Bottom Trawling	0.98	0.91	0.86	0.95
Coastal Development	0.94	0.41	0.75	0.59
Commercial Shipping	0.13	0.03	0.34	0.05
Derelict Fishing Gear	0.54	0.83	0.78	0.87
Dredging and Disposal	0.72	0.36	0.44	0.37
Invasive Species	1.62	0.89	1.37	1.38
Marine Debris	1.01	0.63	1.02	0.70
Oil and Gas Exploration	1.46	1.00	1.17	1.39
Oil Spills	1.40	0.91	1.41	1.12
Overwater Structures	1.46	1.14	1.17	1.45
Recreational Boating	0.24	0.43	0.32	0.40
Storm and Wastewater Discharge	0.64	0.37	0.83	0.70
Submarine Pipeline Cable	1.46	1.14	1.17	1.45
Water Intake Structures	0.70	0.33	0.86	0.43

Table 2. B – Bocaccio Habitat Vulnerability Scores. Habitat vulnerability scores are calculated as weighted averages of scores from Teck et al. 2010, with weights being assigned based on habitat use data spatially overlaid with ecosystem types across defined geographic regions, abbreviated as PS – Puget Sound, and SCB – Southern California Bight.

	Larvae		Juveniles		Adults	
	PS	SCB	PS	SCB	PS	SCB
Altered Freshwater Flow	0.29	0.25	0.29	0.15	0.10	0.17
Aquaculture	0.24	0.10	0.26	0.18	0.25	0.19
Beach Nourishment	0.58	0.55	0.83	0.46	0.30	0.14
Bottom Trawling	0.78	0.83	1.12	1.34	1.60	1.68
Coastal Development	0.45	0.45	0.81	0.42	0.37	0.15
Commercial Shipping	0.66	0.01	0.17	0.09	0.28	0.13
Derelict Fishing Gear	0.81	0.76	0.73	0.82	1.00	1.14
Dredging and Disposal	0.34	0.38	0.53	0.43	0.53	0.31
Invasive Species	0.95	0.89	1.49	1.13	0.86	0.87
Marine Debris	1.04	0.64	1.00	0.81	0.97	0.69
Oil and Gas Exploration	0.98	0.90	1.45	1.62	1.76	1.96
Oil Spills	1.45	0.89	1.41	1.29	1.50	1.23
Overwater Structures	0.98	1.04	1.45	1.65	1.76	1.99
Recreational Boating	0.51	0.43	0.20	0.22	0.22	0.30
Storm and Wastewater Discharge	0.88	0.28	0.73	0.71	0.87	0.96
Submarine Pipeline Cable	0.98	1.04	1.45	1.65	1.76	1.99
Water Intake Structures	0.97	0.35	0.70	0.35	0.40	0.14

Table 2. C – English Sole Habitat Vulnerability Scores. Habitat vulnerability scores are calculated as weighted averages of scores from Teck et al. 2010, with weights being assigned based on habitat use data spatially overlaid with ecosystem types across defined geographic regions, abbreviated as PS – Puget Sound, and SCB – Southern California Bight.

	Larvae	Juveniles	Adults	
	PS	PS	PS	SCB
Altered Freshwater Flow	0.28	0.14	0.05	0.03
Aquaculture	0.27	0.25	0.24	0.20
Beach Nourishment	0.74	0.51	0.26	0.35
Bottom Trawling	1.24	1.48	1.76	1.66
Coastal Development	0.82	0.57	0.35	0.37
Commercial Shipping	0.16	0.18	0.21	0.15
Derelict Fishing Gear	0.71	0.82	1.00	0.88
Dredging and Disposal	0.82	0.69	0.57	0.50
Invasive Species	1.39	1.15	0.86	0.95
Marine Debris	0.99	0.96	0.95	0.94
Oil and Gas Exploration	1.74	1.83	1.92	1.82
Oil Spills	1.44	1.45	1.51	1.47
Overwater Structures	1.74	1.83	1.92	1.82
Recreational Boating	0.28	0.21	0.17	0.12
Storm and Wastewater Discharge	0.78	0.82	0.84	0.75
Submarine Pipeline Cable	1.74	1.83	1.92	1.82
Water Intake Structures	0.53	0.42	0.29	0.32

Table 2. D – Lingcod Habitat Vulnerability Scores. Habitat vulnerability scores are calculated as weighted averages of scores from Teck et al. 2010, with weights being assigned based on habitat use data spatially overlaid with ecosystem types across defined geographic regions, abbreviated as PS – Puget Sound, and SCB – Southern California Bight.

	Eggs		Larvae		Juveniles		Adults	
	PS	SCB	PS	SCB	PS	SCB	PS	SCB
Altered Freshwater Flow	0.29	0.48	0.38	0.28	0.14	0.06	0.27	0.36
Aquaculture	0.27	0.33	0.28	0.08	0.25	0.20	0.25	0.19
Beach Nourishment	0.76	1.09	0.42	0.46	0.50	0.47	0.80	0.29
Bottom Trawling	1.21	0.74	0.60	0.76	1.45	1.47	1.20	1.45
Coastal Development	0.85	1.22	0.30	0.36	0.56	0.46	0.79	0.24
Commercial Shipping	0.16	0.14	0.99	0.01	0.21	0.13	0.13	0.04
Derelict Fishing Gear	0.70	0.61	1.00	0.84	0.83	0.78	0.74	1.09
Dredging and Disposal	0.83	1.15	0.24	0.32	0.67	0.54	0.52	0.16
Invasive Species	1.41	1.70	0.67	0.74	1.14	1.08	1.47	1.41
Marine Debris	0.99	0.99	1.07	0.54	0.96	0.92	1.00	0.57
Oil and Gas Exploration	1.73	1.63	0.75	0.75	1.78	1.71	1.50	2.06
Oil Spills	1.44	1.35	1.47	0.75	1.45	1.40	1.43	1.23
Overwater Structures	1.73	1.63	0.75	0.94	1.78	1.72	1.50	2.07
Recreational Boating	0.29	0.43	0.73	0.52	0.22	0.14	0.16	0.35
Storm and Wastewater Discharge	0.77	0.82	1.09	0.23	0.83	0.71	0.70	1.15
Submarine Pipeline Cable	1.73	1.63	0.75	0.94	1.78	1.72	1.50	2.07
Water Intake Structures	0.54	0.61	1.17	0.29	0.45	0.38	0.65	0.19

Table 3. A – Phase 2 Black Rockfish Normalized Exposure Scores. Exposure scores calculated by spatial overlay of habitat use data with relative intensity of the stressors in two defined geographic regions, abbreviated as PS – Puget Sound, and SCB – Southern California Bight.

	Juvenile		Adults	
	PS	SCB	PS	SCB
Altered Freshwater Flow	1.41	1.00	1.46	1.00
Aquaculture	1.08	1.01	1.01	1.01
Beach Nourishment		1.02		1.01
Bottom Trawling	1.23	2.84	1.35	2.55
Coastal Development	1.07	1.16	1.05	1.09
Commercial Shipping	1.00	2.33	1.00	3.00
Derelict Fishing Gear	3.00	1.13	2.20	1.10
Dredging and Disposal	1.04	1.01	1.00	1.00
Invasive Species	1.32	1.25	1.40	1.22
Marine Debris		1.38		1.17
Oil and Gas Exploration		1.00		1.00
Oil Spills	1.77	1.03	2.20	1.05
Overwater Structures	1.09	1.01	1.06	1.00
Recreational Boating	1.02	1.00	1.01	1.00
Storm and Wastewater Discharge	1.02	1.41	1.01	1.09
Submarine Pipeline Cable	1.03	1.04	1.24	1.02
Water Intake Structures	1.34	1.00	1.00	1.00

Table 3. B – Phase 2 Bocaccio Normalized Exposure Scores. Exposure scores calculated by spatial overlay of habitat use data with relative intensity of the stressors in two defined geographic regions, abbreviated as PS – Puget Sound, and SCB – Southern California Bight.

	Larvae		Juveniles		Adults	
	PS	SCB	PS	SCB	PS	SCB
Altered Freshwater Flow	1.00	1.00	1.03	1.00	1.00	1.00
Aquaculture	1.00	1.00	1.00	1.00	1.00	1.00
Beach Nourishment		1.00		1.00		1.00
Bottom Trawling	1.15	1.97	1.03	1.91	1.08	1.39
Coastal Development	1.00	1.02	1.00	1.01	1.00	1.00
Commercial Shipping	2.42	2.93	2.06	3.00	3.00	2.96
Derelict Fishing Gear	1.01	1.03	1.09	1.04	1.01	1.00
Dredging and Disposal	1.00	1.02	1.00	1.01	1.01	1.00
Invasive Species	1.00	1.11	1.03	1.18	1.00	1.05
Marine Debris		1.04		1.02		1.00
Oil and Gas Exploration		1.00		1.00		1.00
Oil Spills	1.05	1.05	1.09	1.02	1.02	1.01
Overwater Structures	1.00	1.01	1.00	1.00	1.00	1.00
Recreational Boating	1.00	1.00	1.00	1.00	1.00	1.00
Storm and Wastewater Discharge	1.00	1.19	1.00	1.14	1.00	1.02
Submarine Pipeline Cable	1.04	1.03	1.01	1.03	1.04	1.01
Water Intake Structures	1.00	1.16	1.00	1.10	1.02	1.00

Table 3. C – Phase 2 English Sole Normalized Exposure Scores. Exposure scores calculated by spatial overlay of habitat use data with relative intensity of the stressors in two defined geographic regions, abbreviated as PS – Puget Sound, and SCB – Southern California Bight.

	Larvae	Juveniles	Adults	
	PS	PS	PS	SCB
Altered Freshwater Flow	1.01	1.01	1.00	1.00
Aquaculture		1.00	1.00	1.00
Beach Nourishment	1.03			1.00
Bottom Trawling	1.02	1.11	1.12	1.90
Coastal Development	1.02	1.03	1.04	1.03
Commercial Shipping	2.49	1.00	1.00	1.00
Derelict Fishing Gear	1.04	2.63	3.00	3.00
Dredging and Disposal	1.00	1.04	1.01	1.01
Invasive Species	1.02	1.00	1.00	1.01
Marine Debris		1.00	1.00	1.03
Oil and Gas Exploration				1.01
Oil Spills	1.02			1.00
Overwater Structures	1.00	1.04	1.02	1.02
Recreational Boating	1.06	1.01	1.00	1.00
Storm and Wastewater Discharge	1.00	1.00	1.00	1.00
Submarine Pipeline Cable	1.00	1.00	1.00	1.07
Water Intake Structures	1.01	1.02	1.02	1.04

Table 3. D – Phase 2 Lingcod Normalized Exposure Scores. Exposure scores calculated by spatial overlay of habitat use data with relative intensity of the stressors in two defined geographic regions, abbreviated as PS – Puget Sound, and SCB – Southern California Bight.

	Eggs		Larvae		Juveniles		Adults	
	PS	SCB	PS	SCB	PS	SCB	PS	SCB
Altered Freshwater Flow	1.05	1.00	1.00	1.00	1.00	1.00	1.04	1.00
Aquaculture	1.01	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Beach Nourishment		1.04		1.00		1.00		1.00
Bottom Trawling	1.00	1.00	1.22	1.60	1.11	1.62	1.03	1.17
Coastal Development	1.03	1.34	1.00	1.00	1.00	1.01	1.00	1.00
Commercial Shipping	2.68	3.00	2.96	2.21	3.00	2.21	2.38	2.38
Derelict Fishing Gear	1.06	1.00	1.01	1.01	1.05	1.01	1.10	1.05
Dredging and Disposal	1.06	1.25	1.01	1.01	1.00	1.01	1.00	1.00
Invasive Species	1.03	1.20	1.00	1.05	1.00	1.03	1.03	1.28
Marine Debris		2.00		1.01		1.01		1.01
Oil and Gas Exploration		1.00		1.00		1.00		1.00
Oil Spills	1.10	1.90	1.03	1.01	1.04	1.03	1.10	1.00
Overwater Structures	1.03	1.31	1.00	1.00	1.01	1.01	1.00	1.00
Recreational Boating	1.01	1.02	1.00	1.00	1.00	1.00	1.00	1.00
Storm and Wastewater Discharge	1.00	2.16	1.00	1.08	1.00	1.09	1.00	1.01
Submarine Pipeline Cable	1.02	1.00	1.08	1.02	1.04	1.02	1.02	1.00
Water Intake Structures	1.00	2.01	1.00	1.06	1.03	1.08	1.00	1.02

Table 4. A – Black Rockfish Normalized Habitat Vulnerability Scores. Habitat vulnerability scores are calculated as weighted averages of scores from Teck et al. 2010, with weights being assigned based on habitat use data spatially overlaid with ecosystem types across defined geographic regions, abbreviated as PS – Puget Sound, and SCB – Southern California Bight.

	Juvenile		Adults	
	PS	SCB	PS	SCB
Altered Freshwater Flow	1.25	1.32	1.30	1.45
Aquaculture	1.17	1.12	1.18	1.23
Beach Nourishment		1.64		1.89
Bottom Trawling	2.14	2.24	1.98	2.30
Coastal Development	2.08	1.53	1.83	1.79
Commercial Shipping	1.00	1.00	1.29	1.02
Derelict Fishing Gear	1.55	2.12	1.87	2.18
Dredging and Disposal	1.79	1.47	1.42	1.48
Invasive Species	3.00	2.21	2.66	2.90
Marine Debris		1.84		1.94
Oil and Gas Exploration		2.37		2.92
Oil Spills	2.70	2.25	2.71	2.54
Overwater Structures	2.78	2.56	2.39	3.00
Recreational Boating	1.15	1.56	1.25	1.53
Storm and Wastewater Discharge	1.69	1.48	1.94	1.94
Submarine Pipeline Cable	2.78	2.56	2.39	3.00
Water Intake Structures	1.76	1.42	1.98	1.57

Table 4. B – Bocaccio Normalized Habitat Vulnerability Scores. Habitat vulnerability scores are calculated as weighted averages of scores from Teck et al. 2010, with weights being assigned based on habitat use data spatially overlaid with ecosystem types across defined geographic regions, abbreviated as PS – Puget Sound, and SCB – Southern California Bight.

	Larvae		Juveniles		Adults	
	PS	SCB	PS	SCB	PS	SCB
Altered Freshwater Flow	1.23	1.24	1.24	1.14	1.00	1.16
Aquaculture	1.17	1.09	1.19	1.17	1.18	1.18
Beach Nourishment		1.55		1.45		1.13
Bottom Trawling	1.82	1.82	2.23	2.34	2.81	2.68
Coastal Development	1.42	1.44	1.86	1.42	1.32	1.14
Commercial Shipping	1.67	1.00	1.09	1.08	1.23	1.12
Derelict Fishing Gear	1.86	1.75	1.76	1.82	2.09	2.14
Dredging and Disposal	1.29	1.37	1.52	1.43	1.52	1.30
Invasive Species	2.02	1.89	2.68	2.13	1.92	1.86
Marine Debris		1.63		1.81		1.69
Oil and Gas Exploration		1.89		2.62		2.96
Oil Spills	2.63	1.89	2.58	2.29	2.68	2.23
Overwater Structures	2.07	2.04	2.63	2.65	3.00	3.00
Recreational Boating	1.50	1.42	1.12	1.21	1.15	1.29
Storm and Wastewater Discharge	1.95	1.27	1.76	1.70	1.93	1.96
Submarine Pipeline Cable	2.07	2.04	2.63	2.65	3.00	3.00
Water Intake Structures	2.05	1.34	1.73	1.34	1.37	1.13

Table 4. C – English Sole Normalized Habitat Vulnerability Scores. Habitat vulnerability scores are calculated as weighted averages of scores from Teck et al. 2010, with weights being assigned based on habitat use data spatially overlaid with ecosystem types across defined geographic regions, abbreviated as PS – Puget Sound, and SCB – Southern California Bight.

	Larvae	Juveniles	Adults	
	PS	PS	PS	SCB
Altered Freshwater Flow	0.28	0.14	0.05	0.03
Aquaculture	0.27	0.25	0.24	0.20
Beach Nourishment	0.74	0.51	0.26	0.35
Bottom Trawling	1.24	1.48	1.76	1.66
Coastal Development	0.82	0.57	0.35	0.37
Commercial Shipping	0.16	0.18	0.21	0.15
Derelict Fishing Gear	0.71	0.82	1.00	0.88
Dredging and Disposal	0.82	0.69	0.57	0.50
Invasive Species	1.39	1.15	0.86	0.95
Marine Debris	0.99	0.96	0.95	0.94
Oil and Gas Exploration	1.74	1.83	1.92	1.82
Oil Spills	1.44	1.45	1.51	1.47
Overwater Structures	1.74	1.83	1.92	1.82
Recreational Boating	0.28	0.21	0.17	0.12
Storm and Wastewater Discharge	0.78	0.82	0.84	0.75
Submarine Pipeline Cable	1.74	1.83	1.92	1.82
Water Intake Structures	0.53	0.42	0.29	0.32

Table 4. D – Lingcod Normalized Habitat Vulnerability Scores. Habitat vulnerability scores are calculated as weighted averages of scores from Teck et al. 2010, with weights being assigned based on habitat use data spatially overlaid with ecosystem types across defined geographic regions, abbreviated as PS – Puget Sound, and SCB – Southern California Bight.

	Eggs		Larvae		Juveniles		Adults	
	PS	SCB	PS	SCB	PS	SCB	PS	SCB
Altered Freshwater Flow	1.20	1.46	1.30	1.27	1.01	1.05	1.17	1.34
Aquaculture	1.17	1.32	1.18	1.07	1.15	1.18	1.14	1.18
Beach Nourishment		2.05		1.44		1.45		1.27
Bottom Trawling	2.30	1.71	1.57	1.73	2.59	2.42	2.30	2.40
Coastal Development	1.86	2.17	1.20	1.34	1.52	1.44	1.80	1.23
Commercial Shipping	1.03	1.13	2.03	1.00	1.10	1.12	1.00	1.03
Derelict Fishing Gear	1.69	1.58	2.05	1.80	1.84	1.75	1.74	2.05
Dredging and Disposal	1.85	2.11	1.13	1.30	1.65	1.51	1.47	1.15
Invasive Species	2.55	2.63	1.66	1.71	2.21	2.04	2.62	2.35
Marine Debris		1.95		1.52		1.89		1.55
Oil and Gas Exploration		2.57		1.72		2.65		2.99
Oil Spills	2.58	2.30	2.62	1.72	2.59	2.35	2.57	2.19
Overwater Structures	2.93	2.57	1.74	1.90	3.00	2.66	2.65	3.00
Recreational Boating	1.19	1.41	1.72	1.50	1.11	1.13	1.04	1.33
Storm and Wastewater Discharge	1.78	1.79	2.17	1.21	1.84	1.68	1.68	2.11
Submarine Pipeline Cable	2.93	2.57	1.74	1.90	3.00	2.66	2.65	3.00
Water Intake Structures	1.50	1.58	2.26	1.28	1.38	1.36	1.62	1.18

Table 5. A – Black Rockfish Normalized Exposure-Habitat Vulnerability Scores. The standardized exposure and habitat vulnerability scores were combined, using equation 6 above, to yield the final exposure-habitat vulnerability axis scores for each species and life stage, broken down by geographic regions, abbreviated as PS – Puget Sound, and SCB – Southern California Bight.

	Juvenile		Adults	
	PS	SCB	PS	SCB
Altered Freshwater Flow	1.33	1.15	1.38	1.21
Aquaculture	1.12	1.06	1.09	1.11
Beach Nourishment		1.29		1.38
Bottom Trawling	1.62	2.52	1.63	2.42
Coastal Development	1.49	1.33	1.39	1.40
Commercial Shipping	1.00	1.53	1.14	1.75
Derelict Fishing Gear	2.15	1.55	2.03	1.55
Dredging and Disposal	1.36	1.22	1.19	1.22
Invasive Species	1.99	1.66	1.93	1.88
Marine Debris		1.60		1.50
Oil and Gas Exploration		1.54		1.71
Oil Spills	2.19	1.52	2.44	1.63
Overwater Structures	1.74	1.61	1.59	1.74
Recreational Boating	1.08	1.25	1.12	1.24
Storm and Wastewater Discharge	1.31	1.44	1.40	1.46
Submarine Pipeline Cable	1.69	1.63	1.72	1.75
Water Intake Structures	1.54	1.19	1.41	1.25

Table 5. B – Bocaccio Normalized Exposure- Habitat Vulnerability Scores. The standardized exposure and habitat vulnerability scores were combined, using equation 6 above, to yield the final exposure-habitat vulnerability axis scores for each species and life stage, broken down by geographic regions, abbreviated as PS – Puget Sound, and SCB – Southern California Bight.

	Larvae		Juveniles		Adults	
	PS	SCB	PS	SCB	PS	SCB
Altered Freshwater Flow	1.11	1.11	1.13	1.07	1.00	1.08
Aquaculture	1.08	1.04	1.09	1.08	1.09	1.09
Beach Nourishment		1.25		1.21		1.06
Bottom Trawling	1.45	1.90	1.51	2.11	1.74	1.93
Coastal Development	1.19	1.21	1.36	1.20	1.15	1.07
Commercial Shipping	2.01	1.71	1.50	1.80	1.92	1.82
Derelict Fishing Gear	1.37	1.34	1.38	1.38	1.45	1.47
Dredging and Disposal	1.14	1.18	1.23	1.20	1.24	1.14
Invasive Species	1.42	1.45	1.66	1.59	1.39	1.40
Marine Debris		1.30		1.36		1.30
Oil and Gas Exploration		1.38		1.62		1.72
Oil Spills	1.66	1.40	1.67	1.53	1.65	1.50
Overwater Structures	1.44	1.43	1.62	1.63	1.73	1.73
Recreational Boating	1.22	1.19	1.06	1.10	1.07	1.14
Storm and Wastewater Discharge	1.39	1.23	1.33	1.39	1.39	1.41
Submarine Pipeline Cable	1.47	1.45	1.63	1.65	1.77	1.74
Water Intake Structures	1.43	1.25	1.32	1.22	1.18	1.06

Table 5. C – English Sole Normalized Exposure- Habitat Vulnerability Scores. The standardized exposure and habitat vulnerability scores were combined, using equation 6 above, to yield the final exposure-habitat vulnerability axis scores for each species and life stage, broken down by geographic regions, , abbreviated as PS – Puget Sound, and SCB – Southern California Bight.

	Larvae	Juveniles	Adults	
	PS	PS	PS	SCB
Altered Freshwater Flow	1.14	1.05	1.00	1.00
Aquaculture	1.12	1.10	1.10	1.10
Beach Nourishment				1.17
Bottom Trawling	1.53	1.67	1.78	2.31
Coastal Development	1.37	1.27	1.18	1.19
Commercial Shipping	1.07	1.07	1.08	1.07
Derelict Fishing Gear	2.06	2.19	2.46	2.42
Dredging and Disposal	1.38	1.32	1.25	1.24
Invasive Species	1.56	1.48	1.37	1.43
Marine Debris				1.44
Oil and Gas Exploration				1.74
Oil Spills	1.59	1.58	1.60	1.62
Overwater Structures	1.69	1.74	1.75	1.75
Recreational Boating	1.12	1.09	1.06	1.05
Storm and Wastewater Discharge	1.37	1.35	1.36	1.34
Submarine Pipeline Cable	1.68	1.70	1.73	1.79
Water Intake Structures	0.53	0.42	0.29	0.32

Table 5. D – Lingcod Normalized Exposure- Habitat Vulnerability Scores. The standardized exposure and habitat vulnerability scores were combined, using equation 6 above, to yield the final exposure-habitat vulnerability axis scores for each species and life stage, broken down by geographic regions, abbreviated as PS – Puget Sound, and SCB – Southern California Bight.

	Eggs		Larvae		Juveniles		Adults	
	PS	SCB	PS	SCB	PS	SCB	PS	SCB
Altered Freshwater Flow	1.12	1.21	1.14	1.13	1.01	1.02	1.10	1.16
Aquaculture	1.09	1.15	1.08	1.03	1.07	1.09	1.07	1.09
Beach Nourishment		1.46		1.20		1.21		1.13
Bottom Trawling	1.52	1.31	1.38	1.66	1.69	1.98	1.54	1.68
Coastal Development	1.38	1.71	1.09	1.16	1.23	1.20	1.34	1.11
Commercial Shipping	1.66	1.84	2.45	1.49	1.81	1.57	1.54	1.57
Derelict Fishing Gear	1.34	1.26	1.43	1.35	1.39	1.33	1.38	1.47
Dredging and Disposal	1.40	1.63	1.07	1.15	1.29	1.24	1.21	1.07
Invasive Species	1.62	1.78	1.29	1.34	1.49	1.45	1.64	1.73
Marine Debris		1.98		1.24		1.38		1.25
Oil and Gas Exploration		1.60		1.31		1.63		1.73
Oil Spills	1.68	2.09	1.64	1.32	1.65	1.56	1.68	1.48
Overwater Structures	1.74	1.84	1.32	1.38	1.74	1.63	1.63	1.73
Recreational Boating	1.10	1.20	1.31	1.22	1.06	1.06	1.02	1.15
Storm and Wastewater Discharge	1.34	1.97	1.47	1.14	1.36	1.35	1.30	1.46
Submarine Pipeline Cable	1.73	1.60	1.37	1.39	1.76	1.65	1.65	1.73
Water Intake Structures	1.22	1.78	1.50	1.16	1.19	1.21	1.27	1.09

Table 6. Phase 2 Normalized Sensitivity Scores. The sensitivity scores were normalized between 1-3 across all species and life stages.

	Black Rockfish			Bocaccio			English Sole				Lingcod			
	Larvae	Juv.	Adult	Larvae	Juv.	Adult	Egg	Larvae	Juv.	Adult	Egg	Larvae	Juv.	Adult
Altered Freshwater Flow	2.00	2.25	1.25	2.00	2.25	1.25	2.00	2.00	2.25	1.25	2.00	2.00	2.25	1.25
Aquaculture	2.00	2.25	1.75	2.00	2.25	1.75	2.00	2.00	1.75	1.25	2.00	2.00	2.25	1.75
Beach Nourishment	1.50	1.75	1.75	1.50	1.75	1.75	1.50	1.50	1.75	1.75	2.75	1.50	1.75	1.75
Bottom Trawling	2.50	2.50	2.50	2.50	2.50	2.50	2.25	2.25	2.25	2.25	2.25	2.25	2.25	2.25
Coastal Development	1.50	2.25	2.25	1.50	2.25	2.25	1.50	1.50	1.75	1.75	2.50	1.50	2.25	2.25
Commercial Shipping	1.50	1.75	1.75	1.50	1.75	1.75	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
Derelict Fishing Gear	1.25	2.75	2.75	1.25	2.75	2.75	1.25	1.25	2.25	2.25	1.25	1.25	2.75	2.75
Dredging	2.50	2.50	1.50	2.50	2.50	1.50	2.50	2.50	1.75	1.25	1.50	2.50	1.50	1.50
Invasive species	2.75	2.75	2.25	2.50	2.75	2.25	2.50	2.75	2.75	2.25	2.50	2.75	2.75	2.25
Marine Debris	2.25	2.25	2.25	2.25	2.25	2.25	1.50	2.25	1.75	1.75	1.50	2.25	2.25	2.25
Oil and Gas Exploration	2.00	1.75	2.00	2.00	1.75	2.00	2.00	2.00	1.25	1.50	1.50	2.00	1.75	2.00
Oil Spills	2.50	2.50	2.25	2.50	2.50	2.25	2.50	2.50	2.50	2.25	2.50	2.50	2.50	2.25
Overwater Structures	1.50	1.75	1.75	1.50	1.75	1.75	1.50	1.50	1.25	1.25	1.50	1.50	1.75	1.75
Recreational Boating	1.50	1.75	1.75	1.50	1.75	1.75	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
Storm & Wastewater Discharge	2.50	2.25	1.75	2.50	2.25	1.75	2.50	2.50	2.25	1.75	2.50	2.50	2.25	1.75
Submarine Cable Pipeline	1.50	2.25	2.25	1.50	2.25	2.25	1.50	1.50	1.75	1.75	2.00	1.50	2.25	2.25
Water Intake Structures	2.50	1.75	1.25	2.50	1.75	1.25	2.50	2.50	1.75	1.25	1.50	2.50	1.75	1.25

Table 7. A – Phase 2 Black Rockfish Risk Scores. The risk scores for each species were calculated from the normalized exposure-habitat vulnerability and sensitivity scores, using equation 1 above. Scores were calculated by life stage and geographic regions, which are abbreviated as PS – Puget Sound, and SCB – Southern California Bight.

	Juvenile		Adults	
	PS	SCB	PS	SCB
Altered Freshwater Flow	1.37	1.34	0.38	0.21
Aquaculture	1.34	1.33	0.67	0.68
Beach Nourishment		0.73		0.77
Bottom Trawling	1.78	2.26	1.78	2.19
Coastal Development	1.42	1.37	1.39	1.39
Commercial Shipping	0.67	0.85	0.68	1.00
Derelict Fishing Gear	2.31	2.07	2.25	2.07
Dredging and Disposal	1.71	1.68	0.39	0.40
Invasive Species	2.23	2.11	1.63	1.60
Marine Debris		1.46		1.43
Oil and Gas Exploration		0.86		1.23
Oil Spills	2.05	1.75	1.96	1.47
Overwater Structures	1.00	0.90	0.89	0.99
Recreational Boating	0.67	0.71	0.68	0.71
Storm and Wastewater Discharge	1.37	1.40	0.78	0.81
Submarine Pipeline Cable	1.50	1.47	1.52	1.53
Water Intake Structures	0.86	0.69	0.41	0.25

Table 7. B – Phase 2 Bocaccio Risk Scores. The risk scores for each species were calculated from the normalized exposure-habitat vulnerability and sensitivity scores, using equation 1 above. Scores were calculated by life stage and geographic regions, which are abbreviated as PS – Puget Sound, and SCB – Southern California Bight.

	Larvae		Juveniles		Adults	
	PS	SCB	PS	SCB	PS	SCB
Altered Freshwater Flow	1.01	1.01	1.34	1.34	0.00	0.08
Aquaculture	1.00	1.00	1.34	1.34	0.67	0.67
Beach Nourishment		0.41		0.70		0.67
Bottom Trawling	1.73	1.89	1.74	2.00	1.83	1.91
Coastal Development	0.39	0.39	1.38	1.35	1.34	1.34
Commercial Shipping	1.07	0.79	0.83	1.04	1.13	1.06
Derelict Fishing Gear	0.37	0.34	2.04	2.04	2.05	2.05
Dredging and Disposal	1.67	1.68	1.68	1.68	0.41	0.36
Invasive Species	1.72	1.73	2.11	2.08	1.39	1.39
Marine Debris		1.37		1.38		1.37
Oil and Gas Exploration		1.07		0.91		1.23
Oil Spills	1.79	1.72	1.80	1.75	1.49	1.42
Overwater Structures	0.55	0.55	0.91	0.92	0.99	0.99
Recreational Boating	0.40	0.38	0.67	0.67	0.67	0.68
Storm and Wastewater Discharge	1.71	1.68	1.37	1.39	0.77	0.78
Submarine Pipeline Cable	0.57	0.56	1.48	1.48	1.54	1.53
Water Intake Structures	1.72	1.68	0.74	0.70	0.18	0.06

Table 7. C – Phase 2 English Sole Risk Scores. The risk scores for each species were calculated from the normalized exposure-habitat vulnerability and sensitivity scores, using equation 1 above. Scores were calculated by life stage and geographic regions, which are abbreviated as PS – Puget Sound, and SCB – Southern California Bight.

	Larvae	Juveniles	Adults	
	PS	PS	PS	SCB
Altered Freshwater Flow	1.01	1.33	0.00	0.00
Aquaculture	1.01	0.67	0.10	0.10
Beach Nourishment				0.69
Bottom Trawling	1.43	1.49	1.54	1.87
Coastal Development	0.50	0.72	0.69	0.69
Commercial Shipping	0.34	0.34	0.34	0.34
Derelict Fishing Gear	1.06	1.79	1.98	1.95
Dredging and Disposal	1.71	0.74	0.25	0.24
Invasive Species	2.08	2.06	1.38	1.40
Marine Debris				0.80
Oil and Gas Exploration				0.81
Oil Spills	1.77	1.77	1.46	1.47
Overwater Structures	0.77	0.74	0.75	0.75
Recreational Boating	0.35	0.34	0.34	0.34
Storm and Wastewater Discharge	1.71	1.38	0.76	0.75
Submarine Pipeline Cable	0.75	0.97	0.99	1.03
Water Intake Structures	1.68	0.69	0.14	0.17

Table 7. D – Phase 2 Lingcod Risk Scores. The risk scores for each species were calculated from the normalized exposure-habitat vulnerability and sensitivity scores, using equation 1 above. Scores were calculated by life stage and geographic regions, which are abbreviated as PS – Puget Sound, and SCB – Southern California Bight.

	Eggs		Larvae		Juveniles		Adults	
	PS	SCB	PS	SCB	PS	SCB	PS	SCB
Altered Freshwater Flow	1.01	1.02	1.01	1.01	1.33	1.33	0.10	0.16
Aquaculture	1.00	1.01	1.00	1.00	1.34	1.34	0.67	0.67
Beach Nourishment		2.05		0.39		0.70		0.68
Bottom Trawling	1.43	1.37	1.39	1.49	1.50	1.65	1.44	1.49
Coastal Development	1.71	1.81	0.35	0.37	1.35	1.35	1.38	1.34
Commercial Shipping	0.74	0.90	1.49	0.59	0.88	0.66	0.64	0.66
Derelict Fishing Gear	0.34	0.26	0.43	0.35	2.04	2.03	2.04	2.05
Dredging and Disposal	0.52	0.71	1.67	1.67	0.44	0.41	0.40	0.34
Invasive Species	1.78	1.84	2.02	2.03	2.06	2.05	1.48	1.52
Marine Debris		1.03		1.35		1.39		1.36
Oil and Gas Exploration		0.69		1.05		0.92		1.24
Oil Spills	1.80	1.99	1.79	1.70	1.79	1.76	1.50	1.42
Overwater Structures	0.81	0.90	0.46	0.50	0.99	0.92	0.92	0.99
Recreational Boating	0.35	0.39	0.46	0.40	0.34	0.34	0.33	0.37
Storm and Wastewater Discharge	1.70	1.93	1.73	1.67	1.38	1.38	0.73	0.81
Submarine Pipeline Cable	1.24	1.17	0.50	0.51	1.54	1.48	1.48	1.52
Water Intake Structures	0.40	0.85	1.74	1.67	0.69	0.70	0.27	0.09

Table 8. Phase 2 Combined Species Risk Scores. The combined species risk scores are weighted means of risk scores for each life stage, with life stage weights assigned based on AEQ values from life-cycle models (see section 2.2.3 for details). Species level risk scores were calculated for each geographic region, which are abbreviated as PS – Puget Sound, and SCB – Southern California Bight.

	Black Rockfish		Bocaccio		English Sole		Lingcod	
	PS	SCB	PS	SCB	PS	SCB	PS	SCB
Altered Freshwater Flow	0.87	0.77	0.23	0.30	0.04	0.00	0.14	0.19
Aquaculture	1.00	1.00	0.79	0.79	0.12	0.09	0.69	0.69
Beach Nourishment		0.75		0.67		0.67		0.68
Bottom Trawling	1.78	2.22	1.81	1.93	1.54	1.82	1.44	1.50
Coastal Development	1.40	1.38	1.35	1.34	0.69	0.67	1.37	1.34
Commercial Shipping	0.67	0.93	1.08	1.05	0.34	0.33	0.64	0.66
Derelict Fishing Gear	2.28	2.07	2.05	2.05	1.97	1.89	2.03	2.05
Dredging and Disposal	1.04	1.04	0.63	0.59	0.27	0.24	0.40	0.34
Invasive Species	1.93	1.85	1.51	1.51	1.40	1.36	1.50	1.54
Marine Debris		1.44		1.37		0.78		1.36
Oil and Gas Exploration		1.04		1.18		0.79		1.23
Oil Spills	2.00	1.61	1.54	1.48	1.47	1.43	1.50	1.43
Overwater Structures	0.94	0.95	0.98	0.98	0.75	0.73	0.92	0.99
Recreational Boating	0.67	0.71	0.67	0.68	0.34	0.33	0.33	0.37
Storm and Wastewater Discharge	1.07	1.11	0.88	0.89	0.78	0.73	0.75	0.83
Submarine Pipeline Cable	1.51	1.50	1.53	1.52	0.99	1.01	1.48	1.52
Water Intake Structures	0.63	0.47	0.28	0.17	0.15	0.17	0.29	0.11

Appendix H. Phase 2 Data Source Details

Table 1. Data details for anthropogenic drivers that were new in the Phase II analysis.

Anthropogenic Driver	Brief description of dataset	Source	Native resolution	Region
Altered freshwater input	Difference between natural flow and gauge flow from NHD Plus V2	USGS	Point, converted to 30 m^2	PS; SCB
	Water flow estimated at sub-watershed level as part of Puget Sound watershed characterization	DOE	Sub-watershed level, modeled to 30 m^2	PS
Aquaculture	Commercial shellfish harvest sites	WA DOH	Point, converted to 30 m^2	PS
	Fish net pens	WA DOE	Point, converted to 30 m^2	PS
	Areas managed for aquaculture in California	CDFW	Polygon, converted to 30 m^2	SCB
	Aquaculture sites identified in EFH consultations	NOAA	Point, converted to 30 m^2	SCB
Beach nourishment	Beach nourishment history for the California coastline (1920-2000)	CSWG	Polygon, converted to 30 m^2	SCB
	Beach placement area	US ACE	Polygon, converted to 30 m^2	SCB
Bottom trawling	Bottom trawl fishing intensity (modeled from PacFin data)	OSU; PSMFC	Polygon, converted to 30 m^2	PS; SCB
Coastal development	Urban growth areas	WA DOE	Polygon, converted to 30 m^2	PS
	Impervious surface areas (>50% impervious)	PSNERP	Polygon, converted to 30 m^2	PS
	Shoreline armoring	WA DNR	Polyline, converted to 30 m^2	PS
	Urban areas	US Census	Polygon, converted to 30 m^2	SCB
	Coastal armoring	CCC	Polygon, converted to 30 m^2	SCB
	Coastal structures and barriers (man-made structures and natural coastal barriers that have the	CSWG	Polygon, converted to 30 m^2	SCB

	potential to retain sandy beach area, piers removed)			
	Impervious surface areas	NLCD	Polygon, converted to 30 m^2	SCB
Commercial shipping	Density of commercial vessel tracks	USCG	1km, scaled down to 30 m^2	PS; SCB
Derelict fishing gear	Derelict fishing gear removed	WCODP	Point, modeled to 30 m^2	PS; SCB
Dredging and Disposal	Ocean disposal sites	US ACE	Polygon, converted to 30 m^2	PS; SCB
	Dredge and fill sites	NOAA	Polygon, converted to 30 m^2	SCB
In-water structures	Overwater structures mapped from aerial photographs	WA DNR	Polygon, converted to 30 m^2	PS
	Coastal structures and barriers - piers	CSWG	Polygon, converted to 30 m^2	SCB
	Overwater structures	NOAA	Polygon, converted to 30 m^2	SCB
	Docks, piers, and bridges identified in EFH consultations	NOAA	Point, converted to 30 m^2	SCB
Marine debris	Coastline trash removed by annual beach cleanup	CCC	County level, modeled to 30 m^2	SCB
Oil spills	Spill incidents (oil)	OSPR	Point, modeled to 30 m^2	PS
	Oil spill incidents	PSOSTF	Point, modeled to 30 m^2	PS; SCB
	DARRP Case Locations	NOAA	Point, modeled to 30 m^2	PS; SCB
Recreational boating	Marinas	PSNERP; CDFW	Point, converted to 30 m^2	PS; SCB
	State boat launch sites	RCO; CDFW	Point, converted to 30 m^2	PS; SCB
	Water access sites	WDFW	Point, converted to 30 m^2	PS
Species invasion	Tunicate and spartina observations	ISC	Point, modeled to 30 m^2	PS
	Invasive species observations	USGS	Point, modeled to 30 m^2	PS
	Sargassum observations	WA DNR	Point, modeled to 30 m^2	PS
	Invasive species presence on overwater structures	NOAA	Polygon, converted to 30 m^2	SCB
	Sargassum observations	NOAA; OSU	Point, modeled to 30 m^2	SCB
	Active outfalls from PARIS database	WA DOE	Point, converted to 30 m^2	PS

	Combined sewer overflows	People for Puget Sound	Point, converted to 30 m^2	PS
	Man-made outfalls	People for Puget Sound	Point, converted to 30 m^2	PS
Storm and wastewater discharge	Minor discharge points	CDFW	Point, converted to 30 m^2	SCB
	Intermediate discharge area	CDFW	Polygon, converted to 30 m^2	SCB
	Major wastewater discharge area	CDFW	Polygon, converted to 30 m^2	SCB
	Major storm water discharge area	CDFW	Polygon, converted to 30 m^2	SCB
Submarine pipeline/cable installation	Submarine cables	WCODP	Line, converted to 30 m^2	PS; SCB
	Pipelines, outfall pipes and diffusers	CDFW	Line, converted to 30 m^2	SCB
Water intake structures	Power plant entrainment area	CDFW	Polygon, converted to 30 m^2	SCB

Appendix I. Phase 2 Stressor Data References

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Appendix J. Risk Plots with Stressor Prioritization Highlighted

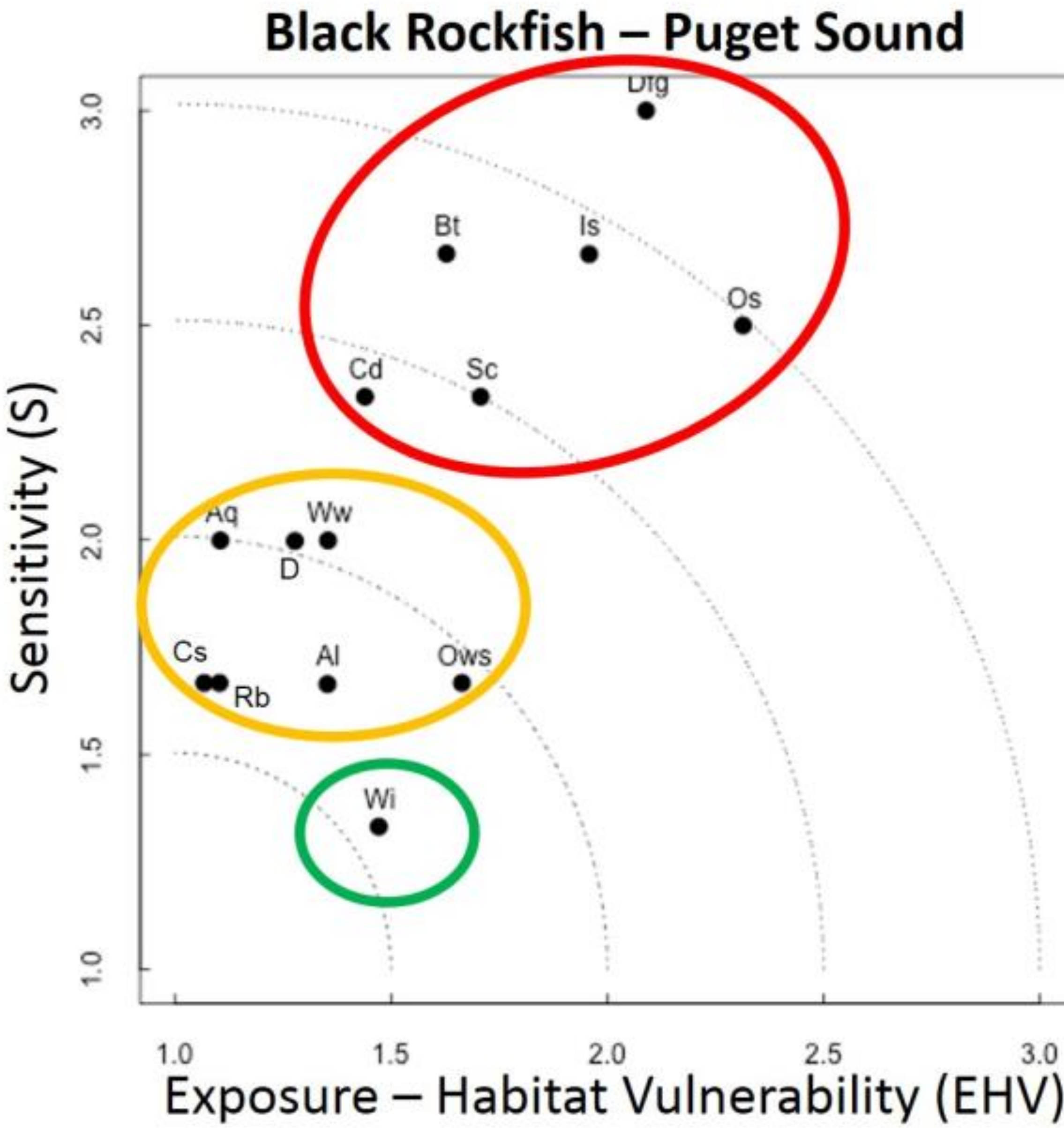

Figure 1. Phase 2 Black rockfish risk scores plotted by sensitivity and EHV by geographic region (PS = Puget Sound, SCB = Southern California Bight). Letters indicate the stressor (Al = Altered Freshwater Flow, Aq = Aquaculture, Bn = Beach Nourishment, Bt = Bottom Trawling, Cd = Coastal Development, Cs = Commercial Shipping, Dfg = Derelict Fishing Gear, D = Dredging & Disposal, Is = Invasive Species, Md = Marine Debris, Og = Oil and Gas Exploration, Os = Oil Spills, Ows = Over Water Structures, Rb = Recreational Boating, Ww = Storm and Wastewater Discharge, Sc = Submarine Cables and Pipelines, Wi = Water Intake Structures). Color circles indicate the prioritization level, red = high, yellow = medium, and green = low.

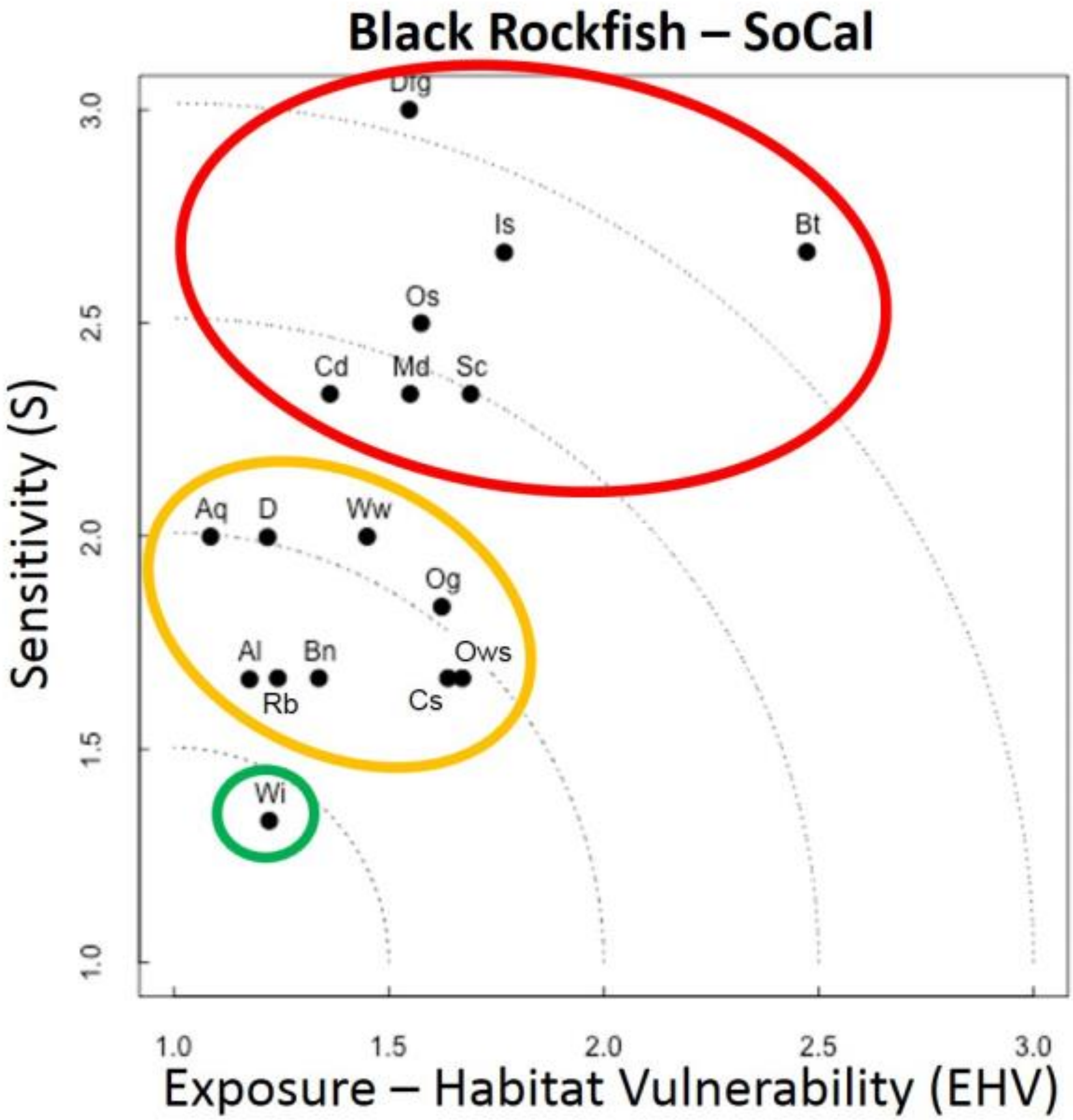

Figure 2. Phase 2 Black rockfish risk scores plotted by sensitivity and EHV by geographic region (PS = Puget Sound, SCB = Southern California Bight). Letters indicate the stressor (Al = Altered Freshwater Flow, Aq = Aquaculture, Bn = Beach Nourishment, Bt = Bottom Trawling, Cd = Coastal Development, Cs = Commercial Shipping, Dfg = Derelict Fishing Gear, D = Dredging & Disposal, Is = Invasive Species, Md = Marine Debris, Og = Oil and Gas Exploration, Os = Oil Spills, Ows = Over Water Structures, Rb = Recreational Boating, Ww = Storm and Wastewater Discharge, Sc = Submarine Cables and Pipelines, Wi = Water Intake Structures). Color circles indicate the prioritization level, red = high, yellow = medium, and green = low.

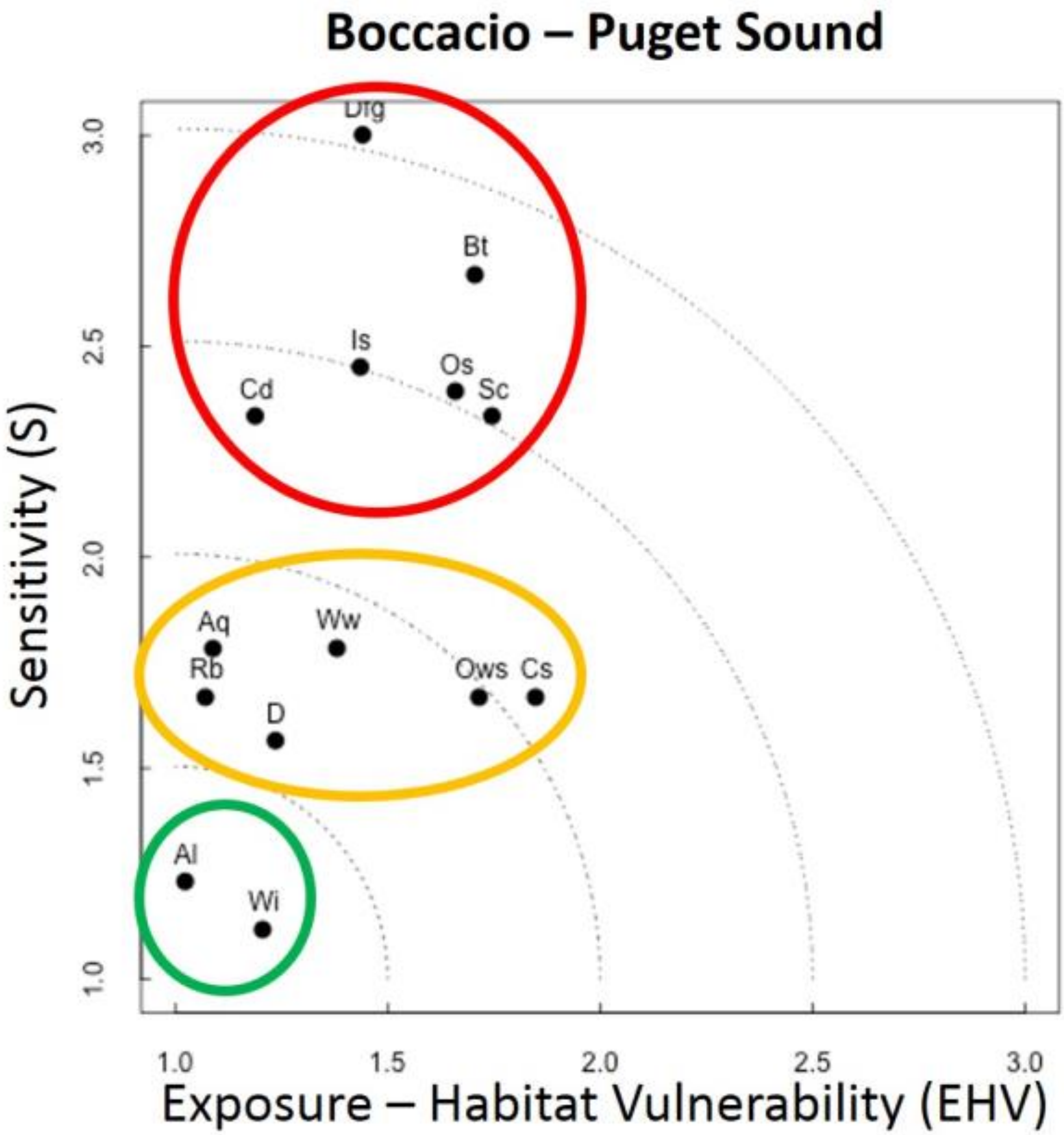

Figure 3. Phase 2 Bocaccio risk scores plotted by sensitivity and EHV by geographic region (PS = Puget Sound, SCB = Southern California Bight). Letters indicate the stressor (Al = Altered Freshwater Flow, Aq = Aquaculture, Bn = Beach Nourishment, Bt = Bottom Trawling, Cd = Coastal Development, Cs = Commercial Shipping, Dfg = Derelict Fishing Gear, D = Dredging & Disposal, Is = Invasive Species, Md = Marine Debris, Og = Oil and Gas Exploration, Os = Oil Spills, Ows = Over Water Structures, Rb = Recreational Boating, Ww = Storm and Wastewater Discharge, Sc = Submarine Cables and Pipelines, Wi = Water Intake Structures). Color circles indicate the prioritization level, red = high, yellow = medium, and green = low.

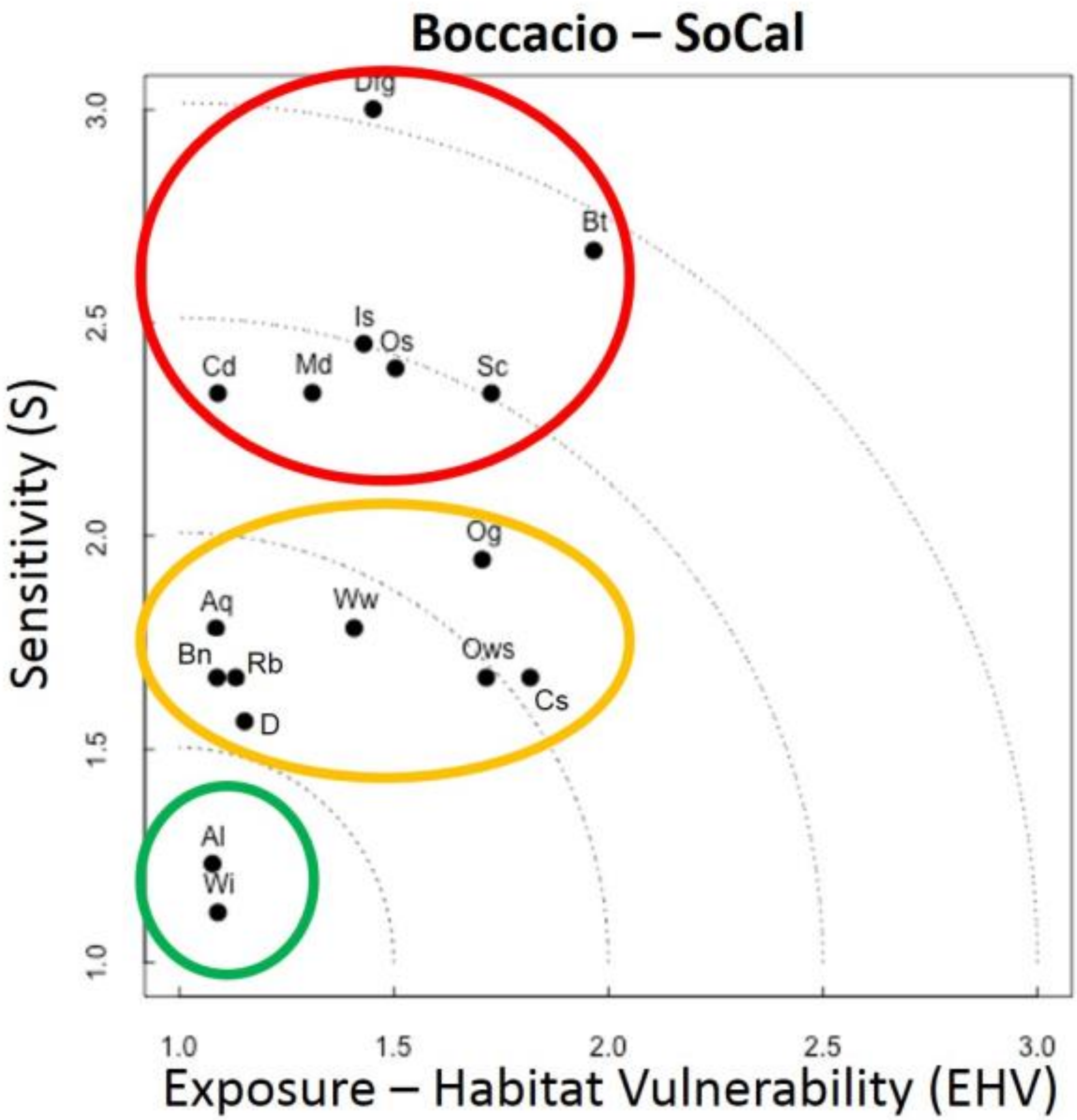

Figure 4. Phase 2 Bocaccio risk scores plotted by sensitivity and EHV by geographic region (PS = Puget Sound, SCB = Southern California Bight). Letters indicate the stressor (Al = Altered Freshwater Flow, Aq = Aquaculture, Bn = Beach Nourishment, Bt = Bottom Trawling, Cd = Coastal Development, Cs = Commercial Shipping, Dfg = Derelict Fishing Gear, D = Dredging & Disposal, Is = Invasive Species, Md = Marine Debris, Og = Oil and Gas Exploration, Os = Oil Spills, Ows = Over Water Structures, Rb = Recreational Boating, Ww = Storm and Wastewater Discharge, Sc = Submarine Cables and Pipelines, Wi = Water Intake Structures). Color circles indicate the prioritization level, red = high, yellow = medium, and green = low.

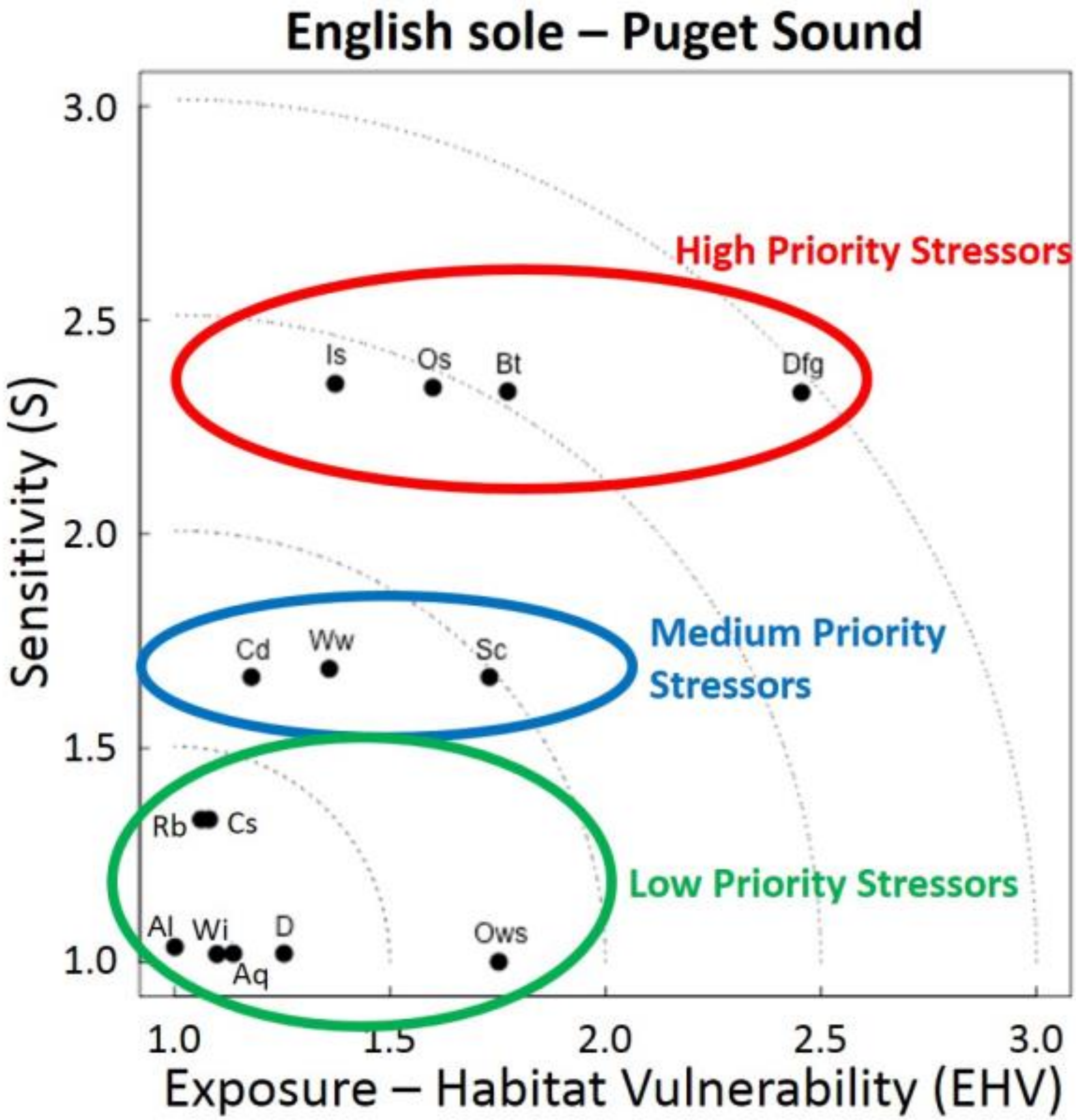

Figure 5. Phase 2 English sole risk scores plotted by sensitivity and EHV by geographic region (PS = Puget Sound, SCB = Southern California Bight). Letters indicate the stressor (Al = Altered Freshwater Flow, Aq = Aquaculture, Bn = Beach Nourishment, Bt = Bottom Trawling, Cd = Coastal Development, Cs = Commercial Shipping, Dfg = Derelict Fishing Gear, D = Dredging & Disposal, Is = Invasive Species, Md = Marine Debris, Og = Oil and Gas Exploration, Os = Oil Spills, Ows = Over Water Structures, Rb = Recreational Boating, Ww = Storm and Wastewater Discharge, Sc = Submarine Cables and Pipelines, Wi = Water Intake Structures). Color circles indicate the prioritization level, red = high, yellow = medium, and green = low.

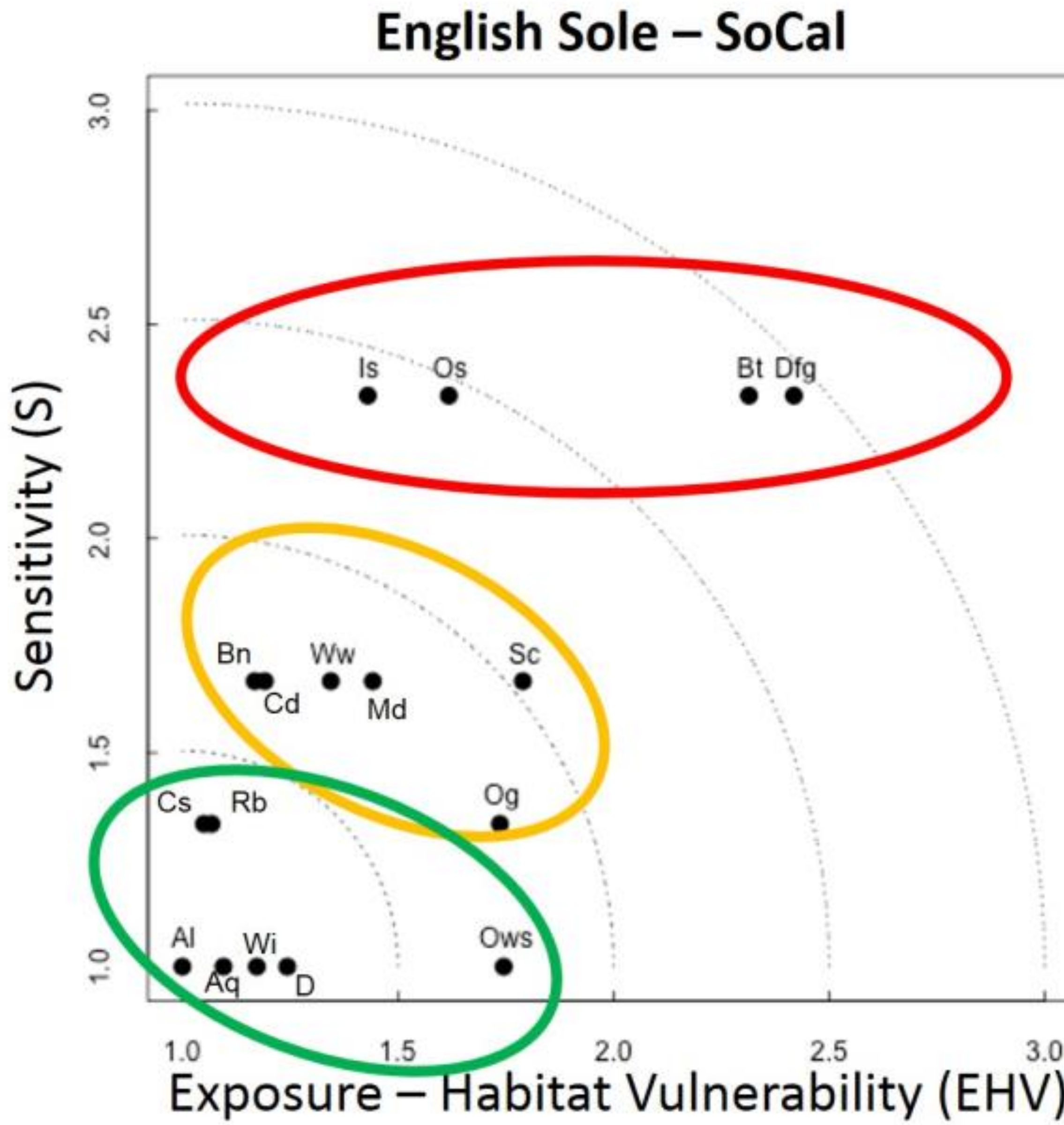

Figure 6. Phase 2 English sole risk scores plotted by sensitivity and EHV by geographic region (PS = Puget Sound, SCB = Southern California Bight). Letters indicate the stressor (Al = Altered Freshwater Flow, Aq = Aquaculture, Bn = Beach Nourishment, Bt = Bottom Trawling, Cd = Coastal Development, Cs = Commercial Shipping, Dfg = Derelict Fishing Gear, D = Dredging & Disposal, Is = Invasive Species, Md = Marine Debris, Og = Oil and Gas Exploration, Os = Oil Spills, Ows = Over Water Structures, Rb = Recreational Boating, Ww = Storm and Wastewater Discharge, Sc = Submarine Cables and Pipelines, Wi = Water Intake Structures). Color circles indicate the prioritization level, red = high, yellow = medium, and green = low.

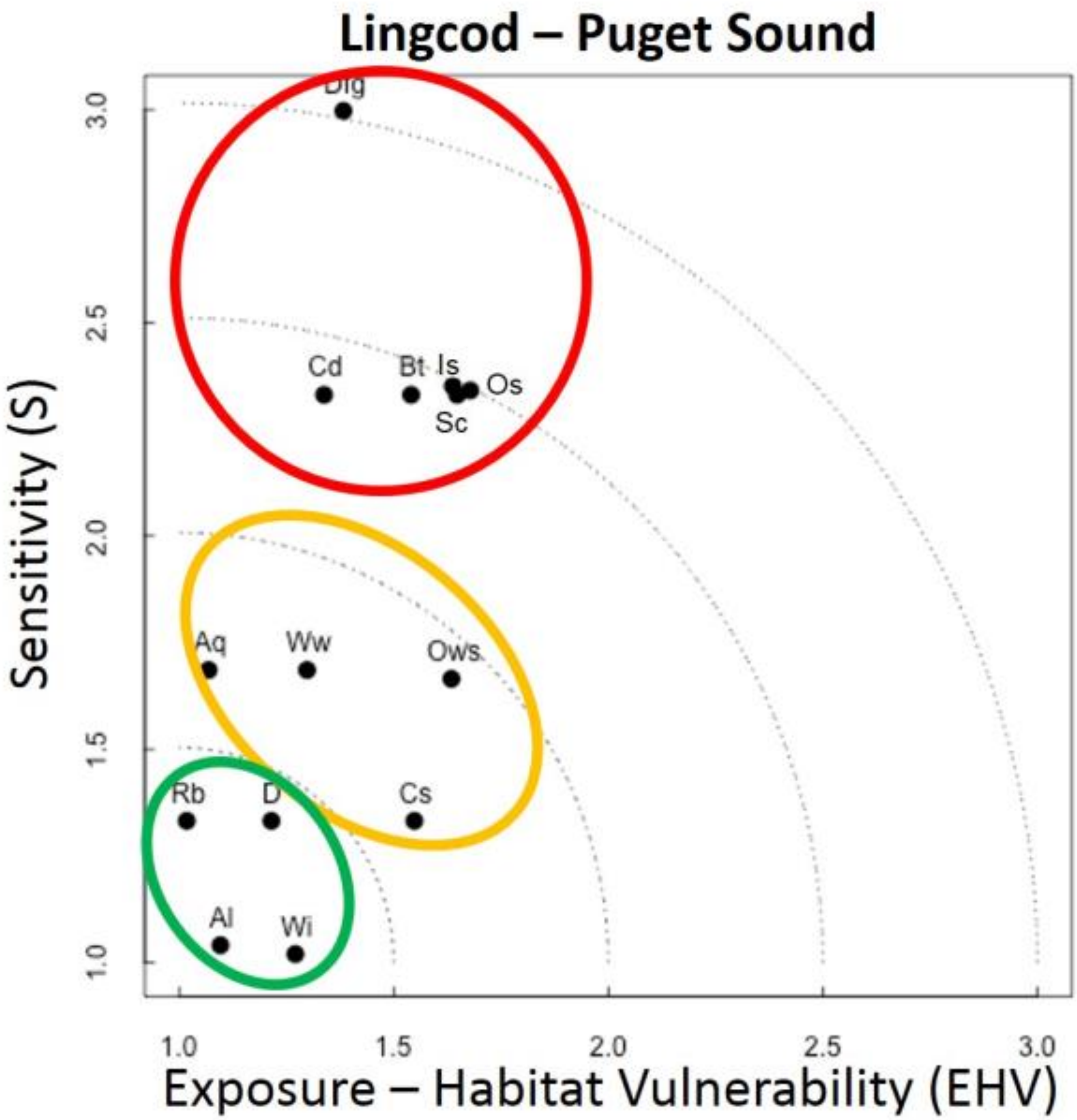

Figure 7. Phase 2 Lingcod risk scores plotted by sensitivity and EHV by geographic region (PS = Puget Sound, SCB = Southern California Bight). Letters indicate the stressor (Al = Altered Freshwater Flow, Aq = Aquaculture, Bn = Beach Nourishment, Bt = Bottom Trawling, Cd = Coastal Development, Cs = Commercial Shipping, Dfg = Derelict Fishing Gear, D = Dredging & Disposal, Is = Invasive Species, Md = Marine Debris, Og = Oil and Gas Exploration, Os = Oil Spills, Ows = Over Water Structures, Rb = Recreational Boating, Ww = Storm and Wastewater Discharge, Sc = Submarine Cables and Pipelines, Wi = Water Intake Structures). Color circles indicate the prioritization level, red = high, yellow = medium, and green = low.

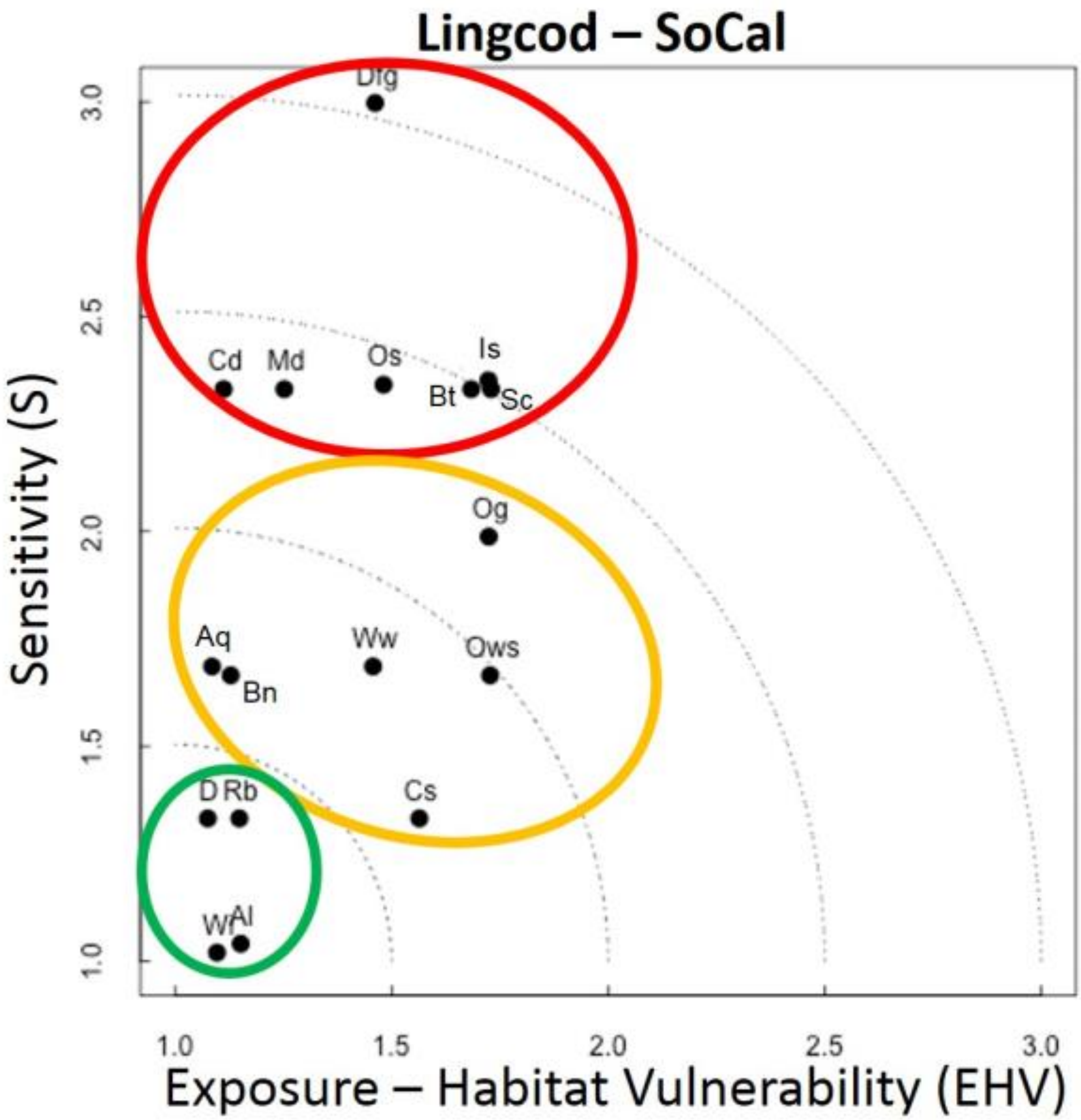

Figure 8. Phase 2 Lingcod risk scores plotted by sensitivity and EHV by geographic region (PS = Puget Sound, SCB = Southern California Bight). Letters indicate the stressor (Al = Altered Freshwater Flow, Aq = Aquaculture, Bn = Beach Nourishment, Bt = Bottom Trawling, Cd = Coastal Development, Cs = Commercial Shipping, Dfg = Derelict Fishing Gear, D = Dredging & Disposal, Is = Invasive Species, Md = Marine Debris, Og = Oil and Gas Exploration, Os = Oil Spills, Ows = Over Water Structures, Rb = Recreational Boating, Ww = Storm and Wastewater Discharge, Sc = Submarine Cables and Pipelines, Wi = Water Intake Structures). Color circles indicate the prioritization level, red = high, yellow = medium, and green = low.

Appendix K. Life cycle model parameters

Table 1. Parameterization of life history transitions in the Salmon River coho salmon model. Numbered transitions correspond to numbered transitions in the life cycle diagram (Fig. 29, repeated below)

Transition #	Life-Stage Transition	Code	Functional Form	Movement	Survival	Capacity	Environmetal variability	Notes and Data Sources
1	Egg-to-Fry	fry[] <- eggs[]	Survival = Constant	NA	EGGS = 0.35	NA	NA	Table 1 Nickelson 1998 Salmon River (2015).xls
2	Fry --> Age-0 FW Summer Parr	FW.1['total'] <- age0_summerFxn(fry[])	Density Dependent	NA	(1) prod.2_3 = 0.45	***(2) Spring_cap = 428,749***	NA	(1), (2) Table 1 Nickelson 1998 Salmon River (2015).xls
3	Fry --> Age-0 Estuary Migrant	Est.1['total'] <- fry[]	(1) Movement = f(Egg Density + Flow); (2) Survival = Density Dependent	log(fry-at-trap/eggs) ~ log(eggs.km) + log(fry.flow)	**(2) Est0.surv/10 = 0.066**	***(3) estCap = 20,000***	(1) Flow: temporal but no spatial autocorrelation (i.e. bad/good years are bad/good for all reaches regardless of how close they are to each other)	(1) Fry movement is a function of flow and egg density estimated from downstream migrant traps in 10 coastal OR coho basins between 1987 and 2015. (2) Estuary survival is a guess. (3) Estuary capacity from expert elicitation and habitat mapping
4	Age-0 FW Summer Parr --> Age-0 FW Winter Parr	FW.2['yearling'] <- FW.1['total']	Density Dependent Survival	NA	(1) SUMMER = 0.71	***(2) Summer_cap = 47,168***	NA	(1), (2) Table 1 Nickelson 1998 Salmon River (2015).xls
5	Age-0 Estuary Migrant --> Age-0 FW Winter Parr Nomad	FW.2['nomad'] <- f(Est.1['total'], FW.2['yearling']	(1) Movement = Density Dependent; (2) Survival = Density Dependent	A proportion trans.5 = 0.5 will move from the Estuary back upstream if SUMMER capacity is available after accounting for Age-0 FW Winter Parr (FW.2['yearling'])	(1) SUMMER = 0.71	***(2) Summer_cap = 47,168***	NA	(1), (2) Table 1 Nickelson 1998 Salmon River (2015).xls
6	Age-0 FW Summer Parr --> Age-0 Estuary Winter	Est.2['parr'] <- FW.1['total'] - FW.2['yearling]	(1) Movement = Density Dependent; (2) Survival = Density Dependent	Density dependent migration to estuary as SUMMER capacity is approached; number that take up residence in estuary is limited by estuary capacity and includes Estuary Migrants	**(1) Est0.surv/10 = 0.066**	***(2) estCap = 20,000***	NA	(1) Estuary survival is a guess. (2) Estuary capacity from expert elicitation and habitat mapping
7	Age-0 Estuary Summer --> Age-0 Estuary Winter	Est.2['fry'] <- Est.1['total']	Survival = Constant	NA	**(1) Est0.surv/10 = 0.066**	***(2) estCap = 20,000***	NA	(1) Estuary survival is a guess. (2) Estuary capacity from expert elicitation and habitat mapping
8	Age-0 FW Summer --> Age-0 Marine Winter	NA	NA	NA	NA	NA	NA	Life history trajectory not currently considered
9	Age-0 FW Winter --> Age-1 FW Summer	NA	NA	NA	NA	NA	NA	Life history trajectory not currently considered
10	Age-0 FW Winter --> Age-1 Marine	Mar.1['yearling','nomad'] <- FW.2['yearling', 'nomad']	Survival = Density Dependent	NA	(1) WINTER = 0.90	***(2) Winter_cap = 72,416***	NA	(1), (2) Table 1 Nickelson 1998 Salmon River (2015).xls
11	Age-0 Estuary Winter --> Age-1 Marine	Mar.1['fry','parr'] <- Est.2['fry','parr']	Movement = f(Egg Density + Flow); Survival = Density Dependent	log(smolts/fry) ~ log(eggs.km) + log(egg.flow)	**(1) Est0.surv = 0.66**	***(2) estCap = 20,000***	(1) Flow: temporal but no spatial autocorrelation (i.e. bad/good years are bad/good for all reaches regardless of how close they are to each other)	(1) Fry movement is a function of flow and egg density estimated from downstream migrant traps in 10 coastal OR coho basins between 1987 and 2015. (2), (3) Table 1 Nickelson 1998 Salmon River (2015).xls
12	Age-1 Summer --> Age-1 Winter	NA	NA	NA	NA	NA	NA	Life history trajectory not currently considered
13	Age-1 Winter --> Age-2 Marine	NA	NA	NA	NA	NA	NA	Life history trajectory not currently considered
14	Age-0 Marine --> Age-1 Marine	NA	NA	NA	NA	NA	NA	Life history trajectory not currently considered
15	Age-1 Marine --> Age-2 Marine	Mar.2['yearling', 'nomad','fry','parr'] <- Mar.1['yearling', 'nomad','fry','parr']	Survival = Constant + Env. Stocasticity	NA	lht_mar: yearling = 0.068, nomad = 0.024, fry = 0.199, parr = 0.373	NA	rnorm(mean = lht_mar, sd = lht_mar *1.1)	June to Adult survival based from "Salmon River modeling results final.xls".
16	Age-2 Marine --> Age-3 Marine	Mar.3[] <- Mar.2[]	NA	NA	1	NA	NA	Age 2 marine survival assumed to be 1 for convenience
17	Age-2 Marine --> Age-2 Spawner	Sp.2[] <- Mar.2[]	NA	NA	0	NA	NA	No Age 2 spawners for convenience
18	Age-3 Marine --> Age-3 Spawner	Sp.3[] <- Mar.3[]	(1) Movement = Constant; (2) Survival = Constant	A constant proporiton of fish [**(1) straying = 0.1**] from each population stray into a non-natal reach	A constant proportion of fish [(2) harvest = 0.15] from each population are harvested	NA	NA	(1) arbitrary stray rate; (2) harvest rate approximates PFMC harvest controls
19	Age-2 Spawner --> Eggs	NA	NA	NA	NA	NA	NA	Age-2 spawners not considered
20	Age-3 Spawner --> Eggs	eggs[] <- Sp.3[]	Reproductive Success = Density Dependent	NA	(1) fec3 = 2500 eggs/female	(2) Spawning_cap = 17,814,186	NA	(1) Nickelson & Lawson 1998; (2) Table 1 Nickelson 1998 Salmon River (2015).xls

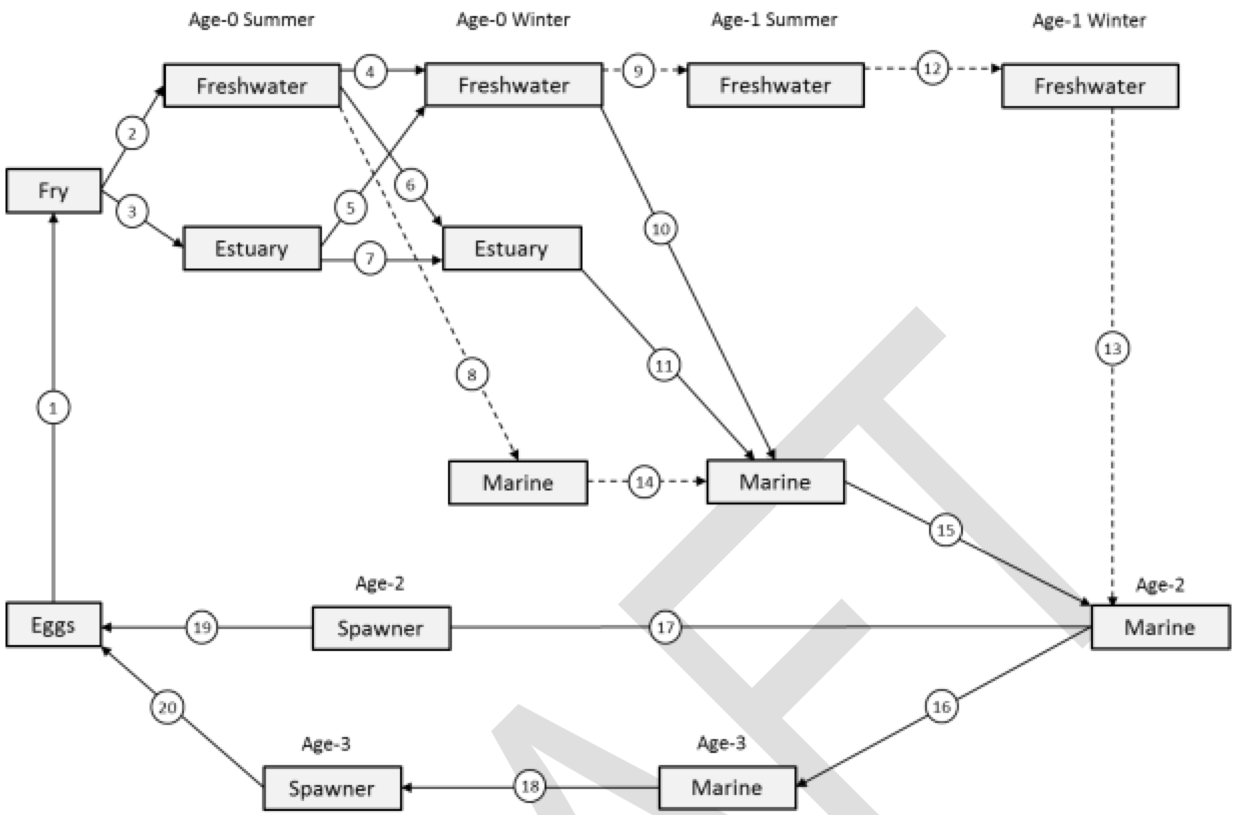

Figure 2. Conceptual life history pathways of Coho salmon populations. Habitat specific life-stages are indicated by boxes and arrows indicate transitions between stages. Numbered circles correspond to the unique function that describes each stage transition. The recovery plan for the Southern Oregon/Northern California Coast ESU of coho salmon includes an additional two life-history types indicated here by a dashed line: sub-yearling that migrate to sea in the fall of their age-0 year and stream-type that migrate to sea at age-2.