Gulf of Alaska Climate Vulnerability Assessment Scoring: Sensitivity Attributes

Participation Timeline

Thank you again for participating in the scoring process for our climate vulnerability assessment! Here is the expected timeline for your participation in the CVA scoring process:

Activity	Format	Proposed Dates
Introductory session	Webinar (recorded)	December 16, 2025
Individual scoring period	Asynchronous	December 17, 2025 – Early January
Deadline for individual scores	Email	One week before scoring workshop
Group workshops	Hybrid / Zoom	3-hour time blocks scheduled in late January and February

Sensitivity Attributes

In our climate vulnerability assessment (CVA) for the Gulf of Alaska, our definition of "vulnerability" is composed of sensitivity and exposure (Fig. 1). Each component is scored on a spectrum from "low" to "very high" to create sensitivity and exposure scores that we combine for species-specific vulnerability. Here, we are focusing on the "sensitivity" component.

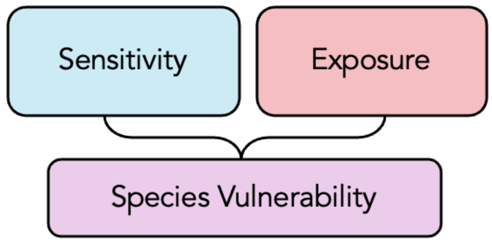

Figure 1: Framework used in the climate vulnerability assessment for the Gulf of Alaska.

The sensitivity component of this CVA is composed of biological attributes that are believed to be indicative of the response that a stock will have to potential changes in climate. Sensitivity includes attributes that describe the stock's resilience (the ability of a stock to survive and recover from a perturbation) and its adaptive capacity (the ability of a stock to adapt, reduce, or mitigate the consequences through evolutionary changes and plastic ecological responses) (Williams *et al.*, 2008).

For each sensitivity attribute, this document provides definitions, links to climate change, guiding questions (which translate directly into guidance for species profiles), and scoring categories. The term "stock" has been used throughout this document, however, where appropriate, it can be replaced by "species" if stock-level information is unavailable.

Sensitivity Scoring Process

To score a species, you need three pieces of information:

1) A species profile.
2) Scoring guidelines for each sensitivity attribute.
3) A scoring sheet where you will input your scores for each species.

1. *Species profiles*

Scorers will review species profiles, which are literature reviews that summarize species-specific information corresponding to each sensitivity attribute. When possible, these profiles provide stock-level information specific to the Gulf of Alaska. For data-limited species, information is included from other regions, at the species level, or even from a related species or taxonomic group. Species profiles provide the information you need to score each sensitivity attribute for each species

Species profiles are in table format. Please pay attention to the first three columns:

- **Column A:** Attribute. This column includes a specific sensitivity attribute.
- **Column B**: Questions. This column includes the guiding question(s) used for the corresponding sensitivity attribute.
- **Column C:** Data. This is the most important column, where all the information relevant to the question(s) in Column B is included. This information is what you use to score the sensitivity attribute for each species.
- **Columns D and E**: Level of Analysis and Region. These tell you about the specificity of the data: whether the information is about the stock in the GOA, species, a related species or broader functional group (e.g., rockfish). If the information is at the stock level, the region in Column E will be "GOA," otherwise the region could include the Bering Sea (BS), Aleutian Islands (AI), California Current (CCLME), Arctic, other region outside of the Northeast Pacific, or a combination of these. This might also indicate if the data is from a laboratory or modeling study. All of these elements will inform the certainty of your score.
- **Column F:** Reference to information provided in the GOA Fisheries Management Plan (FMP) Appendix, including Essential Fish Habitat Maps, if available.
- **Column G:** Sources. Citations for all sources used for Column C.

2. *Scoring guidelines*

The scoring guidelines for each sensitivity attribute are outlined in the next section of this document. Each sensitivity attribute includes the following information:

1. **Goal**: what is being evaluated by that sensitivity attribute.
2. **Background**: the definition of the sensitivity attribute and what it tells us about a stock's response to climate change.
3. **Guiding Question(s)**: the questions answered in species profiles to help score that sensitivity attribute
4. **Scoring guidelines**: how to score the sensitivity attribute.

3. *Your personal scoring sheet*

Scoring of sensitivity follows a five-tally system. For each sensitivity attribute, you will be given five tallies to distribute across four scoring categories: low, moderate, high, and very high (see example below). Because you have five tallies across the four categories, it forces one category to have more tallies than the others. The spread of tallies across categories informs the uncertainty of scores (e.g., a greater spread across the scoring categories indicates greater uncertainty in that score). This system accounts for several sources of uncertainty in the scores.

For example, a score with high certainty would rely on: 1) an aspect of a species' biology that has been well-studied and reviewed in the literature, 2) knowledge at the GOA stock level, and 3) high confidence from your own understanding of this species. High certainty would be reflected by a narrow range of tallies. Experts who are certain about a score may place all five tallies in one bin (e.g., all five tallies can be placed in the low bin).

Example 1: certain score

Low	Moderate	High	Very High
	|	||||	

Conversely, experts who are unsure about a score may spread all five tallies across the relevant bins (for example, they can put two tallies in the high bin, and three in the very high bin). A score with high uncertainty might reflect: 1) an aspect of species' biology that hasn't been well-studied and is sparse in the literature, or is totally unknown, 2) knowledge from a different region, such as the California Current, on a related species, or general knowledge of the functional group, and 3) low confidence in your own understanding of this species. Other reasons for uncertainty include out-of-date information or contradictory information in the literature.

Example 2: very uncertain score

Low	Moderate	High	Very High
|	||	|	|

Example 3: somewhat uncertain score

Low	Moderate	High	Very High
		|||	||

For each species, you will fill in the tallies as numbers for each sensitivity attribute. You do not need to put in zeros for unfilled boxes. Note the "tally count" column to the right of your scoring sheet, which should be highlighted in **red** initially. This column will turn **green** when 5 tallies are added to the scoring row. This column will remain red if any number other than 5 tallies have been inputted. Please make sure the entire column is green before submitting your scoring sheet!

There is also a column for comments that we encourage you to use. This can include your justification for score and degree of uncertainty, any additional information or expertise that helped inform your decisions, and additional references or corrections to literature review results. These comments can also serve as a reminder for how you scored each species during workshop discussions.

Additional Scores

You will see two additional sections of your scoring sheet that I have not mentioned yet.

1. *Data quality*

First, you will also provide a score for the data quality of each sensitivity attribute for each species. This score is based on the type and quality of information you used to score each attribute. You will enter each data quality score from a drop down menu on a scale from 0-3. Use the table below to assign a score.

Data quality	**Description**	**Numerical score**
Adequate	Based on empirical measurements, observations, or modeled results that originate from a reputable source.	3
Limited	Based on information pertaining to a different population or another species. (e.g., same species in California, different species in the GOA)	2
Expert Judgment	Based on your general knowledge of the species and their role in the ecosystem.	1
None	Very little information is available and there is no basis for forming an expert opinion.	0

Why do we ask for this score? Understanding the type and quality of information used to score the attribute will allow end users to identify data gaps and areas for future research. We can calculate a summary data quality score for each species that lets us compare available information among species.

2. *Directional effect of climate change*

In the second tab of your scoring sheet, you will provide a score that seeks to answer the following question: **What is your overall impression of how this species will be impacted by the effects of climate change?**

The scoring categories used for the directional effect include:

- Positive: climate change will have a positive impact on this species
- Neutral: climate change will have a neutral impact on this species
- Negative: climate change will have a negative impact on this species

This scoring also uses a tally system but uses **4 tallies** instead of 5. You will have 4 tallies to distribute across the three scoring categories—positive, neutral, and negative. Similar to the sensitivity scoring, the “tally count” column to the right will turn green when you have added the correct number of tallies (4) and will remain red when any other number of tallies have been inputted.

Why do we ask for this score? This score provides initial feedback to managers on the species that might increase abundance and productivity or expand into the region in response to future changes.

Scoring Guidelines

Habitat

Habitat Specificity

Goal: Evaluate the relative habitat requirements for a given stock while incorporating information on the type and abundance of key habitats.

Habitat generalists can occupy several different habitat types and are more likely to persist in changing environments. Habitat specialists are reliant on specific habitat types and, for example, are more sensitive to available structure, habitat fragmentation, and other limitations on the amount of suitable habitat (Nyboer et al. 2021). Specialists are more reliant on specific habitat types and may be more vulnerable to climate change because they are dependent on their own response to climate change as well as the impact on their habitat (Clavel et al. 2011; Pecl et al. 2014; Wilson et al. 2008). Additionally, not all habitats are expected to be impacted equally. Species that depend on habitats that are abundant and wide-ranging are less likely to be impacted by changes than species that depend on limited or vulnerable habitats. Biological habitats, including deep water corals and sponges, kelp forests, salt marshes, and sea grass beds, are more likely to be impacted by changes, while abiotic habitats, including sand, mud, and rocky bottom, are less likely to be impacted by changes. Vulnerable habitats, including freshwater, estuaries, salt marshes, and corals, are likely to experience larger climate impacts—stocks that require these habitats for any life stage will be impacted. We also expect that habitats created by disturbances (e.g., coral rubble or edge habitats) will increase with climate change, thus species that are dependent on "disturbed" habitats will be neutral or positively affected by climate change.

Guiding Questions: What is the geographic and depth distribution for adult and juvenile life stages? What are the specific habitat requirements for adults and juveniles? What types of habitats is this stock found in? Is the species considered a habitat specialist or a habitat generalist? Does the stock rely on sensitive or disturbed habitats?

Scoring relies on the following categories: 1) whether the stock is a habitat specialist or generalist, 2) what types of habitat the stock relies on, and 3) whether the habitat is limited, abundant, and/or vulnerable.

Scoring Category	Description
Low	Habitat generalist, is broadly distributed within the region of interest, uses abundant abiotic habitats, and/or relies on disturbed habitats.
Moderate	The species most often occurs in a particular abiotic habitat.
High	Relies on particular biological habitat types and/or the species is patchily distributed within the region of interest.
Very High	Habitat specialist that relies on vulnerable and/or rare biological habitats.

Thermal Tolerance

Goal: Evaluate the temperature tolerance of a species using physiological studies or evaluation of temperatures occupied by the stock.

Climate change is not only predicted to lead to general warming but also to greater variability in temperatures (IPCC, 2023); thus, species that are naturally limited to a narrower range of temperature conditions are considered more likely to be impacted than species naturally occurring within broader temperature ranges (Rijnsdorp et al. 2009). Species naturally occurring within a broad range of temperatures and with higher temperature thresholds are likely to be less sensitive to these changes, particularly ocean warming. This sensitivity attribute considers the following:

1. Temperature range: stenotherm organisms (organisms with a narrow range of temperature tolerance) are more sensitive to changes in temperature because their ability to withstand changes in temperature is likely more restricted than that of eurytherm organisms (organisms with a wide range of temperature tolerance).
2. Tolerance to high temperatures: organisms that have a higher tolerance to exceptionally warm temperatures are more likely to withstand higher temperatures than organisms with a lower threshold.

Guiding Questions: What is the stock's optimal temperature range? What are the upper (sublethal) and lethal temperature limits for the stock/species?

Scoring primarily relies on two categories: 1) the stock's optimal temperature range, and 2) the species' upper and lethal temperature limits.

Scoring Category	**Description**
Low	Optimal range: > 15 ºC Maximum threshold: > 9 ºC
Moderate	Optimal range: 10 to 15 ºC Maximum threshold: 7 to 9 ºC
High	Optimal range: 5 to 10 ºC Maximum threshold: 4 to 7 ºC
Very High	Optimal range: < 5 ºC range Maximum threshold: < 4 ºC

Sensitivity to Ocean Acidification

Goal: Evaluate a stock's sensitivity to ocean acidification (OA), either directly or via dependence on sensitive taxa.

Ocean acidification (OA) is a global phenomenon with localized effects on marine species. These effects are predominantly negative, although there is some variability among groups (Doney et al. 2009). "Sensitive taxa" are classified as those that have calcium carbonate or chitin shells or those that lay down calcium carbonate skeletons. These include crustaceans, hard corals, molluscs, calcified algae, and echinoderms (e.g., Kroeker et al. 2013; Long et al. 2013). Species in sensitive classes or that are dependent on species in these classes (e.g., for prey) are considered more sensitive to changes in ocean pH. The direct effect of ocean acidification on finfish is not well understood. Some taxa may be considered "insensitive," where the effects of ocean acidification may be positive or mitigated by biological processes (e.g., Esbaugh et al. 2012; Frommel et al. 2019). However, recent research suggests that ocean acidification impacts on finfish stocks will be most prevalent at the egg and early larval stages (Frommel et al. 2014; Villalobos et al. 2020). Ocean acidification may also affect juvenile and adult olfaction and behavior (Munday et al. 2014, 2009). Ocean acidification may also have indirect negative impacts on finfish through changes at lower trophic levels and in habitats (Haigh et al. 2015).

Guiding Questions: Does the species have a calcium carbonate exoskeleton or shell? Are there known pH effects on this species? Is the stock dependent on another species (e.g., for prey, habitat, or other use) that has a calcium carbonate exoskeleton or shell? To what degree is it dependent (very, moderately, minimally)?

Scoring considers whether or not the species itself is a "sensitive taxa" and whether (and to what degree) the species relies on "sensitive taxa" for prey or another use. When scoring, base your score on the most sensitive life stage, if appropriate. In cases where research has shown that the effects of OA may be positive or mitigated by biological processes (e.g., reduced OA by plant absorption of CO_2), use your expert judgment to inform the score.

Scoring Category	Description
Low	Not reliant on sensitive taxa (e.g., crustaceans, molluscs) for food or habitat, or is expected to respond positively to ocean acidification.
Moderate	Somewhat reliant on sensitive taxa for food or habitat but able to switch to non-sensitive taxa when necessary.
High	Reliant on sensitive taxa for food and cannot switch to non-sensitive taxa.
Very High	Sensitive taxon (e.g., hard coral, mollusc, echinoderm).

Trophic Interactions

Foraging Strategy

Goal: Evaluate the relative prey requirements for a given species.

Generalist predators tend to consume a wide variety of taxa and are likely to undergo prey switching (i.e., consuming taxa in response to their localized densities) (Clavel et al. 2011; Pecl et al. 2014; Wilson et al. 2008). Specialist predators tend to forage on fewer taxa, demonstrating a greater preference or need to consume specific prey types. Generalists demonstrate flexibility in their consumption of prey and are less sensitive to climate-driven changes in prey availability, whereas specialists are more likely to experience negative energetic effects when preferred prey are unavailable.

Guiding Questions: What species/types of food does this stock eat during adult and juvenile life stages? (e.g., Is the stock a detritivore, herbivore, or an omnivore? Does the stock show a strong preference for a particular prey type? Is there evidence that it can expand its diet?)

Scoring categories range from prey generalist to prey specialist. Scoring for this category is limited to juvenile and adult life stages. Prey type refers to groups such as copepods, krill, forage fish, cephalopods, etc.

Scoring Category	Description
Low	Prey generalist: consumes a variety of prey types based on localized densities.
Moderate	Consumes a wide variety of prey taxa but a limited number of (~3) prey types.
High	Diet is composed primarily of one prey type. May be able to switch to different prey types, but with negative effects on fitness.
Very High	Prey specialist: dependent on one prey type and unable to switch to alternative prey.

Mobility

Adult Movement

Goal: Evaluate the capacity of adults to move to new habitats in order to maintain preferred environmental conditions if their current location changes and is no longer favorable for growth and/or survival.

Sedentary species tend to be more site-dependent and less able to move to better habitats when a location becomes unfavorable, thus they are less able to adapt to environmental change than highly mobile species (Foden et al. 2013). Highly mobile adults can easily move from one habitat to another to maximize time spent in optimal conditions and are thus more able to survive changes in habitat (Pecl et al. 2014). Mobile adults may exhibit different degrees of site fidelity or homing behavior (e.g., seasonal migrations).

Guiding Questions: Are adults sessile, have limited mobility, or highly mobile? Do adults perform ontogenetic, daily, or seasonal migrations? Does the stock forage in one area and spawn in another? Are there estimates for home range, degree of site fidelity, or net movements?

Scoring this attribute ranges from mobile, non-site dependent species (e.g., highly migratory species) to non-mobile species (e.g., sedentary species).

Scoring Category	Description
Low	Highly mobile and performs broad-scale movements. Little to no site fidelity.
Moderate	Moderate to high movement rates and/or some degree of site fidelity (e.g., seasonal migrations between spawning and feeding grounds).
High	Limited mobility and high site fidelity. Movement is restricted by environmental or behavioral barriers.
Very High	Sedentary or sessile.

Early Life History

Dispersal Capability

Goal: Evaluate the ability of the species to colonize new habitats as they become available.

Extended larval dispersal is an important strategy for colonizing new areas (Bates et al. 2014). Species with greater larval dispersal capabilities (i.e., longer larval duration, greater dispersal distance) have a greater ability to colonize new habitats in areas that are suitable for survival (Johnson and Welch, 2009; Pineda et al. 2007). Species with limited larval distribution are more likely to be negatively affected if the habitat in their localized area becomes unsuitable. Paleoecology studies support these claims; marine invertebrates with relatively long planktonic larval stages were more persistent in the fossil record than those species with nonplanktonic larvae and had lower extinction rates (Jablonski and Lutz, 1983). In this way, species with longer planktonic stages and greater dispersal distances may be less sensitive to climate change.

Guiding Questions: What is the duration of the planktonic stage (eggs and larvae), if applicable? During the planktonic stage, how far do eggs and/or larvae travel? Do currents transport eggs and/or larvae along the coast or nearshore/offshore? Once eggs and/or larvae disperse, do juveniles settle in new locations, or do they return to original spawning locations?

Scoring this attribute considers planktonic larval duration and distance traveled during the larval stage.

Scoring Category	Description
Low	High dispersal of eggs and larvae. The duration of the planktonic stage is > 8 weeks and/or larvae are dispersed >100 km from spawning locations.
Moderate	Moderate dispersal of eggs and larvae. The duration of the planktonic stage is between 2 and 8 weeks and/or larvae are dispersed 10 to 100 km from spawning locations.
High	Low dispersal of eggs and larvae. The duration of the planktonic stage is < 2 weeks and/or larvae are typically found at the same location as parents.
Very High	Minimal larval dispersal. Benthic eggs and larvae or little to no planktonic early life stages.

Parental Investment

Goal: Evaluate the species' level of parental investment into the survival of eggs and/or young.

This attribute considers a species' level of parental investment and spawning strategy. Broadcast spawners (external fertilizers) release eggs and sperm into the water column and exhibit little to no parental investment. These species often have high fecundities (they produce millions of eggs) but low survival rates, thus they are considered more sensitive to environmental change (Chatten et al. 2025; Walsh et al. 2019). On the other hand, internal fertilization and parental investment enhance the survival of eggs or young. Pre-hatching parental care behaviors take a wide variety of forms in fish, ranging from nest construction and guarding to tending, fanning, and mouthing the eggs as embryos develop (Balon, 1981; Potts, 1984). Species that engage in these activities often expend considerable energy in defending eggs and developing young. In some cases, parents also continue to defend and provision their offspring post-hatch. These behaviors enhance the survival of a brood; thus eggs or young under parental care are less sensitive to environmental change.

Guiding Questions: Is the stock an internal or external fertilizer? Is the stock a broadcast spawner, egg layer, or live bearer? Does the stock lay eggs on/in substrate? What is the stock's degree of parental care? Does the stock protect eggs or young (e.g., through strategic egg laying, nest guarding, mouthbrooding, or fanning behaviour)? Does the stock defend its offspring post-hatching?

Scoring ranges from internal fertilizers with high parental investment in eggs and/or young to external fertilizers with little to no parental investment in eggs and/or young.

Scoring Category	Description
Low	Live bearers with internal fertilization and development. Few offspring with high survival rates.
Moderate	Nest guarders and mouth brooders that tend to eggs until they hatch. Moderate survival rates.
High	Egg layers (on or near the seabed) often attached to surfaces). Little to moderate degree of parental investment.
Very High	Broadcast spawners with little to no parental investment.

Reproduction

Reproductive Plasticity

Goal: Evaluate the ability of a stock to adapt aspects of its reproductive strategy to changing conditions.

Species with reproductive events that are highly associated with a specific location, habitat type, behavior, or physical trait are expected to be more sensitive to changing environmental conditions, whereas species with reproductive events that are less tied to specific locations, habitat types, behaviors, or physical traits may be more adaptable.

This sensitivity attribute considers the following:

1. Stocks that rely on **environmental cues** for reproduction are considered more susceptible to extrinsic effects (Pankhurst and Munday 2011; Alix et al. 2020; Mitra et al. 2023). Examples include effects of temperature, salinity, OA, and deoxygenation on spawning behavior or gametogenesis (e.g., Teal et al. 2008).
2. Stocks that exhibit high **fidelity to specific spawning sites** are considered more vulnerable to environmental changes than those that spawn across broad areas.
3. **Spawning aggregations** require large numbers of individuals to simultaneously arrive at a specific location. Thus, stocks that display spawning aggregations are considered more sensitive to environmental change (Morrison et al. 2015).

There may be other characteristics that may affect reproductive capacity under changing conditions. Please incorporate those and adjust scores appropriately.

Guiding Questions: Does the stock rely on environmental cues for reproduction? Are there known temperature (or other environmental) effects on reproduction? Does the stock display low, moderate, or high site fidelity for spawning? Does the species rely on large spawning aggregations? Is reproduction highly synchronized among individuals?

Scoring relies on information about characteristics that affect reproductive plasticity. If a particular characteristic is suspected to have considerable impacts on the stock, adjust scores appropriately.

Scoring Category	Description
Low	High reproductive plasticity. One characteristic may affect reproductive capacity.
Moderate	Moderate reproductive plasticity. Two characteristics may affect reproductive capacity.
High	Low reproductive plasticity. Three characteristics may affect reproductive capacity.
Very High	Very low reproductive plasticity. Four or more characteristics may affect reproductive capacity.

Spawning Duration

Goal: Evaluate the duration of the spawning cycle and the potential for disruption of reproduction due to climate change.

Stocks that spawn throughout the year will be more likely to be successful in a changing environment as protracted spawning is believed to enhance offspring survival by allowing the stock to “hedge its bet” against adverse environmental conditions (Marteinsdottir and Thorarinsson, 1998). Conversely, stocks that spawn all at once in major events (constricted spawning) are more likely to experience recruitment failure with potential changes in environmental conditions.

Guiding Questions: What is the duration of the spawning season?

Scoring ranges from protracted to constricted spawning. Note that spawning includes the activity of the entire stock, not an individual. For stocks that are born as fully developed juveniles capable of long-distance movements, there is less concern over a short hatching/mating period, and these stocks should be ranked low to moderate.

Scoring Category	Description
Low	Spawning occurs throughout the year (e.g., daily or monthly).
Moderate	Multiple spawning events span more than one season (e.g., spawning activity in spring and fall).
High	Multiple spawning events within a confined time frame (e.g., spawning activity lasts for ~ 3 mo).
Very High	One spawning event per year over a brief period of time.

Population Dynamics

Life History Strategy

Goal: Evaluate the stock's generation time, longevity, and ability to adapt to unpredictable conditions.

Highly productive stocks tend to be more resilient to changing conditions because they respond more quickly to perturbation (Lande, 1993; Pecl et al. 2014). Stocks with lower productivity (e.g., those that are longer lived, slower growing, and have delayed maturation) tend to be more sensitive to climate change because of longer generation time and lower overall reproductive output.

The von Bertalanffy growth coefficient (k) measures how rapidly a fish reaches its maximum size. Stocks with lower productivity tend to have low k values (Patrick et al. 2010). Natural mortality (M) refers to the rate at which individuals die due to natural causes. Stocks with high M require higher levels of productivity to maintain populations (Patrick et al. 2010). If estimates of k or M are not available, score species along a gradient from K-selected (slow-growing organisms that produce few offspring and have long lifespans) to r-selected (fast-growing organisms with high fecundities and short lifespans). Those that are r-selected have greater adaptive capacity because of increased reproductive output, population growth rates, and faster generation times. Those that are K-selected can buffer against short-term environmental change but are slower to respond and adapt.

Guiding Questions: What are the von Bertalanffy growth parameter estimates (k, $L\infty$, and t_0)? What is the length- and/or age-at-50%-maturity (L_{50} or A_{50})? What is the maximum age and length estimated for this stock? What is the estimate of natural mortality (M)? Is the stock K- or r-selected?

Scoring this attribute ranges from K-strategist species to r-strategist species. The categories were developed from an analysis of 141 marine fish species considered to be representative of U.S. fisheries (Morrison et al. 2015; Patrick et al. 2010).

Scoring Category	Description		
Low	k > 0.25 L_{max} < 55 cm	A_{50} < 2 yr A_{max} < 10 yr	M > 0.5 r-selected
Moderate	k = 0.16–0.25 L_{max} = 55–85 cm	A_{50} = 2–3 yr A_{max} = 11–20 yr	M = 0.31–0.50 more r-selected
High	k = 0.11–0.15 L_{max} = 85–150 cm	A_{50} = 4–5 yr A_{max} = 21–30 yr	M = 0.21–0.30 more K-selected
Very High	k < 0.10 L_{max} > 150 cm	A_{50} > 5 yr A_{max} > 30 yr	M < 0.2 K-selected

Stock Status

Goal: Evaluate the relative level of stress on a stock from fishing and stock depletion.

Fish stocks that are already being affected by other stressors are likely to have faster and more acute reactions to climate change (Brander, 2007). Fishing is the largest stressor currently impacting fish stocks (Jackson et al. 2001) and the magnitude of the stress can be estimated through the status of the stock. Stock status can be measured as a ratio of the current stock size (B) over the biomass at maximum sustainable yield (B_{MSY}) and is a commonly used biological reference point for U.S. federally managed stocks. A stock that has a large biomass is more resilient to changes in climate, while stocks with very low biomass are likely to be in a compromised ecological position and may have diminished capability to respond to climate change (Rose, 2004). For other areas, B_{max} may be available and can also be used. For data-poor stocks with an unknown status, or stocks that are analyzed as part of a species group, use your expert opinion to estimate the stock size.

Guiding Questions: What is the value of B/B_{MSY}? If unavailable, what is B_{max}?

Scoring is based on the stock value of B/B_{MSY}.

Scoring Category	Description
Low	$B/B_{MSY} \geq 1.2$ (or proxy)
Moderate	$1.2 \geq B/B_{MSY} \geq 0.8$ (or proxy)
High	$0.8 \geq B/B_{MSY} \geq 0.5$ (or proxy)
Very High	$0.5 > B/B_{MSY}$

Genetic Diversity

Goal: Evaluate the genetic diversity of a stock.

The genetic diversity of a stock can impact its resilience to change. Generally, the more genetically diverse a species is, the less sensitive it is to ecosystem perturbations. Without genetic diversity, a single disease or set of conditions could drive a species to extinction; stocks with limited genetic diversity or evidence of inbreeding could be more negatively impacted by climate change as their offspring would be less variable and thus less likely to have the combination of genes needed to adapt to changes in the environment (Dudley et al. 2021).

Other possible influences on the genetic diversity of marine species include sweepstakes and bottleneck effects. Large variance in family sizes can produce genetic drift among cohorts, or a sweepstakes effect (Li and Hedgecock, 1998). Genetic bottlenecks describe the reduction in genetic diversity that accompanies severe population declines (Palof et al. 2011).

Guiding Questions: Does the stock have high or low genetic diversity? Is there evidence of sweepstakes effects, genetic bottlenecks, or isolation-by-distance? Is there evidence of high or low genetic variation within the area of interest? Is there evidence of local adaptation?

Scoring Category	Description
Low	High genetic diversity and evidence of local adaptation.
Moderate	Genetic diversity is moderate or unknown.
High	Some evidence of low genetic diversity.
Very High	Low genetic diversity. Genetic variation may be compromised and/or there is evidence of inbreeding.

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