Climate Vulnerability Assessment (CVA): How-To Guide

The Environmental Defense Fund's Climate Vulnerability Assessment (CVA) tool provides a framework to assess the relative vulnerability of a suite of fisheries species to climate change, in order to support climate-ready planning and adaptive management. This Excel-based tool is modeled on the CVA framework established in Hare et al. 2016, but has been modified with language to facilitate its use in data-limited contexts.

1. Overview of CVA Components

The CVA combines the **exposure** of a species to climate change with its **sensitivity** to stressors to estimate an overall climate **vulnerability** score.

- **Exposure** is a measure of the projected magnitude of change in physical climate variables (e.g. temperature, salinity, storm intensity) that a species is likely to encounter, given its distribution and behaviour.
- **Sensitivity** is a measure representing the biological traits of a species (e.g. adult mobility, diet, spawning cycle) that determine how it will respond to climate change.
- **Vulnerability** is an estimate of the relative probability of a species experiencing adverse outcomes (e.g. declines in productivity and/or abundance) as a result of climate change.

Exposure

The CVA tool lists 23 exposure factors that are linked to large-scale ocean climate processes. Users score 10 'recommended' climate exposure factors from this list that have been identified as being generally important to fisheries species, and may also score up to four additional exposure factors from the list that are particularly important in their study region. Exposure factors can reflect either a change in the mean state of a climate variable, or changes in variability around the mean. Users are asked to score the projected magnitude of change in each exposure factor in their system ~50 years in the future, relative to a baseline ~50 years in the past. Scores are on a 1-4 scale ranging from a 'low' anticipated magnitude of change, to a 'very high' anticipated magnitude of change. Information with which to score changes in these factors can be integrated from the scientific literature, global climate models (e.g. using the NOAA climate portal), based on expert local or traditional knowledge, or any combination of these sources.

Each exposure factor is scored once per region, then an **overlap score** is used to assess the degree to which an individual species may actually experience the magnitude of change in each exposure factor, given their distribution and habitat preference. Users assess overlap on a 1-4 scale, from 'low' overlap with expected changes to 'very high' overlap with expected changes.

Sensitivity

The CVA tool lists 12 sensitivity attributes that describe biological traits related to a species' ability to respond to climate change. Users score all 12 sensitivity attributes listed in the tool. Scores are on a 1-4 scale, ranging from characteristics conferring a 'low' sensitivity to climate change, to those conferring 'very high' sensitivity to climate change. Users can integrate knowledge of species' traits from sources including scientific literature, online resources including FishBase, stock assessments, expert local and traditional knowledge, or any combination of these sources.

Vulnerability

The final vulnerability score is calculated by multiplying exposure and sensitivity, and is on a 1-4 scale ranging from 'low' to 'very high'. These vulnerability scores are most useful as a way of identifying fisheries species that may be relatively more or less impacted by climate changes expected in a region. This understanding of relative risk can help to prioritise specific management interventions or increased research attention, or to provide a starting point to help communities prepare for changes in the availability of species within their fisheries portfolio.

Final scores for each species can be further explored to identify species with different climate risk profiles: for example, a species with high sensitivity and low exposure may have a high latent vulnerability, where the species may become vulnerable if actual climate change is substantially worse than predicted. A species with low sensitivity and high exposure indicates potential "persisters," species with high plasticity that may allow them to adapt to environmental change and possibly exploit new or vacated niches.

Uncertainty and directionality of change

To account for uncertainty in the information used to score exposure and sensitivity, the user provides a data quality score for each attribute (0-3). This functionality allows users to identify data gaps and potential areas for future research, as well as to characterize the relative uncertainty in the overall vulnerability of each species.

The user also indicates whether each species is expected to respond positively, negatively, or neutrally to the effects of each attribute or factor. This direction of effect score provides a broad indication of how species may change in abundance and productivity, or whether they will expand into or contract from the region.

2. CVA process

The following section describes a detailed, step-by-step process for conducting the CVA:

1. Scoping and planning
2. Assessment preparation
3. Scoring
4. Interpreting results

Scoping and Planning

It is important to ensure that the scope of the CVA is carefully tailored to describe climate changes within the study system, and to meet the needs of stakeholders for planning and management. To do this, it is critical to involve fishers, managers, scientists, decision-makers, and other potentially impacted stakeholders in the scoping and planning phase.

1. *Define Study Area*
    a. Choose an area that matches the scale of relevant regional ocean climate processes, and encompasses the ranges of most species or populations of interest (e.g. a large marine ecosystem may provide an appropriate spatial scale).
2. *Select Species to Include*
    a. On the “Species” tab of the Excel spreadsheet, input the name of each species. The CVA tool allows for scoring up to 50 species (additional species can be scored in a separate copy of the CVA tool).
    b. The tool can be used to score information for the whole species or a specific stock. In some cases, different stocks of the same species may have contrasting vulnerabilities due to geographic differences in exposure factors or biological attributes, or differences in fishing pressure. Implementation at the stock level is encouraged if pertinent stock specific

information is available and stock specific scoring would be most useful to management decisions.

3. *Select Climate Exposure Factors*
    a. The tool provides an initial list of 23 climate exposure factors. The 10 underlined exposure factors are recommended for scoring across all geographies and contexts, and the user can then pick up to 4 additional factors relevant to the study region. When deciding which factors to include, the user should consider the magnitude of expected changes in their region, the importance of the exposure factor to the biology of the main fisheries species, data availability, and confidence in future projections. The user will also need to consider whether changes to the mean and/or variance of the factor will be the most appropriate measure to describe key changes in the region.
    b. Any exposure factors that will not be scored should be omitted for all species and can be ignored.

Assessment Preparation

1. *Species Profiles*
    a. A summary of pertinent life history characteristics of a species can be compiled from literature, online databases, and summary documents (e.g. stock assessments, essential fish habitat documents, environmental impact statements).
    b. Life history attributes should be based on current characteristics, not predicted changes or adaptive potential.
2. *Climate Projections*
    a. Information about predicted climate change impacts in the study region can be compiled from quantitative outputs from climate models like on the NOAA Climate Change Web Portal. Data is available on the Climate Change Web Portal for the Ocean Surface Temperature, Ocean Surface Salinity, Air Temperature, Precipitation, Dissolved Oxygen (Sea Surface Oxygen), and pH exposure factors. Scoring can also be based on qualitative evaluations based on local or traditional expert knowledge.
    b. Models and/or expert knowledge of conditions over the past 50 years should be used as a baseline to assess the magnitude of change in conditions expected in the next 50 years.
3. *Species Distributions*
    a. Knowledge of species' distributions and/or habitat preferences are needed to determine their overlap with exposure factors. Distributional maps are available from existing literature, survey databases, or public online

databases like FishBase and the Ocean Biogeographic Information System (OBIS), or expert ecological/fishing knowledge can be used to assess the probability of overlap.

Scoring

In data-limited contexts, the user may use information on other similar species, general ecological principles, or local knowledge to estimate their scores. Information on the same species located in other regions should be prioritized, then information on similar species in the same family and within the same size class.

1. *Sensitivity Attributes*
    a. On the "CVA 1-35 species" (for the first 35 species) or "CVA 36-50 species" (if there are more than 35 species) tab, **score all 12 sensitivity attributes for each species**. Using the defined scoring bins, the species profile can be used to score the sensitivity attribute for the species from 1-4 as low, moderate, high, or very high.
    b. Detailed descriptions of sensitivity attribute definitions and scoring bins can be found in Appendix A of Hare et al. 2016.
2. *Exposure Factors*
    a. *Magnitude of Change*: On the "Regional Exposure" tab, score each of the selected exposure factors **(score 10 underlined factors plus up to four additional factors)** based on an understanding of how these factors will change in this region in the next 50 years compared to the most recent 50 years. The tool provides a 'primer' column that provides general information about each exposure factor, the way it might be expected to change, and some readily-observable indicators, which may be useful to guide scoring in data-limited contexts. In data-rich contexts, use Rubric A in the Appendix (below) to calculate a score based on a quantitative assessment of the magnitude of change between the past and future projections
    b. *Overlap*: On the "CVA 1-35 species" or "CVA 36-50 species" tab, score overlap between each species and the 10-14 selected exposure factors in turn. Species are scored from 1-4 as low, moderate, high, or very high overlap with each factor, using knowledge of their distribution and habitat preference. A 'primer' column is included in the tool that describes the types of species that might show relatively high overlap with each factor, which may be useful to guide scoring in data-limited contexts. In data-rich contexts, species distribution models may be used to assess overlap between species and areas of relatively high expected change.

3. *Directional Effect of Climate Change*
    a. For each exposure factor or sensitivity attribute, a score of -1, 0, or 1 indicates whether the species is expected to respond positively (1), negatively (-1), or neutrally (0) to the effects of climate change due to the variable.
4. *Data Quality*
    a. The data quality of each exposure factor or sensitivity attribute is scored from 0-3 on the “Regional Exposure” and “CVA ##-## species” tabs.
        i. 3: Adequate Data. The score is based on data that have been observed, modeled or empirically measured for the species or exposure factor in question and comes from a reputable source.
        ii. 2: Limited Data. The score is based on data which has a higher degree of uncertainty. The data used to score the attribute may be based on related or similar species, come from outside the study area, or the accuracy or reliability of the source may be limited.
        iii. 1: Expert Judgment. The attribute score reflects the expert judgment of the reviewer and is based on their general knowledge of the exposure factor or species, rather than any specific observation
        iv. 0: No Data. No information to base a score on. Very little is known about the species or exposure factor and there is no basis for forming an expert opinion. If scored as 0, the data quality cell will have a red background color to highlight a serious data gap.

Interpreting Results

A summary of results is generated on the “CVA results and graphs” tab of the spreadsheet. By examining overall climate vulnerability, potential for distribution change, and directional effect scores, species can be identified that are likely to increase or decrease in productivity, or shift into or out of the study region.

1. *Estimate of Overall Vulnerability*
    a. The overall exposure and sensitivity scores are calculated using a defined logic rule (Rubric B; Appendix). The overall vulnerability score is a multiplication of the exposure and sensitivity scores.
        i. Individual exposure factor scores are scored using the formula a * b / ((a + b) / 2) where a = magnitude of change score and b = overlap score.
    b. A risk heatmap plots each species according to their exposure score on the Y axis and sensitivity score on the X axis.

2. *Potential for Distribution Change*
    a. A bar graph categorizes the potential for distribution change of each species into low, moderate, high, and very high groups.
    b. The potential for a change in species distribution is calculated using a subset of sensitivity attributes related to changing distribution in response to climate change: Habitat Specificity, Dispersal of Early Life Stages, and Adult Mobility. Generally, overall climate vulnerability varies inversely to potential for change in species distribution.
3. *Data Quality*
    a. An overall data quality score, sensitivity data quality score, and exposure data quality score is given for each species using a simple average.
4. *Directional Effect of Climate Change*
    a. An overall score for the directional effect of climate change on each species is given using an average of directional effect scores.
    b. A bar graph categories each species into positive, neutral, and negative groups according to their directional effect of climate change scores.

References

A Vulnerability Assessment of Fish and Invertebrates to Climate Change on the Northeast U.S. Continental Shelf: https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0146756
Methodology for Assessing the Vulnerability of Marine Fish and Shellfish Species to a Changing Climate: https://www.st.nmfs.noaa.gov/Assets/ecosystems/climate/documents/TM%20OSF3.pdf

Appendix

A: List of exposure factors and sensitivity attributes for scoring climate vulnerability in the CVA tool

Exposure Factors

Note: The 10 underlined exposure factors are minimally recommended for scoring, and up to an additional four determined to be important in the study region can be chosen to complement these.

Weather

- Storm Severity
- Mean Precipitation
- Storm Frequency
- Wave Action / Coastal Erosion
- Variability in Precipitation

Oceanography

- Ocean Currents
- Upwelling / Mixing Intensity
- Upwelling / Mixing Duration
- Upwelling / Mixing Timing
- Turbidity
- Interannual and Decadal Ocean Patterns (e.g. ENSO and PDO)

Temperature

- Mean Ocean Surface Temperature
- Variability in Ocean Surface Temperature
- Variability in Air Temperature
- Mean Air Temperature

Chemistry

- Dissolved Oxygen Content
- Variability in Dissolved Oxygen Content
- Mean Ocean Surface Salinity
- Variability in Ocean Surface Salinity
- Mean Ocean pH
- Variability in pH

Structural Changes

- Sea Level Rise
- Ice Melt

Sensitivity Attributes

Habitat Requirements
- Habitat Specificity
- Sensitivity to Ocean Acidification
- Sensitivity to Temperature

Diet
- Prey Specificity

Mobility
- Dispersal of Early Life Stages
- Adult Mobility

Reproduction
- Complexity in Reproductive Strategy
- Early Life History Survival and Settlement Requirements
- Spawning Cycle

Population Characteristics
- Stock Size-Status
- Population Growth Rate

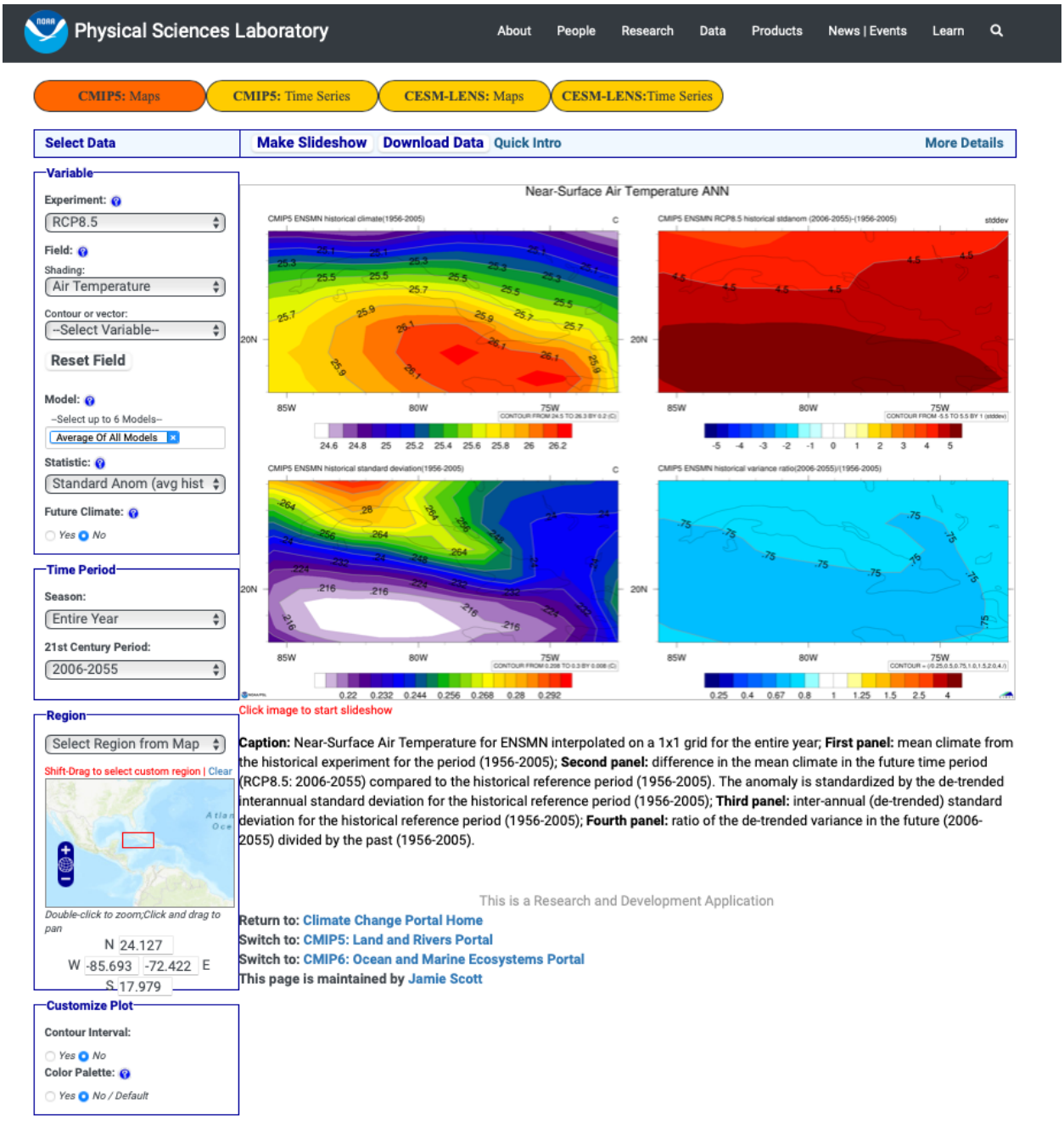
Other
- Other Stressors

Rubric A: Rubric for scoring magnitude of change in exposure factors given available quantitative data ("Regional Exposure" tab).

Magnitude of Change Score	**Numeric Score**	***Factors related to Mean: |future mean - past mean| / past standard deviation**	****Factors related to Variability: variance of future / variance of past**
Very High	4	>2	>1.78
High	3	1.5 - 2	1.54 - 1.78
Moderate	2	0.5 - 1.5	1.15 - 1.54
Low	1	<0.5	<1.15

*On the NOAA Climate Change Web Portal, select "Standard Anom (avg historical)" for Statistic and view the upper right graph for mean factors and and lower right graph for variability factors.

Figure A: An example screenshot of the NOAA Climate Change Web Portal for Air Temperature exposure data.



Rubric B: Rubric for determining overall exposure or sensitivity scores.

Overall Sensitivity or Exposure Score	Numeric Score	Logic Rule
Very High	4	3 or more attributes / factors >= 3.5
High	3	2 or more attributes / factors >= 3.0
Moderate	2	2 or more attributes / factors >= 2.5
Low	1	All other scores

Figure B: Provinces for “Sensitivity to Temperature” sensitivity attribute scoring, from Hare et al. 2016