Choosing and Using Climate-Change Scenarios for Ecological-Impact Assessments and Conservation Decisions

Amy K. Snover[(1)], Nathan J. Mantua[(1,2)], Jeremy S. Littell[(1,3)], Michael A. Alexander[(4)], Michelle M. McClure[(5)], Janet Nye[(6)]

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The Challenge

Consideration of climate change effects is increasingly called for in ecological-impact assessments and conservation decisions. However, effective use of climate change information is limited by misperceptions about the strengths and weaknesses of available information and best practices for coping with uncertainty in future projections.

To account for the major sources of uncertainty associated with projecting future climate, climate-change projections are developed using multiple greenhouse gas scenarios, global climate models, climate model runs, and downscaling methods. The resultant proliferation of climate-change projections poses substantial difficulties for scientists and managers seeking a defensible choice of climate-change scenarios in publicly visible, potentially litigious, decision-making contexts.

A common strategy for coping with the increasingly large array of climate-change projections is to limit the range of outcomes considered by attempting to evaluate and select, *a priori*, the "best" scenario for impact assessment. This approach is ill-founded: the "best" scenario depends on the biological system under consideration and the context and priorities of associated decisions. As a result, the most appropriate scenarios for a particular analysis will not necessarily be the most appropriate for another. Given this complexity, what is a defensible, objective and tractable approach to scenario selection?

Guidelines for Choosing Climate-Change Scenarios for Ecological Impact Assessment

Selecting scenarios for impact assessment requires understanding biological sensitivity to local climate-related environmental factors (*biological expertise*), assessing how well processes controlling changes in these factors are spatially resolved in the development of different climate change scenarios *(expertise of climate and climate impacts science*), coupled with screening criteria appropriate to the decision context *(insights and direction from managers and policymakers)*. Table 1 (back page) addresses common misconceptions about the utility of climate change scenarios.

1. **Begin with the end in mind: identify drivers of biological sensitivity to climate before focusing on climate change projections.**
    a) Develop a conceptual model that links biological response to local climate
    b) Determine the most important climate effect pathways and local climate drivers through sensitivity analysis, expert judgment, or other approaches

(1) Climate Impacts Group, University of Washington; (2) Current address: NOAA/NMFS Southwest Fisheries Science Center; (3) Current address: USGS, Department of Interior Alaska Climate Science Center; (4) NOAA, Earth System Research Laboratory; (5) NOAA/NMFS Northwest Fisheries Science Center; (6) School of Marine and Atmospheric Sciences, Stony Brook University. Primary contact: Amy Snover, aksnover@uw.edu

2. Identify appropriate sources of information for future scenarios of local climate drivers.

Can biological effects of climate change be assessed with output taken directly from global climate models or is downscaling or modeling of intermediary effects necessary? Figure 1 presents a decision tree designed to help answer this question for the local climate driver identified in *Step 1,* with details and marine examples provided in Snover et al. Because each analytical step can add uncertainty, relying on output from as high up the chain toward global climate models is preferred.

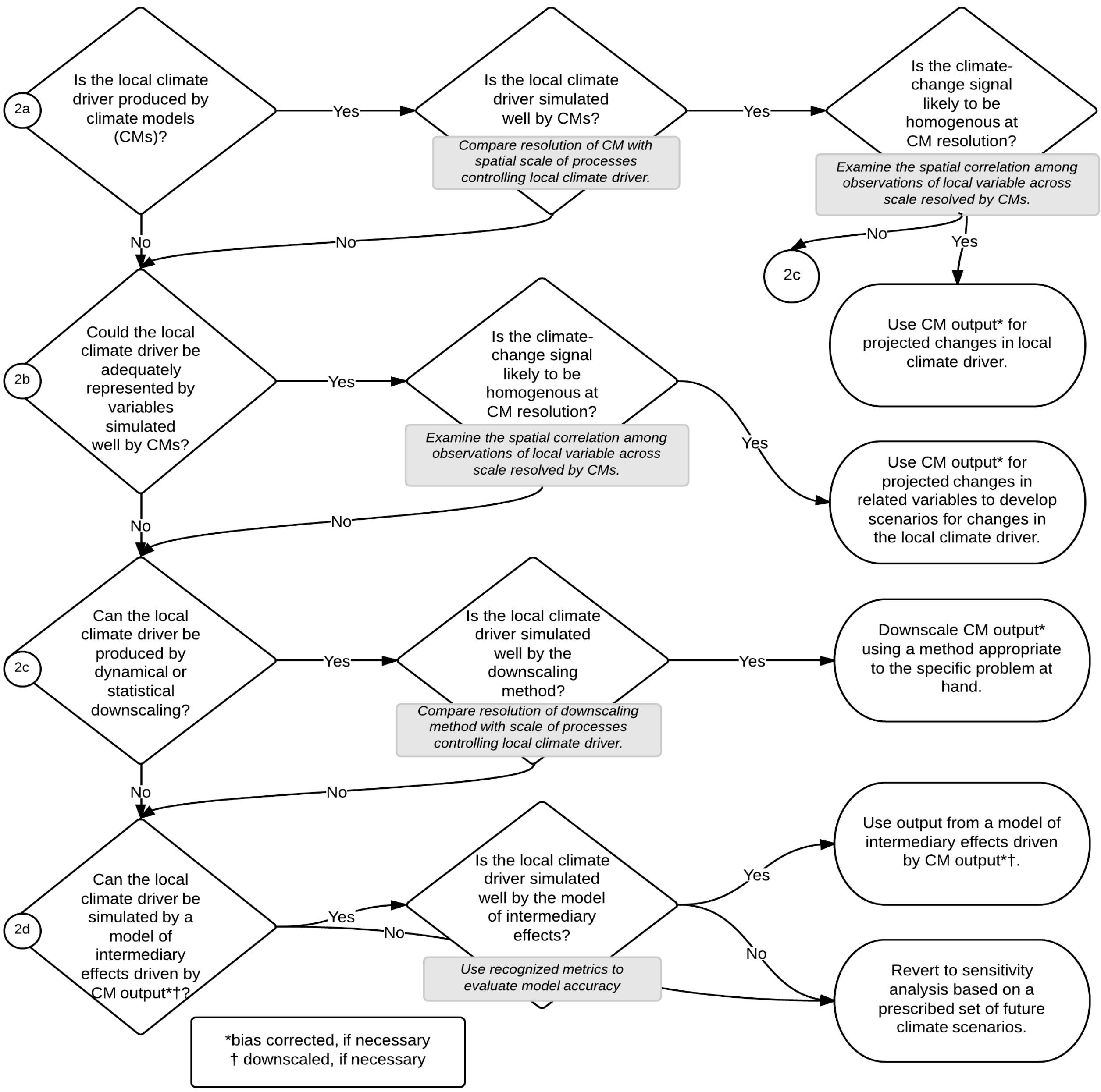

Figure 1: Steps for determining appropriate source(s) of information for constructing climate change scenarios for local climate drivers.

3. **Objectively select (a subset of) scenarios for use in impact assessment**

    a) *Identify available scenarios*

        - Use output from as many global climate models as is feasible, eliminating only models failing to reproduce defining aspects of the system or with errors affecting model sensitivity

        - Use multiple ensemble members (i.e., simulations with the same climate model and emissions scenario but different initial conditions) when the "noise" due to natural variability is expected to be high relative to the "signal" of anthropogenic climate change for the parameter of interest


Western snowy plover, B. Brink/The Oregonian

    b) *Consider limiting scenarios based on emission-scenario characteristics and time horizon for analysis*

    c) *Select a scenario subset for analysis based on decision context*

        - *For risk-averse decisions* (e.g., management of endangered species to avoid extinction): Choose the climate scenario(s) indicating the largest negative impacts or examine only climate scenarios on the basis of probable emissions scenarios.

        - *For risk-tolerant decisions (*e.g., when planning for best case, with ability to adjust management if necessary*):* Depending on actual level of risk tolerance, choose the climate scenarios that indicate the best case or middle-of-the-road projections.

        - *For risk-managing approaches* (e.g., developing strategies robust to future uncertainty by planning for a range of possible outcomes): Select scenarios that represent the full range of existing projections, including two or more scenarios that represent high- and low-end changes in projected effects.


Lemhi River, ID, The Nature Conservancy

Table 1: Common misconceptions about the utility of climate scenarios for ecological-impact assessments and decision making, implications for scenario selection and use, and links to guidelines for scenario selection.

Misconception	*Reality**
Pessimism about climate-change scenarios	
Climate models (CMs) do not produce output variables relevant for determining ecological responses.	CMs simulate a large variety of variables, including many appropriate for direct use in ecological impact assessment (step 2a).
Because CMs are accurate only at continental spatial scales, CM output is unsuitable for projecting regional or local changes and effects.	There are a variety of ways in which the robust output of CMs can be used to drive local biological assessments, depending on the spatial scale of controlling processes (step 2 and Fig. 2).
A single CM simulates all variables equally well or poorly for all locations and time steps.	Accuracy of CM simulations differs significantly by variable, temporal and spatial scale, and geographic region. This diversity must be considered when evaluating CM output for use in local impact assessment (step 2).
Because the projected direction of change in important variables is not the same among CMs, CM output cannot usefully inform decision making.	Despite directional uncertainty in CM projections of some variables, robust scenarios of future conditions can be developed when biological effects are dominated by changes in other better-understood variables. In the western United States, for example, spring snowpack important for wolverine reproductive success is projected to decrease in all future scenarios as a result of projected warming, despite significant uncertainty in future precipitation (McKelvey et al. 2010) (step 1).
The cascade of uncertainty, caused by linking multiple models, combined with the typically large range in climate-change projections means that projected biological effects are too uncertain to be useful.	Evaluations of the ability of joint climatic-biological response modeling to replicate observed conditions can be used to evaluate the degree to which small errors in initial climate conditions lead to larger errors in projections of biological response (Littell et al. 2011).
Every time a new set of climate-change scenarios is released (e.g., by the Intergovernmental Panel on Climate Change (IPCC), impact assessments must be completely redone.	If the assumed linkages among changes in global climate, local climate drivers, and biological effects are clearly articulated, and the ranges of changes projected for local climate drivers identified for the current scenario set, new global climate scenarios can be evaluated for the degree to which they would alter that range and therefore for the necessity of updating decisions associated with projected biological effects of climate change.
Optimism about climate-change scenarios	
Climate-change scenarios are climate predictions.	Climate scientists carefully distinguish between climate projections, which are based on scenarios of future changes in climate forcings, and predictions (or forecasts), which attempt to simulate the actual climate state forward in time. Although the IPCC's 5th assessment report (AR5) will include results of climate-prediction experiments, the expected divergence of these decadal climate forecasts suggests the continued importance of evaluating a range of possible futures.
Climate scientists can identify which scenarios are best or most likely.	Irreducible uncertainty about future greenhouse gas emissions, the fact that there is no single most reliable CM, and the confounding effect of natural variability mean it is impossible to determine the best, or most likely, climate-change scenario. The choice of the "best" scenario depends on the characteristics of the biological system of interest and the associated decision context (Table 1).
Climate-change scenarios define the range of plausible foreseeable outcomes.	Although scenarios indicating the least change seem well founded, the largest change scenario in CM archives does not necessarily represent the largest plausible future change. Managing for the worst case as identified by currently available scenarios may not be sufficient to guarantee resilience, and this should be clearly communicated to decision makers (step 3c).
Climate-change scenarios with higher resolution are necessary, possible, and will improve ability to project biological effects.	Not all aspects of the climate are simulated more accurately with higher resolution (e.g., Stock et al. 2010; Delworth et al. 2012). Development of higher resolution scenarios is limited by fine-scale data for validation of downscaled scenarios (Lundquist & Cayan 2007), especially in oceanic, aquatic, and mountainous environments, where much resource management is focused. Uncertainty regarding future climate changes is often not the primary factor limiting projections of future biological change (step 1).
Uncertainties associated with climate-change scenarios will decrease in the near term, making them more useful for biological assessments.	The IPCC AR5 is expected to increase uncertainty in estimates of climate change due to the increased complexity of current CMs (Knutti & Sedláček 2013). This suggests the need to identify climate-change scenarios that appropriately represent the range of projected outcomes (step 3) and improve understanding of biological linkages to climate so that ecological impact assessments can appropriately use the information provided by CMs (step 1).

**Indicated steps refer to those in the guide for choosing and using scenarios, above.*