Climate Change Refugia

Preparers

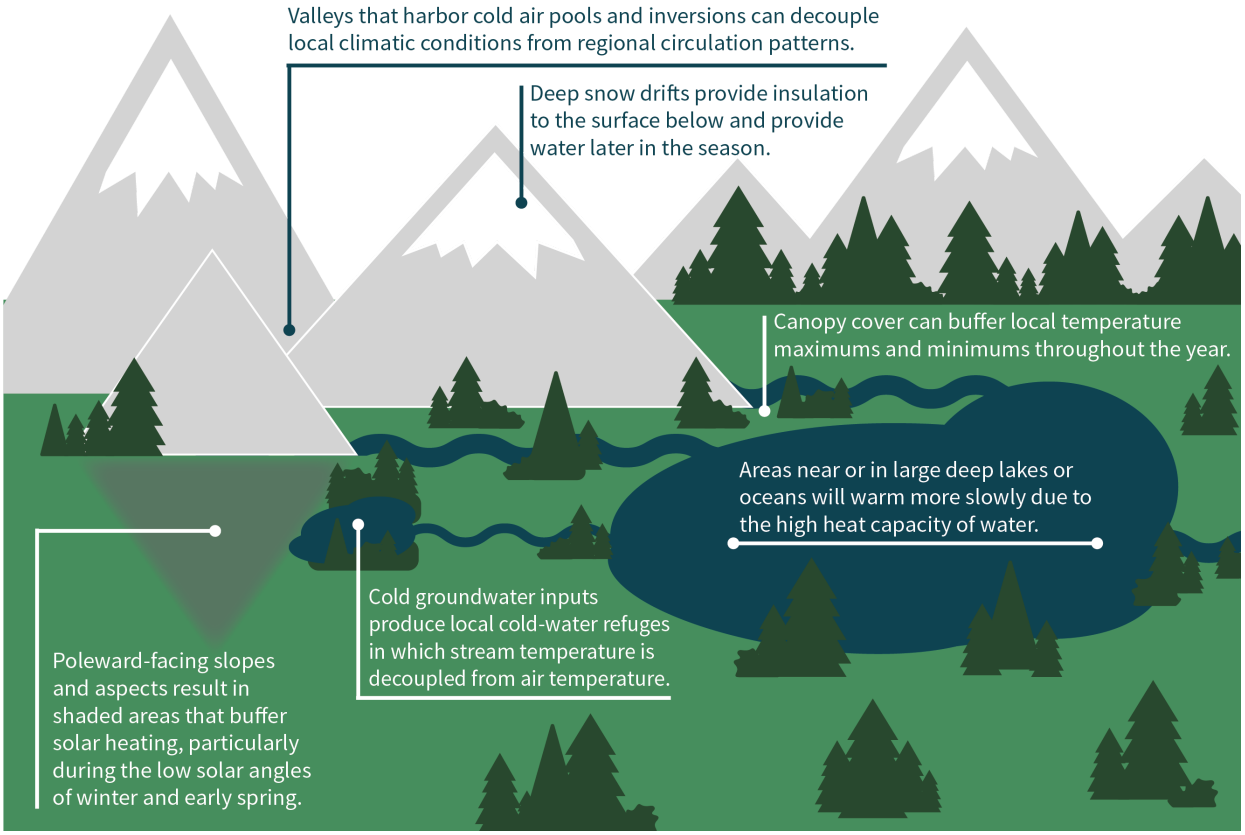
Toni Lyn Morelli, Northeast Climate Science Center, US Geological Survey Connie Millar, Pacific Southwest Research Station, US Forest Service

Introduction

Climate change is affecting the distribution, abundance, and persistence of species and ecosystems around the world [1]. As natural resource managers are tasked with maintaining and protecting species and ecosystems from the effects of a changing climate, options for minimizing impacts are needed. Options for climate adaptation—the policy and management actions taken to minimize negative effects of climate change—include transition, resilience, and resistance strategies [2]. Transition, or response, strategies focus on allowing inevitable changes to certain attributes of an ecosystem or species (e.g, species composition or ranges), while maintaining ecosystem function and/or desired ecosystem services. For example, planting more southerly species during restoration or restocking could ease the ecological transition to warmer climates and avoid catastrophic failures [3]. Resilience strategies instead focus on giving ecosystems or species what they need to be able to rebound from climate stressors (e.g., fire or drought) and return to their original state. A third climate adaptation option is resistance, which seeks to preserve, as much as possible, the historical structure, composition, and function of the ecosystem in the face of changing climates. One of the primary resistance strategies is to identify and preserve what are known as climate change refugia. Climate change refugia are “areas that remain relatively buffered from contemporary climate change over time and enable persistence of valued physical, ecological, and socio-cultural resources” [4]. The key attribute of refugia is their relative persistence, despite changes in the climate in the surrounding landscape. Climate change refugia can result from spatial variability in topography that decouples climatic processes at a smaller scale from broader, regional conditions. One such example is cold-air pooling, where concentrated cold, dense air flows downslope into valleys or basins, creating temperature inversions.

Wetlands, riparian zones, rock glaciers, and talus slopes can also develop unique micro-climate conditions that create climate change refugia. In addition, areas near or in a large body of water, like coastal areas or deep lakes, warm more slowly as they are often buffered from regional warming because more of the sun’s energy is expended in evaporation than in surface heating. The role of decoupling from regional and global climate processes is critical: without this, areas that are cool today may well warm in the future, losing their capacity for species and ecosystem preservation. Areas that are protected from climate-related disturbance such as increasingly severe fires and extreme floods can also be considered as climate change refugia. Vegetation can mediate physical disturbance as well as enhance other refugial properties. Forest canopies buffer against climate

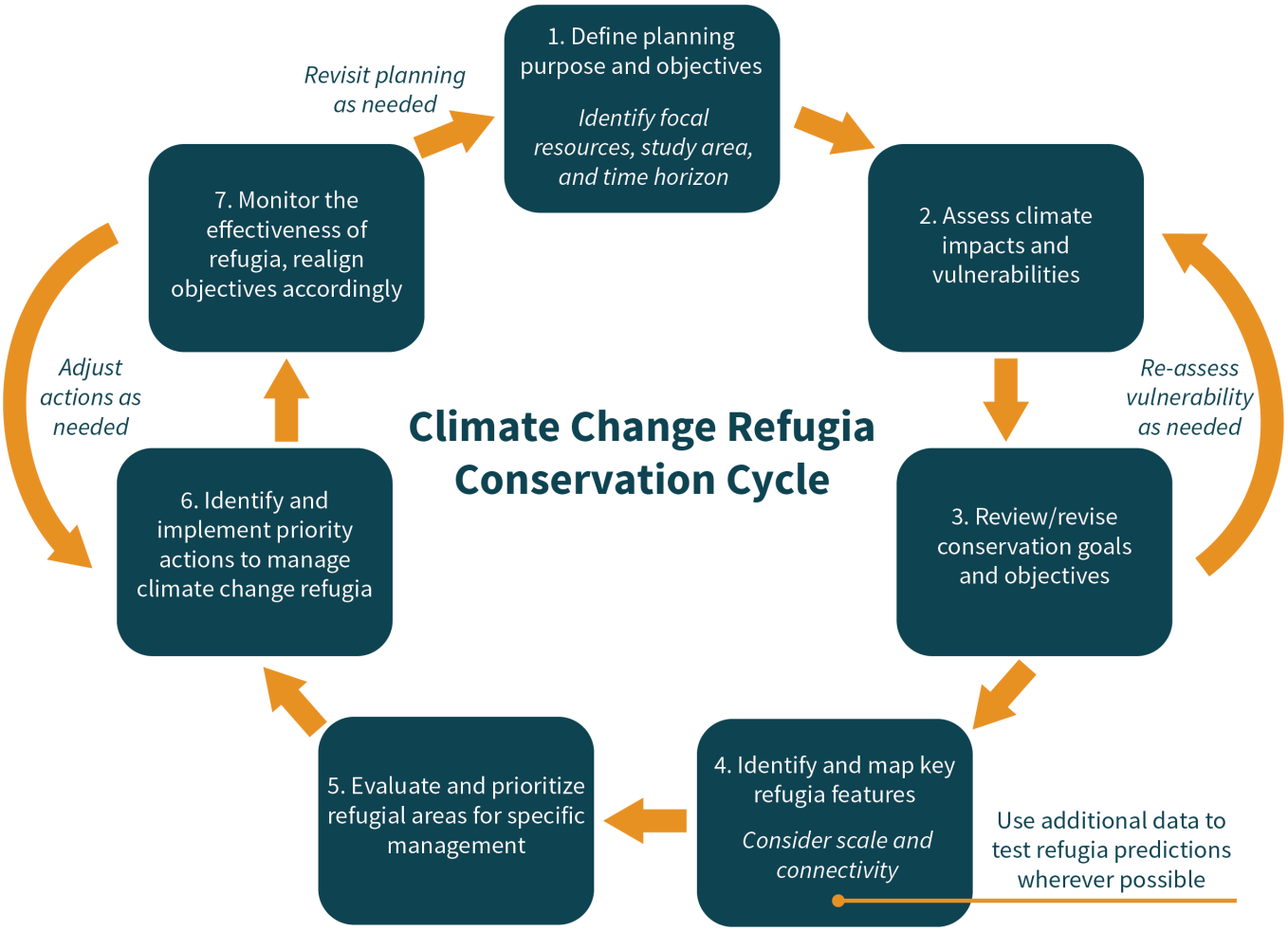
extremes and variability with



consequences for both temperature and water balance. Other vegetation properties (e.g., variable stand densities, forest gaps, evergreen/deciduous mosaics, riparian corridors) can also increase spatial variability in climate, creating shade and allowing for short-distance dispersal and movements to compensate for climate changes. Refugia-enhancing vegetation properties, including vegetation structure and fuel loading that lower the risk of increasingly severe fires, can be influenced by resource managers. However, biological determinants of climate change refugia, such as a forest stand that provides shade, are more dynamic, and thus capable of being lost, than are physical environments such as valleys or springs. There are a variety of ways that managers could apply the concept of climate refugia to conservation. Climate refugia were first documented in the Quaternary Science literature for situations where warm-adapted species were found to have persisted in isolated populations despite frigid, ice-age conditions that developed in landscapes around them. Populations outside of these unusual locations became extirpated due to unfavorable climate. These "safe haven" locations were inferred to have maintained more stable, warmer conditions, allowing the refugial populations to become sources for re-colonization once climates warmed at the end of the Pleistocene. The existence of these examples of historic species persistence despite unfavorable climate changes suggested that similar conditions and locations might exist at present, and that these could serve as climate refugia for contemporary climate change.

Management Challenges and Opportunities

Managing climate change refugia for local persistence of valued resources gains time for systems to adapt and for managers and society to develop longer-term solutions. A resource for managers is the climate change refugia cycle [3]. This cycle provides a framework in seven steps for managers to evaluate the value of refugia, identify refugia, and implement climate change refugial management. The seven steps are briefly outlined here. **Consider target resource needs and vulnerabilities** The starting point of the cycle (Step 1) is to determine the purpose and scope of a potential climate-change refugium project by defining the management or conservation target ("valued resource", e.g., a population, species, wetland). Understanding spatial and temporal scale



is important, is outlined as a framework for analysis, which can differ from the scale for actual on-the-ground management. Next, vulnerability of the valued resource is assessed (Step 2), considering the sensitivity, exposure, and adaptive capacity of the resource to projected changes in climate and its flexibility to adjust. After this, assessment conservation goals are re-evaluated to determine whether climate change refugia are an effective and appropriate strategy (Step 3). **Identify climate change refugia** Determining the best location for climate change refugia—including those areas that can be adequately managed—is a key analytic process (Step 4). A first attempt to delineate such areas can be done based on assessing known physical (e.g., cold-air pooling) and biotic (e.g., forest shading) processes that buffer climate change. Beyond this, creative use of data from long-term climate monitoring stations, comparison of maps generated from alternative future climate scenarios, estimation of climate velocities (the speed at which zones of suitable climate move across the landscape, per Loarie et al. 2009), and use of paleo-ecological data can be useful. **Prioritize refugial areas and implement management actions** Assuming climate-change refugia have been determined to be an effective adaptation tool for valued resources and a set of potential refugia sites mapped, Step 5 involves determining which of the overall set of sites can and should be prioritized for management. While this might depend on logistics and institutional capacity such as access, capacity to protect from disturbance, land designation constraints (e.g., Wilderness), it is also important to take into account local threats and vulnerabilities, opportunities to meet multiple conservation goals, etc. Once manageable locations for climate change refugia are determined, management goals can be developed (Step 6). Managing for climate change refugia will employ many of the same approaches used to conserve non-refugial targets, with an emphasis on use of resistance strategies in the limited areas determined for management. Once climate change refugia are identified, they can be prioritized for both traditional and creative management techniques for decreasing non-climate stressors. Treatment of invasives that cannot be carried out in all locations, can be focused there. Development and other anthropogenic disturbance can be minimized. In some situations,

translocation might be considered. Furthermore, connectivity among refugia will be key; isolated areas of climate change resistance will not increase resource persistence for long. **Monitor climate change refugia** Climate change refugia are only as good as they are effective over time, and thus monitoring is an essential part of the cycle (Step 7). Establishing baseline data relevant to the target resource, and collecting physical data including micro-climate indicators, as soon as possible after delineating refugia is an essential step to monitoring. These data can then be used to evaluate sites at intervals over time. To the extent that monitoring is developed as an adaptive experiment, goals and management actions--including to terminate the climate-refugia project if it is not effective—can be adjusted over time.

Conclusion

Climate change refugia management is not a universal solution. It can be costly, time-consuming, and will only be effective, at least for its original objective, until the climate changes too much for that resource in that place. It is best practiced along with other strategies, including tracking geographic shifts in refugial habitats to keep pace with climate change or maintaining genetic material in seed banks. There is also uncertainty about the scale at which climate change refugia should be identified and managed, the duration of their effectiveness, and how to incorporate multiple species or other resources that will respond to climate change in different ways. Nevertheless, if considered by multiple partners using a network approach, managing climate change refugia for local persistence of valued resources can gain time for systems to adapt and for longer-term solutions to be developed. If regulations or policy require a focus on short-term, immediate protection of high vulnerability areas, limited budgets and staff time might require a tradeoff between managing climate change refugia and other priorities. Managers may need to weigh short-term benefits of conservation of currently limiting habitat against long-term benefits of managing for habitats that are likely to become limiting in the future. Ultimately, a mix of strategies, including distributing management actions across areas with a range of climate vulnerabilities, might be the most effective path.

How to cite

Morelli, T.L.; Millar, C. 2018. Climate Change Refugia. USDA Forest Service Climate Change Resource Center. https://www.fs.usda.gov/ccrc/topics/climate-change-refugia

Recommended Reading

Morelli TL, Daly C, Dobrowski SZ, Dulen DM, Ebersole JL, et al. (2016)Managing Climate Change Refugia for Climate Adaptation. PLOS ONE 12(1): e0169725. Isaak, Daniel & Young, Michael. (2017). Delineating Climate Refugia for Native Aquatic Species with Big Crowd-Sourced Databases. Mountain Views Newsletter. 11. 3-6. Isaak et al. 2015 Cold Water Climate Shield: delineating refugia for preserving salmonid fishes through the 21st century Morelli, et al. 2017

Climate change refugia and habitat connectivity promote species persistence. Climate Change Responses 2017 4:8 Refugia Research Coalition News

Related Links

Refugia Research Coalition – brings together managers and scientists focused around species and ecosystems, including forests, and how climate change refugia can be managed to make them more resistant to climate change.

Research

Designing Sustainable Landscapes Mapping boreal refugia in the northeastern U.S. TNC's Resilience maps Sierra Nevada meadow refugia NorWest cold stream mapping Vernal pool mapping in the northeast Cold-air Pooling in Complex Terrain – downloadable algorithms and instructions with supporting information for mapping topographic regions that promote cold-air pooling; requires a DEM and Matlab Temperature-sensed Snow Cover – instructions for using mini-thermistors to determine when snow covers a site

Tools

Climate Change Refugia Conservation Cycle – framework to help managers to work through a step-by-step plan for conserving climate change refugia for species of conservation concern or vulnerable ecosystems. **Cold Water Climate Shield** – framework with a large toolbox for assessing and conserving cold water streams and reaches within streams that can serve as climate refugia for coldwater-adapted fish **Identify and Protect Climate Refugia** -- Yale University Framework website with overview and list of projects **Climate Change Adaptation Strategies for BLM Resource Management in Southern Nevada** -- NatureServe pilot project to apply the Yale Framework for climate assessment and adaptation, including application of climate refugia **From the Mountains to the Sea: Applying the Yale Framework in Puget Sound** -- Ecoadapt pilot project to apply the Yale Framework for climate assessment and adaptation, including application of climate refugia for at-risk fish species **Re-evaluating Florida's Ecological Conservation Priorities in the Face of Sea Rise** – Florida Natural Area Inventory pilot project to apply the Yale Framework for climate assessment and adaptation,

including application of climate refugia **Rapid Assessment of the Yale Framework and Adaptation Blueprint for the North America Pacific Coastal Rainforest** – GeosInstitute pilot project to apply the Yale Framework for climate assessment and adaptation, including application of climate micro-refugia to protect Pacific Coastal Rainforest ecosystems

References

1. USGCRP, 2017: Climate Science Special Report: Fourth National Climate Assessment, Volume I. U.S. Global Change Research Program, Washington, DC, USA, 470pp., doi: 10.7930/JOJ964J6. 2. Millar, C.I.; Stephenson, N.L.; Stephens, S.L.; 2007. Climate change and forests of the future: Managing in the face of uncertainty. Ecological Applications 17, 2145-2151. 3. Millar, C.I.; Stephenson, N.L.; 2015. Temperate forest health in an era of emerging megadisturbance. Science Vol. 349, Issue 6250, pp. 823-826 DOI: 10.1126/science.aaa9933 4. Morelli, T.L.; Daly, C.; Dobrowski, S.Z.; Dulen, D.M.; Ebersole, J.L.; et al; (2016) Managing Climate Change Refugia for Climate Adaptation. PLOS ONE 12(1): e0169725. https://doi.org/10.1371/journal.pone.0169725

Related Topics

Silvicultura para el Cambio Climático

Agroforestry

Recreation

Assisted Migration

Carbon as One of Many Management Objectives

Urban Forests and Climate Change

Private Forestland Stewardship

Wilderness and Climate Change

Silviculture for Climate Change

About the Climate Change Resource Center

The Climate Change Resource Center welcomes your comments and suggestions:
ccrc@fs.fed.us, USDA FS Climate Change Resource Center