A THREE-STEP DECISION SUPPORT FRAMEWORK FOR CLIMATE ADAPTATION:

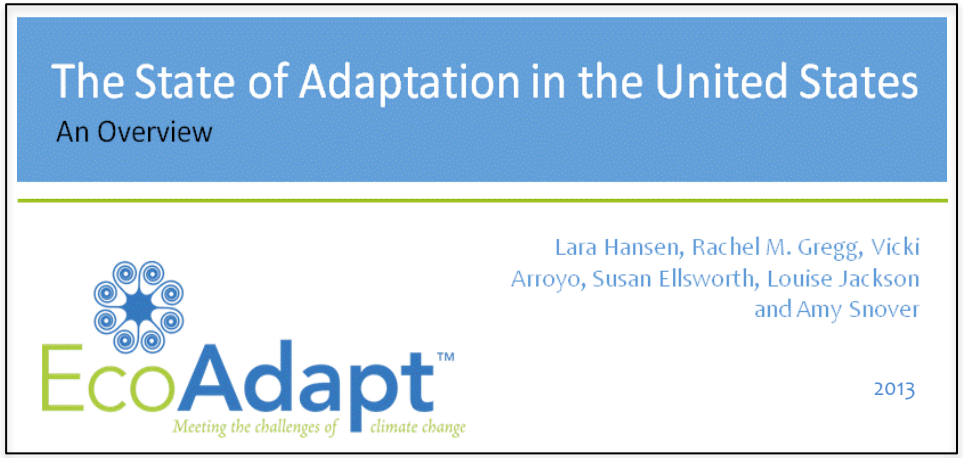
Selecting Climate-Informed Conservation Goals and Strategies for Native Salmonids in the Northern U.S. Rockies

Wildlife Conservation Society | The Center for Large Landscape Conservation | EcoAdapt

Funding provided by: Great Northern Landscape Conservation Cooperative

Lara J. Hansen, PhD~ EcoAdapt
Molly Cross, PhD ~ Wildlife Conservation Society
Regan Nelson, PhD ~
Gary Tabor, PhD/DVM ~ Center for Large Landscape Conservation

Climate Adaptation Progress

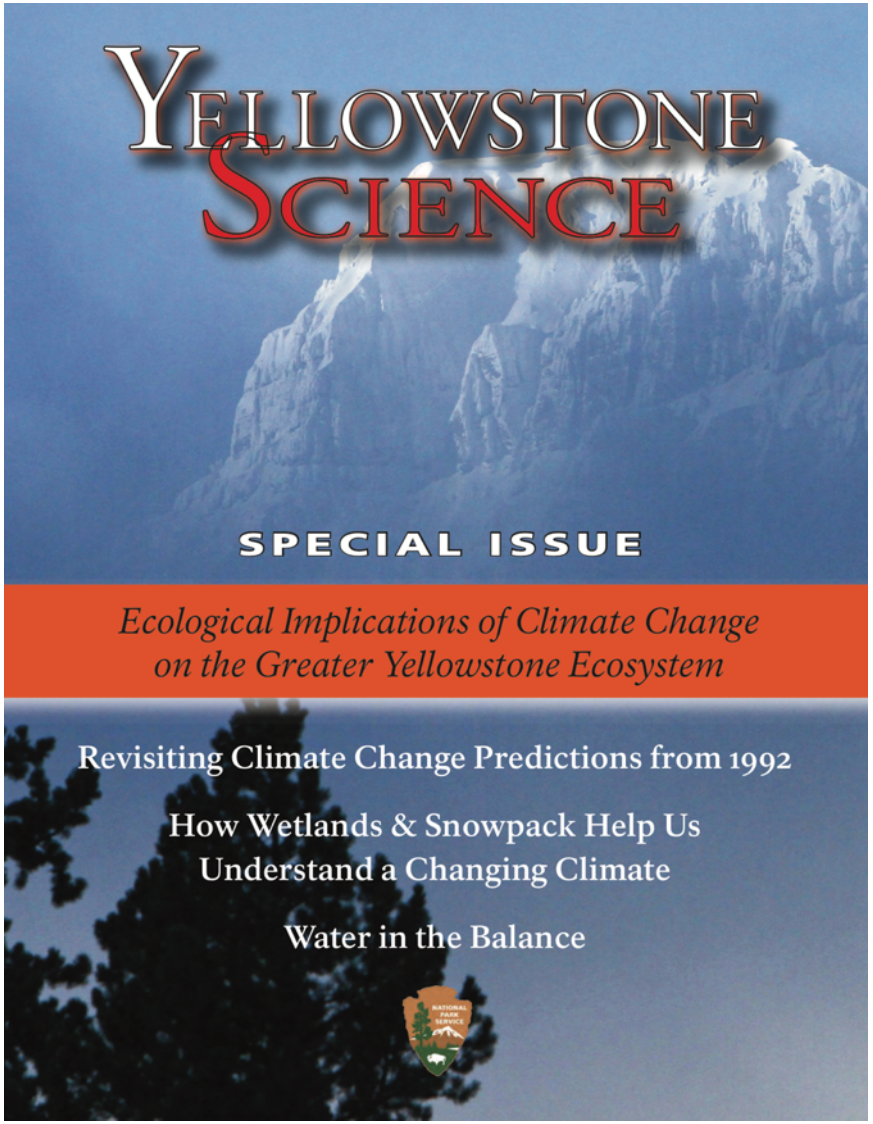


	Impacts Assessment	Vulnerability Assessment	Planning	Capacity Building	Implementation	Resources/ Tools	Monitoring/ Evaluation
Federal							
Tribal							
Region							
State							
Local							

Natural resource management sector

- More Activity
- Moderate Activity
- Less Activity
- Absent or Unknown

Lots of science & assessment



- Past and future climate changes
- Snowpack
- Water balance
- Wetlands
- Forest composition and health
- Fisheries
- Wildlife interactions
- Non-forest vegetation changes
- Wildfire
- Pests, pathogens, diseases
- Paleo-climate-ecology relationships
- *And much more…*

Adaptation Planning & Capacity Building

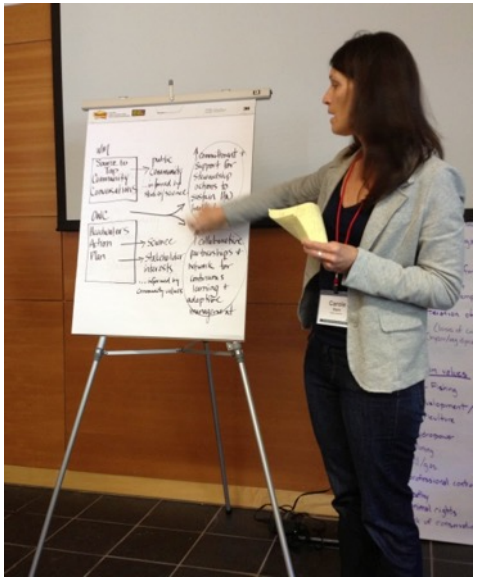
Rocky Mountain Partner Forum Workshop on Climate Adaptation for Cold Water Ecosystems

WCS

THE CENTER FOR LARGE LANDSCAPE CONSERVATION

EcoAdapt

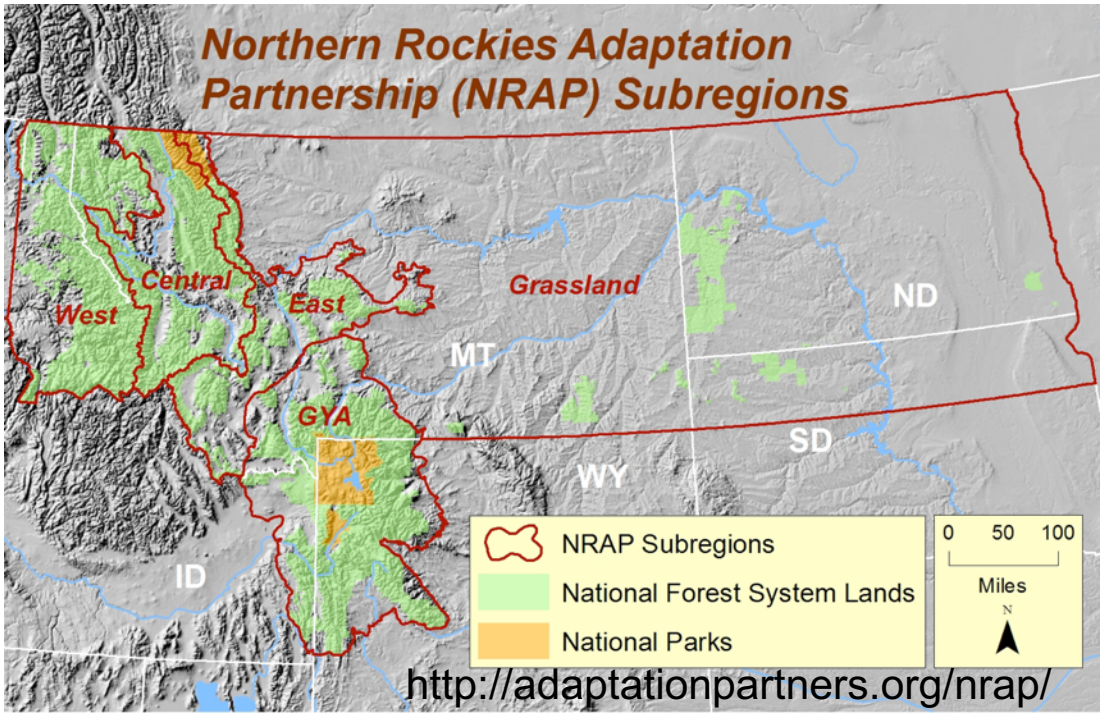
Great Northern LANDSCAPE CONSERVATION COOPERATIVE



- Scientists, managers
- Agencies, tribes, NGOs
- Some presentations, mostly interactive planning and sharing

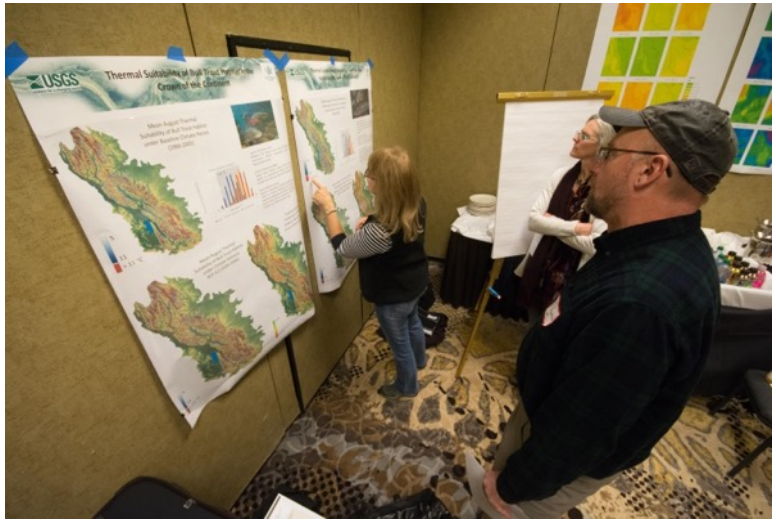
http://greatnorthernlcc.org/partner-forums/rocky-mountain

More Adaptation Planning & Capacity Building



Northern Rockies Adaptation Partnership (NRAP) – Workshops across USFS R1

Crown Adaptation Partnership - Workshop on Adaptation for Native Salmonids



More Adaptation Planning

Menu of adaptation "options"

STRATEGY	TACTIC
Increase resilience of native fish populations to warming stream temperatures and flow changes	Identify and restore "warm-adapted" populations of native trout
	Replicate and supplement native fish populations
	Connect current populations with streams that are currently too cold (and may warm to suitable levels in the future)
	Consider limiting angler pressure on native fish in streams that are at or near temperature thresholds
	Establish large-scale reserves for long-term native cold-water fish conservation
	Conduct field experiments of fish-temperature relationships for multiple species and regions
	Monitor changes in stream temperature for fish distributions
	Understand and map where groundwater inputs are providing cold water
Increase resilience of native fish species by reducing barriers to movement	Replace or retrofit culverts that will not function well during future low base flows and flood periods
	Identify, prioritize, and remove barriers to native fish movements
	Minimize water diversions; where they exist, ensure fish ladders avoid entrainment of native trout
Increase population resilience by increasing native fish health	Increase public education to eliminate disease vectors
	Survey fish health conditions
	Direct treatment or removal of infected fish
Prevent / remove invasive non-native fish	Survey and map non-native species
	Combine non-native mapping with information on migration barriers
	Remove or control non-native fish species (electrofishing, chemical removal, genetic swamping, encouraging increased harvest of non-natives)
	Strategically use physical or electrical barriers to prevent further spread of non-native fish
	Assess status of non-native fish more frequently to better detect changes in invasions (perhaps using citizen science)
	Model future changes in stream flow and habitat to anticipate future invasion hotspots
	Re-establish or replicate native fish populations in areas where non-natives have been removed or are effectively blocked by barriers

Continued on multiple pages…

From Science, Assessment, Capacity Building & Planning to Action

Capacity Building

Adaptation Plans & Options

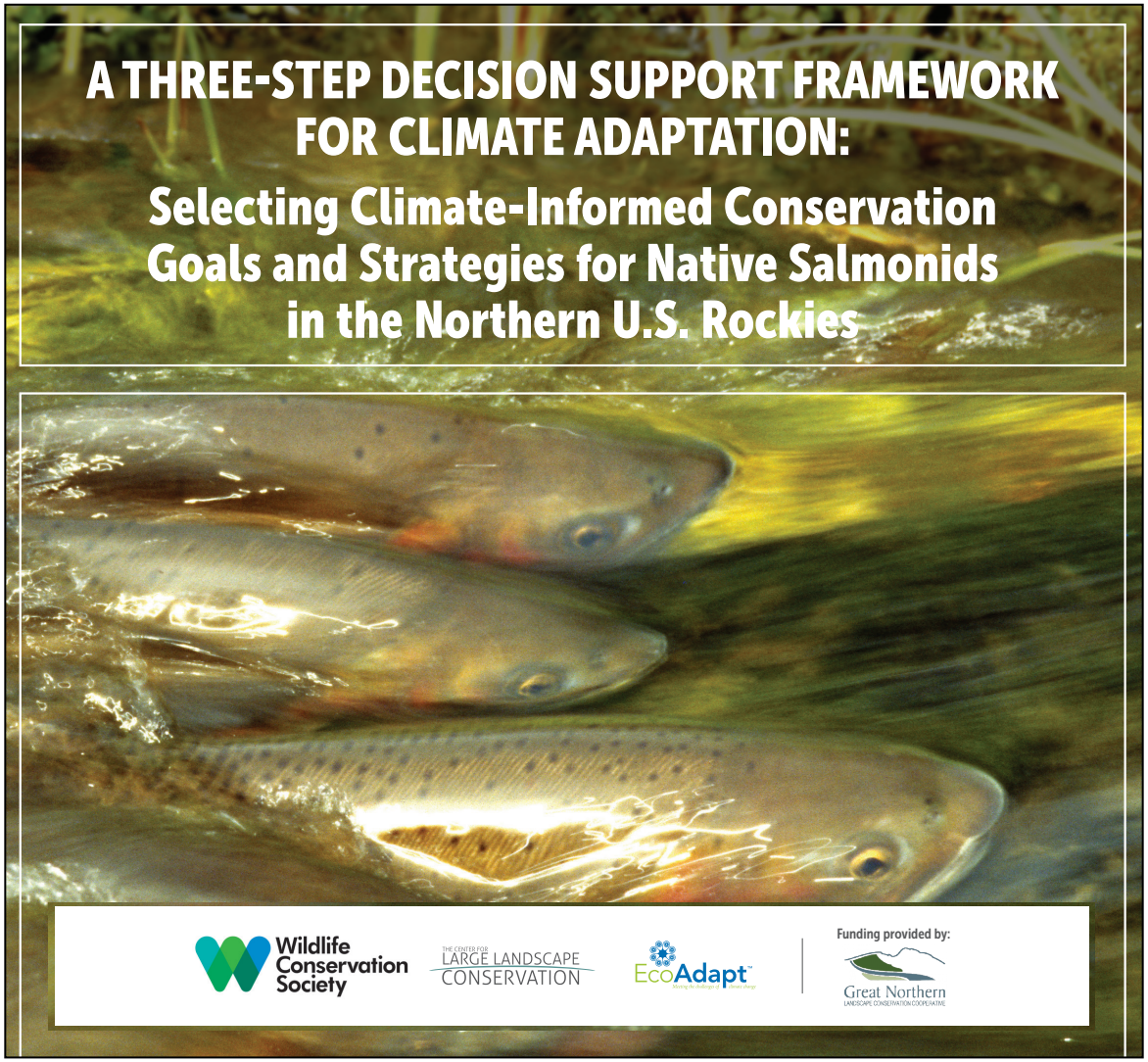
A COMPILATION OF ADAPTATION STRATEGIES AND TACTICS FROM PREVIOUS PLANNING EFFORTS[1]

STRATEGY	TACTIC
Increase resilience of native fish populations to warming stream temperatures and flow changes	Identify and restore "warm-adapted" populations of native trout
	Replicate and supplement native fish populations
	Connect current populations with streams that are currently too cold (and may warm to suitable levels in the future)
	Consider limiting angler pressure on native fish in streams that are at or near temperature thresholds
	Establish large-scale reserves for long-term native cold-water fish conservation
	Conduct field experiments of fish-temperature relationships for multiple species and regions
	Monitor changes in stream temperature for fish distributions
	Understand and map where groundwater inputs are providing cold water
Increase resilience of native fish species by reducing barriers to movement	Replace or retrofit culverts that will not function well during future low base flows and flood periods
	Identify, prioritize, and remove barriers to native fish movements
	Minimize water diversions; where they exist, ensure fish ladders avoid entrainment of native trout
Increase population resilience by increasing native fish health	Increase public education to eliminate disease vectors
	Survey fish health conditions
	Direct treatment or removal of infected fish
Prevent / remove invasive non-native fish	Survey and map non-native species
	Combine non-native mapping with information on migration barriers
	Remove or control non-native fish species (electrofishing, chemical removal, genetic swamping, encouraging increased harvest of non-natives)
	Strategically use physical or electrical barriers to prevent further spread of non-native fish
	Assess status of non-native fish more frequently to better detect changes in invasions (perhaps using citizen science)
	Model future changes in stream flow and habitat to anticipate future invasion hotspots
	Re-establish or replicate native fish populations in areas where non-natives have been removed or are effectively blocked by barriers
Increase spawning habitat resilience by restoring stream and floodplain structure and processes	Restore stream and floodplain complexity, ensuring adequate width-depth ratios and frequency of pools
	Provide alternative habitat for spawning
	Increase use of engineered log jams where feasible
	Prevent or remove aquatic invasive species

Science & Assessment

What to do?
Where to do it?
Towards what goal?

Towards Adaptation Action



Using information on climate vulnerabilities to select goals and actions from a menu of adaptation options

Funding from:

Great Northern
LANDSCAPE CONSERVATION COOPERATIVE

Decision Support Framework

Developed with input from:

Managers on the Custer Gallatin National Forest:

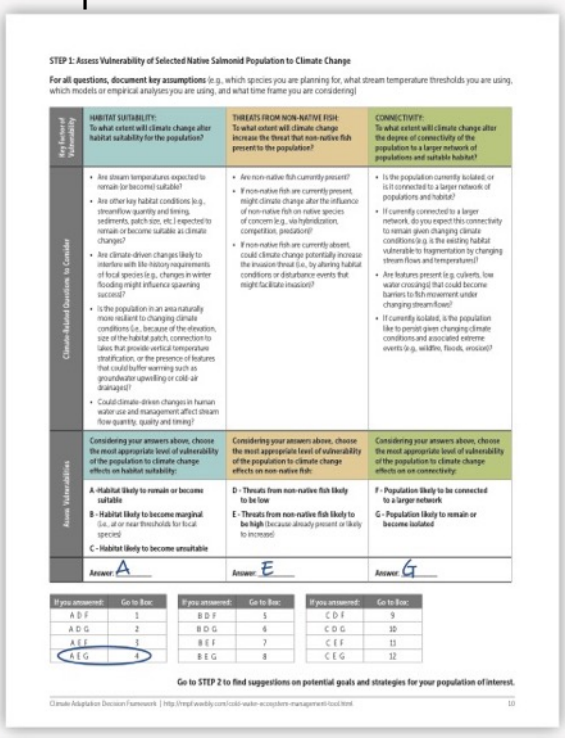
- Scott Barndt (ecosystems leader)
- Andy Efta (hydrologist)
- Dale White (hydrologist)
- Clint Sestrich (fisheries)
- Julie Shea (fire specialist)

Linh Hoang, USFS Region 1 climate coordinator

Decision Support Framework

3-Step Decision Support Framework

Step 1



STEP 1: Assess Vulnerability of Selected Native Salmonid Population to Climate Change

For all questions, document key assumptions (e.g., which species you are planning for, what stream temperature thresholds you are using, which models or empirical analyses you are using, and what time frame you are considering)

Key Factors of Vulnerability	HABITAT SUITABILITY: To what extent will climate change alter habitat suitability for the population?	THREATS FROM NON-NATIVE FISH: To what extent will climate change increase the threat that non-native fish present to the population?	CONNECTIVITY: To what extent will climate change alter the degree of connectivity of the population to a larger network of populations and suitable habitat?
Climate-Related Questions to Consider	• Are stream temperatures expected to remain (or become) suitable? • Are other key habitat conditions (e.g., streamflow quantity and timing, sediments, patch size, etc.) expected to remain or become suitable as climate changes? • Are climate-driven changes likely to interfere with life-history requirements of focal species (e.g., changes in winter flooding might influence spawning success)? • Is the population in an area naturally more resilient to changing climate conditions (i.e., because of the elevation, size of the habitat patch, connection to lakes that provide vertical temperature stratification, or the presence of features that could buffer warming such as groundwater upwelling or cold-air drainages)? • Could climate-driven changes in human water use and management affect stream flow quantity, quality and timing?	• Are non-native fish currently present? • If non-native fish are currently present, might climate change alter the influence of non-native fish on native species of concern (e.g., via hybridization, competition, predation)? • If non-native fish are currently absent, could climate change potentially increase the invasion threat (i.e., by altering habitat conditions or disturbance events that might facilitate invasion)?	• Is the population currently isolated; or is it connected to a larger network of populations and habitat? • If currently connected to a larger network, do you expect this connectivity to remain given changing climate conditions (e.g. is the existing habitat vulnerable to fragmentation by changing stream flows and temperatures)? • Are features present (e.g. culverts, low water crossings) that could become barriers to fish movement under changing stream flows? • If currently isolated, is the population like to persist given changing climate conditions and associated extreme events (e.g., wildfire, floods, erosion)?
Assess Vulnerabilities	Considering your answers above, choose the most appropriate level of vulnerability of the population to climate change effects on habitat suitability: **A -Habitat likely to remain or become suitable** **B - Habitat likely to become marginal** (i.e., at or near thresholds for focal species) **C – Habitat likely to become unsuitable**	Considering your answers above, choose the most appropriate level of vulnerability of the population to climate change effects on non-native fish: **D - Threats from non-native fish likely to be low** **E - Threats from non-native fish likely to be high** (because already present or likely to increase)	Considering your answers above, choose the most appropriate level of vulnerability of the population to climate change effects on on connectivity: **F - Population likely to be connected to a larger network** **G - Population likely to remain or become isolated**
	Answer: A	Answer: E	Answer: G

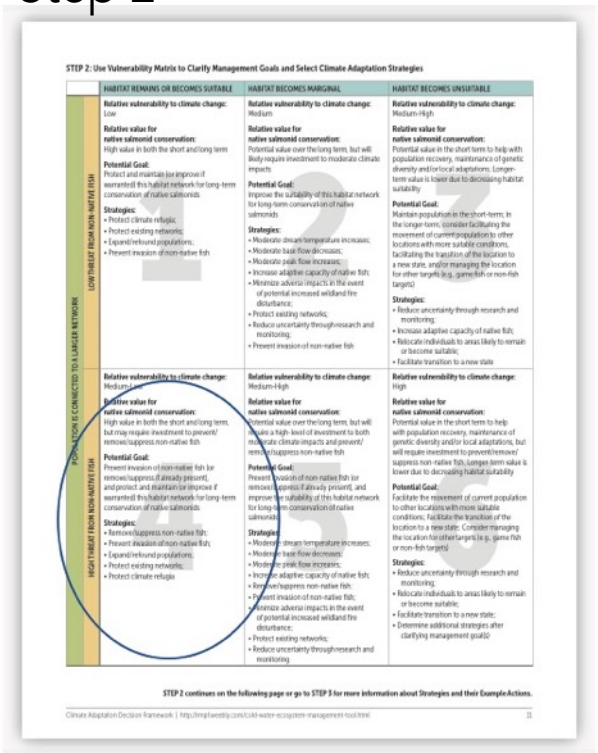
If you answered:	Go to Box:
A D F	1
A D G	2
A E F	3
A E G	4

If you answered:	Go to Box:
B D F	5
B D G	6
B E F	7
B E G	8

If you answered:	Go to Box:
C D F	9
C D G	10
C E F	11
C E G	12

Go to STEP 2 to find suggestions on potential goals and strategies for your population of interest.

Step 2

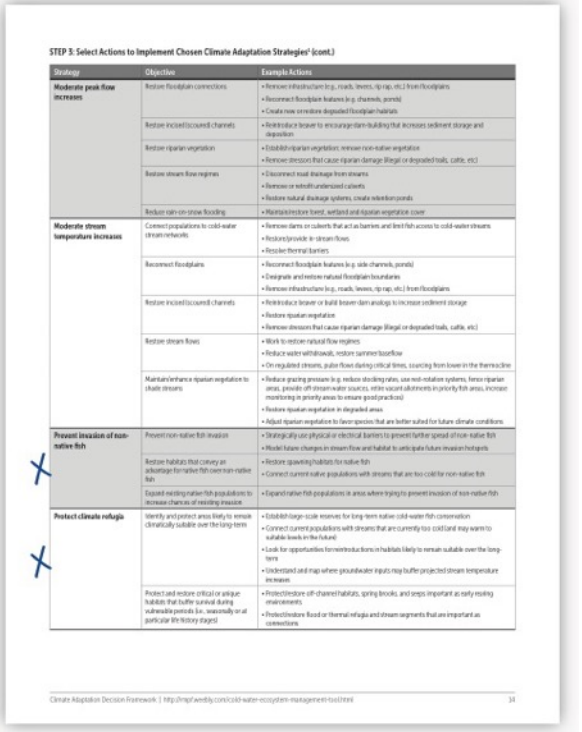


STEP 2: Use Vulnerability Matrix to Clarify Management Goals and Select Climate Adaptation Strategies

POPULATION IS CONNECTED TO A LARGER NETWORK	HABITAT REMAINS OR BECOMES SUITABLE	HABITAT BECOMES MARGINAL	HABITAT BECOMES UNSUITABLE
LOW THREAT FROM NON-NATIVE FISH	**Relative vulnerability to climate change:** Low **Relative value for native salmonid conservation:** High value in both the short and long term **Potential Goal:** Protect and maintain (or improve if warranted) this habitat network for long-term conservation of native salmonids **Strategies:** • Protect climate refugia; • Protect existing networks; • Expand/rebound populations; • Prevent invasion of non-native fish	**Relative vulnerability to climate change:** Medium **Relative value for native salmonid conservation:** Potential value over the long term, but will likely require investment to moderate climate impacts **Potential Goal:** Improve the suitability of this habitat network for long-term conservation of native salmonids **Strategies:** • Moderate stream temperature increases; • Moderate base flow decreases; • Moderate peak flow increases; • Increase adaptive capacity of native fish; • Minimize adverse impacts in the event of potential increased wildland fire disturbance; • Protect existing networks; • Reduce uncertainty through research and monitoring; • Prevent invasion of non-native fish	**Relative vulnerability to climate change:** Medium-High **Relative value for native salmonid conservation:** Potential value in the short term to help with population recovery, maintenance of genetic diversity and/or local adaptations. Longer-term value is lower due to decreasing habitat suitability **Potential Goal:** Maintain population in the short-term; in the longer-term, consider facilitating the movement of current population to other locations with more suitable conditions, facilitating the transition of the location to a new state, and/or managing the location for other targets (e.g., game fish or non-fish targets) **Strategies:** • Reduce uncertainty through research and monitoring; • Increase adaptive capacity of native fish; • Relocate individuals to areas likely to remain or become suitable; • Facilitate transition to a new state
HIGH THREAT FROM NON-NATIVE FISH	**Relative vulnerability to climate change:** Medium-Low **Relative value for native salmonid conservation:** High value in both the short and long term, but may require investment to prevent/remove/suppress non-native fish **Potential Goal:** Prevent invasion of non-native fish (or remove/suppress if already present), and protect and maintain (or improve if warranted) this habitat network for long-term conservation of native salmonids **Strategies:** • Remove/suppress non-native fish; • Prevent invasion of non-native fish; • Expand/rebound populations; • Protect existing networks; • Protect climate refugia	**Relative vulnerability to climate change:** Medium-High **Relative value for native salmonid conservation:** Potential value over the long term, but will require a high level of investment to both moderate climate impacts and prevent/remove/suppress non-native fish **Potential Goal:** Prevent invasion of non-native fish (or remove/suppress if already present), and improve the suitability of this habitat network for long-term conservation of native salmonids **Strategies:** • Moderate stream temperature increases; • Moderate base flow decreases; • Moderate peak flow increases; • Increase adaptive capacity of native fish; • Remove/suppress non-native fish; • Prevent invasion of non-native fish; • Minimize adverse impacts in the event of potential increased wildland fire disturbance; • Protect existing networks; • Reduce uncertainty through research and monitoring	**Relative vulnerability to climate change:** High **Relative value for native salmonid conservation:** Potential value in the short term to help with population recovery, maintenance of genetic diversity and/or local adaptations, but will require investment to prevent/remove/suppress non-native fish. Longer term value is lower due to decreasing habitat suitability **Potential Goal:** Facilitate the movement of current population to other locations with more suitable conditions; facilitate the transition of the location to a new state. Consider managing the location for other targets (e.g., game fish or non-fish targets) **Strategies:** • Reduce uncertainty through research and monitoring; • Relocate individuals to areas likely to remain or become suitable; • Facilitate transition to a new state; • Determine additional strategies after clarifying management goal(s)

STEP 2 continues on the following page or go to STEP 3 for more information about Strategies and their Example Actions.

Step 3



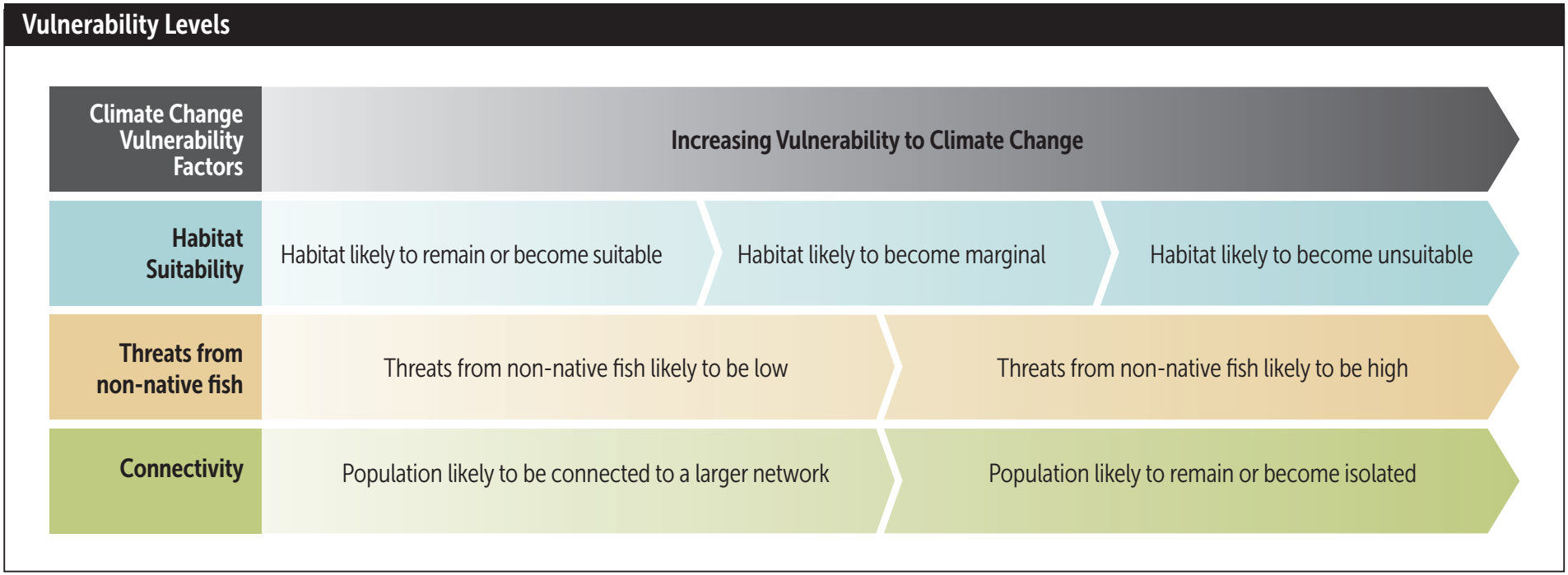
STEP 3: Select Actions to Implement Chosen Climate Adaptation Strategies[2] (cont.)

Strategy	Objective	Example Actions
Moderate peak flow increases	Restore floodplain connections	• Remove infrastructure (e.g., roads, levees, rip-rap, etc.) from floodplains • Reconnect floodplain features (e.g. channels, ponds) • Create new corridors degraded floodplain habitats
	Restore incised/scoured channels	• Reintroduce beaver to encourage dam-building that increases sediment storage and deposition
	Restore riparian vegetation	• Establish riparian vegetation; remove non-native vegetation • Remove stressors that cause riparian damage (illegal or degraded trails, cattle, etc)
	Restore stream flow regimes	• Disconnect road drainage from streams • Remove or retrofit undersized culverts • Restore natural drainage systems, create retention ponds
	Reduce rain-on-snow flooding	• Maintain/restore forest, wetland and riparian vegetation cover
Moderate stream temperature increases	Connect populations to cold-water stream networks	• Remove dams or culverts that act as barriers and limit fish access to cold-water streams • Restore/provide in-stream flows • Resolve thermal barriers
	Reconnect floodplains	• Reconnect floodplain features (e.g. side channels, ponds) • Designate and restore natural floodplain boundaries • Remove infrastructure (e.g., roads, levees, rip-rap, etc.) from floodplains
	Restore incised/scoured channels	• Reintroduce beaver or build beaver dam analogs to increase sediment storage • Restore riparian vegetation • Remove stressors that cause riparian damage (illegal or degraded trails, cattle, etc.)
	Restore stream flows	• Work to restore natural flow regimes • Reduce water withdrawals; restore summer baseflow • On regulated streams, pulse flows during critical times, sourcing from lower in the thermocline
	Maintain/enhance riparian vegetation to shade streams	• Reduce grazing pressure (e.g. reduce stocking rates, use rest-rotation systems, fence riparian areas, provide off-stream water sources, retire vacant allotments in priority fish areas, increase monitoring in priority areas to ensure good practices) • Restore riparian vegetation in degraded areas • Adjust riparian vegetation to favor species that are better suited for future climate conditions
Prevent invasion of non-native fish	Prevent non-native fish invasion	• Strategically use physical or electrical barriers to prevent further spread of non-native fish • Model future changes in stream flow and habitat to anticipate future invasion hotspots
	Restore habitats that convey an advantage for native fish over non-native fish	• Restore spawning habitats for native fish • Connect current native populations with streams that are too cold for non-native fish
	Expand existing native fish populations to increase chances of resisting invasion	• Expand native fish populations in areas where trying to prevent invasion of non-native fish
Protect climate refugia	Identify and protect areas likely to remain climatically suitable over the long-term	• Establish large-scale reserves for long-term native cold-water fish conservation • Connect current populations with streams that are currently too cold (and may warm to suitable levels in the future) • Look for opportunities for reintroductions in habitats likely to remain suitable over the long-term • Understand and map where groundwater inputs may buffer projected stream temperature increases
	Protect and restore critical or unique habitats that buffer survival during vulnerable periods (i.e., seasonally or at particular life history stages)	• Protect/restore off-channel habitats, spring brooks, and seeps important as early rearing environments • Protect/restore flood or thermal refugia and stream segments that are important as connections

Available for download:
http://rmpf.weebly.com/cold-water-ecosystem-management-tool.html

Decision Support Framework

Step 1: Assess vulnerability of selected native salmonid population to climate change



- Asks users "key questions" to assess climate vulnerabilities

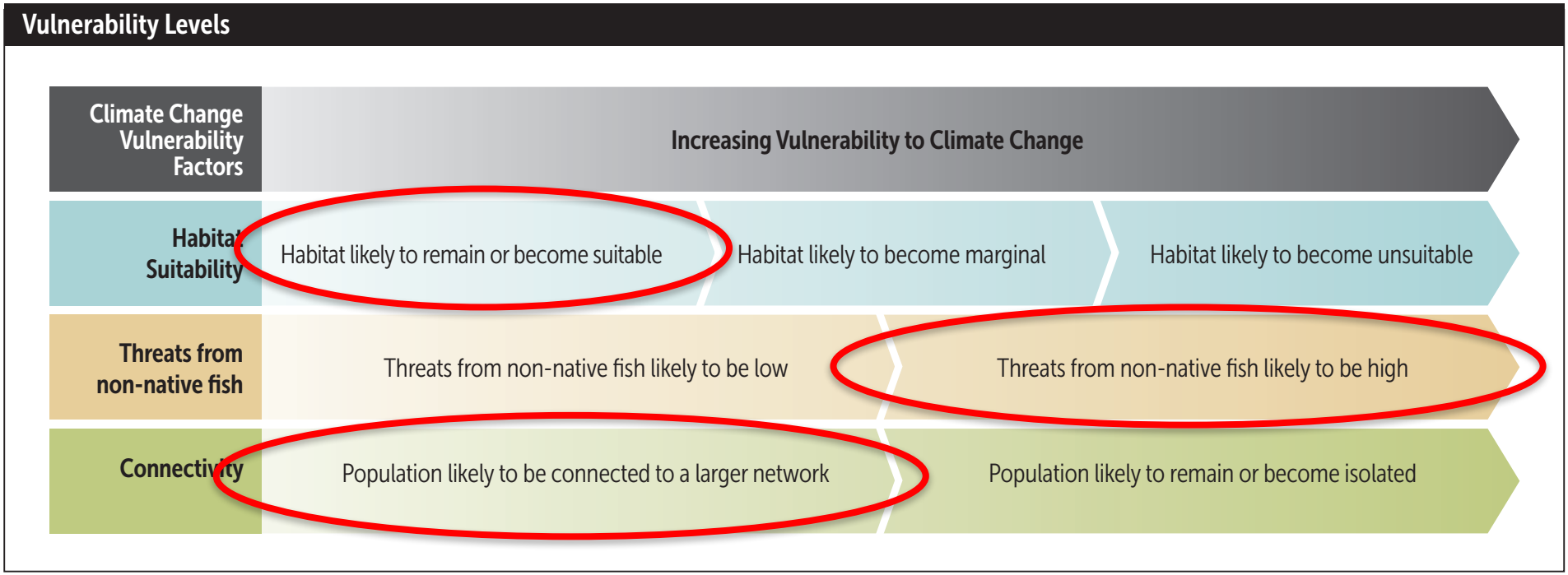
Decision Support Framework

Step 1: Assess vulnerability of selected native salmonid population to climate change

Key Factor of Vulnerability	HABITAT SUITABILITY: To what extent will climate change alter habitat suitability for the population?	THREATS FROM NON-NATIVE FISH: To what extent will climate change increase the threat that non-native fish present to the population?	CONNECTIVITY: To what extent will climate change alter the degree of connectivity of the population to a larger network of populations and suitable habitat?
Climate-Related Questions to Consider	• Are stream temperatures expected to remain (or become) suitable? • Are other key habitat conditions (e.g., streamflow quantity and timing, sediments, patch size, etc.) expected to remain or become suitable as climate changes? • Are climate-driven changes likely to interfere with life-history requirements of focal species (e.g., changes in winter flooding might influence spawning success)? • Is the population in an area naturally more resilient to changing climate conditions (i.e., because of the elevation, size of the habitat patch, connection to lakes that provide vertical temperature stratification, or the presence of features that could buffer warming such as groundwater upwelling or cold-air drainages)? • Could climate-driven changes in human water use and management affect stream flow quantity, quality and timing?	• Are non-native fish currently present? • If non-native fish are currently present, might climate change alter the influence of non-native fish on native species of concern (e.g., via hybridization, competition, predation)? • If non-native fish are currently absent, could climate change potentially increase the invasion threat (i.e., by altering habitat conditions or disturbance events that might facilitate invasion)?	• Is the population currently isolated, or is it connected to a larger network of populations and habitat? • If currently connected to a larger network, do you expect this connectivity to remain given changing climate conditions (e.g. is the existing habitat vulnerable to fragmentation by changing stream flows and temperatures)? • Are features present (e.g. culverts, low water crossings) that could become barriers to fish movement under changing stream flows? • If currently isolated, is the population like to persist given changing climate conditions and associated extreme events (e.g., wildfire, floods, erosion)?

Decision Support Framework

Step 1: Assess vulnerability of selected native salmonid population to climate change



- 12 combinations of vulnerability factors and levels

Decision Support Framework

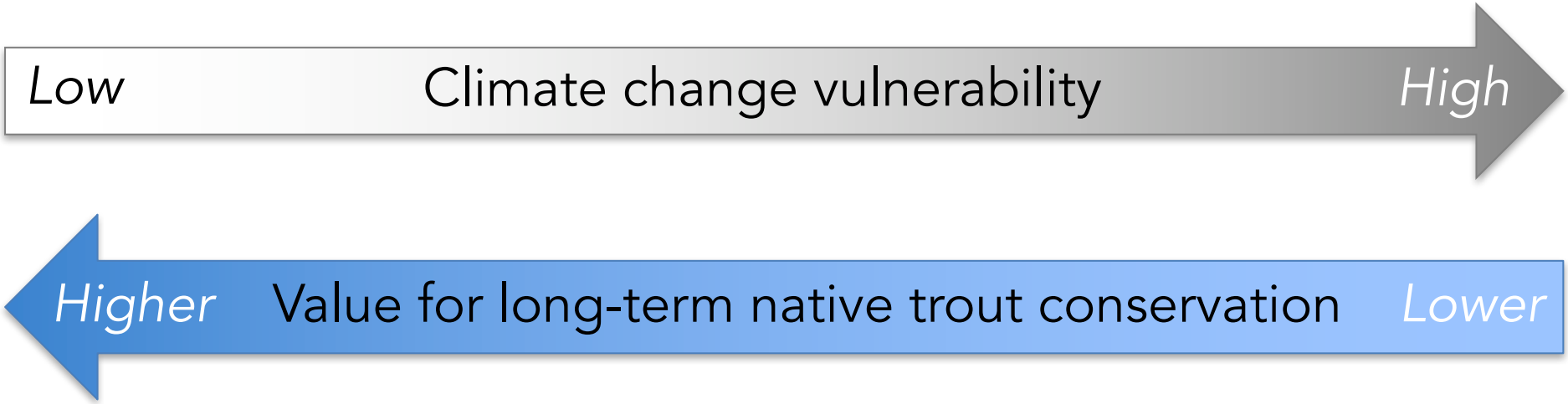
Step 2: Use vulnerability matrix to clarify management goals and select climate adaptation strategies

		HABITAT REMAINS OR BECOMES SUITABLE	HABITAT BECOMES MARGINAL	HABITAT BECOMES UNSUITABLE
POPULATION IS CONNECTED TO A LARGER NETWORK	LOW THREAT FROM NON-NATIVE FISH	**Relative vulnerability to climate change:** Low **Relative value for native salmonid conservation:** High value in both the short and long term **Potential Goal:** Protect and maintain (or improve if warranted) this habitat network for long-term conservation of native salmonids **Strategies:** • Protect climate refugia; • Protect existing networks; • Expand/refound populations; • Prevent invasion of non-native fish	**Relative vulnerability to climate change:** Medium **Relative value for native salmonid conservation:** Potential value over the long term, but will likely require investment to moderate climate impacts **Potential Goal:** Improve the suitability of this habitat network for long-term conservation of native salmonids **Strategies:** • Moderate stream temperature increases; • Moderate base flow decreases; • Moderate peak flow increases; • Increase adaptive capacity of native fish; • Minimize adverse impacts in the event of potential increased wildland fire disturbance; • Protect existing networks; • Reduce uncertainty through research and monitoring; • Prevent invasion of non-native fish	**Relative vulnerability to climate change:** Medium-High **Relative value for native salmonid conservation:** Potential value in the short term to help with population recovery, maintenance of genetic diversity and/or local adaptations; Longer-term value is lower due to decreasing habitat suitability **Potential Goal:** Maintain population in the short-term; In the longer-term, consider facilitating the movement of current population to other locations with more suitable conditions, facilitating the transition of the location to a new state, and/or managing the location for other targets (e.g., game fish or non-fish targets) **Strategies:** • Reduce uncertainty through research and monitoring; • Increase adaptive capacity of native fish; • Relocate individuals to areas likely to remain or become suitable; • Facilitate transition to a new state
	HIGH THREAT FROM NON-NATIVE FISH	**Relative vulnerability to climate change:** Medium-Low **Relative value for native salmonid conservation:** High value in both the short and long term, but may require investment to prevent/remove/suppress non-native fish **Potential Goal:** Prevent invasion of non-native fish (or remove/suppress if already present), and protect and maintain (or improve if warranted) this habitat network for long-term conservation of native salmonids **Strategies:** • Remove/suppress non-native fish; • Prevent invasion of non-native fish; • Expand/refound populations; • Protect existing networks; • Protect climate refugia	**Relative vulnerability to climate change:** Medium-High **Relative value for native salmonid conservation:** Potential value over the long term, but will require a high-level of investment to both moderate climate impacts and prevent/remove/suppress non-native fish **Potential Goal:** Prevent invasion of non-native fish (or remove/suppress if already present), and improve the suitability of this habitat network for long-term conservation of native salmonids **Strategies:** • Moderate stream temperature increases; • Moderate base flow decreases; • Moderate peak flow increases; • Increase adaptive capacity of native fish; • Remove/suppress non-native fish; • Prevent invasion of non-native fish; • Minimize adverse impacts in the event of potential increased wildland fire disturbance; • Protect existing networks; • Reduce uncertainty through research and monitoring	**Relative vulnerability to climate change:** High **Relative value for native salmonid conservation:** Potential value in the short term to help with population recovery, maintenance of genetic diversity and/or local adaptations, but will require investment to prevent/remove/suppress non-native fish; Longer-term value is lower due to decreasing habitat suitability **Potential Goal:** Facilitate the movement of current population to other locations with more suitable conditions; Facilitate the transition of the location to a new state; Consider managing the location for other targets (e.g., game fish or non-fish targets) **Strategies:** • Reduce uncertainty through research and monitoring; • Relocate individuals to areas likely to remain or become suitable; • Facilitate transition to a new state; • Determine additional strategies after clarifying management goal(s)

		HABITAT REMAINS OR BECOMES SUITABLE	HABITAT BECOMES MARGINAL	HABITAT BECOMES UNSUITABLE
POPULATION REMAINS OR BECOMES ISOLATED	LOW THREAT FROM NON-NATIVE FISH	**Relative vulnerability to climate change:** Medium-Low **Relative value for native salmonid conservation:** Potential value for providing genetic diversity and/or local adaptations in both the short and long term, but will likely require investment to address fragmentation **Potential Goal:** Evaluate representativeness of this population across the landscape, and determine what level of protection/reconnection to other habitats is warranted **Strategies:** • Reconnect fragmented networks; • Protect climate refugia; • Minimize adverse impacts in the event of potential increased wildland fire disturbance; • Expand population; • Prevent invasion of non-native fish	**Relative vulnerability to climate change:** Medium **Relative value for native salmonid conservation:** Potential value for providing genetic diversity and/or local adaptations, but will likely require investment to moderate climate impacts and address fragmentation **Potential Goal:** Evaluate representativeness of this population across the landscape, and determine what level of protection/restoration/active management is warranted **Strategies:** • Reconnect fragmented networks; • Moderate stream temperature increases; • Moderate base flow decreases; • Moderate peak flow increases; • Increase adaptive capacity of native fish; • Minimize adverse impacts in the event of potential increased wildland fire disturbance; • Reduce uncertainty through research and monitoring; • Prevent invasion of non-native species	**Relative vulnerability to climate change:** Medium-High **Relative value for native salmonid conservation:** Potential value in short-term for providing genetic diversity and/or local adaptations, but will likely require investment to address fragmentation; Longer-term value is lower due to decreasing habitat suitability **Potential Goal:** Maintain population in the short-term; In the longer-term, consider facilitating the movement of current population to other locations with more suitable conditions, facilitating the transition of the location to a new state, and/or managing the location for other targets (e.g., game fish or non-fish targets) **Strategies:** • Reduce uncertainty through research and monitoring; • Increase adaptive capacity of native fish; • Relocate individuals to areas likely to remain or become suitable; • Facilitate transition to a new state
	HIGH THREAT FROM NON-NATIVE FISH	**Relative vulnerability to climate change:** Medium **Relative value for native salmonid conservation:** Potential value, but may will likely require investment to prevent/remove/suppress non-native fish and address fragmentation **Potential Goal:** Evaluate representativeness of this population across the landscape, and determine what level of protection, reconnection to other habitats, and management on non-native fish is warranted **Strategies:** • Reconnect fragmented networks; • Protect climate refugia; • Minimize adverse impacts in the event of potential increased wildland fire disturbance; • Expand population; • Prevent invasion of non-native fish	**Relative vulnerability to climate change:** Medium-High **Relative value for native salmonid conservation:** Lower value, and will likely require a high-level of investment to moderate climate impacts, prevent/remove/suppress non-native fish, and address fragmentation **Potential Goal:** Facilitate the movement of current population to other locations with more suitable conditions; Facilitate the transition of the location to a new state; Consider managing the location for other targets (e.g., game fish or non-fish targets) **Strategies:** • Reduce uncertainty through research and monitoring; • Relocate individuals to areas likely to remain or become suitable; • Facilitate transition to a new state; • Determine additional strategies after clarifying management goal(s)	**Relative vulnerability to climate change:** High **Relative value for native salmonid conservation:** Low value **Potential Goal:** Facilitate the movement of current population to other locations with more suitable conditions; Facilitate the transition of the location to a new state; Consider managing the location for other targets (e.g., game fish or non-fish targets) **Strategies:** • Reduce uncertainty through research and monitoring; • Relocate individuals to areas likely to remain or become suitable; • Facilitate transition to a new state; • Determine additional strategies after clarifying management goal(s)

Decision Support Framework

Step 2: Use vulnerability matrix to clarify management goals and select climate adaptation strategies



Goal = Maintain/Restore Coldwater Strongholds & Refugia

Goal = Ameliorate Climate Effects on Streams

Goal = Facilitate Transitions

Vulnerability Type + Goals → Specific Climate Adaptation Strategies

Decision Support Framework

Step 3: Select actions to implement chosen climate adaptation strategies *(from list of example actions)*

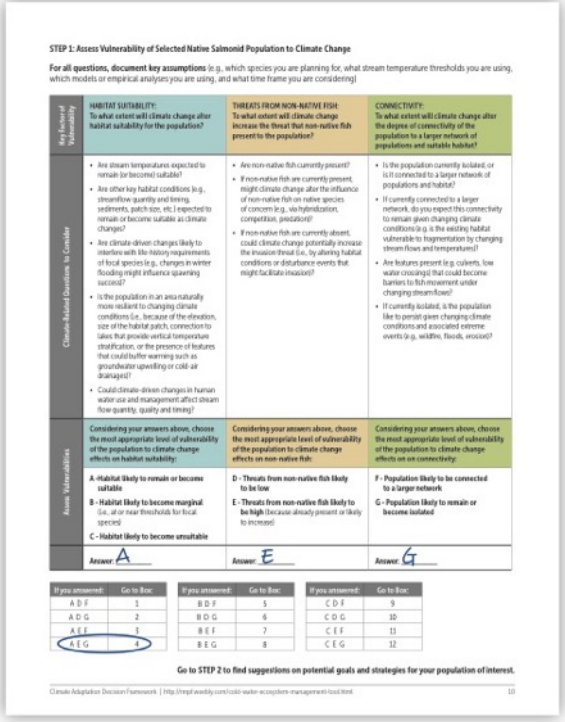
Strategy	Objective	Example Actions
Expand/refound populations	Increase population size and number of populations to recover large, interconnected populations	• Expand populations at or below minimum viable population size • Refound new populations in areas expected to be climatically suitable
Facilitate transition to a new state	Allow colonization by new species that may be better suited to new environments and still provide some ecological function and value	• Remove barriers to invasion • Introduce new species
Increase adaptive capacity of native fish	Increase resilience of native fish populations to warming stream temperatures and flow changes	• Identify and restore "warm-adapted" populations of native trout • Consider limiting angler pressure on native fish in streams that are at or near temperature thresholds • Replicate and supplement native fish populations • Remove non-native fish
	Increase native fish health	• Increase public education to eliminate disease vectors • Treat or remove infected/diseased fish • Eliminate or control pollutants or contaminants
	Conserve genotypic/phenotypic diversity	• Conserve or restore a diverse representation of habitats across river basins • Maintain large population sizes to minimize loss of genetic variability and adaptive potential.
Minimize adverse impacts in the event of potential increased wildland fire disturbance	Identify and minimize negative effects to areas most vulnerable to fire impacts	• Develop a geospatial layer of debris flow potential for pre-fire planning • Manage natural fuel conditions and unplanned wildfire effects through fuel management actions and/or use of unplanned wildfire ignitions to minimize negative effects (severity and extent) of fire.
	Restore areas adversely affected by fire	• Inventory disturbed areas for candidate sites for riparian and upland vegetation restoration • Restore and re-vegetate burned areas to store sediment and maintain channel geomorphology

Continued...

Decision Support Framework

3-Step Decision Support Framework

Step 1



STEP 1: Assess Vulnerability of Selected Native Salmonid Population to Climate Change

For all questions, document key assumptions (e.g., which species you are planning for, what stream temperature thresholds you are using, which models or empirical analyses you are using, and what time frame you are considering)

Key Factors of Vulnerability	HABITAT SUITABILITY: To what extent will climate change alter habitat suitability for the population?	THREATS FROM NON-NATIVE FISH: To what extent will climate change increase the threat that non-native fish present to the population?	CONNECTIVITY: To what extent will climate change alter the degree of connectivity of the population to a larger network of populations and suitable habitat?
Climate-Related Questions to Consider	• Are stream temperatures expected to remain (or become) suitable? • Are other key habitat conditions (e.g., streamflow quantity and timing, sediments, patch size, etc.) expected to remain or become suitable as climate changes? • Are climate-driven changes likely to interfere with life-history requirements of focal species (e.g., changes in winter flooding might influence spawning success)? • Is the population in an area naturally more resilient to changing climate conditions (i.e., because of the elevation, size of the habitat patch, connection to lakes that provide vertical temperature stratification, or the presence of features that could buffer warming such as groundwater upwelling or cold-air drainages)? • Could climate-driven changes in human water use and management affect stream flow quantity, quality and timing?	• Are non-native fish currently present? • If non-native fish are currently present, might climate change alter the influence of non-native fish on native species of concern (e.g., via hybridization, competition, predation)? • If non-native fish are currently absent, could climate change potentially increase the invasion threat (i.e., by altering habitat conditions or disturbance events that might facilitate invasion)?	• Is the population currently isolated; or is it connected to a larger network of populations and habitat? • If currently connected to a larger network, do you expect this connectivity to remain given changing climate conditions (e.g. is the existing habitat vulnerable to fragmentation by changing stream flows and temperatures)? • Are features present (e.g. culverts, low water crossings) that could become barriers to fish movement under changing stream flow? • If currently isolated, is the population like to persist given changing climate conditions and associated extreme events (e.g., wildfire, floods, erosion)?
Assess Vulnerabilities	**Considering your answers above, choose the most appropriate level of vulnerability of the population to climate change effects on habitat suitability:** **A -Habitat likely to remain or become suitable** **B - Habitat likely to become marginal** (i.e., at or near thresholds for focal species) **C - Habitat likely to become unsuitable** Answer: A	**Considering your answers above, choose the most appropriate level of vulnerability of the population to climate change effects on non-native fish:** **D - Threats from non-native fish likely to be low** **E - Threats from non-native fish likely to be high** (because already present or likely to increase) Answer: E	**Considering your answers above, choose the most appropriate level of vulnerability of the population to climate change effects on on connectivity:** **F - Population likely to be connected to a larger network** **G - Population likely to remain or become isolated** Answer: G

If you answered:	Go to Box:
A D F	1
A D G	2
A E F	3
A E G	4

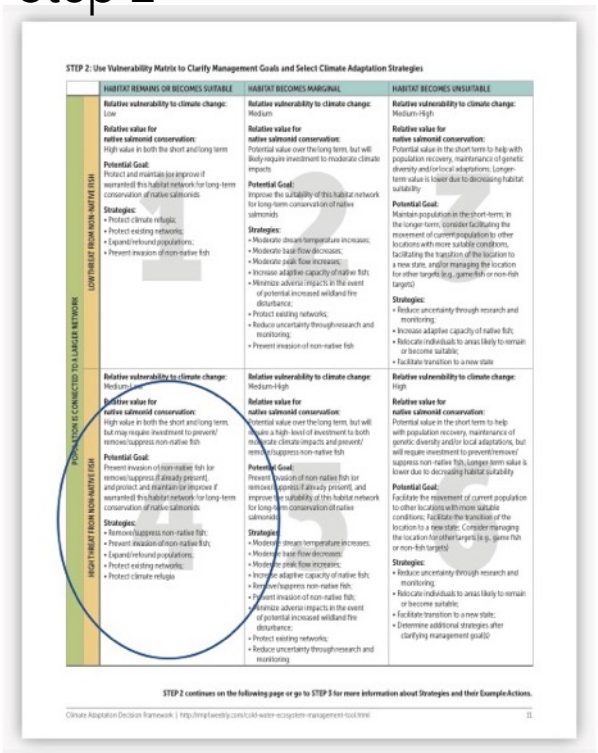
If you answered:	Go to Box:
B D F	5
B D G	6
B E F	7
B E G	8

If you answered:	Go to Box:
C D F	9
C D G	10
C E F	11
C E G	12

Go to STEP 2 to find suggestions on potential goals and strategies for your population of interest.

Climate Adaptation Decision Framework | http://mpf.weebly.com/cold-water-ecosystem-management-tool.html 10

Step 2



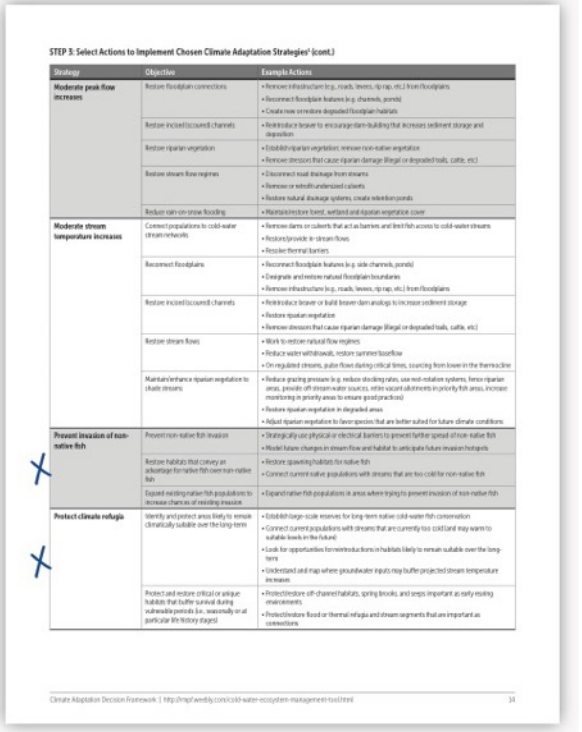
STEP 2: Use Vulnerability Matrix to Clarify Management Goals and Select Climate Adaptation Strategies

POPULATION IS CONNECTED TO A LARGER NETWORK	HABITAT REMAINS OR BECOMES SUITABLE	HABITAT BECOMES MARGINAL	HABITAT BECOMES UNSUITABLE
LOW THREAT FROM NON-NATIVE FISH	**Relative vulnerability to climate change:** Low **Relative value for native salmonid conservation:** High value in both the short and long term **Potential Goal:** Protect and maintain (or improve if warranted) this habitat network for long-term conservation of native salmonids **Strategies:** • Protect climate refugia; • Protect existing networks; • Expand/rebound populations; • Prevent invasion of non-native fish	**Relative vulnerability to climate change:** Medium **Relative value for native salmonid conservation:** Potential value over the long term, but will likely require investment to moderate climate impacts **Potential Goal:** Improve the suitability of this habitat network for long-term conservation of native salmonids **Strategies:** • Moderate stream temperature increases; • Moderate base flow decreases; • Moderate peak flow increases; • Increase adaptive capacity of native fish; • Minimize adverse impacts in the event of potential increased wildland fire disturbance; • Protect existing networks; • Reduce uncertainty through research and monitoring; • Prevent invasion of non-native fish	**Relative vulnerability to climate change:** Medium-High **Relative value for native salmonid conservation:** Potential value over the long term, but will likely require investment to moderate climate impacts **Potential Goal:** Maintain population in the short-term; in the longer-term, consider facilitating the movement of current population to other locations with more suitable conditions, facilitating the transition of the location to a new state, and/or managing the location for other targets (e.g., game fish or non-fish targets) **Strategies:** • Reduce uncertainty through research and monitoring; • Increase adaptive capacity of native fish; • Relocate individuals to areas likely to remain or become suitable; • Facilitate transition to a new state
HIGH THREAT FROM NON-NATIVE FISH	**Relative vulnerability to climate change:** Medium-Low **Relative value for native salmonid conservation:** High value in both the short and long term, but may require investment to prevent/remove/suppress non-native fish **Potential Goal:** Prevent invasion of non-native fish (or remove/suppress if already present), and protect and maintain (or improve if warranted) this habitat network for long-term conservation of native salmonids **Strategies:** • Remove/suppress non-native fish; • Prevent invasion of non-native fish; • Expand/rebound populations; • Protect existing networks; • Protect climate refugia	**Relative vulnerability to climate change:** Medium-High **Relative value for native salmonid conservation:** Potential value over the long term, but will require a high level of investment to both moderate climate impacts and prevent/remove/suppress non-native fish **Potential Goal:** Prevent invasion of non-native fish (or remove/suppress if already present), and improve the suitability of this habitat network for long-term conservation of native salmonids **Strategies:** • Moderate stream temperature increases; • Moderate base flow decreases; • Moderate peak flow increases; • Increase adaptive capacity of native fish; • Remove/suppress non-native fish; • Prevent invasion of non-native fish; • Minimize adverse impacts in the event of potential increased wildland fire disturbance; • Protect existing networks; • Reduce uncertainty through research and monitoring	**Relative vulnerability to climate change:** High **Relative value for native salmonid conservation:** Potential value in the short term to help with population recovery, maintenance of genetic diversity and/or local adaptations, but will require investment to prevent/remove/suppress non-native fish. Longer-term value is lower due to decreasing habitat suitability **Potential Goal:** Facilitate the movement of current population to other locations with more suitable conditions; facilitate the transition of the location to a new state. Consider managing the location for other targets (e.g., game fish or non-fish targets) **Strategies:** • Reduce uncertainty through research and monitoring; • Relocate individuals to areas likely to remain or become suitable; • Facilitate transition to a new state; • Determine additional strategies after clarifying management goal(s)

STEP 2 continues on the following page or go to STEP 3 for more information about Strategies and their Example Actions.

Climate Adaptation Decision Framework | http://mpf.weebly.com/cold-water-ecosystem-management-tool.html 11

Step 3



STEP 3: Select Actions to Implement Chosen Climate Adaptation Strategies[1] (cont.)

Strategy	Objective	Example Actions
Moderate peak flow increases	Restore floodplain connections	• Remove infrastructure (e.g., roads, levees, rip-rap, etc.) from floodplains • Reconnect floodplain features (e.g. channels, ponds) • Create new connections degraded floodplain habitats
	Restore incised/scoured channels	• Reintroduce beaver to encourage/aid dam-building that increases sediment storage and deposition
	Restore riparian vegetation	• Establish riparian vegetation; remove non-native vegetation • Remove stressors that cause riparian damage (illegal or degraded trails, cattle, etc)
	Restore stream flow regimes	• Disconnect road drainage from streams • Remove or retrofit undersized culverts • Restore natural drainage systems, create retention ponds
	Reduce rain-on-snow flooding	• Maintain/restore forest, wetland and riparian vegetation cover
Moderate stream temperature increases	Connect populations to cold-water stream networks	• Remove dams on culverts that act as barriers and limit fish access to cold-water streams • Restore/provide in-stream flows • Resolve thermal barriers
	Reconnect floodplains	• Reconnect floodplain features (e.g. side channels, ponds) • Designate and restore natural floodplain boundaries • Remove infrastructure (e.g., roads, levees, rip-rap, etc.) from floodplains
	Restore incised/scoured channels	• Reintroduce beaver or build beaver dam analogs to increase sediment storage • Restore riparian vegetation • Remove stressors that cause riparian damage (illegal or degraded trails, cattle, etc)
	Restore stream flows	• Work to restore natural flow regimes • Reduce water withdrawals, restore summer baseflow • On regulated streams, pulse flows during critical times, sourcing from lower in the thermocline
	Maintain/enhance riparian vegetation to shade streams	• Reduce grazing pressure (e.g. reduce stocking rates, use rest-rotation systems, fence riparian areas, provide off-stream water sources, retire vacant allotments in priority fish areas, increase monitoring in priority areas to ensure good practices) • Restore riparian vegetation in degraded areas • Adjust riparian vegetation to favor species that are better suited for future climate conditions
Prevent invasion of non-native fish	Prevent non-native fish invasion	• Strategically use physical or electrical barriers to prevent further spread of non-native fish • Model future changes in stream flow and habitat to anticipate future invasion hotspots
	Restore habitats that convey an advantage for native fish over non-native fish	• Restore spawning habitats for native fish • Connect current native populations with streams that are too cold for non-native fish
	Expand existing native fish populations to increase chances of resisting invasion	• Expand native fish populations in areas where trying to prevent invasion of non-native fish
Protect climate refugia	Identify and protect areas likely to remain climatically suitable over the long-term	• Establish large-scale reserves for long-term native cold-water fish conservation • Connect current populations with streams that are currently too cold (and may warm to suitable levels in the future) • Look for opportunities for reintroductions in habitats likely to remain suitable over the long-term • Understand and map where groundwater inputs may buffer projected stream temperature increases
	Protect and restore critical or unique habitats that buffer survival during vulnerable periods (i.e., seasonally or at particular life history stages)	• Protect/restore off-channel habitats, spring brooks, and seeps important as early rearing environments • Protect/restore flood or thermal refugia and stream segments that are important as connections

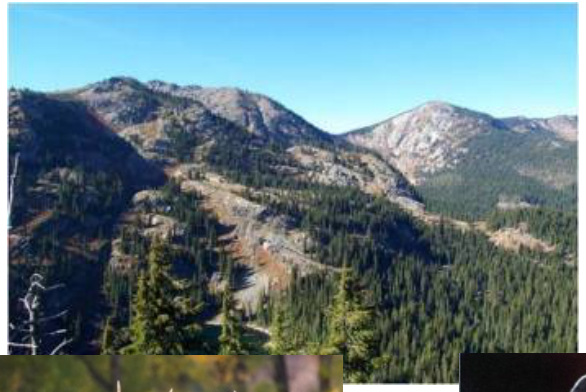
Climate Adaptation Decision Framework | http://mpf.weebly.com/cold-water-ecosystem-management-tool.html 14

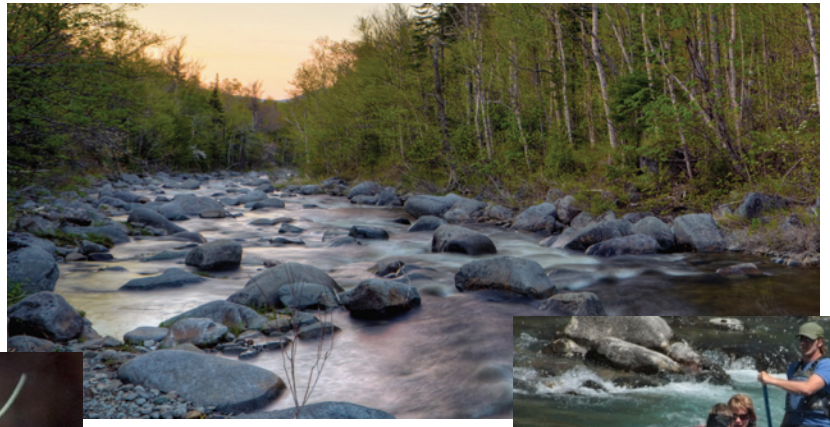
What actions to take? Where to take those actions? Towards what goal?

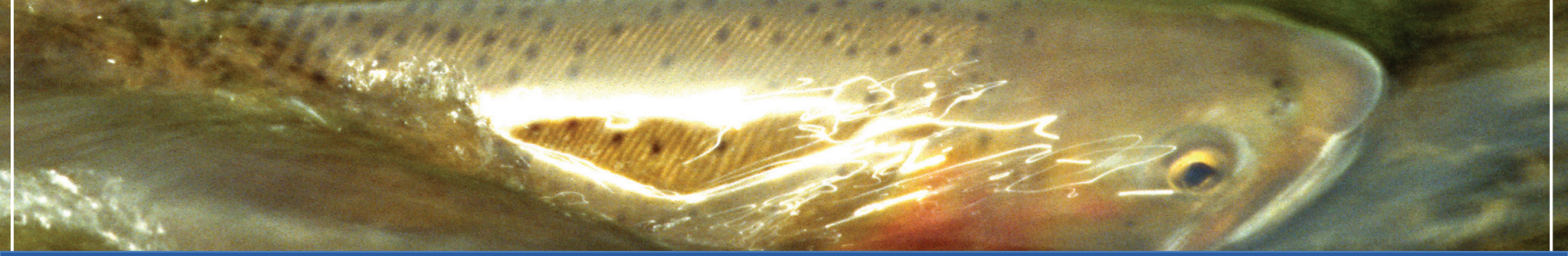
Tailor the Decision Framework

Decision Support Framework Development Process

1. Specify conservation target and unit of analysis
2. Identify key climate change vulnerability factors
3. Develop critical questions for assessing the relative vulnerability of the area or population to climate change
4. Create a 'vulnerability matrix' that aligns relative vulnerability with forward-looking goals and strategies
5. Create a list of example actions to implement each climate adaptation strategy







Decision Support Framework

Ask us questions. Ask us to replicate this tool for your work. Tell us how you've used it.

Lara Hansen, EcoAdapt **Lara@EcoAdapt.org**
Molly Cross, Wildlife Conservation Society **MCross@WCS.org**

Learn more:
www.cakex.org/virtual-library/three-step-decision-support-framework-climate-adaptation-selecting-climate-informed