APPENDIX A. QUALITATIVE ASSESSMENT OF CLIMATE CHANGE VULNERABILITY OF NATIONAL FISH HATCHERIES IN THE PACIFIC REGION: WINTHROP NATIONAL FISH HATCHERY

Initial Qualitative Assessment 2011

The U.S. Fish and Wildlife Service (Service) qualitatively assessed the climate change vulnerabilities of all National Fish Hatcheries (NFHs) during calendar year 2011. These assessments were based on an Excel Spreadsheet template that was developed in the Headquarters Office (HQ) of the Service and distributed to all NFHs. This document summarizes the methods, results, and conclusions of those initial vulnerability assessments for Winthrop NFH.

Methods

The initial vulnerability assessment consisted of two Excel worksheets, *Worksheet 1* and *Worksheet 2* (Tables A1 and A2, respectively).

Worksheet 1

The purpose of *Worksheet 1* was to identify climate change stressors that are likely to occur by the year 2050 ("40 years out") and then assign a risk level for each stressor. Possible risk levels ranged from 1 ("negligible risk") to 5 ("extreme risk") and were based on the projected severity and likelihood of the stressor (Table A1).

The original Excel template for Worksheet 1 was focused on the hatchery and local watershed and did not account for areas where hatchery fish are released or migrate. The ability of NFHs in the Pacific Region to meet their goals for Pacific salmon and steelhead requires that a portion of released fish successfully migrate to the ocean and return back to the hatchery where they can be recaptured for broodstock. Consequently, initial evaluations of climate change effects for NFHs in the Pacific Region were subdivided into two categories: (a) the "hatchery and local watershed", and (b) the "migration corridor". This latter category included all stream and river areas between the hatchery and the ocean (Table A1).

Climate change projections for mean air temperature, precipitation, and several stream/hydrology parameters were obtained from the Climate Impacts Group at the University of Washington (Appendix B; http://www.hydro.washington.edu/2860/). The Climate Impacts Group (CIG-UW) has used 10 general circulation models (GCMs) to develop downscaled projections for monthly mean air temperature and precipitation at nearly 300 specific streamflow locations throughout the Pacific Northwest. CIG-UW has coupled those downscaled projections to historic and future streamflow patterns via the Variable Infiltration Capacity (VIC) hydrologic model (http://www.hydro.washington.edu/2860/new_users/) . A subset of those climate change projections in the form of summary graphs, specific for each hatchery and applicable downstream areas, was provided to the manager of each NFH in the Pacific Region (Appendix B). Figure C1 (from Mantua et al. 2010; see Appendix C) was also provided to each NFH manager in the Columbia River basin to assess the ability of adult salmon and steelhead to migrate upstream past Bonneville Dam during a critical high temperature period when a potential "thermal block" to upstream migration is projected to exist during mid-summer by the year 2040. The manager and Service staffs for each hatchery reviewed the available climate change projections for their respective watershed and identified the specific stressors that would likely affect their hatchery and programs based on their professional experiences and expert opinions (see Table A1 for Winthrop NFH).

Worksheet 2

The purpose of Worksheet 2 was to identify and prioritize, for each hatchery, management actions that could be implemented to adapt or mitigate for the effects of each climate change stressor identifed in Worksheet 1. A template for this worksheet was not provided by HQ of the Service. Rather, Worksheet 2 was developed specifically for Pacific Region NFHs to facilitate the recording of the requested information. Hatchery managers and their staffs used their expert opinions and professional experiences to complete Worksheet 2 (see Table A2 for Winthrop NFH).

Results

Climate change risks at Winthrop NFH

No climate change stressor at Winthrop NFH was assigned a risk score =5; however, many stressors were assigned scores = 4 (*high risk; high priority for action*; Table A1). These latter high risk stressors included the following: (a) decreases in surface and ground water quantity

(summer) and quality; (b) increases in mean air temperature in the summer, fall, and winter; (c) decreases in summer snow pack and earlier snow melt; (c) increases in the number and duration of drought events; (d) increases in pathogens, parasites, disease, and invasive species, both in the local watershed/hatchery and in the migration corridor; and (e) a need for increased skill sets of employees to deal with the effects of climate change stressors (e.g., increased monitoring of disease).

Management actions to adapt or mitigate for effects of climate change stressors

The manager and staff at Winthrop NFH suggested the following potential management actions for adapting or mitigating for the projected effects of climate change based on the time/effort, dollar cost, and feasibility of implementation: (1) reduce rearing densities and the number of fish reared; (2) install oxygen injection and/or a water recirculation system; (3) install water chillers; (4) expand facilities to a location with additional water; and/or (5) rear alternative species, particularly if existing species are unable to return to the hatchery because of decreased surface water quantity or quality (e.g., summer steelhead; see below).

Discussion and Conclusions

A primary concern at Winthrop NFH, based on this initial qualitative assessment of climate change vulnerability, was the projected decrease in water quantity and quality (e.g., increased water temperatures) during the mid-to-late summers at both the hatchery and in the migration corridor. Their concerns were later confirmed by quantitative analyses (Appendix D). Winthrop NFH currently rears spring Chinook salmon, coho salmon, and summer-run steelhead, and each species requires extended rearing to at least the yearling life history stage. The projected thermal block to upstream-migrating salmon and steelhead at Bonneville Dam, beginning by the year 2040 and potentially occurring from mid-July to late August (weeks 28-33; Fig. C1), coincides partially with the current upstream migration timing of summer steelhead in the Columbia River.

A common concern at all NFHs in the Pacific Region was the effects of climate change stressors on disease and increased prevalence of pathogenic organisms, both in the hatchery and in the migration corridor. In general, disease risks for Pacific salmon and steelhead increase with increases in water temperature, density indexes, and flow indexes. Climate models project increased air temperatures and decreased surface water quantities during the summer months throughout the Pacific Northwest, due in large part to more precipitation falling as rain and less as snow during the winter, although the total quantity of annual precipitation may remain relatively constant. A recent example of the interaction between water temperature and disease occurred in 2002 on the Klamath River, California, where over 33,000 adult salmonids, primarily Chinook salmon, died during their upstream migration at a time of low water flows and warm water temperatures. Pathology reports concluded that the fish died from infections of Ich

(*Ichthyophthirius multifilis*) and columnaris (*Flavobacterium columnare*), not elevated water temperatures (CDFG 2004); however both of these pathogens become increasingly infectious with increasing water temperatures

Overall, the manager and staff at Winthrop NFH used their expert opinions and professional experiences to conclude that adaptations/mitigation for the projected effects of climate change were feasible if adjustments in the number of fish reared and/or water supplies are possible.

Worksheet 1 Instructions (see Table A1)

The following steps were used to complete Worksheet 1 of the initial climate change vulnerability assessments of National Fish Hatcheries in the Pacific Region. The completed worksheet for Winthrop NFH is presented as Table A1.

Step 1: Identify climate change stressors (columns 1 and 2). The climate and hydrology projection graphs in Appendix B were used to identify climate change stressors for the evaluated hatchery: in column 2, 0 = not likely to be a stressor; 1= likely to be a stressor.

Step 2: Determine the severity of each stressor on NFH operations and programs (column 3). The following table was used to classify the severity of each stressor on a scale of 1 to 5:

Designation	Impact	Examples
5	Catastrophic	Permanent loss of facility function, loss of all aquatic species, safety concerns
4	Major	Long term loss of function (> six months), loss of all or most of aquatic species
3	Moderate	Disruption and alteration of normal operations related to fish culture for up to six months, loss of aquatic species due to poor water quality or quantity
2	Minor	Disruption of normal operations for a week, no loss of organisms
1	Insignificant	Short-term inconvenience

Step 3. Determine the likelihood that each stressor will occur (column 4). The following table was used to classify the likelihood of each stressor on a scale of 1 (<10%) to 5 (>90%).

Designation	% Likelihood*	Description of Likelihood Level**
5	90-99%	very likely, almost certain, is expected to happen
4	66-90%	likely, will probably happen
3	33-66%	medium, possible, might occur, 50/50 chance of occurring
2	10-33%	unlikely, but possible
1	<10%	very or highly unlikely, but conceivable

Step 4. Determine the risk level of each stressor to NFH operations and programs (column 5). The following table was used to assign a risk level for each stressor as a function of its severity and likelihood.

Risk Level* Likelihood	Severity = 5 Catastrophic	Severity = 4 Major	Severity = 3 Moderate	Severity = 2 Minor	Severity = 1 Insignificant
5 (A: almost certain)	5	5	5	4	3
4 (B: likely)	5	5	4	4	3
3 (C: possible)	5	5	4	3	2
2 (D: unlikely)	5	4	3	2	2
1 (E: rare)	4	4	3	2	1

Risk Level Score	Risk Level
5	E: Extreme risk; immediate action required
4	H: High risk; high priority for action, begin planning as soon as practicable
3	M: Moderate risk; include in response planning, but lower priority.
2	L: Low risk; minimal action likely to be required;
1	None: Negligible risk, no response required

Table A1. Worksheet 1 for qualitatively assessing the climate change vulnerability of Winthrop NFH. The goal of this worksheet was to identify climate change stressors, and then assess their potential severity and likelihood to assign a "risk level" for that stressor.

Winthrop NFH **Potential Stressors from Climate Change**	**Step 1: Identify Hazards Likely to Occur on Hatchery**	**Step 2: Determine the Severity of the stressor**	**Step 3: Determine the Likelihood of Hazard Occurring**	**Step 4: Determine Risk Level**
Utilize Worksheet 2	Utilize Worksheet 2 (1= stressor for hatchery, 0 = not a stressor)	Utilize Worksheet 3 (1, 2, 3, 4, or 5)	Utilize Worksheet 4 (1, 2, 3, 4, or 5)	Utilize Worksheet 5 (1, 2 3, 4, or 5)
SURFACE WATER QUANTITY (Hatchery and local watershed)				
decrease in water quantity (hatchery) (summer)	1	3	3	4
increase in water quantity (hatchery)	0			
SURFACE WATER QUANTITY (Migration Corridor)				
decrease in water quantity (migration corridor)	1	2	3	3
increase in water quantity (migration corridor)	0			
GROUND WATER QUANTITY (Hatchery and local watershed)				
decrease in water quantity (hatchery)	1	3	3	4
increase in water quantity (hatchery)	0			
SURFACE WATER QUALITY (Hatchery and local watershed)				
decrease in water quality (hatchery)	1	2	2	2
increase in water quality (hatchery)	0			
SURFACE WATER QUALITY (Migration Corridor)				
decrease in water quality (migration corridor)	1	2	3	3
increase in water quality (migration corridor)	0			
GROUND WATER QUALITY (Hatchery and local watershed)				
degradation of water quality (hatchery)	1	2	2	2
improvement of water quality (hatchery)	0			
SURFACE WATER TEMPERATURE (Hatchery and local watershed)				
temperature increase (hatchery)	1	2	2	2
temperature decrease (hatchery)	0			
SURFACE WATER TEMPERATURE (Migration Corridor)				
temperature increase (migration corridor)	1	2	3	3
temperature decrease (migration corridor)	0			
GROUND WATER TEMPERATURE (Hatchery and local watershed)				
temperature increase (hatchery)	1	2	2	2
temperature decrease (hatchery)	0			

Table A1. Continued, page 2 of 6.

Winthrop NFH **Potential Stressors from Climate Change**	**Step 1: Identify Hazards Likely to Occur on Hatchery**	**Step 2: Determine the Severity of the stressor**	**Step 3: Determine the Likelihood of Hazard Occurring**	**Step 4: Determine Risk Level**
Utilize Worksheet 2	Utilize Worksheet 2 (1= stressor for hatchery, 0 = not a stressor)	Utilize Worksheet 3 (1, 2, 3, 4, or 5)	Utilize Worksheet 4 (1, 2, 3, 4, or 5)	Utilize Worksheet 5 (1, 2 3, 4, or 5)
AMBIENT TEMPERATURE CHANGES (Hatchery and local watershed)				
increase in annual average temperature	1	2	3	3
decrease in annual average temperature	0			
increase in number of warm days (aka heat waves1)	1	2	3	3
decrease in number of warm days	0			
increase in number of frost days2	0			
decrease in number of frost days	1	2	3	3
increase in spring average air temperatures	0			
increase in summer average air temperatures	1	2	4	4
increase in fall average air temperatures	1	2	4	4
increase in winter average air temperatures	1	2	4	4
decrease in spring average air temperatures	0			
decrease in summer average air temperatures	0			
decrease in fall average air temperatures	0			
decrease in winter average air temperatures	0			
PRECIPITATION CHANGES (Hatchery and local watershed)				
increase in annual average precipitation	0			
decrease in annual average precipitation	1	2	3	3
increase in spring average precipitation	0			
increase in summer average precipitation	0			
increase in fall average precipitation	0			
increase in winter average precipitation	0			
decrease in spring average precipitation	0			
decrease in summer average precipitation	1	1	3	2
decrease in fall average precipitation	0			
decrease in winter average precipitation	1	1	3	2
increase in frequency of extreme thunderstorms	0			

Table A1. Continued, page 3 of 6.

Winthrop NFH **Potential Stressors from Climate Change**	**Step 1: Identify Hazards Likely to Occur on Hatchery**	**Step 2: Determine the Severity of the stressor**	**Step 3: Determine the Likelihood of Hazard Occurring**	**Step 4: Determine Risk Level**
Utilize Worksheet 2	Utilize Worksheet 2 (1= stressor for hatchery, 0 = not a stressor)	Utilize Worksheet 3 (1, 2, 3, 4, or 5)	Utilize Worksheet 4 (1, 2, 3, 4, or 5)	Utilize Worksheet 5 (1, 2 3, 4, or 5)
PRECIPITATION CHANGES (Hatchery and local watershed)				
decrease in frequency of extreme thunderstorms	0			
increase in frequency of extreme snowstorms	0			
decrease in frequency of extreme snowstorms	1	2	2	2
increase in duration of extreme thunderstorms	0			
decrease in duration of extreme thunderstorms	0			
increase in duration of extreme snowstorms	0			
decrease in duration of extreme snowstorms	1	2	2	2
increase in amount of snowpack	0			
decrease in amount of snowpack	1	3	4	4
earlier snow melt date	1	2	4	4
later snow melt date	0			
lower snow line	0			
higher snow line	1	2	4	4
EXTREME WEATHER EVENTS (Hatchery and local watershed)				
increased average wind speed annually	0			
decreased average wind speed annually	0			
increased average wind duration annually	0			
decreased average wind duration annually	0			
change in wind patterns	0			
increased speed and duration of westerly wind flow	0			
decreased speed and duration of westerly wind flow	0			
increased speed and duration of southernly wind flow	0			
decreased speed and duration of southernly wind flow	0			
increase in number of flood events annually	0			
decrease in number of flood events annually	1	2	3	3
increase in the average duration of flood events annually	0			

Table A1. Continued, page 4 of 6.

Winthrop NFH **Potential Stressors from Climate Change**	**Step 1: Identify Hazards Likely to Occur on Hatchery**	**Step 2: Determine the Severity of the stressor**	**Step 3: Determine the Likelihood of Hazard Occurring**	**Step 4: Determine Risk Level**
Utilize Worksheet 2	Utilize Worksheet 2 (1= stressor for hatchery, 0 = not a stressor)	Utilize Worksheet 3 (1, 2, 3, 4, or 5)	Utilize Worksheet 4 (1, 2, 3, 4, or 5)	Utilize Worksheet 5 (1, 2 3, 4, or 5)
EXTREME WEATHER EVENTS (Hatchery and local watershed)				
decrease in the average duration of flood events annually	1	2	3	3
increase in the severity of flood events annually	1	2	3	3
decrease in the severity of flood events annually	0			
increae in number of drought events annually	1	4	2	4
decrease in number of drought events annuaylly	0			
increase in the average duration of drought events annually	1	4	2	4
decrease in the average duration of drought events annually	0			
increase in the number of tornadoes	0			
decrease in the number of tornadoes	0			
increase in the severity of tornadoes	0			
decrease in the severity of tornadoes	0			
increase in the number of hurricanes	0			
decrease in the number of hurricanes	0			
increase in the severity of hurricanes	0			
decrease in the severity of hurricanes	0			
increase in the number of ice storms	1	1	1	1
decrease in the number of ice storms	0			
increase in the severity of ice storms	1	1	1	1
decrease in the severity of ice storms	0			
increase in the number of monsoons	0			
decrease in the number of monsoons	0			
increase in the severity of monsoons	0			
decrease in the severity of monsoons	0			
increase in the number of hail storms	1	1	1	1
decrease in the number of hail storms	0			
increase in the severity of hail storms	1	1	1	1
decrease in the severity of hail storms	0			

Table A1. Continued, page 5 of 6.

Winthrop NFH **Potential Stressors from Climate Change**	**Step 1: Identify Hazards Likely to Occur on Hatchery**	**Step 2: Determine the Severity of the stressor**	**Step 3: Determine the Likelihood of Hazard Occurring**	**Step 4: Determine Risk Level**
Utilize Worksheet 2	Utilize Worksheet 2 (1= stressor for hatchery, 0 = not a stressor)	Utilize Worksheet 3 (1, 2, 3, 4, or 5)	Utilize Worksheet 4 (1, 2, 3, 4, or 5)	Utilize Worksheet 5 (1, 2 3, 4, or 5)
OTHER (Hatchery and local watershed)				
increase in invasive species	1	3	3	4
decrease in invasive species	0			
increase in disease	1	3	3	4
decrease in disease	0			
increase in parasites	1	3	3	4
decrease in parasites	0			
increase in pathogens	1	3	3	4
decrease in pathogens	0			
increase in number of fire events	1	1	3	2
decrease in number of fire events	0			
increase in intensity of fire events	1	1	3	2
decrease in intensity of fire events	0			
extreme precipitation events-hurricane	0			
extreme precipitation events-tropical storm	0			
extreme precipitation events-cyclones	0			
extreme precipitation events	1	1	2	2
OTHER (Migration Corridor)				
increase in invasive species (migration corridor)	1	3	3	4
decrease in invasive species (migration corridor)	0			
increase in disease (migration corridor)	1	3	3	4
decrease in disease (migration corridor)	0			
increase in parasites (migration corridor)	1	3	3	4
decrease in parasites (migration corridor)	0			
increase in pathogens (migration corridor)	1	3	3	4
decrease in pathogens (migration corridor)	0			

Table A1. Continued, page 6 of 6.

Winthrop NFH **Potential Stressors from Climate Change**	**Step 1: Identify Hazards Likely to Occur on Hatchery**	**Step 2: Determine the Severity of the stressor**	**Step 3: Determine the Likelihood of Hazard Occurring**	**Step 4: Determine Risk Level**
Utilize Worksheet 2	Utilize Worksheet 2 (1= stressor for hatchery, 0 = not a stressor)	Utilize Worksheet 3 (1, 2, 3, 4, or 5)	Utilize Worksheet 4 (1, 2, 3, 4, or 5)	Utilize Worksheet 5 (1, 2 3, 4, or 5)
COASTAL (Hatchery and local watershed)				
increase in wave size and intensity	0			
decrease in wave size and intensity	0			
increase in marine cloudiness (decreasing temperature)	0			
decrease in marine cloudiness (increasing temperature)	0			
increase in sea level rise	0			
decrease in sea level rise	0			
change in ocean currents	0			
change in wave patterns	0			
Management				
skill set[1]	1	3	4	4
[1]Additional fish health specialists and biological training of fish culture staff will most likely be needed to address increased fish health risks.				

Worksheet 2 Instructions (see Table A2)

The following steps were used to complete Worksheet 2 of the initial climate change vulnerability assessments of National Fish Hatcheries in the Pacific Region. The climate change stressors identified in Worksheet 1 were listed in the first column of Worksheet 2. The following steps were then completed for each of those identified stressors. The completed worksheet for Winthrop NFH is presented as Table A2.

Step 5: Identify (list) one to five expected effects of each climate change stressor to the hatchery facilities, programs, and/or fish propagated at the hatchery (Column 2).

Step 6. Identify management actions that could be implemented to adapt or mitigate for the identified effects (Step 5) of each climate change stressor (column 3).

Step 7. Determine the time/effort to implement each management action identified in Step 6 (column 4). The following table was used to classify – on a scale of 1 to 5 - the time/effort to implement each management action (column 3) intended to adapt/mitigate for the identified climate change stressor:

TIME/EFFORT* Designation	Classification	Duration	Description
5	extremely difficult	over 1 year	intensive amount of effort and time is needed to implement
4	very difficult	6 months to 1 year	a large amount of effort and time is needed to implement
3	difficult	2 to 6 months	a moderate amount of effort and time is needed to implement
2	moderate	1 week to 2 months	some effort and time is needed to implement
1	easy	less than 1 week	little to no effort or time

Step 8. Determine the dollar ($$$) cost to implement each management action identified in Step 7 (column 5). The following table was used to classify – on a scale of 1 to 5 – the dollar cost to implement each management action (column 3) intended to adapt/mitigate for the identified climate change stressor:

Dollar Cost Classification	Relative expense	Cost	Description
5	Extremely expensive	$$$$$	not able to implement due to cost
4	Very expensive	$$$$	intensive amount of funding is needed to implement
3	Expensive	$$$	a large amount of funding is needed to implement
2	Moderately expensive	$$	a moderate amount of funding is needed to implement
1	Not expensive	$	little to no and funding is needed to implement

Step 9. Determine the feasibility to implement each management action identified in Step 7 (column 6). The following table was used to classify – on a scale of 1 to 5 – the feasibility to implement each management action (column 3) based on time/effort and dollar cost:

Cost to implement	Time/effort. 5: Extremely Difficult	Time/effort. 4: Very Difficult	Time/effort. 3: Difficult	Time/effort. 2: Moderate	Time/effort. 1: Easy
5 = Extremely Expensive	5	5	5	4	3
4 = Very Expensive	5	5	4	4	3
3 = Expensive	5	5	4	3	2
2 = Moderately expensive	5	4	3	2	2
1 = Not Expensive	4	4	3	2	1

Feasibility Level Score	Feasibility
5	Very Low Feasibility
4	Low Feasibility
3	Moderate Feasibility
2	High Feasibility
1	Very High Feasibility

Step 10, part 1. Prioritize or rank the management actions that could be implemented to adapt/mitigate for the identified effects of each climate change stressor (column 7). Each hatchery manager and his/her staff ranked the order, or priority, that they would implement each of the possible management actions based on feasibility of implementation (time/effort + $$$) and professional experience and institutional knowledge.

Step 10, part 2. Provide comments regarding feasibility, constraints, priorty, or any other information regarding the potential difficulty, benefits, risks, etc. of implementing each management action to adapt/mitigate for the effects of each climate change stressor.

Table A2. Worksheet 2, Qualitative assessment of climate change vulnerability of Winthrop NFH.

Winthrop NFH							
Potential Stressors from Climate Change (as identified as "1" in Worksheet 1)	**Step 5: Expected effects from stressor (list each effect in a new row; max.of 5)**	**Step 6: Management actions to adapt/mitigate for effects of stressor**	**Step 7: Time and effort to implement management action (1, 2, 3, 4, or 5)**	**Step 8: Dollar cost to implement management action (1, 2, 3, 4, or 5)**	**to implement management action (1, 2, 3, 4, or 5)**	**Priority/rank of management actions to dapt/mitigate for effects of stressor (enter 1, 2, 3,**	**Step 10, part 2: Comments on feasibility and priority to implement management action to adapt or mitigate for the effects of stressor.**
WATER QUALITY AND QUANTITY CHANGES (Hatchery)							
Decrease in surface water quantity (summer)	Increase in water temperature	Install water chillers	4	5	5	3	Not realistically feasible, use other management options…reduce rearing, inject O2, etc.
Decrease in surface water quality	Increase fish health risks	Reduce rearing densities and number of fish	4	1	4	1	Could violate legal mitigation agreements and U.S. v. Oregon treaty with tribes. Decrease
in ground water quality	Reduced dissolved oxygen	Install oxygen injection/recirc system	3	3	4	2	Feasible, but may not entirely mitigate for water loss
	Reduced carrying capacity of hatchery for rearing fish	Expand facilities to location with additional water	5	5	5	4	water
Decrease in ground water quantity	Reduced dissolved oxygen	Install oxygen injection/recirc system	3	3	4	2	Feasible, but may not entirely mitigate for water loss
	Increase fish health risks	Reduce rearing densities and number of fish	4	1	4	1	Could violate legal mitigation agreements and U.S. v. Oregon treaty with tribes.
		Expand facilities to location with additional water	5	5	5	3	water
Surface water temperature increase	Increased fish health risks	Install water chillers	4	5	5	3	Not realistically feasible, use other management options…reduce rearing, inject O2, etc.
Ground water temperature increase	Potential inability to rear current species	Rear alternative species	4	1	4	1	Could violate legal mitigation agreements and U.S. v. Oregon treaty with tribes.
	Reduced dissolved oxygen	Install oxygen injection/recirc system	3	3	4	2	Feasible, but may not entirely mitigate for water loss
WATER QUALITY AND QUANTITY CHANGES (Migration corridor)							
Decrease in surface water quantity	Increased out-migration time for juvenile fish	Adjust release timing according to flow	2	1	2	1	Could impact rearing densities for all species reared
	Reduced numbers of adult fish available for broodstock	Rear alternative species	4	1	4	2	Could violate legal mitigation agreements and U.S. v. Oregon treaty with tribes.
	Increase in water temperature (thermal barriers)						
Decrease in surface water quality	Creation of thermal barrier to upstream migration of adult salmon and steelhead	Adjust broodstock collection and spawn dates in response to life history adaptations to altered hydrologies and thermal regimes.	2	2	2	1	The dollar cost could increase if the length of time required to hold adult fish prior to spawning increases and/or fish health risks increase.
Increase in surface water temperature	Reduced numbers of adult fish available for broodstock	Rear alternative species	4	1	4	2	Could violate legal mitigation agreements and U.S. v. Oregon treaty with tribes.
	Increase in water temperature (thermal barriers)						
AMBIENT TEMPERATURE CHANGES (Hatchery)							
Increase in annual average temperature	Reduced dissolved oxygen	Install oxygen injection/recirc system	3	3	4	2	Feasible, but may not entirely mitigate for water loss
Increase in number of warm days (aka heat waves1)	Increase fish health risks	Reduce rearing densities and number of fish	4	1	4	1	Could violate legal mitigation agreements and U.S. v. Oregon treaty with tribes.
	Increase in surface water temperature	Install water chillers	4	5	5	3	Not realistically feasible, use other management options…reduce rearing, inject O2, etc.
		Expand facilities to location with additional water	5	5	5	4	water
Decrease in number of frost days	Increased growth rates in species reared	Utilize chilled incubation water	1	1	1	1	Very simple solution for most species reared
Increase in winter average air temperatures	Increase in water temperature	Install water chillers	4	5	5	3	Not realistically feasible, use other management options…reduce rearing, inject O2, etc.
	Increase fish health risks	Reduce rearing densities and number of fish	4	1	4	2	Could violate legal mitigation agreements and U.S. v. Oregon treaty with tribes.
Increase in summer average air temperatures	Increased fish health risks	Install water chillers	4	5	5	3	Not realistically feasible, use other management options…reduce rearing, inject O2, etc.
Increase in fall average air temperatures	Potential inability to rear current species	Rear alternative species	4	1	4	1	Could violate legal mitigation agreements and U.S. v. Oregon treaty with tribes.
	Reduced dissolved oxygen	Install oxygen injection/recirc system	3	3	4	2	Feasible, but may not entirely mitigate for water loss
PRECIPITATION CHANGES (Hatchery and local watershed)							
Decrease in annual average precipitation	Reduced quantity of surface water at hatchery (summer)	See "decrease in surface water quantity (hatchery) (summer)"					
Decrease in summer average precipitation	Reduced quantity of ground water at hatchery	See "decrease in ground water quantity (hatchery)"					
Decrease in winter average precipitation							
Decrease in frequency of extreme snow storms	Reduced surface water availability in late spring and summer	See "decrease in surface water quantity (hatchery) (summer)"					
Decrease in duration of extreme snow storms	Reduced ground water availability in summer	See "decrease in ground water quantity (hatchery)"					
Decrease in amount of snow pack							
Higher snow line							
Earlier snow melt date							

Table A2. continued.

Winthrop NFH							
Potential Stressors from Climate Change (as identified as "1" in Worksheet 1)	**Step 5: Expected effects from stressor (list each effect in a new row; max.of 5)**	**Step 6: Management actions to adapt/mitigate for effects of stressor**	**Step 7: Time and effort to implement management action (1, 2, 3, 4, or 5)**	**Step 8: Dollar cost to implement management action (1, 2, 3, 4, or 5)**	**to implement management action (1, 2, 3, 4, or 5)**	**Priority/rank of management actions to adapt/mitigate for effects of stressor (enter 1, 2, 3,**	**Step 10, part 2: Comments on feasibility and priority to implement management action to adapt or mitigate for the effects of stressor.**
EXTREME WEATHER EVENTS (Hatchery and local watershed)							
Decrease in number of flood events annually	Reduced opportunities to release fish at optimum times	Hold fish longer prior to release	1	1	1	2	Could impact rearing densities for all species reared
Decrease in the average duration of flood events annually	Increased rearing densities	Adjust growth rates to avoid high densities	1	1	1	1	Very simple solution for most species reared
	Increase fish health risks	Reduce rearing densities and number of fish	4	1	4	3	Could violate legal mitigation agreements and U.S. v. Oregon treaty with tribes.
Increase in the severity of flood events annually	Surface water intake debris blockages	Modify intake design/log booms, etc.	2	2	2	1	Could also increase staff to deal with debris removal
Increase in the number of hail storms	Reduced water flow into raceways and ponds	Emergency release fish prior to smoltification	4	1	4	2	Could violate legal mitigation agreements and U.S. v. Oregon treaty with tribes.
Increase in the severity of hail storms							
Increase in number of drought events annually	Reduced surface water availability at hatchery	See "decrease in surface water quantity (hatchery) (summer)"					
Increase in the average duration of drought events annually	Reduced ground water availability at hatchery	See "decrease in ground water quantity (hatchery)"					
Increase in the number of ice storms	Increased risk of freeze-up episodes	Develop additional ground water sources	3	3	4	2	Ground water availability may be an issue
Increase in the severity of ice storms							
OTHER (Hatchery and local watershed)							
Increase in invasive species	Increase fish health risks	Install UV treatment of surface water	4	5	5	1	Water volume (25 to 30 cfs) and turbidity may be cost prohibitive
	Potential inability to rear current species	Rear alternative species	4	1	4	2	Could violate legal mitigation agreements and U.S. v. Oregon treaty with tribes.
	Potential water system blockage (e.g., invasive mussels)	Develop additional ground water sources	3	3	4	3	Ground water availability may be an issue
Increase in disease	Increase fish health risks	Install UV treatment of surface water	4	5	5	1	Water volume (25 to 30 cfs) and turbidity may be cost prohibitive
Increase in parasites	Potential inability to rear current species	Rear alternative species	4	1	4	3	Could violate legal mitigation agreements and U.S. v. Oregon treaty with tribes.
Increase in pathogens	Increase disease incidence	Reduce rearing densities and number of fish	4	1	4	2	Could violate legal mitigation agreements and U.S. v. Oregon treaty with tribes.
Increase in number of fire events	Increase in surface water temperature	Same as "Increase surface water temp" above					
Increase in intensity of fire events							
Extreme precipitation events	Surface water intake debris blockages	Modify intake design/log booms, etc.	2	2	2	1	Could also increase staff to deal with debris removal
		Emergency release of fish prior to smoltification	4	1	4	2	Could violate legal mitigation agreements and U.S. v. Oregon treaty with tribes.
OTHER (Migration corridor)							
Increase in invasive species	Reduced numbers of adult fish available for broodstock	Rear alternative species	4	1	4	2	Could violate legal mitigation agreements and U.S. v. Oregon treaty with tribes.
Increase in disease	Increase fish health risks	Additional screening @ adult collection/spawning	3	2	3	1	
Increase in parasites							
Increase in pathogens							
MANAGEMENT							
Skill set	Reduced ability to adequately monitor, diagnose, and treat fish for disease because of increased work loads.	Increase number of fish health specialists for monitoring, diagnosis, and treatment of fish diseases.	2	3	3	1	
	because of increased physiological stress of fish prior to release.	Increase biological training requirements for fish culture staff.	5	2	5	2	May require reclassification of Position Descriptions.